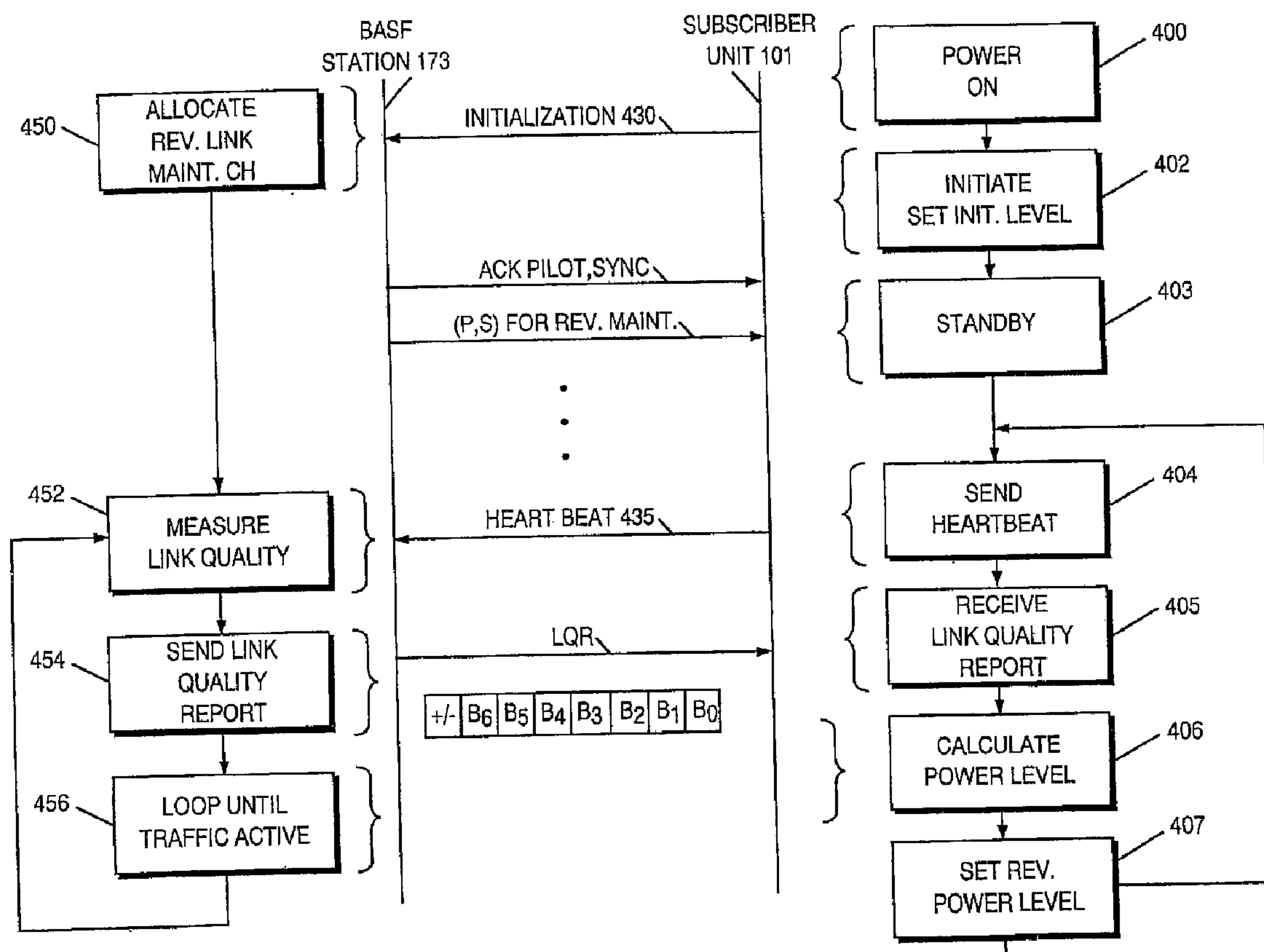




(22) Date de dépôt/Filing Date: 1999/09/09
(41) Mise à la disp. pub./Open to Public Insp.: 2000/03/30
(45) Date de délivrance/Issue Date: 2013/10/29
(62) Demande originale/Original Application: 2 344 821
(30) Priorité/Priority: 1998/09/21 (US09/158,421)

(51) Cl.Int./Int.Cl. *H04W 52/18* (2009.01),
H04B 7/216 (2006.01)
(72) Inventeur/Inventor:
PROCTOR, JAMES A., JR., US
(73) Propriétaire/Owner:
IPR LICENSING, INC., US
(74) Agent: RIDOUT & MAYBEE LLP

(54) Titre : PROTOCOLE DE COMMANDE DE PUISSANCE POUR LIAISON INVERSEE, A DEBIT DE DONNEES
HAUTEMENT VARIABLE, DANS UN SYSTEME DE TELECOMMUNICATIONS
(54) Title: POWER CONTROL PROTOCOL FOR HIGHLY VARIABLE DATA RATE REVERSE LINK OF A WIRELESS
COMMUNICATION SYSTEM



(57) Abrégé/Abstract:

A technique for implementing closed loop power control in a Code Division Multiple Access (CDMA) type wireless system which dynamically assigns coded channels on a demand basis. The technique maintains a proper power level, even when no traffic



(57) **Abrégé(suite)/Abstract(continued):**

channels are allocated, by determining a link quality metric based upon the reverse link power received. This determination is made in response to a heartbeat signal sent at a rate which is only sufficiently fast to maintain code phase lock, for example, depending upon the expected maximum rate at which the subscriber unit will travel.

ABSTRACT OF THE DISCLOSURE

A technique for implementing closed loop power control in a Code Division Multiple Access (CDMA) type wireless system which dynamically assigns coded channels on a demand basis. The technique maintains a proper power level, even when no traffic channels are allocated, by determining a link quality metric based upon the reverse link power received. This determination is made in response to a heartbeat signal sent at a rate which is only sufficiently fast to maintain code phase lock, for example, depending upon the expected maximum rate at which the subscriber unit will travel.

- 1 -

POWER CONTROL PROTOCOL FOR HIGHLY VARIABLE DATA RATE REVERSE LINK OF A WIRELESS COMMUNICATION SYSTEM

This application is a divisional of Canadian patent application Serial No. 2,344,821 filed internationally on September 9, 1999 and entered nationally on March 20, 2001.

BACKGROUND OF THE INVENTION

The increasing use of wireless telephones and personal computers has led to a corresponding demand for advanced telecommunication services that were once thought to only be meant for use in specialized applications. In the 1980's, wireless
5 voice communication became widely available through the cellular telephone network. Such services were at first typically considered to be the exclusive province of the businessman because of expected high subscriber costs. The same was also true for access to remotely distributed computer networks. Until very recently, only business people and large institutions could afford the necessary
10 computers and wireline access equipment. As a result of the widespread availability of both technologies, the general population now increasingly wishes to not only have access to networks such as the Internet and private intranets, but also to access such networks in a wireless fashion as well. This is particularly of concern for the users of portable computers, laptop computers, hand-held personal
15 digital assistants and the like who would prefer to access such networks without being tethered to a telephone line.

There still is no widely available satisfactory solution for providing low cost, high speed access to the Internet, private intranets, and other networks using the existing cellular wireless infrastructure. This situation is most likely an artifact
20 of several unfortunate circumstances. For one, the typical manner of providing high speed data service in the business environment over the wireline network is not readily adaptable to the voice grade service available in most homes or offices. Such standard high speed data services also do not lend themselves well to efficient transmission over standard cellular wireless handsets. Furthermore, the existing
25 cellular network was originally designed only to deliver voice services. As a result,

- 2 -

the emphasis in present day digital wireless communication schemes lies with voice, although certain schemes such as IS-95B do provide some measure of asymmetrical behavior for the accommodation of data transmission. For example, the data rate on an IS-95B forward traffic channel can be adjusted in increments
5 from 1.2 kbps up to 9.6 kbps for so-called Rate Set 1 and in for increments from 1.8 kbps up to 14.4 kbps for Rate Set 2. On the reverse link traffic channel, however, the data rate is fixed at 4.8 kbps.

Existing systems therefore typically provide a radio channel which can accommodate maximum data rates only in the range of 14.4 kilobits per second
10 (kbps) at best in the forward direction. Such a low data rate channel does not lend itself directly to transmitting data at rates of 28.8 or even 56.6 kbps that are now commonly available using inexpensive wireline modems, not to mention even higher rates such as the 128 kbps which are available with Integrated Services Digital Network (ISDN) type equipment. Data rates at these levels are rapidly
15 becoming the minimum acceptable rates for activities such as browsing web pages. Other types of data networks using higher speed building blocks such as the Digital Subscriber Line (xDSL) service are also now coming into use in the United States.

Although such networks were known at the time that cellular systems were originally deployed, for the most part, there is no provision for providing higher
20 speed data services over cellular network topologies. Unfortunately, in wireless environments, access to the channels by multiple subscribers is expensive and there is competition for them. Whether the multiple access is provided by the traditional Frequency Division Multiple Access (FDMA) using analog modulation on a group of radio carriers, or by newer digital modulation schemes the permit sharing of a
25 radio carrier using Time Division Multiple Access (TDMA) or Code Division Multiple Access (CDMA), the nature of the radio spectrum is that it is a medium that is expected to be shared. This is quite dissimilar to the traditional environment for data transmission, in which the wireline bandwidth is relatively wide, and is therefore not typically intended to be shared.

30 CDMA type multiple access schemes are generally thought to, in theory, provide the most efficient use of the radio spectrum. CDMA schemes only work

- 3 -

well, however, when the power levels of individual transmissions are carefully controlled. Present day CDMA wireless systems such as IS-95B use two different types of power control on the uplink in order to ensure that a signal from a given subscriber unit arriving at the base station does not interfere in a disruptive manner with the signals arriving from other subscriber units. In a first process, referred to as open loop power control, a rough estimate of the proper power control level is established by the mobile subscriber unit itself. In particular, after a call is established and as the mobile moves around within a cell, the path loss between the subscriber unit and the base station will continue to change. The mobile continues to monitor the receive power and adjust its transmit power. In particular, the mobile measures a power level on the forward link signal as received from the base station and then sets its reverse link power accordingly. Thus, for example, if the receive power level is relatively weak, then the mobile assumes that it is relatively distant from the base station and increases its power level. The converse is true, in that a signal received at a relatively high level indicates that the mobile is relatively close to the base station and therefore should be transmitting with reduced power.

Since the forward and reverse links are on different frequencies, however, open loop power control is inadequate and too slow to compensate for fast Rayleigh fading. In other words, since Rayleigh fading is frequency dependent, open loop power control alone cannot compensate for it completely in CDMA systems.

As a result, closed loop power control is also used to compensate for power fluctuations. In the closed loop process, once the mobile obtains access to a traffic channel and begins to communicate with the base station, the base station continuously monitors the received power level on the reverse link. If the link quality begins deteriorating, the base station sends a command to the mobile via the forward link to increase its power level. If the link quality indicates excess power on the reverse link, the base station commands the mobile unit to power down.

In the IS-95B standard, the base station sends such power control commands to the mobile using a specially encoded message sent on a forward link traffic channel. These embedded messages contain power control commands in the form of so-called power control bits (PCBs). The amount of power increase and

- 4 -

power decrease per each bit is nominally specified at +1dB and -1dB. The response of the mobile to these power control bits is typically expected to be very fast in order to compensate for fast Rayleigh fading. For this reason, these bits are directly sent over the traffic channel. In particular, certain selected bits from the
5 baseband stream are inserted or "punctured" into the traffic stream to provide a separate power control subchannel at a rate of 800 bits per second. The mobile unit thus continuously receives power control bits every 1.25 ms via such bit "puncturing".

10 SUMMARY OF THE INVENTION

Problem Statement

There recently have been developed certain optimizations of CDMA systems for data transmission. These systems use certain coded phase channel allocation schemes that take away coded phase channels when they are not in use
15 and then reassign them to provide more efficient use of the radio spectrum. Ideally, coded phase channels may be allocated as rapidly as possible to different connections while minimizing radio frequency signaling needed. However, a virtual connection must remain open between each mobile unit and the base station whether a coded phase channel is in use or not. Otherwise, it is necessary to
20 reacquire synchronization, for example, each time that a channel is allocated or deallocated from a particular connection.

Unfortunately, especially for the case of attempting to implement the closed loop power control signaling, there is no active traffic channel in which to embed power control bits every 1.25 milliseconds (ms). It would be impractical to have to
25 reacquire the proper power level each time that a new code phase channel is allocated.

Accordingly, the invention provides a method for use in a base station for providing power control over dynamically assigned reverse link channels, the method comprising: allocating a reverse link channel to a code division multiple
30 access (CDMA) user device; dividing the reverse link channel into multiple subchannels; maintaining the transmit power level for the reverse link channel by sending a maintenance signal for each subchannel at a rate sufficient to maintain a

- 5 -

code phase lock between the user device and the base station; receiving a message from the CDMA user device over the reverse link channel, wherein the CDMA user device is powered on but not actively sending data; determining a link quality metric for the received message; and transmitting a power control bit and a grant
5 on a forward link channel in response to the received message to adaptively control the transmit power level and data rate of the CDMA user device.

The invention further provides a method for use in a code division multiple access (CDMA) user device for providing power control over dynamically assigned reverse link channels, the method comprising: receiving an allocated
10 reverse link channel from a base station, the reverse link channel divided into a plurality of subchannels; transmitting a message to the base station over the reverse link channel, wherein the CDMA user device is powered on but not actively sending data; and receiving a power control bit and a grant on a forward link channel from the base station in response to the transmitted message and based on
15 a link quality metric of the transmitted message, the power control bit for each subchannel received at a rate sufficient to maintain a code phase lock between the user device and the base station; and adaptively controlling and maintaining the transmit power level and data rate of the CDMA user device using the received power control bit and the grant.

20 The invention still further provides a base station comprising: an antenna; a controller configured to allocate a reverse channel to a code division multiple access (CDMA) user device; wherein the reverse link channel is divided into multiple subchannels; a CDMA transceiver configured to receive a message from the CDMA user device over the reverse link, wherein the CDMA user device is
25 powered on but not actively sending data; wherein the controller is further configured to determine a link quality metric for the received message, and to maintain the transmit power level for the reverse link channel by sending a maintenance signal for each subchannel at a rate sufficient to maintain a code phase lock between the user device and the base station; wherein the CDMA transceiver is
30 further configured to transmit a power control bit and a grant on a forward link channel in response to the received message to adaptively control and maintain the transmit power level and data rate of the CDMA user device.

- 5a -

The invention further provides a code division multiple access (CDMA) user device comprising: an antenna; a CDMA transceiver configured to receive an allocated reverse link channel from a base station and to transmit a message to the base station over the reverse link channel, wherein the CDMA user device is
5 powered on but not actively sending data and wherein the reverse link channel is divided into multiple subchannels; a controller configured to maintain the reverse link channel between the CDMA user device and the base station; wherein the controller is further configured to maintain the transmit power level for the reverse link channel by sending a maintenance signal for each subchannel at a rate
10 sufficient to maintain a code phase lock between the user device and the base station; and wherein the CDMA transceiver is further configured to receive a power control bit and a grant on a forward link channel in response to the transmitted message from the base station to control the transmit power level and data rate of the CDMA user device.

15 The invention further provides a method implemented in a subscriber unit for power control during periods when no traffic channels are allocated, the method comprising: sending an initialization message to a base station; receiving an allocation from the base station for a reverse link maintenance channel; sending periodic heartbeat messages during a standby state, the heartbeat messages sent to
20 the base station over the reverse link to permit the base station to determine a link quality metric for the reverse link signal; receiving a link quality report message having the link quality metric over a paging or a sync channel; calculating a reverse power level based on the link quality report; and setting the reverse power level for the standby state based on the calculated reverse power level.

25 The invention further provides a subscriber unit comprising: circuitry configured to transmit first traffic data to a base station; wherein the circuitry is further configured to receive control information; wherein in response to the subscriber unit not having traffic data to send to the base station, the subscriber unit periodically transmitting a single code channel without traffic data in time
30 intervals; wherein the period for transmitting the single code channel is determined from the received control information; wherein the circuitry is further configured to receive power commands in response to the transmitted single code channel and

- 5b -

adjust a transmission power level of the transmitted single code channel in response to the received power commands; wherein the circuitry is further configured to transmit second traffic data to the base station after the periodically transmitting the single code channel; wherein a transmission power level of the
5 transmitted second traffic data is based on the power commands received in response to the single code channel.

The invention further provides a method comprising: transmitting, by a subscriber unit, first traffic data to a base station; receiving, by the subscriber unit, control information; in response to the subscriber unit not having traffic data to
10 send to the base station, periodically transmitting, by the subscriber unit, a single code channel without traffic data in time intervals; wherein the period for transmitting the single code channel is determined from the received control information; receiving power commands, by the subscriber unit, in response to the transmitted single code channel and adjusting, by the subscriber unit, a
15 transmission power level of the transmitted single code channel in response to the received power commands; transmitting, by the subscriber unit, second traffic data to the base station after the periodically transmitting the single code channel; wherein a transmission power level of the transmitted second traffic data is based on the power commands received in response to the single code channel.

20 It is therefore desirable to maintain the proper power level on the reverse link even as code phase channels are deallocated from a particular connection.

Brief Description of the Invention

The present invention is a technique for implementing a code division multiple access system which dynamically assigns coded traffic channels on a demand basis. The technique maintains a known transmit power level for the reverse link channel equipment
5 even when the subscriber unit has entered a standby mode in which no traffic channels are active.

This is accomplished in the standby mode by having the base station measure certain quality parameters of a maintenance heartbeat signal which is periodically sent on a reverse channel by a subscriber unit when in standby mode.

10 The heartbeat signal is a minimal signal sent at a rate which is only sufficient to maintain code phase lock between the subscriber unit and the base station. The rate at which heartbeat signals are sent depends upon the maximum expected rate of physical movement of the subscriber unit. For example, in systems expected to support walking speed-type mobility, the heartbeat signal need only be sent every few seconds.

15 The link quality parameters are preferably a bit error rate measurement, but may also be a noise level measurement or signal power level measurement.

- 7 -

The link quality information is then sent from the base station to the subscriber unit typically formatted as a link quality report message. The link quality reports are sent on a forward link paging or sync channel to a subscriber unit in standby mode.

- 5 The subscriber unit then uses the link quality information as one parameter to a decision logic circuit or function which ultimately determines the transmit power level for the associated reverse link.

BRIEF DESCRIPTION OF THE DRAWINGS

10 The foregoing and other objects, features and advantages of the invention will be apparent from the following more particular description of preferred embodiments of the invention, as illustrated in the accompanying drawings in which like reference characters refer to the same parts throughout the different views.

15 FIG. 1 is a block diagram of a wireless communication system making use of a bandwidth management scheme according to the invention.

 FIG. 2 is a diagram showing how subchannels are assigned within a given radio forward link frequency (RF) channel.

 FIG. 3 is a diagram showing how subchannels are assigned within a given reverse link RF channel.

20 FIG. 4 is a state diagram for a link quality messaging scheme according to the invention.

DETAILED DESCRIPTION OF A PREFERRED EMBODIMENT

25 Turning attention now to the drawings more particularly, FIG. 1 is a block diagram of a system 100 for providing high speed data and voice service over a wireless connection by seamlessly integrating a digital data protocol such as, for example, Integrated Services Digital Network (ISDN), with a digitally modulated wireless service, such as Code Division Multiple Access (CDMA).

30 The system 100 consists of two different types of components, including subscriber units 101-1, 101-2, ..., 101-u (collectively, the subscriber or mobile units 101) and one or more base stations 170. The subscriber units 101 and base stations

- 8 -

170 cooperate to provide the functions necessary in order to provide wireless data services to a portable computing device 110 such as a laptop computer, portable computer, personal digital assistant (PDA) or the like. The base station 170 also cooperates with the subscriber units 101 to permit the transmission of data between
5 the subscriber unit and the Public Switched Telephone Network (PSTN) 180.

More particularly, data and/or voice services are also provided by the subscriber unit 101 to the portable computer 110 as well as one or more other devices such as telephones 112-1, 112-2 (collectively referred to herein as telephones 112). The telephones 112 themselves may in turn be connected to other
10 modems and computers which are not shown in FIG. 1. In the usual parlance of ISDN, the portable computer 110 and telephones 112 are referred to as terminal equipment (TE). The subscriber unit 101 provides the functions referred to as a Network Termination Type 1 (NT-1). The illustrated subscriber unit 101 is in particular meant to operate with a so-called basic rate interface (BRI) type ISDN
15 connection that provides two bearer or "B" channels and a single data or "D" channel with the usual designation being 2B+D.

The subscriber unit 101 itself consists of an ISDN modem 120, a device referred to herein as the protocol converter 130 that performs the various functions according to the invention including spoofing 132 and bandwidth management 134,
20 a CDMA transceiver 140, and subscriber unit antenna 150. The various components of the subscriber unit 101 may be realized in discrete devices or as an integrated unit. For example, an existing conventional ISDN modem 120 such as is readily available from any number of manufacturers may be used together with existing CDMA transceivers 140. In this case, the unique functions are provided
25 entirely by the protocol converter 130 which may be sold as a separate device. Alternatively, the ISDN modem 120, protocol converter 130, and CDMA transceiver 140 may be integrated as a complete unit and sold as a single subscriber unit device 101. Other types of interface connections such as Ethernet or PCMCIA may be used to connect the computing device to the protocol converter 130.

30 The ISDN modem 120 converts data and voice signals between the terminal equipment 110 and 112 to format required by the standard ISDN "U" interface.

- 9 -

The U interface is a reference point in ISDN systems that designates a point of the connection between the network termination (NT) and the telephone company.

The protocol converter 130 performs spoofing 132 and basic bandwidth management 134 functions. In general, spoofing 132 consists of insuring that the
5 subscriber unit 101 appears to the terminal equipment 110, 112 that is connected to the public switched telephone network 180 on the other side of the base station 170 at all times. The bandwidth management function 134 is responsible for allocating and deallocating CDMA radio channels 160, including management of the total
10 the CDMA radio channels 160 in a manner which is also more fully described below.

The CDMA transceiver 140 accepts the data from the protocol converter 130 and reformats this data in appropriate form for transmission through a subscriber unit antenna 150 over CDMA radio link 160-1. The CDMA transceiver
15 140 may operate over only a single 1.2288 MHz radio frequency channel or, alternatively, in a preferred embodiment, may be tunable over multiple ones of such channels.

CDMA signal transmissions are then received and processed by the base station equipment 170. The base station equipment 170 typically consists of
20 multichannel antennas 171, multiple CDMA transceivers 172, and a bandwidth management functionality 174. Bandwidth management 174 controls the allocation of CDMA radio channels 160 and subchannels, in a manner analogous to the subscriber unit 101. The base station 170 then couples the demodulated radio signals to the Public Switch Telephone Network (PSTN) 180 in a manner which is
25 well known in the art. For example, the base station 170 may communicate with the PSTN 180 over any number of different efficient communication protocols such as primary rate ISDN, or other LAPD based protocols such as IS-634 or V5.2.

Continuing to refer to FIG. 1 briefly, bandwidth management 134 and 174 therefore involve having the CDMA transceiver 140 loop back data bits over the
30 ISDN communication path to spoof the terminal equipment 110, 112 into believing that a sufficiently wide wireless communication link 160 is continuously available. However, only when there is actually data present from the terminal equipment to

- 10 -

the wireless transceiver 140 is wireless bandwidth allocated. Therefore, a network layer connection need not allocate the assigned wireless bandwidth for the entirety of the communications session. That is, when data is not being presented upon the terminal equipment to the network equipment, the bandwidth management function
5 134 deallocates initially assigned radio channel bandwidth 160 and makes it available for another transceiver and another subscriber unit 101.

It should also be understood that data signals travel bidirectionally across the CDMA radio channels 160. In other words, data signals received from the PSTN 180 are coupled to the portable computer 110 in a so-called forward link
10 direction, and data signals originating at the portable computer 110 are coupled to the PSTN 180 in a so-called reverse link direction. The present invention involves in particular the manner of implementing a power control mechanism for the reverse link channels.

In order to better understand how bandwidth management 134 and 174
15 accomplish the dynamic allocation of radio channels, turn attention now to FIG.2. This figure illustrates one possible frequency plan for the forward wireless links 160 according to the invention. In particular, a typical transceiver 170 can be tuned on command to any 1.2288 MHz channel within a much larger bandwidth, such as up to 30 MHz. In the case of location in an existing cellular radio frequency bands,
20 these channels are typically made available in the range of from 800 to 900 MHz. For personal communication systems (PCS) type wireless systems, the channels are typically allocated in the range from about 1.8 to 2.0 GigaHertz (GHz). In addition, there are typically two matching bands active simultaneously, separated by a guard band, such as 80 MHz; the two matching bands form the forward and
25 reverse full duplex link.

Each of the CDMA transceivers, such as transceiver 140 in the subscriber unit 101, and transceivers 172 in the base station 170, are capable of being tuned at any given point in time to a given radio frequency channel. It is generally understood that, for example, a 1.2288 MHz radio frequency carrier provides, at
30 best, a total equivalent of about 500 to 600 kbps maximum continuous data rate transmission within acceptable bit error rate limitations.

- 11 -

However, to make more efficient use of the available bandwidth, each 1.2288 MHz radio channel on the reverse link is divided into a relatively large number of subchannels. In the illustrated example, the bandwidth is divided into sixty-four (64) subchannels 300, each providing an 8 kbps data rate. A given
5 subchannel 300 is physically implemented by encoding a transmission with one of a number of different assignable pseudorandom codes and/or code phases. For example, the 64 subchannels 300 may be defined within a single CDMA RF carrier by using a different code phase for each defined subchannel 300.

As mentioned above, subchannels 300 are allocated only as needed. For
10 example, multiple subchannels 300 are granted during times when a particular ISDN subscriber unit 101 is requesting that large amounts of data be transferred. These subchannels 300 are quickly released during times when the subscriber unit 101 is relatively lightly loaded.

The present invention relates in particular to maintaining the reverse link so
15 that a transmit power level for the subchannels does not need to be reestablished each time that subchannels are taken away and then granted back.

FIG. 3 is a diagram illustrating the arrangement of how the subchannels are assigned on the reverse link. It is desirable to use a single radio carrier signal on the reverse link to the extent possible to conserve power as well as to conserve the
20 receiver resources which must be made available at the base station. Therefore, a single 1.2288 MHz channel 350 is selected out of the available radio spectrum.

A relatively large number, N , such as 1000 individual subscriber units are then supported by using a single long pseudonoise (PN) code in a particular way. First, a number, p , of phases of the code are selected from an available $2^{42}-1$
25 different code phases. The p code phase shifts are then used to provide p subchannels. Next, each of the p subchannels are further divided into s time slots. Therefore, the maximum supportable number of supportable subscriber units, N , is p times s . Use of the same PN code with different phases and time slots provides many different subchannels which permits using a single rake receiver in the base
30 station 104.

In the above mentioned channel allocation scheme, radio resources are expected to be allocated on an as-needed basis. However, consideration must also

- 12 -

be given to the fact that, in order set up a new CDMA channel, a given reverse link channel must normally be given time to not only acquire code phase lock, but also to adapt its transmission to the proper power level. The present invention avoids the need to wait for each channel to accomplish this each time that it is set up, by
 5 several mechanisms which are described more fully below. In general, the technique is to send a maintenance signal at a sufficient rate for each subchannel even when it is in a standby mode; that is, even in the absence of data traffic.

One objective here is to minimize the size of each time slot, which in turn maximizes the number of subscribers that can be maintained in an idle mode. The
 10 size, t , of each time slot is determined by the minimum time that it takes to guarantee phase lock between the transmitter at the subscriber unit and the receiver in the base station. In particular, a code correlator in the receiver must receive a maintenance or "heartbeat" signal consisting of at least a certain number of maintenance bits over a certain unit of time. In the limit, this heartbeat signal is
 15 sent by sending at least one bit from each subscriber unit on each reverse link at a predetermined time, e.g., its designated time slot on a predetermined one of the N subchannels.

The minimum time slot duration, t , therefore depends upon a number of factors including the signal to noise ratio and the expected maximum velocity of
 20 the subscriber unit within the cell. With respect to signal to noise ratio, this depends on

$$E_b / (N_o + I_o)$$

25 where E_b is the energy per bit, N_o is the ambient noise floor, and I_o is the mutual interference from other coded transmissions of the other sub-channels on the reverse link sharing the same spectrum. Typically, to close the link requires integration over 8 chip times at the receiver, and a multiple of 20 times that is typically needed to guarantee detection. Therefore, about 160 chip times are
 30 typically required to correctly receive the coded signal on the reverse link. For a 1.2288 MHz code, T_c , the chip time, is 813.33 ns, so that this minimum integration time is about 130 μ s. This in turn sets the absolute minimum duration of a data bit,

- 13 -

and therefore, the minimum duration of a slot time, t . The minimum slot time of $130\ \mu\text{s}$ means that at a maximum, 7692 time slots can be made available per second for each phase coded signal.

Once code phase lock is acquired, the duration of the heartbeat signal is
 5 determined by considering the capture or locking range of the code phase locking circuits in the receiver at the base station. For example, the receiver typically has a PN code correlator running at the code chip rate. One example of such a code correlator uses a delay lock loop consisting of an early-late detector. A loop filter controls the bandwidth of this loop which in turn determines how long the code
 10 correlator must be allowed to operate before it can guarantee phase lock. This loop time constant determines the amount of "jitter" that can be tolerated in the code correlator, such as about $1/8$ of a chip time, T_c .

In the preferred embodiment, the system 100 is intended to support so-called nomadic mobility. That is, high mobility operation within moving
 15 vehicles typical of cellular telephony is not expected to be necessary. Rather, the typical user of a portable computer who is active is moving at only brisk walking speeds of about 4.5 miles per hour (MPH). At 4.5 MPH, corresponding to a velocity of 6.6 feet per second, a user will move 101 feet in $1/8$ of the $1/1.2288$ MHz chip time (T_c). Therefore, it will take about 101 feet divided by 6.6 feet, or
 20 about 15 seconds for such a user to move a distance which is sufficiently far for him to a point where the code phase synchronization loop cannot be guaranteed to remain locked. Therefore, as long as a complete synchronization signal is sent on a given reverse link channel every 15 seconds, the reverse link loop will therefore be maintained. In practice, it is preferred not to push this to the limit, and a
 25 synchronization heartbeat signal is sent every several seconds.

Fig. 4 is a state diagram showing a set of operations performed by the base station 170 and subscriber units 101. The sequence of states entered into by the base station 170 are generally illustrated on the left hand side of the figure, and the sequence of states for the subscriber unit 101 on the right hand side.

30 In a first state 400, the subscriber 101 is initialized such as by turning on its battery power. The subscriber unit 101 then sends an initialization message to the base station 170. In this initialization state 402, the subscriber performs system

- 14 -

determination, pilot channel acquisition, sync channel acquisition, and other timing functions as specified, for example, by the IS-95B air interface standard. In effect, subscriber 101 determines the type of system in which it is operating, for example, a dual mode CDMA or analog mode, acquires acquisition on the pilot channel by
5 synchronizing its timing circuits, and also does a similar timing function on the sync channel. In addition, an initial default open loop reverse power level may be determined such as by measuring a power level received on a forward link, as is known in the art. If the subscriber 101 can perform all of these tasks within a certain specified period of time, then it may successfully enter a standby mode state
10 403.

After it is initialized, the subscriber unit 101 may inform the base station 170 of its successful completion of such tasks by sending an initialization message 430 to the base station 170. The base station 170 then enters a state 450 where it allocates a reverse link maintenance channel to the particular subscriber 101. This
15 can be done after acknowledging pilot and synchronization, by sending a code phase p and time slot s to be used for this particular subscriber unit in a message. Such a message may be, for example, sent on the forward link paging channel which the subscriber unit 101 continues to monitor during the standby mode state 403.

20 Also while in the standby state 403, once an open loop power level is set, the subscriber 101 periodically enters a state 404 in which a heartbeat message is sent to the base station 170 over the reverse link.

Once the base station 170 receives such a heartbeat message, it enters a state 452 in which it determines a link quality metric for the reverse link signal
25 received from the subscriber unit 101.

Next, in state 454, this reverse link quality metric is sent as a link quality report (LQR) message over the reverse link to the subscriber unit 101. The LQR message is sent over a paging or sync channel since no traffic channel is available during the standby mode.

30 The LQR may, for example, contain eight (8) bits of information. The link quality metric may be a bit error rate, a noise energy level expressed as E_b/N_{01} or a power level.

- 15 -

Upon receiving the LQR, subscriber unit enters state 406 in which it calculates its reverse power level using the received LQR and other information.

The subscriber unit then continues to iterate through states 404 through 407 in order to maintain an appropriate power level while in standby mode, until the
5 subscriber unit receives a message indicating that it is to enter an active mode or otherwise leave standby mode.

Similarly, on the base station side, states 452, 454, and 456 are repeated for each of the standby subscriber units while it is in the idle state.

The heartbeat signal 435 is sent to synchronization message on the assigned
10 maintenance channel at a data rate which need only be fast enough to allow the subscriber unit 101 to maintain synchronization with the base station 170. The duration of the heartbeat signal is determined by considering the capture range of the code phase locking circuits and the receiver circuits and the base station 170.

In a preferred embodiment, the system is intended to support so-called
15 nomadic mobility. That is, the relatively high mobility operation such as within moving vehicles typical of cellular telephony is not expected to be encountered. Rather, the typical user of a portable computer is expected to remain connected only when moving about at brisk walking speed at about 4.5 miles per hour. In this situation, a user will move approximately 100 feet and 1/8 of the chip time at
20 1.2288 MHz. Therefore, it takes about 100 feet divided by 6.6 feet or about 15 seconds for such a user to move a distance which is sufficiently far to a point where a code phase synchronization cannot be guaranteed. Therefore, as long as a complete heartbeat signal and power control word for a given reverse link channel are exchanged every 15 seconds, the reverse link will remain at the closed loop
25 power level desired.

For further information concerning the arrangement of the heartbeat signal, please refer to published International Application No. WO 1999/063682 entitled "Fast Acquisition of Traffic Channels for a Highly Variable Data Rate," filed 26 May 1999, and assigned to the same assignee of the present invention.

30 It can now be understood how the present invention implements closed loop power control in a code division multiple access system that dynamically assigns reverse link traffic channels, even when such traffic channels are not allocated.

- 16 -

This is accomplished by the base station determining link quality measurement based on a reverse link received signal that is received in response to maintenance heartbeat signals. The heartbeat signals are sent in a rate which is only sufficiently fast to maintain code phase lock. In response to this, a link quality report message
5 is sent back to the subscriber unit on the forward link, such as on a paging or sync channel.

Instead of ISDN, other wireline and network protocols may be encapsulated, such as Digital Subscriber Loop (xDSL), Ethernet, or X.25, and therefore may advantageously use the dynamic wireless subchannel assignment
10 scheme described herein.

CLAIMS:

1. A method for use in a base station for providing power control over dynamically assigned reverse link channels, the method comprising:
 - allocating a reverse link channel to a code division multiple access (CDMA) user device;
 - dividing the reverse link channel into multiple subchannels;
 - maintaining the transmit power level for the reverse link channel by sending a maintenance signal for each subchannel at a rate sufficient to maintain a code phase lock between the user device and the base station;
 - receiving a message from the CDMA user device over the reverse link channel, wherein the CDMA user device is powered on but not actively sending data;
 - determining a link quality metric for the received message; and
 - transmitting a power control bit and a grant on a forward link channel in response to the received message to adaptively control the transmit power level and data rate of the CDMA user device.
2. The method of claim 1 wherein the allocated reverse link channel is the only traffic channel allocated to the CDMA user device.
3. The method of claim 1 wherein the transmission rate of the message received from the CDMA user device depends on the maximum expected rate of physical movement of the CDMA user device.
4. The method of claim 1 wherein the link quality metric indicates a bit error measurement.
5. The method of claim 1 wherein the link quality metric indicates a noise level measurement.

- 18 -

6. The method of claim 1 wherein the link quality metric indicates a signal power level measurement.
7. The method of claim 1 wherein the power control bit is transmitted on a forward link paging channel.
8. The method of claim 1 wherein the power control bit is transmitted on a sync channel.
9. The method of claim 1 wherein the power control bit is transmitted on a pilot channel.
10. The method of claim 1 wherein the power control bit controls the transmission power level of the CDMA user device over the reverse traffic channel.
11. The method of claim 1 wherein the base station transmits and receives digital signals over at least one radio frequency channel via radio signals.
12. The method of claim 11 wherein each radio frequency channel comprises a plurality of subchannels wherein a plurality of different codes are assigned for each subchannel.
13. A method for use in a code division multiple access (CDMA) user device for providing power control over dynamically assigned reverse link channels, the method comprising:
 - receiving an allocated reverse link channel from a base station, the reverse link channel divided into a plurality of subchannels;
 - transmitting a message to the base station over the reverse link channel, wherein the CDMA user device is powered on but not actively sending data; and
 - receiving a power control bit and a grant on a forward link channel from the base station in response to the transmitted message and based on a link quality metric of the transmitted message, the power control bit for each subchannel

- 19 -

received at a rate sufficient to maintain a code phase lock between the user device and the base station; and

adaptively controlling and maintaining the transmit power level and data rate of the CDMA user device using the received power control bit and the grant.

14. The method of claim 13 wherein the allocated reverse link channel is the only traffic channel allocated to the CDMA user device.

15. The method of claim 13 wherein the transmission rate of the message transmitted to the base station depends on the maximum expected rate of physical movement of the CDMA user device.

16. The method of claim 13 wherein the link quality metric indicates a bit error measurement.

17. The method of claim 13 wherein the link quality metric indicates a noise level measurement.

18. The method of claim 13 wherein the link quality metric indicates a signal power level measurement.

19. The method of claim 13 wherein the power control bit is received on a forward link paging channel.

20. The method of claim 13 wherein the power control bit is received on a sync channel.

21. The method of claim 13 wherein the power control bit is received on a pilot channel.

22. The method of claim 13 wherein the power control bit controls the transmission power level of the CDMA user device over the reverse traffic channel.

- 20 -

23. The method of claim 13 wherein the CDMA user device transmits and receives digital signals over at least one radio frequency channel via radio signals.

24. The method of claim 23 wherein each radio frequency channel comprises a plurality of subchannels wherein a plurality of different codes are assigned for each subchannel.

25. A base station comprising:

an antenna;

a controller configured to allocate a reverse channel to a code division multiple access (CDMA) user device; wherein the reverse link channel is divided into multiple subchannels;

a CDMA transceiver configured to receive a message from the CDMA user device over the reverse link, wherein the CDMA user device is powered on but not actively sending data;

wherein the controller is further configured to determine a link quality metric for the received message, and to maintain the transmit power level for the reverse link channel by sending a maintenance signal for each subchannel at a rate sufficient to maintain a code phase lock between the user device and the base station;

wherein the CDMA transceiver is further configured to transmit a power control bit and a grant on a forward link channel in response to the received message to adaptively control and maintain the transmit power level and data rate of the CDMA user device.

26. The base station of claim 25 wherein the allocated reverse link channel is the only traffic channel allocated to the CDMA user device.

27. The base station of claim 25 wherein the transmission rate of the message received from the CDMA user device depends on the maximum expected rate of physical movement of the CDMA user device.

- 21 -

28. The base station of claim 25 wherein the link quality metric indicates a bit error measurement.
29. The base station of claim 25 wherein the link quality metric indicates a noise level measurement.
30. The base station of claim 25 wherein the link quality metric indicates a signal power level measurement.
31. The base station of claim 25 wherein the power control bit is transmitted on a forward link paging channel.
32. The base station of claim 25 wherein the power control bit is transmitted on a sync channel.
33. The base station of claim 25 wherein the power control bit is transmitted on a pilot channel.
34. The base station of claim 25 wherein the power control bit controls the transmission power level of the CDMA user device over the reverse traffic channel.
35. The base station of claim 25 wherein the base station transmits and receives digital signals over at least one radio frequency channel via radio signals.
36. The base station of claim 35 wherein each radio frequency channel comprises a plurality of subchannels wherein a plurality of different codes are assigned for each subchannel.
37. A code division multiple access (CDMA) user device comprising:
an antenna;

- 22 -

a CDMA transceiver configured to receive an allocated reverse link channel from a base station and to transmit a message to the base station over the reverse link channel, wherein the CDMA user device is powered on but not actively sending data and wherein the reverse link channel is divided into multiple subchannels;

a controller configured to maintain the reverse link channel between the CDMA user device and the base station; wherein the controller is further configured to maintain the transmit power level for the reverse link channel by sending a maintenance signal for each subchannel at a rate sufficient to maintain a code phase lock between the user device and the base station; and

wherein the CDMA transceiver is further configured to receive a power control bit and a grant on a forward link channel in response to the transmitted message from the base station to control the transmit power level and data rate of the CDMA user device.

38. The CDMA user device of claim 37 wherein the allocated reverse link channel is the only traffic channel allocated to the CDMA user device.

39. The CDMA user device of claim 37 wherein the transmission rate of the message transmitted to the base station depends on the maximum expected rate of physical movement of the CDMA user device.

40. The CDMA user device of claim 37 wherein the link quality metric indicates a bit error measurement.

41. The CDMA user device of claim 37 wherein the link quality metric indicates a noise level measurement.

42. The CDMA user device of claim 37 wherein the link quality metric indicates a signal power level measurement.

- 23 -

43. The CDMA user device of claim 37 wherein the power control bit is received on a forward link paging channel.

44. The CDMA user device of claim 37 wherein the power control bit is received on a sync channel.

45. The CDMA user device of claim 37 wherein the power control bit is received on a pilot channel.

46. The CDMA user device of claim 37 wherein the power control bit controls the transmission power level of the CDMA user device over the reverse traffic channel.

47. The CDMA user device of claim 37 wherein the CDMA user device transmits and receives digital signals over at least one radio frequency channel via radio signals.

48. The CDMA user device of claim 47 wherein each radio frequency channel comprises a plurality of subchannels wherein a plurality of different codes are assigned for each subchannel.

49. A method implemented in a subscriber unit for power control during periods when no traffic channels are allocated, the method comprising:

 sending an initialization message to a base station;

 receiving an allocation from the base station for a reverse link maintenance channel;

 sending periodic heartbeat messages during a standby state, the heartbeat messages sent to the base station over the reverse link to permit the base station to determine a link quality metric for the reverse link signal;

 receiving a link quality report message having the link quality metric over a paging or a sync channel;

 calculating a reverse power level based on the link quality report; and

- 24 -

setting the reverse power level for the standby state based on the calculated reverse power level.

50. The method as in claim 49 wherein the link quality metric includes a bit error rate.

51. The method as in claim 49 wherein the link quality metric includes a noise energy level.

52. The method as in claim 49 wherein the link quality metric includes a power level.

53. The method as in claim 49 further comprising maintaining the reverse power level by performing continued iterations of the method.

54. The method as in claim 49 further comprising:

receiving allocations of subchannels during times when large amounts of data are to be transferred to the subscriber unit;

releasing the subchannels allocated during times when the data transfer amounts are relatively lighter; and

maintaining the reverse link power level during the standby state so that a transmit power level for the subchannels does not need to be reestablished with each allocation and release of subchannels.

55. A subscriber unit comprising:

circuitry configured to transmit first traffic data to a base station; wherein the circuitry is further configured to receive control information; wherein in response to the subscriber unit not having traffic data to send to the base station, the subscriber unit periodically transmitting a single code channel without traffic data in time intervals; wherein the period for transmitting the single code channel is determined from the received control information; wherein the circuitry is further configured to receive power commands in response to the transmitted single code

- 25 -

channel and adjust a transmission power level of the transmitted single code channel in response to the received power commands; wherein the circuitry is further configured to transmit second traffic data to the base station after the periodically transmitting the single code channel; wherein a transmission power level of the transmitted second traffic data is based on the power commands received in response to the single code channel.

56. The subscriber unit of claim 55 wherein each time interval is at least one time slot.

57. The subscriber unit of claim 55 wherein the transmitting second traffic data is in response to receiving a grant from the base station.

58. The subscriber unit of claim 55 wherein the transmitting first and second traffic data is substantially continuous.

59. A method comprising:

transmitting, by a subscriber unit, first traffic data to a base station;

receiving, by the subscriber unit, control information;

in response to the subscriber unit not having traffic data to send to the base station, periodically transmitting, by the subscriber unit, a single code channel without traffic data in time intervals; wherein the period for transmitting the single code channel is determined from the received control information;

receiving power commands, by the subscriber unit, in response to the transmitted single code channel and adjusting, by the subscriber unit, a transmission power level of the transmitted single code channel in response to the received power commands;

transmitting, by the subscriber unit, second traffic data to the base station after the periodically transmitting the single code channel; wherein a transmission power level of the transmitted second traffic data is based on the power commands received in response to the single code channel.

- 26 -

- 60. The method of claim 59 wherein each time interval is at least one time slot.
- 61. The method of claim 59 wherein the transmitting second traffic data is in response to receiving a grant from the base station.
- 62. The method of claim 59 wherein the transmitting first and second traffic data is substantially continuous.

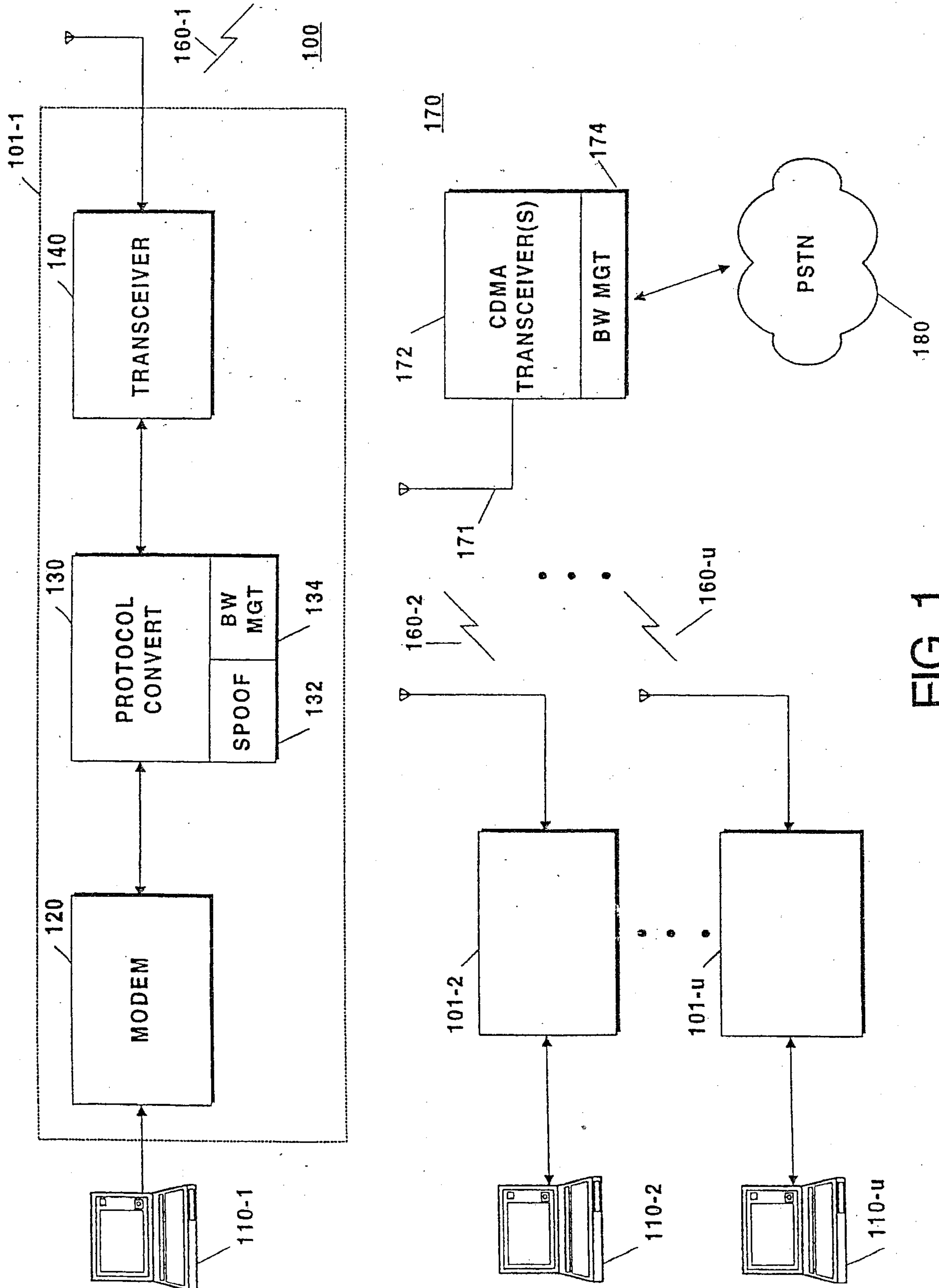


FIG. 1

2/4

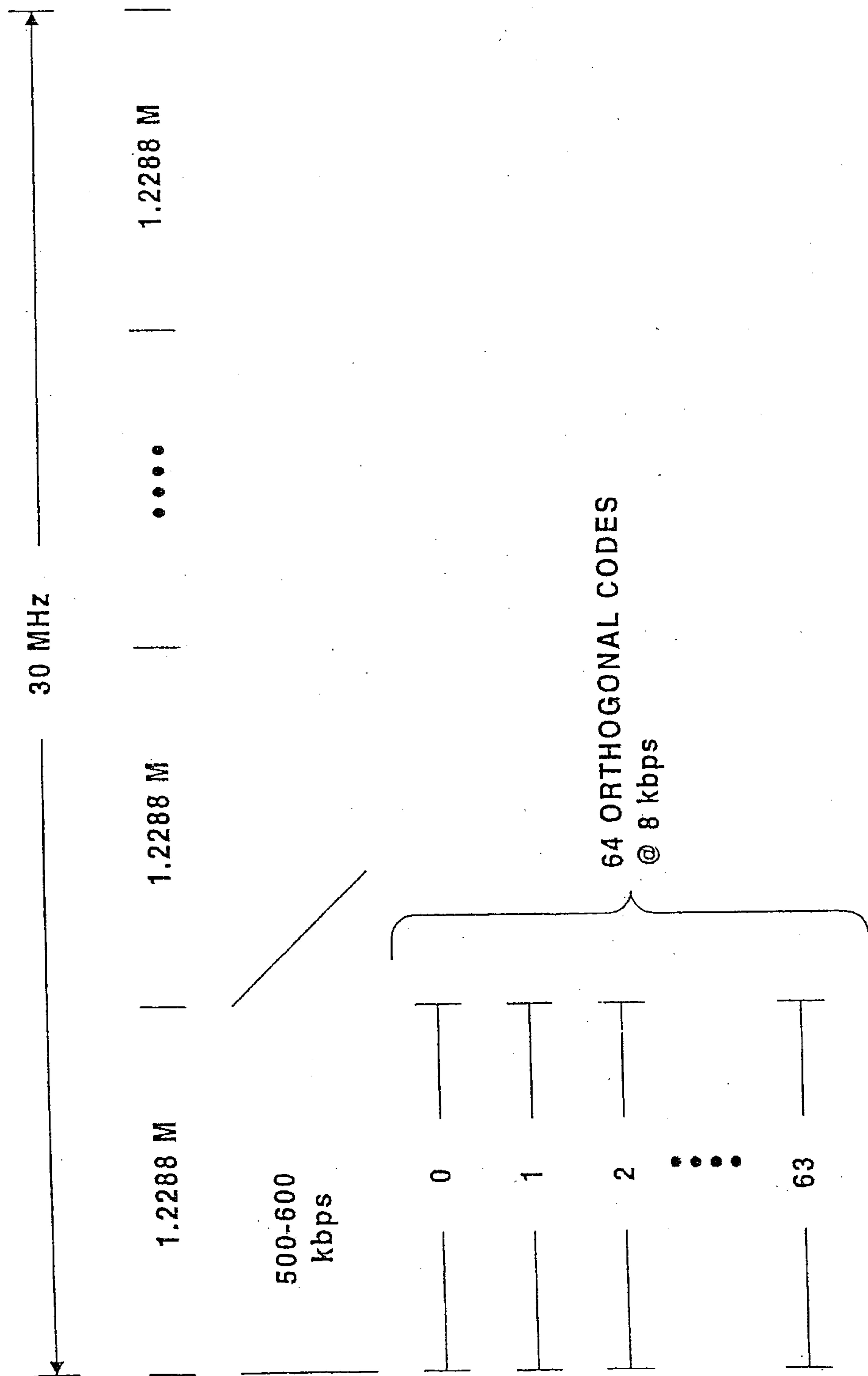


FIG. 2

3/4

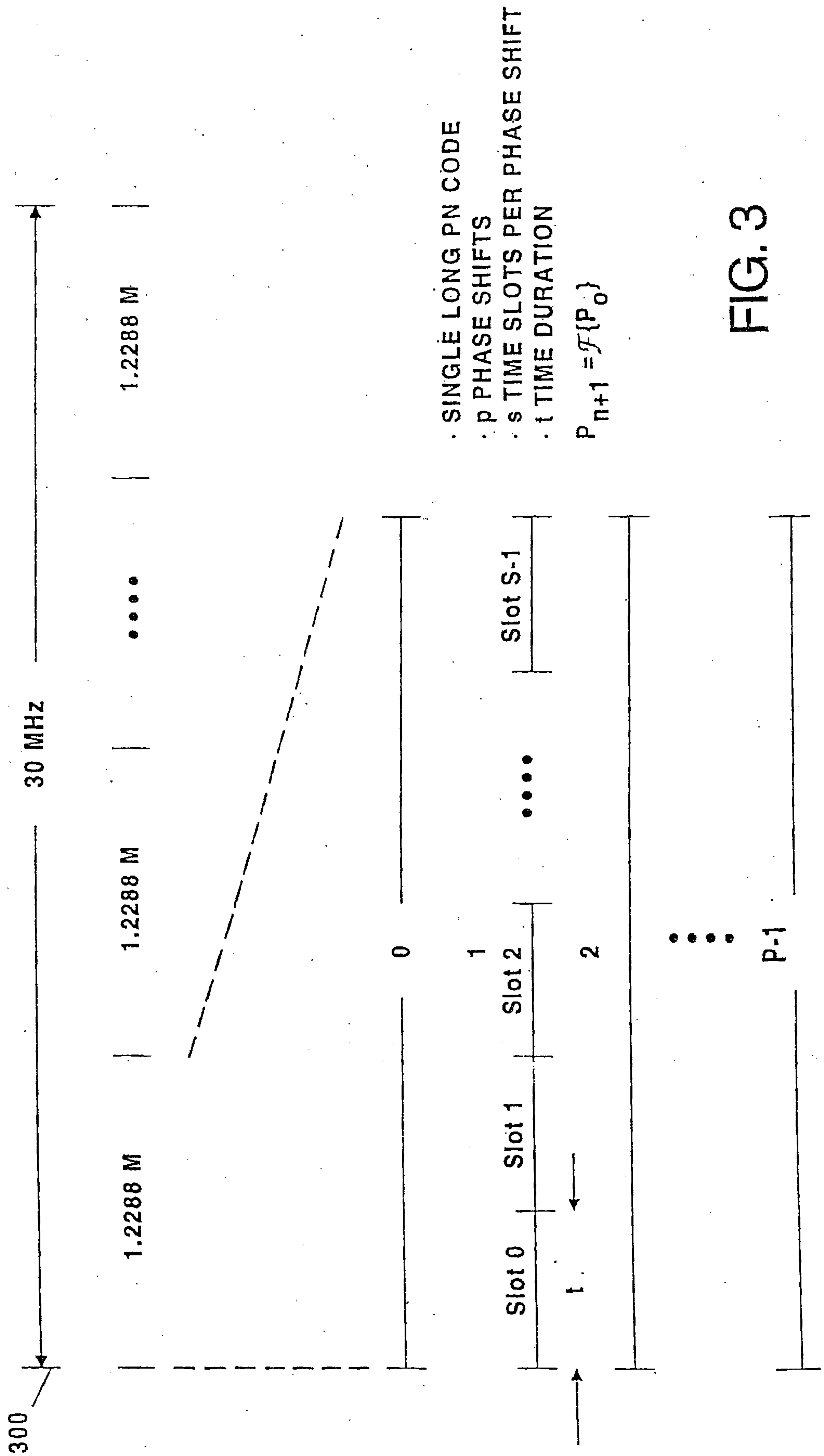


FIG. 3

4/4

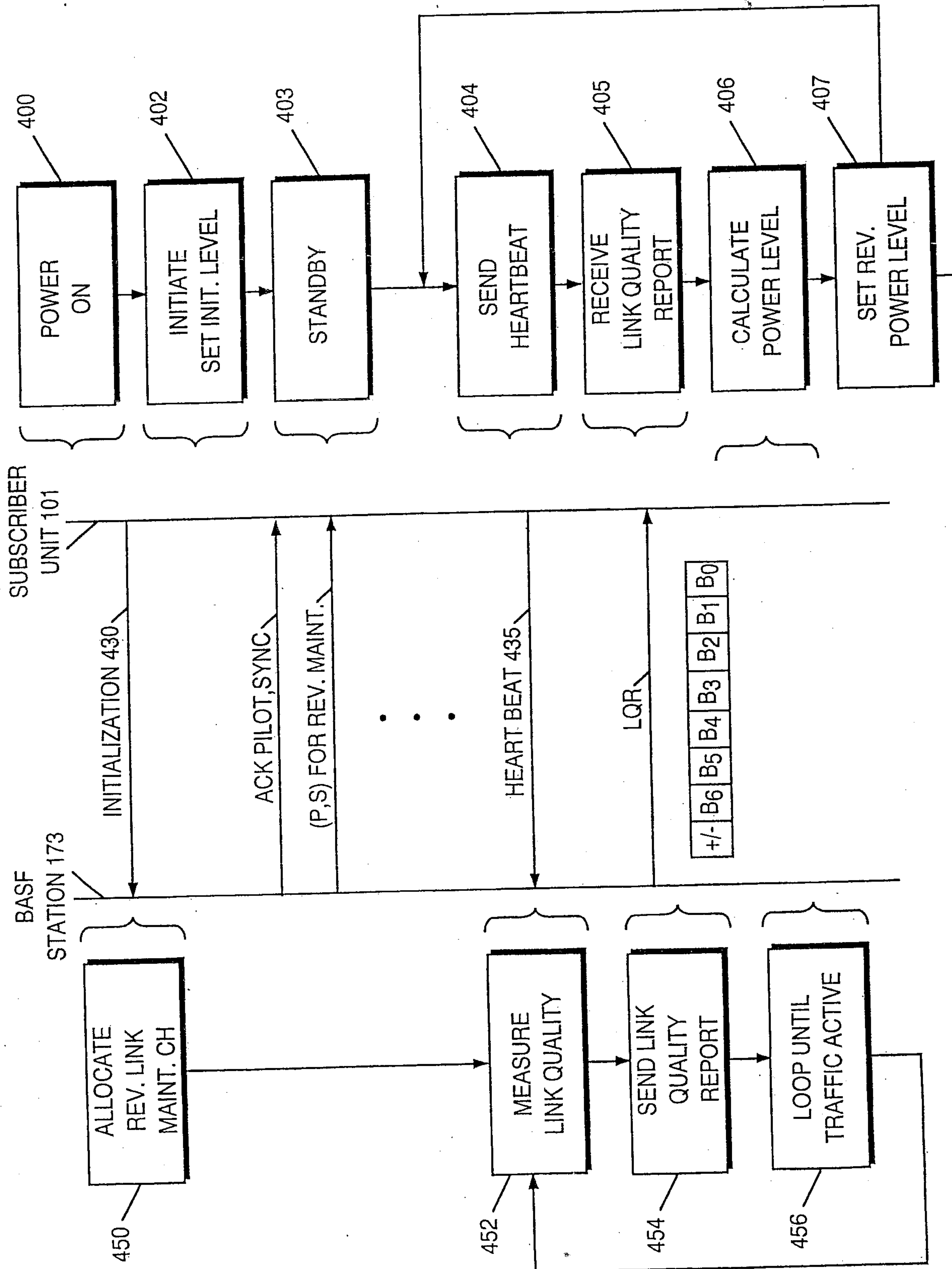


FIG. 4

