THE IMPACT OF MULTICHANNEL SOUND ON CATV SYSTEMS

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A proposed Multichannel Sound (MCS) System for television is described, and differences between three proponent systems are discussed. Each of the proponent systems includes provision for transmission of:

1. L+R information to maintain compatibility with existing receivers
2. L-R information for stereo
3. A Second Audio Program (SAP) channel for a second language, quadraphonic sound or as a tutorial channel; and
4. A non-public channel for voice and/or data telemetry.

Although immediate wide-scale implementation is not expected, the planned system may have a substantial financial impact on the CATV industry. Headend equipment (including processors, modulators, demodulators and microwave transmitters and receivers) may have to be modified or replaced before passing an MCS signal. Present day descramblers will likely suffer deteriorated performance when used on MCS signals, and the MCS signals themselves may suffer degradation when used with descrambling equipment. The introduction of MCS carriers with their increased bandwidth and possible higher levels on a CATV system raise questions about the ability of present day receivers to trap out sound carriers on lower adjacent channels.

The MCS Subcommittee of the NCTA Engineering Committee is conducting tests in cooperation with the Electronics Industries Association and the National Association of Broadcasters to determine the impact MCS signals will have on the CATV industry and to recommend which of the three proponent systems, if any, should be selected.

INTRODUCTION

Multi-Channel Sound for Television and its Implications for CATV

In 1979 the Consumer Electronics Group of the Electronics Industries Association, the National Association of Broadcasters and the Joint Council of Inter-Society Coordination formed the Multichannel Sound Subcommittee to study proposals to introduce multichannel sound (stereo) into the U.S. television system. In August, 1982 the Committee published a 1,000 page report which contained results of tests conducted on three proponent systems.[1] EIA-J, Telesonics and Zenith have each proposed systems which are similar in many respects and different in others.

Each system will maintain compatibility with the existing monophonic system by transmitting an L+R channel with the same characteristics as the present monophonic channel. Each system will transmit stereophonic information using an L-R channel and a corresponding pilot in the spectrum above the L+R channel. A channel called a Second Audio Program (SAP) channel will permit the simultaneous transmission of additional aural information such as a second language or a narrative. The performance of this channel is limited both in fidelity and noise performance when compared with the stereo channel. Finally, a channel called the non-public channel is proposed to transmit data and voice information.

Figure 1 depicts the baseband spectra of each of the proposed systems. Each of the systems has undergone changes to improve performance as test results are analyzed. Most noteworthy among the differences are: the EIA-J systems uses an FM subcarrier for L-R transmission while the Telesonics and Zenith systems use double sideband suppressed carrier amplitude modulation (DSB-SC AM) for L-R transmission. Note, current practice for FM broadcast stereo in the U.S.A. uses DSB-SC AM for stereo transmissions. In the EIA-J and Zenith systems the L-R subcarrier is centered at twice the horizontal scanning frequency ($2f_H$), but in the Telesonics system, the L-R subcarrier is positioned at 2.5 the horizontal frequency. The SAP channel has been subjected to numerous changes. Figure 1 indicates the proposed configurations at the time of this writing.

In August, 1982 the NCTA Engineering Committee formed the MCS Subcommittee to study the impact that MCS will have on CATV system operation and

[1] "Multichannel Television Sound: The Basis for Selection of a Single Standard", by Electronics Industries Association's BTS Committee, Published by the National Association of Broadcasters, Vol. I, July 16, 1982; Vol. II, August 6, 1982.

to recommend one of the three systems if deemed appropriate. The Subcommittee set a precedent in early 1983 when professional help was retained to supplement the volunteer activity in studying the impact. The EIA/NAB Committee has made its laboratory facilities, located near Chicago, available to aid in the study. Tests are now being conducted in that facility with joint cooperation between the two groups.

TECHNICAL IMPLICATIONS FOR THE CATV INDUSTRY

A. Audio Signal/Noise Ratio[2]

In Volume I of the Multichannel Television Sound report, it was indicated[3] that for high quality sound reception, the signal to noise ratio should be at least 60dB, preferably 70dB or better, for the principal community of viewers. For comparison, EIA RS-250B specifies for monaural sound that the minimum unweighted audio SNR for end-to-end television relay facilities be 56dB, including buzz. We should deliver at least a 60dB SNR to the TV receivers connected at the extremities of our systems. To determine the expected SNR (thermal noise only) in cable systems, calculations were performed by several members of the NCTA Subcommittee.

For the case of 36 dB NCTA Video RF-SNR[4], with the sound carrier 15dB below the video peak envelope power, we get the following unweighted audio SNR's.

	Monophonic	Stereo L or R	SAP
Separate Mixing	63.8dB	49.2	39.6
Intercarrier, Video at Blanking Level	63.6	49.0	39.4
Intercarrier, Video at White Level	59.0	44.4	34.8

Obviously we are in trouble if there are subscribers whose ears demand stereo but whose eyes will tolerate 36dB. In addition, the Separate Audio Program SNR will be approximately 10dB less than stereo signal. If we assume that a more typical situation is for the cable system to deliver a 43dB Video SNR, then we find ourselves dealing with a stereo SNR or approximately 55dB and a SAP SNR of approximately 45dB. These are certainly more tolerable conditions and could be improved even more if companding is used. (A separate working group is developing a companding system).

From the calculations it appears that threshold margins are adequate, both for new sets with sound IF bandwidths sufficient to support the broadband signal and for old sets.

B. Visual/Sound Ratio

It is recognized that one way to improve the multichannel sound SNR is to increase the sound carrier level. Above threshold the audio SNR is increased one dB for each dB we raise the sound carrier level. In Volume I[5] of the EIA report, use of the highest feasible sound power is encouraged.

It must be recognized that increasing the sound carrier level in a cable system is undesirable and would create a multitude of problems, as explained in the following:

1. TV Receiver Adjacent Channel Rejection

All cable systems operate with TV channels adjacent to one another. In the early days of cable it was determined that most TV receivers lacked sufficient selectivity to provide for beat-free pictures, unless the lower adjacent sound carrier was reduced in level below the visual/sound ratio being transmitted by broadcast stations. Although the NCTA committee recognized that receiver selectivity has been considerably improved over the years, one must recognize that the proposed multichannel sound standards with their increased deviations (approximately 70kHz) creates sound carriers whose energy occupies a much wider bandwidth than before (approximately 320 kHz for 70 kHz deviation as compared to 80kHz for 25kHz deviation). In a paper written in 1972 by Will Hand of Sylvania entitled "Television Receiver Requirements for CATV Systems", tests were performed on a number of color receivers which represented collectively over 50% of receiver designs in the industry at that time. The data shown below is the weighted results of these measurements. The data was weighted to reflect the proportion of the market held by the receiver manufacturers.

[2] In order to simplify analysis and due to similarities between systems the Zenith was used for discussion and analysis except where clear differences are noted.

[3] Multichannel Television Sound: "The Basis for Selection of a Single Standard", Volume I, The National Association of Broadcasters, July 16, 1982, p. 51.

[4] Minimum allowed CNR for Cable Systems. Part 76 of FCC Regulations.

[5] Multichannel Television Sound Report, p. 164.

	Frequency (kHz)
Adjacent Sound null to 41dB point on low frequency side of IF trap	94
Adjacent Sound null to 41dB point on high frequency side of IF trap	115
The 41dB rejection bandwidth of this trap is 94 + 115 = 209kHz	

One can only conjecture what the rejection of this trap would be to a sound carrier adhering to the proposed multichannel sound standards; however, it goes without question that raising the sound level would only aggravate what already may be an unacceptable operating condition.

Set-top converters with adjacent channel traps would help, although only a few presently in the field have this feature. Separate traps connected to the output of converters and tuned to the lower adjacent sound would help; however, they suffer from the following problems:

a. AFC and fine tuning errors would diminish effectiveness.

b. They would introduce additional group delay errors.

c. The overall cost would be substantial.

d. Subscribers might confuse them with pay TV traps and remove them.

2. Headend Equipment (Signal Processors, Strip Amps and Modulators)

The majority of these devices operate at an output level between +50dBmV to +60dBmV (+60dBmV = 1 volt rms @ 75 ohms) for the video carrier with the sound carrier typically 15dB below this level. Most manufacturers also quote a specification which states that when the unit is operated at maximum output (this is not uncommon), all spurious outputs will be at least 60dB below the desired video carrier. One component of this distortion falls 1.5MHz above the video carrier of the lower adjacent channel. Any attempt to raise the sound carrier level causes a one dB rise in this undesired signal for each dB the sound level is increased. This is a particularly sensitive area of the video spectrum and any interfering carrier must be 55dB to 60dB below the desired carrier not to be perceptible. This problem is only aggravated when scrambling systems are employed which amplitude-modulate the sound carrier with descrambling timing information. The NCTA Subcommittee recognizes that this potential problem can be solved with highly selective bandpass filters on the output of these devices but not without an increase in the envelope delay distortion inherent in these filters. Equipment already in place may have to be replaced or undergo major modification to meet new performance standards.

3. AML Equipment

AML equipment is used to transmit channels of television from one area of a community to another. Increases in aural carrier levels would cause corresponding increases in the lower 4.5MHz products, as described in 2. above. For systems operating at full rated power, it would likely be necessary to reduce output power thereby reducing fade margin. The performance of this equipment is impaired by scrambling systems which cause a 6dB or more increase in the aural level during transmission of descrambling timing pulses. This practice creates a marginal condition to exist with today's practices. Increasing levels for Multichannel Television Sound would be unacceptable.

4. Distribution Equipment

Measurements were conducted to determine the perceptibility of sound carrier beats when the aural carrier levels were increased above 15dB below the visual carriers. From these measurements, perceptibility of sound-carrier beats occurs at a system level 3 to 3-1/2dB above that level which produces barely perceptible video carrier beats (CTB-composite triple beat distortion) when not phase locked. In the same test the system level could be elevated approximately 5dB when phase locked before background images (modulation cross-over) could be seen. These tests were performed with 54 channel Harmonically Related Carriers (HRC) loading. The conclusion to be drawn from these tests indicate if aural levels must be increased to accommodate Multichannel Sound, then the advantage gained from phase locking is lost.

Another problem may surface if aural levels are increased. Many cable operators find it possible to use certain channels in the aeronautical radio service bands by lowering aural carrier levels to +28.75dBmV maximum. In fact, several channels can sometimes only be used this way due to conflicts with both the visual and aural carriers. If aural levels are raised, this practice would be eliminated resulting in the loss of these channels for stereo service.

C. Increased Deviations

In order to achieve the highest possible stereo SNR, plus provide for auxiliary services, all proponents of the multichannel sound systems intend to increase the peak deviation to approximately 70kHz. By doing so, technical problems may be created in both cable headends and set-top converters, not to mention the selectivity problems of TV receivers. The following section discusses the nature of these problems in detail.

1. TV Receiver Selectivity (See Section B.1.)

2. Headend Equipment

a. Signal Processors

Two types are currently in use. One type uses a split sound system where the aural carrier is trapped and processed separately. The second type processes the video and sound combined and uses adjustable traps to reduce the sound carrier level. Both systems will suffer when deviations are increased from 25kHz to 70kHz.

For split sound units, the sound notch must not introduce amplitude or group delay errors in chroma information while attenuating the sound carrier and its sidebands at least 40dB. This has been achieved for 25kHz deviation with a Carson bandwidth of 80kHz. When the new Carson bandwidth for stereo (approximately 350kHz) is measured, attenuation of the upper sideband is on the order of 10dB. With incomplete trapping, a portion of the aural carrier passes through the visual processing circuitry. When this signal recombines with the processed aural signal, impairment of the received aural signal will result. This impairment could result in a substantial reduction in the amount of separation between the left and right channels. More testing needs to be conducted to confirm or dispel this concern.

One processor measured had 2% AM on the FM sound carrier with 25kHz deviation and 16% AM with 70kHz deviation. This would clearly cause a problem when using analog descrambling information on the aural carrier.

In addition to the notch problem, the 3dB bandwidth of the sound path was measured on one type of processor to be approximately 350kHz. No attempt is made to control delay characteristics at the band edge. One member of the Committee described the use of unequalized filters in home stereo receivers. This practice results in stereo separation of 40dB, a number considered adequate. General practice has been to control amplitude characteristics of filters, but no special care is used in controlling delay characteristics. This practice has not been reported to have caused any problems of which the Committee is aware.

In general, the NCTA Subcommittee believes IF circuitry in all existing processors would have to be redesigned for successful MCS operation.

b. Modulators

If external MCS signals are generated and pre-emphasis circuits are removed from modern modulators, it may be possible to use them for MCS transmission without difficulty. Older designs may have problems caused by transformers used for coupling and uncontrolled amplitude and phase characteristics in filters.

c. Demodulators

Volume I of the referenced MCS report discusses the impact MCS will have on TV receivers; since most demodulators use similar circuitry, they will experience many of the same problems. This includes insufficient sound IF bandwidth, problems with buzz caused by intercarrier sound processing and inadequate baseband response to pass MCS subcarrier components.

3. Set-Top Converters(Scrambling/Descrambling)

Of all the possible problems, this one has the potential for the greatest impact on the CATV industry. Devices with the greatest proliferation use either pulse or sinewave sync suppression. Problems with both systems can arise when FM to AM conversion occurs in headend processors, modulators and set-top converter bandpass filters. These products manifest themselves in different ways. In the case of pulse systems, the AM pulse on the sound carrier, and any spurious AM products, fire a trigger circuit, usually a monostable multivibrator. Any stray AM products or noise can cause descrambling pulse jitter due to slicer uncertainty.

An attempt was also made to simulate stereo susceptibility to stray tagging and descrambling pulses. Measurement data seems to indicate compatibility between MCS and pulse scrambling systems; however, reports from the field indicate buzzing is being experienced on some sets imported from Japan which include stereo demodulator circuitry using the Japanese standard. These reports must be investigated prior to reaching any final conclusions.

The sinewave sync suppression system may be most susceptible to FM to AM conversion products. These systems will undoubtedly suffer from the almost certain increase in AM products on the aural carrier. Additional testing is to be performed in this area by the Subcommittee.

Several manufacturers have baseband systems in the field. Since these units have demodulators, the performance and problems will be similar to those experienced with TV sets. Special MCS units will likely be similar to the tuner, IF amp and detector circuitry developed for TV receivers intended for MCS operation. This suggests units already in the field can continue to be used for subscribers with monophonic TV receivers, while units of a new, compatible design would be required for subscribers wishing to avail themselves of the opportunity to have multichannel sound. The one unknown, to be investigated, was discussed earlier in section B.1. of this report. The adjacent channel sound traps in these products could be expected to behave like those in TV sets. One manufacturer uses crystal stabilized local oscillators with AFC and SAW IF filters. When compared with older tube-type television sets with unstable IF circuitry, these units may offer satisfactory performance. This must be verified before concerns can be relaxed.

D. Phase Noise Considerations

In Volume I of the Multichannel Sound Report, mention was made that a return to split-sound TV receiver design could eliminate sound buzz due to incidental phase modulation of the sound carrier generated by mixing with the video carrier. This would certainly be the case; however, all concerned must also recognize there are additional problems created by this technique which will likely be made worse by equipment presently used in cable systems. Indicated below are several areas which need additional investigation before split-sound receiver design should be considered.

1. AML Equipment

On page 161 of Volume I of the MCS report, the EIA Committee discusses a problem with translators in Japan. "During the rebroadcast tests of MCS signals, a large increase in buzz interference within the subchannel was observed. The interference was especially noticeable in split-carrier reception. This was due to amplitude and phase nonlinearities of traveling-wave tube (TWT) power amplifiers used in old translators and also due to cascaded use of such translators." There is reason to believe a similar problem may exist with AML equipment. Tests are underway to determine what impact this equipment will have on future TV receiver design.

Although most operators use phase locked receivers for AML transmission, some operators occasionally use receivers with free running local oscillators. In such cases, the levels of IPM increase substantially. One cable operator measured substantial increases in noise levels using these receivers with synchronous demodulators. MCS TV receivers using split sound systems would experience impaired noise performance as a result of this phenemonon.

2. Headend Equipment

Most signal processors and modulators use oscillator designs which are crystal controlled; however, there are presently on the market several multichannel units (typically used for standby purposes) which use oscillators that are either frequency synthesized or under AFC control. These devices will almost certainly increase the amount of incidental phase modulation present on the sound carrier.

3. Set-Top Converters

Converters which use synthesized tuning systems introduce substantial levels of incidental phase modulation (ICPM) on the TV signal. Older varactor tuned products also introduce ICPM, but to a lesser degree. TV receivers using intercarrier sound detection are not affected by high levels of ICPM when both the visual and aural carriers are subjected to the introduction of ICPM: however, in TV receivers using split sound IF and detection systems ICPM products introduced by CATV converters can contribute to deteriorated noise performance. It is not uncommon for varactor converters to introduce frequency modulation on the TV signal in excess of 10kHz. This suggests a serious problem for the cable industry if split sound TV receivers are introduced in the marketplace.

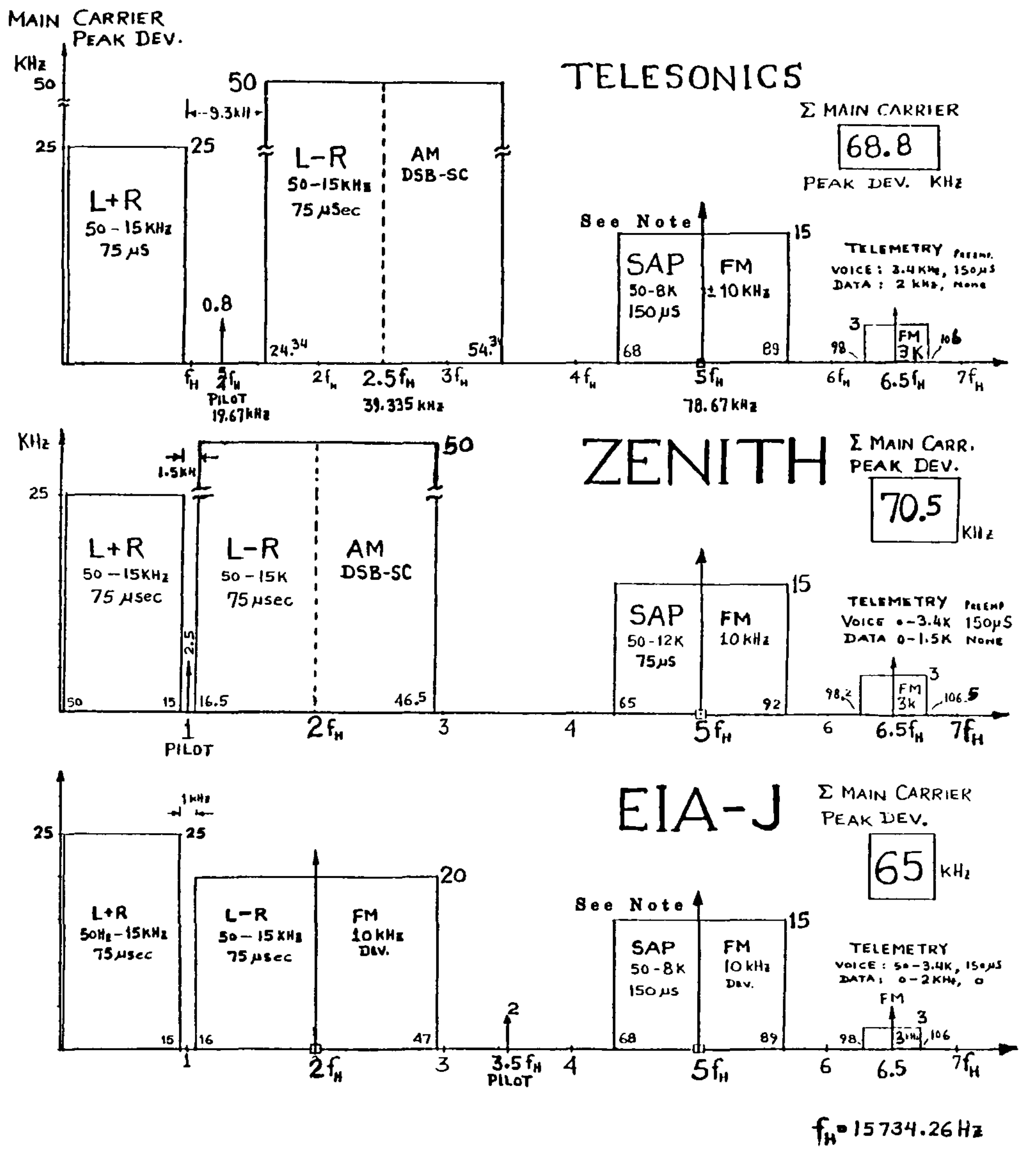
SOME ADDITIONAL THOUGHTS ON MULTICHANNEL SOUND

One must ask if the course of action the television industry is about to embark on is appropriate now. We are introducing 40-year old technology at a time when a quantum leap in digital technology is about to take place. The TV sound system in the United States is already being strained to capacity with performance which can best be described as marginal. The course of action we are about to embark on appears to take a marginal situation and make it worse. This action is taking place at a time when the telephone industry is moving in the direction of digitized voice communications, at a time when the consumer stereo industry is on the verge of moving away from the traditional analog methods into digital technology using laser disks and tape, and when satellite delivery mechanisms such as Public Broadcasting Service (PBS), Home Box Office (HBO) and Direct Broadcast Satellite (DBS) services are moving to digital audio.

The CATV industry is facing some serious problems with the present methods of premium program security. Our premium TV security systems face serious threats not only by tampering but also by units manufacturered and sold on the black market. The industry is also facing pressure in the regulatory and legislative area to make the sound on certain channels unavailable to the owners of cable-ready sets and users of conventional converters. The task of keeping our premium signals secure eventually may come to depend on scrambled digital audio. If the TV industries could successfully develop standards for digital stereo audio which are compatible with the existing monophonic system, then a quantum leap will have been realized which would be a direct benefit to the American viewing public. It will be a challenge to develop cost-effective digital technology compatible with the TV sound system already in place, but engineers using the latest technology have the capacity to overcome difficult challenges. It is true there are difficult compatibility issues to be overcome, but this is a real opportunity to enhance the quality of television in the United States.

CONCLUSION

This paper has described several major elements in CATV systems where the carriage of multi-channel sound might create problems. At the time of this writing the NCTA Engineering Committee has outlined a test plan to investigate these topics. The tests, which began in February and will last about six months, will be performed by representatives of the cable industry working in conjunction with EIA Committee engineers. The results will be described in a comprehensive report including both subjective and objective evaluations of each area of concern. If testing results are negative, it may be appropriate for the industry to lead the drive to develop standards for a digital audio system.



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Note: Telesonics SAP Changed to 50-10k 75μs

EIA-J SAP Changed to 50-12k 75μs

Figure 1

Baseband Spectra (Proposed Systems)

Source: Multichannel Television Sound, Volume I, p. 57