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Dahlman et al.

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(54) **RANDOM ACCESS IN A MOBILE TELECOMMUNICATIONS SYSTEM**

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(22) Filed: **Oct. 5, 1998**

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(52) **U.S. Cl.** **370/347**; 370/337; 370/344; 455/522
(58) **Field of Search** 370/329, 335, 370/336, 337, 346, 347, 441, 328, 321, 327, 342, 503, 322, 515, 528, 324; 455/522; 714/748, 749, 750; 375/200, 130, 142–145, 150–152, 211, 140

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(57) **ABSTRACT**

A method for processing multiple random access requests is disclosed in which a base station transmits an acquisition indicator signal, which indicates that the base station has detected the presence of a random access transmission. The acquisition indicator can be generated based on the amount of energy received on the random access channel (e.g., as opposed to the correct/incorrect decoding of a random access message). Consequently, the delay between the beginning of the random access transmission and the beginning of the acquisition indicator transmission is significantly shorter than the delay to the beginning of an acknowledgment transmission based on the reception of a correctly decoded random access message. If a mobile station does not receive a positive acquisition indicator, it should interrupt the present transmission and start to re-transmit the random access burst in the next time slot, while modifying the transmission power level accordingly between the successive re-transmissions.

56 Claims, 2 Drawing Sheets

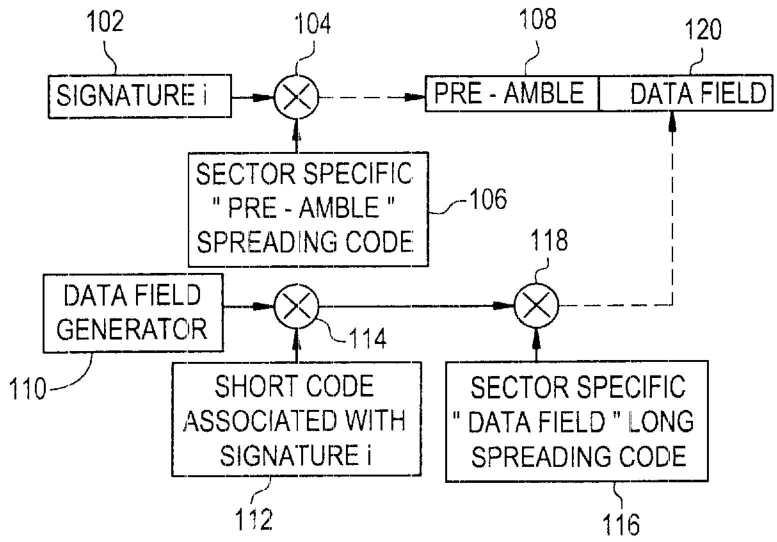


FIG.1

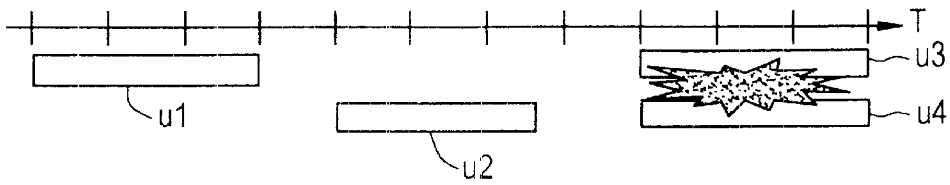


FIG.2

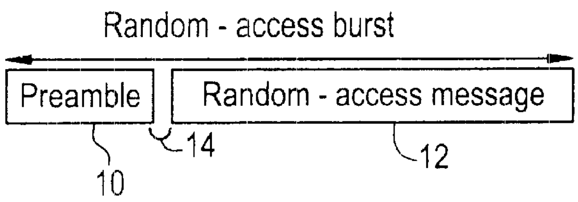


FIG.3

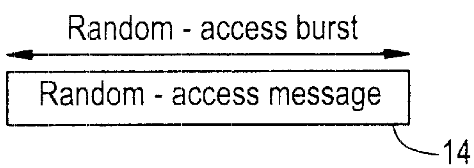


FIG.4

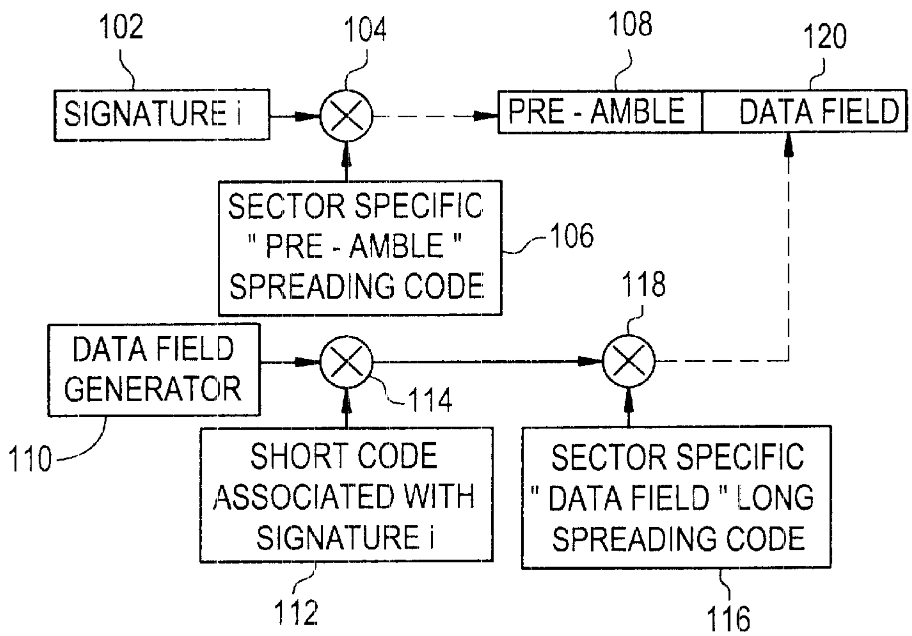


FIG.5

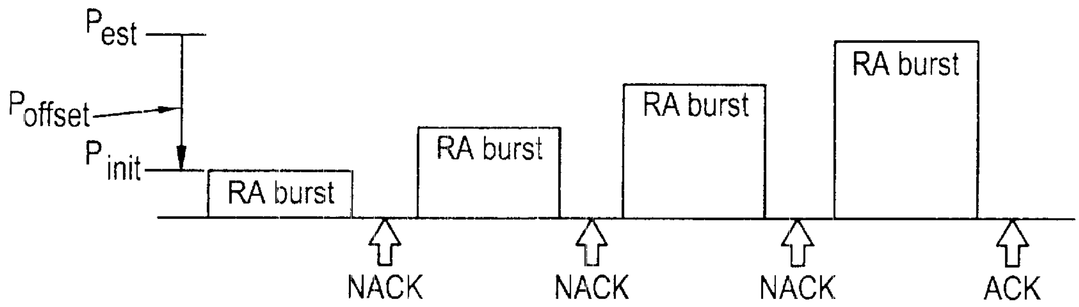


FIG.6

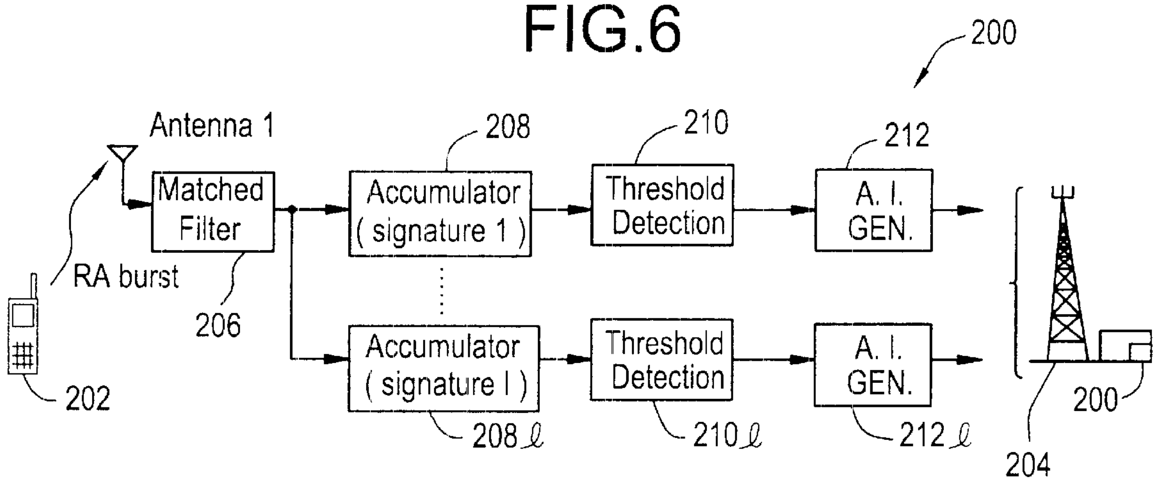


FIG.7

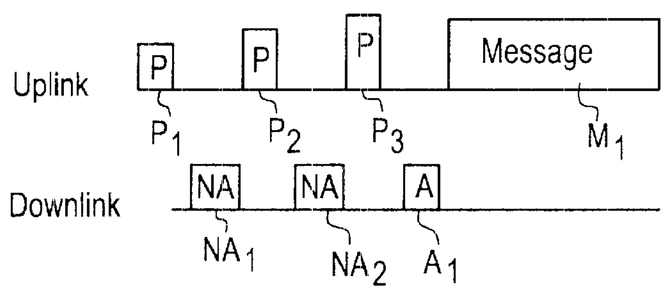
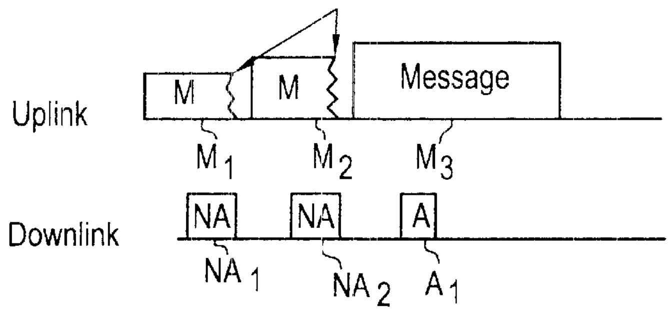


FIG.8

Interrupted transmissions



RANDOM ACCESS IN A MOBILE TELECOMMUNICATIONS SYSTEM

CROSS-REFERENCES TO RELATED APPLICATIONS

This Application for Patent is related by subject matter to commonly-assigned U.S. Applications for Patent Ser. Nos. 08/733,501, 08/847,655, and 09/148,224, filed Oct. 18, 1996, Apr. 30, 1997, and Sep. 4, 1998, respectively, and Provisional Application Ser. No. 60/063,024, filed Oct. 23, 1997. The above-cited Applications are useful for illustrating certain important premises and the state of the art for the present Application, and are hereby incorporated by reference herein in their entirety.

BACKGROUND OF THE INVENTION

1. Technical Field of the Invention

The present invention relates in general to the mobile telecommunications field and, in particular, to a method for processing multiple random access mobile-originated calls.

2. Description of Related Art

The next (so-called "third") generation of mobile communications systems will be required to provide a broad selection of telecommunications services including digital voice, video and data in packet and channel circuit-switched modes. As a result, the number of calls being made is expected to increase significantly, which will result in much higher traffic density on random access channels (RACHs). Unfortunately, this higher traffic density will also result in increased collisions and access failures. Consequently, the ability to support faster and more efficient random access is a key requirement in the development of the new generation of mobile communications systems. In other words, the new generation systems will have to use much faster and more flexible random access procedures, in order to increase their access success rates and reduce their access request processing times.

A European joint development mobile communications system is referred to as the "Code Division Testbed" (CODIT). In a CODIT-based Code Division Multiple Access (CDMA) system, a mobile station can gain access to a base station by first determining that the RACH is available for use. Then, the mobile station transmits a series of access request preambles (e.g., single 1023 chip symbols) with increasing power levels, until the base station detects the access request. As such, the mobile station uses a "power ramping" process that increases the power level of each successive transmitted preamble symbol. As soon as an access request preamble is detected, the base station activates a closed loop power control circuit, which functions to control the mobile station's transmitted power level in order to keep the received signal power from the mobile station at a desired level. The mobile station then transmits its specific access request data. The base station's receiver despreads and diversity-combines the received signals using, for example, a RAKE receiver or similar type of processing.

In many mobile communication systems, a slotted-ALOHA (S-ALOHA) random access scheme is used. For example, systems operating in accordance with the IS-95 standard (ANSI J-STD-008) use an S-ALOHA random access scheme. The main difference between the CODIT and IS-95 processes is that the CODIT process does not use an S-ALOHA random access scheme. Also, another difference is that the IS-95 mobile station transmits a complete random access packet instead of just the preamble. If the base station does not acknowledge the access request, the IS-95 mobile station re-transmits the entire access request packet at a higher power level. This process continues until the base station acknowledges the access request.

In the above-cited Applications and the IS-95 CDMA technical specifications, different random access methods based on S-ALOHA random access schemes have been described. Essentially (as illustrated in FIG. **1**), using a basic S-ALOHA scheme, there are well-defined instants in time (time slots) at which random access transmissions are allowed to begin. Typically, a mobile station (user) randomly selects a time slot in which the transmission of a random access burst (e.g., U**1**, U**2**) is to begin. However, the time slots are not pre-allocated to specific users. Consequently, collisions between the different users' random access bursts can occur (e.g., between U**3**, U**4**).

In a specific mobile communications system using such an S-ALOHA random access scheme, such as the method disclosed in the above-cited U.S. application Ser. No. 08/733,501 (hereinafter, "the '501 Application"), a mobile station generates and transmits a random access packet. A diagram that illustrates a frame structure for such a random access packet is shown in FIG. **2**. The transmitted random access packet ("access request data frame") or "burst" comprises a preamble (**10**) and a message part (**12**). Typically, the preamble does not include user information and is used in the base station receiver primarily to facilitate detection of the presence of the random access burst and derive certain timing information (e.g., different transmission path delays). Note that, as illustrated in FIG. **2**, there can be an idle period (**14**) between the preamble and message part during which time there is no transmission. However, using another technique, as described in the above-cited U.S. Provisional Application Serial No. 60/063,024 (hereinafter, "the '024 Application") and illustrated in FIG. **3**, the random access burst does not include a preamble. Consequently, in this case, the base station's random access detection and timing estimation has to be based on the message part only.

In order to reduce the risk of collisions between the random access bursts of two mobile stations that have selected the same time slot, the concept of burst "signatures" has been introduced. For example, as described in the '501 Application (see FIG. **4**), the preamble of a random access burst is modulated with a unique signature pattern. Also, the message part is spread with a code associated with the signature pattern used. The signature pattern is randomly selected from a set of patterns that can be, but are not necessarily, orthogonal to each other. Since a collision can occur only between mobile stations' bursts that are using the same signature, the risk of a random access collision is reduced in comparison with other existing schemes. As such, the use of this unique signature pattern feature, as described and claimed in the '501 Application, provides a significantly higher throughput efficiency than prior random access schemes.

In the '024 Application, a mobile station transmits a signature on the Q branch within the message part of the burst. In preparing for the transmission, the mobile station randomly selects the signature from a set of predetermined signatures. Again, since a collision can occur only between mobile stations' bursts that are using the same signature (the primary advantage of the novel use of signatures in general), the risk of a random access collision is reduced in comparison with other existing schemes.

Notably, although the random access systems and methods described in the above-cited Applications have numerous advantages over prior random access schemes, a number of problems still exist that remain to be solved. For example, regardless of the random access method used, a mobile station has to decide just how much random access transmission power to use. Ideally, a mobile station should select a transmission power level such that the random access burst is received at the base station with precisely the power needed for correct decoding of the random access message. However, for numerous reasons, it is virtually impossible to ensure that this will be the case.

For example, the power of the received burst as required at the base station is not constant but can vary (e.g., due to variations in the radio channel characteristics and the speed of the mobile station). As such, these variations are to some extent unpredictable and thus unknown to the mobile station. Also, there can be significant errors in estimating the uplink path-loss. Furthermore, even if a mobile station can determine the "correct" transmission power level to use, because of existing hardware limitations, it is impossible to set the actual transmission power level to precisely the correct value needed.

Consequently, for the above-described reasons, there is a significant risk that a random access burst will be received at the base station with too much power. This condition causes excessive interference for other users and thus reduces the capacity of the CDMA system. For the same reasons, there is also a risk that a random access burst will be transmitted with too little power. This condition makes it impossible for the base station to detect and decode the random access burst.

In order to reduce the risk of transmitting with too much power, in the afore-mentioned IS-95 CDMA system, the initial random access request is transmitted with an additional negative power offset (i.e., with a lower power level than the required transmit power level expected), as shown in FIG. **5**. Referring to FIG. **5**, the mobile station then re-transmits the random access burst with a reduced negative power offset, until the base station acknowledges (ACK) that it has correctly decoded the random access message ("NACK" denotes no acknowledgment message transmitted). Typically, the base station's acknowledgment is based on the calculation of a cyclic redundancy check (CRC) over the random access message. However, note that a new estimate of the required transmission power may or may not be calculated for each re-transmission. Consequently, it is only the negative offset that is reduced for each re-transmission.

A significant problem that exists with the above-described power ramping approaches is that there is an obvious trade-off between the time delay incurred due to the mobile station re-transmitting the random access bursts until the base station's acknowledgment message is received, and the amount of interference caused by the random access transmission. As such, with a larger negative initial power offset, on the average, more re-transmissions will be needed before the random access burst is received at the base station with sufficient power. On the other hand, with a smaller initial negative power offset, there is an increased risk that the random access burst will be received at the base station with too much power. On the average, this occurrence will cause more interference for other users. For reasonably large negative power offsets, the delay until the acknowledgment of a correctly decoded random access message is transmitted can be significant, because the base station has to receive an entire random access burst before it can transmit the acknowledgment message. As described in detail below, the present invention successfully resolves the above-described problems.

SUMMARY OF THE INVENTION

In accordance with a preferred embodiment of the present invention, a method for processing multiple random access requests is provided whereby a base station transmits an acquisition indicator signal, which indicates that the base station has detected the presence of a random access transmission. For this exemplary embodiment, the acquisition indicator is generated based on the amount of energy received on the random access channel (e.g., as opposed to the correct/incorrect decoding of a random access message). Consequently, the delay between the beginning of the random access transmission and the beginning of the acquisition indicator transmission is significantly shorter than the delay to the beginning of an acknowledgment transmission based on the reception of a correctly decoded random access message. If a mobile station does not receive a positive acquisition indicator, the mobile station should interrupt the present transmission and start to re-transmit the random access burst in the next time slot, while modifying the transmission power level accordingly between the successive re-transmissions.

An important technical advantage of the present invention is that significantly faster power ramping can be achieved in an S-ALOHA random access system.

Another important technical advantage of the present invention is that with an unchanged initial power offset in an S-ALOHA random access scheme, the random access delay can be significantly reduced, which improves the system performance.

Yet another important technical advantage of the present invention is that for the same delay constraints involved, a larger initial power offset can be used for one user in an S-ALOHA random access system, which reduces the risk of excessive interference for other users.

BRIEF DESCRIPTION OF THE DRAWINGS

A more complete understanding of the method and apparatus of the present invention may be had by reference to the following detailed description when taken in conjunction with the accompanying drawings wherein:

FIG. **1** is a diagram that illustrates how collisions between different users' random access bursts can occur in an S-ALOHA random access scheme;

FIG. **2** is a diagram that illustrates a frame structure for a random access packet in an S-ALOHA random access scheme;

FIG. **3** is a diagram that illustrates a random access burst that does not include a preamble;

FIG. **4** is a diagram that illustrates a preamble of a random access burst modulated with a unique signature pattern, and a message part spread with a code associated with the signature pattern used;

FIG. **5** is a diagram that illustrates a random access transmission with an initial negative power offset;

FIG. **6** is a block diagram of an exemplary detection section (for one antenna) that can be used in a base station's receiver to detect the presence of a random access transmission from a mobile station, in accordance with a preferred embodiment of the present invention;

FIG. **7** is a diagram that illustrates a mobile station receiving an acquisition indicator signal during an idle period in a random access burst, in accordance with the preferred embodiment of the present invention; and

FIG. **8** is a diagram that illustrates a mobile station receiving an acquisition indicator signal in a system where

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