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(71) Applicant: MOTOROLA INC. [US/US]; 1303 East Algonquin Road, Schaumburg, IL 60196 (US).

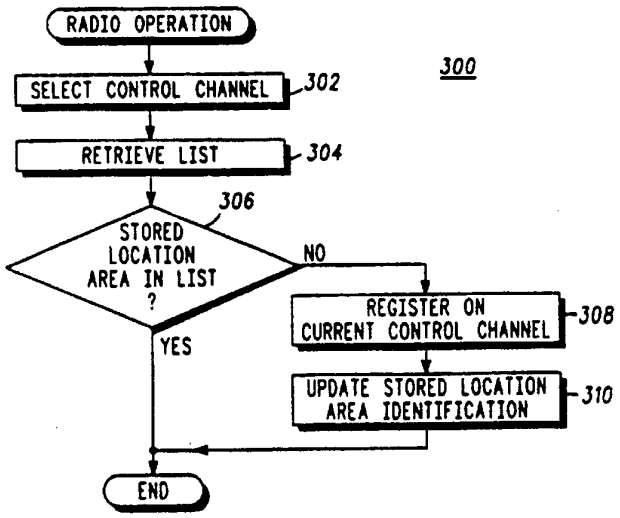
(72) Inventors: ERICKSON, Paul, M.; 965 South Elm Street, Palatine, IL 60195 (US). WILSON, Timothy, John; 931 Canterbury Drive, Schaumburg, IL 60089 (US).

(74) Agents: PARMELEE, Steven, G. et al.; Motorola Inc., Intellectual Property Dept./JAC, 1303 East Algonquin Road, Schaumburg, IL 60196 (US).

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(54) Title: METHOD OF REDUCING CONTROL CHANNEL TRAFFIC IN A RADIO COMMUNICATION SYSTEM



(57) Abstract

A method of reducing control channel traffic in a radio communication system employs a scheme that defines paging areas. A paging area comprises at least a first location area and other coverage areas. Radio communication is provided that exhibits a degree of co-channel interference among control channels serving coverage areas that are associated with different location areas. According to the invention, a record is provided at the fixed end for each of the coverage areas. These records have elements that include an identification (ID) for the associated location area, and an identification for supported coverage areas, which together define a paging area. The elements of the record are transmitted by the fixed end, and the record elements are retrieved (304) by a mobile. The mobile then determines (306) whether or not he is still within the same paging area corresponding to the location area in which he was last registered. Accordingly, the mobile needs not re-register each time it travels from one location area to another.

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METHOD OF REDUCING CONTROL CHANNEL TRAFFIC IN A RADIO COMMUNICATION SYSTEM

Field of the Invention

The invention relates generally to radio communication systems, and particularly to those systems whose radios are subjected, from time to time, to undesirable levels of co-channel interference.

Background of the Invention

Radio communication systems are well known in the telecommunications art. Such radio communication systems (e.g., Motorola's Advanced Mobile Phone System, or "AMPS") use many radio sites to provide radio service to a large metropolitan or rural area. In a system with many coverage areas, it is necessary to identify the coverage area (i.e., site) in which the communication unit (i.e., radio) can be reached to initiate (i.e., transmit) or terminate (i.e., receive) a call. Site identification can be accomplished by employing a number of techniques: e.g., requiring the radio to report its location each time it roams into a new coverage area; or alternatively, requiring the fixed end (site controller) to send out location request messages (i.e., pages) to every coverage area until the radio is located. Both techniques, however, prove to be inefficient for systems with many small coverage areas. Accordingly, it is common practice to define location areas that each consist of multiple coverage areas, and to require that mobiles report their change of location upon moving from one location area to another. Under the foregoing procedure, the system completes a call to a targeted mobile by first sending location requests (i.e., pages) to each coverage area within the location area which last registered the targeted mobile. Thus, having an

accurate account of where the mobile is most likely located is critical to the successful completion of a call. Unfortunately, when the mobile roams near location area borders, this process results in a problem referred to in the art as "chatter"--recurring, alternate registration with two or more location areas. A second problem, whose relationship with the "chatter" will be discussed below, is the problem of co-channel interference--that characteristic which accompanies any system which re-uses frequencies within a larger geographical area.

To further understand the aforementioned problems, a description follows which illustrates some of the design constraints for the design of a cellular communications system. FIG. 1 shows a graphical representation of a simple cellular communications system. The system of FIG. 1 is commonly referred to as a "3/3 re-use system" (i.e., having a system coverage pattern comprising a plurality of adjacent reuse patterns, each reuse pattern having three sites, and each site having three distinct, 120 degree coverage areas). As an example, local reuse pattern 101--denoted by a heavy, solid line--comprises equally partitioned hexagonal shaped sites 103-105, each site being further divided into three coverage areas. At each site, e.g., site 103, there are three directional antennas that provide the three coverage areas within the site. Further, each of the coverage areas use different radio frequencies, denoted in FIG. 1 by the numbers 1-9.

Within reuse pattern 101, each frequency is used only once, so there is no source of co-channel interference within that region. However, since there are adjacent patterns using like frequencies (i.e., frequencies 1-9), co-channel interference can be a problem throughout service area 100. For example, FIG. 1 shows that coverage areas 111 and 112 are each using frequency '1' for communications between site and mobile. Indeed, FIG. 1 shows 4 occurrences where frequency '1' is used (of

course, the pattern is repeated throughout service area 100). Re-use occurrences located equi-distant from an operating site (e.g., coverage area 111) are called first tier co-channel interferes. Of course, since the pattern recurs outwardly from each site, there are higher order interferes (i.e., second, third, etc.) at greater distances. Further, since the first tier of interferes is closest to the site in question, they are generally the strongest interferes. Accordingly, only first tier interferes will be discussed here. It should be noted that, in many cases, the frequencies (denoted 1-9) are commonly a duplex set of frequencies, one for land-to-mobile, and another for mobile-to-land direction, as in the case of typical cellular communication systems used today.

Of course, there are many re-use patterns from which to choose, but that choice substantially determines both the system capacity and radio performance. For example, choosing a large re-use factor (i.e., the total number of coverage areas within a re-use pattern) produces a system with minimal co-channel interference, but a limited number of communication channels available. Further, it limits the number of frequencies that may be deployed at a given site. As an example, consider a service that provides 189 frequency pairs; a 3/3 re-use pattern (i.e., re-use factor of 9) is able to deploy 21 (i.e. 189/9) frequency pairs at each coverage area, thus accommodating many simultaneous users in each coverage area. By contrast, a 3/7 re-use pattern (i.e., re-use factor of 21) is able to deploy only nine (i.e., 189/21) frequency pairs at each coverage area, thus serving fewer simultaneous users.

In addition to capacity constraints, radio communication systems must also be designed to provide an acceptable level of performance to the users (i.e., radio operators). A commonly used indicator of performance for such systems is referred to as carrier-to-interference

(C/I) ratio, which generally quantifies the effect of co-channel interference on a particular channel. That is, the C/I must exceed a minimum threshold to ensure adequate system performance. Unfortunately, increasing the C/I through reduced re-use factors results in reduced system capacity, as earlier described. Accordingly, the system designer strives to find a re-use pattern that provides an acceptable C/I ratio, while simultaneously providing adequate user capacity. Doing so, however, normally results in a re-use pattern which exhibits only marginal C/I performance on the borders of adjacent coverage areas, as herein described.

Mobile units operating in areas near the borders of two adjacent coverage areas receive a signal with C/I near the operating threshold. Therefore, the mobiles have a tendency to "chatter" (switch from operation from one site to another and then back again) between two different coverage areas. If these coverage areas are associated with the same location area, this characteristic does not inhibit performance. However, when the boundary is between two coverage areas associated with two different location areas, the "chatter" produces a large volume of location reports from the mobile, thereby increasing control channel traffic while the mobile attempts to acquire a stable registration location. Of course, this increased traffic reduces the efficiency of the system, and system performance is degraded.

One possible solution available for conventional analog cellular systems is to choose one re-use pattern for the control frequencies, and a second re-use pattern for the bearer/voice channels. By using a larger re-use factor for the control channel, additional C/I margin and larger hysteresis loops (lower C/I threshold before acquisition, and higher thresholds afterwards) can be designed into the system, allowing the mobile to remain longer on a particular control channel. Under this scenario, since the

control channel constitutes only a fraction of the total number of channels, the penalty of less efficient frequency re-use is minimized.

Unfortunately, the foregoing solution cannot be employed in modern time division multiplex (TDM) systems in which there are many logical channels sharing a single frequency pair. That is, in a TDM system, the control channel information and voice channel information are interleaved on different time slots within the same carrier, separated temporally within recurring time frames. Since one frequency pair in each coverage area carries both the control and voice traffic, selecting different re-use patterns for control and voice channels is impossible in a TDM system.

Accordingly, there exists a need for a method of reducing control channel traffic, which at least partially results from co-channel interference in a radio communication system.

Brief Description of the Drawings

FIG. 1 shows a graphical representation of a radio communication system coverage pattern, as is well known in the art;

FIG. 2 shows a graphical representation of a radio communication system coverage pattern, whose operational parameters are determined in accordance with the present invention; and

FIG. 3 shows a flow diagram depicting the operation of a radio, in accordance with the present invention.

Detailed Description of the Preferred Embodiment

The present invention provides a method of reducing the effect of undesirable "chatter" between a mobile attempting to register while near the border between two or more adjacent location areas. That is, the present invention provides for the reduction in the volume of location reports (i.e. registration requests) that would otherwise occur while roaming near the border between location areas. It should be noted that, while the present invention will be illustrated using a frequency division multiplex (FDM) modulation scheme, it finds particular use in more modern TDM communication systems.

Referring to FIG. 2, communication service area 200 comprises a plurality of location areas, e.g., location area 210 (denoted by solid, heavy lines). Location area 210 includes coverage areas 212-215. These four coverage areas might be embodied using a "site" in the center of the hexagonal coverage area, which site might comprise an omni-directional antenna. To facilitate communication throughout service area 200, the location area identifiers are broadcast to the mobiles via the control channels for each of the coverage areas (212 - 215). Additionally, a new sub-region, e.g., paging area 240, is defined for each location area that includes the coverage areas associated with the corresponding location area, as well as a plurality of other coverage areas (e.g., as denoted by the dashed outer boundaries of coverage areas 250-259). These coverage areas, referred to herein as supported coverage areas, might share a common border (i.e., neighbors), or other predetermined amount of geographical area with the coverage areas associated with the corresponding location area (e.g., location area 210). Though FIG. 2 shows only one such paging area, there are, in a preferred embodiment, a plurality of paging areas defined throughout service area 200.

The present invention employs a scheme by which the paging areas--each associated with a location area as defined earlier--overlap one another. Such a scheme ensures that the outer edges (i.e., boundaries) of coverage areas for each location area do not coincide with each other. [Note that in prior art systems, coinciding boundaries occurred, by definition, at the "borders" between adjacent location areas. The problems mentioned earlier are a principal result of this condition]. Accordingly, the mobile is able to communicate (i.e., transmit and receive) throughout a larger area without having to re-register when traveling outside of his last-registered location area.

To facilitate identification of the coverage areas within the paging area, a record (i.e., list) having one or more elements, is kept in memory at the fixed end (e.g., master site controller) corresponding to each coverage area. In particular, there might be a record entry identifying each location area that is associated with at least one coverage area that is geographically adjacent to the coverage area corresponding to that record. That is, the record contains a list identifying all the location areas from which the mobile can receive a page (i.e., call). In this manner, paging areas are defined for each corresponding location area, and hence for each coverage area associated therewith. In a preferred embodiment, the first element identifies the location area logically associated with the coverage area of interest. Successive elements include identities of adjacent, supported location areas, e.g., those location areas that are associated with coverage areas adjacent to the coverage area of interest. To illustrate, Table 1 provides a representative list showing associated location areas, and supported location areas for three coverage areas shown in FIG. 2; namely coverage areas 213, 214, and 253:

	CA213	CA214	CA253
Assoc. LA	210	210	282
Supp. LA1	280	282	210
Supp. LA2	282	284	284
Supp. LA3		286	

Table 1

FIG. 3 shows a flow diagram depicting the operation of a mobile (i.e., radio), in accordance with the present invention. While registered with a current location area (whose identification is stored in memory at the mobile) and monitoring the control channel affiliated with a first coverage area, the radio might determine that another control channel has a greater signal level (e.g., as determined by well known received signal strength indication (RSSI) techniques). Accordingly, the mobile selects (302) the stronger control channel to facilitate subsequent communication. Having acquired a new control channel, the mobile must determine if it has roamed outside of its previous paging area. To accomplish this, the mobile must retrieve (304), from the information broadcast on the control channel, the list of associated and supported location areas. A decision (306) is reached to determine whether or not the identity of the stored (i.e., mobile's last-registered) location area is included in the retrieved list. If the stored location area identification (ID) has no match in the retrieved list, the mobile must register (308) in the new location area using the current control channel. In addition, the mobile updates (310) the stored location area ID with the ID corresponding to the new location area.

By contrast, if the stored ID matches one of the elements in the retrieved list, the mobile is still within the same paging area, and the routine is exited. That is,

even though the mobile may have roamed into the boundaries of a new location area, it is still able to be reached without having to register with the new location area. The foregoing scenario illustrates a dramatic improvement over prior art systems that would require the additional registration traffic on the control channel. It should be noted that the embodiment discussed above is merely representative of one way of reducing control channel traffic typically associated with chatter. That is, any paging area that includes coverage areas from more than one location area, provided the master controller is able to broadcast pages to multiple location areas, would be an improvement over prior art systems.

As an example, an alternate embodiment of the present invention can be described, which embodiment has many of the same characteristics as the aforementioned implementation. A primary distinction, however, lies in the affiliation between the elements of the location area ID list. That is, unlike the first embodiment, the first ID in the list has no special meaning. In particular, the elements in the list simply define the size and shape of the paging area corresponding to the location area associated with that coverage area. Accordingly, the paging areas can be made in a variety of shapes and sizes, depending on the system requirements and typical usage patterns (i.e., they need not be defined by a particular location area, plus selected peripheral coverage areas). For example, a mountainous region between two coverage areas may not be traversed frequently enough to warrant the provision of a paging area which includes both coverage areas. (i.e., and hence providing a transparent hand-off between them). By having this added flexibility, the system designer is afforded the capability of providing as much, or as little, overlap between paging areas as the application requires.

The operation of the mobile is substantially the same as in the first embodiment, except that the stored location area identifier might preferably be provided as part of the registration process (i.e., since the notion of a home location area is no longer relevant). The operation of the fixed end equipment is also substantially the same, except that the response to a registration request (i.e., transmitted to a single radio must transmit a single location area ID that is found in the list, which is also being transmitted. That is, the fixed end tells the mobile which ID should be stored for future comparison with elements in the received list. There are many possible methods of selecting which of the location area ID's to return to the mobile, but it is generally adequate to randomly select the location area ID.

Accordingly, the present invention provides for a reduction in the amount of undesirable registration traffic without compromising system capacity (i.e., through increased C/I margin). In particular, this reduction in control channel traffic is the result of a system that seeks to reduce co-channel interference, and the accompanying tendency of mobiles to chatter among two, or more, control channel frequencies.

What is claimed is:

Claims

1) In a radio communication system for providing radio communication service to a plurality of radios throughout a service area, the service area including a plurality of location areas, each of the location areas having associated therewith a plurality of coverage areas, the provided radio communication being characterized by a degree of co-channel interference among control channels serving coverage areas that are associated with different location areas, a method of reducing control channel traffic resulting from undesirable levels of co-channel interference, the method comprising the steps of:

A) defining a paging area corresponding to a location area, such that the paging area includes the coverage areas associated with the corresponding location area and a plurality of supported coverage areas;

B) providing a record, for each of the coverage areas, having elements that include an identification for the location area associated therewith, and an identification for each of the supported location areas; and

C) transmitting, to at least a first of the plurality of radios, the elements of the record.

2) The method of reducing control channel traffic as recited in claim 1, wherein step B) comprises the step of

B1) identifying the supported location areas as those associated with coverage areas that share a predetermined amount of geographical area with those coverage areas associated with the corresponding location area.

3) The method of reducing control channel traffic as recited in claim 1, further comprising the steps of, at the plurality of radios:

D) storing an identification for a first location area ;

E) receiving the elements of the record; and

F) comparing the stored identification with each of the elements in the record.

4) The method of reducing control channel traffic as recited in claim 3, wherein step D) comprises the step of

D1) identifying said first location area as a location area on which the radio was last registered.

5) The method of reducing control channel traffic as recited in claim 3, further comprising the step of, at the plurality of radios:

G) when the stored identification does not match one of the elements in the record, registering with a second location area.

6) The method of reducing control channel traffic as recited in claim 5, further comprising the step of, at the plurality of radios:

H) updating the stored identification to match the identification for the second location area.

7) The method of reducing control channel traffic as recited in claim 3, wherein step D) comprises the step of

D1) receiving from the controller said identification for said first location area.

8) In a radio communication system that includes a controller for providing radio communication service to a service area, the service area including a plurality of location areas, each of the location areas having associated therewith a plurality of coverage areas, the provided radio communication being characterized by a degree of co-channel interference among control channels serving coverage areas that are associated with different location areas, a method of reducing control channel traffic resulting from undesirable levels of co-channel interference, the method comprising the steps of:

at the controller;

A) defining a paging area corresponding to each location area, such that each of the paging areas include the corresponding location area and a plurality of supported location areas;

B) providing a record, for each of the coverage areas, having elements that include an identification for each of the associated coverage areas and an identification for each of the supported coverage areas;

C) transmitting, to at least a first of the plurality of radios, the elements in the record; and

at the plurality of radios;

D) storing an identification for the location area in which the radio is currently registered;

E) receiving the elements of the record; and

F) comparing the stored identification with each of the elements in the record.

9) The method of reducing co-channel interference as recited in claim 8, further comprising the step of, at the radio:

G) when the stored identification does not match one of the elements in the record, registering with a second location area, and updating the stored identification to match the identification for the second location area.

10) In a time division multiplex (TDM) radio communication system that includes a controller for providing radio communication service to a service area, the service area including a plurality of location areas, each of the location areas having associated therewith a plurality of coverage areas, the provided radio communication being characterized by a degree of co-channel interference among time slots serving coverage areas that are associated with different location areas, a method of reducing control channel traffic resulting from undesirable levels of co-channel interference, the method comprising the steps of:

at the controller;

A) defining a paging area corresponding to each location area, such that each of the paging areas include the corresponding location area and a plurality of supported location areas;

B) providing a record, for each of the coverage areas, having elements that include an identification for each of the associated coverage areas and an identification for each of the supported coverage areas;

C) transmitting, to at least a first of the plurality of radios, the elements in the record; and

at the plurality of radios;

D) storing an identification for the location area in which the radio is currently registered;

E) receiving the record, via a current control channel; and

F) comparing the stored identification with each of the elements in the record.

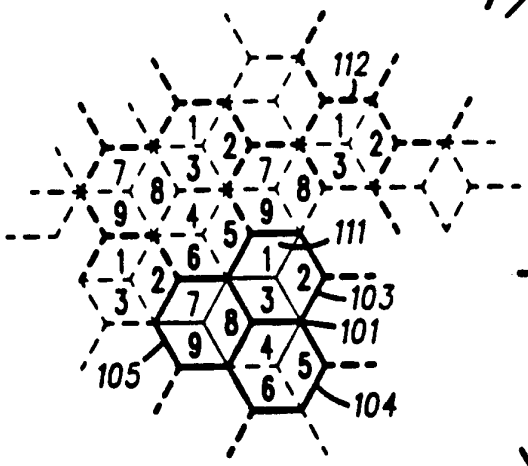


FIG.1

100

— PRIOR ART —

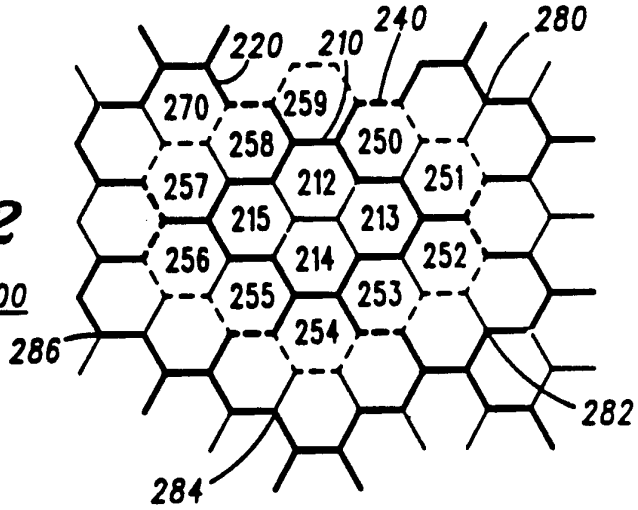


FIG.2

200

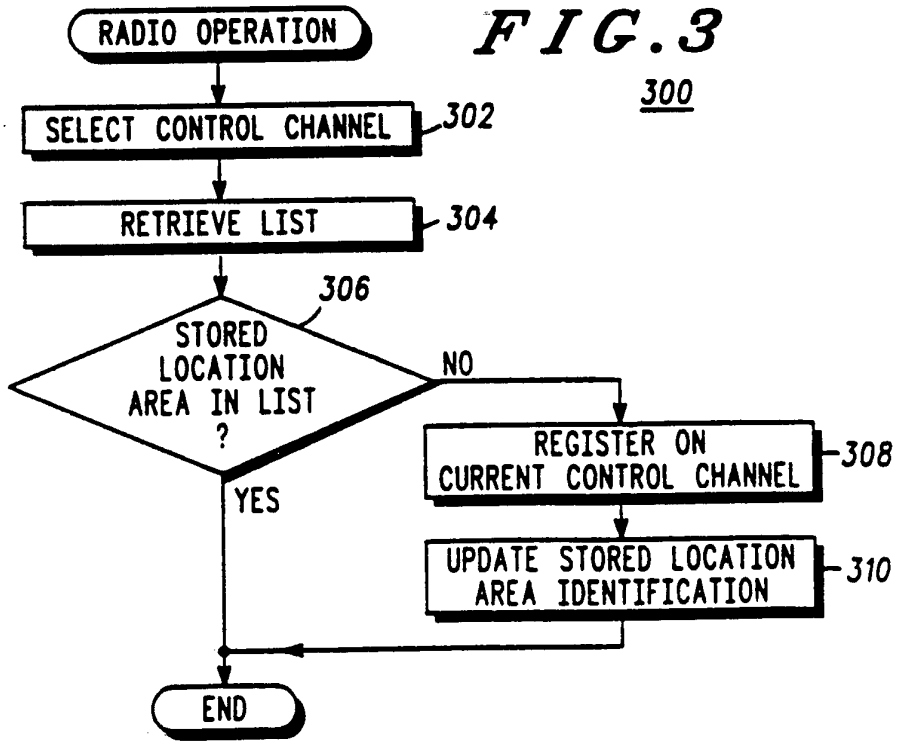


FIG.3

300

INTERNATIONAL SEARCH REPORT

In ational application No.
PCT/US93/12589

A. CLASSIFICATION OF SUBJECT MATTER

IPC(5) :H04Q7/00, 9/00; H04B 1/00, 7/00; H04M 11/00.
US CL :455/33.1, 33.2, 33.4, 54.1, 56.1, 53.1; 379/59, 60.
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)

U.S. 455/33.1, 33.2, 33.4, 54.1, 56.1, 53.1; 379/59, 60 : None

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

None

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

None

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X,P	US, A, 5,212,822 (Fukumine et al) 18 May 1993 see entire reference.	1-10
A	US, A, 5,054,110 (Comroe et al) 01 October 1991 see columns 3-5, figure 2.	1-10
A	US, A, 5,101,500 (Marui) 31 March 1992 see column 2, figures 1-3.	1-10
A	US, A, 4,876,738 (Selby) 24 October 1989 see abstract, columns 5-10, figure 1.	1-10

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

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