AU9336523

(12) PATENT ABRIDGMENT (11) Document No. AU-B-36523/93
(19) AUSTRALIAN PATENT OFFICE (10) Acceptance No. 655356

(54) Title
A METHOD FOR COMMUNICATION IN A TDMA CELLULAR MOBILE RADIO SYSTEM USING FREQUENCY HOPPING

International Patent Classification(s)
(51)[5] **H04B 007/26** **H04J 004/00** **H04J 013/00** **H04Q 007/00**

(21) Application No. : **36523/93** (22) Application Date : **16.02.93**

(87) PCT Publication Number : **WO93/17507**

(30) Priority Data

(31) Number **9200607** (32) Date **28.02.92** (33) Country **SE SWEDEN**

(43) Publication Date : **13.09.93**

(44) Publication Date of Accepted Application : **15.12.94**

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(56) Prior Art Documents
WO 9113502

(57) Claim

14. In a cellular TDMA mobile radio system including a first and a second adjacent cells and plural TDMA radio channels, each divided in time slots grouped in frames, a method of transmitting radio signals pertaining to connections involving mobile stations, comprising the steps of:
transmitting from each of a plurality of mobile stations involved in connections radio signal bursts distributed on a plurality of radio channels in accordance with a radio channel time slot hopping scheme, each burst transmitted from any of the mobile stations being confined to one time slot and separated in time from the succeeding burst transmitted from the same mobile station and relating to the same connection, all of the hopping schemes used by mobile stations in the first cell being free from coincidence on any radio channel with any other of the hopping schemes used for transmission from a mobile station in the first cell, all of the hopping schemes used by mobile stations in the second cell being free from coincidence on any radio channel with any other of the hopping schemes used by any mobile station in

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the second cell, one of the hopping schemes used by mobile stations in the second cell coinciding on any radio channel with at least one of the hopping schemes used by a mobile station in the first cell, the major part of every hopping scheme used by a mobile station in the second cell being free from coincidence on any radio channel with the major part of any hopping scheme used by a mobile station in the first cell.

OPI DATE 13/09/93 APPLN. ID 36523/93
AOJP DATE 25/11/93 PCT NUMBER PCT/SE93/00117

AU9336523

INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 5 : H04B 7/26, H04Q 7/00 H04J 4/00 — A1

(11) International Publication Number: WO 93/17507

(43) International Publication Date: 2 September 1993 (02.09.93)

(21) International Application Number: PCT/SE93/00117

(22) International Filing Date: 16 February 1993 (16.02.93)

(30) Priority data:
9200607-1 28 February 1992 (28.02.92) SE

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(81) Designated States: AU, BR, CA, FI, JP, KR, NO, NZ, European patent (AT, BE, CH, DE, DK, ES, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE).

Published
With international search report.

655356

(54) Title: A METHOD FOR COMMUNICATION IN A TDMA CELLULAR MOBILE RADIO SYSTEM USING FREQUENCY HOPPING

(57) Abstract

A method and means for communication in a cellular TDMA mobile radio communication system with channel hopping, where base and mobile stations transmit radio signal bursts in time slots of a plurality of radio channels in accordance with channel hopping schemes, all of the schemes used by a base and mobile stations in a cell being free from coincidence on any radio channel with any other of the schemes used for transmission within the same cell, a scheme used by a mobile station in one cell occasionally coinciding on a radio channel with a scheme used by a mobile station in an other cell, the major part of every channel shifting scheme used by a mobile station in a cell being free from coincidence on any radio channel with the major part of any channel hopping scheme used by a mobile station in another cell, signal to interference ratio or other signal characteristics such as signal strength or bit error rate for signals received by mobile stations are estimated and compared, the output power of stations being controlled, the existence of further possible channel hopping schemes in a cell, free from coincidence on every radio channel with every other of the channel hopping schemes already in use in that cell, is checked, and when another connection to a particular mobile is desired and there is a possible mobile scheme free from coincidence, the desired connection is established using the possible channel hopping scheme in the cell, only if the estimated C/I for certain mobile stations involved in connections exceed a minimum level.

A method for communication in a TDMA cellular mobile radio system using frequency hopping

This invention relates to the technical field of mobile radio communication. More specificly the invention relates to methods for efficient and flexible use of the frequency spectrum available for communication in a time division multiple access mobile radio communication system. The invention also relates to a base station and a mobile station for flexible and efficient use of the frequency spectrum available in a time division multiple access mobile radio communication system.

BACKGROUND OF THE INVENTION

Many mobile radio systems of various kinds are known and in use. The frequency band available for connections in a mobile radio communication system limits the capacity of mobile radio systems. Two base stations or mobile stations transmitting on the same radio channel of a FDMA system or on the same time slot of the same radio channel in a TDMA system may cause interference to each other. This kind of interference is sometimes called co-channel interference because the interference comes from the same radio channel. If the interfering mobiles or bases are sufficiently close in relation to radio propagation properties the signal strength of the signals relating to one of the connections will not be sufficiently stronger than the interfering signals relating to the other connection. The information on the connection forwarded with the signals transmitted will then be more or less illegible. If the interfering mobiles or base stations are sufficiently distant from each other however, the signals relating to a connection will be sufficiently stronger than the interference signals of the other connection. The information of the connections will the be easily understood.

In order to be able to use the same radio channel in FDMA systems and in TDMA systems also the same time slot of a radio channel for more than one connection, some mobile radio systems are therefore made cellular systems. The geographical area to be covered by a system is then divided into smaller areas called cells and mobiles in a cell communicate with a base station for that cell. Some or all of the available radio channels are distributed among the cells according to a frequency plan.

Normally a conventional frequency plan means different radio channels are allotted to a cluster of adjacent or neighbour cells. No two cells in the same cluster may use the same radio channel. Each radio channel used by the base station or a mobile of one cell in a cluster, is different from every channel used by a base or mobile in an other cell in the same cluster. However, cells in different clusters may use the same radio channels. Thus there may be simultaneous multiple use of a radio channel. Such multiple use is sometimes called channel re-use. The distance between cells using the same radio channel is sometimes called re-use distance.

Many different shapes and sizes of cell clusters are known to those skilled in the art, e.g. 3-cell, 4-cell, 7-cell, 9-cell, 12-cell and 21-cell clusters. Somewhat simplified the largest call handling capacity for a cellular TDMA system is achieved when using the smallest cluster providing sufficiently low co-channel interference.

Athough the frequency plans described provides the important advantage of plural use of radio channels, often called frequency or channel re-use, such fixed fequency plans are cumbersome to do. Due to geographical variations, the cells, or zones covered by each base station antenna, will vary in size and shape. The coverage area of the system will thus normally be covered by several different combinations of the known cluster combinations. Commonly, the cluster configuration, or decisions of which re-use patterns to be used, must be made by the aid of complex computer-analyzes of the topography in the system.

Also other disadvantages are inherent in the use of fixed frequency plans. Normally, the number of desired connections in a cell varies with time and one cell may not be able to handle all desired connections because all channels and all time slots on TDMA channels alotted to the cell are occupied. At the same time the number of desired connections in an adjacent cell or a neigh-bour cell or any cell in the same cluster may be substantially less than the total capacity on all channels allotted to that cell according to the fixed frequency plan. Thus all desired connections can not be handled by the cell cluster in spite of the fact that there is at least one free channel or at least a free time slot on a radio channel which could have been used for the desired connections had this not been forbidden by the fixed frequency plan.

One way of reducing the above mentioned disadvantage of fixed frequency plans is not to distribute all radio channels available for connections in a mobile radio communication system, but to reserve a couple of radio channels. All channels but the reserved are distributed according to a frequency plan. The reserved radio channels may be temporary used by any cell requiring more channels than the channels permanently allotted to that channel in accordance with the frequency plan. Such temporary use of a reserved channel is then subject to not causing co-channel interference for an other cell already using that reserved radio channel. While this method of reserving and temporary allotting some radio channels provides more flexibility as regards variable connection handling capacity than a fixed frequency plan for all available radio channels, the total handling capacity for the whole system may decrease.

A more profound method of obtaining high traffic handling flexibility in a various areas of a cellular mobile radio system is to completely abolish frequency plan and let all radio channels available for connections be a commom resource to all cells. Any cell may use any radio channel available for connections provided there is sufficiently low co-channel interference from others using the same radio channel. This way of using the available radio channels is sometimes called "dynamic channel allocation". While this method certainly affords advantages as regards changing call handling capacity for a cell this method also means disadvantages as regards other aspects not to be further discussed here.

Power conservation is an important aspect of small light weight portable battery powered mobile stations. In an normal telephone call pauses in the speech are frequent and quite long in relation to a radio channel time slot. Transmitting radio signals when there is no information to forward is only a waste of battery power. Discontinous transmission means the transmission is interrupted when there is a pause in the speech of a call or no information to be forwarded on an ongoing connection.

Another way of saving battery power in a mobile station is to control the strength of transmitted radio signals in response to measured signal strength at the receiving base station. If the signal strength at receiveing base station is neglected, a mobile must always transmit radio signals with a strength sufficient for a worst case condition, e.g. when the mobile station is located at the borderline of a cell. For most locations such a signal strength is unnecessary high. If the strength of received signals are measured a base station may send power control messages to the mobile permitting a reduction of the mobile transmit power whenever an excessive signal level is detected.

Some cellular mobile radio communication systems using digital modulation of radio signals transmitted have now come in commercial wide scale use. One type of mobile radio communication system used in USA is specified in the document EIA/TIA, Cellular System, Dual-Mode Mobile station - Base Station Compatibility Standard, IS-54, published by ELECTRONIC INDUSTRIES ASSOCIATION, Engineering Department, 2001 Eye Street, N.W. Washington, D.C. 20006, USA. This system has both FDMA radio channels for radio signals with analog modulation and TDMA radio channels for radio signals with digital modulation. For an exhaustive information on this system reference is given to the mentioned publication the subject matter of which is incorporated herein as a reference.

The pan European digital cellular system abbreviated GSM is a type of digital mobile radio communication systems in use in Europe. This system is specified in the document Recommendation GSM from ETSI/TC GSM, published by European Telecommunication Standardization Institute, ETSI B.P. 152-F-06561 Valbonne Cedex, France. For an exhaustive information on this system reference is given to the mentioned publication the subject matter of which is incorporated herein as a reference.

Both the system according to TIA IS-54 and the GSM system are TDMA systems with many radio channels disposing separate frequency bands. In a TDMA mobile radio system one obvious way of using the radio channels allotted to a cell would be to use one and the same time slot of one and the same radio channel allotted to the cell for a particular connection as long as possible, i.e. until termination or handoff of connection . This is also done according to the mentioned EIA/TIA IS-54 standard.

In a conventional TDMA system where the same radio channel and time slot is used throghout a connection any co-channel interference will last as long as the time both the connections last because the transmissions occur more or less simultaneously on the same radio channel. This means a worst case situation must be considered in frequency planning and cell cluster design. Frequency hopping has been suggested to circumvent this.

According to one optional embodiment of the GSM system, time slots on plural of the radio channels alotted to the cell are used for one and the same connection. Any base and mobile transmits a sequence of radio signal bursts. Each burst is confined to a time slot, but the bursts are distributed on a plurality of radio channels. This affords advantages also as far as multipath propagation is concerned.

Embodiments of a GSM system with frequency hopping are discussed in the article "High performance cellular planning with Frequency Hopping", by Didier Verhulst and Colin Rudolph, published in Proceedings DMR IV, 26-28 June 1990, Oslo, Norway, the subject matter of which is incorporated herein as a reference. According to the article, frequency hopping affords advantages such as smaller optimum cluster size and more flexible frequency planning. The maximum connection handling capacity becomes interference limited and implementation of discontinous transmission affords increased maximum capacity with even smallest cluster sizes. The smallest cluster size investigated is 7-cell but the article also mentines that "plain 3 cell cluster can in fact also be envisaged".

Another type of digital mobile radio communication systems somewhat different from the above described systems using time division multiple access radio channels is the broadband code divison multiple access type systems, abbreviated CDMA. In normal broadband CDMA systems all the radio signal transmissions relating to different connections involving the mobile stations are not separated in time slots or in different narrow band radio channels. Also in a normal broadband CDMA system there is no fixed frequency plan. Instead the base and mobile stations both in the same cell and in surrounding cells deliberately transmit radio signals relating all connections simultaneously on the same wideband radio channel. As a consequence the co-channel interference in a CDMA system will be very high in relation to such interference in previously described TDMA systems. More precisely the interference level in CDMA systems will normally be several times as high as the level of the desired radio signal relating to the connection.

The reason why a CDMA system can cope with this high level of co-channel interference is the wide bandwidth of each radio channel used. The wideband radio channel in CDMA will normally have a bandwidth equivalent to several of the narrow bandwidth radio channels used in TDMA or FDMA systems. The wide bandwidth allows for a high degree of channel coding. Such coding makes it possible for the mobile and base station receivers to recognize the desired signal from all other signals even though the interference level exceeds the level of the desired signal. A feature of the CDMA systems is that the number of connections permitted within a frequency band is not limited by the number of time slots/radio channels. Instead the call handling capacity is limited by the maximum level of co-channel interference still permitting the mobile and base station receivers to detect their desired signals.

In a CDMA system, power control and discontinous transmission reduces the average total power of interfering signals. Thus, discontinous transmission means reduced co-channel interference and increased capacity in a CDMA system, since the capacity generally depends on the average interference level. This is an advantage CDMA systems share with some frequency hopping TDMA systems in relation to prior art TDMA systems without frequency hopping.

Some different types of mobile radio systems similar to CDMA are discussed in the article "Slow Frequency Hopping Multiple Access for Digital Cellular Radiotelephone", by Didier Verhulst, Michel Mouly and Jacques Szpirglas, published in IEEE JOURNAL ON SELECTED AREAS IN COMMUNICATIONS VOL SAC-2, NO 4, JULY 1984, pages 563-574, the subject matter of which is incorporated herein as a reference. Various types of systems with somewhat different frequency hopping protocols, implementation of discontinous transmission and power control are mentioned. One system protocol called "random SFHMA" does not have reuse cluster and each user has his own personal sequence that is uncorrelated with the sequences of the others. However, co-channel interference from mobiles in same cell is not avoided. According to the slow frequency hopping scheme, abbreviated SFH, the mobile stations do not transmit separated radio signal bursts in time slots of frames on TDMA radio channels but transmits more "continously" without burst separations of a length corresponding to time slots. The hopping pattern for transmission from mobile stations is part of the channel coding used to suppress the co-channel interference.

A slow frequency hopping scheme mentioned to be convertible for use in combination with TDMA is discussed in the article

"Cellular Efficiency with Slow Frequency Hopping, Analysis of the Digital SFH 900 Mobile System" by Jean-Louis Dornstetter and Didier Verhulst, published in IEEE JOURNAL ON SELECTED AREAS IN COMMUNICATYTIONS VOL SAC-5, NO 5, JUNE 1987, pages 835-848, the subject matter of which is incorporated herein as a reference. When analyzing possible performance of this system, discontinous transmission and power control are assumed to be implemented. In this article the minimum cluster size mentioned is the 3-cell cluster.

A method and apparatus for frequency hopping in a cellular radiotelephone system is disclosed in PCT patent application WO 91/13502. The object is to increase the number of available carriers to hop between in each coverage area. Instead of permanently allocating to each coverage area (cell) within a reuse diameter (cluster) a fraction of the carriers available within the reuse diameter, all or almost all of the carriers are allocated to each coverage area at non-coinciding time intervals. The hopping is performed in at least rough time-synchronism from sector to sector and from cluster to cluster to avoid same channel interference and adjacent channel interference within reuse diameter. The method relies fundamentally upon sharing a carrier among various coverage areas synchronously in time but does not require a slotted TDMA channel structure. Thus the cells within a cluster are allowed to share available frequencies while still maintaining a re-use pattern. The re-use pattern is maintained on a frame basis, i.e. the hopping may be viewed as using a new frequency plan for each frame. This method has the drawback of requiring synchronized base stations, in particular within each cell cluster, but also to some extent between adjacent clusters. Another disadvantage is that no cell can simultaneously serve a number of mobiles corresponding to the total number of radio channels available to the cluster. Any call can only serve a number of mobiles corresponding to the number of radio channels simultaneously available to that cell, which is only a fraction of the total number.

BRIEF DESCRIPTION OF THE INVENTION

Although the new TDMA systems with frequency hopping and CDMA mobile radio communication systems affords substantial advantages over prior FDMA and TDMA systems without frequency hopping there is a need for even more efficient use of the frequency bands available for connections in the mobile radio systems in order to increase the total connection handling capacity. There is also a need for an even more flexible use of the available frequency bands in order to increase the systems ability to handle a varying number of desired connections in varying parts of the area covered by the systems.

Although prior suggested mobile radio systems may use some kind of frequency hopping in combination with some embodiments of various methods like discontinous transmission and transmission power control, they have not incorporated embodiments of frequency hopping and other methods, the basic principles of which are known per see, in way affording the maximum capacity for handling connections in an individual cell and simultaneously the maximum flexibility in sharing the connections to be handled between adjacent cells.

It is one object of the present invention to provide methods and means providing a very high maximum number of simultaneous connections any cell in a TDMA mobile radio system can handle without increasing the total frequency band(s) available for all connections in the TDMA mobile radio system.

Another object of the present invention is to provide methods and means providing a very flexible sharing of total numbers of connections handled by adjacent cells in a cellular TDMA mobile radio system.

A similar object of the present invention is to make the maximum number of simultaneous connections each cell in a TDMA system can handle substantially dependent upon the number of connections simultaneously handled by adjacent cells, whereby one cell can conveniently undertake to handle substantially more simultaneous connections than the maximum average for a cell if all cells handled the same number, provided some adjacent cells simultaneously handle less simultaneous connections than the maximum average when all cells handle the same number.

Yet another object of the present invention is to reduce if not completely avoid the need for any type of planned sharing of radio channels.

Still another object of the present invention is to provide methods and means whereby the absence of any conventional frequency plan in a cellular TDMA mobile radio system need not cause too severe co-channel interference problems.

In brief and simplified, one might say that methods and means for communication in accordance with the present invention are based on the inventive insight that a TDMA system with frequency hopping, using frequency hopping sequences or schemes avoiding co-channel interference within a cell, but allowing co-channel interference between adjacent cells, avoids the need for frequency planning and affords a very great capacity and flexibility, in particular when discontinous transmission and certain transmission power control is implemented. In fact power control of mobile stations is necessary when a method according to the invention is implemented in a system requiring high capacity and flexibility.

An important element of methods and means according to the present invention is frequency hopping, which may also be described as frequent change of the radio channel used for a connection, which in the following often will be called channel hopping. A base or mobile station involved in a connection does not all the time transmit its radio signal bursts relating to a particular connection in the same time slot of the same radio channel. Instead the bursts of radio signals relating to a particular connection are distributed on the time slots of a plurality of radio channels in accordanve with particular hopping schemes or sequences. According to the invention, mobile stations in the same cell or served by the same base station never simultaneously transmit radio signals in the same time slot of the same radio channel. However a mobile station in one cell of a cellular TDMA mobile radio system may transmit one of its bursts on the same radio channel simultaneously with one of the bursts of a mobile station in an adjacent cell of the same system. However, no mobile involved in a connection in one cell transmits a sequence of bursts relating to a particular connection so that all of them coincide on a radio channel with one burst in a sequence of bursts from one other mobile involved in an other connection in an adjacent cell. Another way of expressing almost the same aspect would be to say that among a large number of bursts transmitted from one mobile station in one cell not more than a small minority coincide on any radio channel with any burst among a large number of bursts transmitted from a different mobile station in an adjacent cell. Still another way of expressing almost the same thing would be to say that a mobile station in one cell selects radio channels and time slots for transmission independently of a mobile station in an adjacent cell. One might also say the channels on which mobile stations transmits in one cell is uncorrelated to the radio channels on which mobile stations transmit in an adjacent cell. Thus coincidence on any radio channel for bursts transmitted from two particular mobiles in adjacent cells involved in connections is infrequent and incidental. However, when there are many mobiles involved in connections in two adjacent cells, coincidence of bursts transmitted from one particular mobile station in one of the cells on any radio channel with any burst transmitted by any mobile in the adjacent cell is more frequent.

According to another aspect of the present invention two or more adjacent cells of a cellular TDMA system may all use some radio channels, and a majority, if not all, of the radio channels any of two adjacent cells may use, the adjacent cell may also use.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 illustrates a cellular mobile telephone system.

Figure 2A to 2E illustrates two frequency bands available for a cellular mobile radio system, a configuration of radio channels within the frequency bands and time formats on radio channels.

Figure 3A to 3E illustrates various clusters of cells associated with frequency plans.

Figure 4A and 4B illustrates one basic difference between conventional communication in a TDMA system and communication in a TDMA-FH system with channel hopping.

Figure 5A and 5B illustrate TDMA-FH in two cells and the co channel interference situation in TDMA-FH.

Figure 6 shows why the commonly used "worst case" design of cluster sizes may be omitted when using TDMA-FH.

Figure 7 shows fractional loading of a cell.

Figure 8 shows a block diagram of a mobile station to be used for communication in a prior art TDMA system or a TDMA-FH system according to the invention.

Figure 9 shows a block diagram of a base station to be used for communication in a prior art TDMA system or a TDMA-FH system according to the invention.

Figure 10 illustrates a comparison of degrading quality in a CDMA system and a comparable TDMA-FH system according to the invention.

Figures 11 and 12 illustrates the ability of comparable CDMA and TDMA-FH systems to increase the capacity of certain cells if the capacity is reduced in other cells.

DETAILED DESCRIPTION OF THE DRAWINGS

Figure 1 illustrates ten cells C1 to C10 in a cellular TDMA mobile radio system. For each cell C1 to C10 there is a corresponding base station,abbreviated BS, denoted B1 to B10. The BSs are situated in the centre of the cells and having omnidirectional antennas. Ten mobile stations, abbreviated MSs, are also shown. They may be small light-weight battery powered portable stations or more bulky, vehicle installed stations, powered by the vehicles electric power system. The BSs are moveable within a cell and from one cell to another. A mobile switching centre, abbreciated MSC, is connected to all the BSs by cables or any other fixed means, like a radio link. Some of these cables or means are omitted in the figure for simplicity. The MSC is also connected by cables or links to a fixed public telephone network or a similar fixed communication network.

During operation the mobile stations will be in contact with the fixed part of the system by transmission of radio signals to and reception of radio signals from the different base stations. Telephone calls, data communication links or other communication paths may be set up between one mobile station and an other mobile station in the system. Calls may also be set up to mobiles in an other system or subscribers in the fixed network. For the purpose of this application they are all called connections irrespective if they originate in a mobile or end in a mobile.

The drawing in figure 1 is a simplification. Normally the system will comprise more cells and base stations. There may be umbrella cells each covering an area also covered by a group of micro cells. Also the number of mobile stations will normally be much larger. Base stations located in the vicinity of the cell borders and with sector antennas are also common. Some cell may be served by more than one base station. Several other MSCs with connected base stations will also normally exist and the mobile stations are usually free to communicate also via these.

Figure 2A illustrates two separate frequency bands available for a cellular mobile radio system. A possible configuration according to IS-54 of radio channels within the frequency bands is also shown.

One frequency band has a range from about 825 MHz to about 845 MHz and contain radio channels used for transmission of radio signals from the mobile stations to the base stations. The other frequency band has a range from about 870 MHz to about 890 MHz and contains radio channels used for transmission of radio signals from the base stations to the mobile stations. Each radio channel has a banwidth of about 30 kHz which means there is room for 666 radio channels in each direction of transmission.

The radio channels may be used in three different ways. As analog traffic channels or as digital traffic channels or as analog control channels. The analog control channels are used for signalling during call setup, for notifying the MS on an incoming call (paging) and for monitoring the status of the MS while not communicating on any traffic channel. The MS will be tuned to an analog control channel as long as it is not involved in a call or other connection over an analog or digital traffic channel. The analog control channels are located at the centre of the frequency bands. Thus the analog control channels from mobile to base stations are the ones located closest to 835 MHz while the control channels for transmission from base to mobile are the ones located closest to 880 MHz.

The analog traffic channels are used for telephone calls and other analog connections involving a mobile station. In addition to speech relating to one call, the radio signals transmitted on an analog traffic channel may carry some signalling associated with the call. A normal telephone call or other bidirectional connection involving a mobile station, requires both transmission from the base station and transmission from the mobile station. Thus for a normal telephone call one analog traffic channel in each direction is required.

The radio channels used for digital traffic channels are divided in time slots. A frame on such a radio channel may comprise three full rate time slots, Tf1 - Tf3, as illustrated in figure 2B, or six half rate time slots Th1 - Th6, as is illustrated in figure 2C. A normal telephone call, or other full rate connection, requires one full rate time slot Tf per frame for transmission from base to mobile and one full rate time slot Tf per frame for transmission from mobile to base station.

The slot format for information on a digital traffic channel is slightly different in different directions. Fig 2D illustrates the format for transmission from mobile station, while figure 2E illustrates the format for transmission from base station. The time slot formats commonly include 260 bits reserved for data transmission, 12 bits for a digital verification voice color code, DVCC, 12 bits for a slow associated control channel, SACCH, and 28 bits for synchronization and training data, SYNC. The slot format from the mobile station to the base station includes two 6 bit blocks for guard time, G, and ramp time, R, information. The slot format from the base station to the mobile station includes a 12 bit block which is reserved for future uses.

A cellular system is based upon reuse of the same radio channel in different cells. In a conventional cellular system, with a fixed frequency plan, all the available radio channels are divided into channel groups, which in turn formes a cluster. To each cell within a particular cluster is alotted a unique group of channels. Thus no two cells in the same cluster are alotted the same channel. However, corresponding cells in different clusters are allotted identical groups of radio channels if a fixed frequency plan is implemented.

Figures 3A to 3E illustrate conventional frequency plans and clusters of cells. Figure 3A illustrates a 3-cell cluster, figure 3B a 4-cell cluster, figure 3C some cells of a cellular system with a 7-cell cluster, figure 3D a 9-cell cluster and figure 3E illustrates a 21 cell cluster. Normally a cellular system comprises many more cells than illustrated in figure 3. Such a system may be arrived at if one of the pattern of cells illustrated in figure 3 is repeated to fill the total geographical coverage-zone of an mobile telephone operator.

As an illustrative example it is assumed that 252 out of the totally 666 radio channels according to figure 2a were awailable for use as digital traffic channels while the rest were used for analog control channels and analog traffic channels. Assuming a fixed frequency plan, each cell would dispose of 84 such radio channels in a 3-cell cluster system, 63 such radio channels in a 4-cell cluster system, 36 such radio channels in a 7-cell cluster system, 28 such radio channels in a 9-cell cluster system and 12 such radio channels in a 21-cell cluster system.

Generally clusters with many cells means the available number of radio channels has to be shared by a large number of cells. Clusters with few cells means the available number of radio channels has to be shared by fewer cells. Thus using clusters with more cells means the average number of radio channels per cells becomes less than when using a cluster with fewer cells. Thus, from this aspect large clusters means less total call handling capacity for the system. From a capacity point of view it would be desirable to have the smallest possible cluster sizes. This is so since this will increase the number of channels per area and thus the system capacity. In prior art TDMA systems small cluster sizes are however not permitted by the high marginals required against co-channel interference from adjacent cells.

Generally, big clusters with many cells of a certain size means a greater distance between base and mobile stations using the same radio channel than small clusters with few cells of the same size. Another way of expressing this would be to say that big clusters have longer re-use distance than smaller clusters. Thus generally clusters with many cells normally means less co-channel interference. Thus from a pure co-channel interference point of view, big clusters are preferred in TDMA systems with fixed frequency plans.

Figure 4A and 4B illustrates one principal difference between a conventional TDMA system and a TDMA-FH system using freqecy hopping. Both systems use six TDMA radio channels, RF1 - RF6, each having three time slots, Tf1 - Tf3, per frame. Four frames are shown on each radio channel. In the conventional system, according to figure 4A, the timeslot Tf1 of each frame of the radio channel RF1, with the highest center frequency, is assigned to the connection C11, the timeslot Tf2 of each frame to connection C12, and the timeslot Tf3 of each frame to connection C13. For the radio channel RF2 the timeslots Tf1 to Tf3 of each frame are assigned to the connections C21 to C23 respectively. The timeslots Tf1 to Tf3 of radio channels RF3 to RF6 are in the conventional system assigned to the connections C31 to C63 respectively. Thus, in the conventional system, any particular of the connections C11 to C63 always disposes the same time slot of the same radio channel until there is a handoff. Assigning of radio channel time slots in a conventional TDMA system could therefore be described as assigning to each connection one combination of a radio channel and a time slot, this combination remaining unchanged until termination or handoff of the connection.

In a TDMA-FH system using channel hopping, according to figure 4B, the timeslot Tf1 of the first frame of radio channel RF1 is assigned to connection C31. However, the timeslot Tf1 of the second frame of radio channel RF1 is assigned to connection C41, the timeslot Tf1 of the third frame of RF1 is assigned to connection C51, and the timeslot Tf1 of the fourth frame of RF1 is assigned to connection C11.

The timeslot Tf2 of the first frame of radio channel RF1 is assigned to connection C42, whereas the timeslot Tf2 of the second frame of radio channel RF1 is assigned to connection C52, the timeslot Tf2 of the third frame is assigned to C32, and the timeslot Tf2 of the fourth frame of RF1 is assigned to C22. The timeslots Tf3 of the first to fourth frames of RF1 are assigned to connections C63, C43, C23 and C33 respectively.

The timeslots Tf1, Tf2 and Tf3 of the first frame of radio channel RF2 are assigned to connections C41, C52 and C13 respectively, whereas the timeslots of the second frame of radio channel RF2 are assigned to connections C21, C12 and C43 respectively. The rest of the assignments are evident and will therefore not be explicitly mentioned.

Comparing the frames of radio channels RF1 to RF6 in figure 4B reveals that the corresponding time slots of succeeding frames of radio channels are assigned differently. All connections are assigned different radio channels in different frames. In the particular example of figure 4B no connection is assigned the same radio channel and timeslot in succeeding frames of the same radio channel. No connection is assigned one combination of a radio channel and a time slot remining unchanged during the time period of plural frames. Instead each connection is assigned a set of four combinations of a frequency and a time slot for use in four succeeding frames. Thus the corresponding time slots, e.g. Tf2, in the four succeding frames of any radio channel, e.g. RF1, are used by different connections in the same cell.

Figure 4B is one of the simplest way of assigning radio channel/time slots in one frame different from an other frame to the connections. In preferred embodiments of the present invention many more radio channels than six are used, whereby any connection for the total time period of plural succeeding radio channel frames, may be assigned different radio channel time slots in a plurality of succeeding frames. Thus each connection could be assigned a scheme including a sequence of a plurality of combinations of radio channels and time slots. In this application such a sequence of combinations of radio channels and time slots is called a channel hopping scheme. It might also be called a frequency hopping scheme or pattern. According to figure 4B a succeding burst pertaining to any connection is always transmitted on a different radio channel than the preceeding burst pertaining to the same connection. This is not a necessary in all embodiments of the invention. Instead two adjacent burst pertaining to the same connection may be transmitted in the same time slot of adjacent frames on the same radio channel. In cellular bidirectional mobile radio communication systems radio channel hopping should preferably be implemented in both directions. If figure 4B illustrates the radio channel time slot combinations used for one direction of communication, e.g. from mobile to base station, then the pattern of radio channel time slot combinations used for the other direction could be the same as figure 4B but using other radio channels of course. However, for certain reasons it might be preferred not to transmit radio signals and simultaneously receive radio signals at a mobile station. Then a different pattern than that of figure 4B should be used for the other direction of communication.

In a conventional TDMA system without frequency hopping, the radio signal bursts pertaining to connections of one cell may be interfered by the radio signal bursts pertaining to connections of a cell at reuse distance. Due to the fact that succeeding bursts pertaining to a connection are transmitted on the same time slot of the same radio channel, the bursts of one connection in one cell will be interfered by the bursts of one connection in the other cell.

Figure 5A and 5B illustrate a co-channel interference situation when using different channel hopping schemes in two cells of a cellular TDMA mobile radio communication system.

Figure 5A illustrates how the bursts pertaining to 18 connections C11, C12, C13, C21, C22, C23, C31, C32, C33, C41, C42, C43, C51, C52, C53, C61, C62 and C63 are transmitted in time slots of six radio channels RF1, RF2, RF3, RF4, RF5 and RF6 during a time period of four frames in a first cell. All time slots of all frames of all radio channels are used in the first cell.

Figure 5B illustrates how the bursts pertaining to 18 connections C11, C12, C13, C21, C22, C23, C31, C32, C33, C41, C42, C43, C51, C52, C53, C61, C62 and C63 are transmitted in the time slots of the same six radio channels RF1, RF2, RF3, RF4, RF5 and RF6 during the same period of four frames in a second cell. All time slots of all frames of all radio channels are used in the second cell. Thus during a frame the same six radio channels are used by both cells. All the six radio channels are common to both cells.

Comparing figures 5A and 5B reveals that the first burst pertaining to connection C11 in the first cell coincides on the radio channel RF5 with the first burst of connection C41 in the second cell, the second burst of C11 coincides on radio channel RF6 with the second burst of connection C51, the third burst of connection C11 coincides with the third burst of connection connection C21 on radio channel RF2, and the fourth burst of connection C11 coincides with the fourth burst of connection C31 on radio channel RF1. The first burst pertaining to connection

C11 in the second cell coincides on the radio channel RF3 with the first burst of connection C21 in the first cell, the second burst of C11 coincides on radio channel RF4 with the second burst of connection C61, the third burst of connection C11 coincides with the third burst of connection connection C51 on radio channel RF1, and the fourth burst of connection C11 coincides with the fourth burst of connection C51 on radio channel RF2.

Generally the bursts pertaining to one connection in one cell do not always interfere with the bursts pertaining to one and the same connection in the other cell as may be the situation in conventional TDMA. Instead the bursts of a connection are interfered by bursts from connections which may vary from frame to frame. According to figure 5 no time slots are unused. However, if there were only a few connections in each of the first and second cells, so that no bursts were tranmitted in many time slots, some bursts would not be interfered at all.

The co-channel interference situation in figures 5A and 5B is a simplification. Normally the number of cells re-using the same radio channels will be many. Some of them vill be closer and some be located at longer distances. Unsynchronized base stations are also possible. In figure 5 synchronization is provided for simplicity of the drawing. The number of radio channels used by each base station would normally be more than six. In a bidirectional communication system, e.g. a cellular mobile radio system, radio channel time slot hopping schemes according to figures 5A and 5B could be used for one direction of communication, e.g. from mobile stations to base stations, and similar or different hopping schemes used for the other direction of communication, i.e. from base to mobile stations.

Figure 6 illustrates estimated co-channel interference in TDMA systems and the reason why TDMA-FH according to the present invention enables a change from "worst case" design of cluster sizes in conventional TDMA, to a design based on the statistical average of the co-channel interference from several connections.

The solid curve in the figure illustrates possible co-channel interference for six radio signal bursts, B1 to B6, transmitted in certain time slots of certain radio channels.

As is illustrated in figure 6, different bursts are subject to different co-channel interference. The first burst B1 experiences the lowest interference of all six bursts. The second burst B2 is subjected to the highest interference, the level of which is indicated in figure 6 by an upper, "worst case" level, dashed line. The co-channel interference for the bursts B3 and B5 is about the same and slightly higher than that of B1. The co-channel interference for B4 and B6 is almost equal and higher than that of B3 an B5. The average of the individual interferences for the individual bursts is indicated with a lower, "average", dashed line in figure 6.

In a conventional TDMA system, without frequency hopping, the bursts pertaining to a particular connection are transmitted in the same timeslot of the same radio channel, at least until handoff. Thus, in figure 6, the bursts B1 to B6 would pertain to different connections. Although succeeding bursts in the same time slot of a radio channel may experience somewhat different co-channel interference e.g. due to mobile station movements, the change in co-channel interference from one burst to the succeeding burst, pertaining to the same connection, is normally small. Thus, for a conventional TDMA system, without frequency hopping, figure 6 may somewhat simplified also illustrate the co-channel interference situation for six different connections. In a conventional TDMA system without frequency hopping the expected "worst case" level is a design criteria when deciding the number of frequency groups in the frequency plan for the system. I.e the system is designed as if all timeslots and radio channels should suffer from the maximum interference level, which in reality is very unlikely to occure.

In TDMA-FH according to the invention the situation is different because the radio signal bursts of a connection are not transmitted on only one and the same channel but on different radio channels. The bursts pertaining to a particular connection will therefore normally be subjected to different amounts of co-channel interference, some of them to more and others to less than average co-channel interference. Thus for a TDMA-FH system according to the invention the bursts B1 to B6 illustrated in figure 6 may pertain to the same connection. Although a burst, e.g. like B2 in figure 6, may be subjected to substantially stronger interference than the average the probability that the proceeding burst, B1 in figure 6 and succeeding burst, B3 in figure 6, will also be subjected to co-channel interference substantially stronger than average, is very small. Thus, although the information in one burst might not be possible to understand all by itself, the information in the preceeding and/or succeeding burst very often can be understood, whereby the total quality for the connection might not be too severely degraded.

Error protective coding of information to be transmitted in bursts and interleaving of information in bursts are advantageous and might be very important in combination with TDMA-FH according to the invention. If e.g. information is interleaved on two bursts, one of which is subjected to very strong interference and the other subjeted to none or very little interference, after the de-interleaving process only half of the bits will be erased. With efficient error correcting coding it might be possible to correct these erased bits and recover the information transmitted in the burst subjected to severe interference. Interleaving over more than two bursts increases the likelihood of recovering information transmitted in a severely interfered radio signal burst.

The channel hopping according to the invention, together with interleaving and error correcting coding, performes interference averaging. Thus, the minimum cluster size is now constrained by a statistical average of the interference level instead of the "worst case". The statistical average interference level is depicted as the lower dashed line. As seen, the average interference level is expected to be much lower than the "worst case".

According to the present invention, frequency planning clusters may be totally avoided.

The interference averaging is not automatically obtained by using any kind of channel hopping. If the channel hopping within cells arranged in a cluster is synchronized, e.g. according to PCT patent application WO/9113502, interference averaging is not obtained unless additional steps are taken. The reason is that such synchronized hopping in a cluster of cells causes any two interfering mobiles to hop from one channel to the other channel simultaneously. Thus two mobiles interfering on one channel prior to the channel hop will hop in the same way and therefore interfere also after the channel hop.

Figure 7 shows the principles of an embodiment of the invention that both eliminates stiffness in connection handling capacity and removes the need for frequency clustering. This embodiment might be called fractionally loaded cells or base stations. This imply that the maximum number of simultaneous connections per cell when all cells serve the same number of connections is substantially less than the total number of time slots on all radio channels availiable for connections at a cell. Fractional loading could also be expressed as limiting the average number of simultaneous connections per cell to be substantially less than the average number of time slots on all radio channels available at a cell.

The figure depicts a subset of ten radio channels Rf1 to Rf10 at base stations in neighbour cells. Each radio channel is divided in frames of three timeslots. The figure shows a fractional load of 60% on the base stations. Thus, the number of simultaneous connections are only 60% of the total number of time slots on all radio channels available for connections. This can easily be concluded, since four out of the ten radio channels are un-used in every timeslot. Note however that a burst of a connection may be transmitted in a timeslot on any of the availiable radio channels. Comparing the radio channel time slots used by the two base stations reveals that some of the bursts of a connection may be interfered, while other bursts of the same connection are not interfered. During a frame some time slots of some radio channels are used by both cells, some time slots of some radio channels are used by one cell only, and some time slots of some radio channels are not used by any cell. Higher or lower fractions than 60% are theoretically possible but in practice normally much lower fractions are preferred, e.g. 20%.

Fractional loading may be implemented in the following way. The signal to interference ratio for signals received from certain mobile stations is estimated. The estimated signal to interference ratio for the signals received from mobile stations are compared with a desired signal to interference ratio. When another connection set up in a cell or handoff of a connection to a cell is desirable, a check is done to find out whether there is available in the cell another possible mobile channel hopping scheme free from coincidence on every radio channel with every other of the mobile channel hopping schemes already in use in the cell. If there is a possible mobile hopping scheme free from coincidence, the desired connection is established by set up or handoff using the possible mobile channel hopping scheme in the cell only if the estimated signal to interference ratio for signals received from certain mobile stations involved in connections equals or exceeds the desired ratio. Said certain mobile stations would normally include all mobile stations involved in connections in the cell where the desired connection is established. Decisions whether to set up or handoff a connection or not in the cell may then be taken by a base station for the cell or by a mobile switching centre. According to a preferred embodiment said certain mobile stations also include all mobile stations involved in a connection in a second cell adjacent to the cell where the desired connection is established or in any cell adjacent to the cell where the desired connection is established. Decisions whether to set up or handoff a desired connection or not in any of the adjacent cells may the be taken by a base station controller for the base stations of the adjacent cells or by a mobile switching centre.

In combination with channel hopping, interleaving and error protective coding it is seen that the fractional loading of base station or cells is a means for controlling the co-channel interference. Thus, by forcing the load at each base station to be lowered, the C/I-constraint may be controlled, allowing unity cluster size, i.e. the total frequency band is reused at all base stations. In this way the cumbersome frequency planning commonly required in TDMA systems may be omitted.

Figure 8 and 9 are block diagrams of embodiments of a mobile station and a base station for communication on TDMA radio channels in a cellular mobile radio system. The base and mobile stations are designed for a system according to EIA/TIA IS-54 standards but also for transmission according to the invention in a TDMA system without analog traffic channels. Since communication on analog control channels may be done substantially according to standard and the invention relates to hopping between digital traffic channels the part of the base and mobile stations used only for analog control channels and analog traffic channels according to EIA/TIA IS-54 are not illustrated.

Normally, a base station is designed for serving many mobiles, i.e. updating/monitoring and handling connections involving many mobile stations. However, in order to make a more eligible drawing, figure 9 only illustrates parts of a base station for handling three simultaneous comnnections in different time slots. Thus the base station has only three channel controllers 1, 2, and 3, each of which handles one of three connections. Furthermore the base station has only one RF modulator and power amplifier receiving bursts from the channel controllers. Normally a base station would have may RF modulators and power amplifiers, each modulator receiving bursts from up to as many channel controllers as there are time slots in a frame.

In the figures, the blocks of one base station controller corresponding to similar mobile station blocks are assigned the same reference number, but with an apostrof '. A very brief description of purpose or operation of each block according to

EIA/TIA IS-54 will be given first. Corresponding blocks are assumed having similar purpose and operation unless othervise mentioned.

A SPEECH CODER 101 in the mobile station converts the analog signal generated by microphone subjected to the human voice, or data received from a not illustrated data source into a bit data stream, divided into data packages, according to the TDMA principle. The SPEECH/DATA CODER 101' in the base station converts incoming digital information into data packages of the same type as the SPEECH CODER 101 in the mobile station.

According to the EIS/TIA IS-54 standards there is a fast associated control channel, FACC, and a slow associated control channel, SACC. The FACC generator 102' in the base station is used during the signaling of control and supervision messages to the mobile station. When preparing a handoff the base station may transmit on FACCH radio channel time slot hopping information, e.g. similar to GSM or the identity of a hopping scheme, to be used by the mobile station for its connection after handoff. The FACC generator 102 in the mobile is used by the mobile during the signaling of control and supervision messages. A FACCH message transmitted by a base or mobile in a timeslot of a frame replaces the speech or data from that base or mobile in that frame.

The SACCH is a "continous control channel" in the meaning that a fixed number (12) of bits is reserved for the SACC in each burst relating to a connection. The SACCH GENERATOR 103' in the base station, is used by the base when exchanging signaling messages with the mobile. Before a handoff the base may transmit on the SACCH hopping information of a kind described later, e.g. according to GSM or the identity of a radio channel and time slot hopping scheme, to be used by the mobile for the connection after handoff. SACCH GENERATOR 103 in mobile station is used by the mobile when exchanging signaling messages with the base.

There is a CHANNEL CODER 104 and 104' connected to each of blocks 101, 101' etc to 103'. A CHANNEL CODER manipulates the incoming data in order to make error detection and correction possible. The mechanisms used are convolutional encoding for protecting important databits in the speech code, and cyclic redundancy check, CRC, where the perceptually significant bits in the speech coder frame, e.g.12 bits, are used for computing a 7-bit check.

A SELECTOR 105 is connected to the CHANNEL DECODER 104 associated with the SPEECH CODER and FACCH GENERATOR. The SELECTOR is controlled by the MICROPROCESSOR CONTROLLER 130 so that, at appropriate times, user information over a particular connection is replaced with messages over FACCH.

The 2 BURST INTERLEAVER 106 interleaves data either from the speech coder 101 or from the FACCH generator 102 over two time slots. The 260 data bits, which constitute one transmitting word, are divided into two equal parts and allotted two consecutive time slots. The effects of Rayleigh fading will be reduced in this way.

The output of the 2 BURST INTERLEAVER is connected to the input of a MOD 2 ADDER 107 so that transmitted data is ciphered, bit by bit, by logical modulo-two-addition of a pseudo-random bit-stream.

Data transmitted over SACCH is interleaved by the INTERLIEVER 22 BURST 106 over 22 time slots, each consisting of 12 bits of information . Two SACCH messages are interleaved in parallel i.e. the second message is delayed 11 bursts compared to the first, according to the diagonal principle.

SYNC WORD DVCC 109 is a store for sync words and digital verification colour codes, DVCC. A 28 bit synchronization word is used for time slot synchronization and identification and also for equalizer training. Different slot identifiers are defined, one for each time slot and another three are reserved for future development. The DVCC is a 8-bit code which is sent by the base to the mobile and vice-versa. The DVCC is used for assuring that the right radio channel is decoded.

Depending on the state of operation, two kinds of bursts are generated by the base station BURST GENERATOR 110'. The voice/traffic channel burst is configured by integrating 260 bits DATA, 12 bits SACCH, 28 bits SYNC, 12 bits Coded DVCC and 12 delimiter bits according to the time slot format specified by EIA/TIA IS-54. In a control channel burst, DATA and SACCH is replaced with data generated by the CONTROL CHANNEL MESSAGE GENERATOR 132'. The transmission of a burst in a time slot of a radio channel is synchronized with the transmission of bursts in the other two time slots, if any.

Depending on the state of operation two kinds of bursts are generated by the mobile station BURST GENERATOR 110. The voice/traffic channel burst is configured by integrating 260 bits DATA, 12 bits SACCH, 28 bits SYNC, 12 bits Coded DVCC and 12 delimiter bits according to the time slot format specified by EIA/TIA IS-54.

Three full rate time slots make up one frame. The 20 mS FRAME COUNTER 111 updates the ciphering code every 20 ms, i.e. once for every transmitted frame. A pseudo random algorithm is used for ciphering. The CIPHERING 112 is controlled by a key unique for each subscriber. KEY 113 comprises a sequencer, updating the ciphering code.

In order to cope with multipath propagation etc., causing time dispersion, an adaptive equalization method is provided by the EQUALIZER 114' in the base station, to improve signal quality. Synchronization with the BURST GENERATOR 110' is provided in order to find the time slot associated with the right received channel. A correlation in the equalizer adjusts to the timing of the received bit stream. Syncword and DVCC are checked for identification reasons.

The mobile station also has an EQUALIZER 114, providing an adaptive equalization method to improve signal quality. A correlation in the equalizer adjusts to the timing of the received bit stream. The base station is the master and the mobile station is the slave regarding frame timing. The mobile station equalizer finds the incoming timing and synchronizes the burst generator. Syncword and DVCC are checked for identification reasons.

The RF MODULATOR 122 modulates the carrier frequency from the TRANSMITTING FREQUENCY SYNTHESIZER 124 according to the pi/4-D-QPSK method (pi/4 shifted, Differentially encoded Quadrature Phase Shift Keying). This technique implies that information is differentially encoded, i.e. 2 bit symbols are transmitted as four possible changes in phase; +/- pi/4 and +/- 3pi/4.

The POWER AMPLIFIER 123 amplifies the signals from the RF MODULATOR 122. The RF power emission level is selected on command by the MICRO PROCESSOR CONTROLLER 130.

The TRANSMITTING FREQUENCY SYNTHESIZER 124' in the base station generates the transmitter carrier frequency in accordance with commands from the µPC 130'. When radio channel hopping is implemented, the micro processor µPC 130' calculates or reads which radio channel to be used for each burst in accordance with hopping information stored in a microprocessor store and the hopping information transmitted to the mobile station intended to receive the burst. The micro processor µPC 130' then sends timed instructions the TRANSMITTER SYNTHESIZER to generate a sequence of carrier frequencies in accordance with the frequency hopping sequence or scheme to be used.

The TRANSMITTING FREQUENCY SYNTHESIZER 124 in the mobile station generates the transmitter carrier frequency in accordance with commands from the the µPC 130. When radio channel hopping is implemented the µPC 130 reads or calculates a sequence of radio channels to be used in accordance with the selected radio channel time slot hopping information recived from the base station on either the control channel during call setup or on one of the associated control channels during a handoff. The µPC 130 sends timed commands regarding the desired radio channel to the SYNTHESIZER.

The RECEIVING FREQUENCY SYNTHESIZER 125' in the base station generates the receiver carrier frequency in accordance with commands from the micro processor μPC 130'. The microprocessor determines which receiver carrier to be used for which time slot in accordance with hopping information stored in a microprocessor store, e.g. according to a radio channel time slot hopping scheme, and sends timed instructions to the SYNTHESIZER 125'.

In the mobile station the RECEIVING FREQUENCY SYNTHEZISER 125 generates the receiver carrier frequency in accordance with the instructions from the micro processor μ130. The appropriate radio channel being read or calculated by μ130 in accordance with a radio channel time slot hopping scheme or other kind of hopping information received from the base station on either the control channel during call setup or on one of the associated control-channels during a handoff.

Radio signals from antennas are received by a RECEIVER 126 in the mobile station and a separate RECEIVER 126' for each antenna in the base station. The radio frequency carrier from a RECEIVER is demodulated in a RF DEMODULATOR 127 or 127', generating an intermediate frequency. In the IF DEMODULATOR 128 the intermediate frequency signal is demodulated, restoring the original pi/4-DQP-SK-modulated digital information. The received signal strength is measured by the SIGNAL LEVEL METER 129 and the value is sent to the micro processor controller 130.

The SYMBOL DETECTOR 115 converts the received 2-bit symbol format from the EQUALIZER 114 to a single bit data stream. The DEINTER-LEAVER 2 BURST 116 reconstructs the speech/FACCH data from the MOD 2 ADDER 107 by assembling and rearranging information from two consecutive frames. SACCH data, which is spread over 22 consecutive frames, is reassembled and rearranged by the DEINTERLEAVER 22 BURST 117.

The convolutionally encoded data from a DEINTERLEAVER is decoded by CHANNEL DECODER 118 using the reversed principle of coding. The received cyclic redundancy check, CRC, bits are checked to determine if any error has occured. The CHANNEL DECODER 118 for the FACCH furthermore detects the distinction between speech channel and FACCH information and directs the decoders accordingly.

The SPEECH DECODER 119 processes the received data in accordance with the speech coder algorithm, VSELP, and generates the received speech signal. The analog signal is finally enhanced by filtering technique. The FACCH DETECTOR 120 detects messages on the fast associated control channel and transfers the information to the MICRO PROCESSOR CONTROLLER 130. During a handoff, the MS may receive the identity of the hopping patterns to be used in the next connection on this channel.

Messages on the Slow Associated Control Channel are detected by the SACCH DETECTOR 121 and the information is transferred to the MICRO PROCESSOR CONTROLLER 130. During a handoff the mobile station may on this channel receive the identity of the shifting schemes to be used in the next connection.

The radio base station activity and the mobile station communication is controlled by the MICRO PROCESSOR CONTROLLER 130' in the base station. Decisions are made in accordance with received messages and measurements made. When hopping is implemented a sequence of combinations of a radio channel and a time slot channel shifting schemes are determined for each of the transmission directions for each mobile station served and involved in a connection.

The mobile station activity and the base station communication is controlled by the mobile station MICRO PROCESSOR CONTROLLER 130, which also handles the terminal KEYBOARD DISPLAY 131 input and output. Decisions are made in accordance with received messages and measurements made. For each timeslot, the transmitter and receiver radio channels will be determined according to the hopping information received and information stored in a microprocessor store. The mobile station KEYBOARD DISPLAY 131 performs the information exchange between the user and the base station.

CONTROL CHANNEL MESSAGE GENERATOR 132 generates control channel messages according to orders received from the micro processor controller 130. The CONTROL CHANNEL MESSAGE DETECTOR 133 detects received control channel messages and send them to the MICRO PROCESSOR CONTROLLER 130.

The TIME SWITCH 34 in the mobile station connects either the transmitter or the receiver to the MS antenna. The timing is synchronized to the receiving and transmitting sequence by the MICRO PROCESSOR CONTROLLER 130.

A tight power control algorithm may be used to reduce the transmitter power on the radio channels in the connections with mobiles located close to the base station. In this way the interference from these connections to other connections will also be reduced, which in turn will give increased capacity. From a pure capacity point of view, the best thing would be to reduce the transmitter power levels to a minimum. However, the reduction in the transmit power level should be a compromize between the reduced signal quality and the resulting increase in capacity.

The base station can decide if a moible shall lower its power by measuring the quality of the received signals relating to the connection with the mobile. Such quality measurements can be measures of the signal strength, C/I and bit error rate. The measurements made, may be translated into a power control command in several different ways. One example could be to compare one of the quality measurements to a desired value and command an decrease in the mobile transmit power if the measured value is above the desired value. If the measured value is below the desired value a command to increase the mobile transmit power may be transmitted. The power control command may be transmitted on either the SACCH channel or the FACCH channel.

The quality measurements of the signals transmitted from the base must be based on measurements in the mobile. Several methods exist for utilizing these measurements for base station power control. One example is that the mobile transmit all measurements directly, on either SACCH or FACCH, to the base station, which in turn evaluate the measurements and adjusts its transmit power according to a given criteria. Another example is that the mobile itself evaluates the measurements and transfer a request for an increase or decrease of the base transmit power. It is probably desirable that the base station, in any case, makes the actual decisions on whether or not to increase the base station transmit power levels.

To speed up the power control of the mobiles, it may be permitted to let the mobiles take a more active part in the desicion of their own transmit power levels. By measuring the quality of the signals received from the base station, the mobile can be able to predict the quality on its own transmitted signals when received at the base. Thus, if the mobile detects a sudden improvement or degradation of the quality of the signal transmitted from the base, it may decide itself to rise its own power level. It is important, however, that the base station has the ability to make a fast re-adjustment of the mobile transmit power level in order to minimize the risk of a mobile unintentionally performing a dramatic increase or decrease of its power level.

When implementing methods for communication according to the present invention in some TDMA mobile radio communication system, e.g. according to GSM or IS-54, normally only minor amendments may be necessary. Much of the procedures for call set up and termination and handoff may be similar to those in a conventional TDMA system. Some amendments are of course necessary. At call set up or handoff of a call already previously set up, the base station in a prior art TDMA system, without channel hopping, informs the mobile station on a fixed radio channel and a fixed time slot to be used for the call to be set up or handed over. When using channel hopping according to the present invention, some other method of synchronizing the transmitter and receiver to the right time slot of the right radio channel is required for the communication to be possible. Most connections are bidirectional, e.g. normal telephone calls and data communications. Both base and mobile stations must therefore not only transmit but also receive radio signals in the right time slot of the right radio channel. Normally the base station will be master in this process and send radio channel and time slot hopping information to the mobile station. In a TDMA-FH system with channel hopping the hopping information is then sent instead of of merely information on a fixed time slot on a fixed radio channel.

When implementing the present invention in a cellular TDMA mobile radio system designed for optional channel hopping, e.g. GSM, even less modifications are normally required. One fundamental difference between the GSM system and a TDMA-FH system according to the present invention is that no frequency plan is required in a system according to the present invention. However, this fundamental difference does not exclude the possibility that a method of determining radio channel and timeslot according to GSM can also be used in a system according to the present invention with only few amendments.

According to the random frequency hopping mode in GSM, a mobile and base station transmits their bursts in timeslots of a sequence of radio channels that the station derives from an algorithm. The radio channel hopping sequences are orthogonal inside one cell, meaning that no collisions occure between communications in the same cell. The radio channel hopping sequences are independent from one cell to another.

The hopping sequences are generated dependent on three different parameters:

a) The set of radio channels to be hopped on

b) The hopping seed of the cell, which allows different sequences in adjacent or neighbouring cells

c) The index offset, to distinguish the different connections of the cell using the same set of radio channels to be hopped on

Thus, according to GSM, the radio channel and time slot hopping information sent from the base to the mobile is the set of frequencies, the hopping seed and the index offset.

In each base and mobile station an algorithm is stored. Inputs to the algorithm are a set of numbers and a seed. Depending upon the seed the algorithm generates a sequence of numbers selected among the set of numbers. Only numbers from the set are generated. Different seeds cause the algorithm to generate different sequences. Irrespective of seed, in any long sequence generated by the algorithm any of the numbers in the set appears substantially as frequent as any other number in the set. Thus, for those not informed on the seed the numbers in the set appears to be selected at random. The sequence generated repeats itself after some time. The length of the sequence is depending upon the algorithm used, and can be made longer than the average duration of a telephone call

Mobiles served by the same cell (base station) receive the same seed and using the same algorithm they would generate identical sequences. However, different mobiles served by the same cell receive different index offset in their hopping information from the base station. Each mobile station adds their individual index offset to the number generated by the algorithm, whereby the mobile stations will get different numbers.

Assuming the set includes N radio channels which are given individual numbers 0, 1, ...N-1, μ130 inputs the seed and the number N in the algorithm and starts executing the algorithm. A sequence of numbers, none exceeding N-1 are then generated. To each number generated by the algorithm the μ130 adds the index offset modulo N. The number obtained by this addition is the number of the next radio channel to be used.

As an illustrative example say that the set includes N=8 radio channels that the station may be hopp to. The random generator could then generate a sequence 2,6,4,0,3,1,6,... for a given hopping seed. The following eight different hopping sequences for eight different connections in the same cell could then be obtained.

Index offset	hopping scheme
0	2,6,4,0,3,1,6,..
1	3,7,5,1,4,2,7,..
2	4,0,6,2,5,3,0,..
3	5,1,7,3,6,4,1,..
4	6,2,0,4,7,5,2,..
5	7,3,1,5,0,6,3,..
6	0,4,2,6,1,7,4,..
7	1,5,3,7,2,0,5,..

Comparing the eight sequences shows all radio channels are used simultaneously but no sequence coincides with any other sequence, i.e. no two mobiles hop to the same radio channel at the same time.

According to GSM there should be a frequency plan. The set of radio channels sent to a mobile served served by one cell is therefore different from all sets of radio channels sent to any mobile served by an adjacent cell or an other cell in the same cell cluster. None of the radio channels included in any set sent to a mobile station served by one cell is included in any set sent to any mobile station served by an other cell in the same cell cluster.

If radio channels in a TDMA-FH according to the present invention would be determined in a way simular to the way in GSM, using radio channel sets, seed, index offset and an algorithm, at least some of the radio channels included in the set sent to a mobile in one cell would also be included in the set sent to a mobile in an adjacent cell. Preferably the majority if not all of the radio channels included in any set sent to any mobile in one cell would also be included in sets sent to mobiles in adjacent cells.

The invention is not limited to embodiments where the time slots and radio channels of hopping sequences are determined by channel set, hopping seed and index offset according to GSM. However, according to the invention hopping shall normally meet at least the following rules:

1) hopping sequences/schemes for connections involving mobiles in the same cell or, expressed somewhat differently, bursts transmitted from mobiles served by the same base station, must not coincide in the same time slot of the same radio channel.

2) hopping schemes/sequences for connections involving mobiles in adjacent cells, or expressed somewhat differently, for mobiles served by adjacent base stations, may only coincide occasionally and shall be uncorrelated or have low correlation with each other.

In a system similar to IS-54 the hopping information may be transmitted from the base station to the mobile station on the control channel during the setup of a call, or on one of the associated control channels, FACCH or SACCH, during a handoff. Most connections are bidirectional, e.g. normal telephone calls and data communications. The hopping information may therefore indicate both radio channel and time slot combinations to be used for the sequences of bursts of radio signals to be transmitted by the base and mobile stations for the purpose of forwarding speech or other information relating to the connection. Instead of specifying complete sequences, the hopping information from a base may be an identification number or code of a scheme or algorithm stored in all base and mobile stations. The hopping information from a base station may also indicate where in the scheme the mobile should start if it should not start at the beginning of the scheme.

An algorithm or a scheme has normally a finite length, i.e. includes or generates only a finite number of radio channel/timeslot combinations. Normally a call lasts for so long time that the number of radio signal bursts transmitted from the mobile station, for the purpose of forwarding the information relating to the call, exceeds the length of the scheme. However, a base or mobile station may use the hopping information for hopping cyclically. When the station has transmitted a burst in accordance with the last combination of radio channel and time slot indicated at the end of the scheme or generated by an algorithm the mobile transmits its next burst in the combination of radio channel and time slot indicated first in the scheme.

According to one embodiment schemes used by mobile stations in a cell are synchronized by a base station for the cell and are cyclical permutations of a basic scheme. As an example it is assumed there are 13 radio channels available for connections. Four basic scheme cycles for four neighbour cells may then be as follows.

A': 1,4,7,10,13,3,6,9,12,2,5,8,11
B': 1,6,11,3,8,13,5,10,2,7,12,4,9
C': 1,8,2,9,3,10,4,11,5 12,6,13,7
D': 1,12,10,8,6,4,2,13,11,9,7,5,3

In a first cell a mobile may transmit according to one of the following synchronized cyclic schemes A01' to A12' obtained by cyclic permutation of the basic scheme cycle A'.

A01' 1;4;7;10;13;3;6;9;12;2;5;8;11;1;4;7;10;13;3;6;9;12;2;5;8;11;
A02' 2;5;8;11;1;4;7;10;13;3;6;9;12;2;5;8;11;1;4;7;10;13;3;6;9;12;
A03' 3;6;9;12;2;5;8;11;1;4;7;10;13;3;6;9;12;2;5;8;11;1;4;7;10;13;
A04' 4;7;10;13;3;6;9;12;2;5;8;11;1;4;7;10;13;3;6;9;12;2;5;8;11;1;
A05' 5;8;11;1;4;7;10;13;3;6;9;12;2;5;8;11;1;4;7;10;13;3;6;9;12;2;
A06' 6;9;12;2;5;8;11;1;4;7;10;13;3;6;9;12;2;5;8;11;1;4;7;10;13;3;
A07' 7;10;13;3;6;9;12;2;5;8;11;1;4;7;10;13;3;6;9;12;2;5;8;11;1;4;
A08' 8;11;1;4;7;10;13;3;6;9;12;2;5;8;11;1;4;7;10;13;3;6;9;12;2;5;
A09' 9;12;2;5;8;11;1;4;7;10;13;3;6;9;12;2;5;8;11;1;4;7;10;13;3;6;
A10' 10;13;3;6;9;12;2;5;8;11;1;4;7;10;13;3;6;9;12;2;5;8;11;1;4;7;
A11' 11;1;4;7;10;13;3;6;9;12;2;5;8;11;1;4;7;10;13;3;6;9;12;2;5;8;
A12' 12;2;5;8;11;1;4;7;10;13;3;6;9;12;2;5;8;11;1;4;7;10;13;3;6;9;
A13' 13;3;6;9;12;2;5;8;11;1;4;7;10;13;3;6;9;12;2;5;8;11;1;4;7;10;

In a second cell adjacent to the first cell a mobile may transmit according to one of the following synchronized cyclic schemes B01' to B12' obtained by cyclic permutation of the basic scheme cycle B'.

B01' 1;6;11;3;8;13;5;10;2;7;12;4;9;1;6;11;3;8;13;5;10;2;7;12;4;9;
B02' 2;7;12;4;9;1;6;11;3;8;13;5;10;2;7;12;4;9;1;6;11;3;8;13;5;10;

B03' 3;8;13;5;10;2;7;12;4;9;1;6;11;3;8;13;5;10;2;7;12;4;9;1;6;11;
B04' 4;9;1;6;11;3;8;13;5;10;2;7;12;4;9;1;6;11;3;8;13;5;10;2;7;12;
B05' 5;10;2;7;12;4;9;1;6;11;3;8;13;5;10;2;7;12;4;9;1;6;11;3;8;13;
B06' 6;11;3;8;13;5;10;2;7;12;4;9;1;6;11;3;8;13;5;10;2;7;12;4;9;1;
B07' 7;12;4;9;1;6;11;3;8;13;5;10;2;7;12;4;9;1;6;11;3;8;13;5;10;2;
B08' 8;13;5;10;2;7;12;4;9;1;6;11;3;8;13;5;10;2;7;12;4;9;1;6;11;3;
B09' 9;1;6;11;3;8;13;5;10;2;7;12;4;9;1;6;11;3;8;13;5;10;2;7;12;4;
B10' 10;2;7;12;4;9;1;6;11;3;8;13;5;10;2;7;12;4;9;1;6;11;3;8;13;5;
B11' 11;3;8;13;5;10;2;7;12;4;9;1;6;11;3;8;13;5;10;2;7;12;4;9;1;6;
B12' 12;4;9;1;6;11;3;8;13;5;10;2;7;12;4;9;1;6;11;3;8;13;5;10;2;7;
B13' 13;5;10;2;7;12;4;9;1;6;11;3;8;13;5;10;2;7;12;4;9;1;6;11;3;8;

In a third cell adjacent to the first cell a mobile may transmit according to one of the following synchronized cyclic schemes C01' to C12' obtained by cyclic permutation of the basic scheme cycle C'.

C01' 1;8;2;9;3;10;4;11;5;12;6;13;7;1;8;2;9;3;10;4;11;5;12;6;13;7;
C02' 2;9;3;10;4;11;5;12;6;13;7;1;8;2;9;3;10;4;11;5;12;6;13;7;1;8;
C03' 3;10;4;11;5;12;6;13;7;1;8;2;9;3;10;4;11;5;12;6;13;7;1;8;2;9.
C04' 4;11;5;12;6;13;7;1;8;2;9;3;10;4;11;5;12;6;13;7;1;8;2;9;3;10;
C05' 5;12;6;13;7;1;8;2;9;3;10;4;11;5;12;6;13;7;1;8;2;9;3;10;4;11;
C06' 6;13;7;1;8;2;9;3;10;4;11;5;12;6;13;7;1;8;2;9;3;10;4;11;5;12;
C07' 7;1;8;2;9;3;10;4;11;5;12;6;13;7;1;8;2;9;3;10;4;11;5;12;6;13;
C08' 8;2;9;3;10;4;11;5;12;6;13;7;1;8;2;9;3;10;4;11;5;12;6;13;7;1;
C09' 9;3;10;4;11;5;12;6;13;7;1;8;2;9;3;10;4;11;5;12;6;13;7;1;8;2;
C10' 10;4;11;5;12;6;13;7;1;8;2;9;3;10;4;11;5;12;6;13;7;1;8;2;9;3;
C11' 11;5;12;6;13;7;1;8;2;9;3;10;4;11;5;12;6;13;7;1;8;2;9;3;10;4;
C12' 12;6;13;7;1;8;2;9;3;10;4;11;5;12;6;13;7;1;8;2;9;3;10;4;11;5;
C13' 13;7;1;8;2;9;3;10;4;11;5;12;6;13;7;1;8;2;9;3;10;4;11;5;12;6;

In a fourth cell adjacent to the first cell a mobile may transmit according to one of the following synchronized cyclic schemes D01' to D12' obtained by cyclic permutation of the basic scheme cycle D'.

D01' 1;12;10;8;6;4;2;13;11;9;7;5;3;1;12;10;8;6;4;2;13;11;9;7;5;3;
D02' 2;13;11;9;7;5;3;1;12;10;8;6;4;2;13;11;9;7;5;3;1;12;10;8;6;4;
D03' 3;1;12;10;8;6;4;2;13;11;9;7;5;3;1;12;10;8;6;4;2;13;11;9;7;5;
D04' 4;2;13;11;9;7;5;3;1;12;10;8;6;4;2;13;11;9;7;5;3;1;12;10;8;6;

D05' 5;3;1;12;10;8;6;4;2;13;11;9;7;5;3;1;12;10;8;6;4;2;13;11;9;7;
D06' 6;4;2;13;11;9;7;5;3;1;12;10;8;6;4;2;13;11;9;7;5;3;1;12;10;8;
D07' 7;5;3;1;12;10;8;6;4;2;13;11;9;7;5;3;1;12;10;8;6;4;2;13;11;9;
D08' 8;6;4;2;13;11;9;7;5;3;1;12;10;8;6;4;2;13;11;9;7;5;3;1;12;10;
D09' 9;7;5;3;1;12;10;8;6;4;2;13;11;9;7;5;3;1;12;10;8;6;4;2;13;11;
D10' 10;8;6;4;2;13;11;9;7;5;3;1;12;10;8;6;4;2;13;11;9;7;5;3;1;12;
D11' 11;9;7;5;3;1;12;10;8;6;4;2;13;11;9;7;5;3;1;12;10;8;6;4;2;13;
D12' 12;10;8;6;4;2;13;11;9;7;5;3;1;12;10;8;6;4;2;13;11;9;7;5;3;1;
D13' 13;11;9;7;5;3;1;12;10;8;6;4;2;13;11;9;7;5;3;1;12;10;8;6;4;2;

A study of the schemes A01' to D13' reveals that any two schemes in adjacent cells coincide once but not more during one cycle of a scheme. Assuming there are m timeslots in a frame on a channel m mobiles in the first cell may use the same scheme,e.g. A07', without any coincidence of bursts transmitted from other mobiles in the same cell provided they transmit in different timeslots. Thus up to maximum 13 x m mobiles in the first cell may transmit according to the schemes A01' to A13' without co-channel interference from other mobiles in the same cell. Since there were 13 radio channels available in the first cell the maximum number equals the total number of time slots available on all radio channels in the cell. Obviously the same is true for each of the ssecond, third and fourth cells.

The basic schemes may be assigned to 3-cell clusters or 4-cell clusters in a way similar to a frequency plan in order to reduce co-channel interference from mobiles in different cells. However there is an inherent fundamental difference between assigning basic schemes like A' to D' and assigning radio channels to cell clusters according to a fixed frequency plan. When assigning schemes according to the invention each cell is still entitled to use every radio channel for connections. Thus when assigning such schemes the maximum connection handling capacity for any cell is not reduced compared to a situation when no schemes are assigned. Using the schemes, and having a base station in a cell with enogh transceivers means the cell can actually handle as many simultaneous connections as the total number of time slots on all the radio channels available and there is no co-channel interference from mobiles in the same cell. Using proper schemes means all co-channel interference comes from adjacent cells and surrounding more distant cells whereby the connection handling capacity of a cell becomes dependent upon the number of simultaneous connections in adjacent and other more distant surrounding cells. Using the schemes means any two mobiles in adjacent cells can cause co-channel interference to each other only during a small minority of the bursts transmitted. This is an advantage in certain situations, e.g. when the power control of a mobile is not good enough. Comparing any two schemes A01' to D13' reveals that any two schemes for different cells, e.g. A03'and C07', have low correlation to each other but any two schemes for the same cell, e.g. B02'and B06', have high correlation to each other.

In the embodiment of a system illustrated in figures 2, 8 and 9 in accordance with the EIA/TIA IS-54 standards, the control channels are analog and base and mobile stations do not transmit bursts in timeslots on the control channels according to the TDMA principle. In a future development of a system according to EIA/TIA IS-54 the control channels could also become digital channels, divided in time slots where base and mobile stations transmit bursts, possibly according to channel shifting schemes.

Figure 10 illustrates how the quality may be degraded in TDMA system, without a fixed frequency plan and implemented methods according to the invention, compared to a CDMA system as the number of subscribers served by the system is increased. The curves are based on simulations of two such systems under equivalent conditions. As seen, the quality is expected to degrade more slowly for the TDMA system according to the invention, which illustrates that a "softer" capacity may be obtained in such a TDMA system than in the CDMA system.

The reason that TDMA-FH with communication methods according to the invention performs better when over-loading the system is that the channels connected to the same base station are separated in time/frequency while in CDMA systems they interfere with each other. Adding one more subscriber in such a TDMA system will not increase the interference for any other subscriber connected to the same base station. Only subscribers connected to surrounding base stations will suffer from the increased interference level. Since the interference produced by the additional subscribers will be reduced by the path-loss to the neighbouring cells, the resulting increase in co-channel interference for these cells will be small.

In the CDMA systems, one additional subscriber will degrade the quality for all subscribers in the system. In particular, one additional subscriber in the CDMA system will cause an increase of the interference level in its own cell where the path-loss is normally small compared to the path-loss to neighbouring cells.

The above phenomena also explains why the TDMA system will provide a geographically more flexible sharing of the radio recources than a CDMA system when a capacity peak is required in one or several of the cells.

Figure 11 and 12 show how the connection handling capacity for each of certain cells, e.g. along a free-way during rush-hour, can be increased at the expence of a capacity reduction in the surrounding cells. The figures are based on simulations of a TDMA-system according to the invention and a CDMA system under equivalent conditions. As seen in figure 11, the CDMA system may increase the capacity to 120% along a line of cells if the capacity in all surrounding cells is reduced to 30%. In the system according to the invention the capacity may be increased to 200% along the line of cells at if the capacity of the surrounding cells is reduced to 65%, as is illustrated by figure 12.

Although the invention has been explained in connection with certain embodiments of TDMA cellular mobile radio system the invention is not limited to such embodiments of systems but methods according to the invention may be implemented in other cellular mobile radio communication systems within the scope of the invention.

CLAIMS

1. In a cellular TDMA mobile radio system including a first and a second adjacent cells and plural TDMA radio channels, a method of transmitting radio signals pertaining to connections involving mobile stations, comprising the steps of:

transmitting to each of a plurality of mobile stations served by the first cell or the second cell, at set up or handoff of a connection involving the mobile station, radio channel and time slot hopping information pertaining to the connection involving the mobile station, the hopping information enabling the mobile station to determine a sequence of combinations, each combination including a TDMA radio channel and a time slot on that radio channel to be used for transmission from the mobile station, the hopping information transmitted to different mobiles served by the first cell causing different mobiles served by the first cell to determine non-coinciding sequences of combinations of one of the TDMA radio channels and a time slot on that radio channel, the hopping information transmitted to different mobiles served by the second cell causing different mobiles served by the second cell to determine non-coinciding sequences of combinations of one of the TDMA radio channels and a time slot on that radio channel, the hopping information transmitted to mobiles served by the first cell and the hopping information transmitted to mobiles served by the second cell causing mobiles served by different cells to determine sequences of combinations including a plurality of common radio channels, the hopping information causing any sequence determined by a mobile served by the first cell to have low correlation with any sequence determined by any mobile served by the second cell, and the major part of the sequence determined by one mobile station served by the second cell to be free from coincidence with the major part of the sequence determined by any mobile station served by the first cell; and

transmitting from any mobile station having a need for transmission of information pertaining to a connection, radio signal bursts distributed on the time slots of plural radio channels in accordance with a sequence determined from the hopping information received, each burst transmitted from any of the mobile stations being confined to one time slot and separated in time from the succeeding burst transmitted from the same mobile station and relating to the same connection.

2. A method according to claim 1 wherein the sequence used by any mobile in the first cell includes more than half of the total number of different TDMA radio channels available to said first cell and its adjacent cells of the TDMA system for transmission from mobiles of radio signals pertaining to connections.

3. A method according to claim 1 wherein a majority of the radio channels included in any sequence used by any mobile station in the first cell are also included in a sequence used by a mobile station in the second cell.

4. A method according to claim 1 comprising the further steps of:
estimating at base station signal levels for signals received from mobile stations served by the base station;
comparing the estimated signal levels for the signals from the mobile station and a desired signal level; and
controlling from the base station the output powers of mobile stations served by the base station for the purpose of reducing differences betweeen the estimated signal levels and the desired signal level.

5. A method according to claim 1 comprising the further steps of:
estimating at base station signal quality for signals received from mobile stations served by the base station;
comparing the estimated signal quality for the signals from the mobile station and a desired signal quality; and
controlling from the base station the output powers of mobile stations served by the base station for the purpose of reducing differences betweeen the estimated signal qualities and the desired signal quality.

6. A method according to claim 1 comprising the further steps of:
estimating at mobile stations signal levels for signals received from the base station serving the mobile station;

comparing at the mobile stations estimated signal levels for the signals received from the serving base station and a desired signal level; and

reducing at the mobile stations the output power of the mobile station transmitter in response to a rapid increase of the estimated signal level over the desired level.

7. A method according to claim 1 comprising the further steps of:

estimating at base station C/I for signals received from served mobile stations;

comparing estimated C/I for the signals received from served mobile stations and a desired C/I;

determining whether another connection involving a particular mobile station in the first cell is desirable for the purpose of connection set up or handoff;

checking if there is another possible radio channel time slot hopping sequence available in the first cell free from coincidence on every radio channel with every other of the hopping sequences already in use in the first cell; and

if another connection to a particular mobile in the first cell is desired and there is a possible hopping sequence free from coincidence, establishing the desired connection and using the hopping sequence in the first cell only if the estimated C/I for signals received from certain mobile stations involved in connections matches a desired level.

8. A method according to claim 7 wherein said certain mobile stations include all mobile stations in the first cell involved in a connection.

9. A method according to claim 7 wherein said certain mobile stations include all mobile stations involved in a connection in the second cell.

10. A method according to claim 1 wherein the average number of simultaneous connections per cell is restricted to substantially less than the average of the total number of time slots on all radio channels availiable for connections at a cell.

11. A method according to claim 1 wherein the average number of simultaneous connections per cell is restricted to 20% or less of the average of the total number of time slots on all radio channels available to the cell for connections.

12. In a cellular TDMA mobile radio system including a first and a second adjacent cells and plural TDMA radio channels, a method of transmitting radio signals pertaining to connections involving mobile stations, comprising the steps of:
transmitting to each of a plurality of mobile stations served by the first cell or the second cell, at set up or handoff of a connection involving the mobile station, radio channel and time slot hopping information pertaining to the connection involving the mobile station, the hopping information enabling the mobile station to determine a sequence of combinations, each combination including a TDMA radio channel and a time slot on that radio channel to be used for transmission from the mobile station, the hopping information transmitted to different mobiles served by the first cell causing different mobiles served by the first cell to determine non-coinciding sequences of combinations of one of the TDMA radio channels and a time slot on that radio channel, the hopping information transmitted to different mobiles served by the second cell causing different mobiles served by the second cell to determine non-coinciding sequences of combinations of one of the TDMA radio channels and a time slot on that radio channel, the hopping information transmitted to mobiles served by the first cell and the hopping information transmitted to mobiles served by the second cell causing mobiles served by different cells to determine sequences of combinations including a plurality of common radio channels but the major part of the sequence determined by one mobile station served by the second cell to be free from coincidence with the major part of the sequence determined by any mobile station served by the first cell, the hopping information allowing two sequences determined by two mobiles served by the same cell to include corresponding timeslots in succeeding frames of a radio channel; and
transmitting from any mobile station having a need for transmission of information pertaining to a connection, radio signal

bursts distributed on the time slots of plural radio channels in accordance with a sequence determined from the hopping information received, each burst transmitted from any of the mobile stations being confined to one time slot and separated in time from the succeeding burst transmitted from the same mobile station and relating to the same connection.

13. In a cellular TDMA mobile radio system including a first and a second adjacent cells and plural TDMA radio channels, a method of transmitting radio signals pertaining to connections involving mobile stations, comprising the steps of:
transmitting to each of a plurality of mobile stations served by the first cell or the second cell, at set up or handoff of a connection involving the mobile station, radio channel and time slot hopping information pertaining to the connection involving the mobile station, the hopping information enabling the mobile station to determine a sequence of combinations, each combination including a TDMA radio channel and a time slot on that radio channel to be used for transmission from the mobile station, the hopping information transmitted to different mobiles served by the first cell causing different mobiles served by the first cell to determine non-coinciding sequences of combinations of one of the TDMA radio channels and a time slot on that radio channel, the hopping information transmitted to different mobiles served by the second cell causing different mobiles served by the second cell to determine non-coinciding sequences of combinations of one of the TDMA radio channels and a time slot on that radio channel, the hopping information transmitted to mobiles served by the first cell and the hopping information transmitted to mobiles served by the second cell causing mobiles served by different cells to determine sequences of combinations including a plurality of common radio channels, the hopping information allowing a sequence determined by a mobile served by the first cell and a sequence determined by a mobile served by the second cell to include the same radio channel during the same frame, the hopping information causing the major part of the sequence determined by one mobile station served by the second cell to be

free from coincidence with the major part of the sequence determined by any mobile station served by the first cell; and transmitting from any mobile station having a need for transmission of information pertaining to a connection, radio signal bursts distributed on the time slots of plural radio channels in accordance with a sequence determined from the hopping information received, each burst transmitted from any of the mobile stations being confined to one time slot and separated in time from the succeeding burst transmitted from the same mobile station and relating to the same connection.

14. In a cellular TDMA mobile radio system including a first and a second adjacent cells and plural TDMA radio channels, each divided in time slots grouped in frames, a method of transmitting radio signals pertaining to connections involving mobile stations, comprising the steps of:
transmitting from each of a plurality of mobile stations involved in connections radio signal bursts distributed on a plurality of radio channels in accordance with a radio channel time slot hopping scheme, each burst transmitted from any of the mobile stations being confined to one time slot and separated in time from the succeeding burst transmitted from the same mobile station and relating to the same connection, all of the hopping schemes used by mobile stations in the first cell being free from coincidence on any radio channel with any other of the hopping schemes used for transmission from a mobile station in the first cell, all of the hopping schemes used by mobile stations in the second cell being free from coincidence on any radio channel with any other of the hopping schemes used by any mobile station in the second cell, one of the hopping schemes used by mobile stations in the second cell coinciding on any radio channel with at least one of the hopping schemes used by a mobile station in the first cell, the major part of every hopping scheme used by a mobile station in the second cell being free from coincidence on any radio channel with the major part of any hopping scheme used by a mobile station in the first cell.

15. A method according to claim 14 wherein each hopping scheme used by a mobile in the first cell includes a plurality of radio channels included in a hopping scheme used by a mobile in the second cell.

16. A method according to claim 14 wherein each hopping scheme used by a mobile served by the first cell includes more than half of the total number of different TDMA radio channels available to said first cell and second cell and any other cell adjacent to the first cell of the TDMA system for transmission from mobiles of radio signals pertaining to connections.

17. A method according to claim 14 wherein a majority of the radio channels included in a hopping scheme used by a mobile station served by the first cell are also included in a hopping scheme used by a mobile station served by the second cell.

18. A method according to claim 12 or 13 wherein any channel hopping sequence used by a mobile station in the first cell have low correlation with any channel hopping sequence used by any mobile station in the second cell.

19. A method according to claim 12, 13 or 14 comprising the further steps of:
estimating signal to interference ratio for signals received by mobile stations served by the first or second cell;
comparing the estimated signal to interference ratio for the mobile stations and a desired signal to interference ratio;
controlling output power of stations for the purpose of reducing differences betweeen signal to interference ratio at different mobile stations and a desired ratio.

20. A method according to claim 12, 13 or 14 comprising the further steps of:
estimating at base stations signal to interference ratio for signals received from mobile stations in the first and second cell;

comparing the estimated signal to interference ratio for the signals received from mobile stations and a desired signal to interference ratio;
determining whether another connection involving a particular mobile station served by the first cell is desirable for the purpose of connection set up or handoff;
checking if there is another possible mobile channel hopping scheme available in the first cell free from coincidence on every radio channel with every other of the mobile channel hopping schemes already in use in the first cell; and
if another connection to a particular mobile in the first cell is desired and there is a possible mobile hopping scheme free from coincidence, establishing the desired connection and using the possible mobile channel hopping scheme in the first cell only if the estimated signal to interference ratio for signals received from certain mobile stations involved in connections equals or exceeds the desired ratio.

21. A method according to claim 20 wherein said certain mobile stations include all mobile stations in the first cell involved in a connection.

22. A method according to claim 20 wherein said certain mobile stations include all mobile stations involved in a connection in the second cell.

23. A method according to claim 1, 12, 13 or 14 comprising the further steps of:
checking at mobile stations involved in connections served by the first or second cells whether there is a need for transmission from the mobile of information pertaining to the connection; and
transmitting from mobile stations involved in connections served by the first or second cell radio signal burst only when there is a need for transmission of information pertaining to the connection.

24. A method according to claim 1, 12, 13 or 14 wherein the sum of the durations of all radio signal bursts transmitted from any

mobile station and pertaining to a particular connection is less than one third of sum of the durations of the busts and the durations of spaces between the bursts.

25. In a cellular TDMA mobile radio system including a first and a second adjacent cells and plural TDMA radio channels, each divided in time slots grouped in frames, a method of transmitting radio signals pertaining to connections involving mobile stations, comprising the steps of:
transmitting from each of a first and a second base station serving mobile stations in the first and second cells respectively, radio signal bursts distributed on a plurality of radio channels in accordance with channel hopping sequences, to mobile stations in the first and second cells respectively, and pertaining to connections involving the mobile stations in the cells, each burst transmitted from the first or second base station and pertaining to a connection being confined to one time slot and separated in time from the succeeding burst transmitted from the same base station and pertaining to the same connection, all of the hopping sequences used by the first base station for transmission to served mobile stations being free from coincidence on any radio channel with any other of the hopping sequences used for transmission from the first base station to served mobile stations, all of the hopping sequences used by the second base station for serving mobiles being free from coincidence on any radio channel with any other of the hopping sequences used by the second base station for serving mobiles, one of the hopping sequences used by the second base station for transmission to mobile stations served by the second base station coinciding on the same radio channel with at least one of the hopping sequences used for transmission from the first base station to a mobile station served by the first base station; and the major part of every hopping sequence used for transmission from the first base station to mobile stations served by the first base station being free from coincidence with the major part of any particular hopping serquence used for transmission from the second base station to the mobile stations served by the second base station.

26. A method according to claim 25 wherein the average number of simultaneous connections per cell is limited to be substantially less than the average of the total number of time slots on all radio channels availiable for connections at a cell.

27. A method according to claim 25 wherein the average number of simultaneous connections per cell is limited to 20% or less of the average of the total number of time slots on all radio channels available to a cell for connections.

28. A method according to claim 25 comprising the further steps of:
measuring signal level for signals received by mobile stations;
reporting from mobile stations to base stations signal levels measured;
comparing the measured signal level for the mobile stations and a desired signal level; and
controlling output power of base stations for the purpose of reducing differences betweeen signal levels estimated at different mobile stations and a desired signal level.

29. A method according to claim 25 comprising the further steps of:
measuring signal quality for signals received by mobile stations;
reporting from mobile stations to serving base station measured signal quality;
comparing reported quality and a desired signal quality; and
controlling output power of base stations for the purpose of reducing differences betweeen signal quality at different mobile stations and a desired signal quality.

30. A method according to claim 25 comprising the further steps of:
checking at base stations, serving mobile stations involved in connections in the first or second cells, whether there is a need for transmission from the base station of information pertaining to a connection; and

transmitting from the base stations to served mobile stations involved in connections in the first or second cell radio signal burst pertaining to the connection only when there is a need for transmission of information pertaining to the connection.

BRIEF OVERVIEW OF SUBJECT MATTER CLAIMED

1.	TDMA-FH without mobile co-channel interference within cell and low correlation for schemes in adjacent cells
2	1 + at least half of the available channels in each sequence
3	1 + the majority of the available channels in each sequence
4	1 + clearer distinction from CDMA disclosed in reference
5	1 + base controls mobile power output
6	1 + base controls mobile output power
7	1 + mobile controls its output power
8	1 + C/I limited number of connections in a cell
9	8 + number limited by C/I for mobiles in same cell
10	8 + number limited by C/I for mobiles in adjacent cell
11	1 + DTX
12	1 + fractional loading
13	1 + max 20% fractional loading
14	TDMA-FH without mobile co-channel interference within cell but two mobiles served by the same cell use corresponding timeslots in succeeding frames of a radio channel
15	TDMA-FH without mobile co-channel interference within cell and two mobiles served by adjacent cells may use the same radio channel during the same frame
16	TDMA-FH without mobile co-channel interference within cell but mobile co-channel interference from adjacent cell
17	16 + plural common radio channels in adjacent cells
18	16 + at least half of the available channels in each sequence (jfr 2)
19	16 + the majority of the available channels in each sequence (jfr 3)
20	16 + sequences in different cells have low correlation
21	16 + power control (jfr 7)
22	16 + C/I limited number of connections in a cell (jfr 8)
23	22 + number limited by C/I for mobiles in same (jfr 9)
24	22 + number limited by C/I for mobiles in adjacent cell (jfr 10)
25	16 + mobile station DTX
26	16 + clearer distinction from CDMA disclosed in reference
27	TDMA-FH without base co-channel interference within cell

but base co-channel interference from adjacent cell

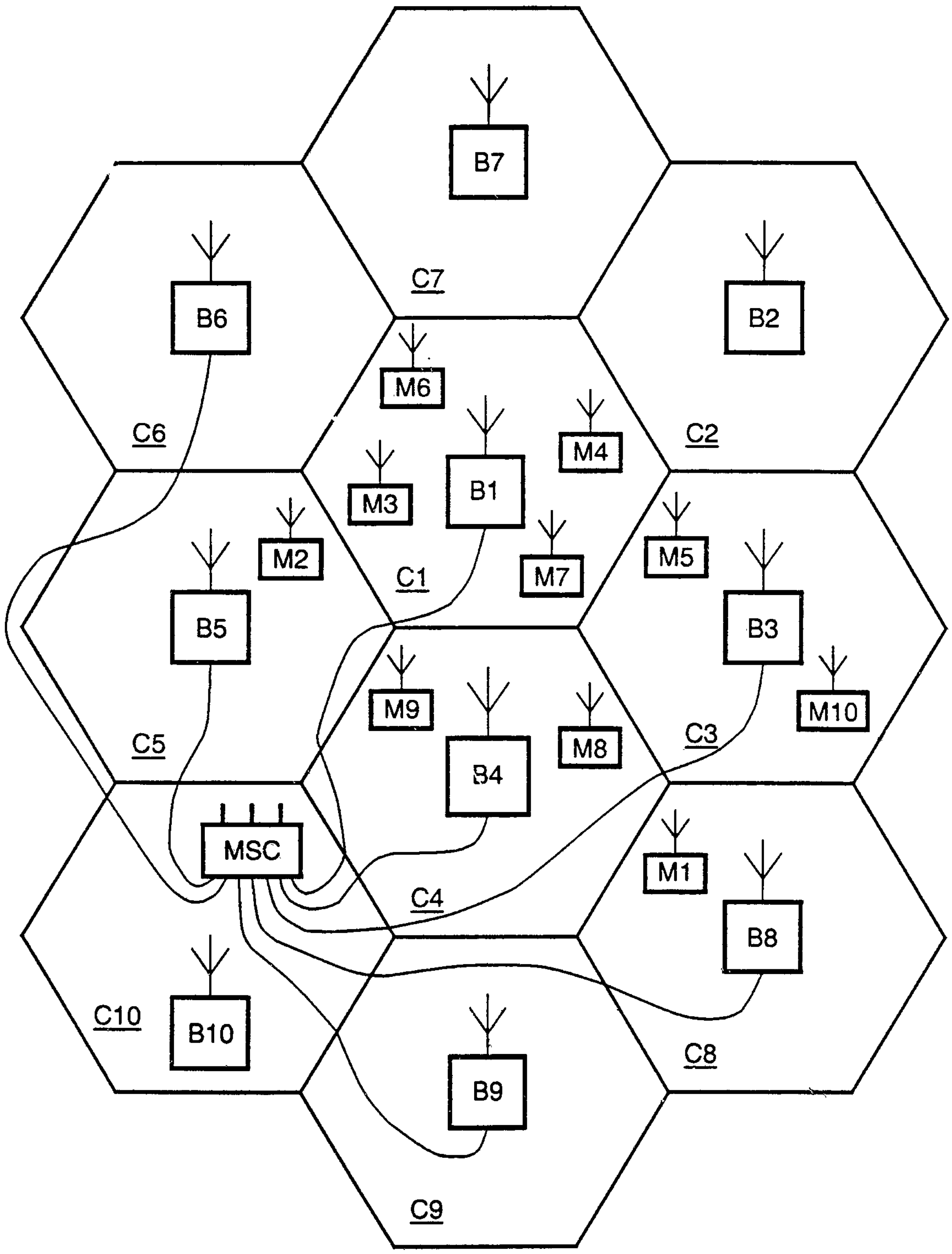
28 27 + fractional loading

29 27 + max 20% fractional loading

30 27 + control of base station output power

31 27 + control of base station output power

32 27 + base station DTX



B7
C7
B6
B2
M6
C6
M4
C2
B1
M3
M2
M5
B5
C1
M7
B3
M10
M9
B4
M8
C3
C5
MSC
M1
B8
C4
C10
B10
B9
C8
C9

Fig. 1

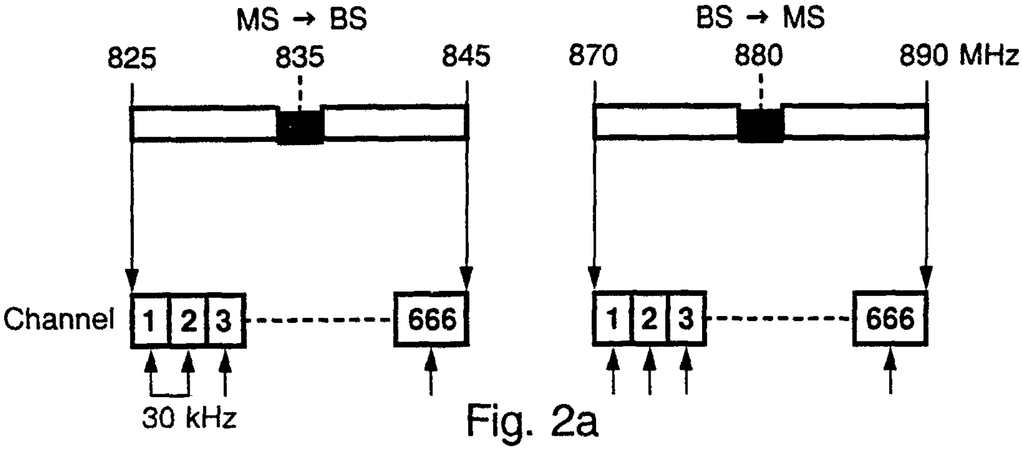


Fig. 2a

Fig. 2b

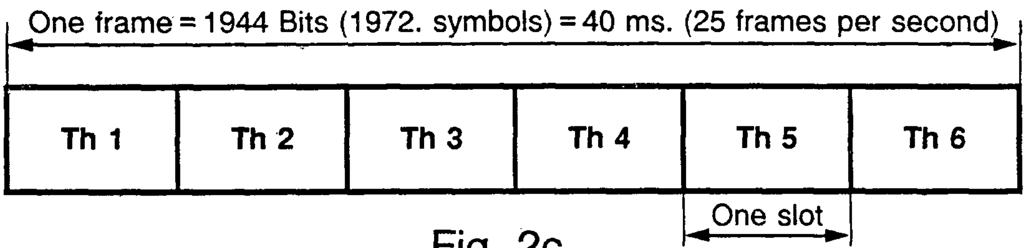
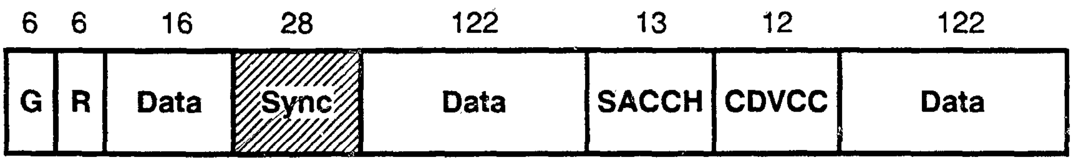
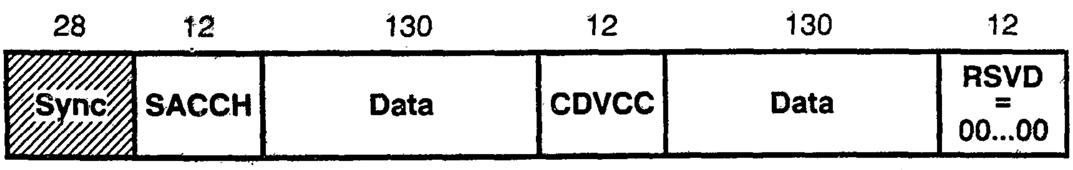


Fig. 2c



Slot format mobile station to base station (traffic channel)

Fig. 2d



Slot format base station to mobile station (traffic channel)

Fig. 2e

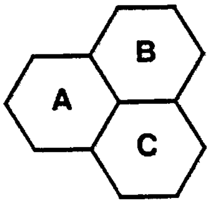


Fig. 3a

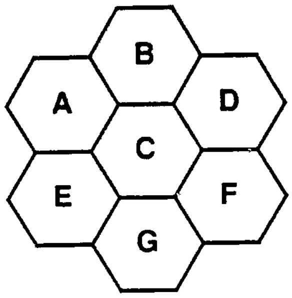


Fig. 3c

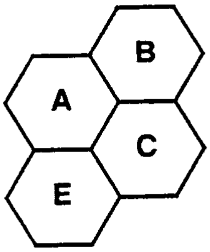


Fig. 3b

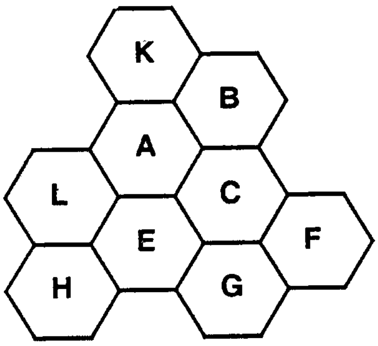


Fig. 3d

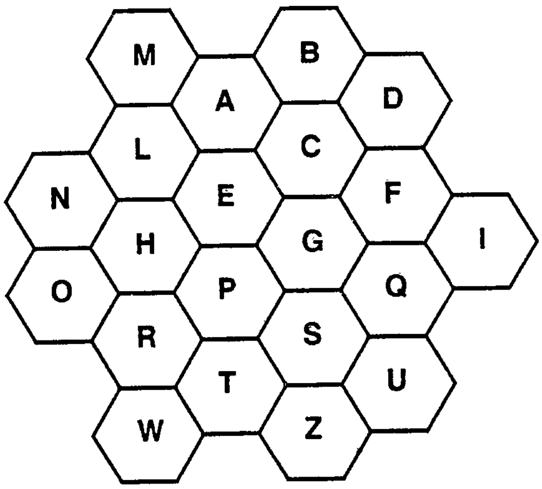


Fig. 3e

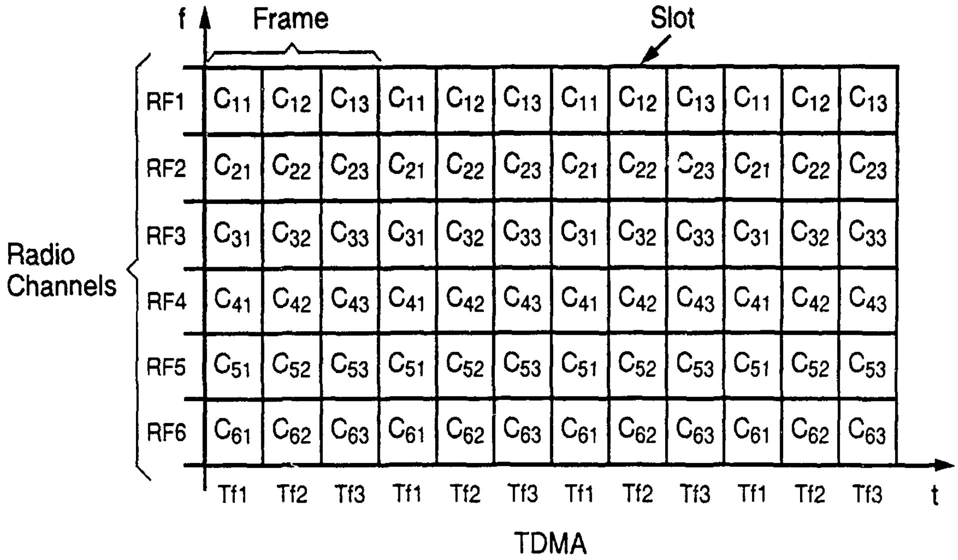

f
Frame
Slot
Radio Channels
RF1 C_{11} C_{12} C_{13} C_{11} C_{12} C_{13} C_{11} C_{12} C_{13} C_{11} C_{12} C_{13}
RF2 C_{21} C_{22} C_{23} C_{21} C_{22} C_{23} C_{21} C_{22} C_{23} C_{21} C_{22} C_{23}
RF3 C_{31} C_{32} C_{33} C_{31} C_{32} C_{33} C_{31} C_{32} C_{33} C_{31} C_{32} C_{33}
RF4 C_{41} C_{42} C_{43} C_{41} C_{42} C_{43} C_{41} C_{42} C_{43} C_{41} C_{42} C_{43}
RF5 C_{51} C_{52} C_{53} C_{51} C_{52} C_{53} C_{51} C_{52} C_{53} C_{51} C_{52} C_{53}
RF6 C_{61} C_{62} C_{63} C_{61} C_{62} C_{63} C_{61} C_{62} C_{63} C_{61} C_{62} C_{63}
Tf1 Tf2 Tf3 Tf1 Tf2 Tf3 Tf1 Tf2 Tf3 Tf1 Tf2 Tf3 t
TDMA

Fig. 4a

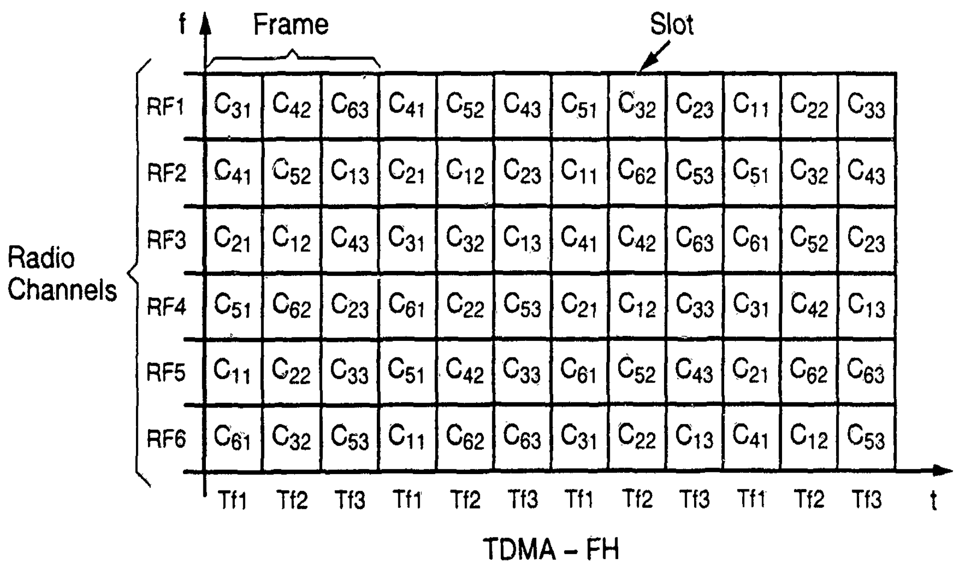

f
Frame
Slot
Radio Channels
RF1 C_{31} C_{42} C_{63} C_{41} C_{52} C_{43} C_{51} C_{32} C_{23} C_{11} C_{22} C_{33}
RF2 C_{41} C_{52} C_{13} C_{21} C_{12} C_{23} C_{11} C_{62} C_{53} C_{51} C_{32} C_{43}
RF3 C_{21} C_{12} C_{43} C_{31} C_{32} C_{13} C_{41} C_{42} C_{63} C_{61} C_{52} C_{23}
RF4 C_{51} C_{62} C_{23} C_{61} C_{22} C_{53} C_{21} C_{12} C_{33} C_{31} C_{42} C_{13}
RF5 C_{11} C_{22} C_{33} C_{51} C_{42} C_{33} C_{61} C_{52} C_{43} C_{21} C_{62} C_{63}
RF6 C_{61} C_{32} C_{53} C_{11} C_{62} C_{63} C_{31} C_{22} C_{13} C_{41} C_{12} C_{53}
Tf1 Tf2 Tf3 Tf1 Tf2 Tf3 Tf1 Tf2 Tf3 Tf1 Tf2 Tf3 t
TDMA – FH

Fig. 4b

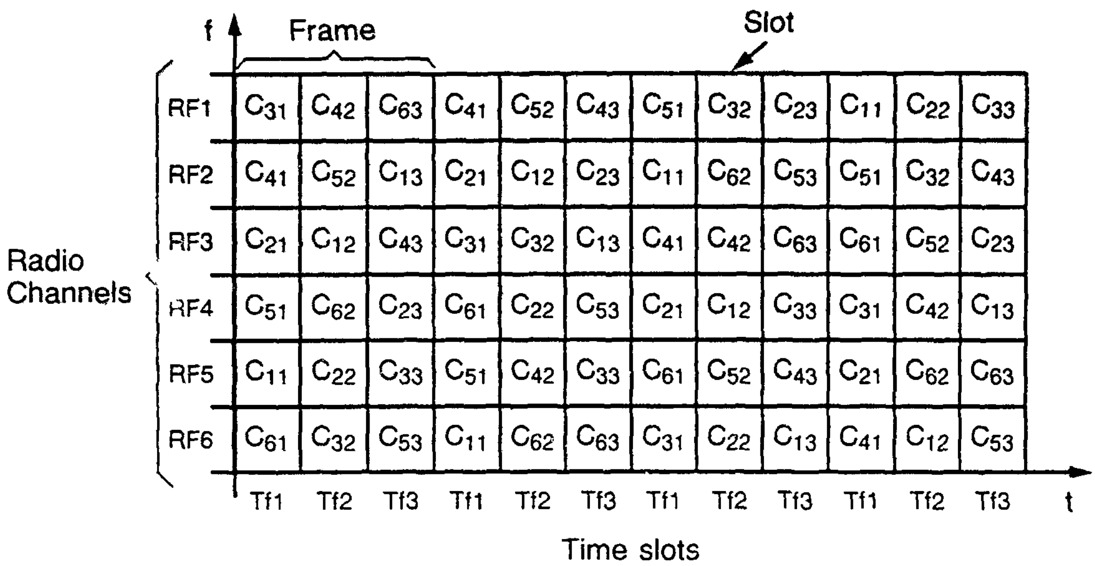

f
Frame
Slot
Radio Channels
RF1 C31 C42 C63 C41 C52 C43 C51 C32 C23 C11 C22 C33
RF2 C41 C52 C13 C21 C12 C23 C11 C62 C53 C51 C32 C43
RF3 C21 C12 C43 C31 C32 C13 C41 C42 C63 C61 C52 C23
RF4 C51 C62 C23 C61 C22 C53 C21 C12 C33 C31 C42 C13
RF5 C11 C22 C33 C51 C42 C33 C61 C52 C43 C21 C62 C63
RF6 C61 C32 C53 C11 C62 C63 C31 C22 C13 C41 C12 C53
Tf1 Tf2 Tf3 Tf1 Tf2 Tf3 Tf1 Tf2 Tf3 Tf1 Tf2 Tf3 t
Time slots

Fig. 5a

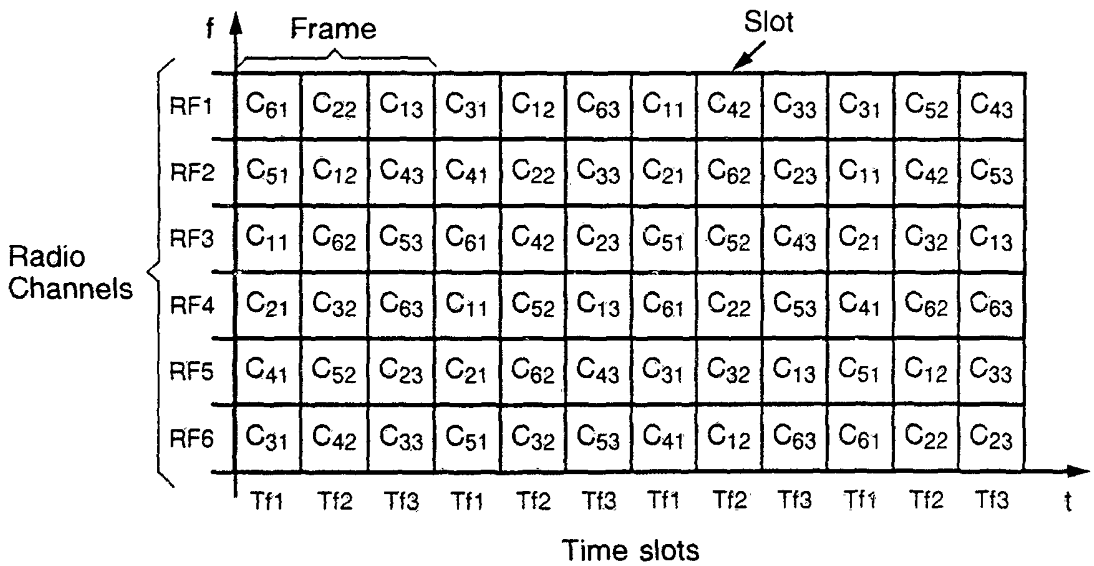

f
Frame
Slot
Radio Channels
RF1 C61 C22 C13 C31 C12 C63 C11 C42 C33 C31 C52 C43
RF2 C51 C12 C43 C41 C22 C33 C21 C62 C23 C11 C42 C53
RF3 C11 C62 C53 C61 C42 C23 C51 C52 C43 C21 C32 C13
RF4 C21 C32 C63 C11 C52 C13 C61 C22 C53 C41 C62 C63
RF5 C41 C52 C23 C21 C62 C43 C31 C32 C13 C51 C12 C33
RF6 C31 C42 C33 C51 C32 C53 C41 C12 C63 C61 C22 C23
Tf1 Tf2 Tf3 Tf1 Tf2 Tf3 Tf1 Tf2 Tf3 Tf1 Tf2 Tf3 t
Time slots

Fig. 5b

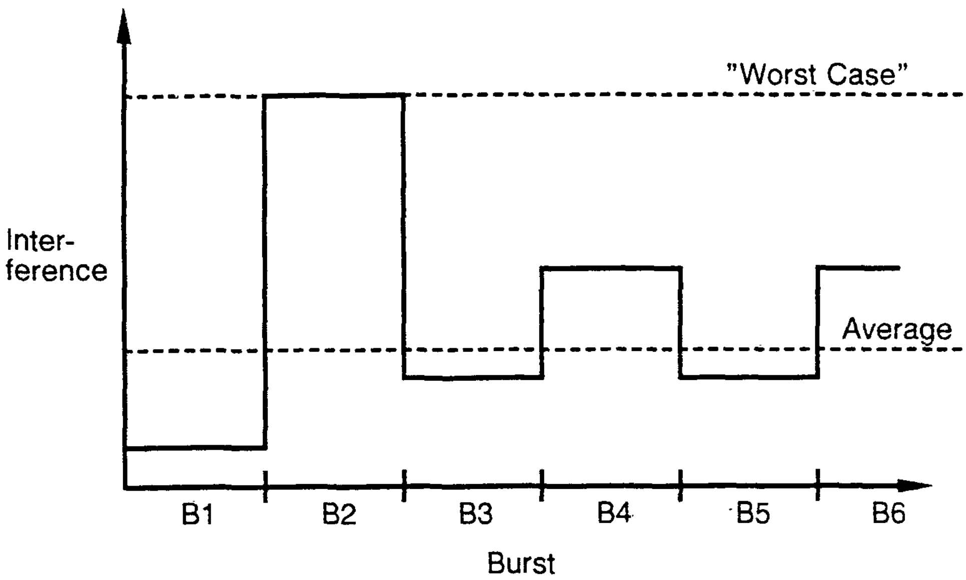


Fig. 6

36523/93

f — Frame — Slot

Radio Channels

	Tf1	Tf2	Tf3	Tf1	Tf2	Tf3	Tf1	Tf2	Tf3	Tf1	Tf2	Tf3
RF1		C_{42}		C_{41}			C_{51}		C_{23}		C_{22}	C_{33}
RF2	C_{31}	C_{52}		C_{21}		C_{43}	C_{11}	C_{32}		C_{11}		
RF3		C_{12}	C_{63}	C_{31}		C_{23}		C_{62}	C_{53}	C_{51}	C_{32}	C_{43}
RF4	C_{41}		C_{13}		C_{52}			C_{42}		C_{61}		C_{23}
RF5	C_{21}		C_{43}	C_{61}		C_{13}	C_{41}		C_{63}		C_{52}	C_{13}
RF6		C_{62}		C_{51}	C_{12}	C_{53}	C_{21}		C_{33}	C_{31}	C_{42}	
RF7	C_{51}	C_{22}	C_{23}		C_{32}		C_{61}	C_{12}		C_{21}		C_{63}
RF8		C_{32}		C_{11}	C_{22}	C_{33}		C_{52}	C_{43}		C_{62}	
RF9	C_{11}		C_{33}		C_{42}		C_{31}			C_{41}		C_{53}
RF10	C_{61}		C_{53}		C_{62}	C_{63}		C_{22}	C_{13}		C_{12}	

t — Time slots

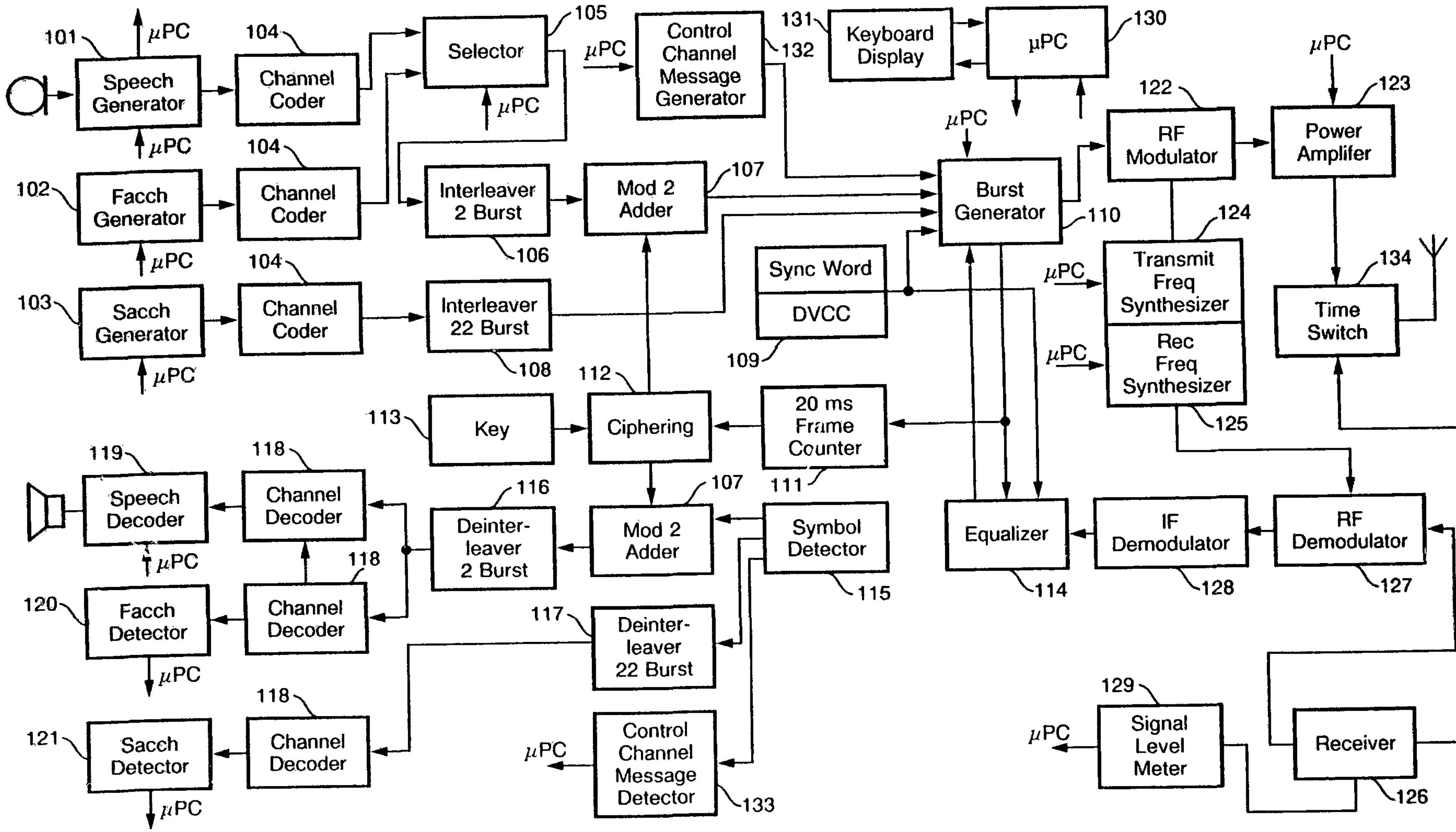
f — Frame — Slot

Radio Channels

	Tf1	Tf2	Tf3	Tf1	Tf2	Tf3	Tf1	Tf2	Tf3	Tf1	Tf2	Tf3
RF1	C_{61}		C_{13}		C_{12}	C_{63}		C_{42}		C_{31}		C_{43}
RF2	C_{51}	C_{22}	C_{43}					C_{62}	C_{33}	C_{11}	C_{52}	C_{53}
RF3	C_{11}			C_{31}	C_{22}		C_{11}	C_{52}		C_{21}	C_{42}	
RF4		C_{12}	C_{53}	C_{41}	C_{42}	C_{33}	C_{21}		C_{23}		C_{32}	
RF5		C_{62}			C_{52}	C_{23}		C_{22}	C_{43}			
RF6	C_{21}	C_{32}	C_{63}	C_{61}			C_{51}			C_{41}	C_{62}	C_{13}
RF7				C_{11}	C_{62}	C_{13}	C_{61}	C_{32}	C_{53}	C_{51}		C_{63}
RF8	C_{41}		C_{23}		C_{32}	C_{43}	C_{31}		C_{13}		C_{12}	C_{33}
RF9		C_{52}	C_{33}	C_{21}				C_{12}	C_{63}	C_{61}		
RF10	C_{31}	C_{42}		C_{51}		C_{53}	C_{41}				C_{22}	C_{23}

t — Time slots

Fig. 7


Speech Generator
Facch Generator
Sacch Generator
Channel Coder
Channel Coder
Channel Coder
Selector
Interleaver 2 Burst
Interleaver 22 Burst
Mod 2 Adder
Control Channel Message Generator
Keyboard Display
μPC
Burst Generator
Sync Word
DVCC
RF Modulator
Power Amplifer
Transmit Freq Synthesizer
Rec Freq Synthesizer
Time Switch
Key
Ciphering
20 ms Frame Counter
Speech Decoder
Facch Detector
Sacch Detector
Channel Decoder
Channel Decoder
Channel Decoder
Deinter-leaver 2 Burst
Deinter-leaver 22 Burst
Mod 2 Adder
Symbol Detector
Control Channel Message Detector
Equalizer
IF Demodulator
RF Demodulator
Signal Level Meter
Receiver
μPC
101
102
103
104
105
106
107
108
109
110
111
112
113
114
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134

Fig. 8

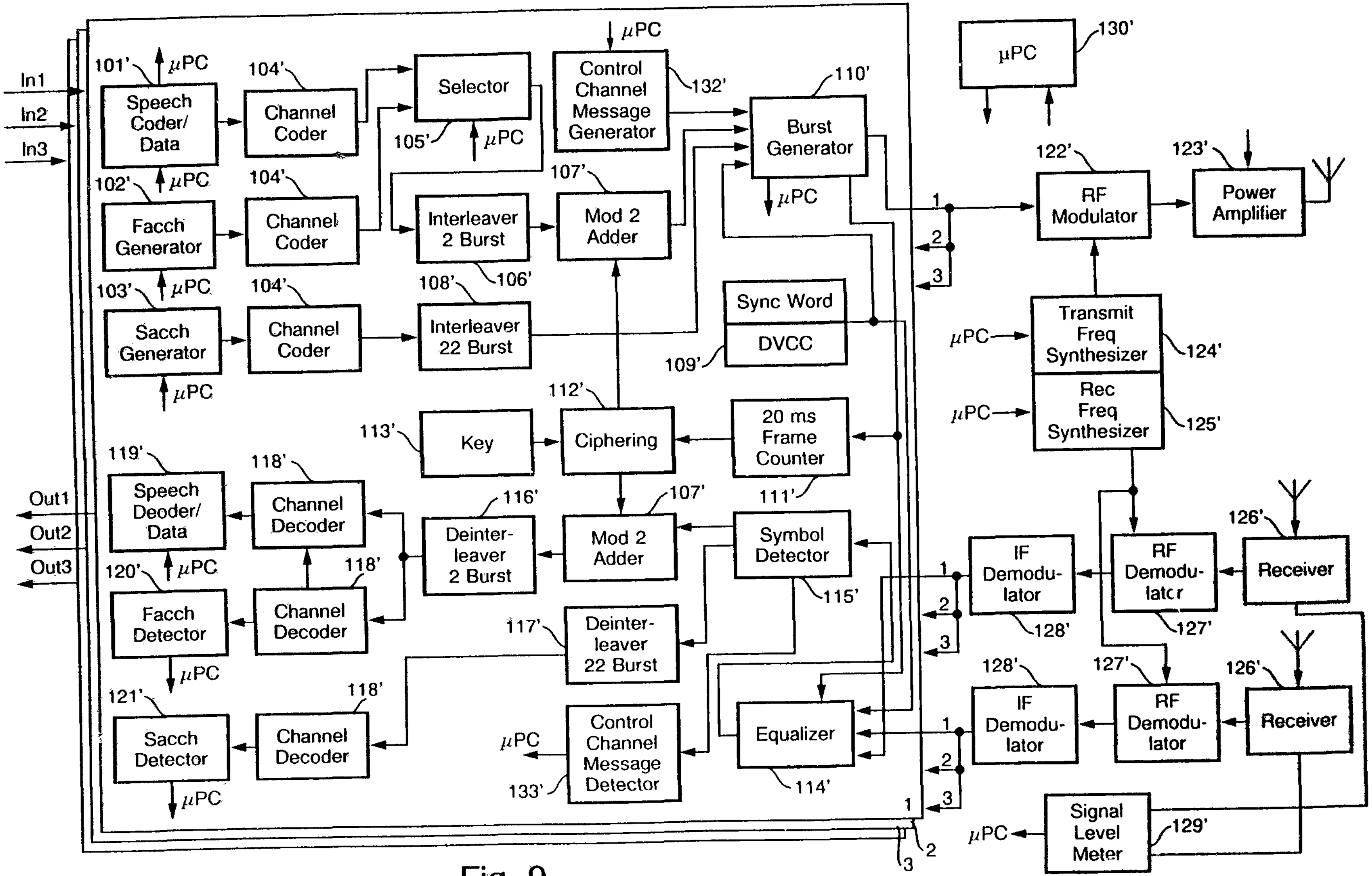
In1
In2
In3
101'
μPC
Speech Coder/ Data
104'
Channel Coder
Selector
105'
μPC
Control Channel Message Generator
132'
110'
Burst Generator
μPC
130'
102'
Facch Generator
104'
Channel Coder
Interleaver 2 Burst
106'
107'
Mod 2 Adder
1
2
3
122'
RF Modulator
123'
Power Amplifier
103'
Sacch Generator
104'
Channel Coder
108'
Interleaver 22 Burst
Sync Word
DVCC
109'
Transmit Freq Synthesizer
124'
Rec Freq Synthesizer
125'
112'
113'
Key
Ciphering
20 ms Frame Counter
111'
119'
Out1
Out2
Out3
Speech Deoder/ Data
118'
Channel Decoder
116'
Deinter-leaver 2 Burst
Mod 2 Adder
Symbol Detector
115'
126'
Receiver
RF Demodu-lator
127'
IF Demodu-lator
128'
120'
Facch Detector
Channel Decoder
117'
Deinter-leaver 22 Burst
121'
Sacch Detector
Channel Decoder
Control Channel Message Detector
133'
Equalizer
114'
Signal Level Meter
129'

Fig. 9

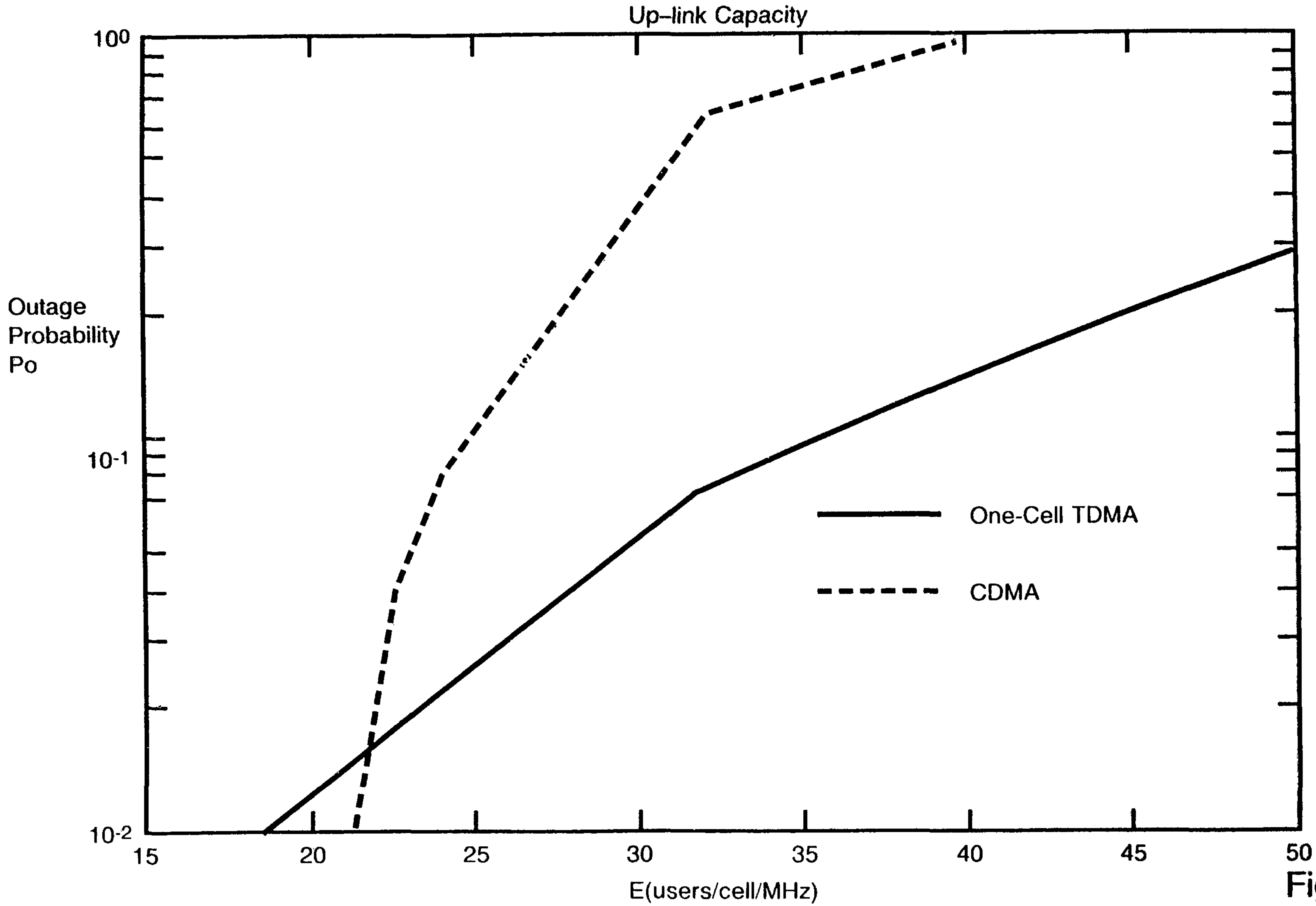
Up–link Capacity
10^0
10^-1
10^-2
Outage
Probability
Po
One-Cell TDMA
CDMA
15
20
25
30
35
40
45
50
E(users/cell/MHz)

Fig. 10

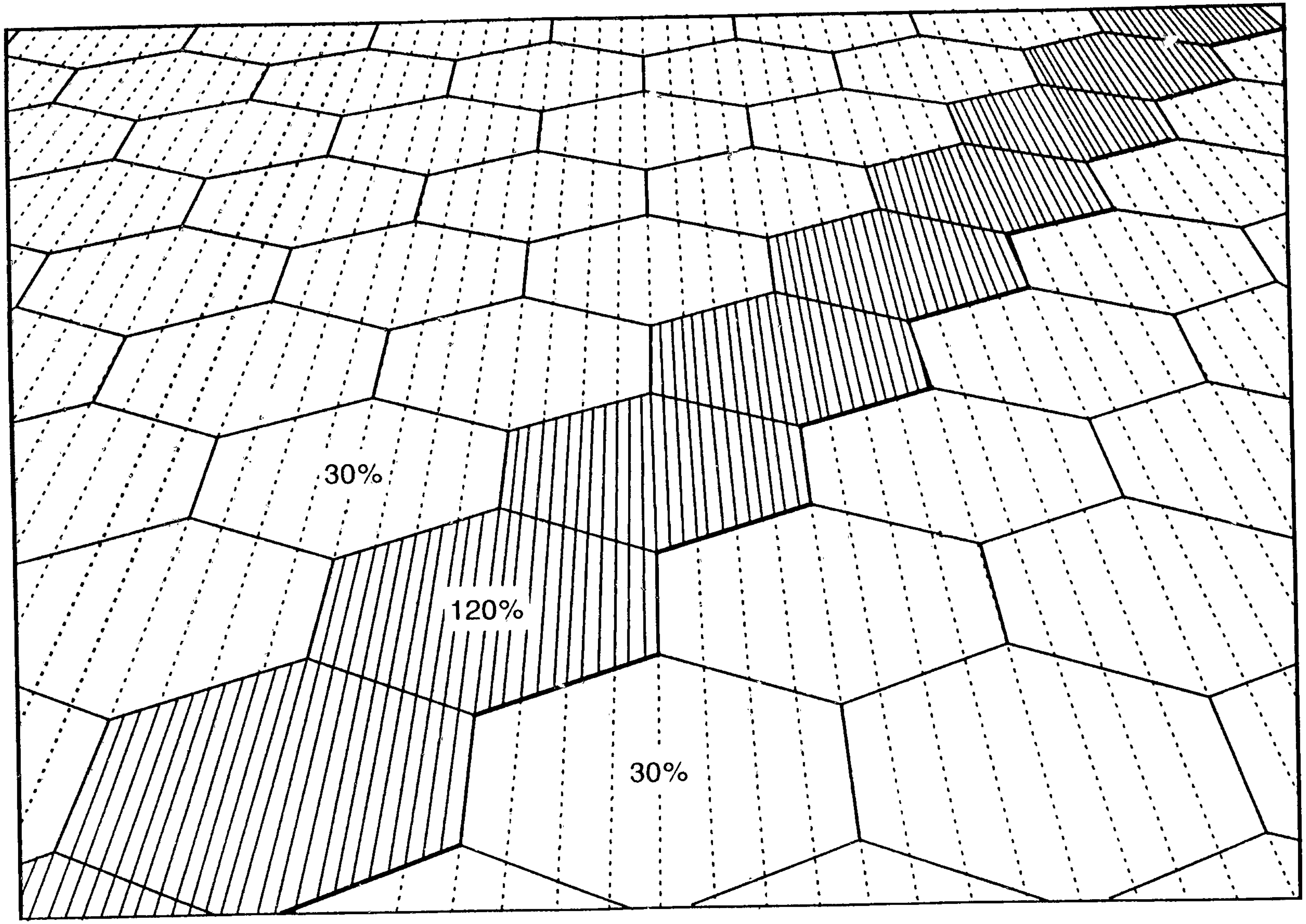

Fig. 11

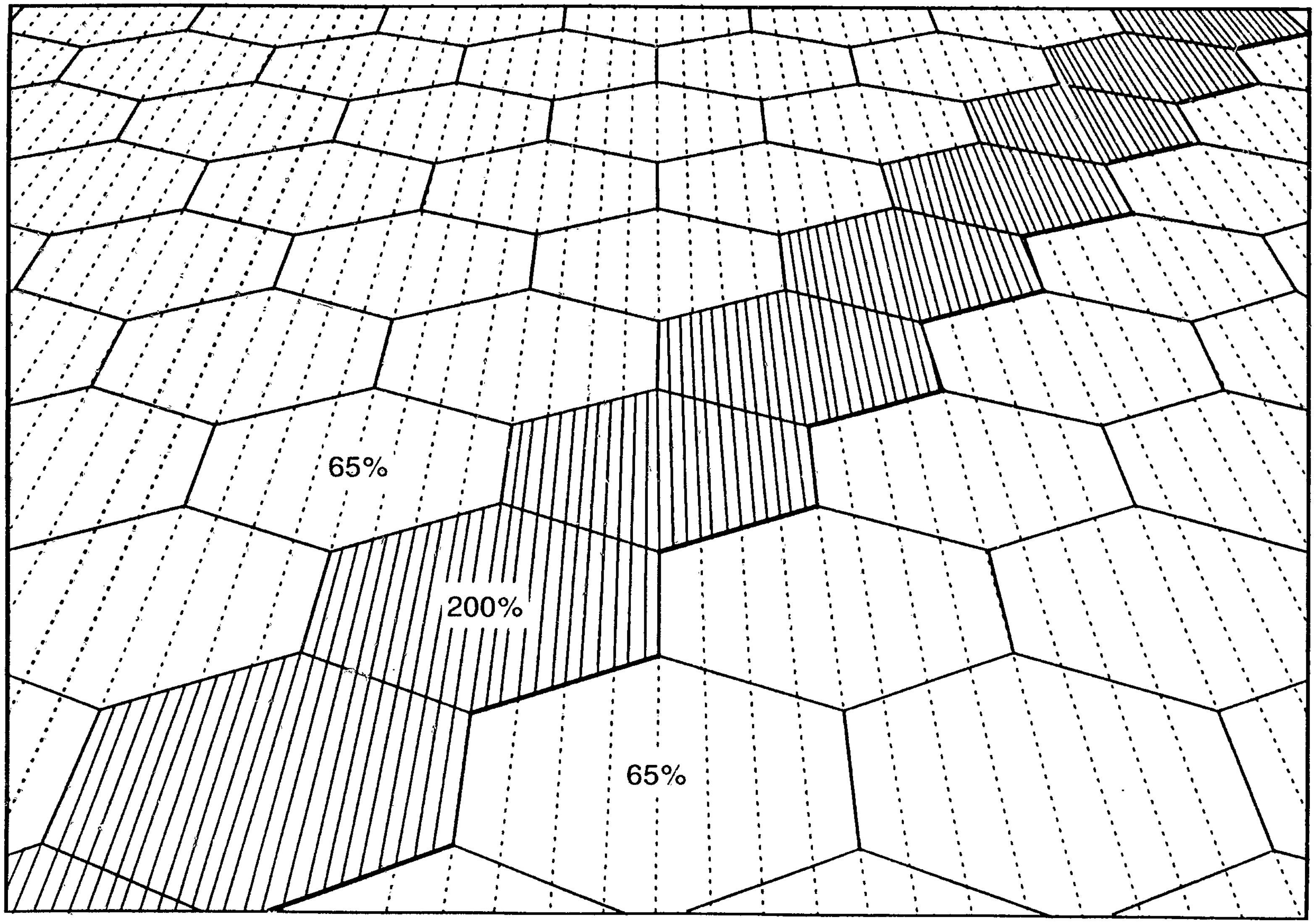

Fig. 12

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE 93/00117

A. CLASSIFICATION OF SUBJECT MATTER

IPC5: H04B 7/26, H04Q 7/00, H04J 4/00

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC5: H04B, H04Q, H04J

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

SE,DK,FI,NO classes as above

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

DIALOG: 125, 340, 351

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO, A1, 9113502 (MOTOROLA, INC.), 5 Sept 1991 (05.09.91), page 4, line 24 - line 35; page 8, line 1 - line 12	1,12-14,25
	--	
A	WO, A1, 9016122 (ITALTEL SOCIETA ITALIANA TELECOMUNICAZIONI S.P.A.), 27 December 1990 (27.12.90), page 3, line 26 - line 34	1,12-14,25
	--	
A	US, A, 4799252 (ALFONS EIZENHÖFFER ET AL), 17 January 1989 (17.01.89), column 5, line 5 - line 19	1,12-14,25
	--	

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

* Special categories of cited documents:

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

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

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

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

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

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

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

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

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
26 April 1993	03 -06- 1993
Name and mailing address of the ISA/ Swedish Patent Office Box 5055, S-102 42 STOCKHOLM Facsimile No. +46 8 666 02 86	Authorized officer Margareta Nylander Telephone No. +46 8 782 25 00

INTERNATIONAL SEARCH REPORT
Information on patent family members

30/04/93

International application No.
PCT/SE 93/00117

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO-A1- 9113502	05/09/91	NONE	
WO-A1- 9016122	27/12/90	EP-A- 0392987	17/10/90
US-A- 4799252	17/01/89	AU-B- 591691	14/12/89
		AU-A- 6059886	05/02/87
		CA-A- 1280228	12/02/91
		DE-A- 3527331	05/02/87
		DE-A- 3685618	16/07/92
		EP-A,B- 0211460	25/02/87