COMPATIBILITY BETWEEN BASEBAND CONVERTERS AND MTS STEREO

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The MTS stereo signal can pass through a baseband converter for input to a stereo television. The composite MTS signal is also available for an internal or external decoder.

MTS uses signal matrixing for compatibility. Left and right channels are summed (L+R) for transmission in the normal 20Hz to 15kHz range. The stereo difference information (L-R) is transmitted on a subcarrier at 31.5 kHz.

The (L-R) signal is dBx companded to reduce noise. There is no companding of the (L+R) signal. As a consequence, stereo separation is optimized only at unity processing gain. There is a fairly wide volume control range over which acceptable separation is maintained, because separation as low as 10 dB yields subjectively pleasing stereo imaging.

Introduction

The advent of Multichannel Television Sound (MTS) has raised many questions for cable operators and equipment manufacturers. One of these questions is whether the MTS format signal will pass through a baseband converter for decoding in a stereo television.

To understand the implications of MTS in the baseband converter, an understanding of three things is necessary:

1. The components of the MTS signal, and the bandwidth required at baseband to pass them

2. The matrix techniques that are used to maintain compatibility with monaural televisions

3. The implications of the use of companding on only one component of the MTS signal

With an understanding of these three items, it becomes apparent that the MTS signal can be passed, but that the use of the volume control in the baseband converter has an effect on stereo separation.

Components of the MTS Signal

The MTS signal is composed of several components, which can best be understood by examining the composite frequency spectrum shown in figure 1.

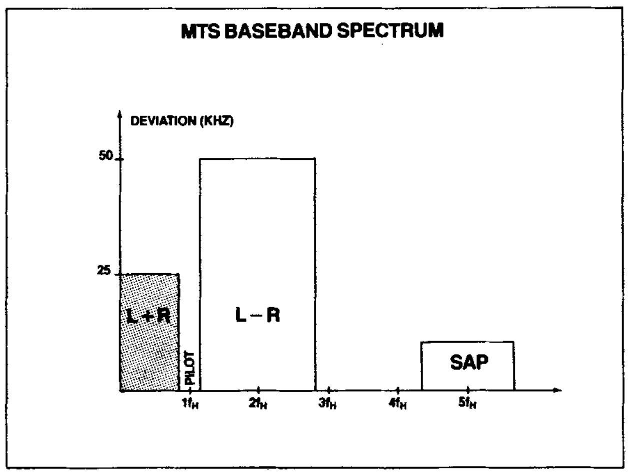


FIGURE 1

The left and right channel source signals are processed in the signal matrixing circuit. Left and right are summed, yielding the (L+R) signal which occupies the 20 Hz to 15 kHz region. This is the frequency range used by monaural television, which receives the proper mix of left and right audio due to the summing.

Immediately above the (L+R) signal, at 15734 Hz (the horizontal line rate, or 1H) is a non-modulated signal called the pilot. This pilot is used in the MTS decoder to generate a signal at 2H.

The right source signal is subtracted from the left source signal (in the matrix circuit of the encoder) yielding a (L-R) signal. This signal occupies the spectrum from 1H to 3H, as a double sideband AM signal on a subcarrier at 2H. Note that the lowest frequency components of the source signal are closest to the 2H subcarrier.

The Secondary Audio Program (SAP) occupies the spectrum between 4H and 6H, centered around a subcarrier at 5H.

The composite signal, including (L+R), (L-R), and SAP (but not including the professional channels) extends from 20 Hz to 88.7 kHz. Any signal path or circuitry used to pass this composite signal must therefore have good amplitude and phase response to at least 90 kHz.

Signal Matrixing for Compatibility

Given a baseband spectrum of 45 kHz, two channels of audio could be transmitted in several ways. One might be to transmit the left channel in the 20 Hz to 1H region, while transmitting the right channel as a modulated subcarrier at 2H (occupying the 1H to 3H region). The disadvantage of this approach would be that monaural televisions would only receive the audio signal below 1H, and would therefore present only the left channel to the listener.

To achieve full compatibility with monaural televisions, the MTS signal uses matrixing. The input signals to the matrix circuit are left and right audio. The sum of these inputs generates one output, called "left plus right" or (L+R). The difference between these inputs generates the other output, called "left minus right" or (L-R). The (L+R) signal contains the information from both channels, providing compatibility with monaural televisions.

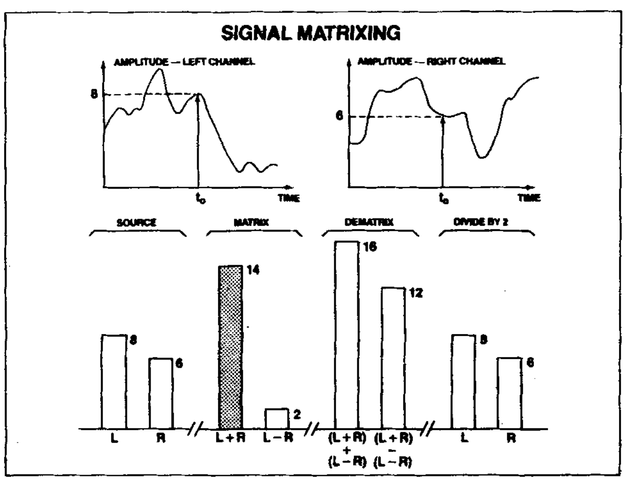


FIGURE 2

An example of matrix signals is shown in figure 2. At time T0, the instantaneous amplitude of the left channel is 8 units. At the same instant in time, the amplitude of the right channel is 6 units. These signal levels are represented graphically under "source". After matrixing, as shown under "matrix", the (L+R) signal is 8+6, or 14 units. The (L-R) signal is of course 2 units. In the dematrix process, the (L+R) signal and the (L-R) signal are both added and subtracted, as shown under "dematrix". The sum signal becomes (L+R)+(L-R), which in this example is 14+2, or 16. The difference signal becomes (L+R)-(L-R), which is 14-2, or 12.

Note that (L+R)+(L-R) equals 2*L+R-R, or simply 2*L. Also note that (L+R)-(L-R) equals L-L+2*R, or 2*R. All that remains to reconstruct the input signals (left, L and right, R) is to divide each output of the dematrix circuit by two.

Signal Companding for Noise Reduction

One common technique for improving the quality of a signal passing through a noisy channel is companding, which is a contraction of "compress" and "expand". The upper left waveform in figure 3 shows a signal without noise as might be input to a transmission channel. The waveform in the top right shows this same waveform after transmission in a noisy channel. Notice that the lowest amplitude portions of the signal fall below the noise "floor", and are masked by the channel noise.

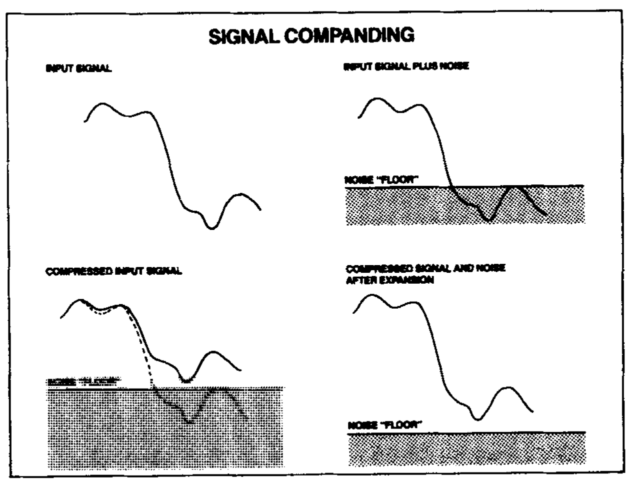


FIGURE 3

The lower left waveform of figure 3 shows the input waveform after compression. The lowest amplitude signals are boosted while the highest amplitude signals are left alone, with a smooth continuum in between. This compression has the beneficial effect of raising the lowest amplitude above the noise floor of the transmission channel.

Unfortunately, it also distorts the original signal, by limiting the dynamic range, or difference between loudest and softest portions of the input source material.

This distortion is corrected, however, in the expansion process, as shown in the lower right of figure 3. The real benefit of the expansion is that the noise floor is pushed lower, beneath the lowest amplitude (softest) portions of the desired signal.

Companding the MTS Signal

Initial tests of the MTS system were done without any companding. It was quickly discovered that several sources of noise degraded the (L-R) channel, such as AM to PM (amplitude modulation to phase modulation) conversion in modulators, transmitters, or television receivers. Because the video signal has strong components at the line rate and harmonics of the line rate, and because this video signal amplitude modulates the picture carrier, any AM to PM conversion in the transmit path will cause phase modulation of the picture carrier at 2H. Essentially all televisions use intercarrier detection of the audio carrier, mixing the picture and sound carriers to generate a 4.5 MHz signal for FM detection. Therefore, any phase modulation of the picture carrier is equivalent to phase modulation of the sound carrier. Thus the incidental, undesired phase modulation produces considerable noise in the audio baseband at all harmonics of the line rate. Recall that the (L-R) information is carried in the composite spectrum around 2H, or exactly centered on the noise from the second harmonic of the line rate. Also recall that the lowest frequency components of the (L-R) signal lie closest to the 2H subcarrier.

The net effect of the MTS spectrum design and the noise generated at 2H was that some form of noise reduction was deemed mandatory. Compatibility issues ruled out the use of any noise reduction on the (L+R) channel, so the dBx noise reduction system was chosen to process only the (L-R) channel.

Impact of Companding Only L-R

Any deviation from unity gain in the path from MTS encoder to decoder causes a reduction in stereo separation. Since the baseband converter can cause a processing gain above or below unity as the volume control setting is changed, it is important to understand the reason for the reduction in separation and its magnitude.

Figure 4 shows a graphical representation

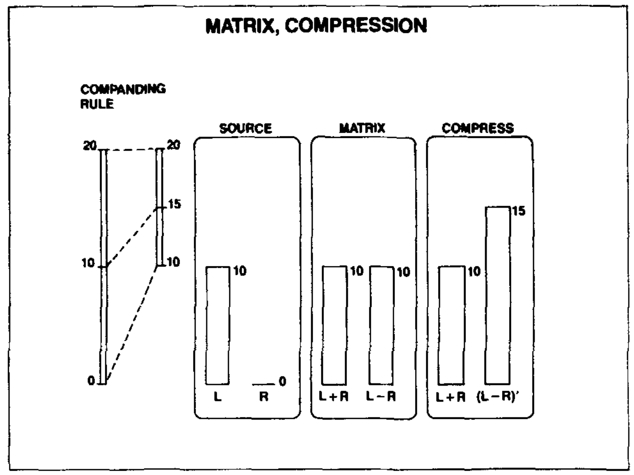


FIGURE 4

of the encoding process. For ease of explanation and understanding of the concept, linear compression of the signal is shown. In fact, logarithmic companding is used in the MTS system.

First examine the "companding rule". Note that in this example an input signal of 10 units is compressed to 15; zero becomes ten; twenty remains twenty. Assume that the source signals are 10 units (left) and 0 (right) - that is, maximum stereo separation. The signals after matrixing are then both 10 units: 10+0=10 (L+R), and 10-0=10 (L-R). Compression then takes place, but only on the (L-R) signal. The L+R signal remains at 10 units, while the compressed (L-R) becomes, in accordance with the companding rule, 15 units. The output of the encoder, then, is 10 and 15 units of (L+R) and (L-R), respectively.

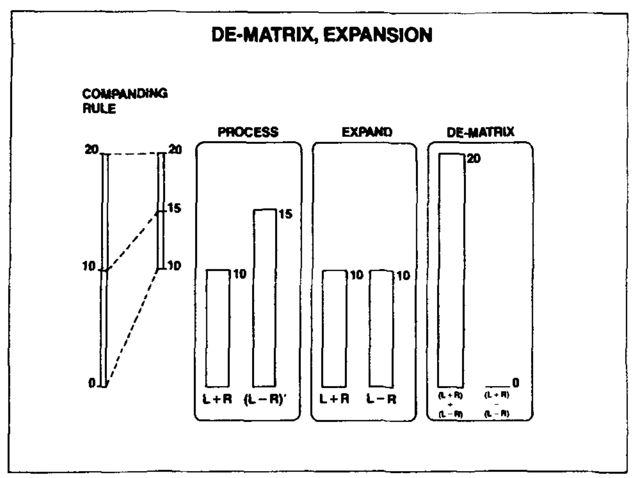


FIGURE 5

Figure 5 shows the decoding of this signal with unity processing gain. In the "process" graph, note that the signal after processing is identical to the encoded signal from figure 4. This processed signal is then expanded, yielding (L+R) and (L-R) both equal to 10 units. On dematrixing, the (L+R)+(L-R) signal (which is twice L) is 20 units. The (L+R)-(L-R) signal (which is twice R) is zero. Perfect separation of the signals has been maintained.

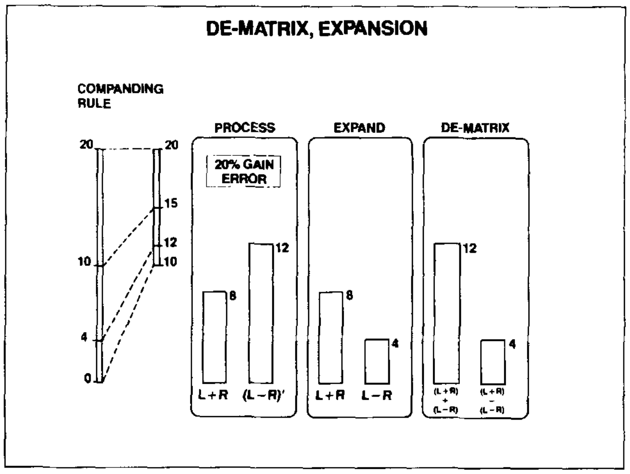


FIGURE 6

Figure 6 shows the effect of non-unity processing gain. In this case a 20% error is introduced in the signal path, so the output levels of the encoder (figure 4) are reduced to 8 units (L+R) and 12 units (L-R). On expansion by the companding rule, the (L+R) signal stays at 8 while the (L-R) signal becomes 4 units. The dematrix circuitry then generates (L+R)+(L-R) of 12 units, and (L+R)-(L-R) of 4 units. The outputs of the dematrix circuit would then be divided by two, yielding 6 units left and 2 units right. Not only is the left channel amplitude incorrect (it started at 10 units), the right channel now has a 2 unit signal (it started at 0 units). This crosstalk from left to right channels is reduction in stereo separation.

Separation Versus Processing Gain

The graph in figure 7 shows, using logarithmic scales, the theoretical separation as processing gain deviates from unity. The separation approaches infinity at exactly unity gain, and falls off to 10 dB at plus or minus 6 dB from unity. The range between these 10 dB points of separation is the usable volume control range of the baseband converter.

Subjective Importance of Separation

To determine the subjective importance of stereo separation, a test was devised where a listener could be presented music with different amounts of separation. Because of the subjective nature of the test, the

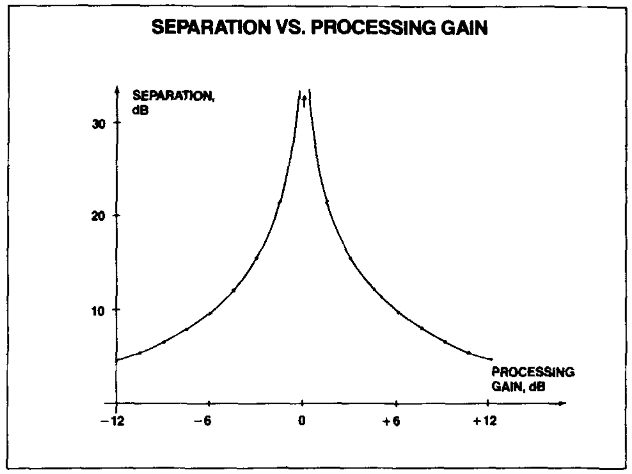
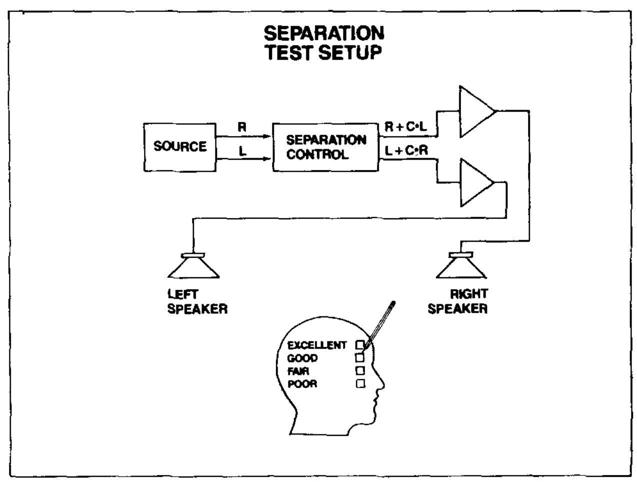


FIGURE 7

subject was simply asked to rate the music as excellent, good, fair or poor. Each participant was initially presented a passsage with no reduction of separation, and was told this. Likewise he was then presented the same passage in monaural and told this. This "best/worst" calibration was repeated, if asked for, anytime during the test.

The same passage of music was then presented at random separation levels, and the subject was asked to rate the acceptability of the stereo image and spaciousness.



Though the results of the test show considerable scatter, as might be expected from such a subjective test, the majority of data points indicate that acceptable separation is perceived at roughly the 10 dB level.

MTS Decoder for Baseband Converter

The baseband converter includes an audio demodulator as well as a video demodulator. This allows the baseband converter to control the volume of the audio signal. An added benefit of this audio demodulator is the availability within the converter of the composite MTS baseband audio signal. This composite signal can be inexpensively decoded in an internal or external MTS decoder circuit. Since a DC signal for electronic volume control is also available in the converter, it can be used to control the volume of the left and right channels in the decoder. Full remote control of volume and mute are thus maintained.

Such a decoder should be welcomed by the consumer who doesn't want to purchase a stereo television, and should generate customer satisfaction and revenue for the cable operator who makes such a decoder available.

Conclusion

Stereo television in the MTS format is an exciting enhancement to the realism of the medium. As more programming is available and the installed base of stereo television increases, the popularity will increase greatly.

The differences between normal television audio and the more complex MTS signal demanded redesign of some sections of the baseband converter, primarily to increase the audio baseband frequency response from 15 kHz to over 90 kHz.

The baseband converter can now pass the MTS signal to stereo television, and can even maintain acceptable volume control and mute capabilities. It can also provide at low cost the composite MTS baseband signal to an internal or external stereo decoder, making stereo television sound available even to those without a stereo television.