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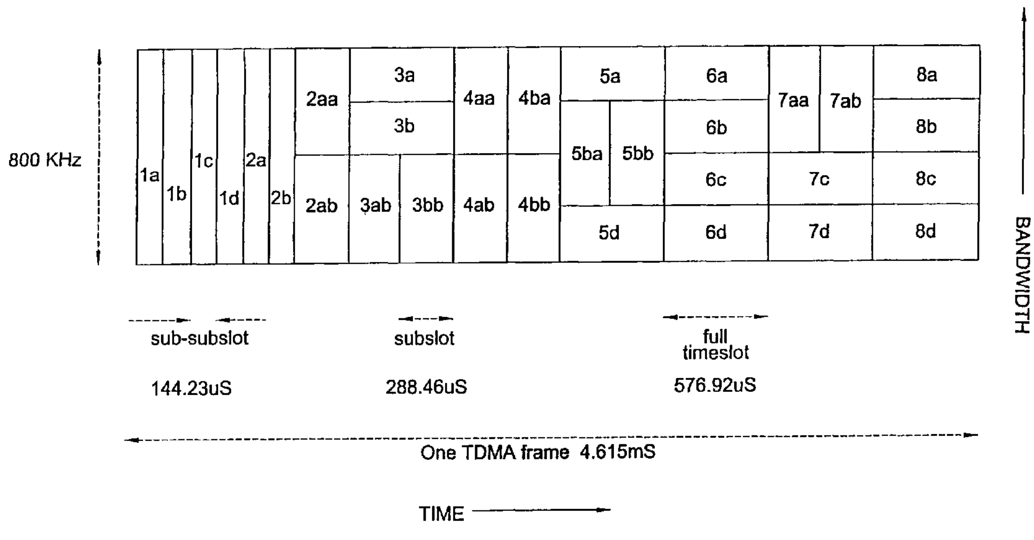
**(54) Title:** COMMUNICATION METHODS AND DEVICES PROVIDING DYNAMIC ALLOCATION O F RADIO RESOURCES




**(57) Abstract:** Communications can be provided by communicating a first data burst using a first bandwidth and a first burst duration, and communicating a second data burst using a second bandwidth and a second burst duration. In particular, the first bandwidth can be greater than the second bandwidth, and the first burst duration can be less than the second burst duration. In addition, a product of the first bandwidth and the first burst duration can be substantially equal to a product of the second bandwidth and the second burst duration.

WO 02/15435 A1

# COMMUNICATION METHODS AND DEVICES PROVIDING DYNAMIC ALLOCATION OF RADIO RESOURCES

## BACKGROUND OF THE INVENTION

The present invention relates to the field of communications and more particularly to wireless communications systems and methods.

In wire-line communications using modems, it may be desirable to adapt a speed of data transmission to a highest datarate achievable while maintaining reliable communications over a wire-line providing a certain level of quality. Such wire-line channels are not generally used simultaneously by multiple users, so that multiple access wire-line communications have not generally been used. These wireline communications have typically adapted the datarate by changing modulation methods or "signal constellation" from one of relatively many bits per symbol for a "good" line to one of fewer bits per symbol for a "bad" line. Alternately, different levels of error correction coding could be selected providing different trade-offs between throughput and reliability.

Wireless communications systems, such as cellular radiotelephone systems, are presently evolving toward providing a greater variety of digital-data based services, and adaptation of modulation and coding has been proposed. The digital cellular standard GSM (Global System For Mobile Communications), for example, originally used GMSK (Gaussian Minimum Shift-Keying) modulation of 1.35 bits per Hertz of bandwidth (before coding). The GSM standard is now evolving to the EDGE standard (Enhanced Data Rate For Global Evolution) which includes the adaptive selection of 8-PSK of 4.05 bits per Hertz of bandwidth (before coding), as an alternative to GMSK, when conditions allow. The choice of GMSK modulation or 8-PSK modulation can be made considering the wanted signal (carrier) to unwanted signal (interference) ratio (C/I), distance from transmitter to receiver (path loss), and/or availability of one mode or the other at either the wireless terminal or the network base station. According to the EDGE standard, both GMSK and 8-PSK modulation operate according to substantially the same channel specifications.

According to a third cellular radiotelephone standard known as 3G (Third Generation), wideband Code Division Multiple Access (WCDMA) with variable rate orthogonal coding can be used to provide a family of available datarates increasing by powers of 2. Factors such as capabilities of the mobile terminal and the network, and availability of capacity, may be used to influence selection of a datarate. If the network is heavily loaded, for example, there may not be enough capacity to give every user the highest datarate so that a lower datarate may be used. In addition, higher datarates may be provided in microcells that have inherently higher capacity per square kilometer. According to the WCDMA standard, the bandwidth may be fixed at 5MHz with datarates being adapted by varying the underlying datarate and changing the spreading to provide a constant bandwidth.

CDMA systems, however, may require accurate feed-back power-control so that neither more nor less than the correct power is used to just permit acceptable reception. To maintain closed loop power control, the receiving terminal may need to be constantly transmitting, thus providing a constant drain on the battery.

TDMA systems are inherently less sensitive to maintaining accurate power control because TDMA systems generally avoid having co-channel interference in the same cell. CDMA systems can migrate to TDMA functionality by reducing a spreading rate, increasing a datarate, and providing high datarate bursts sequentially to different mobile terminals instead of lower datarates in parallel to different mobile terminals to thereby reduce in-cell interference. Maximum datarates provided by a 5MHz bandwidth system may be difficult to decode in the presence of multipath distortion (which typically increases with datarate). In other words, receivers may be unable to decode high datarate transmissions transmitted using a 5MHz bandwidth in the presence of multipath distortion because the receiver complexity required may increase exponentially with respect to increases in multipath delays calculated as a function of data symbol periods.

## SUMMARY OF THE INVENTION

According to aspects of the present invention, communications can be provided by communicating a first data burst using a first bandwidth and a first burst duration, and communicating a second data burst using a second bandwidth and a second burst duration. More particularly, the first bandwidth can be greater than the second bandwidth, and the first burst duration can be less than the second burst duration. Communications between a base station and a mobile terminal(s) can thus be dynamically allocated by bandwidth and burst duration from one time frame to the next. In addition, communications with multiple mobile terminals can be allocated different burst durations and bandwidths during a common time frame.

## BRIEF DESCRIPTION OF THE DRAWINGS

**Figure 1** illustrates first methods and devices allocating bandwidths, TDMA timeslots, and symbol rates according to embodiments of the present invention.

**Figure 2** illustrates second methods and devices allocating bandwidths, TDMA timeslots, and symbol rates according to embodiments of the present invention.

**Figure 3** illustrates common transmit/receive burst formats which can be used for full timeslots, half subslots, and quarter subslots of Figure 1 or 2.

**Figure 4A** illustrates embodiments of mobile terminals and methods according to the present invention.

**Figure 4B** illustrates embodiments of communications networks and methods according to the present invention.

**Figure 4C** illustrates embodiments of network base stations and methods according to the present invention.

**Figure 5** illustrates further embodiments of mobile terminals according to the present invention.

**Figure 6** illustrates other embodiments of mobile terminals according to the present invention.

## DETAILED DESCRIPTION OF THE INVENTION

The present invention will now be described more fully hereinafter with reference to the accompanying drawings, in which preferred embodiments of the invention are shown. This invention may, however, be embodied in many different forms and should not be construed as limited to the embodiments set forth herein; rather, these embodiments are provided so that this disclosure will be thorough and complete, and will fully convey the scope of the invention to those skilled in the art. Like numbers refer to like elements throughout. As will be appreciated by those of skill in the art, the present invention may be embodied as methods or devices. Accordingly, the present invention may take the form of a hardware embodiment, a software embodiment or an embodiment combining software and hardware aspects.

Digital cellular radiotelephone systems such as those operating according to the GSM standard may operate with a transmitted symbol rate of 13MHz/48 transmitted from the network stations to the mobile terminals. A further development of the GSM standard, known as EDGE, introduces 8-PSK modulation at the same symbol rate to provide a higher datarate. The 8-PSK option may thus provide a maximum bitrate before coding of 13MHz/16 during a burst (occupying a timeslot of a time frame), tripling the data throughput compared to GSM's GMSK modulation. Different user needs may be accommodated by dynamically allocating a greater number or lesser number of timeslots to different users while maintaining a common symbol rate and burst/slot format, by selecting the basic (GMSK) or 8PSK modulation, or by the coding. According to tehse technologies, a constant bandwidth is maintained, i.e. 200kHz channel spacing. In other words, a first mobile terminal may be allocated a single timeslot per time frame, while a second mobile terminal may be allocated two or more timeslots per time frame so that a higher datarate is provided to the second terminal and a lower datarate is provided to the first terminal.

Further increases in datarate could possibly be provided by using symbol constellations of greater than 8-PSK modulation. The use of such higher order symbol constellations, however, may not be preferred because of the potential for increased sensitivity to noise, interference, and multipath propagation resulting from such higher order symbol constellations.

Increasing the bandwidth and symbol rate by some factor, such as a factor of 2 or 4, can provide higher burst bitrates, but multipath distortion (also known as delay spread or time-dispersion) may be a greater number of symbol periods when the symbols are of a shorter duration. An equalizer can thus be used to compensate for multipath distortion, and equalizer complexity may increase exponentially with respect to the number of symbol periods of multipath distortion to be equalized. According to embodiments of the present invention, it may thus be desirable to provide an increased symbol rate for a shorter period of time over an increased bandwidth for mobile terminals subject to less multipath distortion, and to provide a decreased symbol rate for a longer period of time over a reduced bandwidth for mobile terminals subject to greater multipath distortion.

For example, communications for a first mobile terminal subject to a relatively high level of multipath distortion could be provided at a first symbol rate for a first transmit/receive burst duration using a first bandwidth; communications for a second mobile terminal subject to a medium level of multipath distortion could be provided at a second symbol rate (such as two times the first symbol rate) for a second transmit/receive burst duration (such as one half the first period of time) using a second bandwidth (such as two times the first bandwidth); and communications for a third mobile terminal subject to a relatively low level of multipath distortion could be provided at a third symbol rate (such as four times the first symbol rate) for a third transmit/receive burst duration (such as one fourth the first period of time) using a third bandwidth (such as four times the first bandwidth). Moreover, these allocations of symbol rate, transmit/receive burst duration, and/or bandwidth, can be made dynamically according to movement of mobile terminals, system capacity, and/or varying services provided to different mobile terminals.

In addition, it may be useful to provide compatibility between systems and methods according to the present invention using varying bandwidths, symbol rates, and/or transmission burst durations, and known systems using fixed bandwidths, symbol rates, and/or transmit/receive burst durations. According to the example discussed above, the first (lowest) symbol rate, the first (longest) transmit/receive burst duration, and the first (lowest) bandwidth can be the same as those used according to the GSM standard. The combination of the first symbol rate, first transmit/receive burst duration, and first bandwidth can be used to provide backwards compatibility with previously existing mobile terminals as well as to accommodate communications with newer terminals when multipath distortion is too great to support the second or third symbol rates. In addition, a new mobile terminal having relative wide and narrow bandwidth channels available may be able to receive and process each type of signal without an excessive increase in the number of different processing chips and/or programs used. Such a system may also be able to accommodate a varying mix of wide and narrowband links according to the terrain (which may affect multipath distortion) and/or a changing population of mobile terminals.

Figure 1 illustrates first examples of allocations of bandwidth, TDMA timeslot, and symbol rate according to the present invention. In Figure 1, each block (**1a-d**, **2a-b**, **2aa-ab**, **3aa-bb**, **4aa-bb**, **5a-d**, **6a-d**, **7a-d**, and **8a-d**) represents a transmit/receive burst where the burst duration (extent in the time domain) is represented along the horizontal axis and the bandwidth (extent in the frequency domain, also known as the spectral or bandwidth occupancy) is represented along the vertical axis. In the examples of Figure 1, the TDMA frame period can be equal to the frame period of the GSM standard (4.615 milliseconds). This frame period can be divided into 8 full timeslots each having a duration of 576.92μs according to the GSM standard. According to embodiments of the present invention, a full time slot can be divided into two half duration subslots each having a duration of 288.46μs, or four quarter duration subslots each having a duration of 144.23μs.

As further shown in Figure 1, a wider bandwidth can be provided for transmit/receive bursts transmitted using subslots having the shorter durations. As shown, transmit/receive bursts **5a-d**, **6a-d**, **7a-d**, and **8a-d** transmitted using full duration timeslots can occupy 200kHz of bandwidth as specified by the GSM standard; transmit/receive bursts **2aa-ab**, **3aa-bb**, and **4aa-bb** transmitted using half duration subslots can occupy 400kHz of bandwidth; and transmit/receive bursts **1a-d** and **2a-b** transmitted using quarter duration subslots can occupy 800kHz of bandwidth. Moreover, the division of full, half, and quarter duration timeslots can be changed dynamically from timeslot to time slot according to the use of system capacity, multipath distortions between the various mobile terminals and the system, and the service supported by the various mobile terminals.

The transmit/receive bursts **5a-d**, **6a-d**, **7a-d**, and **8a-d** occupying full duration timeslots can thus provide compatibility for GSM mobile terminals when GMSK modulation is used, and/or compatibility for EDGE mobile terminals when 8-PSK modulation is used. The full duration timeslots can also be used by mobile terminals according to the present invention when multipath distortions exceed a predetermined threshold. Moreover, service for mobile terminals according to the present invention can be provided using the shortest transmit/receive burst duration available provided that a longer burst duration is not desirable to obtain reliable reception as a result of multipath distortions.

Figure 1 also illustrates that a common time-bandwidth product for the different transmit/receive bursts can be preserved according to particular embodiments of the present invention. By way of example, the transmit/receive burst **6a** provided over a full duration timeslot can have a duration of 576.92μs and a bandwidth of 200kHz to provide a time-bandwidth product of 115.384sHz; the transmit/receive burst **4aa** provided over a half duration subslot can have a duration of 288.46μs and a bandwidth of 400kHz to provide a time-bandwidth product of 115.384sHz; and the transmit/receive burst **2a** provided over a quarter duration subslot can have a duration of 144.23μs and a bandwidth of 800kHz to provide a time-bandwidth product of 115.384sHz. Maintaining a constant time-bandwidth product for each combination of timeslot/subslot duration and channel bandwidth may provide advantages discussed in greater detail below. Systems, terminals, and methods according to the present invention, however, are not limited to embodiments providing a constant time-bandwidth product for timeslots and subslots of different durations.

As further shown in Figure 1, concurrent transmit/receive bursts occupying a full duration timeslot (such as bursts **6a-d**) may occupy different frequency bands of the total 800kHz bandwidth. Similarly, concurrent transmit/receive bursts (communicated during a half duration subslot such as **4aa-ab**) may occupy different frequency bands of the total 800kHz bandwidth. It may be seen in Figure 1 that the center of a 400kHz or 800kHz bandwidth may lie on a boundary between two 200kHz bandwidths, i.e. on an odd 100kHz multiple. This can be avoided if desired, however, by shifting the 400kHz or 800kHz channels by 100kHz relative to the 200kHz channels.

Figure 2 illustrates second allocations of bandwidth, TDMA timeslot, and symbol rate according to the present invention. In Figure 2, each block (**1a-d, 2a-b, 2aa-ab, 3a-b, 3ab-bb, 4aa-bb, 5a, 5ba-bb, 5d, 6a-d, 7aa-ab, 7c-d,** and **8a-d**) represents a transmit/receive burst where the burst duration (extent in the time domain) is represented along the horizontal axis and the bandwidth (extent in the frequency domain, also known as the spectral or bandwidth occupancy) is represented along the vertical axis. As in the examples of Figure 1, the TDMA frame period can be equal to the frame period of the GSM standard (4.615 milliseconds). This frame period can be divided into 8 full timeslots each having a duration of 576.92μs according to the GSM standard. According to embodiments of the present invention, a full timeslot can be divided into two half duration subslots each having a duration of 288.46μs, or four quarter duration subslots each having a duration of 144.23μs.

In Figure 2, blocks **1a-d, 2a-b, 2aa-ab, 3ab-bb, 4aa-bb, 5a, 5d, 6a-d, 7c-d**, and **8a-d** are the same as the respective blocks in Figure 1. Blocks **3a-b, 5ba-bb**, and **7aa-ab**, however, illustrate different allocations of full timeslot and half duration subslots to thereby provide examples of dynamic allocation from one TDMA time frame to another. For example, bursts **3aa** and **3ba** of Figure 1 occupying half duration subslots may provide communications during a first TDMA time frame for two respective mobile terminals according to the present invention each having a propagation path with low enough multipath distortion to accommodate communications over the half duration subslots. If the multipath distortion for one of the two mobile terminals increases above some predetermined threshold, however, a dynamic reallocation of burst duration and bandwidth may be used to accommodate communications with the two mobile terminals in the second TDMA time frame of Figure 2 so that bursts **3a** and **3b** are then used to support communications with the two mobile terminals. Alternately, one of the two mobile terminals may cease communications, and the bursts **3a** and **3b** of Figure 2 may be provided to support communications with conventional mobile terminals according to the GSM and/or EDGE standards. Similar reallocations are illustrated by bursts **5ba-bb** and **7aa-ab**.

Figure 3 illustrates examples of common transmit/receive burst formats which can be used for the full duration timeslots, the half duration subslots, and the quarter duration subslots of Figure 1. These transmit/receive burst formats can be the same as that provided by the GSM and EDGE standards so that mobile terminals operating according to the GSM and EDGE standards can be supported using full duration timeslots. As shown in Figure 3, the transmit/receive format can include an initial upramping period **91**, a set of initial "tail" bits **92**, a first group of 57 data symbols **93**, a first flag bit **94**, 26 synchronization bits **95**, a second flag bit **96**, a second group of 57 data symbols **97**, concluding "tail" bits **98**, and a downramping period **99**.

According to the formats of Figure 3, a symbol transmission rate for a full duration timeslot can be 13MHz/48, so that a symbol duration can be 48/13μs (just under 4μs). A symbol transmission rate for a half duration subslot can be doubled to 13MHz/24 while also doubling the bandwidth to 400kHz, and a symbol transmission rate for a quarter duration subslot can be quadrupled to 13MHZ/12 while also quadrupling the bandwidth to 800kHz. Accordingly, the same volume and format of data can be transmitted during either a full duration time slot, a half duration subslot, or a quarter duration subslot while maintaining a constant time-bandwidth product. In other words, the transmit/receive burst formats of Figure 3 can be retained for all bandwidths by proportionally scaling the time duration of each feature of the format and inversely scaling the bandwidth by the same factor. By using a common burst format for bursts of different durations, common techniques can be used to code, transmit, receive, equalize, and/or decode the bursts thereby potentially reducing transmitter/receiver complexity.

According to an example of the present invention, a plurality of time frames according to the time frames illustrated in Figures 1 and 2 can be defined using a common 800kHz bandwidth frequency band with different bursts in each time frame supporting downlink transmissions from a base station to a plurality of mobile terminals. Burst **3aa** of Figure 1 and burst **3a** of Figure 2, for example, can be used to support transmission from a base station to a first mobile terminal during a communications session. In addition, burst **3ab** of Figure 1 can be used to support transmission from the base station to a second mobile terminal. In other words, the individual bursts according to the time frame structures of Figures 1 and

2 can support downlink transmissions from a base station to a plurality of mobile terminals.

Alternately or in addition, bursts according to the time frame structures illustrated in Figures 1 and 2 can support uplink transmissions from a plurality of mobile terminals to a base station. As will be understood, different 800kHz frequency bands can be provided for uplink and downlink frequency bands. Accordingly, a burst such as burst 3ba of Figure 1 can be used to support a first uplink transmissions from a first mobile terminal to a base station, while a burst such as burst 3b of Figure 2 can be used to support a second uplink transmission from the first mobile terminal to the base station during a communications session. In addition, the bursts making up time frames used for uplink transmissions are provided using a different 800kHz frequency band than the frequency band used for bursts making up time frames for downlink transmissions, with a frequency separation known as the "duplex spacing". Similarly, other bursts can be used to support uplink transmissions from other mobile terminals to the base station.

Referring now to Figure 4A, a mobile terminal according to embodiments of the present invention may include an antenna **300**, a combiner **302**, a receiver **304**, a controller **306**, a transmitter **308**, and an input/output block **310**. The combiner **302** can include a transmit/receive switch and/or a duplexor. The combiner couples signals between the antenna **300** and the receiver **304**, and between the transmitter **308** and the antenna **300**. More particularly, the receiver **304** can include a filter **312** and an equalizer **314**. The filter **312** can be adapted to filter the received signal at the selected bandwidth and frequency, and to sample the signal at one sample per symbol at the selected symbol rate (or a multiple thereof) to capture a predetermined number of samples (such as 156 samples) in memory (which may be considered a part of the receiver **304**).

The captured samples can be processed by the equalizer **314** off-line (*i.e.*, in non-real time) using equalizer techniques that are independent of the bandwidth in use. For example, the equalizer can use the 26 known synchronization bits **95** to determine a set of channel coefficients characterizing the multipath propagation path to the antenna **300**. The equalizer can then demodulate the received samples while compensating for multipath propagation using the determined channel coefficients. Equalizers used to compensate for multipath propagation are described, for example, in the following U.S. Patents: U.S. Patent No. 5,331,666 entitled "Adaptive Maximum Likelihood Demodulator"; U.S. Patent No. 5,335,250 entitled "Method And Apparatus For Bidirectional Demodulation Of Digitally Modulated Signals"; U.S. Patent No. 5,557,068 entitled "Generalized Direct Update Viterbi Equalizer"; U.S. Patent No. 5,557,645 entitled "Channel-Independent Equalizer Device"; U.S. Patent No. 5,841,816 entitled "Diversity Pi/4-DQPSK Demodulation"; and U.S. Patent No. 5,909,465 entitled "Method And Apparatus For Bidirectional Demodulation of Digitally Modulated Signals". Each of these patents is hereby incorporated herein in its entirety by reference. Moreover, the inventor of the present application is an inventor of each of the above referenced patents.

As discussed above, the equalizer **314** can use the synchronization bits **95** to calculate a channel estimate for the propagation path from a network base station to the antenna **300** and to calculate channel coefficients representing the propagation path. If the equalizer determines that multipath distortion is at or beyond the limits of its computational ability, the receiver may output an indication to the controller **306**, and in response, the controller **306** may cause the transmitter **308** to send a signal to a network station to reduce the symbol rate for transmit/receive bursts to the mobile terminal and to reduce bandwidth. By reducing the symbol rate and bandwidth, the time delay spread of the multipath distortion measured in symbol periods can be reduced.

The network base station can then send a new channel allocation to the mobile terminal to receive signals using a reduced bandwidth but increased burst duration. For example, the mobile terminal may be assigned a half duration subslot at 400kHz in place of a previously assigned quarter duration subslot at 800kHz, or the mobile terminal may be assigned a full duration timeslot at 200kHz in place of a previously assigned half duration subslot at 400kHz. The new channel allocation will also indicate the particular timeslot (or subslot) within the time frame and the particular frequency band to be used. Different transmit/receive bursts for different mobile terminals using the same bandwidths can thus be grouped into common timeslots or subslots as illustrated by transmit/receive bursts **2aa-ab**, **3aa-ab**, **3ba-ab**, **4aa-ab**, **4ba-bb**, **5a-d**, **6a-d**, **7a-d**, and **8a-d** of Figure 1.

Digital data that is successfully received at the receiver **304** can be passed by the controller to the input/output block **310**. The input/output block can include output devices such as a speaker, a visual display, and/or a communications link to other devices. The input/output block can also accept input to be transmitted by the controller **306**, the transmitter **308**, the combiner **302**, and the antenna **300** to the network station. The input/output block can include input devices such as a microphone, a keypad, a touch sensitive screen, and/or a communications link to or from other devices.

Examples of cellular communications networks according to the present invention are illustrated in Figure 4B. As shown, a cellular communications network according to the present invention can include two or more base stations **502** and **504** that can be used to provide communications to and from a plurality of mobile terminals **506**, **508**, **510**, **514**, **516**, and **518** over respective wireless communications paths. A mobile telephone switching office (MTSO) **500** can be used to couple base stations within the cellular communications network and to couple the cellular communications network with a public switched telephone network (PSTN) **512**. Each of the mobile terminals can communicate with a respective base station using a transmit/receive (or communications) burst defined by a timeslot/subslot, a bandwidth, and a frequency within a time frame as discussed above with regard to Figures 1, 2, 3, and 4A.

For example, the time frame of Figure 1 and the time frame of Figure 2 may be consecutive time frames for an 800kHz frequency band being used by base station **504** to transmit to a plurality of mobile terminals including mobile terminals **506**, **508**, and **510**. One or more of these mobile terminals may receive and/or transmit a burst having a first bandwidth and duration during the first time frame of Figure 1, and then receive and/or transmit a burst having a second bandwidth and duration during the second time frame of Figure 2. The mobile terminal **506**, for example, may receive a first burst **3aa** over a half duration subslot of Figure 1 having a 400kHz bandwidth during the first time frame, followed by a second burst **3a** over a full timeslot of Figure 2 having a 200kHz bandwidth during the second time frame. The switch to a lower bandwidth communication in the second time frame may be done to accommodate an increase in multipath distortion or to accommodate communication with another mobile terminal using burst **3b** over a full timeslot at 200kHz in the second time frame.

Similarly, the mobile terminal **508** may receive and/or transmit a first burst **5b** using a full timeslot of Figure 1 with a 200kHz bandwidth during a first time frame, and then receive and/or transmit a second burst **5ba** using a half subslot of Figure 2 with a 400kHz bandwidth during a second time frame. The switch to a higher bandwidth can provide communication of the same data over a shorter period of time, and switching to a higher bandwidth may provide a desirable increase in multipath distortion that can improve reception using diversity reception techniques. The use of shorter duration bursts transmitted by the mobile terminal at higher bandwidth can also reduce power consumed by the mobile terminal by allowing the mobile terminal to transmit at closer to full power for a shorter period of time.

The timeslots/subslots and bandwidths used to communicate bursts of data between a network base station and a mobile terminal according to the present invention can thus be dynamically allocated from one time frame to the next. Moreover, the timeslots/subslots and bandwidths for transmission from a network base station to the respective mobile terminals and for transmission from the mobile terminals to the base station can be allocated independently. In addition, timeslot/subslot and bandwidth allocation according to the present invention may be provided for one of transmission or reception by network base stations but not the other.

A network base station **502, 504** according to the present invention can also provide communications with mobile terminals that do not support the dynamic allocation of timeslots/subslots and bandwidths according to the present invention. In the examples discussed above, the mobile terminal **510**, for example, may operate according to the GSM and/or EDGE standard transmitting and receiving bursts over a full timeslot with a 200kHz bandwidth during a time frame. In other words, the mobile terminal **510** could be assigned a full timeslot for every time frame for which communication is desired.

Figure 4C is a block diagram of network base stations according to the present invention. As shown, the network base station can include an antenna 607, a combiner 600, a transmitter 603, a receiver 602, and a controller 605. The combiner **600** can couple the transmitter **603** and receiver **602** to the antenna **607** to reduce interference therebetween. Accordingly, the receiver **602** can receive communications from mobile terminals through the antenna **607** and the combiner **600**, and the transmitter **603** can transmit communications to mobile terminals through the combiner **600** and antenna **607**. Alternately, separate transmit and receive antennas can be used so that a combiner is not required. The controller **605** can thus determine data to be transmitted to respective mobile terminals and the timeslot/subslot and bandwidth to be used for each mobile terminal for each time frame, and the transmitter **603** can transmit bursts as discussed above with regard to Figures 1, 2, 3, 4A, and 4B. Similarly, the receiver **602** can receive bursts transmitted by the mobile terminals over assigned timeslots/subslots and bandwidths.

According to embodiments of the present invention, the allocation of timeslots/subslots and bandwidths for transmission to and reception from mobile terminals is determined by the controller **605** of the network base station. The allocations can be communicated to the respective mobile terminals using control channels, and reallocation of timeslots/subslots and bandwidths can be provided from one time frame to the next provided that the reallocation is communicated to the affected mobile terminal(s). In particular, reallocation can be effected to provide higher bandwidths/datarates to mobile terminals that can support the higher datarates; to provide lower bandwidths/datarates to mobile terminals subject to multipath distortions; to provide a higher bandwidth/datarate when the resulting increase in multipath distortions can improve reception using diversity reception techniques; and/or to provide a higher bandwidth/datarate so that a mobile terminal can transmit at close to full power for a shorter period of time, thereby potentially reducing battery drain.

Further embodiments of mobile terminals according to the present invention are illustrated in Figure 5. Mobile terminals according to Figure 5 can include an antenna **100** coupled through the coupler **101** to the receiver **99** and the transmitter **104**. If simultaneous transmission and reception are not needed (as is often the case for TDMA systems), the coupler **101** can comprise a transmit/receive switch. If simultaneous transmission and reception are required, however, the coupler **101** can comprise a duplexing filter. Received signals from the antenna **100** pass through the coupler **101** to the receiver front end **102** which can include a filter to separate wanted frequency band signals from unwanted frequency band signals (transmit frequency band signals), a low noise amplifier, and a downconverter to downconvert to an intermediate frequency (IF) signal. An intermediate frequency (IF) bandpass filter **105** can operate at the intermediate frequency to selectively pass signals lying within the bandwidth of one channel. An intermediate frequency amplifier **106a** may provide further channel filtering to define receiver selectivity to accept the selected channel and reject adjacent channel signals.

For example, the filter **105** and the intermediate frequency amplifier **106a** may accept the widest channel bandwidth (800kHz in the examples of Figures 1 and 2), and the entire bandwidth can be converted to the digital domain using complex Analog-to-Digital converter **106b**. Complex A-to-D conversion can be performed, for example, using logpolar techniques discussed in U.S. Patent No. 5,048,059 entitled "Log-Polar Signal Processing" wherein phase information can be digitized using, for example, a phase digitizer such as discussed in U.S. Patent No. 5,070,303 entitled "Logarithmic Amplifier/Detector Delay Compensation" or U.S. Patent No. 5,084,669 entitled "Direct Phase Digitization"; and wherein amplitude information can be digitized with compensation for relative delay as discussed, for example, in U.S. Patent No. 5,148,373 entitled "Method And An Arrangement For Accurate Digital Determination Of The Time Or Phase Position Of A Signal Pulse Train". Each of these patents is hereby incorporated herein in its entirety by reference. Moreover, the inventor of the present application is an inventor of each of the above referenced patents.

For embodiments illustrated in Figure 5, physical filtering can be used to pass the widest of the adaptively selectable bandwidths, and digital filtering implemented in the numerical domain by digital signal processor **107** can further reduce the bandwidth for the intermediate and narrowest of the selectable bandwidths. While digital filtering may be limited in dynamic range by the dynamic range of the complex A-to-D converter **106b**, the resulting dynamic range may be adequate if the other signals within the receiver passband are not substantially higher in signal level than the wanted signal.

In addition, signals which occupy different frequency divisions of the widest channel bandwidth during the same timeslot or subslot (for example transmit/receive bursts **4aa-ab** or **5a-d** of Figure 1) can be chosen to be signals of similar strength. If desired, signals can be swapped between time slots using the same frequency division structure to provide sorting by signal strength. In other words, signals transmitted using the full timeslots occupied by transmit/receive bursts **5a-d**, **6a-d**, **7a-d**, and **8a-d** of Figure 1 can be sorted at the network station so that different signals of similar strength are transmitted during common timeslots. Signals transmitted using transmit/receive bursts occupying a common timeslot/subslot and adjacent channel bandwidths, such as bursts **5a** and **5b**, can be better accommodated where one signal strength is not substantially greater than the other.

According to alternate embodiments of Figure 5, the IF filter **105** can include different selectable physical filters adapted to pass the different signal bandwidths. The different selectable filters can be selected via control signals generated by the controller **108** on the control bus **98** according to the bandwidth(s) in use. The use of selectable physical filters may allow greater adjacent channel interference power to be tolerated, and both physical and digital filters may be used together to enhance rejection of unwanted adjacent channel signals. The use of digital filters to convert a wideband receiver to a narrowband receiver is described, for example, in U.S. Patent No. 5,668,837 entitled "Dual-Mode Radio Receiver For Receiving Narrowband And Wideband Signals" which is hereby incorporated herein in its entirety by reference. Moreover, the inventor of the present application is an inventor of the above referenced patent.

The coupler **101** can be a transmit/receive switch in a mobile terminal which does not transmit and receive at the same time. With a transmit/receive switch, the controller **108** can be coupled to the coupler **101** by control bus **98** to determine whether the receiver **99** or the transmitter **104** is coupled to the antenna **100**. The controller **108** can also be coupled to the frequency synthesizer **103** to provide synthesizer tuning codes thereto, and the controller can be coupled to other units as shown to power different units on and off at appropriate times to conserve battery power. The frequency synthesizer **102** can provide a local oscillator signal to a downconvertor within the receiver front end **102**, and also to a modulator and transmit power amplifier within the transmitter **104**. Accordingly, transmission (if needed) can take place on an assigned transmit frequency channel in the transmit frequency band. The digital signal processor **107** may also generate complex modulation signals in the digital domain which can be converted to analog signals using complex D-to-A converter **109** prior to modulating the assigned transmit carrier frequency.

The complex D-to-A converter **109** and a modulator included in the transmitter **104** may be, for example, of the I,Q modulator design described in U.S. Patent No. 5,530,772 entitled "Quadrature Modulator With Integrated Distribution RC Filters" which is hereby incorporated herein in its entirety by reference. Moreover, the inventor of the present application is an inventor of the above referenced patent. Alternately, the complex D-to-A converter and a modulator of the transmitter may use r-theta modulation wherein the modulator first generates a constant amplitude signal varying in phase only in a desired manner, followed by envelop remodulation with the r-signal to impose the desired variations in amplitude. In the case of GMSK modulation (as used, for example, according to the GSM standard), no amplitude variations may need to be remodulated as a GMSK signal is typically a constant-amplitude modulation. In the case of 8-PSK modulation (as used for example according to the GSM/EDGE standard), however, amplitude variation (*i.e.*, linear modulation) may be used better to contain the transmitted signal spectrum within the assigned channel.

Further embodiments of mobile terminals according to the present invention are illustrated in Figure 6 with receivers which incorporate Homodyne techniques. As shown, received signals from the antenna **400** can pass through the coupler **401**, which may comprise a transmit/receive switch, to homodyne downconverter **200**. The received signals can be filtered using bandpass filter **201**, amplified using low-noise amplifier **202**, and quadrature downconverted to the complex baseband using quadrature mixers **203** and **204**. The quadrature mixers **203, 204** mix the signal with cosine and sine local oscillators such as oscillator **205**. The oscillator **205** can be controlled to the center of a desired receive frequency channel using a frequency synthesizer phase lock loop circuit **403**.

The complex baseband signals can be low-pass filtered and amplified using filter-amplifiers **206** and **207** and then A-to-D converted using A-to-D converter

208. Problems relating to DC offset in homodyne receivers may be compensated for by using an A-to-D converter **208** and filter amplifiers **206** and **207** which have sufficient dynamic range so as not to saturate on the DC offset signal. The DC offset may then be estimated and subtracted using the digital signal processor **407** using techniques such as those discussed, for example, in U.S. Patent No. 5,241,702 entitled "D.C. Offset Compensation In A Radio Receiver", and U.S. Patent No. 5,568,520 entitled "Slope Drift And Offset Compensation In Zero-IF Receivers". The disclosures of each of these patents are hereby incorporated herein in their entirety by reference. Moreover, the inventor of the present application is an inventor of each of the above referenced patents. These patents discuss methods of compensating for homodyne receiver imperfections.

An advantage of a homodyne receiver is that channel filtering can be provided by low-pass filters **206** and **207** which can be provided as integrated circuit devices as opposed to the bandpass filter **105** of Figure 5 which may be provided as an external component(s). The use of integrated low-pass filters can reduce size and cost of a mobile terminal. Moreover, several different filter bandwidths may be integrated into a single chip embodying a majority or all of a homodyne receiver **200**, thereby realizing a multiple bandwidth capability without significantly increasing a number of chips or components used. A desired filter bandwidth may be selected by the control processor **408** generating signals along a control bus (not shown in Figure 6 for the purpose of clarity) which couples all blocks needing control signals and/or power on/off signals from the control processor **408**.

A mobile terminal according to the present invention can, thus, select a relatively wide bandwidth and relatively high datarate for communicating data between the wireless network and the mobile terminal, so that the communication is accomplished in a reduced time. While communications capacity, as defined by the product of time and bandwidth, may remain relatively constant because higher datarates may be provided using greater bandwidths over reduced burst durations, it may still be advantageous to the mobile terminal to provide an increased datarate over a shorter period of time. In particular, battery power at the mobile terminal may be conserved because transmission and/or reception can be done in less time.

In certain circumstances, selection of a higher bandwidth with a higher datarate over a shorter transmit/receive burst duration may reduce network resources consumed effecting a given data transfer. In particular, multipath propagation can be beneficial when two or more multipath rays with relative delay equal to a symbol duration or more exhibit independent fading. The independent rays can thus provide an effect similar to that of a diversity reception channel which can significantly reduce the power needed for successful communication and which can improve tolerance to interference. When paths from transmitter to receiver do not provide relative delay greater than or equal to a symbol duration at a relatively narrow bandwidth, a delay difference in terms of symbol periods will be increased if the bandwidth and datarate are increased so that the symbol duration is reduced, thereby improving diversity gain available from multipath propagation.

Conversely, if multipath delays (in terms of symbol periods) are too great to be compensated for by a receiver equalizer (which may be implemented as a part of digital signal processor **107** or **407**), reducing transmit/receive burst bandwidth and datarate (so that the symbol period is increased) can improve communication performance. Accordingly, increasing or reducing transmit/receive bandwidth and datarate to provide a desired range of multipath delay with respect to symbol duration can improve data communications. The network may determine the propagation conditions by receiving an indication from a mobile terminal which can be piggy-backed onto acknowledgements of successful or unsuccessful data reception. Alternately, the network may determine the propagation conditions from the mobile terminal to the network using its own receiver equalizer and channel estimator, and assume that the path from the network to the mobile terminal has a similar multipath delay spread.

When the network decides to change bandwidth, datarate, and burst duration for communications with a mobile terminal, the new bandwidth, frequency channel, and timeslot/subslot allocations can be communicated to the mobile terminal. This reallocation can be done, for example, as an extension of the GSM, GPRS, or EDGE protocols, each of which involves the mobile terminals listening to a control channel to receive channel allocations for transmitting and receiving subsequent data packets. The choice of bandwidth could be fixed for a given batch of data packets, and then, based on success, failure, or other assessments, a decision could be made to make a different channel allocation for a subsequent set of data packets.

The GPRS/EDGE standard typically begins by responding to a request to deliver data to the mobile terminal, for example, by receiving a mouse-click from the mobile terminal's microbrowser. The mobile terminal then listens to the control channel for a message from the network informing it which frequency channel and which timeslot to listen to to receive the requested data. The network transmits a message on the control channel addressed to the mobile terminal that provides the channel assignment parameters which can include a frequency channel, a timeslot, and a modulation type. According to the present invention, this message from the network can also include the bandwidth and symbol rate to be used, and the timeslot designation may further define a subslot thereof. The mobile terminal can acknowledge receipt of the of the channel assignment message, thereby indicating that the mobile terminal will listen on the assigned channel. The network then transmits the requested data on the assigned channel, interspersed with data addressed to other mobile terminals.

The mobile terminal can decode data received on the assigned channel and filter out those data packets (communicated via respective transmit/receive bursts) bearing its own address. Successful reception of data packets can be acknowledged by the mobile terminal to the network. Alternately, the mobile terminal may receive a string of data packets via respective transmit/receive bursts, and only provide an indication of non-receipt of individual data packets if the string is not successfully received. In other words, an indication is sent back to the network for data packets that could not be decoded without errors, and no such indication is sent if all packets in the string can be decoded without error. The network can then repeat transmission of missing or unacknowledged packets.

The channel assignment message can also include a 3-bit temporary short ID code for the terminal to signal the mobile terminal when it may transmit acknowledgements without clashing with transmissions of other mobile terminals. The 3-bit code can be included in data transmitted on the assigned channel even when the transmitted data is addressed to another mobile terminal. When the mobile terminal detects transmission of this 3-bit code in data transmitted on the assigned channel, the mobile terminal is authorized to transmit on a predetermined timeslot in the next time frame.

While a common time-bandwidth product can be maintained for transmit/receive bursts of different datarates according to embodiments of the present invention, there is no particular constraint that the uplink frame format from a mobile terminal to the network stations needs to be divided in time and frequency exactly paralleling the downlink format from the network to the mobile terminals. Instead, it may be advantageous to use different bandwidths in the different directions as discussed, for example, in the following patents: U.S. Patent No. 5,960,364 entitled "Satellite/Cellular Phone Using Different Channel Spacings On Forward And Return Links"; U.S. Patent No. 5,943,324 entitled "Methods And Apparatus For Mobile Station To Mobile Station Communications In A Mobile Satellite Communications System"; U.S. Patent No. 5,809,141 entitled "Method And Apparatus For Enabling Mobile-To-Mobile Calls In A Communication System"; and U.S. Patent No. 5,566,168 entitled "TDMA/FDMA/CDMA Hybrid Radio Access Methods". The disclosures of each of these patents are hereby incorporated herein in their entirety by reference. Moreover, the inventor of the present application is an inventor of each of the above referenced patents.

In particular, it is disclosed therein that it can be advantageous for the mobile terminal to transmit longer bursts of narrower bandwidth when transmitting longer bursts of wider bandwidth would have required excessive peak power. On the other hand, it is disclosed herein that a battery operated terminal may achieve longer battery life by transmitting shorter bursts of wider bandwidth at close to maximum power, when transmitting longer bursts of narrower bandwidth would have required substantially less than maximum power. In general, a mobile terminal transmitter is likely to be used most efficiently if it transmits as close as possible to maximum power for the shortest possible time because transmitting at less than maximum power (*i.e.*, with transmitter back-off) may lead to lower conversion efficiency of battery power to RF power. The channel assignment message can thus define different channel characteristics for bursts transmitted from a network station to a mobile terminal and for bursts transmitted from the mobile terminal to the network station to provide efficient operation of the mobile terminal transmitter.

When uplink path-loss and time-dispersion permit, assignment of a higher bandwidth for transmission by a mobile terminal (allowing transmission at a higher power for a shorter period of time) may also provide increased battery life for the mobile terminal. A mobile terminal can thus transmit at an increased transmission datarate and bandwidth over a reduced burst duration when path loss permits (such as when the mobile terminal is relatively close to a network base station) instead of backing-off from maximum transmitter power to transmit at a slower rate. The latter may be less efficient than transmission at full power for a shorter time, thus adversly affecting battery life.

Communications can, thus, be provided according to the present invention by communicating a first data burst using a first bandwidth and a first burst duration, and communicating a second data burst using a second bandwidth and a second burst duration. More particularly, the first bandwidth can be greater than the second bandwidth, and the first burst duration can be less than the second burst duration. Communications between a base station and a mobile terminal(s) can thus be dynamically allocated by bandwidth and burst duration from one time frame to the next. In addition, communications with multiple mobile terminals can be allocated different burst durations and bandwidths during a common time frame.

For example, communications can be transmitted from a first communications device to a second communications device during a communications session wherein a communications session can be defined to include a plurality of related data transfers used to support a service event such as a telephone call; transmission or reception of e-mail, pages, or other data; an internet session; or other related data transfers between two communications devices. More particularly, a first data burst can be transmitted during the communications session using the first bandwidth and the first burst duration, and a second data burst can be transmitted during the communications session using the second bandwidth and the second burst duration.

A third data burst can also be transmitted using a third bandwidth and a third burst duration, wherein the first and second bandwidths are greater than the third bandwidth, and wherein the first and second burst durations are less than the third burst duration. According to a particular example, the first data burst can be transmitted during a first time frame, and the second data burst can be transmitted during a second time frame wherein the first and second time frames each have a common frame period and a repetitive frame structure to provide time division multiple access using the first and second time frames.

According to a particular embodiment of the present invention, a product of the first bandwidth and the first burst duration can be substantially equal to a product of the second bandwidth and the second burst duration. In addition, the first data burst can be communicated at a first datarate, the second data burst can be communicated at a second datarate, and the first datarate can be higher than the second datarate. According to this embodiment, a common volume of data can be communicated by the first and second data bursts. In addition, the first data burst and the second data burst can share a common burst format, and the common burst format can be scaled according to the respective first and second burst durations of the first and second data bursts.

According to an alternate aspect of the present invention, communications can be transmitted from a base station to respective first and second mobile terminals. In particular, a first data burst can be transmitted to the first mobile terminal using a first bandwidth and a first burst duration, and a second data burst can be transmitted to a second mobile terminal using a second bandwidth and a second burst duration. As before, the first bandwidth can be greater than the second bandwidth, and the first burst duration can be less than the second burst duration. In addition, the first and second data bursts can both be transmitted during a common one of a plurality of time frames wherein the time frames have a common frame period and a repetitive frame structure to provide time division multiple access communications.

Stated in other words, communications methods and devices according to the present invention can provide adaptive bandwidth Time Division Multiple Access wherein a superchannel bandwidth can be defined as equal to an integer multiple of a basic channel bandwidth for a full timeslot in a repetitive time frame. Data bursts can be communicated (transmitted and/or received) using the basic channel bandwidth during a full timeslot and/or communicated using the superchannel bandwidth for a subslot during the time frame wherein the subslot has a duration less than the full time slot.

According to an exemplary embodiment, the superchannel bandwidth can be 800kHz, an intermediate channel bandwidth can be 400kHz, and the basic channel bandwidth can be 200kHz. In this example, a repetitive frame period can be approximately 4.615ms which can be divided into 32 subslots of 144.23μs. A single subslot can be used to communicate a transmit/receive burst using the entire 800kHz bandwidth superchannel at a symbol rate of 13/12 megasymbols per second; two subslots can be combined to communicate two transmit/receive bursts each using a respective 400kHz bandwidth intermediate channel at a symbol rate of 13/24 megasymbols per second; and/or four subslots can be combined to communicate four transmit/receive bursts each using a respective 200kHz bandwidth basic channel at a symbol rate of 13/48 megasymbols per second.

The combination of four subslots having a combined duration of 576.92μs to communicate a transmit/receive burst with a bandwidth of 200kHz at a symbol rate of 13/48 megasymbols per second can be used to support digital cellular communications according to the GSM and/or EDGE standards. Devices and methods according to the present invention can thus provide backward compatibility with respect to existing GSM/EDGE mobile terminals and/or infrastructure.

By providing that a time-bandwidth product for transmit/receive bursts using each of the bandwidth and burst duration combinations is the same, a common data format can be used for transmit/receive bursts using each of the bandwidth and burst duration combinations. In other words, a common data format can be used to communicate the same volume of data using a quarter duration subslot on a 800kHz channel, a half duration subslot on a 400kHz channel, or a full timeslot on a basic 200kHz channel, with the communications differing by a 2:1 or a 4:1 time-compression relative to the basic 200kHz channel. A receiver according to the present invention can thus receive a respective burst by sampling the appropriate bandwidth at a respective sampling rate and storing the samples in memory. These samples can then be processed in non-real time using the same processing techniques for bursts received using any of the bandwidth timeslot/subslot combinations. Accordingly, the processing complexity can be reduced.

In addition, a base station according to the present invention can assign timeslot/subslot durations, bandwidths, and symbol rates for bursts transmitted to mobile terminals communicating therewith so that a multipath time-delay spread does not exceed a predetermined number of symbol periods at the assigned bandwidth. In other words, mobile terminals subject to the greatest multipath time-delay spreads can receive bursts at the lowest symbol rate, and mobile terminals subject to the lowest multipath time-delay spreads can receive bursts at the highest symbol rate. Mobile receiver terminals according to the present invention can thus use the same equalizer to equalize bursts received at any of the available bandwidths/symbol rates using the symbols stored during reception of each burst. Equalizer capabilities can thus be used as a factor to determine channel assignments for mobile terminals.

Bandwidth and time divisions illustrated in the Figures are only exemplary of an instant in time, for example, the single TDMA frame depicted. Bandwidth and time divisions may be completely changed from one TDMA frame to the next so long as mobile terminals being serviced are informed of the channel allocations. Moreover, channel bandwidth division should be provided such that bandwidths assigned to different mobile terminals during a common time period do not overlap.

In addition, receivers may be provided that decode data with a first bandwidth assumption, and, upon failure to detect good data based on this assumption, proceed to reprocess stored data using a second bandwidth assumption. To accommodate this, the data may be sampled with a bandwidth and sampling rate commensurate with the highest bandwidth and stored. The stored data may subsequently be numerically filtered to reduce the bandwidth and sampling rate. Such a receiver may also decode more than one channel division in the same timeslot by reprocessing the stored data with numerical filters of different center frequencies. Receivers may also be instructed to receive and decode multiple timeslots in succession, and, according to the present invention, the successive timeslots may be processed using different bandwidths and datarates. Such techniques may thus permit receivers to receive higher datarates beyond those that can be communicated using a single timeslot per frame or a single frequency channel.

Although the exemplary embodiments discussed herein have been discussed as a potential evolution of the GSM and/or EDGE standards, adaptive bandwidth and timeslot durations according to the present invention can be adapted for use with other mobile communications systems such as the D-AMPS (IS-136) TDMA standard, or CDMA standards such as IS-95. Adaptive bandwidth and timeslot durations according to the present invention may be introduced into the IS-95 CDMA standard by using subdivisions of its 1.2288MHz chip rate and channel bandwidths to create narrower bandwidth channels for use where transmissions of data at the full chip rate may be difficult to equalize due to high multipath delay spread.

In the drawings and specification, there have been disclosed typical preferred embodiments of the invention and, although specific terms are employed, they are used in a generic and descriptive sense only and not for purposes of limitation, the scope of the invention being set forth in the following claims. As used herein, the term communicating can include transmitting or receiving. Accordingly, the act of communicating can be carried out by a transmitter that transmits a data burst(s), a receiver that receives a data burst(s), or a communications system that both transmits and receives a data burst(s).

**What is Claimed is:**

1. A method for transmitting wireless communications from a first communications device to a second communications device during a communications session, the method comprising:

transmitting a first data burst during the communications session using a first bandwidth and a first burst duration; and

transmitting a second data burst during the communications session using a second bandwidth and a second burst duration, wherein the first bandwidth is greater than the second bandwidth, and wherein the first burst duration is less than the second burst duration.

2. The method according to Claim 1 further comprising:

transmitting a third data burst during the communications session using a third bandwidth and a third burst duration, wherein the first and second bandwidths are greater than the third bandwidth, and wherein the first and second burst durations are less than the third burst duration.

3. The method according to Claim 1 wherein:

transmitting the first data burst during the communications session using a first bandwidth and a first burst duration comprises transmitting the first data burst during a first time frame wherein the first data burst has a duration less than a duration of the first time frame; and

transmitting the second data burst during the communications session using a second bandwidth and a second burst duration comprises transmitting the second data burst during a second time frame wherein the second data burst has a duration less than a duration of the second time frame;

wherein the first and second time frames each have a common frame period and a repetitive frame structure to provide time division multiple access communications using the first and second time frames.

4. The method according to Claim 1 wherein a product of the first bandwidth and the first burst duration is substantially equal to a product of the second bandwidth and the second burst duration.

5. The method according to Claim 1 wherein the first data burst is transmitted at a first datarate, wherein the second data burst is transmitted at a second datarate, and wherein the first datarate is higher than the second datarate.

6. The method according to Claim 5 wherein a common volume of data is transmitted by the first and second data bursts.

7. The method according to Claim 1 wherein the first data burst and the second data burst share a common burst format, and wherein the common burst format is scaled according to the respective first and second burst durations of the first and second data bursts.

8. A method according to Claim 1 wherein the first and second data bursts are transmitted using code division multiple access.

9. A method for transmitting wireless communications from a base station to respective first and second mobile terminals, the method comprising:

transmitting a first data burst to the first mobile terminal using a first bandwidth and a first burst duration; and

transmitting a second data burst to the second mobile terminal using a second bandwidth and a second burst duration, wherein the first bandwidth is greater than the second bandwidth, and wherein the first burst duration is less than the second burst duration;

wherein the first and second data bursts are both transmitted during a common one of a plurality of time frames wherein the time frames have a common frame period and a repetitive frame structure to provide time division multiple access communications.

10. The method according to Claim 9 further comprising:

transmitting a third data burst to a third mobile terminal during the common time frame, wherein the third data burst uses a third bandwidth equal to the second bandwidth and a third burst duration equal to the second burst duration, wherein the second and third data bursts are communicated concurrently over different frequency bands.

11. The method according to Claim 9 wherein a product of the first bandwidth and the first burst duration is substantially equal to a product of the second bandwidth and the second burst duration.

12. The method according to Claim 9 wherein the first data burst is transmitted at a first datarate, wherein the second data burst is transmitted at a second datarate, and wherein the first datarate is higher than the second datarate.

13. The method according to Claim 12 wherein a common volume of data is transmitted by the first and second data bursts.

14. The method according to Claim 9 wherein the first data burst and the second data burst share a common burst format, and wherein the common burst format is scaled according to the respective first and second burst durations of the first and second data bursts.

15. The method according to Claim 9 wherein the first and second data bursts are transmitted using code division multiple access.

16. A method for receiving wireless communications at a first communications device from a second communications device during a communications session, the method comprising:

receiving a first data burst from the second communications device during the communications session using a first bandwidth and a first burst duration; and receiving a second data burst from the second communications device during the communications session using a second bandwidth and a second burst duration, wherein the first bandwidth is greater than the second bandwidth, and wherein the first burst duration is less than the second burst duration.

17. The method according to Claim 16 further comprising:

receiving a third data burst from the second communications device during the communications session using a third bandwidth and a third burst duration, wherein the first and second bandwidths are greater than the third bandwidth, and wherein the first and second burst durations are less than the third burst duration.

18. The method according to Claim 16:

wherein receiving the first data burst from the second communications device during the communications session using the first bandwidth and the first burst duration comprises receiving the first data burst during a first time frame;

wherein receiving the second data burst from the second communications device during the communications session using the second bandwidth and the second burst duration comprises receiving the second data burst during a second time frame; and

wherein the first and second time frames each have a common frame period and a repetitive frame structure to provide time division multiple access communications using the first and second time frames.

19. The method according to Claim 16 wherein a product of the first bandwidth and the first burst duration is substantially equal to a product of the second bandwidth and the second burst duration.

20. The method according to Claim 16 wherein the first data burst is received at a first datarate, wherein the second data burst is received at a second datarate, and wherein the first datarate is higher than the second datarate.

21. The method according to Claim 20 wherein a common volume of data is received by the first and second data bursts.

22. The method according to Claim 16 wherein the first data burst and the second data burst share a common burst format, and wherein the common burst format is scaled according to the respective first and second burst durations of the first and second data bursts.

23. The method according to Claim 16 wherein the first and second data bursts are received using code division multiple access.

24. A method for receiving wireless communications at a base station from respective first and second communications devices, the method comprising:

receiving a first data burst from the first mobile terminal using a first bandwidth and a first burst duration; and

receiving a second data burst from the second mobile terminal using a second bandwidth and a second burst duration, wherein the first bandwidth is greater than the second bandwidth, and wherein the first burst duration is less than the second burst duration;

wherein the first and second data bursts are both received during a common one of a plurality of time frames wherein the plurality of time frames have a common frame period and a repetitive frame structure to provide time division multiple access communications.

25. The method according to Claim 24 further comprising:

receiving a third data burst from a third mobile terminal during the common time frame, wherein the third data burst uses a third bandwidth equal to the second bandwidth and a third burst duration equal to the second burst duration, wherein the second and third data bursts are received concurrently over different frequency bands.

26. The method according to Claim 24 wherein a product of the first bandwidth and the first burst duration is substantially equal to a product of the second bandwidth and the second burst duration.

27. The method according to Claim 24 wherein the first data burst is received at a first datarate, wherein the second data burst is received at a second datarate, and wherein the first datarate is higher than the second datarate.

28. The method according to Claim 27 wherein a common volume of data is received by the first and second data bursts.

29. The method according to Claim 24 wherein the first data burst and the second data burst share a common burst format, and wherein the common burst format is scaled according to the respective first and second burst durations of the first and second data bursts.

30. The method according to Claim 24 wherein the first and second data bursts are received using code division multiple access.

31. A communications device comprising:

a controller that generates a first data set and a second data set for communication with a second communications device during a communications session; and

a transmitter that transmits the first data set to the second communications device as a first data burst using a first bandwidth and a first burst duration and that transmits the second data set to the second communications device as a second data burst using a second bandwidth and a second burst duration, wherein the first bandwidth is greater than the second bandwidth, wherein the first burst duration is less than the second burst duration, and wherein the first and second data bursts are transmitted to the second communications device during the communications session.

32. The communications device according to Claim 31 wherein the controller generates a third data set for communication with the second communications device during the communications session and wherein the transmitter transmits the third data set as a third data burst using a third bandwidth and a third burst duration, wherein the first and second bandwidths are greater than the third bandwidth, and wherein the first and second burst durations are less than the third burst duration.

33. The communications device according to Claim 31:

wherein the transmitter transmits the first data burst during a first time frame wherein the first data burst has a duration less than a duration of the first time frame; and

wherein the transmitter transmits the second data burst during a second time frame wherein the second data burst has a duration less than a duration of the second time frame; and

wherein the first and second time frames each have a common frame period and a repetitive frame structure to provide time division multiple access communications using the first and second time frames.

34. The communications device according to Claim 31 wherein a product of the first bandwidth and the first burst duration is substantially equal to a product of the second bandwidth and the second burst duration.

35. The communications device according to Claim 31 wherein the first data burst is transmitted at a first datarate, wherein the second data burst is transmitted at a second datarate, and wherein the first datarate is higher than the second datarate.

36. The communications device according to Claim 35 wherein the first and second data sets comprise a common volume of data.

37. The communications device according to Claim 31 wherein the first data burst and the second data burst share a common burst format, and wherein the common burst format is scaled according to the respective first and second burst durations of the first and second data bursts.

38. The communications device according to Claim 31 further comprising:

a receiver coupled to the controller wherein the receiver receives a third data burst.

39. The communications device according to Claim 31 wherein the communications device comprises one of a base station and a mobile terminals and wherein the second communications device comprises the other of a base station and a mobile terminal.

40. The communications device according to Claim 31 wherein transmitter transmits the first and second data bursts using code division multiple access.

41. A base station that transmits communications to a plurality of mobile terminals, the base station comprising comprising:

a controller that generates a first data set for communications with a first mobile terminal and a second data set for communication with a second mobile terminal; and

a transmitter that transmits the first data set to the first mobile terminal as a first data burst using a first bandwidth and a first burst duration and that transmits the second data set to the second mobile terminal as a second data burst using a second bandwidth and a second burst duration, wherein the first bandwidth is greater than the second bandwidth, and wherein the first burst duration is less than the second burst duration, and wherein the first and second data bursts are both transmitted during a common one of a plurality of time frames wherein the time frames have a common frame period and a repetitive frame structure to provide time division multiple access communications.

42. The base station according to Claim 41 wherein the controller generates a third data set for communication with a third mobile terminal, wherein the transmitter transmits the third data set as a third data burst to the third mobile terminal during the common time frame, wherein the third data burst uses a third bandwidth equal to the second bandwidth and a third burst duration equal to the second burst duration, and wherein the second and third data bursts are communicated concurrently over different frequency bands.

43. The base station according to Claim 41 wherein a product of the first bandwidth and the first burst duration is substantially equal to a product of the second bandwidth and the second burst duration.

44. The base station according to Claim 41 wherein the first data burst is transmitted at a first datarate, wherein the second data burst is transmitted at a second datarate, and wherein the first datarate is higher than the second datarate.

45. The base station according to Claim 44 wherein the first and second data sets comprise a common volume of data.

46. The base station according to Claim 41 wherein the first data burst and the second data burst share a common burst format, and wherein the common burst format is scaled according to the respective first and second burst durations of the first and second data bursts.

47. The base station according to Claim 41 further comprising:

a receiver coupled to the controller wherein the receiver receives a third data burst.

48. The base station according to Claim 41 wherein the transmitter transmits the first and second data bursts using code division multiple access.

49. A communications device comprising:

a receiver configured to receive a plurality of data bursts from a second communications device during a communications session with the second communications device, wherein the receiver receives a first data burst from the second communications device during the communications session using a first bandwidth and a first burst duration, and that receives a second data burst from the second communications device during the communications session using a second bandwidth and a second burst duration, wherein the first bandwidth is greater than the second bandwidth, and wherein the first burst duration is less than the second burst duration.

50. The communications device according to Claim 49 wherein the receiver receives a third data burst from the second communications device during the communications session using a third bandwidth and a third burst duration, wherein the first and second bandwidths are greater than the third bandwidth, and wherein the first and second burst durations are less than the third burst duration.

51. The communications device according to Claim 49:

wherein the receiver receives the first data burst during a first time frame;

wherein the receiver receives the second data burst during a second time frame; and

wherein the first and second time frames each have a common frame period and a repetitive frame structure to provide time division multiple access communications using the first and second time frames.

52. The communications device according to Claim 49 wherein a product of the first bandwidth and the first burst duration is substantially equal to a product of the second bandwidth and the second burst duration.

53. The communications device according to Claim 49 wherein the first data burst is received at a first datarate, wherein the second data burst is received at a second datarate, and wherein the first datarate is higher than the second datarate.

54. The communications device according to Claim 53 wherein a common volume of data is received by the first and second data bursts.

55. The communications device according to Claim 49 wherein the first data burst and the second data burst share a common burst format, and wherein the common burst format is scaled according to the respective first and second burst durations of the first and second data bursts.

56. The communications device according to Claim 49 further comprising:

a transmitter that transmits a third data burst.

57. The communications device according to Claim 49 wherein the communications device comprises one of a base station and a mobile terminal and wherein the second communications device comprises the other of a base station and a mobile terminal.

58. The communications device according to Claim 49 wherein the receiver receives the first and second data bursts using code division multiple access.

59. A base station comprising:

a receiver configured to receive a plurality of data bursts, wherein the receiver receives a first data burst from a first mobile terminal using a first bandwidth and a first burst duration, and that receives a second data burst from a second mobile terminal using a second bandwidth and a second burst duration, wherein the first bandwidth is greater than the second bandwidth, wherein the first burst duration is less than the second burst duration, wherein the first and second data bursts are both received during a common one of a plurality of time frames, and wherein the plurality of time frames have a common frame period and a repetitive frame structure to provide time division multiple access communications.

60. The base station according to Claim 59 wherein the receiver receives a third data burst from a third mobile terminal during the common time frame, wherein the third data burst uses a third bandwidth equal to the second bandwidth and a third burst duration equal to the second burst duration, wherein the second and third data bursts are communicated concurently over different frequency bands.

61. The base station according to Claim 59 wherein a product of the first bandwidth and the first burst duration is substantially equal to a product of the second bandwidth and the second burst duration.

62. The base station according to Claim 59 wherein the first data burst is received at a first datarate, wherein the second data burst is received at a second datarate, and wherein the first datarate is higher than the second datarate.

63. The base station according to Claim 62 wherein a common volume of data is received by the first and second data bursts.

64. The base station according to Claim 59 wherein the first data burst and the second data burst share a common burst format, and wherein the common burst format is scaled according to the respective first and second burst durations of the first and second data bursts.

65. The base station according to Claim 59 further comprising:

a transmitter that transmits a third data burst.

66. The base station according to Claim 59 wherein the receiver receives the first and second data bursts using code division multiple access.

67. A method for transmitting from a communications device to a receiver, the method including:

detecting when a predetermined transmit power level less than a maximum transmit power is sufficient for transmissions of a first datarate and a first transmission duration; and

in response to detecting when the predetermined transmit power level is sufficient for transmissions of the first datarate and the first transmission duration, transmitting at a power level greater than the predetermined power level and with a second datarate higher than the first datarate and with a second duration shorter than the first duration.

68. The method according to Claim 67 wherein transmissions at the first datarate occupy a first bandwidth and transmissions at the second datarate occupy a second bandwidth greater than the first bandwidth.

69. The method according to Claim 67 wherein detecting when a predetermined transmit power level less than a maximum transmit power is sufficient for transmission of a first data rate and a first duration comprises making an estimate of multipath delay spread in the transmission path between the communications device and the receiver.

70. The method according to Claim 69 wherein detecting when a predetermined transmit power level less than a maximum transmit power is sufficient for transmissions of a first data rate and a first transmission duration further comprises comparing the estimate of the multipath delay spread with a predetermined capability of the receiver.

71. The method according to Claim 69 wherein detecting when a predetermined transmit power level less than a maximum transmit power is sufficient further comprises selecting the second datarate when the estimate of the multipath delay spread is less than a predetermined threshold.

72. The method according to Claim 69 wherein detecting when a predetermined transmit power level less than a maximum transmit power is

sufficient further comprises selecting to transmit at the first datarate when the estimate of the multipath delay spread is greater than a predetermined threshold.

73. A method for transmitting from a communications device to a receiver, the method comprising:

detecting that a maximum transmission power is insufficient for transmissions of a first datarate and a first transmission duration; and

in response to detecting that the maximum transmission power is insufficient for transmissions of the first datarate and the first transmission duration, transmitting at a power level no greater than the maximum transmission power with a second datarate lower than the first datarate and with a second duration longer than the first duration.

74. The method of Claim 73 wherein transmissions at the first datarate occupy a first bandwidth and transmissions at the second datarate occupy a second bandwidth longer than the first bandwidth.

75. The method according to Claim 73 wherein detecting that a maximum transmission power is insufficient for transmission of a first data rate and a first transmission duration comprises making an estimate of a multipath delay spread in a transmission path between the communications device and the receiver.

76. The method according to Claim 75 wherein detecting that a maximum transmission power is insufficient for transmission of a first datarate and a first transmission duration comprises comparing the estimate of the multipath delay spread with a predetermined capability of the receiver to compensate for multipath propagation.

77. The method according to Claim 75 wherein detecting that a maximum transmission power is insufficient for transmissions of a first datarate and a first transmission duration further comprises selecting the first datarate when the delay spread estimate is less than a predetermined threshold.

78. The method according to Claim 75 wherein detecting that a maximum transmission power is insufficient for transmissions of a first datarate and a first transmission duration further comprises transmitting at the second datarate when the estimate of the multipath delay spread is greater that a predetermined threshold.

79. A method for transmitting digital data between a communications network and a plurality of mobile terminals, the method comprising:

dividing an amount of assigned radio frequency spectrum into channels of a first channel bandwidth and further dividing the channels of the first channel bandwidth into a number of non-overlapping sub-channels of a second channel bandwidth less than the first channel bandwidth;

dividing a repetitive frame period into timeslots of a first duration, and further dividing the timeslots of a first duration into an number of non-overlapping subslots of a second duration less than the first timeslot duration;

detecting when the transmission path between the communications network and a particular one of the mobile terminals can support transmissions at a first datarate occupying the first channel bandwidth;

in response to detecting when the transmission path between the communications network and the particular one of the mobile terminals can support transmission at the first datarate, allocating at least one of the subslots of the second duration for transmitting the digital data to the particular one of the mobile terminals using the first datarate; and

in the alternative that the transmission path between the communications network and the particular one of the mobile terminals cannot support transmission at the first datarate, allocating at least one of the subslots of the second channel bandwidth for transmitting data at a second datarate less than the first datarate during at least one of the timeslots of the first duration.

80. An adaptive bandwidth Time Division Multiple Access system for communicating data between a communications network station and a plurality of mobile terminals, the system comprising:

a TDMA transmitter/receiver that divides a repetitive TDMA period and a given radio spectrum into timeslots and frequency channels respectively, and that further divides the timeslots and frequency channels into subslots and subchannels respectively;

a Time-Bandwidth allocation circuit that allocates for communications between the network station and each one of the mobile terminals a time period equal to either one of the timeslots or on of the subslots and a channel bandwidth equal to the frequency channel of the subchannel, where the product of the frequency channel bandwidth allocated and the time period is substantially constant.

81. The system according to Claim 80 wherein the repetitive TDMA frame period equals 60000 cycles of a 13 megahertz clock in duration.

82. The system according to Claim 80 wherein the timeslots are one eighth of the frame period duration.

83. The system according to Claim 80 wherein the subslots are one half, one quarter, or one eighth of the timeslots in duration.

84. The system according to Claim 80 wherein the subchannels have a 200kHz bandwidth.

85. The system according to Claim 80 wherein the frequency channels have a bandwidth of 400kHz, 800kHz, or 1600kHz.

86. The system according to Claim 80 wherein the time-bandwidth allocation means allocates a time and a bandwidth subdivision to a particular mobile terminal taking into account at least one of:

a propagation loss between the network station and the subscriber terminal;

a power level necessary for transmission to or from the mobile terminal;

a power available for transmission to or from the mobile terminal;

a multipath delay spread of a propagation path between the network station and the mobile terminal;

relative signal levels transmitted to or received from other of the mobile terminals allocated bandwidth divisions adjacent to the bandwidth subdivision to be allocated to the mobile terminal; and

a capability of an equalizer in either the network or terminal receiver to compensate for multipath distortion.

87. An adaptive bandwidth communications system for communicating data between a communications network station and a plurality of mobile terminals, the system comprising:

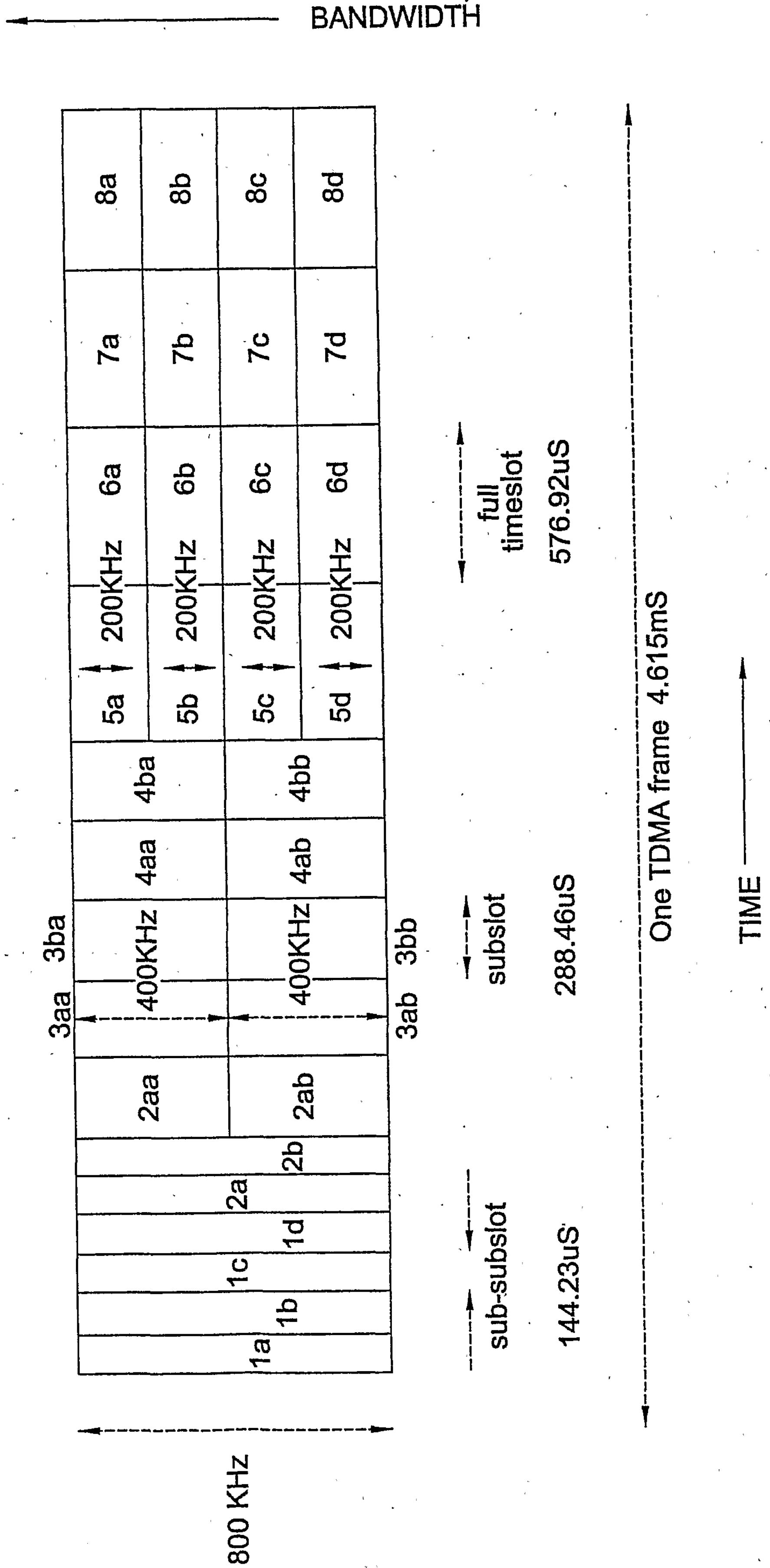
a burst formatter for formatting data for transmission into a predetermined succession of modulation symbols;

a rate-determiner for choosing a symbol rate for transmission;

a transmitter for transmitting a signal modulated with the predetermined succession of modulation symbols at the chosen transmission rate;

a receiver for receiving the transmitted signal and sampling and converting the signal into representative numerical samples stored in a memory buffer;

a signal processor for processing the stored numerical samples to recover the transmitted data, wherein the signal processor processes the numerical samples in substantially the same manner irrespective of the chosen symbol rate.


BANDWIDTH
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8b
8c
8d
7a
7b
7c
7d
6a
6b
6c
6d
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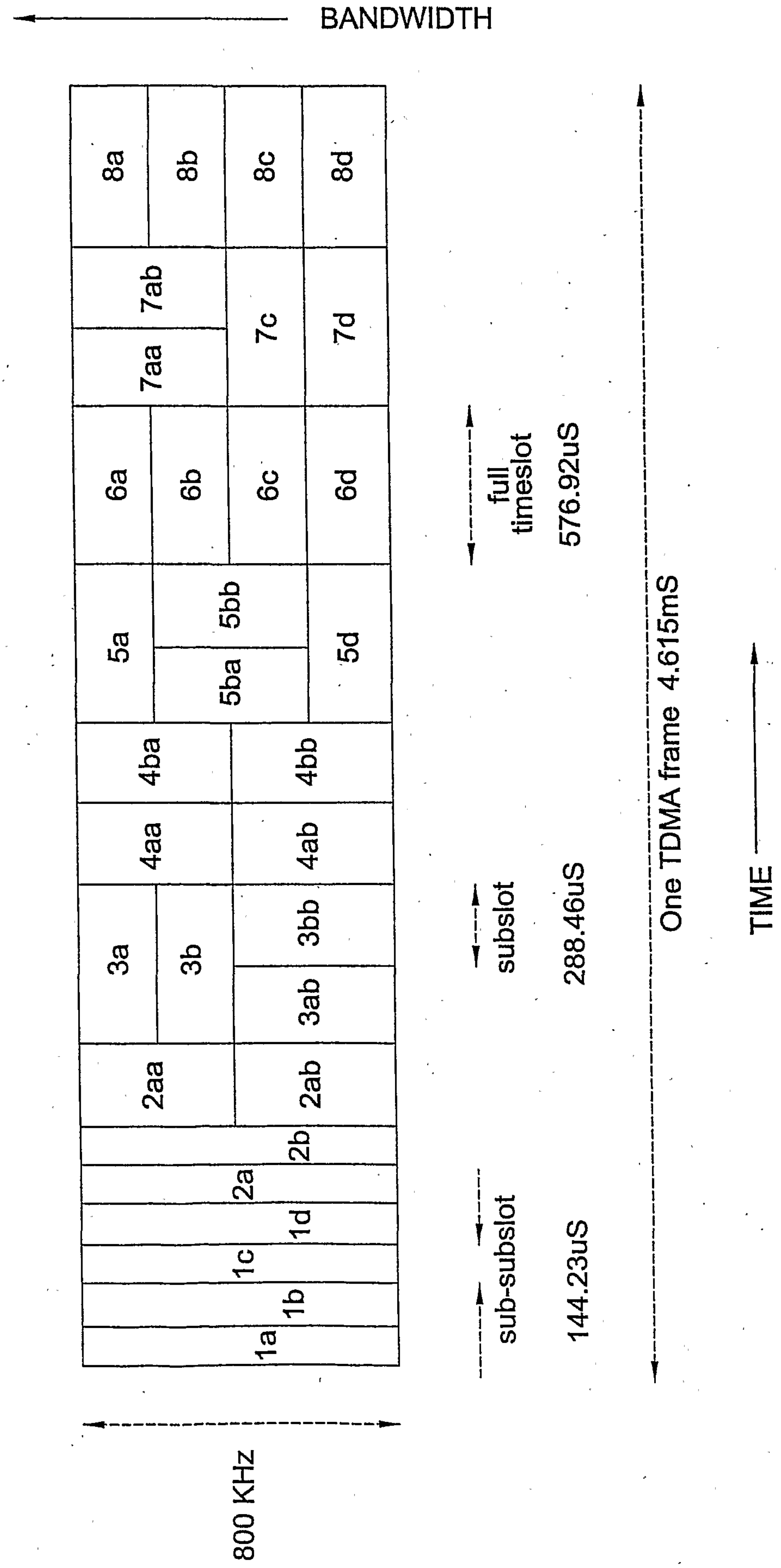
200KHz
200KHz
200KHz
5a
5b
5c
5d
4ba
4bb
4aa
4ab
3ba
3aa
400KHz
400KHz
3bb
3ab
2aa
2ab
2b
2a
1d
1c
1b
1a
full timeslot
576.92uS
subslot
288.46uS
sub-subslot
144.23uS
One TDMA frame 4.615mS
TIME
800 KHz

FIG. 1.


BANDWIDTH
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5d
4ba
4bb
4aa
4ab
3a
3b
3bb
3ab
2aa
2ab
2b
2a
1d
1c
1b
1a
full timeslot
576.92uS
subslot
288.46uS
sub-subslot
144.23uS
One TDMA frame 4.615mS
TIME
800 KHz

FIG. 2.

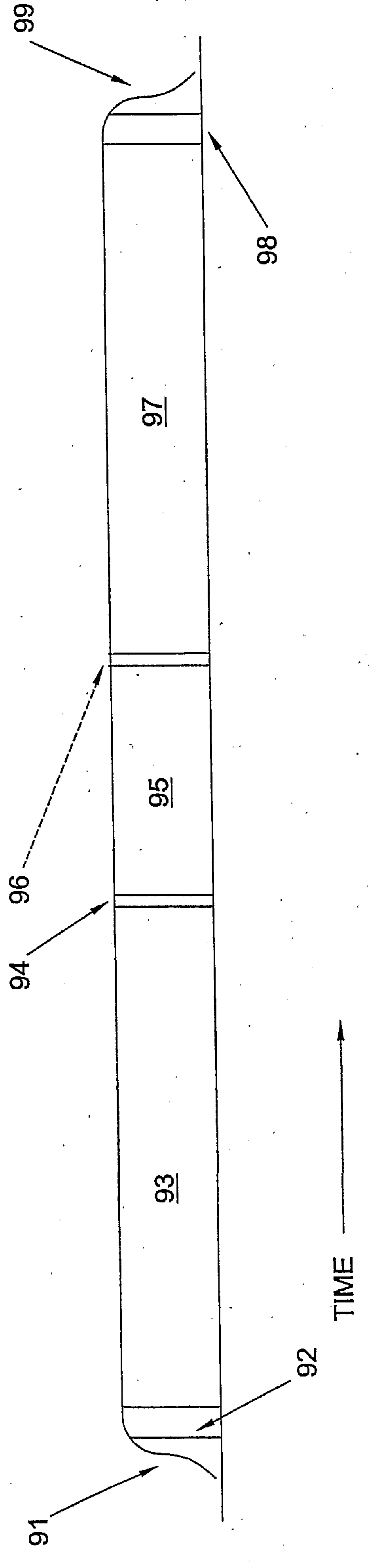



FIG. 3.

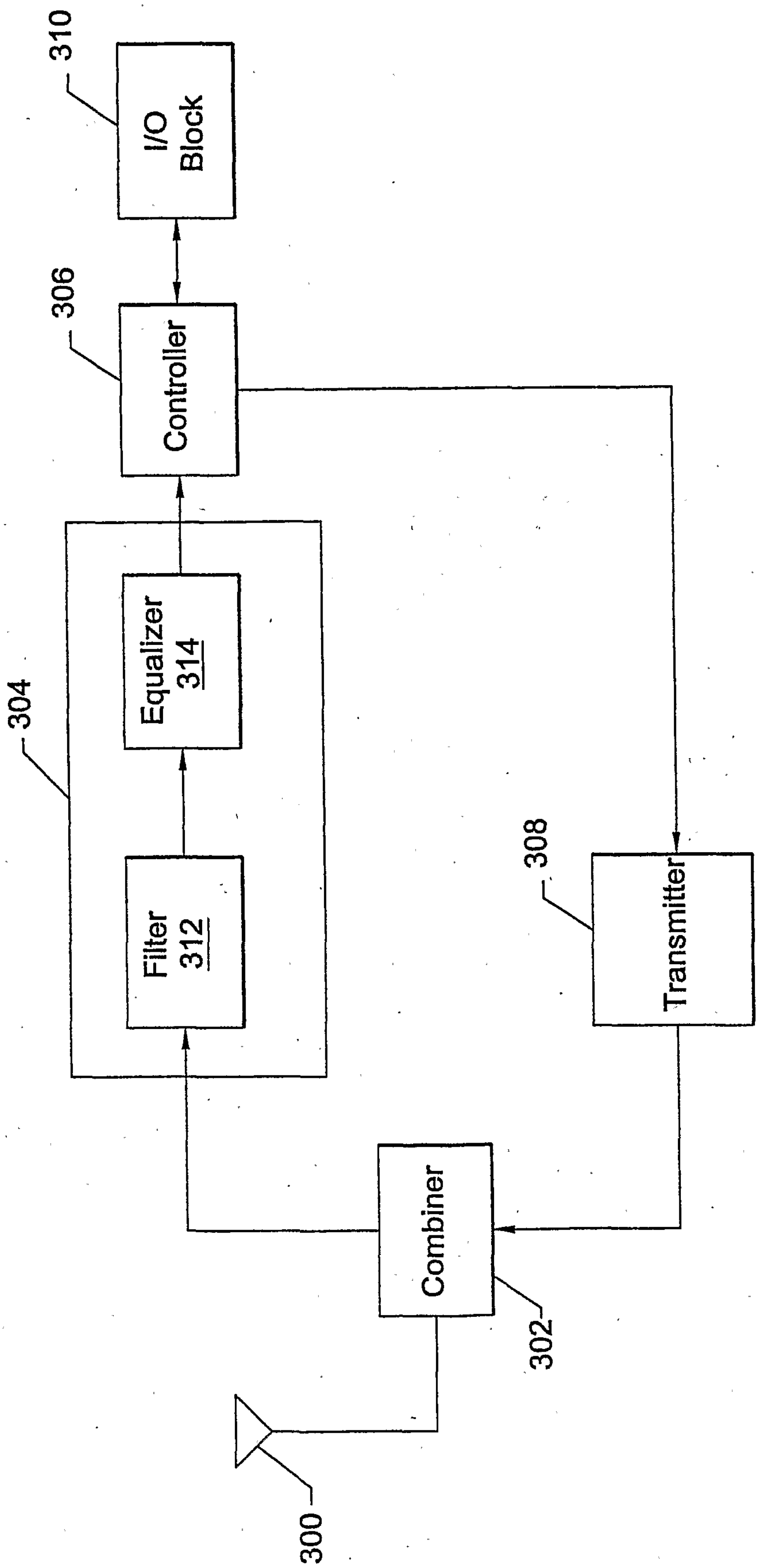

I/O Block
310
Controller
306
Equalizer 314
Filter 312
304
Transmitter
308
Combiner
302
300

FIG. 4A.

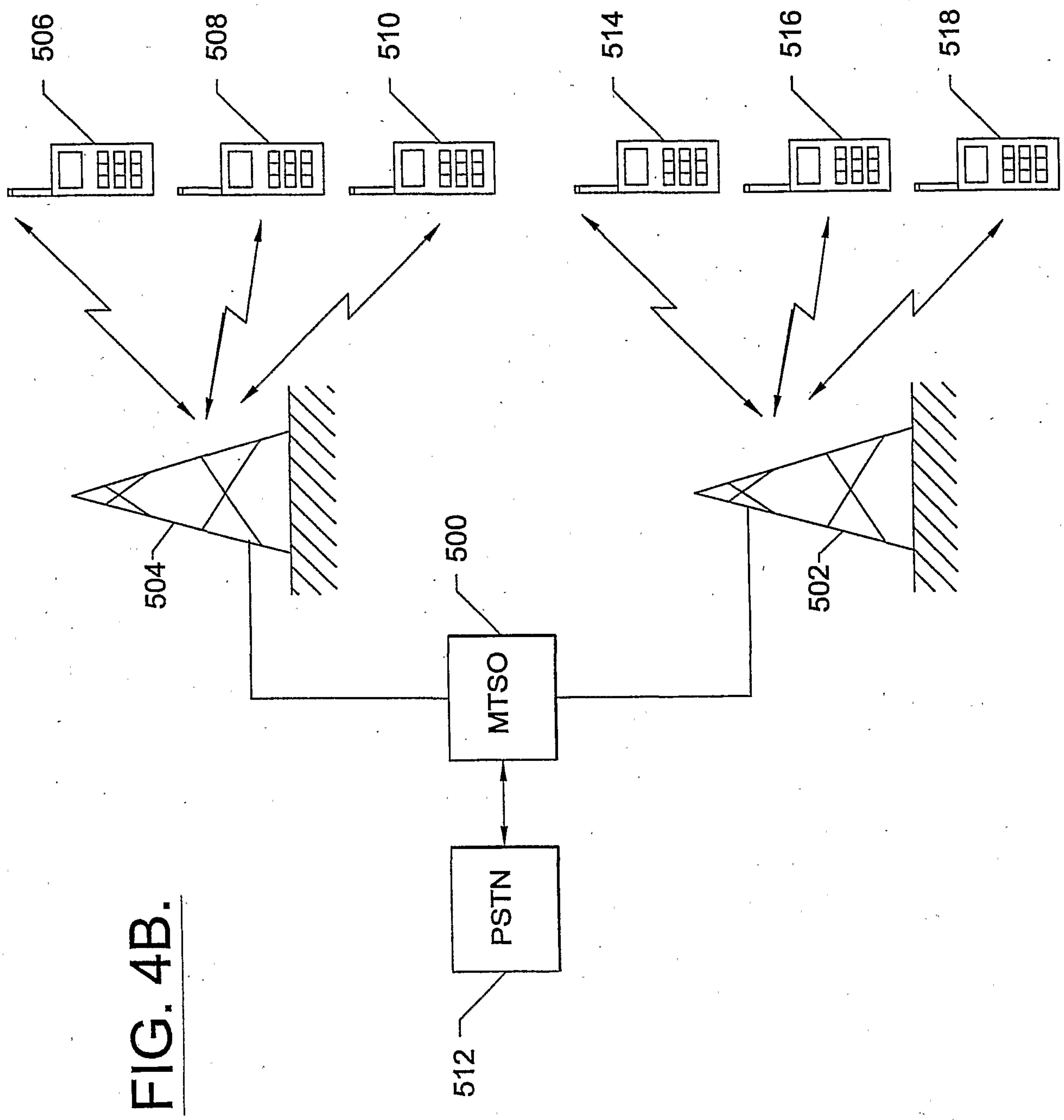



FIG. 4B.

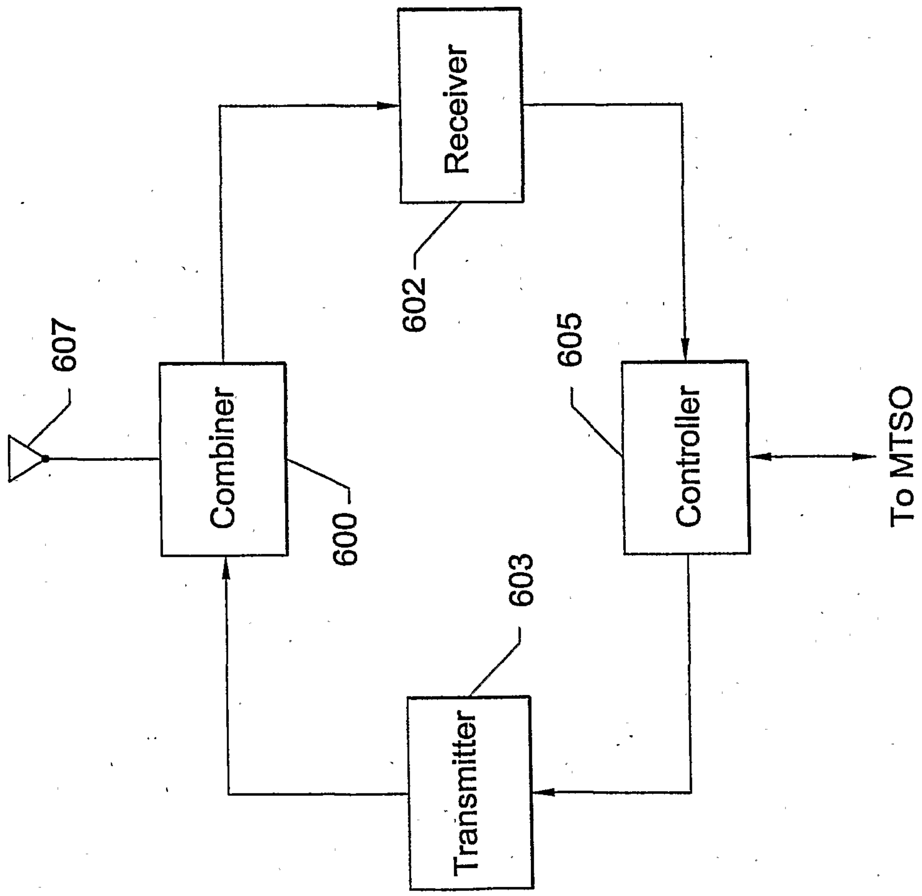

Receiver
602
607
605
Combiner
Controller
600
To MTSO
603
Transmitter

FIG. 4C.

FIG. 5.

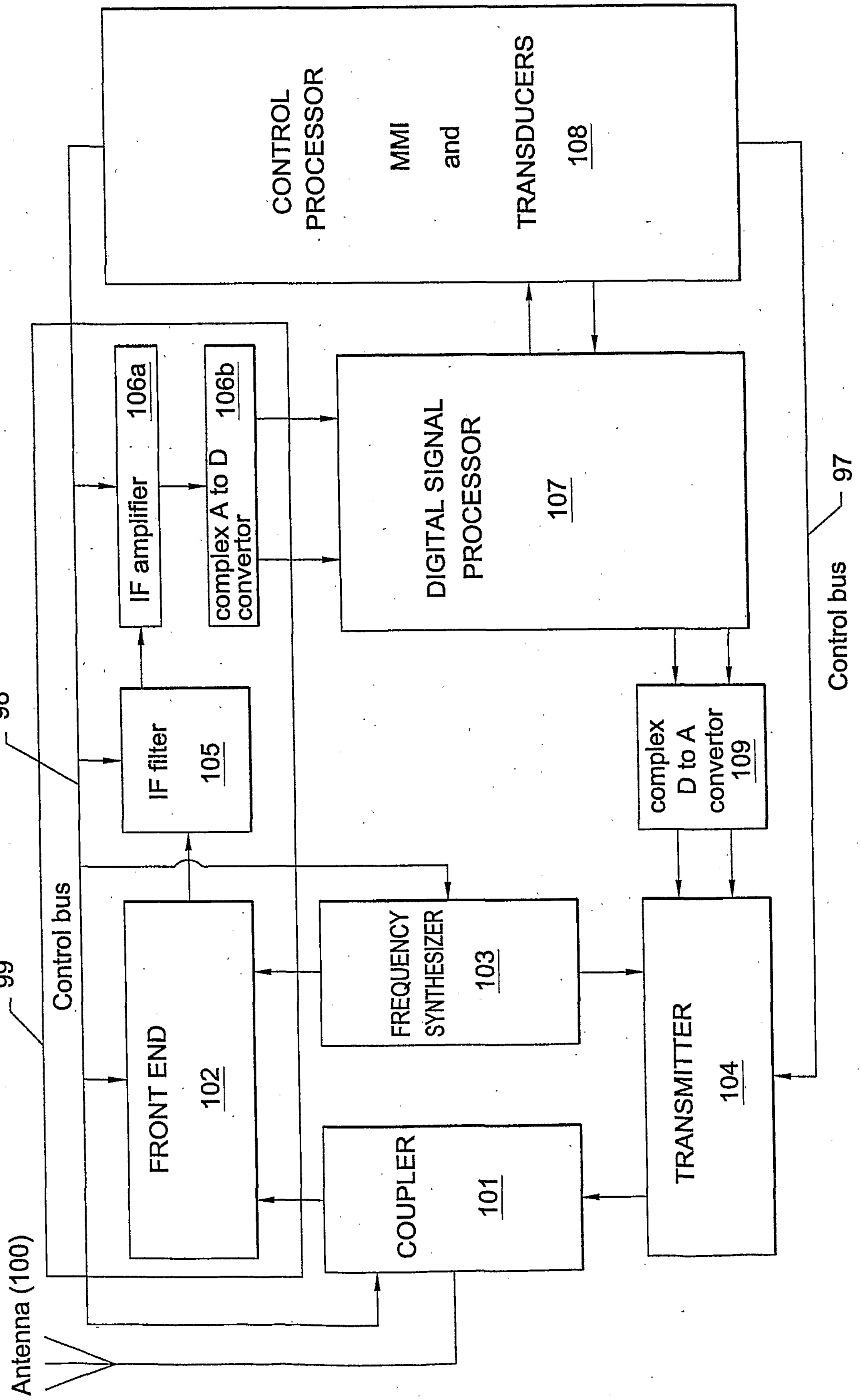
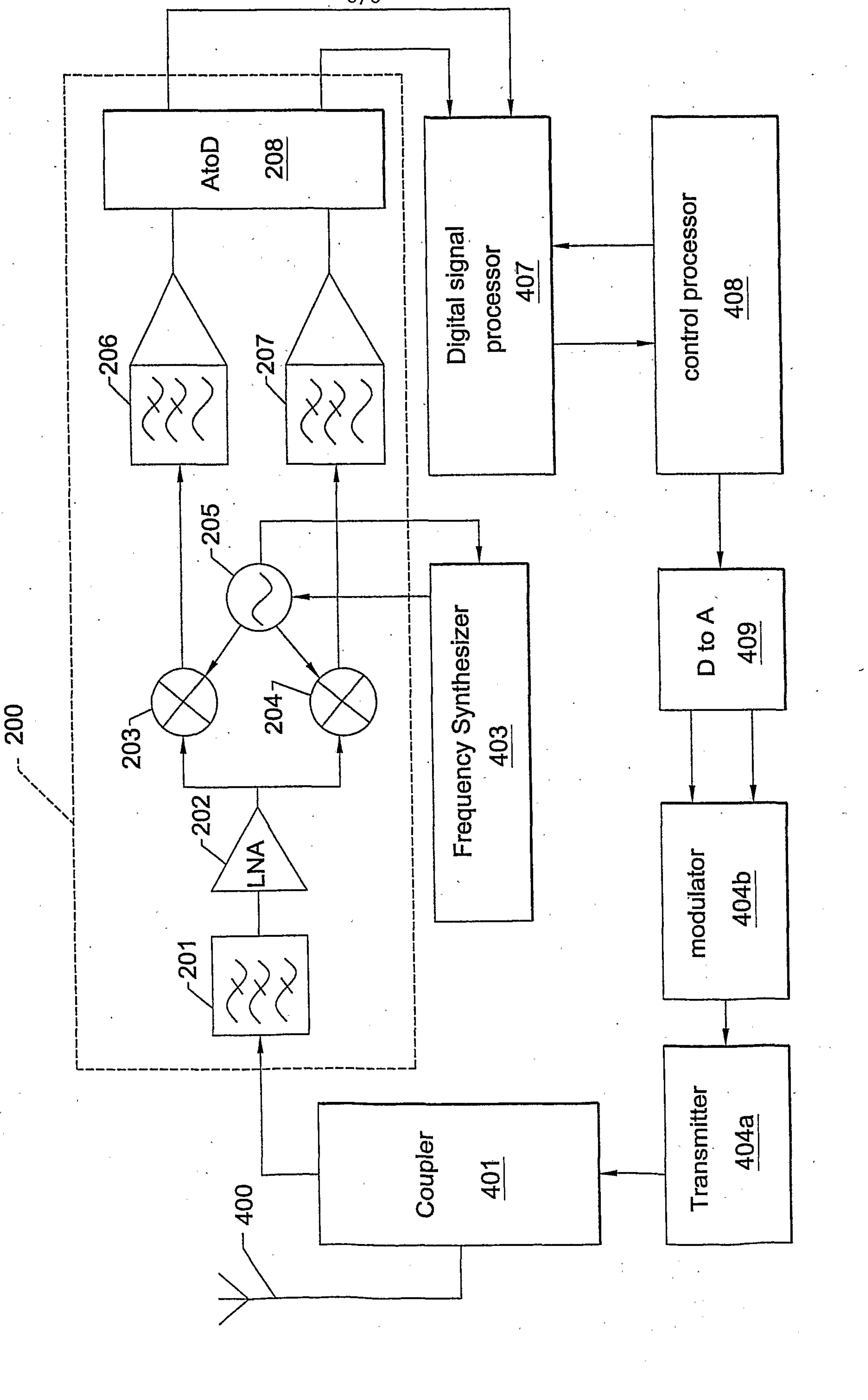

CONTROL PROCESSOR
MMI
and
TRANSDUCERS
108
IF amplifier
106a
complex A to D convertor
106b
DIGITAL SIGNAL PROCESSOR
107
97
Control bus
98
IF filter
105
complex D to A convertor
109
99
Control bus
FRONT END
102
FREQUENCY SYNTHESIZER
103
TRANSMITTER
104
COUPLER
101
Antenna (100)

FIG. 6.


200
AtoD
208
206
207
205
203
204
202
LNA
201
Digital signal
processor
407
control processor
408
Frequency Synthesizer
403
D to A
409
modulator
404b
Transmitter
404a
Coupler
401
400

# INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 01/22330

**A. CLASSIFICATION OF SUBJECT MATTER**
IPC 7 H04B7/26 H04B7/005 H04L1/00

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

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 H04B H04L

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

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

EPO-Internal, WPI Data, PAJ, INSPEC

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| Y | the whole document | 67-79, 86,87 |
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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

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

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

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

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

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

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"&" document member of the same patent family

| Date of the actual completion of the international search | Date of mailing of the international search report |
|---|---|
| 6 November 2001 | 15/11/2001 |

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

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

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| | | | CN | 1213257 | A | 07-04-1999 |
| | | | EP | 0942550 | A1 | 15-09-1999 |
| | | | WO | 9914973 | A2 | 25-03-1999 |
| | | | US | 6289217 | B1 | 11-09-2001 |