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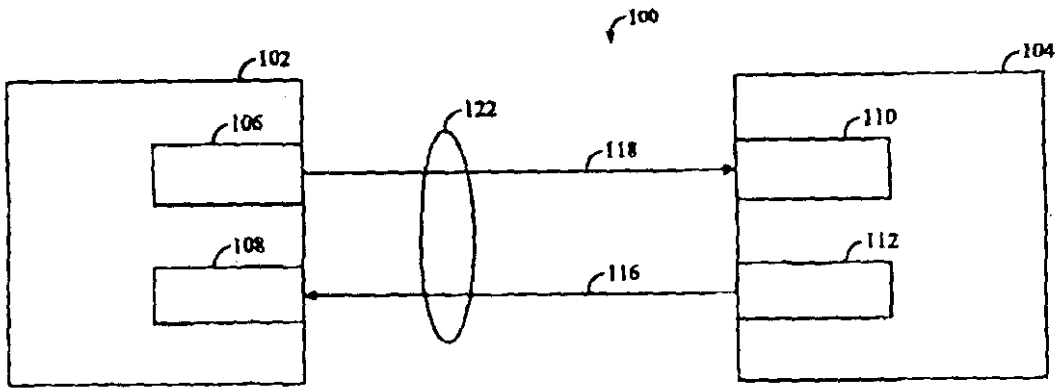
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(54) Title: VARIABLE LOOP GAIN IN DOUBLE LOOP POWER CONTROL SYSTEMS



(57) Abstract

An apparatus and method for using a variable loop gain in a double-loop power control system to control the power of a forward link signal sent by a gateway to a user terminal to compensate for fading in a wireless communications system. In one embodiment the invention includes the steps of detecting fast fading in the forward link signal and informing the gateway of the fast fading; and at the gateway, reducing the loop gain of the power control loop when fast fading is indicated. In another embodiment, the invention includes the steps of, at the gateway, detecting fast fading in a reverse link signal received from the user terminal and reducing the loop gain of the power control loop when fast fading is indicated.

5pr x 12 = 6860

VARIABLE LOOP GAIN IN DOUBLE LOOP POWER CONTROL SYSTEMS

BACKGROUND OF THE INVENTION

I. Field of the Invention

The present invention relates to wireless communication systems. More specifically, the present invention relates to a novel and improved system and method of power control in a wireless communications system.

II. Related Art

Wireless communication networks are enjoying notable popularity in all aspects of business, industry and personal life. As such, portable, hand-held communication devices have experienced widespread growth in recent years. Portable devices such as cellular phones are now commonplace with business and personal users alike. Additionally, advanced systems, such as satellite communications systems using portable, hand held and mobile phones, are currently being deployed.

In wireless communication systems, signals are subject to fading. Fading occurs when environmental factors diminish the power of a signal during its transmission from transmitter to receiver. One measurement that quantifies fading is the signal-to-noise ratio (SNR) of the received signal as measured at the receiver. Systems have been developed to adjust the transmitted power of the signal to compensate for fading. One such system is known as "single-loop" power control.

In a single-loop power control system, the receiver monitors the SNR of the received signal and sends commands to the transmitter to adjust the transmitted power so as to maintain a specified "threshold" SNR at the receiver. Conventional single-loop power control systems generally employ two or three types of such commands. One type of command instructs the transmitter to increase the transmitted power. Another type of command instructs the transmitter to decrease the transmitted power. The amount by which the transmitted power is increased or decreased in response to such a

command is referred to as the "gain" of the loop. In some systems, a third type of command is used to instruct the transmitter to maintain the transmitted power at the current level.

Single-loop power control works well in an environment with slow fading. In slow fading, there is no substantial fading during the time required for a power control command to reach the transmitter and the resulting signal-to-noise ratio to be measured at the receiver, known as the "period" of the loop. One example of a slow fading environment is one having only thermal noise as signal interference.

However, in a signal environment with medium-speed fading, single-loop power control is inadequate. In medium-speed fading, there is substantial fading during a single loop period. One example of a medium-speed fading environment is where the transmitter or receiver is moving rapidly past stationary obstructions, causing rapid changes in signal attenuation. In such a medium-speed fading environment, the threshold SNR may be insufficient to ensure signal quality. This is because the loop is too slow to respond to the rapid variations in the SNR of the received signal.

In digital communication systems, the adequacy of the threshold SNR can be quantified by the ratio of information bits received in error to the total number of bits received. This ratio is generally computed repeatedly for each frame. The ratio thus computed is known as the "frame error rate" (FER) of the signal. One type of system developed to address this problem is known as a "double-loop" power control system.

In a double-loop power control system, the single-loop power control system described above is used as the "inner" loop. The SNR threshold used by the inner loop is modified by an "outer" loop based on the FER of the received signal. For example, when the FER rises above a predetermined FER threshold, the threshold SNR is increased by a fixed, predetermined amount. This process continues until the FER falls below the FER threshold.

One consideration in double-loop power control systems is the selection of the magnitude of the fixed gain employed by the inner loop. The selection of this gain is a trade-off between two conflicting considerations. In a medium-speed fading environment, rapid loop response is required. This consideration argues for a large inner-loop gain. With a large inner-loop gain, fewer loop periods are required to change the threshold SNR by a large amount.

However, in a slow fading signal environment, a large gain will result in large SNR oscillations about the threshold SNR. These oscillations waste transmitter power. Thus a fixed inner-loop gain is not suitable for applications in which the signal will experience both fast fading and slow fading.

Furthermore, fixed gain systems experience difficulty in fast fading signal environments. In fast fading, the SNR experiences several large oscillations within a single outer-loop period (that is, the time required to adjust the SNR threshold based on one or more FER measurements). Fast fading oscillations are typically on the order of hundreds of hertz. In such an environment, the response time of the inner loop is no longer important because the inner loop cannot possibly keep up with the fading. What is needed is a double-loop power control system where the inner-loop gain can be varied to suit the speed of the fading.

SUMMARY OF THE INVENTION

The present invention is an apparatus and method for adjusting the power of a signal sent by a transmitter to a receiver to compensate for fading in a wireless communications system. In one embodiment, the method includes the steps of measuring, at a first station, a signal-to-noise ratio of a signal transmitted by a second station; adjusting a transmitted signal power of the signal as a function of a loop gain, the signal-to-noise ratio, and a signal-to-noise ratio threshold; measuring, at the first station, a signal quality of the received signal; adjusting the signal-to-noise ratio threshold as a function of the signal quality and a signal quality threshold; measuring, at the first station, a fading rate of the signal; and adjusting the loop gain as a function of the fading rate and a fading rate threshold.

In one embodiment, the method includes the steps of measuring, at a first station, a signal-to-noise ratio of a signal transmitted by a second station; adjusting a transmitted signal power of the signal as a function of a loop gain, the signal-to-noise ratio, and a signal-to-noise ratio threshold; measuring, at the first station, a signal quality of the received signal; adjusting the signal-to-noise ratio threshold as a function of the signal quality and a signal quality threshold; measuring, at the second station, a fading rate of a further signal transmitted

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by the first station; and adjusting the loop gain as a function of the fading rate and a fading rate threshold.

One advantage of the present invention is that it mitigates the effects of fast fading.

BRIEF DESCRIPTION OF THE FIGURES

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 corresponding elements throughout and wherein:

FIG. 1 is a block diagram illustrating an exemplary communication system;

FIGS. 2 and 3 are block diagrams illustrating the transceivers of FIG. 1 in greater detail;

FIG. 4 is a flowchart depicting the operation of an inner power control loop according to a preferred embodiment of the present invention;

FIG. 5 is a flowchart depicting the operation of an outer power control loop according to a preferred embodiment of the present invention; and

FIG. 6 is a flowchart depicting the operation of a variable-gain inner double-loop power control loop according to a preferred embodiment of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

The present invention is an apparatus and method for double loop power control in a wireless communications system. In a preferred embodiment, the present invention operates within a code-division multiple-access (CDMA) communications system. Power control loops operating within such systems are disclosed in U.S. Patent Application Serial Nos. 09/164,383, entitled *"System and Method for Selecting Power Control Modes"* (Atty. docket PA667) and 09/164,384, entitled *"System and Method for Optimized Power Control"* (Atty. docket PA668), filed herewith which are assigned to the assignee of the present invention, and incorporated by reference herein. Other examples of techniques for power control in such communication systems are

found in U. S. Patent Nos. 5,383,219, entitled *"Fast Forward Link Power Control In A Code Division Multiple Access System,"* issued January 17, 1995; 5,396,516, *entitled "Method And System For The Dynamic Modification Of Control Parameters In A Transmitter Power Control System,"* issued March 7, 1995; and 5,267,262, entitled *"Transmitter Power Control System,"* issued November 30, 1993, which are incorporated herein by reference.

I. Example Environment

Before describing the invention in great detail, it is useful to describe an example environment in which the invention can be implemented. The present invention can be implemented in any wireless communication system, especially one in which it is desirable to control the amount of power provided by a transmitter. Such environments include, without limitation, cellular communication systems, personal communication systems, satellite communication systems, and many others.

FIG. 1 is a diagram illustrating an exemplary communication system 100. Referring to FIG. 1, system 100 has two transceivers 102 and 104. Transceiver 102 has a transmitter 106 and a receiver 108. Transceiver 104 has a transmitter 112 and a receiver 110.

Data or other information is transmitted between the transceivers over a transmission channel 122. In satellite, cellular and other wireless communication systems, channel 122 is a wireless link. In satellite communication systems, channel 122 includes one or more relay satellites. Channel 122 is a two-way channel that includes a "forward" signal 116 and a "reverse" signal 118.

In some environments, channel 122 is a packetized data path in which the data is transmitted in data packets. This is often the case where the information is in the form of digital data. In other environments, analog data is modulated onto a carrier and transmitted across channel 122.

In the example of a cellular communication system, transceiver 102 is a hand-held or mobile cellular telephone and transceiver 104 is a base station at the local cell site that is providing service in the phone's current area. In the example of a satellite communication system, transceiver 102 is a hand-held, mobile, or fixed transceiver (for example, a satellite telephone) and transceiver

104 is located in a terrestrial gateway. In the satellite communication system example, a satellite is used to relay signals between the transceivers 102 and 104 over channel 122.

The present invention is described in terms of this example environment. Description in these terms is provided for convenience only. It is not intended that the invention be limited to application in this example environment. In fact, after reading the following description, it will become apparent to a person skilled in the relevant art how to implement the invention in alternative environments.

II. Power Control

The present invention is a system and method for adjusting transmitted signal power to compensate for fast fading in a wireless communications system. In fast fading, several signal fades occur during a single outer-loop period. Thus the outer loop is ineffective to mitigate fast fading. Such fast fading is often superimposed upon a slower fading trend. The inventors have found that one good solution to the fast fading case is to ignore the fast (high-frequency) component of the fading and instead track any slower (low-frequency) components of the fading. According to the present invention, when fast fading is detected, the system attempts to track the underlying slow fading rather than attempting to track the fast fading. In a preferred embodiment of the present invention, this is accomplished by using a small inner loop gain.

FIG. 2 is a block diagram illustrating transceiver 102 in greater detail. Transceiver 102 includes transmitter 106, receiver 108, a measurement element 202, a processor 204, a memory 206, a data destination 210 and a data source 212. In operation, receiver 108 receives signal 116 and passes it to data destination 210. Data destination 210 can be any element that makes use of the data, such as a CODEC, MODEM, digital signal processor, and the like. Receiver 108 may perform certain tasks, such as demodulation, on signal 116, as is well-known in the art.

Measurement element 202 makes certain measurements of the characteristics of signal 116, as is described in detail below. For example, these measurements include measurements of SNR, signal quality based on the

presence of one or more error events (such as FER) and fading rate (FR). In a preferred embodiment, measurement element 202 includes a SNR measurement circuit 214 and a frame error measurement circuit 216. SNR measurement circuit 214 obtains measurements of the SNR of received signal 116. Frame error measurement circuit 216 obtains measurements of the error rate, or one or more other error events, of received signal 116. Circuits that accomplish these functions are well-known in the relevant arts. These measurements are passed to a processor 204, which can be any processor known in the art or developed hereafter. Processor 204 employs a memory 206 for storage of data, such as the SNR, FER, and FR measurements, and other values, such as thresholds for comparison with these measurements.

Data source 212 generates data for transmission. Data source 212 can include elements such as CODECs, MODEMs, digital signal processors, and the like, as is well-known in the art. Transmitter 106 receives data from data source 212 and performs such tasks as modulation. Processor 204 may be implemented using hardware, software or a combination thereof and may be implemented as a computer system or other processing system. In one embodiment, processor 204 is implemented as one or more computer systems. In another embodiment, processor 204 is implemented primarily in hardware using, for example, hardware components such as application specific integrated circuits (ASICs). Implementation of a hardware state machine so as to perform the functions described herein will be apparent to persons skilled in the relevant art(s). In yet another embodiment, processor 204 is implemented using a combination of both hardware and software.

FIG. 3 is a block diagram illustrating transceiver 104 in greater detail. Transceiver 104 includes transmitter 112, receiver 110, a measurement element 302, a processor 304, a memory 306, a data destination 310 and a data source 312. In operation, receiver 110 receives signal 118 and passes it to data destination 310. Data destination 310 can be any element that makes use of the data, such as a CODEC, MODEM, digital signal processor, and the like. Receiver 110 may perform certain tasks, such as demodulation, on signal 118, as is well-known in the art.

Measurement element 302 makes certain measurements of the characteristics of signal 118, as is described in detail below. For example, these measurements include measurement of fading rate (FR). In a preferred

embodiment, measurement element 302 includes a SNR measurement circuit 314. SNR measurement circuit 314 obtains measurements of the SNR of received signal 118. Circuits that accomplish this function are well-known in the relevant arts. These measurements are passed to transmitter 112 and/or data source 312 for transmission as part of signal 116. These measurements are passed to processor 304, which can be any processor known in the art or developed hereafter. Processor 304 employs a memory 306 for storage of data, such as the measurements, and other values, such as thresholds for comparison with these measurements.

Data source 312 generates data for transmission. Data source 312 can include elements such as CODECs, MODEMs, digital signal processors, and the like, as is well-known in the art. Transmitter 112 receives data from data source 312 and performs such tasks as modulation before transmitting signal 116. Transmitter 112 also includes a variable-gain amplifier 308 for amplifying the power of the signal prior to transmission to produce signal 116. The gain of amplifier 308 is controlled by processor 304.

FIGS. 4-6 are flowcharts depicting the operation of the present invention according to a preferred embodiment. FIG. 4 depicts the operation of the inner power control loop of the present invention. The function of the inner power control loop is to adjust the signal power transmitted by transmitter 112. In a preferred embodiment, the transmitted signal power is adjusted according to the level of signal power received at receiver 108, as described below.

Transmitter 112 transmits signal 116 over channel 122. Signal 116 is received by receiver 108. The process begins with the measurement by measurement element 202 of the power of signal 116, as shown in step 402. In a preferred embodiment, measurement element 202 measures the signal-to-noise ratio (SNR) of signal 116. More specifically, the present invention measures the quantity Eb/No, where Eb is energy per bit and No is noise density in units of power/cycle. Of course, other measures of signal power can be used without departing from the scope of the present invention. In a preferred embodiment, SNR is measured for every frame of received data.

In communication system 100, a predetermined SNR level, referred to as the "SNR threshold," is associated with receiver 108. The SNR threshold represents the minimum SNR at which signals should be received by receiver 108 in order to ensure data quality. The SNR threshold can be selected

according to methods that are well-known in the relevant arts. One such method is to select a SNR that will keep data errors under a certain percentage, such as one percent. In step 404, receiver 108 compares the SNR measured in step 402 to the SNR threshold.

If the measured SNR is lower than the SNR threshold, then transmitter 106 of transceiver 102 transmits an "increase power" command to transceiver 104, as shown in step 406. In a preferred embodiment, the command is transmitted as part of signal 118 over channel 122. In response, transmitter 112 increases the signal power of the signal 116 by a predetermined amount, referred to as the "gain" of the inner loop, or "inner loop gain." In a preferred embodiment, the value of the inner loop gain, and the value of the signal gain applied by amplifier 308, are stored in memory 306. The value of the signal gain is manipulated by processor 304.

If the measured SNR exceeds the SNR threshold, then transmitter 106 of transceiver 102 transmits a "decrease power" command to transceiver 104, as shown in step 408. In response, transmitter 112 decreases the signal power of signal 116 by the inner loop gain. In either case, the process resumes at step 402.

FIG. 5 depicts the operation of the outer power control loop of the present invention (also referred to as the "outer loop"). The function of the outer power control loop is to adjust the SNR threshold of receiver 108. In a preferred embodiment, the SNR threshold is adjusted according to the quality of the received signal. In a preferred embodiment, the quality of the signal is considered not only for the current frame, but also for a certain number of previous frames. Also, in a preferred embodiment, the measure of signal quality used is the presence of one or more error events, for example using a frame error rate (FER). However, other measures of signal quality, such as parity checks, can be used without departing from the scope of the present invention. In addition, other methods of evaluating the signal quality history, such as averages and weighted averages, can be used.

A type of error often encountered is of the "burst" type. Burst errors are characterized by short duration. In general, the duration of a burst error is less than the inner loop period. Therefore, the inner loop cannot compensate for these errors. For this reason, it is desirable to isolate the inner loop from the effects of burst errors. Burst errors are also characterized by errors in multiple

consecutive frames. The outer loop uses this characteristic to detect burst errors. When the outer loop detects errors in multiple consecutive frames, it determines that a burst error has occurred. When a burst error is detected, the outer loop does not change the SNR threshold of the inner loop. The outer loop changes the SNR threshold of the inner loop only in response to non-burst type errors, thereby isolating the inner loop from burst errors.

Referring to FIG. 5, the process begins by making measurements of a quantity indicative of the presence of errors, for example FER, as shown in step 502. The process determines whether or not errors are present in the current frame using the results of such measurements, as shown in step 504. If no errors are present in the current frame, as indicated by the "N" branch in step 504, then transceiver 102 decreases the SNR threshold by a predetermined amount, as shown in step 506. However, if errors are present in the current frame, as indicated by the "Y" branch in step 504, then the quality history of the received signal is reviewed, as shown in step 508. In a preferred embodiment, the error history comprises a predetermined number of previous frames N. Of course, the error history can be selected in other ways without departing from the scope of the present invention. The error history is preserved in memory 206. If any of the previous N frames contain an error, then transceiver 102 decreases the SNR threshold by the outer loop gain, as shown in step 506, subject to a desired frame or timing delay as discussed below.

However, if the previous N frames contain no errors, then transceiver 102 increases the SNR threshold, as shown in step 506. In a preferred embodiment, two change values are employed: one for decreasing the SNR threshold, and the other for increasing the SNR threshold. The change value for decreasing the SNR threshold is small, so that the SNR threshold, and through the action of the inner loop, the transmitted signal power, is gradually reduced in error-free environments. Conversely, the change value for increasing the SNR threshold is large, so that the SNR threshold, and through the action of the inner loop, the transmitted signal power, is quickly increased in error-prone environments.

In addition, it has been found that it is generally not desirable to quickly change the SNR threshold for a certain number of frames after an increase has been made regardless of the presence or not of errors, at least in some systems. Therefore, in one embodiment, an initial increase in the SNR occurs when

encountering a frame error after a certain number of error free frames as just described, but for a preselected number of frames Z after this adjustment no additional increase is allowed to occur. That is, the detection or not of frame errors does not provide a mechanism for selecting further increases in the threshold value until Z frames or frame periods have occurred after an increase. This is shown by optional step 512 which is positioned between quality history checking step 508 and threshold adjustment step 510. In step 512, a check is made to see whether or not Z data frames have been processed since the last SNR threshold increase. The frame count for this processing step is initially set equal to Z so that the first time an adjustment is requested it is made, as shown by set/reset step 514. Subsequent adjustments will then be determined from the frame count.

Whenever Z frames have not yet been processed or passed through, the SNR threshold is allowed to decrease by a fairly small amount, or at a low rate, for each of the Z frames, as shown in step 516. That is, during or at the end of each frame period the SNR threshold level is decremented or decreased by a small percentage or amount, say on the order of 0.004 dB. Those skilled in the art will readily recognize that other amounts may be used including 0 dB, as desired. Processing then returns to step 512 where measurements continue and so forth. Once the requisite number of preselected frames Z have been reached, the SNR threshold is again increased in step 510 (or decreased in step 506) instead of decremented in step 516. Once an SNR threshold increase occurs, the frame count used in step 512 is reset to zero and the counting process beings anew until Z frames have again passed.

This gradual decrease process or period allows the system to "settle" before further action is taken and assures a more predictable and reproducible response to signal conditions. In addition, due to the bursty nature of some errors and the minimum amount of delay in implementing the power increase commands encountered in some systems (satellite) or situations, making short term requests for power won't help, or have a desired impact. However, waiting a few frames does help decrease the amount of power used.

After the preselected number of Z frames has passed, adjustment of the SNR threshold occurs as before. Detection of errors again causes an increase in the SNR threshold, provided the previous N frames contain no errors. In a preferred embodiment, Z is selected to be six frames after the frame generating

or triggering an increase in SNR threshold, during which no additional increase occurs and a gradual decrease is implemented. However, those skilled in the art will understand that other values can be chosen according to known response characteristics of the communication system in which the invention is employed.

FIG. 6 is a flowchart depicting the operation of a variable-gain inner double-loop power control loop according to a preferred embodiment of the present invention. In step 602, receiver 108 measures a fading rate of a signal received from transceiver 104A. According to a preferred embodiment, receiver 108 measures the SNR of the received signal several times over the course of each frame to produce a series of measurements. This series is applied to a high-pass filter to detect rapid changes in SNR, which indicate the presence of fast fading. The output of the high-pass filter, referred to as the "fading rate" is compared to a predetermined fading rate threshold, as shown in step 604.

When the fading rate does not exceed the threshold, as indicated by the "N" branch from step 604, the fading is not sufficiently rapid to be characterized as fast. In that case, the inner-loop gain is set to a first predetermined gain level G1, as shown in step 606.

When the high-frequency content of the fading exceeds the threshold, as indicated by the "Y" branch in step 604, the fading is sufficiently rapid to be characterized as fast. In that case, the inner-loop gain is set to a second predetermined gain level G2, as shown in step 608. In either case, processing resumes at step 602.

In a preferred embodiment, first gain level G1 is much larger than second gain level G2. In other words, the inner-loop gain applied during fast fading is much less than the inner-loop gain applied otherwise. The result is that, during fast fading, the power control loop does not attempt to track the rapid signal power level fluctuations caused by the fast fading, but rather tracks the slower power level fluctuations caused by slower fading. In one embodiment, G1 is approximately 0.5 dB, and G2 is approximately 0.1 dB.

In one embodiment, the user terminal detects fast fading in the signal transmitted from the gateway to the user terminal. In this embodiment, the user terminal reports the fast fading condition to the gateway, which responds by adjusting the inner-loop gain of the power control loop. Referring to FIG. 1,

fast fading in signal 116 is detected by transceiver 102 in step 604. Transceiver 102 detects fast fading in signal 116 by evaluating fluctuations in its SNR, as described in detail above. Fast fading is detected by evaluating the SNR. Transmitter 106 then transmits a command to receiver 110 to adjust the inner-loop gain. In accordance with that command, transceiver 104 adjusts the inner-loop gain in steps 606 and 608.

In another embodiment, the gateway infers that fast fading exists in the signal transmitted from the gateway to the user terminal by detecting fast fading of a signal transmitted by the user terminal to the gateway. Referring to FIG. 1, the fading rate of signal 116 is inferred by transceiver 104 by evaluating the SNR fluctuations in signal 118 in steps 602 and 604, as described in detail above. Transceiver 104 then adjusts the inner-loop gain in steps 606 and 608 based on that evaluation.

III. Conclusion

The previous description of the preferred embodiments is provided to enable any person skilled in the art to make or use the present invention. 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 with the principles and novel features disclosed herein.

What Is Claimed Is:

CLAIMS

1. An apparatus comprising:

means coupled to a first station for measuring a signal-to-noise ratio of a signal transmitted by a second station;

means for adjusting a transmitted signal power of said signal as a function of a loop gain, said signal-to-noise ratio, and a signal-to-noise ratio threshold;

means coupled to said first station for measuring a signal quality of the received signal;

means for adjusting said signal-to-noise ratio threshold as a function of said signal quality and a signal quality threshold;

means coupled to said first station for measuring a fading rate of said signal; and

means for adjusting said loop gain as a function of said fading rate and a fading rate threshold.

2. The apparatus of claim 1, wherein said signal quality and said signal quality threshold are based on detection of error events.

3. The apparatus of claim 2, wherein said error events are selected from the group comprising error rate, bit error rate, and frame error rate.

4. The apparatus of claim 1, wherein said signal comprises a plurality of frames, and wherein said means for adjusting said signal-to-noise ratio threshold comprises:

means for increasing said signal-to-noise ratio threshold when a current frame has an error and a predetermined number of previous frames have no errors with a preselected minimum period between increases; and

means for decreasing said signal-to-noise ratio threshold otherwise.

5. The apparatus of claim 4, wherein said signal-to-noise ratio threshold is decreased by a preselected small amount over said minimum period.

6. The apparatus of claim 4, wherein:

said means for increasing comprises means for increasing said signal-to-noise ratio threshold by a predetermined amount; and

said means for decreasing comprises means for decreasing said signal-to-noise ratio threshold by much less than said predetermined amount.

7. The apparatus of claim 1, wherein said means for adjusting said loop gain comprises:

means for setting said loop gain to a first loop gain when said fading rate is below said fading rate threshold; and

means for setting said loop gain to a second loop gain when said fading rate is above said fading rate threshold.

8. The apparatus of claim 7, wherein said second loop gain is much smaller than said first loop gain.

9. The apparatus of claim 1, further comprising means for determining that said fading rate is above said fading rate threshold when multiple excursions of said signal-to-noise ratio below said signal-to-noise ratio threshold occur between successive adjustments of said transmitted signal power.

10. The apparatus of claim 1, further comprising:

means for accumulating a plurality of said signal-to-noise ratio measurements to produce a time series; and

a high-pass filter that filters said time series to produce said fading rate.

11. An apparatus comprising:

means coupled to a first station for measuring a signal-to-noise ratio of a signal transmitted by a second station;

means for adjusting a transmitted signal power of said signal as a function of a loop gain, said signal-to-noise ratio, and a signal-to-noise ratio threshold;

means coupled to said first station for measuring a signal quality of the received signal;

means for adjusting said signal-to-noise ratio threshold as a function of said signal quality and a signal quality threshold;

means coupled to said second station for measuring a fading rate of a further signal transmitted by said first station; and

means for adjusting said loop gain as a function of said fading rate and a fading rate threshold.

12. The apparatus of claim 11, wherein said signal quality and said signal quality threshold are based on detection of error events.

13. The apparatus of claim 12, wherein said error events are selected from the group comprising error rate, bit error rate, and frame error rate.

14. The apparatus of claim 11, wherein said signal comprises a plurality of frames, and wherein said means for adjusting said signal-to-noise ratio threshold comprises:

means for increasing said signal-to-noise ratio threshold when a current frame has an error and a predetermined number of previous frames have no errors with a preselected minimum period between increases; and

means for decreasing said signal-to-noise ratio threshold otherwise.

15. The apparatus of claim 14, wherein said signal-to-noise ratio threshold is decreased by a preselected small amount over said minimum period.

16. The apparatus of claim 11, wherein:

said means for increasing comprises means for increasing said signal-to-noise ratio threshold by a predetermined amount; and

said means for decreasing comprises means for decreasing said signal-to-noise ratio threshold by much less than said predetermined amount.

17. The apparatus of claim 11, wherein said means for adjusting said loop gain comprises:

means for setting said loop gain to a first loop gain when said fading rate is below said fading rate threshold; and

means for setting said loop gain to a second loop gain when said fading rate is above said fading rate threshold.

18. The apparatus of claim 17, wherein said second loop gain is much smaller than said first loop gain.

19. The apparatus of claim 11, wherein said means for measuring a fading rate comprises means for measuring a further signal-to-noise ratio of said further signal.

20. The apparatus of claim 19, further comprising means for determining that said fading rate is above said fading rate threshold when multiple excursions of said further signal-to-noise ratio below a further signal-to-noise ratio threshold occur between successive adjustments of said transmitted signal power.

21. The apparatus of claim 11, wherein said means for measuring a fading rate comprises:

means for accumulating a plurality of said further signal-to-noise ratio measurements to produce a time series; and

a high-pass filter that filters said time series to produce said fading rate.

22. A method comprising the steps of:

measuring, at a first station, a signal-to-noise ratio of a signal transmitted by a second station;

adjusting a transmitted signal power of said signal as a function of a loop gain, said signal-to-noise ratio, and a signal-to-noise ratio threshold;

measuring, at said first station, a signal quality of the received signal;

adjusting said signal-to-noise ratio threshold as a function of said signal quality and a signal quality threshold;

measuring, at said first station, a fading rate of said signal; and

adjusting said loop gain as a function of said fading rate and a fading rate threshold.

23. The method of claim 22, wherein said signal quality and said signal quality threshold are based on detection of error events.

24. The method of claim 23, wherein said error events are selected from the group comprising error rate, bit error rate, and frame error rate.

25. The method of claim 22, wherein said signal comprises a plurality of frames, and wherein said step of adjusting said signal-to-noise ratio threshold comprises the steps of:

increasing said signal-to-noise ratio threshold when a current frame has an error and a predetermined number of previous frames have no errors with a preselected minimum period between increases; and

decreasing said signal-to-noise ratio threshold otherwise.

26. The method of claim 25, wherein said signal-to-noise ratio threshold is decreased by a preselected small amount over said minimum period.

27. The method of claim 25, wherein:

said increasing step comprises the step of increasing said signal-to-noise ratio threshold by a predetermined amount; and

said decreasing step comprises the step of decreasing said signal-to-noise ratio threshold by much less than said predetermined amount.

28. The method of claim 22, wherein said step of adjusting said loop gain comprises:

setting said loop gain to a first loop gain when said fading rate is below said fading rate threshold; and

setting said loop gain to a second loop gain when said fading rate is above said fading rate threshold.

29. The method of claim 28, wherein said second loop gain is much smaller than said first loop gain.

30. The method of claim 22, further comprising the step of determining that said fading rate is above said fading rate threshold when multiple excursions of said signal-to-noise ratio below said signal-to-noise ratio threshold occur between successive adjustments of said transmitted signal power.

31. The method of claim 22, further comprising the steps of:

accumulating a plurality of said signal-to-noise ratio measurements to produce a time series; and

a high-pass filter that filters said time series to produce said fading rate.

32. A method comprising the steps of:

measuring, at a first station, a signal-to-noise ratio of a signal transmitted by a second station;

adjusting a transmitted signal power of said signal as a function of a loop gain, said signal-to-noise ratio, and a signal-to-noise ratio threshold;

measuring, at said first station, a signal quality of the received signal;

adjusting said signal-to-noise ratio threshold as a function of said signal quality and a signal quality threshold;

measuring, at said second station, a fading rate of a further signal transmitted by said first station; and

adjusting said loop gain as a function of said fading rate and a fading rate threshold.

33. The method of claim 32, wherein said signal quality and said signal quality threshold are based on detection of error events.

34. The method of claim 33, wherein said error events are selected from the group comprising error rate, bit error rate, and frame error rate.

35. The method of claim 32, wherein said signal comprises a plurality of frames, and wherein said step of adjusting said signal-to-noise ratio threshold comprises the steps of:

increasing said signal-to-noise ratio threshold when a current frame has an error and a predetermined number of previous frames have no errors with a preselected minimum period between increases; and

decreasing said signal-to-noise ratio threshold otherwise.

36. The method of claim 35, wherein said signal-to-noise ratio threshold is decreased by a preselected small amount over said minimum period.

37. The method of claim 35, wherein

said increasing step comprises the step of increasing said signal-to-noise ratio threshold by a predetermined amount; and

said decreasing step comprises the step of decreasing said signal-to-noise ratio threshold by much less than said predetermined amount.

38. The method of claim 32, wherein said step of adjusting said loop gain comprises the steps of:

setting said loop gain to a first loop gain when said fading rate is below said fading rate threshold; and

setting said loop gain to a second loop gain when said fading rate is above said fading rate threshold.

39. The method of claim 38, wherein said second loop gain is much smaller than said first loop gain.

40. The method of claim 32, wherein said step of measuring a fading rate comprises measuring a further signal-to-noise ratio of said further signal.

41. The method of claim 40, further comprising the step of determining that said fading rate is above said fading rate threshold when multiple excursions of said further signal-to-noise ratio below a further signal-to-noise ratio threshold occur between successive adjustments of said transmitted signal power.

42. The method of claim 32, wherein said step of measuring a fading rate comprises the steps of:

accumulating a plurality of said further signal-to-noise ratio measurements to produce a time series; and

a high-pass filter that filters said time series to produce said fading rate.

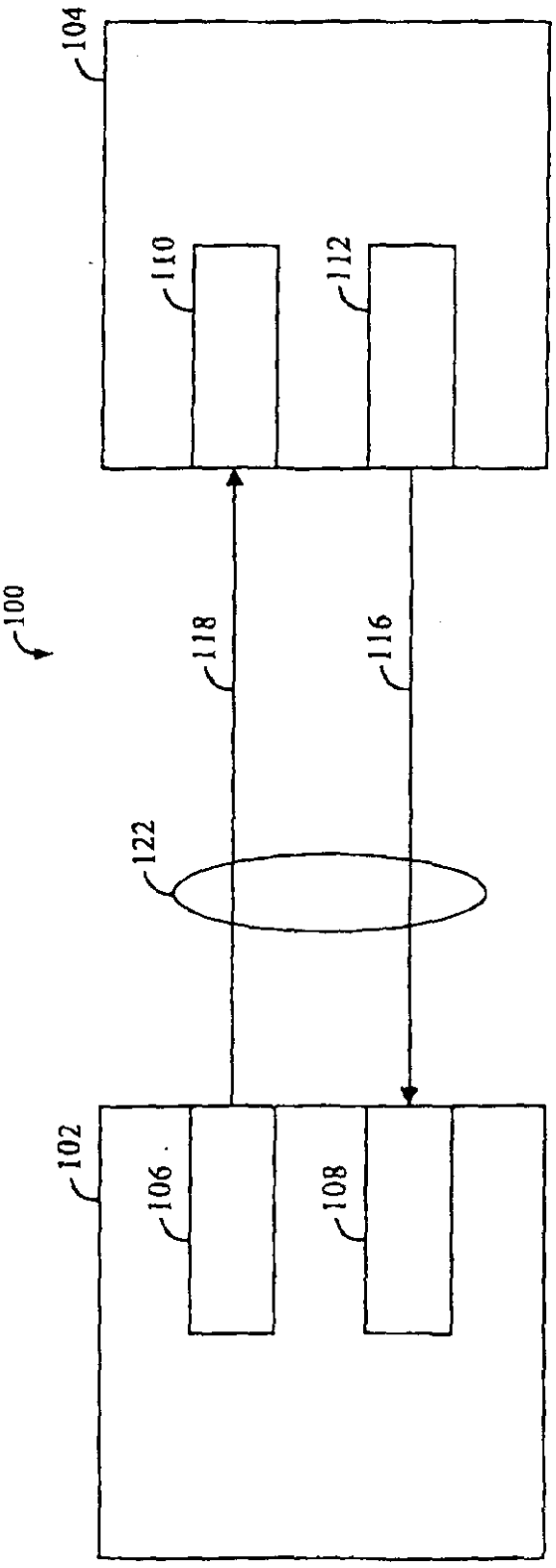


FIG. 1

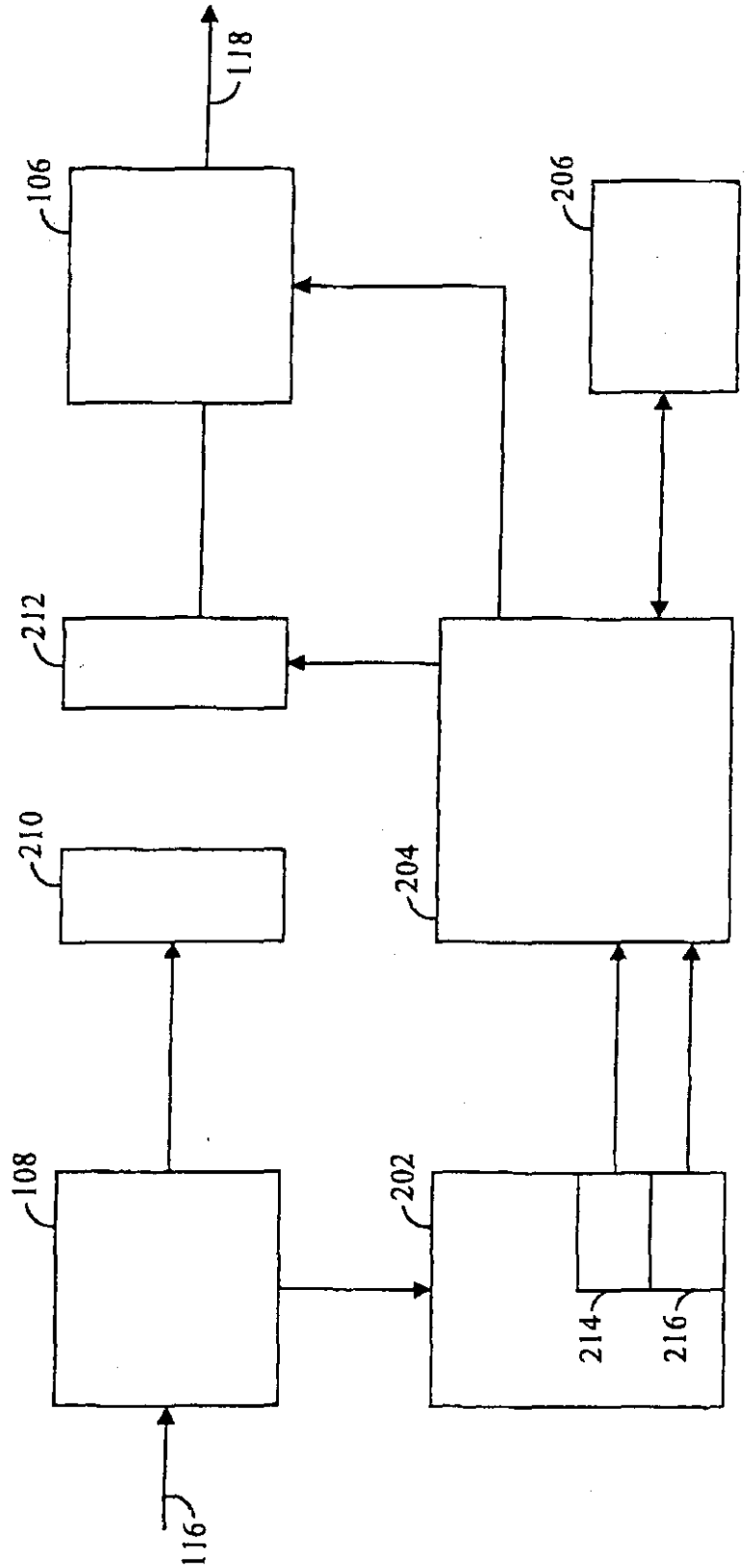


FIG. 2

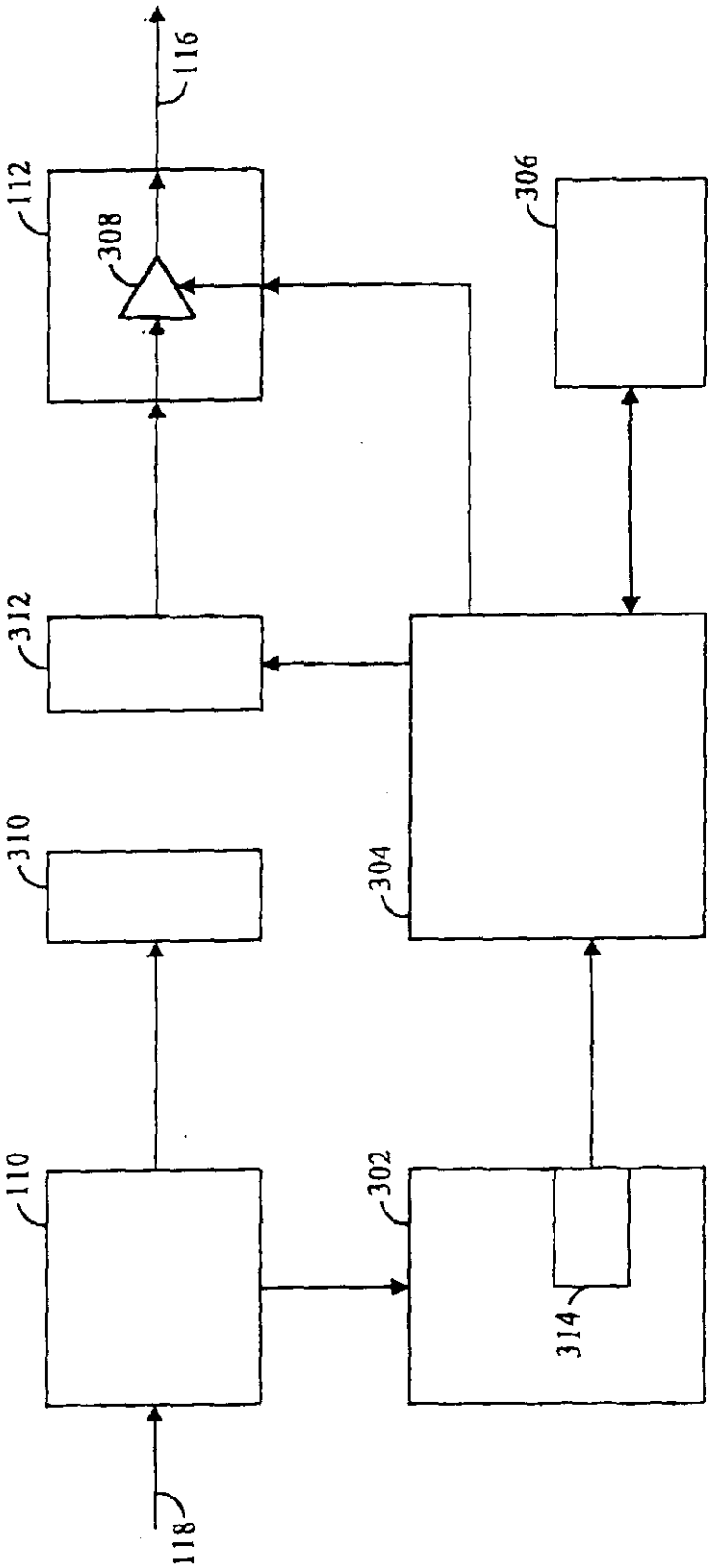


FIG. 3

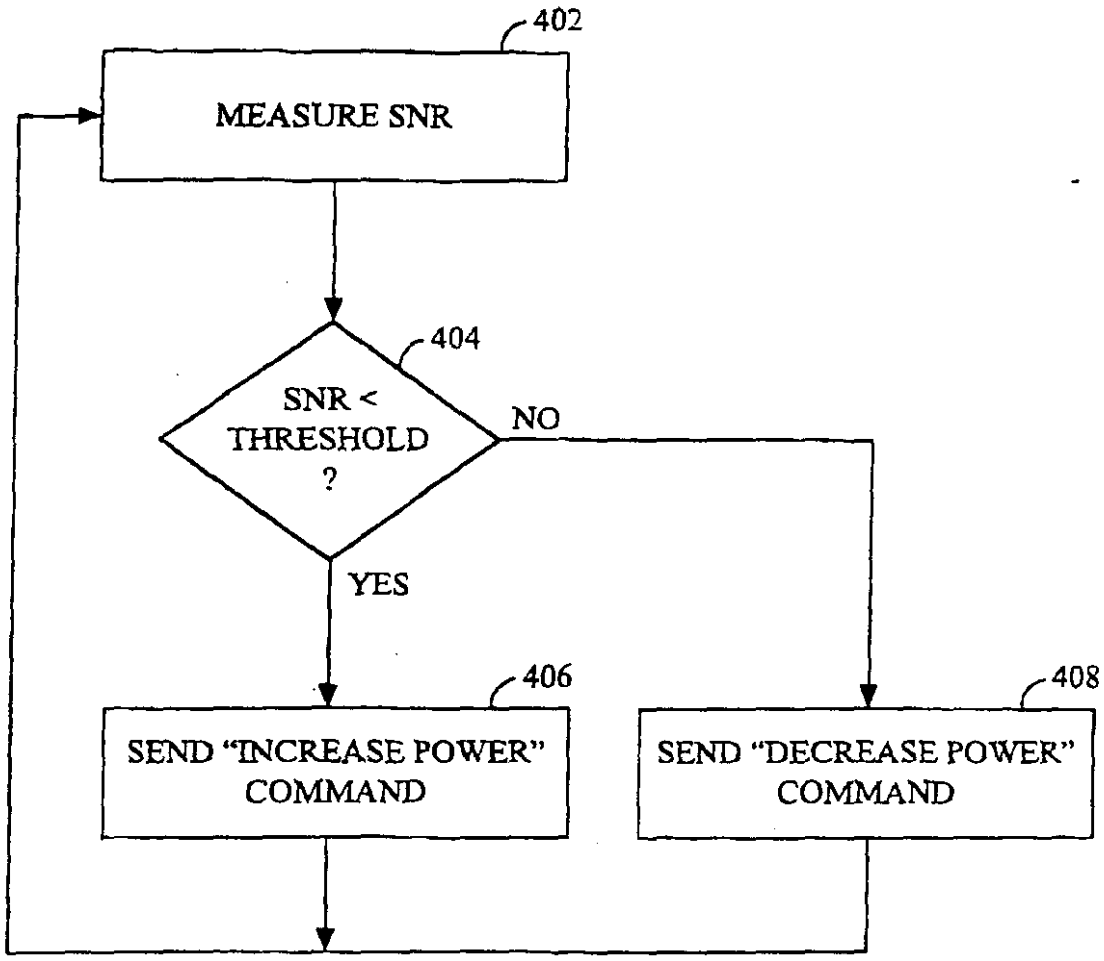

402
MEASURE SNR
404
SNR < THRESHOLD ?
NO
YES
406
SEND "INCREASE POWER" COMMAND
408
SEND "DECREASE POWER" COMMAND

FIG. 4

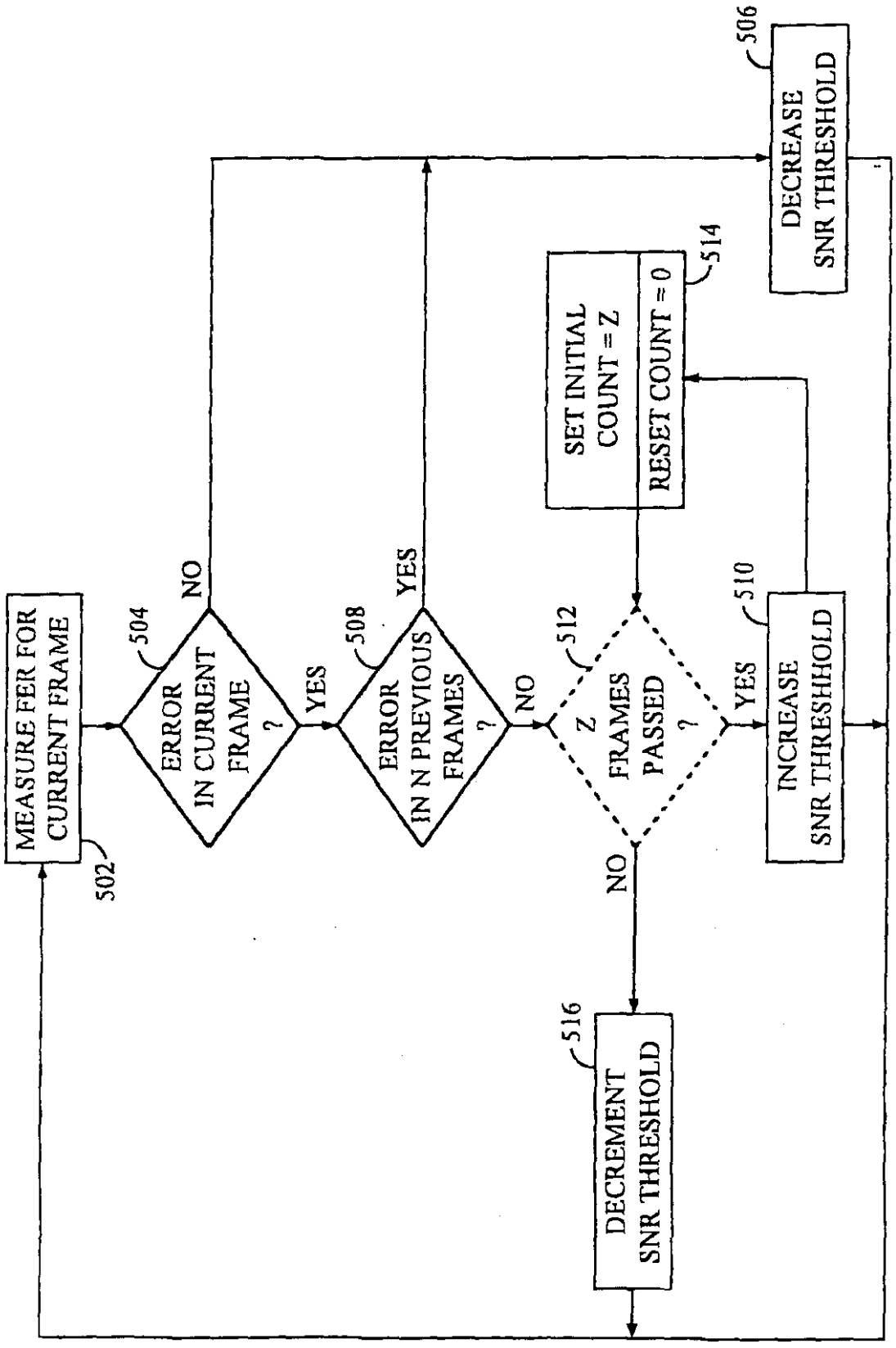

MEASURE FER FOR CURRENT FRAME
502
ERROR IN CURRENT FRAME ?
504
NO
YES
ERROR IN N PREVIOUS FRAMES ?
508
YES
NO
Z FRAMES PASSED ?
512
NO
YES
DECREASE SNR THRESHOLD
506
SET INITIAL COUNT = Z
RESET COUNT = 0
514
INCREASE SNR THRESHHOLD
510
DECREMENT SNR THRESHOLD
516

FIG. 5

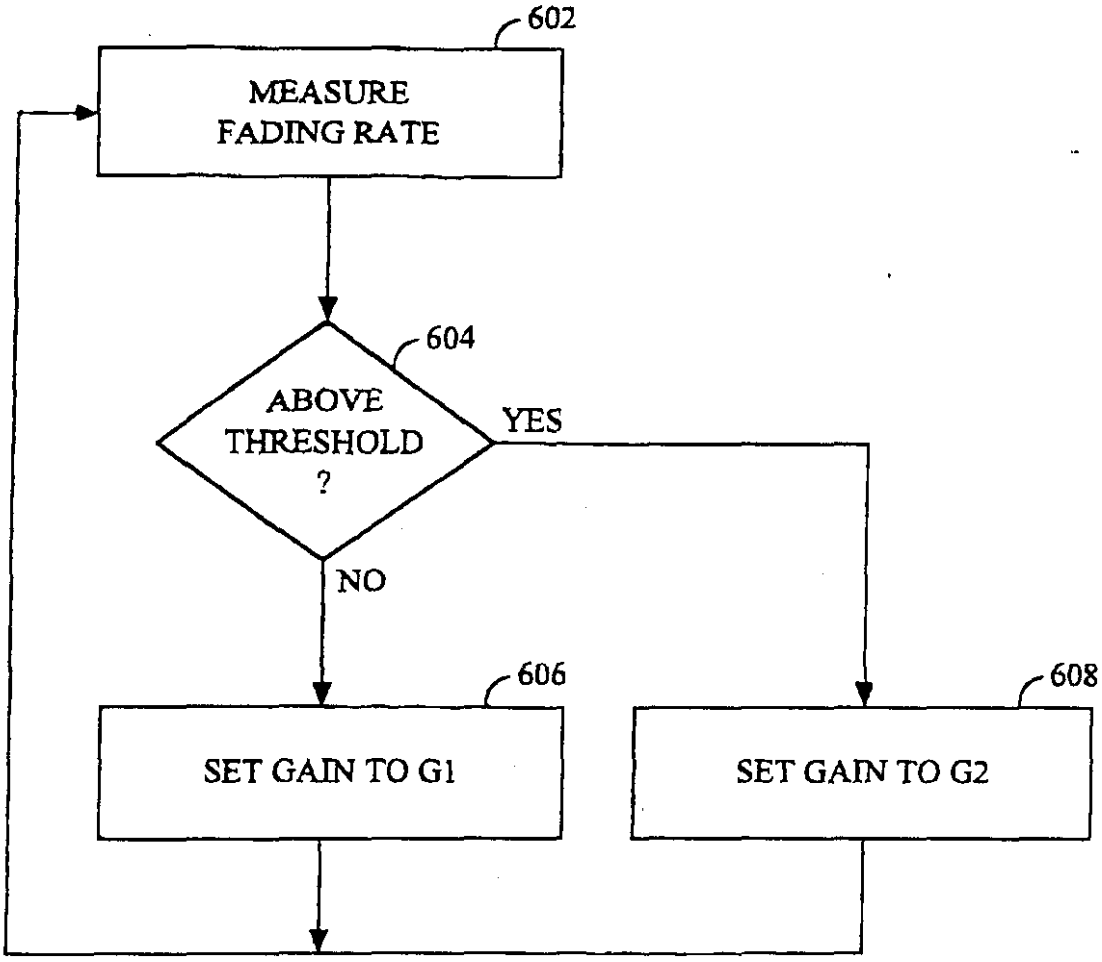

602
MEASURE FADING RATE
604
ABOVE THRESHOLD ?
YES
NO
606
SET GAIN TO G1
608
SET GAIN TO G2

FIG. 6

PATENT COOPERATION TREAT

PCT

INTERNATIONAL SEARCH REPORT

(PCT Article 18 and Rules 43 and 44)

Applicant's or agent's file reference	FOR FURTHER ACTION	see Notification of Transmittal of International Search Report (Form PCT/ISA/220) as well as, where applicable, item 5 below.
QCPA663PCT		
International application No.	International filing date *(day/month/year)*	(Earliest) Priority Date *(day/month/year)*
PCT/US 99/ 25142	26/10/1999	29/10/1998

Applicant

QUALCOMM INCORPORATED

This International Search Report has been prepared by this International Searching Authority and is transmitted to the applicant according to Article 18. A copy is being transmitted to the International Bureau.

This International Search Report consists of a total of 3 sheets.

[X] It is also accompanied by a copy of each prior art document cited in this report.

1. **Basis of the report**

   a. With regard to the **language**, the international search was carried out on the basis of the international application in the language in which it was filed, unless otherwise indicated under this item.

   [ ] *the international search was carried out on the basis of a translation of the international application furnished to this* Authority (Rule 23.1(b)).

   b. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international search *was carried out on the basis of the sequence listing :*

   [ ] contained in the international application in written form.

   [ ] filed together with the international application in computer readable form.

   [ ] furnished subsequently to this Authority in written form.

   [ ] furnished subsequently to this Authority in computer readble form.

   [ ] the statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.

   [ ] the statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished

2. [ ] **Certain claims were found unsearchable** (See Box I).

3. [ ] **Unity of invention is lacking** (see Box II).

4. With regard to the **title**,

   [X] the text is approved as submitted by the applicant.

   [ ] the text has been established by this Authority to read as follows:

5. With regard to the **abstract**,

   [X] *the text is approved as submitted by the applicant.*

   [ ] the text has been established, according to Rule 38.2(b), by this Authority as it appears in Box III. The applicant may, within one month from the date of mailing of this international search report, submit comments to this Authority.

6. The figure of the **drawings** to be published with the abstract is Figure No. 1

   [X] as suggested by the applicant.

   [ ] because the applicant failed to suggest a figure.

   [ ] because this figure better characterizes the invention.

   [ ] None of the figures.

INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 99/25142

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 H04B7/005

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 H04B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	SAMPATH A ET AL: "ON SETTING REVERSE LINK TARGET SIR IN A CDMA SYSTEM" IEEE VEHICULAR TECHNOLOGY CONFERENCE,US,NEW YORK, IEEE, vol. CONF. 47, 1997, pages 929-933, XP000736744 ISBN: 0-7803-3660-7 page 929, left-hand column, line 3 -page 931, left-hand column, line 13 page 931, right-hand column, line 51 -page 932, right-hand column, line 2	1-3,7, 11-13, 16,17, 22-24, 28, 32-34,38

-/--

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
3 March 2000	10/03/2000

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Gkeli, M

Form PCT/ISA/210 (second sheet) (July 1992)

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 5 713 074 A (HULBERT ANTHONY PETER) 27 January 1998 (1998-01-27) abstract column 1, line 12 - line 38 column 2, line 49 -column 4, line 10 claims 1-4	1-3,7, 11-13, 16,17, 22-24, 28, 32-34,38
A	EP 0 853 393 A (NIPPON TELEGRAPH & TELEPHONE) 15 July 1998 (1998-07-15) column 3, line 3 -column 4, line 47 column 5, line 8 -column 8, line 3 claims 1-4 figures 2,3	1,11,22, 32
A	EP 0 715 423 A (AT & T CORP) 5 June 1996 (1996-06-05) abstract column 2, line 17 - line 57 column 3, line 33 -column 4, line 53 column 5, line 43 -column 6, line 55 claims 4,6,8 figures 1,2,4	1,11,22, 32
A	US 5 574 984 A (REED JOHN D ET AL) 12 November 1996 (1996-11-12) abstract column 3, line 16 - line 39 column 3, line 66 -column 4, line 15 column 4, line 43 -column 5, line 4 column 6, line 7 -column 7, line 16 claims 1-7 figure 1	1,11,22, 32

INTERNATIONAL SEARCH REPORT

...ormation on patent family members

International Application No
CT/US 99/25142

Patent document cited in search report		Publication date	Patent family member(s)		Publication date
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			EP	0696857 A	14-02-1996
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			WO	9418756 A	18-08-1994

[19]中华人民共和国国家知识产权局

[51]Int. Cl[7]
H04B 7/005

[12]发明专利申请公开说明书

[21]申请号 99815024.X

[43]公开日 2002年1月16日

[11]公开号 CN 1331868A

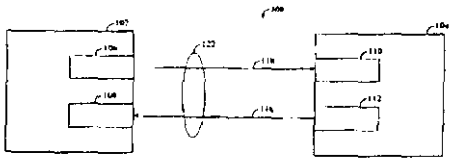
[22]申请日 1999.10.26 [21]申请号 99815024.X
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[32]1998.10.29 [33]US [31]09/183,388
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[87]国际公布 WO00/27045 英 2000.5.11
[85]进入国家阶段日期 2001.6.22
[71]申请人 高通股份有限公司
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[72]发明人 L·N·希夫
[74]专利代理机构 上海专利商标事务所
代理人 李 湘

权利要求书6页 说明书10页 附图页数6页

[54]发明名称 双环功率控制系统中的可变环路增益

[57]摘要

一种在双环功率控制系统中采用可变环路增益来控制网关向用户终端发送的前向链路信号功率从而补偿无线通信系统内衰落的装置和方法,在一个实施例中,本发明包括以下步骤:检测前向链路信号中的快速衰落并且将快速衰落告知网关;以在网关侧当指示快速衰落时降低功率控制环路的环路增益。在另一实施例中,本发明包括在网关侧检测从用户终端接收的反向链路信号中的快速衰落并且当指示快速衰落时降低功率控制环路的环路增益的步骤。



ISSN1008-4274

权　利　要　求　书

1. 一种装置，其特征在于包括：

与第一站点耦合的用于测量第二站点发射信号的信噪比的装置；

用于将所述信号的发射信号功率作为环路增益、所述信噪比和信噪比阈值的函数进行调整的装置；

与所述第一站点耦合的用于测量接收信号的信号质量的装置；

将所述信噪比阈值作为所述信号质量和信号质量阈值的函数进行调整的装置；

与第一站点耦合的用于测量信号的衰落速率的装置；以及

将所述环路增益作为所述衰落速率和衰落速率阈值的函数进行调整的装置。

2. 如权利要求 1 所述的装置，其特征在于所述信号质量和所述信号质量阈值以误码事件的检测为基础。

3. 如权利要求 2 所述的装置，其特征在于所述误码事件从包含误码率、比特误码率和帧误码率的组中选择。

4. 如权利要求 1 所述的装置，其特征在于所述信号包括多幅帧，并且所述调整信噪比阈值的装置包括：

在增加信噪比阈值之间的预选最小间隔内当当前帧存在误码而预设数量的先前帧内无误码时增加信噪比阈值的装置；以及

否则降低所述信噪比阈值的装置。

5. 如权利要求 4 所述的装置，其特征在于在所述最小间隔内将所述信噪比阈值降低一个预选的小数量。

6. 如权利要求 4 所述的装置，其特征在于：

所述增加装置包括将所述信噪比阈值增加一个预设数量的装置；以及

所述降低装置包括将所述信噪比阈值降低一个远远小于所述预设数量的装置。

7. 如权利要求 1 所述的装置，其特征在于所述调整所述环路增益的装置包括：

当所述衰落速率小于所述衰落速率阈值时将所述环路增益设定为第一环路增益的装置；以及

当所述衰落速率大于所述衰落速率阈值时将所述环路增益设定为第二环路增益的装置。

8. 如权利要求 7 所述的装置，其特征在于所述第二环路增益远远小于所述第一环路增益。

9. 如权利要求 1 所述的装置，其特征在于进一步包含当所述发射信号功率连续调整之间多次发生所述信噪比小于所述信噪比阈值时确定所述衰落速率大于所述衰落速率阈值的装置。

10. 如权利要求 1 所述的装置，其特征在于进一步包括：

将多个所述信噪比测量值累积以生成时间序列的装置；以及

对所述时间序列滤波以生成所述衰落速率的高通滤波器。

11. 一种装置，其特征在于包括：

与第一站点耦合的用于测量第二站点发射信号的信噪比的装置；

用于将所述信号的发射信号功率作为环路增益、所述信噪比和信噪比阈值的函数进行调整的装置；

与所述第一站点耦合的用于测量接收信号的信号质量的装置；

将所述信噪比阈值作为所述信号质量和信号质量阈值的函数进行调整的装置；

与第一站点耦合的用于测量所述第一站点进一步发射的信号的衰落速率的装置；以及

将所述环路增益作为所述衰落速率和衰落速率阈值的函数进行调整的装置。

12. 如权利要求 11 所述的装置，其特征在于所述信号质量和所述信号质量阈值以误码事件的检测为基础。

13. 如权利要求 12 所述的装置，其特征在于所述误码事件从包含误码率、比特误码率和帧误码率的组中选择。

14. 如权利要求 11 所述的装置，其特征在于所述信号包括多幅帧，并且所述调整信噪比阈值的装置包括：

在增加信噪比阈值之间的预选最小间隔内当当前帧存在误码而预设数量的先前帧内无误码时增加信噪比阈值的装置；以及

否则降低所述信噪比阈值的装置。

15. 如权利要求 14 所述的装置，其特征在于在所述最小间隔内将所述信噪

比阈值降低一个预选的小数量。

16. 如权利要求 11 所述的装置，其特征在于：

所述增加装置包括将所述信噪比阈值增加一个预设数量的装置；以及

所述降低装置包括将所述信噪比阈值降低一个远远小于所述预设数量的装置。

17. 如权利要求 11 所述的装置，其特征在于所述调整所述环路增益的装置包括：

当所述衰落速率小于所述衰落速率阈值时将所述环路增益设定为第一环路增益的装置；以及

当所述衰落速率大于所述衰落速率阈值时将所述环路增益设定为第二环路增益的装置。

18. 如权利要求 17 所述的装置，其特征在于所述第二环路增益远远小于所述第一环路增益。

19. 如权利要求 11 所述的装置，其特征在于所述测量衰落速率的装置包括测量所述进一步信号的进一步信噪比的装置。

20. 如权利要求 19 所述的装置，其特征在于进一步包含当所述发射信号功率连续调整之间多次发生所述进一步信噪比小于所述进一步信噪比阈值时确定所述衰落速率大于所述衰落速率阈值的装置。

21. 如权利要求 11 所述的装置，其特征在于进一步包括：

将多个所述进一步信噪比测量值累积以生成时间序列的装置；以及

对所述时间序列滤滤以生成所述衰落速率的高通滤波器。

22. 一种方法，其特征在于包括以下步骤：

在所述第一站点测量第二站点发射的信号的信噪比；

将所述信号的发射信号功率作为环路增益、信噪比和信噪比阈值的函数进行调整；

在所述第一站点测量接收信号的质量；

将所述信噪比阈值作为信号质量和信号质量阈值的函数进行调整；

在所述第一站点测量所述信号的衰落速率；以及

将所述环路增益作为所述衰落速率和衰落速率阈值的函数进行调整。

23. 如权利要求 22 所述的方法，其特征在于所述信号质量和所述信号质量阈值以误码事件的检测为基础。

24. 如权利要求 23 所述的方法，其特征在于所述误码事件从包含误码率、比特误码率和帧误码率的组中选择。

25. 如权利要求 22 所述的方法，其特征在于所述信号包括多幅帧，并且所述调整信噪比阈值的步骤包括：

在增加信噪比阈值之间的预选最小间隔内当当前帧存在误码而预设数量的先前帧内无误码时增加所述信噪比阈值；以及

否则降低所述信噪比阈值。

26. 如权利要求 25 所述的方法，其特征在于在所述最小间隔内将所述信噪比阈值降低一个预选的小数量。

27. 如权利要求 25 所述的方法，其特征在于：

所述增加步骤包括将所述信噪比阈值增加一个预设数量；以及

所述降低步骤包括将所述信噪比阈值降低一个远远小于所述预设的数量。

28. 如权利要求 22 所述的方法，其特征在于所述调整所述环路增益的步骤包括：

当所述衰落速率小于所述衰落速率阈值时将所述环路增益设定为第一环路增益；以及

当所述衰落速率大于所述衰落速率阈值时将所述环路增益设定为第二环路增益。

29. 如权利要求 28 所述的方法，其特征在于所述第二环路增益远远小于所述第一环路增益。

30. 如权利要求 22 所述的方法，其特征在于进一步包含当所述发射信号功率连续调整之间多次发生所述信噪比小于所述信噪比阈值时确定所述衰落速率大于所述衰落速率阈值的步骤。

31. 如权利要求 22 所述的方法，其特征在于进一步包括：

将多个所述信噪比测量值累积以生成时间序列；以及

对所述时间序列滤波以生成所述衰落速率的高通滤波器。

32. 一种方法，其特征在于包括以下步骤：

在第一站点测量第二站点发射的信号的信噪比；

将所述信号的发射信号功率作为环路增益、信噪比和信噪比阈值的函数进行调整；

在第一站点测量接收信号的质量；

将所述信噪比阈值作为信号质量和信号质量阈值的函数进行调整；

在所述第二站点测量所述第一站点发射的进一步信号的衰落速率；以及

将环路增益作为所述衰落速率和衰落速率阈值的函数进行调整。

33. 如权利要求 32 所述的方法，其特征在于所述信号质量和所述信号质量阈值以误码事件的检测为基础。

34. 如权利要求 33 所述的方法，其特征在于所述误码事件从包含误码率、比特误码率和帧误码率的组中选择。

35. 如权利要求 32 所述的方法，其特征在于所述信号包括多幅帧，并且所述调整信噪比阈值的步骤包括：

在增加信噪比阈值之间的预选最小间隔内当当前帧存在误码而预设数量的先前帧内无误码时增加信噪比阈值；以及

否则降低所述信噪比阈值。

36. 如权利要求 35 所述的方法，其特征在于在所述最小间隔内将所述信噪比阈值降低一个预选的小数量。

37. 如权利要求 35 所述的方法，其特征在于：

所述增加步骤包括将所述信噪比阈值增加一个预设数量；以及

所述降低步骤包括将所述信噪比阈值降低一个远远小于所述预设数量。

38. 如权利要求 32 所述的方法，其特征在于所述调整所述环路增益的步骤包括：

当所述衰落速率小于所述衰落速率阈值时将所述环路增益设定为第一环路增益；以及

当所述衰落速率大于所述衰落速率阈值时将所述环路增益设定为第二环路增益。

39. 如权利要求 38 所述的方法，其特征在于所述第二环路增益远远小于所述第一环路增益。

40. 如权利要求 32 所述的方法，其特征在于所述测量衰落速率的步骤包括测量所述进一步信号的进一步的信噪比。

41. 如权利要求 41 所述的方法，其特征在于进一步包含当所述发射信号功率连续调整之间多次发生所述信噪比小于所述信噪比阈值时确定所述衰落速率大于所述衰落速率阈值的步骤。

42. 如权利要求 32 所述的方法，其特征在于进一步包括：

将多个所述进一步信噪比测量值累积以生成时间序列；以及

对所述时间序列滤波以生成所述衰落速率的高通滤波器。

说　　明　　书

双环功率控制系统中的可变环路增益

发明领域

本发明涉及无线通信系统。本发明特别涉及一种在无线通信系统中进行功率控制的新型改进的系统和方法。

背景技术

无线通信网络在商业、实业和个人生活的各个方面令人吃惊地得到了普及。便携式、手持通信设备由此在近年来得到广泛的发展。诸如蜂窝电话之类的便携式设备现在对于商务和个人用户来说已是平常之物。此外，诸如卫星通信系统之类利用手持和移动电话的先进系统当前也被采用。

在无线通信系统中，信号会发生衰落。当环境因素造成发射机至接收机发射的信号功率减小时就会发生衰落。衡量衰落程度的一种量度就是接收机侧测量的接收信号信噪比(SNR)。已经研制出通过调整信号发射功率来补偿衰落的系统。一种这样的系统被称为“单环”功率控制。

在单环功率控制系统中，接收机监视接收信号的SNR并且向发射机发送命令来调整发射功率，从而维持接收机侧特定的“阈值”SNR。普通单环功率控制系统一般采用两或三种这样类型的命令。一种类型的命令指示发射机提高发射功率。另一种命令指示发射机降低发射功率。发射功率响应这样的命令而增加或降低的数量被称为环路的“增益”。在某些系统中，采用第三种命令类型指示发射机将发射功率维持在当前水平上。

单环功率控制在衰落较慢的环境中工作得较好。在慢速衰落中，在功率控制命令到达发射机并且在接收机侧测量最终的信噪比所需的时间(称为环路的“周期”)内，衰落变化不大。慢速衰落环境的一个例子是信号干扰只是热噪声的情形。

但是，在中速衰落的信号环境下，单环功率控制是不合适的。在中速衰落中，在单个环路周期内衰落发生重大变化。中速衰落环境的一个例子是发射机或接收机快速经过静止障碍物从而导致信号迅速衰减的情形。在这种中速衰落环境中，阈值SNR不足以保证信号质量。这是因为环路太慢，难以响应接收信

号 SNR 中的快速变化。

在数字通信系统中，阈值 SNR 的适当性可以用接收的错误信息比特与接收比特总数之比来度量。该比率通常针对每帧重复计算。这样计算得到的比率称为信号的“帧误码率”(FER)。为解决这种问题而研制的一种系统称为“双环”功率控制系统。

在双环功率控制系统中，上述单环功率控制系统被用作“内部”环路。内部环路所用的 SNR 阈值由“外部环路”根据接收信号的 FER 修正。例如，当 FER 上升超出预设的 FER 阈值时，阈值 SNR 以固定的预设量增加。该过程持续至 FER 跌落至 FER 阈值之下。

在双环功率控制系统中要考虑的一个问题是内部环路采用的固定增益大小的选择。这种增益的选择是在两种有冲突的出发点之间作折衷。在中速衰落环境中，需要快速环路响应。这样的出发点要求较大的内部环路增益。在较大的内部环路增益下，需要在较少的环路周期内大幅度改变阈值 SNR。但是在慢速衰落信号环境中，大增益将导致 SNR 在阈值 SNR 附近作大的振荡。这些振荡浪费了发射机功率。因此固定的内部环路增益对于快速衰落和慢速衰落都要经受的应用是不合适的。

而且，固定增益系统在快速衰落信号环境中遇到了困难。在快速衰落中，SNR 在单个外部环路周期内(即，根据一次或数次 FER 测量调整 SNR 阈值所需的时间)经历了几次较大的振荡。快速衰落振荡一般是几百赫兹量级。在这样的环境下，由于内部环路不可能跟随衰落，所以响应时间不再重要。所需要的是一种双环功率控制系统，其内部增益可以根据衰落速度而变化。

发明内容

本发明是调整发射机向接收机发送的信号的功率以补偿无线通信系统中衰落的装置和方法。在一个实施例中，方法包括以下步骤：在第一站点测量第二站点发射的信号的信噪比；将信号的发射信号功率作为环路增益、信噪比和信噪比阈值的函数进行调整；在第一站点测量接收信号的质量；将信噪比阈值作为信号质量和信号质量阈值的函数进行调整；在第一站点测量信号的衰落速率；以及将环路增益作为衰落速率和衰落速率阈值的函数进行调整。

在一个实施例中，方法包括以下步骤：在第一站点测量第二站点发射的信号的信噪比；将信号的发射信号功率作为环路增益、信噪比和信噪比阈值的函

数进行调整；在第一站点测量接收信号的质量；将信噪比阈值作为信号质量和信号质量阈值的函数进行调整；在第二站点测量第一站点进一步发射的信号的衰落速率；以及将环路增益作为衰落速率和衰落速率阈值的函数进行调整。

本发明的优点是减弱了快速衰落的影响。

附图简述

通过以下结合附图对本发明的描述可以进一步理解本发明的特征、目标和优点，附图中相同的标号表示对应的单元，其中：

图 1 为示意性通信系统的框图；

图 2 和 3 为图 1 收发机更为详细的框图；

图 4 为按照本发明较佳实施例的内部功率控制环路操作的流程图；

图 5 为按照本发明较佳实施例的外部功率控制环路操作的流程图；以及

图 6 为按照本发明较佳实施例的可变增益内部双环功率控制环路操作的流程图。

实施发明的较佳方式

本发明是一种无线通信系统中双环功率控制的装置和方法。在较佳实施例中，本发明运行在码分多址(CDMA)通信系统内。在题为“选择功率控制模式的系统和方法”和“优化功率控制模式的系统和方法”的美国专利申请 Nos. 09/164,383 和 09/164,384 中揭示了在这种系统内运行的功率控制环路，上述申请已经转让给了本发明的受让人，并且作为参考文献包含在本文中。这种通信系统内功率控制技术的其他例子可以参见 1995 年 1 月 17 日授权的题为“码分多址系统内的快速正向链路功率控制”的美国专利 No. 5,383,219、1995 年 3 月 7 日授权的题为“动态修正发射机功率控制系统中控制参数的方法和系统”的美国专利 No. 5,396,516 和 1993 年 11 月 30 日授权的题为“发射机功率控制系统”的美国专利 No. 5,267,262，它们作为参考文献被包含在本文中。

I. 环境实例

在详细描述本发明之前，先描述本发明可以实施的环境实例是有益的。本发明可以在任何无线通信系统中实施，特别是需要控制发射机提供的功率大小的环境。这种环境包括但不局限于蜂窝通信系统、个人通信系统、卫星通信系

统等等。

图 1 为示意性通信系统 100 的示意图。参见图 1，系统 100 包含两个收发机 102 和 104。收发机 102 包含发射机 106 和接收机 108。收发机 104 包含发射机 112 和接收机 110。

数据或其他信息经传输信道 122 在收发机之间发送。在卫星、蜂窝和其他无线通信系统中，信道 122 为无线链路。在卫星通信系统中，信道 122 包含一颗或多颗中继卫星。信道 122 为包含“前向”信号 116 和“反向”信号 118 的双向信道。

在有些环境下，信道 122 是分组化的数据路径，其中数据以数据分组形式发送。当信息以数字数据形式存在时这种情况经常出现。在其他环境下，模拟数据在载波上调制并且经信道 122 发送。

在蜂窝通信系统的例子中，收发机 102 为手持或移动电话而收发机 104 为位于在电话当前区域内提供服务的本地小区站点上的基站。在卫星通信系统的实例中，收发机 102 为手持移动或固定收发机(例如卫星电话)而收发机 104 位于陆基网关内。在卫星通信系统例子中，卫星用于经信道 122 在收发机 102 与 104 之间中继信号。

本发明以该环境为例进行描述。用这些实例作描述仅仅是为了方便。本发明并不限定于该环境实例。实际上，对于相关领域内的技术人员来说，在阅读了下列描述之后，在其他环境下实现本发明将是显而易见的。

II. 功率控制

本发明是一种调整发送信号功率以补偿无线通信系统内快速衰落的系统和方法。在快速衰落中，单个外部环路周期内发生了几次信号衰落。因此外部环路对于快速衰落的减轻是无效的。这种快速衰落通常叠加在较慢的衰落趋势上。发明人发现，解决快速衰落情况的一个好办法是忽略衰落的快速(高频)分量而代之以跟踪衰落中较慢的(低频)分量。按照本发明，当检测到快速衰落时，系统试图跟踪其基本的较慢的衰落而不是试图跟踪快速衰落。在本发明较佳实施例中，这通过利用小的内部环路增益实现。

图 2 为示出收发机 102 细节的框图。收发机 102 包括发射机 106、接收机 108、测量单元 202、处理器 204、存储器 206、数据收信方 210 和数据源 212。在操作中，接收机 108 接收信号 116 并将其传送至数据收信方 210。数据收信

方 210 可以是任何利用数据的单元，例如编码译码器、调制解调器、数字信号处理器等。接收机 108 可以完成某些任务，例如本领域内公知的在信号 116 上的解调。

如下所述，测量单元 202 对信号 116 的特性作某些测量。例如，这些测量包括 SNR、以是否出现一次或多次误码事件(例如 FER)为基础的信号质量以及衰落速率(FR)的测量。在较佳实施例中，测量单元 202 包括 SNR 测量电路 214 和帧误码测量电路 216。SNR 测量电路 214 获取接收信号 116 的 SNR 的测量值。帧误码测量电路 216 获取接收信号 116 的误码率或一次或多次误码事件的测量值。实现这些功能的电路是相关领域内众所周知的。这些测量值被送至处理器 204，处理器可以是本领域内已知的或今后开发的处理器。处理器 204 采用存储器 206 来存储诸如 SNR、FER 和 FR 测量值之类数据以及诸如与这些测量值比较用的阈值之类的其他数值。

数据源 212 生成传输数据。数据源 212 可以包括本领域内众所周知的单元，例如编码译码器、调制解调器、数字信号处理器等。发射机 106 从数据源 212 接收数据并且完成诸如调制之类的任务。处理器 204 可以利用硬件、软件或者它们的组合实施并且可以计算机系统或其他处理系统形式实施。在一个实施例中，处理器 204 以一个或多个计算机系统的形式实施。在另一实施例中，处理器 204 主要以利用诸如应用专用集成电路(ASIC)之类的硬件单元的硬件形式实施。对于本领域内的技术人员来说，完成所述功能的硬件状态机的实现方式是显而易见的。在另一实施例中，处理器 204 利用硬件与软件的组合实现。

图 3 为示出收发机 104 细节的框图。收发机 104 包括发射机 112、接收机 110、测量单元 302、处理器 304、存储器 306、数据收信方 310 和数据源 312。在操作中，接收机 110 接收信号 118 并将其传送至数据收信方 310。数据收信方 310 可以是任何利用数据的单元，例如编码译码器、调制解调器、数字信号处理器等。接收机 110 可以完成某些任务，例如本领域内公知的在信号 118 上的解调。

如下所述，测量单元 302 对信号 118 的特性作某些测量。例如，这些测量包括衰落速率(FR)的测量。在较佳实施例中，测量单元 302 包括 SNR 测量电路 314。SNR 测量电路 314 获取接收信号 118 的 SNR 的测量值。实现这些功能的电路是相关领域内众所周知的。这些测量值被送至发射机 112 和/或数据源 312 以作为信号 116 的一部分发送。这些测量值被送至处理器 304，处理器可以是

本领域内已知的或今后开发的处理器。处理器 304 采用存储器 306 来存储诸如测量值之类的数据以及诸如与这些测量值比较用的阈值之类的其他数值。

数据源 312 生成传输数据。数据源 312 可以包括本领域内众所周知的单元，例如编码译码器、调制解调器、数字信号处理器等。发射机 112 从数据源 312 接收数据并且在发送信号 116 之前完成诸如调制之类的任务。发射机 112 还包括可变增益放大器 308，用来在发送产生的信号 116 之前放大信号功率。放大器 308 的增益由处理器 304 控制。

图 4－6 为描述按照本发明的较佳实施例的操作流程图。图 4 示出了本发明的内部功率控制环路的操作。内部功率控制环路的功能是调整发射机 112 发射信号的功率。在较佳实施例中，如下所述，发射信号功率按照接收机 108 侧接收的信号功率水平调整。

发射机 112 在信道 122 上发射信号 116。信号 116 由接收机 108 接收。如步骤 402 所示，该过程开始于测量单元 202 测量信号 116 的功率。在较佳实施例中，测量单元 202 测量信号 116 的信噪比(SNR)。具体而言，本发明测量数值 Eb/No，这里 Eb 为能量/比特而 No 为以功率/周(power/cycle)为单位的噪声密度。当然，在不偏离本发明范围的前提下可以采用其他的信号功率量度。在较佳实施例中，对于接收数据的每一帧都测量 SNR。

在通信系统 100 中，称为“SNR 阈值”的预设 SNR 水平与接收机 108 有关。SNR 阈值代表接收机在确保数据质量的前提下接收信号时所处的最小的 SNR。SNR 阈值可以按照相关领域内众所周知的方法选择。一种这样的方法是选择 SNR 使数据错误保持在某一百分比下，例如 1%。在步骤 404 中，接收机 108 将步骤 402 内测量的 SNR 与 SNR 阈值进行比较。

如果测量的 SNR 低于 SNR 阈值，则如步骤 406 所示，收发机 102 的发射机 106 向收发机 104 发送“增加功率”的命令。在一个较佳实施例中，该命令作为信号 118 的一部分在信道 122 上发送。作为响应，发射机 112 将信号的信号功率提高一个预设的数量(称为内部环路的“增益”或者“内部环路增益”)。在较佳实施例中，内部环路增益的数值、放大器 308 作用的信号增益值被存储在存储器 306 内。信号增益的数值由处理器 304 操作。

如果测得的 SNR 大于 SNR 阈值，则如步骤 408 所示，收发机 102 的发射机 106 向收发机 104 发送“降低功率”的命令。作为响应，发射机 112 将信号的信号功率降低一个内部环路增益的大小。在任一情况下，过程都从步骤 402 重

新开始。

图 5 示出了本发明的外部功率控制环路(又称为“外部环路”)的操作。外部功率控制环路的功能是调整接收机 108 的 SNR 阈值。在较佳实施例中，SNR 阈值按照接收信号的质量调整。在较佳实施例中，不仅考虑当前帧的信号质量，而且考虑一定数量先前帧的信号质量。而且在较佳实施例中，所用的信号质量量度为例如利用帧误码率(FER)的一次或多次误码事件的出现。但是在不偏离本发明范围的前提下可以采用诸如一致校验之类的其他的信号质量量度。此外，可以采用诸如平均和加权平均之类的其他评价信号质量历史的方法。

经常遇到的误码类型为“突发(burst)”型。突发误码的特征是持续期短。通常情况下，突发误码的持续期小于内部环路周期。因此内部环路无法补偿这些误码。因此需要将内部环路隔离以免除突发误码的影响。突发误码的特征还在于误码发生于多幅连续帧内。外部环路利用该特征检测突发误码。当外部环路检测到多幅连续帧内的误码时，即判定已发生突发误码。当检测到突发误码时，外部环路不改变内部环路的 SNR 阈值。外部环路仅仅响应非突发型误码而改变内部环路的 SNR 阈值，从而将内部环路与突发误码隔离开来。

参见图 5，如步骤 502 所示，过程开始于测量指示误码发生的量，例如 FER。如步骤 504 所示，过程利用这些测量值判断当前帧内是否存在误码。如果如步骤 504 内的“N”分支所示，当前帧内不存在误码时，则如步骤 506 所示，收发机 102 将 SNR 阈值降低一个预设数量。但是，如果如步骤 504 内的“Y”分支所示，当前帧内存在误码时，则如步骤 508 所示，查看接收信号的质量历史。在较佳实施例中，误码历史包含预设数量为 N 的先前帧。当然，在不偏离本发明范围的前提下以其他方式选择误码历史。误码历史存储在存储器 206 内。如果先前 N 帧的任何帧包含误码，则如步骤 506 所示，经过如下所述的一个所需的帧或时间延迟后，收发机 102 降低 SNR 阈值一个外部环路增益。

但是如果先前的 N 帧不包含误码，则如步骤 506 所示，收发机 102 增加 SNR 阈值。在较佳实施例中，采用两个变化的数值：一个用于降低 SNR 阈值，而另一个用于增加 SNR 阈值。用于降低 SNR 阈值的变化数值较小，因而 SNR 阈值也较小，并且通过内部环路的动作，发射信号功率在无误码环境内逐渐降低。相反，用于增加 SNR 阈值的变化数值较大，因而 SNR 阈值也较大，并且通过内部环路的动作，发射信号功率在易于发生误码的环境内快速增加。

此外，业已发现至少是在某些系统内，不管是否存在误码，一般在已经增加 SNR 阈值之后无需在一定数量帧再迅速改变 SNR 阀值。因此，在一个实施例中，当如上所述在一定数量无误码帧之后遇到帧误码时初次增加了 SNR，但是在这种调整之后的对于预选数量为 Z 的帧， SNR 不允许再作增加。即，是否检测到帧误码并不提供一种进一步增加阈值的选择机制直到阈值增加后经过了 Z 帧或 Z 个帧周期。位于质量历史检验步骤 508 与阈值调整步骤 510 之间的可选步骤 512 示出了这种情况。在步骤 512 内，检验自上次增加 SNR 阈值之后是否处理过 Z 幅数据帧。如设置/复位步骤 514 所示，该处理步骤的帧计数初始设置为 Z，因此第一次请求调整时即进行这样的设置。随后根据帧计数确定后续的调整。

如步骤 516 所示，当无论何时未处理完或经过 Z 帧时，对于 Z 帧的每一帧，SNR 阈值可以降低相对小的量或者以较慢的速率降低。即，在每个帧周期内或结束时，SNR 阈值水平递减或者减少一个较小的百分比或数量，譬如说 0.004 dB 量级。本领域内的技术人员将很容易地认识到，根据需要，其他的数量包括 0 dB 也是可以采用的。处理随后返回步骤 512，继续进行测量等。一旦到达所需数量的预选帧 Z，在步骤 510 中 SNR 阈值再次增加(或者在步骤 506 中降低)来代替步骤 516 中的递减。一旦 SNR 阈值增加，步骤 512 中所用的帧计数被重置为 0 并且计数过程开始更新直到再次经过 Z 帧。

这种逐渐减小的过程或周期使得系统在采取进一步动作之前“固定(settle)”下来并且确保对信号条件作出更为可预测和可重现的响应。此外，由于某些系统(卫星)或情况下遇到的一些误码的突发性质和实施功率增加命令中的最小延迟量，使得对功率的短期请求不会有所帮助或不会没有所需的效果。但是等待几帧的时间的确有助于降低功耗。

在经过预选数量的 Z 帧之后，SNR 阈值的调整象前面发生的一样。假定前面的 N 帧不包含误码，则误码的再次检测导致 SNR 阈值的增加。在较佳实施例中，Z 被选定为在帧生成或触发 SNR 阈值增加之后的 6 帧，在此期间 SNR 阈值没有增加并且实现了逐渐减小。但是本领域内的技术人员将会理解，可以根据采用本发明的通信系统的已知的响应特征选择其他数值。

图 6 为按照本发明较佳实施例的可变增益内部双环功率控制环路操作的流程图。在步骤 602 中，接收机 108 测量从收发机 104A 接收的信号的衰落速率。按照较佳实施例，接收机 108 在每帧进程上几次测量接收信号的 SNR 以生

成一系列的测量值。该系列施加在高通滤波器上以检测在 SNR 方面的快速变化从而指示快速衰落存在与否。如步骤 604 所示，高通滤波器的输出称为“衰落速率”，它与预设衰落速率阈值比较。

当如步骤 604 的“N”分支所示，衰落速率未超过阈值时，衰落的速度不足以符合快速衰落的特征。在这种情况下，如步骤 606 所示，内部环路增益被设定为第一预设增益水平 G1。

当如步骤 604 的“Y”分支所示，衰落的高频分量超过阈值时，衰落的快速足以符合快速衰落的特征。在这种情况下，如步骤 608 所示，内部环路增益被设定为第二预设增益水平 G2。在任一情况下，处理都在步骤 602 处重新开始。

在较佳实施例中，第一增益水平 G1 远远大于第二增益水平 G2。换句话说，在快速衰落期间施加的内部环路增益远远小于其它情况下施加的内部环路增益。其结果是在快速衰落期间，功率控制环路并不试图跟踪快速衰落引起的信号功率电平涨落而是跟踪慢速衰落引起的较慢的功率电平涨落。在一个实施例中，G1 大约为 0.5 dB，而 G2 大约为 0.1 dB。

在一个实施例中，用户终端检测网关向用户终端发送信号的快速衰落。在该实施例中，用户终端向网关报告快速衰落条件，网关通过调整功率控制环路的内部环路增益作出响应。参见图 1，在步骤 604 中，收发机 102 检测信号 116 中的快速衰落。如上所述，收发机 102 通过评估 SNR 中的涨落检测信号 116 中的快速衰落。快速衰落通过评估 SNR 检测。发射机 106 随后向接收机 110 发送命令以调整内部环路增益。根据该命令，收发机 104 在步骤 606 和 608 中调整内部环路增益。

在另一实施例中，网关通过检测用户终端向网关发送信号的快速衰落推断网关向用户终端发送的信号中是否存在快速衰落。参见图 1，如上所述，在步骤 602 和 604 中，收发机 104 通过评估信号 118 中的 SNR 涨落推断信号 116 的衰落速率。收发机 104 随后在步骤 606 和 608 内根据该评估结果调整内部环路增益。

III. 结论

上述较佳实施例的描述使得本领域内技术人员可以制作或利用本发明。在不偏离本发明实质的前提下可以对这些实施例作出各种修改。因此本发明并不

局限于这些实施例，其精神和范围由所附权利要求限定。

说　明　书　附　图

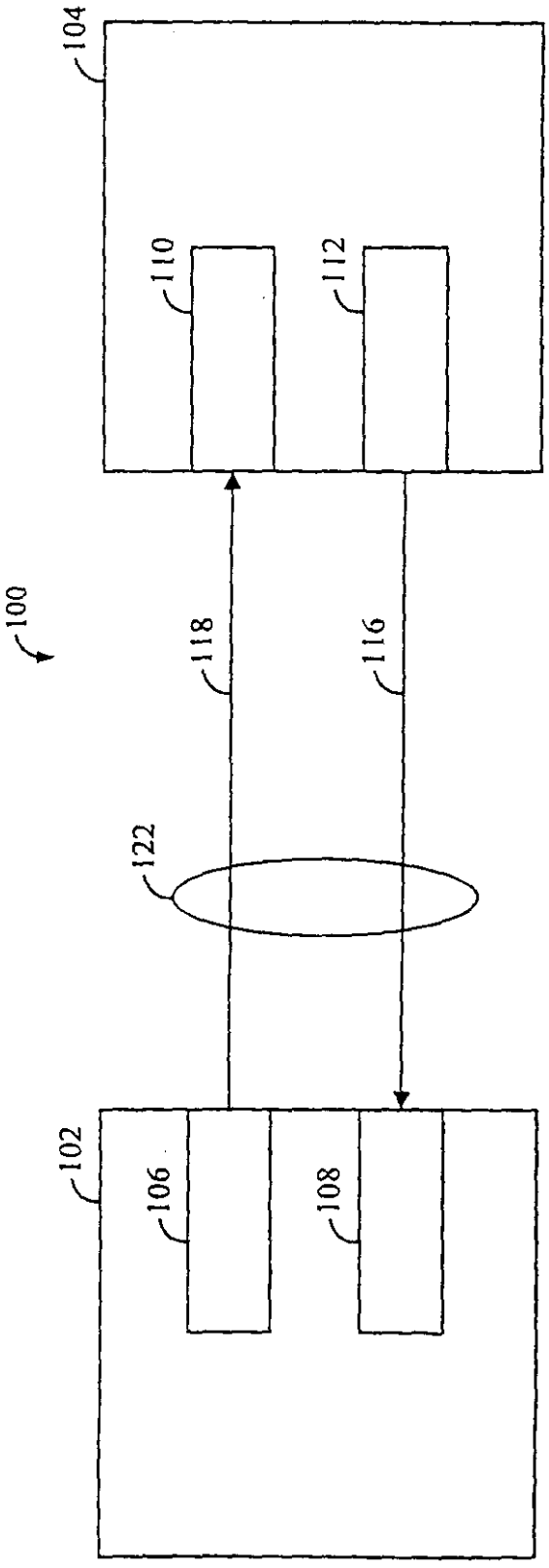


图　1

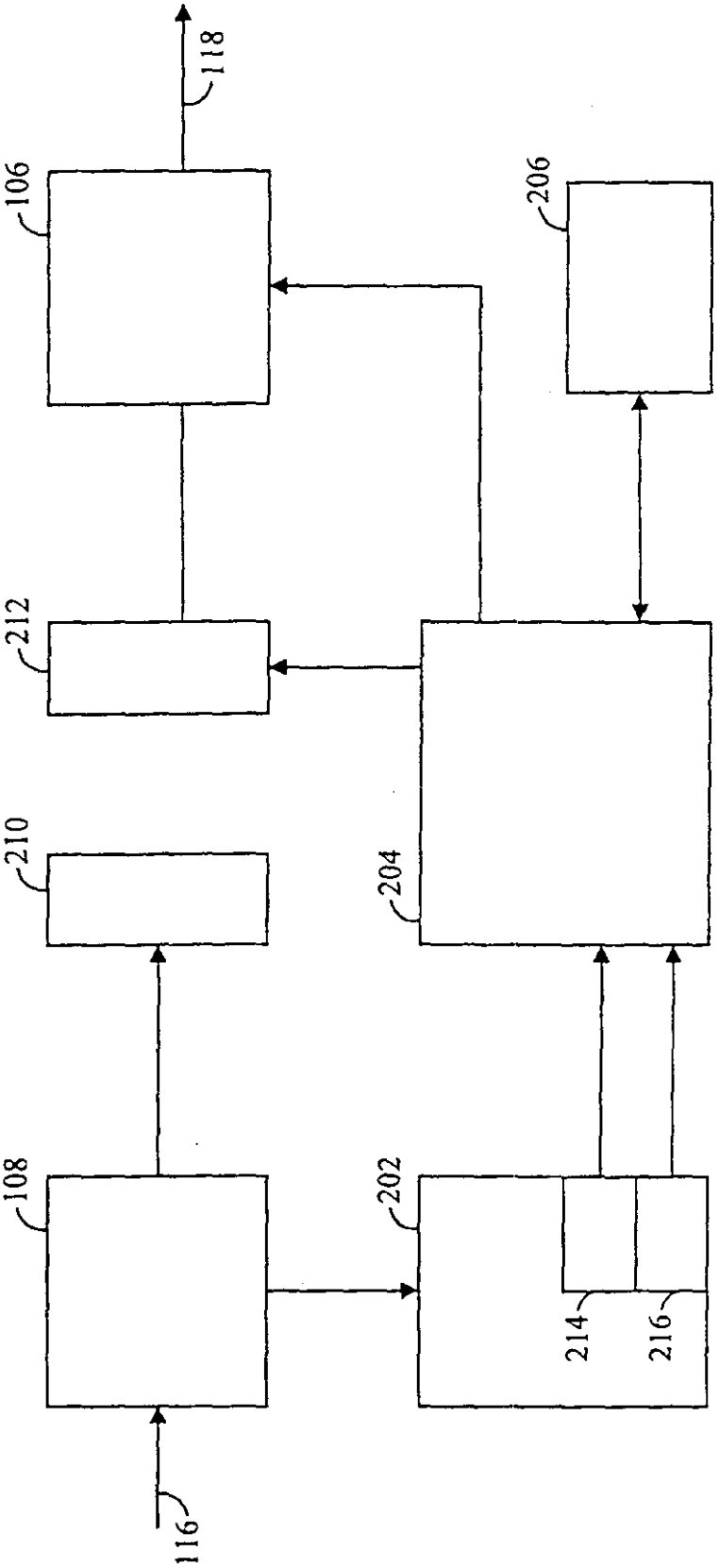


图 2

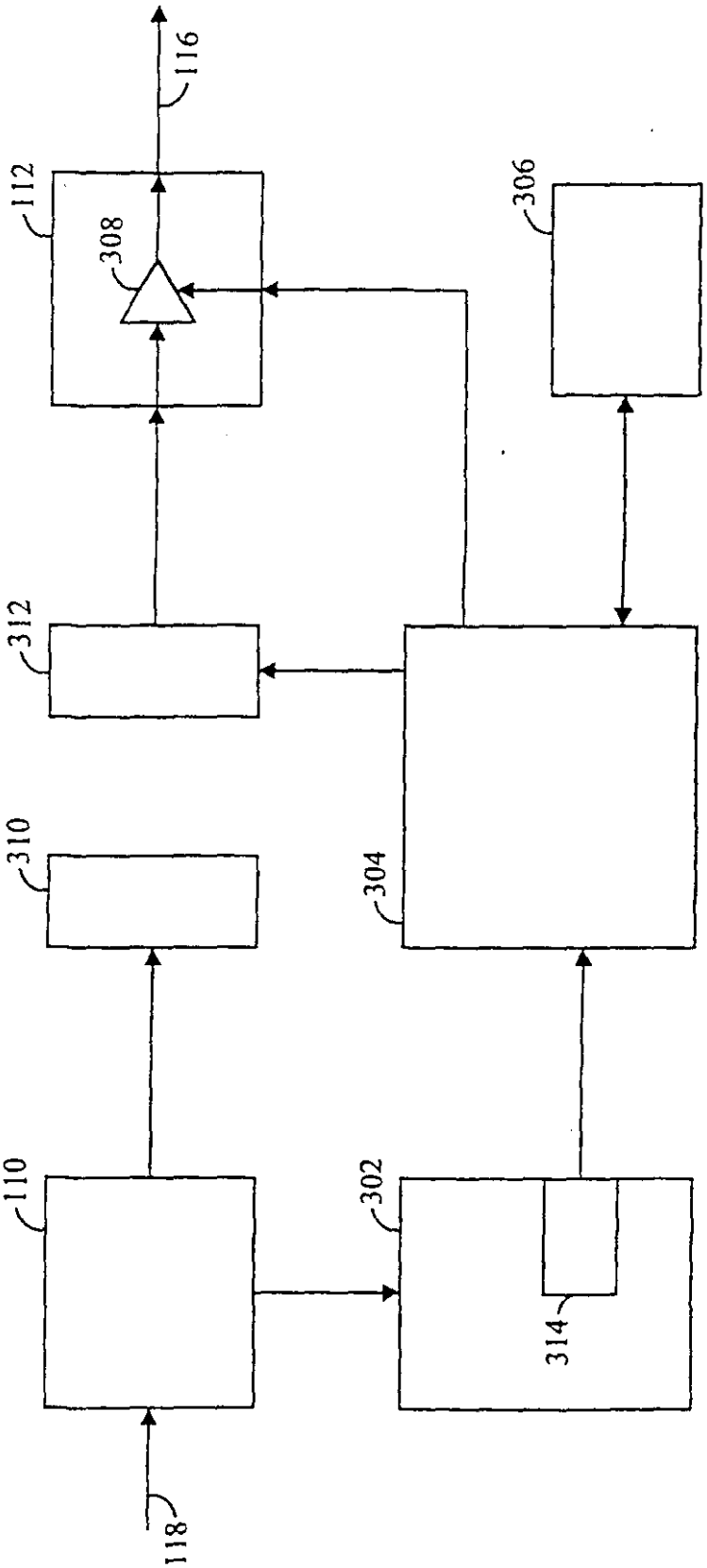


图 3

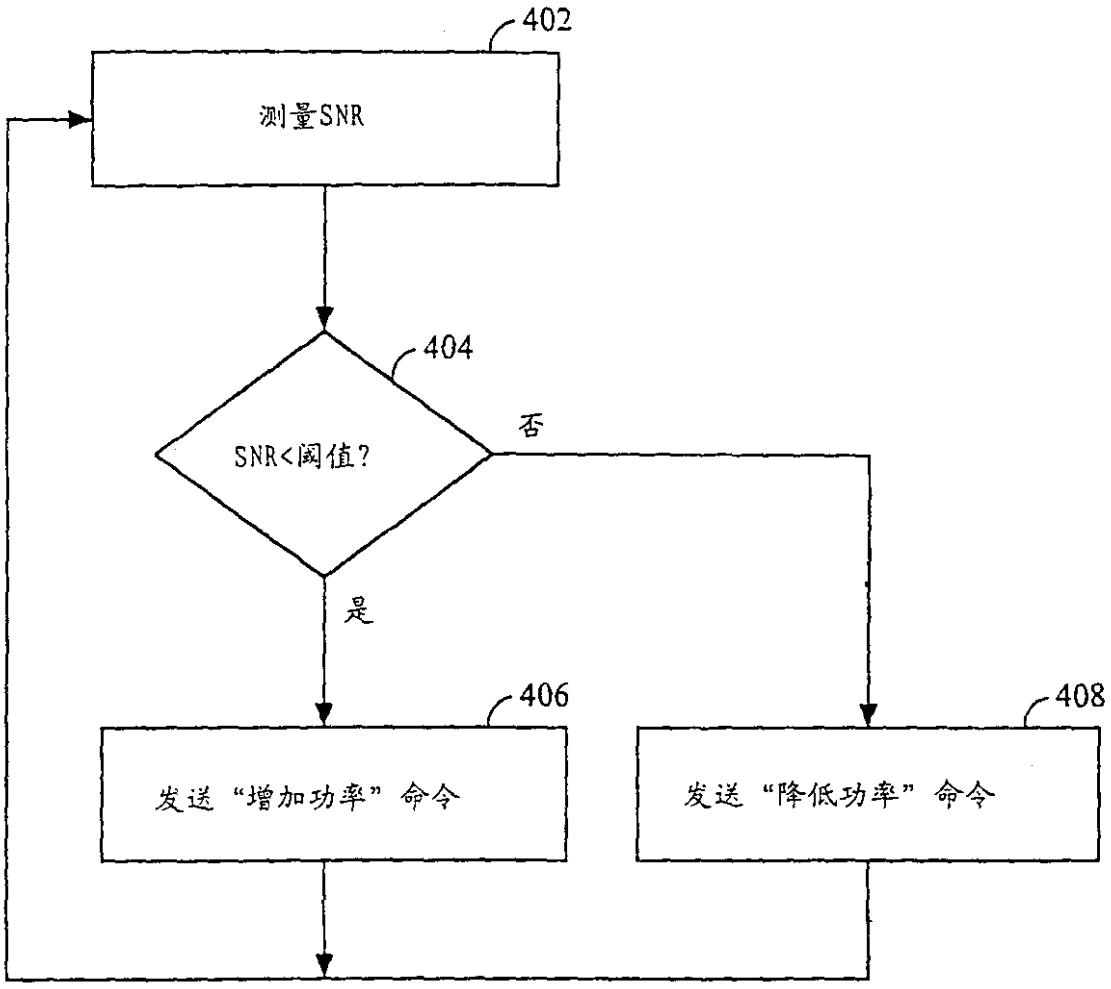


图 4

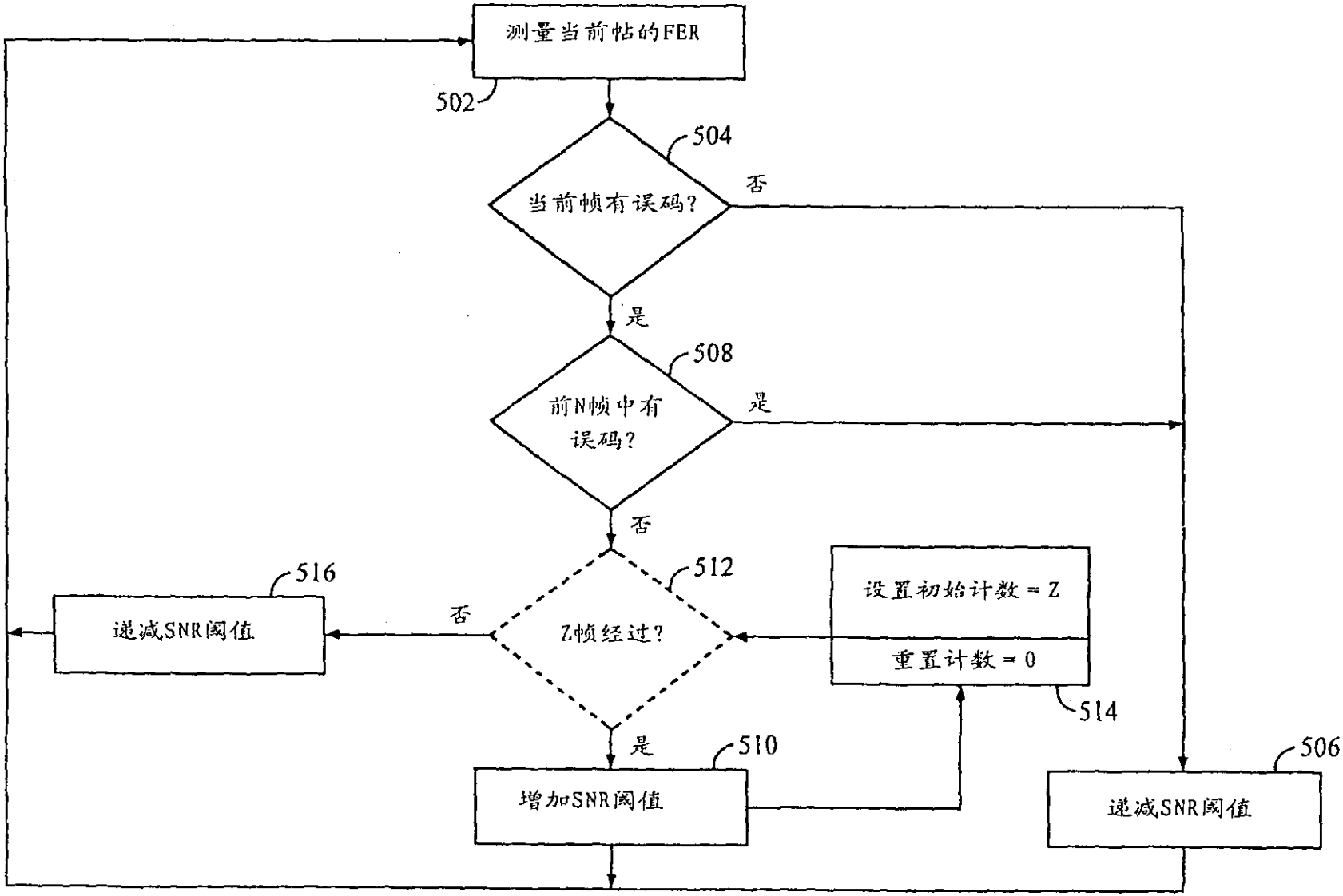

测量当前帧的FER
502
504
当前帧有误码?
否
是
508
前N帧中有误码?
是
否
512
Z帧经过?
否
516
递减SNR阈值
设置初始计数 = Z
重置计数 = 0
514
是
510
增加SNR阈值
506
递减SNR阈值

图 5

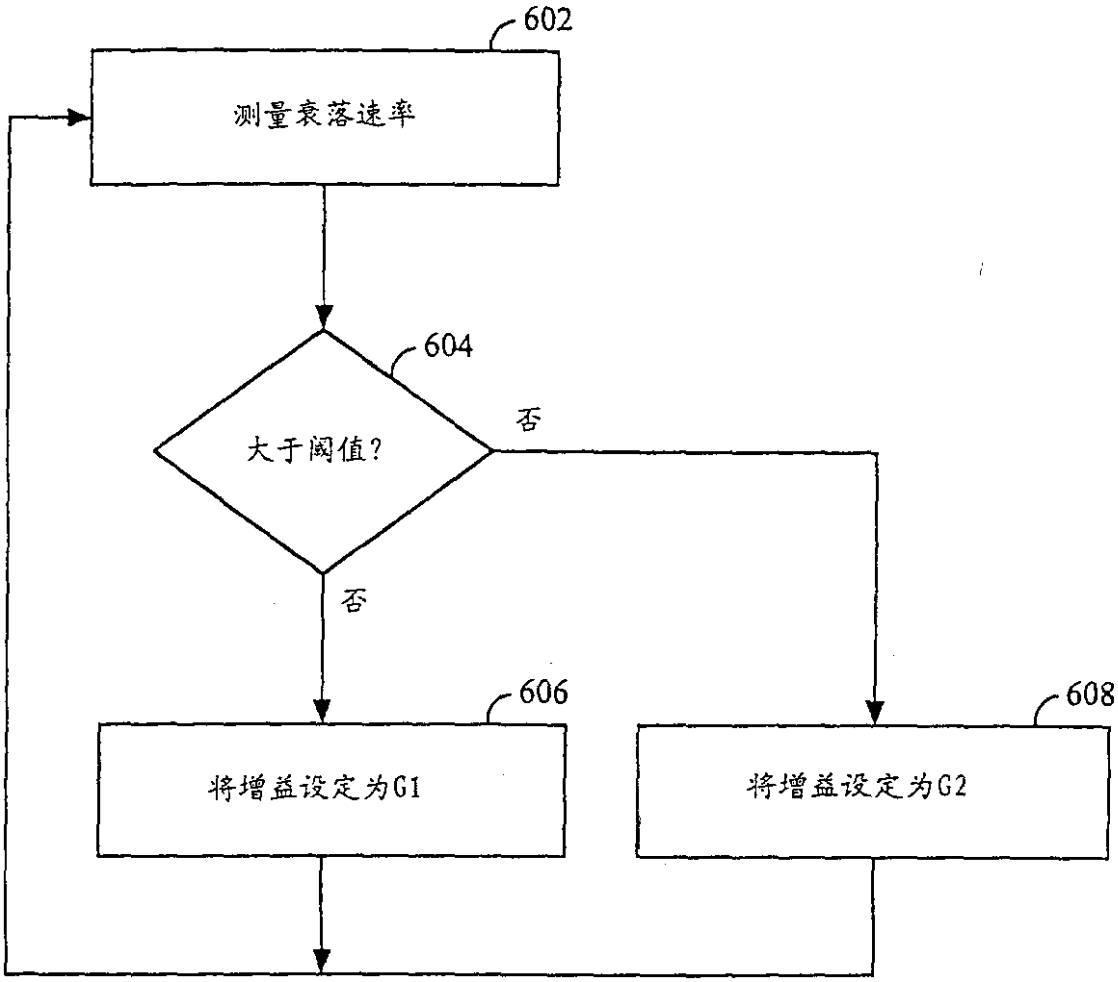


图 6