

METHOD AND APPARATUS FOR
HAND-OFF OF CALL IN PROGRESS

The present invention is generally related to a small-cell mobile radio communication system such as a cellular mobile telephone system and particularly related to a method and apparatus for determining timing of a hand-off for permitting a mobile station to continue a telephone call while the mobile station is roaming across different small cells.

Already-utilized prior art systems of determining timing of a hand-off are classified into the following two types:

- (1) A first type of the prior art system is the system that the hand-off timing is determined on the basis of a ratio of a length of time in which a detected value of a signal-to-noise ratio (hereinunder abbreviated as an SNR) is below a predetermined threshold to the total length of time of detecting or measuring the SNR; and
- (2) Another type of the prior art system is the system that the hand-off timing is determined on the basis of a ratio of a length of time in which a detected value of received signal strength input (hereinunder abbreviated as an RSSI) is below a predetermined threshold value to the total time of measuring the RSSI. A typical system of the first type (hereunder referred to simply as an SNR system)

is the NORDIC mobile telephone system and further that of the second type (hereunder referred to simply as an RSSI system) is the small-cell mobile telephone system developed in the United States of America (hereunder referred to simply as the U.S. cellular system).

Turning now attention to Fig. 5, there is illustrated a block diagram of a conventional hand-off timing detecting system proposed by, for example, ASTRONET CORPORATION in the United States of America. In this figure, the reference numeral 1 designates a receiving antenna; 2 a high frequency amplifier; 3 a first mixer; 4 a first station-originating signal oscillator; 5 a first intermediate-frequency filter; 6 a second station-originating signal oscillator/second mixer; 7 a second intermediate-frequency filter; 8 a second intermediate-frequency amplifier/discriminator; 9 a noise detector; 10 an SAT signal detector; 11 a comparator; 12 a logical circuit/controller; and 13 an output terminal.

Next, the operation of this system will be explained hereinbelow. High-frequency signals received by the receiving antenna 1 are amplified by the high-frequency amplifier 2. Then, the amplified signals from the amplifier 2 are combined with signals from the oscillator 4 by the first mixer 3 to produce first intermediate-frequency signals. Desired waves are selected from the thus obtained first intermediate-frequency signals by use of the band filter 5 and are converted into second intermediate-frequency signals by the second station-originating signal oscillator/second mixer 6. The second intermediate-frequency signals undergo

a selecting process in the band filter 7. Further, the thus selected signals are converted into voice signals by the intermediate-frequency amplifier/discriminator 8 and then the voice signals are fed to an SNR detecting circuit which is composed of the noise detector 9, the SAT signal detector 10 and the comparator 11. The voice signals contain supervisory audio tone (hereunder abbreviated as SAT) signals in addition to ordinary signals representing voices. The SAT signals are used to monitor circuits, and three kinds of waves (namely, waves of 5970 Hz, 6000 Hz and 6030 Hz) are used as the SAT signals in the U.S. cellular system. The SAT signal is detected by the signal detecting circuit 10. On the other hand, noises, of which frequencies are close to the frequency of the SAT signal, are detected by the noise detector 9. Thereafter, an SNR is evaluated by comparing a voltage level S of the detected signal to a voltage level N of the noise in the comparator 11. An output of the comparator 11 is at a level indicating "on" state thereof (hereunder referred to simply as "on" level" when the evaluated value of the SNR exceeds or equals a predetermined threshold (for instance, 20 dB), whereas the output thereof is at another level indicating "off" state thereof (hereunder referred to simply as "off" level) when being below the threshold. The logical circuit/controller 12 detects a ratio of a length of time, in which the output of the comparator 11 is at the "off" level, to the total time of the measurement of an SNR. If the detected rate exceeds the threshold, the logical circuit/controller 12 sends out

a hand-off request by putting the output terminal 13 at a level indicating "ON" status of the SNR detecting circuit (hereunder referred to simply as "ON" status level).

On the other hand, the RSSI system employs an RSSI detecting circuit which substitutes for the above described SNR detecting circuit 9, 10 and 11. Further, in the RSSI detecting circuit by using the similar procedures as in the SNR detecting circuit.

As described above, each prior art system of detecting timing of a hand-off employs either the SNR system or the RSSI system. Comparison between these SNR and RSSI systems reveals the following fact. First, in case that adjacent two small-cells or zones are arranged to overlap with each other slightly or in part, the SNR system surpasses the RSSI system at performance of appropriately detecting timing of a hand-off because the SNR can detect disturbances caused by interference or the like. However, in case that the adjacent two zones overlap with each other in large part, the RSSI system surpasses the SNR system because the RSSI system can detect high RSSI. In spite of this fact there is provided no system which is capable of optimizing the timing of a hand-off in accordance with every type of zone arrangement. The present invention is made to obviate the above-described problems of the prior art.

According to a first aspect the present invention

provides apparatus for effecting a hand-off of a call-in-progress in a cellular mobile radio communication system, including signal processing means for processing the signal received from a mobile station to derive both an SNR and an RSSI simultaneously and independently of each other;

means for selecting at least one of the detected SNR and RSSI;

means for measuring a time period when the selected SNR and/or RSSI is below a corresponding predetermined threshold; and

means for sending out a hand-off signal when at least one of the selected SNR and RSSI is below the predetermined threshold during a predetermined time period.

The invention also provides a method for a hand-off of a call-in-progress in a cellular mobile radio communication system, including the steps of:

converting a signal received from a mobile station into an intermediate-frequency signal;

detecting both an SNR and an RSSI from the intermediate-frequency signal simultaneously and independently with each other;

selecting at least one of the detected SNR and RSSI;

measuring a time period when the selected SNR and/or RSSI is below a corresponding predetermined threshold; and

sending out a hand-off signal when at least one of the selected SNR and RSSI is below the predetermined threshold during a predetermined time period.

According to a further aspect the present invention provides in a cellular mobile radio communication system having a central switching office provided with a hand-off apparatus for determining optimal timing of a

hand-off of a call in-progress and for sending out a hand-off signal at the determined time of a hand-off, a plurality of base stations and a mobile station, said hand-off apparatus including:

signal input means for receiving and amplifying a high-frequency signal from a mobile station and for converting the amplified signal into an intermediate-frequency signal;

an SNR detecting circuit connected to said signal input means for converting the intermediate-frequency signal into a voice signal and for detecting a SNR of the voice signal and for outputting a first "on" state signal when the detected SNR exceeds or equals a predetermined first threshold and a first "off" state signal when the detected SNR is below the first threshold;

an RSSI detecting circuit connected to said signal input means for detecting RSSI of the intermediate-frequency signal independently of said SNR detecting circuit means and for outputting a second "on" state signal when the detected RSSI exceeds or equals a predetermined second threshold and a second "off" state signal when the detected RSSI is below the second threshold; and

control logic means connected to both said SNR and RSSI detecting circuit for selecting one of the outputs from said SNR and RSSI detecting circuit, for measuring a

first total length of time when the selected SNR or RSSI is below the corresponding first or second threshold by timing the first or second "off" state signal, for evaluating a ratio of the first total length of time to a predetermined measuring time of the SNR and RSSI and for sending out a hand-off signal when the evaluated ratio exceeds a predetermined third threshold thereby determining optimal timing of a hand-off of a call-in-progress.

Accordingly, with the present invention a method and apparatus for a hand-off of a call-in-progress optimizes the timing of a hand-off by virtue of a combination of the SNR system and the RSSI system.

A method and apparatus for a hand-off of a call-in-progress according to the present invention is arranged such that both a ratio (hereunder referred to simply as a first ratio) of a length of time, in which a measured value of SNR is below a predetermined "threshold" to a total length of the measuring time, and a ratio (hereunder referred to simply as a second ratio) of a length of time, in which a measured value of RSSI is below a predetermined "threshold", to a total length of the measuring time are detected and that the first ratio functions mainly when the "threshold" of RSSI is predetermined to a relatively low value; and the second ratio functions mainly when the "threshold" of the RSSI is predetermined to a relatively high value, thereby optimizing the hand-off timing.

To evaluate the first ratio according to the present invention, a total length t_1 of time in which a measured value of SNR being below that of the predetermined "threshold" within a length T_1 , of the measuring time is first evaluated. Thereafter, the first ratio (t_1/T_1) is obtained by dividing T_1 into t_1 . Further, the detection of the second ratio according to the present invention is performed in the same way. The detection of the SNR and RSSI and the setting of the "threshold" of the SNR are performed by using hardware of a receiver, while the setting of t_1 and T_1 and of the "threshold" of the RSSI is performed by utilizing information in the data base provided within a central switching office.

As described above, the present invention can provide optimal timing of a hand-off in relation to the given arrangement of the small-cells or zones by making use of a combination of the SNR system and the RSSI system.

Other objects and advantages of the present invention will be understood by those of ordinary skill in the art after referring to the detailed description of a preferred embodiments contained herein and to the drawings, wherein:

Fig. 1 is a block diagram of an apparatus or system for a hand-off of a call-in-progress embodying the present invention;

Fig. 2 is an explanatory diagram showing an example of detecting the first and second ratios in accordance with the present invention;

Fig. 3 is a flowchart for illustrating a procedure of determining timing of a hand-off in one embodiment of the present invention;

Fig. 4 is a flowchart for illustrating another procedure of determining timing of a hand-off in another embodiment of the present invention; and

Fig. 5 is a block diagram of a conventional apparatus or system for a hand-off of a call-in-progress.

It is to be noted that the same numerals indicate the like or corresponding components in the figures.

Hereinafter, one embodiment of the present invention will be detailedly described with reference to the

accompanying drawings. In Fig. 1, reference numerals 1 through 13 indicate the same components as those in the prior art system (excluding software). An RSSI detector generally indicated by reference numeral 14 has an output terminal connected to an input port of a logical circuit/controller 12.

Fig. 2 is an explanatory diagram illustrating a system of detecting a ratio of time when a detected value of the RSSI is below the "threshold" to a length of time of measuring the RSSI. Fig. 3 is a flowchart showing procedures for issuing a hand-off request.

The SNR is detected in the same manner as in the above-described conventional system. A total length t of time in which the detected value of the SNR is below the "threshold" is given by summing up periods of time t_a and t_b shown in Fig. 2 as follows:

$$t = t_a + t_b$$

Further, the first ratio is computed from a ratio of the total length t to a length T_1 of the current measuring time.

On the other hand, in case of the RSSI system, the detection of RSSI involves a step of amplifying an output of a second station-originating signal oscillator/mixer 6 by use of the RSSI detector 14 including a logarithmic amplifier and further steps of rectifying the thus amplified output to produce DC output. The outputs of the RSSI detector 14 are sampled 100 times per 1 millisecond by means of the controller, and a resultant mean value is compared

with the "threshold" of RSSI. Then the second ratio of a length t when the detected value of the RSSI is below the "threshold" as illustrated in Fig. 2 to the time width T_1 is computed.

Next, the procedure for sending out the hand-off request will be described hereinbelow, referring to the flowchart of Fig. 3.

At the time of the system start, a predetermined value of the total length t_1 of time when the detected value of SNR or RSSI is below the predetermined "threshold" thereof, a predetermined value of the length T_1 of the time for measuring or detecting SNR or RSSI and a "threshold" of RSSI for selecting one of the SNR and RSSI systems are down-line-loaded from the data base provided in the central switching office to the logical circuit/controller 12 and are then stored therein. The subsequent step of the procedure is to determine whether the "threshold" of the RSSI is relatively high or low, that is, whether the "threshold" is below or above a preset value (step S1). If below, the SNR system is selected (step S2). Contrarily, if above, the RSSI system is selected (step S6).

First, in case that the SNR system is selected, an output of the SNR detecting circuit, that is, the output level at the output terminal of the SNR detecting circuit is read to judge whether the level of the output terminal indicates "ON" or "OFF" status of the SNR detecting circuit, that is, whether the comparator 11 outputs the "off" state signal or the "on" state signal (step S3). If the output

level of the terminal 13 indicates "ON" status (that is, the output of the comparator 11 indicates "off" state of the comparator 11), the currently existing data of a t-counter are shifted one digit or bit position (step S4), and at the same time 1 (corresponding to a given clocking period) is added to contents of a storing means, for example, another counter (hereunder referred to as a T-counter) provided in the logical circuit/controller 12 for counting the time passed since the start of the current detection or measurement of the SNR. If time of T_1 has elapsed since the start of the detection and further the data obtained by the last measurement of SNR effected in the previous measuring time of T_1 is left in the t-counter, the data are deleted because of their unnecessaryness (step S10).

The contents of the t-counter, which is used to represent the total length t of time when the detected SNR is below the "threshold", are checked (step S11). If the total t exceeds t_1 , a signal indicating the hand-off request (that is, a hand-off signal) is issued (step S12). If not, the system proceeds to the next task (step S13). The task shown in Fig. 3 is executed every clocking period, and hence the hand-off request is sent out just when the hand-off to the next zone is required due to deterioration of the SNR.

Next, in case where the RSSI system is selected, the mean value of the detected RSSI is evaluated by executing another task to make a comparison between the mean value and the "threshold" of RSSI (step S7). If the mean value is below the "threshold", the presently existing data in the

t-counter are shifted one digit, and simultaneously 1 is added to the contents of the T-counter. Subsequently, the hand-off time is determined in the same procedure as those of the SNR system.

Directing now attention to Fig. 4, there is shown the flowchart of the procedure of another embodiment of the present invention. The detection and evaluation of both the RSSI and SNR is constantly effected regardless of the "threshold" of the RSSI; and if timing of a hand-off is determined from either of the evaluated values of the above-described first and second ratios $(t/T)_1$ and $(t/T)_2$, the hand-off request is issued (step P13). Generally, as shown in this figure, a first and second sets (t_1, T_1) and (t_2, T_2) , respectively. Further, as t in the embodiment of Fig. 3, t_1 and t_2 indicate thresholds of the total length t of time when the detected values of the SNR and RSSI are below their corresponding predetermined "thresholds", respectively. Thus, in this embodiment, a t' -counter and a t'' -counter are used to measure such total lengths of the time in which the detected values of the SNR and RSSI are below their "thresholds", respectively (steps P3 and P8). Furthermore, T_1 and T_2 indicate "thresholds" of time passed since the start of the detection of the SNR and RSSI, respectively (steps P4 and P9). In this embodiment, "thresholds" of the first and second ratios $(t/T)_1$ and $(t/T)_2$, may be reset to be different from each other. Thus, in general, data t_1 , t_2 , T_1 and T_2 can be set in the data base of the central switching office such that $t_1 \neq t_2$; and

$T_1 \neq T_2$. However, in practice, these data are usually set as follows:

$$t_1 = t_2; \text{ and}$$

$$T_1 = T_2.$$

In accordance with the procedure for sending out the hand-off request in addition to those in the above-described embodiment, the timing of the hand-off can be determined from a ratio of time, in which either one of the detected SNR and RSSI is below the corresponding "threshold", to the total length of the measuring time. In this case, a truth table is obtained as shown in Table 1.

Table 1
A Truth Table

RSSI	SNR	OUTPUT
0	0	0
1	0	1
0	1	1
1	1	1

Furthermore, it is possible to determine timing of a hand-off from specified equations and a truth table by combining all the factors such as the "threshold" itself of SNR, the first ratio $(t/T)_1$, the "threshold" itself of RSSI, and the second ratio $(t/T)_2$.

Further, although in the above-described embodiments, noises, frequencies of which are close to those of the SAT signals, are utilized for detection of the SNR, it is also feasible to detect the SNR by employing out-band noises.

Further, although noises, frequencies of which being close to those of the SAT signals, are utilized for the detection of the SNR in the above-described embodiments, it is also feasible to detect the SNR by employing out-band noises.



CLAIMS

1. Apparatus for effecting a hand-off of a call-in-progress in a cellular mobile radio communication system, including signal processing means for processing the signal received from a mobile station to derive both an SNR and an RSSI simultaneously and independently of each other;
means for selecting at least one of the detected SNR and RSSI;
means for measuring a time period when the selected SNR and/or RSSI is below a corresponding predetermined threshold; and
means for sending out a hand-off signal when at least one of the selected SNR and RSSI is below the predetermined threshold during a predetermined time period.
2. Apparatus according to claim 1 wherein said signal processing means includes means for converting the received signal into an intermediate frequency signal and deriving the SNR and RSSI thereof.
3. In a cellular mobile radio communication system having a central switching office provided with a hand-off apparatus for determining optimal timing of a hand-off of a call in-progress and for sending out a hand-off signal at the determined time of a hand-off, a plurality of base stations and a mobile station, said hand-off apparatus including:
signal input means for receiving and amplifying a high-frequency signal from a mobile station and for converting the amplified signal into an intermediate-frequency signal;



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an SNR detecting circuit connected to said signal input means for converting the intermediate-frequency signal into a voice signal and for detecting a SNR of the voice signal and for outputting a first "on" state signal when the detected SNR exceeds or equals a predetermined first threshold and a first "off" state signal when the detected SNR is below the first threshold;

an RSSI detecting circuit connected to said signal input means for detecting RSSI of the intermediate-frequency signal independently of said SNR detecting circuit means and for outputting a second "on" state signal when the detected RSSI exceeds or equals a predetermined second threshold and a second "off" state signal when the detected RSSI is below the second threshold; and

control logic means connected to both said SNR and RSSI detecting circuit for selecting one of the outputs from said SNR and RSSI detecting circuit, for measuring a first total length of time when the selected SNR or RSSI is below the corresponding first or second threshold by timing the first or second "off" state signal, for evaluating a ratio of the first total length of time to a predetermined measuring time of the SNR and RSSI and for sending out a hand-off signal when the evaluated ratio exceeds a predetermined third threshold thereby determining optimal timing of a hand-off of a call-in-progress.

4. A hand-off apparatus as set forth in claim 3, wherein said SNR detecting circuit includes:



signal detecting means for detecting an SAT signal in the voice signal;

noise detecting means for detecting noise, the frequency of which is close to that of the SAT signal; and

comparing means connected to both signal and noise detecting means for evaluating a SNR from the detecting SAT signal and noise.

5. Apparatus according to claim 3 or 4 wherein said selecting means selects the output from the SNR and RSSI detecting circuits according to the value of the second threshold.

6. Apparatus according to claim 5 wherein the second threshold is set with reference to a data base within the central switching office.

7. A method for a hand-off of a call-in-progress in a cellular mobile radio communication system, including the steps of:

converting a signal received from a mobile station into an intermediate-frequency signal;

detecting both an SNR and an RSSI from the intermediate-frequency signal simultaneously and independently with each other;

selecting at least one of the detected SNR and RSSI;

measuring a time period when the selected SNR and/or RSSI is below a corresponding predetermined threshold; and

sending out a hand-off signal when at least one of the selected SNR and RSSI is below the predetermined threshold during a predetermined time period.



8. A method for a hand-off of a call-in-progress as set forth in claim 7, wherein the timing of a hand-off is determined on the basis of the detected SNR when a first threshold of RSSI is below a second threshold and determined on the basis of the detected RSSI when a first threshold of RSSI is above or equals the second threshold.

9. A method according to claim 8 wherein the first threshold is set with reference to a data base within the central switching office.

10. A method for a hand-off of a call-in-progress as set forth in claim 7, 8 or 9 wherein the timing of a hand-off is determined by selecting the shorter of a first time detected on the basis of the detected RSSI and second time detected on the basis of the detected SNR.

11. A method for a hand-off of a call-in-progress as set forth in claim 7, 8, 9 or 10 wherein the timing of a hand-off is determined from a first ratio of time in which the detected SNR is below a third threshold to a period of time of detecting SNR or from a second ratio of time in which the detected RSSI is below a first threshold to a period of time of detecting RSSI.

12. A method for a hand-off of a call-in-progress as set forth in claim 7, 8, 9 or 10 wherein the timing of a hand-off is determined on the basis of a combination of said threshold of SNR and first ratio, and of a first threshold of RSSI and the second ratio.



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13. A method for a hand-off of a call-in-progress as set forth in claim 7, 8, 9 or 10 wherein the timing of a hand-off is determined on the basis of all combinations of said threshold of SNR and first ratio, and of a first threshold of RSSI and the second ratio.

14. Apparatus constructed and arranged to operate substantially as hereinbefore described with reference to and as illustrated in Figures 1 to 4 of the accompanying drawings.

15. A method substantially as hereinbefore described with reference to and as illustrated in Figures 1 to 4 of the accompanying drawings.

16. A cellular mobile radio communication system including a hand-off apparatus according to any one of claims 1 to 6 and 14 or operating according to any one of claims 7 to 13 and 15.
