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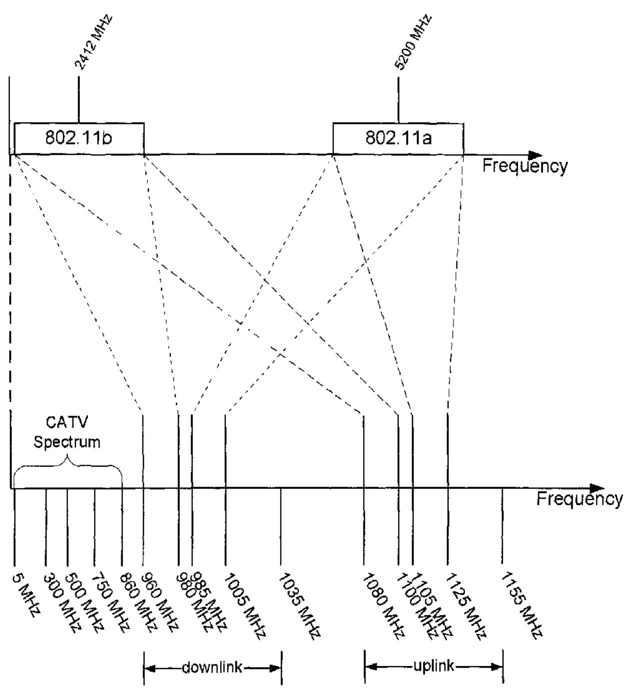

(57) Abstract: WLAN communications are carried from the user device to the access point over a CATV network using the upstream and downstream frequencies of the CATV network. While being carried over the CATV network, the WLAN communications are frequency shifted so as to fit in the bandwidth of the CATV network. Augmenting the CATV network with bypass devices at active points permits shifting the upstream and downstream frequencies above normal CATV traffic.

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WLAN SERVICES OVER CATV.

CROSS REFERENCE TO RELATED APPLICATIONS.

[0001] This application claims the benefit of U.S. Provisional Application 60/402,536, filed August 12, 2002, entitled "WLAN SERVICES OVER CATV NETWORK"; U.S. Provisional Application 60/445,834, filed February 10, 2003, entitled "WLAN SERVICES OVER CATV NETWORK USING SWITCHING MODE PCF PROTOCOL"; U.S. Provisional Application 60/445,826, filed February 10, 2003, entitled "WLAN SERVICES OVER CATV NETWORK"; and U.S. Provisional Application 60/___,___ (Attorney Docket No. P76469), filed August 1, 2003, entitled "WLAN SERVICES OVER CATV", the disclosures of which are incorporated by reference, herein, in their entirety.

FIELD OF THE INVENTION.

[0002] The invention relates to a new topology for wireless local area networks (WLANs) and the like, and a method which enables cable television (CATV) networks to serve high speed WLAN data at an indoor customer premises. In particular, the invention relates to various embodiments for extending conventional WLANs using CATV networks, with the beneficial effects of improved data quality, better coverage, better range, increased network capacity, reduced need for access points, and reduced radiation.

BACKGROUND OF THE INVENTION.

[0003] WLANs are themselves well known. In a typical infrastructure WLAN, a wireless end user device (such as a computer or any of a variety of processor based devices) communicates with a wireless access point (AP or WAP). The WAP provides a way for the end user device to access a network such as a wired LAN (or other wireless devices, even including other WAPs). In a typical peer-to-peer WLAN, a wireless end user device communicates with other wireless end user devices directly, and a WAP may then be used as a repeater.

[0004] The WAP has a transmitter / receiver device for communicating with wireless devices (including other WAPs), and a network adapter for communicating with a wired LAN. The WAP also includes a processor and memory with instructions that allow the WAP to operate according to one or more predetermined protocols. Some protocols commonly used with WLAN communications are the 802.11a, 802.11b, 802.11g, and 802.11e protocols. Since the protocols themselves are not modified in the invention, no in-depth discussion of them is included. The WAP receives, buffers, and transmits data between the WLAN and the wired network infrastructure. Different WLAN channels may be defined to avoid communication interference between closely positioned WAP devices. A single WAP can support a small group of users and can function within ranges of up to several hundred feet.

[0005] The conventional implementation of a WLAN system, for example in the configurations just mentioned, has some important limitations and disadvantages.

[0006] One disadvantage is that wireless communications are subject to radio propagation constraints. The distance over which RF waves can communicate is a function of transmitted power, receiver sensitivity, and the propagation path. The latter factor, the propagation path, is especially important in indoor environments. Interactions with typical building objects, including walls, metal, and even people, affect how the radio energy propagates, and thus what range and coverage a particular system achieves. Furthermore, a radio signal can take multiple paths from a transmitter to a receiver. This phenomenon of radio signal propagation is called multi-path interference. Reflections of the signals can cause them to become stronger or weaker, which can strongly affect data throughput. The effects of multi-path interference depend on the number of reflective surfaces in the environment, the distance from the transmitter to the receiver, the product design and the radio technology.

[0007] Because of radio propagation constraints, it is normally essential to provide a number of WAP devices throughout a building. Larger buildings require more WAPs simply to achieve some coverage in every office / apartment / location.

[0008] Another disadvantage is that a given WAP can handle the traffic for only a limited number of wireless end user devices. Therefore, in areas of high wireless end user device concentration, multiple WAPs may be required. In particular, it is necessary in a conventional WLAN system to have an AP at each floor in the building and/or every 100 to 500 feet, to provide full coverage and to solve capacity problems. Providing so many WAPs can be an important expense, as well as the expense of running a connection from the WAP to the wired LAN.

[0009] There is a need for a WLAN system that mitigates the foregoing disadvantages.

SUMMARY OF THE INVENTION.

[0010] An object of the invention is to overcome the foregoing disadvantages and limitations of conventional WLAN systems by integrating WLAN systems with CATV networks.

[0011] In one embodiment, WLAN communications are carried over a CATV network without modification to the

CATV network. In another embodiment, the CATV network is modified to accommodate the WLAN traffic. In another embodiment, the WLAN communications over the CATV network are performed according to a polling protocol. In yet another embodiment, the upstream location of the WAP is at one of a building, an optical node of the CATV network, and the CATV head end.

[0012] One aspect of the invention includes providing an indoor device that may be simpler and more economical than a WAP. The indoor device is connected with the CATV network at an end user location, and communicates WLAN signals between a wireless end user device and the CATV network. Another aspect of the invention includes providing an upstream device, located upstream in the CATV network with respect to the indoor device, for communicating the WLAN signals between the CATV network and a WAP.

[0013] Since the indoor devices are economical, they can be placed wherever there is a CATV outlet at the end user premises. For example, each apartment or hotel room in a building could be provided with such a device. When the indoor devices are provided in high numbers, the coverage for the WLAN is excellent, and wireless end user devices need only use low radiation power to communicate with the indoor devices. Since the signals received at the indoor devices are carried to a WAP through the CATV network, it is not necessary to provide many WAPs.

[0014] Furthermore, the indoor device and the upstream device provide a way for a CATV provider to allow subscriber broadband access over the CATV network without having to use a cable modem.

[0015] The embodiments and aspects of the invention described above are not meant to limit the invention, and are provided only to give a general idea of the invention. A more complete understanding of the invention will be achieved by studying the details of some of the embodiments presented below, with reference to the enclosed drawing figures.

BRIEF DESCRIPTION OF THE DRAWINGS.

[0016] The drawing figures depict, in highly simplified schematic form, embodiments reflecting the principles of the invention. Many items and details that will be readily understood by one familiar with this field have been omitted so as to avoid obscuring the invention. In the drawings:

- Fig. 1 is a simplified schematic diagram of a conventional CATV network.
- Fig. 2 is a simplified schematic diagram showing a first embodiment according to the invention.

- Fig. 3 is a highly simplified schematic diagram of an indoor device (EID-WiFi) unit according to an aspect of the invention.
- Fig. 4 is a highly simplified schematic diagram of a WLAN entrance module according to an aspect of the invention.
- Fig. 5 is a simplified schematic diagram showing a second embodiment according to the invention.
- Fig. 6 is a simplified schematic diagram showing a bypass device according to an aspect of the invention.
- Fig. 7 is a simplified schematic diagram showing an embodiment of the invention featuring multiple WLAN protocols and multiple WAPs with frequency reuse simultaneously supported.
- Fig. 8 shows, in simplified schematic form, an up/down frequency converter for use in a WLAN entrance module.
- Fig. 9 is a simplified schematic diagram showing an up/down frequency converter for use in a WLAN entrance module that supports multiple WLAN protocols and/or multiple frequency reuse WAPs.
- Fig. 10 shows, in simplified schematic form, an up/down frequency converter for use in an indoor unit (EID-WiFi).

- Fig. 11 is a simplified schematic diagram showing an up/down frequency converter for use in an indoor unit (EID-WiFi) that simultaneously supports multiple WLAN protocols and/or multiple frequency reuse WAPs.
- Fig. 12 is a simplified diagram depicting a PCF frame transfer.
- Fig. 13 shows a state diagram of operating a WLAN over CATV system in a switching mode.
- Fig. 14 graphically depicts a multi-story building with a WLAN over CATV system according to a fourth embodiment of the invention.
- Fig. 15 graphically depicts a multi-story building with a WLAN over CATV system according to the first and the fourth embodiments of the invention.
- Fig. 16 graphically depicts a multi-story building with a WLAN over CATV system according to the second and the fourth embodiments of the invention.
- Fig. 17 shows the frequency channel plan for 802.11b.
- Fig. 18 shows the frequency channel plan for 802.11a.
- Fig. 19 shows one bandwidth allocation plan for 802.11b non-overlapping channels over a system according to the first embodiment of the invention.

- Fig. 20 shows one bandwidth allocation plan for 802.11b overlapping channels over a system according to the first embodiment of the invention.
- Fig. 21 shows one bandwidth allocation plan for 802.11a over a system according to the first embodiment of the invention.
- Fig. 22 shows one bandwidth allocation plan for 802.11b non-overlapping channels over a system according to the second embodiment of the invention.
- Fig. 23 shows one bandwidth allocation plan for 802.11b overlapping channels over a system according to the second embodiment of the invention.
- Fig. 24 shows one bandwidth allocation plan for 802.11a over a system according to the second embodiment of the invention.
- Fig. 25 shows one dual-band bandwidth allocation plan for 802.11b and 802.11a over a system according to the second embodiment of the invention.

DETAILED DESCRIPTION.

[0017] The invention will now be taught using various exemplary embodiments. Although the embodiments are described in detail, it will be appreciated that the invention is not limited to just these embodiments, but has a scope that is significantly broader. The appended claims should be consulted to determine the true scope of the invention.

CATV networks.

[0018] The CATV network is quite ubiquitous, even in rural areas. The delivery of WLAN signals directly to the subscriber's premises, by using the CATV network, allows increase in the WLAN range performance and hence brings an increase of an order of magnitude in the WLAN network's available capacity and data throughput. This is due to the fact that the propagation conditions are greatly improved by using the CATV access path in the vicinity of the customer premises.

[0019] Fig. 1 shows a schematic diagram of a prior art CATV network. The CATV head end is connected to CATV optical nodes. The CATV signal is usually converted at the optical node to CATV cable, and the signal is amplified by CATV amplifiers. The CATV amplifiers have filters that enforce a bandwidth split that separates downstream from upstream communications. Downstream communications from the CATV head end to the subscribers are above the split, and upstream communications from the subscribers to the CATV head end are below the split. The split may commonly be found at around 45-50 MHz (65 MHz in Europe). Thus, signals above the split are filtered out by the amplifiers, and prevented from going upstream to the head end; signals below the split are prevented from going downstream to the subscribers. In Fig. 1, the subscribers all have television sets, and set-top boxes (STB).

First embodiment.

[0020] According to this exemplary embodiment, a CATV network is enabled to communicate WLAN data traffic, without modifying the CATV network itself.

[0021] In this embodiment, the CATV network functions as an access element within the analog portion of the WLAN system, namely in its RF propagation-radiation section. The capabilities of the existing CATV network is substantially preserved, and the WLAN end user terminals do not have to be modified. That is to say, the signals sent according to the WLAN terminal communications protocol traverse the CATV network, without modification to the signals or to the wireless end user device, except that the WLAN signals are frequency converted while in the CATV network

[0022] The radio frequencies and channel structures of the WLAN and the CATV networks are different. Therefore, according to this embodiment, the WLAN signals are converted to uplink and downlink CATV frequencies so that the CATV network can carry them. The frequency up and down conversion is made so as to fit within the CATV spectrum specifications.

[0023] To carry out this embodiment, it is important to discuss one aspect of the invention, namely, the indoor device. The indoor device may be referred to, with no loss of generality, as an Enhanced In Door Wi-Fi Unit (EID-WiFi, also referred to as a PINDU for PASSOVER INDoor Unit). The EID-WiFi is a component which acts as a transmit and receive antenna for the WLAN signals, and as a CATV input output unit for the CATV network. According to one embodiment of the EID-WiFi, WLAN RF signals are converted from the original RF TDD 2.4 GHz and 5.3 GHz frequencies to 20 MHz bandwidth signals in the original CATV 5 to 45/65 MHz frequencies for uplink and to 20 MHz bandwidth signals in the original CATV 500 to 750/860 MHz frequencies for downlink. The frequency converted signals are injected into the CATV network, without any protocol or format changes. Most of the existing CATV video signals are already limited to frequencies under 500MHz (digital CATV goes up to 750/860 MHz) while WLAN systems operate above this limit. Moving the WLAN signals to the CATV frequency range enables the WLAN signals and the CATV signals to coexist, over the CATV network, where a portion of the CATV spectrum is allocated to the WLAN.

[0024] Fig. 2 shows an exemplary WLAN system over a CATV network according to this embodiment of the invention. The figure includes the WLAN Entrance Module (WEM), which converts the original WLAN RF signal to the assigned frequency spectrum to be carried on the CATV network. The WEM is an up down dual band converter that converts the WLAN signals from their original frequencies i.e. 2.4 GHz (due to 802.11b, 802.11g) and or 5.3 GHz (due to 802.11a) to 20 MHz up and 20 MHz down at any frequency in the frequency band of the original CATV spectrum.

[0025] The Enhanced In Door Wi-Fi Unit (EID-WiFi) is indicated in Fig. 2 by reference character "E". The EID-WiFi acts as an up down converter repeater to return the WLAN signals to their original frequencies, and differentiates between the CATV signals to be carried to the TV (or Set Top Box) and the WLAN signals to be transmitted in the customer premises. Signals from the WLAN AP entering at the WEM are converted and distributed through the CATV network. It will be appreciated that, during the discussion below, for the sake of linguistic convenience only, all kinds of TVs and Set Top Boxes, and any other equipment at all that can be connected to a CATV network, are herein referred to simply as TVs without the loss of the intended generality.

[0026] The EID-WiFi is the interface between the WLAN-over-CATV network and the wireless end user device at the customer premises. The WEM is the interface between the WLAN-over-CATV network and the WAP.

EID-WiFi

[0027] A more detailed view of an exemplary EID-WiFi is shown in Fig. 3. The combined WLAN and CATV signals pass through the CATV outlet. Frequency shifted downstream/downlink signals (i.e., including signals coming from the WAP to the end user) come from the CATV outlet along with typical CATV signals. The WLAN and CATV signals are differentiated at a Network Coupling Duplexer (NCD). The NCD can, in the most simple configuration, be pre-set to expect the frequency shifted WLAN signals in a predetermined range. In the drawing figure, the NCD is shown as having three ports. One is for connection to the CATV network, and this may be thought of as a CATV port. One is for connection to the TV device (i.e., the STB in Fig. 2), and this may be thought of as a TV port. The remaining port is for WLAN signals.

[0028] The EID-WiFi has an up and down converter UDC that up-converts the frequency shifted downstream WLAN signals to their original WLAN signal frequencies, and transmits the signals over an antenna. Likewise, for upstream signals from the WLAN end user to the WAP, signals coming from the antenna are down converted to the CATV preassigned frequencies and enter the NCD to be sent over the CATV network. The transmitting and receiving of the WLAN signals over the antenna is handled with radio circuitry (not shown) of any type suitable for the given

WLAN (inasmuch as the selection of such radio circuitry is well within the ability of one familiar with this field, the discussion of any specific radio circuitry is omitted).

[0029] The NCD passes to the TV, without change, any other downstream signals (i.e., other than the signals in the part of the spectrum used for WLAN signals). The NCD passes to the CATV network, without change, any upstream signals received from the TV.

WEM

[0030] Fig. 4 shows one simple embodiment of the WEM. The WEM is the interface between the WLAN and the CATV signals. Downlink WLAN signals from the WAP are down converted to the assigned CATV spectrum and uplink WLAN signals to the WAP are up converted from the assigned CATV frequency spectrum to the original WLAN frequencies. The downlink signals are carried through the WEM and combined through a HP/LP to the CATV signals to be carried through the network, whereas the uplink signals are provided to the WAP. Together, the WEM and WAP may be thought of as an upstream WLAN to CATV controller.

Frequency conversion

[0031] In this embodiment, part of the spectrum of the CATV must be allocated so as to accommodate WLAN signals over the CATV network. The WLAN TDD frequencies (such as the 2.4 GHz or 5.3 GHz WLAN TDD, all of which are above the CATV spectrum) are down-converted to FDD uplink and downlink frequencies in the original spectrum of the CATV (e.g., a 20 MHz bandwidth allocation in the 5 to 45/65 MHz part of the CATV uplink spectrum, and a 20 MHz bandwidth allocation in the 500 to 750/860 MHz part of the CATV downlink spectrum).

[0032] Since the EID-WiFi unit is, in the above identified embodiment, pre-set to shift any signals received from the CATV system within a certain band and communicate them to the antenna, it may be said that the EID-WiFi unit communicates predetermined signals with a WLAN terminal via an antenna. Although selecting WLAN signals using a predetermined frequency is the preferred and least expensive approach, other ways of accomplishing the same result will occur to those familiar with this field. For example, if the part of the downstream bandwidth being used for WLAN signals is used also for some other kind of signal, some means for discriminating between the two would be arranged, and only the ones identified as WLAN signals would be communicated to the user's WLAN terminal via the antenna. Of course, this kind of discriminating circuitry would add to the complexity of the EID-WiFi unit.

Second embodiment.

[0033] According to this exemplary embodiment, a CATV network is enabled to communicate WLAN data traffic, and modifications are made to the CATV network itself to provide for improved WLAN bandwidth thus increasing CATV network capacity, without using CATV original spectrum and for decreased usage of bandwidth already being used by CATV providers.

[0034] As briefly discussed above, a traditional CATV network is a two-way network having a tree topology and including cables, amplifiers, signal splitters/combiners and filters. According to this embodiment, the cables and signal splitters/combiners are not modified, but some of the other elements are. The modified components allow all types of signals (the CATV up and down signals and the Wireless LAN up and down signals) to be carried by the network simultaneously in a totally uncoupled manner, thus avoiding the potential for cross interference brought on in any coupling.

[0035] According to this embodiment, WLAN RF signals are converted to 960 - 1155 MHz and injected into the CATV network, without any protocol or format changes. Moving the WLAN signals to the frequency range of 960 to 1155 MHz enables the WLAN signals and CATV signals to coexist without requiring any allocation of the scarce

CATV upstream bandwidth, and without taking up any CATV programming bandwidth

[0036] Fig. 5 is similar in many ways to Fig. 2, except that the active components of the CATV network, such as amplifiers and filters, have been augmented with bypass devices (BPs). The BPs allow the frequency-shifted WLAN signals to bypass the active components without getting filtered out. That is to say, in this embodiment the WLAN signals have been shifted, but not to frequencies that normally are allocated by the CATV provider for normal upstream traffic. Without the BPs, the upstream WLAN signals would never reach the head end because they are above the bandwidth split imposed by the CATV system active components.

[0037] Fig. 6 shows a more detailed view of the BP device (which also may be referred to as a WLAN transport module, or WTM). In this figure, the uplink direction is from bottom to top, and the down link direction being from top to bottom in the figure. The combined WLAN and cable signals enter the BP device. Through the high-pass / low-pass (HP/LP) filter (see "CATV" and "Above CATV" filters), the signals are distributed into two different channels; one channel carries the CATV signals and the other carries the WLAN signals. At the end of the path the signals are combined again through the HP/LP to be carried through the network. A BP device should be installed wherever it is necessary in the system; this includes active components like CATV amplifiers, and locations at which it is desired to amplify WLAN signals even when a CATV amplifier is not present.

[0038] That is, the combined WLAN and cable signals enter at the entrance of the LP/HP duplexer. The duplexers each differentiate between the CATV signals and the WLAN signals. The CATV signals 5 - 750/860MHz are carried through the LP filter to the CATV amplifier. The output signals from the CATV amplifier are carried to an additional LP filter to be combined again with the WLAN signals. The WLAN signals are carried to/from the HP output to the WLAN filter, the WLAN filter differentiates between the up-link and down-link signals to be amplified by the amplifiers to balance the power budget along the pass. The WLAN signals from the amplifiers are connected to the HP/LP filters via the fibers, to be combined with the CATV signals and carried on through the network.

[0039] The EID-WiFi in this embodiment may have a structure substantially the same as shown in Fig. 3 and described already. The EID-WiFi according to this embodiment, however, converts both of the uplink and downlink signals to frequency bands above the CATV signals instead of to frequency bands within the CATV normal spectrum. Thus, upstream signals in this embodiment are not carried through the CATV network components in the same way as in the first embodiment. In this second embodiment, the uplink signals travel from the EID-WiFi to the WEM via the BPs instead of via the CATV active components.

[0040] Likewise, the WEM in this embodiment may have a structure substantially the same as shown in Fig. 4 and described already, except that the up and down converter converts the uplink and downlink signals to/from different frequency bands above the CATV signals.

Third embodiment.

[0041] According to this exemplary embodiment, a CATV network communicates WLAN data traffic according to a polling protocol to provide for higher control over the WLAN traffic, and overcome the problems of CSMA/CA in the CATV network. This embodiment is used as part of the implementation in the CATV/WLAN systems already described above with respect to the first and second embodiments.

[0042] The conventional implementation of a WLAN is based on Carrier Sense Multiple Access Collision Avoidance (CSMA/CA) mode. In this mode each wireless end user device in the network is listening to the network to identify if the path is free for transmission, and if so, the wireless end user device is allowed to transmit the data. If a collision occurs, the data must be transmitted again. A limitation of CSMA/CA is the reduction in data throughput of the system, as well as the requirement that all the units in the network be able to receive all the uplink/downlink data transmitted through it all the time in the specified coverage area. The CATV tree configuration presents special problems in this area.

[0043] In this embodiment, a WAP controller centrally manages the WLAN system. The interaction between the wireless end user device and the WAP is controlled according to a polling protocol. No end unit is allowed to transmit data without authorization of the controller.

[0044] It will be appreciated that this embodiment can be used with either the first or second embodiment equally well. For example, if this embodiment were combined with the second embodiment, upstream and downstream signals would be converted from TDD signals (2.4 GHz for 802.11b and 802.11g, and 5.3 GHz for 802.11a) coming/going from the access point into the network to FDD signals, (960 to 1035 MHz Uplink and 1080 to 1155 MHz Downlink) and of course any other frequency range above 860 MHz and below 1200 MHz can be defined by the designer. The FDD signals would be transferred over different frequencies in the cable network and therefore not collide. At the customer's premises the FDD signals are converted back to original WLAN TDD signals by the EID-WiFi, to be transmitted in the customer's premises to the wireless end user device, so that the TDD WLAN signals are converted to shifted FDD signals on the CATV system.

[0045] The protocol that will be used as an exemplary polling protocol in this discussion, without limiting the invention, is the Point Coordination Function (PCF) protocol. The PCF protocol is defined by the 802.11 standard, and so does not need to be explained to the person familiar with this field. According to the PCF protocol, a WAP controller is the main manager of the system. With PCF, a point coordinator within the WAP (i.e., the WAP controller) controls which stations can transmit during any give period of time. Within a time period called the contention free period, the point coordinator will step through all stations operating in PCF mode and poll them one at a time.

[0046] For example, the point coordinator may first poll station A, and during a specific period of time station A can transmit data frames (and no other station can send anything). The point coordinator will then poll the next station and continue down the polling list, while letting each station have a chance to send data. Thus, a polling protocol like PCF is a contention-free protocol and enables stations to transmit data frames synchronously, with regular time delays between data frame transmissions. This makes it possible to more effectively support information flows having stiffer synchronization requirements, such as video and control mechanisms.

[0047] In one specific implementation, the EID-WiFi is modified so as to operate in a switching mode. In the switching mode, the uplink and downlink paths can be switched on and off, based on the activity control unit defined by the WAP controller.

[0048] In another specific implementation, the EID-WiFi is a dual mode unit, and is capable of receiving and transmitting signals simultaneously in two different WLAN protocol formats or WLAN with the same protocol and different reuse frequency. For example, the EID-WiFi dual mode unit can operate at both 802.11b and 802.11a frequencies (of 2.4 GHz and 5.3 GHz respectively) at the same time, or the EID-WiFi dual mode unit can operate at 802.11b with center frequency band of 2412 GHz and 2432 GHz or any other frequency combination. In this instance, WLAN RF signals are converted from the original RF 2.4 GHz for 802.11b or 802.11g, and 5.3 GHz for 802.11a frequencies to 960 - 1035 MHz downlink and to 1080 - 1155 MHz uplink (or any other set of uplink, downlink frequencies within the range of 960 to 1200 MHz) and injected into the CATV network.

[0049] Fig. 7 is similar to Figs. 2 and 5 in many ways, although some items appearing in the earlier figures have been omitted for the sake of clarity of depiction. In the discussion that follows, it will be assumed that the exemplary embodiment is in the context of the second embodiment, namely, a system with BPs and the WLAN signals shifted above the CATV signals, with the understanding that the discussion would apply equally well to a system of the first embodiment with appropriate changes.

[0050] In Fig. 7 the WEM, BP (also called WTM), and EID-WiFi are generally the same as described above with respect to the second embodiment, with some changes. At the CATV head end there are shown not one but several WAPs (WAP 1, WAP 2, and WAP 3). Two of these communicate using the 802.11b protocol and one using the 802.11a protocol. Each WAP has a respective WEM. Each WEM communicates with the CATV network via a combiner/splitter unit, and an RF to optical converter.

[0051] Fig. 8 shows the WEM up down converter (UDC) in more detail. The WEM down converts the original 802.11b, or the 802.11a signals received from the access point to intermediate Wi-Fi frequencies to be carried on the CATV network and up converts the intermediate Wi-Fi frequencies carried on the CATV network to the original 802.11b or 802.11a to be received by the access point.

[0052] Fig. 9 shows a dual band WEM up down converter. The dual band WEM enables the carrying of both 802.11b, g and 802.11a signals simultaneously on the CATV network to the customer's premises. Each band is converted to a different portion of the spectrum in the CATV network. For example: 802.11b will be converted to 20 MHz bandwidth up link, and 20 MHz down link within first frequency ranges (960 - 980 MHz, and 1080 - 1100 MHz), and 802.11a will be converted to a different 20 MHz bandwidth up link, and 20 MHz down link within second frequency ranges (1000 - 1020 MHz, and 1120 - 1140 MHz).

[0053] Fig. 10 shows the EID-WiFi UDC for operation with switching mode. The EID-WiFi down converts the original 802.11b, g or the 802.11a signals received from the end user terminal to the assigned CATV network frequencies (960 - 1035 MHz in our example), and up converts the Wi-Fi signals carried on the CATV network (1080 - 1155 MHz) to the original 802.11b, g or 802.11a signals to be transmitted to the end user terminal. When the EID-WiFi functions in the switched mode, the up link and down link paths are switched with switches Su and Sd, respectively. These switches can be remotely controlled from the central equipment (i.e., the WAP controller) or self controlled by the unit.

[0054] Fig. 11 shows a dual band EID-WiFi up down converter. Such a dual band EID WiFi unit enables the receiving and transmitting for both 802.11b, g and 802.11a simultaneously on the CATV network and to the customer end user. For Example: 802.11b can be converted to 20 MHz bandwidth up link, and 20 MHz down link (960 - 980 MHz, and 1080 - 1100 MHz), and 802.11a can be converted to another 20 MHz bandwidth up link, and 20 MHz down link (985 - 1005 MHz, and 1105 - 1125 MHz).

[0055] The switches Sua and Sda can be remotely controlled from the WAP controller to activate or inactivate the upstream and the downstream paths for the 802.11a side, respectively, or self controlled by the unit. Likewise, the switches Sub and Sdb activate or inactivate the paths for the 802.11b side. To put it another way, the EID-WiFi has remotely controllable switches for opening or closing WLAN communication paths.

[0056] Fig. 12 shows the standard PCF frame transfer used to support the switched concept and whole network control.

[0057] There are two basic modes of operation in the switched mode: (a) Downstream open upstream closed - No signals are sent on the cable upstream regardless of 802.11 transmissions that may be present in the air; (b) Both upstream and downstream are closed.

[0058] By using the switched mode of operation, it will prevent noise on the upstream that could be generated by each unit, which will contribute to improved C/N performance.

[0059] When the uplink and downlink are both closed, the radiation from the In-Door unit will be minimal.

Thus, when the unit is not used, there is no radiation from it enters into the customer's premises.

[0060] Wireless end user devices that are not connected to the system yet, are controlled and prohibited from entering the system unless the central system authorizes it. Misbehaved units can be eliminated from the system to prevent interference.

[0061] The system can function in a full duplex mode, which enables to double the capacity of the system. When switching is operational it may be possible to allow STA1 to send upstream data when it is in upstream-open-downstream-closed mode while the AP is sending data to STA2, which is in downstream-open-upstream-closed mode.

[0062] Fig. 13 shows a state diagram of operating in switching mode. It will be appreciated that, within the WAP controller, there may be a function for remotely controlling the switches provided in the EID-WiFi units, and a function for the other more typical access point operations. The function for remotely controlling the switches may be thought of as a switching control function (or switching controller SC) and the access point operations function may be thought of simply as the access point AP.

[0063] The AP creates a polling list before each contention free period (CFP). The creation of the polling list is not described here. The polling list contains *n* stations (STAs) D1,...,Dn to which the AP requires to send data to, and *n* STAs U1,...,Un which the AP wishes to poll. We describe a simple polling cycle in which the AP sends only a single beacon (at the beginning of the CFP). The AP does not attempt to use the upstream (US) and downstream (DS) channels concurrently. The length of the CFP and the contention period (CP) is determined by the AP. The CP is used to allow new STAs to join the system. When the AP receives a successful message during the CP, it associates the MAC address of the transmitting STA with the ID of the current active Switching Unit (SU).

[0064] The following notations are used:

- AP: SEND D(i) - The AP sends a datagram to STA D(i).
- AP: RECV U(i) - The AP receives a datagram from STA U(i).
- DS: CLOSE [OPEN] D(i) U(i) – The switching controller closes [opens] the downstream of STAs D(i) and U(i).
- US: CLOSE [OPEN] D(i) U(i) – The switching controller closes [opens] the upstream of STAs D(i) and U(i).

[0065] The AP first sends a beacon to all STAs to indicate the beginning of the CFP. At this stage the downstream switch of all STAs (active or not) should be open. The AP completes a polling cycle by sending data + poll messages and then receiving an answer from the polled STA. Since switching takes time, the downstream and upstream switches of the STAs with whom the AP intends to communicate, should be opened in advance. Basically, there is no harm if the downstream switch is left open at all times.

[0066] The CP can be used to provide an opportunity for new stations to join. If this is the case, all non active STAs should be in upstream-open-downstream-closed mode during the CP, while active STAs (those on the polling list) should be in closed mode. If the AP detects too many collisions during the CP it may close the upstream for some of the non active STAs in order to reduce possibility of collision. If the cycle is long, additional beacons (to the one sent at the beginning of the cycle) should be sent by the AP to all STAs. The duration between beacons should be lesser than the time the STA is occupied scanning the channel. During beacons, all downstream switches should be open. The beacons are required for new STAs to synchronize.

[0067] There is no particular significance to which processor handles the switching control function and which handles the WAP operations. For the sake of generality, then, it may be said that the functions are both handled in the upstream WLAN to CATV controller.

Fourth embodiment.

[0068] According to this exemplary embodiment, a CATV network communicating WLAN data traffic has an upstream WAP located in the CATV head end, a CATV optical node, or inside a building near the customer premises. Each location can be used with any of the first and second embodiments, and can also be used in cases in which the communication is controlled according to the third embodiment.

[0069] In a full-centralized system, a WAP is located at the CATV Head End. In a semi-centralized system, a WAP is located at a fiber optic node. In a hot spot type of system, a WAP is located at or near the end user premises (e.g., places such as hotels, airports, coffee shops, and apartments).

[0070] In the embodiment of Fig. 2, the WAP is located at the head end. In the embodiment of Fig. 7, the WAP is located away from the head end, at a fiber optic node of the CATV network. In the embodiment of Fig. 14, the WAP is located in the same building as the end user, but the communication in this embodiment is over the internal CATV network cabling of the building. In this specific example, additional CATV architecture can be used where the CATV network in the building is spread without amplifiers. In the arrangement shown in Figs. 14, 15, and 16 it is clear that many users located all over the building can use the same WAP, even though they are separated by walls, or even different floors. In the conventional approach of wireless end users communicating directly with an AP via wireless RF signals, the hot spots of Figs. 14 ,15, and 16 would probably need several WAPs per floor. In the arrangement of Figs. 14, 15, and 16 however, just one WAP can support the entire hot spot, providing that the hot spot is equipped with enough EID-WiFi / PINDU units.

Frequency allocations.

[0071] One familiar with this field will appreciate that frequencies can be allocated in a manner that suits the system designer's goals. For the sake of example, however, and without the loss of generality, various exemplary frequency allocation plans will be discussed.

[0072] Figs. 17 and 18 show the original frequencies for 802.11b and 802.11a channels, respectively.

[0073] Figs. 19, 20, and 21 show one way of allocating part of the spectrum of the CATV so as to accommodate WLAN signals over the CATV network in a system according to the first embodiment. The WLAN TDD frequencies (such as the 2.4 GHz or 5.3 GHz WLAN TDD, all of which are above the CATV spectrum) are down-converted to FDD uplink and downlink frequencies in the original spectrum of the CATV (i.e. a 20 MHz bandwidth in the 5 to 45/65 MHz part of the CATV uplink spectrum, and a 20 MHz bandwidth in the 500 to 750/860 MHz part of the CATV downlink spectrum). In systems according to the first embodiment, in which the uplink is carried over the typical CATV upstream path, the upstream bandwidth is limited.

[0074] Figs. 22, 23, and 24 show one way of allocating part of the spectrum of the CATV system so as to accommodate WLAN signals over the CATV network in a system according to the second embodiment. In particular, Figs. 22 and 23 show a frequency chart of the original 802.11b frequencies (Fig. 22 shows non-overlapping channels, and Fig. 23 shows overlapping channels). These original frequencies are shifted to downlink and uplink frequencies such that the WLAN signals can be carried on the CATV network spectrum. This frequency assignment configuration can support multiple access points on the same CATV network, thus increasing the WLAN system capacity.

[0075] Fig. 24 shows a frequency chart of the original 802.11a frequencies. These original frequencies are shifted to downlink uplink frequencies such that the WLAN Wi-Fi signals can be carried on the CATV network spectrum. This frequency assignment configuration can support multiple access points the same CATV network, thus increasing the WLAN system capacity. Fig 25. shows an example of frequency assignment of one 802.11b access point and one 802.11a access point working together on the same network, in a system according to the second embodiment of the invention.

Recommended variations.

[0076] It will be appreciated that it is not essential that the CATV system actually carry CATV programming. The CATV network cabling can communicate WLAN data traffic even without connection to the CATV data traffic but to any other traditional means of data carriers like ADSL, T1, Frame Relay etc., where the CATV networks act as an access element to the WLAN System. Different frequency and spectrum allocation plans will occur to those familiar with this field. The 802.11a, 802.11b, and 802.11g WLAN protocols have been discussed here, but the invention is applicable to any other WLAN protocol. The EID-WiFi has been described in the context of a radio receiver that receives WLAN signals through an antenna; other ways of providing signals to the EID-WiFi are also within the scope of the invention. The number and location of WAPs may be varied, and WAPs may be distributed throughout the network instead of being centralized. The WAP controller function for the system using the polling protocol may be implemented at any suitable location, in any suitable processor adapted for such control functions. Single and dual band models of the WEM and the EID-WiFi have been shown, but it will be possible for a person familiar with this field to implement even more complex units.

Conclusion.

[0077] The various embodiments and aspects of the invention help overcome coverage range and capacity constraints now faced by operators of WLAN systems. The invention enables increasing the range used by even an indoor WLAN system with one WAP to 1.5-2 Km or even more. This compares very favorably with the conventional approach of using purely wireless communications between the WLAN end user and the WAP.

[0078] By overcoming the above-identified coverage constraints, the cost of providing excellent radio coverage is reduced and service levels are improved. That is to say, even though the EID-WiFi shown and described above could be made more complex, its function can be very inexpensively implemented. A number of EID-WiFi units could be made so as to cost far less than the same number of WAPs. With in-building WLAN coverage becoming thus inexpensive and of a high quality, with high bit rate performance, more people will tend to use their WLAN system in home and in office. CATV system operators will have a potential new source of income. New service packages are possible in which CATV operators will serve not only wired high bit rate data but also wireless high bit rate data to the end user. Thus, it is possible that the CATV provider could provide broadband type internet access to users without the need for a cable modem at the end-user site.

[0079] Many variations to the above-identified embodiments are possible without departing from the scope and spirit of the invention. Possible variations have been presented throughout the foregoing discussion. Recommended variations have been also presented. It will be appreciated that the frequencies mentioned herein are exemplary only, and the invention can be adapted for use in not only the WLAN systems and protocols in use today, but also those developed hereafter.

[0080] Combinations and subcombinations of the various embodiments described above will occur to those familiar with this field, without departing from the scope and spirit of the invention.

CLAIMS.

There is claimed:

1. A method for providing bi-directional wireless local area network (WLAN) communication through a CATV network, comprising:

communicating CATV signals and frequency shifted WLAN signals over the CATV network, between a WLAN access point (WAP) communicating with the CATV network and an indoor termination point of the CATV network, wherein the CATV signals and the frequency shifted WLAN signals are communicated together via the CATV network; and

returning the frequency shifted WLAN signals to WLAN frequencies at the indoor termination point.

2. The method according to claim 1, further comprising, at the indoor termination point of the CATV network:

receiving shifted downlink WLAN signals from the CATV network;

converting the shifted downlink WLAN signals to original frequency downlink WLAN signals;

outputting the original frequency downlink WLAN signals to an antenna;

receiving, at the indoor termination point, original frequency WLAN signals from the antenna;

converting the original frequency uplink WLAN signals to shifted uplink WLAN signals; and

outputting the shifted uplink WLAN signals to the CATV network.

3. The method according to claim 2, further comprising, at the indoor termination point of the CATV network, communicating CATV signals, between the CATV network and a TV device, by coaxial cable.

4. The method according to claim 3, wherein the TV device is one or more of a TV, a set top box, and a cable modem.

5. The method according to claim 2, further comprising communicating the original frequency WLAN signals according to a Wi-Fi protocol.

6. The method according to claim 5, wherein the shifted uplink WLAN signals have a frequency below 50 MHz.

7. The method according to claim 5, wherein the shifted uplink WLAN signals have a frequency above 750 MHz.

8. The method according to claim 5, wherein the original frequency WLAN signals are shifted to a band within the original bandwidth of the CATV network.

9. The method according to claim 5, wherein active points of the CATV network are equipped with bypass devices for passing upstream signals above the original bandwidth of the CATV network, and wherein the original frequency WLAN signals are shifted to the band above the original bandwidth of the CATV network.

10. The method according to any one of claims 1-9, further comprising, at a WLAN entrance module (WEM) communicating with the WAP:

receiving shifted uplink WLAN signals from the CATV network;

converting the shifted uplink WLAN signals to original frequency uplink WLAN signals;

outputting the original frequency uplink WLAN signals to the WAP;

receiving original frequency downlink WLAN signals from the WAP;

converting the original frequency downlink WLAN signals to shifted downlink WLAN signals; and

outputting the shifted downlink WLAN signals to the CATV network.

11. The method according to claim 1, wherein a central WAP controller controls the communication according to a polling protocol.

12. A system for simultaneously communicating wireless local area network (WLAN) signals over a cable television (CATV) network along with CATV signals, the system comprising:

a WLAN entrance module (WEM) at an access point of the CATV network, receiving original downlink signals, including downlink signals from a WLAN access point (WAP), and shifting the original downlink signals to a frequency band within the downstream signal bandwidth of the CATV network to provide shifted downlink WLAN signals, the WEM having a frequency converter for providing frequency conversion; and

an enhanced indoor Wi-Fi unit (EID-WiFi), at an indoor termination point of the CATV network, adapted to receive original uplink WLAN signals, and shifting the original uplink WLAN signals to a frequency band, for communication upstream through the CATV network, to provide shifted uplink WLAN signals.

13. The system according to claim 12, wherein the EID-WiFi includes a network coupling diplexer (NCD) with a CATV port, a TV port, and a WLAN signals port, the NCD separating signals received at the CATV port into WLAN signals to be passed to the WLAN signals port and other signals to be passed to the TV port.

14. The system according to claim 12, wherein the shifted WLAN uplink signals have a frequency in the range of 5 MHz to 60 MHz.

15. The system according to claim 12, wherein the shifted WLAN uplink signals have a frequency above 750 MHz.

16. The system according to claim 12, further comprising a WAP controller for controlling the WLAN traffic according to a polling protocol.

17. The system according to claim 16, wherein the EID-WiFi has uplink and downlink switches remotely controllable by the WAP controller.

18. An Enhanced Indoor Wi-Fi Unit (EID-WiFi), comprising:

a network coupling duplexer (NCD) with a connection for connecting to a CATV network;

radio circuitry for communicating WLAN signals with a wireless end user device via an antenna; and

a connection for communicating signals other than the WLAN signals with a TV device.

19. The EID-WiFi according to claim 18, further comprising one or more remotely controllable switches for opening or closing WLAN communications paths.

20. A communications method, intended for providing broadband internet access to a user, over a CATV network, without the need for a cable modem, the method comprising:

providing an Enhanced Indoor Wi-Fi (EID-WiFi) unit at an indoor user location;

providing a WLAN access point (WAP) at a location of the CATV network upstream of the EID-WiFi;

communicating signals from the WAP to the CATV network via a WLAN entrance module (WEM), wherein the WEM modifies the frequency of the downlink WLAN signals to fit the spectrum of the CATV network; and

communicating signals between the CATV network and another WLAN device via the EID-WiFi, wherein the

EID-WiFi restores the frequency, of the downlink WLAN signals received from the CATV network, to the WLAN frequency.

21. An upstream WLAN to CATV controller, comprising:

a switching control function; and

an access point function;

wherein the access point function includes:

receiving shifted uplink WLAN signals from the CATV network;

converting the shifted uplink WLAN signals to original frequency uplink WLAN signals;

outputting the original frequency uplink WLAN signals to the WAP;

receiving original frequency downlink WLAN signals from the WAP;

converting the original frequency downlink WLAN signals to shifted downlink WLAN signals; and

outputting the shifted downlink WLAN signals to the CATV network; and

wherein the switching control function includes implementing a polling protocol for WLAN communications by sending signals to selectively open or close WLAN communication paths of downstream devices.

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FIG. 1
PRIOR ART

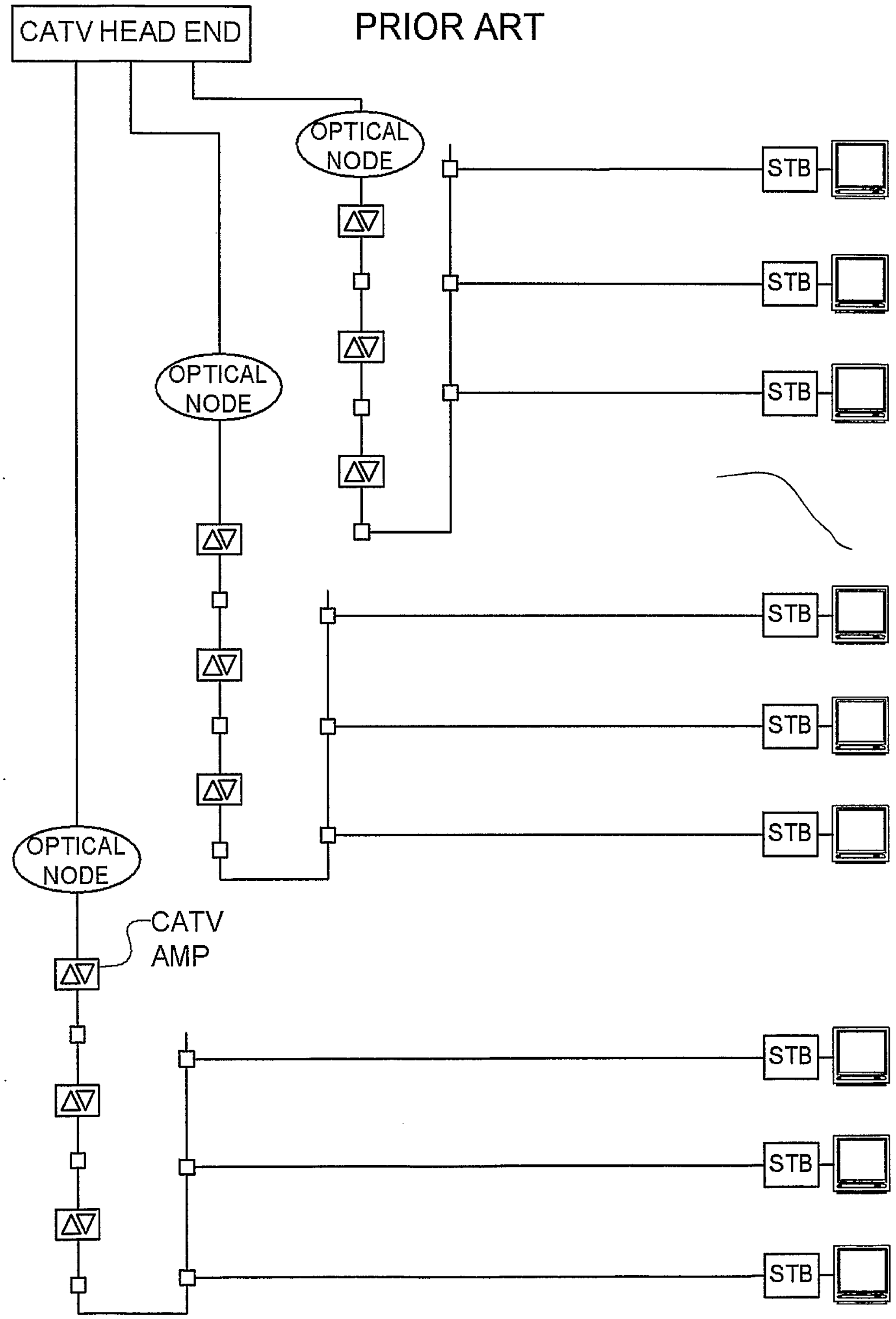

FIG. 2

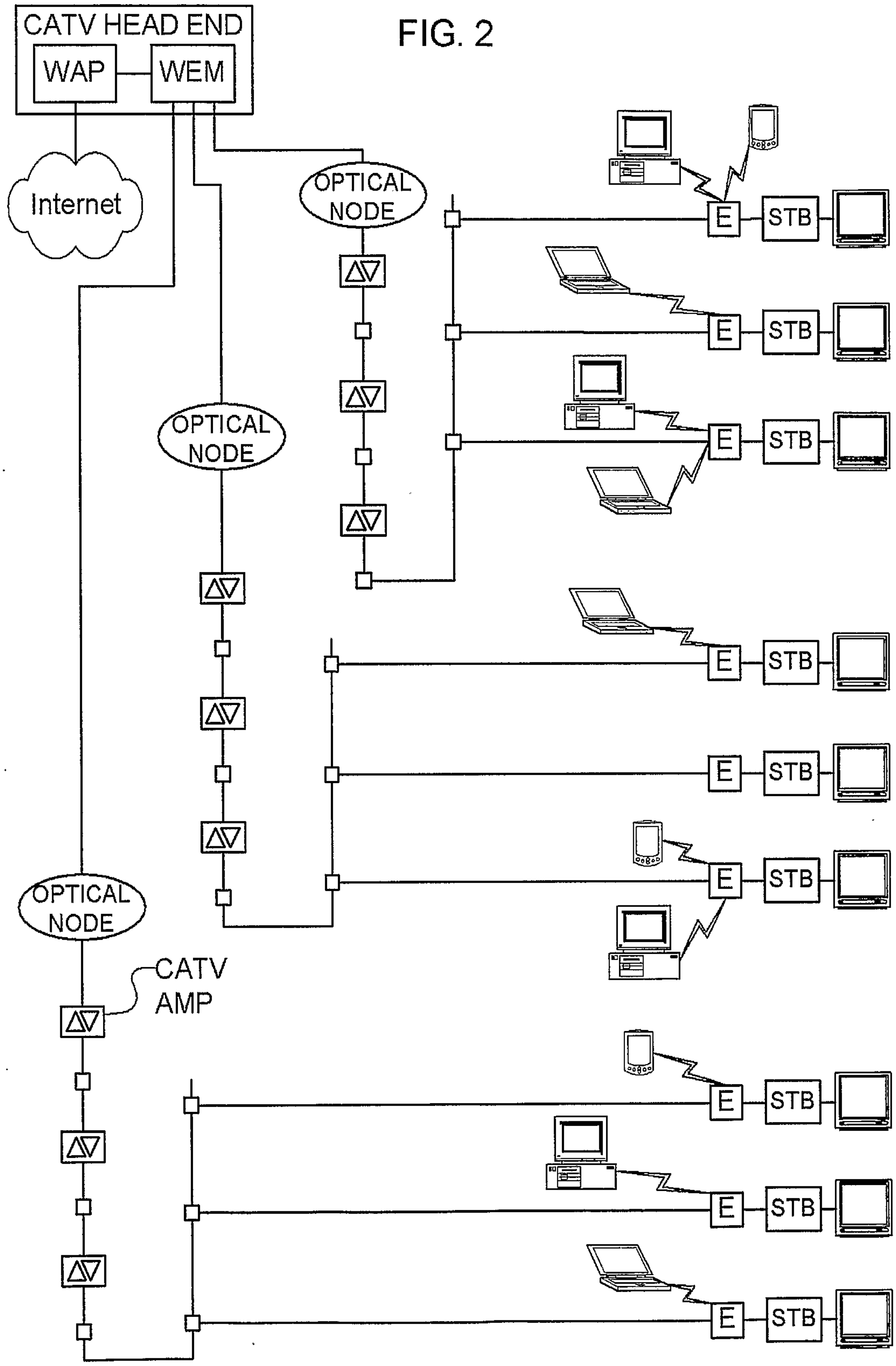
CATV HEAD END
WAP
WEM
Internet
OPTICAL NODE
OPTICAL NODE
OPTICAL NODE
CATV AMP
E
STB

FIG. 3

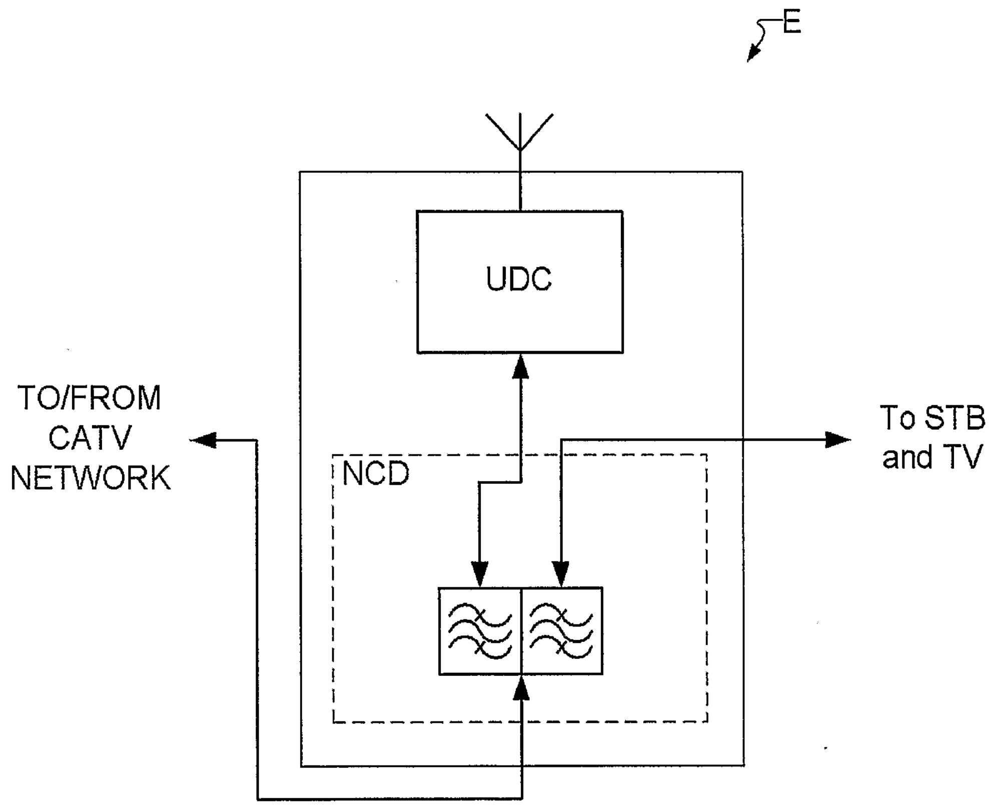

FIG. 4

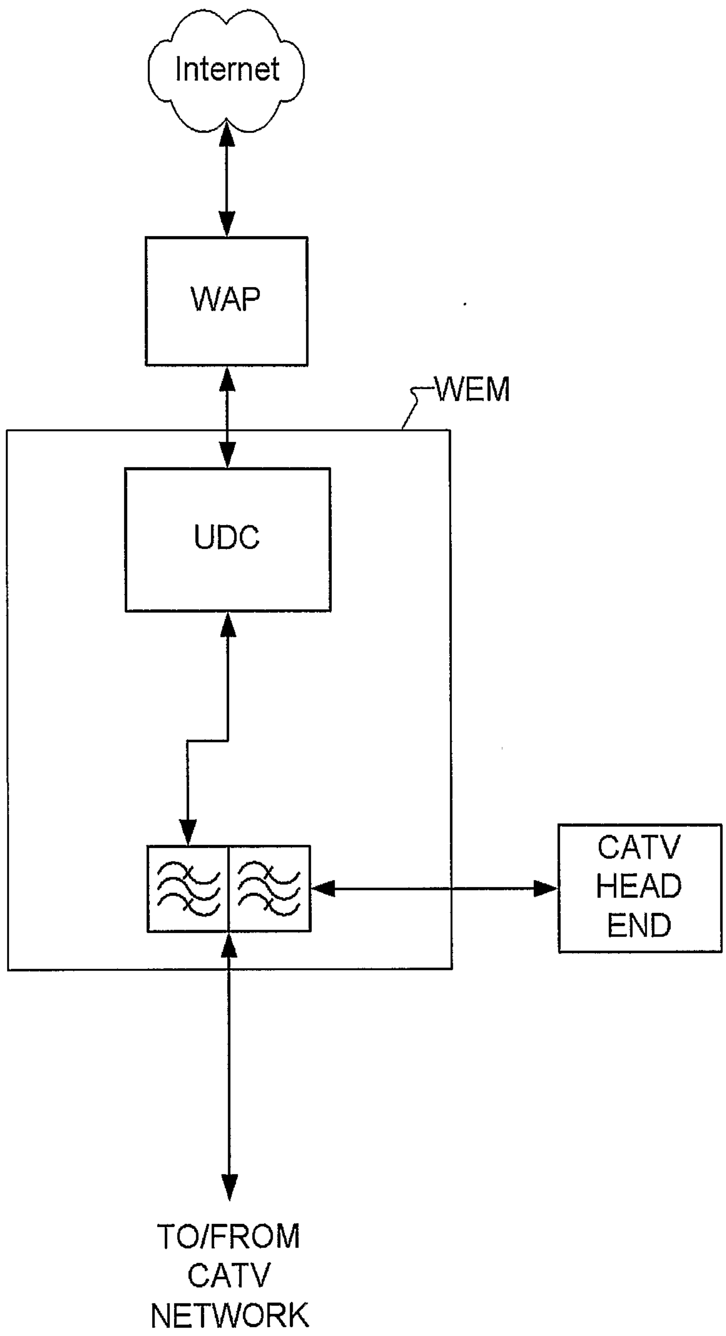

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FIG. 5

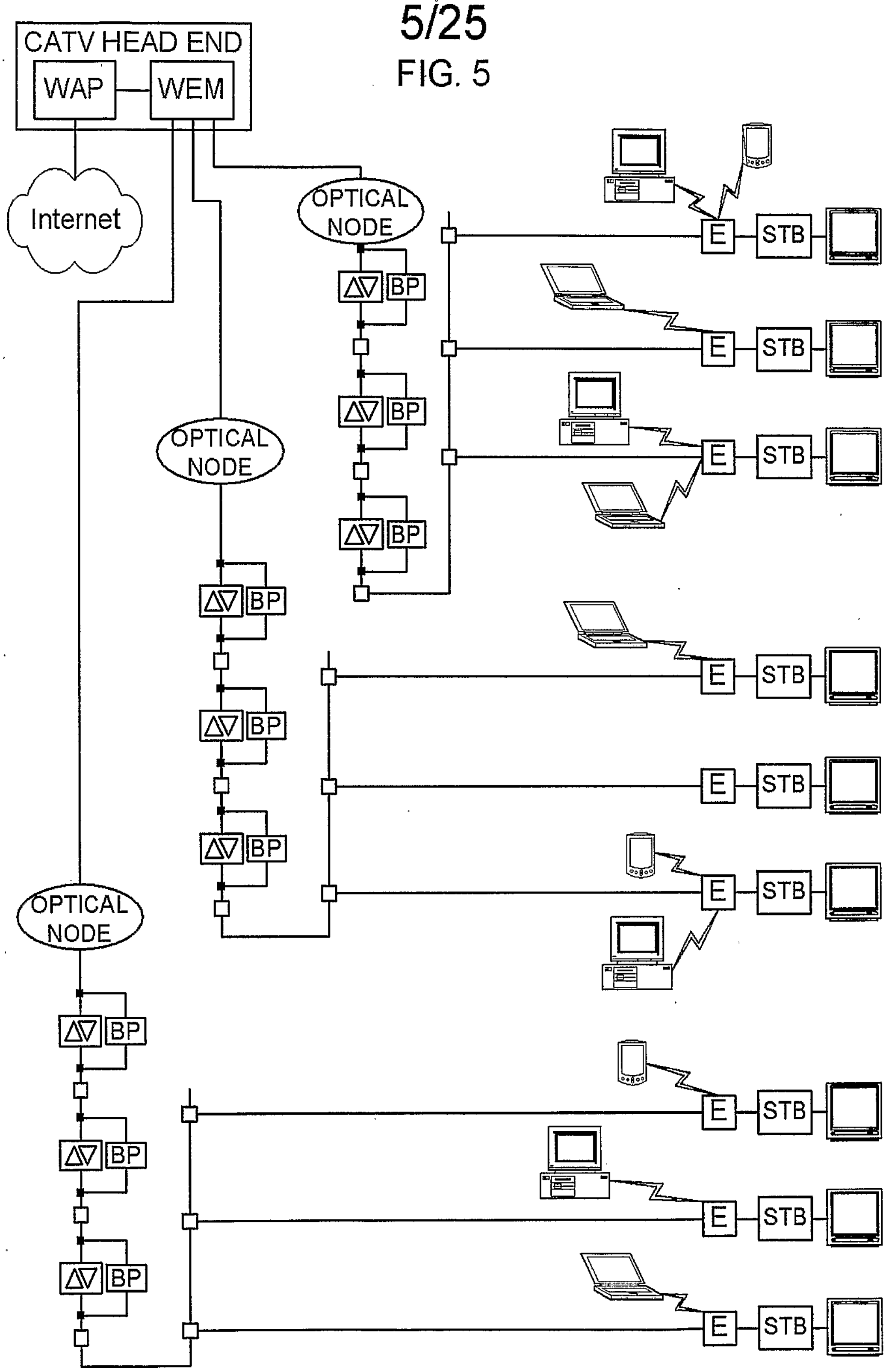

CATV HEAD END
WAP
WEM
Internet
OPTICAL NODE
OPTICAL NODE
OPTICAL NODE
BP
E
STB

FIG. 6

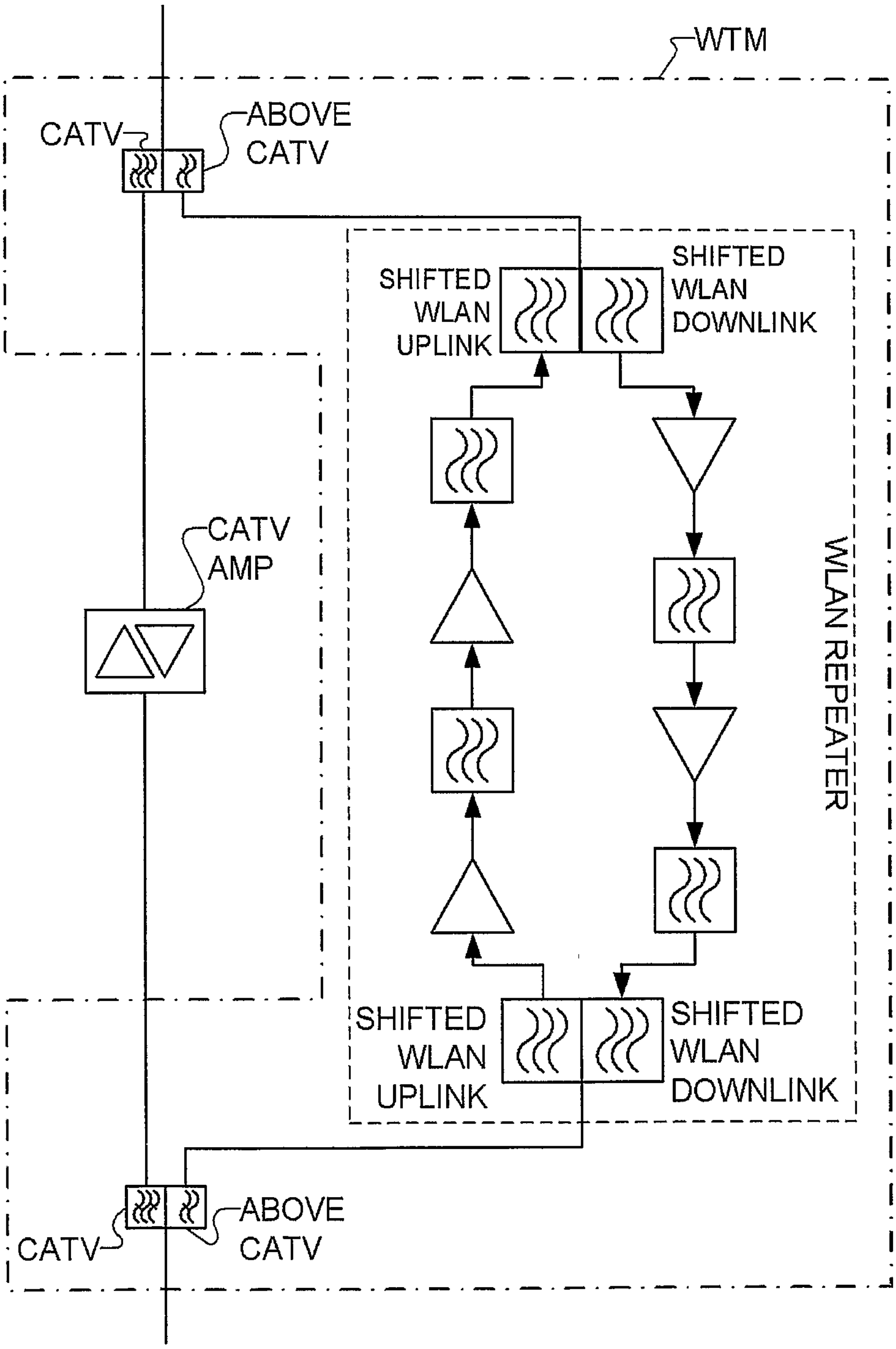

WTM
CATV
ABOVE CATV
SHIFTED WLAN UPLINK
SHIFTED WLAN DOWNLINK
CATV AMP
WLAN REPEATER
SHIFTED WLAN UPLINK
SHIFTED WLAN DOWNLINK
CATV
ABOVE CATV

FIG. 7

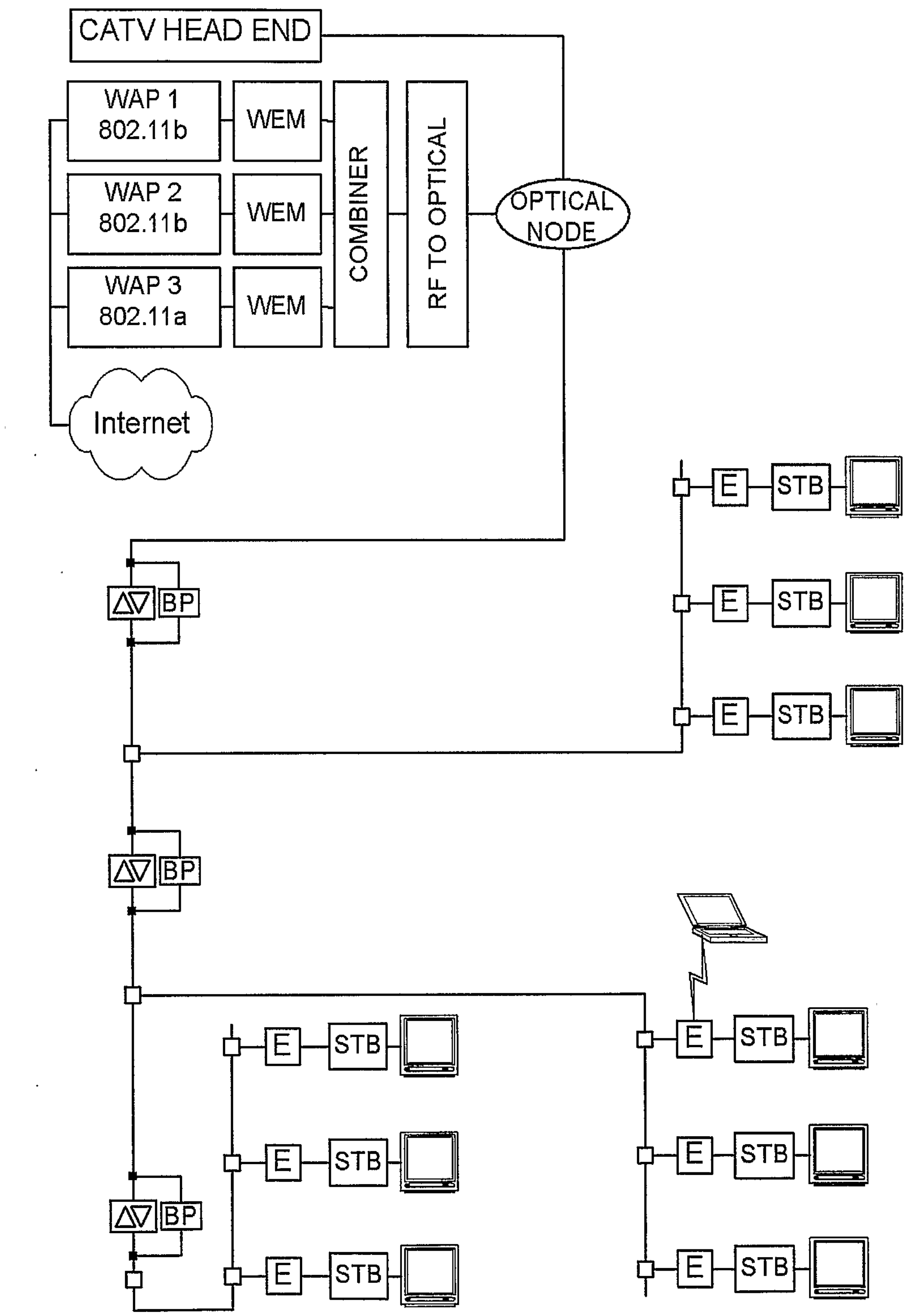

CATV HEAD END
WAP 1
802.11b
WAP 2
802.11b
WAP 3
802.11a
WEM
WEM
WEM
COMBINER
RF TO OPTICAL
OPTICAL
NODE
Internet
BP
BP
BP
E
STB

FIG. 8

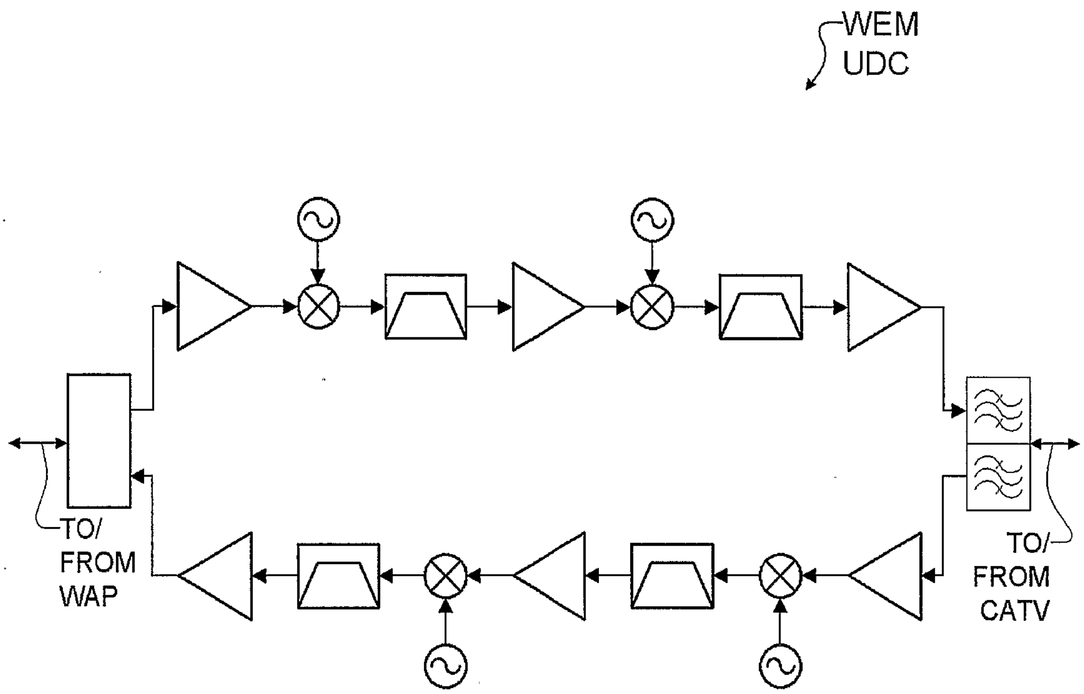


FIG. 9

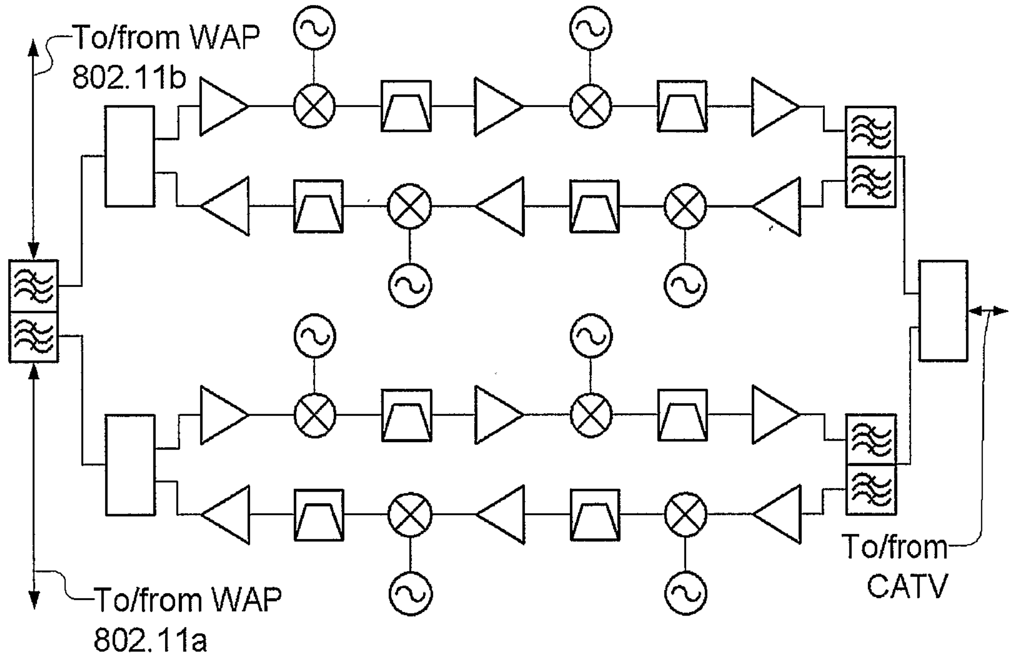


FIG. 10

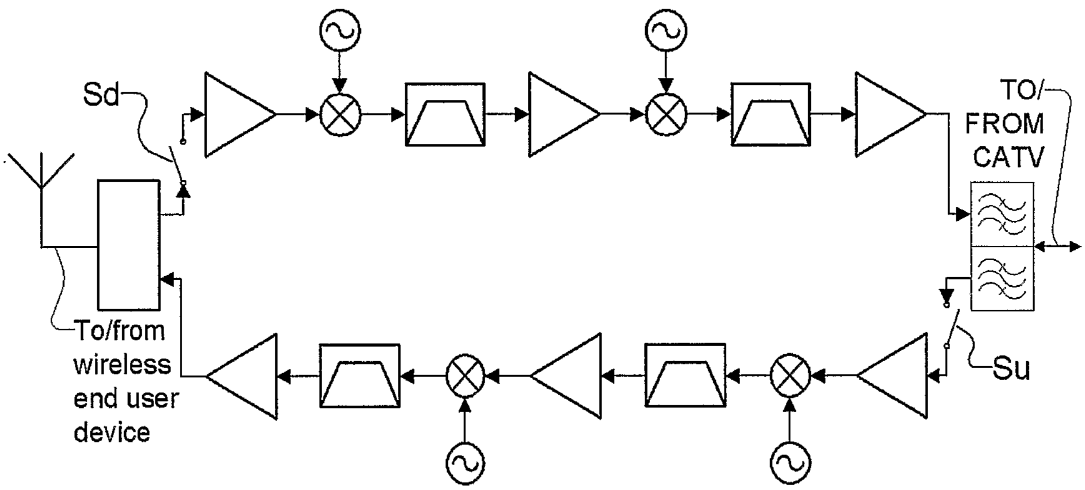


FIG. 11

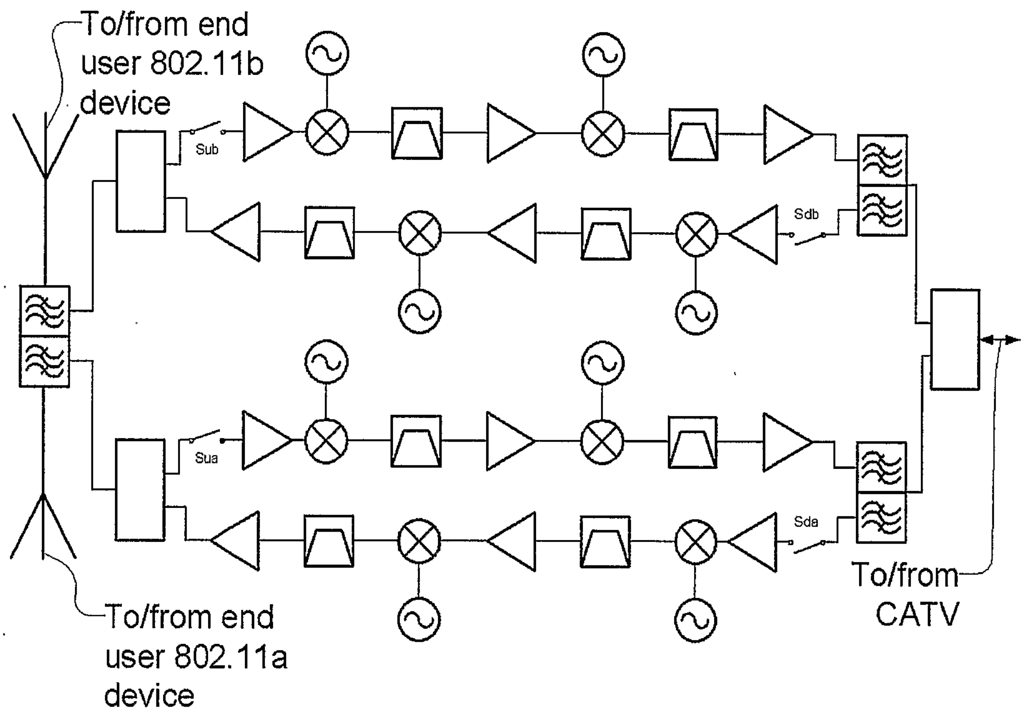
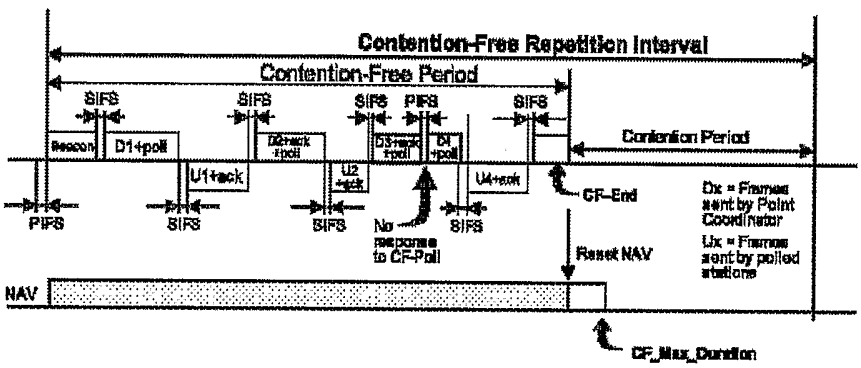

To/from end
user 802.11b
device
Sub
Sdb
Sua
Sda
To/from end
user 802.11a
device
To/from
CATV

FIG. 12



Contention-Free Repetition Interval
Contention-Free Period
SIFS
PIFS
Beacon
D1+poll
U1+ack
D2+ack +poll
U2 +ack
D3+ack +poll
D4 +poll
U4+ack
Contention Period
CF-End
No response to CF-Poll
Reset NAV
NAV
CF_Max_Duration
Dx = Frames sent by Point Coordinator
Ux = Frames sent by polled stations

FIG. 13

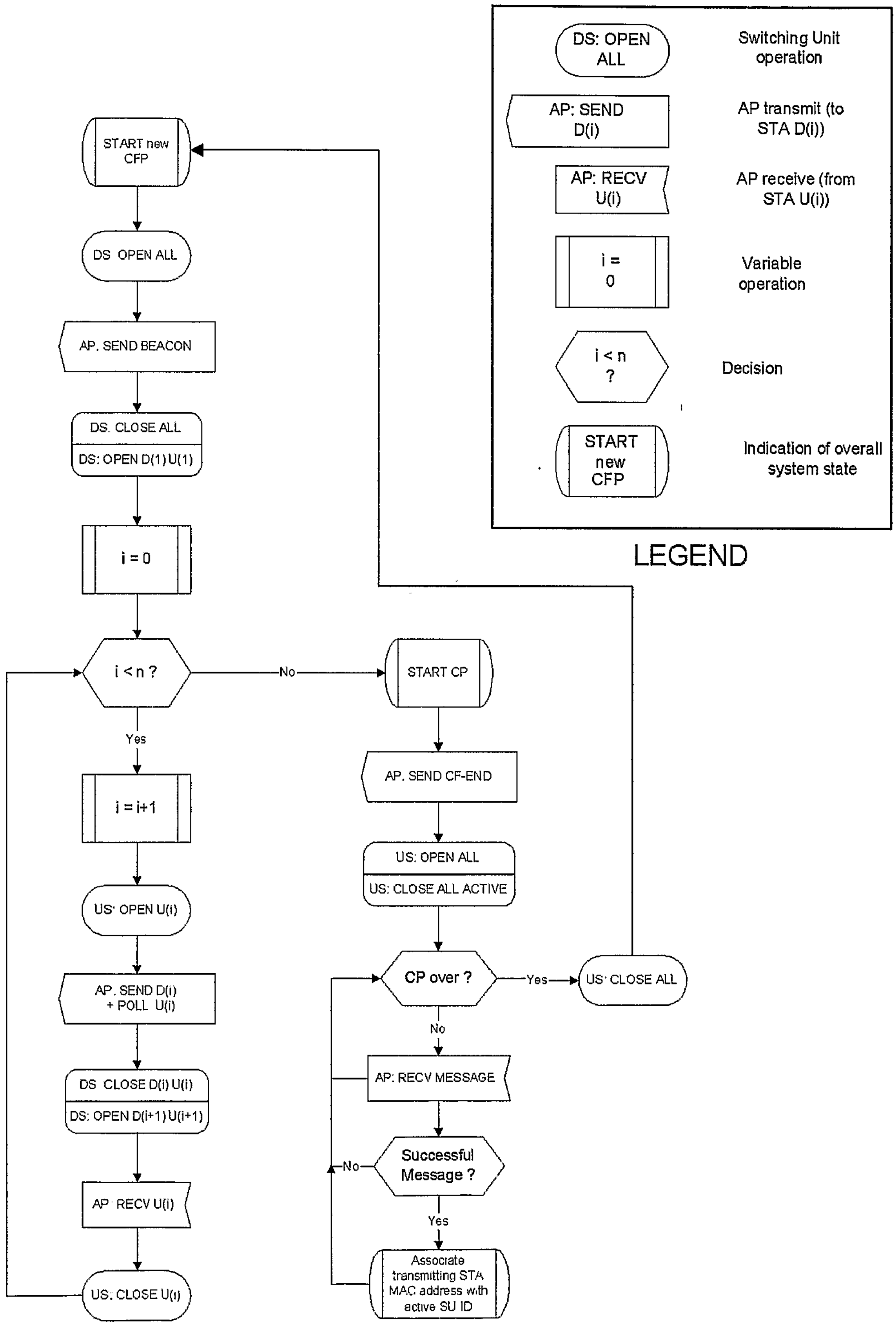

DS: OPEN ALL
Switching Unit operation
AP: SEND D(i)
AP transmit (to STA D(i))
AP: RECV U(i)
AP receive (from STA U(i))
i = 0
Variable operation
i < n ?
Decision
START new CFP
Indication of overall system state
LEGEND
START new CFP
DS OPEN ALL
AP. SEND BEACON
DS. CLOSE ALL
DS: OPEN D(1) U(1)
i = 0
i < n ?
No
Yes
START CP
i = i+1
AP. SEND CF-END
US: OPEN ALL
US: CLOSE ALL ACTIVE
US: OPEN U(i)
AP. SEND D(i) + POLL U(i)
CP over ?
Yes
US: CLOSE ALL
No
DS CLOSE D(i) U(i)
DS: OPEN D(i+1) U(i+1)
AP: RECV MESSAGE
Successful Message ?
No
AP RECV U(i)
Yes
US: CLOSE U(i)
Associate transmitting STA MAC address with active SU ID

FIG. 14

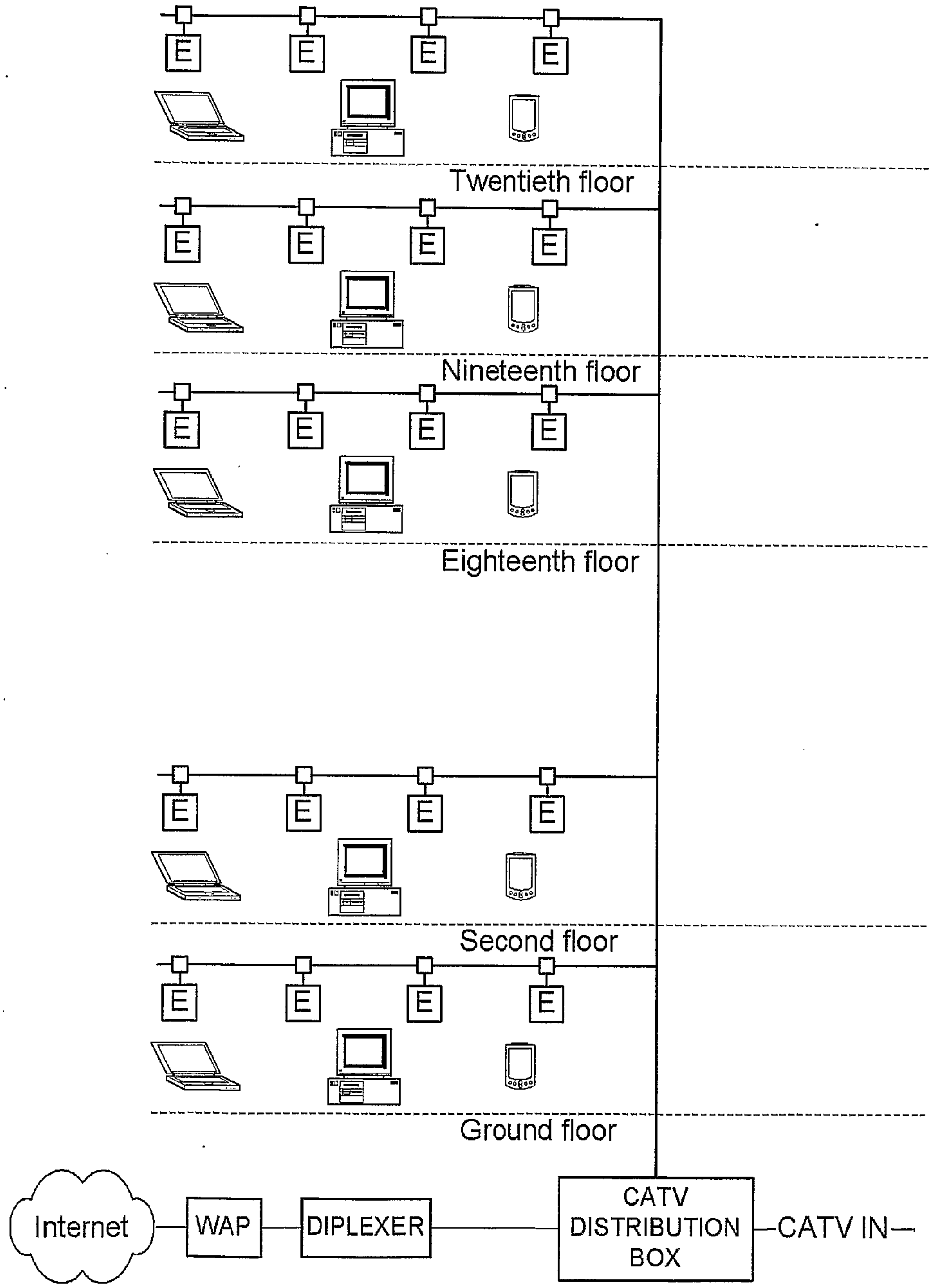

E
Twentieth floor
Nineteenth floor
Eighteenth floor
Second floor
Ground floor
Internet
WAP
DIPLEXER
CATV DISTRIBUTION BOX
CATV IN

FIG. 15

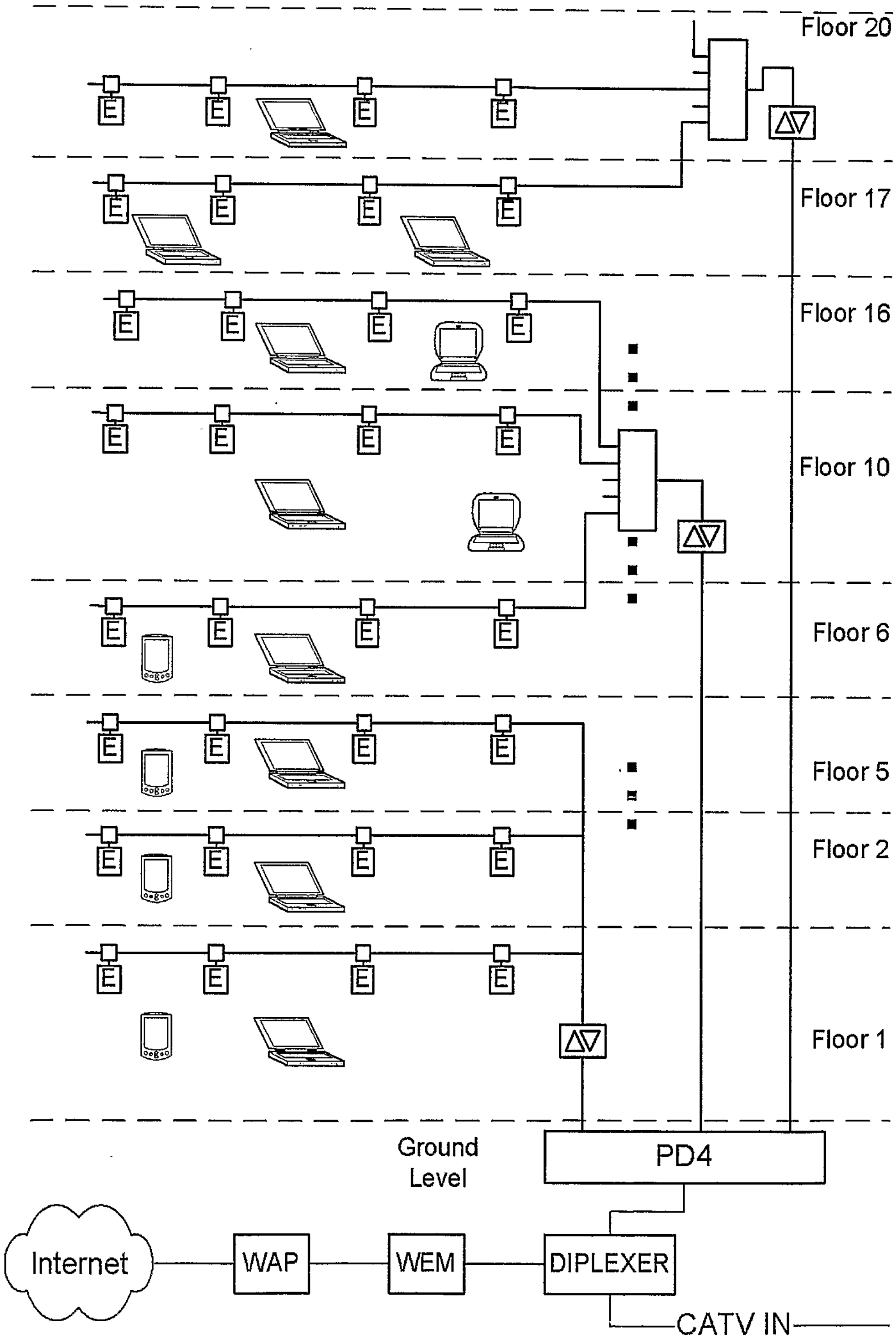

Floor 20
Floor 17
Floor 16
Floor 10
Floor 6
Floor 5
Floor 2
Floor 1
Ground Level
PD4
Internet
WAP
WEM
DIPLEXER
CATV IN

FIG. 16

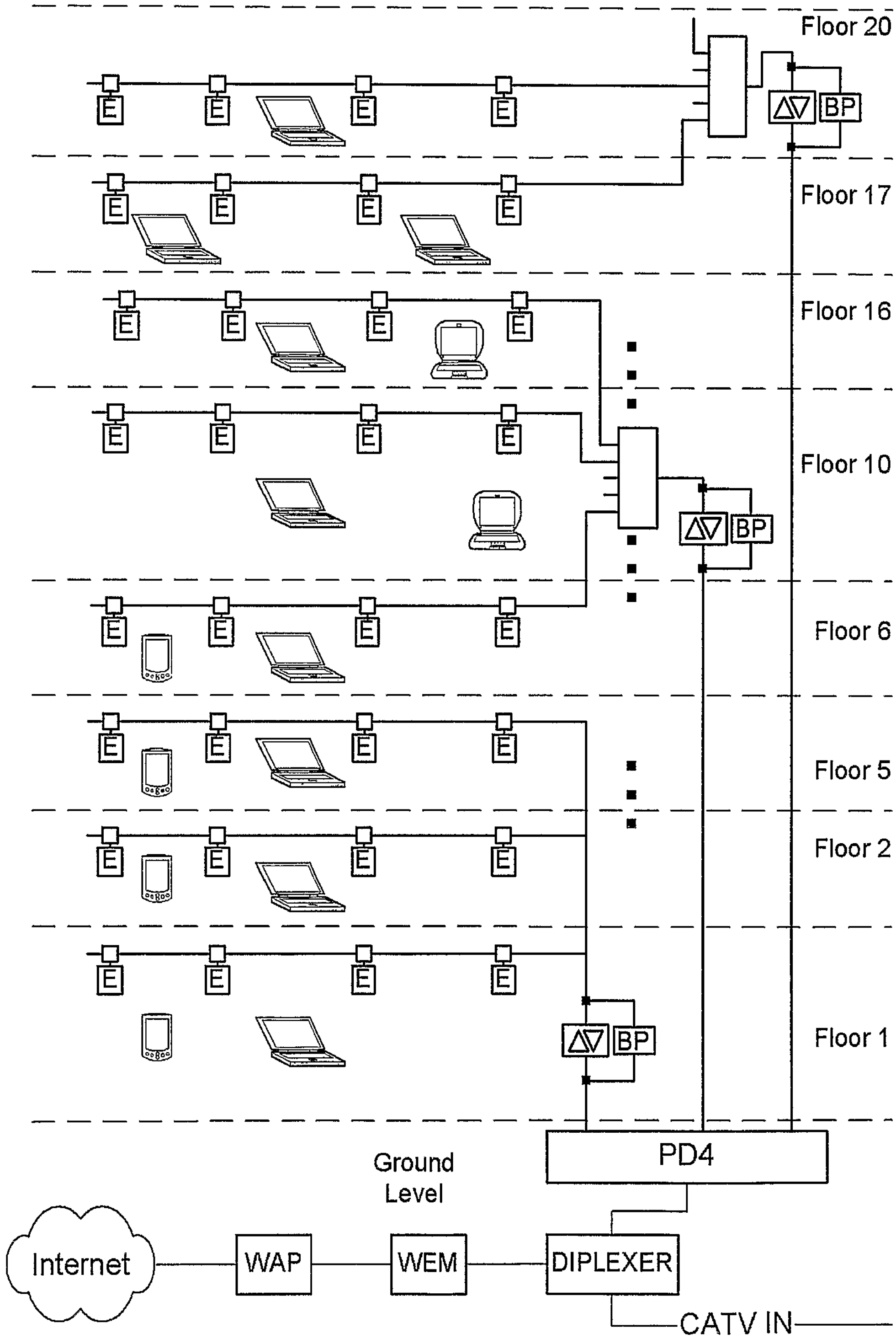

Floor 20
Floor 17
Floor 16
Floor 10
Floor 6
Floor 5
Floor 2
Floor 1
BP
E
PD4
Ground Level
Internet
WAP
WEM
DIPLEXER
CATV IN

FIG. 17

		Regulatory domain					
Channel	Frequency (MHz)	X'10' FCC	X'20' IC	X'30' ETSI	X'31' Spain	X'32' France	X'40' MKK
1	2412	x	x	x	-	-	-
2	2417	x	x	x	-	-	-
3	2422	x	x	x	-	-	-
4	2427	x	x	x	-	-	-
5	2432	x	x	x	-	-	-
6	2437	x	x	x	-	-	-
7	2442	x	x	x	-	-	-
8	2447	x	x	x	-	-	-
9	2452	x	x	x	-	-	-
10	2457	x	x	x	x	x	-
11	2462	x	x	x	x	x	-
12	2467	-	-	x	-	x	-
13	2472	-	-	x	-	x	-
14	2477	-	-	-	-	-	x

FIG. 18

Channel Identifier	Frequency in MHz	Regulatory Domains			
		Americas (-A)	Japan (-J)	Singapore (-S)	Taiwan (-T)
34	5170	—	X	—	—
36	5180	X	—	X	—
38	5190	—	X	—	—
40	5200	X	—	X	—
42	5210	—	X	—	—
44	5220	X	—	X	—
46	5230	—	X	—	—
48	5240	X	—	X	—
52	5260	X	—	—	X
56	5280	X	—	—	X
60	5300	X	—	—	X
64	5320	X	—	—	X
149	5745	—	—	—	—
153	5765	—	—	—	—
157	5785	—	—	—	—
161	5805	—	—	—	—

FIG. 19

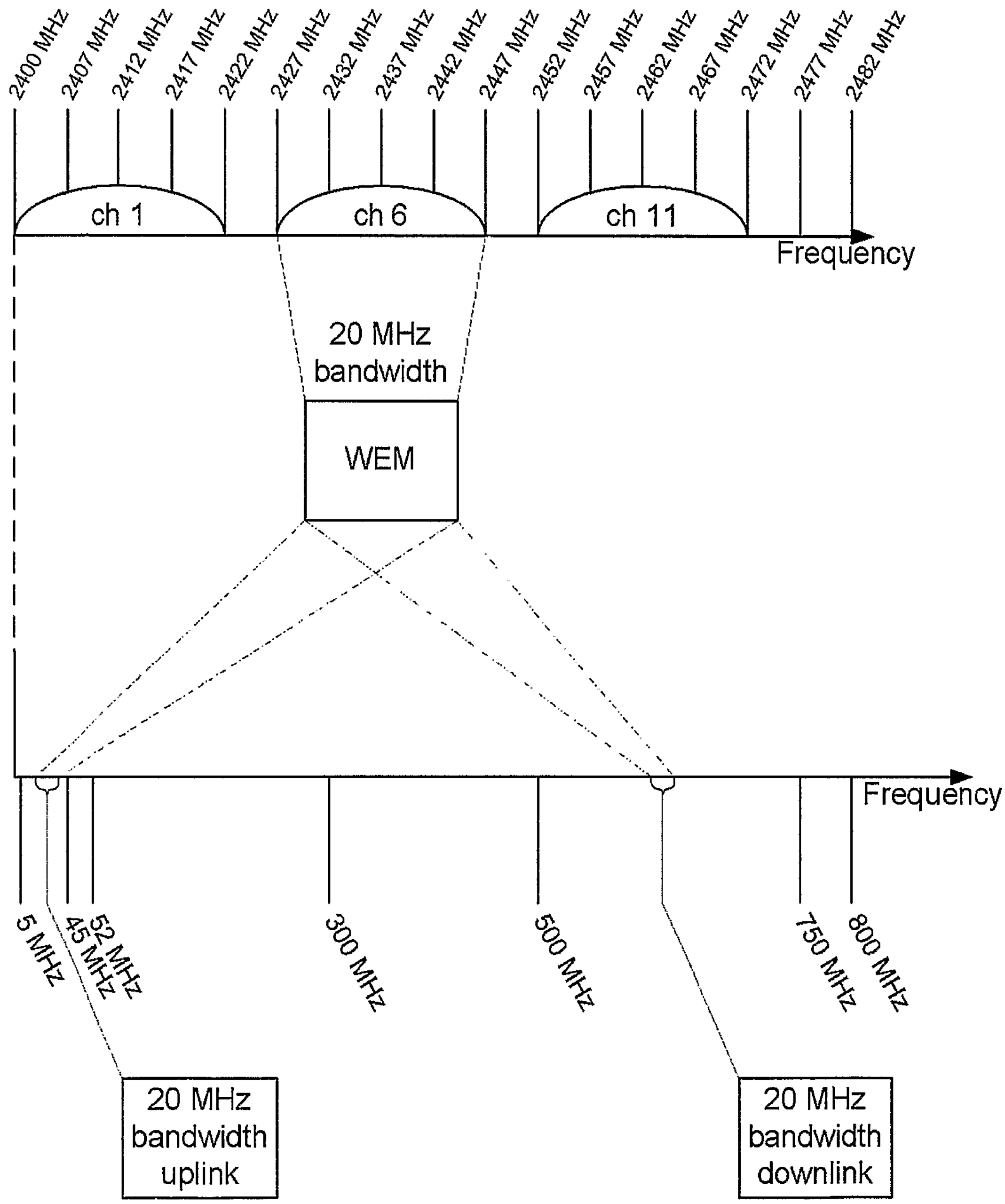

2400 MHz
2407 MHz
2412 MHz
2417 MHz
2422 MHz
2427 MHz
2432 MHz
2437 MHz
2442 MHz
2447 MHz
2452 MHz
2457 MHz
2462 MHz
2467 MHz
2472 MHz
2477 MHz
2482 MHz
ch 1
ch 6
ch 11
Frequency
20 MHz bandwidth
WEM
Frequency
5 MHz
45 MHz
52 MHz
300 MHz
500 MHz
750 MHz
800 MHz
20 MHz bandwidth uplink
20 MHz bandwidth downlink

FIG. 20

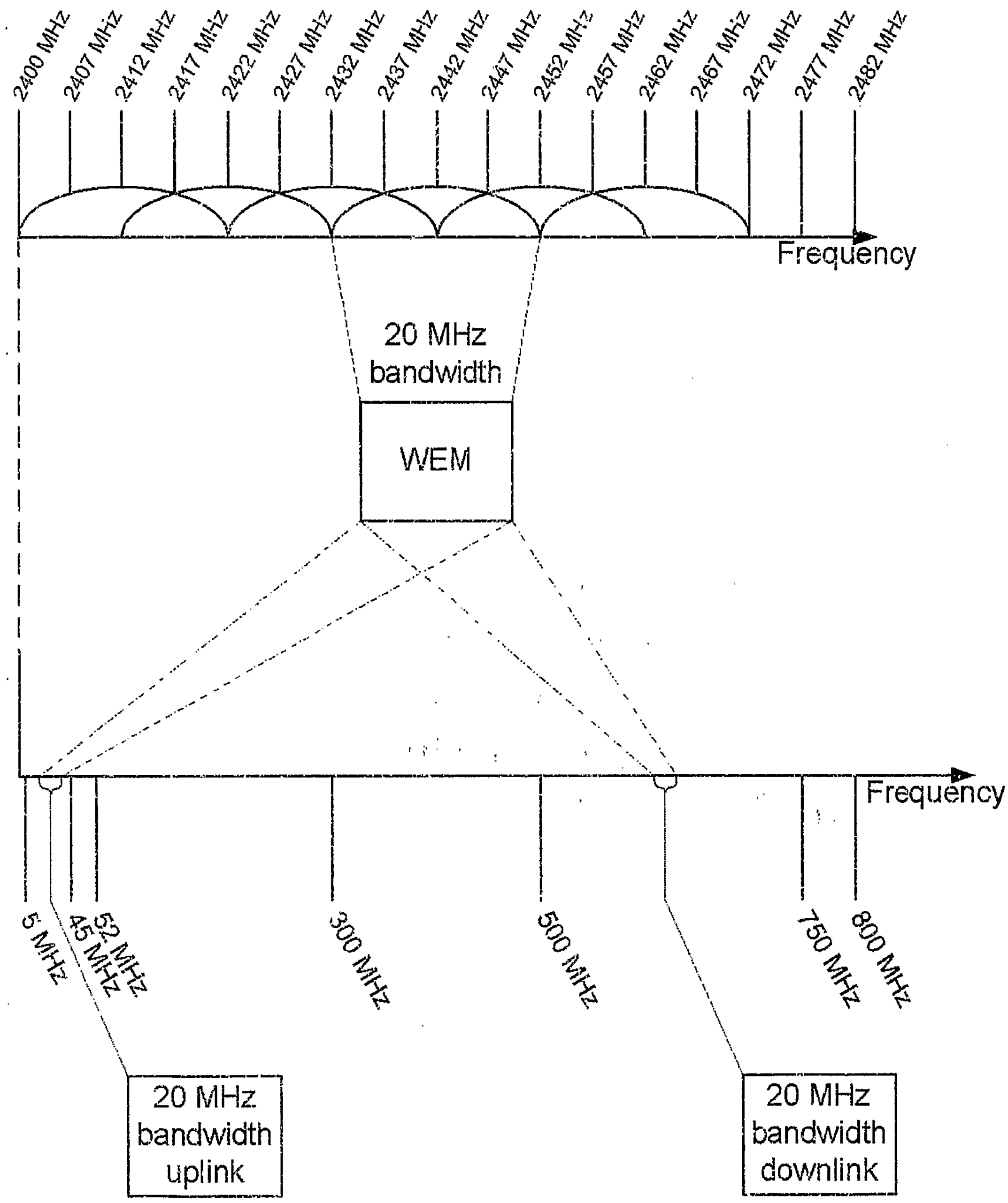

2400 MHz
2407 MHz
2412 MHz
2417 MHz
2422 MHz
2427 MHz
2432 MHz
2437 MHz
2442 MHz
2447 MHz
2452 MHz
2457 MHz
2462 MHz
2467 MHz
2472 MHz
2477 MHz
2482 MHz
Frequency
20 MHz bandwidth
WEM
Frequency
5 MHz
45 MHz
52 MHz
300 MHz
500 MHz
750 MHz
800 MHz
20 MHz bandwidth uplink
20 MHz bandwidth downlink

FIG. 21

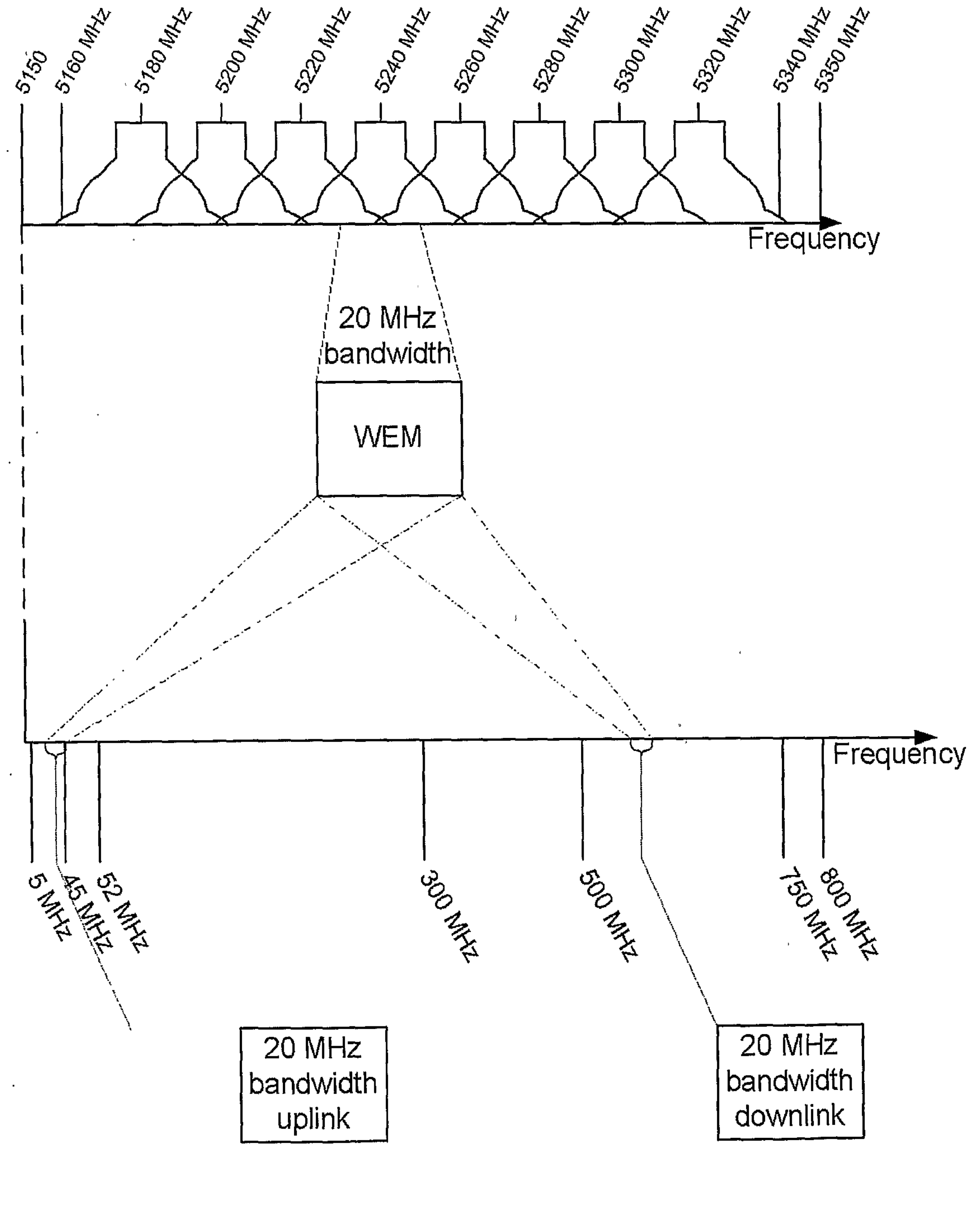

5150
5160 MHz
5180 MHz
5200 MHz
5220 MHz
5240 MHz
5260 MHz
5280 MHz
5300 MHz
5320 MHz
5340 MHz
5350 MHz
Frequency
20 MHz bandwidth
WEM
Frequency
5 MHz
45 MHz
52 MHz
300 MHz
500 MHz
750 MHz
800 MHz
20 MHz bandwidth uplink
20 MHz bandwidth downlink

FIG. 22

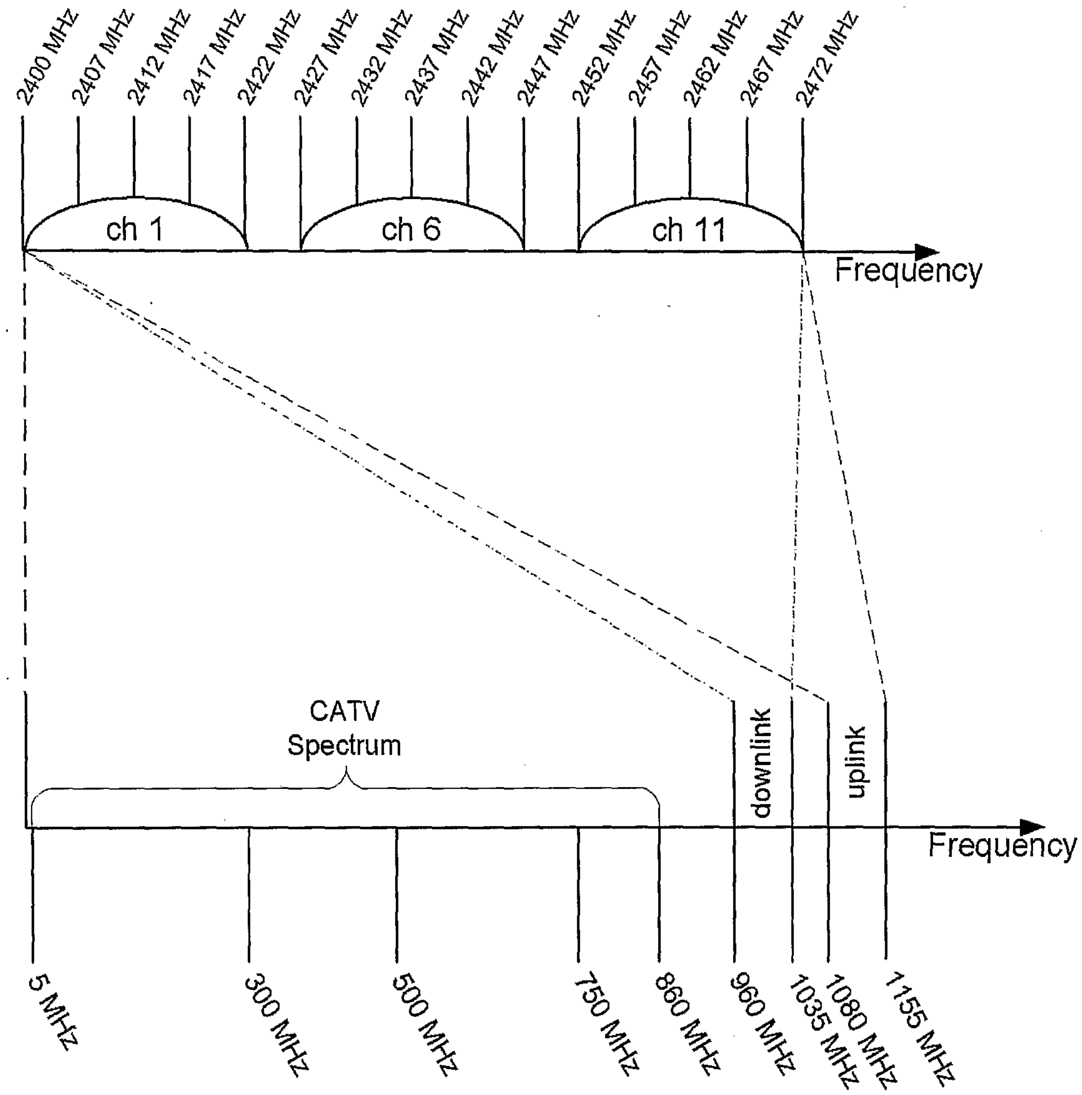

2400 MHz
2407 MHz
2412 MHz
2417 MHz
2422 MHz
2427 MHz
2432 MHz
2437 MHz
2442 MHz
2447 MHz
2452 MHz
2457 MHz
2462 MHz
2467 MHz
2472 MHz
ch 1
ch 6
ch 11
Frequency
CATV
Spectrum
downlink
uplink
Frequency
5 MHz
300 MHz
500 MHz
750 MHz
860 MHz
960 MHz
1035 MHz
1080 MHz
1155 MHz

FIG. 23

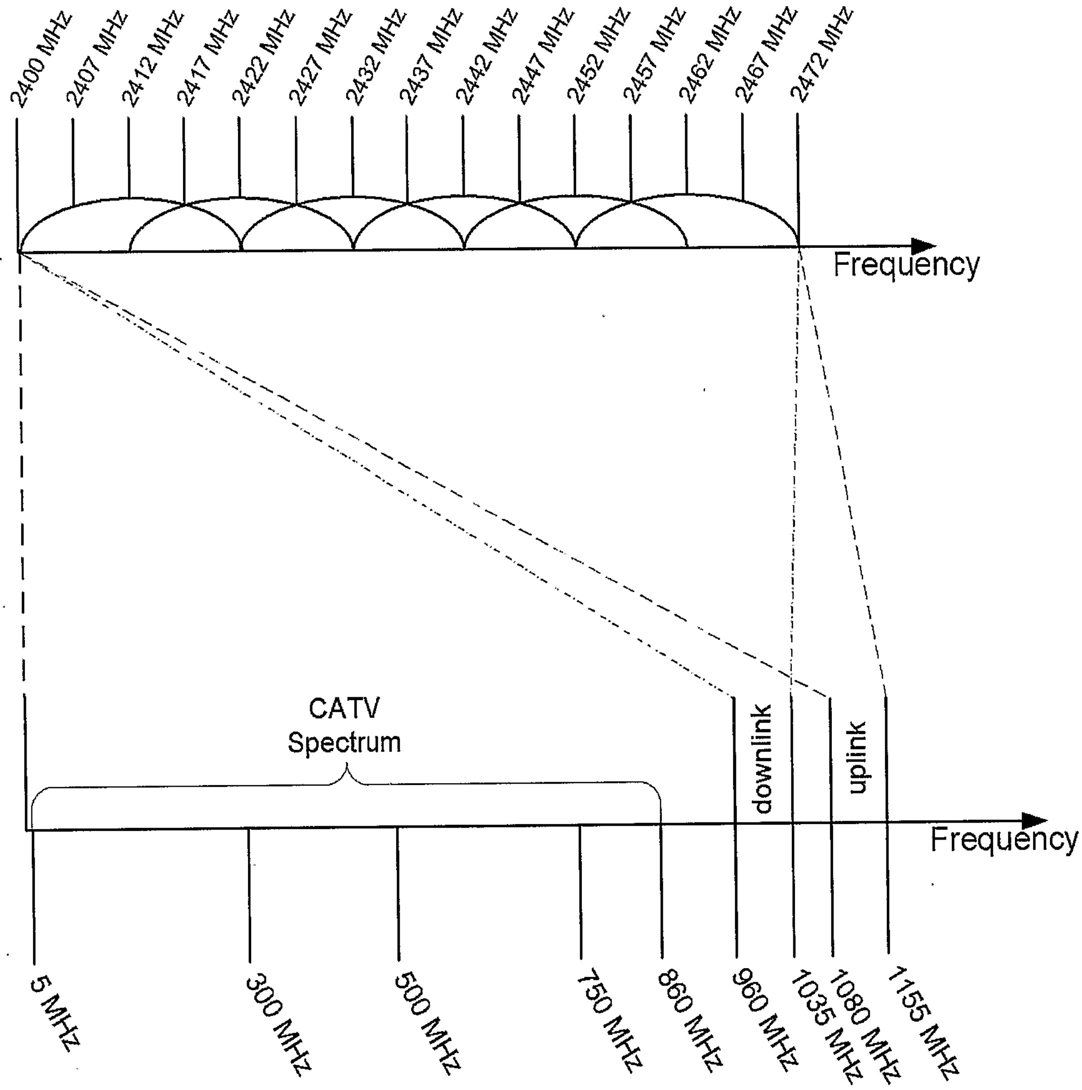

2400 MHz
2407 MHz
2412 MHz
2417 MHz
2422 MHz
2427 MHz
2432 MHz
2437 MHz
2442 MHz
2447 MHz
2452 MHz
2457 MHz
2462 MHz
2467 MHz
2472 MHz
Frequency
CATV
Spectrum
downlink
uplink
Frequency
5 MHz
300 MHz
500 MHz
750 MHz
860 MHz
960 MHz
1035 MHz
1080 MHz
1155 MHz

FIG. 24

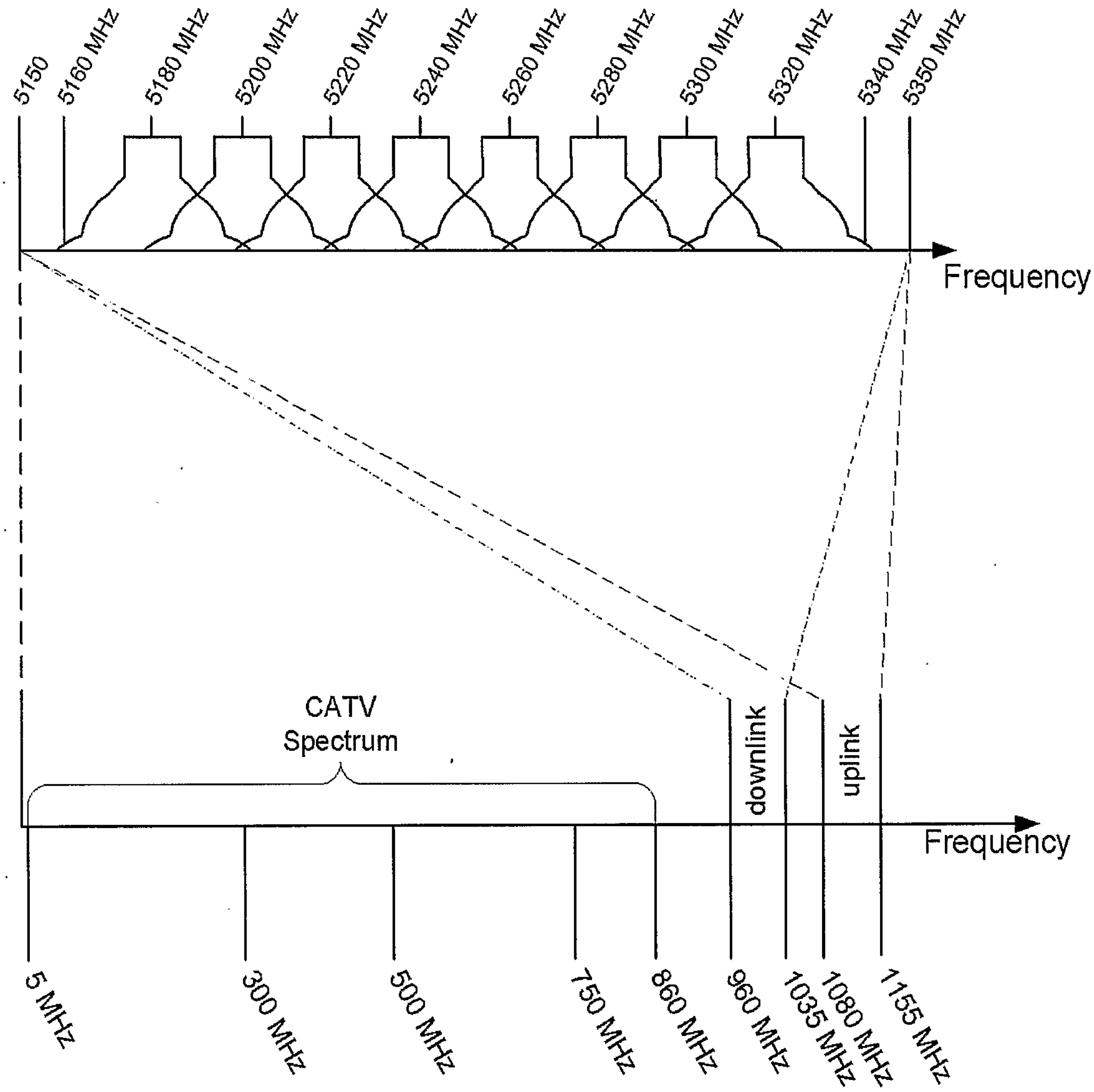
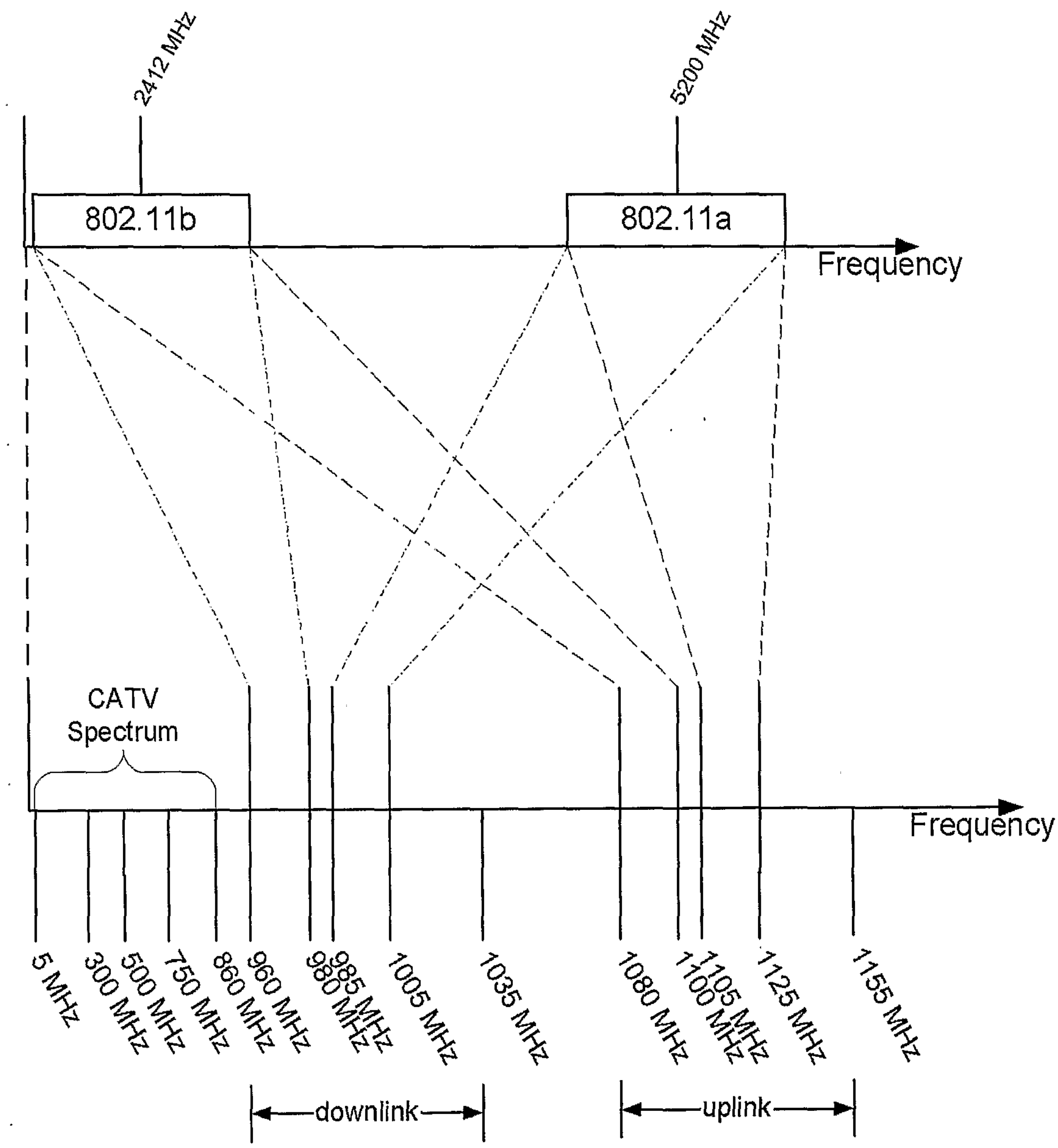

5150
5160 MHz
5180 MHz
5200 MHz
5220 MHz
5240 MHz
5260 MHz
5280 MHz
5300 MHz
5320 MHz
5340 MHz
5350 MHz
Frequency
CATV
Spectrum
downlink
uplink
Frequency
5 MHz
300 MHz
500 MHz
750 MHz
860 MHz
960 MHz
1035 MHz
1080 MHz
1155 MHz

FIG. 25


2412 MHz
5200 MHz
802.11b
802.11a
Frequency
CATV
Spectrum
Frequency
5 MHz
300 MHz
500 MHz
750 MHz
860 MHz
960 MHz
980 MHz
985 MHz
1005 MHz
1035 MHz
1080 MHz
1100 MHz
1105 MHz
1125 MHz
1155 MHz
downlink
uplink