FOR THE PURPOSES OF INFORMATION ONLY

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AM	Armenia	GB	United Kingdom	MW	Malawi
AT	Austria	GE	Georgia	MX	Mexico
AU	Australia	GN	Guinea	NE	Niger
BB	Barbados	GR	Greece	NL	Netherlands
BE	Belgium	HU	Hungary	NO	Norway
BF	Burkina Faso	IE	Ireland	NZ	New Zealand
BG	Bulgaria	IT	Italy	PL	Poland
BJ	Benin	JP	Japan	PT	Portugal
BR	Brazil	KE	Kenya	RO	Romania
BY	Belarus	KG	Kyrgystan	RU	Russian Federation
CA	Canada	KP	Democratic People's Republic of Korea	SD	Sudan
CF	Central African Republic	KR	Republic of Korea	SE	Sweden
CG	Congo	KZ	Kazakhstan	SG	Singapore
CH	Switzerland	LI	Liechtenstein	SI	Slovenia
CI	Côte d'Ivoire	LK	Sri Lanka	SK	Slovakia
CM	Cameroon	LR	Liberia	SN	Senegal
CN	China	LT	Lithuania	SZ	Swaziland
CS	Czechoslovakia	LU	Luxembourg	TD	Chad
CZ	Czech Republic	LV	Latvia	TG	Togo
DE	Germany	MC	Monaco	TJ	Tajikistan
DK	Denmark	MD	Republic of Moldova	TT	Trinidad and Tobago
EE	Estonia	MG	Madagascar	UA	Ukraine
ES	Spain	ML	Mali	UG	Uganda
FI	Finland	MN	Mongolia	US	United States of America
FR	France	MR	Mauritania	UZ	Uzbekistan
GA	Gabon			VN	Viet Nam

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US96/10257

A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) :H04L 9/00
US CL :380/28

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 380/28; 340/825.34, 4, 23

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US, A, 4,908,873 (PHILIBERT et al) 13 MARCH 1990, See col. 5, lines 1-25.	1-32
A	US,A, 4,979,210 (NAGATA et al) 18 DECEMBER 1990, See Fig. 13.	1-32
A	US,A, 5,073,925 (NAGATA et al) 17 DECEMBER 1991, See Fig. 1.	1-32
A	US,A, 5,287,407 (HOLMES) 15 FEBRUARY 1994, See Fig. 1.	1-32
A	US,A, 5,365,586 (INDECK et al) 15 NOVEMBER 1994, See cols. 3 and 4.	1-32
A	US,A, 5,408,505 (INDECK et al) 18 APRIL 1995, See Fig. 4.	1-32

☒ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

*	Special categories of cited documents:	"T"	later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"A"	document defining the general state of the art which is not considered to be of particular relevance		
"E"	earlier document published on or after the international filing date	"X"	document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"L"	document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"Y"	document of particular relevence; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"O"	document referring to an oral disclosure, use, exhibition or other means		
"P"	document published prior to the international filing date but later than the priority date claimed	"&"	document member of the same patent family

Date of the actual completion of the international search

11 JUNE 1996

Date of mailing of the international search report

24 DEC 1996

Name and mailing address of the ISA/US
Commissioner of Patents and Trademarks
Box PCT
Washington, D.C. 20231

Facsimile No. (703) 305-3230

Authorized officer Diane
SALVATORE CANGIALOSI

Telephone No. (703) 305-1837

Form PCT/ISA/210 (second sheet)(July 1992)*

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US96/10257

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US,A, 5,412,718 (NARASIMHALU et al) 02 MAY 1995, See Figs. 6A-6C	1-32

European Patent
Office

SUPPLEMENTARY EUROPEAN SEARCH REPORT

Application Number
EP 96 91 9405

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
X	EP 0 581 317 A (INTERACTIVE HOME SYSTEMS) 2 February 1994 (1994-02-02) * page 3, line 6 - page 4, line 48 * ---	1,3,7	H04L9/00 H04N1/32
X	BENDER W ET AL: "TECHNIQUES FOR DATA HIDING" PROCEEDINGS OF THE SPIE, SPIE, BELLINGHAM, VA, US, vol. 2420, 9 February 1995 (1995-02-09), pages 164-173, XP000566794 ISSN: 0277-786X * paragraphs [03.4],[3.4.1] * ---	1,2,4,8	
L	ZHAO J ET AL: "EMBEDDING ROBUST LABELS INTO IMAGES FOR COPYRIGHT PROTECTION" PROCEEDINGS OF THE KNOWRIGHT. CONFERENCE. PROCEEDINGS OF THE INTERNATIONAL CONGRESS ON INTELLECTUAL PROPERTY RIGHTS FOR SPECIALIZED INFORMATION, KNOWLEDGE AND NEW TECHNOLOGY, XX, XX, 1995, pages 242-251, XP000571967 -----		TECHNICAL FIELDS SEARCHED (Int.Cl.6) H04N G06T

The supplementary search report has been based on the last set of claims valid and available at the start of the search.

Place of search	Date of completion of the search	Examiner
THE HAGUE	5 March 2004	Hazel, J

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

2

EPO FORM 1503 03.82 (P04C04)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US97/00651

A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) :H04L 9/00
US CL : 380/54
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 380/54, 2, 4, 9, 21, 23, 25, 28, 49, 50, 59; 283/73, 113, 17

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 5,349,655 A (MANN) 20 September 1994, see Abstract.	1
X	US 4,262,329 A (BRIGHT et al) 14 April 1981, see Abstract.	7

□ Further documents are listed in the continuation of Box C. □ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search 04 APRIL 1997	Date of mailing of the international search report 29 APR 1997
Name and mailing address of the ISA/US Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231	Authorized officer BERNARR EARL GREGORY
Facsimile No. (703) 305-3230	Telephone No. (703) 306-4153

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US97/00652

A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) :H04L 9/00
US CL :380/20
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 380/20, 54

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y, P	US, A, 5,530,759 (BRAUDAWAY ET AL) 25 June 1996, see Figs. 1-2.	1-11, 22

□ Further documents are listed in the continuation of Box C. □ See patent family annex.

*	Special categories of cited documents:	"T"	later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"A"	document defining the general state of the art which is not considered to be of particular relevance		
"E"	earlier document published on or after the international filing date	"X"	document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"L"	document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"Y"	document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"O"	document referring to an oral disclosure, use, exhibition or other means		
"P"	document published prior to the international filing date but later than the priority date claimed	"&"	document member of the same patent family

Date of the actual completion of the international search

06 MAY 1997

Date of mailing of the international search report

09 JUN 1997

Name and mailing address of the ISA/US
Commissioner of Patents and Trademarks
Box PCT
Washington, D.C. 20231

Facsimile No. (703) 305-3230

Authorized officer
SALVATORE CANGIALOSI

Telephone No. (703) 305-1837

Form PCT/ISA/210 (second sheet)(July 1992)*

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US97/00652

Box I Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)

This international report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. □ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. □ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. □ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box II Observations where unity of invention is lacking (Continuation of item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

Please See Extra Sheet.

1. □ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. □ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.

3. □ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☒ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:
1-11 and 22

Remark on Protest □ The additional search fees were accompanied by the applicant's protest.
□ No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US97/00652

BOX II. OBSERVATIONS WHERE UNITY OF INVENTION WAS LACKING
This ISA found multiple inventions as follows:

Group I, Claims 1-11, 22, drawn to an method of generating an encrypted digital watermark.

Group II, Claims 12-21 and 23 method of making and using a digital watermark.

The inventions listed as Groups I-II do not relate to a single inventive concept under PCT Rule 13.1 because under PCT Rule 13.2, they lack the same or corresponding technical features for the following Reasons: The invention of Group I lack the separate software, hardware devices or content monitoring. The invention of Group II lack the pseudo-Random key.

Form PCT/ISA/210 (extra sheet)(July 1992)★

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US97/11455

A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) :G09C 5/00 H04L 9/00
US CL :380/54, 3, 4, 23, 55; 283/73, 113, 17
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 380/54, 3, 4, 23, 55, 49, 51, 59; 283/73, 113, 17

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A, E	US 5,664,018 A (LEIGHTON) 02 SEPTEMBER 1997	1-27
A, P	US, 5,636,292 A (RHOADS) 03 JUNE 1997	1-27
A, P	US 5,617,119 A (BRIGGS ET AL.) 01 APRIL 1997	1-27
A, P	US 5,568,570 A (RABBANI) 22 OCTOBER 1996	1-27
A, P	US 5,530,759 A (BRAUDAWAY, ET AL.) 25 JUNE 1996	1-27
A	US 5,493,677 A (BALOGH, ET AL.) 20 FEBRUARY 1996	1-27

□ Further documents are listed in the continuation of Box C. □ See patent family annex.

*	Special categories of cited documents:	"T"	later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"A"	document defining the general state of the art which is not considered to be of particular relevance		
"E"	earlier document published on or after the international filing date	"X"	document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"L"	document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"Y"	document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"O"	document referring to an oral disclosure, use, exhibition or other means		
"P"	document published prior to the international filing date but later than the priority date claimed	"&"	document member of the same patent family

Date of the actual completion of the international search 23 OCTOBER 1997	Date of mailing of the international search report 23 DEC 1997
Name and mailing address of the ISA/US Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231 Facsimile No. (703) 305-3230	Authorized officer for DAVID CAIN Telephone No. (703) 305-1836

Form PCT/ISA/210 (second sheet)(July 1992)★

INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 99/07262

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 H04N1/32

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 H04N H04L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 5 613 004 A (MOSKOWITZ SCOTT A ET AL) 18 March 1997 (1997-03-18) abstract column 6, line 30 - column 9, line 49 column 16, line 8 - line 64	1,2, 15-17, 26-28, 30-38,42
A	DELAIGLE J -F ET AL: "DIGITAL WATERMARKING" PROCEEDINGS OF THE SPIE, vol. 2659, 1 February 1996 (1996-02-01), pages 99-110, XP000604065 the whole document	1,5,6

-/--

☒ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search 12 July 1999	Date of mailing of the international search report 21/07/1999
Name and mailing address of the ISA European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Authorized officer Hubeau, R

INTERNATIONAL SEARCH REPORT

Inte onal Application No
PCT/US 99/07262

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
A	SCHNEIDER M ET AL: "ROBUST CONTENT BASED DIGITAL SIGNATURE FOR IMAGE AUTHENTICATION" PROCEEDINGS OF THE INTERNATIONAL CONFERENCE ON IMAGE PROCESSING (IC, LAUSANNE, SEPT. 16 - 19, 1996, vol. 3, 16 September 1996 (1996-09-16), pages 227-230, XP002090178 INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERSISBN: 0-7803-3259-8 the whole document	1,17,18, 26-28
A	COX I J ET AL: "SECURE SPREAD SPECTRUM WATERMARKING FOR MULTIMEDIA" IEEE TRANSACTIONS ON IMAGE PROCESSING, vol. 6, no. 12, 1 December 1997 (1997-12-01), pages 1673-1686, XP000724633 ISSN: 1057-7149 the whole document	1-3,5,6, 26,27
A,P	PING WAH WONG: "A Public Key Watermark for Image Verification and Authentication" IEEE INTERNATIONAL CONFERENCE ON IMAGE PROCESSING, vol. 1, 4 - 7 October 1998, pages 455-459, XP002108799 Los Alamitos, CA, USA the whole document	1-4

INTERNATIONAL SEARCH REPORT

Information on patent family members

Inte onal Application No
PCT/US 99/07262

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 5613004 A	18-03-1997	EP 0872073 A WO 9642151 A US 5687236 A	21-10-1998 27-12-1996 11-11-1997

Form PCT/ISA/210 (patent family annex) (July 1992)

PATENT COOPERATION TREATY

From the INTERNATIONAL SEARCHING AUTHORITY

To: FLOYD B. CHAPMAN
BAKER BOTTS L.L.P.
1299 PENNSYLVANIA AVE., NW
WASHINGTON DC 20004

PCT

NOTIFICATION OF TRANSMITTAL OF THE INTERNATIONAL SEARCH REPORT OR THE DECLARATION

(PCT Rule 44.1)

	Date of Mailing *(day/month/year)* 18 AUG 2000
Applicant's or agent's file reference 066112.0135	**FOR FURTHER ACTION** See paragraphs 1 and 4 below
International application No. PCT/US00/06522	International filing date *(day/month/year)* 14 MARCH 2000
Applicant BLUE SPIKE, INC.	

1. ☒ The applicant is hereby notified that the international search report has been established and is transmitted herewith.

Filing of amendments and statement under Article 19:
The applicant is entitled, if he so wishes, to amend the claims of the international application (see Rule 46):

When? The time limit for filing such amendments is normally 2 months from the date of transmittal of the international search report; however, for more details, see the notes on the accompanying sheet.

Where? Directly to the International Bureau of WIPO
34, chemin des Colombettes
1211 Geneva 20, Switzerland
Facsimile No.: (41-22) 740.14.35

For more detailed instructions, see the notes on the accompanying sheet.

2. □ The applicant is hereby notified that no international search report will be established and that the declaration under Article 17(2)(a) to that effect is transmitted herewith.

3. □ **With regard to the protest** against payment of (an) additional fee(s) under Rule 40.2, the applicant is notified that:

□ the protest together with the decision thereon has been transmitted to the International Bureau together with the applicant's request to forward the texts of both the protest and the decision thereon to the designated Offices.

□ no decision has been made yet on the protest; the applicant will be notified as soon as a decision is made.

4. **Further action(s):** The applicant is reminded of the following:

Shortly after **18 months** from the priority date, the international application will be published by the International Bureau. If the applicant wishes to avoid or postpone publication, a notice of withdrawal of the international application, or of the priority claim, must reach the International Bureau as provided in rules 90 *bis* 1 and 90 *bis* 3, respectively, before the completion of the technical preparations for international publication.

Within **19 months** from the priority date, a demand for international preliminary examination must be filed if the applicant wishes to postpone the entry into the national phase until 30 months from the priority date (in some Offices even later).

Within **20 months** from the priority date, the applicant must perform the prescribed acts for entry into the national phase before all designated Offices which have not been elected in the demand or in a later election within 19 months from the priority date or could not be elected because they are not bound by Chapter II.

Name and mailing address of the ISA/US Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231	Authorized officer PAUL E. CALLAHAN Eugenia Logan

PATENT COOPERATION TREATY

PCT

INTERNATIONAL SEARCH REPORT

(PCT Article 18 and Rules 43 and 44)

Applicant's or agent's file reference 066112.0135	FOR FURTHER ACTION	see Notification of Transmittal of International Search Report (Form PCT/ISA/220) as well as, where applicable, item 5 below.
International application No. PCT/US00/06522	International filing date *(day/month/year)* 14 MARCH 2000	(Earliest) Priority Date *(day/month/year)* 24 MARCH 1999
Applicant BLUE SPIKE, INC.		

This international search report has been prepared by this International Searching Authority and is transmitted to the applicant according to Article 18. A copy is being transmitted to the International Bureau.

This international search report consists of a total of 4 sheets.

☒ It is also accompanied by a copy of each prior art document cited in this report.

1. **Basis of the report**

a. With regard to the language, the international search was carried out on the basis of the international application in the language in which it was filed, unless otherwise indicated under this item.

□ the international search was carried out on the basis of a translation of the international application furnished to this Authority (Rule 23.1(b)).

b. With regard to any nucleotide and/or amino acid sequence disclosed in the international application, the international search was carried out on the basis of the sequence listing:

□ contained in the international application in written form.

□ filed together with the international application in computer readable form.

□ furnished subsequently to this Authority in written form.

□ furnished subsequently to this Authority in computer readable form.

□ the statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.

□ the statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished.

2. □ **Certain claims were found unsearchable** (See Box I).

3. □ **Unity of invention is lacking** (See Box II).

4. With regard to the **title**,

☒ the text is approved as submitted by the applicant.

□ the text has been established by this Authority to read as follows:

5. With regard to the **abstract**,

□ the text is approved as submitted by the applicant.

☒ the text has been established, according to Rule 38.2(b), by this Authority as it appears in Box III. The applicant may, within one month from the date of mailing of this international search report, submit comments to this Authority.

6. The figure of the **drawings** to be published with the abstract is Figure No. 1

☒ as suggested by the applicant.

□ because the applicant failed to suggest a figure.

□ because this figure better characterizes the invention.

□ None of the figures.

INTERNATIONAL SEARCH REPORT

International application No. PCT/US00/06522	

Box III TEXT OF THE ABSTRACT (Continuation of item 5 of the first sheet)

The present invention is a method for protecting a data signal where the method comprises the following steps: applying a data reduction technique [200] to the signal to produce a reduced signal, subtracting [60] the reduced data signal from the original signal to produce a remainder signal [39], embedding [300] a first watermark into the reduced data signal to produce a watermarked reduced data signal, and adding [50] the watermarked reduced signal to the remainder signal to produce an output signal [90]. A second watermark [301] may be embedded into the remainder signal [39] before the final addition [50] step. Cryptographic techniques may be employed to encrypt the remainder signal and/or the reduced signal prior to the addition step [50].

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US00/06522

A. CLASSIFICATION OF SUBJECT MATTER

IPC(7) : HO4N 7/167
US CL : 713/176
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 380/200,206,207,237,238; 705/54; 704/216-218, 226-228, 500, 501, 503,504; 713/176; 360/49; 348/461, 462

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Watermark Digest: Art Unit 2767

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

IEEE, EAST, Internet, Dialog

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X,E	US 6,061,793 A [TEWFIK et al.] 09 MAY 2000, Entire Document	1-25
X	US 5,809,139 A [GIROD et al.] 15 SEPTMBER 1998, Entire Document	1-25
X	US 5,848,155 A [COX] 08 DECEMBER 1998, Entire Document	1-25
A,P	US 5,889,868 A [MOSKOWITZ et al.] 30 MARCH 1999, Entire Document	1-25
A,P	US 5,915,027 A [COX et al.] 22 JUNE 1999, Entire Document	1-25
A,P	US 5,940,134 A [WIRTZ] 17 AUGUST 1999, Entire Document	1-25

☒ Further documents are listed in the continuation of Box C. □ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search 30 JUNE 2000	Date of mailing of the international search report 18 AUG 2000
Name and mailing address of the ISA/US Commissioner of Patents and Trademarks	Authorized officer PAUL F. CALLAHAN

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US00/06522

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A,P	US 5,991,426 A [COX et al.] 23 NOVEMBER 1999, Entire Document	1-25
A,E	US 6,069,914 A [COX] 30 MAY 2000, Entire Document	1-25
A,P	US 5,943,422 A [VAN WIE et al.] 24 AUGUST 1999, Entire Document	1-25

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US00/06522

A. CLASSIFICATION OF SUBJECT MATTER

IPC(7) : HO4N 7/167
US CL : 713/176
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 380/200,206,207,237,238; 705/54; 704/216-218, 226-228, 500, 501, 503,504; 713/176; 360/49; 348/461, 462

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Watermark Digest: Art Unit 2767

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

IEEE, EAST, Internet, Dialog

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X,E	US 6,061,793 A [TEWFIK et al.] 09 MAY 2000, Entire Document	1-25
X	US 5,809,139 A [GIROD et al.] 15 SEPTMBER 1998, Entire Document	1-25
X	US 5,848,155 A [COX] 08 DECEMBER 1998, Entire Document	1-25
A,P	US 5,889,868 A [MOSKOWITZ et al.] 30 MARCH 1999, Entire Document	1-25
A,P	US 5,915,027 A [COX et al.] 22 JUNE 1999, Entire Document	1-25
A,P	US 5,940,134 A [WIRTZ] 17 AUGUST 1999, Entire Document	1-25

☒ Further documents are listed in the continuation of Box C. □ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

30 JUNE 2000

Date of mailing of the international search report

18 AUG 2000

Name and mailing address of the ISA/US
Commissioner of Patents and Trademarks
Box PCT
Washington, D.C. 20231
Facsimile No. (703) 305-3230

Authorized officer
PAUL E. CALLAHAN
Eugenio Logan
Telephone No. (703) 305-1

Form PCT/ISA/210 (second sheet) (July 1998)★

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US00/06522

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A,P	US 5,991,426 A [COX et al.] 23 NOVEMBER 1999, Entire Document	1-25
A,E	US 6,069,914 A [COX] 30 MAY 2000, Entire Document	1-25
A,P	US 5,943,422 A [VAN WIE et al.] 24 AUGUST 1999, Entire Document	1-25

European Patent Office

SUPPLEMENTARY EUROPEAN SEARCH REPORT

Application Number
EP 00 91 9398

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
X	WO 98 37513 A (TELSTRA R & D MAN PTY LTD ;BIGGAR MICHAEL (AU); JOHNSON ANDREW (AU) 27 August 1998 (1998-08-27) * page 6, line 25 - page 7, line 10 * ---	6	H04N7/167 H04N7/26 H04N1/32 G06F17/30
Y	US 4 969 204 A (MELNYCHUCK PAUL W ET AL) 6 November 1990 (1990-11-06) * column 2, line 9 - column 2, line 48 * ---	1-10	
Y	EP 0 651 554 A (EASTMAN KODAK CO) 3 May 1995 (1995-05-03) * column 6, line 43 - column 9, line 19; figure 2 * ---	1-10	
A	JOHNSON A ET AL: "TRANSFORM PERMUTED WATERMARKING FOR COPYRIGHT PROTECTION OF DIGITAL VIDEO" IEEE GLOBECOM 1998. GLOBECOM '98. THE BRIDGE TO GLOBAL INTEGRATION. SYDNEY, NOV. 8 - 12, 1998, IEEE GLOBAL TELECOMMUNICATIONS CONFERENCE, NEW YORK, NY: IEEE, US, vol. 2, 1998, pages 684-689, XP000825846 ISBN: 0-7803-4985-7 * page 685, left-hand column, paragraph 2 - page 685, left-hand column, paragraph 3 * ---	1-10	TECHNICAL FIELDS SEARCHED (Int.Cl.7) H04N G06F
P,X	WO 99 62044 A (HANDEL THEODORE G ;UNIV CALIFORNIA (US); SANDFORD MAXELL T II (US)) 2 December 1999 (1999-12-02) * abstract * * page 4, line 17 - page 5, line 5 * -----	6	

The supplementary search report has been based on the last set of claims valid and available at the start of the search.

Place of search	Date of completion of the search	Examiner
MUNICH	27 June 2002	Schoeyer, M

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

3

P ENT COOPERATION TREATY

From the INTERNATIONAL SEARCHING AUTHORITY

To:

BAKER BOTTS L.L.P.
Attn. CHAPMAN, Floyd B.
THE WARMER
1299 PENNSYLVANIA AVENUE, N.W.
WASSHINGTON, D.C. 20004
UNITED STATES OF AMERICA

PCT

INVITATION TO PAY ADDITIONAL FEES

(PCT Article 17(3)(a) an[illegible]

	Date of mailing *(day/month/year)* 15/03/2001
Applicant's or agent's file reference 066358.0106 031890.0007	PAYMENT DUE within 45 ~~months~~/days from the above date of mailing
International application No. PCT/US 00/18411	International filing date *(day/month/year)* 05/07/2000
Applicant MOSKOWITZ, Scott A.	

1. This International Searching Authority

(i) considers that there are 2 *(number of)* inventions claimed in the international application covered by the claims indicated ~~below~~/on the extra sheet:

and it considers that the international application does not comply with the requirements of unity of invention (Rules 13.1, 13.2 and 13.3) for the reasons indicated ~~below~~/on the extra sheet:

(ii) ☒ has carried out a partial international search (see Annex) □ will establish the international search report on those parts of the international application which relate to the invention first mentioned in claims Nos.:
1-5, 26-29

(iii) will establish the international search report on the other parts of the international application only if, and to the extent to which, additional fees are paid

2. The applicant is hereby **invited,** within the time limit indicated above, to pay the amount indicated below:

EUR 945.00 x 1 = EUR 945.00
Fee per additional invention number of additional inventions total amount of additional fees

Or, ________ x ________ = ________

The applicant is informed that, according to Rule 40.2(c), the payment of any additional fee may be made under protest, i.e., a reasoned statement to the effect that the international application complies with the requirement of unity of invention or that the amount of the required additional fee is excessive.

3. □ Claim(s) Nos. ________ have been found to be unsearchable under Article 17(2)(b) because of defects under Article 17(2)(a) and therefore have not been included with any invention.

Name and mailing address of the International Searching Authority European Patent Office, P.B. 5818 Patentlaan 2 NL-2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Authorized officer Marja Brouwers

Form PCT/ISA/206 (July 1992)

COMMUNICATIC. ,ELATING TO THE RESULTS OF THE PARTIAL INTERNATIONAL SEARCH

In. ,ational Application No
PCT/US 00/18411

1. The present communication is an Annex to the invitation to pay additional fees (Form PCT/ISA/206). It shows the results of the international search established on the parts of the international application which relate to the invention first mentioned in claims Nos.:
1-5, 26-29

2. This communication is not the international search report which will be established according to Article 18 and Rule 43.

3. If the applicant does not pay any additional search fees, the information appearing in this communication will be considered as the result of the international search and will be included as such in the international search report.

4. If the applicant pays additional fees, the international search report will contain both the information appearing in this communication and the results of the international search on other parts of the international application for which such fees will have been paid.

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	NL 1 005 523 C (EINDHOVEN TECH HOCHSCHULE) 15 September 1998 (1998-09-15) abstract; figure 4 page 1, line 35 -page 3, line 9 page 9, line 21 -page 10, line 5 ---	1,2, 26-29
X	WO 97 44736 A (APPLE COMPUTER) 27 November 1997 (1997-11-27) abstract; figures 2A,2B,2C,3 page 2, line 35 -page 3, line 27 page 9, line 10 -page 11, line 28	1,2
Y	---	3,4
Y	EP 0 649 261 A (CANON KK) 19 April 1995 (1995-04-19) page 3, line 53 -page 4, line 5 page 7, line 18 - line 23 ---	3,4
A	US 5 974 141 A (SAITO MAKOTO) 26 October 1999 (1999-10-26) abstract; figures 4A-4G column 8, line 24 - line 67 -----	5,26

□ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

INVITATION TO PAY ADDITIONAL FEES

International application No.

PCT/US 00/18411

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. Claims: 1-5, 26-29

   Protecting the distribution of digital data to be used with a digital player charachterized by encrypting format information and allowing low quality play back in case of lack of decrypting key.

2. Claims: 6-25

   Digital signal encrypting technique combining transfer functions with predetermined key creation.

This finding is based on the following reasons.

The prior art has been identified as NL1005523 (D1). This document shows a method for protecting the distribution of digital information, the digital information including two subparts, a digital sample and format information, comprising the steps of: identifying and separating the two subparts; encoding the format information subpart using a key; recombining the encoded first subpart with the un-encoded second subpart, generating in this way an encoded version of the digital information. A predetermined key corresponding to the encoding key is then required for the decryption of the format information. All the features which form the subject matter of claims 1 and 2 are then disclosed by D1 (see following passages: abstract; page 1, line 35 - page 3, line 9; page 9, line 21 - page 10, line 5; fig. 4)

From the comparison between D1 and the 1st invention (see claim 3) the following technical featuree can be seen to make a contribution over this prior art (in the sense of PCT rule 13.2):
- the digital information is configured to be used with a digital player and the information output from said digital player has a degraded quality unless it is provided with a predetermined key (Special Technical Features 1, STF1).
From these STF1 the objective problem to be solved can be summarized as:
- permitting preview of distributed digital information

From the comparison between D1 and the 2nd invention (see claim 6) the following feature can be seen to make a contribution over the same prior art:
- using a transfer function-based mask set for creating a key to manipulate data at the inherent granularity of the file format of a digital sample (STF2).
From this STF2 the objective problem to be solved can be summarized as:
- improving the security of techniques for data protection

The above analysis shows that inventions 1 and 2 do not have same or similar Special Technical Features. Furthermore, a comparison of the objective problem 1 with the objective problem 2, both seen in the light of the description and the drawings of the present application, indicates that there is no technical correspondence between these problems nor do they show any corresponding technical effect.

INVITATION TO PAY ADDITIONAL FEES

International application No.
PCT/US 00/18411

As a result, inventions 1 and 2 fail to demonstrate a single general inventive concept as required by PCT rule 13.1.

ent Family Annex

Information on patent family members

Inte onal Application No
PCT/US 00/18411

Patent document cited in search report		Publication date	Patent family member(s)		Publication date
NL 1005523	C	15-09-1998	NONE		
WO 9744736	A	27-11-1997	AU	3206397 A	09-12-1997
EP 0649261	A	19-04-1995	JP US	7115638 A 5933499 A	02-05-1995 03-08-1999
US 5974141	A	26-10-1999	US US US	6076077 A 6002772 A 6097818 A	13-06-2000 14-12-1999 01-08-2000

INTERNATIONAL SEARCH REPORT

I nal Application No
PCT/US 00/18411

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 G11B20/00 G06F1/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 G11B G06F H04N

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	NL 1 005 523 C (EINDHOVEN TECH HOCHSCHULE) 15 September 1998 (1998-09-15) abstract; figure 4 page 1, line 35 -page 3, line 9 page 9, line 21 -page 10, line 5 ——	1,2, 26-29
X	WO 97 44736 A (APPLE COMPUTER) 27 November 1997 (1997-11-27) abstract; figure 4 page 2, line 35 -page 3, line 27 page 9, line 10 -page 11, line 28	1,2
Y	—— -/—	3,4

☒ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search 20 July 2001	Date of mailing of the international search report 30. 07. 2001
Name and mailing address of the ISA European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31–70) 340–2040, Tx. 31 651 epo nl, Fax: (+31–70) 340–3016	Authorized officer Sigolo, A

INTERNATIONAL SEARCH REPORT

ional Application No
PCT/US 00/18411

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
X	US 5 687 236 A (MOSKOWITZ SCOTT A ET AL) 11 November 1997 (1997-11-11) cited in the application column 5, line 1 -column 6, line 37 column 7, line 54 -column 10, line 11 column 11, line 31 -column 12, line 10 column 15, line 42 -column 16, line 32	6-12, 19-21
A		22,23
A	US 5 974 141 A (SAITO MAKOTO) 26 October 1999 (1999-10-26) abstract; figures 4A-4G column 8, line 24 - line 67	5,26
X	WO 99 52271 A (MOSKOWITZ SCOTT A) 14 October 1999 (1999-10-14) abstract page 11, line 15 -page 13, line 13	6,7,10
Y	EP 0 649 261 A (CANON KK) 19 April 1995 (1995-04-19) page 3, line 53 -page 4, line 5 page 7, line 18 - line 23	3,4
A	WO 99 63443 A (DATAMARK TECHNOLOGIES PTE LTD; HO ANTHONY TUNG SHUEN (SG); TAM SIU) 9 December 1999 (1999-12-09) page 2, line 10 -page 5, line 16	6-8,11, 12

INTERNATIONAL SEARCH REPORT

ernational application No.
PCT/US 00/18411

Box I Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)

This International Search Report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. □ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. □ Claims Nos.:
because they relate to parts of the International Application that do not comply with the prescribed requirements to such an extent that no meaningful International Search can be carried out, specifically:

3. □ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box II Observations where unity of invention is lacking (Continuation of item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

see additional sheet

1. ☒ As all required additional search fees were timely paid by the applicant, this International Search Report covers all searchable claims.

2. □ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.

3. □ As only some of the required additional search fees were timely paid by the applicant, this International Search Report covers only those claims for which fees were paid, specifically claims Nos.:

4. □ No required additional search fees were timely paid by the applicant. Consequently, this International Search Report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

□ The additional search fees were accompanied by the applicant's protest.

☒ No protest accompanied the payment of additional search fees.

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. Claims: 1-5,26-29

   Protecting the distribution of digital data to be used with a digital player characterized by encrypting format information and allowing low quality play back in case of lack of decrypting key.

2. Claims: 6-25

   Digital signature encrypting technique combining transfer functions with predetermined key creation.

INTERNATIONAL SEARCH REPORT

Information on patent family members

tional Application No
PCT/US 00/18411

Patent document cited in search report		Publication date	Patent family member(s)		Publication date
NL 1005523	C	15-09-1998	NONE		
WO 9744736	A	27-11-1997	AU	3206397 A	09-12-1997
US 5687236	A	11-11-1997	US	5613004 A	18-03-1997
			EP	0872073 A	21-10-1998
			WO	9642151 A	27-12-1996
US 5974141	A	26-10-1999	US	6076077 A	13-06-2000
			US	6002772 A	14-12-1999
			US	6097818 A	01-08-2000
WO 9952271	A	14-10-1999	US	6205249 B	20-03-2001
			EP	1068720 A	17-01-2001
EP 0649261	A	19-04-1995	JP	7115638 A	02-05-1995
			US	5933499 A	03-08-1999
WO 9963443	A	09-12-1999	AU	7683398 A	20-12-1999
			EP	1103026 A	30-05-2001

INTERNATIONAL SEARCH REPORT

Int   onal Application No
PCT/US 00/33126

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7   G06F17/60

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7   G06F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5 903 721 A (SIXTUS TIMOTHY) 11 May 1999 (1999-05-11) abstract column 3, line 26 -column 5, line 31 —	1-19
X	US 5 790 677 A (SPELMAN JEFFREY F ET AL) 4 August 1998 (1998-08-04) abstract column 2, line 6 -column 4, line 39 —	1-19
X	WO 96 29795 A (MICALI SILVIO) 26 September 1996 (1996-09-26) abstract page 5, line 27 -page 8, line 6 — -/—	1-19

☒ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search

20 March 2001

Date of mailing of the international search report

04.04.01

Name and mailing address of the ISA

European Patent Office, P.B. 5818 Patentlaan 2
NL – 2280 HV Rijswijk
Tel. (+31–70) 340–2040, Tx. 31 651 epo nl,
Fax: (+31–70) 340–3016

Authorized officer

Corcoran, P

Form PCT/ISA/210 (second sheet) (July 1992)

INTERNATIONAL SEARCH REPORT

In onal Application No
PCT/US 00/33126

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
X	WO 97 24833 A (MICALI SILVIO) 10 July 1997 (1997-07-10) abstract page 2, line 12 -page 5, line 8	1-19
A	US 5 539 735 A (MOSKOWITZ SCOTT A) 23 July 1996 (1996-07-23) abstract column 1, line 60 -column 4, line 29	1-19
A	SIRBU M ET AL: "NETBILL: AN INTERNET COMMERCE SYSTEM OPTIMIZED FOR NETWORK DELIVERED SERVICES" DIGEST OF PAPERS OF THE COMPUTER SOCIETY COMPUTER CONFERENCE (SPRING) COMPCON,US,LOS ALAMITOS, IEEE COMP. SOC. PRESS, vol. CONF. 40, 5 March 1995 (1995-03-05), pages 20-25, XP000577034 ISBN: 0-7803-2657-1 The whole document	1-19
A	SCHUNTER M ET AL: "A status report on the SEMPER framework for secure electronic commerce" COMPUTER NETWORKS AND ISDN SYSTEMS,NL,NORTH HOLLAND PUBLISHING. AMSTERDAM, vol. 30, no. 16-18, 30 September 1998 (1998-09-30), pages 1501-1510, XP004138681 ISSN: 0169-7552 2. Model for electronic commerce 3. The SEMPER framework	1-19
A	KONRAD K ET AL: "Trust and electronic commerce-more than a technical problem" PROCEEDINGS OF THE 18TH IEEE SYMPOSIUM ON RELIABLE DISTRIBUTED SYSTEMS, PROCEEDINGS 18TH IEEE SYMPOSIUM ON RELIABLE DISTRIBUTED SYSTEMS, LAUSANNE, SWITZERLAND, 19-22 OCT. 1999, pages 360-365, XP002162270 1999, Los Alamitos, CA, USA, IEEE Comput. Soc, USA ISBN: 0-7695-0290-3 3. Trust, Security and Electronic Commerce 4. Technology and Institutions	1-19

-/--

INTERNATIONAL SEARCH REPORT

Inte onal Application No
PCT/US 00/33126

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
A	KINI A ET AL: "Trust in electronic commerce: definition and theoretical considerations" PROCEEDINGS OF THE THIRTY-FIRST HAWAII INTERNATIONAL CONFERENCE ON SYSTEM SCIENCES (CAT. NO.98TB100216), PROCEEDINGS OF THE THIRTY-FIRST HAWAII INTERNATIONAL CONFERENCE ON SYSTEM SCIENCES, KOHALA COAST, HI, USA, 6-9 JAN. 1998, pages 51-61, XP002162271 1998, Los Alamitos, CA, USA, IEEE Comput. Soc, USA ISBN: 0-8186-8255-8 1.3 The Significance of Trust in Electronic Commerce, ---	1-19
A	STEINAUER D D ET AL: "Trust and traceability in electronic commerce" STANDARD VIEW, SEPT. 1997, ACM, USA, vol. 5, no. 3, pages 118-124, XP002162272 ISSN: 1067-9936 the whole document ---	1-19
A	US 5 687 236 A (MOSKOWITZ SCOTT A ET AL) 11 November 1997 (1997-11-11) abstract ---	8,9
A	US 5 745 569 A (MOSKOWITZ SCOTT A ET AL) 28 April 1998 (1998-04-28) abstract ---	8,9

INTERNATIONAL SEARCH REPORT

Information on patent family members

Inte onal Application No
PCT/US 00/33126

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 5903721 A	11-05-1999	AU 6549498 A	29-09-1998
		DE 1008022 T	25-01-2001
		EP 1008022 A	14-06-2000
		ES 2150892 T	16-12-2000
		NO 994428 A	09-11-1999
		WO 9840809 A	17-09-1998
US 5790677 A	04-08-1998	NONE	
WO 9629795 A	26-09-1996	WO 9806198 A	12-02-1998
		CA 2215908 A	26-09-1996
		EP 0815671 A	07-01-1998
		US 5553145 A	03-09-1996
		US 5629982 A	13-05-1997
		US 5666420 A	09-09-1997
		US 6137884 A	24-10-2000
		US 6141750 A	31-10-2000
		EP 0917781 A	26-05-1999
		JP 2000515649 T	21-11-2000
WO 9724833 A	10-07-1997	US 5615269 A	25-03-1997
		AU 1951497 A	28-07-1997
US 5539735 A	23-07-1996	US 5428606 A	27-06-1995
		WO 9701892 A	16-01-1997
US 5687236 A	11-11-1997	US 5613004 A	18-03-1997
		EP 0872073 A	21-10-1998
		WO 9642151 A	27-12-1996
US 5745569 A	28-04-1998	AU 1829497 A	11-08-1997
		WO 9726732 A	24-07-1997

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US 00/33126

Box I Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)

This International Search Report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. □ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☒ Claims Nos.: 20-186
because they relate to parts of the International Application that do not comply with the prescribed requirements to such an extent that no meaningful International Search can be carried out, specifically:
see FURTHER INFORMATION sheet PCT/ISA/210

3. □ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box II Observations where unity of invention is lacking (Continuation of item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. □ As all required additional search fees were timely paid by the applicant, this International Search Report covers all searchable claims.

2. □ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.

3. □ As only some of the required additional search fees were timely paid by the applicant, this International Search Report covers only those claims for which fees were paid, specifically claims Nos.:

4. □ No required additional search fees were timely paid by the applicant. Consequently, this International Search Report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

□ The additional search fees were accompanied by the applicant's protest.

□ No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

International Application No. PCT/US 00 /33126

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

Continuation of Box I.2

Claims Nos.: 20-186

In view of the large number and also the wording of the claims presently on file, which render it difficult, if not impossible, to determine the matter for which protection is sought, the present application fails to comply with the clarity and conciseness requirements of Article 6 PCT (see also Rule 6.1(a) PCT) to such an extent that a meaningful search is impossible.

Moreover, the proliferation of independent claims and the broad manner in which these have been worded make it impossible to determine which parts of the claims may be said to define subject-matter for which protection might legitimately be sought (Article 6 PCT). For these reasons, a meaningful search over the whole breadth of the claim(s) is impossible.

Consequently, the search has been restricted to the subject matter recited in claims 1-19.

The applicant's attention is drawn to the fact that claims, or parts of claims, relating to inventions in respect of which no international search report has been established need not be the subject of an international preliminary examination (Rule 66.1(e) PCT). The applicant is advised that the EPO policy when acting as an International Preliminary Examining Authority is normally not to carry out a preliminary examination on matter which has not been searched. This is the case irrespective of whether or not the claims are amended following receipt of the search report or during any Chapter II procedure.

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
15 March 2001 (15.03.2001)

PCT

(10) International Publication Number
WO 01/18628 A3

(51) International Patent Classification⁷: H04L 9/32, H04N 7/167

(21) International Application Number: PCT/US00/21189

(22) International Filing Date: 4 August 2000 (04.08.2000)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:

60/147,134	4 August 1999 (04.08.1999)	US
60/213,489	23 June 2000 (23.06.2000)	US

(71) Applicant *(for all designated States except US)*: BLUE SPIKE, INC. [US/US]; 16711 Collins Avenue #2505, Miami, FL 33160 (US).

(72) Inventors; and
(75) Inventors/Applicants *(for US only)*: MOSKOWITZ, Scott, A. [US/US]; 16711 Collins Avenue #2505, Miami, FL 33160 (US). BERRY, Michael [US/US]; 12401 Princess Jeanne, Albuquerque, NM 87112 (US).

(74) Agents: CHAPMAN, Floyd, B. et al.; Baker Botts, LLP, The Warner, 1299 Pennsylvania Avenue, N.W., Washington, DC 20004 (US).

(81) Designated States *(national)*: JP, US.

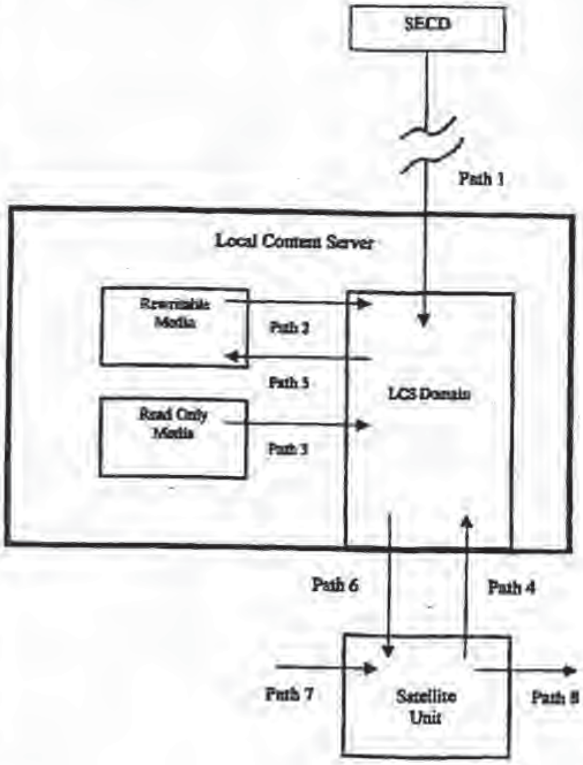
(84) Designated States *(regional)*: European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE).

Published:
— *with international search report*

(88) Date of publication of the international search report: 22 November 2001

[Continued on next page]

(54) Title: A SECURE PERSONAL CONTENT SERVER



(57) Abstract: A local content server system (LCS) for creating a secure environment for digital content is disclosed, which system comprises: a communications port in communication (Path 1) for connecting the LCS via a network to at least one Secure Electronic Content Distributor (SECD), which SECD is capable of storing a plurality of data sets, is capable of receiving a request to transfer at least one content data set, is capable of transmitting the at least one content data set in a secured transmission; a rewritable storage medium (Rewritable Media) whereby content received from outside the LCS may be stored and retrieved; a domain processor that imposes rules and procedures for content being transferred between the LCS and devices outside the LCS; and a programmable address module which can be programmed with an identification code uniquely associated with the LCS. Optionally, the system may further comprise: an interface to permit the LCS to communicate with one or more Satellite Units (SU).

WO 01/18628 A3

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US00/21189

A. CLASSIFICATION OF SUBJECT MATTER

IPC(7) :H04L 9/32; H04N 7/167
US CL :713/176; 705/51, 52, 57; 380/203, 231
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 713/153; 705/51, 52, 57; 380/203, 231

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

APS EAST/BRS text search terms: watermark, audio, copy protect, distribution

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 5,636,292 A (RHOADS) 03 JUNE 1997, col. 33, line 42-col. 34, line 8.	4, 6-15 and 17-29
Y	US 5,629,980 A (STEFIK et al) 13 MAY 1997, col. 26, line 37-col. 27, line 26.	1-30
Y, P	US 5,943,422 A (VAN WIE et al) 24 AUGUST 1999, col. 6, line 53-62 and col. 10, line 18-56.	4, 6-15 and 17-29.
Y	US 5,636,276 A (BRUGGER) 03 JUNE 1997, col. 5, line 53-col. 6, line 8.	1-30.
Y	US 5,341,429 A (STRINGER et al) 23 AUGUST 1994, col. 4, lines 1-22.	30

□ Further documents are listed in the continuation of Box C. □ See patent family annex.

*	Special categories of cited documents:	"T"	later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"A"	document defining the general state of the art which is not considered to be of particular relevance		
"E"	earlier document published on or after the international filing date	"X"	document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"L"	document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"Y"	document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"O"	document referring to an oral disclosure, use, exhibition or other means		
"P"	document published prior to the international filing date but later than the priority date claimed	"&"	document member of the same patent family

Date of the actual completion of the international search 26 JANUARY 2001	Date of mailing of the international search report 23 MAR 2001
Name and mailing address of the ISA/US Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231	Authorized officer GILBERTO BARRÓN Peggy Harrod
Facsimile No. (703) 305-3230	Telephone No. (703) 305-3900

Form PCT/ISA/210 (second sheet) (July 1998)★

2280 HV RIJSWIJK
NETHERLANDS
Tel.: +31 70 340 2040
Fax: +31 70 340 3016

Vossius & Partner
Siebertstrasse 4
81675 München
ALLEMAGNE

EPO Customer Services
Tel.: +31 (0)70 340 45 00

Date
19.10.07

Reference B3379 EP/1	Application No./Patent No. 07112420.0 - 1228
Applicant/Proprietor Wistaria Trading, Inc.	

Communication

The extended European search report is enclosed.

The extended European search report includes, pursuant to Rule 44a EPC, the European search report (R. 44 EPC) or the partial European search report/ declaration of no search (R. 45 EPC) and the European search opinion.

Copies of documents cited in the European search report are attached.

□ additional set(s) of copies of such documents is (are) enclosed as well.

The following have been approved:

☑ Abstract ☑ Title

□ the Abstract was modified and the definitive text is attached to this communication.

The following figure will be published together with the abstract:

Refund of the search fee

If applicable under Article 10 Rules relating to fees, a separate communication from the Receiving Section on the refund of the search fee will be sent later.

European Patent Office

Best Available Copy

EUROPEAN SEARCH REPORT

Application Number
EP 07 11 2420

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	EP 0 581 317 A (INTERACTIVE HOME SYSTEMS) 2 February 1994 (1994-02-02) * page 3, line 6 - page 4, line 48 * -----	1,3,7	INV. H04L9/00 H04N1/32
X	BENDER W ET AL: "TECHNIQUES FOR DATA HIDING" PROCEEDINGS OF THE SPIE, SPIE, BELLINGHAM, VA, US, vol. 2420, 9 February 1995 (1995-02-09), pages 164-173, XP000566794 ISSN: 0277-786X * paragraphs [03.4], [3.4.1] * -----	1,2,4,8	
L	ZHAO J ET AL: "EMBEDDING ROBUST LABELS INTO IMAGES FOR COPYRIGHT PROTECTION" PROCEEDINGS OF THE KNOWRIGHT. CONFERENCE. PROCEEDINGS OF THE INTERNATIONAL CONGRESS ON INTELLECTUAL PROPERTY RIGHTS FOR SPECIALIZED INFORMATION, KNOWLEDGE AND NEW TECHNOLOGY, XX, XX, 1995, pages 242-251, XP000571967 -----		

TECHNICAL FIELDS SEARCHED (IPC)

H04N
G06T

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
The Hague	15 October 2007	Hazel, James

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

5

EPO FORM 1503 03.82 (P04C01)

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO.

EP 07 11 2420

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

15-10-2007

Patent document cited in search report		Publication date	Patent family member(s)			Publication date
EP 0581317	A	02-02-1994	CA	2101673	A1	01-02-1994
			JP	6343128	A	13-12-1994
			JP	3837432	B2	25-10-2006
			JP	2005328528	A	24-11-2005
			JP	2007006504	A	11-01-2007
			JP	2006314125	A	16-11-2006
			US	5721788	A	24-02-1998
			US	5809160	A	15-09-1998

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

The examination is being carried out on the **following application documents**:

Description, Pages

1-37	as originally filed

Claims, Numbers

1-28	as originally filed

The following documents (D) are referred to in this communication; the numbering will be adhered to in the rest of the procedure:

D1: EP-A-0 581 317 (INTERACTIVE HOME SYSTEMS) 2 February 1994 (1994-02-02)

D2: BENDER W ET AL: 'TECHNIQUES FOR DATA HIDING' PROCEEDINGS OF THE SPIE, SPIE, BELLINGHAM, VA, US, vol. 2420, 9 February 1995 (1995-02-09), pages 164-173, XP000566794 ISSN: 0277-786X

0. **It is noted that the present application is a divisional from EP96 919 405.9, which has ended its examination procedure with a grant. The present application has been filed with an identical set of claims to that of the parent application. According to the Guidelines C.IV 6.4, two patents cannot be granted to the same applicant for one invention. It is permissible to allow an applicant to proceed with two applications having the same description where the claims are quite distinct in scope and directed to different inventions.**

1. **Clarity**

The application does not meet the requirements of Article 84 EPC, because claims 1-4,7 and 8 are not clear.

1.1 Claims 1,3 and 4 have been drafted as separate independent claims.

Under Article 84 in combination with Rule 29(2) EPC an application may contain more than one independent claim in a particular category only if the subject matter claimed falls within one or more of the exceptional situations set out in paragraphs (a), (b) or (c) of Rule 29(2) EPC. This appears not to be the case in the present application.

The aforementioned claims therefore lack conciseness, which is contrary to Article 84 EPC. Moreover, lack of clarity of the claims as a whole arises, since the plurality of independent claims makes it difficult, if not impossible, to determine the matter for which protection is sought, and places an undue burden on others seeking to establish the extent of the protection.

1.2 Similar objections arise for independent claims 7 and 8.

1.3 The applicant is requested to file an amended set of claims which complies with Rule 29(2). Failure to do so, or to submit convincing arguments as to why the current set of claims does in fact comply with these provisions, will lead to refusal of the application under Article 97(1) EPC.

1.4 Claim 1 does not meet the requirements of Article 84 EPC in that the matter for which protection is sought is not defined. The claim attempts to define the subject-matter in terms of the result to be achieved (this definition is embodied by the repeated use of the expression "such that"). Such a definition is only allowable under the conditions elaborated in the Guidelines C-III, 4.7. In this instance, however, such a formulation is not allowable because it appears possible to define the subject-matter in more concrete terms, viz. in terms of how the effect is to be achieved.

1.5 The expressions "key" and "mask" seem to be used for the same or corresponding features in claims 1-4,7 and 8. This is confusing and detracts from the clarity of the claims. It is suggested to use only one of these terms. "key" would appear to be preferable since this is a generally accepted term for this feature.

2. Novelty and Inventive Step

The present application does not meet the requirements of Article 52(1) EPC, because the subject-matter of claims 1-4,7 and 8, in so far as it can be understood, does not involve an inventive step in the sense of Article 56 EPC.

D1 (see page 3, line 6 - page 4, line 48) discloses a method and system (apparatus) for encoding (embedding) additional information (a signature) into digitized samples (digital image 24) at a number of signature points, which signature points (in one embodiment) are chosen randomly. It is well known in the field of generating random sequences to use a key as a seed.

D2 (see sections 3.4 and 3.4.1 in particular) discloses a spread spectrum technique for hiding data by encoding it using a pseudo-random noise sequence to spread the frequency spectrum of the data over an available frequency band. The spread data sequence is then added to an original file to hide the data in the file. A key is used to encode the information, and the same key is used to decode it.

The features of the independent claims which are not explicitly disclosed in D1 or D2, in so far as they can be understood, appear to relate to particular details of alternative methods or apparatus for performing known encoding or decoding of additional information. These features would seem obvious to the skilled person as ways of implementing the method or apparatus known according to D1 or D2, and don't appear to solve any particular problem associated with said known method or apparatus. They cannot, therefore, be regarded as inventive.

3. Conclusion

3.1 It is not at present apparent which part of the application could serve as a basis for a new, allowable claim. Should the applicant nevertheless regard some particular matter as patentable, independent claims should be filed taking account of Rule 29 EPC. **The applicant should also indicate in the letter of reply the difference of the subject-matter of the new claim vis-à-vis the state of the art and the**

significance thereof. In particular the problem to be solved by the subject matter of the new independent claim(s) (not more than one in each category) should be discussed in the letter of reply to assist the examining division in assessing the inventive step of the claim(s).

3.2 These independent claims, one per category, should be in two-part form in accordance with Rule 29(1) EPC, with those features known in combination from the prior art (D1) being placed in the preamble (Rule 29(1)(a) EPC) and with the remaining features being included in the charactersing part (Rule 29(1)(b) EPC). If, however, the applicant is of the opinion that the two part form would be inappropriate, then reasons therefor should be provided in the letter of reply.

3.3 To meet the requirements of Rule 27(1)(b) EPC, the documents D1 and D2 should be identified in the description and the relevant background art disclosed therein should be briefly discussed.

3.4 The attention of the applicant is drawn to the fact that the application may not be amended in such a way that it contains subject-matter which extends beyond the content of the application as filed (Article 123(2) EPC). Care should be taken to conform with this Article when bringing the description into conformity with any amended claims, in particular during revision of the introductory portion or any statements of problem or advantage.

3.5 In order to facilitate the examination of the conformity of the amended application with the requirements of Article 123(2) EPC, the applicant is requested to clearly identify the amendments carried out, irrespective of whether they concern amendments by addition, replacement or deletion, and to indicate the passages of the application as filed on which these amendments are based.

3.6 When drawing up the new independent claims, the applicant should further take care to:
1) include all features essential to the definition of the invention (Rule 29 EPC);
2) avoid using features relating to a method in the apparatus claim (Art. 84, EPC); 3) ensure that any additional features introduced, e.g. from the dependent claims, are

clear (Art. 84); and

4) provide the features of the claims with reference signs placed in parantheses to increase the intelligibility of the claims (Rule 29(7) EPC).

XS CPRTENFRDE

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Appl. No.	:	10/049,101	Confirmation No. 8028
Applicant	:	Scott MOSKOWITZ	
Filed	:	July 23, 2002	
TC/A.U.	:	2131	
Examiner	:	Jeremiah L. AVERY	
Docket No.	:	80408.0011	

MAIL STOP: AMENDMENT - IDS
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

INFORMATION DISCLOSURE STATEMENT

Dear Sir:

Applicant(s) submit copies of the references listed on the attached SB08 Form(s) for consideration and request that the U.S. Patent and Trademark Office make them of record in this application.

Applicant(s) state the following:

□ Each item of information contained in this Information Disclosure Statement was cited in a communication from a foreign patent office in a counterpart foreign application not more than three months prior to the filing of the Information Disclosure Statement; or

□ No item of information contained in this Information Disclosure Statement was cited in a communication from a foreign patent office in a counterpart foreign application, and to the knowledge of Applicant(s) no item of information contained in this

Information Disclosure Statement was known to any individual designated in § 1.56(c) more than three months prior to the filing of this Information Disclosure Statement.

□ In accordance with 37 C.F.R. § 1.97(b), this Information Disclosure Statement is believed to be submitted prior to issuance of a first Office Action and/or within three months of the filing date of the application. It is respectfully submitted that no fee is required for consideration of this information.

☒ This Information Disclosure Statement is being submitted after the mailing of a non-final Office Action, but is believed to be prior to a final Office Action or a Notice of Allowance. Pursuant to 37 C.F.R. § 1.97(c), payment in the amount of $180.00 as set forth in 37 C.F.R. § 1.17(p) is enclosed.

While the information and references disclosed in this Information Disclosure Statement are submitted pursuant to 37 C.F.R. § 1.56, this submission is not intended to constitute an admission that any patent, publication or other information referred to is "prior art" to this invention. Applicant(s) reserve the right to contest the "prior art" status of any information submitted or asserted against the application.

Additionally, pursuant to C.F.R. § 1.78, Applicant(s) wish to inform the Examiner of the existence of the following co-pending U.S. patents and patent applications that share a common inventor with the present application. Under 37 C.F.R. § 1.98(a)(1), Applicant(s) also wish to inform the Examiner of the existence of the following co-pending foreign patents and patent applications that share a common inventor with the present application in the "section separate from the citations of other documents" entitled "Foreign Patent Documents", below:

EXAMINER: Please initial if reference is considered, whether or not the citation is in conformance with MPEP § 609. Draw line through citation if not in conformance and not considered. Please include copy of this form with next communication to the applicant.

U.S. PATENT DOCUMENTS

EXAMINER'S
INITIALS:

_____ U.S. Patent Application No. 08/999,766, filed July 23, 1997, entitled "Steganographic Method and Device";

_____ U.S. Patent Application No. 11/894,443, filed August 21, 2007, entitled "Steganographic Method and Device" – Projected Publication Date – March 27, 2008;

_____ U.S. Patent Application No. 11/894,476, filed August 21, 2007, entitled "Steganographic Method and Device" – Publication No. 20070294536 – December 20, 2007;

_____ U.S. Patent Application No. 11/050,779, filed February 7, 2005, entitled "Steganographic Method and Device" – Publication No. 20050177727 – August 11, 2005;

_____ U.S. Patent Application No. 08/674,726, filed July 2, 1996, entitled "Exchange Mechanisms for Digital Information Packages with Bandwidth Securitization, Multichannel Digital Watermarks, and Key Management" (unpublished – issue fee paid – January 23, 2008);

_____ U.S. Patent Application No. 12/009,914, filed January 23, 2008, entitled "Exchange Mechanisms for Digital Information Packages with Bandwidth Securitization, Multichannel Digital Watermarks, and Key Management";

_____ U.S. Patent Application No. 09/545,589, filed April 7, 2000, entitled "Method and System for Digital Watermarking" (issued as U.S. Patent No. 7,007,166);

_____ U.S. Patent Application No. 11/244,213, filed October 5, 2005, entitled "Method and System for Digital Watermarking" – Publication No. 20060101269 – May 11, 2006 (issue fee paid – December 26, 2007);

_____ U.S. Patent Application No. 11/649,026, filed January 3, 2007, entitled "Method and System for Digital Watermarking" – Publication No. 20070113094 – May 17, 2007;

EXAMINER: Please initial if reference is considered, whether or not the citation is in conformance with MPEP § 609. Draw line through citation if not in conformance and not considered. Please include copy of this form with next communication to the applicant.

_____ U.S. Patent Application No. 12/005,230, filed December 26, 2007, entitled "Method and System for Digital Watermarking";

_____ U.S. Patent Application No. 09/046,627, filed March 24, 1998, entitled "Method for Combining Transfer Function with Predetermined Key Creation" (issued as U.S. Patent No. 6,598,162);

_____ U.S. Patent Application 10/602,777, filed June 25, 2003, entitled "Method for Combining Transfer Function with Predetermined Key Creation" – Publication No. 20040086119 – May 6, 2004;

_____ U.S. Patent Application 11/895,388, filed August 24, 2007, entitled "Data Protection Method and Device" – Publication No. 20080016365 – January 17, 2008;

_____ U.S. Patent Application No. 09/053,628, filed April 2, 1998, entitled "Multiple Transform Utilization and Application for Secure Digital Watermarking" (issued as U.S. Patent No. 6,205,249);

_____ U.S. Patent Application No. 09/644,098, filed August 23, 2000, entitled "Multiple Transform Utilization and Application for Secure Digital Watermarking" (issued as U.S. Patent No. 7,035,409);

_____ U.S. Patent Application No. 09/767,733, filed January 24, 2001, entitled "Multiple Transform Utilization and Application for Secure Digital Watermarking" – Publication No. 20010010078 - July 26, 2001;

_____ U.S. Patent Application No. 11/358,874, filed February 21, 2006, entitled "Multiple Transform Utilization and Application for Secure Digital Watermarking" – Publication No. 20060140403 – June 29, 2006;

_____ U.S. Patent Application No. 10/417,231, filed April 17, 2003, entitled "Methods, Systems And Devices For Packet Watermarking And Efficient Provisioning Of Bandwidth" – Publication No. 20030200439 – October 23, 2003 (issued as U.S. Patent No. 7,287,275);

_____ U.S. Patent Application No. 11/900,065, filed September 10, 2007, entitled "Methods, Systems And Devices For Packet Watermarking And

EXAMINER: Please initial if reference is considered, whether or not the citation is in conformance with MPEP § 609. Draw line through citation if not in conformance and not considered. Please include copy of this form with next communication to the applicant.

Efficient Provisioning Of Bandwidth" – Publication No. 20080005571 – January 3, 2008;

_____ U.S. Patent Application No. 11/900,066, filed September 10, 2007, entitled "Methods, Systems And Devices For Packet Watermarking And Efficient Provisioning Of Bandwidth" -- Publication No. 20080005572 – January 3, 2008;

_____ U.S. Patent Application No. 09/789,711, filed February 22, 2001, entitled "Optimization Methods for the Insertion, Protection, and Detection of Digital Watermarks in Digital Data" – Publication No. 20010010078 -- October 11, 2001 (issued as U.S. Patent No. 7,107,451);

_____ U.S. Patent Application No. 11/497,822, filed August 2, 2006, entitled "Optimization Methods for the Insertion, Protection, and Detection of Digital Watermarks in Digital Data" – Publication No. 20070011458 – January 11, 2007;

_____ U.S. Patent Application No. 11/599,964, filed November 15, 2006, entitled "Optimization Methods for the Insertion, Protection, and Detection of Digital Watermarks in Digital Data" – Publication No. 20080046742 – February 21, 2008;

_____ U.S. Patent Application No. 11/599,838, filed November 15, 2006, entitled "Optimization Methods for the Insertion, Protection, and Detection of Digital Watermarks in Digital Data" – Publication No. 20070226506 – September 27, 2007;

_____ U.S. Patent Application No. 11/897,790, filed August 31, 2007, entitled "Optimization Methods for the Insertion, Protection, and Detection of Digital Watermarks in Digital Data" – Publication No. 20070300072 – December 27, 2007;

_____ U.S. Patent Application No. 11/897,791, filed August 31, 2007, entitled "Optimization Methods for the Insertion, Protection, and Detection of Digital Watermarks in Digital Data" – Publication No. 20080022113 – January 24, 2008;

EXAMINER: Please initial if reference is considered, whether or not the citation is in conformance with MPEP § 609. Draw line through citation if not in conformance and not considered. Please include copy of this form with next communication to the applicant.

_____ U.S. Patent Application No. 11/899,661, filed September 7, 2007, entitled "Optimization Methods for the Insertion, Protection, and Detection of Digital Watermarks in Digital Data" – Publication No. 20070300073 – December 27, 2007;

_____ U.S. Patent Application No. 11/899,662, filed September 7, 2007, entitled "Optimization Methods for the Insertion, Protection, and Detection of Digital Watermarks in Digital Data" – Publication No. 20080022114 – January 24, 2008;

_____ U.S. Patent Application No. 10/369,344, filed February 18, 2003, entitled "Optimization Methods for the Insertion, Protection, and Detection of Digital Watermarks in Digitized Data" – Publication No. 20030219143 – November 27, 2003 (issued as U.S. Patent No. 7,095,874);

_____ U.S. Patent Application No. 11/482,654, filed July 7, 2006, entitled "Optimization Methods for the Insertion, Protection, and Detection of Digital Watermarks in Digitized Data" – Publication No. 20060285722 – December 21, 2006;

_____ U.S. Patent Application No. 09/594,719, filed June 16, 2000, entitled "Utilizing Data Reduction in Steganographic and Cryptographic Systems" (issued as U.S. Patent 7,123,718);

_____ U.S. Patent Application No. 11/519,467, filed September 12, 2006, entitled "Utilizing Data Reduction in Steganographic and Cryptographic Systems" – Publication No. 20070064940 – March 22, 2007;

_____ U.S. Patent Application No 09/731,040, filed December 7, 2000, entitled "Systems, Methods And Devices For Trusted Transactions" – Publication No. 20020010684 – January 24, 2002 (issued as U.S. Patent 7,159,116);

_____ U.S. Patent Application No 11/512,701, filed August 29, 2006, entitled "Systems, Methods And Devices For Trusted Transactions" – Publication No. 20070028113 – February 1, 2007;

_____ U.S. Patent Application No. 10/049,101, filed February 8, 2002, entitled "A Secure Personal Content Server" (which claims priority to International

EXAMINER: Please initial if reference is considered, whether or not the citation is in conformance with MPEP § 609. Draw line through citation if not in conformance and not considered. Please include copy of this form with next communication to the applicant.

Application No. PCT/US00/21189, filed August 4, 2000, which claims priority to U.S. Patent Application No. 60/147,134, filed August 4, 1999, and to U.S. Patent Application No. 60/213,489, filed June 23, 2000);

_____ U.S. Patent Application No. 09/657,181, filed September 7, 2000, entitled "Method And Device For Monitoring And Analyzing Signals" (paid issue fee January 23, 2008);

_____ U.S. Patent Application No. 12/005,229, filed December 26, 2007, entitled "Method And Device For Monitoring And Analyzing Signals" -- Publication No. NA –;

_____ U.S. Patent Application No. 10/805,484, filed March 22, 2004, entitled "Method And Device For Monitoring And Analyzing Signals"(which claims priority to U.S. Patent Application No. 09/671,739, filed September 29, 2000, which is a CIP of U.S. Patent Application No. 09/657,181) – Publication No. 20040243540 – December 2, 2004 – abandoned;

_____ U.S. Patent Application No. 09/956,262, filed September 20, 2001, entitled "Improved Security Based on Subliminal and Supraliminal Channels For Data Objects" – Publication No. 20020056041 – May 9, 2002 (issued as U.S. Patent No. 7,127,615);

_____ U.S. Patent Application No. 11/518,806, filed September 11, 2006, entitled "Improved Security Based on Subliminal and Supraliminal Channels For Data Objects" – Publication No. 20080028222 – January 31, 2008;

_____ U.S. Patent Application No. 11/026,234, filed December 30, 2004, entitled "Z-Transform Implementation of Digital Watermarks" – Publication No. 20050135615 – June 23, 2005 (issued as U.S. Patent No. 7,152,162);

_____ U.S. Patent Application No. 11/592,079, filed November 2, 2006, entitled "Linear Predictive Coding Implementation of Digital Watermarks" -- Publication No. 20070079131 – April 5, 2007;

_____ U.S. Patent Application No. 09/731,039, filed December 7, 2000, entitled "System and Methods for Permitting Open Access to Data Objects and

EXAMINER: Please initial if reference is considered, whether or not the citation is in conformance with MPEP § 609. Draw line through citation if not in conformance and not considered. Please include copy of this form with next communication to the applicant.

for Securing Data within the Data Objects" – Publication No. 20020071556 – June 13, 2002 (issued as U.S. Patent No. 7,177,429);

_____ U.S. Patent Application No. 11/647,861, filed December 29, 2006, entitled "System and Methods for Permitting Open Access to Data Objects and for Securing Data within the Data Objects" – Publication No. 20070110240 – April 5, 2007;

_____ U.S. Patent No. 5,428,606, issued June 27, 1995, entitled "Digital Commodities Exchange";

_____ U.S. Patent No. 5,539,735, issued July 23, 1996, entitled "Digital Information Commodities Exchange";

_____ U.S. Patent No. 5,613,004, issued March 18, 1997, entitled "Steganographic Method and Device";

_____ U.S. Patent No. 5,687,236, issued November 11, 1997, entitled "Steganographic Method and Device";

_____ U.S. Patent No. 5,745,569, issued April 28, 1998, entitled "Method for Stega-Protection of Computer Code";

_____ U.S. Patent No. 5,822,432, issued October 13, 1998, entitled "Method for Human Assisted Random Key Generation and Application for Digital Watermark System";

_____ U.S. Patent No. 5,889,868, issued July 2, 1996, entitled "Optimization Methods for the Insertion, Protection, and Detection of Digital Watermarks in Digitized Data";

_____ U.S. Patent No. 5,905,800, issued May 18, 1999, entitled "Method & System for Digital Watermarking";

_____ U.S. Patent No. 6,078,664, issued June 20, 2000, entitled "Z-Transform Implementation of Digital Watermarks";

_____ U.S. Patent No. 6,205,249, issued March 20, 2001, entitled "Multiple Transform Utilization and Application for Secure Digital Watermarking";

EXAMINER: Please initial if reference is considered, whether or not the citation is in conformance with MPEP § 609. Draw line through citation if not in conformance and not considered. Please include copy of this form with next communication to the applicant.

_____ U.S. Patent No. 6,522,767, issued February 18, 2003, entitled "Optimization Methods for the Insertion, Protection, and Detection of Digital Watermarks in Digitized Data";

_____ U.S. Patent No. 6,598,162, issued July 22, 2003, entitled "Method for Combining Transfer Function with Predetermined Key Creation";

_____ U.S. Patent No. 6,853,726, issued February 8, 2005, entitled "Z-Transform Implementation of Digital Watermarks";

_____ U.S. Patent No. 7,007,166, issued February 28, 2006, entitled "Method & System for Digital Watermarking";

_____ U.S. Patent No. 7,035,049, issued April 25, 2006, entitled "Multiple Transform Utilization and Application for Secure Digital Watermarking";

_____ U.S. Patent No. 7,095,874, issued August 22, 2006, entitled "Optimization Methods for the Insertion, Protection, and Detection of Digital Watermarks in Digitized Data";

_____ U.S. Patent No. 7,107,451, issued September 12, 2006, entitled "Optimization Methods for the Insertion, Protection, and Detection of Digital Watermarks in Digital Data";

_____ U.S. Patent No. 7,123,718, issued October 17, 2006, entitled, "Utilizing Data Reduction in Steganographic and Cryptographic Systems";

_____ U.S. Patent No. 7,127,615, issued October 24, 2006, "Improved Security Based on Subliminal and Supraliminal Channels for Data Objects";

_____ U.S. Patent No. 7,152,162, issued December 19, 2006, entitled "Z-Transform Implementation of Digital Watermarks";

_____ U.S. Patent No. 7,159,116, issued January 2, 2007, entitled "Systems, Methods and Devices for Trusted Transactions";

_____ U.S. Patent No. 7,177,429, issued February 13, 2007, entitled "System and Methods for Permitting Open Access to Data Objects and for Securing Data within the Data Objects";

EXAMINER: Please initial if reference is considered, whether or not the citation is in conformance with MPEP § 609. Draw line through citation if not in conformance and not considered. Please include copy of this form with next communication to the applicant.

_____ U.S. Patent No. 7,287,275, issued October 23, 2007, entitled "Methods, Systems And Devices For Packet Watermarking And Efficient Provisioning Of Bandwidth"

EXAMINER: Please initial if reference is considered, whether or not the citation is in conformance with MPEP § 609. Draw line through citation if not in conformance and not considered. Please include copy of this form with next communication to the applicant.

FOREIGN PATENT DOCUMENTS

EXAMINER'S
INITIALS:

_____ PCT Application No. PCT/US95/08159, filed June 26, 1995, entitled, "Digital Information Commodities Exchange with Virtual Menuing";

_____ PCT Application No. PCT/US96/10257, filed June 7, 1996, entitled, "Steganographic Method and Device" – corresponding to – EPO Application No. 96919405.9, entitled "Steganographic Method and Device";

_____ PCT Application No. PCT/US97/00651, filed January 16, 1997, entitled, "Method for Stega-Cipher Protection of Computer Code" – corresponding to AU199718294A (not available);

_____ PCT Application No. PCT/US97/00652, filed January 17, 1997, entitled, "Method for an Encrypted Digital Watermark" – corresponding to AU199718295A (not available);

_____ PCT Application No. PCT/US97/11455, filed July 2, 1997, entitled, "Optimization Methods for the Insertion, Protection and Detection of Digital Watermarks in Digitized Data" – corresponding to AU199735881A (not available);

_____ PCT Application No. PCT/US99/07262, filed April 2, 1999, entitled, "Multiple Transform Utilization and Applications for Secure Digital Watermarking" – corresponding to – Japan App. No. 2000-542907, entitled "Multiple Transform Utilization and Application for Secure Digital Watermarking";

_____ PCT Application No. PCT/US00/06522, filed March 14, 2000, entitled, "Utilizing Data Reduction in Steganographic and Cryptographic Systems";

EXAMINER: Please initial if reference is considered, whether or not the citation is in conformance with MPEP § 609. Draw line through citation if not in conformance and not considered. Please include copy of this form with next communication to the applicant.

_____ PCT Application No. PCT/US00/18411, filed July 5, 2000, entitled, "Copy Protection of Digital Data Combining Steganographic and Cryptographic Techniques" – corresponding to AU200060709A5 (not available);

_____ PCT Application No. PCT/US00/21189, filed August 4, 2000, entitled, "A Secure Personal Content Server";

_____ PCT Application No. PCT/US00/33126, filed December 7, 2000, entitled, "Systems, Methods and Devices for Trusted Transactions" – corresponding to AU200120659A5 (not available);

_____ EPO Divisional Patent Application No. 07112420.0, entitled "Steganographic Method and Device" (corresponding to PCT Application No. PCT/US96/10257, filed June 7, 1996, entitled, "Steganographic Method and Device" – cited above – previously provided)

EXAMINER: Please initial if reference is considered, whether or not the citation is in conformance with MPEP § 609. Draw line through citation if not in conformance and not considered. Please include copy of this form with next communication to the applicant.

In accordance with 37 C.F.R. § 1.97(g), the filing of this Information Disclosure Statement shall not be construed to mean that a search has been made or that no other material information as defined in 37 C.F.R. § 1.56(a) exists. This Information Disclosure Statement is in compliance with 37 C.F.R. § 1.98 and the Examiner is respectfully requested to consider the listed documents and information.

Respectfully submitted,

Date: February 29, 2008

By:

Scott A. Moskowitz
Tel# (305) 956-9041
Fax# (305) 956-9042

For Blue Spike, Inc.

Scott A. Moskowitz
President

EXAMINER: Please initial if reference is considered, whether or not the citation is in conformance with MPEP § 609. Draw line through citation if not in conformance and not considered. Please include copy of this form with next communication to the applicant.

PTO/SB/21 (01-08)
Approved for use through 03/31/2008. OMB 0651-0031
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

TRANSMITTAL FORM

(to be used for all correspondence after initial filing)

Application Number	10/049,101
Filing Date	July 23, 2002
First Named Inventor	MOSKOWITZ
Art Unit	2131
Examiner Name	AVERY
Total Number of Pages in This Submission	
Attorney Docket Number	80408.0011

ENCLOSURES *(Check all that apply)*

☑ Fee Transmittal Form
☑ Fee Attached
☑ Amendment/Reply
□ After Final
□ Affidavits/declaration(s)
☑ Extension of Time Request
□ Express Abandonment Request
☑ Information Disclosure Statement
□ Certified Copy of Priority Document(s)
□ Reply to Missing Parts/ Incomplete Application
□ Reply to Missing Parts under 37 CFR 1.52 or 1.53

□ Drawing(s)
□ Licensing-related Papers
□ Petition
□ Petition to Convert to a Provisional Application
□ Power of Attorney, Revocation Change of Correspondence Address
□ Terminal Disclaimer
□ Request for Refund
□ CD, Number of CD(s) ____
□ Landscape Table on CD

□ After Allowance Communication to TC
□ Appeal Communication to Board of Appeals and Interferences
□ Appeal Communication to TC (Appeal Notice, Brief, Reply Brief)
□ Proprietary Information
□ Status Letter
□ Other Enclosure(s) (please identify below):

Remarks

SIGNATURE OF APPLICANT, ATTORNEY, OR AGENT

Firm Name			
Signature	Scott Moskowitz		
Printed name	SCOTT MOSKOWITZ		
Date	FEB 29 2008	Reg. No.	

CERTIFICATE OF TRANSMISSION/MAILING

I hereby certify that this correspondence is being facsimile transmitted to the USPTO or deposited with the United States Postal Service with sufficient postage as first class mail in an envelope addressed to: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450 on the date shown below:

Signature	Scott Moskowitz		
Typed or printed name	SCOTT MOSKOWITZ	Date	

This collection of information is required by 37 CFR 1.5. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.11 and 1.14. This collection is estimated to 2 hours to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: **Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

If you need assistance in completing the form, call 1-800-PTO-9199 and select option 2.

PTO/SB/17 (10-07)
Approved for use through 06/30/2010. OMB 0651-0032
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
Under the Paperwork Reduction Act of 1995 no persons are required to respond to a collection of information unless it displays a valid OMB control number

Effective on 12/08/2004.
Fees pursuant to the Consolidated Appropriations Act, 2005 (H.R. 4818).

FEE TRANSMITTAL
For FY 2008

☑ Applicant claims small entity status. See 37 CFR 1.27

TOTAL AMOUNT OF PAYMENT ($) 240 00

Complete if Known

Application Number	10/049 101
Filing Date	July 23 2002
First Named Inventor	MOSKOWITZ
Examiner Name	AVERY
Art Unit	2131
Attorney Docket No.	80408.0011

METHOD OF PAYMENT (check all that apply)

□ Check ☑ Credit Card □ Money Order □ None □ Other (please identify):

□ Deposit Account Deposit Account Number: Deposit Account Name:

For the above-identified deposit account, the Director is hereby authorized to: (check all that apply)

□ Charge fee(s) indicated below □ Charge fee(s) indicated below, **except for the filing fee**

□ Charge any additional fee(s) or underpayments of fee(s) under 37 CFR 1.16 and 1.17 □ Credit any overpayments

WARNING: Information on this form may become public. Credit card information should not be included on this form. Provide credit card information and authorization on PTO-2038.

FEE CALCULATION

1. BASIC FILING, SEARCH, AND EXAMINATION FEES

	FILING FEES		SEARCH FEES		EXAMINATION FEES		
		Small Entity		Small Entity		Small Entity	
Application Type	Fee ($)	Fee ($)	Fee ($)	Fee ($)	Fee ($)	Fee ($)	Fees Paid ($)
Utility	310	155	510	255	210	105	
Design	210	105	100	50	130	65	
Plant	210	105	310	155	160	80	
Reissue	310	155	510	255	620	310	
Provisional	210	105	0	0	0	0	

2. EXCESS CLAIM FEES

$240 00

		Small Entity
Fee Description	Fee ($)	Fee ($)
Each claim over 20 (including Reissues)	50	25
Each independent claim over 3 (including Reissues)	210	105
Multiple dependent claims	370	185

Total Claims Extra Claims Fee ($) Fee Paid ($)
_____ - 20 or HP = _____ x _____ = _____
HP = highest number of total claims paid for, if greater than 20.

Multiple Dependent Claims
Fee ($) Fee Paid ($)

Indep. Claims Extra Claims Fee ($) Fee Paid ($)
_____ - 3 or HP = _____ x _____ = _____
HP = highest number of independent claims paid for, if greater than 3.

3. APPLICATION SIZE FEE

If the specification and drawings exceed 100 sheets of paper (excluding electronically filed sequence or computer listings under 37 CFR 1.52(e)), the application size fee due is $260 ($130 for small entity) for each additional 50 sheets or fraction thereof. See 35 U.S.C. 41(a)(1)(G) and 37 CFR 1.16(s).

Total Sheets Extra Sheets Number of each additional 50 or fraction thereof Fee ($) Fee Paid ($)
_____ - 100 = _____ / 50 = _____ (round up to a whole number) x _____ = _____

4. OTHER FEE(S) Fees Paid ($)

Non-English Specification, $130 fee (no small entity discount) $60 00 / $180 00 $240 00

Other (e.g., late filing surcharge): ONE MONTH EXTENSION / IDS AFTER 1st OA

SUBMITTED BY

Signature	Scott Moskowitz	Registration No. (Attorney/Agent)	Telephone 305 956 9041
Name (Print/Type)	✓ SCOTT MOSKOWITZ		Date FEB 29, 2008

This collection of information is required by 37 CFR 1.136. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 30 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

If you need assistance in completing the form, call 1-800-PTO-9199 and select option 2.

(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 0 565 947 B1

(12) EUROPEAN PATENT SPECIFICATION

(45) Date of publication and mention of the grant of the patent:
28.05.1997 Bulletin 1997/22

(51) Int Cl.5: **H04B 14/04**

(21) Application number: **93105323.5**

(22) Date of filing: **31.03.1993**

(54) Procedure for including digital information in an audio signal prior to channel coding

Verfahren zum Einfügen digitaler Daten in ein Audiosignal vor der Kanalkodierung

Méthode pour inclusion d'information digitale dans un signal audio avant decoder le canal

(84) Designated Contracting States:
DE FR GB IT

(30) Priority: **13.04.1992 FI 921644**

(43) Date of publication of application:
20.10.1993 Bulletin 1993/42

(73) Proprietor: **NOKIA TECHNOLOGY GmbH**
75175 Pforzheim (DE)

(72) Inventor: **Kuusama, Juha**
SF-33720 Tampere (FI)

(56) References cited:

EP-A- 0 137 855	EP-A- 0 167 364
WO-A-89/10661	US-A- 5 136 586

Note: Within nine months from the publication of the mention of the grant of the European patent, any person may give notice to the European Patent Office of opposition to the European patent granted. Notice of opposition shall be filed in a written reasoned statement. It shall not be deemed to have been filed until the opposition fee has been paid. (Art. 99(1) European Patent Convention).

Printed by Jouve, 75001 PARIS (FR)

Description

The present invention relates to a method with which data information can be added in an audio signal present in digital form so that after the channel coding of an audio signal accomplished in a transmitter and the coding of an audio signal accomplished in a receiver no information is lost.

In a conference proceedings paper Proc. ICASSP 90, Alberquerque, New Mexico, April 3-6, 1990, p. 1097-1100, W.ten Kate, L. van de Kerkhof and F. Ziderveld: Digital Audio Carrying Extra Information, a encoding method is described with which a four-channel audio signal can be encoded to be appropriate for use in a transmission path of a two-channel audio signal. In said encoding method two characteristic features of the human hearing sense are made use of: hearing threshold and masking effect. The masking effect means that in any audio signal another, less powerful signal can be added, which is not audible to the ear because of the masking effect. The masking effect is a psychoacoustic phenomenon in which the hearing threshold moves upwards when other sounds are present. The masking effect is most successful in sounds in which the spectrum components are in the proximity of the components of the masking sound. The frequency masking declines more rapidly when moving to lower sounds. This is true also in the time plane: the masking effect is greatest in sounds which are simultaneously audible. The dependence of the masking effect on time and frequency is well known in simple signals. The existence of masking effect can be utilized in that signals below the hearing threshold can be added into an audio signal. In principle, this takes place so that an analogous audio signal is sampled and in the place of the bits of the samples not audible to the human ear other information is placed. Thus, information is inserted in place of the less significant bits of the sample in digital form. When such a signal is repeated, the human ear is not at all able to hear the signal added therein because the actual signal intended to be heard masks it. It is the masking ability of the human ear which determines how many less significant bits can be substituted without still being audible. A signal thus added can be used for various purposes. Similarly, when a sound signal is compressed, the signals below the hearing threshold can be excluded from storage, or only the signals audible to the human ear are transmitted.

The principle of said known coding method utilizing the masking effect is presented in Fig. 1. An incoming audio signal is sampled and divided first in a filter bank 1 into a great number of subbands and the signal samples of the subbands are decimated in means 2. The subbands are preferably equal in size so that the sampling frequency meeting the Nyqvist criterion in the decimalizing means 2 of each subband is equal. The samples of each subband are then grouped into subsequent time windows in means 3. The length of a time window is Δ t and it includes samples of one and same point of time from each subband. So, the simultaneous time windows of each subband constitute one block. A power spectrum is calculated for each block in spectrum analysis means 4 and from the spectrum thus derived a masking threshold is determined for each block in means 5. After determining the masking threshold it is clear what the maximum signal power is which can be added in an audio signal of a subband in said time window. DATA IN bits of the data signal are added below the masking threshold calculated for the audio signal. It is carried out so that a given number of subsequent bits of a data flow, e.g. three subsequent bits, form one word. Each word is interpreted to be an address representing a given sample value; thus, in a three bit case there are eight pieces of sample values. Selection of a word and the sample value corresponding thereto is carried out in means 6. The sample values are grouped for appropriate sample windows of the subbands corresponding to the equivalence of the sample value and the threshold of the sample window of a subband, and data bits are substituted for bits of the audio signal samples of a subband in an adder 7. After the substitution, the sample frequency of the signals of the subbands is increased in means 2, and the signals are again connected in the filter bank 9 into a wide-band audio signal which to a listener sounds totally similar to the original audio signal although data information has been added therein. The reception is in principle a reverse incident to the transmission. A typical feature in this method of prior art is that a hearing threshold benefitting the masking effect has to be calculated both in the encoder of the transmitter and in the decoder of the receiver by using a mask modelling model of the human hearing system (i.e. Psycho Acoustic Model). Thus, the encoder and the coder act independent of one another. This results in certain problems.

In the Finnish patent application No. 915114, filing date October 30, 1991, corresponding to EP-A-0 540 330, published 05 May 1993, said application being included as reference in the present application, the information produced by the encoder of the above described system is made use of. Such information includes information concerning data mode, information related to quantisation, and information related to dematrixing. Said information is transmitted on a separate side channel at the same time as the audio signals to a receiver, which controlled by side channel information is enabled to process the two-channel audio signal received and to convert it e.g. into a multichannel audio signal. Thus, the coder of the receiver acts controlled by the transmitter encoder, i.e. as a slave decoder. An audio signal transmitted on a stereo channel and the information data hidden therein are therefore separated using the control information transmitted by the encoder and received on a separate channel.

The principle of the Finnish patent application is shown in Fig. 2. A coding block therein is indicated by reference numeral 31, said block being in essential elements similar to the prior art encoding block shown in Fig. 1. The encoder combines an incoming multichannel audio signal into a combined stereo signal "hiding" a data signal therein by making use of the masking effect. Information about the data mode, quantization and matrixing are received from the encoder. The data mode describes the special arrangements needed for maximizing the transmission capacity of the hidden data. Such arrangements are e.g. information about that certain channels contain no signals compared with the state of the rest of the channels, so that after being coded said channels are attenuatable. On the whole, the mode contains the way of processing the special instances concerning signal coding when these are not included in normal mix-up. The quantization data informs of the quantization steps of the masking signal and the signal to be masked (hidden), and the number of bits as well as the masking threshold calculated for the time intervals of each subband in the manner described above. The matrixing information yields information about how the original multichannel audio signal was downmixed. In brief, all the information required in carrying out the coding can be achieved from the encoder. The combined stereosignal derived from the encoder, in which data has been "hidden", is adapted for the audio signal to be used on a radio path to be transmitted to e.g. the NICAM format. The above information required in coding is transmitted simultaneously on a separate low-speed digital channel. If the data hidden in the audio channel cannot at a point of time be included in the audio channel, because the "masking capacity" of the audio signal does not suffice, said data can be transmitted on said separate data channel, the information transmitted whereon can be called side information because it is transmitted on the side of the actual audio channel.

The coder 32 in the receiver receives the signal of the audio channel and the side information of the data channel, so that controlled by the coding information transmitted therein it is enabled to code the signal of the audio channel and to separate the data hidden therein. Controlled by the matrixing information it is further enabled to form e.g. a multichannel audio signal.

The method of said Finnish patent application is in principle well appropriate for use in transmitting an audio signal containing hidden data on a transmission path, one of its application being the sound transmission of any HDTV system. In transmitting an audio signal digitally through the radio, it must first be encoded to be appropriate for a transmission channel. There are a great number of channel-coding systems available using compressing; the NICAM system may be mentioned here as an example thereof, as it is already in use and as it may become the audio transmission system in the European HDTV system. When the above-described method is applied in the audio signal, which is channel-coded thereafter using any existing method, this raises a difficult problem in practice: the received coded audio signal is not precisely the same as the audio signal of the transmission head prior to channel-coding. This is due to the fact that independent on the system, the channel-coding causes errors. Most often, one or two of the least significant bits may become converted in the encoder, so that the coded bit stream is almost, but not precisely, the same as the bit stream prior to the encoding. Consequently, if an audio signal is used as such in a transmitter as a signal masking some data to be hidden, it would lead either to a significant increase in error rate of the bits being transmitted or to a significant drop in the hiding capacity because the data is hidden specifically by substituting the least significant bits.

According to the invention, this problem can be solved using the characteristic feature of the method disclosed in the Finnish patent application No. 915114, said feature meaning a separate side information channel containing information formation for controlling the encoder. Since not only on the amount of the data to be used is transmitted on said side channel, as suggested in the application, but also precise information on the location of said data samples, an immaculate original data signal can be provided with the aid of said information. Knowledge of the location of the data samples prerequires information about which of the least significant bits of the audio signal can be substituted for data information, that is, which of the bits are sure to pass through the channel-coder without being changed.

This information is described according to claim 1.

The insight of the invention lies in that an original audio signal is separated into two branches, in the first of which the signal is first channel-coded and immediately thereafter it is decoded. In the second branch the signal is delayed as long as in the first branch the signal is encoded and coded. In this step such signals are resulted which almost resemble one another: In the signal of the first branch the encoding/decoding operation caused a few bit errors. Thereafter, the audio signals of both branches are divided into a plurality of subbands in the filter bank and the signal samples of the subbands are decimated. The subbands have to be equal in size. In each branch the samples of every subband are then grouped into subsequent time windows. The length of one time window is Δ T and it includes samples of the same point of time from each subband. The simultaneous time windows of each subband thus form each time one block. Now, the equivalent samples of the subbands of each branch block are mutually comparable. If all bits are the same it is known that said bits have not been affected by the channel-coding. If, instead, e.g. the lowest, i.e. the least significant bit of the sample of the encoding/coding branch differs from the lowest bit of the sample of the non-encoded branch, while the rest of the bits are equal, said lowest bit is known to be a bit not expected to outlast the channel-coding operation, so that a data bit is not substituted therefor. Part of the other bits can be replaced by data bits because they are known to outlive in channel coding. This is the method which is used *for all subbands*. The masking threshold is then calculated for the audio signal and the data to be hidden is added in place of the bits of the audio signal which are known to outlive. The information about which of the bits in each sample have been substituted is included in the side channel information SI, on the basis of which the receiver is able to reconstruct the correct hidden information precisely.

An implementation of the invention is described below, reference being made to the accompanying schematic figures, in which:

Fig. 1 presents an encoder used in the method of prior art,
Fig. 2 shows the coder as disclosed in the Finnish appliation No. FI-915114, and
Fig. 3 shows principally the procedure of the invention.

The procedures shown in Figs 1 and 2 are already described above. The principle of the method according to the invention is presented in Fig. 3. A digital audio signal AUDIO IN, within which DATA IN data information has been hidden utilizing the masking effect, is separated into two branches. In the upper branch the audio signal is channel-coded in an encoder 325 using the same coding method as used in the actual transmission path, for instance in the NICAM coding. An audio signal channel-coded immediately thereafter is coded in a coder 316, whereby it should result in the original audio signal. The audio signal AUDIO IN is at the same time conducted also into the lower branch in which it is delayed in a delay means 317 precisely the time which passes for the encoding and coding in the upper branch. In the interface, marked with P_1, the audio signals are not, however, bit by bit the same, owing to errors caused by the encoder 325 and decoder 316. The defective bits are found by dividing the audio signal in the filter banks 31 and 311, after the interface P_1, into a plurality of subbands, and the signal samples of the subbands are decimated in means 32 and 312. Said subbands are preferably equal in size. The samples of each subband are thereafter grouped into subsequent time windows in means 33 and 315. The lengths Δ T of the time window are the same and they include the same amount of samples of one and same point of time from each subband. Thus the simultaneous time windows of each subband always form one block. So, at one point of time, the signal samples of both the branch of the coded audio signal and of the branch of the delayed audio signal are known, grouped according to their frequency bands. The samples of one point of time are then compared in a comparator 313 so that a sample of one subband of means 33 is compared with a sample of the correspondent subband of means 315. If the encoding / coding process has changed any of the bits, the comparison reveals which of the bits were changed. For instance, if the lowest, i.e. the least significant bit in a sample of block 33 *is different* from the one in the sample of block 315, it is known that no data bit should be placed in the place of said bit because it will in any case be lost in the course of channel-coding. After the interface marked with P_2 it was thus found out which of the bits of the audio signal should not be substituted for by data bits. The essential core of the invention lies precisely in this fact, and the information obtained thereafter can be applied in an encoder complying with the Finnish application No. 915114. The mode of operation is described below in outline.

A spectrum analysis is accomplished in a manner known in the art in the lower branch in means 34 and the calculation of the masking threshold in means 35. After finding out how many of the bits of the audio signal can be substituted for by data bits and which of the bits in the audio signal do not outlive the channel-coding, only the bits below the masking threshold can be substituted in an adder 310 which outlive in the channel coding. On the basis of the masking threshold information by block 35 and the information provided by reference block 313, the data to be hidden is arranged to be appropriate in an arrangement block 36.

The information divulged in reference means 313 is conveyed to the adder 310. For instance, if the spectrum analysis and the calculation of the masking threshold indicate that data bits could be substituted for three bits in a sample, without being audible to the human ear, and if it has been analysed in reference means 313 from the same sample that the first bit will perish in the channel-coding process, only the two bits of the sample are substituted for by data bits which were learnt to outlive the channel coding. The information on the point of a sample of an audio signal at which some data has been hidden, i.e. which of the bits have been substituted for by data bits, is transmitted as side information on a SI channel. On the basis of said information and other information transmitted on the side channel, the receiver is enabled to discover in the audio signal a data signal hidden therein.

All audio samples are analysed similarly in each subband, regarding the duration of the channel coding, and only those bits below the masking threshold are substituted which are sure to outlive the channel-coding. After summing up, the sample frequency of the signals of the subbands is increased in means 38 and the signals are recombined in filter bank 38 into a wideband audio signal which after being channel-coded in the transmitter and decoded in the receiver sound to the listener's ear the same as the original audio signal irrespective of the fact that data information has been added therein and that the data information is received without any deficiencies. A low-speed side channel SI is produced in the manner disclosed in Finnish application No. 915114, included therein an addition that now also information about the location of the bits hidden therein is added therein.

The main features of the method are described above. It is obvious that a practical implementation can be accomplished in a number of ways while remaining within the protective scope of the claims. The method is particularly appropriate for use in association with the method disclosed in Finnish patent application No. 915114 because the side channel disclosed therein is particularly well appropriate for mediating the information about the location of the substituted bits to the receiver.

Claims

1. A method for combining a data signal with an audio signal prior to channel-coding the combined signal, in which

   - an audio signal entering in sample sequence mode is conducted to a first branch and divided into subbands, whereby in each subband an array of audio signal samples of equal size is obtained in one and the same time window,
   - a masking threshold is calculated simultaneously for said sample array in each subband, the sounds wherebelow being unaudible to the human ear,
   - the bits of the data signal are substituted for the bits of the samples of the sample arrays remaining below the masking threshold,
   - the subbands are combined, whereby a combined signal to be transmitted on an audio channel is obtained, and
   - all the information is gathered that is needed in re-separating the combined signal, and said information is transmitted in the form of side information on a separate data channel at the same time with the combined signal,

   whereby

   - an audio signal is conducted also to a second branch in which it is channel-coded and decoded, and thereafter it is divided into as many subbands as in the first branch, whereby in each subband an array of audio signal samples of equal magnitude is obtained in the same time window as in the first branch,
   - the audio signal conducted into the first branch is delayed for a time equivalent to the time required for channel-coding and decoding,
   - the audio signal samples of one and same point of time of the corresponding subbands of each branch are compared,
   - only the bits of the samples of the first branch are substituted for by data bits which are the same as in the second branch, and
   - information on the location of the substituting data bits in the sample is transmitted in the form of side information on said data channel.

2. Method for separating an audio signal and a data signal combined in the manner disclosed in claim 1 in a receiver in which a signal entering in sample sequence mode is coded, divided into subbands, and the bits are separated from the combined signal which remain below the masking threshold, and the separated bits are combined, whereby the receiver receives in the form of side information on a separate data channel such information which is needed for separating the data signal from the audio signal, whereby the decoder accomplishes said separation controlled by the coder, characterized in that the side information also includes information about which of the bits in the audio sample have been substituted for by data bits.

3. An apparatus for combining a data signal with an audio signal before channel-coding the combined signal in the transmitter, said apparatus comprising:

   - a first filter means (311) for dividing an audio signal entering in the form of sample sequence mode into subbands,
   - a grouping means (315) to group in each subband an array of audio signal samples of the same size in one and same time window,
   - an analysing and calculating means (34,35), simultaneously calculating in each subband a masking threshold for a sample group, the sounds below which the human ear is not able to hear,
   - a substituting means (37) in which the bits of a data signal are substituted for the bits of the samples of the sample groups which remain below the masking threshold,
   - a second filter means (39) to combine the subbands, whereby a combined signal to be transmitted on an audio channel is obtained,
   - a data channel control means to gather all the information needed for reseparating the combined signal, which information is transmitted as side information on the data channel simultaneously with the combined signal,

   whereby the apparatus comprises further

   - a parallel branch to which the audio signal is also conducted, while the branch comprises in succession a channel-coder (325) and a decoder (316), a third filter means (31) to divide the output signal of the encoder into as many subbands as the first filter means (311), a second grouping means (33) to group within each subband an equal number of audiosignal samples in one time window, whereby in said sub-band an equal number of audiosignal samples are obtained in one and the same time window as in the first branch,

- a delay means (317) to delay the audio signal entering the first filter means (311) for a period of time which corresponds to the delay of the channel coder (315) and the decoder (316),
- a comparator means (313) which compares the same-moment audio signal samples of the corresponding subbands of the first (315) and the second grouping means (33) with one another, whereby the substituting means substitutes with data bits only for the bits of the samples of the first grouping means (315) which are the same as those in the samples of the second grouping means (33), and the comparator (313, 314) informs the control means of the side channel of the location of the substituting data bits in the sample.

Patentansprüche

1. Verfahren zum Kombinieren eines Datensignals mit einem Tonsignal vor der Kanalcodierung des kombinierten Signals, bei dem

    - ein im Abtastsequenzmodus eingehendes Tonsignal zu einer ersten Verzweigung geleitet und in Teilbänder unterteilt wird, so daß in jedem Teilband eine Reihe von Tonsignalproben gleicher Größe in ein und demselben Zeitfenster erhalten wird,
    - für die genannte Probenreihe gleichzeitig in jedem Teilband eine Maskierungsschwelle errechnet wird, unterhalb derer die Töne für das menschliche Ohr unhörbar sind,
    - die Bits des Datensignals durch die Bits der Proben der unter der Maskierungsschwelle verbleibenden Probenreihen substituiert werden,
    - die Teilbänder kombiniert werden, so daß ein auf einem Tonkanal zu übertragendes kombiniertes Signal erhalten wird, und
    - alle Informationen gesammelt werden, die beim erneuten Trennen des kombinierten Signals benötigt werden, und diese Informationen in der Form von Nebeninformationen auf einem separaten Datenkanal gleichzeitig mit dem kombinierten Signal übertragen werden, wobei
    - ein Tonsignal auch zu einer zweiten Verzweigung geleitet wird, in der es kanalcodiert und -decodiert und danach in ebenso viele Teilbänder wie in der ersten Verzweigung unterteilt wird, so daß in jedem Teilband eine Reihe von Tonsignalproben gleicher Größe in demselben Zeitfenster erhalten wird wie in der ersten Verzweigung,
    - das in die erste Verzweigung geleitete Tonsignal für eine Zeit verzögert wird, die gleich der Zeit ist, die zur Kanalcodierung und -decodierung erforderlich ist,
    - die Tonsignalproben von ein und demselben Zeitpunkt der entsprechenden Teilbänder jeder Verzweigung verglichen werden,
    - nur diejenigen Bits der Proben der ersten Verzweigung durch Datenbits substituiert werden, die dieselben sind wie in der zweiten Verzweigung, und
    - Informationen über den Ort der Substitution von Datenbits in der Probe in der Form von Nebeninformationen über den genannten Datenkanal übertragen werden.

2. Verfahren zum Trennen eines Tonsignals und eines in der in Anspruch 1 offenbarten Weise kombinierten Datensignals in einem Empfänger, in dem ein im Abtastsequenzmodus eingehendes Signal codiert und in Teilbänder unterteilt wird und diejenigen Bits von dem kombinierten Signal getrennt werden, die unterhalb der Maskierungsschwelle bleiben, und die getrennten Bits kombiniert werden, so daß der Empfänger in der Form von Nebeninformationen auf einem separaten Datenkanal solche Informationen erhält, die zum Trennen des Datensignals von dem Tonsignal erforderlich sind, so daß der Decoder die genannte Trennung durch den Codierer gesteuert durchführt, dadurch gekennzeichnet, daß die Nebeninformationen auch Informationen darüber enthalten, welche der Bits in der Tonprobe durch Datenbits substituiert wurden.

3. Vorrichtung zum Kombinieren eines Datensignals mit einem Tonsignal vor der Kanalcodierung des kombinierten Signals in dem Sender, wobei die genannte Vorrichtung folgendes umfaßt:

    - einen ersten Filter (311) zum Unterteilen eines im Abtastsequenzmodus eingehenden Tonsignals in Teilbänder,
    - ein Gruppierungsmittel (315), um in jedem Teilband eine Reihe von Tonssignalproben derselben Größe in ein und demselben Zeitfenster zu gruppieren,
    - ein Analyse- und Berechnungsmittel (34, 35), das gleichzeitig in jedem Teilband eine Maskierungsschwelle für eine Probengruppe errechnet, unterhalb derer der Ton für das menschliche Ohr nicht hörbar ist,
    - ein Substitutionsmittel (37), bei dem die Bits eines Datensignals durch Bits der Proben der Probengruppen substituiert werden, die unterhalb der Maskierungsschwelle bleiben,
    - einen zweiten Filter (39) zum Kombinieren der Teilbänder, so daß ein auf einem Tonkanal zu

übertragendes kombiniertes Signal erhalten wird,

- ein Datenkanal-Steuermittel zum Sammeln aller Informationen, die für die erneute Trennung des kombinierten Signals benötigt werden, wobei diese Informationen als Nebeninformationen gleichzeitig mit dem kombinierten Signal auf dem Datenkanal übertragen werden, wobei die Vorrichtung ferner folgendes umfaßt:
- eine parallele Verzweigung, auf die das Tonsignal ebenso geleitet wird, während die Verzweigung nacheinander folgendes umfaßt: einen Kanalcodierer (325) und einen Decodierer (316), einen dritten Filter (31) zum Unterteilen des Ausgangssignals des Codierers in ebenso viele Teilbänder wie der erste Filter (311), ein zweites Gruppierungsmittel (33), um innerhalb jedes Teilbandes eine gleiche Zahl von Tonsignalproben in einem Zeitfenster zu gruppieren, so daß in dem genannten Teilband eine gleiche Zahl von Tonsignalproben in ein und demselben Zeitfenster wie in der ersten Verzweigung erhalten werden,
- ein Verzögerungsmittel (317) zum Verzögern des in dem ersten Filter (311) eingehanden Tonsignals für eine Zeitperiode, die der Verzögerung des Kanalcodierers (315) und des Decodierers (316) entspricht,
- einen Komparator (313), der die zeitgleichen Tonsignalproben der entsprechenden Teilbänder des ersten (315) und des zweiten (33) Gruppierungsmittels miteinander vergleicht, so daß das Substituierungsmittel nur diejenigen Bits der Proben des ersten Gruppierungsmittels (315) durch Datenbits substituiert, die dieselben sind wie die in den Proben des zweiten Gruppierungsmittels (33), und der Komparator (313, 314) informiert das Steuermittel des Seitenkanals des Ortes der substituierenden Datenbits in der Probe.

Revendications

1. Procédé pour combiner un signal de données avec un signal audio avant de coder en canaux le signal combiné, dans lequel

   - un signal audio entrant dans un mode séquentiel d'échantillons est amené jusqu'à une première branche et divisé en sous-bandes, moyennant quoi dans chaque sous-bande, un ensemble d'échantillons de signal audio de tailles égales est obtenu dans une seule et même fenêtre temporelle,
   - un seuil de masquage est calculé en même temps pour ledit ensemble d'échantillons dans chaque sous-bande, les sons au-dessous de celui-ci étant inaudibles pour l'oreille humaine,
   - les bits du signal de données viennent remplacer les bits des échantillons des ensembles d'échantillons restant sous le seuil de masquage.
   - les sous-bandes sont combinées, moyennant quoi un signal combiné devant être transmis sur un canal audio est obtenu, et
   - toutes les informations sont rassemblées, qui sont nécessaires pour séparer de nouveau le signal combiné, et lesdites informations sont transmises sous la forme d'informations secondaires sur un canal de données séparé au même moment que le signal combiné, moyennant quoi
   - un signal audio est également amené jusqu'à une seconde branche dans lequel il est codé en canaux et décodé, et par la suite, il est divisé en autant de sous-bandes que dans la première branche, moyennant quoi, dans chaque sous-bande, un ensemble d'échantillons de signal audio d'amplitudes égales est obtenu dans la même fenêtre temporelle que dans la première branche.
   - le signal audio amené dans la première branche est retardé pendant une durée équivalente à celle requise pour coder en canaux et décoder,
   - les échantillons de signal audio d'un seul et même instant des sous-bandes correspondantes de chaque branche sont comparés,
   - seuls les bits des échantillons de la première branche sont remplacés par des bits de données qui sont les mêmes que dans la seconde branche, et
   - les informations sur l'emplacement des bits de données de remplacement dans l'échantillon sont transmises sous la formes d'informations secondaires sur ledit canal de données.

2. Procédé pour séparer un signal audio et un signal de données combinés de la manière décrite dans la revendication 1, dans un récepteur dans lequel un signal entrant dans un mode séquentiel d'échantillons est codé, divisé en sous-bandes, et les bits sont séparés du signal combiné qui restent au-dessous du seuil de masquage, et les bits séparés sont combinés, moyennant quoi le récepteur reçoit sous la forme d'informations secondaires, sur un canal de données séparé, les informations qui sont nécessaires pour séparer le signal de données du signal audio, moyennant quoi le décodeur réalise ladite séparation commandée par le codeur, caractérisé en ce que les informations secondaires comprennent également des informations au sujet des bits dans l'échantillon audio qui ont été remplacés par les bits de données.

3. Dispositif pour combiner un signal de données avec un signal audio avant de coder en canaux le signal combiné dans l'émetteur, ledit dispositif comprenant :

- des premiers moyens de filtre (311) pour diviser un signal audio entrant sous la forme d'un mode séquentiel d'échantillons en sous-bandes,
- des moyens de groupement (315) pour grouper dans chaque sous-bande un ensemble d'échantillons de signal audio de la même taille, dans une seule et même fenêtre temporelle,
- des moyens d'analyse et de calcul (34, 35), calculant en même temps dans chaque sous-bande un seuil de masquage pour un groupe d'échantillons, l'oreille humaine n'étant pas capable d'entendre les sons au-dessous de celui-ci,
- des moyens de substitution (37) dans lesquels les bits d'un signal de données remplacent les bits des échantillons des groupes d'échantillons qui restent au-dessous du seuil de masquage,
- des deuxièmes moyens de filtre (39) pour combiner les sous-bandes, moyennant quoi un signal combiné devant être transmis sur un canal audio est obtenu,
- des moyens de commande de canal de données pour rassembler toutes les informations nécessaires pour séparer de nouveau le signal combiné, lesquelles informations sont transmises en tant qu'informations secondaires sur le canal de données en même temps que le signal combiné, le dispositif comprenant en outre
- une branche parallèle vers laquelle le signal audio est également amené, tandis que la branche comprend, à la suite, un codeur (325) de canaux et un décodeur (316), des troisièmes moyens de filtre (31) pour diviser le signal de sortie du codeur en autant de sous-bandes que dans les premiers moyens de filtre (311), des seconds moyens de groupement (33) pour grouper à l'intérieur de chaque sous-bande un nombre égal d'échantillons de signal audio dans une fenêtre temporelle, moyennant quoi on obtient dans ladite sous-bande un nombre égal d'échantillons de signal audio dans une seule et même fenêtre temporelle comme dans la première branche,
- des moyens de retardement (317) pour retarder le signal audio entrant dans les premiers moyens de filtre (311) pour une durée qui correspond au retard du codeur (315) et du décodeur (316) de canaux,
- des moyens formant comparateur (313) qui comparent, les uns avec les autres, les échantillons de signal audio, pris au même moment, des sous-bandes correspondantes des premiers (315) et seconds (33) moyens de groupement, moyennant quoi les moyens de remplacement remplacent par des bits de données seulement les bits des échantillons des premiers moyens de groupement (315) qui sont les mêmes que ceux dans les échantillons des seconds moyens de groupement (33), et le comparateur (313, 314) informe les moyens de commande du canal secondaire de l'emplacement des bits de données de remplacement dans l'échantillon.

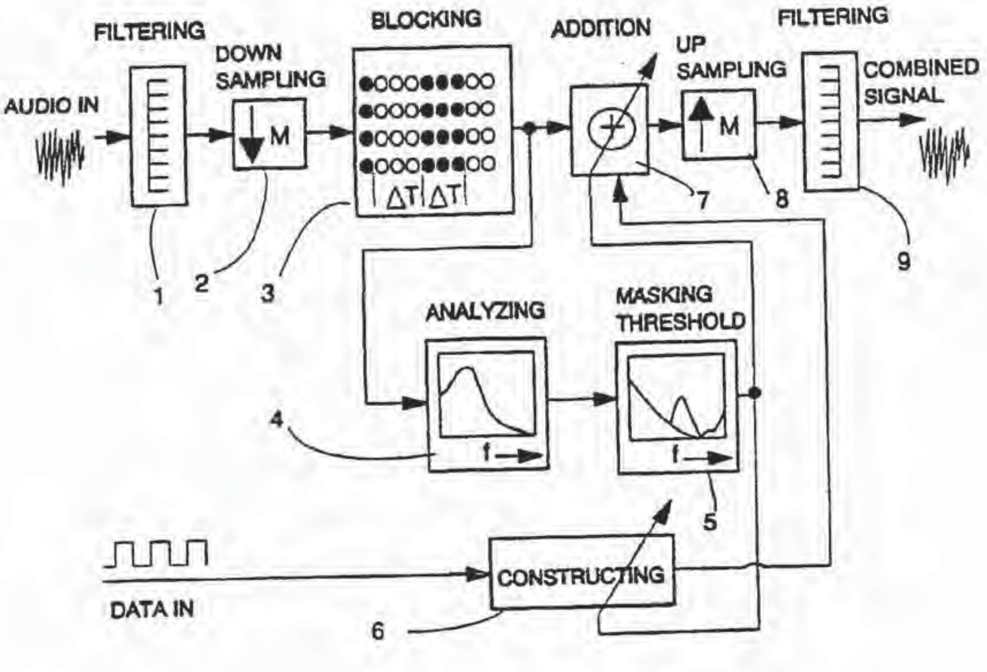

FILTERING
DOWN SAMPLING
BLOCKING
ADDITION
UP SAMPLING
FILTERING
AUDIO IN
M
ΔT ΔT
M
COMBINED SIGNAL
7
8
1
2
3
9
ANALYZING
MASKING THRESHOLD
f
f
4
5
CONSTRUCTING
DATA IN
6

Fig. 1

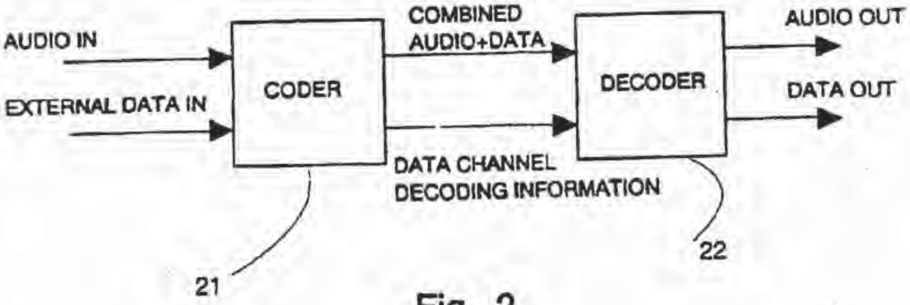

AUDIO IN
EXTERNAL DATA IN
CODER
COMBINED AUDIO+DATA
DATA CHANNEL DECODING INFORMATION
DECODER
AUDIO OUT
DATA OUT
21
22

Fig. 2

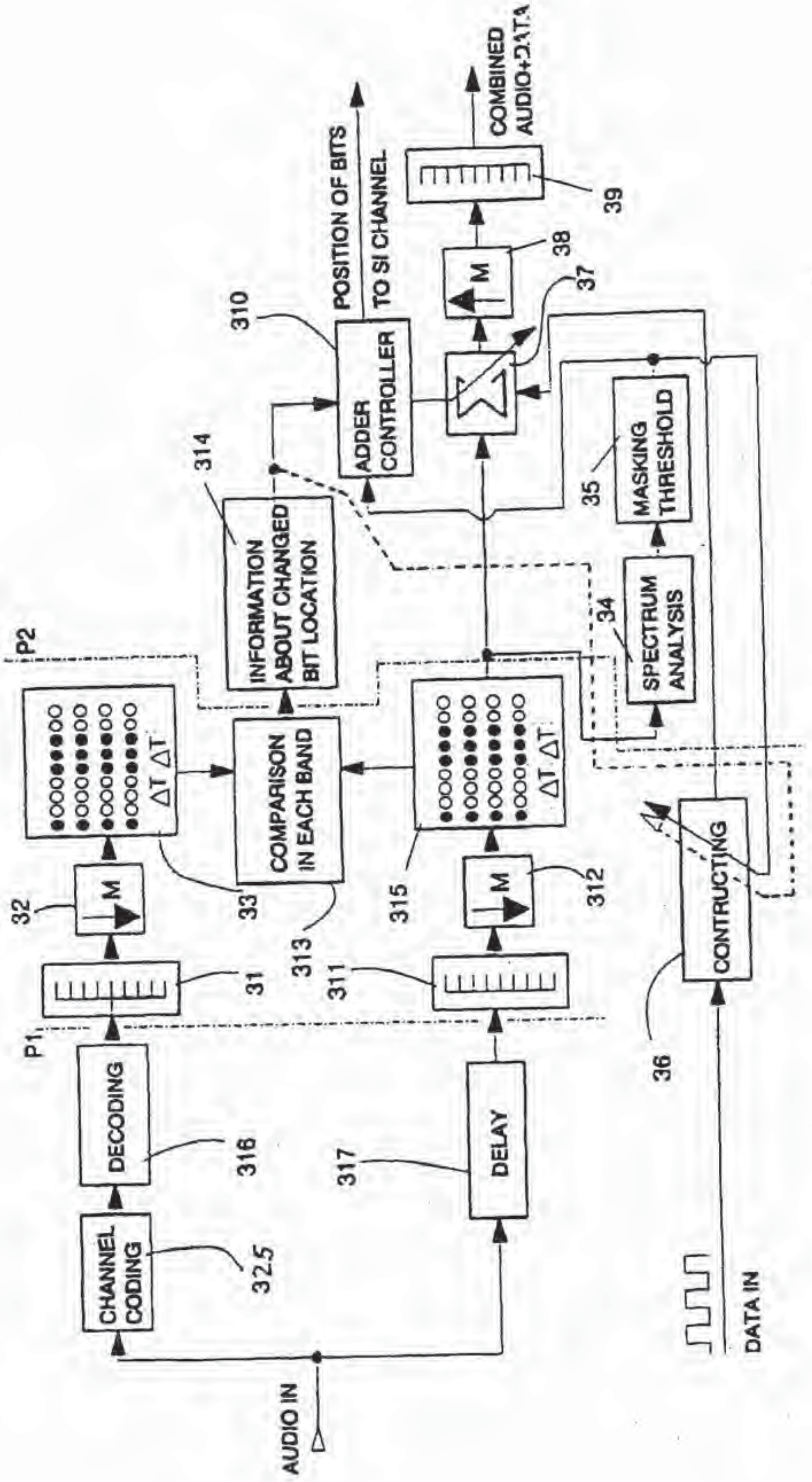

AUDIO IN
CHANNEL CODING
32.5
DECODING
316
DELAY
317
P1
31
311
32
M
312
M
33
ΔT ΔT
ΔT ΔT
315
COMPARISON IN EACH BAND
313
P2
INFORMATION ABOUT CHANGED BIT LOCATION
314
ADDER CONTROLLER
310
POSITION OF BITS
TO SI CHANNEL
34
SPECTRUM ANALYSIS
35
MASKING THRESHOLD
37
38
M
39
COMBINED AUDIO+DATA
CONTRUCTING
36
DATA IN

Fig. 3

PCT WORLD INTELLECTUAL PROPERTY ORGANIZATION
International Bureau

INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 6 : G06K 19/14 A2

(11) International Publication Number: WO 95/14289

(43) International Publication Date: 26 May 1995 (26.05.95)

(21) International Application Number: PCT/US94/13366

(22) International Filing Date: 16 November 1994 (16.11.94)

(30) Priority Data:

154,866	18 November 1993 (18.11.93)	US
215,289	17 March 1994 (17.03.94)	US
327,426	21 October 1994 (21.10.94)	US

(60) Parent Application or Grant
(63) Related by Continuation
US 08/327,426 (CIP)
Filed on 21 October 1994 (21.10.94)

(71) Applicant (*for all designated States except US*): PINECONE IMAGING CORPORATION [US/US]; 363 S.W. Tualatin Loop, West Linn, OR 97068 (US).

(72) Inventor; and
(75) Inventor/Applicant (*for US only*): RHOADS, Geoffrey, B. [US/US]; 363 S.W. Tualatin Loop, West Linn, OR 97068 (US).

(74) Agent: CONWELL, William, Y.; Klarquist, Sparkman, Campbell, Leigh & Whinston, One World Trade Center, Suite 1600, 121 S.W. Salmon Street, Portland, OR 97204 (US).

(81) Designated States: CA, JP, US, European patent (AT, BE, CH, DE, DK, ES, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE).

Published
Without international search report and to be republished upon receipt of that report.

(54) Title: IDENTIFICATION/AUTHENTICATION CODING METHOD AND APPARATUS

(57) Abstract

An identification code signal is impressed on a carrier to be identified (such as an electronic data signal or a physical medium) in a manner that permits the identification signal later to be discerned and the carrier thereby identified. The method and apparatus are characterized by robustness despite degradation of the encoded carrier, and by holographic permeation of the identification signal throughout the carrier. An exemplary embodiment is a processor that embeds the identification signal onto a carrier signal in real time.

FOR THE PURPOSES OF INFORMATION ONLY

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AT	Austria	GB	United Kingdom	MR	Mauritania
AU	Australia	GE	Georgia	MW	Malawi
BB	Barbados	GN	Guinea	NE	Niger
BE	Belgium	GR	Greece	NL	Netherlands
BF	Burkina Faso	HU	Hungary	NO	Norway
BG	Bulgaria	IE	Ireland	NZ	New Zealand
BJ	Benin	IT	Italy	PL	Poland
BR	Brazil	JP	Japan	PT	Portugal
BY	Belarus	KE	Kenya	RO	Romania
CA	Canada	KG	Kyrgystan	RU	Russian Federation
CF	Central African Republic	KP	Democratic People's Republic of Korea	SD	Sudan
CG	Congo			SE	Sweden
CH	Switzerland	KR	Republic of Korea	SI	Slovenia
CI	Côte d'Ivoire	KZ	Kazakhstan	SK	Slovakia
CM	Cameroon	LI	Liechtenstein	SN	Senegal
CN	China	LK	Sri Lanka	TD	Chad
CS	Czechoslovakia	LU	Luxembourg	TG	Togo
CZ	Czech Republic	LV	Latvia	TJ	Tajikistan
DE	Germany	MC	Monaco	TT	Trinidad and Tobago
DK	Denmark	MD	Republic of Moldova	UA	Ukraine
ES	Spain	MG	Madagascar	US	United States of America
FI	Finland	ML	Mali	UZ	Uzbekistan
FR	France	MN	Mongolia	VN	Viet Nam
GA	Gabon				

IDENTIFICATION/AUTHENTICATION CODING METHOD AND APPARATUS

Field of the Invention

The present invention relates to the embedding of robust identification codes in electronic, optical and physical media, and the subsequent, objective discernment of such codes for identification purposes even after intervening distortion or corruption of the media.

The invention is illustrated with reference to several exemplary applications, including identification/authentication coding of electronic imagery, serial data signals (e.g. audio and video), emulsion film, and paper currency, but is not so limited.

Background and Summary of the Invention

"I would never put it in the power of any printer or publisher to suppress or alter a work of mine, by making him master of the copy"

Thomas Paine, *Rights of Man*, 1792.

"The printer dares not go beyond his licensed copy"

Milton, *Aeropagetica*, 1644.

Since time immemorial, unauthorized use and outright piracy of proprietary source material has been a source of lost revenue, confusion, and artistic corruption.

These historical problems have been compounded by the advent of digital technology. With it, the technology of copying materials and redistributing them in unauthorized manners has reached new heights of sophistication, and more importantly, omnipresence. Lacking objective means for comparing an alleged copy of material with the original, owners and possible litigation proceedings are left with a subjective opinion of whether the alleged copy is stolen, or has been used in an unauthorized manner. Furthermore, there is no simple means of tracing a path to an original purchaser of the material, something which can be valuable in tracing where a possible "leak" of the material first occurred.

A variety of methods for protecting commercial material have been attempted. One is to scramble signals via an encoding method prior to distribution, and descramble prior to use. This technique, however, requires that both the original and later descrambled signals never leave closed and controlled networks, lest they be intercepted and recorded. Furthermore, this arrangement is of little use in the broad field of mass marketing audio and visual material, where even a few dollars extra cost causes a major reduction in market, and where the signal must eventually be descrambled to be perceived, and thus can be easily recorded.

Another class of techniques relies on modification of source audio or video signals to include a subliminal identification signal, which can be sensed by electronic means. Examples of such systems are found in U.S. Patent 4,972,471 and European patent publication EP 441,702, as well as in Komatsu et al, "Authentication System Using Concealed Image in Telematics," Memoirs of the School of Science & Engineering, Waseda University, No. 52, p. 45-60 (1988) (Komatsu uses the term "digital watermark" for this technique). An elementary introduction to these methods is found in the article "Digital Signatures," Byte Magazine, November, 1993, p. 309. These techniques have the common characteristic that deterministic signals with well defined patterns and sequences within the source material convey the identification information. For certain applications this is not a drawback. But in general, this is an inefficient form of embedding identification information for a variety of reasons: (a) the whole of the source material is not used; (b) deterministic patterns have a higher likelihood of being discovered and removed by a would-be pirate; and (c) the signals are not generally 'holographic' in that identifications may be difficult to make given only sections of the whole. ('Holographic' is used herein to refer to the property that the identification information is distributed globally throughout the coded signal, and can be fully discerned from an examination of even a fraction of the coded signal. Coding of this type is sometimes termed "distributed" herein.)

Among the cited references are descriptions of several programs which perform steganography - described in one document as "... the ancient art of hiding information in some *otherwise inconspicuous information*." These programs variously allow computer users to hide their own messages inside digital image files and digital audio files. All do so by toggling the least significant bit (the lowest order bit of a single data sample) of a given audio data stream or rasterized image. Some of these programs embed messages quite directly into the least significant bit, while other "pre-encrypt" or scramble a message first and then embed the encrypted data into the least significant bit.

Our current understanding of these programs is that they generally rely on error-free transmission of the of digital data in order to correctly transmit a given message in its entirety. Typically the message is passed only once, i.e., it is not repeated. These programs also seem to "take over" the least significant bit entirely, where actual data is obliterated and the message placed accordingly. This might mean that such codes could be easily erased by merely stripping off the least significant bit of all data values in a given image or audio file. It is these and other considerations which suggest that the only similarity between our invention and the established art of steganography is in the placement of information into data files with minimal perceptibility. The specifics of embedding and the uses of that buried information diverge from there.

Another cited reference is U.S. Patent 5,325,167 to Melen. In the service of authenticating a given document, the high precision scanning of that document reveals patterns and "microscopic grain structure" which apparently is a kind of unique fingerprint for the underlying document media, such as paper itself or post-applied materials such as toner. Melen further teaches that scanning and storing this fingerprint can later be used in authentication by scanning a purported document and comparing it to the original fingerprint. Applicant is aware of a similar idea employed in the very high precision recording of credit card magnetic strips, as reported in the February 8, 1994, Wall Street Journal, page B1, wherein very fine magnetic fluxuations tend to be unique from one card to the next, so that credit card authentication could be achieved through pre-recording these fluxuations later to be compared to the recordings of the purportedly same credit card.

Both of the foregoing techniques appear to rest on the same identification principles on which the mature science of fingerprint analysis rests: the innate uniqueness of some localized physical property. These methods then rely upon a single judgement and/or measurement of "similarity" or "correlation" between a suspect and a pre-recording master. Though fingerprint analysis has brought this to a high art, these methods are nevertheless open to a claim that preparations of the samples, and the "filtering" and "scanner specifications" of Melen's patent, unavoidably tend to bias the resulting judgement of similarity, and would create a need for more esoteric "expert testimony" to explain the confidence of a found match or mis-match. An object of the present invention is to avoid this reliance on expert testimony and to place the confidence in a match into simple "coin flip" vernacular, i.e., what are the odds you can call the correct coin flip 16 times in a row. Attempts to identify fragments of a fingerprint, document, or otherwise, exacerbate this issue of confidence in a judgment, where it is an object of the present invention to objectively apply the intuitive "coin flip" confidence to the smallest fragment possible. Also, storing unique fingerprints for each and every document or credit card magnetic strip, and having these fingerprints readily available for later cross-checking, should prove to be quite an economic undertaking. It is an object of this invention to allow for the "re-use" of noise codes and "snowy images" in the service of easing storage requirements.

U.S. Patent 4,921,278 to Shiang et al. teaches a kind of spatial encryption technique wherein a signature or photograph is splayed out into what the untrained eye would refer to as noise, but which is actually a well defined structure referred to as Moire patterns. The similarities of the present invention to Shiang's system appear to be use of noise-like patterns which nevertheless carry information, and the use of this principle on credit cards and other identification cards.

Others of the cited patents deal with other techniques for identification and/or authentication of signals or media. U.S. Patent 4,944,036 to Hyatt does not appear to be applicable to the present invention, but does point out that the term "signature" can be equally applied to signals which carry unique characteristics based on physical structure.

Despite the foregoing and other diverse work in the field of identification/authentication, there still remains a need for a reliable and efficient method for performing a positive identification between a copy of an original signal and the original. Desirably, this method should not only perform identification, it should also be able to convey source-version information in order to better pinpoint the point of sale. The method should not compromise the innate quality of material which is being sold, as does the placement of localized logos on images. The method should be robust so that an identification can be made even after multiple copies have been made and/or compression and decompression of the signal has taken place. The identification method should be largely uneraseable or "uncrackable." The method should be capable of working even on fractional pieces of the original signal, such as a 10 second "riff" of an audio signal or the "clipped and pasted" sub-section of an original image.

The existence of such a method would have profound consequences on piracy in that it could (a) cost effectively monitor for unauthorized uses of material and perform "quick checks"; (b) become a deterrent to unauthorized uses when the method is known to be in use and the consequences well publicized; and (c) provide unequivocal proof of identity, similar to fingerprint identification, in litigation, with potentially more reliability than that of fingerprinting.

In accordance with an exemplary embodiment of the invention, the foregoing and additional objects are achieved by embedding an imperceptible identification code throughout a source signal. In the preferred embodiment, this embedding is achieved by modulating the source signal with a small noise signal in a coded fashion. More particularly, bits of a binary identification code are referenced, one at a time, to control modulation of the source signal with the noise signal.

The copy with the embedded signal (the "encoded" copy) becomes the material which is sold, while the original is secured in a safe place. The new copy is nearly identical to the original except under the finest of scrutiny; thus, its commercial value is not compromised. After the new copy has been sold and distributed and potentially distorted by multiple copies, the present disclosure details methods for positively identifying any suspect signal against the original.

Among its other advantages, the preferred embodiments' use of identification signals which are global (holographic) and which mimic natural noise sources allows the maximization of identification signal energy, as opposed to merely having it present 'somewhere in the original material.' This allows the identification coding to be much more robust in the face of thousands of real world degradation processes and material transformations, such as cutting and cropping of imagery.

The foregoing and additional features and advantages of the present invention will be more readily apparent from the following detailed description thereof, which proceeds with reference to the accompanying drawings.

Brief Description of the Drawings

Fig. 1 is a simple and classic depiction of a one dimensional digital signal which is discretized in both axes.

Fig. 2 is a general overview, with detailed description of steps, of the process of embedding an "imperceptible" identification signal onto another signal.

Fig. 3 is a step-wise description of how a suspected copy of an original is identified.

Fig. 4 is a schematic view of an apparatus for pre-exposing film with identification information in accordance with another embodiment of the present invention.

Fig. 5 is a diagram of a "black box" embodiment of the present invention.

Fig. 6 is a schematic block diagram of the embodiment of Fig. 5.

Fig. 7 shows a variant of the Fig. 6 embodiment adapted to encode successive sets of input data with different code words but with the same noise data.

Fig. 8 shows a variant of the Fig. 6 embodiment adapted to encode each frame of a videotaped production with a unique code number.

Figs. 9A-9C are representations of an industry standard noise second that can be used in one embodiment of the present invention.

Fig. 10 shows an integrated circuit used in detecting standard noise codes.

Fig. 11 shows a process flow for detecting a standard noise code that can be used in the Fig. 10 embodiment.

Fig. 12 is an embodiment employing a plurality of detectors in accordance with another embodiment of the present invention.

Detailed Description

In the following discussion of an illustrative embodiment, the words "signal" and "image" are used interchangeably to refer to both one, two, and even beyond two dimensions of digital signal. Examples will routinely switch back and forth between a one dimensional audio-type digital signal and a two dimensional image-type digital signal.

In order to fully describe the details of an illustrative embodiment of the invention, it is necessary first to describe the basic properties of a digital signal. Fig. 1 shows a classic representation of a one dimensional digital signal. The x-axis defines the index numbers of sequence of digital "samples," and the y-axis is the instantaneous value of the signal at that sample, being constrained to exist only at a finite number of levels defined as the "binary depth" of a digital sample. The example depicted in Fig. 1 has the value of 2 to the fourth power, or "4 bits," giving 16 allowed states of the sample value.

For audio information such as sound waves, it is commonly accepted that the digitization process discretizes a continuous phenomena both in the time domain and in the signal level domain. As such, the process of digitization itself introduces a fundamental error source, in that it cannot record detail smaller than the discretization interval in either domain. The industry has referred to this, among other ways, as "aliasing" in the time domain, and "quantization noise" in the signal level domain. Thus, there will always be a basic error floor of a digital signal. Pure quantization noise, measured in a root mean square sense, is theoretically known to have the value of one over the square root of twelve, or about 0.29 DN, where DN stands for 'Digital Number' or the finest unit increment of the signal level. For example, a perfect 12-bit digitizer will have 4096 allowed DN with an innate root mean square noise floor of ~0.29 DN.

All known physical measurement processes add additional noise to the transformation of a continuous signal into the digital form. The quantization noise typically adds in quadrature (square root of the mean squares) to the "analog noise" of the measurement process, as it is sometimes referred to.

With almost all commercial and technical processes, the use of the decibel scale is used as a measure of signal and noise in a given recording medium. The expression "signal-to-noise ratio" is generally used, as it will be in this disclosure. As an example, this disclosure refers to signal to noise ratios in terms of signal power and noise power, thus 20 dB represents a 10 times increase in signal amplitude.

In summary, the presently preferred embodiments of the invention embed an N-bit value onto an entire signal through the addition of a very low amplitude encodation signal which has the look of pure noise. N is usually at least 8 and is capped on the higher end by ultimate signal-to-noise considerations and "bit error" in retrieving and decoding the N-bit value. As a practical matter, N is chosen based on application specific considerations, such as the number of unique different "signatures" that are desired. To illustrate, if N=128, then the number of unique digital signatures is in excess of 10^^38 (2^^128). This number is believed to be more than adequate to both identify the material with sufficient statistical certainty <u>and</u> to index exact sale and distribution information.

The amplitude or power of this added signal is determined by the aesthetic and informational considerations of each and every application using the present methodology. For instance, non-professional video can stand to have a higher embedded signal level without becoming noticeable to the average human eye, while high precision audio may only be able to accept a relatively small signal level lest the human ear perceive an objectionable increase in "hiss." These statements are generalities and each application has its own set of criteria in choosing the signal level of the embedded identification signal. The higher the level of embedded signal, the more corrupted a copy can be and still be identified. On the other hand, the higher the level of embedded signal, the more objectionable the perceived noise might be, potentially impacting the value of the distributed material.

To illustrate the range of different applications to which the principles of the present invention can be applied, the present specification details two different systems. The first (termed, for lack of a better name, a "batch encoding" system), applies identification coding to an existing data signal. The second (termed, for lack of a better name, a "real time encoding" system), applies identification coding to a signal as it is produced. Those skilled in the art will recognize that the principles of the present invention can be applied in a number of other contexts in addition to these particularly described.

The discussions of these two systems can be read in either order. Some readers may find the latter more intuitive than the former; for others the contrary may be true.

<u>BATCH ENCODING</u>

The following discussion of a first class of embodiments is best prefaced by a section defining relevant terms:

The <u>original signal</u> refers to either the original digital signal or the high quality digitized copy of a non-digital original.

The N-bit identification word refers to a unique identification binary value, typically having N range anywhere from 8 to 128, which is the identification code ultimately placed onto the original signal via the disclosed transformation process. In the illustrated embodiment, each N-bit identification word begins with the sequence of values '0101,' which is used to determine an optimization of the signal-to-noise ratio in the identification procedure of a suspect signal (see definition below).

The m'th bit value of the N-bit identification word is either a zero or one corresponding to the value of the m'th place, reading left to right, of the N-bit word. E.g., the first (m=1) bit value of the N=8 identification word 01110100 is the value '0;' the second bit value of this identification word is '1', etc.

The m'th individual embedded code signal refers to a signal which has dimensions and extent precisely equal to the original signal (e.g. both are a 512 by 512 digital image), and which is (in the illustrated embodiment) an independent pseudo-random sequence of digital values. "Pseudo" pays homage to the difficulty in philosophically defining pure randomness, and also indicates that there are various acceptable ways of generating the "random" signal. There will be exactly N individual embedded code signals associated with any given original signal.

The acceptable perceived noise level refers to an application-specific determination of how much "extra noise," i.e. amplitude of the composite embedded code signal described next, can be added to the original signal and still have an acceptable signal to sell or otherwise distribute. This disclosure uses a 1 dB increase in noise as a typical value which might be acceptable, but this is quite arbitrary.

The composite embedded code signal refers to the signal which has dimensions and extent precisely equal to the original signal, (e.g. both are a 512 by 512 digital image), and which contains the addition and appropriate attenuation of the N individual embedded code signals. The individual embedded signals are generated on an arbitrary scale, whereas the amplitude of the composite signal must not exceed the pre-set acceptable perceived noise level, hence the need for "attenuation" of the N added individual code signals.

The distributable signal refers to the nearly similar copy of the original signal, consisting of the original signal plus the composite embedded code signal. This is the signal which is distributed to the outside community, having only slightly higher but acceptable "noise properties" than the original.

A suspect signal refers to a signal which has the general appearance of the original and distributed signal and whose potential identification match to the original is being questioned. The suspect signal is then analyzed to see if it matches the N-bit identification word.

The detailed methodology of this first embodiment begins by stating that the N-bit identification word is encoded onto the original signal by having each of the m bit values multiply their corresponding individual embedded code signals, the resultant being accumulated in the composite signal, the fully summed composite signal then being attenuated down to the acceptable perceived noise amplitude, and the resultant composite signal added to the original to become the distributable signal.

The original signal, the N-bit identification word, and all N individual embedded code signals are then stored away in a secured place. A suspect signal is then found. This signal may have undergone multiple copies, compressions and decompressions, resamplings onto different spaced digital signals, transfers from digital to analog back to digital media, or any combination of these items. IF the signal still appears similar to the original, i.e. its innate quality is not thoroughly destroyed by all of these transformations and noise additions, then depending on the signal to noise properties of the embedded signal, the identification process should function to some objective degree of statistical confidence. The extent of corruption of the suspect signal and the original acceptable perceived noise level are two key parameters in determining an expected confidence level of identification.

The identification process on the suspected signal begins by resampling and aligning the suspected signal onto the digital format and extent of the original signal. Thus, if an image has been reduced by a factor of two, it needs to be digitally enlarged by that same factor. Likewise, if a piece of music has been "cut out," but may still have the same sampling rate as the original, it is necessary to register this cut-out piece to the original, typically done by performing a local digital cross-correlation of the two signals (a common digital operation), finding at what delay value the correlation peaks, then using this found delay value to register the cut piece to a segment of the original.

Once the suspect signal has been sample-spacing matched and registered to the original, the signal levels of the suspect signal should be matched in an rms sense to the signal level of the original. This can be done via a search on the parameters of offset, amplification, and gamma being optimized by using the minimum of the mean squared error between the two signals as a function of the three parameters. We can call the suspect signal normalized and registered at this point, or just normalized for convenience.

The newly matched pair then has the original signal subtracted from the normalized suspect signal to produce a difference signal. The difference signal is then cross-correlated with each of the N individual embedded code signals and the peak cross-correlation value recorded. The first four bit code ('0101') is used as a calibrator both on the mean values of the zero value and the one value, and on further registration of the two signals if a finer signal to noise ratio is desired (i.e., the optimal separation of the 0101 signal will indicate an optimal registration of the two signals and will also indicate the probable existence of the N-bit identification signal being present.)

The resulting peak cross-correlation values will form a noisy series of floating point numbers which can be transformed into 0's and 1's by their proximity to the mean values of 0 and 1 found by the 0101 calibration sequence. If the suspect signal has indeed been derived from the original, the identification number resulting from the above process will match the N-bit identification word of the original, bearing in mind either predicted or unknown "bit error" statistics. Signal-to-noise considerations will determine if there will be some kind of "bit error" in the identification process, leading to a form of X% probability of identification where X might be desired to be 99.9% or whatever. If the suspect copy is indeed not a copy of the original, an essentially random sequence of 0's and 1's will be produced, as well as an apparent lack of separation of the resultant values. This is to say, if the resultant values are plotted on a histogram, the existence of the N-bit identification signal will exhibit strong bi-level characteristics, whereas the non-existence of the code, or the existence of a different code of a different original, will exhibit a type of random gaussian-like distribution. This histogram separation alone should be sufficient for an identification, but it is even stronger proof of identification when an exact binary sequence can be objectively reproduced.

Specific Example

Imagine that we have taken a valuable picture of two heads of state at a cocktail party, pictures which are sure to earn some reasonable fee in the commercial market. We desire to sell this picture and ensure that it is not used in an unauthorized or uncompensated manner. This and the following steps are summarized in Fig. 2.

Assume the picture is transformed into a positive color print. We first scan this into a digitized form via a normal high quality black and white scanner with a typical photometric spectral response curve. (It is possible to get better ultimate signal to noise ratios by scanning in each of the three primary colors of the color image, but this nuance is not central to describing the basic process.)

Let us assume that the scanned image now becomes a 4000 by 4000 pixel monochrome digital image with a grey scale accuracy defined by 12-bit grey values or 4096 allowed levels. We will call this the "original digital image" realizing that this is the same as our "original signal" in the above definitions.

During the scanning process we have arbitrarily set absolute black to correspond to digital value '30'. We estimate that there is a basic 2 Digital Number root mean square noise existing on the original digital image, plus a theoretical noise (known in the industry as "shot noise") of the square root of the brightness value of any given pixel. In formula, we have:

$$<\text{RMS Noise}_{n,m}> = \text{sqrt}(4 + (V_{n,m}-30)) \qquad (1)$$

Here, n and m are simple indexing values on rows and columns of the image ranging from 0 to 3999. Sqrt is the square root. V is the DN of a given indexed pixel on the original digital image. The < > brackets around the RMS noise merely indicates that this is an expected average value, where it is clear that each and every pixel will have a random error individually. Thus, for a pixel value having 1200 as a digital number or "brightness value", we find that its expected rms noise value is sqrt(1204) = 34.70, which is quite close to 34.64, the square root of 1200.

We furthermore realize that the square root of the innate brightness value of a pixel is not precisely what the eye perceives as a minimum objectionable noise, thus we come up with the formula:

$$\text{<RMS Addable Noise}_{n,m}\text{>} = X^{*}\text{sqrt}(4+(V_{n,m}-30)\text{^}Y) \qquad (2)$$

Where X and Y have been added as empirical parameters which we will adjust, and "addable" noise refers to our acceptable perceived noise level from the definitions above. We now intend to experiment with what exact value of X and Y we can choose, but we will do so at the same time that we are performing the next steps in the process.

The next step in our process is to choose N of our N-bit identification word. We decide that a 16 bit main identification value with its 65536 possible values will be sufficiently large to identify the image as ours, and that we will be directly selling no more than 128 copies of the image which we wish to track, giving 7 bits plus an eighth bit for an odd/even adding of the first 7 bits (i.e. an error checking bit on the first seven). The total bits required now are at 4 bits for the 0101 calibration sequence, 16 for the main identification, 8 for the version, and we now throw in another 4 as a further error checking value on the first 28 bits, giving 32 bits as N. The final 4 bits can use one of many industry standard error checking methods to choose its four values.

We now randomly determine the 16 bit main identification number, finding for example, 1101 0001 1001 1110; our first versions of the original sold will have all 0's as the version identifier, and the error checking bits will fall out where they may. We now have our unique 32 bit identification word which we will embed on the original digital image.

To do this, we generate 32 independent random 4000 by 4000 encoding images for each bit of our 32 bit identification word. The manner of generating these random images is revealing. There are numerous ways to generate these. By far the simplest is to turn up the gain on the same scanner that was used to scan in the original photograph, only this time placing a pure black image as the input, then scanning this 32 times. The only drawback to this technique is that it does require a large amount of memory and that "fixed pattern" noise will be part of each independent "noise image." But, the fixed pattern noise can be removed via normal "dark frame" subtraction techniques. Assume that we set the absolute black average value at digital number '100,' and that rather than finding a 2 DN rms noise as we did in the normal gain setting, we now find an rms noise of 10 DN about each and every pixel's mean value.

We next apply a mid-spatial-frequency bandpass filter (spatial convolution) to each and every independent random image, essentially removing the very high and the very low spatial frequencies from them. We remove the very low frequencies because simple real-world error sources like geometrical warping, splotches on scanners, mis-registrations, and the like will exhibit themselves most at lower frequencies also, and so we want to concentrate our identification signal at higher spatial frequencies in order to avoid these types of corruptions. Likewise, we remove the higher frequencies because multiple generation copies of a given image, as well as compression-decompression transformations, tend to wipe out higher frequencies anyway, so there is no point in placing too much identification signal into these frequencies if they will be the ones most prone to being attenuated. Therefore, our new filtered independent noise images will be dominated by mid-spatial frequencies. On a practical note, since we are using 12-bit values on our scanner and we have removed the DC value effectively and our new rms noise will be slightly less than 10 digital numbers, it is useful to boil this down to a 6-bit value ranging from -32 through 0 to 31 as the resultant random image.

Next we add all of the random images together which have a '1' in their corresponding bit value of the 32-bit identification word, accumulating the result in a 16-bit signed integer image. This is the unattenuated and un-scaled version of the composite embedded signal.

Next we experiment visually with adding the composite embedded signal to the original digital image, through varying the X and Y parameters of equation 2. In formula, we visually iterate to both maximize X and to find the appropriate Y in the following:

$$V_{dist;n,m} = V_{orig;n,m} + V_{comp;n,m}*X*sqrt(4+V_{orig;n,m}\hat{}Y) \qquad (3)$$

where dist refers to the candidate distributable image, i.e. we are visually iterating to find what X and Y will give us an acceptable image; orig refers to the pixel value of the original image; and comp refers to the pixel value of the composite image. The n's and m's still index rows and columns of the image and indicate that this operation is done on all 4000 by 4000 pixels. The symbol V is the DN of a given pixel and a given image.

As an arbitrary assumption, now, we assume that our visual experimentation has found that the value of X= 0.025 and Y=0.6 are acceptable values when comparing the original image with the candidate distributable image. This is to say, the distributable image with the "extra noise" is acceptably close to the original in an aesthetic sense. Note that since our individual random images had a random rms noise value around 10 DN, and that adding approximately 16 of these images together will increase the composite noise to around 40 DN, the X multiplication value of 0.025 will bring the added rms noise back to around 1 DN, or half the amplitude of our innate noise on the original. This is roughly a 1 dB gain in noise at the dark pixel values and correspondingly more at the brighter values modified by the Y value of 0.6.

So with these two values of X and Y, we now have constructed our first versions of a distributable copy of the original. Other versions will merely create a new composite signal and possibly change the X slightly if deemed necessary. We now lock up the original digital image along with the 32-bit identification word for each version, and the 32 independent random

4-bit images, waiting for our first case of a suspected piracy of our original. Storage wise, this is about 14 Megabytes for the original image and 32*0.5bytes*16 million = ~256 Megabytes for the random individual encoded images. This is quite acceptable for a single valuable image. Some storage economy can be gained by simple lossless compression.

Finding a Suspected Piracy of our Image

We sell our image and several months later find our two heads of state in the exact poses we sold them in, seemingly cut and lifted out of our image and placed into another stylized background scene. This new "suspect" image is being printed in 100,000 copies of a given magazine issue, let us say. We now go about determining if a portion of our original image has indeed been used in an unauthorized manner. Fig. 3 summarizes the details.

The first step is to take an issue of the magazine, cut out the page with the image on it, then carefully but not too carefully cut out the two figures from the background image using ordinary scissors. If possible, we will cut out only one connected piece rather than the two figures separately. We paste this onto a black background and scan this into a digital form. Next we electronically flag or mask out the black background, which is easy to do by visual inspection.

We now procure the original digital image from our secured place along with the 32-bit identification word and the 32 individual embedded images. We place the original digital image onto our computer screen using standard image manipulation software, and we roughly cut along the same borders as our masked area of the suspect image, masking this image at the same time in roughly the same manner. The word 'roughly' is used since an exact cutting is not needed, it merely aids the identification statistics to get it reasonably close.

Next we rescale the masked suspect image to roughly match the size of our masked original digital image, that is, we digitally scale up or down the suspect image and roughly overlay it on the original image. Once we have performed this rough registration, we then throw the two images into an automated scaling and registration program. The program performs a search on the three parameters of x position, y position, and spatial scale, with the figure of merit being the mean squared error between the two images given any given scale variable and x and y offset. This is a fairly standard image processing methodology. Typically this would be done using generally smooth interpolation techniques and done to sub-pixel accuracy. The search method can be one of many, where the simplex method is a typical one.

Once the optimal scaling and x-y position variables are found, next comes another search on optimizing the black level, brightness gain, and gamma of the two images. Again, the figure of merit to be used is mean squared error, and again the simplex or other search methodologies can be used to optimize the three variables. After these three variables are optimized, we apply their corrections to the suspect image and align it to exactly the pixel spacing and masking of the original digital image and its mask. We can now call this the standard mask.

The next step is to subtract the original digital image from the newly normalized suspect image only within the standard mask region. This new image is called the difference image.

Then we step through all 32 individual random embedded images, doing a local cross-correlation between the masked difference image and the masked individual embedded image. 'Local' refers to the idea that one need only start correlating over an offset region of +/- 1 pixels of offset between the nominal registration points of the two images found during the search procedures above. The peak correlation should be very close to the nominal registration point of 0,0 offset, and we can add the 3 by 3 correlation values together to give one grand correlation value for each of the 32 individual bits of our 32-bit identification word.

After doing this for all 32 bit places and their corresponding random images, we have a quasi-floating point sequence of 32 values. The first four values represent our calibration signal of 0101. We now take the mean of the first and third floating point value and call this floating point value '0,' and we take the mean of the second and the fourth value and call this floating point value '1.' We then step through all remaining 28 bit values and assign either a '0' or a '1' based simply on which mean value they are closer to. Stated simply, if the suspect image is indeed a copy of our original, the embedded 32-bit resulting code should match that of our records, and if it is not a copy, we should get general randomness. The third and the fourth possibilities of 3) Is a copy but doesn't match identification number and 4) isn't a copy but does match are, in the case of 3), possible if the signal to noise ratio of the process has plummeted, i.e. the 'suspect image' is truly a very poor copy of the original, and in the case of 4) is basically one chance in four billion since we were using a 32-bit identification number. If we are truly worried about 4), we can just have a second independent lab perform their own tests on a different issue of the same magazine. Finally, checking the error-check bits against what the values give is one final and possibly overkill check on the whole process. In situations where signal to noise is a possible problem, these error checking bits might be eliminated without too much harm.

Benefits

Now that a full description of the first embodiment has been described via a detailed example, it is appropriate to point out the rationale of some of the process steps and their benefits.

The ultimate benefits of the foregoing process are that obtaining an identification number is fully independent of the manners and methods of preparing the difference image. That is to say, the manners of preparing the difference image, such as cutting, registering, scaling, etcetera, cannot increase the odds of finding an identification number when none exists; it only helps the signal-to-noise ratio of the identification process when a true identification number is present. Methods of preparing images for identification can be different from each other even, providing the possibility for multiple independent methodologies for making a match.

The ability to obtain a match even on sub-sets of the original signal or image is a key point in today's information-rich world. Cutting and pasting both images and sound clips is becoming more common, allowing such an embodiment to be used in detecting a copy even when original material has been thus corrupted. Finally, the signal to noise ratio of matching should begin to become difficult only when the copy material itself has been significantly altered either by noise or by significant distortion; both of these also will affect that copy's commercial value, so that trying to thwart the system can only be done at the expense of a huge decrease in commercial value.

An early conception of this invention was the case where only a single "snowy image" or random signal was added to an original image, i.e. the case where N=1. "Decoding" this signal would involve a subsequent mathematical analysis using (generally statistical) algorithms to make a judgment on the presence or absence of this signal. The reason this approach was abandoned as the preferred embodiment was that there was an inherent gray area in the certainty of detecting the presence or absence of the signal. By moving onward to a multitude of bit planes, i.e. N > 1, combined with simple pre-defined algorithms prescribing the manner of choosing between a "0" and a "1", the invention moved the certainty question from the realm of expert statistical analysis into the realm of guessing a random binary event such as a coin flip. This is seen as a powerful feature relative to the intuitive acceptance of this invention in both the courtroom and the marketplace. The analogy which summarizes the inventor's thoughts on this whole question is as follows: The search for a single identification signal amounts to calling a coin flip only once, and relying on arcane experts to make the call; whereas the N>1 preferred embodiment of this invention relies on the broadly intuitive principle of correctly calling a coin flip N times in a row. This situation is greatly exacerbated, i.e. the problems of "interpretation" of the presence of a single signal, when images and sound clips get smaller and smaller in extent.

Another important reason that the N>1 case is the preferred embodiment over the N=1 embodiment is that in the N=1 case, the manner in which a suspect image is prepared and manipulated has a direct bearing on the likelihood of making a positive identification. Thus, the manner with which an expert makes an identification determination becomes an integral part of that determination. The existence of a multitude of mathematical and statistical approaches to making this determination leave open the possibility that some tests might make positive identifications while others might make negative determinations, inviting further arcane debate about the relative merits of the various identification approaches. The N>1 preferred embodiment of this invention avoids this further gray area by presenting a method where no amount of pre-processing of a signal - other than pre-processing which surreptitiously uses knowledge of the private code signals - can increase the likelihood of "calling the coin flip N times in a row."

The fullest expression of the present system will come when it becomes an industry standard and numerous independent groups set up with their own means or 'in-house' brand of applying embedded identification numbers and in their decipherment. Numerous independent group identification will further enhance the ultimate objectivity of the method, thereby enhancing its appeal as an industry standard.

Use of True Polarity in Creating the Composite Embedded Code Signal

The foregoing discussion made use of the 0 and 1 formalism of binary technology to accomplish its ends. Specifically, the 0's and 1's of the N-bit identification word directly multiplied their corresponding individual embedded code signal to form the composite embedded code signal (step 8, figure 2). This approach certainly has its conceptual simplicity, but the multiplication of an embedded code signal by 0 along with the storage of that embedded code contains a kind of inefficiency.

It is preferred to maintain the formalism of the 0 and 1 nature of the N-bit identification word, but to have the 0's of the word induce a subtraction of their corresponding embedded code signal. Thus, in step 8 of figure 2, rather than only 'adding' the individual embedded code signals which correspond to a '1' in the N-bit identification word, we will also 'subtract' the individual embedded code signals which correspond to a '0' in the N-bit identification word.

At first glance this seems to add more apparent noise to the final composite signal. But it also increases the energy-wise separation of the 0's from the 1's, and thus the 'gain' which is applied in step 10, figure 2 can be correspondingly lower.

We can refer to this improvement as the use of true polarity. The main advantage of this improvement can largely be summarized as 'informational efficiency.'

'Perceptual Orthogonality' of the Individual Embedded Code Signals

The foregoing discussion contemplates the use of generally random noise-like signals as the individual embedded code signals. This is perhaps the simplest form of signal to generate. However, there is a form of informational optimization which can be applied to the set of the individual embedded signals, which the applicant describes under the rubric 'perceptual orthogonality.' This term is loosely based on the mathematical concept of the orthogonality of vectors, with the current additional requirement that this orthogonality should maximize the signal energy of the identification information while maintaining it below some perceptibility threshold. Put another way, the embedded code signals need not necessarily be random in nature.

Use and Improvements of the First Embodiment in the Field of Emulsion-Based Photography

The foregoing discussion outlined techniques that are applicable to photographic materials. The following section explores the details of this area further and discloses certain improvements which lend themselves to a broad range of applications.

The first area to be discussed involves the pre-application or pre-exposing of a serial number onto traditional photographic products, such as negative film, print paper, transparencies, etc. In general, this is a way to embed *a priori* unique serial numbers (and by implication, ownership and tracking information) into photographic material. The serial numbers themselves would be a permanent part of the normally exposed picture, as opposed to being relegated to the margins or stamped on the back of a printed photograph, which all require separate locations and separate methods of copying. The 'serial number' as it is called here is generally synonymous with the N-bit identification word, only now we are using a more common industrial terminology.

In Figure 2, step 11, the disclosure calls for the storage of the "original [image]" along with code images. Then in figure 3, step 9, it directs that the original be subtracted from the suspect image, thereby leaving the possible identification codes plus whatever noise and corruption has accumulated. Therefore, the previous disclosure made the tacit assumption that there exists an original without the composite embedded signals.

Now in the case of selling print paper and other duplication film products, this will still be the case, i.e., an "original" without the embedded codes will indeed exist and the basic methodology of the first embodiment can be employed. The original film serves perfectly well as an 'unencoded original.'

However, in the case where pre-exposed negative film is used, the composite embedded signal pre-exists on the original film and thus there will never be an "original" separate from the pre-embedded signal. It is this latter case, therefore, which will be examined a bit more closely, along with observations on how to best use the principles discussed above (the former cases adhering to the previously outlined methods).

The clearest point of departure for the case of pre-numbered negative film, i.e. negative film which has had each and every frame pre-exposed with a very faint and unique composite embedded signal, comes at step 9 of figure 3 as previously noted. There are certainly other differences as well, but they are mostly logistical in nature, such as how and when to embed the signals on the film, how to store the code numbers and serial number, etc. Obviously the pre-exposing of film would involve a major change to the general mass production process of creating and packaging film.

Fig. 4 has a schematic outlining one potential post-hoc mechanism for pre-exposing film. 'Post-hoc' refers to applying a process after the full common manufacturing process of film has already taken place. Eventually, economies of scale may dictate placing this pre-exposing process directly into the chain of manufacturing film. Depicted in Fig. 4 is what is commonly known as a film writing system. The computer, 106, displays the composite signal produced in step 8, figure 2, on its phosphor screen. A given frame of film is then exposed by imaging this phosphor screen, where the exposure level is generally very faint, i.e. generally imperceptible. Clearly, the marketplace will set its own demands on how faint this should be, that is, the level of added 'graininess' as practitioners would put it. Each frame of film is sequentially exposed, where in general the composite image displayed on the CRT 102 is changed for each and every frame, thereby giving each frame of film a different serial number. The transfer lens 104 highlights the focal conjugate planes of a film frame and the CRT face.

Getting back to the applying the principles of the foregoing embodiment in the case of pre-exposed negative film... At step 9, figure 3, if we were to subtract the "original" with its embedded code, we would obviously be "erasing" the code as well since the code is an integral part of the original. Fortunately, remedies do exist and identifications can still be made. However, it will be a challenge to artisans who refine this embodiment to have the signal to noise ratio of the identification process in the pre-exposed negative case approach the signal to noise ratio of the case where the un-encoded original exists.

A succinct definition of the problem is in order at this point. Given a suspect picture (signal), find the embedded identification code IF a code exists at al. The problem reduces to one of finding the amplitude of each and every individual embedded code signal within the suspect picture, not only within the context of noise and corruption as was previously explained, but now also within the context of the coupling between a captured image and the codes. 'Coupling' here refers to the idea that the captured image "randomly biases" the cross-correlation.

So, bearing in mind this additional item of signal coupling, the identification process now estimates the signal amplitude of each and every individual embedded code signal (as opposed to taking the cross-correlation result of step 12, figure 3). If our identification signal exists in the suspect picture, the amplitudes thus found will split into a polarity with positive amplitudes being assigned a '1' and negative amplitudes being assigned a '0'. Our unique identification code manifests itself. If, on the other hand, no such identification code exists or it is someone else's code, then a random gaussian-like distribution of amplitudes is found with a random hash of values.

It remains to provide a few more details on how the amplitudes of the individual embedded codes are found. Again, fortunately, this exact problem has been treated in other technological applications. Besides, throw this problem and a little food into a crowded room of mathematicians and statisticians and surely a half dozen optimized methodologies will pop out after some reasonable period of time. It is a rather cleanly defined problem.

One specific example solution comes from the field of astronomical imaging. Here, it is a mature prior art to subtract out a "thermal noise frame" from a given CCD image of an object. Often, however, it is not precisely known what scaling factor to use in subtracting the thermal frame, and a search for the correct scaling factor is performed. This is precisely the task of this step of the present embodiment.

General practice merely performs a common search algorithm on the scaling factor, where a scaling factor is chosen and a new image is created according to:

$$\text{NEW IMAGE} = \text{ACQUIRED IMAGE} - \text{SCALE} * \text{THERMAL IMAGE} \qquad (4)$$

The new image is applied to the fast fourier transform routine and a scale factor is eventually found which minimizes the integrated high frequency content of the new image. This general type of search operation with its minimization of a particular quantity is exceedingly common. The scale factor thus found is the sought-for "amplitude." Refinements which are contemplated but not yet implemented are where the coupling of the higher derivatives of the acquired image and the embedded codes are estimated and removed from the calculated scale factor. In other words, certain bias effects from the coupling mentioned earlier are present and should be eventually accounted for and removed both through theoretical and empirical experimentation.

Use and Improvements in the Detection of Signal or Image Alteration

Apart from the basic need of identifying a signal or image as a whole, there is also a rather ubiquitous need to detect possible alterations to a signal or image. The following section describes how the foregoing embodiment, with certain modifications and improvements, can be used as a powerful tool in this area. The potential scenarios and applications of detecting alterations are innumerable.

To first summarize, assume that we have a given signal or image which has been positively identified using the basic methods outlined above. In other words, we know its N-bit identification word, its individual embedded code signals, and its composite embedded code. We can then fairly simply create a spatial map of the composite code's amplitude within our given signal or image. Furthermore, we can divide this amplitude map by the known composite code's spatial amplitude, giving a normalized map, i.e. a map which should fluctuate about some global mean value. By simple examination of this map, we can visually detect any areas which have been significantly altered wherein the value of the normalized amplitude dips below some statistically set threshold based purely on typical noise and corruption (error).

The details of implementing the creation of the amplitude map have a variety of choices. One is to perform the same procedure which is used to determine the signal amplitude as described above, only now we step and repeat the multiplication of any given area of the signal/image with a gaussian weight function centered about the area we are investigating.

Universal Versus Custom Codes

The disclosure thus far has outlined how each and every source signal has its own unique set of individual embedded code signals. This entails the storage of a significant amount of additional code information above and beyond the original, and many applications may merit some form of economizing.

One such approach to economizing is to have a given set of individual embedded code signals be common to a batch of source materials. For example, one thousand images can all utilize the same basic set of individual embedded code signals. The storage requirements of these codes then become a small fraction of the overall storage requirements of the source material.

Furthermore, some applications can utilize a universal set of individual embedded code signals, i.e., codes which remain the same for all instances of distributed material. This type of requirement would be seen by systems which wish to hide the N-bit identification word itself, yet have standardized equipment be able to read that word. This can be used in systems which make go/no go decisions at point-of-read locations. The potential drawback to this set-up is that the universal codes are more prone to be sleuthed or stolen; therefore they will not be as secure as the apparatus and methodology of the previously disclosed arrangement. Perhaps this is just the difference between 'high security' and 'air-tight security,' a distinction carrying little weight with the bulk of potential applications.

Use in Printing, Paper, Documents, Plastic Coated Identification Cards, and Other Material Where Global Embedded Codes Can Be Imprinted

The term 'signal' is often used narrowly to refer to digital data information, audio signals, images, etc. A broader interpretation of 'signal,' and the one more generally intended, includes any form of modulation of any material whatsoever. Thus, the micro-topology of a piece of common paper becomes a 'signal' (e.g. it height as a function of x-y coordinates). The reflective properties of a flat piece of plastic (as a function of space also) becomes a signal. The point is that photographic emulsions, audio signals, and digitized information are not the only types of signals capable of utilizing the principles of the present invention.

As a case in point, a machine very much resembling a braille printing machine can be designed so as to imprint unique 'noise-like' indentations as outlined above. These indentations can be applied with a pressure which is much smaller than is typically applied in creating braille, to the point where the patterns are not noticed by a normal user of the paper. But by following the steps of the present disclosure and applying them via the mechanism of micro-indentations, a unique identification code can be placed onto any given sheet of paper, be it intended for everyday stationary purposes, or be it for important documents, legal tender, or other secured material.

The reading of the identification material in such an embodiment generally proceeds by merely reading the document optically at a variety of angles. This would become an inexpensive method for deducing the micro-topology of the paper surface. Certainly other forms of reading the topology of the paper are possible as well.

In the case of plastic encased material such as identification cards, e.g. driver's licenses, a similar braille-like impressions machine can be utilized to imprint unique identification codes. Subtle layers of photoreactive materials can also be embedded inside the plastic and 'exposed.'

It is clear that wherever a material exists which is capable of being modulated by 'noise-like' signals, that material is an appropriate carrier for unique identification codes and utilization of the principles of the invention. All that remains is the matter of economically applying the identification information and maintaining the signal level below an acceptability threshold which each and every application will define for itself.

Appendix A Description

Appendix A contains the source code of an implementation and verification of the foregoing embodiment for an 8-bit black and white imaging system.

REAL TIME ENCODER

While the first class of embodiments most commonly employs a standard microprocessor or computer to perform the encodation of an image or signal, it is possible to utilize a custom encodation device which may be faster than a typical Von Neuman-type processor. Such a system can be utilized with all manner of serial data streams.

Music and videotape recordings are examples of serial data streams -- data streams which are often pirated. It would assist enforcement efforts if authorized recordings were encoded with identification data so that pirated knock-offs could be traced to the original from which they were made.

Piracy is but one concern driving the need for the present invention. Another is authentication. Often it is important to confirm that a given set of data is really what it is purported to be (often several years after its generation).

To address these and other needs, the system 200 of Fig. 5 can be employed. System 200 can be thought of as an identification coding black box 202. The system 200 receives an input signal (sometimes termed the "master" or "unencoded" signal) and a code word, and produces (generally in real time) an identification-coded output signal. (Usually, the system provides key data for use in later decoding.)

The contents of the "black box" 202 can take various forms. An exemplary black box system is shown in Fig. 6 and includes a look-up table 204, a digital noise source 206, first and second scalers 208, 210, an adder/subtracter 212, a memory 214, and a register 216.

The input signal (which in the illustrated embodiment is an 8 - 20 bit data signal provided at a rate of one million samples per second, but which in other embodiments could be an analog signal if appropriate A/D and D/A conversion is provided) is applied from an input 218 to the address input 220 of the look-up table 204. For each input sample (i.e. look-up table address), the table provides a corresponding 8-bit digital output word. This output word is used as a scaling factor that is applied to one input of the first scaler 208.

The first scaler 208 has a second input, to which is applied an 8-bit digital noise signal from source 206. (In the illustrated embodiment, the noise source 206 comprises an analog noise source 222 and an analog-to-digital converter 224 although, again, other implementations can be used.) The noise source in the illustrated embodiment has a zero mean output value, with a full width half maximum (FWHM) of 50 - 100 digital numbers (e.g. from -75 to +75).

The first scaler 208 multiplies the two 8-bit words at its inputs (scale factor and noise) to produce -- for each sample of the system input signal -- a 16-bit output word. Since the noise signal has a zero mean value, the output of the first scaler likewise has a zero mean value.

The output of the first scaler 208 is applied to the input of the second scaler 210. The second scaler serves a global scaling function, establishing the absolute magnitude of the identification signal that will ultimately be embedded into the input data signal. The scaling factor is set through a scale control device 226 (which may take a number of forms, from a simple rheostat to a graphically implemented control in a graphical user interface), permitting this factor to be changed in accordance with the requirements of different applications. The second scaler 210 provides on its output line 228 a scaled noise signal. Each sample of this scaled noise signal is successively stored in the memory 214.

(In the illustrated embodiment, the output from the first scaler 208 may range between -1500 and +1500 (decimal), while the output from the second scaler 210 is in the low single digits, (such as between -2 and +2).)

Register 216 stores a multi-bit identification code word. In the illustrated embodiment this code word consists of 8 bits, although larger code words (up to hundreds of bits) are commonly used. These bits are referenced, one at a time, to control how the input signal is modulated with the scaled noise signal.

In particular, a pointer 230 is cycled sequentially through the bit positions of the code word in register 216 to provide a control bit of "0" or "1" to a control input 232 of the adder/subtracter 212. If, for a particular input signal sample, the control bit is a "1", the scaled noise signal sample on line 232 is <u>added</u> to the input signal sample. If the control bit is a "0", the scaled noise signal sample is <u>subtracted</u> from the input signal sample. The output 234 from the adder/subtracter 212 provides the black box's output signal.

The addition or subtraction of the scaled noise signal in accordance with the bits of the code word effects a modulation of the input signal that is generally imperceptible. However, with knowledge of the contents of the memory 214, a user can later decode the encoding, determining the code number used in the original encoding process. (Actually, use of memory 214 is optional, as explained below.)

It will be recognized that the encoded signal can be distributed in well known ways, including converted to printed image form, stored on magnetic media (floppy diskette, analog or DAT tape, etc.), CD-ROM, etc. etc.

<u>Decoding</u>

A variety of techniques can be used to determine the identification code with which a suspect signal has been encoded. Two are discussed below. The first is less preferable than the latter for most applications, but is discussed herein so that the reader may have a fuller context within which to understand the invention.

More particularly, the first decoding method is a difference method, relying on subtraction of corresponding samples of the original signal from the suspect signal to obtain difference samples, which are then examined (typically individually) for deterministic coding indicia (i.e. the stored noise data). This approach may thus be termed a "sample-based, deterministic" decoding technique.

The second decoding method does not make use of the original signal. Nor does it examine particular samples looking for predetermined noise characteristics. Rather, the statistics of the suspect signal (or a portion thereof) are considered in the aggregate and analyzed to discern the presence of identification coding that permeates the entire signal. The reference to permeation means the entire identification code can be discerned from a small fragment of the suspect signal. This latter approach may thus be termed a "holographic, statistical" decoding technique.

Both of these methods begin by registering the suspect signal to match the original. This entails scaling (e.g. in amplitude, duration, color balance, etc.), and sampling (or resampling) to restore the original sample rate. As in the earlier described embodiment, there are a variety of well understood techniques by which the operations associated with this registration function can be performed.

As noted, the first decoding approach proceeds by subtracting the original signal from the registered, suspect signal, leaving a difference signal. The polarity of successive difference signal samples can then be compared with the polarities of the corresponding stored noise signal samples to determine the identification code. That is, if the polarity of the first difference signal sample matches that of the first noise signal sample, then the first bit of the identification code is a "1." (In such case, the polarity of the 9th, 17th, 25th, etc. samples should also all be positive.) If the polarity of the first difference signal sample is opposite that of the corresponding noise signal sample, then the first bit of the identification code is a "0."

By conducting the foregoing analysis with eight successive samples of the difference signal, the sequence of bits that comprise the original code word can be determined. If, as in the preferred embodiment, pointer 230 stepped through the code word one bit at a time, beginning with the first bit, during encoding, then the first 8 samples of the difference signal can be analyzed to uniquely determine the value of the 8-bit code word.

In a noise-free world (speaking here of noise independent of that with which the identification coding is effected), the foregoing analysis would always yield the correct identification code. But a process that is only applicable in a noise-free world is of limited utility indeed.

(Further, accurate identification of signals in noise-free contexts can be handled in a variety of other, simpler ways: e.g. checksums; statistically improbable correspondence between suspect and original signals; etc.)

While noise-induced aberrations in decoding can be dealt with -- to some degree -- by analyzing large portions of the signal, such aberrations still place a practical ceiling on the confidence of the process. Further, the villain that must be confronted is not always as benign as random noise. Rather, it increasingly takes the form of human-caused corruption, distortion, manipulation, etc. In such cases, the desired degree of identification confidence can only be achieved by other approaches.

The presently preferred approach (the "holographic, statistical" decoding technique) relies on recombining the suspect signal with certain noise data (typically the data stored in memory 214), and analyzing the entropy of the resulting signal. "Entropy" need not be understood in its most strict mathematical definition, it being merely the most concise word to describe randomness (noise, smoothness, snowiness, etc.).

Most serial data signals are not random. That is, one sample usually correlates -- to some degree -- with the adjacent samples. Noise, in contrast, typically is random. If a random signal (e.g. noise) is added to (or subtracted from) a non-random signal, the entropy of the resulting signal generally increases. That is, the resulting signal has more random variations than the original signal. This is the case with the encoded output signal produced by the present encoding process; it has more entropy than the original, unencoded signal.

If, in contrast, the addition of a random signal to (or subtraction from) a non-random signal reduces entropy, then something unusual is happening. It is this anomaly that the preferred decoding process uses to detect embedded identification coding.

To fully understand this entropy-based decoding method, it is first helpful to highlight a characteristic of the original encoding process: the similar treatment of every eighth sample.

In the encoding process discussed above, the pointer 230 increments through the code word, one bit for each successive sample of the input signal. If the code word is eight bits in length, then the pointer returns to the same bit position in the code word every eighth signal sample. If this bit is a "1", noise is added to the input signal; if this bit is a "0", noise is subtracted from the input signal. Due to the cyclic progression of the pointer 230, every eighth sample of an encoded signal thus shares a characteristic: they are all either augmented by the corresponding noise data (which may be negative), or they are all diminished, depending on whether the bit of the code word then being addressed by pointer 230 is a "1" or a "0".

To exploit this characteristic, the entropy-based decoding process treats every eighth sample of the suspect signal in like fashion. In particular, the process begins by adding to the 1st, 9th, 17th, 25th, etc. samples of the suspect signal the corresponding scaled noise signal values stored in the memory 214 (i.e. those stored in the 1st, 9th, 17th, 25th, etc., memory locations, respectively). The entropy of the resulting signal (i.e. the suspect signal with every 8th sample modified) is then computed.

(Computation of a signal's entropy or randomness is well understood by artisans in this field. One generally accepted technique is to take the derivative of the signal at each sample point, square these values, and then sum over the entire signal. However, a variety of other well known techniques can alternatively be used.)

The foregoing step is then repeated, this time subtracting the stored noise values from the 1st, 9th, 17th, 25 etc. suspect signal samples.

One of these two operations will undo the encoding process and reduce the resulting signal's entropy; the other will aggravate it. If adding the noise data in memory 214 to the suspect signal reduces its entropy, then this data must earlier have been subtracted from the original signal. This indicates that pointer 230 was pointing to a "0" bit when these samples were encoded. (A "0" at the control input of adder/subtracter 212 caused it to subtract the scaled noise from the input signal.)

Conversely, if subtracting the noise data from every eighth sample of the suspect signal reduces its entropy, then the encoding process must have earlier added this noise. This indicates that pointer 230 was pointing to a "1" bit when samples 1, 9, 17, 25, etc., were encoded.

By noting whether entropy decreases by (a) adding or (b) subtracting the stored noise data to/from the suspect signal, it can be determined that the first bit of the code word is (a) a "0", or (b) a "1".

The foregoing operations are then conducted for the group of spaced samples of the suspect signal beginning with the second sample (i.e. 2, 10, 18, 26 ...). The entropy of the resulting signals indicate whether the second bit of the code word is a "0" or a "1". Likewise with the following 6 groups of spaced samples in the suspect signal, until all 8 bits of the code word have been discerned.

It will be appreciated that the foregoing approach is not sensitive to corruption mechanisms that alter the values of individual samples; instead, the process considers the entropy of the signal as a whole, yielding a high degree of confidence in the results. Further, even small excerpts of the signal can be analyzed in this manner, permitting piracy of even small details of an original work to be detected. The results are thus statistically robust, both in the face of natural and human corruption of the suspect signal.

It will further be appreciated that the use of an N-bit code word in this real time embodiment provides benefits analogous to those discussed above in connection with the batch encoding system. (Indeed, the present embodiment may be conceptualized as making use of N different noise signals, just as in the batch encoding system. The first noise signal is a signal having the same extent as the input signal, and comprising the scaled noise signal at the 1st, 9th, 17th, 25th, etc., samples (assuming N=8), with zeroes at the intervening samples. The second noise signal is a similar one comprising the scaled noise signal at the 2d, 10th, 18th, 26th, etc., samples, with zeroes at the intervening samples. Etc. These signals are all combined to provide a composite noise signal.) One of the important advantages inherent in such a system is the high degree of statistical confidence (confidence which doubles with each successive bit of the identification code) that a match is really a match. The system does not rely on subjective evaluation of a suspect signal for a single, deterministic embedded code signal.

Illustrative Variations

From the foregoing description, it will be recognized that numerous modifications can be made to the illustrated systems without changing the fundamental principles. A few of these variations are described below.

The above-described decoding process tries both adding and subtracting stored noise data to/from the suspect signal in order to find which operation reduces entropy. In other embodiments, only one of these operations needs to be conducted. For example, in one alternative decoding process the stored noise data corresponding to every eighth sample of the suspect signal is only added to said samples. If the entropy of the resulting signal is thereby increased, then the corresponding bit of the code word is a "1" (i.e. this noise was added earlier, during the encoding process, so adding it again only compounds the signal's randomness). If the entropy of the resulting signal is thereby decreased, then the corresponding bit of the code word is a "0". A further test of entropy if the stored noise samples are subtracted is not required.

The statistical reliability of the identification process (coding and decoding) can be designed to exceed virtually any confidence threshold (e.g. 99.9%, 99.99%, 99.999%, etc. confidence) by appropriate selection of the global scaling factors, etc. Additional confidence in any given application (unnecessary in most applications) can be achieved by rechecking the decoding process.

One way to recheck the decoding process is to remove the stored noise data from the suspect signal in accordance with the bits of the discerned code word, yielding a "restored" signal (e.g. if the first bit of the code word is found to be "1," then the noise samples stored in the 1st, 9th, 17th, etc. locations of the memory 214 are subtracted from the corresponding samples of the suspect signal). The entropy of the restored signal is measured and used as a baseline in further measurements. Next, the process is repeated, this time removing the stored noise data from the suspect signal in accordance with a modified code word. The modified code word is the same as the discerned code word, except 1 bit is toggled (e.g. the first). The entropy of the resulting signal is determined, and compared with the baseline. If the toggling of the bit in the discerned code word resulted in increased entropy, then the accuracy of that bit of the discerned code word is confirmed. The process repeats, each time with a different bit of the discerned code word toggled, until all bits of the code word have been so checked. Each change should result in an increase in entropy compared to the baseline value.

The data stored in memory 214 is subject to a variety of alternatives. In the foregoing discussion, memory 214 contains the scaled noise data. In other embodiments, the unscaled noise data can be stored instead.

In still other embodiments, it can be desirable to store at least part of the input signal itself in memory 214. For example, the memory can allocate 8 signed bits to the noise sample, and 16 bits to store the most significant bits of an 18- or 20-bit audio signal sample. This has several benefits. One is that it simplifies registration of a "suspect" signal. Another is that, in the case of encoding an input signal which was already encoded, the data in memory 214 can be used to discern which of the encoding processes was performed first. That is, from the input signal data in memory 214 (albeit incomplete), it is generally possible to determine with which of two code words it has been encoded.

Yet another alternative *for memory* 214 is that is can be omitted altogether.

One way this can be achieved is to use a deterministic noise source in the encoding process, such as an algorithmic noise generator seeded with a known key number. The same deterministic noise source, seeded with the same key number, can be used in the decoding process. In such an arrangement, only the key number needs be stored for later use in decoding, instead of the large data set usually stored in memory 214.

Alternatively, if the noise signal added during encoding does not have a zero mean value, and the length N of the code word is known to the decoder, then a universal decoding process can be implemented. This process uses the same entropy test as the foregoing procedures, but cycles through possible code words, adding/subtracting a small dummy noise value (e.g. less than the expected mean noise value) to every Nth sample of the suspect signal, in accordance with the bits of the code word being tested, until a reduction in entropy is noted. Such an approach is not favored for most applications, however, because it offers less security than the other embodiments (e.g. it is subject to cracking by brute force).

Many applications are well served by the embodiment illustrated in Fig. 7, in which different code words are used to produce several differently encoded versions of an input signal, each making use of the same noise data. More particularly, the embodiment 240 of Fig. 7 includes a noise store 242 into which noise from source 206 is written during the identification-coding of the input signal with a first code word. (The noise source of Fig. 7 is shown outside of the real time encoder 202 for convenience of illustration.) Thereafter, additional identification-coded versions of the input signal can be produced by reading the stored noise data from the store and using it in conjunction with second through Nth code words to encode the signal. (While binary-sequential code words are illustrated in Fig. 7, in other embodiments arbitrary sequences of code words can be employed.) With such an arrangement, a great number of differently-encoded signals can be produced, without requiring a proportionally-sized long term noise memory. Instead, a fixed amount of noise data is stored, whether encoding an original once or a thousand times.

(If desired, several differently-coded output signals can be produced at the same time, rather than seriatim. One such implementation includes a plurality of adder/subtracter circuits 212, each driven with the same input signal and with the same scaled noise signal, but with different code words. Each, then, produces a differently encoded output signal.)

In applications having a great number of differently-encoded versions of the same original, it will be recognized that the decoding process need not always discern every bit of the code word. Sometimes, for example, the application may require identifying only a group of codes to which the suspect signal belongs. (E.g., high order bits of the code word might indicate an organization to which several differently coded versions of the same source material were provided, with low-order bits identifying specific copies. To identify the organization with which a suspect signal is associated, it may not be necessary to examine the low order bits, since the organization can be identified by the high order bits alone.) If the identification requirements can be met by discerning a subset of the code word bits in the suspect signal, the decoding process can be shortened.

Some applications may be best served by restarting the encoding process -- sometimes with a different code word -- several times within an integral work. Consider, as an example, videotaped productions (e.g. television programming). Each frame of a videotaped production can be identification-coded with a unique code number, processed in real-time with an arrangement 248 like that shown in Fig. 8. Each time a vertical retrace is detected by sync detector 250, the noise source 206 resets (e.g. to repeat the sequence just produced) and an identification code increments to the next value. Each frame of the videotape is thereby uniquely identification-coded. Typically, the encoded signal is stored on a videotape for long term storage (although other storage media, including laser disks, can be used).

Returning to the encoding apparatus, the look-up table 204 in the illustrated embodiment exploits the fact that high amplitude samples of the input data signal can tolerate (without objectionable degradation of the output signal) a higher level of encoded identification coding than can low amplitude input samples. Thus, for example, input data samples having decimal values of 0, 1 or 2 may be correspond (in the look-up table 204) to scale factors of unity (or even zero), whereas input data samples having values in excess of 200 may correspond to scale factors of 15. Generally speaking, the scale factors and the input sample values correspond by a square root relation. That is, a four-fold increase in a value of the sampled input signal corresponds to approximately a two-fold increase in a value of the scaling factor associated therewith.

(The parenthetical reference to zero as a scaling factor alludes to cases, e.g., in which the source signal is temporally or spatially devoid of information content. In an image, for example, a region characterized by several contiguous sample values of zero may correspond to a jet black region of the frame. A scaling value of zero may be appropriate here since there is essentially no image data to be pirated.)

Continuing with the encoding process, those skilled in the art will recognized the potential for "rail errors" in the illustrated embodiment. For example, if the input signal consists of 8-bit samples, and the samples span the entire range from 0 to 255 (decimal), then the addition or subtraction of scaled noise to/from the input signal may produce output signals that cannot be represented by 8 bits (e.g. -2, or 257). A number of well-understood techniques exist to rectify this situation, some of them proactive and some of them reactive. (Among these known techniques are: specifying that the input signal shall not have samples in the range of 0-4 or 251-255, thereby safely permitting modulation by the noise signal; or including provision for detecting and adaptively modifying input signal samples that would otherwise cause rail errors.)

While the illustrated embodiment describes stepping through the code word sequentially, one bit at a time, to control modulation of successive bits of the input signal, it will be appreciated that the bits of the code word can be used other than sequentially for this purpose. Indeed, bits of the code word can be selected in accordance with any predetermined algorithm.

The dynamic scaling of the noise signal based on the instantaneous value of the input signal is an optimization that can be omitted in many embodiments. That is, the look-up table 204 and the first scaler 208 can be omitted entirely, and the signal from the digital noise source 206 applied directly (or through the second, global scaler 210) to the adder/subtracter 212.

It will be further recognized that the use of a zero-mean noise source simplifies the illustrated embodiment, but is not necessary to the invention. A noise signal with another mean value can readily be used, and D.C. compensation (if needed) can be effected elsewhere in the system.

The use of a noise source 206 is also optional. A variety of other signal sources can be used, depending on application- dependent constraints (e.g. the threshold at which the encoded identification signal becomes perceptible). In many instances, the level of the embedded identification signal is low enough that the identification signal needn't have a random aspect; it is imperceptible regardless of its nature. A pseudo random source 206, however, is usually desired because it provides the greatest identification code signal S/N ratio (a somewhat awkward term in this instance) for a level of imperceptibility of the embedded identification signal.

It will be recognized that identification coding need not occur after a signal has been reduced to stored form as data (i.e. "fixed in tangible form," in the words of the U.S. Copyright Act). Consider, for example, the case of popular musicians whose performance are often recorded illicitly. By identification coding the audio before it drives concert hall speakers, unauthorized recordings of the concert can be traced to a particular place and time. Likewise, live audio sources such as 911 emergency calls can be encoded prior to recording so as to facilitate their later authentication.

While the black box embodiment has been described as a stand alone unit, it will be recognized that it can be integrated into a number of different tools/instruments as a component. One is a scanner, which can embed identification codes in the scanned output data. (The codes can simply serve to memorialize that the data was generated by a particular scanner). Another is in creativity software, such as popular drawing/graphics/animation/paint programs offered by Adobe, Macromedia, Corel, and the like.

Finally, while the real-time encoder 202 has been illustrated with reference to a particular hardware implementation, it will be recognized that a variety of other implementations can alternatively be employed. Some utilize other hardware configurations. Others make use of software routines for some or all of the illustrated functional blocks. (The software routines can be executed on any number of different general purpose programmable computers, such as 80x86 PC-compatible computers, RISC-based workstations, etc.)

TYPES OF NOISE, QUASI-NOISE, AND OPTIMIZED-NOISE

Heretofore this disclosure postulated Gaussian noise, "white noise," and noise generated directly from application instrumentation as a few of the many examples of the kind of carrier signal appropriate to carry a single bit of information throughout an image or signal. It is possible to be even more proactive in "designing" characteristics of noise in order to achieve certain goals. The "design" of using Gaussian or instrumental noise was aimed somewhat toward "absolute" security. This section of the disclosure takes a look at other considerations for the design of the noise signals which may be considered the ultimate carriers of the identification information.

For some applications it might be advantageous to design the noise carrier signal (e.g. the Nth embedded code signal in the first embodiment; the scaled noise data in the second embodiment), so as to provide more absolute signal strength to the identification signal relative to the perceptibility of that signal. One example is the following. It is recognized that a true Gaussian noise signal has the value '0' occur most frequently, followed by 1 and -1 at equal probabilities to each other but lower than '0', 2 and -2 next, and so on. Clearly, the value zero carries no information as it is used in the service of this invention. Thus, one simple adjustment, or design, would be that any time a zero occurs in the generation of the embedded code signal, a new process takes over, whereby the value is converted "randomly" to either a 1 or a -1. In logical terms, a decision would be made: if '0', then random(1,-1). The histogram of such a process would appear as a Gaussian/Poissonian type distribution, except that the 0 bin would be empty and the 1 and -1 bin would be increased by half the usual histogram value of the 0 bin.

In this case, identification signal energy would always be applied at all parts of the signal. A few of the trade-offs include: there is a (probably negligible) lowering of security of the codes in that a "deterministic component" is a part of generating the noise signal. The reason this might be completely negligible is that we still wind up with a coin flip type situation on randomly choosing the 1 or the -1. Another trade-off is that this type of designed noise will have a higher threshold of perceptibility, and will only be applicable to applications where the least significant bit of a data stream or image is already negligible relative to the commercial value of the material, i.e. if the least significant bit were stripped from the signal (for all signal samples), no one would know the difference and the value of the material would not suffer. This blocking of the zero value in the example above is but one of many ways to "optimize" the noise properties of the signal carrier, as anyone in the art can realize. We refer to this also as "quasi-noise" in the sense that natural noise can be transformed in a pre-determined way into signals which for all intents and purposes will read as noise. Also, cryptographic methods and algorithms can easily, and often by definition, create signals which are perceived as completely random. Thus the word "noise" can have different connotations, primarily between that as defined subjectively by an observer or listener, and that defined mathematically. The difference of the latter is that mathematical noise has different properties of security and the simplicity with which it can either be "sleuthed" or the simplicity with which instruments can "automatically recognize" the existence of this noise.

"Universal" Embedded Codes

The bulk of this disclosure teaches that for absolute security, the noise-like embedded code signals which carry the bits of information of the identification signal should be unique to each and every encoded signal, or, slightly less restrictive, that embedded code signals should be generated sparingly, such as using the same embedded codes for a batch of 1000 pieces of film, for example. Be this as it may, there is a whole other approach to this issue wherein the use of what we will call "universal" embedded code signals can open up large new applications for this technology. The economics of these uses would be such that the de facto lowered security of these universal codes (e.g. they would be analyzable by time honored cryptographic decoding methods, and thus potentially thwarted or reversed) would be economically negligible relative to the economic gains that the intended uses would provide. Piracy and illegitimate uses would become merely a predictable "cost" and a source of uncollected revenue only; a simple line item in an economic analysis of the whole. A good analogy of this is in the cable industry and the scrambling of video signals. Everybody seems to know that crafty, skilled technical individuals, who may be generally law abiding citizens, can climb a ladder and flip a few wires in their cable junction box in order to get all the pay channels for free. The cable industry knows this and takes active measures to stop it and prosecute those caught, but the "lost revenue" derived from this practice remains prevalent but almost negligible as a percentage of profits gained from the scrambling system as a whole. The scrambling system as a whole is an economic success despite its lack of "absolute security."

The same holds true for applications of this technology wherein, for the price of lowering security by some amount, large economic opportunity presents itself. This section first describes what is meant by universal codes, then moves on to some of the interesting uses to which these codes can be applied.

Universal embedded codes generally refer to the idea that knowledge of the exact codes can be distributed. The embedded codes won't be put into a dark safe never to be touched until litigation arises (as alluded to in other parts of this disclosure), but instead will be distributed to various locations where on-the-spot analysis can take place. Generally this distribution will still take place within a security controlled environment, meaning that steps will be taken to limit the knowledge of the codes to those with a need to know. Instrumentation which attempts to automatically detect copyrighted material is a non-human example of "something" with a need to know the codes.

There are many ways to implement the idea of universal codes, each with their own merits regarding any given application. For the purposes of teaching this art, we separate these approaches into three broad categories: universal codes based on libraries, universal codes based on deterministic formula, and universal codes based on pre-defined industry standard patterns. A rough rule of thumb is that the first is more secure than the latter two, but that the latter two are possibly more economical to implement than the first.

Universal Codes: 1) Libraries of Universal Codes

The use of libraries of universal codes simply means that the techniques of this invention are employed as described, except for the fact that only a limited set of the individual embedded code signals are generated and that any given encoded material will make use of some sub-set of this limited "universal set." An example is in order here. A photographic print paper manufacturer may wish to pre-expose every piece of 8 by 10 inch print paper which they sell with a unique identification code. They also wish to sell identification code recognition software to their large customers, service bureaus, stock agencies, and individual photographers, so that all these people can not only verify that their own material is correctly marked, but so that they can also determine if third party material which they are about to acquire has been identified by this technology as being copyrighted. This latter information will help them verify copyright holders and avoid litigation, among many other benefits. In order to "economically" institute this plan, they realize that generating unique individual embedded codes for each and every piece of print paper would generate Terabytes of independent information, which would need storing and to which recognition software would need access. Instead, they decide to embed their print paper with 16 bit identification codes derived from a set of only 50 independent "universal" embedded code signals. The details of how this is done are in the next paragraph, but the point is that now their recognition software only needs to contain a limited set of embedded codes in their library of codes, typically on the order of 1 Megabyte to 10 Megabytes of information for 50x16 individual embedded codes splayed out onto an 8x10 photographic print (allowing for digital compression). The reason for picking 50 instead of just 16 is one of a little more added security, where if it were the same 16 embedded codes for all photographic sheets, not only would the serial number capability be limited to 2 to the 16th power, but lesser and lesser sophisticated pirates could crack the codes and remove them using software tools.

There are many different ways to implement this scheme, where the following is but one exemplary method. It is determined by the wisdom of company management that a 300 pixels per inch criteria for the embedded code signals is sufficient resolution for most applications. This means that a composite embedded code image will contain 3000 pixels by 2400 pixels to be exposed at a very low level onto each 8x10 sheet. This gives 7.2 million pixels. Using our staggered coding system such as described in the black box implementation of Figs. 5 and 6, each individual embedded code signal will contain only 7.2 million divided by 16, or approximately 450K true information carrying pixels, i.e. every 16th pixel along a given raster line. These values will typically be in the range of 2 to -2 in digital numbers, or adequately described by a signed 3 bit number. The raw information content of an embedded code is then approximately 3/8th's bytes times 450K or about 170 Kilobytes. Digital compression can reduce this further. All of these decisions are subject to standard engineering optimization principles as defined by any given application at hand, as is well known in the art. Thus we find that 50 of these independent embedded codes will amount to a few Megabytes. This is quite reasonable level to distribute as a "library" of universal codes within the recognition software. Advanced standard encryption devices could be employed to mask the exact nature of these codes if one were concerned that would-be pirates would buy the recognition software merely to reverse engineer the universal embedded codes. The recognition software could simply unencrypt the codes prior to applying the recognition techniques taught in this disclosure.

The recognition software itself would certainly have a variety of features, but the core task it would perform is determining if there is some universal copyright code within a given image. The key questions become WHICH 16 of the total 50 universal codes it might contain, if any, and if there are 16 found, what are their bit values. The key variables in determining the answers to these questions are: registration, rotation, magnification (scale), and extent. In the most general case with no helpful hints whatsoever, all variables must be independently varied across all mutual combinations, and each of the 50 universal codes must then be checked by adding and subtracting to see if an entropy decrease occurs. Strictly speaking, this is an enormous job, but many helpful hints will be found which make the job much simpler, such as having an original image to compare to the suspected copy, or knowing the general orientation and extent of the image relative to an 8x10 print paper, which then through simple registration techniques can determine all of the variables to some acceptable degree. Then it merely requires cycling through the 50 universal codes to find any decrease in entropy. If one does, then 15 others should as well. A protocol needs to be set up whereby a given order of the 50 translates into a sequence of most significant bit through least significant bit of the ID code word. Thus if we find that universal code number "4" is present, and we find its bit value to be "0", and that universal codes "1" through "3" are definitely not present, then our most significant bit of our N-bit ID code number is a "0". Likewise, we find that the next lowest universal code present is number "7" and it turns out to be a "1", then our next most significant bit is a "1". Done properly, this system can cleanly trace back to the copyright owner so long as they registered their photographic paper stock serial number with some registry or with the manufacturer of the paper itself. That is, we look up in the registry that a paper using universal embedded codes 4,7,11,12,15,19,21,26,27,28,34,35,37,38,40, and 48, and having the embedded code 0110 0101 0111 0100 belongs to Leonardo de Boticelli, an unknown wildlife photographer and glacier cinematographer whose address is in Northern Canada. We know this because he dutifully registered his film and paper stock, a few minutes of work when he bought the stock, which he plopped into the "no postage necessary" envelope that the manufacturing company kindly provided to make the process ridiculously simple. Somebody owes Leonardo a royalty check it would appear, and certainly the registry has automated this royalty payment process as part of its services.

One final point is that truly sophisticated pirates and others with illicit intentions can indeed employ a variety of cryptographic and not so cryptographic methods to crack these universal codes, sell them, and make software and hardware tools which can assist in the removing or distorting of codes. We shall not teach these methods as part of this disclosure, however. In any event, this is one of the prices which must be paid for the ease of universal codes and the applications they open up.

Universal Codes: 2) Universal Codes Based on Deterministic Formulas

The libraries of universal codes require the storage and transmittal of Megabytes of independent, generally random data as the keys with which to unlock the existence and identity of signals and imagery that have been marked with universal codes. Alternatively, various deterministic formulas can be used which "generate" what appear to be random data/image frames, thereby obviating the need to store all of these codes in memory and interrogate each and of the "50" universal codes. Deterministic formulas can also assist in speeding up the process of *determining the ID code once one is known to exist in* a given signal or image. On the other hand, deterministic formulas lend themselves to sleuthing by less sophisticated pirates. And once sleuthed, they lend themselves to easier communication, such as posting on the Internet to a hundred newsgroups. There may well be many applications which do not care about sleuthing and publishing, and deterministic formulas for generating the individual universal embedded codes might be just the ticket.

Universal Codes: 3) "Simple" Universal Codes

This category is a bit of a hybrid of the first two, and is most directed at truly large scale implementations of the principles of this technology. The applications employing this class are of the type where staunch security is much less important than low cost, large scale implementation and the vastly larger economic benefits that this enables. One exemplary application is placement of identification recognition units directly within modestly priced home audio and video instrumentation (such as a TV). Such recognition units would typically monitor audio and/or video looking for these copyright identification codes, and thence triggering simple decisions based on the findings, such as disabling or enabling recording capabilities, or incrementing program specific billing meters which are transmitted back to a central audio/video service provider and placed onto monthly invoices. Likewise, it can be foreseen that "black boxes" in bars and other public places can monitor (listen with a microphone) for copyrighted materials and generate detailed reports, for use by ASCAP, BMI, and the like.

A core principle of simple *universal* codes is that some basic industry standard "noiselike" and seamlessly repetitive patterns are injected into signals, images, and image sequences so that inexpensive recognition units can either A) determine the mere existence of a copyright "flag", and B) additionally to A, determine precise identification information which can facilitate more complex decision making and actions.

In order to implement this particular embodiment of the present invention, the basic principles of generating the individual embedded noise signals need to be simplified in order to accommodate inexpensive recognition signal processing circuitry, while maintaining the properties of effective randomness and holographic permeation. With large scale industry adoption of these simple codes, the codes themselves would border on public domain information (much as cable scrambling boxes are almost de facto public domain), leaving the door open for determined pirates to develop black market countermeasures, but this situation would be quite analogous to the scrambling of cable video and the objective economic analysis of such illegal activity.

One prior art known to the applicant in this general area of pro-active copyright detection is the Serial Copy Management System adopted by many firms in the audio industry. To the best of applicant's knowledge, this system employs a non-audio "flag" signal which is not part of the audio data stream, but which is nevertheless grafted onto the audio stream and can indicate whether the associated audio data should or should not be duplicated. One problem with this system is that it is restricted to media and instrumentation which can support this extra "flag" signal. Another deficiency is that the flagging system carries no identity information which would be useful in making more complex decisions. Yet another difficulty is that high quality audio sampling of an analog signal can come arbitrarily close to making a perfect digital copy of some digital master and there seems to be no provision for inhibiting this possibility.

The principles of this invention can be brought to bear on these and other problems, in audio applications, video, and all of the other applications previously discussed. An exemplary application of simple universal codes is the following. A single industry standard "1.000000 second of noise" would be defined as the most basic indicator of the presence or absence of the copyright marking of any given audio signal. Fig. 9 has an example of what the waveform of an industry standard noise second might look like, both in the time domain 400 and the frequency domain 402. It is by definition a continuous function and would adapt to any combination of sampling rates and bit quanitizations. It has a normalized amplitude and can be scaled arbitrarily to any digital signal amplitude. The signal level and the first M'th derivatives of the signal are continuous at the two boundaries 404 (Fig. 9C), such that when it is repeated, the "break" in the signal would not be visible (as a waveform) or audible when played through a high end audio system. The choice of 1 second is arbitrary in this example, where the precise length of the interval will be derived from considerations such as audibility, quasi-white noise status, seamless repeatability, simplicity of recognition processing, and speed with which a copyright marking determination can be made. The injection of this repeated noise signal onto a signal or image (again, at levels below human perception) would indicate the presence of copyright material. This is essentially a one bit identification code, and the embedding of further identification information will be discussed later on in this section. The use of this identification technique can extend far beyond the low cost home implementations discussed here, where studios could use the technique, and monitoring stations could be set up which literally monitor hundreds of channels of information simultaneously, searching for marked data streams, and furthermore searching for the associated identity codes which could be tied in with billing networks and royalty tracking systems.

This basic, standardized noise signature is seamlessly repeated over and over again and added to audio signals which are to be marked with the base copyright identification.

Part of the reason for the word "simple" is *seen here*: clearly pirates will know about this industry standard signal, but their illicit uses derived from this knowledge, such as erasure or corruption, will be economically minuscule relative to the economic value of the overall technique to the mass market. For most high end audio this signal will be some 80 to 100 dB down from full scale, or even much further; each situation can choose its own levels though certainly there will be recommendations. The amplitude of the signal can be modulated according to the audio signal levels to which the noise signature is being applied, i.e. the amplitude can increase significantly when a drum beats, but not so dramatically as to become audible or objectionable. These measures merely assist the recognition circuitry to be described.

Recognition of the presence of this noise signature by low cost instrumentation can be effected in a variety of ways. One rests on basic modifications to the simple principles of audio signal power metering. Software recognition programs can also be written, and more sophisticated mathematical detection algorithms can be applied to audio in order to make higher confidence detection identifications. In such embodiments, detection of the copyright noise signature involves comparing the time averaged power level of an audio signal with the time averaged power level of that same audio signal which has had the noise signature subtracted from it. If the audio signal with the noise signature subtracted has a lower power level that the unchanged audio signal, then the copyright signature is present and some status flag to that effect needs to be set. The main engineering subtleties involved in making this comparison include: dealing with audio speed playback discrepancies (e.g. an instrument might be 0.5% "slow" relative to exactly one second intervals); and, dealing with the unknown phase of the one second noise signature within any given audio (basically, its "phase" can be anywhere from 0 to 1 seconds). Another subtlety, not so central as the above two but which nonetheless should be addressed, is that the recognition circuits should not subtract a higher amplitude of the noise signature than was originally embedded onto the audio signal. Fortunately this can be accomplished by merely subtracting only a small amplitude of the noise signal, and if the power level goes down, this is an indication of "heading toward a trough" in the power levels. Yet another related subtlety is that the power level changes will be very small relative to the overall power levels, and calculations generally will need to be done with appropriate bit precision, e.g. 32 bit value operations and accumulations on 16-20 bit audio in the calculations of time averaged power levels.

Clearly, designing and packaging this power level comparison processing circuitry for low cost applications is an engineering optimization task. One trade-off will be the accuracy of making an identification relative to the "short-cuts" which can be made to the circuitry in order to lower its cost and complexity. A preferred embodiment for the placement of this recognition circuitry inside of instrumentation is through a single programmable integrated circuit which is custom made for the task. Fig. 10 shows one such integrated circuit 506. Here the audio signal comes in, 500, either as a digital signal or as an analog signal to be digitized inside the IC 500, and the output is a flag 502 which is set to one level if the copyright noise signature is found, and to another level if it is not found. Also depicted is the fact that the standardized noise signature waveform is stored in Read Only Memory, 504, inside the IC 506. There will be a slight time delay between the application of an audio signal to the IC 506 and the output of a valid flag 502, due to the need to monitor some finite portion of the audio before a recognition can place. In this case, there may need to be a "flag valid" output 508 where the IC informs the external world if it has had enough time to make a proper determination of the presence or absence of the copyright noise signature.

There are a wide variety of specific designs and philosophies of designs applied to accomplishing the basic function of the IC 506 of Fig. 10. Audio engineers and digital signal processing engineers are able to generate several fundamentally different designs. One such design is depicted in Fig. 11 by a process 599, which itself is subject to further engineering optimization as will be discussed. Fig. 11 depicts a flow chart for any of: an analog signal processing network, a digital signal processing network, or programming steps in a software program. We find an input signal 600 which along one path is applied to a time averaged power meter 602, and the resulting power output itself treated as a signal P_{sig}. To the upper right we find the standard noise signature 504 which will be read out at 125% of normal speed, 604, thus changing its pitch, giving the "pitch changed noise signal" 606. Then the input signal has this pitch changed noise signal subtracted in step 608, and this new signal is applied to the same form of time averaged power meter as in 602, here labelled 610. The output of this operation is also a time based signal here labelled as P_{s-pcn}, 610. Step 612 then subtracts the power signal 602 from the power signal 610, giving an output difference signal P_{out}, 613. If the universal standard noise signature does indeed exist on the input audio signal 600, then case 2, 616, will be created wherein a beat signal 618 of approximately 4 second period will show up on the output signal 613, and it remains to detect this beat signal with a step such as in Fig. 12, 622. Case 1, 614, is a steady noisy signal which exhibits no periodic beating. 125% at step 604 is chosen arbitrarily here, where engineering considerations would determine an optimal value, leading to different beat signal frequencies 618. Whereas waiting 4 seconds in this example would be quite a while, especially is you would want to detect at least two or three beats, Fig. 12 outlines how the basic design of Fig. 11 could be repeated and operated upon various delayed versions of the input signal, delayed by something like 1/20th of a second, with 20 parallel circuits working in concert each on a segment of the audio delayed by 0.05 seconds from their neighbors. In this way, a beat signal will show up approximately every 1/5th of a second and will look like a travelling wave down the columns of beat detection circuits. The existence or absence of this travelling beat wave triggers the detection flag 502. Meanwhile, there would be an audio signal monitor 624 which would ensure that, for example, at least two seconds of audio has been heard before setting the flag valid signal 508.

Though the audio example was described above, it should be clear to anyone in the art that the same type of definition of some repetitive universal noise signal or image could be applied to the many other signals, images, pictures, and physical media already discussed.

The above case deals only with a single bit plane of information, i.e., the noise signature signal is either there (1) or it isn't (0). For many applications, it would be nice to detect serial number information as well, which could then be used for more complex decisions, or for logging information on billing statements or whatnot. The same principles as the above would apply, but now there would be N independent noise signatures as depicted in Fig. 9 instead one single such signature. Typically, one such signature would be the master upon which the mere existence of a copyright marking is detected, and this would have generally higher power than the others, and then the other lower power "identification" *noise signatures* would be embedded into audio. Recognition circuits, once having found the existence of the primary noise signature, would then step through the other N noise signatures applying the same steps as described above. Where a beat signal is detected, this indicates the bit value of '1', and where no beat signal is detected, this indicates a bit value of '0'. It might be typical that N will equal 32, that way 2^{32} number of identification codes are available to any given industry employing this invention.

Use of this Technology When the Length of the Identification Code is 1

The principles of this invention can obviously be applied in the case where only a single presence or absence of an identification signal -- a fingerprint if you will -- is used to provide confidence that some signal or image is copyrighted. The example above of the industry standard noise signature is one case in point. We no longer have the added confidence of the coin flip analogy, we no longer have tracking code capabilities or basic serial number capabilities, but many applications may not require these attributes and the added simplicity of a single fingerprint might outweigh these other attributes in any event.

The "Wallpaper" Analogy

The term "holographic" has been used in this disclosure to describe how an identification code number is distributed in a largely integral form throughout an encoded signal or image. This also refers to the idea that any given fragment of the signal or image contains the entire unique identification code number. As with physical implementations of holography, there are limitations on how small a fragment can become before one begins to lose this property, where the resolution limits of the holographic media are the main factor in this regard for holography itself. In the case of an uncorrupted distribution signal which has used the encoding device of figure 5, and which furthermore has used our "designed noise" of above wherein the zero's were randomly changed to a 1 or -1, then the extent of the fragment required is merely N contiguous samples in a signal or image raster line, where N is as defined previously being the length of our identification code number. This is an informational extreme; practical situations where noise and corruption are operative will require generally one, two or higher orders of magnitude more samples than this simple number N. Those skilled in the art will recognize that there are many variables involved in pinning down precise statistics on the size of the smallest fragment with which an identification can be made.

For tutorial purposes, the applicant also uses the analogy that the unique identification code number is "wallpapered" across and image (or signal). That is, it is repeated over and over again all throughout an image. This repetition of the ID code number can be regular, as in the use of the encoder of figure 5, or random itself, where the bits in the ID code 216 of figure 6 are not stepped through in a normal repetitive fashion but rather are randomly selected on each sample, and the random selection stored along with the value of the output 228 itself. in any event, the information carrier of the ID code, the individual embedded code signal, does change across the image or signal. Thus as the wallpaper analogy summarizes: the ID code repeats itself over and over, but the patterns that each repetition imprints change randomly accordingly to a generally unsleuthable key.

Lossy Data Compression

As earlier mentioned, the identification coding of the preferred embodiment withstands lossy data compression, and subsequent decompression. Such compression is finding increasing use, particularly in contexts such as the mass distribution of digitized entertainment programming (movies, etc.).

While data encoded according to the preferred embodiment of the present invention can withstand all types of lossy compression known to applicant, those expected to be most commercially important are the CCITT G3, CCITT G4, JPEG, MPEG and JBIG compression/decompression standards. The CCITT standards are widely used in black-and-white document compression (e.g. facsimile and document-storage). JPEG is most widely used with still images. MPEG is most widely used with moving images. JBIG is a likely successor to the CCITT standards for use with black-and-white imagery. Such techniques are well known to those in the lossy data compression field; a good overview can be found in Pennebaker et al, *JPEG, Still Image Data Compression Standard*, Van Nostrand Reinhold, N.Y., 1993.

Towards Steganography Proper and the Use of this Technology in Passing More Complex Messages or Information

This disclosure concentrates on what above was called wallpapering a single identification code across an entire signal. This appears to be a desirable feature for many applications. However, there are other applications where it might be desirable to pass messages or to embed very long strings of pertinent identification information in signals and images. One of many such possible applications would be where a given signal or image is meant to be manipulated by several different groups, and that certain regions of an image are reserved for each group's identification and insertion of pertinent manipulation information.

In these cases, the code word 216 in figure 6 can actually change in some pre-defined manner as a function of signal or image position. For example, in an image, the code could change for each and every raster line of the digital image. It might be a 16 bit code word, 216, but each scan line would have a new code word, and thus a 480 scan line image could pass a 980 (480 x 2 bytes) byte message. A receiver of the message would need to have access to either the noise signal stored in memory 214, or would have to know the universal code structure of the noise codes if that method of coding was *being used*. To the best of applicant's knowledge, this is a novel approach to the mature field of steganography.

In all three of the foregoing applications of universal codes, it will often be desirable to append a short (perhaps 8- or 16-bit) private code, which users would keep in their own secured places, in addition to the universal code. This affords the user a further modicum of security against potential erasure of the universal codes by sophisticated pirates.

Conclusion

In view of the great number of different embodiments to which the principles of my invention can be put, it should be recognized that the detailed embodiments are illustrative only and should not be taken as limiting the scope of my invention. Rather, I claim as my invention all such embodiments as may come within the scope and spirit of the following claims, and equivalents thereto.

APPENDIX A

```
#include "main.h"

#define XDIM 512L
#define XDIMR 512
#define YDIM 480L
#define BITS 8
#define RMS_VAL 5.0
#define NUM_NOISY 16
#define NUM_DEMOS 3
#define GRAD_THRESHOLD 10

struct char_buf {
    char filename[80];
    FILE *fp;
    fpos_t fpos;
    char buf[XDIMR];
};
struct uchar_buf {
    char filename[80];
    FILE *fp;
    fpos_t fpos;
    unsigned char buf[XDIMR];
};
struct int_buf {
    char filename[80];
    FILE *fp;
    fpos_t fpos;
    int buf[XDIMR];
};
struct cortex_s {
    char filename[80];
    FILE *fp;
    fpos_t fpos;
    unsigned char buf[XDIMR];
};

struct uchar_buf test_image;
struct char_buf snow_composite;
struct uchar_buf distributed_image;
struct uchar_buf temp_image;
struct int_buf temp_wordbuffer;
struct int_buf temp_wordbuffer2;
struct uchar_buf snow_images;
struct cortex_s cortex;

int demo=0;  /* which demo is being performed, see notes */

int our_code;  /* id value embedded onto image */
int found_code=0;  /* holder for found code*/


int waitvbb(void){
    while( (_inp(PORT_BASE)&8) );
    while( !(_inp(PORT_BASE)&8) );
    return(1);
}

int grabb(void){
    waitvbb();
    _outp(PORT_BASE+1,0);
    _outp(PORT_BASE,8);
    waitvbb();
    waitvbb();
    _outp(PORT_BASE,0x10);
    return(1);
```

```
}

int livee(void){
    _outp(PORT_BASE,0x00);
    return(1);
}


int live_video(void){
    livee();
    return(1);
}

int freeze_frame(void){
    grabb();
    return(1);
}

int grab_frame(struct uchar_buf *image){
    long i;

    grabb();
    fsetpos(image->fp, &image->fpos  );
    fsetpos(cortex.fp, &cortex.fpos  );
    for(i=0;i<YDIM;i++){
        fread(cortex.buf,sizeof(unsigned char),XDIMR,cortex.fp);
        fwrite(cortex.buf,sizeof(unsigned char),XDIMR,image->fp);
    }
    livee();
    return(1);
}

int wait_vertical_blanks(int number){
    long i;
    for(i=0;i<number;i++)waitvbb();
    return(1);
}


int clear_char_image(struct char_buf *charbuffer){
    long i,j;
    char *pchar;
    fpos_t tmp_fpos;

    fsetpos(charbuffer->fp, &charbuffer->fpos  );
    for(i=0;i<YDIM;i++){
        fgetpos(charbuffer->fp, &tmp_fpos  );
        pchar = charbuffer->buf;
        fread(charbuffer->buf,sizeof(char),XDIMR,charbuffer->fp);
        for(j=0;j<XDIM;j++) *(pchar++) = 0;
        fsetpos(charbuffer->fp, &tmp_fpos  );
        fwrite(charbuffer->buf,sizeof(char),XDIMR,charbuffer->fp);
    }
    return(1);
}

int display_uchar(struct uchar_buf *image,int stretch){
    unsigned char *pimage;
    unsigned char highest = 0;
    unsigned char lowest = 255;
    long i,j;
    double dtemp,scale,dlowest;
    fpos_t tmp_fpos;

    if(stretch){
        fsetpos(image->fp, &image->fpos  );
        fread(image->buf,sizeof(unsigned char),XDIMR,image->fp);
        fread(image->buf,sizeof(unsigned char),XDIMR,image->fp);
        for(i=2;i<(YDIM-2);i++){
            fread(image->buf,sizeof(unsigned char),XDIMR,image->fp);
            pimage = &image->buf[3];
            for(j=3;j<(XDIM-3);j++){
                if( *pimage > highest )highest = *pimage;
                if( *pimage < lowest )lowest = *pimage;
                pimage++;
            }
        }
        if(highest == lowest ){
            printf("something wrong in contrast stretch, zero
contrast");
            exit(1);
        }
        scale = 255.0 / ( (double)highest - (double)lowest );
        dlowest = (double)lowest;
        fsetpos(image->fp, &image->fpos  );
        for(i=0;i<YDIM;i++){
            fgetpos(image->fp, &tmp_fpos  );
            fread(image->buf,sizeof(unsigned char),XDIMR,image->fp);
            pimage = image->buf;
            for(j=0;j<XDIM;j++){
                dtemp = ((double)*pimage - dlowest)*scale;
                if(dtemp < 0.0)*(pimage++) = 0;
                else if(dtemp > 255.0)*(pimage++) = 255;
                else *(pimage++) = (unsigned char)dtemp;
            }
            fsetpos(image->fp, &tmp_fpos  );
            fwrite(image->buf,sizeof(unsigned
char),XDIMR,image->fp);
        }
    }


    fsetpos(image->fp, &image->fpos  );
    fsetpos(cortex.fp, &cortex.fpos  );
    for(i=0;i<YDIM;i++){
        fread(image->buf,sizeof(unsigned char),XDIMR,image->fp);
        fwrite(image->buf,sizeof(unsigned char),XDIMR,cortex.fp);
    }
    return(1);
}


int clear_int_image(struct int_buf *wordbuffer){
    long i,j;
    int *pword;
    fpos_t tmp_fpos;

    fsetpos(wordbuffer->fp, &wordbuffer->fpos  );
    for(i=0;i<YDIM;i++){
        fgetpos(wordbuffer->fp, &tmp_fpos  );
        pword = wordbuffer->buf;
        fread(wordbuffer->buf,sizeof(int),XDIMR,wordbuffer->fp);
        for(j=0;j<XDIM;j++) *(pword++) = 0;
        fsetpos(wordbuffer->fp, &tmp_fpos  );
        fwrite(wordbuffer->buf,sizeof(int),XDIMR,wordbuffer->fp);
    }
    return(1);
}

double find_mean_int(struct int_buf *wordbuffer){
    long i,j;
    int *pword;
    double mean=0.0;

    fsetpos(wordbuffer->fp, &wordbuffer->fpos  );
    for(i=0;i<YDIM;i++){
        pword = wordbuffer->buf;
        fread(wordbuffer->buf,sizeof(int),XDIMR,wordbuffer->fp);
        for(j=0;j<XDIM;j++) mean += (double) *(pword++);
    }
    mean /= ((double)XDIM * (double)YDIM);

    return(mean);
}

int add_uchar_to_int(struct uchar_buf *image,struct int_buf *word){
    unsigned char *pimage;
    int *pword;
    long i,j;
    fpos_t tmp_fpos;

    fsetpos(image->fp, &image->fpos  );
    fsetpos(word->fp, &word->fpos  );
    for(i=0;i<YDIM;i++){
        pword = word->buf;
        fgetpos(word->fp, &tmp_fpos  );
        fread(word->buf,sizeof(int),XDIMR,word->fp);
        pimage = image->buf;
        fread(image->buf,sizeof(unsigned char),XDIMR,image->fp);
        for(j=0;j<XDIM;j++) *(pword++) += (int)*(pimage++);
        fsetpos(word->fp, &tmp_fpos  );
        fwrite(word->buf,sizeof(int),XDIMR,word->fp);
    }
    return(1);
}


int add_char_to_uchar_creating_uchar(struct char_buf *cimage,
    struct uchar_buf *image,
    struct uchar_buf *out_image){
    unsigned char *pimage,*pout_image;
    char *pcimage;
    int temp;
    long i,j;

    fsetpos(image->fp, &image->fpos  );
    fsetpos(out_image->fp, &out_image->fpos  );
    fsetpos(cimage->fp, &cimage->fpos  );
    for(i=0;i<YDIM;i++){
        pcimage = cimage->buf;
        fread(cimage->buf,sizeof(char),XDIMR,cimage->fp);
        pimage = image->buf;
        fread(image->buf,sizeof(unsigned char),XDIMR,image->fp);
        pout_image = out_image->buf;
        for(j=0;j<XDIM;j++){
            temp = (int) *(pimage++) + (int) *(pcimage++);
            if(temp<0)temp = 0;
            else if(temp > 255)temp = 255;
            *(pout_image++) = (unsigned char)temp;
        }
        fwrite(out_image->buf,sizeof(unsigned
char),XDIMR,out_image->fp);
    }
    return(1);
}


int copy_int_to_int(struct int_buf *word2,struct int_buf *word){
    long i;

    fsetpos(word2->fp, &word2->fpos  );
    fsetpos(word->fp, &word->fpos  );
    for(i=0;i<YDIM;i++){
        fread(word->buf,sizeof(int),XDIMR,word->fp);
        fwrite(word->buf,sizeof(int),XDIMR,word2->fp);
    }
    return(1);
}


void get_snow_images(void){
    unsigned char *psnow,*ptemp;
    int number_snow_inputs;
    int temp,*pword,*pword2,bit;
    long i, j;
    double rms,dtemp;

    live_video(); /* device specific */

    printf("\n\nPlease point camera at a medium lit blank wall. ");
    printf("\nDefocus the lens a bit as well ");
    printf("\nIf possible, place the camera into its highest gain,
and ");
    printf("\nput the gamma to 1.0.");
    printf("  Ensure that the video is not saturated ");
    printf("\nPress any key when ready... ");

    while( !kbhit() );
    printf("\nNow finding difference frame rms value... ");

    /* subtract one image from another, find the rms difference */
    live_video();
    wait_vertical_blanks(2);
    grab_frame(&temp_image);
    live_video();
    wait_vertical_blanks(2);
    grab_frame(&distributed_image); /* use first image as buffer */

    rms = 0.0;
    fsetpos(temp_image.fp, &temp_image.fpos  );
    fsetpos(distributed_image.fp, &distributed_image.fpos  );
    for(i=0;i<YDIM;i++){
        ptemp = temp_image.buf;
        fread(temp_image.buf,sizeof(unsigned
char),XDIMR,temp_image.fp);
        psnow = distributed_image.buf;
        fread(distributed_image.buf,sizeof(unsigned
char),XDIMR,distributed_image.fp);
        for(j=0;j<XDIM;j++){
            temp = (int) *(psnow++)  -  (int) *(ptemp++);
            dtemp = (double)temp;
            dtemp *= dtemp;
            rms += dtemp;
        }
    }
    rms /= ( (double)XDIM * (double)YDIM );
    rms = sqrt(rms);
    printf("\n\nAn rms frame difference noise value of %lf was
found.",rms);
    printf("\nWe want at least %lf for good measure",RMS_VAL);
    /* we want rms to be at least RMS_VAL DN, so ...   */
    if(rms > RMS_VAL) number_snow_inputs = 1;
    else {
        dtemp = RMS_VAL / rms;
        dtemp *= dtemp;
        number_snow_inputs = 1 + (int)dtemp;
    }
    printf("\n%d images will achieve this noise
level",number_snow_inputs);
```

```
    /* now create each snowy image */

    printf("\nStarting to create snow pictures... \n");
    fsetpos(snow_images.fp, &snow_images.fpos  ); /* set on first
image*/
    for(bit = 0; bit < BITS; bit++){

        clear_int_image(&temp_wordbuffer);
        for(i=0;i<number_snow_inputs;i++){
            live_video();
            wait_vertical_blanks(2);
            grab_frame(&temp_image);
            add_uchar_to_int(&temp_image,&temp_wordbuffer);
        }

        clear_int_image(&temp_wordbuffer2);
        for(i=0;i<number_snow_inputs;i++){
            live_video();
            wait_vertical_blanks(2);
            grab_frame(&temp_image);
            add_uchar_to_int(&temp_image,&temp_wordbuffer2);
        }

        /* now load snow_images[bit] with the difference frame
biased by
        128 in an unsigned char form just to keep things clean */
        /* display it on cortex also */
        fsetpos(temp_wordbuffer2.fp, &temp_wordbuffer2.fpos  );
        fsetpos(temp_wordbuffer.fp, &temp_wordbuffer.fpos  );
        fsetpos(temp_image.fp, &temp_image.fpos  );
        for(i=0;i<YDIM;i++){
            pword = temp_wordbuffer.buf;
            fread(temp_wordbuffer.buf,sizeof(int),XDIMR,temp_wordbuf
fer.fp);
            pword2 = temp_wordbuffer2.buf;
            fread(temp_wordbuffer2.buf,sizeof(int),XDIMR,temp_wordbu
ffer2.fp);
            psnow = snow_images.buf;
            ptemp = temp_image.buf;
            for(j=0;j<XDIM;j++) {
                *(psnow++) = *(ptemp++) = (unsigned char)
(*(pword++) - *(pword2++) + 128);
            }
            fwrite(snow_images.buf,sizeof(unsigned
char),XDIMR,snow_images.fp);
            fwrite(temp_image.buf,sizeof(unsigned
char),XDIMR,temp_image.fp);
        }
        freeze_frame();
        display_uchar(&temp_image,0); /*1 signifies to stretch the
contrast*/
        printf("\rDone snowy %d   ",bit);
        wait_vertical_blanks(30);
    }

    return;
}




void loop_visual(void){
    unsigned char *psnow;
    char *pcomp;
    long i,j,count = 0;
    int ok=0,temp,bit,add_it;
```

```
void search_1(struct uchar_buf *suspect){
    unsigned char *psuspect,*psnow;
    int bit,*pword,temp;
    long i,j;
    double add_metric,subtract_metric;
    fpos_t tmp_fpos;

    /* this algorithm is conceptually the simplest.  The idea is to
step
    through each bit at a time and merely see if adding or
subtracting the
    individual snowy picture minimizes some 'contrast' metric.
    This should be the most crude and inefficient, no where to go
but
    better */

    fsetpos(snow_images.fp, &snow_images.fpos  );
    temp=256;
    clear_int_image(&temp_wordbuffer);
    add_uchar_to_int(suspect,&temp_wordbuffer);
    find_grad(&temp_wordbuffer,1); /* 1 means load temp_wordbuffer2
*/
    for(bit=0;bit<BITS;bit++){
        /* add first */
        fgetpos(snow_images.fp, &tmp_fpos  );
        fsetpos(suspect->fp, &suspect->fpos  );
        fsetpos(temp_wordbuffer.fp, &temp_wordbuffer.fpos  );
        for(i=0;i<YDIM;i++){
            pword = temp_wordbuffer.buf;
            psuspect = suspect->buf;
            psnow = snow_images.buf;
            fread(suspect->buf,sizeof(unsigned
char),XDIMR,suspect->fp);
            fread(snow_images.buf,sizeof(unsigned
char),XDIMR,snow_images.fp);
            for(j=0;j<XDIM;j++){
                *(pword++)=(int)*(psuspect++)+(int)*(psnow++)-128;
            }
            fwrite(temp_wordbuffer.buf,sizeof(int),XDIMR,temp_wordbu
ffer.fp);
        }
        add_metric = find_grad(&temp_wordbuffer,0);

        /* then subtract */
        fsetpos(snow_images.fp, &tmp_fpos  );
        fsetpos(suspect->fp, &suspect->fpos  );
        fsetpos(temp_wordbuffer.fp, &temp_wordbuffer.fpos  );
        for(i=0;i<YDIM;i++){
            pword = temp_wordbuffer.buf;
            psuspect = suspect->buf;
            psnow = snow_images.buf;
            fread(suspect->buf,sizeof(unsigned
char),XDIMR,suspect->fp);
            fread(snow_images.buf,sizeof(unsigned
char),XDIMR,snow_images.fp);
            for(j=0;j<XDIM;j++){
                *(pword++)=(int)*(psuspect++)-(int)*(psnow++)+128;
            }
            fwrite(temp_wordbuffer.buf,sizeof(int),XDIMR,temp_wordbu
ffer.fp);
        }
        subtract_metric = find_grad(&temp_wordbuffer,0);

        printf("\nbit place %d: add=%le ,
sub=%le",bit,add_metric,subtract_metric);
        temp/=2;
        if(add_metric < subtract_metric){
            printf("  bit value = 0");
```

```
          }
          else {
               printf("  bit value = 1");
               found_code += temp;
          }
     }
     printf("\n\nYour magic number was %d",found_code);
     return;
}


void search_2(unsigned char *suspect){

     if(suspect);

     return;
}




void loop_simulation(void){
     unsigned char *ptemp,*pdist;
     int *pword,int_mean,ok=0,temp;
     long i,j;
     double mean,scale;

     /* grab a noisy image into one of the temp buffers */
     printf("\ngrabbing noisy frame...\n");
     clear_int_image(&temp_wordbuffer);
     for(i=0;i<NUM_NOISY;i++){
          live_video();
          wait_vertical_blanks(2);
          grab_frame(&temp_image);
          add_uchar_to_int(&temp_image,&temp_wordbuffer);
          j=(long)NUM_NOISY;
          printf("\r%ld of %ld    ",i+1,j);
     }

     /* find mean value of temp_wordbuffer */
     mean = find_mean_int(&temp_wordbuffer);
     int_mean = (int)mean;

     /* now we will add scaled version of this 'corruption' to our
distributed
     image */
     scale = 1.0;
     while( !ok ){
          /* add noise to dist image storing in temp_image */
          fsetpos(distributed_image.fp, &distributed_image.fpos  );
          fsetpos(temp_wordbuffer.fp, &temp_wordbuffer.fpos  );
          fsetpos(temp_image.fp, &temp_image.fpos  );
          for(i=0;i<YDIM;i++){
               pdist = distributed_image.buf;
               pword = temp_wordbuffer.buf;
               ptemp = temp_image.buf;
               fread(distributed_image.buf,sizeof(unsigned
char),XDIMR,distributed_image.fp);
               fread(temp_wordbuffer.buf,sizeof(int),XDIMR,temp_wordbuf
fer.fp);
               for(j=0;j<XDIM;j++){
                    temp = (int) *(pdist++) + *(pword++) - int_mean;
                    if(temp<0)temp = 0;
                    else if(temp > 255)temp = 255;
                    *(ptemp++) = (unsigned char)temp;
               }
```

```
                fwrite(temp_image.buf,sizeof(unsigned
 char),XDIMR,temp_image.fp);
            }


            /* display the dist image and the corrupted image */
            display_uchar(&temp_image,0);

            /* apply new 'corrupted' image to search algorithm 1 for id
value */
            search_1(&temp_image);

            /* apply new 'corrupted' image to search algorithm 2 for id
value */
            /*
            search_2(temp_image);
            */

            /* prompt for upping noise content or ok */
            ok = 1;
        }

        return;
}



int initialize_everything(void){
        long i,j;
        unsigned char *pucbuf;
        char *pcbuf;
        int *pibuf;

        /* initialize cortex */
        strcpy(cortex.filename,"f:image");
        if((cortex.fp=fopen(cortex.filename,"rb"))==NULL){
            system("v f g");
        }
        else fclose(cortex.fp);
        if( (_inp(PORT_BASE) == 0xFF) ){
            printf("oops ");
            exit(0);
        }

        /* open cortex for read and write */
        if((cortex.fp=fopen(cortex.filename,"rb+"))==NULL){
            printf(" No good on open file joe ");
            exit(0);
        }
        fgetpos(cortex.fp, &cortex.fpos  );

/* test_image;  original image */
        strcpy(test_image.filename,"e:tst_img");
        if((test_image.fp=fopen(test_image.filename,"wb"))==NULL){
            printf(" No good on open file joe ");
            exit(0);
        }
        pucbuf = test_image.buf;
        for(i=0;i<XDIM;i++)*(pucbuf++)=0;
        for(i=0;i<YDIM;i++){
            fwrite(test_image.buf,sizeof(unsigned
char),XDIMR,test_image.fp);
        }
        fclose(test_image.fp);
        if((test_image.fp=fopen(test_image.filename,"rb+"))==NULL){
            printf(" No good on open file joe ");
            exit(0);
```

```
    }
    fgetpos(test_image.fp, &test_image.fpos  );

/* snow_composite;  ultimate image added to original image */
    strcpy(snow_composite.filename,"e:snw_cmp");

if((snow_composite.fp=fopen(snow_composite.filename,"wb"))==NULL){
        printf(" No good on open file joe ");
        exit(0);
    }
    pcbuf = snow_composite.buf;
    for(i=0;i<XDIM;i++)*(pcbuf++)=0;
    for(i=0;i<YDIM;i++){

fwrite(snow_composite.buf,sizeof(char),XDIMR,snow_composite.fp);
    }
    fclose(snow_composite.fp);

if((snow_composite.fp=fopen(snow_composite.filename,"rb+"))==NULL){
        printf(" No good on open file joe ");
        exit(0);
    }
    fgetpos(snow_composite.fp, &snow_composite.fpos  );

/* distributed_image;   test_img plus snow_composite */
    strcpy(distributed_image.filename,"e:dst_img");

if((distributed_image.fp=fopen(distributed_image.filename,"wb"))==NU
LL){
        printf(" No good on open file joe ");
        exit(0);
    }
    pucbuf = distributed_image.buf;
    for(i=0;i<XDIM;i++)*(pucbuf++)=0;
    for(i=0;i<YDIM;i++){
        fwrite(distributed_image.buf,sizeof(unsigned
char),XDIMR,distributed_image.fp);
    }
    fclose(distributed_image.fp);

if((distributed_image.fp=fopen(distributed_image.filename,"rb+"))==N
ULL){
        printf(" No good on open file joe ");
        exit(0);
    }
    fgetpos(distributed_image.fp, &distributed_image.fpos  );


/* temp_image;   buffer if needed */
    strcpy(temp_image.filename,"e:temp_img");
    if((temp_image.fp=fopen(temp_image.filename,"wb"))==NULL){
        printf(" No good on open file joe ");
        exit(0);
    }
    pucbuf = temp_image.buf;
    for(i=0;i<XDIM;i++)*(pucbuf++)=0;
    for(i=0;i<YDIM;i++){
        fwrite(temp_image.buf,sizeof(unsigned
char),XDIMR,temp_image.fp);
    }
    fclose(temp_image.fp);
    if((temp_image.fp=fopen(temp_image.filename,"rb+"))==NULL){
        printf(" No good on open file joe ");
        exit(0);
    }
    fgetpos(temp_image.fp, &temp_image.fpos  );

/*  temp_wordbuffer;   16 bit image buffer for averaging */
```

```
     strcpy(temp_wordbuffer.filename,"e:temp_wrd");

 if((temp_wordbuffer.fp=fopen(temp_wordbuffer.filename,"wb"))==NULL){
          printf(" No good on open file joe ");
          exit(0);
     }
     pibuf = temp_wordbuffer.buf;
     for(i=0;i<XDIM;i++)*(pibuf++)=0;
     for(i=0;i<YDIM;i++){

 fwrite(temp_wordbuffer.buf,sizeof(int),XDIMR,temp_wordbuffer.fp);
     }
     fclose(temp_wordbuffer.fp);

 if((temp_wordbuffer.fp=fopen(temp_wordbuffer.filename,"rb+"))==NULL)
 {
          printf(" No good on open file joe ");
          exit(0);
     }
     fgetpos(temp_wordbuffer.fp, &temp_wordbuffer.fpos  );

 /* temp_wordbuffer2;  /* 16 bit image buffer for averaging */
     strcpy(temp_wordbuffer2.filename,"e:tmp_wrd2");

 if((temp_wordbuffer2.fp=fopen(temp_wordbuffer2.filename,"wb"))==NULL
 ){
          printf(" No good on open file joe ");
          exit(0);
     }
     pibuf = temp_wordbuffer2.buf;
     for(i=0;i<XDIM;i++)*(pibuf++)=0;
     for(i=0;i<YDIM;i++){

 fwrite(temp_wordbuffer2.buf,sizeof(int),XDIMR,temp_wordbuffer2.fp);
     }
     fclose(temp_wordbuffer2.fp);

 if((temp_wordbuffer2.fp=fopen(temp_wordbuffer2.filename,"rb+"))==NUL
 L){
          printf(" No good on open file joe ");
          exit(0);
     }
     fgetpos(temp_wordbuffer2.fp, &temp_wordbuffer2.fpos  );

 /* snow_images;  BITS number of constituent snowy pictures */
     strcpy(snow_images.filename,"snw_imgs");
     if((snow_images.fp=fopen(snow_images.filename,"wb"))==NULL){
         printf(" No good on open file joe ");
         exit(0);
     }
     pucbuf = snow_images.buf;
     for(i=0;i<XDIM;i++)*(pucbuf++)=0;
     for(j=0;j<BITS;j++){
     for(i=0;i<YDIM;i++){
         fwrite(snow_images.buf,sizeof(unsigned
char),XDIMR,snow_images.fp);
     }
     }
     fclose(snow_images.fp);
     if((snow_images.fp=fopen(snow_images.filename,"rb+"))==NULL){
         printf(" No good on open file joe ");
         exit(0);
     }
     fgetpos(snow_images.fp, &snow_images.fpos  );

     return(1);
 }
```

```
int close_everything(void){

    fclose(test_image.fp);
    fclose(snow_composite.fp);
    fclose(distributed_image.fp);
    fclose(temp_image.fp);
    fclose(temp_wordbuffer.fp);
    fclose(temp_wordbuffer2.fp);
    fclose(snow_images.fp);

    return(1);
}


main(){
    int i,j;

    printf("\nInitializing...\n\n");
    initialize_everything();  /* device specific and global mallocs
*/

    live_video();

    /* prompt for which of the three demos to perform */
    while( demo < 1 || demo > NUM_DEMOS){
        printf("Which demo do you want to run?\n\n");
        printf("1: Digital Imagery and Very High End Photography
Simulation\n");
        printf("2: Pre-exposed Print Paper and other Dupping\n");
        printf("3: Pre-exposed Original Film (i.e. In-Camera)\n");
        printf("\nEnter number and return:  ");
        scanf("%d",&demo);
        if(demo < 1 || demo > NUM_DEMOS){
            printf("\n eh eh  ");
        }
    }

    /* acquire test image */
    printf("\nPress any key after your test scene is ready... ");
    getch();
    grab_frame(&test_image);  /*grab_frame takes care of device
specific stuff*/

    /* prompt for id number, 0 through 255 */
    printf("\nEnter any number between 0 and 255.\n");
    printf("This will be the unique magic code placed into the
image:  ");
    scanf("%d",&our_code);
    while(our_code<1 || our_code>256){
        printf(" Between 0 and 255 please  ");
        scanf("%d",&our_code);
    }

    /* feed back the binary code which will be embedded in the image
*/
    printf("\nThe binary sequence ");
    for(i=0;i<BITS;i++){
        j = 128 >> i;
        if( our_code & j)printf("1");
        else printf("0");
    }
    printf(" (%d) will be embedded on the image\n",our_code);

    /* now generate the individual snow images  */
    get_snow_images();
    loop_visual();  /* this gives visual feedback on 'tolerable'
noise level */

    printf("\nWe're now to the simulated suspect... \n");
    loop_simulation();

    close_everything();
    return(0);
}
```

Claims

1. A method of identification coding an input signal so as to permit its later identification, the method including the steps:

modulating a noise signal with a code number to produce a signature signal; and

modulating the input signal with the signature signal to produce an identification coded output signal;

wherein the coded output signal can be analyzed to discern the code number with which it was modulated.

2. A method of identification coding an input signal so as to produce an encoded output signal, the input signal being a quantized signal having inherent noise, said signal corresponding to aural or visual information, the identification coding of the output signal preserving the corresponding aural/visual information without human-perceptible degradation, the identification coding permitting later identification of the output signal, the method including modulating a noise signal with a code number to produce a signature signal, adding the signature signal to the input signal to produce an identification coded output signal, the signature signal having an amplitude below a threshold of human aural/visual perceptibility when added to the input signal, the adding step effecting distribution of the signature signal throughout the entirety of the output signal.

3. A method of data processing including: providing a digital carrier signal, and modulating the digital carrier signal to imperceptibly embed an identification signal thereon, the method characterized by: compressing the modulated digital carrier signal with lossy data compression to produce a compressed signal, decompressing the compressed signal, and discerning the embedded identification signal from the decompressed signal, wherein the lossy data compression does not preclude recovery of the embedded identification signal.

4. An apparatus for encoding a sampled input signal, the sampled input signal having inherent noise, the apparatus including an input terminal, a digital noise source, storage for an identification code word, means for maintaining a pointer to a bit of the identification code word, an adder, and an output terminal, the input terminal being coupled to a first input of the adder, the noise source being coupled to a second input of the adder, the pointer providing said bit of the identification code word to a control input of the adder, an output of the adder being coupled to the output terminal.

5. The apparatus of claim 4 which further includes a look-up table, a first scaler, a second scaler, a scale control device, and a memory, the look-up table having an input coupled to the input terminal, one of said scalers having a control input coupled to an output of the look-up table, the other of said scalers having a control input coupled to the scale control device, said scalers being serially interposed between the noise source and the adder, the memory having an input coupled to a location between the noise source and the second input of the adder.

6. A method of identification coding a sampled input signal, the sampled input signal having inherent noise, the method comprising:

providing an N-bit code number;

for each of a plurality of *samples* of the input signal:

(a) providing a sample of a time- or spatially-varying modulation signal;

(b) selecting one bit of the N-bit code number; and

(c) if said bit has a first value, adding the modulation signal sample to the sample of the input signal, yielding a sample of an identification coded output signal.

7. The method of claim 6 which includes performing steps (a) - (c) for each sample of the input signal.

8. The method of claim 6 which further includes storing, for later use, data from which the modulation signal sample can be reconstructed.

9. The method of claim 6 which includes generating the time-varying modulation signal sample by providing a pseudo-random number and weighting said number with a scaling factor, said scaling factor being a function of the input signal sample.

10. The method of claim 6 which includes selecting the one bit of the N-bit code number by cycling through the number, advancing one bit position for each successive sample of the input signal.

11. The method of claim 6 which further includes:

if said selected bit of the N-bit code number has a second value, subtracting the modulation signal sample from the sample of the input signal, yielding a sample of the identification coded output signal.

12. Storage medium having stored thereon a signal processed in accordance with the method of claim 6.

13. The invention of claim 12 in which the storage medium is a magnetic medium.

14. The invention of claim 12 in which the storage medium is a printed medium.

15. The invention of claim 12 in which the storage medium is a compact disk (CD).

16. A method of identification coding each of a plurality of samples of a sampled input signal, the input signal having inherent noise, characterized by:

using the sample of the input signal to obtain a scaling factor uniquely associated thereto;

weighting a signature datum in accordance with said scaling factor; and

modulating the sample of the input signal in accordance with said weighted signature datum.

17. The method of claim 16 in which the scaling factors increase monotonically with the values of the input signal samples with which they are associated.

18. The method of claim 16 in which a four-fold increase in a value of the sampled input signal corresponds to approximately a two-fold increase in a value of the scaling factor associated therewith.

19. A method of processing a sampled input signal with an N-bit signature word to produce an identification-coded output signal, the sampled input signal having inherent noise, wherein the complete N-bit signature finds expression M times in an excerpt of the identification-coded output signal having a length of M*N samples, for some value of M greater than one.

20. The method of claim 19 characterized by processing each sample of the input signal in accordance with at least part of the signature word.

21. In a method of processing a source signal that includes a number of elements, each with an associated value, an improvement characterized by altering the source signal in accordance with an embedded signal so as to encode an identification code therein, the embedded and altered signals each including a number of elements, each with an associated value, wherein an element of the altered signal has a value different than that of corresponding elements in both the source and embedded signals, and in which the identification code and certain pseudo-random reference data are used to generate the embedded signal, the association between the embedded signal and the identification code being undiscernible without availability of the reference data.

22. In a method of processing a source signal that includes a number of elements, each with an associated value, an improvement characterized by:

providing an N bit digital identification code, each bit having a "1" or "0" value;

providing N different reference signals, one being associated with each bit position in the digital identification code;

summing the reference signals for which the corresponding bit position in the identification code has a "1" value, thereby producing an embedded signal;

altering the source signal in accordance with the embedded signal so as to encode an identification code therein;

the embedded and altered signals each including a number of elements, each with an associated value, wherein an element of the altered signal has a value different than that of corresponding elements in both the source and embedded signals.

FIG. 4

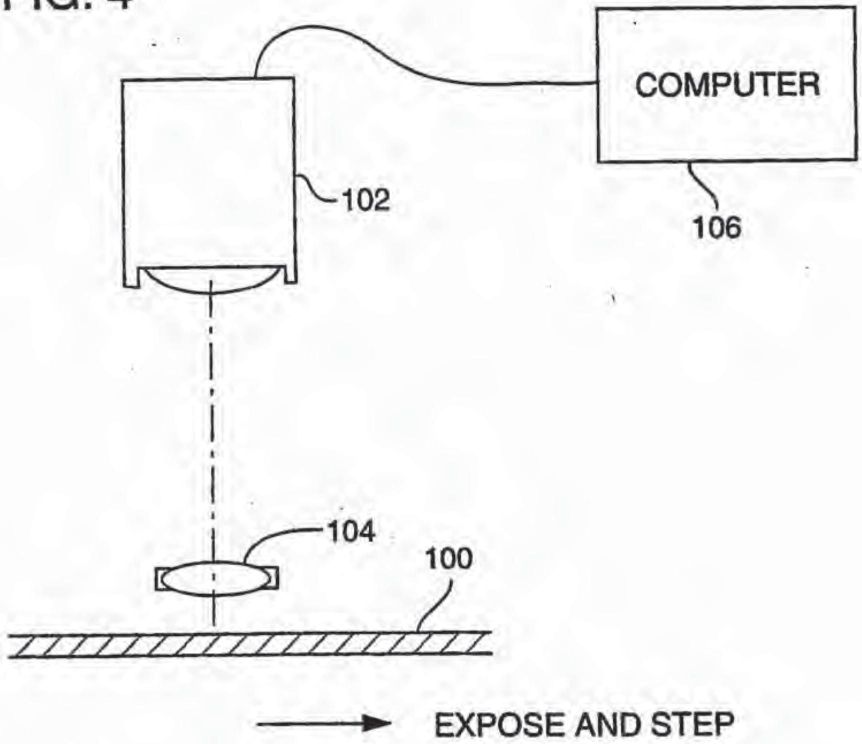

COMPUTER
102
106
104
100
EXPOSE AND STEP

FIG. 1

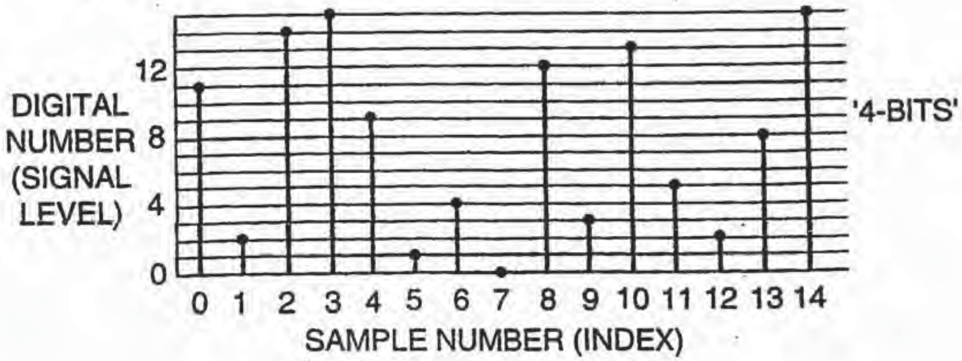

DIGITAL NUMBER (SIGNAL LEVEL)
12
8
4
0
'4-BITS'
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14
SAMPLE NUMBER (INDEX)

FIG. 2

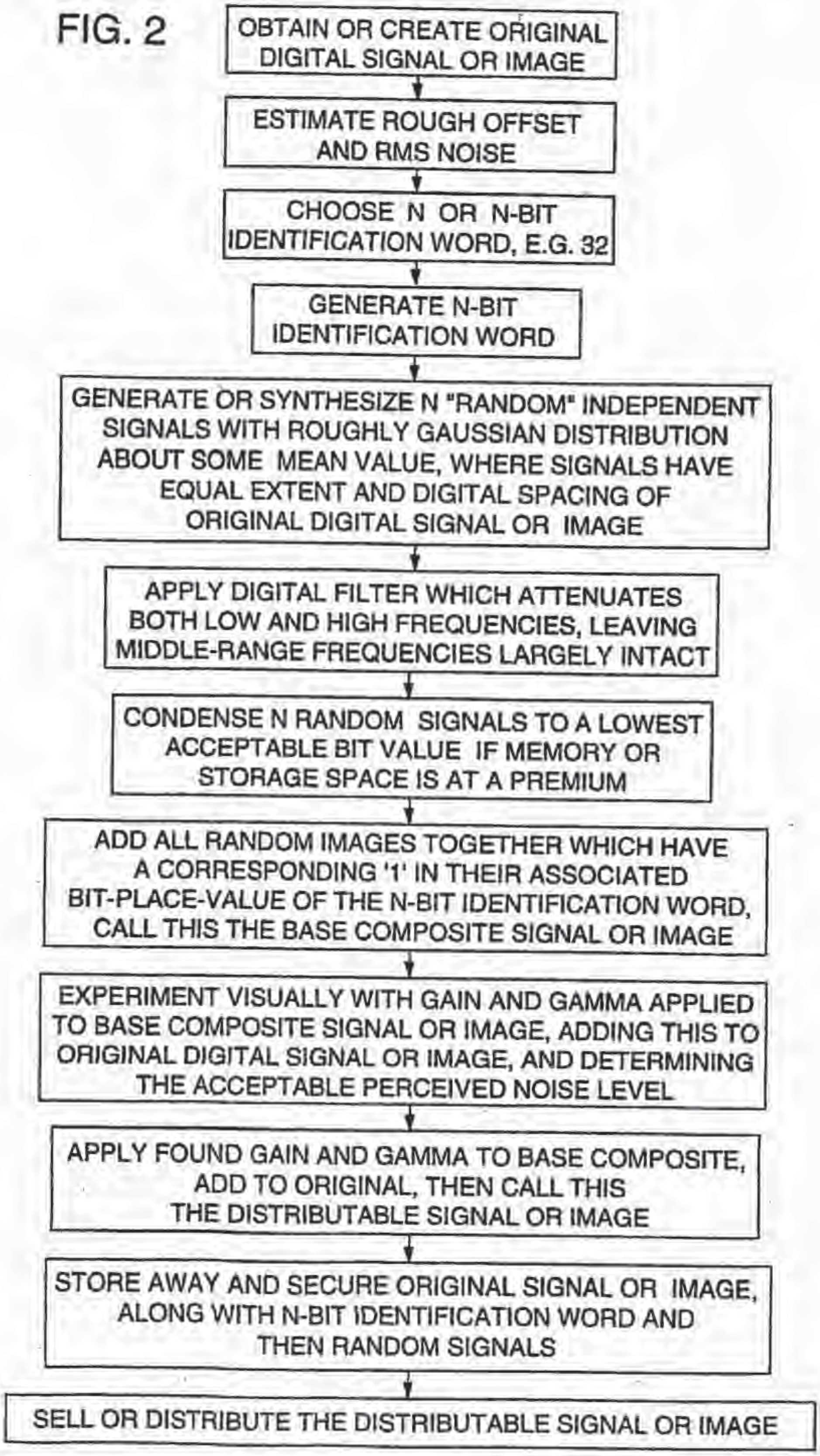

OBTAIN OR CREATE ORIGINAL DIGITAL SIGNAL OR IMAGE
ESTIMATE ROUGH OFFSET AND RMS NOISE
CHOOSE N OR N-BIT IDENTIFICATION WORD, E.G. 32
GENERATE N-BIT IDENTIFICATION WORD
GENERATE OR SYNTHESIZE N "RANDOM" INDEPENDENT SIGNALS WITH ROUGHLY GAUSSIAN DISTRIBUTION ABOUT SOME MEAN VALUE, WHERE SIGNALS HAVE EQUAL EXTENT AND DIGITAL SPACING OF ORIGINAL DIGITAL SIGNAL OR IMAGE
APPLY DIGITAL FILTER WHICH ATTENUATES BOTH LOW AND HIGH FREQUENCIES, LEAVING MIDDLE-RANGE FREQUENCIES LARGELY INTACT
CONDENSE N RANDOM SIGNALS TO A LOWEST ACCEPTABLE BIT VALUE IF MEMORY OR STORAGE SPACE IS AT A PREMIUM
ADD ALL RANDOM IMAGES TOGETHER WHICH HAVE A CORRESPONDING '1' IN THEIR ASSOCIATED BIT-PLACE-VALUE OF THE N-BIT IDENTIFICATION WORD, CALL THIS THE BASE COMPOSITE SIGNAL OR IMAGE
EXPERIMENT VISUALLY WITH GAIN AND GAMMA APPLIED TO BASE COMPOSITE SIGNAL OR IMAGE, ADDING THIS TO ORIGINAL DIGITAL SIGNAL OR IMAGE, AND DETERMINING THE ACCEPTABLE PERCEIVED NOISE LEVEL
APPLY FOUND GAIN AND GAMMA TO BASE COMPOSITE, ADD TO ORIGINAL, THEN CALL THIS THE DISTRIBUTABLE SIGNAL OR IMAGE
STORE AWAY AND SECURE ORIGINAL SIGNAL OR IMAGE, ALONG WITH N-BIT IDENTIFICATION WORD AND THEN RANDOM SIGNALS
SELL OR DISTRIBUTE THE DISTRIBUTABLE SIGNAL OR IMAGE

FIG. 3

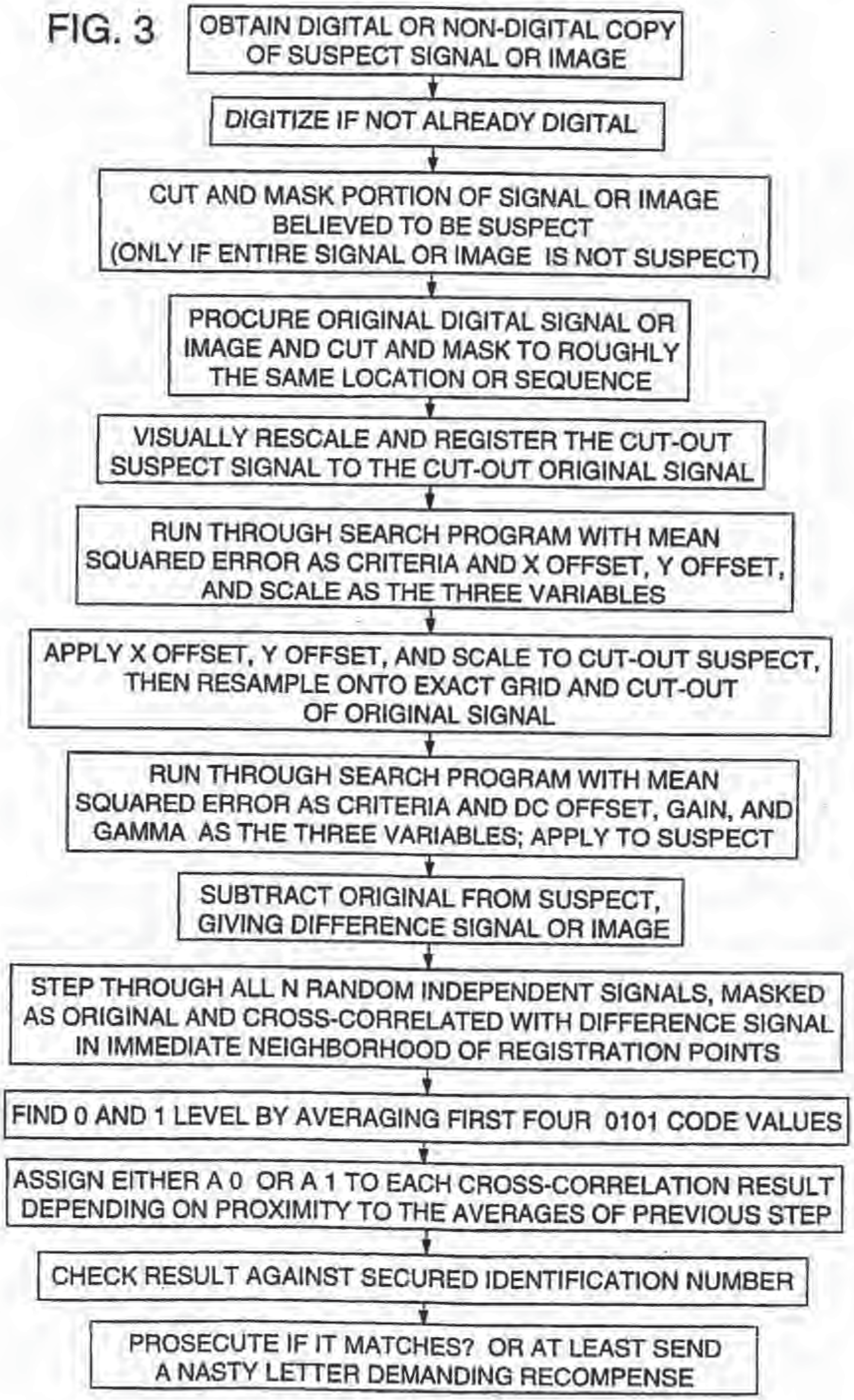

OBTAIN DIGITAL OR NON-DIGITAL COPY OF SUSPECT SIGNAL OR IMAGE
DIGITIZE IF NOT ALREADY DIGITAL
CUT AND MASK PORTION OF SIGNAL OR IMAGE BELIEVED TO BE SUSPECT (ONLY IF ENTIRE SIGNAL OR IMAGE IS NOT SUSPECT)
PROCURE ORIGINAL DIGITAL SIGNAL OR IMAGE AND CUT AND MASK TO ROUGHLY THE SAME LOCATION OR SEQUENCE
VISUALLY RESCALE AND REGISTER THE CUT-OUT SUSPECT SIGNAL TO THE CUT-OUT ORIGINAL SIGNAL
RUN THROUGH SEARCH PROGRAM WITH MEAN SQUARED ERROR AS CRITERIA AND X OFFSET, Y OFFSET, AND SCALE AS THE THREE VARIABLES
APPLY X OFFSET, Y OFFSET, AND SCALE TO CUT-OUT SUSPECT, THEN RESAMPLE ONTO EXACT GRID AND CUT-OUT OF ORIGINAL SIGNAL
RUN THROUGH SEARCH PROGRAM WITH MEAN SQUARED ERROR AS CRITERIA AND DC OFFSET, GAIN, AND GAMMA AS THE THREE VARIABLES; APPLY TO SUSPECT
SUBTRACT ORIGINAL FROM SUSPECT, GIVING DIFFERENCE SIGNAL OR IMAGE
STEP THROUGH ALL N RANDOM INDEPENDENT SIGNALS, MASKED AS ORIGINAL AND CROSS-CORRELATED WITH DIFFERENCE SIGNAL IN IMMEDIATE NEIGHBORHOOD OF REGISTRATION POINTS
FIND 0 AND 1 LEVEL BY AVERAGING FIRST FOUR 0101 CODE VALUES
ASSIGN EITHER A 0 OR A 1 TO EACH CROSS-CORRELATION RESULT DEPENDING ON PROXIMITY TO THE AVERAGES OF PREVIOUS STEP
CHECK RESULT AGAINST SECURED IDENTIFICATION NUMBER
PROSECUTE IF IT MATCHES? OR AT LEAST SEND A NASTY LETTER DEMANDING RECOMPENSE

FIG. 5

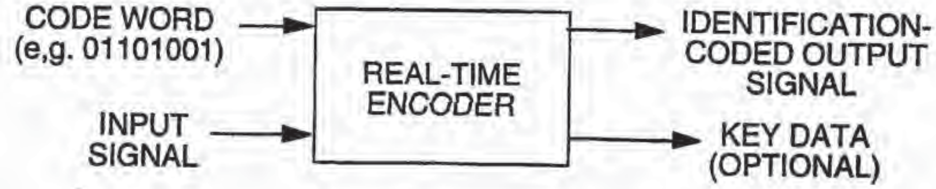
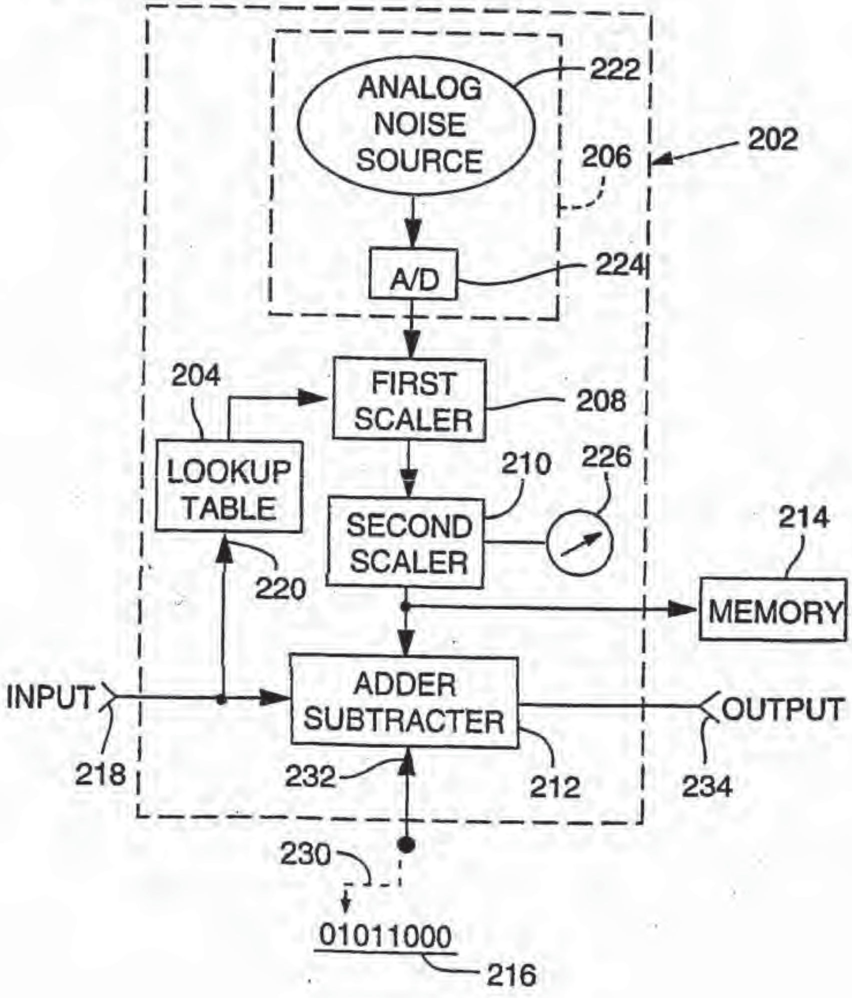

CODE WORD
(e,g. 01101001)
INPUT
SIGNAL
REAL-TIME
ENCODER
IDENTIFICATION-
CODED OUTPUT
SIGNAL
KEY DATA
(OPTIONAL)

FIG. 6


ANALOG
NOISE
SOURCE
222
206
202
A/D
224
204
FIRST
SCALER
208
LOOKUP
TABLE
210
226
SECOND
SCALER
214
220
MEMORY
INPUT
ADDER
SUBTRACTER
OUTPUT
218
232
212
234
230
01011000
216

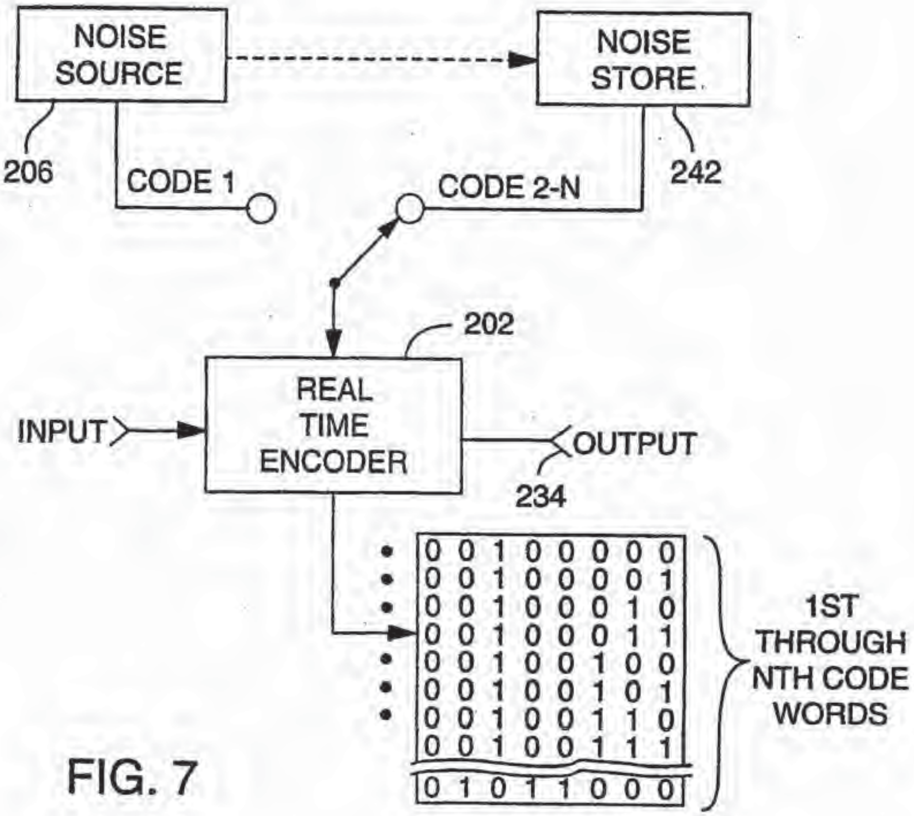

NOISE SOURCE
NOISE STORE
206
242
CODE 1
CODE 2-N
202
REAL TIME ENCODER
INPUT
OUTPUT
234
0 0 1 0 0 0 0 0
0 0 1 0 0 0 0 1
0 0 1 0 0 0 1 0
0 0 1 0 0 0 1 1
0 0 1 0 0 1 0 0
0 0 1 0 0 1 0 1
0 0 1 0 0 1 1 0
0 0 1 0 0 1 1 1
0 1 0 1 1 0 0 0
1ST THROUGH NTH CODE WORDS

FIG. 7

FIG. 8

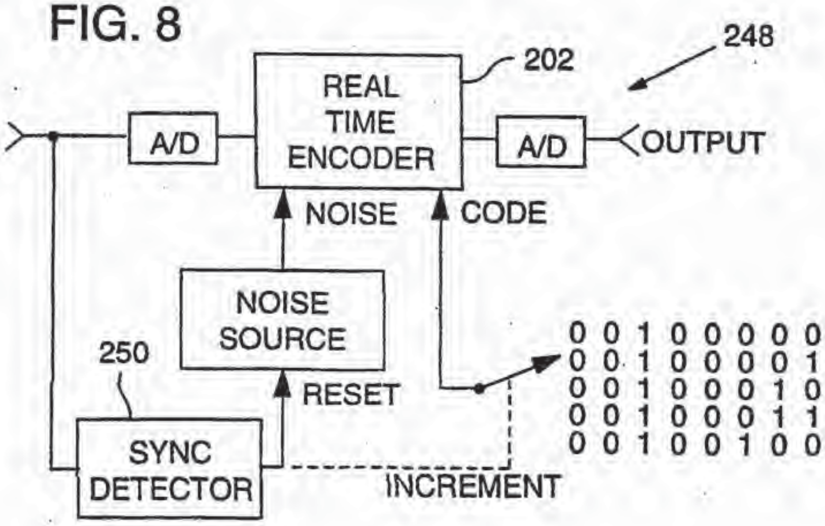

248
202
REAL TIME ENCODER
A/D
A/D
OUTPUT
NOISE
CODE
NOISE SOURCE
250
RESET
SYNC DETECTOR
INCREMENT
0 0 1 0 0 0 0 0
0 0 1 0 0 0 0 1
0 0 1 0 0 0 1 0
0 0 1 0 0 0 1 1
0 0 1 0 0 1 0 0

FIG. 9A

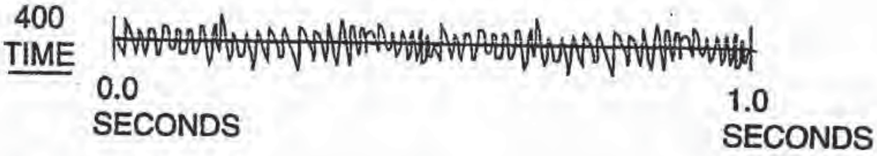


FIG. 9B

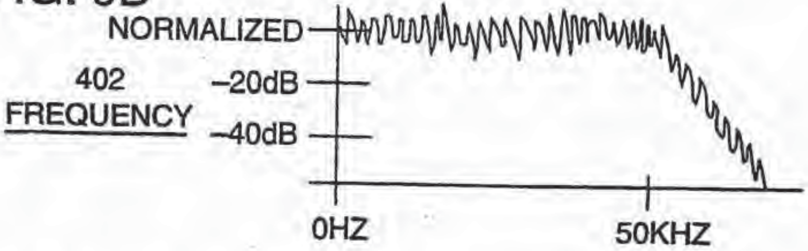


FIG. 9C

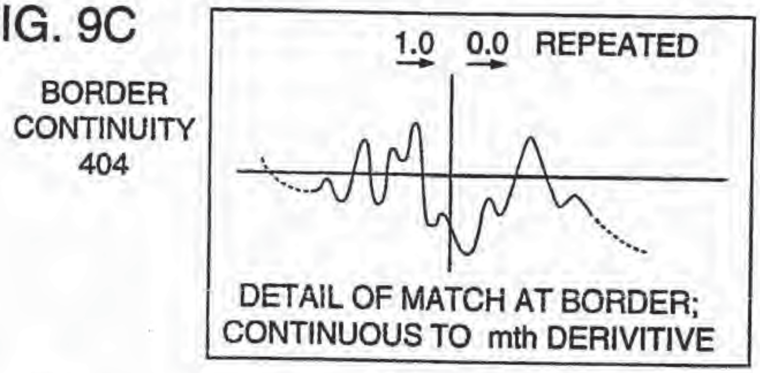


FIG. 10

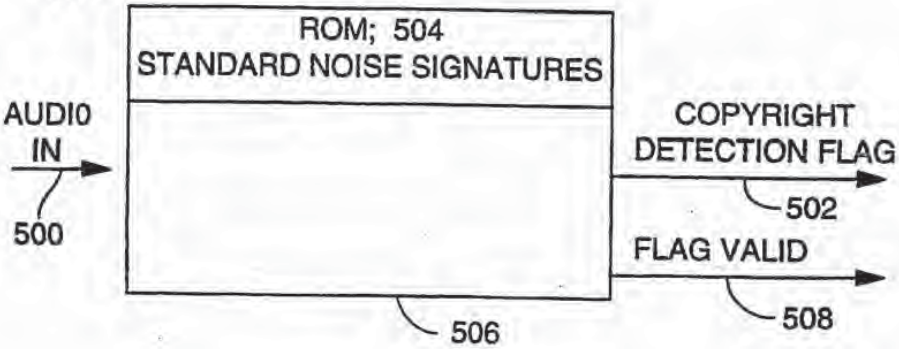


FIG. 11

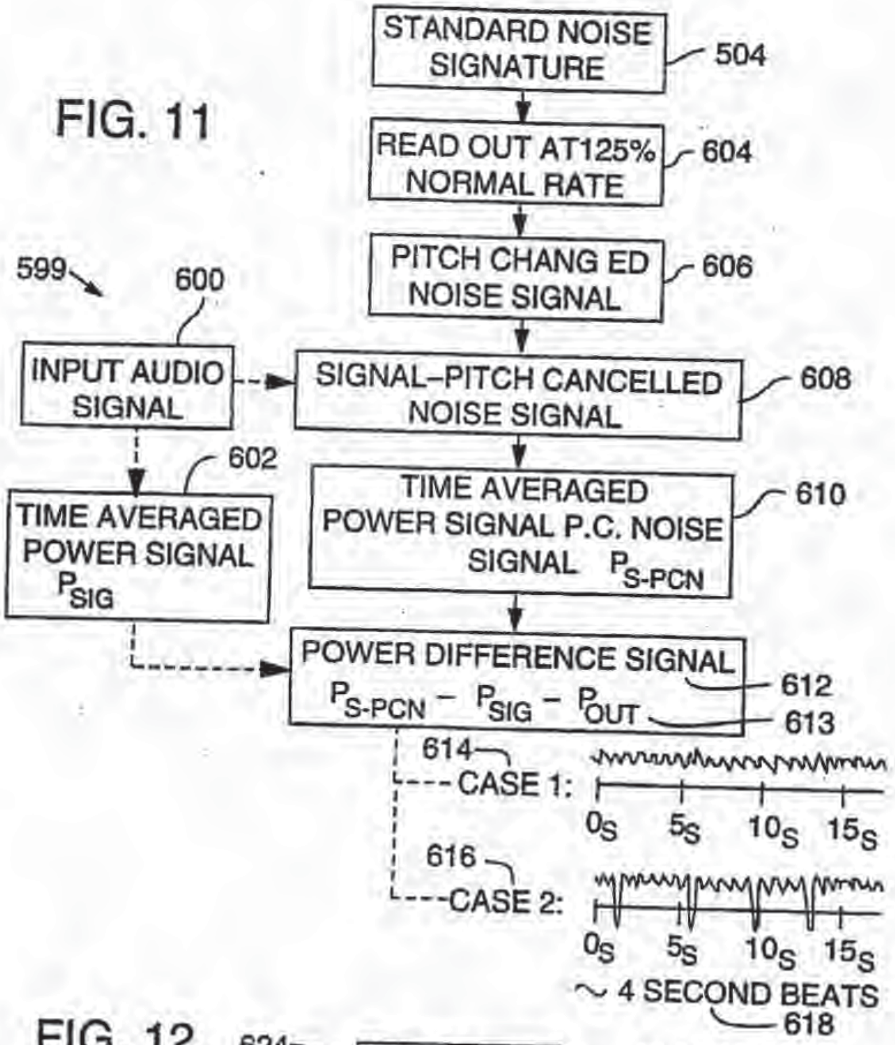
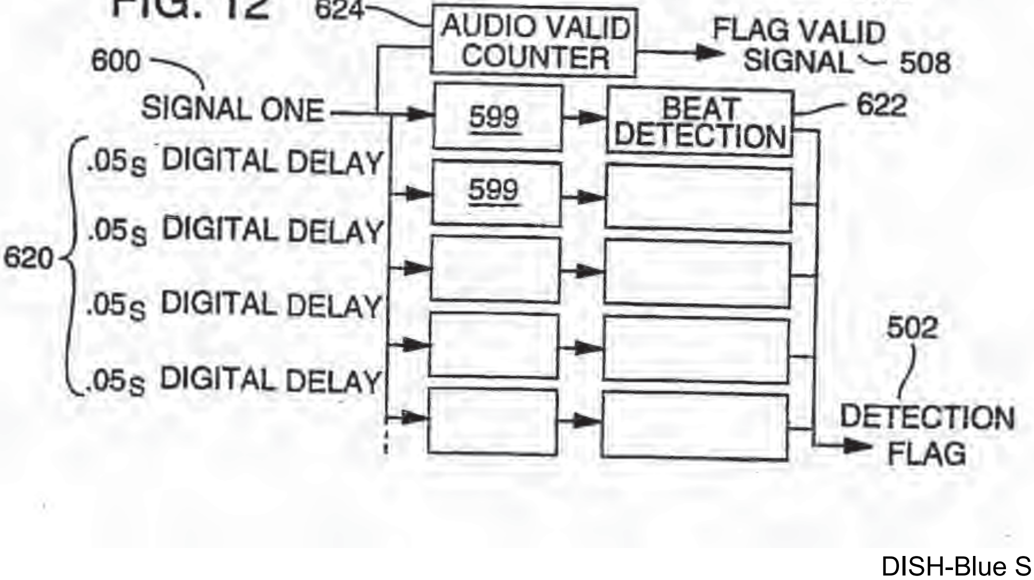

STANDARD NOISE SIGNATURE
504
READ OUT AT125% NORMAL RATE
604
PITCH CHANG ED NOISE SIGNAL
606
599
600
INPUT AUDIO SIGNAL
SIGNAL–PITCH CANCELLED NOISE SIGNAL
608
602
TIME AVERAGED POWER SIGNAL P_{SIG}
TIME AVERAGED POWER SIGNAL P.C. NOISE SIGNAL P_{S-PCN}
610
POWER DIFFERENCE SIGNAL
$P_{S-PCN} - P_{SIG} - P_{OUT}$
612
613
614
CASE 1:
0_S 5_S 10_S 15_S
616
CASE 2:
0_S 5_S 10_S 15_S
~ 4 SECOND BEATS
618

FIG. 12


624
AUDIO VALID COUNTER
FLAG VALID SIGNAL
508
600
SIGNAL ONE
599
BEAT DETECTION
622
599
.05S DIGITAL DELAY
.05S DIGITAL DELAY
.05S DIGITAL DELAY
.05S DIGITAL DELAY
620
502
DETECTION FLAG

PCT

WORLD INTELLECTUAL PROPERTY ORGANIZATION
International Bureau

INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 6 : **H04B 1/66, G11B 20/00**	**A3**	**(11) International Publication Number:** **WO 95/14289** **(43) International Publication Date:** 26 May 1995 (26.05.95)

(21) International Application Number: PCT/US94/13366

(22) International Filing Date: 16 November 1994 (16.11.94)

(30) Priority Data:

154,866	18 November 1993 (18.11.93)	US
215,289	17 March 1994 (17.03.94)	US
327,426	21 October 1994 (21.10.94)	US

(60) Parent Application or Grant
(63) Related by Continuation
US 08/327,426 (CIP)
Filed on 21 October 1994 (21.10.94)

(71) Applicant *(for all designated States except US)*: PINECONE IMAGING CORPORATION [US/US]; 363 S.W. Tualatin Loop, West Linn, OR 97068 (US).

(72) Inventor; and
(75) Inventor/Applicant *(for US only)*: RHOADS, Geoffrey, B. [US/US]; 363 S.W. Tualatin Loop, West Linn, OR 97068 (US).

(74) Agent: CONWELL, William, Y.; Klarquist, Sparkman, Campbell, Leigh & Whinston, One World Trade Center, Suite 1600, 121 S.W. Salmon Street, Portland, OR 97204 (US).

(81) Designated States: CA, JP, US, European patent (AT, BE, CH, DE, DK, ES, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE).

Published
With international search report.
Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.

(88) Date of publication of the international search report: 29 June 1995 (29.06.95)

(54) Title: IDENTIFICATION/AUTHENTICATION CODING METHOD AND APPARATUS

(57) Abstract

An identification code signal is impressed on a carrier to be identified (such as an electronic data signal or a physical medium) in a manner that permits the identification signal later to be discerned and the carrier thereby identified. The method and apparatus are characterized by robustness despite degradation of the encoded carrier, and by holographic permeation of the identification signal throughout the carrier. An exemplary embodiment is a processor that embeds the identification signal onto a carrier signal in real time.

FOR THE PURPOSES OF INFORMATION ONLY

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AT	Austria
AU	Australia
BB	Barbados
BE	Belgium
BF	Burkina Faso
BG	Bulgaria
BJ	Benin
BR	Brazil
BY	Belarus
CA	Canada
CF	Central African Republic
CG	Congo
CH	Switzerland
CI	Côte d'Ivoire
CM	Cameroon
CN	China
CS	Czechoslovakia
CZ	Czech Republic
DE	Germany
DK	Denmark
ES	Spain
FI	Finland
FR	France
GA	Gabon
GB	United Kingdom
GE	Georgia
GN	Guinea
GR	Greece
HU	Hungary
IE	Ireland
IT	Italy
JP	Japan
KE	Kenya
KG	Kyrgystan
KP	Democratic People's Republic of Korea
KR	Republic of Korea
KZ	Kazakhstan
LI	Liechtenstein
LK	Sri Lanka
LU	Luxembourg
LV	Latvia
MC	Monaco
MD	Republic of Moldova
MG	Madagascar
ML	Mali
MN	Mongolia
MR	Mauritania
MW	Malawi
NE	Niger
NL	Netherlands
NO	Norway
NZ	New Zealand
PL	Poland
PT	Portugal
RO	Romania
RU	Russian Federation
SD	Sudan
SE	Sweden
SI	Slovenia
SK	Slovakia
SN	Senegal
TD	Chad
TG	Togo
TJ	Tajikistan
TT	Trinidad and Tobago
UA	Ukraine
US	United States of America
UZ	Uzbekistan
VN	Viet Nam

INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 94/13366

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 H04B1/66 G11B20/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 H04B G11B G06K

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	GB,A,2 196 167 (THORN EMI) 20 April 1988	1,2,5, 21,22
Y		3
A	see page 1, line 35 - page 2, line 35 ---	4,9
Y	EP,A,0 411 232 (IBM) 6 February 1991 see page 4, line 7 - line 12 see page 5, line 28 - line 35 ---	3
A	EP,A,0 372 601 (PHILIPS) 13 June 1990 see column 3, line 47 - column 4, line 12 see column 7, line 3 - line 17 ---	1
A	DE,A,38 06 411 (DEUTSCHE THOMSON-BRANDT) 7 September 1989 see column 3, line 5 - column 4, line 25 -----	1

□ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

1

Date of the actual completion of the international search
16 May 1995

Date of mailing of the international search report
24.05.95

Name and mailing address of the ISA
European Patent Office, P.B. 5818 Patentlaan 2
NL - 2280 HV Rijswijk
Tel. (+31-70) 340-2040, Tx. 31 651 epo nl,
Fax: (+31-70) 340-3016

Authorized officer
Holper, G

(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) Publication number: **0 581 317 A2**

(12) EUROPEAN PATENT APPLICATION

(21) Application number: **93112290.7**

(51) Int. Cl.⁵: **G07D 7/00**, G07F 7/12

(22) Date of filing: **30.07.93**

(30) Priority: **31.07.92 US 923841**

(43) Date of publication of application:
02.02.94 Bulletin 94/05

(84) Designated Contracting States:
AT BE CH DE DK ES FR GB GR IE IT LI LU MC NL PT SE

(71) Applicant: **INTERACTIVE HOME SYSTEMS**
17950 N.E. 65th Street
Redmond, Washington 98052(US)

(72) Inventor: **Powell, Robert D.**
13720 - 246th Avenue Southeast
Issaquah, Washington 98027(US)
Inventor: **Nitzberg, Mark J.**
20A Prescott Street No.3B
Cambridge, Massachusetts 02138(US)

(74) Representative: **Patentanwälte Grünecker, Kinkeldey, Stockmair & Partner**
Maximilianstrasse 58
D-80538 München (DE)

(54) Method and system for digital image signatures.

(57) A method and system for embedding signatures within visual images in both digital representation and print or film. A signature is inseparably embedded within the visible image, the signature persisting through image transforms that include resizing as well as conversion to print or film and back to digital form. Signature points are selected from among the pixels of an original image. The pixel values of the signature points and surrounding pixels are adjusted by an amount detectable by a digital scanner. The adjusted signature points form a digital signature which is stored for future identification of subject images derived from the image. In one embodiment, a signature is embedded within an image by locating relative extrema in the continuous space of pixel values and selecting the signature points from among the extrema. Preferably, the signature is redundantly embedded in the image such that any of the redundant representations can be used to identify the signature. Identification of a subject image includes ensuring that the subject image is normalized with respect to the original image or the signed image. Preferably, the normalized subject image is compared with the stored digital signature.

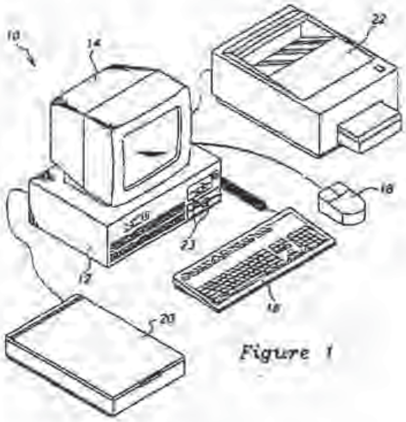


Figure 1

Rank Xerox (UK) Business Services
13.10/3.09/3.3.4

Technical Field

This invention relates to a method of and system for encoding a signature into a digital image and auditing a digital subject image to determine if it was derived from the encoded image.

Background of the Invention

Various images in traditional print or photographic media are commonly distributed to many users. Examples include the distribution of prints of paintings to the general public and photographs and film clips to and among the media. Owners may wish to audit usage of their images in print and electronic media, and so require a method to analyze print, film and digital images to determine if they were obtained directly from the owners or derived from their images. For example, the owner of an image may desire to limit access or use of the image. To monitor and enforce such a limitation, it would be beneficial to have a method of verifying that a subject image is copied or derived from the owner's image. The method of proof should be accurate and incapable of being circumvented. Further, the method should be able to detect unauthorized copies that have been resized, rotated, cropped, or otherwise altered slightly.

In the computer field, digital signatures have been applied to non-image digital data in order to identify the origin of the data. For various reasons these prior art digital signatures have not been applied to digital image data One reason is that these prior art digital signatures are lost if the data to which they are applied are modified. Digital images are often modified each time they are printed, scanned, copied, or photographed due to unintentional "noise" created by the mechanical reproduction equipment used. Further, it is often desired to resize, rotate, crop or otherwise intentionally modify the image. Accordingly, the existing digital signatures are unacceptable for use with digital images.

Summary of the Invention

The invention includes a method and system for embedding image signatures within visual images, applicable in the preferred embodiments described herein to digital representations as well as other media such as print or film. The signatures identify the source or ownership of images and distinguish between different copies of a single image. In preferred embodiments, these signatures persist through image transforms such as resizing and conversion to or from print or film and so provide a method to track subsequent use of digital images including derivative images in print or other form.

In a preferred embodiment described herein, a plurality of signature points are selected that are positioned within an original image having pixels with pixel values. The pixel values of the signature points are adjusted by an amount detectable by a digital scanner. The adjusted signature points form a digital signature that is stored for future identification of subject images derived from the image.

The preferred embodiment of the invention described herein embeds a signature within the original image by locating candidate points such as relative extrema in the pixel values. Signature points are selected from among the candidate points and a data bit is encoded at each signature point by adjusting the pixel value at and surrounding each point. Preferably, the signature is redundantly embedded in the image such that any of the redundant representations can be used to identify the signature. The signature is stored for later use in identifying a subject image.

According to a preferred embodiment, the identification of a subject image includes ensuring that the subject image is normalized, i.e., of the same size, rotation, and brightness level as the original image. If not already normalized, the subject image is normalized by aligning and adjusting the luminance values of subsets of the pixels in the subject image to match corresponding subsets in the original image. The normalized subject image is then subtracted from the original image and the result is compared with the stored digital signature. In an alternate embodiment, the normalized subject image is compared directly with the signed image.

Brief Description of the Drawings

Figure 1 is a diagram of a computer system used in a preferred embodiment of the present invention.

Figure 2 is a sample digital image upon which a preferred embodiment of the present invention is employed.

Figure 3 is a representation of a digital image in the form of an array of pixels with pixel values.

Figure 4 is graphical representation of pixel values showing relative minima and maxima pixel values.

Figure 5 is a digital subject image that is compared to the image of Figure 2 according to a preferred embodiment of the present invention.

Detailed Description of the Invention

The present invention includes a method and system for embedding a signature into an original image to create a signed image. A preferred embodiment includes selecting a large number of candidate points in the original image and selecting a number of signature points from among the candidate points. The signature points are altered slightly to form the signature. The signature points are stored for later use in auditing a subject image to determine whether the subject image is derived from the signed image.

The signatures are encoded in the visible domain of the image and so become part of the image and cannot be detected or removed without prior knowledge of the signature. A key point is that while the changes manifested by the signature are too slight to be visible to the human eye, they are easily and consistently recognizable by a common digital image scanner, after which the signature is extracted, interpreted and verified by a software algorithm.

In contrast to prior art signature methods used on non-image data, the signatures persist through significant image transformations that preserve the visible image but may completely change the digital data. The specific transforms allowed include resizing the image larger or smaller, rotating the image, uniformly adjusting color, brightness and/or contrast, and limited cropping. Significantly, the signatures persist through the process of printing the image to paper or film and rescanning it into digital form.

Shown in Figure 1 is a computer system 10 that is used to carry out an embodiment of the present invention. The computer system 10 includes a computer 12 having the usual complement of memory and logic circuits, a display monitor 14, a keyboard 16, and a mouse 18 or other pointing device. The computer system also includes a digital scanner 20 that is used to create a digital image representative of an original image such as a photograph or painting. Typically, delicate images, such as paintings, are converted to print or film before being scanned into digital form. In one embodiment a printer 22 is connected to the computer 12 to print digital images output from the processor. In addition, digital images can be output in a data format to a storage medium 23 such as a floppy disk for displaying later at a remote site. Any digital display device may be used, such a common computer printer, X-Y plotter, or a display screen.

An example of the output of the scanner 20 to the computer 12 is a digital image 24 shown in Figure 2. More accurately, the scanner outputs data representative of the digital image and the computer causes the digital image 24 to be displayed on the display monitor 14. As used herein "digital image" refers to the digital data representative of the digital image, the digital image displayed on the monitor or other display screen, and the digital image printed by the printer 22 or a remote printer.

The digital image 24 is depicted using numerous pixels 24 having various pixel values. In the gray-scale image 24 the pixel values are luminance values representing a brightness level varying from black to white. In a color image the pixels have color values and luminance values, both of which being pixel values. The color values can include the values of any components in a representation of the color by a vector. Figure 3 shows digital image 24A in the form of an array of pixels 26. Each pixel is associated with one or more pixel values, which in the example shown in Figure 3 are luminance values from 0 to 15.

The digital image 24 shown in Figure 2 includes thousands of pixels. The digital image 24A represented in Figure 3 includes 225 pixels. The invention preferably is used for images having pixels numbering in the millions. Therefore, the description herein is necessarily a simplistic discussion of the utility of the invention.

According to a preferred embodiment of the invention numerous candidate points are located within the original image. Signature points are selected from among the candidate points and are altered to form a signature. The signature is a pattern of any number of signature points. In a preferred embodiment, the signature is a binary number between 16 and 32 bits in length. The signature points may be anywhere within an image, but are preferably chosen to be as inconspicuous as possible. Preferably, the number of signature points is much greater than the number of bits in a signature. This allows the signature to be redundantly encoded in the image. Using a 16 to 32 bit signature, 50-200 signature points are preferable to obtain multiple signatures for the image.

A preferred embodiment of the invention locates candidate points by finding relative maxima and minima, collectively referred to as extrema, in the image. The extrema represent local extremes of luminance or color. Figure 4 shows what is meant by relative extrema. Figure 4 is a graphical representation of the pixel values of a small portion of a digital image. The vertical axis of the graph shows pixel values while the horizontal axis shows pixel positions along a single line of the digital image. Small undulations in pixel values, indicated at 32, represent portions of the digital image where only small changes in luminance or color occur between pixels. A relative maximum 34 represents a pixel that has the highest pixel value for a given area of the image. Similarly, a relative minimum 36 represents a pixel that has the lowest pixel value for a given area of the image.

Relative extrema are preferred signature points for two major reasons. First, they are easily located by simple, well known processing. Second, they allow signature points to be encoded very inconspicuously.

One of the simplest methods to determine relative extrema is to use a "Difference of Averages" technique. This technique employs predetermined neighborhoods around each pixel 26; a small neighborhood 28 and a large neighborhood 30, as shown in Figures 2 and 3. In the present example the neighborhoods are square for simplicity, but a preferred embodiment employs circular neighborhoods. The technique determines the difference between the average pixel value in the small neighborhood and the average pixel value of the large neighborhood. If the difference is large compared to the difference for surrounding pixels then the first pixel value is a relative maxima or minima.

Using the image of Figure 3 as an example, the Difference of Averages for the pixel 26A is determines as follows. The pixel values within the 3x3 pixel small neighborhood 28A add up to 69; dividing by 9 pixels gives an average of 7.67. The pixel values within the 5x5 pixel large neighborhood 30A add up to 219; dividing by 25 pixels gives an average of 8.76 and a Difference of Averages of -1.09. Similarly, the average in small neighborhood 28G is 10.0; the average in large neighborhood 30G is 9.8; the Difference of Averages for pixel 26G is therefore 0.2. Similar computations on pixels 26B-26F produce the following table:

	26A	26B	26C	26D	26E	26F	26G
Small Neighborhood	7.67	10.56	12.89	14.11	13.11	11.56	10.0
Large Neighborhood	8.76	10.56	12.0	12.52	12.52	11.36	9.8
Difference of Averages	-1.09	0.0	0.89	1.59	0.59	0.2	0.2

Based on pixels 26A-26G, there may be a relative maximum at pixel 26D, whose Difference of Averages of 1.59 is greater than the Difference of Averages for the other examined pixels in the row. To determine whether pixel 26D is a relative maximum rather than merely a small undulation, its Difference of Averages must be compared with the Difference of Averages for the pixels surrounding it in a larger area.

Preferably, extrema within 10% of the image size of any side are not used as signature points. This protects against loss of signature points caused by the practice of cropping the border area of an image. It is also preferable that relative extrema that are randomly and widely spaced are used rather than those that appear in regular patterns.

Using the Difference of Averages technique or other known techniques, a large number of extrema are obtained, the number depending on the pixel density and contrast of the image. Of the total number of extrema found, a preferred embodiment chooses 50 to 200 signature points. This may be done manually by a user choosing with the keyboard 16, mouse 18, or other pointing device each signature point from among the extrema displayed on the display monitor 14. The extrema may be displayed as a digital image with each point chosen by using the mouse or other pointing device to point to a pixel or they may be displayed as a list of coordinates which are chosen by keyboard, mouse, or other pointing device. Alternatively, the computer 12 can be programmed to choose signature points randomly or according to a preprogrammed pattern.

One bit of binary data is encoded in each signature point in the image by adjusting the pixel values at and surrounding the point. The image is modified by making a small, preferably 2%-10% positive or negative adjustment in the pixel value at the exact signature point, to represent a binary zero or one. The pixels surrounding each signature point, in approximately a 5 x 5 to 10 x 10 grid, are preferably adjusted proportionally to ensure a continuous transition to the new value at the signature point. A number of bits are encoded in the signature points to form a pattern which is the signature for the image.

In a preferred embodiment, the signature is a pattern of all of the signature points. When auditing a subject image, if a statistically significant number of potential signature points in the subject image match corresponding signature points in the signed image, then the subject image is deemed to be derived from the signed image. A statistically significant number is somewhat less than 100%, but enough to be reasonably confident that the subject image was derived from the signed image.

In an alternate embodiment, the signature is encoded using a redundant pattern that distributes it among the signature points in a manner that can be reliably retrieved using only a subset of the points. One embodiment simply encodes a predetermined number of exact duplicates of the signature. Other redundant representation methods, such as an error-correcting code, may also be used.

In order to allow future auditing of images to determine whether they match the signed image, the signature is stored in a database in which it is associated with the original image. The signature can be stored by associating the bit value of each signature point together with x-y coordinates of the signature point. The signature may be stored separately or as part of the signed image. The signed image is then distributed in digital form.

As discussed above, the signed image may be transformed and manipulated to form a derived image. The derived image is derived from the signed image by various transformations, such as resizing, rotating, adjusting color, brightness and/or contrast, cropping and converting to print or film. The derivation may take place in multiple steps or processes or may simply be the copying of the signed image directly.

It is assumed that derivations of these images that an owner wishes to track include only applications which substantially preserve the resolution and general quality of the image. While a size reduction by 90%, a significant color alteration or distinct-pixel-value reduction may destroy the signature, they also reduce the images significance and value such that no auditing is desired.

In order to audit a subject image according to a preferred embodiment, a user identifies the original image of which the subject image is suspected of being a duplicate. For a print or film image, the subject image is scanned to create a digital image file. For a digital image, no scanning is necessary. The subject digital image is normalized using techniques as described below to the same size, and same overall brightness, contrast and color profile as the unmodified original image. The subject image is analyzed by the method described below to extract the signature, if present, and compare it to any signatures stored for that image.

The normalization process involves a sequence of steps to undo transformations previously made to the subject image, to return it as close as possible to the resolution and appearance of the original image. It is assumed that the subject image has been manipulated and transformed as described above. To align the subject image with the original image, a preferred embodiment chooses three or more points from the subject image which correspond to points in the original image. The three or more points of the subject image are aligned with the corresponding points in the original image. The points of the subject image not selected are rotated and resized as necessary to accommodate the alignment of the points selected.

For example, Figure 5 shows a digital subject image 38 that is smaller than the original image 24 shown in Figure 2. To resize the subject image, a user points to three points such as the mouth 40B, ear 42B and eye 44B of the subject image using the mouse 18 or other pointer. Since it is usually difficult to accurately point to a single pixel, the computer selects the nearest extrema to the pixel pointed to by the user. The user points to the mouth 40A, ear 42A, and eye 44A of the original image. The computer 12 resizes and rotates the subject image as necessary to ensure that points 40B, 42B, and 44B are positioned with respect to each other in the same way that points 40A, 42A, and 44A are positioned with respect to each other in the original image. The remaining pixels are repositioned in proportion to the repositioning of points 40B, 42B and 44B. By aligning three points the entire subject image is aligned with the original image without having to align each pixel independently.

After the subject image is aligned, the next step is to normalize the brightness, contrast and/or color of the subject image. Normalizing involves adjusting pixel values of the subject image to match the value-distribution profile of the original image. This is accomplished by a technique analogous to that used to align the subject image. A subset of the pixels in the subject image are adjusted to equal corresponding pixels in the original image. The pixels not in the subset are adjusted in proportion to the adjustments made to the pixels in the subset. The pixels of the subject image corresponding to the signature points should not be among the pixels in the subset. Otherwise any signature points in the subject image will be hidden from detection when they are adjusted to equal corresponding pixels in the original image.

In a preferred embodiment, the subset includes the brightest and darkest pixels of the subject image. These pixels are adjusted to have luminance values equal to the luminance values of corresponding pixels in the original image. To ensure that any signature points can be detected, no signature points should be selected during the signature embedding process described above that are among the brightest and darkest pixels of the original image. For example, one could use pixels among the brightest and darkest 3% for the adjusting subset, after selecting signature points among less than the brightest and darkest 5% to ensure that there is no overlap.

When the subject image is fully normalized, it is preferably compared to the original image. One way to compare images is to subtract one image from the other. The result of the subtraction is a digital image that includes any signature points that were present in the subject image. These signature points, if any, are compared to the stored signature points for the signed image. If the signature points do not match, then the subject image is not an image derived from the signed image, unless the subject image was changed substantially from the signed image.

In an alternative embodiment, the normalized subject image is compared directly with the signed image instead of subtracting the subject image from the original image. This comparison involves subtracting the subject image from the signed image. If there is little or no image resulting from the subtraction then the subject image equals to the signed image, and therefore has been derived from the signed image.

In another alternate embodiment instead of normalizing the entire subject image, only a section of the subject image surrounding each potential signature point is normalized to be of the same general resolution and appearance as a corresponding section of the original image. This is accomplished by selecting each potential signature point of the subject image and selecting sections surrounding each potential signature point. The normalization of each selected section proceeds according to methods similar to those disclosed above for normalizing the entire subject image.

Normalizing each selected section individually allows each potential signature point of the subject image to be compared directly with a corresponding signature point of the signed image. Preferably, an average is computed for each potential signature point by averaging the pixel value of the potential signature point with the pixel values of a plurality of pixels surrounding the potential signature point. The average computed for each signature is compared directly with a corresponding signature point of the signed image.

While the methods of normalizing and extracting a signature from a subject image as described above are directed to luminance values, similar methods may be used for color values. Instead of or in addition to normalizing by altering luminance values, the color values of the subject image can also be adjusted to equal corresponding color values in an original color image. However, it is not necessary to adjust color values in order to encode a signature in or extract a signature from a color image. Color images use pixels having pixel values that include luminance values and color values. A digital signature can be encoded in any pixel values regardless of whether the pixel values are luminance values, color values, or any other type of pixel values. Luminance values are preferred because alterations may be made more easily to luminance values without the alterations being visible to the human eye.

From the foregoing it will be appreciated that, although specific embodiments of the invention have been described herein for purposes of illustration, various modifications may be made without deviating from the spirit and scope of the invention. Accordingly, the invention is not limited except as by the appended claims.

Claims

1. A method of image signature processing of an original image having pixels with luminance values, comprising:

   locating a plurality of candidate points from among the pixels of the original image;

   selecting a first plurality of signature points from among the candidate points;

   adjusting the pixel values of the signature points to form a signed image, the adjusted signature point pixel values forming a signature for the signed image; and

   storing the signature for future identification.

2. The method according to claim 1 wherein the candidate points are located by locating relative extrema in the original image and wherein the selecting step includes selecting the signature points from among the extrema.

3. The method according to claim 2 wherein the extrema are relative minima or maxima of luminance values of the pixels of the original image.

4. The method according to claim 1, further comprising adjusting a plurality of pixel values surrounding the signature points to provide smooth transitions to the adjusted pixel values at the signature points.

5. The method according to claim 1, further comprising:

   selecting a second plurality of signature points from among the candidate points; and

   adjusting the pixel values of the second plurality of signature points to form a redundant signature for the signed image.

6. A method of image signature processing of an original image having pixels with pixel values, comprising:

   selecting a first plurality of signature points from among the pixels of the original image;

   adjusting the pixel values of the signature points, the adjusted signature point pixel values forming a signature for the image; and storing the signature for future identification.

7. The method according to claim 6, further comprising locating relative extrema in the original image and wherein the selecting step includes selecting the signature points from among the extrema.

8. The method according to claim 7 wherein the extrema are relative minima or maxima of luminance values of the pixels of the original image.

9. The method according to claim 6 further comprising:
selecting a second plurality of signature points from among the candidate points; and
adjusting the pixel values of the second plurality of signature points to form a redundant signature for the signed image.

10. The method according to claim 6 wherein the digital image has a border surrounding the image and the pixel values adjusted are selected so as not to be within a predetermined distance from the border.

11. The method according to claim 6, further comprising adjusting a plurality of pixel values surrounding the signature points to provide smooth transitions to the adjusted pixel values at the signature points.

12. The method according to claim 6 wherein the pixel values adjusted are luminance values.

13. The method according to claim 6 wherein the pixel values adjusted are color values.

14. The method according to claim 6, further comprising analyzing whether a digital subject image constitutes or is derived from a signed image having pixel values that were adjusted to form a signature according to claim 6.

15. The method according to claim 14 wherein the analyzing step includes normalizing the subject image.

16. The method according to claim 15 wherein the normalizing step includes aligning the subject image with the signed image or the original image.

17. The method according to claim 16 wherein the aligning step includes selecting three or more pixels in the subject image and aligning the three or more peels with corresponding pixels in the original or the signed image.

18. The method according to claim 15 wherein the pixel values of the subject image and the original image include luminance values and the normalizing step includes adjusting the luminance values of a subset of the pixels in the subject image to equal the luminance values of a corresponding subset of pixels in the original image.

19. The method according to claim 14 wherein the analyzing step includes subtracting the subject image from the original image to obtain a resulting image and comparing the resulting image with the stored signature.

20. The method according to claim 14 wherein the analyzing step includes comparing the subject image with the signed image.

21. The method according to claim 14 wherein the analyzing step includes selecting a potential signature point in the subject image corresponding to a signature point of the signed image and comparing the pixel value of the selected point to the pixel value of the corresponding signature point of the signed image.

22. The method according to claim 14 wherein the analyzing step includes selecting a potential signature point in the subject image corresponding to a signature point of the signed image, computing an average of pixel values of the potential signature point and a plurality of pixels surrounding the potential signature point, and comparing the average to the pixel value of the corresponding signature point of the signed image.

23. A method of determining whether a subject image having pixels with pixel values constitutes or is derived from a signed image having pixels with pixel values that have been adjusted to collectively form a signature, comprising:

ensuring that the subject image is normalized with respect to an original image or the signal image;

comparing the signature of the signed image with potential signature points of the subject image corresponding to the pixels of the signature.

24. The method according to claim 23 wherein the ensuring step includes normalizing the subject image with respect to the original image or the signed image.

25. The method according to claim 24 wherein the normalizing step includes aligning the subject image with the signal image or the original image.

26. The method according to claim 25 wherein the aligning step includes selecting three or more pixels in the subject image and aligning the three or more pixels with a like number of pixels in the original or signed image.

27. The method according to claim 24 wherein the pixel values of the subject image and the original image include luminance values and the normalizing step includes adjusting the luminance values of a subset of the pixels in the subject image to equal the luminance value of a corresponding subset of pixels in the original image.

28. The method according to claim 23 wherein the comparing step includes subtracting the subject image from the original image to obtain a resulting image and comparing the resulting image with the stored digital signature.

29. The method according to claim 23 wherein the comparing step includes comparing the subject image with the signed image.

30. The method according to claim 23 wherein the comparing step includes selecting the potential signature points corresponding to pixels of the signature, computing an average of the pixel values of each potential signature point and a plurality of pixels surrounding each signature point, and comparing each average to the pixel value of the corresponding signature point of the signed image.

31. A system for image signature processing of an original image having pixels with pixel values, comprising:

a display device for displaying digital images to a user;

selection means for selecting a plurality of signature points from among the pixels of the original image;

a computing device in communication with the display device and the selection means, the computing device adjusting the pixel values of the signature points to form a signed image, the adjusted signature point pixel values forming a signature associated with the signed image; and

memory in communication with the computing device, the memory receiving the signature from the computing device and storing the signature for future identification.

32. The system according to claim 31 wherein the computing device includes location means for locating candidate points from among the pixels in the original image and the selecting means selects signature points from among the candidate points.

33. The system according to claim 32 wherein the selection means includes a pointer operatively connected to the display device and the computing device such that a user can select signature points from among the candidate points displayed on the display device and the computing device alters the signature points selected to form a signature associated with the signed image.

34. The system according to claim 32 wherein the location means includes means for locating pixel value extrema in the original image, the extrema being the candidate points.

35. The system according to claim 31 wherein the computing device includes means for identifying a subject image derived from the signed image.

36. The system according to claim 35, further comprising normalizing means for normalizing the subject image with the original image or the signed image.

37. The system according to claim 36 wherein the normalizing means includes a pointer operatively connected to the display device and the computing device such that a user can select alignment points from among the pixels of the subject image displayed on the display device and the computing device receives the alignment points selected and aligns the subject image with the original image or the signed image in response thereto.

38. The system according to claim 36 wherein the computing device includes comparing means for comparing the normalized subject image with the original image or the signed image.

39. The system according to claim 36 wherein the computing device includes:
subject selection means for selecting a potential signature point on the subject image corresponding to a signature point of the signed image;
averaging means for computing an average of the pixel values of the potential signature point and a plurality of pixels surrounding the potential signature point; and
comparing means for comparing the average to a pixel value of the corresponding signature point of the signed image.

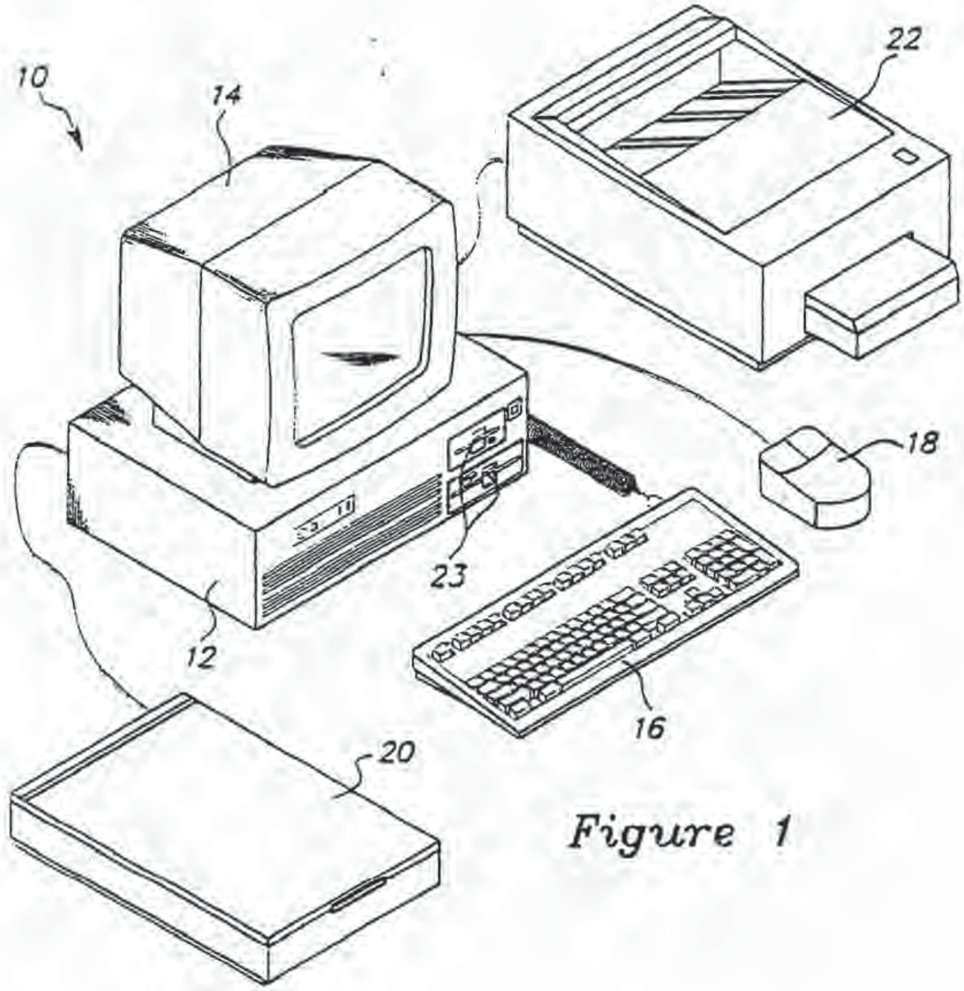


Figure 1

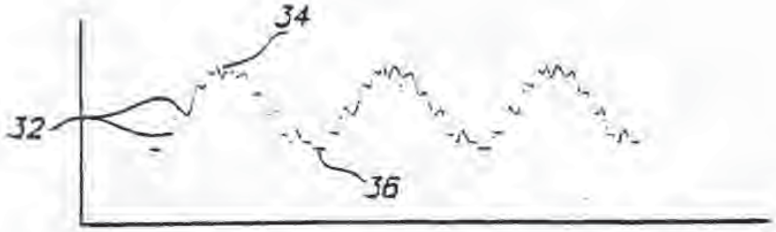
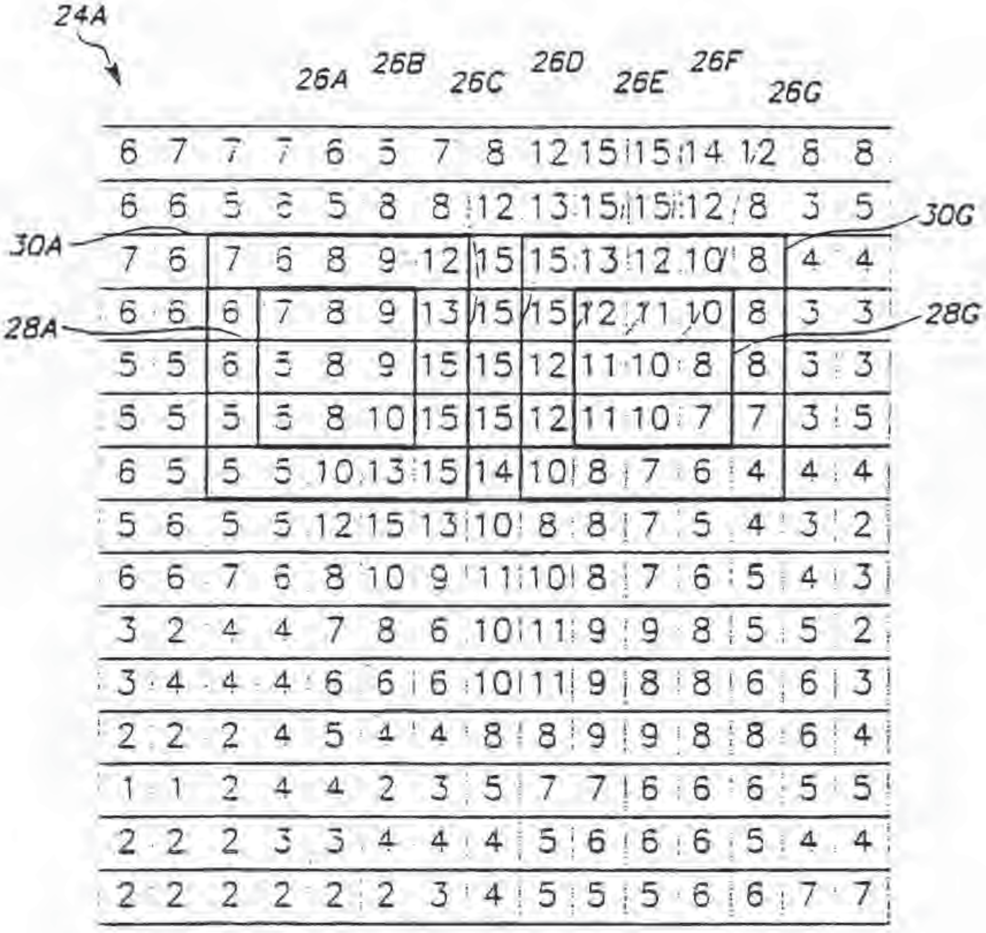


Figure 4



6	7	7	7	6	5	7	8	12	15	15	14	12	8	8
6	6	5	6	5	8	8	12	13	15	15	12	8	3	5
7	6	7	6	8	9	12	15	15	13	12	10	8	4	4
6	6	6	7	8	9	13	15	15	12	11	10	8	3	3
5	5	6	5	8	9	15	15	12	11	10	8	8	3	3
5	5	5	5	8	10	15	15	12	11	10	7	7	3	5
6	5	5	5	10	13	15	14	10	8	7	6	4	4	4
5	6	5	5	12	15	13	10	8	8	7	5	4	3	2
6	6	7	6	8	10	9	11	10	8	7	6	5	4	3
3	2	4	4	7	8	6	10	11	9	9	8	5	5	2
3	4	4	4	6	6	6	10	11	9	8	8	6	6	3
2	2	2	4	5	4	4	8	8	9	9	8	8	6	4
1	1	2	4	4	2	3	5	7	7	6	6	6	5	5
2	2	2	3	3	4	4	4	5	6	6	6	5	4	4
2	2	2	2	2	2	3	4	5	5	5	6	6	7	7

Figure 3

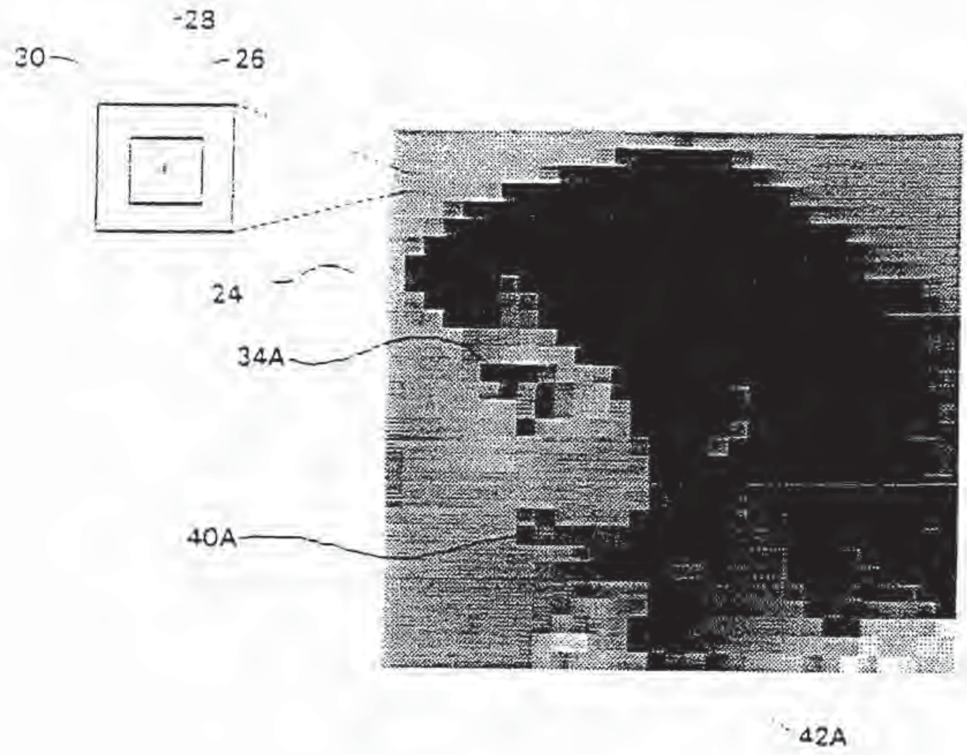


Figure 2

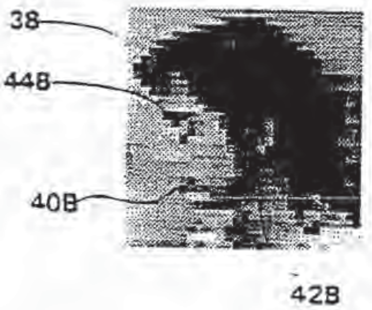


Figure 5

(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 0 581 317 A3

(12) **EUROPEAN PATENT APPLICATION**

(88) Date of publication A3:
01.05.1996 Bulletin 1996/18

(51) Int. Cl.6: **G07D 7/00**, G07F 7/12

(43) Date of publication A2:
02.02.1994 Bulletin 1994/05

(21) Application number: 93112290.7

(22) Date of filing: 30.07.1993

(84) Designated Contracting States:
AT BE CH DE DK ES FR GB GR IE IT LI LU MC NL PT SE

(30) Priority: 31.07.1992 US 923841

(71) Applicant: CORBIS CORPORATION
Bellevue, Washington 98007-6537 (US)

(72) Inventors:
- Powell, Robert D.
  Issaquah, Washington 98027 (US)
- Nitzberg, Mark J.
  D-50677 Köln (DE)

(74) Representative: Grünecker, Kinkeldey,
Stockmair & Schwanhäusser
Anwaltssozietät
Maximilianstrasse 58
D-80538 München (DE)

(54) Method and system for digital image signatures

(57) A method and system for embedding signatures within visual images in both digital representation and print or film. A signature is inseparably embedded within the visible image, the signature persisting through image transforms that include resizing as well as conversion to print or film and back to digital form. Signature points are selected from among the pixels of an original image. The pixel values of the signature points and surrounding pixels are adjusted by an amount detectable by a digital scanner. The adjusted signature points form a digital signature which is stored for future identification of subject images derived from the image. In one embodiment, a signature is embedded within an image by locating relative extrema in the continuous space of pixel values and selecting the signature points from among the extrema. Preferably, the signature is redundantly embedded in the image such that any of the redundant representations can be used to identify the signature. Identification of a subject image includes ensuring that the subject image is normalized with respect to the original image or the signed image. Preferably, the normalized subject image is compared with the stored digital signature.

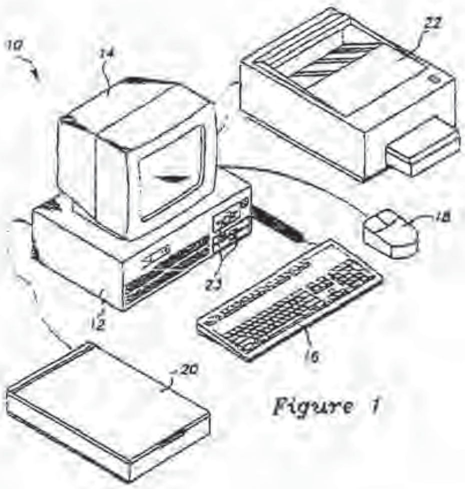


Figure 1

EP 0 581 317 A3

Printed by Rank Xerox (UK) Business Services
2.11.3/3.4

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 93 11 2290

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.5)
X	1979 CARNAHAN CONFERENCE ON CRIME COUNTERMEASURES, 16 - 18 May 1979 UNIVERSITY OF KENTUCKY, LEXINGTON, KENTUCKY USA, pages 101-109, SZEPANSKI, WOLFRAM 'A Signal Theoretic method for creating Forgery-proof Documents for Automatic Verification.' * page 103 - page 104; figures 3.4 , 4 * ---	1-39	G07D7/00 G07F7/12
X	DE-A-29 43 436 (SZEPANSKI WOLFRAM DR ING) 7 May 1981 * page 8, paragraph 3; figure 3 * ---	1-39	
A	US-A-3 914 877 (HINES MARION E) 28 October 1975 * claim 1; figure 2 * ---	1-39	
A	US-A-4 488 245 (DALKE GEORGE W ET AL) 11 December 1984 * claim 1; figure 6 * ---	1-39	TECHNICAL FIELDS SEARCHED (Int.Cl.5)
A	US-A-4 310 180 (MOWRY JR WILLIAM H ET AL) 12 January 1982 * claim 1; figure 1 * -----	1-39	G07D G07F

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	7 March 1996	Kirsten, K

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

EPO FORM 1503 03.82 (P04C01)

(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) Publication number : **0 372 601 B1**

(12) EUROPEAN PATENT SPECIFICATION

(45) Date of publication of patent specification : **22.02.95 Bulletin 95/08**

(51) Int. Cl.^{5} : **H04B 1/66**

(21) Application number : **89202823.4**

(22) Date of filing : **08.11.89**

(54) **Coder for incorporating extra information in a digital audio signal having a predetermined format, decoder for extracting such extra information from a digital signal, device for recording a digital signal on a record carrier, comprising such a coder, and record carrier obtained by means of such a device.**

(30) Priority : **10.11.88 NL 8802769**
25.04.89 NL 8901032

(43) Date of publication of application :
13.06.90 Bulletin 90/24

(45) Publication of the grant of the patent :
22.02.95 Bulletin 95/08

(84) Designated Contracting States :
AT BE DE ES FR GB IT SE

(56) References cited :
EP-A- 0 145 332
EP-A- 0 289 060

(73) Proprietor : **Philips Electronics N.V.**
Groenewoudseweg 1
NL-5621 BA Eindhoven (NL)

(72) Inventor : **Druyvesteyn, Willem Frederik**
c/o INT. OCTROOIBUREAU B.V.
Prof. Holstlaan 6
NL-5656 AA Eindhoven (NL)
Inventor : **Hoogendoorn, Abraham**
c/o INT. OCTROOIBUREAU B.V.
Prof. Holstlaan 6
NL-5656 AA Eindhoven (NL)
Inventor : **Van de Kerkhof, Leon Maria**
c/o INT. OCTROOIBUREAU B.V.
Prof. Holstlaan 6
NL-5656 AA Eindhoven (NL)
Inventor : **Veldhuis, Raymond Nicolaas Johan**
c/o INT. OCTROOIBUREAU B.V.
Prof. Holstlaan 6
NL-5656 AA Eindhoven (NL)

(74) Representative : **van der Kruk, Willem Leonardus et al**
INTERNATIONAAL OCTROOIBUREAU B.V.,
Prof. Holstlaan 6
NL-5656 AA Eindhoven (NL)

EP 0 372 601 B1

Note : Within nine months from the publication of the mention of the grant of the European patent, any person may give notice to the European Patent Office of opposition to the European patent granted. Notice of opposition shall be filed in a written reasoned statement. It shall not be deemed to have been filed until the opposition fee has been paid (Art. 99(1) European patent convention).

Jouve, 18, rue Saint-Denis, 75001 PARIS

Description

The invention relates to a coder for incorporating extra information in the form of an auxiliary signal in a digital audio signal having a predetermined format, to a decoder for extracting this extra information from digital signal, to a device for recording a digital signal on a record carrier and to a record carrier obtained by means of such a device.

In digital sound transmission and recording systems, such as CD players, future television systems, such as D2MAC, and so on, the format, i.e. the sampling rate and the number of bits per sample, in which the digital sound signal is recorded or transmitted, is generally predetermined, for example, in connection with international agreements. Sometimes, however, there is a need for recording or transmitting more information than possible on the basis of the available number of channels. For example, on the basis of international agreements, not more than two high-quality digital audio channels, for example, each channel for 14-bit digital signals, can be available in specific future television systems. These channels are used for transmitting audio information for the respective left and right-hand channels. However, there is a wish to transmit information for rear channels too, for example, a left-hand and a right-hand rear channel for so-called surround sound. Also in other cases it may be very useful if extra information can be added to existing channels for digital signals having a predetermined format, without the need for extending the number of channels for this purpose. In this context one may think of adding music signals containing music information without vocals, which is commonly referred to as Karaoke, so that the user himself can provide the vocals; or adding music signals in which a specific instrument is omitted, so that the user can play this instrument along with the rest of the recording. One may also think of adding extra information by way of data signals, such as, for example, for Ceefax information.

It will be evident that in all these cases the system is desired to be compatible with state of the art systems, that is to say, it should be possible to reproduce the original signal information in an undisturbed manner with equipment not comprising a specific decoder for extracting the extra information from the signal. If, for example, there is a television signal containing surround-sound information, in a television set not equipped for producing surround sound, it should be possible to reproduce the information for the left and right-hand channels without this reproduction being disturbed in any audible way by the "masked" information for extracting the signal from the rear channels.

It is an object of the invention to provide a system presenting this feature and it thereto provides a system of the above type wherein the coder comprises means for analysing the digital signal, means for quantizing the analysed digital signal in an unequivocal manner and means for determining, on the basis of the acoustic properties of the human auditory system, the amount of extra information that can be added to the quantized digital signal without this extra information being audible with unmodified detection; means for combining the extra information and the quantized digital signal to a compound signal. The coder may further comprise means for reconverting the compound signal into a digital signal having the predetermined format.

According to a preferred embodiment of the invention the psychoacoustic property of the human auditory system is exploited that when the audio frequency band is divided into a number of sub-bands, whose bandwidths approximately correspond with the bandwidths of the critical bands of the human auditory system, the quantizing noise in such a sub-band is optimally masked by the signals of this sub-band.

It should be noted in this respect that a coder for generating subband signals is known from EP-A-0 289 080.

In an embodiment in which this masking principle is implemented the means for analysing the digital signal comprise analysis filter means for generating a number of P sub-band signals in response to the digital signal, which analysis filter means divide the frequency band of the digital signal into consecutive sub-bands having band numbers p (1 ≦ p ≦ P) according to a filter method with sample frequency reduction, while the bandwidths of the sub-bands preferably approximately correspond to the critical bandwidths of the human auditory system in the respective frequency ranges although it is likewise possible to use a smaller number of sub-bands, whereas, if the auxiliary signal is a digital audio signal, analysis filter means are preferably also provided for generating a number of P sub-band signals in response to the auxiliary signal, which analysis filter means divide the frequency band of the auxiliary signal into consecutive sub-bands with band numbers p(1 ≦ p ≦ P), according to a filter method with sample frequency reduction, while the bandwidths of the sub-bands again preferably approximately correspond with the critical bandwidths of the human auditory system in the respective frequency ranges, whereas for each of the respective sub-bands means are provided for quantizing the digital signal in an unequivocal manner and means for combining the respective quantized sub-band signals and the corresponding sub-band signals. Preferably, the coder further comprises the auxiliary signal for constituting P compound sub-band signals, and synthesis filter means for constructing a replica of the compound signal in response to the compound sub-band signals, which synthesis filter means combine the subbands according to a filter method with sample frequency enhancement corresponding to the sub-division in the analysis filter means.

For extracting the auxiliary signal incorporated in such a compound signal there are provided a decoder, comprising analysis filter means for generating a number of compound sub-band signals in response to the compound signal, these analysis filter means subdividing the frequency band of the compound signal into consecutive sub-bands having band numbers p (1 ≦ p ≦ P) according to a filter method with sample frequency reduction, the bandwidths of the sub-bands corresponding with those of the analysis filter means in the transmitter; means for quantizing in an unequivocal way the compound subband signals; means for subtracting the respective quantized sub-band signals from the corresponding sub-band signals of the compound signal in order to form sub-band difference signals, and synthesis filter means for constructing a replica of the auxiliary signal in response to subband difference signals, which synthesis filter means combine the subbands according to a filter method with sample frequency enhancement corresponding with the sub-division in the analysis filter means. The analysis filter means and the synthesis filter means together constitute a perfect reconstruction filter both in the coder and the decoder.

Although the invention can be applied to recording digital information on, for example, a compact disc or a video tape, as well as reproducing same, and also applied to transmitting and receiving digital information as is done in, for example, television, transmission and reception will be mentioned in the sequel for brevity, whereas recording and subsequent reproduction are also implicitly referred to.

The invention is based on the recognition of the fact that quantizing the digital audio signal in a predetermined manner enables to mask in resultant quantizing noise extra information in the form of an auxiliary signal, in the form of a discrete time signal, generally a digital signal, or in the form of a data signal, and that this re-quantized digital audio signal with the incorporated auxiliary signal can subsequently be reconverted into a compound digital signal again having the predetermined format, while when receiving this compound digital signal in a receiver that does not comprise a specific decoder, the audio information incorporated in the original digital audio signal can be extracted from this compound signal in the customary fashion, without the auxiliary signal affecting this signal to an audible level because this auxiliary signal lies below the masking threshold of the audio signal and remains masked in the quantizing noise. In a receiver that does comprise a decoder, however, the information relating to the auxiliary signal can be derived from the difference between the compound digital signal and the compound digital signal quantized in the predetermined manner.

The recognition on which the invention is based enables in a relatively simple manner to add extra information, in the form of an auxiliary signal, to an existing digital audio signal having a fixed format, to be called the main signal hereinafter and, subsequently, extract same again, without affecting to an audible extent the original information, whereas this original information can be reproduced even without any modification of the receiving equipment.

The recognition underlying this invention can only be applied if a number of requirements are fulfilled, which are the following:

1) The quantization method for the main signal is to be selected such that the quantization methods implemented both during transmission and reception is always the same;

2) The amplitude of the auxiliary signal to be added is to be smaller than half the quantization step of the main signal; and

3) The quantization of the main signal is to be performed such that the quantization noise is not audibly enhanced.

Condition 1) can be fulfilled in a simple manner when a choice is made in favour of a fixed quantization step, whose size is thus independent of the amplitude of the main signal. When quantization is effected both at the transmit end and the receive end the quantization step is fixed and no problems will occur. In practice, however, an adaptive quantization step is preferably used because it will then be possible to realise a maximum amplitude range for the auxiliary signal. With such an adaptive quantization special measures are to be taken so as to decide always unequivocally on the same quantization during transmission and reception, both at the transmit end and at the receive end, irrespective of the signal amplitude of the main signal.

According to a preferred embodiment of the invention the magnitude of the quantization step per sub-band depends on the amplitude of the main signal, whilst there is an exponential relationship with a predetermined basic number between any consecutive steps. Thus it is possible to obtain adaptive quantization which accommodates itself to the amplitude of the main signal and can be derived in an unequivocal manner from the compound signal at the receive end, so as to reclaim thus the main signal. This matter will be further explained hereinbelow.

The above condition 2) can be fulfilled by attenuating by a specific factor the auxiliary signal per sub-band at the transmit end and amplifying this signal again by the same factor at the receive end, whilst the magnitude of this factor can be selected in dependence on the magnitude of the quantization step used for quantizing the main signal. If the auxiliary signal is a data signal, no attenuation is required because in that case it can be determined for each quantized sample of the main signal how many bits form a half quantization step and, consequently, how many data per sample can be added.

Condition 3) can basically be fulfilled by choosing the quantization steps small enough so that the quantization noise can be maintained at a very low level. However, this will lead to a conflict with condition 2). For, if a small quantization step is concerned, the amplitude available to the auxiliary signal, which amplitude, for that matter, should be smaller than this half quantization step, is also very small, which will lead to problems in connection with noise and reproducibility of the auxiliary signal. Therefore, a rather coarse quantization of the main signal is preferably used in combination with measures to make the resultant quantization noise inaudible to the human auditory system. Such measures are known per se.

A first measure is based on the phenomenon that when the audio signal band is divided into a plurality of sub-bands, whose bandwidths approximately correspond with the bandwidths of the critical bands of the human auditory system in the respective frequency ranges, it may be expected on grounds of psychoacoustic experiments that the quantization noise in such a sub-band will be optimally masked by the signals in this sub-band when the noise masking curve of the human auditory system is taken into account when the quantization is effected. This curve indicates the threshold value for masking noise in a critical band by a single tone in the middle of the critical band. If a high-quality digital music signal, represented, for example, in accordance with the compact disc standard, by 16 bits per signal sample with a sampling rate of 1/T = 44.1 kHz, it turns out that the use of this prior-art sub-band encoding with a suitably chosen bandwidth and a suitably chosen quantization for the respective sub-bands results in quantized transmitter output signals which can be represented by an average number of approximately 2.5 bits per signal sample, whilst the quality of the replica of the music signal does not perceptually differ from that of the original music signal in virtually all passages of virtually all sorts of music signals. For a further explanation of this phenomenon reference is made to the article entitled "THE CRITICAL BAND CODER -- DIGITAL ENCODING OF SPEECH SIGNALS BASED ON THE PERCEPTUAL REQUIREMENTS OF THE AUDITORY SYSTEM" by M.E. Krasner in proceedings IEEE ICASSP 80, Vol. 1, pp. 327-331, April 9-11, 1980. By implementing this so-called simultaneous masking in frequency sub-bands the main signal can yet be quantized with a minimum loss of quality despite a coarse quantization, as a result of which the maximum quantization range for the auxiliary signal, that is to say, the range smaller than a half quantization step, is relatively large, so that this signal too can be reconstructed with a minimum loss of quality.

A further measure known per se utilizes the psycho acoustic effect of temporal masking, that is to say, the property of the human auditory system that the threshold value for perceiving signals shortly before and shortly after the occurrence of another signal having a relatively high signal energy appears to be temporarily higher than during the absence of the latter signal. In the period of time before and after such a signal having a high signal energy, extra information of the auxiliary signal can now be recorded. It is also possible to combine temporal masking with frequency sub-band masking. A first possibility in this respect according to the invention is the implementation of the knowledge about the amplitude of one or more preceding digital signal samples. If there is a decreasing amplitude the quantization step can, in the case of adaptive quantization, be chosen to be larger than would be permissible on the basis of the actual signal amplitude and the selected quantization criterion, because the resultant extra quantization noise at this relatively low amplitude is masked by the preceding larger amplitude(s). Since a coarser quantization can be chosen, more extra information can be masked in the digital signal samples following a large signal amplitude, which favourably affects the signal-to-noise ratio when the auxiliary signal is received. A great advantage of this manner of temporal masking is the fact that no additional delay occurs when the samples are taken in which it is permitted to quantize more coarsely on the basis of temporal masking.

A further possibility is storing the samples of the main signal in blocks and deciding to come to a single quantization step which holds for all samples in that block on the basis of the maximum signal amplitude in that block, whilst assuming that owing to temporal masking the actually too coarse quantization of the samples having a lower sample amplitude is inaudible. However, a block signal sample is invariably to be stored before a quantization step can be determined.

A special use of the coder is in a device for recording a digital signal on a record carrier, for example a magnetic record carrier. The auxiliary signal which is then also recorded may now serve as a copy inhibit code. Said device will be used by the software industry to generate prerecorded record carriers provided with a copy-inhibit code. When such record carriers are played the analog signal obtained after D/A conversion still contains the auxiliary signal which, however, as stated above, is not audible. Every subsequent recording via said analog path, can now be inhibited if a recording device intended for the consumer market comprises a detection unit which is capable of detecting said auxiliary signal.

Such a device for recording a digital audio signal on record carrier comprising a coder for sub-band coding of the digital audio signal of given sample frequency 1/T, the coder comprising: analysis filter means responsive to the audio signal to generate a plurality of P sub-band signals, which analysis filter means divide the frequencyband of the audio signal in accordance with a filter method with sample frequency reduction into consecutive sub-bands having band numbers p(1 ≦ p ≦ P), which analysis filter means are further adapted to apply the P sub-band signals to P outputs, which outputs are coupled to P corresponding inputs of a

- recording unit which is constructed to record the P sub-band signals on the record carrier,

is therefor characterized in that the device further comprises a detection unit coupled to the analysis filter means, in that the detection unit is adapted to detect the presence of an auxiliary signal in one or more sub-band signals and to generate a control signal upon detection of the auxiliary signal and to apply the control signal to an output, in that said output is coupled to a control signal input of the recording unit, and in that the recording unit is adapted to inhibit recording of the audio signal in the presence of the control signal and to record the audio signal in the absence of the control signal. When the auxiliary signal is detected recording is inhibited, or the signal to be recorded is distorted on purpose before it is recorded. It is obvious that reproducing devices should comprise a decoder with which during reproduction the digital audio signal is read together with the auxiliary signal, without the two signals being separated from one another. During a subsequent recording the auxiliary signal in the audio signal can then be detected, if present, so that it is possible to inhibit unauthorized copying of copy-protected audio information.

It is alternatively possible not to inhibit copy-protected information but merely to detect that the audio signal to be copied comprises an auxiliary signal, and to signal that in the relevant case the information is protected and should not be copied.

Such a device, which is also intended for the consumer market, for recording a digital audio signal on the record carrier, comprising a coder for sub-band coding of the digital audio signal of given sample frequency 1/T, wherein the coder comprises:

- analysis filter means responsive to the audio signal to generate a plurality of P sub-band signals, which analysis filter means divide the frequency band of the audio signal into consecutive sub-bands having band numbers p(1 ≦ p ≦ P) in accordance with a filter method using sample frequency reduction, which analysis filter means are further adapted to apply the P sub-band signals to P outputs, which outputs are coupled to P corresponding inputs of a
- recording unit which is constructed to record the P sub-band signals on the record carrier, which device is capable of realizing this, is characterized in that the device further comprises a detection unit coupled to the analysis filter means, in that the detection unit is adapted to detect the presence of an auxiliary signal in one or more of the sub-band signals and to generate a control signal upon detection of the auxiliary signal and to apply the control signal to an output, in that said output is coupled to a signalling unit, and in that the signalling unit is constructed to signal that the audio signal to be recorded, when a control signal is present, is an audio signal containing an auxiliary signal.

The above recording devices, which are intended for the consumer market, may be characterized further in that the coder further comprises signal combination means coupled to the analysis filter means, in that the signal combination means are adapted to selectively add the auxiliary signal, in the absence of a control signal, to one or more of the sub-band signals to form P composite sub-band signals and to apply said P composite sub-band signals to P outputs, which P outputs are coupled to the P corresponding inputs of the recording unit. This enables a user of the device to provide his recordings, if desired, with a copy inhibit code, in order to ensure that no copies can be made of record carriers made by the user and provided with his own recordings.

The devices intended for the consumer market may alternatively be characterized in that the coder further comprises signal combination means coupled to the analysis filter means, in that the signal combination means are adapted to add the auxiliary signal, in the absence of the control signal, to one or more of the sub-band signals to form P composite sub-band signals and to apply said P composite sub-band signals to P outputs, which P outputs are coupled to the P corresponding inputs of the recording unit. In that case there is no longer a selection possibility and in all cases an auxiliary signal will be added to the audio signal to be recorded, which does not yet contain the auxiliary signal. This enables original recordings (not provided with the auxiliary signal) or prerecorded tapes (neither provided with the auxiliary signal) to be copied, while it is not possible to make copies of the recordings thus copied.

Embodiments of the invention will now be described in more detail, by way of example, with reference to the drawings in which:

Fig. 1 shows a block diagram of a preferred embodiment of a transmit-receive system comprising a coder and a decoder in accordance with the invention,

Fig. 2 illustrates diagrammatically the quantization method in the coder,

Fig. 3 shows a device for recording a digital audio signal on a record carrier,

Fig. 4 shows a device for reproducing the signal recorded on the record carrier by means of the device shown in Fig. 3,

Fig. 5 shows another embodiment,

Fig. 6 shows a further embodiment,

Fig. 7 shows still another embodiment, and

Fig. 8 shows yet another embodiment of a device for recording a digital audio signal.

Fig. 1 diagrammatically shows a system comprising a transmitter 1 and a receiver 2 for adding and extracting respectively, extra information to and from a digital audio signal having a predetermined format, which information is transferred via or stored in medium 3. This medium can be a transmission channel but, for example, also a compact disc or a magnetic tape or disc.

The transmitter comprises a coder in the form of a processor 7 having an input terminal 4 for the digital signal u(k) having the predetermined format and an input terminal 5 for the additional digital auxiliary signal v(k) and having an output terminal 6. The output terminal 6 of the processor circuit 7 is coupled to the medium 3.

The receiver 2 comprises a delay circuit 9 having a delay τ, as well as a decoder in the form of a processor circuit 10. The input terminals of these two circuits are connected to one another and arranged for receiving the digital compound signal produced by the medium 3. At the output terminal of the delay circuit 9 the main signal is available again, as will be explained hereinafter, in the form of a signal u'(k) and at the output terminal of processor circuit 10 the auxiliary signal is available in the form of a signal v'(k).

The operation of the system according to Fig. 1 is as follows. At the input terminal of the transmitter 1 consecutive samples of the signal u(k) are presented. For example, in the case of an audio signal formed in accordance with the compact disc standard, each signal sample comprises 16 bits and the sampling rate is 44.1 kHz. In the processor circuit 7 it is determined how much information of the signal v(k) can be added to each sample of the signal u(k) on the basis of the chosen method according to which the auxiliary signal v(k) is added, that is, by means of temporal masking or simultaneous frequency sub-band masking or by means of a combination of the two. If temporal masking is used, this may be done in the time intervals shortly before and/or shortly after a loud passage in the signal u(k) and if simultaneous masking is chosen, it will be possible to add information about the signal v(k) to each signal sample of the signal u(k) by means of the subdivision into frequency sub-bands. As stated earlier, a combination of the two types of masking is possible. The combined output signal of the processor circuit 7 is reconverted in a converter 29 into the predetermined format of the digital main signal and applied to the medium 3.

In the receiver 2 the received signal is subjected to a decoding operation in the processor circuit 10 in order to split up the signals u(k) and v(k), so that at the output of circuit 10 the signal v'(k) is available, whereas through delay circuit 9, whose delay is equal to that which is produced by the processor circuit 10, the signal u'(k) is available in synchronism with the signal v'(k).

In the sequel the structure of the processor circuits 7 and 10 will be explained.

The processor circuit 7 comprises filter banks 22 and 23 for splitting up through sample frequency reduction the respective signals u(k) and v(k) into P consecutive sub-bands, whose bandwidths approximately correspond with the critical bandwidths of the human hearing in the respective frequency bands. The use and structure of such filter banks is known from, for example, the above article by Krasner and the chapter of "Sub-band coding" in the book entitled "Digital coding of waveforms" by N.S. Jayant and p. Noll, Prentice Hall Inc., Englewood Cliffs, New Jersey, 1984, pp. 486-509. Each of the p sub-band signals of filter bank 22 is applied to an adaptive quantizer 24(p), with $1 \leqq p \leqq P$, whereas each sub-band output signal of filter bank 23 is applied to an attenuator 25(p), with $1 \leqq p \leqq P$. The output signals of summing circuit 26(p) are now applied to a synthesis filter bank 27 in which the P sub-bands are combined to a signal having the same bandwidth as the original signals u(k) and v(k). The output signal of the synthesis filter bank 27 is encoded in a converter 29 into a digital signal having a predetermined format, for example, 16 bits, and applied to the medium 3 as a compound signal s(k).

If the number of quantization levels per frequency band in the transmitter 2 is chosen in the right way, nothing can be perceived in the digital signal applied to medium 3 of the addition of the signal v(k), provided that the condition is fulfilled that the amplitude of an auxiliary signal sample to be added is smaller than q/2 in each frequency sub-band for each sample of $u_p(k)$t where q is the quantization step of that sample.

At the receive end the original signal u(k) can now be reproduced directly without any adaptation by means of a non-adapted device, because in the compound digital signal s(k) the extra information of the signal v(k) is not audible, because it is masked by the signal u(k).

A receiver which is indeed suitable for receiving both the signal u(k) and the signal v(k), for example, a D2MAC television receiver with surround-sound reproduction features comprises, however, a filter bank 31 which is arranged in the same way as the filter bank 22. This filter bank 31 splits up again the received compound signal s(k) into P sub-bands having the same bandwidths and central frequencies as the sub-bands of the filter bank 22. Each of these sub-band signals is applied to an adaptive quantizer 33(p), with $1 \leqq p \leqq P$. A proper dimensioning of this quantizer provides that for each sub-band the signal $u_p(k)$ is again obtained from each of the P sub-bands after quantization. By subtracting each of these sub-band signals $u_p(k)$ from the compound sub-band signal $s_p(k)$ in a subtracting circuit 34(p), the signal $v_p(k)$ is obtained for each sub-band p. Each of these signals

$v_p(k)$ is amplified in an amplifier 35(p), with $1 \leq p \leq P$, by a factor G which is the same as that which is used in the coder for attenuating the relevant sub-band and, subsequently, these scaled signals $v_p(k)$ are applied to a synthesis filter bank 36 which reconstructs the signal v'(k) from the individual sub-bands $v_p(k)$. The signal u'(k) can be extracted directly, as observed hereinbefore, from the compound signal s(k) and needs only to be delayed in a delay circuit 9 over a time which is equal to the delay time introduced by the processor 10, if the main signal and the auxiliary signal are desired to be synchronous.

In the case of a television transmit-receive system with surround-sound reproduction facilities, in the left channel the signals u(k) and v(k) may be the digital reproduction of, for example, the signal LV + LA and the signal LA respectively. An unmodified receiver will receive the complete sound signal LV + LA and can reproduce this without complications, whereas in a modified receiver, the signals LA and LV can be applied separately to the relevant reproduction channels after u(k) and v(k) have been split up by means of a subtracting circuit.

In the sequel it will be discussed in what way the adaptive quantizers 24(p) and 33(p) can be arranged in the transmitter and receiver of the system according to Fig. 1 so as to obtain in an unequivocal manner an adaptive quantization for each of the sub-band signals. For this purpose the number of quantization steps desired for each of the sub-bands is determined beforehand, which this number i(p) is constant for each of the sub-bands.

In view of the wish that quantization be adaptive, the quantization steps are to be chosen approximately in proportion to the signal size. For this purpose the amplitude axis is subdidived into sections T, whilst, if the amplitude of a sample of the signal u(k) is situated in a specific section T_n, where n is an integer, the quantization steps for that sample have a specific magnitude which is equal to the magnitude of the section T_n. The quantization level is positioned in the centre of said section, so as to allow the auxiliary signal v(k) to have equal amplitude ranges on either one of the two sides of this section relative to the quantization level, without the compound signal $s_p(k)$ being situated in another quantization section.

Since one wishes to choose the quantization steps in proportion to the maximum signal size, and the number of quantization steps is fixed, the magnitudes of the sections T which always determine the magnitude of the quantization step, have to enhance in proportion to the amplitude. Therefore, the variation of the section magnitudes is preferably exponential, each section varying from $a^{(n-1/2)}$ to $a^{(n+1/2)}$ where $\underline{a}$ is a constant and $\underline{n}$ an integer. The quantization level belonging to a specific section T_n is then $1/2(a^{n+1/2} + a^{n-1/2})$.

Fig. 2 shows an amplitude axis on which the division of the quantization levels according to the embodiment is shown. Depending on the absolute value of the maximum amplitude $\hat{u}(k)$ of the signal u(k) the quantization step is equal to the size of the section in which $\hat{u}(k)$ is located and thus equal to $a^{(n+1/2)} - a^{(n-1/2)}$. In this case the choice of the value of the factor $\underline{a}$ is free However, it is often desired that also the value 0 is a quantization level, because it does not matter then whether the maximum signal level of u(k) is positive or negative, whereas relatively small signal amplitudes are also avoided to be quantized at a considerably higher quantization level. This provides the additional requirement that the chosen quantization level is an integer number of times the quantization step. This requirement limits the choice of the constant $\underline{a}$ to a = (2k + 1)/(2k - 1) with k = 1,2 ...; that is to say, a = 3; a = 5/3; a = 7/5 ... and so on.

The consequence of the choice of the quantization steps according to this preferred embodiment is the fact that in the decoding arrangement the signal $v_p(k)$ can always be extracted from the compound signal s(k) in an unequivocal manner, because with a specific signal amplitude, always the same quantization level is decided on. When this quantization level and thus $u_p(k)$ is determined, $u_p(k)$ can be subtracted from the compound signal so as to thus determine the signal $v_p(k)$.

For controlling the respective quantizers 24(p) and 32(p), the processor circuit 7 comprises quantization step determining circuits 28(p) and processor circuit 10 the quantization step determining circuits 32 respectively, the structure of these circuits being basically identical. The circuits 28(p) and 32(p) comprise memory sections 28'(p) and 32'(p) respectively, in which for each sub-band the predetermined value for the basic number $\underline{a}$ is stored, which may be different for each sub-band. The circuits 28(p) and 32(p) compute for each sample of $u_p(k)$ and $s_p(k)$ respectively, the size of the quantization step on the basis of the above-described quantization procedure and apply through outputs the values of these steps to the respective quantizers 24(p) and 33(p). A value derived from the value $\underline{a}$ in the respective memory sections 28'(p) and 32'(p) is also applied to a control input of the respective attenuators 25(p) and the respective amplifiers 35(p) so as to attenuate and amplify respectively, the signals $v_p(k)$ by a factor G. The attenuation factor or gain factor G respectively, derived from the value $\underline{a}$ is 2a/(a - 1). It is known that $\hat{u}(k)$, the maximum amplitude of the signal u(k), is equal to $a^{(n+1/2)}$ as a maximum whereas the maximum permissible amplitude $\hat{v}(k)$ of the auxiliary signal v(k) is then equal to $1/2[a^{(n+1/2)} - a^{(n-1/2)}]$. Now $\hat{u}(k)/\hat{v}(k) = 2a/(a-1)$. If it is provided beforehand that always $\hat{v}(k) < \hat{u}(k)$, which in practice can be realised without any problems, it is always certain that $\hat{v}(k) < q/2$ if for the factor G is chosen G = 2a/(a - 1). In practical cases the condition $\hat{v}(k) < \hat{u}(k)$ has often been fulfilled automatically because of the relationship which exists between these two signals.

In order to avoid $\hat{v}(k)$ nevertheless exceeding the value q/2 in any way, the output line of each attenuator 25(p) can comprise the limiter 30(p) shown in a dashed line in Fig. 1, which limiter receives information about the limitation value to be set from the circuits 28(p) and limits the output signal of the attenuator 25(p) to a maximum of q/2.

If a choice is made in favour of simultaneous masking combined with temporal masking, the circuits 28(p) and 32(p) comprise the circuits necessary for comparing the current sample of $u_p(k)$ to one or more previous samples so as to decide to a larger quantization step on the basis of pre-stored information about the variation of the temporal masking curve belonging to a specific maximum amplitude of $u_p(k)$, if the current sample has a lower amplitude than the amplitude of one or more of the previous samples.

In the case of block quantization, a buffer circuit is to be provided between each of the P outputs of the filter bank 22 and the input of the relevant quantizer 24(p), which circuit constantly stores a block of M signal samples, determines the maximum block amplitude and uses this value for determining the quantization step for the entire block.

Finally, it is observed that additional room can be found for adding v(k) in a sub-band p by also considering the amplitude variations in adjacent sub-bands. If, in an adjacent sub-band, a large amplitude of u(k) occurs, whereas in the p sub-band amplitude of u(k) is very small or even zero, one may decide, on the basis of the masking properties of the signal in this adjacent sub-band, yet to allow a specific amount of the signal v(k) to enter the sub-band p.

It is further pointed out that at the output of the quantizers 33(p) a signal $u_p(k)$ is available which basically has less quantization noise than the signal s(k) so that in a receiver comprising a decoder a better replica of the signal u(k) can be derived from these output signals by means of an additional synthesis filter.

Fig. 3 shows a device for recording a digital audio signal, such as the digital audio signal u(k) in Fig. 1, on a record carrier. The device comprises a coder 7' which bears much resemblance to the coder shown in Fig. 1. The only difference is that the synthesis filter bank 27 has been dispensed with. Instead, the outputs of the summing circuit 26(p) are coupled to a recording unit 47. This recording unit is constructed to record the P sub-band signals applied to its inputs on a record carrier 48. Averaged over all sub-bands this enables such a data reduction to be achieved that the information to be recorded on the record carrier is recorded with, for example, 4 bits per sample, while the information applied to the input 4 comprises; for example, 16 bits per sample.

The auxiliary signal V(k) is generated in an auxiliary signal generator 40 which has an output coupled to the input 5, to apply the auxiliary signal to the coder 7'. By means of the coder 7' the auxiliary signal is inserted in the audio signal in the manner described hereinbefore. The auxiliary signal can thus be inserted into one or more of the sub-band signals into which the audio signal (k) has been divided.

Preferably, the auxiliary signal is accommodated in one or more of the lower sub-bands (of low frequency). In the sub-bands which are situated in the low-frequency range the signal content of the audio signal is generally maximal. This means that the masking threshold in said sub-band(s) is also high. This enables an auxiliary signal of large amplitude to be inserted in the audio signal. This simplifies detection of the auxiliary signal.

Thus, by means of the device shown in Fig. 3 record carriers 48 are obtained on which the audio signal including the auxiliary signal is recorded. The method of recording on the record carrier 48, as is effected in the recording unit 47, is not relevant to the present invention. It is possible, for example, to employ a recording method as known in RDAT or SDAT recorders. The operation of RDAT and SDAT recorders is known per se and is described comprehensively inter alia in the book "The art of digital audio" by J. Watkinson, Focal Press (London) 1988. Obviously, the recording unit 47 should be capable of converting the parallel data stream of the P sub-band signals into a signal stream which can be recorded by means of an RDAT or SDAT recorder.

Fig. 4 shows diagrammatically a device for reproducing the audio signal as recorded on the record carrier 48 by means of the device shown in Fig. 3. For this purpose the device comprises a read unit 41 which is constructed to read the data stream from the record carrier 48 and to supply the P sub-band signals via P outputs. These P sub-band signals are then applied to P inputs of a synthesis filter bak 27', having the same function as the filter bank 27 in Fig. 1. This means that the P sub-band signals are recombined to form a digital signal of a predetermined format of, for example, 16 bits. After D/A conversion in the D/A converter 42 the audio signal is then available again on the output terminal 43.

The audio signal, then still contains the auxiliary signal. However, this auxiliary signal is not audible because it is masked by the audio signal.

Fig. 5 shows a device for recording an audio signal, for example the audio signal reproduced by the device shown in Fig. 4. Such a device is intended for example for the consumer market. The device is capable of normally recording audio information not containing a copy inhibit code on a record carrier. However, the device comprises a detector unit to detect a copy inhibit code inserted in the audio signal to inhibit recording of this audio signal.

The device shown in Fig. 5 bears much resemblance to the device shown in Fig. 3, the difference being that the device shown in Fig. 5 is not capable of inserting a copy inhibit code into an audio signal. This means that the elements bearing the reference numerals 23, 25(1) to 25(P), 28(1) to 28(P) and 26(1) to 26(P) are dispensed with. The device shown in Fig. 5 further comprises subtractor circuits 34(1) to 34(P), amplifiers 35(1) to 35(P), a synthesis filter bank 36, and a detector unit 50. The section 10' of the device shown in Fig. 5, indicated by means of a solid line, is in fact identical to the decoder 10 in Fig. 1. This means that the section 10' is adapted to filter out the auxiliary signal which, if present in the digital audio signal applied to the input 51, then becomes available on the output 52. The detector unit 50, which has an input 53 coupled to the output 52, is constructed to detect said auxiliary signal and to generate the control signal which is then applied to the control signal input 55 of the recording unit 47' via the output 54.

The recording unit 47' is constructed in such a way that if a control signal appears on the control signal input 55 the recording unit 47' does not record the sub-band signals applied to its inputs or seriously distorts these sub-band signals before they are recorded. In the absence of a control signal on the control signal input 55 the recording unit 47' will record the sub-band signals applied to its inputs.

In this way an audio signal containing a copy-inhibit code in the form of the auxiliary signal inserted in the audio signal is prevented from being recorded on the record carrier 48' by the device.

In the device shown in Fig. 5 it is assumed that the auxiliary signal is accommodated in a number of sub-band signals. However, as already stated, the auxiliary signal may also be inserted in only one sub-band signal. In that case only one subtractor circuit 34 and one amplifier 35 are required and the filter bank 36 comprises only one input. In the synthesis filter bank 36 the auxiliary signal is converted into a digital signal of, for example, 16 bits.

The detector unit 50 may be a detector unit which can directly detect the presence or absence of a digital signal. Another possibility is the use of an analog detector unit 50. In that case the output signal of the filter bank is first converted into an analog signal. The detector unit 50 then comprises a narrow band band-pass filter, a rectifier and a threshold detector. If the input signal of the device is an analog signal an A/D converter is arranged between the terminal 51 and the input of the filter bank 22.

It is now assumed that the auxiliary signal is inserted in only one sub-band, for example the lower sub-band. In that case it may be adequate to use a simpler detection circuit in the form of a digital filter coupled to the output P = 1 of the analysis filter means 22. This filter may be for example a recursive filter having a sharp filter characteristic, the maximum in the filter characteristic coinciding with the frequency of the auxiliary signal. The output of the digital filter may then be coupled to the input 53 of the detector unit 50. In that case the elements 34(1) to 34(P), 35(1) to 35(P) and 36 may be dispensed with.

The embodiment shown in Fig. 6 bears much resemblance to that shown in Fig. 5. The output of the detector unit 50 is now coupled to an input of a signalling unit 56, for example in the form of a light-emitting diode. The auxiliary signal in the audio signal then does not function as a copy inhibit code but merely as a signalling code to signal that it is, in fact, not allowed to copy the relevant audio signal. In this case the decision whether the audio signal is subsequently copied depends on the user himself.

If the presence of the auxiliary signal in the audio signal to be recorded is detected the detector unit 50 generates a control signal upon which the signalling unit 56 (the diode) lights up. The user may now decide to discontinue recording.

From Fig. 6 it is evident that the inputs of the recording unit 57' are now coupled to the outputs of the analysis filter means 22, so that if the user should decide to continue recording, the audio signal, including the auxiliary signal, will be recorded.

Fig. 7 shows another embodiment of the device. The device shown in Fig. 6 is an extension of the device shown in Fig. 5. The controllable amplifiers 35(1) to 35(P) are not shown for simplicity. The device shown in Fig. 6 is in addition adapted to selectively insert a copy inhibit code to the signal to be recorded, assuming that the signal applied to the input 4 does not yet contain a copy inhibit code. In that case recording will be inhibited by means of the control signal applied to the control signal input 55 of the recording unit 47'.

The circuit bearing the reference numeral 7" is substantially identical to the circuit 7' in Fig. 3, the difference being that it comprises an additional control signal input 60 via which a control signal can be applied to switches S_1 to S_p arranged in the lines to the summing circuit 26(1) to 26(P).

If the signal u(k) applied to the input 4 does not contain a copy inhibit code the signal can be recorded on the record carrier 48'. If a control signal is applied to the switches S_1 to S_p via the input 60 the switches will be in the position shown. This means that the auxiliary signal V(k) is added to the signal to be recorded via the summing circuits 26(1) to 26(P), to inhibit further copying. If another control signal is applied to the input 60, the switches S_1 to S_p will be in the position not shown. This means that the value "0" is applied to all the summing circuits 26, so that merely the signal u(k), without auxiliary signal, is recorded on the record carrier 48'.

Again it is obvious that if the auxiliary signal is recorded in only one sub-band only one summing circuit 26(P) is provided and the control signal is applied to only one switch S_p via the terminal 60.

Fig. 8 shows an embodiment which bears much resemblance to the embodiment shown in Fig. 7. The embodiment shown in Fig. 8 excludes the possibility of making a choice whether the audio signal which does not contain a copy inhibit code will be provided with such an inhibit code. This means that if the detector unit 50 detects that the signal to be recorded does not contain an auxiliary signal, this auxiliary signal will be inserted automatically. Fig. 8 shows that interconnections are now arranged between the outputs of the amplifiers 25(1) to 25(P) and the (second) inputs of the signal combination units 26(1) to 26(P). The switches S_1 to S_p and the control signal input 60 in Fig. 7 are consequently dispensed with.

Such a device is very useful if it has been decided to allow copies to be made only of prerecorded record carriers (which are not provided with said auxiliary signal) and original recordings (which neither contain said auxiliary signal), copying of these copies, however, being inhibited. A prerecorded record carrier can now be copied normally. However, the resulting copy is provided with an auxiliary signal and cannot be copied again.

It is to be noted that all the embodiments have been described for devices for recording a digital audio signal on a magnetic record carrier. However, this should not be regarded as a limitation to magnetic record carriers only. The invention likewise relates to devices which record the audio signal on an optical record carrier. In the future this possibility will become available to the consumer. With the advent of the CD erasable and the CD write-once and magnetooptical recording technologies.

Claims

1. A coder for incorporating extra information in the form of an auxiliary signal v(k) in a digital audio signal u(k) having a predetermined format, characterised in that the coder (7) comprises means (22, 28) for analysing the digital signal, means (24) for quantizing the analysed digital signal in an unequivocal manner and means (28') for determining, on the basis of the acoustic properties of the human auditory system, the amount of extra information that can be added to the quantized digital signal without this extra information being audible with unmodified detection; means (26) for combining the extra information and the quantized digital signal to a compound signal.

2. A coder as claimed in Claim 1, characterized in that it comprises means (29) for reconverting the compound signal into a digital signal having the predetermined format.

3. A coder as claimed in Claim 1 or 2, characterised in that the means for analysing the digital signal comprise analysis filter means (22) for generating a number of P sub-band signals in response to the digital signal, which analysis filter means divide the frequency band of the digital signal into consecutive sub-bands having band numbers p ($1 \leq p \leq P$), whereas for each of the respective sub-bands (P) means (24(p)) are provided for quantizing the digital signal in an unequivocal manner and means (26) for combining the respective quantized sub-band signals and the auxiliary signal for constituting P compound sub-band signals.

4. A coder as claimed in Claim 3, where dependent on Claim 2, characterized in that synthesis filter means (27) are provided for constructing a replica of the compound signal in response to the compound sub-band signals, which synthesis filter means combine the sub-bands according to a filter method with sample frequency enhancement corresponding to the sub-division in the analysis filter means (22).

5. A coder as claimed in Claim 4, characterised in that the auxiliary signal v(k) is a digital audio signal and in that analysis filter means (23) are provided for generating a number of P sub-band signals in response to the auxiliary signal v(k), which analysis filter means divide the frequency band of the auxiliary signal into consecutive sub-bands having band numbers p ($1 \leq p \leq P$) according to a filter method with sample frequency reduction.

6. A coder as claimed in Claim 4 or 5, characterised in that the bandwidths of the sub-bands approximately correspond to the critical bandwidths of the human auditory system in the respective frequency ranges.

7. A coder as claimed in Claims 4, 5 or 6, characterised in that the means (24) for quantizing the digital signal in an unequivocal manner are arranged for adaptively quantizing this signal and in that for each sub-band the size of the quantization step depends on the amplitude of the digital signal sample, while there is an exponential relationship with a preset basic number $\underline{a}$ between the possible successive steps.

8. A coder as claimed in Claim 7, characterised in that the size of the quantization step of a sample to be quantized also depends on the size of at least a previous sample.

9. A coder as claimed in Claim 7 or 8, characterised in that means (25) are provided for attenuating each sub-band signal of the auxiliary signal by a

factor G, for which holds G = 2a/(a - 1).

10. A decoder to be used in combination with a coder (7) as claimed in Claims 5 to 9, characterised in that the decoder (10) comprises analysis filter means (31) for generating a number of compound sub-band signals in response to the compound signal, which analysis filter means divide the frequency band of the compound signal into consecutive sub-bands having band numbers p (1 ≦ p ≦ P) according to a filter method with sample frequency reduction, while the bandwidths of the sub-bands correspond with those of the analysis filter means (22) in the coder; means (33) for quantizing compound sub-band signals in an unequivocal manner; means (34) for subtracting the respective quantized sub-band signals from the corresponding sub-band signals of the compound signals for constituting sub-band difference signals, and synthesis filter means (36) for constructing a replica of the auxiliary signal v'(k) in response to the sub-band difference signals, which synthesis filter means combine the sub-bands according to a filter method with sample frequency enhancement corresponding to the sub-division in the analysis filter means.

11. A decoder as claimed in Claim 10, characterised in that the means (33) for quantizing the digital signal in an unequivocal manner are arranged for adaptively quantizing this signal and in that per sub-band the size of the quantization step depends on the amplitude of the sample of the digital signal, whilst between the possible successive steps there is an exponential relationship with a predetermined basic number a.

12. A decoder as claimed in Claim 9, characterised in that means (35) are provided for amplifying each sub-band difference signal by a factor G, which complies with G = 2a/(a - 1).

13. A device for recording a digital audio signal on a record carrier (48), comprising a coder (7) as claimed in any one of the claims 1 to 9.

14. A device for recording a digital audio signal on a record carrier (48'), comprising a coder for sub-band coding of the digital audio signal of given sample frequency 1/T, the coder comprising:

- analysis filter means (22) responsive to the audio signal to generate a plurality of P sub-band signals, which analysis filter means divide the frequency band of the audio signal in conformity with a filter method with sample frequency reduction into consecutive sub-bands having band numbers p(1 ≦ p ≦ P), which analysis filter means are further adapted to apply the P sub-band signals to P outputs, which outputs are coupled to P corresponding inputs of a
- recording unit (47') which is adapted to record the P sub-band signals on the record carrier,

characterized in that the device further comprises a detection unit (50) coupled to the analysis filter means (22), in that the detection unit is adapted to detect the presence of an auxiliary signal in one or more of the sub-band signals and to generate a control signal upon detection of the auxiliary signal and to apply the control signal to an output (54), in that said output is coupled to a control signal input (55) of the recording unit (47'), and in that the recording unit is adapted to inhibit recording of the audio signal in the presence of the control signal and to record the audio signal in the absence of the control signal.

15. A device for recording a digital audio signal on a record carrier (48'), comprising a coder for sub-band coding of the digital audio signal of given sample frequency 1/T, wherein the coder comprises:

- analysis filter means (22) responsive to the audio signal to generate a plurality of P sub-band signals, which analysis filter means divide the frequency band of the audio signal into consecutive sub-bands having band numbers p(1 ≦ p ≦ P) in accordance with a filter method using sample frequency reduction, which analysis filter means are further adapted to apply the P sub-band signals to P outputs, which outputs are coupled to P corresponding inputs of a
- recording unit (47') which is adapted to record the P sub-band signals on the record carrier,

characterized in that the device further comprises a detection unit (50) which is coupled to the analysis filter means (22), in that the detection unit is adapted to detect the presence of an auxiliary signal in one or more of the sub-band signals and to generate a control signal upon detection of the auxiliary signal and to apply the control signal to an output (54), in that said output is coupled to a signalling unit (56), and in that the signalling unit is constructed to signal that the audio signal to be recorded, when the control signal is present, is an audio signal containing an auxiliary signal.

16. A device as claimed in Claim 14 or 15, characterized in that the coder further comprises signal combination means (26, S1 to Sp) coupled to the analysis filter means, in that the signal combination means are adapted to selectively (via 60) add

the auxiliary signal, in the absence of the control signal, to one or more of the sub-band signals to form P composite sub-band signals and to apply said P composite sub-band signals to P outputs, which P outputs are coupled to the P corresponding inputs of the recording unit (47') (Fig 7).

17. A device as claimed in Claim 14 or 15, characterized in that the coder further comprises signal combination means (26) coupled to the analysis filter means (22), in that the signal combination means are adapted to add the auxiliary signal, in the absence of the control signal, to one or more of the sub-band signals to form P composite sub-band signals and to apply said P composite sub-band signals to P outputs, which P outputs are coupled to the P corresponding inputs of the recording unit (Fig 6).

18. A device as claimed in Claim 14, characterized in that the coder forms part of a coder as claimed in any one of the Claims 1 to 9.

19. A record carrier on which a digital audio signal has been recorded by means of a device as claimed in any one of the Claims 13, 16, 17 or 18, characterized in that the audio signal is divided into P sub-band signals and in that the audio signal is combined with an auxiliary signal in one or more of the sub-bands in order to obtain P composite sub-band signals recorded on the record carrier (48), and in that the auxiliary signal is selected in such a way that during reproduction of the composite audio signal recorded on the record carrier via a loudspeaker device said auxiliary signal is substantially imperceptable to a listener.

Patentansprüche

1. Kodierer zum Aufnehmen zusätzlicher 'nformation in Form eines Hilfssignals v(k) in ein digitales Audiosignal u(k) eines vorbestimmten Formats, dadurch gekennzeichnet, daß der Kodierer (7) mit Mitteln (22, 28) zum Analysieren des digitalen Signals, mit Mitteln (24) zum auf eindeutige Art und Weise Quantisieren des analysierten Signals, sowie mit Mitteln (28') zum auf Grund der akustischen Eigenschaften des menschlichen Ohres Bestimmen der Menge zusätzlicher Information, die dem quantisierten digitalen Signal zugefügt werden kann, ohne daß diese zusätzliche Information bei einer unmodifizierten Detektion hörbar ist, und mit Mitteln (26) zum Kombinieren der zusätzlichen Information und des quantisierten digitalen Signals zu einem zusammengesetzten Signal versehen ist.

2. Kodierer nach Anspruch 1,dadurch gekennzeichnet, daß dieser mit Mitteln (29) versehen ist, zum Umwandeln des zusammengesetzten Signals in ein digitales Signal des vorbestimmten Formats.

3. Kodierer nach Anspruch 1 oder 2, dadurch gekennzeichnet, daß die Mittel zum Analysieren des digitalen Signals Analysenfiltermittel (22) aufweisen zum in Antwort auf das digitale Signal Erzeugen von P Teilbandsignalen, wobei diese Analysenfiltermittel das Frequenzband des digitalen Signals nach einem Filterverfahren mit Abtastfrequenzwertverringerung in Aufeinanderfolgende Teilbänder mit Bandnummern p (1 ≦ p ≦ P), wobei für jedes der betreffenden Teilbänder (P) Mittel (24(p) vorgesehen sind zum auf eindeutige Weise Quantisieren des digitalen Signals und Mittel (26) zum Kombinieren der betreffenden quantisierten Teilbandsignale und der entsprechenden Teilbandsignale des Hilfssignals zum Bilden von P zusammengesetzten Teilbandsignalen.

4. Kodierer nach Anspruch 3 insofern abhängig von Anspruch 2, dadurch gekennzeichnet, daß der Kodierer weiterhin mit Synthesefiltermitteln (27) versehen ist zum in Antwort auf die zusammengesetzten Teilbandsignale Bilden einer Replik des zusammengesetzten Signals, wobei die Synthesefiltermittel die Teilbänder nach einem der Aufteilung in den Analysenfiltermitteln entsprechenden Filterverfahren mit Abtastfrequenzwerterhöhung zusammenfügen.

5. Kodierer nach Anspruch 4, dadurch gekennzeichnet, daß das Hilfssignal v(k) ein digitales Audiosignal ist und daß Analysenfiltermittel (23) vorgesehen sind zum in Antwort auf das Hilfssignal Erzeugen einer Anzahl von P Teilbandsignalen, wobei die Analysenfiltermittel das Frequenzband des Hilfssignals v(k) nach einem Filterverfahren mit Abtastfrequenzwertverringerung in aufeinanderfolgende Teilbänder mit bandnummern p (1 ≦ p ≦ P) aufteilen.

6. Kodierer nach Anspruch 4 oder 5, dadurch gekennzeichnet, daß die Bandbreiten der Teilbänder den kritischen Bandbreiten des menschlichen Ohres in den betreffenden Frequenzbereichen annähernd entsprechen.

7. Kodierer nach Anspruch 4, 5 oder 6, dadurch gekennzeichnet, daß die Mittel (24) zum auf eindeutige Weise Quantisieren des digitalen Signals zum adaptiven Quantisieren dieses Signals eingerichtet sind und je Teilband die Größe des Quantisierungsschrittes von der Amplitude eines Abtastwertes des digitalen Signals abhängig ist,

wobei es zwischen den möglichen aufeinanderfolgenden Schritten einen exponentiellen Zusammenhang mil einer orbestimmten Grundzahl a gibt.

8. Kodierer nach Anspruch 7, dadurch gekennzeichnet, daß die Größe des Quantisierungsschrittes eines zu quantisierenden Abtastwertes zugleich von der Größe mindestens eines vorhergehenden Abtastwertes abhängig st.

9. Kodierer nach Anspruch 7 oder 8, dadurch gekennzeichnet, daß Mittel (25) vorgesehen sind um jedes Teilbandsignal des Hilfssignals um einen Faktor G zu dämpfen, wobei gilt: $G = 2a / (a - 1)$.

10. Dekoder zum Gebrauch zusammen mit einem Kodierer (7) nach den Ansprüchen 5 b/e 9, dadurch gekennzeichnet, daß der Dekoder (10) mil Analysenfiltermitteln (31) versehen ist zum in Antwort auf das zusammengesetzte Signal Erzeugen einer Anzahl zusammengesetzter Teilbandsignale, wobei die Analysenfiltermittel das Frequenzband des zusammengesetzten Signals nach einem Filterverfahren mit Abtastfrequenzwertverringerung in aufeinanderfolgende Teilbänder mit Bandnummern p ($1 \leqq p \leqq P$) aufteilen, wobei die Bandbreiten der Teilbänder denen der Analysenfiltermittel (22) in dem Kodierer entsprechen, mit Mitteln (33) zum auf eindeutige Weise Quantisieren der zusammengesetzten Teilbandsignale, mit Mitteln (34) zum Subtrahieren der betreffenden quantisierten Teilbandsignale von den entsprechenden Teilbandsignalen des zusammengesetzten Signals zum Bilden von Teilbanddifferenzsignalen und mit Synthesefiltermitteln (36) zum in Antwort auf die Teilbanddifferenzsignale Bilden einer Replik des Hilfssignals v'(k), wobei die Synthesemittel die Teilbänder nach einem der Aufteilung in den Analysenfiltermitteln entsprechenden Filterverfahren mit Abtastfrequenzwerterhöhung zusammenfügen.

11. Dekoder nach Anspruch 10, dadurch gekennzeichnet, daß die Mittel (33) zum auf eindeutige Weise Quantisieren des digitalen Signals zum adaptiven Quantisieren dieses Signals eingerichtet sind und je Teilband die Größe das Quantisierungsschrittes von der Amplitude eines Abtastwertes des digitalen Signals abhängig ist, wobei es zwischen den möglichen aufeinanderfolgenden Schritten einen exponentiellen Zusammenhang mit einer vorbestimmten Grundzahl a gibt.

12. Dekoder nach Anspruch 11, dadurch gekennzeichnet, daß Mittel (35) vorgesehen sind um jedes Teilbanddifferenzsignal um einen Faktor G zu verstarken, wobei gilt: $G = 2a / (a - 1)$.

13. Anordnung zum Aufzeichnen eines digitalen Audiosignals auf einem Aufzeichnungsträger (48) mit einem Kodierer (7) nach einem der Ansprüche 1 b/e 9.

14. Anordnung zum Aufzeichnen eines digitalen Audiosignals auf einem Aufzeichnungsträger (48) mit einem Kodierer zur Teilbandkodierung des digitalen Audiosignals einer bestimmten Abtastfrequenzwert 1/T, wobei der Kodierer mit den folgenden Elementen versehen ist:
   - Analysenfiltermitteln (22) zum in Antwort auf das Audiosignal Erzeugen einer Anzahl von P Teilbandsignalen, wobei diese Analysenfiltermittel das Frequenzband des Audiosignals nach einem Filterverfahren mit Abtastfrequenzwertverringerung in aufeinanderfolgende Teilbänder mit Bandnummern p ($1 \leqq p \leqq P$) aufteilen, wobei diese Analysenfiltermittel weiterhin dazu eingerichtet sind, P Ausgängen die P Teilbandsignale zuzuführen, wobei diese Ausgänge gekoppelt sind mit P entsprechenden Eingängen,
   - einer Aufzeichnungseinheit (47'), die zum Aufzeichnen der P Teilbandsignale auf dem Aufzeichnungsträger eingerichtet ist,

   dadurch gekennzeichnet, daß die Anordnung weiterhin eine mit den Analysenfiltermitteln (22) gekoppelte Detektionseinheit (50) aufweist, daß die Detektionseinheit zum Detektieren des Vorhandenseins eines Hilfssignals in einem oder mehreren der Teilbandsignale sowie zum Erzeugen eines Steuersignals bei Detektion des Hilfssignals und zum Zuführen dieses Steuersignals zu einem Ausgang (54) eingerichtet ist, daß dieser Ausgang mit einem Steuersignaleingang (55) der Aufzeichnungseinheit (47') gekoppelt ist und daß die Aufzeichnungseinheit zum Sperren der Aufnahme des Audiosignals beim Vorhandensein des Steuersignals und zum Aufzeichnen des Audiosignals beim Fehlen des Steuersignals eingerichtet ist.

15. Anordnung zum Aufzeichnen eines digitalen Audiosignals auf einem Aufzeichnungsträger (48') mit einem Kodierer zur Teilbandkodierung des digitalen Audiosignals mit der bestimmten Abtastfrequenz 1/T, wobei der Kodierer mit den folgenden Elementen versehen ist:
   - Analysenfiltermitteln (22) zum in Antwort auf das Audiosignal Erzeugen einer Anzahl von P Teilbandsignalen, wobei diese Analysenfiltermittel das Frequenzband des Audiosignals nach einem Filterverfahren mit Abtastfrequenzwertverringerung in aufein-

anderfolgende Teilbänder mit Bandnummern p (1 ≦ p ≦ P) aufteilen, wobei diese Analysenfiltermittel weiterhin dazu eingerichtet sind, P Ausgängen die P Teilbandsignale zuzuführen, wobei diese Ausgänge gekoppelt sind mit P entsprechenden Eingängen,

- einer Aufzeichnungseinheit (47'), die zum Aufzeichnen der P Teilbandsignale auf dem Aufzeichnungsträger eingerichtet ist,

dadurch gekennzeichnet, daß die Anordnung weiterhin eine mit den Analysenfiltermitteln (22) gekoppelte Detektionseinheit (50) aufweist, daß die Detektionseinheit zum Detektieren des Vorhandenseins eines Hilfssignals in einem oder mehreren der Teilbandsignale sowie zum Erzeugen eines Steuersignals bei Detektion des Hilfssignals und zum Zuführen dieses Steuersignals zu einem Ausgang (54) eingerichtet ist, daß dieser Ausgang mit einer Anzeigeeinheit (56) gekoppelt ist, die dazu eingerichtet ist, beim Vorhandensein des Steuersignals anzuzeigen, daß das aufzuzeichnende Audiosignal ein mit einem Hilfssignal versehenes Audiosignal ist.

16. Anordnung nach Anspruch 14 oder 15, dadurch gekennzeichnet, daß der Kodierer weiterhin mit Signalkombiniermitteln (26, S1 bis Sp) versehen ist, die mit den Analysenfiltermitteln gekoppelt sind, daß die Signalkombiniermittel dazu eingerichtet sind, beim Fehlen des Steuersignals das Hilfssignal nach Wunsch (über 60) einem oder mehreren der Teilbandsignale hinzuzufügen zur Bildung von P zusammengesetzten Teilbandsignalen und zum Zuführen dieser P zusammengesetzten Teilbandsignale zu P Ausgängen, die mit den P entsprechenden Eingängen der Aufzeichnungseinheit (47') gekoppelt sind (Fig. 7).

17. Anordnung nach Anspruch 14 oder 15, dadurch gekennzeichnet, daß der Kodierer weiterhin mit Signalkombiniermitteln (26) versehen ist, die mit den Analysenfiltermitteln (22) gekoppelt sind, daß die Signalkombiniermittel dazu eingerichtet sind, beim Fehlen des Steuersignals das Hilfssignal einem oder mehreren der Teilbandsignale hinzuzufügen zur Bildung von P zusammengesetzten Teilbandsignalen und zum Zuführen dieser P zusammengesetzten Teilbandsignale zu P Ausgängen, die mit den P entsprechenden Eingängen der Aufzeichnungseinheit gekoppelt sind (Fig.8).

18. Anordnung nach Anspruch 14, dadurch gekennzeichnet, daß der Kodierer einen Teil des Kodierers nach einem der Ansprüche 1 b/e 9 bildet.

19. Aufzeichnungsträger, auf dem mittels der Anordnung nach einem der Ansprüche 13, 16, 17 oder 18 ein digitales Audiosignal aufgezeichnet ist, dadurch gekennzeichnet, daß das Audiosignal in P Teilbandsignale aufgeteilt ist und daß zum Erhalten von P zusammengesetzten Teilbandsignalen, die auf dem Aufzeichnungsträger (48) aufgezeichnet sind, dem Audiosignal in einem oder mehreren der Teilbänder ein Hilfssignal zugefügt worden ist und daß das Hilfssignal derart gewählt worden ist, daß dieses Hilfssignal bei Wiedergabe des auf dem Aufzeichnungsträger aufgezeichneten zusammengesetzten Audiosignals über die Lautsprecheranordnung für einen Zuhörer im wesentlichen nicht wahrnehmbar ist.

Revendications

1. Codeur pour incorporer des informations supplémentaires sous la forme d'un signal auxiliaire v(k) dans un signal audionumérique u(k) ayant un format prédéterminé, caractérisé en ce que le codeur (7) comprend des moyens (22, 28) pour analyser le signal numérique, des moyens (24) pour quantifier le signal numérique analysé de manière non équivoque et des moyens (28') pour déterminer, sur la base des propriétés acoustiques du système auditif humain, la quantité d'informations supplémentaires que l'on peut ajouter au signal numérique quantifié sans que ces informations numériques supplémentaires soient audibles avec une détection non modifiée, des moyens (26) étant prévus pour combiner les informations supplémentaires et le signal numérique quantifié en un signal composite.

2. Codeur selon la revendication 1, caractérisé en ce qu'il comprend des moyens (29) pour reconvertir le signal composite en un signal numérique ayant le format prédéterminé.

3. Codeur selon la revendication 1 ou 2, caractérisé en ce que les moyens d'analyse du signal numérique comprennent des moyens de filtrage analytique (22) pour générer un nombre de P signaux de sous-bandes en réaction au signal numérique, ces moyens de filtrage analytique divisant la bande de fréquences du signal numérique en des sous-bandes consécutives ayant des nombres de bandes p (1 ≦ p ≦ P), tandis que, pour chacune des sous-bandes respectives (p), des moyens (24(p)) sont prévus pour quantifier le signal numérique de manière non équivoque et des moyens (26) sont prévus pour combiner les signaux de sous-bandes quantifiés respectifs et le signal auxiliaire pour constituer P signaux de sous-bandes composites.

4. Codeur selon la revendication 3, découlant de la revendication 2, caractérisé en ce que des moyens de filtrage synthétique (27) sont prévus pour construire une réplique du signal composite en réaciton aux signaux de sous-bandes composites, ces moyens de filtrage synthétique combinant les sous-bandes selon un procédé de filtrage avec augmentation de la fréquence d'échantillonnage correspondant à la subdivision dans les moyens de filtrage analytique (22).

5. Codeur selon la revendication 4, caractérisé en ce que le signal auxiliaire v(k) est un signal audionumérique et des moyens de filtrage analytique (23) sont prévus pour générer un nombre P de signaux de sous-bandes en réaction au signal auxiliaire v(k), ces moyens de filtrage analytique divisant la bande de fréquence du signal auxiliaire en des sous-bandes consécutives ayant des nombres de bandes p ($1 \leqq p \leqq P$) selon un procédé de filtrage avec réduction de la fréquence d'échantillonnage.

6. Codeur selon la revendication 4 ou 5, caractérisé en ce que les largeurs des sous-bandes correspondent approximativement aux largeurs de bande critiques du système auditif humain dans les plages de fréquences respectives.

7. Codeur selon la revendication 4, 5 ou 6, caractérisé en ce que les moyens (24) pour quantifier le signal numérique de manière non équivoque sont conçus pour quantifier ce signal de manière adaptative et que, pour chaque sous-bande, la grandeur du pas de quantification dépend de l'amplitude de l'échantillon de signal numérique, une relation exponentielle avec un nombre de base préréglé $\underline{a}$ existant entre les pas successifs possibles.

8. Codeur selon la revendication 7, caractérisé en ce que la grandeur du pas de quantification d'un échantillon à quantifier dépend également de la grandeur d'au moins un échantillon précédent.

9. Codeur selon la revendication 7 ou 8, caractérisé en ce que les moyens (25) sont prévus pour atténuer chaque signal de sous-bande du signal auxiliaire d'un facteur G, qui répond à la relation $G = 2a/(a - 1)$.

10. Décodeur à utiliser en combinaison avec un codeur (7) selon les revendications 5 à 9, caractérisé en ce que le décodeur (10) comprend des moyens de filtrage analytique (31) pour générer un certain nombre de signaux de sous-bandes composites en réaction au signal composite, ces moyens de filtrage analytique subdivisant la bande de fréquences du signal composite en des sous-bandes consécutives ayant des nombres de bandes p ($1 \leqq p \leqq P$) selon un procédé de filtrage avec réduction de la fréquence d'échantillonnage, tandis que les largeurs des sous-bandes correspondent à celles des moyens de filtrage analytique (22) dans le codeur, des moyens (33) pour quantifier de manière non équivoque les signaux de sous-bandes composites, des moyens (34) pour soustraire les signaux de sous-bandes quantifiés respectifs des signaux de sous-bandes correspondants des signaux composites pour former des signaux de différences de sous-bandes, et des moyens de filtrage synthétique (36) pour construire une réplique du signal auxiliaire v'(k) en réaction aux signaux de différence de sous-bandes, lesdits moyens de filtrage synthétique combinant les sous-bandes selon un procédé de filtrage avec augmentation de la fréquence d'échantillonnage correspondant à la subdivision dans les moyens de filtrage analytique.

11. Décodeur selon la revendication 10, caractérisé en ce que les moyens (33) pour quantifier le signal numérique de manière non équivoque sont agencés pour quantifier de manière adaptative ce signal et que, par sous-bande, la grandeur du pas de quantification dépend de l'amplitude de l'échantillon du signal numérique, tandis qu'entre les pas successifs possibles, il y a une relation exponentielle avec un nombre de base prédéterminé $\underline{a}$.

12. Décodeur selon la revendication 9, caractérisé en ce que des moyens (35) sont prévus pour amplifier chaque signal de différence de sous-bande d'un facteur G qui répond à la formule $G = 2a/(a - 1)$.

13. Dispositif pour enregistrer un signal audionumérique sur un support d'enregistrement (48), comprenant un codeur (7) selon l'une quelconque des revendications 1 à 9.

14. Dispositif d'enregistrement d'un signal audionumérique sur un support d'enregistrement (48), comprenant un codeur pour le codage de sous-bandes du signal audionumérique de fréquence d'échantillon donnée 1/T, ce codeur comprenant :

- des moyens de filtrage analytique (22) réagissant au signal audio pour générer une pluralité de P signaux de sous-bandes, ces moyens de filtrage analytique divisant la bande de fréquences du signal audio selon un procédé de filtrage avec réduction de la fréquence d'échantillonnage en des sous-bandes consécutives ayant des nombres de bandes p ($1 \leq p \leq P$), ces moyens de filtrage analytique étant, en outre, à même d'appliquer les P signaux de sous-bandes à P sorties, lesdites sorties étant couplées à P entrées correspondantes

- d'une unité d'enregistrement (47') qui est conçue pour enregistrer les P signaux de sous-bandes sur le support d'enregistrement,

caractérisé en ce que le dispositif comprend, en outre, une unité de détection (50) reliée aux moyens de filtrage analytique (22), que l'unité de détection est à même de détecter la présence d'un signal auxiliaire dans un ou plusieurs signaux de sous-bandes, de générer un signal de commande lors de la détection du signal auxiliaire et d'appliquer le signal de commande à une sortie (54), que ladite sortie est reliée à une entrée de signal de commande (55) de l'unité d'enregistrement (47') et que l'unité d'enregistrement est à même d'empêcher l'enregistrement du signal audio en présence du signal de commande et d'enregistrer le signal audio en l'absence du signal de commande.

15. Dispositif d'enregistrement d'un signal audionumérique sur un support d'enregistrement (48'), comprenant un codeur pour le codage en sous-bandes du signal audionumérique de fréquence d'échantillonnage donnée 1/T, dans lequel le codeur comprend :

- des moyens de filtrage analytique (22) réagissant au signal audio pour générer un pluralité de P signaux de sous-bandes, ces moyens de filtrage analytique divisant la bande de fréquence du signal audio en des sous-bandes consécutives ayant des nombres de bandes p ($1 \leq p \leq P$) selon un procédé de filtrage avec réduction de la fréquence d'échantillonnage, lesdits moyens de filtrage analytique étant, en outre, à même d'appliquer les P signaux de sous-bandes à P sorties, lesquelles sont couplées à P entrées correspondantes
- d'une unité d'enregistrement (47') qui est conçue pour enregistrer les P signaux de sous-bandes sur le support d'enregistrement,

caractérisé en ce que le dispositif comprend, en outre, une unité de détection (50) reliée aux moyens de filtrage analytique (22), que l'unité de détection est à même de détecter la présence d'un signal auxiliaire dans un ou plusieurs des signaux de sous-bandes, de générer un signal de commande par détection du signal auxiliaire et d'appliquer le signal de commande à une sortie (54), que ladite sortie est reliée à une unité de signalisation (56) et que l'unité de signalisation est conçue pour signaler que le signal audio à enregistrer, lorsqu'un signal de commande est présent, est un signal audio contenant un signal auxiliaire.

16. Dispositif selon la revendication 14 ou 15, caractérisé en ce que le codeur comprend, en outre, des moyens de combinaison de signaux (26 S_1 à S_p) reliés aux moyens de filtrage analytique, les moyens de combinaison de signaux sont à même d'ajouter sélectivement (via 60) le signal auxiliaire, en l'absence de signal de commande, à un ou plusieurs des signaux de sous-bandes pour former P signaux de sous-bandes composites et d'appliquer lesdits P signaux de sous-bandes composites à P sorties, lesquelles sont couplées aux P entrées correspondantes de l'unité d'enregistrement (47')(Fig. 7).

17. Dispositif selon la revendication 14 ou 15, caractérisé en ce que le codeur comprend, en outre, des moyens de combinaison de signaux (26) reliés aux moyens de filtrage analytique (22), que les moyens de combinaison de signaux sont à même d'ajouter le signal auxiliaire, en l'absence du signal de commande, à un ou plusieurs des signaux de sous-bandes pour former P signaux de sous-bandes composites et d'appliquer lesdits P signaux de sous-bandes composites à P sorties, lesquelles sont couplées aux P entrées correspondantes de l'unité d'enregistrement (Fig. 8).

18. Dispositif selon la revendication 14, caractérisé en ce que le codeur fait partie d'un codeur selon l'une quelconque des revendications 1 à 9.

19. Support d'enregistrement sur lequel un signal audionumérique a été enregistré à l'aide d'un dispositif selon l'une quelconque des revendications 13, 16, 17 ou 18, caractérisé en ce que le signal audio est divisé en P signaux de sous-bandes et que le signal audio est combiné avec un signal auxiliaire dans une ou plusieurs de sous-bandes de manière à obtenir P signaux de sous-bandes composites enregistrés sur le support d'enregistrement (48) et que le signal auxiliaire est sélectionné de telle manière qu'au cours de la reproduction du signal audio composite enregistré sur le support d'enregistrement via un dispositif à haut-parleur, ledit signal auxiliaire soit sensiblement imperceptible à un auditeur.

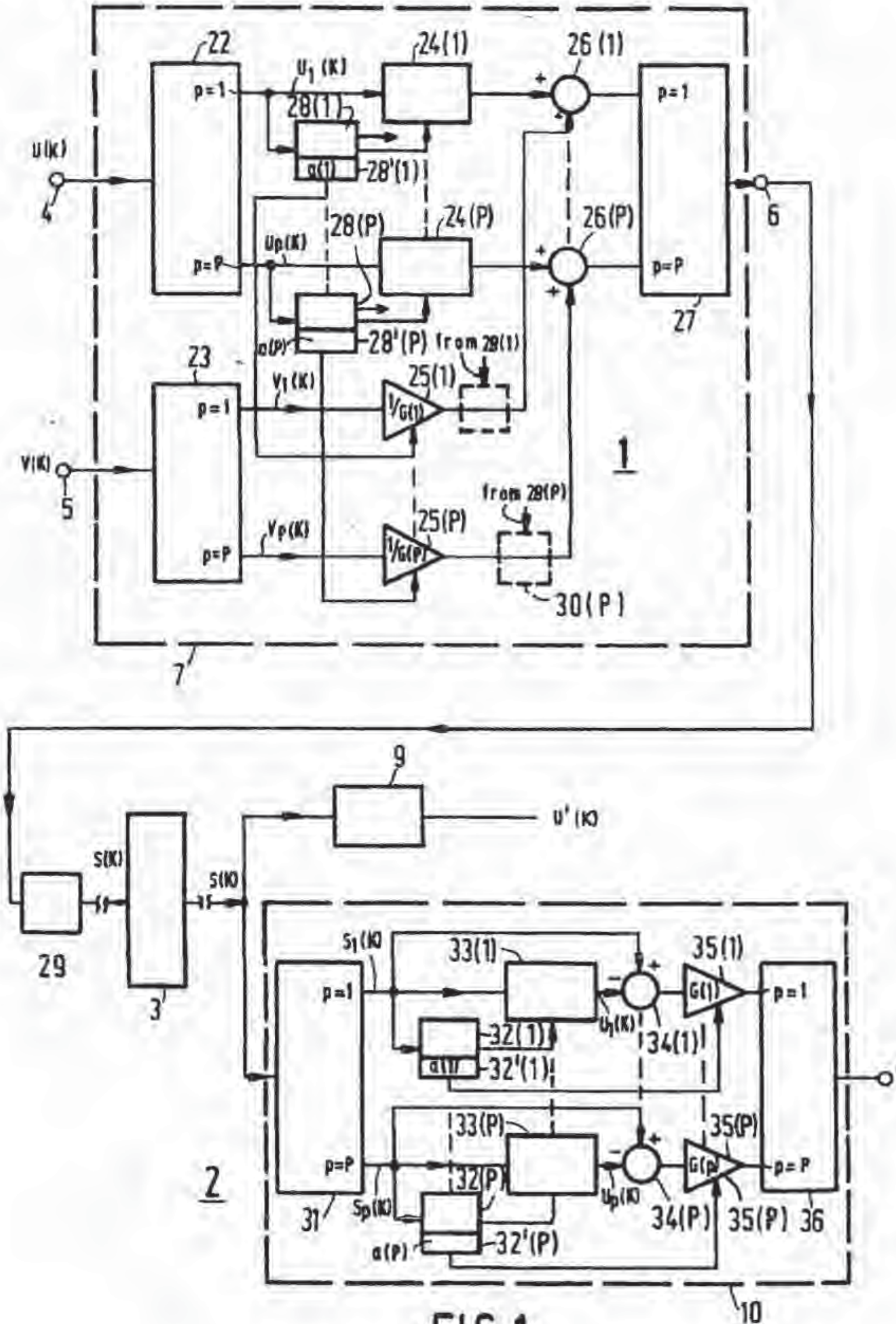
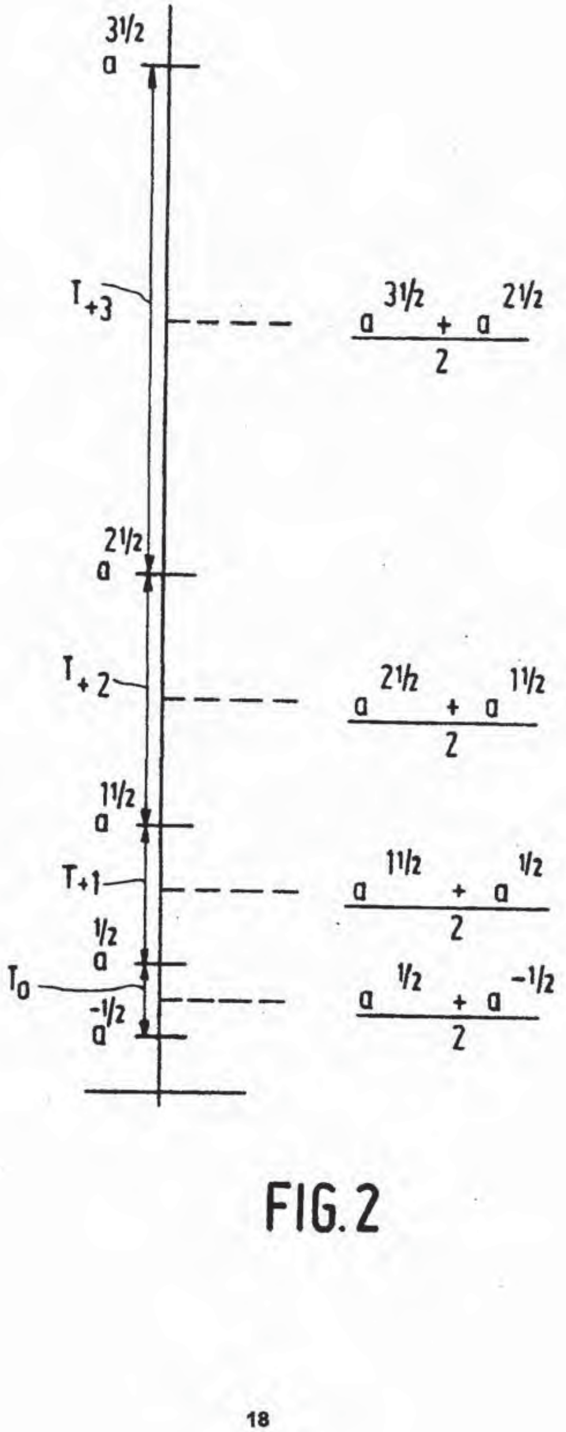

22
U(K)
4
p=1
p=P
U1(K)
24(1)
26(1)
28(1)
28'(1)
a(1)
Up(K)
28(P)
24(P)
26(P)
28'(P)
a(P)
p=1
p=P
6
27
23
V1(K)
25(1)
1/G(1)
from 28(1)
V(K)
5
p=1
p=P
Vp(K)
1/G(P)
25(P)
from 28(P)
30(P)
1
7
9
U'(K)
S(K)
S(K)
29
3
S1(K)
33(1)
35(1)
p=1
32(1)
a(1)
32'(1)
U1(K)
34(1)
G(1)
V'(K)
33(P)
35(P)
p=P
Sp(K)
32(P)
Up(K)
G(P)
34(P)
35(P)
36
2
31
a(P)
32'(P)
10

FIG.1



$a^{3\frac{1}{2}}$
T_{+3}
$\frac{a^{3\frac{1}{2}} + a^{2\frac{1}{2}}}{2}$
$a^{2\frac{1}{2}}$
T_{+2}
$\frac{a^{2\frac{1}{2}} + a^{1\frac{1}{2}}}{2}$
$a^{1\frac{1}{2}}$
T_{+1}
$\frac{a^{1\frac{1}{2}} + a^{\frac{1}{2}}}{2}$
$a^{\frac{1}{2}}$
T_0
$\frac{a^{\frac{1}{2}} + a^{-\frac{1}{2}}}{2}$
$a^{-\frac{1}{2}}$

FIG. 2

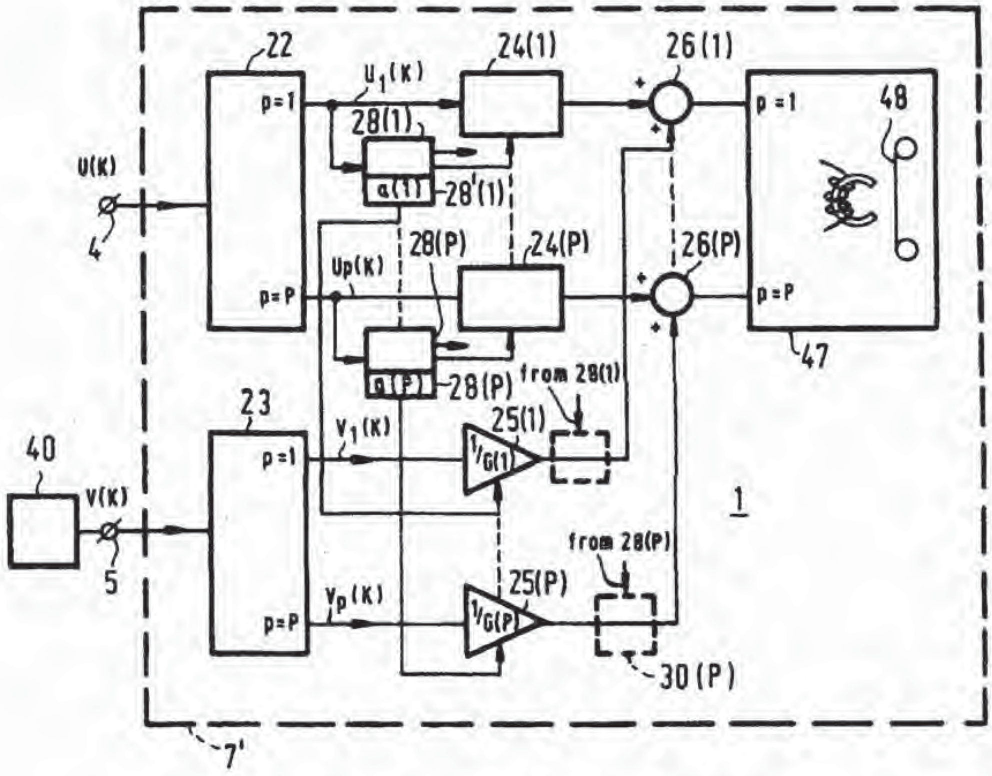

22
U1(K)
24(1)
26(1)
p=1
28(1)
48
U(K)
a(1)
28'(1)
4
28(P)
24(P)
26(P)
Up(K)
p=P
p=P
a(P)
28'(P)
47
from 28(1)
23
V1(K)
25(1)
40
p=1
1/G(1)
V(K)
1
5
from 28(P)
25(P)
Vp(K)
p=P
1/G(P)
30(P)
7'

FIG.3

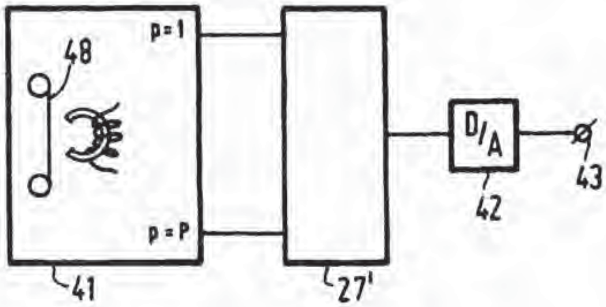

p=1
48
D/A
43
42
p=P
41
27'

FIG.4

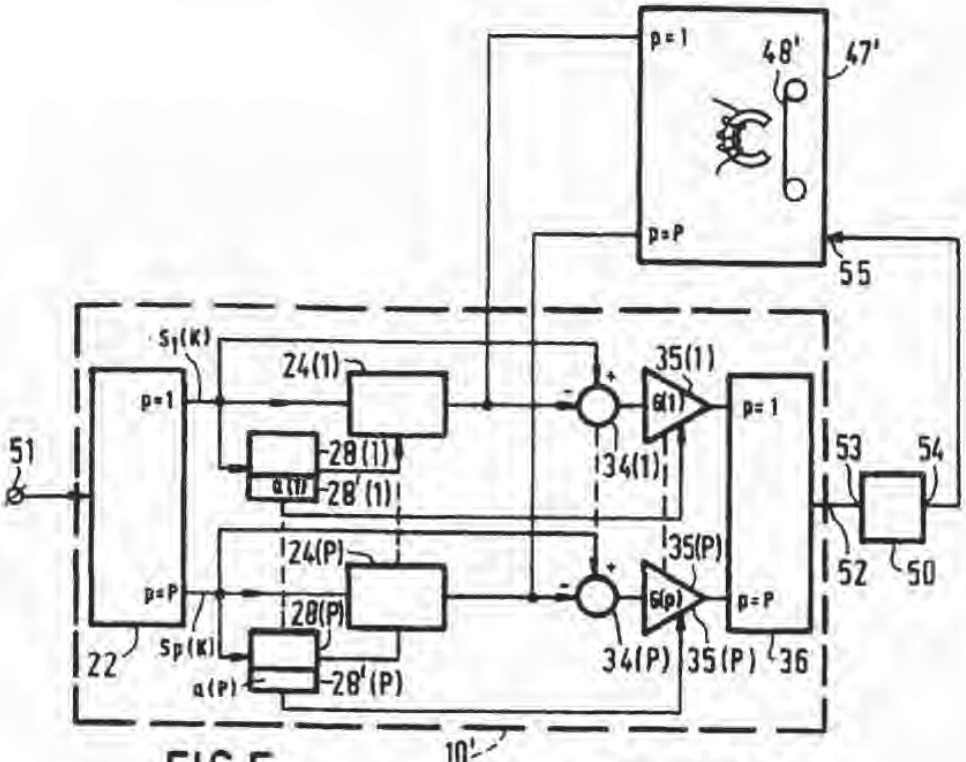

p=1
48'
47'
p=P
55
S1(K)
24(1)
35(1)
p=1
G(1)
p=1
51
28(1)
34(1)
53
54
q(1)
28'(1)
24(P)
35(P)
52
50
p=P
G(p)
p=P
28(P)
Sp(K)
22
34(P)
35(P)
36
q(P)
28'(P)
10'

FIG.5

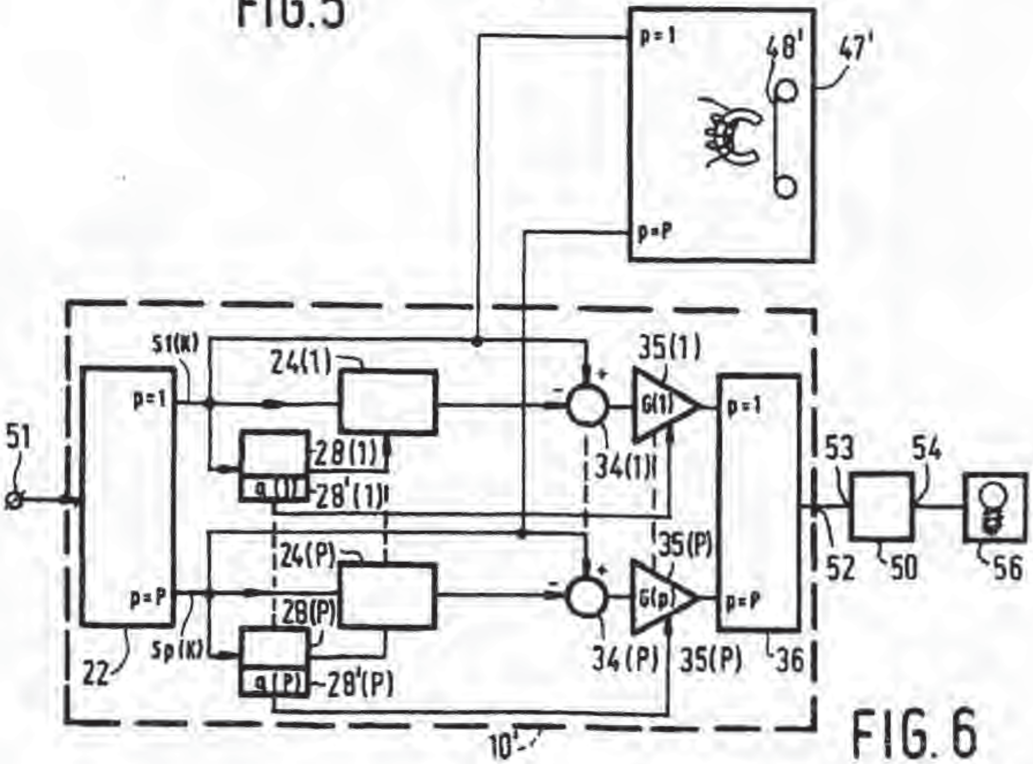

p=1
48'
47'
p=P
S1(K)
35(1)
24(1)
p=1
G(1)
p=1
51
28(1)
34(1)
53
54
q(1)
28'(1)
35(P)
24(P)
52
50
56
p=P
G(p)
p=P
28(P)
Sp(K)
22
34(P)
35(P)
36
q(P)
28'(P)
10'

FIG. 6

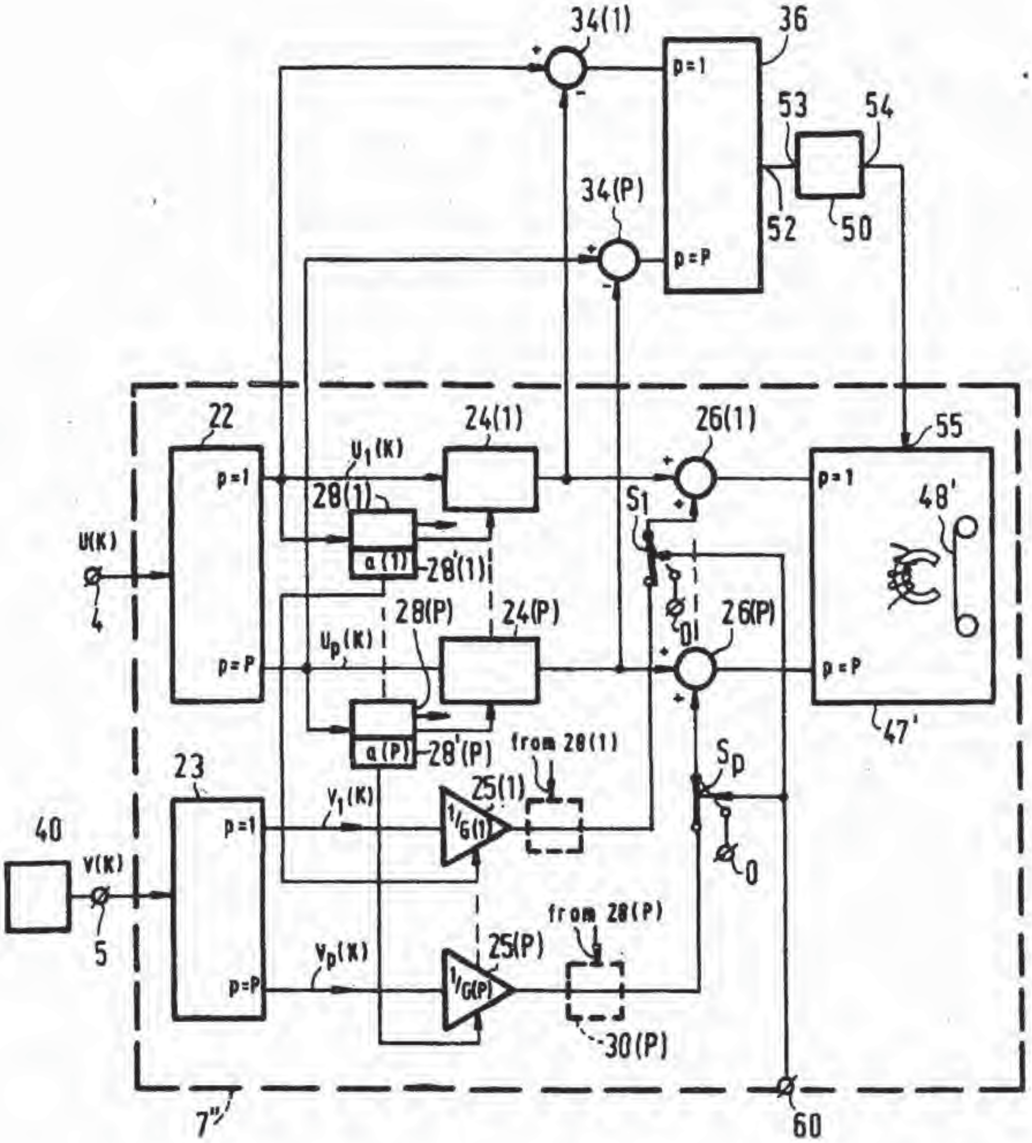

34(1)
36
p=1
53
54
52
50
34(P)
p=P
22
24(1)
26(1)
55
U1(K)
28(1)
p=1
48'
S1
U(K)
a(1)
28'(1)
4
Up(K)
28(P)
24(P)
26(P)
p=P
p=P
47'
a(P)
28'(P)
from 28(1)
23
V1(K)
25(1)
Sp
40
p=1
1/G(1)
V(K)
0
5
from 28(P)
Vp(K)
25(P)
p=P
1/G(P)
30(P)
7''
60

FIG.7

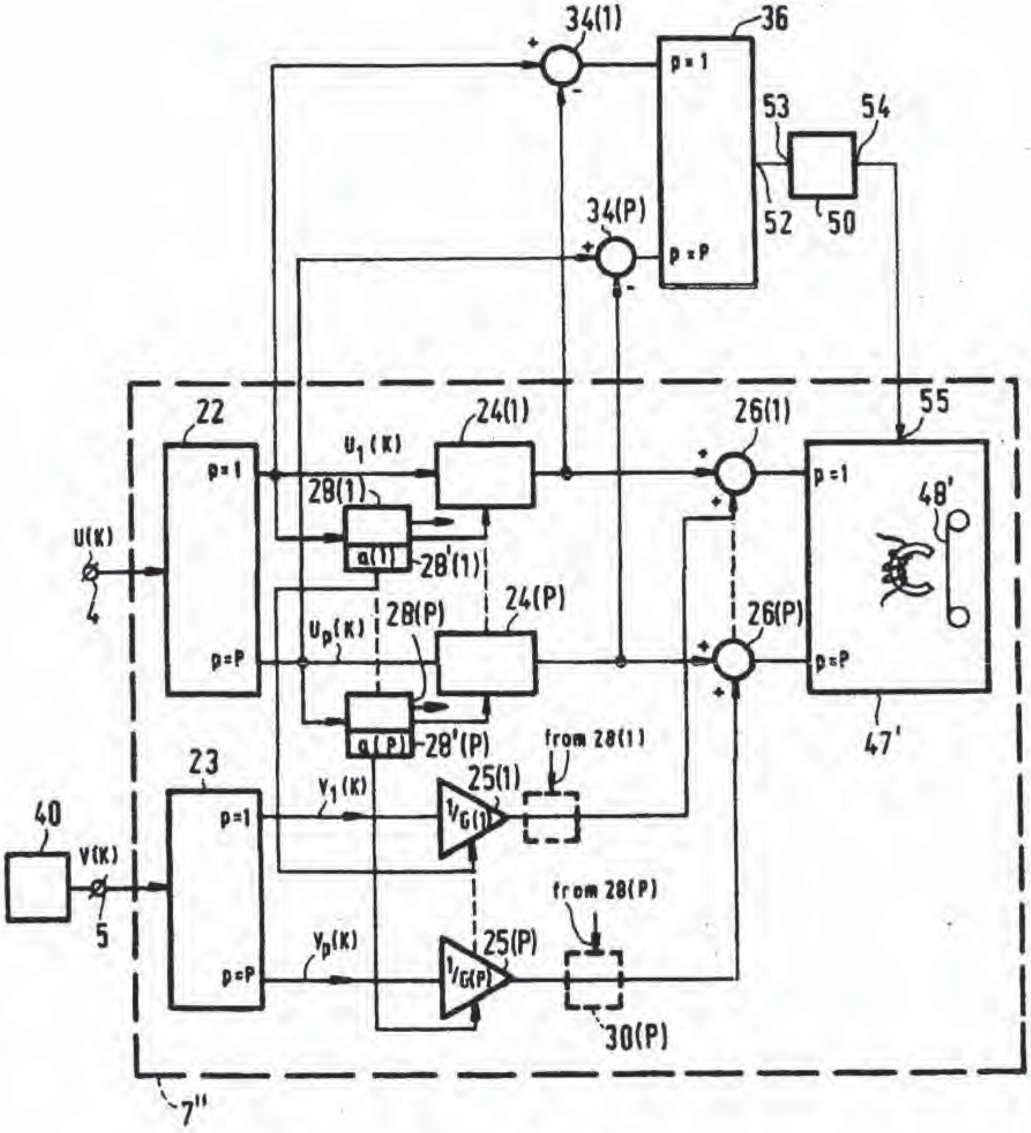

34(1)
36
p=1
53
54
52
50
34(P)
p=P
22
24(1)
26(1)
55
U1(K)
p=1
28(1)
48'
U(K)
4
a(1)
28'(1)
Up(K)
28(P)
24(P)
26(P)
p=P
p=1
p=P
a(P)
28'(P)
from 28(1)
47'
23
V1(K)
25(1)
1/G(1)
40
V(K)
5
p=1
from 28(P)
Vp(K)
25(P)
1/G(P)
p=P
30(P)
7''

FIG.8

PCT

WORLD INTELLECTUAL PROPERTY ORGANIZATION
International Bureau

INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification ^{6} : G06K 19/08, 19/10, H04L 9/00	A1	(11) International Publication Number: WO 98/37513 (43) International Publication Date: 27 August 1998 (27.08.98)

(21) International Application Number: PCT/AU98/00106

(22) International Filing Date: 20 February 1998 (20.02.98)

(30) Priority Data:
PO 5218 20 February 1997 (20.02.97) AU

(71) Applicant *(for all designated States except US)*: TELSTRA R & D MANAGEMENT PTY. LTD. [AU/AU]; 242 Exhibition Street, Melbourne, VIC (AU).

(72) Inventors; and
(75) Inventors/Applicants *(for US only)*: JOHNSON, Andrew [AU/AU]; 21 Sunbury Crescent, Surrey Hills, VIC 3127 (AU). BIGGAR, Michael [AU/AU]; 24 Kalbar Road, Research, VIC 3095 (AU).

(74) Agents: LESLIE, Keith et al.; Davies Collison Cave, 1 Little Collins Street, Melbourne, VIC 3000 (AU).

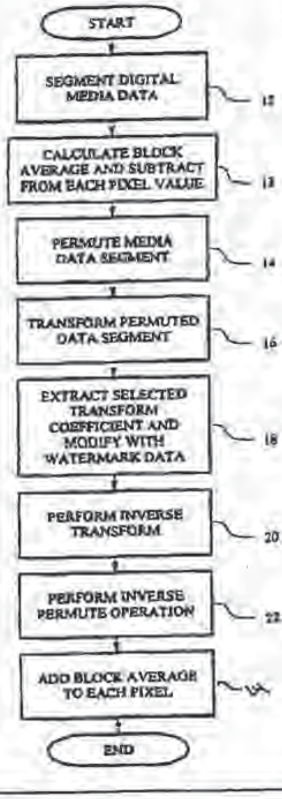
(81) Designated States: AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, DE, DK, EE, ES, FI, GB, GE, GH, GM, GW, HU, ID, IL, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, UA, UG, US, UZ, VN, YU, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, ML, MR, NE, SN, TD, TG).

Published
With international search report.

(54) Title: INVISIBLE DIGITAL WATERMARKS

(57) Abstract

A method and system of insertion and extraction of identification or authentication (watermark) data in digital media data such as video. The video data is divided into blocks and a pseudo–random function, such as a permutation, is applied thereto. The permuted data block is then transformed using an orthogonal transform such as a Walsh Hadamard Transform or a Discrete Cosine Transform. One or more of the ac coefficients generated by the transform are selected and the watermark data is inserted or extracted therefrom. An inverse permutation and inverse transform can then be used to return the video to the unencoded spatial domain. The inserted watermark data is substantially invisible in the reconstructed video since it is spread over the pixels in the block by virtue of the permute and transform.


START
SEGMENT DIGITAL MEDIA DATA
12
CALCULATE BLOCK AVERAGE AND SUBTRACT FROM EACH PIXEL VALUE
13
PERMUTE MEDIA DATA SEGMENT
14
TRANSFORM PERMUTED DATA SEGMENT
16
EXTRACT SELECTED TRANSFORM COEFFICIENT AND MODIFY WITH WATERMARK DATA
18
PERFORM INVERSE TRANSFORM
20
PERFORM INVERSE PERMUTE OPERATION
22
ADD BLOCK AVERAGE TO EACH PIXEL
24
END

FOR THE PURPOSES OF INFORMATION ONLY

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AL	Albania
AM	Armenia
AT	Austria
AU	Australia
AZ	Azerbaijan
BA	Bosnia and Herzegovina
BB	Barbados
BE	Belgium
BF	Burkina Faso
BG	Bulgaria
BJ	Benin
BR	Brazil
BY	Belarus
CA	Canada
CF	Central African Republic
CG	Congo
CH	Switzerland
CI	Côte d'Ivoire
CM	Cameroon
CN	China
CU	Cuba
CZ	Czech Republic
DE	Germany
DK	Denmark
EE	Estonia
ES	Spain
FI	Finland
FR	France
GA	Gabon
GB	United Kingdom
GE	Georgia
GH	Ghana
GN	Guinea
GR	Greece
HU	Hungary
IE	Ireland
IL	Israel
IS	Iceland
IT	Italy
JP	Japan
KE	Kenya
KG	Kyrgyzstan
KP	Democratic People's Republic of Korea
KR	Republic of Korea
KZ	Kazakstan
LC	Saint Lucia
LI	Liechtenstein
LK	Sri Lanka
LR	Liberia
LS	Lesotho
LT	Lithuania
LU	Luxembourg
LV	Latvia
MC	Monaco
MD	Republic of Moldova
MG	Madagascar
MK	The former Yugoslav Republic of Macedonia
ML	Mali
MN	Mongolia
MR	Mauritania
MW	Malawi
MX	Mexico
NE	Niger
NL	Netherlands
NO	Norway
NZ	New Zealand
PL	Poland
PT	Portugal
RO	Romania
RU	Russian Federation
SD	Sudan
SE	Sweden
SG	Singapore
SI	Slovenia
SK	Slovakia
SN	Senegal
SZ	Swaziland
TD	Chad
TG	Togo
TJ	Tajikistan
TM	Turkmenistan
TR	Turkey
TT	Trinidad and Tobago
UA	Ukraine
UG	Uganda
US	United States of America
UZ	Uzbekistan
VN	Viet Nam
YU	Yugoslavia
ZW	Zimbabwe

INVISIBLE DIGITAL WATERMARKS

This invention relates to the provision of identification or authentication data, sometimes referred to as a watermark or signature, in digital media data such as digital image or audio data. In particular, the present invention relates to a method and apparatus for incorporating a watermark in digital media data, and a method and apparatus for retrieving or extracting a watermark from digital media data in which a watermark has been previously incorporated.

In this specification the term "watermark" is used to refer to any distinctive or distinguishing data which may be used for identification or authentication of the digital media data associated therewith, or of some attribute of the media data such as the source thereof. A watermark may comprise image data, such as pixel data forming a logo or the like, or may be in the form of coded text and/or binary numbers, for example, which represent a message. In some applications the watermark data may include error correction coding techniques to improve the robustness of the watermark to image manipulation. The format of the signal that is to be watermarked is not restricted to a multi dimensional representation. It is also possible for audio information to be watermarked. This method of encoding data is not restricted to information associated with copyright and could be used to convey any suitable information in a hidden manner.

Watermarks are utilised in media data for a number of reasons, one being to prevent or discourage copying of the media data if it is subject to copyright, or to at least allow for identification of the media data even if it is copied. Visible watermarks have been employed for many years in varying applications including banknotes and photographs, but have significant disadvantages because of their visible nature. Although a visible watermark may be quite effective in discouraging copying of an associated image, in general it is considered disadvantageous for a watermark to be obtrusive upon the original image.

Besides the issue of whether or not the watermark is visible in an associated image (or audible in the case of watermarked audio media), several other factors are also considered important.

For one, the watermark should be robust to manipulation of the watermarked media, and should be secure so as to not be easily removable by a malicious user. Before the advent of digital media processing and manipulation, a degree of robustness and security was inherent in a visible watermark, because a copy of the watermarked image would generally bring with it the visible watermark itself which would be difficult to remove. However, digital processing makes it possible to perform many sophisticated manipulative operations on watermarked media, which may degrade the visible watermark or be utilised to alter an image to at least substantially remove the watermark. In this case, therefore, the properties of a visible watermark count against the security thereof since it is clearly visible what must be removed or altered in the watermarked image. A paper entitled "Protecting publicly-available images with a visible image watermark" (Gordon Braudaway, Karen Magerlein & Fred Mintzer; SPIE Vol. 2659, pp 126-133) discusses robustness and security in visible image watermarks.

Visible watermarks are considered unsuitable for many modern applications because of the intrusive effect of the watermark on the original media. Watermarking schemes have been developed in which the watermark is substantially invisible on an original image but readily visible on a copy thereof. However, such schemes generally rely upon characteristics of photocopying or electronic scanning apparatus, and so are only suitable for a limited range of applications, such as in images or text on paper documents. In any event, these watermarking schemes are also subject to security difficulties arising from digital processing and manipulation.

In media involving a sequence of images, such as video media, it is particularly undesirable for a watermark to be intrusively visible, since considerable effort is expended in providing the image data to the user in a form which is as visually clear as possible, and a visible watermark may significantly detract from the original image. Visible watermarks are presently used in some video applications, particularly television coverage of live sporting events where a relatively small and faint logo or the like is superimposed on the television picture, typically near one corner thereof. This is not completely satisfactory, besides the visual intrusion, because the logo can be easily cropped from the picture in a copy thereof, or could be relatively easily removed, at least substantially, with digital processing techniques. To make the visible watermark more secure it should be placed over the visually most important part of the image, which also makes the watermark more intrusive and thus less desirable.

Invisible watermarking techniques, particularly for digital media data, have been developed, and one is described in an article entitled "Watermarking Digital Images for Copyright Protection" (J.J.K. O'Ruanaidh, F.M. Boland & O. Sinnen). This article discloses a method of embedding a watermark in a digital image which is said to be invisible and quite robust. The image data is divided into rectangular blocks, and each block is then transformed using either a Walsh transform, discrete cosine transform (DCT) or wavelet transform. The bits defining the watermark graphic are inserted in the digital image by incrementing or decrementing a selected coefficient in the transform domain of the data block. Coefficients are selected according to a criterion based on energy content. Another algorithm described in the article relates to insertion of watermark data based on the use of the discrete Fourier transform (DFT). This method differs fundamentally from the transform domain technique outlined above. The DFT is a complex transform that generates complex transform domain coefficients given a real valued input. The watermark is placed in the phase component of generated transform coefficients when using this transform.

Another article which addresses the difficult issues of digital watermarking is "Secure Spread Spectrum Watermarking for Multimedia" (Ingemar J Cox, Joe Kilian, Tom Leighton & Talal Shamoon; NEC Research Institute, Technical Report 95-10). This article describes an invisible digital watermarking method for use in audio, image, video and multimedia data. The method described in this article also involves a frequency domain transform of the image data and insertion of the watermark data whilst in the transform domain. In practice, in order to place a length n watermark into an N x N image, the discrete cosine transform of the image is computed, and the watermark data encoded into the n highest magnitude coefficients of the transform matrix, excluding the dc component. In other words, the watermark data is placed in transform domain components of greatest perceptual significance, which enables the watermark to be robust to image distortion and unauthorised removal without serious degradation of the image itself. This watermarking algorithm employs an energy compacting transform, which makes the selection of transform coefficients for encoding of the watermark data very important. For most images the coefficients selected will be the ones corresponding to the low spatial frequencies, with the result that significant tampering of the image at those frequencies would destroy the image fidelity before the encoded watermark. The watermarking techniques of J.J.K O'Ruanaidh et al and Ingemar J. Cox et al require the original image when performing the watermark extraction operation. As a consequence, proof of ownership is accomplished only if the original image is certified as being the original by a trusted third party, and the particular segment of the original image must be first identified and found before ownership is verified.

The present invention addresses some of the difficulties identified in the prior art, and embodiments of the invention aim to provide a digital watermarking process in which:

1. the presence of the watermark is invisible (i.e. the watermarked visual or audio material is visually or auditorially substantially indistinguishable from the original);

2. the watermark is robust to signal manipulation and distortion;

3. the watermark is secure;

4. the original media data is not required in order to extract the watermark; and

5. the watermark can be inserted and/or extracted by a simple computational procedure which can be done in real time.

In accordance with the present invention, there is provided a method for inserting identification or authentication data into digital media data, including the steps of:

segmenting the digital media data into data blocks;

applying a pseudo-random reversible function to a block of the digital media data to obtain a modified data block;

applying an orthogonal transform on the modified data block to obtain transform domain data;

modifying at least one selected transform domain data coefficient in accordance with identification or authentication data;

inverse transforming the transform domain data having the at least one modified coefficient; and

applying an inverse pseudo-random function to obtain watermarked digital media data.

The present invention also provides a method for extracting identification or authentication data from watermarked digital media data, including the steps of:

segmenting the digital media data into data blocks;

applying a pseudo-random reversible function to a block of the digital media data to obtain a modified data block;

applying an orthogonal transform to the modified data block to obtain transform domain data; and

extracting identification or authentication data from at least one coefficient of the transform domain data.

Preferably, the pseudo-random reversible function has the property of flattening the power spectral density of the data block (i.e. the function performs a spectral whitening operation), such that each coefficient then generated by the transform contributes substantially equally to the total energy of the block. This allows the watermarking process to be less sensitive, with regard to the introduced distortion, to the selection of the transform coefficient which is modified in the watermark insertion operation.

The insertion and/or extraction method can be performed in real time, which is particularly advantageous when the digital media data has presentation timing restrictions, such as in the case of real time video and/or audio data.

It is preferred for optimal performance that the average (dc) component of the transformed media data be restricted to a single known transform coefficient and that this transform coefficient is not available for modification by the watermark insertion operation. It is also preferred that the pseudo-random reversible function be tolerant to the introduction of noise resulting from signal processing that could subsequently be performed on the watermarked media data. Many different pseudo-random functions could be used for this application. One pseudo-random function that offers good performance in terms of its noise rejection capability, spectral flattening performance and simplicity of implementation is a permutation of the data block based upon a keyed random number generator. In that case, the user should ensure that a permutation is selected that exhibits the desired spectral whitening characteristics as this is not guaranteed by all permutations.

A number of different transforms exist that could be used as the orthogonal transform operation in the preferred method. These include the Walsh Hadamard Transform (WHT), Discrete Cosine Transform (DCT), Discrete Sine Transform (DST) and Fast Fourier Transform (FFT). The Walsh Hadamard Transform is the preferred choice due in part to its low implementation complexity. The AC transform coefficients generated with such a transform in conjunction with an appropriate pseudo-random function, using real image data as input, are characterised by all possessing approximately equal energy. The selection of transform coefficient(s) for modification can thus be based on a random keyed operation to further enhance the security of the watermark.

For functions and transforms that do not restrict the average value of the data block to a single transform coefficient, it is preferred (to minimise watermark visibility) that the average (dc) value for the data block is calculated, stored, and subtracted from each data value in the data block prior to the application of the of the pseudo-random function. The average value is subsequently retrieved and added to each data value making up the watermarked data block immediately after the application of the inverse pseudo-random function.

The application of the pseudo-random function and the application of the orthogonal transform can be combined into a single operation. Similarly with respect to the inverse pseudo-random function and inverse transform. A combined data permutation and transform operation can be considered equivalent to, in the one dimensional case, performing a permutation upon the columns making up the basis matrix of the transform in question. Each permutation will yield an orthogonal transform, hence the number of transforms contained in the set is equal to the number of available permutations. Using this interpretation, the security of the watermark relies not just on which transform coefficient has been modified to contain the watermark data, but also on which member of the set of available transforms has been used.

The present invention further provides apparatus for inserting or extracting watermark data in digital media data, comprising:

segmenting means for segmenting the digital media data into data blocks;

processing means for applying a pseudo-random reversible function to a block of the digital media data to obtain a modified data block and performing a transform on the modified data block to obtain transform domain data; and

means for inserting or extracting watermark data in at least one coefficient of the transform domain data.

Preferably, in the case where watermark data is to be inserted in the digital media data the processing means is also adapted to perform an inverse transformation and inverse pseudo-random function on the transform domain data containing the watermark data so as to obtain watermarked digital media data.

In practice, the segmenting of the digital media data into data blocks might comprise forming blocks of 64x64 pixels of image luminance pixel data, where the watermark is to be inserted into a still image or image sequence. The block size need not be restricted to being square and of dimension 64x64 pixels, both smaller and larger block sizes are possible depending upon application requirements. In practice, the identification/authentication data which is inserted into a data block of digital media data might comprise a pixel from a binary graphic, or data in the form of bits used to represent text and binary numbers, for example. The watermark data is inserted into the data block that has undergone a block transform operation. The distortion introduced due to the insertion of watermark data is dependent upon the block size, the number of transform coefficients modified by the insertion operation and the magnitude of the modification. The watermark data density per block is arbitrary depending upon application requirements. In general, however, the higher the density the more visually noticeable is the inserted watermark in the image. A series of data blocks may be contained in a single image frame or spread over a number of image frames.

The invention is described in greater detail hereinafter, by way of example only, with reference to the accompanying drawings, wherein:

Figure 1 is a flowchart illustrating operations for inserting watermark data into digital media data;

Figure 2 is a flowchart illustrating operations for extracting watermark data from digital media data;

Figure 3 is a diagram of the watermark insertion process of a preferred embodiment of the present invention;

Figure 4 is a flowchart illustrating the operations for a particular implementation of the watermarking insertion procedure;

Figure 5 is a block diagram of watermarking apparatus for real-time video; and

Figure 6 is a block diagram of a media monitoring system.

This invention relates to the insertion and extraction of identification or authentication data for use as a watermark in digital media data, such as digital image data, still or sequential, digital audio data or the like. A watermark provided in digital media data may provide a means for identification of the source or some other attribute of the media data as may be required to prove copyright ownership, for example. As mentioned above, embodiments of the present invention are designed to have a number of advantageous properties, including:

the watermark presence being at least substantially invisible (ie the watermarked visual or audio material is visually or auditorially substantially indistinguishable from the original);

the watermark can be inserted and/or extracted by a simple computational procedure which can be done in real time for audio and/or video media data; and

the original media data not being required in order to extract the watermark from the watermarked media data.

Additionally, as also discussed above, it is desirable for watermarks in digital media data to also be both secure in that a malicious user cannot easily remove or disguise the watermark so as to prevent extraction, and robust to enable the inserted watermark to survive manipulation of the watermarked media data. Digital images and image sequences, for example, are seldom stored or transported over a communications link in their raw format. Frequently some form of compression may be applied to the media data, and it is therefore important that the signal processing associated with the compression algorithm does not remove or wash out the associated watermark inserted in the media data.

Although the following description of embodiments of the present invention refer primarily to still or sequential image data, it is to be understood that the invention is equally applicable to other forms of digital media data, such as digitised audio data.

In an embodiment of the invention, image pixel data is subdivided into 64 x 64 pixel spatial domain blocks in order to provide a manageable data segment in which to insert watermark data. For example, a digital image comprising 1,024 x 768 pixels may be nominally divided into blocks of 64 x 64 pixels so that the entire image is contained in an array of 16 x 12 image data blocks (a total of 192 data blocks). Different watermark data may then be inserted into each data block, so that the watermark data is spread over the entire image. For example, the watermark might comprise a 16 x 12 pixel logo or the like, so that a value representing each pixel of the logo is inserted in a respective data block of the digital image. Alternatively, the watermark may comprise a text message formed in ASCII code and/or binary numbers. A message comprising of 192 bits could be inserted in the digital image if a watermark density of 1/ 4096 (one bit per 64x64 block) was employed.

The invisibility and robustness of the watermark are aided by dividing the image into blocks and distributing the watermark data throughout the data blocks, and are further facilitated by the insertion procedure utilised to insert the watermark data into each data block. The following steps are used to insert a watermark data bit or binary pixel graphic into a 64 x 64 spatial domain luminance data block.

(i) Permute the 64x64 data block using a predetermined random permutation. There exist 4096 factorial different ways in which this permutation can be performed. To minimise the distortion introduced by the watermark modification, a permutation should be selected that performs a spectral whitening operation on a signal that has a predominant low pass power spectral density. The permutation is generated from a keyed pseudo-random operation.

(ii) Transform the permuted data using a Walsh Hadamard Transform. This transform can be implemented as a 4096-point one dimensional fast transform operation.

(iii) Watermark data is inserted into the data block by modification of selected transform coefficient(s). The coefficient selection process is based on a keyed-pseudo random operation, and does not include the dc coefficient in set of coefficients available for modification. To maximise security of the watermarking process, different coefficients are selected via the pseudo-random operation for each data block.

A watermark data bit can be represented by the sign of a selected transform coefficient. A transform coefficient value greater than or equal to zero could represent logic zero and the negative values logic one. Transform coefficient(s) need only be modified if necessary, to ensure that the sign (+/-) corresponds the digital bit to be embedded (1/0).

(iv) An inverse transform is then applied to reconstruct an approximation of the original

64x64 spatial domain data block. In the transform domain, the watermark data is completely contained by one transform coefficient when using a watermark data density 1/4096. In the spatial domain, however, the watermark data is distributed over each of the pixels making up the 64x64 data block.

The watermark read operation is accomplished by repeating steps (i) and (ii) above. The original image or image sequence is not required for the reading operation. The watermark data can be extracted with the knowledge of the permutation applied to the data block, the transform operation. and which of the transform coefficient(s) modified to contain the watermark data. The permutation employed is preferably kept secret by the owner of the image or image sequence. The permutation could be represented by a secret seed number to a well defined pseudo random number generator.

Block transforms such as the classic Walsh Hadamard Transform (WHT), Discrete Cosine Transform (DCT), Discrete Sine Transform (DST) and the Haar Transform (HT) can be employed in the watermarking process in embodiments of the invention. For transforms that isolate the average block value or dc value into one coefficient, that coefficient should not be used to contain watermark data. The WHT is the preferred choice for the transform operation due to its low implementation complexity. Fast transform implementations of the WHT exist that require only summing and one scaling operation, and the transform basis vector contains only +1 and -1 elements. The analysis and synthesis transforms are identical.

Figure 1 illustrates a flow chart of operation involved in insertion of watermark data into digital media data, according to an embodiment of the invention. Beginning at step 12, the digital media data is first segmented into manageable data blocks such as blocks of 64x64 pixels or equivalent data elements. Step 13 calculates the average pixel value for the block which is then subtracted from each pixel. Step 13 is unnecessary when using a transform that contains the block average in a single transform coefficient. This is the case with the WHT and the DCT, for example. The resulting dc transform coefficient should not, however, be used to contain watermark data. The media data block or segment is then subjected to a permute operation (step 14) in which the data elements of the block or segment are rearranged in a pseudo random, but repeatable and reversible manner. Next, at step 16, the permuted spatial domain media data segment is subjected to the transform operation. In this embodiment one of the transform coefficients is selected and modified to include watermark data. When watermarking images or image sequences a watermark data bit could be represented by the sign of the selected transform coefficient. A transform coefficient value greater than or equal to zero could represent logic zero and the negative values logic one.

The watermark data density per block in this case is 1/4096. In some applications, densities greater than 1/4096 may be required.

Following insertion of the watermark data into the transform domain of the media data, the spatial domain media data is then reconstructed through steps 20, 22 and 23 by performing an inverse transformation followed by an inverse permute operation and then the previously subtracted block average value added to each pixel making up the block. Again, step 23 is not necessary when using a transform that contains the block average in a single transform coefficient. The resulting digital media data segment contains watermark data which is robust to manipulation thereof, secure from unauthorised removal, and yet the reconstructed, watermarked media data is substantially indistinguishable from the original spatial domain media data when compared in subjective quality testing.

In order to extract the watermark data form digital media data in which watermark data has been previously inserted, the procedure outlined in the flow chart of Figure 2 may be employed. Essentially this involves steps mirroring the first half of the procedure illustrated in Figure 1. The digital media data is first segmented as discussed previously (step 32), the average pixel value for that block is determined and subtracted from each pixel (step 33) if necessary. The resulting data block is then subjected to a permute operation as shown at step 34. The permute operation must be the same as that performed during insertion of the watermark data, and thus if different permute operations are variously employed, some record must be maintained of which of the particular 4096 factorial permutations applies to the particular media data segment in question. This could be in the form of a secret seed to a well defined pseudo random number generator. The permuted media data segment is then transformed with the same transform used by the insertion operation (step 36). Then it is a simple matter to extract the particular coefficient for the transform domain media data and then recover from this the watermark information.

Figure 3 illustrates a block diagram of the watermark insertion process described in connection with the flow chart of Figure 1. As discussed above, in this embodiment only a single watermark data component, eg a data bit or binary graphic pixel, is inserted into each selected digital media data segment or block, and the information required to reconstruct an entire watermark requires the examination of a number of digital media data segments.

Figure 4 is a flow chart illustrating the insertion process of watermark data into digital media data, which has been segmented into data blocks, over a series of data blocks. Where the digital media data comprises a sequence of images, such as in the case of digital video or the like, a complete watermark (eg the total of the identification data) may in fact be distributed over more than one image or image frame. At step 42 the first data block in the image or sequence of images is selected and, if necessary, the average of that block is then calculated and subtracted from each pixel element in step 43. The resulting data block forming the image segment is subjected to a permute operation, as described hereinabove, at step 44. The permuted image data is then transformed using a block transform. At step 47 a particular transform coefficient is selected for possible modification. The selection process is performed in a pseudo random deterministic manner. Transforms that contain the block average (dc) in one transform coefficient, or set of coefficients, must eliminate this coefficient from the selection process. Step 48 performs the modification operation to incorporate the watermark data into the selected transform coefficient(s). The inverse of the transformation and permute operations are then applied at steps 50 and 52 and step 53 adds to each pixel value the average as determined in step 43, if necessary. A test is then applied at step 54 to determine whether the media data has finished, and if so the watermarking procedure ends. Otherwise, the next block of the digital media data is selected at step 56. The watermark data is then incremented, meaning the next component of the watermark data, such as the next data bit or binary pixel element, is selected at step 58. Of course, it will be recognised that it is unnecessary for every data block of a particular digital media data source to be encoded with watermark data, and only a certain selection of data blocks may in fact be encoded with watermark data in practice. To provide copyright protection for the complete image sequence, the watermark can be repeatedly inserted, with the watermark beginning at different frame locations within the sequence and ensuring that watermarks do not overlap. Of course, acquisition of the signal is important. This can be accomplished, by incorporating in the watermark data, synchronisation information that, once acquired informs the watermark reader the location of the beginning of the watermark message data or binary graphic.

To increase robustness and ensure readability even in the case where the original video signal is significantly changed, such as through reduced spatial resolution or the case where watermarked interlaced material is later converted to non-interlaced format, the watermark can be distributed across both fields in such a way that the watermark can be independently read from either or both fields and/or restricted to the low spatial frequencies. The latter may be accomplished by the application of a 2x2 WHT on each row of the image to produce low and high spatial frequency components. The watermark is then inserted in only the half horizontal resolution frame corresponding to the low spatial frequencies. The full resolution watermarked frame is produced by performing an inverse 2x2 WHT on the rows making up the low spatial frequency watermarked half horizontal resolution frame and the original high spatial frequency half horizontal resolution frame.

In order to further improve security of the watermarking procedure, it is possible to alter the permute operation periodically (step 60 in Figure 4). As mentioned above, it is nevertheless necessary that the particular permute operation performed on each data block be repeatable at a future time to enable extraction of the watermark.

Figure 5 illustrates a block diagram of watermarking apparatus for encoding real time video with watermark data according to an embodiment of the present invention. Real time video feed is provided to the apparatus at a buffer 80 or the like, which provides an input to real time processing circuitry 82. The circuitry 82 may comprise digital processing circuitry in the form of high speed programmable computer circuitry, for example, which carries out the algorithmic steps described in connection with Figure 4, for example. The watermark data is provided from a buffer 84 which may be in the form, for example, of a ring buffer which cyclically feeds watermark data being a component of watermark text or graphic material to the processing circuitry 82. The reconstructed video data containing the watermark data is then passed to an output buffer 86 which provides the video data for transmission, recording or whatever function the video data is required for.

Embodiments of the invention, operating in real time, can be utilised to add watermark data to media such as video and/or audio during live broadcast or other transmission, whilst recording to storage such as tape or disc, during broadcast or other transmission from storage, and during transferral from one storage device to another, for example. Furthermore, embodiments of the invention operating in real time can be used to monitor media such as television transmissions to detect the presence of watermark data incorporated in the media data. A block diagram of such a system is illustrated in Figure 6. Video data is provided to a buffer 90 from a source such as a broadcast receiver or the like. Real time processing circuitry 93 is coupled to receive the media data from the buffer 90 and perform the algorithmic steps described in connection with Figure 2, for example. This results in the extraction of any watermarking data contained in the media data which was inserted according to a process known to the monitoring apparatus (i.e. watermark data which has been added with a known permutation and transform in transform coefficients selected according to a known scheme). A comparison processor 94 can then be used to compare any watermark data which is retrieved with stored watermark data to determine if the retrieved watermark data corresponds to a known watermark indicating the source of the media data.

It will be appreciated from the foregoing description that the original media data is not required by the watermark extraction process in order to extract the watermark data, and therefore it is not required that the original image be certified by a trusted third party or held in escrow in order to prove the presence of a watermark in the media data. Random accessibility of a watermark within an image sequence is easily achieved, as all that is required to extract the watermark is the image or sequence of images that contains sufficient watermark data to reconstruct the entire watermark or a substantial portion thereof, and the secret keys used to seed the random permutation and the random coefficient selection process.

The watermarking process according to an embodiment of the invention has been tested on still images and image sequences, and has been demonstrated to be near invisible to the naked eye in a comparison between the reconstructed, watermarked media data and the original media data. It has also be found to be secure and robust to compression such as 4 Mbps MPEG coding of image sequences and 20% quality setting for JPEG compressed still images. The described watermarking procedure is also robust to digital-to-analogue and analogue-to-digital conversions. Accordingly, embodiments of the invention can be utilised to insert and extract watermark data in analogue media as well as digital media. For example, watermark data can be inserted and extracted from broadcast or home quality analogue or digital video. Tests have been performed demonstrating a successful read operation for watermarked digital video originally of broadcast studio quality which has been temporarily recorded on an analogue consumer VHS tape. In the case where the media is generated, stored and/or transmitted in an analogue form, an analogue-to-digital conversion using known techniques is used to obtain digital media data before inserting or extracting the watermark data (see 92 in Figure 6). The media data may be returned to analogue form, if desired, using known digital-to-analogue techniques.

It will also be appreciated that the simple nature of the computational processes involved in the watermarking process of the present invention allow it to be applied quite readily to real time video data, for example. This is because the only two computationally complex steps in the watermarking procedure, namely the permute and transformation are still relatively simple. This makes for a watermarking process that is very low in complexity, is easily automated, and requires no human intervention in its application.

The foregoing detailed description of the present invention has been presented by way of example only, and is not intended to be considered limiting to the invention as defined in the claims appended hereto.

Claims:

1. A method for inserting identification or authentication data into digital media data, including the steps of:

segmenting the digital media data into data blocks;

applying a pseudo-random reversible function to a block of the digital media data to obtain a modified data block;

applying an orthogonal transform on the modified data block to obtain transform domain data;

modifying at least one selected transform domain data coefficient in accordance with identification or authentication data;

inverse transforming the transform domain data having the at least one modified coefficient; and

applying an inverse pseudo-random function to obtain watermarked digital media data.

2. A method as claimed in claim 1, wherein the pseudo-random function applied to the data block is a keyed function controlled by a cryptographic key.

3. A method as claimed in claim 1 or 2, wherein the pseudo-random function applied to the data block has a property of flattening the power spectral density of the data block.

4. A method as claimed in claim 1, wherein application of the pseudo-random function and application of the orthogonal transform are carried out in the same operation.

5. A method as claimed in claim 1, wherein the at least one transform domain data coefficient selected for modification is selected according to a keyed pseudo-random operation.

6. A method as claimed in claim 1, wherein a plurality of data blocks of the digital media data are modified according to the identification or authentication data.

7. A method as claimed in any one of claims 1 to 6, wherein the digital media data is video data.

8. A method as claimed in any one of claims 1 to 6, wherein the digital media data is audio data.

9. A method as claimed in claim 7 or 8, wherein the identification or authentication data is inserted into the digital media data in real time.

10. A method as claimed in claim 1, wherein at least one coefficient in the transform domain data which represents the average (dc) of the data block is restricted from selection for modification with the identification or authentication data.

11. A method as claimed in claim 1 or 10, wherein the orthogonal transform is a Walsh Hadamard transform.

12. A method as claimed in claim 1 or 10, wherein the orthogonal transform is selected from a discrete cosine transform, a discrete sine transform and a fast Fourier transform.

13. A method as claimed in claim 1, wherein the pseudo-random reversible function is a permutation of the data block based on a keyed pseudo-random number generator.

14. A method as claimed in claim 1, including determining an average of data values in the data block, subtracting the average value from the data values in the data block before applying the pseudo-random function, and adding the average value back to the data values in the data block after applying the inverse pseudo-random function.

15. A method for extracting identification or authentication data from watermarked digital media data, including the steps of:

segmenting the digital media data into data blocks;

applying a pseudo-random reversible function to a block of the digital media data to obtain a modified data block;

applying an orthogonal transform to the modified data block to obtain transform domain data; and

extracting identification or authentication data from at least one coefficient of the transform domain data.

16. A method as claimed in claim 15, wherein the pseudo-random function applied to the data block is a keyed function controlled by a cryptographic key.

17. A method as claimed in claim 15 or 16, wherein the pseudo-random function applied to the data block has a property of flattening the power spectral density of the data block.

18. A method as claimed in claim 15, wherein application of the pseudo-random function and application of the orthogonal transform are carried out in the same operation.

19. A method as claimed in claim 15, wherein the extracting step includes selecting at least one transform domain data coefficient from which to extract identification or authentication data according to a keyed pseudo-random operation.

20. A method as claimed in any one of claims 15 to 19, wherein the digital media data comprises video data.

21. A method as claimed in any one of claims 15 to 19, wherein the digital media data comprises audio data.

22. A method as claimed in claim 20 or 21, wherein the identification or authentication data is extracted from the digital media data in real time.

23. A method as claimed in claim 15, wherein the orthogonal transform is a Walsh

Hadamard transform.

24. A method as claimed in claim 15, wherein the orthogonal transform is selected from a discrete cosine transform, a discrete sine transform and a fast Fourier transform.

25. A method as claimed in claim 15, wherein the pseudo-random reversible function is a permutation of the data block based on a keyed pseudo-random number generator.

26. A method as claimed in claim 15, including determining an average of data values in the data block, and subtracting the average value from the data values in the data block before applying the pseudo-random function.

27. An apparatus for inserting or extracting watermark data in digital media data, comprising:

segmenting means for segmenting the digital media data into data blocks;

processing means for applying a pseudo-random reversible function to a block of the digital media data to obtain a modified data block and performing a transform on the modified data block to obtain transform domain data; and

means for inserting or extracting watermark data in at least one coefficient of the transform domain data.

28. An apparatus as claimed in claim 27, wherein the processing means is also adapted to apply an inverse transformation and inverse pseudo-random function of the transform domain data containing the watermark data so as to generate watermarked digital media data.

29. An apparatus as claimed in claim 27 or 28, wherein the apparatus inserts or extracts watermark data in digital media data in real time

30. An apparatus as claimed in claim 29, wherein the digital media data comprises video data.

31. An apparatus as claimed in claim 29, wherein the digital media data comprises audio data.

32. An apparatus as claimed in claim 27, including means for selecting at least one transform domain data coefficient for the insertion or extraction of identification or authentication data according to a keyed pseudo-random operation.

33. A media data monitoring system comprising:

a media data buffer for temporarily storing media data received from a data source;

a real time processor coupled to receive media data from the media data buffer and adapted to extract identification or authentication data according to the method defined in claim 15; and

a comparison processor coupled to the real time processor for comparing extracted identification or authentication data with known identification or authentication data.

34. A media monitoring system as claimed in claim 33, including an analogue-to-digital converter for converting media data into a digital form before processing by the real time processor.

35. A media monitoring system as claimed in claim 33 or 34, wherein the media data comprises video data.

36. A media monitoring system as claimed in claim 35, wherein the data source of the media data is a receiver of video transmissions.

37. A media data monitoring method comprising:

receiving media data from a data source;

extracting identification or authentication data according to the method defined in claim 15; and

comparing extracted identification or authentication data with known identification or authentication data.

38. A media monitoring method as claimed in claim 37, including converting the media data into a digital form before processing by the real time processor.

39. A media monitoring method as claimed in claim 37 or 38, wherein the media data comprises video data.

40. A media monitoring method as claimed in claim 39, wherein the media data is received from a video transmission.

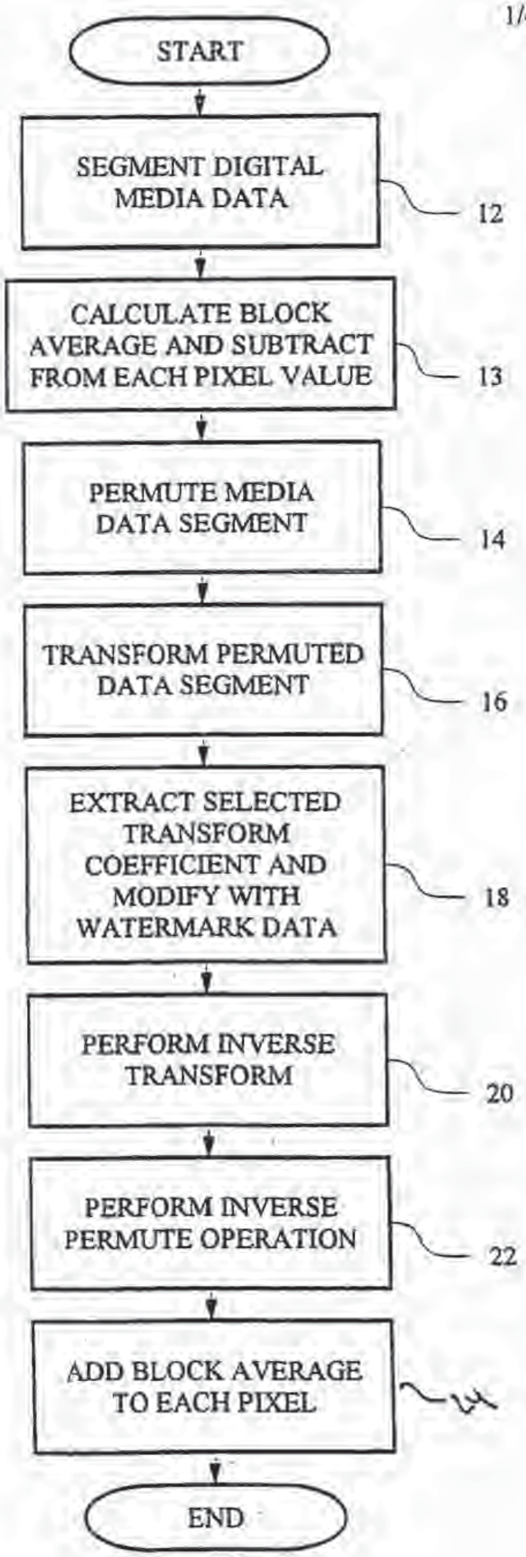

START
SEGMENT DIGITAL MEDIA DATA
12
CALCULATE BLOCK AVERAGE AND SUBTRACT FROM EACH PIXEL VALUE
13
PERMUTE MEDIA DATA SEGMENT
14
TRANSFORM PERMUTED DATA SEGMENT
16
EXTRACT SELECTED TRANSFORM COEFFICIENT AND MODIFY WITH WATERMARK DATA
18
PERFORM INVERSE TRANSFORM
20
PERFORM INVERSE PERMUTE OPERATION
22
ADD BLOCK AVERAGE TO EACH PIXEL
24
END

Figure 1.

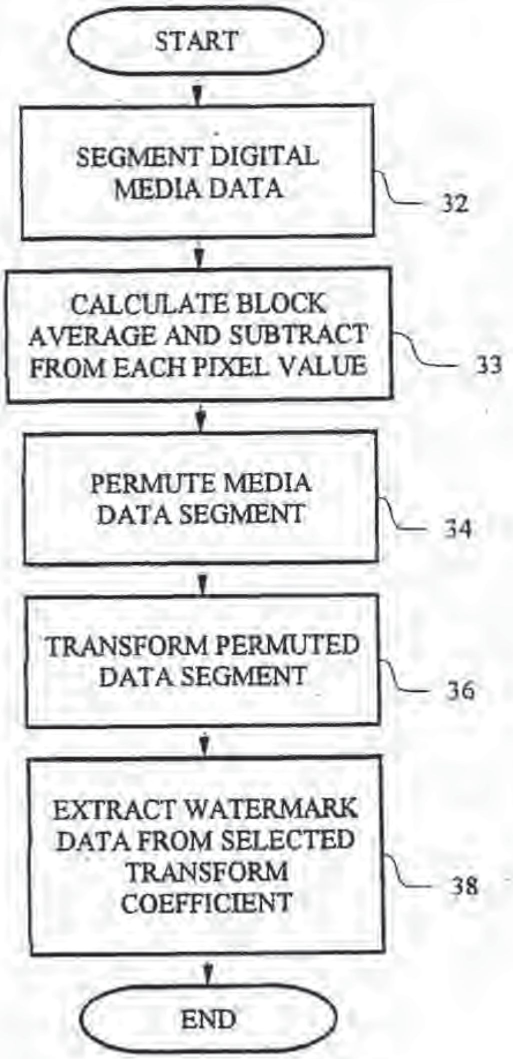

START
SEGMENT DIGITAL MEDIA DATA
32
CALCULATE BLOCK AVERAGE AND SUBTRACT FROM EACH PIXEL VALUE
33
PERMUTE MEDIA DATA SEGMENT
34
TRANSFORM PERMUTED DATA SEGMENT
36
EXTRACT WATERMARK DATA FROM SELECTED TRANSFORM COEFFICIENT
38
END

Figure 2.

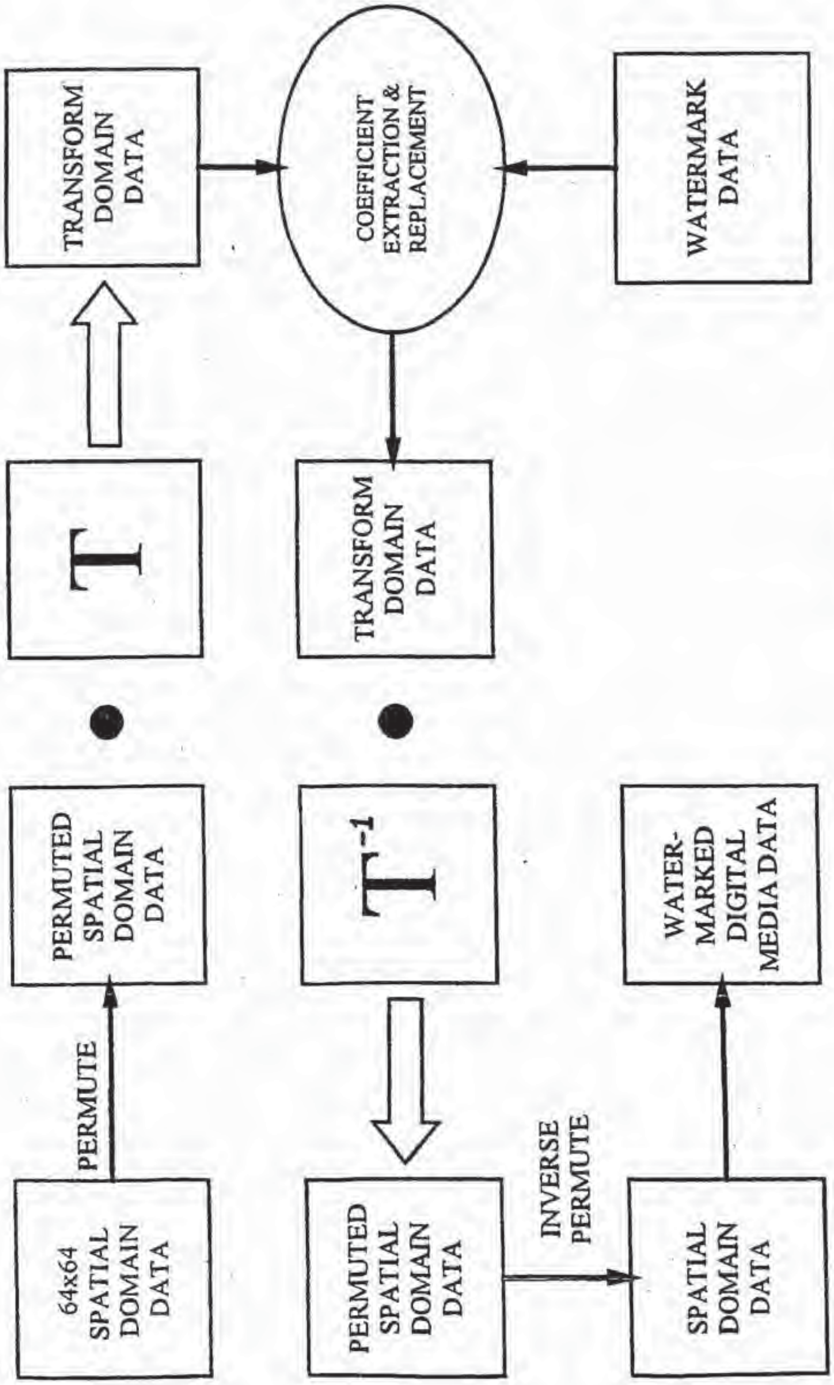

64x64 SPATIAL DOMAIN DATA
PERMUTE
PERMUTED SPATIAL DOMAIN DATA
T
TRANSFORM DOMAIN DATA
COEFFICIENT EXTRACTION & REPLACEMENT
WATERMARK DATA
TRANSFORM DOMAIN DATA
T^-1
PERMUTED SPATIAL DOMAIN DATA
INVERSE PERMUTE
SPATIAL DOMAIN DATA
WATER-MARKED DIGITAL MEDIA DATA

Figure 3.

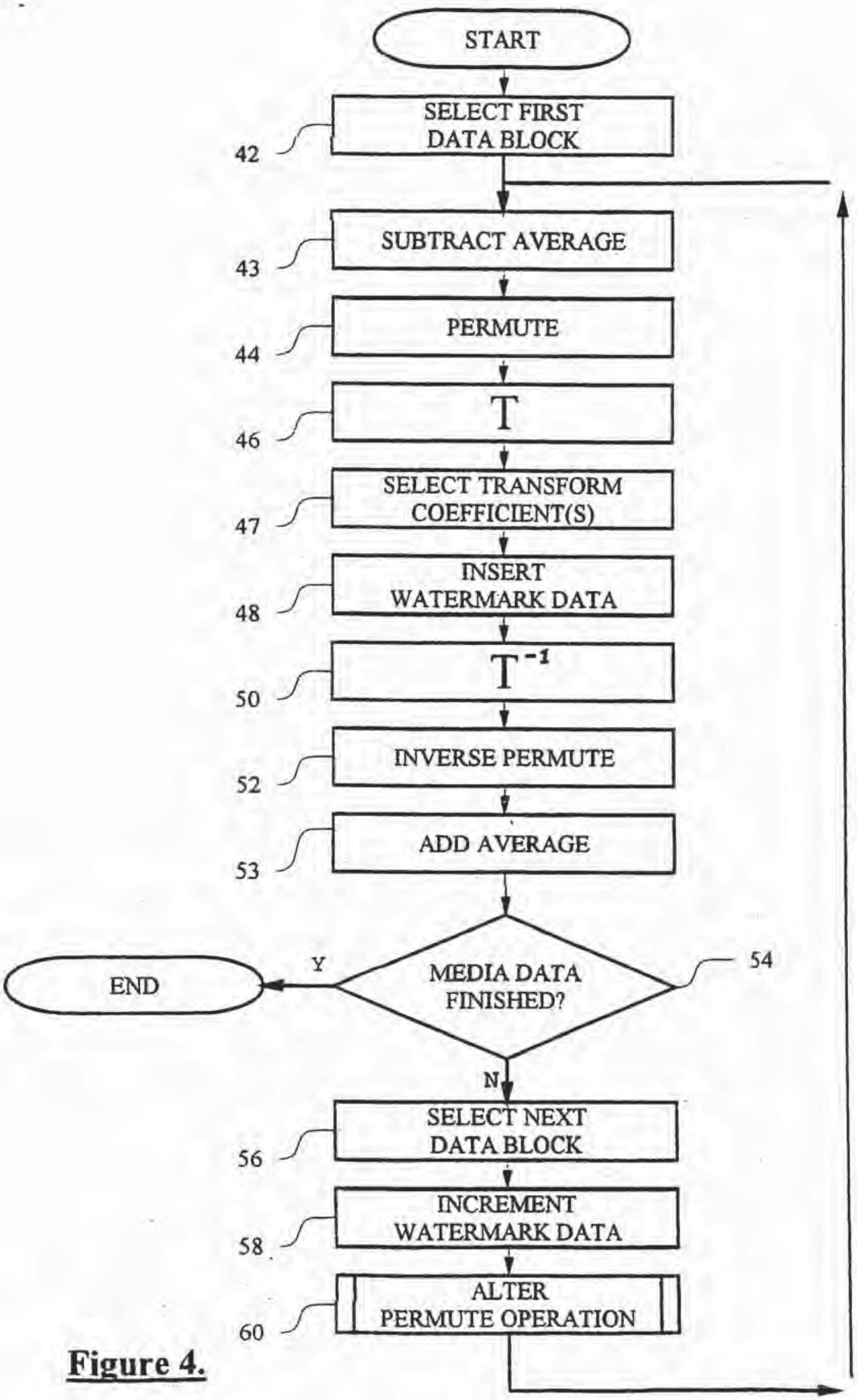

START
SELECT FIRST DATA BLOCK
42
SUBTRACT AVERAGE
43
PERMUTE
44
T
46
SELECT TRANSFORM COEFFICIENT(S)
47
INSERT WATERMARK DATA
48
T^{-1}
50
INVERSE PERMUTE
52
ADD AVERAGE
53
MEDIA DATA FINISHED?
54
Y
END
N
SELECT NEXT DATA BLOCK
56
INCREMENT WATERMARK DATA
58
ALTER PERMUTE OPERATION
60

Figure 4.

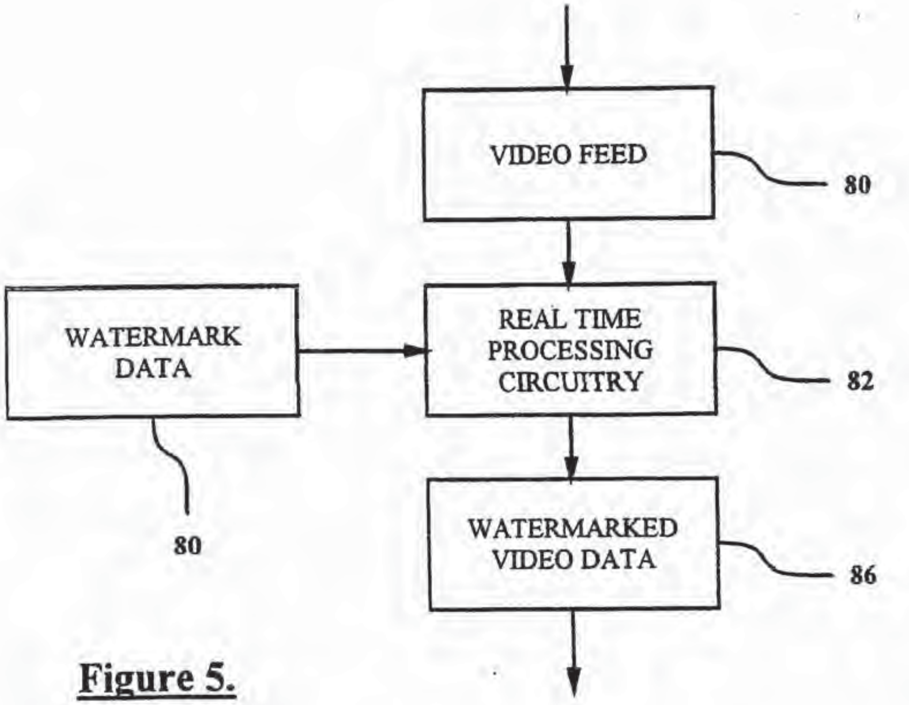


Figure 5.

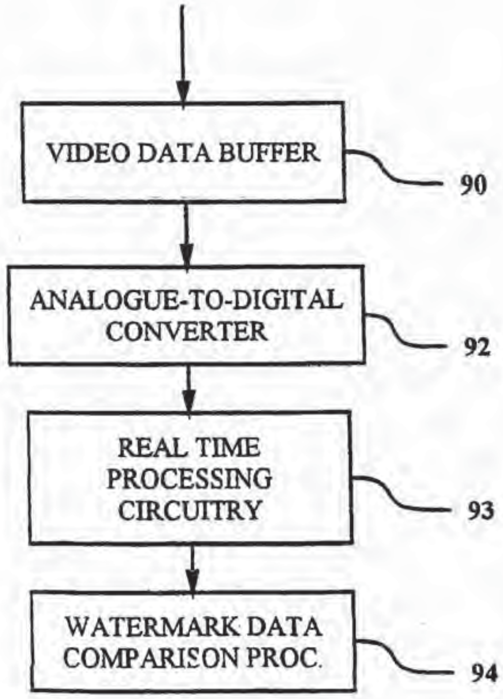

VIDEO DATA BUFFER
90
ANALOGUE-TO-DIGITAL CONVERTER
92
REAL TIME PROCESSING CIRCUITRY
93
WATERMARK DATA COMPARISON PROC.
94

Figure 6.

INTERNATIONAL SEARCH REPORT

International Application No.
PCT/AU 98/00106

A. CLASSIFICATION OF SUBJECT MATTER

Int Cl^6: G06K 19/08, 19/10, H04L/9/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC:as above

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
AU:IPC as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
IBM Patent Database: Digital, Watermark, Transform
Derwent WPAT:Digital, Watermark.

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X, P	EP 766468 (NEC CORPORATION) 2 April 1997	1 to 40
A	BYTE Magazine, January 1997, 'Look, It's Not There', Zhao, J. (INTERNATIONAL FEATURE) page 40is 7-12	1 to 40
X	AU 45073/96 (INTEL CORPORATION) 6 June 1996	33
X, T	AU 26083/97 (V-CAST INC.) 4 December 1997	33

□ Further documents are listed in the continuation of Box C

☒ See patent family annex

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search 17 March 1998	Date of mailing of the international search report 08 APR 1998
Name and mailing address of the ISA/AU AUSTRALIAN PATENT OFFICE PO BOX 200 WODEN ACT 2606 AUSTRALIA Facsimile No.: (02) 6285 3929	Authorized officer J.W.THOMSON Telephone No.: (02) 6283 2214

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No.
PCT/AU 98/00106

This Annex lists the known "A" publication level patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent Document Cited in Search Report		Patent Family Member					
EP	766468	AU	65840/96	CA	2184949	JP	9191394
AU	96/45073	WO	9617292	EP	795154		

END OF ANNEX

(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) Publication number : **0 651 554 A1**

(12) EUROPEAN PATENT APPLICATION

(21) Application number : **94420293.6**

(22) Date of filing : **25.10.94**

(51) Int. Cl.^{6} : **H04N 1/21**, G06F 1/00

(30) Priority : **29.10.93 US 146371**

(43) Date of publication of application :
03.05.95 Bulletin 95/18

(84) Designated Contracting States :
DE GB

(71) Applicant : **EASTMAN KODAK COMPANY**
343 State Street
Rochester, New York 14650-2201 (US)

(72) Inventor : **Rabbani, Majid, Eastman Kodak Company**
Patent Legal Staff,
343 State Street
Rochester, New York 14650-2201 (US)

Inventor : **Melnychuck, Paul W., Eastman Kodak Company**
Patent Legal Staff,
343 State Street
Rochester, New York 14650-2201 (US)

Inventor : **Axman, Michael Stuart, Eastman Kodak Company**
Patent Legal Staff,
343 State Street
Rochester, New York 14650-2201 (US)

Inventor : **Baradar, Ali R., Eastman Kodak Company**
Patent Legal Staff,
343 State Street
Rochester, New York 14650-2201 (US)

(74) Representative : **Boulard, Denis et al**
Kodak-Pathé
Département Brevets
CRT-Zone Industrielle
F-71102 Chalon-sur-Saône Cédex (FR)

(54) Method and apparatus for the addition and removal of digital watermarks in a hierarchical image storage and retrieval system.

(57) An image processing technique is described in the context of a hierarchical image storage and retrieval system. The method allows for the controlled addition and removal of digital watermarks from selected image components in the hierarchy. The method adds a digital watermark in a selected image resolution component and the means to remove it in an additional image component termed the watermark removal component. The method employs the encryption of the watermark removal component, and decryption with a special key, or password during authorized retrieval. This technique allows users of a distributed system the convenience of providing the entire image hierarchy on a single storage medium permitting images containing watermarks to be accessed without restriction for browsing and proofing, while the watermark removal requires knowledge and us of a controlled code.

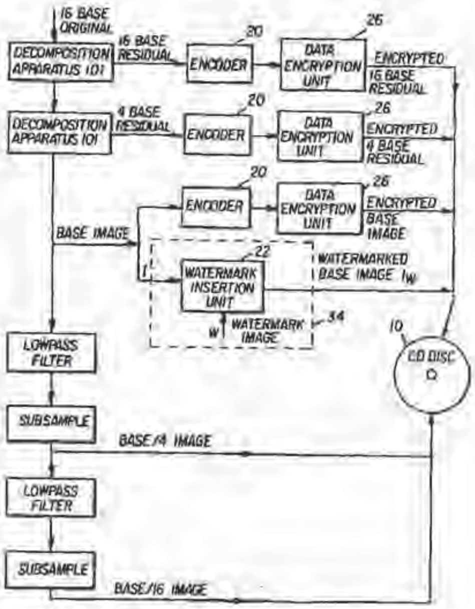


FIG 2

EP 0 651 554 A1

Jouve, 18, rue Saint-Denis, 75001 PARIS

Cross-reference to Related Application:

The present application is related to U.S. Patent Application Serial No. 08/026,726, entitled "Method and Apparatus for Controlling Access to Selected Image Components In An Image Storage and Retrieval System" filed March 5, 1993, by P. W. Melnychuck and assigned to Kodak, the assignee of the present application.

Technical field Of The Invention

The present invention is related to the field of digital image processing and more particularly to methods and associated apparatuses for adding and removing a digital watermark to and from a selected image resolution and the preventing of unauthorized use of associated higher resolution digital image components.

Background Of The Invention

A number of hierarchical techniques for image coding have been described in the open technical literature and in various patents. Of particular relevance to the present invention are the following publications:

P. J. Burt and E. H. Adelson, "The Laplacian Pyramid As A Compact Code," IEEE Trans. Comm., COM-31, 532-540 (1983).

J. Seberry and J. Pieprzyk, "CRYPTOGRAPHY: An introduction to Computer Security" Prentice Hall, 1988 and the following patents:

U.S. Pat No, 4,969,204 entitled "Hybrid Residual-Based Hierarchical Storage And Display Method For High Resolution Digital Images In A Multiuse Environment," by Paul W. Melnychuck and Paul W. Jones, 1990.

U.S. Pat No, 5,048,111 entitled "Hybrid Subband-Based Hierarchical Storage And Display Method For High Resolution Digital Images In A Multiuse Environment," by Paul W. Jones and Paul W. Melnychuck, 1991.

The publication by Burt, et al. teaches an encoding method for images termed the Laplacian pyramid, the Burt pyramid, or the residual pyramid. In this technique, the original image is lowpass filtered, and this lowpass image is subsampled to take advantage of its reduced bandwidth to provide an image of reduced dimension. This process of lowpass filtering and subsampling is repeated three times to generate a hierarchical structure, or pyramid of images of successively smaller dimensions. The total number of resolution levels are created depending on the application. Each lowpass image in this pyramid is then expanded to the dimensions of the next higher level by upsampling (inserting zeros) and filtering to form a prediction image for that level. This prediction image is subtracted from its corresponding lowpass image in a subtractor to generate difference, or residual, images. The residual images corresponding to the levels of the lowpass pyramid form another pyramid which is termed the Laplacian, Burt, or residual pyramid. This technique is motivated by the fact that the residual images have a reduced variance and entropy compared to the original or lowpass images and may be quantized and entropy encoded to provide efficient storage of the data. Reconstruction is performed by interpolating the decoded lowpass image at the bottom of the lowpass pyramid and adding in the corresponding decoded residual to generate the next level in the lowpass pyramid. This process is iterated until the original image size is reached. A progressive improvement in reconstructed image quality and resolution can thus be obtained by displaying the reconstructed lowpass filtered image at each level of the pyramid. Note that errors introduced in the encoding process are propagated from one level to the next higher level in the decoding process.

The patent to Melnychuck and Jones (U. S. Pat. No. 4,969,204) teaches a modification of the Burt pyramid scheme by extending the lowpass pyramid structure to include one or more lowpass filtered images of successively smaller dimensions beyond the set described by Burt, et al. The advancement in the method of Melnychuck and Jones is that the residual pyramid is not extended to include these corresponding extended smaller dimensions. Hence, the Melnychuck and Jones pyramid contains the Burt pyramid plus additional lowpass filtered images of smaller dimensions. In a hierarchical image storage and retrieval system, the additional lowpass filtered images of smaller dimension can be retrieved directly, without interpolation and addition of residual components. In the context of the present invention, the Melnychuck and Jones pyramid provides for low resolution images that can be used for browsing or proofing. The use of these additional low resolution images for browsing and proofing means that the customer may use a simple retrieval mechanism and need not possess a more complex and hence, more expensive retrieval device that would be used to decode the higher resolution components of the pyramid. Of course, higher resolution images requiring interpolation and residual addition may be used for browsing and proofing as well.

A hierarchical image processing method will be described for the addition and removal of digital watermarks in selected image components, and for the restriction of selected high resolution image components from unauthorized use. An image hierarchy is constructed in the context of a multi-resolution environment whereby the user has the option of selecting the type of display medium and the desired resolution of this display medium. In particular, two types of display media are considered: video monitors and color hard copies, although photographic, thermal imaging, and other types are also of interest. In Fig. 1 a prior art technique for decomposing, storing, recomposing, and displaying, a digital image using a hierarchical process is shown. An original digital image is decomposed to provide image versions at various resolutions to allow for the display of an HDTV quality image on video, an NTSC quality image with PAL/SECAM compatibility on video, one or more sub-NTSC quality images on video for overviews and browsing, and a very high quality image on color hard copy. Intermediate to the decomposition and recomposition steps, generally are inserted an encoding step, to compress the data for storage which in turn requires a decoding step when the data is read from storage.

Summary Of The Invention

The present invention places a digital watermark in a selected image resolution component and the means to remove it in an additional image component termed a watermark removal component. Encryption of the watermark removal component is used to prevent use of the image for the generation of unauthorized high quality color hard copy. A watermark is a form of graphic overlay that may contain a copyright notice or information regarding the restricted use of the image. In a distributed image system it is common to deliver an image of compromised image quality for purposes of browsing or proofing. A compromised rendition of the image is commonly distributed to prevent full utility or fulfillment of the image without proper payment for the service that generated the image. The term browsing refers to the process of image selection from a plurality of images based on some user-defined criterion. Such is the case when a user may select an image from a catalog of images depicting a particular object. The term proofing refers to the process of image selection based on the degree of desirability of a given image from a plurality of images. Such is the case when a professional portrait photographer distributes a plurality of images to a customer for selection and approval. The terms watermark, browsing and proofing described herein are not limited to the examples described above.

Upon selection of the desired image by the customer, the professional delivers a high quality rendition of the image, most often in the form of a high quality color hard copy. At all times the professional possesses the sole means of generating the high quality hard copy. In a conventional photographic system the means would be the original negatives of the images; in a digital hierarchical system according to the present invention, the means are higher resolution residual components.

In a digital imaging system, and in particular one that includes a hierarchical form of digital storage and retrieval, the professional may use a suitable digital storage medium such as a CD for the distribution of proofs. In an unrestricted environment, the customer may choose a desired image resolution from the hierarchy for the purposes of browsing, proofing, or hard copy fulfillment. In those instances where it is desirable for the professional to deliver the digital storage medium containing the entire image hierarchy to the customer, it is also most economical to record the entire image hierarchy once onto the digital storage medium and avoid having to make a second copy containing only low resolution components for distribution. However, it is also desirable to restrict the use of selected high resolution components for the purpose of full image quality fulfillment until payment has been received. The professional may choose to provide low resolution image components for browsing or proofing, while maintaining restriction of the higher resolution components. Alternatively, he may be required to deliver a proof of high resolution. Such is the case when the image content contains information of small detail and the rendition of this detail is subject to approval via the proof. With traditional photographic prints, the professional may place a stamp, or watermark on a strategic location on the print, so as to render the print useless from a fulfillment point of view. Note with digital images that fulfillment may mean high quality video at NTSC/PAL/SECAM, HDTV, or hard copy. In the present invention, the professional places a digital rendition of the watermark on a selected image component. The removal of the watermark is done through an additional image component containing the reverse of the watermark. The customer, having possession of the digital storage medium CD would possess the means for generating his own high quality hard copy when authorized by the professional. Upon payment to the professional, the professional or his agent provides to the customer the information necessary to remove the watermark for full image quality fulfillment. In the present invention, that information would be an authorization code, key, or password that would be inputted to the image processing system accessing the storage medium, to unlock the restricted high resolution components. An advantage of this technique is that the customer may possess all information pertinent to generating high quality hard copy without the need to physically return to the professional for additional image components.

It may additionally be desirable to use some form of hierarchical image representation for the purpose of browsing or proofing in a distributed system because the hierarchy naturally provides a plurality of resolutions, and hence levels of image quality, from which to choose the proof image. No additional operation of compromising the image is necessary; the professional simply chooses at what resolution level(s) he wants to restrict access.

Systems that use a hierarchical structuring of the image data have not been employed in the past for distribution purposes because of the lack of means to simultaneously provide low resolution components for browsing and proofing, while offering restricted access to the remaining hierarchical components for full quality image copy. Additionally, the means to generate and remove a digital watermark in a hierarchical image structure had not been previously considered.

The present invention permits the advantages of hierarchical image decomposition to create a series of residual components, direct retrieval of the additional low resolution images according to the Melnychuck and Jones pyramid, the addition and removal of a digital watermark in a selected image resolution component, and prior art encryption methods applied to the watermark removal component and the residuals, to provide for a system of browsing, proofing and restriction of the high resolution image components suitable in a distributed image system. It is assumed that the residual components and the watermark removal component are symbol encoded using the encoder box 20 in Figures 2 and 4 into a binary string of 1's and 0's either via fixed-length coding techniques (where a binary code word of a fixed-length is assigned to each symbol) or variable-length encoding techniques such as Huffman coding or arithmetic coding. The residual data may also be quantized prior to encoding, or it may be encoded in a lossless manner, i.e., without quantization. Data encryption box 26 is applied to the watermark removal component and if desired, also to the encoded quantized (or non-quantized) residual data. It is assumed that the encryption process is reversible. Hence, the decryption box 28 provides the exact data prior to data encryption.

In one embodiment of the invention a storage medium is called for having stored therein at least one low resolution digital image and at least one high resolution digital image, with said high resolution digital image encoded with a watermark that requires an authorization code for removal.

From the foregoing, it can be seen that it is a primary object of the present invention to provide a method and associated apparatus for storing and controllably retrieving digital images stored in a hierarchical format on a suitable digital storage distribution medium that allows the originator of the distribution medium to distribute the medium containing the entire image hierarchy and a controllably removable watermark for the purpose of retrieving low resolution images for browsing or proofing without compromising the originator's need to withhold the means for creating hard copies of the images without the watermark.

It is another object of the present invention to provide the means for controllably inserting and removing a watermark for a digital image.

It is another object of the present invention to provide the means for compromising a selected image component of a hierarchical formatted digital image by adding a digital watermark to the selected image component, and recording the selected image component containing the watermark as part of the image hierarchy on a digital storage distribution medium.

In association with a digital image, it is another object of the present invention to provide a means for creating a watermark removal component, and for controllably restricting access to the watermark removal component.

It is another object of the present invention to provide a means for affixing a watermark to a digital image and for controllably removing the watermark.

The above and other objects of the present invention will become more apparent when taken in conjunction with the following description and drawings wherein like characters indicate like parts and which drawings form a part of the present description.

Brief Description Of The Drawings

Fig. 1 is a block diagram illustrating the prior art Melnychuck and Jones hierarchical storage and display method.

Fig. 2 is a functional block diagram illustrating a hierarchical image decomposition technique incorporating a watermark insertion into an image component.

Fig. 3 is a functional block diagram illustrating a reconstruction technique for reconstructing the images decomposed by the system of Fig. 2.

Fig. 4 is a functional block diagram of another hierarchical image decomposition technique incorporating a watermark insertion into an image component.

Fig. 5 is a functional block diagram illustrating a reconstruction technique for reconstructing the images decomposed by the system of Fig. 4.

Detailed Description of the Invention

In the following description of the preferred embodiments, it will be assumed that the highest resolution of the image hierarchy is composed of 3072 x 2048 pixels and that this resolution is adequate to produce photographic quality originals on an appropriate digital output device. It is also assumed that a moderately high resolution level of the hierarchy composed of 1536 x 1024 pixels is adequate to generate a high quality HDTV display, or a small-sized photographic quality print on an appropriate digital output device. It is also assumed that the lowest resolution levels of 192 x 128 pixels, 384 x 256 pixels, and 768 x 512 pixels are generated and stored onto a digital storage medium such as a CD. These resolution levels are provided to give the reader an insight as to the operation of one or more embodiments of the invention with the understanding that other resolutions or arrangements may be chosen to suit specific needs without detracting from the teachings of the present invention.

Referring now to Fig. 2, a hierarchical residual decomposition technique, for decomposing a 16BASE original image to form a 16BASE residual, a 4BASE residual, a BASE, a BASE/4, and a BASE/16 image, incorporating the teachings found substantially in Fig. 7 of the patent to Melnychuck and Jones (U. S. Pat. No. 4,969,204), in combination with the present invention is shown. The BASE image is processed in box 34 to incorporate a watermark and to provide a watermarked BASE image.

An example of a watermark insertion box 34 is given by the watermark insertion unit 22 whereby a watermark image *W* is combined with the input image *I* to create a watermarked image I_W. In this example, it is assumed that the input image *I* and the watermark image *W* are of the same size and the same bit-depth. For example, if the input image *I* is an 8-bit image representing the luminance component of a color image, the watermark image *W* would also be an 8-bit image. Similarly, the watermarked image I_W would have the same size and each pixel value would be represented with 8 bits. An example of a watermark insertion unit 22 is one where the input image *I* and the watermark image *W* are combined according to the following equation to create the watermarked image I_W.

$$I_W(i,j) = I(i,j) + \alpha W(i,j)$$

Where (i,j) denotes the two-dimensional location of the pixels in the image and the operation is performed for all the pixels in the input image. The watermark image *W* is prepared by the originator of the storage medium and may contain the logo of the originator or any other pattern that the originator may wish to use as a watermark. The parameter α, which can be either positive or negative, controls the watermark contrast and is also selected by the originator and can vary from one image to another. Larger magnitudes of α would, in general, create a higher contrast watermark. Also, to guarantee that the watermarked image I_W has the same bit-depth as the input image *I*, the watermarked image I_W is clipped to the same range as the input image. For example, for an 8-bit image with pixel values in the range of 0 to 255, for every pixel location (i,j), the value of $I_W(i,j)$ is clipped to 255 if the result of the above equation exceeds 255 and is set to zero if that result is less than zero. It should be noted that this example illustrates only one method of implementing the watermark insertion box 34 and the originator of the storage medium may incorporate any other method to generate a watermark that creates the desired effect of inhibiting the use of the image.

The BASE/16, BASE/4, and watermarked BASE images are stored on the digital storage medium 10 in direct (unencrypted) form. The BASE image, which in this case serves as the watermark removal record, is encrypted in the data encryption unit 26. The data encryption unit 26 consists of either a private-key data encryption algorithm (also referred to as symmetric data encryption algorithm) or a public-key data encryption algorithm (also referred to as asymmetric data encryption algorithm) both of which have been explained in the prior art and in the reference book by Seberry and Pieprzyk cited before. Examples of private-key encryption algorithms that can be used in the data encryption unit 26 are either block ciphers such as the Data Encryption Standard (DES) which uses a 56-bit key and operates on blocks of data of length 64 bits at a time, or a stream cipher algorithm such as RC-4, a commercially available encryption software that uses a 40-bit key component. The encrypted BASE image is also stored on the storage medium 10. The 4BASE and 16BASE residual components are also stored on the digital storage medium 10 either in direct (unencrypted) form or in encrypted form depending on the level of security desired by the application. In the case that the encryption of any or all of the residual data are needed, either the same key used in encrypting the BASE image is used or a separate key is used. The use of multiple encryption keys provides the originator of the storage medium with more flexibility in controlling the access to the various resolutions of the image hierarchy.

For browsing or proofing, a procedure illustrated by Fig. 3 is employed. A user retrieves the BASE/16, BASE/4, or watermarked BASE image directly without decryption from the digital storage medium 10. Upon authorization, the user inputs a decryption key(s) to the data decryption unit 28 to allow the decryption of the original BASE image (and the residuals) to be performed. An example of a data decryption unit 28 is a software implementation of a decryption algorithm corresponding to the reverse operation of the encryption algorithm employed in the data encryption unit 26. One example of a set of encryption/decryption algorithms is the Data Encryption Standard (DES) which has been explained in full detail in the reference book by Seberry *et al* mentioned before. Note that the decryption key(s) must be provided by the originator of the storage medium. Upon the decryption of the BASE image and the residual components, these components can be used to arrive at full image quality fulfillment.

In a second embodiment, illustrated in Fig. 4, the 16BASE image is decomposed by decomposition apparatus 101 into a residual pyramid consisting of the 16BASE, 4BASE, and BASE. The BASE image is further decomposed to create the BASE/4 and BASE/16 images, through low pass filtering and subsampling. BASE /4 and BASE/16 are not part of the residual pyramid and hence they are available directly for display on a monitor.

A watermark, as described in the previous embodiment in Fig. 2, is inserted in the BASE image in box 34 to arrive at a watermarked BASE image. This watermarked BASE image is then interpolated to the size of the 4BASE image using linear interpolation as indicated by the interpolator box 24. A difference is formed in subtractor 32 between the original 4BASE image and the interpolated watermarked BASE image to form a modified 4BASE residual that serves as the watermark removal record. The difference in this embodiment versus the first embodiment is that the watermark removal record is the modified 4BASE residual instead of the BASE image. This modified 4BASE residual is encrypted using the data encryption unit 26 as described before and is then stored on the storage media 10 along with the BASE/16, BASE/4, and watermarked BASE image in direct (unencrypted) form. Finally, the 16BASE residual data is stored on the digital storage medium either in direct or encrypted form depending on the application.

For browsing or proofing, the system of Fig. 5 is employed. The user retrieves the BASE/16, BASE/4, or watermarked BASE image directly without decryption from the digital storage medium 10. Upon authorization, the user inputs the decryption key to the data decryption unit 28 to allow the decryption to be performed to generate the modified 4BASE residual. The watermarked BASE image is interpolated using linear interpolation and is added to the decrypted modified 4BASE residual in the reconstruction apparatus 210 to recover the original 4BASE image. If the residuals have not been quantized, the 4BASE image can be exactly recovered. In the case where the residuals have been quantized, some discrepancy between the original 4BASE image and the 4BASE image recovered according to the above scheme would exist. The degree of this discrepancy would depend on the coarseness of the quantizer employed in the quantization of the residual components. Note that the decryption key must be provided by the originator of the storage medium.

It is to be understood that in some instances it may be desirable to place a watermark upon the low resolution images to control their access.

While there has been shown what are considered to be the preferred embodiments of the invention, it will be manifest that many changes and modifications may be made therein without departing from the essential spirit of the invention. It is intended, therefore, in the annexed claims, to cover all such changes and modifications as may fall within the scope of the invention.

Parts List:

10	Digital storage medium (CD-Disc)
20	Encoder
22	Watermark insertion unit
24	Interpolator
26	Data encryption unit
28	Data decryption unit
30	Decoder
32	Subtractor
34	Watermark insertion box
101	Decomposition apparatus
201	Reconstruction apparatus

Claims

1. A storage medium having stored therein at least one low resolution digital image and at least one high resolution digital image, with said high resolution digital image encoded with a watermark that requires an authorization code for removal.

2. The storage medium according to claim 1 and further having stored thereon at least one additional high resolution digital image that is not encoded with a watermark and is accessed with the authorization code in place of the high resolution digital image encoded with the watermark.

3. A storage medium having stored therein at least one low resolution digital image and at least one high resolution digital image in the form of a BASE image, residual image components and a watermark component, with said low resolution digital image, said BASE image or said high resolution image formed by the combination of the BASE image with said residual image components and a watermark component being accessible without an authorization code.

4. The storage medium of claim 3 in combination with an authorization code to remove the watermark component from an accessed high resolution image.

5. A system for controlling the uncompromised use of a high resolution digital image stored on a storage medium as BASE and residual components, comprising:

means for encrypting the residual components stored on said storage medium using a watermark code;

means for accessing the BASE and encrypted residual components;

means for combining the accessed BASE and residual components to reconstruct the high resolution digital image with the watermark code; and

means for authorizing the removal of the watermark code.

6. A system for controlling the uncompromised use of a high resolution digital image comprising:

means for forming a hierarchy of lower resolution digital images from the high resolution digital image;

means for forming residual images that are a function of differences between adjacent images in the hierarchy of lower resolution digital images;

means for encrypting at least one of the formed residual images with a watermark code;

storage means for storing the formed hierarchy of lower resolution images and the at least one encrypted residual image;

means for reconstructing high resolution images by accessing and combining a lower resolution image with a residual image;

means for displaying of the at least one encrypted residual image with the watermark; and

means for controllably removing the watermark code to permit an uncompromised use of the high resolution digital image.

7. A recording medium having stored thereon a plurality of digital images with each of the digital images being comprised of a low resolution digital image component and at least one residual digital image component which is combinable with the low resolution digital image component to form a higher resolution digital image incorporating a watermark which is removable with an authorization code.

8. A method for controlling the use of a digital image stored on a storage medium in a hierarchical form comprised of a BASE image and at least one residual image component, comprising the steps of:

a) associating a watermark with said at least one residual image component;

b) permitting access to the BASE image for low resolution viewing of the digital image;

c) combining the BASE image with the at least one residual image component and an associated watermark to form the digital image for viewing, printing and/or storing; and

d) controllably providing a watermark removal code to remove the watermark from the formed digital image of step c.

9) A storage medium having stored thereon at least one digital image encoded with a watermark that requires an authorization code for removal.

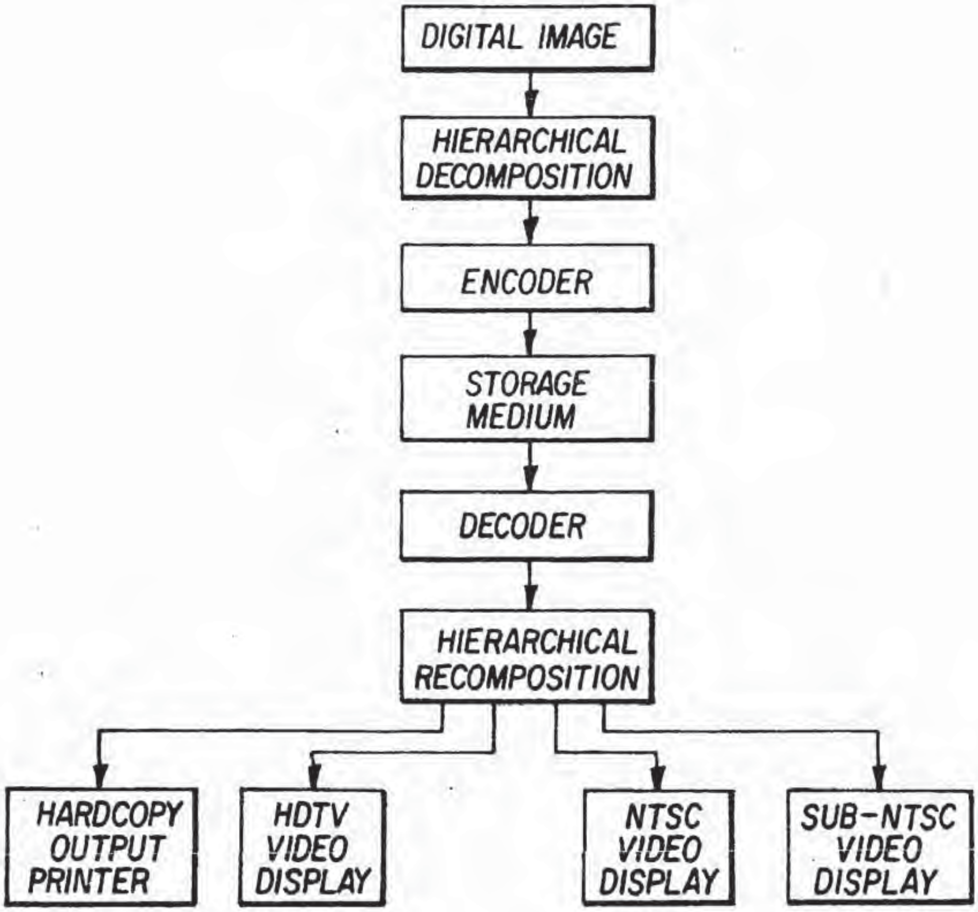


FIG. 1
(prior art)

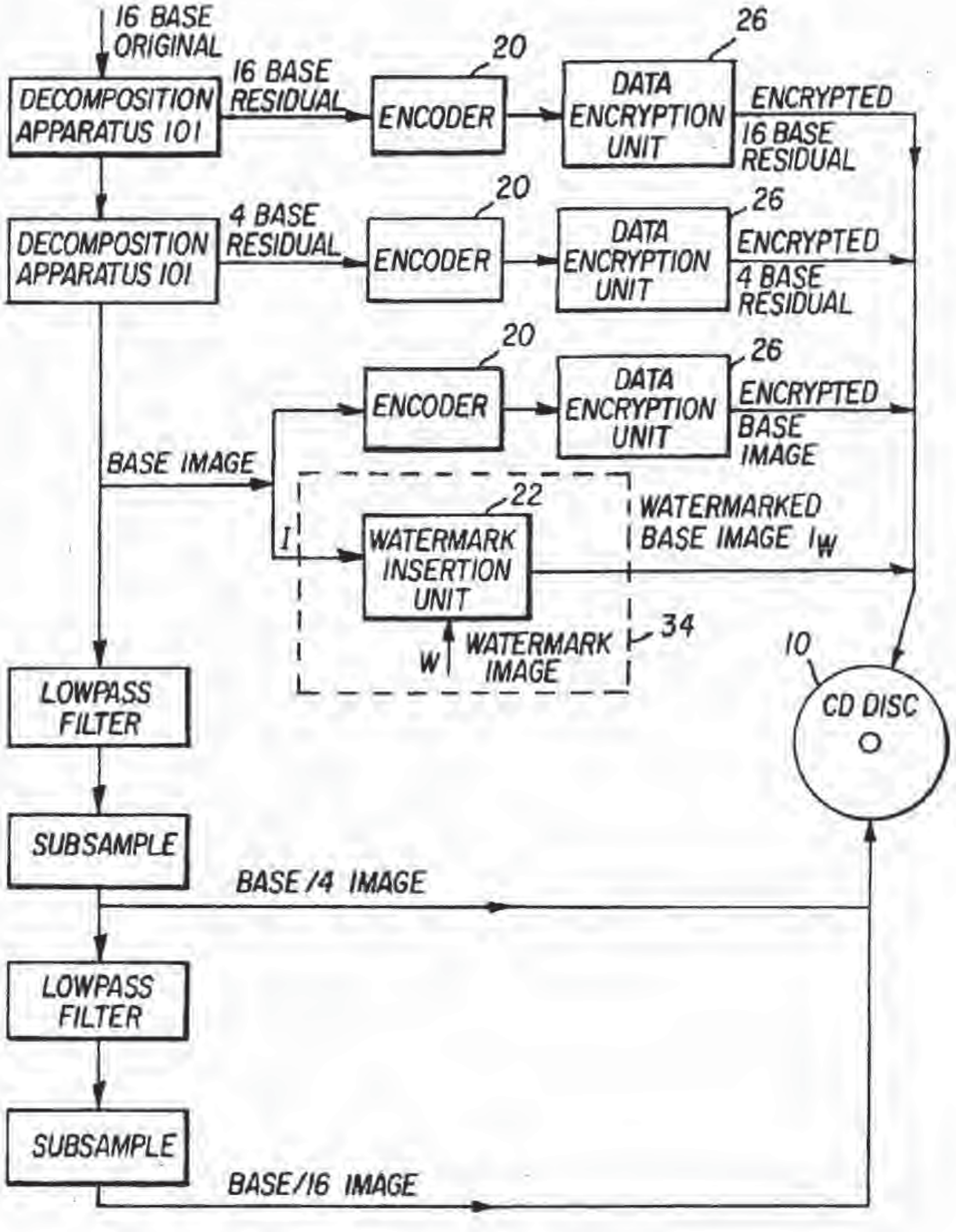

16 BASE ORIGINAL
DECOMPOSITION APPARATUS 101
16 BASE RESIDUAL
20
ENCODER
26
DATA ENCRYPTION UNIT
ENCRYPTED 16 BASE RESIDUAL
DECOMPOSITION APPARATUS 101
4 BASE RESIDUAL
20
ENCODER
26
DATA ENCRYPTION UNIT
ENCRYPTED 4 BASE RESIDUAL
20
ENCODER
26
DATA ENCRYPTION UNIT
ENCRYPTED BASE IMAGE
BASE IMAGE
22
I
WATERMARK INSERTION UNIT
WATERMARKED BASE IMAGE I_W
W
WATERMARK IMAGE
34
10
CD DISC
LOWPASS FILTER
SUBSAMPLE
BASE /4 IMAGE
LOWPASS FILTER
SUBSAMPLE
BASE/16 IMAGE

FIG. 2

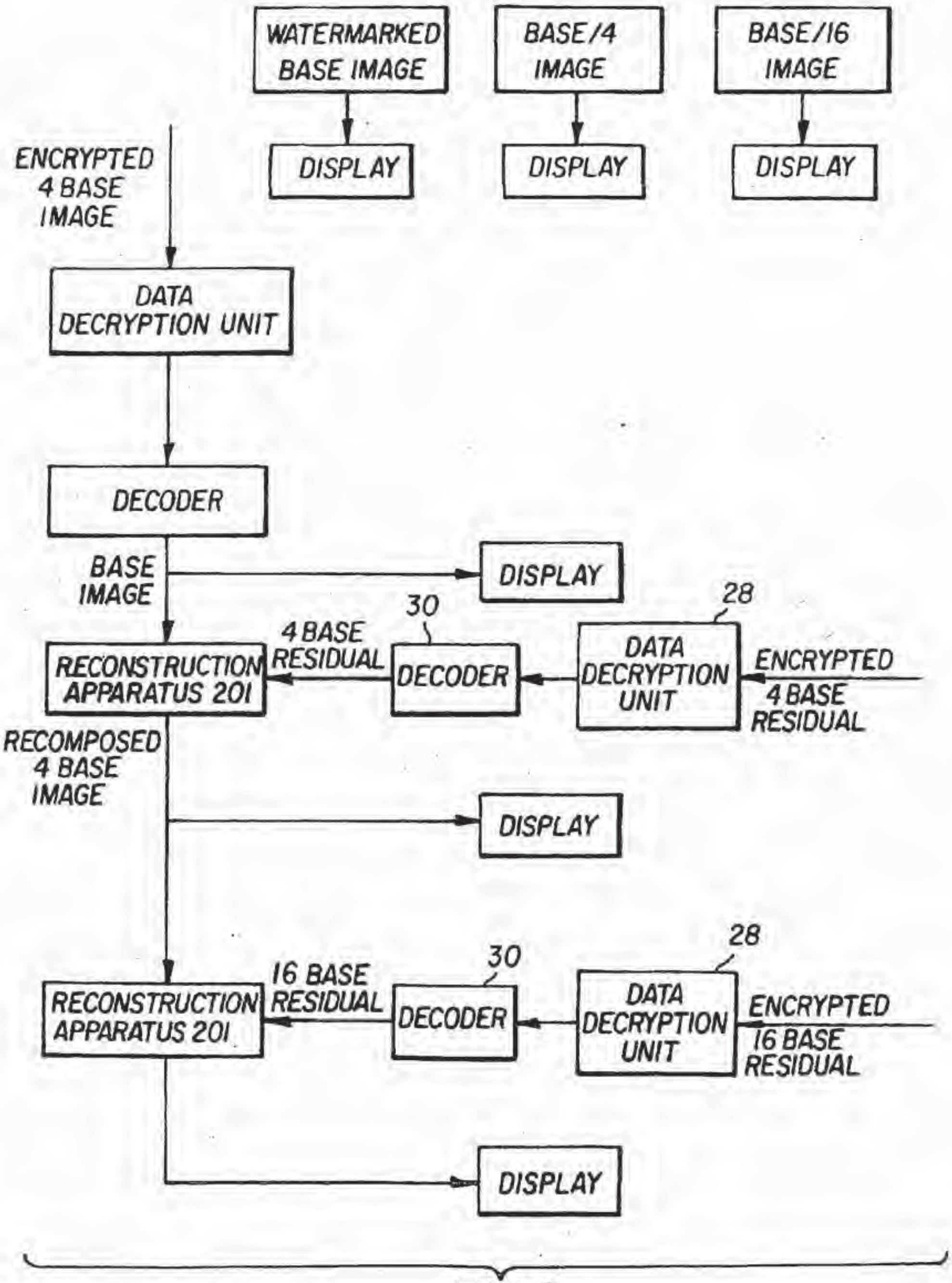

WATERMARKED BASE IMAGE
BASE/4 IMAGE
BASE/16 IMAGE
DISPLAY
DISPLAY
DISPLAY
ENCRYPTED 4 BASE IMAGE
DATA DECRYPTION UNIT
DECODER
BASE IMAGE
DISPLAY
30
28
4 BASE RESIDUAL
RECONSTRUCTION APPARATUS 201
DECODER
DATA DECRYPTION UNIT
ENCRYPTED 4 BASE RESIDUAL
RECOMPOSED 4 BASE IMAGE
DISPLAY
28
30
16 BASE RESIDUAL
RECONSTRUCTION APPARATUS 201
DECODER
DATA DECRYPTION UNIT
ENCRYPTED 16 BASE RESIDUAL
DISPLAY

FIG. 3

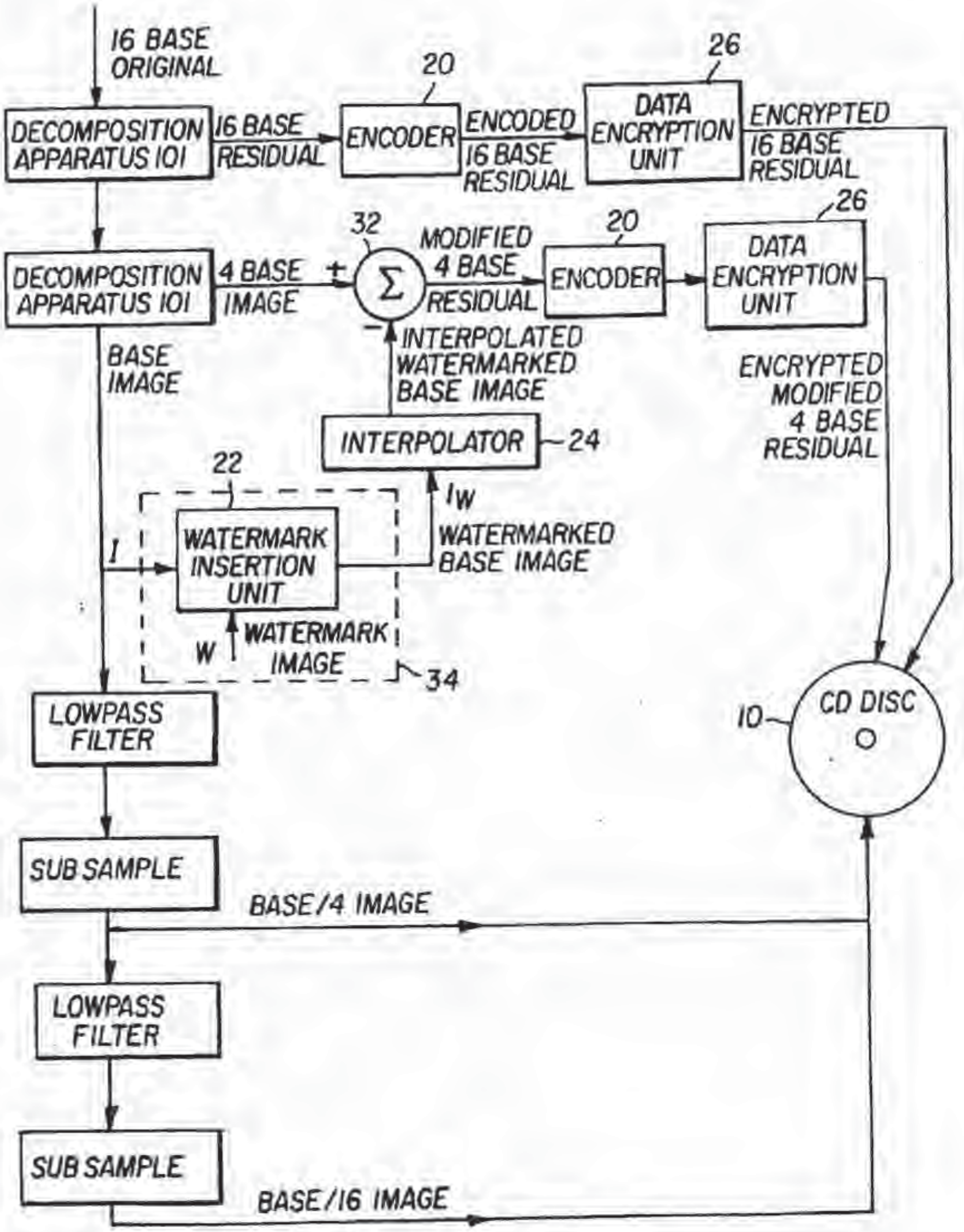

16 BASE
ORIGINAL
DECOMPOSITION
APPARATUS 101
16 BASE
RESIDUAL
20
ENCODER
ENCODED
16 BASE
RESIDUAL
26
DATA
ENCRYPTION
UNIT
ENCRYPTED
16 BASE
RESIDUAL
DECOMPOSITION
APPARATUS 101
4 BASE
IMAGE
+
32
Σ
−
MODIFIED
4 BASE
RESIDUAL
20
ENCODER
26
DATA
ENCRYPTION
UNIT
BASE
IMAGE
INTERPOLATED
WATERMARKED
BASE IMAGE
ENCRYPTED
MODIFIED
4 BASE
RESIDUAL
INTERPOLATOR
24
22
I
WATERMARK
INSERTION
UNIT
I_W
WATERMARKED
BASE IMAGE
W
WATERMARK
IMAGE
34
LOWPASS
FILTER
10
CD DISC
SUB SAMPLE
BASE/4 IMAGE
LOWPASS
FILTER
SUB SAMPLE
BASE/16 IMAGE

FIG. 4

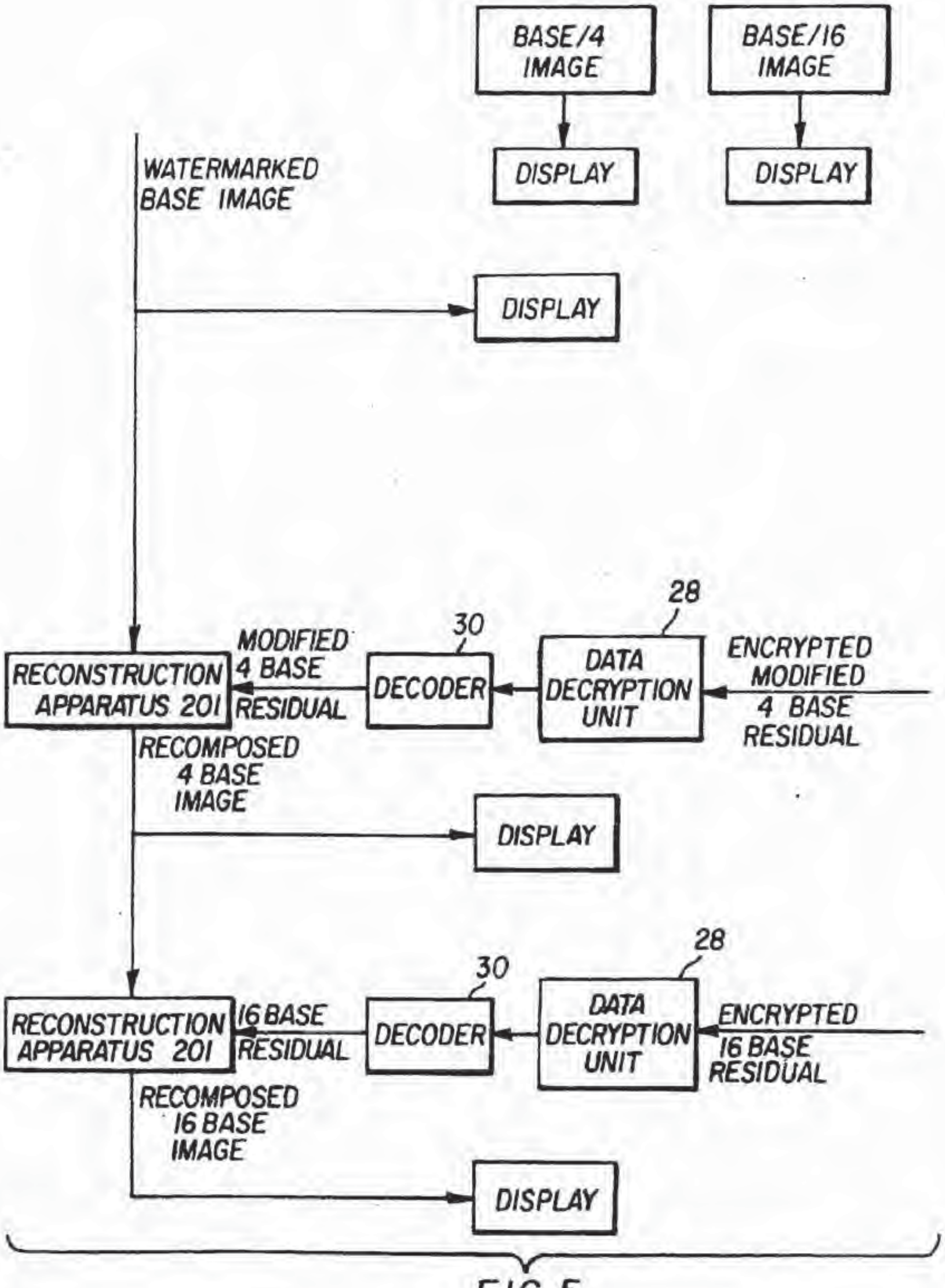

BASE/4 IMAGE
BASE/16 IMAGE
DISPLAY
DISPLAY
WATERMARKED BASE IMAGE
DISPLAY
28
30
MODIFIED 4 BASE RESIDUAL
RECONSTRUCTION APPARATUS 201
DECODER
DATA DECRYPTION UNIT
ENCRYPTED MODIFIED 4 BASE RESIDUAL
RECOMPOSED 4 BASE IMAGE
DISPLAY
28
30
RECONSTRUCTION APPARATUS 201
16 BASE RESIDUAL
DECODER
DATA DECRYPTION UNIT
ENCRYPTED 16 BASE RESIDUAL
RECOMPOSED 16 BASE IMAGE
DISPLAY

FIG. 5

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 94 42 0293

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
D,Y	US-A-4 696 204 (MELNYCHUCK ET AL) * the whole document * ---	1-9	H04N1/21 G06F1/00
Y	ELECTRONICS AND COMMUNICATIONS IN JAPAN, vol.73, no.5, May 1990, NEW YORK, US; pages 22 - 33 N.KOMATSU ET AL 'A Proposal on Digital Watermark in Document Image Communication and Its Application to Realizing a Digital Signature' * figures 1-5 * * page 22, left column, line 1 - page 27, left column, line 23 * ---	1-9	
P,Y	EP-A-0 614 308 (EASTMAN KODAK) * abstract; figure 2 * * column 4, line 52 - column 5, line 4 * -----	2	
			TECHNICAL FIELDS SEARCHED (Int.Cl.6)
			H04N G06F

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	30 January 1995	Powell, D

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

EPO FORM 1503 03.82 (P04C01)

PCT

WORLD INTELLECTUAL PROPERTY ORGANIZATION
International Bureau

INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification ^{6} **:**
G09C 5/00, H04L 9/00

A1

(11) International Publication Number: WO 99/62044

(43) International Publication Date: 2 December 1999 (02.12.99)

(21) International Application Number: PCT/US99/09417

(22) International Filing Date: 30 April 1999 (30.04.99)

(30) Priority Data:
09/085,147 26 May 1998 (26.05.98) US

(71) Applicant *(for all designated States except US)*: THE REGENTS OF THE UNIVERSITY OF CALIFORNIA [US/US]; Business & Patent Law, Mail Stop D412, Los Alamos, NM 87545 (US).

(72) Inventors; and
(75) Inventors/Applicants *(for US only)*: SANDFORD, Maxell, T., II. [US/US]; 160 Monte Rey S., Los Alamos, NM 87544 (US). HANDEL, Theodore, G. [US/US]; 316 Bryce Avenue, Los Alamos, NM 87544 (US).

(74) Agent: WYRICK, Milton, D.; Los Alamos National Laboratory, Mail Stop D412, Los Alamos, NM 87545 (US).

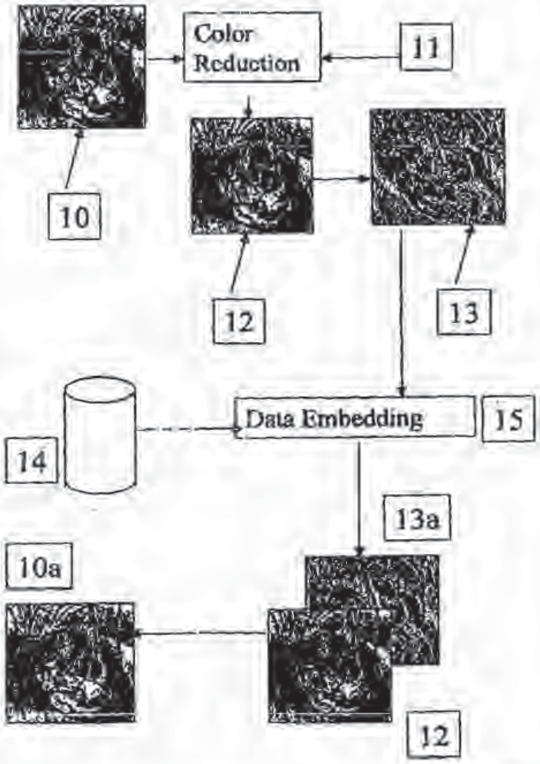
(81) Designated States: AE, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, DE, DK, EE, ES, FI, GB, GE, GH, GM, HR, HU, ID, IL, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, UA, UG, US, UZ, VN, YU, ZA, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SL, SZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

Published
With international search report.

(54) Title: REFERENCE PALETTE EMBEDDING

(57) Abstract

A method of embedding auxiliary information (14) into the digital representation of publication quality color-component digital data (10). The method applies to all digital data for which individual values are represented by discrete numerical values, and for which a corresponding approximation known as a digital reference palette image (12) can be made in terms of a lesser number of discrete digital data values. The invention creates an intermediate, digital, color-component difference image (13) that allows steganographic methods (15) to hide or embed (15) the auxiliary data (14). The invention secures the auxiliary data (14) from detection and from unauthorized removal or use by means of the digital reference palette image and a steganographic key. By a substantially reverse process, the embedded auxiliary data can be an authorized user. The invention provides for a means to combine a removable, visible digital watermark with publication quality digital image data.



FOR THE PURPOSES OF INFORMATION ONLY

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AL	Albania	ES	Spain	LS	Lesotho	SI	Slovenia
AM	Armenia	FI	Finland	LT	Lithuania	SK	Slovakia
AT	Austria	FR	France	LU	Luxembourg	SN	Senegal
AU	Australia	GA	Gabon	LV	Latvia	SZ	Swaziland
AZ	Azerbaijan	GB	United Kingdom	MC	Monaco	TD	Chad
BA	Bosnia and Herzegovina	GE	Georgia	MD	Republic of Moldova	TG	Togo
BB	Barbados	GH	Ghana	MG	Madagascar	TJ	Tajikistan
BE	Belgium	GN	Guinea	MK	The former Yugoslav	TM	Turkmenistan
BF	Burkina Faso	GR	Greece		Republic of Macedonia	TR	Turkey
BG	Bulgaria	HU	Hungary	ML	Mali	TT	Trinidad and Tobago
BJ	Benin	IE	Ireland	MN	Mongolia	UA	Ukraine
BR	Brazil	IL	Israel	MR	Mauritania	UG	Uganda
BY	Belarus	IS	Iceland	MW	Malawi	US	United States of America
CA	Canada	IT	Italy	MX	Mexico	UZ	Uzbekistan
CF	Central African Republic	JP	Japan	NE	Niger	VN	Viet Nam
CG	Congo	KE	Kenya	NL	Netherlands	YU	Yugoslavia
CH	Switzerland	KG	Kyrgyzstan	NO	Norway	ZW	Zimbabwe
CI	Côte d'Ivoire	KP	Democratic People's	NZ	New Zealand		
CM	Cameroon		Republic of Korea	PL	Poland		
CN	China	KR	Republic of Korea	PT	Portugal		
CU	Cuba	KZ	Kazakstan	RO	Romania		
CZ	Czech Republic	LC	Saint Lucia	RU	Russian Federation		
DE	Germany	LI	Liechtenstein	SD	Sudan		
DK	Denmark	LK	Sri Lanka	SE	Sweden		
EE	Estonia	LR	Liberia	SG	Singapore		

REFERENCE PALETTE EMBEDDING

FIELD OF THE INVENTION

The present invention generally relates to digital manipulation of numerical data. More specifically, the invention relates to the embedding of large amounts of external data into the numerical values used to represent a publication quality digital image without altering the appearance of the digital image. This invention was made with Government support under Contract No. W-7405-ENG-36 awarded by the U.S. Department of Energy. The Government has certain rights in the invention.

Many digital representations of image data have resolutions in intensity and color range greater than is required to represent the meaningful content of the information. Digital representations of publication quality images are ordinarily in Truecolor format using eight or more binary bits of information, for each of the three primary colors (red, green, and blue), for a total of at least 24-bit resolution. An alternative publication quality format for digital images uses primary color complements (cyan, yellow, and magenta), and black to represent the image information. The publication quality of Truecolor digital images insures that the all the information necessary to reproduce the original image in print is present in the alternative electronic form. Truecolor digital images are most often the first-generation image data produced by sensors in scanners or electronic cameras capable of recording the highest quality images.

In many situations, fewer than 24 bits resolve an image adequately to convey its meaning and content. Color reduction methods analyze a Truecolor image to determine a smaller number of colors that can be used to reproduce an approximation to the original publication quality image. Color reductions to 256 or fewer colors are used commonly for digital images intended for display in electronic documents or via the Internet worldwide web (www). Images stored in the Compuserve™ Graphics Interchange Format (GIF), the MICROSOFT® Windows Bitmap™ (BMP), and tagged-image file format (TIFF) formats often use a 256-color palette. The color-reduced palette requires 8-bits per picture element (pixel) to approximate the original 24-bits per pixel Truecolor values.

Reference palette embedding is a new steganographic method for manipulating the information in a 24-bits per pixel Truecolor host image, in order to insert auxiliary data with less error than is caused by methods that replace directly some of the 24-bits with the auxiliary data. Reference palette embedding as taught here provides invisibility of the auxiliary information, in comparison with the method disclosed in U.S. Patent number 5,686,782 issued August 19, 1996 for DATA EMBEDDING, which is included herein by reference for all purposes.

The reference palette embedding invention guarantees that the auxiliary information placed into the image affects only the parts of the Truecolor image that are redundant, and therefore unnecessary for representing the image content. Methods that manipulate the picture element (pixel) values directly by either the methods taught in the aforementioned DATA EMBEDDING patent, or

by the methods taught in U.S. Patent Application Serial No. 08/646,837 filed May 8, 1996, for MODULAR ERROR EMBEDDING, also included herein by reference for all purposes, modify significantly the bit values within the image pixel. Hereinafter, the teachings of the above-described U.S. Patent and the above-described U.S. Patent Application will be referred to as DATA EMBEDDING process and MODULAR ERROR EMBEDDING process, respectively. These alternative steganographic methods necessarily affect the image content to some degree. The present invention, reference palette embedding, utilizes a color-reduced version of the Truecolor image as a template to ensure that the embedding process affects the image quality as little as is possible.

Reference palette embedding uses and extends the DATA EMBEDDING process as taught in the above-mentioned US patent. As disclosed in the DATA EMBEDDING patent, the auxiliary data are embedded in a manner that manipulates the noise component of the host data, and that does not modify directly any host data values. In reference palette embedding, as taught herein, the auxiliary data are embedded into the difference between the original Truecolor image, and a color-reduced version of the original image.

The color-reduced image and the digital key taught in the DATA EMBEDDING patent combine to permit the construction of the auxiliary data from the modified Truecolor image.

Data embedded into the host image with the present reference palette embedding invention are recovered by processing the digital image in machine readable, digital form. Human readable versions of images containing auxiliary data, for example images displayed on a screen or printed from the digital data, cannot be processed to recover the embedded information. In a preferred embodiment of the subject invention, the auxiliary data are compressed and encrypted before beginning the reference palette embedding process, in order to randomize the auxiliary bits, and to minimize the effect of the auxiliary data on the difference between the Truecolor and color-palette images.

It is therefore an object of the present invention to provide apparatus and method for embedding data into a digital information stream so that the meaning and content of the digital information stream is not changed significantly.

It is another object of the present invention to provide apparatus and method for concealing auxiliary data within a digital information stream so that the presence of the auxiliary data is not discernible in the digital information stream.

It is yet another object of the present invention to provide apparatus and method for reducing the error caused by the added information, and for thwarting unauthorized access to the auxiliary data embedded into digital information stream.

It is still another object of the present invention to provide apparatus and method for allowing authorized construction of embedded auxiliary data from a digital information stream.

Additional objects, advantages, and novel features of the invention will be set forth in part in the description which follows, and in part will become apparent to those skilled in the art upon examination of the following, or learned by practice of the invention. The objects and advantages of the following, or learned by practice of the invention.

The objects and advantages of the invention may be realized and attained by means of the instrumentalities and combinations particularly pointed out in the appended claims.

SUMMARY OF THE INVENTION

In accordance with the purposes of the present invention there is provided a method of embedding auxiliary data into publication quality digital image data represented by a quantity of color-component values for each picture element comprising the steps of reducing the quantity of color-component values of the publication quality digital image data to create a digital reference palette, wherein the digital color palette represents the quantity of color-component values of the publication quality digital image data; creating a digital representation of the auxiliary data as a sequence of individual bit values; creating a color-component digital difference image by numerically combining the publication quality digital image with the digital reference palette image; modifying the color-component digital difference image by combining the auxiliary data and the color-component digital difference image through use of a data embedding method; creating a modified publication quality digital image indiscernibly containing the auxiliary data by combining the modified color-component digital difference image and the digital reference palette image; and outputting the modified publication quality digital image into a file format specified for the modified publication quality digital image.

In a still further aspect of the present invention, and in accordance with its objects and purposes, a method of constructing indiscernible auxiliary data from a machine readable publication quality digital image representation of unrelated and uncorrelated data comprising the steps of generating a digital reference palette image from values and properties contained within the publication quality digital image; creating a color-component digital difference image by numerically combining the digital reference palette image and the publication quality digital image; constructing the auxiliary data by processing the color-component digital difference image with a data embedding construction method; interpreting the auxiliary data in order to obtain or remove content, validation or

authentication, or otherwise process the publication quality digital image in order to modify its quality.

BRIEF DESCRIPTION OF THE DRAWINGS

The accompanying drawings, which are incorporated in and form a part of the specification, illustrate the embodiments of the present invention and, together with the description, serve to explain the principles of the invention. In the drawings:

FIGURE 1 is a diagram illustrating the reference palette sequence of calculations.

FIGURE 2 is a partial listing of computer code used for calculating the biased difference image color-component values.

FIGURE 3 is a partial listing of computer code used for calculating modified Truecolor image pixel color-component values.

FIGURE 4 is a diagram illustrating the sequence of calculation for constructing auxiliary data from a modified Truecolor image.

FIGURE 5 is a partial listing of computer code used for constructing modified difference color-component values.

DETAILED DESCRIPTION

The present invention allows auxiliary data to be embedded into a digital Truecolor host image with less error than is caused by modifying the pixel color-components directly. The reduction in error follows from the technique of of the present invention of embedding auxiliary data into the pixel color-component values constructed from the difference between the Truecolor host image and a reference palette image, which has been constructed from the Truecolor host image. The invention can be understood most easily through reference to the drawings.

Refer to Figure 1 for an illustration of the process of the present invention. The images in Figure 1 are printed digital images, and are not copies of photographs. Publication quality digital image data 10, such as a Truecolor-format image is approximated or reduced by one of several commonly known color-reduction methods 11 to produce a palette-format image 12. The palette-format image 12 is denoted hereinafter as reference palette image 12. The palette colors of reference palette image 12 are subtracted from the Truecolor pixel color values of publication quality digital image 10 to create a difference image 13. The difference-image 13 pixel values measure directly the accuracy of the color-reduction method. Auxiliary data 14 are taken as bits from a data source and input to data embedding processor 15, which may contain the DATA EMBEDDING process, the MODULAR ERROR EMBEDDING process, or any other effective steganographic method for combining auxiliary data 14 with difference image 13. A new difference image 13a is created by data embedding processor 15. The color values of the pixels in the new difference image 13a are added to reference palette image 12, and produce a new, modified publication quality digital image 10a, containing auxiliary data 14.

Examples of appropriate publication quality Truecolor format publication quality digital image data 10 include, but are not limited to, publication quality television or motion picture images, X-ray or Magnetic Resonance Imaging data, digital camera images, and personal security and identification data. Other examples of publication quality digital image data 10 include black and white images containing a range of digital levels of brightness, and digitized analog audio signals. For digitized audio signals, a reduced-quality version of the digitized analog audio signals serves as the reference palette 12.

If the steganographic method used in data embedding processor 15 is bitslicing or the above-mentioned MODULAR ERROR EMBEDDING process, the first embodiment of the present invention is implemented. If the steganographic method used in DATA EMBEDDING processor 15 is the above-mentioned DATA EMBEDDING process, the second embodiment of the present invention is implemented.

The difference image 13 is a Truecolor image, and negative pixel values are not permitted. Hence, the difference D between the Truecolor and pallet-color pixel colors is biased in the positive direction, in order to represent the difference as a positive number within the range 0-255 permitted for an 8-bit Truecolor-format image. The difference value is restricted to the range ±127, in order that the biased value remain within the 8-bit range. Pixels that are found to contain differences larger in absolute value than 127 are flagged, in order that the invention can place the original Truecolor value in modified image 10a. Flagged pixels are not used by the invention. Figure 2 is a partial listing of computer code in the C++ language that is used for calculating the biased difference image color-component values. Figure 2 contains two nested loops starting at line 5, over the number of rows in the image, and at line 13, over the number of columns in a row.

The biased color differences are placed into a memory buffer named **buffer**. Data from a row of Truecolor image pixels are placed into a memory buffer named **bufftc** in line 7. The **TCFile** object is an instance of the MICROSOFT® MFC **CFile::** class that accesses the bitmap-format Truecolor image. Data from the picture row in the palette-format image is read into a memory buffer named **buffpal**, from the **CFile::** object named **tape7** at line 10, in Figure 2.

The loop over the columns in the image row that begins at line 13 in Figure 2 processes the buffered pixel data. The three color-components in the Truecolor image pixel are processed sequentially within this loop. The index **k** contains the palette-format pixel value. The palette-format pixel colors are accessed by **k**, into the **colormap[]** array. The Truecolor pixel colors are accessed directly with offsets into the **bufftc** memory buffer. Color differences having a the value 255 are not used in data embedding processor 15. The biased color differences are **b_diff**, **g_diff**, and **r_diff** calculated at lines 17, 21, and 25. The differences are set to a limiting value (255) if the palette color values are greater than the arbitrary value of 250, i.e. the colors are near the top of their color ranges. The biased color differences are tested for range at lines 35, 41, and 47 in Figure 2. If the biased difference does not fit into the range 0-255 that is allowed by an 8-bit unsigned character, the difference buffer is set to a flag value (0x01). Color differences that were set to the limiting value are flagged in this process. The color difference **buffer** becomes the output row in the Truecolor difference image.

Returning to Figure 1, the completed color difference image 13 is combined with auxiliary data 14 by means of data embedding processor 15. In data embedding processor 15 this combination can be accomplished through use of bitslicing techniques, the above-mentioned MODULAR ERROR EMBEDDING process, the above-mentioned DATA EMBEDDING process, or any other effective steganographic algorithm. The color difference image 13 is combined with reference palette image 12 to produce a new, modified Truecolor image 10a.

Figure 3 is a partial listing of computer code used for calculating biased difference Truecolor-image-pixel color-component values. Two nested loops begin at line 5 and line 12 in Figure 3. The output buffer for the new, modified Truecolor image pixel row is named **buffer**. The difference image pixels are read into a memory buffer named **bufftc** at line 7, from the **CFile::** object named **tape6**. The palette-format pixel values are read into a buffer named **buffpal**, from the **CFile::** object named tape7, at line 10.

Construction of the new Truecolor image pixel row proceeds in the loop over image columns that starts at line 12. The output **buffer** is filled with the new color-value data. The statements contained in lines 14 through 16 of Figure 3 process the first row of pixels differently, because the first image row is used to hold the key for the DATA EMBEDDING process. Processing the first row of pixels differently than the rest of the image is not part of the present reference palette embedding invention.

The new Truecolor color-component values are calculated in lines 19, 20, and 21, in Figure 3. Pixels in the difference image that contained flagged values are calculated incorrectly in this loop. The output buffer offsets are set directly to the new color difference values, and the row of pixels is written to the new Truecolor image using the **tape8** file object.

The **tape8** image file object is post-processed to replace the flagged pixels with the original Truecolor color-data pixel values. The flagged pixels, i.e. pixels that were not used to contain auxiliary data 14 (Figure 1), therefore appear without modification in the new Truecolor image 10a (Figure 1).

Constructing (recovering) auxiliary data 14 from new Truecolor image 10a requires the exact reference palette image 12 format version of original Truecolor image 10, and the information necessary to construct auxiliary data 14 from new difference image 13a. Figure 4 is a diagram illustrating the sequence of calculation for constructing auxiliary data 14 from a modified Truecolor image 10a. As in Figure 1, the images in Figure 4 are printed digital images, and are not copies of photographs.

The coding to construct auxiliary data 14, according to the process illustrated in Figure 4, is shown in Figure 5. The color difference image 13a is calculated from modified Truecolor image 10a and the reference palette image 12. The digital key is used with the data construction processor 15a to construct auxiliary data 14. The method named **MakeDifferenceFile()** is executed at line 1 in Figure 5. The **MakeDifferenceFile()** method implements the calculation shown in Figure 2. The **OpenBitmapFile()** method executed at line 3 prepares the difference image 13a for processing by either the above-mentioned MODULAR ERROR EMBEDDING data construction process or the above-mentioned DATA EMBEDDING data construction process. The **ExtractData()** method executed at line 4 in Figure 5 constructs the auxiliary data 14 from the appropriate digital key and the difference image 13a.

As with the DATA EMBEDDING process as taught in the above-mentioned US patent, another way of protecting the pair table key taught in that patent is to remove and encrypt it using public-key or another encryption process. The present invention requires the reference palette image 12, as well as the DATA EMBEDDING process key in order to construct auxiliary data 14. The necessary keys for DATA EMBEDDING process or codes for the steganography used to insert auxiliary data 14 into the difference image can be combined with the reference palette image 12 using known and readily available file formats. The COMPUSERVE® Graphic Interchange Format™, the Tagged Image File Format, and the MICROSOFT® bitmap format enable the addition of additional binary information within the file header fields. Thus, the reference palette image 12 serves as the key to construct auxiliary data 14 from a publication quality Truecolor version of the identical picture indiscernibly containing auxiliary data 14.

The foregoing description of the embodiments of the invention have been presented for purposes of illustration and description. It is not intended to be exhaustive or to limit the invention to the precise form disclosed, and obviously many modifications and variations are possible in light of the above teaching. The embodiments were chosen and described in order to best explain the principles of the invention and its practical application to thereby enable others skilled in the art to best utilize the invention in various embodiments and with various modifications as are suited to the particular use contemplated. It is intended that the scope of the invention be defined by the claims appended hereto.

WHAT IS CLAIMED IS:

1. A method of embedding auxiliary data into publication quality digital image data represented by a quantity of color-component values for each picture element comprising the steps of:

reducing said quantity of color-component values of said publication quality digital image data, to create a digital reference palette, wherein said digital color palette represents said quantity of color-component values of said publication quality digital image data;

creating a digital representation of said auxiliary data as a sequence of individual bit values;

creating a color-component digital difference image by numerically combining said publication quality digital image with said digital reference palette image;

modifying said color-component digital difference image by combining said auxiliary data and said color-component digital difference image through use of a data embedding method;

creating a modified publication quality digital image indiscernibly containing said auxiliary data by combining said modified color-component digital difference image and said digital reference palette image; and

outputting said modified publication quality digital image into a file format specified for said modified publication quality digital image.

2. The method as described in Claim 1 further comprising the step of combining said auxiliary data with predetermined information indicative of the presence of said auxiliary data, its file name, and file size, said step to be performed after the step of digitizing said auxiliary data.

3. The method as described in Claim 1 further comprising the step of including an algorithm for removing or hiding a digital watermark signature into said modified publication quality digital image.

4. The method as described in Claim 1, wherein said data embedding method comprises a bitslice process.

5. The method as described in Claim 1, wherein said data embedding method comprises a MODULAR ERROR EMBEDDING process.

6. The method as described in Claim 1, wherein said data embedding method comprises a DATA EMBEDDING process.

7. The method as described in Claim 1, wherein said publication quality digital image originates from a publication quality black and white image containing a range of digital levels of brightness.

8 The method as described in Claim 1, wherein said publication quality digital image originates from a digitized analog audio signal and said reference palette image originates from a reduced-quality version of said digitized audio analog signal.

9. The method as described in Claim 1, wherein said publication quality digital image originates from a television signal or motion picture image.

10. The method as described in Claim 1, wherein said publication quality digital image originates from X-ray or Magnetic Resonance Imaging data.

11. The method as described in Claim 1, wherein said publication quality digital image originates from digitized personal security and identification information.

12. The method as described in Claim 1, wherein said publication quality digital image originates from images made with a camera producing digital images.

13. A method of reconstructing indiscernible auxiliary data from a machine readable publication quality digital image representation of unrelated and uncorrelated data comprising the steps of:

generating a digital reference palette image from values and properties contained within said publication quality digital image;

creating a color-component digital difference image by numerically combining said digital reference palette image and said publication quality digital image;

constructing said auxiliary data by processing said color-component digital difference image with a data embedding construction method;

interpreting said auxiliary data in order to obtain or remove content, validate or authenticate, or otherwise process said publication quality digital image in order to modify auxiliary data quality.

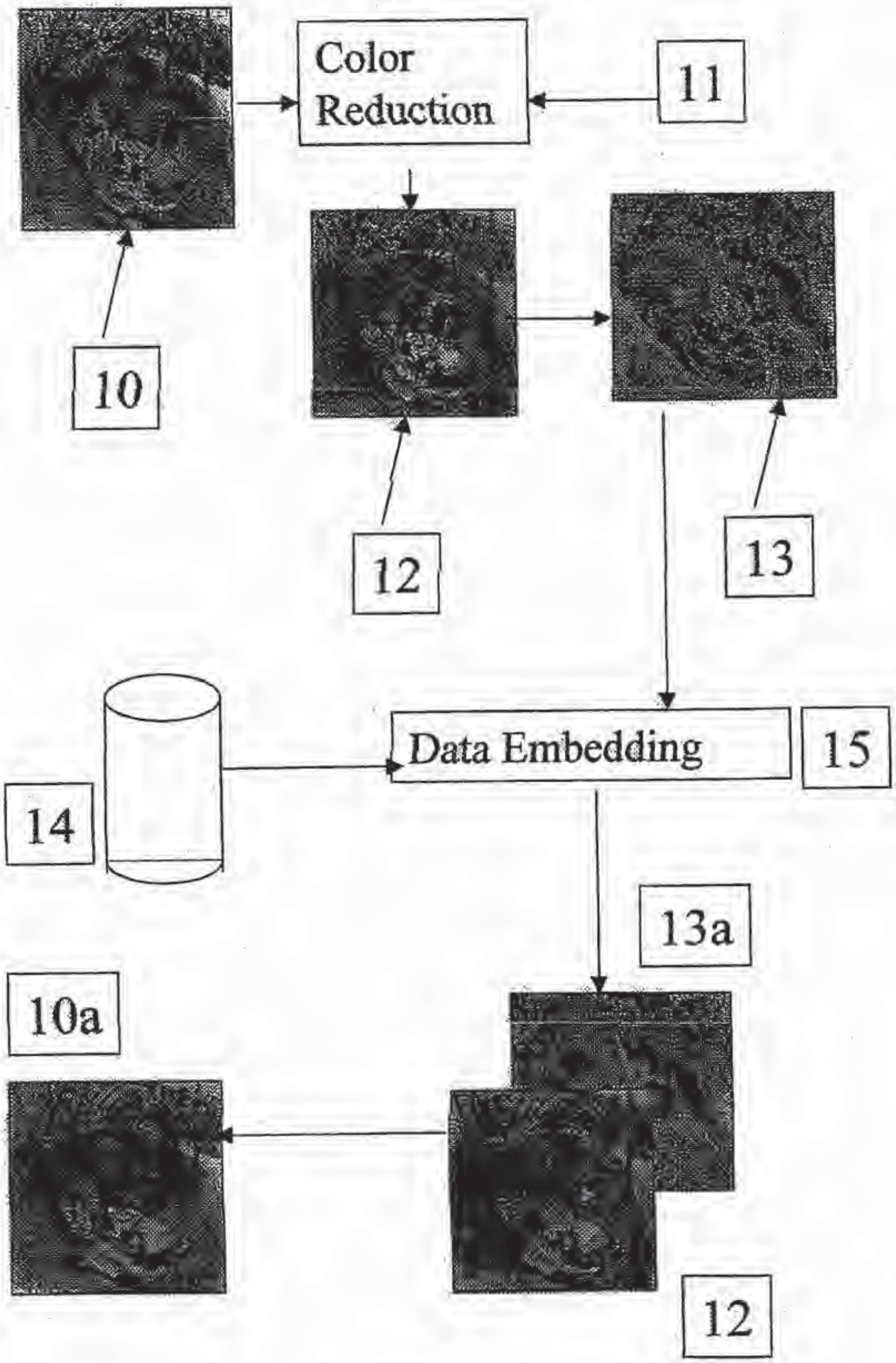


Figure 1

```
// loop to calculate and store the biased-difference of the Truecolor
image
  // difference = 128+(Truecolor - palette)
  // create the Truecolor difference file
  pixelcount = 0L;
  for (i = 0; i < (short)bh.rows; i++)  {
    memset(buffer, 0, BYTES_IN_ROW);
    j = TCFile->Read(bufftc, BYTES_IN_ROW);// Truecolor image row
    ASSERT(j == (short)BYTES_IN_ROW);
    bytesread += j;
    j = tape7.Read(buffpal, bytesinrow); // palette-format image row
    ASSERT(j == bytesinrow);

    for (j = 0; j < (short)bh.cols; j++) {
      short b_diff, g_diff, r_diff;
      char pixval[3];
      k = *(buffpal + j);
      b_diff = 128 + (short)*(bufftc + j * 3) - (short)colormap[k].b;
      if (colormap[k].b > 250) {
        b_diff = 255;  // don't use maximum palette values
      }
      g_diff = 128 + (short)*(bufftc + j * 3 + 1) - (short)colormap[k].g;
      if (colormap[k].g > 250) {
        g_diff = 255;   // don't use maximum palette values
      }
      r_diff = 128 + (short)*(bufftc + j * 3 + 2) - (short)colormap[k].r;
      if (colormap[k].r > 250) {
        r_diff = 255;   // don't use maximum palette values
      }
```

FIGURE 2A

```
        // set pixel to difference only if it is in range of unsigned char
        // otherwise flag with a value that is later removed from the pair-
key
        pixval[0] = pixval[1] = pixval[2] = '\0';
        if (b_diff < 255 && b_diff > 0) {
            *(buffer + j * 3) = (unsigned char)b_diff;
        } else {
            *(buffer + j * 3) = 0x01;    // flag to mark out-of-range pixel
            pixval[0] = 'b';
        }
        if (g_diff < 255 && g_diff > 0) {
            *(buffer + j * 3 + 1) = (unsigned char)g_diff;
        } else  {
            *(buffer + j * 3 + 1) = 0x01;  // flag to mark out-of-range pixel
            pixval[1] = 'g';
        }
        if (r_diff < 255 && r_diff > 0) {
            *(buffer + j * 3 + 2) = (unsigned char)r_diff;
        } else {
            *(buffer + j * 3 + 2) = 0x01;  // flag to mark out-of-range pixel
            pixval[2] = 'r';
        }
```

FIGURE 2B

```
// loop to calculate and store the output version of the Truecolor image
   // note:   difference = 128+(Truecolor - palette)
   // hence:  Truecolor  = (difference -128) + palette

for (i = 0; i < (short)bh.rows; i++)  {
      memset(buffer, 0, BYTES_IN_ROW);
      j = tape6.Read(bufftc, BYTES_IN_ROW);   // difference image row
      ASSERT(j == (short)BYTES_IN_ROW);
      bytesread += j;
      j = tape7.Read(buffpal, bytesinrow);    // palette-format image row
      ASSERT(j == bytesinrow);
      for (j = 0; j < (short)bh.cols; j++) {
         unsigned char b_diff, g_diff, r_diff;
         if (i == 0) {
            memcpy(buffer,bufftc,BYTES_IN_ROW);
            break;      // difference embedding key in 1st row
         }
         k = *(buffpal + j);
         b_diff =  *(bufftc + j * 3) -128 + colormap[k].b;
         g_diff =  *(bufftc + j * 3 + 1) -128 + colormap[k].g;
         r_diff =  *(bufftc + j * 3 + 2) -128 + colormap[k].r;
         *(buffer + j * 3) = b_diff;
         *(buffer + j * 3 + 1) = g_diff;
         *(buffer + j * 3 + 2) = r_diff;
         }
         tape8.Write(buffer, BYTES_IN_ROW); // output one Truecolor
         image row
         }
```

FIGURE 3

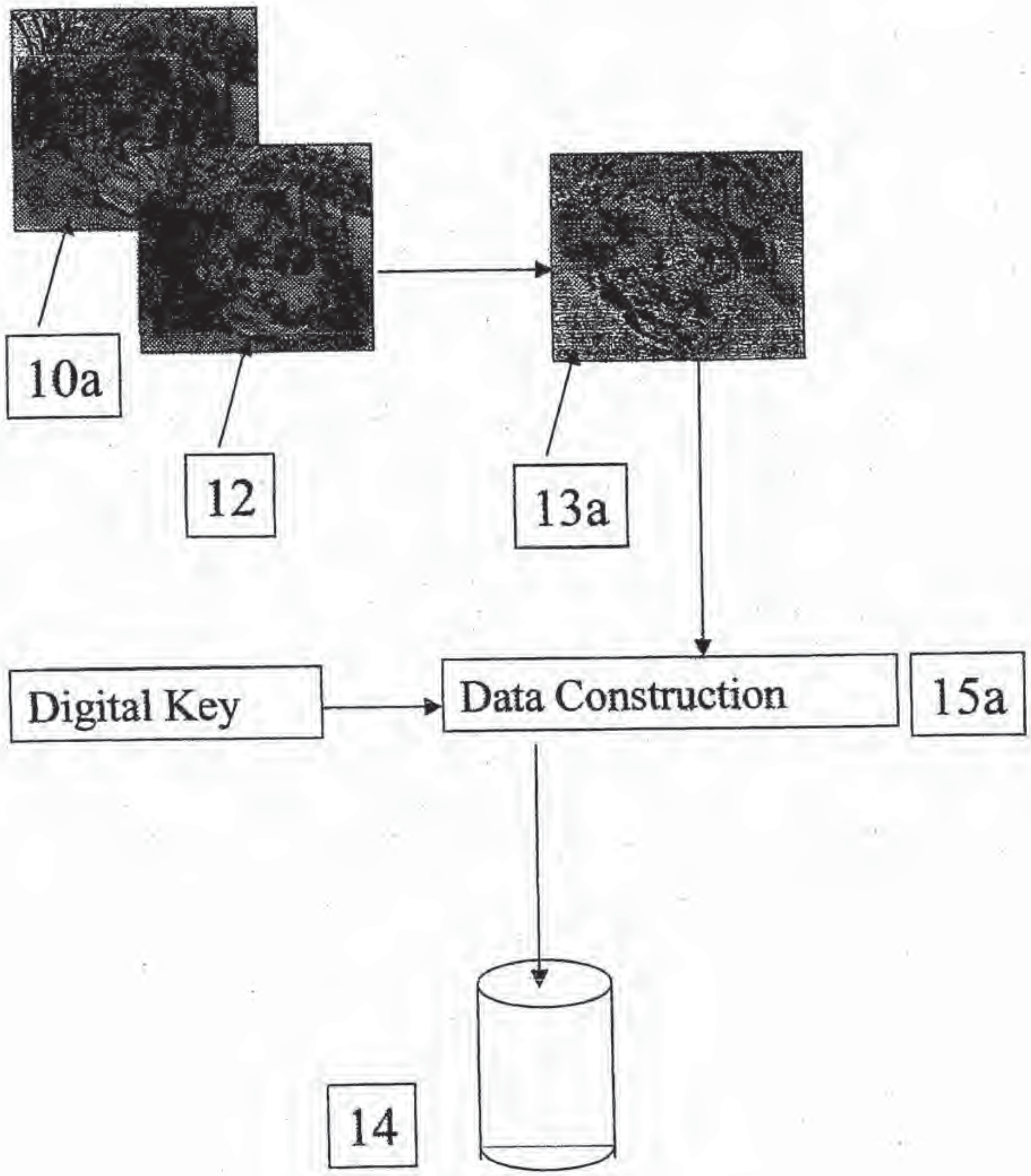


Figure 4

```
MakeDifferenceImage();
// open the difference file and extract the pixel_table information
CImageBitmapFile::OpenBitmapFile(tempstr);
ExtractBitmap();
```

FIGURE 5

WEST (BRS) text search terms: watermark, public, reference image, digital [illegible] image

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 5,659,726 A (SANDFORD, II et al.) 19 AUGUST 1997, see column column 2, lines 40-56.	1-13
A, P	US 5,819,289 A (SANFORD, II et al.) 06 OCTOBER 1998, col. 4, line 50 thru col. 5, line 16.	1-13
A	US 5,636,292 A (RHOADS) 03 JUNE 1997, see col. 5, lines 46-59.	1-13
A	US 5,652,626 A (KAWAKAMI et al.) 29 JULY 1997, see col. 4, lines 8-64.	1-13
A, E	US 5,930,369 A (COX et al.) 27 JULY 1999, see col. 9, lines 6-44.	1-13
A	US 5,530,759 A (BRAUDAWAY et al.) 25 JUNE 1996, see col. 4, line 52 thru col. 5, line 15.	1-13

☒ Further documents are listed in the continuation of Box C. □ See patent family annex.

*	Special categories of cited documents:	"T"	later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"A"	document defining the general state of the art which is not considered to be of particular relevance		
"E"	earlier document published on or after the international filing date	"X"	document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"L"	document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"Y"	document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"O"	document referring to an oral disclosure, use, exhibition or other means		
"P"	document published prior to the international filing date but later than the priority date claimed	"&"	document member of the same patent family

Date of the actual completion of the international search 26 AUGUST 1999	Date of mailing of the international search report 09 SEP 1999
Name and mailing address of the ISA/US Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231 Facsimile No. (703) 305-3230	Authorized officer GILBERTO BARRÓN JR. Joni Hill Telephone No. (703) 305-1830

Form PCT/ISA/210 (second sheet)(July 1992)*

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US99/09417

A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) :G09C 5/00; H04L 9/00
US CL :380/4, 54; 382/232
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 380/4, 54; 382/232

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US99/09417

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 5,537,223 A (CURRY) 16 JULY 1996, see column 3, lines 1-36.	1-13

Form PCT/ISA/210 (continuation of second sheet)(July 1992)★

PCT

WORLD INTELLECTUAL PROPERTY ORGANIZATION
International Bureau

INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 6 :
H04L 9/30

A1

(11) International Publication Number: WO 96/29795

(43) International Publication Date: 26 September 1996 (26.09.96)

(21) International Application Number: PCT/US96/03920

(22) International Filing Date: 21 March 1996 (21.03.96)

(30) Priority Data:
08/408,551 21 March 1995 (21.03.95) US

(71)(72) Applicant and Inventor: MICALI, Silvio [US/US]; 459 Chestnut Hill Avenue, Brookline, MA 02146 (US).

(74) Agent: JUDSON, David, H.; Hughes & Luce, L.L.P., Suite 2800, 1717 Main Street, Dallas, TX 75201 (US).

(81) Designated States: CA, JP, European patent (AT, BE, CH, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE).

Published
With international search report.
Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.

(54) Title: SIMULTANEOUS ELECTRONIC TRANSACTIONS

(57) Abstract

A communication method between a first and second party, in the presence of a trusted party, that enables a transaction in which the second party receives a first value produced by the first party and unpredictable to the second party if and only if the first party receives a second value produced by the second party and unpredictable to the first party. The method includes two basic steps: exchanging a first set of communications between the first and second parties without participation of the trusted party to attempt completion of the transaction, and if the transaction is not completed using the first set of communications between the first and second parties, having the trusted party take action to complete the transaction.

FOR THE PURPOSES OF INFORMATION ONLY

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AM	Armenia
AT	Austria
AU	Australia
BB	Barbados
BE	Belgium
BF	Burkina Faso
BG	Bulgaria
BJ	Benin
BR	Brazil
BY	Belarus
CA	Canada
CF	Central African Republic
CG	Congo
CH	Switzerland
CI	Côte d'Ivoire
CM	Cameroon
CN	China
CS	Czechoslovakia
CZ	Czech Republic
DE	Germany
DK	Denmark
EE	Estonia
ES	Spain
FI	Finland
FR	France
GA	Gabon
GB	United Kingdom
GE	Georgia
GN	Guinea
GR	Greece
HU	Hungary
IE	Ireland
IT	Italy
JP	Japan
KE	Kenya
KG	Kyrgystan
KP	Democratic People's Republic of Korea
KR	Republic of Korea
KZ	Kazakhstan
LI	Liechtenstein
LK	Sri Lanka
LR	Liberia
LT	Lithuania
LU	Luxembourg
LV	Latvia
MC	Monaco
MD	Republic of Moldova
MG	Madagascar
ML	Mali
MN	Mongolia
MR	Mauritania
MW	Malawi
MX	Mexico
NE	Niger
NL	Netherlands
NO	Norway
NZ	New Zealand
PL	Poland
PT	Portugal
RO	Romania
RU	Russian Federation
SD	Sudan
SE	Sweden
SG	Singapore
SI	Slovenia
SK	Slovakia
SN	Senegal
SZ	Swaziland
TD	Chad
TG	Togo
TJ	Tajikistan
TT	Trinidad and Tobago
UA	Ukraine
UG	Uganda
US	United States of America
UZ	Uzbekistan
VN	Viet Nam

SIMULTANEOUS ELECTRONIC TRANSACTIONS

TECHNICAL FIELD

The present invention relates generally to electronic commerce and transactions and more particularly to techniques for enabling users to effect certified mail, contract signing and other electronic notarization functions.

BACKGROUND OF THE INVENTION

The value of many transactions depends crucially on their simultaneity. Indeed, simultaneity may be so important to certain financial transactions that entities often are willing to incur great inconvenience and expense to achieve it. For example, consider the situation where two parties have negotiated an important contract that they now intend to "close." Often, the parties find it necessary to sign the document simultaneously, and thus they meet in the same place to watch each other's actions. Another example is the process of certified mail, where ideally the sender of a message desires that the recipient get the message simultaneously with the sender's obtaining a "receipt". A common certified mail procedure requires a person who delivers the mail to personally reach the recipient and obtain a signed acknowledgement when the message is delivered. This acknowledgement is then shipped to the sender. Again, this practice is costly and time consuming. Moreover, such acknowledgements do not indicate the content of the message.

In recent years, the cost, efficiency and convenience of many transactions have been improved tremendously by the availability of electronic networks, such as computer, telephone, fax, broadcasting and others. Yet more recently, digital signatures and public-key encryption have added much needed security to these electronic networks, making such communication channels particularly suitable for financial transactions. Nevertheless, while electronic communications provide speed, they do not address simultaneity.

The absence of simultaneity from electronic transactions severally limits electronic commerce. In particular, heretofore there has been no effective way of building so-called *simultaneous electronic transactions* ("SET's"). As used herein, a SET is an electronic transaction that is simultaneous at least in a "logically equivalent" way, namely it is guaranteed that certain actions will take place if and only if certain other actions take place. One desirable SET would be certified mail, however, the prior art has not addressed this problem effectively. This can be seen by the following consideration of a hypothetical example, called *extended certified mail* or "ECM".

In an ECM transaction, there is a sender, Alice, who wishes to deliver a given message to an intended recipient, Bob. This delivery should satisfy three main properties. First, if Bob refuses to receive the message (preferably before learning it), then Alice should not get any receipt. Second, if Bob wishes to receive the message, then he will receive it and Alice will get a receipt for the message. Third, Alice's receipt should not be "generic," but closely related to the message itself. Simultaneity is important in this transaction. For instance, Alice's message could be an electronic payment to Bob, and it is desired that she obtains a simultaneous receipt if possible.

Alice could try to get a receipt from Bob of a message m in the following way. Clearly, sending *m* to Bob in the clear as her first communication does not work. Should this message be her digital signature of an electronic payment, a malicious Bob may loose any interest in continuing the conversation so as to deprive Alice of her receipt. On the other hand, asking Bob to send first a "blind" receipt may not be acceptable to him.

Another alternative is that Alice first sends Bob an encryption of *m*. Second, Bob sends Alice his digital signature of this ciphertext as an "intermediate" receipt. Third, Alice sends him the decryption key. Fourth, Bob sends Alice a receipt for this key. Unfortunately, even this transaction is not secure, because Bob, after learning the message when receiving Alice's key, may refuse to send her any receipt. (On the other hand, one cannot consider Bob's signature of the encrypted message as a valid receipt, because Alice may never send him the decryption key.)

These problems do not disappear by simply adding a few more rounds of communication, typically consisting of "acknowledgements". Usually, such additional rounds make it more difficult to see where the lack of simultaneity lies, but they do not solve the problems.

Various cryptographic approaches exist in the literature that attempt to solve similar problems, but they are not satisfactory in many respects. Some of these methods applicable to multi-party scenarios propose use of verifiable secret sharing (see, for example, Chor et al), or multi-party protocols (as envisioned by Goldreich et al) for making simultaneous some specific transactions between parties. Unfortunately, these methods require a plurality of parties, the majority of which are honest. Thus, they do not envision simultaneous transactions involving only two parties. Indeed, if the majority of two parties are honest then both parties are honest, and thus simultaneity would not be a problem. Moreover, even in a multi-party situation, the complexity of these prior art methods and their amount and type of communication (typically, they use several rounds of broadcasting), make them generally impractical.

Sophisticated cryptographic transactions between just two parties have been developed but these also are not simultaneous. Indeed, if just two people send each other strings back and forth, and each one of them expects to compute his own result from this conversation, the first to obtain the desired result may stop all communications, thereby depriving the other of his or her result. Nonetheless, attempts at providing simultaneity for two-party transactions have been made, but by using assumptions or methods that are unsatisfactory in various ways.

For example, Blum describes transactions that include contract signing and extended certified mail and that relies on the two parties having roughly equal computing power or knowledge of algorithms. These assumptions, however, do not always hold and are hard to check or enforce anyway. In addition, others have discovered ways to attack this rather complex method. A similar approach to simultaneity has also been proposed by Even Goldreich and Lempel. In another Blum method for achieving simultaneous certified mail, Alice does not know whether she got a valid receipt. She must go to court to determine this, and this is undesirable as well.

A method of Luby et al allows two parties to exchange the decryption of two given ciphertexts in a special way, namely, for both parties the probability that one has to guess correctly the cleartext of the other is slowly increased towards 100%. This method, however, does not enable the parties to achieve guaranteed simultaneity if one party learns the cleartext of the other's ciphertext with absolute probability (e.g., by obtaining the decryption key); then he can deny the other a similar success.

For this reasons several researchers have tried to make simultaneous two-party transactions via the help of one or more external entities, often referred to as "centers", "servers" or "trustees", a notion that appears in a variety of cryptographic contexts (see, for instance, Needham and Schroder and Shamir). A method for simultaneous contract signing and other transactions involving one trustee (called a "judge") has been proposed by Ben-Or et al. Their method relies on an external entity only if one party acts dishonestly, but it does not provide guaranteed simultaneity. In that technique, an honest party is not guaranteed to have a signed contract, even with the help of the external entity. Ben-Or et al only guarantee that the probability that one party gets a signed contract while the other does not is small. The smaller this probability, the more the parties must exchange messages back and forth. In still another method, Rabin envisions transactions with the help of external party that is active at all times (even when no transaction is going on), but also this method does not provide guaranteed simultaneity.

The prior art also suggests abstractly that if one could construct a true simultaneous transaction (e.g., extended certified mail), then the solution thereto might also be useful for constructing other types of electronic transactions (e.g., contract signing). As noted above, however, the art lacks an adequate teaching of how to construct an adequate simultaneous transaction

There has thus been a long-felt need in the art to overcome these and other problems associated with electronic transactions.

BRIEF SUMMARY OF THE INVENTION

It is an object of the invention to provide true simultaneous electronic transactions.

It is a further object of the invention to provide an electronic transaction having guaranteed simultaneity in a two-party scenario and with minimal reliance and support of a third party.

It is another more specific object of the invention to provide simultaneous electronic transactions between two parties that rely on third parties in a minimal and convenient manner. In particular, it is desired to provide electronic transactions between two parties that guarantee simultaneity via the help of an *invisible* third party. A third party is said to be "invisible" because it does not need not to take any action if the transaction occurs with the parties following certain prescribed instructions. Only if one of the original parties deviates from these instructions may the other invoke the intervention of the up-to-then invisible third party, who then can still guarantee the simultaneity of the transaction even though it has not participated from its inception.

These and other objects are provided in a communication method between a first and second party, in the presence of a trusted party, that enables a transaction in which the second party receives a first value produced by the first party and unpredictable to the second party if and only if the first party receives a second value produced by the second party and unpredictable to the first party. The method includes two basic steps: exchanging a first set of communications between the first and second parties without participation of the trusted party to attempt completion of the transaction, and if the transaction is not completed using the first set of communications between the first and second parties, having the trusted party take action to complete the transaction.

Where the first party's value is a message and the second party's value is a receipt, the transaction is a certified transmission of

the first party's message. Alternatively, the first party's value represents a commitment to a contract and the second party's value represents a commitment to the contract, such that the transaction is a contract closing.

Preferably, according to the method the first party can prove that some information it receives is the second value, and the second party can prove that some information it receives is the first value.

According to the more specific aspects of the method, at least one of the first and second parties and the trusted party can encrypt messages, and at least one of the first and second parties and the trusted party can decrypt messages. The first set of communications includes at least one communication of the first party to the second party of a data string generated by a process including encrypting a second data string with an encryption key of the trusted party. The second data string includes a ciphertext generated with an encryption key of one of the parties, as well as information specifying or identifying at least one of the parties. The first set of communications also includes at least one communication of the second party of a data string generated by a process that includes having the second party digitally sign a data string computed from information received from the first party in a prior communication, wherein the data string generated by the second party is the second party's value.

According to further aspects of the method, if the second party does not get the first value in the first set of communications, the second party sends the trusted party, for further processing, a data string that includes at least part of the data received from the first party. The further processing by the trusted party includes decrypting a ciphertext with a secret decryption key. The trusted party then sends the first party information that enables the first party to compute the second value, and the trusted party sends the second party information that enables the second party to compute the first value. In either case, the trusted party also verifies identity information of at least one of the parties but preferably does not learn the first value.

DETAILED DESCRIPTION

In each of the schemes described below, there is a user Alice and a user Bob. The "invisible" third party may be a financial center that facilitates SETs among its customers, including Alice and Bob. For convenience, the following description shows how to make extended certified mail "simultaneous", although the invention is not so limited. In the context of an ECM system, the third party is called the Post Office. As will be seen, however, contrary to ordinary certified mail, the Post Office here is invisible. The inventive scheme is also preferable to ordinary certified mail because the message receipt also guarantees the content of the message. Also, the electronic transaction is faster, more informative and more convenient than traditional certified mail, and its cost should be substantially lower.

In the preferred embodiment, an extended certified mail system is provided using a single "invisible" trustee or "trusted" party. The system is implemented in a computer network, although it should be realized that telephone, fax, broadcast or other communication networks may be used. Thus, without limitation, it is assumed that each user in the system has a computer capable of sending and receiving messages to and from other computers via proper communication channels.

Each user in the system has a unique identifier. Alice's identifier is denoted by A, and Bob's identifier is B. The identifier of the Post Office is denoted by PO. Users and the Post Office can digitally sign messages. Thus, each has a secret signing key and a matching public verification key. If *m* is a message (string), then SIG_A(m) indicates Alice's signature of *m*. (It is assumed, for convenience, that *m* is always retrievable from its signature. This is the case for most signature schemes, and it is otherwise possible to consider a signed message as the pair consisting of the message and its signature.)

Users and the Post Office can encrypt messages by means of a public-key encryption algorithm (e.g., RSA). Thus, each has a public encryption key and a corresponding secret decryption key. $E_A(m)$, $E_B(m)$, and $E_{PO}(m)$ denote, respectively, the encryption of a message *m* with the public key of Alice, Bob, and the Post Office. For simplicity, it is assumed that these schemes are secure in the sense that each of E_A, E_B, and E_{PO} appear to behave as a random function. The system can be suitably modified if these functions are much less secure.

Again, for simplicity these encryption algorithms are deterministic and uniquely decodable. Thus, given a value *y* and a message *m*, all can verify whether *y* is the encryption of *m* with, for example, the Post Office's key, by checking whether $E_{PO}(m)$ equals *y*. (If the encryption scheme is probabilistic, then one may convince another that a string *y* is an encryption of a message m by providing *m* together with the random bits that were used to encrypt *m*.) If *y* is a ciphertext generated by means of the encryption algorithm *E*, $E^1(y)$ denotes the corresponding cleartext, whether or not *E* defines a permutation. (It may also be possible to use encryption algorithms that are not uniquely decodable, for instance, if it is hard to decrypt a given ciphertext in two different ways.) For simplicity, messages are encrypted directly with a public-key algorithm, however, one could first encrypt a message conventionally with some key *k*, and then encrypt *k* with a public-key algorithm. (Thus, to decrypt *m*, one need only just decrypt *k*).

In one preferred embodiment outlined below, the ECM method requires 5 possible steps of communication: A1 and A2 for user Alice, B1 and B2 for user Bob, and PO for the Post Office. However, at most 3 steps should have to be executed. If Alice and Bob are both honest, only steps A1, B1, and A2 will be executed, and in this order. Step B2 will be executed only if Alice fails to execute Step A2 properly. The execution of Step B2 causes the Post Office to execute its only step, PO. The protocol is as follows:

A1. Given her message *m*, Alice computes $z = E_{PO}((A, B, E_B(m)))$, the encryption in the Post Office public key of a triplet consisting of identifiers A, B and the message m encrypted in Bob's key, and then sends *z* to Bob.

B1. Upon receiving *z* from Alice, Bob digitally signs it and sends it to Alice as the receipt.

A2. If Alice receives the properly signed receipt from Bob, she sends *m* to Bob.

B2. If, within a given interval of time after having executed Step B1, Bob receives a string *m* such that $E_{PO}((A, B, E_B(m))) = z$, the value originally received from Alice, then he outputs *m* as the message and halts. Otherwise, Bob sends the value *z* signed by him to the Post Office indicating that Alice is the sender and he is the recipient.

PO. If Bob's signature relative to *z* is correct, the Post Office decrypts *z* with its secret key. If the result is a triplet consisting of A, B and a string *x*, the Post Office (a) sends Alice the value *z* signed by Bob as the receipt, and (b) sends *x* to Bob.

Preferably, Alice sends *z* to Bob digitally signed by her. In addition, Alice may sign *z* in a standard format that indicates *z* is part of an extended certified mail sent from Alice to Bob, e.g., she may sign the tuple *(ECM, A, B, z)*. In this way, Bob is certain that *z* comes from Alice and that, when Alice holds a receipt for *m* signed by Bob, he will have a certified version of *m*. Further, if *z* is digitally signed by Alice, Bob first checks Alice's signature, and then countersign *z* himself. The adoption of a standard format also insures that, by signing *z* as part of an ECM system, Bob does not sign accidently a message that has been prepared by Alice maliciously. Also, the Post Office may also check Alice's signature or any additional formats if these are used.

In analyzing the protocol, it should be noted that Alice, given Bob's signature of *z* as receipt, can prove the content of the message by releasing *m*. Indeed, all can compute $x = E_B(m)$ and then verify that $E_{PO}((A, B, x)) = z$.

Notice also that the Post Office does not understand the message sent via the ECM protocol, whether or not it is called into action. Rather, the Post Office can only obtain $E_B(m)$, but never *m* in the clear (in this embodiment).

Third, notice that *m* is, by definition, equal to $E^{1}_{B}(x)$, where $(A, B, x) = E_{PO}^{-1}(z)$, and may be non-sensical. Indeed, nothing prevents Alice from sending Bob a garbled message. However, she can only get a receipt for this same garbled message. It is also noted that, if not every string is an encryption of some message, Alice may choose *z* so that it is not the encryption of anything. In such case, however, she cannot ever claim to have a receipt for any message. Alternatively, it may be desirable to use cryptosystems for which either every string is an encryption of some other string or such that it can be easily detected whether *y* encrypts something.

The protocol works for the following reasons. When receiving the value $z = E_{PO}((A, B, E_B(m)))$ from Alice, Bob will have difficulty in computing $E_B(m)$, and thus *m*, from *z* without the Post Office's secret key. Thus, if he halts, Alice would not get her receipt, but Bob would not get *m* either.

Assume now that Bob signs *z* and sends it to Alice. Because this gives Alice a valid receipt from Bob for her message *m*, for the simultaneity constraint to hold, it must be shown that Bob easily obtains *m*. This is certainly true if Alice sends *m* to Bob in Step A1. Assume therefore that Alice does not send him *m*. Then, Bob presents *z* signed by him to the Post Office, essentially asking the Post Office to retrieve (for him) $E_B(m)$ from *z*. The Post Office complies with this request. In doing so, however, the Post Office also sends Alice *z* signed by Bob as the receipt. It does so to prevent one last possibility; that Bob, upon receiving *z* from Alice in Step A1, rather than sending her the receipt in Step B1, goes *directly* to the Post Office in order to have $E_B(m)$ extracted from *z*.

Summarizing, if Alice sends a message encrypted with the Post Office key to Bob, and Bob does not send Alice a receipt, or if he does not access the Post Office, Bob will never learn *m*. Otherwise, Alice is guaranteed to get her receipt for *m* either from Bob or from the Post Office. On the other hand, upon receiving an encrypted message, Bob is guaranteed that he will understand it, either helped by Alice or helped by the Post Office.

In the preferred embodiment above, the triplet (which includes the ciphertext $E_B(m)$) also includes A and B. The ciphertext is customized in this way so that it can be used by the system only for the purpose of Alice sending a message to Bob. Whether or not this customization is performed, the system is very convenient to use because everyone knows the public key of the Post Office, because everyone can encrypt a value with that key, and because the Post Office can remove this encryption layer for those recipients who claim to have been betrayed by their senders. However, without the above (or an equivalent) customization, this same convenience could be exploited by a malicious recipient, who could learn his messages while denying the senders their legitimate receipts.

In particular, assume that this customization is removed altogether. Then, a malicious Bob, upon receiving $z' = E_{PO}(E_B(m))$ - rather than $z = E_{PO}((A, B, E_B(m)))$ - from Alice in Step A1, may behave as follows. First, he does not send Alice any receipt. Second, he signs z'. Third, he gives this signed value to the Post Office complaining that a sender Chris (an accomplice of his) is refusing to send him the message in the clear. At this point, the Post Office, after verifying Bob's signature and not having any way of checking whether Chris is the real sender, retrieves $E_B(m)$ from z' and sends $E_B(m)$ to Bob, while simultaneously sending the signed z' to Chris as his receipt. Of course, Chris may destroy or hide this receipt. Meanwhile Alice, who does not get any receipt after Step

A1, may think that Bob is away or does not want to receive her message. But she believes that Bob will never be able to read her message in any case.

This violation of the simultaneity constraint (i.e., Bob receiving *m* while Alice having no receipt) may still occur if, without any customization, Alice signs *z* when sending it to Bob in Step A1. Indeed, Bob would have no trouble in removing Alice's signature, asking Chris to sign *z'* and then presenting to the Post Office *z'* signed by Chris and countersigned by himself. The Post Office, after verifying Bob's and Chris's signatures, would still (after removing its encryption layer) send $E_B(m)$ to Bob and the receipt to Chris. This violation of simultaneity, however, does not occur with the customization of the triplet to include A and B. Indeed, assume that Bob gives the Post Office the value $z = E_{PO}((A, B, E_B(m)))$ originally received by Alice and signed by him and Chris, claiming that it was sent to him by Chris. Then, the Post Office, after verifying Bob's (and Chris's) signature and after computing the value $E_{PO}^{-1}(z)$, will notice that this value - i.e. $(A, B, E_B(m))$ - does not specify Chris to be the sender and Bob the receiver.

The benefits of this customization may be implemented in varying ways. For instance, Alice's signature of $(B,E_B(m))$ may be sufficient to indicate that the sender is Alice and the receiver is Bob. More generally, any customization that prevents Bob from obtaining $E_B(m)$ from the Post Office while convincing the Post Office not to send Alice the receipt is within the scope of the invention.

It should be realized that any customization for the purpose of simultaneous electronic transactions is itself within the scope of the present invention, whether or not implemented with an invisible third party. For instance, Alice may send $E_{PO}(A,B,E_B(m))$ directly to the

Post Office, which gives $E_B(m)$ to Bob (if Bob signs the receipt for Alice) after checking that Alice and Bob are, respectively, the sender and the receiver. Alternatively, Alice may send the Post Office $E_{PO}(SIG_A(B,E_B(m)))$ for identifying the sender and the recipient in a way that cannot be decoupled from the transaction. Such approaches may be especially useful with a plurality of trustees as described below. Such an approach, which calls into action the trusted party directly with a proper customization step as described, is also useful for hiding the identity of the sender from the recipient. Indeed, the Post Office may solicit a proper receipt from Bob without disclosing Alice's identity (even if the receipt indicates the content of Alice's message).

Although not specified above explicitly, it should be appreciated that all or part of the actions required by the Post Office, Alice or Bob can be realized in software. Some of these actions can also be performed by hardware, or physically secure devices (i.e. devices such as secure chips having at least some portion of which is tamper-proof).

Many variations of the disclosed protocol can be envisioned and are within the scope of the present invention. For instance, while the "receipt" described above witnesses the content of the message sent, the receipt can be made generic, e.g., by having Bob sign a "declaration" (instead of a string including an encrypted version of the message) that he has received an encrypted message from Alice at a given time. Also, if desired, the customization step (i.e. the inclusion of the identifiers A and B in the triplet) can be omitted. This might be advantageous, for example, when no other user may collude with either Alice or Bob to disrupt simultaneity. This may occur where there is no third user, as in the case when certified mail occurs between two predetermined people. In the disclosed system, the Post Office cannot learn the content of the message, but such a restriction can be removed also (e.g., by having Alice compute $z = E_{PO}(A, B, m)$). It may also be convenient to one-way hash strings prior to signing them.

Still another variation would be to impose some temporal element on the transaction. For instance, when Alice sends Bob $z = E_{PO}(A, B, E_B(m))$, she may sign z together with some additional information that specifies a certain time (either absolute or relative to the sending time) after which the Post Office will not help Bob obtain the message. Preferably, Alice specifies this time in a signed manner both outside the Post Office encryption layer as well as within the triplet. In such case, the Post Office must obtain from Bob all necessary information to verify that the time specified outside the PO encryption layer checks with the time specified within the triplet. If it does not, then several possibilities may occur. For example, the Post Office will not help Bob recover the message, or the message is considered unsent (even if Alice obtains a receipt).

Other variations are also possible. Some variations may be used in conjunction or in alternative to the techniques described above. One group of such variants concerns the encryption method used.

For instance, E_B does not need to be interpreted as an encryption algorithm for which Bob has the decryption key. It may just be an encryption algorithm for which Bob can have the message decrypted. For example, and without limitation, the decryption key of E_B may lie with a group of people, each having a piece of the key. These same alternative interpretations apply also to E_A or E_{PO}.

Also, while public-key cryptosystems are quite convenient, it should be realized that conventional cryptosystems could be used for the ECM protocol. For example, *x* may be the conventional encryption of *(A, B, $E_B(m)$)* with a secret key *k* shared between Alice and the Post Office. This key *k* may be released if it is desired that Bob verify *m* to be the genuine message. If, however, it is feared that release of a different key may change the content of the messages, special redundancies could be used. For instance, conventionally a message *M* is encrypted by actually encrypting *(M, H(M))*, where *H* is a one-way function. Thus, if *e* is an encryption of *(M, H(M))* with a key *k*, it is hard to find a second key *K* such that *e* also is an encryption with that key of *(M'H(M'))*. It is preferable that *k*, rather than being a secret key shared by Alice and the Post Office, is a temporary key that Alice may transfer to the Post Office separately by means of a different shared key *K*. This way, divulging *k* (e.g., for the purpose of convincing Bob of the value of *$E_B(m)$)* does not force the Post Office and Alice to agree on another conventional key *k*.

It should also be appreciated that the digital signatures of the ECM system need not be public key signatures. For instance, there may be private key digital signatures or signatures verifiable with the help of other parties, or other suitable forms of message authentication. Thus, as used herein, "digital signatures" and "digital signing" should be broadly construed. Similarly, the notion of encryption with a key of some party should be broadly construed to include encrypting with a public key of that party or encrypting with a secret key shared with that party or known to that party.

There may also be concern that the Post Office will collude with one of the parties. For instance, the Post Office may collude with Bob who, rather than sending the receipt to Alice, goes directly to Post Office, and this enables Bob to understand his message but without giving Alice any receipt. This may occur in ordinary certified mail. Indeed, one who delivers the post may leave a letter with his intended recipient without asking him or her to sign a receipt. Nonetheless, this potential problem may be dealt with effectively and efficiently. For instance, the Post Office may be (or make use of) a physically secure device. Assuming that the Post Office uses such a device in the preferred embodiment, then it will be hard for user Bob to have the Post Office decrypt *(A, B, $E_B(m)$)* for him without sending Alice her receipt. Indeed, the chip can be programmed to perform both operations or none. Although use of physically secure devices might increase the cost of a system, this need not be the case. Indeed, while they may be millions of users, there may be one or much fewer Post Offices. (Each user, of course, may benefit also from being or relying upon physically secure devices.)

While the inventive ECM system is very economical as it requires at most three communication steps, the goals can be accomplished also by more steps. In particular, although the trusted party, upon receiving Bob's communication, can enable Bob to get his message and Alice to get her receipt, without sending messages back and forth, this goal can be accomplished by means of a more complex dialogue. Indeed, more elaborate dialogues, and in particular zero knowledge proofs (see, e.g., Goldwasser et al or Goldreich et al) could be useful (also as an alternative to physically secure devices) to give Bob the message or Alice the receipt so that they learn their respective values, but are not able to "prove" these values to third parties.

A further alternative method envisions a Post Office with a plurality of trustees. A multiplicity of trustees can be beneficial for various aspects, particularly, if the system is set up so that more than one of the trustees must collude for cheating to occur. Presumably, however, each trustee is selected with trustworthiness (or, if it is a device, proper functioning) as a criterion, and thus the possibility that more than one of them is malicious or defective is very small.

A simultaneous ECM system with a multiplicity of trustees may make novel use of prior techniques such as fair cryptography, or secret sharing, verifiable secret sharing or threshold cryptosystems.

In a construction based on fair public cryptosystems, the triplets *(A, B, E_B(m))* are not encrypted with the Post Office's public key, but rather with a user public key. In this embodiment, user Alice computes a pair of public and secret key of a fair public-key cryptosystem, properly shares her secret key with the trustees of the Post Office (e.g., receiving from said trustees a certification that they got legitimate shares of this user key) in some initial phase, and then performs Step A1 of the above ECM protocol. If needed, Bob may turn to the Post Office and instructs the trustees to reconstruct Alice's user key. By doing so, the trustees cannot monitor or cause the Post Office to monitor the message addressed by Alice to Bob, but can reconstruct the triplet *(A, B, E(m))*. To insure that the Post Office trustees do not collude with Bob in depriving Alice of her receipt, it can be arranged that each trustee, when contributing its own piece of a user secret key, also gives a proper acknowledgement to that user. Thus, unless all *n* trustees do not behave properly, Alice would receive at least one receipt.

A possible drawback of this fair-cryptography based system is that Alice must interact with the trustees in order to give them shares of her user key. Thus, the trustees are not fully invisible. This interaction may not even be confined to a single initial phase. This is because Alice may not be able to reuse her key after Bob accesses the Post Office and causes its reconstruction. To alleviate this problem, it might be desirable to use physically secure devices and having the trustees reveal their own pieces to such a device, which would then be able to announce *(A,B,E_B(m))* without proof.

A better approach uses the ECM protocol, but involves splitting the secret key of the Post Office rather than the secret user keys. Thus, Alice would continue to encrypt *(A, B, E_B(m))* with the help of the Post Office public key, whose corresponding secret key is shared among the *n* trustees but is not known to any single entity (nor has it been prepared by any single entity). Thus, the *n* trustees must cooperate, under Bob's proper request, in removing the Post Office's encryption layer. However, they do so without reconstructing the Post Office secret key, not even internally to the Post Office. To this end, a threshold cryptosystem may be used). This solution is now illustrated using the well- known Diffie-Hellman public-key cryptosystem.

In the Diffie-Hellman system, there is a prime *p* and a generator *g* common to all users. A user *X* chooses his own secret key *x* at random between 1 and *p* - 1, and sets his public key to be g^x mod *p*. Let *y* and g^y mod *p*, respectively, be the secret and public keys of user *Y*. Then *X* and *Y* essentially share the secret pair key g^{xy} mod *p*. Indeed, each of *X* and *Y* can compute this pair-key by raising the other's public key to his own secret key mod *p*. On the other hand, without knowledge of *x* or *y*, no other user, given the public keys g^x mod p and g^y mod p and based on any known method, can compute the pair-key g^{xy}. Thus X and y can use this key to secure communications between each other (e.g., by using it as the key of a symmetric cipher).

Let now $T_{1,\ldots,}T_n$ be the trustees of the Post Office. Then, each T_i chooses a secret key xi and a matching public key $g^x{}_i$ mod p. Then the public key of the Post Office is set to be the product of these public keys mod p, g^z mod p (i.e., $g^z = g^{x1+\ldots+xn}$ *mod p*). Thus, each trustee has a share of the corresponding secret key, z. Indeed, the Post Office's secret key would be $z = x1 + \ldots + xn$ mod $p - 1$. Assume now that Alice wishes to encrypt *(A, B, $E_B(m)$)* with the Post Office's key. She selects a (preferably) temporary secret key a and its corresponding public key g^a mod p. She then computes the public pair-key g^{az} mod p, encrypts *(A, B, $E_B(m)$)* conventionally with the secret pair-key g^{az}, and then sends Bob this ciphertext together with the temporary public-key g^a mod p (all in Step A1). If in Step B1 Bob sends Alice back a receipt, namely, his signature of the received message, then Alice, in Step A2, sends him the secret key a. This enables Bob to compute the pair-key g^{az} mod p (from a and the Post Office's public key), and thus decrypt the conventional ciphertext to obtain *(A, B, $E_B(m)$)*. Thus, if both users behave properly, the Post Office is not involved in the transaction. Assume now that Bob properly asks the Post Office to decrypt Alice's ciphertext. To do this, the trustees cooperate (preferably, with proper notice to Alice and to each other) in computing g^{az} mod p. To this end, each trustee T_i raises Alice's public key g^a mod p to its own secret key. That is, T_i computes g^{axi} mod p. Then these shares of the pair-key are multiplied together mod p to obtain the desired private pair-key. In fact, $g^{ax1\ldots}g^{axn}$ mod $p = g^{ax1+\ldots+axn}$ mod $p = g^{a(x1+\ldots+xn)}$ mod $p = g^{az}$

mod *p*. This key may be given to Bob, who can thus obtain $E_B(m)$. In this method, it may be useful to have a Post Office representative handle the communications with Bob, while the individual trustees handle directly their sending Alice receipts.

This method can be adjusted so that sufficiently few (alternatively, certain groups of) trustees cannot remove the Post Office's encryption layer, while sufficiently many (alternatively, certain other groups of) trustees can. For instance, there can be *kn* trustees, and each of the n trustees acting as above can give his own secret key to each of a group of *k* - 1 other trustees. Thus, each distinct group of *k* trustees has knowledge of a secret key as above. Further, the above-described modifications to the single invisible-trustee ECM protocol can be applied to embodiments involving multiple trustees.

In the ECM system involving fair cryptography, even a user might be or rely upon a multiplicity of entities. Indeed, in the invention, "user" or "party" or "trusted party" thus should be construed broadly to include this possibility.

It should be appreciated that the inventive ECM systems enable Alice and Bob to exchange simultaneously two special values, the first, produced by Alice, which is (at least reasonably) unpredictable to Bob, and the second, produced by Bob, which is unpredictable to Alice. Indeed, the value produced by Bob and unpredictable to Alice may be Bob's signature of step B1. If the message is not known precisely by Bob, then the message itself may be the value produced by Alice and unpredictable to Bob. Alternatively, if Bob knows the message precisely (but it is desired that he receive it from Alice in an official and certified manner), then the parties may use a customization step so that, for example

$SIG_A(m,E_B(m))$ is the value produced by Alice and unpredictable to Bob.

The inventive system is useful to facilitate other electronic transactions that require the simultaneous exchange of unpredictable values. One such example, not meant to be limiting, involves a contract "closing" wherein a pair of users desire to sign a contract at a particular time and place. The invention thus allows Alice and Bob to sign a contract simultaneously with an invisible third party. Indeed, the first value may be Alice's signature of the contract C and the second value Bob's receipt for a message consisting of Alice's signature of C.

In particular, assume that Alice and Bob have already negotiated a contract C. Then, Alice and Bob agree (in a preliminary agreement) (a) that Alice is committed to C if Bob gets the message consisting of Alice's signature to C, and (b) that Bob is committed to C if Alice gets Bob's receipt of that message. This preliminary agreement can be "sealed" in many ways, for instance by signing, preferably standardized, statements to this effect conventionally or digitally. It does not matter who signs this preliminary agreement first because Bob does not have Alice's message and Alice does not have Bob's receipt. However, after both parties are committed to the preliminary agreement, the inventive ECM system allows the message and the receipt to be exchanged simultaneously, and thus C is signed simultaneously. Those skilled in the art also may realize it may be more convenient to first one-way hash C prior to signing it.

This method may be much more practical than accessing a commonly trusted lawyer particularly, when the contract in question may be very elementary or arises in an "automatic context". Generalizing, one may view a contract C as any arbitrary signal or string of symbols to which the parties wish to commit in a simultaneous way. The inventive solution is very attractive because it can be implemented in software in many contexts, and because the trustee is invisible and need not be called into use if the signatories behave properly. This minimizes cost and time, among other resources. In this application, the trustee, rather than a post office, may be a "financial service center" that facilitates the transactions of its own customers.

Yet another application of the invention is to make simultaneous the result of applying a given function to one or more secret values, some belonging to Alice and some belonging to Bob. For example, the inventive method allows implementation of "blind" negotiations. In this embodiment, assume a seller Alice and a buyer Bob desire to determine whether Alice's (secret) minimum selling price is lower than Bob's (secret) maximum selling price (in a way that both parties will learn the result simultaneously). If the answer is no, then the parties may either try again or terminate the negotiation. Alternatively, if the answer is yes, then preferably the parties also will be committed to the transaction at some value. (For example, the average of the two secret values).

Another useful application of the invention is during a bid process, such as in an auction. For instance, assume that multiple bidders wish that their secret bids be revealed simultaneously. One bidder may also wish that his or her bid be independent of the other bids.

CLAIMS:

What is claimed is:

1. A communication method between a first and second party, in the presence of a trusted party, enabling a transaction in which the second party receives a first value produced by the first party and unpredictable to the second party if and only if the first party receives a second value produced by the second party and unpredictable to the first party, comprising the steps of:

exchanging a first set of communications between the first and second parties without participation of the trusted party to attempt completion of the transaction; and

If the transaction is not completed using the first set of communications between the first and second parties, having the trusted party take action to complete the transaction.

2. The communication method as described in Claim 1 wherein the first party's value is a message and the second party's value is a receipt, such that the transaction is a certified transmission of the first party's message.

3. The communication method as described in Claim 1 wherein the first party can prove that some information it receives is the second value.

4. The communication method as described in Claim 1 wherein the second party can prove that some information it receives is the first value.

5. The communication method as described in Claim 1 wherein the first party can prove that some information it receives is the second value and the second party can prove that some information it receives is the first value.

6. The communication method as described in Claim 1 wherein the first party's value represents a commitment to a contract and the second party's value represents a commitment to the contract, such that the transaction is a contract closing.

7. The communication method as described in Claim 6 wherein the first party can prove that some information it receives is the second value and the second party can prove that some information it receives is the first value.

8. The communication method as described in Claim 1 wherein at least one of the first and second parties and the trusted party can encrypt messages, and at least one of the first and second parties and the trusted party can decrypt messages.

9. The communication method as described in Claim 8 wherein at least one communication of the first party is a data string generated by a process including encrypting a second data string with an encryption key of the trusted party.

10. The communication method as described in Claim 9 wherein the second data string includes a ciphertext generated with an encryption key of one of the parties.

11. The communication method as described in Claim 9 wherein the second data string contains information identifying at least one of the parties.

12. The communication method as described in Claim 8 wherein at least one communication of the second party is a data string generated by a process that includes having the second party digitally sign a data string computed from information received from the first party in a prior communication, wherein the data string generated by the second party is the second party's value.

13. The communication method as described in Claim 8 wherein if the second party does not get the first value in the first set of communications, the second party sends the trusted party for further processing a data string that 5 includes at least part of the data received from the first party.

14. The communication method as described in Claim 13 wherein the further processing by the trusted party includes decrypting a ciphertext with a secret decryption key.

15. The communication method as described in Claim 14 wherein the trusted party sends the first party information that enables the first party to compute the second value, and the trusted party sends the second party information that enables the second party to compute the first value.

16. The communication method as described in Claim 15 wherein the trusted party also verifies identity information of at least one of the parties and does not learn the first value.

17. The communication method as described in Claim 1 wherein the trusted party takes no action to complete the transaction after a specified time.

18. The communication method as described in Claim 17 wherein the specified time is included within the first set of communications.

19. The communication method as described in Claim 17 wherein the specified time is determined by the time at which certain communications occur.

20. A method by which first and second parties and a trusted party effect a certified mail transaction, each of the parties having matching public and secret keys of a public key encryption scheme, and wherein the first party desires to send a message to the second party and obtain a message receipt indicating the content of the message to thereby complete the certified mail transaction, comprising the steps of:

(a) having the first party generate and send to the second party a data string including an encryption, with the trusted party's public key, of information that prevents the trusted party for enabling the second party to obtain the first party's message without the first party obtaining the message receipt;

(b) upon receipt by the second party of the data string, having the second party generate and send to the first party the message receipt;

(c) upon receipt by the first party of the message receipt, having the first party send to the second party information that enables the second party to retrieve the 20message;

(d) upon receipt by the second party of the information, having the second party attempt to verify whether the message was received; and

(e) if the message was not received, having the second party send information to the trusted party for further processing, wherein the information includes a ciphertext encrypted with a public key of the trusted party.

21. The method as described in Claim 20 further including the step of:

(f) having the trusted party, using the information received from the second party, (i) decrypt some information it receives from the second party using the secret key of its public key encryption scheme to thereby generate an encryption of the first party's message using the second party's public key, and (ii) obtain information that identifies at least the first party.

22. The method as described in Claim 21 further including the unordered steps of;

(g) having the trusted party send the first party, as the message receipt, some of the information the trusted party received from the second party; and

(h) having the trusted party send the second party information from which the second party can retrieve the message.

23. The method as described in Claim 20 wherein at least one of the first and second parties and the trusted party includes a physically secure device.

24. The communication method as described in Claim 20 wherein further processing by the trusted party does not occur after a specified time.

25. The communication method as described in Claim 24 wherein the specified time is included within at least communication between the first and second parties.

26. The communication method as described in Claim 24 wherein the specified time is determined by the time at which certain communications occur.

27. A communication method between a first and second party, in the presence of a plurality of trustees, enabling a transaction in which the second party receives a first value produced by the first party and unpredictable to the second party if and only if the first party receives a second value produced by the second party and unpredictable to the first party, comprising the steps of:

exchanging a first set of communications between the first and second parties without participation of any of the trustees to attempt completion of the transaction; and if the transaction is not completed using the first set of communications between the first and second parties, having a given number of the trustees take action to complete the transaction.

28. The communication method as described in Claim 27 wherein the plurality of trustees hold shares of a given secret key.

29. The communication method as described in Claim 27 wherein at least one of the first and second parties and the trusted party can encrypt messages, and at least one of the first and second parties and the trusted party can decrypt messages.

30. The communication method as described in Claim 27 wherein at least one communication of the second party is a data string generated by a process that includes having the second party digitally sign a data string computed from information received from the first party in a prior communication, wherein the data string generated by the second party is the second party's value.

31. The communication method as described in Claim 30 wherein if the second party does not get the first value in the first set of communications, the second party sends the trusted party for further processing a data string that includes at least part of the data received from the first party.

32. The communication method as described in Claim 27 wherein the trusted party takes no action to complete the transaction after a specified time.

33. The communication method as described in Claim 32 wherein the specified time is included within the first set of communications.

34. The communication method as described in Claim 32 wherein the specified time is determined by the time at which certain communications occur.

35. In a communications network wherein first and second parties desire to effect a transaction overseen by a trusted party of the network, each of the first and second parties having a value that cannot be predicted by the other of the first and second parties, and wherein the predetermined transaction is complete when the first party receives the value generated by the second party and the second party receives the value generated by the first party, a communication method comprising the steps of:

exchanging a first set of communications between the first and second parties without participation of the trusted party to attempt completion of the transaction; and

if the transaction is not completed using the first set of communications between the first and second parties, having the trusted party take action to complete the transaction.

36. In the communications network as described in Claim 35 wherein at least one of the first and second parties is a computer.

37. In the communications network as described in Claim 35 wherein the trusted party is a computer.

38. In the communications network as described in Claim 35 wherein at least one of the first and second parties is a secure device.

39. A communication method between a first and second party enabling a transaction in which the second party receives a first value produced by the first party and unpredictable to the second party if and only if the first party receives a second value produced by the second party and unpredictable to the first party, comprising the steps of:

having the first party use a key of a third party to encrypt a string from which the second party can compute the first value; and having the first, second and third parties exchange a set of communications that include the string.

40. The method as described in Claim 39 wherein the string also includes information that is selected from the group consisting of information specifying the first party, information specifying the second party, and information specifying the first and second parties.

41. The method as described in Claim 39 wherein the key of the third party is held by a plurality of trustees.

42. The method as described in Claim 39 wherein the first party comprises a plurality of entities.

43. The method as described in Claim 39 wherein the second party comprises a plurality of entities.

44. The communication method as described in Claim 39 wherein at least one of the parties takes no action to complete the transaction after a specified time.

45. The communication method as described in Claim 44 wherein the specified time is specified by at least one of the parties.

46. The communication method as described in Claim 44 wherein the specified time is determined by the time at which certain communications are received.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US96/03920

A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) :HO4L 9/30
US CL :380/30
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 380/30

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. *DOCUMENTS CONSIDERED TO BE RELEVANT*

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US, A, 4,438,824 (MUELLER-SCHLOER) 27 March 1984, See entire document.	9-17, 20-26, 30, 31, 37
Y	US, A, 4,458,109 (MUELLER-SCHLOER) 03 July 1984, See entire document.	9-17, 20-26, 30, 31, 37
Y	US, A, 5,214,700 (PINKAS ET AL) 25 May 1993 See Figs. 2 and 4.	9-17, 20-26, 30, 31, 37
Y	US, A, 5,276,737 (MICALI) 04 January 1994, See Fig. 2.	9-17, 20-26, 30, 31, 37
Y	US, A, 5,315,658 (MICALI) 24 May 1994, See Fig. 2.	9-17, 20-26, 30, 31, 37

□ Further documents are listed in the continuation of Box C. □ See patent family annex.

*	Special categories of cited documents:	"T"	later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"A"	document defining the general state of the art which is not considered to be of particular relevance		
"E"	earlier document published on or after the international filing date	"X"	document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"L"	document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"Y"	document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"O"	document referring to an oral disclosure, use, exhibition or other means		
"P"	document published prior to the international filing date but later than the priority date claimed	"&"	document member of the same patent family

Date of the actual completion of the international search 27 JUNE 1996	Date of mailing of the international search report 02 AUG 1996
Name and mailing address of the ISA/US Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231	Authorized officer for SALVATORE CANGIALOSI
Facsimile No. (703) 305-3230	Telephone No. (703) 305-1837

Form PCT/ISA/210 (second sheet)(July 1992)*

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US96/03920

Box I Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)

This international report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☒ Claims Nos.: 1-8, 17-19, 27-29, 32-35, 38-46
because they relate to subject matter not required to be searched by this Authority, namely:

They disclose a method of doing business which is not embodied in any specific means.

2. □ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. □ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box II Observations where unity of invention is lacking (Continuation of item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. □ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. □ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.

3. □ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. □ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest □ The additional search fees were accompanied by the applicant's protest.
□ No protest accompanied the payment of additional search fees.

PCT

WORLD INTELLECTUAL PROPERTY ORGANIZATION
International Bureau

INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 6 :
H04L 9/32

A2

(11) International Publication Number: WO 97/24833

(43) International Publication Date: 10 July 1997 (10.07.97)

(21) International Application Number: PCT/US97/00286

(22) International Filing Date: 3 January 1997 (03.01.97)

(30) Priority Data:

60/009,577	3 January 1996 (03.01.96)	US
08/604,870	22 February 1996 (22.02.96)	US

(81) Designated States: AL, AM, AT, AU, AZ, BB, BG, BR, BY, CA, CH, CN, CZ, DE, DK, EE, ES, FI, GB, GE, HU, IL, IS, JP, KE, KG, KP, KR, KZ, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, TJ, TM, TR, TT, UA, UG, UZ, VN, ARIPO patent (KE, LS, MW, SD, SZ, UG), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, ML, MR, NE, SN, TD, TG).

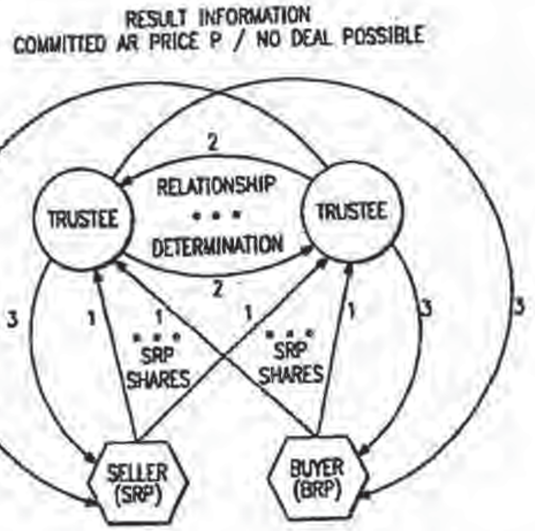
(71)(72) Applicant and Inventor: MICALI, Silvio [US/US]; 459 Chestnut Hill Avenue, Brookline, MA 02146 (US).

(74) Agents: MUIRHEAD, Donald, W. et al.; Foley, Hoag & Eliot L.L.P., One Post Office Square, Boston, MA 02109-2170 (US).

Published
Without international search report and to be republished upon receipt of that report.

(54) Title: IDEAL ELECTRONIC NEGOTIATIONS

(57) Abstract



There is described an electronic communications method between a first party and a second party, with assistance from at least a plurality of trustees, enabling an electronic transaction in which the first party having a selling reservation price (SRP) and the second party having a buying reservation price (BRP) may be commited to a transaction if a predetermined relationship between SRP and BRP is established, but not otherwise. The method begins by having each of the parties transmit shares of their respective reserve prices to the trustees. These shares are such that less than a given number of them does not provide enough useful information for reconstructing the reserve prices while a sufficiently high number of them allows such reconstruction. The trustees then take some action to determine whether the predetermined relationship exists without reconstructing SRP and BRP. If the predetermined relationship exists, then the trustees provide information that allows a determination of the sale price according to a given formula. Otherwise, the trustees determine that no deal is possible. As used herein, "sale" is merely representative as the transaction may be of any type including, without limitation, a sale, lease, license, financing transaction, or other known or hereinafter created financial commercial or legal instrument.

FOR THE PURPOSES OF INFORMATION ONLY

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AM	Armenia	GB	United Kingdom	MW	Malawi
AT	Austria	GE	Georgia	MX	Mexico
AU	Australia	GN	Guinea	NE	Niger
BB	Barbados	GR	Greece	NL	Netherlands
BE	Belgium	HU	Hungary	NO	Norway
BF	Burkina Faso	IE	Ireland	NZ	New Zealand
BG	Bulgaria	IT	Italy	PL	Poland
BJ	Benin	JP	Japan	PT	Portugal
BR	Brazil	KE	Kenya	RO	Romania
BY	Belarus	KG	Kyrgystan	RU	Russian Federation
CA	Canada	KP	Democratic People's Republic	SD	Sudan
CF	Central African Republic		of Korea	SE	Sweden
CG	Congo	KR	Republic of Korea	SG	Singapore
CH	Switzerland	KZ	Kazakhstan	SI	Slovenia
CI	Côte d'Ivoire	LI	Liechtenstein	SK	Slovakia
CM	Cameroon	LK	Sri Lanka	SN	Senegal
CN	China	LR	Liberia	SZ	Swaziland
CS	Czechoslovakia	LT	Lithuania	TD	Chad
CZ	Czech Republic	LU	Luxembourg	TG	Togo
DE	Germany	LV	Latvia	TJ	Tajikistan
DK	Denmark	MC	Monaco	TT	Trinidad and Tobago
EE	Estonia	MD	Republic of Moldova	UA	Ukraine
ES	Spain	MG	Madagascar	UG	Uganda
FI	Finland	ML	Mali	US	United States of America
FR	France	MN	Mongolia	UZ	Uzbekistan
GA	Gabon	MR	Mauritania	VN	Viet Nam

IDEAL ELECTRONIC NEGOTIATIONS

TECHNICAL FIELD

The present invention relates generally to secure electronic communications systems and more particularly to cryptographic methods that enable participants in a negotiation to agree on a common price for a given transaction without requiring either participant to reveal certain information about its bargaining position unless a suitable agreement can in fact be reached.

BACKGROUND OF THE INVENTION

In the past two decades, many secure transactions have been devised that compute quantities from certain hidden data without revealing all such data. For instance, Yao (in the Proceedings of Foundations of Computer Science Conference, 1982) presented a solution to the so-called Two-Millionaire problem that involved this approach. In this problem, two millionaires wish to know who is richer without revealing their respective monetary worth. In Yao's solution, the parties engage in cryptographic exchange, each encoding in a special manner the amount of money he/she owns. At the end of the exchange, one of the millionaires is in possession of information indicating which of the two is the richer one and can then, without proof, announce the result to the other.

In another example, Goldreich, Micali, and Widgerson presented the first of a series of cryptographic protocols for secure multi-party computation. This protocol enabled n parties (whose majority is honest), where party I has a secret input x_i, to evaluate f on their private inputs, without revealing these inputs more than absolutely necessary. At the simplest level, the parties compute $y = f(x_1,\ldots,x_n)$ without revealing more about the x_i's that is implicitly revealed by the value y itself. More sophisticated and precise definitions of this protocol were later described, for instance in the work Micali and Rogaway.

In the past, traditional physical proximity has encouraged sellers and buyers to negotiate in good faith. Physical proximity creates enough circumstantial evidence of an enforceable agreement, and also requires a considerable investment of time and effort on both sides, thus reducing the buyer's temptation of negotiating just for "curiosity" without any serious intentions of buying. Such goals, however, are more difficult to achieve where business transactions are carried out more and more at a distance (e.g., over an electronic network). Consider the example of purchasing a house over the Internet. Photographic information of a piece of property is readily available over the Internet, and digital signatures may help in signing a contract. However, in this new setting, it is possible for a seller to negotiate with many potential buyers simultaneously and at a distance so that the various buyers may not be aware of each other. The seller can then use one buyer's offer for obtaining better offers from others, even with stringent time constraints. At the same time, the new setting makes it very convenient for uncommitted buyers just to shop around for a seller's "true" price, and then possibly sell this information to others.

There remains a need in the art to provide cryptographic protocols that enable parties to negotiate and consummate business and other transactions electronically.

BRIEF SUMMARY OF THE INVENTION

It is the primary object of the present invention to describe an entirely new class of electronic cryptographic-based transactions, referred to herein as "blind negotiations."

A "blind negotiation" (sometimes referred to as an "ideal negotiation") according to the present invention is a new electronic transaction wherein a seller S and a buyer B wish to see whether they can agree on a price for a given good or service. It is assumed that the seller has a "reservation" prices, SRP, at which she is willing to sell now (not necessarily the minimum of such prices). Similarly, the buyer has a reservation price, BRP, at which he is ready to buy now (not necessarily the maximum of such price). In a blind negotiation, the current reservation price of each party is a secret of that party.

A blind negotiation is a cryptographic system that guarantees the following two properties (which are NOT readily obtainable even in a physical or face-to-face transaction):

1. *Enforceable Agreement*. Both parties reach an agreement on a price P (between SRP and BRP) whenever SRP < (or equal to) BRP, or else;
2. *Proved Privacy*. Each party is provided a proof that SRP > BRP that does not reveal the other's reservation price.

In a blind negotiation, if seller and buyer learn that no deal is possible (i.e., that SRP > BRP), then they may decide to try another round of negotiating, presumably after changing their reservation prices, or they may decide to quit negotiating. In the latter case, the seller knows that no one has learned her reservation price, and thus that she can participate in future negotiations with her "bargaining power" intact. If, instead, a deal is possible, a blind negotiation may reveal the two reservation prices. Indeed, for instance, assume that the two parties agree to "split in the middle" when a deal is possible (i.e., they adopt P = SRP+BRP/2 as the actual sale price). Then, after reaching agreement on a price P by means of a blind negotiation, each party can, knowing his own reservation price and the average of the two, easily compute the other's reservation price. Indeed, when a blind negotiation system realizes that SRP < (or equal to) BRP, then the system can just reveal SRP and BRP, so that P=SRP+BRP/2 can be easily computed.

It should be noted that in real-life, blind negotiations are not easily obtainable. In fact, if one of the parties (e.g., the seller) makes an offer to sell at a given price, then that offer already provides valuable information about SRP. A similar problem exists when the first offer is made by the buyer. As a result, in a real-life negotiation, sellers and buyers are unwilling to make first offers. This, however, is not a problem in a blind negotiation system.

It is thus an object of the present invention to provide cryptographic techniques and systems for implementing such blind negotiation schemes.

It is a further more specific object of the invention to facilitate blind negotiations using one or more trusted parties who either preferably do not learn BRP or SRP or, if they do, they cannot misuse such information. Such trusted parties may be actively involved in the negotiation or, alternatively, be required only when initial exchanges of communications between buyer and seller leaves one of the parties with uncertainty about the results of the negotiations.

The constraint that a deal is achievable if SRP < (or equal to) BRP is preferable, although other functional relationships between SRP and BRP may be implemented in the blind negotiation system. Thus any reference to the preferred constraint of SRP < (or equal to) BRP should not be taken to limit the present invention. Similarly, the constraint that the actual sale price is in-between SRP and BRP is merely preferable, but not required either.

Thus, in one embodiment, there is described an electronic communications method between a first party and a second party, with assistance from at least a plurality of trustees, enabling an electronic transaction in which the first party having a selling reservation price (SRP) and the second party having a buying reservation price (BRP) may be committed to a transaction if a predetermined relationship between SRP and BRP is established, but not otherwise. The method begins by having each of the parties transmit shares of their respective reserve prices to the trustees. These shares are such that less than a given number of them does not provide enough useful information for reconstructing the reserve prices while a sufficiently high number of them allows such reconstruction. The trustees then take some action to determine whether the predetermined relationship exists without reconstructing SRP and BRP. If the predetermined relationship exists, then the trustees provide information that allows a determination of the sale price according to a given formula. Otherwise, the trustees determine that no deal is possible. As used herein, "sale" is merely representative as the transaction may be of any type including, without limitation, a sale, lease, license, financing transaction, or other known or hereinafter created financial commercial or legal instrument.

In a modification to this embodiment, the actions are taken not only by the trustees alone, but also in conjunction with the first party and the second party.

In an alternate embodiment, the seller and buyer communicate with a single trustee, who can determine whether a deal is possible without learning SRP or BRP. In a still further embodiment, the trusted party may be a secure piece of hardware that receives an encrypted version of SRP and an encrypted version of BRP and determines whether a deal is possible and at what price.

Yet in another embodiment, the blind negotiation is achieved with "invisible" trustees. In such a case, the seller and buyer do not collaborate with any trustee initially and implement a blind negotiation system if they continue collaborating properly. However, if one of the parties stops collaborating, the other party can access one or more trustees who are capable of completing the interrupted blind negotiation.

Of course, in a blind negotiation according to the invention, the parties need not agree on a final price merely by splitting the difference between their respective reserve prices. Indeed, in a blind negotiation the two parties may agree on the actual sale price by any strategy they want. For instance, if a deal occurs in the first blind negotiation, then the parties may agree to split in the middle, but if a deal becomes possible in the next round of blind negotiation, then they may agree on the actual sale price by means of a formula that favors the party who has made the biggest "concession" in the second round. Alternatively, they may decide to favor the party who has varied his reservation price by a smaller degree in the second round, or by some such other approach.

BRIEF DESCRIPTION OF THE DRAWINGS

For a more complete understanding of the present invention and the advantages thereof, reference should now be made to the following Detailed Description taken in conjunction with the drawings in which:

FIGURE 1 illustrates a preferred embodiment of the invention wherein an electronic process having three conceptual steps (as numbered) is effected by first and second parties, with the assistance of a plurality of trustees, in order to achieve an ideal electronic negotiation.

FIGURE 2 illustrates a preferred embodiment of the invention wherein an electronic process having three conceptual steps is effected by first and second parties, with the assistance of a trustee comprising secure hardware, in order to achieve an ideal electronic negotiation.

FIGURE 3 illustrates an embodiment of the invention wherein an electronic process is effected by having first and second parties exchange messages to attempt to complete an ideal negotiation, and the use of the trusted party to complete the action if needed.

FIGURE 4 illustrates a share method embodiment of the invention, involving three numbered steps, wherein seller and buyer are players who, together with at least one other trustee-player(s), take action in determining whether a given relationship exists between SRP and BRP in order to effect the ideal negotiation.

DETAILED DESCRIPTION

Several different types of blind negotiation systems are described below. For each one of these systems there is also presented several variations and modifications. Such variations and modifications also apply to the other blind negotiation systems and not just the particular schemes with which they are described.

Blind Negotiations With Multiple Trustees/Players

In a first embodiment, an *n*-party secure computation (e.g., the protocol of Goldreich, Micali and Widgerson, or that of Ben-Or, Goldwasser and Widgerson, or that of Rabin and Ben-Or, or that of Chaum, Crèpeau and Damgård) or a "suitable" simplification thereof is used to facilitate a blind negotiation application.

By way of brief background, it is known in the art that secure protocols enable n players (a suitable majority of which is honest) to evaluate a given function f on their private inputs, without revealing these inputs more than absolutely necessary. At the simplest level, the parties compute $y = f(x_1,\ldots,x_n)$ without revealing more about the x_i's that is implicitly revealed by the value y itself. Of course, if each player keeps his own input for himself, the privacy of the inputs x_i is perfectly maintained, but no joint computation of f can occur. Of course too, if a player reveals his input to some other player, this may facilitate some joint computation, but it may not keep the player's input as secret as it should be. Rather, in most secure computation protocols, a player I takes his own secret input x_i and constructs a secret random polynomial $P(x)$ --modulo a prime p, $p > n$, and of degree t, $1 < t < n$ --such that $P(O) = x_i$, his own input. (In other words, the player chooses the last coefficient of the polynomial to be his own input, and all other coefficients at random. If the input of a player is a binary string of at most, say, k bits, then p can be chosen not only $> n$, but also having $k + 1$ bits.)

Then, the player privately gives player a the value $P(a)$, player b the value $P(b)$ and so on. Thus, no single player (other than i), nor any collection of players with less than t members, may know the polynomial $P(x)$, nor the input x_i. However, collectively, the players (indeed any $t+1$ of the players) know $P(x)$. Indeed a t-degree polynomial may be easily obtained by interpolation from its value at $t+1$ different points. Thus, sufficiently many players can easily reconstruct $P(x)$, and thus $P(O) = x_i$, while sufficiently fewer players cannot even guess x_i better than at random.

Each player a thus (1) possesses a share, $P(a)$, of any other player's input, and (2) if the majority of the players want, the input of every player can be revealed, but (3) without the cooperation of the majority of the players, each input remains unpredictable. After sharing each input among all players in such a fashion, a typical secure computation protocol then proceeds to evaluate the given function on the player's inputs, but working on their shares, rather than on the inputs directly. For instance, if the function dictates that the inputs x_i of player i, encoded by a polynomial P (i.e., $P(O) = x_i$), should be added (mod p) to the input x_j of player j, encoded by a polynomial Q (i.e., $O(0) = x_j$), then each player k, whose share of x_i is $i_k = P(k)$ and whose share of x_j is $j_k = Q(j)$, adds i_k and j_k mod p, thereby computing $(P+Q)(k)$, that is, a share of (x_i+x_j mod p), the sum of the two inputs mod p.

As for another example, if the function dictates that the input x_i of player i (encoded by a polynomial P) should be multiplied modulo p with the input x_j of player j (encoded by polynomial Q), then each player k, whose share of x_i is $i_k = P(k)$ and whose share of x_i is $j_k = Q(j)$, multiplies i_k and j_k modulo p, thereby computing $(PQ)(k)$, that is, a share of x_ix_j (mod p), the product of the two inputs modulo p.[1]

Though not all operations on the inputs translate into operations on the shares in a way that is as simple as in the case of the "addition mod p" operation or of a (single) multiplication modulo p, at the end of the secure computation the players have each his own share of $y=f(x_1,\ldots,X_n)$, that is, each player k has the value $F(k)$, where F is a t-degree polynomial such that $F(O) = y$. Thus all players may release their shares, so as to allow the reconstruction of F by polynomial interpolation, and thus the reconstruction of y without releasing any unwanted information about the inputs x_i's. This reconstruction also works in a simple way (provided that there are sufficiently many honest players) even though some players may be bad and release incorrect shares. This is just the basic background

[1] Note that the product polynomial PQ has degree $2t$, and thus one needs $2t$ points for interpolating it. Therefore, there must by sufficiently many honest players. If one had to execute a chain of several multiplications -- e.g., $((P+Q)QQ+Q)P$--by means of the above method, then the number of honest players needed would become totally impractical. Thus, different (degree-reduction) methods have been devised in the literature. The above method, however, is quite practical if one only needs to compute a single product mod p.

on multi-party secure computations. The reader is directed to the art references for further details.

With this background, it can now be described how one such secure computation protocol is used to facilitate a blind negotiation.

A First Share-Method

As noted above, as indicated in FIGURE 1, a secure-computation protocol assumes that there are *n* parties, the majority of which are honest. In a blind negotiation there are two parties, the seller and the buyer. It cannot be assumed that both parties are honest, however. Thus, in this embodiment seller and buyer cooperate with one or more *trustees*. These are additional parties that are assumed to be trustworthy (in particular, trusted to follow the prescribed instructions of a secure computation protocol). By means of a system such as described below, the trustees enable seller and buyer to complete their negotiation in a blind way. It is desired, however, that the trustees should not receive much information, nor should they be able to misuse whatever information they do receive.

The following blind negotiation system further makes use of *digital signatures*. In a digital signature scheme, each party *X* has a secret signing key S_x and a matching public verification key P_x. Party *X* may obtain its digital signature of a message (string) *m*, $SIG_x(m)$, by running an algorithm *SIG* on inputs S_x and *m* (thus, $\mathrm{SIG}_x(m) = \mathrm{SIG}(S_x,m)$). The signature of party *X* on a message *m* is verified by running a verifying algorithm *VER* on the signature and *X*'s public key.

The following now describes how to use a multi-party secure computation protocols for building a blind negotiation systems with trustees and digital signatures. For instance, a secure computation with $n=3$ exists by asking one trustee to join the computation. Thus, if either the seller or the buyer is honest, since a trustee is presumably selected with trustworthiness as a prerequisite, an honest majority exists. If desired, larger values of *n* may be chosen in a secure computation protocol, with the cooperation of more trustees. This way, even if one or more trustees turn out to be malicious, the majority of all players are honest.

Assume now that there are sufficiently many trustees, so that there is a total number of $n>2$ players, a suitable majority of which are honest. Without loss of generality, the seller is player 1, the buyer player 2, and the trustees players 3,...,n. Then, n players are used to perform a particular n-party secure computation, for an especially selected function f, and for especially selected inputs.

Let (S_1,SRP) be the input of player 1, (S_2,BRP) be the input of player 2 and ϵ the input for any other player, where S1 is the secret signing key of the seller, SRP the reserve price of the seller, S2 the secret signing key of the buyer, BRP the reserve price of the buyer, and E; the empty string. Further, let f be the function such that $f((S_1,SRP), (S_2,BRP), \epsilon,\ldots,\epsilon) =$

$(SIG(S_1,(T,SRP+BRP/2)), \quad SIG(S_2,(T,SRP+BRP/2)))$ *if*

$SRP \leq BRP$,

and "NO DEAL" otherwise. Here T is any string describing the transaction in any sufficient way. For instance, T may consist of identifying the seller and the buyer, the negotiated commodity, and/or additional data, such as time data, or an indication of the trustees.

Thus, function f outputs a certified commitment for the seller and buyer to trade, at a meet-in-the-middle price, whenever the deal is possible, i.e., whenever *SRP< (or equal to) BRP*. (Of course, within f, one could replace $SRP+BRP/2$ with any strategy, $g(SRP,BRP)$, to determine the actual trade price.) Therefore, the function f only depends on the inputs of seller and buyer, and not on the inputs of the trustees (these could be any value rather than ϵ, because f may ignore them anyway).

The above is a "blind negotiation" system because both seller and buyer end up with a signed contract with the right price whenever a deal is possible between them; otherwise they end up with a proof that no deal is possible, but which does not reveal what the two reservation prices may be. In case a deal were possible, preferably the contract is signed by both of them digitally. Indeed, in this case the output of the secure computation is the signature of the buyer and the seller that the transaction T has resulted in a sale at a given *Price*. Thus, the above system satisfies the Enforceable Agreement property. Indeed, whenever SRP is greater to or equal to BRP, seller and buyer end up with a binding contract at an agreed price determined by a given formula.

In case a deal were not possible, then the result of the secure computation is NO DEAL, and this is a proof that SRP > BRP (because of the way the function f is defined, because an honest majority exists among the selected players so that f is correctly computed, and because the result of the computation has been produced by the trustees and can be thus "witnessed by them" if necessary). An alternative proof that no deal is possible can be obtained by modifying the function f so that $SIG_S(T,NO\ DEAL)$ and $SIG_B(T,NO\ DEAL)$ is output instead of just NO DEAL (where the subscript S stands for seller and B for buyer). Either way, the reconstruction of NO DEAL does not reveal what the specific values of SRP and BRP may be, save for the fact that SRP > BRP. Indeed, in a secure computation of a function, only the result of the function evaluation is made known, but not the function's inputs. Thus, if a given computation of f results in outputting NO DEAL, then this output reveals that SRP is greater than BRP but not the specific values thereof. Thus, any other information about SRP, BRP and the seller's and buyer's secret signing key is kept totally secret. The above system thus also satisfies the Proved Privacy property.

<u>A Second Share-Method</u>

The above method, however, may be enhanced by having seller's and buyer's signatures computed outside the share computation phase. Before engaging in any secure computation, buyer and seller sign (preferably digitally) an initial agreement of the kind "in this transaction T, with trustees $T_1,T_2,\ldots$, seller S and buyer B agree to trade commodity C at the average of their reserve prices, if their secure computation of function f is YES." Then, seller, buyer and trustees securely evaluate f on inputs $(SRP,BRP,\epsilon,\ldots,\epsilon)$, making sure that this computation is bound to identifier T. Here, f is the function such that $f(SRP,BRP,\epsilon,\ldots,\epsilon)=$ YES if $SRP \leq BRP$, and NO otherwise. Thus, if the result is YES, the players retrieve SRP and BRP from their shares (alternatively, f may output (SRP,BRP) rather than YES), and seller and buyer can then easily both sign $(T,SRP+BRP/2)$. If one of them refuses to do so despite the result of the computation, then the honest trustees may sign in his or her place, and the signatures of a suitable majority of the trustees may be considered equally binding. If the share computation phase indicates that no deal is possible, then seller and buyer will each sign (T,NO), or the trustees will do it on their behalf. (Notice that it is not important who signs an initial agreement first. Indeed, only after both seller and buyer have signed it will a secure computation of f follow or be completed.)

Of course, many variants of this basic method can be implemented. For instance, different types of initial agreements may be stipulated. Also, in any of the blind negotiation systems, seller and buyer may not participate in as players in the secure computation phase. The players of this phase can just be trustees (so that it is easier to have a suitable honest majority). Thus, each of seller or buyer may just give each trustee his or her proper share of the input, and then the entire computation will be carried over the shares by the trustees, until the final result is produced and handed out to both seller and buyer. Also, the trustees (or seller and buyer) may just sign NO or nothing at all, rather than signing *(T,NO)*. As for *T*, it is preferable that it provides a unique identifier of the current negotiation. For instance, T may include some of S, B, the current date and time, a description of the commodity on sale, as well as encryptions of SRP or BRP, or an indication of the trustees, or a random identifier.

A Third Share-Method

The first alternative embodiment, wherein digital signatures are carried out outside the share computation phase, may also be enhanced. Indeed, a typical secure computation protocol succeeds in securely evaluating a given function by means of securely computing some primitive functions, for instance, modular addition and modular multiplication.

Accordingly, rather than directly applying some ready-made secure computation protocols in the secure computation phase of the inventive blind negotiation protocols, it may preferable to write a new *ad hoc* protocol for this purpose that uses the above primitives in an elementary way. One such protocol is now described.

The new protocol uses as a primitive the share computation of $(a-b)r$ mod p, where a, b, and r are secret values in the multiplicative group mod p, and p is preferably a prime (in which case a, b, and r are between 1 and p-1). In this application, a and b may be specific values (e.g., the private inputs of specific players), while r is a random value, possibly chosen during the computation itself, and it may not belong to any particular player. For instance, r may be chosen as the sum mod p of several random secret values r_i's belonging to different players.[2]

One advantage of the *(a-b)r* primitive is that its share computation is readily implemented. Indeed, the share computation of a single addition/subtraction and a single multiplication modulo p of secret values (such as a, b and r) is particularly easy to obtain.

A second advantage of the *(a-b)r* primitive is that it can be used to test whether two given secret inputs a and b are equal without releasing any additional information. In fact, if $a=b$, then $(ab)r=0$ no matter what the actual value of a, b and r may be. Alternatively, if $a \neq b$, $(a-b)$ is a fixed non-zero number. Thus, multiplying modulo p this fixed number by a number r between 1 and p-1, yields a number modulo p different from zero. Moreover, because r is random, this product modulo p is a random number between 1 and p-1, and thus cannot betray what the precise values are of a and b.

These advantages make the *(a-b)r* primitive especially suitable for constructing a practical and general type of blind negotiation. In particular, assume that the seller's and buyer's reserve prices are in the interval *[M,N]*. That is, M and N are, respectively, agreed (or obvious) lower- and upper-bounds to both SRP and BRP in some given currency. That is, each value between M and N is interpreted as a possible price in dollars, or tens of dollars, or thousands of dollars. (Such M and N can be easily made part of the description, T, of a given negotiation.)

In a particular example, the seller is a car dealer. Buyer and seller are "blindly" negotiating over a new compact car (of a given brand, type, and color) over the Internet. Although dealers should welcome offers from customers outside their own trade area, traditionally they do not like negotiations at a distance because they reveal their reserve prices to someone who may not be serious about any offer discussed (and who may just live a few blocks away). In such a setting,

[2] If r is chosen this way, while each r_i may be between 1 and p-1, their sum mod p may be 0. However, if p is suitably large (e.g., 50- or 100-bit long) the probability that the resulting r is 0 when at least one r_i is secretly and randomly chosen, is quite negligible. Thus, from a practical point of view r can be chosen in this matter if desired.

if the players choose thousands of dollars as their currency, they may set $M = 4$ and $N = 40$. (That is, if it is assumed that the car is going to be sold the price will be between $4,000 and $40,000). Alternatively, they may choose $500 or $250 as their basic currency, in which case they may set, respectively, $M = 8$ and $NN = 80$, or $M = 16$ and $N = 160$.

For each price i between M and N, the seller chooses a value S_i as follows. If $i < SRP$, then the seller chooses S_i at random between 1 and p-1 (each such random value is chosen independently from all other such values); else, she sets $S_i = 0$. (Thus, $S_i = 0$ only if price i is acceptable to her.) Symmetrically, for each $I \leq BRP$, the buyer sets $B_i = 0$, and, for each $i > BRP$, he chooses B_i at random between 1 and p-1. (Thus, $B_i = 0$ only if price i is acceptable to him). Then, in the presence of trustees a secure computation of the new primitive is executed for each $i = [M,N]$. That is, for each $i = [M,N]$ the value $(S_i - B_i)R_i$ is computed (without revealing any additional information about S_i and B_i), where each R_i is independently and randomly selected between 1 and p-1. If one of these computations returns a 0, then the deal is possible and agreement if forced. However, if no 0 is obtained, then no agreement is possible and seller and buyer may decide to negotiate again or quit. (Preferably, they had signed an initial agreement prior to executing this procedure indicating their intentions, currency, names, time, etc., and what happens in case of a positive outcome, i.e., in case for some price I the computation of $(S_i - B_i)R_i$ yields zero. This initial agreement can be produced in a standardized manner so as to be more convenient and quite compact.)

How this scheme works can now be explained. Assume first that $SRP \leq BRP$. Then, secure computation of $(S_i - B_i)R_i$ is analyzed in three cases: (1) when $i < SRP \leq BRP$, (2) when $SRP \leq i \leq BRP$, and (3) *when* $SRP \leq BRP < i$. In Case 1, the secure computation of $(S_i - B_i)R_i$ will return a non-zero random number. Indeed, for each such value of i, $B_i = 0$, thus $(S_i - B_i)R_i$ equals just the product mod p of S_i and R_i. Since each of these numbers is different than 0, so will be their product mod p. (Moreover, this product will be a random number between 1 and P-1 because R_i is random.) In Case 2, $S_i = B_i = 0$. Thus $(S_i - B_i)R_i = 0$ for any possible value of R_i. In Case 3, $S_i = 0$. Thus, the secure computation returns the product mod p of B_i and R_i. Since each of these values is different than 0, so is their product mod *p*. (Moreover their product will be a random value between 1 and *p*-1 because so is R_i.).

Assume now that *BRP* <*SRP*. Again, there are three cases to analyze in the secure computation of $(S_i\text{-}B_i)R_i$: (1) $i<BRP<SRP$, (2) $BRP\leq i\leq SRP$, and (3) $BRP\leq SRP<i$. In all three cases, however, what is returned is a random number between 1 and *p*-1, *independent of what specific values SRP and BRP may have*. Thus, such a result, while proving that no deal is possible (i.e., that *SRP*>*BRP*), does not reveal any other detail about the specific values of *SRP* and *BRP*.

Therefore, the new primitive shows only the prices *i* for which both the seller and buyer entered 0 (i.e., all and only those prices at which they are both willing to trade), and thus a sale is possible. Thus, if even a single 0 occurs as the result of the share computation relative to some price i, thanks to their initial agreement, seller and buyer end up with an enforceable agreement to trade at a given price P.

There are several ways to compute price *p*. For instance if *min* is the minimum value of *i* for which 0 was returned and *max* the maximum value of *i* for which a 0 was returned, the initial agreement and the result of the secure computation (as properly witnessed or signed by a suitable number of the players) may be taken to constitute a signed contract to trade the given commodity at price *min* + *max/2*.

Notice that either the seller or the buyer may enter 0 for some values of *i* without entering 0 from that point on (i.e., for all values higher than *i* in the seller's case, and for all values lower than *i* in the buyer's case).[3] This may indicate that the seller (buyer) is willing to sell (buy) at certain prices only, and not, for whatever reason, at all prices higher (lesser) than a given one. The system may recognize this behavior as legitimate (e.g., the final price may be chosen to coincide with a value *i*, $min\leq i\leq max$, properly selected among those for which 0 was returned --e.g., $i=min$, or $i=max$, or, preferably as equidistant as possible from *min* and *max*, with a way to break ties). If it is desired to disincentivize this behavior, however, whenever two or more 0's are returned but

[3] For instance, the seller may just enter 0 for the single value of *i*, strictly less than N and strictly greater than M.

the returned 0's do not constitute a contiguous sub-segment of *[M,N]*, all values S_i and B_i relative to any position between the first 0 and the last 0 are recovered (e.g., from the shares in possession of sufficiently many trustees for secure computation purposes), and if the buyer has put 0 consistently in these positions, then some proper action may be taken. For instance, the seller is obliged to sell at a punishingly cheap price (and a punishingly high price for the buyer). If both the seller and buyer have not put their own 0's in a consistent way, then some proper action may be taken. For instance, the trade price will be decided in some other way, or both will be fined.

Although not meant to be limiting, many of the above computations can be effected in secure hardware by persons using such hardware or other known machines including computers. In addition, although the various methods described are conveniently implemented in a general purpose computer selectively activated or reconfigured by software, one of ordinary skill in the art would also recognize that all methods of the present invention may be carried out in hardware, in software, or in more specialized apparatus constructed to perform the required method steps.

Share-Methods with Players

In a modification of the above embodiment, any of our share-methods for blind negotiations can be implemented so that computing actions are taken by the trustee together with players one and two. This yields a share-based blind negotiation system with a plurality of players, where a player may be the first party, a second party or a trustee. In such modifications, one of the two parties may give a share of his reservation price to the other party. Of course, the two parties have enough information to reconstruct both their own reservation prices but, like in the above share-method, any suitably-small subset that does not include both parties does not possess enough information to construct the reservation price of the (missing) party.

Single-Trustee Blind-Negotiation Systems

It may be preferred that a blind negotiation system use only a single trustee in that it be further simplified. One way of achieving this would be to have the seller tell the trustee her own secret value SRP, and have the buyer tell the trustee his own secret BRP, so that the trustee can announce whether a deal is possible, and at what price, without revealing additional information about SRP and BRP. The trustee, however, then learns both SRP and BRP. Even if he may be trusted to keep the received SRP and BRP confidential, he will nonetheless have learned these values, and this may not be acceptable.[4]

It is therefore preferred to implement a blind-negotiation system with just one trustee possessing the following attractive properties: (1) seller and buyer perform their own computations and then they transmit to the trustee some proper piece of information, which the trustee then further processes to conclude the negotiation; and (2) the trustee does not learn any thing about SRP and BRP (except for learning whether a deal has occurred). Thus, such a system has an elementary and convenient interaction among all parties, and yet does not give the trustee the values of SRP and BRP.

To illustrate this system, it is useful to provide a brief background about the known cryptographic notion of a trap-door permutation. This is a function that is computationally easy to evaluate but overwhelmingly hard to invert unless a special secret is known about the function. Thus, any one can, given x in the range of f, compute $f(x)$. However, only he who knows f's secret can feasibly retrieve x from $f(x)$.

The best known (and essentially the only known) examples of trap-door permutations are based on factoring and modular exponentiation. For instance, consider the RSA function. Let n be the product of two large (e.g., 500-bits), secret, and random primes p and q, $n = pq$. Because selecting such primes p and q is easy, and so is multiplying them, one can easily construct such an n. However, since no fast algorithm for factoring is known, finding the prime factorization of such an n will be hard for everyone else. Thus, the prime factorization of n is a secret relative to n. Let us now see how this secret can be used to invert easily the RSA function.

[4] For instance, assume that, after trusting the trustee to this extreme extent, it turned out that no deal was possible between seller and buyer because *SRP>BRP*. Then the seller should be able to negotiate with others the sale of the same commodity, keeping intact her bargaining power. However, the trustee himself would not be able to negotiate blindly with the seller!

The RSA is a permutation over Z^*_n, the multiplicative group mod n obtained as follows. Let e (for exponent) be relatively prime with $(p-1)(q-1)$, and set $f(x)=X^e$ mod n. Then, $f(x)$ is feasibly evaluated. Indeed, if x, the modulus, and the exponent all are at most k-bit long (e.g., 1,000-bit long), then a modular exponentiation can be computed (by the repeated squaring method) with roughly 1,500 modular multiplications without any need to know n's factorization. Moreover, such a $f(x)$ is a permutation. Indeed, it can be inverted as follows: let d be the multiplicative inverse of e mod $(p-1)(q-1)$; that is, ed mod $(p-1)(q-1)=1$. Then, (always operating mod n, and thus mod $(p-1)(q-1)$ at the exponent) we have $(X^e)^d = e^{ed} = x$; that is, the function X^d mod n is the inverse RSA function (with exponent e), x^d mod $n = s^{-1}(x)$.

This proof not only shows that x^e mod n is an invertible function (independently of how much time inverting it may take), but also that it is a trap-door function. Indeed, he who knows p and q, and thus $(p-1)(q-1)$, can easily compute d and thus easily invert the RSA function.[5]

The inventive system makes use of such a trap-door function $f(x)=x^e$ mod n. While the buyer knows n and e (e.g., because the seller gives them to him, or because they are publicly known), preferably only the seller knows n's factorization, (p,q), or, equivalently, d, the multiplicative inverse of e mod $(p-1)(q-1)$.

The system also makes use of preferably a one-way (possibly collision-free hashing) function H. Thus, while it is easy, given x, to compute $y=H(x)$, it is practically impossible, given y, to compute an x such that $H(x) = y$. (In this setting it is not necessary that H be a trap-door permutation. Indeed, it is preferable that H is not trap-door, and that it is a totally different function all together, and not a RSA-like).

Let now M and N, respectively, be lower- and upper-bounds

[5] The RSA function can be defined more generally - e.g., for any composite number n and any exponent e relatively prime with $\phi(n)$, where ϕ is Euler's totient function. This more general functions may too be used within our inventive blind-negotiation system. Similarly, one could use Rabin-like trap-door functions, or other function, if so wanted.

for the reserve prices of seller and buyer, and let *i* be the actual SRP and *j* the actual BRP (thus, $M \leq i, j \leq N$). The new blind-negotiation system is preferably implemented by means of three steps: a buyer's step, a seller's step, and a trustee's step. Each transmission in the system preferably occurs in a private manner; for instance by encrypting it with a key shared with or owned by the recipient to ensure that no clear text message falls in the wrong hands.

In the buyer's step, the buyer *B* selects, preferably at random, secret *x* mod *n*. Then, he evaluates *f*, on input *x*, *N-M* times, so as to obtain the following sequence of values (presented in reverse order):

$$Z_o = f^{n-m}(x), Z_1 = f^{n-m-1}(x), \ldots, Z_{n-m} = f^o(x) = x.$$

(I.e., Z_1 is the first *f*-inverse of Z_o, Z_2 is the second *f*-inverse of Z_o, and so on.) Because his BRP is *j*, the buyer then computes $H(Z_j)$, and sends this value to the trustee, preferably (digitally) signed together with additional information.[6] To the seller, the buyer instead gives Z_o, preferably signed together with additional information.

In the seller's step, the seller given her knowledge of *f*'s secret information - e.g., *n*'s factorization) may easily compute all the first *N-M* inverses of Z_o. However, because her SRP is *i*, she evaluates the one-way function *H* on the first *i* such inverses, and then evaluates *H* on another *N-M-i* values V_k, each preferably distinct from any of the first *N-M* *f*-inverses of Z_o. Thus, she gives the trustee the resulting sequence of *N-M* values, preferably in random order:

$$H(Z_1), H(Z_2), \ldots, H(Z_i), H(V_1), \ldots, H(V_{N-M-i}).$$[7]

In the trustee step, the trustee preferably makes sure (e.g., by using the additional information), that the seller's list and the buyer's value relate to the

[6] Such additional information preferably describes the transaction and is taken to be a proof of the buyer's willingness of entering it. For instance, the additional information may include any of the following data: seller's information, buyer's information, transaction information, good-on-sale information, time information, Z_o, any other information, or no information.

[7] The seller may just compute the first *i* inverses of Z_o *AND* choose the V_k VALUES at random, if the probability that one of these values V_k EQUALS ONE OF THE FIRST *N - M* INVERSES OF Z_o IS SMALL. Computing all such inverses is desirable, as will be seen.

same negotiation. The trustee checks whether one of the *N-M* values received from the seller equals the value received from the buyer. If so, it announces that a deal is possible; otherwise, it announces that no deal is possible. This announcement is preferably signed by the trustee together with additional information, and sent to both seller and buyer. In case the deal is possible, the dealer preferably includes in his announcement the value of the buyer, $H(Z_j)$, together with the buyer's signature of it, and the seller's list, together with the seller's signature of it.

This scheme works for the following reasons. First, it should be noticed that the trustee does not learn *j* (i.e., the BRP) from the information it receives from the buyer. Indeed, although given Z_o (i.e., within the additional information) the trustee does not know how to invert the RSA function *f*, and thus does not know any of the *N-M* inverses of Z_o. Of course, the trustee could, given Z_j, easily verify that this is the *j*th inverse of Z_o. Indeed, the trustee could evaluate *f* on input Z_j by the buyer, but $H(Z_j)$ should, from a practical point of view, be equivalent to having nothing at all about Z_j. Thus, the trustee has a very hard time determining *j* may be from the buyer's information.

Similarly, the trustee cannot easily learn the value of *i* from the information obtained from the seller. Indeed, the trustee receives from the seller *N-M* items altogether; *i* items obtained by evaluating *H* at inputs that are the first *f*-inverses of Z_o and *N-M* items obtained by evaluating *H* at inputs that are not such *f*-inverses. However, the one-way function H makes it difficult for the trustee to decide whether an individual item is of the first of second type; thus, the trustee cannot count how many type-1 items are there. Indeed, *H* is chosen so that the trustee cannot practically distinguish between a value obtained by evaluating *H* at a *f*-inverse, and one obtained by evaluating *H* at some different input.[8]

[8] Rather than obtaining type-2 values by evaluating *H* at inputs V_k that are not the first *f*-inverses of Z_o, the seller could choose her type-2 values in some other manner (e.g., by choosing *N-M-i* values U_k - of the proper length - at random, because the probability that these chose values happen to be of type 1 is negligible), provided that such values are not easily distinguishable from type-1 values.

Finally, it should be appreciated that, except for the fact of whether or not $i > j$, the trustee may not practically learn anything more about i and j from taking into consideration both the information received from the seller and that received from the buyer.

Indeed, assume first that there is no possible deal (i.e., that $i > j$). Then, the only additional information that the trustee gets from the seller's list and buyer's value taken together is that the buyer's value does not occur in the seller's list. But this does not help the trustee retrieve the precise values of i and j at all.

Assume now that a deal is possible (i.e., that $i \leq j$). Then, the trustee sees that the buyer's value, $H(Z_j)$, is an item in that seller's list, and therefore learns that $H(Z_j)$ has been obtained by evaluating H at one of the first N - M f-inverses of Z_s. However, if the seller's list is presented in random order, the trustee still cannot figure out what the value of j may be, nor the value of i.

In sum, therefore, the single trustee, doing only local and trivial computation, learns whether a deal is possible, but never the values of the reserve

Notice also, that one can, within the scope of the invention, use functions H that are not one-way, but more care is needed. For instance, one can choose $H(x)$ to consist of the last - say - 50 bits of x. Now 50 bits of Z_k may not be enough for reconstructing Z_k. This is not so because taking the last 50 bits is a one-way function, but because 50 bits of crisply-clear information about x are just too few to reconstruct a secret long value x, even if $f(Z_k)$, where f is a trap-door or one-way function, is known, Also, the last 50-bits of the RSA inverses (as evidenced by the results of Alexi et al.) may be unpredictable and thus quite random looking. Thus, it would still be hard to distinguish between the last 50 bits of the RSA inverses (the type-1 values) and 50-bit random values (the type-2 values). However, one has to be careful in constructing the blind-negotiation system so that the buyer cannot misuse the system to invert the RSA. Indeed, it is also shown by Goldwasser et al. and Alexi et al. that given an oracle for guessing the last 50 bits of several RSA inverses, one may discover the full RSA inverse on an input of interest. Now, while in general no such oracle is available, the seller herself may, through the mechanism of the blind-negotiation system, provide such an oracle. Indeed, she is called by the system to provide the last 50 bits of several RSA inverses. However, if H is a proper one-way function, such cryptanalitic attacks will become essentially impossible, and the seller may release H evaluated at any RSA inverse without fear.

prices.[9] The trustee, however, enables the seller and buyer to learn each other's reserve prices - so that they can both, for instance, compute $i + j/2$.

Consider first the seller's situation. Indeed, if the trustee gives the seller the buyer's value $H(z_j)$, she easily learns j, because she knows the value of every single f-inverse of Z_σ, and thus can check which inverse, after evaluating H on it, yields the buyer's value. Further, if the buyer's value is given by the trustee to the seller with the buyer's signature, then the seller receives *a proof* of what j is, and thus a proof that he was willing to buy at price j. Similarly, by receiving the seller-signed seller's list, the buyer receives a proof that she was willing to sell at price i. (In fact, the buyer knows at least the first j f-inverses of Z_σ, and thus (because $j > i$ when the deal is possible), he can check and prove that the seller's list contains the first f-inverses of Z_σ.). These proofs, preferably together with other evidence (e.g., a proper initial agreement between seller and buyer -- preferably including Z_σ together and with other additional information), can be used to prove in court that $i + j/2$ is the agreed trade price resulting from the negotiation.

The above blind-negotiation system is quite convenient from an interaction point of view (because the parties perform mostly local computations and do not talk back and forth too much). It is also computationally attractive.

Running Time Analysis

The above blind-negotiation system requires little computation because the trustee essentially just checks equality (between the buyer's value and the items of the seller's list). The buyer at most evaluates the trap-door function f and the one-way function H in the forward direction $N - M$ times. This is particularly easy to do. First, H is preferably a non-number theoretic function and plenty of very fast

[9] In case a deal is possible, however, and the actual trade price is chosen to be $i + j/2$, protecting the secrecy of i and j from the trustee may be deemed to be less crucial. (Indeed, in this case each of the seller and buyer may, from knowledge of his own reserve price and knowledge of the average of their reserve prices, learn readily the other's reserve price.) If this is case, the seller may actually send her list to the trustee in order rather than randomly permuted. This still does not enable the trustee to learn anything additional if no deal is possible, but lets the trustee learn the value of j if the deal is possible. He can in fact easily see that the buyer's value is the jth item in the seller's list.

non-number theoretic functions are known. Second, the exponent e of the RSA function f can be chosen quite small (e.g., equal to 3, if 3 is relatively prime with p - 1 and q - 1 -and indeed, p and q can be chosen so that this is the case). Thus, rather than requiring a full modular exponentiation, (and thus 1.5k modular multiplications when n, e and x are k-bit long), an RSA evaluation (e.g., a computation of $f(x) = x^e \bmod n$) may require as little as two modular multiplications, and the buyer makes at most $N - M$ such evaluations, and thus at most $2(N - M)$ modular multiplications overall. Moreover, the seller appears instead to perform $N - M$ f-inversions, and thus $N - M$ modular exponentiations, each requiring roughly 1.5k modular multiplications. (Indeed, each such inversion consists of a computation of the type $x^d \bmod n$, where d is the multiplicative inverse of $e \bmod (p-1)\ (q-1)$; thus, even if e is chosen to be quite short, d may not be short at all.) However, the seller's computation of all required inverses may be accomplished by means of just one modular exponentiation and $N - M$ f-evaluations (each involving two modular multiplications if $e = 3$). Indeed, computing Z_{N-M} requires that the seller inverts f, on input Z_o, $N - M$ times. But this means to compute $(Z^d{}_o)_{N-M} = Z^d{}_0{}^{(N-M)} \bmod n$. But because in such a computation the exponents work modulo $(p - 1)\ (q - 1)$, in effect the seller must compute $x^{d'} \bmod n$, where $d' = d(N - M) \bmod (p - 1)\ (q - 1)$. Thus the seller may compute d' (which is thus less than $(p - 1)\ (q - 1)$, and thus less than n, and thus at most k-bit long) with a single modular multiplication, and then $x^{d'} \bmod n$ with just a single modular exponentiation. After she has computed Z_{N-M}, the seller computes all other $N - M - 1$ f-inverses of Z_o by simply evaluating f, on Z_{N-M}, $N - M$ times, and each evaluation requires at most two modular multiplications if e is chosen equal to 3.

It should be noticed also that the value $N - M$ may be quite small. Indeed, in the above blind-negotiations for sale of an automobile, the envisaged values of $N - M$ were, respectively, 36, 72 and 144. Of course, if 144 is an upperbound to the possible reserve prices, so is 1,000. But, independent of other considerations, seller and buyer may have a valid incentive in ensuring that $N - M$ is small. In particular, the trustee of a blind-negotiation (whether of this or another type with lower-and upper-bounds) may actually require payment for his services according to the monetary value of the transaction. Now this value may become clear when a deal occurs, but, because of the very nature of a blind negotiation it will not be revealed otherwise. It is thus desirable that the trustee be paid as a percentage of *N* or *N* - *M*, whether or not a deal occurs. It is thus in the interest of seller and buyer that *N* and *N* - *M* be small.

Enhancing Security

The above-described system has been described in the context of a single given blind negotiation. It should be realized, however, that an enemy may also consider attacks that occur outside a single negotiation, possibly setting up a new blind negotiation in order to discover something about an old one. It is thus recommended, in this and other blind negotiation systems as well, that each portion of a negotiation cannot be used in any other negotiation. Thus, if each individual negotiation is secure, all possible negotiations taken together will be secure as well. For instance, it is quite beneficial that the additional information be used so that it fully specifies the negotiation in question, and, if something wrong appears in such specification, then proper security measures can be taken.

For example, it is desirable that messages exchanged within a blind negotiation be *customized*. For instance, the seller first signs the value she sends to the trustee, and then encrypts this signed message with the trustee's key (and not the other way around - though still in the scope of the invention). This way, after the trustee decrypts, he can check that the cleartext message came from the seller (and it is to her - and to the buyer - that he will send his announcement of the outcome of the negotiation, preferably encrypted with her key). This is a practical way to customize messages; that is, to tie messages to their senders so that, in particular, no one else can take the same message and (possibly without understanding it) send it as his.

The value of customization can be seen by analyzing what may happen if it is not used. For instance (ignoring additional information and most other details), assume that a seller S gives her list L to the trustee after encrypting it with the trustee's key, and then signing the so obtained ciphertext. That is, assume that she sends y = $SIG_S(E_T(L))$, her own signature of the piece of data $x = E_T(L)$. Assume now that a malicious buyer B has blindly negotiated with S, and that the result announced by the trustee was that no deal was possible. Then, B should learn no more than the fact that the seller's reserve price was bigger than his own one. However, by means of some "outside attacks" he can exactly reconstruct the seller's reserve price as follows.

When S sends y to the trustee, B makes a copy of it (without preventing it from reaching the trustee, and without understanding what he is copying). Then, he strips out S's signature (thus obtaining an unsigned string $x = E_T(L)$ which he cannot understand) and substitutes it with the signature of an accomplice of his, C, thus obtaining the string $y' = SIG_C(E_T(L))$. Then, he pretends that he is blindly negotiating with C several times. Each time he uses the same Z_0, and has C send the trustee the string y'. As for his own messages, the first time he pretends that his reserve price is M (thus he sends the trustee a properly signed and encrypted $H(Z_1)$); the second time he pretends that his reserve price is $M + 1$ (thus he sends the trustee $H(Z_2)$; and so on, until, the kth time, the trustee reports that there is a deal. Thus, B learns that the seller's reserve price was $M + k$.

Notice that each time the trustee notifies B and his accomplice C of the outcome of the negotiation, since, without a proper customization of the messages, he believes that B and C are the parties of these negotiations. (Of course, even if the kth time, the commodity is declared as been sold by C to B, C will ignore such sale. Indeed, C does not own the commodity at hand.) In the mean time, poor S is not even aware that this is going on.

Customizing messages neutralizes this attack. For instance, assume that even a mild form of customization is used, where the seller sends the trustee $y = SIG_S(E_T(L,AI))$, where the additional information AI specifies that the seller is S, the buyer B, and the trustee T. Then, copying y, stripping S's signature, and substituting it with that of accomplice C, and having C send T the string $SIG_C(E_T(L,AI)$ does not help much. In fact, after verifying the signature of C and removing his own encryption layer, the trustee will realize that the additional information identifies S to be the seller and not C. Thus he can take proper measures; for instance, stop the negotiation and alert S of what is going on.

Notice that if S adopts the above customization and the encryption system E_T is properly designed, it would be essentially impossible for B to take the data $x = E_T(L,AI)$ and somehow transform it into another piece of data $x' = E_T(L,AI')$ that happens to be the encryption, with the trustee's key, of the same list L plus additional information AI' indicating that C, rather than S, is the seller. Similar difficulties would be encountered by the above attack if the customization is a bit different; for instance, if the sender communicates her list to the trustee by sending $E_T(SIG_S(L,AI))$, or $SIG_S(E_T(SIG_S((L,AI)))$.

A malicious buyer may steal, however, use the same customized message M_s (whether $M_s = E_T(L,AI)$, or $E_TSIG_S(L,AI))$, or $SIG_S(E_T(SIG_S((L,AI)))$, *or* another value), and mount the above attack by keeping on sending M_s to the trustee as if coming from the seller, each time pretending that there is a blind negotiation going on. At each such negotiation, he sends a different buyer's value, and possibly tries to prevent that the trustee's announcement reach the genuine seller, so as to keep her in the dark about the attack.

These types of attack can be prevented by inserting in the additional information some time information. For instance, the seller may specify what is the current date and time, in her communication to the trustee. If the trustee when receiving the information notices that the time is sufficiently old may take some proper actions (including, possibly, stop the negotiation and alerting its parties that something is wrong).

A resourceful malicious buyer, however, may do the following. When the seller in a negotiation with him sends the trustee a customized message M_s (e.g., $M_s = SIG_S(E_T(SIG_S(L,AI))))$ that indicates who are seller and buyer as well as what is the time of the transmission, he may copy M_s, and then send it to many different trustees: T_1, T_2, etc. He then behaves as if Trustee T_i is the single trustee of a blind negotiation between Seller S and the buyer B, and his price is i. Thus the first trustees will inform him that no deal is possible, but if $i = SRP$, then trustee T_i will inform him that a deal exists. At the same time the buyer may try to prevent that these announcement reach S. But even if this does not succeed, he will end up with a legitimate purchase at price $i = SRP$, and thus at the minimum possible price at which the seller was ready to sell.

This attack may be prevented if the additional information *AI* specifies who the trustee of the current blind negotiation is, and thus only his announcement will be regarded as binding, and other trustees receiving a message of a blind negotiation that does not concern them should take proper actions in response. Another way to prevent this attack and other possible attacks consists in adding one or more rounds of communication (in fact, though the fewer these rounds are the more convenient the system is, more interactive systems are within the scope of the invention). Such additional rounds may in particular be used by having the trustee send a randomly selected value so that only responses properly including such values are considered legitimate. This makes it even harder to use portions of a blind negotiation into another blind negotiation.

Blind Negotiations with Invisible Trustees

A blind negotiation system can be implemented with trustees that are *invisible*. This means that an honest seller and buyer can exchange messages so that (for example, and without limitation) the buyer learns whether a deal is possible (e.g., whether $SRP \leq$ BRP) without learning the seller's reserve price, and then proves to the seller whether a deal is possible (and at what price). However, if the buyer refuses to "share" with the seller what he has learned, then the seller can go to a trustee, which up to now has been in the background, and have the trustee take action to prove to her the result of the blind negotiation (and/or any other proper action).

Thus, in such a blind negotiation system seller and buyer exchange a first set of messages in an attempt to complete their transaction, and, if the transaction is not completed, a trustee intervenes so as to complete it.

By way of background, cryptographic protocols have been described in the literature that enable two mutually suspicious players, Alice and Bob, the first having a secret input a and the second a secret input b, to evaluate a given function f on their secret inputs so as to compute the value $f(a, b)$ without divulging more information about a and b than is already implicit in the value $f(a, b)$ itself. A variant of such a method due to Yao was discussed in the paper of Goldreich, Micali, and Wigderson. A particular simple cases arises when the function f is the AND function, Alice has a secret bit a, Bob has a secret bit b, and the two parties want to compute the AND of a and b, i.e., $a \wedge b$, without disclosing their bits more than $a \wedge b$ already does. Recall that $a \wedge b = 1$ if and only if both bits are 1. Thus, if the secret bit of one party is 1 , then, after learning the value $a \wedge b$, that party will immediately also learn the other party's bit; indeed, that will coincide with $a \wedge b$. For the AND function, therefore, computing it on secret inputs without revealing more about these inputs than already implicit in the result means to meet the following two conditions:

1. *(Bob's privacy:)* If Alice has 0 as her secret bit, then, after learning that $a \wedge b = 0$, she should not learn whether Bob's bit is 1 or 0. Symmetrically,

2. *(Alice's privacy:)* If Bob has 0 as her secret bit, then, after learning that $a \wedge b = 0$, he should not learn whether Alice's bit is 1 or 0.

In the above Yao method, one of the parties (e.g., without limitation Bob) furnishes the other party (e.g., without limitation Alice) with various encrypted data having a special structure, in particular, with two ciphertexts (relative to the output bit): E0 and E1. Ciphertext E0 (encrypting a secret value *V0*) is openly labeled 0 and Cipertext E1 (encrypting a different secret value *V1*) is openly labeled *1*.

Having prepared both ciphertexts, Bob knows their decryptions *V0* and *V1*, but Alice does not, she only knows E0 and E1. If $a \wedge b = 0$, then the special structure of the data given from Bob to Alice guarantees that Alice will be able to retrieve *V0*, (but not *V1*); else, if $a \wedge b = 1$, Alice will be able to retrieve *V1* (but not *V0*). Since the labels of these ciphertexts are known, Alice can thus determine whether $a \wedge b = 0$ or $a \wedge b = 1$.

After learning one of the two secrets relative to the output bit, and thus the value of the bit $a \wedge b$, Alice can tell Bob what the output bit was. If Bob does not trust her, she can prove to him what the result of $a \wedge b$ is by releasing the secret she actually learned (i.e., either *V0* or *V1*).

Besides enabling the computation of $a \wedge b$, the method also guarantees Bob's and Alice's privacy conditions. Note, however, that Alice, after learning the actual value of $a \wedge b$, can deprive Bob of this information by simply telling him nothing, not the result $a \wedge b$, not any *proof* that this is indeed the AND of their secret input bits. It is thus a goal to rectify this weakness as well as derive from any such special computation of the AND function a new blind-negotiation system, one that works with invisible trustees.

<u>A New Blind Negotiation System</u>

In particular, assume that *M* and *N* are, respectively, lower-and upper-bounds to the reserve prices of a given commodity, and that Alice is the seller and Bob the buyer. Then, for each possible price *i* between *M* and *N*, let the bit a_i be

1 if *SRP* > *i*, and *0* otherwise; similarly, let the bit b_i be *1* if *i* < BRP, and *0* otherwise.

Since SRP is Alice's secret and BRP Bob's secret, each a_i is a secret bit of Alice, and each b_i a secret bit of Bob. Notice that price *i* is acceptable to both Alice and Bob if and only if $a_i \wedge b_i = 1$. Thus a deal between Alice and Bob is possible (i.e., SRP < BRP) if and only if there exist a value *i* such that $a_i \wedge b_i = 1$. If this is the case, the actual trade price maybe chosen in various ways, for instance, as the average of *l* and *h*, where *l* is the lowest value of *i* such that $a_i \wedge b_i = 1$, and *h* is the highest value of *i* such that $a_i \wedge b_i = 1$.

Thus, Alice and Bob can conduct a blind negotiation by simply computing, for all *i* between *M* and *N*, $a_i \wedge b_i$, by means of a special AND method such as above. (Since we are using such a special AND computation for each value of I between M and N, we may use the .$_I$. to identify the quantities E0, E1, V0 and V1 relative to the Ith computation of the special AND, that is, $E0_i$, $E1_i$, $V0_i$ and $V1_i$.)

If no deal is possible, then the result will be $a_i \wedge b_i = 0$ for all *i*. In this case, Alice cannot learn BRP beyond the fact that it must be lower than her own SRP. Indeed, for each *i* < SRP, $a_i = 0$ and thus $a_i \wedge b_i = 0$, but, because the special AND computation does not release any other knowledge, she will never learn whether $b_i = 1$ or $b_i = 0$ for any *i* < SRP; thus, she cannot learn which the value of BRP may be beyond knowing that it is less than her own SRP.

If a deal is possible, then $a_i \wedge b_i = 1$ for some *i*. In this case, the actual trade price can be computed - for instance, by computing *l* and *h* and setting the trade price to be *(l + h)/2*.[10]

Of course, like in all blind negotiations explained so far, Alice and Bob preferably make use of digital signatures during the process of evaluating each AND in the special way, so, that each can prove who said what to whom when,

[10] Note that also this method allows to avoid certain prices if so wanted. E.g., Bob may choose $b_i = 1$ *and* $b_{i+5} = 1$, but chose $b_{i+3} = 0$. Again, as in one of our prior blind negotiations, this behavior of Bob may be permitted, and interpreted as his wish not to trade at price 1 + 3, no matter what his reasons may be. Alternatively, as indicated above, it may be agreed that setting $b_i = 1$ and $b_{j+5} = 1$ is tantamount to setting $b_j = 1$ for all *j* between *i* and *i* + *5*, independent of the actual value of b_j actually entered by Bob in a special gate.

and relative to which negotiation. Indeed, they may preferably sign an initial agreement, preferably specifying proper additional data for the special AND computation relative to each price *i*. In particular, the additional data for the *i*th special AND may include the ciphertext EO_i and $E1_i$ (which respectively encrypt the secret values VO_i and $V1_i$, which are not part of such additional data). Thus, the release of VO_i *or* $V1_i$ relative to the AND computation of price *i*, does not just prove to Alice or Bob whether *i* is a mutually agreeable price, but, together with other signatures already exchanged, can be part of a provably signed contract of trade between the two parties.

We should now point out that it is (for instance) Alice who finds out the values $a_i \wedge b_i$ first, and she may or may not reveal or prove what these values are to Bob. This is indeed a feature of the above mentioned special AND computation. In our context, this may result in Alice withholding from Bob the result of the negotiation.

To avoid this, the following additional modifications are proposed. First, for each special AND computation, rather than having the encryption of *V0* (denoted by *EO*) be openly labeled with *0* and the encryption of *V1* (denoted by *E1)* be openly labeled with *1*, the labels of *EO* and *E1* may be encrypted, preferably with a key of a trustee. For instance, Bob (who prepares these two labeled ciphertexts) may label *EO* with $E_T(O)$ and *E1* with $E_T(1)$ (where *E(x)* is an encryption scheme of which a trusted party, has the decryption key), and make sure that these two cipertext-label pairs are presented in random order. For instance, he may provide Alice with the label-ciphertext pairs $(E_T(1), E1)$ *and* $(E_T(O), EO)$. (The encryptions of the labels *0* and *1* are preferably probabilistic. For instance, $E_T(O)$ may be the encryption, with a trustee's key, of a random even number, and $E_T(1)$ the encryption (with a trustee's key) or a random odd number.[11])

This way, after Alice computes the decryption of *EO* (i.e., *V0*) or the decryption of *E1* (i.e., *V1*), she does not understand whether the result signifies a

[11] Of course, one may use the same encryption scheme to encrypt *0* and *1*, or different scheme, such a scheme can be public key, or private key, in which case the ordinary encryption/decryption key can be known to both Bob and the trusted party.

0 or a *1*. (In fact, she can see that *EO* is labeled with $E_{T(0)}$ in that *E1* is labeled with $E_{T(1)}$, but she does not know which of E_{T0} and E_{T1} is an encryption of 0 and which is an encryption of 1.) She thus gives *V0* (respectively *V1*) to Bob, and Bob proves to her whether obtaining this decryption means that the AND computation resulted in a *0* or a *1* by decrypting $E_T(O)$ *or* $E_T(1)$ (or both), that is, Bob may give Alice the very even number used in generating E_TO (0) and/or the very odd number used in generating E_T1 (0).

So far, this additional step does not appear to have accomplished much. Indeed, if before it was Alice who could withhold from Bob the result of their blind negotiation, it now appears that it is Bob who could withhold the result from Alice. Indeed, Bob may refuse to provide Alice with the decryption of $E_{T(0)}$ or $E_{T(1)}$. However, Alice may go to the trusted party (preferably with data signed by Bob and data signed by herself, so as to prove that this is part of a blind negotiation). The trusted party will then provide her with the decryption of the desired $E_T(O)$ *or* $E_T(1)$ value.

Thus, the trustee is not needed and is totally in the background if Bob and Alice are honest (because Bob can decrypt himself what he had previously himself encrypted with the trustee's key). However, if this is not the case (like discussed above), the trustee may intervene to complete the negotiation by decrypting what is necessary for completing the transaction.

It is actually preferable that if Alice asks the trustee to decrypt (for example) an "output ciphertext label" $E_T(O)$ after presenting signed data that include her signature of *V0*, that is, her signature of the learned decryption of *EO*, the ciphertext labeled *E(O)*. This reassures the trustee that indeed the negotiation properly started and that Alice is entitled to learning what the learned *V0* means. In informing or proving to Alice that $E_T(O)$ actually means *0*, it is also preferable that the trustee also informs Bob of the result of negotiation; preferably by providing him with at least Alice's signature of *V0*. This way Bob has a proof of what the output of the corresponding AND gate was. Thus, if the trustee provides Alice with such a proof (or result) it also provides Bob with a corresponding proof (or result).

This "joint-notification" is important because otherwise Alice could withhold the result of the negotiation (or its proof) from Bob as follows. She participates to the negotiation *honestly* until she computes the decryption of the output-ciphertext of each special AND gate (i.e., either $V0_i$ *or* $V1_i$, for each gate *i*). Then, she does not tell these learned decryptions to Bob, so as to learn what they mean and inform Bob of the same. Rather, she bypasses Bob altogether, goes to the trustee, and has it *tell her* whether the labels of the output-ciphertexts mean. This way, she learns the result of the negotiation, while keeping Bob in the dark. However, if the trustee also informs Bob whenever it informs Alice, then both Alice and Bob will learn the result. Moreover, if the trustee gives Alice the decryption of each label (e.g., the even number whose encryption was the given $E_T(O)$, or the odd number whose encryption equaled $E_T(1)$), and gives Bob the particular decryption learned by Alice signed by her, then not only will both parties learn the result of their negotiation, but they will both have a proof of what their results are.

Preferably, the labels *0* and *1* are not encrypted in a key known to just one trustee, but with a key that is split among a plurality of trustees (e.g., like in the systems suggested by Micali), so that the cooperation of sufficiently many of them is required for each $E_T(0)$ *or* $E_T(1)$ value to be decrypted. This way, one or sufficiently few trustees may not conspire with (e.g.) Alice in order to let just her know the result of the negotiation. The idea of replacing a single trustee with a multiplicity of trustees possibly holding shares of a given secret key, also applies to other blind negotiation systems of this invention.

It is preferable that Seller and Buyer exchange messages by means of a method that gives certified return receipts. For instance, when Alice gives the learned *V0* secret of a given AND gate, it is recommended that she sends such a *V0* to Bob by means of a certified mail return receipt method that enables her to prove that indeed that particular value *V0* was sent to Bob. Electronic, secure and practical such methods are presented in a copending patent application.

Actually, the use of return-receipt exchanges between Seller and Verifier also enables one to dismiss invisible trustees in the blind-negotiation systems. For instance, if in the above system with a proper initial agreement Alice learns a value V_i relative to the ith AND computation of a price (i.e., V_i equals either $V0_i$ or $V1_i$), and sends it to Bob by a certified return-receipt method (which preferably shows what the sent value actually was), if Bob does not respond with a proof of the result of the computation, she has enough information to receive justice in some form of court. Such courts, however, could be interpreted as invisible trustees too, though not even their keys have been used in the negotiation.

Making Blind Negotiations Transparent

In practice, a single-trustee blind negotiation system may be quite attractive (given that the trustee does not learn the reserve prices anyway). However, one may still fear that the trustee is not trustworthy. For instance, though a blind negotiation indicates that a deal is possible, the trustee may announce that it is not possible and let the buyer know the items appearing in the seller's list. (Note that these items will reveal the seller's reserve price if the buyer knows $Z_{N,M}$).

Thus, although the seller may not mind if the buyer learns her reserve price when a deal occurs, the trustee might enable the buyer to learn the SRP when there is no deal at all.

Some of this cheating may be prevented or dissuaded as follows. When the trustee declares that there is no deal, rather than just saying so, he also signs an encryption of the information he receives from the seller and the buyer. This signed encryption of the seller's list and the buyer's value may consist of the very encryptions that seller and buyer gave the trustee in their respective steps. Indeed, in order to give the trustee her list in a private way, the seller preferably encrypts it with the trustee's key. Similarly the trustee might enable the buyer to learn the SRP when there is no deal at all.

Similarly, the buyer preferably sends the trustee his own value after encrypting it with a trustee's key. Moreover, each of the seller and buyer signs his own data (preferably together with additional data) prior to encrypting it with the trustee's key. Thus the trustee may release these two encrypted signatures when saying that no deal is possible, preferably signing the whole thing himself also.

The reason for announcing such signed encryption when the deal is not possible is to enable either the seller or the buyer to request that the blind negotiation be made "transparent." In this case, the trustee must remove his own encryption layer, thus revealing in an authenticated way the seller's list and the buyer's value.

If, after decrypting the seller's list and the buyer's value, it appears that indeed there was no deal possible (because the buyer's value does not appear in the seller's list), then proper measures can be taken. For instance, assume that the negotiated commodity is yet unsold and that it is the buyer who called for the blind negotiation to become transparent. Then, after learning the values SRP and BRP, and realizing the $SRP > BRP$, the buyer may be forced to purchase the commodity at price SRP (or N, or $SRP + N/2$, or SRP + a given amount -- either fixed or dependent on N, M etc. --) or at any other price deemed proper.

Thus, the seller may not mind that her SRP value was made known because she will be able to sell at that price or better. (Alternatively, the buyer may be properly fined -- e.g., by a fixed amount, or as a percentage of SRP, N, etc. -- e.g., by a fixed amount, or as a percentage of SRP, N, etc. - without forcing a sale of the commodity.)

Assume now that, after the blind negotiation was made transparent at the buyer's request, it appears that indeed no deal was possible, and that the seller has already sold her commodity to someone else. Then, other proper measures may be taken. *For instance*, the buyer may be obliged to pay the amount of SRP to the seller without receiving the commodity in exchange, or he may be fined according to a proper formula, etc. (Alternatively, it may be agreed that after the result of a blind negotiation is negative -- i.e., the outcome is "no deal"-- one has only a prescribed *window* of time to request to make it transparent, and that the seller should not sell the commodity during that time.)

Assume now that, after the negotiation has been made transparent, it appears that the trustee announced the wrong result. Then, other proper measures can be taken. For instance, not only the trustee can be made financially responsible for paying what it is deemed proper, but he can be also criminally prosecuted. Thus, the possibility of having the blind negotiation transparent will add a great incentive for the trustee to remain honest.

Of course, a trustee who has lied within a blind negotiation may not wish to decrypt at all. Thus, measures should be taken that dissuade him from taking this course of action. Alternatively, it may be required that the trustee's key may be shared among many other trustees (e.g., by one of the methods of Micali) so that if the trustee refuse to decrypt, the other trustees may intervene and remove his encryption layer anyone.

Forcing Good Faith in Blind Negotiations

It is desired to ensure that the participants of a blind negotiation act in good faith. By this we mean that, no matter what the reserve price of ones participant, there is at least one choice of reserve value for the other participants so that the deal is possible.

For instance, we want to disallow that a malicious buyer may waste the seller's time and resources by negotiating (without being detected) in a way that guarantees that no deal can be reached. For instance, such a buyer may give the trustee a random number R or $H(R)$ as the buyer's value (rather than the image, under function H, of one of the first N - M f-inverses of Z_o). Herefore, with overwhelming probability, this number will not appear in the seller's list. Accordingly, the trustee will report that no deal is possible.

Engaging in such negotiations with the seller, the buyer may, at least temporarily, prevent that the seller negotiates profitably with others, and in general damage her. Such behavior should thus be made impossible, or easily detected.

Of course, the seller may set $i = M$ in a blind negotiation (i.e., have her SRP to be the minimum possible value). If in these conditions the outcome of the blind negotiation still is that no deal is possible, then clearly the buyer or the trustee are cheating. Thus, appropriate measures can be taken if the seller detects and proves that this is the case. (Some of these measured are discussed in the previous section. For instance, the buyer may be obliged to buy at maximum price, or, if he can prove that his value was properly set, the trustee may be fined or prosecuted.)

However, choosing a minimum SRP may be a too expensive way for the seller to check that the buyer is negotiating in good faith. Indeed, if the buyer happens to act in good faith, the seller will essentially "give away" her commodity. Therefore, better strategies to ensure good faith participation in a blind negotiation should be sought. One of them is described below. Of course, after presenting one such strategy, many others can be easily devised.

In her step, the seller gives the trustee, together with her usual list consisting of N - M items (i of which consist of H evaluated at the first f-inverses of Z_0, and N - M - i of which consist of different values) gives an additional *check list*. The latter consists of another N - M items, preferably in random order: $H(Z_{i+1})$, . . . , $H(Z_{N-M})$ -- i.e., H evaluated at the remaining N - M - i f-inverses – and $H(V_{N-M-i+1})$, . . . , $H(V_{N-M})$ – i.e., H evaluated at i values, preferably different both among themselves and from the first f-inverses of Z_0 as well as from all other V values.

Notice that the trustee, though receiving the seller's list and check list, still does not understand what the value of i may be. Indeed, if H is good, any item in each list may appear as a random number to him. Notice too, however, that the buyer's value $H(Z_j)$ should, if the buyer is honest, appear in one of the two lists. Thus, if this is not the case, the trustee may announce so, preferably in a signed manner. At this point steps can be taken to decide who is right and proper measures can be adopted.

The trustee, rather than just announcing that the buyer's value does not appear in either the primary list nor the check list of the seller, may actually release both the seller's lists and the buyer's value, and since these have been signed by their owners, he will release these signatures too. Thus one can verify in authenticated manner what are the items in the seller's list, the items in the seller's check list, and the buyer's value. If she is right, the seller may further reveal every value Z_k and every value V_k, so that one can verify that her lists were both well constructed (by checking where *$H(Z_k)$ and $H(V_k)$* appear), and become convinced that the buyer participated to the bind negotiation in bad faith. At this point, though the seller's reserve price may be compromised, proper measures can be adopted, such as those discussed in the previous section. For instance, the commodity may be assigned to the buyer at the maximum possible price, or at price i plus a suitable additional amount.

Blind Negotiations with Duplicate Trustees

As we have seen, blind negotiations with a single trustee who does not learn the SRP nor the BRP are most convenient. However, if the trustee is not trustworthy after all, he may declare that no deal is possible (while instead $i < j$) and give, for instance, the buyer the seller's information (i.e., her list).

This event should be rather improbable if the trustee is properly chosen. In any case, the possibility of making negotiations transparent may be quite effective in deterring even this small chance.

There is, however, another way to prevent this cheating: *duplicate trustees*. That is, we envisage running the above single-trustee system with two or more trustees, treating each trustee essentially as if he were the only one. Thus, while in a general blind-negotiation system with multiple trustees, the trustees may engage in non-trivial message exchanges and computations, these duplicate trustees do not. Indeed, to make life for sellers and buyers easier, duplicate trustees may use the same encryption/decryption keys, and sellers and buyers may use these common trustee-keys when talking privately to the duplicate trustee(s). This way each message needs to be encrypted only once (with the common key of the duplicate trustees) rather than many times (with the key of each of the duplicate trustees). If they wish to use different encryptions with each of the different duplicate trustees, however, a proper encryption scheme should be used.[12]

The main advantage of having two or more duplicate trustees is the following: if a deal is possible, then every honest trustee will say so and preferably prove that this is so, thus enabling the deal to go through at the right price. Therefore, for a deal to be illegitimately declared impossible when it is indeed possible, ALL duplicate trustees must be dishonest. And the possibility of this event is even more remote.

Blind-Negotiation Systems with Secure Hardware

In a single-trustee blind negotiation-system, the problem still exists that the trustee, when the deal really is impossible, may give to one participant information relative to the other participant. For instance, he may give the buyer the seller's list(s). Of course, the trustee does not understand the SRP from this information, but the buyer will. This problem does not go away with duplicate trustees. Indeed, the

[12] Indeed, some encryption algorithms (like RSA with small exponents) may be secure if each message is encrypted only with one key. However, if the same message is encrypted with a first key, a second key, a third key and so on, then an enemy who gets hold of these ciphertexts can easily retrieve the message.

other duplicate trustees may just confirm that no deal is possible, but may not be aware that one trustee is tipping off the buyer.

One effective avenue to take care of this problem and others as well is having a trustee consist of or include a secure device, for concreteness purposes only but without loss of generality, a secure chip; that is, a chip a portion of which cannot be read or tampered with from the outside. For instance, because trying to tamper with the chip or trying to read part of its protected areas causes all information in the chip to be destroyed.

One advantage of using secure hardware this way is that once such a chip has been properly manufactured, its input-output behavior cannot be changed. Thus, there is no way to "corrupt" such a trustee an convince him to behave dishonestly.

For instance, the secure chip may be manufactured to correctly perform the following operations. The secure chip receives an input i from the seller and an input j from the buyer (preferably with proper additional information, and having each party properly sign his data and encrypt it with a key known to the chip). The chip then verifies the additional information and compares the values i and j. If the information looks fine and $i > j$, then the chip produces an output indicating that no deal is possible. Else, the chip outputs $g(i, j)$, where g is a function chosen to establish the actual trade price.

In either case, the chip preferably digitally signs its output together with proper additional information. (Again, other features of the above blind negotiation systems can be incorporated here - such as, initial agreement, message customization, time stamping, or having the chip give seller or buyer a random number and demanding that that number be part of future messages in the negotiation.)

Random Checking for Proper Special Structures

As we have mentioned, in the method for computing the AND function so as to satisfy Bob's and Alice's privacy conditions, one of the parties (e.g., Bob) sends Alice various encrypted data having a special structure. If this special structure is different from what it should be, then, rather than computing $a \wedge b$, one may compute a different function (with a one-bit output), or always discover the other party's secret bit.

In the context of the above blind negotiation, it would be in Bob's interest to change the special structure so that the function *f(a, b)* = *a* would be computed instead. This way, in a blind negotiation, Bob would never offer more than Alice's SRP, though he would not know the value of SRP before hand.

It is thus important that the parties are convinced that each piece of encrypted data possesses the right special structure that makes it a special AND. In the mentioned paper of Goldreich, Micali, and Wigderson, it is suggested that (as part of the method) Bob proves to Alice that the provided cryptographic data possesses the desired special structure by means of a zero-knowledge proof. We note, however, that other well-known simpler methods can be used within our application.

For instance, assume that N - M = *k* is the number of possible prices for the negotiated commodity. Then, Bob may present Alice with *2k* (rather than *k*) pieces of encrypted data, claiming that all of them possess the special structure for implementing an AND with our privacy constraints. Alice may then choose *k* of them, and ask Bob to decrypt them, so that she can see that they possess the right structure. If this check is passed, then the remaining *k* pieces of encrypted are believed to implement correctly our AND, and they are used as in the above blind negotiation system.

This way, Bob may cheat with probability at most one half. Indeed, even if he inserts a single incorrect piece of encrypted data, with probability 1/2 Alice will choose it among the *k* piece she asks Bob to decrypt. Further, the probability may be decreased (to 1/3, 1/4, etc.) by having Bob present Alice more "trial" pieces of encrypted data (e.g., *3k*, *4k*, etc.), and then have Alice choose all of them except *k* for decryption. Alternatively, not to increase the amount of computation and transmission too much, we may continue to use a small amount of pieces of encrypted data (e.g., *2k*), but make it counterproductive for Bob to cheat. For instance, relying on a proper initial agreement, it can be arranged that, if Bob is caught cheating or refuses to decrypt the "trial" pieces of encrypted data chosen by Alice, then is obliged to buy the given commodity at price 4N, or is fined for an amount 4N. Therefore, by cheating he expects to lose money. Indeed, if he cheats, he has probability ≤ 1/2 of gaining something (e.g., discovering Alice's SRP, or buying at a price that is guaranteed to be equal to

SRP) whose worth is at most $N, but also has probability 1/2 of loosing $4N. (Of course, the probability of 1/2 of being caught in the amount 4N penalty are purely exemplary in that other values could be chosen in their place).

GENERAL PRIVATE-FUNCTION EVALUATIONS WITH INVISIBLE TRUSTEES

It should also be noted that, as we have already mentioned, the above AND method generalizes so as to enable Alice and Bob to compute any function *f(a,b)* of two secret inputs *a* and *b* so as to satisfy both Alice's and Bob's privacy constraints. Again, this more general method involves Bob sending Alice encrypted data with a special structure, and having every possible output-bit variable correspond to two encryptions, E0 and E1, one labeled 0 and the other 1. The actual value of a given output-bit variable (in a given execution of a special circuitry for *f*) is 0 if Alice computes the decryption of the corresponding E0 value, and 1 if she computes the decryption of the corresponding E1 value.

Again, therefore, one of the parties may withhold from the other the result of a given private-computation of *f*. However, we can again apply the same system developed above. That is, rather than openly labeling EO with 0 and E1 with 1, we can label EO with E_T(O) and E1 with E_T(1), where E_T(x) is an encryption function for which an invisible trustee has the decryption key. The trustee, the first party and the second party act therefore, very much like in the case of the AND function, so as to yield a method where two parties A and B, each possessing a secret input, respectively, *a* and *b*, can, with the help of an invisible trustee and without revealing these inputs, privately evaluate any given function *f* on their inputs so that, if one party learns *y = f (a,b)*, then so does the other. Again, by invisible trustee we mean the following: if both parties are honest, both will learn without involving the trustee at all, but if one of the parties dishonestly tries to keep for him/herself the learned value *y*, then the trustee intervenes so as to ensure that both learn *y* (but not the other's secret input, unless that is implicit in *y*).

While this invisible-trustee method for privately evaluating a two-input function *f* is useful in general, it is particularly useful in blind negotiations. Indeed, Alice may be a seller and Bob a buyer, *a* may be the SRP and *b* the BRP, and with a proper initial agreement and use of digital signatures, they may profitably achieve a blind negotiation with an invisible trustee by privately evaluating the following (comparison) function *f*: $f(a,b) = 1$ if a $\leq$ b, and 0 otherwise.

Again, they may use the decryption-penalty method for "checking" that the special structures involved are present in the pieces of encrypted data used.

It is now possible to summarize the important advantages of the disclosed blind negotiations systems and methods.

IN THE CLAIMS

What is claimed is:

1. An electronic process executed by a first party and a second party, with assistance from at least a plurality of trustees, wherein the first party has a selling reservation price (SRP) and the second party has a buying reservation price (BRP) and the parties are committed to a transaction if a predetermined relationship between the reservation prices is established, but not otherwise, comprising the steps of:

initiating the electronic process by having the first and second parties compute data strings encoding their respective reservation prices, wherein at least one of said parties uses an electronic device for such computation;

having each of the first and second parties transmit to the trustees the data strings that encode their respective reservation prices, wherein at least one of these transmissions is carried out electronically, and wherein a subset of trustees containing less than a given number of trustees does not possess any useful information sufficient for reconstructing the reservation prices; and

having the plurality of trustees participate in the electronic process by taking action to thereby determine whether the predetermined relationship exists, wherein the determination is made without reconstructing the reservation prices.

2. The electronic process as described in Claim 1 further including the step of:

if the predetermined relationship exists, having the trustees continue the electronic process by providing information that commits the parties to the transaction at a price according to a given formula.

3. The electronic process as described in Claim 1 further including the step of:

if the predetermined relationship does not exist, having the trustees continue the electronic process by providing information that indicates that the transaction is not possible without indicating a party's respective reservation price to the other party.

4. The electronic process as described in Claim 3 wherein the information does not reveal a party's reservation price to the other party.

5. The electronic process as described in Claim 2 wherein the predetermined relationship is SRP < or equal to BRP.

6. The electronic process as described in Claim 5 wherein the given formula is SRP + BRP/2.

7. The electronic process as described in Claim 1 wherein at least one of the trustees continues the electronic process by taking action with at least one of the parties to thereby determine whether the predetermined relationship exists.

8. The electronic process as described in Claim 1 wherein at least one of the trustees makes use of secure hardware.

9. An electronic process executed by a first party and a second party, with assistance from at least one or more trustees, wherein the first party has a selling reservation price (SRP) and the second party has a buying reservation price (BRP) and the parties are committed to the transaction if a predetermined relationship between the reservation prices is established, but not otherwise, comprising the steps of:

initiating the electronic process by having the first and second parties compute shares of their respective reservation prices, wherein at least one of said parties uses an electronic device for such computation;

having each of the first and second parties transmit shares of their respective reservation prices to a set of players selected from a set comprising the first and second parties and at least one trustee, wherein a subset of players, containing less than a given number of players and not one of the parties, does not possess any useful information for reconstructing the reservation price of that party, and wherein at least one of the transmissions is carried out electronically; and

having the players participate in the electronic process by taking action to thereby determine whether the predetermined relationship exists, wherein the determination is made without reconstructing the reservation prices.

10. The electronic process as described in Claim 9 further including the step of:

if the predetermined relationship exists, having at least some of the players continue the electronic process by providing information that commits the parties to the transaction at a price according to a given formula.

11. The electronic process as described in Claim 9 further including the step of:

if the predetermined relationship does not exist, having at least some of the players continue the electronic process by providing information that indicates that the transaction is not possible, wherein the information does not reveal a party's reservation price to the other party.

12. The electronic process as described in Claim 9 wherein at least one player uses secure hardware.

13. An electronic process executed by a first party and a second party, with assistance from at least one trustee, wherein the first party has a selling reservation price (SRP) and the second party has a buying reservation price (BRP) and the parties are committed to a transaction if a predetermined relationship between the reservation prices is established, but not otherwise, comprising the steps of:

having each of the first and second parties transmit to the at least one trustee data that does not possess any useful information for enabling the trustee to reconstruct the reservation prices, wherein at least one of the transmissions is carried out electronically;

having at least one trustee participate in the electronic process by taking action to determine whether the predetermined relationship exists; and

if the predetermined relationship exists, having at least one trustee continue the electronic process by providing information that commits the parties to the transaction at a price according to a given formula; and

if the predetermined relationship does not exist, having at least one trustee continue the electronic process by providing information that indicates that the transaction is not possible without revealing the reservation prices.

14. The electronic process as described in Claim 13 wherein, if the predetermined relationship does not exist, the information provided by the trustee does not reveal a party's reservation price to the other party.

15. The electronic process as described in Claim 13 wherein the predetermined relationship is SRP < or equal to BRP.

16. The electronic process as described in Claim 15 wherein the given formula is SRP + BRP/2.

17. The electronic process as described in Claim 13 wherein the trustee comprises a secure piece of hardware.

18. The electronic process as described in Claim 13 wherein the trustee comprises a plurality of agents.

19. The electronic process as described in Claim 18 wherein the plurality of agents hold shares of a common secret key.

20. An electronic process executed by a first party and a second party, with assistance from at least one trusted party comprising secure hardware, wherein the first party has a selling reservation price (SRP) and second party has a buying reservation price (BRP) and the parties are committed to a transaction if a predetermined relationship between the reservation prices is established to exist, but not otherwise, comprising the steps of:

generating an encrypted version of each party's reservation price, wherein at least one of the encrypted versions is generated using an electronic device:

having the first party transmit to the trusted party the encrypted version of SRP and having the second party transmit to the trusted party the encrypted version of BRP, wherein at least one of the transmissions is carried out electronically;

having at least one trusted party participate in the electronic process by taking action to determine whether the predetermined relationship exists between the reservation prices without revealing SRP and BRP outside the secure hardware; and having at least one trusted party continue the electronic process by transmitting result-information to each of the first and second parties, wherein the reservation prices are not revealed if the predetermined relationship does not exist.

21. The electronic process as described in Claim 20 wherein the predetermined relationship is SRP < or equal to BRP, and wherein if the trusted party determines that SRP < or equal to BRP, the result-information commits the parties to the transaction at a price determined at a given formula.

22. The electronic process as described in Claim 20 wherein the predetermined relationship is SRP < or equal to BRP, and wherein if the trusted party determines that SRP > BRP, the result-information indicates that the transaction is not possible at that time without revealing the reservation price of one party to the other party.

23. The electronic process as described in Claim 20 wherein in addition to the encrypted version of the SRP, the first party also transmits to the trusted party additional information, wherein the additional information includes information selected from the following: a description of the transaction, a proof of the first party's willingness to enter into the transaction, an agreed transaction price if the predetermined relationship exists, date and time, and other transaction information.

24. The electronic process as described in Claim 23 wherein the encrypted version of the SRP and the additional information are digitally signed prior to transmission by the first party to the trusted party.

25. The electronic process as described in Claim 20 wherein in addition to the encrypted version of the BRP, the second party also transmits to the trusted party additional information, wherein the additional information includes information selected from the following: a description of the transaction, a proof of the

second party's willingness to enter into the transaction, an agreed transaction price if the predetermined relationship exists, date and time, and other transaction information.

26. The electronic process as described in Claim 25 wherein the encrypted version of the BRP and the additional information are digitally signed prior to transmission by the second party to the trusted party.

27. The electronic process as described in Claim 20 wherein at least one of the first and second parties use secure hardware to encrypt their respective reservation price.

28. An electronic process executed by a first party and a second party, with assistance from an invisible trusted party if needed, wherein the first party has a selling reservation price (SRP) and the second party has a buying reservation price (BRP) comprising the steps of:

(1) having the first and second party agree to execute an ideal negotiation that results in (a) a commitment to a transaction if a predetermined relationship exists between the reservation prices or (b) no commitment and the determination that the predetermined relationship does not exist without revealing the reservation prices;

(2) having the first party and the second party exchange messages to attempt completion of the ideal negotiation, wherein at least one of the messages is exchanged electronically and wherein either party can determine whether the predetermined relationship exists; and

(3) if the ideal negotiation is not completed in step (2), having the invisible trustee take action to complete the ideal negotiation.

29. An electronic process executed by a first party and a second party, with assistance from an invisible trusted party if needed, wherein the first party has a selling reservation price (SRP) and the second party has a buying reservation price (BRP), wherein the first and second parties have agreed to an ideal negotiation that results in (a) a commitment to a transaction if a predetermined relationship exists between the reservation prices or (b) no commitment and the determination that the predetermined relationship does not exist without revealing the reservations prices, comprising the steps of:

(1) having the first party and the second party exchange messages to attempt completion of the ideal negotiation, wherein at least one of the messages is exchanged electronically; and

(2) if one party does not complete certain actions required in step (1), having the invisible trustee take action to complete the ideal negotiation; and

wherein the trusted party comprises secure hardware.

30. The electronic process as described in Claims 1, 9 or 13 wherein the transaction is selected from at least one of the following types of transactions: a sale, a lease, a license and a financing transaction.

31. The electronic process as described in Claim 30 wherein the transaction involves a commodity having a value within a predetermined upper and lower range, and wherein the trustee is provided a fee according to the value.

32. An electronic process executed by a first party and a second party, with assistance from an invisible trusted party if needed, wherein the first party has a private value "a" and the second party has a private value "b" and the first and second parties have agreed to compute a given function "f" on their inputs "a" and "b", comprising the steps of:

(1) having the first party and the second party exchange messages to enable each of the parties to obtain f(a,b) without revealing "a" and "b", wherein at least one of the messages is exchanged electronically and wherein either party can determine whether the obtained value f(a,b) is correct; and

(2) if one party has not obtained f(a,b) in step (1), having the invisible trustee take action so that both parties can obtain f(a,b).

33. An electronic process executed by a first party and a second party, with assistance from at least one trustee, wherein the first party has a private first value and the second party has a private second value and the parties are committed to a transaction if a predetermined relationship between the first and second values is established, but not otherwise, and wherein each party's respective value is unknown to the other party, comprising the steps of:

initiating the electronic process by having the first and second parties compute data strings encoding their respective values, wherein at least one of said parties uses an electronic device for such computation;

having each of the first and second parties transmit to at least one trustee the data strings that encode their respective values, wherein at least one of these transmissions is carried out electronically, and wherein at least one trustee does not possess any useful information sufficient for reconstructing the first and second values; and

having at least one trustee participate in the electronic process by taking action to help determine whether the predetermined relationship exists, wherein the determination is made without reconstructing the private values.

34. The electronic process as described in Claim 33 further including the step of:

if the predetermined relationship exists, having at least one trustee continue the electronic process by contributing information that helps commit the parties to the transaction according to a given formula.

35. The electronic process as described in Claim 33 further including the step of:

if the predetermined relationship does not exist, having at least one trustee continue the electronic process by providing information that contributes to indicating that the transaction is not possible without thereby indicating the first and second private values.

36. An electronic process executed by a first party and a second party, with assistance from at least one or more trustees, wherein the first party has a secret first value and the second party has a secret second value and the parties are committed to the transaction if a predetermined relationship between the first and second values is established, but not otherwise, wherein each party's respective private value is unknown to the other party, comprising the steps of:

initiating the electronic process by having the first and second parties compute shares of their respective values, wherein at least one of said parties uses an electronic device for such computation;

having each of the first and second parties transmit shares of their respective values to a set of players selected from a set comprising the first and second parties and at least one trustee, wherein a subset of players, containing less than a given number of players and not one of the parties, does not possess any useful information for reconstructing the value of that party, and wherein at least one of the transmissions is carried out electronically; and

having the players participate in the electronic process by taking action to thereby determine whether the predetermined relationship exists, wherein the determination is made without reconstructing the first and second values.

37. The electronic process as described in Claim 36 further including the step of:

if the predetermined relationship exists, having at least some of the players continue the electronic process by providing information that commits the parties to the transaction according to a given formula.

38. The electronic process as described in Claim 36 further including the step of:

if the predetermined relationship does not exist, having at least some of the players continue the electronic process by providing information that indicates that the transaction is not possible, wherein the information does not reveal a party's private value to the other party.

39. An electronic process executed by a first party and a second party, with assistance from at least one trustee, wherein the first party has a private first value and the second party has a private second value and the parties are committed to a transaction if a predetermined relationship between the first and second values is established, but not otherwise, wherein each party's respective value is unknown to the other party, comprising the steps of:

having each of the first and second parties transmit to at least one trustee data that does not possess any useful information for enabling the trustee to reconstruct the first and second values;

having at least one trustee participate in the electronic process by taking action to determine whether the predetermined relationship exists; and

if the predetermined relationship exists, having at least one trustee continue the electronic process by providing information that commits the parties to the transaction according to a given formula;

if the predetermined relationship does not exist, having at least one trustee continue the electronic process by providing information that indicates that the transaction is not possible without revealing the first and second private values.

40. An electronic process executed by a first party and a second party, with assistance from at least one trusted party comprising secure hardware, wherein the first party has a private first value and second party has a private second value and the parties are committed to a transaction if a predetermined relationship between the first and second values is established to exist, but not otherwise, wherein each party's respective value is unknown to the other party, comprising the steps of:

generating an encrypted version of each party's private value, wherein at least one of the encrypted versions is generated using an electronic device;

having the first party transmit to the trusted party the encrypted version of the private first value and having the second party transmit to the trusted party the encrypted version of the private second value, wherein at least one of the transmissions is carried out electronically;

having the trusted party participate in the electronic process by taking action to determine whether the predetermined relationship exists without revealing the first and second private values outside the secure hardware; and having the trusted party continue the electronic process by transmitting result-information to each of the first and second parties, wherein the private first and second values are not revealed if the predetermined relationship does not exist.

41. An electronic process executed by a first party and a second party, with assistance from an invisible trusted party if needed, wherein the first party has a private first value and the second party has a private second value, comprising the steps of:

(1) having the first and second party agree to execute and electronic negotiation that results in (a) a commitment to a transaction if a predetermined relationship exists between the private first and second values or (b) no commitment and the determination that the predetermined relationship does not exist without revealing the first and second values, and wherein each party's respective private value is unknown to the other party;

(2) having the first party and the second party exchange messages to attempt completion of the electronic negotiation, wherein at least one of the messages is exchanged electronically and wherein either party can determine whether the electronic negotiation is complete; and

(3) if the electronic negotiation cannot be completed in step (2), having the invisible trustee take action to complete the electronic negotiation.

42. An electronic process executed by a first party and a second party, using secure hardware, wherein the first party has a private first value and the second party has a private second value and the parties are committed to a transaction if a predetermined relationship between the first and second values is established to exist, but not otherwise, wherein each party's respective value is unknown to the other party, comprising the steps of:

providing the secure hardware the private first and second values, wherein at least one of the values is provided electronically;

having the secure hardware determine whether the predetermined relationship exists without revealing the first and second private values outside the secure hardware; and

having the secure hardware provide result-information to at least one of the first and second parties, wherein at least one of the private first and second values is not revealed outside the secure hardware if the predetermined relationship does not exist.

43. The electronic process as described in Claim 42 wherein if the predetermined relationship exists, the result-information provided by the secure hardware indicates a transaction price by evaluating a predetermined function of the first and second private values.

44. The electronic process as described in Claim 42 wherein the result-information is digitally signed.

45. The electronic process as described in Claim 42 wherein the result–information is digitally signed with other information.

46. The electronic process as described in Claim 42 wherein an initial agreement occurs between the first and second parties prior to the secure hardware providing the result-information.

47. The electronic process as described in Claim 42 wherein at least one of the first and second private values is provided to the secure hardware unencrypted.

48. The electronic process as described in Claim 41 wherein the first and second parties further agree that a given penalty is imposed on a party that has been found to have deviated from prescribed steps of the electronic negotiation.

FIG. 1

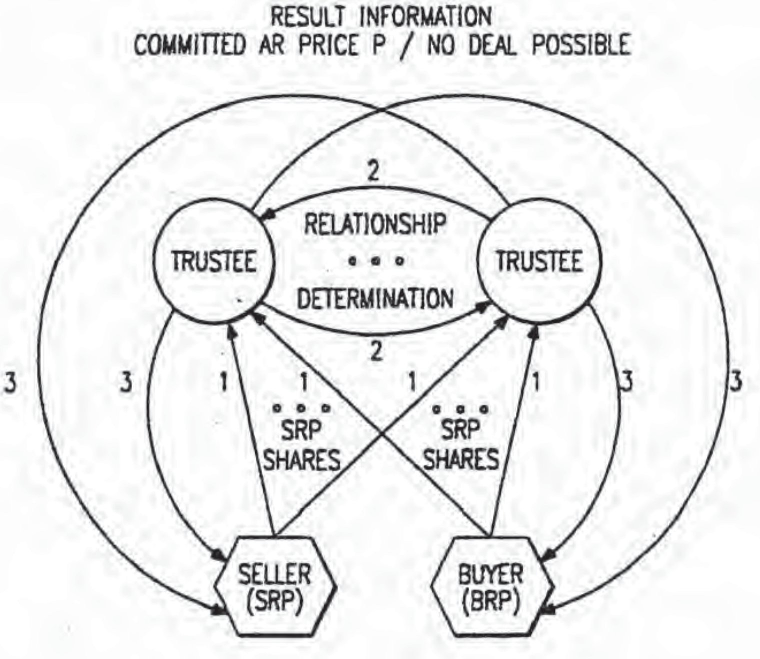

RESULT INFORMATION
COMMITTED AR PRICE P / NO DEAL POSSIBLE
2
RELATIONSHIP
• • •
DETERMINATION
2
TRUSTEE
TRUSTEE
3
3
1
1
1
1
3
3
• • •
SRP
SHARES
• • •
SRP
SHARES
SELLER
(SRP)
BUYER
(BRP)

FIG. 2

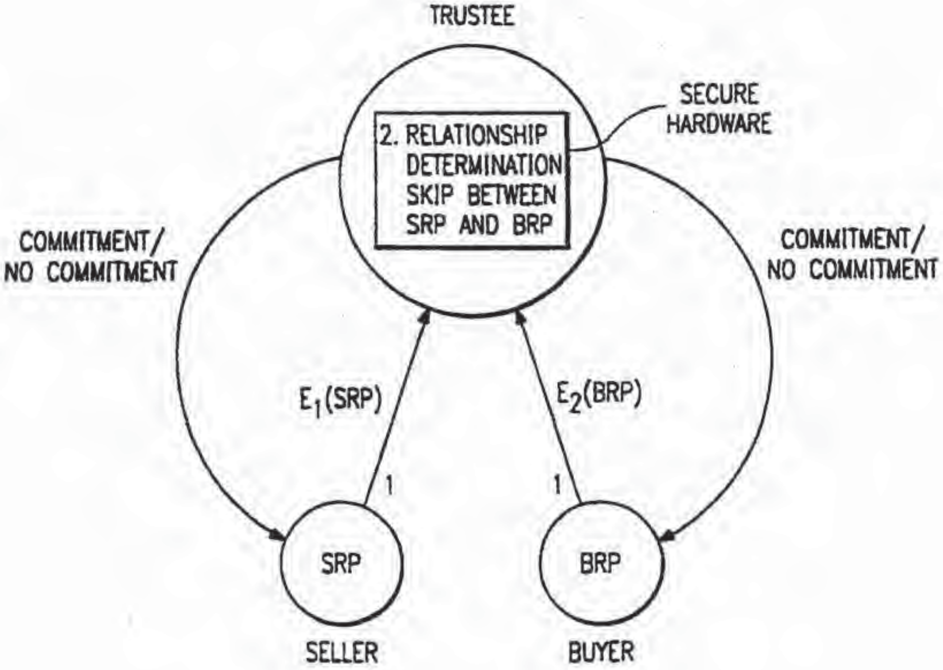

TRUSTEE
2. RELATIONSHIP
DETERMINATION
SKIP BETWEEN
SRP AND BRP
SECURE
HARDWARE
COMMITMENT/
NO COMMITMENT
COMMITMENT/
NO COMMITMENT
E_1(SRP)
E_2(BRP)
1
1
SRP
BRP
SELLER
BUYER

FIG. 3

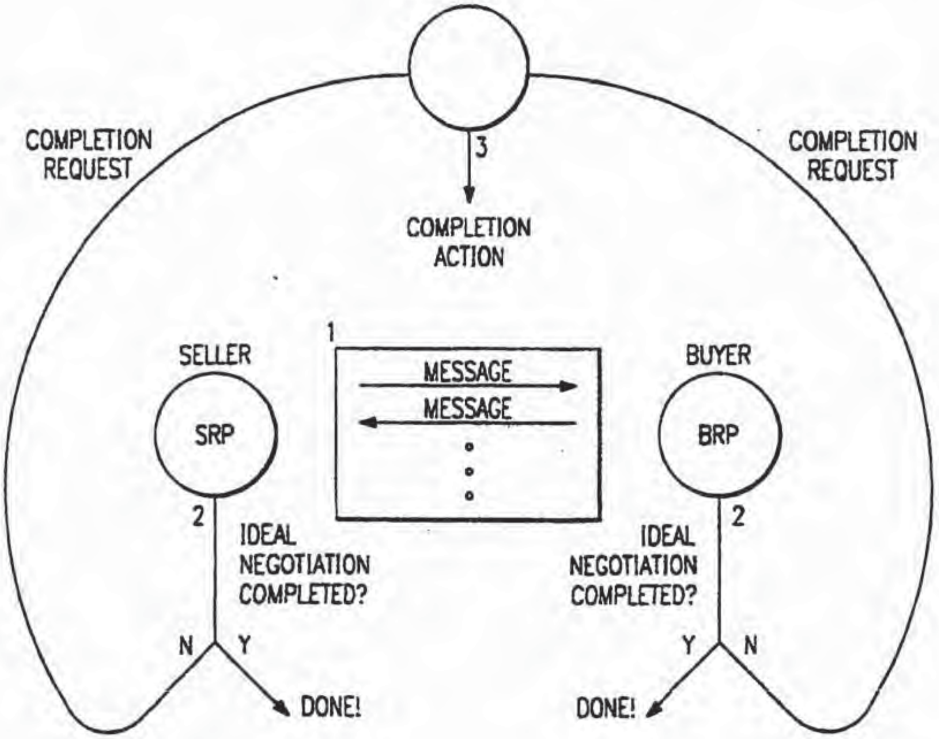
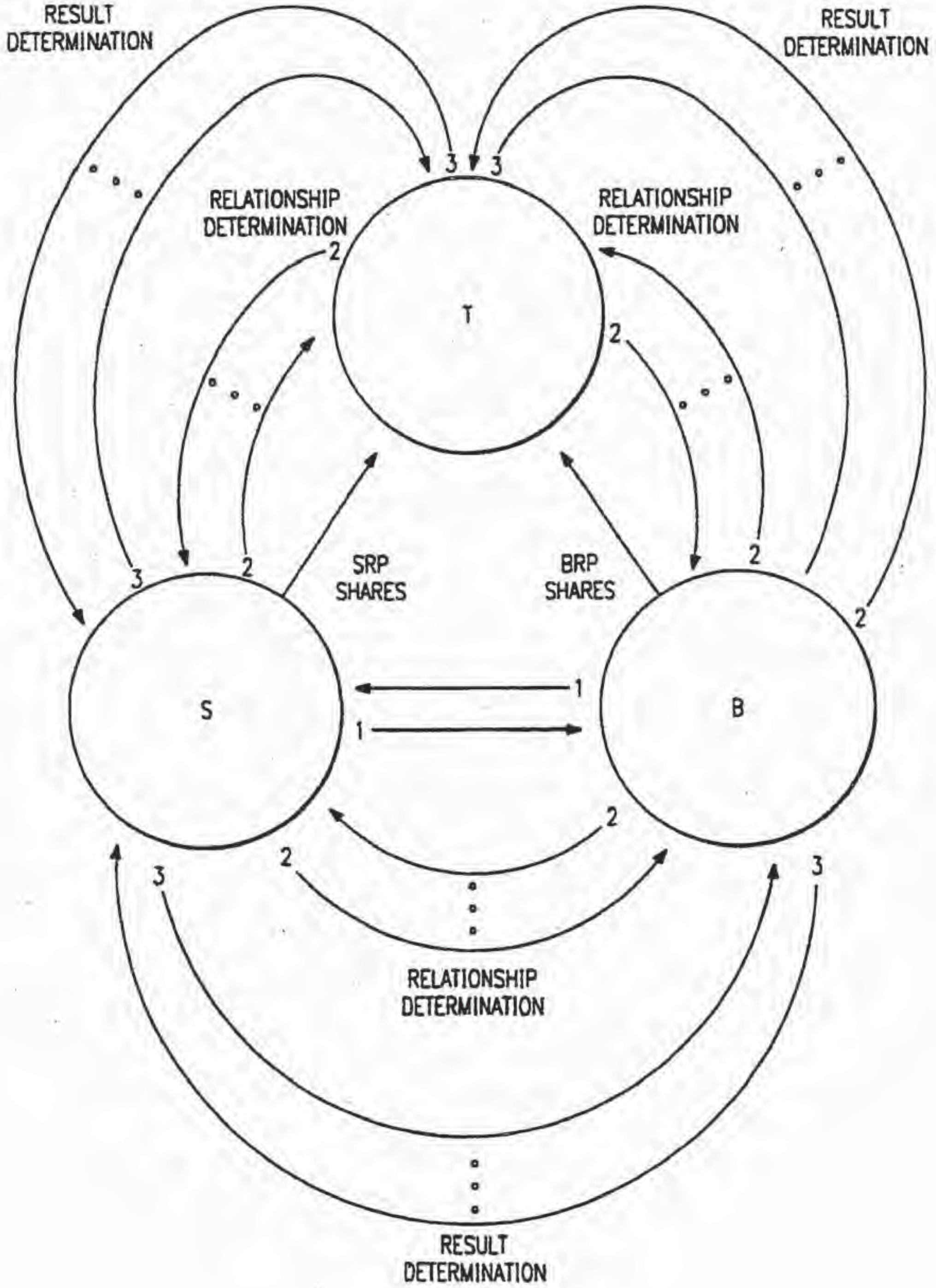

COMPLETION REQUEST
3
COMPLETION REQUEST
COMPLETION ACTION
1
SELLER
MESSAGE
MESSAGE
BUYER
SRP
BRP
2
IDEAL NEGOTIATION COMPLETED?
IDEAL NEGOTIATION COMPLETED?
2
N
Y
Y
N
DONE!
DONE!

FIG. 4


RESULT DETERMINATION
RESULT DETERMINATION
3
3
RELATIONSHIP DETERMINATION
RELATIONSHIP DETERMINATION
2
T
2
SRP SHARES
BRP SHARES
3
2
2
2
S
B
1
1
2
2
3
3
RELATIONSHIP DETERMINATION
RESULT DETERMINATION

(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) **EP 0 649 261 B1**

(12) **EUROPEAN PATENT SPECIFICATION**

(45) Date of publication and mention of the grant of the patent:
23.01.2002 Bulletin 2002/04

(51) Int Cl.7: **H04N 7/24**, H04N 7/167

(21) Application number: **94307609.1**

(22) Date of filing: **17.10.1994**

(54) **Image data processing and encrypting apparatus**

Vorrichtung zur Verarbeitung und Verschlüsselung von Bilddaten

Appareil pour le traitement et le chiffrage de données d'images

(84) Designated Contracting States:
DE ES FR GB IT NL

(30) Priority: **18.10.1993 JP 25977093**

(43) *Date of publication of application:*
19.04.1995 Bulletin 1995/16

(73) Proprietor: **CANON KABUSHIKI KAISHA**
Tokyo (JP)

(72) Inventor: **Enari, Masahiko,**
c/o Canon Kabushiki Kaisha
Ohta-ku, Tokyo (JP)

(74) Representative:
Beresford, Keith Denis Lewis et al
BERESFORD & Co. 2-5 Warwick Court, High Holborn
London WC1R 5DH (GB)

(56) References cited:

EP-A- 0 364 285	EP-A- 0 485 230
EP-A- 0 542 261	EP-A- 0 582 122
EP-A- 0 614 308	EP-A- 0 619 677
WO-A-94/15437	

EP 0 649 261 B1

Note: Within nine months from the publication of the mention of the grant of the European patent, any person may give notice to the European Patent Office of opposition to the European patent granted. Notice of opposition shall be filed in a written reasoned statement. It shall not be deemed to have been filed until the opposition fee has been paid. (Art. 99(1) European Patent Convention).

Printed by Jouve, 75001 PARIS (FR)

Description

[0001] The present invention relates to an image processing apparatus, and more particularly to the encryption of image data.

[0002] Fig. 1 shows a block diagram of a configuration of a prior art image encoding apparatus having an encryption function.

[0003] Fig. 2 shows a block diagram of an image decoding apparatus for decoding the image data encoded by the apparatus of Fig. 1.

[0004] In the encoding apparatus shown in Fig. 1, numeral 110 denotes a high resolution analog video signal (hereinafter referred to as an HD signal), which, in the present example, has the number of scan lines of 1,050 and a frame frequency of 30 Hz. Relative to the HD signal, a video signal of an ordinary resolution having the number of scan lines of 525, a frame frequency of 30 Hz and the number of pixels of 858 is referred to as an SD signal.

[0005] An HD A/D conversion circuit 112 samples the video signal 110 at a sampling frequency of 54.054 MHz to convert it to a digital signal. By virtue of the sampling frequency, the number of pixels per line of the digital HD signal is 1,716. A high resolution (HD)/ordinary resolution (SD) conversion circuit 114 reduces the number of pixels to one half in both vertical direction and horizontal direction to output a video signal of the ordinary resolution having the number of scan lines of 525, the frame frequency of 30 Hz and the number of pixels per line of 858.

[0006] An encoding circuit 116 efficiently encodes the digital SD signal outputted from the conversion circuit 114 by an encoding scheme which is a combination of motion compensated adaptive prediction and DCT. A decoding circuit 118 decodes the encoded signal outputted from the decoded circuit 116 to reproduce an SD signal. An SD/HD conversion signal 120 interpolates pixels to the output video data from the decoding circuit 118 by a factor of two in both vertical direction and horizontal direction to convert it to an HD signal. Namely, the SD/HD conversion circuit 120 outputs a signal corresponding to the high resolution video signal having the number of scan lines of 1,050, the number of pixels per line of 1,716 and the frame frequency of 30 Hz.

[0007] A subtractor 122 subtracts the output of the SD/HD conversion circuit 120 from the output of the A/D conversion circuit 112 for each pixel. The output of the subtractor 122 is referred to as an auxiliary video signal. An encoding circuit 124 encodes the output of the subtractor 122 in the same encoding scheme as that for the encoding circuit 116.

[0008] A multiplexing circuit 126 multiplexes the encoded data (the encoded SD signal) outputted from the encoding circuit 116 and the encoded data (the encoded auxiliary video signal) outputted from the encoding circuit 124 and outputs it to an encryption circuit 128. The encryption circuit 128 encrypts the output of the multiplexing circuit 126 in accordance with an encryption key signal of an encryption key output circuit 130, and an output unit 132 outputs the encrypted data outputted from the encryption circuit 128 to a transmission line. As described above, the transmission line may be a communication line or a recording medium.

[0009] The encryption is briefly explained with reference to Figs. 3 and 4. Following encryption techniques are available.

[0010] Fig. 3 shows a flow chart of the encryption by the US Data Encryption Standard (DES) published in the FIPS Publication 46 dated January 15, 1977, and Fig. 4 shows a function of the encryption of Fig. 3. The data encryption algorithm of the DES has been published as the "Data Encryption Standard" as described above. Referring to Figs. 3 and 4, the DES will be explained.

[0011] The DES handles block encryption to binary data comprising 0's and 1's. In the DES, the binary data is grouped into 64-bit blocks and the transposition and the replacement are repeated for each block to encrypt it. An encryption key is a 64-bit signal, of which 8 bits are check bits for detecting an error. Thus, a 56-bit encryption key is actually effective. The replacement of the digit is controlled by the encryption key in each cycle. Fig. 3 shows an encryption process of the DES. Fig. 4 shows a function fK(R) which is a heart of the encryption.

[0012] As shown in Fig. 3, a 64-bit plain text is first transpositioned. This is a fixed transposition independent from the encryption key. Then, the 64 bits are divided into a left half L_0 and a right half R_0. Then, the following operations are repeated over the 16 stages:

$$L_n = R_{n-1}$$

$$R_n = L_{n-1} + fK_n(R_{n-1}) \qquad (1)$$

where + represents a sum of mode 2 for each bit, L_n and R_n represent the left half 32 bits and the right half 32 bit, respectively, at the end of the operation for the n-th stage, and K_n is generated from the encryption key as shown in the right side of Fig. 3. In Fig.3 s_1,...s_{16} are 1 or 2.

[0013] Condensed transposition is defined as the transposition excluding some of the input. In Fig. 3, 8 bits out of the 56 input bits are excluded so that an output comprises 48 bits. The condensed transposition is irrevocable conversion so that the input cannot be perfectly reproduced from the output. This serves to make the estimation of the encryption key difficult.

[0014] Referring to Fig. 4, the function fK(R) in Fig. 3 is specifically explained. In Fig. 4, to generate the function fK(R), augmented transposition is made to R. The augmented transposition is defined as the overlapped transposition of some inputs. In the illustrated example, 16 bits out of the 32 input bits appear in overlap at the output. K composed by the key is mode 2 added to the output. The resulting 48 bits are divided into eight 6-bit blocks and the respective 6 bits are converted to 4 bits by S_1, S_2, ..., S_8, respectively. Assuming that the 6 bits constitute one character, it may be considered as a kind of replacement. However, since the output is compressed to 4 bits, the conversion is irrevocable. Accordingly, the fK(R) is generally an irrevocable function. This, however, does not mean that the conversion of the formula (1) is irrevocable. The formula (1) may be converted as follows:

$$R_{n-1} = L_n$$

$$L_{n-1} = R_n + fK_n(R_{n-1})$$

$$= R_n + fK(L_n) \qquad (2)$$

It is thus seen that L_{n-1} and R_{n-1} can be calculated from L_n and R_n.

[0015] The calculation of the formula (1) is repeated 16 times and when L_{16} and R_{16} are determined, they are finally transpositioned again and the encryption is terminated.

[0016] In a decoding apparatus shown in Fig. 2, a transmission data input unit 140 receives the data from the transmission line and supplies it to a decryption circuit 142. The decryption circuit 142 decrypts it by utilizing the encryption key signal outputted from the encryption key output circuit 144. In order for the decryption to be correctly done, the exactly same encryption key as that outputted from the encryption key output circuit 130 used in the encoding apparatus (see Fig. 1) should be used.

[0017] The decryption is substantially a reverse operation to the encryption. Briefly, the process proceeds from the bottom to the top in Fig. 3. First, a reverse transposition to the last transposition in the encryption is made, and R_{n-1} and L_{n-1} are determined from the formula (2), and when R_0 and L_0 are determined, a reverse transposition to the first transposition in the encryption is made. In this manner, the original 64 bits are reproduced. In order to decrypt the DES encrypted text, there has been no known method other than examining the keys one by one. Assuming that one microsecond is needed to examine if one key is correct one or not, 2,283 years will be needed to examine all of 2^{56} keys.

[0018] The transmission data decrypted by the decryption circuit 142 is separated by a separation circuit 146 to encoded data of the SD signal and encoded data of the auxiliary video signal, which are supplied to decoding circuits 148 and 150, respectively. The decoding circuit 148 outputs the reproduced SD signal and the decoding circuit 150 output the reproduced auxiliary video signal.

[0019] An SD A/D conversion circuit 152 converts the digital SD signal outputted from the decoding circuit 148 to an analog signal. The output of the SD A/D conversion circuit 152 is an analog video signal having the number of scan lines of 525 and the frame frequency of 30 Hz. This video signal is applied to a monitor device of an ordinary resolution to display the image.

[0020] An SD/HD conversion circuit 154 converts the digital SD signal outputted from the decoding circuit 148 to a digital HD signal in the same process as that of the SD/HD conversion circuit 120. An adder 156 adds the output of the decoding circuit 150 and the output of the SD/HD conversion circuit 154. The output of the adder 156 is a video signal corresponding to the high resolution video signal. An HD D/A conversion circuit 158 converts the digital output of the adder 156 to an analog signal. The output of the HD D/A converter 158 is a video signal having the number of scan lines of 1,050 and the frame frequency of 30 Hz. The video signal is applied to a high resolution monitor to display the image.

[0021] The above prior art video signal encoding and decoding apparatus has a problem in that the video signal cannot be reproduced for those who do not have the encryption key, for both the low resolution video signal and the high resolution video signal.

[0022] There is a demand that charges to users are discriminated between the low resolution display device having the number of scan lines of 525 and the high resolution display device having the number of scan lines of 1,050, for the same content, but the prior art apparatus does not meet the requirement.

[0023] It is known from EP-A-0364285 to divide a television signal into a number of spatiotemporal components and to perform scrambling on those components containing high frequencies in order to reduce the effects of random noise and interference.

[0024] The following references WO-A-94/15437, EP-A-0582122, EP-A-0614308 and EP-A-0619677 are cited against the present application as prior art only to the extent provided by Articles 54(3) and (4) EPC. WO-A-94/15437 discloses partial unscrambling and decoding of a scrambled television signal by receivers having partial access rights.

[0025] EP-A-0582122 discloses scrambling apparatus for encoded video data.

[0026] EP-A-0614308 discloses key encryption of selected image components such that access to low resolution components is available without decryption.

[0027] EP-A-0619677 discloses scrambling of direct cosine transformation coded blocks of video data, including the scrambling of a DC component.

[0028] According to the present invention there is disclosed an image processing apparatus as set out in claim 1.

[0029] Acording to other aspects of the invention there is also disclosed apparatus and method as set out in claims 6, 13 and 18. Further aspects of the invention are set out in the dependend claims.

[0030] Other aspects features and advantages of the invention will become apparent from the following detailed description taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0031]

Fig. 1 shows a block diagram of a prior art image encoding apparatus,
Fig. 2 shows a block diagram of a prior art image decoding apparatus,
Fig. 3 shows a flow of prior art encryption,
Fig. 4 shows a flow of prior art encryption,
Fig. 5 shows a block diagram of a configuration of one embodiment of an image encoding apparatus of the present invention,
Fig. 6 shows a block diagram of a configuration of an embodiment of an image decoding apparatus of the present invention,
Fig. 7 shows a block diagram of a modified portion of a configuration of a modified embodiment of Fig. 6,
Fig. 8 shows a block diagram of a modified portion of a modified embodiment of Fig..6,
Fig. 9 shows a block diagram of a configuration of a second embodiment of the image encoding apparatus of the present invention,
Fig. 10 shows a block diagram of a configuration of a second embodiment of the image decoding apparatus of the present invention,
Fig. 11 illustrates band division of a space frequency,
Fig. 12 shows a block diagram of a configuration of a modified portion of a modified embodiment of Fig. 10,
Fig. 13 shows a block diagram of a configuration of a modified portion of a modified embodiment of Fig. 10,
Fig. 14 shows a block diagram of a specific encoding circuit of the embodiment, and
Fig. 15 shows a block diagram of a specific decoding circuit of the embodiment.

DETAILED DESCRIPTION OF THE EMBODIMENTS

[0032] Fig. 5 shows a block diagram of a configuration of one embodiment of the encoding apparatus of the present invention, and Fig. 6 shows a block diagram of a configuration of the decoding apparatus.

[0033] The encoding apparatus shown in Fig. 5 is first explained. Numeral 10 denotes a high resolution video signal having the number of scan lines of 1,050 and the frame frequency of 30 Hz as the HD signal 110 does. Numeral 12 denotes an HD A/D conversion circuit for converting the video signal 10 to a digital signal, numeral 14 denotes a high resolution (HD)/ordinary resolution (SD) conversion circuit for converting the digital HD signal outputted from the HD A/D conversion circuit 12 to a video signal of the ordinary resolution, numeral 16 denotes an encoding circuit for efficiently encoding the output of the conversion circuit 14, numeral 18 denotes a decoding circuit for decoding the output of the encoding circuit 16, numeral 20 denotes an SD/HD conversion circuit for interpolating the SD signal output of the decoding circuit 18 to convert it to an HD signal, numeral 22 denotes a subtractor for subtracting the output of the SD/HD conversion circuit 20 from the output of the HD A/D conversion circuit 12 for each pixel, and numeral 24 denotes an encoding circuit for encoding the output of the subtactor 22. The circuits 12 - 24 have the same functions as those of the circuits 112 - 124 of Fig. 1 and operate in the same manner.

[0034] Numeral 26 denotes an encryption circuit for encrypting the output of the encoding circuit 24 in accordance with an encryption signal outputted from an encryption key output circuit 28. As the encryption technique, the one which complies with the DES standard is used.

[0035] Numeral 30 denotes a multiplexing circuit for multiplexing the output of the encoding circuit 16 and the encryption circuit 26, and numeral 32 denotes an output unit for outputting transmission data multiplexed by the multiplexing circuit 30 to a transmission line such as a communication line or a recording medium.

[0036] The encoding apparatus shown in Fig. 5 is explained. The operations of the circuits 12 - 24 are same as those of the prior art apparatus. Namely, the encoding circuit 16 outputs the encoded data of the video signal derived by converting the HD signal 10 to the ordinary resolution, and the encoding circuit 24 outputs the encoded data of the auxiliary video signal to reproduce the high resolution video signal from the transmission video data of the ordinary resolution. In the present embodiment, prior to the multiplexing of the both encoded data, the output encoded data of the encoding circuit 24 is encrypted by the encryption circuit 26 by using the encryption key signal outputted from the encryption key output circuit 28 and it is applied to the multiplexing circuit 30.

[0037] Accordingly, in the present embodiment, the multiplexing circuit 30 multiplexes the encoded data of the video signal of the ordinary resolution (the output of the encoding circuit 16) and the encoded data of the encrypted auxiliary video signal and the output unit 32 outputs the output of the multiplexing circuit 30 to the transmission line. Accordingly, the video signal of the ordinary resolution is transmitted without encryption but the information for reproducing the high resolution video signal (auxiliary video signal) is encrypted so that, in the receiving station, the high resolution video signal cannot be reproduced without the encryption key but the video signal of the ordinary resolution can be reproduced without the encryption key.

[0038] The decoding apparatus shown in Fig. 6 is explained. Numeral 40 denotes a transmission data input unit for receiving data from the transmission line, numeral 42 denotes a separation circuit for separating a set stream from the transmission data input unit 40 to a portion related to the encoded data of the SD signal and a portion related to the encoded data of the auxiliary video signal, and numeral 44 denotes a decryption circuit for decrypting the encoded data of the auxiliary video signal from the separation circuit 42 by referencing the encryption key signal outputted from the encryption key output circuit 46.

[0039] Numeral 48 denotes a decoding circuit for decoding the encoded data of the SD signal from the separation circuit 42, numeral 50 denotes a decoding circuit for decoding the encoded data of the auxiliary video signal from the decryption circuit 44, numeral 52 denotes an SD D/A conversion circuit for converting the digital SD signal outputted from the decoding circuit 48 to an analog signal, numeral 54 denotes an SD/HD conversion circuit for converting the digital SD signal outputted from the decoding circuit 48 to a digital HD signal in the same process as that of the SD/HD conversion circuit 20, numeral 56 denotes an adder for adding the output of the decoding circuit 50 to the output of the SD/HD conversion circuit 54, and numeral 58 denotes an HD D/A conversion circuit for converting the digital output of the adder 56 to an analog signal.

[0040] An operation of the decoding circuit shown in Fig. 6 is explained. The transmission data input unit 40 receives the data from the transmission line and supplies it to the separation circuit 42, and the separation circuit 42 separates it to a portion related to the encoded data of the SD signal and a portion related to the encoded data of the encrypted auxiliary video signal and supplies the former to the decoding circuit 48 and the latter to the decryption circuit 44. The decryption circuit 44 decrypts the encryption applied to the encoded data of the auxiliary video signal by using the same encryption key signal outputted from the encryption key output circuit 46 as the encryption key signal outputted from the encryption key output circuit 28 of the encoding circuit (Fig. 1). The encoded data of the auxiliary video signal decrypted by the decryption circuit 44 is applied to the decoding circuit 50 and decoded thereby.

[0041] Thus, the decoding circuit 48 outputs the reproduced digital SD signal and the decoding circuit 50 outputs the reproduced digital auxiliary video signal.

[0042] The SD D/A conversion circuit 52 converts the digital SD signal outputted from the decoding circuit 48 to an analog signal. The SD D/A conversion circuit 52 may be an analog signal having the number of scan lines of 525 and the frame frequency of 30 Hz and the video signal is applied to a monitor device of the ordinary resolution to display the image.

[0043] The SD/HD conversion circuit 54 converts the digital SD signal outputted from the decoding circuit 48 to a digital signal in the same process as that of the SD/HD conversion circuit 120. The adder 56 adds the output of the decoding circuit 50 to the output of the SD/HD conversion circuit 54 for each pixel. The output of the adder 56 is a video signal corresponding to the high resolution video signal. The HD D/A conversion circuit 58 converts the digital output of the adder 56 to an analog signal. The output of the HD D/A conversion circuit 58 is a high resolution video signal having the number of scan lines of 1,050 and the frame frequency of 30 Hz and it may be applied to a high resolution monitor to display the image.

[0044] In the decoding apparatus shown in Fig. 6, without the encryption key or if the encryption key is not correct (hereinafter collectively referred to as without key or no key state), the decryption circuit 44 outputs quite an unstable data pattern so that the output of the HD D/A conversion circuit 58 is also unstable and an unstable pattern such as a noise image is displayed on the screen of the display device such as a CRT.

[0045] Alternatively, a fixed image may be displayed on the high resolution monitor screen in the no key state. Figs. 7 and 8 show portions of block diagrams of such modified encoding apparatus. The like elements in Figs. 7 and 8 are designated by like numerals.

[0046] In Fig. 7, a switch 60 is provided between the decoding circuit 50 and the adder 56, and when the no key state (no input of the encryption key signal) is detected by the decryption circuit 44, the switch 60 is set to '0' by the detection output so that '0' is applied to the adder 56. When the correct encryption key is inputted to the decryption circuit 44', the decryption circuit 44' connects the switch 60 to the output of the decoding circuit 50.

[0047] In Fig. 8, a switch 62 is provided between the adder 56 and the HD D/A conversion circuit 58 so that in the no key state a predetermined level is inputted to the HD D/A conversion circuit 58. The switch 62 normally selects the output of the adder 56, and when the decryption circuit 44' the no key state (no input of the encryption key signal), the switch is set to the predetermined level input. In this manner, when the correct input is present, the high resolution video signal is outputted but in the no key state, the predetermined level signal is outputted and an image corresponding to the predetermined level is displayed on the monitor screen.

[0048] In Figs. 7 and 8, the switches 60 and 62 are illustrated to facilitate the understanding although it is apparent that the function of such switches 60 and 62 may be incorporated in the decoding circuit 50 and/or HD A/D conversion circuit 58. Alternatively, the output of the decoding circuit 50 or the HD D/A conversion circuit may be forced to a predetermined level (for example, zero output) in response to the detection of the no key state by the decryption circuit 44.

[0049] In Figs. 7 and 8, the no key state is detected by the decryption circuit 44 although it may be detected by error code detection or error correction process.

[0050] A second embodiment of the present invention which is applied to a system in which the image information is transmitted by the band division by the space frequency is now explained. Fig. 9 shows a block diagram of a configuration of an encoding apparatus thereof, and Fig. 10 shows a block diagram of a configuration of a decoding apparatus. Fig. 11 illustrates the band division of the space frequency.

[0051] Numeral 210 denotes an analog HD signal to be encoded. In the present embodiment, it is a video signal having the number of scan lines of 1,050 and the frame frequency of 30 Hz. An HD A/D conversion circuit 212 samples the analog HD signal at a sampling frequency of 54.054 MHz to convert it to a digital signal. The number of pixels per line of the sampled HD signal is 1,716.

[0052] The output of the HD A/D conversion circuit 212 is applied to band division filters 214 and 216 and divided by the filters 214 and 216 to a low frequency component and a high frequency component at a horizontal frequency and the number of pixels is reduced to one half, respectively.

[0053] The output of the band division filter 214 is a low resolution component of the horizontal frequency, which is further separated into a low frequency component and a high frequency component at a vertical frequency by band division filters 218 and 220 to reduce the number of pixels to one half. Similarly, the band division filters 222 and 224 separates the output of the band division filter 216 (the high resolution component at the horizontal frequency) into a low frequency component and a high frequency component at the vertical frequency to reduce the number of pixels to one half.

[0054] In this manner, the high resolution video signal having 1,716 pixels in the horizontal direction and 1,024 pixels in the vertical direction is separated into an LL signal (the output of the band division filter 218), an LH signal (the output of the band division filter 220), an HL signal (the output of the band division filter 222) and an HH signal (the output of the band division filter 224) having one half of the total number of pixels in the horizontal direction and the vertical direction, as shown in Fig. 11. Since only the LL signal has the low-pass data in both the horizontal direction and the vertical direction, it is the video information which can be reproduced for display as the image and corresponds to the video signal of the ordinary resolution having the number of scan lines of 525, the frame frequency of 30 Hz and the number of pixels per line of 858. On the other hand, since the LH signal, the HL signal and the HH signal are high-pass data, they cannot be displayed as the image as they are and they are the auxiliary video signals which form the high resolution video signal in cooperation with the LL signal.

[0055] The encoding circuit 226 efficiently encodes the output of the band division filter 218 (LL signal) by an encoding scheme which is a combination of the motion compensated adaptive prediction known as the CCIR Recommendation 723 and the DCT. Encoding circuit 228, 230 and 232 efficiently encode the outputs of the band division filters 220, 222 and 224 (LH signal, HL signal and HH signal), respectively, by a combination of the DPCM and a zero run length encoded and variable length code. The outputs of the encoding circuits 228 - 232 are multiplexed by a multiplexing circuit 234. An encryption circuit 236 encrypts the output of the multiplexing circuit 234 by using the encryption key outputted from the encryption key output circuit 238 in accordance with the encryption technique of the DES standard described above.

[0056] The multiplexing circuit 240 multiplexes the output of the encoding circuit 226 and the output of the encryption circuit 236 and the output thereof is outputted to the transmission line by the output unit 242.

[0057] In the decoding apparatus shown in Fig. 10, the transmission data input unit 250 receives the transmission data from the transmission line and applies it to the separation circuit 252. The separation circuit 252 separates it into a portion related to the encoded data of the LL signal and a portion related to the other LH, HL and HH signals, and applies the former to the decoding circuit 254 and the latter to the decryption circuit 256. The decryption circuit 256 decrypts the encoded data of the LH, HL and HH signals by using the encryption key signal outputted from the encryption key output circuit 258. In order to correctly decrypt it, the encryption key should be same as that used for encoding the encryption key signal.

[0058] The separation circuit 260 separates the output of the decryption circuit 256 to the encoded data of the LH signal, the encoded data of the HL signal and the encoded data of the HH signal, which are applied to the decoding circuits 262, 264 and 266, respectively.

[0059] The decoding circuits 254, 262, 264 and 266 decode the encoded data inputted thereto, respectively. The output of the decoding circuit 254 is the LL signal. The SD D/A conversion circuit 268 converts the output of the decoding circuit 254 to an analog signal. The output of the SD D/A conversion circuit 268 is an analog video signal having the number of scan lines of 525 and the frame frequency of 30 Hz and it can be displayed as an image by an image display device of the ordinary resolution.

[0060] The reproduced LL signal and LH signal are combined at the vertical frequency by the band synthesization filters 270 and 272 and the number of pixels in the vertical direction is interpolated to two times. Similarly, the reproduced HL signal and HH signal are synthesized at the vertical frequency by the band synthesization filters 274 and 276 and the number of pixels in the vertical direction is interpolated to two times. The synthesized signals are combined at the horizontal frequency by the band synthesization filters 278 and 280 and the number of pixels in the horizontal direction is interpolated to two times.

[0061] By those synthesization processes, the digital high resolution video signal having the number of scan lines of 1,050 and the frame frequency of 30 Hz is reproduced. The HD D/A conversion circuit 282 converts the reproduced digital HD signal to an analog signal.

[0062] In the decoding apparatus shown in Fig. 10, in the no key state, the decryption circuit 256 outputs a quite unstable data pattern so that the output of the HD D/A conversion circuit 282 is also unstable and an unstable pattern such as a noise image is displayed on the screen of the display device such as CRT.

[0063] Alternatively, the image of the low resolution or a still image may be displayed on the high resolution monitor screen in the no key state. Figs. 12 and 13 show portions of block diagrams of such modified decoding apparatus. The like elements to those of Fig. 10 are designated by the like numerals.

[0064] In Fig. 12, an SD/HD conversion circuit 284 for converting the output of the decoding circuit 254 to the HD signal and a selection switch for selecting the output of the SD/HD conversion circuit 284 or the synthesized output by the band synthesization filters 278 and 280 and supplying it to the HD D/A conversion circuit 282 are provided. The SD/HD conversion circuit 284 is identical to the SD/HD conversion circuit 54 of Fig. 6. The switch 286 is normally connected to synthezied output of the band synthesization filters 278 and 280, and when no key state is detected by the decryption circuit, it is switched to the output of the SD/HD conversion circuit 284 by the detection output. Thus, in the no key state, the image can be displayed by the high resolution monitor although the quality of the image is not sufficient for the high resolution monitor.

[0065] When the encryption key signal may not be inputted to the decryption circuit 256', it may be possible that the output of the encryption key output circuit 258 is forcibly stopped or the encryption key output circuit 258 itself is not present.

[0066] For the configuration shown in Fig. 12, the high frequency data of the band synthesization filters 270-280 may be reset by the detection output of the decryption circuit 256' to attain the same effect.

[0067] In Fig. 13, a switch 282 is provided between the synthesized output by the band synthesization filters 278 and 280 and the HD D/A conversion circuit 282 so that in the no key state, a predetermined level is inputted to the HD D/A conversion circuit 282. The switch 288 normally selects the synthesized output by the band synthesization filters 278 and 280, and when the no key state is detected by the decryption circuit 256, it is switched to the predetermined level input by the detection output. In this manner, when the correct encryption key is present, the high resolution video signal is outputted, but in the no key state, the predetermined level signal is outputted and the image corresponding to the predetermined level is displayed on the monitor screen.

[0068] When the encryption key signal is not inputted to the decryption circuit 256', it may be possible that the output of the encryption key output circuit is forcibly stopped or the encryption key output circuit 258 itself is not present.

[0069] For the configuration shown in Fig. 13, the switch 288 may not be provided and the output of the HD D/A conversion circuit 282 may be forced to a constant level (for example, zero output) in accordance with the detection output of the no key state by the decryption circuit 44.

[0070] In Figs. 12 and 13, the no key state is detected by the decryption circuit 256 although it may be detected by an error detection code or error correction process.

[0071] Embodiments of the encoding circuit and the decoding circuit used in the respective embodiments are now explained.

[0072] Fig. 14 shows a block diagram of a specific embodiment of the encoding circuit.

[0073] The encoding circuit shown in Fig. 14 comprises a blocking circuit 301, a DCT circuit 302, a quantization circuit 303, a variable length encoding circuit (VLC) 304, a motion compensation circuit 305, a motion vector detection circuit 306, a rate control circuit 307, a local decoding circuit 308 and a buffer memory 309.

[0074] In Fig. 14, image data to be encoded is grouped into 8 x 8 pixel blocks by the block forming circuit 301 and they are supplied to the DCT (discrete cosine transform) circuit 302 through the switch 310.

[0075] The switch 310 is periodically (for example, for each frame or every several fields) switched to a terminal a to prevent erroneous propagation.

[0076] Namely, when it is connected to the terminal a, an intra-frame or intra-field encoding (intra mode) is conducted.

[0077] In the intra mode, it is DCT-transformed by the DCT circuit 302 and the resulting DCT coefficient is quantized by the quantization circuit 303 and further encoded by the variable length encoding circuit 304 and temporarily stored in the buffer 309.

[0078] On the other hand, in other than the intra mode, the switch 310 is connected to a terminal b to conduct the motion compensated prediction encoding.

[0079] Numerals 311 and 312 denote a de-quantization circuit and a de-DCT circuit which constitute the local decoding circuit 308. The data quantized by the quantization circuit 303 is restored to the original image data by the local decoding circuit 308.

[0080] Numeral 313 denotes an adder, numeral 314 denotes a switch which is closed in other than the intra mode, and numeral 316 denotes a subtractor.

[0081] The locally decoded image data refers the motion vector detected by the motion vector detection circuit 306 to output the corresponding block of the predetermined frame (preceding frame, succeeding frame or interpolated frame).

[0082] The output of the motion compensation circuit 305 is subtracted by the input image data by the subtractor 316 to produce a difference.

[0083] The difference is encoded by the DCT circuit 302, the quantization circuit 303 and the variable length encoding circuit 304 and it is stored in the buffer 309.

[0084] The motion vector detection circuit 306 compares the frame data to be encoded with the predetermined reference frame data to produce the motion vector, and the output of the motion vector detection circuit 306 is supplied to the motion compensation circuit 305 to specify the block to be outputted by the motion compensation circuit 305.

[0085] The rate control circuit 307 controls the quantity of encoding by switching the quantization step of the quantization circuit 303 in accordance with an occupation rate of the encoded data in the buffer 309.

[0086] Finally, the motion vector data detected by the motion vector detection circuit 306, an encoding identification code for identifying the intra mode and quantization step data indicating the quantization step are added by an adding circuit 315 and it is outputted as the encoded data.

[0087] Fig. 15 shows a specific block diagram of the decoding circuit.

[0088] The decoding circuit basically operates in the reverse manner to the encoding circuit shown in Fig. 14.

[0089] The decoding circuit shown in Fig. 15 comprises an input buffer memory 401, a variable length decoding circuit 402, a de-quantization circuit 403, a de-DCT circuit 404, a motion compensation circuit 405 and an output buffer memory 406.

[0090] The encoded data sequentially read from the input buffer memory 401 is processed by the variable length decoding circuit 402, the de-quantization circuit 403 and the de-DCT circuit 404 and converted to the space area data.

[0091] The quantization step of the de-quantization circuit 403 is determined by the quantization step data which is transmitted along with the encoded data.

[0092] Numeral 407 denotes an adder for adding the output of the de-DCT circuit 404 to the difference outputted from the motion compensation circuit 405, and numeral 408 denotes a switch for selecting the output of the de-DCT circuit 404 or the output of the adder 407.

[0093] The switch 408 is connected to the terminal a in the intra mode by the encoding identification code detected by the data detection circuit, not shown, and connected to the terminal b in other mode.

[0094] The decoded data is temporarily stored in the output buffer memory 406 and restored to the original space arrangement and outputted as one-frame or one-field image data.

[0095] As will be readily understood from the above description, in accordance with the present embodiment, the high resolution video signal is not reproduced for those who do not have the encryption key and the reproduction of only the low resolution video signal is permitted. The charges to the users may be discriminated between the display device of the low resolution and the display device of the high resolution of the same content.

[0096] The present invention may be implemented in other various forms.

[0097] For example, while the image signal is divided into four frequency bands in the second embodiment, the present invention is not limited thereto.

[0098] In other words, the foregoing description of the embodiments has been given for illustrative purpose only and not to be construed as imposing limitation in every respect.

[0099] The scope of the invention is, therefore, to be determined solely by the following claims and not limited by the text of the specification and alterations made within the scope equivalent to the scope of the claims fall within the scope of the invention.

Claims

1. An image processing apparatus comprising:

   a) input means for inputting an image signal (210);
   b) separation means (214 to 224) for separating said image signal into a low frequency component and a high frequency component in each of horizontal and vertical directions and for producing spatial frequency bands (LL, LH, HL, HH) from said image signal;
   c) encoding means (226 to 232) for high-efficiency encoding the spatial frequency bands (LH, HL, HH) including a highest frequency component and for high-efficiency encoding the spatial frequency band (LL) including a lowest frequency component; and
   d) encryption means (236) for encrypting only the encoded spatial frequency bands including the highest frequency component using an encryption key in accordance with a predetermined encryption algorithm.

2. An apparatus according to claim 1, wherein said separation means is operable to produce a first spatial frequency band (LL) including the low frequency component of the horizontal direction and the low frequency component of the vertical direction, a second spatial frequency band (LH) including the low frequency component of the horizontal direction and the high frequency component of the vertical direction, a third spatial frequency band (HL) including the high frequency component of the horizontal direction and the low frequency component of the vertical direction, and a fourth spatial frequency band (HH) including the high frequency component of the horizontal direction and the high frequency component of the vertical direction.

3. An apparatus according to claim 1 or 2, wherein said encoding means is operable to encode the spatial frequency bands using variable length encoders.

4. An apparatus according to any of claims 1 to 3, fur-

ther comprising:

multiplexing means (234) for multiplexing the spatial frequency bands to be encrypted,
and wherein said encryption means is operable to encrypt an output of said multiplexing means.

5. An apparatus according to any of claims 1 to 4, further comprising second multiplexing means (240) for multiplexing the encoded spatial frequency bands encrypted by said encryption means and the encoded spatial frequency band not encrypted by said encryption means.

6. An image processing apparatus comprising:

a) input means (250) for inputting spatial frequency bands (LH, HL, HH) including a highest frequency component and spatial frequency band (LL) including a lowest frequency component, the spatial frequency bands including the highest frequency component are encrypted;
b) decryption means (256 or 256') for decrypting the spatial frequency bands including the highest frequency component using a decryption key in accordance with a predetermined decryption algorithm; and
c) decoding means (254 to 266) for decoding the decrypted spatial frequency bands including the highest frequency component and for decoding the spatial frequency band including the lowest frequency component.

7. An apparatus according to claim 6, wherein said input means inputs a first spatial frequency band (LL) including the low frequency component of the horizontal direction and the low frequency component of the vertical direction, a second spatial frequency band (LH) including the low frequency component in the horizontal direction and the high frequency component in the vertical direction, a third spatial frequency band (HL) including the high frequency component of the horizontal direction and the low frequency component of the vertical direction and a fourth spatial frequency band (HH) including the high frequency component of the horizontal direction and the high frequency component in the vertical direction.

8. An apparatus according to any of claims 6 and 7, further comprising:

synthesizing means (270 to 280) for synthesizing the decrypted spatial frequency bands with other spatial frequency bands.

9. An apparatus according to any of claims 6 to 8, further comprising demultiplexing means (260) for demultiplexing the decrypted spatial frequency bands, and said decoding means is operable to decode an output of said demultiplexing means.

10. An apparatus according to any of claims 6 to 9, wherein said decoding means is operable to decode the spatial frequency bands using variable length decoders.

11. An apparatus according to any of claims 6 to 10, further comprising inhibiting means (286) operable to inhibit an output of said decryption means when said decryption means cannot decrypt the encrypted spatial frequency band.

12. An apparatus according to any of claims 6 to 11, further comprising means (288) for producing a predetermined signal in lieu of the encrypted spatial frequency band when said decryption means cannot decrypt the encrypted spatial frequency band.

13. An image processing method comprising:

a) an input step of inputting an image signal (210);
b) a separation step of separating said image signal into a low frequency component and a high frequency component in each of horizontal and vertical directions and of producing spatial frequency bands (LL, LH, HL, HH) from said image signal;
c) an encoding step of high-efficiency encoding the spatial frequency bands (LH, HL, HH) including a highest frequency component and of high-efficiency encoding the spatial frequency band (LL) including a lowest frequency component; and
d) an encryption step of encrypting only the encoded spatial frequency bands including the highest frequency component using an encryption key in accordance with a predetermined encryption algorithm.

14. A method as claimed in claim 13, wherein said separation step produces a first spatial frequency band (LL) including the low frequency component of the horizontal direction and the low frequency component of the vertical direction, a second spatial frequency band (LH) including the low frequency component of the horizontal direction and the high frequency component of the vertical direction, a third spatial frequency band (HL) including the high frequency component of the horizontal direction and the low frequency component of the vertical direction, and a fourth spatial frequency band (HH) including the high frequency component of the horizontal direction and the high frequency component of the vertical direction.

15. A method as claimed in any of claims 13 and 14 wherein said encoding step encode the spatial frequency bands using variable length encoders.

16. A method as claimed in any of claims 13 to 15, further comprising:

a multiplexing step of multiplexing the spatial frequency bands to be encrypted, and wherein said encryption step encrypts an output of said multiplexing step.

17. A method as claimed in any of claims 13 to 16, further comprising a second multiplexing step of multiplexing the encoded spatial frequency bands encrypted by said encryption step and the encoded spatial frequency band not encrypted by said encryption step.

18. An image processing method comprising:

a) an input step inputting spatial frequency bands (LH, HL, HH) including a highest frequency component and spatial frequency band (LL) including a lowest frequency component, the spatial frequency bands including the highest frequency component are encrypted;
b) a decryption step of decrypting the spatial frequency bands including the highest frequency component using a decryption key in accordance with a predetermined decryption algorithm; and
c) a decoding step of decoding the decrypted spatial frequency bands including the highest frequency component and of decoding the spatial frequency band including the lowest frequency component.

19. A method as claimed in claim 18, wherein said input step inputs a first spatial frequency band (LL) including the low frequency component of the horizontal direction and the low frequency component of the vertical direction, a second spatial frequency band (LH) including the low frequency component of the horizontal direction and the high frequency component of the vertical direction, a third spatial frequency band (HL) including the high frequency component of the horizontal direction and the low frequency component of the vertical direction and a fourth spatial frequency band (HH) including the high frequency component of the horizontal direction and the high frequency component of the vertical direction.

20. A method as claimed in any of claims 18 and 19, further comprising:

a synthesizing step of synthesizing the decrypted spatial frequency bands with other spatial frequency bands.

21. A method as claimed in any of claims 18 to 20, further comprising a demultiplexing step of demultiplexing the decrypted spatial frequency bands, and said decoding means is operable to decode an output of said demultiplexing means.

22. A method as claimed in any of claims 18 to 21, wherein said decoding means is operable to decode the spatial frequency bands using variable length decoders .

23. A method as claimed in any of claims 18 to 22, further comprising an inhibiting step of inhibiting an output of said decryption step when said decryption step cannot decrypt the encrypted spatial frequency band.

24. A method as claimed in any of claims 18 to 23, further comprising a step of producing a predetermined signal in lieu of the encrypted spatial frequency band when said decryption step cannot decrypt the encrypted spatial frequency band.

Patentansprüche

1. Vorrichtung zur Bildverarbeitung, mit:

a) einem Eingabemittel zur Eingeben eines Bildsignals (210);
b) einem Trennmittel (214 bis 224) zum Trennen des Bildsignals in eine niederfrequente Komponente und in eine hochfrequente Komponente sowohl in Horizontal- als auch in Vertikalrichtung, um aus dem Bildsignal ein Ortsfrequenzband (LL, LH, HL, HH) zu erzeugen;
c) einem Codiermittel (226 bis 232) zum hocheffizienten Codieren der eine Höchstfrequenzkomponente enthaltenden Ortsfrequenzbänder (LH, HL, HH) und des eine Niedrigstfrequenzkomponente enthaltenden Ortsfrequenzbandes (LL); und mit
d) einem Verschlüsselungsmittel (236) zum Verschlüsseln nur der die Höchstfrequenzkomponente enthaltenden codierten Ortsfrequenzbänder unter Verwendung eines Schlüssels gemäß einem vorbestimmten Verschlüsselungsalgorithmus.

2. Vorrichtung nach Anspruch 1, bei der das Trennmittel betriebsbereit ist zum Erzeugen eines ersten Ortsfrequenzbandes (LL) mit der Niederfrequenzkomponente der Horizontalrichtung unter der Niederfrequenzkomponente der Vertikalrichtung, eines zweiten Ortsfrequenzbandes (LH) mit der Niederfrequenzkomponente der Horizontalrichtung und der Hochfrequenzkomponente der Vertikalrichtung, eines dritten Ortsfrequenzbandes (HL) mit der Hochfrequenzkomponente der Horizontalrichtung und der Niederfrequenzkomponente der Vertikalrichtung, und zum Erzeugen eines vierten Ortsfrequenzbandes (HH) mit der Hochfrequenzkomponente der Horizontalrichtung und der Hochfrequenzkomponente der Vertikalrichtung.

3. Vorrichtung nach Anspruch 1 oder 2, bei der das Codiermittel betriebsbereit ist, die Ortsfrequenzbänder unter Verwendung eines längenvariabel codierenden Codierers zu codieren.

4. Vorrichtung nach einem der Ansprüche 1 bis 3, die des weiteren ausgestattet ist mit:

   einem Multiplexmittel (234) zum Multiplexieren der zu verschlüsselnden Ortsfrequenzbänder,

   wobei das Verschlüsselungsmittel betriebsbereit ist, ein Ausgangssignal des Multiplexmittels zu verschlüsseln.

5. Vorrichtung nach einem der Ansprüche 1 bis 4, die des weiteren über ein zweites Multiplexmittel (240) verfügt, um die vom Verschlüsselungsmittel verschlüsselten codierten Ortsfrequenzbänder und das nicht vom Verschlüsselungsmittel verschlüsselte codierte Ortsfrequenzband zu multiplexieren.

6. Vorrichtung zur Bildverarbeitung; mit:

   a) einem Eingabemittel (25) zur Eingabe von Ortsfrequenzbändern (LH, HL, HH) mit einer Höchstfrequenzkomponente und einem Ortsfrequenzband (LL) mit einer Niedrigstfrequenzkomponente, wobei die die Höchstfrequenzkomponente enthaltenden Ortsfrequenzbänder verschlüsselt sind;
   b) einem Verschlüsselungsmittel (256 oder 256') zum Verschlüsseln der Ortsfrequenzbänder, die die Höchstfrequenzkomponente enthalten, unter Verwendung eines Schlüssels gemäß einem vorbestimmten Verschlüsselungsalgorithmus; und mit
   c) einem Codiermittel (254 bis 266) zum Decodieren der verschlüsselten Ortsfrequenzbänder, die die Höchstfrequenzkomponente enthalten, und zum Decodieren des Ortsfrequenzbandes, das die Niedrigstfrequenzkomponente enthält.

7. Vorrichtung nach Anspruch 6, bei der das Eingabemittel ein erstes Ortsfrequenzband (LL), das die Niederfrequenzkomponente der Horizontalrichtung und die Niederfrequenzkomponente der Vertikalrichtung enthält, ein zweites Ortsfrequenzband (LH), das die Niederfrequenzkomponente in Horizontalrichtung und die Hochfrequenzkomponente in Vertikalrichtung enthält, ein drittes Ortsfrequenzband (HL), das die Hochfrequenzkomponente der Horizontalrichtung und die Niederfrequenzkomponente der Vertikalrichtung enthält, und ein viertes Ortsfrequenzband (HH) eingibt, das die Hochfrequenzkomponente der Horizontalrichtung und die Hochfrequenzkomponente der Vertikalrichtung enthält.

8. Vorrichtung nach einem der der Ansprüche 6 bis 8, die des weiteren ausgestattet ist mit:

   einem Synthetisiermittel (270 bis 280) zum Zusammensetzen der entschlüsselten Ortsfrequenzbänder mit anderen Ortsfrequenzbändern.

9. Vorrichtung nach einem der Ansprüche 6 bis 8, die des weiteren über ein Demultiplexmittel (260) verfügt, um die verschlüsselten Ortsfrequenzbänder zu demultiplexieren, und wobei das Decodiermittel betriebsbereit ist, ein Ausgangssignal vom Demultiplexmittel zu decodieren.

10. Vorrichtung nach einem der Ansprüche 6 bis 9, bei der das Decodiermittel betriebsbereit ist, die Ortsfrequenzbänder unter Verwendung von längenvariabel decodierenden Decodierern zu decodieren.

11. Vorrichtung nach einem der Ansprüche 6 bis 10, die des weiteren über ein Sperrmittel (286) verfügt, das betriebsbereit ist zum Sperren eines Ausgangssignals vom Entschlüsselungsmittel, wenn das Entschlüsselungsmittel das verschlüsselte Ortsfrequenzband nicht entschlüsseln kann.

12. Vorrichtung nach einem der Ansprüche 6 bis 11, mit einem weiteren Mittel (288) zum Erzeugen eines vorbestimmten Signals anstelle des verschlüsselten Ortsfrequenzbandes, wenn das Verschlüsselungsmittel das verschlüsselte Ortsfrequenzband nicht entschlüsseln kann.

13. Verfahren zur Bildverarbeitung, mit den Verfahrensschritten:

   a) Eingeben eines Bildsignals (210);
   b) Trennen des Bildsignals in eine Niederfrequenzkomponente und eine Hochfrequenzkomponente jeweils in Horizontal- und Vertikalrichtung und Erzeugen von Ortsfrequenzbändern (LL, LH. HL, HH) aus dem Bildsignal;
   c) hocheffizientes Codieren der Ortsfrequenzbänder (LH, HL, HH), die eine Höchstfrequenzkomponente enthalten, und des Ortsfrequenz-

bandes (LL), das eine Niedrigstfrequenzkomponente enthält; und

d) Verschlüsseln nur der codierten Ortfrequenzbänder, die die Höchstfrequenzkomponente enthalten, unter Verwendung eines Schlüssels gemäß einem vorbestimmten Verschlüsselungsalgorithmus.

14. Verfahren nach Anspruch 13, bei dem der Verfahrensschritt des Trennens ein erstes Ortsfrequenzband (LL), das die Niederfrequenzkomponente der Horizontalrichtung und die Niederfrequenzkomponente der Vertikalrichtung enthält, ein zweites Ortsfrequenzband (LH), das die Niederfrequenzkomponente der Horizontalrichtung und die Hochfrequenzkomponente der Vertikalrichtung enthält, ein drittes Ortsfrequenzband (HL), das die Hochfrequenzkomponente der Horizontalrichtung und die Niederfrequenzkomponente der Vertikalrichtung enthält, und ein viertes Ortsfrequenzband (HH) erzeugt, das die Hochfrequenzkomponente der Horizontalrichtung und die Hochfrequenzkomponente der Vertikalrichtung enthält.

15. Verfahren nach einem der Ansprüche 13 und 14, bei dem der Verfahrensschritt des Codierens die Ortsfrequenzbänder unter Verwendung eines längenvariabel codierenden Codierers codiert.

16. Verfahren nach einem der Ansprüche 13 bis 15, mit den weiteren Verfahrensschritten:

Multiplexieren der zu verschlüsselnden Ortsfrequenzbänder und

wobei der Verfahrensschritt des Verschlüsselns ein beim Multiplexieren abgegebenes Signal verschlüsselt.

17. Verfahren nach einem der Ansprüche 13 bis 16, mit dem weiteren Verfahrensschritt eines zweiten Multiplexierens der im Verfahrensschritt des Verschlüsselns verschlüsselten codierten Ortsfrequenzbänder und dem im Verfahrensschritt des Verschlüsselns nicht verschlüsselten codierten Ortsfrequenzband.

18. Verfahren zur Bildverarbeitung, mit den Verfahrensschritten:

a) Eingeben von eine Höchstfrequenzkomponente enthaltende Ortsfrequenzbändern (LH, HL, HH) und von einem eine Niedrigstfrequenzkomponente enthaltenden Ortsfrequenzband (LL), wobei die die Höchstfrequenzkomponente enthaltende Ortsfrequenzbänder verschlüsselt sind;

b) Entschlüsseln der Ortsfrequenzbänder, die die Höchstfrequenzkomponente enthalten, unter Verwendung eines Schlüssels gemäß einem vorbestimmten Entschlüsselungsalgorithmus; und

c) Decodieren der die Höchstfrequenzkomponente enthaltenden verschlüsselten Ortsfrequenzbänder und des die Niedrigstfrequenzkomponente enthaltenden Ortsfrequenzbandes.

19. Verfahren nach Anspruch 18, bei dem der Verfahrensschritt des Eingebens folgende Eingaben umfaßt: ein erstes Ortsfrequenzband (LL), das die Niederfrequenzkomponente der Horizontalrichtung und die Niederfrequenzkomponente der Vertikalrichtung enthält, ein zweites Ortsfrequenzband (LH), das die Niederfrequenzkomponente der Horizontalrichtung und die Hochfrequenzkomponente der Vertikalrichtung enthält, ein drittes Ortsfrequenzband (HL), das die Hochfrequenzkomponente der Vertikalrichtung und die Niederfrequenzkomponente der Vertikalrichtung enthält, und ein viertes Ortsfrequenzband (HH), das die Hochfrequenzkomponente der Horizontalrichtung und die Hochfrequenzkomponente der Vertikalrichtung enthält.

20. Verfahren nach einem der Ansprüche 18 und 19, mit dem weiteren Verfahrensschritt:

Synthetisieren der entschlüsselten Ortsfrequenzbänder mit anderen Ortsfrequenzbändern.

21. Verfahren nach einem der Ansprüche 18 bis 20, mit den weiteren Verfahrensschritt des Demultiplexierens der entschlüsselten Ortsfrequenzbänder, wobei das Decodiermittel betriebsbereit ist, das Ausgangssignal vom Demultiplexer zu decodieren.

22. Verfahren nach einem der Ansprüche 18 bis 21, bei dem das Decodiermittel betriebsbereit ist, die Ortsfrequenzbänder mit längenvariabel decodierenden Codierern zu decodieren.

23. Verfahren nach einem der Ansprüche 18 bis 22, mit dem weiteren Verfahrensschritt des Sperrens eines beim Entschlüsseln ausgegebenen Signals, wenn der Verfahrensschritt des Entschlüsselns das verschlüsselte Ortsfrequenzband nicht entschlüsseln kann.

24. Verfahren nach einem der Ansprüche 18 bis 23, mit dem weiteren Verfahrensschritt des Erzeugens eines vorbestimmten Signals anstelle des verschlüsselten Ortsfrequenzbandes, wenn der Verfahrensschritt des Entschlüsselns das verschlüsselte Ortsfrequenzband nicht entschlüsseln kann.

Revendications

1. Appareil de traitement d'image, comprenant :

   a) un moyen d'entrée pour introduction d'un signal (210) d'image ;
   b) un moyen (214 à 224) de séparation pour séparer ledit signal d'image en une composante basse fréquence et une composante haute fréquence dans chacune de directions horizontale et verticale et pour produire des bandes (LL, LH, HL, HH) de fréquence spatiale à partir dudit signal d'image ;
   c) un moyen (226 à 232) de codage pour un codage de grande efficacité des bandes (LH, HL, HH) de fréquence spatiale comportant une composante de fréquence supérieure et pour un codage de grande efficacité de la bande (LL) de fréquence spatiale comportant une composante de fréquence inférieure ; et
   d) un moyen (236) de cryptage pour crypter uniquement les bandes codées de fréquence spatiale comportant la composante de fréquence supérieure en utilisant une clé de cryptage en fonction d'un algorithme prédéterminé de cryptage.

2. Appareil selon la revendication 1, dans lequel ledit moyen de séparation peut fonctionner pour produire une première bande (LL) de fréquence spatiale comportant la composante basse fréquence de la direction horizontale et la composante basse fréquence de la direction verticale, une deuxième bande (LH) de fréquence spatiale comportant la composante basse fréquence de la direction horizontale et la composante haute fréquence de la direction verticale, une troisième bande (HL) de fréquence spatiale comportant la composante haute fréquence de la direction horizontale et la composante basse fréquence de la direction verticale, et une quatrième bande (HH) de fréquence spatiale comportant la composante haute fréquence de la direction horizontale et la composante haute fréquence de la direction verticale.

3. Appareil selon la revendication 1 ou 2, dans lequel ledit moyen de codage peut fonctionner pour coder les bandes de fréquence spatiale en utilisant des codeurs de longueur variable.

4. Appareil selon l'une quelconque des revendications 1 à 3, comprenant en outre :

   un moyen (234) de multiplexage pour multiplexer les bandes de fréquence spatiale à crypter,
   et dans lequel ledit moyen de cryptage peut fonctionner pour crypter une sortie dudit moyen de multiplexage.

5. Appareil selon l'une quelconque des revendications 1 à 4, comprenant en outre un deuxième moyen (240) de multiplexage pour multiplexer les bandes codées de fréquence spatiale cryptées par ledit moyen de cryptage et la bande codée de fréquence spatiale non cryptée par ledit moyen de cryptage.

6. Appareil de traitement d'image, comprenant :

   a) un moyen (250) d'entrée pour introduction de bandes (LH, HL, HH) de fréquence spatiale comportant une composante de fréquence supérieure et une bande (LL) de fréquence spatiale comportant une composante de fréquence inférieure, les bandes de fréquence spatiale comportant la composante de fréquence supérieure étant cryptées ;
   b) un moyen (256 ou 256') de décryptage pour décrypter les bandes de fréquence spatiale comportant la composante de fréquence supérieure en utilisant une clé de décryptage en fonction d'un algorithme prédéterminé de décryptage ; et
   c) un moyen (254 à 266) de décodage pour décoder les bandes décryptées de fréquence spatiale comportant la composante de fréquence supérieure et pour décoder la bande de fréquence spatiale comportant la composante de fréquence inférieure.

7. Appareil selon la revendication 6, dans lequel ledit moyen d'entrée introduit une première bande (LL) de fréquence spatiale comportant la composante basse fréquence de la direction horizontale et la composante basse fréquence de la direction verticale, une deuxième bande (LH) de fréquence spatiale comportant la composante basse fréquence dans la direction horizontale et la composante haute fréquence dans la direction verticale, une troisième bande (HL) de fréquence spatiale comportant la composante haute fréquence de la direction horizontale et la composante basse fréquence de la direction verticale et une quatrième bande (HH) de fréquence spatiale comportant la composante haute fréquence de la direction horizontale et la composante haute fréquence dans la direction verticale.

8. Appareil selon l'une quelconque des revendications 6 et 7, comprenant en outre :

   un moyen (270 à 280) de synthèse pour synthétiser les bandes décryptées de fréquence spatiale avec d'autres bandes de fréquence spatiale.

9. Appareil selon l'une quelconque des revendications

6 à 8, comprenant en outre un moyen (260) de démultiplexage pour démultiplexer les bandes décryptées de fréquence spatiale, et ledit moyen de décodage pouvant fonctionner pour décoder une sortie dudit moyen de démultiplexage.

10. Appareil selon l'une quelconque des revendications 6 à 9, dans lequel ledit moyen de décodage peut fonctionner pour décoder les bandes de fréquence spatiale en utilisant des décodeurs de longueur variable.

11. Appareil selon l'une quelconque des revendications 6 à 10, comprenant en outre un moyen (286) d'invalidation pouvant fonctionner pour invalider une sortie dudit moyen de décryptage lorsque ledit moyen de décryptage ne peut pas décrypter la bande cryptée de fréquence spatiale.

12. Appareil selon l'une quelconque des revendications 6 à 11, comprenant en outre un moyen (288) pour produire un signal prédéterminé au lieu de la bande cryptée de fréquence spatiale lorsque ledit moyen de décryptage ne peut pas décrypter la bande cryptée de fréquence spatiale.

13. Procédé de traitement d'image, comprenant :

a) une étape d'entrée, d'introduction d'un signal (210) d'image ;
b) une étape de séparation, de séparation dudit signal d'image en une composante basse fréquence et une composante haute fréquence dans chacune de directions horizontale et verticale et de production de bandes (LL, LH, HL, HH) de fréquence spatiale à partir dudit signal d'image ;
c) une étape de codage, de codage de grande efficacité des bandes (LH, HL, HH) de fréquence spatiale comportant une composante de fréquence supérieure et de codage de grande efficacité de la bande (LL) de fréquence spatiale comportant une composante de fréquence inférieure ; et
d) une étape de cryptage, de cryptage uniquement des bandes codées de fréquence spatiale comportant la composante de fréquence supérieure en utilisant une clé de cryptage en fonction d'un algorithme prédéterminé de cryptage.

14. Procédé selon la revendication 13, dans lequel ladite étape de séparation produit une première bande (LL) de fréquence spatiale comportant la composante basse fréquence de la direction horizontale et la composante basse fréquence de la direction verticale, une deuxième bande (LH) de fréquence spatiale comportant la composante basse fréquence de la direction horizontale et la composante haute fréquence de la direction verticale, une troisième bande (HL) de fréquence spatiale comportant la composante haute fréquence de la direction horizontale et la composante basse fréquence de la direction verticale, et une quatrième bande (HH) de fréquence spatiale comportant la composante haute fréquence de la direction horizontale et la composante haute fréquence de la direction verticale.

15. Procédé selon l'une quelconque des revendications 13 et 14, dans lequel ladite étape de codage code les bandes de fréquence spatiale en utilisant des codeurs de longueur variable.

16. Procédé selon l'une quelconque des revendications 13 à 15, comprenant en outre :

une étape de multiplexage, de multiplexage des bandes de fréquence spatiale à crypter, et dans lequel ladite étape de cryptage crypte une sortie de ladite étape de multiplexage.

17. Procédé selon l'une quelconque des revendications 13 à 16, comprenant en outre une deuxième étape de multiplexage, de multiplexage des bandes codées de fréquence spatiale cryptées par ladite étape de cryptage et de la bande codée de fréquence spatiale non cryptée par ladite étape de cryptage.

18. Procédé de traitement d'image, comprenant :

a) une étape d'entrée introduisant des bandes (LH, HL, HH) de fréquence spatiale comportant une composante de fréquence supérieure et une bande (LL) de fréquence spatiale comportant la composante de fréquence inférieure, les bandes de fréquence spatiale comportant la composante de fréquence supérieure étant cryptées ;
b) une étape de décryptage, de décryptage des bandes de fréquence spatiale comportant la composante de fréquence supérieure en utilisant une clé de décryptage en fonction d'un algorithme prédéterminé de décryptage ; et
c) une étape de décodage, de décodage des bandes décryptées de fréquence spatiale comportant la composante de fréquence supérieure et de décodage de la bande de fréquence spatiale comportant la composante de fréquence inférieure.

19. Procédé selon la revendication 18, dans lequel ladite étape d'entrée introduit une première bande (LL) de fréquence spatiale comportant la composante basse fréquence de la direction horizontale et la composante basse fréquence de la direction verticale, une deuxième bande (LH) de fréquence spatiale comportant la composante basse fréquence de la direction horizontale et la composante haute fréquence de la direction verticale, une troisième bande (HL) de fréquence spatiale comportant la composante haute fréquence de la direction horizontale et la composante basse fréquence de la direction verticale et une quatrième bande (HH) de fréquence spatiale comportant la composante haute fréquence de la direction horizontale et la composante haute fréquence de la direction verticale.

20. Procédé selon l'une quelconque des revendications 18 et 19, comprenant en outre :

> une étape de synthèse, de synthèse des bandes décryptées de fréquence spatiale avec d'autres bandes de fréquence spatiale.

21. Procédé selon l'une quelconque des revendications 18 à 20, comprenant en outre une étape de démultiplexage, de démultiplexage des bandes décryptées de fréquence spatiale, et ledit moyen de décodage peut fonctionner pour décoder une sortie dudit moyen de démultiplexage.

22. Procédé selon l'une quelconque des revendications 18 à 21, dans lequel ledit moyen de décodage peut fonctionner pour décoder les bandes de fréquence spatiale en utilisant des décodeurs de longueur variable.

23. Procédé selon l'une quelconque des revendications 18 à 22, comprenant en outre une étape d'invalidation, d'invalidation d'une sortie de ladite étape de décryptage lorsque ladite étape de décryptage ne peut pas décrypter la bande cryptée de fréquence spatiale.

24. Procédé selon l'une quelconque des revendications 18 à 23, comprenant en outre une étape de production d'un signal prédéterminé au lieu de la bande cryptée de fréquence spatiale lorsque ladite étape de décryptage ne peut pas décrypter la bande cryptée de fréquence spatiale.

FIG. 1

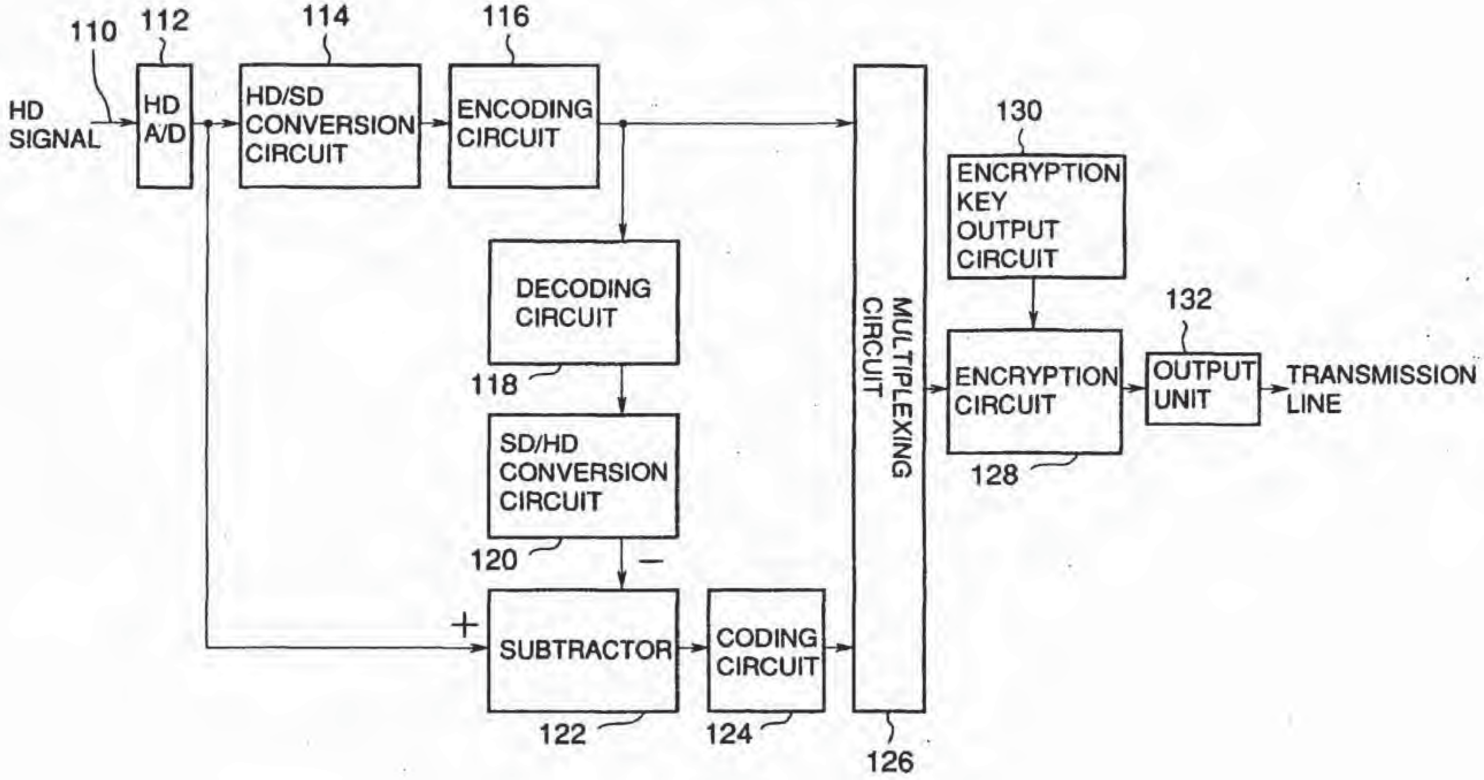

110
112
114
116
HD SIGNAL
HD A/D
HD/SD CONVERSION CIRCUIT
ENCODING CIRCUIT
DECODING CIRCUIT
118
SD/HD CONVERSION CIRCUIT
120
−
+
SUBTRACTOR
122
CODING CIRCUIT
124
MULTIPLEXING CIRCUIT
126
130
ENCRYPTION KEY OUTPUT CIRCUIT
ENCRYPTION CIRCUIT
128
132
OUTPUT UNIT
TRANSMISSION LINE

FIG. 2

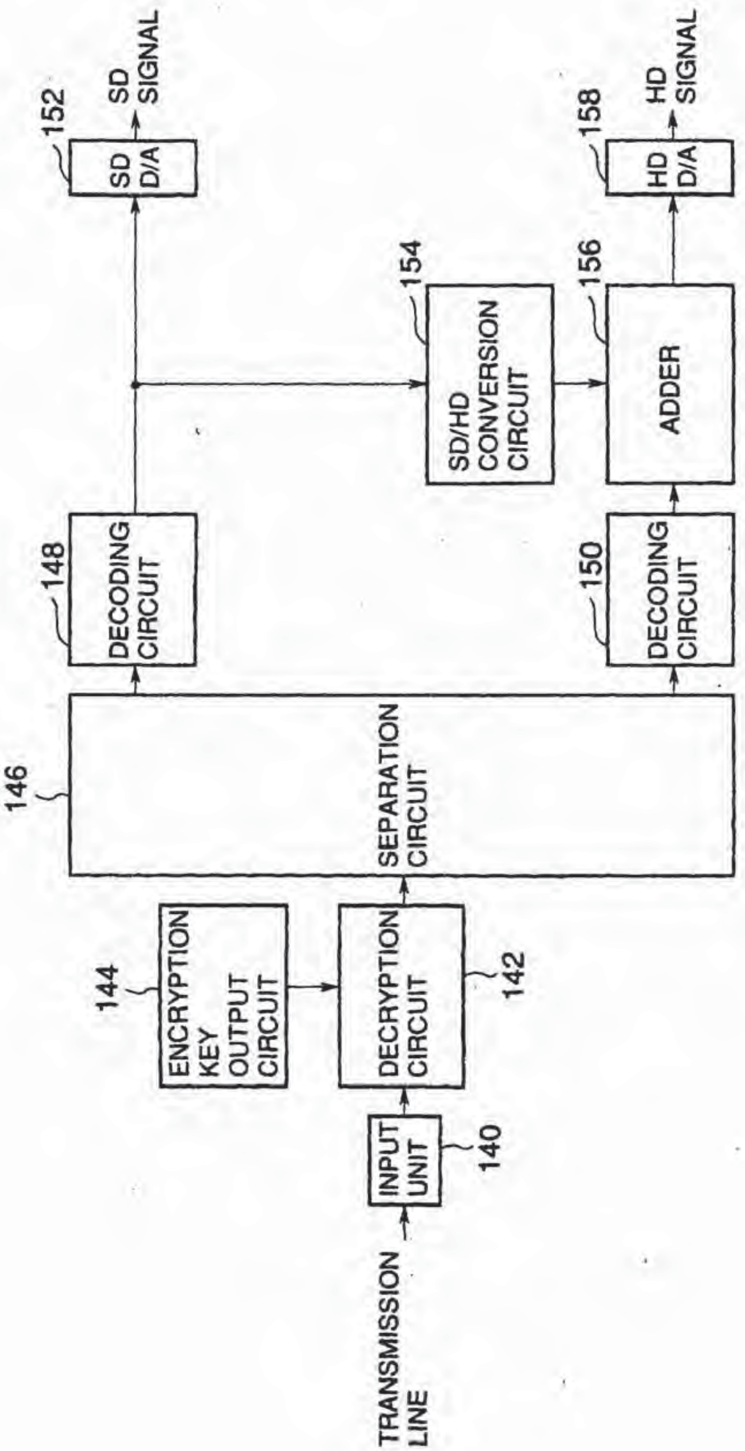

TRANSMISSION LINE
INPUT UNIT
140
DECRYPTION CIRCUIT
142
ENCRYPTION KEY OUTPUT CIRCUIT
144
SEPARATION CIRCUIT
146
DECODING CIRCUIT
148
DECODING CIRCUIT
150
SD/HD CONVERSION CIRCUIT
154
ADDER
156
SD D/A
152
SD SIGNAL
HD D/A
158
HD SIGNAL

FIG. 3

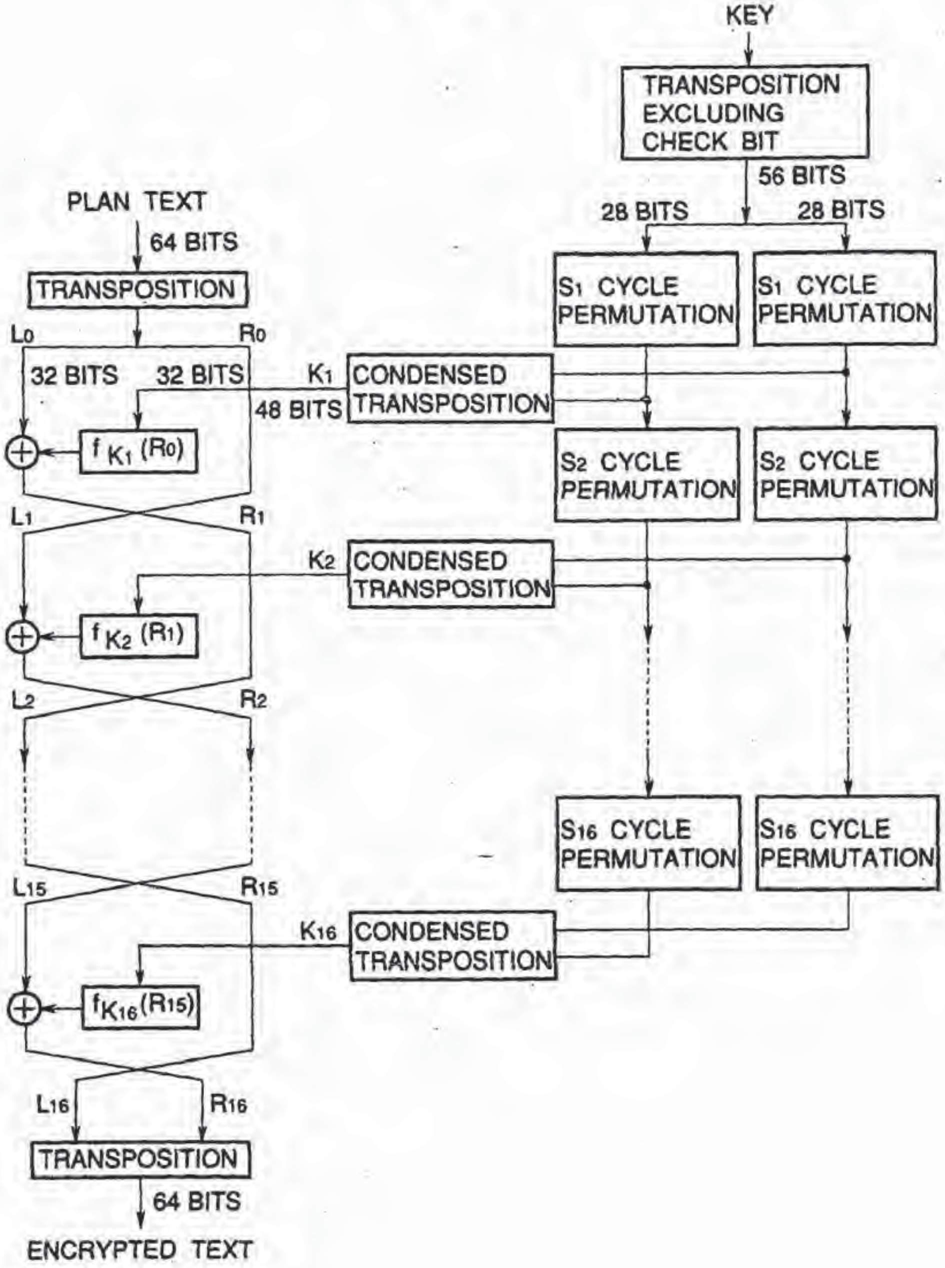

KEY
TRANSPOSITION EXCLUDING CHECK BIT
56 BITS
28 BITS
28 BITS
PLAN TEXT
64 BITS
TRANSPOSITION
L0
R0
32 BITS
32 BITS
S1 CYCLE PERMUTATION
S1 CYCLE PERMUTATION
K1
48 BITS
CONDENSED TRANSPOSITION
f K1 (R0)
S2 CYCLE PERMUTATION
S2 CYCLE PERMUTATION
L1
R1
K2
CONDENSED TRANSPOSITION
f K2 (R1)
L2
R2
S16 CYCLE PERMUTATION
S16 CYCLE PERMUTATION
L15
R15
K16
CONDENSED TRANSPOSITION
fK16 (R15)
L16
R16
TRANSPOSITION
64 BITS
ENCRYPTED TEXT

FIG. 4

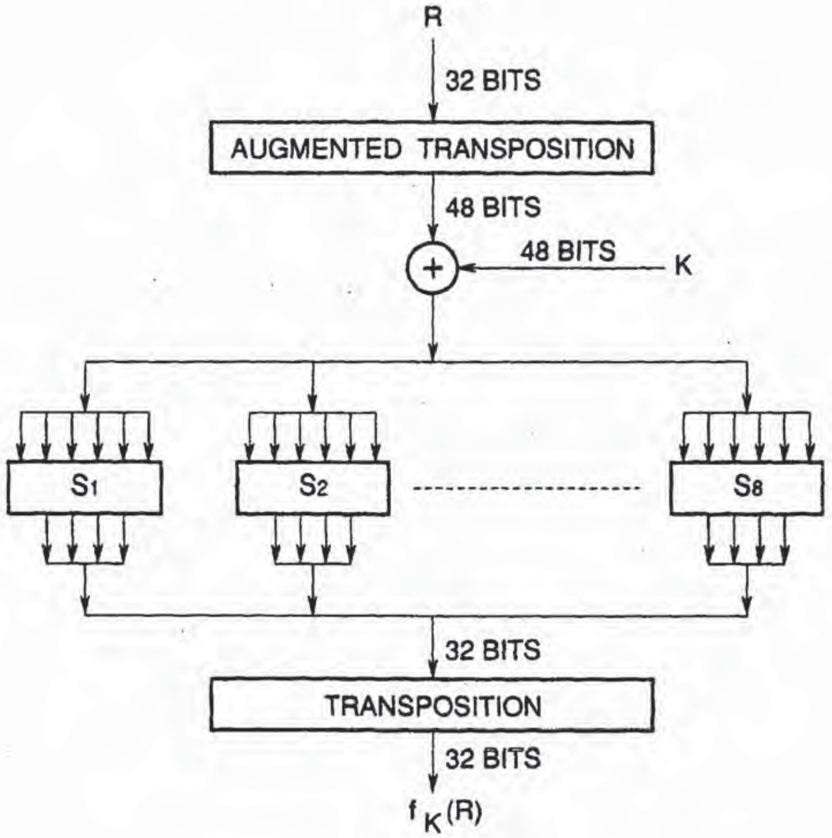

R
32 BITS
AUGMENTED TRANSPOSITION
48 BITS
48 BITS
K
+
S1
S2
S8
32 BITS
TRANSPOSITION
32 BITS
f K(R)

FIG. 5

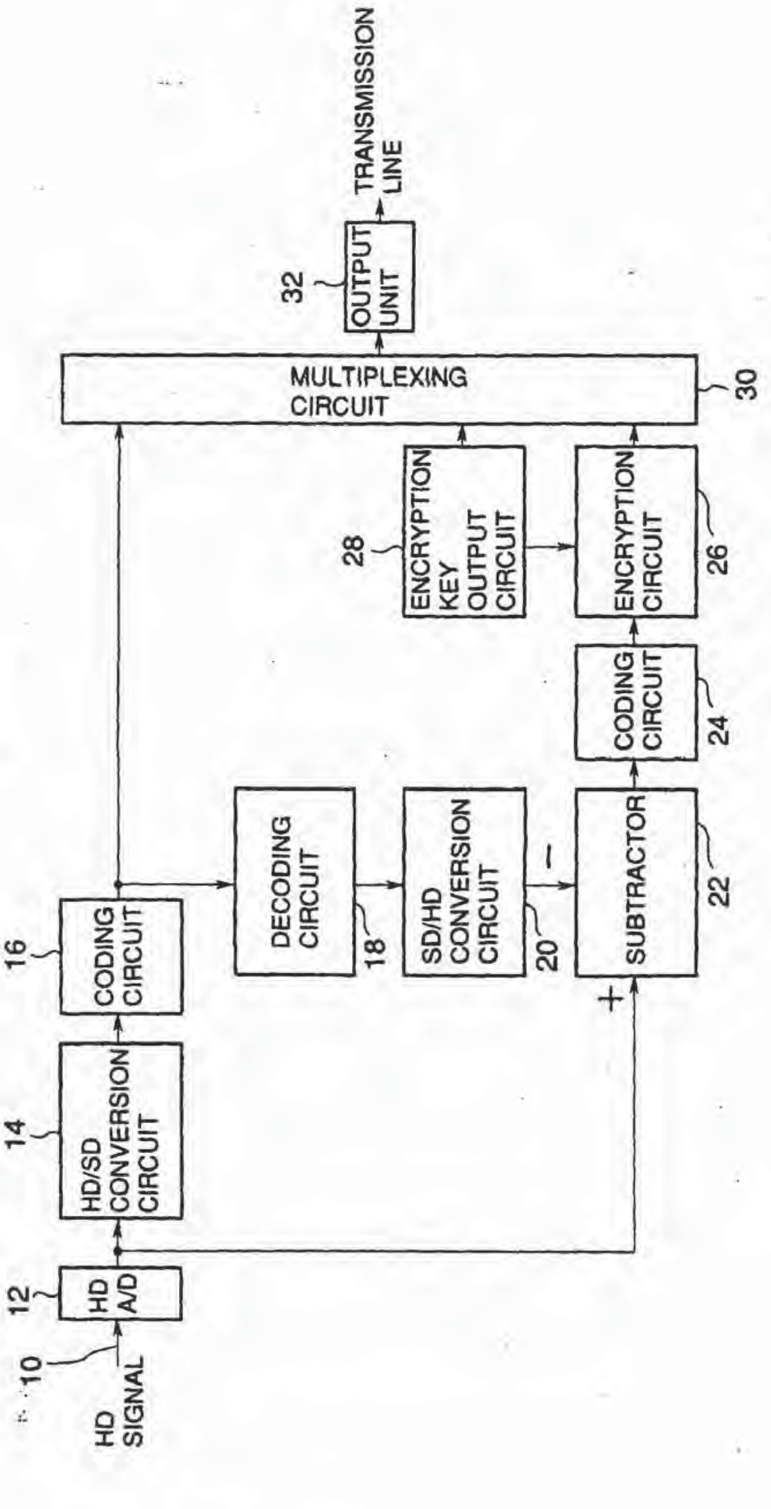

HD SIGNAL
10
12
HD A/D
14
HD/SD CONVERSION CIRCUIT
16
CODING CIRCUIT
DECODING CIRCUIT
18
SD/HD CONVERSION CIRCUIT
20
−
+
SUBTRACTOR
22
CODING CIRCUIT
24
ENCRYPTION CIRCUIT
26
28
ENCRYPTION KEY OUTPUT CIRCUIT
MULTIPLEXING CIRCUIT
30
32
OUTPUT UNIT
TRANSMISSION LINE

FIG. 6

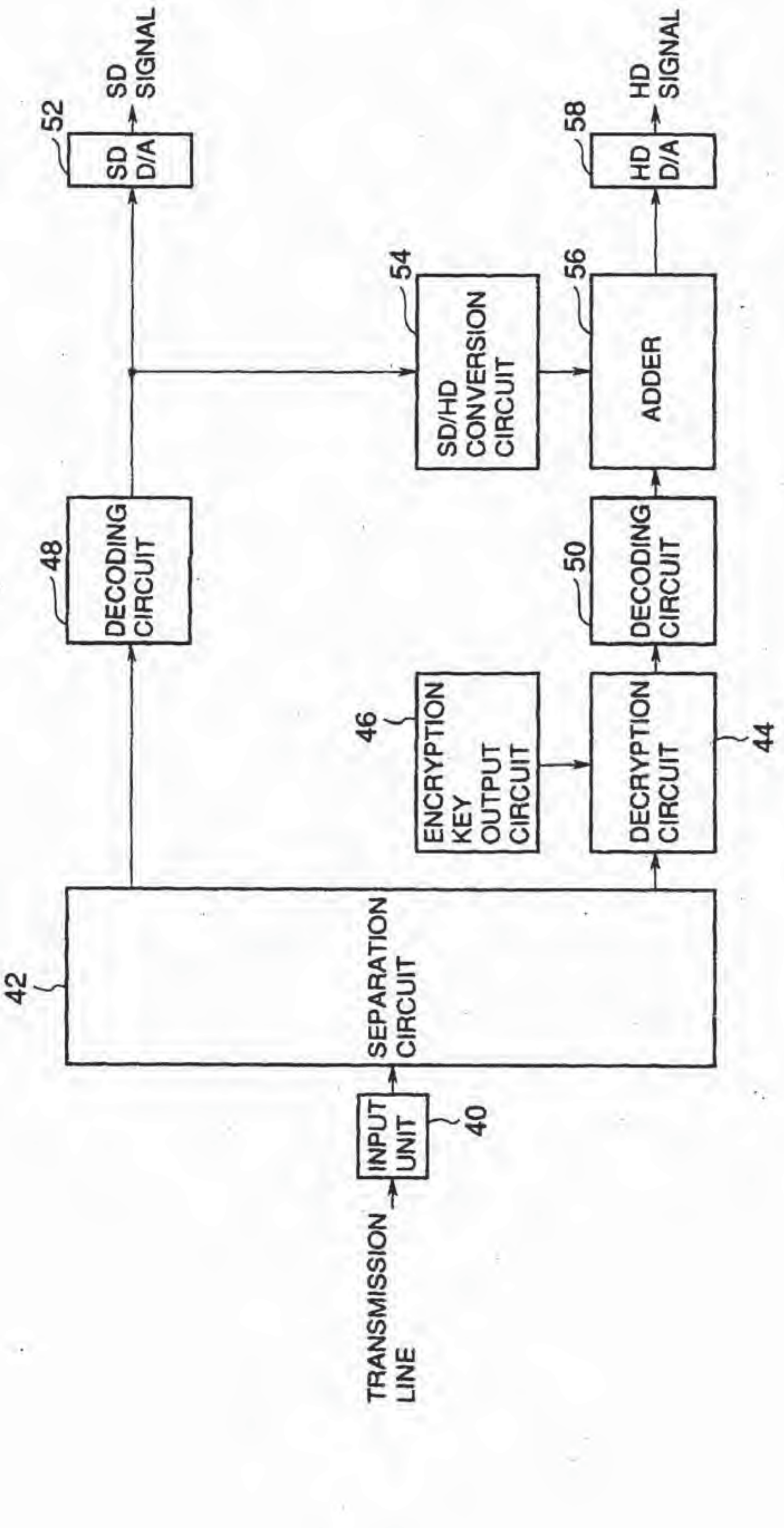

TRANSMISSION LINE
INPUT UNIT
40
SEPARATION CIRCUIT
42
DECODING CIRCUIT
48
SD D/A
52
SD SIGNAL
SD/HD CONVERSION CIRCUIT
54
ENCRYPTION KEY OUTPUT CIRCUIT
46
DECRYPTION CIRCUIT
44
DECODING CIRCUIT
50
ADDER
56
HD D/A
58
HD SIGNAL

FIG. 7

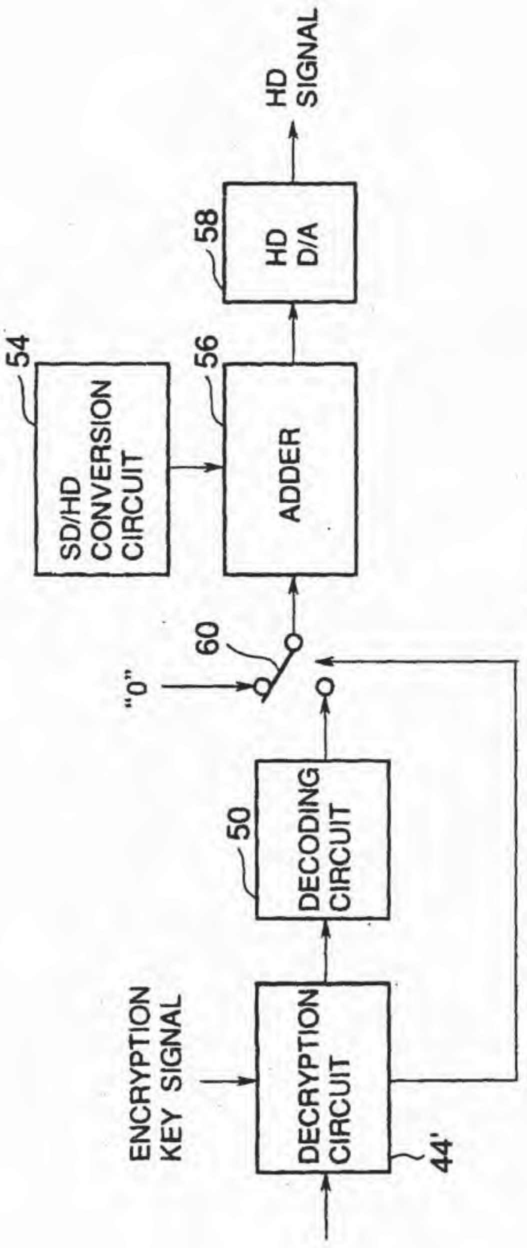

ENCRYPTION KEY SIGNAL
DECRYPTION CIRCUIT
44'
DECODING CIRCUIT
50
"0"
60
SD/HD CONVERSION CIRCUIT
54
ADDER
56
HD D/A
58
HD SIGNAL

FIG. 8

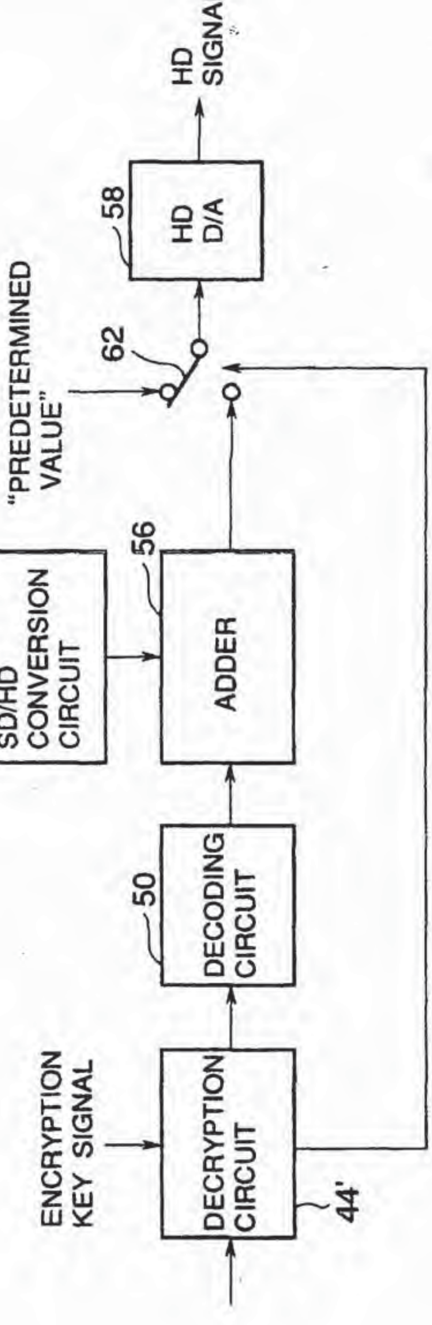

ENCRYPTION KEY SIGNAL
DECRYPTION CIRCUIT
44'
50
DECODING CIRCUIT
54
SD/HD CONVERSION CIRCUIT
56
ADDER
"PREDETERMINED VALUE"
62
58
HD D/A
HD SIGNAL

FIG. 9

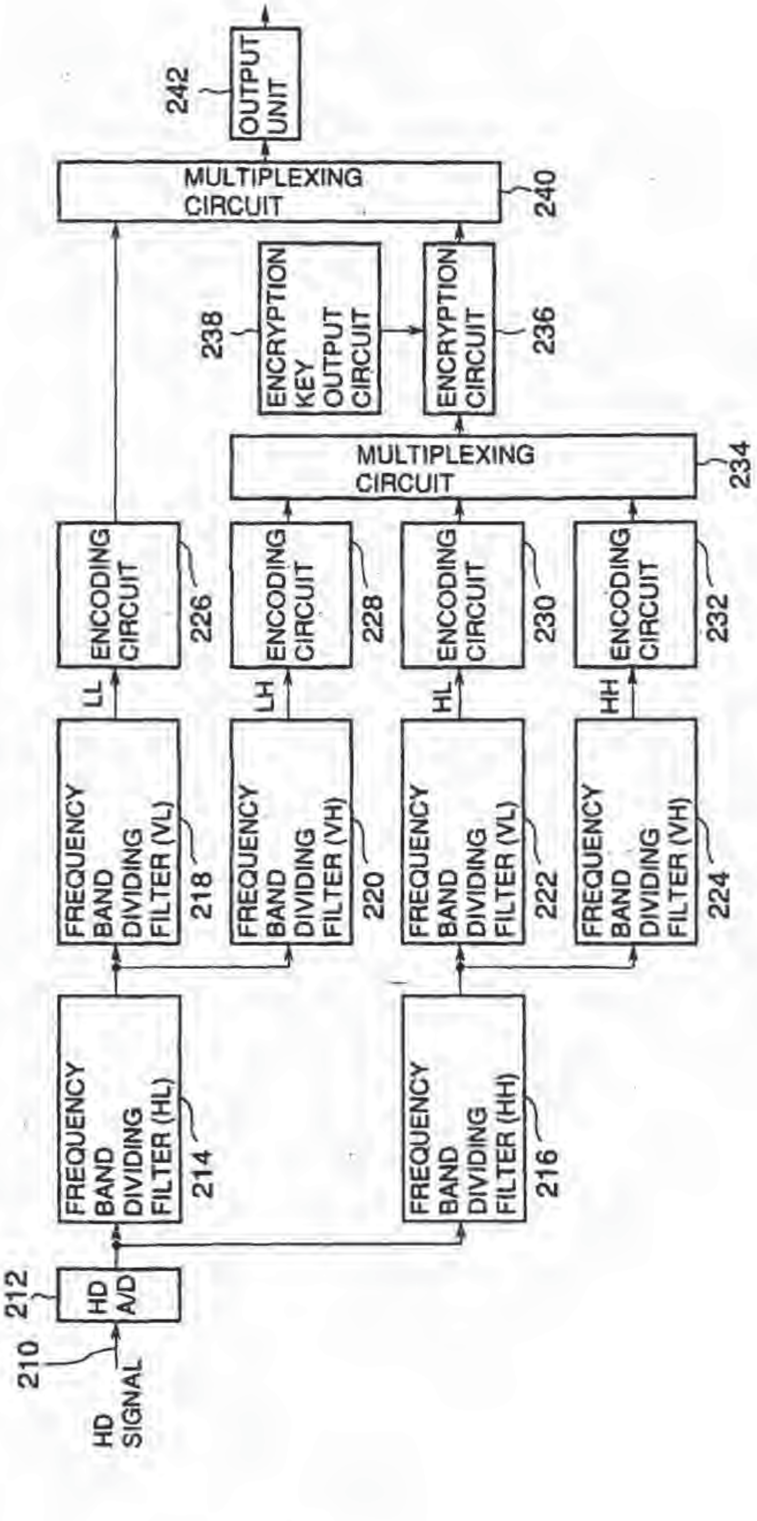

HD SIGNAL
210
HD A/D
212
FREQUENCY BAND DIVIDING FILTER (HL)
214
FREQUENCY BAND DIVIDING FILTER (HH)
216
FREQUENCY BAND DIVIDING FILTER (VL)
218
FREQUENCY BAND DIVIDING FILTER (VH)
220
FREQUENCY BAND DIVIDING FILTER (VL)
222
FREQUENCY BAND DIVIDING FILTER (VH)
224
LL
LH
HL
HH
ENCODING CIRCUIT
226
ENCODING CIRCUIT
228
ENCODING CIRCUIT
230
ENCODING CIRCUIT
232
MULTIPLEXING CIRCUIT
234
ENCRYPTION CIRCUIT
236
ENCRYPTION KEY OUTPUT CIRCUIT
238
MULTIPLEXING CIRCUIT
240
OUTPUT UNIT
242

FIG. 10

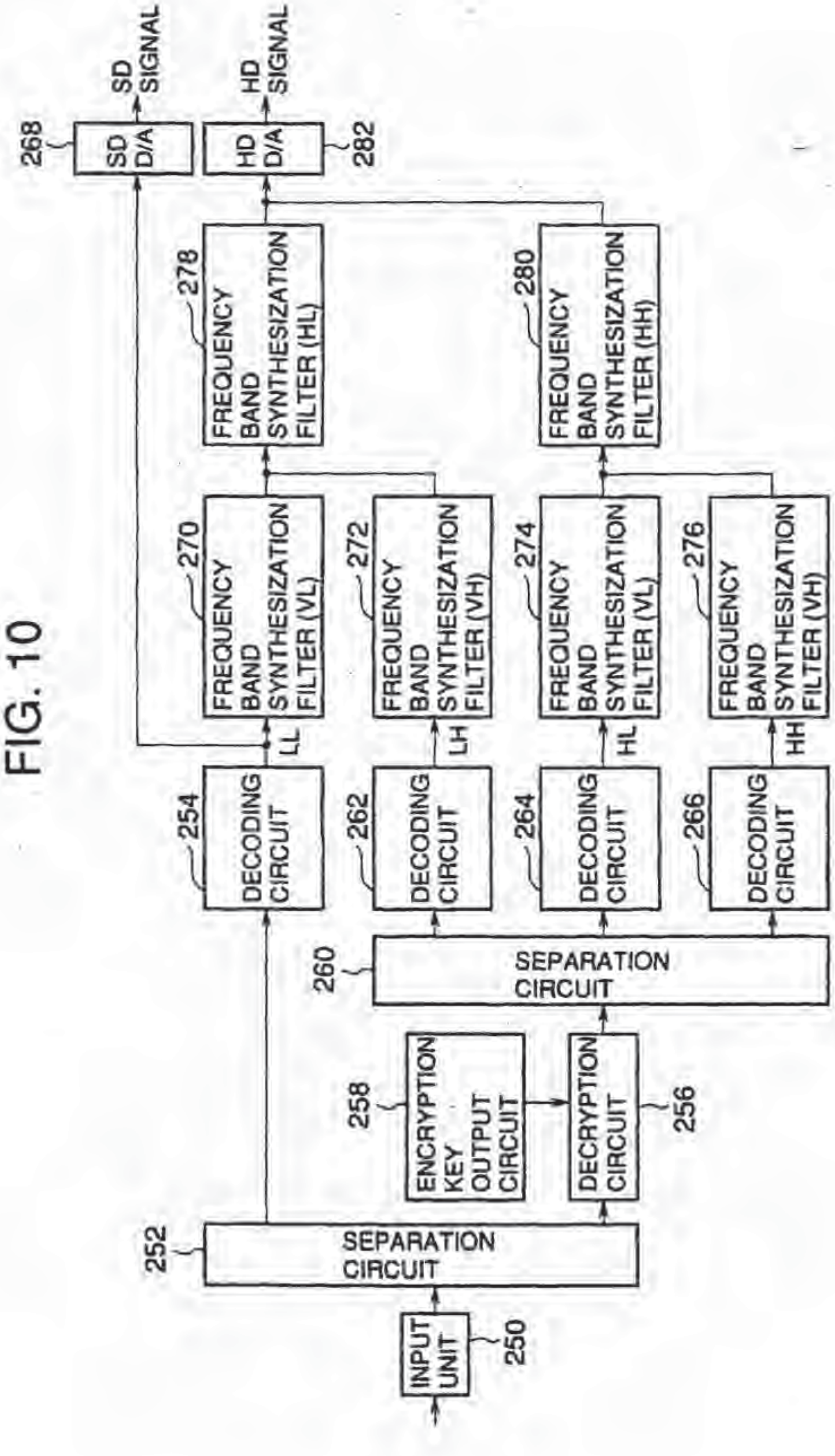

INPUT UNIT
250
SEPARATION CIRCUIT
252
ENCRYPTION KEY OUTPUT CIRCUIT
258
DECRYPTION CIRCUIT
256
SEPARATION CIRCUIT
260
DECODING CIRCUIT
254
DECODING CIRCUIT
262
DECODING CIRCUIT
264
DECODING CIRCUIT
266
LL
LH
HL
HH
FREQUENCY BAND SYNTHESIZATION FILTER (VL)
270
FREQUENCY BAND SYNTHESIZATION FILTER (VH)
272
FREQUENCY BAND SYNTHESIZATION FILTER (VL)
274
FREQUENCY BAND SYNTHESIZATION FILTER (VH)
276
FREQUENCY BAND SYNTHESIZATION FILTER (HL)
278
FREQUENCY BAND SYNTHESIZATION FILTER (HH)
280
SD D/A
268
HD D/A
282
SD SIGNAL
HD SIGNAL

FIG. 11

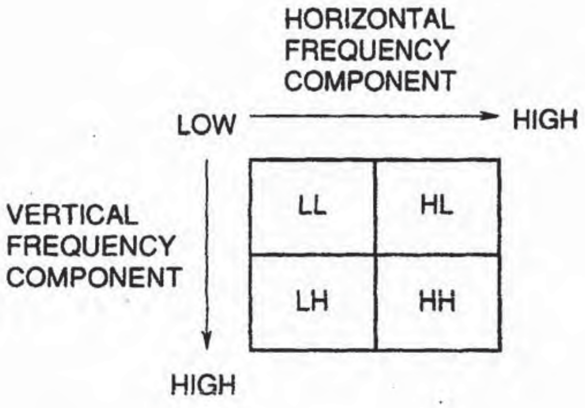

HORIZONTAL FREQUENCY COMPONENT
LOW
HIGH
VERTICAL FREQUENCY COMPONENT
HIGH
LL
HL
LH
HH

FIG. 12

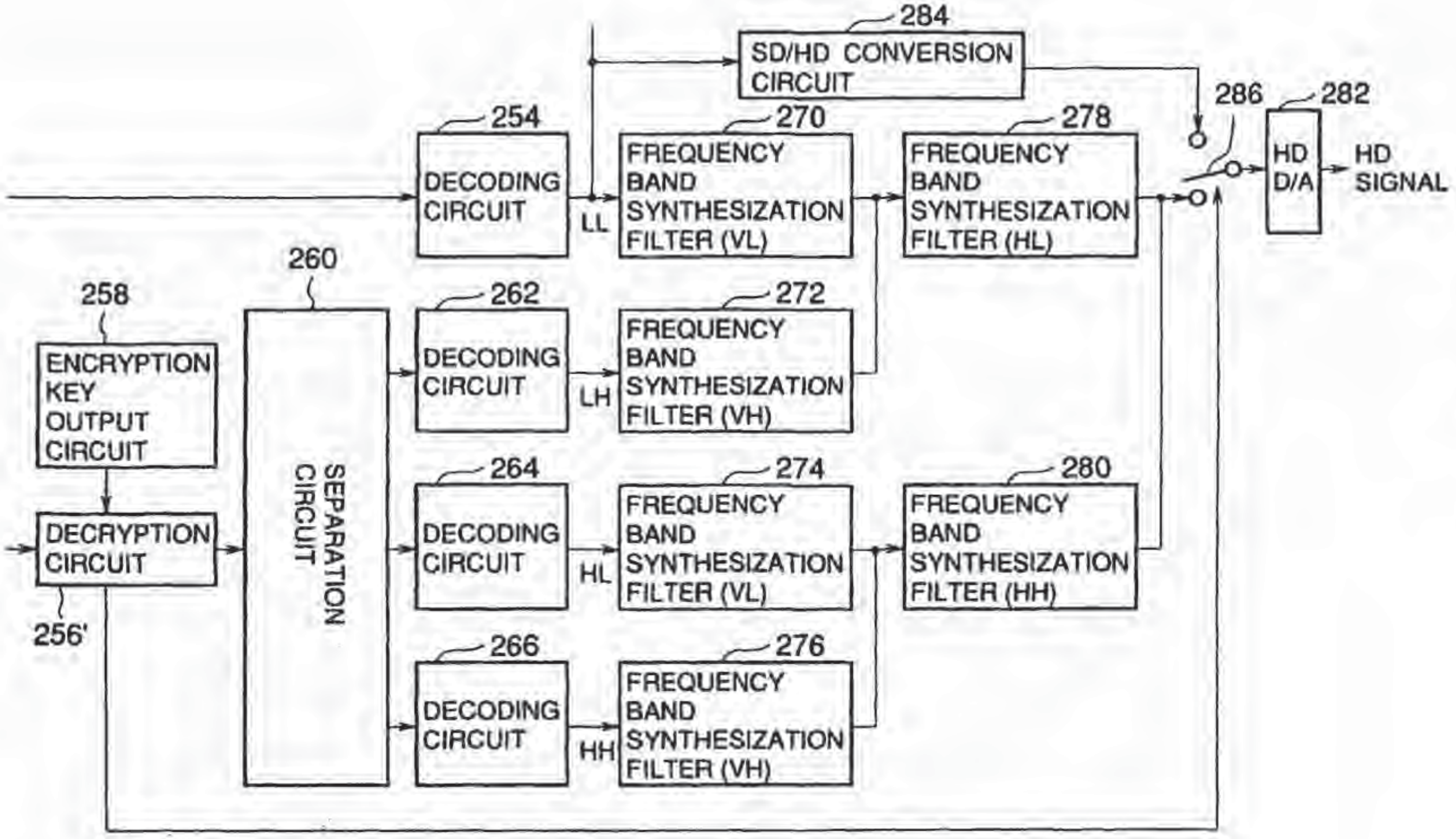

284
SD/HD CONVERSION CIRCUIT
254
DECODING CIRCUIT
LL
270
FREQUENCY BAND SYNTHESIZATION FILTER (VL)
278
FREQUENCY BAND SYNTHESIZATION FILTER (HL)
286
282
HD D/A
HD SIGNAL
260
SEPARATION CIRCUIT
258
ENCRYPTION KEY OUTPUT CIRCUIT
DECRYPTION CIRCUIT
256'
262
DECODING CIRCUIT
LH
272
FREQUENCY BAND SYNTHESIZATION FILTER (VH)
264
DECODING CIRCUIT
HL
274
FREQUENCY BAND SYNTHESIZATION FILTER (VL)
280
FREQUENCY BAND SYNTHESIZATION FILTER (HH)
266
DECODING CIRCUIT
HH
276
FREQUENCY BAND SYNTHESIZATION FILTER (VH)

FIG. 13

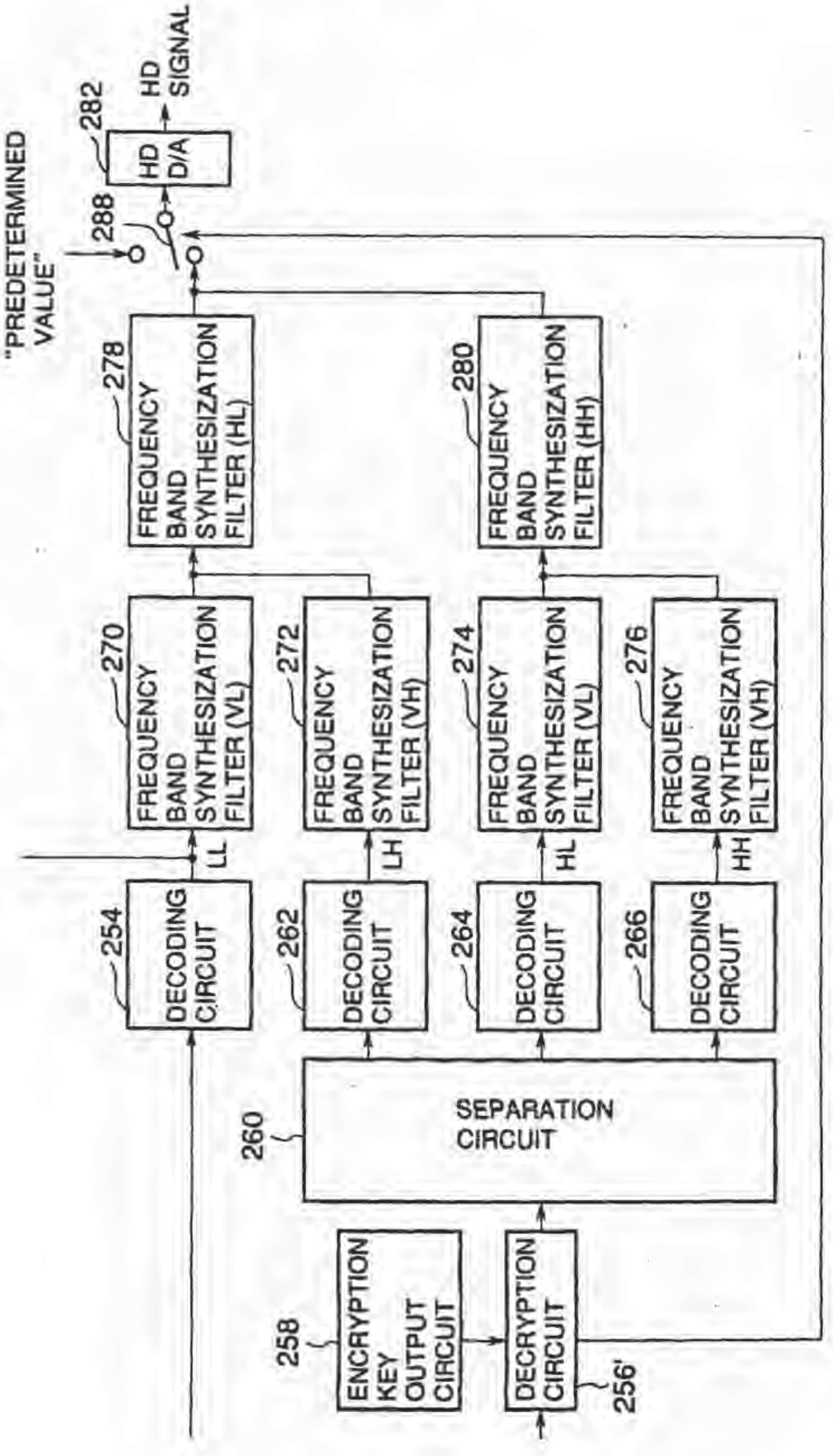

"PREDETERMINED VALUE"
288
282
HD D/A
HD SIGNAL
278
FREQUENCY BAND SYNTHESIZATION FILTER (HL)
280
FREQUENCY BAND SYNTHESIZATION FILTER (HH)
270
FREQUENCY BAND SYNTHESIZATION FILTER (VL)
272
FREQUENCY BAND SYNTHESIZATION FILTER (VH)
274
FREQUENCY BAND SYNTHESIZATION FILTER (VL)
276
FREQUENCY BAND SYNTHESIZATION FILTER (VH)
LL
LH
HL
HH
254
DECODING CIRCUIT
262
DECODING CIRCUIT
264
DECODING CIRCUIT
266
DECODING CIRCUIT
260
SEPARATION CIRCUIT
258
ENCRYPTION KEY OUTPUT CIRCUIT
DECRYPTION CIRCUIT
256'

FIG. 14

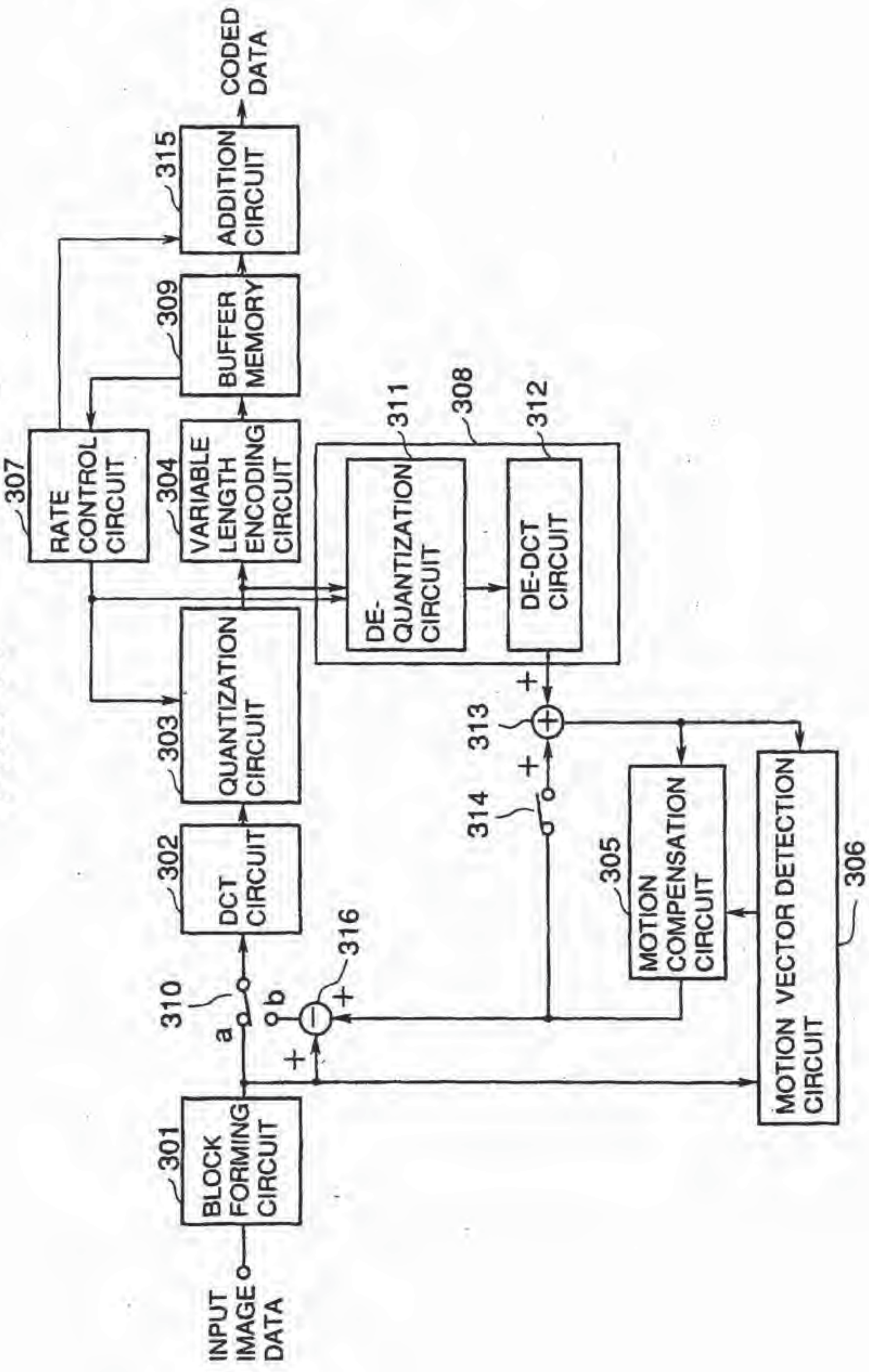
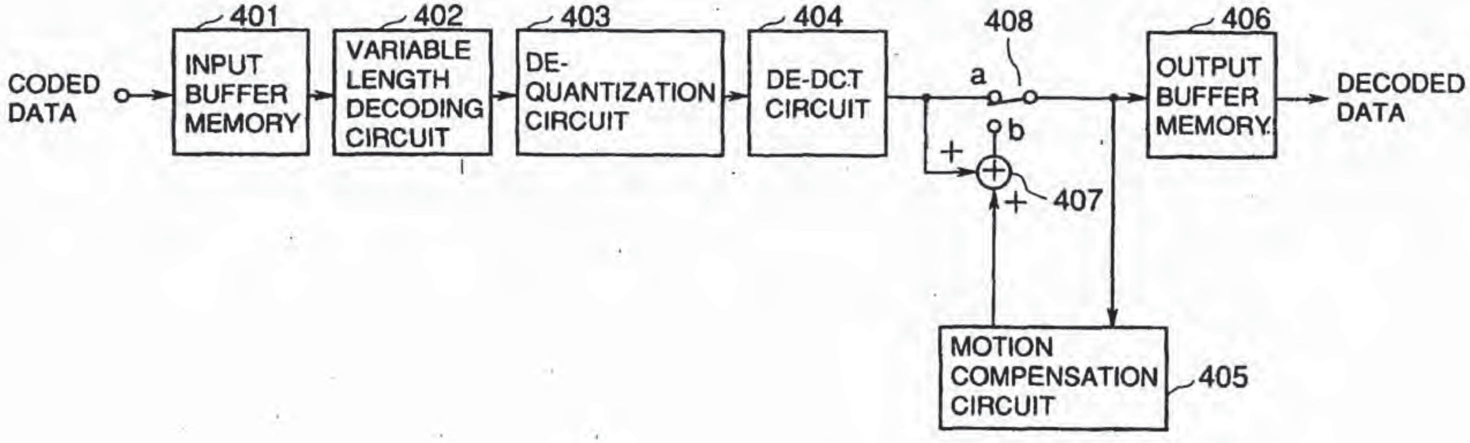

INPUT IMAGE DATA
301
BLOCK FORMING CIRCUIT
310
a
b
+
+
316
302
DCT CIRCUIT
303
QUANTIZATION CIRCUIT
307
RATE CONTROL CIRCUIT
304
VARIABLE LENGTH ENCODING CIRCUIT
309
BUFFER MEMORY
315
ADDITION CIRCUIT
CODED DATA
308
311
DE-QUANTIZATION CIRCUIT
312
DE-DCT CIRCUIT
+
+
313
314
305
MOTION COMPENSATION CIRCUIT
306
MOTION VECTOR DETECTION CIRCUIT

FIG. 15


CODED DATA
401
INPUT BUFFER MEMORY
402
VARIABLE LENGTH DECODING CIRCUIT
403
DE-QUANTIZATION CIRCUIT
404
DE-DCT CIRCUIT
408
a
b
+
+
407
406
OUTPUT BUFFER MEMORY
DECODED DATA
MOTION COMPENSATION CIRCUIT
405

(19) Bureau voor de
Industriële Eigendom
Nederland

(11) **1005523**

(12) C **OCTROOI**^{20}

(21) Aanvrage om octrooi: **1005523**

(22) Ingediend: **13.03.97**

(51) Int.Cl.^{6}
H04K1/00, H04L9/00, H04B1/69, H04N7/167

(41) Ingeschreven:
15.09.98

(47) Dagtekening:
15.09.98

(45) Uitgegeven:
02.11.98 I.E. 98/11

(73) Octrooihouder(s):
Technische Universiteit Eindhoven te Eindhoven.

(72) Uitvinder(s):
Giok-Djan Khoe te Eindhoven
Robert Peter Christina Wolters te Montfort
Alfons Willy Leo Janssen te Utrecht

(74) Gemachtigde:
Ir. J.J.H. Van kan c.s. te 5600 AP Eindhoven.

(54) **Werkwijze en communicatiesysteem voor het in gedeeltelijk gecodeerde vorm overdragen van informatiesignalen.**

(57) Werkwijze en middelen voor het in een communicatiesysteem overdragen van informatiesignalen onder toepassing van veilige coderingstechnieken, waarbij een informatiesignaal wordt gesplitst in een voor verwerking van het signaal relevant deel en een restdeel. Het relevante deel wordt in een veilig gecodeerde vorm en het restdeel wordt in ongecodeerde vorm via het communicatiesysteem overgedragen. Na het decoderen daarvan wordt een overgedragen relevant deel van een informatiesignaal met een bijbehorend overgedragen restdeel tot het oorspronkelijke informatiesignaal gereconstrueerd. Het te coderen relevante deel van het informatiesignaal wordt bij voorkeur onder toepassing van 'Code Division Multiple Access' (CDMA)-techniek gecodeerd overgedragen. Het communicatiesysteem kan een 'point-to-multipoint' signaaldistributienet omvatten, waarbij verschillende gebruikers gelijktijdig informatiesignalen kunnen ontvangen en/of verzenden, waaronder begrepen een 'Community Antenna TeleVision' (CATV)-net en distributienetten voor elektrische energie.

NL C 1005523

De inhoud van dit octrooi komt overeen met de oorspronkelijk ingediende beschrijving met conclusie(s) en eventuele tekeningen.

Korte aanduiding: Werkwijze en communicatiesysteem voor het in gedeeltelijk gecodeerde vorm overdragen van informatiesignalen.

De uitvinding heeft betrekking op een werkwijze voor het in een communicatiesysteem overdragen van informatiesignalen onder toepassing van veilige coderingstechnieken.

Veilige overdracht van data is een belangrijk aspect bij communicatie via een "point-to-multipoint"-signaaldistributienet, waarbij verschillende gebruikers gelijktijdig informatiesignalen kunnen ontvangen en/of verzenden, zoals een "Community Antenna TeleVision" (CATV)-net of distributienetten voor elektrische energie, waaronder begrepen distributienetten voor elektrische tractie.

Een netwerkbeheerder dient in staat te zijn de toegang tot het net te controleren en dient verder te kunnen verzekeren dat overgedragen informatiesignalen alleen kunnen worden ontvangen door de geadresseerde. Met ontvangen wordt in dit verband bedoeld dat de geadresseerde de inhoud van de betreffende informatiesignalen tot zich kan nemen.

Voor het in een signaaldistributienet veilig overdragen van informatiesignalen zijn een groot aantal coderingstechnieken bekend zoals bijvoorbeeld de "Rivest, Shamir, Aldehman" (RSA) en "Data encryption Standard" (DES) encryptie-algoritmes waarbij met codeersleutels wordt gewerkt. Het over te dragen informatiesignaal wordt dan in zijn geheel gecodeerd en via het signaaldistributienet overgedragen, waarbij alleen de ontvanger welke de voor het decoderen van het bericht benodigde sleutel kent, in staat is om de inhoud van het informatiesignaal tot zich te nemen.

De mate van beveiliging hangt naast het gekozen codeeralgoritme ook af van de lengte van de codeersleutel. In het bijzonder geldt dat bij relatief breedbandige informatiesignalen en bij relatief lange codeer- en decodeersleutels, er een aanzienlijke hoeveelheid tijd gemoeid kan zijn met het overdragen van informatiesignalen. In veel praktische toepassingen is een extra vertraging bij de overdracht van signalen echter niet gewenst.

Aan de uitvinding ligt daarom in eerste instantie de opgave ten grondslag een werkwijze aan te geven voor het in een communicatiesysteem overdragen van informatiesignalen onder toepassing van veilige coderingstechnieken met een gereduceerde invloed op de overdrachtssnelheid van informatiesignalen.

Volgens de uitvinding wordt dit daardoor bereikt dat een informatiesignaal wordt gesplitst in een voor verwerking van het signaal relevant deel en een restdeel, waarbij het relevante deel in een veilig gecodeerde vorm en het restdeel in ongecodeerde vorm via het communicatiesysteem worden overgedragen en dat een overgedragen relevant deel van een informatiesignaal wordt gedecodeerd en met een bijbehorend overgedragen restdeel tot het oorspronkelijke informatiesignaal wordt gereconstrueerd.

Aan de uitvinding ligt het inzicht ten grondslag dat, door het van een over te dragen informatiesignaal afsplitsen van een voor de verwerking van het signaal relevant deel, het resterende gedeelte onbruikbaar is geworden. Onder een 'voor verwerking relevant deel' van het signaal worden in dit verband één of meer delen van een signaal begrepen waarmee, bij het ontbreken hiervan, de informatie in het restdeel niet meer kan worden herkend dan wel dat door het ontbreken van het betreffende relevante deel of de relevante delen het signaal niet meer kan worden gereconstrueerd. Overeenkomstig de oplossing volgens de uitvinding kan voor het veilig gecodeerd overdragen van informatiesignalen worden volstaan met het coderen van het betreffende relevante deel van het informatiesignaal, waarbij het resterende gedeelte ongecodeerd kan worden overgedragen.

Door het volgens een verdere uitvoeringsvorm van de uitvinding zodanig selecteren van het te coderen relevante deel van een informatiesignaal dat dit deel een relatief gering, bij voorkeur een zo gering mogelijk deel van de bandbreedte van het informatiesignaal in beslag neemt, kan er voor worden gezorgd dat de door het codeer- en decodeerproces veroorzaakte vertragingen in de signaaloverdracht minimaal zijn.

In bijvoorbeeld een gecodeerd digitaal videosignaal kunnen verschillende velden worden onderscheiden, bijvoorbeeld specifiek op de signaaloverdracht betrekkende hebbende velden waarmee, wanneer zij niet in het signaal aanwezig zijn, het onmogelijk is om de informatie-inhoud van het digitale videosignaal tot zich te nemen. Voorbeelden van dergelijke velden zijn bijvoorbeeld synchronisatievelden of het FEC-veld in een "Digital Video Broadcasting" (DVB)-videosignaal. Deze velden beslaan slechts een relatief gering aantal bits van het totale videosignaal. De werkwijze volgens de uitvinding is in wezen bij alle digitale data-overdracht toepasbaar, omdat vrijwel elk data-overdrachtsprotocol bepaalde stuur-, controle- of andere gegevensvelden bezit welke noodzakelijk zijn om het betreffende signaal te kunnen reconstrueren. De werkwijze volgens de uitvinding is ook toepasbaar bij de overdracht van analoge signalen, waarbij in het algemeen ook door het afsplitsen van een relevant deel van het signaal het resterende deel onbruikbaar wordt.

In een communicatiesysteem dat verschillende transmissiekanalen omvat worden in een voorkeursuitvoeringsvorm van de uitvinding de gecodeerde relevante delen van informatiesignalen via een ander transmissiekanaal overgedragen dan de ongecodeerde restdelen. Hierdoor is het mogelijk om, in plaats van het afzonderlijk veilig coderen van de relevante delen, deze ook via een betreffend beveiligd transmissiekanaal over te dragen, zoals een transmissiekanaal waarop data middels de zogeheten "Code Division Multiple Access" (CDMA)-techniek gecodeerd worden overgedragen.

Het gebruik van CDMA-technieken garandeert een lage kans op onderschepping, zonder dat de betreffende relevante delen van informatiesignalen afzonderlijk moeten worden gecodeerd.

Een derde welke een betreffend informatiesignaal wil onderscheppen, dient derhalve in staat te zijn om het gecodeerde relevante deel te onderscheppen en het bijbehorende restdeel. Zelfs wanneer dit tot een resultaat zou lijden, dient er ook nog kennis te bestaan omtrent de wijze waarop de betreffende delen tot het oorspronkelijke informatiesignaal moeten worden gecombineerd. Derhalve geniet het de voorkeur om niet steeds eenzelfde relevant deel van een informatiesignaal af te splitsen en gecodeerd over te dragen maar, voor zover mogelijk, verschillende relevante signaaldelen te onderscheiden en van de over te dragen informatiesignalen afwisselend verschillende relevante delen te selecteren.

De uitvinding heeft tevens betrekking op een communicatiesysteem, omvattende codeermiddelen voor het in gecodeerde vorm veilig overdragen van informatiesignalen en decodeermiddelen voor het decoderen van overgedragen informatiesignalen, verder gekenmerkt door middelen voor het splitsen van een over te dragen informatiesignaal in een voor verwerking van het signaal relevant deel en een restdeel, welke middelen werkzaam zijn gekoppeld met de codeermiddelen voor het in veilig gecodeerde vorm overdragen van het relevante deel van een informatiesignaal en met middelen voor het in ongecodeerde vorm overdragen van het restdeel van een informatiesignaal, waarbij de decodeermiddelen zijn ingericht voor het decoderen van een overgedragen relevant deel van een informatiesignaal en werkzaam zijn gekoppeld met middelen voor het tot een oorspronkelijk informatiesignaal reconstrueren van een gedecodeerd relevant deel en een overgedragen bijbehorend restdeel.

In de voorkeursuitvoeringsvorm van het communicatiesysteem volgens de uitvinding zijn de codeermiddelen ingericht voor het CDMA-gecodeerd overdragen van de relevante delen van een informatiesignalen.

De uitvinding heeft tevens betrekking op signaalsplitsmiddelen en signaalcombinatiemiddelen voor het respectievelijk splitsen en combineren van relevante delen en restdelen van een informatiesignaal, zoals boven beschreven.

De uitvinding wordt in het navolgende meer gedetailleerd beschreven en getoond in de bijgevoegde tekeningen, waarin:

fig. 1 schematisch de werkwijze volgens de uitvinding illustreert;

fig. 2 een vereenvoudigd blokschema van een "Direct Sequence" CDMA (DS-CDMA)-systeem toont;

fig. 3 een voorbeeldschema van een CATV-net toont, waarin de werkwijze volgens de uitvinding kan worden toegepast;

fig. 4 een vereenvoudigd blokschema van een eerste uitvoeringsvorm van een communicatiesysteem volgens de uitvinding toont, en

fig. 5 een vereenvoudigd blokschema van een voorkeursuitvoeringsvorm van een communicatiesysteem volgens de uitvinding toont.

Fig. 1 illustreert, in de vorm van een stroomdiagram, de werkwijze volgens de uitvinding, waarbij door middel van pijlen de bewerkingsvolgorde is geïllustreerd. Een informatiesignaal 1 wordt als eerste aan een splitsingsoperatie 2 onderworpen. Het informatiesignaal wordt hier gesplitst in een voor de signaalverwerking relevant deel 3 en een restdeel 4.

Het relevante deel kan uit één of meer delen van het informatiesignaal zijn opgebouwd, welke afzonderlijk of in combinatie noodzakelijk zijn voor de verdere verwerking van het informatiesignaal, dat wil zeggen zodanig dat samen met het restdeel een bruikbaar informatiesignaal wordt verkregen. Het relevante deel 3 kan dus zowel bestaan uit een gedeelte van de informatie-inhoud van het signaal en/of informatie voor het reconstrueren van het signaal, zoals synchronisatie en andere stuurinformatie. Het informatiesignaal kan daarbij bestaan uit zowel een digitaal als een analoog signaal.

In het geval dat een informatiesignaal verschillende voor de verwerking van het signaal relevante delen bezit, kan de splitsingsoperatie 2 zodanig worden uitgevoerd, dat van de arriverende informatiesignalen 1 telkens een selectie uit de relevante delen 3 kan worden gemaakt, zodanig dat van opeenvolgende informatiesignalen de relevante delen 3 en de restdelen 4 qua opbouw verschillend zijn. De wijze waarop de betreffende relevante delen 3 worden geselecteerd kan van te voren vastgelegd zijn of middels een kenmerk worden overgedragen.

Het geselecteerde relevante deel 3 wordt vervolgens aan een codeeroperatie 5 onderworpen. Deze codeeroperatie 5 heeft tot het doel het relevante deel te coderen voor veilige overdracht 6 over een transmissienet, zoals bijvoorbeeld een "point-to-multipoint" signaaldistributienet. Voorbeelden van dergelijke signaaldistributienetten zijn "Community Antenna TeleVision" (CATV)-netten en distributienetten voor elektrische energie zoals het elektriciteitsdistributienet in huizen, kantoren etc. en ook distributienetten voor elektrische tractie zoals in gebruik bij spoorweg-, tram- en trolleybusmaatschappijen.

Voor het coderen van het relevante deel zijn op zichzelf bekende coderingstechnieken bekend, welke met beveiligde codeer- en decodeersleutels werken zoals de "Rivest, Shamir, Aldehman (RSA) en "Data Encryption Standard" (DES) encryptie-algoritmes welke geen deel uitmaken van de onderhavige uitvinding. Voor een meer uitgebreide beschrijving van encryptie-algoritmes wordt verwezen naar het boek "Applied Cryptography", door Bruce Shneier, 2nd edition, John Wiley & Sons 1995.

Aan de ontvangende zijde wordt het overgedragen gecodeerde relevante deel 3 in een decodeeroperatie 7 gedecodeerd. Het restdeel 4 wordt na overdracht 8 aan de ontvangende zijde met het gedecodeerde relevante deel gecombineerd 9, zodanig dat het aldus verkregen informatiesignaal 10 overeenkomt met het oorspronkelijk overgedragen informatiesignaal 1.

Overeenkomstig de uitvinding kan het restdeel 4 in ongecodeerde vorm worden overgedragen omdat het informatiesignaal 1 zodanig is gesplitst, dat het restdeel 4 op zichzelf onbruikbaar is. Onder ongecodeerde overdracht 8 wordt bedoeld dat het restdeel 4 niet wordt begrepen aan een vorm van encryptie of codering van de informatie waarbij het betreffende restdeel zonder kennis omtrent codeer- en/of decodeersleutels niet kan worden verwerkt. Uiteraard kan het restdeel 4 wel volgens een bekend protocol of bekende modulatietechniek worden overgedragen.

In plaats van het afzonderlijk coderen van relevante delen 3, kunnen de codeer-, overdracht- en decodeeroperaties 5, 6 en 7 worden uitgevoerd door het transmissiemedium waarover het relevante deel 3 wordt overgedragen. Dit is in het bijzonder van voordeel in een communicatiesysteem met verschillende transmissiekanalen, waarbij het relevante deel 3 van een informatiesignaal via een veilig gecodeerd transmissiekanaal wordt overgedragen en het restdeel 4 via een niet-beveiligd kanaal kan worden verzonden. In een voorkeursuitvoeringsvorm van de uitvinding wordt het relevante deel 3 overgedragen onder toepassing van de zogeheten "Code Division Multiple Access" (CDMA)-techniek.

CDMA of "Spread Spectrum" (SS) is een transmissietechniek waarbij de databits van een over te dragen digitaal signaal in een aantal elementen of chips worden gecodeerd, zodanig dat elk databit als een reeks van symbolen wordt overgedragen. Deze symbolen kunnen op zichzelf de logische waarde "1" of "0" aannemen of in het ritme van de betreffende reeks overgedragen frequentievariaties. In het eerste geval spreekt van "Direct Sequence CDMA" (DS-CDMA) en in het tweede geval van "Frequency Hopping CDMA" (FH-CDMA). In beide gevallen kan het overgedragen signaal weer worden gereconstrueerd indien de volgorde van de overgedragen chips of de frequenties bij de ontvanger bekend zijn. Afhankelijk van de omvang van de reeks, dat wil zeggen het aantal symbolen waarin het overgedragen bit wordt gecodeerd, zijn een veelvoud van onafhankelijke codes beschikbaar waardoor gelijktijdig verschillende gebruikers van eenzelfde transmissiekanaal gebruik kunnen maken. Alleen de gebruiker met de juiste code is in staat om de met deze code overgedragen databits te ontvangen.

Figuur 2 toont een vereenvoudigd blokschema van een DS-CDMA systeem met een transmissiekanaal 11, een zender 12 en een ontvanger 13. Het kanaal 11 kan een draadgebonden, optisch of draadloos communicatiekanaal zijn waaronder begrepen een radiokanaal, een infraroodkanaal en een ultrasoon-transmissiekanaal. In een CDMA-transmissiesysteem wordt door verschillende gebruikers j tegelijkertijd informatie over het transmissiekanaal 11 overgedragen, zoals gerepresenteerd middels een sommatieblok 16 waarbij een aantal van j = 1 tot en met N gebruikers 15 is verondersteld. Het totale signaal op het transmissiekanaal 11 wordt dan theoretisch gevormd door de som van een ruisbron 14 en de signalen van de gebruikers 15, zoals schematisch aangeduid door een sommator 17.

De zender 12 bestaat in wezen uit een modulator 18 met een ingang 19 waaraan over te dragen databits worden toegevoerd. De modulator 18 verwerkt de databits 19 tot geschikte signalen voor overdracht via het transmissiekanaal 11. De ontvanger 13 bezit een demodulator 20 met een uitgang 21 voor het afgeven van de overgedragen gedemoduleerde databits.

Voor transmissie volgens het DS-CDMA principe worden de van een zender 12 naar een ontvanger 13 door een gebruiker j over te dragen databits elk met een, door een codegenerator 22 opgewekte code $C_j^N(t)$ en een mengschakeling 23 in een aantal symbolen (chips) gecodeerd. Een logische "1" wordt bijvoorbeeld door de betreffende code zelf en een logische "0" wordt bijvoorbeeld door de inverse van de code gerepresenteerd. Naarmate de code langer is zal het over te dragen signaal meer en meer een ruissignaal benaderen, waardoor detectie zonder kennis van de betreffende code nagenoeg onmogelijk is.

Het op deze wijze in de frequentie gespreide DS-CDMA signaal van de gebruiker j kan na een transmissievertragingstijd τ_j bij de ontvanger 13 via eenzelfde codegenerator 22 echter met de code $C_j^N(t)$ en mengschakeling 24 worden gereconstrueerd, mits de code bekend is waarmee de databits voor de j-de gebruiker zijn gecodeerd.

Voor een meer gedetailleerde uitleg van CDMA- en Spread Spectrum-technieken wordt verwezen naar op dit vakgebied bekende literatuur, waaronder de boeken "Spread Spectrum Systems with Applications", door R.C. Dixon, John Wiley & Sons, Inc., 1994 en "CDMA, Principles of Spread Spectrum Communications", door A.J. Viterbi, Addison-Wesley Publishing Company. In de werkwijze volgens de voorkeursuitvoeringsvorm van de uitvinding wordt derhalve de vereiste veilige codering van het relevante deel van een informatiesignaal door het betreffende transmissiekanaal verzorgt waarover de overdracht plaatsvindt. Het gebruik van CDMA-technieken garandeert een lage kans op onderschepping.

Omdat ook het restdeel via een gemeenschappelijk of een veelheid van gemeenschappelijke transmissiekanalen van een communicatiesysteem wordt overgedragen, zal het zelfs bij onderscheppen van een gecodeerd relevant deel 3 nog bijzonder moeilijk zijn om het bijbehorende restdeel 4 te selecteren en wanneer het relevante deel 3 afwisselend uit een veelvoud van relevante signaaldelen wordt geselecteerd, zal het eveneens problematisch zijn om de beide delen tot het oorspronkelijke informatiesignaal te combineren.

Het relevante deel 3 wordt, in het geval van een relatief breedbandig signaal, zoals een videosignaal, zodanig gekozen, dat het slechts een relatief gering gedeelte van de totale signaalbandbreedte in beslag neemt. In een praktische situatie wordt het relevante deel 3 bij voorkeur zodanig gekozen, dat het via een 64 kb/s transmissiekanaal kan worden overgedragen, terwijl het restdeel 4, bijvoorbeeld in het geval van een videosignaal, via een breedbandig transmissiekanaal in de ordegrootte van 2 Mb/s of hoger wordt overgedragen. Het zal duidelijk zijn dat bij een overdrachtstechniek waarbij meerdere gebruikers tegelijkertijd op eenzelfde kanaal actief kunnen zijn, zoals CDMA, maar ook volgens de zogeheten "Time Division Multiple Access" (TDMA)-techniek werkende transmissiekanalen, met de werkwijze volgens de uitvinding op veilige wijze informatie in een distributienet kan worden overgedragen.

Een voorbeeld van een point-to-multipoint datadistributienet is het reeds eerder genoemde CATV-net, waarvan fig. 3 een voorbeeldsuitvoeringsvorm toont. In de getoonde netstructuur 25 wordt informatie vanaf een hoofdstation 26 naar eindaansluitpunten 27 overgedragen. Tussen het hoofdstation 26 en de eindaansluitpunten 27 zijn diverse bi-directionele versterkers 28, 29, 30 geschakeld, voor het opheffen van transmissieverliezen in het net 25, dat gebruikelijk uit coaxiale kabel 32 is opgebouwd.

In de getoonde uitvoeringsvorm zijn de versterkers 28 in de vorm van een zogeheten ringnet op het hoofdstation 26 aangesloten, waarbij de van een versterker 28 ontvangen signalen in een districtstation 31 verder via een groepsversterker 29 worden gedistribueerd. De gebruikers of eindaansluitpunten 27 zijn stervormig op een eindversterker 30 aangesloten die signalen van een groepsversterker 29 ontvangt.

In Nederlands CATV-netten zijn de versterkers 28, 29 en 30 in het algemeen zodanig ingericht, dat zij signalen vanaf het hoofdstation 26 naar de eindaansluitpunten 27 in een brede frequentieband van circa 50 MHz tot boven 750 MHz doorlaten. De transmissierichting vanaf het hoofdstation 26 naar de eindaansluitpunten 27 wordt ook wel met "stroomafwaarts" aangeduid. In de andere richting, dat wil zeggen vanaf de eindaansluitpunten 27 naar het hoofdstation 26, ook wel "stroomopwaarts" genoemd, is een transmissiefrequentieband van 5 MHz tot circa 50 MHz beschikbaar. Gestreefd wordt naar een volledig passieve transmissiefrequentieband in het frequentiegebied tot ca. 70 MHz, dat wil zeggen zonder versterkers.

Onder meer afhankelijk van de lengte van de code waarmee databits in CDMA worden gecodeerd, kunnen meer dan 100 gebruikers gelijktijdig op eenzelfde transmissiekanaal informatie overdragen.

Fig. 4 toont een vereenvoudigd blokschema van een eerste uitvoeringsvorm van een communicatiesysteem voor het gedeeltelijk gecodeerd overdragen van informatiesignalen volgens de uitvinding. Een over te dragen informatiesignaal wordt aan een ingang 33 van signaalsplitsmiddelen 34 toegevoerd, welke aan een eerste uitgang 35 de relevante signaaldelen en aan een uitgang 36 het restdeel van het over te dragen informatiesignaal afgeven.

Het relevante deel 35 wordt in codeermiddelen 37 veilig gecodeerd volgens een op zichzelf bekende coderingstechniek en aan een uitgang 38 afgegeven. De signalen aan de uitgangen 36 en 38 worden in een multiplexer 39 tot een voor overdracht via een zender 48 en transmissiekanaal 40 geschikt signaal gecombineerd. Het door een ontvanger 49 ontvangen overgedragen signaal wordt in een demultiplexer 41 weer gescheiden in een restdeel en het gecodeerde relevante deel, respectievelijk afgegeven aan uitgangen 42 en 43. Het gecodeerde signaal op de uitgang 43 wordt aan decodeermiddelen 44 toegevoerd en het aan een uitgang 45 van de decodeermiddelen 44 afgegeven gedecodeerde signaal wordt samen met het op de uitgang 42 van de demultiplexer 41 beschikbare restdeel in signaalcombinatiemiddelen 46 tot een informatiesignaal gecombineerd, dat vervolgens op een uitgang 47 van de signaalcombinatiemiddelen 46 beschikbaar is.

Fig. 5 toont een voorkeursuitvoeringsvorm van een communicatiesysteem volgens de uitvinding, waarbij de signalen op de uitgangen 35 en 36 van de signaalsplitsmiddelen 34 via afzonderlijke transmissiekanalen 50, 51 worden overgedragen.

Het kanaal 51, waarover het restdeel van een informatiesignaal 33 wordt overgedragen, kan van het type zijn waarover informatie op ongecodeerde, dat wil zeggen niet versleutelde of anderszins beveiligde wijze, wordt overgedragen via zend- en ontvangmiddelen 52, 53. Uiteraard kan het restdeel wel volgens een geschikt of voorgeschreven transmissieprotocol tot een voor overdracht via het transmissiekanaal 51 geschikt formaat zijn verwerkt.

Overeenkomstig de in fig. 3 geïllustreerde uitvoeringsvorm, kan het relevante deel van het informatiesignaal 33 aan de uitgang 35 van de signaalsplitsmiddelen 34 op geschikte wijze gecodeerd 54, verzonden 55, ontvangen 56 en gedecodeerd 57 worden, onder toepassing van een daartoe geschikt transmissieprotocol en codeeralgoritme.

In de voorkeursuitvoeringsvorm van de uitvinding wordt het relevante deel van een informatiesignaal 33 via een veilig transmissiekanaal overgedragen, in het bijzonder een CDMA-gecodeerd transmissiekanaal, zoals aangegeven met de onderbroken lijnen 58 in fig. 5. De codeer- en zendmiddelen 54, 55 en de ontvang- en decodeermiddelen 56, 57 zijn ingericht voor CDMA-overdracht zoals besproken aan de hand van fig. 2.

De transmissiekanalen 50 en 51 kunnen deel uitmaken van een meer omvangrijke communicatiesysteem zoals een CATV-net waarbij meerdere gebruikers gelijktijdig over een informatiekanaal informatie overdragen. In het bijzonder bij CDMA-data-overdracht kunnen de relevante delen van verschillende gebruikers gelijktijdig over het transmissiekanaal 50 op een veilige wijze worden overgedragen zodanig, dat alleen de eindgebruiker welke beschikt over de juiste sleutel waarmee een betreffend relevant deel is gecodeerd de informatie uit de veelheid van relevante delen van verschillende gebruikers kan terugwinnen.

Voor het combineren van een bijbehorend relevant deel en een restdeel kan aan elk van de delen een specifieker kenmerk worden toegevoegd, zoals een bestemmingsnummer of gebruikersnummer en een volgnummer, zodanig dat de signaalcommunicatiemiddelen 46 de betreffende signaaldelen tot een uiteindelijk compleet informatiesignaal aan de uitgang 47 kunnen combineren.

In plaats van CDMA-transmissie kan ook elke andere vorm van veilige transmissie voor het doel van de uitvinding worden toegepast, zoals bijvoorbeeld transmissie in versleutelde vorm middels een "Time Division Multiple Access" (TDMA)-transmissieprotocol overeenkomstig het "Global Systems voor Mobile Communications" (GSM) of de "Digital Enhanced Cordless Telecommunications" (DECT)-standaard waarbij de informatie standaard in gecodeerde of versleutelde vorm wordt overgedragen.

Hoewel in de figuren 4 en 5 een communicatiesysteem voor simplex-overdracht (d.w.z. éénrichtingsverkeer) is getoond, zal het voor een deskundige geen toelichting behoeven dat de de uitvinding ook voor duplex-overdracht (d.w.z. voor tweerichtingsverkeer) geschikt is.

Conclusies

1. Werkwijze voor het in een communicatiesysteem overdragen van informatiesignalen onder toepassing van veilige coderingstechnieken, met het kenmerk, dat een informatiesignaal wordt gesplitst in een voor verwerking van het signaal relevant deel en een restdeel, waarbij het relevante deel in een veilig gecodeerde vorm en het restdeel in ongecodeerde vorm via het communicatiesysteem worden overgedragen en dat een overgedragen relevant deel van een informatiesignaal wordt gedecodeerd en met een bijbehorend overgedragen restdeel tot het oorspronkelijke informatiesignaal wordt gereconstrueerd.

2. Werkwijze volgens conclusie 1, met het kenmerk, dat het te coderen relevante deel van het informatiesignaal zodanig wordt geselecteerd dat dit een relatief gering deel van de bandbreedte van het informatiesignaal in beslag neemt.

3. Werkwijze volgens conclusie 1 of 2, met het kenmerk, dat het communicatiesysteem verschillende transmissiekanalen omvat, waarbij het gecodeerde relevante deel en het ongecodeerde restdeel van het informatiesignaal elk via verschillende transmissiekanalen worden overgedragen.

4. Werkwijze volgens conclusie 1, 2 of 3, met het kenmerk, dat het te coderen relevante deel van het informatiesignaal onder toepassing van "Code Division Multiple Access" (CDMA)-techniek gecodeerd wordt overgedragen.

5. Werkwijze volgens conclusie 1, 2, 3 of 4, met het kenmerk, dat het communicatiesysteem een "point-to-multipoint" signaaldistributienet omvat, waarbij verschillende gebruikers gelijktijdig informatiesignalen kunnen ontvangen en/of verzenden, waaronder begrepen "Community Antenna TeleVision" (CATV)-netten en distributienetten voor elektrische energie.

6. Communicatiesysteem, omvattende codeermiddelen voor het in gecodeerde vorm veilig overdragen van informatiesignalen en decodeermiddelen voor het decoderen van overgedragen informatiesignalen, verder gekenmerkt door middelen voor het splitsen van een over te dragen informatiesignaal in een voor verwerking van het signaal relevant deel en een restdeel, welke middelen werkzaam zijn gekoppeld met de codeermid-

delen voor het in veilig gecodeerde vorm overdragen van het relevante deel van een informatiesignaal en met middelen voor het in ongecodeerde vorm overdragen van het restdeel van een informatiesignaal, waarbij de decodeermiddelen zijn ingericht voor het decoderen van een overgedragen relevant deel van een informatiesignaal en werkzaam zijn gekoppeld met middelen voor het tot een oorspronkelijk informatiesignaal reconstrueren van een gedecodeerd relevant deel en een overgedragen bijbehorend restdeel.

7. Communicatiesysteem volgens conclusie 6, met het kenmerk, dat de middelen voor het splitsen van het informatiesignaal zijn ingericht voor het selecteren van een relevant deel van het informatiesignaal met een relatief geringe bandbreedte ten opzichte van de bandbreedte van het totale informatiesignaal.

8. Communicatiesysteem volgens conclusie 6 of 7, met het kenmerk, dat het communicatiesysteem verschillende transmissiekanalen omvat voor het via een verschillend transmissiekanaal overdragen van het relevante deel en het restdeel van een informatiesignaal.

9. Communicatiesysteem volgens conclusie 6, 7 of 8, met het kenmerk, dat de codeermiddelen zijn ingericht voor het in "Code Division Multiple Access" (CDMA)-gecodeerd overdragen van het relevante deel van een informatiesignaal.

10. Signaalsplitsmiddelen voor gebruik in een communicatiesysteem volgens conclusie 6, 7, 8 of 9, voor het splitsen van een over te dragen informatiesignaal, met het kenmerk, dat de signaalsplitsmiddelen zijn ingericht voor het, van het informatiesignaal afsplitsen van een voor de verwerking van het signaal relevant deel.

11. Signaalcombinatiemiddelen voor gebruik in een communicatiesysteem volgens conclusie 6, 7, 8 of 9, met het kenmerk, dat de signaalcombinatiemiddelen zijn ingericht voor het tot een totaal informatiesignaal combineren van een gedecodeerd overgedragen relevant deel en een overgedragen bijbehorend restdeel van een informatiesignaal.

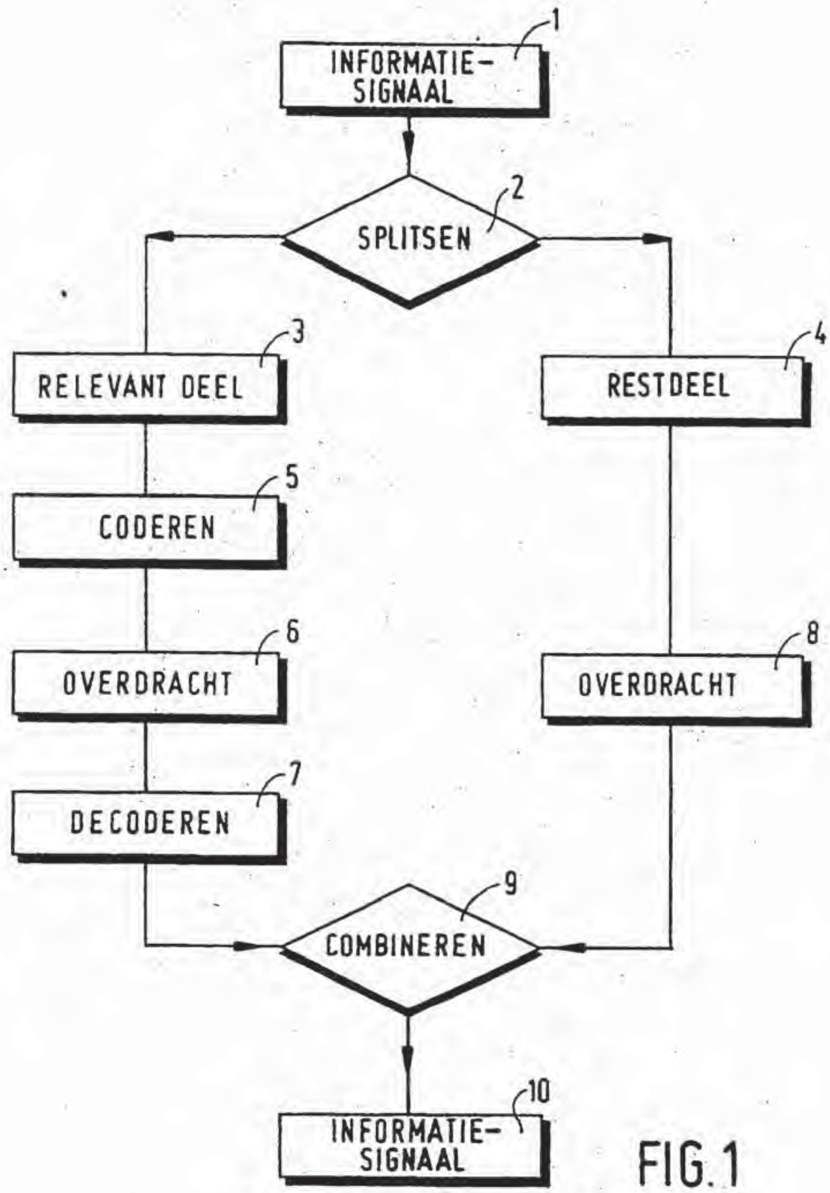


FIG.1

1005523

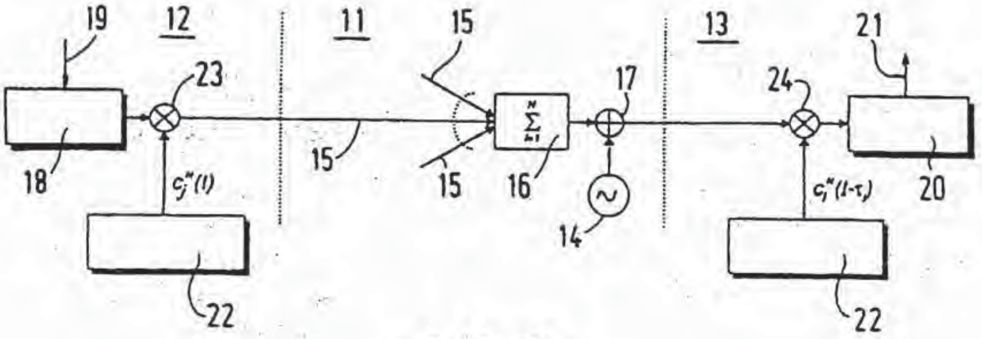

19
12
11
15
13
21
23
17
24
15
15
16
18
$c_j^N(l)$
$c_j^N(l-\tau_j)$
20
14
22
22

FIG. 2

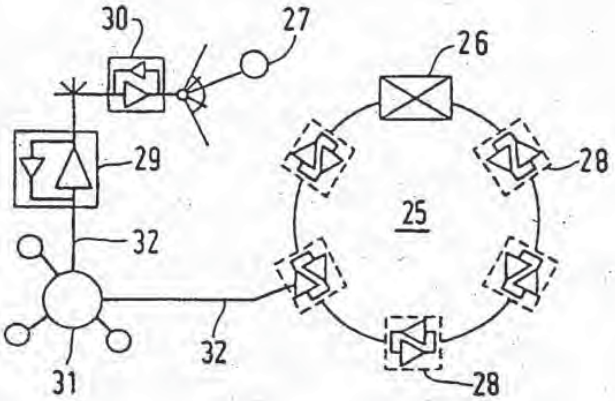

30
27
26
29
28
25
32
32
31
28

FIG. 3

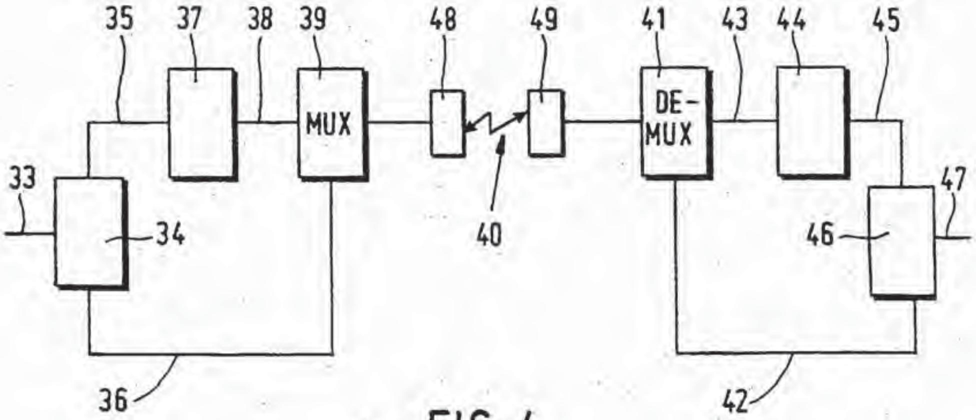

35
37
38
39
MUX
48
49
41
DE-
MUX
43
44
45
33
34
40
46
47
36
42

FIG. 4

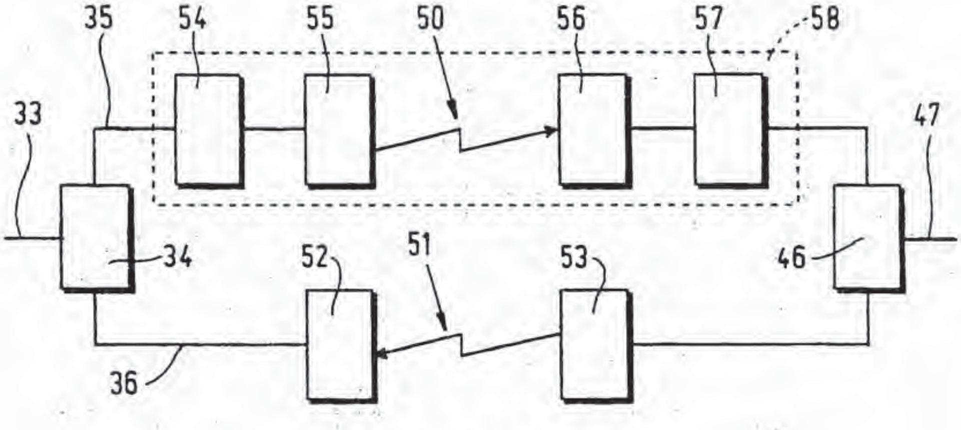

35
54
55
50
56
57
58
33
47
34
52
51
53
46
36

FIG.5

SAMENWERKINGSVERDRAG (PCT)

RAPPORT BETREFFENDE NIEUWHEIDSONDERZOEK VAN INTERNATIONAAL TYPE

IDENTIFIKATIE VAN DE NATIONALE AANVRAGE	Kenmerk van de aanvrager of van de gemachtigde 37739/JD/jr
Nederlandse aanvrage nr. 1005523	Indieningsdatum 13 maart 1997
	Ingeroepen voorrangsdatum
Aanvrager (Naam) TECHNISCHE UNIVERSITEIT EINDHOVEN	
Datum van het verzoek voor een onderzoek van internationaal type --	Door de Instantie voor Internationaal Onderzoek (ISA) aan het verzoek voor een onderzoek van internationaal type toegekend nr. SN 28858 NL

I. CLASSIFICATIE VAN HET ONDERWERP (bij toepassing van verschillende classificaties, alle classificatiesymbolen opgeven)

Volgens de Internationale classificatie (IPC)

Int. Cl.^{6}: H 04 N 7/167, H 04 N 7/26

II. ONDERZOCHTE GEBIEDEN VAN DE TECHNIEK

Onderzochte minimum documentatie

Classificatiesysteem	Classificatiesymbolen
Int. Cl.^{6}	H 04 N

Onderzochte andere documentatie dan de minimum documentatie voor zover dergelijke documenten in de onderzochte gebieden zijn opgenomen

III. □ **GEEN ONDERZOEK MOGELIJK VOOR BEPAALDE CONCLUSIES** (opmerkingen op aanvullingsblad)

IV. □ **GEBREK AAN EENHEID VAN UITVINDING** (opmerkingen op aanvullingsblad)

20

VERSLAG VAN HET NIEUWHEIDSONDERZOEK VAN INTERNATIONAAL TYPE

Nummer van het verzoek om een nieuwheidsonderzoek
NL 1005523

A. CLASSIFICATIE VAN HET ONDERWERP
IPC 6 H04N7/167 H04N7/26

Volgens de Internationale Classificatie van octrooien (IPC) of zowel volgens de nationale classificatie als volgens de IPC.

B. ONDERZOCHTE GEBIEDEN VAN DE TECHNIEK

Onderzochte minimum documentatie (classificatie gevolgd door classificatiesymbolen)
IPC 6 H04N

Onderzochte andere documentatie dan de minimum documentatie, voor dergelijke documenten, voor zover dergelijke documenten in de onderzochte gebieden zijn opgenomen

Tijdens het internationaal nieuwheidsonderzoek geraadpleegde elektronische gegevensbestanden (naam van de gegevensbestanden en, waar uitvoerbaar, gebruikte trefwoorden)

C. VAN BELANG GEACHTE DOCUMENTEN

Categorie *	Geciteerde documenten, eventueel met aanduiding van speciaal van belang zijnde passages	Van belang voor conclusie nr.
A	TIHAO CHIANG ET AL: "HIERARCHICAL CODING OF DIGITAL TELEVISION" IEEE COMMUNICATIONS MAGAZINE, deel 32, nr. 5, 1 Mei 1994, bladzijden 38-45, XP000451094 zie bladzijde 41, rechter kolom, regel 40 - bladzijde 43, linker kolom, regel 23 zie figuur 3 ---	1,2,5-7, 10,11
A	DE 44 25 197 A (DEUTSCHE BUNDESPOST TELEKOM) 25 Januari 1996 zie kolom 1, regel 7 - kolom 4, regel 42 zie figuren 1,2 -----	1-11

☐ Verdere documenten worden vermeld in het vervolg van vak C.

☒ Leden van dezelfde octrooifamilie zijn vermeld in een bijlage

* Speciale categorieën van aangehaalde documenten

"A" document dat de algemene stand van de techniek weergeeft, maar niet beschouwd wordt als zijnde van bijzonder belang

"E" eerder document, maar gepubliceerd op de datum van indiening of daarna

"L" document dat het beroep op een recht van voorrang aan twijfel onderhevig maakt of dat aangehaald wordt om de publicatiedatum van een andere aanhaling vast te stellen of om een andere reden zoals aangegeven

"O" document dat betrekking heeft op een mondelinge uiteenzetting, een gebruik, een tentoonstelling of een ander middel

"P" document gepubliceerd voor de datum van indiening maar na de ingeroepen datum van voorrang

"T" later document, gepubliceerd na de datum van indiening of datum van voorrang en niet in strijd met de aanvrage, maar aangehaald ter verduidelijking van het principe of de theorie die aan de uitvinding ten grondslag ligt

"X" document van bijzonder belang; de uitvinding waarvoor uitsluitende rechten worden aangevraagd kan niet als nieuw worden beschouwd of kan niet worden beschouwd op inventiviteit te berusten

"Y" document van bijzonder belang; de uitvinding waarvoor uitsluitende rechten worden aangevraagd kan niet worden beschouwd als inventief wanneer het document beschouwd wordt in combinatie met één of meerdere soortgelijke documenten, en deze combinatie voor een deskundige voor de hand ligt

"&" document dat deel uitmaakt van dezelfde octrooifamilie

1

Datum waarop het nieuwheidsonderzoek van internationaal type werd voltooid 2 December 1997	Verzenddatum van het rapport van het nieuwheidsonderzoek van internationaal type
Naam en adres van de instantie European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax (+31-70) 340-3016	De bevoegde ambtenaar Van der Zaal, R

Formulier PCT/ISA/201 (tweede blad) (juli 1992)

VERSLAG VAN HET NIEUWHEIDSONDERZOEK VAN INTERNATIONAALTYPE

Informatie over leden van dezelfde octrooifamilie

Nummer van het verzoek om een nieuwheidsonderzoek

NL 1005523

In het rapport genoemd octrooigeschrift	Datum van publicatie	Overeenkomend(e) geschrift(en)	Datum van publicatie
DE 4425197 A	25-01-96	GEEN	

Formulier PCT/ISA/201 (vervolgblad octrooifamilie) (juli 1992)

P ENT COOPERATION TREATY

From the INTERNATIONAL SEARCHING AUTHORITY

To:
BAKER BOTTS L.L.P.
Attn. CHAPMAN, Floyd B.
THE WARMER
1299 PENNSYLVANIA AVENUE, N.W.
WASSHINGTON, D.C. 20004
UNITED STATES OF AMERICA

PCT

INVITATION TO PAY ADDITIONAL FEES

(PCT Article 17(3)(a) an

Add'l Fees Due
16 Apr / 29 Apr 2001

Date of mailing *(day/month/year)* 15/03/2001

Applicant's or agent's file reference
066358.0106 031890.0007

PAYMENT DUE within 45 XXXXs/days from the above date of mailing

International application No.
PCT/US 00/ 18411

International filing date *(day/month/year)* 05/07/2000

Applicant

MOSKOWITZ, Scott A.

1. This International Searching Authority

(i) considers that there are 2 *(number of)* inventions claimed in the international application covered by the claims indicated XXXX/on the extra sheet:

and it considers that the international application does not comply with the requirements of unity of invention (Rules 13.1, 13.2 and 13.3) for the reasons indicated XXXX/on the extra sheet:

(ii) ☒ has carried out a partial international search (see Annex) □ will establish the international search report on those parts of the international application which relate to the invention first mentioned in claims Nos.:
1-5, 26-29

(iii) will establish the international search report on the other parts of the international application only if, and to the extent to which, additional fees are paid

2. The applicant is hereby **invited**, within the time limit indicated above, to pay the amount indicated below:

EUR 945,00 x 1 = EUR 945,00
Fee per additional invention — number of additional inventions — total amount of additional fees

Or, ________ x ________ = ________

The applicant is informed that, according to Rule 40.2(c), **the payment of any additional fee may be made under protest**, i.e., a reasoned statement to the effect that the international application complies with the requirement of unity of invention or that the amount of the required additional fee is excessive.

3. □ Claim(s) Nos. ________ have been found to be unsearchable under Article 17(2)(b) because of defects under Article 17(2)(a) and therefore have not been included with any invention.

Name and mailing address of the International Searching Authority
European Patent Office, P.B. 5818 Patentlaan 2
NL-2280 HV Rijswijk
Tel. (+31-70) 340-2040, Tx. 31 651 epo nl,
Fax: (+31-70) 340-3016

Authorized officer
Marja Brouwers

Patent Family Annex

Information on patent family members

International Application No

PCT/US 00/18411

Patent document cited in search report		Publication date	Patent family member(s)		Publication date
NL 1005523	C	15-09-1998	NONE		
WO 9744736	A	27-11-1997	AU	3206397 A	09-12-1997
EP 0649261	A	19-04-1995	JP US	7115638 A 5933499 A	02-05-1995 03-08-1999
US 5974141	A	26-10-1999	US US US	6076077 A 6002772 A 6097818 A	13-06-2000 14-12-1999 01-08-2000

Annex 'orm PCT/ISA/206
COMMUNICATIC. ,ELATING TO THE RESULTS
OF THE PARTIAL INTERNATIONAL SEARCH

In. ..tional Application No
PCT/US 00/18411

1. The present communication is an Annex to the invitation to pay additional fees (Form PCT/ISA/206). It shows the results of the international search established on the parts of the international application which relate to the invention first mentioned in claims Nos.:
1-5,26-29

2. This communication is not the international search report which will be established according to Article 18 and Rule 43.

3. If the applicant does not pay any additional search fees, the information appearing in this communication will be considered as the result of the international search and will be included as such in the international search report.

4. If the applicant pays additional fees, the international search report will contain both the information appearing in this communication and the results of the international search on other parts of the international application for which such fees will have been paid.

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	NL 1 005 523 C (EINDHOVEN TECH HOCHSCHULE) 15 September 1998 (1998-09-15) abstract; figure 4 page 1, line 35 -page 3, line 9 page 9, line 21 -page 10, line 5 ---	1,2, 26-29
X	WO 97 44736 A (APPLE COMPUTER) 27 November 1997 (1997-11-27) abstract; figures 2A,2B,2C,3 page 2, line 35 -page 3, line 27 page 9, line 10 -page 11, line 28	1,2
Y	---	3,4
Y	EP 0 649 261 A (CANON KK) 19 April 1995 (1995-04-19) page 3, line 53 -page 4, line 5 page 7, line 18 - line 23 ---	3,4
A	US 5 974 141 A (SAITO MAKOTO) 26 October 1999 (1999-10-26) abstract; figures 4A-4G column 8, line 24 - line 67 -----	5,26

□ Further documents are listed in thecontinuation of box C.

☒ Patent family members are listed in annex.

* Special categories of cited documents :

"A" document defining the general state of theart which is not considered to be of particular relevance

"E" earlier document but published on or after theinternational filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the internationalfiling date but later than the priority date claimed

"T" later document published after theinternational filing date or priority date and not in conflict with theapplication but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimedinvention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimedinvention cannot be considered to involve an inventive step when the document is combined with one or more othersuch documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

3

INVITATION TO PAY ADDITIONAL FEES	International application No. PCT/US 00/18411

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. Claims: 1-5, 26-29

   Protecting the distribution of digital data to be used with a digital player charachterized by encrypting format information and allowing low quality play back in case of lack of decrypting key.

2. Claims: 6-25

   Digital signal encrypting technique combining transfer functions with predetermined key creation.

This finding is based on the following reasons.

The prior art has been identified as NL1005523 (D1). This document shows a method for protecting the distribution of digital information, the digital information including two subparts, a digital sample and format information, comprising the steps of: identifying and separating the two subparts; encoding the format information subpart using a key; recombining the encoded first subpart with the un-encoded second subpart, generating in this way an encoded version of the digital information. A predetermined key corresponding to the encoding key is then required for the decryption of the format information. All the features which form the subject matter of claims 1 and 2 are then disclosed by D1 (see following passages: abstract; page 1, line 35 - page 3, line 9; page 9, line 21 - page 10, line 5; fig. 4)

From the comparison between D1 and the 1st invention (see claim 3) the following technical featuree can be seen to make a contribution over this prior art (in the sense of PCT rule 13.2):
- the digital information is configured to be used with a digital player and the information output from said digital player has a degraded quality unless it is provided with a predetermined key (Special Technical Features 1, STF1).
From these STF1 the objective problem to be solved can be summarized as:
- permitting preview of distributed digital information

From the comparison between D1 and the 2nd invention (see claim 6) the following feature can be seen to make a contribution over the same prior art:
- using a transfer function-based mask set for creating a key to manipulate data at the inherent granularity of the file format of a digital sample (STF2).
From this STF2 the objective problem to be solved can be summarized as:
- improving the security of techniques for data protection

The above analysis shows that inventions 1 and 2 do not have same or similar Special Technical Features. Furthermore, a comparison of the objective problem 1 with the objective problem 2, both seen in the light of the description and the drawings of the present application, indicates that there is no technical correspondence between these problems nor do they show any corresponding technical effect.

INVITATION TO PAY ADDITIONAL FEES

International application No.
PCT/US 00/18411

As a result, inventions 1 and 2 fail to demonstrate a single general inventive concept as required by PCT rule 13.1.

PCT WORLD INTELLECTUAL PROPERTY ORGANIZATION
International Bureau

INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification ^{6} :
G06F 12/14

A1

(11) International Publication Number: WO 97/44736

(43) International Publication Date: 27 November 1997 (27.11.97)

(21) International Application Number: PCT/US97/08264

(22) International Filing Date: 15 May 1997 (15.05.97)

(30) Priority Data:
08/652,862 23 May 1996 (23.05.96) US

(71) Applicant: APPLE COMPUTER, INC. [US/US]; 1 Infinite Loop - MS: 38-PAT, Cupertino, CA 95014 (US).

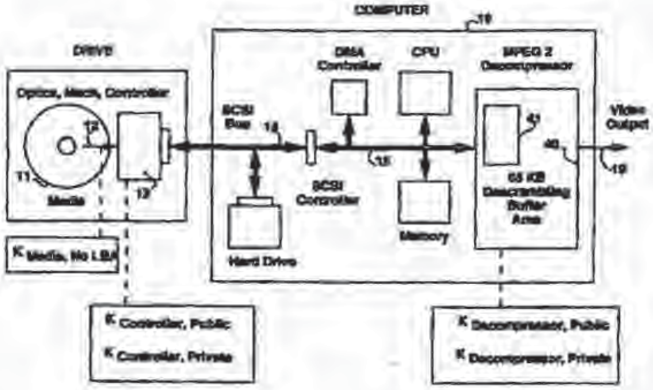
(72) Inventor: WEHRENBERG, Paul, J.; 3516 Ross Road, Palo Alto, CA 94303 (US).

(74) Agents: CARMICHAEL, Paul, D. et al.; Apple Computer, Inc., 1 Infinite Loop - MS: 38-PAT, Cupertino, CA 95014 (US).

(81) Designated States: AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, DE, DK, EE, ES, FI, GB, GE, GH, HU, IL, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, TJ, TM, TR, TT, UA, UG, UZ, VN, YU, ARIPO patent (GH, KE, LS, MW, SD, SZ, UG), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, ML, MR, NE, SN, TD, TG).

Published
With international search report.
Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.

(54) Title: METHOD AND APPARATUS FOR TWO-LEVEL COPY PROTECTION



(57) Abstract

An apparatus and method for providing two levels of copy protection, including a first method for copy protection, including a key, and a second method for copy protection. One level of copy protection is a moderately secure level to allow decrypting a medium- to high-bandwidth data stream without significant delay of the data stream. The second level of copy protection can be highly secure but can be utilized less often and so can be decrypted more slowly. One useful combination is to use a key encryption scheme for the first level of copy protection of a primary data stream, then to use the second protection scheme to securely transfer the first level key from a protected storage location to a decoding location. Encoded primary data can be stored on a removable media, together with the decryption key stored in a special location. The media drive unit can access the special location and, using the second level copy protection scheme, transfer the key securely to a descrambling unit. The first level copy protection can involve selective reordering of data subunits within a data unit according to a scrambling vector, then encoding the scrambling vector using the first key, and storing the encoded scrambling vector with the corresponding data unit.