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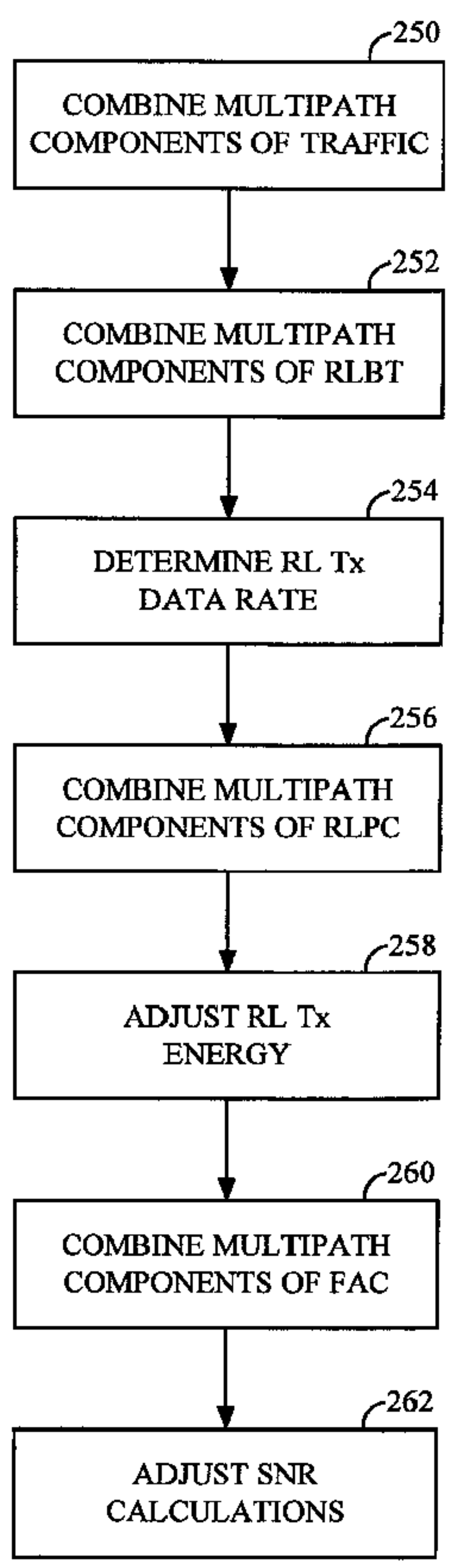
(72) **Inventeurs/Inventors:**
BENDER, PAUL E., US;
GROB, MATTHEW STUART, US;
KARMI, GADI, US;
PADOVANI, ROBERTO, US

(73) **Propriétaire/Owner:**
QUALCOMM INCORPORATED, US

(74) **Agent:** SMART & BIGGAR

(54) **Titre :** PROCEDE ET SYSTEME POUR DETERMINER UNE VITESSE DE TRANSMISSION PAR LIAISON INVERSE DANS UN SYSTEME DE COMMUNICATION SANS FIL

(54) **Title:** METHOD AND APPARATUS FOR DETERMINING A REVERSE LINK TRANSMISSION RATE IN A WIRELESS COMMUNICATION SYSTEM



(57) **Abrégé/Abstract:**
Reverse link busy bits are independently generated by each base station (102, 104 and 106) and indicative of whether the transmitting base station (102, 104 and 106) has reached a reserve link capacity limit. In a first exemplary embodiment, the remote

(57) Abrégé(suite)/Abstract(continued):
station (122) combines the multipath components of the reverse link busy bits from each of the transmitting base stations (102, 104 and 106) in its Active Set and in response transmits a reverse link signal only when all of the reverse link busy bits indicate that the base stations (102, 104 and 106) in the remote stations Active Set have reverse link capacity. In a first alternative embodiment, the remote station weights, the reverse link busy signals in accordance with the signal strength of the base station (102, 104 or 106) transmitting the busy signal and determines whether to transmit based on the weighted sum of the busy signals.

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(71) Applicant: **QUALCOMM INCORPORATED** [US/US]; 5775 Morhouse Drive, San Diego, CA 92121-1714 (US).

(72) Inventors: **BENDER, Paul, E.**; 2879 Angell Avenue, San Diego, CA 92122 (US). **GROB, Matthew, Stuart**; 2757 Bordeaux Avenue, La Jolla, CA 92037 (US). **KARMI, Gadi**; 10968 Corte Playa Barcelona, San Diego, CA 92124 (US). **PADOVANI, Roberto**; 13693 Penfield Drive, San Diego, CA 92130 (US).

(74) Agents: **WADSWORTH, Philip, R.** et al.; Qualcomm Incorporated, 5775 Morehouse Drive, San Diego, CA 92121-1714 (US).

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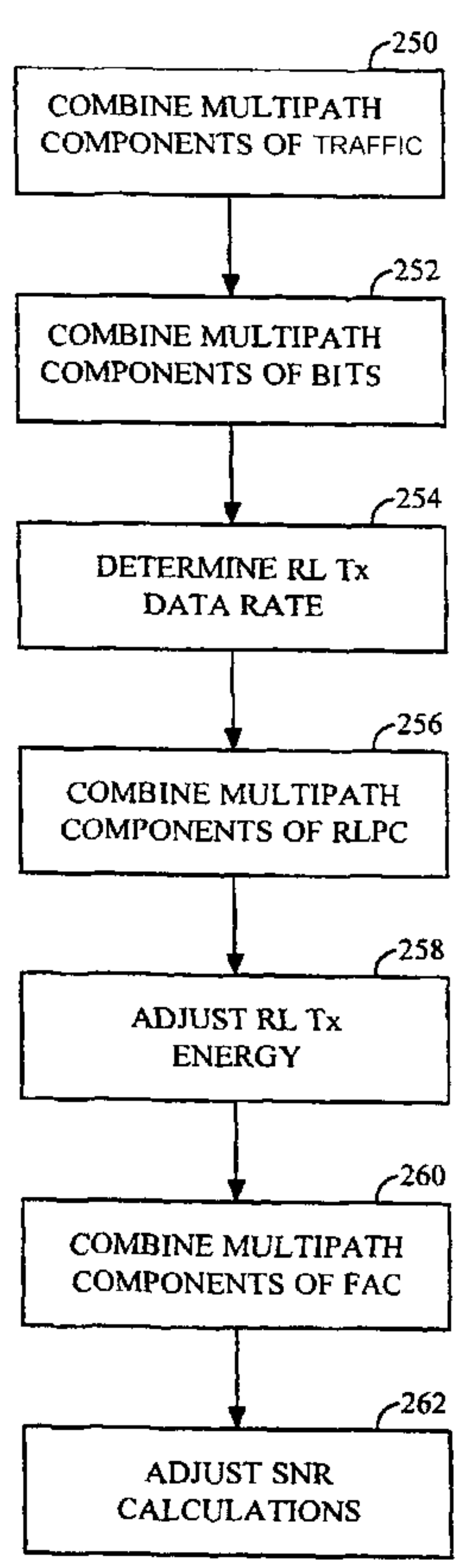

(57) Abstract: Reverse link busy bits are independently generated by each base station (102, 104 and 106) and indicative of whether the transmitting base station (102, 104 and 106) has reached a reserve link capacity limit. In a first exemplary embodiment, the remote station (122) combines the multipath components of the reverse link busy bits from each of the transmitting base stations (102, 104 and 106) in its Active Set and in response transmits a reverse link signal only when all of the reverse link busy bits indicate that the base stations (102, 104 and 106) in the remote stations Active Set have reverse link capacity. In a first alternative embodiment, the remote station weights, the reverse link busy signals in accordance with the signal strength of the base station (102, 104 or 106) transmitting the busy signal and determines whether to transmit based on the weighted sum of the busy signals.

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METHOD AND APPARATUS FOR DETERMINING A REVERSE LINK TRANSMISSION RATE IN A WIRELESS COMMUNICATION SYSTEM

BACKGROUND OF THE INVENTION

I. Field of the Invention

The present invention relates to communications. More particularly, the present invention relates to a novel and improved method and apparatus for performing signal combining during soft handoff in a wireless communication system.

II. Description of the Related Art

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 art. However, the spread spectrum modulation technique of CDMA has 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 USING SATELLITE OR TERRESTRIAL REPEATERS", assigned to the assignee of the present invention. 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 CELLULAR TELEPHONE SYSTEM", assigned to the assignee of the present invention.

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 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 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.

A useful method of power control of a mobile in a communication system is to monitor the power of the received signal from the mobile station at a base station. The base station in response to the monitored power level transmits power control bits to the mobile station 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.

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 remote station to a central base station is to allow the remote station to send the data using spread spectrum techniques of CDMA. One method that is proposed is to allow the remote station to transmit its information using a small set of orthogonal channels, this method is described in detail in U.S. Patent No. 6,396,804 entitled "HIGH DATA RATE CDMA WIRELESS COMMUNICATION SYSTEM", assigned to the assignee of the present invention.

SUMMARY OF THE INVENTION

The present invention is a novel and improved method and apparatus describing the combining of signals in a high rate wireless communication system. In the exemplary embodiment, each base station in communication with a remote station transmits forward link data including traffic data, pilot symbols and overhead data. In the exemplary embodiment, the overhead data includes a reverse link busy bit, reverse link power control (RPC) commands and a forward link activity (FAC) bit. The reverse link busy bit indicates when the base station has reached its reverse link capacity limit. The RPC bit indicates to each mobile station in communication with the base station whether their transmission energy should be increased or decreased. The FAC bit is a message that indicates when a base station will have no forward link data to transmit a predetermined number of slots in the future.

In the exemplary embodiment of the present invention, the forward link traffic is only transmitted from one base station to a given remote station. Thus, there is no soft handoff of the forward link traffic data. The multipath components of the forward link traffic data are combined using a traditional RAKE receiver to provide an improved estimate of the forward link traffic data.

In the exemplary embodiment of the present invention, the reverse link busy bits are independently generated by each base station and indicative of whether the transmitting base station has reached a reverse link capacity limit. In a first exemplary embodiment, the remote station combines the multipath components of the reverse link busy bits from each of the transmitting base stations in its Active Set and in response transmits a reverse link signal only when all of the reverse link busy bits indicate that the base stations in the remote stations Active Set have reverse link capacity. In a first alternative embodiment, the remote station weights the reverse link busy signals in accordance with the signal strength of the base station transmitting the busy signal and determines whether to transmit based on the weighted sum of the busy signals. In a second alternative embodiment, the remote station weights the reverse link busy signals in accordance with the signal strength of the base station transmitting the busy signal and determines a maximum reverse link data rate based on the weighted sum of the busy signals.

In the exemplary embodiment, the FAC signals are independently generated. The FAC signals from common base stations, multipath components, are soft combined and decoded. Each of the FAC signals is provided to a corresponding SNR calculator for each base station. The calculated SNR for each base station is used to determine which base station should transmit forward link data to the remote station and at what data rate.

According to one aspect the invention provides in a communication system in which each base station in communication with a remote station transmits a reverse link busy bit indicating whether its reverse link capacity has been exhausted, a method of determining a reverse link transmission rate of said remote station comprising:

determining said reverse link transmission rate in accordance with a combined reverse link busy signal generated in accordance with reverse link busy bits transmitted by each base station; and transmitting reverse link data in accordance with said reverse link transmission rate.

According to another aspect the invention provides a communication apparatus, comprising: means for determining a reverse link transmission rate of a remote station in accordance with a combined reverse link busy signal generated in accordance with reverse link busy bits transmitted by each base station in communication with the remote station; and means for transmitting reverse link data in accordance with the reverse link transmission rate.

According to another aspect the invention provides a remote station, comprising: a receiver; a transmitter; a reverse link busy demodulator coupled to the receiver, the reverse link busy demodulator configured to demodulate a received signal to provide estimates of reverse link busy bits transmitted by each base station in communication with the remote station; and a rate determination element configured to receive the estimates of the reverse link busy bits from the reverse link busy demodulator.

BRIEF DESCRIPTION OF THE DRAWINGS

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 diagram illustrating the components and signals of a soft handoff environment;

FIG. 2 is an illustration of the forward link slot format of the exemplary embodiment;

FIG. 3 is a flowchart illustrating the method of combining signals in the exemplary embodiment;

FIG. 4 is a block diagram illustrating the base station transmission system of the exemplary embodiment;

FIG. 5 is a block diagram of the remote station of the present invention;

FIG. 6 is a block diagram of the traffic demodulator of the exemplary embodiment;

FIG. 7 is a block diagram of the reverse link busy bit demodulator of the exemplary embodiment;

FIG. 8 is a block diagram power control demodulator of the exemplary embodiment;

FIG. 9 is a block diagram of the forward link activity (FAC) demodulator of the exemplary embodiment; and

FIG. 10 is a block diagram of the remote station transmission subsystem.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

FIG. 1 illustrates the elements of a wireless communication system during a soft handoff operation. In the soft handoff condition illustrated in FIG. 1, remote station **122** is in simultaneous communication with base station **102, 104** and **106.** A method and apparatus for performing soft handoff in a wireless communication system is disclosed in the aforementioned U.S. Patent No. 5,101,501. Base station controller **100** sends information to be transmitted to remote station **122** as to base stations **102, 104** and **106.**

In the exemplary embodiment, the forward link traffic data is transmitted to remote station **122** by the selected base station (**102, 104** or **106**) with the best propagation path to remote station **122.** Base stations **102, 104** and **106** transmit forward link signals, including forward link traffic, pilot symbols and overhead data on forward link signals **110, 114** and **118**, respectively. In the exemplary embodiment, forward link signals **110, 114** and **118,** as well as multipath component signal **108,** are code division multiple access (CDMA) communications signals.

Signal **108** illustrates the condition referred to as multipath, whereby the signal transmitted by base station **102** traverses two different propagation paths to remote station **122.** The first signal **110** traverses a line of sight propagation path, while a second signal is reflected from an obstacle **124** as forward link signal **108.** In a CDMA communications system, multipath components can be combined at the receiver to provide an improved estimate of the transmitted data as is disclosed in the aforementioned U.S. Patent No. 5,109,390.

Remote station **122** transmits data to base stations **102, 104** and **106** on reverse link signals **112, 116** and **120,** respectively. In the exemplary embodiment, reverse link signals **112, 116** and **120** are CDMA communications signals. The reverse link signals received by base stations **102, 104** and **106** are soft combined in base station controller (BSC) **100** to provide a better estimate of the information transmitted by remote station **122.** It should be noted that reverse link signals **112, 116** and **120** are actually the same signal traversing different propagation paths.

FIG. 2 illustrates a forward link slot of the exemplary embodiment. In the exemplary embodiment, a slot is 1.66 ms in duration. The slot includes two pilot bursts **206** and **214**. The second pilot burst **214** has overhead data **212** and **216** included on both sides of it. The overhead data of the exemplary embodiment includes forward link activity (FAC) information, reverse link busy bits and reverse link power control commands. The different overhead data are distinguished from one another by means of an orthogonal covering. Orthogonal coverings are well known in the art and are disclosed in the aforementioned U.S. Patent No. 5,103,459. Forward link activity information is a bit that when set indicates that a predetermined number of slots in the future, there will be no forward link traffic data to be transmitted by the base station. The reverse link busy bits indicate that the reverse link capacity limit of the base station has been reached. The power control commands are covered with unique Walsh coverings and request that a particular remote station increase or decrease its transmission energy. Forward link data is transmitted in the remainder of the frame in sections **202**, **210** and **218**.

FIG. 3 is a flowchart describing the received signal combining operations performed by remote station **122** when in soft handoff with a plurality of base stations. In block **250**, the multipath components of the forward link signal carrying traffic data to remote station **122** are combined. In the exemplary embodiment, only the base station with the best propagation path between it and remote station **122** transmits forward link traffic data to remote station **122**. If for example base station **102** has the best propagation path to remote station **122**, then base station **102** transmits forward link traffic data to remote station **122**. In this example, remote station **122** soft combines multipath signals **108** and **110** to provide an improved estimate of the forward link traffic data. In the exemplary embodiment, the soft combining is performed as a weighted sum wherein the weight of demodulated symbols is determined in proportion to the received signal strength of the signal carrying the symbols. The act of soft combining of multipath signals is described in detail in aforementioned U.S. Patent No. 5,109,390.

In block **252,** remote station **122** soft combines multipath components of the reverse link busy bits transmitted by each base station in the Active Set of remote station **122** to provide an estimate of the reverse link busy bit transmitted by each base station. It should be noted that the power control commands from different base stations may have different values and so cannot be combined meaningfully. That is base station **102** may have exhausted its reverse link capacity while base station **104** may still have remaining reverse link capacity, and as such would transmit reverse link busy bits having different values.

In block **254,** the reverse link busy bits from each of base stations **102, 104** and **106** are combined to determine a maximum data rate for the next reverse link transmission by remote station **122.** In a first exemplary embodiment, the remote station transmits a reverse link signal only when all of the reverse link busy bits indicate that the base stations in the Active Set have additional reverse link capacity. In a first alternative embodiment, the remote station **122** weights the reverse link busy bits in accordance with the signal strength of the base station transmitting the busy bit and determines whether to inhibit its reverse link transmissions based on the weighted sum of the busy bits. In a second alternative embodiment, the remote station weights the reverse link busy bits in accordance with the signal strength of the base station transmitting the busy bit and determines a maximum reverse link data rate at which to transmit based on the weighted sum of the busy bits.

In block **256**, remote station **122** soft combines the multipath components of the reverse power control bits transmitted by each base station to provide an estimate of the reverse power control bits transmitted by each base station. It should be noted that the power control commands from different base stations may not be the same value and so cannot be combined meaningfully. For example, reverse link signal travelling **114** may exceed the energy necessary for reliable transmission of signals to base station **104**, while simultaneously the energy of the reverse link signal **112** may be inadequate for reliable reception by base station **102**. In this case, base station **102** would transmit an "Up" command, while base station **104** would transmit a "Down" command. Thus, soft combining of power control commands from different base stations should not be performed. In the exemplary embodiment, for each base station, a hard decision regarding the value of its power control command is determined. Proceeding to block **258**, in the exemplary embodiment, remote station **122** increases its transmission energy only when all of the power control commands transmitted by the base stations in its Active Set request remote station **122** to increase its transmission energy.

In block **260**, the forward link activity bits (FAC) received on multiple paths from common base stations are soft combined. In block **262**, each of the combined forward activity bits are then provided to a corresponding SNR calculator which uses the information in its computation of the signal to noise ratio energy for a corresponding base station in the Active Set of remote station **122**. Referring back to FIG. 2, if the slot does not include data then the estimated signal to noise ratio computation for the slot must be adjusted to account for this gated portion of the frame during which no signal energy is present.

FIG. 4 is a block diagram illustrating the elements of base stations **102**, **104** and **106**. Forward link traffic data is provided to Walsh spreading element **300** and is covered in accordance with Walsh code (W_T). The covered traffic data is then provided to multiplexer **312**. It will be understood by one skilled in the art that processing of the signal prior to its provision to Walsh spreading element **300** is within the scope of the present invention. In particular, it is anticipated that the forward link traffic data will be forward error correction coded using a convolutional encoder, turbo coder or other forward error correction coder that is known in the art. In the exemplary embodiment, thirty two Walsh sequences of length thirty two are used to cover the forward link transmissions. Generation of and spreading in accordance with Walsh codes is disclosed in aforementioned U.S. Patent No. 5,103,459.

A predetermined set of pilot symbols, typically all ones, is provided to Walsh spreading element **302** and, in the exemplary embodiment, covered in accordance with Walsh code zero (W_0). Covering by Walsh zero is a no op and may operationally be omitted but is provided for illustrative purposes. The covered pilot symbols are then provided to multiplexer **312**.

The forward activity (FAC) bit is provided to spreading element **304** and covered in accordance with Walsh code one W_1. The reverse link busy bit is provided to Walsh spreading element **306** and covered using Walsh code seventeen (W_{17}). In addition, up to twenty eight power control commands (PC_1-PC_{29}) are provided to Walsh spreading elements **308a-308n** and are covered using Walsh sequences (W_2-W_{15} and W_{18}-W_{31}). The Walsh spread overhead bits including the FAC, the reverse link busy bit and the power control commands are summed in summer **310** and provided to multiplexer **312**.

Multiplexer **312** inserts into the slot the forward link traffic data and two pilot bursts with the second pilot burst having the overhead bits on either side of it. In the exemplary embodiment, the overhead information on both sides of the second pilot burst are replicas of one another and each are 64 Walsh chips in duration spread using thirty two bit Walsh codes providing four redundant versions of each piece of overhead information.

The slot, including the forward link traffic, the pilot bursts and overhead bits, as illustrated in FIG. 2 are provided to PN spreader **314**. In the exemplary embodiment, each base station spreads the data for transmission using a different PN sequence. In the preferred embodiment, each base station generates its PN sequence using different phase offsets of generate using a common PN generator polynomial as is described in the aforementioned U.S. Patent 5,103,459. In the preferred embodiment, the data is transmitted in accordance with a QPSK modulation wherein the in-phase and quadrature phase components are spread using to different pseudonoise sequences (PN_I and PN_Q). The PN spread signal is provided to transmitter (TMTR) **316** which up converts, amplifies and filters the signal for transmission through antenna **318**.

FIG. 5 illustrates remote station **122** of the present invention. The forward link signal is received at antenna **500** and provided through duplexer **502** to receiver (RCVR) **504**. The received signal is provided to traffic demodulator **506**, which demodulates the received signal to provide the forward link traffic data to the user of the remote station.

The received signal is provided to reverse link busy demodulator **508** which demodulates the signal to provide an estimate of the reverse link busy bits transmitted by each of the base stations in communication with remote station **122**. The reverse link busy bits are provided to rate determination element **510**. In the exemplary embodiment, rate determination element **510**, inhibits the transmission of the reverse link signal when any of the busy bits from a base station in the Active Set indicate that the reverse link capacity limit for that base station has been reached. In an alternative embodiment, rate determination element **510** selectively inhibits the reverse link transmissions based on a weighted sum of the received busy bits from the base stations in the Active Set of remote station **122**. In the first alternative embodiment, the received busy bits are weighted in accordance with the energy of the received signals. In a second alternative embodiment, rate determination element **510** selects a maximum reverse link data rate based on the received busy bits. For example, if the signal from a base station indicating that it has reached reverse link capacity is very weak, rate determination element **510** may select a non zero reverse link data rate that it estimates will not cause undue interference to the base station due to its poor propagation path to that base station. A signal indicative of either the maximum data rate or an inhibition of the reverse link signal is provided to transmit control processor **520**, which determines a set of parameters for transmitting the reverse link signal.

In the preferred embodiment, the mobile station is aware of a transmission rate profile for the base stations in its Active Set in which each of its potential reverse links transmission rates has a known probability of successful transmission under the condition that the base stations in the Active Set are not in a capacity limit condition. In the preferred embodiment, remote station **122** computes a metric referred to herein as a Derating Metric (DM) in accordance with the equation:

$$DM = 1 - \left\lfloor 1, \left(\sum_i SNR_i \cdot RLB_i\right)\left(\frac{1}{Max\,SNR_i}\right)\right\rfloor, \qquad (1)$$

where SNR_I is the estimated signal to noise ratio of the ith base station, Max SNR_I is the maximum signal to noise ratio of the base stations in the Active Set of remote station i, RLB_i is the value of the reverse link busy bit for the ith base station in the Active set which takes a value of 0 or 1. Using equation 1, the stronger the forward link signal from a base station transmitting a reverse link busy bit indicating a reverse link capacity limit condition, the greater will be the derating. This derating metric assumes a value of between 0 and 1 which is used to scale the transmission rate profile such that rates are reduced for a given probability of successful transmission.

The reverse link signal is also provided to reverse link power control demodulator **512**. Reverse link power control demodulator **512** demodulates the received signal and combines the multipath components from common base stations to generate improved estimates of the reverse link power control command transmitted by each of the base stations in the Active Set of remote station **122**. In the exemplary embodiment, each remote station in communication with a given base station demodulates its reverse link power control commands in accordance with a unique Walsh code assigned to that mobile station. It should be noted that the reverse link power control Walsh codes assigned to the remote station may be different for different base stations in communication with remote station **122**.

The improved estimates of the power control commands from each base station are provided to power control combiner **514**. In the exemplary embodiment, remote station **122** increases its transmission energy only when all base stations in the Active Set of remote station **122** transmit power control commands requesting remote station **122** to increase its transmission energy. Otherwise, remote station **122** decreases its transmission energy. In addition, the present invention is equally applicable to multi-bit power control systems wherein the base station specifies the amount of the transmission energy adjustment requested. In the simplest implementation of power control combiner **514** for use in a multi-bit power control system, power control combiner **514** selects the smallest requested increase or largest requested decrease in transmission energy.

FAC combiner **518** combines the FAC bits from multipath components of the forward link signal of a common base station to provide an improved estimate of the FAC bit transmitted by each of the base stations. Transmit control processor **520** receives each of the FAC bit estimates and adjusts the computation of the signal to noise ratio for each base station based on the estimate of the FAC bit transmitted by that base station. Transmit control processor **520** uses the calculated signal noise ratio of each of the base stations to select the base station with the best propagation path and to determine the maximum data rate of the transmission.

Based on the estimates of the reverse link busy bits, the reverse link power control commands, and the forward activity bits, transmit control processor **520** determines the rate of its next reverse link transmission, an adjustment to its reverse link transmission energy and selects the base station with the best propagation path and the maximum forward link data rate that can be reliably transmitted upon that propagation path. These parameters are provided to transmit subsystem **522** which generates the reverse link signal in accordance therewith. The reverse link signal from transmit subsystem **522** is provided through duplexer **502** for transmission through antenna **500**.

FIG. 6 illustrates the elements of traffic demodulator **506**. Searcher **600** searches potential PN offsets for string forward link signals. Searcher **600** assigns PN despreaders **602** PN offsets to demodulate. In the exemplary embodiment, each of PN despreaders **602A-602I** despreads the received signal in accordance with a different PN offset and provides the result to a corresponding demultiplexer **604**. In the exemplary embodiment, PN despreader **602** despreads the received signal in accordance with a single PN sequence used to spread a BPSK signal. However, the present invention is equally applicable to complex PN despreaders that use two distinct PN code sequences (PN_I and PN_Q) to complex despread a QPSK signal. The implementation of PN despreader **602** is well known in the art for both PN despreading of a BPSK signal and complex PN despreading of a QPSK signal.

Demultiplexer **604A-604I** separates the pilot burst portion of the received signal and provides the demodulated pilot symbols to synchronization (SYNC) element **606**. Synchronization element **606A-606I** determines adjustments to the frequency and phase of a corresponding Walsh demodulator **608**. A signal indicative of the adjustments to the phase and frequency are provided to Walsh demodulators **608**.

Demultiplexer **604** separates out the portions of the slot carrying forward link traffic data and provides those portions to Walsh demodulator **608**. Walsh demodulator **608** demodulates the receive signal in accordance with the

Walsh sequence W_T. The implementation of Walsh demodulator **608** is well known in the art and described in detail in U.S. Patent No. 5,103,459.

The demodulated forward link symbols are provided to soft combiner **610** which accumulates the multipath components of the base station transmitting the forward link traffic data to remote station **122.** The accumulated demodulated symbol energies are then provided to decoder **612** which decodes the forward traffic data and provides the decoded symbols to the user of remote station **122.** In the exemplary embodiment, decoder **612** is either a trellis decoder, such as a Viterbi decoder, or a turbo decoder.

FIG. 7 illustrates the elements of reverse link busy bit demodulator **508.** As described with respect to FIG. 6, searcher **600** searches potential PN offsets for strong forward link signals. Searcher **600** assigns PN offsets to each PN despreaders **602.** As described above, each of PN despreaders **602A-602R** despreads the received signal in accordance with a different PN offset and provides the result to a corresponding demultiplexer **704.**

Demultiplexer **704A-704R** separates the pilot burst portion of the slot and provides the pilot symbols to synchronization (SYNC) element **706.** Synchronization element **706** determines adjustments to the frequency and phase of a corresponding Walsh demodulator **708.** A signal indicative of the adjustments to the phase and frequency are provided to Walsh demodulators **708.** It will be understood by one skilled in the art that synchronization elements **706** and synchronization elements **606** perform identical operations and are shown as distinct elements for illustrative purposes only.

Demultiplexer **704** separates out the portions of overhead data from the received slot and provides those portions to Walsh demodulator **708A-708R.** In the exemplary embodiment, Walsh demodulator **708** demodulates the received signal in accordance with the Walsh code W_{17}.

The demodulated forward link symbols are provided to soft combiner **710A-710J** which accumulates the multipath symbols from each of the base stations. The accumulated symbol energies are then provided to rate determination logic **510** which operates as described previously.

FIG. 8 illustrates the elements of reverse link power control demodulator **512.** As described with respect to FIG. 6, searcher **600** searches potential PN offsets for strong forward link signals. Searcher **600** assigns PN offsets to each PN despreaders **602.** As described above, in the exemplary embodiment, each of PN despreaders **602** despreads the received signal in accordance with a different PN offset and provides the result to a corresponding demultiplexer **804.**

Demultiplexer **804A-804R** separates the pilot burst portion of the slot and provides the pilot symbols to synchronization (SYNC) element **806A-806R.** Synchronization element **806** determines adjustments to the frequency and phase of a corresponding Walsh demodulator **808.** A signal indicative of the adjustments to the timing phase and frequency are provided to Walsh demodulators **808A-808R.** It will be understood by one skilled in the art that synchronization elements **806** and synchronization elements **606** perform identical operations and are shown as distinct elements for illustrative purposes only.

Demultiplexer **804** separates out the portions of overhead data from the received slot and provides those portions to Walsh demodulator **808**. In the exemplary embodiment, Walsh demodulator **808** demodulates the received signal in accordance with a Walsh code that is specific for transmission of the power control signals for a corresponding base station. For example, base station **102** may cover its power control commands to remote station **122** using Walsh code five, while base station **104** may cover its power control commands to remote station **122** using Walsh code thirteen. Thus, the multipath components of forward link transmitted from a common base station are demodulated using a common Walsh code to extract the power control commands from that base station. Whereas, power control commands from different base stations are demodulated using different Walsh codes.

The demodulated power control commands from each base station are provided to soft combiners **810A-810J** which accumulate the multipath symbols for a corresponding one of the base stations in its Active Set. The accumulated symbol energies are then provided to power control combiner **514** which operates as described previously.

FIG. 9 illustrates the elements of FAC demodulator **516**. As described with respect to FIG. 6, searcher **600** searches potential PN offsets for strong forward link signals. Searcher **600** assigns PN offsets to each of PN despreaders **602A-602R**. As described above, in the exemplary embodiment, each of PN despreaders **602** despreads the received signal in accordance with a different PN offset and provides the result to a corresponding demultiplexer **904**.

Demultiplexer **904A-904R** separates the pilot burst portion of the slot and provides that to synchronization (SYNC) element **906**. Synchronization element **906** determines adjustments to the frequency and phase of a corresponding

Walsh demodulator **908**. A signal indicative of the adjustments to the phase and frequency are provided to Walsh demodulators **908**. It will be understood by one skilled in the art that synchronization elements **906A-906R** and synchronization elements **606** perform identical operations and are shown as distinct elements for illustrative purposes only.

Demultiplexer **904** separates out the portions of overhead data from the received slot and provides those portions to Walsh demodulator **908**. In the exemplary embodiment, Walsh demodulator **908** demodulates the received signal in accordance with a Walsh code one (W_1). The demodulated FAC symbols from common base stations are provided to a combiner **910**. Combiners **910** combine the energies of the FAC symbols to provide an improved estimate of the FAC bits for each base station in the Active Set of remote station **122**.

The maximum data rate from rate determination element **510**, the combined power control command from power control combiner **514** and the estimated forward activity bits for each of the base stations in the Active Set of remote station **122** are provided to transmit control processor **520**. In accordance therewith, transmit control processor **520** determines the data rate of the next reverse link transmission, from remote station **122** generates a signal to adjust the transmission energy of the reverse link signal, selects the base station to send forward link traffic data to remote station **122** and then determines the maximum rate at which the forward link data can be reliably transmitted.

FIG. 10 illustrates the elements of transmit control processor **520** and transmit subsystem **522**. In transmit control processor **520**, the combined power control command (PC) is provided to gain adjustment element **1000.** The power control command in the exemplary embodiment is a single bit up/down command in response to which gain adjustment element **1000** generates a control signal increasing or decreasing the transmission energy of the reverse link signal by adjusting the gain of a variable gain amplifier (not shown) within transmitter (TMTR) **1010.**

The FAC estimates for each base station are provided to a corresponding signal to noise computers **1002 A-1002I.** In response to the FAC bits, signal to noise computers **1002** calculate the signal to noise ratio of the forward link signals from a base station in the Active Set of remote station **122.** Slots received without forward link traffic data are incorporated into the signal to noise ratio computation differently from those frames that include forward link traffic data. If the occurrence of frames without forward link traffic data is sufficiently rare, these frames may be excluded from the computation entirely. In a preferred embodiment, the signal to noise energy of frames without forward link traffic data are scaled prior to being accumulated into the signal to noise ratio computation.

The estimates of the signal to noise ratio for the forward link signal from each base station is provided from signal to noise computers **1002** to DRC control processor **1004.** DRC control processor **1004** selects the base station that has the highest signal to noise ratio and determines a maximum transmission rate in accordance with the signal to noise ratio of the selected base station. A signal indicative of the identity of the selected base station and the maximum data rate is generated by DRC control processor **1004** and provided to multiplexer (MUX) **1016.**

The reverse link data rate derated by the method described with respect to equation (1) is determined by rate determination element **510** and provided to reverse link controller **1006**. Reverse link controller **1006** determines the rate at which to transmit its reverse link signal in accordance with this maximum data rate. In the exemplary embodiment, reverse link controller **1006** determines the reverse link data rate in accordance with the maximum data rate, the amount of data queued to be transmitted by remote station **122**, and the amount of battery power remaining in remote station **122**.

A signal indicative of the selected reverse link data rate is provided to message generator **1008**. In response message generator **1008** generates a signal indicative of the selected reverse link data rate and provides the reverse rate indicator (RRI) message to multiplexer **1016**. In addition, reverse link controller **1006** provides a signal indicative of the selected reverse link data rate to reverse link traffic processing element **1018**.

In response to the reverse link data rate signal, memory element **1020** in reverse link traffic processing element **1018** provides an amount of data for transmission. The data is encoded by encoder **1022**. The encoding rate and encoding algorithm used by encoder **1022** may also be selected in response to the selected reverse link data rate. The encoded symbols are provided to interleaver (INT) **1024** which reorders the symbols in accordance with a predetermined interleaving format. The interleaved symbols are provided to Walsh modulator **1026**.

In the exemplary embodiment, the Walsh modulation is performed using variable length Walsh sequences in which the length of the Walsh sequence (and accordingly the spreading gain) is varied inversely with rate of the reverse link transmission. The use of variable length Walsh sequences is described in detail in U.S. Patent No. 5,571,761, entitled "SYSTEM AND METHOD FOR ORTHOGONAL SPREAD SPECTRUM SEQUENCE GENERATION IN VARIABLE DATA RATE SYSTEMS", which is assigned to the assignee of the present invention.

The Walsh spread reverse link traffic data is provided to complex PN spreader **1012**. Multiplexer **1016** multiplexes the data rate control message and the reverse rate indicator message with pilot symbols and provides the multiplexed data to Walsh modulator **1014**. Walsh modulator **1014** spreads the multiplexed data in accordance with the Walsh code zero and provides the spread data to complex PN spreader **1012**.

In the exemplary embodiment, the PN spreading of the reverse link signal is performed in accordance with two distinct PN sequences (PN_I and PN_Q) in order to evenly distribute the load the in-phase and quadrature-phase components of the transmitted QPSK signal. The implementation of complex PN spreader **1012** is disclosed in the aforementioned U.S. Patent No. 6,396,804.

The complex PN spread data is provided to transmitter **1010** which amplifies, filters and upconverts the complex PN spread signal for transmission.

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.

CLAIMS:

1. In a communication system in which each base station in communication with a remote station transmits a reverse link busy bit indicating whether its reverse link capacity has been exhausted, a method of determining a reverse link transmission rate of said remote station comprising:

determining said reverse link transmission rate in accordance with a combined reverse link busy signal generated in accordance with reverse link busy bits transmitted by each base station; and

transmitting reverse link data in accordance with said reverse link transmission rate.

2. The method of claim 1 further comprising soft-combining multipath components of the reverse link busy bits from each base station to provide an estimate of the reverse link busy bit transmitted by each base station.

3. The method of claim 1 wherein said determining said reverse link transmission rate comprises inhibiting the transmission of said reverse link data when any of said reverse link busy bits indicate a base station is in a reverse link capacity condition.

4. The method of claim 1 wherein said determining said reverse link transmission rate is performed in accordance with values of the reverse link busy bits transmitted by each base station and strength of forward link signals from each base station as received by said remote station.

5. The method of claim 1 wherein said determining said reverse link transmission rate comprises:

computing a derating metric in accordance with values of the reverse link busy bits transmitted by each base station and strength of forward link signals from each base station as received by said remote station;

adjusting a rate transmission profile indicative of the probability of successful transmission for each potential reverse link transmission rate in accordance with said derating metric; and

selecting said reverse link transmission rate in accordance with said adjusted rate transmission profile.

6. The method of claim 5 wherein said computing said derating metric (DM) is performed in accordance with the equation:

$$DM = 1 - \left\lfloor 1, \left(\sum_i SNR_i \cdot RLB_i \right) \left(\frac{1}{Max\, SNR_i} \right) \right\rfloor$$

where SNR_i is an estimated signal-to-noise ratio of the ith base station, Max SNR_i is a maximum signal-to-noise ratio of the base stations in an Active Set of remote station i, RLB_i is a value of the reverse link busy bit for the ith base station in the Active Set.

7. The method of claim 1, further comprising increasing a transmission energy of the remote station when power control commands transmitted by base stations in an Active Set of the remote station request an increase in the transmission energy.

8. The method of claim 1, further comprising:

soft-combining forward link activity bits (FAC) received on multiple paths from a plurality of base stations;

providing the combined forward link activity bits to a signal-to-noise calculator for each base station;

calculating the signal-to-noise ratio of each base station; and

determining the base station to transmit forward link data based on the calculated signal-to-noise ratio for each base station.

9. A communication apparatus, comprising:

means for determining a reverse link transmission rate of a remote station in accordance with a combined reverse link busy signal generated in accordance with reverse link busy bits transmitted by each base station in communication with the remote station; and

means for transmitting reverse link data in accordance with the reverse link transmission rate.

10. The apparatus of claim 9, further comprising means for soft-combining multipath components of the reverse link busy bits from each base station to provide an estimate of the reverse link busy bit transmitted by each base station.

11. The apparatus of claim 9, further comprises means for inhibiting the transmission of the reverse link data when any of the reverse link busy bits indicate a base station is in a reverse link capacity condition.

12. The apparatus of claim 9, wherein said means for determining the reverse link transmission rate operates in accordance with values of the reverse link busy bits transmitted by each base station and strength of forward link signals from each base station as received by the remote station.

13. The apparatus of claim 9, further comprising:

means for computing a derating metric in accordance with values of the reverse link busy bits transmitted by each base station and strength of forward link signals from each base station as received by the remote station;

means for adjusting a rate transmission profile indicative of the probability of successful transmission for each potential reverse link transmission rate in accordance with the derating metric; and

means for selecting the reverse link transmission rate in accordance with said adjusted rate transmission profile.

14. The apparatus of claim 13, wherein said means for computing said derating metric (DM) operates in accordance with the equation:

$$DM = 1 - \left\lfloor 1, \left(\sum_i SNR_i \cdot RLB_i \right) \left(\frac{1}{Max\,SNR_i} \right) \right\rfloor$$

where SNR_i is an estimated signal-to-noise ratio of the ith base station, Max SNR_i is a maximum signal-to-noise ratio of base stations in an Active Set of remote station i, RLB_i is a value of the reverse link busy bit for the ith base station in the Active Set.

15. The apparatus of claim 9, further comprising means for increasing a transmission energy to the remote station when power control commands transmitted by base stations in an Active Set of the remote station request an increase in the transmission energy.

16. The apparatus of claim 9, further comprising:

means for soft-combining forward link activity bits (FAC) received on multiple paths from common base stations;

means for providing the combined forward link activity bits to a signal-to-noise calculator for each base station;

means for calculating the signal-to-noise ratio of each base station; and

means for determining the base station to transmit forward link data based on the calculated signal-to-noise ratio for each base station.

17. A remote station, comprising:

a receiver;

a transmitter;

a reverse link busy demodulator coupled to the receiver, the reverse link busy demodulator configured to demodulate a received signal to provide estimates of reverse link busy bits transmitted by each base station in communication with the remote station; and

a rate determination element configured to receive the estimates of the reverse link busy bits from the reverse link busy demodulator.

18. The remote station of claim 17, wherein the rate determination element is further configured to inhibit reverse link transmission when any of the estimates of the reverse link busy bits from a base station in an Active Set of the remote station indicate that the reverse link capacity limit for the base station has been reached.

19. The remote station of claim 18, further comprising a transmit control processor configured to receive a signal from the rate determination element and instruct the transmitter not to transmit the reverse link data.

20. The remote station of claim 18, wherein the rate determination element is further configured to selectively inhibit the reverse link transmission based on a weighed sum of the reverse link busy bits received from base stations in an Active Set of the remote station.

21. The remote station of claim 20, wherein the rate determination element is further configured to weigh the estimates of the reverse link busy bits in accordance with the energy of the received signal.

22. The remote station of claim 21, wherein the rate determination element is further configured to select a maximum reverse link data rate based on the estimates of the reverse link busy bits.

23. The remote station of claim 22, further comprising a transmit control processor configured to receive a signal from the rate determination element and instruct the transmitter to transmit the reverse link data in accordance with the maximum reverse link data rate.

24. The remote station of claim 17, further comprising an FAC demodulator coupled to the receiver, configured to demodulate the received signal to generate estimates of reverse link signal from each base station.

25. The remote station of claim 24, further comprising an FAC combiner coupled to the FAC demodulator and configured to combine the FAC bits to provide an estimate of the FAC bit transmitted by each base station.

26. The remote station of claim 25, further comprising a transmit control processor configured to receive the FAC bit estimates and adjust a computation of a signal-to-noise ratio for each base station based on the FAC bit estimates.

SMART & BIGGAR

OTTAWA, CANADA

PATENT AGENTS

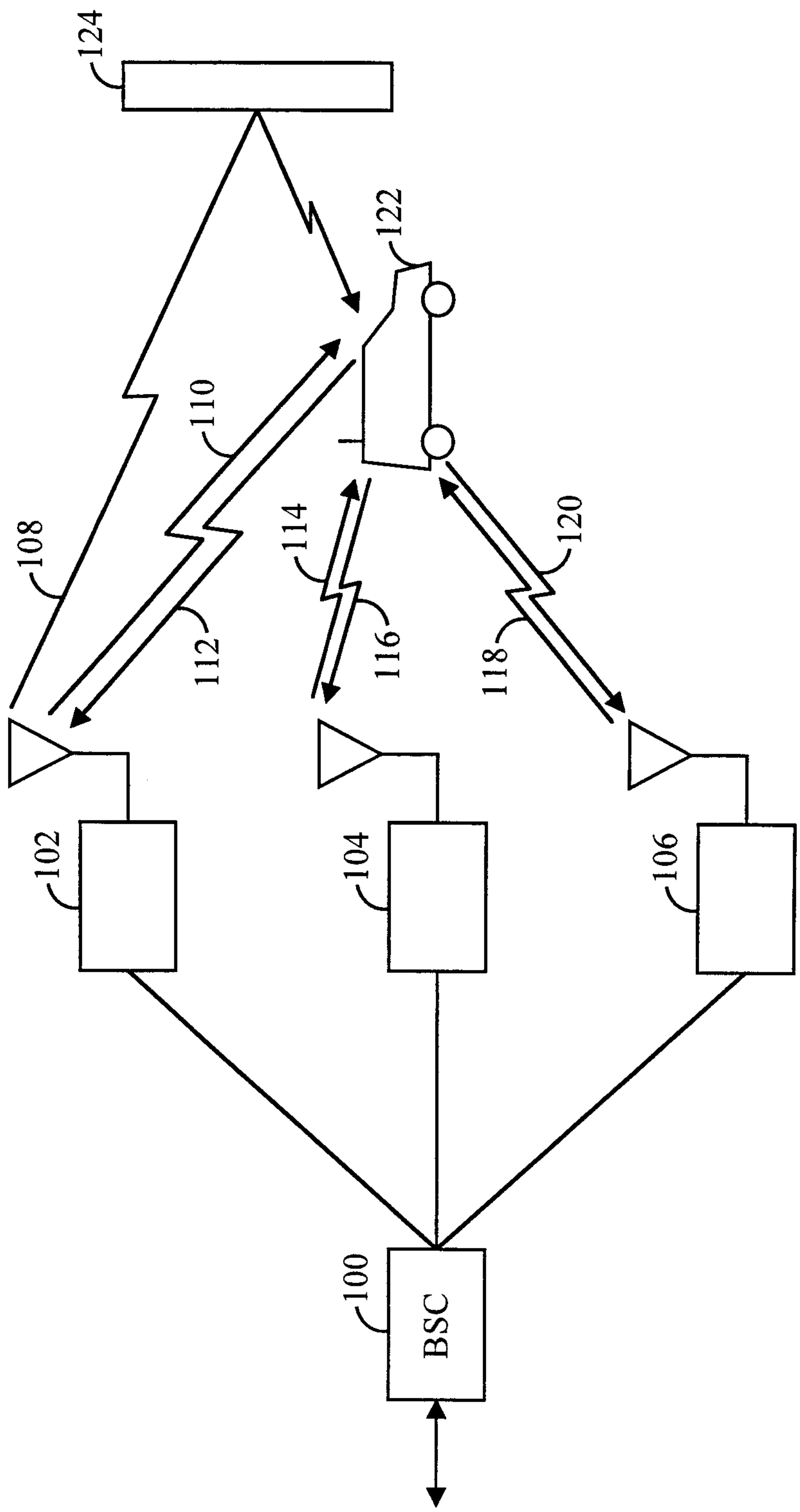
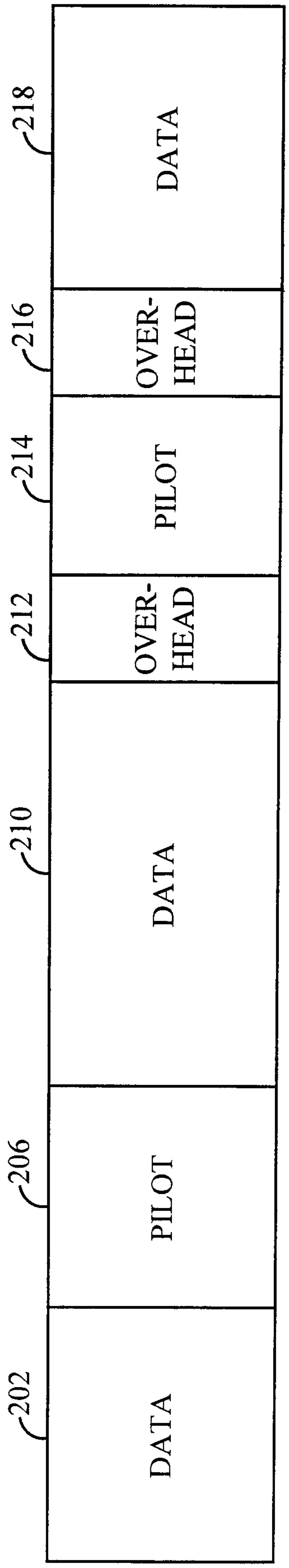


FIG. 1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HEAD
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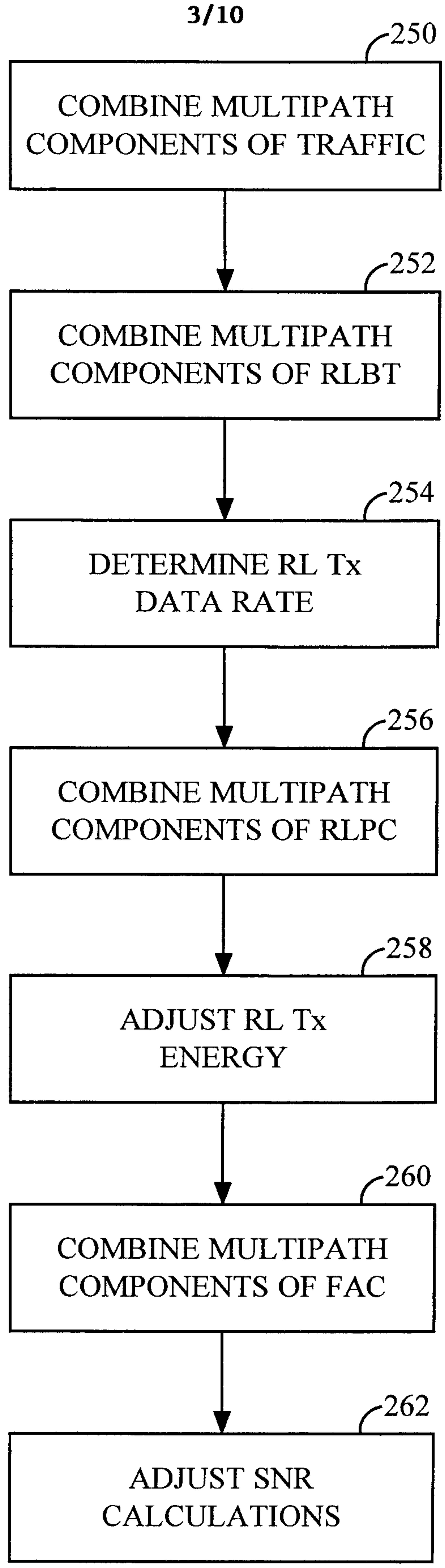
DATA

FIG. 2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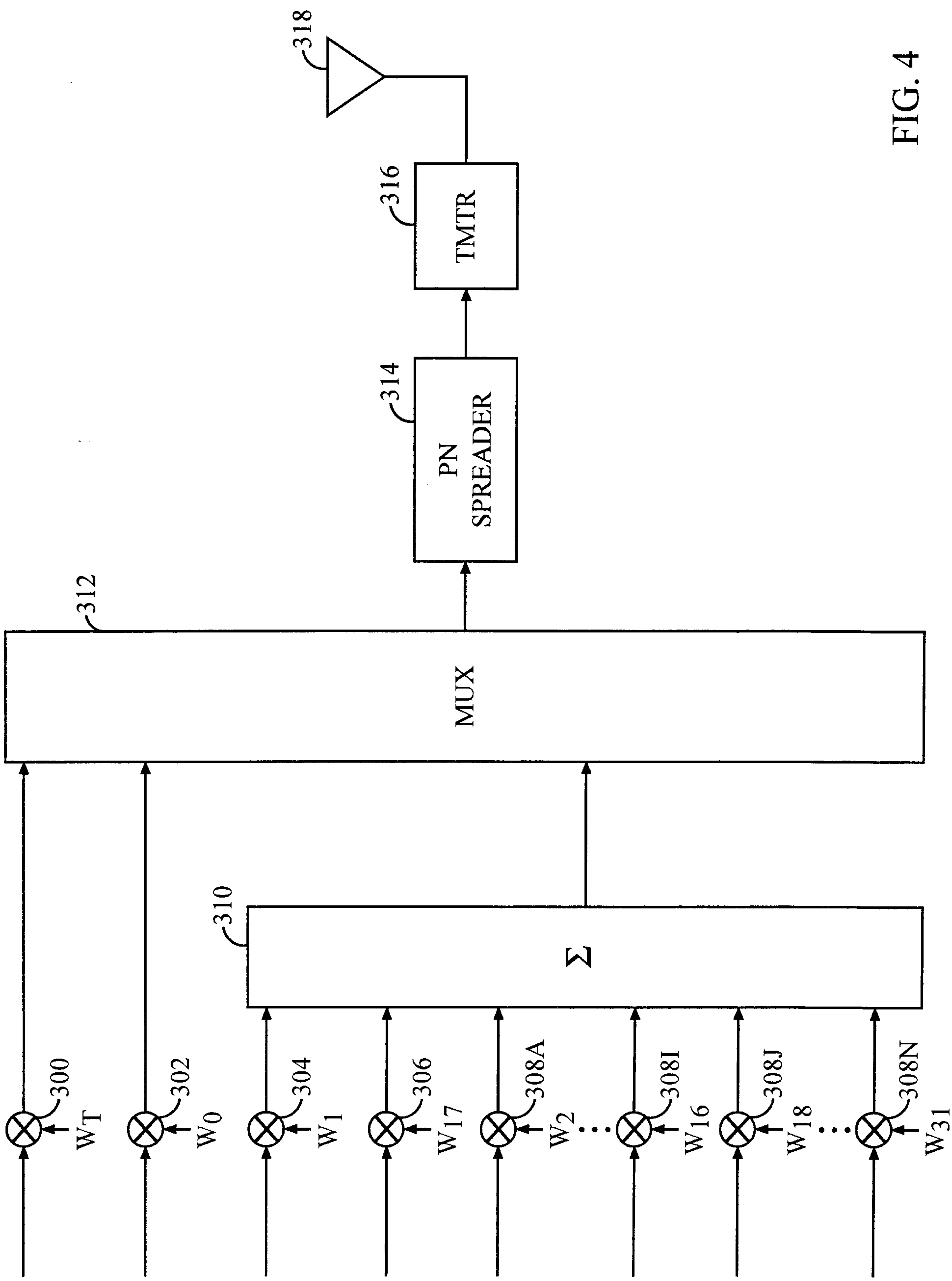
252
COMBINE MULTIPATH COMPONENTS OF RLBT
254
DETERMINE RL Tx DATA RATE
256
COMBINE MULTIPATH COMPONENTS OF RLPC
258
ADJUST RL Tx ENERGY
260
COMBINE MULTIPATH COMPONENTS OF FAC
262
ADJUST SNR CALCULATIONS

FIG. 3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316
TMTR
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PN
SPREADER
312
MUX
310
Σ
300
302
304
306
308A
308I
308J
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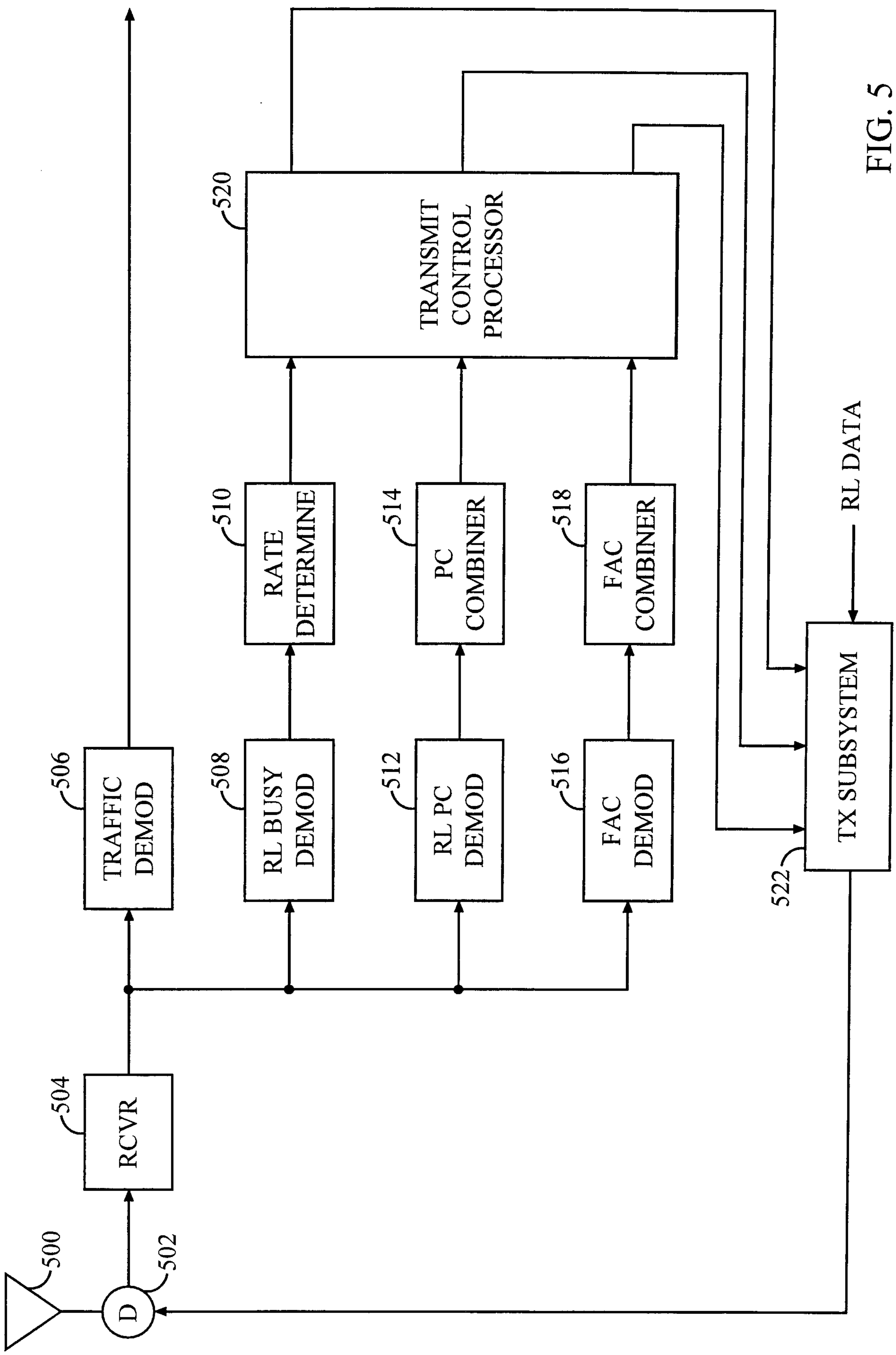
W_T
W_0
W_1
W_{17}
W_2
W_{16}
W_{18}
W_{31}

FIG. 4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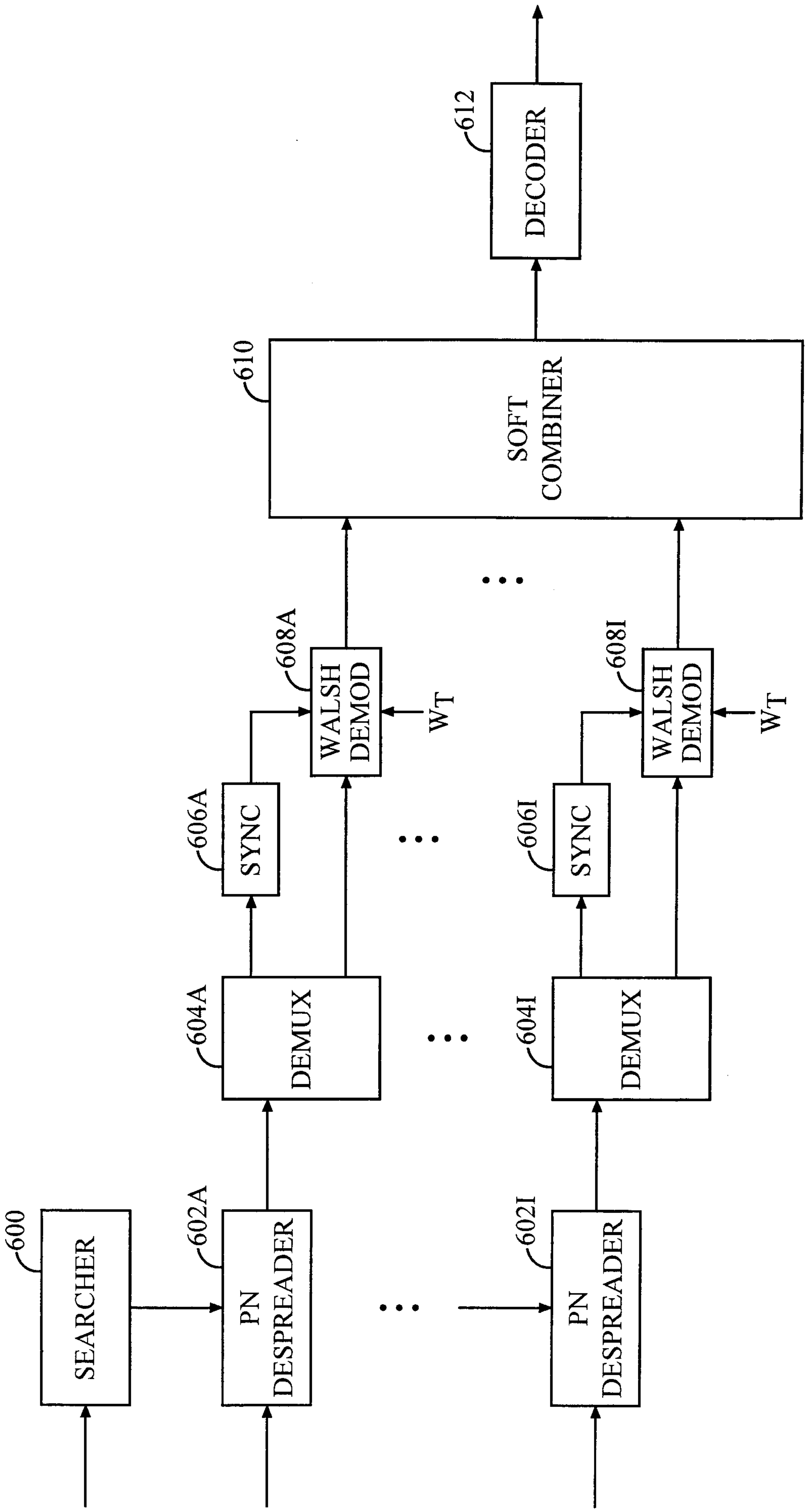
D
502
RCVR
504
TRAFFIC DEMOD
506
RL BUSY DEMOD
508
RATE DETERMINE
510
RL PC DEMOD
512
PC COMBINER
514
FAC DEMOD
516
FAC COMBINER
518
TRANSMIT CONTROL PROCESSOR
520
TX SUBSYSTEM
522
RL DATA

FIG. 5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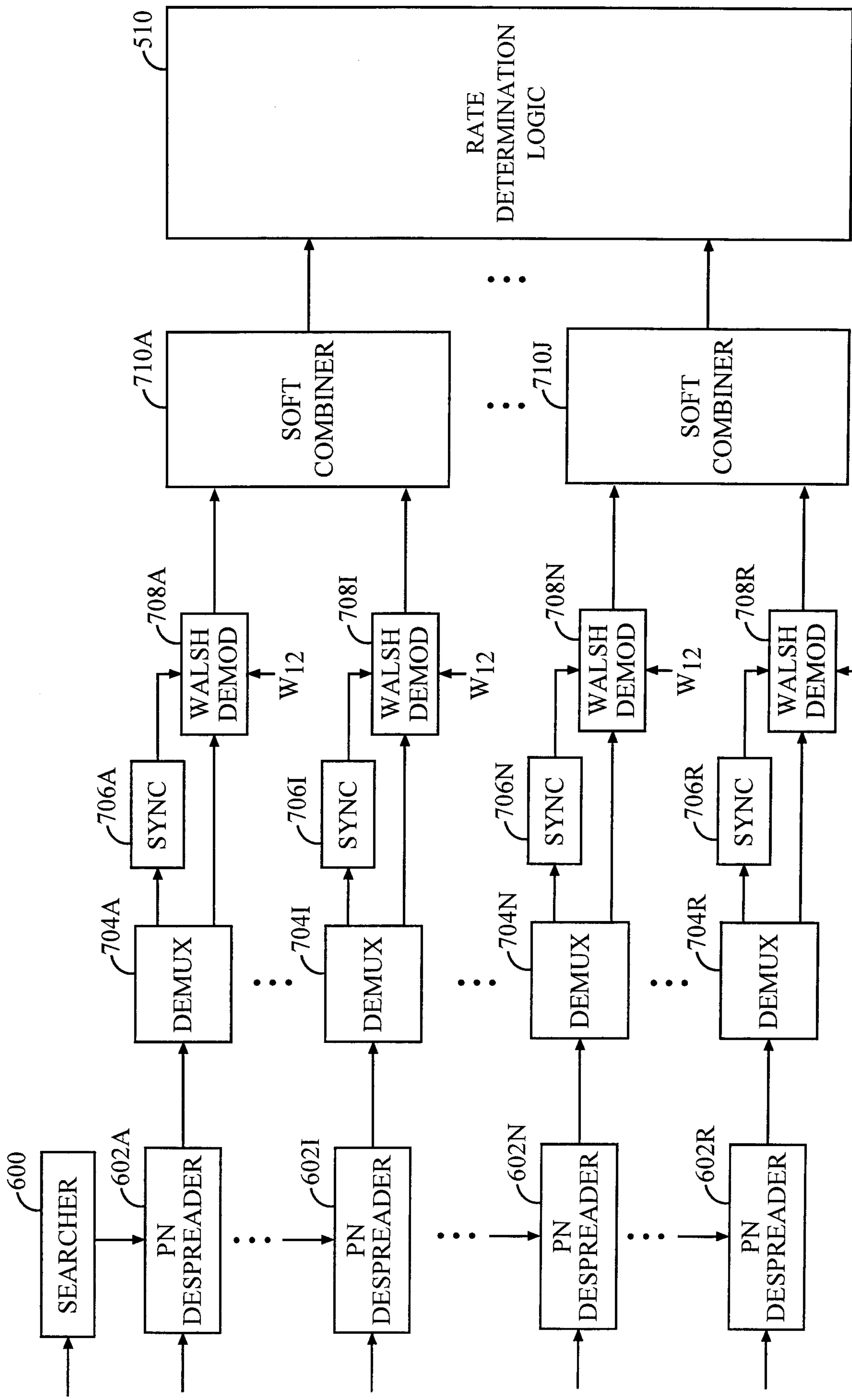
SEARCHER
602A
PN DESPREADER
602I
PN DESPREADER
604A
DEMUX
604I
DEMUX
606A
SYNC
606I
SYNC
608A
WALSH DEMOD
608I
WALSH DEMOD
W_T
W_T
610
SOFT COMBINER
612
DECODER

FIG. 6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RATE DETERMINATION LOGIC
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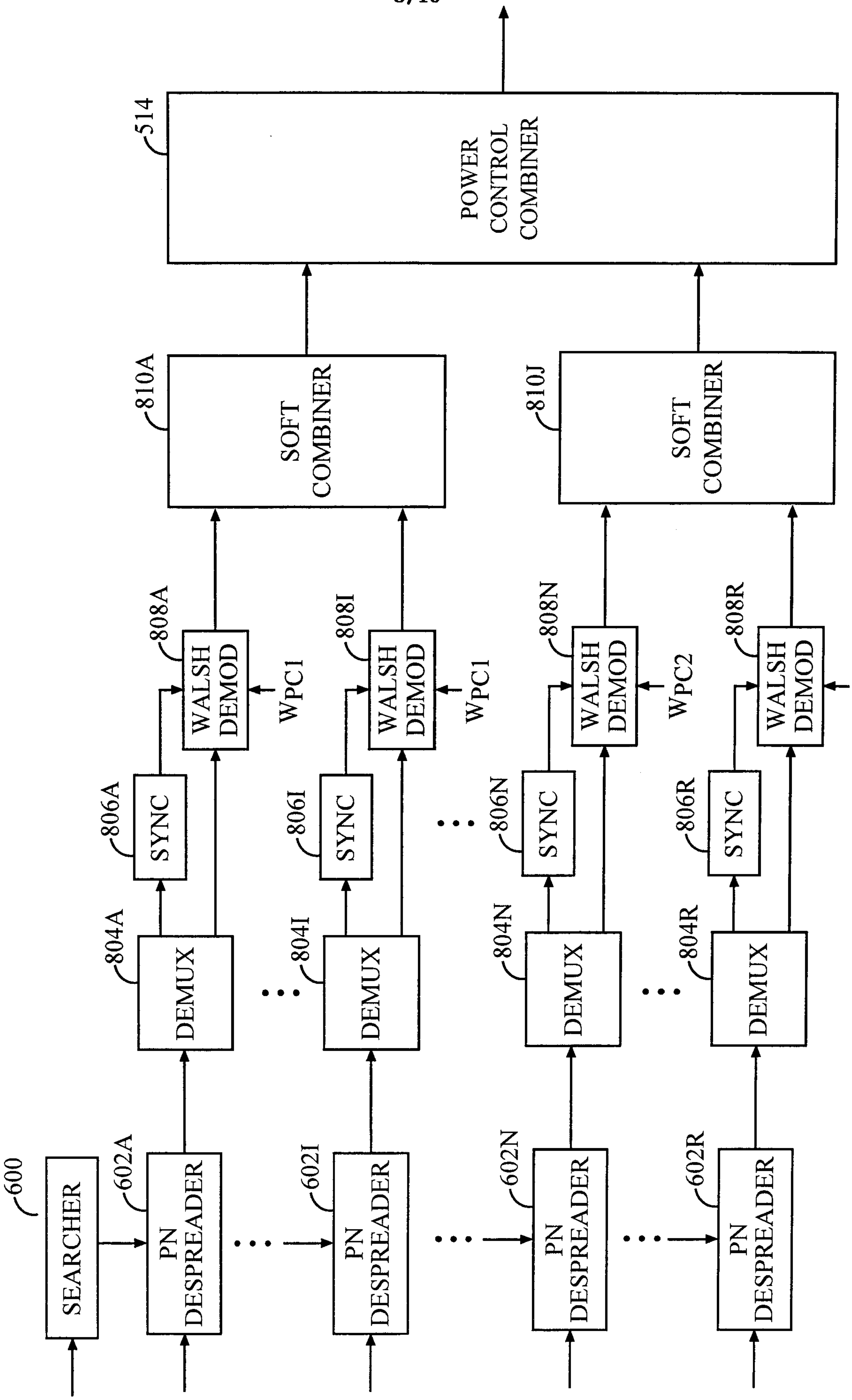
SOFT COMBINER
710J
SOFT COMBINER
708A
WALSH DEMOD
W_{12}
708I
708N
708R
706A
SYNC
706I
706N
706R
704A
DEMUX
704I
704N
704R
600
SEARCHER
602A
PN DESPREADER
602I
602N
602R

FIG. 7



600
SEARCHER
602A
PN DESPREADER
602I
PN DESPREADER
602N
PN DESPREADER
602R
PN DESPREADER
804A
DEMUX
804I
DEMUX
804N
DEMUX
804R
DEMUX
806A
SYNC
806I
SYNC
806N
SYNC
806R
SYNC
808A
WALSH DEMOD
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808I
WALSH DEMOD
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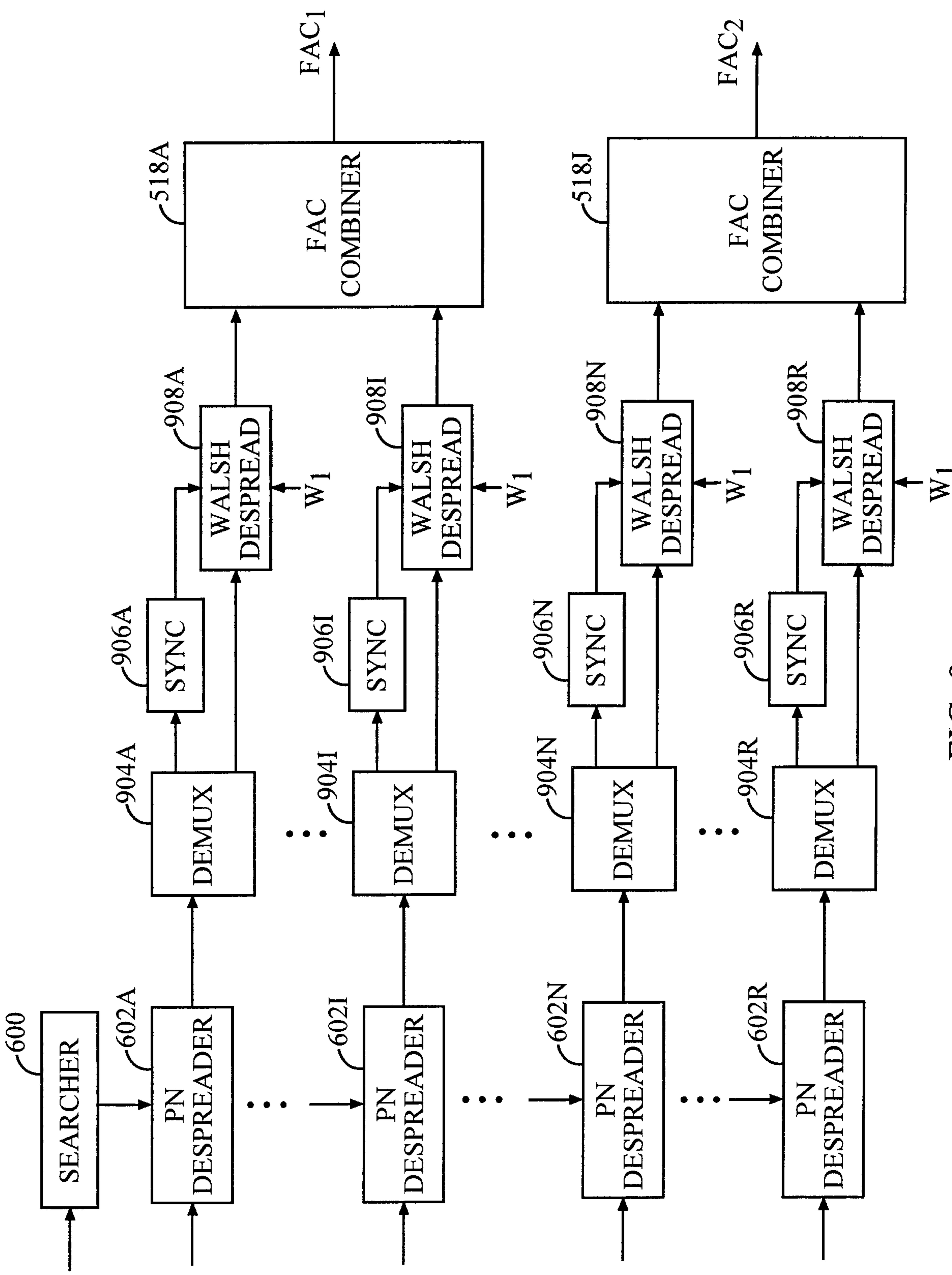
808N
WALSH DEMOD
W_{PC2}
808R
WALSH DEMOD
W_{PC2}
810A
SOFT COMBINER
810J
SOFT COMBINER
514
POWER CONTROL COMBINER

FIG. 8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PN DESPREADER
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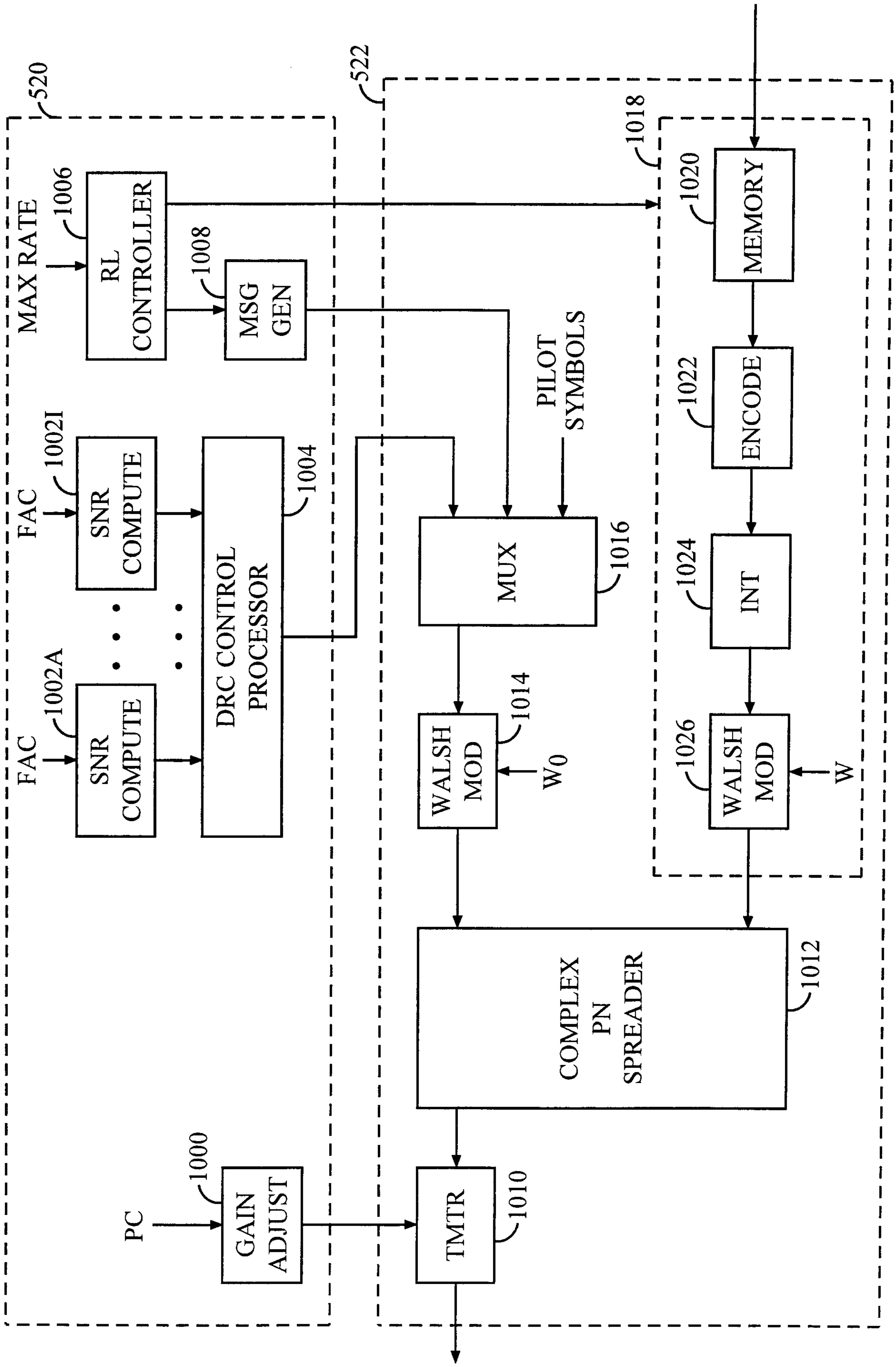
602I
602N
602R
DEMUX
904A
904I
904N
904R
SYNC
906A
906I
906N
906R
WALSH DESPREAD
908A
908I
908N
908R
W_1
FAC COMBINER
518A
518J
FAC_1
FAC_2

FIG. 9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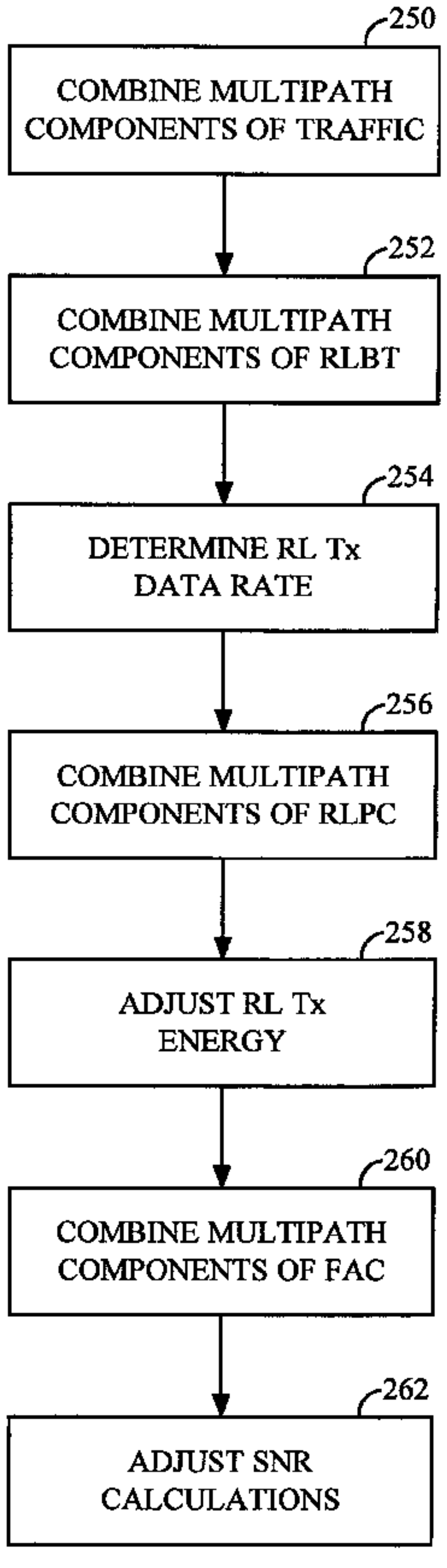
522
MAX RATE
1006
RL CONTROLLER
1008
MSG GEN
FAC
1002I
SNR COMPUTE
1002A
SNR COMPUTE
DRC CONTROL PROCESSOR
1004
PILOT SYMBOLS
MUX
1016
WALSH MOD
1014
W0
COMPLEX PN SPREADER
1012
PC
1000
GAIN ADJUST
TMTR
1010
1018
1020
MEMORY
1022
ENCODE
1024
INT
1026
WALSH MOD
W

FIG. 10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COMBINE MULTIPATH COMPONENTS OF TRAFFIC
252
COMBINE MULTIPATH COMPONENTS OF RLBT
254
DETERMINE RL Tx DATA RATE
256
COMBINE MULTIPATH COMPONENTS OF RLPC
258
ADJUST RL Tx ENERGY
260
COMBINE MULTIPATH COMPONENTS OF FAC
262
ADJUST SNR CALCULATIONS