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(54) Titre : ARCHITECTURE DE SYSTEME DE COMMUNICATION MULTI-UTILISATEUR A EMETTEURS DISTRIBUES
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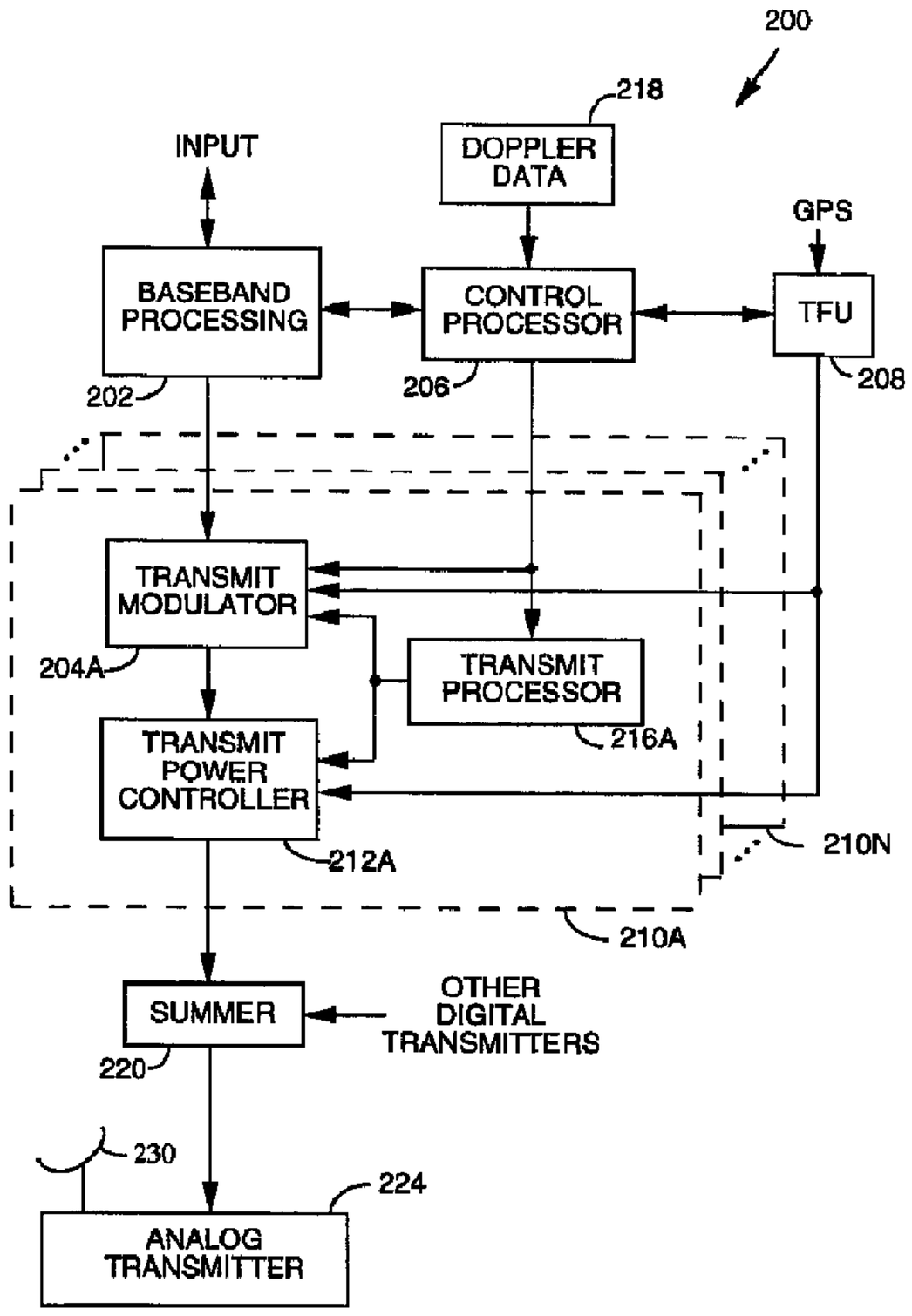

(57) Abrégé/Abstract:
A new signal processing architecture for base stations and gateways (124, 126) used in spread spectrum communication systems (100) that simplifies data transfer, reduces required bus capacity, and does not require special synchronization of signals that are to

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(57) Abrégé(suite)/Abstract(continued):
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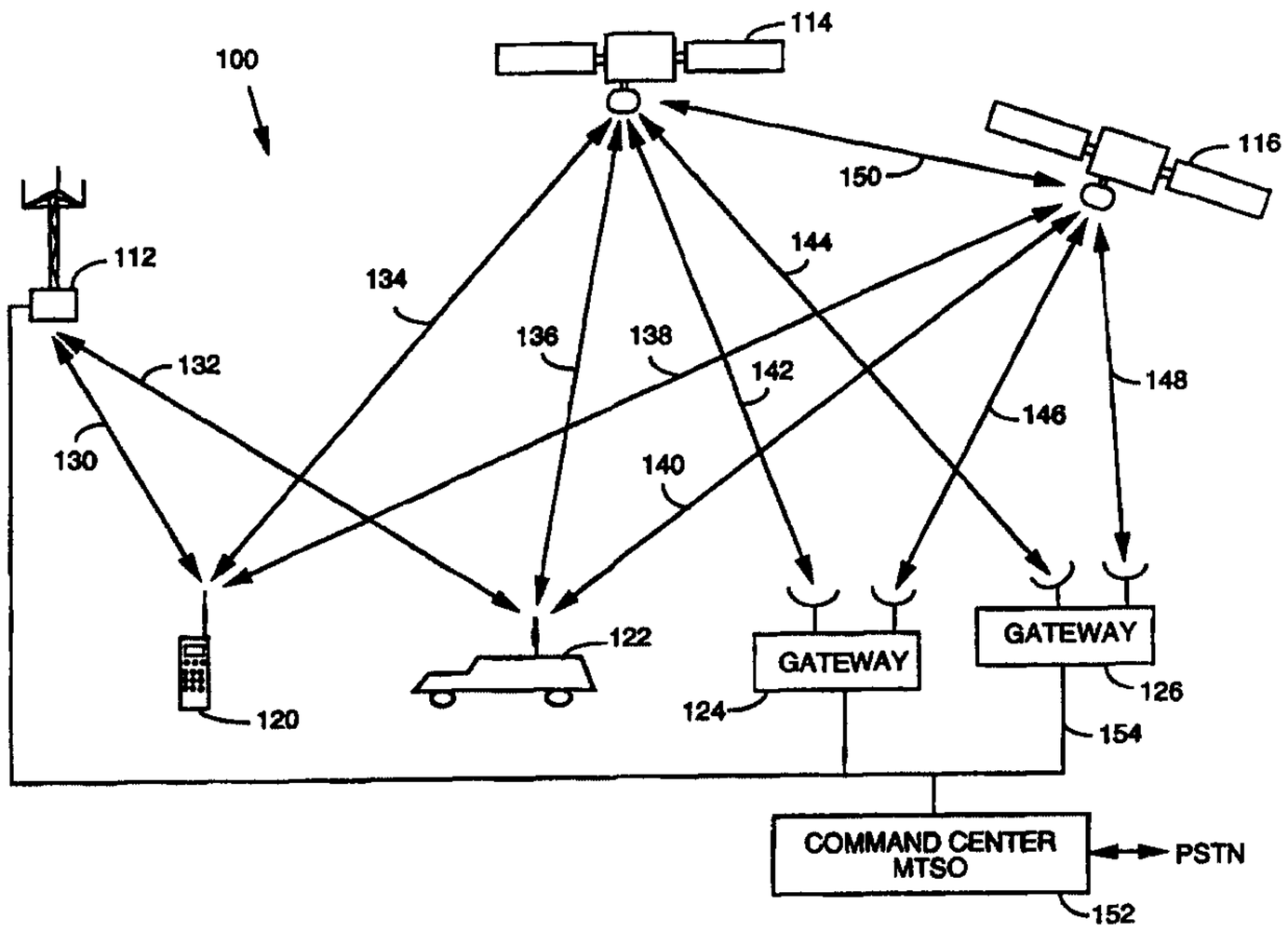
(54) Title: A MULTI–USER COMMUNICATION SYSTEM ARCHITECTURE WITH DISTRIBUTED TRANSMITTERS

(57) Abstract

A new signal processing architecture for base stations and gateways (124, 126) used in spread spectrum communication systems (100) that simplifies data transfer, reduces required bus capacity, and does not require special synchronization of signals that are to be combined. A series of transmission modules (508_1–508_M) are used to transfer data to corresponding ones of a series of analog transmitters (412_1–412_M) used to form communication circuits for each system user. Each transmission module (508_1–508_M) employs a series of encoders (502_{MR}) and modulators (504_{MS}) to form spread communication signals, using appropriate PN spreading codes. Spread spectrum communication signals from each module (508) for each system user (D), are summed together (510_1–510_M) and transferred to a single analog transmitter (412) associated with that module. The signals being combined are automatically synchronized by common timing signals used for elements within each module. The number of processing elements within each module is such that at least one processing path is available for each user or user channel over which it is desired to transmit information through the connected analog transmitter (412_1–412_M). Data is output from the modules (508_1–508_M) at a greatly reduced transfer rate which can be more easily accommodated using current technology. This is very useful for satellite based communication systems, or high capacity cellular systems, and this system architecture can be accomplished cost effectively using a series of easily manufactured circuit modules.



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A MULTI-USER COMMUNICATION SYSTEM ARCHITECTURE WITH DISTRIBUTED TRANSMITTERS

BACKGROUND OF THE INVENTION

I. Field of the Invention

The present invention relates to multiple access communication systems, such as wireless data or telephone systems, and spread spectrum communication systems using satellites. More specifically, the invention relates to a communication system architecture in which communication signals are transmitted using transmission modules employing connected sets of modulators and spreading elements coupled to respective analog transmitters, to decrease data transfer requirements. The invention further relates to a method of redistributing certain signal modulation functions in a CDMA spread spectrum communication system to decrease data transfer rates.

II. Description of the Related Art

A variety of multiple access communication systems and techniques have been developed for transferring information among a large number of system users. The use of spread spectrum modulation techniques, such as code division multiple access (CDMA), in multiple access communication systems is disclosed in the teachings of U. S. Patent No. 4,901,307, which issued February 13, 1990 under the title "Spread Spectrum Multiple Access Communication System Using Satellite Or Terrestrial Repeaters", and U. S. Patent No. 5691,974, which issued November 25, 1997 under the title "Method And Apparatus For Using Full Spectrum Transmitted Power In A Spread Spectrum Communication System For Tracking Individual Recipient Phase Time And Energy," which are both assigned to the assignee of the present invention.

These patents disclose wireless communication systems in which a number of generally mobile or remote system users or subscribers employ transceivers to communicate with other system users or desired signal

recipients, such as through a public telephone switching network. The transceivers typically communicate through gateways and satellites, or base stations (also referred to as cell-sites or cells) using code division multiple access (CDMA) spread spectrum type communication signals.

Base stations cover cells, while satellites have footprints on the surface of the Earth. In either system, capacity gains can be achieved by sectoring, or subdividing, the geographical regions being covered. Cells can be divided into "sectors" by using directional antennas at the base station. Similarly, a satellite's footprint can be geographically divided into "beams", through the use of beam forming antenna systems. These techniques for subdividing a coverage region can be thought of as creating isolation using relative antenna directionality or space division multiplexing. In addition, provided there is available bandwidth, each of these subdivisions, either sectors or beams, can be assigned multiple CDMA channels through the use of frequency division multiplexing (FDM). In satellite communication systems, each CDMA channel can be referred to as a "sub-beam" because there may be several of these channels per "beam", or occupying the area covered by a beam.

In a typical spread-spectrum communication system, one or more, generally a set or pair of, preselected pseudonoise (PN) code sequences are used to modulate or "spread" user information signals over a predetermined spectral band prior to modulation onto a carrier signal for transmission as communication signals. PN spreading, a method of spread-spectrum transmission that is well known in the art, produces a signal for transmission that has a bandwidth much greater than that of the data signal. In the base station- or gateway-to-user communication link, PN spreading codes or binary sequences are used to distinguish between signals transmitted by different base stations or over different beams, as well as between multipath signals. These codes are typically shared by all communication signals within a given CDMA channel or sub-beam.

Orthogonal channelizing codes are used to reduce interference and discriminate between different users within a cell or between user signals transmitted within a satellite sub-beam on a forward link. That is, each user terminal has its own orthogonal channel provided on the forward link by

using a unique "covering" orthogonal code. Walsh functions are generally used to implement channelizing codes, with a typical length being on the order of 64 code chips for terrestrial systems and 128 code chips for satellite systems.

In addition, some form of signal diversity is used to reduce the deleterious effects of fading and additional problems associated with relative user, or satellite, movement within a communication system. Generally, three types of diversity are used in spread spectrum communication systems, including time, frequency, and space diversity. Time diversity is obtainable using error correction coding or simple repetition and time interleaving of signal components. A form of frequency diversity is inherently provided by spreading the signal energy over a wide bandwidth. Therefore, frequency selective fading affects only a small part of the CDMA signal bandwidth. Space diversity is provided using multiple signal paths, typically, through different antennas or communication signal beams.

Base stations for terrestrial cellular communication systems typically use six antennas, two per each of three sectors in a sub-divided cell. Some designs plan for using additional antennas and polarization modes, providing additional CDMA channels. Base stations used with satellites, also referred to as gateways or hubs, use an array of transmitters, on the order of 32 or more, connected to one or more antennas to accommodate multiple beams on each carrier frequency. Gateways also provide service to multiple satellites, typically on the order of three or four at any given time. In one exemplary system, on the order of six satellites are used in each of eight orbital planes and even more satellites are contemplated for some systems. In addition, the number of communication channels or circuits per sub-beam in a satellite is on the order of 128 channels rather than the 64 typically found in terrestrial cellular systems. These factors greatly increase the amount of data and signal processing that must be accommodated within a system gateway as opposed to typical base stations.

When information, including voice, in the form of digital data is to be transferred to system users or subscribers by a gateway it is first encoded and interleaved as desired, and then "covered" and "spread" using appropriate

orthogonal and spreading codes. Each data signal is processed by at least one modulator for each analog signal path over which it is to be transferred, for diversity purposes. The spread encoded data is then transferred to one or more analog transmitters where it is up-converted to an appropriate intermediate frequency and used to modulate a carrier waveform to form a desired communication signal.

Each analog transmitter represents one pre-selected diversity signal path for a signal, and multiple user signals are typically transferred through each analog transmitter, at any time. The signals for each analog transmitter are received from an array or number of modulator elements within the gateway, or base station, which are each assigned to process communications for particular users using particular signal path diversities. The signals from several modulators are combined to form a single output waveform for each analog transmitter. This means that data intended for each analog transmitter must be transferred along common busses or cable assemblies connected to the outputs of all modulators. That is, all modulators and analog transmitters are interconnected or connected using one set of common data busses in order to potentially process multiple path (diversity) signals for any given combination of analog transmitter, antenna, satellite, and user.

For current traffic channel data rates found within communication systems, the gateway busses transferring signals between digital modulators and analog transmitters would have to handle on the order of several gigabits-per-second (Gbps) or more. The output of each modulator provides data at rates on the order of 40 megabits-per-second (Mbps). Potentially, signals for up to 128 user channels can be transmitted on each CDMA channel or frequency using from 2 to 64 diversity paths. This results in total data bus transfer rates in excess of 5-10 Gbps (for example, 40 Mbps x 128 x 2). Data transfer rates of this magnitude exceed the current limits of commercially viable bus transfer structures, within reasonable cost and reliability constraints. In addition, cabling and physical interconnection structures for transferring this volume of data among various processing circuit structures also becomes prohibitively complex and potentially unreliable. Higher

capacity terrestrial or cellular base stations will also probably have similar processing or data transfer demands in the future.

The control, switching, timing, and so forth, that must be implemented for this data transfer volume is also prohibitively complex for use in cost effective gateway systems. The relative timing of each user signal being transferred to a given analog transmitter must be synchronized to within less than one-half of the chip interval for the spreading code being used, for all other user signals being transferred to the same analog transmitter, in order to be combined for transmission by a common analog transmitter. Such synchronization requires unduly complex and sophisticated control mechanisms, and impacts signal processing flexibility.

Therefore, it is desirable to reduce the quantity of data that must be transferred from one functional element or stage to another within the architecture of a gateway or base station, especially for satellite systems. It is also desirable to make more efficient use of lower cost modular components to provide for easy implementation of complex signal processing structures in a cost effective manner.

SUMMARY

In view of the above and other problems found in the art relative to processing communication signals in gateways or base stations in spread spectrum communication systems, one purpose of the present invention is to distribute signal processing requirements for modulating orthogonal channels within communication signals to be transmitted from a gateway or base station.

A second purpose of the invention is to decrease the total volume of data per unit time that is transferred along common signal busses between digital and analog signal processing sections of a gateway in a spread spectrum communication system.

Another purpose is to provide a technique that allows for a more cost effective allocation of processing resources in association with each analog transmitter in a gateway.

One advantage of the invention is that it uses spread spectrum and other digital signal processing modules that are very reliable, easy to manufacture, and cost effective to distribute into parallel arrays for use with gateway analog transmitters.

Other advantages of the invention is that it simplifies data transfer, reduces required bus capacity, and does not require special synchronization of signals that are to be combined into a single analog output. The invention reduces data transfer rates on circuit backplanes, and the number of cables, conductors, or other distribution elements required.

These and other purposes, objects, and advantages are realized in a signal processing architecture for use within a base station in a spread spectrum multiple access communication system, such as code division multiple access (CDMA) type wireless telephone/data communication systems. In these systems, users or system subscribers communicate through base stations or satellites and gateways, using different encoded communication signal channels within given carrier frequencies or CDMA channels. Digital data signals intended for transmission to one or more system users are each transferred to one or more of a plurality of transmission modules, each being associated with a corresponding analog output communication path over which data signals are to be transferred. The number of modules to which each user data signal is transferred is equal to the number of analog communication paths over which it is desired to transfer a given user data signal.

Within each transmission module, the digital data signals are received and encoded, and generally also interleaved, to produce encoded data symbols. The encoded data symbols are then also spread or spread spectrum modulated using at least one preselected pseudorandom noise (PN) spreading code, to form spread communication signals. The outputs for each of a plurality of spread spectrum modulators in each each module are summed together and transferred to a single analog transmitter associated with the transmission module. The analog transmitter forms part of a given analog communication signal output path. This produces a single spread

communication signal or channel at a preselected carrier frequency for each module and corresponding analog transmitter.

The transmission modules are defined by or each comprise an encoding and/or interleaving section, and a modulation or channelizing and spreading section. An array of encoders, and when desired corresponding interleavers, form the encoding section, while an array of spread spectrum modulators form the modulation section.

In some embodiments, there are an equivalent number of interleavers and modulators. However, in other embodiments some predetermined degree of time sharing for these elements can be employed. In these configurations, a preselected number of encoders and/or interleavers are used which is less than the total number of user channels to be accommodated by the analog transmitter. The number corresponding spread spectrum modulators is generally larger than the number of encoders and/or interleavers, but may still be less than the total number of users or user channels. Multiplexing of signals may be used in some configurations.

User data or information to be transmitted to one or more users is received and encoded by the encoding section, and the resulting encoded data is processed in the spreading section to generate spread data symbols for each diversity path for each user. The number of processing elements, primarily encoders and spreading elements, within each module is such that at least one processing path is available for each user or user communication channel over which it is desired to transmit information through using a given analog transmitter. The invention allows a large degree of modular construction and circuit integration for purposes of cost reduction and reliability.

In further embodiments of the invention, the encoded data symbols for each analog communication path intended for a given user are covered with one of a plurality of orthogonal functions. The same function is used for each signal transferred on each analog communication path for a given user. Orthogonal code transformers or transformation circuits are also disposed in the transmission modules and work with the spreading sections to perform orthogonal transformations or mappings on encoded data symbols. This

generates representative orthogonal user channel data for each user channel operating through a corresponding analog transmitter. Walsh functions are generally used for the orthogonal functions.

In still further embodiments of the invention, the modulation modules spread each of the digital communication signals using preselected in-phase (I) and quadrature (Q) phase pseudorandom noise (PN) code sequences for the particular communication system, with off-sets or time shifts as appropriate. These preselected pseudonoise (PN) sequences are also used to demodulate the in-phase and quadrature signal components when the signals are received by intended recipients.

In this manner, a number of communication or user information signals are transmitted over one or more diversity transfer paths for multiple system users using analog transmitters associated with transmission modules that encode, interleave, and spread the signal, which are transmitted on at least one carrier frequency. The analog transmitters convert digital communication signals to analog communication signals at predetermined sampling rates.

The present invention is very useful for reducing the complexity of signal transfer structures in gateway type base stations which are communicating with at least one satellite based repeater to transfer the communication channel signals to user terminals within the communication system from analog transmitters. This is especially useful where there are at least two satellites in communication with the gateway at any given time.

According to one aspect of the present invention, there is provided a method of transmitting signals in a

communication system in which separate user information signals are communicated using common carrier communication signals, said method comprising: receiving digital user data signals intended for transmission to one or more users in said system, comprising: transferring each user data signal to a plurality of transmission modules, each module being associated with a corresponding one of a plurality of analog communication paths over which data signals are to be transferred, the total number of modules to which each user data signal is transferred being one module for each of the plurality of analog communication paths over which it is desired to transfer said user data signal; processing each user data signal in each transmission module to which it is transferred to produce a respective user communication signal; for each transmission module summing user communication signals to be transferred over the associated analog communication path to form a single common communication signal for that transmission module; and transferring each common communication signal to a respective single analog transmitter associated with that transmission module; wherein: said analog transmitter is one of a series of analog transmitters.

According to another aspect of the present invention, there is provided apparatus for transmitting signals in a communication system in which separate user information signals are communicated using common carrier communication signals, said apparatus comprising: means for receiving digital user data signals intended for transmission to one or more users in said system, wherein said apparatus further comprises: a plurality of transmission modules, each module being associated with a corresponding one of a plurality of analog communication paths over which data signals are to be transferred, the

total number of modules to which each user data signal is transferred being one module for each analog communication path over which it is desired to transfer said user data signal; means for transferring each user data signal to said plurality of transmission modules; means for processing each user data signal in each transmission module to which it is transferred to produce a respective user communication signal; for each transmission module, means for summing user communication signals to be transferred over the associated analog communication path to form a single common communication signal for that transmission module; and means for transferring each common communication signal to a respective single analog transmitter associated with that transmission module; wherein: said analog transmitter is one of a series of analog transmitters.

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 like elements throughout and wherein:

FIG. 1 illustrates an exemplary wireless communication system;

FIG. 2 illustrates exemplary gateway modulation and signal transmission apparatus for the wireless communication system of FIG. 1;

FIG. 3 illustrates exemplary modulation circuitry useful for constructing the transmitter modules shown in the apparatus of FIG. 2;

FIG. 4a illustrates a typical gateway architecture using multiple independent data modulators, combiners, and analog transmitters;

FIG. 4b illustrates a more general form of the gateway architecture of FIG. 4a;

FIG. 5a illustrates a new gateway architecture using multiple distributed data processing and transmission modules;

FIG. 5b illustrates a more general form of the gateway architecture of FIG. 5a; and

FIG. 6 illustrates a multiple distributed transmission module architecture using packet switching.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

The present invention provides a new signal processing architecture for base stations and gateways used in spread spectrum communication systems. The method and apparatus of the present invention transfers data signals intended for each of a series of analog transmitters, used to form communication circuits or links for system users, to transmission modules associated with each analog transmitter. Each transmission module has a series or set of signal modulators which can be assigned to each of the signals to be accommodated by a single corresponding analog transmitter. The signals are first encoded and interleaved as desired by encoders connected in series with each modulator and then modulated using appropriate PN spreading codes. Common timing signals or controls are used for each set of modulators within each transmission module, or assigned to a given analog transmitter, resulting in automatically synchronized modulated data signals. These signals can be easily summed or combined. The final combined signal is then introduced into the associated analog transmitter for transmission to system users.

Data is output from digital signal processing stages within a gateway at a reduced bit rate which can be more easily accommodated or manipulated using current technology. Data provided from this processing level is more readily transferred to a series of encoders at lower data rates than traditional encoded/interleaved/spread data symbols for a large number of outbound communication signals. This is very useful for satellite based communication systems, or higher capacity cellular systems. The transmission layers of this system architecture can be accomplished cost effectively using a series of easily manufactured circuit modules.

An exemplary wireless communication system, such as a wireless telephone system, in which the present invention is used is illustrated in FIG. 1. A communication system **100** illustrated in FIG. **1** uses spread spectrum modulation techniques in communicating between communication system remote or mobile user terminals and system gateways or base stations. In the portion of the communication system illustrated in FIG. **1**, one base station **112** and two satellites **114** and **116**, and two associated gateways or hubs **124** and **126** are shown for effecting communications with two user terminals **120** and **122**.

User terminals **120** and **122** each have or comprise a wireless communication device such as, but not limited to, a cellular telephone. Typically, such units are either hand-held or vehicle mounted as desired. Other wireless devices are also contemplated such as message receivers and data transfer devices (e.g., portable computers, personal data assistants, modems, fax machines). Here, user terminal **120** is illustrated as a portable handheld telephone. While these user terminals are discussed as being mobile, it is also understood that the teachings of the invention are applicable to fixed units or other types of terminals where remote wireless service is desired. This type of service is particularly relevant to establishing communication links in many remote areas of the world otherwise lacking a communications infrastructure. This includes for example, fixed stations or phones, pay phones, wireless local loop services, or remote data retrieval or analysis devices and equipment. The latter being useful where extremely remote, or inhospitable or harsh environments are involved.

The terms base station, gateway, and hub are sometimes used interchangeably in the art, with gateways generally understood as comprising specialized base stations that direct communications through satellites. User terminals are also referred to as subscriber units, mobile stations, or simply "users," "mobiles," or "subscribers" in some communication systems, depending on preference.

In FIG. 1, some possible signal paths are illustrated for communications, communication links, or "circuits" being established between user terminals **120** and **122** and base station **112**, or through satellites **114** and **116** to one or more gateways or centralized hubs **124** and **126**. The base station-user terminal portions of communication links between base station **112** and user terminals **120** and **122** are illustrated by lines **130** and **132**, respectively. The satellite-user portions of communication links between gateways **124** and **126** and user terminals **120** and **122** through satellite **114** are illustrated by lines **134** and **136**, respectively. The satellite-user portions of communication links between gateways **124** and **126** and user terminals **120** and **122** through satellite **116** are illustrated by lines **138** and **140**, respectively. The gateway-satellite portions of these communication links are illustrated by a series of lines **142**, **144**, **146**, and **148**. The arrowheads on these lines illustrate exemplary signal directions for each communication link, as being either a forward or a reverse link, only for purposes of clarity and not as any limitation. In some configurations, it may also be possible to establish direct satellite-satellite communications such as over a link indicated by line **150**.

As seen in FIG. 1, communication system **100** generally uses one or more system control centers and switch network **152**, also referred to as a Mobile Telephone Switching Office (MTSO) in cellular systems, or a Ground Operations and Control Center (GOCC) in satellite communications systems. System controller **152** typically includes interface and processing circuitry for providing system-wide control for gateways, satellites, or base stations, to maintain system-wide traffic control and signal synchronization, such as for PN or orthogonal code allocation and timing. System controller **152** also controls general routing of telephone calls between public switched telephone networks (PSTN) and gateways, and user terminals. However, each gateway

generally has a PSTN or similar interface for connection to such networks. Communication links **154** that couple system controller **152** to various system gateways or base stations can be established using known techniques such as, but not limited to, dedicated telephone lines, optical fiber links, or microwave or dedicated satellite communication links.

While only two satellites are illustrated in FIG. **1**, the communication system generally employs multiple satellites **114** and **116** traversing different orbital planes. A variety of multi-satellite communication systems have been proposed with an exemplary system employing on the order of 48 or more satellites, traveling in eight different orbital planes in Low Earth Orbit (LEO). However, those skilled in the art will readily understand how the teachings of the present invention are applicable to a variety of satellite system, gateway, or base station configurations, including other orbital distances and constellations.

It is contemplated for this example that base station **112** provides service over one individual geographic region or "cell", while multiple beams from satellites **114** and **116** are directed to cover other generally non-overlapping respective geographic regions. Generally, multiple beams at different frequencies, also referred to as CDMA channels, "sub-beams", or FDM signals or channels, can be directed to overlap the same region. However, it is readily understood that the beam coverage or service areas for different satellites and cellular base stations may overlap completely or partially in a given region depending on the communication system design and the type of service being offered. For example, each may provide service to different sets of users with different features at different frequencies, and a given user terminal may use multiple frequencies and multiple service providers with overlapping geophysical coverage. Accordingly, at various points in the communication process hand-offs may be made between base stations or gateways servicing the various regions or cells, and diversity may also be achieved between any of these communication regions or devices in some systems.

Space or path diversity is obtained within communication system **100** by providing multiple signal paths through simultaneous links with a mobile

station or user terminal through two or more base stations (or sectors), for terrestrial-based repeater systems, or two or more satellite beams or individual satellites, for satellite systems. That is, path diversity may be obtained by transmitting or receiving communications for a single user using multiple communication paths (antennas or transceivers). Furthermore, path diversity may be obtained by exploiting a multipath environment by allowing a signal arriving over different paths, each with a different propagation delay, to be received and processed separately for each path. If two or more paths are available with sufficient delay differential, say greater than one microsecond, two or more receivers may be employed to separately receive these signals.

Examples of using path diversity in multiple access communication systems are illustrated in U. S. Patent No. 5,101,501 entitled "Soft Handoff In A CDMA Cellular Telephone System," issued March 31, 1992, and U. S. Patent No. 5,109,390 entitled "Diversity Receiver In A CDMA Cellular Telephone System," issued April 28, 1992.

Exemplary spread spectrum type communication systems, such as those discussed in the previously-mentioned patent documents and shown in FIG. 1, use a waveform based on a direct sequence pseudorandom noise (PN) spread-spectrum carrier. That is, a signal to be transmitted is modulated using a pseudorandom noise (PN) binary sequence, or pair of sequences, to achieve a desired spreading effect. PN codes are used to spread the spectrum of all communications signals transmitted over gateway-to-user links to distinguish between signals transmitted over different sub-beams, and to discriminate between multipath signals. Such PN sequences are generally referred to as "spreading" codes.

Each PN sequence consists of a series of "chips" occurring over a preselected PN code period at a frequency much higher than the baseband communications signal being spread. An exemplary chip rate for satellite systems is around 1.2288 MHz or Mcps (Mega-chips per second) with a PN code sequence length of 1024 chips. However, the present invention is also useful with other chip rates and code lengths, as will be apparent to those

skilled in the relevant art. For instance, some terrestrial cellular systems use spreading codes having 2^{15} = 32,678 chips. Each communications system design specifies the type and distribution of spreading codes within a communications system according to criteria well known in the art, such as the total bandwidth desired or allowable signal interference. An exemplary generation circuit for these sequences is disclosed in U. S. Patent No. 5,228,054 entitled *"Power Of Two Length Pseudo-Noise Sequence Generator With Fast Offset Adjustments,"* issued July 13, 1993, which is assigned to the assignee of the present invention.

Several carrier waveforms can be used within communication system **100**, with a typical embodiment employing a sinusoidal carrier that is modulated by a pair of binary PN sequences. In this approach, the sequences are generated by two different PN generators of the same sequence length. One sequence bi-phase modulates an in-phase channel (I Channel) of the carrier and the other sequence bi-phase modulates a quadrature phase or just quadrature channel (Q Channel) of the carrier. The resulting signals are summed to form a composite signal.

In a typical configuration, all signals transmitted by a gateway or base station share the same PN spreading codes for both I and Q channels, with one code being offset in phase from the other. The signals are also encoded or covered with an orthogonal code generated by using Walsh functions, as noted above. The Walsh function size or length used is typically on the order of 128 chips creating up to one hundred and twenty-eight different orthogonal communication signals or forward link channels, for each carrier frequency. One or more of these sequences may be dedicated to pilot, synchronization and paging channel functions (one or more), for each sub-beam (CDMA channel or signal). A signal addressed to a particular user is combined with the PN spreading code or codes and the particular Walsh sequence, or sequence of Walsh chips, assigned by the gateway or communication system controller. An orthogonal function, Walsh code, creates an orthogonal channel in the spread spectrum signal. A user terminal is assigned to employ a particular Walsh code to place the user terminal on a particular orthogonal channel for a communication link. This CDMA channel coding (covering)

on the forward link produces user signals also referred to as traffic signals or traffic channels.

In synchronization, paging, or voice or traffic channels or signals, input data is digitized as necessary, typically encoded, provided with repetition, and then interleaved to provide error detection and correction functions. This allows the communication system to operate with lower signal-to-noise and interference ratios. The repetition process assures that the data or encoded data symbols are transferred at a preselected rate. For example, 4800 bps data symbols could be repeated once, and 2400 bps data symbols four times within a data frame to acquire a desired 9600 bps rate. Techniques for encoding, repetition and interleaving are well known in the art.

The symbols in the error correction encoded symbol stream for each channel are then combined with an assigned orthogonal code sequence or channelizing code, as discussed above, and with the PN spreading codes creating basic digital communications signals. Alternatively, the channelizing and spreading codes may be combined with each other first. The resulting spread symbol streams for each signal are then added together to form a composite waveform.

A single PN code sequence, or pair of sequences, is generally employed for the spreading function in a communications system. Signals for different beams are generally differentiated by providing different time offsets of the basic PN code sequence for each beam relative to its neighbors. That is, user terminals operating within the service area of a given beam share a single PN spreading code time offset, while other beams use different offsets of the same PN code. The basic signal timing established by each gateway for users being served on a given frequency (CDMA channel) is the same. Alternatively, beams can be differentiated by providing different PN code sequences (different polynomial) for each beam or sub-beam.

The resulting PN-spread and orthogonally-encoded output signals are then typically bandpass-filtered and modulated onto an RF carrier. This is typically accomplished by bi-phase modulating a quadrature pair of sinusoids that are summed into a single communications signal. The resulting signals may be further amplified and filtered before being summed with other

forward link signals and radiated by an antenna for the gateway. The filtering, amplification, and modulation operations are well understood in the art. Alternate embodiments may interchange the order of some of these operations for forming a gateway transmitted signal. Additional details on the operation of this type of transmission apparatus are found in U.S. Patent No. 5,103,459, issued April 7, 1992, entitled "System And Method For Generating Signal Waveforms In A CDMA Cellular Telephone".

Exemplary transmission apparatus **200** for use in base stations or gateways used to implement a CDMA communication system is illustrated in further detail in FIG. **2**. In a typical base station, transmitter sections or systems are utilized, each having separate analog transmitters, and sometimes separate antenna, for effecting space diversity transmission. In a gateway, multiple analog transmitters are utilized to achieve frequency diversity, as discussed earlier. That is, in a gateway, each analog transmitter transmits different frequency signals through different satellite beams or sub-beams. As desired, and cost permitting, separate antennas are also used to effect some of this signal transmission. In either case, communication signals are processed substantially the same in each of the modulator sections and then undergo a combination process.

When voice or other data is prepared as an output message or communications signal for a user terminal, user baseband circuitry or processing elements **202** is used to receive, store, process, and otherwise prepare the desired data for transmission. Baseband circuitry **202** comprises apparatus well known in the art and not illustrated in further detail here. Exemplary baseband apparatus includes a variety of known elements such as, but not limited to, vocoders, data modems, analog-to-digital converters, and digital data switching and storage components. Baseband circuitry **202** receives inputs such as voice (analog), digital data, or messages and provides digital data to one or more transmit modulators **204** operating under the control of at least one control processor **206**.

Gateway control processor **206** is electrically coupled to transmit modulators **204** and baseband circuitry **202**. Control processor **206** provides

command and control signals to effect functions such as, but not limited to, signal processing, timing signal generation, power control, handoff control, diversity path selection, and system interfacing. In addition, control processor **206** assigns PN spreading codes, orthogonal code sequences, and specific transmitters or modules for use in user communications. Control processor **206** also controls the generation and power of pilot, synchronization, and paging channel signals. Control processor **206** is implemented using known processing elements such as digital signal processors, microprocessors, computers, and other elements that may operate under software or firmware control.

As shown in FIG. **2**, a time and frequency unit (TFU) **208** can be used to provide timing and frequency reference signals for the various processing elements in the gateway. A TFU typically uses a GPS receiver (not shown) to acquire Universal Time (UT) signals to maintain synchronization across the communications system. Central controllers can also provide such information in some configurations. TFU **208** can be configured to operate with other circuits or circuit elements, such as clock signal generators, to retard or advance the relative timing of (clock) signals, under processor control, by predetermined amounts, as desired.

Signals to be transmitted to user terminals, then, are each electrically coupled to one or more appropriate digital transmitters **210**A-N. A typical gateway uses a number of such transmit transmitters **210** to provide service to many user terminals simultaneously, and for several satellites and beams simultaneously. The number of transmission transmitters **210**A-N used by a gateway is determined by factors well known in the art, including system complexity, number of satellites usually in view, user capacity, degree of diversity chosen, and the like, as discussed elsewhere.

A transmit modulator **204**A-N within each digital transmitter spread-spectrum modulates data for transmission and generally has an output electrically coupled to a digital transmit power controller **212**, which controls the transmission power used for the outgoing digital signal.

The output of each transmit power controller **212** (A-N) is transferred to a summer **220** where it is summed with the outputs from other transmit

power control circuits. Those outputs are signals for transmission to other user terminals at the same frequency and within the same beam as the output of transmit power controller **212** (A-N). The output of summer **220** is provided to an analog transmitter **224** for digital-to-analog conversion, conversion to the appropriate RF carrier frequency, further amplification, filtering, and output to one or more antennas **230** for radiating to satellites and/or user terminals.

While control processor **206** can be electrically coupled directly to the modulator (**204**A-N) or power controller elements (**214**A-N), these elements are sometimes grouped together into transmitters **210**A-N, and each generally comprises a transmitter-specific processor, such as transmit processor **216**A-N, which controls the elements of that digital transmitter. Thus, in a preferred embodiment, control processor **206** is electrically coupled to transmit processor **210**A-N, as shown in FIG. **2**. In this manner, a single control processor **206** can control the operations of a large number of digital transmitters and resources more efficiently. Transmit processor **210** controls generation of, and signal power for, pilot, synchronization, paging signals, and traffic channel signals, and their respective coupling to a power controller **212**A-N

When desired one or more frequency or timing precorrection elements (not shown) may be used by the gateway. Preferably, such elements are used to adjust signal frequency or timing at baseband frequency, using well known techniques. Precorrection of signal parameters is discussed in further detail in Australian Patent No. 719962.

An exemplary signal modulator design for implementing transmission modulators **204**A-N is illustrated in FIG. **3**. In FIG. **3**, an encoder **302** and an interleaver **304** are also shown, which may be part of transmit modulators **216**A-N or form another part of digital transmitters **210**A-N. As discussed later on, transmit modulation typically refers to the orthogonal code covering or channelization, and spreading operations. Prior to application of orthogonal coding or spreading user data signals carried by each channel are

generally convolutionally encoded, with repetition, and interleaved in order to provide error detection and correction functions. The encoding provides data "symbols" which are then processed to form the desired communication signals. Techniques for convolutional encoding, repetition, and interleaving are well known in the art.

The interleaved data symbols may be multiplied by a binary PN_U sequence in a logic element **306**. This sequence is provided by output of a long PN code generator **38**, typically also clocked at the system spreading code chip rate, and then decimated in a decimator **310** to provide a lower rate such as 19,200 bps. The output of the decimator is connected to one input of logic element **306**, here a multiplier, with a second input connected to interleaver **304**. In the alternative, the output of decimator **310** could be connected in series with other elements such as a multiplier **320** to be multiplied by resulting covered data. When Walsh code and PN_U sequences consist of binary '0' and '1' values, instead of '-1' and '1', the multipliers can be replaced by logic elements such as exclusive-OR gates, as is well known.

Code sequence PN_U corresponds to a unique PN phase offset for a known long PN code used in the communication system. This offset sequence is generated by or for each user terminal and can be constructed using a variety of known elements configured for this purpose. A unit address or user ID may also be used to provide additional user terminal identification or security. The format of the PN_U sequence should conform to that of the Walsh codes applied to logic element **306**. That is, either '-1/1' or '0/1' values are used together, and conversion elements can be used on the output of a code generator to convert a '0/1' type sequence to a '1/-1' type sequence, as required. In the alternative, a non-linear encryption generator, such as an encryptor using the data encryption standard (DES), may be utilized in place of PN generator **318** as desired. The PN_U sequence may be either assigned for the duration of a given link or permanently to one unit.

The interleaved data symbols **312** from interleaver **304**, or from the output of logic element **306**, are then orthogonally encoded or covered with an assigned orthogonal code sequence, here a Walsh function or code, supplied by at least one code generator **322**. The code from generator **322** is

multiplied by or combined with the symbol data in a logic element **320**. The orthogonal function is typically clocked in at the same rate as the spreading code chip rate. It is also possible to employ other known elements such as a Fast Hadamard Transformer to perform the orthogonal encoding process. This type of processing is shown in further detail in U. S. Patent Application No. 5,757,767.

The modulator circuitry also includes at least one and generally two PN generators, **330** and **332**, which generate or provide the two different short PN_I and PN_Q spreading codes or code sequences for the In-Phase (I) and Quadrature (Q) channels. This code generation can also form a functional part of one or more control processors or storage elements used in the gateway. In the alternative, these generators could be time shared among several receivers using appropriate interface elements. Exemplary generation circuits for these sequences is well known, and is disclosed in U. S. Patent No. 5,228,054, referred to above. These PN generators can also be responsive to an input signal corresponding to a beam or cell identification signal from the control processor so as to provide a predetermined time delay or offset for the PN sequences. Although only two PN generators are illustrated for generating the PN_I and PN_Q sequences, it is readily understood that many other PN generator schemes may be implemented within the teachings of the invention, as would be known.

The orthogonally covered symbol data **324** output by logic element or multiplier **320** is then combined with or multiplied by the PN_I and PN_Q spreading codes using a pair of logic elements or multipliers **324** and **326**, respectively. The resulting signals are then transferred to appropriate power control and amplification circuitry, transmit power controller **212** and analog transmitter **224**. Here, they are modulated onto an RF carrier, typically by bi-phase modulating a quadrature pair of sinusoids that are summed into a single signal with other traffic channel signals, along with the pilot and any setup channel signals. Summation may be accomplished at several different points in the signal processing such as at baseband or intermediate

frequencies, either before or after combination with the PN sequence associated with the CDMA channel.

A typical overall gateway transmission system design for processing data signals for many users and diversity paths at one time and transmitting them to targeted users or recipients is shown in FIGS. 4a and 4b. FIG. 4a shows a specific data bus structure while FIG. 4b shows a more generalized form including an analog transfer path. In FIGS. 4a and 4b, user data **400** (**400**$_1$-**400**$_D$), that is data intended for a given user, traffic, or communication channel D (1 of 128, D=1,128) is input to the gateway. Data **400**$_D$ is transferred in a predetermined data frame format, with preselected periodicity, to one of a series of encoder/interleaver elements **402** (**402**$_1$-**402**$_D$), where the data is interleaved and encoded. In FIG. 4b, the interleaving portion is omitted as optional for elements **402'** (**402'**$_1$-**402'**$_D$).

The data for each traffic (or other) channel is then modulated in a modulator **404** (**404**$_{11}$-**404**$_{DK}$), there being several such modulators to establish a desired number of K diversity mode signals, signal paths, or circuits for a given user. That is, it is desirable to be able to transmit the signals for a given channel over multiple signal paths (antennas, sub-beams, transmitter paths, etc.) and a typical system could allow for say up to 64 such diversity modes. Therefore, K would typically be as large as 64, although other numbers of modulators can be used depending on known design factors such as a desired maximum amount of diversity allowable, system complexity, cost, and reliability. In this example, there are 64 modulators (K=64) for each user data channel D input (maximum value for D is maximum number of orthogonal codes). This results in a substantially large number of modulators and outputs to control.

Note that these modulators typically reside in digital transmitters as discussed earlier. Here, transmitter controllers and power control elements have been omitted for purposes of clarity in illustration. The modulators can comprise or use several known processing elements including, but not limited to, digital signal processors, which are used to prepare the signal for transmission. While covering and spreading are discussed below and in the example modulation circuti of FIG. 3, for purposes of clarity in explanation, it

should be clear that orthogonal covering or channelizing is not required for operation of the invention, and is not used in some applications. The invention reduces complexity by reorganizing the manner in which data is processed, regardless of the modulation scheme being used (CDMA, spread-spectrum, other).

The outputs from each modulator **404** (**404**$_{11}$-**404**$_{DK}$) are then transferred to input stages of each of the analog transmitters or transmission stages **408** (**408**$_1$-**408**$_M$) employed by the gateway to transmit their respective signals. This transfer occurs over a data bus or a series of known cables, signal conductors, data busses, or other known distribution mechanism, **406**. Bus **406** is generally DxK data words wide, with each word being the number of bits used for each symbol. Again, the total number M of analog transmitters **408**$_M$ depends on known system design factors such as number of antennas, satellites, system complexity, diversity modes being processed, CDMA channels and channel capacity, and so forth. A typical number of analog transmitters **408**$_M$ would be at least 3 (M=3) and more probably on the order of one for each sub-beam (CDMA channel), in one or more beams (frequencies), on possibly 4 or more satellites. A typical satellite communication system might employ 13 sub-beams on or with 1 to 16 beams being transferred by the gateway through 2 to 4 satellites at a time, or a total of 32 to 832 analog transmitters (M=32 to 832) in the gateway. Additional polarization modes and other factors can increase, or decrease, the number of analog transmitters **408**$_M$ employed, as would be known.

Each of the analog transmitters **408** (**408**$_1$-**408**$_M$) uses a signal combining stage or element **410**$_M$ (**410**$_1$-**410**$_M$) and a transmission amplifier or power stage **412** (**412**$_1$-**412**$_M$), here labeled as analog transmitters. Combiner **410** (**410**$_1$-**410**$_M$) combines up to D user channels of modulated data symbols into a single signal for transmission over an analog transfer path **416** (**416**$_1$ - **416**$_M$), which includes an analog transmitter and an antenna **230**, with the maximum value of D based on the number of orthogonal codes used or available, as above. Elements to combine or multiplex signals in a D:1 (here, 128:1) combination or mapping are well known in the art, and not described in further detail

here. Analog transmitters **412** (**412**$_1$-**412**$_M$) are connected to antennas **230** (**230**$_1$-**230**$_M$), the number being dependent upon the system design and gateway design factors well understood in the art. Since each gateway typically has 4 or fewer antennas, although more can be used, several analog transmitters could be connected to an antenna through other coupling and summation elements, devices, or circuits, not shown.

As discussed above, one problem with the typical configuration shown in FIGS. **4**a and **4**b is the overall magnitude of data that is being transferred to generate or form the output signals from analog transmitters **412** (**412**$_1$- **412**$_M$). If a typical 8 bits per symbol sample is used with a two-times (2x) oversampling rate, and a typical 1.288 Mcps chip rate for the PN spreading code in the modulator, on each of an in-phase (I) and quadrature (Q) channel, then there are about 40 Mbps of data on the output of each diversity mode modulator **404**$_{DK}$. Note that in FIG. **4**b the I and Q channels are shown as single common lines for clarity in illustration. However, there are up to 128 user data signals (minus pilot, paging, and synchronization channels with their own data requirements), having from 2 up to 64 diversity modes available to each, which results in data busses trying to transfer on the order of 40 x 128 x (2 to 64) Mbps (10 to 327 Gbps) of data among or to the various analog transmitters. The transfer of this much data is not practical with current systems.

In addition, in order to combine the various channel signals, it can be appreciated that their data frames or encoded and spread data symbols must be synchronized to within less than one-half of the chip timing for the PN spreading codes being used. It is readily seen that on this scale, maintaining that level of synchronization for this number of signals and exercising precise control over the transfer of data are themselves extremely burdensome and impractical tasks. It requires synchronizing a large number of dynamically changing signals with 0.4 microsecond accuracy, which may not be possible in most commercially viable systems, even with the available TFU signals.

The present invention reduces the burden of data transfer, making more cost efficient and reliable transmission stages for gateways possible. This is accomplished by separating certain signal processing functions into

modular groups associated with the individual analog transmitters. By transferring the data to appropriate modules for processing at rates commensurate with the signal processing in a module, the data transfer rates are greatly reduced over that required for conventional processing transfers. The rates used for individual modules or signal processing operations are lower than those required to transfer processed data to all of the analog transmitters at one time. By multiplexing this data transfer such as through the use of packetizing channel data together at a lower data rate, and then transferring it from D inputs to M transmitter elements for processing, the transfer rate is reduced.

This new technique is shown in FIGS. 5a and 5b, which illustrate a new gateway architecture using multiple distributed data transmitters and modular transmission processing elements. In FIGS. 5a and 5b, the data symbols from each user channel **400** (400_1-400_D) are transferred directly over a data bus, cables, or other known distribution mechanism, **506** to a series of transmission stages, sections, devices, or modules **508**. Within each transmitter or transmission module **508** (508_1-508_M), there is an array of encoder/interleavers **502** (502_{11}-502_{MR}) and corresponding modulators **504** (504_{11}-504_{MS}), which are used to process the signals in a manner similar to that previously discussed. Each transmission module **508** of the M modules (M being as before), employ a number of input stages or processing paths equal to the number of channels (R and S, bounded by the orthogonal codes/code length) that can be processed by that transmission module. Assuming the coding structure described above, that would be a maximum of 128 channels, minus pilot channel. Therefore, R and S would be D or less from the above example.

In the illustrated embodiment, each signal transfer or processing path uses an encoder/interleaver 502_R and a modulator 504_S. Although there are up to 128 per transmission module or corresponding transmitter (here N = S = R = 128), they form a more compact interconnected module than used in the previous structure. However, the number of encoder/interleavers 502_R and modulators 504_S used in each transmission module **508** does not have to be

equal to the maximum, or even permanently fixed. That is, a one-to-one correspondence is not required. Fewer elements can be used based on system design characteristics that limit the average number of diversity paths used or data being transferred along a given analog path. System testing or historical data can be used to tailor or adjust this number. In addition, some of these elements can be time shared. In a preferred embodiment, fewer than D encoder/interleavers $\mathbf{502}_R$ are used to serve as input stages for a larger number of modulators $\mathbf{504}_S$. For example, as few as 8 to 10 interleavers may accommodate the signals processed by 32 to 64 modulators, or an even larger ratio could be used. Those skilled in the art will understand how to assign fewer or more elements to accomplish these functions based on a specific communication system design and capacity.

The inputs for encoder/interleavers $\mathbf{502}_R$ and modulators $\mathbf{504}_S$ can also be controlled or assigned in several ways. That is, depending on the number of elements used, each one can have a preassigned channel over which to receive input. In this configuration, encoder/interleaver $\mathbf{502}_1$ always receives data from user or traffic channel 1, $\mathbf{502}_2$ receives from traffic channel 2, and so forth. Modulators $\mathbf{504}_R$ could be assigned in a similar fashion. Where there are fewer encoder/interleavers $\mathbf{502}_S$ than channels, they can be prearranged groups of channels. Alternatively, and more preferably, encoder/interleavers and modulators are used in an order of availability. That is, the first traffic or user data channel is input to the first available interleaver, based on not being in use and some predetermined order of usage across the set of elements. The interleaver outputs would then be transferred to modulators using a similar scheme. Elements such as the control processor or gateway transmit processors can be used to determine the order and location for transfer of these signals

The encoder/interleavers and modulators can be constructed as inexpensive modules that can easily be manufactured and grouped with the analog transmitters in electronic sub-systems for the gateway RF processing sections. In some configurations, the encoder/interleavers and modulators can be combined into single modules, forming encoding modulators tat

perform the entire encoding, interleaving, modulation processing in a single circuit, element, or device. This may require more elements to form a transmission module in this situation, since time sharing of encoders/interleavers would be substantially reduced or eliminated.

The encoder/interleaver and modulator elements may also be capable of being reassigned across the "boundaries" of the transmission modules as shown. That is, these elements are grouped together to form transmission modules based on element task assignments, but not on physical location within a gateway. These elements could be implemented in larger arrays using well known components such as, but not limited to, digital signal processors, microprocessors, encoders, modulator integrated circuits, memory elements, and so forth, which are programmed or connected together using electronic switching elements well known in the art. The switching elements can be used by control elements or processors to select to which analog transmitter the elements or devices they are connected. This can allow reallocation of resources as need for particular analog paths. This further reduces the number of elements needed in some systems based on lower average diversity mode usage. That is, fewer modulators and such need to be reserved for use.

One advantage of the above arrangements is that the input data for each encoder, and, consequently, each analog transmission section, is transferred over bus or mechanism **506** typically at a rate on the order of 9600 bps or less; or whatever is desired in the particular system. Therefore, the main data busses in a gateway can now operate at greatly reduced data transfer rates, are far less complicated or complex, and much simpler to control. In addition, the number of physical inter-connections needed to create this data transfer is greatly reduced as well. It only requires the N channels of input (S where smaller than N) to each of the analog transmitters (M), which can be configured as a D data word wide bus (here, max D=128). The reduction in complexity can also be seen in FIG. **5b** where each user information input is only transferred to some of the analog transmitters, that is, K<M, and all interconnections do not have to be maintained as in FIG. **4a**.

Once the encoded and modulated data for each channel is received at the input to the analog transmitters, the data for each of the user signals is automatically synchronized for combination with the data for other user signals for that transmitter. This is the result of using common clocks and other signals to control each of the processing chains within each transmission module, so that time synchronization is automatically maintained throughout the transmission module processing. This timing control is shown as the TFU/OTHER input, command, or control line in FIG. 5a, which is connected to the TFU, processor circuits discussed above, or other known timing control and clock signal elements.

Since the data symbols are being transferred from D or N (S) elements to M elements, a N-to-M multiplexing or data transposition element can be used to make more efficient use of the data paths between these elements. This is shown in FIG. **6**, where a multiplexing element **600** is used to receive data symbols on a data bus or input lines **602**, and transfer them onto one or more output data busses or lines **604** leading to the various transmission modules **508**. Multiplexing element **600** can be constructed as a packet switching element or packetizer, using techniques and apparatus well understood in the art.

As seen in FIG. **6**, data from each user channel D is transferred to one or more transmission modules **508** using multiplexer/packet element **602**. The data input over bus **602** typically comprises 9600 bps user data plus some additional overhead information to indicate to which transmission modules or paths the data should be transferred. An exemplary embodiment would allocate approximately an additional 50 percent data rate to account for the overhead information. Therefore, transfers on the input side of multiplexer **600** would occur at roughly 9600x1.5 bps or 14400 bps, which is still well below the previous requirements for data transfers in the gateway using a conventional approach.

The output side of multiplexer/packet element **600** transfers signals or data for each user channel **400** (D) to the appropriate transmission modules. Multiplexer/packet element **600** uses the overhead information as to which transmission module or path receives which user data to configure the

output data. The user data transfer occurs by transferring the data from all users intended for each transmission module to one module at a time. This results in a data transfer rate on the order of 9600 bps, with the overhead information removed, times the number of user signals being transferred to each transmission module. The maximum for this latter value is the maximum for N in the present example, resulting in a maximum transfer rate of 9600x128 = 1.22 Mbps. The number of users sending signals to each transmission module is likely to be substantially less than 128 at any given time since that would imply a diversity of M for every user signal (each goes to every one of M transmitters). The lower average value for D on data bus 604, further reduces the transfer rate. This approach further reduces the amount of data that needs to be transferred at any time within the gateway.

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, such as the number and type of antennas and analog transmitters, and the generic principles defined herein may be applied to other embodiments without the use of the inventive faculty. Thus, the present invention is not intended to be limited to the embodiments shown herein but is to be accorded the widest scope consistent with the principles and novel features disclosed herein.

What I claim as my invention is:

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CLAIMS:

1. A method of transmitting signals in a communication system in which separate user information signals are communicated using common carrier communication signals, said method comprising:

receiving digital user data signals intended for transmission to one or more users in said system, comprising:

transferring each user data signal to a plurality of transmission modules, each module being associated with a corresponding one of a plurality of analog communication paths over which data signals are to be transferred, the total number of modules to which each user data signal is transferred being one module for each of the plurality of analog communication paths over which it is desired to transfer said user data signal;

processing each user data signal in each transmission module to which it is transferred to produce a respective user communication signal;

for each transmission module summing user communication signals to be transferred over the associated analog communication path to form a single common communication signal for that transmission module; and

transferring each common communication signal to a respective single analog transmitter associated with that transmission module; wherein:

said analog transmitter is one of a series of analog transmitters.

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2. The method of Claim 1, wherein each transmission module comprises a preselected set of encoders coupled to a preselected set of modulators.

3. The method of Claim 1, wherein said analog transmitters are provided within a gateway type base station and at least one satellite based repeater is employed to transfer said communication channel signals to user terminals within said communication system from said analog transmitters.

4. The method of Claim 3, wherein at least two satellites are in communication with said gateway at any given time.

5. The method of Claim 1, further comprising applying a common timing signal to each element within a given transmission module.

6. The method of Claim 1, further comprising applying a N-to-M multiplexing function of up to N digital data signals before transferring them to M transmission modules.

7. The method of Claim 1, wherein:

said communication system is a spread spectrum communication system and said user information signals are communicated using orthogonally encoded channels on said common carrier communication signals;

said user communication signal is a spread communication signal; and

each said common communication signal is a single spread spectrum communication signal.

8. The method of Claim 1, wherein:

said communication system is a spread spectrum communication system in which said user information signals are communicated using orthogonally encoded channels on said common carrier communication signals; and

said processing comprises modulating said user data signals using preselected pseudorandom noise type code sequences.

9. Apparatus for transmitting signals in a communication system in which separate user information signals are communicated using common carrier communication signals, said apparatus comprising:

means for receiving digital user data signals intended for transmission to one or more users in said system, wherein said apparatus further comprises:

a plurality of transmission modules, each module being associated with a corresponding one of a plurality of analog communication paths over which data signals are to be transferred, the total number of modules to which each user data signal is transferred being one module for each analog communication path over which it is desired to transfer said user data signal; means for transferring each user data signal to said plurality of transmission modules;

means for processing each user data signal in each transmission module to which it is transferred to produce a respective user communication signal;

for each transmission module, means for summing user communication signals to be transferred over the associated analog communication path to form a single common communication signal for that transmission module; and

means for transferring each common communication signal to a respective single analog transmitter associated with that transmission module; wherein:

said analog transmitter is one of a series of analog transmitters.

10. The apparatus of Claim 9, further comprising means for applying a common timing signal to each signal processing-element within a given transmission module.

11. The apparatus of Claim 9, wherein each analog transmission path comprises a corresponding analog transmitter.

12. The apparatus of Claim 9, further comprising means for covering encoded data symbols for each analog communication path intended for a given user with one of a plurality of orthogonal functions, the same function being used for each analog communication path for a given user to generate representative orthogonal user channel data for a user channel operating through a corresponding analog transmitter.

13. The apparatus of Claim 9, further comprising a N-to-M multiplexer connected to receive up to N digital data signals before transferring them to M transmission modules.

14. The apparatus of Claim 9, wherein said analog transmitters are provided within a gateway type base station in a wireless communication system having at least one satellite based repeater and are employed to transfer said communication channel signals to user terminals within said communication system.

15. The apparatus of Claim 14, wherein there are at least two satellites in communication with said gateway at any given time.

16. The apparatus of claim 9, wherein:

said communication system is a spread spectrum communication system;

each transmission module comprises:

a series of encoders for encoding digital data signals received by each transmission module to produce encoded data symbols;

modulation means for spectrum spreading encoded data symbols forming user signals using at least one preselected pseudorandom noise spreading code in said transmission module; and

said means for summing, wherein said means for summing receives and sums together spread signals to form a single spread communication signal; and

said means for transferring transfers each spread communication signal.

17. The apparatus of Claim 9, wherein said communication system is a spread spectrum communication system and said user information signals are communicated over orthogonally encoded communication signal channels within said communication signals transmitted by system base stations, gateways, and satellites to system user terminals, said apparatus further comprising:

means for segmenting said user information signals into diversity user signals on the basis of at least one diversity subscriber signal for each of the plurality of

analog communication paths over which said user information signals are to be transferred to said user terminals;

wherein:

said user data signals received by said transmission modules are said diversity user signals; and

said means for processing comprises means for modulating the received diversity user signals using preselected pseudorandom noise (PN) type code sequences; and

said means for summing is arranged to sum the modulated signals.

SMART & BIGGAR

OTTAWA, CANADA

PATENT AGENTS

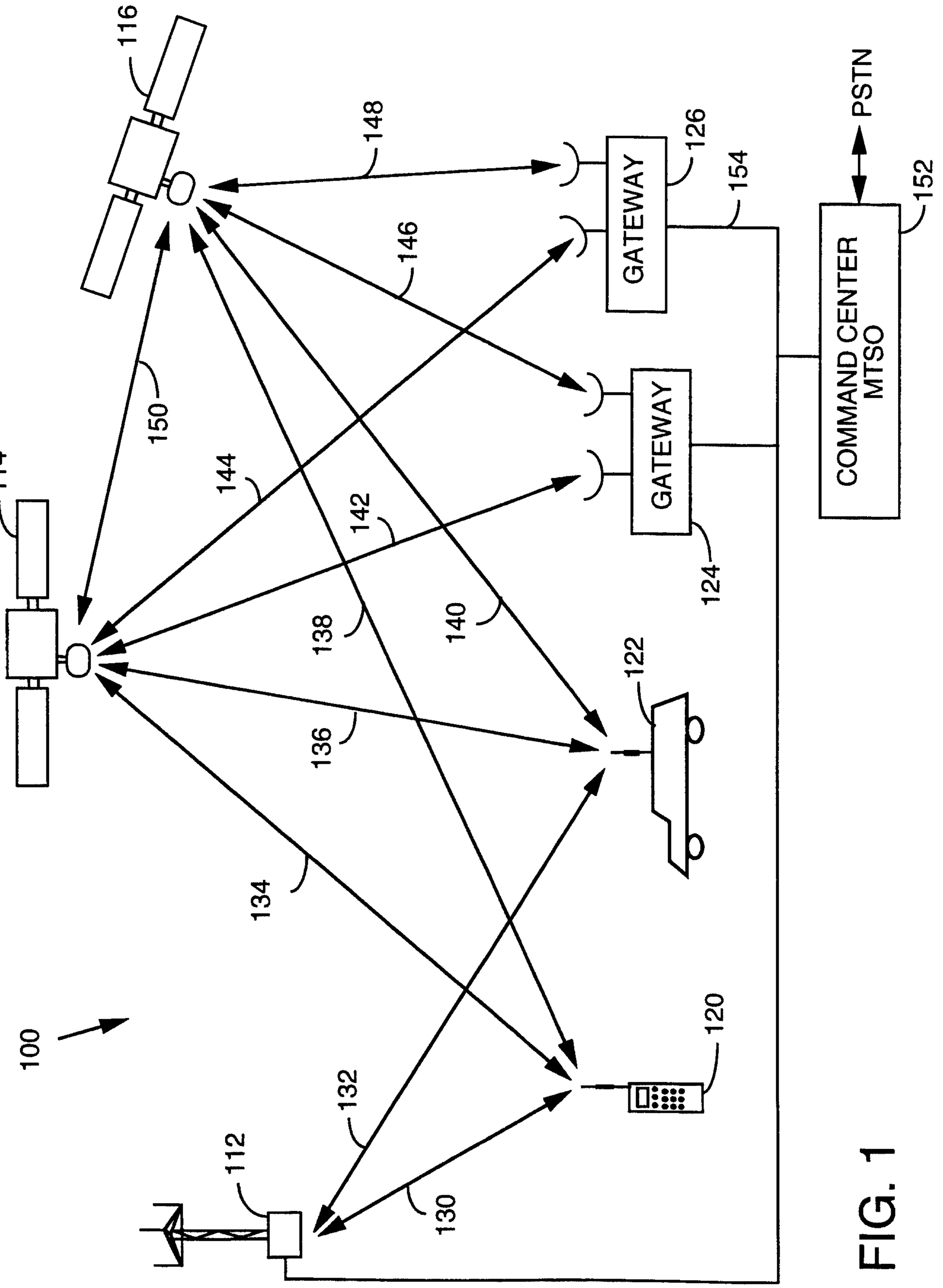

100
112
114
116
120
122
124
126
130
132
134
136
138
140
142
144
146
148
150
152
154
GATEWAY
GATEWAY
GATEWAY
COMMAND CENTER
MTSO
PSTN

FIG. 1

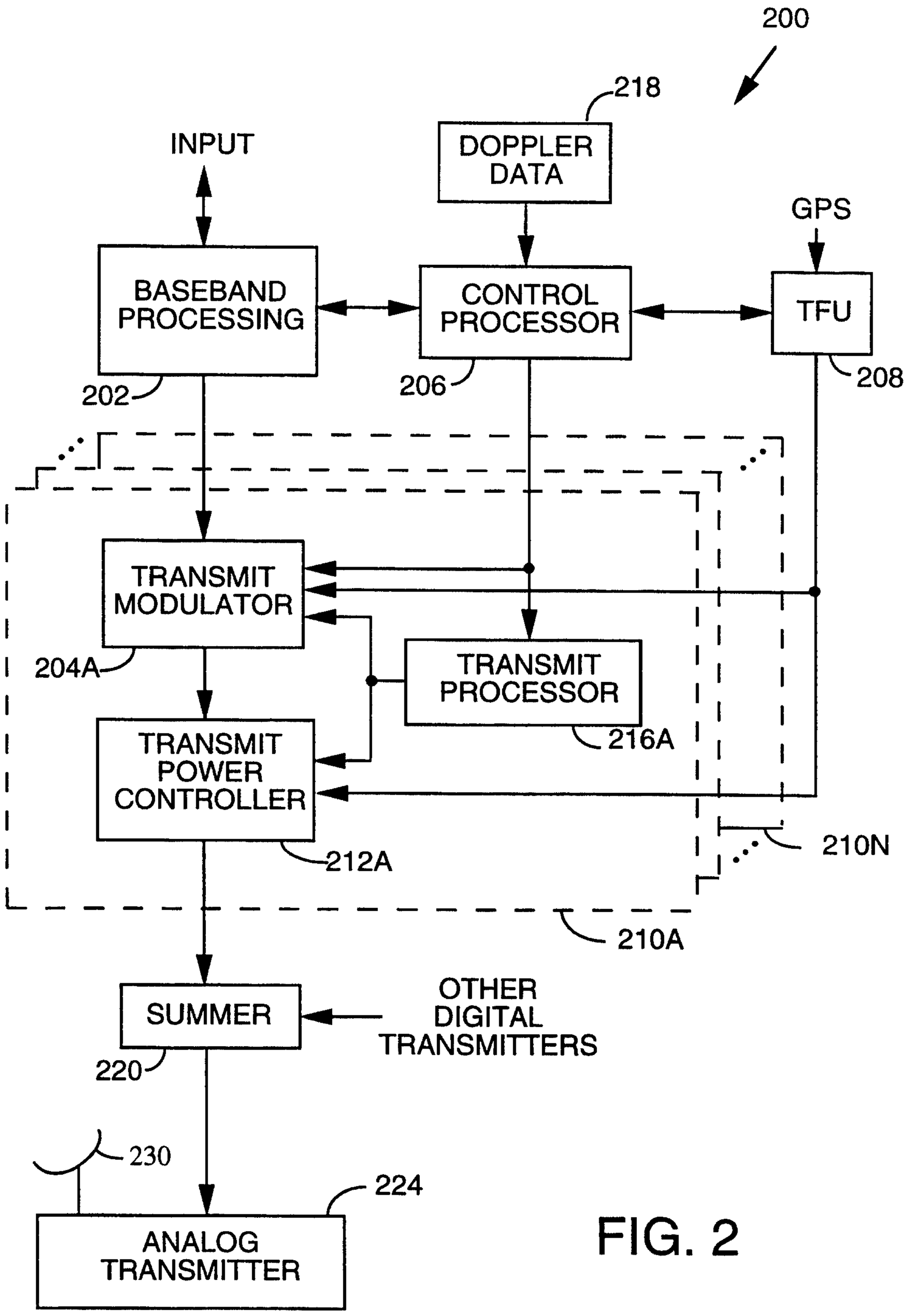

200
218
INPUT
DOPPLER DATA
GPS
BASEBAND PROCESSING
CONTROL PROCESSOR
TFU
202
206
208
TRANSMIT MODULATOR
204A
TRANSMIT PROCESSOR
216A
TRANSMIT POWER CONTROLLER
212A
210N
210A
SUMMER
OTHER DIGITAL TRANSMITTERS
220
230
224
ANALOG TRANSMITTER

FIG. 2

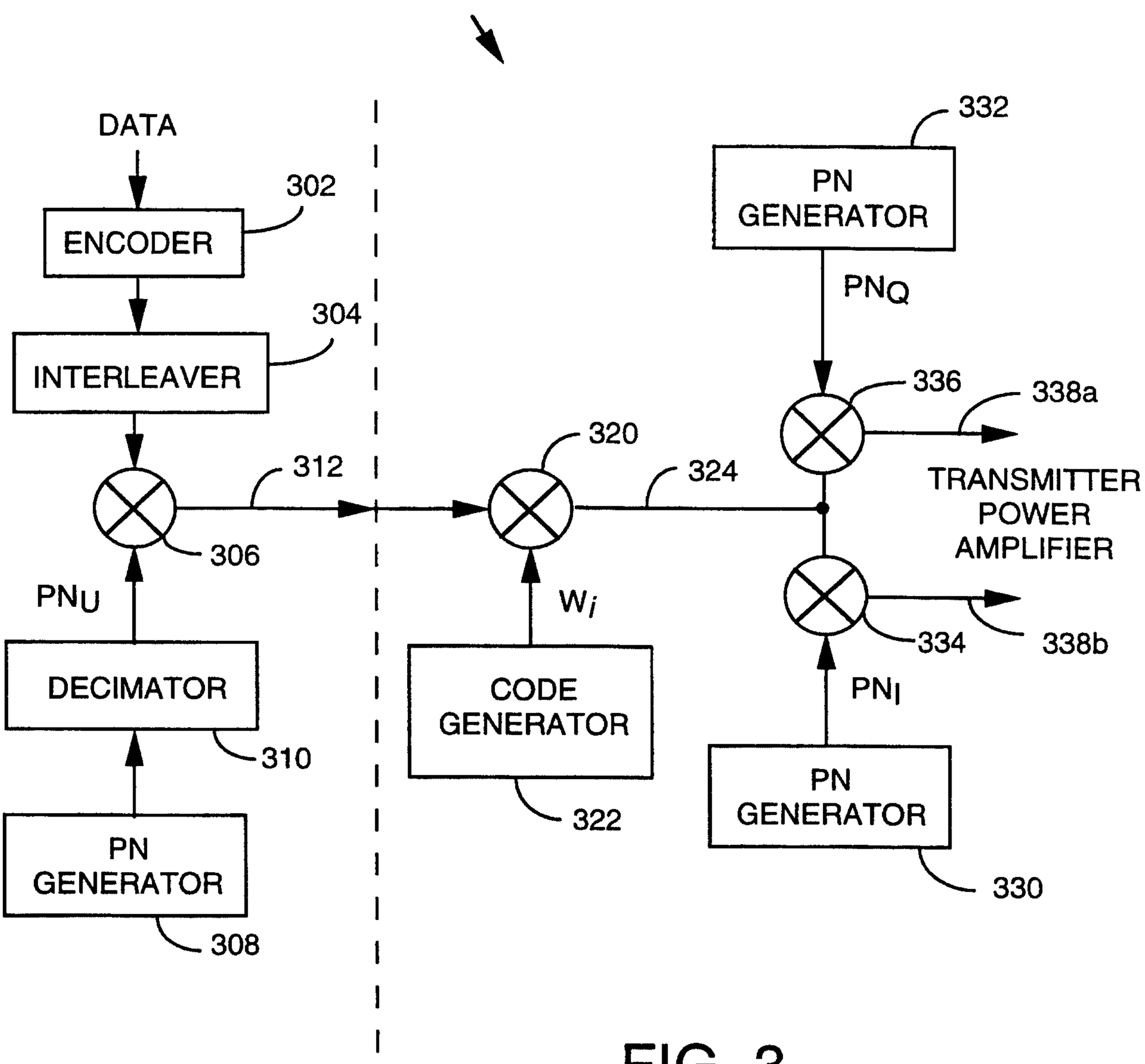

206
DATA
ENCODER
302
INTERLEAVER
304
312
306
PNU
DECIMATOR
310
PN GENERATOR
308
320
324
Wi
CODE GENERATOR
322
PN GENERATOR
332
PNQ
336
338a
TRANSMITTER POWER AMPLIFIER
334
338b
PNI
PN GENERATOR
330

FIG. 3

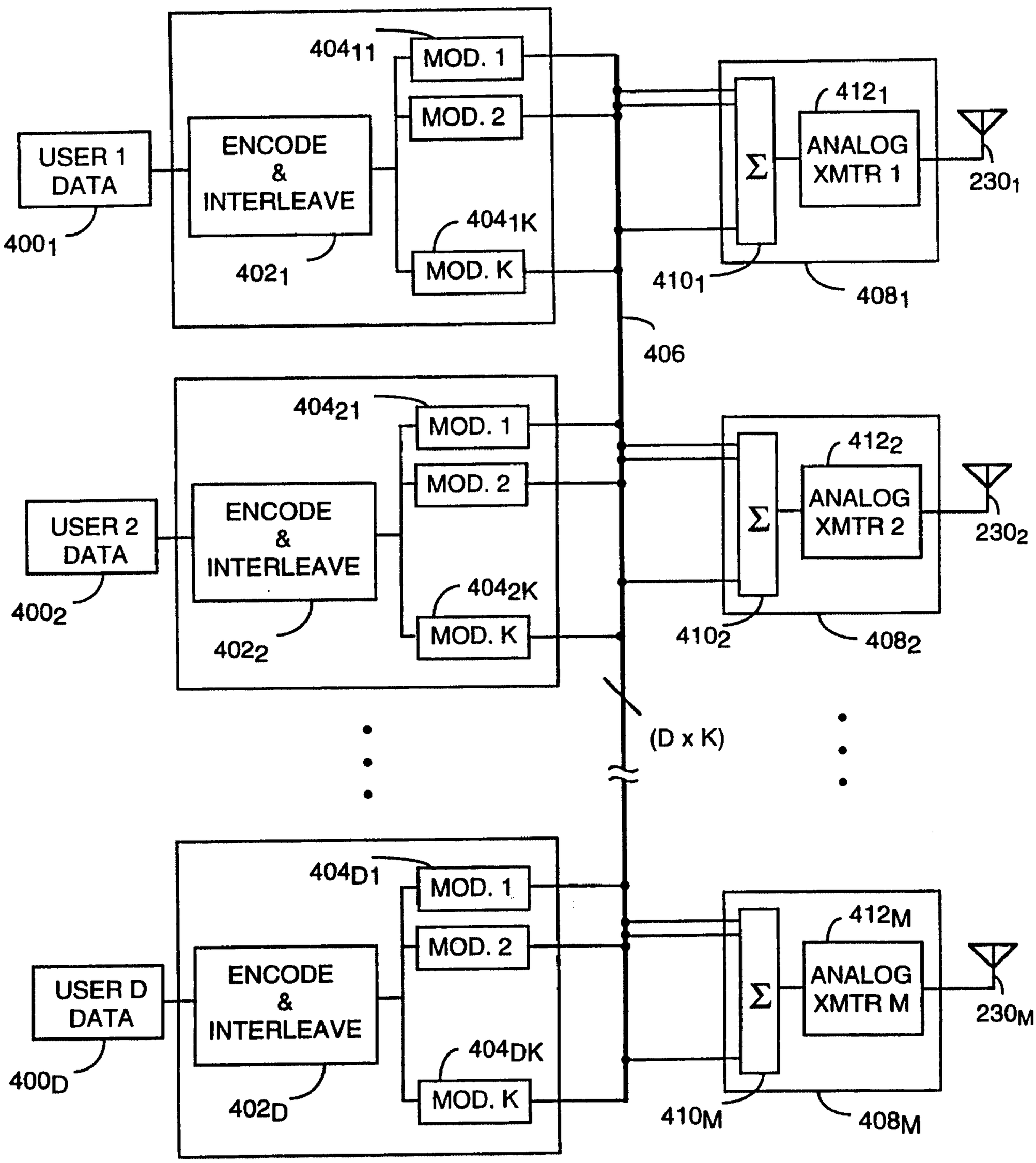

40411
MOD. 1
MOD. 2
USER 1 DATA
ENCODE & INTERLEAVE
4041K
MOD. K
4001
4021
4121
ANALOG XMTR 1
Σ
2301
4101
4081
406
40421
MOD. 1
MOD. 2
USER 2 DATA
ENCODE & INTERLEAVE
4042K
MOD. K
4002
4022
4122
ANALOG XMTR 2
Σ
2302
4102
4082
(D x K)
404D1
MOD. 1
MOD. 2
USER D DATA
ENCODE & INTERLEAVE
404DK
MOD. K
400D
402D
412M
ANALOG XMTR M
Σ
230M
410M
408M

FIG. 4a

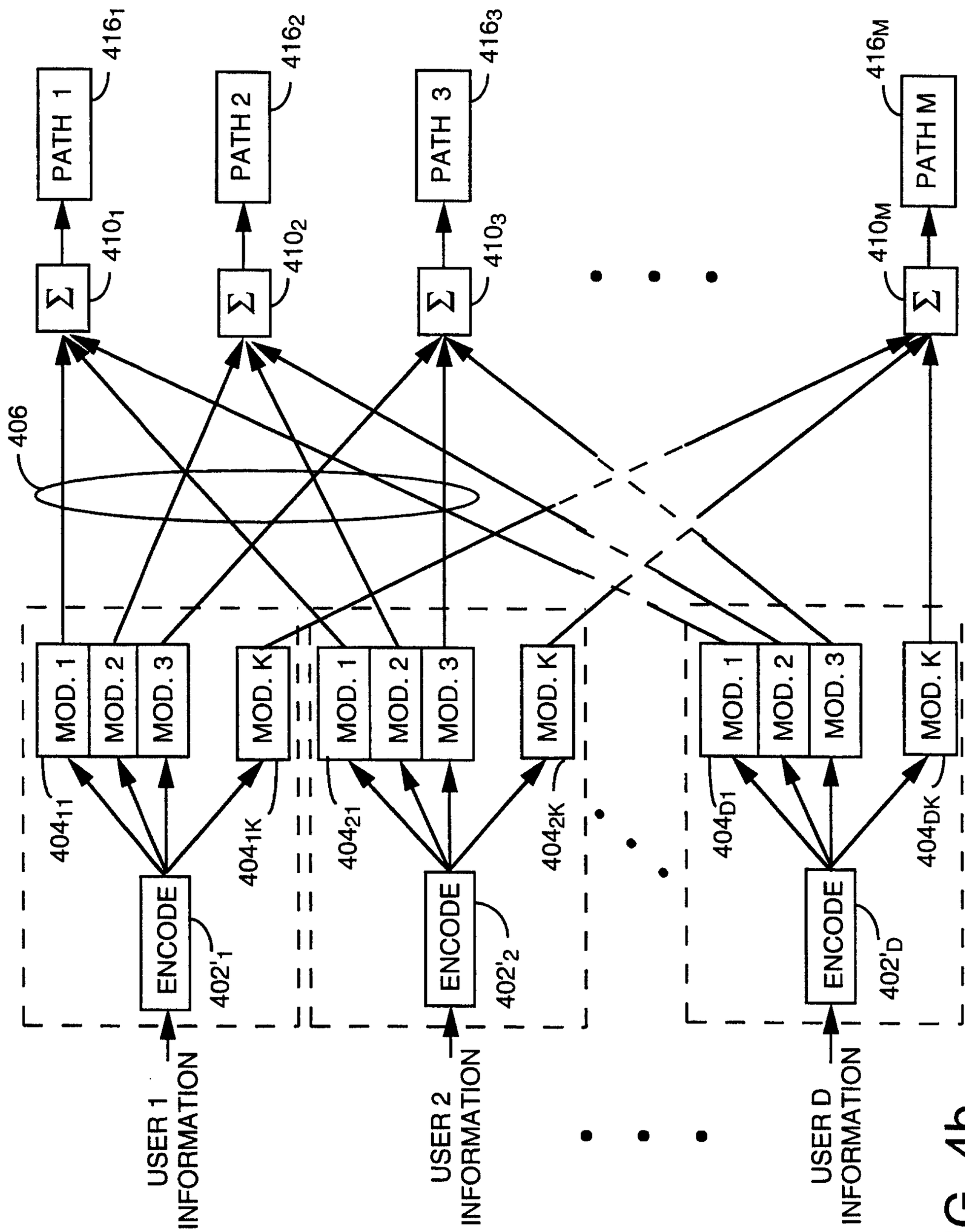

USER 1 INFORMATION
USER 2 INFORMATION
USER D INFORMATION
ENCODE
ENCODE
ENCODE
402'1
402'2
402'D
MOD. 1
MOD. 2
MOD. 3
MOD. K
404111
404121
404D1
404211
404221
404D2
404311
404321
404D3
404M11
404M21
404MD
406
Σ
410M
PATH 1
PATH 2
PATH 3
PATH M
416M

FIG. 4b

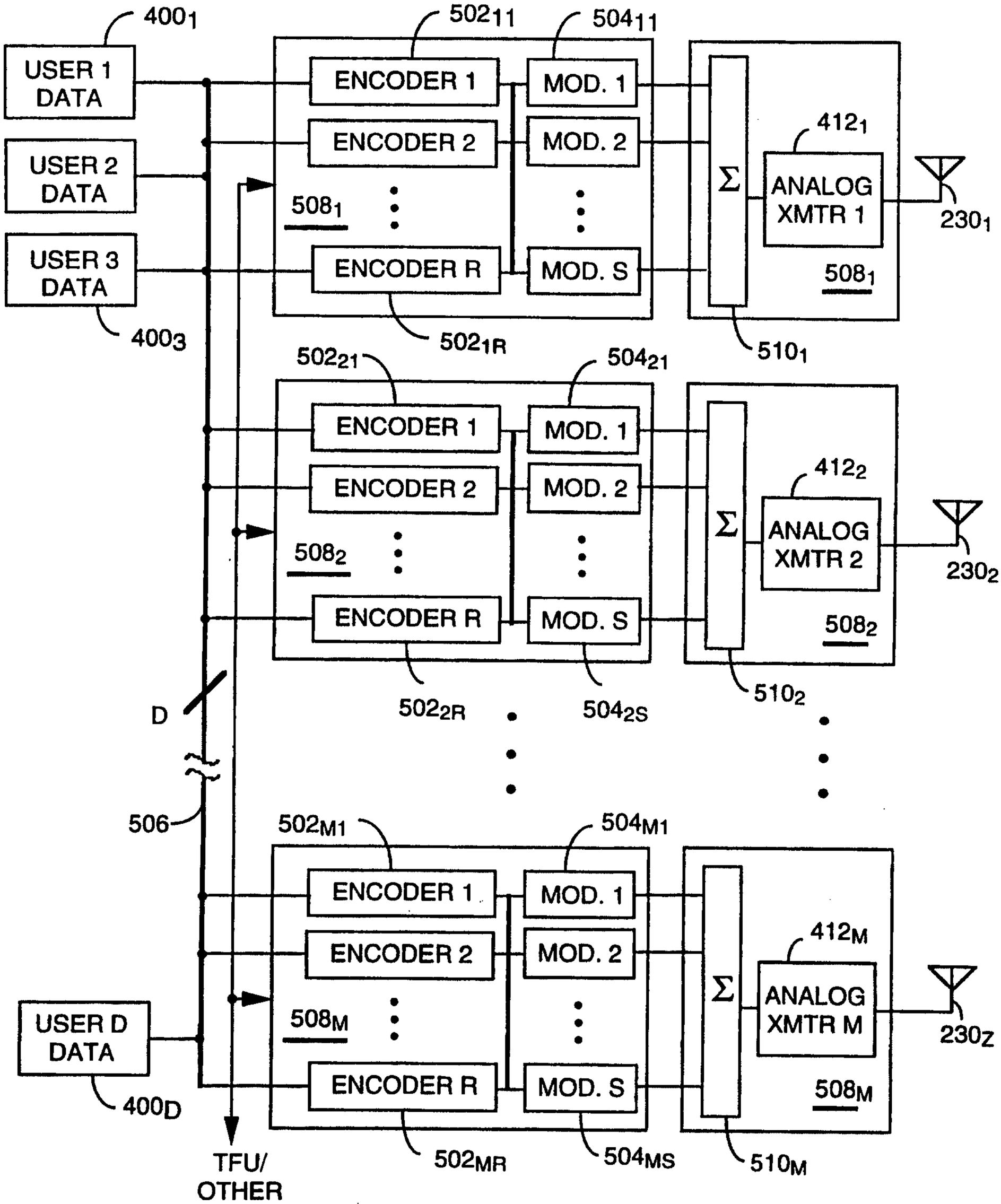

400₁
USER 1 DATA
USER 2 DATA
USER 3 DATA
400₃
D
506
USER D DATA
400D
TFU/ OTHER
50211
50411
ENCODER 1
ENCODER 2
ENCODER R
MOD. 1
MOD. 2
MOD. S
508₁
502₁R
504₁S
Σ
412₁
ANALOG XMTR 1
230₁
510₁
502₂₁
504₂₁
508₂
502₂R
504₂S
412₂
ANALOG XMTR 2
230₂
510₂
502M1
504M1
508M
502MR
504MS
412M
ANALOG XMTR M
230Z
510M

FIG. 5a

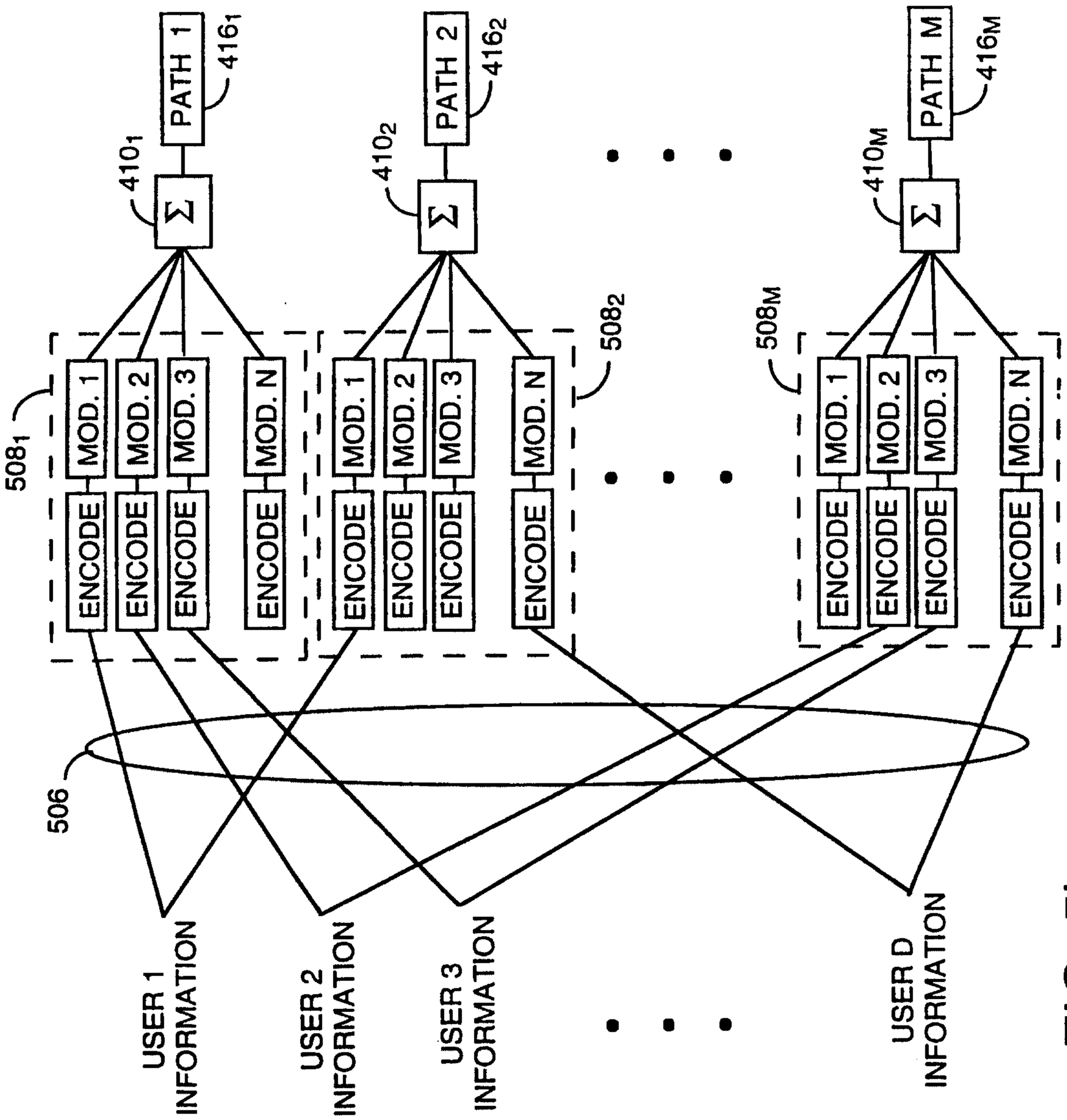

PATH 1
PATH 2
PATH M
416_1
416_2
416_M
410_1
410_2
410_M
Σ
508_1
508_2
508_M
MOD. 1
MOD. 2
MOD. 3
MOD. N
ENCODE
506
USER 1 INFORMATION
USER 2 INFORMATION
USER 3 INFORMATION
USER D INFORMATION

FIG. 5b

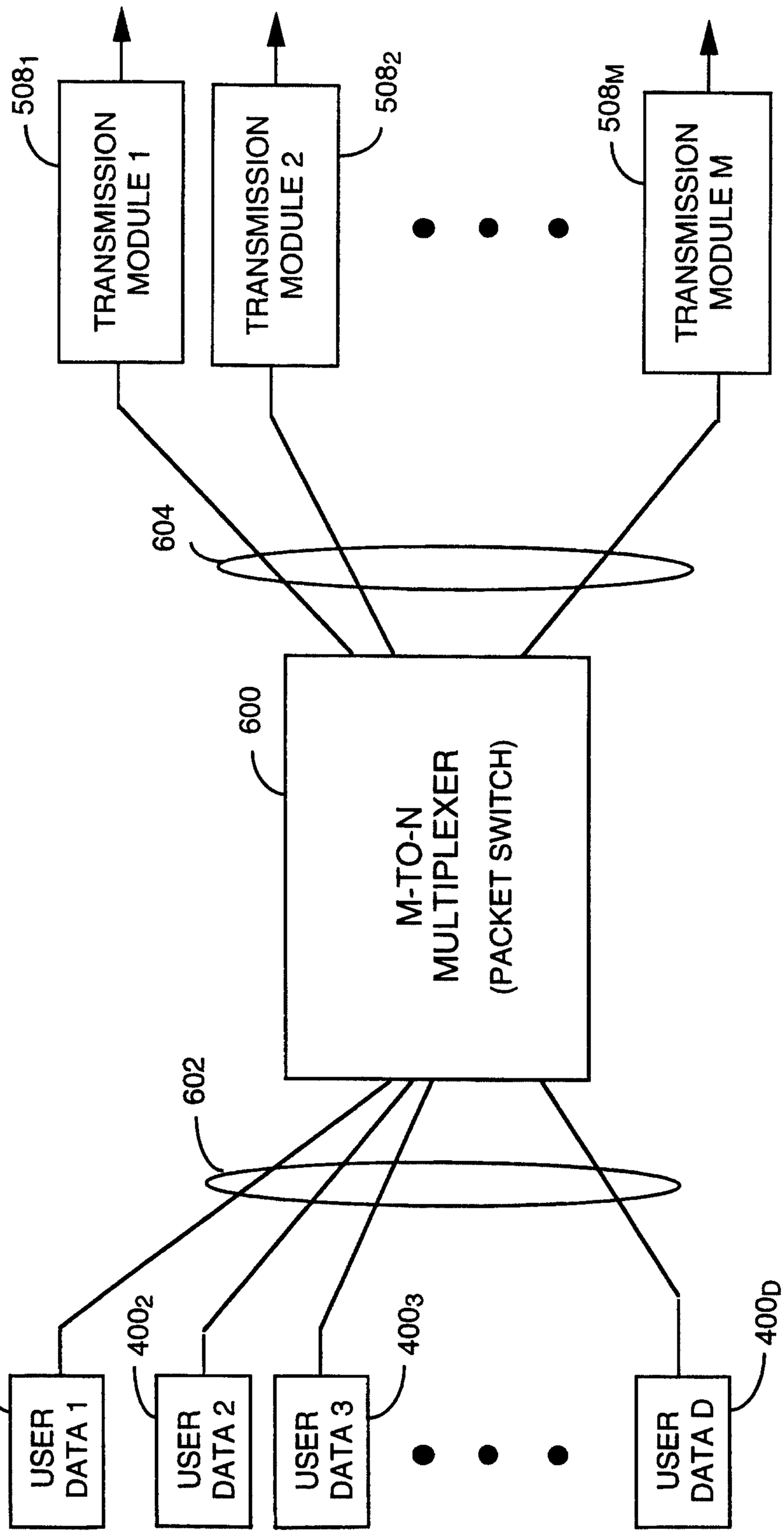
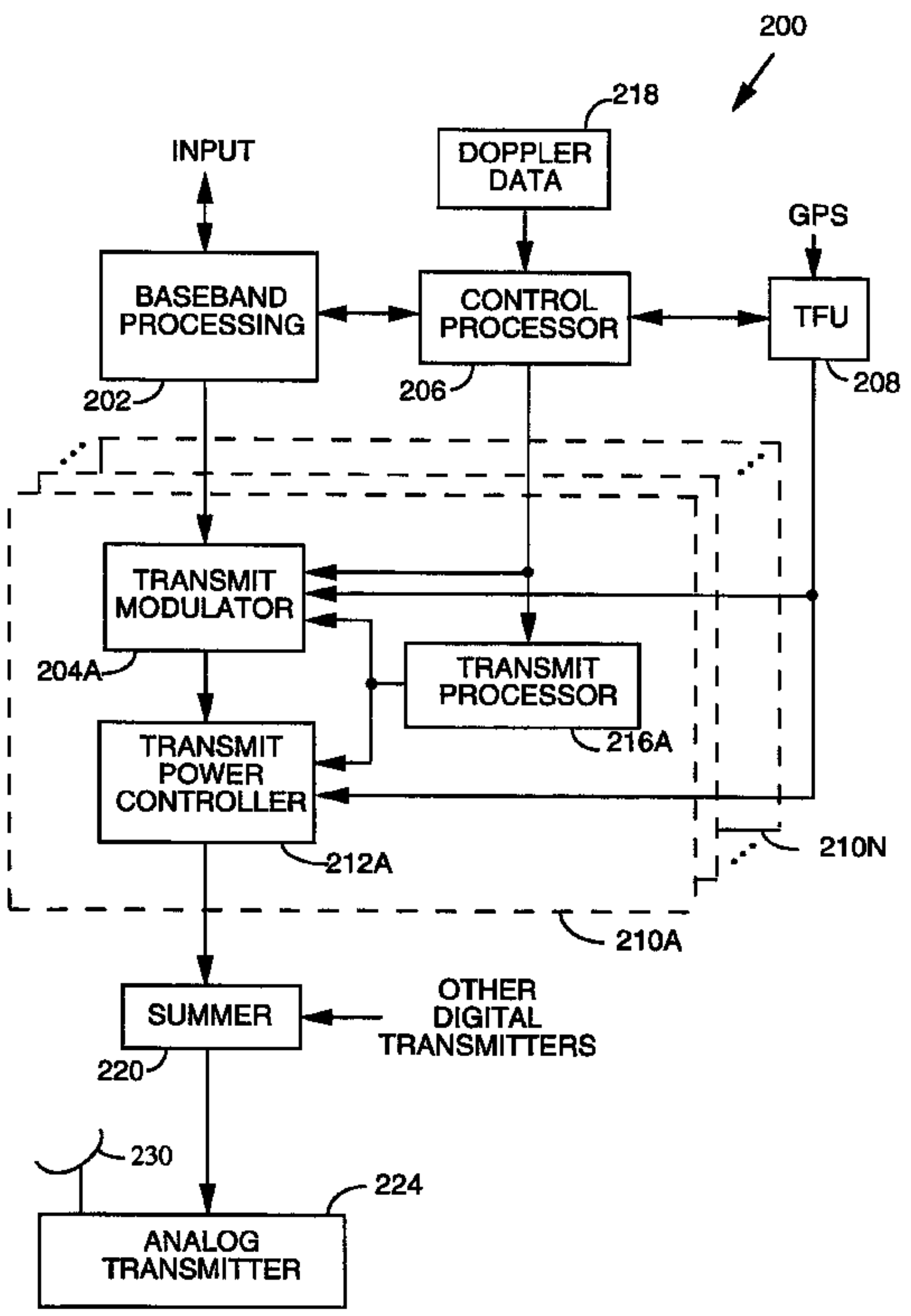

400_1
USER DATA 1
400_2
USER DATA 2
400_3
USER DATA 3
400_D
USER DATA D
602
600
M-TO-N MULTIPLEXER (PACKET SWITCH)
604
508_1
TRANSMISSION MODULE 1
508_2
TRANSMISSION MODULE 2
508_M
TRANSMISSION MODULE M

FIG. 6


200
218
INPUT
DOPPLER DATA
GPS
BASEBAND PROCESSING
CONTROL PROCESSOR
TFU
202
206
208
TRANSMIT MODULATOR
204A
TRANSMIT PROCESSOR
216A
TRANSMIT POWER CONTROLLER
212A
210N
210A
SUMMER
OTHER DIGITAL TRANSMITTERS
220
230
224
ANALOG TRANSMITTER