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Cable System Preparation Guide for Two-Way Data

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1 Introduction

With the advent of new digital services on the horizon, the cable operator will face new requirements in terms of system performance. This guide focuses on one of those new services, High Speed Digital Data over Cable.

This guide is intended to give the cable operator general information on plant preparation for two-way services. This guide is not intended as a replacement for existing system guidelines.

Throughout this document, we reference system specifications as dictated by the FCC (Federal Communications Commission) in the United States. In the international community, each country may have its own set of regulations for cable operators. These regulations should not differ too greatly from the FCC, but they may. This guide is a tool for deployment of two-way cable data services. When in doubt about key regulations, please check with your local engineering contacts about the applicability on cable data solutions in your system.

Current technical specifications for cable systems are dictated by the FCC. These specifications are for analog signals only. These specifications have evolved over the years to keep up with the technology advances in both cable systems and television receivers. The current rules were adopted in the early 1990s. The major specifications require that the total degradation through the cable plant be no worse than 43 dB carrier-to-noise ratio (C/N) and -51 dBc composite triple beat (CTB) and composite second order (CSO) distortion levels. Hum, frequency response, levels and various video parameters are also specified.

The FCC’s specifications include the contributions of headend equipment, distribution network and operator-furnished converters. Performance is to be measured under normal signal conditions. In order to meet the end-to-end requirements with adequate margin, the broadband distribution plant (from the output of the headend to the subscriber tap) is commonly designed to degrade the signal by no more than 48 dB C/N and 53 dB CTB and CSO (tested using unmodulated carriers).

The most common architecture for newly rebuilt or upgraded systems is known generically as Hybrid Fiber/Coax or HFC. In an HFC system the signals from the headend combiners are split to feed linear optical transmitters. The output from the transmitters are sent through optical fibers to nodes, where they are converted back into broadband RF to feed coaxial distribution networks.

One property of HFC systems is the ability to feed different signals to each node. Taking advantage of this network segmentation, operators can offer narrowcast services such as high speed data instead of strictly broadcast services. An important system parameter for subscriber-specific services is the amount of node-specific bandwidth (both downstream and upstream) divided by the number of customers per node.

2 Headend Distribution

1. Downstream Combining

In traditional headend design, all of the services are combined into a common spectrum for distribution to all nodes. This combining is represented in Figure 2-1. Special consideration has to be used when combining narrowcast services, as the same frequencies will carry different signals to different nodes. The combining must be done so that these channels do not interfere with each other. An example of narrowcast combining is shown in Figure 2-2. The combination of couplers, splitters and amplifiers used must provide at least 60 dB of isolation between nodes.

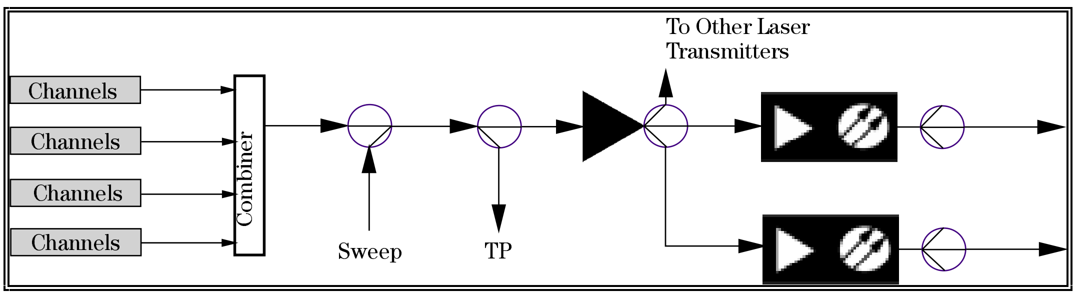

Figure 2-1 Traditonal Headend Combining

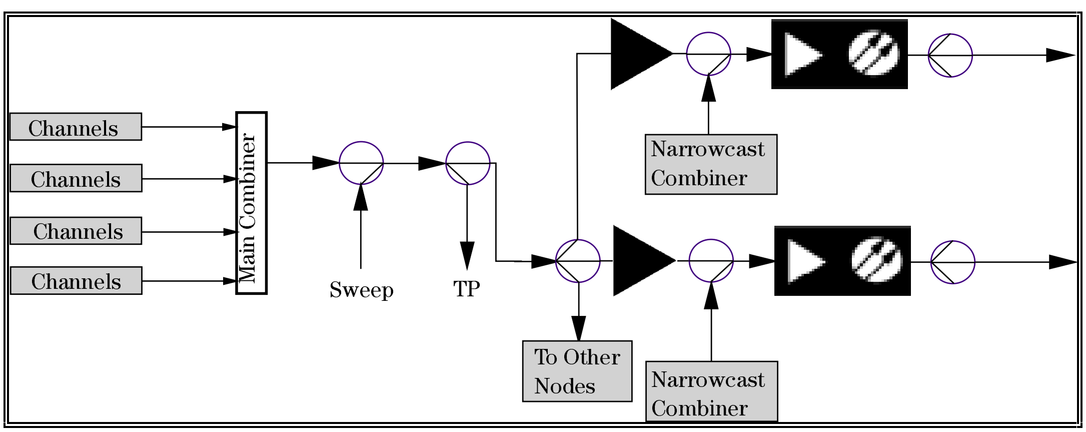

Figure 2-2 Headend Combining with Data Services

The final configuration is dependent upon the number of homes passed in the service area or node and the number of potential nodes that are served from the headend/hub.

Upconverter output levels should be set so that the digital data carrier level is approximately 10 dB lower than analog video levels.

2. Upstream Combining

Signals from the headend optical receivers may first be split to feed other upstream applications as shown in Figure 2-3. The data signals may then optionally be combined with those from other nodes before driving a data receiver. While this allows a greater number of subscribers to share a receiver port, it also combines the noise and ingress signals from the nodes.

As a second option, multiple upstream frequencies may be employed and a splitter used to drive multiple receiver ports. This increases the maximum possible upstream data rate as each receiver will independently support an additional data rate. Please check with your modem vendor to determine the best method for your system.

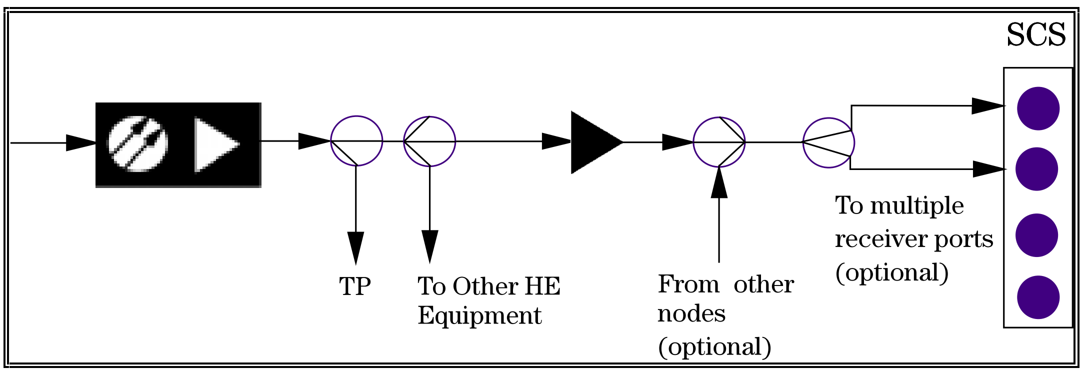

Figure 2-3 Upstream Combining

All of the above figures represent only simplistic examples of combining. Company engineering standards, as well as sound engineering practices, will dictate the final combining specifications. Key to successful operation of these networks is to maintain integrity and isolation of the combining networks and minimize additional noise and distortion components.

3. Planning for Orderly Growth

A single transmitter may provide a downstream data rate of about 30 Mb/s (about 27.5 Mb/s effective payload rate after FEC), while each receiver port may provide an upstream data rate of about 3 Mb/s (about 2.5 Mb/s effective payload rate after FEC). The number of data service subscribers that can be supported by these is dependent upon:

- The number of data subscribers
- The percentage of users who simultaneously wish to use the network

- The average upstream and downstream data rate per simultaneous user
- The effective return path characteristics.

a. Planning for Growth

In order that the system be re-configurable with minimal effort and data service interruption, operators may wish to route the outputs from all upstream optical receivers and the inputs to all data receivers to a common location (the Data Input Patch Panel) where sets of splitters and combiners can be configured as required.

Figure 2-4 shows a possible configuration of a panel which would allow combining sets of up to four nodes and use of up to eight upstream frequencies per set. Jumpers could be used to connect the various inputs and outputs to four-way combiners and eight-way splitters connected in pairs.

Similarly, the outputs of data upconverters and one input from each narrowcast combiner can be routed to a Data Output Patch Panel where appropriate transmitter splitters could be located.

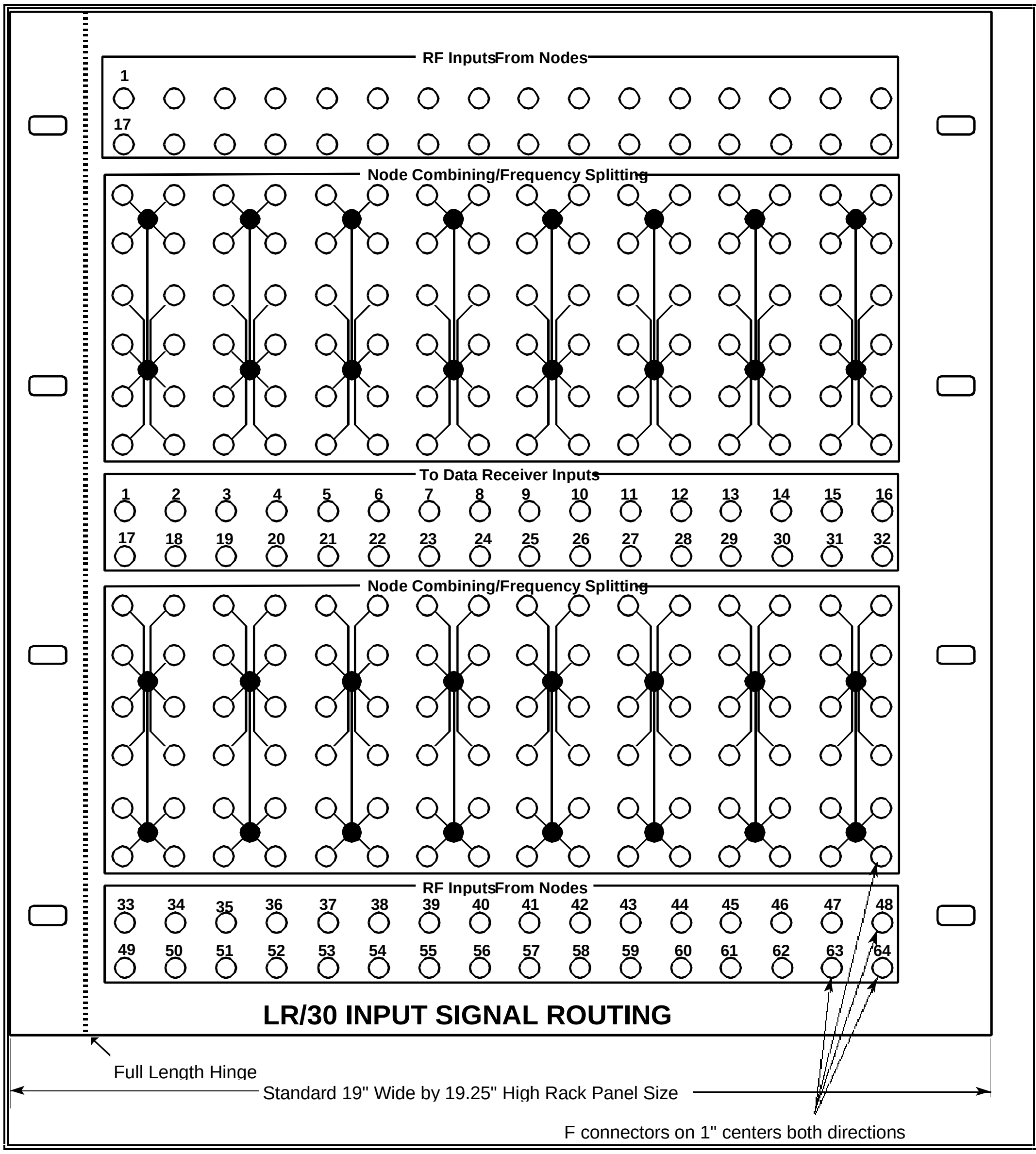

Figure 2-4 Suggested Data Input Patch Panel

3 Distribution Plant

A high-speed data over cable link is designed to be integrated into an existing HFC cable plant. The main area that may be new to the cable operator is the upstream, or reverse direction. This section will recapture the downstream specifications, highlight the upstream specifications, and discuss ongoing maintenance in the upstream. We will also discuss some concerns in the drop portion of the plant.

A. Downstream

1. Downstream Transmission Environment

“Downstream” describes that portion of the spectrum used for transmission from the headend to subscribers. HFC networks are broadband, linear systems. The basic signal multiplexing method is Frequency Division Multiplexing (FDM), in which each signal occupies a different portion of the total available bandwidth.

In the majority of HFC systems, this spectrum is primarily occupied by broadcast format analog (NTSC, PAL or SECAM) television signals. In the near-future, however, digitally-modulated carriers will be added to carry compressed cable television video services, High-Definition Television (HDTV) and Standard Definition Television (SDTV). Each carrier may contain the time-division-multiplexed combination of several video programs.

In addition to video signals the spectrum may be occupied by:

- Digital or analog audio services
- Wireline telephony services
- Packet data services
- Communications relevant to "interactive" television and information services

2. Normal Operating Practices in HFC Networks

In order to achieve the best balance between the needs of analog and digitally modulated signals with respect to noise and distortion, the following operating practices are typically followed:

- The frequency response of the fiber-optic link is nominally flat with respect to frequency.

- The levels of analog channels in the FDM spectrum used to modulate the transmitter are equal, while the levels of digitally modulated carriers are suppressed by about 10 dB.

- The frequency response of each amplifier has a uniform upward slope as a function of frequency.

Levels entering coaxial amplifiers are kept approximately equal (except for the reduced levels of digital signals) to equalize the noise degradation in each channel as the signal passes through cascaded amplifiers. Since coaxial cable loss varies with frequency, the amplifier response must slope upwards to compensate. This also allows higher overall levels for the same degree of distortion by avoiding unnecessarily high levels at the lower channels. Since digital channels do not need the same C/N as analog channels for reliable operation, suppressing them reduces the overall power output requirement for each amplifier.

Signals sharing the forward bandwidth of an HFC network with analog video carriers will be subject to the following types of impairments:

- Random noise

- Intermodulation products resulting primarily from mixing among the analog luminance carriers of analog signals

- Composite intermodulation noise resulting from mixing where one or more of the signals is digitally modulated

- Clipping in fiber-optic transmitters as a result of high peak-to-average voltage level in the FDM spectrum of analog channels

- Hum modulation occurring as a result of inadequate filtering in amplifier power supplies and also due to non-linear effects in magnetics which carry both power and signals

- Microreflections, in-band response variations and group delay resulting from mismatches in both the transmission and drop portion of the system

- Variations in level as a result of both time and temperature variations and periodic system alignment.

In general, systems which are in full compliance with FCC performance rules (C.F.R.47§76.601-76.630) will be able to transport downstream data signals.

B. Upstream

1. Upstream Transmission Environment

The upstream path describes that portion of the spectrum used for transmission from points in the distribution system (for instance, subscriber drops) to the headend. Like the downstream direction, it is a broadband linear transmission system. Typical channel conditions, however, are markedly different.

Although upstream paths are sometimes used to transport analog video, it is anticipated that the principal use will be for digital traffic of several types, including:

- Status monitoring signals from distribution equipment
- Signals generated by terminal equipment in support of subscriber interactive services
- Digitized voice signals from wired telephony services
- Digitized voice signals from PCS stations (or frequency translated signals from PCS antennas)
- Packetized data signals from subscriber RF modems.

In the downstream direction, degradations are well understood and related to the presence of many analog television carriers. There is a relatively small amount of industry experience with upstream transmission. Degradations in the upstream direction are typically dominated by signals which are not generated by or under the control of the system operators, so that channel conditions are less predictable. Nevertheless, it is possible to specify system electrical requirements and to make some predictions about the relationship between interfering signals and data transmission performance.

2. Normal Operating Practices in HFC Networks

Unlike the downstream direction, in which each amplifier's output levels are precisely set to an ideal level, in the upstream direction amplifier module input levels are matched. Since the cable losses are much lower, this results in a smaller output slope than in the downstream direction.

There is no established practice for setting levels of digital signals. Since the network is not typically shared between analog and digital signals, there is some logic in setting digital levels to "full" power (typically +20 dBmV at each amplifier module input). The reason is that external interference tends to be the limiting factor in network performance rather than signal-to-intermodulation products. This method, however, only works when the total number of carriers will not exceed the number of 6 MHz channels.

A more general approach that allows for future service expansion is the “constant dB/Hz method.” When the channel loading specifications are known for upstream amplifiers and lasers, the db/hertz level can easily be calculated. Assume for example that the input specification for an upstream laser is +20 dBmV for a single analog video channel and that the total return bandwidth is 5 - 40 MHz. To determine the input level per Hertz for 35 MHz of bandwidth, the formula is:

- (specification input in dBmV)-(10LOG(total bandwidth))= dBmV/Hz, or
- 20-(10LOG(35000000)) = -55 dBmV/Hz.

Now reverse the formula to determine the maximum level per carrier. A typical upstream signal occupies 2 MHz carrier. The formula is:

- (level per Hertz)+(10LOG(bandwidth))= carrier level, or
- -55+(10LOG(2,000,000)) = 8 dBmV for the 2 MHz carrier.

System specifications will determine the input and output levels of the amplifiers and fiber equipment. We suggest that the system determine these levels before beginning any upstream balancing.

3. Impairments in the Upstream

Signals transmitted through the network in the upstream direction are subject to the following types of impairments:

- Random noise
- Intermodulation products resulting from
  - mixing among the signals carried in the upstream direction, and
  - mixing among the signals carried in the downstream direction, where the mixing products fall into the upstream spectrum (“common path intermodulation distortion”)
- Clipping in fiber-optic transmitters as a result of high peak voltage levels
- Hum modulation, as occurs in the downstream direction
- Electrical interference from harmonics of electrical transients coupled into the upstream transmission system
- Microreflections resulting from mismatches in both the transmission and drop portion of the system

- Group delay due to the response of the diplex filters in amplifiers and microreflections
- Discrete interfering signals, including
  - local oscillator and other conducted interference from other receivers in the same node serving area
  - signals picked up from over-air sources by any portion of the same node serving area, including receivers and drop wiring and coupled into the upstream path
- Interference due to amplifier overload due to high level signals from legitimate upstream transmitters.

Unlike the downstream situation, where FCC regulations specify minimum channel conditions, there is no Federal regulation of upstream communications quality. As a result, there are also no testing requirements. Finally, equipment manufacturers are just beginning to specify equipment performance in a meaningful way.

Each of the types of channel impairment will be discussed in the following sections.

a. Broadband Random Noise

In the downstream direction, each amplifying component receives signal from one other component. In the coaxial portion of the network, assuming that each amplifier has the same noise figure and input level, the noise builds up as the logarithm of the number of amplifiers in series.

In the upstream direction, each coaxial amplifier typically receives signal from several sources because of branches in the network. Again assuming equal input levels and noise figures, the noise builds as the logarithm of the total number of amplifiers feeding the point of measurement. The ratio of downstream cascade to total number of amplifiers in the node can easily be 20:1, causing a 13 dB difference in noise buildup. This effect is known as "noise funneling."

As an example, assume a network is designed to deliver 48 dB C/N to subscriber taps. If the fiber-optic link provides a C/N of 52 dB, then the downstream coaxial distribution system must have a C/N of 50.2 dB. If the downstream cascade is three and the node contains 60 amplifiers total (a 1:20 ratio), then the expected upstream coaxial C/N would be about 37 dB for video signals (still assuming equal input levels and amplifier noise figures).

In order to calculate the upstream digital C/N, we need to correct for the bandwidth (2 MHz, rather than 6 MHz), the return amplifier noise figures (typically 15 dB rather than 10 dB) and the input level difference, if any. Assuming equal input levels, the final coaxial upstream C/N would be about 37 dB. Allowing for operational variations, a conservative estimate of the C/N at the input to the node optical transmitter is 35 dB.

Return path optical transmitters are typically lower powered than downstream transmitters. Even with a higher optical modulation index per channel, the C/N is typically only 42 dB in the upstream direction for data carriers.

In this example, the combination of coaxial and fiber-optic return sections results in a net return C/N of 34 dB. If the signals from four of these nodes were combined in the headend, the noise would degrade by another 7 dB for a net result of 27 dB C/N.

b. Intermodulation Products from Upstream Signals

No manufacturer specifies CIN for return amplifiers. Manufacturers generally provide specifications when the plant is carrying four CW carriers, though the specifications vary widely. Return optical links also vary widely. Operators should consult with amplifier manufacturers regarding expected distortion performance under expected signal loading conditions.

c. Intermodulation Products From Downstream Signals: Common Path Distortion

In a properly operating plant, downstream IM products are isolated from the upstream plant due to the diplex filters in amplifiers. Occasionally, however, a loose connection (such as an inadequately tightened seizure screw) will form a virtual diode and will generate high levels of IM distortion products in the return band. The strongest of these products will occur at harmonics of 6 MHz with lesser amplitude products at 7.25 and integral multiples of 6 MHz above 7.25 MHz. Typically the levels of these common path IM products will be greatest at 6 MHz and will decline by 20-40 dB across the return spectrum.

d. Hum Modulation

Hum modulation resulting from power supply lack of regulation or parametric modulation of magnetic devices is essentially a broadband phenomenon and should affect downstream and return paths equally. Cable plants meeting the FCC 3% downstream specifications are adequate.

e. Electrical Interference

In the downstream direction, the most common form of electrical interference results when high-voltage transmission lines are within the pattern of off-air receiving antennas. The most affected channels are at the low end of the spectrum, as the noise is essentially made up of harmonics of the 60 Hz repetition rate arcing.

Return band signals are even more affected by electrical transients and arcing that is coupled into the distribution system. The most common coupling mechanism for externally, generated electrical noise is through consumer receivers, especially those which use "hot chassis" designs where the external antenna connector shield is isolated from the internal chassis by a capacitor which allows the manufacturer to use a transformer-less power supply. Unfortunately the reactance of the capacitors used increases with decreasing frequency so that, while it is sufficiently low to allow the receiver to meet the FCC's Part 15 shielding requirements (which relate only to radiation of internally generated signals), the shielding effectiveness is rather poor at frequencies below 50 MHz.

Not only are these receivers receptive to power line interference, but also electrical noise from within homes, particularly that originating from motorized appliances and tools. Due to its intermittent nature, this type of interference may be very hard to localize in the cable system.

A second mechanism whereby electrical interference can be coupled into the return spectrum occurs because of the multiplexed power in the coaxial system. At 60 V rms, the level of the power "signal" is 50-100 dB above the normal individual channel signal levels, so even very small percentages of electrical noise can be large compared with the communications carriers. Since they are present in the same coaxial cable, the power transients are very tightly coupled to the communications circuits.

Depending on the total transient energy that falls in the return spectrum bandwidth, electrical transients may cause wide-band quasi-noise interference, but can also cause optical transmitter clipping as discussed below.

f. Microreflections

Microreflections arise in upstream channels due to the same mechanisms that create microreflections in the downstream channels. Due to lower cable losses, however, the amplitude of reflections is likely to be greater. Typical losses in trunk cable, for instance, are only 0.11 dB/100', leading to microreflections with amplitudes as high as -24 dBc, even with properly terminated taps.

Within the home, the same factors apply. The loss of RG-6 drop cable at 5 MHz is only 0.6 dB/100' increasing to 1.1 dB/100' at 30 MHz. The isolation of consumer splitters typically is only 15-20 dB at return band frequencies, while the input reflection of television receivers is essentially infinite. Taps, especially 1 GHz bandwidth units, have port-to-port isolation values of only 18 dB in the return band. Combined with the low cable losses, these could result in reflections at neighboring houses with amplitudes as high as -20 dBc, even allowing for typical drop cable lengths, at the entry to the home. Reflections could be generated within the home wiring with amplitudes as high as -15 dBc.

g. Group Delay

Each active device includes diplex filters at the input and output that separate the upstream and downstream signals. These are low cost devices with significant delay variation across the return band. Figure 3-1 shows the typical delay per amplifier characteristic from one manufacturer. The group delay variation can be calculated from the difference in delays across the frequency range of interest times the number of cascaded amplifiers. For instance a signal occupying the 2 MHz of bandwidth between 29 and 31 MHz will experience, a differential group delay of about 150 nsec when transmitted through a five amplifier cascade using diplex filters designed for a 5-33 MHz return band. If the same signal were moved up to the 33 MHz limit, the differential group delay would increase to 300 nsec. In addition to filters, group delay variations will result from micro-reflections, especially when low-value taps are not properly terminated.

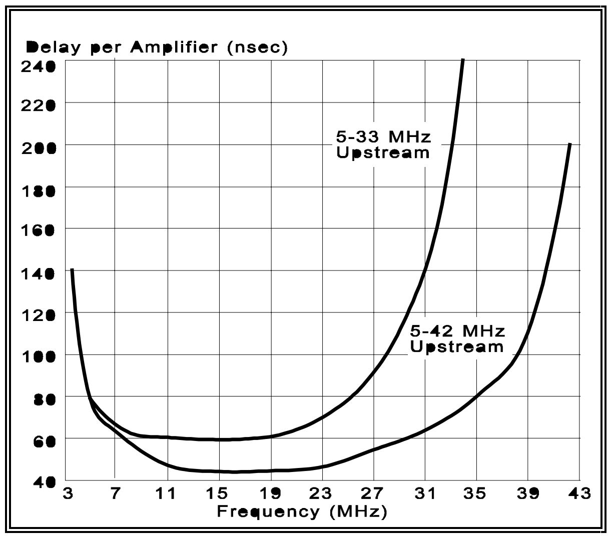

Figure 3-1 Group Delay of a Typical Amplifier

h. Local Oscillator and Other Receiver-Generated Interfering Signals

To the extent that neighboring receivers generate signals within the return band which appear at their input terminals, those signals will be transmitted in the upstream direction through the cable system and can potentially interfere with intentional upstream communications.

In a study of cable converters, C.T. Jones[i] found that the greatest amplitude return band signals were generated from cable converters, rather than from TV sets and VCRs. In particular, he found that three of the four converter types tested generated signals at levels as high as -19 dBmV, all at frequencies below 16 MHz. While the signal level from a single converter will be approximately 60 dB below a modem output level of +40 dBmV, the composite effect of the signal leakage from hundreds of similar converters in a fiber node serving area must be evaluated if all subscriber drops are left “open” to return transmissions.

A potentially more serious source of interference is harmonics of two-way converters which fall into data channels. All converter models should be examined to determine possible interference modes.

i. Ingress Interference: In-Band Interference

The hardest to predict source of interference to upstream communications is off-air signals which are picked up by equipment in customer's homes and transmitted upstream through the network. Secondarily, such signals may be picked up in the drop system or through faulty cable or distribution component shields.

Managing ingress interference is made more difficult by the nature of the interfering signals, which include:

- High-power broadcast stations whose signal strength varies widely depending on propagation conditions and which occupy several frequencies, particularly in the 10-15 MHz range.

- Licensed amateur radio operators who are widely dispersed and who transmit intermittently with power levels as high as 20 kW effective radiated power (ERP). Amateur operators can transmit at any frequency within their bands near 4, 7, 14, 21 and 28 MHz.

- Citizens band operators who are even more widely dispersed and numerous and who can legally operate at power levels of 5 Watts in the band from 26.96-27.45 MHz. This band is also used for various remote control devices, such as garage door openers.

In general, ingress signals most heavily pollute the spectrum below about 20 MHz. In the most thoroughly controlled test to date, CableLabs found this characteristic interference pattern in systems widely dispersed in the U.S. and Canada. While the systems varied widely as a function of size, condition and local off-air radio amplitudes, the highest amplitude interfering signals typically were at least equal to the data carrier amplitudes and sometimes as much as 20 dB higher.[ii]

In the upper frequency bands, selected frequencies were still seriously affected by ingress, but frequency ranges which were free of this problem were available.

Given the number of variables, it is not possible to make general predictions about the level of interfering ingress carriers in a given RF channel. Network operator frequency assignments, node size, off-air signal strengths, blocking of drops to non-interactive customers, etc., all affect the level of ingress into a given data channel.

j. Out-of-Band Ingress Interference: Clipping

As noted, CableLabs found that ingress levels in the lower end of the spectrum could be much higher in amplitude than the desired data carriers. In addition, some intentional transmitters (such as IPPV converters) may transmit at high and uncontrolled levels. Thus, the total RF energy present at the input of return amplifiers and, in particular, driving return optical transmitters, may well be dominated by signals other than data signals.

The peak voltage combination of those signals may well cause the same clipping effect as the comb of analog signals in the downstream direction. Additional causes of clipping may be RF energy from electrical arcing.

In the case of known, high amplitude, constant frequency ingress signals, it may be possible to block those specific signals at the input to the optical transmitter.

4. Summary of the Upstream Path Channel Conditions in Typical HFC Networks

Unlike downstream transmission where signal loading and channel degradations are well known and controlled, the dominant error-causing degradations in upstream channels can only be described in generalities. Specific frequency ranges in specific cable systems will need to be evaluated in order to predict transmission quality and even then, as CableLabs found it its study, the performance of entire nodes can change radically as a result of routine maintenance activities or weather conditions.

Certain upstream conditions, such as random noise and signal levels, are related to steady-state network operation. The degree of tolerance to these and in-band interfering signals is specified in Appendix A. Higher amplitude transient conditions may cause data errors and therefore packet retransmission, which will lower the effective network throughput.

C. Upstream Operations

1. Return Path Setup Procedure

In order to optimize cable system performance for carrying digital signals, it is essential that the systems be aligned so that return amplifiers and electro-optical components operate at the best compromise between noise and distortion. Similarly, when evaluating system conditions, the system must first be set up properly so that the subsequent performance measurements are meaningful. The following procedures are designed to accomplish that. Any required deviations from this procedure should be documented in the setup records so their effect can be ascertained.

The aim of these procedures is to establish system gains such that the levels of the data carriers at the input of every return amplifier module, (not amplifier station) are equal to a predetermined level and that the level driving upstream optical transmitters is optimal.

a. Alignment Methods

It is worth taking the time at this point to review some of the options available for aligning the return path. There are three prevalent methods:

- Return sweep generator with headend sweep receiver and ingress monitor
- Video monitor and portable 2 or 4 carrier generator in the field with a headend spectrum analyzer and video modulator to send the response downstream
- Signal level meter and portable 2 carrier generator in the field with headend receiver which generates balance indicator on a downstream pilot.

Table 3-1 provides a short summary of the pros and cons of these methods.

Table 3-1 Comparison of Alignment Methods

Pros	Cons
Return Sweep	
uses minimal forward BW	slower ingress response
provides best frequency resolution	requires functional return communications
technician carries one box for all tests	
Video Monitor	**(with 4 carrier generator)**
Pros	**Cons**
utilizes readily available hardware	technician carries multiple boxes
ingress and gain balance on same screen	requires 6 MHz forward BW
real-time ingress response	limited frequency resolution
Signal Level Meter	**(with 2 carrier generator)**
Pros	**Cons**
uses minimal forward BW	minimum frequency resolution
lowest cost approach	typically provides no ingress information
	may not function with excessive ingress

If using the carrier generator approach, it is important that the technician be familiar with the passives in the system, since rolloff in the passives may be compensated for by mis-adjusting the amplifier slope. Some of the newer 1 GHz passives rolloff below 10 MHz, so the carriers should be placed at frequencies that are within the flat response range of the passives. A return sweep system has several advantages:

- Flatness discontinuities and suckouts can be seen
- Rolloffs at the band edges are visible and diplexer problems may be eliminated
- Reflections and return loss problems often show up as ripple in the sweep response and can be repaired
- Modern sweep systems with short duration sweep pulses can be used in the presence of carriers without interfering and don't take up the bandwidth required by CW carriers.

b. Ingress Problems

If the return ingress is high, repairs may be required prior to establishing the reference levels. Typically, 70% of ingress problems occur in the home, 25% in the drop, and only

5% in the coaxial trunk itself.[iii] Excessive ingress can interfere with the sweep systems, and may even drive the laser into compression, causing the output levels to be in error.

In order to follow the process described in this section for return system alignment, you need to be able to start from the fiber node and proceed through the network (one visit per location is the goal). Return path "blockers", or some alternate methods of disconnecting the return input to the amplifier currently being tested, need to be available to establish proper set-up from the current location back to the headend. This will be an important step in reducing return path test time and meeting the one visit per location goal.

c. Alignment Process

The approach to alignment of the return path is similar to the forward path in the sense that it should be aligned for unity gain. The difference is that in the return the unity gain is referenced to the input of the return amplifier modules (not stations) versus the forward path which is referenced to the output of the amplifiers. Attention to details in the return path is critical to successful alignment. A poorly aligned amplifier further out in the trunk may make further alignment impossible due to excessive noise in the communications path. The steps for proper return path alignment follow.

1) Establish reference output

The first step in the alignment is to measure the output level at the headend for each return path using a given reference level input to the return laser at the fiber node. When choosing this reference input level, consideration must be made for optical and RF noise floors as well as clipping due to overdrive. A typical manufacturer's specification for optimum analog video input level to the return laser is +20 dBmV. It is becoming common practice to use this as the reference level. Modern sweep systems are designed to operate 10 dB or greater below optimum carrier levels, so we will use +10 dBmV as our reference input level in these discussions.

An accurate and flat input to each laser is necessary to establish the proper headend reference and this reference level must be maintained in order for the return system to operate properly. This input may be provided by any of the methods discussed earlier. The sweep system has the added advantage of allowing you to see problems in the return frequency response during the alignment.

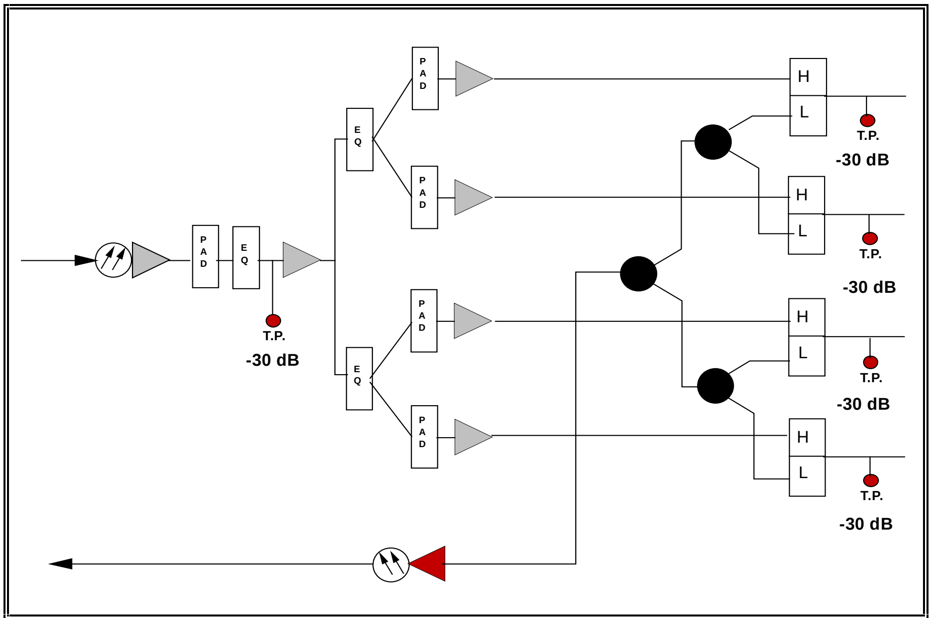

Figure 3-2 Typical Fiber Node

It is important at this point to familiarize yourself with the amplifier and optics schematics and block diagrams (see Figure 3-2). Internal coupling and test point variations determine the loss between the sweep insertion point (IP) and the input to the amplifier or laser. Inattention to this detail is a major source of error. We recommend developing a level matrix for your equipment which the technicians can refer to when setting the source level. An example of such a matrix is provided in Table 3-2. It may be necessary to contact the manufacturers of your specific hardware to verify the configurations. This matrix also assumes that you have determined all proper operating levels as described in Section B-2.

Table 3-2 Source Level Matrix

	Type of Hardware			
	Laser Hub	**Line Ext.**	**Trunk Amp**	**Bridger Amp**
Sweep Input Level	+10 dBmV	+10 dBmV	+10 dBmV	+10 dBmV
Int. Coupling Loss	9 dB	1 dB	5 dB	13 dB
Test Point Loss	30 dB	20 dB	20 dB	20 dB
Total IP Loss	39 dB	21 dB	25 dB	33 dB
Source Level	**+49 dBmV**	**+31 dBmV**	**+35dBmV**	**+43 dBmV**

2) Normalize outputs

The output at the headend may be measured with a spectrum analyzer or sweep receiver. Since the output from each return laser will vary due to the different lengths of return fiber, the next step is to normalize all of these outputs to the lowest level return by attenuating the higher level returns. This step creates a common output at the headend for all returns with +10 dBmV input to the laser. We will refer to this output level as the "X" level.

3) Check and align sweep response

All subsequent amplifiers should be adjusted to re-establish the "X" level output at the headend with the same +10 dBmV at each amplifier module input. The amplifier is adjusted using the return path output plug-in pad and equalizer for course adjustment and the gain and slope controls for the fine adjustment. The alignment should proceed out from the fiber node making sure each amplifier is calibrated properly before moving on.

Again, this may be done with a carrier generator approach or a sweep system. Care must be taken if using the carrier generator approach since the frequency resolution is limited and flatness problems may be missed. Once again, it is critical that the proper source levels be used. The level matrix created earlier minimizes the errors in this step.

Once this return alignment process is completed, the return carriers will be operating at the optimum level throughout the network.

2. Return Characterization

a. Service Requirements

Unlike the forward spectrum, the upstream bandwidth varies considerably in quality as a function of frequency. While white noise and the effect of clipping transients may be relatively uniform, such factors as common path IM distortion and ingressing carriers will affect the spectrum in a non-uniform manner.

Similarly, different possible two-way services may have different signal quality requirements. For example, IPPV converters may use very rugged transmission formats and be able to retransmit should any data be lost, while telephony signals may use QPSK modulation with no opportunity to recover from lost packets of data.

Operators should first characterize intended uses for the upstream spectrum, then evaluate the return system for channel quality, and finally assign frequencies or frequency ranges which best match service requirements to spectral quality.

Suggested parameters for characterizing a service include:

- Occupied signal bandwidth (a function of modulation format and information rate)

- Frequency agility (and, if provided, tuning resolution)
- Recommended C/N for acceptable data error rate (a function of modulation format)
- Tolerance of discrete interfering signals
- Acceptable uncorrected bit error rate (BER) (A function of service requirement and forward error correction, if provided).

The occupied bandwidth is important as a narrow signal may be able to fit between two areas of degraded quality where a wider signal may not. Similarly, a channel that can be moved in small frequency increments will be better able to find optimal spectral locations.

Uncorrected bit errors in a digital stream can result from all of the various channel impairments, including random noise, discrete carriers/beats and electrical transients. If the uncorrected error rate likely to be achieved in a cable system is unacceptable, the equipment supplier may have provided a means of automatically correcting for the error patterns they feel are most likely to occur. This is known as forward error correction or FEC. In order to assign services in an optimal way to available spectral slots, however, it is the uncorrected error rate that must be used as a parameter.

b. Plant Evaluation Testing

With an understanding of the requirements of each service, the next step is evaluation of the return spectrum and equipment configuration.

1) Carrier to Noise Ratio

The most fundamental parameter expressing channel condition is C/N. Unlike downstream measurements where test conditions are well known and this is a simple test, there are many variables affecting upstream C/N testing:

- Carrier level: In the upstream alignment section, we defined an "X" level which was the headend level corresponding to a CW carrier driving an upstream amplifier at +10 dBmV. Using the "constant power per Hz" methods of setting digital carrier levels (with a "standard" level of +20 dBmV/6 MHz at the input of modules), the proper level for a 2 MHz carrier would be about +15 dBmV, or 5 dB above the X level. That is the level that should be used for the carrier level in this measurement. (Note that a digital carrier whose total rms power in the channel is +15 dBmV will appear to have a lower level when measured on a spectrum analyzer or signal level meter unless that instrument has been calibrated to measure digital signal power level).
- Noise bandwidth: The noise should be measured in the bandwidth occupied by the data signal: 2 MHz in the case of an upstream signal. If the analyzer used does not provide this bandwidth as one of the options, then correct it using the following formula:

Actual noise level = apparent noise level + 10 log (2 MHz/instrument bandwidth)

- Noise definition: In downstream measurements, noise measurements are made in such a way as to include only "white" (broadband) noise and to exclude any discrete products. Digital circuits tend to respond to the total energy, both noise and interfering products, in the band of interest. Thus, the bandwidth should be as close as possible to 2 MHz (or at least the spectrum should be examined to make sure that no significant products are inadvertently included or excluded from the measurement).

2) Continuous Discrete Interfering Signals

After the noise measurement is made, the spectrum should be examined at a narrower bandwidth to assess the levels of discrete products in accordance with that specification.

The results of the C/N and interfering signal tests will identify frequency ranges suitable for operation of digital data signals.

3) Signal Levels

There are three steps to this evaluation. First, determine that a carrier which drives an upstream amplifier module at the reference level used for the C/N test (normally 5 dB above the X level) will be within the desired signal range (-5 to +20 dBmV) at the input to the LR/30 receiver port. Adequate provision must be made for any headend combiners and/or splitters plus cabling and possibly isolation amplifiers.

Second, examine the plant design and intended drop configuration (discussed below) to confirm whether modems operating in their design power output range (+35 to +55 dBmV) will be able to deliver the required power at the input of the first active device in the return path (the level necessary to drive the return amplifier module at about +15 dBmV).

Third, insert signals at representative end-of-line locations at levels equal to those that will be used by modems and measure the level as received at the headend LR/30 receiver over time and temperature to determine that they stay within the required range. This should be conducted in the same manner as a standard downstream 24 hour stability test.

4) In-Band Response Variations

Response variations can result from improperly operating diplex filters, improperly equalized plant or improperly terminated low-value taps. Tests should be conducted from representative end-of-line locations using a narrowband sweeper in conjunction with a spectrum analyzer at the headend, or an equivalent test method.

5) Hum Modulation

Hum modulation can be measured by any of the means described in the *NCTA Recommended Practices for Measurements on Cable Television Systems,* Second Edition, published by the NCTA, Washington D.C., or equivalent measurements using similar equipment.

6) Group Delay

Direct measurement of group delay through the return cable plant is difficult. The effect of the amplifier diplex filters can be calculated as described earlier, however. If the diplex filter component is within the prescribed specification, use of proper terminators on all unused tap ports will assure probable compliance.

7) Ingress Interference

Even though plant operating conditions are within the specified conditions for data operation and signals are placed in parts of the spectrum where noise and distortion products are within specifications, there will generally be data errors due to intermittent interference from external sources. The two main sources of interference are discrete interfering signals and electrical transients. There are three approaches that can be taken to evaluating the magnitude of this interference:

- Discrete carrier interference can be measured over a period of time using a programmable spectrum analyzer with average and peak-hold data gathering capability. If the analyzer is set up to make measurements over repeated intervals of time, then the data downloaded to a computer for analysis, it is possible to create statistical charts of interference level as a function of both frequency and time. These can be used to select the best frequencies for operation.

- Electrical transient interference tends to affect the entire spectrum, especially if the amplitude is sufficient to drive the return laser into clipping. One approach to determining probable interference levels is to insert a CW carrier anywhere in the node at a level which results in a received signal 5 dB above the “X” level. Tune the carrier on a spectrum analyzer in the “zero span” mode with in IF and video bandwidth approaching 2 MHz. Set the display trigger level to fire when the display exceeds the normal carrier level by an amount sufficient to cause a data error. Count the trigger events using an external counter. While this will not give an accurate count of resultant data errors, it will be give a general indication.

- The most accurate way to measure the effect of all error causes is to directly measure BER using a modulated test signal inserted into the plant, a test receiver at the headend, and a pair of matching bit error rate testers. While this gives a direct measure of end performance, it does not aid in identifying the degradation or combination of degradations which caused the errors.

Hewlett Packard is currently working on improved methodology for evaluating the magnitude of ingress interference in cable plants.

3. Return Maintenance

a. Return vs. Forward

Preventative maintenance for the return path is similar to many of the current maintenance programs used in networks today involving periodic system sweep, end of line monitoring, and periodic performance tests. Some of the tests performed on the return path are different from the corresponding tests performed on the forward path. Variations of services and the nature of the return path causes these differences. For example, a carrier-to-noise measurement in the forward path is typically made relative to a visual carrier, where as a carrier-to-ingress measurement on the return path is typically made relative to an intermittent data carrier.

Experience indicates the labor cost required for the maintenance of the return path is at least equal to the labor cost for the forward path, despite the reduced bandwidth and simplified amplifiers. Much of the increase in labor is due to multiple trips to the same location to repair self inflicted problems. The goal of return path maintenance should be to minimize trips to a given site by maintaining precise gain alignment and including return path ingress monitoring in the normal forward path test program.

b. Ingress Monitoring

Continuously monitoring the ingress levels and level changes over time will help operators predict system problems. It also provides a measure of the availability of the system. Stored measurements can be compared to current measurements for troubleshooting purposes. For example, an increase in noise in a node may be coincidental with an installation of a new section of the system, a particular weather pattern, an accident, or even an installation of a new subscriber.

c. Sweep Testing

As stated previously, sweep testing of the return path gives the technician many advantages over other alignment methods. Performing a sweep of the forward system at the same time reduces labor. In addition, many amplifier designs have return signal paths on the mother board for the forward amplifier. Therefore, if the forward amplifier is replaced, the return amplifier is also affected. Faulty grounding of the modules in the amplifier can cause ingress problems in the return, but only have a minor affect on the forward path. Checking both paths at the same time can eliminate future problems.

Earlier in this section we discussed using a level matrix to set the sweep source level for initial alignment. The same levels must be used for routine sweep testing. Routine sweeping of the return should include sweeping the fiber link and reconfirming the normalized levels at the headend (the “X” level) to verify the performance of the optics.

If it is necessary to sweep from a tap in the return, we use this same level matrix. We can determine the new source level by ignoring the amplifier test point loss and adding the loss from the tap to the amplifier output (return input). The level matrix in Table 3-3 illustrates an example of this new calculation. This same approach can be used for testing the return path from any return insertion point in the system.

Table 3-3 Source Level Matrix with Taps

	Type of Hardware			
	Laser Hub	**Line Ext.**	**Trunk Amp**	**Bridger Amp**
Sweep Input Level	+10 dBmV	+10 dBmV	+10 dBmV	+10 dBmV
Int. Coupling Loss	9 dB	1 dB	5 dB	13 dB
Test Point Loss	30 dB	**0 dB**	20 dB	20 dB
Tap Loss		**24 dB**		
Cable Loss		**8 dB**		
Total IP Loss	39 dB	21 dB	25 dB	33 dB
Source Level	**+49 dBmV**	**+43 dBmV**	**+35dBmV**	**+43 dBmV**

D. Subscriber Drop

1. Cabling

Historically, most ingress has taken place in the drop and home. To reduce the susceptibility of the drop system, operators are urged to use:

- messengered cable with corrosion inhibitor for overhead drops
- flooded cable for buried drops
- good quality, sealed F connectors and passives
- proper grounding/bonding procedures.

In areas with very strong off-air signals, the use of tri-shield or quad-shield cables may be appropriate.

The drop system must deliver a data signal level of at least -15 dBmV to the modem. Since data signals are typically suppressed 10 dB relative to analog television visual carrier levels, this is equivalent to delivering an analog video signal level of -5 dBmV.

The suggested cabling configuration is shown in Figure III-3. The DC-9 located at the ground block location creates an isolated drop for the modem, while causing about 1.6 dB loss to the cable signals feeding the existing house wiring. A high pass filter in the through leg blocks ingress from the remainder of the house wiring and television receiving equipment (see discussion below).

Providing adequate signal level for the modem, assuming 4 dB for the loss of the modem drop and a 9 dB directional coupler, requires that the video signal level at the ground block be at least +8 dBmV. If system levels are insufficient at some homes to provide the required modem input level, then alternate configurations (such as equal level splitters or drop amplifiers) are required. Any drop amplifiers must provide return path continuity for the upstream signals.

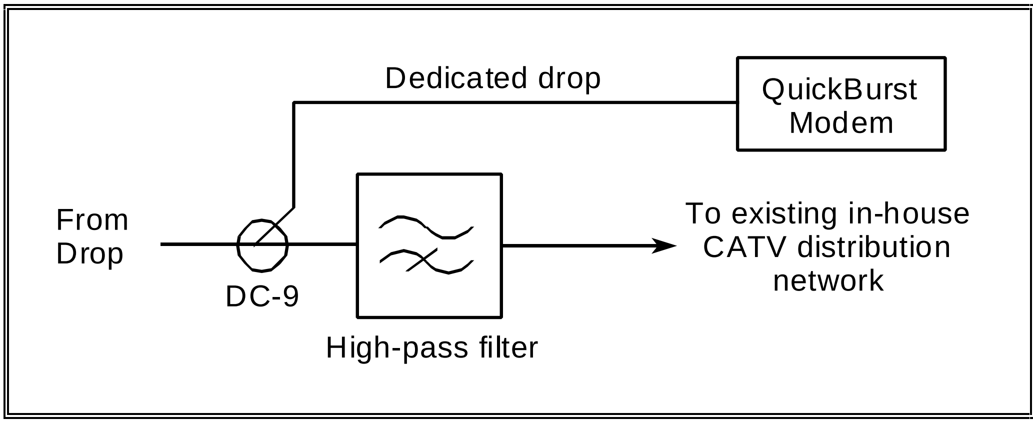

Figure 3-3 Suggested Drop Configuration

2. Filters

Filters applicable to modem installations are of two types: high pass and band stop. High pass filters block signals anywhere in the upstream spectrum from entering the network. When installed as shown in the figure above, they block all ingress from the existing home cable television wiring and/or receiving equipment. They can also be installed at either the tap or the ground block of non-subscribers. In addition to protection against inadvertent ingress, high pass filters also protect the system against possible sabotage via signals introduced through drops.

For systems which must transmit other signals from within homes (such as two-way set-top boxes), an alternate is to use a band-stop filter that only blocks signals in the frequency range used by modems, while passing those generated by the set-top boxes. In the typical case where set-top boxes transmit near the low end of the spectrum, these provide an added benefit in that they also block harmonics or spurious signals from those boxes which might otherwise interfere with modem signals. They provide less network protection than high-pass filters, however, since a high level signal originating within the home could still drive upstream lasers into clipping.

The use of filters and their placement is an option that system operators should consider based on their observed levels of ingress and standards for network protection.

3. Drop Equalizers

Signal levels in the downstream direction are approximately equalized at each tap by choosing tap values which just compensate for interconnecting cable and tap through-losses. In the upstream direction, however, cable losses are much less, with the result that the upstream loss from subscribers located at the far ends of tap strings is much less. While many modems have a controllable power output which is automatically adjusted to compensate for this difference, an incidental effect of the differential loss is that the network is much more sensitive to ingress from those most-distant homes.

Drop equalizers are designed to compensate for this problem by introducing a loss which affects only the return path. It is suggested that operators consider the use of drop equalizers as a means of reducing the average level of ingress in nodes.

Appendix A

A. Cable Plant Specifications

1. General

The following specifications apply to the complete transmission path from the headend to the modem. In the case of downstream signals, this includes the upconverter, headend combining and signal processing, broadband transmission network, drop, and in-house wiring. In the case of upstream signals, this includes in-home wiring, drop, broadband transmission network, and the head-end path to the port of the upstream data receiver in the headend.

2. Downstream Requirements

The system should be in full compliance with the FCC performance standards contained in C.F.R. 47 § 76.601-76.630. These specifications specify the total signal degradation from headend input to converter output. These standards include the following which may impact data signals:

Carrier-to-noise ratio for video signals	≥ 43 dB[1]
Composite triple beat distortion	≤ -51 dBc (≤ -47 dBc for HRC and IRC systems)
Composite second-order distortion	≤ -51 dBc (≤ -47 dBc for HRC systems)
Hum Modulation	≤ 3%peak-to-peak (1.5% peak carrier modulation)
Signal level at customer outlets	≥ 0 dBmV
Video signal variation across spectrum	≤ 10 dB + 1 dB per 100 MHz (or portion thereof) above 300 MHz upper frequency limit
In-band amplitude response variation	≤ 4 dB peak-to-peak from 0.75 to 5 MHz above lower channel edge
Aural carrier levels	10 to 17 dB below luminance carrier sync peak level
Isolation between subscriber terminals	≥ 18 dB

In addition, the downstream channel used for data signals should meet the following requirements:

Channel frequency	Any ANSI/EIA Standard, IRC, or HRC channel, or most CCIR channels, completely contained within 54 - 860 MHz
Relative data signal level	Suppressed ≤ 10 dB relative to analog video
Data signal level delivered to modem	-15 to +7 dBmV[2]
Phase Noise	≤ -40 dBc/Hz @ 1 KHz ≤ -60 dBc/Hz @ 2 KHz ≤ -83 dBc/Hz @ 10 KHz ≤ -89 dBc/Hz @ 20 KHz
Differential group delay	≤ 90 ns
In-channel frequency response	≤ 4 dB peak-to-peak across full 6 MHz channel
Reflected/delayed signals	≤ -10 dBc for delays of ≤ 1.2 µs(microreflections) ≤ -35 dBc for delays of > 1.2 µs
Optical transmitter modulation	Optical modulation index (OMI) must be sufficiently low that BER from clipping peaks is $\le 10^{-10}$

3. Upstream Requirements

Frequency range	One or more bands, each at least 2 MHz wide, within 10-40 MHz
Carrier-to-noise ratio for data signals	≥ TBD
Carrier to discrete interfering signals	≤ -20 dBc[3]
Hum Modulation	≤ 3% peak-to-peak (1.5%carrier modulation)
Signal level delivered to Link Router	-5 to +15 dBmV[1] (+5 dBmV nominal)
Differential group delay	≤ 150 ns
In-channel frequency response	≤ 1 dB peak-to-peak across any 2 MHz
Reflected/delayed signals	≤ -15 dBc
Optical transmitter modulation	Optical modulation index (OMI) must be sufficiently low that BER from clipping peaks is $\le 10^{-10}$
No AGC in the upstream path	

The usable data rate will be degraded by intermittent occurrences of:

- Ingressing carriers whose level is in excess of the discrete interfering signal specification
- Electrical transient ingress
- Laser clipping due to the presence of high level out-of-band signals

Notes:

1. Analog video noise level is measured in a 4 MHz bandwidth centered in the channel.
2. The power of a digitally modulated signal is defined as the total rms energy in the occupied bandwidth. Signal level meters and spectrum analyzers not specifically designed to read digital power levels may give erroneous readings.
3. Upstream discrete interfering signals include ingressing carriers, conducted signals originating from terminal equipment, intermodulation products among carried signals, common-path intermodulation products from downstream signals or any other signals from whatever source.

Glossary of Related Terms

10BaseT An implementation of the IEEE standard on 24 gauge unshielded, twisted-pair wiring, a baseband medium, at 10 megabits per seconds.

100BaseT An implementation of the IEEE standard on 24 gauge unshielded, twisted-pair wiring, a baseband medium, at 100 megabits per seconds.

64 QAM 64 Quadrature Amplitude Modulation. A modulation scheme where 16 bits of serial data are encoded into a single phase state or symbol.

802.3 As defined by IEEE, defines the Carrier Sense Multiple Access/Collision Detection (CSMA/CD) network access method used in Ethernet networks.

802.14 Under definition by IEEE, specifies the Cable Data Transmission standard over HFC.

ACK Acknowledge character. Transmission control character transmitted as an affirmative response to a connecting station or to a sender; may also be used as an accuracy control character.

address A unique identifier for a device on a network. An address can be a name, a set of numbers (for example 255.110.110.20), or a sequence of bits. All devices on a network must have an address so information can be transmitted to it.

Application Layer The layer of the OSI Reference Model that specifies protocols for user or application programs.

asynchronous Data that is transmitted one bit at a time.

ATM Asynchronous Transfer Mode. (1) High-bandwidth, low-delay packet switching and multiplexing technique used to transfer voice, video, images and character-based data. (2) Method of formatting, multiplexing, cross-connecting and switching information in 53 byte cells.

bandwidth The capacity of the network to transmit data using a particular cable, measured in bits per second. The higher the bandwidth, the faster data can be transferred.

baseband A type of network transmission that uses the entire bandwidth of

	a network to transmit a signal. See also broadband.
BER	Bit error rate. Number of erroneous bits divided by the total number of bits over a stipulated period of time. Usually expressed as a number and a power of 10 (2.5 erroneous bits out of 100,000 bits transmitted would be 2.5 in 10_5 or $2.5x10^{-5}$).
BPSK	Bi-Phase Shift Keying, digital modulation method
bridge	A device that connects two networks so devices within each network can communicate with devices in the other network. Bridges connect networks that use the same communications protocol.
broadband	A type of network transmission that allows several channels to be transmitted simultaneously over the same cable or wire. Cable TV uses broadband to carry up to 100 channels simultaneously over the cable medium.
broadcast transmission	A message sent over the network to all devices.
checksum	A computation performed on data that is transmitted to ensure its integrity. The bytes that are used for data are added together and their sum is appended to the data packet. When data is received, it is recomputed and compared to the data sum that was sent.
client	The software application running on the requesting computer in a client/server relationship. The server computer runs the software that provides the service the client requests.
collision	This happens when two network devices transmit simultaneously. Data is garbled since the transmissions run into one another. See CSMA/CD for fallback procedure.
CSMA	Carrier Sense Multiple Access - A method that network devices use to gain access to a single channel so they can transmit data. A network device listens or senses the traffic on the network and transmits if the network is clear.
CSMA/CD	Carrier Sense Multiple Access/Collision Detection - A collision detection scheme allows a network device to determine whether a collision has occurred, usually by not receiving an a transmission acknowledgment. The devices retransmit after a random time period.
datagram	Defined in the Internet Protocol as a packet containing a

destination address and data.

DES encryption Cryptographic algorithm designed by the National Bureau of Standards to encipher and decipher data.

Diffie-Hellman A key agreement protocol (also called exponential key agreement) that allows two users to exchange a secret key over an insecure medium without any prior secrets.

downstream In cable systems, the transmission direction from the headend to the subscriber site.

e-mail Electronic mail.

Ethernet A data link protocol jointly developed by Intel, Xerox, and DEC. Afterwards it was adopted by the IEEE as a standard.

FEC Forward Error Correction. (1) Technique for regenerating lost data transmission or errored messages. (2) Retransmission of any information by the transmitter, typically by adding bits to each transmitted character or code clock using a predetermined algorithm. Does not need a feedback channel, therefore may be used in a one-way transmission system.

frame A format for encapsulating a series of bytes within a header. Used at the data link layer of the OSI reference model. The term is also used interchangeably with "packet."

FTP (File Transfer Protocol) In the TCP/IP network, an upper layer protocol that allows copying files across the network.

gateway An network device that connects two networks operating with a different set of protocols. A gateway forwards data to the other network and translates the data into the appropriate protocol.

header The part of a packet that contains control information. The header is located at the front of the packet and usually contains information for identifying the packet type, destination address, packet sequence number, and so forth.

hop A transmission of data through one router to another, allowing the data to be transferred into another network.

IEEE Institute of Electrical and Electronic Engineers. A major standards setting group in the US. A part of the ISO.

Internet A collection of networks connected to each other using the IP protocol and other similar protocols. The Internet provides file transfer, remote login, electronic mail, news and other services.

IP Internet Protocol. A protocol residing at layer 3 of the TCP/IP protocol suite, used to provide functions for addressing, routing, and switching packets.

ISO International Standards Organization. An organization that has defined the OSI network standards and the OSI Reference Model.

LAN Local area network. A network physically located in one area, not one connected by modems or telephone lines.

layer A set of networking protocols that is part of a complete group of protocols, as in the OSI Reference Model. A layer is responsible for performing a set of functions for transmitting data over a network.

MAC Media Access Control. Lower portion of the OSI model data link layer concerned with media access issues, such as whether token passing or contention will be used.

MIB Management Information Base. Information used by SNMP for maintaining the status and control of a network device. Information in the MIB is conveyed by an SNMP agent to network management software.

multicast address An address that is a group address meant for a subset of addresses on the network.

Multiplexing The process of mixing two data transmission sources so they can share a common transmission medium so that each source has its own channel. With frequency division multiplexing, two or more channels are split into frequency bands, each of which constitutes a distinct channel.

network A group of individually controlled devices that are interconnected so that they can communicate together.

Network Layer The layer in the OSI Reference Model that defines protocols governing data routing.

NIC Network Interface Controller. A board that allows a device to connect to a network. A NIC is built for the type of network it must interface with, including the appropriate cable connectors and chips that contain software for the specific protocol.

NTSC	National Television System Committee. Developers of a color television system adopted by the US and other countries as their national standard.
OSI Reference Model	The OSI (Open Systems Interconnection) Reference Model is a model for the modularization of network protocols and their functions. The model consists of seven layers. Each layer communicates with only the layer above and below it. The layers, from the bottom up are: Physical Layer, Data Link Layer, Network Layer, Transport Layer, Session Layer, Presentation Layer, and Application Layer.
packet	A group of bits including address, data, and control elements, that are switched and transmitted together.
phase-shift keying	Modulation scheme for transmitting digital information where that information is sent by selecting discrete phase changes of the carrier.
protocol	A procedural rule or convention for sending information over a network, as in the OSI Reference Model.
protocol layers	The functional divisions of processing to send and receive data on a network. The layers refer to the main tasks the networking software has to accomplish to transmit and receive data.
proxy agent	A network device managed by an SNMP agent. See "SNMP."
QPSK	Quaternary (Quadrature) Phase Shift Keying, digital modulation method
router	A network device that connects two networks and maintains addressing information for each network.
Session Layer	The layer in the OSI Reference Model that defines protocols that govern communications between applications.
SNMP	Simple Network Management Protocol. A protocol in the TCP/IP suite for managing network devices. SNMP uses agents on managed devices to maintain a MIB and transmit MIB data to the management software upon request.
TCP	Transmission Control Protocol. The transport layer protocol of the TCP/IP protocol suite. TCP provides connection-oriented, end-to-end transport of packets between workstations.

TCP/IP	The standard for internetwork communication established in the U.S. Department of Defense network.
telnet	An application program on the Internet that allows remote login to another computer system.
UNIX	An operating system that was important to the development of the Internet, although it is not necessary for accessing the Internet.
upstream	In cable systems, the transmission direction from the subscriber site to the headend.
WWW	World Wide Web. A hypertext-based system for finding and accessing Internet resources.

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