BTSC PERFORMANCE MEASUREMENT IN THE LAB AND FIELD

Clyde Robbins - Sr. Project Engineer
Joseph Vittorio - Product Manager

Jerrold Subscriber Systems Division
General Instrument Corporation

ABSTRACT

The U.S. television viewing public has recently been turned onto the phenomenon of stereo TV thanks to the development of the BTSC multi-channel sound system. The BTSC system offers the ease of inband tuning, backward compatibility with monaural receiving equipment and true high fidelity stereo performance. Cable television viewers are in a favorable position to enjoy stereo TV even more because of the wealth of high fidelity stereo programming available on many of the basic and premium services (19 cable channels are in stereo already).

The great potential that BTSC stereo over cable offers will not be realized if cable operators provide anything less than true, high quality BTSC stereo. There is a crying need for reasonably priced test equipment that a cable operator can utilize in obtaining a quantitative measure of the signal quality he is delivering. There is also an immediate need for the development of training programs to bring system engineers and technicians up to working speed with this new audio signal processing area.

All to often, BTSC encoding equipment is installed in the easiest manner rather than by a method which will yield the highest quality the system is capable of and which subscribers deserve. This paper will describe the recommended test equipment and techniques which encoder manufacturers and cable system operators may use to ensure that the best possible signal is being provided to the subscriber, within the confines of a typical cable system environment. A discussion of signal quality concerns from the source through the satellite link, FML, AML, headend distribution, and subscriber equipment will be included.

BTSC TODAY

BTSC stereo is here to stay. At the present, stereo TV sales are the fastest growing segment of the TV market. The growth curve for stereo TV is similar to that of the compact disc player, a product which has rejuvinated the music industry. The National Broadcasting Network (NBC) has contributed greatly to the growth of stereo TV by converting the majority of its prime time programming over to stereo, much as it led the way with color broadcasting.

The Cable TV world has seen premium programming services such as HBO and Showtime/TMC as the major promoters of stereo broadcasting via satellite. In this area it has grown quickly and its application on satellite delivered channels will be commonplace this year. The performance that the BTSC system can deliver in the CATV environment is nothing short of excellent. Achieving the best performance, however requires an understanding of the system and its potential pitfalls.

Although there have been numerous technical papers published outlining the difficulties with BTSC stereo, this paper will present test data showing new levels of performance which have been achieved, describe how the measurements are made, what test equipment is required and what the significance of the measurements are. Recommended test equipment will be described ranging from the sophisticated to the simple to fit the budget of the most cost conscious cable operators.

In addition, a step by step approach to checking performance in the field will be outlined, along with techniques for correcting commonly encountered problems. Specific topics discussed include: video modulation; video bandwidth; group delay; ICPM; VITS; relative carrier amplitudes; hum; buzz, THD; S/N; dynamic range; deviation adjustment and stereo separation.

GARBAGE IN, GARBAGE OUT

Cable operators have a responsibility to their subscribers to provide the highest quality signals feasible. However, if the service provider does not start with a quality source, there is little that a cable operator can do. It is up to the major MSO's to pressure the service providers to live up to the capabilities of the transmission system. These service providers must remember that the growth in popularity of stereo and HI-FI VCR's have established a new level of home video entertainment expectations.

If a film, for example, was originally recorded in stereo (and is available on videocassette in stereo), it should appear in stereo on the premium service. If the programmer was not able to obtain a stereo version of a current movie, selective, tasteful stereo synthesis at the uplink should be used as a service to customers equipped for stereo reception. High quality synthesis is economically justifiable at an uplink, and indeed, should not be the responsibility of the cable operator who is paying a monthly fee for the service.

Another example of poor performance can be found on a number of music video services. Many of the tapes they play regularly have totally unacceptable levels of hiss on them. This is 1987 not 1967! These services should be reminded that their growth in popularity was due to a desire for enhanced video/audio entertainment. Many viewers have invested considerable sums in their entertainment systems only to be bombarded with poor quality audio tracks. Satellite Services which use VideoCipher scrambling have at their disposal a transmission link capable of providing a quality audio signal ideally suited to BTSC stereo encoding. VideoCipher incorporates 14 Bit Digital Audio companded to 10 Bit, yielding 84 dB dynamic range and 60 dB instantaneous signal to noise.

GETTING IT THERE SAFELY

Once a satellite delivered service is received, it is necessary in some situations to transfer or retransmit it to distant locations. If FM modulation is utilized (i.e. FML or FM supertrunk) it is strongly recommended that the discrete left and right audio signals modulate separate FM subcarriers. Using a 4.5 MHz modulated BTSC signal as a subcarrier of the video is generally a poor choice for FML. Degradation of audio signal to noise and dynamic range will definetely occur due to video interference (buzz). Placing the BTSC stereo encoder at the receiving end of the FM link will give the proper performance.

Other remote applications might require AML. This transmission technique is broadband and nearly linear. Reducing the sound carrier level to -17 dB with respect to the video carrier will have a small, negative effect on BTSC noise performance compared with -15 dB. But the dbx companding, which is a required part of the BTSC stereo system, does an excellent job of eliminating transmission hiss.

A common pitfall in interfacing BTSC encoders to modulators is to try to combine 4.5 MHz and video into the video modulator as a single input. This will result in reduced video or audio quality, or both. This is because the 4.5 MHz trap in the video path, before the video chopper modulator, is not wide enough or deep enough and as a result some of the stereo sidebands will pass through the video path causing interference. In order to avoid this interference the 4.5 MHz sound carrier must be kept low relative to the video; however, with the sound carrier low, the same problem as mentioned with FML will occur. The high frequency video components cross over the audio spectrum and create buzz in the audio. This type of interface is also likely to reduce stereo separation. Not only is the 4.5 MHz trap too narrow, but the 4.5 MHz bandpass filter is often not wide enough. The final IF audio spectrum which is a result of the video and audio paths would by no means be flat in frequency or group delay response.

When faced with interfacing with a modulator that does not have either a 4.5 MHz or a 41.25 MHz Input, it is best to either: 1) modify the unit according to the manufacturer's procedure by adding a 4.5 MHz or 41.25 MHz input, or; 2) replace the modulator with another unit which has separate inputs.

The distribution system, being broadband and linear has very little effect on BTSC audible performance. System noise is well masked in BTSC by the dbx noise reduction system. Customers will complain about noisy pictures long before the signal degrades because of the system introduced noise (hiss) in the stereo audio. Stereo separation is essentially unaffected by the cable distribution system.

On the individual subscribers side, RF converters are generally transparent to BTSC stereo. First generation baseband decoders generally do not pass stereo through because of the de-emphasis and low pass filtering used. Second generation baseband converters, however, have been designed for wide audio bandwidth, thus allowing stereo pass-through. Volume control, which is a very popular feature on baseband converters, is accomplished by changing audio deviation which changes stereo separation. Whenever the volume control is operated in the vicinity (± 6 dB) of the unity gain point (where deviation in equals deviation out) relatively good stereo separation can be achieved. Thus, reasonable although less than ideal, stereo performance can still be achieved when using the volume control feature of a baseband converter. A point worth noting here is that recognizable directionality is maintained to as low as 6 dB separation, which means that many subscribers will continue to use the volume control feature of their baseband converter with their new stereo TV receivers and be pleased with the performance.

With regard to stereo separation, a general rule of thumb for acceptable performance would follow the following scheme. The stereo encoder manufacturers should aim for 40 dB of separation across the full bandwidth (50Hz to 14 KHz), operators should delivery 30 dB in practice and TV manufacturers (as well as stand-alone decoder manufacturers) should deliver product with 20dB or better separation. Following these guidelines will yield separation that is perceived to be perfect as far as audio detectability in the typical home viewing/ listening environment is concerned.

Separation is only a small fraction of what determines the quality of the delivered sound. Stereo TV's and VCR's generally have not set any milestones in audio quality. However, in comparison with the audio system of a typical monaural TV, they can be quite impressive. Since there have been indications that quality audio helps sell high end sets it can be expected that more emphasis will be placed on audio reproduction in the future. We have already seen the introduction of a unique Bose audio system for TV's and there will be several sets produced with Dolby™ surround sound decoders built-in later this year. The dual detector receiving system developed by General Instrument will become available for licensing later this year, thus allowing TV receiver manufacturers to substantially reduce buzz levels.

WHAT EXACTLY AM I DELIVERING?

After purchasing and installing BTSC encoding equipment, the first question that comes to mind is how good is the equipment I have just installed and how well is it functioning in my particular application. Figures 1 and 2 illustrate the test equipment required and its interconnection for making pertinent BTSC measurements. BTSC set-up is an exercise in analog precision and as such, the test equipment to authoritatively make numerical measurements is fairly expensive. As shown, the price is in excess of $100000. The equipment listed is not meant to be an exclusive list, rather it is just one example of equipment which has proven to be effecitve.

The first test most often desired is stereo separation. In order to perform testing to 40 dB accuracy, the baseband input level to a reference decoder must be set within a few tenths of a percent. This requires calibration at the start of each testing session. The only method of deviation adjustment offering this level of precision is with a sine wave, monitored by a frequency counter and a bessel null greater than 60 dB observed on an RF spectrum analyzer. The measuring set-up must be calibrated before testing can begin. The best technique is to apply a very slowly swept (20 to 50 sec.) audio tone to one channel of the stereo encoder and measuring the output on that channel from the stereo decoder. Use the desired channel output as a reference and then measure the output of the undesired (not driven) channel. It is very important to sweep the audio at a low enough level so that as pre-emphasis occurs, overmodulation will not. Specifically, this requires a sweep at about 20 dB below the full scale point for a low frequency signal such as 300 Hz.

Frequency response is another test which is a useful measure of the level of performance of a stereo encoder. Generally, lower priced encoders will not provide the full 15 KHz bandwith specified for BTSC. In order to test the performance of only the encoder and not the combination of the encoder/decoder, it is best to switch the encoder into mono operation, disable the pre-emphasis, and connect the encoder baseband output directly to the measuring device (i.e. the network analyzer). The displayed sweep will indicate the response of all filtering in the L plus R path which must be identical to that in the L minus R path in order to achieve stereo separation. Full 15 KHz bandwidth is desireable in order to keep as much detail of the original sound source as possible. Although most stereo TV receivers today do not reproduce 15 KHz, it is reasonable to assume that high end products will do so in the very near future.

Total harmonic distortion (THD) is a measure of the maximum received signal level versus the level of all signals present in the audio band except the fundamental. With professional equipment and extreme care in eliminating ground loops, it is possible to get meaningful readings of harmonic distortion with a distortion analyzer, expecially with separate sound detection or video removed. Usually, THD is measured to check for non-linearity. If the measurement is affected by spurious signals, an audio spectrum analyzer will be easier to use for reading THD. This is generally the case with BTSC. Note that THD will vary with frequency and may become non-harmonic, especially at high frequencies, due to intermodulation effects of the L - R pilot and L and R signal components.

Dynamic range is the measure of the ratio of the largest signal received (i.e. full modulation) to what is left over when no signal is transmitted. In the BTSC system, dynamic range is not a single number, but rather a curve which varies wth frequency. Signal-to-noise ratio is another measurement which is often confused with dynamic range. In a companded system such as BTSC, signal-to-noise is measured by applying a signal and viewing the noise present with the signal on an audio spectrum analyzer. Then, you must calculate the difference between signal and noise based on resolution bandwidth and correction factors.

Subjectively, dynamic range indicates how quiet the noise and interference will be in between audio passages. Signal-to-noise ratio indicates how clean, or pure, the audio will sound. Due to video interference, this is the weak link in BTSC stereo. Dynamic range and S/N are the areas where the cable operator, not the stereo encoder manufacturer, has control and his or her actions can have the greatest positive or negative effect.

TABLE I: RECENT TEST DATA
with TEST CONFIGURATIONS OF FIG. 1 & 2

CHARACTERISTIC	MEASUREMENTS	
FREQUENCY RESPONSE	15 KHz	-1.5 dB
	15.734 KHz	-73 dB
DYNAMIC RANGE ● 1 KHz	BASEBAND	>85 dB
	RF	78 dB
THD ● 1 KHz	BASEBAND	0.03 %
	RF	0.15 %
STEREO SEPARATION	50 to 14 KHz	RF MEASURED
	-WORST POINT	35 dB
	-BEST POINT	70 dB

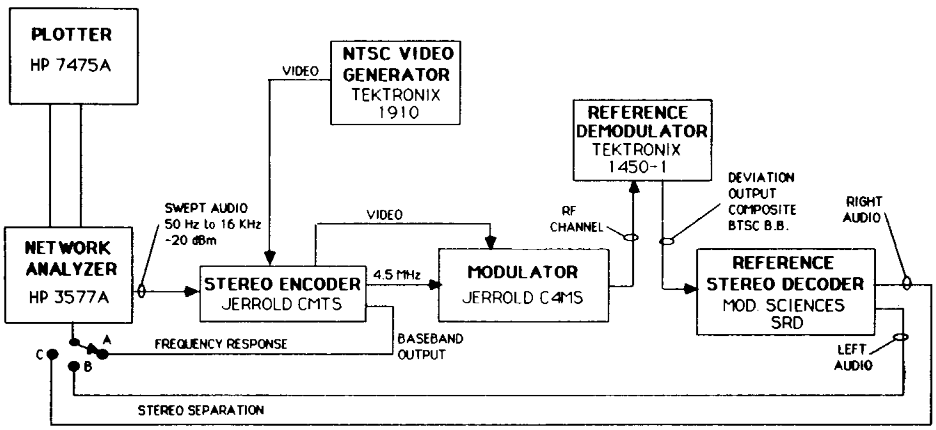

FIGURE 1: AUDIO PERFORMANCE TEST CONFIGURATION
-SEPARATION & FREQUENCY RESPONSE

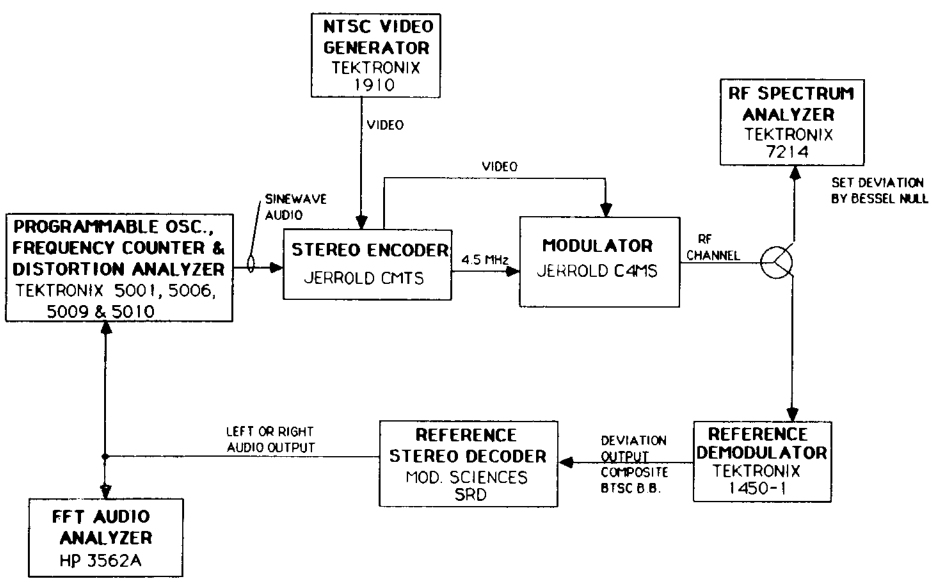

FIGURE 2: AUDIO PERFORMANCE TEST CONFIGURATION
-DEVIATION, DYNAMIC RANGE, THD & S/N

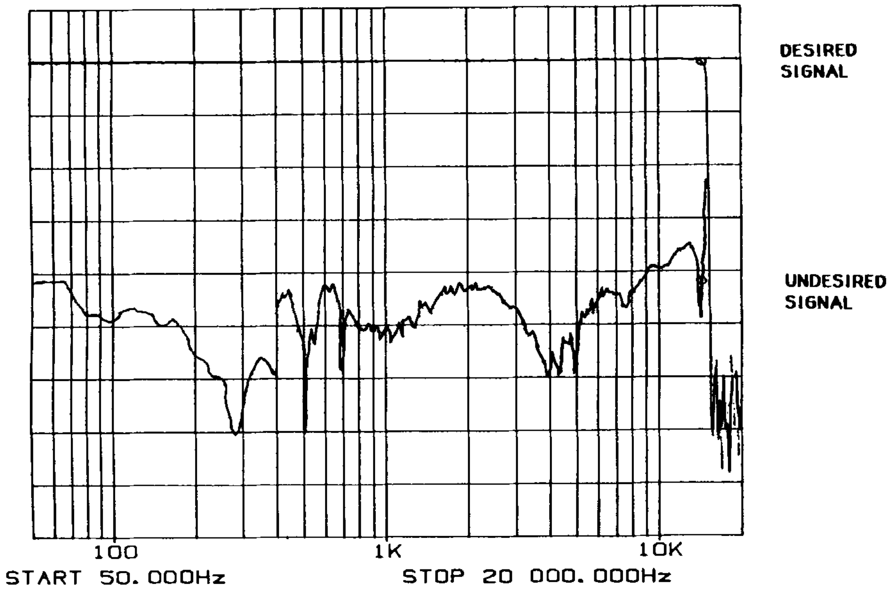

FIGURE 3: RESULTANT STEREO SEPARATION VERSUS FREQUENCY
with TEST CONFIGURATION SHOWN IN FIGURE 1.

Obviously, the test set-ups described in Figures 1 and 2 are not practical for normal on-site testing since this kind of equipment does not usually exist at the typical system headend. What follows is a step-by-step procedure for installing and testing BTSC encoders to insure optimum performance on-site, concentrating on the area where the cable engineer is in control - the elimination of unnecessary video interference. The primary measuring instrument here is a pair of human ears. Getting in the practice of using them correctly is the first step in providing quality stereo TV.

HOW TO PREP A CHANNEL AND INSTALL A STEREO ENCODER

The following is a minimum list of test equipment required for this procedure:

1. RF Spectrum Analyzer
2. Dual Trace Oscilloscope
3. Stereo Amplifier
4. Stereo Headphones
5. Television Stereo Receiver (BTSC)

Step 1 - RF Interference Check

Connect the RF spectrum analyzer to a system test point. Tune to the channel under test. Switch the modulator power off. Check for interference within the channel limits. Any signals present should be no greater than 65 dB below the video carrier level. If interference is found to be present, locate the source and eliminate the problem before proceeding.

Step 2 - Video Interference Check

Disconnect the audio input to the modulator. Switch the modulator power on. Measure the video depth of modulation. Do not trust panel meters or indicator lights. Be certain that maximum white level, such as during VITS signals, does not exceed 87.5% modulation (18 dB on a log scale or 7 out of 8 divisions on a linear scale). If overmodulation exists at any time during the video fields (including VITS) reduce the modulation. It is better to be slightly under rather than slightly overmodulated. Overmodulation will cause buzz in stereo TV receivers.

Tune the spectrum analyzer to the desired channel sound carrier. Observe the area on both sides of the sound carrier. There should be no video modulation sidebands at a level higher than 60 dB below peak video carrier level within +/-150 KHz of the sound carrier. If video sidebands are present in the sound carrier area greater than -60 db, a video low pass filter should be installed in the video path before the modulator. To prevent picture quality degradation the low pass filter should be delay equalized within 50 nanoseconds to 4.08 MHz.

Step 3 - ICPM Check

Connect the television stereo receiver audio outputs to the stereo amplifier. Connect the TV stereo receiver to the system test point. Note: Do not overload the TV receiver, +10 dBmV is a recommended level. It may be desirable to use an RF converter in front of the TV receiver in order to tune all channels or eliminate cross-mod problems. Tune to the channel under test. With video present, but no audio, listen on the headphones for buzz, increasing the amplifier volume until buzz becomes clearly audible. Remove the headphones. Reconnect the audio source to the modulator and verify that proper deviation occurs. Carefully start to replace the headphones. If the audio is too loud to listen to, then the video modulator ICPM is acceptable. If the audio is not too loud, then this indicates excessive ICPM and adjustment is necessary to remove audible buzz during quiet passages. To adjust for minimum ICPM; remove the audio input. Listen to the buzz at high volume level. Adjust the trim capacitor(s) on the diode chopper modulator starting from minimum capacitance and increasing slowly until minimum buzz level is heard. Fortunately, best video performance occurs at the same point as minimum ICPM buzz. If you are not comfortable making this adjustment, arrange for servicing by a qualified service center. Be sure to indicate that minimum ICPM (<2 degrees) is required.

Step 4 - Left and Right Audio Source Check

Connect the L and R audio outputs of the satellite subcarrier receiver or decryptor to the auxilliary inputs of the stereo amplifier. Listen to the sound quality on the headphones. The audio should be free of hiss, hum, buzz, pops, clicks, or obvious distortion. Move the balance control all the way to each side and listen to each channel carefully. If audio problems exist, troubleshoot and correct the problem before proceeding.

Connect the left channel subcarrier receiver output to both channels of the dual trace oscilloscope, Adjust the gain and position controls so that the identical waveform is observed on both channels. Connect one scope channel to the right audio output. If level adjustments are available, adjust the outputs for about 2 Vpp on audio peaks. Check that both channels are of the same polarity, that is rising and falling together most of the time on the low frequency portions of the audio. The polarity of both channels must be the same for proper stereo operation.

Step 5 - Connecting Audio to the Stereo Encoder

Connect the L and R audio from the subcarrier receiver or decryptor to the left and right inputs of the stereo encoder. Balanced connections are desirable and should be used where available. Correct polarity must be maintained. After making connection according to the encoder installation manual, verify polarity with the oscilloscope as in Step 4. Adjust the input level controls for proper bar graph indications. Switch the stereo encoder to mono operation. Connect the stereo encoder composite audio baseband output to one of the auxiliary inputs of the stereo amplifier. Switch the subcarrier receiver power off. Increase the volume of the amplifier and listen on the headphones for hum indicating ground loop problems. If excessive hum is present, experiment with connecting and disconnecting the audio cable ground at the stereo encoder, while listening for minimum hum. If possible, power the amplifier, subcarrier receiver, stereo encoder, and modulator from the same power strip. After minimizing the hum, reduce the stereo amplifier volume and switch the subcarrier receiver power back on. Listen to the L and R (mono portion) of the stereo encoder output. It should not be distorted or have hum, buzz, or hiss.

Step 6 - Modulator - Encoder Interface

Connect the 4.5 MHz or 41.25 MHz from the stereo encoder to the modulator as indicated in the encoder installation manual for your desired configuration. Set the sound carrier level by observing at the system test point with the RF spectrum analyzer. For stereo performance, the higher the sound carrier the better within FCC limits. For example, -13 dB from video carrier is preferable to -17 dB.

Step 7 - Performance Verification

Connect the TV stereo receiver to the stereo amp and to the system test point. Tune to the desired channel. Listen to the program audio. It should be free of hum, buzz, hiss or distortion. Now remove the left channel audio input to the stereo encoder. Listen to the headphones. The sound should be entirely on the right channel. Connect the oscilloscope probes to the left and right TV stereo receiver outputs. Measure the relative amplitude of the peak to peak signal present on the two channels. If you are using a consumer grade receiver, the level should be about ten times larger on the desired channel than the undesired. A commercial grade receiver should indicate thrity times larger or more. Reconnect the left input. Your are now ready for stereo operation.