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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 Hysteris 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 ($S\sigma$) of RSSIs varies with the Averaging period T; the hysteresis margin H is a function of $S\sigma$, and frequency of probability of unnecessary handover P_u ; and Handover delay D is the sum of the Averaging Delay and Hysteris 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 Hysteris 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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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 Hysteresis 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.

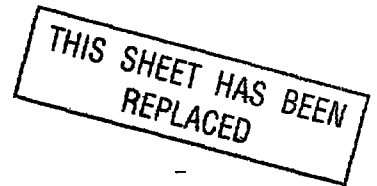
Typical values for the $LTA=T$, and $STA=T_2$, and $HM_N=H_1$ and $HM_W=H_2$ are shown in Figure 7.

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

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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 OR_1 , 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;

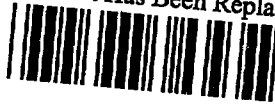
summing with first averaged data for one base station the larger of two differing hysteresis margins and summing with the second averaged data for that base station the smaller of the differing hysteresis margins, to provide a first and a second signal strength indicator respectively;

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.



* C L M S *

(Fig. 5)

ABSTRACT

CELLULAR RADIO

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; the system having on the one hand first means ($LTA_0, LTA_1, \dots, LTA_N$) for time averaging handover criterion (HOC) measurements over a first averaging period, means (S_N) for applying a first hysteresis margin to the time averaged HOC measurements to provide a first handover indicator, and having on the other hand a second means ($STA_0, STA_1, \dots, STA_N$) for time averaging HOC measurements over a second averaging period which is relatively short compared to the first averaging period, and means (S_w) for applying a second hysteresis margin, which is relatively large compared to the first hysteresis margin, to the time averaged HOC measurements to provide a second handover indicator, and means (OR_1) 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 HOC can be assessed and on the other hand relatively sudden variations in HOC can also be assessed.

Fig.1.

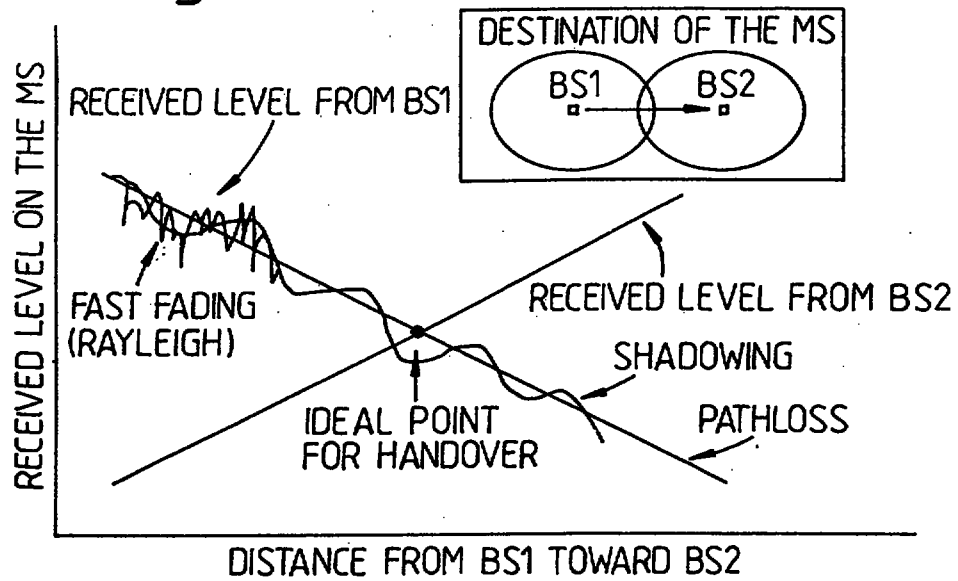


Fig.2.

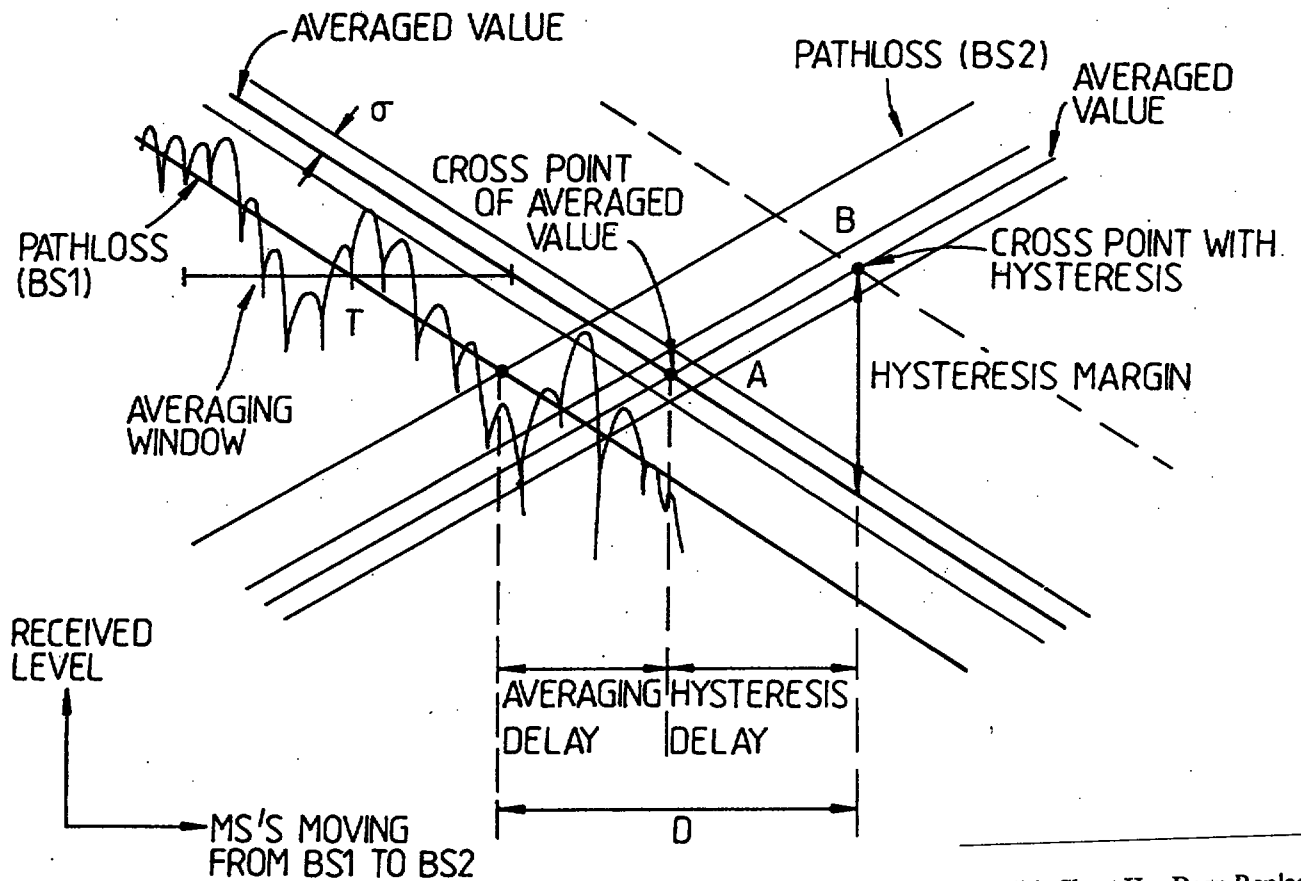


Fig. 3.

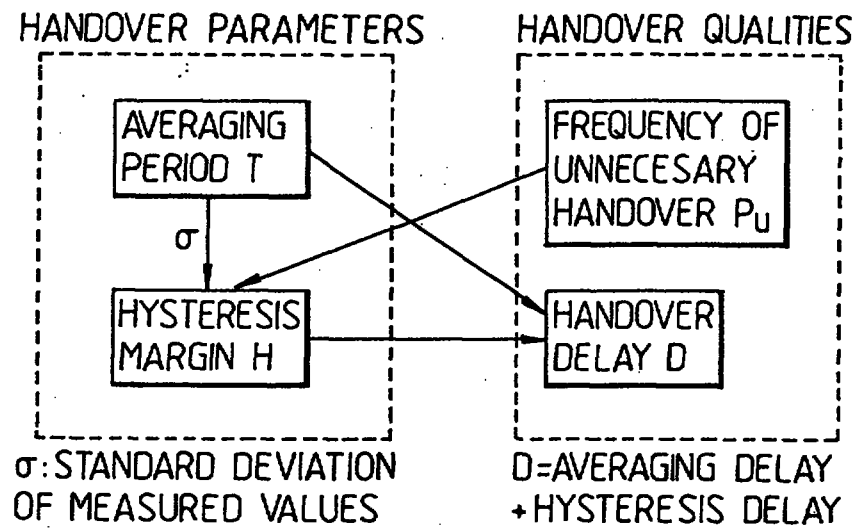


Fig. 4.

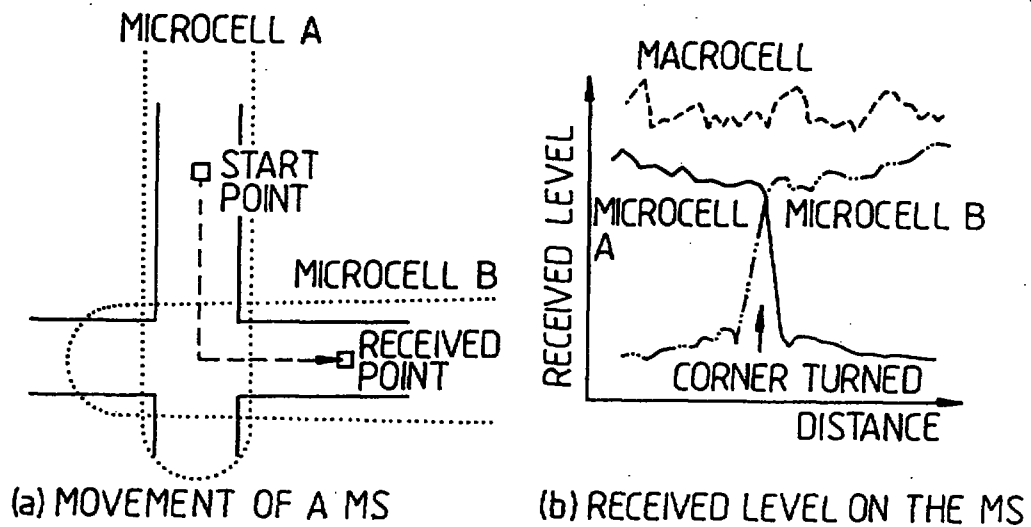
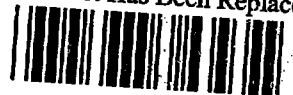
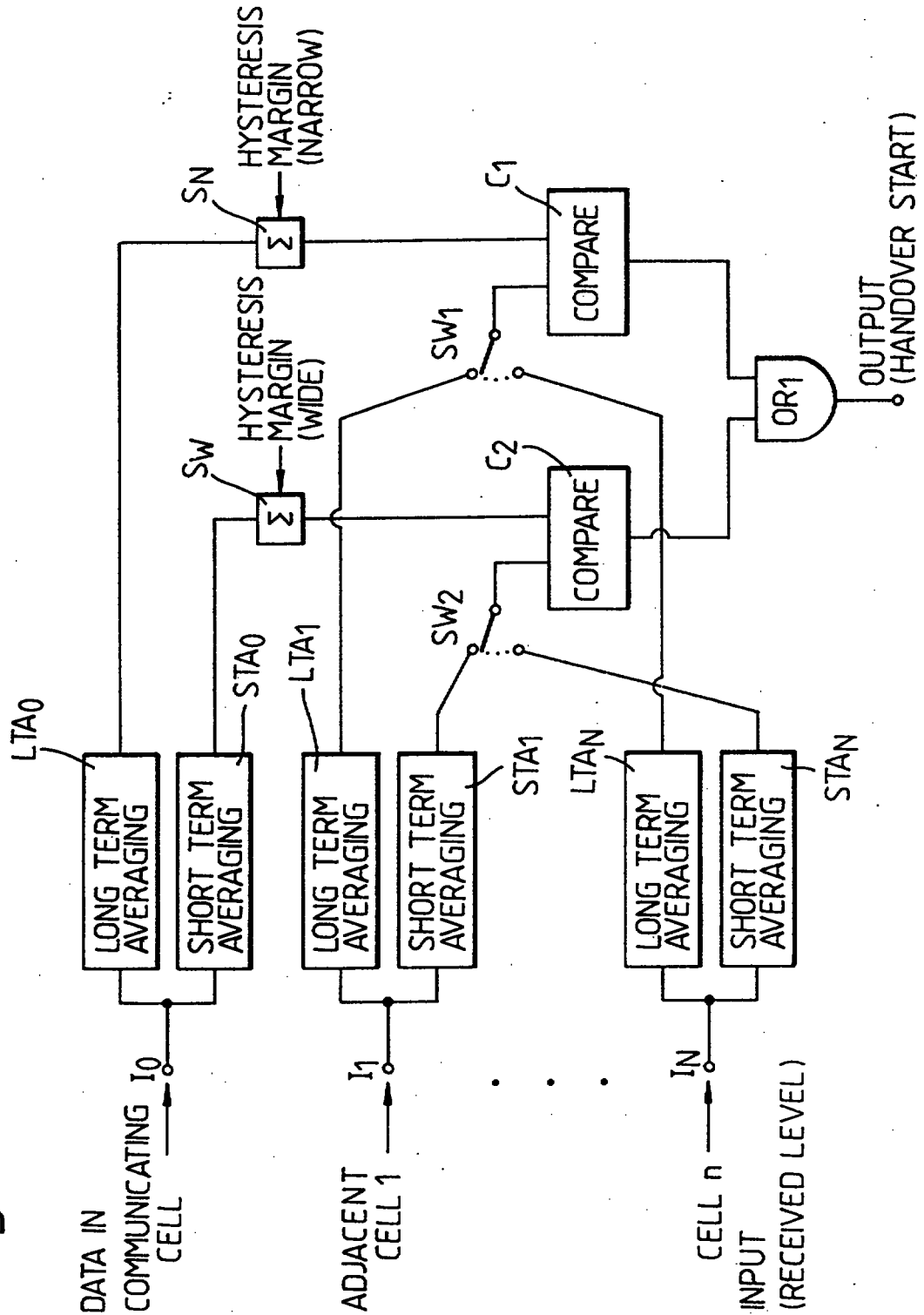


Fig. 5.



ROAD CORNER HANDOVER

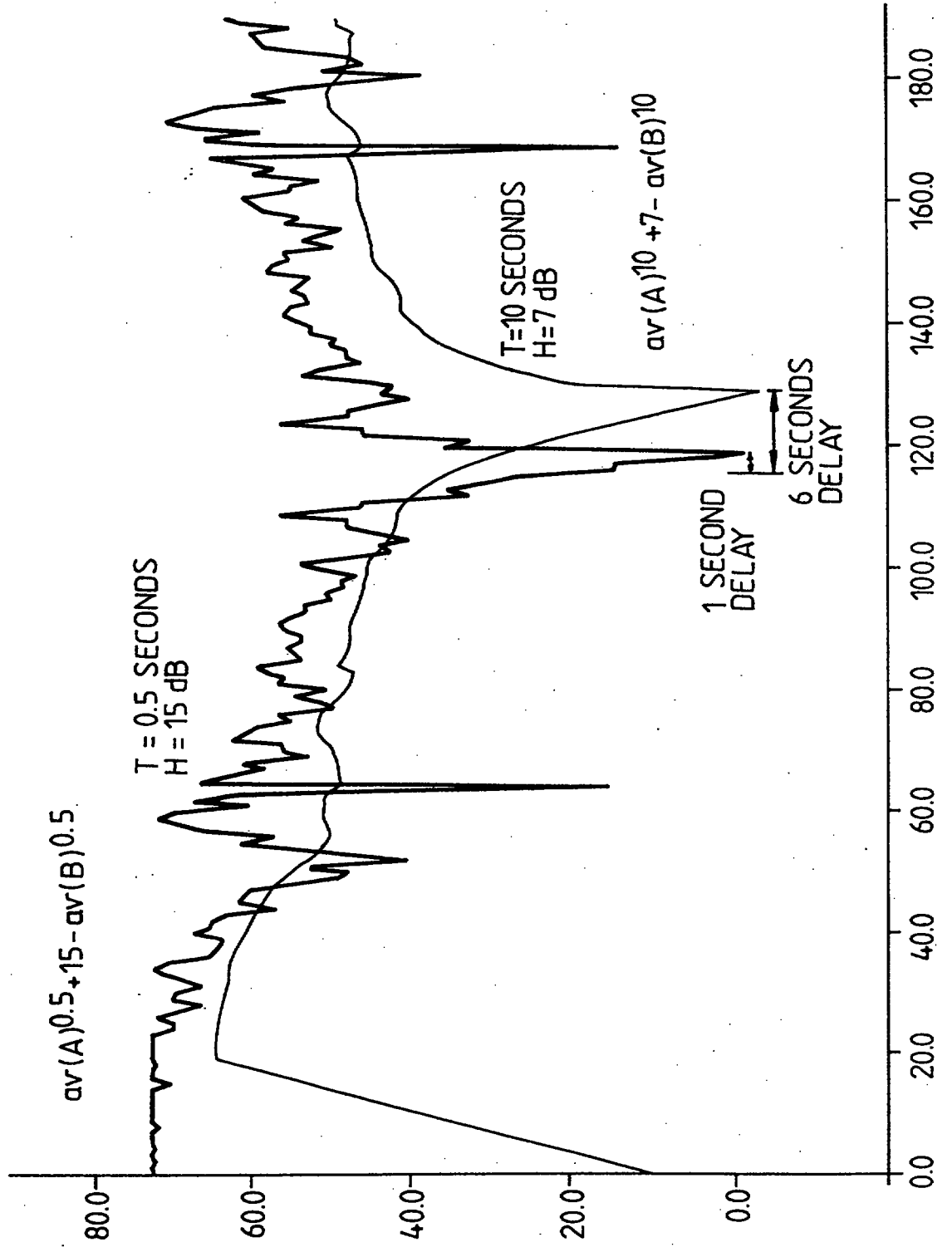


Fig. 6.

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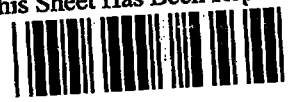


Fig. 7.

	CONVENTIONAL TECHNIQUE	THIS INVENTION
PARAMETERS (T=AVERAGING PERIOD) (H=HYSTERESIS MARGIN)	T=10 SECONDS H=7 dB	$\begin{cases} T = 10 \text{ SECONDS} \\ H_1 = 7 \text{ dB} \end{cases}$ $\begin{cases} T_2 = 480 \text{ ms} \\ H_2 = 15 \text{ dB} \end{cases}$ BOTH EFFECTIVE INDEPENDENTLY
DELAY IN TYPICAL PATHLOSS (CELLRADIUS 3km)	700 ~ 800m	700 ~ 800m
DELAY IN SUDDEN PATHLOSS	7 SECONDS	UNDER 1 SECOND

VEHICULAR VELOCITY: 50 km/h

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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 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. 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,
- 20 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).

25 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 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 "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.

35 Proposals for microcellular systems suggest their application to road network, for

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5 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 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 relatively short distances, for example in
10 an urban environment.

Taking RSSI as an example of a possible handover 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.

15 Considering a simplified situation, see inset sketch in Figure 1, where a mobile station MS moves between two cells served respectively by base stations BS1 and BS2, (serving microcells A and B respectively), 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 varies with fast (Rayleigh) fading and
20 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 and shadowing lead to uncertainty of the level of RSSI and to pathloss, hence render determination of the correct handover point more difficult.

25 However by time-averaging the RSSIs the effect of fading and shadowing can to some extent be overcome. This time averaging does introduce a delay, referred to as the time averaging delay, into the 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
30 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. The principle of handover hysteresis is
35 discussed by Toshihito Kanai in the Proceedings of the 38th IEEE Vehicular

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- 5 Technology Conference (June 1988:Philadelphia USA) pages 170-175. 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.
- 10 The two handover parameters, Averaging period (T) and Hysteris 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
- 15 delay D is the sum of the Averaging Delay and Hysteris 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 $H = 7$ dB. Such criterion can provide satisfactory results in a macrocell environment, however if
- 20 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 sketch in Figure 4, microcells A + B overlap at a road junction, and generally provide

25 coverage over only their respective road. When a mobile MS moves from the road served by base station BS1 into the road served by base station BS2, 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

30 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.

It is known from US patent number 4556760, granted in 1984 to

35 Goldman, to take account of long-term and short-term variations in the signal

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5 quality by time-averaging over two or more different periods, and summing the result. This allows a compromise between responsiveness and reliability to be achieved. However, this arrangement is a compromise, and takes no account of the characteristics of the individual cells.

10 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 a base station; a first means for time averaging first handover criterion measurements over a first averaging period, a second means for time averaging second handover criterion measurements over a second averaging period which is relatively short compared to the first averaging period, and means for assessing handover requirements of the mobile station on the basis of the time averaged first and second criterion measurements; and characterised by assessment means having means for applying a first hysteresis margin to the first time averaged handover criterion measurements to provide a first handover indicator; 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; whereby relatively gradual variations in handover criterion can be assessed using the first
25 handover indicator and relatively sudden variations in handover criterion can be assessed using the second handover indicator.

By determining whether the signal meets either of two hysteresis margins for different averaged values, the handover decision can be measured against two independent criteria, instead of a single compromised one.

30 Preferably the first averaging period is several times the second time averaging period, typically 10 to 100 times, and in particular of the order of 20 times. Preferably the first hysteresis margin is a significant fraction of the second hysteresis margin, typically between one quarter and three quarters, and in particular of the order of one half.

35 A corresponding method is also provided.

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- 5 In a preferred arrangement the method 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 first averaging period and a second averaged data over the second averaging period;
- 10 summing with first averaged data for one base station the first of two differing hysteresis margins and summing with the second averaged data for that base station the second 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
- 15 measurement for at least one other base station averaged over the first averaging period;
- comparing the second signal strength indicator with signal strength measurements for the at least one other base station averaged over the second averaging period,
- 20 and determining on the basis of the comparisons the necessity for handover from the first base station to the other base station or re-selection of the first base station.

A preferred embodiment of the invention will now be described by way
25 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;

30 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;

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5 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;

10 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.

15 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
20 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
25 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
30 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 selectively connectable via a first switch SW_1 to the first
35 comparator C_1 , and the remaining short term averaging units (STA_1 - STA_N) are

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5 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 $LTA=T_1$, and $STA=T_2$, and $HM_N=H_1$ and $HM_W=H_2$ as shown in Figure 7.

10 In a situation where pathloss varies gradually, e.g. a macrocell, the system operates in general as described above with the LTA_0/S_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 output which, via the OR
15 gate OR1, forms a Handover initiation signal. On the other hand in a situation where pathloss is a sudden, step function, e.g. the microcellular situation of Figure 4, the STA_0/HSW circuit operates to generate in the second comparator C_2 an output which provides the signals necessary to determine handover. An example response based on the signal patterns of 4 is shown in Figure 6. Curve
20 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 BS1 of microcell A (Figure 4), while the curve B, i.e. comparator C_2 , also produces a response but some 6 seconds after the step
25 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.

In certain circumstances the signal may deteriorate, triggering start of the handover process, when no suitable candidate station is available. In such a
30 case the handover process will identify the current base station BS1 as still being the optimum, and the current cell will be reselected for re-registration.

CLAIMS

REPLACEMENT SHEET

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1. A cellular radio system comprising: a plurality of base stations (BS_1 , BS_2) each having a radio transceiver serving a cell of the system; a mobile station (MS) having a radio transceiver for communicating with a base station (BS_1 , BS_2), a first means (LTA) for time averaging first handover criterion measurements over a first averaging period, a second means (STA) for time averaging second handover criterion measurements over a second averaging period which is relatively short compared to the first averaging period, and means for assessing handover requirements of the mobile station on the basis of the time averaged first and second criterion measurements;

characterised by assessment means having means (S_w) for applying a first hysteresis margin (H_1) to the first time averaged handover criterion measurements to provide a first handover indicator; and means (S_w) for applying a second hysteresis margin (H_2), which is relatively large compared to the first hysteresis margin, to the second time averaged handover criterion measurements to provide a second handover indicator; whereby relatively gradual variations in handover criterion can be assessed using the first handover indicator and relatively sudden variations in handover criterion can be assessed using the second handover indicator.

20

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,

25

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.

5

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
10 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.

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

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

20

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 (MS) in
25 a cellular radio system in which a plurality of base stations (BS₁, BS₂) each have a radio transceiver serving a cell of the system and the mobile station (MS) has a radio transceiver for communicating with one or other of the base stations (BS₁, BS₂), comprising the steps of:

time averaging handover criterion measurements over a first averaging
30 period,

time averaging handover criterion measurements over a second averaging period which is relatively short compared to the first averaging period,



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and assessing handover requirements of the mobile station (MS) on the basis of the first and second measurements;

characterised in that the method comprises: applying a first hysteresis margin (H_1) to the time averaged handover criterion measurements to provide a first handover indicator; and applying a second hysteresis margin (H_2), which is relatively large compared to the first hysteresis margin, to the time averaged handover criterion measurements to provide a second handover indicator.

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

10 averaging over first and second differing averaging periods signal strength measurements of at least some of the base stations (BS_1 , BS_2) taken at the mobile stations, to provide a first averaged data over the first averaging period and a second averaged data over the second averaging period;

summing with first averaged data for one base station (BS_1) the first of two differing hysteresis margins (H_1) and summing with the second averaged data for that base station (BS_1) the second of the differing hysteresis margins (H_2), to provide a first and a second signal strength indicator respectively;

15 comparing the first signal strength indicator with signal strength measurement for at least one other base station (BS_2) averaged over the first averaging period;

20 comparing the second signal strength indicator with signal strength measurements for the at least one other base station (BS_2) averaged over the second averaging period,

and determining on the basis of the comparisons the necessity for handover from the first base station (BS_1) to the other base station (BS_2) or re-selection of the first base station (BS_1).

11. A method according to claim 9 or 10, wherein the handover criterion is selected from:

- 30
- 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.

5

12. A method according to claim 9, 10 or 11, wherein the first averaging period is several times the second averaging period.

13. A method according to claim 9, 10, 11 or 12, wherein the first averaging period is between 10-100 times the second averaging period.

14. A method according to claim 9, 10, 11, 12 or 13, wherein the first averaging period is substantially 20 times the second averaging period.

15. A method according to claim 9, 10, 11, 12, 13, or 14, wherein the first hysteresis margin is a significant fraction of the second hysteresis margin.

16. A method according to claim 9, 10, 11, 12, 13, 14 or 15, wherein the first hysteresis margin is between 0.25 and 0.75 of the second hysteresis margin.

20

17. A method according to claim 9, 10, 11, 12, 13, 14, 15 or 16, wherein the first hysteresis margin is substantially 0.5 of the second hysteresis margin.

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Fig.1.

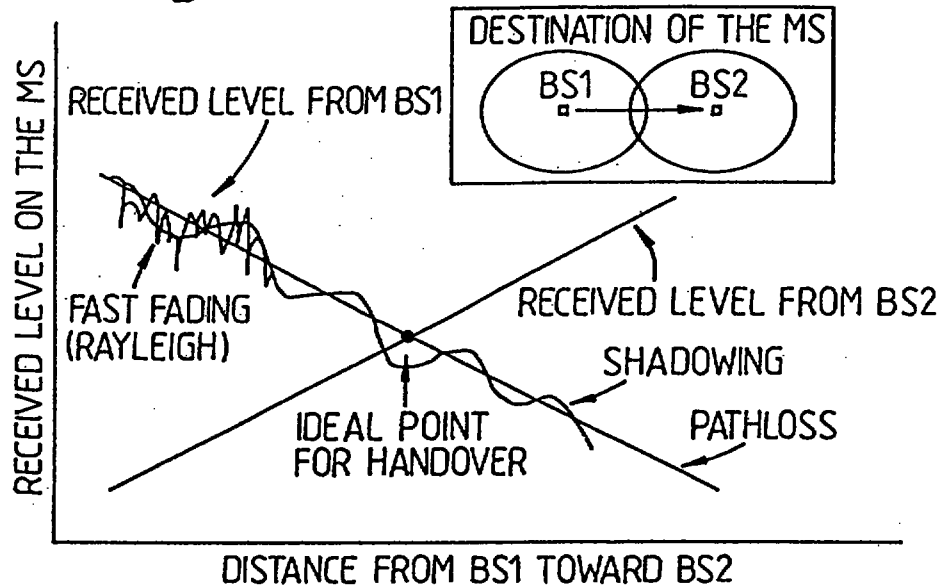
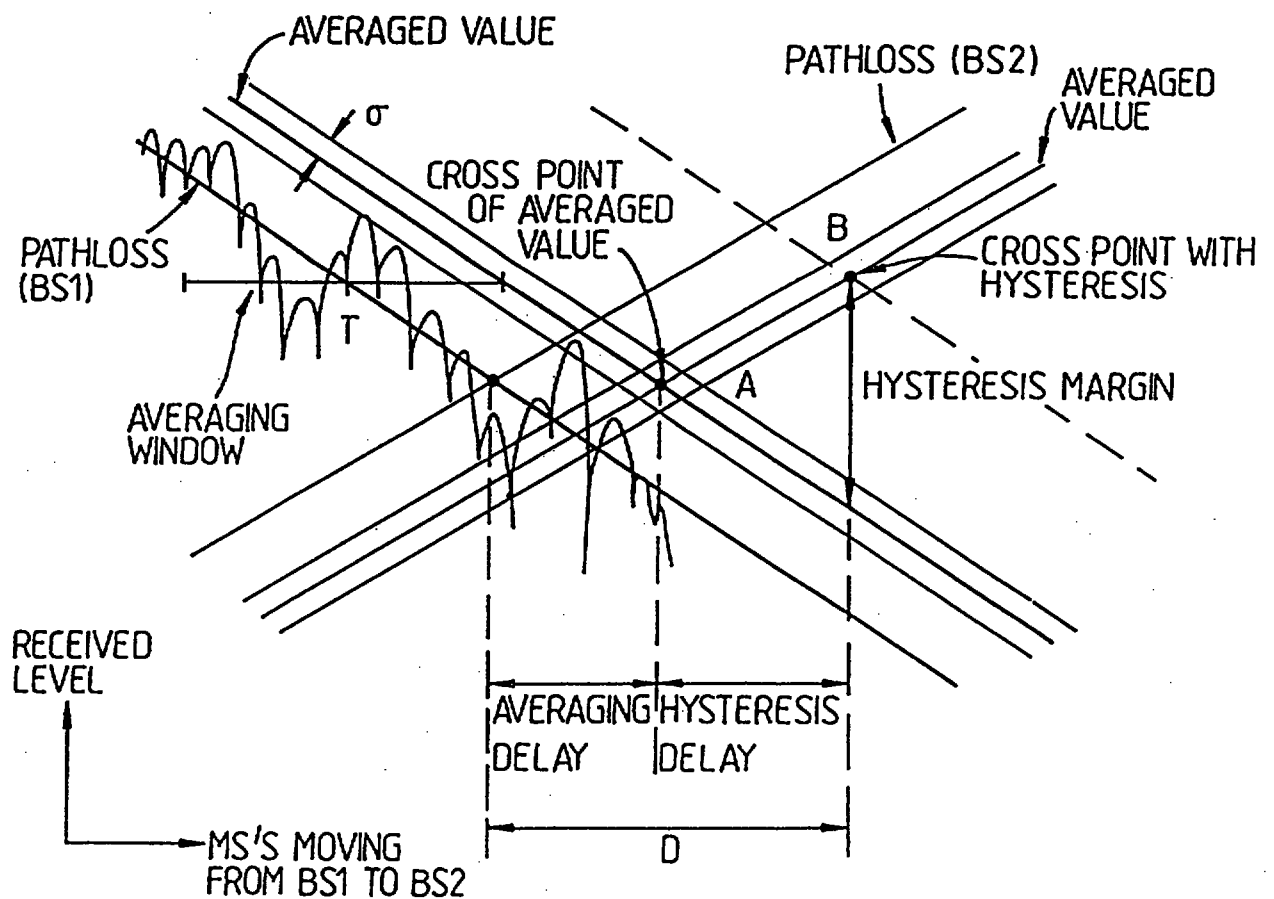


Fig. 2.



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ROAD CORNER HANDOVER

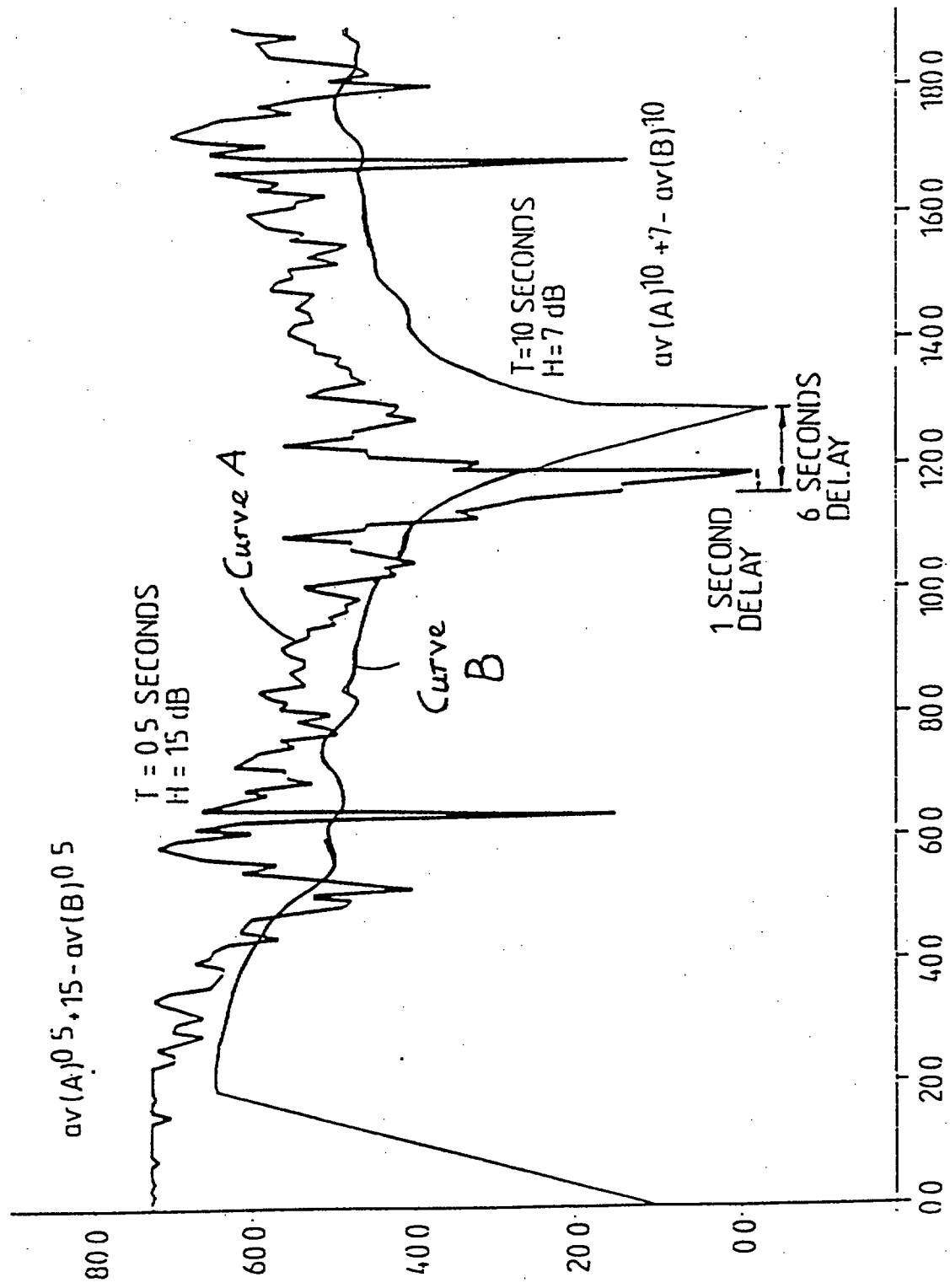


Fig. 6.