



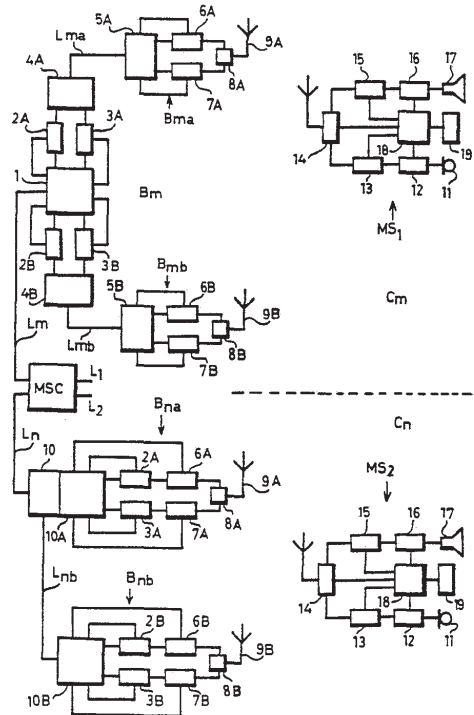
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(54) Title: CELLULAR DIGITAL MOBILE RADIO SYSTEM WITH PLURAL BASE STATION TRANSMITTERS AND METHOD OF TRANSMITTING INFORMATION IN SUCH A SYSTEM

(57) Abstract

The invention relates to a cellular digital mobile radio system including base stations ( $B_m, B_n$ ) and mobile stations ( $MS_1, MS_2$ ) with transmitters and receivers. The invention also relates to a method of transmitting message information digitally between mobile and base stations in such a system. In accordance with the invention, at least two base station transmitters ( $B_{ma}, B_{mb}, B_{na}, B_{nb}$ ) at a given transmitting distance from each other are assigned to each of certain cells ( $C_m, C_n$ ) within a restricted geographical area. The base station transmitters which are assigned to the same cell transmit digitally modulated radio signals within the same frequency range at least partially simultaneously to the mobile stations of the cell. The radio signals from different base station transmitters associated with the same cell are digitally modulated with the same message information to the mobile stations in the cell. Different base station transmitters (9A, 9B) preferably transmit the digitally modulated radio signals with the same message information to a given mobile station with a given mutual transmission time shift. Here, the transmission time shift is selected individually for each mobile station, such that corresponding digitally modulated radio signals with the same message information to a given mobile station from different base station transmitters arrive practically simultaneously at the mobile station.



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Cellular digital mobile radio system with plural base station transmitters and method of transmitting information in such a system

#### TECHNICAL FIELD

The present invention relates to mobile radio systems. More specifically the invention relates to a digital, cellular, mobile radio system. The invention also relates to a method of transmitting information digitally to and from mobile stations in a cellular mobile radio system.

#### BACKGROUND ART

5 The mobile radio systems that were first taken into common use were of analogue type, i.e. message information was transmitted in analogue form to and from mobile stations by transmitting and receiving analogue-modulated radio signals. In such systems it is known to have two or more base station transmitters at a distance from each other simultaneously transmitting radio  
10 signals within the same frequency range and modulated with the same message information to the mobile stations. Such mobile radio systems are described in EP 0040731 and EP 0072479, as well as in the two publications: NTG-Fachberichte, Bewegliche Funkdienste, Vorträge der NTG-Fachtagung vom 25. bis 27 November in Munich, "GLEICHKANALFUNKSYSTEME FÜR DIE FRE-  
15 QUENZÖKONISCHE VERSORGUNG GROSSER GEBIETE" Berndt Heynisch pp 41-46, VDE-VERLAG GmbH, Berlin, Elektrizitätswirtschaft, Jg. 80(1981), Heft 6, pp 187-198 "Quasissynchroner Gleichwellenfunk-ein Gleichkanalfunk-Verfahren zur Erhöhung der Erreichbarkeit in Mobilfunknetzen.

20 In known systems of the kind in question here, it is known to transmit message information from a central station or exchange to the base station transmitters either via cables or radio signals. It is also known to have equalisers in the fixed part of the mobile radio system for equalising differences in propagation time and attenuation in transmission from the exchange to the base station transmitters. The equalisers can be at the exchange and/or at the base station  
25 transmitters. The object of the equalisers is that irrespective of position in relation to the exchange the base station transmitters shall transmit the radio signals simultaneously, and modulated with the same message information.

Digital mobile radio systems in which message information is transmitted digitally to and from mobile stations by transmission and reception of digitally modulated signals have been proposed in US 4675863 and "Digital Mobile Telephone System Using TD/FDMA Scheme", Kota Kinoshita, Masaharu Hata and Kenkichi Hirade, IEEE TRANSACTIONS ON VEHICULAR TECHNOLOGY, 5 VOL. VT-31, NO.4, NOVEMBER 1982, pp 153-157.

It has been proposed to have adaptive equalisers in mobile radio stations in digital radio systems, whereby multi-path propagation of radio signals can be used to improve signal quality, instead of the multipath propagation acting as 10 noise. Among the publications on adaptive equalisers in digital mobile radio systems can be mentioned: "Multi-path Equalization for Digital Cellular Radio Operation at 300 k. bit/s". K Raith, J-E Stjernvall and J Uddenfeldt, 36th IEEE Vehicular Technology Conference, pp 268-272, Dallas, Texas, USA May 1986. "Radio Test Performance of a Narrowband TDMA System", J-E Stjernvall, B. 15 Hedberg, and S Ekmark, IEEE Vehicular Conference, Tampa, Florida, USA, June 1987, RADIO TEST PERFORMANCE OF A NARROWBAND TDMA SYSTEM-DMS 90, J-E Stjernvall, B. Hedberg, K Raith, T Bäckström and R Lofdahl.

#### DISCLOSURE OF INVENTION

In mobile radio systems there are problems due to reflections and radio shadows from natural obstacles such as rocks and hills, as well as structures such as 20 buildings. These problems are especially troublesome in transmitting information requiring great accessibility/reliability and high transmission speed. In particular the problems may become large in certain urban environments where the propagation conditions for radio signals can vary heavily within a small geographic area, while radio traffic is intensive at the same time. Up to now 25 attempts have been made to solve these problems by having adaptive equalisers in the mobile stations and small cells with specially selected positioning of the base station transmitters. In areas with much traffic it is, however, a desire to be able to select the size of the cells and their positions in the mobile radio system cell plan in an optimum way with respect to the traffic handling 30 capacity of the system. Reducing the cell size and selecting the positions of the small cells to avoid radio shadows thus involves a complication. Another complication resulting from the reduction of cell size to below what is necessary for reasons of capacity is that the number of handovers increases.

The object of the invention is to solve the above-mentioned problems and complications, and to provide a method and a cellular digital mobile radio system which are also suitable for transmitting information requiring great accessibility/reliability and high transmission speed.

5       What is distinguishing for a method and a digital cellular mobile radio system in accordance with the invention, and particularly preferred embodiments thereof is disclosed in the independent and dependent claims. Somewhat simplified, it may be said that according to the invention there are utilised at least two base station transmitters for each of a plurality of cells, these transmitters being at  
10       a distance from each other and at least partially simultaneously transmitting radio signals within the same frequency range digitally modulated with the same message information to the mobile stations in the cell. The digital modulation is changed with a modulation time interval which is adapted to the greatest transmitting distance between two base station transmitters serving  
15       the same cell in an area. The mobile stations have adaptive equalizers for reconstructing the digital modulation in the transmitted signals from the signals received during a reception time interval, which is also adapted to the greatest transmitting distance between two base station transmitters serving the same cell in an area.

20       In a preferred embodiment of a method in accordance with the invention, the digitally modulated signals are transmitted with the same message information to a given mobile station with a given, mutual transmission time shift from the different base stations. The transmission shift is then selected such that it counteracts the difference in arrival time for the signals from the different  
25       base station transmitters to this mobile station.

In each mobile station, there is preferably estimated the arrival time shift between the digitally modulated radio signals with the same message information from the different base station transmitters. Information about the estimated arrival time shift at the respective mobile station is transmitted  
30       from there to at least one base station transmitter. This estimated arrival time shift is utilised at the base station for selecting the transmission time shift for at least one base station transmitter. A transmission time shift is thus obtained individually for each affected mobile station, and which is adjusted for this

particular mobile stations's position in relation to the base station transmitters. The amount of transmissions time shift can thus vary from mobile station to mobile station.

5 According a somewhat different, preferred embodiment, there is estimated in different base station receivers the reception time shift between corresponding radio signals with the same message information from the mobile station. This estimated reception time shift is utilised for selecting the transmission time shift between corresponding base station transmitters. A transmission time shift can thus be individually obtained for each affected mobile station such  
10 that it is adjusted to the position of this particular mobile station in relation to the base station transmitters. The amount of transmission time shift can thus vary from mobile station to mobile station.

15 A preferred embodiment of a mobile radio system in accordance with the invention has time measurement means for estimating the mutual reception time shift in a mobile station between, on one hand, digitally modulated radio signals transmitted to the mobile station via a base station transmitter for the cell where this mobile station is, and, on the other hand, corresponding digitally modulated signals transmitted to this station via another base station transmitter for the cell. In this embodiment the mobile radio system has transmission time shifting means for mutually time shifting the transmission times  
20 for base station transmitters of the same cell so that they transmit corresponding digitally modulated signals to the mobile station with greater or less mutual transmission time shifting in response to estimated reception time shift.

25 The time measurement means preferably include arrival time comparison means in at least certain mobile stations, for comparing the arrival times for corresponding digitally modulated signals transmitted from different base station transmitters for the same cell.

30 According to a somewhat different, preferred embodiment, the time measurement means include arrival time comparison means in the stationary part of the mobile radio system, for comparing the arrival times of digitally modulated signals transmitted from a mobile station in a cell and received at different base station transceivers of the cell.

A method and a cellular digital mobile radio system in accordance with the invention provide substantial advantages. The coverage degree can be made greater, signifying better opportunities for establishing new connections and maintaining those already established. The coverage degree can be made greater without the cell size needing to be reduced, which give greater freedom in the selection of cell plan and a lesser number of handovers. In preferred embodiments, the transmission time shift, which is individually selectable for each mobile station, reduces the risk of noise and interruption of calls in progress, when a mobile station goes from receiving signals chiefly from one base station transmitter to receiving signals chiefly from another base station transmitter. When a mobile station simultaneously receives signals from at least two base station transmitters of the same cell, the variable transmission time shift enables the received signals together to be more like the signals obtained from a single base station transmitter in conjunction with reflections.

#### BRIEF DESCRIPTION OF DRAWINGS

Figure 1 illustrates cells and positioning of transmitters in base stations in one embodiment of a mobile radio system in accordance with the invention. Figure 2 illustrates parts of a mobile radio system in accordance with the invention.

#### BEST MODES FOR CARRYING OUT THE INVENTION

A cellular mobile radio system in accordance with the invention has mobile stations and base stations with transmitters and receivers for radio signals. Message information is transmitted digitally to and from the mobile stations by transmission and reception of signals digitally modulated in correspondance with the message information. The radio signals are transmitted on one of a plurality of radio channels. Signals can be transmitted in time multiple to and from several mobile stations on the same radio channel.

The mobile stations move within and between the cells of the system. The base station transmitters are assigned to the cells so that there is at least one base station transmitter for each cell, for transmitting signals to the cell's mobile stations.



Somewhat simplified, there is illustrated in Figure 1 the division of an area into cells and the assignation of base station transmitters to the cells in a mobile telephone system in accordance with the invention. For the sake of simplicity in Figure 1, all cells C1 to C24 are illustrated as regular hexagones with sides L. In practice, the cells will probably have different sizes and shapes. In addition, depending on service conditions, it will often be suitable with overlapping in the boundary areas between the cells. To a certain extent, the base station transmitter can then off-load each other by handling transmission to mobile stations where such transmission should from a purely geographical point of view be performed by the base stations of a contiguous cell.

For each cell C1-C24 there is an ordinary base station transmitter BS1-BS24. For contiguous cells these transmitters are conventionally collocated in groups of three. For example, the base station transmitter BS1 for the cell C1 is collocated with the base station transmitter BS3 for the cell C3 and the base station transmitter BS5 for the cell C5. Correspondingly, the base station transmitter BS14 for the cell C14 is collocated with the base station transmitter BS16 for the cell C16 and with the base station transmitter BS18 for the cell C18. These co-positioned ordinary base station transmitters are situated in the boundary areas between the cells to which they are assigned. For example, the ordinary base station transmitters BS2, BS4 and BS6 are co-located in the boundary areas between the cells C2, C4 and C6.

Further to the ordinary base station transmitters BS1-BS24 the system includes a number of extra base station transmitters for certain of the cells. Cells C6, C7, C10, C11, C13, C14, C19 and C20 each has one extra base station transmitter. For each of the cells C15, C18 and C22 there are two extra base station transmitters. The extra base station transmitters XS6, XS7, XS10, XS11, XS13, XS15A, XS15B, XS18A, XS18B, XS19, XS20 and XS22A are co-located in groups with three extra base station transmitters in each group in a similar manner as the ordinary base station transmitters. Accordingly, for example, the extra base station transmitter XS18B for the cell C15 is co-located with the extra base station transmitter XS19 for the cell C19 and the extra base station transmitter XS18A for the cell C18. On the other hand, neither the extra base station transmitter XS14 for the cell C14 nor the extra base station transmitter XS22B for the cell C22 are co-located with any other base station transmitter,



but are situated approximately at the centre of the cell with which they are associated.

5 An extra base station transmitter does not need to differ technically from an ordinary base station transmitter. For a given cell an extra base station transmitter can thus have technical equipment of the same type as an ordinary base station transmitter for the same cell. In principle it can also function in the same way as the ordinary one. If there are two identical base station transmitters for a given cell, in certain cases either of them may be respectively regarded as ordinary or extra.

10 The extra base station transmitter or transmitters for a given cell transmit radio signals which are substantially the same as those sent by the ordinary base station transmitter of the cell. The radio signals are digitally modulated with digital message information to the mobile stations in the cell. A mobile station in a cell for which there is one or more extra base station transmitter can therefore receive, at least in certain cases, corresponding radio signals from more than one base station transmitter approximately simultaneously within the same frequency range (radio channel). Depending on the mutual, relative positions in the cell of the mobile and base stations as well as the transmission times and propagation paths of the radio signals from the base station transmitters to the mobile stations, corresponding radio signals from different base station transmitter can be received without, or with a given time shift at the mobile station. The greater is the distance between the base station transmitters associated with the cell, the greater in general can be the time shift. When the ordinary base station transmitters and the extra base station transmitters are situated according to Figure 1, the distance between two base station transmitters for the same cell varies between L and 2L, i.e. between the side and diameter of the regular hexagones. If, for the sake of simplicity, reflections are ignored and the assumption made that the transmitters transmit without mutual time shifting, the time reception shift at the mobile station could then attain a maximum of  $2L/c$ , where c is the propagation speed of the radio signals. C is approximately 300000 km/s.

In Figure 2 there are illustrated parts of a mobile radio system in accordance with the invention. A mobile radio exchange MSC is connected via cables  $L_1$ ,

$L_2, \dots, L_m, L_n$  to a plurality of base stations, of which two,  $B_m$  and  $B_n$  are illustrated in the Figure.

The base station  $B_m$  has a central unit connected via cables  $L_{ma}$  and  $L_{mb}$  to two transceiver units  $B_{ma}$  and  $B_{mb}$  situated at a distance from the central unit.  
5 The central unit of the base station  $B_m$  includes a central line and control unit 1, transmission time shifting means 2A and 2B, one for each of the transceivers, reception time shifting means 3A and 3B, one for each of the transceivers and line units 4A and 4B, one for each of the transceivers.

Both transceivers in the base station  $B_m$  are alike. Each such transceiver  
10 contains a line and control unit 5A or 5B, transmitter means 6A or 6B, receiver means 7A or 7B, a transmission-reception filter 8A or 8B and an antenna 9A or 9B.

The base station  $B_n$  differs partly from station  $B_m$ , primarily due to its central line and control unit 10 being situated in connection with one of its transceivers  
15  $B_{na}$ . Accordingly, no cable with associated line units corresponding to  $L_m, L_{mb}, 4A-5B$  is needed for the transceiver  $B_{na}$ , but only to the other transceiver  $B_{nb}$ . In addition, no transmission or reception time shifting means are included in any central unit in  $B_n$ , but the corresponding means 2A, 2B, 3A and 3B are respectively included in transceivers  $B_{na}$  and  $B_{nb}$ .

20 The mobile stations  $MS_1$  and  $MS_2$  are mutually alike. Each mobile station includes sound sensing means 11, encoding means 12, transmitting means 13, transmit-receive switch 14, reception means 15, equaliser and decoding means 16, sound reproducing means 17, control means 18 and means 19 for feeding in our out or presentation of digital information.

25 Apart from the base stations having two transceiver units at a distance from each other, and having controllable transmission and reception time shifting means, the mobile radio system in Figure 2 functions in most respects in a way well-known in cellular mobile radio systems. No complete description of how the system functions in different respects should therefore be necessary for one  
30 skilled in the art, and it should only be necessary to describe what is unique or unusual in the cellular mobile radio system according to Figure 2. One not

skilled in the art of cellular mobile radio systems is referred to the technical literature and to the publications mentioned under the section "Background Art".

5 Message information that the mobile radio exchange forwards to a mobile station in the cell  $C_m$ , e.g. the station  $MS_1$ , is transmitted from the mobile radio exchange via the cable  $L_m$  to the line and control unit 1. From the line and control unit 1 the information is transferred via the transmission time shifting means 2A, line unit 4A, cable  $L_{ma}$  and line and control unit 5A to the transmitting means 6A. The transmitting means transmits via the transmission  
10 reception filter 8A and antenna 9A radio signals with digital modulation in correspondance with the message information from the mobile radio exchange.

The message information from the mobile radio exchange is also transferred from the line and control unit 1 via the transmission time shifting means 2B, line unit 4B, cable  $L_{mb}$  and line and control unit 5B to the transmission means  
15 6B in the transceiver  $B_{mb}$ . The transmission means 6B transmits via the transmission reception filter 8B and antenna 9B radio signals with digital modulation in correspondance with the information from the mobile radio exchange.

Depending on the delay in transferring the message information to the  
20 transmission means 6A and the corresponding delay in transferring to the transmission means 6B the radio signals can be transmitted from the antenna 9A of the transceiver unit  $B_{ma}$  substantially without time shifting, or time shifted in relation to the transmission of corresponding radio signals from the antenna 9B of the other transceiver  $B_{mb}$ .

25 The signals from the antenna 9A in  $B_{ma}$  arrive at a given mobile station in the cell  $C_m$ , e.g. the mobile station  $MS_1$ , with or without time shift in relation to corresponding radio signals from the antenna 9B in  $B_{mb}$ . The possible time shift on arrival at the mobile station depends partly on possible time shifting at transmission from the antennas and partly on possible difference in propagation  
30 time for the radio waves from the antennas. The transmission time shifting means 2A and 2B have a variable delay and can be controlled by the line and control unit 1, such that the radio signals are transmitted from the antenna 9A

in  $B_{ma}$  time-shifted more or less before or after corresponding radio signals from the antenna 9B in  $B_{mb}$ . In the preferred embodiment according to Figure 2, the line and control unit 1 controls the variable delays in the transmission time shifting means 2A and 2B so that the differences in delay in the cables  $L_{ma}$  and  $L_{mb}$  as well as the differences in the radio signal propagation times are counteracted. This may also be expressed by saying that the line and control unit controls the variable delays in the transmission time shifting means 2A and 2B, such that the time shift of the radio waves on arrival at the mobile station is decreased compared if the means 2A and 2B had the same fixed delay. It could be thought that the ideal case were that the line and control unit controlled the delays in the time shifting means 2A and 2B so that the digitally modulated radio signals transmitted from the antenna in  $B_{ma}$  arrived at the antenna in  $MS_1$ , exactly simultaneously and in phase with corresponding radio signals transmitted from the antenna in  $B_{mb}$ . In practice, this is neither striven for nor achieved. Reflections occur in the propagation of the radio signals between the antennas, and the mobile station has an adaptive equaliser. It is therefore not necessary for the signals from the different transceiver units to arrive exactly simultaneously to the mobile station. On the contrary, there is preferably sought a small time shift to achieve diversity against Rayleigh fading. One not skilled in this art and who is desirous of obtaining further information can find it in the publications mentioned in the section "Background Art", e.g. "Radio Test Performance of a Narrow-band TDMA System-DMS 90".

In principle, there are at least two conceivable methods of determining how the line and control unit 1 may control the delay in the transmission time shifting means 2A and 2B. One method is to estimate in the fixed part of the mobile radio system the time shift between the mobile station radio signals at one of the transceivers  $B_{ma}$  and the corresponding radio signals at the other transceiver  $B_{mb}$ . There is thus obtained an estimation of the differences in propagation time to the mobile station, these differences depending on the position of the mobile station. Remaining differences in delay are related to the fixed part of the mobile radio system, e.g. differences in length of the cables  $L_{ma}$  and  $L_{mb}$  and are not dependent on the position of the mobile station. In the embodiment according to Figure 2, this method can be applied in practice such that the delays in the reception time shifting means 3A and 3B are adjusted so that information received from the mobile station  $MS_1$  at  $B_{ma}$

arrives at the line and control unit 1 simultaneously as corresponding information received at  $B_{mb}$  from the mobile station  $MS_1$  arrives at the line and control unit 1. The delays in the transmission time shifting means 2A and 2B are subsequently adjusted in correspondence with the optimum delays in the reception time shifting means 3A and 3B.

The other method is to estimate in the mobile station the difference in arrival time or time shift between the digitally modulated radio signals from one transceiver  $B_{ma}$  and the corresponding digitally mobile radio signals from the other transceiver  $B_{mb}$ . Some kind of encoding of the radio signals is required for this, which indicates from which transceiver they are transmitted. In TDMA systems it is known to transmit special synchronising words. These can be utilised if they are formed or supplemented so that two base station transmitters for the same cell do not only have identical synchronising words. Alternatively, radio signals digitally modulated with special synchronising words can be transmitted from the base station transmitters solely to enable the mobile station to estimate the differences in arrival times or time shifts. The mobile station transmits information about the estimated arrival time difference or time shift via radio signals to the fixed part of the system, where it is utilised for controlling the transmission time shifting means 2A and 2B. The line and control unit 1 then receives, via the respective line units 5A, 4A and 5B, 4B, information about estimated arrival time difference from the mobile station in the same way as the line and control unit obtains message information from the mobile station.

It is conceivable per se, but hardly to be preferred, to combine both methods for controlling the transmission time shift in a mobile radio system according to Figure 2.

Measuring the difference in arrival time or time shifting for corresponding radio signals can be performed in a conventional way, e.g. with the aid of correlation. In the cases where the radio signals conventionally contain predetermined synchronising patterns (words), the time difference between these patterns (words) in different signals can be measured using conventional methods. A mobile station control means 18 and/or a base station line and control unit 1,9 possible in combination with the transceivers' line units 5A and 5B can then

comprise time measurement means for estimating reception time shifting or the arrival time comparison means for comparing arrival times.

When so required, a base station preferably utilises conventionally the same transmitter means and antenna for transmitting, in time multiplex within the same frequency range on the same radio channel, radio signals digitally modulated with message information to different mobile stations associated with the same cell. The radio signals with information to a given mobile station are then transmitted from different base station transmitter with a possible transmission time shift which is specially adjusted with regard to the position of this particular mobile station. The case can arise where a base station in a mobile radio system needs to transmit a radio signal with information intended for reception by several or all of the mobile stations in the cell, e.g. information as to the identity of the base station/cell. Such signals are preferably transmitted without mutual time shifting from the transceivers  $B_{ma}$ ,  $B_{mb}$  and  $B_{na}$ ,  $B_{nb}$  of the base stations in a mobile radio system according to Figure 2. The transmission time shifting means are then controlled to a balancing state where the delay of information from the line and control unit 1 to the antenna in one transceiver  $B_{ma}$  is equally as great as the delay of information from the line and control unit 1 to the antenna in the other transceiver  $B_{mb}$ . The corresponding situation can apply when a base station "listens" in unoccupied combinations of time slot and frequency range channel for calls from mobile stations of unknown positions relative to the transceivers of the base stations. The reception time shifting means 3A and 3B can then be controlled to a balancing state where the delay of the message information from the antenna in one transceiver  $B_{na}$  to the line and control unit 9 is equally as great as the delay of information from the antenna in the other transceiver  $B_{nb}$  to the line and control unit 9.

The mobile stations  $MS_1$  and  $MS_2$  have adaptive equalisers, whereby the digital modulation during a modulation time interval in the radio signals transmitted from a base station transmitter can be reconstructed from signals received during a reception time interval. In known cellular digital mobile radio systems with only one base station transmitter per cell, the reception time interval of the equalisers is dimensioned according as the dispersion on the radio channel, i.e. expected time shifts between corresponding signals from a single base



station transmitter due to multipath propagation and reflections. Because of the equaliser, not only the radio signal having the greatest amplitude or arriving first to the mobile station is utilised for reconstructing the digital modulation, but also other corresponding radio signals arriving with a time shift within the extent of the equaliser's reception time interval can be utilised. The mobile stations in a system in accordance with the invention have equalisers which are dimensioned such that the reception time interval of the mobile station in reconstruction of the digital modulation is greater than the time it takes for signals to propagate a distance as long as the greatest distance between two base station transmitters associated with the same cell within a restricted geographical area. With the base station transmitters placed according to Figure 1, and the restricted area being the area composed of the cells C1 to C24, the mobile station equalisers would thus be dimensioned for a reception interval of reconstruction which is greater than  $2L/c$ . Taking into account that there can be dispersion, and that reflections can extend the propagation time from base station transmitter to a mobile station more than the extension of the propagation time from another base station transmitter for the same cell, the reception time interval of the mobile stations is preferably substantially greater than the time it takes for radio signals to propagate a distance which is just as great as the greatest distance between two base station transmitters associated with the same cell within the geographical area in question.

In prior art mobile radio systems it is known to have cells of small size in city areas or densely populated areas with many calls per hour and to have cells of large size in rural areas with few calls per hour. Outside the restricted geographical area composed of cells C1 to C24 in figure 1 there might be cells of greater size than that of C1 to C24. Occasionally such cells may have plural base stations transmitting the same information for overcoming radio shadows from mountains. A mobile radio according to the present invention may be used outside the restricted area and in such a cell but the advantages conferred by the invention can not be expected if the transmission distance between the transmitters assigned to such a cell is too great in relation to the reception time interval.

In mobile radio systems in accordance with the invention, the modulation time interval of the digital modulation of the signals can be of the same order of



magnitude as the time it takes for radio signals to propagate a distance just as long as the greatest transmitting distance between two base station transmitters serving the same cell within a particular area. Although the invention affords greater advantages the smaller the modulation time interval is in relation to this propagation time, and the invention has its greatest importance when the modulation time interval is less than the mentioned propagation time, the invention can mean substantial advantages even when the modulation time interval is some few times greater than the mentioned propagation time.

It is conceivable to use different kinds of digital modulation in a mobile radio system, whereby somewhat different relationships can exist between information transmission rate and modulation time interval. In digital modulation of the radio signals involving transmission of one symbol at a time of a sequence of uncorrelated symbols, the modulation time interval will be the time during which a single symbol is decisive for the modulation. For example, if a sequence of binary symbols individually and one at a time determine the modulation, the modulation time interval will be the time during which one symbol determines the modulation. This can also be expressed by saying that the modulation time interval will be the inverted value of the transmission rate in bits. In digital modulation of the signals involving two or more at a time of a sequence of digital symbols being decisive for the modulation during wholly or partly overlapping times, the modulation interval can be the time when a preceding, but not the nearest subsequent symbol affects the modulation. For example, in digital modulation according to SE 8102802-9, Figures 1-2, a symbol affects the phase of a carrier wave during a time interval  $3T$ . The nearest preceding symbol also affects the phase change of the carrier wave during a first part  $2T$  of the time interval  $3T$ . The nearest subsequent symbol also affects the change of phase of the carrier wave during a last part of  $2T$  of the time interval  $3T$ . In this case the modulation time interval will be  $T$ , which agrees with what is called the symbol time interval in SE 8102802-9. In general, it can be said that the modulation time interval is to be interpreted as the interval in time between two successive changes in the transmitted digital modulation.

A method and a cellular digital mobile radio system in accordance with the invention is not restricted to the described embodiments, and can be modified within the scope of the claims. For example, it is conceivable to co-locate at

least parts of the equipment in an ordinary base station transmitter, with parts of the equipment in the extra base station transmitter for the same cell, providing that their antennas are spaced from each other. In an extreme case it is conceivable in principle to have all equipment except the antennas co-located in one place, e.g. in the vicinity of one of the antennas, and that the antenna are fed with radio frequency signals by cable from this position. By "base station transmitter" is there fore meant at least a transmitter antenna for radio signals and preferably more or fewer of the remaining means required in a base station. In a base station transmitter there are preferably included at least means corresponding to 6A and 6B included in a transceiver unit  $B_{ma}$  or  $B_{mb}$  in Figure 2.

## CLAIMS

1. A method in a cellular mobile radio system, of transmitting message information digitally between mobile radio stations ( $MS_1, MS_2$ ) and base stations (BS, BX) associated with the cells (C1, C2,....), radio signals with digital modulation in correspondence with the message information being transmitted and received by transmitters and receivers in the mobile and base stations, where the digital modulation of the radio signals transmitted from the base stations is reconstructed in the mobile stations from received radio signals with the aid of equalizers, characterised in that to mobile stations within one of a plurality of cells within a restricted area there are transmitted digitally modulated signals with the same information from at least two base station transmitters (9A or  $B_{ma}$  or  $B_{na}$ , 9B or  $B_{mb}$  or  $B_{nb}$ ) at a given transmitting distance from each other, these digitally modulated radio signals being transmitted at least partially simultaneously and within the same frequency range from both the transmitters of the base stations, in that on transmission of message information the digital modulation of the radio signals is changed with modulation time intervals, said modulation time intervals being shorter than the time for the radio signals to propagate a distance which is just as long as the greatest transmitting distance (21) between two base station transmitters (9A, 9B) associated with the same cell in the area, in that for reconstructing the digital modulation there are utilised in the mobile station radio signals received during a reception time interval, said reception time interval being at least equally as long as the time it takes for signals to propagate a distance which is just as long as the greatest transmitting distance (21) between two base station transmitters (9A, 9B) associated with the same cell in the area.

2. A method as claimed in claim 1, characterized in that the digitally modulated radio signals with the same message information are transmitted from the different base station transmitters ( $B_{ma}, B_{mb}$ ) to a given mobile station ( $MS_1, MS_2$ ) with mutually variable transmission time shifting, and in that said transmission time shifting is selected such that it counteracts the differences in propagation time for the signals from the different base station transmitters (9A, 9B) to the mobile station ( $MS_1, MS_2$ ).

3. A method as claimed in claim 2, characterized in that the arrival time shift between the digitally modulated radio signals with the same message information from the different base station transmitters is estimated at the mobile station ( $MS_1, MS_2$ ), in that information on the estimated arrival time shift is transmitted from the mobile station to at least one base station ( $B_m$ ), and in that the estimated arrival time shift is utilised for selecting transmission time shifting for at least one base station transmitter ( $B_{ma}, B_{mb}$ ).
4. Method as claimed in claim 2, characterized by estimation of the reception time shift between reception by different base station receivers (7A, 7B) of corresponding radio signals with the same message information from the mobile station, and by said reception time shift being utilised for selecting the transmission time shift for corresponding base station transmitters ( $B_{na}, B_{nb}$ ).
5. A cellular mobile radio system with mobile stations ( $MS_1, MS_2$ ) movable within and between the cells ( $C_1, C_2...$ ) and base stations ( $BS_1, BS_2...$ ) assigned to the cells for digital transmission of message information, said mobile and base stations including transmitters (6A, 13) and receivers (7A, 15) for radio signals with digital modulation in correspondence with said message information, said transmitters changing the digital modulation with modulation time intervals on transmission of said message information, said receivers including equalizers (16) for reconstructing from received radio signals the digital modulation in transmitted radio signals, characterized in that at least two base station transmitters are assigned to each of at least certain cells ( $C_m, C_n$ ) within a limited geographical area, said at least two base station transmitters being disposed a given transmitting distance ( $L, 2L,...$ ) from each other and transmitting at least partially simultaneously digitally modulated radio signals within the same frequency range with the same message information to the mobile stations within the cell, said at least two base station transmitters having modulation time intervals which are shorter than the time it takes for signals to propagate a distance which is just as long as the greatest transmitting distance (21) between two base station transmitters associated with the same cell in the area, and in that the equalizers in the receivers of the mobile stations are disposed for reconstructing the digital modulation from radio signals received during a time interval which is at least equally as long as the time it takes for radio signals to propagate a distance which is just as great as

the greatest transmitting distance between two base station transmitters associated with the same cell in the area.

5 6. A mobile radio system as claimed in claim 5, characterized by time measurement means (18) for estimating mutual reception time shifting in a mobile station, ( $MS_1$ ) between, on the one hand, digitally modulated radio signals transmitted to the mobile station via a base station transmitter ( $B_{ma}$ )  
10 for the cell ( $C_m$ ) where the mobile station is, and, on the other hand, corresponding digitally modulated radio signals transmitted to the mobile station ( $MS_1$ ) via another base station transmitter ( $B_{mb}$ ) for the cell ( $C_m$ ), and by transmission time shifting means (2A, 2B) for mutually time shifting the transmission times for the base station transmitters ( $B_{ma}$ ,  $B_{mb}$ ) for the same  
15 cell ( $C_m$ ) such that they transmit corresponding digitally modulated radio signals to the mobile station with greater or less mutual transmission time shifting in response to estimated reception time shifting.

5 7. A mobile radio system as claimed in claim 6, characterized in that the time measurement means include arrival time comparison means (18), at least in certain mobile stations, for comparing the arrival times for corresponding digitally modulated radio signals transmitted from different base station transmitters (9A, 9B) for the same cell.

5 8. A mobile radio system as claimed in claim 6, characterized in that the time measurement means include arrival time comparison means (1,9) in the stationary part of the mobile radio system, for comparing the arrival times for digitally modulated radio signals transmitted from a mobile station ( $MS_2$ ) in a  
5 cell ( $C_n$ ) and received at different base station transceivers ( $B_{na}$ ,  $B_{nb}$ ) associated with the cell.

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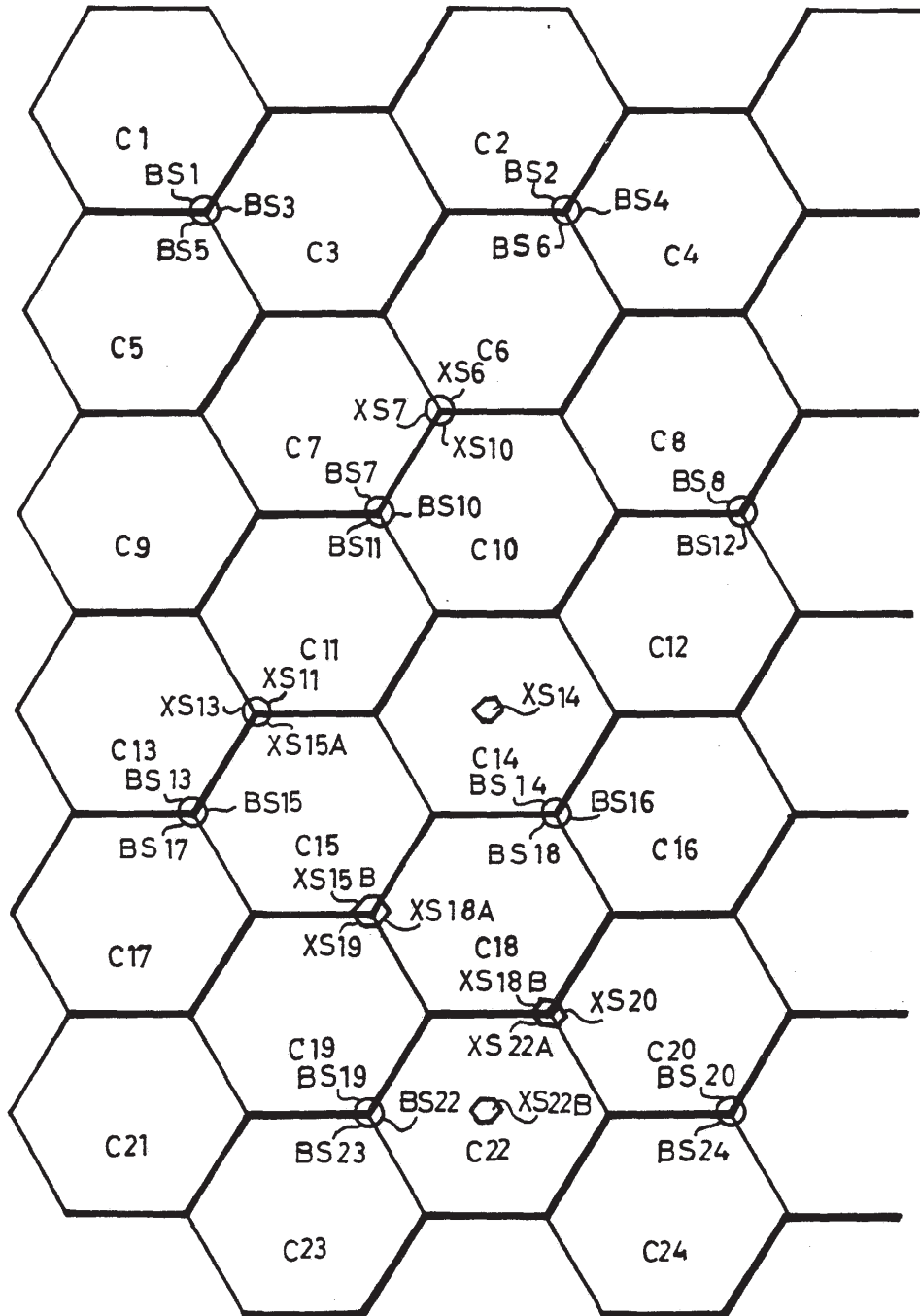


Fig.1

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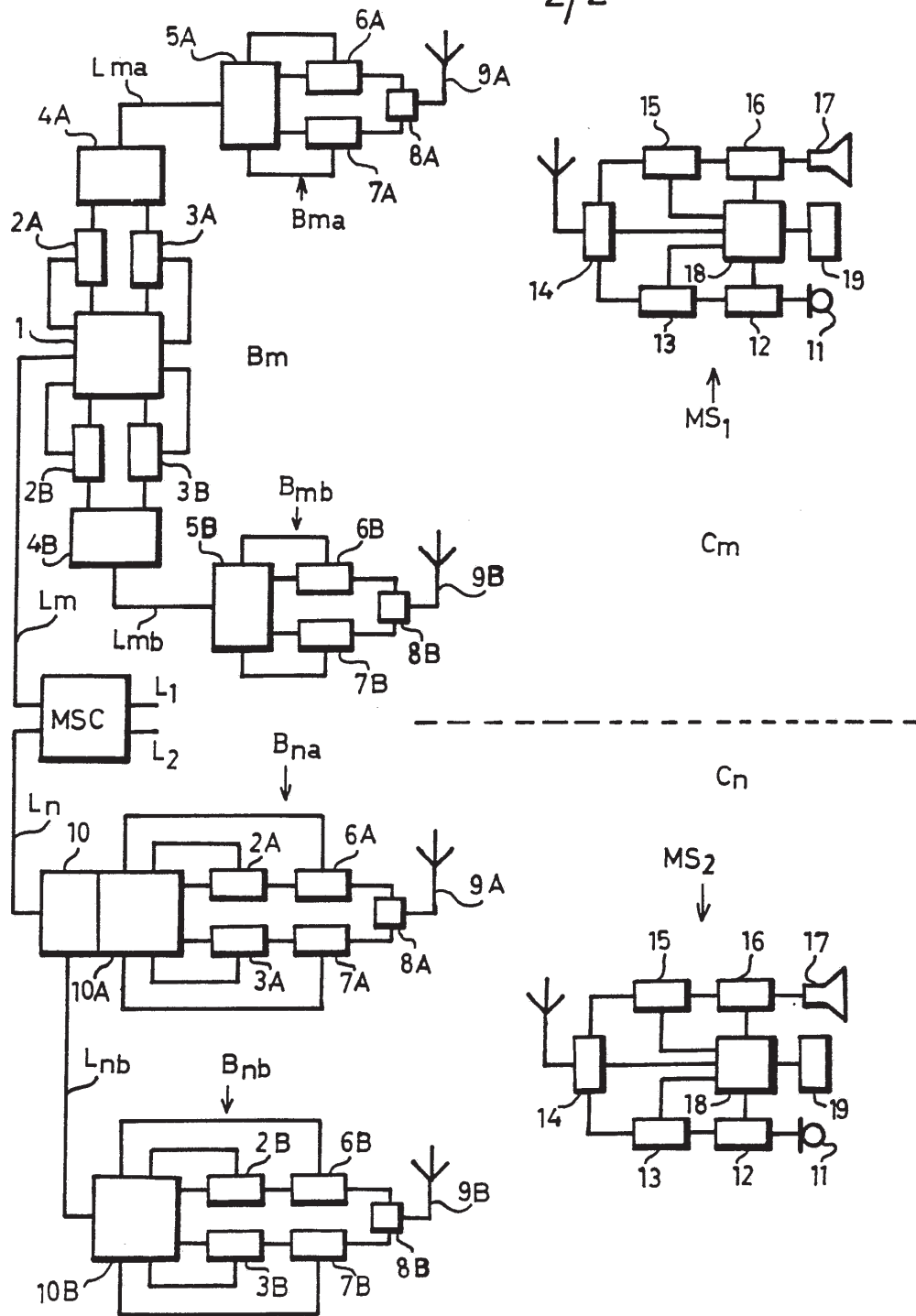



Fig.2



# INTERNATIONAL SEARCH REPORT

International Application No PCT/SE 89/00049

<b>I. CLASSIFICATION OF SUBJECT MATTER</b> (if several classification symbols apply, indicate all) <sup>6</sup>		
According to International Patent Classification (IPC) or to both National Classification and IPC IPC4: H 04 B 7/26, H 04 H 3/00		
<b>II. FIELDS SEARCHED</b>		
Minimum Documentation Searched <sup>7</sup>		
Classification System	Classification Symbols	
IPC4	H 04 B, H 04 H, H 04 L	
Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched <sup>8</sup>		
SE, NO, DK, FI classes as above		
<b>III. DOCUMENTS CONSIDERED TO BE RELEVANT<sup>9</sup></b>		
Category <sup>10</sup>	Citation of Document, <sup>11</sup> with indication, where appropriate, of the relevant passages <sup>12</sup>	Relevant to Claim No. <sup>13</sup>
A	DE, A1, 3022425 (LOGEMANN) 24 December 1981, see the whole document --	1
A	US, A, 4696051 (R.L. BREEDEN) 22 September 1987, see abstract --	1
A	US, A, 4255814 (J.L. OSBORN) 10 March 1981, see abstract --	1
A	US, A, 4718109 (R.L. BREEDEN ET AL) 5 January 1988, see abstract --	1
A	US, A, 4516269 (J.V. KRINOCK) 7 May 1985, see abstract --	1
<p><sup>10</sup> Special categories of cited documents: <sup>10</sup></p> <p>"A" document defining the general state of the art which is not considered to be of particular relevance</p> <p>"E" earlier document but published on or after the international filing date</p> <p>"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)</p> <p>"O" document referring to an oral disclosure, use, exhibition or other means</p> <p>"P" document published prior to the international filing date but later than the priority date claimed</p> <p>"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</p> <p>"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step</p> <p>"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.</p> <p>"&amp;" document member of the same patent family</p>		
<b>IV. CERTIFICATION</b>		
Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report	
1989-05-11	1989-05-17	
International Searching Authority	Signature of Authorized Officer	
Swedish Patent Office	 Bengt Jonsson	

Form PCT/ISA/210 (second sheet) (January 1985)

III. DOCUMENTS CONSIDERED TO BE RELEVANT (CONTINUED FROM THE SECOND SHEET)		
Category *	Citation of Document, with indication, where appropriate, of the relevant passages	Relevant to Claim No
A	EP, A1, 0072984 (NEDTWIG) 2 March 1983, see the whole document --	1-2,4,5-6, 8
A	EP, A1, 0040731 (BURK) 12 February 1981, see abstract -- -----	1

**ANNEX TO THE INTERNATIONAL SEARCH REPORT  
ON INTERNATIONAL PATENT APPLICATION NO. PCT/SE 89/00049**

This annex lists the patent family members relating to the patent documents cited in the above-mentioned international search report.

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
DE-A1- 3022425	24/12/81	EP-A-B- 0042144 AT-E- 7557	23/12/81 15/06/84
US-A- 4696051	22/09/87	NONE	
US-A- 4255814	10/03/81	NONE	
US-A- 4718109	05/01/88	NONE	
US-A- 4516269	07/05/85	NONE	
EP-A1- 0072984	02/03/83	DE-A- 3133120	03/03/83
EP-A1- 0040731	12/02/81	DE-A- 3020176	03/12/81