DESIGN CURVES FOR $Bi_{12}GeO_{20}$ SPIRAL ACOUSTIC SURFACE WAVE DELAY LINES

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Abstract

Design curves accounting for all geometrical effects (axial offset, total distance, and time delay) are presented for $Bi_{12}GeO_{20}$ spiral acoustic surface wave delay lines. Crystalline anisotropy results in considerable deviation from a helical path.

The critical need for ultra long UHF and microwave frequency time delays for military, television and data processing applications has generated considerable interest in acoustic spiral or wrap-around surface wave delay lines[1-6]. Until the present time, however, transducers could not be accurately placed and fixed on the substrates due to lack of design information[7]. It is therefore the purpose of this paper to provide complete design curves for $Bi_{12}GeO_{20}$ wrap around acoustic surface wave delay lines.

The device to be treated is shown schematically in Fig. 1a. The problem is to determine the correct cant angle for the transducers and corresponding axial offset distance such that the output transducer intercepts the acoustic beam. The acoustic path need not, of course, be limited to only a single spiral before intercepting the output transducer. To simplify the generation of design curves the geometry shown in Fig. 1b will be adopted. The actual device of Fig. 1a can easily be synthesized from that of Fig. 1b by inserting the well known propagation characteristics on a flat plate. The particular crystalline geometry to be treated in detail in this paper is shown in Fig. 1c. It corresponds to one of the popular choices for wrap-around delay lines[7].

The parameters with which we must deal are defined in Fig. 2a. The surface wave is launched from an input transducer canted with respect to the cylindrical circumference line by an angle ν. Due to the noncolinearity of the phase and group velocity vectors the surface wave energy is offset from the transducer by a distance Z which is a function of both θ and ν. This offset as well as the path length L and the total time delay τ are the functions of the surface wave velocity and power flow angle curves which are themselves dependent on ν and θ as illustrated in Fig. 3.

Solution of this problem is straightforward with reference to the infinitesmal geometrical propagation diagram of Fig. 2b and the following relations valid for propagation around a cylinder of constant radius, R.

$$dP = R d\theta$$

$$dZ = dP \tan [\phi(\theta,\nu) + \nu] = \tan [\phi(\theta,\nu) + \nu] R d\theta$$

$$dL = \frac{R d\theta}{\cos [\phi(\theta,\nu) + \nu]}$$

$$d\tau = \frac{dL \cos \phi(\theta,\nu)}{v_s (\theta,\nu)} = \frac{R d\theta}{v_s(\theta,\nu)} \frac{\cos \phi (\theta,\nu)}{\cos [\phi(\theta,\nu) + \nu]}$$

Applying the usual rules of calculus we have

$$Z (0, \theta) = \int_0^\theta R \tan [\phi,(\theta,\nu) + \nu] d\theta$$

$$L (0, \theta) = \int_0^\theta \frac{R d\theta}{\cos [\phi(\theta,\nu) + \nu]}$$

$$\tau(0,\theta) = \int_0^\theta \frac{\cos \phi (\theta,\nu)}{\cos [\phi(\theta,\nu) + \nu]} \frac{R d\theta}{v_s (\theta,\nu)}$$

Solution of the above three equations using computer generated velocity and power flow angle data yields the design curves we seek. Note how all quantities scale linearly with R allowing universal application of design curves.

Fig. 4 illustrates the surface wave axial offset as a function of θ for four different values of cant angle and shows quite clearly that due to the crystalline anisotropy a simple helix path is not followed. Since the surface wave energy "wanders" considerably, intercepting it at various values of θ with taps, for example, requires knowledge of the data presented here. Fig. 5 represents a compilation of values of Z (0,360), L (0,360) and τ (0,360) as a function of cant angle. These plots of offset, distance and time delay are exactly the information necessary for the proper design of a wrap-around delay line. The proper cant angle is chosen to obtain a given axial offset (generally set by transducer width and number of spirals desired) such that the output transducer exactly intercepts the acoustic beam. Delay time is then read directly. For completeness Fig. 6 shows the offset obtained as a function of cant angle when propagation is on a flat plate. One can therefore easily design for the actual device geometry as shown in Fig. 1a.

The curves presented in this paper allow for complete geometrical design (that is, neglecting loss and diffraction) of $Bi_{12}GeO_{20}$ spiral delay lines. The curves are universal since all data scales linearly with cylinder radius. Curves similar to those shown here have also been computed for other popular wrap-around acoustic surface wave delay line materials and orientations and will be presented.

References

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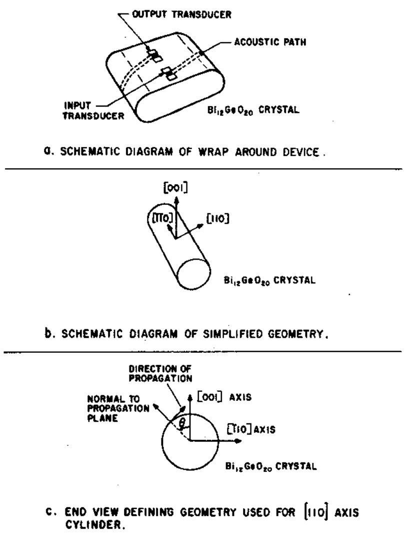

FIG. 1 - DIAGRAMS OF WRAP-AROUND ACOUSTIC SURFACE WAVE DELAY LINES TREATED IN THIS PAPER.

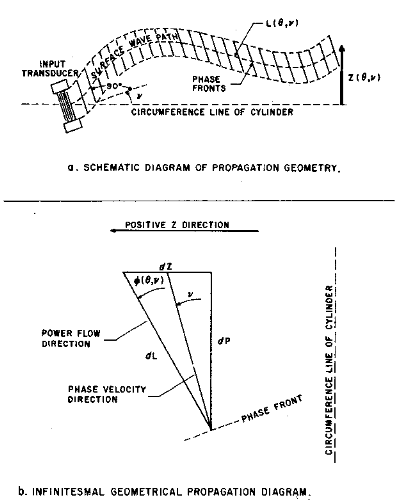

FIG. 2 - DIAGRAMS ILLUSTRATING THE RELATIONSHIP OF VARIOUS PARAMETERS NECESSARY TO DEFINE PROPAGATION AROUND ANISOTROPIC CYLINDERS.

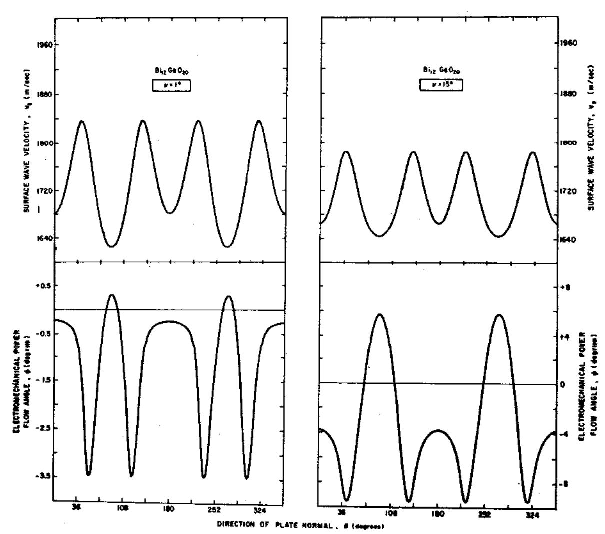

FIG. 3 - SURFACE WAVE VELOCITIES AND POWER FLOW ANGLES FOR PROPAGATION AROUND A (110) AXIS $Bi_{12}GeO_{20}$ CYLINDER AT CANT ANGLES OF 1° AND 15°.

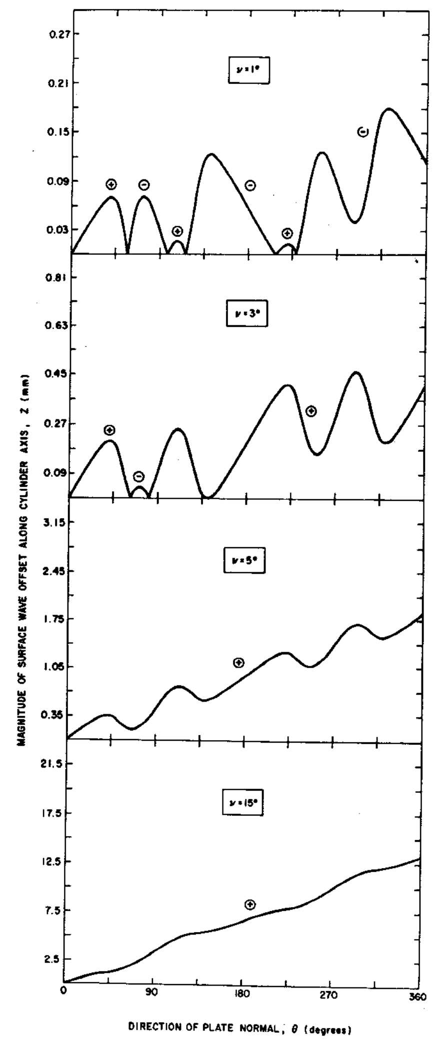

FIG. 4 - MAGNITUDE OF THE SURFACE WAVE AXIAL OFFSET FOR PROPAGATION AROUND A (110) AXIS $Bi_{12}GeO_{20}$ CYLINDER AT VARIOUS CANT ANGLES. NO OFFSET OCCURS AT $\nu = 0^{\circ}$. THE DIRECTION OF OFFSET IS INDICATED BY THE SIGNS SUPERIMPOSED ON THE CURVES. THIS DATA APPLIES TO A 10mm CYLINDER BUT SCALES LINEARLY FOR OTHER RADII.

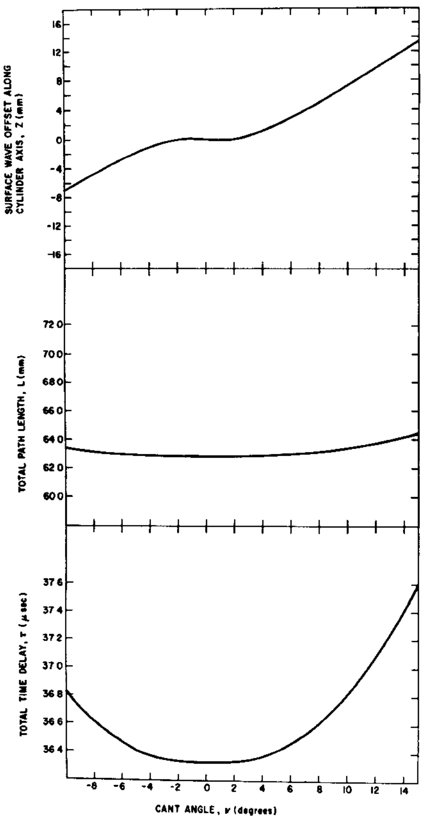

FIG. 5 - SURFACE WAVE AXIAL OFFSET, TOTAL PROPAGATION DISTANCE, AND TOTAL TIME DELAY FOR PROPAGATION ONCE AROUND A (110) AXIS $Bi_{12}GeO_{20}$ CYLINDER AS A FUNCTION OF CANT ANGLE. THESE ARE THE BASIC DESIGN CURVES. THIS DATA APPLIES TO A 10mm CYLINDER BUT SCALES LINEARLY FOR OTHER RADII.

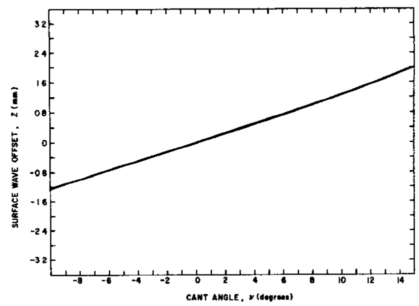

FIG. 6 - SURFACE WAVE OFFSET FOR PROPAGATION ON A [001]-CUT, [110]-PROPAGATING $Bi_{12}GeO_{20}$ PLATE AS A FUNCTION OF CANT ANGLE. PLATE LENGTH IS 10mm BUT DATA SCALES LINEARLY.