MTS COMPATIBILITY IN ENCRYPTED BASEBAND SCRAMBLING SYSTEMS

JAMES R. HOLZGRAFE
Senior Staff Scientist

ARTHUR E. VIGIL
Staff Scientist

Oak Communications Inc.

INTRODUCTION

The advent of the MTS stereo standard has created new revenue opportunities for the MSO. MSO's may now offer premium programming with the added attraction of high-quality stereo sound. The problem of how to insure the security of the signal assumes new importance, however, and in some ways the problem is more difficult than it may appear.

Digitally encrypted audio provides the ultimate in signal security, and modern digital technology coupled with careful system design can provide two high-quality channels, utilization of which opens the possibility of a highly secure stereo signal for premium programming.

This paper will discuss the issues involved in the adaptation of a digitally encrypted baseband audio system to meet these needs, and will further discuss the technical requirements, using Oak's "SIGMA" line of converters as an example.

Realistically, it is imperative that the ultimate interface to the subscriber is in the MTS format, such that his stereo TV set can properly process and deliver the two channels of information. This format creates a signal whose bandwidth extends to at least 46 KHz, and whose amplitude and phase characteristics throughout that band are critical to proper performance.

The easiest solution would seem to be simply to directly encrypt the MTS signal, deliver it to the decoder, decrypt it, and send it on to the TV. Unfortunately, the wide bandwidth and severe phase accuracy requirements of the format make this extremely difficult and consequently quite expensive to do properly.

Moreover, the MSO is faced with the problem of non-MTS-formatted source material, such as direct left/right channel feeds from laser disc players, VCR's, and satellite receivers.

The details of the MTS requirements are easier to describe than to deal with (reference Figure 1): As with conventional FM Broadcast Stereo, the left and right channel audio signals are first combined to form two new channels, the "sum" channel (Left plus Right) and the "stereo difference" channel (Left minus Right). The sum channel is the normal monaural signal, and needs no special handling. The stereo difference channel, on the other hand, requires very special handling indeed. It is first processed through a complex and elegant compression system, then modulated to form a double-sideband suppressed carrier (DSSC) subcarrier and added to the monaural sum channel. Finally, to assist in demodulation of the difference subcarrier, a pilot tone is added to the sum/difference ensemble. The MTS baseband signal spectrum is shown in Figure 2.

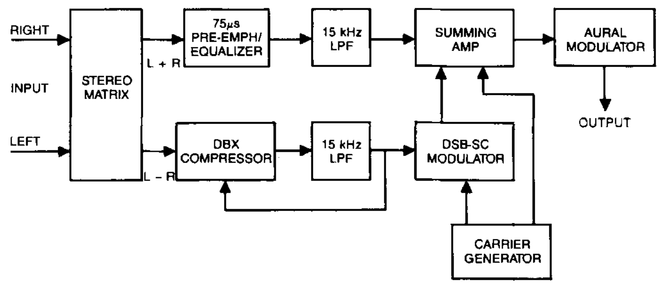

FIGURE 1. BASIC MTS ENCODER

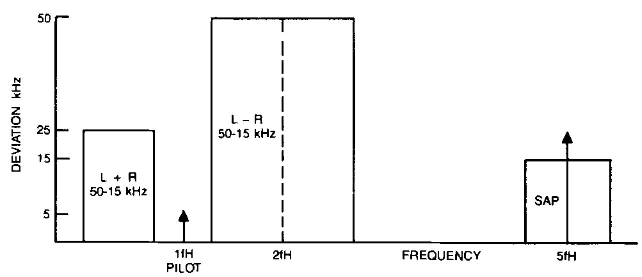

FIGURE 2. MTS BASEBAND SPECTRUM

In the receiver (reference Figure 3), the demodulated stereo difference subcarrier is expanded, dematrixed back to simple Left and Right channels, and finally amplified to drive the speakers.

In order to maintain stereo separation of 20dB or better, the amplitude and phase of the compressed stereo difference signal must match and track those of the uncompressed monaural sum signal to within +/-1 dB and +/-6 degrees. In addition, to insure accurate demodulation of the DSSC difference subcarrier (so as to enable the gain accuracy mentioned above), the pilot tone phase must be maintained within +/-3 degrees of that of the (suppressed) subcarrier.

Finally, if it is not to seriously impact the system equipment investment budget, all of the above must be achieved within severe cost constraints.

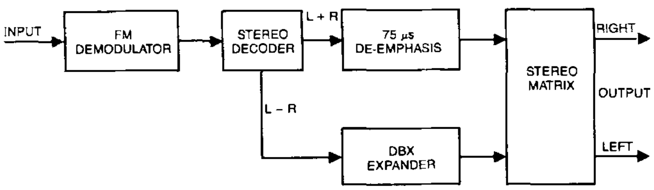

FIGURE 3. BASIC MTS RECEIVER

SYSTEM CONSIDERATIONS

The final system must meet two major requirements: it must be MSO-friendly, providing the requisite signal security and still permitting a maximum of installation flexibility; and it must be subscriber-friendly, offering convenient installation and operation.

Meeting the MSO's needs is straightforward, if not easy. The system must be easy to install, require a minimum of adjustment and provide a maximum of stability, permit a random mix of stereo TV's and hifi-only systems, and be fully compatible with the existing services. On the other hand, while the system should not be unduly expensive, it still must provide the MSO with the signal security he needs to protect his premium programming.

Dealing with the subscriber's problem is more complicated. The average home TV/VCR/Cable adapter complex is already far too cluttered and cumbersome, both physically, electrically, and operationally. Adding a stereo "sidecar" or "hotplate" would make an already clumsy situation totally unworkable. The complications of audio signal paths, control priorities, quantities of audio input/output ports, switching networks, etc., presage significant confusion and consequent dissatisfaction on the part of the subscriber.

The ideal is a system in which the installer has only to unbox and connect the cable decoder appropriate to the subscriber's TV (and add, if necessary, an audio cable from the decoder to the subscriber's hi-fi system), after which the MSO merely authorizes the services for which the subscriber has paid.

APPROACH
(Reference Figures 4 and 5)

Given that the MTS format itself occupies too much bandwidth to permit direct digitization and encryption, some ingenuity must be employed. The basic approach used here is to transmit encrypted, digital stereo, and, in the converter, convert the decrypted stereo into MTS format for remodulation and output to the stereo TV.

There are two fundamental difficulties that must be overcome. The first of these is economic: conversion or encoding into MTS requires DBX compression of the stereo difference signal, in a process that requires extreme precision and stability, and consequently is relatively expensive. The second is also essentially economic, but more subtle than it might appear: The pilot tone and the stereo difference subcarrier must be phase-locked

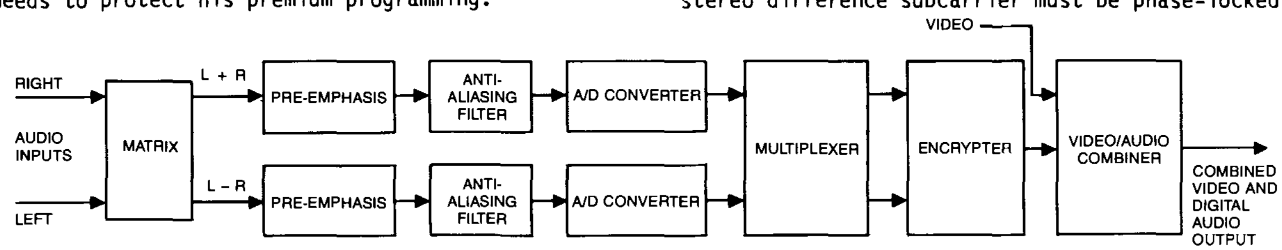

FIGURE 4. ENCODER BEFORE UPGRADE

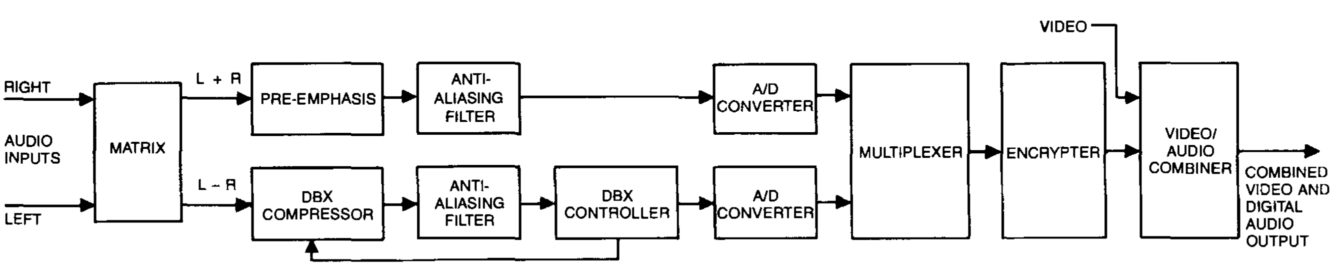

FIGURE 5. ENCODER UPGRADED FOR MTS COMPATIBILITY

to the horizontal scan rate, and to each other within +/-3 degrees; in addition, the pilot tone, at least, must be a relatively clean sine wave.

In the interests of preserving maximum stereo separation, given that the accuracy of the home stereo TV is unknown, it behooves us to make the cable portion of the stereo system as accurate as possible. Unfortunately, this aggravates the economics even further.

Ironically, with a digitally-encoded audio transmission system, and unlike the ordinary stereo-difference subcarrier approach, there is no noise penalty to the second channel. This means that the DBX compression is required simply to match the MTS format of non-encrypted stereo channels.

The answer is to do the DBX compression in the headend (reference Figure 5). There, it only needs to be done once, rather than loading the cost of each decoder; moreover, in the context of headend costs, the DBX compression is relatively inexpensive. The scheme, then, is to matrix the left and right channel audio inputs into sum and difference signals and DBX compress the difference signal; then the normal sum (monaural) and the compressed stereo difference signal are digitized, encrypted, and transmitted.

This approach yields a pair of signals which, while not yet completely in the MTS format, are nonetheless halfway there, and have, as yet, incurred no bandwidth penalties. Moreover, the most expensive portion of the MTS formatting has been accomplished with minimum cost impact to the system. After decryption, it only remains to modulate the compressed difference signal onto the subcarrier, add a suitably accurate and stable pilot tone, and sum the composite result onto the monaural sum signal.

THE DECODER
(Reference Figures 6 and 7)

The real challenge is in the decoder. Double sideband suppressed carrier modulation of the decrypted stereo difference signal is not at all difficult. Generating a clean, sinusoidal pilot tone that is accurate in amplitude and stable in phase with respect to the generated stereo difference subcarrier, however, can be expensive.

In principle, the problem appears simple: one merely phase-locks a pair of sine-wave oscillators, one at horizontal rate and the other at twice horizontal rate, to the incoming horizontal synchronizaton signal, such that the two sine waves have the proper phase relation to each other. The H-rate sine wave is then the pilot tone, and the 2H-rate sine wave is the carrier for the stereo difference signal. Unfortunately, this method is both complex and expensive. Voltage controlled sine-wave oscillator circuits with accurate, stable output amplitudes are not simple to make. Digitally synthesized sine waves are stable and accurate but require a great deal of circuitry to produce.

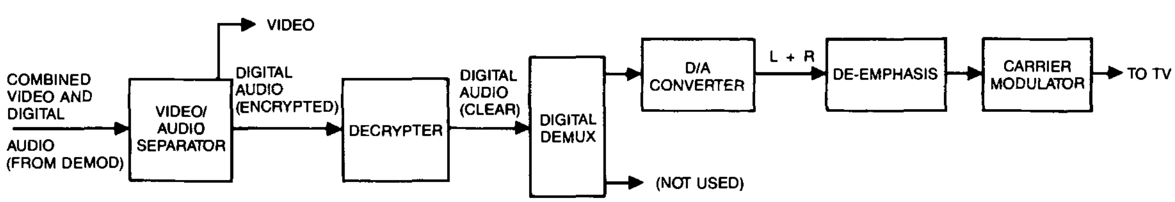

FIGURE 6. DECODER BEFORE UPGRADE. (SIGMA 1)

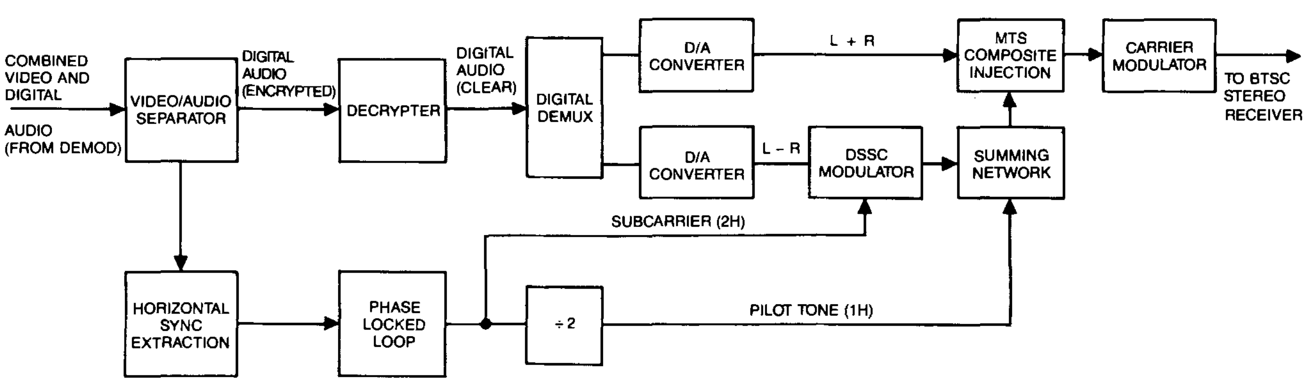

FIGURE 7. DECODER UPGRADED FOR MTS-COMPATIBLE ENCRYPTED STEREO. (SIGMA 3D)

One alternative is to generate the timing digitally and filter the resultant square waves into sinusoidal form. This also presents difficulties: the principle frequency component to be rejected is the third harmonic, which is only about 1.5 octaves above the fundamental. The filter required is large, complex, difficult to tune, and expensive to make stable; and since the desired sine wave is necessarily at the edge of the passband, the filter generates a great deal of phase shift and thus a great deal of phase uncertainty -- not an attractive proposition for a system with an allowable phase error of only 3 degrees.

The decision was made to utilize the advantages of digital timing to solve the sine-wave problem in an unusual way. An analog integrator, dating back to the days of analog computers, has the unique property of a fixed, stable, 90-degree phase shift, unaffected by component tolerances or drift. One integrator thus converts a digitally-generated square wave into an accurate triangle wave, with a fixed 90-degree phase shift. A second, identical integrator converts the triangle wave into a parabolic approximation of a sine wave, with an additional 90 degrees of phase shift. The result is a sinusoidal wave which is accurately and stably 180 degrees out of phase with the digitally generated input square wave -- that is, it is inverted.

The double mathematical integration can actually be accomplished even more simply. The smallest circuit realized to date consists of one transistor, three capacitors, and four resistors; it produces a sine wave in which the third harmonic is 30 dB below the fundamental, and whose phase shift with respect to the input is within specifications.

The double-sideband suppressed-carrier modulation of the stereo difference signal is done with a simple double balanced modulator, and the previously formed pilot tone is resistively summed into its output. The resultant composite signal is then injected into the normal (monaural) audio path at a point where its presence or absence won't otherwise affect the monaural signal, and the entire stereo difference/pilot circuit is simply switched on or off to accomodate the mode of the input program.

The decoder's remodulator thus supplies a normal Channel 3/Channel 4 MTS stereo signal to the subscriber's stereo TV, regardless of the type of input channel -- standard or encrypted premium.

SYSTEM FLEXIBILITY CONSIDERATIONS

Temporarily at least, provision must be made for subscribers who do not yet own a stereo TV, yet still who want to receive premium stereo programming. Moreover, it must be done in a way which maintains the security of the premium programming, without complicating the subscriber's life.

The subscriber without a stereo TV must use his hi-fi system to hear stereo. Existing systems may offer stereo simulcasts in the FM band, but this is cumbersome for the subscriber and expensive for the MSO (redundant equipment). What is needed is a baseband audio Left and Right channel output from the decoder that the subscriber can feed directly into his hi-fi, without further fuss. Ironically, the problems are just the reverse of the system described above. A baseband stereo encryption system can deliver Left and Right audio signals directly, but for standard MTS channels, a stereo decoder must be provided. Fortunately, incorporation of consumer-grade MTS decoder circuitry into the cable decoder is not prohibitively expensive, and the system has the added advantage that the DBX expander required for MTS decoding may also be used to expand the DBX compressed stereo difference signal generated by the encryption system.

EIA MULTIPORT

The EIA has recently completed its "EIA Multiport" standard (IS-15), which provides a baseband interface between the TV receiver and the descrambler. This interface feeds demodulated, baseband scrambled video to the decoder's descrambling circuitry, and accepts the baseband, descrambled video output for reinsertion into the TV's circuitry. The process minimizes cost and reliability problems by avoiding the existing redundancy of RF circuitry: at present, all baseband descramblers must contain both a complete TV tuner and a complete TV remodulator -- circuitry which is already present and operating in the TV receiver itself.

The decoder supplied for Multiport-compatible TV's is as simple as those described above. The decrypted sum channel is simply de-emphasized; the decrypted difference channel must be DBX expanded. The recovered sum and difference signals are then dematrixed to form the desired Left and Right channels which are fed back to the TV. Access to the input of a stereo TV's own DBX expander would, of course, further simplify and cost-reduce the system; it is to be hoped that this can be included at a later date.

CONCLUSION

The system described here achieves total stereo/nonstereo TV compatibility, and requires only that the subscriber specify which type(s) of TV he will be using. Subscribers with stereo TV's use cable decoders to convert the decrypted stereo audio into MTS format, and thus supply a standard MTS Channel 3/4 RF output to the stereo TV; those with non-stereo sets use cable decoders containing an MTS decoder, and which feed the resultant Left and Right audio into their hi-fi systems.

ACKNOWLEDGMENT

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