

A COMPATABLE STEREO SYSTEM  
VIA SATELLITE

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ABSTRACT

In the domestic satellite medium video service generally enjoys the allocation of full transponder bandwidth. Such allocation can provide abundant spectrum space for in band, ancillary services.

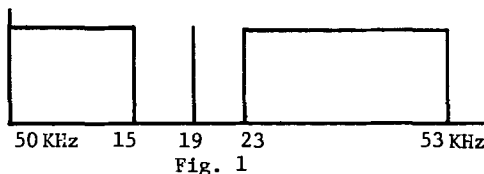
Thoughtful use of the available spectrum and efficient modulation loading can yield dynamically increased information transfer with little more than statistical impairment to extant signals.

One such application provides for the enhancement of satellite delivered program audio into compatible non-redundant stereo.

The technique addressed is an adaptation of the sum and difference scheme introduced by Zenith - G.E. in 1961 and applied here to the conventions of satellite transmission into CATV systems.

INTRODUCTION

To efficiently distribute FM stereo signals without loss of fidelity or monophonic compatibility the multiplex scheme of L+R, L-R double sideband suppressed carrier was put into use in the United States.



To the credit of its developers it has enjoyed widespread acceptance since its inception despite what from a strictly parametric appraisal, was a compromise of virtually all major modulation parameters, in the interest of compatibility. i.e. The FM broadcast band, developed to accommodate a monaural baseband (1 channel audio not exceeding 15KHz) set a peak

deviation limit of 75 KHz. As figure 1 indicates to incorporate stereo, a second baseband channel must be multiplexed above the first, extending the baseband excursions to 53KHz. This reduction in FM improvement ratio coupled with the anomalies of de-matrixing the sum and difference signals results in a S/N reduction, in stereophonic reception, of some - 20dB from monophonic reception of the same signal. It is beyond the scope of this paper to discuss further, however, since stereo transmission constitutes the vast majority of all current FM broadcast allocations, it's nearly universal acceptance, despite the inherent degradations, bears testimony to the dynamic subjective appeal of stereophonic sound in the transmission of music.

SATELLITE APPLICATIONS

The application of the sum and difference technique to satellite video transmission however may exploit the scheme to much greater advantage in the absence of the stringent deviation constraints imposed by broadcast regulations.

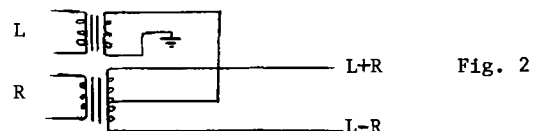
Two techniques will be discussed:

1. Adhere strictly to NCTA recommendations for main aural subcarrier modulation. The advantage being compatibility in an existing universe.

2. An optimum modulation loading and signal processing technique, emphasizing audio as the prominent signal component.

In both cases, the proposal utilizes generic or public domain techniques. The affiliated participant is not limited to proprietary equipment designs in an as yet undefined equipment universe.

A simple technique for obtaining sum and difference signals is indicated in figure 2.



In the (L+R) output, left and right channel baseband inputs are added to form the monaural signal for use in conventional reception.

In the stereo receiver the (L-R) signal is combined with the (L+R) signal to regain the original left and right channel, stereo relationship as follows:

$$\begin{aligned}(L+R) + (L-R) &= 2 L \\ (L+R) - (L-R) &= 2 R\end{aligned}$$

To provide the stereo receiver with proper information to perform the above summation it is necessary to transmit the stereo (L-R) information on separate multiplex subcarrier.

Applied to a Cablenet I transponder, video associated audio may be transmitted in stereo with no redundant signals. Matrixing at the uplink transmitter, the sum (L+R) channel is modulated upon the 6.8MHz subcarrier. A conventional video receiver will detect this as a monaural signal and provide a baseband output. The difference (L-R) channel is modulated upon a separate subcarrier. For discussion let's choose 5.8MHz. Figure 3

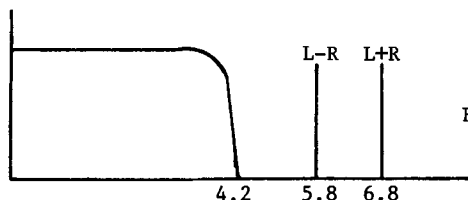


Fig. 3

As per NCTA recommended practices, additional subcarriers may be multiplexed above video, on full transponder (36MHz) services. For the limited subcarrier case, a root sum squared rule applies in determining peak composite deviation and thus occupied bandwidth.

$$F_{\text{comp}} = \left[ \Delta F_v^2 + \Delta F_e^2 + \sum_{i=1}^n \left( \frac{\chi}{F_{s1}} F_{s1} \right)^2 \right]^{1/2} \quad (1)$$

where:

- $F_v$  = deviation of main carrier by video = 10.75MHz
- $F_e$  = deviation of main carrier by energy dispersal waveform = 1mHz
- $\chi$  = deviation of main carrier by existing subcarrier = (2mHz)
- $F_{s1}$  = frequency of existing subcarrier = (6.8MHz)
- $F_{s1-n}$  = frequency of additional subcarrier(s)

For the single subcarrier case, assuming conventional subcarrier modulation indices of 1:0.29\* and deviation standards (as per NCTA document # ) of 100KHz peak deviation, composite

deviation is equal to:

$$\left[ (10.75^2 + 1^2) + \left( \frac{2}{6.8} \times 6.8 \right)^2 \right]^{1/2} = 10.98\text{mHz}$$

Applying Carson's Rule to determine occupied bandwidth;

$$BW = 2 (\Delta F + FM)$$

where:

$\Delta F$  = peak composite deviation

$FM$  = max instantaneous modulating frequency

Then:

$$(6.8 + .100)$$

$$BW = 2(10.98 + 6.9) = 35.76\text{mHz}$$

This may be rounded to Bandwidth = 36mHz. Thus it may be assumed that in order to add information, in the form of additional subcarrier(s), some reduction in peak deviation of existing service(s) must be accomplished, (1) To avoid overdeviating. Decreasing video deviation to accommodate our difference (L-R) channel subcarrier imposes a minimal penalty, manifest as an imperceptible reduction in video S/N.

Consider, the second subcarrier of 100KHz peak deviation, 1:0.29 modulation index at 5.8MHz. Scaling according to modulation index, yields subcarrier deviations of main carrier.

$$F_{\text{comp}} = \left[ \Delta F_v + \Delta F_v + (.29 \times 6.8)^2 + (.29 \times 5.8)^2 \right]^{1/2} = 11.1\text{mHz} \quad (2)$$

Statistically, according to Carson's BW rule, this would cause a slight overdeviation. Some parameter ( $F_v$ ) must be reduced.

#### SIGNAL/NOISE PERFORMANCE

Video deviation, and subsequent video signal to noise ratio penalty, attributed to the additional subcarrier, is then;

$$\Delta F_v = \left[ (123.21 - 1^2 - 2^2 - 1.68^2) \right]^{1/2} = 10.74\text{mHz}$$

or, approximately a -.01dB reduction in video S/N. A minimal tradeoff to accommodate stereo audio.

Audio signal to noise ratio is identical to one channel operation when modulation indices are maintained.

or;

$$S/N_a = C/N + BW + P + 10 \log \frac{3}{4} \left[ \frac{\chi^2}{F_a^3} \frac{F_s^2}{F_s^2} \right] \quad (3)$$

where:

- $BW$  = bandwidth in decibels = 75 dB
- $P$  = Preemphasis improvement (75u) = 13.2
- $\chi$  = deviation of main carrier by subcarrier (1.68mHz)
- $F_a$  = top modulating frequency (15KHz)
- $F_s^a$  = subcarrier frequency (5.8mHz)
- $F_s$  = subcarrier peak deviation ( $\pm$  100KHz)

Then assuming a C/N of 12 dB:

$$S/N = 12 + 75 + 13.2 + 10 \log \frac{3}{4} \left[ \frac{(1.68 \times 10^6)^2 (100 \times 10^6)}{(15 \times 10^3)^3 (5.8 \times 10^6)^2} \right]$$

$$= 63 \text{ dB}$$

63 dB represents a quite acceptable audio S/N ratio, and should yield excellent quality, at the T.V.R.O., with no apparent effect upon video or monaural audio subcarrier.

Consider however, as mentioned earlier, that prior to carriage over a cable system the conversion to broadcast FM format must be undergone, replete with its - 20 dB signal to noise penalty. This, coupled with average cable system noise figures, will yield signal typically 40 dB above the noise floor.

Several methods are available to improve this figure. The most apparent is of course increased subcarrier deviations.

#### OPTIMIZED TRANSMISSION

In delivery services where audio enjoys a unique prominence, such as Warner - Amex proposed MTV music channel, deviation and processing may be employed which reflects that prominence.

For example, extending deviation peaks to 237 KHz (75KHz + 10 dB headroom) will yield S/N ratios on the order of 70 dB (C/N=12 dB). Again, achieved at minimal penalty to existing services.

The MTV optimized system may utilize subcarriers of 6.6MHz. In the interest of improved threshold performance.

Then, applying the techniques just discussed

$$F_v = \left[ \frac{BW^2}{4} - (BW \cdot F_{\max})^2 + F_{\max}^2 - F_e^2 - F_1^2 - F_2^2 \right]^{1/2}$$

$$= \left[ \frac{36^2}{4} - 246.132 + 6.84^2 - 1^2 - 1.98^2 - 1.68^2 \right]^{1/2}$$

$F_v = 10.8\text{MHz}$ ; no video S/N penalty to the 36MHz BW receiver.

Audio S/N =

$$S/N_a = C/N + BW + P + 10 \log_{3/4} \left[ \frac{(\infty)^2 (F_s)^2}{(F_a)^3 (F_s)^2} \right]$$

$$= 12 + 75 + 13.2 + 10 \log_{3/4} \left[ \frac{(1.98)^2 \times (.237)^2}{(.015)^3 (5.8)^2} \right]$$

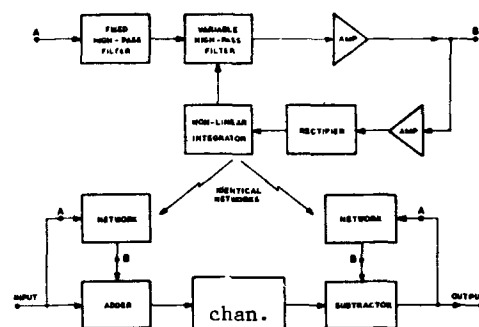
$$S/N_a = 71.8 \text{ dB}$$

a striking improvement, which may be improved further.

#### NOISE REDUCTION

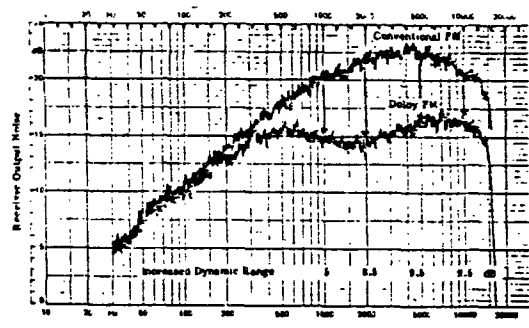
An additional technique, which exploits the freedom of the CATV industry is the addition of a world renowned noise reduction system. B type Dolby encoding.\*

The Dolby B system, (fig. 4) boosts high



Block Diagram of B-Type Noise Reduction System.

frequencies by 10 dB. In decode an equal and opposite cut is applied, restoring the signal to its original characteristics. In the process all low level noise introduced between encoder (Uplink) and decoder (T.V.R.O.) is attenuated, as per Fig.5



Overall improvement due to Dolby FM/25 usec system.

MTV, Movie Channel and NICKELODEON transmissions will incorporate "B" type Dolby encoding.

Extensive tests, worldwide have shown the "B" system to be compatible.

The compatible nature of the system permits the CATV operator to allow the encoded signal to pass directly to his subscribers. This accords the noise reduction advantages (Fig.5) of the compander to those equipped with Dolby receivers at no perceptible detriment to non-Dolby or TV receivers.

#### RECEPTION

Reception of stereo subcarriers may be accomplished by the simple addition of appropriate subcarrier demodulator cards to the satellite video receiver.

Serious caveats apply, and this technique, while enticingly simple, is not recommended at this time.

Consider the following, for good stereo reception it is necessary that the L and R channels remain well separated (that is, audio in one channel shall not appear in the output of the other channel). The FCC requires 29.7 dB separation (which was about the best achievable when the rules were adopted). Exciters soon became available which were capable of better than 35 dB separation.

In order to maintain good separation, it is necessary that the amplitude and phase of the L+R and L-R paths be nearly identical. The channel separation as a function of these three factors is given in the following equation.

$$20 \log \left[ \frac{\left( \cos \theta + \frac{S}{M} \cos \phi \right)^2 + (\sin \theta)^2}{\left( \cos \theta - \frac{S}{M} \cos \phi \right)^2 + (\sin \theta)^2} \right]^{\frac{1}{2}}$$

where:

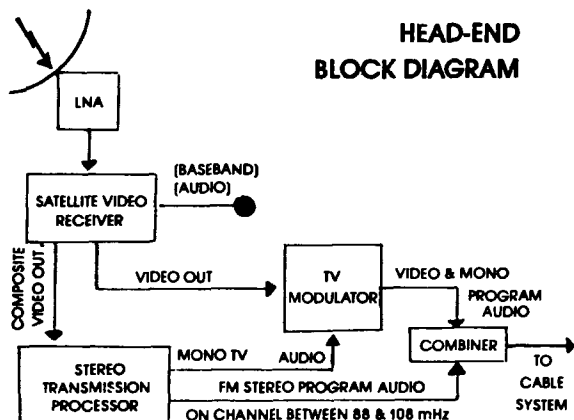
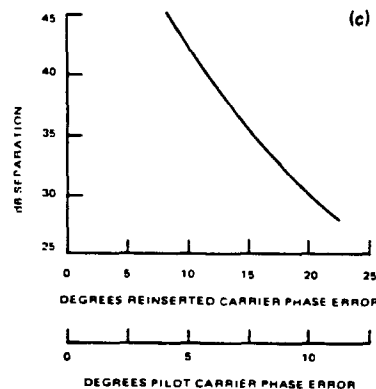
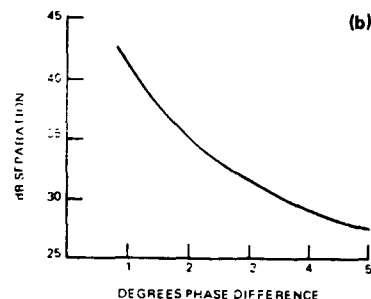
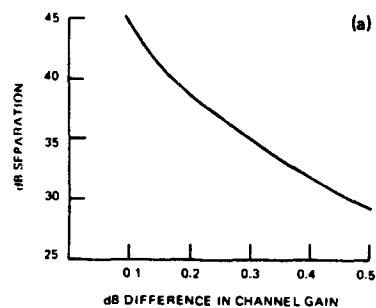
- M is the gain of the main L+R path
- S is the gain of the stereo L-R path
- $\phi$  is phase error of reinserted 38 kHz sub-carrier
- $\theta$  is difference in phase between L+R and L-R paths.

The effect of each alone upon the separation is shown in Fig. . In practice, loss of separation is due to some of each. Therefore, to achieve 35 dB separation, the amplitudes must match to about 1 percent and the phase to about  $1^\circ$  over the entire audio range from 50 Hz to 15 kHz. These are very stringent requirements. For this reason, designers keep the amount of circuitry in the separate L+R and L-R paths to a minimum.

Propagation delay deltas, long term component degradations and manufacturing differences make independent subcarrier demodulator cards impractical as stereo receivers, at this time.

A number of efficiencies are inherent in a reception scheme like that of Fig.6, not the least of which is the preservation of stereo separation in the long term.

Additionally, wide deviations may be implemented in the absence of receiver imposed roofing limitations, thus yielding the benefits of optimized transmission.



### SUMMARY

ALL WARNER AMEX SATELLITE ENTERTAINMENT COMPANY services (MTV, Movie Channel, NICKELODEON) emanating from the new NETWORK OPERATIONS CENTER will incorporate compatible stereophonic audio.

In accordance with NCTA recommended practice THE MOVIE CHANNEL and NICKELODEON will adhere to deviation standards set forth therein.

MTV, as accords with it's format, will employ the optimized transmission technique discussed here, in the interest of superior audio.

Both stereo systems, as well as conventional reception of all WARNER AMEX SATELLITE ENTERTAINMENT COMPANY programming will enjoy the advantages of Dolby noise reduction encoding.

I wish to thank the people of Dolby Laboratories, Leaming Industries and Wegener Communication for their dedicated participation in this project.

### CONCLUSION

We have striven to develop a system uniquely suited to the needs of the CATV industry.

A wholly non-proprietary design will allow competition to stabilize costs.

A modern companding technique will allow efficient use of transponder space at no detriment to non-companded receivers and authority compromise to the generic nature of the system.

And, finally as a business person who must mediate between a diverse group of claimants, the CATV operator is well aware of the not insignificant marketing advantages the term "DOLBY" conveys to subscribers.