REDUCTION OF REFLECTIONS IN SURFACE WAVE DEVICES WITH QUARTER-WAVE TAPS

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Abstract

The reflections and back-voltages present in a multiply tapped delay line have been measured. Taps spaced by one-quarter wavelength were found to have lower reflections and back-voltages than the customary half-wavelength-spaced taps.

The actualization of large time-bandwidth-product, low-insertion-loss acoustic surface wave signal processing devices is critically dependent on reducing second order effects such as reflections between the lines of the interdigital transducers. In this paper, we have reduced reflections and back voltages in the 50-tap sin f/f filter configuration shown in Figure 1 (which is also appropriate for bi-phase codes[1]) by using interdigital taps spaced by one quarter wavelength between centers rather than the customary half-wavelength. The motivation for using the quarter wave spacing is the fact that the reflection from two such unconnected lines vanishes for a continuous wave, while the reflection from two lines spaced by one-half wavelength is a maximum. Of course, the quarter-wave spacing reduces the detection efficiency[2,3], but this has the advantage of reducing the spurious signals due to the back voltage effect: the electrical output from one tap can regenerate an undesired acoustic signal at all the other taps to which it is connected. In fact, Vasile et. al.[4] have reduced second order effects under the taps of a binary decoder by decoupling them from the strong piezoelectric lithium niobate substrate with a silicon monoxide thin film. Our new method of using quarter-wave taps has the advantages that the dispersion of a thin-film is not present and that the device is monolithic but the disadvantage is that quarter-wave lines are generally more difficult to fabricate.

Experiments were performed with the aluminum-thin-film transducer pattern shown in Figure 1 deposited on the highest known piezoelectric coupling material: the 41.5°-cut, X-propagating orientation of lithium niobate[5]. The continuous wave input impedance of the two identical 21 line interdigital transducers measured with a Hewlett-Packard network analyzer, is shown in Figure 2. No electrical matching networks were used with the transducers. The minimum in the electrical reflection coefficient occurs at 160 MHz. Two narrow-band reflection resonances from the 50 taps, which are spaced about 8 MHz apart are seen superposed on these curves. The reflections from the open circuited quarter-wave taps are smaller than those from the half-wave spaced taps.

Time domain measurements were made by exciting the 21 line interdigital transducer with a 3 n sec pulse. This generated a 10 cycle, 63 nsec output pulse which was initially observed at the single tap. The input pulse used for the half-wave tap was smaller than that for the quarter-wave tap, so that its lower efficiency gave the same output. This initial output is off-scale at the beginning of the oscilloscope traces of Figure 3, as the gain was set to show the reflections and the back voltages generated in the 50 taps. This initial output is 32 dB above the reflections from the half-wave taps, which were terminated in an external short circuit, and 36 dB above the reflections from the quarter-wave taps. The reflections from the shorted quarter-wave taps is as expected; a series of 63 nsec pulses separated by 63 nsec spaces. When the taps are terminated by a 50 ohm load, the back voltage, which is generated during the 3.2 μ sec that it takes the incident pulse to transverse the 50 taps, appears in the spaces and interferes with reflections. Larger reflections and back voltages are observed for the half-wave taps. The external short is not completely effective in eliminating the back voltage generated within the half-wavelength taps.

It is interesting to compare in Figure 3 the reflections from the 3rd half-wave tap with that of the 5th quarter-wave tap. Both taps were disconnected or open circuited at the tap edges from the "bus bar," which connects the remaining taps together. The 3rd open-circuited half-wave tap is 2.6 dB below the adjacent taps connected to the "bus bar", which is itself terminated in an external short. The 5th open-circuited quarter wave tap is about 13 dB below the adjacent taps. These observations are consistent with the theoretical prediction that the impedance discontinuity of open circuited electrodes is less than that of short circuited electrodes[6,7]. These observations also show that the open-circuited quarter wave tap is a very poor reflector indeed. The connection of the quarter wave tap to the "bus bar" appears largely responsible for its reflectivity, and the implication is that the reduction in reflections and back voltages already observed for high-coupling lithium niobate may be even greater for lower piezoelectric coupling materials such as quartz. This new method for reducing second order effects in the multiply taped delay line having a sin f/f filter response may also be extended to large time-bandwidth dispersive delay lines[8].

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References

1. P.A. DeVito, P.H. Carr, W.J. Kearns, and J.H. Silva, "Encoding and Decoding with Elastic Surface Waves at 10 Megabits per Second," Proc. IEEE, Vol. 59, Oct. 1971, pp 1523-1525.

2. G.A. Coquin and H.F. Tiersten, "Analysis of the Excitation and Detection of Piezoelectric Surface Waves in Quartz by Means of Surface Electrodes," J.Acoust. Soc.Amer., vol 41, April 1967, pp 921-939.

3. R.F. Milson and M. Redwood, "Generation of Acoustic Waves by Single Pair of Electrodes on Surface of Piezoelectric Ceramic," Electronics Letters, vol. 7, Sept 1971, pp 541-542.

4. C.F. Vasile, R. LaRosa, and G. Aiello, "A Low-Loss Surface Wave Tapped Delay Line Design for Large Time-Bandwidth Products," Paper Q-8, IEEE Ultrasonics Symposium, Dec 1971.

5. A.J.Slobodnik,Jr. and E.D. Conway, "New High-Frequency High-Coupling Low-Beam-Steering Cut for Acoustic Surface Waves on $LiNbO_3$", Electronics Letters, vol 6, March 1970, pp 171-172.

6. S.G. Joshi and R.M. White,"Dispersion of Surface

Elastic Waves Produced by a Conducting Grating on a Piezoelectric Crystal," J.Appl.Phys., vol 39, December 1968, pp 5819-5827.

7. R. H. Tancrell and R.C. Williamson, "Wavefront Distortion of Acoustic Surface Waves from Apodized Interdigital Transducers," Appl.Phys.Letters, vol 19, December 1971, pp 456-459.

8. R.H. Tancrell and M.G. Holland, "Acoustic Surface Wave Filters," vol. 59, March 1971, pp 393-409.

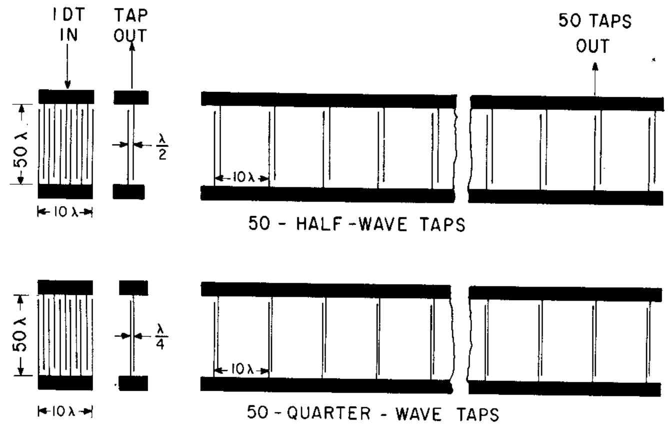

FIG. 1 - EXPERIMENTAL MULTIPLY TAPPED DELAY LINE CONFIGURATION USED ON THE SAME SUBSTRATE TO DEMONSTRATE THE SMALLER SECOND ORDER EFFECTS FROM THE QUARTER WAVE TAPS.

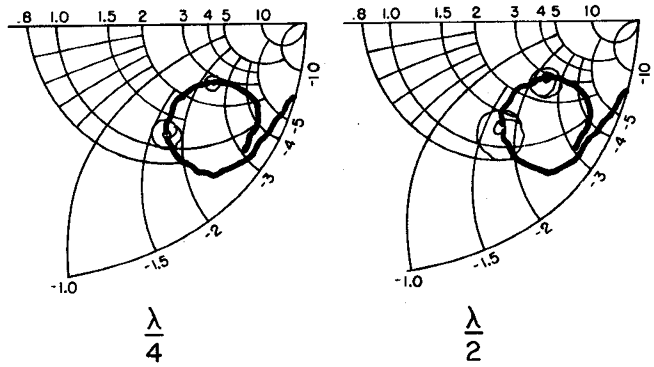

FIG. 2 - INPUT IMPEDANCE OF THE TWO IDENTICAL 21 LINE INTERDIGITAL TRANSDUCERS ON 41.5-X LITHIUM NIOBATE SHOWING THE SMALLER REFLECTION RESONANCES FROM THE QUARTER WAVE TAPS.

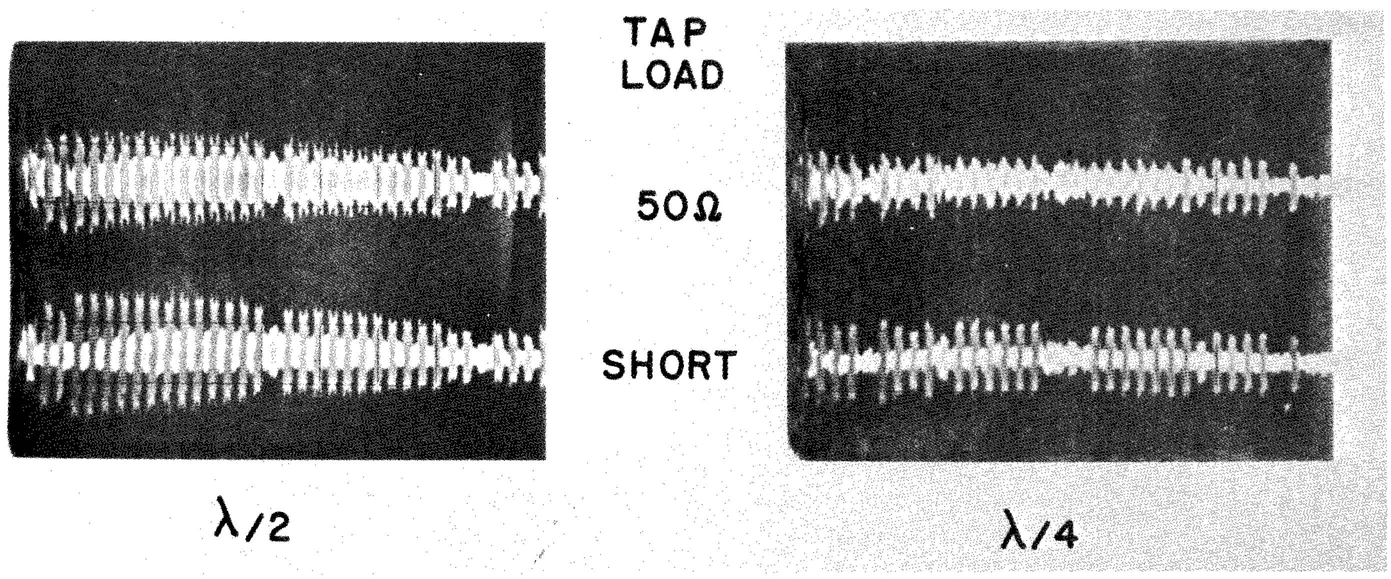

FIG. 3 - OSCILLOSCOPE TRACES OF THE REFLECTIONS AND BACK VOLTAGES FROM THE 50 TAPS ARE OBSERVED AT THE SINGLE TAP OUTPUT, SCALE 1 mV/DIV VERTICAL, 0.5 μ sec HORIZONTAL.

NOTES