THE DEPENDENCE OF AM STEREO PERFORMANCE ON TRANSMITTER LOAD PHASE

BY:

JERRY M. WESTBERG

RF DESIGN ENGINEER

WESTBERG CONSULTING

QUINCY, ILLINOIS

BROADCAST ELECTRONICS INC.

4100 N. 24TH ST., P.O. BOX 3606, QUINCY, IL 62305-3606 U.S.A., PHONE (217) 224-9600, TELEX 250142, FAX (217) 224-9607

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Jerry M. Westberg, RF Design Engineer
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ABSTRACT

It has been shown that in regard to stereo performance, AM transmitters perform well into a load which is 50 ohms over a 20 kHz span about the carrier frequency. When the load varies as a function of frequency, the transmitter performance is degraded. It was demonstrated that by orienting a non-ideal load with the use of a phase shifter (line stretcher) that the stereo performance would approach that of an ideal 50 ohm load.

This paper gives results of stereo performance done at 590 kHz where a non-ideal load was rotated by the use of a line stretcher.

INTRODUCTION

It is well known that the addition of a line stretcher located between the transmitter and the load can improve the monaural performance of the transmitter. The phase shift required out of this network, usually a tee network, is dependent on the transmitter used. That is, one transmitter will require a different phase shift than a transmitter of a different design. The ideal load is a function of the power amplifiers of the transmitter and the output network. In general, the load presented to the power amplifiers of the transmitter should be symmetrical at the sideband frequencies. For example the load presented to the power amplifiers at plus and minus 10 kHz should have the same resistive component and equal and opposite reactive components.

This has not been proven for stereo performance. It has been said that if a transmitter performs well in monaural mode that it will perform well in stereo. It is the purpose of this investigation to determine if good monaural performance will result in good stereo performance and to determine the optimum load impedance orientation for a Broadcast Electronics, Inc. (BEI) model AM-1 stereo transmitter.

PROCEDURE

The transmitter used for this investigation is the BEI AM-1 stereo transmitter with a built-in stereo exciter. This transmitter eliminated many of the variables in aligning the stereo exciter. The stereo exciter contains circuitry that eliminates the need to equalize for the transmitter. The only variable that would result in additional stereo equalization is sideband impedances of the load presented to the transmitter.

The transmitter was loaded with an artificial antenna. The artificial antenna design is shown in Figure 1. The design consists of a series resonant inductor and capacitor in series with a test load. The reactance of the inductor and capacitor was adjusted to produce approximately a 1.6:1 VSWR at the 10kHz sideband frequencies. Between the transmitter and the series resonant load is an adjustable tee network. The tee network was used to change the phase orientation of the load impedances that are presented to the transmitter.

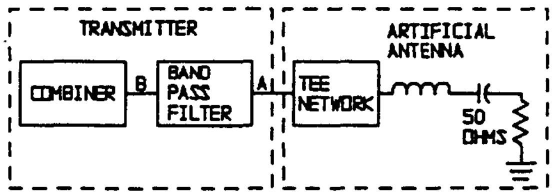


Figure 1. Artificial Antenna

The tee network was adjusted to 7 different phase shifts at 22.5 degree increments. The tee network was removed for a zero degree phase shift.

Impedance sweeps were taken at the output of the transmitter (Point A on Figure 1) and the input to the bandpass filter network of the transmitter (Point B on Figure 1) using a vector impedance meter. These impedances for the two cases discussed in this paper can be found in Tables 1 and 2.

Table 1
Transmitter Load Impedance

Tee Network Phase	Frequency (kHz)	Impedance R±jx (Ohms)
Case 2	580	42.0-j18.7
	590	58.0+j0.0
-22.5 Degrees	600	84.1+j20.2
Case 3	580	41.1+j15.8
	590	58.0+j0.0
-75 Degrees	600	53.0-j27.0

Table 2
Normalized
Bandpass Filter Input Impedance

Tee Network Phase	Frequency (kHz)	Impedance R±jx (Ohms)
Case 2	580	.69+j.17
	590	1.0+j0.0
-22.5 Degrees	600	.88-j.39
Case 3	580	1.43+j.36
	590	1.0+j0.0
-75 Degrees	600	.61+j.18

The procedure for aligning the stereo exciter was done the same way for all setups. A 1 kHz sine wave at 50% modulation was put into the left audio input. A sample was received and demodulated with an AS-10 modulation monitor. An x-y plot of L versus R was viewed on an oscilloscope. The delay and level potentiometers on the stereo exciter were adjusted for maximum separation.

The modulating audio frequency was then increased to 7 kHz. The peak and cutoff potentiometers, high frequency equalization controls, on the stereo exciter were adjusted for maximum separation.

The right channel was aligned in a similar fashion.

A proof of performance was then obtained using an Audio Precision System One, and a BEI model AS-10 AM stereo modulation monitor. A procedure was written to obtain Incidental Phase Modulation (IPM), which is measured in dB below 100% L-R C-QUAM^{R} modulation (1.57 radians max). Monaural distortion, stereo distortion, and stereo separation were also measured.

RESULTS

A wide range in stereo performance could be obtained depending on the phase shift of the tee network. For the purpose of simplicity, only three cases will be compared. Case 1, which is used as a reference, will be with the transmitter loaded with 50 ohms non-reactive, Case 2, which exhibited the worst performance, the transmitter will be loaded with the artificial antenna with a tee network phase shift of -22.5 degrees. For Case 3, which showed the best performance, the transmitter will be loaded with the artificial antenna with a tee network phase shift of -75 degrees. Below are the results of these three cases.

C-QUAM^{R} is a registered trademark of Motorola,Inc.

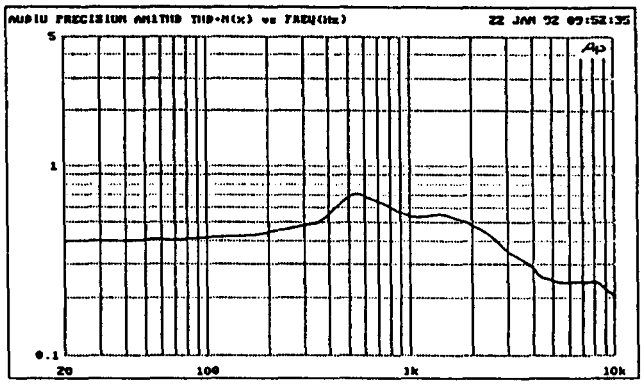


Figure 2. Case 1 Mono THD+N vs. Frequency, 90% modulation, 50 ohm load

For Case 1, the total harmonic distortion for the frequency sweep does not exceed 0.7%.

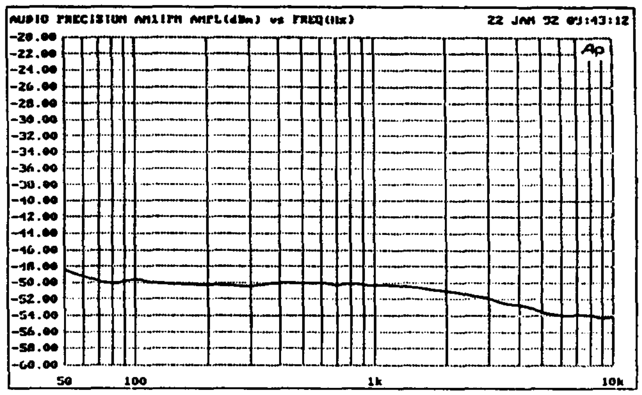
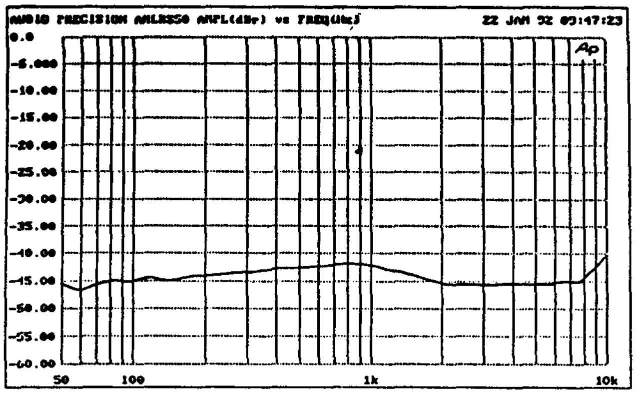
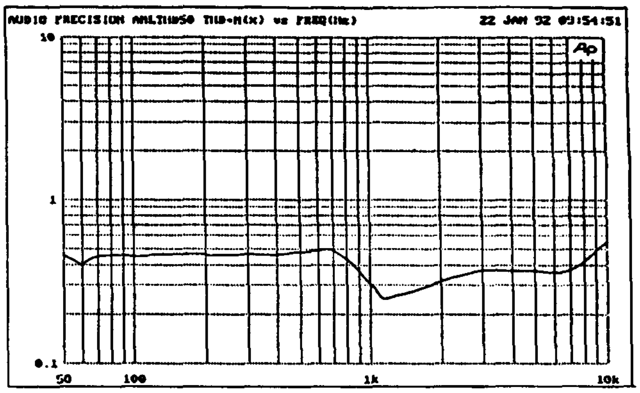


Figure 3. Case 1 IPM, 95% Modulation, 50 ohm load

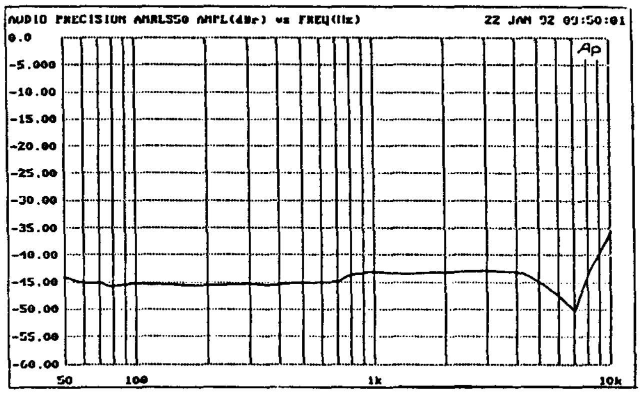
For Case 1 the IPM does not exceed -48 dB.



Left to Right Separation

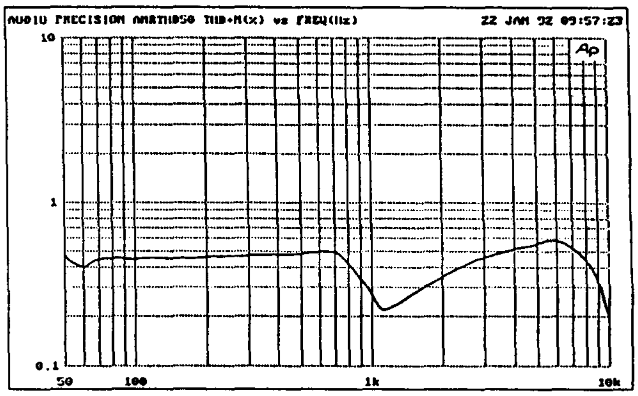


Left Channel



Right to Left Separation

Figure 4. Case 1 Channel Separation, 50% Modulation, 50 ohm load



Right Channel

Figure 5. Case 1 THD+N, 50% Modulation, 50 ohm load

For Case 1, the left to right channel separation is better than 40 dB. The right to left channel separation is better than 35 dB.

For Case 1, the left and right channel THD is less than .6%.

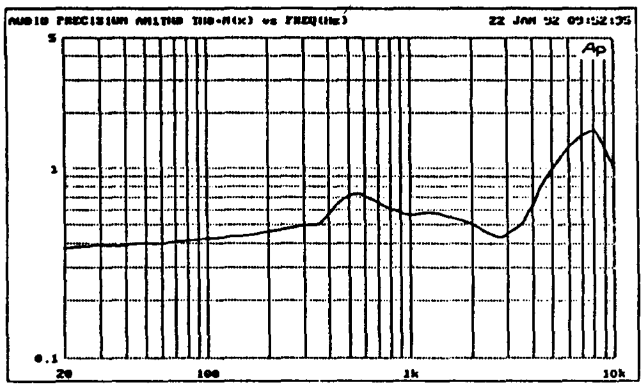


Figure 6. Case 2 Mono THD+N vs. Frequency, 90% modulation, Artificial Antenna, -22.5 Degree

For Case 2, the total harmonic distortion for the frequency sweep went as high as 1.7% at 10kHz.

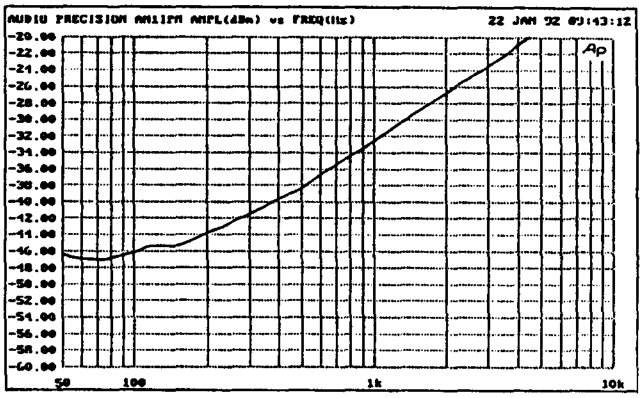
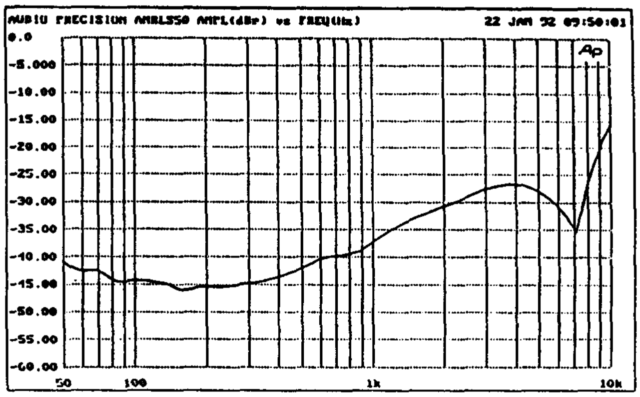
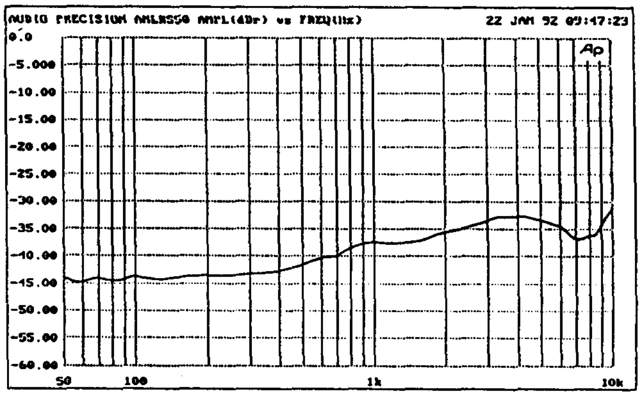


Figure 7. Case 2 IPM, 95% Modulation, Artificial Antenna, -22.5 Degrees

For Case 2, the IPM exceeds -17 dB at 10kHz.



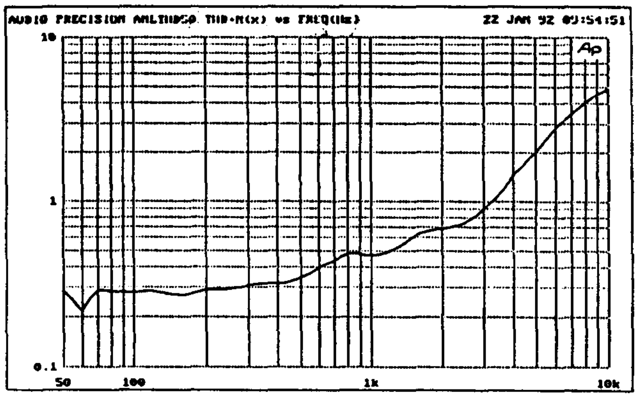
Left to Right



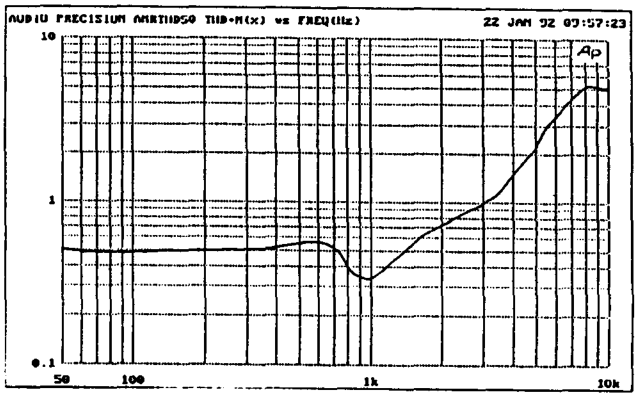
Right to Left

Figure 8. Case 2 Channel Separation, 50% Modulation, Artificial Antenna, -22.5 Degrees

For Case 2, the left to right channel separation degrades to 17 dB at 10 kHz while the right to left channel separation is still better than 30 dB.



Left Channel



Right Channel

Figure 9. Case 2 THD+N, 50% Modulation, Artificial Antenna, -22.5 Degrees

For Case 2, the left and right channel THD rose as high as 5% at 10kHz.

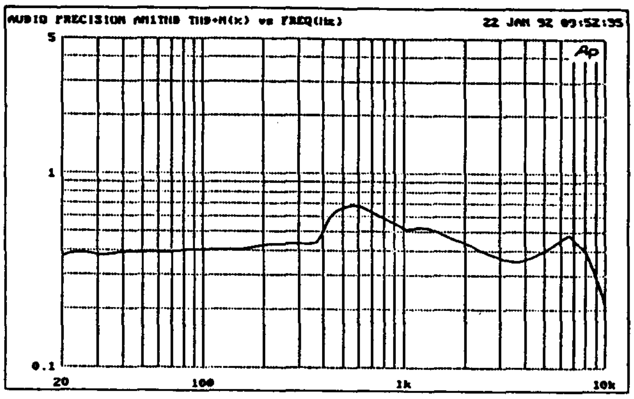


Figure 10. Case 3 Mono THD+N vs. Frequency, 90% modulation, Artificial Antenna, -75 Degrees

For Case 3, the total harmonic distortion for the frequency sweep was less than .6%.

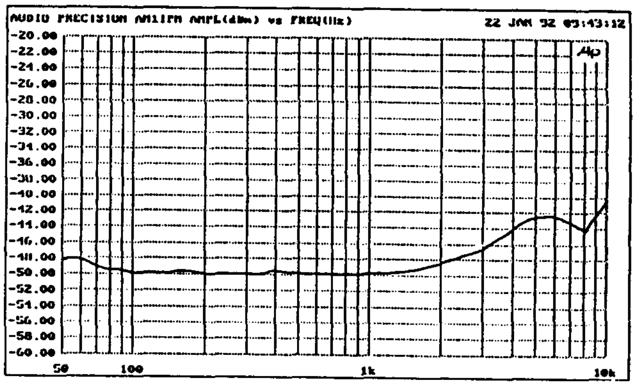
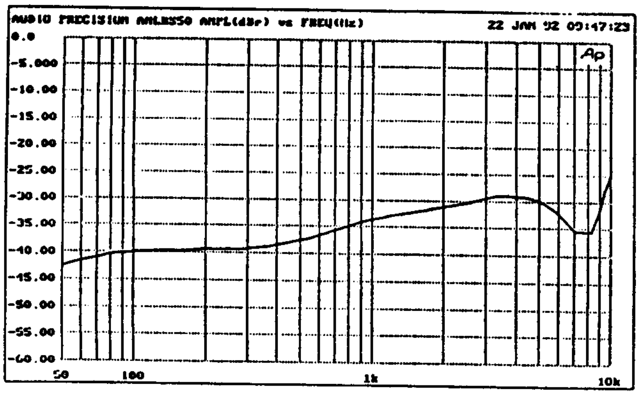
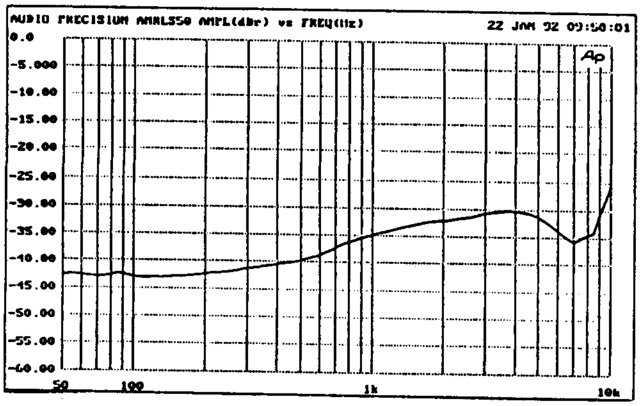


Figure 11. Case 3 IPM, 95% Modulation, Artificial Antenna, -75 Degrees

For Case 3, the IPM does not exceed -40 dB.



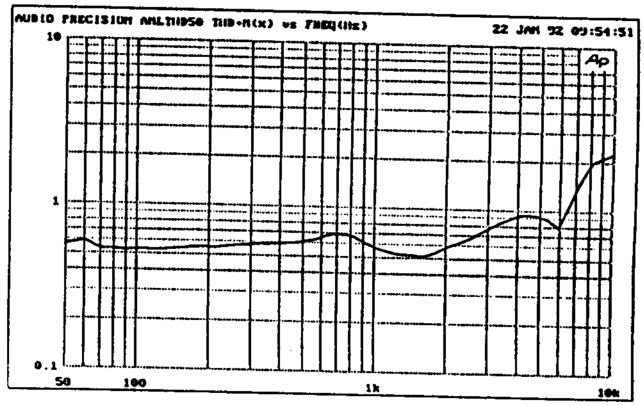
Left to Right



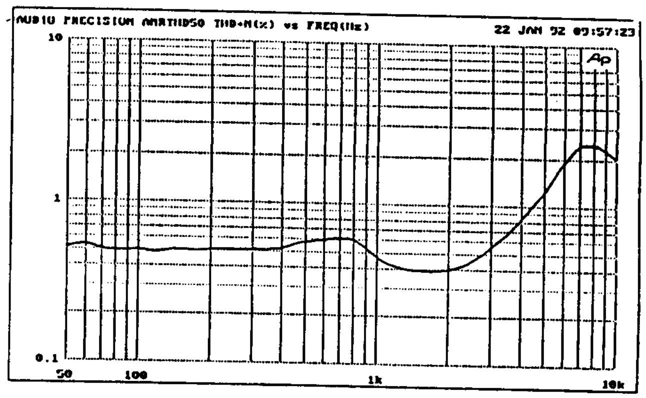
Right to Left

Figure 12. Case 3 Channel Separation, 50% Modulation, Artificial Antenna, -75 Degrees

For Case 3, the left to right and the right to left channel separation is better than 25 dB.



Left Channel



Right Channel

Figure 13. THD+N, 50% Modulation, Artificial Antenna, -75 Degrees

For Case 3, the left and right channel THD has been reduced to 2.5% or better.

CONCLUSION

It can be seen by comparing the results of case 1 to case 2 that the mono and stereo performance of the AM-1 stereo transmitter was degraded by a load that varies with frequency.

The Mono THD for case 1 is .25% at 8 kHz, where Case 2 is 1.7%. The IPM at 10 kHz for Case 1 is -54 dB, where Case 2 is -17 dB. The channel separation for Case 1 is up to 20 dB better than for Case 2 depending on the audio modulating frequency. The left and right channel THD is over 4% higher at 10 kHz for Case 2 than for Case 1.

The only difference between the load in Case 2 and Case 3 is the phase shift of the tee network. The VSWR of each load is the same. This difference in phase shift will present a changed load to the power amplifiers at the sideband frequencies causing significant changes in transmitter performance. The IPM of Case 3 is better than 40 dB which approaches that of Case 1. The channel separation for Case 3 is better than 25 dB which is about a 10 dB improvement over Case 2. The worst channel distortion for Case 3 is 2.5% which is half that of Case 3. Even though the load VSWR for Case 3 is the same as Case 2, the performance is considerable better.

To be able to predict the best load impedance orientation, further investigation needs to be done at different carrier frequencies. Once this is done the impedance sweeps for each frequency tested can be compared to determine the optimum load at any carrier frequency. At 590 kHz, a Smith chart plot of the desired transmitter impedance for the BEI AM-1 stereo transmitter is shown in Figure 14. The resulting impedance at the bandpass filter input terminals (Point B on Figure 1) is shown in Figure 15.

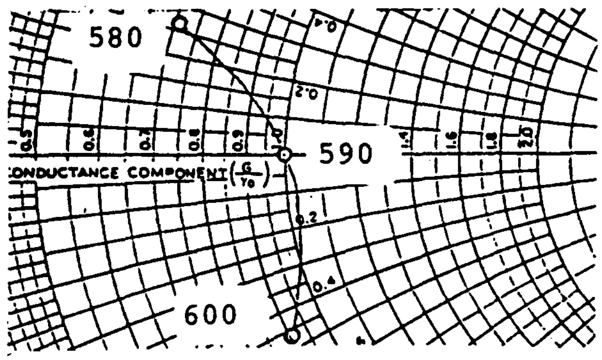


Figure 14. Normalized Transmitter Load Impedance (Point A, Fig.1)

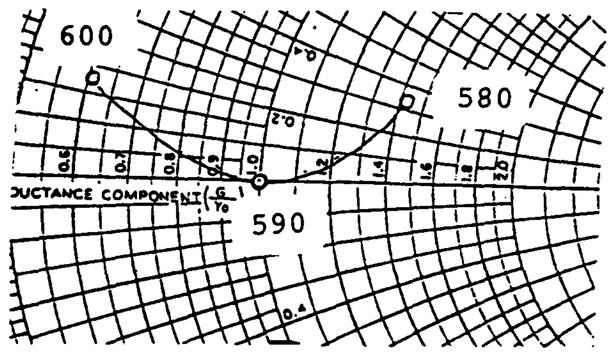


Figure 15. Normalized Impedance at the BPF (Point B, Fig. 1)

SUMMARY

For a load with a given VSWR, the stereo performance may be optimized by presenting this load with the proper phase orientation. This can be accomplished by inserting a tee network between the load and the transmitter. Although the stereo performance will not be as good as the transmitter operating into a 50 ohm non-reactive load, it will be significantly better than with other load impedance orientations.

For the case of 590 kHz using a BEI AM-1 stereo transmitter, the plot of the best load phase orientation is given in Figures 14.