BTSC STEREO AND CABLE SYSTEMS
Measurement Techniques and Operating Practices

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ABSTRACT

In August of 1982 the NCTA Engineering Advisory Committee, concerned about the capability of cable systems to provide quality transmissions of stereo audio, formed an ad hoc subcommittee to investigate multichannel television sound. In September of 1982 the subcommittee sent a report to the Chairman of the EIA BTSC committee outlining the areas of technical concern. The cable industry also went on record as being opposed to any of the stereo formats being proposed. The opposition centered on the selection of a subcarrier scheme (very similar to the 30+ year old FM broadcast system) at a time when digital audio systems were becoming widespread in the consumer marketplace. More important, there were cable carriage problems which were explained in detail in a report to the EIA BTSC committee.

In March of 1983 the NCTA subcommittee wrote a comprehensive test plan and hired a test engineer to measure the impact of cable equipment on the proposed stereo systems. The testing was completed in September of 1983 and the results documented in a report titled "Multichannel Television Sound Report." As a result of the efforts of the cable industry, plus others, the FCC granted a "non must-carry" status to the newly selected stereo system in February of 1985.

After the conclusion of the test report in 1983, the BTSC subcommittee entered a phase of providing a clearinghouse for inputs on both successful and unsuccessful attempts by the cable industry in providing quality stereo reception to our customers. As a result of this effort, one fact became evident. The cable industry needed a comprehensive set of measurement procedures and operating practices to verify optimum performance for stereo encoding equipment plus insure quality delivery through the remainder of the system. As a result the subcommittee reconvened its efforts in 1987. In November of 1988 a draft report on BTSC measurements and operating practices was presented to the NCTA Engineering Committee. What follows is a summary of that document.

INTRODUCTION

Listed below is the Table of Contents for the complete report.

The complete report consists of 58 pages. Anyone interested in making stereo measurements should obtain a copy of the full document.

During the development of this report, much discussion took place on the quality of test equipment required to obtain meaningful results. The dilemma revolved around whether the subcommittee should recommend precision decoders and demodulators, knowing that many operators don't presently have access to this type of equipment. The alternative was to suggest the use of consumer type test equipment severely limiting the accuracy of the resulting measurements, and in many cases rendering the results useless. After all, in most instances what we are attempting to determine is the performance level of a high quality stereo encoder. Attempting to measure its performance through a device whose specifications are worse than the device(s) being tested will only lead to erroneous conclusions. Because of this, you will find that only precision test equipment is recommended in the "required test equipment" lists in each of the measurement descriptions.

BTSC MODE VS. EQUIVALENT MODE

A second dilemma involved the issue of whether the measurements should be made with the equipment operating in the BTSC Mode or the Equivalent Mode. To help us understand equivalent mode, look at a block diagram of the BTSC system in Figures 1 and 2. What sets Multichannel Television Sound (MTS) apart from conventional FM broadcast stereo is the BTSC noise reduction that makes possible buzz-free stereo operation with intercarrier sound detection. Unfortunately, the presence of this compressor and expander in the L-R channel that is not duplicated in the L+R channel creates a whole host of problems that do not exist in conventional FM stereo. FM stereo broadcasting is much simpler than MTS because the FM system is linear throughout.

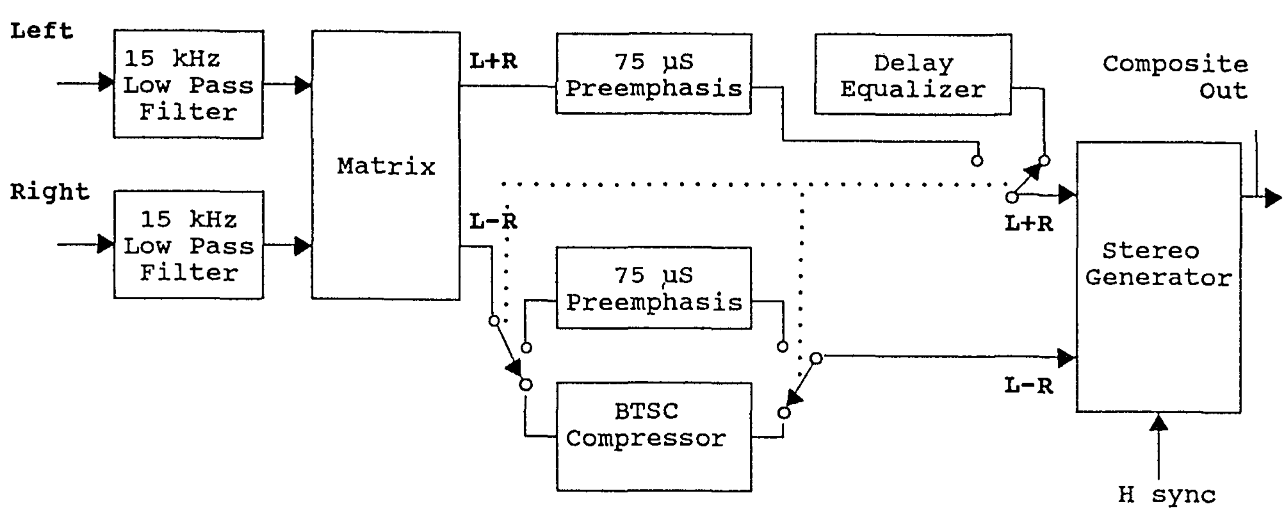

Figure 1 - MTS Stereo Encoder

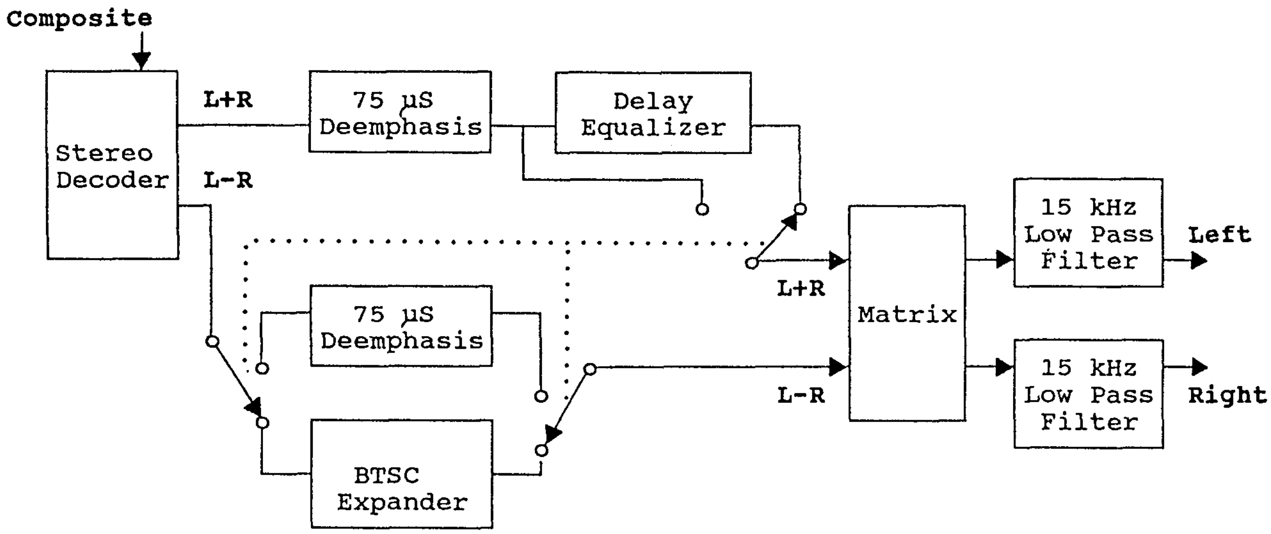

Figure 2 - Stereo MTS Decoder

Measurements made in the BTSC mode (Expander/Compressor active in circuit), while more difficult to make accurately, gives us an indication of how the system actually operates in the real world. One of the major areas of concern is the level setting accuracy. For the expander and compressor to track one another correctly they must have a common reference. For this to occur the absolute FM deviation of CATV modulator must be accurate. The total allowable error budget, input to output, on the L-R channel is ±.1744 db for 40 db of separation and ± .550 db for 30 db of separation. Although many knowledgeable engineers strongly urge that stereo measurements (especially separation) be made with the encoder/decoder operating in the equivalent mode (expander/compressor replaced with 75 usec pre-emphasis/de-emphasis network), we have chosen not to do that for two reasons. First, not all BTSC encoders designed for cable applications have the capability of being operated in the equivalent mode. Second, interpreting the results of measurements made in this mode of operation is confusing when attempting to relate the numbers to real world operation.

MEASUREMENT TECHNIQUES

At this point, I would like to provide a synopsis of each of the measurements defined in the table of contents in the Introduction section of this paper. Because of space limitations, I will not go into the actual measurement procedure but instead will provide the definition, performance objective, and a limited discussion for each of the measurements.

a. Signal-to-Noise Ratio

Definition: Audio signal-to-noise ratio is defined to be the ratio of the audio signal power output to the noise power in the entire audio pass band.

Performance Objective: The BTSC signal delivered to the subscriber's receiver shall be capable of providing a sum channel signal-to-noise ratio, for sum channel peak modulation levels of +/- 25 Khz, of no less than 55 db, when demodulated and decoded by precision BTSC stereo equipment.

When a scrambling system that puts amplitude modulation energy on the sound carrier is employed, this measurement should show no less than 53 db sum channel signal-to-noise ratio.

Discussion: The measurement defined here is referred to as the sum channel signal-to-noise ratio. Since in this measurement L = R, no difference energy should be present and the companding system should be operating at minimum gain. Two measurements may be used to characterize the noise performance of the BTSC system. The sum channel signal-to-noise procedure is used to evaluate output noise effects that are not a function of the companding process. The signal-to-buzz measurement described next evaluates output noise including effects of the receiver's expander.

b. Signal-to-Buzz Ratio

Definition: Signal-to-buzz ratio (S/B) is the ratio in dB of the peak-to-peak signal voltage divided by the peak-to-peak buzz voltage as seen using an oscilloscope at the output of a BTSC stereo decoder. The buzz measurement is made while the signal is present.

Performance Objective: More than 35 db unweighted should be measured using a precision demodulator and stereo decoder at the output of a complete system. In systems with scrambling a minimum of 27 db should be measured. Measurements made with consumer equipment may produce lower numbers.

Discussion: The results of the measurement depend almost completely on the ability of the test demodulator and decoder to reject video and AM on the sound carrier. A consumer demodulator/decoder may be more sensitive to this than precision equipment, and may be more advantageous in terms of finding system buzz problems. For this reason numbers obtained by this measurement should be regarded as comparative and not absolute. The performance objective listed here should be interpreted accordingly.

c. Frequency Response of BTSC Stereo Transmission System

Definition: Frequency response of the MTS stereo system is the variation in system gain versus frequency from input of the stereo encoder to the output of the test decoder. The frequency response measurement may include part or all of the cable distribution system.

Performance Objective: The frequency response, peak-to-valley, should be within three dB from 50 Hz to 14 Khz.

Discussion: Frequency response is a common audio measurement used to determine the transparency of the system to signals within the passband of the system. If the frequency response is greater than the three dB recommended then the subscriber may observe less than a satisfactory performance with the system.

d. Separation Measurements of the BTSC Stereo System

Definition: Stereo separation is the difference in output level between the demodulated left audio channel and the right audio channel exclusive of noise when only a left or right audio input channel is supplied to the stereo system including the encoder, distribution system and decoder. Separation is expressed as a voltage ratio in decibels.

Performance Objective: Separation through the total system, to the subscriber's stereo television or decoder of 20 dB from 100 Hz to 8 KHz with a taper of 4 dB to 14 dB at 40 Hz and 14 Khz.

Discussion: The measurement of separation in the BTSC television sound system is by far the most complex. The BTSC system uses the dbx companding system in the (L-R) difference channel to reduce noise. This channel is very sensitive to transmission error. For the system to deliver a high degree of separation, the dbx compressor in the encoder must track the expander in the decoder with a high degree of accuracy. If you wish to measure an encoder with a 35 dB specification, a decoder whose performance has been verified must be used. If you wish to measure an encoder with a 20 dB specification, a high quality consumer decoder may be used.

e. Total Harmonic Distortion of the BTSC Stereo Transmission System

Definition: Total Harmonic Distortion is defined as undesirable harmonic content of a modulating signal that is detected and presented at the output of a detector. With respect to stereo audio, it is the amount of unwanted input related signal.

Performance Objective: At all levels and all frequencies, the measured total harmonic distortion should be 1.0% or less.

Discussion: Total harmonic distortion is a common audio measurement that is one indication of overall audio quality. Distortion levels on audio equipment should easily meet the 1% objective. The test method outlined exercises all aspects of the BTSC transmission system including the noise reduction system.

f. Incidental Carrier Phase Modulation (ICPM)

Definition: Incidental Carrier Phase Modulation (expressed in degrees) is defined as Phase Modulation of the video carrier with changes in video input signal level, as the signal level varies from blanking to reference white (0 to 100 IRE).

Performance Objective: Incidental Carrier Phase Modulation should be kept below three degrees or audio buzz may become unacceptable.

Discussion: ICPM is a phenomenon that can create both audio and video related problems. The most common malady exhibited by ICPM is audio buzz which is caused in a home TV receiver when the ICPM riding on the video is transferred to the audio carrier in the TV's intercarrier detector.

OPERATING PRACTICES

In addition to the actual hardware measurements outlined above, there are operational considerations which must be addressed when installing a BTSC encoder. Once again, the following sections attempt to provide a summary of the extensive discussions included in the complete report. The reader is urged to obtain a copy of the entire document to get the complete story.

a. Interconnecting at Baseband Audio

Discussion: The BTSC composite signal is created by the stereo encoder. This signal contains energy in the band between 50 Hz and about 47 Khz. When SAP is used, energy components are present to about 90 Khz. The aural carrier is frequency modulated by the BTSC composite signal. The deviation sensitivity of the aural carrier modulator must be precisely set to maintain the performance (separation) of the system. The procedure for setting Audio Modulator Deviation describes how to use the Bessel null technique to precisely set levels from the BTSC encoder to the aural carrier modulator.

Performance Objective: The deviation sensitivity of the aural carrier modulator must be matched to the operating output level of the BTSC encoder to within +/- .1 dB. An error of only .28 dB will limit the best achievable separation to 30 dB.

b. Interconnect with CATV Modulators at 4.5 MHz

Discussion: As discussed in the previous section, the generation of BTSC stereo signals requires precise calibration of baseband audio levels. For this reason, it is very common to interface a BTSC encoder in such a manner that only non-critical adjustments must be made at the time of installation and on an on-going routine basis. Such is the case when the encoder contains a built-in 4.5 Mhz subcarrier modulator. In this case the encoder manufacture is performing all critical baseband level adjustments as an internal part of the encoder.

Summary: When interconnecting a BTSC encoder to a cable modulator using a 4.5 Mhz interface, only two adjustments are necessary. One is the 4.5 Mhz interface level which is normally set at 100 mv p-p and the second is the aural carrier level which is typically 15 dB below the video carrier level.

c. Interconnect with CATV Modulators at 41.25 MHz.

Discussion: This interface scheme is used primarily when the modulator being used has no provisions for accepting an external 4.5 MHz input. In many cases modifications are required to the modulator for interfacing with an external 41.25 MHz source. It should also be realized that when interfacing at a frequency of 41.25 MHz, the visual/sound intercarrier frequency spacing will be determined by two different frequency sources. One is the frequency accuracy of the 45.75 MHz video source and the other is the frequency accuracy of the 41.25 MHz audio source. It is important that the spacing between these two carriers be maintained at 4.5 MHz $\pm$ 1 KHz.

Summary: This method of interface is preferred over the baseband audio interface however when this scheme is used one must take care to insure that the proper visual/aural amplitude ratio at the output of the modulator is achieved.

d. On-line Checks: Critical parameters of BTSC stereo performance include signal-to-noise ratio, signal-to-buzz ratio, frequency response, stereo separation, and relative phase between the left and right signals. Presented in this section in the complete report are methods for on-line checks of stereo performance without interruption of service. These methods provide qualitative indications of performance or allow subjective evaluation of various parameters. They provide a continuous method of monitoring stereo signals to obtain a reasonable amount of confidence in signal quality.

Summary: Numerical standards for stereo performance are given elsewhere in the NCTA operating practices. The procedures given in this section in the complete report are sufficient only to indicate the occurrence of catastrophic system failures or major changes in stereo performance. They are supplied as an aid to the recognition and troubleshooting of system failures.

e. BTSC Operational Guidelines

Discussion: In most installations, the operation of BTSC stereo encoding may encounter difficulties caused not specifically by the encoder, but rather due to operating conditions. In most cases, the difficulties can be avoided through adherence to a few basic operating guidelines and practices.

This section in the complete report discusses such issues as: satellite video spectral content, encryption systems, commercial insertion, modulator interfaces, ICPM, character generators, phasing of left and right signals,and signal level variations.

Summary: While it is not possible to cover all potential problems, the adherence to several basic recommendations will alleviate the majority of difficulties.

f. Transportation of Stereo Signals Over FM Links

Discussion: Field experience as well as laboratory tests have shown that the delivery of quality stereo television over a CATV system is feasible. The effect of the distribution system itself is slight. The interface between stereo encoder and modulator, though critical, has received much attention and is well under control. Scrambling is fairly well understood, and at least some systems cause little degradation. The transportation of stereo between hubs, satellite receiving stations, and headends, however, has received very little attention.

AML's and FM links are routinely used in CATV systems. When used properly this equipment is nearly transparent to video and audio signals. Care should be taken however, when adapting existing systems to carry BTSC stereo. FM links in particular can cause significant degradation of the stereo signal if improperly used.

Summary: It cannot be denied that it is possible to transmit BTSC stereo as a 4.5 MHz subcarrier added to video over an FM link. By disabling active clamps, checking frequency response, filtering any spectral overflow and reducing deviation the BTSC signal should survive, though bruised with a marginal S/N. The problem is that the FM link is only a small part of a complex distribution system. No reasonable degradation budget could allow for any one part of the system to be so marginal.

By contrast, transmission of separate left and right audio information over individual channels of an FM link is an excellent way to transport stereo and entirely avoid budgeting any degradation to the FM link.

CABLE ERROR BUDGET (Separation)

Definition: A system separation budget is a calculation of the expected stereo separation through the entire cascade of headend, transportation link, distribution equipment and cable. The budget calculation is based on the required performance of the individual pieces of equipment. Measurements can be performed on the individual pieces of equipment to evaluate suitability, or to initially decide on numbers for the budget. The complete report provides a detailed description of a technique employing "Generalized Error Coefficients" to determine the separation of a cascade of devices once the separation is known for each individual piece.

Performance Objective: A minimum of 24 dB of separation (worse case) should be measured using a laboratory quality receiver and stereo decoder at the output of a complete system. This system performance, combined with a typical consumer decoder separation of 22 dB will provide a worse case separation of 17 dB (typical separation of 21 dB) to the subscriber.

CONCLUSION

BTSC Stereo, having been "protected" by the FCC in 1984, is now the de-facto standard in the United States. To date, more than 20% of the television receivers in use in the U.S. have the capability of receiving stereo audio through built-in decoders. This number will rise to 50% in the next few years.

Cable operators, slow to react initially because of low stereo receiver penetrations, are now providing BTSC stereo on satellite delivered channels in ever increasing quantities. It is not uncommon to see as many as 12-15 channels of BTSC stereo in many cable headends.

Obviously, the quality of this audio service becomes critical to the overall customer satisfaction when viewing channels providing BTSC stereo. The intent of this paper is to provide a description of both measurement techniques and operating practices which could provide the basis for equipment evaluations and installation and operating practices to help insure the required level of audio quality. In addition, a concept is introduced utilizing "Generalized Error Coefficients" to allow the calculation of overall separation for a cascade of devices once the separation for each piece is known.

The credit for authorship of the individual sections of the complete report goes to the following individuals: Jim Farmer (Scientific Atlanta), Brian James (NCTA), Ned Mountain (Wegener Communications), Karl Poirier (Triple Crown Electronics), Louis Rovira (Scientific Atlanta), Dave Sedacca (Scientific Atlanta), and Russ Skinner (United Artist Cable Corp.).