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Petrovic et al.

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(54) **APPARATUS AND METHOD FOR EMBEDDING AND EXTRACTING INFORMATION IN ANALOG SIGNALS USING DISTRIBUTED SIGNAL FEATURES**

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(*) Notice: This patent issued on a continued prosecution application filed under 37 CFR 1.53(d), and is subject to the twenty year patent term provisions of 35 U.S.C. 154(a)(2).

Under 35 U.S.C. 154(b), the term of this patent shall be extended for 0 days.

(21) Appl. No.: **08/974,920**

(22) Filed: **Nov. 20, 1997**

Related U.S. Application Data

(63) Continuation-in-part of application No. 08/858,562, filed on May 19, 1997, now Pat. No. 5,940,135.

(51) **Int. Cl.**[7] **H04N 7/087**

(52) **U.S. Cl.** **380/42**; 380/252; 380/253; 380/254

(58) **Field of Search** 380/3, 4, 6, 8, 380/252, 253, 254, 42; 713/176

(56) **References Cited**

U.S. PATENT DOCUMENTS

4,497,060	*	1/1985	Petrovic et al.	348/473
4,876,617	*	10/1989	Best et al.	360/60
4,937,807	*	1/1990	Weitz et al.	369/85
4,972,471		11/1990	Gross et al. .	
5,113,437	*	5/1992	Best et al.	380/3
5,319,735	*	6/1994	Preuss et al.	704/205
5,379,345	*	1/1995	Greenberg	380/23
5,404,377	*	4/1995	Moses	375/200
5,450,490	*	9/1995	Jensen et al.	380/6
5,473,631	*	12/1995	Moses	375/202
5,612,729	*	3/1997	Ellis et al.	348/2
5,613,004	*	3/1997	Cooperman et al.	380/28
5,687,236	*	11/1997	Moskowitz et al.	380/28
5,764,763	*	6/1998	Jensen et al.	380/6
5,848,155	*	12/1998	Cox	380/4
5,850,481	*	12/1998	Rhoads	382/232
5,889,868	*	3/1999	Moskowitz	380/51
5,893,067	*	4/1999	Bender et al.	704/502
5,930,369	*	7/1999	Cox et al.	380/54
5,933,798	*	8/1999	Linnartz	702/191
5,940,135	*	1/1985	Petrovic et al.	348/473

FOREIGN PATENT DOCUMENTS

2260246	4/1993	(GB) .
2292506	2/1996	(GB) .

OTHER PUBLICATIONS

Bruce Schneier, Applied Cryptography, Second Edition: Protocols, Algorithms and Source Code in C, pp. 9–10, 29–31, 79–80., Oct. 1995.*

Arthur F. Coxford, Advanced Mathematics: A Preparation for Calculus, Second Edition, 35–46, 1978.*

* cited by examiner

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(57) **ABSTRACT**

Apparatus and methods are provided for embedding or embedding digital data into an analog host or cover signal. A distributed signal feature of the cover signal in a particular domain (time, frequency or space) is calculated and compared with a set of predefined quantization values corresponding to an information symbol to be encoded. The amount of change required to modify the signal feature to the determined target quantization value is calculated and the cover signal is modified accordingly to so change the feature value over a predefined interval. Information symbols are extracted by the opposite process.

23 Claims, 3 Drawing Sheets

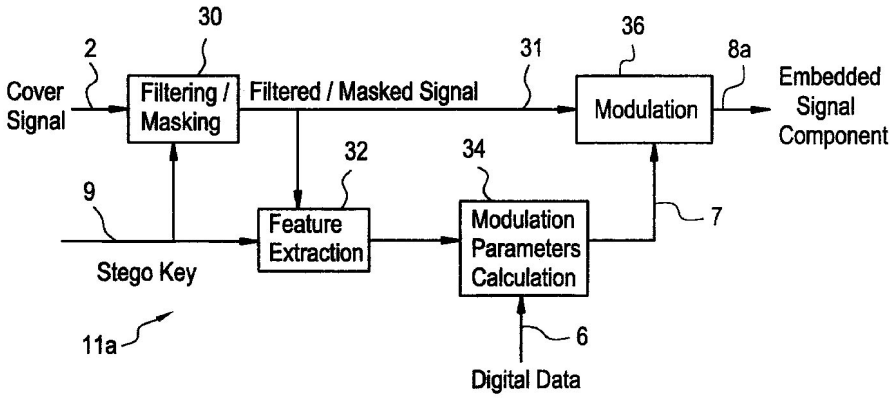

FIG.1

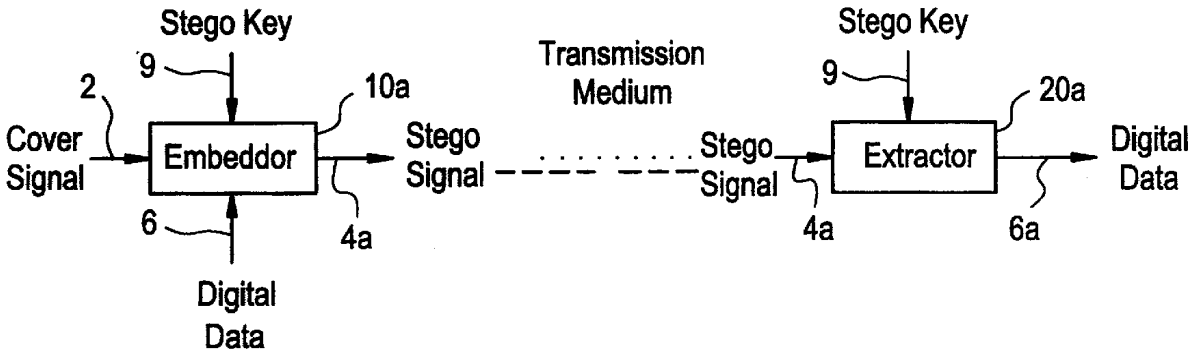

FIG.2

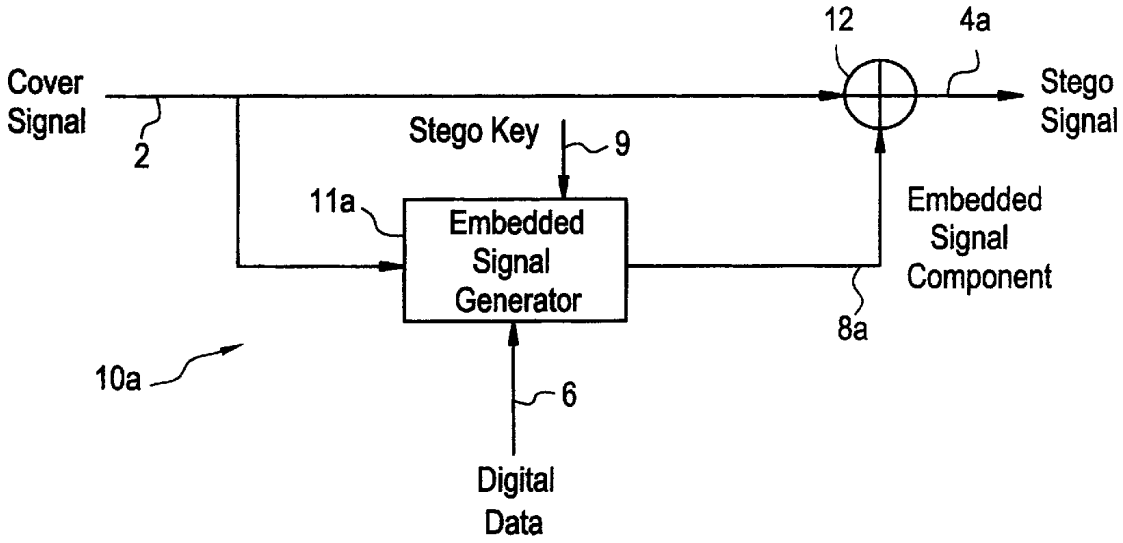

FIG.3

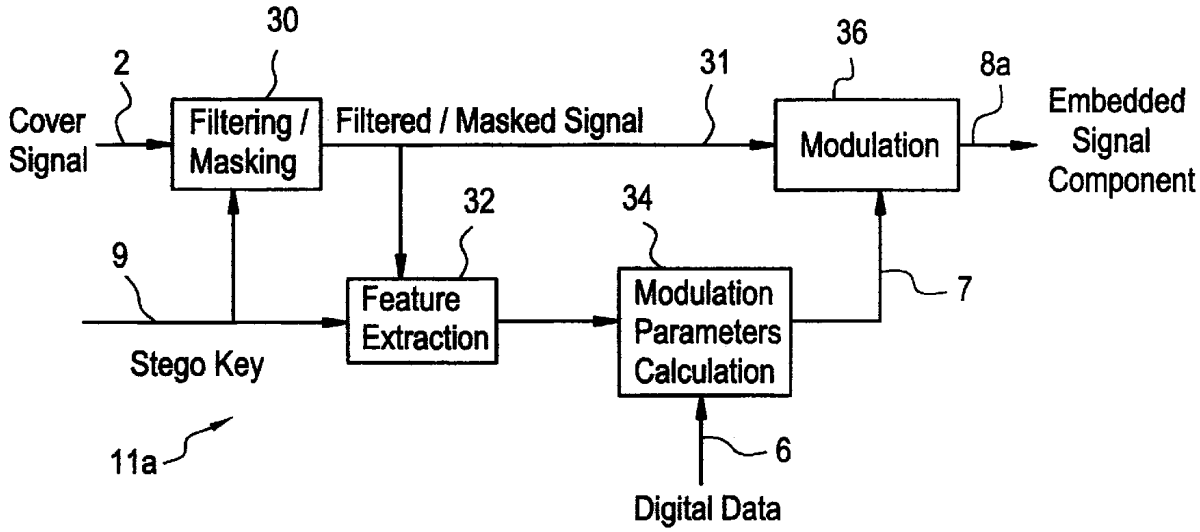

FIG.4

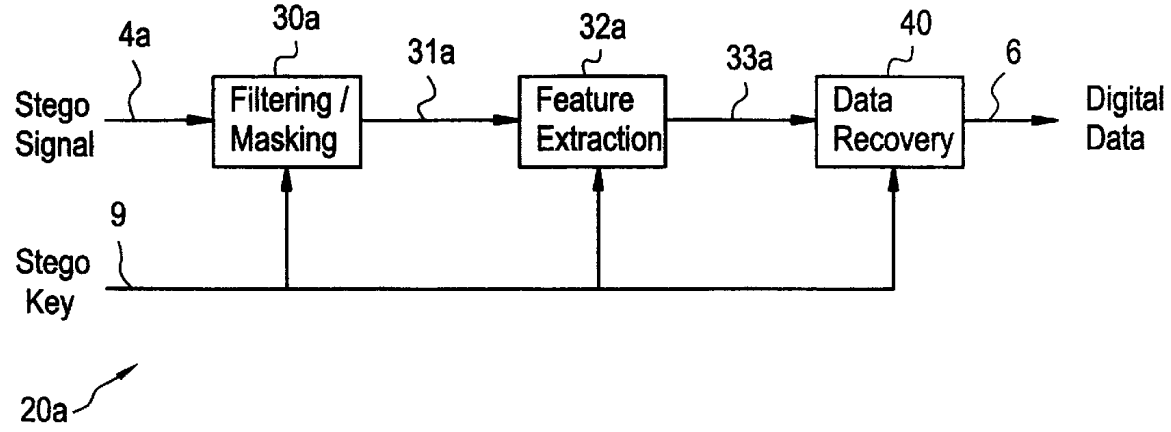

FIG.5

frequency band	5000Hz - 6000Hz
time intervals	T = 20 -ms, sequential
distributed signal feature i- th symbol, i = 1, 2, ...	$\frac{I_{1,i} - I_{2,i}}{I_{1,i} + I_{2,i}}$, $I_{1,i} = \int_{(i-1)T}^{(i-0.5)T} s^2(t)\,dt$, $I_{2,i} = \int_{(i-0.5)T}^{iT} s^2(t)\,dt$
quantization grid, binary symbols	Symbol 1 : Q_1 = - 0.9, - 0.5, - 0.1, 0.3, 0.7 Symbol 0 : Q_0 = - 0.7, - 0.3, 0.1, 0.5, 0.9

APPARATUS AND METHOD FOR EMBEDDING AND EXTRACTING INFORMATION IN ANALOG SIGNALS USING DISTRIBUTED SIGNAL FEATURES

CROSS REFERENCE TO RELATED APPLICATION

This application is a continuation-in-part of pending application Ser. No. 08/858,562 filed May 19, 1997, now U.S. Pat. No. 5,940,135, and assigned to the same assignee herein.

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to apparatus and methods for encoding and decoding information in analog signals, such as audio, video and data signals, either transmitted by radio wave transmission or wired transmission, or stored in a recording medium such as optical or magnetic disks, magnetic tape, or solid state memory.

2. Background and Description of Related Art

An area of particular interest to certain embodiments of the present invention relates to the market for musical recordings. Currently, a large number of people listen to musical recordings on radio or television. They often hear a recording which they like enough to purchase, but don't know the name of the song, the artist performing it, or the record, tape, or CD album of which it is part. As a result, the number of recordings which people purchase is less than it otherwise would be if there was a simple way for people to identify which of the recordings that they hear on the radio or TV they wish to purchase.

Another area of interest to certain embodiments of the invention is copy control. There is currently a large market for audio software products, such as musical recordings. One of the problems in this market is the ease of copying such products without paying those who produce them. This problem is becoming particularly troublesome with the advent of recording techniques, such as digital audio tape (DAT), which make it possible for copies to be of very high quality. Thus it would be desirable to develop a scheme which would prevent the unauthorized copying of audio recordings, including the unauthorized copying of audio works broadcast over the airwaves. It is also desirable for copyright enforcement to be able to insert into program material such as audio or video signals digital copyright information identifying the copyright holder, which information may be detected by appropriate apparatus to identify the copyright owner of the program, while remaining imperceptible to the listener or viewer.

Various prior art methods of encoding additional information onto a source signal are known. For example, it is known to pulse-width modulate a signal to provide a common or encoded signal carrying at least two information portions or other useful portions. In U.S. Pat. No. 4,497,060 to Yang (1985) binary data is transmitted as a signal having two differing pulse-widths to represent logical "0" and "1" (e.g., the pulse-width durations for a "1" are twice the duration for a "0"). This correspondence also enables the determination of a clocking signal.

U.S. Pat. No. 4,937,807 to Weitz et al. (1990) discloses a method and apparatus for encoding signals for producing sound transmissions with digital information to enable addressing the stored representation of such signals. Specifically, the apparatus in Weitz et al. converts an analog signal for producing such sound transmissions to clocked digital signals comprising for each channel an audio data stream, a step-size stream and an emphasis stream.

With respect to systems in which audio signals produce audio transmissions, U.S. Pat. Nos. 4,876,617 to Best et al. (1989) and 5,113,437 to Best et al. (1992) disclose encoders for forming relatively thin and shallow (e.g., 150 Hz wide and 50 dB deep) notches in mid-range frequencies of an audio signal. The earlier of these patents discloses paired notch filters centered about the 2883 Hz and 3417 Hz frequencies; the later patent discloses notch filters but with randomly varying frequency pairs to discourage erasure or inhibit filtering of the information added to the notches. The encoders then add digital information in the form of signals in the lower frequency indicating a "0" and in the higher frequency a "1". In the later Best et al. patent an encoder samples the audio signal, delays the signal while calculating the signal level, and determines during the delay whether or not to add the data signal and, if so, at what signal level. The later Best et al. patent also notes that the "pseudo-random manner" in moving the notches makes the data signals more difficult to detect audibly.

Other prior art techniques employ the psychoacoustic model of the human perception characteristic to insert modulated or unmodulated tones into a host signal such that they will be masked by existing signal components and thus not perceived. See, e.g. Preuss et al., U.S. Pat. No. 5,319,735, and Jensen et al., U.S. Pat. No. 5,450,490. Such techniques are very expensive and complicated to implement, while suffering from a lack of robustness in the face of signal distortions imposed by perception-based compression schemes designed to eliminate masked signal components.

The prior art fails to provide a method and an apparatus for encoding and decoding auxiliary analog or digital information signals onto analog audio or video frequency signals for producing humanly perceived transmissions (i.e., sounds or images) such that the audio or video frequency signals produce substantially identical humanly perceived transmission prior to as well as after encoding with the auxiliary signals. The prior art also fails to provide relatively simple apparatus and methods for encoding and decoding audio or video frequency signals for producing humanly perceived audio transmissions with signals defining digital information. The prior art also fails to disclose a method and apparatus for limiting unauthorized copying of audio or video frequency signals for producing humanly perceived audio transmissions.

SUMMARY OF THE INVENTION

The present invention provides apparatus and methods for embedding or encoding, and extracting or decoding, digitized information in an analog host or cover signal in a way which has minimal impact on the perception of the source information when the analog signal is applied to an appropriate output device, such as a speaker, a display monitor, or other electrical/electronic device.

The present invention further provides apparatus and methods for embedding and extracting machine readable signals in an analog cover signal which control the ability of a device to copy the cover signal.

In summary, the present invention provides for the encoding or embedding of a data signal in an analog host or cover signal, by modulating the host or cover signal so as to modify a distributed signal feature of the signal within the predefined region. As used herein, a "distributed signal

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