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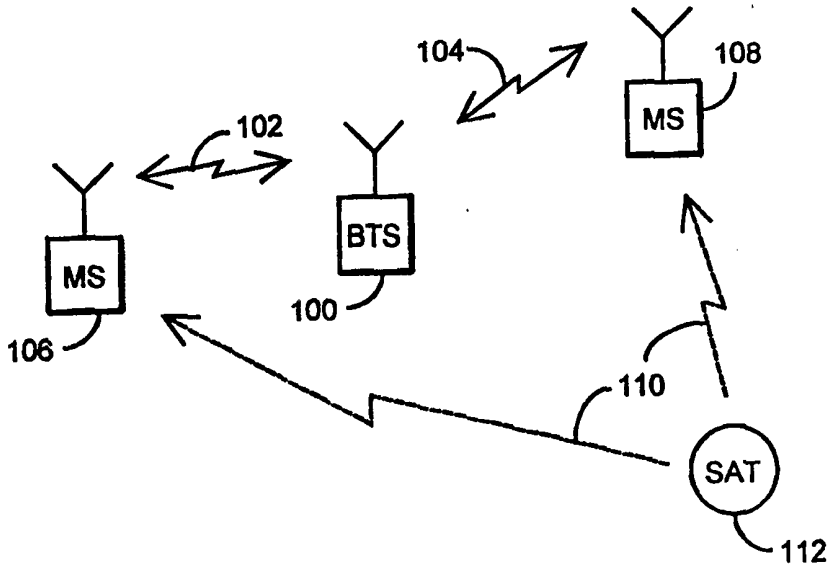
(57) Abstract

The invention relates to a mobile telephone system comprising a number of coverage areas, each coverage area being served by at least one base station (100), a number of subscriber terminals (106, 108) communicating with one or more base stations, and from which terminals at least some are arranged to determine their geographical location and to inform the base station of the location. The terminals are arranged to inform the base station of their geographical location at certain intervals. To improve the call set–up quality of the terminal, the base station is arranged to store one or more location information items transmitted by each terminal, and to determine the direction of travel and the speed of the terminal on the basis of the location information transmitted by the terminal.



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DETERMINATION OF THE GEOGRAPHICAL LOCATION OF A MOBILE TERMINAL IN A MOBILE TELEPHONE SYSTEM

FIELD OF THE INVENTION

The invention relates to a mobile telephone system comprising a number of coverage areas, each coverage area being served by at least one base station, a number of subscriber terminals communicating with one or more base stations, and from which terminals at least some are arranged to determine their geographical location and to inform the base station of the location.

BACKGROUND OF THE INVENTION

A typical mobile telephone system covers a wide geographical area and comprises several coverage areas, or cells, each being normally served by one base station. A cell size varies greatly, generally according to the volume of call traffic within the area. The cells are generally smaller in high traffic density areas than in regions where fewer calls are set up. Irrespective of the cell size, situations often occur where it is useful to know the geographical location or the direction of travel of a mobile telephone.

Several different methods have been provided in order to determine the geographical location of terminals. The distance between the terminal and the base station communicating with it can be easily determined on the basis of the propagation delay of a signal. One of the most commonly used methods is called triangulation, in which three or more base stations measure the signal of the terminal, and the location of the terminal is calculated on the basis of the propagation delay of the signals. However, the location of the terminal cannot be detected very accurately on the basis of the triangulation, and, consequently, the location information so obtained cannot therefore be utilized in applications requiring accurate geographical location parameters.

The direction of travel of a terminal has previously been determined on the basis of successive signal strength measurements made by the base station or the terminal. The direction of travel can also be estimated on the basis of the triangulation. These means cannot fully describe the actual direction of travel and the speed.

US 5546445 discloses a solution in which a mobile telephone comprises a GPS receiver by means of which the mobile telephone determines its location using a satellite positioning system. In the disclosed solution, the location information is utilized in call invoicing.

Existing mobile telephone systems have not been able to efficiently utilize the location information in call maintenance.

BRIEF DESCRIPTION OF THE INVENTION

An object of the invention is to provide a mobile telephone system so as to solve the above mentioned problems. This is achieved by a mobile telephone system of the type presented in the introduction, which is characterized in that the terminals are arranged to inform the base station of their geographical location at certain intervals, the base station is arranged to store one or more location information items transmitted by each terminal and to determine the direction of travel and the speed of the terminal on the basis of the location information transmitted by the terminal.

The invention further relates to a mobile telephone system of the type presented in the introduction, which is characterized in that the terminals are arranged to inform the base station of their geographical location at certain intervals, the base station is arranged to store one or more location information items transmitted by each terminal, and when the terminal transmits an emergency call, the base station is arranged to inform an emergency call receiver of the geographical location of the terminal.

The invention is based on the idea that the location of a mobile telephone can be detected rapidly and accurately by a satellite positioning system, whereby this information can be advantageously applied to various problems to which the application of the location information has previously been impossible.

The system of the invention provides many advantages. The invention enables accurate and fast location determination of a telephone, and the location information can be efficiently utilized in call maintenance. The preferred embodiments of the invention are disclosed in the dependent claims.

BRIEF DESCRIPTION OF THE DRAWINGS

In the following, the invention will be described in more detail by means of preferred embodiments with reference to the accompanying drawings, in which:

Figure 1 shows an example of the mobile telephone system of the invention,

Figure 2 illustrates the operation of the invention when the direction of travel of a terminal is determined and in connection with handover,

Figure 3 illustrates the operation of the invention when a beam forming technique is used,

Figure 4 illustrates the operation of the invention in connection with an emergency call, and

Figure 5 illustrates an example of the structure of a terminal of the mobile telephone system according to the invention.

DETAILED DESCRIPTION OF THE INVENTION

Figure 1 illustrates part of the mobile telephone system to which the method of the invention can be applied. The system comprises a base station 100 having a bi-directional connection 102-104 with subscriber terminals 106-108. The system of the invention can apply any known multiple access method, since the essential features of the invention are independent of the multiple access method used. In the system of the invention, the terminals set up a connection with the base station by using a random access channel. When the connection is set up, the terminal and the base station can transmit signalling information to one another using an associated signalling channel of the connection.

In the system of the invention, at least some of the terminals are arranged to determine their geographical location and to inform the base station of the location. This is preferably done by means of a satellite positioning system. One such satellite positioning system is a Global Positioning System GPS. In that case, the terminals 106, 108 receive a signal 110 from a satellite system 112 via several satellite stations and can determine their location by the known methods.

Let us first study Figure 2 describing the operation of the invention when the direction of travel of a terminal is determined. The terminal 106 receives the signal 110 from the satellite system 112, and uses the signal for determining its location at predetermined, for example regular, intervals. The terminal informs the base station 100 of the location at certain intervals. The information can be transmitted on the random access channel or, if the terminal has a call in progress, on the associated signalling channel of the connection.

The terminals can inform the base station of their geographical location at regular intervals. Alternatively, after determining their location, the terminals compare the new location information with the information last transmitted to the base station. If the new location differs for a pre-set thresh-

old from the location reported to the base station, the terminal informs the base station of the geographical location. It is thus possible to reduce signalling traffic between the terminal and the base station.

The base station 100 receives and stores the location information of the terminal. The base station calculates the speed and the direction of travel of the terminal on the basis of two or more pieces of successive location information. Using this information, the base station can eliminate the effect of the Doppler shift from the signal of the terminal. In fast terminal (such as bullet trains or other fast vehicles) connections, the speed of the terminal brings about signal interference, i.e. the Doppler shift. It is known that the Doppler shift can be solved by the formula

$$D = f * v * \cos(\alpha)$$

where f stands for the frequency, v stands for the speed of the terminal, and α stands for the direction of travel of the terminal with respect to the base station.

The solution of the invention can also be applied to a base station using a beam forming technique. In that case, an antenna beam is directed to each communicating terminal. This is illustrated in Figure 3. The system comprises a base station 100 communicating with subscriber terminals 106-108 in such a way that the base station forms specific antenna beams 300, 302 for each terminal by using the known beam forming techniques. The beams can be formed by suitably phasing a signal to be transmitted by means of an antenna array composed of several antenna elements, for example. When directional antenna beams are used, the base station naturally needs information on the direction in which the terminal is located. The antenna beam can be directed in the correct direction at each point of time on the basis of the location information transmitted by the terminal.

The terminals can inform the base station of the location in connection with a call set-up message. The base station can thus use antenna beams that are correctly directed in connection with a call set-up acknowledgement, because the location of the terminal is known.

The solution of the invention is also suitable for use in connection with emergency calls. In that case it is important to rapidly find out the location of the terminal. Let us study Figure 4 describing the method of the invention. The subscriber terminal 106 determines its location by means of the satellite system 112 and informs the base station 100 of the location at regular inter-

vals. When an emergency call is coming from the terminal 106, the base station checks the latest location information transmitted by the terminal and forwards it upward in the network hierarchy to be further delivered to an emergency call receiver 400.

Furthermore, the solution of the invention can be applied to a number of other targets of application. For example, the location and direction information of the terminal can be utilized in connection with handover between base stations when a base station is selected under whose command the terminal should advantageously move. Let us study Figure 2 describing the operation of the invention in connection with handover. The terminal 106 receives the signal 110 from the satellite system 112 and determines its location at predetermined, for example regular, intervals by means of the signal. The terminal informs the base station 100 of the location at certain intervals. The system also comprises a second base station 200 and a base station controller 202 controlling the operation of the base stations and transmitting traffic to other parts of the system and to external systems. An entity comprising a base station controller and base stations subject to it is called a base station system.

When the terminal moves towards the second base station the base station controller follows the movement of the terminal and optimally performs the handover. In the arrangement of the invention, the base station system can reserve a channel from a new cell on the basis of the location information of the terminals.

In some systems, the terminals maintain a list of the nearby base stations for measurement purposes, for example. In the system of the invention, the base station system can update, using the location information of the terminal, the list of the neighbouring cells that is maintained by the terminals.

Let us study Figure 5 illustrating an example of the structure of a terminal of the mobile telephone system according to the invention. The terminal comprises an antenna 500 receiving a signal 502 coming from a base station and a signal 504 coming from a satellite positioning system. In reception direction, the signal is applied from the antenna to a filter 506, from where it is applied to radio frequency parts 508, to an analog-to-digital converter 510 and to a decoder 512, and from there further to other parts 524 of the receiver. In transmission direction, a signal 526 to be transmitted is applied to a coder 518 and further to a modulator 516, and via radio frequency parts 514 and the filter

506 to the antenna 500. When localization is involved, the signal is applied from the antenna to a localization signal receiver 522 which can be a prior art GPS receiver integrated to the terminal, for example. The integration can be implemented in many ways, as it is obvious to those skilled in the art. The terminal further comprises a control unit 520 controlling the operation of the parts of the equipment and being typically implemented by a signal processor or a general purpose processor, and in which control unit, the method steps of the invention can be advantageously implemented by software.

In other words, the terminal receives the signal 504 from the satellite positioning system with the GPS receiver means 522 by means of which the terminal is able to determine its location by using the known methods. The control means 520 direct the terminal to inform the base station of the location via signalling channels at regular intervals. It is to be noted that the figure shows only an example of the structure of a receiver, and the solution of the invention can also be implemented in another type of receiver.

Although the invention is described above with reference to the example according to the accompanying drawings, it is obvious that the invention is not restricted thereto but it can be modified in many ways within the scope of the inventive idea presented in the attached claims.

CLAIMS

1. A mobile telephone system comprising a number of coverage areas, each coverage area being served by at least one base station (100), a number of subscriber terminals (106, 108) communicating with one or more base stations, and from which terminals at least some are arranged to determine their geographical location and to inform the base station of the location, **characterized** in that

the terminals are arranged to inform the base station of their geographical location at certain intervals,

the base station is arranged to store one or more location information items transmitted by each terminal and to determine the direction of travel and the speed of the terminal on the basis of the location information transmitted by the terminal.

2. A system as claimed in claim 1, **characterized** in that the base station is arranged to eliminate the effect of the Doppler shift from a terminal signal on the basis of the direction of travel and the speed of the terminal.

3. A mobile telephone system comprising a number of coverage areas, each coverage area being served by at least one base station (100), a number of subscriber terminals (106, 108) communicating with one or more base stations, and from which terminals at least some are arranged to determine their geographical location and inform the base station of the location, **characterized** in that

the terminals are arranged to inform the base station of their geographical location at certain intervals,

the base station is arranged to store one or more location information items transmitted by each terminal, and when the terminal transmits an emergency call, the base station is arranged to inform an emergency call receiver of the geographical location of the terminal.

4. A system as claimed in claim 1 or 3, **characterized** in that the terminals are arranged to determine their geographical location by means of a satellite positioning system (112).

5. A system as claimed in claim 1 or 3, **characterized** in that the base station is arranged to set up a connection with the terminals by using directional antenna beams, and that the base station is arranged to utilize the location information of the terminal in the directing of the beams.

6. A system as claimed in claim 1 or 3, **characterized** in that the terminals are arranged to inform the base station of the location in connection with a call set-up message.

7. A system as claimed in claim 1 or 3, **characterized** in that the terminals are arranged to inform the base station of the location on a general signalling channel.

8. A system as claimed in claim 1 or 3, **characterized** in that the terminals are arranged to inform the base station of their geographical location at regular intervals.

9. A system as claimed in claim 1 or 3, **characterized** in that after determining their location, the terminals compare the new location information with the information last transmitted to the base station, and if the new location differs for a pre-set threshold from the location reported to the base station, the terminal informs the base station of the geographical location.

10. A system as claimed in claim 1 or 3, **characterized** in that the base station (100) and a base station controller (202) are arranged to utilize the location information of the terminal in connection with handover.

11. A system as claimed in claim 1 or 3, **characterized** in that a base station (200) and the base station controller (202) are arranged to reserve a channel from a new cell on the basis of the location information of the terminals.

12. A system as claimed in claim 1 or 3, **characterized** in that the base station (100) and the base station controller (202) are arranged to update, using the location information of the terminal, the list of neighbouring cells that is maintained by the terminal.

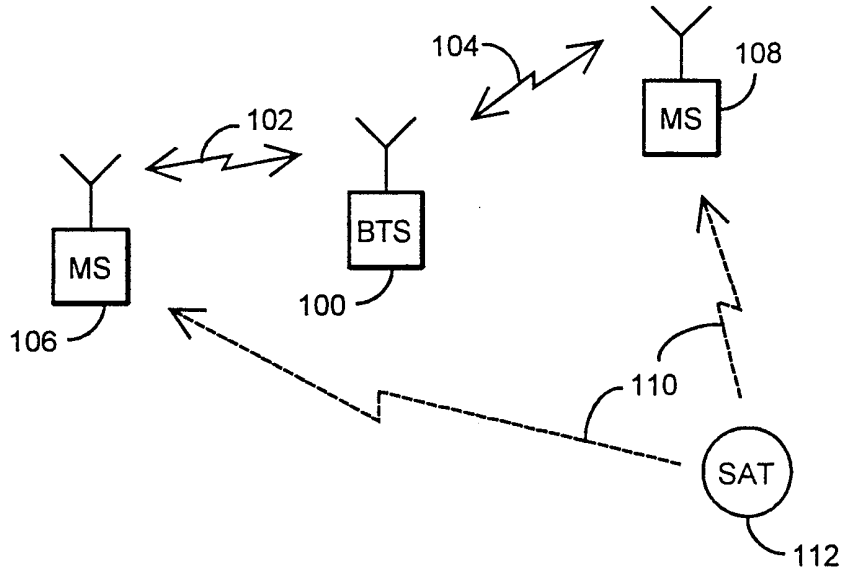

Fig. 1

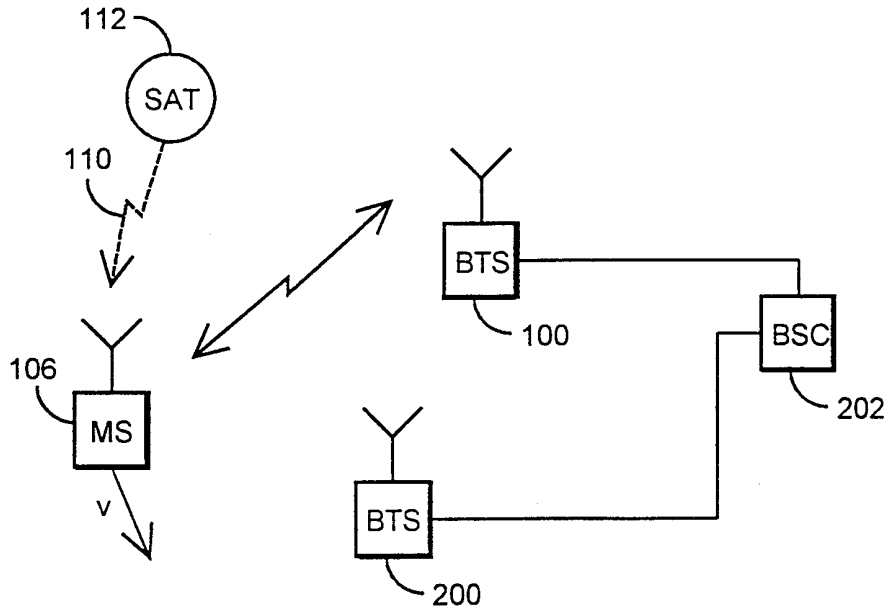

Fig. 2

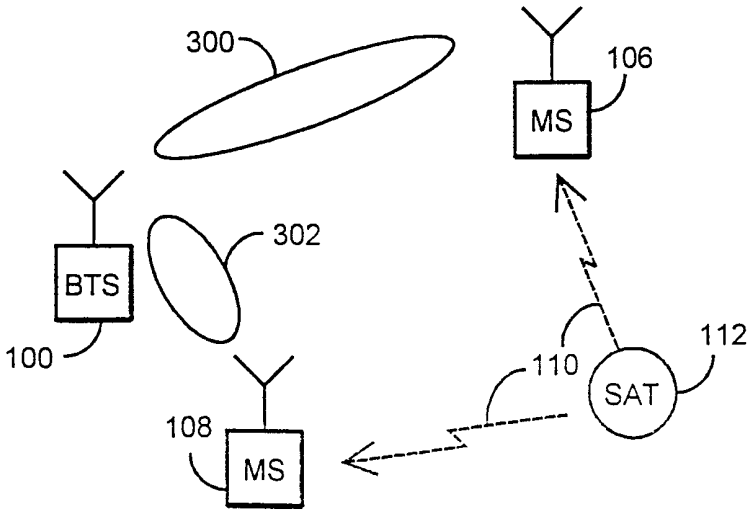

Fig. 3

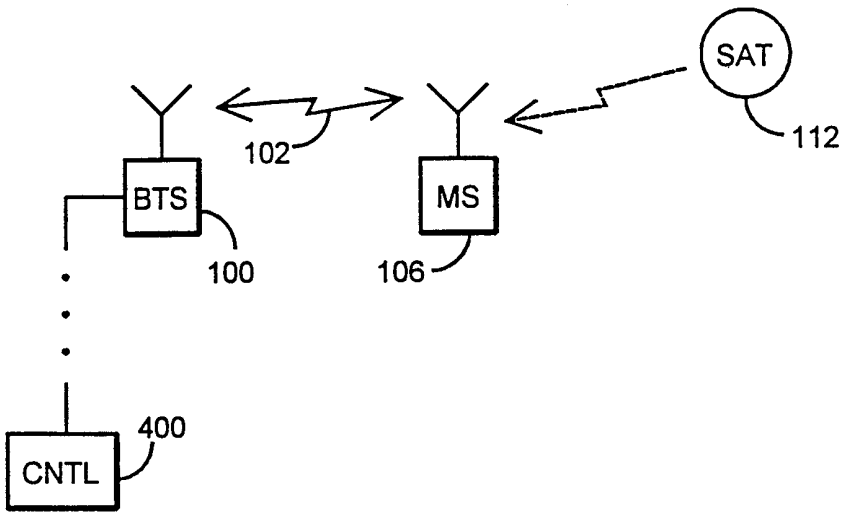
SAT
112
102
BTS
100
MS
106
400
CNTL

Fig. 4

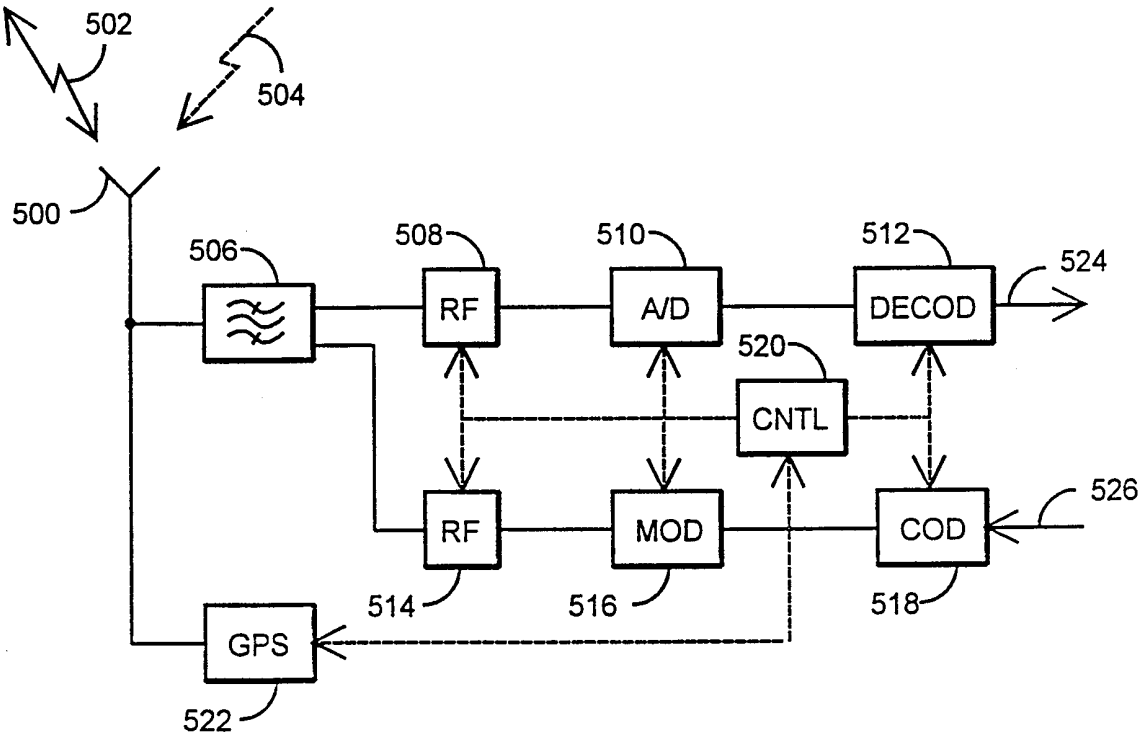
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Fig. 5