AUSTRALIAN BROADCASTING CONTROL BOARD

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ENGINEERING SERVICES DIVISION

REPORT NO. 35

TITLE: Report on Kahn's Stereophonic System for Broadcasting in the MF Band

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PREFACE

This Report was prepared in response to an enquiry concerning the possible use at a medium frequency broadcast transmitter, of a stereophonic transmission adapter developed by Kahn Communications Inc. (U.S.A.), details of which were published in the IEEE Transactions on Broadcasting, Volume BC-17 Number 2, June, 1971, pp. 50-55.

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Report on Kahn's Stereophonic System for Broadcasting in the MF Band

1. Stereophonic Reception

Kahn's compatible single sideband modulators produce sidebands on one side only of the carrier by a process of amplitude and phase modulation. He has also developed a similar modulator which in combination with matrix and phase change networks, is claimed to produce compatible stereophonic signals of a type suitable for broadcasting in the MF band. Under this system two conventional MF receivers are all that is needed for stereophonic reception.

Equation 1 shows the fundamental relationship between carrier and sideband signals for separate audio sinewave signals L from the left hand side, and R from the right hand side.

$$E = C \sin \Omega t + R_1 \sin (\Omega+\omega)t + \frac{R_1^2}{4C} \sin (\Omega+2\omega)t + L_1 \sin (\Omega-\omega_1)t + \frac{L_1^2}{4C} \sin (\Omega-2\omega_1)t \qquad (1)$$

where $R = R_1 \cos \omega t$

$L = L_1 \cos \omega_1 t$

Tuning one side or the other of the carrier gives an undistorted carrier envelope of L or R signals in an ideal case.

When tuning a narrow band receiver (4 kHz IF bandwidth) for best reception of a CSSB signal, one can not tune too close to the skirt of the response without producing noticeable distortion, so the tuning position would probably be 1 kHz to 1.5 kHz off the central response position.

Consequently with any typical MF receiver, it may not be possible to gain sufficient L and R signal separation at mid to low frequencies without introducing noticeable distortion. A compromise must therefore be reached between distortion and mid to low frequency L and R signal separation. The stereophonic effect would likewise be compromised at these frequencies.

2. Compatibility

For any system of the type being discussed, central tuning of the receiver will produce an output narrower in bandwidth but which contains L and R signals. To simplify the situation assume a central sinewave sound source.

i.e. $\omega = \omega_1$

and $L = R$.

In an ideal case the detector input should be -

$$E = C \sin \Omega t + R_{,} \sin (\Omega + \omega)t + L_{,} \sin (\Omega - \omega)t \quad (2)$$

and this must dictate the phase relationship between the modulation of L and R channels in this system, but there are also a pair of sideband signals separated from the carrier by the baseband signal second harmonic frequency, similarly related in phase. The resulting signal is therefore amplitude modulated but not phase modulated, and the detector output will contain a second harmonic component.

For such reception, the maximum permitted sideband signal amplitude is half that of the carrier, which brings the second harmonic level to 12%, and for lower modulation indices the harmonic content decreases linearly, i.e. with 50% modulation the second harmonic content would be 6%. This is to be compared with the second harmonic envelope content for a single sideband plus carrier of 2 1% (full modulation), 12% (50% modulation).

3. The Kahn Stereophonic Adapter

Kahn endeavours to overcome the situation described above by combining the L and R signals to form sum and difference signals M and S which are passed through phase change metworks so that if M = S the ouput of the phase change network is such that M = S $\underline{/90^{\circ}}$

The difference signal S, phase modulates the carrier in the required non-linear manner for CSSB, whereas the sum signal M amplitude modulates this phase modulated signal.

Only an adapter incorporating one phase modulator, and one conventional AM transmitter are needed in this system, details of which are shown in Figure 1.

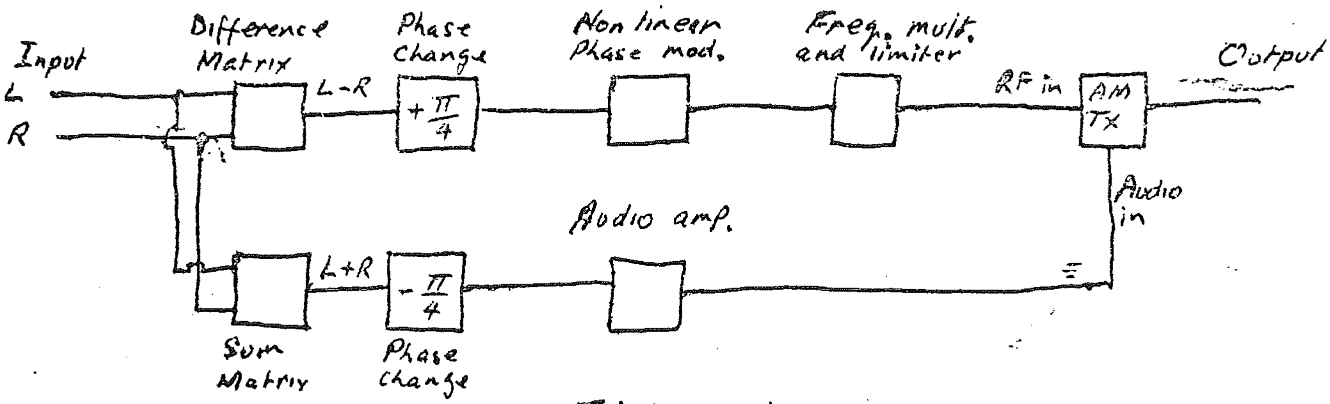

Figure 1

As the sense of phase modulation in relation to that of the amplitude modulation, determines whether upper or lower sideband components are produced, the output is in accordance with equation (1), except that when S=0 ie L=R there is no phase modulation and consequently a double sideband signal is produced. This is the situation for a central sound source - a common occurrence in stereophonic reproduction. Detuned receivers, one for the left channel and one for the right will detect from a carrier and one sideband which will not contain the second harmonic signal necessary to avoid harmonic distortion. Consequently the output of each receiver in this particular case will contain harmonic distortion appropriate to the envelope of a carrier and single sideband for up to 100% double sideband modulation i.e. 50% for a single sideband and carrier. If the receivers could be tuned for no unwanted sideband component, i.e. maximum channel separation, the maximum distortion in each channel would occur at maximum modulation and would be as follows, depending upon frequency, IF bandwidth, and audio section bandwidth -

Harmonic	2nd	3rd	4th
$\frac{\text{Harmonic amp}}{\text{Fundamental amp}} \times 100$	12	3	1

Tuning each receiver to a more central response reduces the harmonic distortion but increases linear crosstalk between the L and R channels, so that if the sound source moves to one side, sound localisation is impaired.

Test Transmissions

In order to confirm these theoretical predictions of system performance, the following tests should be conducted.

(a) With normal stereophonic programme into the adapter, tune and adjust two receivers for best stereophonic reproduction.
Replace the programme by a single test tone so that L = R and levels are at a maximum, i.e. 100% modulation DSBAM. Without retuning the receivers, measure the total harmonic distortion in each.

(b) Replace the single test tone by two tones not harmonically related, one to the left channel and one to the right channel, and without retuning the receivers measure the linear cross talk between the channels L and R.

(c) Repeat the above tests at appropriate frequencies up to 5 kHz.

Conclusion

It is difficult to envisage how any system of combined amplitude and phase modulation could be arranged to provide low harmonic distortion simultaneously on stereophonic and monophonic reception, using conventional MF receivers. A compromise between harmonic distortion on monophonic or stereophonic reception, the maximum modulation level, and linear cross talk between the stereophonic channels L and R appears to be inevitable.

In the Kahn system this compromise is between harmonic distortion on stereophonic reception with a central sound source, and linear cross talk between the stereophonic channels L and R when the sound source moves to one side.

The extent of this compromise has yet to be determined for various permitted maximum modulation levels.