

(19) World Intellectual Property
Organization
International Bureau



(43) International Publication Date
17 November 2005 (17.11.2005)

PCT

(10) International Publication Number
WO 2005/109705 A1

- (51) International Patent Classification⁷: **H04J 3/00**
- (21) International Application Number:
PCT/US2005/014835
- (22) International Filing Date: 29 April 2005 (29.04.2005)
- (25) Filing Language: English
- (26) Publication Language: English
- (30) Priority Data:
60/567,234 1 May 2004 (01.05.2004) US
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- (81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NA, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RU, SC, SD, SE, SG, SK, SL, SM, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, YU, ZA, ZM, ZW.
- (84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IS, IT, LT, LU, MC, NL, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).
- Published:**
- with international search report
 - before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments
- For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.*



WO 2005/109705 A1

(54) Title: METHODS AND APPARATUS FOR COMMUNICATION WITH TIME-DIVISION DUPLEXING

(57) Abstract: Methods and apparatus for an adaptable frame structure are disclosed, where a transmission frame consists of multiple subframes, each containing a downlink transmission period and an uplink transmission period. A downlink broadcasting signal is used to indicate the configuration of each subframe. The downlink and uplink period configuration in each subframe can be independently adapted to support applications with a variety of traffic patterns, from symmetric to highly asymmetric. A great variety of applications from normal two-way data communications to voice communications and video or data broadcasting can be supported efficiently in a single frequency band, while multiple frequency bands can be used to increase capacity or add more flexibility.

METHODS AND APPARATUS FOR COMMUNICATION WITH TIME-DIVISION DUPLEXING

CROSS-REFERENCE TO RELATED APPLICATION(S)

[0001] This application claims the benefit of U.S. Provisional Patent Application No. 60/567,234, filed on May 1, 2004. This application also relates to PCT Application No. PCT/US2005/001939 filed January 20, 2005, which claims the benefit of U.S. Provisional Application No. 60/540,032 filed January 29, 2004; PCT Application No. PCT/US2005/004601 filed February 14, 2005, which claims the benefit of U.S. Provisional Application No. 60/544,521 filed February 13, 2004; PCT Application No. PCT/US2005/003889 filed February 7, 2005, which claims the benefit of U.S. Provisional Application No. 60/542,317 filed February 7, 2004; and PCT Application No. PCT/US2005/008169 filed March 9, 2005, which claims the benefit of U.S. Provisional Application No. 60/551,589 filed March 9, 2004.

BACKGROUND

[0002] It is foreseeable that in future wireless communications will include voice, interactive data, video and audio on-demand, and digital video and audio broadcasting services. It will be efficient and cost-effective for a single system to provide these services simultaneously. The challenges in developing such a system lie in two aspects of the distinctive transmission characteristics associated with these applications: traffic symmetry and signal interaction environment. For example, voice traffic is symmetric on both the downlink and uplink, whereas interactive-data traffic is asymmetric, with heavier load on the downlink. Voice services are based on unicast, where signals from other base stations are considered as unwanted interference and thus should be minimized, and whereas data broadcast services are spectral-efficiently provided if every base station within the network transmit the same signal in synchronization.

[0003] In general, existing wireless systems are inadequate in dealing with both aspects of these challenges. Some time-division duplex systems are designed to support asymmetric two-way applications, but are unequipped to carry out

broadcasting efficiently. Some systems are designed for broadcast, but are unable to provide two-way applications. There is a need to overcome such underlying difficulties.

BRIEF DESCRIPTION OF THE DRAWINGS

[0004] Figure 1 illustrates a multi-cell, multi-user cellular system.

[0005] Figure 2 illustrates frame structure of an exemplary TDD system, where a frame is divided into four subframes and each subframe can have a different ratio of downlink and uplink periods.

[0006] Figure 3 illustrates four examples of the subframe structure depicted in the exemplary system of Figure 2.

[0007] Figure 4 illustrates a basic structure of a multi-carrier signal in the frequency domain, which is made up of subcarriers that can be grouped into subchannels. The pilot subcarriers are also distributed over the entire channel. Figure 4 illustrates interleaved subchannels.

[0008] Figure 5 illustrates a radio resource divided into small units in both the frequency and time domains – subchannels and time-slots. The basic structure of a multi-carrier signal in the time domain is made up of symbols.

[0009] Figure 6 illustrates a time-slot structure of an OFDMA system, where one time-slot is comprised of four OFDM symbols, and each OFDM symbol contains a cyclic prefix and a basic OFDM signal.

[0010] Figure 7 illustrates a block diagram of an OFDMA system using adaptable frame structure (AFS).

DETAILED DESCRIPTION

[0011] The multi-carrier system mentioned here can be of any format such as OFDM, or Multi-Carrier Code Division Multiple Access (MC-CDMA). The disclosed methods can also be applied to downlink, uplink, or both, where the duplexing technique is either Time Division Duplexing (TDD) or Frequency Division Duplexing (FDD).

[0012] The following description provides specific details for a thorough understanding of the various embodiments and for the enablement of one skilled in the art. However, one skilled in the art will understand that the invention may be practiced without such details. In some instances, well-known structures and functions have not been shown or described in detail to avoid unnecessarily obscuring the description of the embodiments.

[0013] Unless the context clearly requires otherwise, throughout the description and the claims, the words "comprise," "comprising," and the like are to be construed in an inclusive sense as opposed to an exclusive or exhaustive sense; that is to say, in the sense of "including, but not limited to." Words using the singular or plural number in this Detailed Description section also include the plural or singular number respectively. Additionally, the words "herein," "above," "below" and words of similar import, when used in this application, shall refer to this application as a whole and not to any particular portions of this application. When the claims use the word "or" in reference to a list of two or more items, that word covers all of the following interpretations of the word: any of the items in the list, all of the items in the list and any combination of the items in the list.

[0014] In a cellular system with base stations and mobile stations, the transmission from a base station to a mobile station is called a downlink and the transmission from a mobile station to a base station is called an uplink. The coverage area of a base station is called a cell, which may be further divided into multiple sectors. In this description no distinction is made between a cell and a sector. Both are generally called a cell. Figure 1 is an illustration of a multi-cell, multi-user cellular system.

[0015] In accordance with the principles of the invention, a transmission frame consists of multiple subframes, each containing a downlink transmission period and an uplink transmission period. The same structure of the transmission frame is used by all the cells within the network, and frames are transmitted in synchronization among the cells. That is, a transmission frame begins at substantially the same time in each cell. Proper guard periods (GP1 and GP2) are inserted to account for the time needed to turn on and off transmitters and receivers, as well as radio propagation delay.

[0016] The ratio of downlink and uplink transmission periods in each subframe can be independently adapted to support applications with a variety of traffic patterns, from symmetric to highly asymmetric, during initial deployment or system run time. This way, a great variety of applications from normal two-way data communication, to voice communication, video or data broadcasting, can be supported efficiently in a single frequency band, while multiple frequency bands can be used to increase capacity or add more flexibility.

[0017] In the example shown in Figure 2, a 10-ms frame is divided into four subframes. The downlink and uplink ratio can be different for different subframes. For example, the downlink is longer than the uplink in subframe #1, while the downlink is shorter than the uplink in subframe #4.

[0018] In one embodiment, each subframe is further divided into multiple slots. The time-slot configuration within each individual subframe can be adjusted to a different ratio of the number of downlink slots to that of the uplink slots. In the example shown in Figure 3, each subframe consists of six time-slots. To support different applications ranging from symmetric services to highly asymmetric services, the six time-slots within each individual subframe of this example can be configured to seven different downlink and uplink ratios (3:3, 4:2, 5:1, 6:0, 2:4, 1:5, and 0:6). The first four configurations are illustrated in Figure 3.

[0019] In an embodiment that provides multiple services, a transmission frame is comprised of subframes with different downlink and uplink ratios. For example, amongst the four subframes, a 6:0-ratio subframe is used to support digital video broadcasting services; a 3:3-ratio subframe is used to support symmetric voice over IP (VoIP) services; and two 4:2-ratio subframes are used to support typical asymmetric data services.

[0020] The described frame structure allows for lower overhead while maintaining short subframes. This makes fast feedback possible between mobile stations and their base stations and enables an adaptable frame structure (AFS) system to make more effective use of other advanced technologies such as link adaptation, hybrid ARQ, beamforming, and transmit diversity.

[0021] In one embodiment, the subframe is limited to a relatively small duration with respect to the channel coherence time, thereby effectively making use of other

radio technologies that require a fast feedback channel. In correspondence with the above example, the subframe duration is designed to be around 2.4ms, which is much less than 7.66 ms, the coherence time for a 60-km/h mobile channel at 2.35GHz.

[0022] In one embodiment, each frame contains a special downlink period (SDP), during which a base station broadcasts signals for control information, such as the ratio of downlink and uplink in each subframe in that frame, cell identity information, and other system and adaptive control information. The SDP can be placed either outside of individual subframes, preferably at the beginning of a frame, as shown in Figure 2, or within the downlink of subframes. Multiple SDPs can also be inserted into a frame. Also, multiple subframes can share the use of the same SDP to reduce the overhead and to increase the overall system spectral efficiency.

[0023] In another embodiment, each frame contains at least one special uplink period (SUP), during which mobile stations may carry out functions such as initial ranging during power up and handoff, periodic ranging, and bandwidth request, channel sounding to assist downlink scheduling or advanced antenna technologies, and other radio functions. The SUP can be placed outside of individual subframes. Alternatively, the SUP can be placed within the uplink period of individual subframes, preferably, in the beginning of the uplink period. Multiple SUPs can be inserted into a frame. Also, multiple subframes can share the same SUP to reduce the overhead and to increase the overall system spectral efficiency.

[0024] In yet another embodiment, the SUP is either based on contention or coordination. In the latter case, the use of the SUP is fully or partially scheduled by the base station and the scheduling information is carried by the downlink signal.

[0025] In accordance with the embodiments of this invention, adaptive transmission techniques such as adaptive modulation and coding (AMC) and power control may be applied to downlink transmission, uplink transmission, or both.

[0026] In one embodiment, a mobile station monitors the downlink signal quality and sends the channel quality information (CQI) to its serving base station. The base station adjusts modulation and coding schemes (MCS) based on the received CQI for the downlink transmission to this mobile station and sends the indication of MCS to this mobile station.

[0027] In another embodiment, the downlink transmission uses power control. A mobile station monitors the downlink signal quality and sends the power control requests to its serving base station. The base station adjusts transmission power to this mobile station accordingly.

[0028] In yet another embodiment, AMC and power control are jointly performed. The feedback from a mobile station contains information for both AMC and power control. The base station adjusts MCS and power level for the transmission to this mobile accordingly, and sends indication signal to this mobile station about the adjustments.

[0029] In another embodiment, the uplink transmission uses AMC. The base station monitors uplink signals and sends the CQI to mobile stations. Mobile stations adjust the MCS based on the received CQI and also send the indication of MCS to the base station. Alternatively, the base station makes decisions on the MCS for each mobile station uplink transmission based on its received uplink signals. Then the base station sends the command to mobile stations to dictate the use of the decided MCS.

[0030] In yet another embodiment, the uplink transmission uses power control. The base station monitors the uplink signal quality and sends the power control requests to mobile stations. Mobile stations adjust transmission power accordingly.

[0031] In still another embodiment, AMC and power control are jointly performed. The feedback or the decision from the base station contains information for both AMC and power control. Mobile stations adjust MCS and power level accordingly.

[0032] In accordance with the aspects of this invention, hybrid ARQ is applied to the downlink transmission, uplink transmission, or both. In one embodiment, mobile stations detect the transmitted packet from the base station and send the acknowledgement (ACK) or negative acknowledgement (NAK) to the base station. If NAK is received at the base station, it either re-transmits the same packet or transmits more redundancy to facilitate the further decoding of the previously failed packet at the mobile station.

[0033] In another embodiment, a base station detects the transmitted packet from the mobile stations and sends the acknowledgement (ACK) or negative

acknowledgement (NAK) to the mobile stations. If NAK is received at the mobile station, it either re-transmits the same packet or transmits more redundancy to facilitate the further decoding of the previously failed packet at the base station.

[0034] In accordance with the principles of this invention, different types of services can be provided via different subframes. For example, two-way data communication is carried out using a subframe, for example the first subframe, while data (including video) broadcasting is carried out using another subframe, for example the second subframe. Therefore, the first and second subframes can be configured, based on their own transmission characteristics, with different system parameters, such as a scrambler or randomizer, subchannel (in OFDM) or code (in CDMA) construction, size of FFT (Fast Fourier Transform) (in OFDM) or length of spreading codes (in CDMA), and training signal configuration.

[0035] In one embodiment, in the first subframe, the scrambler or randomizer, and the training symbol configuration are different in individual cells to achieve inter-cell interference randomization and to facilitate frequency reuse among multiple cells. In the second subframe, the scrambler or randomizer, and the training symbol configuration on the downlink are set to be the same for different cells; therefore, multiple base stations and cells form a single frequency network (SFN). This improves broadcasting performance because broadcast data is the same for all cells in the network.

[0036] In another embodiment, the entire said second subframe is used for downlink broadcasting or at least one uplink time-slot is used to facilitate a continuous flow of channel feedback information, potentially improving the communication efficiency in other subframes.

[0037] In yet another embodiment, a base station provides two-way data communication services using the first subframe and another base station provides broadcasting services using the second subframe. Cell size is not necessarily the same for these two base stations. For example, broadcasting base stations use higher transmission power to cover a larger area than do two-way data communication base stations.

[0038] In accordance with the embodiments in this invention, the AFS makes it feasible and practical to configure the system to achieve the equivalent effects of

frequency reuse. For example, in the case in Figure 3, amongst the four subframes within a frame, the odd-number subframes may be allocated for one group of cells; and the even-number subframes allocated for another group of base stations, thus creating an operating environment with a frequency reuse factor of 2. In this case, the flexible frequency reuse factor makes it possible to have one frequency band to support frequency reuse of one and two.

[0039] Furthermore, the use of this type of subframe structure makes it possible for run-time configuration to adapt to the change in service type without interrupting the service. For instance, one subframe can be turned off momentarily for all the cells and re-configured to a different DL/UL ratio when the traffic pattern changes, while normal communication is maintained in other subframes.

[0040] The physical media resource (e.g., radio or cable) in a multi-carrier communication system can be divided in both frequency and time domains. This canonical division provides a high flexibility and fine granularity for resource sharing. Within a particular spectral band or channel, there are a fixed number of subcarriers. The basic structure of a multi-carrier signal in the frequency domain is made up of subcarriers. There are three types of subcarriers:

1. Data subcarriers, which carry information data;
2. Pilot subcarriers, whose phases and amplitudes are predetermined and made known to all receivers and which are used for assisting system functions such as estimation of system parameters; and
3. Silent subcarriers, which have no energy and are used for guard bands and DC carrier.

[0041] The data subcarriers can be arranged into groups called subchannels to support scalability and multiple-access. The carriers forming one subchannel are not necessarily adjacent to each other. Each user may use part or all of the subchannels. The concept is illustrated in Figure 4 for the interleaved subchannels at the base station transmitter. The resource division in both the frequency and time domains is depicted in Figure 5.

[0042] Figure 6 illustrates a structure of a time-slot, where each time-slot consists of multiple OFDM symbols (4 in the example). In one embodiment, one

OFDM symbol is used on the downlink in a subframe to indicate the downlink MCS for each used subchannel and the command for uplink MCS and power control. One OFDM symbol is used on the uplink in the subframe to indicate the measured downlink CQI for corresponding mobile stations. Different mobile stations fill different bit fields in the OFDM symbol, corresponding to their downlink subchannels respectively.

[0043] Figure 7 illustrates the functional block diagram of an OFDMA system using AFS. Input data 710 for a subchannel are first randomized in randomization element 720, encoded with forward error correcting codes (FEC) in FEC element 730, passed through an interleaver 740, and then modulated in modulation facility 750. The modulated symbols as well as pilot symbols, which are inserted in pilot insertion facility 760, are mapped to subcarriers by element 770 according to a subchannel-subcarrier configuration. An IFFT (Inverse Fast Fourier Transform) 780 converts the subcarriers from frequency domain to time domain, and then cyclic prefixes are added in cyclic prefix facility 790. A controller controls the randomization, the pilot configuration, subcarrier mapping, FFT size, and cyclic prefix length based on the cell identity and the subframe characteristics. For example, if the first subframe is used to provide voice services, the controller sets the randomization, the pilot configuration, subcarrier mapping, etc., which are different from those used in other cells. On the other hand, if the second subframe is used to provide broadcast services, the controller sets these parameters to be the same as others. Additionally, the modulation, coding, and the transmission power can also be adaptively controlled based on the channel status.

[0044] Two-way data communication may be carried out using a subframe called a third subframe while data (including video) broadcasting is carried out using another subframe called a fourth subframe. OFDM is used in both subframes. The system configuration, such as the randomizer, the subchannel construction, the FFT size, the length of cyclic prefix, and pilot configuration, for the third subframe can be different from those of the fourth subframe, corresponding to their different transmission characteristics.

[0045] In one embodiment, in the third subframe, the randomizer, the pilot configuration, or the subcarrier permutation within a subchannel are different in individual cells to achieve inter-cell interference randomization and to facilitate

frequency reuse among multiple cells. For the fourth subframe, the randomizer, the pilot configuration, and the subcarrier permutation within a subchannel are the same in different cells. Therefore, for the fourth subframe, multiple base stations and cells form a single frequency network (SFN). This improves the broadcasting performance because the broadcast data are the same for all cells in the network. Figure 7 also shows a controlling mechanism for different types of subframes.

[0046] In another embodiment, the entire fourth subframe is used for the downlink broadcasting or at least one uplink time-slot is used to facilitate a continuous flow of channel feedback information, potentially improving the communication efficiency in other subframes.

[0047] While specific circuitry may be employed to implement the above embodiments, aspects of the invention can be implemented in a suitable computing environment. Although not required, aspects of the invention may be implemented as computer-executable instructions, such as routines executed by a general-purpose computer, e.g., a server computer, wireless device or personal computer. Those skilled in the relevant art will appreciate that aspects of the invention can be practiced with other communications, data processing, or computer system configurations, including: Internet appliances, hand-held devices (including personal digital assistants (PDAs)), wearable computers, all manner of cellular or mobile phones, multi-processor systems, microprocessor-based or programmable consumer electronics, set-top boxes, network PCs, mini-computers, mainframe computers, and the like. Indeed, the terms "computer," "host," and "host computer" are generally used interchangeably herein, and refer to any of the above devices and systems, as well as any data processor.

[0048] Aspects of the invention can be embodied in a special purpose computer or data processor that is specifically programmed, configured, or constructed to perform one or more of the processes explained in detail herein. Aspects of the invention can also be practiced in distributed computing environments where tasks or modules are performed by remote processing devices, which are linked through a communications network, such as a Local Area Network (LAN), Wide Area Network (WAN), or the Internet. In a distributed computing environment, program modules may be located in both local and remote memory storage devices.

[0049] Aspects of the invention may be stored or distributed on computer-readable media, including magnetically or optically readable computer discs, hard-wired or preprogrammed chips (e.g., EEPROM semiconductor chips), nanotechnology memory, biological memory, or other data storage media. Indeed, computer implemented instructions, data structures, screen displays, and other data under aspects of the invention may be distributed over the Internet or over other networks (including wireless networks), on a propagated signal on a propagation medium (e.g., an electromagnetic wave(s), a sound wave, etc.) over a period of time, or they may be provided on any analog or digital network (packet switched, circuit switched, or other scheme). Those skilled in the relevant art will recognize that portions of the invention reside on a server computer, while corresponding portions reside on a client computer such as a mobile or portable device, and thus, while certain hardware platforms are described herein, aspects of the invention are equally applicable to nodes on a network.

[0050] The above detailed description of the embodiments of the invention is not intended to be exhaustive or to limit the invention to the precise form disclosed above. While specific embodiments of, and examples for, the invention are described above for illustrative purposes, various equivalent modifications are possible within the scope of the invention, as those skilled in the relevant art will recognize. For example, while processes or blocks are presented in a given order, alternative embodiments may perform routines having steps, or employ systems having blocks, in a different order, and some processes or blocks may be deleted, moved, added, subdivided, combined, and/or modified. Each of these processes or blocks may be implemented in a variety of different ways.

[0051] Also, while processes or blocks are at times shown as being performed in series, these processes or blocks may instead be performed in parallel, or may be performed at different times. Where the context permits, words in the above Detailed Description using the singular or plural number may also include the plural or singular number respectively.

[0052] The teachings provided herein can be applied to other systems, not necessarily the system described herein. The elements and acts of the various embodiments described above can be combined to provide further embodiments. All of the above patents and applications and other references, including any that

may be listed in accompanying filing papers, are incorporated herein by reference. Aspects of the invention can be modified, if necessary, to employ the systems, functions, and concepts of the various references described above to provide yet further embodiments of the invention.

[0053] Particular terminology used when describing certain features or aspects of the invention should not be taken to imply that the terminology is being redefined herein to be restricted to any specific characteristics, features, or aspects of the invention with which that terminology is associated. In general, the terms used in the following claims should not be construed to limit the invention to the specific embodiments disclosed in the specification, unless the above Detailed Description section explicitly defines such terms. Accordingly, the actual scope of the invention encompasses not only the disclosed embodiments, but also all equivalent ways of practicing or implementing the invention.

[0054] The above detailed description of the embodiments of the invention is not intended to be exhaustive or to limit the invention to the precise form disclosed above or to the particular field of usage mentioned in this disclosure. While specific embodiments of, and examples for, the invention are described above for illustrative purposes, various equivalent modifications are possible within the scope of the invention, as those skilled in the relevant art will recognize. Also, the teachings of the invention provided herein can be applied to other systems, not necessarily the system described above. The elements and acts of the various embodiments described above can be combined to provide further embodiments.

[0055] All of the above patents and applications and other references, including any that may be listed in accompanying filing papers, and the PCT Application entitled "Methods and Apparatus for Multi-Carrier Communications with Variable Channel Bandwidth," filed April 29, 2005, assigned to Waltical Solutions, (Attorney Docket No. 42938-8010) are incorporated herein by reference. Aspects of the invention can be modified, if necessary, to employ the systems, functions, and concepts of the various references described above to provide yet further embodiments of the invention.

[0056] Changes can be made to the invention in light of the above "Detailed Description." While the above description details certain embodiments of the

invention and describes the best mode contemplated, no matter how detailed the above appears in text, the invention can be practiced in many ways. Therefore, implementation details may vary considerably while still being encompassed by the invention disclosed herein. As noted above, particular terminology used when describing certain features or aspects of the invention should not be taken to imply that the terminology is being redefined herein to be restricted to any specific characteristics, features, or aspects of the invention with which that terminology is associated.

[0057] In general, the terms used in the following claims should not be construed to limit the invention to the specific embodiments disclosed in the specification, unless the above Detailed Description section explicitly defines such terms. Accordingly, the actual scope of the invention encompasses not only the disclosed embodiments, but also all equivalent ways of practicing or implementing the invention under the claims.

[0058] While certain aspects of the invention are presented below in certain claim forms, the inventors contemplate the various aspects of the invention in any number of claim forms. Accordingly, the inventors reserve the right to add additional claims after filing the application to pursue such additional claim forms for other aspects of the invention.

CLAIMS

We claim:

1. A process of generating an adaptable signal for wireless transmission in a communication system, the process comprising:
 - utilizing subcarriers and subchannels that include groups of subcarriers to makeup the signal; and
 - forming a signal transmission frame, wherein the transmission frame is partitioned into multiple subframes, and wherein each subframe is further divided into multiple time-slots;
 - configuring a number of downlink time-slots and a number of uplink time-slots within each subframe with a predetermined ratio, wherein the ratio of the number of downlink time-slots and the number of uplink time-slots may be different from one subframe to the next;
 - inserting a guard period at the beginning of a subframe, before the down link time-slots, and another guard period before the uplink time-slots, both within the subframe; and
 - inserting at least one special downlink period (SDP) in a frame, during which a base station broadcasts control and system information, and inserting at least one special uplink period (SUP) in a frame, during which a mobile station is capable of carrying out radio functions.

2. The process of claim 1, wherein a subframe is limited to a relatively small duration relative to a channel coherence time, and wherein:
 - during at least one of the SDP the base station broadcasts signals comprising ratios of downlink and uplink time-slots in each subframe, a cell identity information, and adaptive control information, and wherein the SDP can be placed either outside of the subframes or within the downlink period of a subframe, and wherein multiple SDPs can be inserted into a frame and multiple subframes can share an SDP;

during at least one of the SUP mobile stations carry out radio functions including initial ranging during power-up and handoff, periodic ranging and bandwidth request, and channel sounding, and wherein the SUP can be placed either outside of the subframes or within the uplink period of individual subframes, and wherein multiple SUPs can be inserted into a frame and multiple subframes can share an SUP; and

wherein the SUP is either based on contention or coordination, where, in the coordination case, a use of SUP is fully or partially scheduled by the base station and scheduling information is carried in the downlink signal.

3. The process of claim 1, wherein adaptive transmission techniques are applied to downlink transmission, uplink transmission, or both, and wherein:

a mobile station monitors the downlink signal quality and sends channel quality information (CQI), power control request, or both to a serving base station that in turn adjusts modulation and coding schemes (MCS), transmission power level, or both on the downlink transmission to the mobile station and sends an indication of MCS to the mobile station;

a base station monitors uplink signals from a mobile station and sends the CQI, power control request, or both to the mobile station, which in turn adjust the MCS, transmission power level, or both accordingly and sends the indication of MCS to the base station;
or

a base station monitors uplink signals from a mobile station and makes decisions on the MCS and the uplink transmission power level for the mobile station and sends a command to the mobile station to dictate to the mobile station the decided MCS and transmission power.

4. The process of claim 1, wherein hybrid ARQ (Automatic Repeat Request) is applied to the downlink transmission, uplink transmission, or both, and wherein:

- a mobile station detects a transmitted packet from a base station and sends an acknowledgement (ACK) or a negative acknowledgement (NAK) to the base station, which, upon receiving the NAK, either re-transmits the same packet or transmits more redundancy to facilitate further decoding of the previously failed packet at the mobile station; and
- a base station detects the transmitted packet from a mobile station and sends an acknowledgement (ACK) or a negative acknowledgement (NAK) to the mobile station, which, upon receiving the NAK, either re-transmits the same packet or transmits more redundancy to facilitate further decoding of the previously failed packet at the base station.

5. The process of claim 1, wherein different subframes within a frame are configured with different system parameters in accordance with transmission characteristics required by different types of services, and a configuration wherein:

- in a two-way data subframe, a scrambler or a randomizer, subchannel configuration and a training symbol configuration are structured differently in individual cells;
- in a broadcast subframe, the scrambler or the randomizer, subchannel configuration and the training symbol configuration on the downlink are structured in the same way in all the cells, forming a single frequency network (SFN);
- a broadcast subframe is used for downlink broadcasting, or at least one uplink time-slot within the subframe is used to facilitate a continuous flow of channel feedback information;
- a base station provides two-way data communication services using the two-way data subframe and another base station provides

broadcasting services using the broadcast subframe and cell sizes are not necessarily the same for these two base stations;
a subframe within a frame is capable of being allocated for use by a different group of cells;
a subframe within a frame can be temporarily set idle for a group of cells in the network such that this particular subframe is reconfigured to meet service requirements while normal services are maintained by other subframes; or
any combination thereof.

6. The process of claim 1, wherein time-slots are composed of a specified number of OFDM symbols, and wherein:

within a subframe, an OFDM symbol is used on the downlink to indicate a downlink modulation and coding scheme (MCS) for each used subchannel and a command for uplink MCS and power control;
and

within a subframe, an OFDM symbol is used on the uplink to indicate a measured downlink channel quality information (CQI) by mobile stations, each of which uses a bit field that corresponds to a mobile station's own downlink subchannel in the OFDM symbol.

7. The process of claim 1, wherein the communication system is a multi-carrier system of any format including OFDM and Multi-Carrier Code Division Multiple Access (MC-CDMA), and wherein the process can be applied to downlink, uplink, or both, where the duplexing technique is either Time Division Duplexing (TDD) or Frequency Division Duplexing (FDD).

8. In an adaptable wireless communication system capable of communicating under multiple different communication schemes, wherein a mobile transceiver transmits signals to a stationary transceiver in an uplink transmission and the stationary transceiver transmits signals to the mobile transceiver in a downlink transmission, a signal comprising:

signal transmission frames, wherein each frame is partitioned into multiple subframes, and wherein each subframe is further divided into multiple time-slots, wherein;

a number of downlink time-slots and a number of uplink time-slots incorporated within each subframe has one of multiple predetermined ratios, and wherein the ratio of at least one subframe in a frame differs from the ratio of another subframe in one other frame or in the same frame; and

a guard period is inserted in relation to down link time-slots, and another guard period in relation to uplink time-slots.

9. The signal of claim 8, wherein at least one special downlink period (SDP) is inserted in a frame, during which a base station broadcasts control and/or system information, or at least one special uplink period (SUP) is inserted in the frame, during which mobile stations is capable of carrying out radio functions, and wherein:

during at least one of the SDP the stationary transceiver broadcasts signals comprising ratios of downlink and uplink time-slots in each subframe, a cell identity information, and adaptive control information, and wherein the SDP can be placed either outside of the subframes or within the downlink period of a subframe, and wherein multiple SDPs can be inserted into a frame and multiple subframes can share an SDP;

during at least one of the SUP the mobile transceiver carries out radio functions including initial ranging during power-up and handoff, periodic ranging and bandwidth request, and channel sounding; and wherein the SUP can be placed either outside of the subframes or within the uplink period of individual subframes, and

wherein multiple SUPs can be inserted into a frame and multiple subframes can share an SUP; and

wherein the SUP is either based on contention or coordination, where in the coordination case, a use of SUP is fully or partially scheduled by the stationary transceiver and scheduling information is carried in the downlink signal.

10. The signal of claim 8, wherein:

a mobile transceiver monitors the downlink signal quality and sends channel quality information (CQI), power control request, or both to a serving stationary transceiver that in turn adjusts modulation and coding schemes (MCS), transmission power level, or both on the downlink transmission to the mobile transceiver and sends an indication of MCS to the mobile transceiver;

a stationary transceiver monitors uplink signals from a mobile transceiver and sends the CQI, power control request, or both to the mobile transceiver, which in turn adjust the MCS, transmission power level, or both accordingly and sends the indication of MCS to the stationary transceiver; or

a stationary transceiver monitors uplink signals from a mobile transceiver and makes decisions on the MCS and the uplink transmission power level for a mobile transceiver and dictates to the mobile transceiver the decided MCS and transmission power.

11. The signal of claim 8, wherein hybrid ARQ (Automatic Repeat Request) is applied to the downlink transmission, uplink transmission, or both, and wherein:

a mobile transceiver detects a transmitted packet from a serving stationary transceiver and sends an acknowledgement (ACK) or a negative acknowledgement (NAK) to the stationary transceiver, which, upon receiving the NAK, either re-transmits the same packet or transmits more redundancy to facilitate further decoding of the previously failed packet at the mobile transceiver; and

a stationary transceiver detects the transmitted packet from a mobile transceiver and sends an acknowledgement (ACK) or a negative acknowledgement (NAK) to the mobile transceiver, which, upon receiving the NAK, either re-transmits the same packet or transmits more redundancy to facilitate further decoding of the previously failed packet at the stationary transceiver.

12. The signal of claim 8, wherein different subframes within a frame are configured with different system parameters in accordance with transmission characteristics required by different types of services, and a configuration wherein:

in a two-way data subframe, a scrambler or a randomizer, subchannel configuration and a training symbol configuration are structured differently in individual cells;

in a broadcast subframe, the scrambler or the randomizer, subchannel configuration and the training symbol configuration on the downlink are structured in the same way in all the cells;

a broadcast subframe is used for downlink broadcasting, or at least one uplink time-slot within the subframe is used to facilitate a continuous flow of channel feedback information;

a stationary transceiver provides two-way data communication services using the two-way data subframe and another stationary transceiver provides broadcasting services using the broadcast subframe and cell sizes are not necessarily the same for these two stationary transceivers;

a subframe within a frame can be allocated for use by a different group of cells;

a subframe within a frame can be temporarily set idle for a group of cells in the network such that this particular subframe is reconfigured to meet service requirements while normal services are maintained by other subframes; or

any combination thereof.

13. The signal of claim 8, wherein time-slots are composed of a specified number of OFDM symbols, and wherein:

within a subframe, an OFDM symbol is used on the downlink to indicate a downlink modulation and coding scheme (MCS) and a command for uplink MCS; and

within a subframe, an OFDM symbol is used on the uplink to indicate a measured downlink channel quality information (CQI) by mobile stations.

14. A mobile station capable of receiving, generating, and transmitting adaptable frame wireless signals in a wireless communication network, the mobile station comprising:

a signal generator facility for generating adaptable signal frames, wherein each of the signal frames is partitioned into multiple subframes, and wherein each of the subframes is further partitioned into at least one downlink time-slot and at least zero uplink time-slot, and wherein:

the number of downlink time-slots and the number of uplink time-slots between two subframes of at least one frame differs; and

at least one special downlink period (SDP) is provided in a frame, during which a downlink control signal dictates the number of downlink time-slots and the number of uplink time-slots of the subframes of the frame, or at least one special uplink period (SUP) is provided in a frame, during which the mobile station is capable of carrying out radio functions.

15. The mobile station of claim 14, wherein:

the SDP can be placed either outside of the subframes or within the downlink period of a subframe, and wherein multiple SDPs can be inserted into a frame and multiple subframes can share an SDP; and

the SUP can be placed either outside of the subframes or within the uplink period of individual subframes, and wherein multiple SUPs can be inserted into a frame and multiple subframes can share an SUP.

16. The mobile station of claim 14, wherein the mobile station is in communication with a control station and exchanges information and control signals with the control station, and wherein:

the mobile station monitors the downlink signal quality and sends channel quality information (CQI), power control request, or both to the control station that in turn adjusts modulation and coding schemes (MCS), transmission power level, or both on the downlink transmission to the mobile station and sends an indication of MCS to the mobile station;

the control station monitors uplink signals from the mobile station and sends the CQI, power control request, or both to the mobile station, which in turn adjust the MCS, transmission power level, or both accordingly and sends the indication of MCS to the control station; or

the control station monitors uplink signals from the mobile station and makes decisions on the MCS and the uplink transmission power level for the mobile station and dictates to the mobile station the decided MCS and transmission power.

17. The mobile station of claim 14, wherein the mobile station is in communication with a control station and exchanges information and control signals with the control station, and wherein:

the mobile station detects a transmitted packet from a control station and sends an acknowledgement (ACK) or a negative acknowledgement (NAK) to the control station, which, upon receiving the NAK, either re-transmits the same packet or transmits more redundancy to facilitate further decoding of the previously failed packet at the mobile station; and

the control station detects the transmitted packet from a mobile station and sends an acknowledgement (ACK) or a negative acknowledgement (NAK) to the mobile station, which, upon receiving the NAK, either re-transmits the same packet or transmits more redundancy to facilitate further decoding of the previously failed packet at the control station.

18. The mobile station of claim 14, wherein time-slots are further composed of a specified number of OFDM symbols.

19. A wireless communication method utilizing differing subframes, the method comprising:

forming signal frames of fixed duration;

partitioning each frame into a fixed number of subframes;

partitioning each subframe into at least one downlink time-slot and at least zero uplink time-slot, wherein a total number of downlink time-slots and uplink time-slots is fixed for all subframes of a frame, and wherein for at least some frames a number of downlink and uplink time-slots in one subframe differs from a number of downlink and uplink time-slots in another subframe of the frame;

partitioning each time-slot into a fixed number of Code Division Multiple Access (CDMA) or Orthogonal Frequency Division Multiplexed (OFDM) symbols; and

inserting at least one special downlink portion in at least some frames to indicate a number of downlink and a number of uplink time-slots for subframes.

20. The method of claim 19, wherein within a subframe an OFDM symbol is used:

on the downlink to indicate a downlink modulation and coding scheme (MCS) and a command for uplink MCS and power control; and

on the uplink to indicate a measured downlink channel quality information (CQI).

21. The method of claim 19, wherein at least one special uplink period is inserted in a frame for carrying out radio functions, and wherein at least one guard period is inserted in a subframe.

22. The method of claim 19, wherein a same structure of the signal frame is used by all cells within a wireless communication network, and wherein a signal frame begins and ends at substantially a same time at each cell.

23. A means for generating wireless adjustable frame signals, the means comprising:

a means for generating adaptable signal frames;

a means for partitioning the frames into multiple subframes;

a means for partitioning the subframes into at least zero downlink time-slots and at least zero uplink time-slots, wherein the number of downlink time-slots and the number of uplink time-slots in one subframe of a frame may be different from another subframe of the frame;

a means for inserting at least one guard period within a subframe; and

a means for inserting at least one special downlink period (SDP) in a frame, during which a downlink control signal dictates the number of downlink time-slots and the number of uplink time-slots of the subframes of the frame.

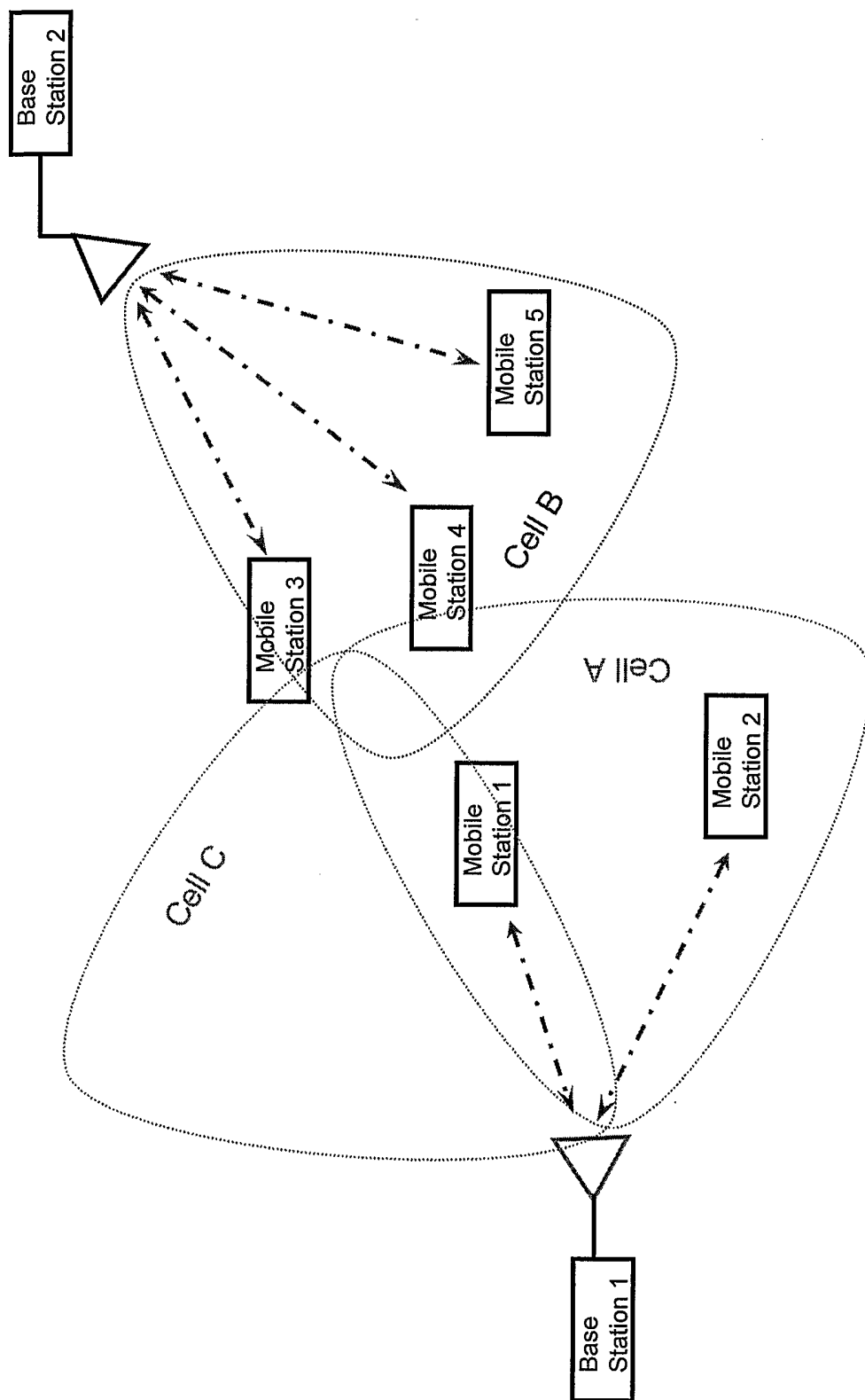


FIG. 1

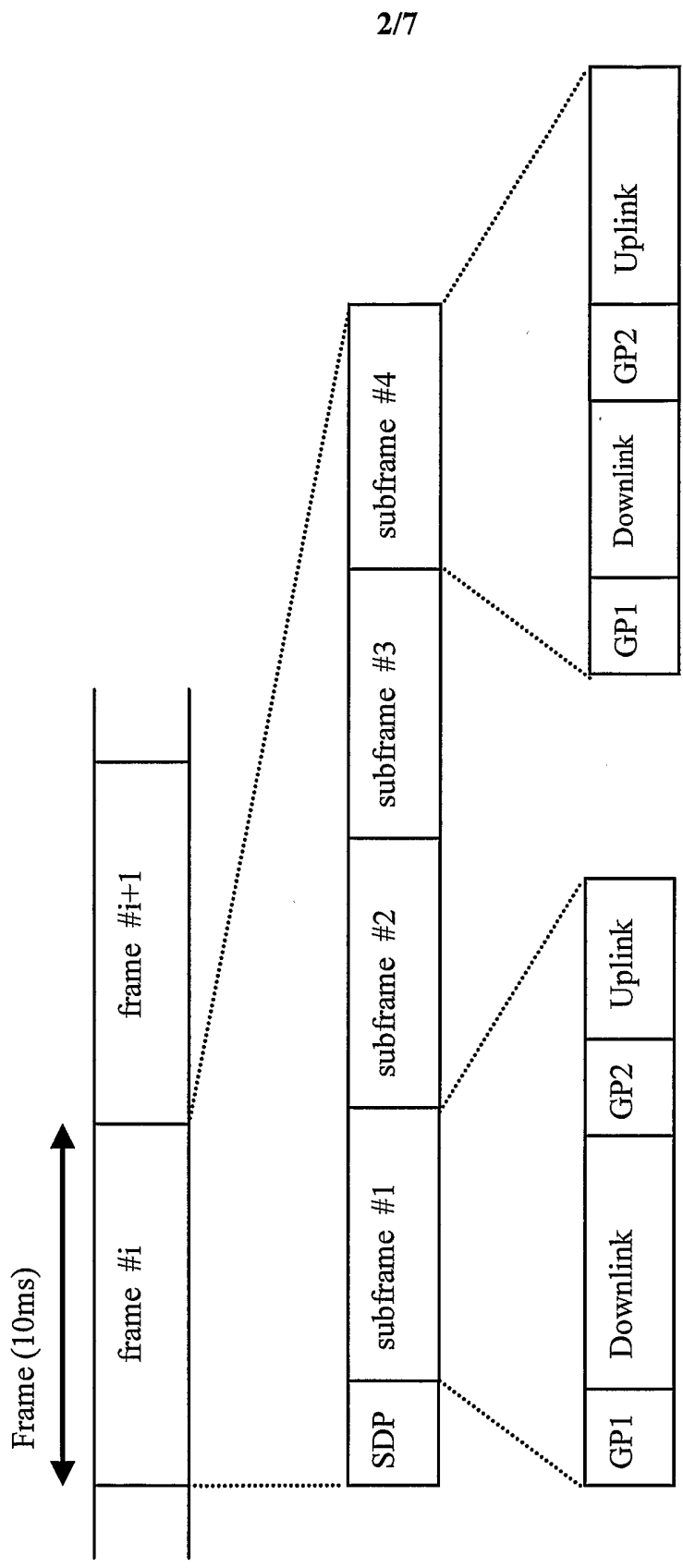


FIG. 2

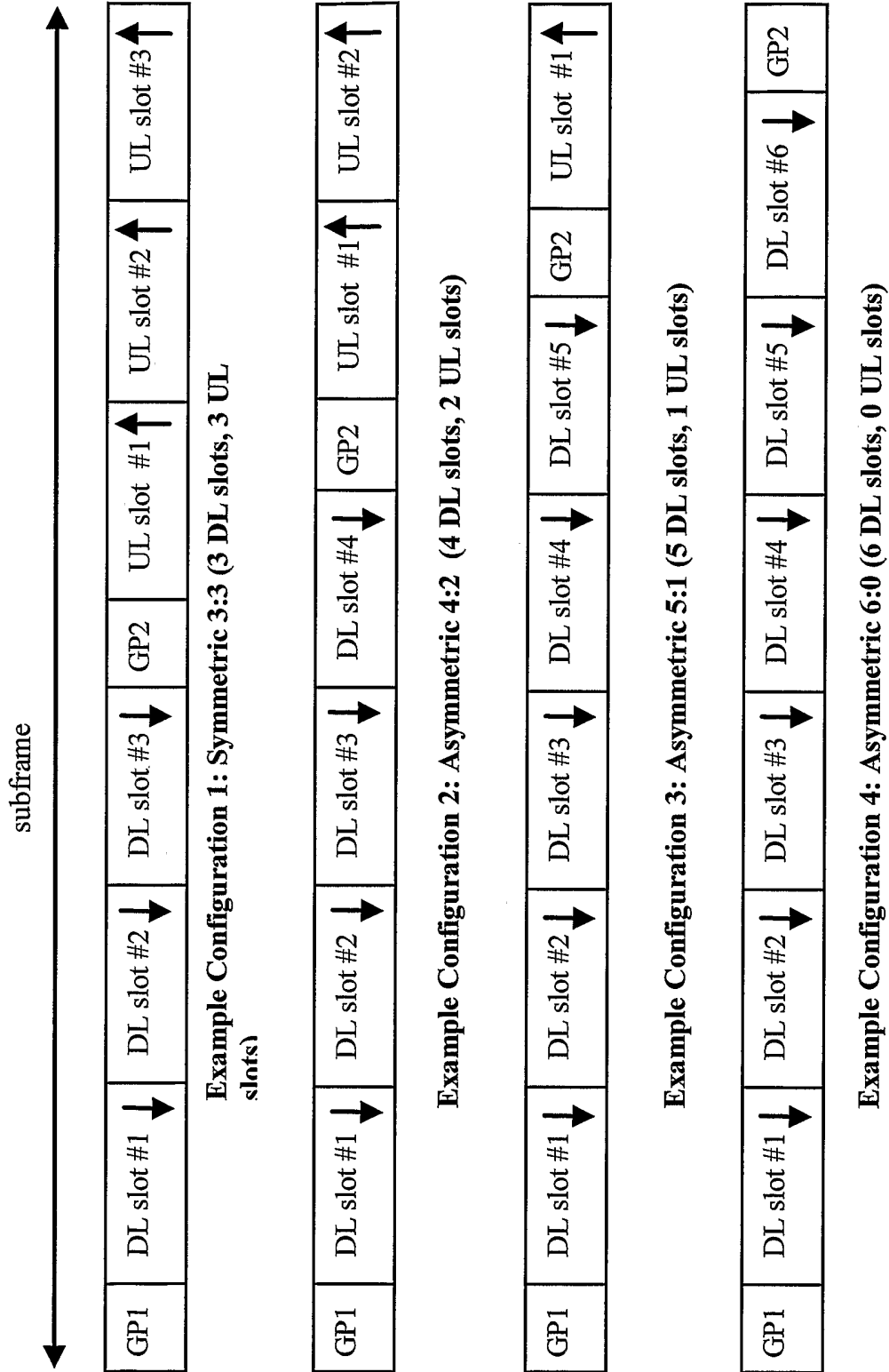


FIG. 3

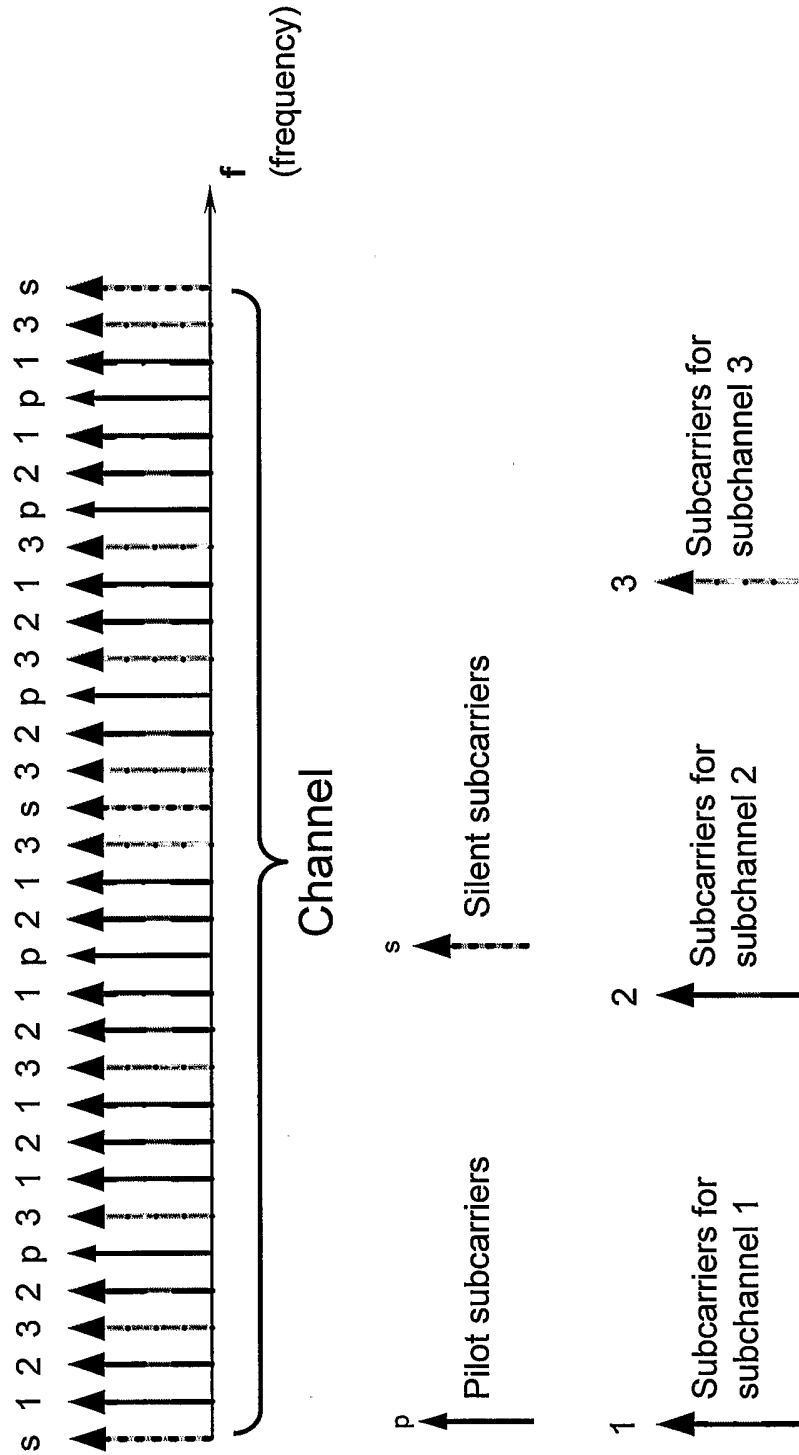


FIG. 4

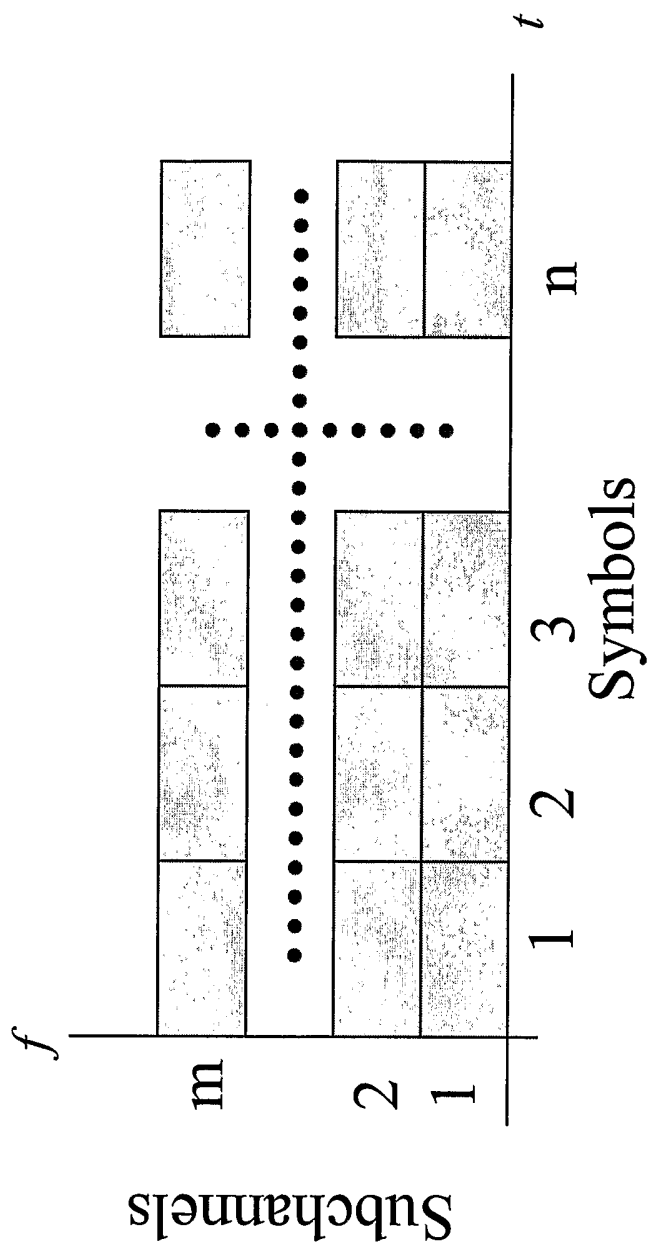


FIG. 5

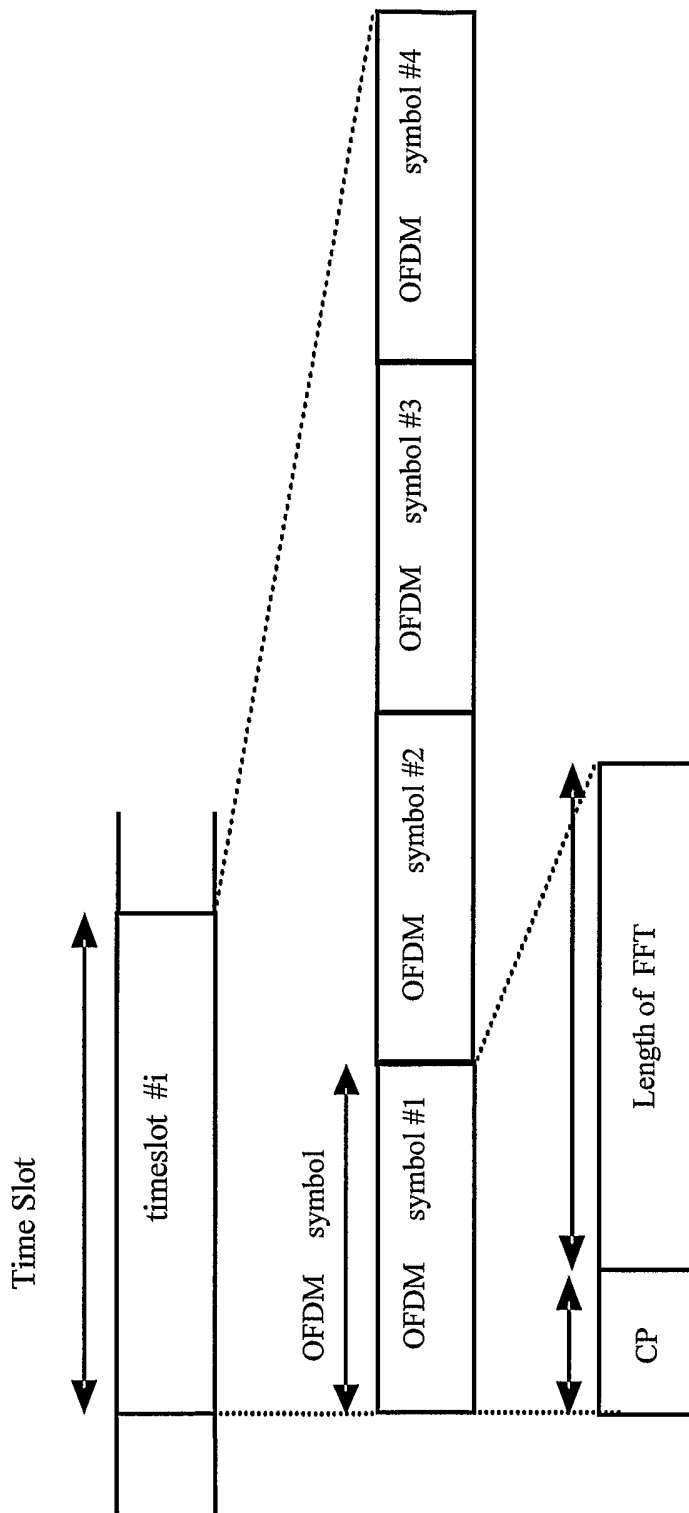


FIG. 6

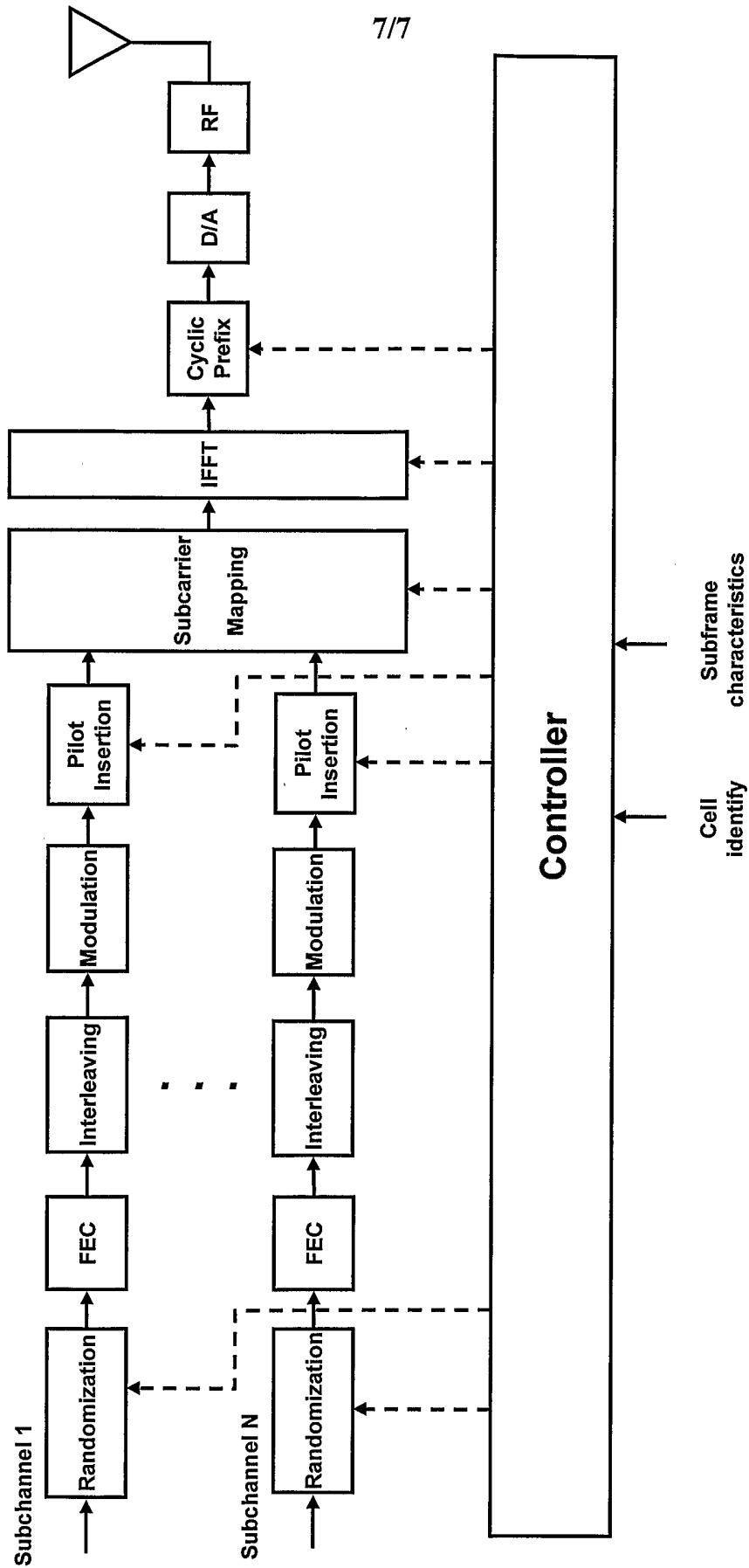
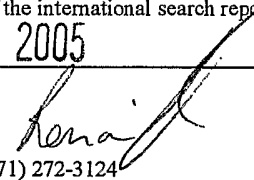


FIG. 7

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US05/14835

A. CLASSIFICATION OF SUBJECT MATTER IPC(7) : H04J 3/00 US CL : 370/337 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) U.S. : 370/252,328,336,337,345,347 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 practicable, search terms used)		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 5,594,720 A (PAPADOPOULOS et al) 14 January 1997 (14.01.1997), column 4, lines 29-67; column 5, lines 11-36; column 6, lines 16-45; and column 8, line 59 to column 9, line 29	1,8,14,19,23
Y	US 6,016,311 A (GILBERT et al) 18 January 2000 (18.01.2000), column 4, lines 33-39; column 7, line 14 to column 9, line 11; column 9, lines 36-42; column 13, lines 4-18 and lines 40-50; column 15, lines 5-67; and column 18, line 23 to column 19, line 13.	1,7,8,14,18,19,21-23
Y	US 6,334,057 B1 (MALMGREN et al) 25 December 2001 (25.12.2001), column 1, lines 28-67.	1,8,14,19,23
Y	US 6,577,641 B1 (IZUMI) 10 June 2003 (10.06.2003), column 1, line 62 to column 2, line 6; and column 5, lines 9-28.	1,8,14,19,23
Y	US 6,577,650 B1 (TATE et al) 10 June 2003 (10.06.2003), column 1, line 51 to column 2, line 10; and column 3, line 66 to column 4, line 14.	1,8,14,19,23
Y	US 2002/0067709 A1 (YAMADA et al) 06 June 2002 (06.06.2002), sections 0007-0017; and sections 0057-0065.	1,8,14,19,23
Y	US 2002/0105918 A1 (YAMADA et al) 08 August 2005 (08.08.2005), sections 0005-0008; and section 0040.	1,8,14,19,23
Y	US 2002/0122393 A1 (CALDWELL et al) 05 September 2002 (05.09.2002), sections 0023-0028; and section 0038.	1,7,8,14,18,19,21-23
<input type="checkbox"/> Further documents are listed in the continuation of Box C. <input type="checkbox"/> See patent family annex.		
* Special categories of cited documents:		
"A" document defining the general state of the art which is not considered to be of particular relevance	"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	
"E" earlier application or patent published on or after the international filing date	"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	
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art	
"O" document referring to an oral disclosure, use, exhibition or other means	"&" document member of the same patent family	
"P" document published prior to the international filing date but later than the priority date claimed		
Date of the actual completion of the international search 26 August 2005 (26.08.2005)	Date of mailing of the international search report 27 SEP 2005	
Name and mailing address of the ISA/US Mail Stop PCT, Attn: ISA/US Commissioner for Patents P.O. Box 1450 Alexandria, Virginia 22313-1450 Facsimile No. (703) 305-3230	Authorized officer Christine Ng  Telephone No. (571) 272-3124	