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UNDERSTANDING & CONTROLLING NOISE IN A CATV NETWORK

This article looks at the various sources of noise in a CATV network. It also examines measures that will minimise noise. Simple non mathematical methods are offered to estimate noise, particularly at the Headend and from distribution amplifiers.

While the concept of noise in day to day life is well understood, giving it a specific, technical definition is a difficult task. Noise can probably be defined as random signals that are not part of the intended signal. Let us consider the case of a simple, small cable network transmitting signals on channels E-2 to E-12. Any randomly fluctuating signals on this network that are not part of the specific channel audio and video carriers are noise.

Noise is inevitable and occurs in every system. The key here is to keep noise below a level where it would cause deterioration in the received picture or sound at your most distant subscriber. Noise will occur within each channel. It will also occur across the entire frequency spectrum. The noise occurring across the entire spectrum is referred to as "Broadband Noise".

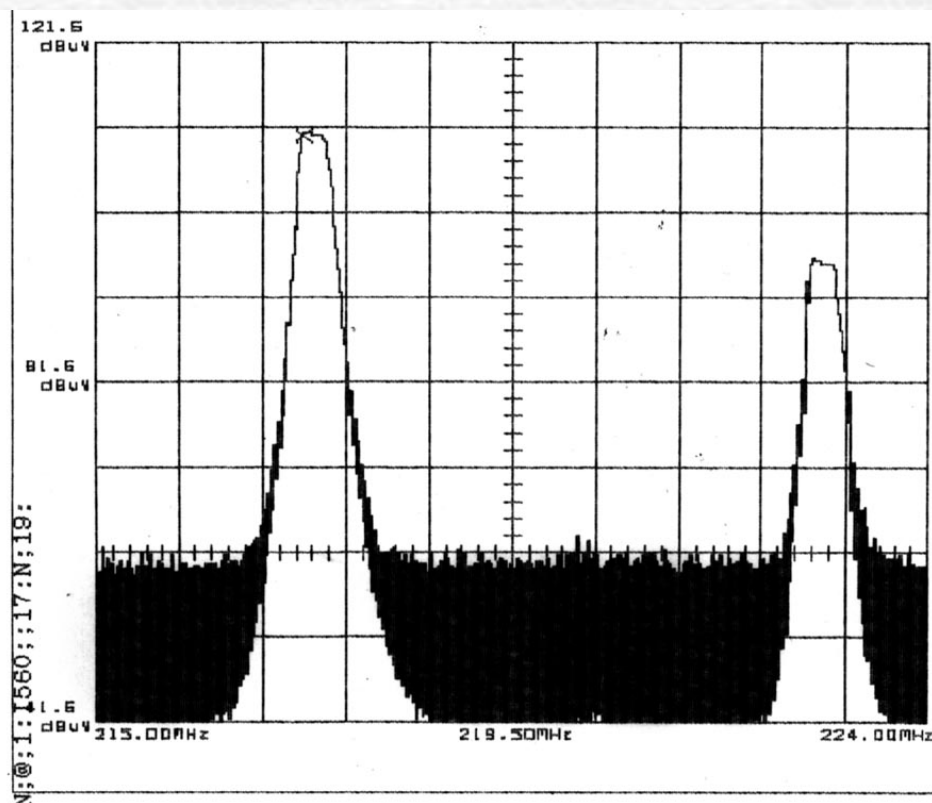


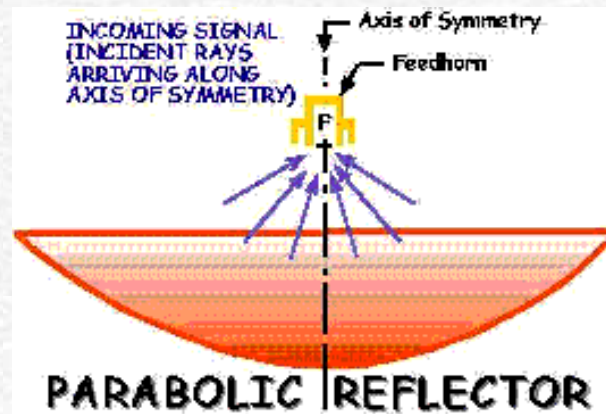
Figure 1 shows a Spectrum display of a particular channel of the audio and video carriers as well as the noise within that channel. As you will see from this picture the noise components (spikes) are approximately 50 dB less than the video carrier of this channel. This simply implies that the Carrier to Noise (C/N) ratio for this channel is approximately 50 dB.

Noise occurs at every stage of electronic signal processing or amplification. Noise is also added during transmission of a signal even along a passive component such as a cable. This article does not aim to review the physics aspect of noise such as Shot Noise, Thermal Noise, Johnson Noise, etc. But will restrict discussions to practical concerns in a Cable TV network. Let us now systematically examine the noise at each stage in a cable network.

THE DISH ANTENNA

The Dish Antenna is required to collect a few Pico Watts of signal (1 Pico Watt is 1 Millionth of a Millionth of a Watt !). Clearly at such low levels of signal, great precaution must be taken to minimise noise. The best measure is to use as large a dish as possible to maximise the signal collected by the dish. The dish collects the signal and focuses it at the LNB (Low Noise Block Converter). This is shown in Figure 2.

THE LNB



The LNB's task is to receive this very tiny C Band signal and amplify it more than 100,000 times, then down convert its frequency so that it can be carried with a relatively low loss on an ordinary coax cable from the LNB to the satellite receiver. The amount of noise contributed to the LNB is usually expressed in degrees Kelvin (degree K). Without going into the physics aspect, it would suffice to know that the lower the noise figure in degree K, the better the LNB, because the LNB will contribute less noise of its own to the signal.

Typical, commercially available LNBs have a noise figure of 15 degree K to 30 degree K. All other things being equal, the 15 degree K LNB will amplify signals with less noise compared to a 30 degree K LNB. It may be relevant to point out that better performance would be obtained usually by installing a larger dish, than an LNB with a lower noise figure. At least a 12 foot dish antenna should always be used on cable networks even if you are receiving signals from a powerful satellite. The difference in picture quality may not be visible at the control room but would clearly show up at your most distant subscriber, after a long distribution network. Small dish sizes are best suited only for personal dish reception systems.

THE SATELLITE RECEIVER

Despite the large amplification provided by the LNB, signals arriving at a satellite receiver are of the level of a few micro volts only. The satellite receiver therefore needs to detect and further amplify these signals to provide a good picture. The lowest level of signal that a satellite receiver can linearly / proportionately detect is referred to as the receivers "threshold". A Low Threshold (LT) Satellite Receiver will linearly detect even low level satellite signals and provide good picture quality. If a large dish is used to receive a fairly strong satellite signal, an LT satellite receiver is not necessary.

SAT RECEIVER BANDWIDTH

Satellite receivers also try to improve picture quality of weak signals by reducing the bandwidth. As one can imagine, broad band noise would be less of a problem if the bandwidth was reduced to 18 MHz compared to a bandwidth of 27 MHz. Broad band noise is uniformly distributed at all frequencies. Hence reducing the range of frequencies (bandwidth) will reduce the noise picked up. Remember that the wider you open your window, the more dust flies in ! Ofcourse reducing the bandwidth also reduces picture sharpness. Hence the user should reduce the reception bandwidth of the satellite receiver, only if he is receiving a noisy picture inspite of using a large dish antenna. In a CATV network, the signal from the satellite receiver is fed to a modulator. So lets look at the next link in the chain.

THE MODULATOR

The CATV Modulator receives an audio and video signal, and modulates it to an RF output frequency. This electronic signal processing generates its own noise. The amount of noise generated by a modulator is indicated by its Carrier-to-Noise ratio. A typical modulator output is shown in Figure 1.

IN BAND NOISE

The noise that a modulator generates within its operating channel is referred to as In Band Noise. Hence the noise generated by a Channel 2 modulator over the frequency span of 48 MHz to 55 MHz would be the modulator's In Band Noise.

OUT OF BAND NOISE

The Modulator also generates broad band noise, often at all frequencies in the CATV Spectrum. A channel 2 modulator would therefore generate some noise at all frequencies probably from 5 MHz to 1 GHz and above. While the out of band noise does not affect the picture quality of that specific modulator it will certainly affect the picture quality of other modulators operating at other frequencies. Most important, the out of band noise of all the modulators at the Headend adds up and causes an overall deterioration in the picture. Let us take an actual example.

CALCULATION OF MODULATOR NOISE AT THE HEADEND

Let us suppose that a typical modulator has an in band Carrier to Noise ratio of -65 dB and an out of band Carrier to Noise ratio of -65 dB. Let us assume that there are 64 such modulators at the Headend. The noise of all these 64 modulators will add up, let us calculate. The exact mathematical formula for calculation of noise is :

$C/N_n = C/N_1 - 10 \log n$ where:

C/N_1 is the Carrier To Noise ratio of the 1st Modulator n : The Total Number of Modulators at the Headend C/N_n : Resulting C/N of the total n modulators.

However let us ignore elaborate mathematics. Fairly accurate estimates can be arrived by simple "Rule of Thumb". "Doubling the number of Amplifiers or Modulators increases the total noise by 3 dB i.e. the Carrier to Noise ratio reduces by 3 dB". The out of band noise of 1 modulator is assumed to be -65 dB.

Therefore 2 modulators would reduce the C/N to -62 dB.

4 modulators C/N -59 dB. 8 modulators C/N -56 dB.

16 modulators C/N -53 dB. 32 modulators C/N -50 dB.

64 modulators C/N -47 dB.

It quickly becomes apparent that the out of band noise is now a bigger concern than the noise generated by each modulator within its own channel bandwidth !

In practice, the situation sometimes is a little better because manufacturers often provide output filters on their modulators which reduce all signals including noise at frequencies far away from the operating frequency. High quality international modulators such as BARCO have an out of band C/N of approximately -90dB and an In band C/N of -70 dB. A Headend of 64 Modulators would therefore reduce this by 18 dB i.e. the C/N of just the modulators put together would have deteriorated to -52 dB.

This ofcourse excludes the noise contributed by the Dish + LNB and the Satellite Receiver !

THE AMPLIFIER

The input level signal to an Amplifier is of crucial importance to the noise performance. Low

level signals deteriorate rapidly with the injection of noise. On the other hand noise contributed to high level signals plays a less significant role. Given this basic understanding, a good starting point is to always ensure that input level signals are maintained fairly high for each Amplifier. An input signal level of atleast 65 dBu, preferably 70 dBu should be maintained at the input of each Amplifier, throughout the entire Cable TV network. Lets take a closer look.

To start with, we need to estimate the noise performance of a single Amplifier. Once this noise is estimated, it would be a relatively simple matter to estimate the overall noise performance of the cascade of similar Amplifiers on the network. Keep in mind that we need to estimate the noise performance of the cascade of Amplifiers i.e. the chain of Amplifiers where the output of one feeds the other. Let us assume that a Cable TV network has 3 trunk lines. The first trunk has a chain (cascade) of 8 Amplifiers, the second trunk with 12 Amplifiers and the third trunk with 9 Amplifiers. The network therefore has a total of 29 Amplifiers but the worse noise will be at the end of trunk 2 which has 12 Amplifiers in cascade. Hence the total noise of 12 Amplifiers needs to be estimated, not of 29 Amplifiers.

NOISE OF THE FIRST AMPLIFIER

Most Hybrid Amplifiers utilise the Motorola 5342 (450 MHz) or 6342 (550 MHz) or their equivalent Philips ICs. These Hybrid ICs have similar noise figures of 5.5 dB. Lets take this to be 6 dB. If we use this as a starting point, we would arrive at reasonably good estimates for cascades of Hybrid Amplifiers.

The noise performance of one Hybrid Amplifier is given by the equation :

C / N1 : C/N Ratio of the 1st Amplifier

$C/N1 = (i/p \text{ in dBu} - 1) - \text{Noise Figure of Amp}$

$= (i/p \text{ in dBu} - 1) - 6$

Clearly, the noise performance is better if the level of the input signal is higher. Let us assume that the input signal with the Amplifier is 70 dBu. $C/N1 = (70-1) - 6$

This yields a noise performance of the first Amplifier of 63 dB. However, if a network installs amplifiers so that each amplifier receives an input signal of 55 dB, the Noise of the first amplifier itself will be 48 dB. This clearly shows how the noise performance can be adversely affected, if levels are not correctly maintained throughout the network. It is not necessary to install expensive amplifiers to keep noise to a low level. It simply requires proper signal levels.

NOISE OF THE CASCADE

The exact formula to calculate the Noise of a cascade of amplifiers is : $C / Nn = C / N1 - 10 \log (n)$ n = No. of Amplifiers in Cascade Further, the BIS specifies that C/Nn should not be worse than 43 dB. Ofcourse this formula is daunting for anyone short of an engineer with a Scientific Calculator ! Lets take a a simpler approach.

Once the noise of the first Amplifier is determined it is simple to estimate the total noise of the Amplifier cascade, without even a calculator ! Similar to the case of Modulators, the noise performance is reduced by 3 dB for a doubling of the number of Amplifiers. Hence :

2 Amplifiers 60 dB 4 Amplifiers 57 dB

8 Amplifiers 54 dB 16 Amplifiers 51 dB

32 Amplifiers 49 dB

In most actual systems, the cascade will not exceed 12 to 16 Amplifiers. Hence, for a 16 Hybrid Amplifier cascade, with an input signal level of 70 dBu for each Amplifier, the output signal will have a carrier to noise ratio of 51 dB. The BIS specifies that the carrier to noise ratio to the last customer should not be worse than 43 dB. Ofcourse this 43 dB is a noise contribution of the Amplifier cascade, the Modulators and the Dish Antenna, LNB + Satellite Receiver, etc. However it is clear that the Amplifiers in such a cable network will not contribute significantly in terms of noise.

CONCLUSION

It is often believed that good noise performance can only be achieved by expensive trunk Amplifiers. The facts are quite different. Infact as shown in Table 2, the noise performace of the same amplifier reduces drastically , and can be used for a cascade of just amplifiers, if fed an input signal of 55dB per amplifier. The same product, if fed an input of 70dBU can be used for a cascade of amplifiers.

The key to good noise and distortion performance is the proper adjustment of signal level. Good noise performance dictates that the input levels be maintained fairly high. An input signal level of atleast 65 dBU preferably 70 dBU for Hybrid IC based Amplifiers is ideal. The next article in this series will examine distortion in Amplifiers and once again look at the optimal settings for the lowest practical distortion.

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