UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

HTC CORPORATION; HTC AMERICA, INC.; SAMSUNG ELECTRONICS
CO., LTD.; and SAMSUNG ELECTRONICS AMERICA, INC.
Petitioner

v.

E-WATCH, INC. and E-WATCH CORPORATION
Patent Owner

CASE IPR2014-00987[1]
Patent No. 7,365,871 B2

DECLARATION OF KENNETH PARULSKI

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[1] Case IPR2015-00541 has been joined with this proceeding.

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DECLARATION OF KENNETH PARULSKI
IPR2014-00987 (U.S. PATENT NO. 7,365,871 B2)

I. INTRODUCTION

1.   My name is Kenneth Parulski. I was the former Chief Scientist in the Digital Camera and Devices Division of Eastman Kodak Company and I am currently Chief Scientist and Managing Member of aKAP Innovation, LLC, which I founded in June 2012. aKAP Innovation, LLC provides innovation and digital photography related consulting services, and participates in the development of ISO ("International Organization for Standardization") standards for digital photography.

2.   I have been engaged by, and compensated by, HTC Corporation and HTC America, Inc. ("HTC") to investigate and opine on certain issues relating to U.S. Patent No. 7,365,871 B2, entitled "APPARATUS FOR CAPTURING, CONVERTING AND TRANSMITTING A VISUAL IMAGE SIGNAL VIA A DIGITAL TRANSMISSION SYSTEM" ("the '871 Patent").

3.   I provided a declaration that accompanied HTC's petition for *inter partes* review (IPR) in CASE IPR2014-00987, filed on June 9, 2014 ("HTC Petition"), as Exhibit 1006 (my "2014 Declaration"), which I incorporate by reference. My 2014 Declaration provides an explanation of my credentials and experience, the technology relevant to the '871 patent, and my opinions with respect to the '871 Patent.

4.   I understand that, on January 7, 2015, Samsung Electronics Co., Ltd. and Samsung Electronics America, Inc. filed an IPR petition under CASE IPR2015-00541 ("Samsung Petition") that is essentially a copy of the HTC Petition and which includes a copy of my 2014 Declaration. I also understand the Patent Trial and Appeal Board (PTAB) has ordered to join the IPR proceeding based on the Samsung Petition into the IPR proceeding based on the HTC Petition under CASE IPR2014-00987.

5.   I make this declaration to address issues raised in Patent Owner's ("PO") Response filed on February 20, 2015 (Paper 16, "PO Response"), and the Expert Declaration of Dr. Jose Luis Melendez (Exhibit 2001, "Melendez Declaration").

6.   This declaration is based on the information currently available to me, including the '871 Patent, the prosecution history for the '871 Patent, and the documents in IPR2014-00987 (including the prior art references and information discussed in this declaration and my 2014 Declaration, other references specifically identified in this declaration and my 2014 Declaration, and the PO Response (Paper 16), including the Melendez Declaration (Ex. 2001) and other exhibits). I also rely upon my education, experience and expertise in the relevant technologies and systems. If additional information becomes available, I reserve the right to continue my investigation and study.

II.   SUMMARY OF OPINIONS

7.   For the purpose of this declaration, I have been asked to provide facts, analysis and my opinions in response to specific arguments and evidence raised by the PO Response and the Melendez Declaration.

8.   As set forth in this declaration, as well as in my 2014 Declaration (*see* Exhibit 1006 at ¶¶ 79-108), it is my opinion that all of the limitations of claims 1-8 and 12-15 are taught or suggested by the combination of Wilska (Ex. 1002) and Yamagishi-114 (Ex. 1003).

9.   The PO Response and the Melendez Declaration address only certain limitations of independent claims 1, 6 and 12, a subset of all claims that are at issue in this IPR proceeding. It is my understanding that PO did not contest and therefore conceded that the remaining elements of claims 1, 6 and 12, as well as the remaining claims under review, including dependent claims 2-5, 7, and 13-15, are taught or suggested by the combination of Wilska and Yamagishi-114. In this declaration, I will address the issues related to the specific limitations of claims 1, 6 and 12 that were raised in the PO Response and the Melendez Declaration, but I reserve the right to further opine on additional limitations.

III.   QUALIFICATIONS AND EXPERIENCE

A.   Education and Work Experience

10.   A more detailed explanation of my educational and work credentials is provided in Paragraphs 11 through 20 of my June 9, 2014 declaration in Ex. 1006 and in my CV, which was included in Attachment A to Ex. 1006. I received a Master of Science degree and a Bachelor of Science degree in Electrical Engineering from the Massachusetts Institute of Technology in 1980. I completed my master's thesis research while working at Motorola Corporate Research Labs from 1978 through 1980, where I developed a system for transmitting a series of digital images from a moving vehicle over a wireless communications link to a base station.

11.   I spent over 30 years at Eastman Kodak Company and held a variety of positions including Chief Scientist, Chief Architect, Research Fellow, and Director. I was involved in numerous research and development projects related to wireless digital cameras and camera phones, beginning in 1994. I am also a named inventor on over 35 issued US patents which relate to wireless transmission of images from digital cameras. Examples of these patents include U.S. Patent No. 5,666,159, titled "Electronic camera system with programmable transmission capability," U.S. Patent No. 6,731,952, titled "Mobile telephone system having a detachable camera / battery module," and U.S. Patent No. 6,784,924, titled

"Network configuration file for automatically transmitting images from an electronic still camera."

12.   I have authored more than 50 presentations and papers, including invited talks on digital cameras in the US, Europe and Asia. I authored the "Digital Photography" chapter in the Consumer Digital Electronics Handbook by McGraw-Hill 1997, and co-authored the "Color Image Processing for Digital Cameras" chapter in the Digital Color Imaging Handbook; CRC Press 2003. I have also developed and taught Kodak internal courses on video technology and digital cameras.

13.   I am a named inventor on more than 200 issued United States patents. Most of these inventions related to digital cameras and digital photography systems, and have been broadly licensed by Kodak to more than 40 companies for use in digital cameras, smart phones, and photo sharing services. Licensing these patents provided Kodak with earnings of more than $2 Billion dollars from 2005 to 2010.

14.   I have served as Chair of the IT10 standards committee for digital photography since 1994. This group provides the officially recognized United States input for many international standards used by digital cameras, including smart phone digital cameras. In addition, from March 2007 through February 2013, I was chair of ISO technical committee 42 (ISO/TC42), which is responsible

for all international photography standards. In May 2013, I was elected chair of

the US technical advisory group to ISO/TC42. From June 3-7, 2013, I served as

head of the US delegation to the 23rd plenary meeting of ISO/TC42, held at the

National Museum in Copenhagen, Denmark.

15.   In short, I spent my career conducting digital imaging research,

inventing new technologies and features for digital cameras and digital

photography systems, developing industry standards used by current digital

cameras and smart phones, and designing a wide range of digital cameras and other

digital imaging products that were sold by Eastman Kodak Company

IV.   LEVEL OF ORDINARY SKILL IN THE ART

16.   As I explained in my 2014 Declaration, "it is my opinion that a person

having ordinary skill in the art would have at least a bachelor's degree in electrical

engineering, computer science, or a related field, and 3-5 years of experience in

designing digital imaging devices. This description is approximate and additional

educational experience in digital imaging could make up for less work experience

and vice versa." (Ex. 1006 at ¶ 28).

17.   In the Melendez Declaration (Ex. 2001), PO's expert states, "In

contrast to the declaration of Mr. Parulski . . . , I strongly disagree that a person

having no experience in the design of cellular communications devices could be a

POSITA" (Ex. 2001 at 31). PO's expert argued that "[c]ellular communication

systems have improved significantly, and rapidly, over the past decades and are highly complex, such that a person not skilled in the art area would be likely to overstate the capabilities of cellular systems and/or oversimplify them, and as such would not be able to effectively develop a product with capabilities as disclosed and claimed in the '871 Patent." (Ex. 2001 at ¶ 31). The statements by PO's expert do not correctly characterize the '871 patent, and misapprehend the statements in my 2014 Declaration.

18. First, the '871 patent provides no new teachings related to the design of cellular communications devices. It simply describes the use of conventional, well-known imaging related formats and protocols such as the well-known Group-III facsimile encoding and compression, and Group-III facsimile transmission protocol, JPEG and wavelet compression and PC modems. For example, there is no detailed discussion of the designs and capabilities of the cellular telephone which connects to the cellular interface 130 in FIG. 5; Figures 6A and 6B also only show a picture of a cellular telephone 164. The '871 patent treats the cellular telephone 164 as a mere add-on device "whereby the image data signal can be transmitted via the cellular telephone to a remote facsimile machine over standard cellular and telephone company facilities" (Ex. 1001 at 10:45-48).

19. Second, I do not agree with PO's expert that my definition of a POSITA excluded "experience in the design of cellular communications devices."

To the contrary, the definition I provided assumed that the person would have had

a sufficient level of familiarity and knowledge with communications devices

capable of transmitting digital image data.

20.　Finally, in the event that the Board finds that the level of skill that I

used is different than what has been suggested by the PO, my opinions regarding

the '871 patent would not change even under the PO's definition.

V.　CLAIMS 1-8 AND 12-15

A. All Limitations of Claims 1, 6 and 12 are Taught or Suggested by Wilska and Yamagishi-114

1.　Non-audio Digital Signals

21.　In the PO Response, PO contends that Wilska does not disclose the

limitation of "the wireless telephone being selectively operable to transmit and

receive non-audio digital signals, the non-audio digital signals including a selected

digitized framed image," as recited in claim 12, and that Wilska does not use "non-

audio" signals to transmit images because Wilska only describes using fax, which

uses "audio tones" rather than "non-audio" signals (Paper 16 at 8:10-21; see also

Melendez Declaration in Ex. 2001 at ¶¶ 38-39). I disagree, because PO's

contention contradicts the clear teachings in Wilska, as well as what is described in

the claims and detailed description of the '871 Patent with respect to claim 12.

22.　Based on my review of the '871 Patent specification, the term "non-

audio digital signal" is not used anywhere in the text or drawings. The prosecution

file history of the '871 Patent shows that PO added the term "non-audio digital signal" when adding a new independent claim 55 in an amendment filed on Jan. 6, 2005, in response to an office action, which later became issued claim 12.

23.   PO seems to contend that "non-audio digital signal" means a digital signal that is not transmitted or received by means of audio signals, and therefore excludes transmissions or receptions by a fax machine since such transmissions use audio signals "as recognized by anyone who has answered a call from a fax machine and heard audio tones" (id. at 8:10 to 9:1). PO's interpretation of "non-audio digital signal" is inconsistent with the language of claim 12, which shows that "non-audio digital signal" refers to what is being transmitted, not how data is being transmitted. For example, claim 12 recites one type of a non-audio digital signal by stating "the non-audio digital signals including a selected digitized framed image."

24.   PO's interpretation of a "non-audio digital signal" also ignores a large portion of the '871 Patent specification that describes embodiments that use Group-III fax, which uses so-called "audio tones" as described by the PO (*see* Ex. 1001, 5:2-59, 6:15-49; 7:3-48; 8:53-65; 9:17-30; 10:5-25; 10:61-67).

25.   Notably, claim 12 does not place any specific requirements or restrictions on the transmission method that the recited wireless telephone uses to transmit non-audio digital signals, which include a selected digitized framed

image. For example, there is no requirement in claim 12 that the non-audio digital

signals be transmitted using carrier signals outside the audible range, or that the

digitized audio signals be transmitted using carrier signals inside the audible range.

The relevant portion in Claim 12 recites:

> [T]he wireless telephone being selectively operable to accept and digitize
>
> audio signals to be transmitted, the wireless telephone being selectively
>
> operable to convert received digitized audio signals into acoustic audio, the
>
> wireless telephone being selectively operable to transmit and receive non-
>
> audio digital signals, the non-audio digital signals including a selected
>
> digitized framed image.

26.   The first part of the above portion of claim 12 relates to acoustic

audio, and states that the wireless telephone is "selectively operable to convert

received digitized audio signals into acoustic audio." This feature implies that the

digitized audio signals are not audible and must be converted into acoustic audio in

order to be audible, but this feature is separate from the reception or transmission

of non-audio digital signals. It is common engineering knowledge that an analog

audio signal is sampled by an Analog to Digital Converter (ADC) circuit at a

certain selected sampling rate (e.g., 44.1 KHz for digital sound for audio CD,

48KHz for digital sound for standard DVD and 96KHz for digital sound for Blu-

Ray DVD) to convert the analog signal into a digitized audio signal. Such

digitized audio signals are not audible signals, and need to be converted back into analog signals, to produce audible sound.

27. Regardless, as shown in my 2014 Declaration, Wilska discloses the claimed "non-audio digital signals" under both (1) my interpretation of the term, which focuses on the underlying data being transmitted, and (2) PO's contended interpretation, which focuses on the transmission protocol used to transmit the underlying data.

28. My 2014 Declaration explains that Wilska describes transmitting and receiving non-audio digital signals, such as digitized framed images captured by a camera, in various ways or formats, e.g., a bitmap format, emails and fax (Ex. 1002 at 5:22 to 6:2; 9:28 to 10:7; 12:23-26; 13:2-18; 13:25-27; Ex. 1006 at ¶¶ 80, 91 and Table 1). My 2014 Declaration also explains that Wilska describes an implementation where "cellular mobile phone unit 17 of the notebook computer and the related cellular mobile phone controller 8 are implemented as a digital GSM system" (Ex. 1002 at 13:20-21; Paper 1 at 20:5-6). As explained in my 2014 Declaration, Wilska describes that email functionality can be implemented in such a digital GSM system (Ex. 1002 at 13:29-30). For example, Wilska explains that "text or a figure written or drawn on digitizer pad 29 . . . can be stored later as an image in memory unit 13" (i.e., in the form of a bitmap) (Ex. 1002 at 12:15-17; *see also id.* at 11:29-32), and that "[t]he bitmap images . . . can be later forwarded via

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telefax or electronic mail services" (*id.* at 12:23-26). Because Wilska teaches that images captured by camera unit 14 are also stored in memory 13 as bitmap images, and makes no distinction between bitmap images representing an image captured by a camera and bitmap images representing text or figures written or drawn on a digitizer pad, a POSITA would have understood that Wilska teaches that any bitmap image stored in memory 13 can be transmitted via electronic mail, including a bitmap image that represents an image captured by camera unit 14.

29.   Therefore, with respect to the claim term "non-audio digital signals," under my interpretation, my 2014 Declaration explains that Wilska teaches or suggests wireless transmission of non-audio signals, including digital images, and therefore discloses "the wireless telephone being selectively operable to transmit and receive non-audio digital signals," as recited in claim 12. Examples in Wilska as cited in my 2014 Declaration include a digital GSM network, a bitmap format, emails and fax.

30.   Under PO's interpretation as "a digital signal which has been transmitted or received using a transmission or reception technique that does not use audio tones or audio signals," my 2014 Declaration provides specific citations in Wilska for disclosing transmission of images using non-audio digital signals, e.g., disclosing wireless telephone transmission of images using non-audio digital signals via email and a digital GSM network. (Ex. 1006 at ¶¶ 86, 93,; Ex. 1002 at

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13:20-21.) I also explained in my 2014 Declaration that Wilska discloses a GSM

modem, which uses digital modulation and network level architectures and

services (Ex. 1006 at ¶¶ 86, 93, 96; Ex. 1002 at 13:20-21).

31.   Also, a person of ordinary skill in the art at the time of filing of the

'871 Patent in 1998 would have understood that the digital modulation used in

GSM clearly does NOT use "audio tones."

32.   I described in my 2014 Declaration (Ex. 1006 at ¶ 61) that Global

System for Mobile (GSM) was introduced in Europe in 1991 in order to provide a

unified cellular telephony standard and a wide range of network services. The

well-known textbook by Rappaport referenced in my 2014 Declaration (*id*.)

describes some of the features of GSM. In order to respond to the specific points

raised by the Melendez Declaration regarding GSM's inability to transmit image

data, certain relevant sections of the Rappaport book are reproduced in

Attachment AA to this declaration. As corroborated by these excerpts from

Rappaport's textbook, "the GSM standard is gaining worldwide acceptance as the

first universal digital cellular system with modern network features extended to the

mobile user" (**Attachment AA** at 4, "page 9"), "GSM is the world's first cellular

system to specify *digital modulation* and *network level architectures and*

services" (*id*., emphasis added), and "Figure 10.5 shows the block diagram of the

GSM system architecture" (*id*. at 8, "page 503"). This figure, reproduced below,

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shows that mobile stations (MS) can communicate with ISDN and other data

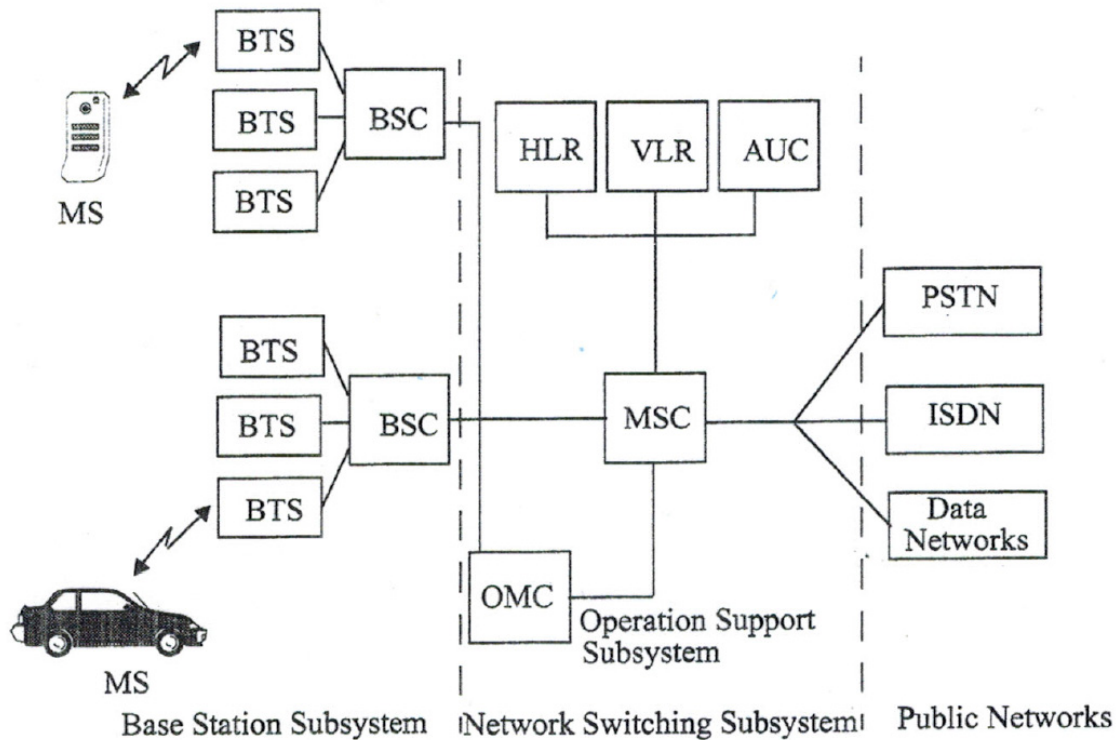networks using the GSM system.

Figure 10.5
GSM system architecture.

33.   The 1994 description in Wilska (a UK Patent filed by the European

Company Nokia) postdates the 1991 introduction of GSM in Europe by several

years. Therefore, the "digital GSM system" of Wilska (Ex. 1002 at 13:20-21)

would have been well understood by a POSITA to use digital transmission

technologies capable of transmission and reception of both speech and data, as

depicted in Figure 10.5 of Rappaport shown above.

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34.   As explained in the Petition and in my 2014 Declaration, Wilska also teaches transmission of images using email, and describes that captured images are stored "in the form of a bitmap" (Ex. 1002 at 9:23-24), and that "bitmap images . . . can be later forwarded via . . . electronic mail services" (id. at 12:23-27) (Ex. 1006 at ¶¶ 85-86, 91-92). Also, attaching image files to an email message was a well-known method of transmitting images over networks.

2.   "Visual Image Transmission"

35.   In the PO Response, PO contends that claims 1-8 require "transmitting a captured visual image" rather than "the transmission of fax data merely derived from the image" (Paper 16 at 10:14-20; see also Ex. 2001 at ¶¶ 43-50). I disagree for reasons that are explained below.

36.   Claim 1 simply recites transmitting an "image data signal" and claim 6 simply recites transmitting the "digitized framed image." There is no limitation in claim 1 or 6 that qualifies the quality of the visual images that can be reproduced using the transmitted image or that restrict the transmissions to only non-fax transmissions.

37.   The detailed description of the '871 Patent is almost entirely devoted to a description of various embodiments which employ Group-III fax. As admitted by PO (Paper 16 at 12:6-8; 14:15-19; Ex. 2001, ¶¶ 43-45), all of such Group-III fax transmissions in the '871 Patent must also transmit "fax data merely derived from

the image," and therefore also do not meet the limitations in claims 1-8, according

to the PO's interpretation. This interpretation is unreasonable since it excludes the

Group-III fax processing and transmission path that is in each of Figures 1 to 5 of

the '871 patent, including the admittedly representative embodiment of Figure 4

(Ex. 2001 at ¶ 37).

38.   Additionally, the PO Response and Melendez Declaration do not

describe any way of obtaining an "image data signal" or "digitized framed image"

that is NOT "merely derived from the image." Each of the formats A-D in Fig. 4

of the '871 Patent are compressed (for example by JPEG compressor 62, wavelet

compressor 66 or compatible compressor 67) before the signal is introduced to the

communications interface module 83 (Ex. 1001 at 7:23-36; Figure 4). It is well

known that baseline JPEG compression uses a lossy compression technique (see

Attachment BB at 3 to 6, "pp. 9.2-9.5"). Baseline JPEG compression uses the

discrete cosine transform (DCT) to convert blocks of image data into DCT

coefficients, which are coarsely quantized in order to provide a high compression

ratio. When the resulting JPEG-compressed image data is decompressed at the

receiver, these quantization errors degrade the reproduced image, resulting in the

loss of some of the original visual image data, which cannot be recovered.

Therefore, the communications interface module 83 receives "data merely derived

from the image" using every specific format described in the '871 patent for transmission through the communication channel 32.

39.   Further, even under PO's interpretation, Wilska describes an embodiment which transmits a "captured visual image" since Wilska teaches transmission of images using email attachments over digital GSM networks (as an alternative to telefax) (Ex. 1002 at 13:20-21, 13:29-30; Paper 1 at 20:5-6, 35:16), which was a well-know approach to transmitting digital images.

40.   Wilska also states that fax images (bitmap files) can be reproduced on a receiving mobile device for viewing (Ex. 1002 at 10:2-7; Paper 1 at 35:7-8), which once again contradicts the PO's characterization of Wilska that the "fax" signals that are transmitted by Wilska's device cannot be used to reconstruct the visual image (Paper 16 at 13:12-15).

3.   Motivation to Combine

41.   PO argues that (1) "the manner in which Wilska implements such digital camera and portable wireless telephone functionality is critically different" than the manner in which Yamagishi-114 implements it (Paper 16 at 17:13-18), and (2) "the proposed combination would require change in the principle of operation of Wilska," since "[h]aving the central processor 6 of Wilska continually active for enabling the viewfinder functionality . . . is at direct odds with the admitted essential functionality of Wilska having a specific division of processing

image information between a main unit processing element and a camera

processing unit element" (Paper 16 at 43:14 to 44: 11, 46:17 to 47:6).

42.   The Melendez Declaration further argues that (3) concerning the steps

for using the viewfinder described by Yamagishi-114, "[t]he complexity of these

processes cast doubt on the physical ability of combining them with Wilska's

processes for recording and transmitting images" (Ex. 2001 at ¶ 51), and that (4)

"usage of the telephone and a camera functions are wholly separate" (id. at ¶ 52) in

Yamagishi-114 and that "[t]his separation of telephone and imaging functionality

discourages any combination of Yamagishi" (id.) with Wilska.

43.   I disagree with the above assertions by the PO and Dr. Melendez. To

explain Wilska's implementation, the PO cites extensively from a reexamination

proceeding concerning a patent related to Wilska, which began in 2012, including

an office action dated June 14, 2014, and implies that a POSITA in 1998 would

have understood the teachings of Wilska in light of what the PO wrote more than a

decade later during reexamination of a different patent. Clearly a POSITA in 1998

would not have had access to this material, and could rely only on the information

in the published Wilska patent application.

44.   Even if the arguments made in 2014 had instead been made in 1998,

they pertain only to the specific claims in the reexamined patent that required two

processors (see Ex. 2002, claim 1 in U.S. 6,427,078 C1 and claim 73 in 6,427,078

B1). Wilska's patent owner was simply attempting to persuade the patent office

that these two-processor claims should be found patentable over prior art that

disclosed only one processor. These arguments cannot be generalized to

characterize the entire disclosure of Wilska, nor do they suggest that Wilska's

device could not have operated using only a single processor. To the contrary,

every claim of Wilska (Ex. 1002 at 15:2-7) is directed to a device which includes

only a single data processing unit (2). There is no requirement in any of the claims

that the device include a second processing element (e.g. microprocessor 23).

Therefore, it is clear that using two processing elements is not the principle of

operation of Wilska.

45.   As the PO admits, "Wilska and Yamagishi both include disclosure

relating to implementation of devices that can function as both a digital camera and

a portable wireless telephone" (Paper 16 at 17:13-15). A POSITA would have

understood that the number of processing elements used in a combination camera /

wireless telephone is merely a design choice, and that the features performed by a

single processing element could be split between two or more processing elements

for a variety of reasons, including the availability and capabilities of existing

components.

46.   Even if the PO's assertions are taken at face value, that Wilska

offloads some of the processing to a second processor to keep the main

"microprocessor . . . free to handle the other tasks of the cell phone, e.g., operating system management, application processing, call control" and that "[k]eeping the microprocessor free to handle the last of these tasks can be particularly advantageous because the user interface signals are often time-sensitive" (Paper 16 at 25:4-20), such statements simply confirm that Wilska's division of processing was a design choice that was made based on economic considerations to avoid using a single, high-performance processor for handling all the required operations, which likely would have been more expensive and would have dissipated more power. Furthermore, processors in January of 1998 (i.e., the alleged priority date of the '871 Patent) were considerably more powerful than those in 1994, when Wilska's patent was filed (see, for example, **Attachment CC** at 5, "page 42, Figure 1.16," which shows a more than five fold growth in processor performance between 1994 and 1998). Therefore, a POSITA in 1998 would have known that a more powerful processor could have been used to avoid the time delay issues that Wilska's device may have faced using processors available in 1994.

47. Such design choices and economic considerations in no way represent the essential principle of operation of Wilska (as alleged by the Patent Owner response and Melendez Declaration), and do not alter the principles of image capture and processing operations that could have been carried out by Wilska's device. More importantly, having a single or a multi-processor design would not

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have prevented a POSITA from combining the relevant features of the devices of

Wilska and Yamagishi-114.

48.   In my opinion, both Wilska and Yamagishi-114 disclose devices

having multiple processors. Fig. 1 of Yamagishi-114 shows both image pickup

control 40, which "denotes an image pickup control circuit for controlling the

whole of the image pickup means" (Ex. 1003 at 4:35-36), and control 60, which

"denotes control means for controlling the whole information processing apparatus

300" (Ex. 1003 at 5:6-7). Contrary to the assertions in the PO Response and the

Melendez Declaration, a POSITA would have recognized a strong similarity

between the processing elements described in Wilska and Yamagishi-114. Both

include two types of processors, one which controls the camera hardware

components (microprocessor 23 in Wilska and image pickup control 40 in

Yamagishi-114) and a second which is responsible for the high-level control of the

device (central processor 4 in Wilska and control 60 in Yamagishi-114). There is

simply no merit to PO's argument that Wilska and Yamagishi-114 use "entirely

different processing element" structures (Paper 16 at 32:11-13).

49.   The Melendez Declaration further argues that concerning the steps for

using the viewfinder described by Yamagishi-114, "[t]he complexity of these

processes cast doubt on the physical ability of combining them with Wilska's

processes for recording and transmitting images" (Ex. 2001 at ¶ 51). However, the

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Melendez Declaration does not describe which processes in Yamagishi-114 are particularly complex, or what physical feature prevents them from being combined with Wilska's processes or features. Wilska describes a small, portable, device which includes a camera and a cellular mobile phone unit. Pictures captured by the camera can be viewed immediately on a display. Because the device does not include an optical viewfinder, a POSITA would have understood that the display 9 necessarily serves as an electronic viewfinder when capturing images (Ex. 1006 at ¶ 80). Yamagishi-114 describes in detail how an LCD display is used as a viewfinder, which is also an inherent functionality of the LCD display in Wilska. A POSITA would have been motivated to apply the teachings of Yamagishi-114 to Wilska's device in order to display images as they are being framed using the "through-mode" described by Yamagishi-114, or after they have been captured and stored using the "monitor-mode" described by Yamagishi-114, or to simultaneously display a "through-mode" window and a "monitor-mode" window on the LCD display of the Wilska device (id. at ¶ 82).

50. There are many ways that a POSITA would have been able to utilize the existing components of Wilska to implement the through-mode functionality of Yamagishi-114. For example, a POSITA would have understood that the "through-mode" processing described by Yamagishi-114 could be implemented using one or both of microprocessor 23 or central processor 4. Displaying the

image framed by the camera 14 on the display 9 would provide an electronic viewfinder, which a POSITA would have recognized as a critical feature in a digital camera, which is necessary in order to compose the image.

51.   In Wilska, the data processing unit 2, which includes central processor 4, also includes display controller 6, which provides the data to display 9. A POSITA would have understood that one of several ways to implement the "through-mode" described by Yamagishi-114 using the hardware in Wilska would be using the microprocessor 23 to perform image processing in order to generate the image data signal representing the image framed by the camera 14, and to provide this image data signal to the display 2 via the IO-controller 5 and the display controller 6. Based on this design choice, there would have been no need for the central processor 4 to perform image processing in the "through-mode." Thus, a POSITA would have clearly understood that the camera unit processing element (i.e. microprocessor 23) could perform the "through-mode" image processing, keeping the main unit processing element (i.e. central processor 4) free to handle other tasks. In this example, a POSITA would not have doubted the physical ability of the microprocessor 23 to perform all of the processes used in the "through-mode" described by Yamagishi-114.

52.   The Melendez Declaration argues that "usage of the telephone and camera functions are wholly separate within Yamagishi's description" (Id. at ¶ 52)

in Yamagishi-114 and that "[t]his separation of telephone and imaging

functionality discourages any combination of Yamagishi with Wilska's imaging

and transmission functionality" (id.). I disagree, since both Wilska and Yamagishi-

114 provide combinations of digital cameras and mobile phones which are

intended to be used for only one purpose at a time. Yamagishi-114 can be used as

a mobile phone to make and receive phone calls, or as a digital camera to capture

images, but cannot simultaneously capture an image while making a phone call

(Ex. 1003 at 18:36-45). Wilska's specification does not state or imply that its

phone and camera are used simultaneously. A POSITA would have therefore

recognized that the cited statement in Yamagishi-114 regarding the use of phone

and camera functionality one at a time (id.) is also applicable to Wilska, since a

POSITA would have understood that the camera unit 14 can be turned off when a

phone call is being made. The cited statement would certainly not have

discouraged a POSITA from combining Wilska and Yamagishi-114.

53.   Non-simultaneous use of phone and camera functionalities is also

described in the '871 patent:

With specific reference to the circuitry associated with relay 112, **it will be**

noted that when the handset is switched away from the phone line to the

tone source, the modem transformer 110 is switched to the telephone

line 114. This blocks normal audio telephone service and permits the

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transmission of an image signal from the RAM devices 71 or 72,

through the modem 104, and to the telephone line 114 (Ex. 1001 at: 9:10-

16; emphasis added).

In sum, and as provided in my 2014 Declaration, the combination of Wilska and

Yamagishi-114 teaches or suggests each of claims 1, 6 and 12 (Ex. 1006 at ¶¶ 79-

108 and Table 1). A POSITA would have been motivated to modify the device of

Wilska to include the above discussed features of Yamagishi-114 in order to

provide an electronic viewfinder, which is a critical function in a digital camera.

The PO Response and Melendez Declaration do not provide any credible evidence

or arguments to the contrary.

B.   Responses to Specific Arguments in Melendez Declaration

54.   The Melendez Declaration asserts that Wilska is "a rudimentary

camera envisioned to convert visual images into telefax data" and "[t]he camera is

envisioned as an alternate means for inputting text by a scanner" (Ex. 2001 at ¶ 9).

To the contrary, Wilska discloses a "small, portable workstation" (which today

would be called a smart phone - see Ex. 1006 at ¶ 85) for taking photos of people

and normal scenes, not just documents, and which states that "[t]his data collection

unit can be used to transfer data presented on paper or the like **as well as an image**

taken of the surroundings, for instance of a person" (Ex. 1001 at 5:5-7,

emphasis added), and that "a picture of a document **or three-dimensional**

environment taken by camera 14a through optics 14b is transferred to image processing unit 14c" (Id. at 7:21-16, emphasis added).

55.   The Melendez Declaration further asserts, in reference to my 2014 Declaration, that "Parulski . . . appears to suggest (¶31) that transmitting digital images over "conventional communications channels" would have been trivial in 1977, yet offers no explanation as to why smartphones . . . did not exist even over two decades later" (Ex. 2001 at ¶ 32). My 2014 Declaration does not state that "transmitting digital images would have been **trivial** in 1977" (Ex. 1006 at 31). Rather, it states that "Mr. Sasson recognized that images from electronic cameras could be sent over conventional communication channels with little or no modification" (*id.*). In other words, Mr. Sasson recognized that one advantage of an electronic camera was the ability to send captured images over existing communications channels (such a phone lines) to remote locations. Clearly, by 1977 facsimile machines (including digital fax machines) were already using these communications channels to transmit scanned documents which could include images.

56.   The Melendez Declaration further claims that the statement in my 2014 Declaration that "[w]ithout expert knowledge as to limitations of cellular transmission in late 1990s, one could imagine . . . that cellular systems at the time of the '871 invention were capable of transmitting anything, which is simply not

true" (Ex. 2001 at 33). Dr. Melendez never states what exactly these cellular systems were NOT capable of transmitting. GSM, which is used in Wilska, was among the world's first cellular systems to specify digital modulation and network level architectures and services (see ¶ 32 above). The GSM network was designed in a way that it could support not just digital images, but also videotelephony. By 1995, videophones using GSM had been demonstrated by GSMA and discussed in the literature (see, for example, the IEEE article in **Attachment DD**, which discusses video transmissions using GSM and other cellular networks - e.g., page 305, right hand column). Even as far back as 1993, the spread spectrum modulation technique used in CDMA (code division multiple access) cellular systems also was capable of transmitting digital data such as video and facsimile (see, for example, US Patent No. 5,581,575, in **Attachment EE**, which describes the use of CDMA spread spectrum techniques for transmitting digital data such as video - e.g., at 1:17-27 and 5:25-29). This objective evidence is contrary to the Melendez Declaration's assertions that transmission of images via wireless telephone networks was a novel concept at the time of filing of the '871 Patent in 1998.

57. Another assertion in the Melendez Declaration is that "[i]t would be critical for a patent reference such as . . . Wilska and Yamagishi to provide an enabling disclosure of how to achieve an integrated digital cellular camera

telephone, which they do not" (Ex. 2001 at ¶ 34). Dr. Melendez does not state

what is lacking in either Wilska or Yamagishi, nor does he specifically describe

where the '871 patent provides such an enabling disclosure. As admitted by PO, in

the configuration shown in FIG. 6B of the '871 Patent, "the image data signal can

be transmitted via the cellular telephone to a remote facsimile machine over

standard cellular and telephone company facilities" (Ex. 1001 at 10:45-48) using

"any of a variety of widely available modems or modem chip sets currently in

commercial use" (id. at 8:53-55). Thus, PO admits that transmission of images via

a wireless network could have been simply attained by off-the-shelf modem chips

using standard cellular phone capabilities. Regardless, both Wilska and

Yamagishi-114 devote large sections of their disclosures to describing the

constituent components within their mobile devices and how different circuits

interact with one another to provide picture taking, image processing and image

communication operations (e.g., Ex. 1002 at 3:17 to 7:19, Figures 1-5; Ex. 1003 at

4:11 to 6:5, 10:1 to 12:14, 18:11-45, Figures 1-3, 6 , 8, 13 and 14).

58.   The Melendez Declaration further asserts that "Figure 4 of the '871

patent is particularly instructive as it demonstrates a variety of embodiments of the

'871 Patent in addition to the G-III protocol that specifically include several

compression and transmission protocols that are capable of being 'reversed' at the

receiver in order to extract the captured framed image (52 in Figure 4 of '871) at

the recipient device (unlike for a fax, as will be discussed later herein)" (Ex. 2001

at ¶ 37). First, Dr. Melendez is referencing component 52 in Figure 4, which is

labeled "operator capture," and is described in the '871 specification as "operator

interface/capture interface 52" (Ex. 1001 at 6:34-37). This component does not

appear to have any relevance to the "reversibility" of captured images.

59.   Second, what Dr. Melendez calls the "G-III protocol" is described in

the '871 patent as "Group-III facsimile" (Ex. 1001 at 1:41-42) or "Group-III fax"

(*id.* at 2:15). This is further confirmed by the specification of the '871 patent,

which states: "The versatile capability of the system permits **transmission of**

captured data to a **standard bi-level facsimile machine such as Group III"** (Id.

at 2:39-40, emphasis added). It is unclear why Dr. Melendez points to Figure 4 as

a representative illustration of the challenged claims, yet at the same time attempts

to exclude from the challenged claims the facsimile transmission path. Finally,

and most tellingly, Dr. Melendez does not indicate which of the "several

compression and transmission protocols" are capable of being reversed, or exactly

what "reversed" means. For example, he does not state how JPEG compression is

capable of being reversed. As discussed earlier in this Declaration (see ¶ 38),

baseline JPEG compression is a lossy compression technique, and results in an

irreversible loss of some data.

60.   The Melendez Declaration also states that "'standard' cellular technologies at the time of Wilska did not support Multimedia Messaging Service (MMS)" and that "[m]aking the assumption that such descriptions [in Wilska] include image transmission would be inconsistent with the absence of MMS at the time of Wilska" (Ex. 2001 at ¶ 40). This statement, however, is based on the erroneous assumption that MMS is a requirement for wireless transmission of images using standard cellular technology. MMS is certainly not the only way to transmit images over cellular communications networks. For one, Wilska states that "bitmap images . . . can be later forwarded via . . . electronic mail services" (Ex. 1002 at 12:23-26). The transmission of digital images as attachments to email messages was widely known at the time.

61.   In addition, a POSITA at the time would have known that GSM supported email and images. For example, the Nokia 9000 communicator, launched in Europe in 1996 (which is 2 years prior to the priority date of the '871 Patent), used GSM and supported a graphical web browser (see, for example, **Attachment FF**, which provides an overview of Nokia 9000 features and capabilities) and its manual made it clear that email attachments could include images (see **Attachment GG**, specifically at 55, "page 7-9," right hand column, the subheadings "Menu" and "Attachments," which describe how email attachments can be any one of text, image, audio, video or application, and can be

forwarded to another recipient). The Nokia 9000 communicator could also

connect to the World Wide Web (WWW) over GSM and automatically download

JPEG and GIF format images included as part of web pages (see id. at 57, "page 7-

11," right hand column, the subheading "Autoload images"). Additionally, GSM

"Phase 2 data/fax bearer services" were launched in 1994, and video over GSM

was demonstrated in 1995, according to GSMA, the trade association of over 800

mobile operators (see **Attachment HH**). These examples, which are introduced

here to explicitly rebut the assertions made by the Patent Owner and Dr. Melendez,

illustrate that GSM-enabled mobile devices with email and image attachment and

transmission capabilities were well known (and even commercially available)

several years prior to the 1998 priority date of the '871 Patent.

62.   In 1993, several years before the 1998 priority date of the '871 patent,

AT&T introduced EO 440 Communicator, which was a portable, hand-held device

with handwriting-recognition technology and wireless FAX, email, and cell phone

capabilities (see **Attachment II**, which provides an overview of EO 440

Communicators functions and capabilities). EO 440 was capable of sending and

receiving emails, in addition to sending and receiving faxes using Group III

protocol (id.). Using the fax option, a digitized image (an electronic picture) of the

contents of a page could be transmitted to another fax recipient (such as another

EO 440 device) either via landline or through cellular transmission. In the email

option, the EO 440 Communicator allowed a user to include attachments in

different file formats that including text, ASCII and TIFF files (see, for example,

Attachment JJ, "pages 96, and 103 and 105-106" of the Lookup Guide). TIFF is

a tag-based file format for storing and interchanging raster images (see

Attachment KK at 4). The email, including the attached file, could then be

transmitted using standard cellular technology to any recipient with an email

address (see, for example, **Attachment LL**, which is a newspaper advertisement

highlighting some of the EO 440's features). The EO 440 is another example that I

am introducing in this declaration to rebut PO's and Dr. Melendez's assertion that

the wireless transmission of images was not possible in the mid-1990s. To the

contrary, based on the commercial availability of devices such as EO 440 in 1993,

a POSITA would have known that the wireless transmission of digitized images

was well known many years prior to the 1998 priority date of the '871 Patent.

63.   The Melendez Declaration further states that the "Preamble requires

that the apparatus of Claim 1 be capable of transmitting a captured visual image,

exemplified by the phrase 'for capturing a visual image and transmitting it,"

"eliminating from the purview of Claim 1 the transmission of fax data merely

derived from the image" (Ex. 2001 at ¶ 43). This is an extremely narrow

interpretation, with no support in the '871 specification. The '871 specification is

almost exclusively a description of Group III fax (e.g., "According to

embodiments, a system is particularly well suited for sending and/or receiving images via a standard Group III facsimile transmission system" (Ex. 1001 at 5:2-5)). Dr. Melendez contends that fax data is "merely derived" from the image, but does not cite any supporting passage in the '871 patent. For example, there is nothing in the '871 specification that describes any difference between Group III fax and JPEG compression (or any of the other format select interface switch 60 options) that would indicate that option A (fax) is "merely derived" from the captured visual image while other options are not. Dr. Melendez does not explain which switch 60 options he believes fall within the purview of the challenged claims, and which do not. Clearly Dr. Melendez believes that Group III fax is outside the purview of the claims, for the reasons stated in paragraphs 44 and 45 of the Melendez Declaration. But what about JPEG compression? Baseline JPEG data is NOT the original visual image, it is also "derived" from the image, and cannot be used to exactly recover the captured image due to lossy compression resulting from the coarse quantization of the DCT coefficients (see also ¶¶ 38 and 59 of this Declaration).

64.   The Melendez Declaration further asserts that "[a] fax transmission … required a one-way permanent transformation of a captured image into fax data represented as a series of tones (signals) that could be transmitted over a telephone line and interpreted by a recipient fax machine into a black and white derivative of

the captured image, but could never be used to recover the captured image itself"

(Ex. 2001 at ¶ 45). This statement seems to imply that the claims require a

received image to be in color. Yet, there are no claim limitations that preclude

having a black-and-white image. Further, the '871 specification describes systems

that transmit only black-and-white images, stating: "While a system for black and

white (gray tones) for Group-III facsimile transmission is described in detail

herein, the invention could be readily adapted to transmission of color images"
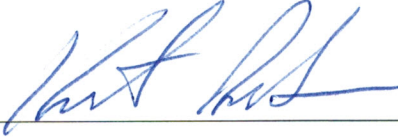
(Ex. 1001 at 5:13-15).

65.   The Melendez Declaration also states that "Wilska's brief mentions of

'electronic mail' are clearly for text" (Ex. 2001 at ¶ 46). This is wrong. As

discussed above in this Declaration, Wilska clearly states that "bitmap images . . .

can be later forwarded via . . . electronic mail services" (Ex. 1002 at 12:23-26),

GSM is capable of transmitting electronic mail, and it was well-known that images

could be transmitted as email attachments.

66.   I hereby declare that all statements made in this declaration are based

on my own knowledge and are true based on information and belief, and that all

statements were made with the knowledge that willful false statements and the like

are punishable by fine or imprisonment, or both under 18 U.S.C. 1001.

67.   I declare under the penalty of perjury that the following is true and

correct.

Executed on April _20_ , 2015 in _ROCHESTER, NY_.

_____

KENNETH PARULSKI

Wireless Communications

Principles and Practice

Theodore S. Rappaport

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Table 1.2 Major Mobile Radio Standards in Europe

Standard	Type	Year of Intro-duction	Multiple Access	Frequency Band	Modula-tion	Channel Bandwidth
E-TACS	Cellular	1985	FDMA	900 MHz	FM	25 kHz
NMT-450	Cellular	1981	FDMA	450-470 MHz	FM	25 kHz
NMT-900	Cellular	1986	FDMA	890-960 MHz	FM	12.5 kHz
GSM	Cellular /PCS	1990	TDMA	890-960 MHz	GMSK	200 kHz
C-450	Cellular	1985	FDMA	450-465 MHz	FM	20 kHz/ 10 kHz
ERMES	Paging	1993	FDMA	Several	4-FSK	25 kHz
CT2	Cordless	1989	FDMA	864-868 MHz	GFSK	100 kHz
DECT	Cordless	1993	TDMA	1880-1900 MHz	GFSK	1.728 MHz
DCS-1800	Cordless /PCS	1993	TDMA	1710-1880 MHz	GMSK	200 kHz

Table 1.3 Major Mobile Radio Standards in Japan

Standard	Type	Year of Introduction	Multiple Access	Frequency Band	Modula-tion	Channel Bandwidth
JTACS	Cellular	1988	FDMA	860-925 MHz	FM	25 kHz
PDC	Cellular	1993	TDMA	810-1501 MHz	$\pi/4$-DQPSK	25 kHz
NTT	Cellular	1979	FDMA	400/800 MHz	FM	25 kHz
NTACS	Cellular	1993	FDMA	843-925 MHz	FM	12.5 kHz
NTT	Paging	1979	FDMA	280 MHz	FSK	12.5 kHz
NEC	Paging	1979	FDMA	Several	FSK	10 kHz
PHS	Cordless	1993	TDMA	1895-1907 MHz	$\pi/4$-DQPSK	300 kHz

data and voice transmissions for office and business users. In the U.S., the PACS standard, developed by Bellcore and Motorola, is likely to be used inside office buildings as a wireless voice and data telephone system or radio local loop. The Personal Handyphone System (PHS) standard supports indoor and local loop applications in Japan. Local loop concepts are explained in Chapter 9.

The world's first cellular system was implemented by the Nippon Telephone and Telegraph company (NTT) in Japan. The system, deployed in 1979, uses 600 FM duplex channels (25 kHz for each one-way link) in the 800 MHz band. In Europe, the Nordic Mobile Telephone system (NMT 450) was developed in 1981 for the 450 MHz band and uses 25 kHz channels. The Extended European Total Access Cellular System (ETACS) was deployed in 1985 and is virtually identical

to the U.S. AMPS system, except that the smaller bandwidth channels result in a slight degradation of signal-to-noise ratio (SNR) and coverage range. In Germany, a cellular standard called C-450 was introduced in 1985. The first generation European cellular systems are generally incompatible with one another because of the different frequencies and communication protocols used. These systems are now being replaced by the Pan European digital cellular standard GSM (Global System for Mobile) which was first deployed in 1991 in a new 900 MHz band which all of Europe dedicated for cellular telephone service [Mal89]. As discussed in Chapter 10, the GSM standard is gaining worldwide acceptance as the first universal digital cellular system with modern network features extended to each mobile user, and is a strong contender for PCS services above 1800 MHz throughout the world. In Japan, the Pacific Digital Cellular (PDC) standard provides digital cellular coverage using a system similar to North America's USDC.

1.4   Examples of Mobile Radio Systems

Most people are familiar with a number of mobile radio communication systems used in everyday life. Garage door openers, remote controllers for home entertainment equipment, cordless telephones, hand-held walkie-talkies, pagers (also called paging receivers or "beepers"), and cellular telephones are all examples of mobile radio communication systems. However, the cost, complexity, performance, and types of services offered by each of these mobile systems are vastly different.

The term *mobile* has historically been used to classify *any* radio terminal that could be moved during operation. More recently, the term *mobile* is used to describe a radio terminal that is attached to a high speed mobile platform (e.g. a cellular telephone in a fast moving vehicle) whereas the term *portable* describes a radio terminal that can be hand-held and used by someone at walking speed (e.g. a walkie-talkie or cordless telephone inside a home). The term *subscriber* is often used to describe a mobile or portable user because in most mobile communication systems, each user pays a subscription fee to use the system, and each user's communication device is called a *subscriber unit*. In general, the collective group of users in a wireless system are called *mobiles* or *users*, even though many of the users may actually use portable terminals. The mobiles communicate to fixed *base stations* which are connected to a commercial power source and a fixed *backbone network*. Table 1.4 lists definitions of terms used to describe elements of wireless communication systems.

Mobile radio transmission systems may be classified as *simplex, half-duplex* or *full-duplex*. In simplex systems, communication is possible in only one direction. Paging systems, in which messages are received but not acknowledged, are simplex systems. Half-duplex radio systems allow two-way communication, but use the same radio channel for both transmission and reception. This

10.2.2 United States Digital Cellular Derivatives (IS-94 and IS-136)

The added networking features provided in IS-54 have led to new types of wireless services and transport topologies. Because TDMA provides MAHO capability, mobiles are able to sense channel conditions and report these to the base station. This, in turn, allows greater flexibility in cellular deployment. For example, MAHO is used to support dynamic channel allocation which can be carried out by the base station. This allows an MSC to use a larger number of base stations placed in strategic locations throughout a service area and provides each base station with greater control of its coverage characteristics.

The IS-94 standard exploits capabilities provided by IS-54, and enables cellular phones to interface directly with private branch exchanges (PBX). By moving the intelligence of an MSC closer to the base station, it becomes possible to provide wireless PBX services in a building or on a campus, while using small base stations (microcells) that can be placed in closets throughout a building. IS-94 specifies a technique to provide private, or closed, cellular systems that use nonstandard control channels. IS-94 systems were introduced in 1994, and are proliferating throughout office buildings and hotels.

The IS-54 Rev.C standard provides 48.6 kbps control channel signaling on the USDC-only control channels and 10 kbps FSK control channels on the original AMPS channels. However, closed network capabilities are not fully developed under IS-54 Rev.C. A new interim standard, IS-136, has been developed to provide a host of new features and services that positions the cellular carriers for competition from PCS. IS-136 specifies short messaging capabilities and private, user group features, making it well-suited for wireless PBX applications and paging applications. Furthermore, IS-136 specifies a "sleep mode" that instructs compatible cellular phones to conserve battery power. IS-136 subscriber terminals are not compatible with those produced for IS-54, since IS-136 uses 48.6 kbps control channels exclusively on all control channels (the 10 kbps FSK is not supported). This allows IS-136 modems to be more cost effective, since only the 48.6 kbps modem is needed in each portable unit.

10.3 Global System for Mobile (GSM)

Global System for Mobile (GSM) is a second generation cellular system standard that was developed to solve the fragmentation problems of the first cellular systems in Europe. GSM is the world's first cellular system to specify digital modulation and network level architectures and services. Before GSM, European countries used different cellular standards throughout the continent, and it was not possible for a customer to use a single subscriber unit throughout Europe. GSM was originally developed to serve as the pan-European cellular service and promised a wide range of network services through the use of ISDN. GSM's success has exceeded the expectations of virtually everyone, and it is now the world's most popular standard for new cellular radio and personal communi-

cations equipment throughout the world. It is predicted that by the year 2000, there will be between 20 and 50 million GSM subscribers worldwide [Mou92], [Dec93].

The task of specifying a common mobile communication system for Europe in the 900 MHz band was taken up by the GSM (Groupe spe'cial mobile) committee which was a working group of the Confe'rence Europe'ene Postes des et Te'le'communication (CEPT). Recently, GSM has changed its name to the Global System for Mobile Communications for marketing reasons [Mou92]. The setting of standards for GSM is currently under the aegis of the European Technical Standards Institute (ETSI).

GSM was first introduced into the European market in 1991. By the end of 1993, several nonEuropean countries in South America, Asia, and Australia had adopted GSM and the technically equivalent offshoot, DCS 1800, which supports Personal Communication Services (PCS) in the 1.8 GHz to 2.0 GHz radio bands recently created by governments throughout the world.

10.3.1 GSM Services and Features

GSM services follow ISDN guidelines and are classified as either *teleservices* or *data services*. Teleservices include standard mobile telephony and mobile-originated or base-originated traffic. Data services include computer-to-computer communication and packet-switched traffic. User services may be divided into three major categories:

- **Telephone services**, including emergency calling and facsimile. GSM also supports Videotex and Teletex, though they are not integral parts of the GSM standard.

- **Bearer services** or **data services** which are limited to layers 1, 2, and 3 of the open system interconnection (OSI) reference model (see Chapter 9). Supported services include packet switched protocols and data rates from 300 bps to 9.6 kbps. Data may be transmitted using either a transparent mode (where GSM provides standard channel coding for the user data) or nontransparent mode (where GSM offers special coding efficiencies based on the particular data interface).

- **Supplementary ISDN services**, are digital in nature, and include call diversion, closed user groups, and caller identification, and are not available in analog mobile networks. Supplementary services also include the *short messaging service* (SMS) which allows GSM subscribers and base stations to transmit alphanumeric pages of limited length (160 7 bit ASCII characters) while simultaneously carrying normal voice traffic. SMS also provides *cell broadcast*, which allows GSM base stations to repetitively transmit ASCII messages with as many as fifteen 93-character strings in concatenated fashion. SMS may be used for safety and advisory applications, such as the broadcast of highway or weather information to all GSM subscribers within

reception range.

From the user's point of view, one of the most remarkable features of GSM is the *Subscriber Identity Module* (SIM), which is a memory device that stores information such as the subscriber's identification number, the networks and countries where the subscriber is entitled to service, privacy keys, and other user-specific information. A subscriber uses the SIM with a 4-digit personal ID number to activate service from any GSM phone. SIM's are available as smart cards (credit card sized cards that may be inserted into any GSM phone) or plug-in modules, which are less convenient than the SIM cards but are nonetheless removable and portable. Without a SIM installed, all GSM mobiles are identical and nonoperational. It is the SIM that gives GSM subscriber units their identity. Subscribers may plug their SIM into any suitable terminal — such as a hotel phone, public phone, or any portable or mobile phone — and are then able to have all incoming GSM calls routed to that terminal and have all outgoing calls billed to their home phone, no matter where they are in the world.

A second remarkable feature of GSM is the on-the-air privacy which is provided by the system. Unlike analog FM cellular phone systems which can be readily monitored, it is virtually impossible to eavesdrop on a GSM radio transmission. The privacy is made possible by encrypting the digital bit stream sent by a GSM transmitter, according to a specific secret cryptographic key that is known only to the cellular carrier. This key changes with time for each user. Every carrier and GSM equipment manufacturer must sign the Memorandum of Understanding (MoU) before developing GSM equipment or deploying a GSM system. The MoU is an international agreement which allows the sharing of cryptographic algorithms and other proprietary information between countries and carriers.

10.3.2 GSM System Architecture

The GSM system architecture consists of three major interconnected subsystems that interact between themselves and with the users through certain network interfaces. The subsystems are the *Base Station Subsystem* (BSS), *Network and Switching Subsystem* (NSS), and the *Operation Support Subsystem* (OSS). The *Mobile Station* (MS) is also a subsystem, but is usually considered to be part of the BSS for architecture purposes. Equipment and services are designed within GSM to support one or more of these specific subsystems.

The BSS, also known as the *radio subsystem*, provides and manages radio transmission paths between the mobile stations and the Mobile Switching Center (MSC). The BSS also manages the radio interface between the mobile stations and all other subsystems of GSM. Each BSS consists of many Base Station Controllers (BSCs) which connect the MS to the NSS via the MSCs. The NSS manages the switching functions of the system and allows the MSCs to commu-

nicate with other networks such as the PSTN and ISDN. The OSS supports the operation and maintenance of GSM and allows system engineers to monitor, diagnose, and troubleshoot all aspects of the GSM system. This subsystem interacts with the other GSM subsystems, and is provided solely for the staff of the GSM operating company which provides service facilities for the network.

Figure 10.5 shows the block diagram of the GSM system architecture. The Mobile Stations (MS) communicate with the Base Station Subsystem (BSS) over the radio air interface. The BSS consists of many BSCs which connect to a single MSC, and each BSC typically controls up to several hundred *Base Transceiver Stations* (BTSs). Some of the BTSs may be co-located at the BSC, and others may be remotely distributed and physically connected to the BSC by microwave link or dedicated leased lines. Mobile handoffs (called *handovers*, or HO, in the GSM specification) between two BTSs under the control of the same BSC are handled by the BSC, and not the MSC. This greatly reduces the switching burden of the MSC.
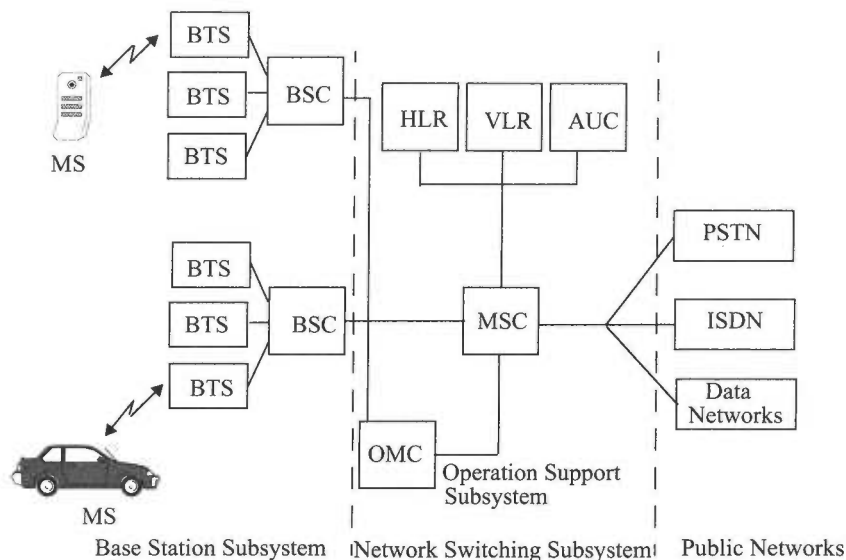

Figure 10.5
GSM system architecture.

As shown in Figure 10.6, the interface which connects a BTS to a BSC is called the *Abis interface*. The Abis interface carries traffic and maintenance data, and is specified by GSM to be standardized for all manufacturers. In practice, however, the Abis for each GSM base station manufacturer has subtle differences, thereby forcing service providers to use the same manufacturer for the BTS and BSC equipment.
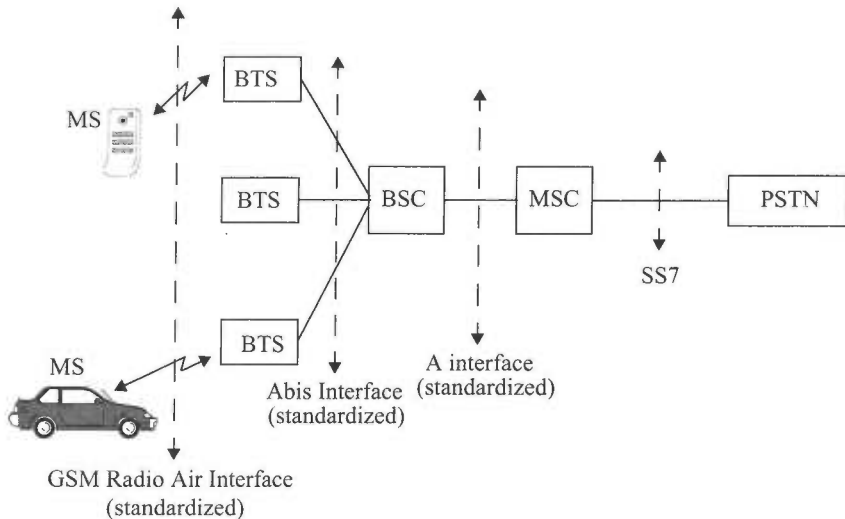
Figure 10.6
The various interfaces used in GSM.

The BSCs are physically connected via dedicated/leased lines or microwave link to the MSC. The interface between a BSC and a MSC is called the *A interface*, which is standardized within GSM. The A interface uses an SS7 protocol called the *Signaling Correction Control Part* (SCCP) which supports communication between the MSC and the BSS, as well as network messages between the individual subscribers and the MSC. The A interface allows a service provider to use base stations and switching equipment made by different manufacturers.

The NSS handles the switching of GSM calls between external networks and the BSCs in the radio subsystem and is also responsible for managing and providing external access to several customer databases. The MSC is the central unit in the NSS and controls the traffic among all of the BSCs. In the NSS, there are three different databases called the *Home Location Register* (HLR), *Visitor Location Register* (VLR), and the *Authentication Center* (AUC). The HLR is a database which contains subscriber information and location information for each user who resides in the same city as the MSC. Each subscriber in a particular GSM market is assigned a unique *International Mobile Subscriber Identity* (IMSI), and this number is used to identify each home user. The VLR is a database which temporarily stores the IMSI and customer information for each roaming subscriber who is visiting the coverage area of a particular MSC. The VLR is linked between several adjoining MSCs in a particular market or geographic region and contains subscription information of every visiting user in the area. Once a roaming mobile is logged in the VLR, the MSC sends the necessary information to the visiting subscriber's HLR so that calls to the roaming mobile can be appropriately routed over the PSTN by the roaming user's HLR. The

Authentication Center is a strongly protected database which handles the authentication and encryption keys for every single subscriber in the HLR and VLR. The Authentication Center contains a register called the *Equipment Identity Register* (EIR) which indentifies stolen or fraudulently altered phones that transmit identity data that does not match with information contained in either the HLR or VLR.
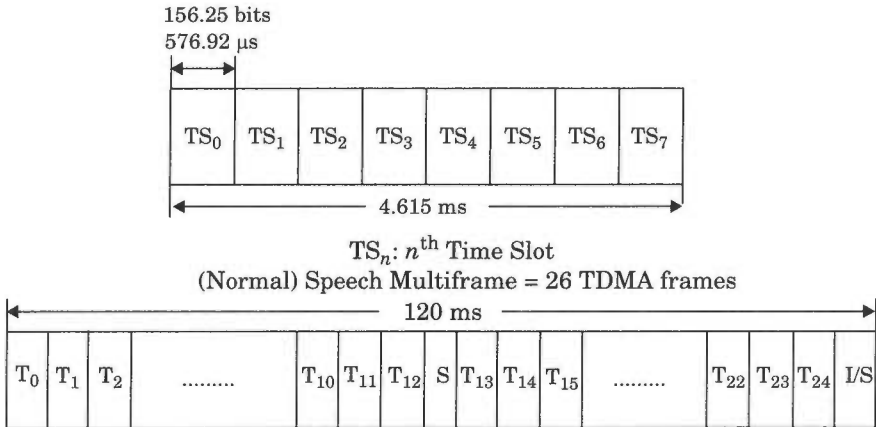
The OSS supports one or several *Operation Maintenance Centers* (OMC) which are used to monitor and maintain the performance of each MS, BS, BSC, and MSC within a GSM system. The OSS has three main functions, which are 1) to maintain all telecommunications hardware and network operations with a particular market, 2) manage all charging and billing procedures, and 3) manage all mobile equipment in the system. Within each GSM system, an OMC is dedicated to each of these tasks and has provisions for adjusting all base station parameters and billing procedures, as well as for providing system operators with the ability to determine the performance and integrity of each piece of subscriber equipment in the system.

10.3.3 GSM Radio Subsystem

GSM utilizes two bands of 25 MHz which have been set aside for system use in all member countries. The 890-915 MHz band is used for subscriber-to-base transmissions (reverse link), and the 935-960 MHz band is used for base-to-subscriber transmissions (forward link). GSM uses FDD and a combination of TDMA and FHMA schemes to provide base stations with simultaneous access to multiple users. The available forward and reverse frequency bands are divided into 200 kHz wide channels called ARFCNs (Absolute Radio Frequency Channel Numbers). The ARFCN denotes a forward and reverse channel pair which is separated in frequency by 45 MHz and each channel is time shared between as many as eight subscribers using TDMA.

Each of the eight subscribers uses the same ARFCN and occupies a unique timeslot (TS) per frame. Radio transmissions on both the forward and reverse link are made at a channel data rate of 270.833 kbps (1625.0/6.0 kbps) using binary BT=0.3 GMSK modulation. Thus, the signaling bit duration is 3.692 µs, and the effective channel transmission rate per user is 33.854 kbps (270.833 kpbs/8 users). With GSM overhead (described subsequently), user data is actually sent at a maximum rate of 24.7 kbps. Each TS has an equivalent time allocation of 156.25 channel bits, but of this, 8.25 bits of guard time and 6 total start and stop bits are provided to prevent overlap with adjacent time slots. Each TS has a time duration of 576.92 µs as shown in Figure 10.7, and a single GSM TDMA frame spans 4.615 ms. The total number of available channels within a 25 MHz bandwidth is 125 (assuming no guard band). Since each radio channel consists of 8 time slots, there are thus a total of 1000 traffic channels within GSM. In practical implementations, a guard band of 100 kHz is provided at the

upper and lower end of the GSM spectrum, and only 124 channels are implemented. Table 10.3 summarizes the GSM air interface.

156.25 bits
576.92 µs

| TS$_0$ | TS$_1$ | TS$_2$ | TS$_3$ | TS$_4$ | TS$_5$ | TS$_6$ | TS$_7$ |

4.615 ms

TS$_n$: n^{th} Time Slot
(Normal) Speech Multiframe = 26 TDMA frames

120 ms

| T$_0$ | T$_1$ | T$_2$ | .... | T$_{10}$ | T$_{11}$ | T$_{12}$ | S | T$_{13}$ | T$_{14}$ | T$_{15}$ | .... | T$_{22}$ | T$_{23}$ | T$_{24}$ | I/S |

T$_n$: n^{th} TCH frame

S: Slow Associated Control Channel frame

I: Idle frame

Figure 10.7
The Speech Dedicated Control Channel Frame and multiframe structure.

Table 10.3 GSM Air Interface Specifications Summary

Parameter	Specifications
Reverse Channel Frequency	890 - 915 MHz
Forward Channel Frequency	935 - 960 MHz
ARFCN Number	0 to 124 and 975 to 1023
Tx/Rx Frequency Spacing Tx/Rx Time Slot Spacing	45 MHz 3 Time slots
Modulation Data Rate	270.833333 kbps
Frame Period	4.615 ms
Users per Frame (Full Rate)	8
Time slot Period	576.9 µs
Bit Period	3.692 µs
Modulation	0.3 GMSK
ARFCN Channel Spacing	200 kHz
Interleaving (max. delay)	40 ms
Voice Coder Bit Rate	13.4 kbps

The combination of a TS number and an ARFCN constitutes a *physical channel* for both the forward and reverse link. Each physical channel in a GSM system can be mapped into different *logical channels* at different times. That is, each specific time slot or frame may be dedicated to either handling traffic data (user data such as speech, facsimile, or teletext data), signaling data (required by the internal workings of the GSM system), or control channel data (from the MSC, base station, or mobile user). The GSM specification defines a wide variety of logical channels which can be used to link the physical layer with the data link layer of the GSM network. These logical channels efficiently transmit user data while simultaneously providing control of the network on each ARFCN. GSM provides explicit assignments of time slots and frames for specific logical channels, as described below.

10.3.4 GSM Channel Types

There are two types of GSM logical channels, called *traffic channels* (TCH) and *control channels* (CCH) [Hod90]. Traffic channels carry digitally encoded user speech or user data and have identical functions and formats on both the forward and reverse link. Control channels carry signaling and synchronizing commands between the base station and the mobile station. Certain types of control channels are defined for just the forward or reverse link. There are six different types of TCHs provided for in GSM, and an even larger number of CCHs, both of which are now described.

10.3.4.1 GSM Traffic CHannels (TCH)

GSM traffic channels may be either full-rate or half-rate and may carry either digitized speech or user data. When transmitted as full-rate, user data is contained within one TS per frame. When transmitted as half-rate, user data is mapped onto the same time slot, but is sent in alternate frames. That is, two half-rate channel users would share the same time slot, but would alternately transmit during every other frame.

In the GSM standard, TCH data may not be sent in TS 0 within a TDMA frame on certain ARFCNs which serve as the broadcast station for each cell (since this time slot is reserved for control channel bursts in most every frame, as described subsequently). Furthermore, frames of TCH data are broken up every thirteenth frame by either slow associated control channel data (SACCH) or idle frames. Figure 10.7 illustrates how the TCH data is transmitted in consecutive frames. Each group of twenty-six consecutive TDMA frames is called a *multiframe* (or *speech multiframe*, to distinguish it from the control channel multiframe described below). For every twenty-six frames, the thirteenth and twenty-sixth frames consist of Slow Associated Control Channel (SACCH) data, or the idle frame, respectively. The twenty-sixth frame contains idle bits for the

case when full-rate TCHs are used, and contains SACCH data when half-rate TCHs are used.

Full-Rate TCH

The following full rate speech and data channels are supported:

- **Full-Rate Speech Channel (TCH/FS)** — The full-rate speech channel carries user speech which is digitized at a raw data rate of 13 kbps. With GSM channel coding added to the digitized speech, the full-rate speech channel carries 22.8 kbps.
- **Full-Rate Data Channel for 9600 bps (TCH/F9.6)** — The full-rate traffic data channel carries raw user data which is sent at 9600 bps. With additional forward error correction coding applied by the GSM standard, the 9600 bps data is sent at 22.8 kbps.
- **Full-Rate Data Channel for 4800 bps (TCH/F4.8)** — The full-rate traffic data channel carries raw user data which is sent at 4800 bps. With additional forward error correction coding applied by the GSM standard, the 4800 bps is sent at 22.8 kbps.
- **Full-Rate Data Channel for 2400 bps (TCH/F2.4)** — The full-rate traffic data channel carries raw user data which is sent at 2400 bps. With additional forward error correction coding applied by the GSM standard, the 2400 bps is sent at 22.8 kbps.

Half-Rate TCH

The following half-rate speech and data channels are supported:

- **Half-Rate Speech Channel (TCH/HS)** — The half-rate speech channel has been designed to carry digitized speech which is sampled at a rate half that of the full-rate channel. GSM anticipates the availability of speech coders which can digitize speech at about 6.5 kbps. With GSM channel coding added to the digitized speech, the half-rate speech channel will carry 11.4 kbps.
- **Half-Rate Data Channel for 4800 bps (TCH/H4.8)** — The half-rate traffic data channel carries raw user data which is sent at 4800 bps. With additional forward error correction coding applied by the GSM standard, the 4800 bps data is sent at 11.4 kbps.
- **Half-Rate Data Channel for 2400 bps (TCH/H2.4)** — The half-rate traffic data channel carries raw user data which is sent at 2400 bps. With additional forward error correction coding applied by the GSM standard, the 2400 bps data is sent at 11.4 kbps.

10.3.4.2 GSM Control Channels (CCH)

There are three main control channels in the GSM system. These are the *broadcast channel* (BCH), the *common control channel* (CCCH), and the *dedicated control channel* (DCCH). Each control channel consists of several logical

channels which are distributed in time to provide the necessary GSM control functions.

The BCH and CCCH forward control channels in GSM are implemented only on certain ARFCN channels and are allocated timeslots in a very specific manner. Specifically, the BCH and CCCH forward control channels are allocated only TS 0 and are broadcast only during certain frames within a repetitive fifty-one frame sequence (called the *control channel multiframe*) on those ARFCNs which are designated as broadcast channels. TS1 through TS7 carry regular TCH traffic, so that ARFCNs which are designated as control channels are still able to carry full-rate users on seven of the eight time slots.

The GSM specification defines thirty-four ARFCNs as standard broadcast channels. For each broadcast channel, frame 51 does not contain any BCH/CCCH forward channel data and is considered to be an idle frame. However, the reverse channel CCCH is able to receive subscriber transmissions during TS 0 of any frame (even the idle frame). On the other hand, DCCH data may be sent during any time slot and any frame, and entire frames are specifically dedicated to certain DCCH transmissions. GSM control channels are now described in detail.

- **Broadcast Channels (BCH)**— The broadcast channel operates on the forward link of a specific ARFCN within each cell, and transmits data only in the first time slot (TS 0) of certain GSM frames. Unlike TCHs which are duplex, BCHs only use the forward link. Just as the forward control channel (FCC) in AMPS is used as a beacon for all nearby mobiles to camp on to, the BCH serves as a TDMA beacon channel for any nearby mobile to identify and lock on to. The BCH provides synchronization for all mobiles within the cell and is occasionally monitored by mobiles in neighboring cells so that received power and MAHO decisions may be made by out-of-cell users. Although BCH data is transmitted in TS0, the other seven timeslots in a GSM frame for that same ARFCN are available for TCH data, DCCH data, or are filled with dummy bursts. Furthermore, all eight timeslots on all other ARFCNs within the cell are available for TCH or DCCH data.

The BCH is defined by three separate channels which are given access to TS 0 during various frames of the 51 frame sequence. Figure 10.8 illustrates how the BCH is allocated frames. The three types of BCH are now described.

(a) *Broadcast Control CHannel (BCCH)* — The BCCH is a forward control channel that is used to broadcast information such as cell and network identity, and operating characteristics of the cell (current control channel structure, channel availability, and congestion). The BCCH also broadcasts a list of channels that are currently in use within the cell. Frame 2 through frame 5 in a control multiframe (4 out of every 51 frames) contain BCCH data. It

should be noted from Figure 10.8 that TS 0 contains BCCH data during specific frames, and contains other BCH channels (FCCH and SCH), common control channels (CCCHs), or an idle frame (sent every 51st frame) during other specific frames.

(b) *Frequency Correction CHannel (FCCH)* — The FCCH is a special data burst which occupies TS 0 for the very first GSM frame (frame 0) and is repeated every ten frames within a control channel multiframe. The FCCH allows each subscriber unit to synchronize its internal frequency standard (local oscillator) to the exact frequency of the base station.

(c) *Synchronization CHannel (SCH)* — SCH is broadcast in TS 0 of the frame immediately following the FCCH frame and is used to identify the serving base station while allowing each mobile to frame synchronize with the base station. The *frame number* (FN), which ranges from 0 to 2,715,647, is sent with the *base station identity code* (BSIC) during the SCH burst. The BSIC is uniquely assigned to each BST in a GSM system. Since a mobile may be as far as 30 km away from a serving base station, it is often necessary to adjust the timing of a particular mobile user such that the received signal at the base station is synchronized with the base station clock. The BS issues coarse *timing advancement* commands to the mobile stations over the SCH, as well. The SCH is transmitted once every ten frames within the control channel multiframe, as shown in Figure 10.8.

• **Common Control CHannels (CCCH)** — On the broadcast (BCH) ARFCN, the common control channels occupy TS 0 of every GSM frame that is not otherwise used by the BCH or the Idle frame. CCCH consists of three different channels: the paging channel (PCH), which is a forward link channel, the random access channel (RACH) which is a reverse link channel, and the access grant channel (AGCH), which is a forward link channel. As seen in Figure 10.8, CCCHs are the most commonly used control channels and are used to page specific subscribers, assign signaling channels to specific users, and receive mobile requests for service. These channels are described below.

(a) *Paging CHannel (PCH)* — The PCH provides paging signals from the base station to all mobiles in the cell, and notifies a specific mobile of an incoming call which originates from the PSTN. The PCH transmits the IMSI of the target subscriber, along with a request for acknowledgment from the mobile unit on the RACH. Alternatively, the PCH may be used to provide *cell broadcast* ASCII text messages to all subscribers, as part of the SMS feature of GSM.

(b) *Random Access Channel (RACH)* — The RACH is a reverse link channel used by a subscriber unit to acknowledge a page from the PCH, and is also used by mobiles to originate a call. The RACH uses a slotted ALOHA access scheme. All mobiles must request access or respond to a PCH alert within TS
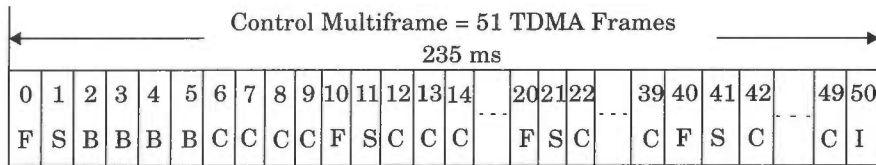
F : FCCH burst (BCH)
S : SCH burst (BCH)
B : BCCH burst (BCH)
C : PCH/AGCH burst (CCCH)
I : Idle

(a)
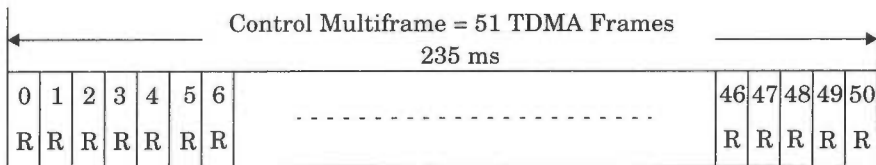
R : Reverse RACH burst (CCCH)

(b)

Figure 10.8
(a) The Control Channel Multiframe (Forward link for TS0)
(b) The Control Channel Multiframe (Reverse link for TS0)

0 of a GSM frame. At the BTS, every frame (even the idle frame) will accept RACH transmissions from mobiles during TS 0. In establishing service, the GSM base station must respond to the RACH transmission by allocating a channel and assigning a stand-alone dedicated control channel (SDCCH) for signaling during a call. This connection is confirmed by the base station over the AGCH.

(c) *Access Grant Channel (AGCH)* — The AGCH is used by the base station to provide forward link communication to the mobile, and carries data which instructs the mobile to operate in a particular physical channel (time slot and ARFCN) with a particular dedicated control channel. The AGCH is the final CCCH message sent by the base station before a subscriber is moved off the control channel. The AGCH is used by the base station to respond to a RACH sent by a mobile station in a previous CCCH frame.

- **Dedicated Control Channels (DCCH)** — There are three types of dedicated control channels in GSM, and, like traffic channels (see Figure 10.7), they are bidirectional and have the same format and function on both the forward and reverse links. Like TCHs, DCCHs may exist in any time slot and on any ARFCN *except TS0* of the BCH ARFCN. The stand-alone dedicated control channels (SDCCH) are used for providing signaling services required by the users. The Slow- and Fast- Associated Control Channels

(SACCH and FACCH) are used for supervisory data transmissions between the mobile station and the base station during a call.

(a) *Stand-alone Dedicated Control Channels (SDCCH)* — The SDCCH carries signaling data following the connection of the mobile with the base station, and just before a TCH assignment is issued by the base station. The SDCCH ensures that the mobile station and the base station remain connected while the base station and MSC verify the subscriber unit and allocate resources for the mobile. The SDCCH can be thought of as an intermediate and temporary channel which accepts a newly completed call from the BCH and holds the traffic while waiting for the base station to allocate a TCH channel. The SDCCH is used to send authentication and alert messages (but not speech) as the mobile synchronizes itself with the frame structure and waits for a TCH. SDCCHs may be assigned their own physical channel or may occupy TS0 of the BCH if there is low demand for BCH or CCCH traffic.

(b) *Slow Associated Control Channel (SACCH)* — The SACCH is always associated with a traffic channel or a SDCCH and maps onto the same physical channel. Thus, each ARFCN systematically carries SACCH data for all of its current users. As in the USDC standard, the SACCH carries general information between the MS and BTS. On the forward link, the SACCH is used to send slow but regularly changing control information to the mobile, such as transmit power level instructions and specific timing advance instructions for each user on the ARFCN. The reverse SACCH carries information about the received signal strength and quality of the TCH, as well as BCH measurement results from neighboring cells. The SACCH is transmitted during the thirteenth frame (and the twenty-sixth frame when half-rate traffic is used) of every speech/dedicated control channel multiframe (Figure 10.7), and within this frame, the eight timeslots are dedicated to providing SACCH data to each of the eight full-rate (or sixteen half-rate) users on the ARFCN.

(c) *Fast Associated Control Channels (FACCH)* — FACCH carries urgent messages, and contains essentially the same type of information as the SDCCH. A FACCH is assigned whenever a SDCCH has not been dedicated for a particular user and there is an urgent message (such as a handoff request). The FACCH gains access to a time slot by "stealing" frames from the traffic channel to which it is assigned. This is done by setting two special bits, called stealing bits, in a TCH forward channel burst. If the stealing bits are set, the time slot is known to contain FACCH data, not a TCH, for that frame.

10.3.5 Example of a GSM Call

To understand how the various traffic and control channels are used, consider the case of a mobile call origination in GSM. First, the subscriber unit must be synchronized to a nearby base station as it monitors the BCH. By receiving the FCCH, SCH, and BCCH messages, the subscriber would be locked on to the

system and the appropriate BCH. To originate a call, the user first dials the intended digit combination and presses the "send" button on the GSM phone. The mobile transmits a burst of RACH data, using the same ARFCN as the base station to which it is locked. The base station then responds with an AGCH message on the CCCH which assigns the mobile unit to a new channel for SDCCH connection. The subscriber unit, which is monitoring TS 0 of the BCH, would receive its ARFCN and TS assignment from the AGCH and would immediately tune to the new ARFCN and TS. This new ARFCN and TS assignment is physically the SDCCH (not the TCH). Once tuned to the SDCCH, the subscriber unit first waits for the SACCH frame to be transmitted (the wait would last, at most, 26 frames or 120 ms, as shown in Figure 10.7), which informs the mobile of any required timing advance and transmitter power command. The base station is able to determine the proper timing advance and signal level from the mobile's earlier RACH transmission and sends the proper value over the SACCH for the mobile to process. Upon receiving and processing the timing advance information in the SACCH, the subscriber is now able to transmit normal burst messages as required for speech traffic. The SDCCH sends messages between the mobile unit and the base station, taking care of authentication and user validation, while the PSTN connects the dialed party to the MSC, and the MSC switches the speech path to the serving base station. After a few seconds, the mobile unit is commanded by the base station via the SDCCH to retune to a new ARFCN and new TS for the TCH assignment. Once retuned to the TCH, speech data is transferred on both the forward and reverse links, the call is successfully underway, and the SDCCH is vacated.

When calls are originated from the PSTN, the process is quite similar. The base station broadcasts a PCH message during TS 0 within an appropriate frame on the BCH. The mobile station, locked on to that same ARFCN, detects its page and replies with an RACH message acknowledging receipt of the page. The base station then uses the AGCH on the CCCH to assign the mobile unit to a new physical channel for connection to the SDCCH and SACCH while the network and the serving base station are connected. Once the subscriber establishes timing advance and authentication on the SDCCH, the base station issues a new physical channel assignment over the SDCCH, and the TCH assignment is made.

10.3.6 Frame Structure for GSM

Each user transmits a burst of data during the time slot assigned to it. These data bursts may have one of five specific formats, as defined in GSM [Hod90]. Figure 10.9 illustrates the five types of data bursts used for various control and traffic bursts. Normal bursts are used for TCH and DCCH transmissions on both the forward and reverse link. FCCH and SCH bursts are used in TS 0 of specific frames (shown in Figure 10.8a) to broadcast the frequency and

time synchronization control messages on the forward link. The RACH burst is used by all mobiles to access service from any base station, and the dummy burst is used as filler information for unused time slots on the forward link.

Normal

3 start bits	58 bits of encrypted data	26 training bits	58 bits of encrypted data	3 stop bits	8.25 bits guard period

FCCH burst

3 start bits	142 fixed bits of all zeroes		3 stop bits	8.25 bits guard period

SCH burst

3 start bits	39 bits of encrypted data	64 bits of training	39 bits of encrypted data	3 stop bits	8.25 bits guard period

RACH burst

8 start bits	41 bits of synchronization	36 bits of encrypted data	3 stop bits	68.25 bit extended guard period

Dummy burst

3 start bits	58 mixed bits	26 training bits	58 mixed bits	3 stop bits	8.25 bits guard period

Figure 10.9
Time slot data bursts in GSM.

Figure 10.10 illustrates the data structure within a normal burst. It consists of 148 bits which are transmitted at a rate of 270.833333 kbps (an unused guard time of 8.25 bits is provided at the end of each burst). Out of the total 148 bits per TS, 114 are information-bearing bits which are transmitted as two 57 bit sequences close to the beginning and end of the burst. The midamble consists of a 26 bit training sequence which allows the adaptive equalizer in the mobile or base station receiver to analyze the radio channel characteristics before decoding the user data. On either side of the midamble there are control bits called stealing flags. These two flags are used to distinguish whether the TS contains voice (TCH) or control (FACCH) data, both which share the same physical channel. During a frame, a GSM subscriber unit uses one TS to transmit, one TS to receive, and may use the six spare time slots to measure signal strength on five adjacent base stations as well as its own base station.

As shown in Figure 10.10, there are eight timeslots per TDMA frame, and the frame period is 4.615 ms. A frame contains $8 \times 156.25 = 1250$ bits, although some bit periods are not used. The frame rate is 270.833 kbps/1250 bits/frame, or 216.66 frames per second. The 13th or 26th frame are not used for traffic, but for
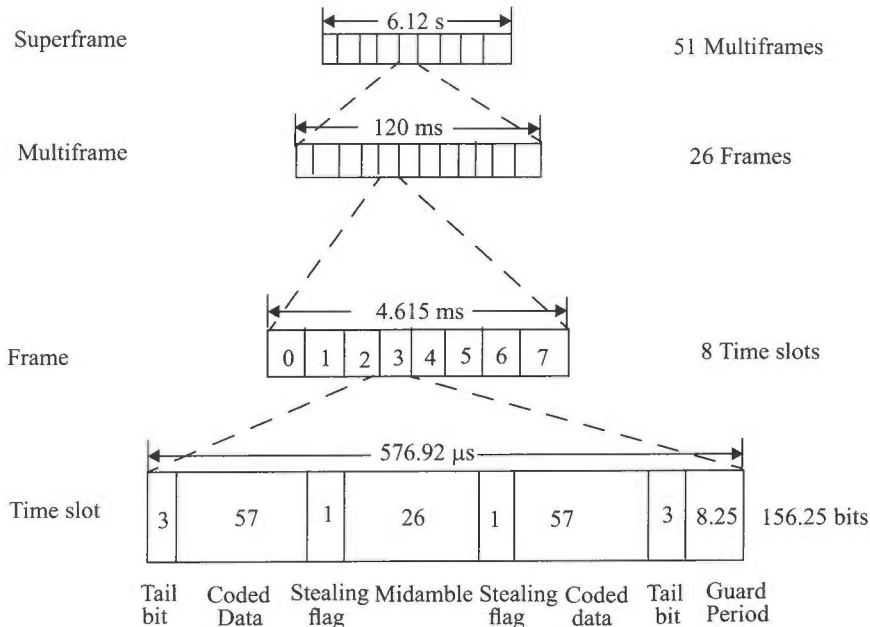
Figure 10.10
GSM frame structure.

control purposes. Each of the normal speech frames are grouped into larger structures called *multiframes* which in turn are grouped into *superframes* and *hyperframes* (hyperframes are not shown in Figure 10.10). One multiframe contains 26 TDMA frames, and one superframe contains 51 multiframes, or 1326 TDMA frames. A hyperframe contains 2048 superframes, or 2,715,648 TDMA frames. A complete hyperframe is sent about every 3 hours, 28 minutes, and 54 seconds, and is important to GSM since the encryption algorithms rely on the particular frame number, and sufficient security can only be obtained by using a large number of frames as provided by the hyperframe.

Figure 10.8 shows that the control multiframes span 51 frames (235.365 ms), as opposed to 26 frames (120 ms) used by the traffic/dedicated control channel multiframes. This is done intentionally to ensure that any GSM subscriber (whether in the serving or adjacent cell) will be certain to receive the SCH and FCCH transmissions from the BCH, no matter what particular frame or time slot they are using.

10.3.7 Signal Processing in GSM

Figure 10.11 illustrates all of the GSM operations from transmitter to receiver.
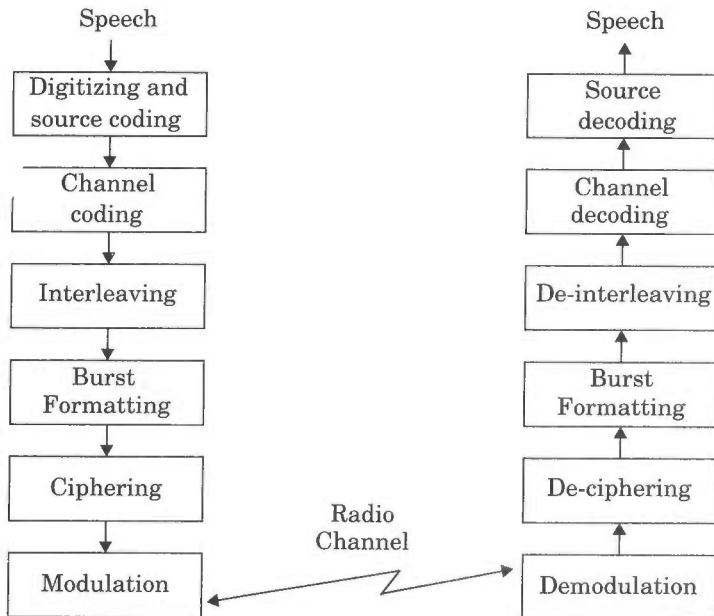
Speech   Speech

Digitizing and source coding		Source decoding
Channel coding		Channel decoding
Interleaving		De-interleaving
Burst Formatting		Burst Formatting
Ciphering		De-ciphering
Modulation		Demodulation

Radio
Channel

Figure 10.11
GSM operations from speech input to speech output.

Speech Coding — The GSM speech coder is based on the Residually Excited Linear Predictive Coder (RELP), which is enhanced by including a Long-Term Predictor (LTP) [Hel89]. The coder provides 260 bits for each 20 ms blocks of speech, which yields a bit rate of 13 kbps. This speech coder was selected after extensive subjective evaluation of various candidate coders available in the late 1980s. Provisions for incorporating half-rate coders are included in the specifications.

The GSM speech coder takes advantage of the fact that in a normal conversation, each person speaks on average for less than 40% of the time. By incorporating a voice activity detector (VAD) in the speech coder, GSM systems operate in a *discontinuous transmission mode* (DTX) which provides a longer subscriber battery life and reduces instantaneous radio interference since the GSM transmitter is not active during silent periods. A comfort noise subsystem (CNS) at the receiving end introduces a background acoustic noise to compensate for the annoying switched muting which occurs due to DTX.

TCH/FS, SACCH, and FACCH Channel Coding — The output bits of the speech coder are ordered into groups for error protection, based upon their significance in contributing to speech quality. Out of the total 260 bits in a frame, the most important 50 bits, called type Ia bits, have 3 parity check (CRC) bits added to them. This facilitates the detection of non-correctable errors at the

receiver. The next 132 bits along with the first 53 (50 type Ia bits + 3 parity bits) are reordered and appended by 4 trailing zero bits, thus providing a data block of 189 bits. This block is then encoded for error protection using a rate 1/2 convolutional encoder with constraint length $K = 5$, thus providing a sequence of 378 bits. The least important 78 bits do not have any error protection and are concatenated to the existing sequence to form a block of 456 bits in a 20 ms frame. The error protection coding scheme increases the gross data rate of the GSM speech signal, with channel coding, to 22.8 kbps. This error protection scheme as described is illustrated in Figure 10.12.
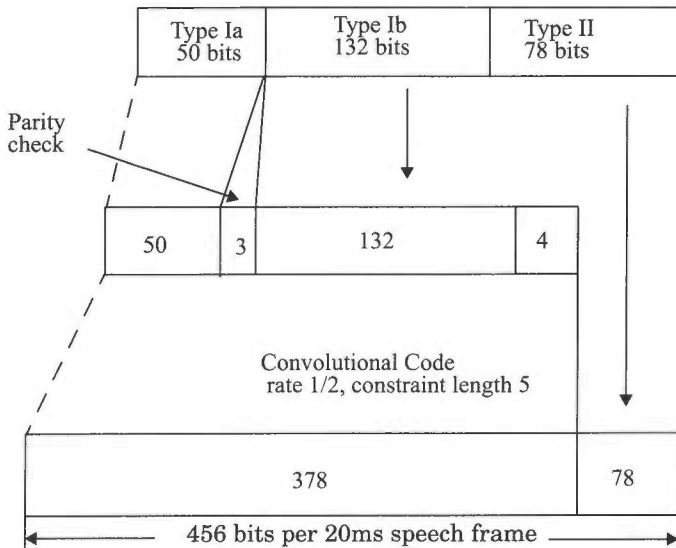
Figure 10.12
Error protection for speech signals in GSM.

Channel Coding for Data Channels — The coding provided for GSM full rate data channels (TCH/F9.6) is based on handling 60 bits of user data at 5ms intervals, in accordance with the modified CCITT V.110 modem standard. As described by Stallings [Ste92] (Chapter 8), 240 bits of user data are applied with 4 tailing bits to a half-rate punctured convolutional coder with constraint length $K = 5$. The resulting 488 coded bits are reduced to 456 encoded data bits through puncturing (32 bits are not transmitted), and the data is separated into four 114 bit data bursts that are applied in an interleaved fashion to consecutive time slots.

Channel Coding for Control Channels — GSM control channel messages are defined to be 184 bits long, and are encoded using a shortened binary cyclic fire code, followed by a half-rate convolutional coder.

The fire code uses the generator polynomial

$$G_5(x) = (x^{23} + 1)(x^{17} + x^3 + 1) = x^{40} + x^{26} + x^{23} + x^{17} + x^3 + 1$$

which produces 184 message bits, followed by 40 parity bits. Four tail bits are added to clear the convolutional coder which follows, yielding a 228 bit data block. This block is applied to a half-rate $K = 5$ convolutional code (CC(2,1,5)) using the generator polynomials $G_0(x) = 1 + x^3 + x^4$ and $G_1(x) = 1 + x + x^3 + x^4$ (which are the same polynomials used to code TCH type Ia data bits). The resulting 456 encoded bits are interleaved onto eight consecutive frames in the same manner as TCH speech data.

Interleaving — In order to minimize the effect of sudden fades on the received data, the total of 456 encoded bits within each 20 ms speech frame or control message frame are broken into eight 57 bit sub-blocks. These eight sub-blocks which make up a single speech frame are spread over eight consecutive TCH time slots. (i.e., eight consecutive frames for a specific TS). If a burst is lost due to interference or fading, channel coding ensures that enough bits will still be received correctly to allow the error correction to work. Each TCH time slot carries two 57 bit blocks of data from two different 20 ms (456 bit) speech (or control) segments. Figure 10.13 illustrates exactly how the speech frames are diagonally interleaved within the time slots. Note that TS 0 contains 57 bits of data from the 0th sub-block of the nth speech coder frame (denoted as "a" in the figure) and 57 bits of data from the 4th sub-block of the $(n - 1)$st speech coder frame (denoted as "b" in the figure).

Frame Number

i+0	i+1	i+2	i+3	i+4	i+5	i+6	i+7

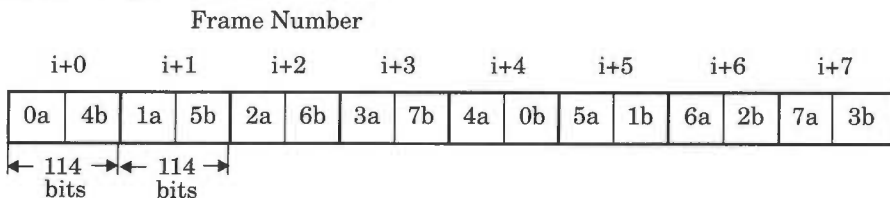| 0a	4b	1a	5b	2a	6b	3a	7b	4a	0b	5a	1b	6a	2b	7a	3b

← 114 →← 114 →
 bits   bits

Figure 10.13
Diagonal interleaving used for TCH/SACCH/FACCH data. Eight speech sub-blocks are spread over eight successive TCH time slots for a specific time slot number.

Ciphering — Ciphering modifies the contents of the eight interleaved blocks through the use of encryption techniques known only to the particular mobile station and base transceiver station. Security is further enhanced by the fact that the encryption algorithm is changed from call to call. Two types of ciphering algorithms, called A3 and A5, are used in GSM to prevent unauthorized network access and privacy for the radio transmission respectively. The A3 algorithm is used to authenticate each mobile by verifying the users passcode within the SIM with the cryptographic key at the MSC. The A5 algorithm provides the scrambling for the 114 coded data bits sent in each TS.

Burst Formatting — Burst formatting adds binary data to the ciphered blocks, in order to help synchronization and equalization of the received signal.

Modulation — The modulation scheme used by GSM is 0.3 GMSK where 0.3 describes the 3 dB bandwidth of the Gaussian pulse shaping filter with rela-

tion to the bit rate (e.g., $BT = 0.3$). As described in Chapter 5, GMSK is a special type of digital FM modulation. Binary ones and zeros are represented in GSM by shifting the RF carrier by ± 67.708 kHz. The channel data rate of GSM is 270.833333 kbps, which is exactly four times the RF frequency shift. This minimizes the bandwidth occupied by the modulation spectrum and hence improves channel capacity. The MSK modulated signal is passed through a Gaussian filter to smooth the rapid frequency transitions which would otherwise spread energy into adjacent channels.

Frequency Hopping — Under normal conditions, each data burst belonging to a particular physical channel is transmitted using the same carrier frequency. However, if users in a particular cell have severe multipath problems, the cell may be defined as a *hopping cell* by the network operator, in which case *slow frequency hopping* may be implemented to combat the multipath or interference effects in that cell. Frequency hopping is carried out on a frame-by-frame basis, thus hopping occurs at a maximum rate of 217.6 hops per second. As many as 64 different channels may be used before a hopping sequence is repeated. Frequency hopping is completely specified by the service provider.

Equalization — Equalization is performed at the receiver with the help of the training sequences transmitted in the midamble of every time slot. The type of equalizer for GSM is not specified and is left up to the manufacturer.

Demodulation — The portion of the transmitted forward channel signal which is of interest to a particular user is determined by the assigned TS and ARFCN. The appropriate TS is demodulated with the aid of synchronization data provided by the burst formatting. After demodulation, the binary information is deciphered, de-interleaved, channel decoded, and speech decoded.

10.4 CDMA Digital Cellular Standard (IS-95)

As discussed in Chapter 8, Code Division Multiple Access (CDMA) offers some advantages over TDMA and FDMA. A U.S. digital cellular system based on CDMA which promises increased capacity [Gil91] has been standardized as Interim Standard 95 (IS-95) by the U.S. Telecommunications Industry Association (TIA) [TIA93]. Like IS-54, the IS-95 system is designed to be compatible with the existing U.S. analog cellular system (AMPS) frequency band, hence mobiles and base stations can be economically produced for dual mode operation. Pilot production, CDMA/AMPS, dual mode phones were made available by Qualcomm in 1994.

IS-95 allows each user within a cell to use the same radio channel, and users in adjacent cells also use the same radio channel, since this is a direct sequence spread spectrum CDMA system. CDMA completely eliminates the need for frequency planning within a market. To facilitate graceful transition from AMPS to CDMA, each IS-95 channel occupies 1.25 MHz of spectrum on each one-way link, or 10% of the available cellular spectrum for a U.S. cellular

DIGITAL CONSUMER ELECTRONICS HANDBOOK

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coding—are combined to achieve good compression performance. The standard specifies the format of the input/output images and the algorithm of the compression/decompression process. It provides algorithms for both lossless and lossy compression. Unlike H.261 or MPEG, the JPEG standard allows the image format to be rather flexible. There are four different compression modes in JPEG.

- The baseline system (sequential DCT-based lossy mode) is the basic mode and is the minimum configuration supported by all JPEG encoders/decoders. This mode will be described in greater detail in this chapter.
- The extended DCT-based lossy mode improves the baseline system and provides more functionalities and further compression.
- The lossless mode provides perfect reconstruction of the original image at the cost of lowered compression ratio.
- The hierarchical mode enables compression and decompression of the image at different resolutions. The compression algorithm used here is one of the previous three modes.

9.3   BASELINE SYSTEM: SEQUENTIAL DCT-BASED LOSSY MODE

The baseline system is the fundamental lossy compression mode in JPEG. Every JPEG decoder should at least be able to decode the baseline mode. Simplified block diagrams of the encoder and the decoder of this mode are shown in Fig. 9.1 and Fig. 9.2, respectively.
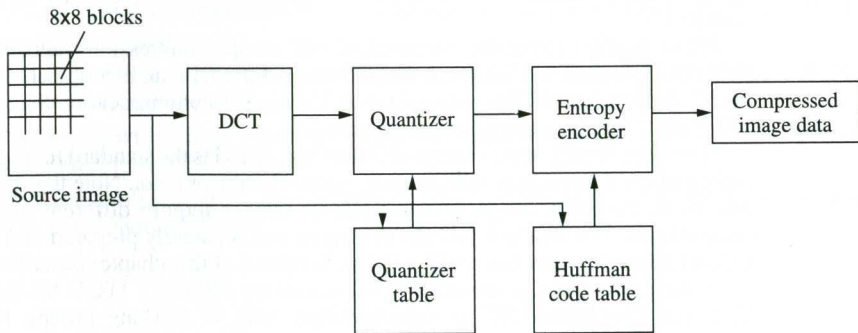

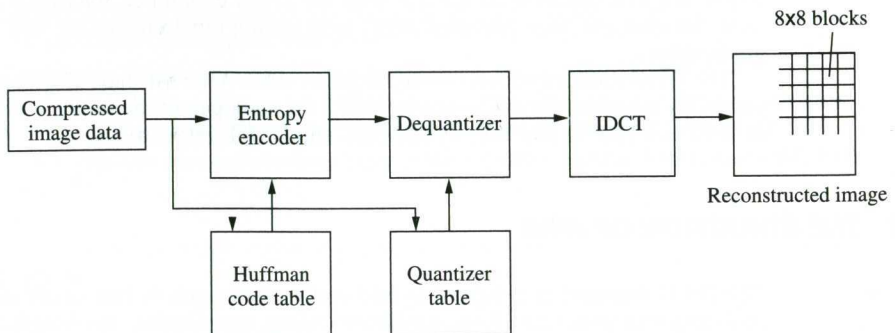**FIGURE 9.1**   Simplified block diagram of a JPEG baseline encoder.

FIGURE 9.2   Simplified block diagram of a JPEG baseline decoder.

9.3.1 Source Image Format

In this mode the input image is represented by 8 bits (0–255) per pixel. There can be several such image planes. A common choice of the number of image planes is one (monochrome) or three (color). Each plane of the original image is partitioned into 8×8 pixel units, called *blocks*.

9.3.2 DCT (Discrete Cosine Transform)

Each block goes through an orthogonal transform, called *DCT*, for energy compaction and decorrelation. The DCT was invented by Ahmed, Natarajan, and Rao in 1974.[4] Since then there have been some variations in the definition of the DCT, but here we shall use the one that is adopted in the international standards of H.261, JPEG, and MPEG.

$$F(u, v) = \frac{2c(u)c(v)}{n} \sum_{j=0}^{n-1} \sum_{k=0}^{n-1} f(j, k) \cos\left[\frac{(2j + 1)u\pi}{2n}\right] \cos\left[\frac{(2k + 1)v\pi}{2n}\right] \qquad (9.1)$$

where

$$c(w) = \begin{cases} 1/\sqrt{2}, & \text{for } w = 0 \\ 1, & \text{for } w = 1, 2, \ldots, n - 1 \end{cases}$$

Among many well-known orthogonal transforms, the DCT provides nearly optimal performance in image compression in terms of energy compaction and decorrelation. Ideally, the KLT (Karhunen-Loeve transform, or Hotelling transform) is the optimum orthogonal transform for compression purpose, but its kernel functions are signal-dependent because they are derived from eigenanalysis of the covariance matrix of the stationary signal.[5] Theoretically, the DCT kernel functions are very close to those of the KLT of the first-order Markov sequence having high correlation (> 0.95) between adjacent samples. Note that typical images are well approximated by 2-D first-order Markov sequences with a very high correlation coefficient.

At the decoder, the 2-D inverse DCT (IDCT) is carried out to produce the 8×8 spatial domain pixels from the dequantized 8×8 DCT coefficients.

$$f(j, k) = \frac{2}{n} \sum_{u=0}^{n-1} \sum_{v=0}^{n-1} c(u)c(v)F(u, v) \cos\left[\frac{2(j + 1)u\pi}{2n}\right] \cos\left[\frac{2(k + 1)v\pi}{2n}\right] \qquad (9.2)$$

A number of efficient algorithms and architectures for fast computation of DCT/IDCT have been reported.[6]

9.3.3 Quantization

After the 8×8 pixel block is transformed into the frequency domain through the 2-D DCT, each of the 64 real-valued DCT coefficients of the block is quantized to be represented by an integer. The quantization is a lossy process, and, as a reward of loss, a higher compression ratio is generally obtained.

The human visual system (HVS) is incorporated in the quantization process. That is, the human eyes are less sensitive to the quantization noise at higher frequencies, and the quantization at higher frequencies is usually coarser for balanced human perception. For this purpose, two quantization tables with 64 entries each are often used—one for luminance, the other for chrominance. There are no default quantization tables in the JPEG standard. The tables are instead provided by the application. Thereby, the quantization of the 64 DCT coefficients can be controlled

separately, and some frequency components can be treated more significantly, depending on the application.

Figure 9.3 is a typical quantization matrix for luminance, which is obtained empirically and included in the JPEG standard as an informative part. The table entries are 8-bit integers and are determined according to the HVS, the sampling structure of the image, and the desired compression ratio (or desired image quality). The same tables are used at the encoder (quantizer) and at the decoder (dequantizer).

16	11	10	16	24	40	51	61
12	12	14	19	26	58	60	55
14	13	16	24	40	57	69	56
14	17	22	29	51	87	80	62
18	22	37	56	68	109	103	77
24	35	55	64	81	104	113	92
49	64	78	87	103	121	120	101
72	92	95	98	112	100	103	99

FIGURE 9.3 A typical 8×8 quantization table for luminance.

The DCT coefficients are quantized as follows:

$$S(u, v) = \text{Nearest Integer} \left[\frac{F(u, v)}{Q(u, v)} \right] \tag{9.3}$$

where $\{F(u, v)\}$ are DCT coefficients and $\{Q(u, v)\}$ are the quantization matrix elements. At the decoder the inverse quantization is carried out as follows:

$$\hat{F}(u, v) = S(u, v)Q(u, v) \tag{9.4}$$

9.3.4 Entropy Coding

The quantized DCT coefficients are integer values. Because of the energy-compaction (into low frequencies) property of the DCT and the increasing-with-frequency property of the quantization tables, many of the high-frequency coefficients are reduced to zero. Utilizing this statistical characteristic, further data compression is possible through entropy coding. Unlike the quantization process, this step is a lossless (reversible) process.

The dc and ac coefficients are handled separately. The dc coefficients carry a significant amount of the image information and have high correlation between adjacent blocks. As shown in Fig. 9.4, the difference in the dc values between the current and the previous blocks are taken first, then it is classified into several categories, and finally it is Huffman-coded[7] using the dc Huffman table.

DC $_{i-1}$ DC $_i$

Block $_{i-1}$ Block $_i$
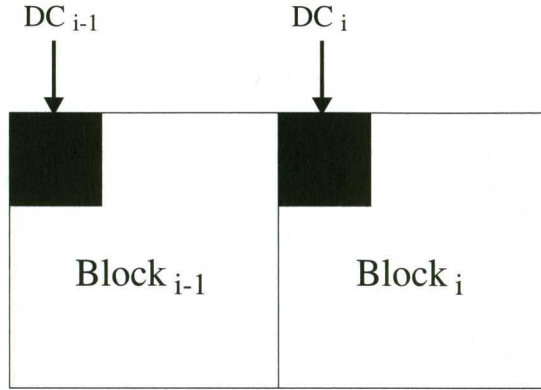
$$DIFF = DC_i - DC_{i-1}$$

FIGURE 9.4 Differential PCM of dc coefficients for efficient entropy coding.

Taking into account that most nonzero values are concentrated in the low-frequency region, the ac coefficients are run length–coded first using the zigzag scan as shown in Fig. 9.5. It results in a sequence of symbols of (RUN, LEVEL), where RUN is the number of successive zeros and LEVEL is the nonzero coefficient following the successive zeros. When the last LEVEL of the block is reached, the corresponding (RUN, LEVEL) is followed by the EOB (end-of-block) mark. As is the case with dc, the (RUN, LEVEL) symbol is classified into several categories depending on the value of LEVEL, and then it is Huffman-coded using the ac Huffman table.

0	1	5	6	14	15	27	28
2	4	7	13	16	26	29	42
3	8	12	17	25	30	41	43
9	11	18	24	31	40	44	53
10	19	23	32	39	45	52	54
20	22	33	38	46	51	55	60
21	34	37	47	50	56	59	61
35	36	48	49	57	58	62	63

FIGURE 9.5 Zigzag scanning order for 8×8 DCT coefficients.

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THE HARDWARE/SOFTWARE INTERFACE

David A. Patterson
University of California, Berkeley

John L. Hennessy
Stanford University

With contributions by

Perry Alexander
The University of Kansas

Peter J. Ashenden
Ashenden Designs Pty Ltd

Javier Bruguera
Universidade de Santiago de Compostela

Jichuan Chang
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FIGURE 1.16   Growth in processor performance since the mid-1980s. This chart plots performance relative to the VAX 11/780 as measured by the SPECint benchmarks (see Section 1.8). Prior to the mid-1980s, processor performance growth was largely technology-driven and averaged about 25% per year. The increase in growth to about 52% since then is attributable to more advanced architectural and organizational ideas. By 2002, this growth led to a difference in performance of about a factor of seven. Performance for floating-point-oriented calculations has increased even faster. Since 2002, the limits of power, available instruction-level parallelism, and long memory latency have slowed uniprocessor performance recently, to about 20% per year.

Product	AMD Opteron X4 (Barcelona)	Intel Nehalem	IBM Power 6	Sun Ultra SPARC T2 (Niagara 2)
Cores per chip	4	4	2	8
Clock rate	2.5 GHz	~ 2.5 GHz ?	4.7 GHz	1.4 GHz
Microprocessor power	120 W	~ 100 W ?	~ 100 W ?	94 W

FIGURE 1.17   Number of cores per chip, clock rate, and power for 2008 multicore microprocessors.

Why has it been so hard for programmers to write explicitly parallel programs? The first reason is that parallel programming is by definition performance programming, which increases the difficulty of programming. Not only does the program need to be correct, solve an important problem, and provide a useful interface to the people or other programs that invoke it, the program must also be fast. Otherwise, if you don't need performance, just write a sequential program.

The second reason is that fast for parallel hardware means that the programmer must divide an application so that each processor has roughly the same amount to

Adaptive Low-Rate Wireless Videophone Schemes

Lajos Hanzo, *Senior Member, IEEE*, and Jürgen Streit

Abstract—The design and performance of a range of wireless videophone transceivers are presented. Highly bandwidth efficient, fixed but arbitrarily programmable rate, perceptually weighted Discrete Cosine Transform (DCT) based video codecs are proposed for quarter common intermediate format (QCIF) videophone sequences. Perceptually weighted cost/gain controlled motion compensation and quad-class DCT-based compression is applied with and without run-length coding. Specifically, we propose video codecs having transmission rates in the range of 5–11.36 kbps and preselected the 11.36 kbps Codec 1, the 8.52 kbps Codec 2 and the 8 kbps Codec 2a, for which we designed the intelligent reconfigurable Systems 1–5. After sensitivity-matched binary Bose–Chaudhuri–Hocquenghem (BCH) forward error correction (FEC) coding the data rate associated with Codec 1 and Codec 2a became 20.32 kbps, while that of Codec 2 was 15.24 kbps. Throughout these systems a partial forced update (PFU) technique was invoked in order to keep transmitter and receiver aligned amongst hostile channel conditions. When using Codec 1 in System 1 and coherent pilot symbol assisted 16-level quadrature amplitude modulation (16-PSAQAM), an overall signalling rate of 9 kBd was yielded. Over lower quality channels the 4QAM mode of operation had to be invoked, which required twice as many time slots to accommodate the resulting 18 kBd stream. The system's robustness was increased using Automatic Repeat Requests (ARQ), inevitably reducing the number of users supported, which was between 6 and 19 for the various systems. In a bandwidth of 200 kHz, similarly to the Pan-European GSM mobile radio system's speech channel, using System 1 for example 16 and 8 videophone users can be supported in the 16QAM and 4QAM modes, respectively. All system features are summarized in Table III.

I. INTRODUCTION AND MOTIVATION

IN RECENT YEARS, there has been an increased research activity in the field of videophony [33], [2]–[4], [6]–[9], [27], in particular for mobile channels. The motion pictures expert group [10], [11] (MPEG) and the p × 64 kbps CCITT H261 video codecs have been contrived for high-rate, low bit error rate fixed channels. Although the new MPEG 4 working group's activities target mobile videophony [12], to date there are no appropriate video standards for mobile videophony over existing standard radio systems.

Some authors have investigated the deployment of the H261 codec over mobile channels [5], [7] while others [2], [6], [33] have contrived a range of different run-length coded variable rate arrangements, such as subband coded schemes [9], [14]–[16], fractal-based [8] or discrete cosine transformed [27] systems. A common feature of most previously proposed systems is that they typically generate a variable output rate.

In contrast to the above variable rate schemes, in this treatise we set out to contrive a range of programmable constant-rate videophone codecs, which can adjust their coding rate in order to accommodate their stream in a conventional speech channel, such as for example that of the Pan-European GSM system [59], the Japanese PDC [19], and the American IS-54 [20] as well as IS-95 systems [21]. The corresponding speech rates are 13, 6.7, 8, and 9.6 kbps and the proposed video codecs are capable of operating at a scanning rate of 10 frames/s, while maintaining such low bit rates. Their further advantage is that they are capable of programmable multirate operation in the 3rd generation adaptive multimedia, multimode terminal of the near future, which is currently under intensive study within the European Community's Fourth Framework Programme in the field of Advanced Communications Technologies and Services (ACTS) [13].

In this short treatise we cannot consider the performance of the proposed video codecs in all of the above 2nd and 3rd generation mobile radio systems. Our main goal is to describe the design philosophy of our prototype video codecs and document their performance using three different characteristic fixed bit rates within the above mentioned typical speech coding rate range. Furthermore, we will devote special attention to transmission robustness issues and devise and evalute a range of error control measures. In particular, a variety of unequal protection coded modulation [26], [25] and Automatic Repeat Request (ARQ) techniques are invoked and assessed in robustness, complexity, and bandwidth efficiency terms and the benefits of a particular multimode scenario are analyzed. The aspects of devising reliable transceiver reconfiguration protocols and analysing the associated switching transients as well as signalling issues are left for future studies.

Specifically, the video source rate was fixed to 8, 8.52, or 11.36 kbps, and this stream was then transmitted using an intelligent transceiver, which can configure itself as a robust but less bandwidth efficient scheme or can double its bandwidth efficiency at the cost of requiring better channel conditions. Note that although the 11.36 kbps video rate differs from the 13 kbps GSM speech rate, some of the systems proposed accommodate exactly 16 or 8 videophone users, as the full- and half-rate GSM speech system.

System Concept: According to Shannon's pioneering work [22], which was further exposed in [23] and [24], in case of lossless coding the lowest achievable source coded rate is given by the source entropy [28]. Such an ideal source encoder produces a completely uncorrelated sequence, where all symbols are mutually independent and have the same significance or error sensitivity. Any further rate reduction implies that some distortion is inflicted. Since our source

codecs operate well below the source entropy, the design philosophy hinges around the principle as to how best the total distortion is distributed over the source message in the time- or frequency-domain in order to minimise its subjective effects.

When using Shannon's ideal source codecs and channel codecs over memoryless AWGN channels, where bit errors occur randomly, there is no advantage in treating source and channel coding jointly. Our nonideal source codecs however produce sequences, which still retain correlation and unequal error sensitivity. Over fading mobile channels this problem is aggravated by the bursty error statistics, which can only be randomized using infinite memory channel interleavers inflicting infinite delays. In this situation source-matched channel coding [9], [18], [23], which takes account of the source significance information [23] (SSI) brings substantial advantages in terms of reducing the required minimum channel SNR.

Joint coding and modulation in the form of trellis coded modulation (TCM) or block coded modulation (BCM) was also proposed in the literature in order to reduce the required channel SNR [51], [52], while in [18] and [25] source-matched joint source/channel coding and modulation was introduced. In this treatise we will follow a similar design philosophy in order to achieve best videophone performance over fading channels.

The schematic of the proposed transceiver is portrayed in Fig. 7 and this treatise follows the same structure. Speech source coding issues are not considered here, the reader is referred to [34] and [33] for the choice of the appropriate speech codec. Channel coding issues are addressed in [50], while a detailed discussion of modulation is given in [26]. Section II outlines the design of a variety of programmable, but fixed-rate video source codecs and analyzes their bit sensitivity. Section III details modulation and transmission aspects, which is followed by the description of the source-matched transceiver in Section IV. The system's performance is characterized in Section V, before offering some conclusions in Section VI.

II. VIDEOPHONE CODECS

2.1. Codec 1

Let us initially focus our attention on the proposed discrete cosine transform [28] (DCT) based video codec depicted in Fig. 1, which was designed for hostile mobile channels. The codec uses 176 × 144 pixels Quarter Common Intermediate Format (QCIF) images scanned at 10 frames/s. For the sake of communications convenience and simple networking our aim was to develop a fixed-rate codec which is able to dispense with an adaptive feed-back-driven bit-rate control buffer. Therefore a constant bit-rate source codec was required, which in Codec 1 forced us to avoid using efficient variable-rate compaction algorithms, such as Huffman coding. This was achieved by fixing both the number of 8 × 8 blocks to be motion-compensated and those to be subjected to DCT to 30 out of 22 × 18 = 396. The selection of these blocks is based on a gain-controlled approach, which will be highlighted next.

In order to curtail error propagation across image frames the codec was designed to switch between intraframe and
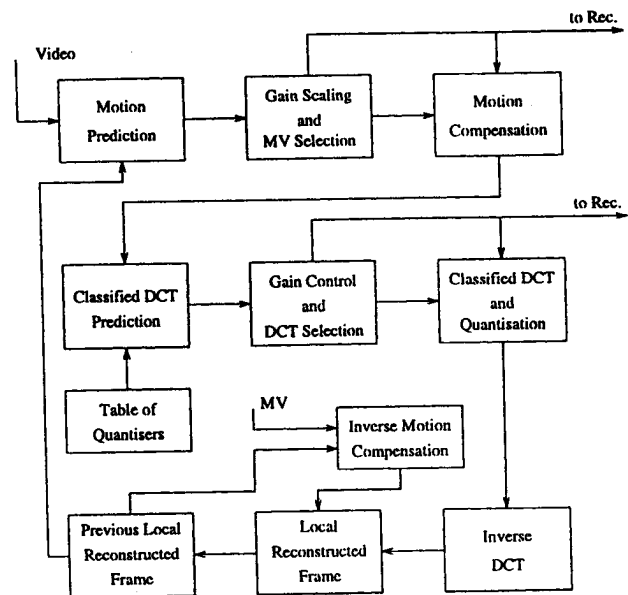
Fig. 1. Video encoder schematic.

interframe modes of operation. In the **intraframe mode** the encoder transmits the coarsely quantized block averages for the current frame, which provides a low-resolution initial frame required for the operation of the interframe codec at both the commencement and during later stages of communications in order to prevent encoder/decoder misalignment. The **interframe mode** of operation is based on a combination of gain-controlled motion compensation and gain-controlled DCT coding as seen in Fig. 1.

Gain Controlled Motion Detection: At the commencement of the encoding procedure the motion compensation (MC) scheme determines a motion vector (MV) for each of the 8 × 8 blocks. The MC search window is fixed to 4 × 4 pels around the center of each block. Before the actual motion compensation takes place the codec tentatively determines the potential benefit of the compensation in terms of motion compensated error energy reduction. In order to emphasize the subjectively, more important eye and mouth region of the videophone images the potential gains for each motion compensated block are augmented by a factor of two in the center of the screen. Then the codec selects the thirty blocks resulting in the highest scaled gain, and motion compensation is applied only to these blocks, whereas for all other so-called passive blocks the codec applies simple frame differencing.

Gain Controlled Quadruple-Class DCT: Pursuing a similar approach, gain control is also applied to the DCT-based compression. Every block is DCT transformed and quantized. Because of the nonstationary nature of the motion compensated error residual (MCER) the energy distribution characteristics of the DCT coefficients vary. Therefore four different sets of DCT quantizers are available, as examplified in Fig. 2. All four bit allocation schemes are tentatively invoked in order to select the best set of quantizers resulting in the highest energy compaction gain. Ten bits are allocated for each quantizer, each of which are trained Max-Lloyd quantizers catering for a specific frequency-domain energy
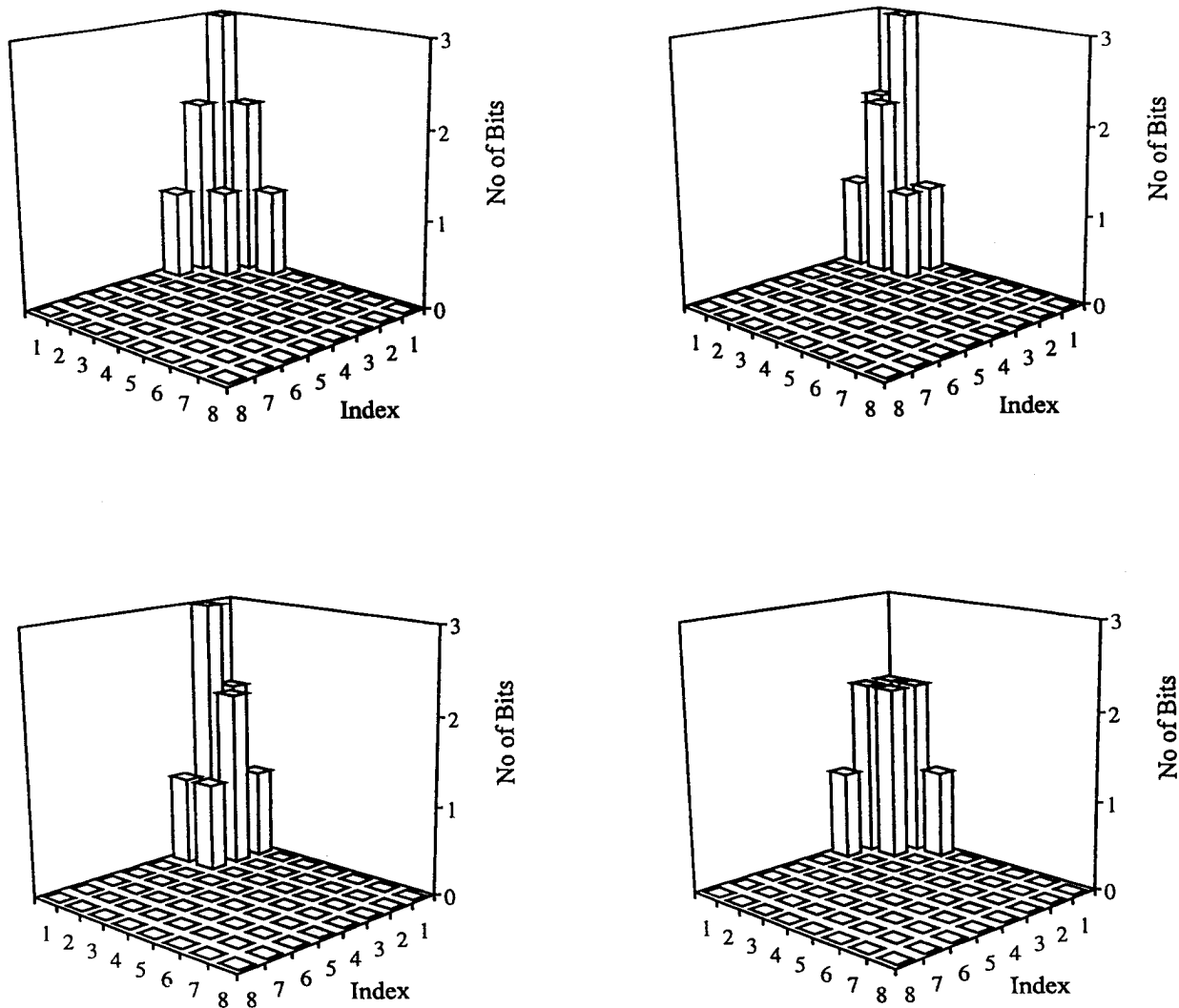
Fig. 2. Quad-class DCT quantization schemes.

distribution class. Again, the energy compaction gain values are scaled to emphasise the eye and mouth region of the image and the DCT coefficients of the thirty highest-compression blocks are transmitted to the decoder.

Partial Forced Update: The disadvantage of interframe codecs is their vulnerability to channel errors. Every channel error results in a misalignment between the reconstructed frame buffer of the encoder and decoder. The errors accumulate and do not decay, unless a leakage-factor or a partial forced update (PFU) technique is employed. In our proposed codec in every frame 22 out of the 396 blocks, scattered over the entire frame, are periodically updated using the 4-b quantized block means, which are partially overlayed on to the contents of the reconstructed frame buffer. The overlaying is performed such that the block's contents in the local buffer is weighted by 0.7 and superimposed on to the received block average, which is scaled by 0.3. The bit-rate contribution of this PFU process is a moderate $22 \times 4 = 88$ bits per QCIF frame and it refreshes about 5.6% of each frame.

Bit Allocation Strategy: The bit allocation scheme was designed to deliver 1136 b per frame, which begins with a

22-b frame alignment word (FAW). This is necessary to assist the video decoder's operation in order resume synchronous operation after loss of frame synchronization over hostile fading channels. The partial intraframe update refreshes only 22 out of 396 blocks every frame. Therefore every 18 frames or 1.8 s the update refreshes the same blocks. This periodicity is signalled to the decoder by transmitting the inverted FAW. A MV is stored using 13 b, where 9 b are required to identify one of the 396 the block indexes using the enumerative method and 4 b for encoding the 16 possible combinations of the X and Y displacements. The 8×8 DCT-compressed blocks use a total of 21 b, again 9 for the block index, 10 for the DCT coefficient quantizers, and 2 b to indicate which of the four quantizer has been applied. The total number of bits becomes $30 \cdot (13 + 21) + 22 \cdot 4 + 22 + 6 = 1136$, where six dummy bits were added in order to obtain a total of 1136 b suitable in terms of bit packing requirements for the specific forward error correction block codec used. The video codec's peak signal-to-noise ratio (PSNR) performance is portrayed in Fig. 3 for the well-known 'Miss America' sequence and for

Fig. 3. PSNR performance of the 11.36 kbps Codec 1.

Fig. 4. PSNR degradation profile for Bits 2 and 11 of the MV in Codec 1.

TABLE I
BIT ALLOCATION TABLE

FAW	PFU	MV Index	MV	DCT Index	DCT	Padding	Total
22	22×4	30×9	30×4	30×9	30×12	6	1136

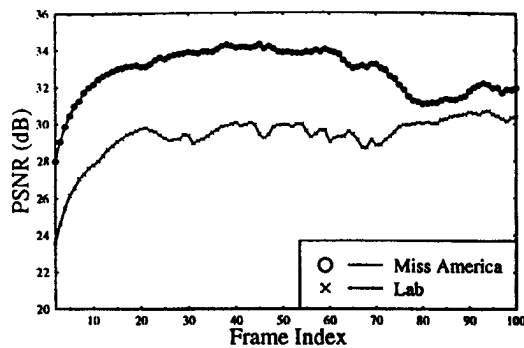a high-activity sequence referred to as the 'Lab sequence.'[1] For 'Miss America' an average PSNR of about 33 dB was maintained, which was associated with pleasant videophone quality. The bit allocation scheme is summarized in Table I and the complexity of this codec is about 50 Mflops, which can be reduced to about 25 Mflops without significant performance penalty. In our further discourse we will refer to the above scheme as Codec 1. After addressing the bit sensitivity issues of Codec 1 we will propose a lower bit rate but more error sensitive arrangement, Codec 2, and analyze their advantages and disadvantages.

Source Sensitivity: In order to apply source-sensitivity matched protection the video bits were subjected to sensitivity analysis. In [9] we have consistently corrupted a single bit of a video coded frame and observed the image peak signal-to-noise ratio (PSNR) degradation inflicted. Repeating this method for all bits of a frame provided the required sensitivity figures and on this basis bits having different sensitivities can be assigned matching FEC codes. This technique, however, does not take adequate account of the phenomenon of error propagation across image frame boundaries. Therefore in this treatise we propose to use the method suggested in [17], where we corrupted each bit of the same type in the current frame and observed the PSNR degradation for the consecutive frames due to the error event in the current frame. As an example, Fig. 4 depicts the PSNR degradation profile in case of corrupting all 'No 1' Bits, the most significant bit (MSB) of the PFU and all 'No 11' Bits, one of the address bits of the MV, in frame 21. In the first case, the MSB of all PFU blocks are corrupted causing a scattered pattern of artifacts across the image. Those blocks will be replenished by the PFU exactly every 18 frames, revealed in the 'staircase' effect in Fig. 4. The impact of the corrupted MV is randomly distributed across the frame and hence, mitigated continuously by the PFU.

In order to quantify the overall sensitivity of any specific bit we have integrated (summed) the PSNR degradations over the consecutive frames, where they have had a measurable

[1] The MA sequence encoded at 11.36 kbps can be viewed under the address www:/whirligig.ecs.soton.ac.uk/~jss.
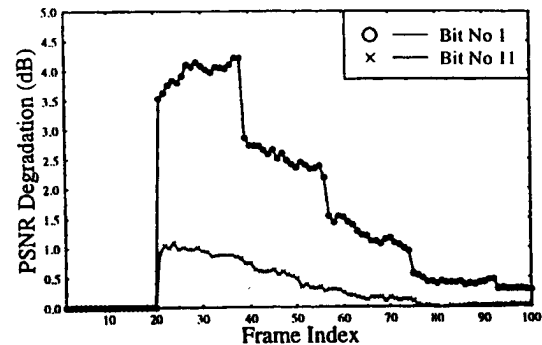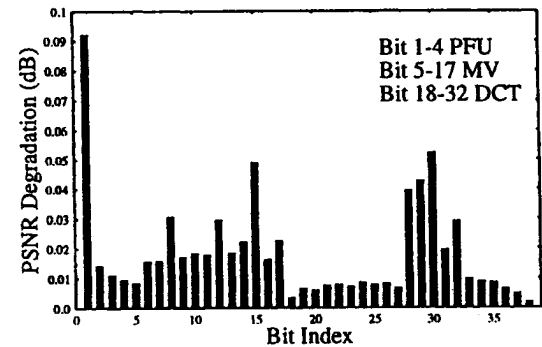
Fig. 5. Integrated PSNR bit sensitivities of Codec 1.

effect and averaged these values for all the occurrences of the corresponding bit errors. These results are shown in Fig. 5 for the 13 MV bits and 21 DCT bits of an 8 × 8 block, as well as for the 4 partial forced update bits.

2.2. Codec 2

In an attempt to improve the bandwidth efficiency of Codec 1 and to explore the range of design trade-offs, we have studied the statistical properties of the various parameters of Codec 1 in order to identify any persisting residual redundancy. We found that the motion activity table and the table of DCT-active blocks were potentially amenable to further data compression using run length coding (RLC). Therefore we set out to contrive a range of run length coded video codecs with bit rates as low as 5, 8, and 10 kbps, which we refer to as Codec 2.

The schematic diagram of Codec 2 is akin to that of Codec 1 shown in Fig. 7, but the above mentioned coding tables are further compressed by RLC. Similarly to Codec 1, the operation of Codec 2 is also initialized in the **intraframe mode,** where the encoder transmits the coarsely quantized block averages for the current frame. This provides a low-resolution initial frame required for the operation of the motion compensated **interframe** codec at both the commencement and during later stages of communications in order to prevent encoder/decoder misalignment. However, for the sake of maintaining a total bit rate R in the range of 5–10 kb/s for our 176 × 144 pixel CCITT standard QCIF images at a scanning rate of 10 frames/s we now limited the number of encoded bits per frame in Codec 2 to 500, 800, and 1000 b/frame, respectively. In order to

transmit all block averages with a 4-b resolution, as in Codec 1, while not exceeding the above stipulated maximum bit rate, we fixed the initial intraframe block size to 10×10, 12×12, or 14×14 pixels for the above three target bit rates. The intraframe block size in Codec 1 was 10×10 pixels.

However, in the motion-compensation (MC) we retained the block-size of 8×8 and the search window size of 4×4 around the center of each block. Furthermore, the previously proposed gain-controlled MC and quad-class DCT quantization was invoked. This method of classifying the blocks as motion-active and motion-passive results in an active/passive table, which consists of a one bit flag for each of the 396 blocks, marking it as passive or active. These tables are compressed using the elements of a two stage quad tree (QT) as follows.

First the 396-entry activity table containing the binary flags is grouped in 2×2 blocks and a four bit symbol is allocated to those blocks which contain at least one active flag. These four-bit symbols are then run length encoded and transmitted to the decoder. This concept requires a second active table containing $396/4 = 99$ flags in order to determine which of the two by two blocks contain active vectors. Three consecutive flags in this table are packetized to a symbol and then run length encoded. As a result, a typical 396-b active/passive table containing 30 active flags can be compressed to less than 150 b. The motion vectors do not lend themselves to run length encoding.

If at this stage of the encoding process the number of bits allocated to the compressed motion- and DCT-activity tables as well as to the active MV's exceeds half of the total number of available bits/frame, some of the blocks satisfying the initial motion-active criterion will be relegated to the motion-passive class. This process takes account of the subjective importance of various blocks and and does not ignore motion-active blocks in the central eye and lip regions of the image, while relegating those, which are closer to the fringes of the frame. The DCT blocks are handled using a similar procedure. Depending on the actual fixed-length transmission burst and the free buffer space, a number of active DCT blocks is chosen and the corresponding compressed tables are determined. If the total bit count overspills the transmission burst or if there are too many bits left unused, a different number of active blocks is estimated and new tables are determined.

The PSNR versus frame index performance of a 5, 8, and 10 kbps RLC scheme is shown for the 'Miss America' sequence in Fig. 6 and the average results are summarized is Table II. Although due to the low-resolution intraframe mode at the commencement of communications it takes a few frames for the image to reproduce fine details, this effect is not objectionable. This is because the subjectively more important center of the screen is processed first. Fig. 6 demonstrates that at 5 kbps the codec operates at its limits and hence it takes a long time before the steady-state PSNR value is reached. However, at rates at or above 8 kbps a pleasant quality is maintained leading to an average PSNR in excess of 30 dB, which is exceeded in the center of the image. Based on these findings, in the run length coded System 2 we have opted for an **8.52 kbps** implementation of **Codec 2,** generating 852 b per frame and maintaining an average PSNR of about

TABLE II
AVERAGE PSNR PERFORMANCE OF CODEC 2 FOR THE 'MISS AMERICA' AND 'LAB' SEQUENCES

Sequence	'Miss America'	'Lab'
5 kb/s	30.26 dB	21.87 dB
8 kb/s	33.29 dB	24.34 dB
10 kb/s	33.52 dB	26.91 dB
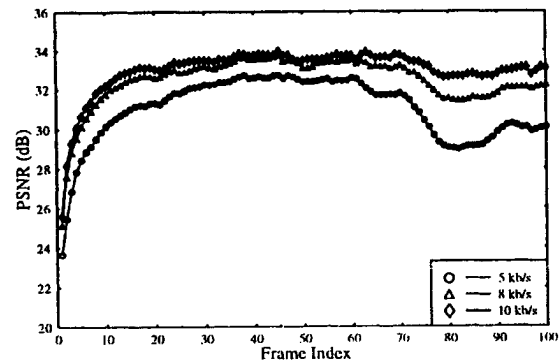
Fig. 6. PSNR versus frame index performance of Codec 2 for the 'Miss America' sequence.

33.3 dB for the MA sequence. We also note that in some of the proposed systems an **8 kbps** reduced-rate version of Codec 2 will be invoked, which we refer to as **Codec 2a.** Before we continue with the description of the source-matched transceiver schemes it must be emphasized that, in contrast to Codec 1 where no RLC is employed, if the RL-coded activity table bits are corrupted, the rest of that frame will be completely corrupted. Hence automatic repeat request (ARQ) techniques are preferred in the systems employing the RL-coded Codec 2. The sensitivity of the remaining bits is similar to that of the corresponding Class Two bits of Codec 1.

III. MODULATION AND TRANSMISSION

Over mobile channels constant envelope modulation techniques, such as for example Gaussian Minimum Shift Keying (GMSK) used in the Pan-European GSM system [59] has successfully been applied. In contrast, until quite recently QAM research was mainly focused at applications over AWGN channels [35]. However, fuelled by the drive towards ever higher bandwidth efficiency and facilitated by advances, such as noncoherent star QAM [45], coherent pilot symbol assisted modulation [55] and the transparent tone in band [56], [57] (TTIB) technique, during the last few years its employment has also become realistic over mobile channels [36]–[48]. In order to achieve high bandwidth efficiency, QAM encodes information on both the phase and magnitude of the complex transmitted signal and hence it requires a linear transceiver, which suffer from low power efficiency [53], [54]. However, in low-power pico- or microcellular applications this is not a serious limitation, since the power consumption of the high-complexity digital circuitry is more crucial. In fact, due to its reduced signalling rate such a transceiver may be able to operate in a nondispersive scenario, without a channel equalizer, which reduces the power consumption.

The innate sensitivity of QAM against co-channel interference in an interference limited scenario is mitigated by the partitioning walls in indoors pico-cells and can be further reduced using the channel segregation algorithm proposed in [49]. Instead of tolerance-sensitive linear-phase Nyquist filtering nonlinear filtering (NLF) joining time-domain signal transitions with a smooth curve can be employed [26]. In case of coherent detection better performance can be achieved than using lower-complexity noncoherent differential modems. In order to phase-coherently recover the orthogonal quadrature carriers at the receiver, which will assist to recover the transmitted data, the Transparent-tone-in-band (TTIB) principle [56]–[58] or Pilot Symbol Assisted Modulation (PSAM) [55], [48] can be invoked.

Differentially coded noncoherent QAM modems [45] have typically low complexity than their coherent counterparts, but they inflict a characteristic 3 dB differential coding SNR penalty over AWGN channels, which persists also over Rayleigh channels. Hence they require higher SNR and SIR values than the more complex coherent schemes [26]. Therefore in our video transceiver second-order switched-diversity assisted coherent Pilot Symbol Assisted Modulation (PSAM) using the maximum-minimum-distance square QAM constellation is used [26].

IV. SOURCE-MATCHED TRANSCEIVER

4.1. System 1

System Concept: The system's schematic is portrayed in Fig. 7, where the source encoded video bits generated by Codec 1 are split in two sensitivity classes and sensitivity matched channel coding/modulation is invoked. The proposed system was designed for mobile packet video telephony and it had two different modes of operation, namely 4-level and 16-level quadrature amplitude modulation (QAM) [26]. Our intention was to contrive a system, where the more benign propagation environment of indoors cells would benefit from the prevailing higher signal-to-noise ratio (SNR) by using bandwidth efficient 16QAM and thereby requiring only half the number of packets compared to 4QAM. When the portable station (PS) is handed over to an outdoors microcell or roams in a lower SNR region towards the edge of a cell, the base station (BS) instructs the PS to lower its number of modulation levels to 4 in order to maintain an adequate robustness under lower SNR conditions. Let us now focus our attention on specific details of System 1.

Sensitivity-Matched Modulation: Best robustness against channel errors is achieved, if sensitivity-matched forward error correction coding is used. Similarly to our approach in [18], Wei [25] has also suggested to use unequal protection multilevel coded modulation in order to achieve high bandwidth efficiency. Following similar principles here, in our proposed videophone schemes we will exploit that 16-level pilot symbol assisted quadrature amplitude modulation [26] (16-PSAQAM) provides two independent 2-b subchannels having different bit error rates (BER). Specifically, the BER of the higher integrity C1 subchannel is a factor 2–3 times
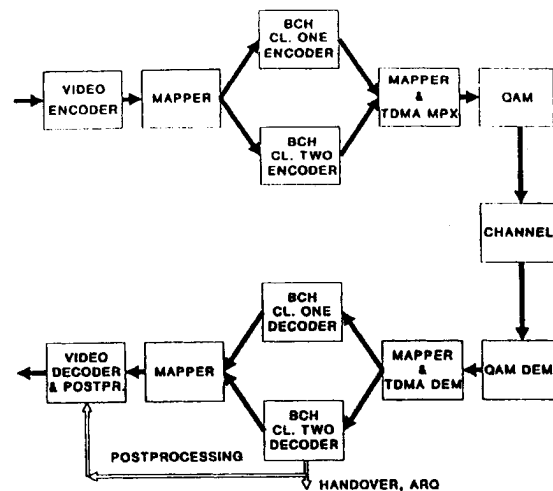
Fig. 7. System's schematic.
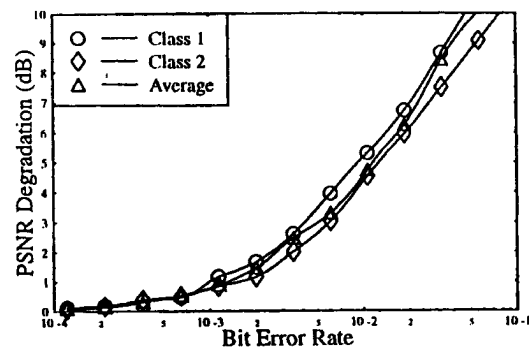
Fig. 8. PSNR versus BER degradation of Codec 1 for class one and two.

lower than that of the lower quality C2 subchannel. Both subchannels support the transmission of two bits per symbol. This implies that the 16-PSAQAM scheme inherently caters for sensitivity-matched protection, which can be fine-tuned using appropriate FEC codes to match the source requirements. This property is not retained by the 4QAM scheme, but the required different protection for the source coded bits can be ensured using appropriately matched channel codecs.

Source Sensitivity: In order to find the appropriate FEC code for our video codec, its output stream was split in two equal sensitivity classes, Class One and Two according to our findings in Fig. 5. Note that the notation Class One and Two introduced here for the more and less sensitive video bits is different from the higher and lower integrity C1 and C2 modulation channels. Then the PSNR degradation of both Class One and Two as well as the average PSNR degradation was evaluated for a range of BER values in Fig. 8. These results showed that a factor two lower BER was required by Class One bits than by Class Two bits, in order to maintain similar PSNR degradations in the range of 1–2 dB. These integrity requirements conveniently coincided with the integrity ratio of the C1 and C2 subchannels of our 16-PSAQAM modem [26]. Hence we can apply the same FEC protection to both Class One and Two source bits and direct Class One bits to the C1 16-PSAQAM subchannel, while Class Two bits to the C2 subchannel.

TABLE III
SUMMARY OF SYSTEM FEATURES

Feature	System 1	System 2	System 3	System 4	System 5
Video Codec	Codec 1	Codec 2	Codec 1	Codec 2a	Codec 2a
Video rate (kbps)	11.36	8.52	11.36	8	8
Frame Rate (fr/s)	10	10	10	10	10
C1 FEC C2 FEC Header FEC	BCH(127,71,9) BCH(127,71,9) BCH(127,50,13)	BCH(127,50,13) BCH(127,92,5) BCH(127,50,13)	BCH(127,71,9) BCH(127,71,9) BCH(127,50,13)	BCH(127,50,13) BCH(127,50,13) BCH(127,50,13)	(BCH(127,50,13) (BCH(127,50,13) (BCH(127,50,13)
FEC-coded Rate (kbps)	20.36	15.24	20.36	20.36	20.36
Modem	4/16-PSAQAM	4/16-PSAQAM	4/16-PSAQAM	4/16-PSAQAM	4/16-PSAQAM
ARQ	None	Cl. One	Cl. One & Two	Cl. One & Two	None
User Signal. Rate (kBd)	18 or 9	6.66	18 or 9	18 or 9	18 or 9
System Signal. Rate (kBd)	144	144	144	144	144
System Bandwidth (kHz)	200	200	200	200	200
No. of Users	8 or 16	(21-2)=19	6 or 14	6 or 14	8 or 16
Eff. User Bandwidth (kHz)	25 or 12.5	10.5	33.3 or 14.3	33.3 or 14.3	25 or 12.5
Min. AWGN SNR (dB)	7 or 15	15	6 or 13	5 or 11	8 or 12
Min. Rayleigh SNR (dB)	12 or 20	25	7 or 20	7 or 14	15 or 16

Forward Error Correction: Both convolutional and block codes can be successfully used over mobile radio links [50], but in our proposed scheme we have favored binary Bose–Chaudhuri–Hocquenghem (BCH) codes. BCH codes combine a good burst error correction capability with reliable error detection, a facility useful to invoke image post-enhancement, to monitor the channel's quality and to control handovers between traffic cells. The preferred $R = 71/127 \approx 0.56$-rate BCH(127,71,9) code can correct 9 errors in a block of 127 b, a correction capability of about 7.1%. The number of channel coded bits per image frame becomes $1136 \times 127/71 = 2032$, while the bit rate is 20.32 kbps at an image frame rate of 10 frames/s.

Transmission Format: The transmission packets are constructed using one Class One BCH(127,71,9) code, one Class Two BCH(127,71,9) code, and a stronger BCH(127,50,13) is allocated to the packet header, yielding a total of 381 b per packet. In case of 16QAM these are represented by 96 symbols and after adding 11 pilot symbols using a pilot spacing of $P = 10$ as well as 4 ramp symbols to ensure smooth power amplifier ramping the resulting 111-symbol packets are transmitted over the radio channel. Eight such packets represent a whole image frame and hence the signalling rate becomes 111 symb/12.5 ms ≈ 9 kBd. When using a time division multiple access (TDMA) channel bandwidth of 200 kHz, such as in the Pan-European second generation mobile radio system known as GSM and a modulation excess bandwidth of 38.8%, the signalling rate becomes 144 kBd. This allows us to accommodate 144/9 = 16 users, which coincides with the number of so-called half-rate speech users supported by the GSM system [59].

When the prevailing channel SNR does not allow 16QAM communications, 4QAM must be invoked. In this case the 381-b packets are represented by 191 2-b symbols and after adding 20 pilot symbols and 4 ramp symbols the packet-length becomes 225 symb/12.5 ms, yielding a signalling rate of 18 kBd. In this case the number of videophone users supported by System 1 becomes 8, as in the full-rate GSM speech channel. The system also facilitates mixed-mode operation, where 4QAM users must reserve two slots in each 12.5 ms TDMA frame towards the fringes of the cell, while in the central section of the cell 16QAM users will only require one slot per frame in order to maximize the number of users supported. Assuming an equal proportion of 4 and 16QAM users the average number of users per carrier becomes 12. The equivalent user bandwidth of the 4QAM PS's is 200 kHz/8 = 25 kHz, while that of the 16QAM users is 200 kHz/16 = 12.5 kHz.

For very high quality mobile channels or for conventional telephone lines 64-QAM can be invoked, which further reduces the required bandwidth at the cost of a higher channel SNR demand. However, the packet format of this mode of operation is different from that of the 16 and 4QAM modes and hence requires a different slot length. The 381-b payload of the packet is represented by 64 6-b symbols, four ramp symbols are added along with 14 pilot symbols, which corresponds to a pilot spacing of $P = 5$. The resulting 82-symbol/12.5 ms packets are transmitted at a signalling rate of 6.6 kBd, which allows us to host 22 videophone users. The user bandwidth becomes 200 kHz/22 ≈ 9.1 kHz.

The above-mentioned features of the 16/4QAM System 1 along with the characteristics of a range of other systems about to be introduced in the next section are summarized in Table III.

Clearly, the required signalling rate and bandwidth are comparable to those of most state-of-art mobile radio speech links, which renders our scheme attractive for mobile video telephony in the framework of existing mobile radio systems. Furthermore, this rate can also be readily accommodated by conventional telephone subscriber loops.

4.2. System 2

In order to improve the bandwidth efficiency of Codec 1 we introduced the run-length coded Codec 2. Hence Codec 2 became more vulnerable against transmission errors than Codec 1 and their effect is particularly objectionable, if the run length coded activity table bits are corrupted. Therefore in System 2, which was designed to incorporate Codec 2, the more sensitive run length coded activity table bits are protected by the powerful binary Bose–Chaudhuri–Hocquenghem BCH(127,50,13) codec, while the less vulnerable remaining bits by the weaker BCH(127,92,5) code. Note that the overall

coding rate of $R = (50 + 92)/(127 + 127) \approx 0.63$ is identical to that of System 1, but the RL-coded Class One bits are more strongly protected. At a fixed coding rate this inevitably assumes a weaker code for the protection of the less vulnerable Class Two bits. The 852 b/100 ms video frame is encoded using six pairs of such BCH code words, yielding a total of 6· 254 = 1524 b, which is equivalent to a bit rate of 15.24 kbps.

As in System 1, the more vulnerable run length and BCH(127,50,13) coded Class One bits are then transmitted over the higher integrity C1 16QAM subchannel. The less sensitive BCH(127,92,5) coded Class Two DCT coefficient bits are conveyed using the lower-integrity C2 16QAM subchannel. This arrangement is favored in order to further emphasize the integrity differences of the BCH codecs used, which is necessitated by the integrity requirements of the video bits.

The transmission burst is constructed by adding an additional BCH(127,50,13) code word for the packet header and the resulting 381 b are again converted to 96 16QAM symbols, and pilot as well as ramp symbols are added. In System 2 six such packets represent a video frame, hence the single-user signalling rate becomes 666 symb/100 ms, which corresponds to 6.66 kBd. This allows us to accommodate now Integer[144kBd/6.66] = 21 such users, if no time slots are reserved for packet re-transmissions. This number will have to be reduced in order to accommodate ARQ's.

Automatic Repeat Request: ARQ techniques have been successfully used in data communications [29]–[32] in order to render the bit and frame error rate arbitrarily low. However, due to their inherent delay and the additional requirement for a feed-back channel for message acknowledgement they have not been employed in interactive speech or video communications. In our packet video system however there exists a full duplex control link between the BS and PS, which can be used for acknowledgements and the short TDMA frame length ensures a low packet delay, hence ARQ can be invoked.

In System 2 when the more powerful BCH codec conveying the more sensitive run-length coded Class One bits over the C1 16QAM subchannel is overloaded by channel errors, we re-transmit these bits only using robust 4QAM. Explicitly, for the first transmission attempt (TX1) we use contention-free Time Division Multiple Access (TDMA). If an ARQ-request occurs, the re-transmitted packets will have to contend for a number of earmarked time slots similarly to Packet Reservation Multiple Access (PRMA) [26]. The intelligent base station (BS) detects these events of packet corruption and instructs the portable stations (PS) to re-transmit their packets during the slots dedicated to ARQ-packets. Reserving slots for ARQ-packets reduces the number of video users supported depending on the prevailing channel conditions, as we will show in the Results Section, Section V.

Although the probability of erroneous packets can be reduced by allowing repeated re-transmissions, there is a clear trade-off between the number of maximum transmission attempts and the BCH-coded frame error rate (FER). In order to limit the number of slots required for ARQ-attempts, which potentially reduce the number of video users supported, in System we invoke ARQ only, if the more sensitive run-length

coded Class One bits transmitted via the C1 16-PSAQAM channel and protected by the BCH(127,50,13) codec are corrupted. Furthermore, we re-transmit only Class One bits, but in order to insure a high success rate, we use 4-PSAQAM, which is more robust than 16-PSAQAM. Since only half of the information bits are re-transmitted, they can be accommodated within the same slot interval and same bandwidth, as the full packet. If there are only C2 bit errors in the packet, it is not re-transmitted, which implies that typically there will be residual Class Two errors. In order to limit the number slots dedicated to re-transmissions we limited the number of transmission attempts to three, which implies that a minimum of two slots per frame must be reserved for ARQ. In order to maintain a low system complexity we dispense with any contention mechanism and allocate two time slots to that particular user, whose packet was first corrupted within the TDMA frame. Further users cannot therefore invoke ARQ, since there are no more unallocated slots. A further advantage is that in possession of three copies of the transmitted packet majority decisions can be invoked, if all three packets became corrupted. The basic features of System 2 designed to accommodate Codec 2 are also summarized in Table III.

4.3. Systems 3–5

In order to explore the whole range of available trade-offs we have contrived three further systems, namely Systems 3–5.

System 3 uses the same video and FEC codecs as well as modems as System 1, but it allows a maximum of three transmission attempts in case of C1 BCH(127,71,9) decoding errors. If there are only C2 errors no ARQ is invoked. Employing ARQ in System 1 constitutes a further trade-off in terms of reducing the number of subscribers supported by two, while potentially improving the communications quality at a certain BER, or allowing an expansion of the range of operating channel SNR towards lower values.

System 4 employs a run-length coded source compression scheme similar to Codec 2, but with a slightly reduced bit rate of 8 kbps or 800 b per frame, which we refer to as **Codec 2a.** This system followed the philosophy of System 3, but Class One and Two bits were protected by the more powerful BCH(127,50,13) code instead of the BCH(127,71,9) scheme. The slightly reduced video rate of 8 kbps was imposed in order to be able to accommodate the BCH(127,50,13) code in both 16QAM subchannels, while maintaining the same 20.36 kbps overall rate, as Systems 1 and 3. Clearly, System 4 will allow us to assess, whether it is a worthwhile complexity investment to introduce run-length coding in Codec 1 in order to reduce the source bit rate and whether the increased error sensitivity of Codec 2a can be compensated for by accommodating the more complex and more powerful BCH(127,50,13) codec.

In order to maximise the number of video subscribers supported, the performance of System 4 can also be studied without ARQ techniques. We will refer to this scheme as **System 5.** Again, these system features are summarized in Table III. Having designed the video transceivers their performance results are presented in the next section.
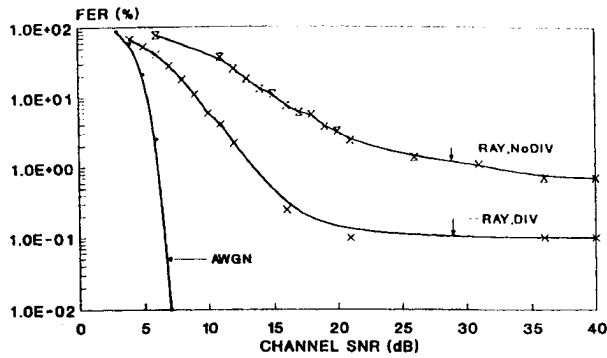
Fig. 9. 4QAM BCH(127,71,9) FER versus channel SNR performance of the 18 kBd mode of operation of System 1 over AWGN and Rayleigh (RAY) channels with diversity (DIV) and without diversity (NoDIV).

Fig. 10. 16QAM C1 and C2 BCH(127,71,9) FER versus channel SNR performance of the 9 kBd mode of operation of System 1 over AWGN and Rayleigh (RAY) channels with diversity (DIV) and without diversity (NoDIV).
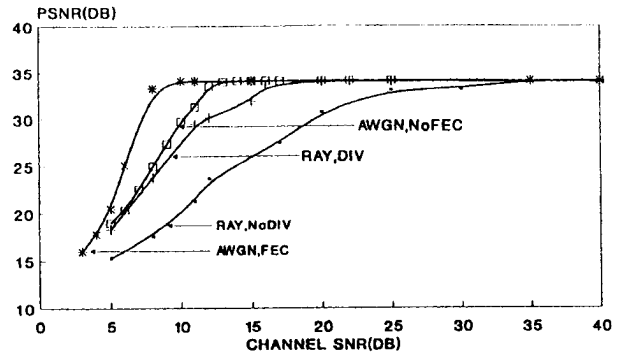

Fig. 11. 4QAM PSNR versus channel SNR performance of System 1 in its 18 kBd mode of operation over various channels.
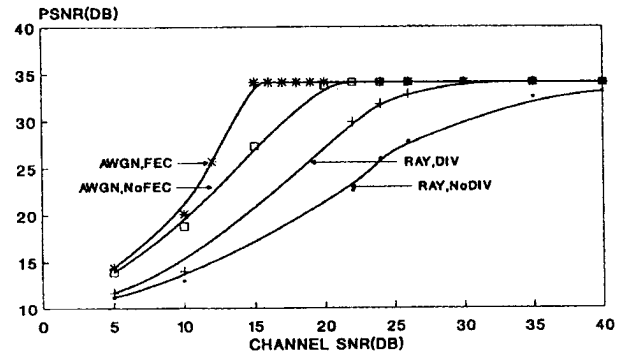
Fig. 12. 16QAM PSNR versus channel SNR performance of System 1 in its 9 kBd mode of operation over various channels.

Fig. 13. 64QAM PSNR versus channel SNR performance of System 1 in its 6.6 kBd mode of operation over various channels.

V. SYSTEM PERFORMANCE

5.1. Performance of System 1

In our experiments the signalling rate was 144 kBd, while the propagation frequency and the vehicular speed were 1.8 GHz and 30 mph, respectively. For pedestrian speeds the fading envelope fluctuates less dramatically and hence our experimental conditions constitute a GSM-like urban worst-case scenario.

Here we characterise the performance of the transceiver in terms of the BCH(127,71,9) coded frame error rate (FER) versus channel signal-to-noise ratio (SNR), as portrayed in Figs. 9 and 10 in case of the 4QAM and 16QAM modes of operation of System 1. In these figures we displayed the FER over both AWGN and Rayleigh channels, in case of the latter both with and without diversity. Note that for near-unimpaired video quality the FER must be below 1%, but preferably below 0.1%. This requirement is satisfied over AWGN channels for SNR's in excess of about 7 dB for 4QAM. In case of 16QAM and AWGN channels the C1 and C2 FER's are reduced to about 0.1% for SNR's above 13 and 15 dB, respectively. Observe in the figures that over Rayleigh-fading (RAY) channels with diversity (DIV) the corresponding FER values are increased to about 15 dB for 4QAM and 20 dB for 16QAM, while without diversity (NoDIV) further increased SNR values are necessitated.

The overall video PSNR versus channel SNR (ChSNR) performance of System 1 is shown in Figs. 11 and 12 for the 4QAM and 16QAM modes of operation, respectively. The PSNR versus ChSNR characteristics of the 6.6 kBd 64QAM arrangement are also given for the sake of completeness in Fig. 13. Observe in the above PSNR versus channel SNR figures that the AWGN performance was evaluated also without forward error correction (FEC) coding in order to indicate the expected performance in a conventional AWGN environment, such as telephone or satellite channels without FEC coding.

Due to its limited bandwidth efficiency gain, high SNR requirement and incompatible slot structure we recommend the 64QAM system for applications, where the bandwidth is at absolute premium and in our further discourse we favor the

Fig. 14. BCH(127,50,13) and BCH(127,92,5) FER versus channel SNR performance of System 2 over AWGN channels.

Fig. 15. BCH(127,50,13) and BCH(127,92,5) FER versus channel SNR performance of System 2 over Rayleigh channels without diversity.

16QAM/4QAM modes of System 1. The corresponding figures suggest that best performance was achieved over AWGN channels with FEC, requiring a channel SNR of about 15 and 7 dB in case of the 16QAM and 4QAM modes of operation, respectively, in order to achieve an unimpaired image quality associated with a PSNR value of about 34 dB. Without FEC coding over AWGN channels these SNR values had to be increased to about 20 and 12 dB, respectively. Over Rayleigh channels with second order diversity the system required ChSNR values of about 15 and 25 dB in the 4QAM and 16QAM modes in order to reach an image PSNR within 1 dB of its unimpaired value of 34 dB. This 1 dB PSNR degradation threshold will be used in all scenarios to characterise the near unimpaired image quality. Lastly, without diversity over Rayleigh channels SNR's of about 25 and 33 dB were needed for near-unimpaired PSNR performance in the 4QAM and 16QAM modes.

5.2. Performance of System 2

FER versus ChSNR: In order to evaluate the overall video performance of System 2, 100 frames of the MA sequence were encoded and transmitted over both the best-case Additive White Gaussian Noise (AWGN) channel and the worst-case narrowband Rayleigh-fading channel. The BCH(127,50,13) and BCH(127,92,5) decoded frame error rate (FER) was evaluated for both the C1 and C2 bits after the first transmission attempt (TX1) over AWGN and Rayleigh channels with and without second-order diversity, as seen in Figs. 14–16. These figures also portray the C1 FER after the second (TX2) and third (TX3) transmission attempts, which were carried out using 4QAM in order to maximise the success rate of the C1 bits, representing the vulnerable run-length coded activity table.

Over AWGN channels a C1 FER of less than 1% can be maintained for channel SNR's in excess of about 5 dB, if three transmission attempts are allowed, although at such low SNR's the C2 bit errors are inflicting an unacceptably high video degradation. The corresponding C2 FER over AWGN channels becomes sufficiently low for channel SNR's above about 14–15 dB in order to guarantee unimpaired video communications, which is significantly higher than that required by the C1 subchannel. Over the Rayleigh channel, but without diversity a channel SNR of about 12 dB was required
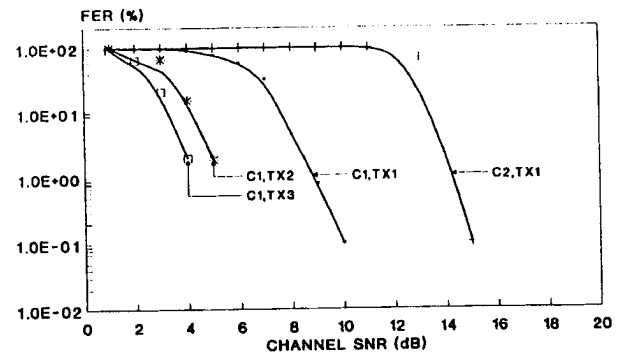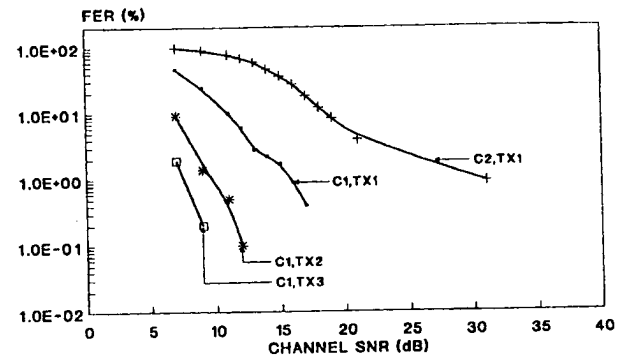
Fig. 16. BCH(127,50,13) and BCH(127,92,5) FER versus channel SNR performance of System 2 over Rayleigh channels with diversity.

with maximum three transmissions in order to reduce the C1 FER below 1% or FER $= 10^{-2}$, as shown in Fig. 15. But the C2 FER curved flattened out for high SNR values, which resulted in a severe 'leakage' of erroneous C2 bits and this resulted in a somewhat impaired video performance. When diversity reception was used, the minimum required SNR value necessary to maintain a similar C1 FER was reduced to around 10 dB, while the C2 FER became adequately low for SNR's in excess of about 20–25 dB, as demonstrated by Fig. 16.

Slot Occupancy: As mentioned before, the ARQ attempts require a number of reserved time slots, for which the re-transmitting MS's have to contend. When the channel SNR is too low, there is a high number of re-transmitted packets contending for too low a number of slots. The slot occupancy increase versus channel SNR performance, which was defined as the ratio of original packets to total transmitted packets, is portrayed for a range of scenarios in Fig. 17. For SNR values in excess of about 10, 15, and 25 dB, when using 16QAM over AWGN as well as Rayleigh channels with and without diversity, respectively, the slot occupancy was increased due to re-transmissions only marginally. Therefore reserving two time slots per frame for a maximum of two re-transmission attempts ensures a very low probability of packet collision during ARQ operations, while reducing the number of subscribers supported by two. In a simplistic approach this would imply that for a channel SNR value, where the FER is below 1% and assuming 20 users the reserved ARQ slots will be only
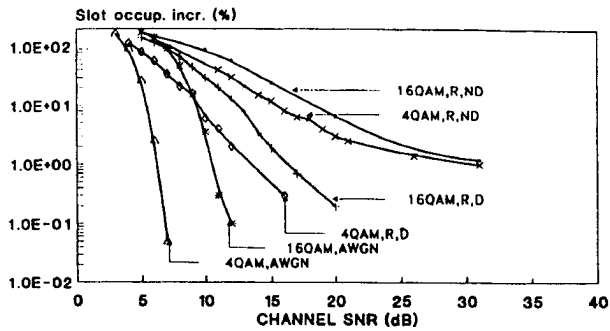
Fig. 17. Slot occupancy increase versus channel SNR performance of the proposed transceivers over AWGN and Rayleigh channels with (D) and without (ND) diversity.
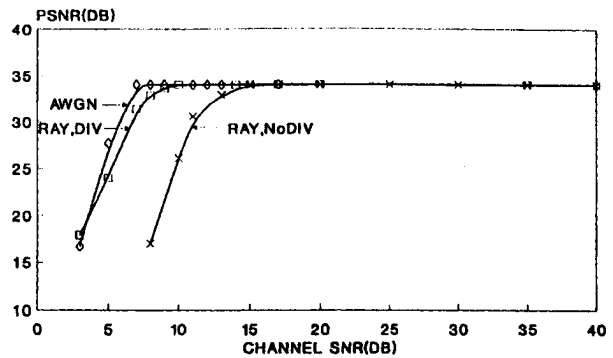
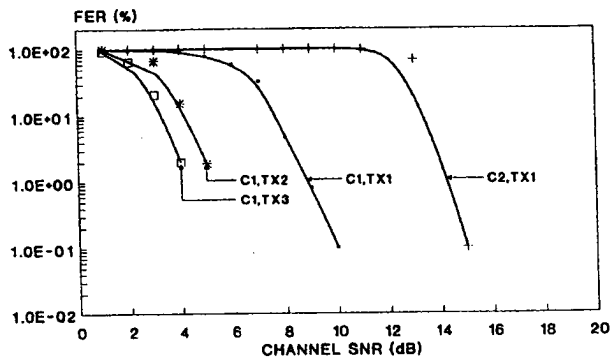Fig. 19. PSNR versus channel SNR performance of the 18 kBd 4QAM mode of System 3 over various channels using three transmission attempts.

Fig. 18. PSNR versus channel SNR performance of the 6.6 kBd System 2 over various channels.

Fig. 20. PSNR versus channel SNR performance of the 9 kBd 16QAM mode of System 3 using three transmission attempts over various channels.

occupied in about every fifth frame. However, we cannot earmark less than two slots for two additional transmission attempts. The 4QAM slot occupancy is even more modest at a given channel SNR than that of the 16QAM schemes, as suggested by Fig. 17.

The PSNR versus ChSNR performance of System 2 is characterized by Fig. 18. Observe that over AWGN channels ChSNR values in excess of 15 dB are required for unimpaired video performance. Over Rayleigh channels with diversity about 20 dB ChSNR is necessitated for an unimpaired PSNR performance, while without diversity the PSNR performance seriously suffers from the leaking Class Two bit errors. Overall, the 6.6 kBd System 2 has a lower robustness than the 9 kBd System 1, since its behavior is predetermined by the initially transmitted Class Two video bits, which were protected by the weaker BCH(127,92,5) code. Recall that System 1 used the BCH(127,71,9) code in both the C1 and C2 subchannels. In fact the performance of the 6.6 kBd System 2 is more similar to that of the 6.6 kBd 64QAM system characterized in Fig. 13, which does not use ARQ. Re-transmission attempts to improve the integrity of the initially received Class One bits and ensure an adequate integrity for these vulnerable bits, but without enhancing the quality of the initial 16QAM C2 subchannel, System 2 cannot outperform System 1. Furthermore, System 2 is inherently more complex than System 1 and only marginally more bandwidth efficient. Therefore in contriving the remaining systems we set out to improve the noted deficiencies of System 2.

5.3. Performance of Systems 3–5

Clearly, our experience with System 2 suggested that it was necessary to re-transmit both Class One and Two bits, if the overloading of the C1 FEC codec indicated poor channel conditions. This plausible hypothesis was verified using System 3, which is the ARQ-assisted System 1. This allowed us to assess the potential benefit of ARQ's in terms of the minimum required channel SNR, while its advantages in terms of FER reduction were portrayed in Figs. 14–16. The corresponding PSNR curves of System 3 are plotted in Figs. 19 and 20 for its 18 kBd 4QAM and 9 kBd 16QAM modes, respectively. Re-transmission was invoked only, if the C1 FEC decoder was overloaded, but in these cases both the C1 and C2 subchannels were re-transmitted. Comparison with Figs. 11 and 12 revealed very substantial ChSNR reduction over Rayleigh channels, in particular without diversity. This was due to the fact that in case of a BCH frame error by the time of the second or third transmission attempt the channel typically emerged from a deep fade. Over AWGN channels the channel conditions during any further ARQ attempts were similar to those during the previous ones, hence ARQ offered more limited ChSNR reduction. The minimum required ChSNR values for the 4QAM mode over AWGN and Rayleigh channels with and without diversity are 7, 8, and 13 dB, while for the 16QAM mode 13, 18, and 27 dB, respectively, as also shown in Table III.

In System 4 the employment of ARQ was more crucial than in System 3, since the corrupted run-length coded activity
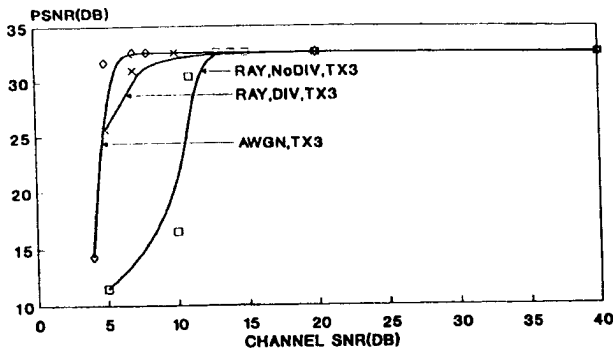
Fig. 21.   PSNR versus channel SNR performance of the 18 kBd 4QAM mode of System 4 using three transmission attempts over various channels.
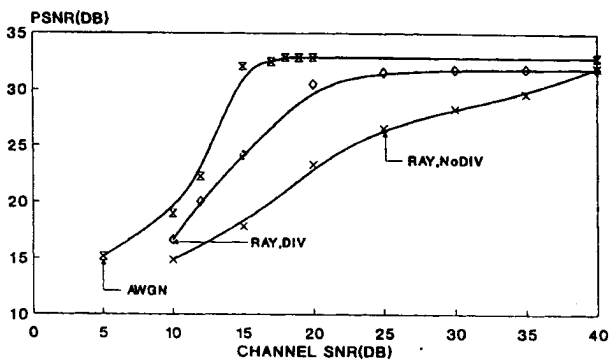

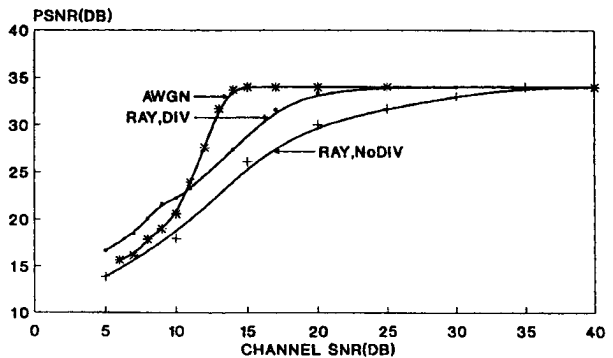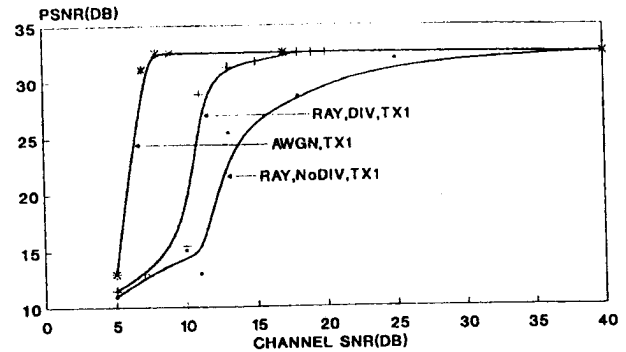Fig. 23.   PSNR versus channel SNR performance of the 18 kBd 4QAM mode of System 5 over various channels.
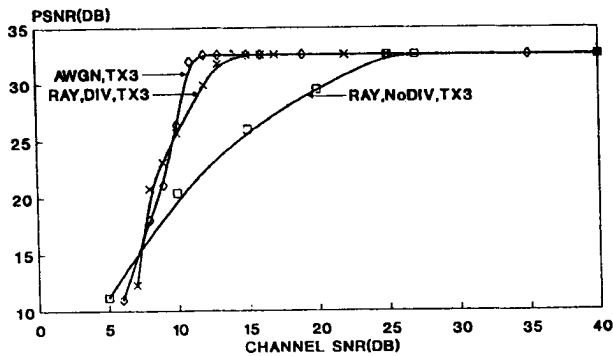
Fig. 22.   PSNR versus channel SNR performance of the 9 kBd 16QAM mode of System 4 using three transmission attempts over various channels.
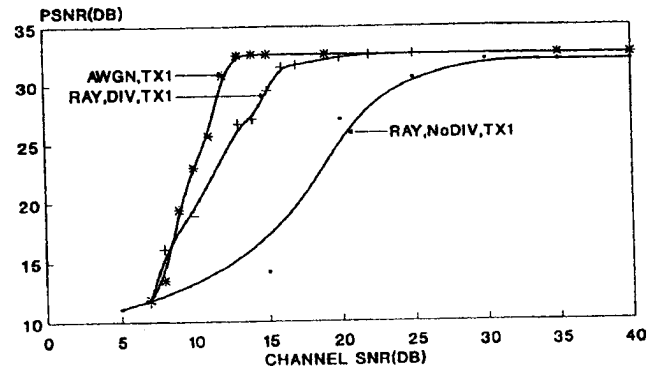
Fig. 24.   PSNR versus channel SNR performance of the 9 kBd 16QAM mode of System 5 over various channels.

tables would inflict severe quality degradations for the whole frame. The corresponding PSNR curves are portrayed for the 18 and 9 kBd 4QAM and 16QAM operating modes in Figs. 21 and 22 over various channels, which can be contrasted with the results shown for System 5 without ARQ in Figs. 23 and 24. Again, over Rayleigh channels the ChSNR requirement reductions due to ARQ are substantial, in particular without diversity, where the received signal typically emerges from a fade by the time ARQ takes place. Over AWGN channels the benefits of ARQ are less dramatic, but still significant. This is because during re-transmission each packet faces similar propagation conditions, as during its first transmission. The required ChSNR thresholds for near-perfect image reconstruction in the 4QAM mode of System 4 are about 6, 8, and 12 dB over AWGN and Rayleigh channels with and without diversity, which are increased to 11, 14, and 27 dB in the 16QAM mode. In contrast, System 5 necessitates ChSNR's of 8, 13, and 25 dB as well as 12, 16, and 27 dB under the previously stated conditions over 4QAM and 16QAM, respectively.

VI. SUMMARY AND CONCLUSIONS

A range of bandwidth efficient, fixed-rate mobile videophone transceivers have been presented, which retain the features summarized in Table III. The video source rate can be fixed to any arbitrary value in order be able to accommodate the videophone signal by conventional 2nd generation mobile radio speech channels, such as for example that of the Pan-

European GSM system [59], the Japanese PDC [19], and the American IS-54 [20] as well as IS-95 systems [21] at bit rates between 6.7 and 13 kbps.

In System 1 the 11.36 kbps Codec 1 was used, which has a lower rate than the 13 kbps speech rate of the GSM system. After BCH(127,71,8) coding the channel rate becomes 20.32 kbps. When using an adaptive transceiver, which can invoke 16QAM and 4QAM depending on the channel conditions experienced, the signalling rate becomes 9 and 18 kBd, respectively. Accordingly, 16 or 8 videophone users can be accommodated in the GSM bandwidth of 200 kHz, which implies user bandwidths of 12.5 and 25 kHz, respectively. Over line-of-sight AWGN channels SNR values of about 15 and 7 dB are required, when using 16QAM and 4QAM, respectively, in order to maintain unimpaired PSNR values of about 34 dB. An increased channel SNR of about 20 and 12 dB is needed over the diversity-assisted Rayleigh scenario.

In System 2 we have opted for an 8.52 kbps videophone codec, maintaining a PSNR of about 33 dB for the MA sequence. The source-coded bit stream was sensitivity-matched binary BCH(127,50,13) and BCH(127,92,5) coded and transmitted using pilot assisted 16QAM. Due to the lower source coded rate of 8.52 kbps of Codec 2 the single-user signalling rate of System 2 was reduced to 6.66 kBd, allowing us to accommodate $21 - 2 = 19$ video-telephone users in the 200 kHz GSM bandwidth. If the signal-to-interference ratio (SIR) and signal-to-noise ratio (SNR) values

are in excess of about 15, and 25 dB over the AWGN and diversity-assisted nondispersive Rayleigh fading channels, respectively, pleasant videophone quality is maintained. The implementation complexity of System 1 is lower than that of System 2, while System 2 can accommodate more users, although it is less robust, as also demonstrated by Table III. This is due to the fact that only the C1 bits are re-transmitted.

On the basis of our experience with System 2 the fully ARQ-assisted System 3 was contrived, which provided a better image quality and a higher robustness, but was slightly less bandwidth efficient than Systems 1 and 2 due to reserving two time slots for ARQ. Furthermore, the question arose, whether it was better to use the more vulnerable run-length coded Codec 2a with stronger and more complex FEC protection, as in Systems 4 and 5, or the slightly higher rate Codec 1 with its weaker and less complex FEC was preferable. In terms of robustness System 5 proved somewhat more attractive than System 4, although the performances of the non-ARQ based System 1 and System 5 are rather similar.

Overall, using schemes similar to the proposed ones mobile videotelephony is becoming realistic over existing mobile speech links, such as the Pan-European GSM system [59], the Japanese PDC [19], and the American IS-54 [20] as well as IS-95 systems [21] at bit rates between 6.7 and 13 kbps. Our future work in this field will be targeted at improving the complexity/quality balance of the proposed schemes using a variety of other video codecs, such as parametrically assisted quad-tree and vector quantized codecs. A further important research area to be addressed is devising reliable transceiver reconfiguration algorithms.

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Lajos Hanzo (M-91–SM'92) graduated with the degree in electronics in 1976 and the Ph.D. degree in 1983 from the Technical University of Budapest Hungary.

During his 19 year career in telecommunications, he has held various research and academic posts in Hungary, Germany, and the United Kingdom. Since 1986, he has been with the Department of Electronics and Computer Science, University of Southampton, U.K., and has been a Consultant to Multiple Access Communications Ltd., U.K.

Dr. Hanzo has co-authored two books on mobile radio communications, published more than 80 research papers, and was awarded a number of distinctions. He is a member of the IEE.
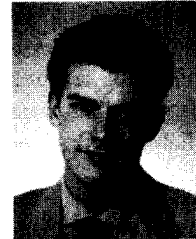
Jürgen Streit was born in Cologne, Germany in 1968. He received the Dipl.-Ing. degree in electronic engineering from the Aachen University of Technology in 1993.

Since 1992, he has been with the Department of Electronics and Computer Science, University of Southampton, U.K., working with the mobile multimedia research group. He is currently working towards the Ph.D. degree in image coding.

US005581575A

United States Patent [19]

Zehavi et al.

[11] Patent Number: 5,581,575

[45] Date of Patent: Dec. 3, 1996

[54] **METHOD AND APPARATUS FOR TRANSMISSION OF VARIABLE RATE DIGITAL DATA**

[75] Inventors: **Ephraim Zehavi**, San Diego; **Andrew J. Viterbi**, La Jolla, both of Calif.

[73] Assignee: **Qualcomm Incorporated**, San Diego, Calif.

[21] Appl. No.: **539,490**

[22] Filed: **Oct. 5, 1995**

Related U.S. Application Data

[63] Continuation of Ser. No. 146,643, Nov. 1, 1993, abandoned.

[51] **Int. Cl.**^{6} **H04L 27/30**
[52] **U.S. Cl.** **375/200**; 375/281; 370/335; 370/468
[58] **Field of Search** 375/200–210, 375/281; 370/94.1, 18; 380/34

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Primary Examiner—Stephen Chin
Assistant Examiner—T. Ghebretinsae
Attorney, Agent, or Firm—Russell B. Miller; Gregory D. Ogrod

[57] **ABSTRACT**

A communication system for transmitting variable rate data is disclosed wherein redundancy is added to the variable rate data to provide repetition symbols. The repetition symbol data is transmitted with symbol energy scaled in accordance to the rate of the variable rate data when the variable rate data is greater than or equal to a nominal data rate. When the variable rate data is less than the nominal data rate, the symbol data is transmitted at nominal symbol energy and redundancy is removed by transmission gating of a proportion of the transmission symbol data determined in accordance with the rate of the variable rate data. Furthermore, a receiver for receiving the variable rate data is disclosed which uses the redundancy in the transmitted data symbol stream to make a corrected estimate of the transmitted symbol data.
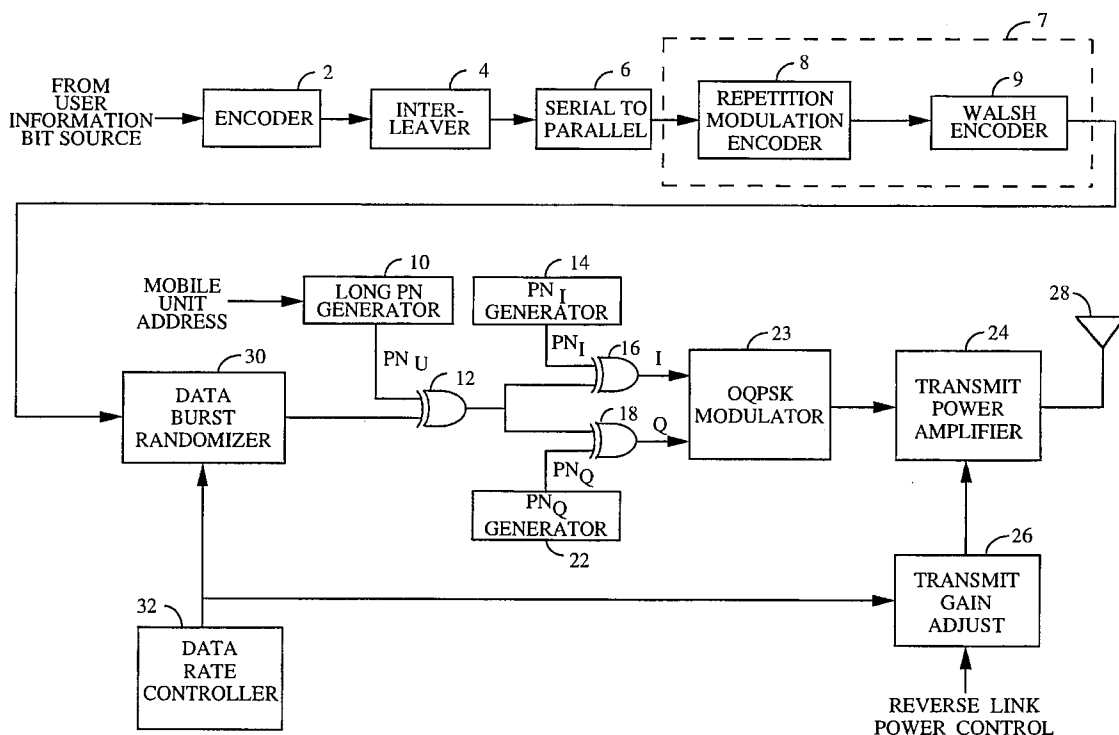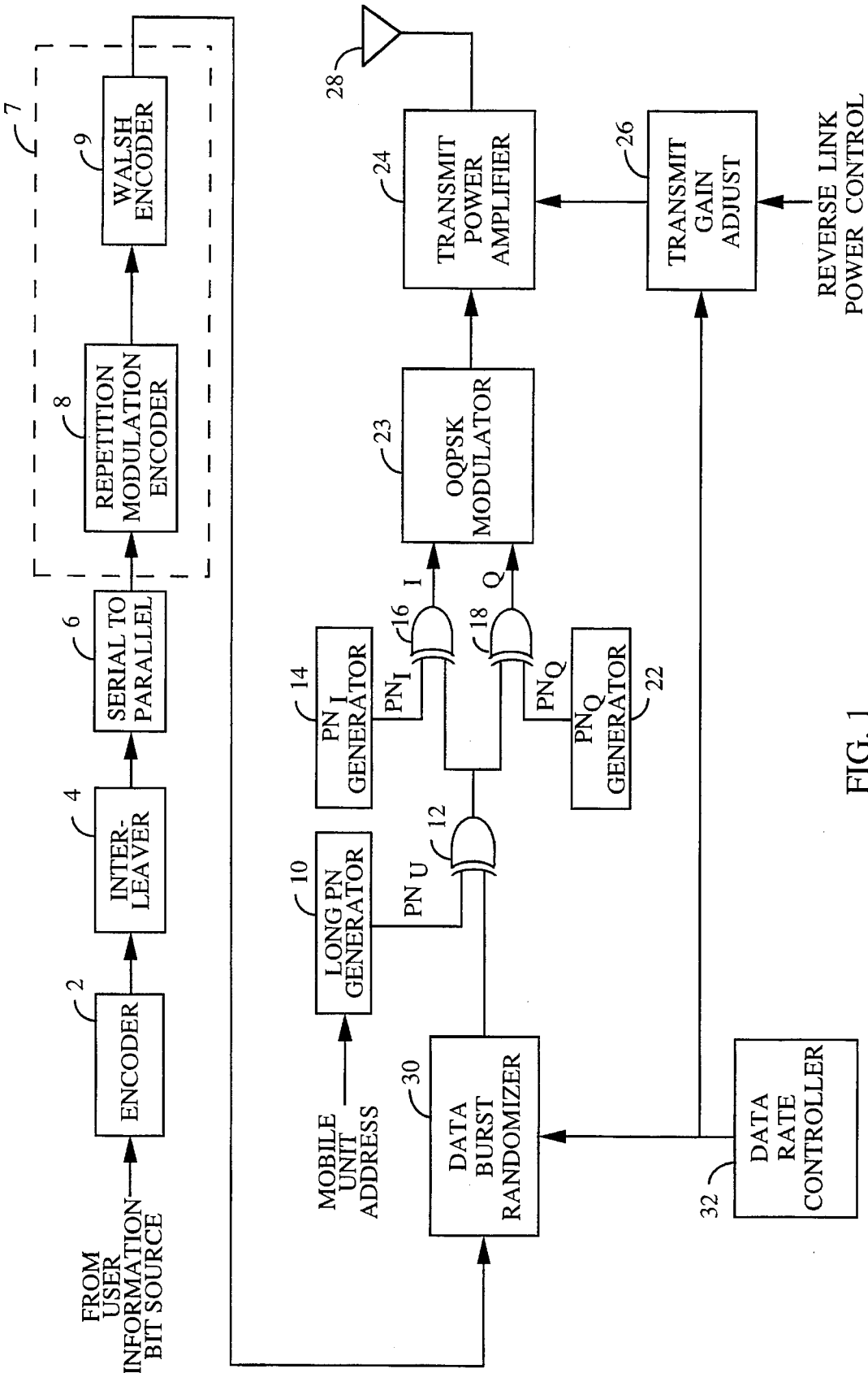
29 Claims, 4 Drawing Sheets
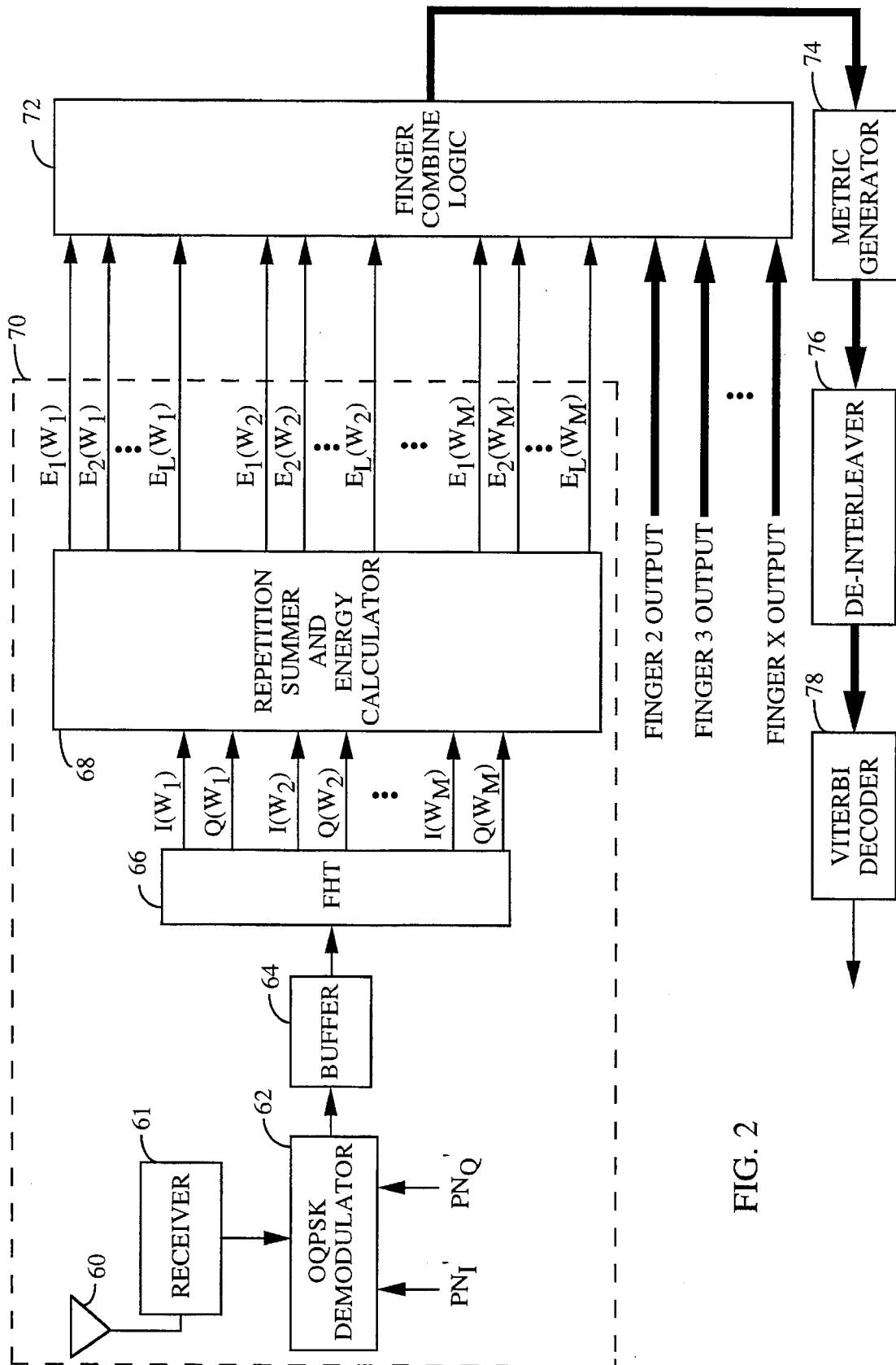
FIG. 1
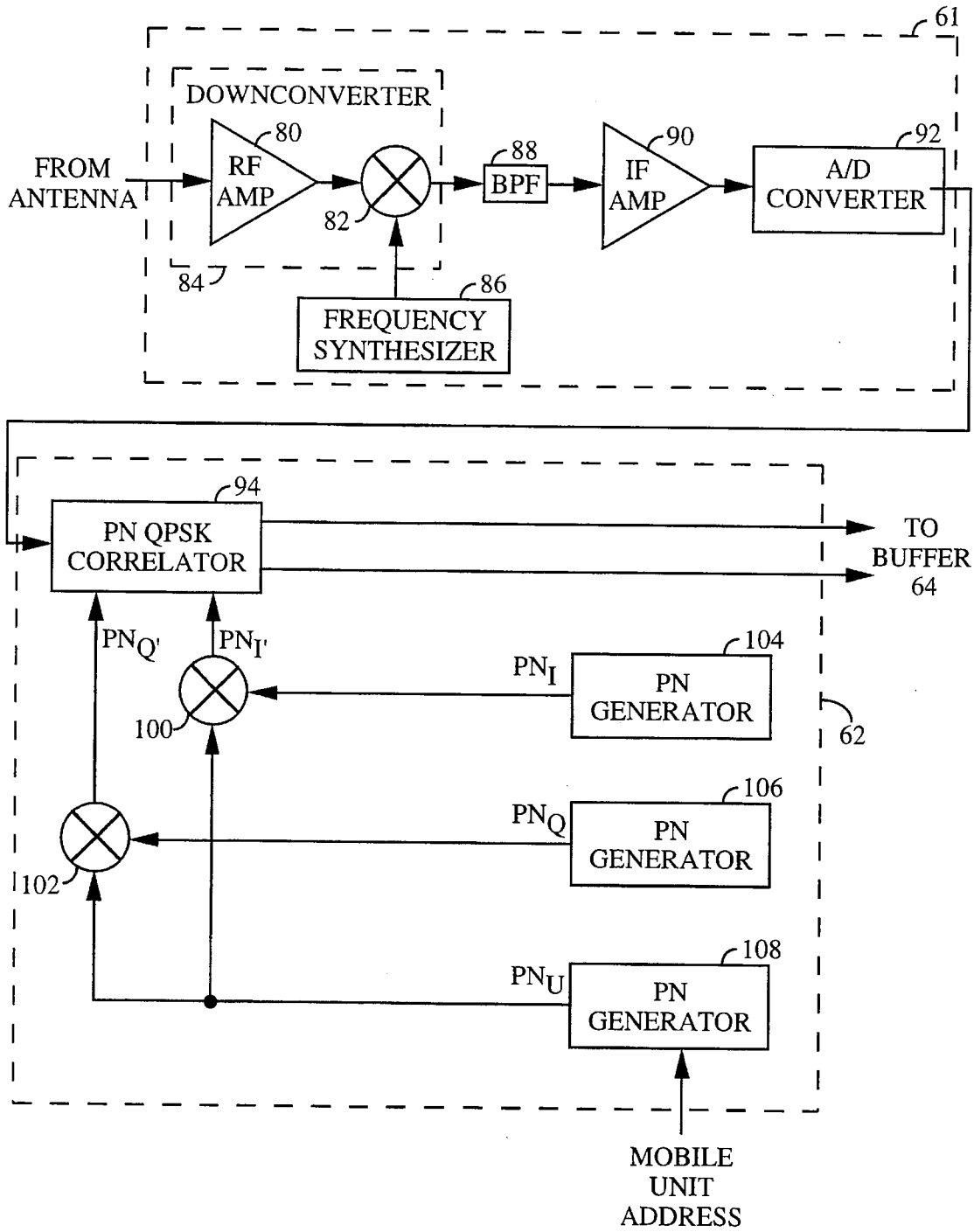
FIG. 2

FIG. 3
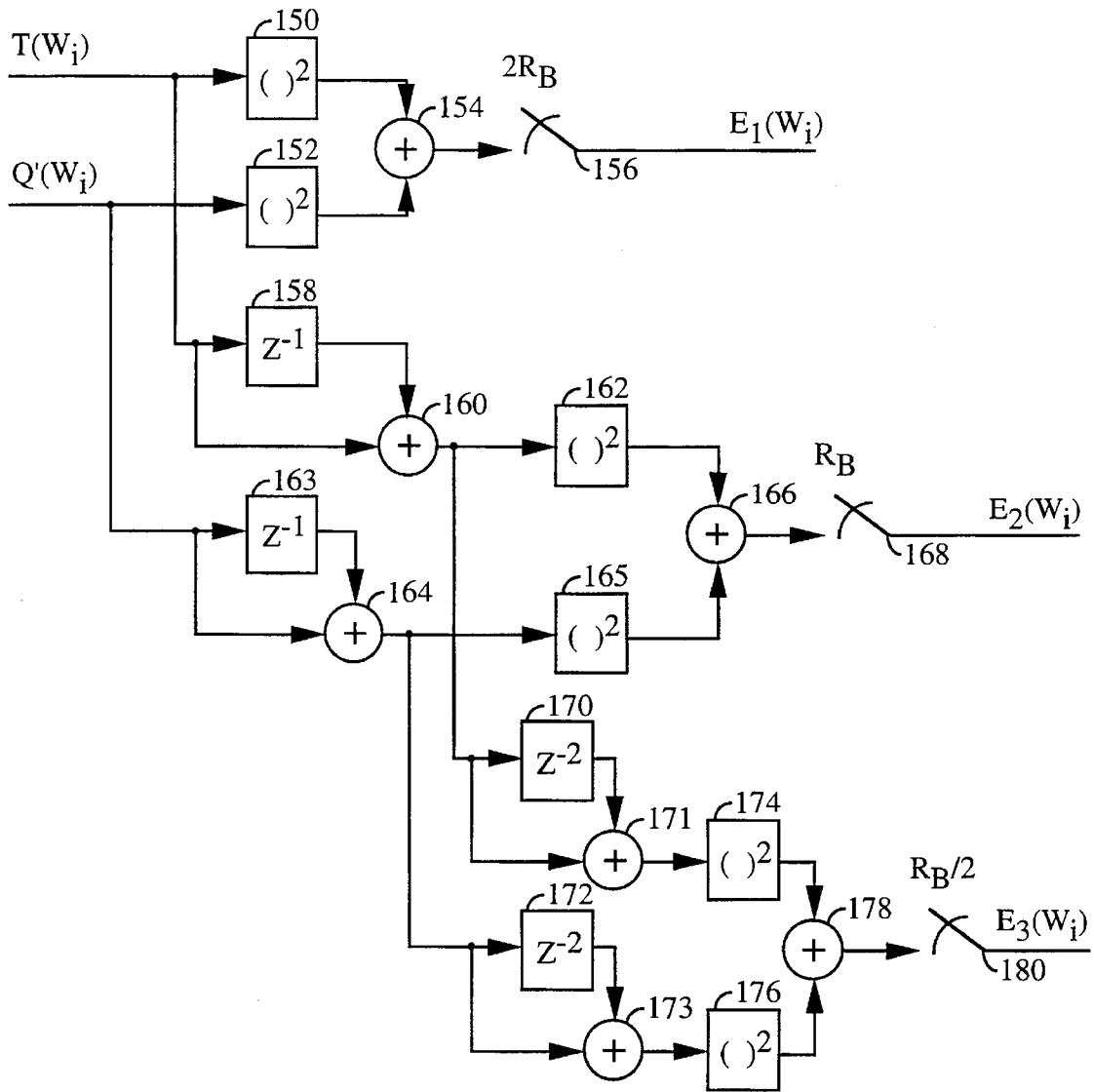
FIG. 4

5,581,575

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METHOD AND APPARATUS FOR TRANSMISSION OF VARIABLE RATE DIGITAL DATA

This is a continuation of application Ser. No. 08/146,643, filed Nov. 1, 1993, now abandoned.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to cellular telephone systems. More specifically, the present invention relates to a novel and improved system and method for communicating variable data rate information using spread spectrum communication signals.

2. Description of the Related Art

The use of code division multiple access (CDMA) modulation techniques is one of several techniques for facilitating communications in which a large number of system users are present. Other multiple access communication system techniques, such as time division multiple access (TDMA), frequency division multiple access (FDMA) and AM modulation schemes such as amplitude companded single sideband (ACSSB) are known in the art. However, the spread spectrum modulation technique of CDMA has significant advantages over these modulation techniques for multiple access communication systems. The use of CDMA techniques in a multiple access communication system is disclosed in U.S. Pat. No. 4,901,307, issued Feb. 13, 1990, entitled "SPREAD SPECTRUM MULTIPLE ACCESS COMMUNICATION SYSTEM USING SATELLITE OR TERRESTRIAL REPEATERS", assigned to the assignee of the present invention, of which the disclosure thereof is incorporated herein by reference.

In the just mentioned patent, a multiple access technique is disclosed where a large number of mobile telephone system users each having a transceiver communicate through satellite repeaters or terrestrial base stations (also referred to as cell-sites stations, cell-sites or for short, cells) using code division multiple access (CDMA) spread spectrum communication signals. In using CDMA communications, the frequency spectrum can be reused multiple times, thus, permitting an increase in system user capacity. The use of CDMA results in a much higher spectral efficiency than can be achieved using other multiple access techniques.

The satellite channel typically experiences fading that is characterized as Rician. Accordingly, the received signal consists of a direct component summed with a multiple reflected component having Rayleigh fading statistics. The power ratio between the direct and reflected component is typically on the order of 6–10 dB, depending upon the characteristics of the mobile unit antenna and the environment about the mobile unit.

Contrasting with the satellite channel, the terrestrial channel experiences signal fading that typically consists of the Rayleigh faded component without a direct component. Thus, the terrestrial channel presents a more severe fading environment than the satellite channel in which Rician fading is the dominant fading characteristic.

The Rayleigh fading characteristic in the terrestrial channel signal is caused by the signal being reflected from many different features of the physical environment. As a result, a signal arrives at a mobile unit receiver from many directions with different transmission delays. At the UHF frequency bands usually employed for mobile radio communications, including those of cellular mobile telephone systems, significant phase differences in signals traveling on different paths may occur. The possibility for destructive summation of the signals may result, with on occasion deep fades occurring.

Terrestrial channel fading is a very strong function of the physical position of the mobile unit. A small change in position of the mobile unit changes the physical delays of all the signal propagation paths, which further results in a different phase for each path. Thus, the motion of the mobile unit through the environment can result in a quite rapid fading process. For example, in the 850 MHz cellular radio frequency band, this fading can typically be as fast as one fade per second per mile per hour of vehicle speed. Fading this severe can be extremely disruptive to signals in the terrestrial channel resulting in poor communication quality. Additional transmitter power can be used to overcome the problem of fading. However, such power increases effect both the user, in excessive power consumption, and the system by increased interference.

The CDMA modulation techniques disclosed in U.S. Pat. No. 4,901,307 offer many advantages over narrow band modulation techniques used in communication systems employing satellite or terrestrial repeaters. The terrestrial channel poses special problems to any communication system particularly with respect to multipath signals. The use of CDMA techniques permit the special problems of the terrestrial channel to be overcome by mitigating the adverse effect of multipath, e.g. fading, while also exploiting the advantages thereof.

In a CDMA cellular telephone system, the same frequency band can be used for communication in all cells. The CDMA waveform properties that provide processing gain are also used to discriminate between signals that occupy the same frequency band. Furthermore, the high speed pseudonoise (PN) modulation allows many different propagation paths to be separated, provided the difference in path delays exceed the PN chip duration, i.e. 1/bandwidth. If a PN chip rate of approximately 1 MHz is employed in a CDMA system, the full spread spectrum processing gain, equal to the ratio of the spread bandwidth to system data rate, can be employed against paths that differ by more than one microsecond in path delay from the desired path. A one microsecond path delay differential corresponds to differential path distance of approximately 1,000 feet. The urban environment typically provides differential path delays in excess of one microsecond, and up to 10–20 microseconds are reported in some areas.

In narrow band modulation systems such as the analog FM modulation employed by conventional telephone systems, the existence of multiple paths results in severe multipath fading. With wide band CDMA modulation, however, the different paths may be discriminated against in the demodulation process. This discrimination greatly reduces the severity of multipath fading. Multipath fading is not totally eliminated in using CDMA discrimination techniques because there will occasionally exist paths with delay differentials of less than the PN chip duration for the particular system. Signals having path delays on this order cannot be discriminated against in the demodulator, resulting in some degree of fading.

It is, therefore, desirable that some form of diversity be provided which would permit a system to reduce fading. Diversity is one approach for mitigating the deleterious effects of fading. Three major types of diversity exist: time diversity, frequency diversity and space diversity.

Time diversity can best be obtained by the use of repetition, time interleaving, and error detection and coding which

is a form of repetition. The present invention employs each of these techniques as a form of time diversity.

CDMA by its inherent nature of being a wideband signal offers a form of frequency diversity by spreading the signal energy over a wide bandwidth. Therefore, frequency selective fading affects only a small part of the CDMA signal bandwidth.

Space or path diversity is obtained by providing multiple signal paths through simultaneous links from a mobile user through two or more cell-sites. Furthermore, path diversity may be obtained by exploiting the multipath environment through spread spectrum processing by allowing a signal arriving with different propagation delays to be received and processed separately. Examples of path diversity are illustrated in U.S. Pat. No. 5,101,501 entitled "SOFT HAND-OFF IN A CDMA CELLULAR TELEPHONE SYSTEM", filed Nov. 7, 1989, and U.S. Pat. No. 5,103,459 entitled "DIVERSITY RECEIVER IN A CDMA CELLULAR TELEPHONE SYSTEM", also filed Nov. 7, 1989, both assigned to the assignee of the present invention.

The deleterious effects of fading can be further controlled to a certain extent in a CDMA system by controlling transmitter power. A system for cell-site and mobile unit power control is disclosed in U.S. Pat. No. 5,056,109 entitled "METHOD AND APPARATUS FOR CONTROLLING TRANSMISSION POWER IN A CDMA CELLULAR MOBILE TELEPHONE SYSTEM", filed Nov. 7, 1989, also assigned to the assignee of the present invention.

The CDMA techniques as disclosed in U.S. Pat. No. 4,901,307 contemplates the use of coherent modulation and demodulation for both directions of the link in mobile-satellite communications. Accordingly, disclosed therein is the use of a pilot carrier signal as a coherent phase reference for the satellite-to-mobile link and the cell-to-mobile link. In the terrestrial cellular environment, however, the severity of multipath fading, with the resulting phase disruption of the channel, precludes usage of coherent demodulation technique for the mobile-to-cell link. The present invention provides a means for overcoming the adverse effects of multipath in the mobile-to-cell link by using noncoherent modulation and demodulation techniques.

The CDMA techniques as disclosed in U.S. Pat. No. 4,901,307 further contemplated the use of relatively long PN sequences with each user channel being assigned a different PN sequence. The cross-correlation between different PN sequences and the autocorrelation of a PN sequence for all time shifts other than zero both have a zero average value which allows the different user signals to be discriminated upon reception.

However, such PN signals are not orthogonal. Although the cross-correlations average to zero, for a short time interval such as an information bit time the cross-correlation follows a binomial distribution. As such, the signals interfere with each other much the same as if they were wide bandwidth Gaussian noise at the same power spectral density. Thus, the other user signals, or mutual interference noise, ultimately limits the achievable capacity.

The existence of multipath can provide path diversity to a wideband PN CDMA system. If two or more paths are available with greater than one microsecond differential path delay, two or more PN receivers can be employed to separately receive these signals. Since these signals will typically exhibit independence in multipath fading, i.e., they usually do not fade together, the outputs of the two receivers can be diversity combined. Therefore, a loss in performance only occurs when both receivers experience fades at the same time. A system that provides for the provision of two or more PN receivers in combination with a diversity combiner and a system for generating a waveform that permits path diversity combining operations to be performed is disclosed in U.S. Pat. No. 5,103,459 entitled "System and Method for Generating Signal Waveforms in CDMA Cellular Telephone System".

In order to support data transmission at variable data rates it has generally been required to vary the rates of encoding, interleaving and modulation in accordance with the input data rate. This rate variation has typically required relatively sophisticated control of channel encoding and decoding processes, thereby increasing system cost, complexity, in addition to requiring a modification of the current waveform signals.

Accordingly, it is the objective of the invention to provide a spread spectrum communication system in which communication channels are available for data transmission at both higher and lower than the nominal system rate. It is yet another object of the present invention to provide a spread spectrum communication system in which a common format is used for encoding, interleaving and modulating data to be transmitted at various data rates.

SUMMARY OF THE INVENTION

The present invention is a novel and improved method and apparatus for transmitting and receiving variable rate data in a spread spectrum communication system.

In the transmitter of the present invention, a plurality of user bit rates are accommodated for transmission. Those user bit rates can be grouped into those that are equal to or greater than a nominal bit rate, and those less than the nominal bit rate. The user data is provided to a repetition coder which provides redundancy into the user bits for user bit rates that are below a maximum bit rate such that the repetition symbol rate provided from the repetition coder is the same for all user bit rates. The repetition coded symbols are then provided to a transmit power amplifier, which operates in accordance with a signal provided from a transmission controller.

The transmission controller is responsive to the user bit rate in providing the control signal to the transmit power amplifier. For bit rates less than the nominal bit rate the transmission controller gates the transmission of the repetition symbols, so as to remove a predetermined portion of the redundancy in the repetition symbols. The transmission gated symbols are then transmitted at a symbol energy that is the same for transmitted symbols where the user bit data is less than the nominal bit rate. When the user bit rate is greater than or equal to the nominal bit rate, the redundancy is not removed, rather the symbol energy is scaled down in proportion to the amount of redundancy in the repetition symbol data.

In the receiver of the present invention, the signals transmitted as described above are received. The received signals are demodulated and provided to a repetition summer and energy calculator. The repetition summer and energy calculator takes advantage of the redundancy in the repetition symbols by summing the energies of the received repeated symbols to provide a series of energy values that correspond to the energies of received hypotheses. These energies are then provided to a metric calculator that provides a set of metrics, which are indicative of the likelihood of different received signal hypotheses. The metrics are then provided to a decoder which in response to the computed metrics estimates the transmitted signal.

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<table><tr><td>5</td><td>6</td></tr></table>

BRIEF DESCRIPTION OF THE DRAWINGS

The features, objects, and advantages of the present invention will become more apparent from the detailed description set forth below when taken in conjunction with the drawings in which like reference characters identify correspondingly throughout and wherein:

FIG. 1 is an exemplary block diagram of the transmitter of the present invention;

FIG. 2 is an exemplary block diagram of the receiver system of the present invention;

FIG. 3 is a an exemplary block diagram of the receiver and demodulator of the present invention; and

FIG. 4 is an exemplary block diagram of the repetition summer and energy calculator of the present invention;

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

It is envisioned that the present invention is applicable to any variable rate digital communication system. The present invention is illustrated in an exemplary embodiment of a reverse link (remote user to central communications center) communications system in a personal communications system. FIG. 1 illustrates an exemplary embodiment of the variable data rate transmitter of the present invention. The variable rate user information bit data may be digital speech data or digital data such as video, facsimile, modem or other digital data. The user information bit rates can be divided into those above or equal to a predetermined nominal bit rate $R_{b(nom)}$ and those below $R_{b(nom)}$. The maximum user information bit rate that is accommodated by the communication system is denoted $R_{b(max)}$. In the exemplary embodiment, the user information bit rates include 1.2, 1.8, 2.4, 3.6, 4.8, 7.2, 9.6, 14.4, 19.2, and 38.4 kbps, where 9.6 kbps is the nominal bit rate $R_{b(nom)}$ and 38.4 kbps is the maximum bit rate $R_{b(max)}$. The rates provided represent exemplary embodiments. It is envisioned that the subject matter of the present invention is equally applicable to any digital transmission rate. Furthermore, the selection of 9.6 kbps as $R_{b(nom)}$ is again for exemplary purposes within the context of the exemplary set of rates. Within the context of the exemplary set of rates an alternative $R_{b(nom)}$ of interest is 4.8 kbps.

In the personal system-to-cell link, user analog voice signals are typically provided through a handset (not shown) as an input to an analog to digital (A/D) converter (not shown) which converts the analog signal to digital form. The digital signal is provided to a variable rate digital vocoder (not shown) where it is encoded. The vocoder will combine this signal with any other source of digital information that can be transmitted within a preset frame format of a fixed length, where the number of information bits per frame varies.

The user information bit data is provided to forward error correction (FEC) encoder 2 at a bit rate R_b, where in the exemplary embodiment the user information bit data is convolutionally encoded to provide encoded symbols. Encoder 2 is a rate r encoder, meaning that encoder 2 generates 1/r encoded symbols for each user information bit it receives. Thus, the encoded symbol rate of encoder 2 is R_b/r. In the exemplary embodiment, the message encoding and modulation process begins with a convolutional encoder of constraint length K=9 and code rate r=⅓. The generators for the code are G_1=557 (octal), G_2=663 (octal), and G_3=711 (octal). The number of code symbols in 20 msec, at the

nominal bit rate $R_{b(nom)}$ of 9600 bps and a code rate r=⅓, is 576. At a nominal data rate of R_b=9600 bits per second, the encoder produces 28,800 binary symbols per second.

The encoded symbols are provided to interleaver 4 which in the exemplary embodiment is a block interleaver spanning 20 msec, exactly one frame in duration. The code symbols are written into the interleaver memory array by rows and read out by columns.

When the user information bit rate R_b is less than the nominal bit rate $R_{b(nom)}$, or alternatively the encoded symbol rate R_b/r is less than the nominal encoded symbol rate $R_{b(nom)}/r$, interleaver 4 has a secondary role of providing redundancy to the encoded symbols. When the user information bit rate R_b is less than $R_{b(nom)}$, the interleaver introduces an encoded symbol redundancy (red1) where:

$$red1 = \frac{R_{B(nom)}}{R_B} \qquad (1)$$

The interleaved symbols comprise a first version of each encoded symbol and red1-1 repeated versions of each encoded symbol. Thus, the interleaved symbols are provided at rate $R_{b(nom)}/r$ when the user information bit rate is less than or equal to the nominal bit rate $R_{b(nom)}$. For user bit rates greater than or equal to the nominal bit rate $R_{b(nom)}$, the interleaved symbol rate is the same as the encoded symbol rate.

Interleaver 4 provides the interleaved symbols to serial to parallel element 6 which provides the interleaved symbol data as n-tuples of the interleaved symbols such that the n-tuples rate is equal to the rate at which the data is provided from interleaver 4 divided by n. So if the user information bit rate R_b was greater than or equal to the nominal bit rate $R_{b(nom)}$ then the n-tuple rate is $R_b/(r.n)$. If the user information bit rate R_b is less than the nominal bit rate $R_{b(nom)}$ then the n-tuple rate is $R_{b(nom)}/(r.n)$, due to the redundancy introduced by interleaver 4. In the exemplary embodiment, n is equal to 6, so that the n-tuple rate for the nominal user bit rate of 9600 is 4800 n-tuples/s.

Serial to parallel element 6 provides the n-tuples to overlay encoding element 7. Overlay encoding element 7 comprises repetition modulation encoder 8 and Walsh encoder 9. The n-tuples are provided to repetition modulation encoder 8 which provides symbol repetition based on the user information bit rate (R_b) to provide repetition modulation symbols. Repetition modulation encoder 8 provides redundancy (red2) of the form:

$$red2 = \begin{cases} R_{B(max)}/R_{B(nom)} & \text{for } R_B < R_{B(nom)} \\ R_{B(max)}/R_B & \text{for } R_B \geq R_{B(nom)} \end{cases} \qquad (2)$$

For each n-tuple provided to repetition modulation encoder 8, repetition modulation encoder 8 provides red2 identical and consecutive n-tuple outputs referred to as repetition modulation symbols, such that the resulting repetition modulation symbol rate is a constant $R_{b(max)}/(r.n)$ for all input data rates R_b. In the exemplary embodiment, where $R_{b(max)}$ is 38.4 kbps the repetition modulation symbol rate is 19,200 repetition symbols per second where each repetition symbol is six binary digits in size.

In the personal communication system-to-cell link also referred to as the reverse link, the channel characteristics dictate that the modulation techniques be modified. In particular, the use of a pilot carrier as is used in the cell-to-personal system link is no longer feasible. The pilot carrier must be powerful in order to provide a good phase reference for data modulation. With the cell-site transmitting many simultaneous transmissions to personal systems, a single pilot signal can be shared by all the personal systems.

Therefore, the pilot signal power per active personal system is quite small.

In the personal system-to-cell link, however, each personal system has its own phase reference. If a pilot were used, it would require that each personal system transmit it own pilot. This situation is clearly not desirable since overall system capacity would be greatly reduced due to the interference caused by the presence of a larger number of high power pilot signals. Therefore, a modulation capable of efficient demodulation without a pilot signal must be used.

With the personal system-to-cell channel corrupted by Rayleigh fading, resulting in a rapidly varying channel phase, coherent demodulator techniques, such as a Costas loop which derives phase from the received signal, are not feasible. Other techniques such as differentially coherent PSK can be employed but fail to provide the desired level of signal-to-noise ratio performance.

Thus, in the exemplary embodiment, the repetition modulation symbols are provided to an orthogonal waveform coder that maps the six binary digit repetition modulation symbols into an orthogonal signal set. It is well known in the art that a set of n orthogonal binary sequences, each of length n, for n any power of 2 can be constructed, see *Digital Communications with Space Applications*, S. W. Golomb et al., Prentice-Hall, Inc., 1964, pp. 45–64. In fact, orthogonal binary sequence sets are also known for most lengths which are multiples of four and less than two hundred. One class of such sequences that is easy to generate is called the Walsh function, also known as Hadamard matrices.

A Walsh function of order n can be defined recursively as follows:

$$W(n) = \left| \begin{array}{c} W(n/2), W(n/2) \\ W(n/2), W'(n/2) \end{array} \right|$$

where W' denotes the logical complement of W, and W(1)= |0|. Thus,

$$W(2) = \left| \begin{array}{c} 0,0 \\ 0,1 \end{array} \right| \text{ and}$$

$$W(4) = \left| \begin{array}{c} 0,0,0,0 \\ 0,1,0,1 \\ 0,0,1,1 \\ 0,1,1,0 \end{array} \right|$$

W(8) is as follows:

$$W(8) = \left| \begin{array}{c} 0,0,0,0,0,0,0,0 \\ 0,1,0,1,0,1,0,1 \\ 0,0,1,1,0,0,1,1 \\ 0,1,1,0,0,1,1,0 \\ 0,0,0,0,1,1,1,1 \\ 0,1,0,1,1,0,1,0 \\ 0,0,1,1,1,1,0,0 \\ 0,1,1,0,1,0,0,1 \end{array} \right|$$

A Walsh sequence is one of the rows of a Walsh function matrix. A Walsh function of order n contains n sequences, each of length n bits.

A Walsh function of order n (as well as other orthogonal functions) has the property that over the interval of n code symbols, the cross-correlation between all the different sequences within the set is zero, provided that the sequences are time aligned with each other. This can be seen by noting that every sequence differs from every other sequence in exactly half of its bits. It should also be noted that there is

always one sequence containing all zeroes and that all the other sequences contain half ones and half zeroes.

Neighboring cells and sectors can reuse the Walsh sequences because the outer PN codes used in neighboring cells and sectors are distinct. Because of the differing propagation times for signals between a particular personal system's location and two or more different cells, it is not possible to satisfy the condition of time alignment required for Walsh function orthogonality for both cells at one time. Thus, reliance must be placed on the outer PN code to provide discrimination between signals arriving at the personal system unit from different cells.

Referring to FIG. 1, each repetition modulation symbol is provided to an M-ary Walsh encoder 9, where in the exemplary embodiment $M=2^n=64$. In response, M-ary Walsh encoder 9, for each repetition modulation symbol, each comprising n=6 binary symbols, generates a Walsh symbol comprising M Walsh chips. The resulting Walsh chip rate out of M-ary Walsh encoder 9 is $(M.R_{b(max)})/(r.n)$ or in the exemplary embodiment 1,228.8 ksps. The Walsh chips are provided to data burst randomizer 30, which is responsive to signals provided by data rate control element 32.

Data burst randomizer 30 selectively removes some of the introduced redundancy for data at input rates R_b less than $R_{b(nom)}$. A preferred method and apparatus of a data burst randomizer is disclosed in copending U.S. Patent Application entitled "DATA BURST RANDOMIZER", Ser. No. 07/846,312, filed Jan. 16, 1992, also assigned to the assignee of the present invention. For data at rates less than $R_{b(nom)}$, data burst randomizer 30 removes the amount of redundancy introduced by interleaver 4. That is, for user information bit rates R_b less than $R_{b(nom)}$ data burst randomizer 30 removes red-1 redundant Walsh chips of every red1 Walsh chips received. Data burst randomizer 30 further temporally rearranges the Walsh chips in accordance with pseudorandom code to provide randomized symbols. For user information bit rates R_b less than the nominal bit rate $R_{b(nom)}$, the average randomized Walsh chip rate is $(M.R_{b(max)}.R_b)/(r.n.R_{b(nom)})$. For user information bit rates greater than or equal to the nominal bit rate the symbol rate remains unchanged.

The randomized Walsh chips are provided to one input to exclusive-OR gate 12. PN generator 10, responsive to a mobile unit address, provides PN sequence PN_U. This PN sequence can either be assigned only for the duration of the call or assigned permanently to the personal system unit. PN_U in the exemplary embodiment is a user specific 42-bit sequence that is provided at a rate of $R_c=1.2288$ MHz such that there is exactly one PN chip for each Walsh chip. PN_U is a zero-shift sequence, also referred to as the pilot sequences. PN_U provides the second input to exclusive-OR gate 12. The randomized Walsh chips and the PN_U sequence are exclusive-OR'ed an exclusive-OR gate 12 and provided as in input to both of exclusive-OR gates 16 and 18.

PN generators 14 and 22 generate PN_I and PN_Q sequences, respectively. In the exemplary embodiment, PN_I and PN_Q generators are 15-bit generators running at $R_c=1.2288$ MHz. PN_I and PN_Q sequences are zero-shift sequences, also referred to as the pilot sequences. In the exemplary embodiment, all personal communication stations use the same PN_I and PN_Q sequences. The other input of exclusive-OR gates 16 and 18 are respectively provided with the PN_I and PN_Q sequences output from PN generators 14 and 22. The sequences PN_I and PN_Q are exclusive-OR'ed in the respective exclusive-OR gates with the output form exclusive-OR gate 12 to provide the I and Q modulation symbols.

In an alternative embodiment, two different phases of the user PN code might be produced and used to modulate the

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9   10

two carrier phases of the quadraphase waveform, dispensing with the need for using the length 32768 sequences. In yet another alternative, the personal system-to-cell link might utilize only bi-phase modulation, also dispensing with the need for the short sequences.

In another alternative modulation scheme for the personal system-to-cell link, the same modulation scheme would be used as for the cell-to-personal system link. Each personal system would utilize the pair of 32768 length sector codes as outer codes. The inner code would utilize a length M (M=64) Walsh sequence that is assigned to the personal system for use while it is in that sector. Nominally, the same Walsh sequence would be assigned to the personal system for the personal system-to-cell link as is used for the cell-to-personal system link.

The two resulting modulation sequences I and Q are provided to OQPSK modulator **23** wherein the sequences bi-phase modulate a quadrature pair of sinusolds and are summed. The resulting signal is then bandpass filtered, translated to the final RF frequency, filtered and provided to transmit power amplifier **24**. The ordering of the filtering, translation and modulation operations may be interchanged.

The modulation signal is provided to transmit power amplifier **24**, which is a variable gain amplifier controlled by transmit gain adjust element **26**. Transmit gain adjust ele-

ment is responsive to a signal indicative of the data rate of the signal for transmission from data rate controller **32** determines a gain for transmit power amplifier **24**. Transmit Gain adjust element **26** determines the transmission energy of each symbol in accordance the following formula:

$$
E_w = \begin{cases} 2E_b & \text{for } R_b = R_{b(max)} \\ \dfrac{R_b}{R_{b(max)}} E_b & \text{for } R_{b(nom)} < R_b < R_{b(max)} \\ \dfrac{R_{b(nom)}}{R_{b(max)}} & \text{for } R_b \leq R_{b(nom)} \end{cases} ,
$$

where E_b is the fixed bit energy. In the preferred embodiment, transmit gain adjust element **26** is further responsive to a reverse link power control signal. The amplified modulation signal is provided to antenna **28** for transmission through the air.

A summary of the symbol rates and transmission energies for the exemplary embodiment is provided in the table below.

Parameter	960	4800	2400	1200	Units
PN Chip Rate	1.2288	1.2288	1.2288	1.2288	Mcps
Code Rate	1/3	1/3	1/3	1/3	bits/code sym
Transmit Duty Cycle	100.0	50.0	25.0	12.5	%
Code Symbol Rate	28,800	28,800	28,800	28,800	sps
Modulation	6	6	6	6	code sym/mod symbol
Modulation Symbol Rate	4800	4800	4800	4800	sps
Repetition Modulation Symbol Code Rate	1/4	1/4	1/4	1/4	mod symbols/Walsh symbol
Walsh SymbolRate	19200	19200	19200	19200	kcps
Walsh ChipRate	1.2288	1.2288	1.2288	1.2288	Mcps
Mod Symbol Duration	208.33	208.33	208.33	208.33	μs
PN Chips/Code Symbol	42.67	42.67	42.67	42.67	PN chip/code symbol
PN Chips/Walsh symbol	64	64	64	64	PN chip/mod symbol
PN Chips/Walsh Chip	1	1	1	1	PN chips/Walsh chip
Energy Per Walsh Symbol	$E_b/2$	$E_b/2$	$E_b/2$	$E_b/2$	

Parameter	14400	7200	3600	1800	Units
PN Chip Rate	1.2288	1.2288	1.2288	1.2288	Mcps
Code Rate	1/2	1/2	1/2	1/2	bits/code sym
Transmit Duty Cycle	100.0	50.0	25.0	12.5	%
Code Symbol Rate	28,800	28,800	28,800	28,800	sps
Modulation	6	6	6	6	code sym/mod symbol
Modulation Symbol Rate	4800	4800	4800	4800	sps
Repetition Modulation Symbol Code Rate	1/4	1/4	1/4	1/4	mod symbols/Walsh symbol
Walsh SymbolRate	19200	19200	19200	19200	kcps
Walsh ChipRate	1.2288	1.2288	1.2288	1.2288	Mcps
Mod Symbol Duration	208.33	208.33	208.33	208.33	μs
PN Chips/Code Symbol	42.67	42.67	42.67	42.67	PN chip/code symbol
PN Chips/Walsh symbol	64	64	64	64	PN chip/mod symbol
PN Chips/Walsh Chip	1	1	1	1	PN chips/Walsh chip
Energy Per Walsh Symbol	$3E_b/4$	$3E_b/4$	$3E_b/4$	$3E_b/4$	

Parameter	9600	19200	38400	Parameter	Units
PN Chip Rate	1.2288	1.2288	1.2288	R_{chip}	Mcps
Code Rate	1/3	1/3	1/3	r	bits/code sym
Transmit Duty Cycle	100.0	100.0	100.0		%
Code Symbol Rate	28800	57600	115200	R_s	sps
Modulation	6	6	6	log M	code sym/mod symbol
Modulation Symbol Rate	4800	9600	19200	R_m	sps
Repetition Modulation Symbol Code Rate	1/4	1/2	1	R_p	mod symbols/Walsh symbol

-continued

Walsh SymbolRate	19200	19200	19200	R_w	kcps
Walsh ChipRate	1.2288	1.2288	1.2288	R_{wchip}	kcps
Mod Symbol Duration	208.33	104.16	52.08	$1/Tw$	μs
PN Chips/Code Symbol	42.67	21.33	10.67	R_c/R_m	PN chip/code symbol
PN Chips/Walsh symbol	64	64	64	R_c/R_s	PN chip/mod symbol
PN Chips/Walsh Chip	1	1	1	R_c/R_{wchip}	PN chips/Walsh chip
Energy Per Walsh Symbol	$E_b/2$	E_b	$2E_b$	R_c/R_{wchip}	PN chips/Walsh chip

10

In the exemplary-embodiment, each cell-site utilizes two receiver systems with each having a separate antenna and analog receiver for space diversity reception. In each of the receiver systems the signals are processed identically until the signals undergo a finger combination process.

Now turning to FIG. 2, a receiver is illustrated for receiving and demodulating the data sent by the transmitter of FIG. 1. The signal transmitted by antenna 28 is received by antenna 60 accompanied by possible deleterious effects of the channel. Signals received on antenna 60 are provided to analog receiver 61. The details of receiver 61 are further illustrated in FIG. 3.

Signals received on antenna 60 are provided to downconverter 84 which is comprised of RF amplifier 80 and mixer 82. The received signals are provided as an input to RF amplifier 80 where they are amplified and output to an input of mixer 82. A second input of mixer 82 is coupled to the output from frequency synthesizer 86. The amplified RF signals are translated in mixer 82 to an IF frequency by mixing with the frequency synthesizer output signal.

The IF signals are then output from mixer 82 to bandpass filter (BPF) 88, typically a Surface Acoustic Wave (SAW) filter having a passband of 1.25 MHz, where they are bandpass filtered. The filtered signals are output from BPF 88 to IF amplifier 90 where the signals are amplified. The amplified IF signals are output from IF amplifier 90 to analog to digital (A/D) converter 92 where they are digitized at a rate of about $8R_c$ or $4R_c$ (corresponding to 9.8304 or 4.9152 MHz clock), where R_c is the PN chip rate 1.288 MHz. The digitized IF signals are output from (A/D) converter 92 to demodulator 62. The signals output from receiver 61 are I' and Q' channel signals. Although illustrated with A/D converter 92 being a single device with later splitting of the I' and Q' channel signals, it is envisioned that channel splitting may be done prior to digitizing with two separate A/D converters provided for digitizing the I' and Q' channels. Schemes for the RF-IF-Baseband frequency downconversion and analog to digital conversion for I' and Q' channels are well known in the art.

Each data receiver tracks the timing of the received signal it is receiving. This is accomplished by the well known technique of correlating the received signal by a slightly early local reference PN and correlating the received signal with a slightly late local reference PN. The difference between these two correlations will average to zero if there is no timing error. Conversely, if there is a timing error, then this difference will indicate the magnitude and sign of the error and the receiver's timing is adjusted accordingly.

As illustrated in FIG. 3, receiver 62 includes two PN generators, PN generators 104 and 106, which generate two different short code PN sequences of the same length. These two PN sequences are common to those of all cell-site receivers and all personal system units with respect to the outer code of the modulation scheme. PN generators 104 and 106 provide the output sequences PN_I' and PN_Q' respectively. The PN_I' and PN_Q' sequences are referred to as the In-Phase (I') and Quadrature (Q') channel PN sequences.

The two PN sequences, PN_I' and PN_Q', are generated by different polynomials of degree 15, augmented to produce sequences of length 32768 rather than 32767 which would normally be produced. For example, the augmentation may appear in the form of the addition of a single zero to the run of fourteen 0's in a row which appears one time in every maximal linear sequence of degree 15. In other words, one state of the PN generator would be repeated in the generation of the sequence. Thus the modified sequence contains one run of fifteen 1's and one run of fifteen 0's. Such a PN generator circuit is disclosed in U.S. Pat. No. 5,228,054 entitled "POWER OF TWO LENGTH PSEUDO-NOISE SEQUENCE GENERATOR WITH FAST OFFSET ADJUSTMENTS", filed Apr. 3, 1992, and assigned to the assignee of the present invention.

In the exemplary embodiment, demodulator 62 also includes a long code PN generator 108 which generates a PN_U sequence corresponding to a PN sequence generated by the personal system unit in the personal system-to-cell link. PN generator 124 can be a maximal linear sequence generator that generates a user PN code that is very long, for example degree 42, time shifted in accordance with an additional factor such as the personal system unit address or user ID to provide discrimination among users. Thus the cell-site received signal is modulated by both the long code PNU sequence and the short code PN_I and PN_Q sequences. In the alternative, a non-linear encryption generator, such as an encryptor using the data encryption standard (DES) to encrypt a M-symbol representation of universal time using a user specific key, may be utilized in place of PN generator 108. The PN_U sequence output from PN generator 108 is mixed with the PN_I and PN_Q sequences, respectively, in mixers 100 and 102 to provide the sequences PN_I' and PN_Q'.

The sequences PN_I' and PN_Q' are provided to PN QPSK correlator 94 along with the I and Q channel signals output from receiver 61. Correlator 94 in the exemplary embodiment operates in conjunction with a sample decimator or interpolation filter (not shown). The sample decimator or interpolation filter acts in accordance with a timing signal (not shown) to provide samples at a rate equal to the Walsh chip rate to a correlation measurement element (not shown). The correlation element within correlator 94 is utilized to correlate the I' and Q' channel data with the PN_I' and PN_Q' sequences. The correlated I' and Q' data are provided as inputs to buffer 64. Buffer 64 then provides an F-block and a Q'-block, each of M elements (where M=64 in the exemplary embodiment).

The demodulator in the cell-site could build up a phase reference over a short interval using the technique described in the article "Nonlinear Estimation of PSK-Modulated Carrier with Application to Burst Digital Transmission", Andrew J. Viterbi and Audrey M. Viterbi, IEEE Transactions On Information Theory, Vol IT-29, No. 4, July 1983. For example, a phase reference could be averaged over only a few successive modulation symbols as described in the aforementioned article.

The performance of the just described alternative scheme, however, will be inferior to the preferred embodiment in the

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presence of severe Rayleigh fading and multipath conditions. However, in certain environments where fading and multipath are less severe or changing slowly, for example, indoor personal communication systems, low mobility personal communication systems, satellite to personal communication system channels and in certain land to personal communication system channels, the performance of the alternative system could be better than the exemplary embodiment.

In an alternative approach of maintaining time alignment between the transmitter and the receiver of the present invention, each cell receiver determines the time error from nominal timing of each received signal. If a given received signal lags in timing, then the associated cell modulator and transmitter will transmit a command to this personal communication system to advance its transmit timing by a small increment. Conversely, if the received signal timing of a personal communication system leads the nominal timing, a command to retard by a small increment is transmitted to the personal communication system. The timing adjustment increments are made on the order of $\frac{1}{8}$ PN chip or 101.7 nanoseconds. The commands are transmitted at a relatively low rate, on the order of 10 to 50 Hz and consist of a single bit inserted into the digital voice data flow.

If each cell receiver receiving a personal communication system signal performs the above time error measurement and correction transmission operation, then all the personal communication systems' received signals will normally be received with approximately the same timing, resulting in reduced interference.

FHT element **66** computes dot products between each of the possible M Walsh symbols and the I' block and Q' block to provide 2M dot product values. The dot product between the I' block and Q' block and a given Walsh symbol W_i is denoted $I'(W_i)$ and $Q'(W_i)$ respectively. The dot products are then provided to repetition summer and energy calculator (RSEC) **68**.

RSEC **68** operates to take advantage of the redundancy introduced by repetition modulation encoder **8**. FIG. **4** illustrates an exemplary embodiment of RSEC **68**. The RSEC illustrated in FIG. **4** would be typical of the design used in the cases where repetition modulation encoder **8** provides redundancy of order 1, 2 or 4 (that is red2=1, 2 or 4), and where $E_1(W_i)$, $E_2(W_i)$ and $E_3(W_i)$ are the energy values corresponding to the assumption that W_i was sent with red2 equal one, two and four, respectively.

The computation of $E_1(W_i)$ is performed under the assumption that red2=1 where there is no redundancy in the received modulation symbols I' and Q', so the energy computation is a summing the squares operation. The $I'(W_i)$ symbol is provided to squaring element **150** and the $Q'(W_i)$ symbol is provided to squaring element **152** which provide the squares of inputs, $(I'(W_i))^2$ and $(Q'(W_i))^2$, respectively. $(I'(W_i))^2$ and $(Q'(W_i))^2$ are provided to summing element **154** which provides the sum of the squares of the inputs, that is, $(I'(W_i))_2 + (Q'(W_i))^2$. Switch **156** closes when the computed energy value from summing element **154** is valid which is at a rate of $R_{b(max)}/(r.logM)$.

In the computation of $E_2(W_i)$ there is an assumed redundancy of order **2** in the modulation symbols I' and Q', so the energy computation involves summing two consecutive modulation symbols which should be equal under the presupposition of redundancy of order **2**. Delay elements **158** and **163** serve to delay their inputs by one modulation symbol period. Thus, in summer **160** the current modulation symbol $I'(W_i)(t)$ and the modulation symbol $I'(W_i)(t-T_w)$, where T_w is the Walsh symbol period equal to r.logM/

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$R_{b(max)}$, that immediately preceded it are summed. Similarly, in summer **164** the current modulation symbol $Q'(W_i)(t)$ and the modulation symbol $Q'(W_i)(t-T_w)$ that immediately preceded it are summed. The sums of the consecutive symbols for each of the modulation symbols $I'(W_i)$ and $Q'(W_i)$ are then squared by squaring elements **162** and **165** respectively, and the squares are summed in summer **166**. Switch **168** closes when the computed energy value is valid at a rate of $(0.5.R_{b(max)})/(r.logM)$.

In the computation of $E_3(W_i)$ it is presupposed that there is redundancy of order 4 in the received modulation symbols I' and Q', so the energy computation involves summing four consecutive modulation symbols which should all be equal. The architecture shown in FIG. 3 exploits the fact that the sums of two consecutive symbols has already been computed by summers **160** and **164**. Thus, in order to determine the sum of four consecutive symbols the sum of two consecutive sums of two symbols is computed. Delay element **170** serves to delay its input by two modulation symbol periods, $2.T_w$ where T_w is defined as above. Thus, in summer **171** the sum of the two most current $I'(W_i)$ modulation symbols for hypothesis W_i and the sum of two $I'(W_i)$ modulation symbols for the same hypothesis two symbol periods previous is computed.

Similarly, in summer **173** the sum of the two most current $Q'(W_i)$ modulation symbols and the sum of two $Q'(W_i)$ modulation symbols two symbol periods previous is computed. The sums of the four consecutive symbols for modulation symbols $I'(W_i)$ and $Q'(W_i)$ are then squared by squaring elements **174** and **176**, respectively and the squares are summed in summer **178**. Switch **180** closes when the energy data is valid at a rate of $(0.25.R_{b(max)})/(r.logM)$. The computed energy values are then provided to finger combine logic **72**. An alternative method for computing $E_3(W_i)$ is by means of partial integration wherein the $E_2(W_i)$ outputs provided through switch **168** are summed in pairs to provide $E_3(W_i)$. The partial integration technique is particularly useful in high mobility environments.

The energy value outputs of RSEC **68** are the outputs of first finger or receiver system **70**. The second receiver system processes the received signals in a manner similar to that discussed with respect to the first receiver system of FIGS. **2**, **3** and **4**. The energy values for each L rate hypotheses and corresponding M Walsh code hypotheses are provided to finger combine logic **72**. Similarly, any number of additional receiver apparatus can be placed in parallel to provide additional energy data from signals received by different antennas or by signals received by the same antenna but temporally differentiated, as in the case of reception of multipath signals.

The energy values from first finger demodulation apparatus **70** and all other fingers is provided to finger combine logic **72**. Finger combine logic then combines the signals of the various fingers as a weighted sum and provides the cumulative energy values to metric generator **74**.

Metric generator **74** in response to the energy values determines a set of metrics for each rate, an exemplary embodiment of such a metric generator is disclosed in copending U.S. patent application entitled "Dual Maxima Metric Generation", Ser. No, 08/083,110, and assigned to the assignee of the present invention. The sets of metrics are provided to de-interleaver **76**. De-interleaver **76** performs a function as the inverse of interleaver **4**.

The deinterleaved metrics are then provided to variable rate decoder **78** which in accordance with the received metrics generates an estimate of the transmitted information data bits. A typical implementation of decoder **78** is a Viterbi

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decoder of a type capable of decoding data encoded at the personal system unit with a constraint length K=9, and of a code rate r=⅓. The Viterbi decoder is utilized to determine the most likely information bit sequence. Periodically, nominally 1.25 msec, a signal quality estimate is obtained and transmitted as a personal system unit power adjustment command along with data to the personal system unit. Further information on the generation of this quality estimate is discussed in further detail in the copending application mentioned above. This quality estimate is the average signal-to-noise ratio over the 1.25 msec interval. Exemplary embodiments of the decoder are disclosed in copending U.S. patent application entitled "Rate Determination", Ser. No. 08/079,196.

The previous description of the preferred embodiments is provided to enable any person skilled in the art to make or use the present invention. The various modifications to these embodiments will be readily apparent to those skilled in the art, and the generic principles defined herein may be applied to other embodiments without the use of the inventive faculty. Thus, the present invention is not intended to be limited to the embodiments shown herein but is to be accorded the widest scope consistent with the principles and novel features disclosed herein.

We claim:

1. An apparatus for transmitting a variable rate data packet of data symbols, said apparatus comprising:

repetition generator means for receiving said packet and when the number of said data symbols in said packet is less than a first value generating duplicates of said data symbols and combining said data symbols and said duplicates of said data symbols in said packet; and

transmitter means for transmitting said packet from said repetition generator means, wherein when the number of data symbols in said packet equals said first value, transmitting said packet at a first energy level and when the number of data symbols in said packet is less than said first value and greater than a second value, transmitting said packet at a second energy level which is less than said first energy level, and when the number of data symbols in said packet is less than said second value gating ones of said data symbols and said duplicates of said data symbols and transmitting said packet at a third energy level.

2. The apparatus of claim 1 further comprising spreading means interposed between said repetition generator means and said transmitter means for receiving said packet and modulating said packet in accordance with a spread spectrum modulation format.

3. The apparatus of claim 2 wherein said spreading means comprises:

first PN generator means for generating a first pseudorandom noise sequence; and

first mixing means for receiving said packet and said first pseudorandom noise sequence and for spreading said packet in accordance with said first pseudorandom noise sequence to output a spread packet.

4. The apparatus of claim 3 wherein said spreading means further comprises:

second PN generator means for generating a second pseudorandom noise sequence;

second mixing means for receiving said spread packet and said second pseudorandom noise sequence and for digitally mixing said spread packet with said second pseudorandom noise sequence;

third PN generator means for generating a third pseudorandom noise sequence; and

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third mixing means for receiving said spread packet and said third pseudorandom noise sequence and for digitally mixing said spread packet with said third pseudorandom noise sequence.

5. The apparatus of claim 4 further comprising offset quadrature phase shift keying (OQPSK) modulation means interposed between said spreading means and said transmitter means for receiving said spread packet and modulating said packet in accordance with an offset quadrature phase shift keying modulation format.

6. The apparatus of claim 1 wherein said transmitter means is further for reordering said data symbols and said duplicates of said data symbols in accordance with a pseudorandom reordering format when the number of data symbols in said packet is less than said second value.

7. The apparatus of claim 1 further comprising an encoder means preceding said repetition generator means for receiving said packet and for encoding said data symbols in accordance with an error correction encoding format.

8. The apparatus of claim 7 further comprising an interleaver means interposed between said encoder means and said repetition generator means for receiving said packet from said encoder means and for reordering said data symbols in said packet in accordance with an interleaving format.

9. The apparatus of claim 1 wherein said second energy level is one of a set of possible second energy levels and wherein said third energy level is the minimum energy level in said set of possible second energy levels.

10. The apparatus of claim 1 wherein the ratio between said second energy level and said first energy level equals the ratio between the said number of data symbols in said packet and said first value.

11. A method for transmitting a variable rate data packet of data symbols, said method comprising the steps of:

receiving said packet;

when the number of said data symbols in said packet is less than a first value generating duplicates of said data symbols and combining said data symbols and said duplicates of said data symbols in said packet;

when the number of data symbols in said packet equals said first value, transmitting said packet at a first energy level;

when the number of data symbols in said packet is less than said first value and greater than a second value, transmitting said packet at a second energy level which is less than said first energy level; and

when the number of data symbols in said packet is less than said second value gating ones of said data symbols and said duplicates of said data symbols and transmitting said packet at a third energy level.

12. The method of claim 11 further comprising the step of modulating said packet in accordance with a spread spectrum modulation format.

13. The method of claim 12 wherein said step of modulating said packet in accordance with a spread spectrum modulation format comprises the steps of:

generating a first pseudorandom noise sequence; and

spreading said packet in accordance with said first pseudorandom noise sequence to output a spread packet.

14. The method of claim 13 wherein said step of modulating said packet in accordance with a spread spectrum modulation format further comprises the steps of:

generating a second pseudorandom noise sequence;

digitally mixing said spread packet with said second pseudorandom noise sequence;

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generating a third pseudorandom noise sequence; and

digitally mixing said spread packet with said third pseudorandom noise sequence.

15. The method of claim **14** further comprising the step of modulating said packet in accordance with an offset quadrature phase shift keying (OQPSK) modulation format.

16. The method of claim **11** further comprising the step of reordering said data symbols and said duplicates of said data symbols in accordance with a pseudorandom reordering format when the number of data symbols in said packet is less than said second value.

17. The method of claim **11** further comprising the step of encoding said data symbols in accordance with an error correction encoding format.

18. The method of claim **17** further comprising the step of reordering said data symbols in said packet in accordance with an interleaving format.

19. The method of claim **1** wherein said second energy level is one of a set of possible second energy levels and wherein said third energy level is the minimum energy level in said set of possible second energy levels.

20. The method of claim **11** wherein the ratio between said second energy level and said first energy level equals the ratio between the said number of data symbols in said packet and said first value.

21. A system for transmitting a variable rate data packet of data symbols, said system comprising:

a repetition generator having an input and having an output;

a transmitter having an input coupled to said repetition generator output and having an output;

a spread spectrum modulator interposed between said repetition generator and said transmitter having an input coupled to said repetition generator output and having an output coupled to said transmitter input, said spread spectrum modulator comprising:

a first PN generator having an output; and

a first mixer having a first input coupled to said repetition generator output and having a second input coupled to said first PN generator output and having an output.

22. The system of claim **21** wherein said spread spectrum modulator comprises:

a second PN generator having an output;

a second mixer having a first input coupled to said first mixer output and having a second input coupled to said second PN generator output;

a third PN generator having an output; and

third mixer having a first input coupled to said first mixer output and having a second input coupled to said third PN generator output.

23. The system of claim **21** further comprising an offset quadrature phase shift keying modulator having a first input coupled to said second mixer output and having a second

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input coupled to said third mixer output and having an output coupled to said transmitter input.

24. A system for transmitting a variable rate data packet of data symbols, said system comprising:

a repetition generator having an input connected to receive said packet of data symbols for generating duplicates of said data symbols when the number of data symbols in said packet is less than a first value and having an output at which a combination of said data symbols and said duplicates of said data symbols in said packet is provided as a data packet; and

a transmitter having an input connected to receive the output of said repetition generator and having an output from which data symbols received from said repetition generator are transmitted at a first energy level when the number of data symbols in said packet equals said first value, at a second energy level, which is less than said first energy level, when the number of data symbols in said packet is less than said first value.

25. The system of claim **24** wherein said transmitter transmits data symbols:

at said second energy level when the number of data symbols in said packet is less than said first value but greater than a second value, and

at a third energy level when the number of data symbols in said packet is less than said second value.

26. The system of claim **24** further comprising a spread spectrum modulator interposed between said repetition generator and said transmitter having an input coupled to said repetition generator output and having an output coupled to said transmitter input.

27. The system of claim **26** wherein said spread spectrum modulator comprises:

a first PN generator having an output; and

a first mixer having a first input coupled to said repetition generator output and having a second input coupled to said first PN generator output and having an output.

28. The system of claim **27** wherein said spread spectrum modulator comprises:

a second PN generator having an output;

a second mixer having a first input coupled to said first mixer output and having a second input coupled to said second PN generator output;

a third PN generator having an output; and

a third mixer having a first input coupled to said first mixer out-put and having a second input coupled to said third PN generator output.

29. The system of claim **27** further comprising an offset quadrature phase shift keying modulator having a first input coupled to said second mixer output and having a second input coupled to said third mixer output and having an output coupled to said transmitter input.

* * * * *

Nokia 9000 Communicator (left) and Nokia E7 Communicator / Wikipedia

The Gadget We Miss: The Nokia 9000 Communicator

Nokia's first Smartphone was a ground–breaking gadget for the traveller

The evolution of the modern smartphone is a complex business, with numerous extinct species that never quite made it. Some of these were just plain odd, and others were just before their time. The Nokia 9000 Communicator was one of these, a cell phone that was a smartphone before the word was invented. It rolled all of the features of a computer into a phone, putting email, web browsing, fax, word processing and spreadsheets into a single pocketable device. And it

did it years before Blackberry became the iconic symbol of the mobile professional.

The Nokia 9000 Communicator in its open configuration / AllAboutSymbian

Launched in 1996, the Nokia 9000 Communicator showed a company at the peak of its design powers: the Communicator was a mobile powerhouse, with 8MB of memory and a 33MHz processor. This combination ran Nokia's own GEOS operating system (a predecessor to the Symbian OS used on later models), combined with a suite of business programs that could read and edit Microsoft Office files from a desktop PC. Inside the clamshell style case was a chiclet QWERTY keyboard, complete with function keys for the major features and a series of programmable buttons by the screen. This screen was a black and white LCD, with a then-high resolution of 640 x 200 pixels. This long, thin screen meant that it could offer a first: a graphical web browser on a mobile device.

Nokia marketed the 9000 Communicator to business users, as you can tell from this ad featuring a business dude intent on leveraging the paradigm to maximize shareholder return / Nokia

Previous phones had offered only text web browsing, but the 9000 Communicator could render graphics in all their monochrome glory and connect to the Internet over the built-in 9600 bits per second GSM modem, which worked with the new digital GSM phone networks that were being rolled out across the world. However, this was before the days of always-on connections: to get your email, you had to connect to the mobile network, rather like dialing up on a land line, but without the noises. The US model was launched in 1997 (the Nokia 9000i Communicator), running on the GSM 1900 frequency offered by carriers like Microcell in Canada.

The 9000 Communicator in its closed position, with dialing keypad and secondary screen. Note the GSM antenna on the top. / Wikimedia Commons

All of these features added bulk, though: the 9000 Communicator was over 1.5 inches thick and weighed a hefty 14oz (397 grams). Compare

that with a contemporary phone like the Motorola StarTAC that weighed just 3.1 ounces, and which was half an inch thick.

The screen was also not very easy to see in sunlight, with the low-contrast LCD screen getting blasted out by even moderate sun.

The Nokia 9000 Communicator was a rather chunky 1.5 inches thick / PureViewClub.com

But the real problem was the price. It cost at least $800 in the USA, and about £1000 in the UK. That price scared off many users, as did the bulk and complexity of the device. To be successful, the technology had to wait several years to get smaller, sleeker and to be easier to use. Former Nokia CEO Jorma Ollia told the Wall Street Journal that *"we had exactly the right view of what it was all about... We were about five years ahead."*

The diminishing size of Nokia Communicators from 1996 to 2004. From left: Nokia 9000, 9110i, 9210i, 9300 and 9500 / Sergio Oliviera

Nokia came out with several revisions of the Communicator over the next few years, adding a color screen, slimming the unit down and updating the operating system. These sold well in Europe, but the Communicator remained more of a niche product in the USA, as Nokia struggled to get the dominant carriers to sell their phones. Models such as the 9300 Communicator were available in the US, but the reluctance of the US networks to switch over to the dominant GSM standard (or Nokia's reluctance to support the US standards, depending on your perspective) meant that they were relatively expensive and slow. The last Communicator model was the E90, released in 2007, which was only available in the US as an import. This sported a full color screen, 128GB of RAM and 4GB of storage space. It was also much lighter than the 9000 Communicator, weighing just 7.4oz.

The Nokia E90, the last Communicator, released in 2007 / GSMArena

The reason that we miss the 9000 Communicator is that it was the first of its type, a genre defining smartphone that existed before the word was coined. It was the first device to offer the heady combination of keyboard, good screen and business and Internet software in one simple package. And it was a product ahead of its time: modern users take features like mobile email and web browsing for granted, but the Nokia 9000 Communicator was the first device to offer these in a single device. It may have been a bulky, clunky device, but we still miss it.

You can relive the thrill of unpacking a new Nokia 9000 Communicator at PureViewClub. Models also show up frequently on eBay, especially UK, European and International models.

Electronic user´s guide released subject to "Nokia User´s Guides Terms and Conditions, 7th June, 1998".

User's Manual
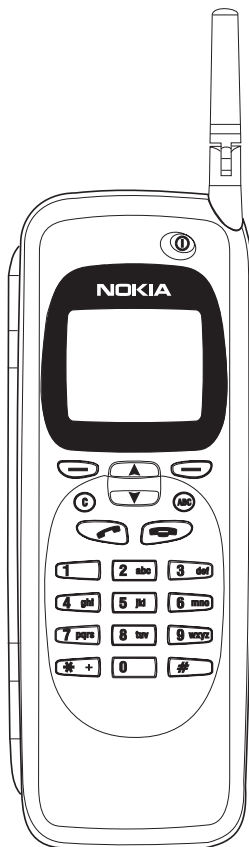
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The products described in this manual conform to the European Council directives EMC Directive (89/336/EEC) and TTE Directive (91/263/EEC).

FOR YOUR SAFETY Read these simple guidelines. Breaking the rules may be dangerous or illegal. More details are included in chapter 16 "Important safety information" on page 16-1.

ROAD SAFETY COMES FIRST Don't use the communicator while driving; park!

SWITCH OFF IN HOSPITALS Follow any regulations or rules. Switch off near medical equipment.

USE SENSIBLY Use only in the normal position (to ear). Don't touch the antenna unnecessarily.

SWITCH OFF WHEN REFUELLING Don't use the phone interface at a refuelling point.

SWITCH OFF NEAR BLASTING Always follow special regulations. Don't use near chemicals, fuel, etc.

MAKING CALLS VIA THE PHONE IN–TERFACE Close the cover and switch on the phone interface. Enter the phone number, including the area code, then press ☎. To end a call press ☎. To answer a call press ☎.

SWITCH OFF PHONE INTERFACE IN AIRCRAFT Mobile phones can cause interference. Using them in an aircraft is illegal.

QUALIFIED SERVICE FACILITY Only qualified service personnel should repair or install equipment. Use only approved accessories and batteries.

INTERFERENCE All mobile phones may get interference which could affect performance.

EMERGENCY CALLS Close the device cover. If the phone interface is not on, switch it on (press the ① key). Hold **C** briefly to clear the display. Enter the emergency number, then press ☎. Give your location and mobile number. Do not end the call until told to do so.

MAKE BACKUP COPIES Remember to make backup copies of all important data.

INFRARED PRECAUTIONS Do not point the IR beam at anyone's eye or allow it to interfere with other IR devices.

CONNECTING TO OTHER DEVICES When connecting the communicator to any other device, read its user's guide for detailed safety instructions. Do not connect incompatible products.

Table of contents

1. Introduction

Congratulations on purchasing the Nokia 9000i Communicator. The Nokia 9000i Communicator is a versatile communications tool: it is a mobile phone, messaging device, access terminal and a palmtop organiser in one compact package.

This chapter helps you understand how the Nokia 9000i Communicator operates. The following "Getting started" chapter helps you begin using the Nokia 9000i Communicator, as it explains the start-up procedure and outlines the special features. The rest of this manual deals with the communicator interface applications and the phone interface.
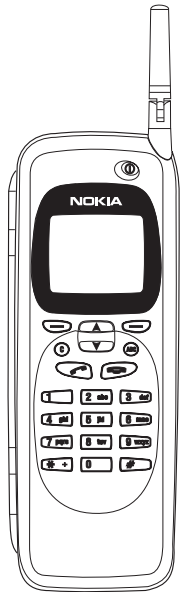
If you are an experienced mobile phone and mobile office user, read at least this introductory chapter and the "Getting started" chapter. Basic information about the communicator applications is always available in the context sensitive help, which can be activated by pressing the Help button on the communicator interface keyboard.

The Nokia 9000i Communicator has two interfaces, the phone interface (see figure 1-1) and the communicator interface (see figure 1-2). The phone interface is on the device cover and the communicator interface is under the cover.

The word "interface" emphasises the fact that both of these two aspects of the Nokia 9000i Communicator use the same resources and work closely together - they are not separate devices. For example, the phone interface uses the names and phone numbers stored in the communicator interface's Contacts directory, and the communicator interface uses the phone interface for communicating with the "outside world" (for
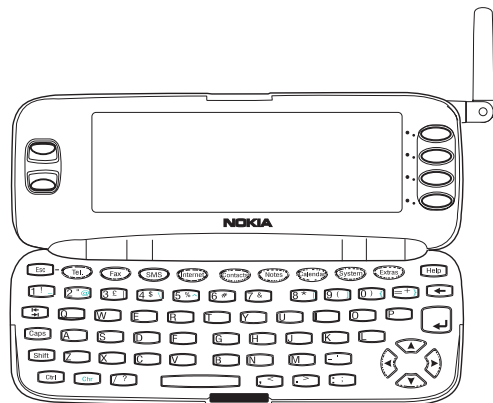
Figure 1-1

Figure 1-2

example, when sending or receiving faxes and connecting to remote computers).

The phone interface is designed for making and receiving calls quickly. It looks and operates like other Nokia mobile phones (except that the earpiece and microphone are on the backside of the device). The phone interface is switched on and off by pressing the ① button on the cover.

> **IMPORTANT!** Do not switch on the phone interface when mobile phone use is prohibited or when it may cause interference or danger.

The communicator interface has many organiser and communication applications. The QWERTY keyboard, command buttons and large display make using the applications easy. The communicator interface has no power on/off button – the communicator interface activates itself when you open the cover and deactivates when you close the cover.

Things to remember

Services

In order to utilise the communication capabilities of the Nokia 9000i Communicator, you may have to subscribe to certain services separately. If the service requires a separate phone number or specific settings, they must be stored in the communicator's settings. For example,

- Fax sending and receiving requires that fax service is supported by the network you are using and activated for your SIM card.
- Using the communicator as a fax modem requires that data service is supported by the network you are using and activated for your SIM card.
- Internet access also requires that data service is supported by the network you are using and activated for your SIM card. In addition, to access the Internet, you must have obtained an Internet access point from an Internet service provider (contact your dealer for details).

Document outbox

To help with cellular data transmission (see chapter 16 "Important safety information: Facts about cellular data transmission" on page 16-3), the communicator has an outgoing communications manager called the Document outbox. When you send faxes, short messages and mail, they always go first to the Document outbox. The outbox prepares your fax, short message or mail and then sends it through the phone interface. If the phone interface is off or the cellular signal

strength is inadequate, the document will not be sent until the phone interface is switched on and the signal strength is sufficient. You do not have to worry about whether the phone or fax called might be off or busy: after the first attempt, the Document outbox tries to send the document nine more times.

The Document outbox can be accessed in the Fax, SMS, Mail and Notes applications' main views, where it is shown at the bottom of the folders list. The Document outbox is discussed in more detail in chapter 12 "Document outbox" on page 12-1.

There is no document inbox. When you receive faxes, short messages or fetch mail, they go directly in their own received document folders. Each application shows a received document folder containing documents that can be viewed in that application. For example, the Fax application shows the Received faxes folder and the Mail application shows the Received mail folder.

Access codes

The communicator uses several access codes to protect against unauthorised use of your communicator and the SIM card. You can make changes to the access codes in the settings of the Security application (see chapter 10 "System: Security" on page 10-2) or in the phone interface (see chapter 13 "Phone interface: Menus - Security options (Menu 5)" on page 13-11).

For access codes that can be changed and are used by both interfaces, you can make the changes via either interface.

The communicator interface's Internet applications use passwords and user names to protect from unauthorised use of the Internet and Internet services. These passwords are changed in the settings of the Internet applications.

The access codes you need most often are the lock code (provided in the sales package) and the Personal Identity Number (PIN) code (provided with the SIM card). The access codes are described in more detail in chapter 10 "System: Security" on page 10-2. See also chapter 13 "Phone interface: Menus - Security options (Menu 5)" on page 13-11.

Contact information

All contact information (names, addresses, phone numbers, E-mail addresses, etc.) you store goes into the Contacts directory. Each application and interface has its own view of the Contacts directory. The information shown depends on the information the selected application can use. For example, when you are making a call via the phone interface, you can view the name and the phone number(s) of the contact – possible fax numbers, E-mail addresses, job titles, etc., are not shown.

You can customise your contact information according to your preferences, see chapter 3 "Contacts: Contact cards - Customising contact cards" on page 3-2. Customising only affects new contact information; existing contacts will not be affected. If you customise your contact card template in an early phase, you will not have to edit your contact cards manually.

Texts

With the communicator interface's text editor, you can create new texts in many applications (Notes, Fax, SMS, Mail, Calendar). The editor, however, works in each application in a way that corresponds to the sending format of that application. For example, because short messages cannot contain text formattings, the SMS editor removes text formattings. For this reason, the text editor is called Note editor in the Notes application, Mail editor in the Mail application, and

2. Getting started

When you open the sales package, check that it contains the following:

- Nokia 9000i Communicator.
- This User's Manual and the combined Quick Guide and Accessories Guide.
- High Power Battery, see the Accessories Guide.
- Adapter, see the Accessories Guide.
- AC charger, see the Accessories Guide.
- RS-232 Adapter Cable, see the Accessories Guide.
- Software for PC connectivity and a list of AT commands on a diskette (see chapter 10 "System: Connecting to a PC" on page 10-5).
- CD-ROM with software developed for the Nokia 9000i Communicator.
- A sticker with the communicator's serial number and the lock code (see chapter 10 "System: Security" on page 10-2).

For information about other Nokia 9000i Communicator accessories, see the Accessories Guide.

This chapter covers the following topics:

- How to personalise your communicator, see "First start-up" on page 2-1.
- How to install a valid SIM card, see "SIM card" on page 2-2.
- How to supply power to the communicator, see "Connectors" on page 2-4 and "Battery" on page 2-4.
- How the communicator operates, see "Communicator interface" on page 2-6 and "Communicator applications" on page 2-8.
- For information about the common features of the applications, see "Special features" on page 2-11.

Note: In this User's Manual, the command names appear in **bold** and settings, options and values shown on the application area are in *italics*.

First start-up

When you activate the communicator interface after having removed and replaced the battery, you will always see first a welcome screen while the device performs a self-test. The following steps, however, will be shown only during the first, personalisation, start-up.

① If you have not already installed your SIM card, install it, as described in "SIM card" on page 2-2, and switch on the phone interface. If you do not have a SIM card yet, go to the next step (see the section "SIM card contents"

on page 2-2).
Although you do not need a SIM card to use the communicator interface, a SIM card is required to send and receive calls and documents.

② Open the cover.

③ Select your home country from the list by scrolling the selection frame over it with the scroll keys on the left of the display. Press the button on the right of the display next to the command **OK**. The capital of your home country will be set as your home city. You can

change your home city later in the Clock application, see chapter 11 "Extras: Clock" on page 11-3.

④ Accept or change the date shown and press **OK**. If you change the date, use the format *dd.mm.yy* (for example, *24.08.97*). You can later change the date format in the System settings. (Time and date can be changed in the Clock application's settings.)

⑤ Accept or change the time shown and press **OK**. If you change the time, use the 24-hour format *hh:min* (for example, *17:25*). You can later change the time format in the System settings.

⑥ Enter user data and press **OK**. You can later change the information in the System application's User data view.

The personalisation procedure is now completed.

SIM card contents

After the personalisation procedure, if the installed SIM card contains stored names or numbers, you will be asked if you want to copy the SIM card contents into the communicator's memory (Contacts directory). If the phone interface is switched off, the question will be asked the next time the phone interface is on and you activate the communicator interface.

If you want to do the copying later, you can answer no, and do it manually via the phone interface, see chapter 13 "Phone interface: Menus - Memory functions (Menu 8)" on page 13-13.

After start-up, the communicator (or "B") memory is selected automatically as the active memory. If you want, you may later set the phone interface to use the SIM card ("A") memory instead of the communicator memory. The communicator interface applications, however, will always use the communicator memory. Also, the communicator memory can hold much more information than the SIM card memory.

All phone numbers copied from the SIM memory to the Contacts directory will go to the *Tel* field of the contact cards. Therefore, you must move all mobile phone numbers manually into the correct field. See chapter 3 "Contacts: Contact cards" on page 3-1.

SIM card

A valid miniature plug-in SIM (Subscriber Identity Module) card is required for making and receiving calls. The card is supplied by your network operator or service provider.

The SIM card contains all information the cellular network needs for identification of the network user. The network operator or service provider may prevent the use of the communicator with any other but the operator's or provider's own SIM cards. If an unacceptable SIM card is inserted, the message INVALID SIM CARD will be displayed. Should this happen, contact your dealer or network operator.

Note: Keep all miniature SIM cards out of small children's reach.

Before installing the SIM card, close the device cover and switch off the phone interface (press ①).

① Remove the battery: press the catch (1) at the bottom of the battery (2) and lift away the battery (figure 2-1).
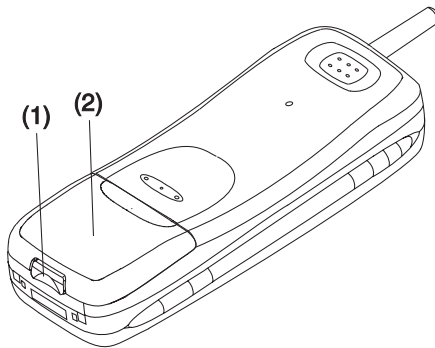
Figure 2-1

② Slide the card into the SIM card slot (figure 2-2). Make sure that the gold contacts of the SIM card are facing down and the bevelled corner of the card is on the right side.
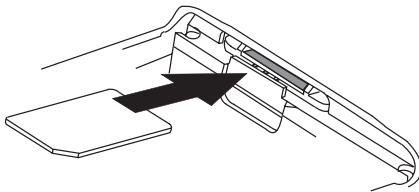
Figure 2-2

When the SIM card is properly inserted into the SIM card slot, the bevelled corner will remain visible (figure 2-3).
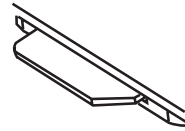
Figure 2-3

When you are sure that the SIM card is correctly installed, replace the battery:

① Insert the battery in the communicator so that the side with the four golden connector plates goes in first (figure 2-4).
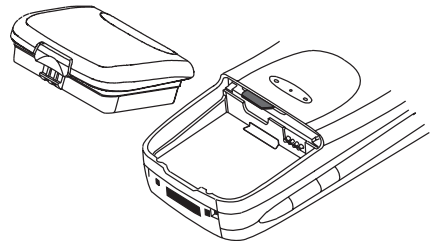
Figure 2-4

② Push the battery down towards the catch until it clicks into place. Make sure the battery is properly installed before switching on the power.

Note: The battery does not fit into place if the SIM card is not correctly installed. Do not force the battery into place! Check that you have inserted the SIM card into the slot as described above.

Connectors

(1) IrDA-SIR infrared port for connecting to a PC or a printer (figure 2-5). For more information on infrared connections, see chapter 10 "System: Connecting to a PC" on page 10-5.

(2) Antenna connector for car installation (figure 2-5).
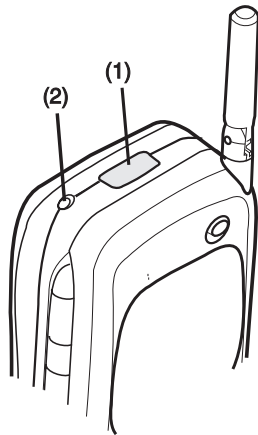
(3) System connector for car installation and for the adapter (figure 2-6)

(4) Adapter for connecting the charger and the RS-232 cable to the communicator. The connector on the left side (5) of the adapter is for the RS-232 cable plug and the one on the right (6) is for the charger plug (figure 2-6).
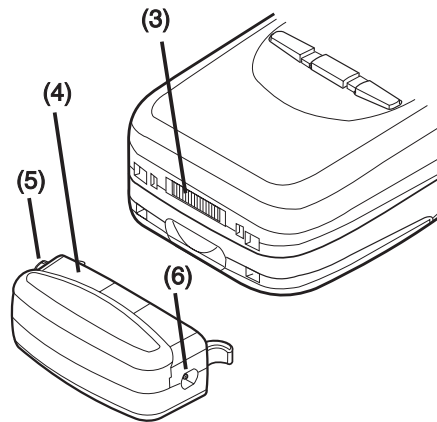
Figure 2-5

Figure 2-6

Battery

Your Nokia 9000i Communicator is powered by a rechargeable Lithium-Ion battery. The High Power Battery provides up to three hours of talk/fax/terminal time or 35 hours of standby time. Use only batteries approved by the communicator manufacturer.

Charging the battery

Use only chargers approved by the communicator manufacturer for charging a Lithium-Ion battery.

The communicator can be used during charging.

To charge a battery with the adapter and a charger:

① Install the battery.

② Attach the adapter to the bottom of the communicator as shown in figure 2-7. Insert the curved pin into the right-hand side aperture at the end of the communicator. Push the left side of the adapter gently towards the com-

municator until the left locking pin engages. (If you try to force the adapter into place upside down, you may accidentally break off the curved guiding pin.)
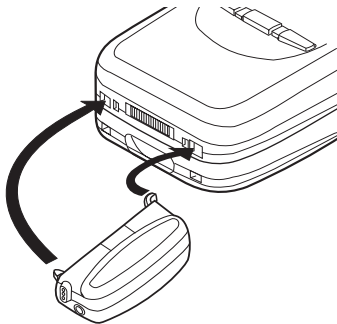
Figure 2-7

③ Connect the charger lead to the adapter, as shown in figure 2-8.
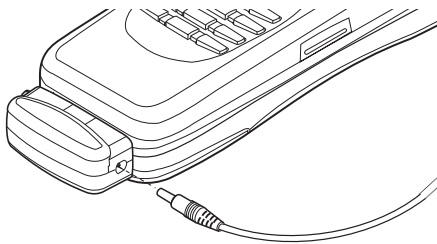
Figure 2-8

④ Connect the charger to an AC wall outlet. If the phone interface is switched on, the CHARGING message appears on the display and segments of the battery indicator bar on the right side of the phone interface display will start scrolling. (Charging information is also shown on the communicator interface display, see "Indicators" on page 2-9.)

⑤ When the battery is fully charged (the bars stop scrolling and five bars are displayed), you may remove the adapter from the communicator: Hold down the release button on the left side of the adapter (see figure 2-7), and turn the adapter away from the communicator.

When the charge is low and only a few minutes of operation time remain, a warning tone will be heard, and the message BATTERY LOW will be repeated at regular intervals on the display. When the charge level becomes too low for operation, the RECHARGE BATTERY message will be displayed, accompanied by a warning tone. If you do not connect the communicator to a charger, the communicator automatically switches itself off.

Note: If the tones have been switched off (see chapter 4 "Telephone: Telephone settings - Ringing settings" on page 4-6), only the display messages will appear.

Using the battery

Use only batteries approved by the communicator manufacturer. With approved chargers and accessories, the battery can be charged continuously.

The battery need not be fully discharged before recharging. When a charger is not in use, disconnect it from the power source.

The battery can be charged and discharged hundreds of times, but it will eventually wear out. When the operation time (talk-time and standby time) is noticeably shorter than normal, it is time to buy a new battery.

Temperature extremes will affect the ability of your battery to charge: it may require cooling or warming first.

Battery operation time is affected by the following: whether both interfaces are on, radio signal strength, various phone settings, and the length of the communicator interface's screen blanker period (set in System application's settings, see chapter 10 "System: System settings" on page 10-1).

It is recommended always to keep a charged battery in the communicator. Keeping the battery charged maximises the lifetime of the backup battery supplying power to the communicator's real-time clock. In case the backup battery is drained, it may be replaced by qualified personnel.

Always close the device cover before removing the battery. Closing the cover will save all data.

Note:

- Use the battery only for its intended purpose.
- Never use any charger or battery that is damaged or worn out.
- Do not short circuit the battery. Accidental short circuiting can occur when a metallic object (coin, clip or pen) causes direct connection of the + and - terminals of the battery, for example, when you carry a spare battery in your pocket or purse. Short circuiting the terminals may damage the battery or the connecting object.

- Leaving the battery in hot or cold places, such as in a closed car in summer or winter conditions, will reduce the capacity and lifetime of the battery. Always try to keep the battery between +15° C (+59° F) and +25° C (+77° F). A communicator with a hot or cold battery may temporarily not work, even when the battery is fully charged. Li-Ion batteries' performance is particularly limited in temperatures below 0° C (+32° F).
- Dispose of used batteries in accordance with local regulations. Recycle! Do not dispose of batteries in a fire!

Communicator interface
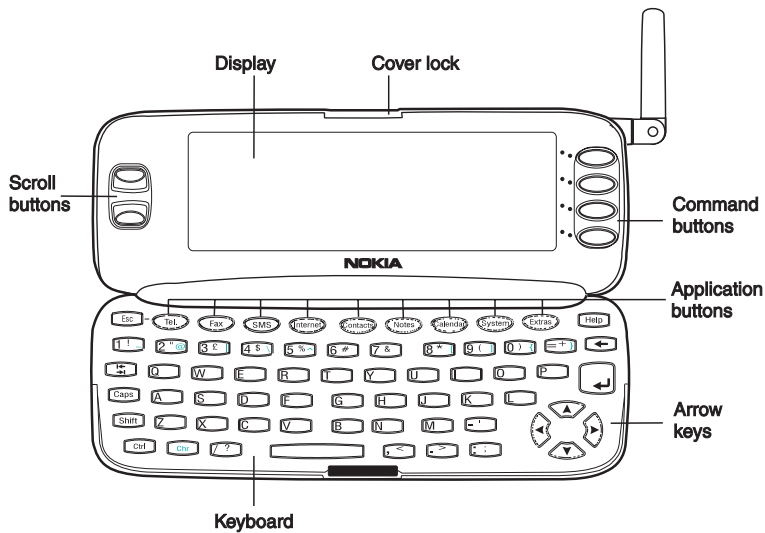
Figure 2-9

The communicator interface is activated by pressing the cover lock catch and opening the cover (see figure 2-9).

The applications are run in the middle of the display. The indicators (see figure 2-10) show application and system-related information (see

"Indicators" on page 2-9). The commands always relate to the column of four command buttons on the right side of the display cover.

Whenever the selection frame is shown, you can select items by moving the selection frame with

the scroll buttons or the up/down arrow keys (see

Indicators   Selection frame   Commands

Scroll buttons   Search field   Scroll bar   Command buttons
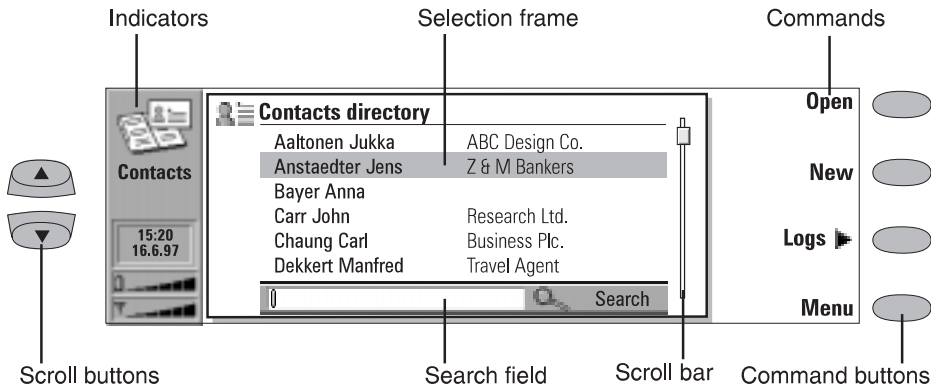
Figure 2-10

"Keyboard" on page 2-10). When the search field appears at the bottom of the display, you can search for items by entering text into the search field with the keyboard.

After the correct item has been selected, press the command button corresponding to the command you wish to apply to the item, for example, **Open**.

The following figures illustrate certain communicator interface conventions:

1. When a command appears dimmed, the command cannot be used (see the figure below).

2. When a value appears on a dotted line with a cursor, enter a new value manually via the keyboard.
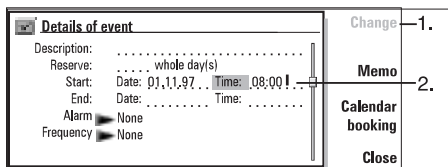
3. A pop-up box. Choose an item and press **OK** or **Cancel** (see the figure below).
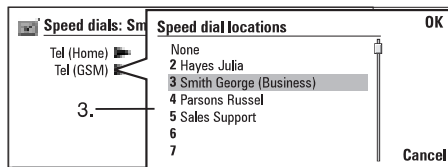
When a setting with ▶ next to it is selected, pressing **Change** toggles the value or opens a pop-up box. See the figure above. When a setting with ⇨ next to it is selected, pressing **Change** opens a new settings view. When you press a command with ▶ next to its name, as in **Logs** ▶ in figure 2-10, only the command set changes.

HTC and Samsung, Ex. 1008
HTC v. E-Watch, IPR2014-00987

Communicator applications

The coloured application buttons on the communicator interface keyboard are used to start the corresponding applications (described in the following chapters of this manual).

Tel. — Telephone is used for managing voice calls.

Fax — Fax enables you to send any of your own documents as a fax. Received faxes can be read or forwarded.

SMS — Short Message Service enables you to send short messages. Received short messages can be read, forwarded or replied to.

Internet — Internet applications include Internet and modem-based applications: Mail, World Wide Web, Telnet and Terminal (VT100 compliant).

Contacts — Contacts is used for managing your contact information: names, numbers and addresses. You can exchange contact information as business cards via the SMS application.

Notes — Notes is used for text editing, printing and document management. You can also send documents as short messages, fax or mail in the Notes application.

Calendar — Calendar contains an appointment book and a to-do list. You can set alarms and attach memos to events.

System — System contains desktop connectivity, security and other system related applications.

Extras — The Extras application group includes Text Web, Calculator, Clock, Composer, Converter, and Wireless data backup.

Using the applications

When the cover is opened, the application that was active when you closed the cover, appears in the same state. However, if you have made or answered a voice call via the phone interface and switch to the communicator interface by opening the device cover, the Telephone application activates automatically.

To switch to another application, press the corresponding application button. You can do this even during an active call.

Note: You need not "exit" any application before starting another. All inactive applications are run in the background until they are activated again. However, if the battery is removed or completely discharged, all data will be saved, but the applications return to their default states.

Note: Information need not be specifically saved (there is no "Save" command). Nokia 9000i Communicator saves all data automatically.

To send or receive calls or messages with any of the communications applications, remember that the phone interface must be switched on and in a service area with adequate cellular signal strength.

Indicators

The application icon and the application name show the currently active application, i.e., the application you are in at the moment.

The icons that appear on the Call status and Inbox/Outbox indicator rows, change according to the application and current situation. The battery level and field strength indicators are the same as are shown on the phone interface display when the phone interface is on (see chapter 13 "Phone interface: Display indicators" on page 13-2).

- Application icon
- Application name
- Call status
- Inbox/Outbox
- Battery level
- Field strength

Internet
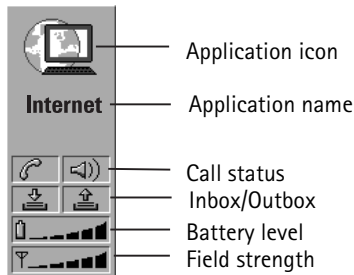
Call status

– You have a voice call and the hands-free loudspeaker and microphone are on. In handsfree use, you can talk to the phone from a short distance. See chapter 4 "Telephone: Audio control" on page 4-1.

– A voice call with the handsfree off (the loudspeaker and microphone are muted).

DATA – An open data connection, see chapter 7 "Internet" on page 7-1.

FAX – The communicator is receiving or sending a fax, see chapter 5 "Fax" on page 5-1.

PC-CONN. – The communicator is connected to a PC, see chapter 10 "System: Connecting to a PC" on page 10-5.

MODEM – The communicator is being used as a fax modem, see chapter 10 "System: Fax modem" on page 10-6.

SILENT – The communicator is being used in the silent service mode, see chapter 4 "Telephone: Telephone settings" on page 4-6.

FLIGHT – The communicator is in flight mode, see chapter 4 "Telephone: Telephone settings" on page 4-6.

– The communicator is trying to establish an infrared connection, see chapter 10 "System: Connecting to a PC" on page 10-5.

– An infrared connection has been established.

– The infrared connection is obstructed.

Inbox/Outbox

– Inbox (left half). You have received a fax, short message or mail (if your remote mailbox is capable of sending this information). Received faxes and short messages go in the application's received documents folder. To fetch new mail, you must connect to your remote mailbox, see chapter 7 "Internet: Reading mail" on page 7-9.

– Outbox (right half), the sending buffer, contains all unsent messages, see chapter 12 "Document outbox" on page 12-1.

13:47
20.6.97
– Time and date are shown when the Call status and Inbox/Outbox rows are empty. Time and date can be adjusted within Clock, see chapter 11 "Extras: Clock - Clock settings" on page 11-5.

Battery level

LOW – Battery is low. The battery should be recharged.

– Battery is charging (the bar scrolls until it is fully charged). The outlet plug icon indicates that the communicator is connected to an external power source (usually a wall outlet).

– Battery is fully charged (five bars displayed).

Field strength

– The communicator is connected to a cellular network. When all five indicator bars are shown, radio signal reception is good. If the signal strength is not good, you can try to improve reception by moving the phone slightly or by using the communicator in the handsfree mode.

NO SERVICE – The phone interface is on, but the communicator is outside of a network coverage area.

PHONE OFF – The phone interface is off. The communicator cannot send or receive calls or messages (via either interface).

Keyboard

In addition to the normal character and number keys, the keyboard has several special keys, as shown in figure 2-11.

1. Application buttons
The row of buttons at the top of the keyboard (starting from Tel.) activate the corresponding applications.

2. Escape (ESC)
To cancel an action, you can either press **Cancel** or the escape key. The escape key can only be used when **Cancel** is among the available commands. All information notes shown on the display can also be dismissed with the escape key (instead of pressing the **OK** command).

3. Tabulator
In editors, the tabulator key moves the cursor to the next tabulator stop. In settings etc., the tabulator key can be used to move to the next field.
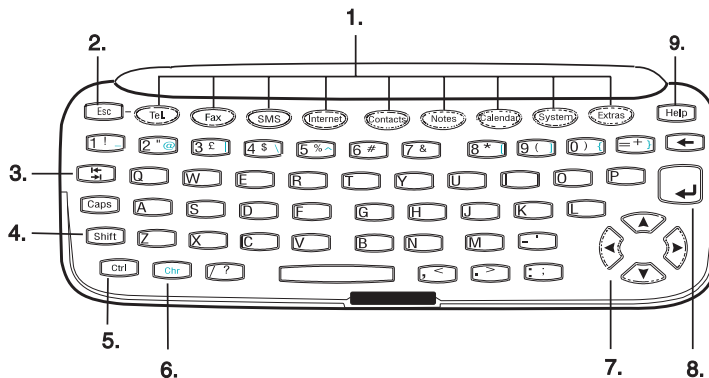
Figure 2-11

4. Shift

When you press the Shift key and then a letter key, an uppercase letter is inserted in front of the cursor. The Shift key does not need to be held down when pressing a key – once you have pressed Shift, the next key press always generates a shifted character. In most text editors, the Shift and arrow keys (7.) can be used to select text, see "Special features: Shortcuts" on page 2-12.

5. Control (Ctrl)

Pressed together with certain keyboard keys, the control key generates shortcut commands which can be used in most viewers and text editors.

6. Character (Chr)

The character key is used to generate characters not on the communicator keyboard. A single press of the character key opens the special character table. Some special characters are also printed on the keyboard as the third (green) character. These, and certain other, characters can be generated by pressing and holding the character key while pressing the corresponding key, see chapter 8 "Notes: Editing - Special characters" on page 8-2.

7. Arrow keys

The arrow keys can be used to move the cursor or the selection frame (in the same way as the scroll keys). In some applications, the arrow keys have special functions, see "Special features: Shortcuts" on page 2-12.

8. Enter

When the cursor is shown, pressing Enter moves the cursor to the beginning of the next line or adds a new line. The Enter key can also be used to select contacts and contact information in the Contacts directory and to open folders and documents. When information notes are shown, you may press Enter instead of the **OK** command. In options and settings, when a value can be toggled, you may press Enter instead of **Change**.

9. Help

Pressing the Help button activates a context-sensitive help. See "Special features: Help" on page 2-13.

Special features

Received communication note

When you open the cover of the communicator and have new received faxes, short messages, unsent documents or missed calls, a note will be shown (figure 2-12). The note can be dismissed by pressing **Cancel**. The same note is shown only once.

To read the received documents or to check who has made the missed calls, select the corresponding item on the list and press **View**.
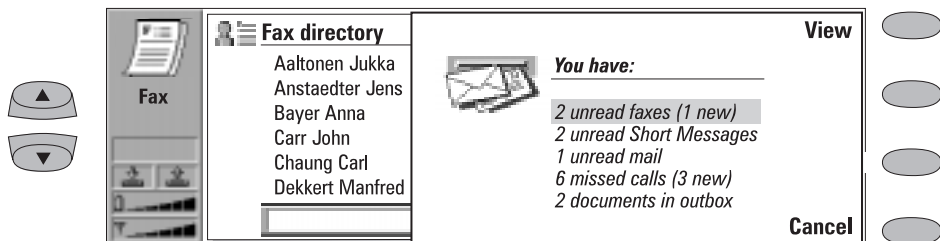
Figure 2-12

Settings and Menus

Most applications have **Settings** as one of the main view commands. The values of these settings will be used as defaults for that application. Options chosen elsewhere affect only the document, card or item that is active or being sent.

Most applications also have **Menu** as one of the commands. When you press **Menu**, a pop-up box opens listing a number of new commands which depend on the application you are in.

Multiselection

Where multiselection is available, you can select several items at once. The commands you use affect all the selected items. Multiselection works in most lists; for example you can select several contacts and delete them at once in the Contacts directory, or select several documents and transfer them to PC at the same time in the File transfer application.

There are two ways to select several items:

1. Scroll to the item and press Ctrl-Space bar, or

2. Press and hold Shift and move up or down the list with the arrow keys to the last selected item.

To remove an item from the selection, scroll to the item and press Ctrl-Space bar again.

If you want to select every item in a list, press Ctrl-A. If you want to remove the selection, press Ctrl-A again or the ESC button.

Naming a document

Every time you close a new document for the first time, you will be asked to enter a name for the document in the input field. The highlighted name in the input field is the communicator's suggestion for the name.

Shortcuts

There are several shortcuts you can use in the document applications (SMS, Fax, Notes, Mail). The following table lists the available shortcuts:

Shortcut	Function
Ctrl-C (copy)	Copies selected text
Ctrl-X (cut)	Cuts selected text
Ctrl-V (paste)	Pastes selected text
Ctrl-Z	Cancels the most recent operation
Ctrl-B	Applies bold
Ctrl-I	Applies italics
Ctrl-U	Applies underlining
Ctrl-T	Adds current time
Ctrl-D	Adds current date
Ctrl-M	Adds user's name
Ctrl-H	Moves the cursor to the beginning or the end of the document
Ctrl-E	
Chr-(left arrow)	Moves the cursor to the beginning or end of the line
Chr-(right arrow)	
Chr-up or down arrow	Scrolls the list or document view up or view down
Shift-(up/down/ right/left arrow)	While Shift is held down, each press of an arrow key selects one text character or line
Shift-Chr-up or down arrow	Selects text page by page inside a document
Ctrl-Space bar	Multiselection
Ctrl-A	Select all

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Help

Help is activated by pressing the Help button on the communicator interface keyboard. The application icon in the indicator area (on the left side of the screen) remains in view, reminding you of the application where help was requested.

The help texts deal with issues relating to the view that was on the display when help was activated. If no special help is available for the current view, a list of available application topics is shown instead.

To view the list of all help topics for the current application, press **Application topics**. The following commands become available:

> To open the selected topic, press **Open**.
> To show common help topics, press **General topics**.
> To return to the active application, press **Close**.

To view the list of general communicator topics, press **General topics**. The following commands become available:

> To open the selected topic, press **Open**.
> To return to the active application's help topics list, press **Application topics**.
> To return to the active application, press **Close**.

If the help topic that you wanted was not among the help topics of the current application or General topics, close the help, start the correct application and press Help again.

Useful settings information

The following chart contains settings information for various features of your communicator. All paths take you from the main view of the application. Following the conventions of this manual, the command names appear in **bold**, and settings, options and values shown in the application area are in *italics*.

How to ...	Application key	Path
Set voice mailbox number	Tel.	**Settings**, *Other settings*
Set ringing tones and volume	Tel.	**Settings**, *Ringing settings*
Set calling card number and access code	Tel.	**Settings**, *Calling card settings*
Activate flight mode	Tel.	**Settings**, *Other settings*
Set font, margins, etc. for Fax	Fax	**Write fax**, **Style**
Set message centre number[1] (to send SMS messages)	SMS	**Settings**, *Message centre number*[1]
Set fields to be included when sending business cards via SMS	SMS	Business cards, **Open**, **Options**
Define contact card template	Contacts	**Menu**, *Settings*, *Contact card template*
Define Internet access point[2]	Internet	**Settings**, *Internet access*, **New**[2], (*Advanced settings*[2])
Define remote mailbox information[3]	Internet	Mail, **Settings**, *Remote mailbox settings*[3]
Create folders	Notes	(open any folder), **Menu**, *Create folder*
Set own information in User data	System	User data
Set distinct ringing tones for individual applications	System	**Settings**, *System sounds*, *Application tones*
Set time and date format	System	**Settings**, *Preferences*
Set time and date	Extras	Clock, **Settings**
Reset home country	Extras	Clock, **Settings**

1. You may obtain this information from your network service provider.

2. You may obtain this information from your Internet service provider.

3. You may obtain this information from your remote mailbox provider (either an Internet service provider, or your own company).

3. Contacts

The Contacts application is used for:

- Creating, editing, and managing all contact information, such as phone numbers, addresses and speed dials.
- Viewing logs of all incoming and outgoing calls (voice, data and fax calls and SMS messages), see "Logs" on page 3-3.

Telephone, Fax, SMS and Mail applications all use information found in the Contacts application.

You will find the Nokia HelpLine contact cards in the Contacts directory. The HelpLine answers questions and offers instructions over the phone.

Contact cards

Contacts main view shows the Contacts directory, which is a list of all contact cards. The contact cards are listed in alphabetical order according to the name in each contact card's *Name* field.

To create a new contact card, press **New** in the Contacts main view.

To open an existing contact card, locate the contact card you want to open and press **Open**. A contact can be located in two ways:

1. Scrolling the contact list — Move the selection frame with the scroll buttons until the contact you are searching for is shown within the selection frame.

2. Using the search field — Enter text into the search field. The search looks for matches in the *Name*, *Company* and *Address* fields. The search results can be cleared by deleting characters one by one from the search field with the backspace key.

Pressing **Menu** in the Contacts directory opens a new set of commands:

Delete — Erases selected card.
Copy card — Creates a duplicate card.
Directory info — Shows the amount of con-

tact data.
Settings — Allows you to change the following settings:

Contact card template — The contact card template defines which fields are included in all new contact cards you create. You can modify the contact card template as described in "Editing contact cards" below. Changes made to the template affect all new, but not existing contact cards. You cannot enter text into the template's fields.

Log length — With *Log length*, you can define how recent contacts will be listed in the General and Individual logs. The possible values are: *Zero / 10 days / 30 days* (default) */ 1 year / User defined: days* (0 – 365 days).

Editing contact cards

When you have opened a contact card, you can enter new and edit existing contact information in the various fields. To move from one field to another, use the scroll or arrow keys. You can add

ter key. To return to the Contacts directory, press **Close**.

Figure 3-1

When entering phone numbers into the *Tel* fields, by storing a **+** character in front of the country code, you can use the same phone number abroad. You can enter numbers and the following characters in the *Tel*, *DTMF* and *Fax* fields (for information on the functions of these characters see table 3-1):

Tel field: **+**, **#**, *****, **p**, **w**, **–**, [space]

DTMF field: **#**, *****, **p**, **w**, **–**, [space]

Fax field: **+**, **–**, [space]

When storing phone numbers or DTMF sequences, you can use hyphens and spaces to arrange the appearance of the strings. This will not affect the way the numbers or DTMF tones will be dialled.

Customising contact cards

If you want to remove or add fields, or edit the field labels of the currently opened contact card, press **Fields** in the contact card view (see figure 3-1). If you want to modify the field settings of all future contact cards, you must edit the contact card template, see "Contact cards" on page 3-1.

To add new fields to the contact card:
① Press **Add field**. A pop-up box opens, listing the available fields.
② Select a field and press **OK**. There can only be one *Name*, *Job title*, *Company* and *Note* field.

Note: The *Tel/Fax* field is for alternating calls (see chapter 4 "Telephone: Managing calls - Alternating calls" on page 4–5). The *Password* field is for the booking password (see chap-

ter 9 "Calendar: Calendar booking - Booking password" on page 9-4).

To customise the label of the selected field:
① Select the field and press **Change label**.
② Select one of the predefined labels or scroll down to the field with a dotted line and write the label text, e.g., *Cottage* or *Modem*, and press **OK**.

To delete the currently selected field:
Press **Delete field**. The *Name* field cannot be deleted.

Note: You can only send short messages to mobile phone numbers stored in the *Tel(GSM)* or *Tel(PCN)* fields.

If you press **Menu** in an opened contact card, the following commands become available:
Copy card — Creates a copy of the current card.
Copy contents — Copies the contents of the card to a clipboard. You can add this information to faxes, notes and other documents by pressing Ctrl-V.
Delete card — Deletes the opened card.
Next card and *Previous card* — Opens the next and the previous card in the list respectively.
Copy to hotlist — Copies the URL field of the contact card to the WWW hotlist (see chapter 7 "Internet: Hotlist" on page 7-12).

Speed dials

The **Speed dials** command (see figure 3-1) lets you assign speed dials to eight phone numbers

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(number 1 is reserved for calling your voice mailbox, see chapter 4 "Telephone: Telephone settings" on page 4-6). For information on how to use the speed dials, see chapter 13 "Phone interface: Using memory - Dialling shortcuts" on page 13-5.

To set speed dials:

① Press **Speed dials** in an opened contact card. All phone number fields of the contact card are shown.

② Select a field to which you want to assign a speed dial and press **Change**. Select a location and press **OK**.

To change or remove speed dials:

① Select the speed dial you want to change or remove and press **Change**.

② Move the selection frame to the location you want to use and press **OK**. If you want to remove a speed dial location, choose *None*.

Storing DTMF tones

The Dual Tone Multi Frequency (DTMF) tones allow you to communicate with voice mailboxes, computerised telephony systems, etc. For information on how to send DTMF tones, see chapter 4 "Telephone: Managing calls - Sending DTMF tones" on page 4-5, or chapter 13 "Phone interface: Sending DTMF tones" on page 13-3.

- If you only communicate with the contact using DTMF tones, create a contact card for the DTMF contact.

- If you need both a voice and a DTMF phone number for the contact, add a new field to an existing contact card. The DTMF sequence can be stored either in the *Tel* field, after the telephone number, or separately, in a *DTMF* field. If you store the sequence in a *Tel* field, the phone number and the DTMF sequence must be separated by one of the DTMF special characters. Label the field (with **Change label**) so you can identify the DTMF sequence.

The DTMF special characters are listed in the following table:

Character	Function
* and #	May be used if the DTMF service requires them.
p (pause)	Inserts a pause of 2.5 seconds in front of, or between, DTMF digits.
w (wait)	When the "w" character is stored in a sequence, the rest of the sequence is not sent until you press **Send** again in the Telephone application.

Table 3-1

Logs

The Contacts application shows all communication events as two logs:

- General log shows all (or certain types of) communication events in chronological order, see figure 3-2.

- Individual log shows a list of all communication events relating to the selected contact.

To access the logs:

① Press **Logs** in the Contacts main view. The command set changes.

② Select the desired log type by pressing either **Individual log** or **General log**.

To erase the contents of the log:

① Press **Clear list**. A pop-up box opens to let you define which contacts will be deleted (measured in days). The clearing procedure reflects on the other log, as well.

To create a new contact card:

① Open the General log.

② Select a log event and press **Create card**. If the contact card already exists, the command is dimmed.
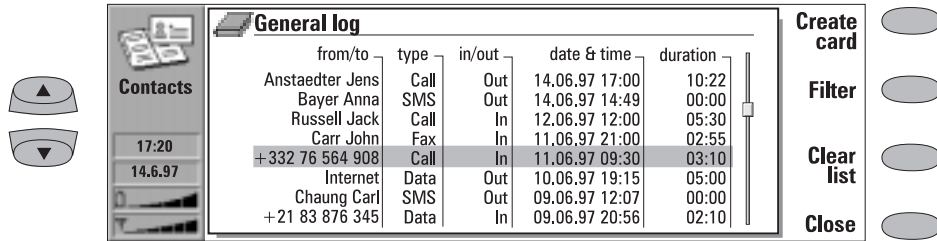
Figure 3-2

To view only certain communication types:

① Open the General log and press **Filter**.

② Select the communication type you want to view and press **OK**.

Note: Remote mailbox, Terminal and Internet connections are logged as data calls.

Contacts directory and the phone interface

Copying contact information between the interfaces is possible only via the phone interface (see chapter 13 "Phone interface: Menus - Memory functions (Menu 8)" on page 13-13, except when a new SIM card is inserted into the communicator and you open the communicator interface. In that case, you will be prompted to confirm the copying of the SIM memory contents into the Contacts directory, as described in chapter 2 "Getting started: First start-up - SIM card contents" on page 2-2.

When the memory contents of a SIM card are copied to the directory, the Contacts application will create the same number of new contact cards as the number of memory locations in use on the SIM card. The numbers in the SIM card memory locations are inserted in the *Tel* field of the contact card.

When contact information is copied from the Contacts directory to the SIM card, the contact names may not fully fit in the SIM card's memory.

Entering contact information via the phone interface

Entering new or editing existing contact names and phone numbers via the phone interface will create a new contact card in the Contacts directory. See chapter 13 "Phone interface: Using memory - Storing information via the phone interface" on page 13-5.

Note: When you store or copy phone numbers from the phone interface to the Contacts directory, the phone numbers go to the *Tel* field, not to the *Tel(GSM)* or *Tel(PCN)* field. Sending SMS messages requires, however, that the recipient's mobile phone number is stored in the *Tel(GSM)* or *Tel(PCN)* field.

Check that the phone numbers are in the correct fields in the contact card.

4. Telephone

In order to make phone calls, the following requirements must be met:

- An activated SIM card must be inserted.
- The phone interface must be switched on.

For a description of the phone interface keys and especially the ① button, see chapter 13 "Phone interface" on page 13-1.

Note: The phone interface keys are not functional when the device cover is open.

The Telephone application is started by pressing the Tel. application button on the keyboard. Some of the telephony operations explained here can be made in many ways, for example, via the phone interface.

Note the following Telephone features:

- Opening or closing the cover does not affect active phone calls.
- If you have made a voice call via the phone interface and you open the cover, the Telephone application starts automatically. You can continue the call after activating the handsfree mode (see "Audio control").
- When you make a call via the communicator interface (with the Telephone application), the handsfree mode is activated automatically.

Audio control

The audio control enables you to adjust the volume level and to activate the communicator's loudspeaker for handsfree operation. The audio control is available only when you have an active call.

In the handsfree mode, you can speak and listen to the phone from a short distance away when the cover is open. This function is not available when the cover is closed (except in a car installation). The Telephone setting *Audio when cover opened* (in the settings group *Other settings*, see "Telephone settings" on page 4-6), determines whether the handsfree mode is activated automatically after you open the cover. To activate the handsfree mode manually, press the **Audio on** command button.

After audio has been activated, the command changes to **Audio control**. Pressing **Audio control** lets you adjust the speaker volume or turn audio off. The indicator in the audio control view shows the chosen volume level.

Making a call
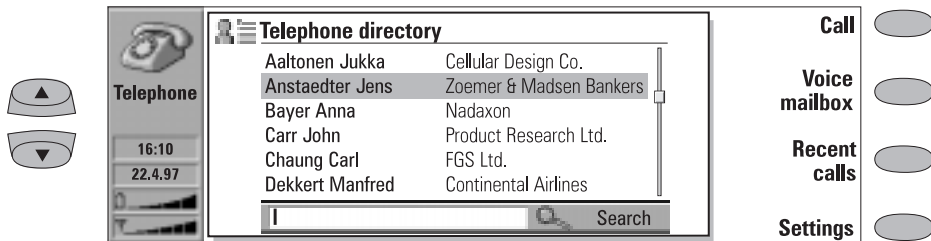
There are three ways to make a call:

1. Make the call manually:

   Write the telephone number to the search field and press **Call**.

2. Call the selected contact using the Telephone directory:

   When you have no active voice calls, the Telephone main view shows the Telephone directory (figure 4-1). Contact cards that do not contain any phone numbers appear dimmed in the Telephone directory and cannot be selected. (Phone numbers can be added to the contact cards in the Contacts application.)

   Choose a contact in the Telephone directory, either by scrolling or by searching (type text in the search field), and press **Call**.

   If the contact has more than one phone number, a pop-up box opens, listing all phone numbers. Choose a number from the list and press **Call**.

3. Call a number in the Recent calls list:
   ① Press the **Recent calls** command button.
   ② Select one of the recent calls lists (dialled, received or missed calls) and press **Open**.
   ③ Select a number from the list and press **Call**.

Once you have made the call, you can close the cover and continue the call in the phone interface, unless you want to use the handsfree mode.

Note: If you press **Clear all lists** in the Recent calls view, all the information in the lists is removed. When you open one of the lists and select a contact, **Copy number** copies the phone number to a clipboard where it can be copied to documents by pressing Ctrl-V.

Calling card call

A phone calling card is a credit or debit card especially for phone charges. A calling card may be useful when making long distance calls while travelling, to benefit from the discounted rates offered by certain calling card companies.

Define the calling card information in the Calling card settings (see "Telephone settings: Calling card settings" on page 4-7).

To make a call with a calling card:
① Select a contact from the Telephone directory, or enter the number in the search field.
② Press **Call** for more than three seconds until the command changes into **Calling card call**.
③ Release the button, wait for a tone and then press **OK**.

You can also make a calling card call from the phone interface:
① After entering the phone number, press the ☎ key for three seconds.
② Wait for the tone and then press **OK**.

Answering a call

When you receive a call while having the communicator cover open, a note about the incoming call is shown on the screen. If you are called by a person who has a contact card (as in figure 4-2), the caller is identified by his/her name (if supported by the network).

To answer the call:

Close the device cover and answer the call via the phone interface (by pressing 📞).

Or, alternatively,

When you receive the incoming call note, press **Answer**.

Note: You cannot have two active calls at the same time: the previous active call is automatically put on hold when you answer a waiting call (the network service Call waiting must be activated).

If you do not want to take the voice call, press **End call**. The caller will hear the alerting tone change to a "line busy" tone.

Managing calls

When you have made a call, information about the call(s) is shown on the display within a frame (see figure 4-2). In addition to the active call, you can have a held call and a waiting call at the same time. The conference call, which can contain up to five remote participants, is handled as a single call.

To switch between multiple calls, use the scroll or arrow keys. The command buttons change according to the selected call's status. For example

the held call can be changed into an active call by pressing **Activate**.

Call information may include the following:

- The name or phone number of the caller (if available).
- Call status shows whether the current call is active, on hold, or waiting, and whether the audio is off.

The call within the shadowed frame is selected   Call cost counter

Call status icon   Call timer

Figure 4-2

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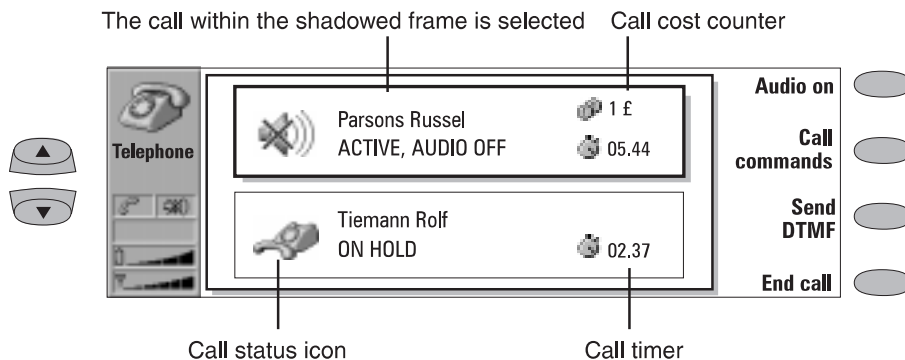
- Call timer displays how much time has expired since the beginning of the call. The timer also counts time spent on hold (see figure 4-2).
- Call cost counter shows the cumulative cost of the call, if this network service is available and the call cost setting is on. The call costs are calculated according to the settings determined in the phone interface (in currency or charging units). See chapter 13 "Phone interface: Menus - Duration and cost (Menu 6)" on page 13-12.

To end a call, select the call you want to end and press **End call**.

Making a new call

When you already have one active call, the **New call** command is shown in the Telephone main view. To make a new call, press **New call** and make the new call normally, or press **Cancel** to cancel the new call.

If you already have an active and a held call, you cannot make new calls before either dropping a previous call or merging them into a conference call.

Conference call

The conference call is a network service; contact your network operator to check if this service is available. In a conference call, you and up to five remote persons can hear each other simultaneously.

To create a conference call:

① Make the first call normally.

② Once this person has answered, make a call to the second participant by pressing **New call**.

③ Wait until the second person answers the call.

④ To join the first participant in the call, press **Call commands** and choose the *Conference call* option from the pop-up box. If you want to include a new person in the conference call, repeat this operation. When all participants have been included in the conference call, the best voice quality is achieved by closing the cover and continuing the call via the phone interface.

To end the call with a conference call participant:

① Press **Conference commands**.

② Select one caller from the list of participants (figure 4-3) and press **Drop**. To return to the previous view, press **Close**.

To talk privately to one of the conference call participants:

① Press **Conference commands**.

② Select a participant from the list and press **One to one**. The conference call is now split into two calls: the conference is on hold and the one-to-one call is the active call.

③ Once you have finished the private conversation, you can add the person back into the conference call by pressing **Conference call**.

		Participants	One to one
Telephone	CONFERENCE CALL 4 participants	Anstaedter Jens Bayer Anna Chaung Carl Dekkert Manfred	Drop
			Close
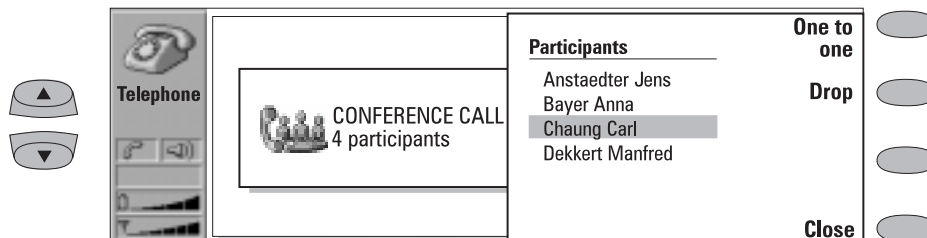
Figure 4-3

Voice call transfer

The voice call transfer is a network service which enables you to connect two voice calls together and disconnect yourself from both calls.

Note: The transfer operation can be made only if you have one held call and one active call; all calls are voice calls (fax or data calls cannot be transferred); and none of the calls is a conference call.

There are two ways to transfer voice calls from the phone interface:

1. Press **4** followed by ☎, or

2. Press and hold the **Menu** key for a second. Choose the *Transfer* option in the menu and press **OK**, or press **Quit** to cancel.

Calls can also be transferred from the communicator interface. When you have one call on hold and another call active, press **Call commands** and choose the option *Transfer call*. Press **OK**.

Answering a waiting call

Call waiting is a network service which must be activated before you can use it (see "Telephone settings" on page 4-6).

When Call waiting is active, and you receive a new call while you already have an active voice call, you will see a note informing you of this.

A waiting call is answered, like any call, by selecting the waiting call and pressing **Answer**. The previous call will be put on hold.

Sending DTMF tones

The Dual Tone Multi Frequency (DTMF) tones allow you to communicate with voice mailboxes, computerised telephony systems, etc. Besides the numbers 0 - 9, you can also use the characters **p**, **w**, ***** and **#** (for information on the functions of these characters, see chapter 3 "Contacts: Contact cards - Storing DTMF tones" on page 3-3).

To send a DTMF sequence when you have an active call:

① Key the digits from the communicator interface keyboard. Each keystroke will generate a DTMF tone which will be transmitted directly.

Or alternatively,

① Press **Send DTMF**. A list of stored DTMF sequences is shown (for information on how to store DTMF sequences, see chapter 3 "Contacts: Contact cards - Storing DTMF tones" on page 3-3).

② Select a DTMF sequence. You can edit the sequence, or, if there are no stored sequences, you can enter the DTMF string manually into the field.

③ Press **Send** to send the DTMF sequence shown in the input field, at the bottom of the display.

Note: You cannot access the DTMF view during a conference call. However, you can send DTMF tones during a conference call by entering the digits from the keyboard.

Alternating calls

Alternating calls can be made to a fax box, for example: you initiate the call as a voice call, but it changes into a fax call when your fax box starts to send you your faxes.

To make alternating calls you need to add a special *Tel/Fax* field to the contact cards of the recipients of your alternating calls (see chapter 3 "Contacts: Contact cards - Customising contact cards" on page 3-2).

You can also change the mode of the call from voice to fax manually by pressing **Change mode**.

Alternating calls cannot be put on hold or incorporated into a conference call.

Incoming faxes, short messages and data

Faxes, short messages and incoming data are received automatically, provided that the phone

interface is on and within cellular coverage area. While a data/fax connection is active (check the call status indicator), you cannot make calls.

If you want to make a voice call, you can either wait until the data/fax call ends, or you can ter-minate the data/fax call by starting to make a call normally. When you press **Call**, you will be asked if you want to terminate the data call. Press **Terminate** to confirm.

Telephone settings

Press **Settings** in the Telephone main view to open a list of several settings groups:

Ringing settings, Voice call diverting, Voice call barring, Voice call waiting, Calling card settings, Single number settings, Other settings.

To change the settings:

① Select a group and press **Change** to open it.
② Select a setting and press **Change**. The cur-rent value of the setting is displayed after the setting name, unless the setting is one the network services: call diverting, barring or waiting. See the following sections.

Ringing settings

All sounds — Sets the incoming call alert and all other alarms to *Ring, Beep, Silent* or *Silent for*.
> *Silent for* lets you set the length of time you want the silent mode to be active. You may want to use this setting in order not to forget to turn the ringing tone back on after a meet-ing, for example. Enter the time in the format *hh:mm*.
> When sounds are set to *Beep, Silent* or *Silent for*, the call status indicator shows the text SILENT. This setting affects both interfaces. Whatever the chosen setting, an incoming call is always indicated by a note.

Ringing volume — Adjusts the ringing volume (*1* is the lowest, *5* the highest).

Ringing tone — Determines the ringing tone. To compose your own ringing tones, go to the Extras application and start the Composer. For more in-formation about composing, see chapter 11 "Ex-tras: Composer" on page 11-5.

Changing the settings of network services

The network services call diverting, call barring and call waiting, may not be supported by all op-erators, or you may have to subscribe to them.

Information about the status of these services is stored in the network. Therefore, the current set-tings are not shown until you request the infor-mation from the network by pressing **Get status**.

While the communicator is making a request to the network, a query note is shown on the dis-play. After a successful request, the new status now appears on the settings list.

When a divert is active and you make a call, a text is shown on the phone interface display, re-minding you that your incoming calls will be di-verted to another phone number. The text will appear only if your network operator supports this feature.

To cancel all call diverts or barrings, press **Cancel call diverts** or **Cancel call barrings**.

Voice call diverting

The voice call diverting network service allows you to direct your incoming voice calls to anoth-er phone number (fax diverting is activated via the Fax application's settings).

The network will store the number to which your calls are diverted, even if you cancel the diverts.

Choose a divert mode:

Divert all calls — All incoming calls are diverted.

Divert when phone is busy — Incoming calls are diverted only when the phone interface is busy.

Divert when not answered — Incoming calls are diverted when you do not answer them.

Divert if not reachable — Incoming calls are diverted when the phone interface is switched off or outside of the network service area.

After pressing **Change**, the following options become available:

> *To . . .* — Enter the number to which you want to divert the calls.
> *To voice mailbox* — Calls will be diverted to your voice mailbox. The phone number of the voice mailbox must be set in Other settings.
> *Off* — Calls are not diverted.

Voice call barring

The voice call barring network service allows you to place restrictions on outgoing and incoming voice calls (fax barring is activated in the Fax application's settings and data barring is activated in the Internet application's settings). Activating call barring or changing the barring settings requires the barring password, which you obtain from the operator. Once you have the barring password, you can change it in the Security settings (the Security application is found in the System main view).

The available modes are:

All outgoing calls — Calls cannot be made.

All international calls — Calls cannot be made to foreign countries.

International except home country — When abroad, calls can be made only within the current country and to your home country, i.e., the country where your home network operator is located.

All incoming calls — Calls cannot be received.

Incoming calls when abroad — Calls cannot be received when you are outside your home country.

Note: When calls are barred, calls may be possible to certain emergency numbers in some networks (e.g., 112 or other official emergency number).

Voice call waiting

When the network service voice call waiting is set on, the network will notify you of a new incoming voice call while you have a call in progress. If your network allows you to view the caller's phone number, the caller's phone number (or name) and the text WAITING will be displayed.

Calling card settings

If you want to change the calling card settings, you need to enter your lock code first.

Card in use — Allows you to determine which card you want to use.

Calling cards — Allows you to edit or delete existing cards or add new ones.

Single number settings

In some networks you have the same phone number for all your voice, fax and data calls. If you want to receive any calls, you must set your phone to some answering mode. The available modes are *Voice*, *Fax*, *Data* and *Voice/Fax*.

Other settings

Call cost display — This setting turns the call cost counter on or off. The counter is shown only if the network operator supports this feature.

Audio when cover opened — When you have a voice call and this setting is *Off* (default), each time you open the cover, you must press the **Audio on** command before you can use the communicator in the handsfree mode. If you change this setting to *On*, the handsfree mode is activated automatically after the cover is opened.

Flight mode — The flight mode (see figure 4-4) prevents you from accidentally turning on your phone interface in an aircraft.

> **IMPORTANT!** Never use the phone interface when in an aircraft. If the aircraft personnel allow use of the communicator interface, you MUST activate the flight mode. The flight mode will allow use of the communicator interface only and will prevent use of the phone interface.

Be aware that all communications applications (Telephone, Fax, SMS, Mail, Internet) require use of the phone interface.

With the flight mode active, you may read previously downloaded mail, write mail, notes, short messages, faxes, or update your calendar. Once you have left the aircraft, you can turn off the flight mode by pressing **Exit flight mode**, turn

on the phone interface by pressing $\textcircled{0}$, and your short messages, faxes and mail will be sent automatically.

When the communicator is in the flight mode, emergency calls must be made from the phone interface:

① Press $\textcircled{0}$. The phone interface will read FLIGHT MODE ACTIVE.

② While the FLIGHT MODE ACTIVE text is visible (for approximately five seconds) you can enter the emergency number (e.g. 112).

③ Press 📞.

Voice mailbox number — Set a new or change the current voice mailbox phone number.

To call your voice mailbox: press **Voice mailbox** in the Telephone main view.

You can also call your voice mailbox from the phone interface:

1. Press **1** and then 📞, or:

2. Go to Menu 2 1 (Listen to voice messages) and press **Select**.

Note: Your network operator may be able to update your voice mailbox number via a special SMS message. Contact your network operator for details.

Figure 4-4

HTC and Samsung, Ex. 1008
HTC v. E-Watch, IPR2014-00987
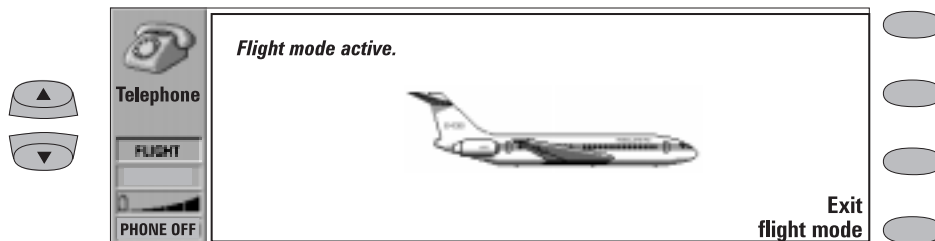
5. Fax

Fax is activated by pressing the Fax application button on the communicator interface keyboard.

To send and receive faxes the following requirements must be met:

- The phone interface must be on.
- The network you are using must support fax calls.
- This service is activated for your SIM card.

Contact your service provider for details.

When a fax is being sent or received, the FAX indicator appears in the display's indicator row.

The Fax main view shows:

- Own texts folder — Contains all created faxes, short messages, memos, notes and mail stored on the communicator.
- Received faxes folder — Contains all received faxes.

- Document Outbox — See chapter 12 "Document outbox" on page 12-1.

Both folders, Own texts and Received faxes, have **Menu** as one of the commands. **Menu** provides the following options:

Write fax — This option is available only inside Own texts folder.

Rename — You can rename the selected subfolder or document.

Copy — You can choose a folder into which the document is copied.

Move — You can select a folder into which the document is moved. Memos cannot be moved.

Create folder — You can make a new subfolder.

If any of these commands is not available, the command will be dimmed.

Sending faxes

Faxes can be sent in the Fax, Notes (see chapter 8 "Notes: Sending" on page 8-3) and Calendar applications (see chapter 9 "Calendar: Daily schedule - Memos" on page 9-3). You can send any previously created (or received) document as a fax, or you can create a new one.

To write a new fax:
① Press **Write fax** in the Fax main view.
② Write the fax in the opened editor.

③ Press **Recipient**. The Fax directory opens.

To send your own text as a fax:
① Select the Own texts folder in the Fax main view and press **Open**.
② Select a document and press **Open**.
③ Press **Recipient** to access the Fax directory.

To forward a received fax:
① Select the Received faxes folder in the Fax

② Select a fax and press **Open**.
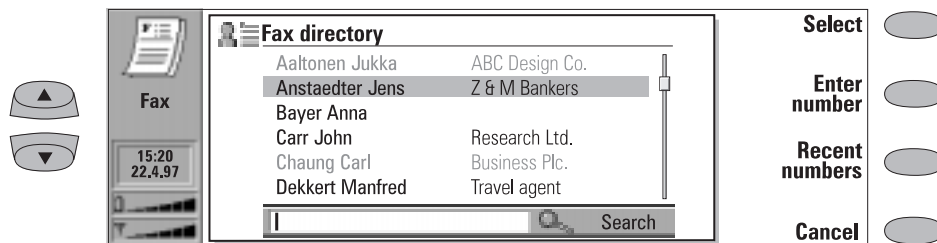
Figure 5-1

③ Press **Forward** to access the Fax directory. By forwarding the fax to the nearest fax machine, you can use this option to get a printed copy of the fax.

Note: Forward options allows you to select the specific pages you want to send (*All pages*, *This page*, or *Pages*). Choose *Pages* to enter the page numbers (first through last, e.g. 3-5) that you want to forward.

Fax directory

To choose a recipient in the Fax directory, select a contact (by scrolling or searching) and press **Select** (see figure 5-1). The names of contacts who have no fax number are dimmed and cannot be selected (switch to the Contacts application to edit stored contact information).

- If a contact has several fax numbers, a pop-up box opens. Choose a number from the list and press **Select**. The fax cover page opens.

- To enter the information manually, press **Enter number**. The fax cover page opens.
- To fetch the information from the Recent fax numbers list, press **Recent numbers**. The list contains the fax numbers with which you have recently had contact. Choose a number and press **Select**. The cover page opens.

Note: If you press **Clear both lists** in the recent numbers view, all the information in the lists is removed. When you open one of the lists and select a contact, **Copy number** copies the fax number to a clipboard where it can be copied to documents by pressing Ctrl-V.

Fax cover page and send options

The fax cover page contains three information fields (see figure 5-2). You can edit the entries in all cover page fields. The *From* field is always filled automatically according to the information

Figure 5-2

HTC v. E-Watch, IPR2014-00987
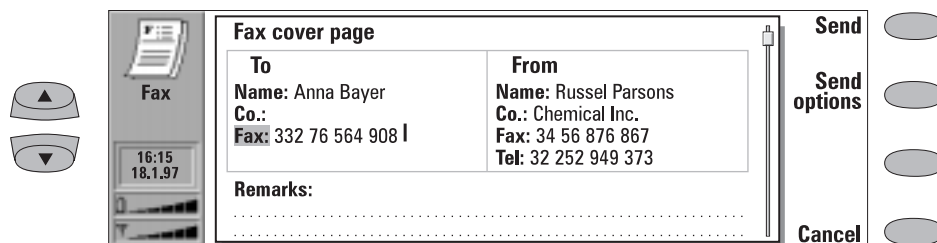
- To send the fax, press **Send**. The fax is handed over to the Document outbox, which will send the fax as soon as possible.
- To adjust fax sending options, press **Send options**. The send options are: *Cover page*, *Send resolution*, *Logo file*, *Signature file*, *Begin sending*, and *Resend pages*. For more information about these, see "Fax settings" on page 5-4. To change these, select one of the options and press **Change**.

Received faxes

Faxes are received automatically, provided that this service is available and that the phone interface is on and within cellular coverage area. All received faxes go to the Received faxes folder.

If you do not wish to receive the fax, close the cover and press ☎ on the phone interface.

When a new fax has been received, you will hear a tone (unless the system is set to silent service mode) and an information note is shown on the screen. Unread faxes in the Received faxes folder are marked with 📋.

To delete the selected fax, open the Received faxes folder and press **Delete**.

There are two ways to read a received fax:

1. When you receive a note informing that you have received a fax, press **View**. To read the fax later, press **Cancel**.

2. Select the Received faxes folder and press **Open**. Select the fax and press **Open**. The fax viewer opens (figure 5-3).

You can use the scroll or arrow keys to scroll the fax up or down. The left and right arrow keys can be used for horizontal scrolling when the fax page is being zoomed.

To delete the viewed fax, press **Delete**.

To zoom the viewed fax, press **View**. A new set of commands becomes available:

- Each press of **Zoom in** enlarges the view of the document on the screen. The view can be scrolled horizontally with the left and right arrow keys.
- Each press of **Zoom out** reduces the image.
- Each press of **Rotate** rotates the viewed fax 90 degrees clockwise with each press of the command button.

Note: A list of shortcuts for viewing faxes (and other operations) can be found in chapter 2 "Getting started: Special features - Shortcuts" on page 2-12.

To return the previous commands, press **Back**.
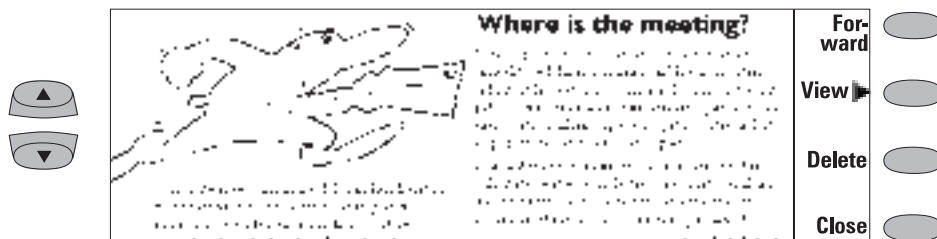
Figure 5-3

Fax settings

Press **Settings** in the Fax main view to change the default sending options of all your faxes.

- *Cover page* — Provides you with the following options:

    Header — The cover page contents will be attached to the beginning of the first document page.
    Separate page — Only the cover page contents are shown on the first page of the fax.
    None — No cover page information will be attached to the fax. The first page of the document will be the first fax page.

- *Begin sending* — Lets you choose when the fax is sent:

    Immediately — The fax is sent right away.
    At [time] — You can determine the time when the fax is sent. Use the time format *hh:mm*. This option enables you to take advantage of cheaper calling times.

- *Receive resolution:*

    Standard — The fax will be received using 200 (width) x 100 (height) dots per inch (dpi) resolution.
    Fine — (200 x 200 dpi). Receiving faxes with fine resolution will take longer and requires approximately twice as much memory as with standard resolution.

- *Send resolution:*

    Standard — 200 x 100 dpi.
    Fine — (200 x 200 dpi). Sending faxes with fine resolution takes longer and temporarily requires more free memory than when using standard resolution.

- *Logo file* — Enables you to add for example your company's logo to the fax cover page (the logo is not shown in the Cover page view).

    None — No logo is attached to the fax.
    [File name] — All the available gif and jpg files in the Downloaded files folder are listed in the pop-up box. Select the one you want to attach to the fax.

- *Signature file* — Allows you to add your signature to the fax cover page. The signature is placed under the *Remarks* field.

    None — No signature is attached to the fax.
    [File name] — All the available gif and jpg files in the Downloaded files folder are listed in the pop-up box. Select the one you want to attach to the fax.

- *Fax barring* and *Fax diverting* — These are supplementary services, like normal voice call barring and diverting.

    Fax barring — You can place restrictions on outgoing and incoming faxes.
    Fax diverting — You can divert incoming faxes to another fax. For more information and instructions on how to change diverting and barring settings, see chapter 4 "Telephone: Telephone settings" on page 4-6.

- *Resend* — Allows you to choose which pages will be sent again if the fax sending has failed and the Document outbox tries to send the fax again.

    All pages — All pages are resent.
    Missed pages — Only the pages which were not sent completely are resent.

- *ECM in reception* — When the Error Correction Mode is *On*, any faxes containing errors are automatically received again until the defects are corrected. This may prolong the fax call.

- *Fax polling* — Some networks provide this service which allows you to make a fax call to a number specified by the network, then receive certain information by fax. Contact your network service provider for further details.

Note: When you set *Fax polling* to *On*, **Fax polling** becomes one of the commands in the Fax main view.

- *Alternate fax receiving* — As default, this setting must be set to *As fax*. If you need to receive alternate voice/fax calls, you must set this to *As voice/fax*. This setting applies also to the Fax modem application.

6. Short messages

The Short Message application is activated by pressing the SMS application button on the communicator interface keyboard.

To send and receive short messages the following requirements must be met:

- Short Message Service (SMS) must be supported by the network you are using.
- SMS must be activated for your SIM card.
- You must store the SMS message centre number in the SMS application's settings.

Contact your home service provider for details.

The Short Message Service enables you to send and receive short alphanumeric text messages of up to 160 characters over the digital cellular network. If the message is longer, it will be sent as several short messages.

The advantages of short messages are: sending is practically instantaneous, messages can be sent or received even during a voice or data call and messages can be read in any mobile phone that has the capability. The SMS message centre will take care of delivering the message even if the receiving phone is off at the time of sending.

The SMS main view shows the following folders:

- Own texts — Texts that you have written.
- Received messages — Messages that you have received.

- Standard messages — Predefined message templates (see "Standard messages" on page 6-5).
- Business cards — All contact cards in the Contacts directory (see "Business cards" on page 6-4).
- Info service — Informative messages sent by the network.
- Delivery reports — Information about the status of sent messages (see "SMS settings" on page 6-5).
- Document outbox — See chapter 12 "Document outbox" on page 12-1.

Note: You can only send short messages to phone numbers stored in the *Tel(GSM)* or *Tel(PCN)* fields of contact cards.

One of the commands inside each folder is **Menu**. When you press **Menu** a pop-up box opens with the choices:

Write message

Rename

Copy

Move

Create folder

For more information on these options, see chapter 5 "Fax" on page 5-1.

If any of these choices is not possible, the choice will be dimmed.

Sending messages
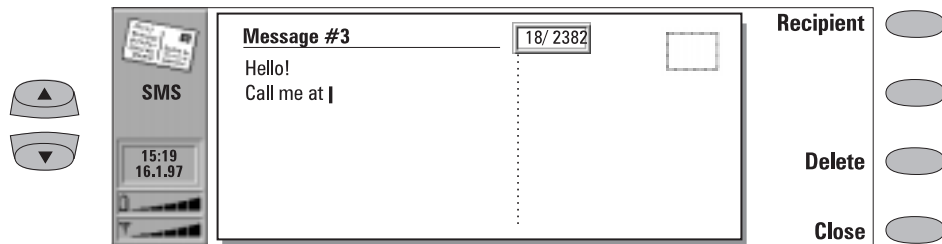
Figure 6-1

Short messages can be created and sent in the SMS, Notes (see chapter 8 "Notes: Sending" on page 8-3) and Calendar applications (see chapter 9 "Calendar: Daily schedule - Memos" on page 9-3).

To create a new short message:

① Press **Write message** in the SMS main view to open the short message editor.

A short message in the editor resembles a postcard. A character counter showing how many characters you have typed and how many are still available appears at the top of the editor, see figure 6-1.

In received messages, the stamp on the right half of the message is postmarked, and the time and date the message was sent are shown below the sender's name or number.

② When the message is ready to be sent, press **Recipient**. The Short Message directory opens, see "Sending messages: SMS directory" on page 6-2.

To send a previously created document:

① Select the Own texts, Standard messages or Business cards folder and press **Open**.

② Select a document and press **Open**. When you open a text containing formatting, you will be asked whether you wish to make a copy of the text (press **Copy**), or edit the original text (press **Edit**). Editing will lose the formatting of the original text.

③ When the message is ready to be sent, press **Recipient**. The SMS directory opens.

④ Select a recipient, press **Select**, and send the message by pressing **Send**.

Note: If your message is longer than 160 characters, it will be sent as two or more short messages.

SMS directory

The SMS application supports three ways to select a recipient:

1. Select a contact in the SMS directory:
   Select a contact (by scrolling or searching) and press **Select**. The contact must have a phone number in the *Tel(GSM)* or *Tel(PCN)* contact card field. Once the address of the message has been selected, the sending view opens.

2. Enter the phone number manually:
   Press **Enter number**. The sending view opens. Enter the destination number.

3. Use the address information in the recent contacts list:
   Press **Recent numbers** to get a list of recent short message numbers (sent and received), open one of the lists, select a contact, and press **Select**.

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To send the message to several recipients, use multiselection (see chapter 2 "Getting started: Special features - Multiselection" on page 2-12).

When the message is ready to be sent, press **Send** to hand the message over to the Document outbox which sends the message as soon as possible (see chapter 12 "Document outbox" on page 12-1).

Note: If you press **Clear both lists** in the Recent numbers view, all the information in the lists is deleted. When you open one of the lists and select a contact, **Copy number** copies the phone number to a clipboard where it can be copied to documents by pressing Ctrl-V.

To adjust the sending options for the current message, press **Send options**. Press **Change** to set a new value for the current message. The send options (*Reply via same centre*, *Validity period*, *Message conversion* and *Request delivery report*) are the same as in the SMS settings, see "SMS settings" on page 6-5.

Received messages

Short messages are received automatically, provided that this service is available and that the phone interface is on and within cellular coverage area. All received short messages go in the Received messages folder.

When a new short message has arrived, a tone will sound (unless the system is set to silent service mode) and an information note is shown on the display.

A received short message can be a normal short message, business card (see "Business cards" on page 6-4), service card (see "Received service cards" on page 6-4) or notification of a voice message in your voice mailbox. Unread received messages are marked with ▤ and unread received business cards are marked with ▤.

There are two ways to read a received message:

1. When you receive a note informing you about a received short message, press **View** to read the message.

2. To read the short message later, press **Cancel** to dismiss the note. You can then open the Received messages folder, select the message and press **Open**.

To reply to a received message:

① Select the Received messages folder and press **Open**.

② Open the selected document and press **Reply**. The contents of the received message are not included in the new message automatically. If you want to include them, press **Menu** and choose the *Reply (include text)* option.

To forward a received message:

① Select the Received messages folder and press **Open**.

② Open the selected document, press **Menu** and choose the *Forward* option. The contents of the received message are included in the new message.

③ Press **Recipient** and select a recipient in the SMS directory.

④ To send the message, press **Send**.

When you press **Menu** in an opened received message, you can also use the following commands:

Use number — You may make a phone call to the sender of the message as well as call a number in the message.

① Open the received message, press **Menu** and choose the *Use number* option.

② If the message contains phone numbers both in the text and the *From* field, press **Next number** to toggle between these numbers and to select one of them.

③ To call the selected number, press **Call**.

Copy URL — If the message you have received contains a URL address, you can add it to the WWW hotlist (see chapter 7 "Internet: Hotlist" on page 7-12).

Received service cards

A DTMF service provider may send DTMF sequences to its subscribers in the form of a service card that can be stored as DTMF contact cards. For more information on Dual Tone Multi Frequency (DTMF) tones, see chapter 13 "Phone interface: Sending DTMF tones" on page 13-3.

Business cards

The business card is a special short message containing personal information about a contact, just like a normal business card. You can send your own business card or any contact card as a business card.

Business cards sent from a device that supports the Nokia 9000i Communicator contact card format can be saved directly as new contact cards in the Contacts directory:

- Press **Menu** in an opened received business card and select *Create card.*
- The option *Use number* allows you to make a phone call to any phone number in the business card (see "Received messages" on page 6-3).

When you have received a business card, press **Reply** to send your own business card to the sender.

To send a contact card as a business card:

① Open the Business cards folder. Select a business card and press **Open**.

② Press **Options** to define which fields to include (and show) in the business card (figure 6-2). **Change** toggles the fields on or off. The message can be up to 160 characters in length.

③ Press **Recipient** to select a recipient for the business card. Send the message normally, as described in the section "Sending messages" on page 6-2.

CellularWare 1.0 note: When a business card you send is received with the Nokia CellularWare 1.0 software, the label texts of *Tel* fields are added to the phone numbers. The label texts must be removed before the phone numbers can be used.

SMS	**Parsons Russel**	Recipient
	Chemical Inc.	
	Technical Manager	
	Tel:+32 252 949 373	
15:20	Fax:+34 56 876 867	
16.1.97	russel.parsons@chem.co.uk	Options
		Close

Figure 6-2

Standard messages

You can store frequently used short messages as standard messages, and send them instead of writing a new message every time. Standard messages are stored in the Standard messages folder.

When a standard message has been opened in the short message editor, the text STANDARD MESSAGE on the right top half of the card distinguishes between a normal message and a standard message.

When you open the Standard messages folder and press **Menu**, you can write a new standard message. The commands in a new standard message are:

> **Recipient**— Opens the SMS directory, as described in "Sending messages: SMS directory" on page 6-2.
> **Rename** — Opens a box where you can enter a new name for the current standard message.
> **Delete** — Removes the selected standard message from the Standard messages list.

SMS settings

Press **Settings** in the SMS application main view to change the default settings. The settings you define here are used until you change them again.

Reply via same centre: Yes / No (default) — This network service allows the recipient of your short message to reply using your short message centre. By setting this option to *Yes*, you allow the recipient to reply to your message, even if the recipient does not subscribe to the Short Message Service (provided that the recipient has the means to type a reply message).

Validity period: 1 h / 6 h / 24 h (default) / *One week / Maximum* — If the recipient of a message cannot be reached within the set validity period, the message is deleted from the message centre. If *Maximum* is chosen, the validity period is set to the maximum value allowed by the message centre.

Message conversion: None (send as a normal short message, default) / *Fax / X.400 / Paging / E-mail / ERMES / Speech* (message synthesised from a short message) — In order to receive a converted message, the recipient must have an appropri-

ate terminal device available. For example, if you choose the *Fax* format, the recipient must have a telefax machine or similar device connected to the number.

Message centre number — In order to be able to send short messages, you must enter the SMS message centre number here.

Note: Your network service provider may be able to set the message centre number to your communicator via a special SMS message. Contact your service provider for details.

Request delivery report: Yes/No (default) — When this is set to *Yes*, the status of the sent message (*Delivered, Pending, Failed*) is shown in the Delivery reports folder.

Receive info messages: Yes/No/View index — If your network supports this feature, it will send you information about various topics. If you choose *View index*, the network will send you a list of topics, and you can select on what kind of topics you want to receive information.

Info service mode: Display and save/ Display only/ Save only — If this is set to *Display and save*, messages are displayed and saved in the Info service folder. If you select *Save only*, info messages are not displayed but saved in the folder. If you select *Display only*, messages are displayed but not saved.

Info service topics — Message topics vary according to the operator. You can define here what type of messages you want to receive.

For more information about Info service, contact your service provider.

7. Internet

The Internet applications are used to access computerised information services via a data call. To obtain access to the Internet, the following requirements must be met:

- Data calls must be supported by the network you are using.
- Data service must be activated for your SIM card (contact your network service provider for details).
- You have obtained an Internet Access Point (IAP) from an Internet service provider. Contact your dealer for details.

- You have entered the proper Internet settings.

Your service provider will give you instructions on how to configure the Internet settings. Follow the instructions carefully.

Activate the Internet application by pressing the Internet button on the communicator interface. From the Internet main view, select an application by scrolling and press **Select**.

With one Internet application active, you can quickly switch to another by pressing the Internet button.

To close an active application, press **Close**.

Internet applications

Mail — An electronic mail application which lets you send and receive messages all over the world using the Internet.

World Wide Web (WWW) — A hypertext-based system for finding and accessing resources on the Internet.

Telnet — Allows your communicator to connect to computers that provide terminal services through the Internet.

Terminal — Allows your communicator to connect to computers, such as mainframe computers, that provide direct dial-in terminal services.

Both the Telnet and Terminal applications emulate the VT100 terminal.

Note: Depending on the network configuration and load, establishing an Internet connection may take up to one minute (or even longer).

When you want to disconnect, press **Hang up**.

When you disconnect from the Internet, a note will be shown on the display and the data call indicator will disappear.

Internet glossary

Cookies

Cookies are little pieces of information, given by the server to you, to store session informa-

tion between the times you visit the same web site. When you accept cookies, the server is able to store and use information about your actions on the visited web site.

Domain name and Host name

Terms "domain name" and "host name" are sometimes, slightly inaccurately, used as synonyms. In a fully qualified domain name (e.g., *www.club.nokia.com*), the first part of the name is the name of the host and the following parts are names of domains to which the host belongs. Each host name corresponds to a certain IP address (see below). Host names are used because they are easier to remember than IP addresses.

Hypertext Markup Language (HTML)

A language used to define WWW documents' appearance and content.

Hypertext Transfer Protocol (HTTP)

A document transfer protocol used in the WWW system.

Images (Inline, External)

Images within a fetched WWW page are inline images. Larger images are often placed as external images and have to be viewed separately.

Internet Access Point

Where your communicator connects to Internet by way of a data call. An Internet access provider can be, for example, a commercial Internet service provider or your own company.

Internet Mail Access Protocol, version 4 (IMAP4)

A protocol used for accessing the remote mailbox.

Internet Protocol (IP) address

All computers and other devices connected to the Internet using the Internet Protocol have their own individual addresses. The address consists of four numbers separated by full stops: for example, "131.227.21.167."

Multipurpose Internet Mail Extensions (MIME)

A standard Internet format which permits including multiple mail objects in a single message. The mail objects can be, for example, formatted multifont text messages and non-textual elements, such as images and audio fragments.

Plug-in

A plug-in is add-on software that can be downloaded from the WWW. The communicator uses plug-ins to display a document that the WWW application itself cannot show. See "Plug-ins" on page 7-15.

Point to Point Protocol (PPP)

A common networking software protocol making it possible for any computer with a modem and a phone line to connect directly to the Internet.

Post Office Protocol, version 3 (POP3)

Another common mail protocol that can be used for accessing the remote mailbox.

Protocol

A formal set of rules that govern how data is transferred between two devices.

Proxy

In some networks, the connection between the WWW application and the resource you want to connect to is blocked by a firewall. The firewall protects the internal network from unauthorised external access. A proxy is an intermediary program which enables access through the firewall. A proxy can also serve as a network "cache", which speeds up the fetching process.

Simple Mail Transport Protocol (SMTP)

An Internet protocol governing the transfer of electronic mail.

SSL (Secure Socket Layer)

A security protocol that prevents eavesdropping, tampering, or message forgery over the Internet.

If you want your Nokia 9000i Communicator to support SSL encryption, it can be installed later. Contact http://www.club.nokia.com for more information.

TCP Port

Identifies the data port of the destination computer.

Transmission Control Protocol/Internet Protocol (TCP/IP)

A protocol that governs the data communication in the Internet and in the TCP/IP networks.

Uniform Resource Locator (URL)

Link information required by the WWW service to connect to a given WWW host computer. The URL usually starts with *http://* followed by *www*. For example, the Club.Nokia home page can be found at http://www.club.nokia.com. URLs are often referred to with phrases like "Home page location," "Site location," "can be found at... ."

Internet settings

To define Internet settings:

- Press **Settings** in the Internet application's main view. The Internet settings main view (figure 7-1) opens.

To define an Internet access point:

① In the Internet settings main view choose *Internet access* and press **Change**.

② To define a new Internet access point, press **New**. To modify or change an existing one, press **Edit**.

Note: The Internet settings apply to all Internet applications.

Information concerning the settings must be obtained from your Internet service provider. The service provider may be able to configure the access point for you via a special SMS message. This message sets all the necessary Internet access settings (see the following section) and adds a new entry to the list of defined Internet access points.

The Internet settings are:

Modem initialisation — Allows you to define your communicator's modem settings.

  Autobauding (default) — The data transmission rate is determined automatically.
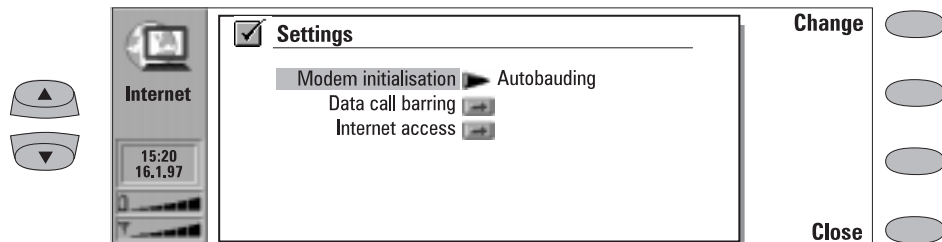
Figure 7-1

Autobauding with V.42bis compression — Speeds up data transfer (e.g. mail sending or receiving) when supported by the cellular network.

Fixed 9600 b/s — Fixed data transmission rate

is used. If you experience problems with establishing a data call, try this option.

Custom — When a data call is established, the modem is first set to the factory defaults and then initialised according to the string you enter here. In the case of Terminal connections, see "Defining Terminal connections" on page 7-18.

Data call barring — Initiates a data call barring dialogue, similar to that in the Telephone application (see chapter 4 "Telephone: Telephone settings - Voice call barring" on page 4-7). To see the current barring mode, press **Get status**. To cancel all barrings, press **Cancel data barrings**.

Internet access — Lists the defined Internet access points. You can configure the communicator differently for each Internet access point. Press **Edit** to change the settings of an existing access point. Press **New** to define a new access point. Press **Delete** to remove an access point.

Provider name — The Internet access provider's name which appears on the access point list. If you define the access point manually, the name can be edited freely.

Phone number — Telephone number of the Internet access point.

User name — Used in the PPP authentication process if required by the Internet access provider.

Prompt for password: Yes / No (default) – If you must enter a new password every time you log on to a server, or you do not want to save the password, change this setting to *Yes*.

Password — Used in the PPP authentication process if required by the Internet access provider.

Advanced settings — Opens a new view where you can make further adjustments for an Internet access point, if required:

Modem initialisation — Enter any modem initialisation string containing AT commands here, if needed. This initialisation string is executed after the initialisation string you define in *Modem initialisation: Custom* view of the Internet settings.

Login customisation: *None*, *Manual* — Some Internet access points do not automatically enable PPP. In such cases you need to choose either *Manual*, as it allows you to enter manually your login name and password over a terminal connection, or press **New** in the pop-up box, to write and save a new login script.
If you choose *None*, your password and user name are automatically taken from the Internet access point settings.
For more information on login scripts, see the *scripts.txt* file on the diskette supplied with the communicator.

Compression: On/Off (default) —Speeds up data transfer (e.g. mail sending or receiving) when supported by the remote PPP server.

IP address — The communicator's own IP address.

Default gateway — The IP address of the system that is a gateway out of the local network.

Network mask — Shows which portion of the communicator's IP address identifies the network.

Primary nameserver — The IP address of the primary nameserver.

Secondary nameserver — The IP address of the secondary nameserver.

Note: You may define several Internet access points, as well as specify an IAP to be used for a certain connection.

Mail

The Nokia 9000i Communicator mail system is compliant with the Internet standards SMTP, IMAP4, POP3, MIME1 and MIME2.

Mail is started in the Internet applications main view by selecting *Mail* and pressing the **Select** command button. The Mail main view shows the following folders:

Own texts — Contains the texts you have created with the communicator. The listed documents may contain formatted text, but the text will appear in the editor without formatting.

Received mail — Contains mail fetched from the remote mailbox. See "Reading mail" on page 7-9.

Remote mailbox — Your electronic mailbox service which receives all your mail. This service may be offered by a network operator, your company, or a commercial Internet access provider. The mail protocol used between the communicator and the remote mailbox is IMAP4 or POP3. Required mailbox and Internet access point settings are described in "Reading mail" on page 7-9.

Document outbox — The communicator's outgoing communications manager. See chapter 12 "Document outbox" on page 12-1.

Mail settings

Be sure to define your Internet access point as described in "Internet settings" on page 7-3.

To define the mail settings:
① Go to the Mail main view.
② Press **Settings**.

To change one of the following items, select it and press **Change**:

Internet access — Refers to the Internet access point you will use to send and receive mail. To define a new or edit an existing Internet access point, see "Internet settings" on page 7-3.

Show header fields — The term header field refers to the information given at the top of an E-mail message. This setting controls which header fields within the received message will be shown when the message is opened:

All will show all possible fields.

Basic (default) will show the *Date, From, To* and *Subject* fields.

None will not show any header fields (the sender and the subject of the message are still shown in the name of the message).

Font — URW Mono / URW Roman / URW Sans (default). Choose the font you prefer for your mail. This setting determines the font used in the mail editor and viewer.

Sending settings — Changing this setting opens a new set of options:

Own E-mail address — A standard Internet format address. The address must contain the @ character. This entry is obligatory if Internet mail services are to be used. Replies to your messages will be sent to this address.

Sending host — The IP address or host name of the computer which sends your Internet mail.

Send mail — Immediately (default) / Upon request / During next connection. Choose Immediately to send mail automatically, Upon request if you want to write several mail messages and send them at your convenience, or During next connection if you want your mail sent the next time you make a connection to the Internet access point that your mailbox uses (see "Sending mail: Send mail upon request" on page 7-8).

Copy to own E-mail address — *Yes* / *No* (default). If the setting is *Yes*, the mail will be automatically sent to the address defined in *Own E-mail address*.

MIME character encoding — *On* (default) / *Off*. MIME character encoding allows another MIME compliant mail system to read the character set used in your communicator. Only when text containing special characters (e.g. á, ä, ß) is sent to a non MIME compliant mail reader should the MIME character encoding be turned off. When MIME character encoding is off the special characters are automatically converted to ASCII characters: 'ä' becomes 'a' and so on.

Remote mailbox settings — Changing this setting opens a new set of options, described below. Your remote mailbox service provider will supply you with the required information.

Remote mailbox user name and *Remote mailbox password* — These may be required to connect to the server and to open your mailbox.

The password characters appear as asterisks (*) on the display. The user name and password stored here will be automatically offered to the server. You will only have to enter your user name and password if you have stored them incorrectly (in this case, you will be prompted when you connect to the remote mailbox).

Pressing **Cancel**, or entering your user name and password incorrectly three times will ter-

minate the connection to the remote mailbox. For information on how to change the Remote mailbox password, contact your remote mailbox service provider.

Receiving host — The IP address or host name of the computer that receives your Internet mail.

Remote mailbox folder — INBOX is the default folder name for your incoming mail. Do not change this name without consulting with your remote mailbox service provider. This option is only available when the remote mailbox protocol is IMAP4.

Remote mailbox protocol — *IMAP4* (default)/ *POP3*. Choose the mail protocol your mailbox service provider recommends.

Fetch headers — *All* (default) / *Recent*. Determines whether all mail headers or just the headers for mail received since the last connection will be fetched. It is possible to have old or unread mail (that you have chosen not to download or delete) in the remote mailbox.

Fetch attachments — *Yes* (default) / *No*. Determines whether possible mail attachments are fetched or not. Text attachments are always fetched. This option is only available if the remote mailbox protocol is IMAP4.

Delete fetched — *Yes* / *No* (default). Determines whether fetched mail will be automatically deleted from the remote mailbox. All fetched mail goes to the Received mail folder.

Sending mail

Mail can be sent either via the Mail, Notes (see chapter 8 "Notes: Sending" on page 8-3) or Calendar (see chapter 9 "Calendar: Daily schedule - Memos" on page 9-3) applications.

To create new mail:

① Press **Write mail** in the Mail main view. An

empty mail editor opens.

② Write the message. You can change the font within the Mail settings.

③ When the message is ready to be sent, press **Recipient** to select an address from the Mail

directory. See "Sending mail: Mail directory" on page 7-7.

```
┌─────────────────────────────────────────────┐        Send  ◯
│ Mail #3                                       │
│ -------------Replied message-------------     │              ◯
│ Date: Thu,22 May 1997 12:00:33 -0700          │
│ From: John Smith <JNS@kub.Xanadu.EDU>         │
│ To: mmlab@xor.mailbox.co                      │
│ Subject: Multimedia mail demonstration        │      Delete ◯
│                                               │
│ Hello, John!                                  │
│ ▎                                             │      Close  ◯
└─────────────────────────────────────────────┘
```
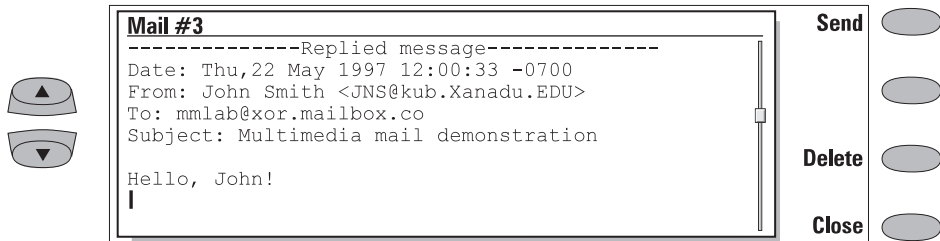
Figure 7-2

To send previously created documents:

① Select the Own texts folder in the Mail main view and press **Open**.

② Select a document and press **Open**. The document is loaded in the mail editor using the font chosen in the Mail settings. If the document contains text formattings, before you can edit the document, you will be asked if you want to edit the original (and lose all formattings) or create a copy in the Own texts folder and edit the copy instead.

③ When the document is ready to be sent, press **Recipient** to open the Mail directory. See "Sending mail: Mail directory" on page 7-7.

④ Select the recipient or enter the mail address and press **Send**. Your mail will go to the Document outbox.

To reply to received mail:

① Select the Received mail folder and press **Open**.

② Select a message and press **Open**. The document is opened in the mail viewer, and a new set of commands appears.

③ Press **Menu** and select *Reply*. If the received mail message is a MIME document, only the first text part is included in the reply. (For more information about the **Menu** command, see "Reading mail" on page 7-9.)

④ When the reply is ready to be sent, press **Send**. The Mail envelope view opens, see "Mail envelope" on page 7-8.

To forward received mail:

① Select the Received mail folder and press **Open**.

② Select a message and press **Open**. The document is opened in the mail viewer.

③ Press **Menu**, and select *Forward*. The mail editor opens. The contents of the message you are forwarding will be included in the new message. If the received mail message is a MIME document, only the first text part is copied to the forwarded message and may be edited. Any MIME attachments are included in the forwarded message, but they are not visible in the editor.

④ When the message is ready to be sent, press **Recipient** to open the Mail directory. See the following "Mail directory" section.

Mail directory

The directory shows a list of contacts that have electronic mail addresses in the Mail field(s) of their contact cards.

To select a recipient listed in the Mail directory:

① Move the selection frame over the contact's name and press **Select**. If the contact has only one mail address, the Mail envelope opens.

② If the contact has several mail addresses, a pop-up box opens, listing the available mail addresses. Select an address and press **Select** to open the Mail envelope. See "Sending mail: Mail envelope" on page 7-8.

To enter the recipient's address manually:

① Press **Enter address**. The Mail envelope

opens. See "Sending mail: Mail envelope" on page 7-8.

Figure 7-3

Mail envelope

The Mail envelope opens whenever you are about to send mail (figure 7-3). All field entries are freely editable.

To determine how the current mail message will be sent:

Press **Send options**. To change the current setting, press **Change**. The possible options are:

Send mail — Immediately/ Upon request/ During next connection

Copy to own E-mail address — Yes / No (default)

MIME character encoding — On/ Off

For more information, see "Mail settings" on page 7-5.

To add addresses to the *To* or *Cc* fields in the Mail directory:

Press **Add recipient**. The new address will be entered into the field that was selected when you pressed **Add recipient**. (If the *Subject* field is selected, the command is dimmed.)

Multiple addresses in the *To* and *Cc* fields must be separated by a comma.

You can also enter standard Internet mail addresses manually. The basic format of an Internet mail address is *mailbox@domain*. The mailbox part identifies the mail recipient within a domain.

To add attachments to the message:

Scroll down to *Attachments* and press **Attachments**. A list of attachments opens. To add documents to the list, press **Add**. You can select documents from the Own texts and Downloaded files folders. To remove documents from the attachment list, press **Remove**. When all the desired attachments are in the list, press **Close**.

To send the message, press **Send**.

Send mail upon request

When you have several mail messages to send, you may want to use the *Upon request* (you choose the time and initialise the sending) or *During next connection* (your mail will be sent automatically the next time you make an connection to the Internet access point your remote mailbox uses) option, which are set in the Mail settings. This way you may send all your mail during the same data call.

To send *Upon request*:

① Write your mail, select the recipient and press **Send options**.

② Select the *Upon request* option and then press **Send** to send the mail.

③ Go to the Document outbox and press **Open**.

④ Press **Start** to send your mail.

Reading mail

```
John Smith <jn  Multimedia mai                          Menu
Date: mon,6 Feb 1996 02:53:47 +0300 (PST)
From: John Smith <JNS@kub.Xanadu.EDU>                   Attach-
To: mmlab@xor.mailbox.co                                ments
Subject: Multimedia mail demonstration
Parts/attachments:
  1     Shown   3 lines Text, "Explanation"            Delete
  2             4.9 KB    Message, "Rich text demo"
  2.1   Shown  16 lines Text
  2.2.1 Shown  13 lines Text                            Close
```
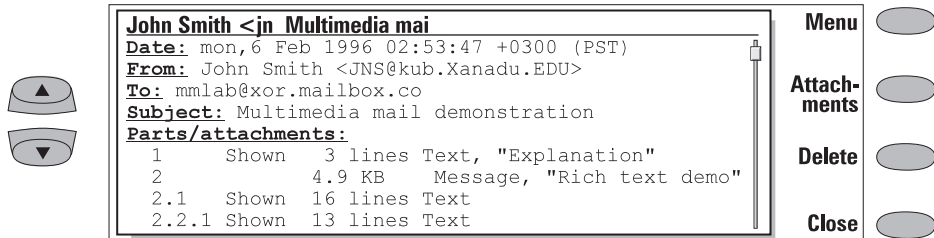
Figure 7-4

Unlike faxes, Internet mail addressed to you is not automatically received by your communicator, but a remote mailbox (figure 7-5). This is to let you determine which messages you want to read and when. To read your mail, you must first connect to your remote mailbox and then select the messages you wish to fetch onto your communicator. Connection to the remote mailbox is established via a data call.

If your remote mailbox server is capable of sending you special short messages, you will hear tone (unless the system is set to silent service mode) and see a note when new mail arrives in your remote mailbox.

Mail that you fetch from your remote mailbox is stored in the Received mail folder. To open the Received mail folder, select it in the Mail main view and press **Open**. The folder lists received mail messages. Mail messages that have not yet been opened in the communicator are marked with ⬚.

- To rename or delete a document press **Rename** or **Delete**.
- To close the Received mail folder, press **Close**.
- To view the selected message, press **Open**. The selected message is opened in the mail viewer.

From the Received mail folder, when you open a received mail the following command buttons are displayed:

Menu — Opens up a pop-up box with the reply and forward options:

Reply (include text) — Replies to a mail message and includes the received mail in your reply.

Reply — Replies to a mail message without including the received mail in your reply.

Reply all (include text) — Replies to all persons who received the mail and includes the received mail in your reply.

Reply all — Replies to all persons who received the mail without including the received mail in your reply.

Forward — Forwards a received mail and the possible mail attachments.

Scroll to any of these and press **Select**.

Attachments — Lists all MIME attachments (text, image, audio, video or application). If no attachments are contained in the message, this command is dimmed. When viewing the list of attachments you may select an attachment and choose from the following options:

View will open and display the attachment, provided there is enough memory and a viewer associated with the attachment.

Save will save the attachment in the Downloaded files folder.

Close returns you to the previous screen.

Delete — Deletes the open mail message.

Close — Returns you to the previous screen.
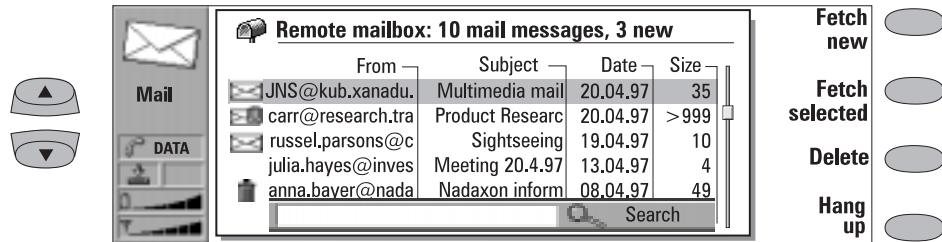
Figure 7-5

Connecting to remote mailbox

To connect to the remote mailbox, move the selection frame in the Mail main view over the Remote mailbox and press **Connect**.

Unread messages are marked with ![icon], messages with attachments with ![icon] and deleted messages with ![icon].

The Mail and Internet access point settings must be configured correctly. Read "Mail settings" on page 7-5 and follow the instructions given by your remote mailbox and Internet service providers.

Fetching mail

Once you have connected to the remote mailbox, you can fetch and delete mail. If the *Delete fetched* setting is on (see "Mail settings" on page 7-5), fetched messages are marked as deleted. These messages will be retained in Received mail folder, and deleted from the remote mailbox.

To fetch all new mail:

- Press **Fetch new**. All mail with the new mail icon is fetched to the Received mail folder. After new mail has been fetched, connection to the remote mailbox is closed and the Mail main view returns.

To fetch a selected message:

- Select the mail message(s) you want to fetch and press **Fetch selected**. After mail has been fetched, the Remote mailbox view returns.

To delete/undelete a mail message:

- Select a message and press **Delete** or **Undelete**. The messages will be deleted when you exit the remote mailbox. You can also use multiselection, see chapter 2 "Getting started: Special features - Multiselection" on page 2-12.

To disconnect from the remote mailbox:

- Press **Hang up**. If you have messages marked as deleted, you will be prompted to confirm the deletion. The connection to remote mailbox closes, and the Mail application main view returns on the display.

World Wide Web

To connect to the World Wide Web, your SIM card has to be activated for the service and you need an account with an Internet service provider.

To open the World Wide Web (WWW) application:
- Select *WWW* in the Internet applications main view, and press **Select**.

To exit the WWW application:
- Press **Hang up** in the WWW main view (the Hotlist). The data call will end and the WWW application will close.

WWW settings

To enter the WWW settings view, press the **Settings** command button in the WWW main view. To change the setting, select it and press **Change**.

Internet access point — Contains your current Internet settings. Although the proxy settings may be left blank, an Internet access point must be defined before you can make an Internet connection (see "Internet settings" on page 7-3).

Internet access — To change the Internet access point, press **Change**. Choose one of the IAPs you have defined in the Internet settings (main view). The Internet access point that was selected when the Internet access view was closed is set as the default access point.

HTTP proxy — The hostname of the HTTP proxy server.

Proxy port — The port number that the proxy server uses.

No proxy for — You may define domains for which the proxy must not be used. Domain names are delimited by commas (for example, nokia.com,edu.fi). You may specify the domains as accurately as you wish.

Proxy settings allow you to use a proxy (see "Internet glossary" on page 7-1). The *HTTP proxy* server name and *Proxy port* must be defined before using the proxy.

Autodisconnect time — *2 min*/ *3 min* (default)/*5 min*/*Maximum*. Determines the length of time the communicator will be connected to the Internet in an idle state before automatically disconnecting.

Show E-mail address — *Yes* (default) / *No*. If set to *Yes*, your mail address is included in the fetch request when fetching a WWW page. The mail address is defined in the Mail application's Remote mailbox settings.

Autoload images — *Yes* / *No* (default). If the autoload images option is *Yes*, inline (JPG or GIF) images on the WWW page are fetched automatically. When the setting is *No*, WWW pages are fetched without the images and shown much faster.

Clear cache and history — *Yes* (default) / *No*. Most recently fetched WWW pages are kept in the communicator's temporary memory, the "cache".

If set to *Yes*, the WWW cache, history list and cookie file are automatically emptied after you exit the WWW application. If set to *No*, the cache stores as much information as possible. When you restart the WWW application, the most recently stored information can be fetched from the cache and history without making a new data call.

URL entry box visible — *Yes* (default) / *No*. When *Yes* is chosen, the URL entry box is shown in the WWW browser main view, and the URL is read

from the entry box. When the option is *No*, the URL is read from the Hotlist.

Accept cookies — Yes / No (default). Determines whether the cookies functionality is enabled (see "Internet glossary" on page 7-1).

Plug-ins — Contains a list of installed plug-ins. See "Navigating in WWW: Plug-ins" on page 7-15.

Hotlist

The WWW main view shows the Hotlist (a list of predefined WWW page locations), with the name of the Internet access point to be used for your next Internet connection. Below the Hotlist is the URL entry field which shows the address of the last visited WWW page.

To view a page:

① Select an entry in the Hotlist or enter an address in the URL entry field (use the backspace key to delete the address shown)

② Press **Fetch**.

To add a new Hotlist item:

① Press **Define**. A new set of commands is activated.

② Press **New**.

③ Enter the *Item name* you want for your new Hotlist item, then move to the *URL* field.

④ Enter the HTTP address (e.g. www.nokia.com).

⑤ The *Autoselect IAP* field is for those who want to use a specific Internet access point (IAP) to connect to a certain web site. If you have no preferences about which IAP is used, leave the *Autoselect IAP* at *Yes*. To specify an IAP,

choose *No*. You may then move down to the *Internet access* field, press **Change**, and select from among the predefined access points.

URL addresses begin by default: "http://," but the prefix "file:///" (note: three slashes) can also be used. The WWW application checks that the syntax of the URL you enter is correct. If a prefix is missing, "http://" will be added automatically.

To edit the Hotlist:

① In the WWW main view, press **Define**. A new set of commands is activated.

② Scroll to the Hotlist item you wish to edit, and Press **Edit**. You can also use multiselection (see chapter 2 "Getting started: Special features - Multiselection" on page 2-12).

③ Make your changes and press **Close** to exit the view.

If the WWW page is stored locally (stored in the communicator memory), the prefix "file:///" can be used (see "Connecting to WWW: Locally stored WWW pages" on page 7-13).

Press **Delete** to delete the selected Hotlist entry.

Connecting to WWW

Select a WWW page from the Hotlist or enter a URL address into the URL entry box (see "Navigating in WWW" on page 7-14) and press **Fetch**.

If the WWW page was already recently fetched, the page is fetched from temporary working mem-

ory (or "cache"). If not, the page is fetched from the Internet by making a data call to the selected Internet access point. You can also fetch WWW pages stored on the communicator by using the

prefix "file:///." See "Connecting to WWW: Locally stored WWW pages" on page 7-13.
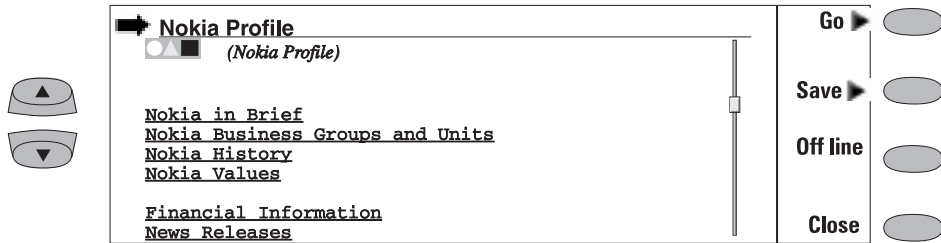

Figure 7-6

Some servers have access restrictions that require a valid user name and password. In this case, you must enter the user name and password before the document can be fetched. The communicator stores the passwords and user names that you enter to gain access to that domain, and the next time you connect to the same domain, they will be offered automatically. If automated login does not succeed, you must enter the information manually.

Note: Stored passwords to individual web sites are removed when the communicator is rebooted.

The fetched WWW page is loaded in the WWW browser. The status line on top of the display shows the status of the connection, the title of the document and how many bytes of the document file have been received.

To reload a web page, press Ctrl-R.

After the WWW page has been fetched, the following commands are available (see figure 7-6):

Go activates the WWW navigation commands, see "Navigating in WWW" on page 7-14.

Save activates a new set of commands:
   Copy text/Copy image copies the text (or image) on the opened page into the Downloaded files folder. Possible text formattings are retained in the copy.
   Add to hotlist adds on the Hotlist a link pointing to this WWW page.
   Copy HTML saves the HTML code of the currently opened WWW page or inline image into the Downloaded files folder and adds on

the Hotlist a link pointing to this WWW page. See "Connecting to WWW: Locally stored WWW pages" on page 7-13.
   Back returns the previous set of commands.

Go off line ends the data call and disconnects from the Internet. Once you are off line, this command changes to **Go on line**.

You may use the off line function, for example, to read copied text off line. The copied text can be read or edited (see chapter 8 "Notes: Editing" on page 8-2).

To reconnect to the Internet, press **Go on line**. While you are off line, commands **Fetch**, **Fetch image** or **Previous**, or other applications may also return you to on line.

Close returns to the Hotlist.

Locally stored WWW pages

To store fetched WWW pages locally (i.e. on your communicator):
① From the WWW page you have fetched, press **Save**. A new set of commands is activated.
② Press **Copy source**.

The current WWW page HTML code is stored in the Downloaded files folder and a link pointing to this WWW page is added on the Hotlist.

Locally stored WWW pages are marked by [HTML] in the Hotlist.

If you want to view the HTML code of the saved WWW page, open the document in the Note editor (in the Downloaded files of the Notes appli-

cation). If you want to view the document as it would appear in the World Wide Web, open the document in the WWW browser (in the WWW application). A locally stored WWW page is opened in the WWW browser by using the prefix "file:///" instead of "http://".

You can edit the HTML code in the Own texts folder.

A fetched WWW document may contain an SMS form. You can send the contents of an SMS form as a short message.

Navigating in WWW

If there are hyperlinks or hotspots in the part of the WWW document shown in the application window, one will always be selected (see figure 7-7).

Hyperlinks are links to other documents or images, used to send or receive information from the World Wide Web.

Hotspots (such as selection lists, text entry fields and reset/submit buttons) enable you to input information into the World Wide Web.

Use the scroll buttons to scroll the view and to choose hyperlinks and hotspots. Each scroll key press selects the nearest hyperlink or hotspot, or moves the view one line up or down.

The following commands may be available in this view, depending on the hyperlink or hotspot:

Fetch follows a hyperlink.

Fetch image loads an image (see "Navigating in WWW: Viewing images" on page 7-14).

Press is available when a hyperlink should be chosen by pressing a button.

Change activates various items, such as check boxes.

Previous opens the previously visited WWW page. Command is dimmed if there is no previous page.

Back returns the WWW browser commands.

History activates the History view. You can select a previously fetched WWW page from the list and press **Fetch**. The history list contains the most recently fetched documents (and their URLs – shown in the URL entry box). After the maximum list length is reached, older pages are deleted one by one as new ones are stored.

If you wish to clear the list, choose **Clear now**. All the items from the History list and the cache will be deleted.

Viewing images

Images that are part of the fetched WWW page are called inline images. By default, inline images are not fetched with the WWW page (see the option *Autoload images* in "WWW settings" on page 7-11), but will be displayed as icons. To fetch an image, select the icon and press **Fetch image**.

Inline images can also be image maps. An inline image map acts like a hyperlink. A fetched and
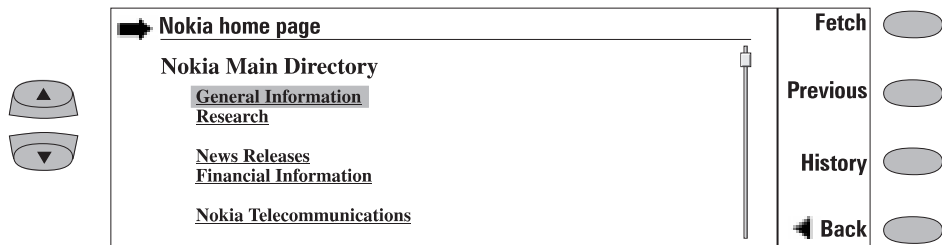
Figure 7-7

selected image map contains a cursor which can be moved with the keyboard arrow keys. When you press **Fetch**, the pixel coordinates of the cursor are sent to the URL, and the corresponding WWW page is fetched.

Images that are separate documents and not part of a hypertext document are called external images. When an external image is fetched, it is viewed separately from the hypertext document in the image viewer.

The external image viewer commands are:

Copy image copies the external image in the Downloaded files folder with its server-given name.

View enables zooming, see chapter 5 "Fax: Received faxes" on page 5-3.

Plug-ins

The Nokia 9000i Communicator is capable of accepting software plug-ins that can increase web browser functionality. The WWW application activates the plug-ins when necessary.

To download a plug-in:
① Move the cursor over the hypertext link that points to the plug-in and press **Fetch**.
② Press **Install**. If there is sufficient memory available, the plug-in will be installed. Installed plug-ins can be removed in the Plug-ins list in the WWW settings.

Downloading add-on software

The WWW application can be used to install applications on your communicator.
① Go to the WWW site where the add-on software package exists.
② Select the hypertext link that points to the add-on software package.
③ Press **Fetch** to fetch the package. After the software package has been successfully fetched, the software installation view opens.
④ Press **Install** to install the software.

Caution: Beware of viruses. Install into the Nokia 9000i Communicator only software you have obtained from sources that offer adequate protection against viruses.

Telnet

The Telnet application is activated in the Internet main view by selecting Telnet and pressing **Select**.

The Telnet application is used to make a connection to a remote computer via the Internet.

The Telnet application is similar to the Terminal application, in that both applications emulate the VT100 terminal display (see figure 7-8). The display occupies the left side of the screen. The screen size is 80 characters in 24 lines.

Once a Telnet connection is established, you must in most cases enter your login name and a password in order to be able to use the services provided by the host computer. The Telnet main view shows all pre-defined Telnet hosts.

To connect with a pre-defined Telnet host, select a host and press **Connect** (see "Defining Telnet connections: Telnet connection" on page 7-16).

To create new or edit existing connections, press **Define**. See " Defining Telnet connections" below.

Defining Telnet connections

After you have pressed **Define** in the Telnet main view, the defined Telnet connections are shown.

To edit existing connections, press **Edit**.
To define new Telnet connections, press **New**.
To delete the selected connection, press **Delete**.

Pressing **Edit** or **New** opens the Define Telnet connection view, where you can define the following settings:

Connection name — Edit an existing or enter a new connection name. The name can be defined freely.

Destination host — Edit an existing or enter a new connection address. The host is identified by either a numeric IP address or a correct textual host name.

Internet access — Select a service provider from those currently defined. To change the preferred service provider, press the **Change** command button.

Backspace key — Defines whether the keyboard backspace key is used as a backspace (*BS* - default) or delete (*DEL*) key.

Telnet connection

When you have connected to the remote system, the following commands become available (see figure 7-8):

Press **Keys** to emulate the VT100 special keys, which are not available on the communicator keyboard. The special keys include:

- Four programmable function keys (PF1-4)
- All VT100 application keypad keys (numbers 1-9, minus, comma, period, dash, enter)
- The following VT100 functions: reset terminal, Ctrl-\, Ctrl-], Ctrl-~.

In a Telnet connection, these special keys include the following commands (can be used in remote systems that support them):

Interrupt — Interrupts the current process on the remote computer.
Skip command output — Prevents command output from being displayed on the screen.
Are you there? — Enquires whether the remote system is still running (if the execution of a

task seems to take too long).

```
Username: JOHN                                                              Keys
Password:

   ****************************************************************
   *                                                              *
   *    WELCOME TO RESEACH LTD                                    *
   *    VAXstation 4000/90 VMS 5.5-2 COMPUTER                     *    Texts ▶
   *                                                              *
   *    SURREY/KNIGHTSBRIDGE                                      *
   *                                                              *
   *    NODE PRSSUR                                               *
   *                                                              *
   *    UNAUTHORIZED USE IS PROHIBITED                           *    Zoom
   *                                                              *      in
   ****************************************************************

     Last interactive login on Friday, 12-SEP-1997 12:16
     Last non-interactive login on Friday, 12-SEP-1997 12:11      Hang
   WARNING - Your password expires on Friday, 19-SEP-1997 17:00     up
   /tmp_mnt/disks/surusers01/john % ls -la
```
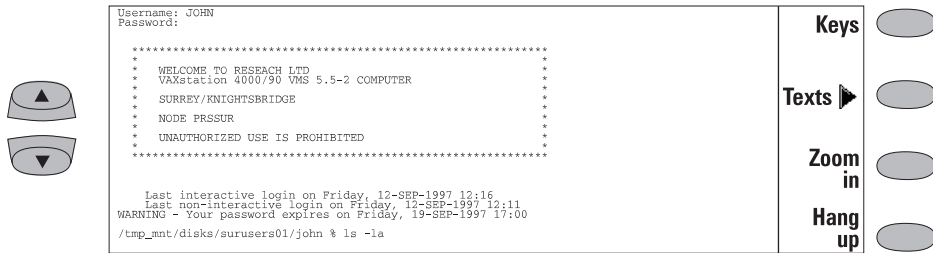
Figure 7-8

The selected special character is entered to the left of the cursor by pressing **Insert**. The inserted special characters send a control signal to the remote computer – they are not displayed on the screen.

Press **Zoom in** if the whole emulated screen and, consequently, character size is too small. The **Zoom out** command returns the unzoomed view. When the view is being zoomed, the scroll keys can be used to switch between the upper and lower parts of the terminal screen.

Press **Texts** to activate the text transfer commands, see "Defining Telnet connections: Text transfers" on page 7-17.

Press **Hang up** to close the connection to the host, end the data call and return to the Telnet application main view.

The scroll up/down buttons can be used for scrolling the view. Scrolling does not affect the cursor position. Pressing any keyboard key returns the view to the cursor position.

Text transfers

The purpose of the text transfer function is to enable you to download (capture) or upload (send) texts between the host computer and the communicator. This feature can be used, for ex-

ample, to send pre-written mail messages to the company mainframe computer, or alternatively, copy received mail and then read it later, off line.

Once you have connected to the host, press **Texts** in the Telnet or Terminal main view to access the Text transfer view.

To send text to the host computer:
① Press **Send text**.
② Open one of the folders shown and select the document you want to send.
③ Press **Send**.

While the text is being uploaded, the keyboard is inactive.

To copy text from the host computer:
① Prepare the text reading application on the host.
② Press **Capture text**. All interaction with the host will be recorded in a file in the Downloaded files folder. Control characters, except line changes, will not be stored.
③ Press **Stop capture** to end the text capture process.

Press **Back** to return to the previous set of commands.

Terminal

The Terminal application is activated in the Internet main view by selecting Terminal and pressing **Select**. The Terminal application is used to connect directly (not via Internet) to a remote computer by way of a data call.

The Terminal main view shows defined Terminal connections. The Terminal application is similar to the Telnet application, in that both applications emulate the VT100 terminal display (see figure 7-8). The display occupies the left side of

the screen. The screen size is 80 characters in 24 lines.

Selecting the host and the connection initiation procedures are done in the same way as with Telnet connections. To connect with the selected pre-defined Terminal connection, press **Connect**. See "Defining Terminal connections: Terminal connection" on page 7-19.

To create new or edit existing connections, press **Define**. See "Defining Terminal connections" on page 7-18.

Defining Terminal connections

After you have pressed **Define** in the Terminal main view, the defined Terminal connections are shown.

To edit existing connections, press **Edit**.

To define new Terminal connections, press **New**.

To delete the selected connection, press **Delete**.

Pressing **Edit** or **New** opens the Define Terminal connection view (figure 7-9):

Connection name — Edit an existing or enter a new connection name. The name can be defined freely.

Phone number — The phone number for accessing the service. The phone number may include spaces and hyphens.

Data bits — Service/host specific communication parameter: *7/8* (default).

Parity — Service/host specific communication parameter: *None* (default)/*Odd/Even*.

Stop bits — Service/host specific communication parameter: *1* (default)/*2*.

Local echo — Controls whether characters typed from the communicator keyboard are echoed to the communicator interface display (i.e., locally) or to the remote host computer: *On* (echoed locally)/*Off* (echoed to the remote host – default).
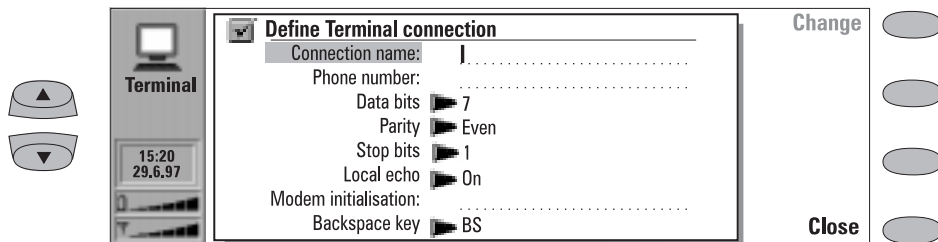

Figure 7-9

Modem initialisation — Any modem initialisation string containing AT commands may be entered here, if needed. The initialisation string you enter here is executed after the initialisation string you define in the Internet settings (in *Modem initialisation: Custom* view).

Backspace key — Defines whether the keyboard backspace key is used as a backspace (*BS* - default) or delete (*DEL*) key.

Terminal connection

When you have connected to the remote system, the following commands become available:

Press **Keys** to emulate the VT100 special keys, which are not available on the communicator keyboard. The special keys include:
- Four programmable function keys (PF1-4).
- All VT100 application keypad keys (numbers 1-9, minus, comma, period, dash, enter).

- The following VT100 functions: reset terminal, Ctrl-\, Ctrl-], Ctrl-~.

The selected special character is entered to the left of the cursor by pressing **Insert**.

Press **Texts** to activate the text transfer commands, see "Defining Telnet connections: Text transfers" on page 7-17.

Press **Zoom in** if the whole emulated screen and, consequently, character size is too small. The **Zoom out** command returns the unzoomed view. When the view is being zoomed, the scroll keys can be used to switch between the upper and lower parts of the terminal screen.

Press **Hang up** to close the connection to the host, end the data call and return to the Terminal application main view.

The scroll up/down buttons can be used for scrolling the view. Scrolling does not affect the cursor position. Pressing any keyboard key returns the view to the cursor position.
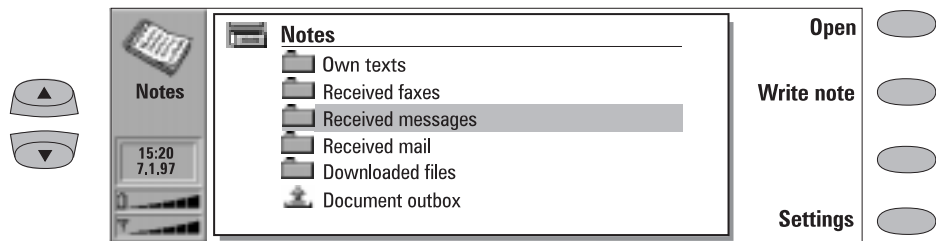
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8. Notes

Figure 8-1

Notes is used for writing notes and managing various documents stored on the communicator. Notes is the only application where documents can be printed.

Folders in the Notes main view are (see figure 8-1):

Own texts — Created mail, faxes, short messages, notes and memos.

Received faxes, Received messages, Received mail — All received documents.

Downloaded files — Documents downloaded with the Internet applications.

Document outbox — Documents waiting to be sent.

To read a document in any of the above folders:
① Select a folder and press **Open**.
② Select a document from the folder's document list and press **Open**.

To delete a document:
① Select a folder and press **Open**.
② Select a document from the folder's document list and press **Delete**.

To create a new document:
① Press **Write note** in the Notes main view. A new document is created in the Own texts folder and the note editor opens.
② Write the document.

Menu

Each folder has **Menu** as one of the commands. When you press **Menu**, the following options become available:

Write note — Available only inside Own texts folder.

Rename — You can rename the selected subfolder or document. Memos cannot be renamed.

Copy — Choose a folder into which the document is copied.

Move — You can select in which folder to move the document. Memos cannot be moved.

Create folder — Allows you to make a new subfolder.

Editing

When you open a document, the document is opened in the appropriate editor or viewer (received faxes are opened in the fax viewer, downloaded figures in the image viewer, etc.). The available commands vary according to the editor/viewer.

If the opened document is very large (dozens of pages), the time required before the document opens and can be scrolled or edited is longer than with smaller documents.

Documents that open in the Note editor can be directly edited and formatted. To format the text, press **Style**. The following options are available:

Font: URW Mono / URW Roman / URW Sans (default) (true type fonts)

Size: 10 / 12 (default)*/ 14 / 18 / 24 / 36 / User defined* (measured in points)

Bold (Ctrl-B): On / Off

Italics (Ctrl-I): On / Off

Underlined (Ctrl-U): On / Off

Justification: Left / Centred / Right / Full

Margins — Opens a new view where you can choose a value (default is 2.54 centimetres/1 inch) for the top, bottom, left and right margins. The unit of measurement is chosen in the System settings (see chapter 10 "System: System settings" on page 10-1).

A new style setting affects all new text from the cursor point forward. The margin settings, however, apply to the whole document. To change the settings permanently, you must do it in the main view settings (see "Notes settings" on page 8-4).

Special characters

The special character key Chr on the keyboard is used to create characters that are not included in the keyboard. The character key can always be used when you are able to enter characters from the keyboard. The case of the inserted special character is determined by whether the Shift or Caps lock key has been pressed.

To enter special characters from the character table:

① Press and release the Chr key and a special character table opens on the screen.

② Move the selection frame over the desired special character with the arrow keys, scroll buttons or by pressing a keyboard key.

③ Press **Insert** to close the character table and to insert the selected character to the left of the cursor.

To insert special characters from the keyboard:

- Press and hold the Chr key and simultaneously press a key with a special character printed on the key as the third (green) character. The special key will be inserted on the display.

- In addition, special characters can be generated in the above described way using certain unmarked keys, for example, "a" and "e". If you continue to hold the Chr key down and press the same letter key again, the second special character is shown in the place of the first, and so on, until the first character is shown again.

For information about the available editing shortcuts see chapter 2 "Getting started: Special features - Shortcuts" on page 2-12.

Created and downloaded texts

All created documents, as well as downloaded and captured texts (see chapter 7 "Internet: Connecting to WWW" on page 7-12 and "Defining Telnet connections: Text transfers" on page 7-17), can be opened in the Note editor.

Read-only documents

Received short messages, received mail and AS-CII text files (transferred to the communicator with the File transfer application, see chapter 10 "System: File transfer" on page 10-6) are read-only documents. Read-only documents themselves cannot be edited, but an editable copy can be created:

① Open a read-only document – the contents are shown as plain text.

② In the opened read-only document, press any character key. You will be asked if you want to create an editable copy.

③ Press **Create** to close the original file and copy its contents to a new, created text file. The DOS file will be deleted after an editable copy has been created.

④ Edit the new created note normally.

Received faxes and downloaded figures

The contents of a received fax cannot be converted into text or edited. Opening a fax activates the fax viewer (see chapter 5 "Fax: Received faxes" on page 5-3) and opening an image activates the image viewer (see chapter 7 "Internet: Navigating in WWW" on page 7-14).

Sending

When you send a document in the Notes application, you can choose whether to send the document as a fax, mail or short message.

Pressing the **Print/Send** command button in Notes opens a pop-up box listing printing and different sending options. Select the option you want and press **Select**:

• To print the file, select *Print*. The print commands view opens. Printing will be described in more detail in the following "Printing" section.

• To send as a fax, select *Send as fax*. The fax directory opens. The sending procedure from this point on is similar to that described in chapter 5 "Fax: Sending faxes - Fax directory" on page 5-2.

• To send as a short message, select *Send as short message*. The sending procedure is similar to that described in chapter 6 "Short messages: Sending messages" on page 6-2.

• To send as mail, select *Send as mail*. The sending procedure is similar to that described in chapter 7 "Internet: Sending mail" on page 7-6.

Printing

Documents can be directly printed in Notes only. Printing is possible only to a printer that has an IrDA compatible infrared port. To print to other printers, transfer the file to a PC, as described in chapter 10 "System: File transfer" on page 10-6.

Please refer to the User's Guide of the printer for detailed safety instructions on the device.

To establish an infrared serial connection:
Make sure that the communicator's infrared port faces the infrared port of the printer. Keep the infrared connection clear. In the event the infrared connection is obstructed for too long (for example, something is moved between the infrared sensors or the communicator is moved), printing is interrupted.

To print a document:

Open the document, press **Print/Send** and select *Print*.

For information on the supported printers, read the *readme.txt* file on the diskette supplied in the communicator sales package, or see the Club.Nokia home page in the World Wide Web (found at the address http://www.club.nokia.com).

More printer drivers can be installed with the Install/Remove software application under System.

After the communicator has checked that you do not already have an active PC connection, it starts to scan for a printer. This means that you cannot print while you are, for example, transferring files from the communicator to a PC. If the printer cannot be found, a failure note is shown and the editor view returns. If the correct printer is found, the printer driver is selected automatically and the printing view shows the name of the document and the selected printer.

Press **Start** to start printing.

Printing problems

Though the communicator may detect a connected printer, certain complications might still occur.

If the printer found is not recognised:

Select the correct printer driver manually. You can choose another printer after pressing **Printers**.

If the printer found is not recognised, and the communicator does not have the correct driver for the printer:

You can try to print the document using one of the available printer drivers.

Notes settings

You can change the note editor's default settings by pressing the **Settings** command button in the Notes main view. The settings are the default values for note and fax editors' text options and margins, and they are valid until they are changed again in the Settings view.

To change the settings, choose a setting and press **Change**.

Font: URW Mono / URW Roman / URW Sans (default)

Size: 10 points / *12* (default) / *14 / 18 / 24 / 36 / User defined*

Margins — Opens a new view where you can define values for the following (the unit of measure is chosen in the *Preferences* of the System application's settings):

Top margin (default 2.54 cm / 1 inch)

Bottom margin (default 2.54 cm / 1 inch)

Left margin (default 2.54 cm / 1 inch)

Right margin (default 2.54 cm / 1 inch)

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9. Calendar

In the Calendar application, you can view your scheduled events, keep a list of tasks in the To-do list, set calendar alarms and link memos to events (see "Daily schedule: Memos" on page 9-3).

The Calendar contains:

- Monthly schedule — Shows a month at a time as well as the events of a selected day. The monthly schedule is the main view in Calendar.
- Daily schedule — Shows a list of events for the selected day.
- Weekly schedule — Shows the timetable of a week as well as the events of a selected day.
- To-do list — Allows you to make a list of tasks that are not associated with any particular day, and prioritise your list.

One of the commands in the monthly, daily and weekly schedules is **Menu**. Pressing **Menu** provides you with the following options:

To-do list
*View month /View week**
Today
*Next month/week/day (Ctrl-N)**
*Previous month/week/day (Ctrl-P)**
Settings

* These menu choices vary according to the schedule you are in when you press **Menu**.

Select *Settings* to see the following options:

Booking password — Used to protect your calendar from receiving scheduled events from anyone except those who have your password (see "Calendar booking: Booking password" on page 9-4). When a password is written in the field, all characters appear as asterisks.
Default alarm — Used when you set an alarm to an event. The alarm will go off 10 minutes before the scheduled time of an event, unless you specify otherwise here.

Figure 9-1

Monthly schedule

The monthly schedule shows the days of the current month in columns according to the number
of the week (on the top row).

- Today's date is shown in a frame (in the figure 9-1, April 22nd).
- The currently selected date is darkened with white digits (April 2nd).
- Days that have scheduled events are indicated by a grey bar on the left.
- If the selected day contains scheduled events (as in the figure, on April 2nd), they are shown in a separate daily events list on the right side of the display. The schedule can be edited by selecting a date and pressing **Day**. If you just

start writing the event in the monthly schedule, the Details view opens automatically.

- If the whole day has been reserved for an event, there is a dark grey bar to the left of the day, and the event appears in **bold** in the daily events list (as "Meeting with Sarah" in figure 9-1).

Use the scroll or arrow keys to move the selection frame.

To write yourself reminders of important matters, press **To-do list**.

Daily schedule

Activate the daily schedule by pressing **Day** in the monthly or weekly schedule. The daily events list displays the events of the selected day. The contents of event entries are freely editable.

The symbols in the daily schedule are:

    — Attached alarms.

    — Calendar bookings.

    — Attached memos.

    — Recurring events.

    — Annual events.

The symbol appears next to the event's name (see figure 9-2). For each event, only the symbol with the highest priority is shown (the symbols will appear in the order listed above).

To add events:

① Move the selection frame over the starting time of the event.

② Type the event on the dotted line. If you want to add an event without a start time, write the event, press **Details** and remove the start time. The event will be shown with a hyphen.
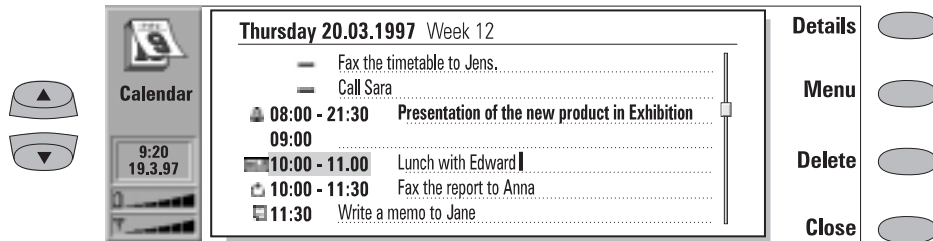

Figure 9-2

To delete events:

    Select the event and press **Delete**. If you delete (or edit) recurring events, you will be asked if you want to apply the changes to all or only to the selected event.

To adjust the details of the selected event:

    Press **Details**. A new view opens, allowing you to adjust the following details:

Description — The description of the event.

Reserve: whole day(s) — You can write down the number of days required for the event.

Start:

Date — The date of the event. The default date is that of the selected day. The year is always given using two digits.
Time — The time when the event starts. The default start time is the selected time row in the daily events list.

End:

Date — The date when the event ends (optional).
Time — The time when the event ends (optional).

Alarm — You can set an alarm for the selected event. See "Alarms" on page 9-5.

Frequency — You may define how often the event repeats. The options are *None* (default) /*Daily* /*Weekly* /*Monthly* /*Annually*/*Every other week*/*Working days*.

Repeat until: (date) — You can write down the last date of the event.

Event sent to — A list of all the people to whom you have sent the current event as a request or a reservation (see "Calendar booking" on page 9-4). The list shows the status of the sent event:

Accepted or *Confirmed* means that the re-cipient has accepted the event.
Discarded indicates that the recipient has rejected the event.
No reply means that no information has been received from the recipient.
Forced means that the event has been sent as a reservation.

If you press **Cancel event** in the "Event sent to" list, the event is cancelled from the recipient's calendar (see "Calendar booking: Cancelling and changing bookings" on page 9-5).

Memos

To attach memos to an event:

① Move the selection frame over the desired event and press **Details** in the daily schedule.

② Press **Memo** to open the note editor. In the note editor you can:

- press **Print/Send** and select whether to print or send the memo as a fax, SMS or mail, (see chapter 8 "Notes: Sending" on page 8-3 and "Printing" on page 8-3).

- press **Style** to format text. (See chapter 8 "Notes: Editing" on page 8-2.)

- press **Delete** to delete the memo.

- press **Close** to link the memo to the selected event.

Weekly schedule

The weekly schedule shows the timetable of the selected week.

- Today's date is outlined by a square frame (June 17th in figure 9-3).

- The currently selected time box is shaded (Thursday 19th, 12:00 in figure 9-3).

- All the events are marked with grey bars according to their start and end times. The bars are thinner if the events of the day overlap (Friday 20th in figure 9-3).

- If the whole day has been reserved for an event, all the time boxes are marked with a dark grey bar (Tuesday 17th in figure 9-3).
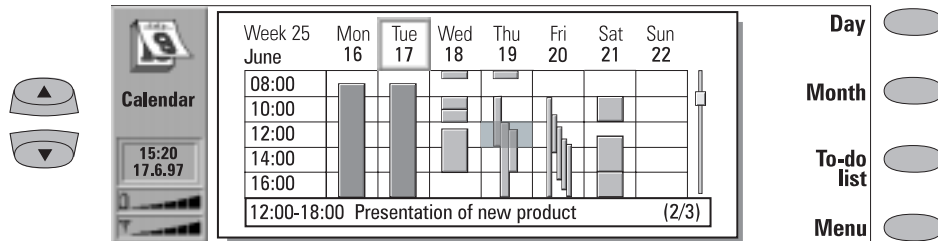

Figure 9-3

To enter an event in the weekly schedule, type the event description. The Details view will open automatically.

To open the daily schedule or the monthly schedule, press **Day** or **Month**, respectively.

You can use the scroll buttons and arrow keys to scroll inside a day in the weekly schedule.

If you scroll to a time box containing an event, the bar across the bottom of the weekly schedule will show the basic details of the event (see figure 9-3). The numbers to the right of the event description indicate the number of events that are contained within that time box (e.g., "2/3" means that you are seeing the details of the second of three events).

If a time box contains more than one event, you may view the basic details of each event in the time box by scrolling to the time box and pressing the Tab key on the keyboard. Press Shift and Tab to view the previous event.

Calendar booking

Calendar booking enables you to send event requests or reservations to other calendars. The difference between an event request and an event reservation is that the recipient may decide whether to accept or discard an event request, but event reservations can only be accepted.

Booking password

Sending event reservations requires that you know the recipient's booking password. If you add the recipient's password to the booking password field of the recipient's contact card in the Contacts application, the password is automatically taken from there when you send a reservation (see chapter 3 "Contacts: Contact cards – Customising contact cards" on page 3-2).

You can give your own booking password to those whom you allow to send reservations to your calendar. If you do not set a password, your communicator accepts all reservations.

Define your booking password in the Calendar settings. See page 9-1.

The booking password is not needed when you send event requests.

Making requests and reservations

① Select an event in the daily schedule or write

a new one.

② Press **Calendar booking** in the Details view and select whether to make the booking as a request or a reservation.

③ **Send as SMS** opens the SMS directory where you can select the recipient.

④ Press **Send** to send the booking.

The name or number of the recipient is added to the "Event sent to" list (see "Daily schedule" on page 9-2).

Receiving requests

When you receive an event request, a note appears on the display showing the details of the event, and the name or number of the sender.

If you press **Accept** or **Deny**, your communicator sends a reply to the sender informing about your decision. Accepted events are moved to your calendar.

The request can be dismissed by pressing **Cancel**.

Receiving reservations

When you receive an event reservation, a note appears on the display giving the details of the event.

When you press **OK**, the reservation is moved to your calendar. If you press **Confirm**, the event is moved to your calendar and a confirmation note is sent to the sender of the reservation.

Old events are not removed when new events are added, even if they have the same date and time.

Cancelling and changing bookings

There are two ways to cancel bookings that you have sent to other peoples' calendars:

1. Delete the event from your own calendar. Your communicator will check the "Event sent to" list and send a special SMS to any remote calendars that share the event, deleting the event in the remote calendars as well.

2. Select a recipient in the "Event sent to" list and press **Cancel event**.

To change a booking that you have sent:

Select the event and press **Details**. Make the desired changes. The changes are sent to the calendars of the persons to whom you originally sent the booking.

Alarms

Alarms are set in the daily schedule by pressing the **Details** command button and then selecting the *Alarm* option. The alarm will be attached to the currently selected event.

You can choose the alarm tone in the System application's System sounds settings.

To set alarms that are not related to any calendar event, use the Clock application, see chapter 11 "Extras: Clock – Alarm clock" on page 11-3.

The alarm options are:

None (default) / *At start time* / *. . . minutes before event* (enter a value).

An active alarm is indicated by an icon in the daily schedule (in the figure 9-2, the 8:00 event). When the alarm occurs, an alarm note is shown on both interface displays.

The alarm sound can be turned off by pressing any key. If you have set the communicator to the silent mode (in the System application's settings), only the alarm note will be shown.

To-do list

To access the To-do list:

1. Press the **To-do list** command button in the monthly or weekly schedule, or

2. Press **Menu** and select the *To-do list* option in any of the schedules.

The To-do list is a list of tasks which must be completed eventually, but are not connected to any specific time or day. After a calendar alarm has occurred, you have the opportunity to move the message contents of the alarm to the To-do list by pressing the **Move to To-do list** command button.

The entries in the To-do list are numbered, and they can be given high priority. High priority en-

tries are always shown at the top of the list (see figure 9-4).

To change the status of the selected task:

① Press **Priority**. A pop-up box opens.

② Change the status of the entry to *High priority* or *Normal priority* (default), or mark the task as *Completed* (as task number four in figure 9-4).

To create a new to-do task, press **New**. A new empty entry field is added at the end of the To-do list.

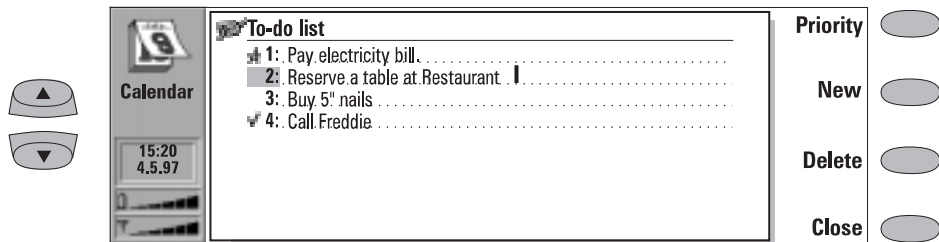To remove the currently selected entry from the list, press **Delete**.

Figure 9-4

HTC v. E-Watch, IPR2014-00987

10. System

System contains applications for security, system and PC connectivity.

The System applications are started by pressing the System application button, selecting an application in the System main view and pressing **Select**. If one System application is active, you must close it by pressing **Close** in the application's main view before you can start another.

Note: When one of the PC connection applications or the fax modem application is activated, the communicator consumes more power than normally. To extend the battery operation time, these applications should be closed when they are not in use.
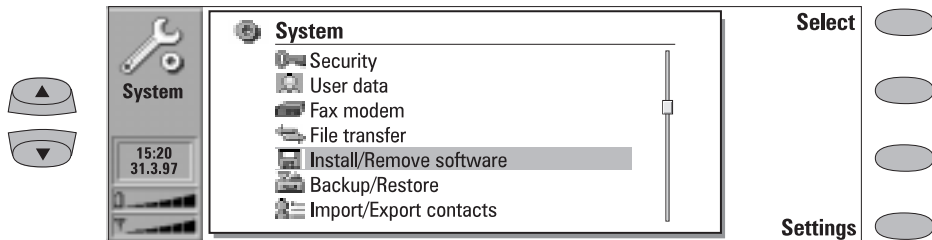
Figure 10-1

System settings

System settings includes all system-related permanent settings. To enter the System settings view, press **Settings** in the System main view. You may define the settings of the following features after selecting a feature and pressing **Change**.

Contrast control — The contrast view shows a test picture and a set of commands that can be used to adjust the picture. The '**+**' command button increases the contrast. The '**–**' command button decreases the contrast. When the setting seems satisfactory, press **OK**.

Screen blanker period — The screen blanker period setting sets the time period after which the display will blank out if the device remains inac-

tive. This feature saves the battery and increases the communicator's operation time. The time-out value can be between 2 to 15 minutes. The screen blanker cannot be turned off.

System sounds — Includes all the sounds in the communicator. The available settings are:

All sounds — *Ring / Beep / Silent/ Silent for.* The *All sounds* setting affects incoming call alerts and other alarms on both interfaces, with the exception of clock alarm. With *Silent for* the communicator remains in the silent mode until the time you have entered there has passed. Use the format *hh:mm*.

Ringing volume — Level 1/2/3/4/5

Ringing tone — You can select one of the tones in the pop-up box or compose a special ringing tone for your telephone in the Extras application (see chapter 11 "Extras: Composer" on page 11-5).

Key click — Off / Quiet / Loud

Warning tone — On/Off

Application tones — Calendar alarm, Clock alarm, Received fax, Received SMS, Received mail

> For each of these individual settings you can set a specific ringing. You would then be able to tell by the tone whether you have received a fax or a short message, for example.

The clock alarm will always sound. When a phone call is active and the communicator is used in handsfree operation, all sounds except the clock alarm are automatically turned off.

Preferences — Preferences lets you change date and time formats and the measurement unit. The preferences list contains the following items:

Date format — dd.mm.yy / mm.dd.yy / yy.mm.dd. For example, 25.10.97 / 10.25.97 / 97.10.25.

Time format — 24 hour / AM/PM. For example, 09:35 / 9:35 AM.

Unit of measure — Choose either Centimetre or Inch as the basic unit of measure.

Security

To lock the communicator:
- You can manually lock the communicator in the Security application's main view by pressing **Lock system**.
- If autolock (*Autolock period*, defined in the Security settings) is off, you must first enter the correct lock code (provided in the sales package).
- If autolock is on, pressing **Lock system** will lock the device immediately. Or, after the defined inactivity period, the communicator will lock automatically.
- Alternatively, you can also lock the system in the phone interface menu 5 8 (see chapter 13 "Phone interface: Menus - Security options (Menu 5)" on page 13-11).

After the communicator has been locked, it cannot be used until the correct lock code is given. Incoming voice calls can, however, be answered via the phone interface.

Note: When the communicator is locked, it may be possible to make a call via the phone

interface to the emergency number programmed into your phone (e.g., 112 or other official emergency number).

Security settings

To change the security settings:
① Press **Settings** in the Security main view.
② Select the setting and press **Change**.
③ If you are prompted for a code, enter it and press **OK**.
④ Choose a new value.

The codes are shown as asterisks. If you are changing a code, you will be prompted for the current code and then the new code twice. The code cannot be changed if the corresponding security feature is not in use.

Note: Avoid using codes that are similar to emergency numbers to prevent accidental dialling of the emergency number.

HTC and Samsung, Ex. 1008
HTC v. E-Watch, IPR2014-00987

Pressing **Close** will close the security settings view and return to the Security main view.
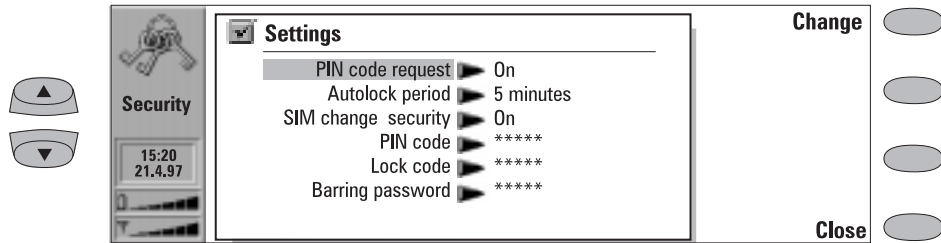

Figure 10-2

The security settings list is as follows:

PIN code request — On / Off (default)

If you set the PIN (Personal Identity Number) code request on, the system requests the code every time when the phone interface is turned on by pressing ①. You can also turn the PIN code request on or off in the phone interface Security options menu (Menu 5 1). This setting cannot be changed if the phone interface is switched off.

Note: Some SIM cards do not allow you to turn the PIN code request off.

If you enter the PIN code incorrectly three times in a row, you will need a PUK code to unblock the SIM card. When the SIM card is blocked, you cannot make or receive any calls (including faxes, short messages, mail, etc.), except emergency calls. Otherwise, the communicator can be used normally.

Autolock period — Autolock off (default) */ 1 / 2 / 5 / 10 / 15 minutes*

This setting determines the security time-out period, after which the system will lock. The timer is reset by any input, calls or data transfer/printing activity.

SIM change security — On (default) */ Off*

When active, this security option checks whether the SIM card in the communicator has been changed. The check is made every time the phone interface is switched on. The SIM change security option can also be activated in the phone interface Security options

menu (Menu 5 2).

If the SIM card has been changed and the new SIM card has not previously been used with your communicator, the communicator locks itself until the lock code, supplied with the phone, is correctly entered. The communicator recognises five different SIM cards as the owner's cards.

PIN code

When the phone interface is switched on, this setting allows you to change the PIN code. The changing procedure is as described at the beginning of this "Security" section. The new PIN code must be 4 to 8 digits long. The PIN code can also be changed in the phone interface Security options menu (Menu 5 6 2).

The PIN code is supplied with the SIM card. When the PIN code request is enabled, the code is required each time the phone interface is switched on. The PIN code request must be turned on to change the code.

If you enter a wrong PIN code three times in succession, the PIN code is disabled and cannot be used any more. At the prompt, key in the PUK code (see below) and follow the instructions on the display.

Lock code

This setting allows you to change the lock code. The changing procedure is as described at the beginning of this "Security" section. The new code must be 5 digits long. The lock code can also be changed in the phone inter-

face Security options menu (Menu 5 6 1).

The lock code is needed to lock (except when the autolock period is in use) and unlock the communicator. The device can be locked in both the communicator interface (System, Security: **Lock system**) and the phone interface (System lock, Menu 5 8). The lock code is also required when you change the SIM change security setting and turn the Autolock period on or off. You can find the lock code on a sticker in the sales package of your communicator. Keep it secret and in a safe place, separate from the communicator.

If you key in an incorrect lock code (you get a code error message) several times in succession, the communicator must be sent back to the dealer to be unlocked.

Barring password

When the phone interface is switched on, this setting allows you to change the barring password. The new code must be 4 digits long. The barring password can also be changed in the phone interface Security options menu (Menu 5 6 4).

The barring password is needed to change call barrings, see chapter 4 "Telephone: Telephone settings" on page 4-6. You obtain the password from your network operator when you subscribe to the service.

If the password is changed correctly, the communicator requests the network to perform the desired operation (see chapter 4 "Telephone:

Telephone settings - Changing the settings of network services" on page 4-6).

Other codes

PIN2 code (4 to 8 digits)

The PIN2 code can only be changed in the phone interface Security options menu (Menu 5 3).

The PIN2 code is supplied with some SIM cards. The PIN2 code is required to access some functions, such as call charging unit counters, which must be supported by the SIM card. If you enter a wrong PIN2 code three times in succession, the PIN2 code is disabled and cannot be used any more.

PUK and PUK2 codes (8 digits)

You cannot change the PUK (PIN Unblocking Key) codes. If you lose the code, contact your network operator.

The PUK is supplied with the SIM card. The code is required when you want to change a disabled PIN code. If you enter a wrong PUK code ten times in succession, the SIM card is rejected and you cannot make or receive any calls, except emergency calls. Contact your network operator for a new card.

The PUK2 code is supplied with some SIM cards. The code is required when you want to change a disabled PIN2 code. If you enter a wrong code ten times in succession, you will not be able to access the functions which require the PIN2 code. To utilise these functions, contact your network operator for a new card.

User data

The User data card contains your personal information. You can freely edit the information in the *Name, Company, Job title, Address, Tel, Fax, Tel(GSM), Fax(GSM), Mail* and *URL* fields.

The User data will automatically be included in the corresponding fields of the fax cover page within the Fax application. Likewise, the SMS application uses this information when you send your own business card.

Connecting to a PC

To use the System applications that allow you to connect to a PC (File transfer, Install/Remove software, Backup/Restore, Import/Export contacts, Import/Export calendar data), you must first install the Nokia Communicator Server programme (provided on a diskette in the sales package) on the PC and then launch it. The Nokia Communicator Server software requires Microsoft Windows 3.1 (or later) or Windows NT 3.51 (or later) and a free serial or infrared (IrDA compatible) port to run. See the *readme.txt* file on the diskette supplied in the communicator sales package.

To install the connectivity software on the PC:
① Insert the diskette in your diskette drive.
② In the Program Manager of your Windows, click on the "File" menu.
③ Click on menu item "Run" and type *a:\server* in the command line.
④ Press Enter.
⑤ Follow the instructions shown on the screen.

To establish an infrared serial connection:
① The IrDA software must be installed and running on your PC in order to establish an infrared connection. If you have Windows 95, you will need to download the IrDA driver software from the Internet site of Microsoft. The default IrDA port for the software is COM4; however, the physical port may be COM1 or COM2.
② Make sure that the communicator's infrared port faces the infrared port of the PC (or printer). Keep the infrared link clear – check the infrared indicators in the indicator area, see chapter 2 "Getting started: Indicators" on page 2-9. In the event the infrared link is ob-

structed for too long (for example, something is moved between the infrared sensors or the communicator is moved), the operation is interrupted.
③ Start the connectivity software on the PC. Check that the COM port reported by the connectivity software is correct.

Note: When using the communicator as a fax modem, use the infrared connection (see "Fax modem" on page 10-6).

To establish a serial cable connection:
① Connect the adapter to the communicator (for instructions on how to do this, see chapter 2 "Getting started: Connectors" on page 2-4).
② Connect the 9-pin adapter end of the RS-232 cable to the COM port of the PC and the other end to the adapter (into the connector on the left side of the adapter).
③ Start the connectivity software on the PC. Check that the COM port reported by the connectivity software is correct.

After you have established a connection to a PC and the connectivity software is running on the PC, you can start the communicator's connectivity applications. When the PC connection is active, the call status indicator shows the text PC-CONN. If the connection to the PC cannot be created, check the settings of the connectivity application. You must define the COM port and the PC drive or path correctly.

Note: Making or answering to phone calls during a PC connection is not recommended as it might disrupt the operation.

Remember to make backup copies of all important data!

Fax modem

Before your computer can recognise the communicator as a fax modem, the computer needs to be properly configured. Consult the user's guide of your computer on how to install new modems. Computers with Microsoft Windows 95 or NT 3.51 (or higher) operating systems can use the modem information file found on the Nokia Communicator Server diskette. See also the *readme.txt* file on the diskette.

Using the communicator as a fax modem requires that data calls are supported by the network you are using and that this service is activated for your SIM card. If you want to receive data calls, your SIM card also needs a data number. Contact your home service provider for details.

① Connect the communicator to the PC via an infrared link as described in "Connecting to a PC" on page 10-5.

② Wait until the connection is established.

③ Press **Activate** in the Fax modem main view. This will change the communicator to a fax modem. When the communicator is used as a fax modem, the call status indicator shows the text MODEM.

④ To stop using communicator as a fax modem, press **Disable**.

Operations of a modem can be controlled by AT commands and S-registers. These commands give the advanced user an opportunity to control all the features of the modem. However, it is not always necessary to enter the AT commands manually. Most PC communications applications have a user-friendly interface that hides the AT commands from the user. Should you need to enter the commands manually, consult the documentation of the PC application that you are using. A list of the common AT commands (based on the ETSI 07.07 standard) supported by the Nokia 9000i Communicator are available as an ASCII text file on the diskette that came with the sales package of your communicator.

When the communicator is used as a fax modem, its normal communication features are disabled (otherwise, the applications remain functional).

If an active PC connection is idle for longer than 20 minutes, the fax modem mode is automatically disabled to conserve power. However, when the communicator is connected to an electrical outlet (for example, while charging a battery), the time-out is not active.

To change the Fax modem settings, press **Settings** and select:

Connection type — Infrared (recommended)/ *Cable*. The cable connection is intended for use with the communicator's own PC connectivity applications for backup, file transfer, export/import and software installation purposes. The functionality of a cable connection when the communicator is used as a fax modem is not guaranteed.

File transfer

To select the serial connection type (infrared or cable) and the PC drive used, press **Settings** in File transfer application's main view.

To connect to a PC:

① Make sure that the connectivity software has been installed on your PC and is running (see "Connecting to a PC" on page 10-5).

② Press **Connect to PC** in the File transfer main view.

When you are connected to a PC, there are two system windows on the communicator interface display. The left window shows the folders on the communicator (the same folders as seen in the Notes main view) and the right window shows

the contents of the selected PC directory. The currently active window has a thick frame and the selection frame can be moved inside it.

You can change the active window by pressing the **Change window** command button, or alternatively, the keyboard Tab key. In addition, the left and right arrow keys can be used to activate the left or right window.

The following files can be transferred:

Text files — Nokia 9000i Communicator text files transferred to a PC can be read and edited in a PC environment with standard Windows or MS-DOS text editors. Correspondingly, PC text files can be read and edited in the communicator.

Graphics files (figures) — When transferring files from a PC to the communicator, files with the extensions JPG and GIF are considered as graphics files. Graphics files transferred to the communicator can be viewed with the image viewer.

Transferring files from the communicator

To transfer files to and from the communicator, you must open both the correct PC directory and communicator folder. When the File transfer view opens for the first time, all of the communicator's folders are closed. Files can be copied to or from an opened folder only.

After the connection type and PC drive have been selected in the settings, and you are connected to the PC:

① If the PC directory shown in the right window is not the directory to which you want to copy the file(s), you must change it as follows:

- Press the right arrow key to activate the PC window.
- If necessary, press **Close** to close the current directory.
- Press **Open** to open the correct directory.
- Press **Change window** (or the left arrow key) to activate the communicator window.

② Press **Open** (or the enter key) to open the folder containing the file(s) you want to transfer. Select a file by moving the selection frame over it.

Use the Chr-up or down arrow key combination to scroll through the files screen by screen. If the file you want is in a different folder, press **Close** and select another folder. If you want to copy more than one file, use multiselection (scroll to the desired items and press Ctrl-Space bar; see chapter 2 "Getting started: Special features - Multiselection" on page 2-12) and repeat the procedure from step ①.

③ Press **Copy to PC** to start file transfer.

Before files can be copied to a PC, you must change the name of the copied file to a PC compatible format. The communicator will suggest a name, but you can also enter it yourself. The maximum allowed length of the name is 8 + 3 characters separated by a full stop.

Transferring files to the communicator

After the connection type and PC drive have been selected in the settings:

① Press the left arrow key to activate the communicator window.

② Select the correct destination folder and press **Open**.

③ Press **Change window** (or the right arrow key) to activate the PC window.

④ Press **Open** to open the directory containing the file(s) you want to transfer. The window shows the subdirectories and then the files in alphabetical order. Open a subdirectory, if necessary, then select the file by moving the selection frame over it.

⑤ Press **Copy from PC** to start the file transfer. If you want to copy more files, use multiselection (see chapter 2 "Getting started: Special features - Multiselection" on page 2-12) and repeat the procedure from step ①.

To terminate the connection to the PC, press **Disconnect**.

Install/Remove software

The Install/Remove software application enables you to install communicator software from a PC and later remove the software from the communicator.

The Install/Remove software main view displays the serial connection type and the PC drive used. Press **Settings** to change the connection type or to redefine the PC drive used. The connection type is changed by pressing **Change**. The directory name and path can be edited manually.

Before using this application, make sure that the connectivity software has been installed on your PC and is running (see "Connecting to a PC" on page 10-5).

To install software:

① Press **Install** in the Install/Remove software view. The communicator starts to search for software to install from the designated PC drive. If installable software is found, it will be listed on the screen.

② Select the software you want to install with the selection frame and press **Install**.

When installation is complete, the confirmation note tells you under which application button the software was installed (destination cannot be selected). If an application with the same name as the software to be installed already exists, you will be asked to confirm the replacement operation by pressing **Replace** or to cancel it with **Cancel**.

To remove software

① Press **Remove** to search for removable software on the communicator. The amount of free space on your communicator is also displayed.

② Select the software you want to remove and press **Remove**.

Note: The set of applications that are on the communicator at the time of purchase cannot be removed.

Caution: Beware of viruses! Install into the Nokia 9000i Communicator only software you have obtained from sources that offer adequate protection against viruses.

Backup/Restore

The Backup/Restore application enables you to make backups of various data on your communicator, and to restore it later. Data is backed up in sets which are stored in separate directories on the PC.

Before using this application, make sure that the connectivity software has been installed on your PC and is running (see "Connecting to a PC" on page 10-5).

When data is backed up the previous contents of the backup directories will be deleted. If you want to keep the previous backup set, you should

copy the files to another directory on the PC, or change the backup directory in the Backup/Restore settings before making a new backup.

When data is restored, only files with similar names in the destination folder will be overwritten.

The Backup/Restore main view shows the data group which will be backed up or restored, the connection type (infrared or cable) and the backup or restoration directory. Press **Settings** to change the connection type or the path to the PC directory.

The sets of data you can back up are:

All data — Backing up all data means backing up your communicator exactly as it is at the moment (except for contact logs).

Documents — Document backup covers all documents in the application folders that can be opened for viewing (except contact cards and logs).

Contacts — The contact directory backup file cannot be edited. If you want to edit the Contacts database contents, use the Import/ Export contacts application (see the next section).

Calendar — The data in your calendar can be backed up and restored.

Press **Backup** or **Restore** to start the respective operations. A backup directory will be created if necessary.

While the Backup/Restore is in progress, the communicator's other applications cannot be used. To interrupt the operation, for example, to make an emergency call, press **Cancel** and confirm by pressing **Interrupt**.

Import/Export contacts

The Import/Export contacts application allows you to export contact cards to a PC and import them back to the communicator. The contact information is exported to the PC as a single ASCII text file, *contacts.txt*, which can be edited as any ASCII file. If you edit the contents of the file, you should be very careful not to delete accidentally any record or field definition strings, placed inside square brackets [ ]. Do not delete any of the brackets, either. It is always a good idea to back up your data before doing any editing.

Alternatively, you can open the exported contact information in an application or database compatible with the Nokia 9000i Communicator's contact card format.

The main view shows the connection type used and the default path in the PC. To change the connection settings, press **Settings**.

Before using this application, make sure that the connectivity software has been installed on your PC and is running (see "Connecting to a PC" on page 10-5).

To import contacts:

Press **Import** in the Import/Export contacts main view. When the data in the defined PC directory has been copied to the communicator, you will be asked to confirm the conversion of the imported data as contact cards. The imported contacts will be added to your contacts directory.

To export contacts:

Press **Export** in the Import/Export contacts main view. If a file with the default name (*contacts.txt*) already exists on the PC, the existing file will be overwritten.

Import/Export calendar data

The Import/Export calendar data application allows you to export calendar data (events, event details and to-do list) onto a PC and import it back to the communicator. The calendar data is exported to the PC as a single ASCII text file, *cal-*

endar.txt. You can edit the calendar data the same way as exported contact cards. Note that memos attached to the events are referenced in the *calendar.txt* file, but not exported (to export memos, use the File transfer application).

The main view shows the connection type used and the default path in the PC. To change the connection settings, press **Settings**.

Before using this application, make sure that the connectivity software has been installed on your PC and is running (see "Connecting to a PC" on page 10-5).

To import calendar data:

Press **Import** in the Import/Export calendar data main view. When the data in the defined PC directory has been copied to the communicator you will be asked to confirm the conversion of the imported data as calendar data.

Note: The imported calendar data will replace all your current calendar data.

To export calendar data:

Press **Export** in the Import/Export calendar data main view. If a file with the default name (*calendar.txt*) already exists on the PC, the existing file will be overwritten.

Data removal

The Data removal application comes in handy if you want to remove personal information from the communicator, for example, before lending it to someone else. This way you do not need to remove data one by one.

The removable data is arranged in four groups: *All data, Calendar data, Documents, Contacts and Speed dials*.

Select the desired data group by moving the selection frame and press **Delete**. Before any data is removed, you must enter the lock code (see "Security" on page 10-2). When deleting calendar data, you can choose to delete all calendar data or only events that occur before a given date.

Note: Even if you choose the *All data* option, your Internet settings will not be erased.

If you want to restore your communicator in the same state it was in at the time of purchase, see chapter 14 "Troubleshooting" on page 14-1.

Memory

This view shows the amount of available free memory for storing data and installing new software. Pressing **Details** will open up a list of folders and other data in the communicator, and the amount of memory each of them uses. The list is updated every time it is opened.

If the memory is getting low, you should delete some documents. Before deleting, you can send them or transfer them to a PC.

About this product

This view displays information about the Nokia 9000i Communicator.

11. Extras

The Extras application group contains:
- Text Web
- Calculator
- Clock
- Composer
- Converter
- Wireless data backup

To start one of the applications, select an application and press **Select**.

With one Extras application active, you can quickly switch to another by pressing the Extras button.

To close an active application, press **Close**.

Text Web

With Text Web you can fetch information from the Internet, using SMS. Such information can include for example flight schedules, weather reports and stock news. You can also access services provided by your network operator and Nokia.

The Text Web main view includes the following items:
- Nokia services
- Operator services
- User-defined services
- Saved forms

To select one of these services, choose the service with the scroll or arrow keys and press **Select**.

To change the access numbers of Nokia and Operator services, or to change, add or delete service access points that you have defined yourself, press **Settings**.

Nokia services

The contents are maintained by Nokia, and they cannot be changed. Nokia updates the contents from time to time with special short messages.

Operator services

The Operator services allows the network operator to provide various services to their subscribers. The operator-specific items may vary from subscriber to subscriber, and are updated by the network operator.

User-defined services

To define new service access points, press **Settings** in the Text Web main view. Press **New** to open an empty service information card. Enter the title of the service, the server number (SMS message centre number) and the service number (phone number).

To fetch information:

① In the Text Web main view, scroll to one of the service access points that you have defined and press **Select**.

② Enter in the space provided a word (keyword) that describes the type of information you are looking for.

If you press **Get keywords**, you will receive a list of available keywords. **History list** contains previously used keywords.

③ To send the keyword, press **Send**. When you receive a reply from the service provider, the TTML browser opens up. Press the arrow keys in the browser to move from one hotspot to another.

The commands in the browser are:

Send — To send the form, press **Send**.

Fetch/Change — **Fetch** will appear if the selected hotspot is a hyperlink. When the command is **Change**, you can tick off boxes and buttons.

Menu — To add the form to the Saved forms list, select *Save form*. To copy the text to Downloaded files folder, select *Save as text*.

Saved forms

Saved forms grants you quick access to Internet services. You can add items to Saved forms list from the other services.

To open the selected form, press **Open**. The TTML browser opens up with the same commands as above.

To rename a service, press **Rename** in the Saved forms main view.
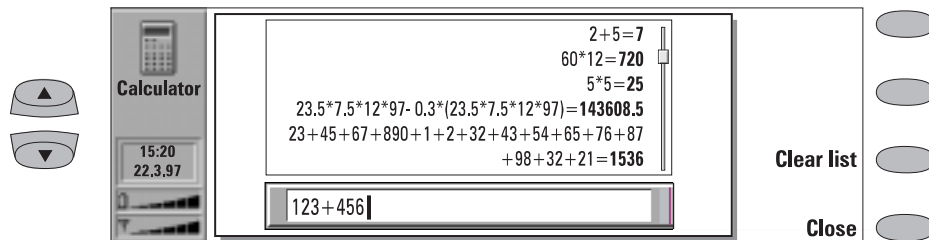
Calculator

Figure 11-1

The Calculator contains an entry field at the bottom of the screen and above it a "tape" where previous calculations can be seen (if any). The tape can be scrolled using the scroll or arrow keys. The most recent calculations are shown at the bottom of the tape

The results of the calculations appear in **bold**. In the case of a syntax error, the calculation remains in the entry field for editing. As long as you have not pressed Enter or "=", you can move in the calculation string with the arrow keys and edit the string.

All data and calculation commands are entered from the keyboard. The following characters can be used for the corresponding operations:

Numbers **0** to **9**	
. (full stop)	decimal point
(space)	can be entered, ignored in the calculation
+	addition
–	subtraction
*	multiplication
/	division

%	percent calculation
( )	parenthesis
= or Enter	sum
C	clears the entry field

Pressing **Clear list** will erase previous calculations from the calculator tape.

The maximum number of characters per calculation is 100. The maximum length of the calculator tape is 100 lines.

Calculating percentages

The following examples demonstrate the principles for calculating percentages with Calculator:

- How much is 20% of 1000?
  1000 * 20% = 200
- What percent of 50 is 10?
  10 / 50% = 20
- What would be a 22% markup of 500?
  500 + 22% = 610
- What would be a 17.5% discount of 500?
  500 - 17.5% = 412.5
- How much is 20%?
  20% = 0.2

Clock

The Clock shows the time and date in your home city and country, as well as in several other cities and countries in the world. The Clock also includes an alarm clock.

The "Alarm active" symbol and time of the alarm are shown only if an alarm is active.

Alarm clock

The Alarm clock is activated with the **Alarm clock** command in the Clock main view. The alarms will occur according to the home city time (note this when in a different time zone, e.g. when travelling abroad).

An alarm can be set to occur within the next 24 hours. Alarms that occur later than this are set in the Calendar application.
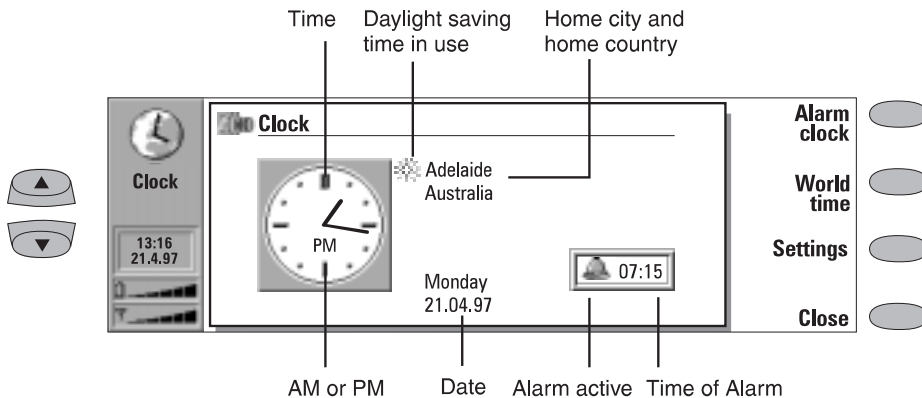

Figure 11-2

To set an alarm:

① Press **+** or **–** to adjust the time shown in the alarm clock display. Each press changes the time by one minute, but if you hold the button down a while longer, the time will start to change in steps of 15 minutes.

② Press **OK** to accept the set alarm.

There can only be one active alarm. If an alarm is already active, the command names are different. A counter on the lower right side of the screen shows how much time remains to the time of the alarm.

Press **Change alarm time** if you want to readjust the time of the alarm.

Press **Delete alarm** to cancel the alarm.

When the alarm sounds, it can be turned off by pressing any phone interface or communicator interface key.

If the alarm is not turned off, or it is turned off by pressing other than the **OK** button on the Communicator display, the alarm will sound five more times or until you press the **OK** button.

Note that if the alarm interval is set to zero, the alarm will sound only once. Set the alarm interval in the clock settings.

World time

World time (figure 11-3) is activated with the **World time** command in the Clock main view (see figure 11-2).

The *Home* box shows the name of the currently selected home city, country, time, date and whether daylight saving time is in use.
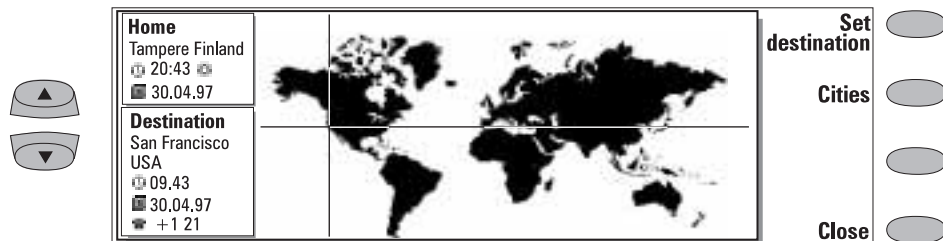
The *Destination* box shows the same information for the currently selected destination city, as well as the international call prefixes needed to make a call from the home city to the destination city.

The world map shows the currently selected destination city in the world map in cross hairs.

To select the destination city:

Press **Set destination**, and select a city from the list. You can also type the first letter of the city to move the cursor to the first city name beginning with that letter.

Editing the cities database

Press **Cities** in the world time view to open the Cities list.

To make changes to existing city cards, press **Edit city**. The city information is presented in the form of a data card. The city card contains the following fields:

City — The name shown in the Cities list. Can be entered manually.
Country — The name of the country associated with the city. The country name is selected from a list of countries.
Area code — The area code required when calling the city. The area code can be entered with or without a national prefix. Only numbers can be entered.
GMT offset — Indicates by how much the local time differs from the Greenwich Mean Time. Select a value for the offset from a list. The offset can range from –12 to +12 hours.
Set position — Opens a world map view where you can determine the position of a city by

| Home |
| Tampere Finland |
| 20:43 |
| 30.04.97 |

| Destination |
| San Francisco |
| USA |
| 09.43 |
| 30.04.97 |
| +1 21 |

Set destination

Cities

Close

Figure 11-3

moving the cross hairs with the arrow keys. When the city is where you want it to appear, press **OK**.

To create a new city card, press **Add city**.

To remove a city from the database, press **Delete city**. The current home city cannot be deleted (change the home city first).

Clock settings

The Clock application's settings are adjusted with **Settings** in the Clock main view. Select the setting you want to change and press **Change** or type the new time or date from the keyboard.

Home city — Select the home city by scrolling the city list with the scroll keys, or type the first letter of the city name to jump to the first name starting with that letter. When your home city has been selected, press **OK**. Your new home city now appears in the home city window in the world time view. If you select a city that is in a

different time zone than your current home city, the system time will change.

Time — Enter the new time in the current time format (24 hour or AM/PM, selected in System Settings: *Preferences*).

Date — Enter the new date in the current date format.

Alarm interval — *0/1/2/3/4/5* minutes. You can choose the interval between alarms. If you select *0*, the alarm clock will go off only once.

Daylight saving — You can set the home city and destination city daylight saving time *On* or *Off*. This setting remains the same even if the home/destination city is changed.

Changing the time or daylight saving time of a home city will also adjust the time of the whole time zone, as well as the system time. If a set alarm is skipped because of changes in any of the above fields, the alarm goes off immediately.

Composer

The Composer application enables you to create your own, customised ringing tones.

Note: You can change the phone ringing tone in the Telephone application's settings (see chapter 4 "Telephone: Telephone settings - Ringing settings" on page 4-6) or in System application's System sound settings (see chapter 10 "System: System settings" on page 10-1).

To start the composer for the selected tune, press **Open**.

To compose a new custom tune press **Compose tune**.

To play the composition shown on the staff, press **Play tune**. While the composition is being played, the command changes into **Stop playing**.

Custom tune options

Press **Options** to do one of the following:

Tempo opens the tempo pop-up box with a new set of commands. Tempo is measured in beats per minute. To alter the tempo, use backspace and enter a new value in the box.

> To accept the tempo, press **OK**.
> To test the tempo, press **Test**. The tune will be played with the tempo shown in the entry field.
> To use the default tempo (150 beats/min.), press **Default**.

Clear tune deletes the tune shown on the staff.

Undo changes restores the tune to what it was before editing.

Editing a custom tune

To edit the tune, press **Edit**. In the editor, a cursor appears at the bottom of the screen, indicating the currently selected note or rest. The cursor can be moved with the **Left** and **Right** commands or the left and right arrow keys. The editing commands affect the note/rest in the selected column.

To create a note, a rest or alter the note's pitch:
Press the scroll or arrow keys. Each press up or down changes the note's pitch. A rest will appear after all possible note levels have been scrolled through.

To alter the length of the selected note or rest:
Press **Duration**. Choose sixteenth note, eighth note, quarter note (default), half note or whole note. Press the command button until the value you want is shown.

While in the editing mode, you can use the following shortcuts:

Enter	Plays the tune
Colon (:)	Staccato
Hyphen (-)	Inserts a rest
Spacebar	Inserts an empty column to the left of the cursor. Moves all following columns to the right
Backspace	Deletes the selected column (containing a note or a rest). Moves all following columns to the left
Full stop (.)	Lengthens the duration of the note or rest by half

For quick composing, press the corresponding letter key on the keyboard to generate a note. For example pressing C generates the note C. When you press Shift and the corresponding letter key, a sharp note is generated, e.g. Shift-D generates D sharp.

Menu

When you press **Menu** in the Composer main view, the following options become available:

Copy — Copies a tune.

Delete — Deletes a tune.

Rename — You can write the new name into the input field.

Send as SMS — Opens up the SMS directory where you can select a recipient for the composition. To send the composition, press **Send**.

When you receive a composition, a note showing the name or number of the sender and the name of the sent composition will appear on the display. To add the composition to the list of tunes, press **Accept**. To discard the composition, press **Cancel**.

Note: If you have received several compositions at once, they cannot be accepted or discarded one by one. However, you may delete them individually after you have accepted them.
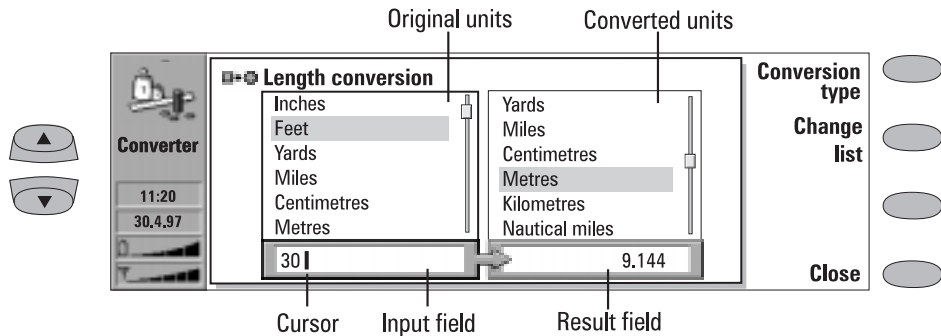
Converter

Figure 11-4

This application allows you to make conversions between different units of measure, which include: length, area, volume, mass, velocity, temperature, power, energy, and currency.

The converter main view shows two identical lists containing the units to be converted. Below them on the left is the input field, and on the right the result field. The frame of the currently active list is darkened and the cursor is in the input field.

To make a conversion:

① Press **Conversion type** to open the list of units of measure.

② Select one of the conversion types by scrolling the list and press **OK**.

③ When the main view returns, scroll the selection frame in the original units list (on the left) to the unit from which you want to convert. Change between lists by pressing **Change list**.

④ Scroll the selection frame in the converted units list (on the right) to the units to which you want to convert.

⑤ Enter the amount to be converted. Any amount you enter will automatically appear in the input field. The result will appear in the result field.

Currency converter

If you select currency as the conversion type, the command **Rates** will appear. As there are no pre-set exchange rates in the communicator, you will have to set the base currency and the exchange rates before you can use the currency converter.

Within the Rates view, **Edit unit** allows you to change the name of the currency.

To use the currency converter:

① In the Currency conversion main view, press **Rates**, then **Base currency**.

② Scroll to the currency you would like to set as the base currency and press **OK**.

③ The screen returns to the list of available currency units. Enter the exchange rates compared to the base currency. Press **Close** to return to the Currency conversion main view.

④ Select the currency from which you want to convert in the list on the left, and the currency to which you want to convert in the list on the right.

⑤ Enter the quantity you would like to convert. The amount is displayed in the result field.

Note: Changing the base currency will clear all set exchange rates.

Wireless data backup

The Wireless data backup application allows you to backup and restore data over the digital cellular network via a data call.

To use this application you must first obtain this service from a service provider. Contact Nokia HelpLine (see the Accessories Guide) for more information.
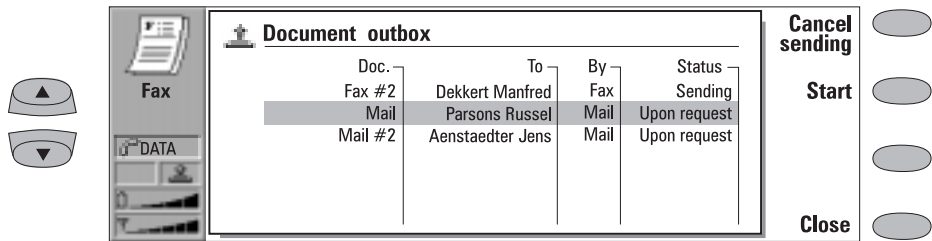
12. Document outbox

Figure 12-1

All documents you send go through the Document outbox. The Document outbox sends the documents whenever it is possible (see also chapter 1 "Introduction: Things to remember" on page 1-2).

The Document outbox can be accessed in the Fax, SMS, Mail and Notes applications' main views, where it is shown at the bottom of the folders list. To open the Document outbox, select the Document outbox from the list and press **Open**.

The document at the top of the list will be sent next. The document's position in the list reflects its sending status. As the status changes, the document will be moved up or down the list. For example, if sending fails, the document is placed at the bottom of the list and Document outbox will try to send it again later.

The main statuses that documents can have:

- *Sending* — The document is currently being sent.
- *Waiting* — The document is waiting for sending to become possible (e.g., when the phone interface is switched on, cellular signal strength becomes adequate, previous phone call ends).

- *Retry [time]*— Sending of the document failed and it will be sent again later (at the time given in square brackets).
- *Queued* —The document is waiting for its turn in the sending queue.
- *At [time]* — The fax is waiting to be sent at the time you have specified (see chapter 5 "Fax: Fax settings" on page 5-4).
- *Sending [current page/total pages]* — The number of the fax page that is being sent and the total number of the pages.
- *[number] % sent* — An E-mail message is being sent, and the Document outbox shows the percentage that has been sent.
- *Upon request* — E-mail messages may have this status if the *Send mail* setting has been set to *Upon request* (see chapter 7 "Internet: Mail settings" on page 7-5). These messages will not be sent until you select one and press **Start**. All mail with the *Upon request* status will be sent during the same connection.

To speed up manually the sending of documents with the status *Waiting*, *Retry* or *Upon request*:

- Select the document and press **Start**. The document(s) will be sent as soon as possible.

A document is removed from the Document outbox only if:

- Sending succeeds.

- You cancel the sending manually by pressing **Cancel sending**.
- Sending fails ten times or fails because of missing or inadequate sending information. In this case, an information note will be shown.

13. Phone interface

When operating the phone interface, keys are pressed one at a time. Two keys are never to be pressed simultaneously.

Ⓘ switches the phone interface on and off.

Note: This button does not function when the device cover is open.

As with any other radio transmitting device, avoid unnecessary contact with the antenna when the phone interface is switched on.

ABC switches between alpha mode and numeric mode. In the menu facility, this key produces a help text on the current function.

C deletes characters or exits the menu facility and memory functions.

▼ and ▲ are used to scroll through menus, submenus or settings. If there are no active calls, the scroll keys can be used to browse through the memory contents. When a call is active, pressing the scroll keys adjusts the volume level.

📞 dials a phone number and answers a call.

📞 ends any active call or cancels a dialled call.

0 ... 9 are the number and alpha keys. To call your voice mailbox, press and hold **1**.

✱ # are used for special purposes in certain functions.

— Selection keys. The function of these two keys (on both sides of the scroll keys) depends on the text shown on the bottom line of the display. See figure 13-2.
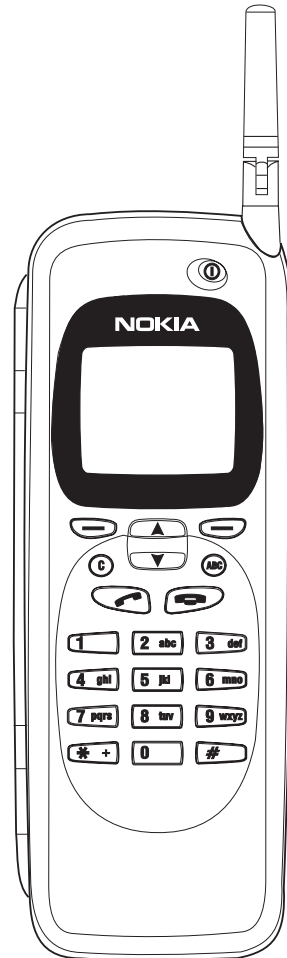
Figure 13-1

Using the selection keys

When this manual instructs you to press a key (the name of the function appears in **bold**), it means that you should press the selection key under the function name; for example, pressing **Menu** (the selection key under the text *Menu*) gains access to the menu functions and **Memory** (the selection key under the text *Memory*) to the memory functions. The functions change according to the situation and previous selection.

Note: The selection must often be confirmed by pressing **OK**. Whenever the **Quit** function is shown, it can be used to return to the previous menu level without making any changes.
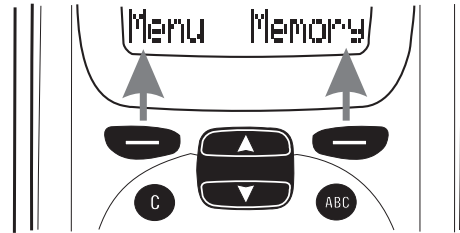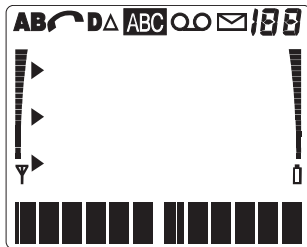
Figure 13-2

Display indicators

Figure 13-3

A or **B** Indicates which memory is currently selected. "A" refers to the SIM card memory and "B" to the communicator's memory.

📞 A voice call is in progress.

D A data or fax call is in progress.

△ Roaming — The communicator is used in other than your home network.

▮▮ The phone interface is in alpha mode (letters, as well as digits, can be entered).

✉ You have received an SMS message, fax or mail.

188 Indicates one of the following: memory location, menu, submenu or setting option.

◆ Indicates that you should use the scroll keys to reach items that are currently not shown on the screen.

▶ Indicates that there is a list of options to select from. The pointer also indicates the currently selected option.

📶 and bar. Indicates the current signal strength at your location. The higher the bar, the better the signal. When this antenna symbol is not visible, you are outside network's service area.

🔋 and bar. Indicates how much charge there is left in the battery. The higher the bar, the more charge in the battery

📼 Nokia 9000i Communicator PCN model only: If your network supports this feature, the spool symbol appears on the display when a message has been left with your answering service. The symbol remains on the display until you listen to and either delete or save the message. If you simply listen to the message, the spool symbol will remain on the display. To play the message, press **Listen**.

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Making a call

The communicator can make and receive calls only when:

- The phone interface is switched on.
- The communicator has a valid SIM card fitted.
- The communicator is located in the service area of the cellular network (▼ is shown).

Note: Emergency calls to the international emergency number 112 can usually be made without the SIM card. Check with your network operator. For more information about making emergency calls, see chapter 16 "Important safety information: Emergency calls" on page 16-2.

① Key in the area code and the phone number of the person you wish to call. If you make a mistake, you can delete the digits one by one by pressing **C** repeatedly, or clear the whole display by pressing and holding down the **C** key.

For international calls, start by pressing **✱** twice quickly. The international call character **+** appears on the display, which informs the network centre to select the country-specific international prefix. Enter the country code, area code and the subscriber number.

② Press 📞 to dial the phone number.

③ When the phone number disappears and the text *Call 1* is shown, the call is connected.

Note: The microphone and earpiece are on the backside of the device.

When a call is active, you can use the ▼ and ▲ keys to lower or raise the volume level of the phone interface's earpiece.

Receiving a call

When you receive a call, the communicator gives a ringing tone and the text CALL flashes on the display. If you have selected *Silent* in Menu 10, only the keypad and display lights will flash. If you have selected *Beep*, only a single beep will be heard. If the caller can be identified, the caller's phone number (or name if stored in memory) and the text CALLING will be displayed instead.

You can answer the call any time, even while using the memory or menu functions.

To answer an incoming voice call, press 📞 or any other key except ① or ☎.

If you do not want to answer the call, simply press ☎. The caller will hear the alerting tone change to a busy tone, and the call will be diverted to your voice mailbox if *Divert when phone is busy* is on and set to *To voice mailbox*, see chapter 4 "Telephone: Telephone settings - Voice call diverting" on page 4-6.

Sending DTMF tones

If you need to send long DTMF strings, it is more convenient to send them within the communicator interface, see chapter 4 "Telephone: Managing calls - Sending DTMF tones" on page 4-5.

① Make a call to the desired phone number.

② Key in the digits you want to send as DTMF tones. The digits are sent one by one to the network. DTMF tones can be transmitted even when the keypad tones are set off.

Automatic transmission

In order to send DTMF tones automatically, you must store them first. Storing DTMF strings is most conveniently done in the communicator interface, see chapter 3 "Contacts: Contact cards - Storing DTMF tones" on page 3-3. If you want to store DTMF strings in the phone interface, see "Using memory: Storing information via the phone interface" on page 13-5.

① Press **Memory**. Key in the name of the contact card that contains the DTMF service phone number and the DTMF digits and press **Find**.

For how to recall information, see "Using memory: Recalling information" on page 13-5.

Note: When stored DTMF tones are recalled in the phone interface, only DTMF strings that have been stored in a *Tel* field can be used.

② When the recalled string (containing the phone number and the DTMF digits) is on the display, press ☎.

After the connection has been established, the DTMF tones will be sent directly, after a small pause (if the sequence contained the **p** character) or after you press ☎ for the second time (if the sequence contained the **w** character).

Using memory

The phone numbers and names you store are normally located in the standard memory of the communicator, indicated by the letter "B" on the phone interface display.

The "B" memory is the communicator memory, known as the Contacts directory. When the communicator is started up for the first time, the "B" memory is selected automatically.

The "A" memory is located on the SIM card that is inserted in the communicator. The SIM card memory uses numbered memory locations to store data. When numbers are saved in the SIM card ("A") memory, a message will indicate its location number. The number of standard memory locations available on SIM cards varies from one card to another.

When the "A" memory is selected, the phone interface stores all contact information on the SIM card and cannot access the Contacts directory. Therefore, the use of the communications applications of the communicator interface will be less convenient (you will have to enter most contact information manually). This manual will assume that you use the standard "B" memory.

Keying in a name

① Press the **Memory** selection key to switch to the alpha mode (the ▮▮ indicator is shown on the phone interface display).

② Press the key that has the desired character. If the character you want is not the first to be displayed, press the key again within one second (before the cursor appears) to display the next character. Keep pressing the key until the desired character appears.

③ If you miss a character, keep pressing the key until it appears again; or first press **C** and then start pressing the key again.

If you want a lower case character, press and hold a key until the character appears in lower case. All further letters will appear in lower case until a key is pressed and held once again.

To enter a space between characters, press **#**.

To correct a mistake, press **C**.

④ Once the desired character is on the display and you want to enter a new character, do either of the following:

If the next required character is located on some key other than the previously pressed key, press the new key and the first character on the key will appear.

If the next required character is located on the same key as the present one, wait one second. The vertical cursor will appear to the right of the character just pressed. Alternatively: press ✱ and select the character without waiting for the cursor to appear.

Note: In the alpha mode, the numeric characters available for each key are only for use with names. You cannot use the characters as ordinary phone numbers.

Storing information via the phone interface

To store names and phone numbers via the phone interface (to enter other contact information, use the Contacts application):

① Press **Memory**.
② Key in the name (of up to 30 characters) that you want to store with the phone number. For details, see "Using memory: Keying in a name" on page 13-4.
③ Press **Save**.
④ Key in the international access and country codes (if necessary), area code and phone number. Instead of the country-specific international access code, you can use the **+** character (press ✱ twice). When the **+** character is used, the cellular network will automatically add the international access code of the country from which you are trying to call.

If you are storing DTMF sequences and want to use the DTMF special characters, for a pause, press ✱ three times quickly, so that a **p** is displayed. For a wait character, press ✱ four times quickly, so that a **w** is displayed. For more information on storing DTMF se-

quences, see chapter 3 "Contacts: Contact cards - Storing DTMF tones" on page 3-3.
⑤ Press **Save**. The message SAVED will appear (in the middle of the display). The entry will be automatically saved in the Contacts directory in alphabetical order (numbers will precede letters).

See also chapter 3 "Contacts: Contacts directory and the phone interface" on page 3-4.

A quick way to save text or numbers on the display is to press **Memory** for three seconds.

Recalling information

You may fetch phone numbers and names from memory by the name with which the required phone number was stored or by the speed dial number of the Contacts directory entry.

To recall a phone number by corresponding name:
① Press **Memory**.
② Key in the name or its first letter(s).
③ Press **Find**. The name closest to the keyed in characters will appear.
④ You can move to the next name containing the same characters by pressing **Next**, or scroll through the names with ▼ or ▲ until you reach the correct one.

To review the phone number stored with the name:
① Press **ABC**. If the phone number has been designated a speed dial number, the location number of the name and phone number is shown in the upper right corner of the display.

Dialling shortcuts

The dialling shortcuts provide quick and convenient ways to make voice calls.

Speed dialling

Speed dialling is a handy way to call frequently-used phone numbers by keying one digit and the 📞 key. You can define up to eight speed dial numbers in the communicator memory ("B" memory). For information on how to assign phone number speed dials, see

chapter 3 "Contacts: Contact cards - Speed dials" on page 3-2.

① Key in the number of the memory or speed dial location where you have stored the phone number.

② Press 📞.

The phone interface will recall the number from the memory, display it briefly, and then dial it. If the speed dial location is empty, an error message will be displayed.

Number 1 is the speed dial location of your voice mailbox. To call your voice mailbox, press **1** and then 📞, or just press and hold **1**.

Note: Speed dialling is not possible during a call.

Speed search

① Press **Memory** and key in as many characters as needed to identify the contact.

② Press **Find**. The first matching name appears with the cursor blinking under the last matching character you keyed in.

③ If the name found was not the one you searched for, press **Next** to view the next matching name. Note that the **Next** selection

key will only show names that match the keyed in sequence. If the initial character sequence produced too many matches, key in more characters and continue from step ②.

④ When the name of the contact you want to call is shown on the display, press 📞.

Last number redial

The communicator stores the phone numbers you dial, i.e., call or attempt to call. However, only the last twenty phone numbers (and associated names) can be stored in the memory at a time.

① If there are any characters on the display, clear the display by pressing and holding **C**.

② Press 📞. The last dialled number will appear on the display.

③ You can scroll the numbers with ▼ or ▲ until the desired number is displayed.

④ Press 📞 to dial the number.

You can also recall Recent dialled calls (Menu 01 1), Recent received calls (Menu 01 2) and Recent missed calls (Menu 01 3), see "Recent calls (Menu 01)" on page 13-8.

Using the menus

The phone interface offers a set of menu functions, which allow you to tailor the phone interface to your particular use. In each menu and submenu, you can check and alter the setting of any particular function. The menus and submenus can be entered by scrolling the menu or using appropriate menu shortcuts.

You can access the menu functions even during a call.

Menu scrolling

① Press **Menu** to enter the menu facility. The display will read *View menu*.

② Press either ▼ or ▲ to scroll the list of menus until you reach the desired menu.

③ Press **Select** to enter the menu. If the menu contains any submenus, reach the one you want with ▼ or ▲.

④ Press **Select**. The current setting of the function is indicated on the display by the pointer ▶.

⑤ Press ▼ or ▲ to scroll the list of setting options until the pointer points to the desired option.

⑥ Press **OK** to select the option. If you don't want to change the setting after all, you can return to the previous menu level by pressing **Quit**.

Pressing **C** or pressing and holding **Quit** will exit the menu facility.

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Menu shortcuts

All the menus, submenus and settings are numbered. This index number is shown in the upper right corner of the display.

To access a menu function by its shortcut:

① Press **Menu**.

② Key in the number of the main menu under which the desired submenu is located.

③ Key in the number of the submenu where the function can be found before the *View options* text appears.

④ Key in the number of the desired setting option.

For instance, to select the ringing volume level 2 (Menu 4 2 2): Press **Menu** (to enter the menu facility), **4** (to enter the Phone settings menu), **2** (to enter the Ringing volume submenu), **2** (to select ringing level 2).

Main menu structure

The following menu structure lists the names of the main menus and their submenus. Third-level menus are not shown here. Some menu items are shown only when the menu list mode has been set to *Complete* in Phone settings: Menu list (Menu 4 13). These menus are indicated by the ✔ symbol in the following menu list.

Some menu functions are network services, indicated by the ⅄ symbol in the following menu list. These functions can be utilised only if provided by your cellular network. To make use of a network service, you must first subscribe to it. Note that network services are specific to each SIM card. If you change the SIM card and you do not have obtained the service for the new card, you will not be able to use the service.

MENU	FUNCTION	SUBMENUS
MENU 01	RECENT CALLS ✔	1 Dialled calls, 2 Received calls, 3 Missed calls, 4 Erase all recent calls
MENU 2	MESSAGES	1 Listen to voice messages (⅄), 2 Read messages (⅄), 3 Show delivery reports ⅄, 4 Read info messages, 5 Message settings
MENU 3	VOICE CALL DIVERTING ⅄	1 Divert all voice calls, 2 Divert when busy, 3 Divert when not answered, 4 Divert if not reachable, 5 Cancel all diverts
MENU 4	PHONE SETTINGS	1 Lights ✔, 2 Ringing volume ✔, 3 Ringing tone ✔, 4 Keypad tones ✔, 5 Warning tones ✔, 6 One-touch dialling ✔, 7 Automatic answer ✔, 8 Date and time, 9 Cell info display ✔ ⅄, 10 Own number sending ✔ ⅄, 11 Call waiting ✔ ⅄, 12 Restore factory settings, 13 Menu list
MENU 5	SECURITY OPTIONS ✔	1 PIN code request, 2 SIM change security, 3 Voice call barring, 4 View fixed dial list, 5 Fixed dialling, 6 Change access codes, 7 Closed user group, 8 System lock
MENU 6	DURATION AND COST ✔	1 Call duration, 2 Call costs ⅄, 3 Call costs limit, 4 Show costs in ⅄
MENU 7	NETWORK SELECTION ✔	
MENU 8	MEMORY FUNCTIONS	1 Memory selection, 2 SIM card memory status ✔, 3 Copy between memories, 4 Erase SIM card memory ✔, 5 Show own numbers
MENU 9	IN-CALL OPTIONS ✔	
MENU 10	ALL SOUNDS	
MENU 11	KEYPAD LOCK	

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Menus

When you have reached the correct menu, use ▼ or ▲ to scroll through the menu options.

Recent calls (Menu 01)

In this menu, you can review and erase the phone numbers stored automatically. Note that the Received calls and Missed calls functions are network services which work only in networks that allow you to view the caller's phone number. These functions are described in chapter 4 "Telephone: Making a call" on page 4-2.

Dialled calls (Menu 01 1), Received calls (Menu 01 2), Missed calls (Menu 01 3).

Note: The communicator only registers missed calls when the phone interface is switched on and it is used within the network's service area.

Erase all recent calls (Menu 01 4)

Caution: The phone numbers are erased without warning. You cannot undo the operation.

Messages (Menu 2)

The Short Message Service (SMS) function is a network service and may not be supported by your network. Contact your home service provider for details. The phone interface can be used for recording and listening to voice messages in voice mailboxes and for reading received short messages. Reading short messages is, however, more convenient via the larger display of the communicator interface. To read or send short messages, use the communicator interface's SMS application (see chapter 6 "Short messages" on page 6-1) or the Notes application (see chapter 8 "Notes" on page 8-1).

Listen to voice messages (Menu 2 1)

When you enter this function, the communicator dials the phone number stored in Menu 2 5 1. If required, key in the access code of the mailbox (or answering machine). It is sent as

DTMF tones to the receiving end.

Read messages (Menu 2 2)

When you receive a short message, the text MESSAGE RECEIVED and the ✉ indicator will be displayed and a tone will sound (if the communicator has not been set to silent service in Menu 10). A note is also shown when you receive faxes or mail. To read received faxes or mail, you must use the respective applications of the communicator interface. To read the message immediately, press **Read**. To read the message later, press **Quit**.

Press ▼ to view the first message. The messages are shown in the order they were received.

Once you have read the message, you can press **Quit** or **Option**. The options available in the phone interface are:

Read next — Shows the next message.
Erase — Erases the selected message from memory.
Use number — Copies the phone number from the message and moves it onto the phone interface display. You can now call the number or save it.

Show delivery reports (Menu 2 3)

Delivery reports give information about the status of sent messages. The sent message can be either successfully delivered, pending, or the sending of the message has failed.

Read info messages (Menu 2 4)

This network service allows you to receive short messages on various topics. You may select from topics that are pre-defined on the communicator interface see chapter 6 "Short messages: SMS settings" on page 6-5. Press **Select** to view the list of available topics.

Use ▼ or ▲ to scroll through the topic list. To read a topic, press **Read**: the content of the topic is displayed. If the topic contains no information, the text NO MESSAGE ON THIS TOPIC is displayed.

You can scroll the text with ▼ or ▲. Pressing **Option** gives you the following options:

Use number — Copies the phone number from the current message onto the display, from which you can dial it or store it elsewhere in the normal way. (Instead of this function, you may press ☏ while viewing the message.)

Off — Turns the info message receiving off.

If you want to read a message again, choose the message from the menu. The message will appear immediately on the display.

Message settings (Menu 2 5)

Set voice mailbox number (Menu 2 5 1)

The phone number that you enter here will be dialled when you select the *Listen to voice messages* function in Menu 2 1. A voice mailbox can be a network service or your personal answering machine. You may enter a new or edit an existing phone number. The number will be used until you change the number again.

Info service (Menu 2 5 2)

This menu allows you to control the info service settings.

On — Activates the reception of topics that are pre-defined in the communicator interface and which can also be seen within the Read info messages menu (Menu 2 4).

Off — Deactivates new topic reception. You can still read previously saved messages.

Index — You receive only the list of available topics, no messages. Any previously received index list will be shown and updated automatically by the service provider.

To receive the messages for the chosen topics, you must first select the topics from the list (via the communicator interface), then change the setting to *On*.

Voice call diverting (Menu 3)

The call divert network service allows you to direct your incoming calls to another phone number when you do not want to be disturbed, or when the phone interface is switched off or outside of the network coverage area. The call diverting functions are described in more detail in

chapter 4 "Telephone: Telephone settings - Voice call diverting" on page 4-6.

Note: Call diverts made via the phone interface only apply to voice calls. Fax diverting is done in the Fax application's settings (see chapter 5 "Fax: Fax settings" on page 5-4).

① Select the desired call divert mode in the main menu:

Divert all voice calls (Menu 3 1), Divert when busy (Menu 3 2), Divert when not answered (Menu 3 3), Divert if not reachable (Menu 3 4), Cancel all diverts (Menu 3 5)

Unless you chose **Cancel all diverts**, the following options are now available:

Press ▼ or ▲ to move the pointer to *Activate*. You will be asked for the phone number to which you wish to divert the incoming voice calls (to your voice mailbox or some other number). See chapter 4 "Telephone: Telephone settings - Voice call diverting" on page 4-6 for details.

When the phone interface is in idle state (you have no active calls and you are not in any menu), you can modify the phone number to which your calls will be diverted by using a manual command string.

The delay time, after which the call is diverted, can be modified by a command string programmed by your network operator.

Cancel — Sets the divert mode off.

Status — Shows call types that are being diverted.

Phone settings (Menu 4)

Lights (Menu 4 1)

The keypad and display of the phone interface are fitted with lights to make them easy to read. When the communicator is used as a handportable phone or is connected to a charger, this setting determines whether the lights remain on for 15 seconds after the last keystroke or an incoming call alert (*On*) or remain permanently off (*Off*).

The lights can be switched on for 15 seconds by pressing ⓪ quickly even if *Off* is selected. When the communicator is connected to a

handsfree car kit, the lights always remain on (*On*) or extinguish after 15 seconds (*Off*).

Ringing volume (Menu 4 2)

The ringing tone will be heard when you receive a call. There are several ringing tone volume levels available. If you have set the communicator to *Silent* or *Beep* in Menu 10, the ringing tone will not be heard.

Ringing tone (Menu 4 3)

You can select from a range of different tone patterns. When you change the ringing tone, a short sample tone will be heard. If you have set the communicator to *Silent* or *Beep* in Menu 10, the ringing tone will not be heard.

Keypad tones (Menu 4 4)

A short tone sounds each time you press a key. You can select a suitable volume level or set the keypad tones off. If you have set the communicator to *Silent* or *Beep* in Menu 10, the keypad tones will not be heard.

Warning tones (Menu 4 5)

A warning tone, i.e., error or confirmation tone will sound, for example, when the cellular network is currently too busy to allow new calls or the battery charge is too low. If you have set the communicator to *Silent* or *Beep* in Menu 10, the warning tones will not be heard.

One-touch dialling (Menu 4 6)

When this function is set on, you can dial phone numbers stored in speed dial locations 1 to 9 by simply pressing and holding the assigned speed dial key.

Automatic answer (Menu 4 7)

When this function is set on, the communicator will automatically receive an incoming call.

This function can only be used when the communicator is connected to an approved handsfree car kit equipped with ignition sense. The ignition sense has to be installed and ignition has to be switched on. Note that this function works with voice calls only.

Date and time (Menu 4 8)

You can select whether the date and time are shown on the display.

Cell info display (Menu 4 9)

When this function is set on, the phone interface will indicate when it is using a network cell based on Micro Cell Network (MCN) technology. The setting will remain in effect even if the SIM card is changed or the phone interface is switched off.

Note: The communicator consumes more power when the Cell info display is on.

Own number sending (Menu 4 10)

The setting of this function determines whether the phone number of your current SIM card is revealed to the receiving end. This function works only in cellular networks that allow you to view the caller's phone number. For subscription to this service, contact your network operator.

Choose *Preset*, *On* or *Off*. *Preset* selects the preferential setting (*On* or *Off*) that you have agreed upon with your network operator. When you change the SIM card, the *Preset* setting is automatically selected.

Call waiting (Menu 4 11)

Call waiting is a network service. Contact your operator for subscription. See chapter 4 "Telephone: Telephone settings - Voice call waiting" on page 4-7.

Choose *Activate* to set call waiting on, *Cancel* to set call waiting off or *Status* to show call types with which call waiting may be used.

Restore factory settings (Menu 4 12)

You can reset the settings of the menu functions to their original values. When you activate this setting, you will be prompted for the five-digit lock code. This function will not affect stored phone numbers and names, access codes, earpiece volume setting, call timers and cost counters (Menu 6).

Menu list (Menu 4 13)

If you do not need all menu functions frequently, you may hide some of the menus and submenus. When *Complete* is selected, the phone interface will show all its menu functions. When *Short* is selected, only the main functions are shown and can be accessed.

Security options (Menu 5)

The purpose of the security system is to prevent unauthorised use or the altering of important settings. Activating or changing the security options requires, in most cases, the appropriate access code (see chapter 10 "System: Security" on page 10-2).

Note: When call barring, fixed dialling, closed user group, or system lock is in use, calls may be possible to certain emergency numbers in some networks (e.g., 112 or other official emergency number).

PIN code request (Menu 5 1)

See chapter 10 "System: Security" on page 10-2: *On* or *Off.*

SIM change security (Menu 5 2)

See chapter 10 "System: Security" on page 10-2: *On* or *Off.*

Voice call barring (Menu 5 3)

Call barring is a network service; contact your operator for subscription. See chapter 4 "Telephone: Telephone settings - Voice call barring" on page 4-7. In this submenu you can choose the following call barring modes: **Outgoing calls (Menu 5 3 1), International calls (Menu 5 3 2), Int except to home country (Menu 5 3 3), Incoming calls (Menu 5 3 4), Incoming calls if abroad (Menu 5 3 5), Cancel all barrings (Menu 5 3 6).**

Note: Call barrings made via the phone interface only apply to voice calls. Fax barrings are made in the Fax application's settings (chapter 5) and data barrings are made in the Internet main settings (chapter 7).

View fixed dial list (Menu 5 4)

In this submenu, you can review the contents of the fixed dialling list that you created in Menu 5 5. If you have selected *Off* in the Menu 5 5, calls to all numbers are possible.

Fixed dialling (Menu 5 5)

You may restrict your outgoing calls to a predetermined set of phone numbers. This 'fixed dialling' function works only with SIM cards

that support it. When the function is set on, you can only call a phone number which is included in the fixed dialling list or which begins with the same digits as a phone number on the list.

Enter the PIN2 code. Select *On*, *Off* or *Numbers* (to edit the fixed dialling list). If you selected *Numbers*, the first number in the list will be displayed.

Press **Option** and choose *Erase all, Add, Remove* or *Edit*. The *Remove* and *Edit* options affect the name (and the associated phone number) which was on the display when you pressed **Option**.

Change access codes (Menu 5 6)

In this submenu, you can change the following access codes: Lock code (Menu 5 6 1), PIN code (Menu 5 6 2), PIN2 code (Menu 5 6 3), Barring password (Menu 5 6 4). See chapter 10 "System: Security" on page 10-2.

Note: The access codes may only include digits 0 to 9.

Closed user group (Menu 5 7)

This network service allows the restriction of outgoing calls to and incoming calls from a selected group of people. For details on creating a user group and activating this service, contact your network operator. You may be a member of up to 10 user groups (the groups need not necessarily be assigned numbers from 1 to 10).

Select one of the following options:

None — Calls can be made and received in the normal way. This option overrides all other user group settings. You can use this option only if you are entitled to do so.

Preset — Use a preferential user group that the SIM card owner has agreed upon with the network operator.

Set — Use a particular user group. Calls can be made to or received from the members of the selected group only.

System lock (Menu 5 8)

When the system lock is activated in this menu, the communicator will lock immediately. Even if you remove and replace the bat-

tery and switch on the phone interface, the communicator will remain locked.

The communicator can also be locked automatically if the *Autolock period* is turned on in the communicator interface (see chapter 10 "System: Security" on page 10-2).

To lock the communicator, press **Select** to activate the lock code prompt and enter the lock code. The communicator locks immediately.

To unlock the communicator, press **Unlock** and enter the lock code.

Note: To prevent the communicator from locking itself again after the autolock period, deactivate the option in the Security application settings (see chapter 10 "System: Security").

Duration and cost (Menu 6)

In this menu, you can view the duration and cost of your outgoing and incoming calls, reset the timers and counters, limit the duration of calls and select whether the call costs are shown in charging units or units of currency.

Note: The actual time invoiced for calls and services from your service provider may vary, depending upon network features, rounding-off for billing, taxes and so forth.

Call duration (Menu 6 1)

The communicator provides two call timers which help you monitor the duration of your calls.

Last call duration (Menu 6 1 1)

Shows the duration of the last, or current, outgoing or incoming call in hours, minutes and seconds, e.g., *00:02:15.*

Note: The duration of incoming calls is not displayed when you are within your home network.

All calls duration (Menu 6 1 2)

Shows the total cost of all calls made or received with any SIM card that you have used with the communicator.

Clear timers (Menu 6 1 3)

Resets all timers.

Note: There is no way to undo the reset operation.

Call costs (Menu 6 2)

This network service allows you to check various call costs. The costs are shown in charging units or units of currency that you have set in Menu 6 4. The call cost is shown for each SIM card separately. For these settings you need the PIN2 code. Contact your service provider for more information.

Last call units (Menu 6 2 1)

Shows the cost of the last, or current, call in charging units or the currency set in Menu 6 4.

All calls units (Menu 6 2 2)

Shows the total cost of all calls in charging units or units of currency that you have set in Menu 6 4.

Clear counters (Menu 6 2 3)

Resets all cost counters. Resetting requires the PIN2 code. This service is not available with SIM cards that do not support the PIN2 code.

Note: There is no way to undo the reset operation.

Call costs limit (Menu 6 3)

This function allows you to limit the total costs of outgoing calls to a specified number of charging units or units of the currency that you have set in Menu 6 4. For this service you need the PIN2 code.
Emergency calls to the number 112 can be made even if there are no charging units left.

Changing the call costs limit requires the PIN2 code. To turn the limit on, select *Set.* Key in the cost limit in charging units or currency units. If you define the limit in currency units, you can press ✱ or # to insert a decimal point.

After the limit has been turned on, the quantity of remaining charging or currency units will be continuously shown on the display when in idle mode. When all units have been used, no calls can be made except for emergency calls to the number 112.

To turn the limit off, select *None.*

Show costs in (Menu 6 4)

In this submenu, you may select whether the call cost limits (and the amount of remaining calling time) will be displayed in currency or charging units. Contact your network operator for charging unit prices. Changing the call costs unit requires the PIN2 code.

To show limits in currency units, select *Currency*, or *Units* to show limits in charging units. If you selected *Currency*, key in the charging unit price. Use ✱ or # to insert a decimal point. Next, enter the currency name.

Network selection (Menu 7)

The communicator can be set to select automatically one of the cellular networks available in your area, or you may select the desired network manually in this menu. This function comes in handy when you want to select a particular network, e.g., due to lower call charges.

When the *Automatic* option is selected, the communicator tries to utilise the network it was last registered on. Outside of the home network service area, the communicator will select one of the networks that have a roaming agreement with the home network.

In the *Manual* mode, when you pick up a network manually from the network list, the communicator will always attempt to register on that network. If the communicator cannot reach or loses contact with the selected network, you are prompted to select another network.

Memory functions (Menu 8)

Memory selection (Menu 8 1)

In this submenu, you can set the phone interface to use either the SIM card memory ("memory A") or the communicator's internal memory ("memory B"). The letter indicating the currently selected memory is shown in the top left corner of the phone interface display. The memory selection does not affect the communicator interface applications, which will always use "memory B."

Choose *A:Card*, or *B:Phone*, the recommended choice.

SIM card memory status (Menu 8 2)

In this submenu, you may review the number of empty and full memory locations on the SIM card.

Copy between memories (Menu 8 3)

In this submenu, you can copy phone numbers and names between the communicator memory and the SIM card memory. You can copy:

From phone to SIM card (Menu 8 3 1)

You can choose to copy contact cards *One by one* (Menu 8 3 1 1) or copy all *Speed dials* (Menu 8 3 1 2).

Note: All Contacts directory contacts may not fit in the SIM card.

From SIM Card to Phone (Menu 8 3 2)

You can copy locations *One by one* (Menu 8 3 2 1) or *Copy all* SIM card locations (Menu 8 3 2 2) to the Contacts directory.

Note: All copied phone numbers go to the *Tel* field of the contact card. If you want to send SMS messages to these numbers, they must be moved to the *Tel(GSM)* or *Tel(PCN)* field.

Erase SIM card memory (Menu 8 4)

This function allows you to remove phone numbers and names from some or all locations of the SIM, or "A," memory (not the communicator memory). The SIM memory does not need to be selected in order to erase its contents.

Note: Once erased, the memory contents are permanently lost.

You can erase individual locations *One by one* (Menu 8 4 1) or *Erase all* locations (Menu 8 4 2).

Show own numbers (Menu 8 5)

You may view the phone number(s) assigned to the SIM card you are currently using. Some SIM cards do not hold the number and, therefore, the number cannot be shown. If the SIM card is provided with several phone numbers, you may scroll the list.

In-call options (Menu 9)

The phone interface provides a number of control functions that you can use during a call. To access the in-call options during a call, simply press and hold the **Menu** for a second. The in-call options are not numbered. You cannot, therefore, access them by the shortcut method.

Mute / Unmute — Switches off or on the communicator's microphone. If the communicator is connected to a hands free car kit, *Mute* turns off the microphone of the car kit, as well.

Hold / Unhold — Hold allows you to put a currently active call on hold, so that another call can be initiated. After you have finished the new call (with *Drop call*, see below), the original call can be made active again by selecting *Unhold*. If the held call is the only call, you can also unhold it by pressing 📞.

Swap — This function is available when you have one active and one held call. *Swap* makes the held call active and puts the currently active call on hold. In this way, you may converse with one party without ending the other call. Instead of using this function, you can press 📞 to swap between the calls if no numbers have been keyed in.

Drop call — Ends the currently active call. This function is useful when there is an active call, as well as a held call. In such a situation, pressing 📞 would terminate both calls.

Join / Private — *Join* includes a new participant in a conference call. During a conference call, *Private* allows you to converse privately with a selected call participant.

Transfer — The voice call transfer enables you to connect two voice calls together and disconnect yourself from both calls. See chapter 4 "Telephone: Managing calls - Voice call transfer" on page 4-4.

Data — When you have an alternating call active, this option changes the mode of the call from voice to fax or data (see chapter 4 "Telephone: Managing calls - Alternating calls" on page 4-5).

Speech — When you have an alternating call active, this option changes the mode of the call from fax or data to voice.

Send DTMF — Transmits Dual Tone Multi Frequency tones. This function helps you communicate with answering machines, computerised telephony systems, etc. For more details, see "Sending DTMF tones" on page 13-3.

All sounds (Menu 10)

You can select the indication mode for incoming calls and all alerts from the following options. This setting affects both interfaces. You can adjust the same settings in the System settings, see chapter 10 "System: System settings" on page 10-1.

Ring — A ringing tone will sound.

Beep — One short beep will sound and the phone interface will flash its display lights.

Silent — Turns on the silent service: the communicator will flash its display lights. No tones will be heard, including keypad and warning tones. When silent service is selected, the text SILENT will be shown on the display in idle mode.

Keypad lock (Menu 11)

The keypad lock prevents the keypad keys being accidentally pressed when the communicator is, for example, in your pocket. The keypad can be locked or unlocked even during a call.

When the keypad lock is on:

> To answer a call, press 📞 normally. During a call, the keypad is unlocked and the communicator can be operated in the normal way. After the call, the keypad lock is automatically turned back on.

The keypad lock will be automatically turned off when the communicator is connected to a car kit. When the communicator is removed from the car kit, without being switched off previously, the keypad lock will be activated automatically again.

To activate the keypad lock:

① Press **Menu** and use ▼ or ▲ to reach the menu *Keypad lock*.

② Press **Select**.

Or, alternatively

① Press **Menu** and then the ✳ key within 5 seconds of the first press.

While the keypad lock is active, the text KEYPAD LOCKED and the **Unlock** selection key are displayed all the time.

To deactivate the keypad lock:

① Press **Unlock** and then the ✳ key within 5 seconds of the first press.

Note: When the keypad lock is on, calls may be possible to the emergency number programmed into your communicator (e.g., 112 or other official emergency number).

Help

Most menu functions are provided with a help text, which gives a brief description of the displayed function. Enter the menu facility about which you want help. Now you can view the help text of the function in two ways:

Wait for 5 seconds. The first page of the help text will appear. The text is scrolled automatically.

Or, press **ABC**. The first page of the help text will appear. For additional pages, press **ABC** as many times as necessary.

Once you have read the text, either press **Select** to enter the function or press **Quit** to return to the title screen.

While reading a help text, you can move to the next or previous menu function by pressing ▼ or ▲.

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14. Troubleshooting

Note: You will find the Nokia HelpLine contact card in the Contacts directory. The Help-Line answers questions and offers instructions over the phone.

1. Phone interface or communicator interface does not start (both displays remain blank)

Make sure the battery is properly installed and charged.

Make sure that the contacts on the battery and the charging stand are clean.

Battery charge may be too low for operation. Check the display and listen for the low battery warning tones. Charge the battery with the adapter and charger as described in chapter 2 "Getting started: Battery" on page 2-4. If the NOT CHARGING message is displayed, the charging is suspended. In that case check that the temperature of the battery is not above +45° C (+113° F). Wait for a while, disconnect the charger, connect it again and retry. If charging still fails, contact your local Nokia dealer.

2. Power comes on, but the phone interface does not work

Remove the battery and replace it again (reboot).

Try charging the communicator. If you see the battery charging indicator on the phone interface but the phone does not work, contact your local Nokia dealer.

Check the field strength indicator, you might be out of the cellular service area. See the answer to problem number 6.

Check if there is an error message on the display after switching on. If so, contact your local dealer.

Check that the SIM card is correctly installed, see chapter 2 "Getting started: SIM card" on page 2-2.

3. Communicator does not activate or applications stop responding

Close the cover and open it again. If this does not help, close the cover and remove the battery. Replace the battery and open the cover again. Wait while the communicator performs a self-test and starts. See also problem 4.

4. Resetting the communicator

Sometimes, for example, removing the battery in mid-sending may cause errors in the communicator's file system. If you receive internal memory or system error messages and/or reboot prompts, or the device does not respond to commands normally, the reset operations help you to recover from most of these problems. Try the reset operations in the order they have been listed: if checking the file system does not help, try deleting temporary files, and so on. To reset the communicator:

① Close the cover.

② Remove the battery.

③ Place the connector end of the battery (the end with the four metal strips) in the battery cavity, but do not press the other end in place yet.

④ Place the communicator on a flat surface with the phone interface display upwards (do not let the battery slip from its place).

⑤ Open the cover.

⑥ Press and hold down the required key combination and simultaneously push the battery end of the communicator down, so that the battery clicks in place. Hold down the keys until you see progress messages or a confirmation prompt on the display.

⑦ In some cases you must confirm the action by pressing a command button.

After the reset, the communicator will reboot and start normally.

1) Check the file system

Key combination: Shift-ESC-(left arrow)
Symptoms: The Memory application (in the System main view) shows too much (over 2 megabytes) or too little memory (even if you have just deleted some documents), or the communicator interface applications crash when opening a document.
Caution: If there are problems in the file system, the corrupted files will be removed.
If there are no problems, this operation does not affect any documents or settings.

2) Delete temporary files

Key combination: Shift-ESC-(right arrow)
Symptoms: The communicator interface is in a reboot cycle or a note saying that an .ini file is corrupted is displayed.
Caution: All temporary files are removed. The Document outbox is cleared, default application settings are restored (for example, the SMS message centre number, Internet access point and remote mailbox settings are lost).
Stored documents are not affected.

3) Format file system

Key combination: Shift-ESC-F
Symptoms: The communicator interface is in a reboot cycle or does not boot up.
Caution: Formats the file system. All data you have entered will be lost. This operation will restore your communicator in the same state it was in at the time of purchase. Remember that backed up data can be restored in all cases. If these measures do not help, contact your local dealer.

5. Calls cannot be made or received

The phone interface is off. Close the cover and switch the phone interface on.

If you get the message INVALID SIM CARD, your SIM cannot be used in the communicator. Contact you dealer or network operator.

Check the status of your call barrings and diverts, see chapter 4 "Telephone: Telephone settings" on page 4-6.

The phone interface is already busy (data or fax being sent or received, the communicator is used as a fax modem). Wait for the data/fax transmission to end or drop the call (by pressing the ⬛ key on the phone interface keyboard).

6. Call quality is poor

Your location may not allow better call quality. This problem may occur especially in a moving car or train. Move to a location where radio signal reception is better. See chapter 16 "Important safety information: Facts about cellular data transmission" on page 16-3.

Reception is usually better above ground level, outdoors and while stationary. Sometimes even moving the mobile phone slightly will improve reception. You can also try using the communicator in the handsfree mode with the communicator interface's Telephone application (see chapter 4 "Telephone: Audio control" on page 4-1). Remember to turn the antenna to an upright position.

7. Calls, faxes or data cannot be diverted or barred

The service in question may not be subscribed to, or is not supported by the network, or the message centre number and voice mailbox number (required for call diverting) may be missing or incorrect.

Fax diverts and barrings are set in the Fax application's settings. Data barring is set in the Internet main settings (data calls cannot be diverted).

8. Cannot access numbers stored on the SIM

Use the phone interface's Menu 8 3 2 to copy the SIM card entries into the Contacts directory. See chapter 13 "Phone interface: Menus - Memory functions (Menu 8)" on page 13-13.

9. Cannot open a directory entry in the directory view

If you cannot select a contact in the Telephone, Fax, SMS or Mail directory, it means that the contact card does not have a telephone number, fax number, mobile telephone number or an E-mail address. Within the Contacts application, add the missing information to the contact card.

10.Common reasons why faxes, short messages or mail cannot be sent or received

The phone interface is off, or you have no subscription to the network service, or the communicator is low on memory (see problem 16).

The number format used is invalid, or the called number does not answer (within 10 tries) or you are calling to a wrong phone number.

The phone interface is already busy (data or fax being sent or received, the communicator is used as a fax modem). Wait for the data/fax transmission to end or drop the call (by pressing the ⬯ key on the phone interface keyboard).

Fax/data barrings or fax diverts may be active (fax barrings/diverts are set in Fax application's settings, data barrings are set in the Internet settings).

Fax reception: The SIM does not have a fax number.

Mail reception: The SIM does not have a phone number for data connections. Contact your cellular service provider.

Short message sending: You have not subscribed to the Short Message Service or the Short Message centre number is missing or incorrect. Contact your cellular service provider.

Mail sending: You do not have a remote mailbox service, or the mail server (which delivers your mail) does not comply with the SMTP protocol. Contact your E-mail service provider. If you are using the *Upon request* sending option, mail sending must be started in the

Document outbox, see chapter 12 "Document outbox" on page 12-1.

The failure reason can also depend on the cellular network: no network support for SMS, no network support for fax, no network support for data/mail, network out of order, network is busy, the field strength is not adequate for sending.

11.Cannot establish a terminal or Internet connection

Internet, Mail, WWW, Telnet or Terminal settings and configurations may be missing or incorrect. Check your Internet access point number (in Internet main settings). Contact your Internet service provider for the correct settings. See also "Internet settings" on page 7-3.

If you receive internal error messages, remove and replace the battery and try again. If the problem persists, see problem 4.

If you receive service provider error messages when connecting to your remote mailbox, contact your remote mailbox service provider. Your remote mailbox may contain corrupted mail messages or the mail server settings may be incorrect.

12.Cannot print

Direct printing is possible via an infrared link only. The remote infrared port must be compatible to the IrDA standard. Check the IR connection, see chapter 10 "System: Connecting to a PC" on page 10-5.

You are using an incorrect printer driver, see chapter 8 "Notes: Printing".

If you fail to establish a working infrared connection, transfer the file to a PC and use the PC to print the document. See chapter 10 "System: File transfer" on page 10-6. Alternatively, you can send the document as a fax to the nearest fax machine. See chapter 5 "Fax: Sending faxes" on page 5-1.

13.PC connectivity problems

The PC software for desktop connectivity is not installed. The software is found on the

diskette included in the communicator sales package.

Check the cable or IrDA connection used. If an infrared connection is used, the IR ports must be facing each other. See chapter 10 "System: Connecting to a PC" on page 10-5.

14. Fax modem problems

When the communicator is used as a fax modem (see chapter 10 "System: Connecting to a PC" on page 10-5), use autobauding. The communicator and the PC must be using the same baud rate. For the communicator, this is set in System settings. For the PC, the baud rate is set in the PC's connectivity software.

If a cable connection is used, fully compatible operation with all PC fax and terminal software cannot be guaranteed (consult with your dealer). If you experience problems with your PC fax software, use the infrared connection.

If you experience problems establishing a data connection with the remote modem, you can try fixing the data transmission rate by using an AT command, for example, ATS35=6, which defines the remote modem as a V.32 modem. Common AT commands (based on the ETSI 07.07 standard) supported by the Nokia 9000i Communicator are listed in the file *atcomm.txt* on the diskette supplied with the product. For information on how to use the AT commands, consult the documentation of the telecommunication or fax application that you use on your PC.

15. Access code problems

The lock code is included in the communicator sales package. If you forget or lose the lock code, contact your communicator dealer.

If you forget or lose a PIN or PUK code, or you have not received such a code, contact your network operator.

For information about Internet or terminal passwords, contact your Internet service provider.

16. Low on memory

If you notice that your communicator's memory is getting low or you receive a warning note about insufficient memory, check the Memory details (see chapter 10 "System: Memory" on page 10-10). Use the memory details to determine what kind of data takes up most memory.

First, make a backup of all important data. Next, either delete some data manually (documents, received faxes, etc.) You can also use the Data removal application (see chapter 10 "System: Data removal" on page 10-10). With the Data removal application you can delete old calendar data, for example.

Note: Downloaded images and received faxes can take up significant amounts of memory space.

17. Distorted characters in Terminal

If the data bits/stop bits/parity settings are different from those defined to the data service by the operator, characters may look distorted on the display.

18. Infrared connection

The communicator may be connected to a computer, laptop or printer via an infrared connection.

If you wish to use an infrared connection, the computer to which you want to establish a connection must have an IrDA compatible infrared port; installed and activated IrDA drivers; and Microsoft Windows 95 (for more information on IrDA drivers and their use in Windows 95, contact Microsoft).

If the IrDA drivers are activated on your computer, the computer will automatically detect the presence of the communicator.

If you want use a printer which does not have an infrared port, you may try to connect to the printer via an IrDA adapter (not supplied with the Nokia 9000i Communicator).

For further information see the *readme.txt* file on the diskette supplied with the communicator.

15. Care and maintenance

Your Nokia 9000i Communicator is a product of superior design and craftsmanship and should be treated with care. The suggestions below will help you to fulfil any warranty obligations and to enjoy this product for many years.

Keep the communicator and all its parts and accessories out of small children's reach.

Keep the communicator dry. Precipitation, humidity and liquids contain minerals that will corrode electronic circuits.

Do not use or store the communicator in dusty, dirty areas. Its moving parts can be damaged.

Do not store the communicator in hot areas. High temperatures can shorten the life of electronic devices, damage batteries, and warp or melt certain plastics.

Do not store the communicator in cold areas. When the communicator warms up (to its normal temperature), moisture can form inside the communicator, which may damage electronic circuit boards.

Do not attempt to open the communicator. Non-expert handling of the communicator may damage it.

Do not drop, knock or shake the communicator. Rough handling can break internal circuit boards.

Do not use harsh chemicals, cleaning solvents, or strong detergents to clean the communicator. Wipe it with a soft cloth slightly dampened in a mild soap-and-water solution.

If the communicator or any of its accessories are not working properly, take them to your nearest qualified service facility. The personnel there will assist you, and if necessary, arrange for service.

16. Important safety information

Traffic safety

- Do not use the communicator while driving a vehicle. Park the vehicle before using the communicator.
- Always secure the communicator in its holder, and ensure that the locking mechanism on top of the holder is properly engaged; do not place the communicator on the passenger seat or where it can break loose in a collision or sudden stop.
- The use of an alert device to operate a vehicle's lights or horn on public roads is not permitted.
- Remember, road safety always comes first!

Operating environment

- Remember to follow any special regulations in force in any area, and always switch off your communicator's phone interface whenever it is forbidden to use a mobile phone, or when it may cause interference or danger.
- Operation of any radio transmitting equipment, including the Nokia 9000i Communicator, may interfere with the functionality of inadequately protected medical devices. Consult a physician or the manufacturer of the medical device if you have any questions. Other electronic equipment may also be subject to interference.
- As with other mobile radio transmitting equipment, users are advised that for the satisfactory operation of the equipment and for the safety of personnel, it is recommended that the equipment should only be used in the normal operating position.
- Users are advised to switch off the phone interface when at a refuelling point (service station). Users are reminded of the need to observe restrictions on the use of radio equipment in fuel depots (fuel storage and distribution areas), chemical plants or where blasting operations are in progress.
- Do not store or carry flammable liquids, gases or explosive materials in the same compartment as the communicator, its parts or accessories.
- Only qualified personnel should install or service the communicator in a vehicle. Faulty installation or service may be dangerous and may invalidate any warranty which may apply to the unit.
- Electronic fuel injection systems, electronic anti-skid braking systems, electronic cruise control systems and other electronic systems can malfunction due to the lack of protection from radio signals. Check regularly that all mobile phone equipment in your vehicle is mounted and operating properly.
- Remember to make backup copies of all important data to protect against its possible loss or alteration.
- When connecting the communicator to a PC or printer, please refer to the User's Guides of those devices for detailed safety instructions.
- The infrared beam of the communicator may interfere with the functioning of other infrared devices that are not IrDA certified. Do not point the infrared beam at anyone's eye.

- Consult aircraft personnel as to whether you may use the communicator interface applications in an aircraft. However, always switch off the phone interface before boarding an aircraft. The use of mobile telephones in an aircraft may be dangerous to the operation of the aircraft, disrupt the cellular network and is illegal.
- Failure to observe these instructions may lead to suspension or denial of mobile telephone services to the offender, or legal action or both.

Emergency calls

IMPORTANT!

The Nokia 9000i Communicator, like any mobile phone, operates using radio signals, cellular and landline networks, as well as user-programmed functions which cannot guarantee connection in all conditions. Therefore, you should never rely solely upon any mobile phone for essential communications (e.g. medical emergencies).

Remember, to make or receive any calls the communicator's phone interface must be switched on and in a service area with adequate cellular signal strength.

Emergency calls may not be possible on all cellular phone networks or when certain network services and/or phone features are in use. Check with local cellular service providers.

Some networks may require that a valid SIM card is properly inserted in the communicator.

To make an emergency call:

① If the device cover is open, close the cover.
② If the phone interface is not on, switch it on (press the ⓞ key).
③ Press and hold the **C** key for several seconds to ready the phone interface for calls. If there is an active data or fax call, drop the call first by pressing the ☎ key.
④ Key in the emergency number for your present location (e.g., 112 or other official emergency number). Emergency numbers vary by location.
⑤ Press the ☎ key.

If certain features are in use (call barring, fixed dialling, closed user group, system lock, keypad lock, etc.), you may first need to turn those features off before you can make an emergency call. Consult this document and your local cellular service provider.

When making an emergency call, remember to give all the necessary information as accurately as possible. Remember that your mobile phone may be the only means of communication at the scene of an accident - do not cut off the call until given permission to do so.

Using this manual

The mobile phone described in this manual is approved for use in the digital cellular networks. This manual is used for both the Nokia 9000i Communicator GSM and PCN models.

A number of features described in this manual are called Network Services. They are special services provided by cellular service providers. Before you can take advantage of any of these Network Services, you must subscribe to the service(s) you require from your home service provider. You can then activate these functions as described in this manual. The manual activation commands for various services are not presented in this manual (e.g., using the ✳ and # characters for activating or deactivating services). The Nokia 9000i Communicator, nevertheless, is capable of handling commands given in that form. For these commands, please consult with your service providers.

WARNING! This apparatus is intended for use when supplied with power from a Lithium-Ion battery and chargers ACH-4E, ACH-4X and ACH-4A. Other usage will invalidate any approval given to this apparatus and may be dangerous.

Use only accessories approved by the communicator manufacturer. The use of any other types will invalidate any approval or warranty applying to the apparatus, and may be dangerous.

When you disconnect the power cord of any accessory, grasp and pull the plug, not the cord.

Facts about cellular data transmission

The Nokia 9000i Communicator employs the digital data transmission capabilities of the digital cellular network to send faxes, short messages, mail and to establish connections with remote computers.

Cellular data connections can be made from most locations where your mobile phone operates. However, it is recommended that you move the communicator to a location where the strongest possible cellular signal can be obtained. When the signal is strong, data transmission is efficient. In general, you should not expect the same performance from cellular data communications as from landline communications due to the inherent characteristics of the cellular environment.

The following factors may impair cellular connections:

Noise

Radio interference from electronic appliances and equipment, as well as from other mobile phones in metropolitan areas where mobile telephones are prevalent.

Handover

As the mobile phone user moves from one network cell to another, the signal strength of the channel drops and the cellular telephone exchange may hand the user over to a different cell and frequency, where the signal is stronger. A cell handover may also occur when the user is stationary due to varying cellular traffic loads. Such handovers may cause slight delays.

Electrostatic discharge (ESD)

A discharge of static electricity from a finger or a conductor may cause erroneous functions in electric devices. The discharge can result in "garbled" display and unstable software operation. Cellular connections may become unreliable, data may be corrupted, and the transmission halted. In this case you need to end the existing call (if any), switch off the phone interface (if on) and remove the battery. Then replace the battery and establish a new cellular connection.

Dead spots and dropouts

Dead spots are areas where radio signals cannot be received. Dropouts occur when the mobile phone user passes through an area where the radio signal is blocked or reduced by geographic or structural obstructions.

Signal impairment

Distance and obstacles can cause out-of-phase reflected signals that result in a loss of signal strength.

Low signal strength

Due to either distance or obstacles, the radio signal strength from a cell site may not be strong enough or stable enough to provide a reliable cellular connection for communication. Therefore, to ensure the best possible communication, remember to consider the following points:

- The data connection works best when the communicator is in a stationary position. Attempting cellular communication while in a moving vehicle is not recommended. Fax transmission is more easily impaired than data or short message transmission.

- Do not place the communicator on a metal surface.

- Check that the cellular signal strength on the communicator displays is sufficient (see chapter 2 "Getting started: Communicator applications - Using the applications" on page 2-8 and chapter 13 "Phone interface: Display indicators" on page 13-2). Moving the communicator within a room especially towards a window, may result in a stronger signal. If the cellular signals are not strong enough to support a voice call, data connection should not be attempted until you can find a location with better signal reception.

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ABOUT US   WHAT WE DO   MEMBERSHIP

NEWSROOM

History

Brief History of GSM & the GSMA

1982
Groupe Speciale Mobile (GSM) is formed by the Confederation of European Posts and Telecommunications (CEPT) to design a pan-European mobile technology.

1984
France & Germany sign a joint development agreement for GSM.

1985

ATTACHMENT HH

1986

EU Heads of State endorse the GSM project. The European Commission initiatitive proposes to reserve 900MHz spectrum band for GSM, agreed in the EC Telecommunications Council.

Quadripartite agreement between France, Germany, Italy and the UK cooperation agreement signed (to support the standards work and exchange research data).

Trials of different digital radio transmission schemes and different speech codecs in several countries, with comparative evaluation by CEPT GSM in Paris.

1987

Basic parameters of the GSM standard agreed in February.

Proposal agreed by four ministers from the quadripartite countries to create an Operator Agreement in the form of a 'Memorandum of Understanding'. The 'MoU' was drawn up and signed in Copenhagen in September by 15 members from 13 countries that committed to deploying GSM.

1988

Completion of first set of detailed GSM specifications for infrastructure tendering purposes.

Simultaneous issue of invitation to tender for networks by ten GSM network operators – all subsequently signed in the same year.

1989

Groupe Speciale Mobile (transferred to an ETSI technical committee) defines the GSM standard as the internationally accepted digital cellular telephony standard.

The UK's Department of Trade & Industry (DTI) produced a document 'Phones on the Move' that first proposed PCN (Personal Communications Networks (later known as DCS 1800 and subsequently GSM 1800) networks to operate in the 1800 MGhz frequency band.

1990

GSM adaptation work started for the DCS1800 band.

1991

First GSM call made by Radiolinja in Finland.

1992

First international roaming agreement signed between Telecom Finland and Vodafone (UK).
First SMS sent.

1993

Telstra Australia becomes the first non-European operator to sign the GSM MoU 32 networks on air in 18 countries or territories

First truly hand portable terminals are launched commercially. World's first DCS1800 (later GSM1800) network opened in the UK.

1994
GSM Phase 2 data/fax bearer services launched
GSM MoU membership surpasses 100 operators
GSM subscribers hit one million.

1995
GSM MoU group is formally registered as the GSM MoU Association in Switzerland 117 networks on air.
Global GSM subscribers exceed 10 million.
GSM World Congress held in Madrid, Spain.
Formation of GSMA Regional Interest Groups (RIGs).
Fax, data and SMS services started, video over GSM demonstrated.
The first North American PCS 1900 (now GSM 1900) network opened – via a phone call by US Vice President Al Gore.

1996
First GSM networks in Russia and China go live.
Pre-paid GSM SIM cards launched.
GSM MoU membership approaches 200 operators from nearly 100 countries.
167 networks live in 94 countries.
GSM World Congress moves to Cannes, France.
GSM subscribers hit 50 million.
GSMA Awards launched.

1997
15 GSM networks on air in the USA using the 1900MHz band.
100 countries on air globally
First tri-band handsets launched.

1998
Global GSM subscribers surpass 100 million.

1999
WAP trials begin in France and Italy.
Contracts placed for GPRS systems.

2000
First commercial GPRS services launched.
3G license auctions commence.
First GPRS handsets enter the market.
Five billion SMS messages sent in one month.

ATTACHMENT HH

2001

First WCDMA (3GSM) network goes live.
3GSM World Congress held in Cannes, France.
Fifty billion SMS messages sent in first three months.
GSM subscribers exceed 500 million.
First mobile phone colour screens launched

2002

GSM introduced for 800MHz band.
First Multimedia Messaging Services go live.
95% of nations worldwide have GSM networks.
400 billion SMS messages sent in the year.
First mobile camera phones launched.

2003

First EDGE networks go live.
GSMA creates new CEO-level Board.
Membership of GSM Association breaks through 200-country barrier.
Over half a billion handsets produced in a year.

2004

GSM SURPASSES ONE BILLION CUSTOMERS.
More than 50 WCDMA networks live.
GSM Association and Ovum announce market data venture: Wireless
Intelligence.

2005

GSM surpasses 1.5 billion customers.
GSM accounts for 3/4 of global mobile market.
First HSDPA network goes live.
Over 100 WCDMA networks launched.
120+ WCDMA handset models launched or announced.
First ever sub-$30 mobile phone announced.
Over one trillion SMS sent in the year

2006

GSM SURPASSES TWO BILLION CUSTOMERS.
Over 120 commercial WCDMA networks in more than 50 countries and
almost 100 million subscriptions.
Approximately 85 HSDPA networks in commercial launch by year end.
66 HSDPA devices available from 19 suppliers, including 32 handset
models.
GSMA membership exceeds 900 companies (including over 700 operators).
Over 980 million handsets sold by year end.

2007

Further HSDPA network launches and introduction of HSUPA.
First GSMA Mobile Asia Congress held in Macau SAR, China.
GSMA celebrates 20th anniversary.

ATTACHMENT HH

2008
HSPA surpasses 50 million connections
191 HSPA networks live and 740 HSPA devices available
More than 55,000 visitors to the GSMA's Mobile World Congress in Barcelona.
GSM SURPASSES 3 BILLION CONNECTIONS
LTE standards completed
GSMA passes a resolution enabling LTE operators to join the Association
GLOBAL MOBILE CONNECTIONS SURPASS 4 BILLION

2009
First commercial HSPA+ network launched
First GSMA Mobile Asia Congress held in Hong Kong
First commercial LTE networks launched
More than 165 million HSPA connections worldwide
285 HSPA commercial networks supported by more than 1,600 HSPA devices

2010
GLOBAL MOBILE CONNECTIONS SURPASS 5 BILLION
More than 300 million HSPA connections worldwide
162 HSPA networks and 52 HSPA+ networks live
17 LTE commercial LTE networks
1.6 billion worldwide mobile device sales to end users

2011
More than 60,000 visitors to the Mobile World Congress in Barcelona
Anne Bouverot appointed as Director General of the GSMA
GSMA selects Barcelona as the Mobile World Capital
More than 500 million HSPA connections worldwide
GLOBAL MOBILE CONNECTIONS SURPASS 6 BILLION

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Working Groups

The Mobile Economy
NORTH AMERICA 2014

GSMA.

SMS Messages

2.8tn
2008

7.5tn
2012

28% CAGR

What We Do

Spectrum for Mobile Broadband	Personal Data Mobile Connect	Digital Commerce
		Network 2020
Public Policy	Mobile for Development	Rich Communications
Mobile Policy Handbook	Mobile for Development	HD Voice
Policy Case Studies	Impact	VoLTE
Capacity Building in	Digital Inclusion	
Mobile Sector Regulation	Mobile Money for the	OneAPI
Mobile and Privacy	Unbanked	
mYouth	Utilities	Managed Services
Mobile Energy Efficiency	mAgri	Number Portability
Tax	mHealth	Services
Roaming	Mobile for Employment	Spam Management &
Mobile and Health	Disaster Response	Prevention
Government Programme		Device Blacklist Services
Mobile and Environment	Connected Women	Device Model Characteristics
		Mobile Equipment
Smarter Apps Guidelines	Mobile Economy	Identity
GSMA Documents	Connected Living	
	Automotive	
	Learning	
	Health	
	Utilities	
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	Shanghai	

Mobile 360 Series
Industry Events

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Timeline:
Show Images

Year	Computer
1970	Datapoint 2200
1971	Kenbak-1
1972	HP-9830A NEW!
1973	Micral
	Scelbi-8H
1974	Mark-8
1975	MITS Altair 8800
	SwTPC 6800
	Sphere
	IMSAI 8080
	IBM 5100
1976	MOS KIM-1
	Sol-20
	Hewlett-Packard 9825
	PolyMorphic
	Cromemco Z-1
	Apple I
	The Digital Group
	Rockwell AIM 65
	Compucolor 8001
1977	ELF, SuperELF
	Wameco QM-1A
	Vector Graphic Vector-1
	RCA COSMAC VIP
	Apple II
	Commodore PET
	Radio Shack TRS-80
	Atari VCS (2600)
	NorthStar Horizon
	Heathkit H8
	Intel MCS-85
	Heathkit H11
1978	Bally Astrocade
	Netronics ELF II
	IBM 5110
	VideoBrain Family Computer
	Compucolor II
	Exidy Sorcerer
	Ohio Scientific Superboard II
	Synertek SYM-1
	Interact Model One
	Research Machines 380Z
	Magnavox Odyssey 2
	Cybervision 2001
	APF Imagination Machine
	Cromemco System 3
1979	Z80 Starter Kit
	TRS-80 model II
	Bell & Howell
	SwTPC S/09
	Heathkit H89
	Atari 400
	Atari 800
	TI-99/4
	Findex
	Sharp MZ 80K
	Intertec SuperBrain

AT&T EO 440
Personal Communicator

Available: April 1993

Price: US$1,999+

Size: 7x11x1 inches, 2.2 lbs

CPU: AT&T "Hobbit" @2MHz

Memory: 4-12MB RAM

Display: 4.3 x 6-inch monochrome LCD
7.5-inch diagonal
480 x 640 graphics

Ports: serial, parallel ports
PCMCIA, PS/2 keyboard

Storage: optional internal 20MB HD
optional external floppy drive
PCMCIA flash card

OS: GO PenPoint on 8MB ROM card

1980	HP-85
	Micro Ace
	IBM 5120
	TRS-80 Color Computer
	TRS-80 model III
	TRS-80 Pocket Computer
	NNC 80W
	Sinclair ZX80
1981	Dynabyte 5100
	TFC 3450 By Fujitsu
	Commodore VIC-20
	Sinclair ZX81
	Apple III
	Xerox 820
	Osborne 1
	Micro-Professor
	TI-99/4A
	IBM System/23
	IBM PC
	LNW-80
	Rockwell AIM 65/40
	BBC Micro
	NEC PC-6001A
1982	Timex Sinclair 1000
	Kaypro II
	Otrona Attache
	GRiD Compass 1101
	Victor 9000
	NEC APC
	SAGE II
	DEC Rainbow 100
	Sinclair ZX-Spectrum
	Lobo MAX-80
	Panasonic/ Quasar HHC
	Franklin Ace 100
	Franklin Ace 1000
	HP-75C
	Commodore 64
	Commodore B128
	Toshiba T100
	Epson HX-20
	Zorba
1983	Dynalogic Hyperion
	Compaq Portable
	TI CC-40
	Jupiter Ace
	Apple Lisa
	TRS-80 model 100 Kyotronic 85 Olivetti M-10 NEC PC-8201a
	Tomy Tutor
	Gavilan SC
	SAGE IV
	Altos 586
	Pied Piper
	Spectravideo CompuMate
	Mattel Aquarius
	Coleco Adam
	Timex Sinclair 1500
	TRS-80 MC-10
	Apple III Plus
	Visual Commuter
	TI Portable Professional
	Commodore SX-64

Internet

It took about six years from concept to fruition before you could purchase your own **EO-440 Personal Communicator** system - a portable, hand-held pen-only PDA (**P**ersonal **D**igital **A**ssistant) computer system with handwriting-recognition technology. When fully decked-out, the **EO-440** becomes the world's first phablet (phone + tablet) with wireless FAX, email, and cell phone capabilites.

With your **EO-440** you can calculate your budget, then FAX it directly to the office, while you relax at the beach; Write a stern memo, and e-mail it to multiple team members listed in your address book, with an attached audio message for additional vocal emphasis; Track daily tasks, appointments, and events in the Day Planner, then make a cell-phone call to confirm your reservations.

It all started in August of 1987 when GO Corporation was founded by Jerry Kaplan, formerly of Lotus Development Corp, to create his dream - a leading-edge, hand-held, pen-operated computer, which he first envisioned a few months earlier in February 1987.

After two years of work and million of dollars, in June of 1989, GO Corp. had a hobbled-together partially-working prototype to demonstrate to investing partners. State Farm Insurance and IBM were two of their largest potential customers.

After another two years, in April 1991, their PenPoint operating system "developers release" is completed and available to third-party developers. Designed to run on Intel CPU-based systems, it is an entirely new computer operating system, not just an addition to MS-DOS, utilizing a notebook-like user-interface with graphical icons, drag-and-drop capabilities, and dozens of simple pen-based gestures for document editing and on-screen navigation.

Later that year, BYTE magazine awards GO's PenPoint operating system their Award of Excellence in their annual Best Products edition.

While GO did produce a model G400 prototype, they were having difficulties developing both the software and hardware aspects, and to appease their largest investor - IBM, in July 1991 GO spun-off a separate and independant company named "EO Inc." ("eo" is Latin for "go") - GO would concentrate on the software, EO would produce and market the hardware. AT&T becomes a major investor in new EO, owning 20% of the company.

AT&T also buys Active Book Company, who is working on a simlar project, utilizing the ARM processor, just months from release. Active Book Company is dissolved and incorporated into EO. This new company will concentrate on producing a pen-based system using AT&T's new Hobbit CPU chipset, which was originally developed for the Apple Newton, a competing pen-based portable computer system from Apple Computer. Unsatisified with the Hobbit, the Apple Newton eventually went with the ARM processor instead.

In April of 1992, GO released PenPoint version 1.0 to all interested third-party developers. IBM announces their ThinkPad 700T (model 2521) hand-held pen-based tablet, running the PenPoint operating system, to ship in October 1992. NCR and GRiD also announce products running PenPoint OS.

Within 16 months of spinning-off from GO, EO's **440 Personal Communicator**, not yet for sale, was demonstrated in the AT&T booth at the Fall 1992 COMDEX show, in Las Vegas, NV. The industrial design (basically the ears on the sides to differentiate it from competitors) was by Frog Design, Inc.

1984	Apple Macintosh
	Sinclair QL
	IBM Portable
	TRS-80 model 200
	Epson PX-8
	Ampro Little Board
	IBM PCjr
	Apple IIc
	Sord IS-11
	HP 110
	Amstrad CPC
	Tano Dragon
	Data General One
	Morrow Pivot
	Tandy 1000
	Sharp PC-5000
1985	Atari 520ST
	Franklin Ace 2000
	Franklin Ace 500
	Osborne Vixen
	Kaypro 2000
	Amiga 1000
	Zenith Z-171
	Sharp PC-7000
	AT&T UNIX PC
	Toshiba T1100
	Amstrad PCW
1986	Compaq Portable II
	IBM Convertible
	Apple IIGS
1987	Zenith eazy PC
	Amiga 500
	Amiga 2000
	DynaMac
	Canon Cat
	Linus Write-Top
	Commodore 128D (USA)
	Compaq Portable III
1988	Apple IIc Plus
1989	Atari Portfolio
	Macintosh Portable
	Atari Stacy
	NeXT
	Atari ST Book
	Psion MC-600
	Zenith MinisPort
	GRiDPad
	Outbound

The **EO-440** and it's larger sibling the **EO-880** were available to the public on April of 1993. They were advanced but expensive, with the most basic system going for almost $2,000.

Every EO owner received a free subscription to AT&T EasyLink Mail for both fax and e-mail messages.
Included with and installed in every EO are these pen-based software packages:
- Pensoft Personal Perspective - an appointments calendar, address book, and information manager you use to manage time and monitor to-do items.
- EO Phone - dial the phone and place voice calls.
- EO Sound - add voice notes - sound recordings - to documents.
- EO Calc - a miniature "columnar pad" you use to work with numbers.
- EO Lock - provides password protection for the EO to keep your data secure.
- GO Mail - to send, receive, and work with electronic mail (e-mail) (requires 8MB RAM).
- GO Fax - send and receive group-3 compatible faxes (requires 8MB RAM).
- GO MiniNote - create simple graphics and handwritten notes in electronics ink.
- GO PenTOPS and PenCentral - allows exchange of data with IBM compatatible personal computers directly or remotely.

The AT&T Hobbit chipset is composed of four large chips, which consume a large portion of the system motherboard. Other prominent chips are by Wacom, for their electromagnetic resonance pen-sensing technology, with additional components incorporated into the LCD display.

The optional **EO-440** internal hard drive is the tiny and amazing Kittyhawk 20MB 1.3-inch micro-drive from Hewlett-Packard, at the time the smallest hard drive in the world. Fragile? No - a built-in accelerometer parks the drive heads to protect itself from hard falls, in fact making it the most reliable hard drive available. Kittyhawk was claimed to be able to survive a 3-foot drop onto concrete while operating without loss of data - perfect for use in a handheld portable computer system. The Dauphin DTR-1 from 1993 also utilized the tiny Kittyhawk hard drive.

For removeable mass storage, consider the SunDisk (not SanDisk) PCMCIA flash card, which allows quick and easy,

System	Price
EO-440 w/ 4MB RAM	$1,999
EO-880 w/ 4MB RAM	$2,499
internal 14.4K / FAX modem	$499
4MB RAM module	$299
8MB RAM mudule	$499
external floppy drive	$199
internal 20MB HD (EO-440)	$499
internal 64MB HD (EO-880)	$699
cell phone module	$799

Page 3 of 5

ATTACHMENT II
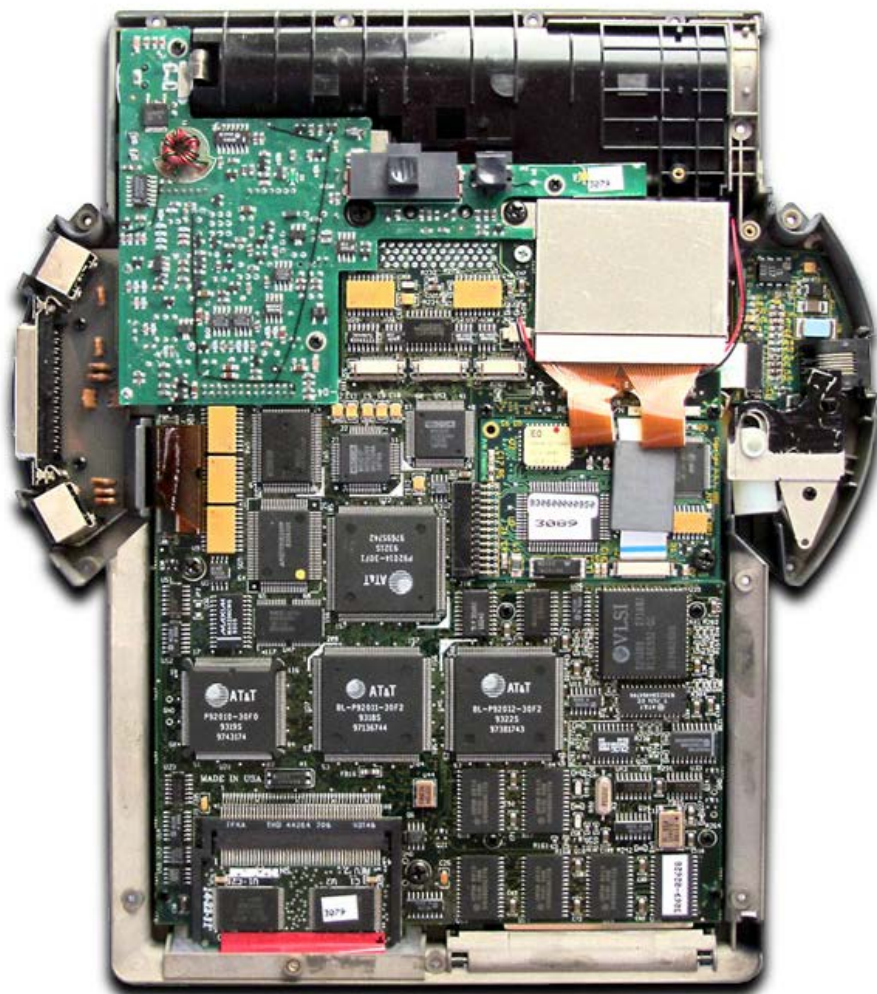
1990	Poqet PC
	Atari TT030
	Amiga 3000
1991	Commodore CDTV
	HP 95LX
	NCR-3125
	Macintosh PowerBook
1992	Amiga 600
	Zeos Pocket PC
	Amiga 4000
	Amiga 1200
	IBM ThinkPad
1993	AT&T EO 440
	Amstrad PenPad
	Dauphin DTR-1
	Apple Newton

GREEN=Acquired
RED=Wanted

Click on the blue text for more information

but very expensive, data storage expansion. Sizes available include: 1.8MB ($249), 5MB ($449), 10MB ($749), 20MB ($1,199).

The larger (13x9x1-inch, 4.0 lbs) and more powerful **EO-880** ($2,499) has a faster CPU - 30MHz instead of 20MHz, and a larger 9.4-inch display, which is backlit instead of reflective as in the **EO-440**. A larger 64MB hard drive ($699) as well as VGA, SCSI, and a second PCMCIA port round-out this powerful system.

Using the serial port and included software, Both **EO-440** and **EO-880** can communicate with IBM-compatible machines for sending and retrieving data.
The parallel port is to connect to laser and dot-matrix printers, and data storage on the optional external 3-1/2 inch 1.44MB floppy drive. A standard PS/2 connector allows the use of an external PC-compatible keyboard for heavy data entry.

GO and EO both had a hard time of it, though, as cheaper but less capable systems were available from other companies, and predatory Microsoft had effectively locked them out of the Intel-based market. In June of 1993, AT&T acquired a majority 51% stake in EO, and in August buys GO entirely, combining the two companies into EO, only to shut it down entirely in July 1994 when it was obvious that their products were selling poorly. It is estimated that about 10,000 EO systems were sold.

Kaplan, the founder of GO, wrote a book about his experiences at GO Corporation entitled "Startup--A Silicon Valley Adventure", published in May of 1995 by Houghton-Mifflin.

Related Links

- Excerpts from the book 'A History of Silicon Valley' from Piero Scaruffi
- About Tablet Computing, Old and New from Dan Bricklin
- The DigiBarn collection
- "I worked at EO..." from David Hembrow

- Personal Computer World review from David Tebbutt
- PC Magazine review, Aug 1993
- Office Depot sells the AT&T EO-440 - Dec 1993

- Go Computer, Inc. v. Microsoft Corp.
- Newly Released Documents Shed Light on Microsoft Tactics

- Videos:
- Introducing PenPoint - GO Corporation - 1991
- PenPoint Demonstration - GO Corporation - 1991
- Computer Chronicles PDA Review - 1993
- "Getting Acquainted With Your AT&T EO Personal Communicator" - 1993
- "AT&T - You will..." 1993 TV commercials
- Demonstration of PenPoint for ATT EO - 1994

ATTACHMENT II

Return to the Obsolete Technology Homepage

Enter comments for this page (all info will be made public):

Your name:	E-mail:	Location:

Comments:

If you're a human, type this word: **Lisa** in here-->>

Comments may be subject to approval by moderator before posted.

Lookup Guide

To the EO™ Personal Communicator
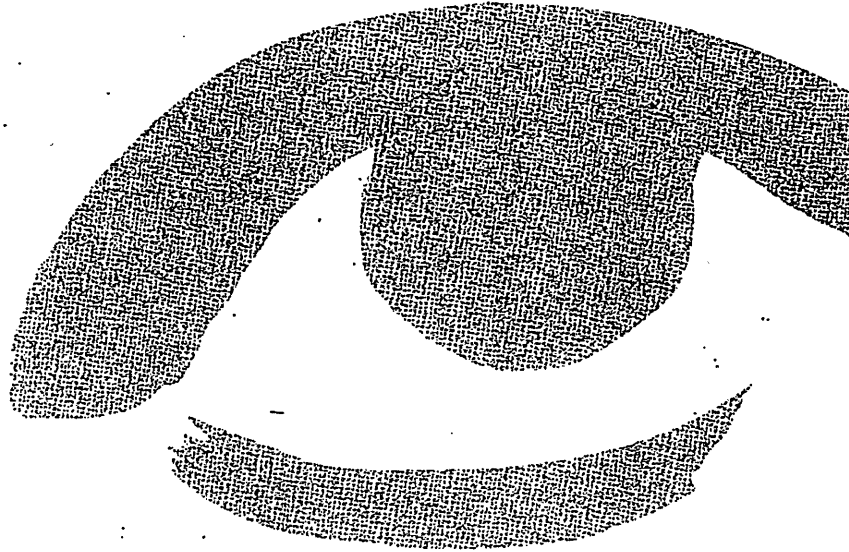
For Your Records

The serial number can be found on the label on the back of your
EO, printed just below the bar code. Record the serial number in
the space provided below. Refer to this number whenever you
contact EO Customer Service for assistance.

Serial Number: ☐☐ - ☐☐☐☐☐☐

Lookup Guide
To the EO™ Personal Communicator

Lookup Guide to the EO Personal Communicator

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EO Publications
This manual was written by Ann Cullen, under the direction of
Ted Barnett, Product Manager. The book was designed by
frogdesign.

Printed on recycled paper.

ii

Welcome

Welcome to the world of EO personal communications. This guide was designed to be used as a reference when you need information about your EO™ Personal Communicator 440 or EO™ Personal Communicator 880.

Where to Start

Your EO Personal Communicator (referred to in this guide as your EO) comes with a complete set of publications that introduce the EO and provide reference information when you need it.

First
Work through *Getting Started with Your EO Personal Communicator*. This guide shows you how to set up your EO, open on-screen tutorials, and become familiar with basic EO features. *Getting Started* also contains your owner registration card and registration instructions for AT&T Mail. As an EO owner, you're eligible for a free EO Preferred Mail Account on AT&T.

Second
Look through *The World of Messaging: An Introduction to Personal Communications*. This guide describes the AT&T EasyLink Services' AT&T Mail network and the free EO Preferred Account subscription for which you're eligible. *The Word of Messaging* also provides many tips on using fax and electronic mail messaging for more efficient, effective communications.

Third
Turn to this *Lookup Guide to the EO Personal Communicator* only when you need it. The *Lookup Guide* provides reference information and how-to instructions on hardware maintenance,

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Lookup Guide to the EO Personal Communicator
Welcome

power states, and battery replacement. It also provides detailed
instructions for using the applications that are built into the EO.

How to Use This Guide

This guide is a reference and how-to resource and is not meant
to be read straight through. To find the information you need,
follow these guidelines:

To look up general topics, refer to the table of contents
The table of contents lists section names and the topics within
sections, with page numbers. The table of contents is the place
to look for information in a general subject area.

To look up specific items, refer to the index
The index at the end of this guide provides page numbers for
specific topics, tasks, and features.

Flipping through the pages works, too
The running title at the bottom of each page shows you the
name of the major topic covered on that page.

Boldfaced words are defined in the dictionary
The EO Dictionary near the end of this guide lists definitions for
words that appear in **boldface** in the guide.

On-screen help is a question mark away
As you use your EO, remember that you can get help on many
topics by writing a question mark anywhere on the screen.

If You Don't Read Manuals

If you don't read manuals, here are a few suggestions for a
quick introduction.

iv How to Use This Guide
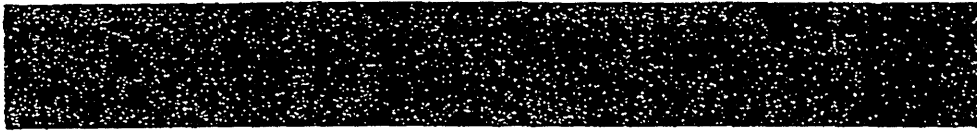
Work through the introductory on-screen tutorials
The on-screen tutorials are short and very helpful in learning to use the EO pen and pen gestures. At the least, you should work through the on-screen lessons in "Gesture Practice" and "Handwriting Practice." For instructions on opening these lessons, refer to *Getting Started with Your EO Personal Communicator*.

Don't miss important information about power
Getting Started with Your EO Personal Communicator provides important information about restoring the charge to the main battery, about using the power adapter, and about setting up for phone communications.

If You're an Experienced Mouse User

The pen is not a mouse. If you're an experienced mouse user, you may be tempted to use the EO pen as you would a mouse button. Although tapping with the pen is similar to clicking a mouse button, many conventions are different. For example, a double tap with the pen may have a different effect than a double click with a mouse. Generally you need to tap an item only once to open it. Also, you should avoid the temptation to "close" the Notebook. Use the tabs to move to the Table of Contents.

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6

For voice and data calls, you set up a dialing location sheet
For voice calls, e-mail, and faxes, you set up a dialing location sheet that tells the EO where you are—your current phone number, time zone, and area code. You set up the dialing location sheet once and modify the sheet only if you change locations.

You address messages and send them to the Outbox
You address e-mail and faxes and then send them to the EO Outbox. E-mail and faxes can collect in the Outbox until it's convenient for you to transmit them.

The Inbox collects incoming messages
When you connect to AT&T Mail or another service, the EO receives any incoming messages from your account and places the messages in your Inbox. Incoming messages remain in the Inbox until you move them elsewhere or delete them.

Deciding Between E-mail and Fax

Electronic mail (e-mail) and faxing involve different technologies. The differences are important when you decide whether you want to send a message by e-mail or by fax. For detailed information on this topic, refer to *The World of Messaging: An Introduction to Personal Communications.*

E-mail messages generally contain only text, although you can send ink documents to other PenPoint users. Because they are usually text-based, most e-mail messages are much smaller than faxes. When a message is small, you save time and money because transmission time is shorter.

A fax message contains a digitized image—an electronic picture—of whatever is on a page. Digitized images can be very large, so a fax occupies more storage space and may require significant transmission time. But a fax has the advantage of conveying a picture, for example, or a personal note.

96   Deciding Between E-mail and Fax

A special benefit of faxing is that you can send a fax to anyone who has an ordinary phone-based fax machine. E-mail can only be received by someone who has an e-mail account or a personal communicator.

Setting Up for Communications

This topic gives instructions for connecting the EO to a phone line. If you worked through *Getting Started with Your EO Personal Communicator*, you've probably already completed these steps.

To connect a standard phone line

1. Take the EO phone cord and duplex phone jack out of the Accessory Kit.

   Special phone cord The EO phone cord has a small "bump" near one end of the cord. This bump contains electronics that help reduce electrical emissions during telephone transmissions. Whenever you connect your EO to a phone jack, you should use the EO phone cord provided and make sure that the end nearest the bump is plugged into the EO.

2. Unplug the existing phone cord from its wall outlet and plug the duplex jack into the wall outlet.
   Using the duplex jack allows you to keep both the EO and a standard phone connected to the wall outlet.

Duplex jack

Setting Up for Communications   97

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6
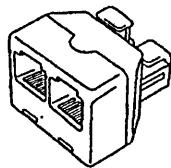
3. **Insert the existing phone cord into one side of the duplex jack.**

4. **Insert the non-bump end of the EO phone cord into the other side of the duplex jack.**
   For an explanation of the bump, refer to the note on the previous page.

5. **Insert the bump end of the EO phone cord into the phone port of the EO.**
   The phone port is on the right side of the EO as you face the screen. A telephone icon identifies the port.

> *Standby You may find that connecting the phone line turns the EO on if it was in Standby and set up to receive faxes. If this happens, simply press the On/Standby button to return to Standby.*

Attaching the
phone line

Phone port
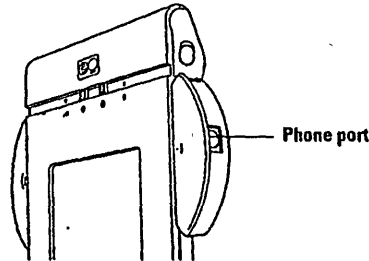
To set up an EO Cellular Module

Refer to *Connecting with Your EO Cellular Module* and return to this section when you've attached the phone.
The EO Cellular Module comes with a complete guide to assembling, attaching, and using the phone.

Using GO Mail

Before you can send and receive e-mail messages through your EO Preferred AT&T Mail Account, you need to specify certain settings for the GO Mail application and for AT&T Mail.

> *Other services This topic describes setup for the AT&T Mail service. If you add a different service you may need to change some of the options to match that service's requirements.*

You can set up automatic connections so that you can receive mail at any time. For example, you can set up your EO to connect to AT&T Mail every night at 3:00 A.M. and receive messages while you're asleep.

To set up GO Mail in the Outbox

1. Tap ⋎ the Outbox icon to open the Outbox notebook.

2. Draw a check mark ✓ over the GO Mail title.
   You see the GO Mail options sheet.

Specifying GO
Mail options
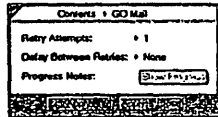
3. Choose the options you want from the retry pop-up lists and tap ⋎ Apply.
   The option sheet remains open.

4. Tap the arrow in the option sheet title line and choose Dialing Location from the pop-up list.
   The Dialing Location sheet opens.

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GO Mail and GO Fax

Specifying
where you are

Contents ▸ Dialing Location
Fill in the information below. This tells PenPoint how to dial phone numbers from your current location.
Where are you now?   ▸ USA or Canada
Area Code: 415
Need an outside line?   ▸ No
Using a Calling Card?   ▸ No
What access numbers do you need to dial?
Long Distance: 1
International: 011
What type of phone line are you using?
Dial Type: ▸ Tone

You need to complete this sheet only once, unless you change
locations. For example, if you change countries, you need to
update the country code. You also need to change the outside
line setting if, for example, you move from an office setting
where an outside line is required to a home setting where you're
using a standard phone line.

There is only one Dialing Location sheet. Whether it appears
with GO Mail, Go Fax, or EO Phone, it is the same sheet.
Changes made in any application will affect all others.

5. **Fill in your area code and other information on the Dialing
Location sheet.**
The EO translates as you go. If you need to make a correction,
draw a circle ○ gesture over a word or number to open an
editing pad and make your corrections there.

If you're using a credit card, tap ⋎ Yes and add your card
number.

6. **When the sheet is complete, tap ⋎ Apply & Close.**

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To set up for AT&T Mail

1. In the Outbox, draw a check mark ✓ over the GO Mail title.
   You see the GO Mail options sheet

2. Tap ⌄ the arrow in the option sheet title line and tap AT&T Mail
   in the pop-up list.
   The AT&T Setup options sheet opens.

Setting up for AT&T Mail

In Canada: Change the
preset AT&T Mail
number to 416-502-3000

Phone line or
wireless (cellular)

For other access numbers outside the United States, refer
to *The World of Messaging: An Introduction to Personal
Communications.*

3. Fill in the setup sheet using the information supplied in the
   AT&T Mail welcome kit.
   This information includes your user name and password and the
   AT&T Mail 800 phone number.

4. In the Modem pop-up list, specify the type of connection you
   plan to use.
   - Tap ⌄ Phone Line for a standard phone line.
   - Tap ⌄ Wireless for an EO Cellular Module.

5. Tap ⌄ Apply & Close.

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GO Mail and GO Fax

Setting other AT&T Mail options

To do this	Do this
Switch the modem speaker on and off	In the Outbox, tap ⅄ GO Mail to select the name and choose AT&T Setup from the Options menu. In the AT&T Mail title line, choose Modem Settings from the pop-up list. Tap ⅄ the option you want and then tap ⅄ Apply & Close.
Change the modem speaker volume	In the Outbox, tap ⅄ GO Mail to select the name and choose AT&T Setup from the Options menu. In the AT&T Mail title line, choose Modem Settings from the pop-up list. Tap ⅄ the option you want and then tap ⅄ Apply & Close.
Schedule GO Mail to send and receive messages automatically at times that you choose.	In the Outbox, tap ⅄ GO Mail to select the name and choose AT&T Setup from the Options menu. In the AT&T Mail title line, choose Link Scheduling from the pop-up list. Tap ⅄ to turn on Link Scheduling and then tap ⅄ the days and times you wish to link. The times apply for every selected day.

Addressing E-mail Messages

To send a document by e-mail, you first address the item and send it to the Outbox. For convenience you can batch messages in the Outbox and transmit them all at once.

To prepare a document for mail

1. **Open the document you want to send (for example, a MiniText document).**
   You can also select the document title in the Table of Contents.

2. **Choose Send > GO Mail from the Document menu.**
   You see the GO Mail message sheet, with a request that you choose a format for the document you're sending. The formats

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available depend on the type of document you're sending and
on the type of equipment the recipient uses.

Choosing a format

Format

Reference document
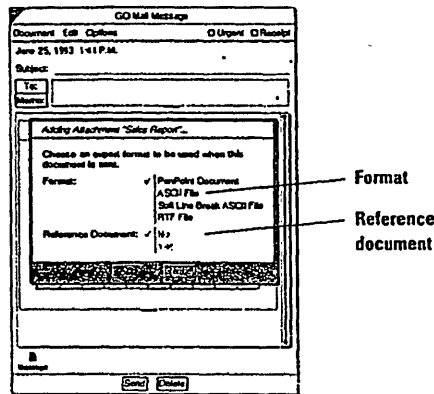
3. **If you're sending to another EO owner, tap ⸙ PenPoint Document.**
   Refer to "File formats," on page 105, for tips on the other formats that may be available.

4. **To include any changes to the document that you make before you transmit the message, tap ⸙ Yes under Reference Document.**

5. **Tap ⸙ Add**
   Icons for the cover message and the document you're sending appear in the Enclosures area.

> *Reference Document The Reference Document option allows you to set up GO Mail to transmit the latest version of the document, if you've made changes since you attached the document. This option is only available when you drag a document into the enclosures area.*

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Lookup Guide to the EO Personal Communicator
GO Mail and GO Fax

Message
sheet

Cover message (tap Y
Memo to open)

Document you're sending

To address an e-mail message

1. **Write a short name for the message in the Subject line and select message options.**

   • To set a priority for the message, tap Y Urgent.

   • To request acknowledgment of your message, tap Y Receipt.

2. **Write a cover message if you wish.**
   Tap Y the Memo button if you want to use full MiniText menus to edit or style the cover message.

3. **Tap Y the To button.**
   A Recipient sheet opens. The preset Recipient sheet is for AT&T Mail. If you add another service, the Link pop-up list gives you a choice of services.

Addressing a
message

104   Addressing E-mail Messages
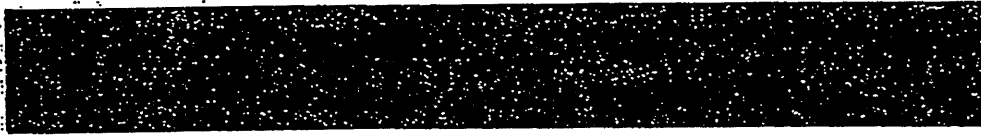
- To send the message to AT&T Mail, leave the Link
  option as is.

- To choose another service, tap ⋎ its name in the Link
  pop-up list.

You can send e-mail to contacts who use other mail systems if
you know the correct addresses. You must also know how to
format the address. For more information on addressing, refer to
*The World of Messaging: An Introduction to Personal
Communications*.

4. **Write the recipient's first name, last name, and e-mail address,
   and tap ⋎ Add Recipient.**
   The AT&T Address line is preset with an exclamation point (!).
   If you're sending to an address that doesn't require the
   exclamation point, draw a circle ○ over the address line and
   write the correct address in the editing pad.

5. **When you've finished addressing the message, tap ⋎ Send.**
   The EO sends the message to the Outbox.

> *Start Links If you previously enabled GO Mail
> in the Outbox, you see a Start Links message.
> Tap ⋎ Start to transmit the message
> immediately. For information, refer to
> "Transmitting E-mail Messages," on page 108.*

File formats

Format	Choose if
PenPoint Document	You're sending to an EO owner or to someone who has another PenPoint computer.
ASCII File	The recipient has a non-PenPoint computer (for example, a desktop PC). The most commonly accepted format.
Soft Line Break ASCII File	This format is specified by the recipient.

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GO Mail and GO Fax

Format	Choose if
Text File	The recipient has a non-PenPoint computer. Note that if you attempt to e-mail an ink document as text (for example, a MiniNote page with scribbled ink on it), the EO will attempt to translate the ink into text before sending.
Perspective Data	You're sending a Perspective document to another EO (or PenPoint) user.
ASCII Delimited	You're sending a Perspective document to a non-PenPoint user.
RTF File	The recipient uses Microsoft Windows or an Apple Macintosh.
TIFF	You're faxing an ink document.

To send a Quick Message

1. **Make sure that no documents are open and that nothing is selected in the Table of Contents.**

2. **Choose Send > GO Mail from the Document menu.**
   You see the GO Mail Message sheet, with its boxed pad.

3. **Print your message in the boxed pad, tap Y OK to translate, and make any corrections required.**
   If you need to correct a name, draw a circle ○ gesture around the translated name to open an editing pad and make corrections there.

4. **Tap Y To to open the Recipient sheet, then address the message.**
   For details, refer to "Setting Up for Communications," on page 97.

5. **When you've finished the message and addressed it, tap Y Send.**
   The EO sends only the Quick Message to the Outbox, without enclosures.

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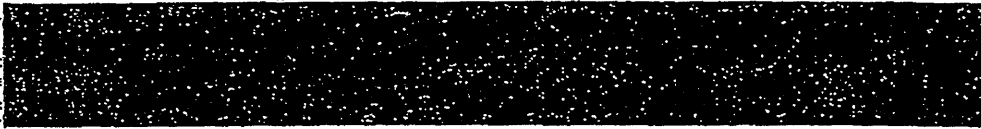
Messages in
the Outbox
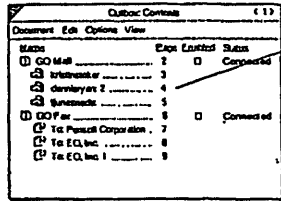
Mail messages

Addressing tips for e-mail

To do this	Do this
Add a recipient using the Address Book	Tap the Address Book icon, select a name, and tap Add Recipient.
Copy an entry from the Recipient sheet to the Address Book	Tap Add to Address Book.
Find a name you don't see in the Address Book	Scroll the list, or write the first few letters of the last name in the Find field.
Add a new recipient to the list by hand	Draw a caret $\wedge$ gesture in the list to open a Recipient sheet. (If you see the Address Book view, tap the Address Book icon to switch back to the Recipient sheet. Add the recipient name and tap Add Recipient.
Edit a recipient's name or address	Draw a circle $\circ$ over the name to open the Recipient sheet and make the changes there.
Send a copy to someone else,	In the Recipient sheet, tap cc: (copy with name attached) or bcc: (blind copy, no name attached).
Set a time to send the message	Choose When to Send from the Options menu. You can specify that the message be sent immediately, when you connect, on a certain day and time, or at daily or weekly intervals.
Add a document to the Enclosures area	Float the Table of Contents (double tap the Contents tab), and then drag the document into the Enclosures area of the envelope.
Delete a message from the Outbox	Open the Outbox and draw a cross-out χ gesture over the Message name.

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TIFF ™

Revision 6.0

Final — June 3, 1992

Adobe Developers Association

Adobe Systems Incorporated
1585 Charleston Road
P.O. Box 7900
Mountain View, CA   94039-7900

E-Mail: devsup-person@adobe.com

A copy of this specification can be found in

http://www.adobe.com/Support/TechNotes.html

and

ftp://ftp.adobe.com/pub/adobe/DeveloperSupport/
TechNotes/PDFfiles

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Production Notes

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Contents

Introduction

About this Specification

This document describes TIFF, a tag-based file format for storing and interchanging raster images.

History

The first version of the TIFF specification was published by Aldus Corporation in the fall of 1986, after a series of meetings with various scanner manufacturers and software developers. It did not have a revision number but should have been labeled Revision 3.0 since there were two major earlier draft releases.

Revision 4.0 contained mostly minor enhancements and was released in April 1987. Revision 5.0, released in October 1988, added support for palette color images and LZW compression.

Scope

TIFF describes image data that typically comes from scanners, frame grabbers, and paint- and photo-retouching programs.

TIFF is not a printer language or page description language. The purpose of TIFF is to describe and store raster image data.

A primary goal of TIFF is to provide a rich environment within which applications can exchange image data. This richness is required to take advantage of the varying capabilities of scanners and other imaging devices.

Though TIFF is a rich format, it can easily be used for simple scanners and applications as well because the number of required fields is small.

TIFF will be enhanced on a continuing basis as new imaging needs arise. A high priority has been given to structuring TIFF so that future enhancements can be added without causing unnecessary hardship to developers.

Features

- TIFF is capable of describing bilevel, grayscale, palette-color, and full-color image data in several color spaces.

- TIFF includes a number of compression schemes that allow developers to choose the best space or time tradeoff for their applications.

- TIFF is not tied to specific scanners, printers, or computer display hardware.

- TIFF is portable. It does not favor particular operating systems, file systems, compilers, or processors.

- TIFF is designed to be extensible—to evolve gracefully as new needs arise.

- TIFF allows the inclusion of an unlimited amount of private or special-purpose information.

Revision Notes

Minor changes to TIFF 6.0, March 1995

Updated contact information and TIFF administration policies, since Aldus Corporation merged with Adobe Systems Incorporated on September 1, 1994.

The technical content and pagination are unchanged from the original June 3, 1992 release.

TIFF 5.0 to TIFF 6.0

This revision replaces TIFF Revision 5.0.

In the main body of the document, paragraphs that contain new or substantially-changed information are shown in italics.

New Features in Revision 6.0

Major enhancements to TIFF 6.0 are described in Part 2. They include:

- CMYK image definition
- A revised RGB Colorimetry section.
- YCbCr image definition
- CIE L*a*b* image definition
- Tiled image definition
- JPEG compression

Clarifications

- The LZW compression section more clearly explains when to switch the coding bit length.
- The interaction between Compression=2 (CCITT Huffman) and PhotometricInterpretation was clarified.
- The data organization of uncompressed data (Compression=1) when BitsPerSample is greater than 8 was clarified. See the Compression field description.
- The discussion of CCITT Group 3 and Group 4 bilevel image encodings was clarified and expanded, and Group3Options and Group4Options fields were renamed T4Options and T6Options. See Section 11.

Organizational Changes

- To make the organization more consistent and expandable, appendices were transformed into numbered sections.
- The document was divided into two parts—Baseline and Extensions—to help developers make better and more consistent implementation choices. Part 1, the Baseline section, describes those features that all general-purpose TIFF readers should support. Part 2, the Extensions section, describes a number of features that can be used by special or advanced applications.
- An index and table of contents were added.

Changes in Requirements

- To illustrate a Baseline TIFF file earlier in the document, the material from Appendix G ("TIFF Classes") in Revision 5 was integrated into the main body of the specification . As part of this integration, the TIFF Classes terminology was replaced by the more monolithic Baseline TIFF terminology. The intent was to further encourage all mainstream TIFF readers to support the Baseline TIFF requirements for bilevel, grayscale, RGB, and palette-color images.
- Due to licensing issues, LZW compression support was moved out of the "Part 1: Baseline TIFF" and into "Part 2: Extensions."
- Baseline TIFF requirements for bit depths in palette-color images were weakened a bit.

Changes in Terminology

In previous versions of the specification, the term "tag" reffered both to the identifying number of a TIFF field and to the entire field. In this version, the term "tag" refers only to the identifying number. The term "field" refers to the entire field, including the value.

Compatibility

Every attempt has been made to add functionality in such a way as to minimize compatibility problems with files and software that were based on earlier versions of the TIFF specification. The goal is that TIFF files should never become obsolete and that TIFF software should not have to be revised more frequently than absolutely necessary. In particular, Baseline TIFF 6.0 files will generally be readable even by older applications that assume TIFF 5.0 or an earlier version of the specification.

However, TIFF 6.0 files that use one of the major new extensions, such as a new compression scheme or color space, will not be successfully read by older software. In such cases, the older applications must gracefully give up and refuse to import the image, providing the user with a reasonably informative message.

TIFF Administration

Information and Support

The most recent version of the TIFF specification is available in PDF format on the Adobe WWW and ftp servers See the cover page of the specification for the required addresses.

Because of the widespread use of TIFF for in many environments, Adobe is unable to provide a general consulting service for TIFF implementors. TIFF developers are encouraged to study sample TIFF files, read TIFF documentation thoroughly, and work with developers of other products that are important to you.

If your TIFF question specifically concerns compatibility with an Adobe Systems product, please contact Adobe Developer Support at devsup-person@adobe.com.

Most companies that use TIFF can answer questions about support for TIFF in their products. Contact the appropriate product manager or developer support service group.

Private Fields and Values

An organization might wish to store information meaningful to only that organization in a TIFF file. Tags numbered 32768 or higher, sometimes called private tags, are reserved for that purpose.

Upon request, the TIFF administrator (send email to devsup-person@adobe.com) will allocate and register one or more private tags for an organization, to avoid possible conflicts with other organizations. You do not need to tell the TIFF administrator what you plan to use them for, but giving us this information may help other developers to avoid some duplication of effort. We will likely make the tag database public at some point.

Private enumerated values can be accommodated in a similar fashion. For example, you may wish to experiment with a new compression scheme within TIFF. Enumeration constants numbered 32768 or higher are reserved for private usage. Upon request, the administrator will allocate and register one or more enumerated values for a particular field (Compression, in our example), to avoid possible conflicts.

Tags and values allocated in the private number range are not prohibited from being included in a future revision of this specification. Several such instances exist in the current TIFF specification.

Do not choose your own tag numbers. Doing so could cause serious compatibility problems in the future. However, if there is little or no chance that your TIFF files will escape your private environment, please consider using TIFF tags in the "reusable" 65000-65535 range. You do not need to contact Adobe when using numbers in this range.

If you need more than 10 tags, we suggest that you reserve a single private tag, define it as a LONG TIFF data type, and use its value as a pointer (offset) to a private IFD or other data structure of your choosing. Within that IFD, you can use whatever tags you want, since no one else will know that it is an IFD unless you tell them.

Submitting a Proposal

Any person or group that wants to propose a change or addition to the TIFF specification should prepare a proposal that includes the following information:

- Name of the person or group making the request, and your affiliation.
- The reason for the request.
- A list of changes exactly as you propose that they appear in the specification. Use inserts, callouts, or other obvious editorial techniques to indicate areas of change, and number each change.
- Discussion of the potential impact on the installed base.
- A list of contacts outside your company that support your position. Include their affiliation.

Please send your proposal to devsup-person@adobe.com.

The TIFF Advisory Committee

The TIFF Advisory Committee is a working group of TIFF experts from a number of hardware and software manufacturers. It was formed in the spring of 1991 to provide a forum for debating and refining proposals for the 6.0 release of the TIFF specification.

If you are a TIFF expert and think you have the time and interest to work on this committee, contact devsup-person@adobe.com for further information. For the TIFF 6.0 release, the group met every two or three months, usually on the west coast of the U.S. Accessibility via Internet email is a requirement for membership, since that has proven to be an invaluable means for getting work done between meetings.

Other TIFF Extensions

~~The Aldus TIFF sections on CompuServe and AppleLink~~ (new location is under construction; check the Adobe WWW home page (http://www.adobe.com) for future developements) will contain proposed TIFF extensions from other companies that are not approved by Adobe as part of Baseline TIFF.

These proposals typically represent specialized uses of TIFF that do not fall within the domain of publishing or general graphics or picture interchange. Generally, these features will not be widely supported. If you do write files that incorporate these extensions, be sure to either not call them TIFF files or mark them in some way so that they will not be confused with mainstream TIFF files.

If you have such a document, send it to devsup-person@adobe.com. All submissions must be PDF documents or simple text. Be sure to include contact information—at least an email address.

Part 1: Baseline TIFF

The TIFF specification is divided into two parts. Part 1 describes *Baseline TIFF*.
Baseline TIFF is the core of TIFF, the essentials that all mainstream TIFF devel-
opers should support in their products.

Section 1: Notation

Decimal and Hexadecimal

Unless otherwise noted, all numeric values in this document are expressed in decimal. (".H" is appended to hexidecimal values.)

Compliance

Is and *shall* indicate mandatory requirements. All compliant writers and readers must meet the specification.

Should indicates a recommendation.

May indicates an option.

Features designated 'not recommended for general data interchange' are considered extensions to Baseline TIFF. Files that use such features shall be designated "Extended TIFF 6.0" files, and the particular extensions used should be documented. A Baseline TIFF 6.0 reader is not required to support any extensions.

Section 2: TIFF Structure

TIFF is an image file format. In this document, a *file* is defined to be a sequence of 8-bit bytes, where the bytes are numbered from 0 to N. The largest possible TIFF file is 2**32 bytes in length.

A TIFF file begins with an 8-byte *image file header* that points to an *image file directory* (*IFD*). An image file directory contains information about the image, as well as pointers to the actual image data.

The following paragraphs describe the image file header and IFD in more detail.

See Figure 1.

Image File Header

A TIFF file begins with an 8-byte image file header, containing the following information:

Bytes 0-1:   The byte order used within the file. Legal values are:

"II"   (4949.H)

"MM" (4D4D.H)

In the "II" format, byte order is always from the least significant byte to the most significant byte, for both 16-bit and 32-bit integers This is called *little-endian* byte order. In the "MM" format, byte order is always from most significant to least significant, for both 16-bit and 32-bit integers. This is called *big-endian* byte order.

Bytes 2-3   An arbitrary but carefully chosen number (42) that further identifies the file as a TIFF file.

The byte order depends on the value of Bytes 0-1.

Bytes 4-7   The offset (in bytes) of the first IFD. The directory may be at any location in the file after the header but *must begin on a word boundary*. In particular, an Image File Directory may follow the image data it describes. Readers must follow the pointers wherever they may lead.

The term *byte offset* is always used in this document to refer to a location with respect to the beginning of the TIFF file. The first byte of the file has an offset of 0.

Figure 1

Header		
0		Byte Order
2		42
4	A	Offset of 0th IFD
6		

	Directory Entry	
X		Tag
X+2		Type
X+4		Count
X+8		Value or Offset

IFD		
A	B	Number of Directory Entries
A+2		Directory Entry 0
A+14		Directory Entry 1
A+26		Directory Entry 2
A+2+B*12		Offset of next IFD

	Value
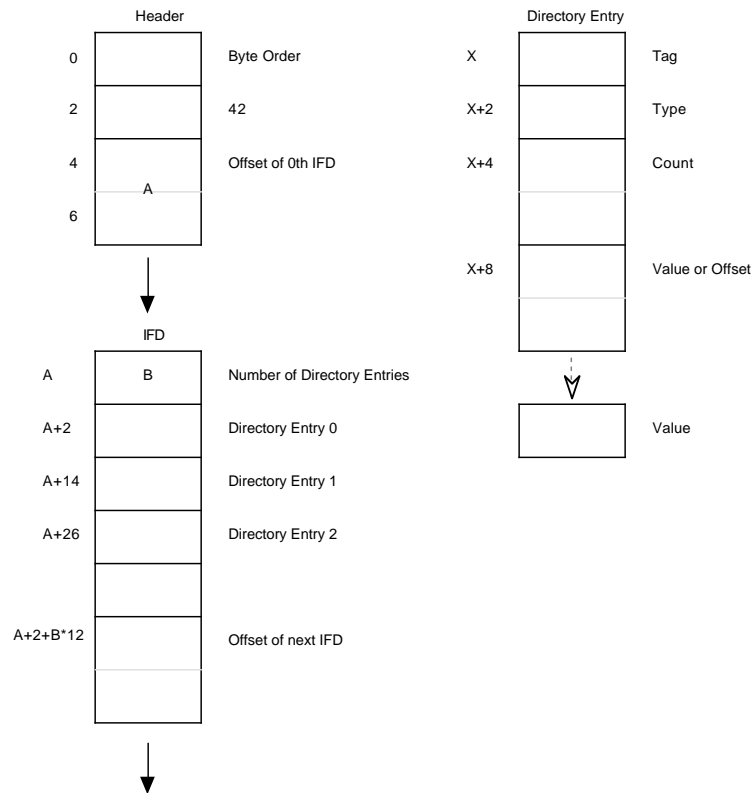
Image File Directory

An *Image File Directory* (*IFD*) consists of a 2-byte count of the number of direc-
tory entries (i.e., the number of fields), followed by a sequence of 12-byte field
entries, followed by a 4-byte offset of the next IFD (or 0 if none). (Do not forget to
write the 4 bytes of 0 after the last IFD.)

There must be at least 1 IFD in a TIFF file and each IFD must have at least one
entry.

See Figure 1.

IFD Entry

Each 12-byte IFD entry has the following format:

Bytes 0-1   The Tag that identifies the field.

Bytes 2-3   The field Type.

Bytes 4-7   The number of values, *Count* of the indicated Type.

Bytes 8-11   The Value Offset, the file offset (in bytes) of the Value for the field. The Value is expected to begin on a word boundary; the corresponding Value Offset will thus be an even number. This file offset may point anywhere in the file, even after the image data.

IFD Terminology

A *TIFF field* is a logical entity consisting of TIFF tag and its value. This logical concept is implemented as an *IFD Entry*, plus the actual value if it doesn't fit into the value/offset part, the last 4 bytes of the IFD Entry. The terms *TIFF field* and *IFD entry* are interchangeable in most contexts.

Sort Order

The entries in an IFD must be sorted in ascending order by Tag. Note that this is not the order in which the fields are described in this document. The Values to which directory entries point need not be in any particular order in the file.

Value/Offset

To save time and space the Value Offset contains the Value instead of pointing to the Value if and only if the Value fits into 4 bytes. If the Value is shorter than 4 bytes, it is left-justified within the 4-byte Value Offset, i.e., stored in the lower-numbered bytes. Whether the Value fits within 4 bytes is determined by the Type and Count of the field.

Count

Count—called *Length* in previous versions of the specification—is the number of values. Note that Count is not the total number of bytes. For example, a single 16-bit word (SHORT) has a Count of 1; not 2.

Types

The field types and their sizes are:

1 = BYTE	8-bit unsigned integer.
2 = ASCII	8-bit byte that contains a 7-bit ASCII code; the last byte must be NUL (binary zero).
3 = SHORT	16-bit (2-byte) unsigned integer.
4 = LONG	32-bit (4-byte) unsigned integer.
5 = RATIONAL	Two LONGs: the first represents the numerator of a fraction; the second, the denominator.

The value of the Count part of an ASCII field entry includes the NUL. If padding is necessary, the Count does not include the pad byte. Note that there is no initial "count byte" as in Pascal-style strings.

Any ASCII field can contain multiple strings, each terminated with a NUL. A single string is preferred whenever possible. The Count for multi-string fields is the number of bytes in all the strings in that field plus their terminating NUL bytes. Only one NUL is allowed between strings, so that the strings following the first string will often begin on an odd byte.

The reader must check the type to verify that it contains an expected value. TIFF currently allows more than 1 valid type for some fields. For example, ImageWidth and ImageLength are usually specified as having type SHORT. But images with more than 64K rows or columns must use the LONG field type.

TIFF readers should accept BYTE, SHORT, or LONG values for any unsigned integer field. This allows a single procedure to retrieve any integer value, makes reading more robust, and saves disk space in some situations.

In TIFF 6.0, some new field types have been defined:

6 = SBYTE	An 8-bit signed (twos-complement) integer.
7 = UNDEFINED	An 8-bit byte that may contain anything, depending on the definition of the field.
8 = SSHORT	A 16-bit (2-byte) signed (twos-complement) integer.
9 = SLONG	A 32-bit (4-byte) signed (twos-complement) integer.
10 = SRATIONAL	Two SLONG's: the first represents the numerator of a fraction, the second the denominator.
11 = FLOAT	Single precision (4-byte) IEEE format.
12 = DOUBLE	Double precision (8-byte) IEEE format.

These new field types are also governed by the byte order (II or MM) in the TIFF header.

Warning: It is possible that other TIFF field types will be added in the future. Readers should skip over fields containing an unexpected field type.

Fields are arrays

Each TIFF field has an associated Count. This means that all fields are actually one-dimensional arrays, even though most fields contain only a single value.

For example, to store a complicated data structure in a single private field, use the UNDEFINED field type and set the Count to the number of bytes required to hold the data structure.

Multiple Images per TIFF File

There may be more than one IFD in a TIFF file. Each IFD defines a *subfile*. One potential use of subfiles is to describe related images, such as the pages of a fac-simile transmission. A Baseline TIFF reader is not required to read any IFDs beyond the first one.

Section 3: Bilevel Images

Now that the overall TIFF structure has been described, we can move on to filling the structure with actual fields (tags and values) that describe raster image data.

To make all of this clearer, the discussion will be organized according to the four Baseline TIFF image types: bilevel, grayscale, palette-color, and full-color images. This section describes bilevel images.

Fields required to describe bilevel images are introduced and described briefly here. Full descriptions of each field can be found in Section 8.

Color

A bilevel image contains two colors—black and white. TIFF allows an application to write out bilevel data in either a white-is-zero or black-is-zero format. The field that records this information is called PhotometricInterpretation.

PhotometricInterpretation

Tag   = 262 (106.H)

Type   = SHORT

Values:

0 =   WhiteIsZero. For bilevel and grayscale images: 0 is imaged as white. The maximum value is imaged as black. This is the normal value for Compression=2.

1 =   BlackIsZero. For bilevel and grayscale images: 0 is imaged as black. The maximum value is imaged as white. If this value is specified for Compression=2, the image should display and print reversed.

Compression

Data can be stored either compressed or uncompressed.

Compression

Tag   = 259 (103.H)

Type   = SHORT

Values:

1 =   No compression, but pack data into bytes as tightly as possible, leaving no unused bits (except at the end of a row). The component values are stored as an array of type BYTE. Each scan line (row) is padded to the next BYTE boundary.

2 =   CCITT Group 3 1-Dimensional Modified Huffman run length encoding. See

Section 10 for a description of Modified Huffman Compression.

32773 = PackBits compression, a simple byte-oriented run length scheme. See the PackBits section for details.

Data compression applies only to raster image data. All other TIFF fields are unaffected.

Baseline TIFF readers must handle all three compression schemes.

Rows and Columns

An image is organized as a rectangular array of pixels. The dimensions of this array are stored in the following fields:

ImageLength

Tag   = 257 (101.H)

Type   = SHORT or LONG

The number of rows (sometimes described as *scanlines*) in the image.

ImageWidth

Tag   = 256 (100.H)

Type   = SHORT or LONG

The number of columns in the image, i.e., the number of pixels per scanline.

Physical Dimensions

Applications often want to know the size of the picture represented by an image. This information can be calculated from ImageWidth and ImageLength given the following resolution data:

ResolutionUnit

Tag   = 296 (128.H)

Type   = SHORT

Values:

1 =   No absolute unit of measurement. Used for images that may have a non-square aspect ratio but no meaningful absolute dimensions.

2 =   Inch.

3 =   Centimeter.

Default = 2 (inch).

XResolution

Tag   = 282 (11A.H)

Type   = RATIONAL

The number of pixels per ResolutionUnit in the ImageWidth (typically, horizontal - see Orientation) direction.

YResolution

Tag   = 283 (11B.H)

Type   = RATIONAL

The number of pixels per ResolutionUnit in the ImageLength (typically, vertical) direction.

Location of the Data

Compressed or uncompressed image data can be stored almost anywhere in a TIFF file. TIFF also supports breaking an image into separate strips for increased editing flexibility and efficient I/O buffering. The location and size of each strip is given by the following fields:

RowsPerStrip

Tag   = 278 (116.H)

Type   = SHORT or LONG

The number of rows in each strip (except possibly the last strip.)

For example, if ImageLength is 24, and RowsPerStrip is 10, then there are 3 strips, with 10 rows in the first strip, 10 rows in the second strip, and 4 rows in the third strip. (The data in the last strip is not padded with 6 extra rows of dummy data.)

StripOffsets

Tag   = 273 (111.H)

Type   = SHORT or LONG

For each strip, the byte offset of that strip.

StripByteCounts

Tag   = 279 (117.H)

Type   = SHORT or LONG

For each strip, the number of bytes in that strip *after any compression*.

Putting it all together (along with a couple of less-important fields that are discussed later), a sample bilevel image file might contain the following fields:

A Sample Bilevel TIFF File

Offset (hex)	Description	Value (numeric values are expressed in hexadecimal notation)			
Header:					
0000	Byte Order	4D4D			
0002	42	002A			
0004	1st IFD offset	00000014			
IFD:					
0014	Number of Directory Entries	000C			
0016	NewSubfileType	00FE	0004	00000001	00000000
0022	ImageWidth	0100	0004	00000001	000007D0
002E	ImageLength	0101	0004	00000001	00000BB8
003A	Compression	0103	0003	00000001	8005 0000
0046	PhotometricInterpretation	0106	0003	00000001	0001 0000
0052	StripOffsets	0111	0004	000000BC	000000B6
005E	RowsPerStrip	0116	0004	00000001	00000010
006A	StripByteCounts	0117	0003	000000BC	000003A6
0076	XResolution	011A	0005	00000001	00000696
0082	YResolution	011B	0005	00000001	0000069E
008E	Software	0131	0002	0000000E	000006A6
009A	DateTime	0132	0002	00000014	000006B6
00A6	Next IFD offset	00000000			
Values longer than 4 bytes:					
00B6	StripOffsets	Offset0, Offset1, ... Offset187			
03A6	StripByteCounts	Count0, Count1, ... Count187			
0696	XResolution	0000012C 00000001			
069E	YResolution	0000012C 00000001			
06A6	Software	"PageMaker 4.0"			
06B6	DateTime	"1988:02:18 13:59:59"			
Image Data:					
00000700		Compressed data for strip 10			
xxxxxxxx		Compressed data for strip 179			
xxxxxxxx		Compressed data for strip 53			
xxxxxxxx		Compressed data for strip 160			
.					
.					

End of example

Comments on the Bilevel Image Example

- The IFD in this example starts at 14h. It could have started anywhere in the file providing the offset was an even number greater than or equal to 8 (since the TIFF header is always the first 8 bytes of a TIFF file).

- With 16 rows per strip, there are 188 strips in all.

- The example uses a number of optional fields such as DateTime. TIFF readers must safely skip over these fields if they do not understand or do not wish to use the information. Baseline TIFF readers must not require that such fields be present.

- To make a point, this example has highly-fragmented image data. The strips of the image are not in sequential order. The point of this example is to illustrate that strip offsets must not be ignored. Never assume that strip N+1 follows strip N on disk. It is not required that the image data follow the IFD information.

Required Fields for Bilevel Images

Here is a list of required fields for Baseline TIFF bilevel images. The fields are listed in numerical order, as they would appear in the IFD. Note that the previous example omits some of these fields. This is permitted because the fields that were omitted each have a default and the default is appropriate for this file.

TagName	Decimal	Hex	Type	Value
ImageWidth	256	100	SHORT or LONG	
ImageLength	257	101	SHORT or LONG	
Compression	259	103	SHORT	1, 2 or 32773
PhotometricInterpretation	262	106	SHORT	0 or 1
StripOffsets	273	111	SHORT or LONG	
RowsPerStrip	278	116	SHORT or LONG	
StripByteCounts	279	117	LONG or SHORT	
XResolution	282	11A	RATIONAL	
YResolution	283	11B	RATIONAL	
ResolutionUnit	296	128	SHORT	1, 2 or 3

Baseline TIFF bilevel images were called TIFF Class B images in earlier versions of the TIFF specification.

Section 4: Grayscale Images

Grayscale images are a generalization of bilevel images. Bilevel images can store only black and white image data, but grayscale images can also store shades of gray.

To describe such images, you must add or change the following fields. The other required fields are the same as those required for bilevel images.

Differences from Bilevel Images

Compression = 1 *or 32773 (PackBits).* In Baseline TIFF, grayscale images can either be stored as uncompressed data or compressed with the PackBits algorithm.

Caution: PackBits is often ineffective on continuous tone images, including many grayscale images. In such cases, it is better to leave the image uncompressed.

BitsPerSample

Tag   = 258 (102.H)

Type   = SHORT

The number of bits per component.

Allowable values for Baseline TIFF grayscale images are **4** and **8**, allowing either 16 or 256 distinct shades of gray.

Required Fields for Grayscale Images

These are the required fields for grayscale images (in numerical order):

TagName	Decimal	Hex	Type	Value
ImageWidth	256	100	SHORT or LONG	
ImageLength	257	101	SHORT or LONG	
BitsPerSample	258	102	SHORT	4 or 8
Compression	259	103	SHORT	1 or 32773
PhotometricInterpretation	262	106	SHORT	0 or 1
StripOffsets	273	111	SHORT or LONG	
RowsPerStrip	278	116	SHORT or LONG	
StripByteCounts	279	117	LONG or SHORT	
XResolution	282	11A	RATIONAL	
YResolution	283	11B	RATIONAL	
ResolutionUnit	296	128	SHORT	1 or 2 or 3

Baseline TIFF grayscale images were called TIFF Class G images in earlier versions of the TIFF specification.

Section 5: Palette-color Images

Palette-color images are similar to grayscale images. They still have one component per pixel, but the component value is used as an index into a full RGB-lookup table. To describe such images, you need to add or change the following fields. The other required fields are the same as those for grayscale images.

Differences from Grayscale Images

PhotometricInterpretation = 3 (Palette Color).

ColorMap

Tag   = 320 (140.H)

Type   = SHORT

N   = 3 * (2**BitsPerSample)

This field defines a Red-Green-Blue color map (often called a lookup table) for palette color images. In a palette-color image, a pixel value is used to index into an RGB-lookup table. For example, a palette-color pixel having a value of 0 would be displayed according to the 0th Red, Green, Blue triplet.

In a TIFF ColorMap, all the Red values come first, followed by the Green values, then the Blue values. In the ColorMap, black is represented by 0,0,0 and white is represented by 65535, 65535, 65535.

Required Fields for Palette Color Images

These are the required fields for palette-color images (in numerical order):

TagName	Decimal	Hex	Type	Value
ImageWidth	256	100	SHORT or LONG	
ImageLength	257	101	SHORT or LONG	
BitsPerSample	258	102	SHORT	4 or 8
Compression	259	103	SHORT	1 or 32773
PhotometricInterpretation	262	106	SHORT	3
StripOffsets	273	111	SHORT or LONG	
RowsPerStrip	278	116	SHORT or LONG	
StripByteCounts	279	117	LONG or SHORT	
XResolution	282	11A	RATIONAL	
YResolution	283	11B	RATIONAL	
ResolutionUnit	296	128	SHORT	1 or 2 or 3
ColorMap	320	140	SHORT	

Baseline TIFF palette-color images were called TIFF Class P images in earlier versions of the TIFF specification.

Section 6: RGB Full Color Images

In an RGB image, each pixel is made up of three components: red, green, and blue. There is no ColorMap.

To describe an RGB image, you need to add or change the following fields and values. The other required fields are the same as those required for palette-color images.

Differences from Palette Color Images

BitsPerSample = 8,8,8. Each component is 8 bits deep in a Baseline TIFF RGB image.

PhotometricInterpretation = 2 (RGB).

There is no **ColorMap**.

SamplesPerPixel

Tag   = 277 (115.H)

Type   = SHORT

The number of components per pixel. This number is 3 for RGB images, unless extra samples are present. See the ExtraSamples field for further information.

Required Fields for RGB Images

These are the required fields for RGB images (in numerical order):

TagName	Decimal	Hex	Type	Value
ImageWidth	256	100	SHORT or LONG	
ImageLength	257	101	SHORT or LONG	
BitsPerSample	258	102	SHORT	8,8,8
Compression	259	103	SHORT	1 or 32773
PhotometricInterpretation	262	106	SHORT	2
StripOffsets	273	111	SHORT or LONG	
SamplesPerPixel	277	115	SHORT	3 or more
RowsPerStrip	278	116	SHORT or LONG	
StripByteCounts	279	117	LONG or SHORT	
XResolution	282	11A	RATIONAL	
YResolution	283	11B	RATIONAL	
ResolutionUnit	296	128	SHORT	1, 2 or 3

The BitsPerSample values listed above apply only to the main image data. If ExtraSamples are present, the appropriate BitsPerSample values for those samples must also be included.

Baseline TIFF RGB images were called TIFF Class R images in earlier versions of the TIFF specification.

Section 7: Additional Baseline TIFF Requirements

This section describes characteristics required of all Baseline TIFF files.

General Requirements

Options. Where there are options, TIFF writers can use whichever they want. Baseline TIFF readers must be able to handle all of them.

Defaults. TIFF writers may, but are not required to, write out a field that has a default value, if the default value is the one desired. TIFF readers must be prepared to handle either situation.

Other fields. TIFF readers must be prepared to encounter fields other than those required in TIFF files. TIFF writers are allowed to write optional fields such as Make, Model, and DateTime, and TIFF readers may use such fields if they exist. TIFF readers must not, however, refuse to read the file if such optional fields do not exist. *TIFF readers must also be prepared to encounter and ignore private fields not described in the TIFF specification.*

'MM' and 'II' byte order. TIFF readers must be able to handle both byte orders. TIFF writers can do whichever is most convenient or efficient.

Multiple subfiles. TIFF readers must be prepared for multiple images (subfiles) per TIFF file, although they are not required to do anything with images after the first one. TIFF writers are required to write a long word of 0 after the last IFD (to signal that this is the last IFD), as described earlier in this specification.

If multiple subfiles are written, the first one must be the full-resolution image. Subsequent images, such as reduced-resolution images, may be in any order in the TIFF file. If a reader wants to use such images, it must scan the corresponding IFD's before deciding how to proceed.

TIFF Editors. Editors—applications that modify TIFF files—have a few additional requirements:

- TIFF editors must be especially careful about subfiles. If a TIFF editor edits a full-resolution subfile, but does not update an accompanying reduced-resolution subfile, a reader that uses the reduced-resolution subfile for screen display will display the wrong thing. So TIFF editors must either create a new reduced-resolution subfile when they alter a full-resolution subfile or they must delete any subfiles that they aren't prepared to deal with.

- A similar situation arises with the fields in an IFD. It is unnecessary—and possibly dangerous—for an editor to copy fields it does not understand because the editor might alter the file in a way that is incompatible with the unknown fields.

No Duplicate Pointers. No data should be referenced from more than one place. TIFF readers and editors are under no obligation to detect this condition and handle it properly. This would not be a problem if TIFF files were read-only enti-

ties, but they are not. This warning covers both TIFF field value offsets and fields that are defined as offsets, such as StripOffsets.

Point to real data. *All strip offsets must reference valid locations. (It is not legal to use an offset of 0 to mean something special.)*

Beware of extra components. *Some TIFF files may have more components per pixel than you think. A Baseline TIFF reader must skip over them gracefully, using the values of the SamplesPerPixel and BitsPerSample fields. For example, it is possible that the data will have a PhotometricInterpretation of RGB but have 4 SamplesPerPixel. See ExtraSamples for further details.*

Beware of new field types. *Be prepared to handle unexpected field types such as floating-point data. A Baseline TIFF reader must skip over such fields gracefully. Do not expect that BYTE, ASCII, SHORT, LONG, and RATIONAL will always be a complete list of field types.*

Beware of new pixel types. *Some TIFF files may have pixel data that consists of something other than unsigned integers. If the SampleFormat field is present and the value is not 1, a Baseline TIFF reader that cannot handle the SampleFormat value must terminate the import process gracefully.*

Notes on Required Fields

ImageWidth, ImageLength. Both "SHORT" and "LONG" TIFF field types are allowed and must be handled properly by readers. TIFF writers can use either type. TIFF readers are not required to read arbitrarily large files however. Some readers will give up if the entire image cannot fit into available memory. (In such cases the reader should inform the user about the problem.) Others will probably not be able to handle ImageWidth greater than 65535.

RowsPerStrip. SHORT or LONG. Readers must be able to handle any value between 1 and 2**32-1. However, some readers may try to read an entire strip into memory at one time. If the entire image is one strip, the application may run out of memory. Recommendation: Set RowsPerStrip such that the size of each strip is about 8K bytes. Do this even for uncompressed data because it is easy for a writer and makes things simpler for readers. Note that extremely wide high-resolution images may have rows larger than 8K bytes; in this case, RowsPerStrip should be 1, and the strip will be larger than 8K.

StripOffsets. SHORT or LONG.

StripByteCounts. SHORT or LONG.

XResolution, YResolution. RATIONAL. Note that the X and Y resolutions may be unequal. A TIFF reader must be able to handle this case. Typically, TIFF pixel-editors do not care about the resolution, but applications (such as page layout programs) do care.

ResolutionUnit. SHORT. TIFF readers must be prepared to handle all three values for ResolutionUnit.

Section 8: Baseline Field Reference Guide

This section contains detailed information about all the Baseline fields defined in this version of TIFF. A *Baseline field* is any field commonly found in a Baseline TIFF file, whether required or not.

For convenience, fields that were defined in earlier versions of the TIFF specification but are no longer generally recommended have also been included in this section.

New fields that are associated with optional features are not listed in this section. See Part 2 for descriptions of these new fields. There is a complete list of all fields described in this specification in Appendix A, and there are entries for all TIFF fields in the index.

More fields may be added in future versions. Whenever possible they will be added in a way that allows old TIFF readers to read newer TIFF files.

The documentation for each field contains:

* the name of the field
* the Tag number
* the field Type
* the required Number of Values (N); i.e., the Count
* comments describing the field
* the default, if any

If the field does not exist, readers must assume the default value for the field.

Most of the fields described in this part of the document are not required or are required only for particular types of TIFF files. See the preceding sections for lists of required fields.

Before defining the fields, you must understand these basic concepts: A Baseline TIFF *image* is defined to be a two-dimensional array of *pixels*, each of which consists of one or more color *components*. Monochromatic data has one color component per pixel, while RGB color data has three color components per pixel.

The Fields

Artist

Person who created the image.

Tag   = 315 (13B.H)

Type   = ASCII

Note: some older TIFF files used this tag for storing Copyright information.

BitsPerSample

Number of bits per component.

Tag   = 258 (102.H)

Type   = SHORT

N   = SamplesPerPixel

Note that this field allows a different number of bits per component for each
component corresponding to a pixel. For example, RGB color data could use a
different number of bits per component for each of the three color planes. Most RGB
files will have the same number of BitsPerSample for each component. Even in this
case, the writer must write all three values.

Default = 1. See also SamplesPerPixel.

CellLength

The length of the dithering or halftoning matrix used to create a dithered or
halftoned bilevel file.

Tag   = 265 (109.H)

Type   = SHORT

N   = 1

This field should only be present if Threshholding = 2

No default. See also Threshholding.

CellWidth

The width of the dithering or halftoning matrix used to create a dithered or
halftoned bilevel file.Tag = 264 (108.H)

Type   = SHORT

N   = 1

No default. See also Threshholding.

ColorMap

A color map for palette color images.

Tag   = 320 (140.H)

Type   = SHORT

N   = 3 * (2**BitsPerSample)

This field defines a Red-Green-Blue color map (often called a lookup table) for
palette-color images. In a palette-color image, a pixel value is used to index into
an RGB lookup table. For example, a palette-color pixel having a value of 0
would be displayed according to the 0th Red, Green, Blue triplet.

In a TIFF ColorMap, all the Red values come first, followed by the Green values, then the Blue values. The number of values for each color is 2**BitsPerSample. Therefore, the ColorMap field for an 8-bit palette-color image would have 3 * 256 values.

The width of each value is 16 bits, as implied by the type of SHORT. 0 represents the minimum intensity, and 65535 represents the maximum intensity. Black is represented by 0,0,0, and white by 65535, 65535, 65535.

See also PhotometricInterpretation—palette color.

No default. ColorMap must be included in all palette-color images.

Compression

Compression scheme used on the image data.

Tag   = 259 (103.H)

Type   = SHORT

N   = 1

1 =   No compression, but pack data into bytes as tightly as possible leaving no unused bits except at the end of a row.

If	Then the sample values are stored as an array of type:
BitsPerSample = 16 for all samples	SHORT
BitsPerSample = 32 for all samples	LONG
Otherwise	BYTE

Each row is padded to the next BYTE/SHORT/LONG boundary, consistent with the preceding BitsPerSample rule.

If the image data is stored as an array of SHORTs or LONGs, the byte ordering must be consistent with that specified in bytes 0 and 1 of the TIFF file header. Therefore, little-endian format files will have the least significant bytes preceding the most significant bytes, while big-endian format files will have the opposite order.

If the number of bits per component is not a power of 2, and you are willing to give up some space for better performance, use the next higher power of 2. For example, if your data can be represented in 6 bits, set BitsPerSample to 8 instead of 6, and then convert the range of the values from [0,63] to [0,255].

Rows must begin on byte boundaries. *(SHORT boundaries if the data is stored as SHORTs, LONG boundaries if the data is stored as LONGs).*

Some graphics systems require image data rows to be word-aligned or double-word-aligned, and padded to word-boundaries or double-word boundaries. Uncompressed TIFF rows will need to be copied into word-aligned or double-word-aligned row buffers before being passed to the graphics routines in these environments.

2 =   CCITT Group 3 1-Dimensional Modified Huffman run-length encoding. See Section 10. BitsPerSample must be 1, since this type of compression is defined only for bilevel images.

32773 = PackBits compression, a simple byte-oriented run-length scheme. See Section 9 for details.

Data compression applies only to the image data, pointed to by StripOffsets.

Default = 1.

Copyright

Copyright notice.

Tag   = 33432 (8298.H)

Type   = ASCII

Copyright notice of the person or organization that claims the copyright to the image. The complete copyright statement should be listed in this field including any dates and statements of claims. For example, "Copyright, John Smith, 19xx. All rights reserved."

DateTime

Date and time of image creation.

Tag   = 306 (132.H)

Type   = ASCII

N   = 20

The format is: "YYYY:MM:DD HH:MM:SS", with hours like those on a 24-hour clock, and one space character between the date and the time. The length of the string, including the terminating NUL, is 20 bytes.

ExtraSamples

Description of extra components.

Tag   = 338 (152.H)

Type   = SHORT

N   = m

Specifies that each pixel has *m* extra components whose interpretation is defined by one of the values listed below. When this field is used, the SamplesPerPixel field has a value greater than the PhotometricInterpretation field suggests.

For example, full-color RGB data normally has SamplesPerPixel=3. If SamplesPerPixel is greater than 3, then the ExtraSamples field describes the meaning of the extra samples. If SamplesPerPixel is, say, 5 then ExtraSamples will contain 2 values, one for each extra sample.

ExtraSamples is typically used to include non-color information, such as opacity, in an image. The possible values for each item in the field's value are:

0 =   Unspecified data

1 =   Associated alpha data (with pre-multiplied color)

2 =   Unassociated alpha data

Associated alpha data is opacity information; it is fully described in Section 21. Unassociated alpha data is transparency information that logically exists independent of an image; it is commonly called a soft matte. Note that including both unassociated and associated alpha is undefined because associated alpha specifies that color components are pre-multiplied by the alpha component, while unassociated alpha specifies the opposite.

By convention, extra components that are present must be stored as the "last components" in each pixel. For example, if SamplesPerPixel is 4 and there is 1 extra component, then it is located in the last component location (SamplesPerPixel-1) in each pixel.

Components designated as "extra" are just like other components in a pixel. In particular, the size of such components is defined by the value of the BitsPerSample field.

With the introduction of this field, TIFF readers must not assume a particular SamplesPerPixel value based on the value of the PhotometricInterpretation field. For example, if the file is an RGB file, SamplesPerPixel may be greater than 3.

The default is no extra samples. This field must be present if there are extra samples.

See also SamplesPerPixel, AssociatedAlpha.

FillOrder

The logical order of bits within a byte.

Tag   = 266 (10A.H)

Type   = SHORT

N   = 1

1 =   pixels are arranged within a byte such that pixels with lower column values are stored in the higher-order bits of the byte.

1-bit uncompressed data example: Pixel 0 of a row is stored in the high-order bit of byte 0, pixel 1 is stored in the next-highest bit, ..., pixel 7 is stored in the low-order bit of byte 0, pixel 8 is stored in the high-order bit of byte 1, and so on.

CCITT 1-bit compressed data example: The high-order bit of the first compression code is stored in the high-order bit of byte 0, the next-highest bit of the first compression code is stored in the next-highest bit of byte 0, and so on.

2 =   pixels are arranged within a byte such that pixels with lower column values are stored in the lower-order bits of the byte.

We recommend that FillOrder=2 be used only in special-purpose applications. It is easy and inexpensive for writers to reverse bit order by using a 256-byte lookup table. *FillOrder = 2 should be used only when BitsPerSample = 1 and the data is either uncompressed or compressed using CCITT 1D or 2D compression, to avoid potentially ambiguous situations.*

Support for FillOrder=2 is not required in a Baseline TIFF compliant reader

Default is FillOrder = 1.

FreeByteCounts

For each string of contiguous unused bytes in a TIFF file, the number of bytes in the string.

Tag   = 289 (121.H)

Type   = LONG

Not recommended for general interchange.

See also FreeOffsets.

FreeOffsets

For each string of contiguous unused bytes in a TIFF file, the byte offset of the string.

Tag   = 288 (120.H)

Type   = LONG

Not recommended for general interchange.

See also FreeByteCounts.

GrayResponseCurve

For grayscale data, the optical density of each possible pixel value.

Tag   = 291 (123.H)

Type   = SHORT

N   = 2**BitsPerSample

The 0th value of GrayResponseCurve corresponds to the optical density of a pixel having a value of 0, and so on.

This field may provide useful information for sophisticated applications, but it is currently ignored by most TIFF readers.

See also GrayResponseUnit, PhotometricInterpretation.

GrayResponseUnit

The precision of the information contained in the GrayResponseCurve.

Tag   = 290 (122.H)

Type   = SHORT

N   = 1

Because optical density is specified in terms of fractional numbers, this field is necessary to interpret the stored integer information. For example, if GrayScaleResponseUnits is set to 4 (ten-thousandths of a unit), and a GrayScaleResponseCurve number for gray level 4 is 3455, then the resulting actual value is 0.3455.

Optical densitometers typically measure densities within the range of 0.0 to 2.0.

1 =   Number represents tenths of a unit.

2 =   Number represents hundredths of a unit.

3 =   Number represents thousandths of a unit.

4 =   Number represents ten-thousandths of a unit.

5 =   Number represents hundred-thousandths of a unit.

Modifies GrayResponseCurve.

See also GrayResponseCurve.

For historical reasons, the default is 2. However, for greater accuracy, 3 is recommended.

HostComputer

The computer and/or operating system in use at the time of image creation.

Tag   = 316 (13C.H)

Type   = ASCII

See also Make, Model, Software.

ImageDescription

A string that describes the subject of the image.

Tag   = 270 (10E.H)

Type   = ASCII

For example, a user may wish to attach a comment such as "1988 company picnic" to an image.

ImageLength

The number of rows of pixels in the image.

Tag   = 257 (101.H)

Type   = SHORT or LONG

N   = 1

No default. See also ImageWidth.

ImageWidth

The number of columns in the image, i.e., the number of pixels per row.

Tag   = 256 (100.H)

Type   = SHORT or LONG

N   = 1

No default. See also ImageLength.

Make

The scanner manufacturer.

Tag   = 271 (10F.H)

Type   = ASCII

Manufacturer of the scanner, video digitizer, or other type of equipment used to generate the image. Synthetic images should not include this field.

See also Model, Software.

MaxSampleValue

The maximum component value used.

Tag   = 281 (119.H)

Type   = SHORT

N   = SamplesPerPixel

This field is not to be used to affect the visual appearance of an image when it is displayed or printed. Nor should this field affect the interpretation of any other field; it is used only for statistical purposes.

Default is 2^{**}(BitsPerSample) - 1.

MinSampleValue

The minimum component value used.

Tag   = 280 (118.H)

Type   = SHORT

N   = SamplesPerPixel

See also MaxSampleValue.

Default is 0.

Model

The scanner model name or number.

Tag   = 272 (110.H)

Type   = ASCII

The model name or number of the scanner, video digitizer, or other type of equipment used to generate the image.

See also Make, Software.

NewSubfileType

A general indication of the kind of data contained in this subfile.

Tag = 254 (FE.H)

Type = LONG

N = 1

Replaces the old SubfileType field, due to limitations in the definition of that field.

NewSubfileType is mainly useful when there are multiple subfiles in a single TIFF file.

This field is made up of a set of 32 flag bits. Unused bits are expected to be 0. Bit 0 is the low-order bit.

Currently defined values are:

Bit 0   is 1 if the image is a reduced-resolution version of another image in this TIFF file; else the bit is 0.

Bit 1   is 1 if the image is a single page of a multi-page image (see the PageNumber field description); else the bit is 0.

Bit 2   is 1 if the image defines a transparency mask for another image in this TIFF file. The PhotometricInterpretation value must be 4, designating a transparency mask.

These values are defined as bit flags because they are independent of each other.

Default is 0.

Orientation

The orientation of the image with respect to the rows and columns.

Tag   = 274 (112.H)

Type   = SHORT

N   = 1

1 =   The 0th row represents the visual top of the image, and the 0th column represents the visual left-hand side.

2 =   The 0th row represents the visual top of the image, and the 0th column represents the visual right-hand side.

3 =   The 0th row represents the visual bottom of the image, and the 0th column represents the visual right-hand side.

4 =   The 0th row represents the visual bottom of the image, and the 0th column represents the visual left-hand side.

5 =   The 0th row represents the visual left-hand side of the image, and the 0th column represents the visual top.

6 =   The 0th row represents the visual right-hand side of the image, and the 0th column represents the visual top.

7 =   The 0th row represents the visual right-hand side of the image, and the 0th column represents the visual bottom.

8 =   The 0th row represents the visual left-hand side of the image, and the 0th column represents the visual bottom.

Default is 1.

Support for orientations other than 1 is not a Baseline TIFF requirement.

PhotometricInterpretation

The color space of the image data.

Tag   = 262 (106.H)

Type   = SHORT

N   = 1

0 =   WhiteIsZero. For bilevel and grayscale images: 0 is imaged as white. 2**BitsPerSample-1 is imaged as black. This is the normal value for Compression=2.

1 =   BlackIsZero. For bilevel and grayscale images: 0 is imaged as black. 2**BitsPerSample-1 is imaged as white. If this value is specified for Compression=2, the image should display and print reversed.

2 =   RGB. In the RGB model, a color is described as a combination of the three primary colors of light (red, green, and blue) in particular concentrations. For each of the three components, 0 represents minimum intensity, and 2**BitsPerSample - 1 represents maximum intensity. Thus an RGB value of (0,0,0) represents black, and (255,255,255) represents white, assuming 8-bit components. For PlanarConfiguration = 1, the components are stored in the indicated order: first Red, then Green, then Blue. For PlanarConfiguration = 2, the StripOffsets for the component planes are stored in the indicated order: first the Red component plane StripOffsets, then the Green plane StripOffsets, then the Blue plane StripOffsets.

3=   Palette color. In this model, a color is described with a single component. The value of the component is used as an index into the red, green and blue curves in the ColorMap field to retrieve an RGB triplet that defines the color. When PhotometricInterpretation=3 is used, ColorMap must be present and SamplesPerPixel must be 1.

4 =   Transparency Mask.

This means that the image is used to define an irregularly shaped region of another image in the same TIFF file. SamplesPerPixel and BitsPerSample must be 1. PackBits compression is recommended. The 1-bits define the interior of the region; the 0-bits define the exterior of the region.

A reader application can use the mask to determine which parts of the image to display. Main image pixels that correspond to 1-bits in the transparency mask are imaged to the screen or printer, but main image pixels that correspond to 0-bits in the mask are not displayed or printed.

The image mask is typically at a higher resolution than the main image, if the main image is grayscale or color so that the edges can be sharp.

There is no default for PhotometricInterpretation, *and it is required.* Do not rely on applications defaulting to what you want.

PlanarConfiguration

How the components of each pixel are stored.

Tag   = 284 (11C.H)

Type   = SHORT

N   = 1

1 =   *Chunky* format. The component values for each pixel are stored contiguously. The order of the components within the pixel is specified by PhotometricInterpretation. For example, for RGB data, the data is stored as RGBRGBRGB…

2 =   *Planar* format. The components are stored in separate "component planes." The values in StripOffsets and StripByteCounts are then arranged as a 2-dimensional array, with SamplesPerPixel rows and StripsPerImage columns. (All of the columns for row 0 are stored first, followed by the columns of row 1, and so on.) PhotometricInterpretation describes the type of data stored in each component plane. For example, RGB data is stored with the Red components in one component plane, the Green in another, and the Blue in another.

PlanarConfiguration=2 is not currently in widespread use and it is not recommended for general interchange. It is used as an extension and Baseline TIFF readers are not required to support it.

If SamplesPerPixel is 1, PlanarConfiguration is irrelevant, and need not be included.

If a row interleave effect is desired, a writer might write out the data as PlanarConfiguration=2—separate sample planes—but break up the planes into multiple strips (one row per strip, perhaps) and interleave the strips.

Default is 1. See also BitsPerSample, SamplesPerPixel.

ResolutionUnit

The unit of measurement for XResolution and YResolution.

Tag   = 296 (128.H)

Type   = SHORT

N   = 1

To be used with XResolution and YResolution.

1 =   No absolute unit of measurement. Used for images that may have a non-square aspect ratio, but no meaningful absolute dimensions.

The drawback of ResolutionUnit=1 is that different applications will import the image at different sizes. Even if the decision is arbitrary, it might be better to use dots per inch or dots per centimeter, and to pick XResolution and YResolution so that the aspect ratio is correct and the maximum dimension of the image is about four inches (the "four" is arbitrary.)

2 =   Inch.

3 =   Centimeter.

Default is 2.

RowsPerStrip

The number of rows per strip.

Tag   = 278 (116.H)

Type   = SHORT or LONG

N   = 1

TIFF image data is organized into strips for faster random access and efficient I/O buffering.

RowsPerStrip and ImageLength together tell us the number of strips in the entire

image. The equation is:

StripsPerImage = floor ((ImageLength + RowsPerStrip - 1) / RowsPerStrip).

StripsPerImage is *not* a field. It is merely a value that a TIFF reader will want to

compute because it specifies the number of StripOffsets and StripByteCounts for the

image.

Note that either SHORT or LONG values can be used to specify RowsPerStrip.

SHORT values may be used for small TIFF files. It should be noted, however, that

earlier TIFF specification revisions required LONG values and that some software

may not accept SHORT values.

The default is 2**32 - 1, which is effectively infinity. That is, the entire image is one strip.

Use of a single strip is not recommended. Choose RowsPerStrip such that each strip is

about 8K bytes, even if the data is not compressed, since it makes buffering simpler

for readers. The "8K" value is fairly arbitrary, but seems to work well.

See also ImageLength, StripOffsets, StripByteCounts, TileWidth, TileLength, TileOffsets, TileByteCounts.

SamplesPerPixel

The number of components per pixel.

Tag   = 277 (115.H)

Type   = SHORT

N   = 1

SamplesPerPixel is *usually* 1 for bilevel, grayscale, and palette-color images. SamplesPerPixel is *usually* 3 for RGB images.

Default = 1. See also BitsPerSample, PhotometricInterpretation, *ExtraSamples*.

Software

Name and version number of the software package(s) used to create the image.

Tag   = 305 (131.H)

Type   = ASCII

See also Make, Model.

StripByteCounts

For each strip, the number of bytes in the strip after compression.

Tag   = 279 (117.H)

Type   = SHORT or LONG

N   = StripsPerImage for PlanarConfiguration equal to 1.

        = SamplesPerPixel * StripsPerImage for PlanarConfiguration equal to 2

This tag is required for Baseline TIFF files.

No default.

See also StripOffsets, RowsPerStrip, TileOffsets, TileByteCounts.

StripOffsets

For each strip, the byte offset of that strip.

Tag   = 273 (111.H)

Type   = SHORT or LONG

N   = StripsPerImage for PlanarConfiguration equal to 1.

        = SamplesPerPixel * StripsPerImage for PlanarConfiguration equal to 2

The offset is specified with respect to the beginning of the TIFF file. Note that this implies that each strip has a location independent of the locations of other strips. This feature may be useful for editing applications. This required field is the only way for a reader to find the image data. *(Unless TileOffsets is used; see TileOffsets.)*

Note that either SHORT or LONG values may be used to specify the strip offsets. SHORT values may be used for small TIFF files. It should be noted, however, that earlier TIFF specifications required LONG strip offsets and that some software may not accept SHORT values.

For maximum compatibility with operating systems such as MS-DOS and Windows, the StripOffsets array should be less than or equal to 64K bytes in length, and the strips themselves, in both compressed and uncompressed forms, should not be larger than 64K bytes.

No default. See also StripByteCounts, RowsPerStrip, TileOffsets, TileByteCounts.

SubfileType

A general indication of the kind of data contained in this subfile.

Tag   = 255 (FF.H)

Type   = SHORT

N   = 1

Currently defined values are:

1 = full-resolution image data

2 = reduced-resolution image data

3 = a single page of a multi-page image (see the PageNumber field description).

Note that several image types may be found in a single TIFF file, with each subfile described by its own IFD.

No default.

This field is deprecated. The NewSubfileType field should be used instead.

Threshholding

For black and white TIFF files that represent shades of gray, the technique used to convert from gray to black and white pixels.

Tag   = 263 (107.H)

Type   = SHORT

N   = 1

1 = No dithering or halftoning has been applied to the image data.

2 = An ordered dither or halftone technique has been applied to the image data.

3 = A randomized process such as error diffusion has been applied to the image data.

Default is Threshholding = 1. See also CellWidth, CellLength.

XResolution

The number of pixels per ResolutionUnit in the ImageWidth direction.

Tag   = 282 (11A.H)

Type   = RATIONAL

N   = 1

It is not mandatory that the image be actually displayed or printed at the size implied by this parameter. It is up to the application to use this information as it wishes.

No default. See also YResolution, ResolutionUnit.

YResolution

The number of pixels per ResolutionUnit in the ImageLength direction.

Tag   = 283 (11B.H)

Type   = RATIONAL

N   = 1

No default. See also XResolution, ResolutionUnit.

Section 9: PackBits Compression

This section describes TIFF compression type 32773, a simple byte-oriented run-length scheme.

Description

In choosing a simple byte-oriented run-length compression scheme, we arbitrarily chose the Apple Macintosh PackBits scheme. It has a good worst case behavior (at most 1 extra byte for every 128 input bytes). For Macintosh users, the toolbox utilities PackBits and UnPackBits will do the work for you, but it is easy to implement your own routines.

A pseudo code fragment to unpack might look like this:

```
Loop until you get the number of unpacked bytes you are expecting:
    Read the next source byte into n.
    If n is between 0 and 127 inclusive, copy the next n+1 bytes literally.
    Else if n is between -127 and -1 inclusive, copy the next byte -n+1
    times.
    Else if n is -128, noop.
Endloop
```

In the inverse routine, it is best to encode a 2-byte repeat run as a replicate run except when preceded and followed by a literal run. In that case, it is best to merge the three runs into one literal run. Always encode 3-byte repeats as replicate runs.

That is the essence of the algorithm. Here are some additional rules:

*   Pack each row separately. Do not compress across row boundaries.
*   The number of uncompressed bytes per row is defined to be (ImageWidth + 7) / 8. If the uncompressed bitmap is required to have an even number of bytes per row, decompress into word-aligned buffers.
*   If a run is larger than 128 bytes, encode the remainder of the run as one or more additional replicate runs.

When PackBits data is decompressed, the result should be interpreted as per compression type 1 (no compression).

Section 10: Modified Huffman Compression

This section describes TIFF compression scheme 2, a method for compressing bilevel data based on the CCITT Group 3 1D facsimile compression scheme.

References

- "Standardization of Group 3 facsimile apparatus for document transmission," Recommendation T.4, Volume VII, Fascicle VII.3, Terminal Equipment and Protocols for Telematic Services, The International Telegraph and Telephone Consultative Committee (CCITT), Geneva, 1985, pages 16 through 31.
- "Facsimile Coding Schemes and Coding Control Functions for Group 4 Facsimile Apparatus," Recommendation T.6, Volume VII, Fascicle VII.3, Terminal Equipment and Protocols for Telematic Services, The International Telegraph and Telephone Consultative Committee (CCITT), Geneva, 1985, pages 40 through 48.

We do not believe that these documents are necessary in order to implement Compression=2. We have included (verbatim in most places) all the pertinent information in this section. However, if you wish to order the documents, you can write to ANSI, Attention: Sales, 1430 Broadway, New York, N.Y., 10018. Ask for the publication listed above—it contains both Recommendation T.4 and T.6.

Relationship to the CCITT Specifications

The CCITT Group 3 and Group 4 specifications describe communications protocols for a particular class of devices. They are not by themselves sufficient to describe a disk data format. Fortunately, however, the CCITT coding schemes can be readily adapted to this different environment. The following is one such adaptation. Most of the language is copied directly from the CCITT specifications.

See Section 11 for additional CCITT compression options.

Coding Scheme

A line (row) of data is composed of a series of variable length code words. Each code word represents a run length of all white or all black. (Actually, more than one code word may be required to code a given run, in a manner described below.) White runs and black runs alternate.

To ensure that the receiver (decompressor) maintains color synchronization, all data lines begin with a white run-length code word set. If the actual scan line begins with a black run, a white run-length of zero is sent (written). Black or white run-lengths are defined by the code words in Tables 1 and 2. The code words are of two types: Terminating code words and Make-up code words. Each run-length is represented by zero or more Make-up code words followed by exactly one Terminating code word.

Run lengths in the range of 0 to 63 pels (pixels) are encoded with their appropriate Terminating code word. Note that there is a different list of code words for black and white run-lengths.

Run lengths in the range of 64 to 2623 (2560+63) pels are encoded first by the Make-up code word representing the run-length that is nearest to, not longer than, that required. This is then followed by the Terminating code word representing the difference between the required run-length and the run-length represented by the Make-up code.

Run lengths in the range of lengths longer than or equal to 2624 pels are coded first by the Make-up code of 2560. If the remaining part of the run (after the first Make-up code of 2560) is 2560 pels or greater, additional Make-up code(s) of 2560 are issued until the remaining part of the run becomes less than 2560 pels. Then the remaining part of the run is encoded by Terminating code or by Make-up code plus Terminating code, according to the range mentioned above.

It is considered an unrecoverable error if the sum of the run-lengths for a line does not equal the value of the ImageWidth field.

New rows always begin on the next available byte boundary.

No EOL code words are used. No fill bits are used, except for the ignored bits at the end of the last byte of a row. RTC is not used.

An encoded CCITT string is self-photometric, defined in terms of white and black runs. Yet TIFF defines a tag called PhotometricInterpretation that also purports to define what is white and what is black. Somewhat arbitrarily, we adopt the following convention:

The "normal" PhotometricInterpretation for bilevel CCITT compressed data is WhiteIsZero. In this case, the CCITT "white" runs are to be interpretated as white, and the CCITT "black" runs are to be interpreted as black. However, if the PhotometricInterpretation is BlackIsZero, the TIFF reader must reverse the meaning of white and black when displaying and printing the image.

Table 1/T.4 Terminating codes

White run length	Code word	Black run length	Code word
0	00110101	0	0000110111
1	000111	1	010
2	0111	2	11
3	1000	3	10
4	1011	4	011
5	1100	5	0011
6	1110	6	0010
7	1111	7	00011
8	10011	8	000101
9	10100	9	000100
10	00111	10	0000100
11	01000	11	0000101
12	001000	12	0000111
13	000011	13	00000100
14	110100	14	00000111
15	110101	15	000011000
16	101010	16	0000010111
17	101011	17	0000011000
18	0100111	18	0000001000
19	0001100	19	00001100111
20	0001000	20	00001101000
21	0010111	21	00001101100
22	0000011	22	00000110111
23	0000100	23	00000101000
24	0101000	24	00000010111
25	0101011	25	00000011000
26	0010011	26	000011001010
27	0100100	27	000011001011
28	0011000	28	000011001100
29	00000010	29	000011001101
30	00000011	30	000001101000
31	00011010	31	000001101001
32	00011011	32	000001101010
33	00010010	33	000001101011
34	00010011	34	000011010010
35	00010100	35	000011010011
36	00010101	36	000011010100
37	00010110	37	000011010101
38	00010111	38	000011010110
39	00101000	39	000011010111
40	00101001	40	000001101100
41	00101010	41	000001101101
42	00101011	42	000011011010
43	00101100	43	000011011011
44	00101101	44	000001010100
45	00000100	45	000001010101
46	00000101	46	000001010110
47	00001010	47	000001010111
48	00001011	48	000001100100
49	01010010	49	000001100101
50	01010011	50	000001010010
51	01010100	51	000001010011

White run length	Code word	Black run length	Code word
52	01010101	52	000000100100
53	00100100	53	000000110111
54	00100101	54	000000111000
55	01011000	55	000000100111
56	01011001	56	000000101000
57	01011010	57	000001011000
58	01011011	58	000001011001
59	01001010	59	000000101011
60	01001011	60	000000101100
61	00110010	61	000001011010
62	00110011	62	000001100110
63	00110100	63	000001100111

Table 2/T.4 Make-up codes

White run length	Code word	Black run length	Code word
64	11011	64	0000001111
128	10010	128	000011001000
192	010111	192	000011001001
256	0110111	256	000001011011
320	00110110	320	000000110011
384	00110111	384	000000110100
448	01100100	448	000000110101
512	01100101	512	0000001101100
576	01101000	576	0000001101101
640	01100111	640	0000001001010
704	011001100	704	0000001001011
768	011001101	768	0000001001100
832	011010010	832	0000001001101
896	011010011	896	0000001110010
960	011010100	960	0000001110011
1024	011010101	1024	0000001110100
1088	011010110	1088	0000001110101
1152	011010111	1152	0000001110110
1216	011011000	1216	0000001110111
1280	011011001	1280	0000001010010
1344	011011010	1344	0000001010011
1408	011011011	1408	0000001010100
1472	010011000	1472	0000001010101
1536	010011001	1536	0000001011010
1600	010011010	1600	0000001011011
1664	011000	1664	0000001100100
1728	010011011	1728	0000001100101
EOL	000000000001	EOL	00000000000

Additional make-up codes

White and Black run length	Make-up code word
1792	00000001000
1856	00000001100
1920	00000001101
1984	000000010010
2048	000000010011
2112	000000010100
2176	000000010101
2240	000000010110
2304	000000010111
2368	000000011100
2432	000000011101
2496	000000011110
2560	000000011111

Part 2: TIFF Extensions

Part 2 contains extensions to Baseline TIFF. TIFF Extensions are TIFF features that may not be supported by all TIFF readers. TIFF creators who use these features will have to work closely with TIFF readers in their part of the industry to ensure successful interchange.

The features described in this part were either contained in earlier versions of the specification, or have been approved by the TIFF Advisory Committee.

Section 11: CCITT Bilevel Encodings

The following fields are used when storing binary pixel arrays using one of the encodings adopted for raster-graphic interchange in numerous CCITT and ISO (International Organization for Standards) recommendations and standards. These encodings are often spoken of as "Group III compression" and "Group IV compression" because their application in facsimile transmission is the most widely known.

For the specialized use of these encodings in storing facsimile-transmission images, further guidelines can be obtained from the TIFF Class F document, available on-line in the same locations as this specification. This document is administered by another organization; paper copies are not available from Adobe.

Compression

Tag   = 259 (103.H)

Type   = SHORT

N   = 1

3 =   T4-encoding: CCITT T.4 bi-level encoding as specified in section 4, Coding, of CCITT Recommendation T.4: "Standardization of Group 3 Facsimile apparatus for document transmission." International Telephone and Telegraph Consultative Committee (CCITT, Geneva: 1988).

See the T4Options field for T4-encoding options such as 1D vs 2D coding.

4 =   T6-encoding: CCITT T.6 bi-level encoding as specified in section 2 of CCITT Recommendation T.6: "Facsimile coding schemes and coding control functions for Group 4 facsimile apparatus." International Telephone and Telegraph Consultative Committee (CCITT, Geneva: 1988).

See the T6Options field for T6-encoding options such as escape into uncompressed mode to avoid negative-compression cases.

Application in Image Interchange

CCITT Recommendations T.4 and T.6 are specified in terms of the serial bit-by-bit creation and processing of a variable-length binary string that encodes bi-level (black and white) pixels of a rectangular image array. Generally, the encoding schemes are described in terms of bit-serial communication procedures and the end-to-end coordination that is required to gain reliable delivery over inherently unreliable data links. The Group 4 procedures, with their T6-encoding, represent a significant simplification because it is assumed that a reliable communication medium is employed, whether ISDN or X.25 or some other trustworthy transport vehicle. Because image-storage systems and computers achieve data integrity and communication reliability in other ways, the T6-encoding tends to be prefered for imaging applications. When computer storage and retrieval and interchange of facsimile material are of interest, the T4-encodings provide a better match to the

current generation of Group 3 facsimile products and their defenses against data corruption as the result of transmission defects.

Whichever form of encoding is preferable for a given application, there are a number of adjustments that need to be made to account for the capture of the CCITT binary-encoding strings as part of electronically-stored material and digital-image interchange.

PhotometricInterpretation. An encoded CCITT string is self-photometric, defined in terms of white and black runs. Yet TIFF defines a tag called PhotometricInterpretation that also purports to define what is white and what is black. Somewhat arbitrarily, we adopt the following convention:

The "normal" PhotometricInterpretation for bilevel CCITT compressed data is WhiteIsZero. In this case, the CCITT "white" runs are to be interpretated as white, and the CCITT "black" runs are to be interpreted as black. However, if the PhotometricInterpretation is BlackIsZero, the TIFF reader must reverse the meaning of white and black when displaying and printing the image.

FillOrder. When CCITT encodings are used directly over a typical serial communication link, the order of the bits in the encoded string is the sequential order of the string, bit-by-bit, from beginning to end. This poses the following question: In which order should consecutive blocks of eight bits be assembled into octets (standard data bytes) for use within a computer system? The answer differs depending on whether we are concerned about preserving the serial-transmission sequence or preserving only the format of byte-organized sequences in memory and in stored files.

From the perspective of electronic interchange, as long as a receiver's reassembly of bits into bytes properly mirrors the way in which the bytes were disassembled by the transmitter, no one cares which order is seen on the transmission link because each multiple of 8 bits is transparently transmitted.

Common practice is to record arbitrary binary strings into storage sequences such that the first sequential bit of the string is found in the high-order bit of the first octet of the stored byte sequence. This is the standard case specified by TIFF FillOrder = 1, used in most bitmap interchange and the only case required in Baseline TIFF. This is also the approach used for the octets of standard 8-bit character data, with little attention paid to the fact that the most common forms of data communication transmit and reassemble individual 8-bit frames with the low-order-bit first!

For bit-serial transmission to a distant unit whose approach to assembling bits into bytes is unknown and supposed to be irrelevant, it is necessary to satisfy the expected sequencing of bits over the transmission link. This is the normal case for communication between facsimile units and also for computers and modems emulating standard Group 3 facsimile units. In this case, if the CCITT encoding is captured directly off of the link via standard communication adapters, TIFF FillOrder = 2 will usually apply to that stored data form.

Consequently, different TIFF FillOrder cases may arise when CCITT encodings are obtained by synthesis within a computer (including Group 4 transmission, which is treated more like computer data) instead of by capture from a Group 3 facsimile unit.

Because this is such a subtle situation, with surprisingly disruptive consequences for FillOrder mismatches, the following practice is urged whenever CCITT bilevel encodings are used:

a. TIFF FillOrder (tag 266) should always be explicitly specified.

b. FillOrder = 1 should be employed wherever possible in persistent material that is intended for interchange. This is the only reliable case for widespread interchange among computer systems, and it is important to explicitly confirm the honoring of standard assumptions.

c. FillOrder = 2 should occur only in highly-localized and preferably-transient material, as in a facsimile server supporting group 3 facsimile equipment. The tag should be present as a safeguard against the CCITT encoding "leaking" into an unsuspecting application, allowing readers to detect and warn against the occurence.

There are interchange situations where fill order is not distinguished, as when filtering the CCITT encoding into a PostScript level 2 image operation. In this case, as in most other cases of computer-based information interchange, FillOrder=1 is assumed, and any padding to a multiple of 8 bits is accomplished by adding a sufficient number of 0-bits to the end of the sequence.

Strips and Tiles. When CCITT bi-level encoding is employed, interaction with stripping (Section 3) and tiling (Section 15) is as follows:

a. Decompose the image into segments—individual pixel arrays representing the desired strip or tile configuration. The CCITT encoding procedures are applied most flexibly if the segments each have a multiple of 4 lines.

b. Individually encode each segment according to the specified CCITT bi-level encoding, as if each segment is a separate raster-graphic image.

The reason for this general rule is that CCITT bi-level encodings are generally progressive. That is, the initial line of pixels is encoded, and then subsequent lines, according to a variety of options, are encoded in terms of changes that need to be made to the preceding (unencoded) line. For strips and tiles to be individually usable, they must each start as fresh, independent encodings.

Miscellaneous features. There are provisions in CCITT encoding that are mostly meaningful during facsimile-transmission procedures. There is generally no significant application when storing images in TIFF or other data interchange formats, although TIFF applications should be tolerant and flexible in this regard. These features tend to have significance only when facilitating transfer between facsimile and non-facsimile applications of the encoded raster-graphic images. Further considerations for fill sequences, end-of-line flags, return-to-control (end-of-block) sequences and byte padding are introduced in discussion of the individual encoding options.

T4Options

Tag = 292 (124.H)

Type = LONG

N = 1

See Compression=3. This field is made up of a set of 32 flag bits. Unused bits must be set to 0. Bit 0 is the low-order bit.

Bit 0 is 1 for 2-dimensional coding (otherwise 1-dimensional is assumed). For 2-D coding, if more than one strip is specified, each strip must begin with a 1-

dimensionally coded line. That is, RowsPerStrip should be a multiple of "Parameter K," as documented in the CCITT specification.

Bit 1   is 1 if uncompressed mode is used.

Bit 2   is 1 if fill bits have been added as necessary before EOL codes such that EOL always ends on a byte boundary, thus ensuring an EOL-sequence of 1 byte preceded by a zero nibble: xxxx-0000 0000-0001.

Default is 0, for basic 1-dimensional coding. See also Compression.

T6Options

Tag   = 293 (125.H)

Type   = LONG

N   = 1

See *Compression = 4.* This field is made up of a set of 32 flag bits. Unused bits must be set to 0. Bit 0 is the low-order bit. The default value is 0 (all bits 0).

bit 0   is unused and always 0.

bit 1   is 1 if uncompressed mode is allowed in the encoding.

In earlier versions of TIFF, this tag was named Group4Options. The significance has not changed and the present definition is compatible. The name of the tag has been changed to be consistent with the nomenclature of other T.6-encoding applications.

Readers should honor this option tag, and only this option tag, whenever T.6-Encoding is specified for Compression.

For T.6-Encoding, each segment (strip or tile) is encoded as if it were a separate image. The encoded string from each segment starts a fresh byte.

There are no one-dimensional line encodings in T.6-Encoding. Instead, even the first row of the segment's pixel array is encoded two-dimensionally by always assuming an invisible preceding row of all-white pixels. The 2-dimensional procedure for encoding the body of individual rows is the same as that used for 2-dimensional T.4-encoding and is described fully in the CCITT specifications.

The beginning of the encoding for each row of a strip or tile is conducted as if there is an imaginary preceding (0-width) white pixel, that is as if a fresh run of white pixels has just commenced. The completion of each line is encoded as if there are imaginary pixels beyond the end of the current line, and of the preceding line, in effect, of colors chosen such that the line is exactly completable by a code word, making the imaginary next pixel a changing element that's not actually used.

The encodings of successive lines follow contiguously in the binary T.6-Encoding stream with no special initiation or separation codewords. There are no provisions for fill codes or explicit end-of-line indicators. The encoding of the last line of the pixel array is followed immediately, in place of any additional line encodings, by a 24-bit End-of-Facsimile Block (EOFB).

000000000001000000000001.B.

The EOFB sequence is immediately followed by enough 0-bit padding to fit the entire stream into a sequence of 8-bit bytes.

General Application. Because of the single uniform encoding procedure, without disruptions by end-of-line codes and shifts into one-dimensional encodings, T.6-encoding is very popular for compression of bi-level images in document imaging systems. T.6-encoding trades off redundancy for minimum encoded size, relying on the underlying storage and transmission systems for reliable retention and communication of the encoded stream.

TIFF readers will operate most smoothly by always ignoring bits beyond the EOFB. Some writers may produce additional bytes of pad bits beyond the byte containing the final bit of the EOFB. Robust readers will not be disturbed by this prospect.

It is not possible to correctly decode a T.6-Encoding without knowledge of the exact number of pixels in each line of the pixel array. ImageWidth (or TileWidth, if used) must be stated exactly and accurately. If an image or segment is overscanned, producing extraneous pixels at the beginning or ending of lines, these pixels must be counted. Any cropping must be accomplished by other means. It is not possible to recover from a pixel-count deviation, even when one is detected. Failure of any row to be completed as expected is cause for abandoning further decoding of the entire segment. There is no requirement that ImageWidth be a multiple of eight, of course, and readers must be prepared to pad the final octet bytes of decoded bitmap rows with additional bits.

If a TIFF reader encounters EOFB before the expected number of lines has been extracted, it is appropriate to assume that the missing rows consist entirely of white pixels. Cautious readers might produce an unobtrusive warning if such an EOFB is followed by anything other than pad bits.

Readers that successfully decode the RowsPerStrip (or TileLength or residual ImageLength) number of lines are not required to verify that an EOFB follows. That is, it is generally appropriate to stop decoding when the expected lines are decoded or the EOFB is detected, whichever occurs first. Whether error indications or warnings are also appropriate depends upon the application and whether more precise troubleshooting of encoding deviations is important.

TIFF writers should always encode the full, prescribed number of rows, with a proper EOFB immediately following in the encoding. Padding should be by the least number of 0-bits needed for the T.6-encoding to exactly occupy a multiple of 8 bits. Only 0-bits should be used for padding, and StripByteCount (or TileByteCount) should not extend to any bytes not containing properly-formed T.6-encoding. In addition, even though not required by T.6-encoding rules, successful interchange with a large variety of readers and applications will be enhanced if writers can arrange for the number of pixels per line and the number of lines per strip to be multiples of eight.

Uncompressed Mode. Although T.6-encodings of simple bi-level images result in data compressions of 10:1 and better, some pixel-array patterns have T.6-encodings that require more bits than their simple bi-level bitmaps. When such cases are detected by encoding procedures, there is an optional extension for shifting to a form of uncompressed coding within the T.6-encoding string.

Uncompressed mode is not well-specified and many applications discourage its usage, preferring alternatives such as different compressions on a segment-by-segment (strip or tile) basis, or by simply leaving the image uncompressed in its

entirety. The main complication for readers is in properly restoring T.6-encoding after the uncompressed sequence is laid down in the current row.

Readers that have no provision for uncompressed mode will generally reject any case in which the flag is set. Readers that are able to process uncompressed-mode content within T.6-encoding strings can safely ignore this flag and simply process any uncompressed-mode occurences correctly.

Writers that are unable to guarantee the absence of uncompressed-mode material in any of the T.6-encoded segments must set the flag. The flag should be cleared (or defaulted) only when absence of uncompressed-mode material is assured. Writers that are able to inhibit the generation of uncompressed-mode extensions are encouraged to do so in order to maximize the acceptability of their T.6-encoding strings in interchange situations.

Because uncompressed-mode is not commonly used, the following description is best taken as suggestive of the general machinery. Interpolation of fine details can easily vary between implementations.

Uncompressed mode is signalled by the occurence of the 10-bit extension code string

0000001111.B

outside of any run-length make-up code or extension. Original unencoded image information follows. In this unencoded information, a 0-bit evidently signifies a white pixel, a 1-bit signifies a black pixel, and the TIFF PhotometricInterpretation will influence how these bits are mapped into any final uncompressed bitmap for use. The only modification made to the unencoded information is insertion of a 1-bit after every block of five consecutive 0-bits from the original image information. This is a transparency device that allows longer sequencences of 0-bits to be reserved for control conditions, especially ending the uncompressed-mode sequence. When it is time to return to compressed mode, the 8-bit exit sequence

0000001t.B

is appended to the material. The 0-bits of the exit sequence are not considered in applying the 1-bit insertion rule; up to four information 0-bits can legally precede the exit sequence. The trailing bit, 't,' specifies the color (via 0 or 1) that is understood in the next run of compressed-mode encoding. This lets a color other than white be assumed for the 0-width pixel on the left of the edge between the last uncompressed pixel and the resumed 2-dimensional scan.

Writers should confine uncompressed-mode sequences to the interiors of individual rows, never attempting to "wrap" from one row to the next. Readers must operate properly when the only encoding for a single row consists of an uncompressed-mode escape, a complete row of (proper 1-inserted) uncompressed information, and the extension exit. Technically, the exit pixel, 't,' should probably then be the opposite color of the last true pixel of the row, but readers should be generous in this case.

In handling these complex encodings, the encounter of material from a defective source or a corrupted file is particularly unsettling and mysterious. Robust readers will do well to defend against falling off the end of the world; e.g., unexpected EOFB sequences should be handled, and attempted access to data bytes that are not within the bounds of the present segment (or the TIFF file itself) should be avoided.

Section 12: Document Storage and Retrieval

These fields may be useful for document storage and retrieval applications. They will very likely be ignored by other applications.

DocumentName

The name of the document from which this image was scanned.

Tag = 269 (10D.H)

Type = ASCII

See also PageName.

PageName

The name of the page from which this image was scanned.

Tag = 285 (11D.H)

Type = ASCII

See also DocumentName.

No default.

PageNumber

The page number of the page from which this image was scanned.

Tag = 297 (129.H)

Type = SHORT

N = 2

This field is used to specify page numbers of a multiple page (e.g. facsimile) document. PageNumber[0] is the page number; PageNumber[1] is the total number of pages in the document. If PageNumber[1] is 0, the total number of pages in the document is not available.

Pages need not appear in numerical order.

The first page is numbered 0 (zero).

No default.

XPosition

X position of the image.

Tag = 286 (11E.H)

Type = RATIONAL

N = 1

The X offset in ResolutionUnits of the left side of the image, with respect to the left side of the page.

No default. See also YPosition.

YPosition

Y position of the image.

Tag   = 287 (11F.H)

Type   = RATIONAL

N   = 1

The Y offset in ResolutionUnits of the top of the image, with respect to the top of the page. In the TIFF coordinate scheme, the positive Y direction is down, so that YPosition is always positive.

No default. See also XPosition.

Section 13: LZW Compression

This section describes TIFF compression scheme 5, an adaptive compression scheme for raster images.

Restrictions

When LZW compression was added to the TIFF specification, in Revision 5.0, it was thought to be public domain. This is, apparently, not the case.

The following paragraph has been approved by the Unisys Corporation:

"The LZW compression method is said to be the subject of United States patent number 4,558,302 and corresponding foreign patents owned by the Unisys Corporation. Software and hardware developers may be required to license this patent in order to develop and market products using the TIFF LZW compression option. Unisys has agreed that developers may obtain such a license on reasonable, non-discriminatory terms and conditions. Further information can be obtained from: Welch Licensing Department, Office of the General Counsel, M/S C1SW19, Unisys Corporation, Blue Bell, Pennsylvania, 19424."

Reportedly, there are also other companies with patents that may affect LZW implementors.

Reference

Terry A. Welch, "A Technique for High Performance Data Compression", IEEE Computer, vol. 17 no. 6 (June 1984). Describes the basic Lempel-Ziv & Welch (LZW) algorithm in very general terms. The author's goal is to describe a hardware-based compressor that could be built into a disk controller or database engine and used on all types of data. There is no specific discussion of raster images. This section gives sufficient information so that the article is not required reading.

Characteristics

LZW compression has the following characteristics:
- LZW works for images of various bit depths.
- LZW has a reasonable worst-case behavior.
- LZW handles a wide variety of repetitive patterns well.
- LZW is reasonably fast for both compression and decompression.
- LZW does not require floating point software or hardware.

- LZW is lossless. All information is preserved. But if noise or information is removed from an image, perhaps by smoothing or zeroing some low-order bitplanes, LZW compresses images to a smaller size. Thus, 5-bit, 6-bit, or 7-bit data masquerading as 8-bit data compresses better than true 8-bit data. Smooth images also compress better than noisy images, and simple images compress better than complex images.

- LZW works quite well on bilevel images, too. On our test images, it almost always beat PackBits and generally tied CCITT 1D (Modified Huffman) compression. LZW also handles halftoned data better than most bilevel compression schemes.

The Algorithm

Each strip is compressed independently. We strongly recommend that RowsPerStrip be chosen such that each strip contains about 8K bytes before compression. We want to keep the strips small enough so that the compressed and uncompressed versions of the strip can be kept entirely in memory, even on small machines, but are large enough to maintain nearly optimal compression ratios.

The LZW algorithm is based on a translation table, or string table, that maps strings of input characters into codes. The TIFF implementation uses variable-length codes, with a maximum code length of 12 bits. This string table is different for every strip and does not need to be reatained for the decompressor. The trick is to make the decompressor automatically build the same table as is built when the data is compressed. We use a C-like pseudocode to describe the coding scheme:

```
InitializeStringTable();
WriteCode(ClearCode);
Ω = the empty string;
for each character in the strip {
        K = GetNextCharacter();
        if Ω+K is in the string table {
                Ω = Ω+K; /* string concatenation */
        } else {
                WriteCode (CodeFromString(Ω));
                AddTableEntry(Ω+K);
                Ω = K;
        }
} /* end of for loop */
WriteCode (CodeFromString(Ω));
WriteCode (EndOfInformation);
```

That's it. The scheme is simple, although it is challenging to implement efficiently. But we need a few explanations before we go on to decompression.

The "characters" that make up the LZW strings are bytes containing TIFF uncompressed (Compression=1) image data, in our implementation. For example, if BitsPerSample is 4, each 8-bit LZW character will contain two 4-bit pixels. If BitsPerSample is 16, each 16-bit pixel will span two 8-bit LZW characters.

It is also possible to implement a version of LZW in which the LZW character depth equals BitsPerSample, as described in Draft 2 of Revision 5.0. But there is a major problem with this approach. If BitsPerSample is greater than 11, we can not

use 12-bit-maximum codes and the resulting LZW table is unacceptably large. Fortunately, due to the adaptive nature of LZW, we do not pay a significant compression ratio penalty for combining several pixels into one byte before compressing. For example, our 4-bit sample images compressed about 3 percent worse, and our 1-bit images compressed about 5 percent better. And it is easier to write an LZW compressor that always uses the same character depth than it is to write one that handles varying depths.

We can now describe some of the routine and variable references in our pseudocode:

InitializeStringTable() initializes the string table to contain all possible single-character strings. There are 256 of them, numbered 0 through 255, since our characters are bytes.

WriteCode() writes a code to the output stream. The first code written is a ClearCode, which is defined to be code #256.

Ω is our "prefix string."

GetNextCharacter() retrieves the next character value from the input stream. This will be a number between 0 and 255 because our characters are bytes.

The "+" signs indicate string concatenation.

AddTableEntry() adds a table entry. (InitializeStringTable() has already put 256 entries in our table. Each entry consists of a single-character string, and its associated code value, which, in our application, is identical to the character itself. That is, the 0th entry in our table consists of the string <0>, with a corresponding code value of <0>, the 1st entry in the table consists of the string <1>, with a corresponding code value of <1> and the 255th entry in our table consists of the string <255>, with a corresponding code value of <255>.) So, the first entry that added to our string table will be at position 256, right? Well, not quite, because we reserve code #256 for a special "Clear" code. We also reserve code #257 for a special "EndOfInformation" code that we write out at the end of the strip. So the first multiple-character entry added to the string table will be at position 258.

For example, suppose we have input data that looks like this:

Pixel 0:<7>

Pixel 1:<7>

Pixel 2:<7>

Pixel 3:<8>

Pixel 4:<8>

Pixel 5:<7>

Pixel 6:<7>

Pixel 7:<6>

Pixel 8:<6>

First, we read Pixel 0 into K. ΩK is then simply <7>, because Ω is an empty string at this point. Is the string <7> already in the string table? Of course, because all single character strings were put in the table by InitializeStringTable(). So set Ω equal to <7>, and then go to the top of the loop.

Read Pixel 1 into K. Does ΩK (<7><7>) exist in the string table? No, so we write the code associated with Ω to output (write <7> to output) and add ΩK (<7><7>) to the table as entry 258. Store K (<7>) into Ω. Note that although we have added the string consisting of Pixel 0 and Pixel 1 to the table, we "re-use" Pixel 1 as the beginning of the next string.

Back at the top of the loop, we read Pixel 2 into K. Does ΩK (<7><7>) exist in the string table? Yes, the entry we just added, entry 258, contains exactly <7><7>. So we add K to the end of Ω so that Ω is now <7><7>.

Back at the top of the loop, we read Pixel 3 into K. Does ΩK (<7><7><8>) exist in the string table? No, so we write the code associated with Ω (<258>) to output and then add ΩK to the table as entry 259. Store K (<8>) into Ω.

Back at the top of the loop, we read Pixel 4 into K. Does ΩK (<8><8>) exist in the string table? No, so we write the code associated with Ω (<8>) to output and then add ΩK to the table as entry 260. Store K (<8>) into Ω.

Continuing, we get the following results:

After reading:	We write to output:	And add table entry:
Pixel 0		
Pixel 1	<7>	258: <7><7>
Pixel 2		
Pixel 3	<258>	259: <7><7><8>
Pixel 4	<8>	260:<8><8>
Pixel 5	<8>	261: <8><7>
Pixel 6		
Pixel 7	<258>	262: <7><7><6>
Pixel 8	<6>	263: <6><6>

WriteCode() also requires some explanation. In our example, the output code stream, <7><258><8><8><258><6> should be written using as few bits as possible. When we are just starting out, we can use 9-bit codes, since our new string table entries are greater than 255 but less than 512. *After adding table entry 511, switch to 10-bit codes (i.e., entry 512 should be a 10-bit code.) Likewise, switch to 11-bit codes after table entry 1023, and 12-bit codes after table entry 2047.* We will arbitrarily limit ourselves to 12-bit codes, so that our table can have at most 4096 entries. The table should not be any larger.

Whenever you add a code to the output stream, it "counts" toward the decision about bumping the code bit length. This is important when writing the last code word before an EOI code or ClearCode, to avoid code length errors.

What happens if we run out of room in our string table? This is where the ClearCode comes in. As soon as we use entry 4094, we write out a (12-bit) ClearCode. (If we wait any longer to write the ClearCode, the decompressor might try to interpret the ClearCode as a 13-bit code.) At this point, the compressor reinitializes the string table and then writes out 9-bit codes again.

Note that whenever you write a code and add a table entry, Ω is not left empty. It contains exactly one character. Be careful not to lose it when you write an end-of-table ClearCode. You can either write it out as a 12-bit code before writing the ClearCode, in which case you need to do it right after adding table entry 4093, or

you can write it as a 9-bit code after the ClearCode . Decompression gives the same result in either case.

To make things a little simpler for the decompressor, we will require that each strip begins with a ClearCode and ends with an EndOfInformation code. Every LZW-compressed strip must begin on a byte boundary. It need not begin on a word boundary. LZW compression codes are stored into bytes in high-to-low-order fashion, i.e., FillOrder is assumed to be 1. The compressed codes are written as bytes (not words) so that the compressed data will be identical whether it is an 'II' or 'MM' file.

Note that the LZW string table is a continuously updated history of the strings that have been encountered in the data. Thus, it reflects the characteristics of the data, providing a high degree of adaptability.

LZW Decoding

The procedure for decompression is a little more complicated:

```
while ((Code = GetNextCode()) != EoiCode) {
        if (Code == ClearCode) {
                InitializeTable();
                Code = GetNextCode();
                if (Code == EoiCode)
                        break;
                WriteString(StringFromCode(Code));
                OldCode = Code;
        }  /* end of ClearCode case */
        else {
                if (IsInTable(Code)) {
                        WriteString(StringFromCode(Code));
                        AddStringToTable(StringFromCode(OldCode
)+FirstChar(StringFromCode(Code)));
                        OldCode = Code;
                } else {
                        OutString = StringFromCode(OldCode) +
FirstChar(StringFromCode(OldCode));
                        WriteString(OutString);
                        AddStringToTable(OutString);
                        OldCode = Code;
                }
        } /* end of not-ClearCode case */
} /* end of while loop */
```

The function GetNextCode() retrieves the next code from the LZW-coded data. It must keep track of bit boundaries. It knows that the first code that it gets will be a 9-bit code. We add a table entry each time we get a code. So, GetNextCode() must switch over to 10-bit codes as soon as string #*510* is stored into the table. *Similarly, the switch is made to 11-bit codes after #1022 and to 12-bit codes after #2046.*

The function StringFromCode() gets the string associated with a particular code from the string table.

The function AddStringToTable() adds a string to the string table. The "+" sign joining the two parts of the argument to AddStringToTable indicates string concatenation.

StringFromCode() looks up the string associated with a given code.

WriteString() adds a string to the output stream.

When SamplesPerPixel Is Greater Than 1

So far, we have described the compression scheme as if SamplesPerPixel were always 1, as is the case with palette-color and grayscale images. But what do we do with RGB image data?

Tests on our sample images indicate that the LZW compression ratio is nearly identical whether PlanarConfiguration=1 or PlanarConfiguration=2, for RGB images. So, use whichever configuration you prefer and simply compress the bytes in the strip.

Note: Compression ratios on our test RGB images were disappointingly low: between 1.1 to 1 and 1.5 to 1, depending on the image. Vendors are urged to do what they can to remove as much noise as possible from their images. Preliminary tests indicate that significantly better compression ratios are possible with less-noisy images. Even something as simple as zeroing-out one or two least-significant bitplanes can be effective, producing little or no perceptible image degradation.

Implementation

The exact structure of the string table and the method used to determine if a string is already in the table are probably the most significant design decisions in the implementation of a LZW compressor and decompressor. Hashing has been suggested as a useful technique for the compressor. We have chosen a tree-based approach, with good results. The decompressor is more straightforward and faster because no search is involved—strings can be accessed directly by code value.

LZW Extensions

Some images compress better using LZW coding if they are first subjected to a process wherein each pixel value is replaced by the difference between the pixel and the preceding pixel. See the following Section.

Acknowledgments

See the first page of this section for the LZW reference.

The use of ClearCode as a technique for handling overflow was borrowed from the compression scheme used by the Graphics Interchange Format (GIF), a small-color-paint-image-file format used by CompuServe that also uses an adaptation of the LZW technique.

Section 14: Differencing Predictor

This section defines a Predictor that greatly improves compression ratios for some images.

Predictor

Tag   = 317 (13D.H)

Type   = SHORT

N   = 1

A predictor is a mathematical operator that is applied to the image data before an encoding scheme is applied. Currently this field is used only with LZW (Compression=5) encoding because LZW is probably the only TIFF encoding scheme that benefits significantly from a predictor step. See Section 13.

The possible values are:

1 =   No prediction scheme used before coding.

2 =   Horizontal differencing.

Default is 1.

The algorithm

Make use of the fact that many continuous-tone images rarely vary much in pixel value from one pixel to the next. In such images, if we replace the pixel values by differences between consecutive pixels, many of the differences should be 0, plus or minus 1, and so on. This reduces the apparent information content and allows LZW to encode the data more compactly.

Assuming 8-bit grayscale pixels for the moment, a basic C implementation might look something like this:

```
char      image[ ][ ];
int       row, col;

/* take horizontal differences:
 */
for (row = 0; row < nrows; row++)
        for (col = ncols - 1; col >= 1; col--)
                image[row][col] -= image[row][col-1];
```

If we don't have 8-bit components, we need to work a little harder to make better use of the architecture of most CPUs. Suppose we have 4-bit components packed two per byte in the normal TIFF uncompressed (i.e., Compression=1) fashion. To find differences, we want to first expand each 4-bit component into an 8-bit byte, so that we have one component per byte, low-order justified. We then perform the horizontal differencing illustrated in the example above. Once the differencing has been completed, we then repack the 4-bit differences two to a byte, in the normal TIFF uncompressed fashion.

If the components are greater than 8 bits deep, expanding the components into 16-bit words instead of 8-bit bytes seems like the best way to perform the subtraction on most computers.

Note that we have not lost any data up to this point, nor will we lose any data later on. It might seem at first that our differencing might turn 8-bit components into 9-bit differences, 4-bit components into 5-bit differences, and so on. But it turns out that we can completely ignore the "overflow" bits caused by subtracting a larger number from a smaller number and still reverse the process without error. Normal two's complement arithmetic does just what we want. Try an example by hand if you need more convincing.

Up to this point we have implicitly assumed that we are compressing bilevel or grayscale images. An additional consideration arises in the case of color images.

If PlanarConfiguration is 2, there is no problem. Differencing works the same as it does for grayscale data.

If PlanarConfiguration is 1, however, things get a little trickier. If we didn't do anything special, we would subtract red component values from green component values, green component values from blue component values, and blue component values from red component values. This would not give the LZW coding stage much redundancy to work with. So, we will do our horizontal differences with an offset of SamplesPerPixel (3, in the RGB case). In other words, we will subtract red from red, green from green, and blue from blue. The LZW coding stage is identical to the SamplesPerPixel=1 case. We require that BitsPerSample be the same for all 3 components.

Results and Guidelines

LZW without differencing works well for 1-bit images, 4-bit grayscale images, and many palette-color images. But natural 24-bit color images and some 8-bit grayscale images do much better with differencing.

Although the combination of LZW coding with horizontal differencing does not result in any loss of data, it may be worthwhile in some situations to give up some information by removing as much noise as possible from the image data before doing the differencing, especially with 8-bit components. The simplest way to get rid of noise is to mask off one or two low-order bits of each 8-bit component. On our 24-bit test images, LZW with horizontal differencing yielded an average compression ratio of 1.4 to 1. When the low-order bit was masked from each component, the compression ratio climbed to 1.8 to 1; the compression ratio was 2.4 to 1 when masking two bits, and 3.4 to 1 when masking three bits. Of course, the more you mask, the more you risk losing useful information along with the noise. We encourage you to experiment to find the best compromise for your device. For some applications, it may be useful to let the user make the final decision.

Incidentally, we tried taking both horizontal and vertical differences, but the extra complexity of two-dimensional differencing did not appear to pay off for most of our test images. About one third of the images compressed slightly better with two-dimensional differencing, about one third compressed slightly worse, and the rest were about the same.

Section 15: Tiled Images

Introduction

Motivation

This section describes how to organize images into tiles instead of strips.

For low-resolution to medium-resolution images, the standard TIFF method of breaking the image into strips is adequate. However high-resolution images can be accessed more efficiently—and compression tends to work better—if the image is broken into roughly square tiles instead of horizontally-wide but vertically-narrow strips.

Relationship to existing fields

When the tiling fields described below are used, they replace the StripOffsets, StripByteCounts, and RowsPerStrip fields. Use of tiles will therefore cause older TIFF readers to give up because they will have no way of knowing where the image data is or how it is organized. **Do not** use both strip-oriented and tile-oriented fields in the same TIFF file.

Padding

Tile size is defined by TileWidth and TileLength. All tiles in an image are the same size; that is, they have the same pixel dimensions.

Boundary tiles are padded to the tile boundaries. For example, if TileWidth is 64 and ImageWidth is 129, then the image is 3 tiles wide and 63 pixels of padding must be added to fill the rightmost column of tiles. The same holds for TileLength and ImageLength. It doesn't matter what value is used for padding, because good TIFF readers display only the pixels defined by ImageWidth and ImageLength and ignore any padded pixels. Some compression schemes work best if the padding is accomplished by replicating the last column and last row instead of padding with 0's.

The price for padding the image out to tile boundaries is that some space is wasted. But compression usually shrinks the padded areas to almost nothing. Even if data is not compressed, remember that tiling is intended for large images. Large images have lots of comparatively small tiles, so that the percentage of wasted space will be very small, generally on the order of a few percent or less.

The advantages of padding an image to the tile boundaries are that implementations can be simpler and faster and that it is more compatible with tile-oriented compression schemes such as JPEG. See Section 22.

Tiles are compressed individually, just as strips are compressed. *That is, each row of data in a tile is treated as a separate "scanline" when compressing.* Compres-

sion includes any padded areas of the rightmost and bottom tiles so that all the tiles in an image are the same size when uncompressed.

All of the following fields are required for tiled images:

Fields

TileWidth

Tag   = 322 (142.H)

Type   = SHORT or LONG

N   = 1

The tile width in pixels. This is the number of columns in each tile.

Assuming integer arithmetic, three computed values that are useful in the following field descriptions are:

TilesAcross = (ImageWidth + TileWidth - 1) / TileWidth

TilesDown = (ImageLength + TileLength - 1) / TileLength

TilesPerImage = TilesAcross * TilesDown

These computed values are not TIFF fields; they are simply values determined by the ImageWidth, TileWidth, ImageLength, and TileLength fields.

TileWidth and ImageWidth together determine the number of tiles that span the width of the image (TilesAcross). TileLength and ImageLength together determine the number of tiles that span the length of the image (TilesDown).

We recommend choosing TileWidth and TileLength such that the resulting tiles are about 4K to 32K bytes before compression. This seems to be a reasonable value for most applications and compression schemes.

TileWidth must be a multiple of 16. This restriction improves performance in some graphics environments and enhances compatibility with compression schemes such as JPEG.

Tiles need not be square.

Note that ImageWidth can be less than TileWidth, although this means that the tiles are too large or that you are using tiling on really small images, neither of which is recommended. The same observation holds for ImageLength and TileLength.

No default. See also TileLength, TileOffsets, TileByteCounts.

TileLength

Tag   = 323 (143.H)

Type   = SHORT or LONG

N   = 1

The tile length (height) in pixels. This is the number of rows in each tile.

TileLength must be a multiple of 16 for compatibility with compression schemes such as JPEG.

Replaces RowsPerStrip in tiled TIFF files.

No default. See also TileWidth, TileOffsets, TileByteCounts.

TileOffsets

Tag   = 324 (144.H)

Type   = LONG

N   = TilesPerImage for PlanarConfiguration = 1

        = SamplesPerPixel * TilesPerImage for PlanarConfiguration = 2

For each tile, the byte offset of that tile, as compressed and stored on disk. The offset is specified with respect to the beginning of the TIFF file. Note that this implies that each tile has a location independent of the locations of other tiles.

Offsets are ordered left-to-right and top-to-bottom. For PlanarConfiguration = 2, the offsets for the first component plane are stored first, followed by all the offsets for the second component plane, and so on.

No default. See also TileWidth, TileLength, TileByteCounts.

TileByteCounts

Tag   = 325 (145.H)

Type   = SHORT or LONG

N   = TilesPerImage for PlanarConfiguration = 1

        = SamplesPerPixel * TilesPerImage for PlanarConfiguration = 2

For each tile, the number of (compressed) bytes in that tile.

See TileOffsets for a description of how the byte counts are ordered.

No default. See also TileWidth, TileLength, TileOffsets.

Section 16: CMYK Images

Motivation

This section describes how to store separated (usually CMYK) image data in a TIFF file.

In a separated image, each pixel consists of N components. Each component represents the amount of a particular ink that is to be used to represent the image at that location, typically using a halftoning technique.

For example, in a CMYK image, each pixel consists of 4 components. Each component represents the amount of cyan, magenta, yellow, or black process ink that is to be used to represent the image at that location.

The fields described in this section can be used for more than simple 4-color process (CMYK) printing. They can also be used for describing an image made up of more than 4 inks, such an image made up of a cyan, magenta, yellow, red, green, blue, and black inks. Such an image is sometimes called a high-fidelity image and has the advantage of slightly extending the printed color gamut.

Since separated images are quite device-specific and are restricted to color prepress use, they should not be used for general image data interchange. Separated images are to be used only for prepress applications in which the imagesetter, paper, ink, and printing press characteristics are known by the creator of the separated image.

Note: there is no single method of converting RGB data to CMYK data and back. In a perfect world, something close to cyan = 255-red, magenta = 255-green, and yellow = 255-blue should work; but characteristics of printing inks and printing presses, economics, and the fact that the meaning of RGB itself depends on other parameters combine to spoil this simplicity.

Requirements

In addition to satisfying the normal Baseline TIFF requirements, a separated TIFF file must have the following characteristics:

- **SamplesPerPixel = N.** SHORT. The number of inks. (For example, N=4 for CMYK, because we have one component each for cyan, magenta, yellow, and black.)

- **BitsPerSample = 8,8,8,8 (for CMYK).** SHORT. For now, only 8-bit components are recommended. The value "8" is repeated SamplesPerPixel times.

- **PhotometricInterpretation = 5 (Separated - usually CMYK).** SHORT. The components represent the desired percent dot coverage of each ink, where the larger component values represent a higher percentage of ink dot coverage and smaller values represent less coverage.

Fields

In addition, there are some new fields, all of which are optional.

InkSet

Tag   = 332 (14C.H)

Type = SHORT

N   = 1

The set of inks used in a separated (PhotometricInterpretation=5) image.

1 =   CMYK. The order of the components is cyan, magenta, yellow, black. Usually, a value of 0 represents 0% ink coverage and a value of 255 represents 100% ink coverage for that component, but see DotRange below. The InkNames field should not exist when InkSet=1.

2 =   not CMYK. See the InkNames field for a description of the inks to be used.

Default is 1 (CMYK).

NumberOfInks

Tag   = 334 (14E.H)

Type = SHORT

N   = 1

The number of inks. Usually equal to SamplesPerPixel, unless there are extra samples.

See also ExtraSamples.

Default is 4.

InkNames

Tag   = 333 (14D.H)

Type = ASCII

N   = total number of characters in all the ink name strings, including the NULs.

The name of each ink used in a separated (PhotometricInterpretation=5) image, written as a list of concatenated, NUL-terminated ASCII strings. The number of strings must be equal to NumberOfInks.

The samples are in the same order as the ink names.

See also InkSet, NumberOfInks.

No default.

DotRange

Tag   = 336 (150.H)

Type   = BYTE or SHORT

N   = 2, or 2*SamplesPerPixel

The component values that correspond to a 0% dot and 100% dot. DotRange[0] corresponds to a 0% dot, and DotRange[1] corresponds to a 100% dot.

If a DotRange pair is included for each component, the values for each component are stored together, so that the pair for Cyan would be first, followed by the pair for Magenta, and so on. *Use of multiple dot ranges is, however, strongly discouraged in the interests of simplicity and compatibility with ANSI IT8 standards.*

A number of prepress systems like to keep some "headroom" and "footroom" on both ends of the range. What to do with components that are less than the 0% aim point or greater than the 100% aim point is not specified and is application-dependent.

It is strongly recommended that a CMYK TIFF writer not attempt to use this field to reverse the sense of the pixel values so that smaller values mean more ink instead of less ink. That is, DotRange[0] should be less than DotRange[1].

DotRange[0] and DotRange[1] must be within the range [0, (2**BitsPerSample) - 1].

Default: a component value of 0 corresponds to a 0% dot, and a component value of 255 (assuming 8-bit pixels) corresponds to a 100% dot. That is, DotRange[0] = 0 and DotRange[1] = (2**BitsPerSample) - 1.

TargetPrinter

Tag   = 337 (151.H)

Type   = ASCII

N   = any

A description of the printing environment for which this separation is intended.

History

This Section has been expanded from earlier drafts, with the addition of the **InkSet, InkNames, NumberOfInks, DotRange**, and **TargetPrinter**, but is backward-compatible with earlier draft versions.

Possible future enhancements: definition of the characterization information so that the CMYK data can be retargeted to a different printing environment and so that display on a CRT or proofing device can more accurately represent the color. ANSI IT8 is working on such a proposal.

Section 17: HalftoneHints

This section describes a scheme for properly placing highlights and shadows in halftoned images.

Introduction

The single most easily recognized failing of continuous tone images is the incorrect placement of highlight and shadow. It is critical that a halftone process be capable of printing the lightest areas of the image as the smallest halftone spot capable of the output device, at the specified printer resolution and screen ruling. Specular highlights (small ultra-white areas) as well as the shadow areas should be printable as paper only.

Consistency in highlight and shadow placement allows the user to obtain predictable results on a wide variety of halftone output devices. Proper implementation of theHalftoneHints field will provide a significant step toward device independent imaging, such that low cost printers may to be used as effective proofing devices for images which will later be halftoned on a high-resolution imagesetter.

The HalftoneHints Field

HalftoneHints

Tag   = 321 (141.H)

Type   = SHORT

N   = 2

The purpose of the HalftoneHints field is to convey to the halftone function the range of gray levels within a colorimetrically-specified image that should retain tonal detail. The field contains two values of sixteen bits each and, therefore, is contained wholly within the field itself; no offset is required. The first word specifies the highlight gray level which should be halftoned at the lightest printable tint of the final output device. The second word specifies the shadow gray level which should be halftoned at the darkest printable tint of the final output device. Portions of the image which are whiter than the highlight gray level will quickly, if not immediately, fade to specular highlights. There is no default value specified, since the highlight and shadow gray levels are a function of the subject matter of a particular image.

Appropriate values may be derived algorithmically or may be specified by the user, either directly or indirectly.

The HalftoneHints field, as defined here, defines an achromatic function. It can be used just as effectively with color images as with monochrome images. When used with opponent color spaces such as CIE L*a*b* or YCbCr, it refers to the achromatic component only; L* in the case of CIELab, and Y in the case of

YCbCr. When used with tri-stimulus spaces such as RGB, it suggests to retain tonal detail for all colors with an NTSC gray component within the bounds of the R=G=B=Highlight to R=G=B=Shadow range.

Comments for TIFF Writers

TIFF writers are encouraged to include the HalftoneHints field in all color or grayscale images where BitsPerSample >1. Although no default value is specified, prior to the introduction of this field it has been common practice to implicitly specify the highlight and shadow gray levels as 1 and 2**BitsperSample-2 and manipulate the image data to this definition. There are some disadvantages to this technique, and it is not feasible for a fixed gamut colorimetric image type. Appropriate values may be derived algorithmically or may be specified by the user directly or indirectly. Automatic algorithms exist for analyzing the histogram of the achromatic intensity of an image and defining the minimum and maximum values as the highlight and shadow settings such that tonal detail is retained throughout the image. This kind of algorithm may try to impose a highlight or shadow where none really exists in the image, which may require user controls to override the automatic setting.

It should be noted that the choice of the highlight and shadow values is somewhat output dependent. For instance, in situations where the dynamic range of the output medium is very limited (as in newsprint and, to a lesser degree, laser output), it may be desirable for the user to clip some of the lightest or darkest tones to avoid the reduced contrast resulting from compressing the tone of the entire image. Different settings might be chosen for 150-line halftone printed on coated stock. Keep in mind that these values may be adjusted later (which might not be possible unless the image is stored as a colorimetric, fixed, full-gamut image), and that more sophisticated page-layout applications may be capable of presenting a user interface to consider these decisions at a point where the halftone process is well understood.

It should be noted that although CCDs are linear intensity detectors, TIFF writers may choose to manipulate the image to store gamma-compensated data. Gamma-compensated data is more efficient at encoding an image than is linear intensity data because it requires fewer BitsPerPixel to eliminate banding in the darker tones. It also has the advantage of being closer to the tone response of the display or printer and is, therefore, less likely to produce poor results from applications that are not rigorous about their treatment of images. Be aware that the PhotometricInterpretation value of 0 or 1 (grayscale) implies linear data because no gamma is specified. The PhotometricInterpretation value of 2 (RGB data) specifies the NTSC gamma of 2.2 as a default. If data is written as something other than the default, then a GrayResponseCurve field or a TransferFunction field must be present to define the deviation. For grayscale data, be sure that the densities in the GrayResponseCurve are consistent with the PhotometricInterpretation field and the HalftoneHints field.

Comments for TIFF Readers

TIFF readers that send a grayscale image to a halftone output device, whether it is a binary laser printer or a PostScript imagesetter should make an effort to maintain the highlight and shadow placement. This requires two steps. First, determine the highlight and shadow gray level of a particular image. Second, communicate that information to the halftone engine.

To determine the highlight and shadow gray levels, begin by looking for a HalftoneHints field. If it exists, it takes precedence. The first word represents the gray level of the highlight and the second word represents the gray level of the shadow. If the image is a colorimetric image (i.e. it has a GrayResponseCurve field or a TransferFunction field) but does not contain a HalftoneHints field, then the gamut mapping techniques described earlier should be used to determine the highlight and shadow values. If neither of these conditions are true, then the file should be treated as if a HalftoneHints field had indicated a highlight at gray level 1 and a shadow at gray level 2**BitsPerPixel-2 (or vice-versa depending on the PhotometricInterpretation field). Once the highlight and shadow gray levels have been determined, the next step is to communicate this information to the halftone module. The halftone module may exist within the same application as the TIFF reader, it may exist within a separate printer driver, or it may exist within the Raster Image Processor (RIP) of the printer itself. Whether the halftone process is a simple dither pattern or a general purpose spot function, it has some gray level at which the lightest printable tint will be rendered. The HalftoneHint concept is best implemented in an environment where this lightest printable tint is easily and consistently specified.

There are several ways in which an application can communicate the highlight and shadow to the halftone function. Some environments may allow the application to pass the highlight and shadow to the halftone module explicitly along with the image. This is the best approach, but many environments do not yet provide this capability. Other environments may provide fixed gray levels at which the highlight and shadow will be rendered. For these cases, the application should build a tone map that matches the highlight and shadow specified in the image to the highlight and shadow gray level of the halftone module. This approach requires more work by the application software, but will provide excellent results. Some environments will not have any consistent concept of highlight and shadow at all. In these environments, the best an application can do is characterize each of the supported printers and save the observed highlight and shadow gray levels. The application can then use these values to achieve the desired results, providing the environment doesn't change.

Once the highlight and shadow areas are selected, care should be taken to appropriately map intermediate gray levels to those expected by the halftone engine, which may or may not be linear Reflectance. Note that although CCDs are linear intensity detectors and many TIFF files are stored as linear intensity, most output devices require significant tone compensation (sometimes called gamma correction) to correctly display or print linear data. Be aware that the PhotometricInterpretation value of 0, 1 implies linear data because no gamma is specified. The PhotometricInterpretation value of 2 (RGB data) specifies the NTSC gamma of 2.2 as a default. If a GrayResponseCurve field or a TransferFunction field is present, it may define something other than the default.

Some Background on the Halftone Process

To obtain the best results when printing a continuous-tone raster image, it is seldom desirable to simply reproduce the tones of the original on the printed page. Most often there is some gamut mapping required. Often this is because the tonal range of the original extends beyond the tonal range of the output medium. In some cases, the tone range of the original is within the gamut of the output medium, but it may be more pleasing to expand the tone of the image to fill the range of the output. Given that the tone of the original is to be adjusted, there is a whole range of possibilities for the level of sophistication that may be undertaken by a software application.

Printing monochrome output is far less sophisticated than printing color output. For monochrome output the first priority is to control the placement of the highlight and the shadow. Ideally, a quality halftone will have sufficient levels of gray so that a standard observer cannot distinguish the interface between any two adjacent levels of gray. In practice, however, there is often a significant step between the tone of the paper and the tone of the lightest printable tint. Although usually less severe, the problem is similar between solid ink and the darkest printable tint. Since the dynamic range between the lightest printable tint and the darkest printable tint is usually less than one would like, it is common to maximize the tone of the image within these bounds. Not all images will have a highlight (an area of the image which is desirable to print as light as possible while still retaining tonal detail). If one exists, it should be carefully controlled to print at the lightest printable tint of the output medium. Similarly, the darkest areas of the image to retain tonal detail should be printed as the darkest printable tint of the output medium. Tones lighter or darker than these may be clipped at the limits of the paper and ink. Satisfactory results may be obtained in monochrome work by doing nothing more than a perceptually-linear mapping of the image between these rigorously controlled endpoints. This level of sophistication is sufficient for many mid-range applications, although the results often appear flatter (i.e. lower in contrast) than desired.

The next step is to increase contrast slightly in the tonal range of the image that contains the most important subject matter. To perform this step well requires considerably more information about the image and about the press. To know where to add contrast, the algorithm must have access to first the keyness of the image; the tone range which the user considers most important. To know how much contrast to add, the algorithm must have access to the absolute tone of the original and the dynamic range of the output device so that it may calculate the amount of tone compression to which the image is actually subjected.

Most images are called normal key. The important subject areas of a normal key image are in the midtones. These images do well when a so-called "sympathetic curve" is applied, which increases the contrast in midtones slightly at the expense of contrast in the lighter and darker tones. White china on a white tablecloth is an example of a high key image. High key images benefit from higher contrast in lighter tones, with less contrast needed in the midtones and darker tones. Low key images have important subject matter in the darker tones and benefit from increasing the contrast in the darker tones. Specifying the keyness of an image might be attempted by automatic techniques, but it will likely fail without user input. For example, a photo of a bride in a white wedding dress it may be a high key image if

you are selling wedding dresses, but may be a normal key image if you are the parents of the bride and are more interested in her smile.

Sophisticated color reproduction employs all of these principles, and then applies them in three dimensions. The mapping of the highlight and shadow becomes only one small, albeit critical, portion of the total issue of mapping colors that are too saturated for the output medium. Here again, automatic techniques may be employed as a first pass, with the user becoming involved in the clip or compress mapping decision. The HalftoneHints field is still useful in communicating which portions of the intensity of the image must be retained and which may be clipped. Again, a sophisticated application may override these settings if later user input is received.

Section 18: Associated Alpha Handling

This section describes a scheme for handling images with alpha data.

Introduction

A common technique in computer graphics is to assemble an image from one or more elements that are rendered separately. When elements are combined using compositing techniques, matte or coverage information must be present for each pixel to create a properly anti-aliased accumulation of the full image [Porter84]. This matting information is an example of additional per-pixel data that must be maintained with an image. This section describes how to use the ExtraSamples field to store the requisite matting information, commonly called the associated alpha or just alpha. This scheme enables efficient manipulation of image data during compositing operations.

Images with matting information are stored in their natural format but with an additional component per pixel. The ExtraSample field is included with the image to indicate that an extra component of each pixel contains associated alpha data. In addition, when associated alpha data are included with RGB data, the RGB components must be stored premultiplied by the associated alpha component and component values in the range [0,2**BitsPerSample-1] are implicitly mapped onto the [0,1] interval. That is, for each pixel (r,g,b) and opacity A, where r, g, b, and A are in the range [0,1], (A*r,A*g,A*b,A) must be stored in the file. If A is zero, then the color components should be interpreted as zero. Storing data in this pre-multiplied format, allows compositing operations to be implemented most efficiently. In addition, storing pre-multiplied data makes it possible to specify colors with components outside the normal [0,1] interval. The latter is useful for defining certain operations that effect only the luminescence [Porter84].

Fields

ExtraSamples

Tag   = 338 (152.H)

Type   = SHORT

N   = 1

This field must have a value of 1 (associated alpha data with pre-multiplied color components). The associated alpha data stored in component SamplesPerPixel-1 of each pixel contains the opacity of that pixel, and the color information is pre-multiplied by alpha.

Comments

Associated alpha data is just another component added to each pixel. Thus, for example, its size is defined by the value of the BitsPerSample field.

Note that since data is stored with RGB components already multiplied by alpha, naive applications that want to display an RGBA image on a display can do so simply by displaying the RGB component values. This works because it is effectively the same as merging the image with a black background. That is, to merge one image with another, the color of resultant pixels are calculated as:

$$C_r = C_{over} * A_{over} + C_{under} * (1 - A_{over})$$

Since the "under image" is a black background, this equation reduces to

$$C_r = C_{over} * A_{over}$$

which is exactly the pre-multiplied color; i.e. what is stored in the image.

On the other hand, to print an RGBA image, one must composite the image over a suitable background page color. For a white background, this is easily done by adding 1 - A to each color component. For an arbitrary background color C_{back}, the *printed color* of each pixel is

$$C_{print} = C_{image} + C_{back} * (1 - A_{image})$$

(since C_{image} is pre-multiplied).

Since the ExtraSamples field is independent of other fields, this scheme permits alpha information to be stored in whatever organization is appropriate. In particular, components can be stored packed (PlanarConfiguration=1); this is important for good I/O performance and for good memory access performance on machines that are sensitive to data locality. However, if this scheme is used, TIFF readers must not derive the SamplesPerPixel from the value of the PhotometricInterpretation field (e.g., if RGB, then SamplesPerPixel is 3).

In addition to being independent of data storage-related fields, the field is also independent of the PhotometricInterpretation field. This means, for example, that it is easy to use this field to specify grayscale data and associated matte information. Note that a palette-color image with associated alpha will not have the colormap indices pre-multiplied; rather, the RGB colormap values will be pre-multiplied.

Unassociated Alpha and Transparency Masks

Some image manipulation applications support notions of transparency masks and soft-edge masks. The associated alpha information described in this section is different from this *unassociated alpha* information in many ways, most importantly:

- Associated alpha describes opacity or coverage at each pixel, while clipping-related alpha information describes a boolean relationship. That is, associated alpha can specify fractional coverage at a pixel, while masks specify either 0 or 100 percent coverage.

- Once defined, associated alpha is not intended to be removed or edited, except as a result of compositing the image; it is an integral part of an image.

Unassociated alpha, on the other hand, is designed as an ancillary piece of information.

References

[Porter84] "Compositing Digital Images". Thomas Porter, Tom Duff; Lucasfilm Ltd. ACM SIGGRAPH Proceedings Volume 18, Number 3. July, 1984.

Section 19: Data Sample Format

This section describes a scheme for specifying data sample type information.

TIFF implicitly types all data samples as unsigned integer values. Certain applications, however, require the ability to store image-related data in other formats such as floating point. This section presents a scheme for describing a variety of data sample formats.

Fields

SampleFormat

Tag   = 339 (153.H)

Type   = SHORT

N   = SamplesPerPixel

This field specifies how to interpret each data sample in a pixel. Possible values are:

1 =   unsigned integer data

2 =   two's complement signed integer data

3 =   IEEE floating point data [IEEE]

4 =   undefined data format

Note that the SampleFormat field does not specify the size of data samples; this is still done by the BitsPerSample field.

A field value of "undefined" is a statement by the writer that it did not know how to interpret the data samples; for example, if it were copying an existing image. A reader would typically treat an image with "undefined" data as if the field were not present (i.e. as unsigned integer data).

Default is 1, unsigned integer data.

SMinSampleValue

Tag   = 340 (154.H)

Type   = the field type that best matches the sample data

N   = SamplesPerPixel

This field specifies the minimum sample value. Note that a value should be given for each data sample. That is, if the image has 3 SamplesPerPixel, 3 values must be specified.

The default for SMinSampleValue and SMaxSampleValue is the full range of the data type.

SMaxSampleValue

Tag   = 341 (155.H)

Type   = the field type that best matches the sample data

N   = SamplesPerPixel

This new field specifies the maximum sample value.

Comments

The SampleFormat field allows more general imaging (such as image processing) applications to employ TIFF as a valid file format.

SMinSampleValue and SMaxSampleValue become more meaningful when image data is typed. The presence of these fields makes it possible for readers to assume that data samples are bound to the range [SMinSampleValue, SMaxSampleValue] without scanning the image data.

References

[IEEE] "IEEE Standard 754 for Binary Floating-point Arithmetic".

Section 20: RGB Image Colorimetry

Without additional information, RGB data is device-specific; that is, without an absolute color meaning. This section describes a scheme for describing and characterizing RGB image data.

Introduction

Color printers, displays, and scanners continue to improve in quality and availability while they drop in price. Now the problem is to display color images so that they appear to be identical on different hardware.

The key to reproducing the same color on different devices is to use the CIE 1931 XYZ color-matching functions, the international standard for color comparison. Using CIE XYZ, an image's colorimetry information can fully describe its color interpretation. The approach taken here is essentially calibrated RGB. It implies a transformation from the RGB color space of the pixels to CIE 1931 XYZ.

The appearance of a color depends not only on its absolute tristimulus values, but also on the conditions under which it is viewed, including the nature of the surround and the adaptation state of the viewer. Colors having the same absolute tristimulus values appear the same in identical viewing conditions. The more complex issue of color appearance under different viewing conditions is addressed by [4]. The colorimetry information presented here plays an important role in color appearance under different viewing conditions.

Assuming identical viewing conditions, an application using the tags described below can display an image on different hardware and achieve colorimetrically identical results. The process of using this colorimetry information for displaying an image is straightforward on a color monitor but it is more complex for color printers. Also, the results will be limited by the color gamut and other characteristics of the display or printing device.

The following fields describe the image colorimetry information of a TIFF image:

WhitePoint   chromaticity of the white point of the image

PrimaryChromaticities chromaticities of the primaries of the image

TransferFunction   transfer function for the pixel data

TransferRange extends the range of the transfer function

ReferenceBlackWhite pixel component headroom and footroom parameters

The TransferFunction, TransferRange, and ReferenceBlackWhite fields have defaults based on industry standards. An image has a colorimetric interpretation if and only if both the WhitePoint and PrimaryChromaticities fields are present. An image without these colorimetry fields will be displayed in an application and hardware dependent manner.

Note: In the following definitions, BitsPerSample is used as if it were a single number when in fact it is an array of SamplesPerPixel numbers. The elements of

this array may not always be equal, for example: 5/6/5 16-bit pixels. BitsPerSample should be interpreted as the BitsPerSample value associated with a particular component. In the case of unequal BitsPerSample values, the definitions below can be extended in a straightforward manner.

This section has the following differences with Appendix H in TIFF 5.0:

- removed the use of image colorimetry defaults
- renamed the ColorResponseCurves field as TransferFunction
- optionally allowed a single TransferFunction table to describe all three channels
- described the use of the TransferFunction field for YCbCr, Palette, WhiteIsZero and BlackIsZero PhotometricInterpretation types
- added the TransferRange tag to expand the range of the TransferFunction below black and above white
- added the ReferenceBlackWhite field
- addressed the issue of color appearance

Colorimetry Field Definitions

WhitePoint

Tag   = 318 (13E.H)

Type   = RATIONAL

N   = 2

The chromaticity of the white point of the image. This is the chromaticity when each of the primaries has its ReferenceWhite value. The value is described using the 1931 CIE xy chromaticity diagram and only the chromaticity is specified. This value can correspond to the chromaticity of the alignment white of a monitor, the filter set and light source combination of a scanner or the imaging model of a rendering package. The ordering is white[x], white[y].

For example, the CIE Standard Illuminant D65 used by CCIR Recommendation 709 and Kodak PhotoYCC is:

　　　　3127/10000,3290/10000

No default.

PrimaryChromaticities

Tag   =319 (13F.H)

Type   = RATIONAL

N   = 6

The chromaticities of the primaries of the image. This is the chromaticity for each of the primaries when it has its ReferenceWhite value and the other primaries have their ReferenceBlack values. These values are described using the 1931 CIE xy chromaticity diagram and only the chromaticities are specified. These values can correspond to the chromaticities of the phosphors of a monitor, the filter set and light source combination of a scanner or the imaging model of a rendering package. The ordering is red[x], red[y], green[x], green[y], blue[x], and blue[y].

For example the CCIR Recommendation 709 primaries are:

> 640/1000,330/1000,
>
> 300/1000, 600/1000,
>
> 150/1000, 60/1000

No default.

TransferFunction

Tag   =301 (12D.H)

Type   = SHORT

N   = {1 or 3} * (1 << BitsPerSample)

Describes a transfer function for the image in tabular style. Pixel components can be gamma-compensated, companded, non-uniformly quantized, or coded in some other way. The TransferFunction maps the pixel components from a non-linear BitsPerSample (e.g. 8-bit) form into a 16-bit linear form without a perceptible loss of accuracy.

If N = 1 << BitsPerSample, the transfer function is the same for each channel and all channels share a single table. Of course, this assumes that each channel has the same BitsPerSample value.

If N = 3 * (1 << BitsPerSample), there are three tables, and the ordering is the same as it is for pixel components of the PhotometricInterpretation field. These tables are separate and not interleaved. For example, with RGB images all red entries come first, followed by all green entries, followed by all blue entries.

The length of each component table is 1 << BitsPerSample. The width of each entry is 16 bits as implied by the type SHORT. Normally the value 0 represents the minimum intensity and 65535 represents the maximum intensity and the values [0, 0, 0] represent black and [65535,65535, 65535] represent white. If the TransferRange tag is present then it is used to determine the minimum and maximum values, and a scaling normalization.

The TransferFunction can be applied to images with a PhotometricInterpretation value of RGB, Palette, YCbCr, WhiteIsZero, and BlackIsZero. The TransferFunction is not used with other PhotometricInterpretation types.

For RGB PhotometricInterpretation, ReferenceBlackWhite expands the coding range, TransferRange expands the range of the TransferFunction, and the TransferFunction tables decompand the RGB value. The WhitePoint and PrimaryChromaticities further describe the RGB colorimetry.

For Palette color PhotometricInterpretation, the Colormap maps the pixel into three 16-bit values that when scaled to BitsPerSample-bits serve as indices into the TransferFunction tables which decompand the RGB value. The WhitePoint and PrimaryChromaticities further describe the underlying RGB colorimetry.

A Palette value can be scaled into a TransferFunction index by:

index= (value * ((1 << BitsPerSample) - 1)) / 65535;

A TransferFunction index can be scaled into a Palette color value by:

value= (index * 65535L) / ((1 << BitsPerSample) - 1);

Be careful if you intend to create Palette images with a TransferFunction. If the Colormap tag is directly converted from a hardware colormap, it may have a device gamma already incorporated into the DAC values.

For YCbCr PhotometricInterpretation, ReferenceBlackWhite expands the coding range, the YCbCrCoefficients describe the decoding matrix to transform YCbCr into RGB, TransferRange expands the range of the TransferFunction, and the TransferFunction tables decompand the RGB value. The WhitePoint and PrimaryChromaticities fields provide further description of the underlying RGB colorimetry.

After coding range expansion by ReferenceBlackWhite and TransferFunction expansion by TransferRange, RGB values may be outside the domain of the TransferFunction. Also, the display device matrix can transform RGB values into display device RGB values outside the domain of the device. These values are handled in an application-dependent manner.

For RGB images with non-default ReferenceBlackWhite coding range expansion and for YCbCr images, the resolution of the TransferFunction may be insufficient. For example, after the YCbCr transformation matrix, the decoded RGB values must be rounded to index into the TransferFunction tables. Applications needing the extra accuracy should interpolate between the elements of the TransferFunction tables. Linear interpolation is recommended.

For WhiteIsZero and BlackIsZero PhotometricInterpretation, the TransferFunction decompands the grayscale pixel value to a linear 16-bit form. Note that a TransferFunction value of 0 represents black and 65535 represents white regardless of whether a grayscale image is WhiteIsZero or BlackIsZero. For example, the zeroth element of a WhiteIsZero TransferFunction table will likely be 65535. This extension of the TransferFunction field for grayscale images is intended to replace the GrayResponseCurve field.

The TransferFunction does not describe a transfer characteristic outside of the range for ReferenceBlackWhite.

Default is a single table corresponding to the NTSC standard gamma value of 2.2. This table is used for each channel. It can be generated by:

```
NValues = 1 << BitsPerSample;
for (TF[0]= 0, i = 1; i < NValues; i++)
            TF[i]= floor(pow(i / (NValues - 1.0), 2.2) * 65535 + 0.5);
```

TransferRange

Tag   = 342 (156.H)

Type   = SHORT

N   = 6

Expands the range of the TransferFunction. The first value within a pair is associated with TransferBlack and the second is associated with TransferWhite. The ordering of pairs is the same as for pixel components of the PhotometricInterpretation type. By default, theTransferFunction is defined over a range from a minimum intensity, 0 or nominal black, to a maximum intensity,(1 << BitsPerSample) - 1 or nominal white. Kodak PhotoYCC uses an extended range TransferFunction in order to describe highlights, saturated colors and shadow detail beyond this range. The TransferRange expands the TransferFunction to support these values. It is defined only for RGB and YCbCr PhotometricInterpretations.

After ReferenceBlackWhite and/or YCbCr decoding has taken place, an RGB value can be represented as a real number. It is then rounded to create an index into the TransferFunctiontable. In the absence of a TransferRange tag, or if the tag has the default values, the rounded value is an index and the normalized intensity value is:

```
index = (int) (value + (value < 0.0? -0.5 : 0.5));
intensity = TF[index] / 65535;
```

If the TransferRange tag is present and has non-default values, it provides an offset to be used with the rounded index. It also describes a scaling. The normalized intensity value is:

```
index = (int) (value + (value < 0.0? -0.5 : 0.5));
intensity = (TF[index + TransferRange[Black]] -
         TF[TransferRange[Black]])
         / (TF[TransferRange[White]] - TF[TransferRange[Black]]);
```

An application can write a TransferFunction with a non-defaultTransferRange as follows:

```
black_offset = scale_factor * Transfer(-TransferRange[Black]ar /
         (TransferRange[White] - TransferRange[Black]));
for (i = 0; i < (1 << BitsPerSample); i++)
         TF[i] = floor(0.5 - black_offset + scale_factor
                 * Transfer((i - TransferRange[Black])
                 / (TransferRange[White] - TransferRange[Black])));
```

The TIFF writer chooses scale_factor such that the TransferFunction fits into a 16-bit unsigned short, and chooses the TransferRange so that the most important part of the TransferFunction fits into the table.

Default is [0, NV, 0, NV, 0, NV] where NV = (1 <<BitsPerSample) - 1.

ReferenceBlackWhite

Tag   =532 (214.H)

Type   = RATIONAL

N   = 6

Specifies a pair of headroom and footroom image data values (codes) for each pixel component. The first component code within a pair is associated with ReferenceBlack, and the second is associated with ReferenceWhite. The ordering of pairs is the same as those for pixel components of the PhotometricInterpretation type. ReferenceBlackWhite can be applied to images with a PhotometricInterpretation value of RGB or YCbCr. ReferenceBlackWhite is not used with other PhotometricInterpretation values.

Computer graphics commonly places black and white at the extremities of the binary representation of image data; for example, black at code 0 and white at code 255. In other disciplines, such as printing, film, and video, there are practical reasons to provide footroom codes below ReferenceBlack and headroom codes above ReferenceWhite.

In film applications, they correspond to the densities Dmax and Dmin. In video applications, ReferenceBlack corresponds to 7.5 IRE and 0 IRE in systems with and without setup respectively, and ReferenceWhite corresponds to 100 IRE units.

Using YCbCr (See Section 21) and the CCIR Recommendation 601.1 video standard as an example, code 16 represents ReferenceBlack, and code 235 represents ReferenceWhite for the luminance component (Y). For the chrominance components, Cb and Cr, code 128 represents ReferenceBlack, and code 240 represents ReferenceWhite. With Cb and Cr, the ReferenceWhite value is used to code reference blue and reference red respectively.

The full range component value is converted from the code by:

```
FullRangeValue = (code - ReferenceBlack) * CodingRange
        / (ReferenceWhite - ReferenceBlack);
```

The code is converted from the full-range component value by:

```
code = (FullRangeValue * (ReferenceWhite - ReferenceBlack)
        / CodingRange) + ReferenceBlack;
```

For RGB images and the Y component of YCbCr images, CodingRange is defined as:

```
CodingRange = 2 ** BitsPerSample - 1;
```

For the Cb and Cr components of YCbCr images, CodingRange is defined as:

```
CodingRange = 127;
```

For RGB images, in the default special case of no headroom or footroom, this conversion can be skipped because the scaling multiplier equals 1.0 and the value equals the code.

For YCbCr images, in the case of no headroom or footroom, the conversion for Y can be skipped because the value equals the code. For Cb and Cr, ReferenceBlack must still be subtracted from the code. In the general case, the scaling multiplication for the Cb and Cr component codes can be factored into the YCbCr transform matrix.

Useful ReferenceBlackWhite values for YCbCr images are:

[0/1, 255/1,128/1, 255/1, 128/1, 255/1]

no headroom/footroom

[15/1, 235/1, 128/1, 240/1, 128/1, 240/1]

CCIR Recommendation 601.1 headroom/footroom

Useful ReferenceBlackWhite values for BitsPerSample = 8,8,8 Class R images are:

[0/1, 255/1,0/1, 255/1, 0/1, 255/1]

no headroom/footroom

[16/1, 235/1, 16/1, 235/1, 16/1, 235/1]

CCIR Recommendation 601.1 headroom/footroom

Default is [0/,NV/1, 0/1, NV/1, 0/1, NV/1] where NV = 2 ** BitsPerSample - 1.

References

[1] *The Reproduction of Colour in Photography, Printing and Television,* R. W. G. Hunt, Fountain Press, Tolworth, England,1987.

[2] *Principles of Color Technology*, Billmeyer and Saltzman, Wiley-Interscience, New York, 1981.

[3] *Colorimetric Properties of Video Displays*, William Cowan, University of Waterloo, Waterloo, Canada, 1989.

[4] *TIFF Color Appearance Guidelines*, Dave Farber, Eastman Kodak Company, Rochester, New York.

Section 21: YC$_b$C$_r$ Images

Introduction

Digitizers of video sources that create RGB data are becoming more capable and less expensive. The RGB color space is adequate for this purpose. However, for both digital video and image compression applications a color difference color space is needed. The television industry depends on YC$_b$C$_r$ for digital video. For image compression, subsampling the chrominance components allows for greater compression. TIFF YC$_b$C$_r$ (which we shall call *Class Y*) supports these images and applications.

Class Y is based on CCIR Recommendation 601-1, "Encoding Parameters of Digital Television for Studios." Class Y also has parameters that allow the description of related standards such as CCIR Recommendation 709 and technological variations such as component-sample positioning.

YC$_b$C$_r$ is a distinct PhotometricInterpretation type. RGB pixels are converted to and from YC$_b$C$_r$ for storage and display.

Class Y defines the following fields:

YC$_b$C$_r$Coefficients   transformation from RGB to YC$_b$C$_r$

YC$_b$C$_r$SubSampling   subsampling of the chrominance components

YC$_b$C$_r$Positioning   positioning of chrominance component samples relative
                              to the luminance samples

In addition, ReferenceBlackWhite, which specifies coding range expansion, is required by Class Y. See Section 20.

Class Y YC$_b$C$_r$ images have three components: Y, the luminance component, and C$_b$ and C$_r$, two chrominance components. Class Y uses the international standard notation YC$_b$C$_r$ for color-difference component coding. This is often incorrectly called YUV, which properly applies only to composite coding.

The transformations between YC$_b$C$_r$ and RGB are linear transformations of uninterpreted RGB sample data, typically gamma-corrected values. The YC$_b$C$_r$Coefficients field describes the parameters of this transformation.

Another feature of Class Y comes from subsampling the chrominance components. A Class Y image can be compressed by reducing the spatial resolution of chrominance components. This takes advantage of the relative insensitivity of the human visual system to chrominance detail. The YC$_b$C$_r$SubSampling field describes the degree of subsampling which has taken place.

When a Class Y image is subsampled, each C$_b$ and C$_r$ sample is associated with a group of luminance samples. The YC$_b$C$_r$Positioning field describes the position of the chrominance component samples relative to the group of luminance samples: centered or cosited.

Class Y requires use of the ReferenceBlackWhite field. This field expands the coding range by describing the reference black and white values for the different components that allow headroom and footroom for digital video images. Since the

default for ReferenceBlackWhite is inappropriate for Class Y, it must be used explicitly.

At first, it might seem that the information conveyed by Class Y and the RGB Colorimetry section is redundant. However, decoding YC_bC_r to RGB primaries requires the YC_bC_r fields, and interpretation of the resulting RGB primaries requires the colorimetry and transfer function information. See the RGB Colorimetry section for details.

Extensions to Existing Fields

Class Y images use a distinct PhotometricInterpretation Field value:

PhotometricInterpretation

Tag   = 262 (106.H)

Type   = SHORT

N   = 1

This Field indicates the color space of the image. The new value is:

6 = YC_bC_r

A value of 6 indicates that the image data is in the YC_bC_r color space. TIFF uses the international standard notation YC_bC_r for color-difference sample coding. Y is the luminance component. C_b and C_r are the two chrominance components. RGB pixels are converted to and from YC_bC_r form for storage and display.

Fields Defined in Class Y

YC_bC_r Coefficients

Tag   = 529 (211.H)

Type   = RATIONAL

N   = 3

The transformation from RGB to YC_bC_r image data. The transformation is specified as three rational values that represent the coefficients used to compute luminance, Y.

The three rational coefficient values, *LumaRed*, *LumaGreen* and *LumaBlue*, are the proportions of red, green, and blue respectively in luminance, Y.

Y, C_b, and C_r may be computed from RGB using the luminance coefficients specified by this field as follows:

Y = (*LumaRed* * R + *LumaGreen* * G + *LumaBlue* * B)

C_b = (B - Y) / (2 - 2 * *LumaBlue*)

$$C_r = (R - Y) / (2 - 2 * LumaRed)$$

R, G, and B may be computed from YC_bC_r as follows:

$$R = C_r * (2 - 2 * LumaRed) + Y$$

$$G = (Y - LumaBlue * B - LumaRed * R) / LumaGreen$$

$$B = C_b * (2 - 2 * LumaBlue) + Y$$

In disciplines such as printing, film, and video, there are practical reasons to provide footroom codes below the ReferenceBlack code and headroom codes above ReferenceWhite code. In such cases the values of the transformation matrix used to convert from YC_bC_r to RGB must be multiplied by a scale factor to produce full-range RGB values. These scale factors depend on the reference ranges specified by the ReferenceBlackWhite field. See the ReferenceBlackWhite and TransferFunction fields for more details.

The values coded by this field will typically reflect the transformation specified by a standard for YC_bC_r encoding. The following table contains examples of commonly used values.

Standard	*LumaRed*	*LumaGreen*	*LumaBlue*
CCIR Recommendation 601-1	299 / 1000	587 / 1000	114 / 1000
CCIR Recommendation 709	2125 / 10000	7154 / 10000	721 / 10000

The default values for this field are those defined by CCIR Recommendation 601-1: 299/1000, 587/1000 and 114/1000, for *LumaRed*, *LumaGreen* and *LumaBlue*, respectively.

$YC_bC_rSubSampling$

Tag   = 530 (212.H)

Type   = SHORT

N   = 2

Specifies the subsampling factors used for the chrominance components of a YC_bC_r image. The two fields of this field, $YC_bC_rSubsampleHoriz$ and $YC_bC_rSubsampleVert$, specify the horizontal and vertical subsampling factors respectively.

The two fields of this field are defined as follows:

Short 0: $YC_bC_rSubsampleHoriz$:

1 =   ImageWidth of this chroma image is equal to the ImageWidth of the associated luma image.

2 =   ImageWidth of this chroma image is halfthe ImageWidth of the associated luma image.

4 =   ImageWidth of this chroma image is one-quarter the ImageWidth of the associated luma image.

Short 1: $YC_bC_rSubsampleVert$:

1 =   ImageLength (height) of this chroma image is equal to the ImageLength of the associated luma image.

2 =   ImageLength (height) of this chroma image is half the ImageLength of the associated luma image.

4 =   ImageLength (height) of this chroma image is one-quarter the ImageLength of the associated luma image.

Both C_b and C_r have the same subsampling ratio. Also, *YC$_b$C$_r$SubsampleVert* shall always be less than or equal to *YC$_b$C$_r$SubsampleHoriz.*

ImageWidth and ImageLength are constrained to be integer multiples of *YC$_b$C$_r$SubsampleHoriz* and *YC$_b$C$_r$SubsampleVert* respectively. TileWidth and TileLength have the same constraints. RowsPerStrip must be an integer multiple of *YC$_b$C$_r$SubsampleVert.*

The default values of this field are [2, 2].

YC$_b$C$_r$Positioning

Tag   = 531 (213.H)

Type   = SHORT

N   = 1

Specifies the positioning of subsampled chrominance components relative to luminance samples.

Specification of the spatial positioning of pixel samples relative to the other samples is necessary for proper image post processing and accurate image presentation. In Class Y files, the position of the subsampled chrominance components are defined with respect to the luminance component. Because components must be sampled orthogonally (along rows and columns), the spatial position of the samples in a given subsampled component may be determined by specifying the horizontal and vertical offsets of the first sample (i.e. the sample in the upper-left corner) with respect to the luminance component. The horizontal and vertical offsets of the first chrominance sample are denoted Xoffset[0,0] and Yoffset[0,0] respectively. Xoffset[0,0] and Yoffset[0,0] are defined in terms of the number of samples in the luminance component.

The values for this field are defined as follows:

Tag value	YC$_b$C$_r$ Positioning	X and Y offsets of first chrominance sample
1	centered	Xoffset[0,0] = *ChromaSubsampleHoriz* / 2 - 0.5 Yoffset[0,0] = *ChromaSubsampleVert* / 2 - 0.5
2	cosited	Xoffset[0,0] = 0 Yoffset[0,0] = 0

Field value 1 (centered) must be specified for compatibility with industry standards such as PostScript Level 2 and QuickTime. Field value 2 (cosited) must be specified for compatibility with most digital video standards, such as CCIR Recommendation 601-1.

As an example, for *ChromaSubsampleHoriz* = 4 and *ChromaSubsampleVert* = 2, the centers of the samples are positioned as illustrated below:

YC_bC_r Positioning = 1 YC_bC_r Positioning = 2

×   Luminance samples

○   Chrominance samples
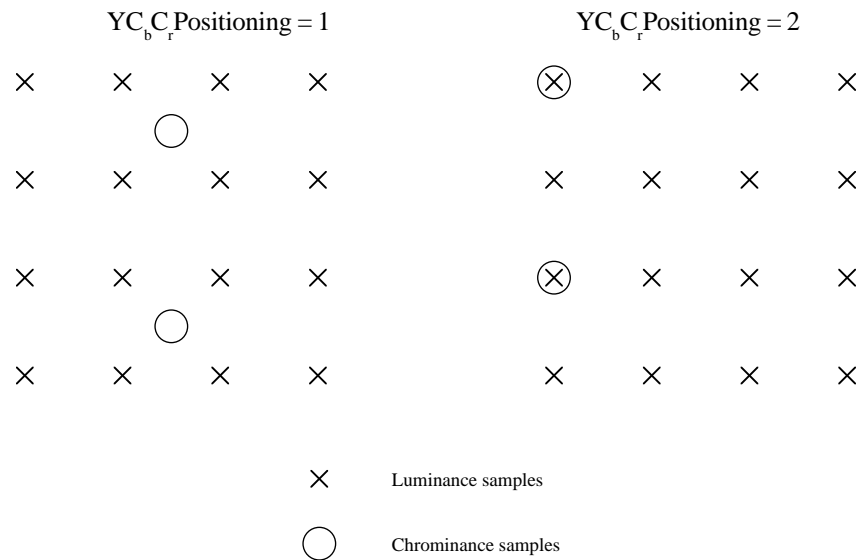
Proper subsampling of the chrominance components incorporates an anti-aliasing filter that reduces the spectral bandwidth of the full-resolution samples. The type of filter used for subsampling determines the value of the YC_bC_r Positioning field.

For YC_bC_r Positioning = 1 (centered), subsampling of the chrominance components can easily be accomplished using a symmetrical digital filter with an even number of taps (coefficients). A commonly used filter for 2:1 subsampling utilizes two taps (1/2,1/2).

For YC_bC_r Positioning = 2 (cosited), subsampling of the chrominance components can easily be accomplished using a symmetrical digital filter with an odd number of taps. A commonly used filter for 2:1 subsampling utilizes three taps (1/4,1/2,1/4).

The default value of this field is 1.

Ordering of Component Samples

This section defines the ordering convention used for Y, C_b, and C_r component samples when the PlanarConfiguration field value = 1 (interleaving). For PlanarConfiguration = 2, component samples are stored as 3 separate planes, and the ordering is the same as that used for other PhotometricInterpretation field values.

For PlanarConfiguration = 1, the component sample order is based on the subsampling factors, *ChromaSubsampleHoriz* and *ChromaSubsampleVert,* defined by the YC_bC_r SubSampling field. The image data within a TIFF file is comprised of one or more "data units", where a data unit is defined to be a sequence of samples:

- one or more Y samples
- a C_b sample
- a C_r sample

The Y samples within a data unit are specified as a two-dimensional array having *ChromaSubsampleVert* rows of *ChromaSubsampleHoriz* samples.

Expanding on the example in the previous section, consider a YC_bC_r image having *ChromaSubsampleHoriz* = 4 and *ChromaSubsampleVert* = 2:

| Y component | Cb component | Cr component |

| Y00 | Y01 | Y02 | Y03 | Y04 | Y05 | | |

| Cb00 | |

| Cr00 | |
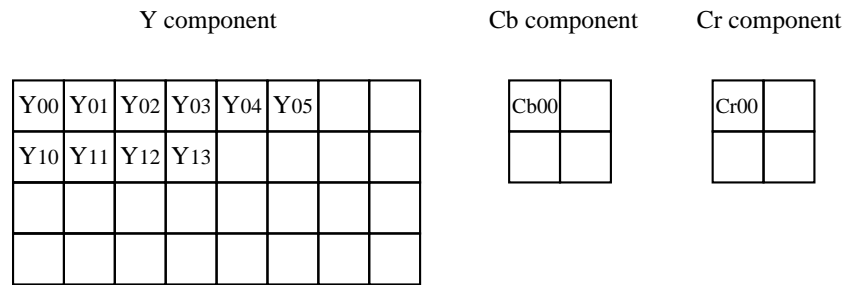
For PlanarConfiguration = 1, the sample order is:

$$Y_{00}, Y_{01}, Y_{02}, Y_{03}, Y_{10}, Y_{11}, Y_{12}, Y_{13}, Cb_{00}, Cr_{00}, Y_{04}, Y_{05}...$$

Minimum Requirements for YCbCr Images

In addition to satisfying the general Baseline TIFF requirements, a YCbCr file must have the following characteristics:

- SamplesPerPixel = 3. SHORT. Three components representing Y, Cb and Cr.
- BitsPerSample = 8,8,8. SHORT.
- Compression = none (1), LZW (5) or JPEG (6). SHORT.
- PhotometricInterpretation = YC_bC_r (6). SHORT.
- ReferenceBlackWhite = 6 RATIONALS. Specify the reference values for black and white.

If the conversion from RGB is not according to CCIR Recommendation 601-1, code YC_bC_r Coefficients.

Section 22: JPEG Compression

Introduction

Image compression reduces the storage requirements of pictorial data. In addition, it reduces the time required for access to, communication with, and display of images. To address the standardization of compression techniques an international standards group was formed: the Joint Photographic Experts Group (JPEG). JPEG has as its objective to create a joint ISO/CCITT standard for continuous tone image compression (color and grayscale).

JPEG decided that because of the broad scope of the standard, no one algorithmic procedure was able to satisfy the requirements of all applications. It was decided to specify different algorithmic processes, where each process is targeted to satisfy the requirements of a class of applications. Thus, the JPEG standard became a "toolkit" whereby the particular algorithmic "tools" are selected according to the needs of the application environment.

The algorithmic processes fall into two classes: lossy and lossless. Those based on the Discrete Cosine Transform (DCT) are lossy and typically provide for substantial compression without significant degradation of the reconstructed image with respect to the source image.

The simplest DCT-based coding process is the baseline process. It provides a capability that is sufficient for most applications. There are additional DCT-based processes that extend the baseline process to a broader range of applications.

The second class of coding processes is targeted for those applications requiring lossless compression. The lossless processes are not DCT-based and are utilized independently of any of the DCT-based processes.

This Section describes the JPEG baseline, the JPEG lossless processes, and the extensions to TIFF defined to support JPEG compression.

JPEG Baseline Process

The baseline process is a DCT-based algorithm that compresses images having 8 bits per component. The baseline process operates only in sequential mode. In sequential mode, the image is processed from left to right and top to bottom in a single pass by compressing the first row of data, followed by the second row, and continuing until the end of image is reached. Sequential operation has minimal buffering requirements and thus permits inexpensive implementations.

The JPEG baseline process is an algorithm which inherently introduces error into the reconstructed image and cannot be utilized for lossless compression. The algorithm accepts as input only those images having 8 bits per component. Images with fewer than 8 bits per component may be compressed using the baseline process algorithm by left justifying each input component within a byte before compression.
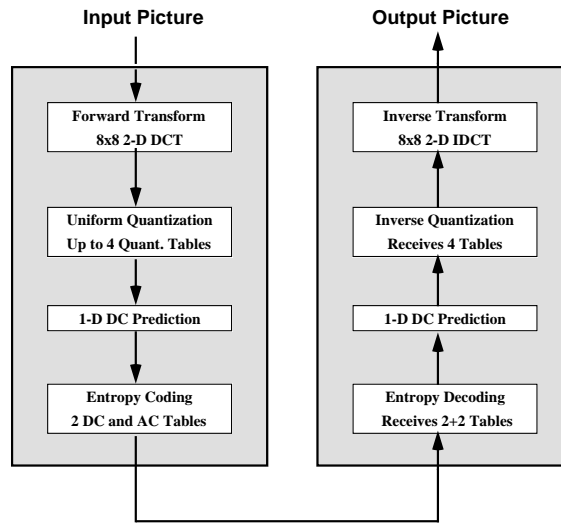
Figure 1. Baseline Process Encoder and Decoder

A functional block diagram of the Baseline encoding and decoding processes is contained in Figure 1. Encoder operation consists of dividing each component of the input image into 8x8 blocks, performing the two-dimensional DCT on each block, quantizing each DCT coefficient uniformly, subtracting the quantized DC coefficient from the corresponding term in the previous block, and then entropy coding the quantized coefficients using variable length codes (VLCs). Decoding is performed by inverting each of the encoder operations in the reverse order.

The DCT

Before performing the foward DCT, input pixels are level-shifted so that they range from -128 to +127. Blocks of 8x8 pixels are transformed with the two-dimensional 8x8 DCT:

$$F(u,v) = \frac{1}{4} C(u)C(v) \sum\sum f(x,y) \cos\frac{\pi(2x+1)u}{16} \cos\frac{\pi(2y+1)v}{16}$$

and blocks are inverse transformed by the decoder with the Inverse DCT:

$$f(x,y) = \frac{1}{4} \sum \sum C(u)C(v) F(u,v) \cos\frac{\pi(2x+1)u}{16} \cos\frac{\pi(2y+1)v}{16}$$

with $u, v, x, y = 0, 1, 2, ... 7$

where x, y = spatial coordinates in the pel domain
          u, v = coordinates in the transform domain
                    $C(u), C(v) = 1 / \text{sqrt}(2)$ for $u, v = 0$

                                      1   otherwise

Although the exact method for computation of the DCT and IDCT is not subject to standardization and will not be specified by JPEG, it is probable that JPEG will adopt DCT-conformance specifications that designate the accuracy to which the DCT must be computed. The DCT-conformance specifications will assure that any two JPEG implementations will produce visually-similar reconstructed images.

Quantization

The coefficients of the DCT are quantized to reduce their magnitude and increase the number of zero-value coefficients. The DCT coefficients are independently quantized by uniform quantizers. A uniform quantizer divides the real number line into steps of equal size, as shown in Figure 2. The quantization step-size applied to each coefficient is determined from the contents of a 64-element quantization table.
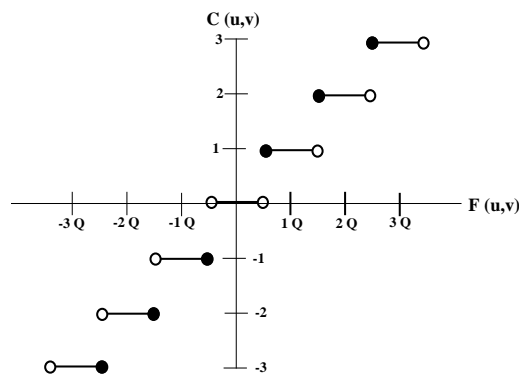
Figure 2. Uniform Quantization

The baseline process provides for up to 4 different quantization tables to be defined and assigned to separate interleaved components within a single scan of the input image. Although the values of each quantization table should ideally be determined through rigorous subjective testing which estimates the human psycho-visual thresholds for each DCT coefficient and for each color component of the input image, JPEG has developed quantization tables which work well for CCIR 601 resolution images and has published these in the informational section of the proposed standard.

DC Prediction

The DCT coefficient located in the upper-left corner of the transformed block represents the average spatial intensity of the block and is referred to as the "DC coefficient". After the DCT coefficients are quantized, but before they are entropy coded, DC prediction is performed. DC prediction simply means that the DC term of the previous block is subtracted from the DC term of the current block prior to encoding.

Zig-Zag Scan

Prior to entropy coding, the DCT coefficients are ordered into a one-dimensional sequence according to a "zig-zag" scan. The DC coefficient is coded first, followed by AC coefficient coding, proceeding in the order illustrated in Figure 3.
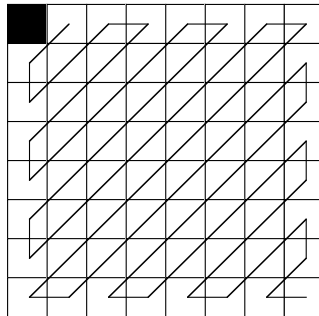

Figure 3. Zig-Zag Scan of DCT Coefficients

Entropy Coding

The quantized DCT coefficients are further compressed using entropy coding. The baseline process performs entropy coding using variable length codes (VLCs) and variable length integers (VLIs).

VLCs, commonly known as Huffman codes, compress data symbols by creating shorter codes to represent frequently-occurring symbols and longer codes for occasionally-occurring symbols. One reason for using VLCs is that they are easily implemented by means of lookup tables.

Separate code tables are provided for the coding of DC and AC coefficients. The following paragraphs describe the respective coding methods used for coding DC and AC coefficients.

DC Coefficient Coding

DC prediction produces a "differential DC coefficient" that is typically small in magnitude due to the high correlation of neighboring DC coefficients. Each differential DC coefficient is encoded by a VLC which represents the number of significant bits in the DC term followed by a VLI representing the value itself. The VLC is coded by first determining the number of significant bits, SSSS, in the differential DC coefficient through the following table:

SSSS	Differential DC Value
0	0
1	-1, 1
2	-3,-2, 2,3
3	-7..-4, 4..7
4	-15..-8, 8..15
5	-31..-16, 16..31

6	-63..-32, 32..63
7	-127..-64, 64..127
8	-255..-128, 128..255
9	-511..-256, 256..511
10	-1023..-512, 512..1023
11	-2047..-1024, 1024..2047
12	-4095..-2048, 2048..4095

SSSS is then coded from the selected DC VLC table. The VLC is followed by a VLI having SSSS bits that represents the value of the differential DC coefficient itself. If the coefficient is positive, the VLI is simply the low-order bits of the coefficient. If the coefficient is negative, then the VLI is the low-order bits of the coefficient-1.

AC Coefficient Coding

In a similar fashion, AC coefficients are coded with alternating VLC and VLI codes. The VLC table, however, is a two-dimensional table that is indexed by a composite 8-bit value. The lower 4 bits of the 8-bit value, i.e. the column index, is the number of significant bits, SSSS, of a non-zero AC coefficient. SSSS is computed through the same table as that used for coding the DC coefficient. The higher-order 4 bits, the row index, is the number of zero coefficients, NNNN, that precede the non-zero AC coefficient. The first column of the two-dimensional coding table contains codes that represent control functions. Figure 4 illustrates the general structure of the AC coding table.
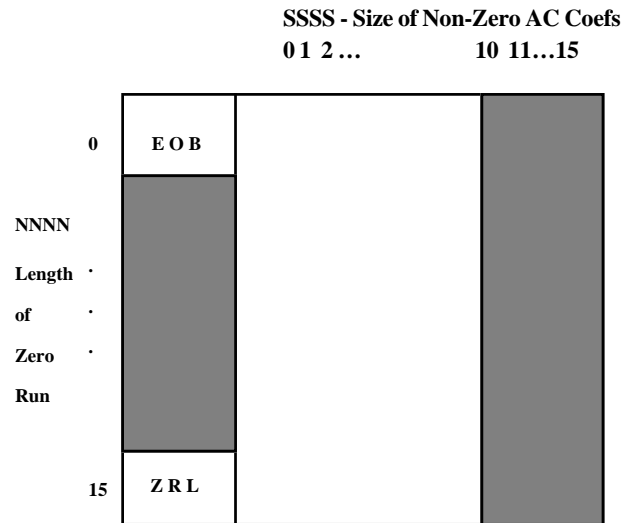

Figure 4. 2-D Run-Size Value Array for AC Coefs
The shaded portions are undefined in the baseline process

The flow chart in Figure 5 specifies the AC coefficient coding procedure. AC coefficients are coded by traversing the block in the zig-zag sequence and count-

ing the number of zero coefficients until a non-zero AC coefficient is encountered. If the count of consecutive zero coefficients exceeds 15, then a ZRL code is coded and the zero run-length count is reset. When a non-zero AC coefficient is found, the number of significant bits in the non-zero coefficient, SSSS, is combined with the zero run-length that precedes the coefficient, NNNN, to form an index into the two-dimensional VLC table. The selected VLC is then coded. The VLC is followed by a VLI that represents the value of the AC coefficient. This process is repeated until the end of the block is reached. If the last AC coefficient is zero, then an End of Block (EOB) VLC is encoded.
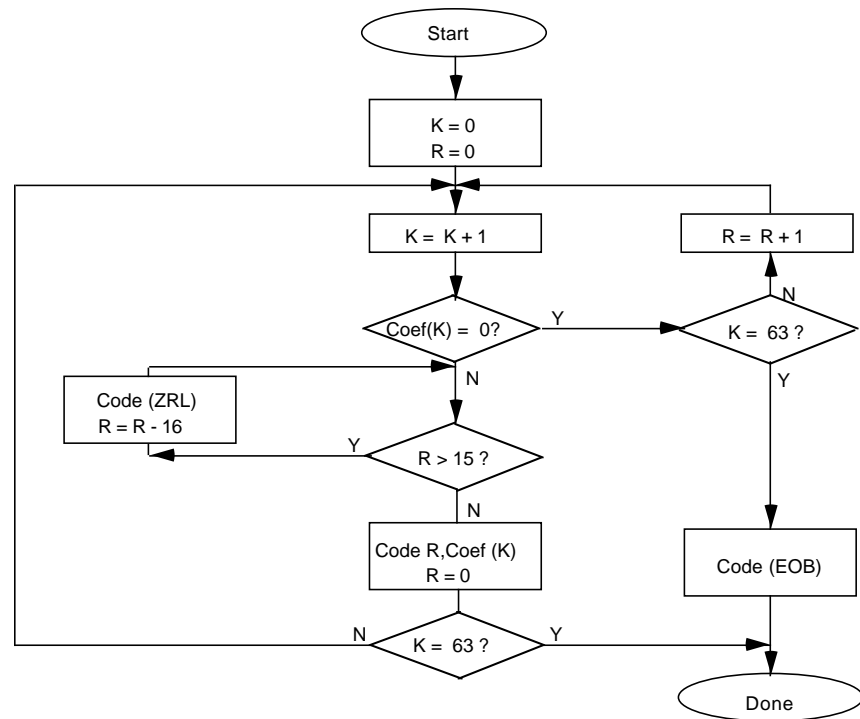

Figure 5. Encoding Procedure for AC Coefs

JPEG Lossless Processes

The JPEG lossless coding processes utilize a spatial-prediction algorithm based upon a two-dimensional Differential Pulse Code Modulation (DPCM) technique. They are compatible with a wider range of input pixel precision than the DCT-based algorithms (2 to 16 bits per component). Although the primary motivation for specifying a spatial algorithm is to provide a method for lossless compression, JPEG allows for quantization of the input data, resulting in lossy compression and higher compression rates.

Although JPEG provides for use of either the Huffman or Arithmetic entropy-coding models by the processes for lossless coding, only the Huffman coding model is supported by this version of TIFF. The following is a brief overview of the lossless process with Huffman coding.

Control Structure

Much of the control structure developed for the sequential DCT procedures is also used for sequential lossless coding. Either interleaved or non-interleaved data ordering may be used.

Coding Model

The coding model developed for coding the DC coefficients of the DCT is extended to allow a number of one-dimensional and two-dimensional predictors for the lossless coding function. Each component uses an independent predictor.

Prediction

Figure 6 shows the relationship between the neighboring values used for prediction and the sample being coded.
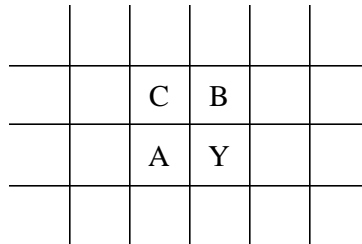

Figure 6. Relationship between sample and prediction samples

Y is the sample to be coded and A, B, and C are the samples immediately to the left, immediately above, and diagonally to the left and above.

The allowed predictors are listed in the following table.

Selection-value	Prediction
0	no prediction (differential coding)
1	A
2	B
3	C
4	A+B-C
5	A+((B-C)/2)
6	B+((A-C)/2)
7	(A+B)/2

Selection-value 0 shall only be used for differential coding in the hierarchical mode. Selections 1, 2 and 3 are one-dimensional predictors and selections 4, 5, 6, and 7 are two dimensional predictors. The divide by 2 in the prediction equations is done by a arithmetic-right-shift of the integer values.

The difference between the prediction value and the input is calculated modulo 2**16. Therefore, the prediction can also be treated as a modulo 2**16 value. In the decoder the difference is decoded and added, modulo 2**16, to the prediction.

Huffman Coding of the Prediction Error

The Huffman coding procedures defined for coding the DC coefficients are used to code the modulo 2**16 differences. The table for DC coding is extended to 17 entries that allows for coding of the modulo 2**16 differences.

Point Transformation Prior to Lossless Coding

For the lossless processes only, the input image data may optionally be scaled (quantized) prior to coding by specifying a nonzero value in the point transformation parameter. Point transformation is defined to be division by a power of 2.

If the point transformation field is nonzero for a component, a point transformation of the input is performed prior to the lossless coding. The input is divided by 2**Pt, where Pt is the value of the point transform signaling field. The output of the decoder is rescaled to the input range by multiplying by 2**Pt. Note that the scaling of input and output can be performed by arithmetic shifts.

Overview of the JPEG Extension to TIFF

In extending the TIFF definition to include JPEG compressed data, it is necessary to note the following:

- JPEG is effective only on continuous-tone color spaces:

Grayscale   (Photometric Interpretation = 1)

RGB   (Photometric Interpretation = 2)

CMYK   (Photometric Interpretation = 5)   (See the CMYK Images section.)

YC_bC_r (Photometric Interpretation = 6)   (See the YCbCr images section.)

- Color conversion to YC_bC_r is often used as part of the compression process because the chrominance components can be subsampled and compressed to a greater degree without significant visual loss of quality. Fields are defined to describe how this conversion has taken place and the degree of subsampling employed (see the YCbCr Images section).

- New fields have been defined to specify the JPEG parameters used for compression and to allow quantization tables and Huffman code tables to be incorporated into the TIFF file.

- TIFF is compatible with compressed image data that conforms to the syntax of the JPEG interchange format for compressed image data. Fields are defined that may be utilized to facilitate conversion from TIFF to interchange format.

- The PlanarConfiguration Field is used to specify whether or not the compressed data is interleaved as defined by JPEG. For any of the JPEG DCT-based processes, the interleaved data units are coded 8x8 blocks rather than component samples.

- Although JPEG codes consecutive image blocks in a single contiguous bitstream, it is extremely useful to employ the concept of tiles in an image. The TIFF Tiles section defines some new fields for tiles. These fields should be stored in place of the older fields for strips. The concept of tiling an image in both dimensions is important because JPEG hardware may be limited in the size of each block that is handled.

- Note that the nomenclature used in the TIFF specification is different from the JPEG Draft International Standardittee Draft (ISO DIS 10918-1) in some respects. The following terms should be equated when reading this Section:

TIFF name	JPEG DIS name
ImageWidth	Number of Pixels
ImageLength	Number of Lines
SamplesPerPixel	Number of Components
JPEGQTable	Quantization Table
JPEGDCTable	Huffman Table for DC coefficients
JPEGACTable	Huffman Table for AC coefficients

Strips and Tiles

The JPEG extension to TIFF has been designed to be consistent with the existing TIFF strip and tile structures and to allow quick conversion to and from the stream-oriented compressed image format defined by JPEG.

Compressed images conforming to the syntax of the JPEG interchange format can be converted to TIFF simply by defining a single strip or tile for the entire image and then concatenating the TIFF image description fields to the JPEG compressed image data. The strip or tile offset field points directly to the start of the entropy coded data (not to a JPEG marker).

Multiple strips or tiles are supported in JPEG compressed images using restart markers. Restart markers, inserted periodically into the compressed image data, delineate image segments known as restart intervals. At the start of each restart interval, the coding state is reset to default values, allowing every restart interval to be decoded independently of previously decoded data. TIFF strip and tile off-sets shall always point to the start of a restart interval. Equivalently, each strip or

tile contains an integral number of restart intervals. Restart markers need not be present in a TIFF file; they are implicitly coded at the start of every strip or tile.

To maximize interchangeability of TIFF files with other formats, a restriction is placed on tile height for files containing JPEG-compressed image data conforming to the JPEG interchange format syntax. The restriction, imposed only when the tile width is shorter than the image width and when the JPEGInterchangeFormat Field is present and non-zero, states that the tile height must be equal to the height of one JPEG Minimum Coded Unit (MCU). This restriction ensures that TIFF files may be converted to JPEG interchange format without undergoing decompression.

Extensions to Existing Fields

Compression

Tag   = 259 (103.H)

Type   = SHORT

N   = 1

This Field indicates the type of compression used. The new value is:

    6 = JPEG

JPEG Fields

JPEGProc

Tag   = 512 (200.H)

Type   = SHORT

N   = 1

This Field indicates the JPEG process used to produce the compressed data. The values for this field are defined to be consistent with the numbering convention used in ISO DIS 10918-2. Two values are defined at this time.

1=   Baseline sequential process

14=   Lossless process with Huffman coding

When the lossless process with Huffman coding is selected by this Field, the Huffman tables used to encode the image are specified by the JPEGDCTables field, and the JPEGACTables field is not used.

Values indicating JPEG processes other than those specified above will be defined in the future.

Not all of the fields described in this section are relevant to the JPEG process selected by this Field. The following table specifies the fields that are applicable to each value defined by this Field.

Tag Name	JPEGProc =1	JPEGProc =14
JPEGInterchangeFormat	X	X
JPEGInterchangeFormatLength	X	X
JPEGRestart Interval	X	X
JPEGLosslessPredictors		X
JPEGPointTransforms		X
JPEGQTables	X	
JPEGDCTables	X	X
JPEGACTables	X	

This Field is mandatory whenever the Compression Field is JPEG (no default).

JPEGInterchangeFormat

Tag   = 513 (201.H)

Type   = LONG

N   = 1

This Field indicates whether a JPEG interchange format bitstream is present in the TIFF file. If a JPEG interchange format bitstream is present, then this Field points to the Start of Image (SOI) marker code.

If this Field is zero or not present, a JPEG interchange format bitstream is not present.

JPEGInterchangeFormatLength

Tag   = 514 (202.H)

Type   = LONG

N   = 1

This Field indicates the length in bytes of the JPEG interchange format bitstream. This Field is useful for extracting the JPEG interchange format bitstream without parsing the bitstream.

This Field is relevant only if the JPEGInterchangeFormat Field is present and is non-zero.

JPEGRestartInterval

Tag   = 515 (203.H)

Type   = SHORT

N   = 1

This Field indicates the length of the restart interval used in the compressed image data. The restart interval is defined as the number of Minimum Coded Units (MCUs) between restart markers.

Restart intervals are used in JPEG compressed images to provide support for multiple strips or tiles. At the start of each restart interval, the coding state is reset to default values, allowing every restart interval to be decoded independently of previously decoded data. TIFF strip and tile offsets shall always point to the start of a restart interval. Equivalently, each strip or tile contains an integral number of restart intervals. Restart markers need not be present in a TIFF file; they are implicitly coded at the start of every strip or tile.

See the JPEG Draft International Standard (ISO DIS 10918-1) for more information about the restart interval and restart markers.

If this Field is zero or is not present, the compressed data does not contain restart markers.

JPEGLosslessPredictors

Tag   = 517 (205.H)

Type   = SHORT

N   = SamplesPerPixel

This Field points to a list of lossless predictor-selection values, one per component.
The allowed predictors are listed in the following table.

Selection-value	Prediction
1	A
2	B
3	C
4	A+B-C
5	A+((B-C)/2)
6	B+((A-C)/2)
7	(A+B)/2

A, B, and C are the samples immediately to the left, immediately above, and diagonally to the left and above the sample to be coded, respectively.

See the JPEG Draft International Standard (ISO DIS 10918-1) for more details.

This Field is mandatory whenever the JPEGProc Field specifies one of the lossless processes (no default).

JPEGPointTransforms

Tag   = 518 (206.H)

Type   = SHORT

N   = SamplesPerPixel

This Field points to a list of point transform values, one per component. This Field is relevant only for lossless processes.

If the point transformation value is nonzero for a component, a point transformation of the input is performed prior to the lossless coding. The input is divided by $2^{**}Pt$, where Pt is the point transform value. The output of the decoder is rescaled to the input range by multiplying by $2^{**}Pt$. Note that the scaling of input and output can be performed by arithmetic shifts.

See the JPEG Draft International Standard (ISO DIS 10918-1) for more details. The default value of this Field is 0 for each component (no scaling).

JPEGQTables

Tag   = 519 (207.H)

Type = LONG

N   = SamplesPerPixel

This Field points to a list of offsets to the quantization tables, one per component. Each table consists of 64 BYTES (one for each DCT coefficient in the 8x8 block). The quantization tables are stored in zigzag order.

See the JPEG Draft International Standard (ISO DIS 10918-1) for more details.

It is strongly recommended that, within the TIFF file, each component be assigned separate tables. This Field is mandatory whenever the JPEGProc Field specifies a DCT-based process (no default).

JPEGDCTables

Tag   = 520 (208.H)

Type = LONG

N   = SamplesPerPixel

This Field points to a list of offsets to the DC Huffman tables or the lossless Huffman tables, one per component.

The format of each table is as follows:

> 16 BYTES of "BITS", indicating the number of codes of lengths 1 to 16;
>
> Up to 17 BYTES of "VALUES", indicating the values associated with those codes, in order of length.

See the JPEG Draft International Standard (ISO DIS 10918-1) for more details.

It is strongly recommended that, within the TIFF file, each component be assigned separate tables. This Field is mandatory for all JPEG processes (no default).

JPEGACTables

Tag   = 521 (209.H)

Type = LONG

N   = SamplesPerPixel

This Field points to a list of offsets to the Huffman AC tables, one per component. The format of each table is as follows:

16 BYTES of "BITS", indicating the number of codes of lengths 1 to 16;

Up to 256 BYTES of "VALUES", indicating the values associated with those codes, in order of length.

See the JPEG Draft International Standard (ISO DIS 10918-1) for more details.

It is strongly recommended that, within the TIFF file, each component be assigned separate tables. This Field is mandatory whenever the JPEGProc Field specifies a DCT-based process (no default).

Minimum Requirements for TIFF with JPEG Compression

The table on the following page shows the minimum requirements of a TIFF file that uses tiling and contains JPEG data compressed with the Baseline process.

```
Tag    = NewSubFileType (254)              Single image
Type   = Long
Length = 1
Value  = 0
```
```
Tag    = ImageWidth (256)
Type   = Long
Length = 1
Value  = ?
```
```
Tag    = ImageLength (257)
Type   = Long
Length = 1
Value  = ?
```
```
Tag    = BitsPerSample (258)              8 : Monochrome
Type   = Short                            8,8,8 : RGB
Length = SamplesPerPixel                  8,8,8 : YCbCr
Value  = ?                                8,8,8,8 : CMYK
```
```
Tag    = Compression (259)                6 : JPEG compression
Type   = Long
Length = 1
Value  = 6
```
```
Tag    = PhotometricInterpretation (262)  0,1 : Monochrome
Type   = Short                            2 : RGB
Length = 1                                5 : CMYK
Value  = ?                                6 : YCbCr
```
```
Tag    = SamplesPerPixel (277)            1 : Monochrome
Type   = Short                            3 : RGB
Length = 1                                3 : YCbCr
Value  = ?                                4 : CMYK
```
```
Tag    = XResolution (282)
Type   = Rational
Length = 1
Value  = ?
```
```
Tag    = YResolution (283)
Type   = Rational
Length = 1
Value  = ?
```
```
Tag    = PlanarConfiguration (284)        1 : Block Interleaved
Type   = Short                            2 : Not interleaved
Length = 1
Value  = ?
```
```
Tag    = ResolutionUnit (296)
Type   = Short
Length = 1
Value  = ?
```
```
Tag    = TileWidth (322)                  Multiple of 8
Type   = Short
Length = 1
Value  = ?
```
```
Tag    = TileLength (323)                 Multiple of 8
Type   = Short
Length = 1
Value  = ?
```
```
Tag    = TileOffsets (324)
Type   = Long
Length = Number of tiles
Value  = ?
```
```
Tag    = TileByteCounts (325)
Type   = Long
Length = Number of tiles
Value  = ?
```
```
Tag    = JPEGProc (512)                   1 : Baseline process
Type   = Short
Length = 1
Value  = ?
```
```
Tag    = JPEGQTables (519)                Offsets to tables
Type   = Long
Length = SamplesPerPixel
Value  = ?
```
```
Tag    = JPEGDCTables (520)               Offsets to tables
Type   = Long
Length = SamplesPerPixel
Value  = ?
```
```
Tag    = JPEGACTables (521)               Offsets to tables
Type   = Long
Length = SamplesPerPixel
Value  = ?
```

References

[1] Wallace, G., "Overview of the JPEG Still Picture Compression Algorithm", Electronic Imaging East '90.

[2] ISO/IEC DIS 10918-1, "Digital Compression and Coding of Continuous-tone Still Images", Sept. 1991.

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Section 23: CIE L*a*b* Images

*What is CIE L*a*b*?*

CIE La*b* is a color space that is colorimetric, has separate lightness and chroma channels, and is approximately perceptually uniform. It has excellent applicability for device-independent manipulation of continuous tone images. These attributes make it an excellent choice for many image editing functions.

1976 CIEL*a*b* is represented as a Euclidean space with the following three quantities plotted along axes at right angles: $L*$ representing lightness, $a*$ representing the red/green axis, and $b*$ representing the yellow/blue axis. The formulas for 1976 CIE $L*a*b*$ follow:

$$L* = 116(Y/Y_n)^{1/3} - 16 \qquad \text{for } Y/Y_n > 0.008856$$

$$L* = 903.3(Y/Y_n) \qquad \text{for } Y/Y_n <= 0.008856 \qquad \text{*see note below.}$$

$$a* = 500\left[(X/X_n)^{1/3} - (Y/Y_n)^{1/3}\right]$$

$$b* = 200\left[(Y/Y_n)^{1/3} - (Z/Z_n)^{1/3}\right].$$

where X_n, Y_n, and Z_n are the CIE X, Y, and Z tristimulus values of an *appropriate* reference white. Also, if any of the ratios X/X_n, Y/Y_n, or Z/Z_n is equal to or less than 0.008856, it is replaced in the formulas with

$$7.787F + 16/116,$$

where F is X/X_n, Y/Y_n, or Z/Z_n, as appropriate (note: these low-light conditions are of no relevance for most document-imaging applications). Tiff is defined such that each quantity be encoded with 8 bits. This provides 256 levels of $L*$ lightness; 256 levels (+/- 127) of $a*$, and 256 levels (+/- 127) of $b*$. Dividing the 0-100 range of $L*$ into 256 levels provides lightness steps that are less than half the size of a "just noticeable difference". This eliminates banding, even under conditions of substantial tonal manipulation. Limiting the theoretically unbounded $a*$ and $b*$ ranges to +/- 127 allows encoding in 8 bits without eliminating any but the most saturated self-luminous colors. It is anticipated that the rare specialized applications requiring support of these extreme cases would be unlikely to use CIELAB anyway. All object colors, in fact all colors within the theoretical MacAdam limits, fall within the +/- 127 $a*/b*$ range.

The TIFF CIELAB Fields

PhotometricInterpretation

Tag   = 262 (106.H)

Type   = SHORT

N   = 1

8 =   1976 CIE $L*a*b*$

Usage of other Fields.

BitsPerSample: 8

SamplesPerPixel - ExtraSamples: 3 for $L*a*b*$, 1 implies $L*$ only, for mono-chrome data.

Compression: same as other multi-bit formats. JPEG compression applies.

PlanarConfiguration: both chunky and planar data could be supported.

WhitePoint: does not apply

PrimaryChromaticities: does not apply.

TransferFunction: does not apply

Alpha Channel information will follow the lead of other data types.

The reference white for this data type is the *perfect reflecting diffuser* (100% diffuse reflectance at all visible wavelengths). The $L*$ range is from 0 (perfect absorbing black) to 100 (perfect reflecting diffuse white). The $a*$ and $b*$ ranges will be represented as signed 8 bit values having the range -127 to +127.

Converting between RGB and CIELAB, a Caveat

The above CIELAB formulae are derived from CIE XYZ. Converting from CIELAB to RGB requires an additional set of formulae for converting between RGB and XYZ. For standard NTSC primaries these are:

$$\begin{bmatrix} 0.6070 & 0.1740 & 0.2000 \\ 0.2990 & 0.5870 & 0.1140 \\ 0.0000 & 0.0660 & 1.1110 \end{bmatrix} * \begin{bmatrix} R \\ G \\ B \end{bmatrix} = \begin{bmatrix} X \\ Y \\ Z \end{bmatrix}$$

Generally, D65 illumination is used and a perfect reflecting diffuser is used for the reference white.

Since CIELAB is not a directly displayable format, some conversion to RGB will be required. While look-up table accelerated CIELAB to RGB conversion is certainly possible and fast, TIFF writers may choose to include a low resolution RGB subfile as an integral part of TIFF CIELAB.

Color Difference Measurements in CIELAB

The differences between two colors in L^*, a^*, and b^* are denoted by DL^*, Da^*, and Db^*, respectively, with the total (3-dimensional) color difference represented as:

$$\Delta E^*_{ab} = \left[(\Delta E^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2\right]^{1/2}.$$

This color difference can also be expressed in terms of L^*, C^*, and a measure of hue. In this case, h_{ab} is *not* used because it is an angular measure and cannot be combined with L^* and C^* directly. A linear-distance form of hue is used instead:

CIE 1976 *a,b hue-difference,* ΔH^*_{ab}

$$\Delta H^*_{ab} = \left[(\Delta E^*)^2 - (\Delta L^*)^2 - (\Delta C^*)^2\right]^{1/2}.$$

where DC^* is the chroma difference between the two colors. The total color difference expression using this hue-difference is:

$$\Delta E^*_{ab} = \left[(\Delta L^*)^2 + (\Delta H^*)^2 + (\Delta b^*)^2\right]^{1/2}.$$

It is important to remember that color difference is 3-dimensional: much more can be learned from a DL*a*b* triplet than from a single DE value. The DL*C*H* form is often the most useful since it gives the error information in a form that has more familiar perception correlates. Caution is in order, however, when using DH* for large hue differences since it is a straight-line approximation of a curved hue distance.

The Merits of CIELAB

Colorimetric.

First and foremost, CIELAB is colorimetric. It is traceable to the internationally-recognized standard CIE 1931 Standard Observer. This insures that it encodes color in a manner that is accurately modeled after the human vision system. Colors seen as matching are encoded identically, and colors seen as not matching are encoded differently. CIELAB provides an unambiguous definition of color without the necessity of additional information such as with RGB (primary chromaticities, white point, and gamma curves).

Device Independent.

Unlike RGB spaces which associate closely with physical phosphor colors, CIELAB contains no device association. CIELAB is not tailored for one device or device type at the expense of all others.

Full Color Gamut.

Any one image or imaging device usually encounters a very limited subset of the entire range of humanly-perceptible color. Collectively, however, these images and devices span a much larger gamut of color. A truly versatile exchange color space should encompass all of these colors, ideally providing support for all visible color. RGB, PhotoYCC, YCbCr, and other display spaces suffer from gamut limitations that exclude significant regions of easily printable colors. CIELAB is defined for all visible color.

Efficiency

A good exchange space will maximize accuracy of translations between itself and other spaces. It will represent colors compactly for a given accuracy. These attributes are provided through visual uniformity. One of the greatest disadvantages of the classic CIE system (and RGB systems as well) is that colors within it are not equally spaced visually. Encoding full-color images in a linear-intensity space, such as the typical RGB space or, especially, the XYZ space, requires a very large range (greater than 8-bits/primary) to eliminate banding artifacts. Adopting a *non*-linear RGB space improves the efficiency but not nearly to the extent as with a perceptually uniform space where these problems are nearly eliminated. A uniform space is also more efficiently compressed (see below).

Public Domain / Single Standard

CIELAB maintains no preferential attachments to any private organization. Its existence as a single standard leaves no room for ambiguity. Since 1976, CIELAB has continually gained popularity as a widely-accepted and heavily-used standard.

Luminance/Chrominance Separation.

The advantages for image size compression made possible by having a separate lightness or luminance channel are immense. Many such spaces exist. The degree to which the luminance information is fully-isolated into a single channel is an important consideration. Recent studies (Kasson and Plouffe of IBM) support CIELAB as a leading candidate placing it above CIELUV, YIQ, YUV, YCC, and XYZ.

Other advantages support a separate lightness or luminance channel. Tone and contrast editing and detail enhancement are most easily accomplished with such a channel. Conversion to a black and white representation is also easiest with this type of space.

When the chrominance channels are encoded as opponents as with CIELAB, there are other compression, image manipulation, and white point handling advantages.

Compressibility (Data).

Opponent spaces such as CIELAB are inherently more compressible than tristimulus spaces such as RGB. The chroma content of an image can be compressed to a greater extent, without objectionable loss, than can the lightness content. The opponent arrangement of CIELAB allows for spatial subsampling and efficent compression using JPEG.

Compressibility (Gamut).

Adjusting the color range of an image to match the capabilities of the intended output device is a critical function within computational color reproduction. Luminance/chrominance separation, especially when provided in a polar form, is desirable for facilitating gamut compression. Accurate gamut compression in a tri-linear color space is difficult.

CIELAB has a polar form (*metric hue angle,* and *metric chroma*, described below) that serves compression needs fairly well. Because CIELAB is not perfectly uniform, problems can arise when compressing along constant hue lines. Noticeable hue errors are sometimes introduced. This problem is no less severe with other contending color spaces.

This polar form also provides advantages for local color editing of images. The polar form is not proposed as part of the TIFF addition.

Getting the Most from CIELAB

Image Editors

The advantages of image editing within a perceptually uniform polar color space are tremendous. A detailed description of these advantages is beyond the scope of this section. As previously mentioned, many common tonal manipulation tasks are most efficiently performed when only a single channel is affected. Edge enhancement, contrast adjustment, and general tone-curve manipulation all ideally affect only the lightness component of an image.

A perceptual polar space works excellently for specifying a color range for masking purposes. For example, a red shirt can be quickly changed to a green shirt without drawing an outline mask. The operation can be performed with a loosely, quickly-drawn mask region combined with a hue (and perhaps chroma) range that encompasses the shirt's colors. The hue component of the shirt can then be adjusted, leaving the lightness and chroma detail in place.

Color cast adjustment is easily realized by shifting either or both of the chroma channels over the entire image or blending them over the region of interest.

Converting from CIELAB to a device specific space

For fast conversion to an RGB display, CIELAB can be decoded using 3x3 matrixing followed by gamma correction. The computational complexity required

for accurate CRT display is the same with CIELAB as with extended luminance-chrominance spaces.

Converting CIELAB for accurate printing on CMYK devices requires computational complexity no greater than with *accurate* conversion from any other colorimetric space. Gamut compression becomes one of the more significant tasks for any such conversion.

Part 3: Appendices

Part 3 contains additional information that is not part of the TIFF specification, but may be of use to developers.

Appendix A: TIFF Tags Sorted by Number

TagName	Decimal	Hex	Type	Number of values
NewSubfileType	254	FE	LONG	1
SubfileType	255	FF	SHORT	1
ImageWidth	256	100	SHORT or LONG	1
ImageLength	257	101	SHORT or LONG	1
BitsPerSample	258	102	SHORT	SamplesPerPixel
Compression	259	103	SHORT	1
Uncompressed	1			
CCITT 1D	2			
Group 3 Fax	3			
Group 4 Fax	4			
LZW	5			
JPEG	6			
PackBits	32773			
PhotometricInterpretation	262	106	SHORT	1
WhiteIsZero	0			
BlackIsZero	1			
RGB	2			
RGB Palette	3			
Transparency mask	4			
CMYK	5			
YCbCr	6			
CIELab	8			
Threshholding	263	107	SHORT	1
CellWidth	264	108	SHORT	1
CellLength	265	109	SHORT	1
FillOrder	266	10A	SHORT	1
DocumentName	269	10D	ASCII	
ImageDescription	270	10E	ASCII	
Make	271	10F	ASCII	
Model	272	110	ASCII	
StripOffsets	273	111	SHORT or LONG	StripsPerImage
Orientation	274	112	SHORT	1
SamplesPerPixel	277	115	SHORT	1
RowsPerStrip	278	116	SHORT or LONG	1
StripByteCounts	279	117	LONG or SHORT	StripsPerImage
MinSampleValue	280	118	SHORT	SamplesPerPixel
MaxSampleValue	281	119	SHORT	SamplesPerPixel
XResolution	282	11A	RATIONAL	1
YResolution	283	11B	RATIONAL	1
PlanarConfiguration	284	11C	SHORT	1
PageName	285	11D	ASCII	
XPosition	286	11E	RATIONAL	
YPosition	287	11F	RATIONAL	
FreeOffsets	288	120	LONG	
FreeByteCounts	289	121	LONG	
GrayResponseUnit	290	122	SHORT	1

GrayResponseCurve	291	123	SHORT	2**BitsPerSample
T4Options	292	124	LONG	1
T6Options	293	125	LONG	1
ResolutionUnit	296	128	SHORT	1
PageNumber	297	129	SHORT	2
TransferFunction	301	12D	SHORT	{1 or SamplesPerPixel}* 2** BitsPerSample
Software	305	131	ASCII	
DateTime	306	132	ASCII	20
Artist	315	13B	ASCII	
HostComputer	316	13C	ASCII	
Predictor	317	13D	SHORT	1
WhitePoint	318	13E	RATIONAL	2
PrimaryChromaticities	319	13F	RATIONAL	6
ColorMap	320	140	SHORT	3 * (2**BitsPerSample)
HalftoneHints	321	141	SHORT	2
TileWidth	322	142	SHORT or LONG	1
TileLength	323	143	SHORT or LONG	1
TileOffsets	324	144	LONG	TilesPerImage
TileByteCounts	325	145	SHORT or LONG	TilesPerImage
InkSet	332	14C	SHORT	1
InkNames	333	14D	ASCII	total number of charac ters in all ink name strings, including zeros
NumberOfInks	334	14E	SHORT	1
DotRange	336	150	BYTE or SHORT	2, or 2* NumberOfInks
TargetPrinter	337	151	ASCII	any
ExtraSamples	338	152	BYTE	number of extra compo- nents per pixel
SampleFormat	339	153	SHORT	SamplesPerPixel
SMinSampleValue	340	154	Any	SamplesPerPixel
SMaxSampleValue	341	155	Any	SamplesPerPixel
TransferRange	342	156	SHORT	6
JPEGProc	512	200	SHORT	1
JPEGInterchangeFormat	513	201	LONG	1
JPEGInterchangeFormatLngth	514	202	LONG	1
JPEGRestartInterval	515	203	SHORT	1
JPEGLosslessPredictors	517	205	SHORT	SamplesPerPixel
JPEGPointTransforms	518	206	SHORT	SamplesPerPixel
JPEGQTables	519	207	LONG	SamplesPerPixel
JPEGDCTables	520	208	LONG	SamplesPerPixel
JPEGACTables	521	209	LONG	SamplesPerPixel
YCbCrCoefficients	529	211	RATIONAL	3
YCbCrSubSampling	530	212	SHORT	2
YCbCrPositioning	531	213	SHORT	1
ReferenceBlackWhite	532	214	LONG	2*SamplesPerPixel
Copyright	33432	8298	ASCII	Any

Appendix B: Operating System Considerations

Extensions and Filetypes

The recommended MS-DOS, UNIX, and OS/2 file extension for TIFF files is ".TIF".

On an Apple Macintosh computer, the recommended Filetype is "TIFF". It is a good idea to also name TIFF files with a ".TIF" extension so that they can easily imported if transferred to a different operating system.

Index

14A WEDNESDAY, DECEMBER 22, 1993 — The Ledger

Allegations revive debate over public right to know

By Gary Blonston and Aaron Epstein
Knight-Ridder Newspapers

WASHINGTON — Here we go again. For the second time in two years, Bill Clinton has been publicly, elaborately accused of marital infidelity, and once again the questions arise:

Should a president be judged by his sex life?

If such vaunted figures as Franklin D. Roosevelt, Dwight D. Eisenhower, John F. Kennedy and Lyndon B. Johnson were chronically unfaithful, how much does it matter what Bill Clinton has or hasn't done?

In 1992, when candidate Clinton was accused of a long affair with a woman named Gennifer Flowers, political pundits predicted it would be fatal to his public career.

But half the country dismissed the whole flap as politically irrelevant, and 70 percent said the news media pursued the story just to win viewers and sell newspapers. By Election Day only 1 in 10 voters — almost all of them George Bush supporters — told pollsters they thought a candidate's marital fidelity was a very important consideration.

Now, in the face of fresh claims by Arkansas state troopers that they helped Clinton, then the governor, arrange illicit sexual encounters, a number of political analysts predict that, if the public turns against him, mere sex won't be the reason.

Clinton will suffer serious political damage, they say, only if Americans become convinced that he tried to silence the troopers or that he broke the implicit promise he made on national television last year to stop fooling around.

In the words of Suzanne Garment, author of a recent book on political scandal, "People don't like being lied to, even about something they'd rather not know about."

Presidential scholar Stephen Hess says, "There was complete acceptance (of the fact) he had been an adulterer," ever since the night in January 1992 when Clinton told a "60 Minutes" interviewer: "I have acknowledged wrongdoing. I have acknowledged causing pain in my marriage."

"Americans elected an admitted adulterer," Hess says. "It's that clear. That's not even a controversial statement."

But most didn't think they had elected a fool. If the public comes to believe that Clinton continued his sexual escapades long after that television confessional, "it could be a real blow to him," says University of North Carolina historian William E. Leuchtenburg.

"It suggests that he ignored the warnings instead of saying, 'Wow, that was a narrow escape; I'll never do that again.' It suggests something almost self-destructive about him."

Associated Press
Amy Hagadorn, 9, who suffers from cerebral palsy, receives a 3-foot-tall Barbie doll from Santa Claus, Daryl McIntire, while visiting the WJLT-FM radio station on Tuesday in Fort Wayne, Ind.

Troopers say others too intimidated

The Associated Press

LITTLE ROCK, Ark. — Two Arkansas troopers who allege they helped arrange sexual trysts for Bill Clinton said Tuesday they believe other officers are too intimidated to speak out.

"I've been transferred already, transferred from one assignment to another . . . within the department, and threatened by influential men across the state, one in particular," Roger Perry said. "I think they feel some intimidation."

Asked why he waited so long to tell his story, the other trooper, Larry Patterson, cited intimidation.

"This started during the campaign. We were told that if we talked to any reporter, anyone with the media, that we were in trouble."

Neither trooper was more specific about the source of the alleged threats.

First lady

► Continued from 1A

White House in recent weeks.

While first ladies have historically been fierce defenders of their spouses in private and strongly supportive in general terms in public, Hillary Clinton's very specific counter-attack was highly unusual.

She was responding to accusations, published and broadcast widely this week, that her husband had used the state troopers who guarded him while he was governor of Arkansas to arrange meetings with other women and to hide those meetings from her.

The White House has strongly denied the accusations made by two troopers but disavowed by the six women the men identified. The White House acknowledged that Clinton had telephoned other troopers to ask about the reports and solicit their support in offering denials to journalists.

Hillary Clinton also said she was "bewildered" by the continued interest in the investment and the her husband made in an Arkansas development scheme that ultimately went bankrupt and that it tied them to a failed savings and loan institution and the business partners who controlled it.

She said she saw no reason to make public any of the files on the development project that were retrieved from the office of Foster, who was deputy White House counsel when he killed himself in a park last summer.

"I just think what we've said is adequate," she told The Associated Press.

Federal law-enforcement officials said Tuesday that they would seek to examine files relating to President and Hillary Clinton's private land dealings in Arkansas that were removed from Foster's office shortly after his death. The Justice Department has begun separate investigations into the circumstances surrounding Foster's death and the failure of Madison Guaranty Savings & Loan, the Arkansas thrift institution owned by James McDougal, the Clintons' partner in the real estate venture.

The president has not spoken publicly about these issues recently, and the first lady's remarks Tuesday were the most explicit part of a White House campaign to present the first family as victims of unwarranted attack at a time when Clinton is posting his highest approval ratings ever in published polls.

Wish

► Continued from 1A

people with cerebral palsy want to become Amy's pen pals. A Toronto mother whose son was born with half a skull is sending a videotape on how children should act around people with disabilities. And a Tennessee woman said she planned to use Amy's story in her Sunday school class.

"This has been great for her, and for her self-esteem," Amy's mother, Patti, said. "It's touched the lives of so many.

"The response has been overwhelming."

So overwhelming, in fact, that Patti Hagadorn and her

husband, Jim, worry that the outpouring may obscure the broader message in Amy's letter: All people should be treated with compassion.

The Hagadorns have asked people to "help the other Amys out there" by showing concern for a disabled child in their own community.

Amy's encounter with teasers began this fall after she was moved from special education classes into a regular classroom. Most of the children accepted her, but a few made fun at her. While Amy's parents and teacher worked to curtail the jibes, they hadn't realized how much it hurt her until she wrote to Santa.

Yeltsin

► Continued from 1A

his own supporters fared so poorly in the balloting. But it provided no clue as to whether he will retreat from his wrenching economic reforms, the principal cause of the setback.

Some analysts have voiced concern that Yeltsin might use the growing popularity of extremist groups as justification for expanding his personal power, in preparation for a drawn-out confrontation with the new legislature.

Purging the security apparatus will reinforce such fears. Yeltsin made it clear that all current employees of the security apparatus will be scrutinized for political loyalty before being offered posts in the renamed agency.

In its bloody showdown with Parliament in October, the Kremlin faulted the security ministry for not warning that radicals were conspiring to stage an armed uprising designed to seize key Moscow facilities and drive Yeltsin from office.

Just weeks before, Yeltsin had moved to bolster his control over the security forces by firing the minister, Viktor Barannikov, ostensibly for corruption.

Barannikov later joined the anti-Yeltsin forces holed up in the besieged Parliament building, and he is now awaiting trial for his role in the violence. Some security officers sided with him openly, and many more were reported to have sympathized silently.

In announcing his plans to purge the security apparatus and give it its second new name in less than two years, Yeltsin denounced it as having "outlived its usefulness." He called it "a burden on the state . . . slowing down political and economic reforms."

But at the same time, he picked the current security minister, Viktor Golushko, a career KGB agent and a political conservative, to head up the new agency, the Federal Counterintelligence Service, and, presumably play a major role in culling its ranks.

Church

► Continued from 1A

The assets reported in the various documents filed with the IRS totaled $398 million.

The Los Angeles-based church does not keep combined balance sheets but "the combined total, if kept, would be somewhere in the range you list," Scientology spokeswoman Leisa Goodman said.

The church was founded in 1954 by science fiction writer L. Ron Hubbard, whose best-selling "Dianetics: The Modern Science of Mental Health," advocated the use of an "electropsychometer" — a lie detector-like device to purge negative images from people's minds.

The IRS recognized one branch, the Church of Scientology of California, as a tax-exempt religious organization in 1957. But it revoked that status in 1967, questioning, for example, the way the church charged for classes that are part of the religious practice.

None of the IRS letters in the files explained the legal reasoning behind granting tax exemption this year. Some noted, however, that the IRS found no evidence of "inurement," or

private enrichment, which is barred.

According to the documents, most church officials receive modest salaries. David Miscavige, director of the Religious Technology Center and holder of the highest ecclesiastical position in Scientology, was listed as being paid $62,604 in 1991 and $34,779 in 1992.

Several Scientologists, however, earned six-figure commissions for raising donations to church entities, including the International Association of Scientologists.

The 440-foot cruise ship Freewinds is operated by Scientology's Flag Ship Service Organization as "a safe, distraction-free environment for the ministry of the highest and most confidential Scientology auditing level," FSSO said in its application for tax exemption.

"Auditing" is a technique developed by Hubbard in which adherents are connected to an electropsychometer, which "measures the mental state and change of state in individuals," according to Scientology literature.

Documents valued the ship at $12.5 million for insurance purposes.

Bowler

► Continued from 1A

tioned 900 series in history remains to be seen. James said the ABC will withhold judgment on that until it receives a full report, in about a week.

"It's our understanding that this was in a step-ladder type of tournament," James said by telephone from the ABC headquarters in Wisconsin. "We have to look at our bylaws, and see if this meets the standards."

There is a chance Ockerman won't meet the standards for a 900 series, because his games weren't bowled in the same match.

Ockerman, an 11-year bowler with a 216 average, was the second-seeded qualifier in the tournament. In his first match, he beat Jerry Schulze 300-258. Then he won the tournament by beating top-seeded Jim Porter 300-237. That advanced Ockerman to the match against the previous month's "king," Wayne Bunce, whom he defeated 300-204.

"I have no doubt that he'll be awarded the three 300s," James said. "That, in itself, is a tremendous feat. But it may not be a series, as we know it."

The ABC's official series record is an 899 bowled by Tom Jordon of

Union, N.J. in 1989. He shot 300-299-300-299 in a four-game tournament and the first three were recognized as a series.

Bowling's only other known bid for a 900 series came on July 1, 1982, by Glenn Allison at the 900 Bowl in La Habra, Calif. But the lanes did not pass ABC standards when they were inspected after the series.

Since then, ABC lane conditioning and sanctioning procedures have changed. The lanes at Riverbend Bowl in Corunna had been given ABC certification eight days before Ockerman's feat.

"We're going to have to change the game now, because someone's perfected it," said Charles A. Wilkerson Jr., Ockerman's roommate and former teammate.

Ockerman hopes his roll will carry him into the ranks of professional bowlers, a dream he said had faded since he first aspired to it six years ago.

"I'm hoping this can be a springboard," he said. "This will get me noticed."

He said two companies that represent potential contracts for product endorsements have called him.

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Allegations revive debate over public right to know

By Gary Blonston and Aaron Epstein
Knight-Ridder Newspapers

WASHINGTON — Here we go again. For the second time in two years, Bill Clinton has been publicly, elaborately accused of marital infidelity, and once again the questions arise:

Should a president be judged by his sex life?

If such vaunted figures as Franklin D. Roosevelt, Dwight D. Eisenhower, John F. Kennedy and Lyndon B. Johnson were chronically unfaithful, how much does it matter what Bill Clinton has or hasn't done?

In 1992, when candidate Clinton was accused of a long affair with a woman named Gennifer Flowers, political pundits predicted it would be fatal to his public career.

But half the country dismissed the whole flap as politically irrelevant, and 70 percent said the news media pursued the story just to win viewers and sell newspapers. By Election Day only 1 in 10 voters — almost all of them George Bush supporters — told pollsters they thought a candidate's marital fidelity was a very important consideration.

Now, in the face of fresh claims by Arkansas state troopers that they helped Clinton, then the governor, arrange illicit sexual encounters, a number of political analysts predict that, if the public turns against him, mere sex won't be the reason.

Clinton will suffer serious political damage, they say, only if Americans become convinced that he tried to silence the troopers or that he broke the implicit promise he made on national television last year to stop fooling around.

In the words of Suzanne Garment, author of a recent book on political scandal, "People don't like being lied to, even about something they'd rather not know about."

Presidential scholar Stephen Hess says, "There was complete acceptance (of the fact) he had been an adulterer," ever since the night in January 1992 when Clinton told a "60 Minutes" interviewer: "I have acknowledged wrongdoing. I have acknowledged causing pain in my marriage."

"Americans elected an admitted adulterer," Hess says. "It's that clear. That's not even a controversial statement."

But most didn't think they had elected a fool. If the public comes to believe that Clinton continued his sexual escapades long after that television confessional, "it could be a real blow to him," says University of North Carolina historian William E. Leuchtenburg.

"It suggests that he ignored the warnings instead of saying, 'Wow, that was a narrow escape; I'll never do that again.' It suggests something almost self-destructive about him."

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Amy's mother, Patti,

Troopers say others too intimidated

The Associated Press

LITTLE ROCK Ark — Two

First lady

► Continued from 1A
White House in recent weeks.

While first ladies have historically been fierce defenders of their spouses in private and strongly supportive in general terms in public. Hillary Clin-

She said she saw no reason to make public any of the files on the development project that were retrieved from the office of Foster, who was deputy White House counsel when he killed himself in a park last summer.

Annotated newspaper section, showing the date and name of the newspaper

Annotated advertisement for EO 440 Personal Communicator