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(54) **METHOD AND APPARATUS FOR LOCATION DETERMINATION OF A CELLULAR TELEPHONE**

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(52) **U.S. Cl.** **455/456**; 455/343; 455/552; 342/357.06
(58) **Field of Search** 455/343, 456, 455/552, 553, 574, 12.1, 427, 67.1, 226.1, 226.2; 342/357.01, 357.06, 357.09; 370/311, 320, 335

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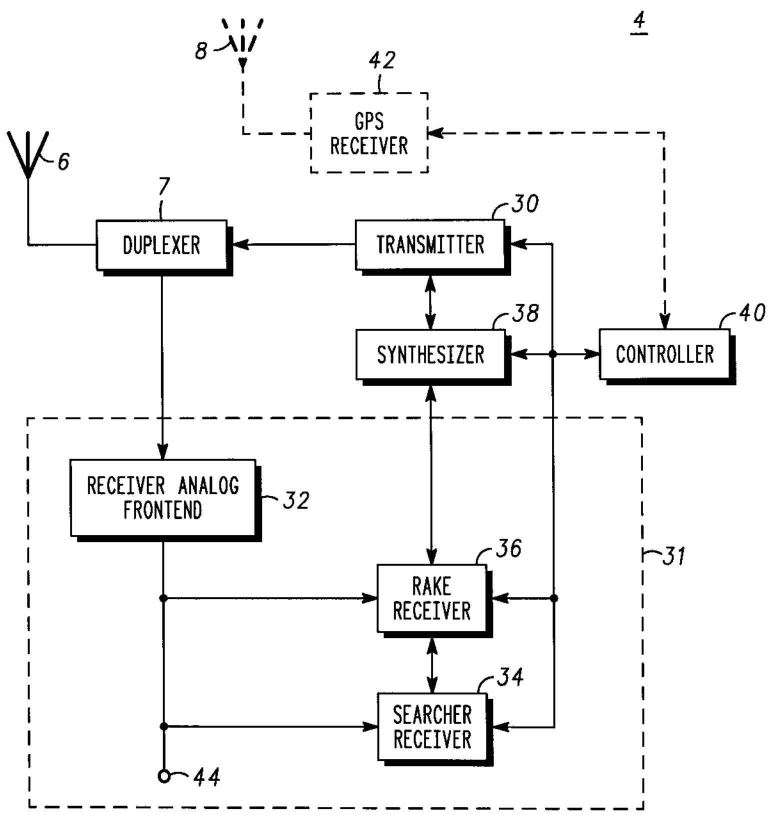
(57) **ABSTRACT**

A method of making a geographic location determination via a cellular telephone in signal communication with a base station. The mobile station first attempts to detect a position location signal. Upon determining that the position location signal is insufficient to use in a position location calculation, the mobile station deactivates at least a portion of a receiver. The mobile station receives a cellular communication signal and measures a signal quality of the cellular communication signal. Responsive to the signal quality improving by a predetermined amount, the mobile station reactivates the receiver portion and re-attempts to detect the position location signal.

23 Claims, 2 Drawing Sheets



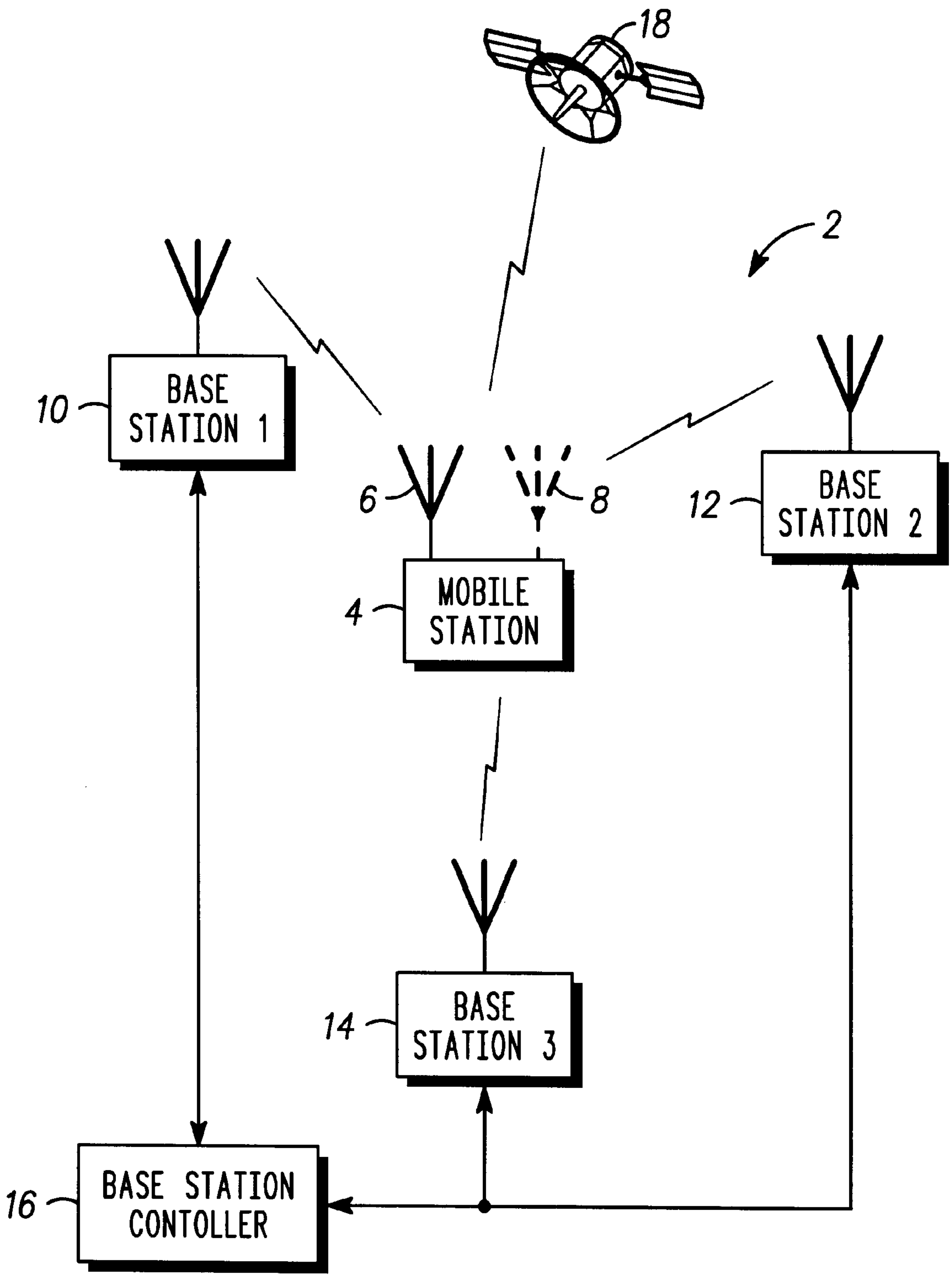

18
2
BASE STATION 1
10
6
8
12
BASE STATION 2
MOBILE STATION
4
BASE STATION 3
14
BASE STATION CONTOLLER
16

FIG.1

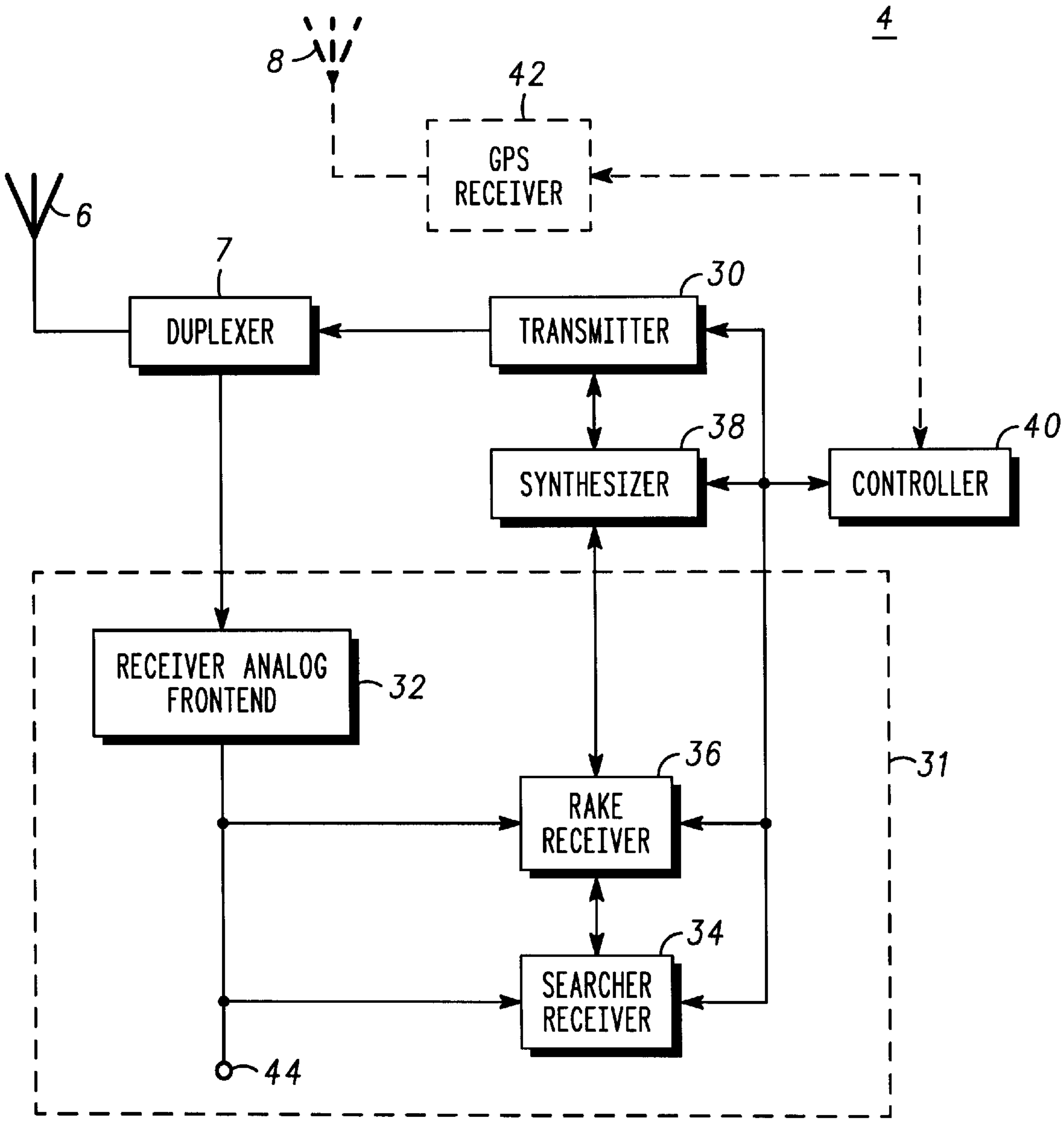

4
8
42
GPS RECEIVER
6
7
30
DUPLEXER
TRANSMITTER
38
40
SYNTHESIZER
CONTROLLER
RECEIVER ANALOG FRONTEND
32
36
31
RAKE RECEIVER
34
SEARCHER RECEIVER
44

FIG. 2

METHOD AND APPARATUS FOR LOCATION DETERMINATION OF A CELLULAR TELEPHONE

FIELD OF THE INVENTION

This invention generally relates to geographic location determination. More specifically, this invention relates to geographic location determination via a cellular telephone.

BACKGROUND OF THE INVENTION

In the near future cellular telephones will have the capability to make a geographic location determination. Many methods have been proposed to implement the location determination feature in a cellular telephone. One method is to integrate a Global Positioning System (GPS) receiver in the cellular telephone. The GPS receiver periodically receives timing signals from GPS satellites and processes the timing signals to make a location determination.

Under various conditions, GPS receivers have significant trouble receiving the necessary satellite timing signals. For example, if a user is inside a building, the GPS signals may not be strong enough for the user's GPS receiver to detect the signals. The GPS signals may become even weaker (e.g. more difficult to detect) as the cellular telephone is deeper within a building and away from any windows. In this situation, the cellular telephone GPS receiver would continually check for the GPS signals, and this continuous "checking" can significantly drain the cellular telephone battery. The same problem may be encountered if other position location technology (e.g. triangulation) is employed. Therefore, there is a need for a method and apparatus for making location measurements via a cellular telephone without unnecessarily draining the battery power of the cellular telephone.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a system diagram incorporating a cellular communication network and a global positioning system (GPS) satellite for position location determination; and

FIG. **2** shows a block diagram of an exemplary embodiment of a mobile station.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

FIG. **1** shows a system diagram of a cellular communication network **2** incorporating global positioning system (GPS) satellites, here represented by GPS satellite **18**, for position location determination. The cellular communication network **2** includes a plurality of base stations, including first base station **10**, second base station **12**, and third base station **14**. A base station controller **16** is coupled to the plurality of base stations generally for controlling operation of the cellular communication network **2** as is known in the art. Mobile station **4** communicates to another destination via at least one of the plurality of base stations.

The cellular communication network **2** can operate using any of several kinds of communication protocols, such as code division multiple access (CDMA) technology, time division multiple access (TDMA) technology, or frequency division multiple access (FDMA) technology as is known in the art. In the illustrated embodiment, the cellular communication network **2** operates via CDMA air interface standard as outlined in TIA/EIA Interim Standard IS-95 entitled "Mobile Station-Base Station Compatibility Standard for Dual-Mode Wideband Spread Spectrum Cellular System" and incorporated by reference. Additionally, the communication network **2** can comprise a plurality of communication technologies, such as both CDMA and TDMA.

Location determination technology is employed to allow for the calculation of the geographic location of the mobile station **4**. Moreover, the hardware configuration of the mobile station **4** depends upon the type of location determination system deployed.

In the illustrated embodiment, the mobile station **4** employs a global positioning system (GPS) receiver for communication with the GPS satellites **18**. The mobile station **4** employs a first antenna **6** for communication with the cellular communication network **2** and a second antenna **8** for communication with the GPS satellites **18**. Alternatively, the mobile station **4** may utilize a single antenna for detecting both position location signals and cellular communication signals.

For what is commonly referred to as autonomous GPS position location, the mobile station **4** acquires and measures GPS satellite signals without the aid of the cellular communication network **2**. In an alternate embodiment, the cellular communication network **2** employs network assisted GPS, wherein the cellular communication network **2** provides information to the mobile station **4** to aid in acquiring the GPS satellite signals as is known in the art.

In another alternate embodiment, the mobile station **4** is equipped to receive and process downlink signals from the plurality of base stations to aid in location determination of the mobile station **4**; this is commonly known as forward link triangulation. Thus, the mobile station **4** processes multiple communication signals from multiple base stations and determines the arrival times for each of the communication signals as part of the position determination as is known in the art.

FIG. **2** shows a block diagram of an exemplary embodiment of the mobile station **4**. The mobile station **4** is configured to receive and transmit spread spectrum communication signals to communicate with a plurality of base stations. The base stations (FIG. **1**) transmit various spread spectrum signals, such as an information signal on a traffic channel, to the mobile station **4**. In addition to traffic channels, the base stations broadcast other communication signals such as a spread spectrum pilot signal over a pilot channel, a synchronization signal over a synchronization channel, and a paging signal over a paging channel. The pilot channel is commonly received by all mobile stations within range and is used by the mobile station **4** for identifying the presence of a CDMA system, initial system acquisition, idle mode hand-off, identification of initial and delayed rays of communicating and interfering base stations, and for coherent demodulation of the synchronization, paging, and traffic channels. The synchronization channel is used for synchronizing mobile station timing to base station timing. The paging channel is used for sending paging information from the first base station **10** to mobile stations including mobile station **4**. Signals transmitted by the base stations are spread using a pseudorandom noise (PN) sequence as is known in the art.

In alternate embodiments, the pilot signals comprise multiple pilot signals transmitted over a plurality of channels. Some of the pilot signals can be used, for example, for initial acquisition and signal strength determination. Other of the pilot signals can be used for storing group information, such as a group of base station identities.

The mobile station **4** comprises a first antenna **6**, a conventional transmitter **30**, cellular receiver **31**, a synthesizer **38**, and a controller **40**. Conventional duplexer **7** allows for simultaneous transmission and reception as is known in the art. The controller **40** comprises a microprocessor to control operation of the mobile station **4**. The controller may alternatively, or in addition, comprise any of logic circuitry, timing and clock circuitry, a digital signal processor, and microprocessor as is known in the art. This additional circuitry interconnection to other blocks of the mobile station **4**, as well as the user interface (microphone, speaker, etc.) are not shown in FIG. **2** so as to not unduly complicate the drawing figure.

The cellular receiver **31** comprises an analog front end **32**, a searcher receiver **34**, and a rake receiver **36**. The antenna **6** detects RF signals from the first base station **10** and from other base stations in the vicinity. Some of the received RF signals are direct line of sight rays transmitted by the base station. Other received RF signals are reflected or multi-path rays and are therefore delayed in time relative to the line of sight rays. Received RF signals are converted to electrical signals by the antenna **6** and provided to the analog front end **32**. The analog front end **32** performs functions such as filtering, automatic gain control, and conversion of signals to baseband signals as is known in the art. The analog baseband signals are converted to streams of digital data for further processing.

Generally, the searcher receiver **34** detects pilot signals from the streams of digital data. The searcher receiver **34** despreads the pilot signals using a correlator and PN codes generated in the mobile station **4** as is known in the art. After this despreading, the signal values for each chip period are accumulated over a pre-selected interval of time, and the correlation energy is compared against a threshold level. Correlation energies exceeding the threshold level generally indicate a suitable pilot signal ray that can be used for pilot signal timing synchronization.

Once a suitable ray is identified and timing synchronization is accomplished, a demodulation branch of the RAKE receiver **36** is assigned to that signal path. The mobile station **4** can then demodulate information signals as is known in the art.

In the illustrated embodiment the mobile station **4** utilizes GPS signaling for geographic location analysis and thus employs a conventional GPS receiver **42**. The second antenna **8** detects location information signals from the GPS satellites **18** (FIG. **1**), and the GPS signals are processed by the conventional GPS receiver **42** as is known in the art and then forwarded to the controller **40**. The GPS receiver **42** and the cellular receiver **31** may alternatively share at least some circuitry to reduce the size and cost of the mobile station **4**. The combined GPS receiver and cellular receiver may then be generally referred to as a mobile station receiver.

In operation, the controller **40** periodically activates the GPS receiver **42** to detect and process location signaling transmitted by the GPS satellites **18** (FIG. **1**). For example, the GPS receiver can periodically activate at a rate of substantially every five seconds, thirty seconds or minute. This periodic activation rate is referred to as a first rate, and other frequencies of activation may be chosen for the first rate as necessary. The more frequently the activation, the more up-to-date the position location information will be. The tradeoff for higher frequencies for the first rate of activation is battery drain.

After detecting the position location signals, the GPS receiver process the signals by performing conventional GPS receiver functions such as frequency conversion, filtering, and demodulation. One particular analysis in which the GPS receiver is involved is the determination as to whether the position location signals are even sufficient for a position location calculation. For example, the GPS receiver **42** will determine the signal strength of the received position location signals, and if the signals are below a predetermined threshold, then the position location signals are too weak to process. In the illustrated embodiment, the GPS receiver **42** sensitivity is −155 dBm. The GPS receiver **42** can perform the received signal strength measurement, or alternatively the GPS receiver **42** can forward a signal to another portion of the mobile station **4** (such as the cellular receiver **31** and/or the controller **40**) for the received signal strength determination.

Further, the signal strength of the position location signals can be determined in any number of conventional methods. For example, and intermediate analog signal can be utilized for the calculation, or a digitized version of the baseband signal can be utilized. Other means for determining the quality of the link between the GPS receiver **42** and the GPS satellites **18** (FIG. **1**) can alternatively be employed. For example, the bit error rate or frame erasure rate resulting from processing the position location signals can be used as a criteria for determining whether the received position location signals are suitable for processing.

If the position location signals are suitable for processing, normal operation continues and the position signals are used for geographic location as is known in the art. The GPS receiver **42** continues to periodically activate at the first predetermined rate to detect and process new position location signaling.

If the position location signals are not suitable for processing (e.g. too weak), the controller **40** decreases the frequency at which the GPS receiver **42** periodically activate to detect position location signaling. This is done to save battery power. The position location signals may be too weak based upon the position of the mobile station. For example, if the user is within a building, the satellite signals may not suitably penetrate the building for detection. If the user is deep within a building away from any windows, the satellite signals may be even weaker.

Thus, the controller **40** will decrease the frequency of GPS receiver **42** activation to a second, predetermined rate. This second predetermined rate can be on the order of every five minutes, ten minutes, twenty minutes, or more. In the illustrated embodiment, the rate of activation is reduced to once every twenty minutes. Once again, the rate of activation is a design tradeoff between how current the geographic location information is and battery conservation.

During each twenty minute period, at least a portion of the receiver, here GPS receiver **42**, is deactivated to conserve power. However, the quality of the communication link between the mobile station **4** and the cellular base stations (FIG. **1**) is constantly monitored. The controller **40** then reactivates the GPS receiver **42** responsive to the quality of the cellular communication link improving by a predetermined amount. The GPS receiver then attempts to detect position location signaling.

In determining whether the quality of the communication link has improved by a predetermined amount, the mobile station can use received signal strength of the received cellular signal. Alternatively, the mobile station can use bit error rate or frame erasure rate as the criteria.

For example, in its determination of the quality of the communication link, the mobile station makes several signal measurements. If received signal strength is used as the determination factor, the mobile station **4** makes a first

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