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A7 Cable TV

A7.1 CATV Systems

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Modern cable TV systems collect video signals from a wide range of sources at a headend and distribute them hubs by means of FM carriers. Each incoming video channel is used to deviate an FM carrier by 1 to 4 MHz. The video signal is then routed from the hubs to the individual subscriber. CATV companies generally carry between 20 to 54 video channels.

Intermodulation can occur if there is some non-linearity in the system. This causes several of the channels to interfere with one another. To reduce spurious signal, CATV operators may frequency lock all of the channels to a common carrier, spacing them at 6 MHz intervals. This is known as the HRC [harmonically related carrier] scheme. Or they may use the IRC [incrementally related carriers] plan, spacing the video carriers at 6n+1.25 MHz intervals.

A7.1.1 Two Way CATV Systems

Two-way systems are a significant departure from traditional CATV facilities. The most obvious difference is in the distribution amplifiers which now must be bi-directional repeaters. The design of such amplifies is eased somewhat when one realized that the down-stream signal requirements are considerable different than those in the up-steam.

In the down-stream path (to the subscriber), there may be up to 52 video channels and one or two of these may be reserved for signaling to provide:

- Information on request
- Polling
- Equipment adjustment

The much less demanding up-stream path, consists only of signaling information:

- Requests for service
- Alarms or metering
- Polling responses

A relatively easy way to provide up-stream signaling is by means of FDM. Each subscriber is allocated a return channel. There may be up to 500 such analog channel carriers spaced at 20 KHz intervals from 5 to 15 MHz.

An alternate approach is to use a TDM signaling scheme. Each subscriber is allocated a time slot that may be acquired on either a scheduling or a demand basis.

Some CATV systems provide a return video channel. This would allow local programming to be received by the head end (cable station), and redistributed over the network. Normally this is provided by 2 carriers spaced 6 MHz apart, between 18 and 30 MHz.

The distribution system may include satellite links, terrestrial microwave links, fiber optics, and coaxial cable. To take the greatest advantage of these transmission facilities, local video switches may be deployed at hub sites.

A7.1.2 Noise Considerations

The noise power delivered from a transmission line to a matched load is given by:

$$P = kTB \ [\text{watts}] \qquad k = 1.38 \times 10^{-23} \ \left[\text{joules}/^{\text{o}}\text{K}\right] \text{Boltzmann's Constant}$$

$$T = \text{ temperature in } ^{\text{o}}\text{K}$$

$$B = \text{ bandwidth in Hz}$$

For a 4 MHz wide video channel at room temperature, this would amount to:

$$P = 1.38 \times 10^{-23} \times 300 \times 4 \times 10^{6} = 1.656 \times 10^{-14} \text{ watts}$$

This seems like an insignificant amount of power, until we realize that the characteristic impedance of a typical video cable is 75 Ω and the reference voltage level is 1 mV.

Since $P = \frac{E^2}{R}$ the power reference level is:

$$P_{ref} = \frac{\left(1 \times 10^{-3}\right)^2}{75} = 1.333 \times 10^{-8} \text{ watts}$$

Therefor the minimum noise level is:

$$10 \log \frac{P_n}{P_r} = 10 \log \frac{1.656 \times 10^{-14}}{1.333 \times 10^{-8}} = -59.06 \text{ dBmV}$$

This is theoretically the lowest possible noise level found in a 75 Ω CATV system. Since this value changes by only 1 dB over a 50$^{\text{o}}$C temperature range, it is considered a constant.

For good picture quality, the S/N ratio should be 40 dB or better. A signal with a S/N ratio of 25 dB or less is considered unusable.

A typical CATV amplifier has a gain of about 20 dB. However, like all electronic devices, it creates noise. Therefor the noise in any system gradually increases as the system gets larger. The amount of noise contributed by an amplifier is known as the noise figure and is given by:

$$F = \frac{\text{input S/N}}{\text{output S/N}}$$

Often the noise figure is specified in dB:

$$F_{dB} = \text{input S/N}_{\text{dB}} - \text{output S/N}_{\text{dB}}$$

It is informative to examine a cascade of amplifiers to see how noise builds up in a large system.

The S/N ratio is defined as the ratio of signal power to noise power:

$$\frac{S}{N} = \frac{P_S}{P_N} = \frac{\text{Signal Power}}{\text{Noise Power}}$$

Therefore: $F = \dfrac{P_{Sin} / P_{N\,in}}{P_{Sout} / P_{N\,out}} = \dfrac{P_{S\,in}}{P_{N\,in}} \times \dfrac{P_{N\,out}}{P_{Sout}}$

Gain can be defined as: $G = \dfrac{P_{S\,out}}{P_{S\,in}}$

Therefore the output signal power is: $P_{S\,out} = GP_{Sin}$

and the noise factor can be rewritten as:

$$F = \frac{P_{Sin}}{P_{N\,in}} \times \frac{P_{N\,out}}{GP_{S\,in}} = \frac{P_{N\,out}}{GP_{N\,in}}$$

The output power can now be written: $P_{N\,out} = FGP_{N\,in}$

The theoretical minimum input noise is: $P_{N\,in} = kTB$

Therefore: $P_{N\,out} = FGkTB$

From this we observe that the input noise has been increased by the noise factor as it passed through the amplifier. A noiseless amplifier would not have contributed any more noise and would therefore have a noise factor of 1 or in terms of decibels, 0 dB.

The output noise of a perfect amplifier would be: $P_{N\,out\,perfect} = GkTB$

Therefore the noised added by the amplifier is:

$$\begin{aligned} P_{N\,out\,added} &= P_{N\,out} - P_{N\,out\,perfect} \\ &= FGkTB - GkTB \\ &= (F-1)GkTB \end{aligned}$$

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This is the added noise, as it appears at the output. The total noise coming out of the amplifier is then given by:

$$P_{T\,noise} = \underbrace{G\,kTB}_{\text{input noise}} + \underbrace{(F-1)GkTB}_{\text{additional noise due to the amp}}$$

If a second amplifier were added in series, the total noise would consist the first stage noise amplified by the second stage gain, plus the additional noise of the second amplifier:

$$P_{T\,noise} = G_1G_2kTB + (F_1 - 1)G_1G_2kTB + (F_2 - 1)G_2kTB$$

If we divide both sides of this expression by: G_1G_2kTB

We obtain:

$$\frac{P_{T\,noise}}{G_1G_2kTB} = \frac{G_1G_2kTB + (F_1 - 1)G_1G_2kTB + (F_2 - 1)G_2kTB}{G_1G_2kTB}$$

Recall: $F = \dfrac{P_{N\,out}}{GP_{N\,in}} = \dfrac{P_{T\,noise}}{G_1G_2kTB}$

Then: $F = F_1 + \dfrac{F_2 - 1}{G_1}$

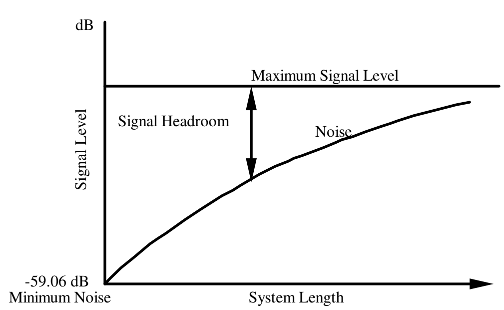
This process can be repeated for *n* stages resulting in Friiss' Formula:

$$F = F_1 + \frac{F_2 - 1}{G_1} + \frac{F_3 - 1}{G_1G_2} + \cdots$$

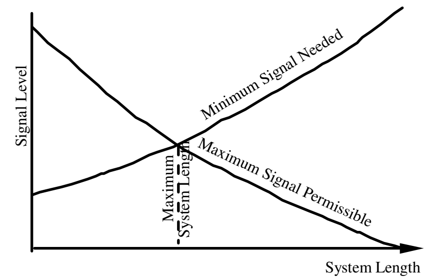
From an examination of this equation, it is readily apparent that the overall system noise factor is largely determined by the noise factor of the first stage in a cascade.

The system length is sometimes specified in dB rather than physical distance. This is because the physical distance is a function of the cable quality but the total system loss is a fundamental limit imposed by the laws of physics.

Noise builds up as the system length increases. Since amplifiers have a finite signal output power, the signal headroom decreases.



This phenomenon implies that there is an optimum amplifier gain to provide the maximum system length.



It has been determined that amplifiers with a gain of 20 log *e* = 8.69 dB will provide the maximum system length of about 3300 dB. This gain is too low for practical systems, since it would require too many repeaters, and be highly sensitive to small gain changes in the amplifiers.

A more practical repeater gain is 20 dB, which provides a maximum system length of about 2000 dB.

Typical CATV Amplifier Specs	
Bandwidth	20 - 270 MHz
Flatness	±0.25 dB
Output Level	32 dBmV
Maximum Gain	23 dB
Gain Control Range	7 dB
Input Return Loss	18 dB
Output Return Loss	16 dB
Noise Figure [270 MHz]	10 dB
Distortion	-80 dB
Power Requirements	35 W

A7.2 Wireless Cable TV

In many jurisdictions, regulatory agencies have kept a separation between certain types on communications networks: cable systems, radio broadcast stems, and telephone systems. Some of these restrictions are being lifted, with the net result that cable TV companies can now provide wireless or even telephony services.

As of 1993, there were 140 wireless cable TV companies with a total of 400,000 subscribers in the US.[1] Systems are currently being operated in 40 different countries, the largest being in Mexico.

Wireless operators transmit a 2.5 GHz signal on a direct line of sight basis. The subscriber has a 5 inch flat plate antenna generally mounted on the outside and an addressable, multi-channel, converter located on the TV set. Each broadcast transmitter can cover a radius of 50 to 60 miles.

1 Microwaves & RF, September 1993, page 42

Some equipment manufacturers are contemplating adding a 2 GHz transmitter to the home converter, thus creating a base station in a PCS† environment. This could be used for both voice and data transmission.

The CellularVision system in New York uses cellular techniques to combine pay TV and telephony services. The system operates between 27.5 to 29.5 GHz. Each 1 GHz band carries 49 video channels broadcast using FM and occupying 20 MHz. Two-way communications channels are inserted between the video channels and use reverse polarization, thus allowing frequency reuse. Some operators are proposing that return channels be supported by cable and telephone besides the radio link.

A.7.2.1Fiber Optics

Fiber optic cable is well suited to the carrying of high speed digital signals. For this reason, it has been suggested that HDTV should be made digital and not broadcast in the standard manner, but rather placed on fiber. This one application may make fiber to the home a reality.

Currently, fiber is being used to deliver video signals however, the modulation scheme is AM or intensity modulation. Unlike digital modulation schemes, where the noise is largely due to the receiver, in AM the noise is due to:

- Shot noise - quantum noise in the electro/optical conversion
- Laser intensity noise - relative intensity noise caused by variations in the laser output
- Interferometric noise - reflections caused by splices, imperfections, or variations in optical properties
- Front-end noise - a general catch all of all noise sources found in the receiver

Although laser diodes are inherently non-linear devices, a narrow range of currents will produce a linearly varying light intensity. The diode is modulated by RF carriers. It would appear that at the moment, AM fiber is the preferred method of modernizing or upgrading coaxial video distribution systems.

† Personal Communications System

Assignment Questions

1. What is the minimum noise possible in a cable TV system?
2. What is the typical repeater spacing in a CATV system?
3. Given a 75 ohm cable system with a 4 MHz per channel bandwidth, and 250 mVrms signal level, find:
    a) The minimum theoretical noise power level in dBm
    b) The minimum theoretical noise signal level in dBmV
    c) The S/N ratio
4. What is noise figure?
5. What do we learn from Friiss' formula?
6. An amplifier has an input return loss of 18 dB. If the incident signal has a voltage level of 10 dBmV, what is the level of the reflected voltage?

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For Further Research

http://www.catv.org/

http://www.cabledirect.com/

http://www.catv.org/GIP/cablesystems/index.html#canadian