THE IMPORTANCE OF SETTING AND MAINTAINING CORRECT SIGNAL AND MODULATION LEVELS IN A CATV SYSTEM CARRYING BTSC STEREO SIGNALS

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ABSTRACT

There has been much discussion in the recent literature concerning the pro's and con's of carrying BTSC Stereo on a CATV System. The discussions have primarily been associated with one of three subjects:

1. What is the BTSC format?
2. How will the CATV system impair stereo performance?
3. How will the BTSC audio signal impair CATV video performance?

While these discussions have been meaningful and in some cases helpful to the CATV Operator's understanding of how the system works, they have in many cases fallen short of addressing the practicality of setting up the Headend once the operator knows that he will, in fact, be carrying stereo. In this paper, the importance of setting and maintaining correct audio modulation levels, especially with reference to the interface between the BTSC Stereo Encoder and the Video Modulator, will be discussed. This interface is critical to the overall performance of the BTSC system. If the interface is handled incorrectly, stereo performance could be severely impaired, resulting in a multitude of service related calls from a now "stereo-aware" public. No longer will the CATV engineer be able to treat audio as the unimportant portion of the television signal. An increased awareness of audio quality by the public as well as improvements in the state-of-the-art in television stereo processing in the home (VCR's, Stereo Adapters, Stereo TV's), will require that the CATV engineer exercise new levels of caution in the handling of audio information.

Throughout the history of television and certainly throughout the history of CATV, the audio information carried by a television signal has been considered by most of us to be a non-critical item. We simply haven't paid it much attention. After all, the limiting factor in audio quality has always been the consumer's own television set. Why should we be worrying about preserving audio quality in the CATV plant when the customer didn't need or even expect good audio performance out of his set? The answer in most cases is obvious as we have simply ignored audio and have concentrated on providing good quality video to the customer. But recently, and for several reasons, our customers have become much more aware of the benefits of good quality audio. The Compact Disc Player, Stereo or Hi-Fi VCR and now Stereo TV with its associated barrage of consumer advertising have enlightened the CATV customer to the point that he is beginning to expect and in fact demand "good" stereo-audio performance. This is especially true of the new Stereo-TV owner. Because of this increased customer awareness, the CATV operator must begin to better understand what good audio quality really is and how it can be preserved as it passes through the CATV headend. Our methods of processing a stereo signal in the CATV headend can make the difference between the deliberate transmission of actual stereo or the inadvertant transmission of monaural audio. To make matters even worse, mishandling the stereo signal in the CATV headend can also create poor sounding monaural audio for the vast majority of our current customers who are non-stereo equipped.

This paper, in addition to investigating the importance of modulation levels will outline other key areas of concern to the CATV operator to ensure preservation of the stereo signal.

KEY HEADEND INTERFACES

Headends which are configured to receive over-the-satellite stereo-audio broadcasts for subsequent processing and transmission in the BTSC format will require a variety of different equipment. In addition, the equipment may be configured in any of several different ways. Figure 1 outlines a few of the methods of interface between a satellite receiver and BTSC encoder while Figure 2 shows several methods of interface between the BTSC encoder and TV modulator.

The Receiver-Encoder Interface

The method of interface between a satellite receiver and BTSC encoder is dependent upon several factors including the use of uplink, encryption, narrow-band companding or any previously provided out-of-band (FM simulcast) stereo service. The most simple interface, shown in Figure 1A, is made by connecting the encoder and receiver together via the composite video output port of the receiver. In this case, a dual audio subcarrier demodulator within the BTSC encoder

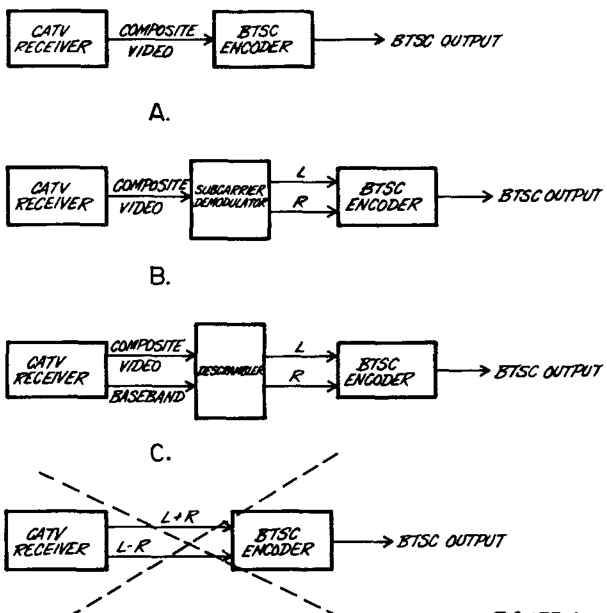


FIGURE 1

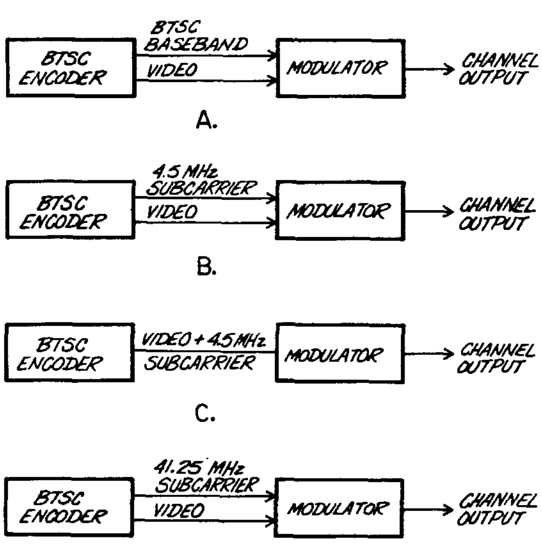


FIGURE 2

itself demodulates the two audio subcarriers to left and right audio for re-encoding into the BTSC format.

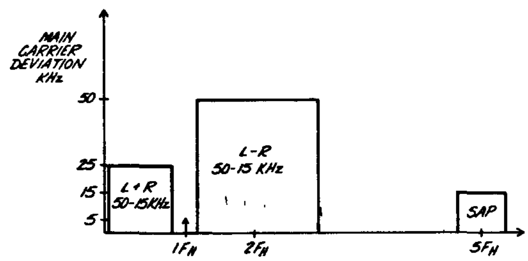
CATV systems which have previously been supplying out-of-band (FM simulcast) stereo signals to their subscribers will likely have access to left and right audio information out of an existing dual subcarrier demodulator. In this case (Figure 1B), the existing subcarrier demodulator and satellite receiver maintain their present interface via the composite video port of the receiver. Left and Right audio out of the subcarrier demodulator are then routed to the encoder for BTSC processing.

With the advent of over-the-satellite encryption, left and right audio will be provided via the headend descrambler as shown in Figure 1C. Of course in this scheme, subcarrier demodulators are no longer necessary. Each of the major manufacturer's encryption schemes provide these necessary stereo outputs.

Another very tempting but highly undesirable practice might be the use of a pair of subcarrier demodulators in a satellite receiver to provide L+R and L-R audio to the BTSC encoder. While L+R and L-R stereo information can certainly be provided by a typical satellite receiver containing two subcarrier demodulators (if the signals are wideband and not compressed like Disney, TMC, and MTV), this is not recommended due to the difficulty in optimizing BTSC stereo performance under these circumstances. This phenomenon will be much better understood after reading later sections of this paper.

The Encoder-Modulator Interface

Figure 2 identifies several of the various methods of interfacing a stereo encoder with a TV Modulator. As shown, the interface can be made at either BTSC composite baseband or at some audio subcarrier assignment such as 4.5 MHz. This is a very key interface in the headend because of the importance of setting and maintaining the correct audio modulation level of the main subcarrier by the composite BTSC signal. Figure 2A indicates the connection directly at composite baseband. Here, the baseband BTSC signal (Figure 3) is connected directly to the baseband audio input port of the TV modulator.



BTSC BASEBAND SPECTRUM

FIGURE 3

In this application the modulator's audio pre-emphasis must be disabled, and its baseband bandwidth and deviation capability must be compatible with BTSC signal requirements (100 Khz bandwidth and 73 KHz deviation). In addition the modulator's overdeviation indicator circuitry must be compatible with the BTSC input or it will erroneously indicate overdeviation all of the time. When interfacing the encoder and modulator at some audio subcarrier as in Figure 2B, 2C, and 2D, the requirements on the modulator are less stringent and simply require adequate bandwidth to ensure minimal degradation to the stereo signal.

While the CATV operator has no control over what goes on inside a manufacturer's piece of equipment and must instead rely on the respective manufacturer's knowledge of handling stereo signals, he does have control over his method of interfacing these various products. As a result, he must understand and eliminate any potential problem areas in these interfaces. Some of these potential problem areas with reference to both the stereo and mono signal are described in the following paragraphs.

PRESERVATION OF THE STEREO SIGNAL

Stereo by definition is the transmission of two separate though perhaps somewhat correlated channels of information. This correlation between Left and Right channel may range from zero in some program material to full correlation (mono) in other program material. Normally, most stereo program material does have some correlation between channels. This signal, known as the common-mode signal because equal amounts are transmitted in each channel, may contain for example the lead vocal and/or a base guitar or drums. The remaining information in each channel would be uncorrelated and would contain the remainder of the stereo information. In order for the stereo signal to be accurately recovered at the subscriber's home, the transmission path, including the CATV headend, must not alter the frequency response, separation, special location, or depth perception of the sound as perceived by the subscriber. All of these parameters unfortunately can be disrupted through mishandling the stereo signal in the interfaces described in Figures 1 and 2. The CATV operator can help to ensure the integrity of the stereo image through his headend by understanding and adhering to a few simple rules:

1. When interfacing with sum (L+R) and difference (L-R) channels the amplitude (or gain) and the group delay of the sum channel path must be exactly equal to that of the difference path.

2. When interfacing with Left and Right channel information, the gain and group delay of the left channel must equal that of the right channel.

3. Audio modulation levels especially with reference to the main audio subcarrier deviation must be set precisely.

Rule #1 is precisely the reason that broadcasters typically do not process signals in the sum and difference format. This is also the reason that Figure 1D is not a recommended practice in interfacing receivers and encoders in a headend. Amplitude and phase errors in the two signal paths become very critical when trying to maintain optimum stereo separation. This can be best understood if you remember that Left and Right channel information is derived from L+R and L-R information through a process called dematrixing. The accuracy of the dematrixing process is totally dependent upon the relative amplitude and phase of the sum and difference signals. This dependance is described by the following equation.

$$\text{Separation (dB)} = 20 \log \left[\frac{(\cos\theta + K\cos\phi)^2 + (\sin\theta)^2}{(\cos\theta - K\cos\phi)^2 + (\sin\theta)^2}\right]$$

When: K = Ratio of L-R to L+R signal level or gain
θ = Phase difference between L+R and L-R
ϕ = Subcarrier phase error

Note: For example that an amplitude error of as little as 1 dB results in stereo separation of no greater than 25 dB if everything else is perfect. Similarly, a 10 degree phase error results in no more than 20 dB of separation if everything else is perfect. Combining amplitude errors with phase errors will quickly erode stereo separation as shown in Figure 4.

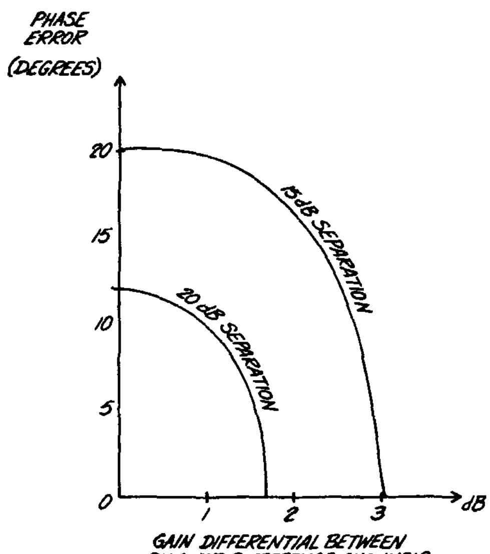


FIGURE 4

What all of this means is that you must be extremely careful if the signal being processed is in the sum and difference format. The equipment being used to transport the signal whether it be cabling, distribution amplifiers, audio switches, etc., must minimize any differences in gain and group delay in the two signal paths. Now I think you can begin to understand the difficulty in trying to interface a receiver and encoder directly at baseband as shown in Figure 1D. With program audio, how could you possibly set signal levels accurately enough to ensure optimum stereo performance? It becomes a virtually impossible task.

Rule #2 is certainly applicable to most of us because in most headends the stereo signal will be routed as Left and Right channel information; commonly referred to as the discrete format. It is interesting to note however that in this case, it is the monaural signal, not the stereo signal that is in jeopardy due to the mishandling of the L and R signals. While it is true that both the special location and depth perception of the sound is dependent upon both the amplitude and phase of the L and R signals and that upsetting either of these parameters will alter the stereo image. This is not nearly as critical to the stereo listener as it may be to the monaural listener. A 1 dB amplitude variation or a 10 degree phase variation between the two channels simply won't make much difference to the stereo signal. In this case it is the monaural listener that will suffer. And remember, in the next few years it will be the monaural listener who will continue to be in the majority of our customer base. This degradation in the monaural signal occurs because prior to transmission in the BTSC format, the Left and Right channel information must first be matrixed into an L+R or monaural signal to ensure compatibility with existing TV sets. If the two channels were completely uncorrelated (no common information between the two signals) then the relative amplitude or phase between the two channels would not create a problem in the L+R signal. But since most stereo programming does have a common-mode component, any phase difference between the Left and Right channels will result in a spectral comb-filter effect which will show up as "suck-outs" within the audio spectrum of monaural sum. In the limit, if the two channels were 180 degrees out of phase, then the common-mode signal would be completely eliminated! This comb-filtering effect can result in a monaural signal which sounds mushy or tinny to the customer.

In reality, most CATV operators have no control over the amplitude or phase of either the discrete or matrixed stereo channel paths.

In the vast majority of circumstances, the signal path between the receiver and encoder, or between the encoder and modulator consists of nothing but a pair of shielded wires. Only rarely is some form of baseband routing or switching utilized in a headend and it is in these cases that the operator must pay strict attention to these rules to ensure adequate performance. There is however one interface which the CATV operator can directly control and which is absolutely crucial in order to maintain adequate stereo performance. I am referring to the need to precisely set and maintain audio modulation levels in the headend.

Setting and Maintaining Precise Modulation Levels

As was shown in Figure 3, the accurate transmission of the BTSC signal requires that precise deviations of the main aural carrier be maintained. These deviations are: 25 KHz for the sum (L+R) signal, 50 KHz for the stereo difference (L-R) signal and 15 KHz for the Second Audio Program. These are the deviations that any stereo decoder or stereo TV will be designed and factory set to receive. Any variation from nominal deviations will cause substantial degradation in channel separation in the stereo signal.

There are several ways to ensure that accurate modulation levels are maintained in the headend. One way is to rely on the CATV equipment manufacturer to produce a quality interface as shown in Figure 2B, 2C and 2D. Here, all modulation levels are set up within the encoder itself. All that is necessary is to provide Left, Right and SAP audio information to the encoder, and the encoder does all of the work for you, precisely setting the relative modulation depths on the main carrier (4.5 MHz) by the BTSC signal. An alternative is to interface at baseband as was shown in Figure 2A and take it upon yourself to accurately set the precise deviation of the main audio carrier. While this approach is certainly feasible, unless the manufacturer has provided you with the necessary tools, it isn't a trivial task.

Figure 5 is a graph which plots errors in main carrier modulation level against stereo separation in an otherwise perfect system.

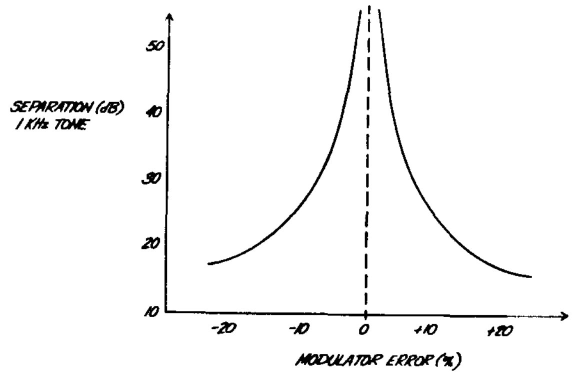


FIGURE 5

This graph clearly indicates the need to keep modulation levels to within +-5% of their optimum value or stereo separation will suffer tremendously. This is not a trivial task when dealing with live audio. In fact, accurately setting the deviation of the system with live audio is next to impossible. For this reason, Scientific-Atlanta has opted to provide the operator with test tone output from the encoder which will help him to precisely set main carrier deviation. The tone, derived within the encoder, is output to the modulator at a fixed frequency and signal level. The operator simply adjusts the audio modulator's deviation pot until the overdeviation lamp just flickers "on". Once this adjustment has been made, the test tone is turned off and the BTSC signal is applied. All signal levels out of the BTSC encoder are precisely referenced to the internal test tone thus ensuring precise main carrier deviations. It has been found that with a properly designed overdeviation light on the aural modulator, this method provides extremely accurate results. It also provides a method of alignment without the use of any test equipment.

Keep in mind that while it is important to accurately set modulation levels in the headend in order to achieve optimum stereo separation, separation alone should not be used as a measure of precise modulation levels. A look at Figure 6 will reveal why.

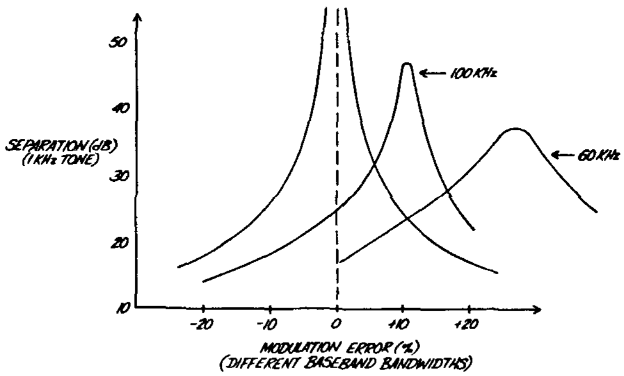


FIGURE 6

The previous discussion may have led you to believe that one method of setting the main carrier deviation would be to drive only one channel of the stereo encoder with audio while adjusting the deviation of the audio modulator until you hear a null in the undriven channel when the signal is monitored on a stereo TV. While this method does produce optimum stereo separation for that particular TV, it is not an accurate method of setting main carrier modulation levels. In fact, it has been found that it is possible to actually correct for imperfections in the bandwidth of the television or elsewhere in the transmission path by allowing errors in the modulation level. As shown in Figure 6, if the bandwidth of the transmission path were reduced to 60 KHz, optimum stereo separation would occur at nearly 27% overdeviation!

In light of the above discussions, one habit which must be eliminated in the casual headend is the daily tweaking of the modulator's deviation pot. Once precise deviation levels are set up, leave them alone except for scheduled maintenance where precise test tones can be used to ensure accuracy. Remember, the modulation level cannot be accurately set in the headend with program audio. It is best set through the use of a precise test tone.

CONCLUSION

Audio in a CATV headend can no longer be ignored. An increased consumer awareness in quality audio is beginning to force the CATV operator to focus his attention on the preservation of good quality stereo audio through the CATV plant. Attention was focused on both the Receiver/Encoder interface and the Encoder/Modulator interface to outline the many and varied methods of arranging such equipment for the transmission of BTSC stereo. In addition, three key rules to follow to ensure the preservation of the stereo signal were outlined. Of these three, perhaps the most important, and certainly the one which the CATV operator has the most control over, is the set-up and maintenance of accurate main-carrier modulation levels.

REFERENCES

Hoffner, Randy, "Route Stereo Signal with Care , TV Technology, September 1985.

Mendenhall, Geoffrey N., "Tuning for Stereo", Broadcast Engineering, October 1985.

Small, E., "Broadcasting Stereo in a Mono World", Millimeter, May 1985.

Small, E., "Problems of Mono/Stereo Compatibility in Broadcasting", IEEE Transactions on Broadcasting, June 1971.

Woodward, William, "Considerations in the Operation of CATV Headends Carrying BTSC Stereo Signals", NCTA Technical Transcripts for 1985.