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The influence of a bulk waves on the characteristics of a SAW filters

Adam Kawalec[1], Marta Walenczykowska[1],
[1] Military University of Technology, 2 Gen. Kaliskiego, Warsaw, Poland,
adam.kawalec@wat.edu.pl

Summary:

The effective surface permittivity, which uniquely characterize its electrical surface properties of a piezoelectric substrate is presented. This approach allows to transform a complex problem from the mechanics of a continuous medium into the field theory. The imaginary part of this permittivity is related to the excitation of an acoustic bulk waves by an interdigital transducer. Using the presented calculation results for a given piezoelectric substrate, it is possible to estimate the band in which bulk waves occur, distorting the characteristics of filters with a surface acoustic wave (SAW).

Keywords: Surface Acoustic Wave filters, bulk waves, dispersive delay lines, radar signal processing

Background, Motivation an Objective

One of the main components of the acoustic surface wave (SAW) is a filter consisting of two cooperating interdigital transducers used to excite and receive the surface acoustic wave. Each of the transducers contains an array of metal electrodes distributed evenly or unevenly on the surface of the piezoelectric. The piezoelectric material, on the surface of which metal electrodes are deposited, influences the characteristics of these components. Therefore, the surface properties of the piezoelectric material described by the effective surface permittivity [1], [2] are extremely important in the analysis and synthesis of filters with two co

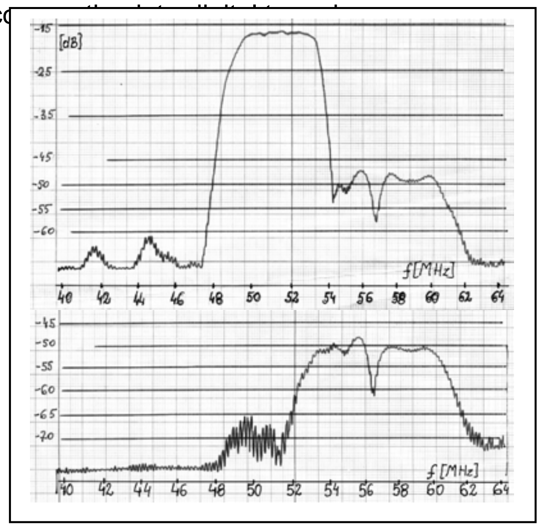

Fig. 1. Amplitude response of a bandpass filter on a lithium niobate (Y,Z) substrate.

Experimental confirmation of the presence of bulk waves in addition to the useful surface waves is the amplitude characteristic of the bandpass filter shown in Figure 1 and the characteristic of the same filter with the surface wave suppressed by applying a surface wave-absorbing material between two cooperating interdigital transducers. The distortions of the amplitude characteristics of the filter made on a lithium niobate substrate with orientation (Y,Z) coincide with the range of occurrence of volume waves [2].

The effective surface permittivity

The relationship between the electric field component parallel to the induction component normal to the piezoelectric surface uniquely characterizes the electrical properties of the piezoelectric and significantly simplifies the theoretical analysis of the interdigital transducer. The description of the excitation of an acoustic surface wave can be based on the effective surface permittivity, which characterizes the phenomena on the piezoelectric surface, taking into account the acoustic properties of the piezoelectric substrate. The effective dielectric permittivity is calculated as a function of the unknown velocity and depends on the material properties and crystal orientation [2].

$$\varepsilon_s / \varepsilon_\infty = \frac{r^2 - k_v^2}{r^2 - k_o^2}(1+\chi) \qquad (1)$$

where: k_v, k_o - SAW denotes wave vectors for an electrically open surface and for an electrically short-cuited surface.

There is a certain value of wavenumber above which the effective surface permittivity is real. The real part of this permittivity is zero for wavenumber $r=k_v$, which corresponds to the free surface of the piezoelectric, and has a pole for r=k_o corresponding to the metallized surface. The effective surface permittivity also contains a small imaginary part χ responsible for the excitation of bulk waves and as shown in Figure 2 it is complex in a certain wavenumber range.

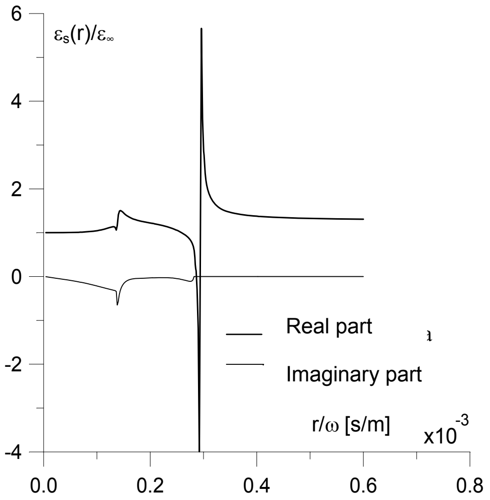

Fig. 2. Comparison of the normalized surface permittivity with the approximated one (dashed line) for lithium niobate (YZ)

Experimental and simulation results

With the appropriate selection of the transducer structure frequency, it is possible to limit the influence of bulk waves excited by the interdigital transducer on the frequency response of the synthesized filter. The dispersive filter made on a bismuth-germanium oxide substrate with orientation (111),[110] contained three transducers [1] in a simple - dispersive - simple configuration. The dispersive transducer with periodic electrodes placed between the simple transducers had two operating bands, the basic one located around the frequency of 23.4MHz and the additional one located around the frequency of 33.5MHz. Figure 3 shows the measured amplitude characteristics of the simple-dispersive (P-D) and simple-simple (P-P) filters. The base band of the dispersive filter is not distorted, but in the additional band there is a significant distortion of the characteristic due to the attenuation of the surface wave, the energy of which is converted into bulk waves. Similar distortions can also be observed in the amplitude characteristics of two cooperating simple transducers (P-P).

The theoretical curve of the imaginary part of the surface permittivity shown in Figure 4 for bismuth germanium oxide with orientation (111),[110] is comparable to the curve of the disturbance occurring on the frequency response in the range of the additional dispersive filter (P-D) and the filter created by two cooperating simple transducers (P-P) [2]. The imaginary part of the surface permittivity therefore provides important information about the possible areas of occurrence of volume waves excited by interdigital transducers.

Fig. 3. Amplitude characteristics of filters with two cooperating transducers: simple-dispersive (P-D) and simple-simple (P-P)

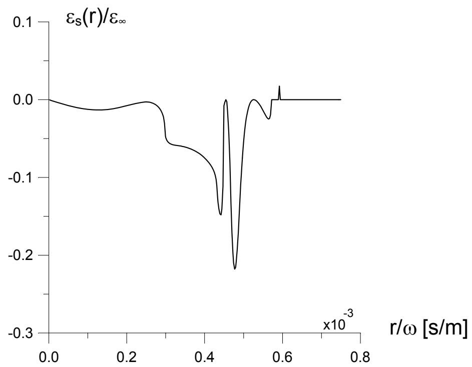

Fig. 4. Imaginary part of EPPU for bismuth germanium oxide (Bi12GeO20) with (111),[110] orientation

Conclusions

The above-presented effective surface permittivity curves for piezoelectrics are complicated functions, with distinct "peaks" for precisely defined wave numbers, indicating the attenuation of the surface wave due to partial conversion of its energy into the energy of the bulk wave. Knowledge of the surface permittivity function is particularly useful for broadband components with an acoustic surface wave and filters using higher harmonics excited by an interdigital transducer.

References

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