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# RETURN PATH PERFORMANCE REQUIREMENTS IN CONTEMPORARY CATV SYSTEMS

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## INTRODUCTION

Recent developments in entertainment and information transfer (e.g., on-line services, PC networking, and interactive video) reflect a significant cultural development : Media traditionally considered as information delivery vehicles now are beginning to be used as two-way communication "return" systems which enable consumers to communicate via cable technologies to CATV points of origin. This change creates a need for re-evaluation of return systems and of the performance standards that will enable the CATV industry to meet customer demands..... This paper is intended as a primer to aid in the understanding of overall return system design.

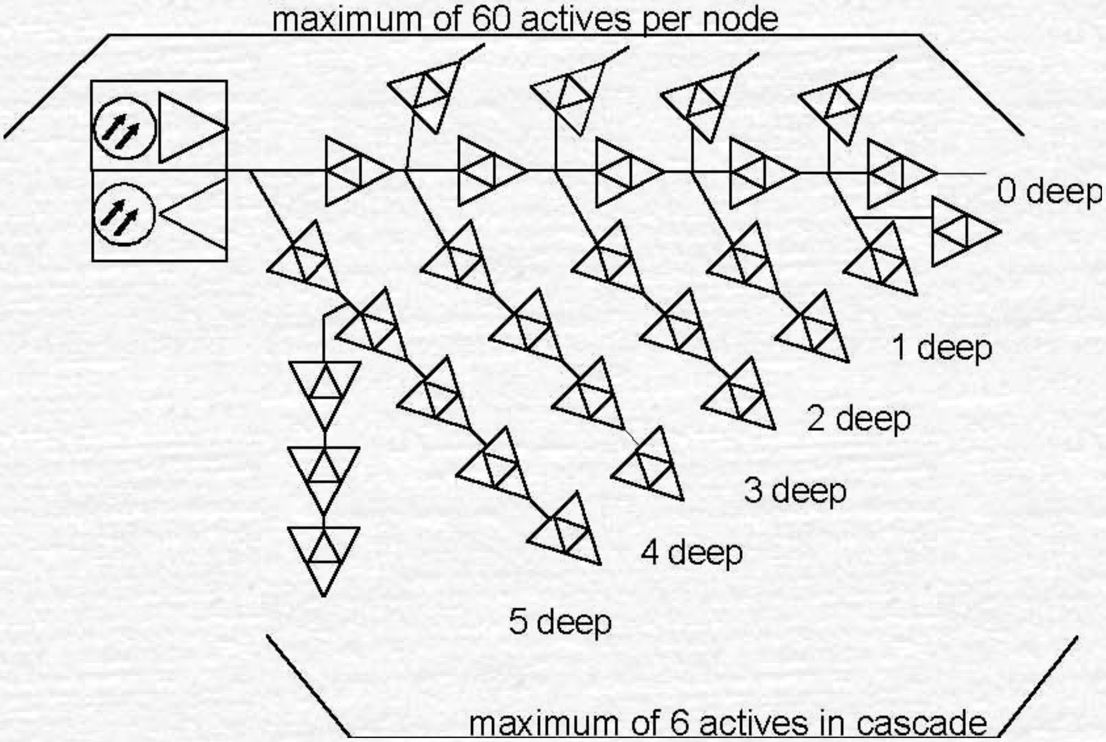
This paper illustrates a model system with performance specifications, and goes on to develop key issues in each of four parameters: carrier-to-noise (C/N) ratio, input levels, return module gain, and distortion / interference.

## PERFORMANCE STANDARDS FOR RETURN SYSTEMS

Given the constant improvement in digital technologies and the concurrent rise in customer expectations for quality, performance required from return systems has risen accordingly. It is acknowledged that specific performance requirements vary with different system requirements; For the purpose of this analysis, the following set of model specifications will be used in calculations:

Minimum
Carrier to Noise (C/N) Ratio with all actives accounted for shall be 47 dB.
Minimum Station Gain in any return station will be 17 dB.
CATV System Content will be network amplifiers and line extenders.
Embedding losses for stations:
- Line Extender :
 1.5 dB input and 1.5 dB output
- Network Amplifiers :
 7.0 dB input and 1.5 dB output
Amplifier noise figure : 5 dB
Cable Span Loss : 30 dB (typical) at 750 MHz.
Return System Carrier / Distortion : 55 dB maximum.

Figure 1: Model Return System




**PROPOSED RETURN-SYSTEM MODEL**

Contemporary system design utilizes "Short Cascade" systems rather than "Long Trunk" systems, in which 20 to 30 amplifiers were previously cascaded in series. As shown in Figure 1, the proposed "Short Cascade" return system has two basic design characteristics:

(A) Maximum of six actives (amplifiers) in any series path.

(B) Maximum of 60 actives (amplifiers) in any given node.

**CARRIER-TO-NOISE RATIO**

Noise calculations in the forward path (i.e., from headend to subscriber) differ from calculations in the return path (i.e., from subscriber to headend) in one major way; In the forward path, the transfer of system power is made by successive amplification and division (splitting). In the return direction, the opposite is true: The transfer of system power is made by successive amplification and addition (combining). The addition of signals creates noise "funneling" in the return path; As the desired signals combine in the return path, so do the undesired signals (ingress and thermal noise). More specifically, total noise in the forward direction adds as (noise degradation) = 10 LOG X (1) where X= maximum number of amplifiers in cascade (also known as Xc). The return system uses the same equation; however, the value of "X" equals the total number of amplifiers in the node (also known as Xt), not just the maximum number of actives in cascade. This higher value for "X" in the return direction results from the noise funneling effect.

To "derate" for noise funneling in a 60-amplifier node, each amplifier must make the system specification C/N plus an additional amount based on 10 Log addition of noise power :

C/N (required per amp) = (2)

(C/N Specification) + (10 Log [Xt])

For the system model :

47 dB C/N + 10 Log 60 = 47 + 18=

65 dB C/N per amplifier

**RETURN MODULE GAIN**

Both the line extender and network amplifier stations contain finite losses between their station ports and the ports of the plug-in return amplifier module. Losses result mainly from the presence of diplex filters and return power combiners in the network amplifiers; the return amplifier is embedded in these losses.... (re-stated for reference)

Embedding losses for stations:

- Line Extender :

 1.5 dB input and 1.5 dB output

- Network Amplifiers :

 7.0 dB input and 1.5 dB output

A return amplifier module must provide the host station's advertised gain after overcoming its embedding losses. Then,

Minimum return amp gain req'd = (3) (req'd station gain) + ( station embedding losses) For a return amplifier module operating in a line extender, the gain required is 17 + 1.5 + 1.5
(station gain) + (input embedding loss) + (output embedding loss)

For one line extender, 20 dB is the needed return amp gain. For a network amplifier, the same calculation is 17 + 7.0 + 1.5 For one network amplifier, 25.5 dB is the needed return amp gain.

## REQUIRED INPUT LEVELS

What input levels are required to achieve the minimum 65 dB C/N per amplifier (determined in the C/N calculation) ? Given the assumption that the thermal noise floor exists at -59 dBmV (based on NTSC video channel with 4.3 MHz bandwidth), an input of 0 dBmV yields a C/N of 59 dB:

C/N = 59 + (input level in +/- dBmV) (4)

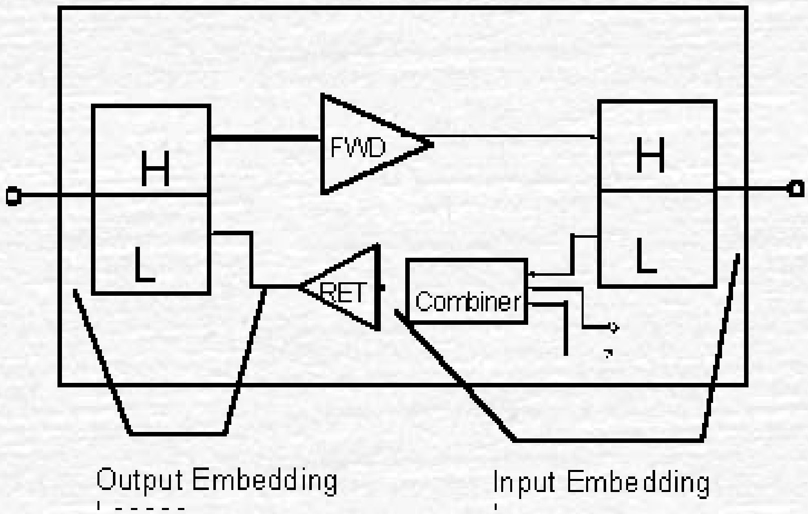
To add the effects of noise figure (which appears as subtractive loss), the equation becomes C/N = 59 + (input level) - NF. (5)

Re-written to isolate the input level variable, the equation may be expressed as (input level dBmV) = C/N - 59 + NF (5A)

Given the specifications used as standards for calculations in this paper, the required external station input level using eqn. 5A is :

(input level) = C/N - 59 + NF
(input level) = 65 - 59 + 5
(input level) = + 11 dBmV

Figure 2: Illustration of Embedding Losses in a Typical Station




While +11 dBmV into the station externally will yield the desired C/N, both stations have associated embedding losses. These input embedding losses must be accounted for by increasing the input level accordingly if system C/N performance specifications are to be met. This leads to a further step in developing eqn. 5A, to add embedding loss :

(input level dBmV) = C/N - 59 + NF (6) + input embedding loss

Equation 6 illustrates that, for purposes of calculating required input level, input embedding losses appear to add on to the amplifier's noise figure. Using eqn. 6, we can calculate the input levels needed for a network amplifier and for a line extender :

Network Amplifier :

(input level dBmV) = C/N - 59 + NF + input embedding loss
(input level dBmV) = 65 - 59 + 5 + 7.0 (input level dBmV) = +18 Line Extender : (input level dBmV) = 65 - 59 + 5 + 1.5 (input level dBmV) = +12.5

Note that, to make a given C/N number, a network amplifier will generally require a higher input signal level (dBmV) than a line extender; This is because the network amplifier has a return combiner added to its input embedding loss. Also note that previous input level calculations assume a 4.3 MHz bandwidth (as for NTSC video); For other bandwidths, an adjustment is necessary to obtain correct results.

Furthermore, thermal signal level change may adversely affect system performance. With the growth of fiberoptic network components, further research is necessary to determine acceptable limits for thermally induced changes.

## DISTORTIONS AND INTERFERENCE

Note that CSO, CTB, and XMD do not "funnel" because two carriers of like frequency are not permitted simultaneously on the system. Consequently, the correct quantity for number of actives "X" in calculations of CSO, CTB and XMD is the maximum number of actives to be found in cascade (Xc) and not the maximum number of actives to be allowed in a node (Xt), as is used for noise funneling calculations.

## COMPOSITE SECOND ORDER (CSO) DISTORTION

The additive process of CSO itself has been the subject of much discussion, focusing on the addition of CSO products using 10 Log Xc to 15 Log Xc, where "Xc" is the number of actives in cascade. Combination of CSO products is influenced by the number of actives in a cascade, differential delay, and statistical distribution. ("10 Log" is considered the minimum acceptable for statistical consideration.) For CSO calculations performed here, we will assume CSO addition on 13 Log Xc basis. This approximation is used as a guide to allow results which are worse than best case. Such a "correction" is justified because short cascade runs do not always allow the full statistical mean to occur.

CSO req'd = (CSO spec.) (7) + (13 log [# of actives])

Calculation of required CSO performance (with our model specifications) is :

CSO (req'd) = 55 + 13 Log 6
= 55 + 10
= 65 dB

Thus, in order to make 55 dB CSO with 6 actives in cascade, each active must make 65 dB CSO by itself. Composite Triple Beat (CTB) and Cross Modulation Distortion (XMD)

Because CTB and XMD specifications for the proposed return system model are identical, CTB and XMD calculations are identical. The CTB / XMD calculation is identical to the CSO calculation, except that CTB and XMD are combined using a multiplier of 20 Log Xc because they are third order entities :

CTB req'd = (CTB spec.) (8) + (20 Log [Xc])

Applying this (given our specifications), we get...

CTB (req'd) = 55 + 20 Log 6
= 55 + 16
= 71 dB

(Thus, this calculation indicates that each active must have CTB and XMD products at or below 71 dB in order to make 55 dB CTB and XMD when 6 actives are cascaded.)

Differential Delay

Delay itself is not distortion (i.e., nonlinear intermodulation function); rather, delay is a linear network parameter which affects signal quality. Mainly as a consequence of the design of diplex filters used in CATV equipment, the low-pass and band-pass portions of the filters in return paths exhibit nonlinear delay as a function of frequency. This nonlinear delay in the frequency spectrum results in an unequal phase shift of certain components of a modulated signal. Video channels are sensitive to this delay variation, which often manifests itself as "the funny paper effect"; that condition in which color information is seen to lead or to lag the rest of the picture (i.e., a form of video chroma distortion).

Non-video channels, such as those carrying digital data, are also sensitive to differential delay. In such channels, the delay causes phase shift which varies with frequency within the channel's bandwidth. If severe enough, this phase shift can degrade bit error rate (BER), and limit the channel's data-transport performance. Different modulation schemes have varying sensitivities to differential delay; The modulation scheme utilized is chosen to be compatible with the delay characteristics of the system in which it will be used.

The delay phenomena is always worst at points where a filter is becoming selective (i.e., at the band edges). For this reason, differential delay in the return path is most likely to become affected at the upper band edge. Differential delay at the lower edge of the return band is also a consideration; This delay most often results from power choke compensation circuitry. (In the forward path, differential delay is most problematic at the lower edge of the band, as high pass networks most often make up the forward portion of CATV diplex filters.)

## NOISE INGRESS

Noise ingress is, by itself, the subject of much study. Noise ingress originates from many sources, and, for the purposes of this writing, noise ingress in the return system can be viewed to "originate" evenly from all return sources (i.e., subscribers). This ingress undergoes a noise "funneling" effect much in the same manner as thermal noise funneling. Because of its spectral content, ingress is partially treated like thermal noise (in that it "funnels" toward the headend); however, ingress may be either random or discrete and generally affects certain areas of the return band more than other areas. Thus, noise ingress is not treated exactly as thermal noise is treated. Most often, ingress noise presents the greatest difficulty at the lower portion of the return band.

Most successful control measures involve isolating ingress signals at the point of origin (subscriber and drop cable), before these signals can enter the CATV system and funnel toward the headend. Because the lower portion of the return band generally contains an additional undesirable quantity in the form of added noise (ingress), system designers must often make additional allowances for noise performance of carriers which exist in the lower portion of the return band.  Quantification of this allowance comes from research of ingress noise, which varies with application and specific system environment.

## SUMMARY

Recent developments in entertainment and information transfer have altered the way in which return systems are viewed.  Broader use of the return path has increased the need for return components in CATV systems, and demands for enhanced return system performance are redefining requirements for return system components.

Though return systems share some common performance parameters with the forward path (e.g., C/N, CTB, CSO, and XMD), other performance parameters (e.g., noise ingress and noise funneling) are unique to return systems.  As we acknowledge the similarities and differences between forward and return systems, we also acknowledge the fact that return systems posess their own identity. This comes increasingly into play as we proceed up the "on-ramp" to the information-superhighway.

We would like to thank Philips India for submitting this article for publication. Philips India Market the range of Magnavox CATV products in India. - Ed

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