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CELLULAR RADIO

10 The present invention relates to cellular radio, and
in particular, although not exclusively, to a cellular
radio system having overlapping macrocells and microcells.

 A conventional cellular radio system has a number of
radio base stations each serving a respective radio
15 coverage area or cell, with which a mobile radio station
can communicate over a radio link. As a mobile station
moves from one cell to the next, the communication link is
transferred from the present base station to the next base
station using a procedure known as hand-over or hand-off.
20 The need for hand-over is usually determined on the basis
of one or more criteria. Commonly used criteria are:

- 1) received signal strength indication (RSSI) of the
mobile at the base station, or base stations at a mobile
station,
- 25 2) relative distance measurement of the mobile from
the two closest base stations,
- 3) level of interference from the nearest base station
operating on the same frequency, and
- 4) in digital systems, bit error rate (BER).

30 The cells of conventional cellular radio systems are
relatively large, typically several kilometres across, and
this allows time for data to be acquired for even a fast
moving mobile station and a decision made on the basis of
trends in that data. Recently there have been moves
35 towards having cellular radio systems with relatively small
cells of up to a few kilometres in diameter, and typically
less than one kilometre in diameter, and these are often
referred to as "microcells" while the relatively large,
sometimes called wide area cells are often referred to as

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"macrocells". These terms do not indicate absolute size limitations but rather reflect the relative size of these two cell types. Microcellular radio systems should provide a better frequency re-use and hence greater user density.

5 Proposals for microcellular systems suggest their application to road network, for example motorways where high speed mobile stations will pass through a microcell very quickly. This means that the time available for measurement of a handover criterion, e.g. RSSI, BER or
10 interference level, for use in a hand-over decision is limited. Furthermore, the radio coverage of microcells is subject to large variations in signal strength over short distances relatively, for example in an urban environment.

Taking RSSI as an example of a possible handover
15 criterion in the handover decision or cell reselection for an idle mobile, its use in conventional cellular radio systems is complicated by the variation of RSSI, caused by factors other than pathloss due to changing distance of the mobile from a base station. Considering a simplified
20 situation, see inset sketch in Figure 1, where a mobile station MS moves between two cells served respectively by base stations BS1 and BS2, the received signal strength of the two base stations at the mobile station varies not only with distance, i.e. diminishes due to path loss, but also
25 varies with fast (Rayleigh) fading and shadowing, see graph in Figure 1. In this simplified example the 'ideal' point for handover is half way between the base station where the RSSI for both base stations is the same - where their pathloss curves intersect. However the effects of fading
30 and shadowing lead to uncertainty of the level of RSSI and to pathloss, hence render determination of the correct handover point more difficult. However by time-averaging the RSSIs the effect of fading and shadowing can to some extent be overcome. This time averaging does introduce a
35 delay, referred to as the time averaging delay, into the

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handover/cell reselection process. The situation is further complicated, however, because if handover occurs where the averaged values for RSSI are the same there is a significant probability that variation in the momentary levels will be sufficient to trigger the system to make an unnecessary handover back to the original base station. To reduce the probability of such unnecessary handover occurring a hysteresis quantity is introduced which, in effect offsets the RSSI of the current base station relative to the RSSI of destination base station. A simplified example of this is shown in Figure 2, in relation to the idealised situation of Figure 1, in Figure 2 the path loss curve for BS1 is shown offset by a hysteresis element H, with the result that the intersection (handover) point with the path loss curve (2) for BS2 is also offset, in positional terms towards BS2.

The two handover parameters, Averaging period (T) and Hysteresis margin H, are related to the two handover qualities frequency of unnecessary handover, and handover delay D as shown in Figure 3. The standard deviation (σ) of RSSIs varies with the Averaging period T; the hysteresis margin H is a function of σ , and frequency of probability of unnecessary handover P_u ; and Handover delay D is the sum of the Averaging Delay and Hysteresis delay. For macrocells of a few kilometres diameter where the Handover Delay in distance terms is of the order of several hundred metres e.g. 700-800 metres, the Averaging period T and Hysteresis margin H could typically be $T = 10$ secs and $H = 7\text{dB}$. Such criterion can provide satisfactory results in a macrocell environment, however if applied to a microcell context problems occur.

In a microcellular environment large variations of signal level, and hence RSSI of a base station at a mobile station, occur over relatively short distances, as shown by the example graph in Figure 4. As indicated in the inset

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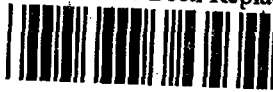
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sketch in Figure 4, microcells A + B overlap at a road junction, and generally provide coverage over only their respective road. When a mobile MS moves from the road served by base station A into the road served by base station B, as shown in the inset sketch in Figure 4, the mobile MS experiences the variation in signal strength from the base stations of the graph in Figure 4. The significant effect occurs as the mobile turns the corner, as indicated on the graph, where an almost step function pathloss effect occurs. The present invention is concerned with a cellular radio system which seeks to cope with such microcellular situations while still maintaining the quality of handover control in macrocellular situations.

According to a first aspect the present invention provides a cellular radio system comprising: a plurality of base stations each having a radio transceiver serving a cell of the system; a mobile station having a radio transceiver for communicating with one or other of the base stations; and characterized by the system having on the one hand first means for time averaging handover criterion measurements over a first averaging period, means for applying a first hysteresis margin to the time averaged handover criterion measurements to provide a first handover indicator, and having on the other hand a second means for time averaging handover criterion measurements over a second averaging period which is relatively short compared to the first averaging period, and means for applying a second hysteresis margin, which is relatively large compared to the first hysteresis margin, to the time averaged handover criterion measurements to provide a second handover indicator, and means for assessing handover requirements of the mobile station on the basis of the first and second handover indicators; whereby on the one hand relatively gradual variations in handover criterion

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can be assessed and on the other hand relatively sudden variations in handover criterion can also be assessed.

Preferably the first averaging period is several times the second time averaging period, in particular of the order of 20 times. Preferably the first hysteresis margin is a significant fraction of the second hysteresis margin, in particular of the order of half.

A corresponding method is also provided.

A preferred embodiment of the invention will now be described by way of example and with reference to the accompanying drawings:

Figure 1 shows a graph illustrating the variations of received signal strength at a mobile station (ms) of two base stations (BS1, BS2) at points between them, with inset a sketch illustrating the simplified arrangement of the radio cells of the two base stations;

Figure 2 shows a graph similar to that of Figure 1 with factors of time averaging and hysteresis introduced;

Figure 3 is a diagram illustrating the inter-relationship of handover parameters and handover qualities;

Figure 4 shows a graph of received signal strength at a mobile station of two base stations (A, B) in a microcellular system, with inset a simplified plan of the two radio cells;

Figure 5 is a schematic block diagram of apparatus forming part of the preferred embodiment;

Figure 6 shows a graph illustrating the response of the apparatus in Figure 5 in a microcellular environment; and

Figure 7 is a table comparing typically examples of averaging delays and hysteresis margins for conventional systems and that of the preferred embodiment.

The base station and mobile station transceiver equipment for the cellular system are conventional and will

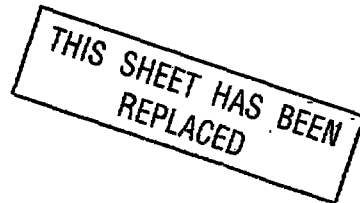


not be described further. The mobile station has signal strength measuring equipment for measuring the received signal strength of base stations, which is likewise conventional and will not be described further. The apparatus of the preferred embodiment additional to these equipments is shown in Figure 5 and may be either at mobile or base station.

The additional apparatus of the preferred embodiment has inputs (I_0 to I_N) for receiving received signal strength data for the current cell (I_0) and adjacent cells (I_1 to I_N) to which the mobile station obtaining the data may be handed over. Each input I is connected to a long term averaging unit (LTA_0 - LTA_N) and a short term averaging unit (STA_0 - STA_N). The long term averaging unit (LTA_0) provided with the data for the current communicating cell is connected to a first summer S_N which is provided with a narrow hysteresis margin HM_N while the short term averaging unit STA_0 which is also provided with the data for the current communicating cell is connected to a second summer S_W provided with a wide Hysteris Margin HM_W . The output of the first summer S_N is connected to a first comparator C_1 and the output of the second summer S_W is connected to a second comparator C_2 . The outputs of the remaining long term averaging units (LTA_1 - LTA_N) are selective connectable via a first switch SW_1 to the first comparator C_1 , and the remaining short term averaging units (STA_1 - STA_N) are similar connectable via a switch SW_2 to the second comparator C_2 . The outputs of the comparators C_1 , C_2 are connected as inputs to an OR gate OR1, the output of which forms a Handover signal.

Typical values for the $LTA=T$, and $STA=T_2$, and $HM_N=H_1$ and $HM_W=H_2$ are shown in Figure 7.

In a situation where pathloss varies gradually, e.g. a macrocell, the system operates general as described above with LTA/HM_N circuit providing for the current cell the



significant comparison figure which is compared in the first comparator C_1 with similar data for adjacent cells. When conditions for handover occur the first comparator C_1 produces an out which via OR gate OR1, forms a Handover initiation signal. On the other hand in situation where pathloss is a sudden, step function e.g. the microcellular situation of Figure 4 that STA/HMw circuits operate to provide the signals necessary to determine handover. An example response based on the signal patterns of 4 is shown in Figure 6. Curve A shows the output of the second comparator C_2 , while curve B shows the output of the first comparator C_1 . The curve A produces, (e.g. Fig. 4) an output forming a handover request with a 1 second delay after the sudden step function in the RSSI of the base station A (Figure 4), while the curve B, i.e. comparator C_2 , also produces a response but some 6 seconds after the step function occurs. Thus in the, e.g. microcellular step function pathloss case the apparatus of the preferred embodiment provides the necessary handover on a time scale appropriate to the circumstances.



CLAIMS

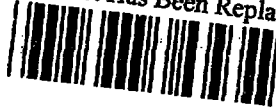
1. A cellular radio system comprising: a plurality of base stations each having a radio transceiver serving a cell of the system; a mobile station having a radio transceiver for communicating a base station; and characterized by the system having a first means for time averaging handover criterion measurements over a first averaging period, and means for applying a first hysteresis margin to the time averaged handover criterion measurements to provide a first handover indicator; a second means for time averaging handover criterion measurements over a second averaging period which is relatively short compared to the first averaging period, and means for applying a second hysteresis margin, which is relatively large compared to the first hysteresis margin, to the second time averaged handover criterion measurements to provide a second handover indicator; and means for assessing handover requirements of the mobile station on the basis of the first and second handover indicators; whereby relatively gradual variations in handover criterion can be assessed and relatively sudden variations in handover criterion can also be assessed.

2. A cellular radio system as claimed in claim 1 wherein the handover criterion is selected from:

- 1) signal strength of base station at the mobile station,
- 2) signal strength of the mobile station at the base station,
- 3) bit error rate of the communication between the mobile station and the base station,



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4) level of interference of two base stations operating at substantially the same frequency,

5) relative distance measurement of the mobile from the two closest base stations.

3. A cellular radio system as claimed in claim 1 or 2 wherein the first averaging period is several times the second averaging period.

4. A cellular radio system as claimed in claim 1, 2 or 3 wherein the first averaging period is between 10-100 times the second averaging period.

5. A cellular radio system as claimed in any preceding claim wherein the first averaging period is substantially 20 times the second averaging period.

6. A cellular radio system as claimed in any preceding claim where the first hysteresis margin is a significant fraction of the second hysteresis margin.

7. A cellular radio system as claimed in any preceding claim where the first hysteresis margin is between 0.25 and 0.75 of the second hysteresis margin.

8. A cellular radio system as claimed in any preceding claim wherein the first hysteresis margin is substantially 0.5 of the second hysteresis margin.

9. A method of assessing handover requirements of a mobile station in a cellular radio system in which a plurality of base stations each have a radio transceiver serving a cell of the system and the mobile station has a radio transceiver for communicating with one or other of the base stations, comprising the steps of:



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time averaging handover criterion measurements over a first averaging period, and applying a first hysteresis margin to the time averaged handover criterion measurements to provide a first handover indicator;

time averaging handover criterion measurements over a second averaging period which is relatively short compared to the first averaging period, and applying a second hysteresis margin, which is relatively large compared to the first hysteresis margin, to the time averaged handover criterion measurements to provide a second handover indicator;

assessing handover requirements of the mobile station on the basis of the first and second handover indicators.

10. A method according to claim 9 which comprises the steps of:

averaging over first and second differing averaging periods signal strength measurements of at least some of the base stations taken at the mobile stations, to provide a first averaged data of over the shorter averaging period and a second averaged data over the longer averaging period;

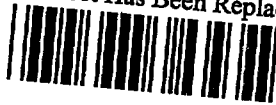
summing with first averaged data for one base station the larger of two differing hysteresis margins and summing with the second averaged data for that base station the smaller of the differing hysteresis margins, to provide a first and a second signal strength indicator respectively;

comparing the first signal strength indicator with signal strength measurement for at least one other base station averaged over the shorter averaging period;

comparing the second signal strength indicator with signal strength measurements for at least one other base station averaged over the larger averaging period,



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and determining on the basis of the comparisons the necessity for handover or cell re-selection for re-registration.

11. A cellular radio system substantially as herein described, and with reference to the accompanying drawings.

12. A method of determining handover or cell re-selection substantially as herein described, and with reference to the accompanying drawings.



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