VIII-3 BROADBAND, FIXED TUNED, ACOUSTIC DELAY LINES AT L AND S BAND FREQUENCIES

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This paper is concerned with the design and development of broadband, fixed tuned, non-dispersive delay lines. These delay lines utilize multi-layer transducers incorporating CdS thin films of the type used by deKlerk[1], sapphire delay media, and suitable electrical matching networks in either coaxial or strip transmission lines. The design of two broadband units are presented which operate at center frequencies of 1.80 GHz and exhibit 50 db bandwidths of approximately 50% with midband loss of approximately 40 db. The experimental data for these units are found to be in good agreement with theoretical values.

Before the specific designs of the two units are considered, the transducer impedance relationships are reviewed. The impedance is obtained by solving the piezoelectric equations subject to the boundary conditions shown in Figure 1. The impedance is given by[2]

$$Z = -\frac{jL}{\omega A\epsilon} + \frac{k^2 v}{\omega^2 A\epsilon}\left[\frac{\frac{2\xi_0}{-\xi_2}\left(1 - \frac{1}{\cos\beta L}\right) + j\tan\beta L}{1 + j\frac{\xi_0}{\xi_2}\tan\beta L}\right]$$

$$Z = R(\omega) - j\,X_c - j\,X(\omega)\ .$$

This equation corresponds to the standard equivalent circuit of Figure 1b but is less convenient in that form. For many transducer configurations using CdS in the GHz range, $R(\omega)$ may be as small as .01 ohm making possible only loose coupling from electromagnetic to acoustic energy. Correspondingly large mismatches are obtained (3000:1 for a 50-ohm line). Evans[2] has shown that this situation may be altered by adjusting the ratio ξ_0/ξ_2. Since ξ_2 is the acoustic impedance seen looking into right electrode of Figure 1, various metallic layers may be used here to adjust the value of ξ_2. Figure 2 is a plot of values of $R(\omega)$ and $X(\omega)$ versus normalized frequency for various values of ξ_0/ξ_2.

The relationships of Figure 2 are useful in bandwidth considerations and indicate that a device having a large $R(\omega)$ will of necessity, be a narrow band device. For cases in which ξ_2 is obtained from multi-layer electrode arrangements, the ratio, ξ_0/ξ_2, will exhibit a frequency dependence and the relationships of Figure 2 will be modified.

In order to design broadband delay devices centered at 1.8 GHz, a computer program was prepared and several candidate multi-layer electrode configurations were investigated. Some of the more interesting designs are shown in Figure 3. In calculating these curves an additional series contact resistance, R_c, of value one ohm has been used. This resistance has been measured in physical configurations where spring like contacts are used in connecting the RF energy to the acoustic transducer electrode.

After evaluating the various transducer configurations, Design D of Figure 3 was selected as presenting the best electrical characteristics while offering ease of implementation. The physical transducer patterned after Design D is shown in Figure 4a. Here, thin combined layers of chromium and gold are used as the electrical electrodes while a 200 Å layer of SiO is included to insure isolation between the electrodes should pin holes be present in the CdS films. In this design, the CdS thickness was reduced due to resonator loading by the additional films. The attenuation characteristics for the overall transducer were calculated and found to be virtually the same as the original Design D. The diameters of the transducers were slected as .030 inches to provide the largest $R(\omega)$ without adding significant diffraction loss when used in delay devices.

Two delay lines were designed and fabricated using the transducers of Figure 4a. The coaxial matching structure of Figure 4b was used in one device. Here two section Chebyshev transformers having characteristic impedances of 15.4 and 2.7 ohms are used for matching. The experimental attenuation and VSWR data for this device are given in Figure 5. The theoretical loss for two transducers also is included. It may be seen that the difference between the two curves can be accounted for by loss in the delay medium and in mismatch loss at the band edges. By incorporating a small absorber in the coaxial section of the device, the VSWR was reduced to below 2:1 over the bandwidth shown in the figure.

A second unit was designed in strip transmission line. In this design, three section Chebyshev matching transformers are utilized. In the matching sections, .030 and .010 inch ground plane spacings are used. A photograph of the partially assembled unit is shown in Figure 6. The attenuation data for this device are approximately the same as for the coaxial design while an improvement in VSWR is obtained (VSWR $<$ 2:1 across 50% band).

In the paper, additional designs which operate at center frequencies of 450 and 850 MHz are discussed briefly. It is indicated that a total insertion loss of less than 13 db for 4 μseconds of delay have been obtained over a 30% bandwidth for the 450 MHz device.

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REFERENCES

1. J. deKlerk and E.F. Kelly, "Vapor Deposited Thin Film Piezoelectric Transducers," Rev. Scientific Instruments, Vol. 36, No. 4, 1965, p. 506.
2. G.E. Evans, "Fixed Tuned CdS Transducers," presented at 1966 Ultrasonic Symposium, Cleveland, Ohio, October 1966.

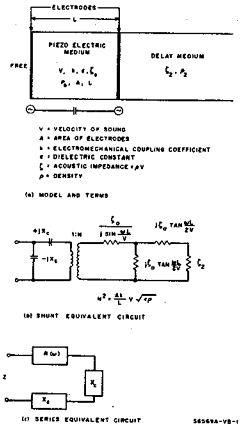

FIG. 1 - Transducer Relationships

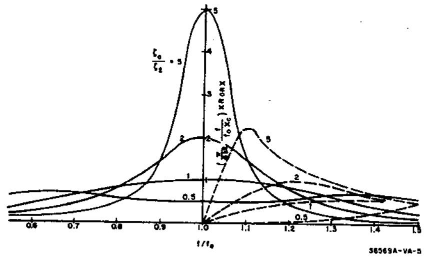

FIG. 2 - R(W) and X(W) Versus Normalized Frequency for Various for Various Values of $\varepsilon_0/\varepsilon_2$

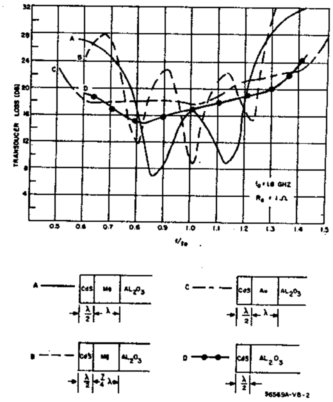

FIG. 3 - Transducer Loss Versus Frequency

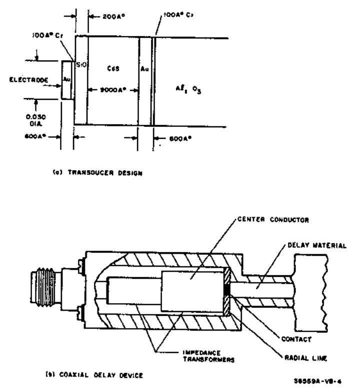

FIG. 4 - Delay Device

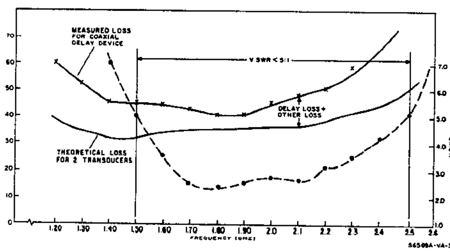

FIG. 5 - Theoretical and Experimental Data for Coaxial Delay Device

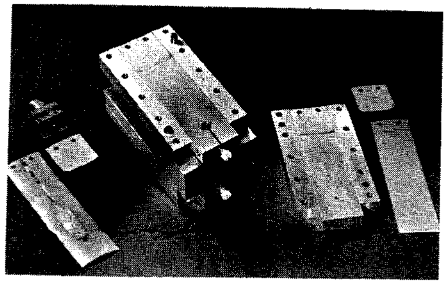

FIG. 6 - Photograph of Partially Assembled Ship Transmission Line Device