DESCRIPTION

PORTABLE TELEPHONE

Technical Field

The present invention relates to a portable telephone that is used as a mobile station in a cordless telephone system where communication takes place between a mobile station and a base station according to a communication method such as a TDMA/TDD (Time Division Multiplex Access/Time Division Duplex) method. More particularly, the present invention relates to a technique for improving handovers.

Background Art

In a cordless telephone system where each area is made up of a plurality of radio zones, a portable telephone needs to move between the plurality of radio zones without interrupting communication. To do so, the portable telephone switches from a traffic channel used for a currently serving base station to a different traffic channel for a newly serving base station while continuing communication. This process is generally called a "handover".

Several standards have been established for handovers. These are described in detail in various documents, such as "The Second-Generation Cordless Telephone System Standard (RCR STD-28)" published by Radiowave System Development Center

Foundation. The operation performed by a conventional portable telephone during a handover is described below.

Fig. 1 is a timing chart illustrating the operation of a conventional portable telephone during the handover. It should be noted here that in this drawing, "reception" on the upper level indicates that the portable telephone receives a signal from a base station when the line projects upward, while "transmission" on the lower level indicates that the portable telephone transmits a signal to a base station when the line projects upward.

After communication is started, the portable telephone continuously monitors the level of a current traffic channel and the reception quality. More specifically, the portable telephone successively monitors the value of each RSSI (received signal strength indication) and the frame error rate. When detecting deterioration in the traffic channel level or the reception quality (when detecting that an RSSI value falls below a predetermined threshold value, for instance), the portable telephone initiates a handover operation.

After initiating the handover operation, the portable telephone starts to receive signals transmitted on a control channel (hereinafter referred to as a "C channel" or "CCH") and searches for other base stations whose RSSI values are at least equal to a predetermined value (CCH search processing period). The portable telephone performs this operation by switching a reception channel to the C channel and continuously receiving the signals transmitted on the C channel for a certain period

(usually set in a range from around one to several tenths of a second). While receiving the transmitted signals, the portable telephone monitors RSSI values.

It should be noted here that in the conventional portable telephone system described here, each base station intermittently transmits a control signal on the C channel at intervals of 100 ms (20 frames), with adjacent base stations transmitting control signals using different time slots within such 20 frames. Accordingly, when searching for other base stations, the conventional portable telephone receives control signals from up to 80 base stations within 100 ms.

If the portable telephone finds one or more other base stations with sufficiently high RSSI values, an identifier (hereinafter referred to as a "CS-ID") and the RSSI value of each of these base stations are stored in the memory of the portable telephone. In the memory, each CS-ID is associated with the corresponding RSSI value. By doing so, CS-IDs of other base stations to which the portable telephone can be handed-over are sequentially stored in the memory.

The portable telephone searches for a most suitable base station, that is a base station having the highest RSSI value, out of the base stations with sufficiently high RSSI values in the memory. The portable telephone then issues a link channel setup request to the most suitable base station. On receiving this request, the base station judges whether a traffic channel (hereinafter referred to as a "T channel" or "TCH") can be assigned to the portable telephone and, if so, assigns the T

channel to the portable telephone (link channel setup processing period).

Following this, the portable telephone synchronizes to the new base station and message exchanges are performed between the new base station and the portable telephone on the assigned T channel before conversation is resumed (conversation resumption processing period). This conversation resumption processing usually takes about 400ms.

Therefore, the conventional portable telephone falls into a silent condition before conversation is resumed after the initiation of the CCH search processing (usually about one second, although this time varies according to settings and conditions).

While handover has conventionally been carried out within a single area (a paging area), recalling-type connection function to other CS among paging areas will be implemented in the future. Such function is hereinafter referred to as an "inter-area handover" in this specification. The conversation resumption processing for an inter-area handover is expected to take more time (up to about four seconds). This is because switching operations need to be performed between public network exchange stations that have control over base stations in individual areas. As the conversation resumption processing takes longer, the silent period also becomes longer.

In view of the stated problems, the object of the present invention is to provide a portable telephone that shortens the silent period and ultimately avoids the silent condition during handover.

Disclosure of the Invention

The stated object is achieved by a portable telephone that has a handover function and performs time-division multiplex communication, including: a search unit for finding candidate base stations when a handover is initiated, the candidate base stations being base stations to which the portable telephone is capable of switching; a request unit for requesting one of the candidate base stations to assign a communication channel; a judging unit for judging whether it is possible to use time slots of the assigned communication channel with time slots of a current communication channel; a connection unit for performing a connection operation using the assigned communication channel if a judgement result by the judging unit is affirmative; and a communication continuation unit for continuing communication on the current communication channel while the connection unit is performing the connection operation.

With this construction, the portable telephone of the present invention performs the conversation resumption processing only if the time slots of the communication channel assigned by a new base station are appropriate, that is, only if handover processing, such as message exchanges with the new base station, can be performed without interrupting conversation via an original base station. In this manner, the portable telephone performs the conversation via the original base station during the conversation resumption processing period. Therefore, the silent condition is avoided in this period and

the entire silent period during handover is shortened.

Here, the search unit finds the candidate base stations among base stations that transmit control signals using time slots that do not coincide with the time slots of the current communication channel and, while the search unit is finding the candidate base stations, the communication continuation unit continues the communication on the current communication channel by selecting (a) a frequency synthesizer generating a local oscillator signal corresponding to the current communication channel in the time slots of the current communication channel and (b) a frequency synthesizer generating a local oscillator signal corresponding to the control signals in the time slots in which the control signals are transmitted. With this construction, the silent condition is also avoided during the CCH search processing period. Therefore, it is possible to totally avoid the silent condition during handover, as will be described in an embodiment later. However, to do so with the technique available when the present invention was made, the portable telephone needs to include two synthesizer circuits.

Brief Description of the Drawings

These and other objects, advantages and features of the invention will become apparent from the following description thereof taken in conjunction with the accompanying drawings which illustrate a specific embodiment of the invention. In the drawings:

Fig. 1 is a timing chart illustrating a handover

operation performed by a conventional portable telephone;

Fig. 2 shows the entire construction of a portable telephone of an embodiment of the present invention;

Fig. 3A shows the frame structure for a TDMA/TDD method;

Fig. 3B also shows the frame structure for the TDMA/TDD method;

Fig. 4 is a flowchart showing the operation performed by a control unit 18 during a handover operation;

Fig. 5 is a timing chart showing the handover operation;

Fig. 6 is a flowchart showing the detailed operation in the CCH search processing;

Fig. 7 is a flowchart showing the detailed operation in the link channel setup processing;

Fig. 8 is a timing chart illustrating the handover operation where the link channel setup processing is shown in detail; and

Fig. 9 is a flowchart showing the detailed operation during the conversation resumption processing.

Best Mode for carrying Out the Invention

An embodiment of the portable telephone of the present invention is described below with reference to the drawings.

(1) Construction of Portable Telephone

Fig. 2 is a functional block diagram showing the

construction of a portable telephone of this embodiment. As shown in this drawing, the portable telephone of the present embodiment includes an antenna 10, a transmission/reception switch unit (hereinafter referred to as a "t/r switch unit") 11, a radio unit 12, a modem unit 13, a TDMA/TDD unit 14, an audio processing unit 15, a microphone 16, a speaker 17, and a control unit 18.

The t/r switch unit 11 is a switch that switches between a transmission position and a reception position according to timings designated by a timing generation unit 180. Transmission and reception are performed via the antenna 10 using a TDD method.

The radio unit 12 includes a transmission unit 121, a synthesizer 122, a reception unit 123, and an RSSI detection unit 124. Here, the synthesizer 122 of the present embodiment includes two synthesizer circuits 122A and 122B.

The transmission unit 121 includes an amplifier and a mixer that performs conversion into a transmission frequency. The transmission unit 121 receives modulated signals of audio and control signals from the modem unit 13, converts the modulated signals into transmission waves, and transmits the transmission waves.

The synthesizer 122 stores a table including carrier numbers and local frequencies (local oscillator frequencies) corresponding to respective carrier numbers, with each carrier number being associated with the corresponding local frequency. On receiving a frequency change designation that includes an

indication of a carrier number from a synthesizer control unit 183, the synthesizer 122 generates a local frequency signal corresponding to the carrier number and supplies the local frequency signal to the transmission unit 121 and the reception unit 123. Note that the synthesizer 122 of this embodiment takes about 300 μs to generate a stable local frequency signal after receiving a frequency change designation, though this time lag, or "lock time", does not present a problem for the present portable telephone. In this portable telephone, different frequencies (carriers) can be used in successive time slots by switching between two synthesizer circuits 122A and 122B. This aspect will be described in detail later.

The reception unit 123 receives reception waves on the C and T channels that are inputted from the antenna 10 via the t/r switch unit 11, converts the reception waves into intermediate frequency signals, amplifies the intermediate frequency signals, and outputs the amplified intermediate frequency signals to the modem unit 13.

The RSSI detection unit 124 detects RSSI values by measuring the strength of each reception signal while the reception unit 123 is amplifying the intermediate frequency signals. The RSSI detection unit 124 then outputs the RSSI values to the control unit 18. During communication on the T channel, the RSSI detection unit 124 detects RSSI values of the T channel and supplies the RSSI values for use in the monitoring of communication quality. On the other hand, during a handover operation, the RSSI detection unit 124 detects RSSI values of

the C channel and supplies the RSSI values for use in the search for a base station to which the portable telephone is to be handed-over. Here, a base station to which the portable telephone is handed-over is hereinafter referred to as a "take-over base station". Also, a currently serving base station is hereinafter referred to as a "handover base station".

Each element of the radio unit 12 described above performs transmission and reception using a TDMA/TDD method in compliance with the timing control and frequency switching designations issued by the control unit 18 described later.

The following is a description of the frame structure used for transmission and reception according to the TDMA/TDD method. Each of Figs. 3A and 3B shows the frame structure of the present embodiment for the TDMA/TDD method.

In this embodiment, each frame of the TDMA/TDD method is five milliseconds in length and is divided into eight slots. The first to fourth slots are assigned to downlink communication (communication from a base station to a portable telephone), while the fifth to eighth slots are assigned to uplink communication (communication from a portable telephone to a base station) (see Fig. 3A). Slots used for downlink communication are hereinafter referred to as "downlink slots" and slots used for uplink communication as "uplink slots". A downlink slot (one of the first to fourth slots) corresponds to the uplink slot (one of the fifth to eighth slots) that lags behind the downlink slot by 2.5 ms. Each downlink slot makes up one channel with the corresponding uplink slot. Accordingly, when the second slot

is used as a downlink slot, the sixth slot is used as an uplink slot (see Fig. 3B).

Note that because the portable telephone of the present embodiment includes two synthesizer circuits (122A and 122B), as described above, it is possible to perform transmission and reception using channels having different carrier numbers in successive slots (the second and third slots, for instance) (see Fig. 3B). That is, by stabilizing the frequency generated by the synthesizer circuit 122B when or before the synthesizer circuit 122A receives a signal transmitted on a channel in the second slot, a signal transmitted on another channel can be received in the third slot by merely switching from the synthesizer circuit 122A to the synthesizer circuit 122B. The same applies to other successive slots.

In the portable telephone system of the present embodiment, each base station intermittently transmits control signals on the C channel at 100ms (20 frames) intervals. Also, adjacent base stations transmit control signals using different time slots within group of 20 frames. Therefore, when searching for base stations that are selectable (candidates) as a take-over base station, the portable telephone of the present embodiment can receive control signals from up to 80 base stations within 100ms. Such base stations that are selectable as a take-over base station are hereinafter referred to as "candidate base stations".

The modem unit 13 performs /4QPSK (Quadrature Phase Shift Keying) modulation and demodulation on signals that are

transferred between the radio unit 12 and the TDMA/TDD unit 14. The TDMA/TDD unit 14 controls the time division multiplex duplex communication based on the TDMA/TDD method. The audio processing unit 15 encodes, decodes, and amplifies audio data that is inputted via the microphone 16 and is to be outputted via the speaker 17.

The control unit 18 includes a ROM (read-only memory) and a RAM (random-access memory) and controls the entire portable telephone by executing various programs stored in the ROM. The portable telephone of the present embodiment performs the CCH search processing, link channel setup processing, and conversation resumption processing during a handover operation. The control unit 18 judges whether a new T channel assigned by a base station found in the CCH search processing satisfies a predetermined condition. If the predetermined condition is satisfied, the control unit 18 has the operation proceed to the conversation resumption processing (an operation for connecting the portable telephone to the new T channel). Here, the predetermined condition is whether the conversation resumption processing can be performed without interrupting communication over the current T channel. As described above, the portable telephone of the present embodiment includes two synthesizer circuits. Therefore, this predetermined condition is satisfied when the time slots of the new T channel do not coincide with those of the current T channel.

The control unit 18 controls the portable telephone to perform the conversation resumption processing without

interrupting the communication on the current T channel only if the predetermined condition is satisfied. In this manner, the conversation resumption processing can be performed without the line falling silent. The control unit 18 includes a timing generation unit 180, a memory 181, a comparison judgement unit 182, a synthesizer control unit 183, a CPU (central processing unit) 184, and a timing judgement unit 185.

The timing generation unit 180 generates TDMA/TDD slot timings and outputs the generated timings to the comparison judgement unit 182, the synthesizer control unit 183, the CPU 184, the radio unit 12, and the t/r switch unit 11.

The memory 181 holds RSSI values of reception signals that are sequentially detected by the RSSI detection unit 124. The RSSI values held in the memory 181 are supplied to the comparison judgement unit 182. During conversation on the T channel, the comparison judgement unit 182 uses the RSSI values to monitor the communication quality. On the other hand, during the CCH search processing, the comparison judgement unit 182 uses the RSSI values to judge whether each base station can be selected as a candidate base station. If at least one candidate base station is found during the CCH search processing, that is, if at least one base station has a control signal whose RSSI value is at least equal to a predetermined threshold value, the CS-ID and the RSSI value of each are stored in the memory 181, with the CS-ID being associated with the RSSI value.

The comparison judgement unit 182 monitors the communication quality by comparing each RSSI value stored in the

memory 181 with a predetermined threshold value during the conversation over the T channel. When a RSSI value falls short of the predetermined threshold value, the comparison judgement unit 182 outputs a signal showing this to the CPU 184, which then initiates a handover operation. During the CCH search processing, the comparison judgement unit 182 compares each RSSI value stored in the memory 181 with a predetermined threshold value to find candidate base stations. If the RSSI value of a base station is no less than the predetermined threshold value, the CS-ID and the RSSI value of the base station are stored in the memory 181.

The synthesizer control unit 183 outputs a frequency switch designation that includes an indication of a career number to the synthesizer circuits 122A and 122B according to slot timings outputted from the timing generation unit 180. The contents of the frequency switch designation are controlled by the CPU 184.

The timing judgement unit 185 issues a link channel setup request to one of the candidate base stations found during the CCH search processing. The candidate base station to which a link channel setup request is issued is hereinafter referred to as the "target base station". The timing judgement unit 185 then judges whether the slot timing of the T channel newly assigned by the target base station is appropriate and informs the CPU 184 of the judgement result. The slot timing of the newly assigned T channel can be obtained during the link channel setup processing. If the obtained slot timing does not coincide with

that of the currently used T channel, the slot timing of the newly assigned T channel is judged to be appropriate.

The slot timing of the new T channel can be calculated from an absolute slot number and a relative slot number that are obtained during the link channel setup processing. Therefore, in both a handover within a single area and an inter-area handover, it can be judged whether the slot timing of the newly assigned T channel is appropriate by comparing the calculated timing with the current slot timing. Here, the "absolute slot number" is a numeric value from one to four that shows which time slot in the frame structure shown in Fig. 3 is used as the downlink slot of the T channel. Also, the "relative slot number" is a number obtained by setting the slot that lags behind the issuance of a link channel assignment message by 2.5 seconds as the first slot.

(2) Operation of Control Unit 18

The operation performed by the control unit 18 during handover is described in detail below with reference to Figs. 4 and 5.

Fig. 4 is a flowchart showing the operation performed by the control unit 18 during a handover. Fig. 5 is a timing chart showing the handover operation.

As described above, after communication is started, the comparison judgement unit 182 continuously monitors the communication quality of the T channel used for the communication with a current base station by detecting RSSI values of the T

channel. If an RSSI value falls short of a predetermined threshold value, that is, if the deterioration of the communication quality is detected (S101:Yes), the comparison judgement unit 182 outputs a signal showing this deterioration to the CPU 184 to initiate a handover operation. The CCH search processing is first performed during the handover operation (S102).

Fig. 6 is a flowchart showing the detailed operation in the CCH search processing. As shown in this drawing, during the CCH search processing, the channel received by the reception unit 123 is changed to the C channel under the control of the synthesizer control unit 183 (S201). Then the t/r switch unit 11 is placed in the reception position and signals transmitted on the C channel are continuously received for a predetermined period (100*N ms) (see Fig. 5) to search for candidate base stations (S202). In this case, the portable telephone receives control signals from the maximum number of base stations, which is to say 80 base stations.

As described above, the portable telephone of the present embodiment includes a plurality of synthesizer circuits (122A and 122B) and can perform communication by switching channels in successive time slots. Therefore, the portable telephone can perform the CCH search processing while continuing conversation via the handover base station. More specifically, the synthesizer circuit 122A is set for a carrier of the T channel used for the conversation via the handover base station and the synthesizer circuit 122B is set for the C channel. Conversation

takes place using the synthesizer circuit 122A only in the time slots used for the conversation via the handover base station. In other time slots, control signals are received with the synthesizer circuit 122B. In this manner, the CCH search processing is performed while the conversation is continued via the handover base station. This means that the number of base stations whose control signals can be received is decreased to 60, but enables the conversation to continue during the CCH search processing period and avoids the silent condition.

If the comparison judgement unit 182 judges that the RSSI value of a base station is at least equal to the predetermined threshold value (S203:Yes), the CS-ID and the RSSI value of the base station are stored in the memory 181 (S204). After performing the CCH search processing for a predetermined period (100 ms to several 100 ms) (S205:Yes), the candidate base stations (CS-IDs) stored in the memory 181 are arranged in decreasing order of RSSI value (S206). In this manner, the CCH search processing is completed.

It should be noted here that if conversation via the handover base station is not performed in the CCH search processing period, transmission to the handover base station does not need to be performed during this period (see Fig. 5). In such a case, the transmission channel of the transmission unit 121 does not need to be changed to the C channel during the CCH search processing because it is sufficient that the transmission channel is changed before a link channel setup request is issued. However, in the example shown in Fig. 5, the transmission channel

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is changed along with the reception channel.

On the other hand, if conversation via the handover base station is to be maintained during the CCH search processing period, it is preferable to set the reception channel as the T channel used for the conversation via the handover base station. The conversation via the handover base station is maintained by performing transmission to the handover base station using the same slot as that used before the CCH search processing was initiated. Note that when an inter-area handover is performed, control signals may be received by opening a reception gate at the timings other than the transmission timings.

After the CCH search processing is performed in this manner, the process returns to the flowchart shown in Fig. 4 and it is judged whether at least one candidate base station is found (S103). Here, a state where no candidate base station is found means a situation where none of the base stations whose control signals were received has a sufficiently high RSSI value. There are various conceivable methods for coping with a situation where the judgement result in S103 is affirmative. In this embodiment, the portable telephone returns to the conversation on the current T channel via the handover base station (S104).

If at least one candidate base station is found (S103:No), the link channel setup processing is performed. Here, in this embodiment, if two or more candidate base stations are found, a link channel setup request is first issued to a most suitable base station among the candidate base stations. That is, link channel setup requests are sequentially issued to the

candidate base stations in decreasing order of RSSI value. When a candidate base station assigns an appropriate T channel to the portable telephone or when a predetermined condition is satisfied regardless of whether the portable telephone has been assigned an appropriate T channel, the link channel setup processing is finished.

The link channel setup processing of this embodiment is described in detail below, with reference to Figs. 7 and 8. Fig. 7 is a flowchart showing the detailed operation of the link channel setup processing in this embodiment. Fig. 8 is a timing chart illustrating the handover operation where the link channel setup processing being shown in detail. As shown in Fig. 7, a variable k is initially set as one during the link channel setup processing (S301). This variable k will be described later.

When the link channel setup processing is started, the reception channel of the reception unit 123 has already been changed to the C channel (see Fig. 8). The portable telephone first receives a control signal from the kth candidate base station and maintains the reception timing of the control signal (S302). The variable k corresponds to the order of the candidate base stations (CS-IDs) that were arranged in decreasing order of RSSI value in step S206. Because the variable k is set as one the first time this step is performed (see S301), a link channel setup request is issued to the first candidate base station. As described above, the candidate base stations (CS-IDs) are arranged in step S206 so that the first candidate base station has the largest RSSI value, the second candidate

base station has the next largest RSSI value, and so on.

Control signals are received from candidate base stations and the reception timings are maintained as follows. In the CCH search processing, control signals are sequentially received from the candidate base stations and CS-IDs of the base stations are obtained from the received control signals. It should be noted here that in the portable telephone system of this embodiment, each of control signals and traffic signals includes a bit arrangement called a unique word (hereinafter referred to as "UW"). Also, each control signal includes a 32-bit UW, while each traffic signal includes a 16-bit UW. Therefore, when the reception mode is changed to receive control signals, the settings of the portable telephone need to be changed so that 32-bit UWs are detected.

The comparison judgement unit 182 fetches the CS-ID of the kth base station from the memory 181 and successively compares the fetched CS-ID with the CS-ID obtained from each reception signal when the link channel setup processing is started. On judging that the CS-ID of the kth base station has been obtained from a reception signal, the portable telephone holds the reception timing of the reception signal. The portable telephone then issues a link channel setup request to the kth base station according to the held timing.

Because a base station to which a link channel setup request is issued transmits control signals at intervals of 100ms (20 frames), the portable telephone of this embodiment continues the conversation via the handover base station after holding the

reception timing of the control signal (see Fig. 8). Fig. 8 shows the case where the target base station is the base station with the first control signal received in the link channel setup processing. In the 19 frames before the next control signal is received from the target base station, the conversation is performed via the handover base station. More specifically, after a control signal of the target base station is received, the reception channel of the reception unit 123 is changed to the T channel used for the communication with the handover base station (see the lower level of Fig. 8). By doing so, the conversation via the handover base station is performed in downlink slots. Note that in this case, the UW detection mode is changed from 32-bit mode to 16-bit mode.

Following this, a link channel setup request is issued to the target base station in a uplink slot (S303). The link channel setup request is issued when a time period "2.5+5*R(ms)" has passed after the timing held in step S302. Here, R is a random number generated for the issuance of the link channel setup request and is an integer between one and eighteen. After the link channel setup request is issued, a timer t is activated (S304).

The link channel setup request is issued by changing the transmission channel of the transmission unit 121 to the control channel and transmitting a necessary control signal to the target base station on the control channel. In this embodiment, both of the reception channel and transmission channel are changed to the C channel when the CCH search

processing is initiated. Therefore, this channel switching does not need to be performed to issue the link channel setup request. However, if the conversation via the handover base station is maintained during the CCH search processing, the channel switching needs to be performed with appropriate timing.

Note that after the link channel setup request is issued, the transmission channel in uplink slots is restored to the T channel to perform the communication with the handover base station (see the lower level of Fig. 8). The conversation is then performed on the T channel via the handover base station until a link channel setup request needs to be issued again. A link channel setup request needs to be reissued when a T channel of the target base station is not assigned or the slot timing of a newly assigned T channel does not satisfy the predetermined condition described above.

On the other hand, to receive control signals that are intermittently transmitted from the target base station, the reception channel of the reception unit 123 is changed to the C channel and the UW detection mode is switched to the 32-bit mode at intervals of 100ms with respect to the timing kept in step S302. In some cases, the control signal that is first sent from the target base station after the link channel setup request was issued does not specify the assignment of a link channel of the target base station. Therefore, for a predetermined time period, the portable telephone of this embodiment continues to receive control signals that are intermittently transmitted from the target base station. If a T channel has not been assigned

within the predetermined time period, the portable telephone judges that a T channel cannot be assigned by the target base station.

If a T channel is newly assigned to the portable telephone (S305:Yes), it is then judged whether the assigned T channel is appropriate (S306). Here, this judgement is made according to whether the conversation resumption processing for the assigned channel can be performed without interrupting the conversation via the handover base station. More specifically, it is judged whether time slots for the conversation via the handover base station can be used while time slots of the newly assigned T channel are used. As described above, the portable telephone of the present embodiment includes two synthesizer circuits 122A and 122B. Therefore, the newly assigned T channel is appropriate when the time slots of the newly assigned T channel do not coincide with those used for the conversation via the handover base station.

The present invention also applies to a portable telephone with only one synthesizer circuit. In this case, the judgement in this step is made so that the newly assigned T channel is appropriate if there is at least one slot between the time slot of the assigned T channel and the time slot of the T channel used for the conversation via the handover base station. For instance, if a slot used for the current T channel is the first slot and a slot used for the new T channel is the third slot in Fig. 3, the new T channel is appropriate. This is because if a portable telephone includes only one synthesizer circuit, it

is necessary to take into account the lock time taken by the synthesizer circuit to generate a stable frequency.

As the operation of the timing judgement unit 185, the slot timing of the newly assigned T channel is determined in the manner described below. In either the single area handover or the inter-area handover, the slot timing is determined from the absolute slot number and relative slot number.

If the newly assigned T channel is judged as being appropriate (S306:Yes), the link channel setup processing is finished and the process returns to the flowchart shown in Fig. 4.

Here, if a new T channel is not assigned by the control signal that was first received after the link channel setup request was issued (S305:No), the portable telephone judges whether the timer t has counted for a predetermined period T (S307). Here, the predetermine period T is a maximum period for receiving control signals from the target base station and is, for instance, set as 1.2 seconds according to the regulation by RCR STD-28.

If the timer t has not counted for the predetermined period T (S307:No), the process returns to step S305 to receive a control signal again. Note that conversation can be performed in 19 frames between time slots for receiving control signals from the target base station in the manner described above.

If a new T channel has not been assigned by the end of the predetermined period T (S307:Yes), the portable telephone judges that a new T channel cannot be assigned by the target base

station and increments the variable k by one (S308). Then it is judged whether the value of the variable k exceeds the total number n of the base stations found as candidates for the take-over base station or exceeds the maximum number m of base stations to which link channel setup requests should be issued (S309). If the judgement result is affirmative (S309:Yes), the link channel setup processing is terminated without a link channel being established and the process returns to the flowchart shown in Fig. 4. If the judgement result in step S309 is negative, the process returns to step S302 and a link channel setup request is issued to another candidate base station without interrupting the conversation via the handover base station. Note that in this embodiment, if the newly assigned T channel is judged as being inappropriate in step S306 (S306:No), the process proceeds to step S308 and the value of the variable k is incremented. However, in such a case, the process may proceed to step S303 to reissue the link channel setup request to the target base station. Also, in such a case, the process may proceed to step S307 to wait for the target base station to assign a channel for the predetermined period T.

After the link channel setup processing is finished, the process returns to the flowchart shown in Fig. 4 and it is judged whether an appropriate new T channel is assigned (S106). It should be noted here that if none of the assigned channels is appropriate, the same operation is performed as when no channel has been assigned. That is, if no appropriate T channel is assigned, the portable telephone returns to the communication

with the current base station to continue the conversation via the current base station (S104). If an appropriate new T channel is assigned (S106:Yes), the process proceeds to the conversation resumption processing (S107).

Fig. 9 is a flowchart showing the detailed operation performed in the conversation resumption processing. Each of the timing charts shown in Figs. 5 and 8 illustrates the conversation resumption processing in the case where each time slot of a previously assigned T channel (hereinafter referred to as an "old TCH") immediately precedes a time slot of the newly assigned T channel (hereinafter referred to as a "new TCH").

For instance, the synthesizer circuits 122A and 122B are respectively fixed for the old TCH and the new TCH during the conversation resumption processing. Communication on the new TCH is performed while communication on the old TCH continues by switching these synthesizer circuits so that the synthesizer circuit 122A is used in the time slots of the old TCH and the synthesizer circuit 122B is used in the time slots of the new TCH. That is, the operation for connecting the portable telephone to the take-over base station, such as synchronous processing and message exchanges, is performed using the new TCH, with conversation being performed over the old TCH. Therefore, the silent period during the handover is shortened. Furthermore, if the conversation via the handover base station is also performed during the CCH search processing, the silent condition is avoided.

The operation in the conversation resumption

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processing is described below with reference to the flowchart shown in Fig. 9. During the conversation resumption processing, the operation for connecting the portable telephone to the take-over base station is performed while the synthesizer switching described above is performed. During this operation, a U wave (i.e., interference wave) of the new TCH is first measured (S401). If the measurement result of the U wave exceeds a predetermined value, certain operations need to be performed. However, it is assumed that no problem is caused by the U wave in this embodiment.

Steps S403-S408 are related to the operation for connecting the portable telephone to the take-over base station (synchronous processing and message exchanges). This connection operation is well-known and conforms to an existing technical standard except that the synthesizer circuits are switched with conversation being performed on the old TCH. Therefore, the detailed explanation of the connection operation is not given here.

Note that if an inter-area handover needs to be performed, the operation necessary for the inter-area handover (such as switching of lines between base stations) is performed prior to the operation in steps S403-SS410, that is, the operation for synchronizing the portable telephone with the new T channel. In Fig. 8, this necessary operation is performed at the timing of the first gap in each line during the conversation resumption processing. The detailed description of the necessary operation is not given here. However, because the conversation continues

via the handover base station during this necessary operation, there will be no silence, even if an inter-area handover is performed.

After the operation described above, the conversation is transferred to the take-over base station (S409) and the communication with the handover base station is disconnected (S410) to finish the conversation resumption processing. In this manner, the handover operation is completed and the conversation is resumed with the new base station (see Fig. 4).

By performing a handover operation in the manner described above, the silent period during the handover operation is shortened to only one hundred milliseconds or several hundred milliseconds in the CCH search processing period. The same can be said for an inter-area handover. Furthermore, as described above, if the conversation via the handover base station is also performed during the CCH search processing period, the portable telephone does not fall into a silent condition during handover. It should be noted here that in the present embodiment, a silent condition during the link channel setup processing period is also avoided. However, even if a silent condition occurs during the link channel setup processing, the entire silent period is shortened to one second or less. Therefore, even in such a case, the present invention produces the effect of shortening the silent period during handover.

<Modifications>

The portable telephone of the present invention has

been described above by means of the embodiment, although it should be obvious that the present invention is not limited to the embodiment. Further variations are described below.

(1) In the above embodiment, if no take-over base station is found in the CCH search processing, or an appropriate T channel is not assigned to the portable telephone during the link channel setup processing, the portable telephone returns to the communication with the handover base station and makes the judgement in step S101 again (see Fig. 4, S104 and S101). However, even if the portable telephone returns to the communication with the handover base station in step S104 and makes the judgement in step S101 again after a handover operation ended in failure, there is a high possibility that the judgement result in step S101 will be the same as the previous one. Also, even if the handover operation is repeated, there is a high probability that the repeated handover operation will end in a situation where no take-over base station is found or no appropriate T channel is assigned.

To cope with this situation, the operation procedure may be modified as follows. That is, after a handover operation ends in failure, the operation in step S104 is performed. Then the portable telephone returns to the communication with the handover base station and a timer is activated. Until the timer has counted for a certain period, a handover operation is not initiated and the communication via the handover base station is performed even if deterioration of the communication quality is detected in step S101. The certain period may be fixed to

a range from several seconds to several dozen seconds. Also, the certain period may be variable. For instance, the certain period may be changed according to the number of base stations that were found in the CCH search processing of a handover operation that was performed immediately before the current handover operation and achieved success. If the number of base stations found in the previous handover operation is small, the certain period is shortened.

(2) As described in the embodiment, if conversation is also performed in the CCH search processing period, the number of base stations whose control signals are received within 20 frames is reduced from 80 to 60. Therefore, if no candidate base station is found in the CCH search processing (see Fig. 4, S103:No) or no appropriate T channel is assigned, the CCH search processing may be performed again, with the conversation being interrupted.

(3) Each time the portable telephone returns to the communication with the handover base station in step S104, the portable telephone may count the number of returns to the communication with the handover base station. As the count value increases, the CCH search processing period for searching for candidate base stations may be extended or the predetermined threshold value used during the CCH search processing may be lowered.

(4) In the above embodiment, CS-IDs and RSSI values of candidate base stations found in the CCH search processing are stored in the memory 181, with each CS-ID being associated with

the corresponding RSSI value. However, every time a candidate base station is found, the timing when the candidate base station is found may also be stored in the memory 181. In this case, a link channel setup request can be instantly issued in step S302 during the link channel setup processing (see Fig. 7). This is because in this case, it becomes unnecessary to receive a control channel and hold the reception timing of the control channel before a link channel setup request is issued.

(5) The above embodiment concerns the case where a portable telephone includes two synthesizer circuits. However, as briefly described in the embodiment, even if a portable telephone includes only one synthesizer, the silent condition occurring in the conversation resumption processing period can be avoided. In such a case, the operation of the portable telephone proceeds to the conversation resumption processing only if time gaps that are each at least equal to a lock time necessary to change the frequency of the synthesizer 122 exist between the time slots used for the conversation via the handover base station and time slots of a newly assigned T channel. However, the silent condition of a portable telephone including only one synthesizer cannot be avoided in the CCH search processing period. This is because if conversation is performed via the handover base station and control signals are received under the condition where such time gaps exist, a new T channel that satisfies the stated condition cannot be assigned.

(6) In the above embodiment, the portable telephone of the present invention is applied to the so-called second-

generation cordless telephone system (PHS system). However, the most important aspect of the present invention is that an appropriate new T channel is selected to perform a handover operation without interrupting the communication with the handover base station. This aspect may be applied to any other type of cordless telephone system. That is, the present invention is applicable to any type of portable telephone having a handover function.

Industrial Applicability

The present invention can be applied to portable telephones having a handover function.

Claims

1. A portable telephone that has a handover function and performs time-division multiplex communication, comprising:

a search means for finding candidate base stations when a handover is initiated, the candidate base stations being base stations to which the portable telephone is capable of switching;

a request means for requesting one of the candidate base stations to assign a communication channel;

a judging means for judging whether it is possible to use time slots of the assigned communication channel with time slots of a current communication channel;

a connection means for performing a connection operation using the assigned communication channel if a judgement result by the judging means is affirmative; and

a communication continuation means for continuing communication on the current communication channel while the connection means is performing the connection operation.

2. The portable telephone of Claim 1 further comprising two frequency synthesizers which each generate a local oscillator signal,

wherein the judging means judges whether the time slots of the assigned communication channel do not coincide with the time slots of the current communication channel,

one of the frequency synthesizers generates a local

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oscillator signal corresponding to the current communication channel and the other of the frequency synthesizers generates a local oscillator signal corresponding to the assigned communication channel, and

while the connection means is performing the connection operation, the communication continuation means selects

(1) the frequency synthesizer generating the local oscillator signal corresponding to the current communication channel in the time slots of the current communication channel, and

(2) the frequency synthesizer generating the local oscillator signal corresponding to the assigned communication channel in the time slots of the assigned communication channel.

3. The portable telephone of Claim 2,

wherein the search means finds the candidate base stations among base stations that transmit control signals using time slots that do not coincide with the time slots of the current communication channel,

one of the frequency synthesizers generates the local oscillator signal corresponding to the current communication channel and the other of the frequency synthesizers generates a local oscillator signal corresponding to the assigned communication channel, and

while the search means is finding the candidate base stations, the communication continuation means continues the

communication on the current communication channel by selecting

(3) the frequency synthesizer generating the local oscillator signal corresponding to the current communication channel in the time slots of the current communication channel, and

(4) the frequency synthesizer generating the local oscillator signal corresponding to the assigned communication channel in the time slots of the assigned communication channel.

4. The portable telephone of Claim 1 further comprising a frequency synthesizer that generates a local oscillator signal,

wherein the judging means judges whether time gaps that are each no shorter than a lock time exist between the time slots of the assigned communication channel and the time slots of the current communication channel, the lock time being a time taken by the frequency synthesizer to change a frequency of the local oscillator signal, and

while the connection means is performing the connection operation, the communication continuation means has the frequency synthesizer generate the local oscillator signal

(5) at a frequency corresponding to the current communication channel in the time slots of the current communication channel, and

(6) at a frequency corresponding to the assigned communication channel in the time slots of the assigned communication channel.

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5. The portable telephone of one of Claims 1-4, wherein the request means requests another candidate base station to assign a communication channel when the judging means judges that it is impossible to use the time slots of the assigned communication channel with the time slots of the current communication channel.