

METHOD AND APPARATUS FOR CONTROLLING TRANSMISSION GATED COMMUNICATION SYSTEM

BACKGROUND OF THE INVENTION

5

I. Field of the Invention

The present invention relates to communications. More particularly,
10 the present invention relates to a novel and improved method and
apparatus for transmitting variable rate data in a wireless communication
system.

II. Description of the Related Art

15 The use of code division multiple access (CDMA) modulation
techniques is one of several techniques for facilitating communications in
which a large number of system users are present. Other multiple access
communication system techniques, such as time division multiple access
(TDMA) and frequency division multiple access (FDMA) are known in the
20 art. However, the spread spectrum modulation techniques of CDMA have
significant advantages over these modulation techniques for multiple access
communication systems. The use of CDMA techniques in a multiple access
communication system is disclosed in U.S. Patent No. 4,901,307, entitled
"SPREAD SPECTRUM MULTIPLE ACCESS COMMUNICATION SYSTEM
25 USING SATELLITE OR TERRESTRIAL REPEATERS", assigned to the
assignee of the present invention, and incorporated by reference herein.
The use of CDMA techniques in a multiple access communication system is
further disclosed in U.S. Patent No. 5,103,459, entitled "SYSTEM AND
METHOD FOR GENERATING SIGNAL WAVEFORMS IN A CDMA
30 CELLULAR TELEPHONE SYSTEM", assigned to the assignee of the present
invention and incorporated by reference herein.

CDMA by its inherent nature of being a wideband signal offers a form
of frequency diversity by spreading the signal energy over a wide bandwidth.
Therefore, frequency selective fading affects only a small part of the CDMA
35 signal bandwidth. Space or path diversity is obtained by providing multiple
signal paths through simultaneous links from a mobile user through two or
more cell-sites. Furthermore, path diversity may be obtained by exploiting

the multipath environment through spread spectrum processing by allowing a signal arriving with different propagation delays to be received and processed separately. Examples of path diversity are illustrated in U.S. Patent No. 5,101,501 entitled "METHOD AND SYSTEM FOR PROVIDING A
5 SOFT HANDOFF IN COMMUNICATIONS IN A CDMA CELLULAR TELEPHONE SYSTEM", and U.S. Patent No. 5,109,390 entitled "DIVERSITY RECEIVER IN A CDMA CELLULAR TELEPHONE SYSTEM", both assigned to the assignee of the present invention and incorporated by reference herein.

10 A method for transmission of speech in digital communication systems that offers particular advantages in increasing capacity while maintaining high quality of perceived speech is by the use of variable rate speech encoding. The method and apparatus of a particularly useful variable rate speech encoder is described in detail in U.S. Patent No.
15 5,414,796, entitled "VARIABLE RATE VOCODER", assigned to the assignee of the present invention and incorporated by reference herein.

The use of a variable rate speech encoder provides for data frames of maximum speech data capacity when the speech encoder is providing speech data at a maximum rate. When the variable rate speech encoder is
20 providing speech data at a less than maximum rate, there is excess capacity in the transmission frames. A method for transmitting additional data in transmission frames of a fixed predetermined size, wherein the source of the data for the data frames is providing the data at a variable rate, is described in detail in U.S. Patent No. 5,504,773, entitled "METHOD AND
25 APPARATUS FOR THE FORMATTING OF DATA FOR TRANSMISSION", assigned to the assignee of the present invention and incorporated by reference herein. In the above mentioned patent application a method and apparatus is disclosed for combining data of differing types from different sources in a data frame for transmission.

30 In frames containing less data than a predetermined capacity, power consumption may be lessened by transmission gating a transmission amplifier such that only parts of the frame containing data are transmitted. Furthermore, message collisions in a communication system may be reduced if the data is placed into frames in accordance with a predetermined
35 pseudorandom process. A method and apparatus for gating the transmission and for positioning the data in the frames is disclosed in U.S.

Patent No. 5,659,569, entitled "DATA BURST RANDOMIZER", assigned to the assignee of the present invention and incorporated by reference herein.

A useful method of power control of a mobile in a communication system is to monitor the power of the received signal from the wireless communication device at a base station. In response to the monitored power level, the base station transmits power control bits to the wireless communication device at regular intervals. A method and apparatus for controlling transmission power in this fashion is disclosed in U.S. Patent No. 5,056,109, entitled "METHOD AND APPARATUS FOR CONTROLLING TRANSMISSION POWER IN A CDMA CELLULAR MOBILE TELEPHONE SYSTEM", assigned to the assignee of the present invention and incorporated by reference herein.

In a communication system that provides data using a QPSK modulation format, very useful information can be obtained by taking the cross product of the I and Q components of the QPSK signal. By knowing the relative phases of the two components, one can determine roughly the velocity of the wireless communication device in relation to the base station. A description of a circuit for determining the cross product of the I and Q components in a QPSK modulation communication system is disclosed in U.S. Patent No. 5,506,865, entitled "PILOT CARRIER DOT PRODUCT CIRCUIT", assigned to the assignee of the present invention and incorporated by reference herein.

There has been an increasing demand for wireless communications systems to be able to transmit digital information at high rates. One method for sending high rate digital data from a wireless communication device to a central base station is to allow the wireless communication device to send the data using spread spectrum techniques of CDMA. One method that is proposed is to allow the wireless communication device to transmit its information using a small set of orthogonal channels. Such a method is described in detail in co-pending U.S. Patent Application Serial No. 08/886,604, entitled "HIGH DATA RATE CDMA WIRELESS COMMUNICATION SYSTEM", assigned to the assignee of the present invention and incorporated by reference herein.

In the just-mentioned application, a system is disclosed in which a pilot signal is transmitted on the reverse link (the link from the wireless communication device to the base station) to enable coherent demodulation of the reverse link signal at the base station. Using the pilot signal data,

coherent processing can be performed at the base station by determining and removing the phase offset of the reverse link signal. Also, the pilot data can be used to optimally weigh multipath signals received with different time delays before being combined in a rake receiver. Once the phase offset is removed, and the multipath signals properly weighted, the multipath signals can be combined to decrease the power at which the reverse link signal must be received for proper processing. This decrease in the required receive power allows greater transmission rates to be processed successfully, or conversely, the interference between a set of reverse link signals to be decreased.

While some additional transmit power is necessary for the transmission of the pilot signal, in the context of higher transmission rates the ratio of pilot signal power to the total reverse link signal power is substantially lower than that associated with lower data rate digital voice data transmission cellular systems. Thus, within a high data rate CDMA system, the E_b/N_0 gains achieved by the use of a coherent reverse link outweigh the additional power necessary to transmit pilot data from each wireless communication device.

However, when the data rate is relatively low, a continuously-transmitted pilot signal on the reverse link contains more energy relative to the data signal. At these low rates, the benefits of coherent demodulation and reduced interference provided by a continuously-transmitted reverse link pilot signal may be outweighed by the decrease in talk time and system capacity in some applications.

SUMMARY OF THE INVENTION

The present invention is a novel and improved method and system for communicating a frame of information according to a discontinuous transmit format. In particular, the present invention describes a method of transmitting eighth rate speech or data frames employing transmit gating and energy scaling which simultaneously reduces the battery usage of a variable rate wireless communication device, increases the capacity of the reverse link and provides reliable communication of the eighth rate frames. In the present invention, four methods are presented for transmitting an eighth rate data frame in which half of the frame is gated out and the remaining data is

transmitted at nominal transmission energy to accomplish the aforementioned goals.

BRIEF DESCRIPTION OF THE DRAWINGS

5 The features, objects, and advantages of the present invention will become more apparent from the detailed description set forth below when taken in conjunction with the drawings in which like reference characters identify correspondingly throughout and wherein:

FIG. 1 is a functional block diagram of an exemplary embodiment of the transmission system of the present invention embodied in wireless communication device 50;

FIG. 2 is a functional block diagram of an exemplary embodiment of modulator 26 of FIG. 1;

15 FIGS. 3A-3G illustrate the energy used to transmits the variable rate frames t for four different data rates an including four alternative embodiments for transmitting an eighth rate frame;

FIG. 4 is a functional block diagram of selected portions of a base station 400 in accordance with the present invention;

FIG. 5 is an expanded functional block diagram of an exemplary single demodulation chain of demodulator 404 of FIG. 4; and

20 FIG. 6 is a block diagram illustrating the forward link power control mechanism of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

25 FIG. 1 illustrates a functional block diagram of an exemplary embodiment of the transmission system of the present invention embodied in wireless communication device 50. It will be understood by one skilled in the art that the methods described herein could be applied to transmission from a central base station (not shown) as well. It will also be understood that various of the functional blocks shown in FIG. 1 may not be present in other embodiments of the present invention. The functional block diagram of FIG. 1 corresponds to an embodiment that is useful for operation according to the TIA/EIA Standard IS-95C, also referred to as IS-30 2000. Other embodiments of the present invention are useful for other standards including Wideband CDMA (WCDMA) standards as proposed by the standards bodies ETSI and ARIB. It will be understood by one skilled in

the art that owing to the extensive similarity between the reverse link modulation in the WCDMA standards and the reverse link modulation in the IS-95C standard, extension of the present invention to the WCDMA standards is easily accomplished.

5 In the exemplary embodiment of FIG. 1, the wireless communication device transmits a plurality of distinct channels of information which are distinguished from one another by short orthogonal spreading sequences as described in the aforementioned U.S. Patent Application Serial No. 08/886,604. Five separate code channels are transmitted by the wireless
10 communication device: 1) a first supplemental data channel 38, 2) a time multiplexed channel of pilot and power control symbols 40, 3) a dedicated control channel 42, 4) a second supplemental data channel 44 and 5) a fundamental channel 46. The first supplemental data channel 38 and second supplemental data channel 44 carry digital data which exceeds the
15 capacity of the fundamental channel 46 such as facsimile, multimedia applications, video, electronic mail messages or other forms of digital data. The multiplexed channel of pilot and power control symbols 40 carries pilots symbols to allow for coherent demodulation of the data channels by the base station and power control bits to control the energy of
20 transmissions of the base station or base stations in communication with wireless communication device 50. Control channel 42 carries control information to the base station such as modes of operation of wireless communication device 50, capabilities of wireless communication device 50 and other necessary signaling information. Fundamental channel 46 is the
25 channel used to carry primary information from the wireless communication device to the base station. In the case of speech transmissions, the fundamental channel 46 carries the speech data.

Supplemental data channels 38 and 44 are encoded and processed for transmission by means not shown and provided to modulator 26. Power
30 control bits are provided to repetition generator 22 which provides repetition of the power control bits before providing the bits to multiplexer (MUX) 24. In multiplexer 24 the redundant power control bits are time multiplexed with pilot symbols and provided on line 40 to modulator 26.

Message generator 12 generates necessary control information
35 messages and provides the control message to CRC and tail bit generator 14. CRC and tail bit generator 14 appends a set of cyclic redundancy check bits which are parity bits used to check the accuracy of the decoding at the base

station and appends a predetermined set of tail bits to the control message to clear the memory of the decoder at the base station receiver subsystem. The message is then provided to encoder 16 which provide forward error correction coding upon the control message. The encoded symbols are provided to repetition generator 20 which repeats the encoded symbols to provide additional time diversity in the transmission. Following repetition generator certain symbols are punctured according to some predetermined puncturing pattern by puncturing element (PUNC) 19 to provide a predetermined number of symbols within the frame. The symbols are then provided to interleaver 18 which reorders the symbols in accordance with a predetermined interleaving format. The interleaved symbols are provided on line 42 to modulator 26.

Variable rate data source 1 generates variable rate data. In the exemplary embodiment, variable rate data source 1 is a variable rate speech encoder such as described in aforementioned U.S. Patent No. 5,414,796. Variable rate speech encoders are popular in wireless communications because their use increases the battery life of wireless communication devices and increases system capacity with minimal impact on perceived speech quality. The Telecommunications Industry Association has codified the most popular variable rate speech encoders in such standards as Interim Standard IS-96 and Interim Standard IS-733. These variable rate speech encoders encode the speech signal at four possible rates referred to as full rate, half rate, quarter rate or eighth rate according to the level of voice activity. The rate indicates the number of bits used to encode a frame of speech and varies on a frame by frame basis. Full rate uses a predetermined maximum number of bits to encode the frame, half rate uses half the predetermined maximum number of bits to encode the frame, quarter rate uses one quarter the predetermined maximum number of bits to encode the frame and eighth rate uses one eighth the predetermined maximum number of bits to encode the frame.

Variable rate data source 1 provides the encoded speech frame to CRC and tail bit generator 2. CRC and tail bit generator 2 appends a set of cyclic redundancy check bits which are parity bits used to check the accuracy of the decoding at the base station and appends a predetermined set of tail bits to the control message in order to clear the memory of the decoder at the base station. The frame is then provided to encoder 4, which provides forward error correction coding on the speech frame. The encoded symbols are

provided to repetition generator 8 which provides repetition of the encoded symbol. Following repetition generator certain symbols are punctured by puncturing element 9 according to a predetermined puncturing pattern to provide a predetermined number of symbols within the frame. The symbols
5 are then provided to interleaver 6 which reorders the symbols in accordance with a predetermined interleaving format. The interleaved symbols are provided on line 46 to modulator 26.

In the exemplary embodiment, modulator 26 modulates the data channels in accordance with a code division multiple access modulation
10 format and provides the modulated information to transmitter (TMTR) 28, which amplifies and filters the signal and provides the signal through duplexer 30 for transmission through antenna 32.

In the exemplary embodiment, variable rate data source 1 sends a signal indicative to the rate of the encoded frame to control processor 36. In
15 response to the rate indication, control processor 36 provides control signals to transmitter 28 indicating the energy of the transmissions.

In IS-95 and cdma2000 systems, a 20 ms frame is divided into sixteen sets of equal numbers of symbols, referred to as power control groups. The reference to power control is based on the fact that for each power control
20 group, the base station receiving the frame issues a power control command in response to a determination of the sufficiency of the received reverse link signal at the base station.

FIG. 3A-3C illustrate the transmission energy versus time (in power control groups) for the three transmission rates- full, half, and quarter. In
25 addition, FIGS. 3D-3G illustrate four separate alternative embodiments for the transmission at eighth rate frames in which half of the time no energy is transmitted. Because there is much redundancy introduced into the frames that are of less than full rate, the energy at which the symbols are transmitted may be reduced in approximate proportion to amount of
30 additional redundancy in the frame.

In FIG. 3A, for full rate frame 300, each power control group PC_0 through PC_{15} are transmitted at energy E. For the sake, of simplicity the frames are illustrated as being transmitted at an equal energy for the duration of the frame. One skilled in the art will understand the energy will
35 vary over the frame and that what is represented in FIGS-3A-3G can be thought of as the baseline energy at which the frames would be transmitted absent external effects. In the exemplary embodiment, remote station 50

responds to closed loop power control commands from the base station and from internally generated open loop power control commands based on the received forward link signal. The responses to the power control algorithms will causes the transmission energy to vary over the duration of a frame.

5 In FIG. 3B, for half rate frame 302, the energy is equal to half the predetermined maximum level, or $E/2$. This is represented in FIG. 3B. The interleaver structure is such that it distributes the repeated symbols over the frame in such a way to attain maximum time diversity.

10 In FIG. 3C for quarter-rate transmission 304, the frame is transmitted at approximately one-quarter of the predetermined maximum level, or $E/4$.

In the exemplary embodiment, during the transmission of full rate, half rate and quarter rate frames, the pilot signal is continuously transmitted. However, in FIGS. 3D-3G transmitter 28 gates the transmission of half of the frame. In the preferred embodiment, during the periods in
15 which the traffic channel transmissions are gated off, the pilot channel is also gated off to reduce battery consumption and increase reverse link capacity. In each of the embodiments, the frames are transmitted at a 50% duty cycle in which half of the time the energy of the transmission is gated off. During the period in which the frame is transmitted, the energy is
20 scaled to approximately the energy at which a quarter rate frame is transmitted $E/4$. However, the inventors have through extensive simulation, determined the preferred average or baseline energy at which the eighth rate frames should be transmitted for each of the alternative embodiments for transmitting eighth rate frames. These energies have been
25 computed to maximize battery savings and reverse link capacity while maintaining the level of reliability of transmission.

In the first embodiment, illustrated in FIG. 3D, the frame is transmitted such that it is gated off at alternating 1.25 ms. intervals. Thus, transmitter 28 is initially gated off for the first 1.25ms. The second power
30 control group (PCG1) is transmitted then with energy E_1 during the second 1.25 ms. The third power control group (PCG2) is gated off. In this embodiment, all the odd PCGs (1, 3, 5, 7, 9, 11, 13, 15) are transmitted while all the even PCGs (0, 2, 4, 6, 8, 10, 12, 14) are gated off. The puncturing structure discards half of the repeated symbols and provides approximately
35 four versions of each transmitted symbol. In the preferred first embodiment, the symbols are transmitted at an average or baseline energy of $0.385E$. In the preferred embodiment, the gating of transmitter 28 is

performed such that the last portions of the frame are not gated off. This is preferred because it allows for meaningful closed power control commands to be sent by the receiving base station to assist in reliable transmission of the subsequent frame.

5 In the second embodiment, which is the preferred embodiment of the present invention, illustrated in FIG. 3E, the frame is transmitted such that it is gated off at alternating 2.5 ms. intervals. The transmission method illustrated in FIG. 3E represents the preferred embodiment, because it results in optimum battery savings and reverse link capacity. During the first 2.5
10 ms. interval (PCG0 and PCG1) transmitter 28 is gated off. Then, transmitter 28 is gated on for next 2.5 ms (PCG2 and PCG3) and so on. In this embodiment PCGs 2, 3, 6, 7, 10, 11, 14, 15 are gated on, while PCGs 0, 1, 4, 5, 8, 9, 12, 13 are gated off. The puncturing structure is such that it discards exactly half of the repeated symbols during gate off in this embodiment. In the preferred
15 second embodiment, the symbols are transmitted at an average or baseline energy of 0.32E.

In the third embodiment, illustrated in FIG. 3F, the frame is transmitted such that it is gated off at alternating 5.0 ms. intervals. During the first 5.0 ms. interval (PCG0-PCG3), transmitter 28 is gated off. Then, in
20 the next 5.0 ms interval PCGs 4, 5, 6, 7 are transmitted and so on. In this embodiment PCGs 4, 5, 6, 7, 12, 13, 14, 15 are transmitted, while PCGs 0, 1, 2, 3, 8, 9, 10, 11 are gated off. The puncturing structure is such that it discards exactly half of the repeated symbols during gate off in this embodiment. In the preferred third embodiment, the symbols are transmitted at an average
25 or baseline energy of 0.32E.

In the fourth embodiment, illustrated in FIG. 3G, the frame is transmitted such that it is gated off during the first 10 ms. In the next 10ms interval PCGs 8 through 15 are transmitted. In this embodiment PCGs 8, 9,
30 10, 11, 12, 13, 14, 15 are transmitted, while PCGs 0, 1, 2, 3, 4, 5, 6, 7 are gated off. The interleaver structure is such that it discards exactly half of the repeated symbols during gate off in this embodiment. In the preferred second embodiment, the symbols are transmitted at an average or baseline energy of 0.335E.

FIG. 2 illustrates a functional block diagram of an exemplary
35 embodiment of modulator 26 of FIG. 1. The first supplemental data channel data is provided on line 38 to spreading element 52 which covers the supplemental channel data in accordance with a predetermined spreading

sequence. In the exemplary embodiment, spreading element 52 spreads the supplemental channel data with a short Walsh sequence (++--). The spread data is provided to relative gain element 54 which adjusts the gain of the spread supplemental channel data relative to the energy of the pilot and power control symbols. The gain adjusted supplemental channel data is provided to a first summing input of summer 56. The pilot and power control multiplexed symbols are provided on line 40 to a second summing input of summing element 56.

Control channel data is provided on line 42 to spreading element 58 which covers the supplemental channel data in accordance with a predetermined spreading sequence. In the exemplary embodiment, spreading element 58 spreads the supplemental channel data with a short Walsh sequence (+++-----). The spread data is provided to relative gain element 60 which adjusts the gain of the spread control channel data relative to the energy of the pilot and power control symbols. The gain adjusted control data is provided to a third summing input of summer 56.

Summing element 56 sums the gain adjusted control data symbols, the gain adjusted supplemental channel symbols and the time multiplexed pilot and power control symbols and provides the sum to a first input of multiplier 72 and a first input of multiplier 78.

The second supplemental channel is provided on line 44 to spreading element 62 which covers the supplemental channel data in accordance with a predetermined spreading sequence. In the exemplary embodiment, spreading element 62 spreads the supplemental channel data with a short Walsh sequence (++--). The spread data is provided to relative gain element 64 which adjusts the gain of the spread supplemental channel data. The gain adjusted supplemental channel data is provided to a first summing input of summer 66.

The fundamental channel data is provided on line 46 to spreading element 68 which covers the fundamental channel data in accordance with a predetermined spreading sequence. In the exemplary embodiment, spreading element 68 spreads the fundamental channel data with a short Walsh sequence (+++-----). The spread data is provided to relative gain element 70 which adjusts the gain of the spread fundamental channel data. The gain adjusted fundamental channel data is provided to a second summing input of summer 66.

Summing element 66 sums the gain adjusted second supplemental channel data symbols and the fundamental channel data symbols and provides the sum to a first input of multiplier 74 and a first input of multiplier 76.

5 In the exemplary embodiment, a pseudonoise spreading using two different short PN sequences (PN_I and PN_Q) is used to spread the data. In the exemplary embodiment the short PN sequences, PN_I and PN_Q , are multiplied by a long PN code to provide additional privacy. The generation of pseudonoise sequences is well known in the art and is described in detail
10 in aforementioned U.S. Patent No. 5,103,459. A long PN sequence is provided to a first input of multipliers 80 and 82. The short PN sequence PN_I is provided to a second input of multiplier 80 and the short PN sequence PN_Q is provided to a second input of multiplier 82.

The resulting PN sequence from multiplier 80 is provided to
15 respective second inputs of multipliers 72 and 74. The resulting PN sequence from multiplier 82 is provided to respective second inputs of multipliers 76 and 78. The product sequence from multiplier 72 is provided to the summing input of subtractor 84. The product sequence from multiplier 74 is provided to a first summing input of summer 86. The
20 product sequence from multiplier 76 is provided to the subtracting input of subtractor 84. The product sequence from multiplier 78 is provided to a second summing input of summer 86.

The difference sequence from subtractor 84 is provided to baseband filter 88. Baseband filter 88 performs necessary filtering on the difference
25 sequence and provides the filtered sequence to gain element 92. Gain element 92 adjusts the gain of the signal and provides the gain adjusted signal to upconverter 96. Upconverter 96 upconverts the gain adjusted signal in accordance with a QPSK modulation format and provides the unconverted signal to a first input of summer 100.

30 The sum sequence from summer 86 is provided to baseband filter 90. Baseband filter 90 performs necessary filtering on difference sequence and provides the filtered sequence to gain element 94. Gain element 94 adjusts the gain of the signal and provides the gain adjusted signal to upconverter 98. Upconverter 98 upconverts the gain adjusted signal in accordance with a
35 QPSK modulation format and provides the upconverted signal to a second input of summer 100. Summer 100 sums the two QPSK modulated signals and provides the result to transmitter 28.

Turning now to FIG. 4, a functional block diagram of selected portions of a base station 400 in accordance with the present invention. Reverse link RF signals from the wireless communication device 50 (FIG. 1) are received by receiver (RCVR) 402, which downconverts the received reverse link RF signals to an baseband frequency. In the exemplary embodiment, receiver 402 down converts the received signal in accordance with a QPSK demodulation format. The baseband signal is then demodulated by demodulator 404. Demodulator 404 is further described with reference to FIG. 5 below.

The demodulated signal is provided to accumulator 405. Accumulator 405 sums the symbol energies of the redundantly transmitted power control groups of symbols. The accumulated symbols energies are provided to de-interleaver 406 which reorders the symbols in accordance with a predetermined de-interleaving format. The reordered symbols are provided to decoder 408 which decodes the symbols to provide an estimate of the transmitted frame. The estimate of the transmitted frame is then provided to CRC check 410 which determines the accuracy of the frame estimate based on the CRC bits included in the transmitted frame.

In the exemplary embodiment, base station 400 performs a blind decoding on the reverse link signal. Blind decoding describes a method of decoding variable rate data in which the receiver does not know a priori the rate of the transmission. In the exemplary embodiment, base station 400 accumulates, deinterleaves and decodes the data in accordance with each possible rate hypothesis. The frame selected as the best estimate is based on quality metrics such as the symbol error rate, the CRC check and the Yamamoto metric.

An estimate of the frame for each rate hypothesis is provided to control processor 414 and a set of quality metrics for each of the decoded estimates is also provided. Quality metrics that may include the symbol error rate, the Yamamoto metric and the CRC check. Control processor selectively provides one of the decoded frames to the remote station user or declares a frame erasure.

Turning now to FIG. 5, an expanded functional block diagram of an exemplary single demodulation chain of demodulator 404 is shown. In the preferred embodiment, demodulator 404 has one demodulation chain for each information channel. The exemplary demodulator 404 of FIG. 5 performs complex demodulation on signals modulated by the exemplary

modulator 26 of FIG. 1. As previously described, receiver (RCVR) 402 downconverts the received reverse link RF signals to a baseband frequency, producing I and Q baseband signals. Despreaders 502 and 504 respectively despread the I and Q baseband signals using the long code from FIG. 1.

5 Baseband filters (BBF) 506 and 508 respectively filter the I and Q baseband signals.

Despreaders 510 and 512 respectively despread the I and Q signals using the PN_I sequence of FIG. 2. Similarly, despreaders 514 and 516 respectively despread the Q and I signals using the PN_Q sequence of FIG. 2.

10 The outputs of despreaders 510 and 512 are combined in combiner 518. The output of desreader 516 is subtracted from the output of desreader 512 in combiner 520.

The respective outputs of combiners 518 and 520 are then Walsh-uncovered in Walsh-uncoverers 522 and 524 with the Walsh code that was used to cover the particular channel of interest in FIG. 2. The respective

15 outputs of the Walsh-uncoverers 522 and 524 are then summed over one Walsh symbol by accumulators 530 and 532.

The respective outputs of combiners 518 and 520 are also summed over one Walsh symbol by accumulators 526 and 528. The respective

20 outputs of accumulators 526 and 528 are then applied to pilot filters 534 and 536. Pilot filters 534 and 536 generate an estimation of the channel conditions by determining the estimated gain and phase of the pilot signal data 40 (see FIG. 1). The output of pilot filter 534 is then complex multiplied by the respective outputs of accumulators 530 and 532 in complex

25 multipliers 538 and 540. Similarly, the output of pilot filter 536 is complex multiplied by the respective outputs of accumulators 530 and 532 in complex multipliers 542 and 544. The output of complex multiplier 542 is then summed with the output of complex multiplier 538 in combiner 546. The output of complex multiplier 544 is subtracted from the output of complex

30 multiplier 540 in combiner 548. Finally, the outputs of combiners 546 and 548 are combined in combiner 550 to produce the demodulated signal of interest 405.

A second aspect of the present invention is directed toward controlling forward link transmission energy in the face of potentially gated reverse link

35 transmissions. Forward link performance is effected when the reverse link is in gated mode of operation. Forward link power control bit is punctured into reverse link pilot based on which the base station increases or decreases

transmission power. Therefore when the reverse link is gated off 50% of the time, the actual forward link power control command is sent at 400 Hz instead of 800 Hz. However, base station does not know a priori whether the mobile station is gated off. So in normal operation it will increase the power during the interval when mobile station is gated off. By simulation it has been found that there is a performance degradation of about 1 dB if the base station is ignorant of mobile station's transmission mode than if the base station knew that the mobile station is in gated mode and react to forward link power control command that are sent in the reverse link pilot (400Hz). Therefore, there should be a method by which the base station can detect mobile station's transmission mode (gated/non gated).

One method of doing this is by defining a forward link power control bit erasure decision region. That is, when the dot product magnitude (summed over all combining fingers) is less than a threshold, decide erasure and keep forward power unchanged. In this way, the base station will react effectively to 400Hz forward link power control sent over the reverse link pilot in the gated mode.

As described above, in the exemplary embodiment, the forward power control symbols are multiplexed into the pilot symbol stream. The demodulated pilot and power control symbols are provided to demultiplexer 412, which separates out the power control bit energies and provides the power control bit energies to control processor 414.

Control processor 414 also receives the power control bit energies for other fingers of the reverse link signal provided from remote station 50. From the summed energies from the different demodulated fingers, control processor 414 generates commands for controlling the transmission energy of the forward link signal and provides those commands to transmitter (TMTR) 420. In the present invention control processor 414 detects when the reverse link frame has gated out the power control bits by comparing the summed energies of those bits to a threshold and if the summed energy is less than a threshold amount inhibiting closed loop power control response.

Forward link traffic data for transmission to remote station 50 is provided to processing element 416 which formats the data and encodes and interleaves the resultant frame of data. The processed frame of data is provided to modulator 418. Modulator 418 modulates the data for transmission on the forward link. In the exemplary embodiment, the

forward link signal is modulated in accordance with a CDMA modulation format and in particular with a cdma2000 or IS-2000 modulation format.

The modulated signal is provided to transmitter 420, which upconverts, amplifies and filters the signal for transmission. The energy at
5 which the signal is transmitted is determined in accordance with the control signal from control processor 414.

FIG. 6 illustrates the operation performed by control processor 414. The uncovered pilot and power control symbols from summers 526 and 528 of FIG. 5 are provided to demultiplexers 600 and 602 which separate out the
10 multiplexed power control symbol energies. The power control bit symbol energies from all of the fingers being demodulated are summed in finger combiner 604. The summed energy is provided to comparator 606 which compares the summed energy to a predetermined threshold and outputs a signal indicative of the comparison.

15 If the energy of the power control bits is below the threshold value, then power control processor 608 determines that the forward link power control bit has been gated out and inhibits adjustment of the forward link transmission energy. If the energy of the power control bits is above the threshold value, then power control processor 608 determines that the
20 forward link power control bit has not been gated out and adjusts the forward link transmission energy in accordance with the estimated value of the received power control bit.

The previous description of the preferred embodiments is provided to enable any person skilled in the art to make or use the present invention.
25 The various modifications to these embodiments will be readily apparent to those skilled in the art, and the generic principles defined herein may be applied to other embodiments without the use of the inventive faculty. Thus, the present invention is not intended to be limited to the embodiments shown herein but is to be accorded the widest scope consistent
30 with the principles and novel features disclosed herein.

WE CLAIM:



CLAIMS

1. In a wireless communication device, a method for transmitting
2 eighth rate frames of information wherein a frame is divided into sixteen
frame intervals of equal duration comprising an equal number of symbols,
4 the method comprising the steps of:
 - (a) gating off transmissions during the first said frame intervals;
6 and
 - (b) transmitting the next said frame intervals;
2. The method of claim 1 wherein the resultant pattern of
2 transmission steps (a)- and (b) are subsequently repeated seven times.
3. The method of claim 1 wherein said eighth rate frame is
2 transmitted at a baseline energy of approximately 38.5% of a predetermined
transmission energy for a maximum rate transmission.
4. In a wireless communication device, a method for transmitting
2 eighth rate frames of information wherein a frame is divided into sixteen
frame intervals of equal duration comprising an equal number of symbols,
4 the method comprising the steps of:
 - (a) gating off transmissions during a first and second said frame
6 intervals; and
 - (b) transmitting symbols during a third and fourth of said frame
8 intervals.
5. The method of claim 4 wherein the resultant pattern of
2 transmission from steps (a)-(b) are subsequently repeated three times.
6. The method of claim 4 wherein said eighth rate frame is
2 transmitted at a baseline energy of approximately 32% of a predetermined
transmission energy for a maximum rate transmission.
7. In a wireless communication device, a method for transmitting
2 eighth rate frames of information wherein a frame is divided into sixteen
frame intervals of equal duration comprising an equal number of symbols,
4 the method comprising the steps of:



- 6 (a) gating off transmissions during a first, second, third and fourth
of said frame intervals; and
- 8 (b) transmitting a symbols during a fifth, sixth, seventh and
eighth of said frame intervals.

2 8. The method of claim 7 wherein the resultant pattern of
transmission from steps (a)-(b) are subsequently repeated once.

2 9. The method of claim 7 wherein said eighth rate frame is
transmitted at a baseline energy of approximately 32% of a predetermined
transmission energy for a maximum rate transmission.

2 10. In a wireless communication device, a method for transmitting
eighth rate frames of information wherein a frame is divided into sixteen
frame intervals of equal duration comprising an equal number of symbols,
4 the method comprising the steps of:

- 6 (a) gating off transmissions during the first through eighth of said
frame intervals; and
- 8 (b) transmitting symbols during a ninth through a sixteenth of
said frame intervals.

2 11. The method of claim 10 wherein said eighth rate frame is
transmitted at a baseline energy of approximately 33.5% of a predetermined
transmission energy for a maximum rate transmission.

2 12. In a base station, a method for controlling the transmission
energy of forward link signals comprising the steps of:

4 receiving a potentially gated reverse link signal including forward
link power control bits;

6 determining whether said power control bits have been gated out;
and

8 adjusting forward link transmission energy in accordance with said
forward link power control bits only when said determination as to whether
said forward link power control bits have been gated out indicates that said
10 power control bits have not been gated out.

13. The method of claim 12 wherein said step of determining
2 whether said power control bits have been gated out comprises:
measuring the energy of the received power control bits; and
4 comparing the energy of the power control bits to a predetermined
threshold.

