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(54) Title: FULL DUPLEX WIDEBAND COMMUNICATIONS SYSTEM FOR A LOCAL COAXIAL NETWORK
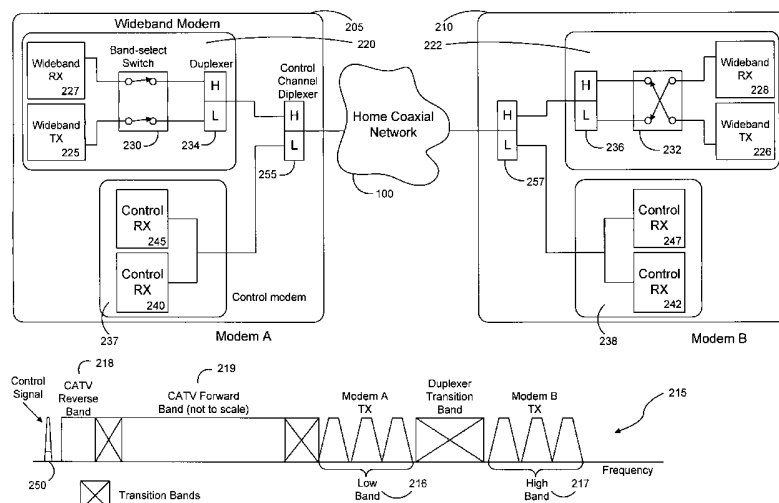
(57) **Abstract:** Systems and methods are disclosed for a full duplex wideband communications system for a local (e.g. in-home) coaxial network. The system employs a Frequency-division duplex (FDD) scheme that allows identical wideband modems to communicate with each other. To achieve this, the wideband modems contain a duplexer and a switch that allows reversing the connection of the wideband transmitter and receiver to the duplexer. Each wideband modem includes a control modem that is used to control access to the wideband channels. A wideband transmitter, which may be included in a modem associated with a server set-top terminal (STT), transmits a video presentation to a wideband receiver, which may be included in a modem associated with a client STT.

FULL DUPLEX WIDEBAND COMMUNICATIONS SYSTEM
FOR A LOCAL COAXIAL NETWORK

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RELATED APPLICATIONS

10   This patent application is a continuation-in-part of copending U.S. patent application serial no. 10/342,670 filed January 15, 2003.

FIELD OF THE INVENTION

This invention relates in general to broadband communications systems, and more

15   particularly, to the field of a full duplex wideband communications system operating within a local coaxial network.

DESCRIPTION OF THE RELATED ART

Subscriber premises receiving cable television or satellite service typically have a

20   coaxial network for providing received signals to various rooms in the premises. The coaxial network typically connects set-top terminals (STT) for decoding the signals (e.g., cable or satellite television (CATV) signals) to a communications system. It will be appreciated that other equipment, such as cable modems and video recorders, to name a couple, can also be connected to the coaxial network. The transmitted signals may be,

25   therefore, video/audio signal, telephony signals, or data signals.

Traditionally, an individual STT could not communicate with the other networked STTs; they were receiving devices that may have had the capability to transmit data to a headend facility in the system. As technology progressed, a server STT could communicate with a plurality of remote STTs in a network. This communication is

30   desirable in that the server STT could share files or programs with the remote STTs upon command from the remote STT. By way of example, the server STT may contain storage media, such as hard disk drives, to store video programs. Accordingly, the networked remote STTs may want to view those stored programs. In this manner, upon request, the server STT can transmit a program to the requesting remote STT for viewing at that STT.

35   Further information regarding a networked multimedia system that includes a server and

remote STTs can be found in copending U.S. patent application serial no. 10/342,670 filed January 15, 2003, the disclosure and teachings of which are hereby incorporated by reference.

A need exists, however, for systems and methods that improve upon

5   communications among networked equipment in a subscriber premises.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention can be better understood with reference to the following drawings. The components in the drawings are not necessarily drawn to scale, emphasis instead being placed upon clearly illustrating the principles of the invention. In the drawings, like

5   reference numerals designate corresponding parts throughout the several views.

FIG. 1 illustrates a block diagram of a coaxial network 100 that includes a plurality of STTs for receiving and decoding CATV signals.

FIG. 2 illustrates a block diagram of two networked modems and a frequency range plan that are suitable for employing the full duplex wideband communications in

10   accordance with the present invention.

FIG. 3 illustrates a simplified block diagram of the RF portion of a set-top terminal.

FIG. 4 illustrates a simplified STT including a wideband modem in accordance with the present invention.

15   FIG. 5 is a graph illustrating a frequency response of a wideband modem in a coaxial network having a multipath environment.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

20   Preferred embodiments of the invention can be understood in the context of a broadband communications system and a local network. Note, however, that the invention may be embodied in many different forms and should not be construed as limited to the embodiments set forth herein. For example, transmitted broadband signals include at least one of video/audio, telephony, data, or Internet Protocol (IP) signals, to

25   name but a few. Devices included in the broadband communications system for receiving the transmitted broadband signals may include a set-top terminal (STT), a television, a consumer electronics device such as a DVD player/recorder, a computer, a personal digital assistant (PDA), or other type of electronics device. Furthermore, in accordance with the present invention all of these receiving devices may include a modem or be

30   connected to a stand-alone modem for receiving high speed data. All examples given herein, therefore, are intended to be non-limiting and are provided in order to help clarify the description of the invention.

The present invention is directed towards a full duplex wideband communications device and system that are suitable for use in a coaxial network. The coaxial network is

typically confined to a subscriber premises. It will be appreciated, however, that the network can also be used in a multi-unit dwelling, business, school, hotel, or hospital, among others. Advantageously, the present invention allows for full duplex wideband communications among STTs or modems that are connected in the coaxial network. The

5 communications between any pair of STTs (e.g., a server STT and a remote STT or two remote STTs) are at data rates suitable for high definition video transmissions. The present invention also allows multiple STTs to share the network without interference with each other. Additionally, a STT, for example, the server STT, is capable of providing different content to different remote STTs concurrently. Furthermore, the

10 communication between STTs and the reception of conventional CATV signals occur simultaneously without interference to the received CATV signals. As mentioned, the modem can be a standalone device that is connected to an STT and still utilize the full duplex wideband communications in accordance with the present invention.

FIG. 1 illustrates a block diagram of a coaxial network 100 that includes coaxial

15 cables 105 and power splitters 106. The coaxial network 100 is designed to connect set-top terminals (STTs) 110a-n within the premises to the CATV communications system. In the coaxial network, the STTs 110a-n (or other devices connected to the network 100) should preferably be able to communicate with each other. However, there is high loss between the STTs 110a-n due to port-port isolation of the splitters 106. To reduce the

20 loss between the STTs 110a-n, a reflector 120 is inserted between the coaxial network 100 and the CATV communications system. The reflector 120 contains one or more band-reject filters that are centered on frequencies used to communicate between the STTs 110a-n. The filters reflect signals at these frequencies with low loss, so that the loss between STTs is minimized. Additionally, the band reject filters prevent the in-home

25 signals from entering the CATV communications system. It will be appreciated that the block diagram of FIG. 1 can be reconfigured into several different configurations. For example, the splitters 106 can be incorporated into the reflector 120. Additionally, the reflector 120 shown operates using reflection of the signals, but other techniques could be used to reduce loss in the desired frequency bands. For example, it is possible to design a

30 splitter that has reduced isolation in particular frequency bands, particularly in the modem's low band and high band. If this method were used, it would still be desirable to keep the coaxial network signals from leaking into the communications system. To reduce this leakage, an amplifier having sufficient reverse isolation could be placed in line with the cable from the communications system to the coaxial network. Further

information regarding the reflector 120 can be found in copending U.S. patent application serial no. 10/342,670 filed January 15, 2003, the disclosure and teachings of which are hereby incorporated by reference.

. FIG. 2 illustrates a block diagram of two networked modems 205, 210 and a
5   frequency range plan 215 that are suitable for employing the full duplex wideband communications in accordance with the present invention. Two modems 205, 210 are shown connected to the coaxial network 100. Specifically, the modems 205, 210 communicate with each other, or other modems. In accordance with the present invention, the modems 205, 210 communicate in full duplex wideband mode. That is to
10   say that modem A 205 may transmit signals in a low band 216 and modem B 210 may transmit in a high band 217 with each other. As will be discussed further below, the channel allocated to the modems 205, 210 may change. Only two modems 205, 210 are shown in this illustration; however, since several modems may be operating simultaneously in the coaxial network 100, there are preferably multiple wideband
15   channels in bands 216 and 217 in the frequency range 215 to avoid conflict. Other signals transmitted in the frequency range 215 comprise a reverse band 218 from, for example, 5 MHz to 40 MHz that the STTs 110 use to communicate back to the headend facility in the system. Additionally, a forward band 219, ranging from 50 MHz to 870 MHz, carries several channels of downstream programs that are broadcasted from the
20   headend facility to the STTs 110 throughout the system.

The modems 205, 210 each include a wideband modem 220, 222 comprising transmitters 225, 226 and receivers 227, 228 for high data rate communications, such as, transmitting and receiving stored video presentations, within the coaxial network 100. The preferred modulation method for the wideband data communications is QAM
25   (quadrature amplitude modulation), and typically the frequencies are above the forward band 219. The wideband modems 220, 222 also include a band-select switch 230, 232 and a duplexer 234, 236 for routing the wideband signals.

A medium access method is similar to frequency division multiple access with frequency division duplex (FDMA/FDD). FDMA/FDD is appropriate for systems having
30   a base station and multiple users, such as cellular telephone. In the FDMA/FDD system, the base station transmits in a downlink band, and the users transmit in an uplink band. The receiver is isolated from the transmitter by a duplexer. In accordance with the present invention, however, coupled modems 205, 210, or STTs that include modems 205, 210, communicate directly with each other (e.g., from STT 110a to STT n) rather

than the conventional method. In other words, there is no base station in the coaxial network 100. To allow any two wideband modems 205, 210 to communicate in this manner, however, the FDD scheme is no longer sufficient.

To allow the wideband modems 205, 210 to communicate in accordance with the present invention, the modems 205, 210 can transmit and receive in either of two bands (e.g., low band 216 and high band 217). The electronically-controlled band select switch 230, 232 allows reversing the connection of the transmitter 225, 226 and receiver 227, 228 to the duplexer 234, 236. As shown in FIG. 2, modem A 205 is set to transmit in the low band 216 and receive in the high band 217, and modem B 210 is set to transmit in the high band 217 and receive in the low band 216. Transmitting and receiving in a frequency included in either the high band or the low band can be optimized and is discussed further below. For either setting of the band select switch 230, 232, the duplexer 234, 236 attenuates the transmit signal so that the receiver sensitivity is not degraded by the transmitter (i.e., modem A's transmitter 225 does not affect modem A's receiver 227). Each band 216, 217 may contain multiple signals to allow multiple pairs of modems to communicate simultaneously. The transmitters 225, 226 and receivers 227, 228 need to be able to function over a frequency range that includes both the high and low bands. The switch 230, 232 should preferably be a monolithic double-pole double-throw type. The duplexer 234, 236 should preferably use dielectric resonator technology, while the control channel diplexer 255, 257 is preferably an LC filter.

The modems 205, 210 also include a control modem 237, 238 comprising transmitters 240, 242 and receivers 245, 247 used for control communications among the modems 205, 210 within the coaxial network 100. More specifically, the control transmitter 240, 242 provides control information, such as an optimized transmitting frequency of the wideband modem, or requests, such as a request for a stored video presentation, to at least one control receiver 245, 247. The control receiver 245, 247 then receives the information or request and acts accordingly.

In contrast to the full duplex wideband modems 220, 222, the control modems 237, 238 operate on a single frequency and in half duplex mode. Additionally, the single frequency is separate from bands 216, 217 used by the wideband modems 220, 222. The control frequency 250 used by the control modem 237, 238 is typically below the reverse band 218, for example, at 4.5 MHz. The control signals and the wideband data communications signals are routed to the coaxial network 100 using the control channel diplexer 255, 257.

The control modems 237, 238 send and receive data packets as burst packages using a modulation scheme such as FSK (frequency shift keying). Each packet includes an error-detection code and a destination address. The control modems 237, 238 use a random access protocol similar to ALOHA in a known manner. A protocol for control communications from, for example, modem A 237 to modem B 238 may be summarized as follows:

Modem A 237 sends a packet to modem B 238 and then waits for acknowledgement;

assuming modem B 238 receives the packet with no errors and the address is that of modem B 238, modem B 238 sends a short acknowledgement;

if the acknowledgement signal is received by modem A 237, then modem A 237 sends the next packet. If the acknowledgement signal is not received within a specified time, modem A 237 waits a random time and resends the initial packet.

FIG. 3 illustrates a simplified block diagram of a radio frequency (RF) portion of a set-top terminal (STT). STT 300 includes diplexer 305, which isolates tuners 310, 320, 330 from a reverse transmitter 308. The reverse transmitter 308 transmits signals to the headend facility in the communications system. Tuners 310, 320, 330 can be used to receive live television signals (CATV signals), record to a hard drive, or receive cable modem signals. The tuners 310, 320, 330 are capable of receiving QAM signals. Advantageously, a wideband modem 220, 222 that uses some of these existing STT functions can be added to the STT 300.

FIG. 4 illustrates a simplified STT including a wideband modem in accordance with the present invention. CATV signals are received from the communications system at diplexer 305. Diplexer 405 provides the CATV signals and any modem RF signals to the intended destination depending upon the received signal frequency. In accordance with the present invention, tuner 410 can be configured to act as the wideband receiver 227 shown in FIG. 2, and switch 415 is added to select the appropriate signal path depending upon the type of received signals. Accordingly, switch 415 connects the tuner 410 to receive wideband communications signals from another modem 210. In the event that the STT 400 requires a third tuner to receive CATV signals, the switch 415 connects the tuner 410 to the communications system. The STT's reverse transmitter 420 may be shared between the CATV reverse band 218 and the control channel signals 250. The reverse transmitter 420 may be configured as an FSK transmitter.

Returning to FIG. 2, a communications protocol needs to be established between two modems. A simplified example of a protocol used by the initiating modem 205 and the receiving modem 210 follows assuming knowledge of unused frequencies and that it is arbitrarily chosen that modem A 205 transmits in the low band.

5   Modem A 205 sets the band switch to Tx/Rx = low/high;

modem A 205 chooses from the unused frequencies low and high band frequencies (f_L and f_H);

modem A 205 uses the control transmitter 240 to send the chosen frequency information to modem B 210;

10   modem B 210 sends an acknowledgement using control transmitter 242 and, based on the frequency chosen by modem A 205, sets the band switch 232 to Tx/Rx = high/low and tunes the wideband receiver 228 to the frequency in the low band (f_L);

modem A 205 then tunes its wideband receiver 227 to the frequency in the high band (f_H) and begins transmitting data at f_L;

15   modem B 210 begins transmitting at f_H; and

modem A 205 uses control transmitter 240 to send a message to any other modems on the network indicating that the two chosen frequencies (f_L and f_H)are currently in use.

Another embodiment of a full duplex communications modem for the coaxial

20   network 100 is a client modem. A client modem includes a wideband receiver and a control transmitter. The client modem does not include a wideband transmitter or control receiver. In this manner, the client modem uses the control transmitter to request a wideband transmission from a server wideband modem and then receives the wideband transmission using its wideband receiver. A typical application for the client modem is to

25   request and receive video programs stored in an STT that is connected to or containing the wideband communications modem 205.

As previously discussed, the modem signals are reflected and contained within the coaxial network 100 by filters within the reflector 120 (FIG. 1). In this manner, the loss between modems is minimized. However, referring to FIG. 1, the signal between

30   modems may take several paths other than the path to and from the reflector 120. For example, there is a path between modems included in STT 110a and STT 110b across the splitter 130. The multiple signal paths (i.e., multipath environment) cause distortions to the frequency response of the coaxial network 100, which may include deep nulls 505 (FIG. 5).

FIG. 5 is a graph illustrating a frequency response 500 of a coaxial network 100 having a multipath environment. The frequency response 500 is within the full duplex wideband communications signal band. The control modem signal is not very susceptible to multipath distortion since its bandwidth is small and the modulation method is usually simple (e.g., FSK).

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The present invention includes methods to optimize communication between wideband modems in a multipath environment. The methods involve optimizing the QAM signal parameters based on RF center frequency; bandwidth; and QAM constellation. The last two parameters affect the maximum data rate of the channel. When two modems 205, 210 connect for the first time, a search algorithm can be used to determine the best signal parameters for each direction of communication. For example, using an FSK signal in the control channel, modem A 205 can request modem B 210 to transmit at a given frequency. Modem A 205 can then measure the signal quality at that frequency. This is repeated at several frequencies until the optimal frequency is found. An example of a possible search sequence is shown in Table 1. Once the optimal signal parameters are found, those parameters are stored by both modems 205, 210 so that the search algorithm need not be repeated. Signal quality is determined from measurements made by the receiving modem, including one or more of the following: signal amplitude, constellation SNR (signal to noise ratio); tap values of the adaptive equalizer, and bit error rate.

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Table 1: Example of Search Sequence for Optimal Transmit Signal Parameters

Parameter Set	Center Frequency	Bandwidth (MHz)	Constellation	Data Rate
1	873	6	256	Highest
2	874	6	256	Highest
3	875	6	256	Highest
4	876	6	256	Highest
5	877	6	256	Highest
6	878	6	256	Highest
7	879	6	256	Highest
8	873	6	64	
9	874	6	64	
10	876	6	64	
11	877	6	64	
12	878	6	64	
13	879	6	64	
14	879	6	64	
15	873	3	256	
16	874	3	256	
17	875	3	256	
18	876	3	256	
19	877	3	256	
20	878	3	256	
21	879	3	256	
22	873	3	64	Lowest
23	874	3	64	Lowest
24	875	3	64	Lowest
25	876	3	64	Lowest
26	877	3	64	Lowest

27	878	3	64	Lowest
28	879	3	64	Lowest

If there are several modems connected to the coaxial network 100, for example, one server modem and several client modems, the server modem may have to transmit to two or more client modems simultaneously. Considering a two-client example, it may happen that, due to multipath distortion, the frequency responses from server modem 110a to client modems 110b and 110d are not similar. In this case, the optimization of the signal parameters should take both frequency responses into account. On initial connection, each client modem performs the search algorithm described hereinabove. An integer quality score based on signal measurements is assigned to each parameter set of Table 1, with 7 equal to the highest quality. Any score above 0 indicates an acceptable quality. The signal parameter table for client modems 110b and 110d is stored in the server modem 110a. Therefore, the server modem 110a can sort the tables to find the highest scores for each client modem 110b-n. By way of example, the overall score could be calculated as: overall score = min(client 110b score, client 110d score). The result might appear as shown in Table 2. For this example, parameter set i is optimal.

Table 2: Example of Sorted Signal Quality Scores

	Score		Overall Score	Data Rate
Parameter Set	Client Modem 110b	Client Modem 110d		
i	4	3	3	Medium
j	6	3	3	Lowest
k	5	2	2	Medium
m	0	2	0	Highest
n	2	0	0	Highest
Etc.	Etc.	Etc.	Etc.	Etc.

It should be emphasized that the above-described embodiments of the invention are merely possible examples, among others, of the implementations, setting forth a clear understanding of the principles of the invention. Many variations and modifications may be made to the above-described embodiments of the invention without departing

substantially from the principles of the invention. All such modifications and variations are intended to be included herein within the scope of the disclosure and invention and protected by the following claims. In addition, the scope of the invention includes embodying the functionality of the preferred embodiments of the invention in logic embodied in hardware and/or software-configured mediums.

What is claimed is:

CLAIMS

1.   A full duplex wideband modem, comprising:

a wideband transmitter for transmitting high data rate communications;

a wideband receiver for receiving high data rate communications;

a band select switch coupled to the transmitter and receiver for selecting one of a high band or a low band in accordance with a first frequency associated with the transmitted high data rate communications and a second frequency associated with the received high data rate communications.

2.   The full duplex wideband modem of claim 1, further comprising:

a control transmitter for sending control information, wherein the control information includes controlling the first frequency of at least one connected full duplex wideband modem; and

a control receiver for receiving control information from the at least one connected full duplex wideband modem.

3.   The full duplex wideband modem of claim 2, wherein a high frequency band includes a plurality of frequencies in which to transmit and receive the high data rate communications, and wherein a low frequency band includes a plurality of frequencies in which to transmit and receive the high data rate communications.

4.   The full duplex wideband modem of claim 1, wherein the high data rate communications is a video presentation.

5.   The full duplex wideband modem of claim 1, the wideband modem further comprising:

a duplexer for isolating the wideband receiver from the wideband transmitter, wherein the band select switch reverses the connection of the wideband transmitter and the wideband receiver to a high-pass and a low-pass port of the duplexer, thereby allowing two wideband modems with the band select switch set in opposite positions to communicate with each other.

6.   A coaxial network for communicating high data rate signals, the coaxial network comprising:

        a plurality of wideband modems for transmitting and receiving high data rate communications between two or more of the plurality of modems in the coaxial network, a wideband modem comprising:

                a transmitter for transmitting the high data rate communications;

                a receiver for receiving the high data rate communications; and

                a band select switch coupled to the transmitter and receiver for selecting one of a high band or a low band in accordance with a first frequency associated with the transmitted high data rate communications and a second frequency associated with the received high data rate communications.

7.   The coaxial network of claim 6, wherein the band select switch of one of the plurality of wideband modems and a band select switch of a second of the plurality of wideband modems communicate with each other when the band select switch is set in opposite positions.

8.   The coaxial network of claim 7, wherein the high data rate communications include a video presentation.

9.   The coaxial network of claim 7, the wideband modem further comprising:

        a duplexer for isolating the transmitter from the receiver, the duplexer coupled to the band select switch for receiving and providing the transmitted high data rate communications to the coaxial network, and for receiving and providing the received high data rate communications to the band select switch, wherein the high data rate communications are isolated from other signals by the high pass filter.

10.   The coaxial network of claim 9, the wideband modem further comprising:

        a control modem for providing information regarding the first frequency associated with the transmitted high data rate communications.

11.   The coaxial network of claim 9, the wideband modem further comprising a control modem, wherein the control modem comprises:

a control transmitter for providing information regarding the first frequency associated with the transmitted high data rate communications; and

a control receiver for receiving information from another of the plurality of wideband modems.

12.   The coaxial network of claim 11, wherein a high frequency band includes a plurality of frequencies in which to transmit and receive the high data rate communications, and wherein a low frequency band includes a plurality of frequencies in which to transmit and receive the high data rate communications.

13.   A system for receiving a video presentation over a local network, the system comprising:

a server set-top terminal (STT) including a wideband modem, the server STT for storing video presentations;

a client set-top terminal (STT), comprising:

a control transmitter for requesting a stored video presentation from the server STT; and

a wideband receiver for receiving the requested video presentation over a first frequency.

14.   The system of claim 13, wherein the received video presentation is provided to a television for viewing.

15.   The system of claim 13, wherein the wideband receiver is a tuner included in the client STT, and wherein the tuner receives one of cable television signals from a communications system or the stored video presentations from the server STT depending upon a receive switch.

16.   The system of claim 13, wherein the server STT comprises:

a control receiver for receiving the request for a stored video presentation from the control transmitter; and

a wideband transmitter for transmitting the requested video presentation.

17.   The system of claim 16, wherein the server STT further comprises:

a control transmitter for providing information to other modems in the local network regarding a transmission frequency associated with the transmitted video presentation, wherein the frequency can be in one of a high band or a low band.

18.   The system of claim 13, the client STT further comprising:

a wideband transmitter for transmitting high data rate communications;

a control receiver for receiving information regarding the first frequency of the requested video presentation; and

a band select switch that selects between the high band and the low band depending upon the first frequency associated with the requested video presentation.

19.   A set-top terminal (STT), comprising:

a control transmitter for requesting a stored video presentation from a server STT, wherein the request includes a requesting STT address;

at least one tuner for receiving one of cable television signals or high data rate communications, wherein the high data rate communications is a transmitted video presentation; and

a receive switch for receiving a routing one of the cable television signals or the high data rate communications to the at least one tuner,

wherein the received video presentation is subsequently provided to a viewing device for display.

20.   The STT of claim 19, wherein the STT requests the stored video presentation from a server STT in a coaxial network, the server STT comprising:

a control receiver for receiving the request for the stored video presentation;

a control transmitter for providing information regarding the frequency in accordance with an optimized frequency in one of the high band or the low band;

a modulator for modulating the video presentation to the optimized frequency; and

a wideband transmitter for transmitting the modulated video presentation,

wherein the modulated video presentation includes the address of the requesting STT.

21.   The STT of claim 20, wherein the server STT further comprises a band select switch; wherein the server STT sets the band select switch to transmit the modulated video presentation in one of the high band or the low band; and wherein the control transmitter associated with the server STT sends a control signal to a processor in the STT for setting the band select switch of the STT to receive in the server STT selected high band or low band.
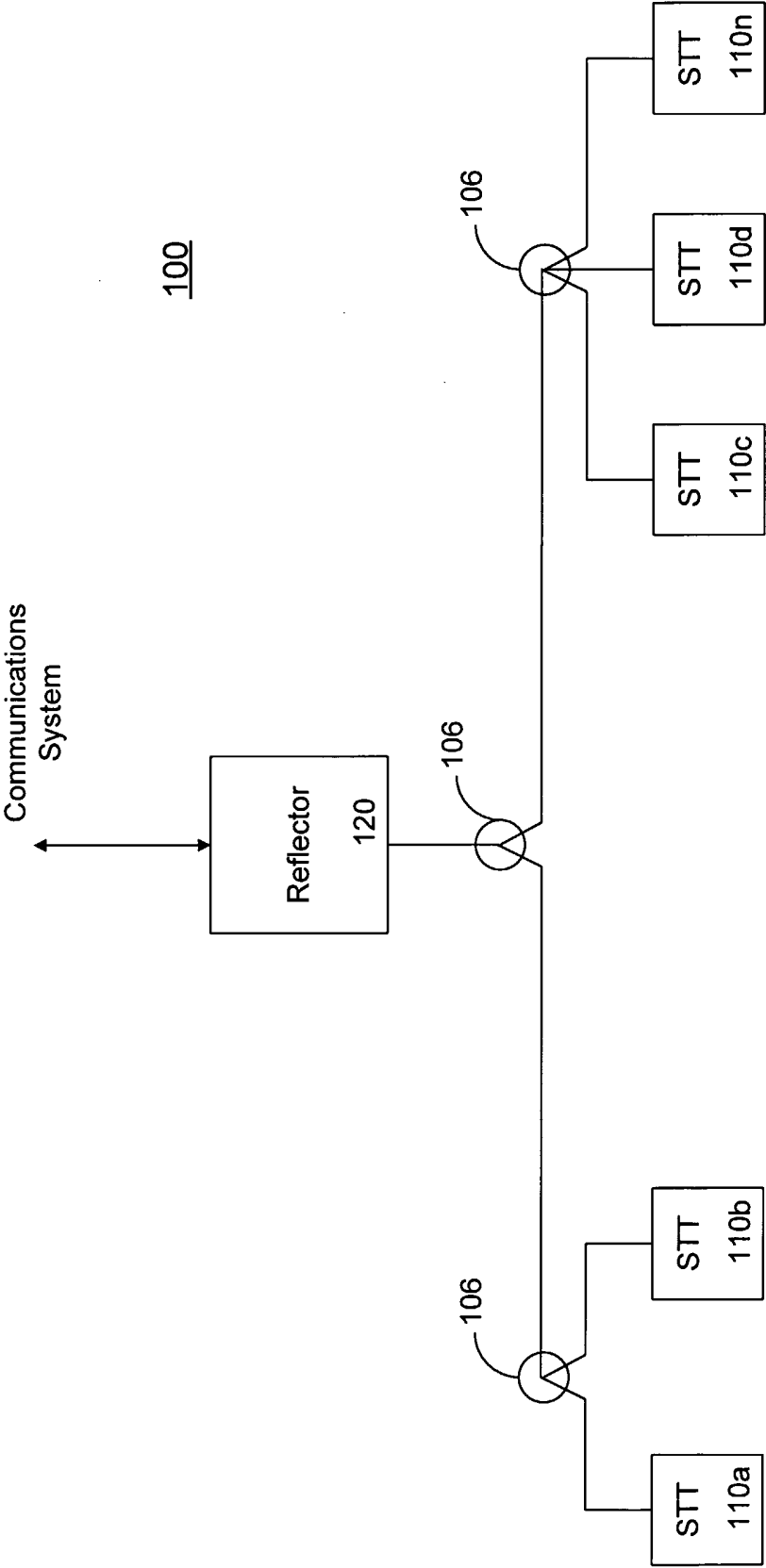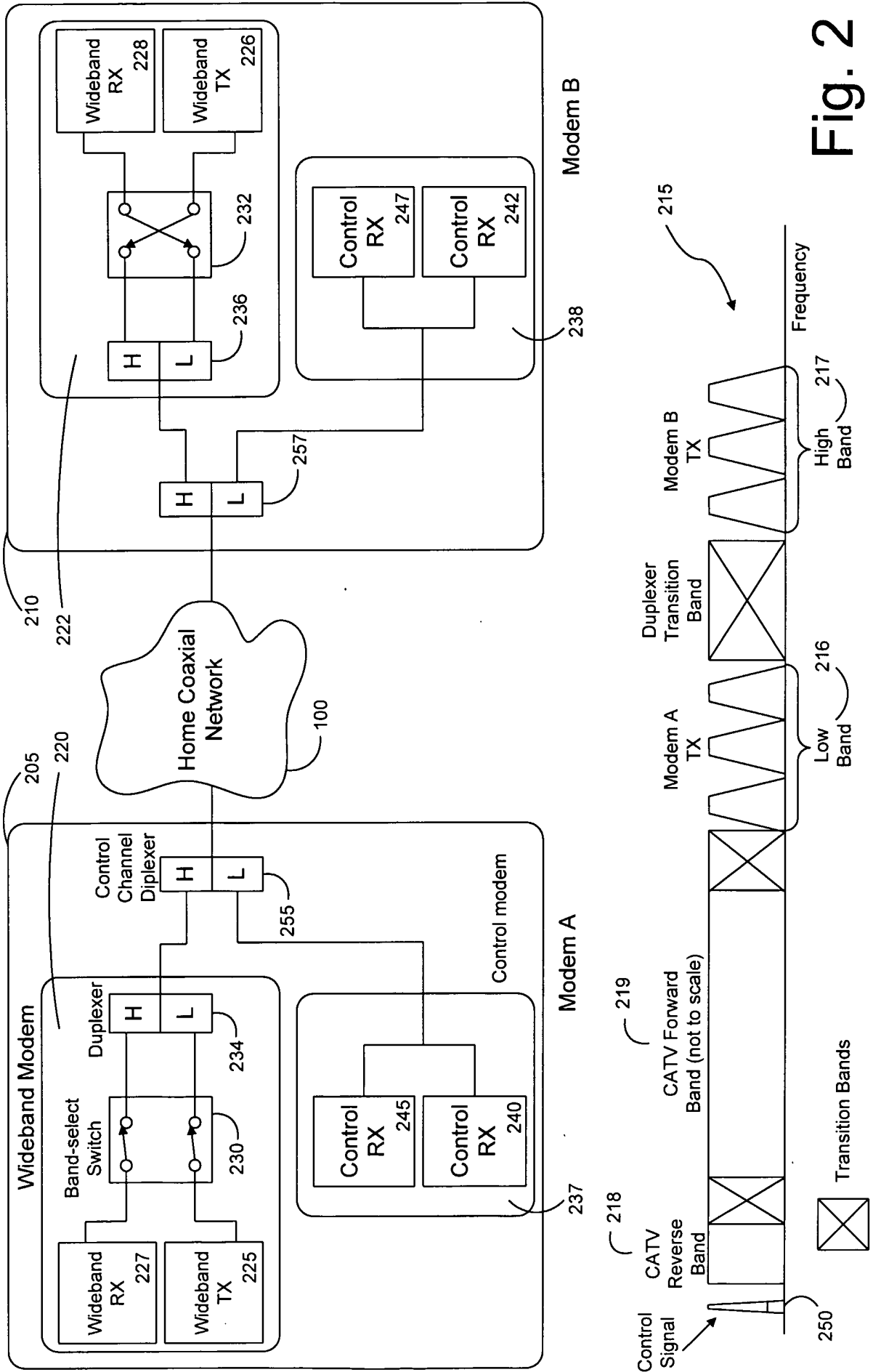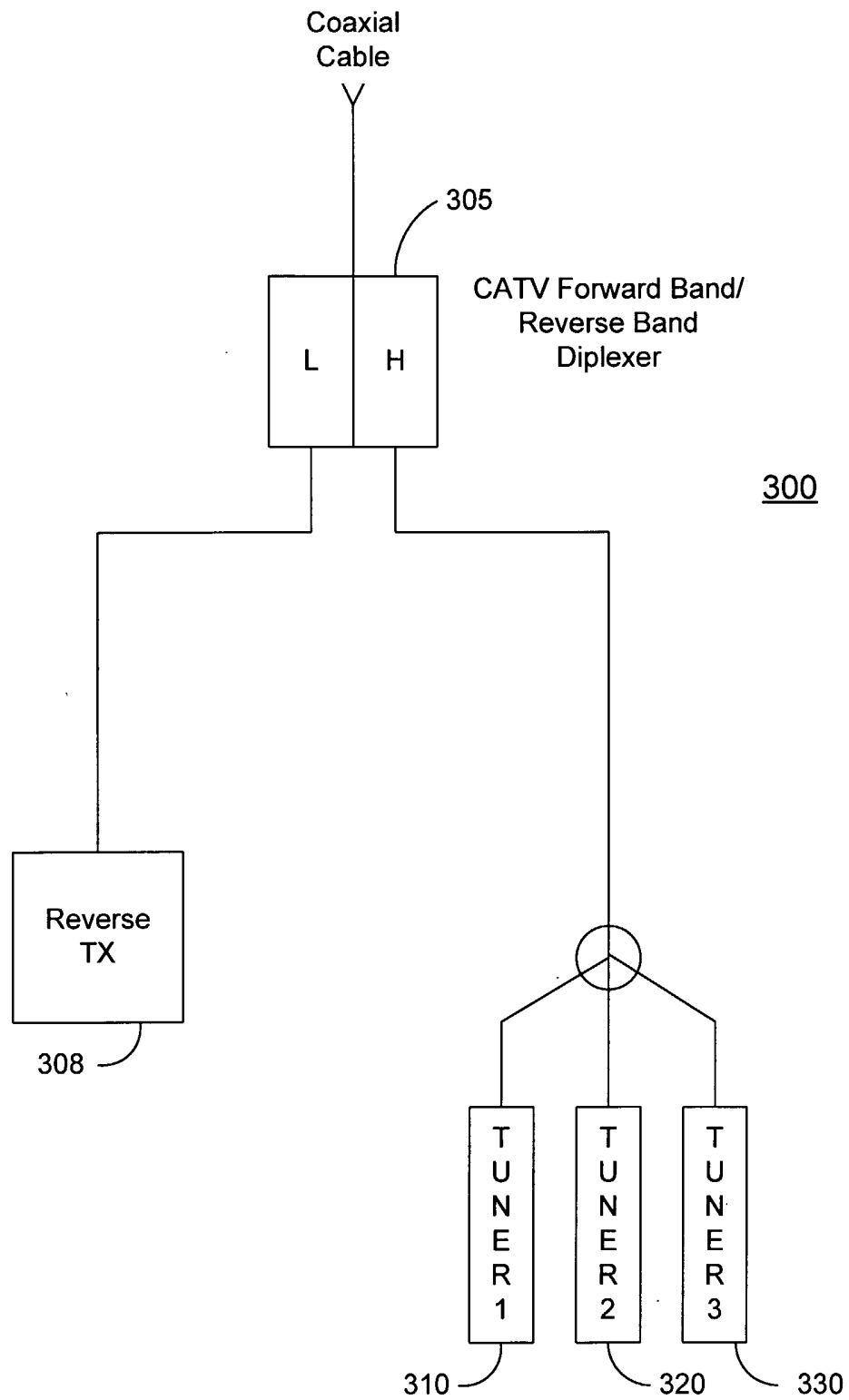
Fig. 1

Fig. 2

Coaxial
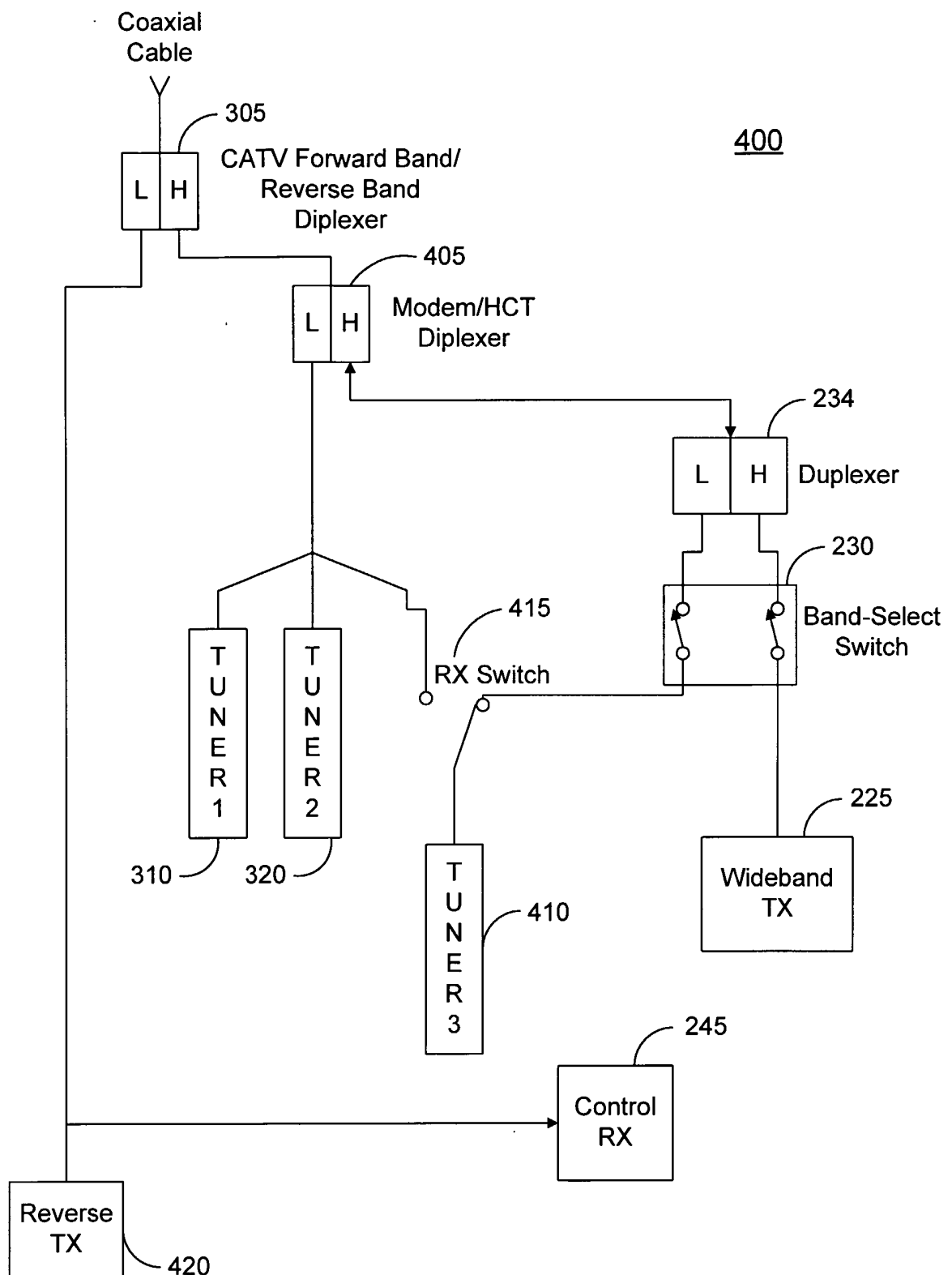Cable

305

CATV Forward Band/
Reverse Band
Diplexer

L   H

300

Reverse
TX

308

T U N E R 1

T U N E R 2

T U N E R 3

310   320   330

Fig. 3

Fig. 4

Fig. 5