

Operation and Design of the HFC Network

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Introduction

Welcome to Operation and Design of the HFC Network

This course will provide participants an understanding of components, functions, and fundamental design concepts for HFC networks, including:

- HFC Architecture
- Coaxial Distribution System Components and Function
- System Print Symbols and System Design
- Gain and Loss Specifications (coaxial system components)
- Unity Gain and Distortion Accumulation
- Calculating System Distortion Levels
- Calculating RF Input Level / Equalizer/ Pad Values for Active Devices
- Coaxial Amplifiers:
 - Component Design (pre and post amp)
 - Setup
 - Reference Level
 - Equalizer Response Signatures
 - Unity Gain Applied
- System Qualification (Performance Standards)
- System Power:
 - Ohm's Law and Formulas
 - AC and RF waveforms and Measurements
 - AC and Coaxial Cable Impedance
 - Amperage and Voltage
 - Loop Resistance
 - Rectified Voltage

Introduction (cont.)

HFC System architecture uses a fiber optic backbone, strategically placing fiber nodes to provide services to 500 homes. The optical node is like a converter, converting inbound light signals (forward) to RF energy, and return RF signals to light.

At the node, RF signals are configurable to any of the 4 coaxial connector ports with a coaxial seizure fitting (standard coaxial cable connector). Return signals are picked up (diplexed) from the coaxial cable ports and combined at the optical converters input. The RF is converted to light and sent to the head-end. The node is a local digital hub that transports local requests over the optical network and back to the customer home via the coaxial system cables.

Bandwidth is the element of system capacity. Over the past 20 years, telecommunication companies have been through a series of system upgrades, with small capacity increases of 50-100 MHz. **System upgrades were limited by predictable distortions associated with amplifier cascade length (amplifiers in a row or string) and the system channel load (number of channels or system bandwidth).**

Fiber optics effectively overcame the need for the long cascade of amplifiers, covering greater distance (16 miles without re-amplification), with less distortion from the channel load. HFC System outages are limited to a smaller portion of the customer base, compared to the old CATV cascaded amplifier system. If amplifier 1 went out, all 40 amplifiers were out. As more channels or services are carried on a network/system, predictable distortions will increase. We will come to understand how to keep the undesirable elements of distortion low, and system performance high, for analog and digital signal formats carried by the system.

System Components

Fiber Optic Node

The fiber optic node is a transceiver. Fed from the head-end via fiber cable, the node acts as the local head end, dedicated to serving up to 500 homes in a given area, over a coaxial distribution system. The node converts all upstream RF signals to light (return), and all downstream light signals (forward) to standard RF energy. This unit will receive power through one of the coaxial cables connected to the coaxial ports of the node. The node will feed no more than four coaxial amplifiers in cascade, to preserve system performance and quality of service. This is the "Platform of Choice".

Mini-Bridger / Line Extender

These are coaxial amplifiers. These will re-amplify system signals to their original power or designed amplitude level, and positive slope. We will use the mini-bridger where multiple coaxial feeds are required, as this unit can have up to four coaxial feeds active on dedicated ports. This provides configuration options for efficient signal distribution through a specific area. The line extender has one output port, which requires additional external splitters for multiple coaxial outputs. Each device can be configured to pass or stop AC power as needed.

Power Supply and Power Inserter

The power supply is interfaced on the coaxial system cables, using a fuse protected power inserter (a diplexer or dc) to combine AC with the coaxial system cable. One supply will be dedicated to feed one node and the coaxial amplifiers the node feeds. The supply is the buffer between the power utility and our system components, regulating and grooming the AC output to active system devices. A typical supply will have stand-by capability, which provides system power in the event of a power utility outage. This is done using batteries and an inverter module to convert DC to AC for the system components. Stand-by supplies provide up to 3 hours of power to the system, depending on the amperage draw from system components, and the state of battery charge, at the time of inversion. Typical HFC power supplies deliver 87.5 VAC output @ 15 amperes, to the HFC system. The supplies require 110-120 VAC input from the local power company/utility.

Coaxial System Cables

These cables come in several sizes, and naturally larger cables are more efficient than smaller ones. Size is expressed as decimal values .500 (half inch), .650, .750 (three-quarters of an inch), .875, and 1.000 (one inch). The coax carries forward, return, and AC power to and from the node and to all active system devices the node feeds. The cable size used to build a system will impact cost and design. Depending on the bandwidth of the system, larger cables may improve system performance, by reducing the amplifier cascade. All coaxial cable impedance values are 75 ohms.

System Components (cont.)

MLS / DC / Directional Couplers (splitter or diplexer)

On the system, splitters are called MLS's or DC's. Depending on your perspective (forward / return), the unit can be perceived as a combiner or a splitter. System DC's come in several values, with different loss specs for each output leg. This permits signal power to be distributed as needed, matching local logistics.

Aside from the DC 3 (2-way split 4 dB loss each leg) output values are expressed with reference to the thru leg / down leg (high leg / low leg or system leg / tap leg). Each expression specifies low / high signal loss in that order.

In-line or Fixed Equalizer

A device that attenuates low band signals only, compensating for non-linear frequency dependent loss through the coaxial cable system. In-line equalizers are usually found towards the end of the distribution system, to avoid a reverse slope (low band is higher than hyper band) of system levels at the last few taps on the system. This device looks like a standard tap, without F-port connections for a drop. Insertion loss will vary between manufacturers, typical in-line equalizer signatures will be about -2 / -8 insertion loss, to the system input levels (1-2 dB insertion loss on the hyper band, and a 6-8 dB drop on the low-band). These are fixed equalizers, as no adjustments to signal level are provided.

Variable Equalizers

Variable equalizers are used in active device setup to attenuate low-band signals. Variable means: 1) Some controls are available to adjust non-linear input signals, for a linear input signal to an amplifier: 2) The equalizers come in several varying fixed values to compensate cable loss, and provide linear or flat input levels to the amplifier, based on dB of cable.

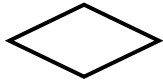
Taps

The tap is the customer's drop interface to the coaxial system. Taps are designed in various values in increments of 3 dB, (with 4 or 8 F ports) to allow amplitude consistency along the distribution system. Inside, the tap has a DC, the thru leg for the system and the down leg feeds to a splitter or series of splitters, depending on the number of ports on the tap (4 or 8). The total loss between the tap input and the tap F port (drop connections) will be the tap's value (23, 20, 17, 14, etc). Tap values close to an active will be high, and decrease in value as levels attenuate from cable and insertion losses. Moving away from an active, tap values decrease, while the tap F-port signal levels remain reasonably consistent at every tap.

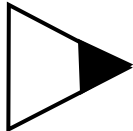
System Print Symbols



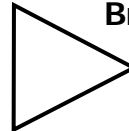
Utility Pole



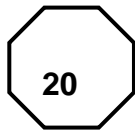
Inline Equalizer



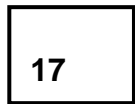
Line Extender
(with AGC)



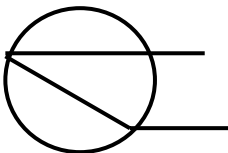
Bridger amps



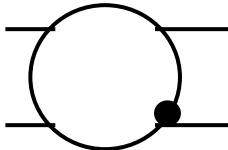
8-way Tap



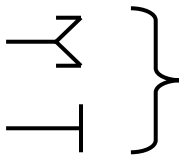
4- way Tap



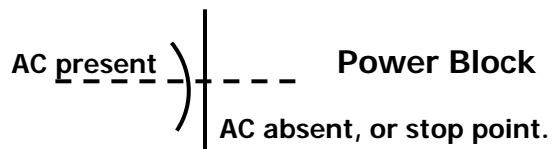
DC (splitter) unequal values indicated by the line inside the circle as the high loss leg (DC-8 shown)
A DC-12 would be blackened inside this section
A DC-3 has no line in the circle



A 636 splitter has the low loss leg indicated by a dot
Insertion loss is 3.9/ 7.4/ 7.4



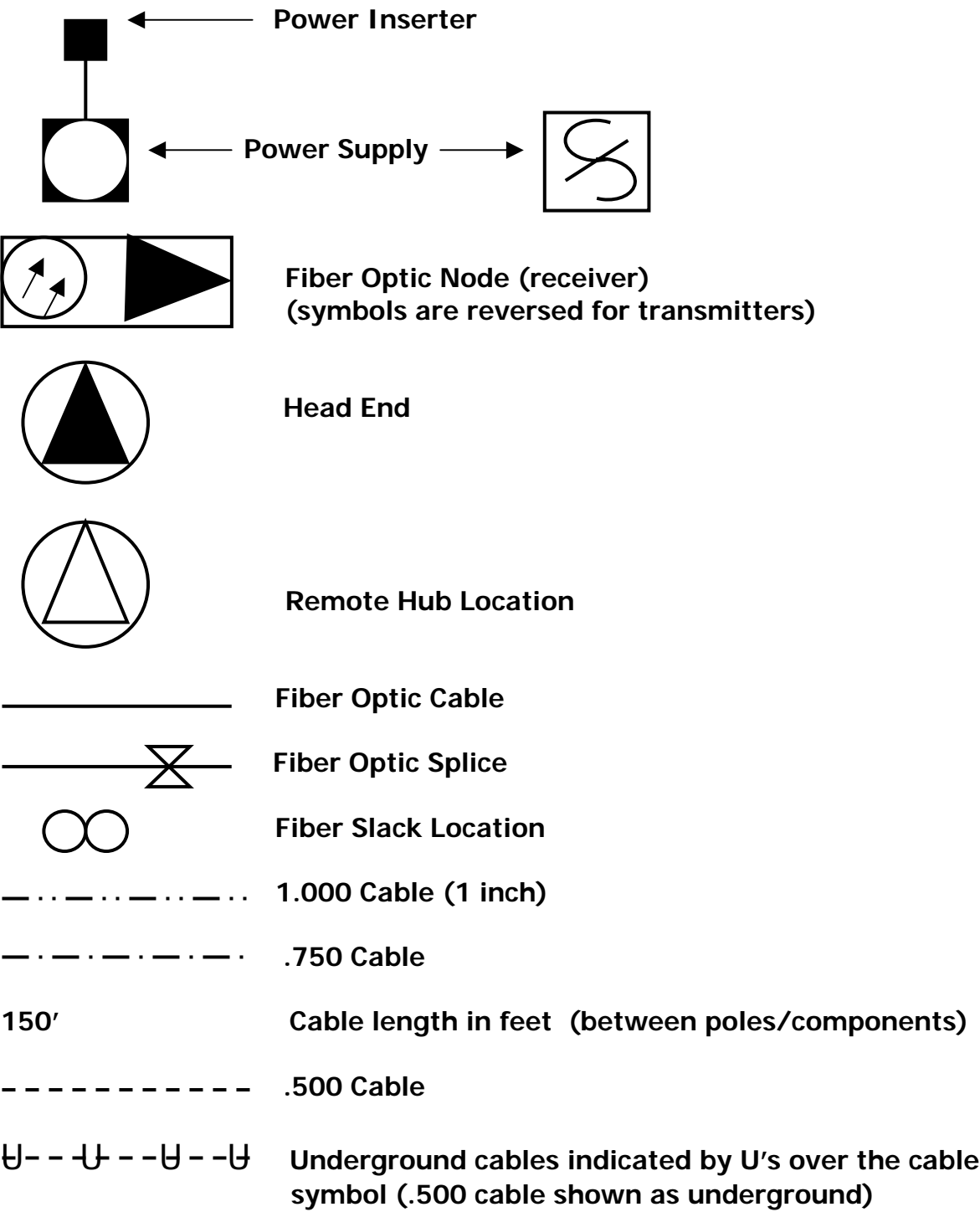
System Termination Symbols



Power Block

AC absent, or stop point.

System Print Symbols (cont.)



Cable and Passive Specifications

(Loss specifications given for MC₂ cable @68 degrees F.)

Exhibit 1. Frequency Loss Specifications per 100 feet of cable

<u>Cable</u>	<u>30 MHz.</u>	<u>55 MHz.</u>	<u>500 MHz.</u>	<u>750 MHz.</u>
1.000	0.18	0.24	0.78	0.97
.750	0.25	0.34	1.03	1.25
.650	0.28	0.38	1.19	1.50
.500	0.35	0.48	1.48	1.83

Exhibit 2. Tap Insertion Loss Specifications (at 750 / 50 MHz.)

(Tap / Splitter specifications from Scientific Atlanta Reference guide)

<u>4-way*</u>	<u>Tap Values*</u>	<u>8-way*</u>
1.4 / 0.9	29	1.6 / 1.1
1.4 / 0.9	26	1.6 / 1.1
1.4 / 0.9	23	1.6 / 1.1
1.7 / 1.1	20	1.9 / 1.4
2.0 / 1.4	17	2.9 / 2.0
2.8 / 2.1	14	*5.1 / 3.9
*4.3 / 3.0	11	N/A
	* 8 (2-way only)	4.1 / 3.0

**Note: Self-terminating taps, tap values, and insertion specifications may vary slightly between manufacturers.*

Exhibit 3. MLS / Splitter / DC Insertion Loss Specifications (at 750 / 50 MHz.)

MLS / DC 3 (two-way split)	4.5 / 4.0	
MLS / DC 636 (three-way split)	8.0 / 7.2 (two down legs)	4.6 / 3.8 thru leg
MLS / DC 8 (two way split)	9.3 / 9.1 down-leg	2.2 / 1.7 thru-leg
MLS / DC 12 (two way split)	13.2 / 13.2 down-leg	1.5 / 1.1 thru-leg
MLS / DC 16 (two way split)	17 / 16.6 down-leg	1.4 / 1.0 thru-leg
Power Inserter / PI		0.8 / 0.7

Review

- HFC systems are comprised of a fiber fed node, a coaxial cable distribution system, amplifiers, and a power supply, feeding up to 500 homes.
- System power is provided by a power supply and a power inserter, spliced in to the coaxial distribution cable, combining electrical power with the forward and return signals.
- The cable distribution system typically provides the path for electrical power and RF signals to be sent and received from customer terminals to the node. Coaxial amplifiers overcome the loss elements of the coaxial distribution systems cable and device insertion losses.
- The node is like having a head-end in your neighborhood, improving system reliability and signal quality, by eliminating long strings of amplifiers (amp cascade) in a row to feed remote areas of the system.
- Coaxial cables vary in size and efficiency. Efficiency is expressed in dB as a loss in signal power for a specific frequency, across 100 feet of coaxial cable, at 68 degrees (F). Temperature will change coaxial efficiencies.
- All coaxial system devices (passive and active) will pass RF signals and / or AC energy. Amplifiers and DC's are configurable for passing or stopping AC.
- Passive devices cause signal level to drop from insertion loss of the device.
- Insertion loss varies between passive components, and is frequency dependent.
- Signal loss is frequency dependent. Higher frequencies lose more amplitude than low frequencies through a common device or equal length of a coaxial cable or conductive path.
- The unequal loss of signal power is referred to as non-linear, and is a function of frequency and the transmission medium (path) length.

System Design Theory: Unity Gain

Defining PQ (Picture Quality)

Before we discuss Unity Gain and system distortion, it may be wise to categorize degrees of impairment, regarding PQ (picture quality). Picture quality is subjective, yet it has been defined by the NTSC (National Television Standards Committee) in a study defining degrees of analog video impairment to the average viewer.

Impairment(s) were not specified, as the objective was to define a scale, regarding video quality and degrees of impairment. There are a few things to be mindful of regarding the PQ rating results:

1. TV's do not display identical impairments equally
2. Some viewers will be more discriminating than others
3. Analog TV was the format used in the study. NTSC PQ descriptions follow:

Acceptable – no visible impairments (good or standard)

Perceivable – some impairment observed (less than standard quality)

Objectionable – impairment diminishes resolvable image detail (poor)

Un-watch-able – impairment dominates the image (un-watch able)

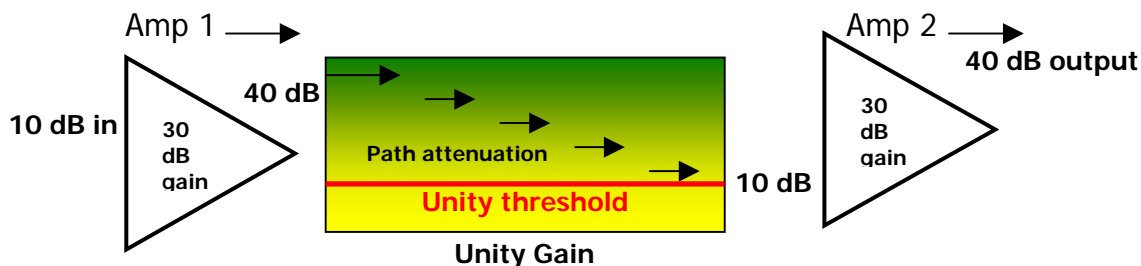
As a technician, these PQ ratings may help you to understand a customer PQ problem, that he / she may be having difficulty describing to you. You may find the terms useful to detail a system problem referral, where video quality is the issue. Of course, digital video cannot be used to validate PQ as analog can. Ironically, FEC (forward error correction), which repairs video errors (masks digital errors from the viewer), also causes the cliff-edge in digital video (the point where errors exceed the receiver terminal's capacity to correct them), which would fall in the category of objectionable or un-watch-able.

System performance is commonly qualified as the relationship between noise, distortions, and a reference video signal level.

System Design Theory: Unity Gain (cont.)

The quality of video source signals will not be perfect. A degree of distortion (undesirable energy) resides within the signal elements of audio, video, and color. These may be from the camera / broadcast equipment, or processing. The signal information is combined with a carrier frequency (modulated), and transmitted. Transmitting a signal along a conductive physical path will cause a portion of the signal's original or source amplitude to attenuate. This is a result of the path's resistance to the energy applied. Attenuation will be proportionate to the path's efficiency, length, and original amplitude level(s) and frequency. Systems are designed to deliver signals across considerable distance, and we must restore signal level to compensate for the path length and loss, delivering a usable signal with specific amplitude to the system extremities. **Amplifiers are placed along the path, at specific locations, where path loss (including insertion loss) is less than amplifier operational gain rating.**

Assume: Amplifier dB Gain rating=30 dB
System Design Output=40 dB

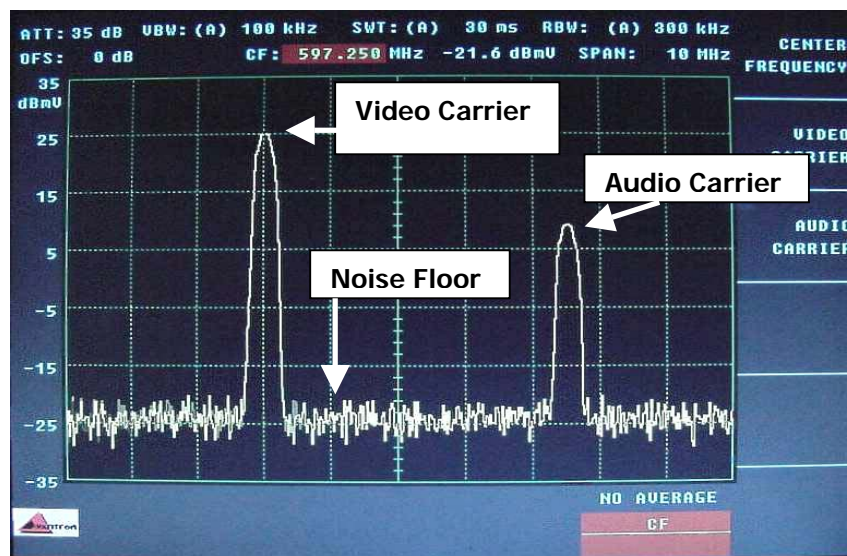


The dB of gain rating becomes the maximum path loss specification between amplifiers for the system. Here is where unity gain is applied. Path loss between amplifiers must be less than amplifier gain.

If unity is not maintained, amplifier output / input changes will give rise to distortion levels. Amplifiers (cascade) must be set with identical output level, to obtain the desirable low-distortion and high gain performance specifications of the amplifier. There is a limit to how many times signals can be re-amplified, and maintain a desirable signal (system) to distortion performance. Additional analysis / details follow.

System Design Theory: Unity Gain (cont.)

Attenuation of RF signal energy occurs as the signal propagates along the conductive path. Signal attenuation is actually due to some electrons being lost, typically as heat, similar to heat generated by friction, from path resistance. As each carrier loses electrons (attenuation), they accumulate. As more channels are added, more thermal energy accumulates. These fractional amplitudes combine mathematically, based on the original frequencies. There will be a worst-case resident thermal noise level within the spectrum at the most common mathematically related frequency of all carrier signals. As we view a carrier on a spectrum analyzer, the noise appears as miniature low-level carriers, bunched together at the bottom of the display. This is the forward system noise floor.



Avatron Spectrum Analyzer 597.25 MHz. center frequency

Look at the video carrier, and then look at the noise floor.

Estimate the C/N, observing the dB scale on the left (10 dB per division).

The carrier looks to be +25 dB. The noise floor looks to be about -20 dB.

The C/N in the analyzer screen above is about 45 dB.

We can think of C/N as the "amplitude distance" between the two, expressed in dB.

There is "45 dB of distance," between noise and carrier amplitudes.

Technically, this is a ratio of amplitude levels: carrier level vs. noise level.

System Design Theory: Unity Gain (cont.)

A spectrum analyzer measures noise levels, just as carriers are measured. Thus we have Carrier to Noise or C/N, the ratio in dB, between a carrier signal and the noise level. Noise becomes perceivable in analog TV when the C/N ratio falls to about 41 dB. This is an estimate, of when C/N becomes visible on the TV display, adding a grainy quality to the display. FCC Proof of Performance Test specification for C/N is equal to or greater than 43 dB at the test point (tap). Cablevision maintains a system specification of equal to or greater than 45 dB for C/N.

Signal to noise or S/N is often confused with carrier to noise. Both are ratios, expressed in dB, qualifying a reference signal level to the noise level.

S/N is the worst-case noise resident across the **6 MHz.*** slot of the channel. It is generally accepted that S/N is equal to C/N minus four dB. In other words picture quality is the same if each test is done and the S/N number is 4 dB less than C/N. The difference is C/N is the worst-case noise level across 4 MHz. (the video bandwidth) of the 6 MHz. channel slot. C/N is a valuable figure of merit for system performance. S/N is better suited for troubleshooting discrete channel problems and discrete processor components, commonly found in the head-end.

The node is the ultimate system reference for system technicians. If performance specifications are not met here, coaxial system performance degrades will follow, and increase through each coaxial amplifier.

Consider what processes each forward signal undergoes prior to arriving at the customer's tap. Signal manipulation adds a degree of distortion.

- (1) A signal is created (camera or recorded media), formatted and transmitted.
- (2) Received at the head-end, and down-converted.
- (3) De-modulated and processed as needed (digitized/groomed)
- (4) Modulated to a carrier frequency
- (5) Combined and amplified in the head-end to overcome the insertion loss of combining the forward spectrum
- (6) Up-converted from RF and encoded as light
- (7) Amplified and transmitted to the node or remote hub (Ion transport)
- (8) The node decodes the light pulses to RF again, and amplifies it
- (9) RF is then passed to the coaxial system for distribution.
- (10) The coaxial amplifiers process the signals to arrive at X dB at the last tap.

*** 6 MHz. is the standard bandwidth allocation for a single analog video carrier.**

System Distortions

Unity Gain applied ensures system performance specifications of the amplifiers, regarding gain, and desirable ratios of distortion. The expected distortions from each active device is predictable, and is specified by the manufacturer, based on a reference level minimum input, a system designed output level, and the channel load on the system.

Noise in particular, is the most significant element to control in the system, as noise comes from many sources, and in three distinct forms. The system noise we discussed to this point is noise from signal processing. This is accounted for in system design. Noise can be categorized to three main sources:

- 1. System Noise**
- 2. Impulse Noise**
- 3. Phase Noise**

Impulse noise is carrier energy from the off-air environment, migrating onto our system. This is ingress. Ingress occurs when some element of system shielding is compromised, allowing our signals out (egress) and off-air signals in (ingress). Impulse noise is typically associated with the return system. This type of noise is usually high in power, but short in duration or peak time. This is from wireless communications like CB radio, police/fire departments, and paging services, just to name a few. System integrity is the key to minimizing intruding CB carriers and other off-air sub-band frequency services, from entering the coaxial system.

Considerations for the return are different from the forward, as the return system does not carry video signals. Return signals are data, which may corrupt when an off-air intruding signal enters the return system (0's become 1's or vice versa). Each interactive service is assigned a portion of the return spectrum for return data. When impulse noise rises, errors occur. The degree of error(s) is proportionate to the degree of ingress on the return system. At the receiver, errors will be detected and corrected, to a point. If errors are too great, the damaged part of the data stream cannot be read, and the receiver requests the data be re-transmitted. This will affect each service differently. A phone conversation would suffer drops in the conversation, and in severe instances, disconnect. Internet service would slow or error at the user end. A VOD request may be slowed, or the user may receive a server error stating, "unable to process request".

Phase Noise – This is noise induced from electrical sources where imbalance exists between the positive and negative AC phases. A defective device, poor ground/bond, or power utility can cause phase noise. This will manifest as 60 / 120 cycle hum in analog video, and cause digital errors. Digital constellations take on a rotational appearance, in the presence of phase noise.

System Distortions (cont.)

System Carrier to Noise

Defined, C/N is the ratio of the peak carrier level to the average noise in the same video-bandwidth (the video portion of the bandwidth), referenced across 4 MHz. Carrier to noise may be written as C/N or CNR (carrier to noise ratio). C/N, or noise, adds on a power basis. If the input level and the Noise Figure* (NF) for the amplifier are known, C/N can be calculated using the formula below.

Carrier to Noise for 1 amplifier: $C/N = \text{Input level (dB)} + 59 - NF$
59 - represents best-case thermal noise @ 4 MHz. video bandwidth
NF – is the manufacturer established noise figure for the amplifier module.

Assume input = 14 dB NF=18 dB. Insert these numbers to the formula.
 $C/N = 14 + 59 = 73$. $73 - 18 = 55$. $C/N = 55 \text{ dB}$

To calculate C/N for multiple similar amplifiers, use the formula below.

$$C/N_S = C/N_1 - 10 \log S$$

C/N_S - Let S= the number of amplifiers
C/N₁ – Let 1 = carrier to noise for 1 amplifier

Noise will degrade 3 dB, each time the amplifier cascade doubles.

- | | |
|-------------------------|--|
| 1. Node | C/N = 55 dB (amp 1)
(-3 dB) |
| 2. Mini-bridger | C/N = 52 dB (amp 2) double |
| 3. Line extender | (-3 dB) |
| 4. Line extender | C/N = 49 dB (amp 4) double |

Noise is the most critical element effecting analog / digital signals, and will manifest as a poor BER measurement and possibly pixilation or loss of A/V synch. Analog TV picture quality will appear grainy from noise.

***Noise Figure is a manufacturer established rating for amplifier modules. NF is expressed in dB. You can obtain amp module NF by contacting the manufacturer online, or on the documentation the unit is shipped with.**

System Distortions (cont.)

Noise is an input function.

Signal level changes on the input of an amplifier will change the C/N ratio on the output of the amplifier. The volatile relationship between the distortion elements comes in to play here, as you will see in the example below.

Increasing input level by 1 dB:

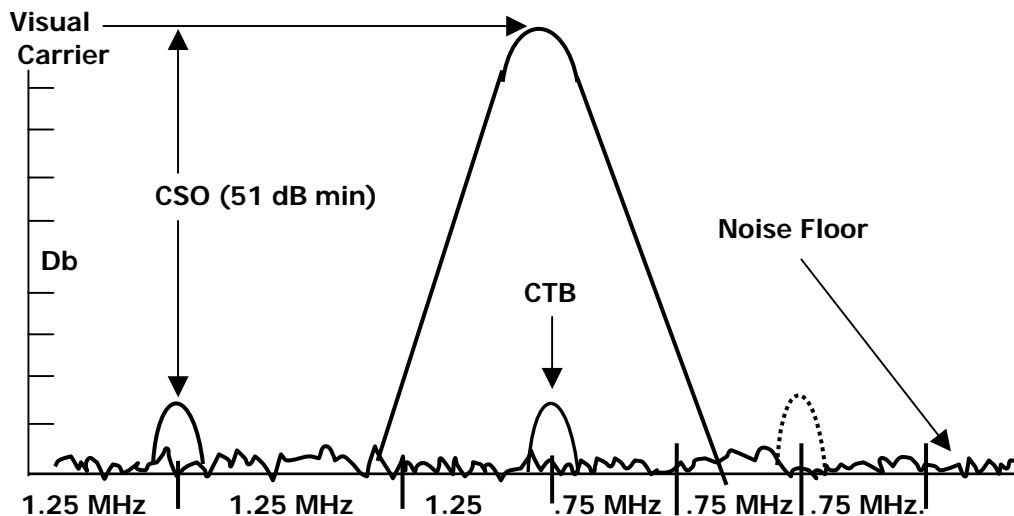
Improves C/N on the output @ 1/1.
 Degrades CSO @ 1/1,
 Degrades CTB degrades @2/1

Decreasing input level by 1 dB:

Degrades C/N by 1 dB
 Improves CSO by 1 dB
 Improves CTB by 2 dB

CSO (Composite Second Order) and CTB (Composite Triple Beat)

CSO is second order beats. We stated earlier that distortions accumulate, based on several factors, one of which is the channel load. CSO are beats generated by all possible combinations of **two frequencies**. With so many forward frequencies, this becomes a considerable distortion. CSO beats will fall at either 0.75 or 1.25 MHz. above or below the carrier frequencies. Carrier to CSO should be greater than 51 dB.



The dotted beat to the right of the carrier shows a 0.75 MHz. offset. This indicates channels 5 and/or 6 are contributing to the distortion.

System Distortions (cont.)

The illustration on the previous page shows the CTB beat directly under the visual carrier, with second order beats 1.25 MHz. offset below the carrier. This will be above (to the right) the carrier as well. The beat, shown as a dotted wave, is a CSO beat too, but is offset by 0.75 MHz. When a CSO beat is seen here, we know we have a low band beat (channels 5 and/or 6) contribution. How do we know this?

The entire forward spectrum is based on a standard 6 MHz. channel slot, for analog or digital carriers. The 6 MHz. spacing is consistent; except for a four MHz. slot between channels 4 and 5 (10 MHz. between video carriers 67.25 and 77.25 MHz.). This was a guard-band, for microwave pilot tone, used to synchronize transmitter and receiver at remote head-ends prior to fiber optics. The tone would become audible in channel 4's audio, and/or degrade channel 5's video, if the filter or the pilot frequency (tone) drifted. This space in the spectrum is no longer needed for this purpose, but the frequency allocations and channels remain allocated to this four MHz. of space. This frequency offset is how we know when one of the two channels is involved, because all other frequencies spaced @ 6 MHz. will add to a beat offset of 1.25 MHz.

**CSO is a beat resulting from all possible combinations of two frequencies.
CTB is the resulting beat from all possible combinations of all frequencies.**

FCC system specification for CSO: equal to or greater than 51 dB.

FCC system specification for CTB: equal to or greater than 51 dB.

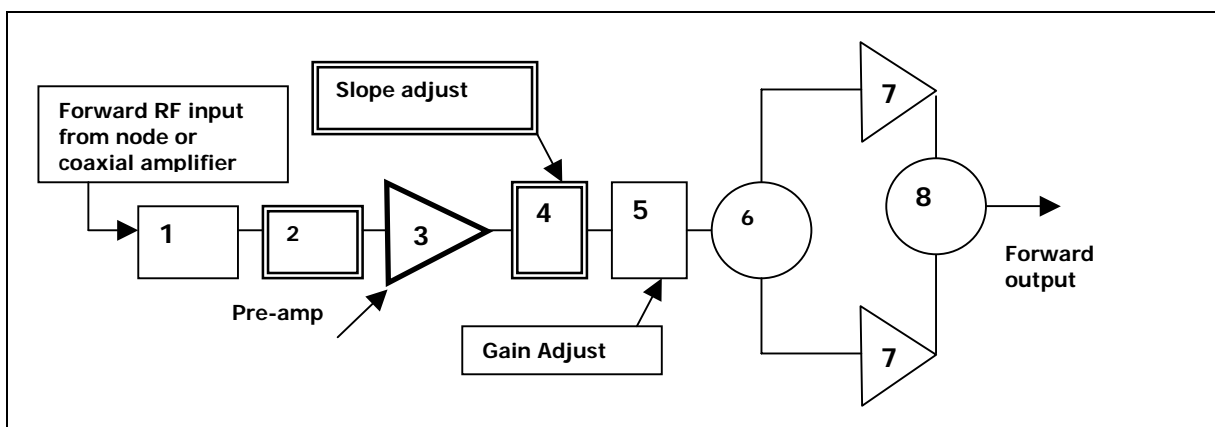
FCC system specification for C/N: equal to or greater than 43 dB.

Amplifier Design and Setup

The system levels of these distortions are linked to amplifier setup, through the amplifier balancing process, including proper pad and equalizer values. The relationship between distortions is volatile, where if one improves, others degrade. Distortions will exceed expected levels if pad and equalizer values are not properly matched to the input level for the amplifier. Below is a typical amplifier schematic.

The gain and slope pots control the post-amp output level (#7).

The pre-amp is where most of the gain takes place (#3).



Schematic details:

1. Plug-in pad (variable value attenuator)
2. Plug-in equalizer* (variable values, based on dB of cable no adjustments for L/E*)
Items with a double line are for slope (low band) level control.
3. Pre-amp. This is where most of the gain takes place. Notice the pre-amp is configured at the input of the variable field adjustments for gain and slope.
4. **Slope adjustment.** Monitoring levels at the output test point, the low band reference level is set with this potentiometer.
5. **Gain adjustment.** Monitoring levels at the output test point, hyper band reference level is set with this potentiometer.
6. Splitter or diplexer
7. Post amps
8. DC (diplexer) combines the two inputs from the post amps (3 dB additional gain).

The pots (potentiometers) on the amplifier module (gain and slope) provide variable adjustments for the hyper-band and low band output. After installing the proper pad and equalizer values, adjust the gain and slope to your reference level.

***Amplifier (like Mini-bridger) equalizers may have several response pots on the equalizer, or an optional response board. Do not attempt adjustments on individual equalizer/response board pots, without a Calan meter or spectrum analyzer. We will see why in a minute.**

Amplifier Design and Setup (cont.)

Notice the variable pots, marked Slope and Gain adj., are **post amp functions**. Most of the gain has already taken place in the pre-amp. Pad and equalizer values must be correct, based on the input signal level, to obtain the desired performance specifications of the module. This configuration is typical of modern coaxial distribution modules. It should be obvious that pad/equalizer errors (wrong value based on inputs) may produce high distortion levels, and cannot be “balanced out” using the gain/slope controls. This is the principle of, “garbage in = garbage out”, an old, yet wise cable truism.

System performance is commonly qualified as the relationship between noise, distortions, and a reference video signal level.

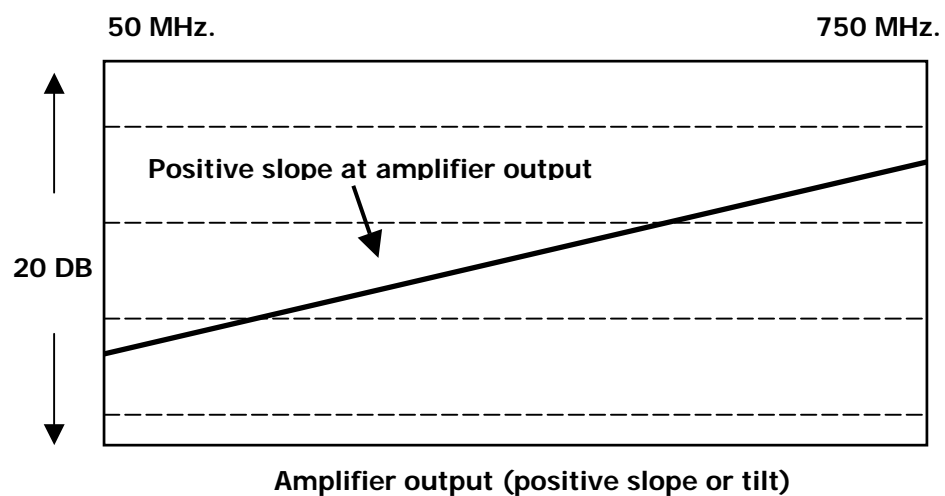
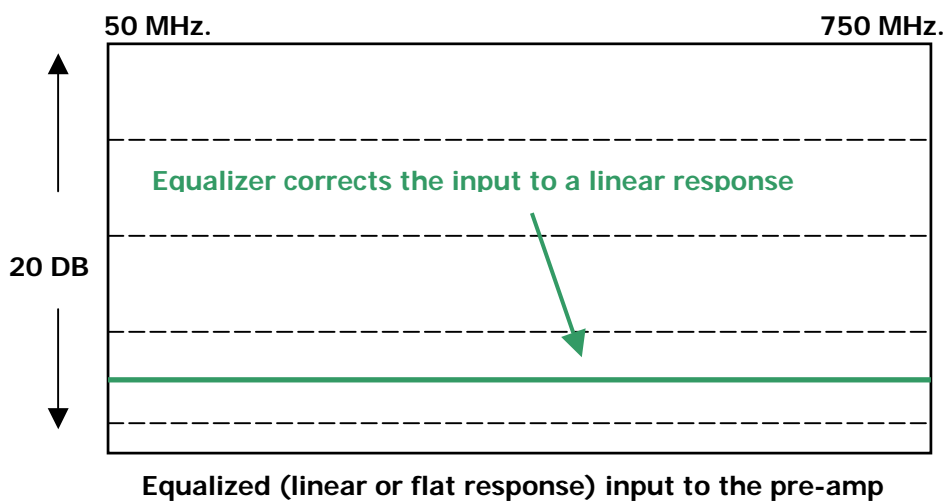
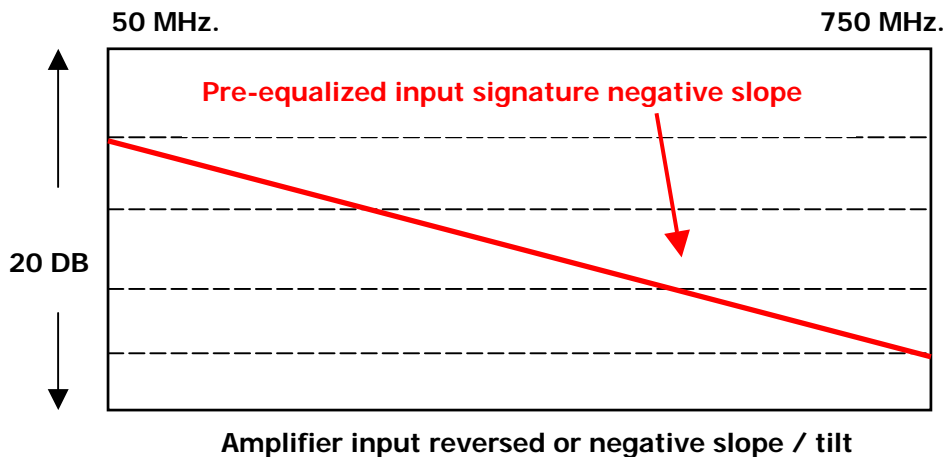
There are numerous documents, from various sources that define setting up an active device on a CATV system. Follow the manufacturers process to set up temperature reserves on AGC (automatic gain control) equipped amp modules, and follow the same for the fixed type of thermal plug in compensation boards and equalizer selection, commonly used in line extenders. These recommendations are based on cable footage between actives and the ambient temperature when you setup the amplifier / line extender slope reserves.

The following method has proven to be successful for setting up several different manufacturers coaxial amplifiers including Jerrold and SA gear. Obtain the specifications for the exact model of the module/amp you are setting up. If literature is unavailable from the box, call or go online for technical specifications. You want the specification listed as **NF**. This is the modules **noise figure**, which is expressed in dB like this: NF = 11 dB. Add 4 dB to the NF listed for the amp module. This is the ideal input to the chip or pre-amp section of the gain circuit (pad and equalize the device's input signal to the noise figure + 4 dB). The pots where we adjust gain or slope while measuring output level are in the post-amp section, and quality of the signal here is based on the pre-amp, receiving a specific linear input level (with the correct equalizer and pad installed).

If amplifier input level is incorrect (improperly padded or equalized), distortions rise at the pre-amp, and are passed to the post-amp. The gain and slope adjustments (post-amp) **may** range the output level close to reference, however distortions will remain, regardless of gain and slope level output settings. System slope signatures are illustrated on the next page, showing amplifier input, equalized (flat or linear) response, and amplifier output signatures (positive slope).

Amplifier Design and Setup (cont.)

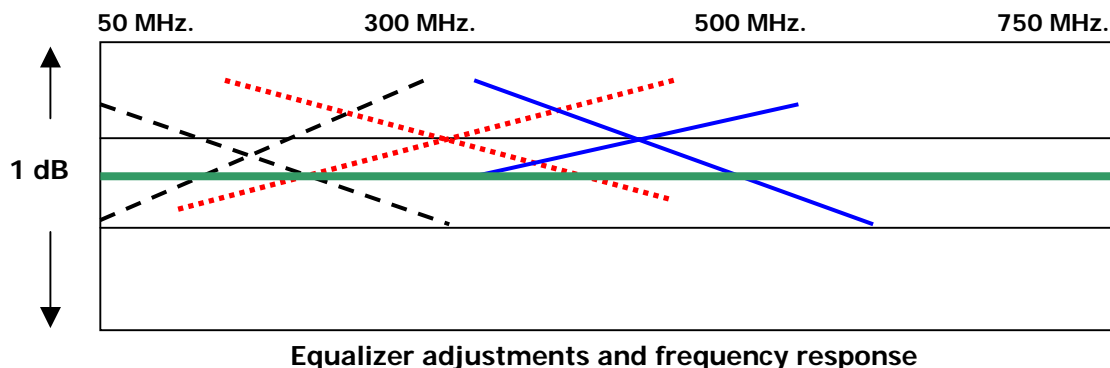
Typical system signatures show how positive slope is restored at an active.



Variable Equalizers / Response boards

Adjustable response boards and variable equalizers require the use of a Calan or spectrum analyzer to see the effects of adjusting the pots. Adjustments are not linear across the frequency band, rather these adjustments pivot from a fixed frequency, like a seesaw. Each pot may overlap upper or lower adjacent frequency ranges.

The line patterns simulate the response / range for each equalizer pot. The center line simulates the ideal system response (linear), or signature.



SLMs lack the resolution of a Calan or analyzer, and will not show the subtle response changes, as each pot is adjusted. Generally these adjustments are made when a system is being swept. An SLM does not capture sufficient detail to accurately capture and display 1/10 of a dB in level, across a 30-40 MHz. span. Level changes of 0.10 dB per pot, make a drastic difference in how the response looks on a spectrum or Calan display screen, while an RF meter may not register the change in level at all. Proper adjustments here can be the difference between passing / failing an FCC Proof of Performance Test, for system linearity, channel deviation, and peak to valley testing.

A word on potentiometer (pot) adjustments:

Potentiometer (pot) settings (equalizer / response boards and gain / slope) should be made with a **non-conductive tweak tool**. If a metallic tweak (mini-screw-driver like device) is used, it will be nearly impossible to set the correct level while adjusting a pot. The amplifier EMF energy will be induced on to the tweak, causing a jump (up or down) in signal level readings, as the pot is contacted by the tweak, and as the tweak is removed from the pot. This is true for all control pots on active devices. Furthermore, a little finger pressure in one direction or another can sufficiently change your response while sweeping the system, as opposed to an eighth or quarter of a turn on a pot control. A sense of touch for this process is usually acquired on a short term.

Calculating System Level

Calculating level for a drop or a section of system cable is exactly the same, except for the loss specifications, and greater lengths of cable. On the system, technicians may refer to coaxial cable loss as **dB of cable**. This expression is commonly used by equipment manufacturers, to specify equalizer values for amplifiers, based on the cable footage between two active devices. The equalizer effectively reverses the non-linear frequency dependent loss characteristics of RF signals (loss ratio between hyper and low band signals).

Calculating the correct equalizer value (dB of cable) will restore signal linearity at the device's pre-amp. The amplifier pre/post-amps restore a positive slope to system level at the device output. Calculate input as follows:

1. Reference the device that feeds your amplifier (**assume 49/41**).
2. Total cable footage between the two amps (assume 1240' of .650 cable. Loss for .650 @750 MHz. = 1.5/100 feet).
3. Multiply your footage total, by the .650 loss spec.
(**1.5 dB /100 ft. for .650 cable = 1.5 X 12.4= 18.60 dB of cable**).
4. Look up the OEM equalizer recommendations for 18.60 dB of cable loss @750 MHz., and install the recommended equalizer value.

MODEL (EQ-750-*)	02	04	06	08	10	12	14	16	18	20	22
dB OF CABLE EQUALIZATION	2	4	6	8	10	12	14	16	18	20	22

Jerrold Mini-Bridger Equalizer / dB of cable chart

With 18.6 dB of cable, install the EQ 750-18 value, according to the OEM chart.

As a rule of thumb, if calculations are between two equalizer values, choose the higher value. This will generally provide a better frequency response for the hyper-band channels on the output.

Calculating System Level (cont.)

With the correct equalizer calculated and installed, we need to figure the forward pad value for our mini-bridger. Our dB of cable (input) calculation will be used again, after we add our insertion losses together for all passive devices between our two amplifiers. Tap and splitter loss specifications are on page 7 of this guide.

Assume 11.5 dB of insertion loss from taps and splitters. Add this to our dB of cable.

(Assume a reference @49/41. Assume mini-bridger has 34 dB of gain).

(1.5 dB /100 ft. for .650 cable = $1.5 \times 12.4 = 18.60$ dB of cable).

18.60 dB of cable

+ 11.50 Insertion Loss

30.10 dB = total loss between the reference amp and our mini-bridger.

With our reference of 49 @750 MHz. we subtract our total loss of 30.10, and calculate (18.90 dB), about 19 dB @750 MHz. to the mini-bridger input. It is wise to verify calculated input level with an RF meter, remembering to add the test point loss to your RF reading (typically amplifier test points are 20 dB down from actual level).

Expect actual level to be + / - 1 dB (within 2 dB) of the calculated level.

With a 19 dB input and 34 dB of gain, add these together, for a total of 53 dB. Subtract your high channel reference (49 @750 MHz.) from 53. The answer will be your pad value for this mini-bridger.

$53 - 49 = 4$ dB, or Input + module gain (53) minus reference (49) = pad

Install a 4 pad in the mini-bridger input. Connect your meter to the output test point, and balance the module to reference (49 / 41). Factor the test point loss to your signal level reading (-20 dB for a mini-bridger). 49 / 41 will read as 29/ 21 through a 20 dB down test point.

An easy method to deal with test points and the different values between manufacturers is to add the test point dB value to actual RF meter level.

This gets a little confusing looking at input levels to an active through a test point.

The 19 dB @ the mini-bridger input from our sample above, would read - 1 dB, through the 20 down test point.

Remember: Set your test equipment (dB / attenuation / scale) to read signal level at the upper third of the display screen or scale, for accurate measurements.

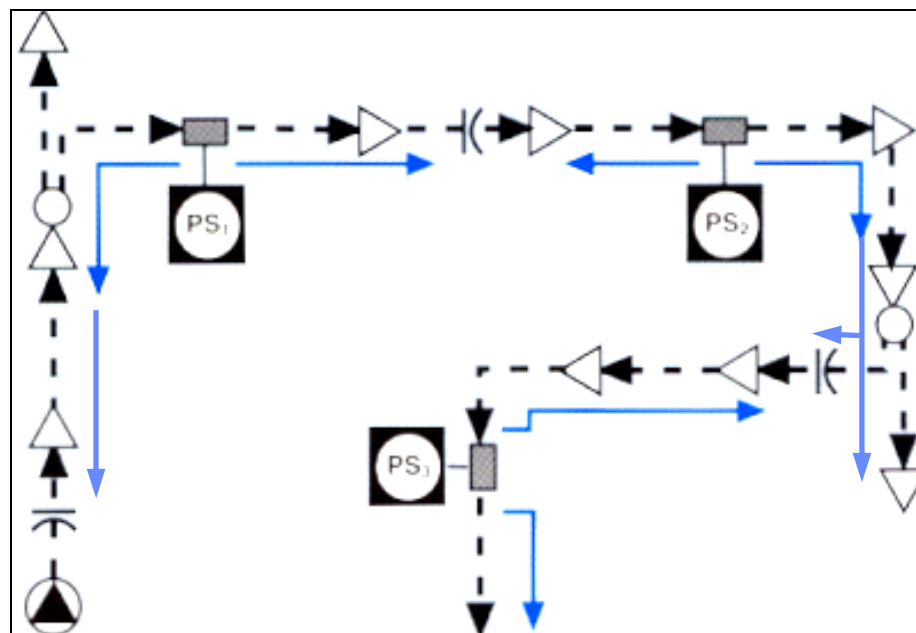
System Power

Active devices (Node, mini-bridger, line extender, status monitor modules) require AC (electricity) to function. Each device has an amperage/voltage requirement to perform a designed function. HFC systems typically have a power supply dedicated to a fiber node, and all the coaxial amplifiers the node feeds, consistent with Cablevision's HFC platform of choice design (1 node for up to 500 homes). Fiber optic cable is a thin strand of glass, and glass is non-conductive. Power for the node must come from a conductive path, connected to the node.

Coaxial cable **is** conductive, and is used as such, to deliver AC energy to the active devices on the coaxial system. The node's input/output (aside from the fiber cable) is after all, configured to accept standard coaxial seizure fittings at each port.

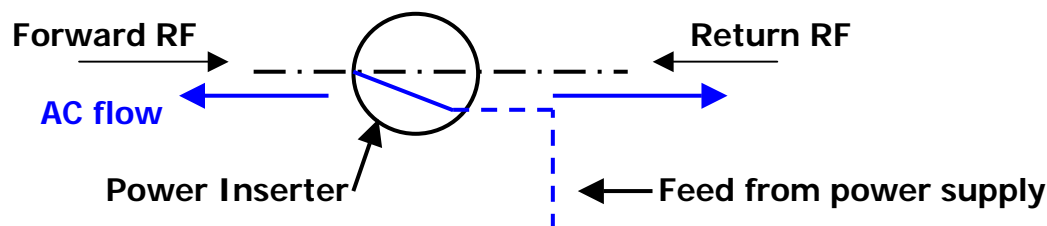
Like an extension cord, coaxial cables have two conductive paths: center conductor (CC), and shield. The CC serves as the positive phase or conductor and the shield as the negative. Our coaxial amplifiers are configurable, to pass or stop AC from flowing / combining with input and / or output cable connections. The cable path will attenuate some of the AC energy applied from the cable's resistance, similar to frequency dependent RF signal attenuation, and loss of AC and RF energies is proportionate to cable length. This is the loop resistance specification of the cable, expressed in ohms, and is listed with frequency attenuation specifications.

AC is omni-directional. It will flow along any conductive path. The triangle points refer to forward RF flow. The solid line arrows indicate AC power flow along the coaxial cable. Notice the power-block symbols, defining where power flow terminates for each power supply or power loop.



System Power (cont.)

The power supply protects system components from fluctuations in the power grid. The power from the utility goes through a step down transformer, providing 87.5 volts AC output. The coaxial system distribution cables are configured to the power supply through a power inserter. This is a fuse protected DC, with the power from the supply combined at the down leg of the DC as shown below.



Each side of the inserter has a 15-amp fuse, protecting the supply and system components, from an overload. The supply has a maximum capacity of 15 amperes. Generally, the devices fed from the supply, or power loop, should equal about 75% of the power supplies maximum amperage capacity, or 12 amperes total.

The amperage requirement of each device in the power loop is added, along with the loop resistance of the coaxial cable. Loop resistance is a specification (in Ohms) for coaxial attenuation of voltage. Voltage and amperage are linked elements of AC power, where if one goes up the other goes down. This is similar to water pressure. A thumb on the end of a hose causes water to shoot further away (more pressure, less gallons per minute or water flow) as opposed to no thumb on the hose (less pressure, more gallons per minute or water flow).

Amperage is the current flow potential of AC energy. Voltage is the electromotive force potential. Without amperage voltage has no potential or power. Amperage is measured in amperes or amps. Naturally, devices requiring less than 1 amp have ratings expressed as decimal values or milliamps, like .250 or .500 for a quarter or half an amp respectively. A device requiring half an ampere specifies for the device to function normally, half an ampere is the device specific load or draw on the power supply, along with a minimum input voltage, for normal operation.

The amplifier converts the AC input to DC power (rectifier circuit) to operate the forward/return modules in the amplifier. Technicians must concern themselves with both power elements, as amplifier performance is based on AC input voltage/current, for proper DC voltage/current to operate the amplifier modules. Typically, CATV amplifiers deliver +24 Volts DC to its amplifier modules. DC is actually rectified or rectifier voltage.

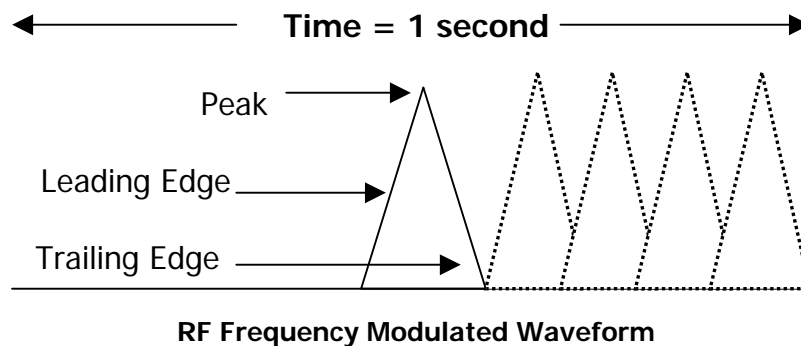
System Power (cont.)

AC is high in power and low in frequency, measured in Hz. RF is low in power and high frequency, measured in MHz. Both AC and RF are voltages.

The frequency difference is best observed as waveforms. This will help explain the difference of power potential between the two.

Hertz is an acronym for cycles, expressed over a specific time frame, typically 1 second. Hertz = cycles per second. The prefix's Kilo, Mega, and Giga are exponential increases in the number of cycles per second. Cycles are the element of frequency.

An RF waveform (frequency modulated) consists of a leading edge, a peak, and a trailing edge. The frequency is equal to the number of peaks per second.



The prefixes make cycles per second, or frequency, easier to express and qualify. We know the video peak for channel 4 is 67.25 MHz., or we could say 6,725,000.00 Hz. Either one is correct, while MHz. is the industry standard, and 67.25 is more easily managed vs. 6.725 million. The dB was developed as a measurement tool, to quantify energy levels below 1 volt. The expression, dB, makes RF power a simple, understandable, numeric expression absent the decimal point and endless zeros to express power values accurately where 1 volt is considered absolute power.

The dB is an expression of two powers, where 1 volt is absolute. Everything else then, is less than the absolute value (one volt). Zero dBmV is equal to the signal power of one millivolt, across characteristic impedance @75-ohms.

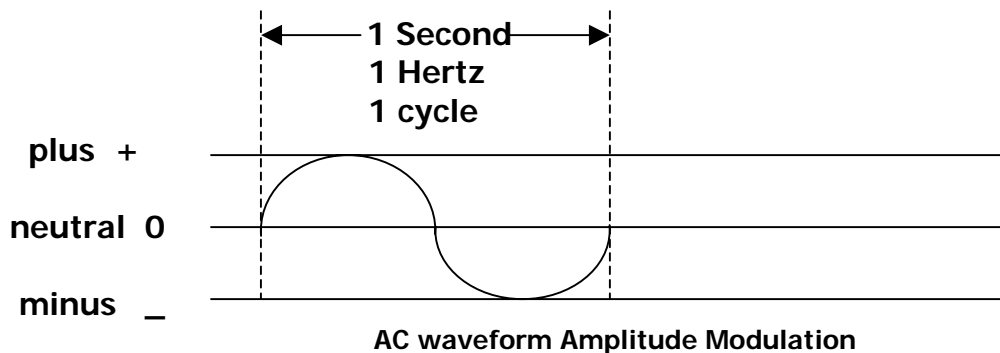
RF will always seek the path of least resistance.

AC will always seek the path of most resistance, or a path to ground.

RF and AC are both voltages.

System Power (cont.)

Alternating Current or AC is named for the character of the waveform, which alternates between positive and negative states. This is Amplitude Modulation.



The AC waveform does not peak like the RF waveform. Its' rounded wave, and phase alternation take more time to complete 1 cycle, compared to RF cycle peaks. The AC wave has more power potential, as the wave peak remains high for a longer time. Most home appliances will say on the power cord, "120 VAC @ 60 Hz." That is 60 plus/60 minus peaks per second, or 60 cycles, or 60 Hertz of alternating current.
AC will always seek the path of most resistance, or a path to ground.

Our HFC power supply specifications / configurations:

Input Requirements

110-120 VAC @ 60 Hz. input from the local power utility

Output Specifications:

87.5 VAC @ 60 Hz. output to the system

@15 amperes (maximum)

Typically designed for 75% of the maximum rating or 12 amperes

Stand-by capable (battery configurations may vary)

System Power Calculation

Knowledge of Ohm's Law will be helpful to calculate voltage/ampereage/wattage for any device at any point on the system. Applying Ohm's Law is fairly simple. We must know two element values of a circuit, to calculate the third, or unknown element. The elements are on the left, and the Ohm's Law formula characters are listed to the right, for each element of electrical power:

Amperage or current	= I (expressed as amperes)
Voltage	= V or E (expressed as volts)
Impedance or resistance	= R (expressed as ohms)
Watts or Wattage	= P (expresses as watts)
(750 watts is equal to 1 horsepower)	

Watts is an expression of how much "work" is produced, or the output from a device, given a specific input power (amperes and volts). Light bulbs use watt expressions we are familiar with, as more watts=more light. The expression of watts is included in power calculations to qualify ampereage and voltage consumption vs. yield or output (part of Joules law). This is more an expression of device efficiency, based on power consumed and the resulting output, function, or yield.

Loop Resistance* for coaxial cable is calculated as follows:

1. Add the total footage from the supply to the device you are checking (calculating). Assume 1000 feet of .750 MC2 cable.
2. Verify the loop resistance specification for the cable used.
(0.73 ohms per 1000 feet for .750 MC2 cable)
3. Multiply the footage by the loop resistance specification, expressing 1000 feet as 1.0 (1472 feet as 1.472, 2204 feet as 2.204 etc.). This is the R variable in Ohm's law /equation shown below.

$$E = I \times R$$

$$E \text{ (voltage loss per device)} = I \text{ (current/amperes)} \times R \text{ (impedance)}$$

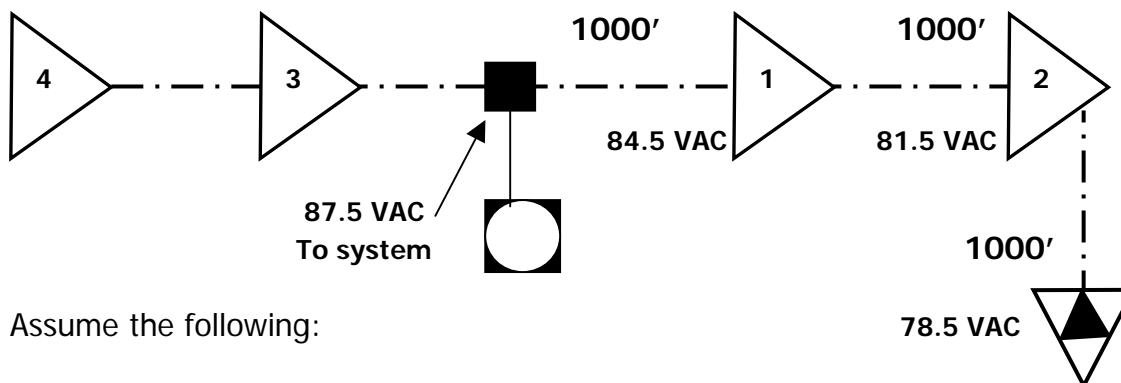
I= current requirement of all devices on one side of the power inserter between your device/amplifier and the power supply/inserter.

R= Loop resistance specification (in ohms) for the cable used

***Cable DC loop resistance specifications are available in any of the CATV reference guides, under cable loss specifications. Be sure to select the correct type and size from the list, as specifications change with nomenclature and type of semi-conductor/di-electric.**

System Power Calculation (cont.)

Calculate the voltage input for the line extender off amplifier #2, in the configuration below.



Assume the following:

Power supply 87.5 VAC to the system (15 amperes max.)

Assume each Amplifier requires 1.5 amperes (current)*

Assume each Line Extender requires 1.1 amperes (current)*

.750 cable loop resistance= .73 ohms per 1000 feet

Calculate the voltage drop to the line extender off amplifier 2 from the power supply.

$$E = I \times R$$

Add the amperage (current rating) for each amplifier, on the supply between your amp and the power supply/ inserter; $1.5 + 1.5 + 1.1 = 4.1$ amperes or current.

Insert the total current draw (4.1) into the equation with the loop resistance specification (0.73).

$$E = 4.1 \text{ amperes} \times 0.73 \text{ ohm's}$$

$$E = 2.993 \text{ volts per 1000 feet (3 volts per 1000')}$$

Use 3 volts as the drop between actives for simplicity.

$$87.5 - 3 = 84.5 \text{ VAC at amplifier 1 input}$$

$$84.5 - 3 = 81.5 \text{ VAC at amplifier 2 input}$$

$$81.5 - 3 = 78.5 \text{ VAC at the line extender input.}$$

* Each device's current draw must include forward/return module amperage loads specified by the equipment manufacturer. Devices equipped with status monitor modules should include the amperage draw of the status monitor module, for accurate calculation.

System Power Calculation (cont.)

At the active device, AC and RF energies enter the input diplexer. This is simply a DC with different resistive/capacitive values on each of the two output legs. We said earlier AC will seek high resistance values and RF seeks low resistance values. The diplexer is set to emulate these values, and we have separated the AC / RF to different paths within the amplifier. RF is routed through the pad / equalizer network and arrives with a desirable linear signal level at the pre-amp.

The AC path is routed to the rectifier circuit, and then to the output of the device (if so configured). The rectifier converts AC to DC voltage and sends DC voltage to the forward and return amplifier modules through the chassis. DC voltage powers the modules, supplying power for the function of gain to the forward and return signals. The amplified signals are then passed to a diplexer again (re-combined), and sent up or downstream as needed, with or without AC voltage, depending on system power configurations of the power loop.

Technicians need to concern themselves with AC and DC power measurements at each active device.

If AC input to a device is too low, the DC output will also be low. This may result in poor signal quality at the device output, hum problems, or cause the DC power supply fuse in the device to open (blown fuse), from the higher amperage draw of the device, when AC voltage inputs drop below specification. Typical DC voltage output to the modules is +24 VDC. The AC input range is specified for each device by the manufacturer and is typically forgiving (70 – 90 VAC input), while maintaining a 24-volt DC output from the rectifier to the amplifier modules.

Review 2

- RF is voltage where power is less than 1 volt. RF is high in frequency, but low in amplitude or power. RF will always seek the path of least resistance.
- AC is low in frequency, but high in amplitude or power. AC will always seek the path of most resistance, or a path to ground.
- High frequencies are faster than lower frequencies, and have a smaller waveform, with shorter rise and fall times between cycles.
- Low frequencies are slower than high frequencies, and have a larger waveform, thus a longer rise and fall time between cycles.
- RF is directional, maintaining original orientation or direction, away from a source or amplifier.
- AC is omni-directional, or non-directional, flowing along any conductive path.
- Voltage and amperage behavior is like water flow. If pressure goes up, volume goes down, and vice-versa. So it is with amperage and voltage; if one goes up the other goes down.
- Power circuits are designed to a maximum of three-quarters of the total amperage capacity of the supply.
- A Rectifier is a circuit that changes AC voltage to DC voltage
- Diplexers combine and separate two different energies or signals.
- Diplexers create separate paths by offering different resistive values at two output paths, to two energies or signals on a common path or input.
- The coaxial system cable is the path for RF and AC energies
- System performance is commonly qualified as a ratio between noise, distortions, and a reference video signal level or amplitude.

Knowledge Check

1. What is a diplexer?
2. The principle stating, "Loss between actives must be less than the actives gain rating" is called _____?
3. What does RF stand for?
4. DC voltage is also known as _____ voltage?
5. What is Cablevisions platform of choice?
6. What does HFC stand for?
7. The device combining AC power, from the power supply, to the coaxial system is _____?
8. What is C/N?
9. True or False? Fiber optic nodes are transceivers.
10. True or False? The numeric value on the tap indicates the signal level at each tap / drop port.
11. What active device component corrects the reverse slope at the coaxial amplifier inputs?
12. What is an 8 dB slope, with regard to coaxial system distribution amplifiers?
13. What is meant by a linear or flat response?
14. Signal attenuation is a function of _____?
15. Coaxial cables are all rated at _____ ohms.
16. Inside a coaxial amplifier, amplification is a two-stage process. Name the two stages of amplification.
17. Coaxial amplifiers typically require _____ volts DC to operate.
18. How many amperes (total) of capacity are our system power supplies rated for?
19. What is the value of the fuse inside the power inserter?
20. How is loop resistance expressed (unit of measurement)?
21. Power circuits are usually designed to about _____ of the amperage capacity.
22. What is meant by the expression, "dB of cable"?
23. Is insertion loss included in "dB of cable"?
24. _____ is the most critical system distortion effecting quality of service.
25. Most of the gain occurs in the coaxial amplifier _____ amp stage.

Glossary

Active device - Any device using power to manipulate one or more elements of RF signal or signals. Nodes, Power Supplies, Amplifiers and Line Extenders are active devices. Taps, DC's, equalizers, and pads are passive devices.

Amplifier - a device that processes attenuated signal level, restoring the designed or original amplitude to the system signals.

Attenuation - Loss of applied signal power from the resistance of the transmission medium or path (coaxial cable loss).

Bandwidth –1 the space occupied within the RF spectrum by a channel, carrier, or specific transmission format, usually measured in Hertz, Kilohertz, Megahertz, or Gigahertz. 2. The capacity of a given system or network, referenced to RF frequency. 3. Spectral requirements for transmission of specific signal formats.

Composite - A group of channels or signals, considered collectively. A converter's input cable is considered composite (all channels), while the output is considered discrete (one channel).

dB of Cable - An industry expression of loss between two specific points on the system due to **coaxial cable only, at the highest frequency**. No insertion loss is included. "Ten dB of cable," means a ten dB loss from cable only.

Discrete – A singular signal or channel, isolated from other signals or channels. The F connector converter output to the TV is considered discrete, converting the selected channel (composite input) to channel 3 (discrete output).

Downstream - Signals traveling from the head end to the customer.

Diplexer - Electronic components that combine or separate signals or waveforms, by varying resistive/capacitive values (outputs) to a common input or path with different waveforms or signals (splitter and DC function).

Directional Coupler or DC - A splitter-like device used to distribute/combine signal power. A forward perspective is the single port side of the device is input (standard splitter configuration), while a return perspective sees the same single side of the device as output.

Distribution system - Refers to the coaxial system of cables, taps, splitters, and amplifiers that distribute signals to and from the node for our customers.

Glossary (cont.)

Electronic Signature - Active devices perform an intended function to the input received, providing the function on the output. Two identical devices set exactly the same will not yield matching results. The subtle variable between two identical components is a result of each device having a unique electronic signature.

Equalizer- A device that reverses the non-linear attenuation of frequencies caused by the coaxial path, restoring a degree of linearity or positive slope between hyper and low band frequencies by attenuating the low-band only.

Feeder - See distribution system.

Frequency Agile - A device that will change its up or downstream frequency, within a designated bandwidth, if interference is present on the frequency currently used to communicate.

Insertion loss - Insertion loss occurs whenever a device is inserted (spliced) on a coaxial cable. Typically, taps and splitters will have insertion loss values specified from the manufacturer.

Pad - Plug-in attenuators (typically in 1 dB increments for active devices) are used to reduce input level to a device specific level, to yield desirable amplifier gain with minimal distortion.

Passive device - Passive devices (taps, equalizers, and splitters) divide and / or pass signal power but do not perform active processing (modification) of signal elements. Passive devices do not use power to function.

Power Inserter - A directional coupler, the inserter combines AC power to the coaxial system cable for distribution to the active devices on the system.

Power loop - a group of active devices that receive AC power from a common power supply.

Power Supply- A device that regulates and grooms AC power from the local power utility and supplies power to a specific group of active system devices. The supply buffers our equipment from fluctuations within the power company grid (highs and lows), and supplies system power during utility outages and/or fluctuations.

RF – Radio Frequency

Glossary (cont.)

RX – Abbreviation for receive or receiver

Slope - 1. The designed difference in system level between the highest and lowest forward frequencies in a system (48/40), to compensate non-linear attenuation of frequencies along the coaxial path. A system designed @ 48/40 has an 8 dB tilt or slope. 2. Slope generally refers to low band RF (slope control adjustments in an amplifier).

Spectrum Analyzer - An analysis tool like a field strength meter, with greater resolution for composite and discrete testing and measurement of RF signals. Signal information can be analyzed at an elemental level for, chrominance, luminance, frame synchronization, and blanking intervals. Analyzers can isolate and measure distortions, such as beats and thermal noise. Spectrum analyzers are used to submit FCC system compliance tests.

Spectrum - The range of all RF frequencies used within a network or system. Our forward spectrum is between 50 and 750 MHz. Our return spectrum is between 5 and 40 MHz.

Status Monitoring - Computer based software interface that allows remote monitoring of active system devices equipped with a status monitor module. Typical functions monitored are: input/output RF level, AC, DC, Amperage, and mode or status for power supplies. An operator, at a central office or location, will monitor system components via a dedicated PC with status monitor software, in composite or discrete modal displays. On the computer screen, a flashing icon, or change of icon color, indicates the device has violated a monitored parameter.

Test point - Active devices have points where input and output level is verified. Test points are specified as XX dB down, meaning add the test point value to the signal level read. Some equipment requires a unique probe to connect meter and test point. Most manufacturers use F-81 barrel plug-in for test points.

Tilt – see slope

Transceiver- A device that can transmit and receive signals and/or data.

TX – Abbreviation for transmit

Upstream- (Return) Signals sent from the customer terminals (homes) to the head-end.