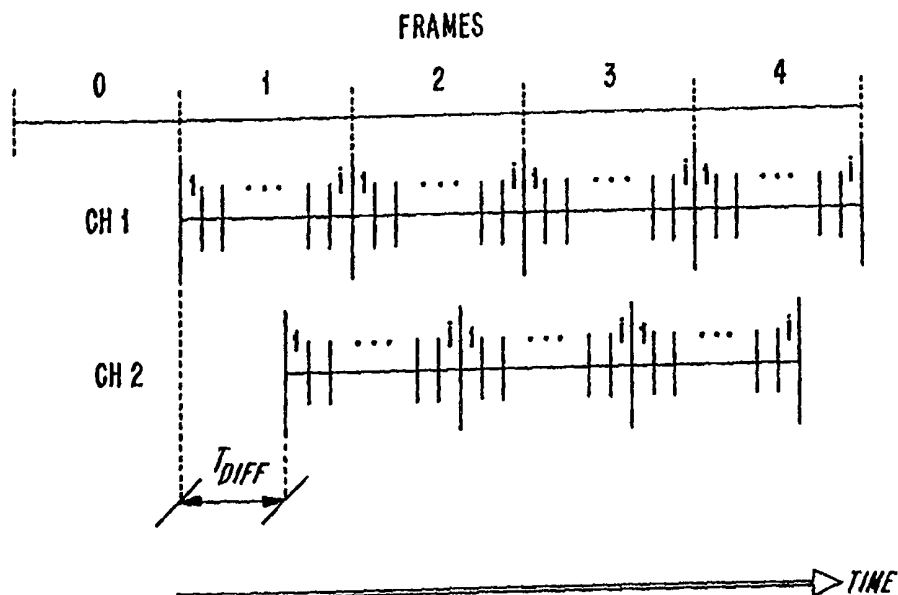




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(54) Title: METHOD AND APPARATUS FOR DETERMINING OPTIMAL TIME DIFFERENCES BETWEEN COMMUNICATION CHANNELS



(57) Abstract

An apparatus and a method for a remote station that may be part of a communication system having at least one base station, and in which base stations and the mobile station communicate by exchanging messages through respective channels that are organized by frames and a base station controls a rate of transmission of the remote station. An optimal time difference between the frames of the respective channels is selected by determining an internal delay of the remote station. Messages to the base station are sent in frames that begin at times based on the internal delay. The channels may be implemented on radio frequency carrier signals and the time difference is selected so that radio resources of the communication system are used maximally.

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METHOD AND APPARATUS FOR DETERMINING OPTIMAL TIME DIFFERENCES BETWEEN COMMUNICATION CHANNELS

BACKGROUND

5 This invention relates generally to electrical telecommunication and more particularly to selecting time differences between wireless communication channels and even more particularly to methods and apparatus for selecting optimal time differences between uplink and downlink radio channels to maximize use of resources.

Modern communication systems, such as cellular and satellite radio systems,
10 employ various modes of operation (analog, digital, dual mode, etc.), and access techniques such as frequency division multiple access (FDMA), time division multiple access (TDMA), code division multiple access (CDMA), and hybrids of these techniques.

Digital cellular communication systems have expanded functionality for optimizing system capacity and supporting hierarchical cell structures, i.e., structures of
15 macrocells, microcells, picocells, etc. The term "macrocell" generally refers to a cell having a size comparable to the sizes of cells in a conventional cellular telephone system (e.g., a radius of at least about 1 kilometer), and the terms "microcell" and "picocell" generally refer to progressively smaller cells. For example, a microcell might cover a public indoor or outdoor area, e.g., a convention center or a busy street, and a picocell
20 might cover an office corridor or a floor of a high-rise building. From a radio coverage perspective, macrocells, microcells, and picocells may be distinct from one another or may overlap one another to handle different traffic patterns or radio environments.

FIG. 1 is an exemplary hierarchical, or multi-layered, cellular system. An umbrella macrocell 10 represented by a hexagonal shape makes up an overlying cellular
25 structure. Each umbrella cell may contain an underlying microcell structure. The umbrella cell 10 includes microcell 20 represented by the area enclosed within the dotted line and microcell 30 represented by the area enclosed within the dashed line corresponding to areas along city streets, and picocells 40, 50, and 60, which cover individual floors of a building. The intersection of the two city streets covered by the

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microcells 20 and 30 may be an area of dense traffic concentration, and thus might represent a hot spot.

FIG. 2 is a block diagram of an exemplary cellular mobile radiotelephone system, including an exemplary base station 110 and mobile station 120. The base station includes a control and processing unit 130 which is connected to a mobile switching center (MSC) 140 which in turn is connected to the public switched telephone network (PSTN) (not shown). General aspects of such cellular radiotelephone systems are known in the art. The base station 110 handles a plurality of voice channels through a voice channel transceiver 150, which is controlled by the control and processing unit 130. Also, each base station includes a control channel transceiver 160, which may be capable of handling more than one control channel. The control channel transceiver 160 is controlled by the control and processing unit 130. The control channel transceiver 160 broadcasts control information over the control channel of the base station or cell to mobiles locked to that control channel. It will be understood that the transceivers 150 and 160 can be implemented as a single device, like the voice and control transceiver 170, for use with control and traffic channels that share the same radio carrier.

The mobile station 120 receives the information broadcast on a control channel at its voice and control channel transceiver 170. Then, the processing unit 180 evaluates the received control channel information, which includes the characteristics of cells that are candidates for the mobile station to lock on to, and determines on which cell the mobile should lock. Advantageously, the received control channel information not only includes absolute information concerning the cell with which it is associated, but also contains relative information concerning other cells proximate to the cell with which the control channel is associated, as described for example in U.S. Patent No. 5,353,332 to Raith et al., entitled "Method and Apparatus for Communication Control in a Radiotelephone System".

In North America, a digital cellular radiotelephone system using TDMA is called the digital advanced mobile phone service (D-AMPS), some of the characteristics of which are specified in the TIA/EIA/IS-136 standard published by the

Telecommunications Industry Association and Electronic Industries Association (TIA/EIA). Another digital communication system using direct sequence CDMA is specified by the TIA/EIA/IS-95 standard, and a frequency hopping CDMA communication system is specified by the EIA SP 3389 standard (PCS 1900). The PCS 1900 standard is an implementation of the GSM system, which is common outside North America, that has been introduced for personal communication services (PCS) systems.

Several proposals for the next generation of digital cellular communication systems are currently under discussion in various standards setting organizations, which include the International Telecommunications Union (ITU), the European Telecommunications Standards Institute (ETSI), and Japan's Association of Radio Industries and Businesses (ARIB). Besides transmitting voice information, the next generation systems can be expected to carry packet data and to inter-operate with packet data networks that are also usually designed and based on industry-wide data standards such as the open system interface (OSI) model or the transmission control protocol/Internet protocol (TCP/IP) stack. These standards have been developed, whether formally or de facto, for many years, and the applications that use these protocols are readily available. The main objective of standards-based networks is to achieve interconnectivity with other networks. The Internet is today's most obvious example of such a standards-based packet data network in pursuit of this goal.

In most of these digital communication systems, communication channels are implemented by frequency modulating radio carrier signals, which have frequencies near 800 megahertz (MHz), 900 MHz, 1800 MHz, and 1900 MHz. In TDMA systems and even to varying extents in CDMA systems, each radio channel is divided into a series of time slots, each of which contains a block of information from a user. The time slots are grouped into successive frames that each have a predetermined duration, and successive frames may be grouped into a succession of what are usually called superframes. The kind of access technique (e.g., TDMA or CDMA) used by a communication system affects how user information is represented in the slots and frames, but current access techniques all use a slot/frame structure.

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Time slots assigned to the same user, which may not be consecutive time slots on the radio carrier, may be considered a logical channel assigned to the user. During each time slot, a predetermined number of digital bits are transmitted according to the particular access technique (e.g., CDMA) used by the system. In addition to logical channels for voice or data traffic, cellular radio communication systems also provide logical channels for control messages, such as paging/access channels for call-setup messages exchanged by base stations and mobile stations. In general, the transmission bit rates of these different channels need not coincide and the lengths of the slots in the different channels need not be uniform.

10 In cellular telephone systems, an air interface protocol is required in order to allow a mobile station to communicate with the base stations and an MSC. The air interface protocol is used to initiate and to receive cellular telephone calls and is defined in the communications industry by Layer 1 (physical layer), Layer 2 (link layer), and Layer 3 (radio resource control (RRC) layer). The functionality of a Layer 2 includes the delimiting, or framing, of Layer 3 messages, which may be sent between communicating Layer 3 peer entities residing within mobile stations and cellular switching systems. The physical layer (Layer 1) defines the parameters of the physical communications channel, e.g., carrier radio frequency spacing, modulation characteristics, etc. Layer 2 defines the techniques necessary for the accurate transmission of information within the constraints of the physical channel, e.g., error correction and detection, etc. Layer 3 defines the procedures for reception and processing of information transmitted over the physical channel. TIA/EIA/IS-136 and TIA/EIA/IS-95 for example specify air interface protocols.

Communications between mobile stations and the cellular switching system (the base stations and the MSC) can be described in general with reference to FIGS. 3 and 4. FIG. 3 schematically illustrates pluralities of Layer 3 messages 11, Layer 2 frames 13, and Layer 1 time slots, or channel blocks, 15. In FIG. 3, groups of time slots corresponding to Layer 3 messages may constitute a logical channel, and as described above, the time slots for a given Layer 3 message would usually not be consecutive slots on a carrier. On the other hand, the time slots could be consecutive; as soon as one time

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slot ends, the next time slot could begin. FIG. 4 shows a general example of a channel configured as a succession of time slots 1, 2, . . . , i in each of a succession of frames 1, 2, . . . , j that would be sent on a carrier signal. Each group of j frames might constitute a superframe. It will be appreciated that this description does not change significantly for TDMA and CDMA techniques.

A feature of many systems is that the rates at which both the MS and the BS can transmit user information bits can be different for different channels in the system and can change from time to time even within a channel, for example in response to changes in the amount of information to be transmitted. The rate is sometimes permitted to change only at the beginnings of frames and must keep a constant value throughout an entire frame. This is typical of the third generation system currently being considered by ARIB. An MS is allocated a set of different rates that can be used for the transmission of information bits. The BS controls the allocation of the rate for each channel and sends messages to the MS to inform the MS which rates it is allowed to use. Such a message can be sent by a BS in each frame it transmits.

Since time is required for a radio signal to propagate from a transmitter to a receiver, the slot/frame structure of a BS will be temporally offset from the slot/frame structure of a MS. In addition, the processor in an MS needs some time to prepare each frame. Thus, there will be a delay between the MS's receipt of a frame message calling for a rate change and the frame when the MS actually changes the rate of transmission. This time difference can cause a waste of the communication system's radio resources because the MS does not change its rate as fast as it is capable of doing.

SUMMARY

It is therefore an object of the present invention to select an optimal time difference between uplink and downlink channels to maximized use of resources.

In one aspect of Applicant's invention, there is provided an apparatus for selecting an optimal time difference between frames of communication channels between a base station and a remote station. The apparatus includes a device for determining an internal

delay of the remote station and a device for transmitting messages to the base station in frames that begin at times based on the internal delay. The apparatus may employ channels that are implemented on radio frequency carrier signals and the time difference may be selected so that radio resources of the communication system are used maximally.

5 In the apparatus, the device that determines the internal delay may further include a device for configuring the remote station for communication at a first transmission rate; a device for providing a rate-change message to the remote terminal; a device for measuring a time elapsed until the remote station's configuration has changed to a second transmission rate in accordance with the rate-change message; and a device for adjusting
10 the measured elapsed time to derive the internal delay. In such an apparatus, elapsed time measurements may be obtained for each combination of a set of first and second transmission rates. Also, a plurality of elapsed times may be measured, and a selected one of the elapsed time measurements may be adjusted to derive the internal delay.

 In another aspect of Applicant's invention, there is provided a method of
15 determining an optimal time difference between frames of communication channels in a communication system having at least one base station and remote station and in which base stations control rates of transmission of remote stations. The method includes the steps of: configuring a remote station for communication at a first transmission rate; providing a rate-change message to the remote terminal; measuring a time elapsed until
20 the remote station's configuration has changed to a second transmission rate in accordance with the rate-change message; and adjusting the measured elapsed time to derive the optimal time difference.

 In the method, the optimal time difference may be derived such that radio resources of the communication system are used maximally. Moreover, elapsed time
25 measurements may be obtained for each combination of a set of first and second transmission rates. Also, a plurality of elapsed times may be measured, and a selected one of the elapsed time measurements may be adjusted to derive the optimal time difference.

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BRIEF DESCRIPTION OF THE DRAWINGS

The features, objects, and advantages of this invention will become apparent by reading this description in conjunction with the accompanying drawings, in which like reference numerals refer to like elements and in which:

- 5 FIG. 1 illustrates a hierarchical, or multi-layered, cellular communication system;
 FIG. 2 is a block diagram of a cellular mobile radiotelephone system;
 FIG. 3 illustrates pluralities of Layer 3 messages, Layer 2 frames, and Layer 1
time slots;
 FIG. 4 shows a general example of a channel configured as a succession of time
10 slots 1, 2, . . . , i in each of a succession of frames 1, 2, . . . , j;
 FIG. 5 illustrates a time relation between channels in a communication system;
and
 FIG. 6 is a flow chart of a method of determining a time difference between
channels.

15

DETAILED DESCRIPTION

For illustrative purposes, the following description is directed to a cellular radio communication system, but it will be understood that this invention is not so limited and applies to other types of communication systems.

- 20 FIG. 5 illustrates a time relation between channels in a communication system. A channel CH1 comprises a succession of time slots 1, 2, . . . , i in each of a succession of frames 0, 1, 2, . . . , j sent on one carrier signal, and another channel CH2 is also configured as a later occurring succession of time slots 1, 2, . . . , i in each of a succession of frames 1, 2, . . . , j sent on a second carrier signal. The channel CH1 may be a forward
25 (downlink) channel from a BS to a MS that includes messages transmitted by the transceivers 150, 160 shown in FIG. 2, and the channel CH2 may be a reverse (uplink) channel from the MS to the BS that includes messages transmitted by the transceiver 170 also shown in FIG. 2.

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The time relation between the slot/frame structures of CH1 and CH2 is determined when the MS sets up the uplink, i.e., the first time the MS begins to transmit on CH2. This time relation or time difference may be called T_{diff} as shown in FIG. 5. This time relation of the slot/frame structures of the BS and MS is due to the time needed for propagation of signals between the BS and MS as well as any time the MS processor 180 and transceiver 170 needs for preparing and transmitting each frame. Although illustrated in FIG. 5 as less than a frame length, it will be understood that the time difference may be greater than one frame length. The length of a frame in some current communication systems is 20 msec and in others it is 10 msec, and some current remote stations need about 2.5 msec to prepare and transmit a frame.

Also, the time difference may be in addition to or subsumed by an intentional delay that may be called for by the air interface protocol. It is not necessary for a communication system to use frame number or slot number synchronization, although some systems use a relative slot synchronization. This means that a slot sent by a MS is temporally related to a received slot from the BS by a certain value, but not that an uplink slot number k (where $k = 0, 1, \dots, i-1$) must follow downlink slot number k . For example, Section 3.2.6.2 of the Specification for the Air-Interface for the 3G Mobile System, vol. 3 of the ARIB specification, calls for delaying uplink transmissions by one-half of a time slot relative to downlink transmissions.

Thus, a message calling for a rate change that is sent by the BS in frame 0 of CH1 will not be implemented by the MS until sometime later, i.e., T_{diff} in FIG. 5. An arbitrary fixed value has been used in the past for the time relation between the frames of channels CH1, CH2. Usually, a fixed value for T_{diff} has not been chosen according to any specific rule, i.e., any value could be chosen regardless of the possible transmission rates on CH1 and CH2. This time difference can cause a waste of communication system resources because the MS does not change its rate as fast as it can; this waste is eliminated by Applicant's invention.

According to Applicant's invention, the MS, either by operation of the processing unit 180 or another suitable means, determines an optimal value of T_{diff} instead of using a

fixed value of T_{diff} . The determined value of T_{diff} , which may have been stored in a suitable memory like a register, RAM, EEPROM, etc., is fetched by the terminal's processing unit 180 when the terminal is setting up an uplink channel.

The optimal value of T_{diff} can be determined for each permitted transmission rate either once, e.g., when the terminal is manufactured, or from time to time during the life of the mobile, e.g., when the terminal is powered up. One way this can be done is by running a special test program in the terminal, a flow diagram of which is illustrated in FIG. 6. In essence, the terminal is initially configured for communication at a first transmission rate (step 602), and then a simulated rate-change message either is generated internally by the terminal or is provided to the terminal by an external test equipment (step 604). A timer that is either in the terminal or in the external test equipment then measures the time elapsed until the terminal's configuration has changed to the commanded rate (step 606). This procedure may be followed for each possible combination of beginning and ending transmission rates (step 608), and the procedure may be carried out more than once for each combination, with one (e.g., the largest) elapsed time measurement or an average of the measurements being retained for each combination (step 610). Once a set of elapsed times has been determined, the set can be used as the desired values of T_{diff} or more preferably can first be adjusted by adding a safety margin, e.g., 10% of the respective measured elapsed time (step 612).

These steps can be implemented in a software or firmware routine that is executed by a terminal's processing unit 180 or by an external test equipment that would include an appropriate rate-message generator and a timer. A special-purpose device, e.g., a portion of an application specific integrated circuit (ASIC) could be used for determining T_{diff} rather than the terminal's general-purpose processor. In addition, rather than using a simulated rate change message, the terminal could be configured to carry out the procedure of FIG. 6 while it is communicating with the network. It might be necessary to accumulate elapsed time values in a piecemeal fashion, rather than all at once for a whole rate set, and the first uplink channel and one or more subsequent uplinks might not be optimal because it or they would not be established based on measured elapsed times, but

communication could be established more quickly by not having to wait for the execution of a special test routine.

The value of T_{diff} that is determined by the processing unit 180 is preferably "optimal" in that communication system resources are maximally utilized; this usually means that T_{diff} is as small as possible. The MS chooses T_{diff} such that the MS can change its transmission rate as fast as possible, most preferably in the first frame or slot starting after a rate-change message has been received from the BS. Thus, it may be expected that each remote station may have a respective value of T_{diff} since the performance of the components of each remote station can be expected to differ slightly from the performance of components of other remote stations.

In general, the value T_{diff} may vary as a function of how the internal delay of the remote station relates to the set of possible transmission rates on the channel. Since the possible set of rates can vary widely in many communication systems, T_{diff} can also vary for a single MS, depending on which rate set and which rate is used.

It will be understood that rather than determining T_{diff} for each possible transmission rate and in each remote station, it may be advantageous simply to select one or more fixed values that permit most remote stations to handle rate change as fast as possible.

It will further be understood that transmitting messages in frames that begin at times based on the time relation T_{diff} can be readily modified to transmitting messages in slots that begin at times based on the time relation T_{diff} .

It will be appreciated by those of ordinary skill in the art that this invention can be embodied in other specific forms without departing from its essential character. The embodiments described above should therefore be considered in all respects to be illustrative and not restrictive.

I CLAIM:

1. An apparatus for selecting an optimal time difference between frames of communication channels between a base station and a remote station, comprising:
5 means for determining an internal delay of the remote station; and
 means for transmitting messages to the base station in frames that begin at times based on the internal delay.
2. The apparatus of claim 1, in which the channels are implemented on radio
10 frequency carrier signals and the time difference is selected so that radio resources of the communication system are used maximally.
3. The apparatus of claim 1, wherein the determining means comprises means for configuring the remote station for communication at a first transmission rate; means for
15 providing a rate-change message to the remote terminal; means for measuring a time elapsed until the remote station's configuration has changed to a second transmission rate in accordance with the rate-change message; and means for adjusting the measured elapsed time to derive the internal delay.
- 20 4. The apparatus of claim 3, wherein elapsed time measurements are obtained for each combination of a set of first and second transmission rates.
5. The apparatus of claim 3, wherein a plurality of elapsed times are measured,
 and a selected one of the elapsed time measurements is adjusted to derive the internal
25 delay.
6. A method of determining an optimal time difference between frames of communication channels in a communication system having at least one base station and

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remote station and in which base stations control rates of transmission of remote stations, comprising the steps of:

- configuring a remote station for communication at a first transmission rate;
- providing a rate-change message to the remote terminal;
- 5 measuring a time elapsed until the remote station's configuration has changed to a second transmission rate in accordance with the rate-change message;
- adjusting the measured elapsed time to derive the optimal time difference.

7. The method of claim 6, wherein the optimal time difference is derived such
10 that radio resources of the communication system are used maximally.

8. The method of claim 6, wherein elapsed time measurements are obtained for each combination of a set of first and second transmission rates.

15 9. The method of claim 6, wherein a plurality of elapsed times are measured, and a selected one of the elapsed time measurements is adjusted to derive the optimal time difference.

10. A communication system, comprising:
20 at least one base station and at least one remote station, wherein base stations and remote stations communicate by exchanging messages through respective channels that are organized by frames, and a base station controls a rate of transmission of a remote station; and

means for selecting an optimal time difference between the frames of the
25 respective channels, wherein the selecting means includes means for determining an internal delay of a remote station, and means for transmitting messages to a base station in frames that begin at times based on the internal delay.

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11. The apparatus of claim 10, in which the channels are implemented on radio frequency carrier signals and the time difference is selected so that radio resources of the communication system are used maximally.

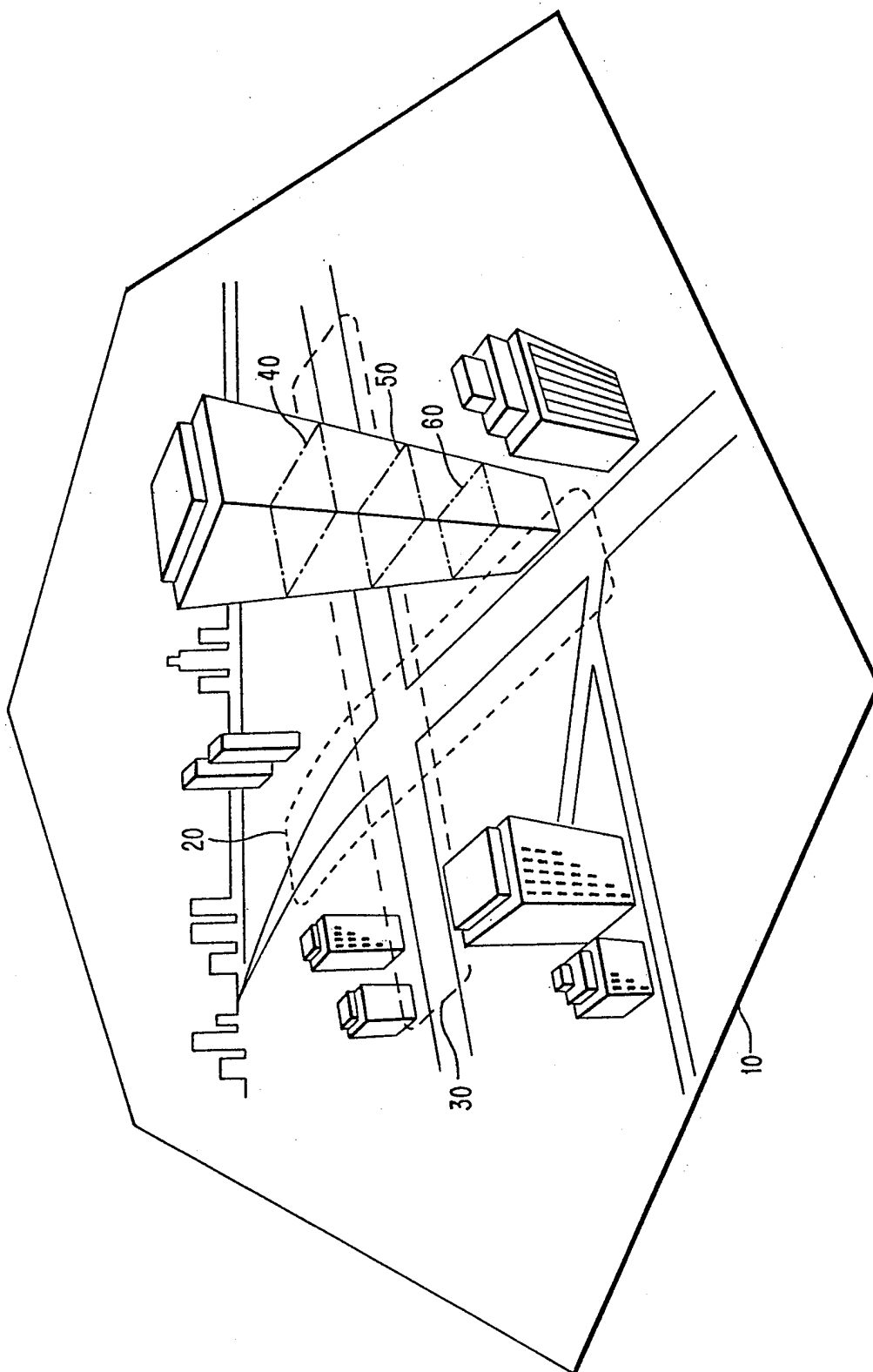
5 12. The apparatus of claim 10, wherein the determining means comprises means for configuring the remote station for communication at a first transmission rate; means for providing a rate-change message to the remote terminal; means for measuring a time elapsed until the remote station's configuration has changed to a second transmission rate in accordance with the rate-change message; and means for adjusting the measured
10 elapsed time to derive the internal delay.

13. The apparatus of claim 12, wherein elapsed time measurements are obtained for each combination of a set of first and second transmission rates.

15 14. The apparatus of claim 12, wherein a plurality of elapsed times are measured, and a selected one of the elapsed time measurements is adjusted to derive the internal delay.

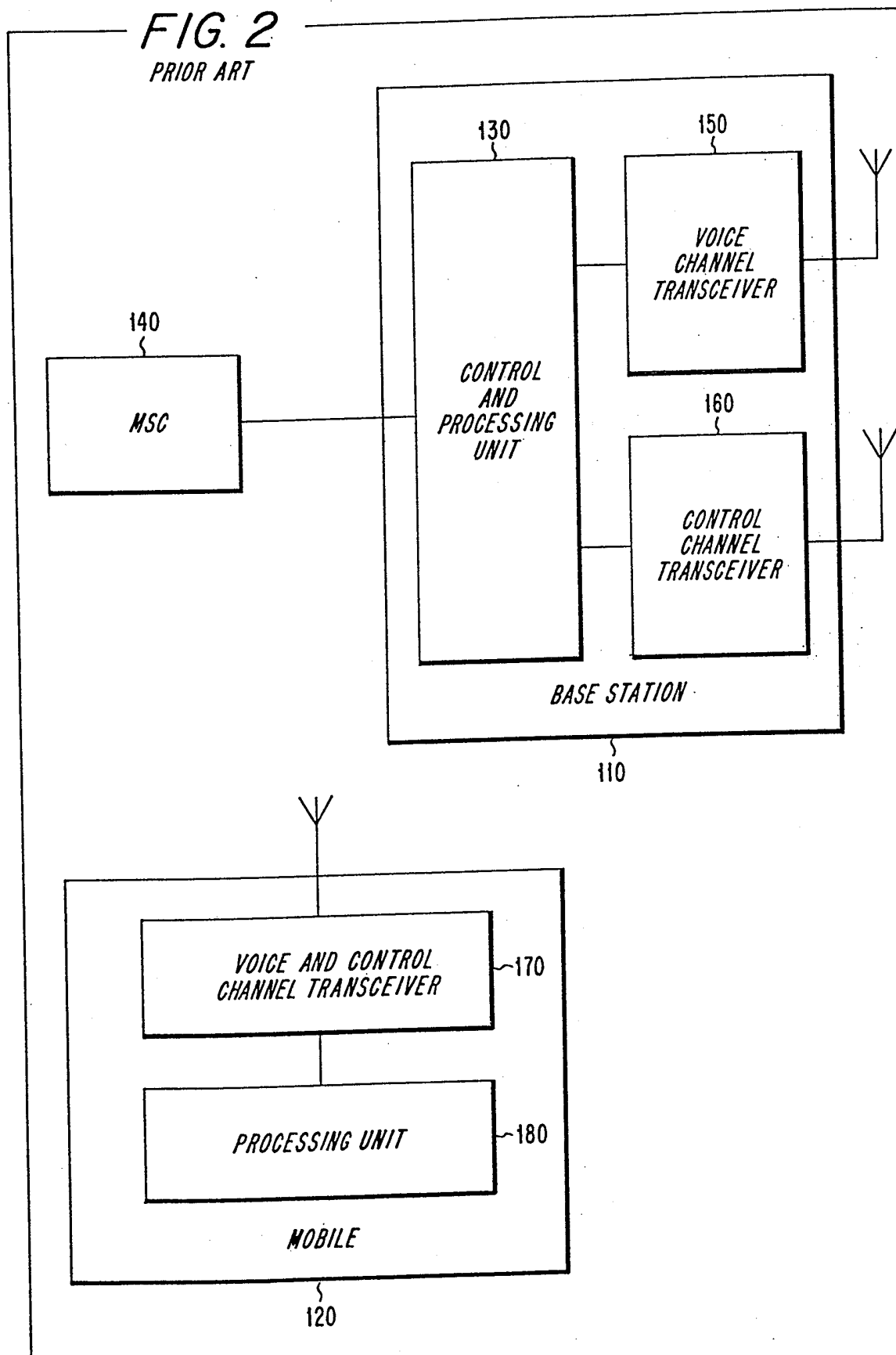
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FIG. 1
PRIOR ART



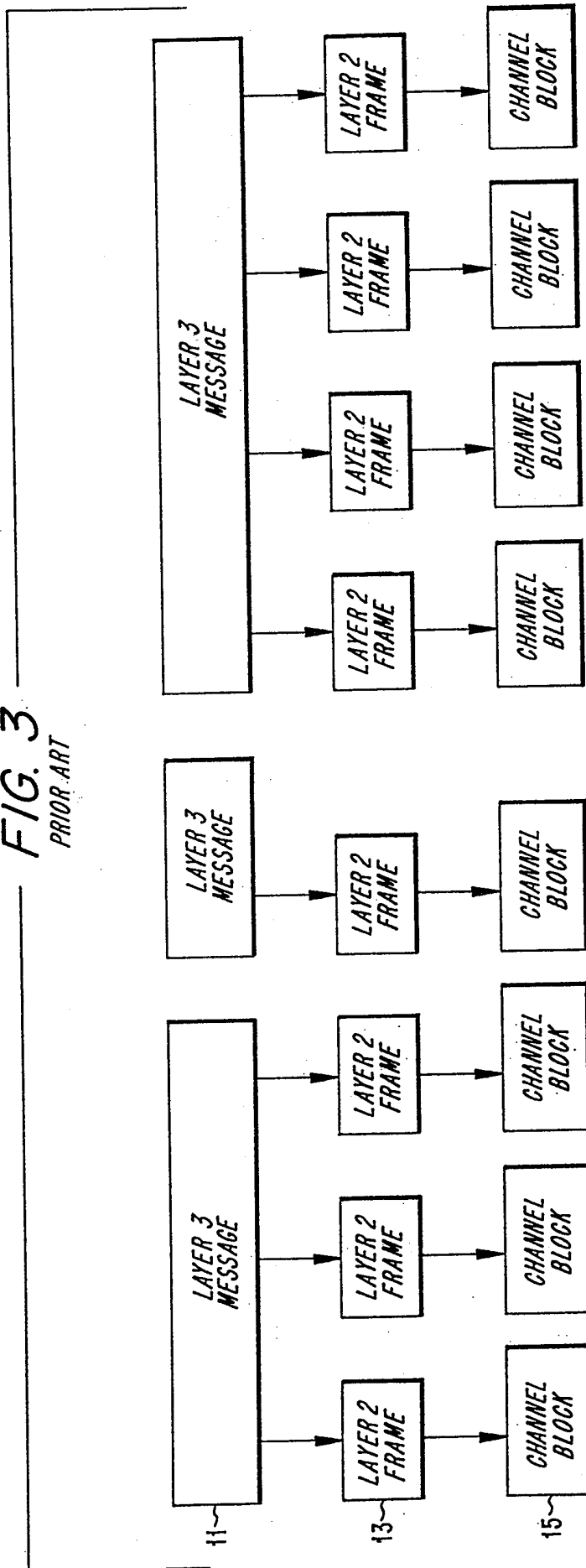
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FIG. 2
PRIOR ART



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FIG. 3
PRIOR ART



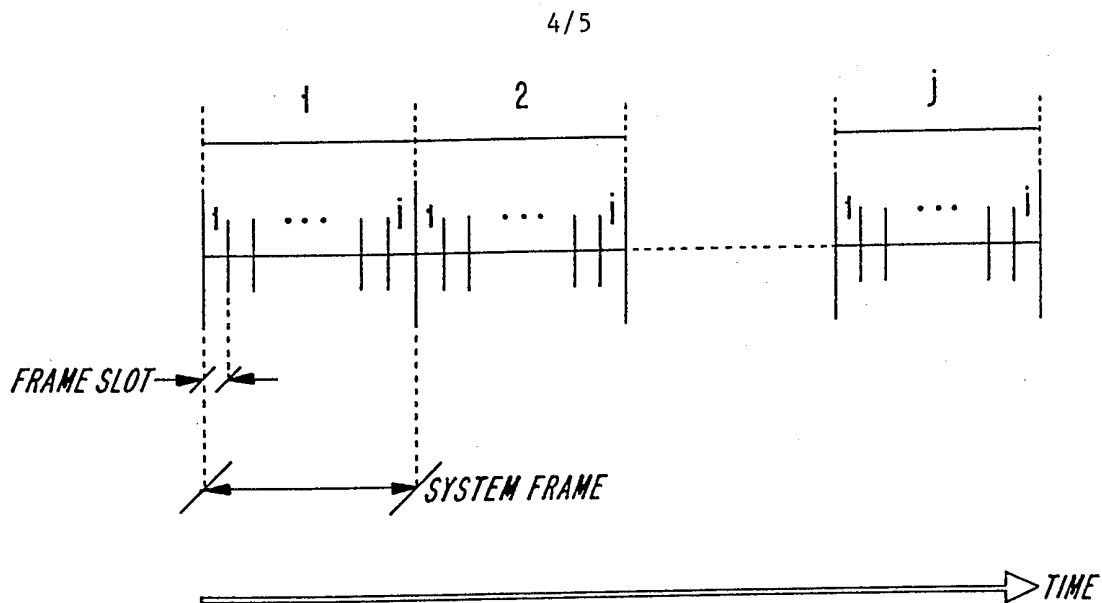


FIG. 4
PRIOR ART

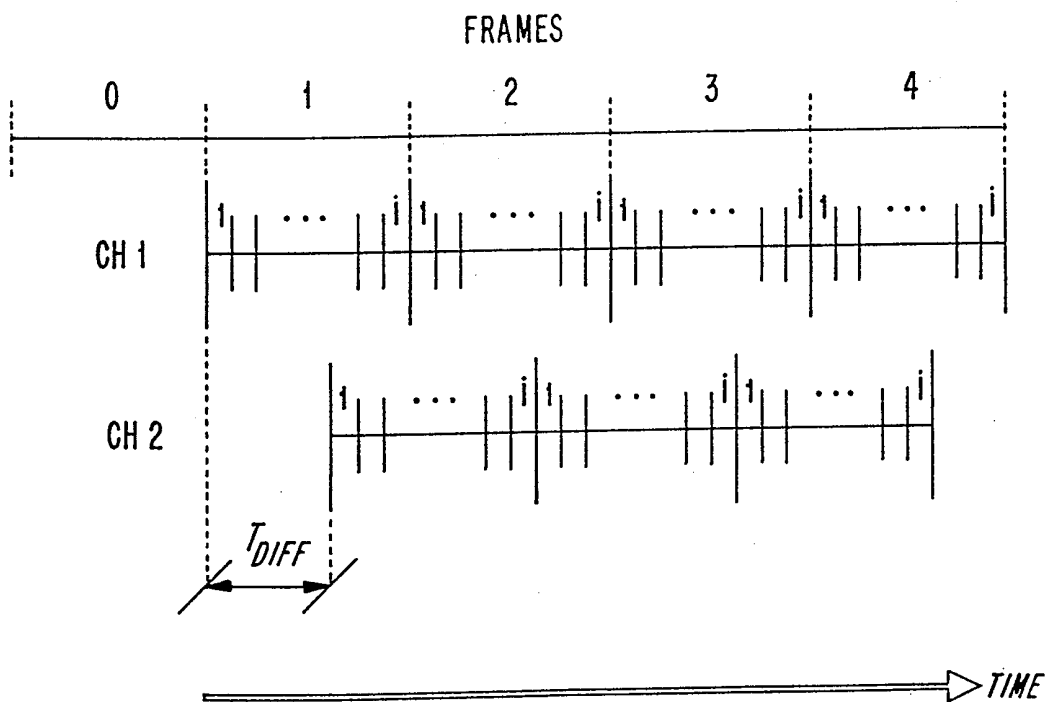


FIG. 5

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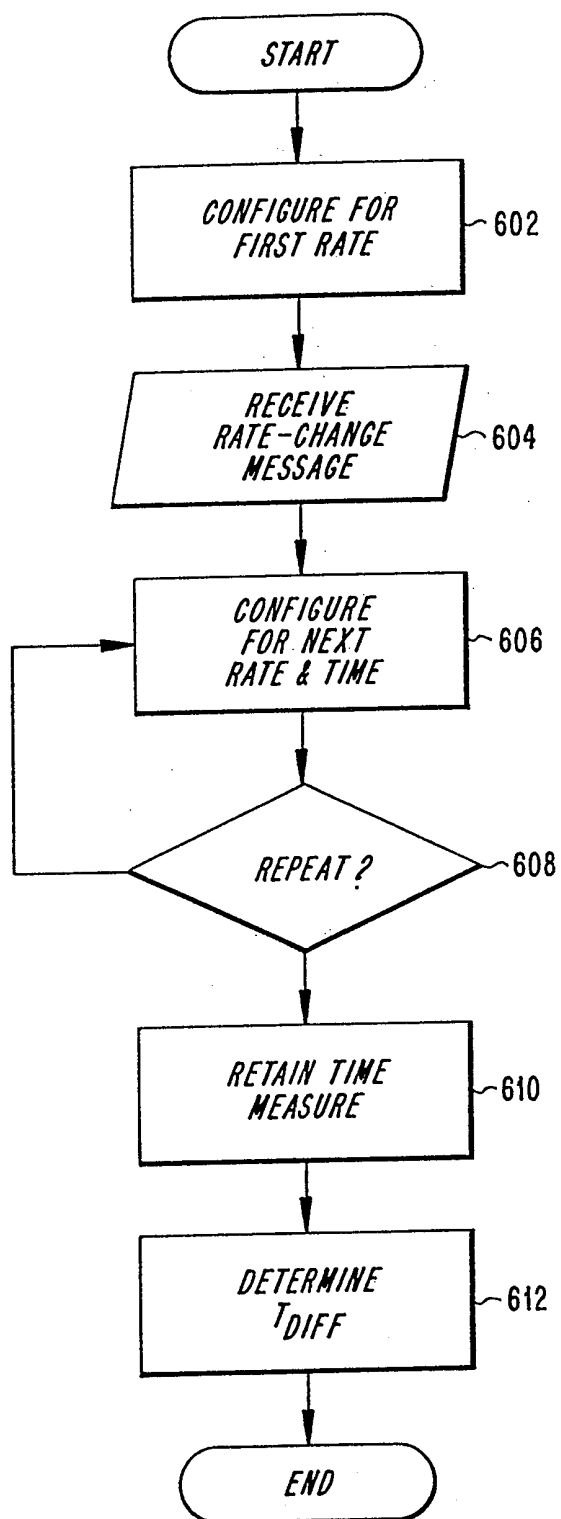


FIG. 6

INTERNATIONAL SEARCH REPORT

International Application No
PCT/SE 99/01269

A. CLASSIFICATION OF SUBJECT MATTER

IPC 7 H04B7/26

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 H04B

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

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 4 937 812 A (ITOH ET AL.) 26 June 1990 (1990-06-26)	1
Y	column 3, line 9 - line 56; claim 1 ---	6,10
Y	WO 95 12257 A (MOTOROLA INC) 4 May 1995 (1995-05-04) claim 1 ---	6,10
A	WO 97 15131 A (ERICSSON) 24 April 1997 (1997-04-24) page 16, line 1 -page 17, line 5 -----	1-14

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

☒ Patent family members are listed in annex.

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Date of the actual completion of the international search

7 October 1999

Date of mailing of the international search report

13/10/1999

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INTERNATIONAL SEARCH REPORT

information on patent family members

International Application No

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