IEEE Std 802.7-1989

IEEE Recommended Practices for Broadband Local Area Networks

Sponsor

Technical Committee on Computer Communications of the IEEE Computer Society

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IEEE Standards Board

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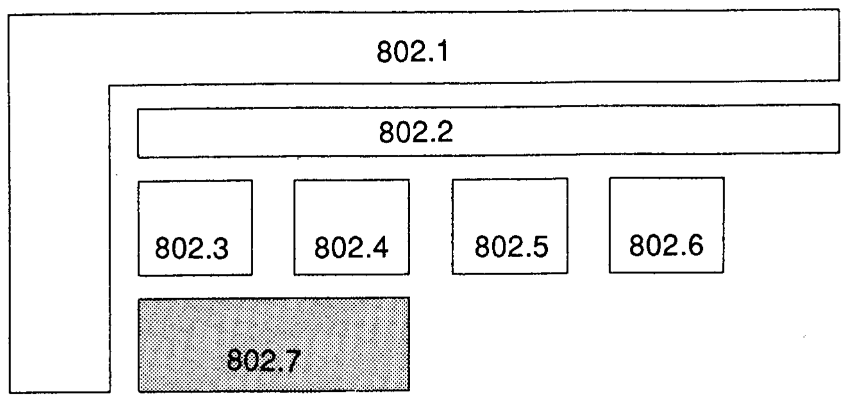
Abstract: IEEE 802.7-1989, IEEE Recommended Practices for Broadband Local Area Networks (LANs) specifies the design, installation, and test parameters for a broadband cable medium. The medium supports the communication of IEEE 802.3b, IEEE 802.4, video, and narrow-band radio frequency (RF) modem devices. The broadband bus topology consists of amplifiers, coaxial cable, and directional couplers that create a full duplex directional medium. Inbound signals flow from user outlet transmitters to a central headend location. The headend processes the signals and then transmits the signals via an outbound path to all the user outlets. The medium utilizes frequency division multiplexing (FDM), which supports the simultaneous coexistence of services. Each service is assigned a unique inbound and outbound channel frequency.

Foreword

(This Foreword is not a part of IEEE Std 802.7-1989, IEEE Recommended Practices for Broadband Local Area Networks.)

This recommended practices document is part of a family of standards for Local Area Networks (LANs). The relationship between this recommended practices document and other members of the IEEE 802 family is illustrated and described below.



Note—The numbers refer to IEEE standards.

P802.1 P802.1 describes the relationship among 802 standards and their relationship to the ISO Open Systems Interconnection Reference Model. This document will contain network management and interconnection standards.[1]

802.2 IEEE Std 802.2-1989 (ISO 8802-2), logical link control protocol.

802.3 ANSI/IEEE Std 802.3-1988 (ISO 8802-3), a bus utilizing CSMA/CD as the access method.

802.4 ANSI/IEEE Std 802.4-1985 (ISO 8802-4), a bus utilizing token passing as the access method.[2]

802.5 IEEE Std 802.5-1989 (ISO 8802-5), a ring utilizing token passing as the access method.

802.7 IEEE Std 802.7-1989, This document provides information pertaining to establishing and maintaining a broadband cable medium. The purpose for the medium is to transport communications of IEEE 802.3b and 802.4 broadband services.

The following participants were members in the Recommended Practices effort of the IEEE Project 802.7 Working Group. Those names followed by an asterisk(*) were voting members at the time of approval of Revision 8 of this document:

[1]Project currently under development.

[2]Publication of this standard's revision, IEEE Std 802.4-1990 (ISO 8802-4), is anticipated in the Spring of 1990.

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We wish to express our gratitude to Ed Cooper and Jim Montrose, our previous chairmen (1984-1987); and to David Slim and Jeff Blowers, our previous vice chairmen.

Special thanks are due to the late James Berger, who was instrumental in obtaining critical support for this effort.

The following persons were on the balloting committee that approved this document for submission to the IEEE Standards Board:

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When the IEEE Standards Board approved this standard on October 19, 1989,† it had the following membership:

†Approved conditionally on August 17, 1989. Final conditions were not met on date shown above.
**Member Emeritus

Contents

IEEE Recommended Practices for Broadband Local Area Networks

1. Introduction

1.1 Scope

This document specifies the physical, electrical, and mechanical characteristics of a properly designed IEEE 802.7 broadband cable medium. The characteristics described herein are intended as the minimum acceptable parameters for the design, installation, and test of an IEEE 802.7 cable plant. Single and dual cable systems are specified for the support of existing IEEE 802.3b[1][3] and 802.4[2] broadband devices.

NOTE—IEEE 802.7 specifications may not be appropriate for cable plants that do not support IEEE 802.3b and 802.4 devices. These recommended practices are inappropriate for cable TV (CATV) systems, MATV systems, and wide area broadband networks.

1.2 Assumptions

IEEE 802.7 specifies the media performance necessary to support IEEE 802.3b, IEEE 802.4, video, and narrow-band services.

NOTE—The words *shall* or *must* indicate a requirement of IEEE 802.7. The words *should* or *may* indicate a recommendation of IEEE 802.7.

1.3 Document organization

This document is organized into the following sections:

Introduction: The introduction section describes the organization, presentation, and content of the document.

Medium Specifications: The medium specifications section establishes the minimum performance required to support the simultaneous operation of IEEE 802.3b and 802.4 services. The specifications will allow the coexistence of video and narrow-band modems on the same network.

Medium Utilization: This section establishes proper spectrum planning and channel allocation practices for the broadband medium.

Documentation: This section addresses documentation requirements of the broadband cable system.

Installation Guidelines: The installation guidelines section provides information related to construction and safety guidelines for a broadband cable plant.

[3]The numbers in brackets correspond to those of the references listed in 1.6; when preceded by B, they correspond to those of the Bibliography (Appendix C).

Testing: The test section specifies the processes necessary to validate and certify the cable plant.

Maintenance: The maintenance section provides guidance in establishing the controls and practices necessary to maintain a broadband medium.

Appendixes: The appendix sections contain reference material related to the broadband cable medium.

1.4 Definitions

The following terms are used synonymously in this document:

CABLE SYSTEM TERMINOLOGY
Cable Plant
Coaxial Cable System
Broadband Cable System
Broadband Coaxial Cable System
Broadband Medium
Physical Medium
Medium

Terms that are critical in developing an understanding of this document are defined below.

NOTE—Terms other than those found here are defined in the Glossary (Appendix D). Abbreviations and acronyms can be found in Appendix A.

1.4.1 directional coupler (tap): A passive device used in cable systems to divide and combine RF signals. It has at least three ports: line in and line out ports with a loss referred to as the *insertion loss*. A small portion of the signal power applied to the line in port passes to the tap port. A signal applied to the tap port is passed to the line in port less the tap attenuation value. The tap signals are isolated from the line out port to prevent reflections. A signal applied to the line out port passes to the line in port and is isolated from the tap port. Some devices provide more than one tap port (multi-taps).

1.4.2 headend: The physical location where the inbound and outbound paths are accessible. The headend is also called the central retransmission facility.

1.4.3 headend port(s): An interface where connection(s) may be made to insert signals or remove signals from the cable plant. The headend ports are usually referred to with a direction (inbound or outbound). Headend ports provide central access to the cable system.

1.4.4 inbound: The direction of RF signal flow towards the headend location from the user outlet ports.

1.4.5 outbound: The direction of RF signal flow away from the headend and towards the user outlet ports.

1.4.6 user outlet port(s): A connection port, located at a user location, which provides user access to the cable system.

1.5 Medium overview

The medium consists of coaxial cable, amplifiers, directional couplers, and passive devices that establish characteristics through which radio frequency (RF) signals may be transmitted and received. The medium has two types of locations where signals enter and leave the medium. These are the headend and user locations. The ports at the headend and user outlet locations provide points of attachment for devices such as Medium Attachment Units (MAUs) and headend equipment.

The connector most commonly found at the user outlet port as well as on RF modems is an F-type connector. While this connector has become a defacto standard for CATV outlets, improvements are still evolving for broadband Local Area Networks (LANs). Furthermore, in dual cable broadband LANs, variations in the normal "F" design have been used to distinguish between the transmit and receive ports. It is essential in dual cable systems to permanently cue the user, so that the transmit and receive ports are not confused.

Broadband systems use directional couplers to route signals in a desired direction. This directional aspect establishes signal paths and attenuates undesired reflections. The directional aspect establishes a signal flow that is different from the signal flow associated with the baseband bus technology. The broadband bus has two directions of travel, called *paths*.

The topology of the broadband network is a branched directional bus that is termed a *tree*. The tree topology depicts a multiple bus hierarchy that contains a central location (headend) and multiple node locations (outlets). Signals flow in two separate paths to establish two-way communication. To establish communication, the signals are directed to one central location (headend) that is capable of receiving transmissions from any port. The path that carries transmissions from any node to the headend is referred to as the *inbound path*. The headend processes the signals if required and then transmits the signals into the *outbound path*.

The outbound path distributes signals to all user outlet ports on the system, while the inbound path collects signals from all the user outlet ports. Throughout the evolution of broadband technology, several terms have evolved to represent the directional concept. In this document the terms inbound and outbound path will be used to describe the flow of RF signals. Terms such as the following have also been used to describe signal direction:

PATH TERMINOLOGY

INBOUND	OUTBOUND
Uplink	Downlink
Reverse	Forward
Transmit	Receive
Upstream	Downstream
Return	

A broadband coaxial cable system serves as a wide bandwidth communications medium that is capable of transporting independent and simultaneous applications including data, video, voice, security, and energy management. Simultaneous operation of different services is accomplished by using different channels for each application. The signals of each service are designated to reside in a defined area of spectrum called a channel. Channels identify the frequency band through which devices establish a unique physical connection.

1.5.1 Path loss

Path loss is defined as signal attenuation between the user outlets and the headend. The path attenuation is specified for the inbound and outbound paths for all frequencies within the "system bandwidth." Inbound "path loss" is the signal attenuation from any user outlet to the headend inbound port(s). Outbound "path loss" is the signal attenuation between any headend outbound port(s) and any user outlet port.

1.5.2 Loop loss

Loop loss is the signal level difference (attenuation) between the transmit and receive frequencies at the user outlet ports. The loop loss specification identifies the cable plant attenuation for dual cable systems, or the device (service) transmitter to receiver signal level difference on single or dual cable systems.

1.5.3 Frequency division multiplexing (FDM)

FDM is the technique of assigning different services to different channels. FDM is used on both single and dual cable systems. Multiple services are capable of coexisting on a cable plant when services are assigned to different channel frequencies. Services operate independently, provided the signal energy stays within the designated operating channel.

Data communication equipment connected to a broadband cable system usually requires a two-way communication path. On a dual cable system, a single designated channel may be used on the inbound and outbound cable to establish a full loop path between the devices. The assigned channel is different for every service and is, therefore, frequency division multiplexed.

In a single cable system, inbound and outbound transmissions must be carried on different channels of the same cable. The outbound signals are usually assigned to the higher channels, and the inbound transmissions are assigned to the lower channels. A two-way communication path for a single cable system requires two channel selections for a service. One channel is assigned for the inbound path, and another channel is assigned for the outbound path. The assignment of two channels is therefore required to designate the requirements for frequency division multiplexed services on a single cable system.

1.6 Referenced standards

These recommended practices have utilized existing standards and codes to establish consistency within related disciplines. The most current approved revision of each should be used as the accurate source of information. The standards and codes are as follows:

[1] ANSI/IEEE Std 802.3–1988 (ISO 8802-3 : 1989), Carrier Sense Multiple Access with Collision Detection (CSMA/CD) Access Method and Physical Layer Specifications, and ANSI/IEEE Std 802.3b, c, d, e (1989 Edition), Supplements (with particular reference to Supplement b: Type 10BROAD36).[4]

[2] ANSI/IEEE Std 802.4–1985 (ISO 8802-4), Token-Passing Bus Access Method and Physical Layer Specifications.

[3] EIA-IS6 (1983), Recommended Cable TV Channel Identification Plan.[5]

[4] IEC Publication 716 (1981), Expression of the Properties of Signal Generators.[6]

[5] *NCTA Recommended Practices for Measurements on Cable Television Systems*. National Cable Television Association, Washington, DC, 2nd Edition, 1990.[7]

[6] NCTA/SCTE. *Graphic Symbols for Cable Television Systems*. National Cable Television Association. Washington, DC, August 1985.

[4]ANSI/IEEE publications are available from the Institute of Electrical and Electronics Engineers, Service Center, 445 Hoes Lane, Piscataway, NJ 08855-1331, or from the Sales Department, American National Standards Institute, 1430 Broadway, New York, NY 10018.

[5]EIA publications are available from the Electronic Industries Association, Standard Sales Department, 2001 Eye St., NW, Washington, DC 20006.

[6] IEC publications are available in the U.S. from the Sales Department, American National Standards Institute, 1430 Broadway, New York, NY 10018.

[7] NCTA publications are available from the Industry Communications Department, National Cable Television Association, 1724 Massachusetts Ave., NW, Washington, DC 20036.

[7] United States FCC Rules and Regulations, Vol. II, Part 15: Radio Frequency Devices; Part 76: Cable TV Service Rules, Subpart K, Sections 76.601–76.619; Part 78: Cable TV Service Relay Rules.[8]

[8] United States FCC Second Report & Order in Docket 21006, October 1, 1984, and modified in June 1985.

1.6.1 Connectors

F-type connector standards have been considered by the EIA-550 Committee for use on local area networks. An FD-type connector has been developed for use on local area network devices employing F-type connectors. To date, IEEE 802.7 has not established a position relative to the use of FD-type connectors.

2. Medium specifications

This section provides the recommended design and operational specifications for a broadband coaxial cable system, the primary purpose of which is the support of IEEE 802 standards for local area networks.

It is not the intention of these recommendations to preclude the transmission of other services, and indeed the specifications have been designed with compatibility and coexistence issues in mind. In particular, the possibility that broadband LANs may be required to support significant numbers of video channels has been considered, and specific recommendations concerning such signals are given.

2.1 Purpose

These recommended practices may be used by the system purchaser as the basis for a purchase specification, by the system designer as the minimum set of design goals, and by testing and maintenance personnel to ensure adherence to the original requirements. The total anticipated system requirements (including future expansions) should be considered when defining the original system requirements. This ensures that future expansions will meet the specifications of the standard.

It will be noted that unless otherwise stated, all specifications apply to the performance exhibited at user outlet port(s). By choosing this interface as a reference, a clear relationship is established between the specifications of the coaxial cable system and the characteristics of the attached devices. Furthermore, the internal operating characteristics of the cable plant may be chosen as to take advantage of particular architectures or types of hardware which may be more applicable in some installations than in others.

2.2 Frequency range

Most data communication equipment connected to a broadband coaxial cable system requires the use of channels in the inbound and outbound signal paths, to establish two-way communication. The frequency range of the cable system is defined to be the usable range(s) from the lowest to highest system frequencies. See Section 3 for further details of frequency offsets and allocations.

The bandwidth of the medium may vary from one coaxial cable system to another. It is recommended that the minimum bandwidth shown in Table 1 be certified for use.

[8] US Government publications are available from the Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402.

2.3 Path loss and loop loss

2.3.1 Single cable inbound

The total inbound path loss, measured between any user outlet port and the input of any headend remodulating/translating/amplifying device, shall be 44 dB, with a permissible uncertainty due to all factors of ± 5 dB.

Table 1—Minimum system bandwidth

	Inbound (MHz)	Outband (MHz)
Dual cable:	54-400	54-400
Single cable, mid-split:	10-108	174-400
Single cable, high-split:	10-174	234-400

NOTE—IEEE 802.3b extends the dual cable inbound/outbound lower band-edge frequency to 36 MHz.

2.3.2 Single cable outbound

The total outbound path, measured between the output of any headend remodulating/translating/amplifying device and any user outlet port, shall be 44 dB, with a permissible uncertainty due to all factors of ± 5 dB.

2.3.3 Looped dual cable system

The total loop loss between any transmit and receive user outlet ports shall be 44 dB, with a permissible uncertainty due to all factors of ± 10 dB.

2.4 Transmit signal levels

The nominal Carrier Wave (CW) signal within 6 MHz used for the purposes of design or certification shall be +54 dBmV when injected into any user outlet port or transmitted from any headend device. In no case shall the CW signal level exceed +56 dBmV.

2.4.1 Derating formula

When more than one carrier is contained in a 6 MHz channel, each carrier shall be adjusted in amplitude according to the following equation:

$$C = +54 - 10 \log_{10} N$$

where

N the number of carriers contained in a 6 MHz channel
C the signal level for each carrier in dBmV

2.5 Carrier-to-noise ratio (CNR)

For the purpose of carrier-to-noise specifications, a 4 MHz noise bandwidth shall be used.

2.5.1 Single cable inbound CNR

The carrier-to-noise ratio of a CW signal injected into any inbound user outlet port at a +54 dBmV level shall be no less than 41 dB measured at any headend translator/remodulator input port.

2.5.2 Single cable outbound CNR

The carrier-to-noise ratio of a CW signal at +54 dBmV that originates at any headend outbound port, and is unaffected by the accumulation of inbound noise, shall have no less than a 43 dB CNR at any user outlet port.

2.5.3 Dual cable CNR

The carrier-to-noise ratio of a CW signal injected at any transmit user outlet port at +54 dBmV shall be no less than 40 dB measured at any receive user outlet port.

2.6 Intermodulation distortion

All intermodulation distortion specifications apply when the fundamental carriers are placed into the system at a nominally rated signal level of +54 dBmV. Along with the fundamental carriers, an additional CW signal shall be injected into the system near the frequency of the discrete intermodulation distortion product to be measured. All carrier-to-distortion specifications are to be referenced to this “nearby” carrier.

In a single cable system, the distortion specifications apply to the individual inbound and outbound paths. In a dual cable system, the specifications apply to the total system, including the contributions of the inbound and outbound paths.

2.6.1 Second order distortion

The carrier-to-discrete second order distortion ratio shall be greater than or equal to 60 dB.

2.6.2 Third order distortion

The carrier-to-discrete third order intermodulation distortion ratio shall be greater than or equal to 78 dB.

2.7 Channel frequency response

Frequency response describes the amplitude vs. frequency characteristic within a specified channel bandwidth, due to the broadband coaxial cable system only. Peak-to-valley response is defined to be the maximum minus the minimum response level within the channel bandwidth. In a single cable system, it is measured from any user outlet port to the input of any headend remodulating/translating/amplifying device, and from the output of any headend remodulating/translating/amplifying device to any user outlet port. In a dual cable system, the response is measured from any transmit user outlet port to any receive user outlet port. The channel frequency response is specified in Table 2.

The instantaneous rate of change of amplitude with respect to frequency across the specified channel bandwidth shall not exceed 0.33 dB per any 1 MHz for dual cable loop, or 0.17 dB per 1 MHz for single cable paths.

2.8 Incidential modulation (Hum)

This specification describes the amplitude modulation of a CW signal, principally at frequencies corresponding to that of the power supply and harmonics thereof. It is specified in terms of the percentage of peak-to-average level of the amplitude modulation with respect to the average level of the desired CW signal. The maximum permissible value is 2%.

Table 2—Channel response table

Specified channel bandwidth (MHz)	**Permissible amplitude variation (peak-to-valley) (dB)**	
	Path (single)	**Loop (dual)**
6	1	2
12	1.5	3
18	2	4

2.9 Characteristic impedance

The nominal impedance of the broadband coaxial cable system shall be 75 Ω.

2.10 Outlet return loss

The return loss of the system user outlet ports shall be greater than or equal to 16 dB within the specified bandwidth.

2.11 Outlet isolation

The minimum isolation between any two user outlet ports measured at any frequency within the system bandwidth (see Table 1) shall be 25 dB.

2.12 Cable system signal leakage

The permissible amount of cable plant leakage shall not exceed the current recommendations for CATV leakage specified in Table 3.

2.13 Environmental

All specifications shall be maintained over the operating environment range of the medium.

2.14 Terminations

All unused ports of components of the broadband coaxial cable system, including couplers, taps, splitters, and user outlet ports, shall be terminated with terminating resistors to minimize internal signal reflections and noise ingress/egress.

2.15 Drop cables

Cable routing and tap location shall permit servicing access. All drop cables shall be constructed of multiple braid/foil shielding to minimize noise ingress and signal leakage from the system.

Table 3—Cable system signal leakage

Frequency	Leakage level	Measurement distance	
	µV/m	ft	m
Less than or equal to 54 MHz	15	100	30
From 54 to 216 MHz	20	10	3
Greater than 216 MHz	15	100	30

NOTE—Where more stringent regulatory constraints apply, they shall take precedence. (Also, refer to FCC Rules and Regulations, Parts 15, 76, and 78 [7] and FCC Docket 21006 [8].)

3. Medium utilization

3.1 Spectrum management

This section provides recommendations for resource management of a broadband communications system. The allocation of cable spectrum requires a frequency plan. The frequency plan allocates portions of the spectrum for use. The spectral planning process may require that areas of the spectrum remain vacant, either for future use or to avoid conflict with sensitive regulated frequencies.

Section 3 presents issues related to the operation of a broadband cable medium. The recommended practices for the activation, monitoring, and diagnosis of the medium are located at the end of Section 3. (Refer to 3.6.)

3.1.1 Usable spectrum

The frequency spectrum of a broadband medium should be utilized in a logical and consistent manner to achieve the maximum potential from the system. A portion of the spectrum must be reserved for pilot frequencies, monitoring channels, and other cable plant support systems. The remaining spectrum is usable for system services.

3.1.2 Spectrum allocation

Broadband systems may support multiple applications, including two-way video (VSB-AM) signals, point-to-point and point-to-multipoint transmissions, and networking (multiple access) services. In recognition of the fact that this Technical Advisory Group (TAG) was formed under the aegis of the IEEE 802 Standards Project, particular emphasis has been placed upon the spectral allocation related to IEEE 802.3b and 802.4 broadband services.

3.2 Organization of the spectrum

3.2.1 Channel conventions

Broadband cable systems evolved from CATV cable technology. It is expected that CATV technology and equipment will continue to influence the planning and design of broadband networks. It is for these reasons that standard CATV channel designators are used for spectrum allocation planning.

3.2.2 The CATV frequency plan

The current NCTA 6 MHz video channel definitions are the result of evolution within the CATV industry. The EIA-IS6 [3] channel plan (Channels 1 through 100) evolved and changed to exploit the majority of the current technology in use today (550 MHz). This evolution has led to the addition of channel capacity and the exploitation of the mid-VHF band (Channels A-2 to I), and superband (Channels J to W). Recently the hyperband channels AA to ZZ and frequencies beyond 456 MHz have been allocated. The channel conventions that are relevant to current broadband technology are illustrated in Tables 4-6.

Table 4—Standard CATV channel assignments

	Standard channel mnemonic	EIA-IS6 [3] channel mnemonic	Lower channel boundary (MHz)	Upper channel boundary (MHz)	Picture carrier frequency (MHz)	Color carrier frequency (MHz)	Audio carrier frequency (MHz)
S	T-7		5.75	11.75	7.00	10.58	11.50
U	T-8		11.75	17.75	13.00	16.58	17.50
B	T-9		17.75	23.75	19.00	22.58	23.50
	T-10		23.75	29.75	25.00	28.58	29.50
V	T-11		29.75	35.75	31.00	34.58	35.50
H	T-12		35.75	41.75	37.00	40.58	41.50
F	T-13		41.75	47.75	43.00	46.58	47.50
	T-14		47.75	53.75	.	.	.
L	2	2	54.00	60.00	55.25	58.83	59.75
O	3	3	60.00	66.00	61.25	64.83	65.75
W	4	4	66.00	72.00	67.25	70.83	71.75
	A-8	1	72.00	76.00	.	.	.
V	5	5	76.00	82.00	77.25	80.83	81.75
H	6	6	82.00	88.00	83.25	86.83	87.75
F							
	A-5	95	90.00	96.00	91.25	94.83	95.75
	A-4	96	96.00	102.00	97.25	100.83	101.75
	A-3	97	102.00	108.00	103.25	106.83	107.75
	A-2	98	108.00	114.00	109.25	112.83	113.75
	A-1	99	114.00	120.00	115.25	118.83	119.75
M	A	14	120.00	126.00	121.25	124.83	125.75
I	B	15	126.00	132.00	127.25	130.83	131.75
D	C	16	132.00	138.00	133.25	136.83	137.75
B	D	17	138.00	144.00	139.25	142.83	143.75
A	E	18	144.00	150.00	145.25	148.83	149.75
N	F	19	150.00	156.00	151.25	154.83	155.75
D	G	20	156.00	162.00	157.25	160.83	161.75
	H	21	162.00	168.00	163.25	166.83	167.75

Table 4—Standard CATV channel assignments *(continued)*

	Standard channel mnemonic	EIA-IS6 [3] channel mnemonic	Lower channel boundary (MHz)	Upper channel boundary (MHz)	Picture carrier frequency (MHz)	Color carrier frequency (MHz)	Audio carrier frequency (MHz)
	I	22	168.00	174.00	169.25	172.83	173.75
H	7	7	174.00	180.00	175.25	178.83	179.75
I	8	8	180.00	186.00	181.25	184.83	185.75
G	9	9	186.00	192.00	187.25	190.83	191.75
H	10	10	192.00	198.00	193.25	196.83	197.75
	11	11	198.00	204.00	199.25	202.83	203.75
V	12	12	204.00	210.00	205.25	208.83	209.75
H	13	13	210.00	216.00	211.25	214.83	215.75
F							
S	J	23	216.00	222.00	217.25	220.83	221.75
U	K	24	222.00	228.00	223.25	226.83	227.75
P	L	25	228.00	234.00	229.25	232.83	233.75
E	M	26	234.00	240.00	235.25	238.83	239.75
R	N	27	240.00	246.00	241.25	244.83	245.75
B	O	28	246.00	252.00	247.25	250.83	251.75
A	P	29	252.00	258.00	253.25	256.83	257.75
N	Q	30	258.00	264.00	259.25	262.83	263.75
D	R	31	264.00	270.00	265.25	268.83	269.75
	S	32	270.00	276.00	271.25	274.83	275.75
	T	33	276.00	282.00	277.25	280.83	281.75
	U	34	282.00	288.00	283.25	286.83	287.75
	V	35	288.00	294.00	289.25	292.83	293.75
	W	36	294.00	300.00	295.25	298.83	299.75
H	AA	37	300.00	306.00	301.25	304.83	305.75
Y	BB	38	306.00	312.00	307.25	310.83	311.75
P	CC	39	312.00	318.00	313.25	316.83	317.75
E	DD	40	318.00	324.00	319.25	322.83	323.75
R	EE	41	324.00	330.00	325.25	328.83	329.75
B	FF	42	330.00	336.00	331.25	334.83	335.75
A	GG	43	336.00	342.00	337.25	340.83	341.75
N	HH	44	342.00	348.00	343.25	346.83	347.75
D	II	45	348.00	354.00	349.25	352.83	353.75
	JJ	46	354.00	360.00	355.25	358.83	359.75
	KK	47	360.00	366.00	361.25	364.83	365.75
	LL	48	366.00	372.00	367.25	370.83	371.75
	MM	49	372.00	378.00	373.25	376.83	377.75
	NN	50	378.00	384.00	379.25	382.83	383.75
	OO	51	384.00	390.00	385.25	388.83	389.75
	PP	52	390.00	396.00	391.25	394.83	395.75

Table 4—Standard CATV channel assignments *(continued)*

Standard channel mnemonic	EIA-IS6 [3] channel mnemonic	Lower channel boundary (MHz)	Upper channel boundary (MHz)	Picture carrier frequency (MHz)	Color carrier frequency (MHz)	Audio carrier frequency (MHz)
QQ	53	396.00	402.00	397.25	400.83	401.75
RR	54	402.00	408.00	403.25	406.83	407.75
SS	55	408.00	414.00	409.25	412.83	413.75
TT	56	414.00	420.00	415.25	418.83	419.75
UU	57	420.00	426.00	421.25	424.83	425.75
VV	58	426.00	432.00	427.25	430.83	431.75
WW	59	432.00	438.00	433.25	436.83	437.75
XX	60	438.00	444.00	439.25	442.83	443.75
YY	61	444.00	450.00	445.25	448.83	449.75
ZZ	62	450.00	456.00	451.25	454.83	455.75

Table 5—Harmonically related carrier channel assignments

HRC channel mnemonic	Sub channel mnemonic	Lower channel boundary (MHz)	Upper channel boundary (MHz)	Picture carrier frequency (MHz)	Color carrier frequency (MHz)	Audio carrier frequency (MHz)
	T-7	5.75	11.75	7.00	10.58	11.50
	T-8	11.75	17.75	13.00	16.58	17.50
	T-9	17.75	23.75	19.00	22.58	23.50
	T-10	23.75	29.75	25.00	28.58	29.50
	T-11	29.75	35.75	31.00	34.58	35.50
	T-12	35.75	41.75	37.00	40.58	41.50
	T-13	41.75	47.75	43.00	46.58	47.50
	T-14	47.75	53.75	.	.	.
2H		52.75	58.75	54.00	57.58	58.50
3H		58.75	66.75	60.00	65.58	66.50
4H		66.75	70.75	68.00	69.58	70.50
54H		70.75	76.75	72.00	75.58	76.50
5H		76.75	82.75	78.00	81.58	82.50
6H		82.75	88.75	84.00	87.58	88.50
57H		88.75	94.75	90.00	93.58	94.50
58H		94.75	100.75	96.00	99.58	100.50
59H		100.75	106.75	102.00	105.58	106.50
60H		106.75	112.75	108.00	111.58	112.50
61H		112.75	118.75	114.00	117.58	118.50
14H		118.75	124.75	120.00	123.58	124.50
15H		124.75	130.75	126.00	129.58	130.50

Table 5—Harmonically related carrier channel assignments *(continued)*

HRC channel mnemonic	Sub channel mnemonic	Lower channel boundary (MHz)	Upper channel boundary (MHz)	Picture carrier frequency (MHz)	Color carrier frequency (MHz)	Audio carrier frequency (MHz)
16H		130.75	136.75	132.00	135.58	136.50
17H		136.75	142.75	138.00	141.58	142.50
18H		142.75	148.75	144.00	147.58	148.50
19H		148.75	154.75	150.00	153.58	154.50
20H		154.75	160.75	156.00	159.58	160.50
21H		160.75	166.75	162.00	165.58	166.50
22H		166.75	172.75	168.00	171.58	172.50
7H		172.75	178.75	174.00	177.58	178.50
8H		178.75	184.75	180.00	183.58	184.50
9H		184.75	190.75	186.00	189.58	190.50
10H		190.75	196.75	192.00	195.58	196.50
11H		196.75	202.75	198.00	201.58	202.50
12H		202.75	208.75	204.00	207.58	208.50
13H		208.75	214.75	210.00	213.58	214.50
23H		214.75	220.75	216.00	219.58	220.50
24H		220.75	226.75	222.00	225.58	226.50
25H		226.75	232.75	228.00	231.58	232.50
26H		232.75	238.75	234.00	237.58	238.50
27H		238.75	244.75	240.00	243.58	244.50
28H		244.75	250.75	246.00	249.58	250.50
29H		250.75	256.75	252.00	256.58	256.50
30H		256.75	262.75	258.00	261.58	262.50
31H		262.75	268.75	264.00	267.58	268.50
32H		268.75	274.75	270.00	273.58	274.50
33H		274.75	280.75	276.00	279.58	280.50
34H		280.75	286.75	282.00	285.58	286.50
35H		286.75	292.75	288.00	291.58	292.50
36H		292.75	298.75	294.00	297.58	298.50
37H		298.75	304.75	300.00	333.58	304.50
38H		304.75	310.75	306.00	309.58	310.50
39H		310.75	316.75	312.00	315.58	316.50
40H		316.75	322.75	318.00	321.58	322.50
41H		322.75	328.75	324.00	327.58	328.50
42H		328.75	334.75	330.00	333.58	334.50
43H		334.75	340.75	336.00	339.58	340.50

Table 5—Harmonically related carrier channel assignments *(continued)*

HRC channel mnemonic	Sub channel mnemonic	Lower channel boundary (MHz)	Upper channel boundary (MHz)	Picture carrier frequency (MHz)	Color carrier frequency (MHz)	Audio carrier frequency (MHz)
44H		340.75	346.75	342.00	345.58	346.50
45H		346.75	352.75	348.00	351.58	352.50
46H		352.75	358.75	354.00	357.58	358.50
47H		358.75	364.75	360.00	363.58	364.50
48H		364.75	370.75	366.00	369.58	370.50
49H		370.75	376.75	372.00	376.58	376.50
50H		376.75	382.75	378.00	381.58	382.50
51H		382.75	388.75	384.00	387.58	388.50
52H		388.75	394.75	390.00	393.58	394.50
53H		394.75	400.75	396.00	399.58	400.50

Table 6—Channel pairs for 192.25 MHz offset

Inbound channel mnemonic	Lower channel boundary (MHz)	Upper channel boundary (MHz)	Outbound channel mnemonic	Lower channel boundary (MHz)	Upper channel boundary (MHz)
T-7	5.75	11.75	11	198.00	204.00
T-8	11.75	17.75	12	204.00	210.00
T-9	17.75	23.75	13	210.00	216.00
T-10	23.75	29.75	J	216.00	222.00
T-11	29.75	35.75	K	222.00	228.00
T-12	35.75	41.75	L	228.00	234.00
T-13	41.75	47.75	M	234.00	240.00
T-14	47.75	53.75	N	240.00	246.00
2’	53.75	59.75	O	246.00	252.00
3’	59.75	65.75	P	252.00	258.00
4’	65.75	71.75	Q	258.00	264.00
4A’	71.75	77.75	R	264.00	270.00
5’	77.75	83.75	S	270.00	276.00
6’	83.75	89.75	T	276.00	282.00
FM1’	89.75	95.75	U	282.00	288.00
FM2’	95.75	101.75	V	288.00	294.00
FM3’	101.75	107.75	W	294.00	300.00
A2’	107.75	113.75	AA	300.00	306.00
A1’	113.75	119.75	BB	306.00	312.00
A’	119.75	125.75	CC	312.00	318.00

Table 6—Channel pairs for 192.25 MHz offset *(continued)*

Inbound channel mnemonic	Lower channel boundary (MHz)	Upper channel boundary (MHz)	Outbound channel mnemonic	Lower channel boundary (MHz)	Upper channel boundary (MHz)
B’	125.75	131.75	DD	318.00	324.00
C’	131.75	137.75	EE	324.00	330.00
D’	137.75	143.75	FF	330.00	336.00
E’	143.75	149.75	GG	336.00	342.00
F’	149.75	155.75	HH	342.00	348.00
G’	155.75	161.75	II	348.00	354.00
H’	161.75	167.75	JJ	354.00	360.00
I’	167.75	173.75	KK	360.00	366.00
7’	173.75	179.75	LL	366.00	372.00
8’	179.75	185.75	MM	372.00	378.00
9’	185.75	191.75	NN	378.00	384.00

3.2.3 Channel designations

As shown in Table 4, the channel mnemonics alternate between numbers, letters, and combinations of the two. The channel designations (mnemonics) can be traced to the earliest days of CATV when the standard VHF broadcast channels were carried. From the conception of the original mnemonics (2 through 13) the channel definition has remained unchanged. Modern CATV systems carry sixty or more television channels. Requirements for additional channels led to definition of the midband area (the gap between low and high VHF television stations), and the superband channels (from the VHF high band to 330 MHz). Channel designations in the mid- and high bands carry a single alphabet letter (A to Z). Developments in amplifier technology and expanding programming sources led to the development of superband (up to 450 MHz). The superband mnemonics use double alphabet letter designators (from AA to ZZ). Beyond ZZ lies the television UHF band with number designations from 14 to 83.

The current CATV channel definitions are defined with letter-number combinations. Mnemonics, while providing a convenient visual aid for memorization, are not consecutively assigned within the standard CATV plan.

Several channel designation schemes have been developed to define the CATV spectrum in a more consistent manner. The incremental frequency assignment system was developed to ensure that all third order distortion products will fall on the carrier frequencies. The Incrementally Related Carrier (IRC) frequency plan uses numbers to completely describe all channels within the standard CATV plan. The EIA-IS6 [3] frequency plan uses the channel designators of the VHF bands (2 through 13) as a historical apex. The IRC frequency plan ensures the third order distortion products fall on the carrier frequencies.

The Harmonically Related Carrier (HRC) frequency plan was developed to ensure the third order distortion products and the second order distortion products fall on the carrier frequencies. The letter “H” is found next to the number to represent an HRC assignment. Table 5 provides the HRC channel allocations.

3.2.4 System bandwidth nomenclatures

Early CATV splitband cable systems used the spectrum below Channel 2 for the inbound path. The sub-split band nomenclature identifies the division of spectrum for the inbound and outbound paths. The division falls below the low VHF channels. The inbound spectrum of the sub-split format provides a sufficient bandwidth for the monitoring and maintenance of CATV amplifiers. The use of sub-split institutional networks expanded with the use of two-way services. The need for additional two-way bandwidth formed the basis for the development of mid-split networks.

Mid-split technology was introduced in the early 1970s. The term mid-split signifies the division of the inbound and outbound paths between the low and high VHF bands. The frequency offset of the devices used for a mid-split system was often 156.25 MHz. New systems often use devices having a 192.25 MHz frequency offset.

The expansion of local area networking in the early 1980s led to the development of high-split cable systems. The high-split format defines the division between the inbound and outbound paths to occur within the high VHF band. The high-split format defines additional inbound bandwidth with respect to the mid-split system. The frequently used frequency offset of the devices used on a high-split system is 192.25 MHz. Channel pairs that are offset by 192.25 MHz efficiently map the high-split inbound spectrum into a corresponding outbound spectrum of similar bandwidth.

A dual cable system has a separate cable for the inbound and outbound paths. Dual cable systems provide more than twice the bandwidth of a high-split cable network. Dual cable networks efficiently support devices that do not have a frequency offset. A service operating on a dual cable system will normally use the same channel for the inbound and outbound path. It is not necessary to electrically establish a path connection at the headend since the same channel is used for both directions. The path may be broken at the headend, to insert a remodulating, re-timing, or channel processor headend device. The use of such a device may be required or optional, depending on the service assigned to a particular channel.

The transmission, translation, and FDM properties of a single cable system may be supported on a dual cable system. Devices in 156.25 MHz and 192.25 MHz offsets are both capable of operating on a dual cable system. Operating more than one offset on a cable system may cause spectral overlap. With an offset, each inbound channel has an assumed target (outbound) channel. When multiple offset formats are used, it is possible to have two different source (inbound) channels competing for a target channel. This conflict may make one source channel unusable.

The bandwidth and allocation relationships for mid-split, high-split, and dual cable systems are illustrated in Fig 1.

3.2.5 IEEE channel conventions

High-split technology and outbound channel contention caused by devices using disimilar frequency offsets led to the development of the prime channels. The prime channels are offset from standard channels to eliminate the gap between the T-channels and Channel 2. The prime channels, when combined with a 192.25 MHz offset, efficiently use the spectrum from 5.75-400 MHz. The IEEE prime channel definitions are located in Table 6.

3.3 Reserved spectrum

The entire system certification bandwidth (see Section 2) is normally available for any service use. The bandwidth certified for use may not be available for a service for several possible reasons. The bandwidth may be reserved to comply with an FCC regulation. The channel may not be usable due to powerline noise ingress or off-air channel interference. The bandwidths may be reserved for future expansion, security, or system pilot/transponder usage. A detailed explanation of cable system bandwidth and the planning of its use is provided below.

3.3.1 Frequency rolloff response

There is almost universal agreement among manufacturers on the band-edge definitions for split-band equipment. The definition of the system certification bandwidth identifies frequency bands that may be obtained. The lower band-edge of the inbound path is required to be certified down to 10 MHz. Amplitude roll off and group delay distortion generally make operation in Channel T-7 difficult. Therefore, these practices do not make it necessary to design, certify, or maintain services in the 5-10 MHz band-pass. The band from 5-10 MHz may be used for status monitoring, maintenance signaling, or pilot carriers.

3.3.2 Leakage regulations

LAN installations are subject to applicable national standards. An example of an applicable national standard that regulates nonlicensed cable installation leakage is shown in Table 3. The permissible leakage limits are substantially less restrictive than the limits imposed on cable TV facilities.

Notwithstanding compliance within the leakage limits, the operator of apparatus is required to promptly take steps to eliminate the source of any harmful interference.

Cable TV is also subject to the general signal leakage requirements of FCC Rules and Regulations. Section 76.605(a) [7], as set forth in Table 3. Broadband LAN facilities are not subject to all of the rules of a CATV cable system. This document requires adherence to the CATV leakage regulations to protect LAN users from future legislative changes.

Signal leakage should be regularly checked. Prompt repair of leaks, determination of a cumulative leakage index (CLI), notifications to FCC, and responsibility for correcting actual cases of harmful interference are operator responsibilities for CATV plants of over 1000 subscribers. It is recommended that any interference to the reception of radio or TV signals, land-mobile, amateur, or other licensed services shall be corrected by the broadband cable plant operator, per FCC Rules and Regulations, Part 15 [7].

Other countries, particularly those of western Europe, may have more stringent requirements for leakage. Designers and operators, planning a broadband coaxial cable system outside the United States, are advised to take special note of local regulations relating to signal leakage. For example, see IEC Publication 716 (1981) [4].

3.3.3 Sensitive spectrum regulations

At the time this document was written (1988), LAN installations were not subject to the more restrictive rules of FCC Rules and Regulations, Part 76 [7]. Part 76 regulates the use of CATV frequencies in the aviation radio bands, 108-136 MHz and 225-400 MHz; and the special emergency distress frequencies, 121.5, 156.8, and 243.0 MHz. These regulations were developed to minimize the possibility of interference to air navigation and communication radio services as a result of malfunction of the CATV coaxial networks.

The design and function similarities between LAN and CATV networks present comparable risk of generating interference. The leakage due to damaged cables, loose connectors, unterminated ports, improper terminal equipment, or accidental or inadvertent malfunctions is the subject of regulatory discussion. For these reasons, it appears that LAN installations are likely (at some future time) to be subject to comparable regulations. In the meantime, in the interest of public safety, it is recommended that the design and installation of broadband LAN facilities shall comply with the frequency separation standards (i.e., offsets) specified for cable TV systems in FCC Rules and Regulations, Sections 76.612 and 76.618 [7].

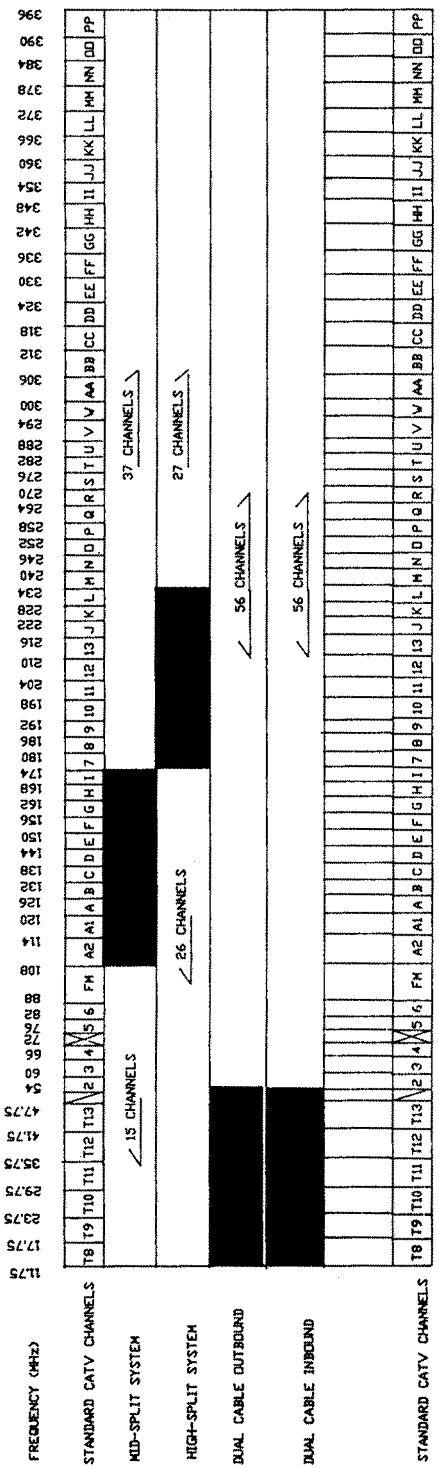

Figure 1—Broadband channel allocation chart

Within the sensitive spectrum mentioned above, the FCC Rules and Regulations permit cable TV systems to use any carrier frequencies (except 121.5, 156.8, and 243.0 MHz). The signal level shall be less than 100 μW (-10 dBm; 38.75 dBmV) average power in any 25 kHz band for any 160 μs period. Carriers may be operated at higher powers in these bands with the specified frequency offsets as described below.

In the aeronautical radio communication bands, 118-136 MHz and 225-400 MHz (except the glide slope band, 328.6-335.4 MHz), higher powered carriers may be operated at frequencies offset by 12.5 ± 5 kHz from any frequency which is an integral multiple of 25 kHz, and may be used by aeronautical radio services licensed by the FCC or operated by the United States Government or its agencies.

In the aeronautical radio navigation bands, 108-118 MHz and 328.6-335.4 MHz, higher powered carriers may be operated at frequencies offset by 25 ± 5 kHz from any frequency that is an integer multiple of 50 kHz.

Carriers with peak power greater than -20 dBm (28.75 dBmV) are prohibited within 100 kHz of 121.5 MHz and within 50 kHz of 156.8 MHz and 243.0 MHz.

For the special provisions permitting higher powered operation by cable TV systems using HRC channeling plans, refer to FCC Rules and Regulations, Section 76.612 [7].[9]

The critical areas of the spectrum are in Channels A2, A1, A, B, and C, which cover the band from 108-136 MHz. In this band lie the air signal distress and air traffic control frequencies, which clearly must be kept as free from interference as possible. While the recommended frequencies for broadband physical layer devices defined in IEEE 802.3b and 802.4 do not encompass this critical band, there may be other data communications devices that are capable of transmission on these frequencies and that produce signal levels that should be of considerable concern.

If such devices are to be used, the system operator is advised to examine other options before placing signals in the band of 108-136 MHz, as well as refer to FCC Second Report and Order in Docket 21006 [8], adopted October 1, 1984, and modified in June 1985.

3.3.4 Pilot and transponder frequencies

System pilots are used to provide reference for Automatic Gain Control (AGC) and Automatic Slope Control (ASC) circuits. These circuits automatically compensate for coaxial cable attenuation changes due to frequency and temperature (e.g., cable attenuation changes [in dB] of about 1% for each 10 ˚F or 2% for 10 ˚C temperature change).

Not all systems require pilots for automatic control (e.g., a very small system, or one located entirely within a temperature-controlled environment, may not require compensation or may be compensated by “open-loop” thermal sensors).

Pilot carriers on a single cable system are located within the inbound and outbound paths. There may be one or two carrier wave (CW) pilots, for each path, depending on the manufacturer’s slope compensation (ASC) techniques. They are placed at frequencies corresponding to video carriers close to the lower band-pass edge and/or as close to the upper band-pass edge as is practical. In a two-pilot system, the wide separation is used to accurately determine the cable “slope” change, which is the difference in cable attenuation between the highest and lowest frequency signals in the system. Single pilot systems may also correct for slope changes using a programmed slope compensated gain control technique. Video carrier signals may also be chosen as a pilot frequency.

[9]The FCC Rules and Regulations referenced in this document were adopted in 1985, superseding the previous rules requiring 100 kHz offsets from actual aeronautical assignments within 60 nmi (nautical miles), and prior to approval for the use of carrier power greater than -20 dBm.

The user/designer should be aware that there can be adjacent channel rejection interference in some AGC/ ASC equipment. The pilot receivers within the AGC/ASC circuits may respond to adjacent channels. The designer will need to carefully monitor vendor requirements to make sure the AGC/ASC requirements are satisfied. It is recommended that status monitoring equipment manufacturers limit the receive bandwidth of future AGC/ASC receivers to less than the standard channel bandwidth (FCC and the National Television System Committee [NTSC] “6 MHz” TV channel in the US) for all LAN compatible products.

A dual cable system normally uses the same pilot frequencies for both the inbound and outbound paths. For a single cable system, inbound and outbound pilot frequencies are necessarily different. In either system, the inbound pilot generators, unlike outbound pilot generators, may be installed at the remote points of several branches. The pilots will then combine and interact at points where these branches combine. In order to guarantee that inbound pilots combine in a predictable and repeatable manner, the use of notch filters at the branch combiners is required. The inbound channels that contain pilot frequencies will be unavailable for use by services on the system.

Recommended pilot frequencies for inbound and outbound pilots are listed in Table 7. For a dual cable system, it is anticipated that the lower pilot frequency will be between 11.75 and 17.75 MHz.

3.3.5 Ingress accumulation

The problem of ingress noise in the inbound path has been extensively discussed within the CATV industry and by potential users of the broadband coaxial cable medium. Concern is focused on the inbound frequency range of 5-30 MHz, which does not effect IEEE 802.3b and 802.4 services but may effect video or narrowband services. Frequencies on the cable plant of less than 30 MHz coincide with transmissions from potential ingress noise sources, such as amateur radio, international shortwave, citizen’s band, and standard timekeeping transmissions. The extent of the problem varies enormously with the system size, quality, and location of the cable plant. High power lines and noise-generating equipment may interfere with the lower frequencies of a cable plant. These interferences seldom affect frequencies above 30 MHz.

Table 7—Recommended pilot and status monitoring frequencies

Single cable		**Mid-split (MHz)**	**High-split(MHz)**
Inbound	Lower:	5.00-11.75	5.00-11.75
	Upper:	102.00-108.00	150.00-186.00
Outbound	Lower:	168.00-186.00	222.00-240.00
	Upper:	300.00-400.00 +	300.00-306.00
			378.00-400.00 +
Dual cable			
Inbound and Outbound		Lower:	5.00-17.75
			95.75-101.75
		Upper:	300.00-400.00 +

NOTE—The status monitoring command channels and the pilot frequencies must coexist with each other and with any data or video services present on the cable. Allocation of pilot and transponder frequencies should not conflict with the system “services.” The level of the pilot should be such that the system dynamic range (signal levels through the amplifiers) are properly controlled.

It can be shown experimentally that the levels of such noise and discrete interfering tones, even in small systems, can preclude the use of TV, and may have an undesirable effect on certain types of data transmission in the range of 5-30 MHz. However, low-speed, narrow bandwidth data transmission using Frequency Shift Keying (FSK), Phase Shift Keying (PSK), or Binary Phase Shift Keying (BPSK) modulation schemes may tolerate the levels of noise commonly encountered in the most unfavorable conditions. It is, therefore, suggested that the channels in this frequency range be reserved for such transmissions.

NOTE—Most interfering noise in broadband coaxial cable systems is avoidable. When interference occurs, it is usually curable. Attention to the quality of construction can significantly reduce interference. Consideration of component selection, cable routing, and routine maintenance can avoid most interfering noises.

3.3.6 Off-air channels ingress

Systems that have adequate shielding effectiveness may suffer from off-air TV channel interference if the transmitter has sufficient power or is close to the cable plant. When local transmitters leak into a cable plant, off-air ingress is the result. A channel may be rendered unusable if the interference is sufficiently large. Ingress that exceeds the normal operating levels of the amplifiers may require protective steps to prevent amplifier overload. If excessive inbound ingress occurs, band-traps may be placed in the system to prevent signal accumulation and overload.

3.3.7 Ingress monitoring

It is recommended that an ingress monitoring schedule is established to prevent unchecked degradation in cable plant performance. For susceptible cable plants located in areas of high signal levels, ingress monitoring may be a useful tightness indicator of system connections.

3.3.8 Secured bandwidth

Essential services, such as energy management systems or encoded data transmissions, may be hidden from distribution system to prevent access or accidental interference. The process of trapping bandwidth to prevent user access is called secured bandwidth. The security of the bandwidth is normally ensured by placing traps at building entrances or remote headend locations.

3.4 Spectrum allocation

3.4.1 Single and dual cable systems

Figure 1 shows that two-way transmission using a single cable is accomplished by forfeiture of a guardband range of frequencies between the inbound and outbound paths. The diplexers employed in single cable amplifiers are typically 6-pole elliptic filters with a minimum stopband rejection range of 40-45 dB. To ensure adequate isolation between inbound and outbound paths, a crossover region is a necessity. The crossover region is removed from a single cable system and, therefore, is not usable for network services.

In a mid-split system, the usable bandwidth in the inbound path is capable of accommodating up to 17 channels. Practical considerations may restrict the capacity to 11 channels. For fully interactive communications services, this may be the limiting factor of system capacity since the band-pass of the outbound path may be as high as 550 MHz. Only channels that can be paired with inbound channels may be used by two-way data devices, effectively limiting the system services. See Table 6.

3.4.2 Allocating IEEE 802.3b services

The IEEE 802.3b standard provides for a broadband interconnection using binary Differential Phase Shift Keying (DPSK) modulation, with a bandwidth of 18 MHz. Six possible overlapping triple-channel “slots” are available in the inbound (transmit) spectrum, and are paired with corresponding slots in the outbound (receive) spectrum. Note also that translation schemes of 156.25 MHz and 192.25 MHz are supported. The 192.25 MHz offset is suggested for new system design.

IEEE 802.3b supports dual cable systems where the transmit and receive signals (carried on separate cables) are designated as the same channel. The designer may select one of twelve triple-channel slots: six in the low-VHF band, and six in the superband.

NOTE—The six low-VHF slots have band-edges that are offset by 0.25 MHz relative to the transmit slot recommended for a single cable system. The actual RF carrier frequencies are identical for both dual and single cable systems.

The complete list of frequency options for IEEE 802.3b services are summarized in Table 8.

3.4.3 Allocating IEEE 802.4 services

The IEEE 802.4 standard employs duobinary Amplitude Modulated Phase Shift Keying (AM/PSK) modulation technique that approximately provides 0.8 bit per hertz spectral efficiency. The transmission bandwidths of 1.5, 6, or 12 MHz support data transmission rates of 1, 5, and 10 Mb/s, respectively. If a 5 Mb/s service (6 MHz channel) is chosen, the standard designates six possible channels in the inbound range, each paired with a corresponding 6 MHz channel in the outbound spectrum. When using a 12 MHz bandwidth, two adjacent 6 MHz channels are combined, providing three channel options in the inbound spectrum paired with corresponding adjacent channels in the outbound spectrum.

The dual cable channel selections provide twelve channel options that may be used for IEEE 802.4 services. Channel options of the IEEE 802.4 services are shown in Table 9 where six channels are allocated in the low-VHF band and six channels are allocated in the superband. When using a 12 MHz bandwidth, two adjacent channels are combined, supporting up to six (10 Mb/s) IEEE 802.4 services. The single cable transmit and receive frequency options may also be used on a dual cable system with the single cable remodulator.

Table 8—Channel allocations for IEEE 802.3b services

	Transmit MHz	Receive MHz		
		156.25 Offset		192.25 Offset
Transmit and receive channel options for IEEE 802.3b services (Single cable plant)	1) 35.75-53.75	192.00-210.00	or	228.00-246.00
	2) 41.75-59.75	198.00-216.00	or	234.00-252.00
	3) 47.75-65.75	204.00-222.00	or	240.00-258.00
	4) 53.75-71.75	210.00-228.00	or	246.00-264.00*
	5) 59.75-77.75	216.00-234.00	or	252.00-270.00
	6) 65.75-83.75	222.00-240.00	or	258.00-276.00
				*(Preferred)
	Transmit and receive			
Transmit and receive channel options for IEEE 802.3b services (Dualcable plant)	1) 36.00-54.00			
	2) 42.00-60.00			
	3) 48.00-66.00			
	4) 54.00-72.00			
	5) 60.00-78.00			
	6) 66.00-84.00	(Preferred)		
	7) 228.00-246.00			
	8) 234.00-252.00			
	9) 240.00-258.00			
	10) 246.00-264.00	(Preferred)		
	11) 252.00-270.00			
	12) 258.00-276.00			

3.4.4 Allocating other services

Data transmissions (point-to-point and multi-point) using robust modulation schemes may be allocated to Channels T-8 through T-10 inbound and 11 through J outbound. The potentially noisy environment of the 10-30 MHz band should be utilized by a service that can tolerate a low signal-to-noise ratio and high group delay environment.

Channels A2, A1, A, and B may be used by narrow-band, voice, or supervisory signals where the signal levels are lower than the 6 MHz carrier power. The restrictions on signal level, defined by FCC or other regulatory agencies, should be observed.

3.4.5 Other countries

The recommended frequencies, herein, for transmission of IEEE 802.3b and 802.4 network services may be utilized on cable plants installed in other countries. However, channel boundaries, bandwidth, and allocations may conflict with local standards.

3.4.6 Protocol timing limitations

Refer to IEEE 802.3 [1] and IEEE 802.4 [2] for specific requirements pertaining to propagation delay that establish limits for the distance of operation on the cable plant.

3.4.7 Group delay distortion

In cable systems, filters can introduce significant group delay distortion near the band-pass edges. Diplex filters, power chokes, equalizers, high-pass filters, low-pass filters, and notch filters may introduce group delay that requires consideration at the time of service configuration. Each service should be configured in such a way that meets the device specification for maximum permissible group delay.

Table 9—Channel allocation for IEEE 802.4 services

	Transmit MHz	**Receive MHz**
Transmit and receive channel options for IEEE802.4 services (Single cable plant)	1) 59.75-65.75 2) 65.75-71.75 3) 71.75-77.75 4) 77.75-83.75 5) 83.75-89.75 6) 89.75-95.75	252.00-258.00 258.00-264.00 264.00-270.00 270.00-276.00 276.00-282.00 282.00-288.00
	Transmit and receive MHz	
Transmit and receive options for IEEE 802.4 services (Dual cable plant)	1) 59.75-65.75 2) 65.75-71.75 3) 71.75-77.75 4) 77.75-83.75 5) 83.75-89.75 6) 89.75-95.75 7) 252.00-258.00 8) 258.00-264.00 9) 264.00-270.00 10) 270.00-276.00 11) 276.00-282.00 12) 282.00-288.00	

NOTE—For 10 Mb/s transmission, channels are paired as follows: 1-2, 3-4, 5-6.

The effect that group delay distortion has on data signals depends on the nature of the modulation technique. In general, phase non-linearity results in inter-symbol interference (ISI), and thus contributes to the bit error rate. The influence of differential group delay distortion on video transmissions is termed chroma delay. Chroma delay is defined as the difference in time between the luminance and chrominance signals over the video passband. It is perceived by the viewer as misregistration of color. Performance objectives set forth by NCTA state that a chroma delay magnitude of 150 ns is perceptible and objectionable.

The group delay characteristics for several mid- and high-split amplifiers is shown in Table 10. The worst-case composite performance of these amplifiers is shown in Fig 2. The group delay distortion will accumulate in proportion to the amplifiers in cascade. It should be noted that the total differential delay for a cascade of 16 amplifiers with in-line equalizers could produce distortion of 180 ns over a 6 MHz channel near band-edges. This magnitude would certainly cause problems with high-speed data services as well as for AM-VSB video services. It is recommended that high-speed data services be allocated to portions of the spectrum that provide minimal group delay.

Table 10—Differential delay distortion for amplifiers

Single amplifier group delay for two diplex filters (in nonoseconds from band-edge to band-edge)							
Frequency (MHz)	**Mid-split amplifiers**			**High-split amplifiers**			**Composite data**
	A	**B**	**C**	**A**	**B**	**C**	**Mid-/high-splits**
35.75-41.75	0.3	1.0	1.0	0.1	1.0	1.0	1.0/1.0
41.75-47.75	0.4	1.0	0.0	0.2	0.5	0.5	1.0/0.5
47.75-53.75	0.5	1.5	0.3	0.1	0.5	0.5	1.5/0.5
53.75-59.75	0.7	1.5	1.5	0.2	0.5	0.5	1.5/0.5
59.75-65.75	0.9	2.0	1.5	0.2	0.5	0.5	2.0/0.5
65.75-71.75	1.3	2.0	1.5	0.2	0.5	0.5	2.0/0.5
71.75-77.75	1.6	2.5	1.5	0.3	0.5	0.5	2.5/0.5
77.75-83.75	2.2	2.5	1.5	0.3	0.5	0.0	2.5/0.5
83.75-89.75	3.5	2.0	1.5	0.3	0.5	0.0	3.5/0.5
89.75-95.75	5.0	2.5	1.0	0.3	0.5	0.0	5.0/0.5
192-198	-1.25	-1.0	-0.5				-1.25
198-204	-1.0	-0.9	-0.5				-1.0
204-210	-0.9	-0.9	-0.5				-0.9
210-216	-0.8	-0.7	-0.5				-0.8
216-222	-0.7	-0.6	-0.5				-0.7
222-228	-0.65	-0.5	-0.5				-0.65
228-234	-0.5	-0.5	-0.5	-4.9	-6.0		-0.5/-6.0
234-240	-0.5	-0.5	-0.5	-3.4	-5.0	-9.0	-0.5/-4.0
240-246	-0.35	-0.5	0.0	2.5	-4.0	-4.0	-0.5/-4.0
246-252	-0.35	-0.5	0.0	-1.85	-3.0	-2.0	-0.5/-3.0
252-258	-0.3	-0.5	0.0	-1.4	-2.2	-3.0	-0.5/-3.0
258-264	-0.3	-0.5	0.0	-1.2	-1.7	-2.0	-0.5/-2.0
264-270	-0.3	-0.5	0.0	-0.8	-1.5	-1.0	-0.5/-1.5
270-276	-0.25	-0.5	0.0	-0.6	-1.2	-1.0	-0.5/-1.2
276-282	-0.15	-0.5	0.0	-0.6	-1.0	-1.0	-0.5/-1.0
282-288	-0.1	-0.5	0.0	-0.6	-1.0	-1.0	-0.5/-1.0

NOTE—Group Delay polarity indicates from lower to upper band-edge frequency.

The composite group delay distortion shown in Fig 2 may be used as a guide to indicate safe and unsafe operating configurations of IEEE 802.3b and 802.4 services. Estimates for the typical upper limit of amplifiers in cascade may be made using the composite amplifier data. Maximum amplifier cascade for IEEE 802.3b and 802.4 services are shown in Table 11.

The table indicates that the media may support cascade lengths of up to 10 amplifiers for IEEE 802.3b services. The typical amplifier spacing of 1800 ft would produce a length of 18 000 ft. This distance is greater than the protocol timings limitations for the IEEE 802.3b service. The actual distance supported on a cable plant may be specified in terms of bit times traveling through the media, or propagation delay of the media. In any case, the limiting condition of group delay accumulation or media propagation delay must be observed to ensure the proper operation of the service.

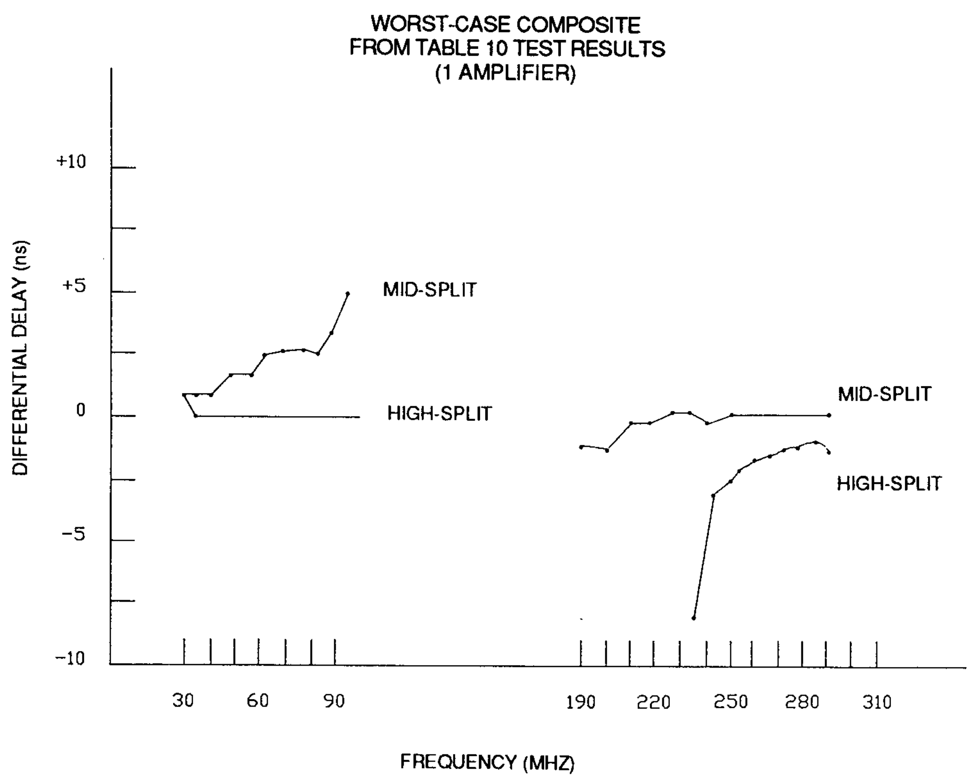

Figure 2—Composite differential group delay distortion

3.5 Initializing services

Services should be introduced on to the cable system in a controlled manner. As new or additional services are introduced on to the cable system, the operation of the services should be tested for suitable operation, performance, and error rate. This practice will identify problems prior to the use of a device on a large scale, when problem isolation may be more difficult. Two common problems that often cause interruption of network services are modems with high transmit levels, and maintenance sweeping of active data channels. Installation and maintenance of cable plant devices should be scheduled, and supervised by the network manager.

3.5.1 Calibrating services to rms power

The calibration of signal levels for IEEE 802.3b, IEEE 802.4, and other services should be related to CW power level. This may be accomplished by using the appropriate bandwidth scaling factor and normalization factors. In some cases the measurement may be made with a known modem signal level (i.e., a calibration carrier) and the appropriate conversion factor (i.e., average power for the scrambled IEEE 802.4 signal is approximately 3 dB lower than the power measured during the transmission of unscrambled ones). Video services should be calibrated to peak unmodulated carrier.

Table 11—Maximum amplifier cascade for IEEE 802.3b and 802.4 services

Service		TX band (MHz)	Mid-split/high-split amplifiers	
			156 MHz frequency offset	192 MHz frequency offset
IEEE 802.3b	10 Mb/s	35.75-53.75	8 (N/R)	10(1)
		41.75-59.75	8 (N/R)	8(1)
		47.75-65.75	6 (N/R)	6(2)
		53.75-71.75	5 (N/R)	5(3)
		59.75-77.75	5 (N/R)	5(4)
		65.75-83.75	4 (N/R)	5(6)
IEEE 802.4	10 Mb/s	59.75-71.75		7(6)
		71.75-83.75		6(11)
		83.75-95.75		3(15)
IEEE 802.4	5 Mb/s	59.75-65.75		30(20)
		65.75-71.75		30(30)
		71.75-77.75		24(40)
		77.75-83.75		24(50)
		83.75-89.75		17(60)
		89.75-95.75		12(60)

()—number of amplifiers for a high-split system
N/R—not recommended

NOTE—The cable system should be evaluated for group delay performance before IEEE 802.3b and 802.4 devices are placed into service. The analysis presented may not represent actual system constraints. It is recommended that group delay calculations be made prior to assigning a service to a particular channel.

3.5.2 Good neighbor policies

Good neighbor policies ensure that devices attached to the network do not interfere with other services on the network. The system integrator should verify that a broadband modem is IEEE 802.7 cable plant compatible. Modem parameters that should be evaluated include return loss, shielding, spurious output, transmitter spectrum shape, and receiver dynamic range specifications.

The introduction of new services on a network should be performed in a controlled environment. Each new service should be checked for spectral occupancy, operating levels, and noninterference with adjacent services. The specification for outlet-to-outlet isolation is given in Section 2 as 25 dB, and is considered adequate for these recommended practices. However, spurious output can increase above tolerable levels if modems are introduced that have high transmitter levels.

3.5.3 Amplifier overload

The system designer, being aware of amplifier operational specifications, should specify an amplifier level that considers channel loading and the inbound dynamic range when devices are transmitting properly. A power margin should be provided to ensure that an expected deviation from the nominal will not cause distortion or noise problems.

The opportunity to increase transmitter power exists for a very large number of users, and it is unreasonable to expect that only one user in a given system will do so, either deliberately or accidentally. Therefore, the knowledge of the internal operating levels of the system is of little help in defining an “excessive” transmitting power for any one user. The only safe and reasonable course to pursue is one which ensures that all transmitting levels are maintained at the values specified in 2.4.

3.6 Spectrum maintenance

After a cable plant has become operational, and the services on the network have been checked for proper operation, a maintenance plan should be initiated. The cable plant spectrum should have an appropriate frequency plan that designates the bandwidth occupied by network services. Monitoring the frequency plan for changes in distortion, noise, signal, or ingress levels should be part of the scheduled maintenance plan.

3.6.1 Spectrum monitoring

Broadband equipment manufacturers have developed remote system diagnostic aids, referred to as “status monitoring,” and spectrum monitoring devices. These devices provide the ability to monitor the frequency spectrum, monitor amplifier conditions, and control the inbound path. Status monitoring systems with switching capability may disconnect inbound paths by means of control commands sent to the devices.

Monitoring devices that are fitted with transponders are given a unique address which may be polled by a headend controller. Devices that may have intelligent transponders are amplifiers, amplifiers with redundancy features, power supplies with battery backup, redundant power supplies, redundancy (or A/B) switches, modems, and remote spectrum monitors. Stand-alone transponders establish basic communication capability by sending regular keep-alive messages. Circuitry in intelligent transponders may obtain various performance parameters associated with the monitored device, and provide control functions that change the configuration of the device.

3.6.2 Status monitoring

Status monitoring provides information that enhances cable plant reliability. The parameters given in Section 7 provide information that may be expected from a status monitoring system. Because status monitoring indicates the general location of faults or failures, maintenance staff can be sent directly to the problem site, reducing the time for location and repair of the cable plant (MTTR).

3.6.3 Use of inbound switching

Inbound switching aids diagnosis and maintenance by significantly reducing the time to locate and isolate problems. The maintenance staff may systematically use switching to identify a problem or identify the trouble area during system servicing. Isolation of the noise interference may be isolated and prevent service disruption by isolating the system through inbound switching.

The localization of ingress by switching is initiated by the control of a remote attenuator located in the inbound path. When using on-off switching to localize problems, services on the cable are disrupted. Using attenuators, the same localization can be accomplished by monitoring for a slight ingress level reduction, identifying the problem leg. The level reduction will not normally affect service operation allowing the identification of problems without service disruption.

Isolation of an individual distribution leg should cut the system off from disruptive interference levels. This action allows the majority of the system to operate, while localizing the area of system requiring repair.

Once the problem has been located using switching, the on/off switch may be used to isolate the problem from the system.

3.6.4 Status monitoring channels

If the status monitoring or inbound switching functions, or both, are required as part of a broadband LAN installation, the frequency allocations for transponder signaling are shown in Table 7.

4. Documentation

This section provides guidance in the documentation necessary to design, install, test, and maintain a broadband coaxial system.

The documentation generated for an IEEE 802.7 cable plant may be generated by several different groups of individuals or companies. It is important that the documentation be self explanatory. The goal of any portion of the documentation package is to allow persons unfamiliar with the system to work efficiently and effectively, solely by using the documentation provided.

4.1 Tracking system

The documentation should provide an efficient tracking system of the documentation package. The tracking system should include a table of contents, page numbering to total pages, revision level, date, and appropriate referencing to other required documentation or materials.

4.2 Design package

The designer is required to generate a specification for the system that clearly indicates the designed performance of the cable plant. The documentation should have revision numbering to track changes of the cable plant. The system description should contain a description of the system defined during the site survey and requirement definition phase.

The designer of a cable system may require architectural and site drawings of the facility. The drawings should detail the routing of all existing utilities, points of access to buildings, location of buildings, and the required user outlet locations. This information should be verified during the site survey.

The designer must provide drawings in sufficient detail so as to support third party installation. The design package shall be complete and comprehensive, as it establishes the authoritative source of information for the installation, certification, and operation of the network. Modifications to the design documentation should carry the authorization of the cable plant designer to be considered valid.

4.2.1 Layout drawing(s)

Layout drawings shall indicate the geographical features of the cable plant. The layout drawings may require different levels of detail to indicate the location and identification of every portion of the system. The drawings should indicate map features that include location, distances, direction, the location and component tags for components, cable routing, and test points.

4.2.2 Alignment specifications

The alignment specifications shall identify test points and provide procedures that will achieve the proper system balancing. The specifications should indicate target levels and allowable installation error.

4.2.3 Power/grounding system detail(s)

The power/grounding system detail drawing(s) shall indicate important aspects of power flow and grounding requirements. These drawings should indicate the location of all power supplies, power blocking devices, and safety information that is required at the time of installation and test. Systems incorporating coax power supplies should include a power calculation table that indicates amplifier voltage and total power supply currents.

4.2.4 Bill of materials

The bill of materials should list all components to be installed, including recommended initial spares, and pads and equalizers required for system alignment. The list should contain quantity, part number, manufacturer, and description.

4.2.5 System design parameters

The design parameters should describe any deviation or enhancement made to the specifications of the IEEE 802.7 cable plant. This should be made if any provision had to be made at the time of design to accommodate features or functions that are different from IEEE 802.3b and 802.4 services.

4.2.6 System schematic drawing(s)

The purpose of a system schematic drawing(s) is to provide information defining the design of the system. The drawing package should have an overview drawing that identifies the individual schematics that define the entire system. The overview drawing should provide continuity between detailed and full-scale drawings. Information contained on the system drawings must be accurate and complete. The drawings may, when sufficiently complex, be separated into more than a single sheet. The electrical schematic provides the design information relating component specification, configuration, and operation conditions. The installation drawings contain information required for the construction of the cable plant. The installation drawings should clearly indicate component grade and location. The drawings should have a title block that clearly identifies the purpose of the drawing. Each set of drawings for a given system should include the following minimum set of information.

4.2.6.1 Drawing key

A drawing key should identify all drawings of the document package. Each drawing should be identified by type (schematic, bill of material, installation detail), use (design, instruction, installation, as-built), title, and current revision level. All drawings in a sequence should be related by title or sequence number. The drawing key should also include a symbol table to identify components used in the system. Drawings that identify the headend and key service installations should include the description (headend, amplifiers, test point) and the location in the drawing title block.

4.2.6.2 Scale

Each drawing should clearly indicate the distances of construction interior and exterior (aerial and underground) details. All dimensioned drawings shall indicate a drawing scale. The preferred drawing scale is from 2:1000 to 1:2500 for outside systems. Indoor drawings may vary from 1:8 to 1:32, depending on building size.

4.2.6.3 Location identification tags

The location of each device (active and passive) should be identified. This may entail a physical description of the building, area, or room at which a given component is located.

4.2.6.4 Component identification tags

All components should be labeled using a component identification scheme that is consistent for all drawings and tables. Furthermore, the scheme should be explained in the design package.

4.2.6.5 Amplifier table

The amplifier table should identify the component identification tag, the amplifier manufacturer model and type, bandwidth, path of use (inbound or outbound), pad values, equalizer type, input level, output level, frequency level relationship, and test point level if required.

NOTE—The symbols used on the drawings and schematics should conform with the NCTA graphic symbols guidelines [6].

4.3 Installation documents

Prior to installation, the installer is required to have the design package, the architectural drawings (complete with construction details), the installation sheets (available from the component manufacturer), and pertinent customers agreements that relate to the quality, coordination, or responsibilities of the installer.

The installation phase does not generate a significant amount of documentation. However, deviations or changes made to the design package must be recorded. The design package and the changes generated and proved at the time of certification define the as-built documentation. The accuracy of these drawings will be critical to future maintenance of the system. Changes to component locations, test point locations, cable routing, or the addition of new components and splices shall be noted.

4.4 Certification report

The certification process verifies that the system meets the design specifications. Testing of the specifications, and performance of the system design and installation, are normally a part of the certification process. The as-built documentation is required to specify and perform the system certification.

The certification report is the test report that establishes the proper operating configuration of the system components. Adjustments made to the design package and as-built prints should be made in the certification report. The certification report should address all the items mentioned in the medium testing section. The results should be assembled and presented to the system owner for their records.

The certification report should be updated after repairs or additions are made. The new report should be compared to the original (or most recent) certification as well as to the design specifications.

4.5 Maintenance records

Maintaining a cable plant requires that the as-built drawings be maintained and revised to indicate any changes made during the operation and maintenance of the system. A log should be maintained to record all maintenance activity. All user complaints should be recorded, and relevant IEEE 802.3b and 802.4 device error counters should be monitored to help identify potential problems that could be analyzed as a trend.

A report of the results/findings of any alignment tests shall also be made. The report shall record the output signals at strategic points in the system. The maintenance record should begin with a copy of the alignment report. The test point record will be used as a repair indicator. The record will also be used to verify repair actions. The test file records should include update sheets that indicate system maintenance or modifications.

Updates should be marked “current” or “historical” to maintain an accurate event log. Also see 3.1 and Section 7.

5. Installation guidelines

The information and procedures presented in this section set forth recommended medium construction practices for an IEEE 802.7 broadband coaxial medium. The majority of the information is presented in chronological order. The installation and management recommendations of this section may not be appropriate for a small system.

5.1 Construction practices

Construction and installation of a broadband coaxial cable system follows the same basic practices and principles as other types of medium. The issues related to the management of installation are the planning, scheduling, progress reviews, testing, and documentation. Experience in installation of broadband systems is essential for a successful installation. A system that is properly constructed will provide years of maintenance-free operation.

One can obtain documentation and guidelines on specific aspects of broadband installation in the bibliography in Appendix C. The bibliography includes reading material and the national electrical and safety codes, ANSI C2-1990 [B1] and ANSI/NFPA 70-1990 [B2].

5.2 Site preparation

Preliminary Requirements: It is recommended that the following be completed prior to the start of construction. These items are proposed as guidelines for construction management.

— Consult applicable local, state, and national codes, such as ANSI C2-1990 [B1] and ANSI/NFPA 70-1990 [B2].
— Building Permits
— System Drawings
— Contracts
— Installation Notification — Advise other departments that construction will begin and will affect their area.
— Hardware Procurement — Ensure that the materials, tools, and installation devices (cones, signs, protective devices) are at the job site and ready for use.
— Insurance — Bonds and insurance certificates have been reviewed and filed with the site and system owners.
— Safety — Ensure the safety of all personnel according to local and national safety organizations, such as the Occupational Safety Health Administration (OSHA), and verify that personnel have been properly trained to use the equipment and to install the materials.
Bonding and grounding shall comply to the prevailing local and national electrical and safety codes.
— Component Installation — The installation of components, including but not limited to cable, amplifiers, and power supplies, should adhere to the manufacturer’s procedures. Failure to do so may require repair or replacement.

5.3 Aerial installation

Since aerial construction involves very specific terms and construction methods, it falls outside the scope of this document. Information on aerial construction is located in the bibiography in Appendix C.

5.4 Underground construction

In the situations where the cable is installed below grade, the following procedures should be observed:

- A soil evaluation should be performed for large underground projects to determine the content of the soil for proper component selection.
- Use sweeping 90 degree conduits to avoid cable damage during installation.
- Before digging, have the construction areas marked out to show where and how deep other services exist, such as water, power, gas, sewage, and telephone lines.
- It is recommended that coaxial cables be buried below the frost line. All burial cable that is not installed in conduit should be constructed of armored jacketed flooded cable.
- Underground cable should not be spliced except in manholes, pedestals, or inside buildings.
- Active devices can be installed in underground environments; however, access and future maintenance should be considered. In some cases, it may be better to install active devices at locations convenient for service access.
- Do not leave trench areas, man-holes, or any other below-grade construction unattended. Supervision should be continuous until the surface has been properly restored. Below-grade construction represents a hazard to small children requiring appropriate site safety.
- Restoration of the property should include back-filling and grading of the property. The property should be left in a state equivalent to the original condition.
- Ensure that all construction areas are kept as clean as possible at all times.
- Observe all national safety regulations as required (e.g., ANSI C2-1990 [B1], ANSI/NFPA 70-1990 [B2], OSHA). It is important that man-hole operations employ the proper ventilation, gas detection, and hoist equipment.
- Situations requiring design deviations should require written approval prior to the installation of a change.

5.5 Building construction

Building design and local electrical codes will be a significant factor in the routing of a cable. The scope of this recommended practices document cannot cover every building situation that could be encountered, but, in general, the following practices are required.

5.5.1 Semi-rigid cable installation

Trunk and feeder cables are to be pulled in continuous sections only and are to be free of splices, except for the insertion of active or passive components.

- Cables laid in building air ducts or passages should be of approved plenumtype only. Consult local and national building codes for specific restrictions.
- Cables routed in suspended ceilings and floors should be mechanically secured.
- All cable equipment components should be firmly attached to the building structure.
- Observe the manufacturer's minimum bending radius for the cable.
- Periodic grounding of the trunk and feeder cable should be specified in the installation details. Each cable building attachment should be grounded in accordance with community and national requirements, e. g., Article 820.7 of ANSI/NFPA 70-1990 [B2]. Situations where long cable runs are pulled and not grounded until the next day should be avoided, since an intervening lightning storm could charge the cable.
- Expansion loops for semi-rigid cable should be used at amplifiers, taps, splitters, structural flex joints, building expansion joints, and other locations where cable stress is probable.

5.5.2 Flexible cable installation

Proper care must be used in preparing and installing RG-type cables. The installation of flexible cables requires the allocation of a service loop at each end of the cable.

Cables should be clearly identified on each end with a numbered marker placed at each end of the cable. Similar connections at multiple ports of the same device may require unique identification of each cable connection. Cable runs of significant length (user outlet port) require individual numbers for each connection to a multi-tap or splitter. Individual numbers will eliminate the need to disconnect all wires to identify a single cable fault. Inbound and outbound cables should be identified as such in a dual cable system.

Use a cable preparation procedure recommended by the cable connector manufacturer. The F-type connector should incorporate a crimp sleeve integral with the connector body or be constructed in a fashion that provides equivalent signal leakage performance. The prepared cable end should be attached to the proper port and securely tightened using the torque recommended by the connector manufacturer.

Drop or trunk cables shall not be attached with fasteners that physically distort the cable. Cables that have structural return loss problems must be replaced.

5.5.3 Miscellaneous guidelines

A colored identifier may be placed where components are not visible. The identifier should not significantly affect the aesthetics of the surrounding areas. For example a ceiling tile installation may incorporate colored dots on cross members to minimize component location time. Different colored dots may be used to identify different component types.

All user outlet ports should be properly labeled to identify the outlet as part of the broadband local area network.

6. System test

This section defines broadband coaxial system tests recommended for IEEE 802.7 compliance. Section 6 is divided into four subsections that define installation, activation, certification, and optional tests.

The installation tests describe the verification of proper component installation, function, and workmanship.

The activation tests describe the process used to prepare the broadband cable system for certification. This process includes applying power to the cable system, removing frequency response anomalies, and alignment of the frequency/amplitude response characteristics of the system. This process also includes fault isolation and functional operation of all system components.

The certification tests demonstrate the performance of the system. The certification process should verify that the design, installation, and activation of the cable system meet the specified performance criteria of IEEE 802.7.

Optional tests describe the quality control measures that may be requested by the user. The results of cable plant testing should adhere to Section 4 requirements.

6.1 Installation

6.1.1 Cable reel test

Cable testing for structural return loss should occur prior to installation. Visual inspection of all coax concentricity shall be performed. (This requires a small section of cable cut from the reel at both ends.) Attenuation and structural return loss characteristics shall be measured per cable manufacturer's recommendations while the cable is still on the reel. Structural return loss over the operational bandwidth of the system shall meet 30 dB for semi-rigid cable and 26 dB for flexible cable. The test described will usually identify damage occurring during transportation.

6.1.2 Installed cable test

Any cable installed by a method that could conceivably cause degradation to the cable (such as pulling through conduit that contains bends and curves) shall be tested for structural return loss. The installed structural return loss for any cable shall be 26 dB across the operational bandwidth of the system.

6.1.3 Visual inspection

A series of visual inspection activities should be performed. The items below represent a minimum set of verification activities:

1) Documentation must be available and complete.
2) The installation must correlate with the system design. Check that the component value, location, direction, mounting, and access are according to design and acceptable. The cable type and rating should be as specified in the system design and meet the applicable codes for the environment for which it is installed. The cable routing and labeling should match the as-built drawings for future maintenance operations.
   Inspect installation for applicable standards of workmanship and neatness.
3) All points of system entry must be terminated.

6.1.4 Grounding test

The system shall be inspected to ensure that the grounding required by the system design has been properly installed and conforms with local and national codes. The grounding lines should be measured for proper impedance and continuity. The grounding test should be performed prior to the application of power to the cable plant.

6.1.5 Voltage test

This section is applicable for systems where power flows through coaxial cable—

1) Verify that the alternating current (ac) blocking components are installed and prevent hazardous ac voltage through F-type connectors.
   Verify that terminations are ac blocking or use appropriate voltage blocking techniques to prevent hazardous conditions upon application of system power.
2) Verify that voltage range settings, fusing, and power routing devices are properly installed and match the design.
3) Remove the power passing plugs/fuses from each coax-powered active device (amplifier or status monitor) on the network.
4) Prior to the connection of power to coax-powered devices, the system may be tested for a short circuit at the transformer and at amplifier locations.

Energizing cable plant power—

5) Once power has been successfully applied to the system, verify the ac continuity and powering of each coax-powered device throughout the system.

NOTE—The ac voltage available to powered cable devices should be above the minimum specified by the system designer or equipment manufacturer. The following measurement approach is recommended:

6) Activate the coax-powered devices one at a time by inserting the power plugs/fuses.
7) Verify ac voltage levels on the cable at each device between the appropriate test point and the chassis.
8) Verify proper power supply operation at each powered location by the appropriate test or indicator. Improper powering may create a fire hazard. The proper operation of the power supply should be tested immediately upon application of ac power to the device.
9) Verify that each amplifier has the appropriate regulated supply outputs. This test may be made at the appropriate test point.
10) Once coax power has been verified to the extremities of the system, the voltages at the amplifiers and currents of the power supplies should be measured and recorded.

NOTE—Systems that use ac line power do not require the voltage test procedures identified above, but should include, at the minimum, an ac line voltage and an amplifier dc voltage test, as mentioned above.

6.1.6 Sweep test

The cable system frequency response should be tested by sweeping the system band-pass. The cable plant should be swept in segments to avoid masking imperfections by response equalization. The test should include sweeping at locations that verify the integrity of installed semi-rigid cable connections. Connections that introduce reflection generated response variations shall be corrected prior to system alignment.

6.2 Activation

6.2.1 System alignment

System alignment is the process of adjusting active and passive devices to establish the proper response for a specified stimuli. The alignment process is accomplished by adjusting levels and frequency response characteristics of amplifiers and passive devices to balance the characteristics throughout the system. The alignment of outbound and inbound paths is accomplished by injecting specific levels at specified locations and adjusting the gains and slopes of amplifiers, equalizers, and taps. The proper system balance will achieve the specified system performance of Section 2 between the headend and outlet ports. The balanced system should be documented at the amplifier input and output test points, for the specified frequencies, in order to identify the conditions that establish a properly aligned system.

6.2.2 Alignment verification test

Alignment verification determines conditions that identify a properly aligned system. The verification testing should include the designer specified tests, conditions, locations, levels, and frequencies to calibrate the cable plant. The alignment testing should indicate conformance to the cable plant design. The verification includes the following tests that are performed within the system certification bandwidth:

1) Path loss in the inbound and outbound paths should be verified between the headend and the user outlet ports, as designated by the system designer.
2) System flatness and frequency response should be acceptable throughout the system.
3) The amplifier levels, and calibration information should be documented in the form specified in the design documentation.
4) Test points should have the appropriate signal levels

5) A signal level test of the outlet should be made to verify connection to an active cable plant. The test should be made with a signal level meter or a spectrum analyzer. The outlet should be terminated if it is not of the self-terminating variety.

NOTE—The designer should be consulted if the specified system performance cannot be verified.

6.3 Certification

Certification testing ensures that the cable system meets end user requirements. The certification testing is performed after the conclusion of alignment verification testing. The documentation, performance, and operation of the system services should be checked and verified to be acceptable. The certification process is considered for the cable plant, and for the support of the services that use it.

6.3.1 Path loss test

Path loss testing should be performed for single and dual cable systems between the designated headend and user outlet ports. The path loss test should demonstrate conformance of the cable plant.

6.3.2 Loop loss test

Loop loss testing should be performed for dual cable systems between the transmit and receive ports at the designated outlets. The loop loss test should demonstrate conformance of the cable plant.

6.3.3 Carrier-to-noise test

The carrier-to-noise measurements should be made with an inbound carrier level at the headend inbound port of 3 dBmV, and an outbound headend port injection level of 54 dBmV. The inbound and outbound CNR should be measured and recorded for all extremities of the cable plant. The test should include measurements for all cascades of amplifiers. The measurement should also verify path loss conformance to establish valid CNR measurement. The test should be made for single and dual cable systems.

6.3.4 Loop carrier-to-noise test

The loop carrier-to-noise measurement should be made for dual cable systems. The test should verify the loop CNR performance with an injected level of 54 dBmV at any user outlet port. The test should include measurements for all cascades of amplifiers.

6.3.5 Distortion

Amplifiers are not perfectly linear and therefore distort a signal as it passes through the amplifier. When signals are passed through an amplifier, the distortion characteristic causes the formation of harmonics and intermodulation products. The strength of the distortion products are dependent on the signal levels that are passed through the amplifier. Measuring the difference between these unwanted signals and the reference test signal(s) determines the carrier-to-harmonic or intermodulation ratio. To ensure that the system does not exceed the maximum distortion specification, a series of tests are required.

Tests should demonstrate the presence of second order distortion and discrete third order effects. The test should be performed with either two or three carriers, respectively. The CW carriers should be injected at the maximum permissible levels at the worst-case branch (minimum path loss) and longest amplifier cascade and measured at the headend outlet ports for the inbound path. For the outbound path, the carriers are injected at the headend outlet port at the maximum permissible levels and monitored at the end of the longest cascade's worst-case (minimum path loss) branch.

The tests should be performed for the inbound and outbound paths of single and dual cable systems.

6.3.6 Hum modulation

Hum modulation should be measured through all cascades of amplifiers to verify that hum is below the specified levels.

6.3.7 Frequency response test

System response sweep testing should be performed at representative interfaces throughout the system in order to verify the usable system bandwidth and the frequency response in the inbound and outbound paths for single cable systems. The frequency response should be tested for the loop path for the dual cable system.

6.3.8 Egress test/signal leakage

With CW signals injected at any point on the cable system and at any frequency in the specified band, RF emanating from the cable system shall not exceed the maximum allowable limits when measured within a resolution of 30 kHz. The RF signal leakage limits shall conform to applicable regulatory standards. See Table 3.

6.4 Optional tests

6.4.1 Ingress

Ingress is the measurement of the cable shielding effectiveness. An RF signal source with known field strength should be monitored and equated to the cable system level at the inbound headend ports and the outbound user outlet ports. The ingress level from the known source gives an indication of shielding effectiveness at the test frequency. Also see 3.6.1, spectrum monitoring.

6.4.2 Component sampling

Because failure rates are very low for CATV devices, the testing of the components individual specifications is generally considered optional. Pre-installation testing may identify a mislabeled or defective lot of components. If pre-installation lot sampling is required, the testing procedures may be obtained from the component manufacturer.

6.4.3 Functional verification test

A set of deliverable system functions should be tested to demonstrate acceptable operation to the end user. These tests are intended to verify operation of hardware that might not be tested for function.

- — Headend combiner ports
- — Unused cable runs
- — Test points
- — Redundant amplifiers or switching systems
- — Backup power systems
- — Expansion ports
- — Taps not connected to outlets
- — Status monitoring devices

6.5 Reference

6.5.1 Equipment accuracy

Prior to the start of testing, test equipment should be calibrated or certified to be in calibration during the time of use on the cable system.

6.5.2 Specification measurement

Specifications measured on the cable plant should be made with defined test configurations from appropriate sources. Several recognized sources are *Cable Television System Measurements Handbook* [B12], *No Loose Ends, The Tektronix Proof-of-Performance Program for CATV* [B17], *NCTA Recommended Practices for Measurements on Cable Television Systems* [5]. When measuring a parameter, relative errors of the test configuration should be removed to ensure optimum accuracy. One common source should be used for every measurement configuration, and its accuracy should be traceable to the National Institute for Standards (NIST), formerly known as National Bureau of Standards (NBS).

7. Maintenance

This section is intended to provide guidance for the maintenance of installed IEEE 802.7 media. Maintenance of the medium should include preventative maintenance functions and remedial correction work. This section also presents media monitoring system information. The management and monitoring of services are beyond the scope of this document. Information on monitoring IEEE 802.3b and 802.4 services is located within P802.1, Local Area Networks: Architecture and Overview.[10]

7.1 Purpose

The purpose of the cable plant maintenance program is to minimize downtime. The proper maintenance and monitoring will identify degradation that could influence services on the network. While the inherent nature of broadband is to be highly reliable, certain applications place additional MTBF and MTTR requirements on the media. In order to establish the reliability requirements, the applications for the medium should be reviewed, and the appropriate maintenance plans, contracts, and equipment should be considered.

Effective system maintenance plans ensure system integrity and address the cost of preventive and redundant coverage versus the downtime cost for a given system application. Items to consider in determining the scope of a maintenance program should be the following:

- System application
- System management facilities
- Potential causes of failures
- Potential cost of application loss
- Mean Time To Repair (MTTR)
- Mean Time Between Failure (MTBF)
- Cost of protective measures

The evaluation should weigh the prospective cable plant reliability against the uptime requirements for a given application. A cost analysis should be performed for strategic services on the cable system. The prospective cost of the preventative maintenance plan should be compared to the cost incurred during the loss of a critical application. In this manner, the proper system investment into maintenance equipment and available personnel can be established. A maintenance contract that is established for the cable plant, and/or the

[10]See footnote 1.

entire system, should specify the scope, response, and schedule of service that is provided to the user. The factors in establishing the degree of maintenance should include the following:

— Systems employing noncritical, light load services should be maintained by a system manager with support from an outside maintenance firm.
— Systems employing critical, heavy load services, such as continuous production or factory automation, should have sufficient on-site personnel to respond immediately in the event of system failure.
— Systems employing services that operate in sensitive areas of government spectrum should be regularly monitored for signal leakage.
— Cable plants that have large geographic coverage may require a combination of internal and external expertise to design the maintenance plan.

7.2 Administration

The administration of the medium is an important consideration for long-term operation. The administration is the key control that determines system function, operation, and reliability. The system administration may be assigned to internal or external parties whose responsibilities include management of the cable network. The following activities are considered essential for control of large cable plant operations.

7.2.1 Record keeping

Regardless of the size of the broadband cable plant, proper record keeping must be established. The system documentation must be filed and kept current. The file should include, but not be limited to, changes, additions and repairs, design documentation, as-built blueprints, component documents, and problem determination logs and procedures.

7.2.2 Media manager

It is recommended that a single manager be assigned to the overall administration of the media. In the case where there are multiple media, a single point of contact for the broadband medium should be assigned in the organizational chart. The broadband medium manager's responsibilities include a central point of contact for the coordination of installation, operation, and maintenance pertinent to cable plant operations.

7.3 Monitoring

7.3.1 Path loss monitoring

Path loss monitoring is considered to be a test that is part of a maintenance plan. Path loss monitoring may be a scheduled maintenance test that is performed manually or has automatic monitoring devices at locations that monitor amplifier levels and/or path attenuation.

There are path loss errors that cannot be demonstrated at the time of system acceptance, including temperature effects, component aging, drift, and AGC/ASC tracking errors. The overall path loss tolerance during operation of the cable plant is ± 5 dB. When path loss variations are greater than ± 5 dB, the system should be realigned.

7.3.2 Automated system monitoring

Advances in status monitoring systems offer a means to remotely monitor integrity of the system. Typical monitoring systems include transponders that communicate with a controlling headend modem that is connected to a computer system. The controlling computer polls each transponder in the system, which in turn responds with information about the status of the transponder and the device. This information is stored and compared to additional polling information to develop an operating history. Changes in the monitored parameters are logged and reported to the system manager for diagnosis and corrective action. Additionally, the status monitor can detect and log faults and parameters that exceed user-defined thresholds.

7.3.3 Automated monitoring

Monitoring a system may be of particular concern if the uptime of critical services is required. The monitoring may be measured by manual or automated spectrum analysis instruments. The signal levels and ingress tests are normally documented for historical reference, to monitor for a progressive increase in ingress.

7.4 Status monitoring

A recommended minimum set of parameters that should be measured, controlled, and reported by each status monitoring transponder are as follows:

a) *RF Measurement* — One RF measurement in the inbound and outbound path. This measurement provides the user with the capability to monitor each path, to analyze and trace signal levels (transponder or pilot carriers), to detect degrading levels, and to provide corrective actions.
b) *Power Supply Measurement* — One power supply measurement. This measurement allows the user to monitor power supply voltages and detect failures or degradations that enable the user to take corrective action at the problem location.
c) *Alarm Levels* — The ability to set major and minor alarm levels on each measurement in (1) and (2). This feature provides an automatic alarm that informs repair personnel that a condition exists that requires immediate attention. Audio and visual alarms should be provided.
d) *Alarm Disables* — The ability to individually enable/disable each alarm. This feature allows the user to disable the alarm on a unit that is being removed for service or testing.
e) *Other Alarms* — If the transponder is used with trunk amplifiers, it should also report status, and provide alarms for—
    1) *Lid Closure* — This status allows the user to detect an open housing (a possible source of ingress) and correct the condition before the system is degraded.
    2) *Inbound Path Switch Status* (if an inbound switching capability is provided) — The status of feeder switches is used to ensure that the switch position is in the desired state.
    3) *Redundant Amplifier Status* (if a redundant amplifier capability is provided) — Notifies the user that the backup amplifier is in use so that corrective maintenance can be scheduled.
    4) *Control Inbound Feeder Path Switch* (if an inbound feeder path switching capability is provided) — Used at the central monitoring point to perform fault diagnosis and ingress source determination.
f) *Backup Power* — If the transponder is used with backup power supplies, it should also report status and provide alarms for—
    1) *Backup Supply Status* — Notifies the user that the backup supply is in use so that corrective maintenance can be scheduled on the primary.
    2) *Backup Supply Test* — Enables a test of the backup mode.
g) *Redundancy Switches* — If the transponder is used with redundancy switches, it should also report status and provide alarms for—
    1) *Switch Status* — Notifies the user that the redundant component(s) are in use so that corrective maintenance can be scheduled on the primary.
    2) *Switch Position* — The control facility should provide the capability to set the redundancy switch position.

Appendixes

(These Appendixes are not a part of IEEE Std 802.7-1989, IEEE Recommended Practices for Broadband Local Area Networks, but are included for information only.)

Appendix A

Abbreviations and acronyms

ac	alternating current
AGC	Automatic Gain Control
AM/PSK	Amplitude Modulated Phase Shift Keying
ASC	Automatic Slope Control
BPSK	Binary Phase Shift Keying
CATV	Community Antenna TeleVision
CLI	Cumulative Leakage Index
CNR	Carrier-to-Noise Ratio
CTB	Composite Triple Beat
C/H	Carrier-to-Hum ratio
C/N	Carrier-to-Noise ratio (CNR)
CW	Carrier Wave
dB	deciBel
dBm	deciBel referred to 1 mW
dBmV	deciBel referred to 1 mV
dc	direct current
DPSK	Differential Phase Shift Keying
EIA	Electronic Industries Association
FCC	U.S. Federal Communications Commission
FDM	Frequency Division Multiplexing
FM	Frequency Modulation
FSK	Frequency Shift Keying
HRC	Harmonically Related Carriers
Hz	Hertz
IEC	International Electrotechnical Commission
IRC	Incrementally Related Carrier
ISI	Inter-Symbol Interference
kHz	kiloHertz
LAN	Local Area Network
MATV	Master Antenna TeleVision
MAU	Media Access Unit
MHz	MegaHertz
modem	MOdulator-DEModulator
MTTR	Mean Time To Repair
MTBF	Mean Time Between Failure
NCTA	U.S. National Cable Television Association
OSHA	U.S. Occupational Safety and Health Administration
PSK	Phase Shift Keying

RFI	Radio Frequency Interference
RF	Radio Frequency
TDM	Time Division Multiplexing
UHF	Ultra-High Frequency
VHF	Very High Frequency

Appendix B

Design calculations

This appendix defines common design practices and equations that relate to broadband systems. The calculations illustrated represent common RF design equations.

Conversion Factors for dBm and dBmV

As previously stated, 0 dBmV = 1 mV across 75 Ω. Another commonly used unit is the decibel referred to 1 mW, abbreviated dBm, and defined as

number of dBm = 10 log (P/1 mW)

where

P power in milliwatts

This equation provides a positive value when P is greater than 1 mW, and a negative value when P is less than the reference value of 1 mW.

A useful equation relates dBmV and dBm. This equation is based on an assumed impedance value. The common value for CATV systems is 75 Ω. For a 1 mV drop across a 75 Ω resistor, the power consumed can be calculated and converted to dBm.

Given 0 dBmV = 1 mV across 75 Ω,

$$P = V^2 / R = 1.3(10)^{-8} \text{watts}$$

$$P = 10 \log(1.3(10)^{-8} / (10)^{-3}) \text{dBm}$$

$$P = -48.75 \text{ dBm}$$

Therefore, 0 dBmV = -48.75 dBm in a 75 Ω system

Thermal Noise Definition

The basic definition of thermal noise power is

$$P_n = kTB \text{ watts}$$

where

k	$1.38(10)^{-23}$ joule/°Kelvin (Boltzmann's constant)
T	ambient temperature in °Kelvin
B	bandwidth in Hertz

When room temperature is assumed (293 °Kelvin),

$$P = 4.1B(10)^{-21} \text{ watts (at T = 300 °Kelvin)}$$

Converting this to dBm gives

$$P_n = 10\log(4.1B(10)^{-21}/(10)^{-3})$$

$$P_n = -174 + 10\ \log(B)\ \text{dBm}$$

A noise level in dBmV can also be calculated:

$$E_n = -174 + 10\ \log(B) + 49\ \text{dBmV}$$

$$E_n = -125 + 10\ \log(B)\ \text{dBmV}$$

The minimum noise level (noise floor) for a 4 MHz channel can be found:

$$E_n = -125 + 10\ \log 4 \times 10^6$$

$$E_n = -59\ \text{dBmV}$$

Carrier-to-Noise Ratio Calculations

The noise output of a single amplifier, E_{N1}, is

$$E_{N1} = E_{nf} + G + F_o\ \text{dBmV}$$

where

E_{nf}	noise floor
G	amplifier gain
F_o	amplifier noise figure

The carrier-to-noise ratio of one amplifier (C/N_o) is

$$C/N_o = S - E_{n1}$$

$$C/N_o = S - E_{nf} - G - F_o$$

$$C/N_o = E_{nf} + A - F_o$$

where

S amplifier output level
A amplifier input level

For example, if noise floor is -59 dBmV, input level is 10 dBmV, and F_o is 7 dB, C / N_o = -(-59) + 10 - 7 = 62 dB

In a cascaded system where N is the number of cascaded amplifiers,

$$\text{system noise figure} = F = F_o + 10\ \log(N)$$

$$\text{system } C/N_o = -E_{nf} + A - F$$

$$= -E_{nf} + A - F_o - 10\ \log(N)$$

$$= C/N_o - 10\ \log(N)$$

Appendix C

Bibliography

[B1] ANSI C2-1990, American National Standard National Electrical Safety Code.

[B2] ANSI/NFPA 70-1990, National Electrical Code.

[B3] Arnold, Bert. Third Order Intermodulation Products in a CATV System. *IEEE Transactions on CATV*, April 1977, pp. 67-80.

[B4] Bell Labs. *Transmission Systems for Communications*. Fourth Edition, 1970, Chapter 10, pp. 237-43.

[B5] Comm/Scope Marketing, Inc. *CATV Cable Construction Mini Manual*, Catawba, North Carolina 28609.

[B6] Cooper, Bernarr. *ITFS Instructional Television Fixed Service (2500 Megahertz), What It Is—How to Plan*. National Education Association, Washington, DC, 1967.

[B7] Cooper, Edward B. *Broadband Network Technology*. Prentice Hall and Sytek Press, #83-51319, 1983.

[B8] Copperweld Bimetallics Group. *Practical Grounding*. Publication No. 143-4-79. Copperweld Steel Company, Pittsburgh, PA, 1972.

[B9] Cunningham, John. *Cable Television*. Second Edition, #21755, Indianapolis, Howard W. Sams & Co., Inc., 1980.

[B10] General Instrument Corporation, Jerrold Division. *CATV Reference Guide*. RD-14, Hatboro, PA, 1983.

[B11] Grant, William. *Cable Television*. Prentice-Hall, 1983.

[B12] Hewlett Packard. *Cable Television System Measurements Handbook*. #5955-8509, Santa Rosa, CA, Hewlett-Packard Co., 1977.

[B13] Lessman, Anthony M. Subjective Effects of Delay Difference Between Luminance and Chrominance Information of the NTSC Color Television Signal. *Journal of the SMPTE*, August 1971, pp. 620-23.

[B14] Olszewski, J.A. and H. Lubars. Structural Return Loss Phenomenon in Coaxial Cables. *Proceedings of the IEEE*, July 1970, pp. 1036-62.

[B15] Powers, Robert S., Ralph A. Haller, and Jean E. Adams. Airspace Fields Due to Signal Leakage from Cable Television Systems. *IEEE Transactions on CATV*, October 1980, pp. 169-89.

[B16] Salvati, M. J. *RF Interference Handbook*, New York, Sony Corporation of America, Technical Publications Department, 1977.

[B17] Schrock, Clifford B. *No Loose Ends, The Tektronix Proof-of-Performance Program for CATV*. Tektronix Application Note, Revised 1983, #26W-5260.

[B18] Simons, Ken. *Technical Handbook For CATV Systems. Third Edition*, #436-001-01, Hatboro, PA, General Instrument Corporation, Jerrold Division, 1968.

[B19] Simons, K.A. The Decibel Relationships Between Amplifier Distortion's Products. *Proceedings of the IEEE: Special Issue on Cable Television*, July 1970, p. 1071.

[B20] Simons, K.A. The Optimum Gain for a CATV Line Amplifier. *Proceedings of the IEEE: Special Issue on Cable Television*, July 1970, p. 1050.

[B21] Taylor, Archer. *Characteristics of Cable TV Network and the Transmission Media for Data*. IEEE 0733-8716, 1985.

<u>NCTA Technical Papers—Conference Proceedings from the Annual NCTA Convention</u>

[B22] Braun, Warren L. A New Active CATV System Echo Testing Technology. *NCTA Technical Papers*, June 1984, p. 33.

[B23] Bruce, Ronda M. Remote Diagnostics for Off Premises Cable Systems. *NCTA Technical Papers*, March 1986, pp. 148-53.

[B24] Citta, Richard and Dennis Mutzabaugh. Two-Way Cable Plant Characteristics. *NCTA Technical Papers*, June 1984, pp. 270-77.

[B25] Crandall, Kenneth C. RF Modem Specifications . . . Testing Between the Lines. *NCTA Technical Papers*, June 1984, pp. 29-32.

[B26] Dickinson, Robert V.C. Current Configurations and Field Installations of Multiple Service Communications Systems. *NCTA Technical Papers*, June 1983, pp. 30-33.

[B27] Dickinson, Robert V.C. Local Area Networks and Cable Television. *NCTA Technical Papers*, March 1986, pp. 39-43.

[B28] Dusbabek, Lee M. Effective Status Monitoring Through Hierarchical Distributed Processing. *NCTA Technical Papers*, March 1986, pp. 154-57.

[B29] Ellis, Michael G. Effects of Channel Loading on Composite Triple Beat and Cross Modulation. *NCTA Technical Papers*, June 1985, pp. 88-95.

[B30] Groff, Donald E. Noise Figure Measurements on Distribution Systems. *NCTA Technical Papers*, June 1984, pp. 34-38.

[B31] Haller, Ralph A. The Cumulative Leakage Index (CLI) Made Easy. *NCTA Technical Papers*, June 1985, pp. 24-26.

[B32] Katz, Dr. Harold W. Thermal Noise Revisited. *NCTA Technical Papers*, June 1983, pp. 111-20.

[B33] Kellar, Bradford S. Measurement of Intermodulation Products Generated by Corroded or Loose Connections in CATV Systems. *NCTA Technical Papers*, June 1984, pp. 23-28.

[B34] Kostka, William G. Broadband Sweeping: A New Approach. *NCTA Technical Papers*, June 1985, pp. 83-87.

[B35] Marron, Henry B. and Andrew W. Barnhart. System Considerations in Design of a Two-Way Transmissions System. *NCTA Technical Papers*, June 1970, pp. 546-85.

[B36] Mitchell, J. E. Composite Second Order Distortion and Distribution System Performance. *NCTA Technical Papers*, June 1985, pp. 80-82.

[B37] Niraj, Jain, Tarek Saadawi, and Mischa Schwartz. Technical Considerations of Two-Way Interactive CATV. *NCTA Technical Papers*, June 1985, pp. 296-303.

[B38] Pidgeon, Rezin E. and David H. Slim. Frequency Allocation for Data and Video. *NCTA Technical Papers*, June 1983, pp. 64-68.

[B39] Polis, Thomas J. Data Network Parameters. *NCTA Technical Papers*, June 1983, pp. 44-47.

[B40] Quelly, M. and E. Frech. Contention vs. Polling, A Theoretical Look at Protocols in CATV Systems. *NCTA Technical Papers*, June 1983, pp. 53-58.

[B41] Reichert, Jr., Harry J. CATV System Return Path Interference. *NCTA Technical Papers*, May 1982, pp. 197-201.

[B42] Reichert, Jr., Harry J. The Magic Tee Amplifier and Distribution Systems. *NCTA Technical Papers*, June 1984, pp. 173-79.

[B43] Ridley, Jonathan R. Return System Sweep/Balance and Maintenance. *NCTA Technical Papers*, June 1983, pp. 228-32.

[B44] Schrock, Clifford B. Can Noise and Ingress Coexist with Two-Way Services? *NCTA Technical Papers*, May 1982, pp. 205-9.

[B45] Simons, Ken. Sweep Testing of Coaxial Cable. *NCTA Technical Papers*, July 1965, pp. I(185-98).

[B46] Stratton, Frank. Broadband Packet-Switching. *NCTA Technical Papers*, June 1985, pp. 304-7.

[B47] Vankoughnet, Jim B. A Broadband Network Status Monitoring System Using Multiple Processors. *NCTA Technical Papers*, June 1985, pp. 253-59.

[B48] Ward, Jr., John W. Ingress-Sources and Solutions. *NCTA Technical Papers*, June 1985, pp. 11-17.

[B49] West, Lamar. Standard Methods For Calculation of Carrier to Noise Ratio in Modern CATV Equipment. *NCTA Technical Papers*, June 1985, pp. 102-9.

Appendix D

Glossary

access method. A communication technique where data is allowed or disallowed access to a communication system.
active. A cable plant component that consumes electrical power to perform its intended function. Examples of active devices include status monitors and amplifiers.
address ID. An address ID is a unique digital identification sequence that is used to identify a device on a network.
allocation. The assignment of specific broadcast frequencies by a national organization (such as the FCC) for various communications uses (e.g., commercial television and radio, land-mobile radio, defense communications, microwave links). This divides the available spectrum between competing services and minimizes interference between them. The manager of a broadband network must allocate the available bandwidth of the cable among different services for the same reason.
amplifier. A device that increases the amplitude of an electrical signal. Amplifiers are placed in a cable system to strengthen signals weakened by cable and component attenuation.
attachment unit interface (AUI). The cable, connectors, and transmission reception circuitry used to interconnect the physical layer signaling and MAU.
attenuation. Attenuation is the quantity of reduction of a defined parameter. For this document, the parameter is expressed in dB.
attenuator. An attenuator is a two-port device that provide a fixed amount of signal loss over a wide range of frequencies (*attenuation*). These devices have identical attenuation in either direction.
balancing. Adjusting the gains and losses in each path of a system to achieve proper cable plant characteristics.
band-edge. The highest or lowest frequency passed for a defined range of frequencies. The band-edge frequencies are normally identified to be the half power points of a frequency band.
band-pass. A range of frequencies that express the difference between the lowest and highest frequencies of interest. The band-pass frequencies are normally associated with frequencies that define the half power points.
band-pass filter. A filter that allows passage of a desired range of frequencies and attenuates frequencies outside the desired range.
band-stop filter. A band-stop or band reject filter attenuates a desired range of frequencies and passes frequencies that are higher and lower than the rejection band.
bandwidth. The frequency range that a component, circuit, or system passes or uses. For example, voice transmission by telephone requires a bandwidth of about 3000 Hz (3 kHz). A television channel occupies a bandwidth of 6 000 000 Hz (6 MHz). Cable systems occupy 5-300 MHz or higher of the electromagnetic spectrum.
binary phase shift keying (BPSK). A specific form of PSK that defines two states of carrier phase that are digitally encoded in a binary data stream. The states have a change in phase of 180 degrees that corresponds to the 0 or 1 binary state.
bit error rate. The rate of errors to the total number of bits being sent in a data transmission from one location to another.
bridger (or bridging amplifier). The point of amplification of signals between a *trunk* and a *feeder* cable, usually consisting of an additional amplifier module fitted into a *trunk amplifier station*.
branch. A cable distribution line in a broadband coaxial network that is connected to a trunk line.

broadband. In general, wide bandwidth equipment or systems that can carry signals occupying a large portion of the electromagnetic spectrum. A broadband communication system can simultaneously accommodate television, voice, data, and many other services.
cable attenuation. (See *cable tilt.*)
cable powered. Supplying power to active CATV equipment (for example, amplifiers) from the coaxial cable. This ac or dc power does not interfere with the RF information signal.
cable tilt (loss). The amount of RF signal attenuation by a given coaxial cable. Cable attenuation is mainly a function of signal frequency, cable length, and diameter. Cables attenuate higher frequency signals more than lower frequency signals (*tilt*). Cable losses are usually referenced to the highest frequency carried (greatest loss) on the cable.
cable TV. Previously called *community antenna television (CATV)*. A communication system that simultaneously distributes several different channels of broadcast programs and other information to customers via a coaxial cable.
carrier-to-noise ratio (CNR). The carrier-to-noise ratio expresses the relationship between signaling and noise power on a communications medium. The ratio is normally referenced to a specific noise bandwidth that corresponds to the signaling bandwidth.
cascade. The number of amplifiers connected in series.
CATV. Community antenna television. (See *cable TV.*)
channel. The bandwidth required for the transportation of a signal. The bandwidth will vary according to the information being transported. A band of frequencies dedicated to a certain service transmitted on a broadband medium.
chrominance. The portion of a video signal that contains color information.
CLI (cumulative leakage index). CLI is a measurement of cumulative RF signal leakage of a cable system. The measurement is usually specified for a given area.
coaxial cable. A cable with two conductors where one completely surrounds the other. Coax cables are unbalanced transmission lines that have an outer conductor that shields the center conductor from electrostatic interference. The two conductors are spaced by an insulating dielectric that, depending on the mechanical and material configuration, affects the speed, attenuation, and impedance of transmission.
composite triple beat (CTB) distortion. The combination of all possible third order beat frequencies ($F_1 \pm F_2 \pm F_3$) that occurs within a channel of the cable plant.
composite video signal. The complete video signal. For monochrome systems, it comprises the picture, blanking, and synchronizing signals. For color systems it includes additional color synchronizing signals and color picture information.
cross-modulation distortion. Cross-modulation is the process where the modulation of one carrier is imposed onto another carrier. The exchange of modulation information involves the change of an amplifier's transfer characteristic brought about by a change in amplifier loading. The non-ideal amplifier has an associated compression and expansion characteristic that is dependent on amplifier loading. The change in load caused by the total power of signals and their modulation will create a variation in transfer gain. The change in load due to modulation change is normally the primary cause of cross-modulation. Broadband networks have data devices that have switched carrier transmissions that express cross-modulation as a change in transmission characteristics dependent on channel loading and traffic.
decibel (dB). A standard unit for expressing the ratio between two parameters using logarithms to the base 10. Decibels provide a convenient format to express voltages or powers that range several orders of magnitude for a given system.
dBm. Decibels relative to 1 milliwatt.
dBmV. Decibels relative to 1 mV across 75 Ω. Zero dBmV is defined as 1 mV across 75 Ω.

$$\text{dBmV} = 20 \log 10(V_1 / V_2)$$

V_1 is the measurement of voltage at a point having identical impedance to V_2 (0.001 V across 75 Ω).

diplex filter. A filter having a low pass and high pass filter that divide the frequency spectrum into two separate frequency bands that do not overlap. The conventional designation assigns the low band of frequencies to the inbound path, and the high band of frequencies to the outbound path. The diplex filter allows the placement of duplex signals onto a cable by the use of frequency division multiplexing.

directional coupler (tap). A passive device used in cable systems to divide and combine RF signals. It has at least three ports: line in, line out, and the tap. The signal passes between line in and line out ports with loss referred to as the insertion loss. A small portion of the signal power applied to the line in port passes to the tap port. A signal applied to the tap port is passed to the line in port less the tap attenuation value. The tap signals are isolated from the line out port to prevent reflections. A signal applied to the line out port passes to the line in port and is isolated from the tap port. Some devices provide more than one tap output line (*multi-taps*).

distribution amplifier. A high gain amplifier used to overcome high losses encountered in signal distribution. The generic term referring to any amplifier in a broadband coaxial system. In this document, the term signifies an amplifier which is used to operate at the higher levels that are normally associated with the distribution portion of the cable plant.

distortion. The creation of additional or undesired effects due to nonlinearities in the system. (See *intermodulation distortion, time distortion, composite triple beat distortion,* and *cross-modulation distortion*.)

downtime. The time interval during which a network is not available for access by the user.

drop cable. The cable assembly that connects a distribution tap to a user outlet. The cable is usually a flexible RG type 75 Ω coax.

drop line. The type or specific cable that is used in a drop cable.

dual cable. A type of broadband coaxial cable system that uses separate cables to carry the inbound and outbound signals.

echo. See *reflections*.

egress. The process whereby signals exit the cable system, i.e., signal leakage.

equalization. A technique used to modify the frequency response of an amplifier or network to compensate for variations in the frequency response across the network bandwidth. The ideal result is a flat overall response. This slope compensation is often done by a module within an amplifier enclosure.

F-type connector. A 75 Ω connector used to connect coaxial cable to equipment.

FDM. See *frequency division multiplexing*.

feeder (system). It is the portion of a broadband coaxial cable system that distributes signals to and receives signals from the user outlet ports. It is characterized primarily by the presence of cable taps and distribution amplifiers.

feeder maker. A splitting device used to provide multiple line connections from trunk amplifiers.

filter. A circuit that selects or rejects one or more components of a signal related to frequency.

flat loss. Loss created by a component or set of components that maintains a constant attenuation across a specified bandwidth.

flooded cable. A special coaxial cable containing a corrosion-resistant material between the aluminum sheath and the outer jacket. The corrosion inhibitor flows into imperfections in the jacket to prevent sheath corrosion in high moisture environments.

frequency. The number of times a periodic signal repeats itself in a unit of time, usually one second. One hertz (Hz) is one cycle per second. One kilohertz (kHz) is 1000 cycles per second. One megahertz (MHZ) is 1 000 000 cycles per second.

frequency division multiplexing (FDM). Dividing a communication channel's bandwidth among several sub-channels with different carrier frequencies. Each sub-channel can carry separate data signals.

frequency response. The change of a parameter (usually signal amplitude) with frequency.

frequency translation. Shifting the spectral location of a RF signal frequency from one location to another.

frequency translator. See *translator*.

good neighbor. A term used to describe "well-behaved" devices operating on a broadband medium that do not cause interference to any other service operating on the cable plant.

group delay. See *time distortion*.

guardband (channel). A designated unoccupied portion of the frequency spectrum that exists between two occupied portions of the spectrum.

harmonic distortion. A form of interference caused by the generation of signals according to the relationship N_f, where N is an integer greater than one and f is the original signal's frequency.

headend. The central location that has access to signals traveling in both inbound and outbound directions. The logical root of the broadband coaxial cable system.

hertz (Hz). A unit of frequency equal to one cycle per second.

high frequencies. Frequencies allocated for transmission in the outbound direction. In a mid-split broadband system, approximately 160-300 MHz or higher.

high-split. A frequency division scheme that allows two-way traffic on a single cable. Inbound path signals come to the headend from 5 to 174 MHz. Outbound path signals go from the headend from 234 MHz to the upper frequency limit. The guardband is located from 174 to 234 MHz.

hub. A central location of a network that connects network nodes through spokes. Similar to a headend for bi-directional networks except that it more often associated with a star architecture. A hub is usually a site that is responsible for providing services to headends located at remote sights. Microwaves or other communication methods may be used to connect the hub to a headend.

impedance. A measure of the complex resistive and reactive attributes of a component in an alternating current circuit.

inbound. The direction of RF signal flow toward the headend. Referred to in the CATV industry as "upstream" or "reverse."

ingress. The process whereby unwanted signals enter the cable system to occupy spectrum that would otherwise remain free of signal energy.

insertion loss. The loss of signal level in a cable path caused by insertion of a passive device. Also called *through loss*.

intermodulation distortion. Intermodulation distortion refers to the family of system performance impairments caused by the nonlinear transfer characteristic of a broadband system, which produces spurious output signals (called *intermodulation products*) at frequencies that are linear combinations of those of the input. The system output (S_o) can generally be related to the system input by the transfer equation:

$$S_o = AS_i + BS^2{}_i + CS^3{}_i$$

AS_i the fundamental signal term

The terms $BS^2{}_i$ and $CS^3{}_i$ represent the second order and third order distortion terms, respectively. The second order term produces a second harmonic frequency component for every input signal frequency and intermodulation frequency components of the form $f_1 \pm f_2$. The third order term produces a third harmonic frequency component for every input signal frequency and intermodulation frequency components of the form $f_1 \pm f_2 \pm f_3$ and $2f_1 \pm f_2$. Third order distortion also produces cross-modulation where modulation of one carrier can appear on another carrier on the system even when the second carrier is unmodulated when input into the system.

In CATV systems where the video carriers are spaced at 6 MHz intervals, the summation of the third order intermodulation distortion signals is called *composite triple beat distortion*. CTB can become significant when all distortion components fall near a video carrier. In CATV systems, it is common practice to specify composite triple beat and cross-modulation distortion, and design the cable system to meet these specifications. The amplifier distortion levels are specified by the manufacturer for a full channel load condition (a single video carrier in each 6 MHz channel at a given level).

In broadband systems, different types of carriers and modulation techniques may be operating on a cable system so that the composite triple beat and cross-modulation distortions are difficult to determine. In broadband systems it is common practice to design the system to composite triple beat specifications based on CATV practices. In addition, the carrier to discrete second order beat and third order beat ratios are specified.

The distortion ratios are specified independently under referenced conditions for the inbound and outbound paths. Inbound distortion is specified at the headend with signals injected prior to the most remote amplifier of the worst-case inbound path. Outbound distortion is specified following the most remote (from the headend) amplifier of the worst-case outbound path.

Second Order Distortion

This parameter describes the spurious signals that are produced as a result of the second order curvature of the transfer characteristic of the system components, when two discrete input signals are applied. The dominant members lie at frequencies given by

$F_{21} = |F_a + F_b|$ and

$F_{22} = |F_a - F_b|$

where

F_a and F_b the frequencies of the input signals

Third Order Distortion

This parameter describes the spurious output signals that are produced as a result of the third order curvature of the transfer characteristic of the system components, when three discrete input signals are applied. The dominant member lies at frequencies given by

$F_3 = |F_a \pm F_b \pm Fc|$

where

F_a , F_b , and F_c the frequencies of the input signals

ISO. International Standards Organization.
kilohertz (kHz). A unit of frequency equal to 1000 cycles per second.
line extender (amplifier). An RF amplifier required to compensate for losses in the *feeder system*.
loop loss. The difference in signal level for the inbound and outbound paths at a user outlet.
loss. See *attenuation*.
low frequencies. Frequencies allocated for transmission in the inbound direction in a mid-split broadband system, approximately 5-108 MHz.
main trunk. See *trunk line*.
MATV. Master antenna television system. A small television antenna distribution system usually restricted to one or two buildings.
MAU (Medium Attachment Unit). The MAU is the device that interfaces the communications system to the medium. The MAU incorporates the circuitry from the PLS (physical layer signaling interface) to the medium interface.
medium. The physical layer utilized to allow transmission of signals to communicate to various devices connected to it. For example, the medium of a CATV system is a broadband coaxial cable.
megahertz (MHz). A unit of frequency equal to 1 000 000 cycles per second.
midband. The part of the electromagnetic frequency spectrum that is located between television Channels 6 and 7.
mid-split. A frequency division scheme that allows two-way traffic on a single cable. Inbound path signals come to the headend from 5 to 108 MHz. Outbound path signals go from the headend from 162 MHz to the upper frequency limit. The guardband is located from 108 to 162 MHz.

modem. A modulator-demodulator device. The modulator encodes digital information onto an analog carrier signal by varying the amplitude, frequency, or phase of that carrier. The demodulator extracts digital information from a similarly modified carrier. A modem transforms digital signals into a form suitable for transmission over an analog medium.

modulation. Modulation is the method whereby information is superimposed onto a RF carrier to transport signals through a communications channel.

multi-tap. A passive distribution component composed of a directional coupler and a splitter with two or more output connections. (See *tap*.)

NIU. Network Interface Unit (see MAU).

node. A point of junction between two connectors. The location where a line has a defined position. The point where signals leave one system and enter another.

noise. Any unwanted signal in a communications system. White noise (or random noise) is random energy (e.g., shot noise and thermal noise) that has a uniform distribution of energy across the band-pass. The analogy for white noise is white light. Johnson noise (thermal) is the noise generated by electron movement (current through a resistor) above absolute zero. The noise level is proportional to temperature. Shot noise is the type of unrandom noise generated when current flows across an abrupt junction. Shot noise is characteristic of semiconductor devices.

noise factor. The noise factor is the ratio noise energy of the input to the output of a device. The noise factor has an associated bandwidth of measurement.

noise figure. The ratio of the total white noise energy at the output to the amount of Johnson noise at the output. The Johnson noise is due to the noise generated by the impedance of the signal source.

noise floor. The noise level at a referenced location and bandwidth. The video bandwidth is assumed to be a 4 MHz bandwidth. A terminated 75Ω cable operating at 68 ˚F or 20 ˚C has a 4 MHz noise floor of -59 dBmV.

outbound. The direction of RF signal flow away from the headend. Referred to in the CATV industry as "downstream" or "forward."

outlet. See *tap outlet*.

path loss. Path loss is the amount of attenuation between a headend port and a user outlet port.

passive device. A device that does not require power and contains no active components. The term encompasses taps, directional couplers, splitters, power inserters, and in-line equalizers.

pilot. A signal transmitted either inbound or outbound through the system in order to provide a reference for automatic gain or automatic slope control (AGC or ASC circuits within the amplifier).

port. A port is an electrical interface that has defined operating boundaries. The specific references within this document assume ports to be 75Ω transmission line interfaces that have an associated connector to which the signals pass.

reflections. Echoes created in a cable system by impedance mismatches and cable discontinuities or irregularities. (See *echo*.)

remodulator. A device located at the headend of a broadband coaxial cable system that receives inbound transmissions and converts them to outbound transmissions via an intermediate step in which the inbound signals are converted to the baseband level. The device may or may not perform operations on the contents of the baseband signal.

return loss. The degree of impedance mismatch for an RF component or system. The return loss term expresses the coefficient of reflection in decibels. At the location of an impedance mismatch, part of the incident signal is reflected back toward its source, creating a reflected signal. The return loss is the number of decibels that the reflected signal level is below the incident signal level.

return path. Direction towards the headend. (See *inbound*.)

RG. RG specifies a flexible type of coaxial cable. RG is a military term.

signal level. The measured voltage or power of a signal usually stated in dBmV.

single cable system. A type of broadband system that uses a single cable for the transmission of the inbound and outbound paths.

slope. The gain (or loss) versus frequency characteristic of cable, amplifiers, and other devices.

slope compensation. The action of a slope-compensated gain control. The gain of the amplifier and the slope of amplifier equalization are changed simultaneously to provide equalization for different lengths of cable; normally specified in terms of cable loss.

splitter. Splitters divide or combine power. The power division causes an insertion loss and a small amount of internal loss that contributes to the attenuation of the signals passing through the device. The splitter has a common port and split port(s). The signals between the common and split port(s) has an insertion loss of 10 log *n*, where *n* equals the number of power splits. The splitter also has an isolation that attenuates signals passing between port(s).

structural return loss. A term used to describe the structural integrity of the coaxial cable. Structural return loss defines impedance variation due to deformed coaxial cable concentricity.

sub-split. A frequency division scheme that allows two-way traffic on a single cable. Inbound path signals come to the headend from 5 to 30 MHz. Outbound path signals go from the headend from 54 to the upper frequency limit. The guardband is located from 30 to 54 MHz.

surge arrester. A device that protects electronic equipment against surge voltage and transient signals on trunk and distribution lines.

system acceptance. System acceptance is the formal approval of system operation parameters.

tap. A passive device in the feeder system that provides a connection between the drop cable and the feeder. The tap is the principal means of access to the cable system by the user. It removes a portion of the signal power from the distribution line and delivers it to the drop line. The amount of power tapped off the main line depends on the input power to the tap and the attenuation value of the tap. Only the information signal (and not 60 Hz power) goes to the outlet ports. (See also *multi-tap*.)

tap outlet. An F-type connector port on a tap used to attach a drop cable to an outlet.

terminator. A terminator is a single-port, 75Ω device that is used to absorb energy from a transmission line or RF device. Terminators prevent energy from reflecting back into a cable plant by absorbing the RF signals. A terminator is usually shielded, which also prevents ingress and egress from an unused port.

through loss. See *insertion loss*.

tilt. The relative level of multiplexed carriers with respect to a designated reference carrier. The gross difference in level between signals at the upper and lower frequency of the bandwidth of interest. (See also *cable tilt*.)

time distortion. Time distortion (group delay) is the difference in transmission time between frequencies of a service. The broadband service usually resides in a single channel, but the delay distortion may be specified over a bandwidth that is different than the bandwidth of the channel. Video specifies the time delay distortion to be less than a channel bandwidth. Video channels (6 MHz) normally specify the group delay between the video and color carriers (3.58 MHz). The delay distortion in video services may influence color rendition. In data services, group delay may influence the bit error rate. The specification for group delay must always be applied across a referenced bandwidth to be valid. This distortion is most prominent at the frequency band-edges of a diplex filter, but may also be observed in band-pass, band-stop, and equalizing filters.

time division multiplexing (TDM). Sharing a communication channel among several users by allowing each to use the channel for a given period of time in a defined, repeated sequence.

translator. A frequency conversion device located at the headend. Its sole purpose is to provide gain and convert inbound signal frequencies to the outbound frequency range.

transponder. A device that responds to a physical or electrical stimulus and emits an electrical signal in response to the stimulus.

trunk (system). That portion of a broadband coaxial cable system that serves as the RF signal path between the headend and the feeders.

trunk amplifier station. A low distortion amplifier that amplifies RF signals for long-distance transport. An active device designed to compensate for cable losses in the trunk system.

trunk cable. Coaxial cable used for distribution of RF signals over long distances throughout a cable system. Usually the largest rigid cable used in the system.

trunk line. The major cable from the headend to downstream branches. Also called *main trunk*.

unity gain. A design principle wherein amplifiers supply enough signal gain at appropriate frequencies to compensate for the system's cable loss and flat loss: cable loss + flat loss = amplifier gain.

user. An individual whose principal concern is the transfer of information through the system, and to whom the system is transparent. The user is assumed to be in possession of a device that is capable of one- or two-way communication through the system.

user outlet port. A broadband attachment location that provides connection access to the broadband coaxial cable system.