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U.S. **UTILITY** Patent Application

PATENT NUMBER
ISSUE DATE

APPLICATION NUMBER	FILING DATE	CLASS	SUBCLASS	GROUP ART UNIT	EXAMIN
		370		2661	

ABANDONED

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NOTICE OF ALLOWANCE MAILED		Assistant Examiner	CLAIMS ALLOWED	
			Total Claims	Print Claim for O.G
ISSUE FEE			DRAWING	
Amount Due	Date Paid		Sheets Drwg. / Figs.Drwg. / Print Fig.	
		Primary Examiner		
☐ TERMINAL DISCLAMER		PREPARED FOR ISSUE	Application Examiner	

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FEE RECORD SHEET

09/03/2002 AADOF01 00000082 10230687

01 FC:201 370.00 OP
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PTO-1556
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UTILITY PATENT APPLICATION TRANSMITTAL

(Only for new nonprovisional applications under 37 CFR 1.53(b))

Attorney Docket No.	9223
First Inventor	Anton Monk
Title	Broadband Network for Coaxial Cable Using Multi-carrier Modulation
Express Mail Label No.	EU498728012US

APPLICATION ELEMENTS

See MPEP chapter 600 concerning utility patent application contents.

1. [X] Fee Transmittal Form (e.g., PTO/SB/17) *(Submit an original and a duplicate for fee processing)*
2. [X] Applicant claims small entity status. See 37 CFR 1.27.
3. [X] Specification [Total Pages 21] *(preferred arrangement set forth below)*
   - Descriptive title of the invention
   - Cross Reference to Related Applications
   - Statement Regarding Fed sponsored R & D
   - Reference to sequence listing, a table, or a computer program listing appendix
   - Background of the Invention
   - Brief Summary of the Invention
   - Brief Description of the Drawings *(if filed)*
   - Detailed Description
   - Claim(s)
   - Abstract of the Disclosure
4. [X] Drawing(s) *(35 U.S.C. 113)* [Total Sheets 10]
5. Oath or Declaration [Total Pages]
   a. [ ] Newly executed (original or copy)
   b. [ ] Copy from a prior application (37 CFR 1.63 (d)) *(for continuation/divisional with Box 18 completed)*
      i. [ ] DELETION OF INVENTOR(S) Signed statement attached deleting inventor(s) named in the prior application, see 37 CFR 1.63(d)(2) and 1.33(b).
6. [ ] Application Data Sheet. See 37 CFR 1.76

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7. [ ] CD-ROM or CD-R in duplicate, large table or Computer Program *(Appendix)*
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ACCOMPANYING APPLICATION PARTS

9. [ ] Assignment Papers (cover sheet & document(s))
10. [ ] 37 CFR 3.73(b) Statement *(when there is an assignee)* [ ] Power of Attorney
11. [ ] English Translation Document *(if applicable)*
12. [ ] Information Disclosure Statement (IDS)/PTO-1449 [ ] Copies of IDS Citations
13. [ ] Preliminary Amendment
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15. [ ] Certified Copy of Priority Document(s) *(if foreign priority is claimed)*
16. [ ] Nonpublication Request under 35 U.S.C. 122 (b)(2)(B)(i). Applicant must attach form PTO/SB/35 or its equivalent.
17. [ ] Other: .....

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[ ] Continuation [ ] Divisional [ ] Continuation-in-part (CIP) of prior application No.: _____/_____

Prior application information: *Examiner* _____ *Group Art Unit:* _____

For CONTINUATION OR DIVISIONAL APPS only: The entire disclosure of the prior application, from which an oath or declaration is supplied under Box 5b, is considered a part of the disclosure of the accompanying continuation or divisional application and is hereby incorporated by reference. The incorporation can only be relied upon when a portion has been inadvertently omitted from the submitted application parts.

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Name (Print/Type)	Michael W. Landry	Registration No. (Attorney/Agent)	38,216
Signature	Michael W. Landry	Date	8/29/2002

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08/29/02

FEE TRANSMITTAL for FY 2002

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[x] Applicant claims small entity status. See 37 CFR 1.27

TOTAL AMOUNT OF PAYMENT ($) 412

Complete if Known	
Application Number	
Filing Date	8/29/2002
First Named Inventor	Anton Monk
Examiner Name	
Group Art Unit	
Attorney Docket No.	9223

METHOD OF PAYMENT *(check all that apply)*

[x] Check [ ] Credit card [ ] Money Order [ ] Other [ ] None

[x] Deposit Account:

Deposit Account Number: 502165

Deposit Account Name: Michael W. Landry

The Commissioner is authorized to: *(check all that apply)*

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1. BASIC FILING FEE

Large Entity Fee Code	Large Entity Fee ($)	Small Entity Fee Code	Small Entity Fee ($)	Fee Description	Fee Paid
101	740	201	370	Utility filing fee	370
106	330	206	165	Design filing fee	
107	510	207	255	Plant filing fee	
108	740	208	370	Reissue filing fee	
114	160	214	80	Provisional filing fee	

SUBTOTAL (1) ($) 370

2. EXTRA CLAIM FEES FOR UTILITY AND REISSUE

		Extra Claims	Fee from below	Fee Paid
Total Claims	10	-20** = 0	X	=
Independent Claims	4	- 3** = 1	X 42	= 42
Multiple Dependent				=

Large Entity Fee Code	Large Entity Fee ($)	Small Entity Fee Code	Small Entity Fee ($)	Fee Description
103	18	203	9	Claims in excess of 20
102	84	202	42	Independent claims in excess of 3
104	280	204	140	Multiple dependent claim, if not paid
109	84	209	42	** Reissue independent claims over original patent
110	18'	210	9	** Reissue claims in excess of 20 and over original patent

SUBTOTAL (2) ($) 42

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FEE CALCULATION (continued)

3. ADDITIONAL FEES

Large Entity Fee Code	Large Entity Fee ($)	Small Entity Fee Code	Small Entity Fee ($)	Fee Description	Fee Paid
105	130	205	65	Surcharge - late filing fee or oath	
127	50	227	25	Surcharge - late provisional filing fee or cover sheet	
139	130	139	130	Non-English specification	
147	2,520	147	2,520	For filing a request for *ex parte* reexamination	
112	920*	112	920*	Requesting publication of SIR prior to Examiner action	
113	1,840*	113	1,840*	Requesting publication of SIR after Examiner action	
115	110	215	55	Extension for reply within first month	
116	400	216	200	Extension for reply within second month	
117	920	217	460	Extension for reply within third month	
118	1,440	218	720	Extension for reply within fourth month	
128	1,960	228	980	Extension for reply within fifth month	
119	320	219	160	Notice of Appeal	
120	320	220	160	Filing a brief in support of an appeal	
121	280	221	140	Request for oral hearing	
138	1,510	138	1,510	Petition to institute a public use proceeding	
140	110	240	55	Petition to revive - unavoidable	
141	1,280	241	640	Petition to revive - unintentional	
142	1,280	242	640	Utility issue fee (or reissue)	
143	460	243	230	Design issue fee	
144	620	244	310	Plant issue fee	
122	130	122	130	Petitions to the Commissioner	
123	50	123	50	Processing fee under 37 CFR 1.17(q)	
126	180	126	180	Submission of Information Disclosure Stmt	
581	40	581	40	Recording each patent assignment per property (times number of properties)	
146	740	246	370	Filing a submission after final rejection (37 CFR § 1.129(a))	
149	740	249	370	For each additional invention to be examined (37 CFR § 1.129(b))	
179	740	279	370	Request for Continued Examination (RCE)	
169	900	169	900	Request for expedited examination of a design application	

Other fee (specify) _____

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SUBMITTED BY				Complete *(if applicable)*	
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Signature	Michael W. Landry			Date	8/29/2002

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Broadband Network for Coaxial Cable Using Multi-carrier Modulation

Inventors:
Anton Monk, Brett Bernath, Itzhak Gurantz, Ladd El Wardani, Ron Porat
Docket: 9223

RELATED APPLICATIONS

This application claims priority to U.S. provisional patent application No. 60/316,820, filed August 30, 2001 entitled "Broadband Local Area Network Using Coaxial Cable"; U.S. provisional patent application No. 60/363,420 filed March 12, 2002 entitled "Method of bit and energy loading to reduce interference effects in devices sharing a communication medium"; and U.S. provisional patent application No. 60/385,361, filed June 3, 2002 entitled "Power loading to reduce interference effects in devices sharing a communication medium", each of which is incorporated herein by reference.

Related application: "Network interface and broadband local area network using coaxial cable" serial number 09/910412 filed July 21, 2001, incorporated herein by reference.

TECHNICAL FIELD

This invention relates to broadband communication networks and specifically to communications using coaxial cable building wiring.

BACKGROUND

In a coaxial cable based local area network (LAN), communication between nodes occurs over a shared coaxial cable. When the coaxial cable used for the LAN is shared with a community aerial television or cable TV (CATV) service the signals must be separated to avoid interference. The LAN signal can use one band of frequencies and the cable TV service can use a different band. A typical cable TV configuration for a home is shown in Fig. 1. Signal splitters are used to distribute downstream signals from the point of entry (POE) to the various terminals in the home, which can include cable converter

boxes, televisions, and cable modems, generally referred to as customer premise equipment (CPE). Each terminal device may have the ability to transmit as well as receive. The upstream signals transmitted by the terminal device flows through the signal splitters back to the POE and into the cable plant and are received by the head end. The signal splitters are functioning as signal combiners for upstream signals. Devices communicating with the head end generally do not communicate with each other.

Signal splitters are commonly used in home and other building type coaxial cable wiring. They have an input port and multiple output ports. The input port can also be considered a common port. The output ports can also be considered tap ports. Splitters are generally passive devices and can be constructed using lumped element circuits with discrete transformers, inductors, capacitors, and resistors. Splitters can also be constructed using strip line or microstrip circuits. A typical two-way splitter splits the power equally between the two output ports if each port is terminated equally. Thus each output would have a power level 3 dB lower than the input. Ideally, a splitter transfers all power from the input port to the output ports. In a practical implementation there is a modest power loss in the splitter due to impedance mismatches, non-zero resistances, dissipative losses in circuit elements, and other non-ideal properties. These losses amount to approximately 0.5 dB, thus a practical two-way splitter provides –3.5dB power level to each output.

Splitters are generally bi-directional; they can also function as signal combiners, which sum the power from multiple ports into a single output. The ports used as outputs in a splitter configuration become inputs ports for the combining configuration. The common port becomes the output port.

A splitter may have 3 or more tap ports. There is typically an N-way splitter at the point of entry of a building that distributes the incoming CATV signal to each room of the building. The N-way splitter also combines the signals from each room, providing a return path for devices such as cable modems to transmit back to the cable head-end.

Splitters can be designed with power dividing ratios that are not equal. Instead of a 3 dB loss to each port, one port can have, for example 1.15 dB loss, and the other 6 dB. This corresponds to 75%/25% coupling. This type of splitter could be used to balance signal power at all terminal devices when there

are multiple levels of signal splitters. A branch that terminates directly to a terminal device would be connected to a higher loss tap port. A branch that contains additional splitters would be connected to a lower loss tap port, which provides extra power to compensate for the loss of additional splitters.

Another characteristic of interest in signal splitters is the isolation between output ports. The isolation is typically between 10 dB and 40 dB. This isolation attenuates signals communicating between tap ports. The signal splitter/combiner is therefore directional, power flows to and from the common port to the tap ports, but power is attenuated between tap ports.

In a conventional cable TV or cable modem use, this isolation is desirable because terminal devices do not communicate with each other, they only communicate through the POE with the cable head-end. In a LAN system, terminal devices must communicate directly with each other, therefore attenuation between tap ports in the signal splitters results in an undesirable signal loss. Presenting a further problem to terminal to terminal communications is the variation in attenuation in different branches of the building wiring. All terminal devices are not connected directly to the main splitter, but may be connected at a secondary splitter, for example in a room. The level of attenuation between different pairs of terminal devices needing to communicate may vary by 10 to 40 dB or more.

Several buildings may be connected to one splitter at the street. Although the isolation of this splitter is high, some coupling between taps occurs, allowing transmission from one building to another. This is a source of interference between LANs in neighboring buildings.

Another approach to overcoming the splitter inter-port isolation is to replace the main splitter at the building POE with a symmetric power splitter/combiner. In a symmetric splitter, power entering any port is divided among the other ports. A symmetric splitter/combiner is not directional. This type of splitter has 3 dB or more additional loss compared to a directional signal splitter. The additional loss is greater depending on the number of tap ports. A power amplifier may be required to boost the signal to compensate for this loss. A bi-directional device, such as a cable modem, requires a reverse path so the amplifier needs to be bi-directional. Another disadvantage to this approach is that installation is required; each coax connected to the existing N-way directional splitter must be disconnected and

moved to the new splitter. Another disadvantage of this approach is that power must be available for the amplifier, which is not generally present in the area a typical main splitter is located.

Imperfect terminations at connections create micro reflections within the cable wiring. The dominant main signal and reflected signal combine in the channel. A reflection anywhere in the wiring produces a multipath signal in some or all wiring branches that creates inter-symbol interference (ISI). The multipath signal has a delay and amplitude difference relative to the main signal. In the frequency domain, a reflection produces ripples in the response of the channel, creating amplitude variations across the pass band. In the time domain, ISI is seen as an impairment to the shape of the digital signal pulses. ISI will degrade the bit error rate (BER) performance of the communication channel. To overcome the effects of reflections, an adaptive equalizer is commonly used in the terminal device receiver. This creates a filter response that restores a flat frequency response impaired by the multipath signal.

The signals transmitted by LAN devices can create interference with televisions and set top boxes even though the LAN signals are out of band of these receivers, due to down conversion and signal mixing in the receivers.

Broadband networks are described in U.S. patent 5,889,765 "Bi-directional communications Network" issued to Gibbs, U.S. patents 5,940,387 and 6,005,861 "Home Multimedia Network Architecture" issued to Humpleman, U.S. patent 5,870,513 "Bi-directional Cable Network with a Mixing Tap or Suppressing Undesirable Noise in Signals From a Remote End of the Network" issued to Williams, U.S. patent 5,805,591 Subscriber Network Interface issued to Naboulsi, U.S. patent 6,008,368 "Ethernet Transport Facility Over Digital Subscriber Lines issued to Rubinstain", U.S. patent 6,137,793 "Reverse Path Multiplexer for Use in High Speed Data Transmissions" issued to Gorman, and U.S. patent 6,091,932 "Bidirectional Point to Multipoint Network Using Multicarrier Modulation" issued to Langlais, each of which is incorporated herein by reference.

Gibbs discloses a broadband network overlaid with the cable service frequencies using dynamically allocated TDMA protocols. Humpleman patents disclose a home network using an active network interface unit to couple the home network to the external network. Williams discloses a method of reducing noise accumulated in the frequency bands used by an upstream signal. Naboulsi discloses an

active network interface for an asynchronous transfer mode (ATM) network. Rubinstain discloses a method of transporting Ethernet over twisted pair lines. Gorman discloses an active reverse path multiplexer for communication between the cable head-end and subscriber cable modems. Langlais discloses a two-way data transmission system for communicating between an upstream and downstream unit using OFDM.

U.S. patent 6,091,932 "Bidirectional point to multipoint network using multicarrier modulation", incorporated herein by reference, discloses various techniques for implementing OFDM communication. This reference discloses the use of OFDM for communicating between a terminal device and the cable head-end.

U.S. patent 6,292,651 "Communication system with multicarrier transport distribution network between a head end terminal and remote units" incorporated herein by reference discloses communication between a cable head end and remote units and discloses techniques using OFDM for such communication. U.S. patent 5,959,967 "Digital transmission system", incorporated herein by reference, issued to Humphrey discloses an OFDM transmission system used to communicate over a twisted pair loop. U.S. patent 5,371,548 "System for transmission of digital data using orthogonal frequency division multiplexing", incorporated herein by reference, issued to Williams discloses an OFDM system for data transmission during the vertical blanking interval of a television signal. U.S. patent 5,488,632 "Transmission and reception in a hostile interference environment", incorporated herein by reference, issued to Mason discloses additional techniques for implementing an OFDM modulator and demodulator. U.S. patent 3,488,445 "Orthogonal Frequency Multiplex Data Transmission System", incorporated herein by reference, issued to Chang and U.S. patent 3,511,936 "Multiply Orthogonal System for Transmitting Data Signals Through Frequency Overlapping Channels", incorporated herein by reference, disclose OFDM data transmission techniques.

A reflected signal and an attenuated signal passing through a splitter port creates a multipath environment. The received power level of the direct signal relative to the reflected signals can vary between equal levels to one signal being substantially greater than the other. The multipath environment impairs the ability to achieve high data rates in a communication network. The signal reflections and tap port isolation of splitters existing in a typical cable TV wiring configuration presents a problem to

shared usage of the cable for a LAN system. The prior art references address communicating between a cable head end and in-home units but do not address the impairments present in the home wiring that restricts high bandwidth communication between devices within the home.

SUMMARY OF THE INVENTION

The present invention uses a form of multi-carrier modulation, orthogonal frequency division multiplex (OFDM), to transmit digital data signals through the coaxial cable wiring installed in homes. Communication is achieved through splitters and signal impairments caused by reflections and attenuation are overcome. Bit loading, along with power loading, adaptive power control, and frequency coordination can be used individually or in combination to implement a network that overcomes the problem of multipath and high attenuation in building cable wiring that would restrict the ability of terminal devices to communicate with each other.

Channel probing messages formed using a predetermined bit sequence and length are transmitted between network devices to estimate the channel characteristics, including the multipath characteristics and a profile of the signal to noise ratio over the frequency band of interest. The probe messages are transmitted using robust modulation, for example QPSK, to insure the message can be received. The probe messages are transmitted without bit loading, that is all carriers have the same robust modulation and all carriers have the same power. The receiving device processes the probe messages as received and determines the impairment present at each carrier frequency. Based on the estimate of the channel, bit loading is applied to increase the modulation order at carriers with high signal to noise ratio and lower the modulation order at carriers with low signal to noise ratio.

Power loading of the individual carriers forming the OFDM signal allows the data network signal to minimize interference to the other services using the cable. Selective avoidance of specific carrier frequencies avoids interference from the other services to the network signal.

The data network established allows point-to-point communication between any two devices connected to the network and point-to-multipoint communication for broadcast or multicast of data messages. The

data network overlays cable or satellite services and uses parts of the frequency spectrum not used by these other services.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a diagram showing a prior art coaxial signal distribution plan.

Fig. 2 is a diagram showing a signal distribution plan according to the present invention.

Fig. 3 shows a representative frequency allocation between network services and other services on a coaxial wiring system, including the use by two different networks.

Fig. 4 shows a representative frequency allocation between cable service upstream/downstream signals and an overlaid local area network.

Fig. 5. shows a block diagram of an OFDM modulator in accordance with the present invention.

Fig. 6. shows a block diagram of an OFDM demodulator in accordance with the present invention.

Fig. 7 shows an example of a bit loading probe message in accordance with the present invention.

Fig. 8 shows a multipath signal created by a splitter.

Fig. 9 shows a time domain and frequency domain plot of a signal experiencing multipath.

Fig.10 shows a bit loaded OFDM waveform in accordance with the present invention overlaid on an impaired frequency response.

DETAILED DESCRIPTION OF THE INVENTION

Referring to Fig. 2, LAN modem 270 provides modulation and demodulation of the waveform transmitted over the cable. LAN modem 270 has an interface to communicate with a LAN device 280, which is the source or destination of data transmitted over the LAN. LAN device 280 can be, for example, a personal computer (PC). LAN device 282 can be, for example, a modulator to produce a signal for driving a TV through a signal combiner. Network interface 210 is optional, it provides an additional signal coupling path between wiring branches if needed and is described more fully in co-pending application 09/910412 "Network interface and broadband local area network using coaxial cable". Additional networks can be connected to taps in the cable plant. The networks can reside in the same or different building.

LAN devices 280 and 282 can be used for digital video services or data services. LAN device 282, for example, can extract digital video data from a transport stream, such as an MPEG stream, transmitted over the network and decode the transport stream to produce an analog video signal suitable for connection to a standard TV set.

Existing devices, such as TV 240 and cable modem 250 connected to PC 260, use frequency bands distinct from the frequency band used by the LAN and therefore operate in a normal manner.

The frequencies used by the LAN can be located above the standard cable use frequencies, which extend to 550 MHz, 750 MHz, or 850 MHz. Other frequency plans can be used, for example where a block of frequencies is available in the middle of the cable band. The filter cut-off frequencies are selected according to the frequencies bands used. Satellite systems generally use frequencies above 950 MHz to communicate the received signal from the out door unit (ODU) to the integrated receiver decoder (IRD) set top box. A LAN would use frequencies below 950 MHz in this case.

Referring to Fig 3, more than one network can occupy the frequency band used for network services. The amount of spectrum used by a particular network depends on the data bandwidth needed for the service provided. Fig. 4 shows the spectrum used by cable upstream and downstream signals with a network signal using the spectrum above the cable band.

The present invention can use a time division duplex (TDD) protocol for communications. In a TDD system, receive and transmit data are communicated during different time intervals, generally using the same frequency. The advantage of using TDD is that the transceiver design is simplified. Different users share a common frequency channel through the use of time division multiple access (TDMA). In a TDMA system each user transmits during a different time interval. Users are assigned one or more slots of predetermined length in a framing structure that contains multiple slots. All users are synchronized by a beacon message broadcast on the network. The beacon message provides a common time reference to the users and can include other network management information.

Some building wiring possesses reflections due to mismatched impedances and inter-port coupling in splitters to provide sufficient signal path between terminal devices for communication. Loss from one

terminal device to another is in the range of approximately 25 dB to 50 dB. In a coaxial cable environment signal-to-noise ratio (SNR) is generally high. To be useful the SNR is preferably in the range of 8 to greater than 30 dB.

Individual terminal devices will receive different power levels that vary according to the signal loss experienced between the transmitting device and the receiving device. An automatic gain control (AGC) circuit in the receiver levels the power presented to the intermediate frequency (IF) or base band processing sections. The AGC measures received power, at an RF, IF, or base band signal point and controls an amplifier to produce a constant level at the measurement point, or some other predetermined processing point.

Adaptive Power Control

The signal loss between terminal devices may be unknown and variable. In the present invention, an adaptive transmit power level is used to control the power level received by a terminal device. This function can be implemented in each terminal device or as part of the network management function provided by a central controller. An AGC circuit in the receiver can correct the residual variations in the signal power level.

An originating terminal device transmits a channel probing message to a responding terminal device for the purpose of determining received power level. The responding device measures the power and communicates a reply message containing the received power level. This message exchange can be transmitted using a robust modulation such as BPSK or QPSK, where the main messaging could be transmitted using higher order modulation, for example multilevel QAM.

Alternatively, the power measurement messaging can be transmitted using FM, which in not sensitive to power levels. Soft clipping in the RF, IF, and base band circuits may occur. This levels the signal and produces some harmonic content that is removed by low-pass filters and allows demodulation and decoding of the message.

The originating terminal device transmits the channel probing message at a predetermined power level. Alternatively, the message can embed a data field that indicates the transmitted power of the message. Using either source of information, the responding terminal device can adapt its transmitted power during the response to provide a desired power level at the originating device. By evaluating the received power measurement data in the response message, the originating device has a direct evaluation of the signal loss due to the channel. The power level of subsequent transmissions by the originating device to a responding device is set according to the channel loss measurement. An acknowledgement message is sent from the originating device to the responding device to conclude the communication establishment sequence.

In one embodiment, the power measurement can be made by observing the AGC control level, which represents the received power level.

OFDM Waveform Modulator and Demodulator

Multi-tone modulation uses a set of modulating carriers that are integer multiples of a common frequency and the symbol period is the inverse of the common frequency. Multi-tone modulation is also called discrete multi-tone (DMT) and orthogonal frequency division multiplexing (OFDM). OFDM utilizes quadrature phase shift keying (QPSK) and multi-level quadrature amplitude modulation (QAM) wherein each OFDM carrier can be modulated by an amplitude/phase-varying signal. QPSK is composed a sine and a cosine wave of identical frequency with phase modulation applied to each carrier independently. QAM is composed of sine and cosine waves with phase modulation and amplitude modulation. QPSK is an m-ary QAM signal with m=2. These signals can be represented using complex numbers. To modulate, data bits are encoded into a number of m-ary QAM constellations, which then modulate the respective carriers. The carriers are summed together for transmission over the channel. Each carrier is independent and can be independently decoded in the receiver. All carriers are related in frequency, being an integer multiple of a base frequency.

Micro reflections tend to have a time displacement relative to the main signal ranging from several nanoseconds to a few microseconds. If the time displacement is longer than an information symbol period ISI is created when the reflected signal from a prior symbol arrives during a later symbol. In

OFDM, the user data bits generated at a high rate are distributed over many carriers, each with a lower data rate and therefore longer symbol period. At a symbol period longer than the multipath delay, the main and reflected signals arrive at a receiver during the same symbol reducing the effects of ISI. For example, if a data rate of 100 mbps is modulated using QPSK, which provides 2 bits per symbol; the symbol period is 20 nS. Using OFDM with 100 carriers, the data rate of each carrier is 1 mbps. With QPSK modulation the symbol period for each carrier is 2 uS.

OFDM processes all carriers as a block using a time to frequency transform. Furthermore, a cyclic prefix is added to the beginning of each OFDM symbol and transmitted to simulate periodicity. The cyclic prefix is created by replicating data from the end of the block at the beginning of the block. The length of the cyclic prefix is a function of the multipath time displacement. By adding a cyclic prefix to the transmitted data the OFDM signal is robust in a multipath environment by providing a guard interval between symbols. Hence, OFDM provides a mechanism to overcome the frequency selective channel impairments present in coaxial building wiring.

The OFDM waveform is generated by applying an inverse discrete Fourier transform (IDFT) to a complex vector that results in a real valued time domain sequence. The time domain sequence is applied to an up converter to place the waveform at the proper RF frequency.

Bit loading is a method of allocating a higher order signal constellation to carriers that have higher signal to noise ratio and a lower order constellation to carriers that have lower signal to noise ratio. Higher SNR channels can support higher data capacity. Frequency bins occupying parts of the channel where the SNR is high can be used to transmit more bits. Each carrier may be modulated with a different order constellation, where higher SNR frequencies can bear a higher order constellation, and the resulting closer spacing of the constellation points. Frequencies with the lower SNR use lower order constellations such as QPSK. U.S. patent 6,438,174 "Multi-carrier transmission systems" incorporated herein by reference, discloses discrete multi-tone modulation and a technique for bit loading applied to point-to-point twisted pair wiring. U.S. patent 6,259,746 "Method for allocating data and power in a discrete multi-tone communication system" discloses a technique for bit loading applied to discrete multi-tone modulation.

The frequency channels in OFDM may be called frequency bins or simply bins. The power in individual frequency bins can be adjusted to compensate for insertion loss that varies as a function of frequency. The power level in regions of the channel can be altered by scaling the complex valued vector for the bins where power adjustment is needed before applying the inverse Fourier transform. In order to avoid interference with certain bands in the RF spectrum, the power level of certain bins can be reduced to zero.

An OFDM receiver uses a discrete Fourier transform (DFT) to convert the modulated signal back into data. The OFDM receiver receives all the carriers at once and performs the transform on a block of data points.

Various types of forward error correction can be applied to transmitted data blocks, such as Reed-Solomon and convolutional coding. Interleaving can be applied to data blocks to increase the robustness of the error correction. De-interleaving and error correction coding are applied in the receiver to recover the transmitted data without errors.

An OFDM receiver may also employ time domain equalization (TEQ), frequency domain equalization (FEQ), or both. Equalizers can be adaptive and may be of the decision feedback (DFE) type or decision directed type such as least mean square (LMS) algorithm.

Fig 5 shows a block diagram of a representative OFDM modulator according to the present invention. Data input is optionally coded with check bits by error correction coder 510 to facilitate error correction in the receiver. QAM encoder 520 divides the input data into many bit streams and applies a QAM symbol mapping to each bit stream. The bit streams correspond to the carriers. Symbol mapping maps a short sequence of bit, from 2 for QPSK to 8 for 256-QAM, into an I and Q amplitude value. The I and Q amplitude values output from QAM encoder 520 are modified by power adjustment table 530, which adjusts the amplitude levels to effect the power level of each carrier in the transmitted signal. The values in power adjustment table 530 are empirically derived or analytically derived and set to levels that avoid interference with other devices. Inverse Fast Fourier Transform (IFFT) 540 performs a frequency domain to time domain transformation that converts the complex series of frequency amplitude values into a time sequence. The IFFT output array is converted to a serial data stream by a

parallel to serial converter 542 as part of IFFT 540. The digital time sequence is converted to an analog representation by digital to analog (DAC) 550. The analog signal is translated to a suitable carrier frequency by up converter 560. The time sequence can be either real valued or complex valued samples. In the case of complex values, DAC 550 would be a dual DAC and up converter 560 would be a quadrature modulator. An amplifier provides the appropriate overall power for the signal to be inserted into the communications medium.

Power adjustment table 530 may also be used to influence the order of modulation generated by QAM encoder 520 for each of the carriers. Higher power level carriers can support higher order of modulation and lower power levels require lower order modulation. The selection of QAM modulation order is bit loading, the selection of carrier power is power loading. The power profile used to avoid interference can alter both the power in each carrier and the number of bits transmitted in each symbol of each carrier.

Fig. 6 is a block diagram of a representative demodulator for use with the present invention. The inverse of the modulator operations are performed to reproduce digital data. Not shown are operations of carrier and symbol timing recovery, which can be performed using techniques well known in the art.

Multi-carrier system architecture is covered in ADSL/VDSL Principles by DR. Dennis J. Rauchmayer, Macmillan Technical Publishing, 1999 and DSL Simulation Techniques and Standards Development for Digital Subscriber Line Systems by Dr. Walter Y. Chen, Macmillan Technology Publishing, 1998, incorporated herein by reference.

Channel Probing Message

Channel probing messages are transmitted between network devices to estimate the channel characteristics. The channel probe uses a predetermined bit sequence which in known by the receiving device. By passing a known data sequence through the channel, the response of the channel can be determined, including multipath and SNR profile.

Probe packets are sent by devices upon command from a cycle master. This request for transmission of a probe message may be periodic or as part of scheduled activity. A probe packet is analyzed by the receiving node, a bit loading profile is computed, and the bit loading information is transmitted back to the sending node. The sending node then uses the requested bit loading until a new bit loading is requested by the receiving node.

In a symmetric channel the receiving device can determine bit loading for transmitted it own messages based on channel characteristics measured from a received probe message. The bit loading is valid for sending messages to the device that transmitted the probe message. In a non-symmetric channel, the receiving device must communicate the results of the analysis, either as raw data or as a bit loading profile, back to the sending device for the sending device to modify the transmission parameters.

Fig. 7 shows an example of a bit loading probe message 700, comprised of a preamble 710, channel estimation training sequence 720, and a bit loading training sequence 730. The preamble portion 710 of the message 700 is used to compute an estimate of the carrier frequency offset and sample timing offset. The preamble 710 is 2 OFDM symbols in length transmitted in time domain as 512 bits. The channel estimation training sequence 720 is 8 OFDM symbols transmitted in the frequency domain with 256 carriers using QPSK modulation and is used to compute the transfer function of the channel. From the transfer function, equalizer coefficients are computed and loaded the taps of an equalizer. The remaining portion of the probe message is processed with the benefit of equalization on the signal.

The bit loading training sequence 730 is 80 symbols transmitted in the frequency domain using BPSK modulation and is used to compute the actual bit loading needed for data traffic. The bit loading training sequence provides for averaging over a large number of symbols. The SNR in each frequency bin is calculated and the bit loading profile is generated. Determination of a channel response, multipath, and SNR profile from a known signal is well known in the art. The data pattern chosen for the preamble and training sequences can be a pseudo-random data sequence of the specified length. A preferred pattern for the preamble uses a selected pattern for the first half of the preamble and a bit inversion of the selected pattern for the second half of the preamble. This pattern provides desirable auto-correlation properties.

Schmidl, et al. "Robust Frequency and Timing Synchronization for OFDM", IEEE Transactions on Communications, vol. 45, No. 12, pp. 1613-1621 (1997) and Minn, et al. "On Timing Offset Estimation for OFDM Systems", IEEE Communications Letters, Vol. 4, No. 7, pp. 242-244, incorporated herein by reference, describe techniques for forming and processing sequences to synchronize receivers to data transmissions over frequency-selective channels.

The signal processing and computations performed on signal samples needed for modulating, demodulating, channel estimation, and other operations can be performed by dedicated hardware resources or by a programmed signal processor. A typical system will utilize both hardware and software techniques to perform the needed signal processing. Signal processing circuitry can be integrated into a single system on a chip (SOC), partitioned into several chips, or programmed into a field programmable gate array (FPGA).

Fig. 8 shows a schematic representation of a splitter 810 with a signal burst 820 of power P entering splitter port A. The signal burst will couple to port B with attenuation of, for example, 20 dB producing signal P1. The signal burst will also couple to port C with a loss of 3.5 dB and pass up the wiring branch to a point that produces some reflection with a particular attenuation. The reflected signal will pass down the wiring branch to splitter port C and couple to port B with a power level of P2. The resulting signal 830 present at port B will be a signal burst of power P1 followed by the echo of power P2. Depending on the level of the reflection and the isolation from port A to port B, the first signal burst arriving at port B can be higher or lower in power than the second signal burst arriving. The time displacement of the two arrivals is dependant upon the cable length of the wiring branch connected to port C.

Fig. 9 shows a time domain plot of two signal bursts, one arriving at time 0 and the other arriving at time t.sub.e. The corresponding frequency domain plot shows nulls in the spectrum with a separation of 1/t.sub.e. This diagram shows the effect of two time displaced signals arriving at a single point and the effect on the frequency response of the signal.

Fig.10 shows a bit loaded OFDM waveform in accordance with the present invention overlaid on an impaired frequency response. The band used to transmit the OFDM signal is segmented into frequency

bins of width f.sub.b. Each frequency bin is encoded with a QAM constellation of 4, 16, 64, or 256 points. The level of response through the channel at each frequency bin, which corresponds to the SNR, determines the order of modulation used. The higher the channel response in a particular bin, the more information is encoded by using a higher density constellation. Frequencies bins located at deep nulls may have insufficient SNR to support a useful signal and are not used. No signal is transmitted in these bins.

Frequency Coordination

When a terminal device is powered up, it scans the available frequency band to determine if there is communication activity occurring and determine the frequencies that are already in use. This activity can be originating from a network in the same building as the terminal device, another building where the signal is leaking through the tap, or from cable or satellite services sharing the cable. The scan can be done using the same receiver signal path that is used for data communication. An FFT performed on an array of data samples taken from the A/D converter provide information about signal activity in the channel. The LO can be changed to sweep the scan over wider frequency band than a single FFT. The step size can be from less than 1 MHz to 10 MHz or more, and depends on the frequency spacing established for the network.

Alternatively to the FFT approach, detection of activity can be achieved by measuring the received signal power with an envelope detector, which can be done using digital samples or an AM detector using a diode and filter circuit. Another approach to envelope detection is monitoring an automatic gain control (AGC) level that represents the received signal strength.

Another approach to activity detection is to fully demodulate the received signal and decode the data stream. Using this technique, the terminal can recognize a network or device identifier contained in the data frames to decide if the activity is from a desired network or undesired network. If a desired network is detected, the terminal will attempt to gain access. If an undesired network is detected the frequency band used will be logged as unusable. The network or device ID can be transmitted in a base coding modulation, such as QPSK. This allows the scanning terminal to synchronize to and decode

enough information to identify the activity without knowing the specific modulation used in the terminal specific and payload portions of the frame.

Once a clear area of the available frequency band is determined, the network controller node can begin transmitting network access information to allow other devices to gain access to the network within the home.

An alternative to frequency coordination between networks is to insert a blocking filter at the POE of the home. This prevents egress of signals from the home and ingress of signals from other homes. The filter is a low pass or band pass filter that allows CATV signals to pass unaffected and blocks the frequencies used by the network. An additional benefit is to insure privacy of the network data. The communication activity scan would then detect any cable or satellite services and use other frequency bands for the network.

What is claimed is:

1. A data communication network comprising:

at least two network devices, each network device comprising a multi-carrier modulator for modulating data, an up converter for translating the modulated data to an RF carrier frequency, a down converter for translating an RF signal, and a multi-carrier demodulator for demodulating the translated RF signal to produce data; and

cable wiring comprising a splitter with a common port and a plurality of tap ports, and a plurality of segments of coaxial cable connecting between the splitter tap ports and the network devices;

whereby network devices communicate with each other through the cable wiring using multi-carrier signaling.

2. The data communication network of claim 1 wherein network devices transmit probe messages through the cable wiring and analyze received probe message signals to determine channel characteristics and bit loading is selected based on the determined channel characteristics.

3. The data communication network of claim 2 wherein a network device comprises a means for determining signal activity and selects a frequency band for operation that is not used by other services.

4. The data communication network of claim 2 wherein the network shares the cable wiring with a cable television service and the network device up converter translates the modulated data to an RF carrier frequency above the frequency used by the cable television service.

5. A method of communicating digital data between a plurality of terminal devices connected to coaxial wiring installed in a building comprising a splitter and segments of coaxial cable, the method comprising the steps of:

in a first terminal device, modulating the digital data using bit loaded orthogonal frequency division multiplex (OFDM) to create a modulated signal;

up converting the modulated signal to a predetermined radio frequency to create a radio frequency signal;

transmitting the radio frequency signal over the coaxial wiring network at a predetermined power level;

in a second terminal device, receiving the radio frequency signal from the coaxial wiring network;

downconverting the radio frequency signal to create a base band signal; and

demodulating the base band signal to create received digital data.

6. The method of claim 5 wherein the predetermined radio frequency is above the frequency used by other services transmitting over the coaxial wiring.

7. The method of claim 5 comprising the further steps of:

scanning all possibly frequencies for activity; and

selecting a frequency for network communication where no activity is detected.

8. A method of characterizing a communication channel used for communication between devices comprising the steps of:

forming a probe message comprising a preamble, a channel estimation training sequence, and a bit loading training sequence;

transmitting the probe message through the communication channel;

receiving the probe message;

from the received probe message, analyzing the preamble to estimate carrier and timing offset, analyzing the channel estimation training sequence to produce a set of equalizer coefficients, and analyzing the bit loading training sequence to determine a bit loading profile used for transmitting data.

9. The method of claim 8 wherein the preamble is a predetermined sequence of QPSK encoded data bits; the channel estimation training sequence is a predetermined sequence of QPSK encoded OFDM symbols; and the bit loading training sequence is a predetermined sequence of BPSK encoded OFDM symbols.

10. A network device for communicating data to other network devices over a coaxial wiring system comprising a splitter and a plurality of cable segments connected between the splitter and the network devices, the network device comprising:

a data modulator to produce a multicarrier modulated signal;

a demodulator for multicarrier modulated signal to produce data;

means for producing and transmitting a probe message; and

means for receiving and analyzing a probe message to determine a bit loading profile used to transmit data.

US 7,697,592 B2

ABSTRACT

A broadband local area data network uses coaxial cable wiring for interconnection of terminal devices. Orthogonal frequency division multiplexing (OFDM) with bit loading is used to overcome channel impairments and provide a path for terminal devices to transmit to and receive from other terminal devices. Probe messages are sent between devices to characterize the communication channel and determine optimum bit loading. The data network shares the cable spectrum with other services and uses frequency bands not used by other services. Adaptive power control can be used to maintain signal to noise ratio in a communication between terminal devices. Frequency coordination can be used to avoid interference between the LAN communications and other services transmitted on the cable.

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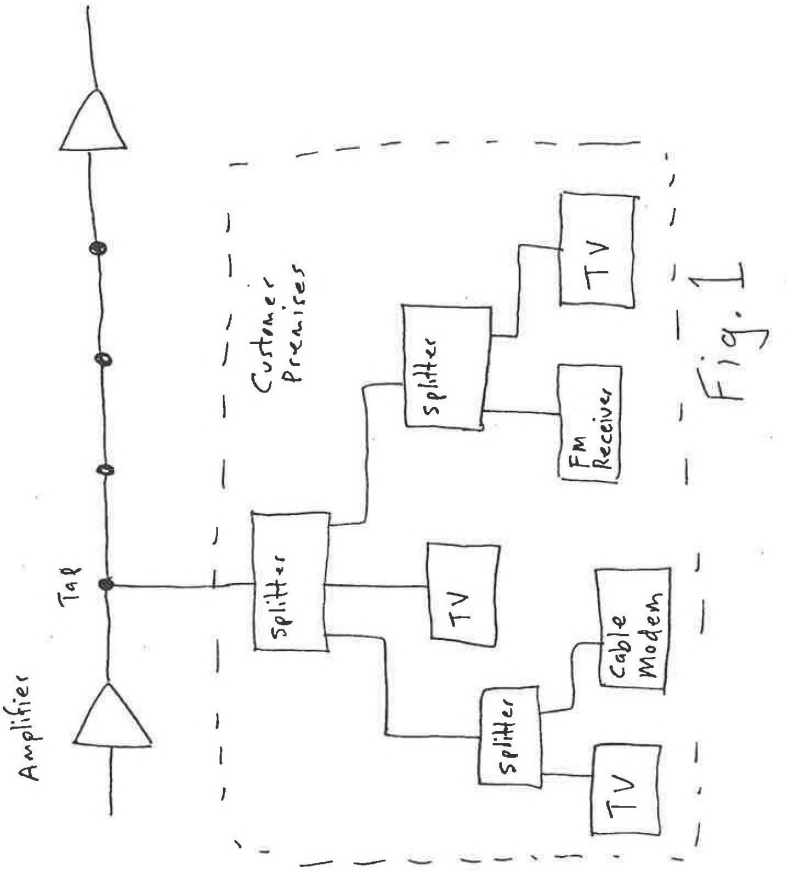
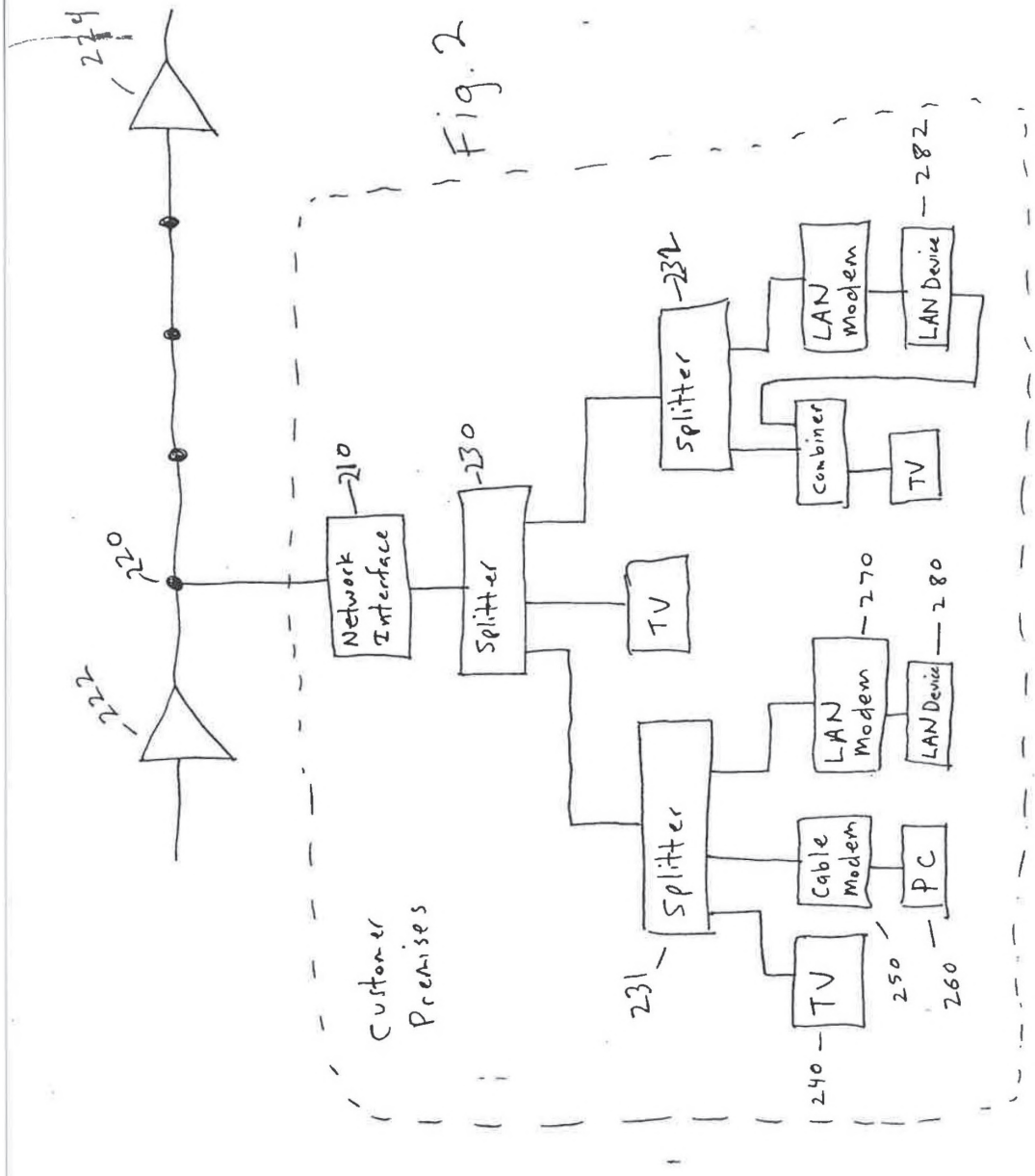


Fig. 1

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Frequency Usage on a coax system

Fig 3

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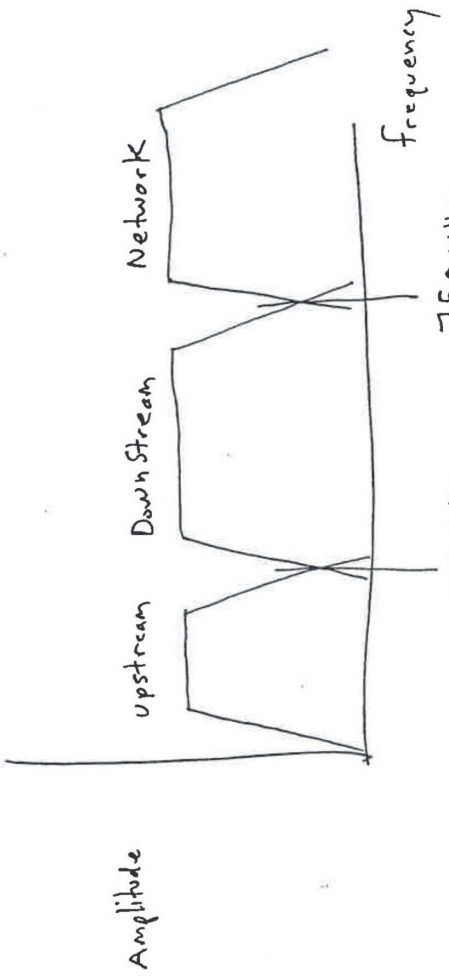


Fig 4

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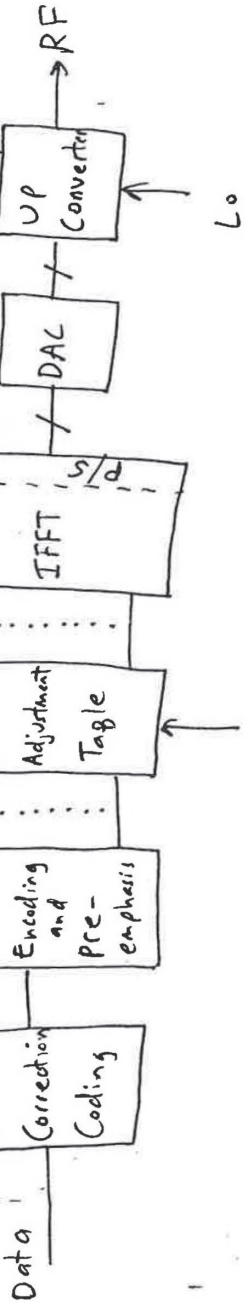
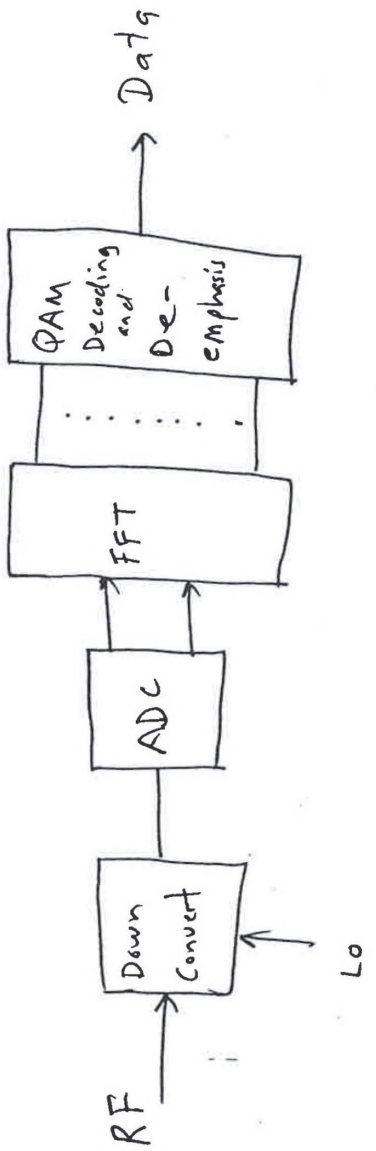


Fig 5

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Fig 6



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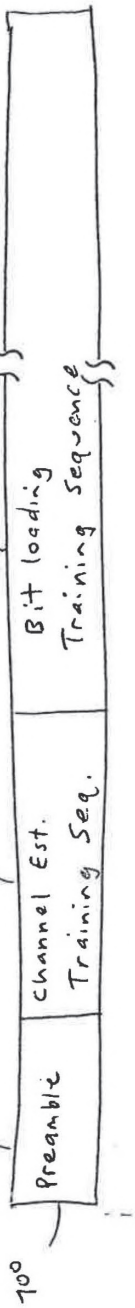


Fig 7

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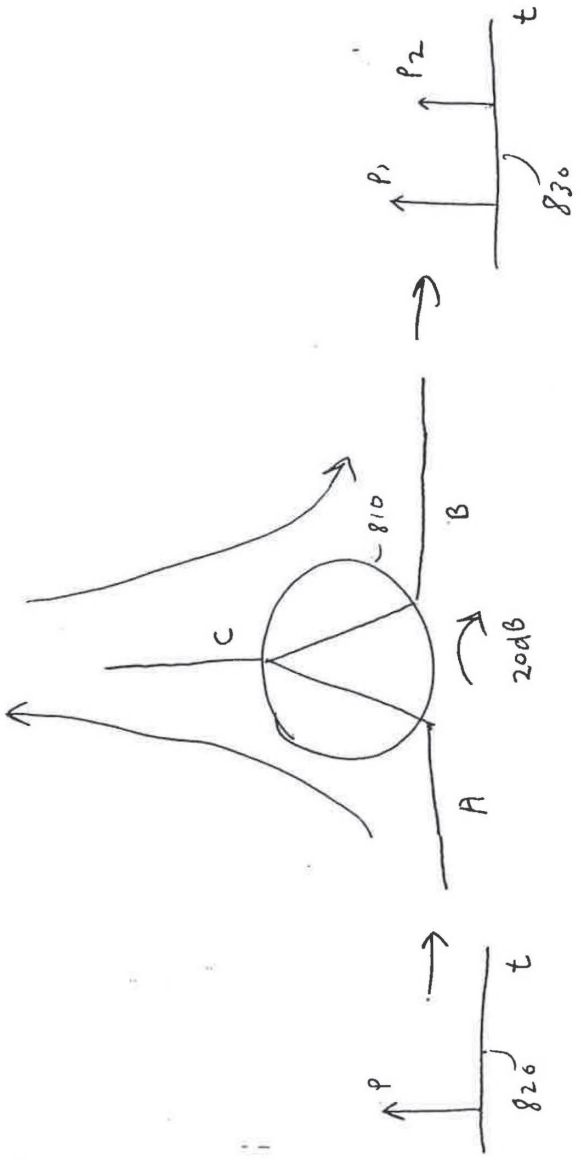


Fig 8

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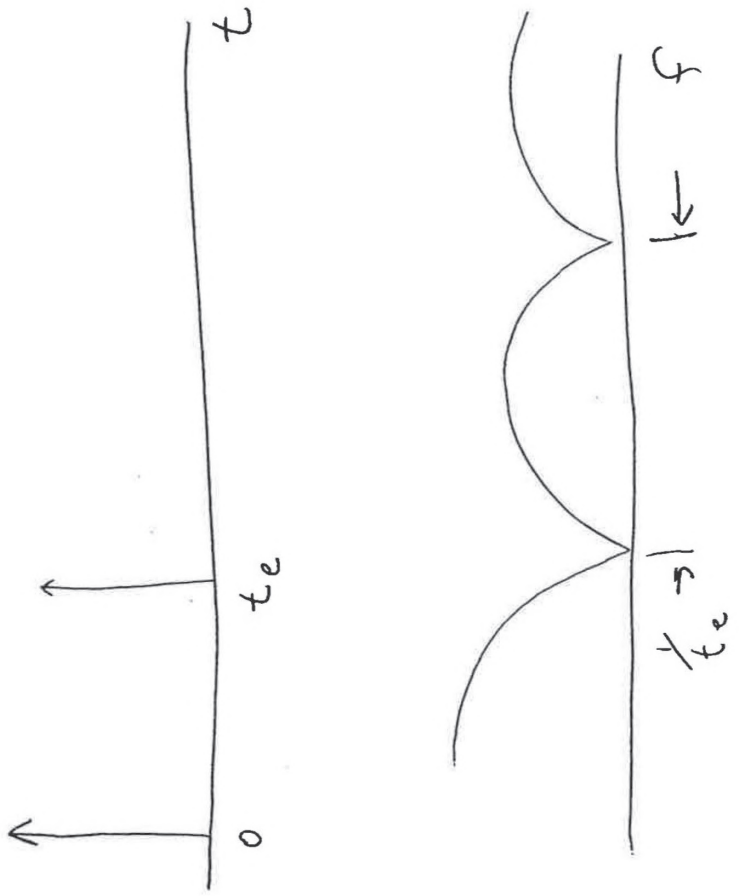


Fig 9

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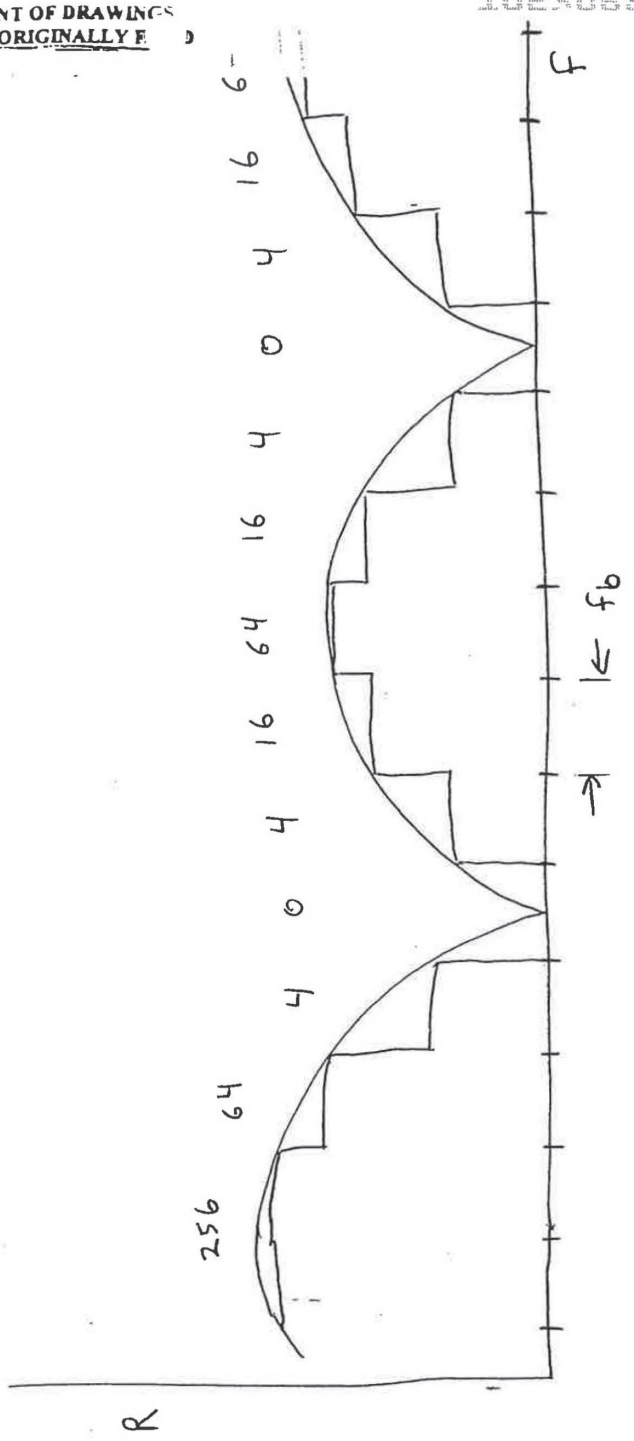


Fig 1D

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APPLICATION NUMBER	FILING/RECEIPT DATE	FIRST NAMED APPLICANT	ATTORNEY DOCKET NUMBER
10/230,687	08/29/2002	Anton Monk	9223

CONFIRMATION NO. 3287

24244
MICHAEL W LANDRY
5098 SEACHASE STREET
SAN DIEGO, CA 92130

FORMALITIES LETTER

OC000000008882424

Date Mailed: 10/01/2002

NOTICE TO FILE MISSING PARTS OF NONPROVISIONAL APPLICATION

FILED UNDER 37 CFR 1.53(b)

Filing Date Granted

Items Required To Avoid Abandonment:

An application number and filing date have been accorded to this application. The item(s) indicated below, however, are missing. Applicant is given **TWO MONTHS** from the date of this Notice within which to file all required items and pay any fees required below to avoid abandonment. Extensions of time may be obtained by filing a petition accompanied by the extension fee under the provisions of 37 CFR 1.136(a).

- The oath or declaration is missing.
  A properly signed oath or declaration in compliance with 37 CFR 1.63, identifying the application by the above Application Number and Filing Date, is required.
- To avoid abandonment, a late filing fee or oath or declaration surcharge as set forth in 37 CFR 1.16(e) of $65 for a small entity in compliance with 37 CFR 1.27, must be submitted with the missing items identified in this letter.

The application is informal since it does not comply with the regulations for the reason(s) indicated below.

The required item(s) identified below must be timely submitted to avoid abandonment:

- Replacement drawings in compliance with 37 CFR 1.84 and 37 CFR 1.121 are required. The drawings submitted are not acceptable because:
  - The drawing sheets do not have the appropriate margin(s) (see 37 CFR 1.84(g)). Each sheet must include a top margin of at least 2.5 cm. (1 inch), a left side margin of at least 2.5 cm. (1 inch), a right side margin of at least 1.5 cm. (5/8 inch), and a bottom margin of at least 1.0 cm. (3/8 inch).See Figures(s) 3, 10.

SUMMARY OF FEES DUE:

Total additional fee(s) required for this application is **$65** for a Small Entity

- **$65** Late oath or declaration Surcharge.

A copy of this notice <u>MUST</u> be returned with the reply.

C. Harrison

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APPLICATION NUMBER	FILING OR 371(C) DATE	FIRST NAMED APPLICANT	ATTY. DOCKET NO./TITLE
10/230,687	08/29/2002	Anton Monk	9223

CONFIRMATION NO. 3287

ABANDONMENT/TERMINATION LETTER

OC000000011746452

24244
MICHAEL W LANDRY
5098 SEACHASE STREET
SAN DIEGO, CA 92130

Date Mailed: 01/22/2004

NOTICE OF ABANDONMENT UNDER 37 CFR 1.53 (f) OR (g)

The above-identified application is abandoned for failure to timely or properly reply to the Notice to File Missing Parts (Notice) mailed on 10/01/2002.

- No reply was received.

A petition to the Commissioner under 37 CFR 1.137 may be filed requesting that the application be revived.

Under 37 CFR 1.137(a), a petition requesting the application be revived on the grounds of **UNAVOIDABLE DELAY** must be filed promptly after the applicant becomes aware of the abandonment and such petition must be accompanied by: (1) an adequate showing of the cause of unavoidable delay; (2) the required reply to the above-identified Notice; (3) the petition fee set forth in 37 CFR 1.17(l); and (4) a terminal disclaimer if required by 37 CFR 1.137(d).

Under 37 CFR 1.137(b), a petition requesting the application be revived on the grounds of **UNINTENTIONAL DELAY** must be filed promptly after applicant becomes aware of the abandonment and such petition must be accompanied by: (1) a statement that the entire delay was unintentional; (2) the required reply to the above-identified Notice; (3) the petition fee set forth in 37 CFR 1.17(m); and (4) a terminal disclaimer if required by 37 CFR 1.137(d).

Any questions concerning petitions to revive should be directed to the "Office of Petitions" at (703) 305-9282.Petitions should be mailed to: Mail Stop Petitions, Commissioner for Patents, P.O. Box 1450, Alexandria VA 22313-1450.

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REQUEST FOR ACCESS TO AN ABANDONED APPLICATION UNDER 37 CFR 1.14

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In re Application of

Application Number	Filed
10/230687	8/29/02

Paper No. #4

I hereby request access under 37 CFR 1.14(a)(1)(iv) to the application file record of the above-identified ABANDONED application, which is not within the file jacket of a pending Continued Prosecution Application (CPA) (37 CFR 1.53(d)) and which is identified in, or to which a benefit is claimed, in the following document (as shown in the attachment):

United States Patent Application Publication No. _____, page, _____ line _____,

United States Patent Number 7295518, column _____, line, _____.

WIPO Pub. No. _____, page _____, line _____.

Related Information About Access to Applications Maintained in the Image File Wrapper System (IFW) and Access to Pending Applications in General

A member of the public, acting without a power to inspect, cannot order applications maintained in the IFW system through the FIU. If the member of the public is entitled to a copy of the application file, then the file is made available through the Public Patent Application Information Retrieval system (Public PAIR) on the USPTO internet web site (www.uspto.gov). Terminals that allow access to Public PAIR are available in the Public Search Room. The member of the public may also be entitled to obtain a copy of all or part of the application file upon payment of the appropriate fee. Such copies must be purchased through the **Office of Public Records** upon payment of the appropriate fee (37 CFR 1.19(b)).

For published applications that are still pending, a member of the public may obtain a copy of: the file contents; the pending application as originally filed; or any document in the file of the pending application.

For unpublished applications that are still pending:

(1) If the benefit of the pending application is claimed under 35 U.S.C. 119(e), 120, 121, or 365 in another application that has: (a) issued as a U.S. patent, or (b) published as a statutory invention registration, a U.S. patent application publication, or an international patent application publication in accordance with PCT Article 21(2), a member of the public may obtain a copy of: the file contents; the pending application as originally filed; or any document in the file of the pending application.

(2) If the application is incorporated by reference or otherwise identified in a U.S. patent, a statutory invention registration, a U.S. patent application publication, or an international patent application publication in accordance with PCT Article 21(2), a member of the public may obtain a copy of the pending application as originally filed.

Ricardo G. Garcia
Signature

5/10/13
Date

Ricardo Garcia
Typed of printed name

Registration Number, if applicable

703 916 1508
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This collection of information is required by 37 CFR 1.11 and 1.14. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.11 and 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. BRING TO: File Information Unit, Suite 3A20, 2800 South Randolph Street, Arlington, Virginia.

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