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(71) Applicant:
    TELEFONAKTIEBOLAGET LM ERICSSON
    (publ) [SE/SE]; S-126 25 Stockholm (SE).

(72) Inventors:
    SAMMOUR, Mohammed; Apartment #1011, 1100
    Dr. Penfield, Montreal, Quebec H3A 1A8 (CA).
    DESGAGNE, Michel; 6606 Des Marronniers, St-Hubert, Que-
    bec J3Y 8T4 (CA).

(74) Agent:
    ERICSSON RADIO SYSTEM AB; Common Patent
    Department, S-164 80 Stockholm (SE).

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    SYSTEM AND METHOD FOR EFFICIENT USAGE OF BROADCAST POWER WHILE MINIMIZING CO-CHANNEL
    CELL SITE INTERFERENCE

(57) Abstract

A cell structure and associated method of cell and frequency planning are presented which reduce co-channel interference between
nearby co-channel cell sites. The cell and frequency planning method involves the definition of a number of frequency channel sub-groups
(SG) within each existing cell (10). Each frequency channel sub-group includes a number of frequency channels being broadcast at particular
power levels ranging from low power to high power. During a mobile station call (360), the lowest, yet sufficient power level is used for
the call (361). The cell sites are configured such that the frequency channel sub-groups being broadcast at the highest broadcast powers are
transmitted at lower broadcast powers in nearby co-channel cell sites.
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SYSTEM AND METHOD FOR EFFICIENT USAGE OF BROADCAST POWER WHILE MINIMIZING CO-CHANNEL CELL SITE INTERFERENCE

BACKGROUND OF THE INVENTION

Technical Field of the Invention

The present invention relates to cellular telecommunications networks and, in particular, to broadcast power allocation within cells in a telecommunications network.

Description of Related Art

Reference is now made to FIGURE 1 wherein there is illustrated an exemplary cell structure and frequency plan assignment for use in a radio frequency reuse cellular telephone system. An arbitrary geographic region (hereinafter "the service area") is divided into a plurality of contiguous cell sites 10 schematically represented by hexagons. The cell sites 10 are then grouped into clusters 12 (outlined in bold to ease recognition). For example, in the frequency plan of FIGURE 1, each cluster 12 includes seven cell sites 10(1)-10(7). It will, of course, be understood that each cluster 12 may have more or less cell sites 10 as required by the selected frequency plan.

The available frequencies in the allocated hyperband are divided in accordance with the frequency plan into frequency channel groups 14, with the frequency channel groups assigned amongst each of the cell sites 10 in a cluster 12 such that the radio frequency channels of the allocated hyperband are reused in each cluster. For example, in a plan having seven cell sites 10 per cluster 12 like that shown in FIGURE 1, each cell site 10(1) in the service area is assigned use of radio frequency channels from frequency channel group A of the allocated hyperband, each cell site 10(2) is assigned use of radio frequency channels from frequency channel group B of the allocated hyperband, and so on up to each cell site 10(7) being assigned the use of radio frequency channels from frequency channel group G of the allocated hyperband.

It will be noted that in such a frequency plan for a Frequency Division Multiple Access/Time Division Multiple Access (FDMA/TDMA) system, adjacent cell sites 10 are typically not assigned use of the same frequency channel group. Reuse of identical
frequency channel groups in the service area is preferably made with a separation of at least more than one cell site 10 along with a regulation of broadcast power from each cell to constrain radio broadcast substantially within the cell site area. Cell sites 10 using the same frequency channel groups are known as co-channel cells. For example, cell sites 10(1) and 10(1)(a) each use frequency channel group A and are therefore co-channel cell sites with respect to one another. Furthermore, it will be noted that typically no one cell site 10 utilizes frequency channels in the allocated hyperband that do not meet some minimal frequency channel separation. By arranging the cell sites 10 in clusters 12 as shown in FIGURE 1 and regulating broadcast power of communications within the cell as mentioned above, the likelihood of interference is reduced while simultaneously providing effective cellular communications services across a very large service area.

Each of the cell sites 10 in a cellular telephone system such as that illustrated in FIGURE 1 includes at least one base station (BS) 18 configured to facilitate radio frequency channel communications with mobile stations 20 moving throughout the service area. The base stations 18 are illustrated as being positionally located at or near the center of each of the cell sites 10. However, depending on geography and other known factors, the base stations 18 may instead be located at or near the periphery of, or otherwise away from the centers of, each of the cell sites 10.

The base stations 18 are connected by communications links (generally shown by arrow 16) to at least one mobile switching center (MSC) 22 operating to control the operation of the system for providing cellular communications with the mobile stations 20. Operation of the mobile switching center 22 and base station 18 to provide cellular telephone service is well known to those skilled in the art, and will not be described.

With further reference to FIGURE 1, the cell site 10 includes a base station 18 for engaging in radio communications with the mobile stations 20 located within the cell site 10. The radio communications are conducted on the frequency channels allocated to the cell site 10. The frequency channels include at least one control channel and a number of traffic channels. The traffic channels are further divided into uplink channels and downlink channels.
The control channel is used to communicate various control signals between the base station 18 and the mobile station 20. For example, during an incoming call directed to a particular mobile station 20, the base station 18 alerts the mobile station 20 of the incoming call by paging the mobile station 20 using the control channel. The traffic channels are used during phone calls to broadcast voice signals between the base station 18 and the mobile station 20. During a phone call between a subscriber at a mobile station 20 and another party, the traffic signals broadcast from the mobile station 20 to the base station 18 (known as up-link signals) represent the speech of the subscriber at mobile station 20, while the traffic signals broadcast from the base station 18 to the mobile station 20 (known as down-link signals) represent the speech from the other party. Accordingly, a phone call involving a mobile station 20 involves two frequency channels to carry the voice signals, wherein one frequency channel (the uplink channel) is used to carry up-link voice signals, and the other frequency channel (the down-link channel) is used to carry down-link voice signals. The foregoing is known in the art as full-duplexing. The service area, and the cell sites 10 therein are designed and laid out in a manner such that the broadcast power of the downlink signals is regulated to avoid interference with co-channel cell sites.

Ideally, the broadcast power of downlink signals is commensurate with the power needed to provide a signal with acceptable quality to the mobile station 20. However, the quality of the signal received by the MS 20 is dependent upon numerous factors including, for example, the distance between the MS 20 and the BS 18, and the presence of obstructions, such as a building, therebetween. In certain cases, the broadcast power of the downlink signal must be increased to deliver a signal with acceptable quality to a remote MS 20(a). However, increasing the broadcast power of the downlink signals can cause co-channel interference with a base station 18 in a co-channel cell site 10. In other cases, such as for a MS 20(b) located nearby a BS 18, the broadcast power required to deliver downlink signals with an acceptable degree of quality may be substantially lower than the broadcast power of the BS 18. The foregoing case represents inefficient energy utilization leading to increased costs. Accordingly, it would be advantageous if the broadcast power could be managed such that the broadcast power is sufficient to reach a mobile station, and at the same time,
controlled to minimize instances of interference between two co-channel cell sites.

SUMMARY OF THE INVENTION

A cell structure and associated algorithm for minimizing the likelihood of co-channel interference are presented. In accordance with the algorithm, the broadcast power is allocated such that for each cell site of a nearby co-channel cell site pair, different frequency channel sub-groups are broadcast at highest broadcast power.

A system and method for assigning power transmission levels to frequency channels in a cell-site which improves the downlink signal quality by more efficiently allocating transmission power are also presented. The frequency channels assigned to each cell site are divided into frequency channel sub-groups, where one of the frequency channel sub-groups is broadcast at a low transmission power, one of the frequency channel sub-groups is broadcast at a high transmission power, and one of the frequency channel sub-groups is broadcast at an intermediate transmission power.

During a phone call involving a mobile station, a frequency channel is selected from the frequency channel sub-group that is being broadcast with the lowest, yet sufficient power level to provide the mobile station with an acceptable quality signal where available. If the frequency channel sub-group being broadcast with the lowest, yet sufficient power does not have an available idle frequency channel, a frequency channel from a frequency channel sub-group being broadcast with a higher broadcast power is assigned, and the broadcast power of the frequency channel is reduced. Where none of the frequency channel sub-groups broadcast at a higher broadcast power has an available idle frequency channel, a frequency channel from a frequency channel sub-group being broadcast with a lower broadcast power is assigned, and the broadcast power of that frequency channel is increased.

BRIEF DESCRIPTION OF THE DRAWINGS

A more complete understanding of the method and apparatus of the present invention may be obtained by reference to the following Detailed Description when taken in conjunction with the accompanying Drawings wherein:

FIGURE 1 is a block diagram of an exemplary cell structure wherein the
present invention can be practiced;

FIGURE 2 is a block diagram of an exemplary cell site embodying the present invention;

FIGURE 3 is a flow diagram describing the operation of the cell site of FIGURE 2 selecting a frequency channel for a mobile station call;

FIGURE 4 is a flow diagram describing the operation of the cell site of FIGURE 2 performing an intra-cell handoff;

FIGURE 5 is a block diagram of an exemplary cell structure embodying the present invention; and

FIGURE 6 is a flow diagram of an algorithm for assigning power transmission levels in accordance with the present invention.

**DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS**

Referring now to FIGURE 2, there is illustrated an exemplary cell site 210 within an FDMA/TDMA or FDMA/Code Division Multiple Access (CDMA) embodying the present invention. The cell site includes a base station 218 for engaging in radio communications on frequency channels allocated to the cell site 210 with any number of mobile stations 220 located therein. The frequency channels support at least one control channel (digital or analog) and a number of traffic channels (digital or analog). The traffic channels are further divided into uplink channels and downlink channels. Ideally, the broadcast power for the downlink channels is commensurate with the power needed to provide a downlink signal with acceptable quality to the mobile station 220. However, the quality of the signal received by the mobile station 220 is dependent on numerous factors including, for example the geographic distance between the mobile station 220 and the base station 218 and the presence of obstructions, such as a building, therebetween. Accordingly, in certain cases, a higher level of broadcast power is required to provide an acceptable quality signal, while in other cases, a lower level is required.

To more efficiently allocate the broadcast power at base stations 218 within the cell site 210 with an acceptable quality downlink signal, the present invention proposes grouping the frequency channels used in a cell site 210 into a number of frequency
channel sub-groups (SG(0)-SG(N)) wherein each of the downlink frequency channels within a particular frequency channel sub-group are broadcast from the base station 218 at the same power level. Each frequency channel sub-group 232 within the cell site 210 is broadcast at a different power level, such that one frequency channel sub-group, SG(0), broadcasts at a lowest power level, PL(0), one frequency channel sub-group, SG(N), broadcasts at a highest power level, PL(N), and each of the remaining frequency channel sub-groups, (SG(1)-SG(N-1)), broadcast at incrementally increasing power levels (PL(0)-PL(N-1)) therebetween.

The downlink channels of frequency channel sub-group SG(0) are broadcast at a power level sufficient for mobile stations 220 within the cell site 210 requiring the lowest power level to receive a signal of acceptable quality. The mobile stations 220 requiring the lowest power level to receive a signal of acceptable quality are generally closest in geographic distance to the base station 218, and are primarily found within a substantially concentric ring 35(0) centered about the base station with a predetermined radius. Each successive frequency channel sub-group SG(1)-SG(N) operates at a power level for a predetermined proportion of mobile stations 220 within the cell site 210 requiring successively higher power level to receive a signal of acceptable quality. The mobile stations 220 requiring a successively higher power level are generally found in a substantially concentric ring 35(1)-35(N) about the base station 218 with a predetermined inner radius and a predetermined outer radius.

Referring now to FIGURE 3, there is illustrated a flow diagram describing the operation of the cell site of FIGURE 2, during a pending call involving the mobile station 220. At step 360, a call is established involving mobile station 220. During the call, the best power level for communication and the best base station 218 are continuously evaluated (step 361). For newly established call, or when the best base station 218 changes from a presently serving base station (during step 362), the frequency channel sub-group used by the base station 218 that broadcasts at the best power level for communication with that mobile station 220 is searched (step 366) and a determination is made whether that frequency channel sub-group includes an idle frequency channel (step 368). If the frequency channel sub-group used by the base station 218 that broadcast at the best power level includes an idle frequency channel,
the idle frequency channel is selected to serve the mobile station 220 (step 370), thereby completing the process.

On the other hand, if the frequency channel sub-group does not have an available idle frequency channel, frequency channel sub-groups broadcasting at the new base station 218 that broadcast at power levels higher than the best power level are searched for an available idle frequency channel (step 372), and a determination is made whether there exists such an available idle frequency channel (step 374). If available idle frequency channels exist, the available idle frequency channel belonging to the frequency channel sub-group broadcasting at the lowest power exceeding the best power level is selected to serve the mobile station 220 (step 376). The transmission power level of the selected idle frequency channel is then reduced to the best power level (step 376), thereby terminating the process.

On the other hand, if none of the frequency channel sub-groups at the base station 218 broadcasting at power levels higher than the best power level include an available idle frequency channel, frequency channel sub-groups at the base station 18 broadcasting at transmission power levels lower than the best power level are searched for an available idle frequency channel (step 380), and a determination is made whether there exists such an available idle frequency channel exists (step 382). If available idle frequency channels exist in frequency channel sub-groups broadcasting at a transmission power levels lower than the best power level, the available idle frequency channel belonging to the frequency channel sub-group broadcasting at the highest power below the best power level is selected to serve the mobile station 220 (step 384). The transmission power level is then increased to the best power level (step 384), thereby completing the process. If an available idle frequency channel does not exist during step 382, then the frequency channels are exhausted, and the call from the mobile station 20 must be dropped (step 386), thereby terminating the process.

If the best power level changes during step 364, an intra-cell handoff may have to be performed. Referring now to FIGURE 4, there is illustrated a block diagram describing the operation of the cell site of FIGURE 2, when the best power level changes. The best power level is compared to the transmission power level of the frequency channel sub-group which includes the frequency channel the mobile station
220 currently using (the default power level) (step 418). It is noted that the frequency channel the mobile station 220 is currently using may be broadcasting at a different power level than the default power level due to adjustments during, e.g., steps 376, or 384. If the new best power level is equal to the default power level, then the frequency channel currently in use by the mobile station is adjusted to the default power level (step 420), and no intra-cell hand-off occurs.

If the new best power level is different from the default power level, the frequency channel sub-group broadcasting at the new best power level is examined (step 422) to determine if an idle frequency channel exists (step 424). If an idle frequency channel exists, the idle frequency channel is selected for the mobile station 220 to receive the hand-off of the pending phone call (step 426), thereby completing the intra-cell hand-off.

On the other hand, if there does not exist an idle frequency channel during step 424, a determination is made whether the best power level exceeds the default power level (step 428). Where the best power level exceeds the default power level, successive power levels exceeding the best power level are searched (step 430) and a determination is made whether the frequency channel sub-groups broadcasting at successive power levels exceeding the best power level include available idle frequency channels (step 432). If the frequency channel sub-groups broadcasting at successive power levels exceeding the best power level include available idle frequency channels, the lowest available idle frequency channel is selected to receive the hand-off of the pending call and the power level of the frequency channel is reduced to the best power level (step 434), thereby completing the intra-cell handoff.

On the other hand, if no frequency channel sub-groups broadcasting at successive power levels exceeding the best power level include available idle frequency channels, the frequency channel sub-groups broadcasting at power levels between the default power level and the best power level are examined for available idle frequency channels (step 436) and a determination is made whether such available idle frequency channels exist (step 438). Where such available idle frequency channels exist, the available idle frequency channel from the sub-group broadcasting at the highest power level is selected to receive the hand-off of the pending call and the power level of the
frequency channel is increased to the best power level (step 440), thereby completing
the intra-cell handoff. If no such frequency channel exists, no intra-cell handoff occurs
and the current frequency channel used by the mobile station 20 is adjusted to the best
power level (step 442), thereby completing the process.

If during step 428, the default power level exceeds the best power level, the
frequency channel sub-groups broadcasting at power levels between the best power
level and the default power level are examined (step 444), and a determination is made
whether the frequency channel sub-groups broadcasting at power levels between the
best power level and the default power level include available idle frequency channels
(step 446). If the frequency channel sub-groups broadcasting at power levels between
the best power level and the default power level include available idle frequency
channels, the available idle frequency channel in the frequency channel sub-group
broadcasting at the lowest power level is selected to receive the hand-off of the pending
call and the power level of the frequency channel is adjusted to the best power level
(step 448), thereby terminating the process. If no available idle frequency channel
exists, no intra-cell handoff occurs and the power level of the current frequency channel
used by the mobile station 220 is adjusted to the best power level (step 450), thereby
terminating the process.

By dividing the frequency channels into frequency channel sub-groups SG(0)-
SG(N) and serving mobile stations 220 with the lowest sufficient power level to
provide an acceptable quality signal, higher transmission power frequency channels are
reserved for mobile stations 220 in geographic locations requiring higher broadcast
power for acceptable downlink signal quality. Additionally, lower transmission power
frequency channels are used for mobile stations 220 in geographic locations requiring
lower broadcast power, thereby reducing energy costs.

However, use of increased broadcast power for downlink frequency channels,
e.g., frequency channel sub-group SG(N) may cause co-channel interference with a
nearby co-channel cell site 210. To avoid co-channel interference with nearby co-
channel cell sites 210, the present invention proposes the following unique method of
cell planning.

Referring now to FIGURE 5, there is illustrated an exemplary service area 540
with a frequency plan assignment configured in accordance with the present invention. Each cell is schematically illustrated such that the frequency channel sub-group indicated in the largest concentric ring is broadcast at the highest power level and the frequency channel sub-group indicated in the smallest concentric ring is broadcast at the lowest power level. The service area 540 comprises any number of clusters 512, each cluster including any number of cell sites, such as cell site 210 described in FIGURE 3.

The frequency channels allocated cell site 210(a) are further divided into three frequency channel sub-groups SG(0), SG(1), and SG(2), wherein the downlink channels of frequency channel sub-group SG(2) are broadcast at the lowest power level, while the downlink channels of frequency channel sub-group SG(1) are broadcast at an intermediate power level, and the downlink channels of frequency channel sub-group SG(0) are broadcast at the highest power level. Broadcasting frequency channel sub-group SG(0) at a high transmission power level can potentially cause co-channel interference with neighboring co-channel cell sites, e.g., 210(b)-210(g). A neighboring co-channel cell site is a co-channel cell site forming a portion of a neighboring cluster 12. To minimize the likelihood of co-channel interference, the transmission power assigned to the frequency sub-groups must be assigned such that no two neighboring co-channel cell sites 210(b)-210(g) use the same frequency sub-group SG(0), SG(1), SG(2) for high-level transmission power.

Referring now to FIGURE 6, there is illustrated a flow chart describing an algorithm for assignment of transmission power levels to frequency channel sub-groups of neighboring co-channel cell sites, such as of neighboring co-channel cell sites 210(a)-210(g). The flow chart will be described with reference to FIGURE 5. The algorithm begins by selecting a reference cell site (step 652), e.g., cell site 210(a), and assigning the high transmission power level to a frequency channel sub-group SG(x), where SG(x) is selected from the available frequency channel sub-groups, SG(0), SG(1), and SG(2) (step 653). In the exemplary case illustrated in FIGURE 5, the high transmission power level is assigned to frequency channel sub-group SG(0). Next, for each of the neighboring co-channel cell sites 210(b)-210(g), the frequency channel sub-group SG(x+1), and SG(x+2), where addition is performed in modulo-3 fashion, are
alternatingly assigned the highest broadcast power in the neighboring cell sites 210(b)-210(g), as a circular ring is traversed about cell site 210(a) (step 654). In the present exemplary case, frequency channel sub-groups SG(1) and SG(2) are alternatingly assigned the highest broadcast power for the ring of neighboring co-channel cell sites beginning with 210(b) and terminating at 210(g). The frequency channel sub-group power transmission levels assignments are expanded throughout the service area of FIGURE 5 by selecting a neighboring co-channel cell site (step 656), e.g., cell site 210(1)(e). The neighboring co-channel cell sites surrounding cell site 210(1)(e) include cell sites 210(1)(f), 210(1)(a), 210(1)(d). The high transmission power frequency channel sub-group in these cells is SG(0), SG(1), and SG(2), respectively. The frequency channel sub-group power transmission levels assignments can then be expanded by alternating the high transmission power frequency channel sub-group SG(0) and SG(1) in the remaining neighboring co-channel cell sites 210 surrounding the cell site 210(1)(e) (step 657). This process can then be repeated recursively for each cell site 210 that is co-channel with cell site 210(a) in the service area 540. Furthermore, power transmission levels can be allocated to the other cell sites 210(2)-210(7) and recursively expanded in a similar manner as with cell site 210(1).

Although the method and apparatus of the present invention has been illustrated in the accompanying Drawings and described in the foregoing Detailed Description, it will be understood that the invention is not limited to the embodiment(s) disclosed, but is capable of numerous rearrangements, modifications and substitutions without departing from the spirit of the invention as set forth and defined by the following claims.
WHAT IS CLAIMED IS:

1. A telecommunications system for wireless communications, said telecommunication system comprising:
   a first cell cluster comprising a first cell-site allocated a first plurality
   of frequency channels including a first sub-group of frequency channels, a second
   sub-group of frequency channels, and a third sub-group of frequency channels, wherein
   the first sub-group of frequency channels is assigned and broadcast at a low
   transmission power level, the second sub-group of frequency channels is assigned and
   broadcast at an intermediate transmission power level, the intermediate transmission
   power level exceeding the low transmission power level, and the third sub-group of
   frequency channels is assigned and broadcast at a high transmission power level, the
   high transmission power level exceeding the intermediate transmission power level.

2. The telecommunications system of claim 1, further comprising:
   a second cell cluster adjacent to the first cluster, the second cluster
   comprising a second cell-site also allocated the first plurality of frequency channels, wherein
   the first sub-group of frequency channels is assigned and broadcast at a high
   transmission power level.

3. The telecommunications system of claim 1, further comprising:
   a second cluster adjacent to the first cluster, the second cluster
   comprising a second cell-site allocated the first plurality of frequency channels, wherein
   the second sub-group of frequency channels is assigned and broadcast at a high
   transmission power level.

4. The telecommunications system of claim 3, further comprising:
   a third cluster adjacent to the first cluster and adjacent to the second
   cluster, the third cluster comprising a third cell-site allocated the first plurality of
   frequency channels, wherein the first sub-group of frequency channels is assigned and
   broadcast at a high transmission power level.
5. A method for assigning a frequency channel to a mobile station at a cell site broadcasting signals on a plurality of frequency channels, the plurality of frequency channels divided into a plurality of frequency channel sub-groups, each of the plurality of sub-groups comprising assigned use of a different particular one of a plurality of transmission power levels, said method comprising the steps of:

- determining a best power level to serve the mobile station, the best power level comprising the lowest one of the plurality of transmission power levels which is sufficient to provide the mobile station an acceptable quality signal;
- determining whether a first particular one of the plurality of frequency channel sub-groups that is assigned use of the determined best power level has an available idle frequency channel; and
- assigning that available idle frequency channel to the mobile station.

6. The method of claim 5, further comprising the step of:

- wherein the available idle frequency channel is not found during said step of examining the first particular one of the plurality of frequency channel sub-groups for the available idle frequency channel:
- determining whether a second particular one of the plurality of frequency channel sub-groups that is assigned use of a transmission power level exceeding the best power level has an available idle frequency channel; and
- assigning that available idle frequency channel to the mobile station and adjusting the transmission power level of the frequency channel to the best power level.

7. The method of claim 6, further comprising the step of:

- wherein the available idle frequency channel is not found during said step of examining the second particular one of the plurality of frequency channel sub-groups for the available idle frequency channel:
- determining whether a third particular one of the plurality of frequency channel sub-groups that is assigned use of a transmission power level lower than the best power level has an available idle frequency channel; and
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assigning that available idle frequency channel to the mobile station and adjusting the transmission power level of the frequency channel to the best power level.

8. A method for maintaining a pending call involving a mobile station using a current frequency channel at a current transmission level, said method comprising the steps of:

- determining the best power level for the mobile station; and
- wherein the best power level is different than the current transmission level:

- determining a default transmission power associated with the current frequency channel; and
- wherein the default transmission power associated with the current frequency channel is equal to the best power level, adjusting the current transmission level to the default transmission level.

9. The method of claim 8, further comprising the steps of:

- wherein the best power level exceeds the default power level:

- determining whether a first frequency channel sub-group comprising a plurality of frequency channels has a first idle frequency channel, the first frequency channel sub-group associated with a first assigned transmission power, the first assigned transmission power exceeding the best power level;

- wherein the first idle frequency channel exists during the determining step, handing off the pending call to that first idle frequency channel; and

- wherein the first idle frequency channel does not exist during the searching step, determining whether a second frequency channel sub-group comprising a plurality of frequency channels has a second idle frequency channel, wherein the second frequency channel sub-group is associated with a second assigned transmission power, and wherein the second assigned transmission power exceeds the default power level.
FIG. 3