PROPERTIES AND APPLICATIONS OF THE ACOUSTIC WAVE JUNCTION BETWEEN PLATED AND UNPLATED SUBSTRATES

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Summary

The junction between the plated and unplated portions of a substrate theoretically exhibits zeros of both transmission and reflection for acoustic surface waves incident at certain angles from either region. These properties offer some useful device possibilities.

The junction between the plated and unplated surfaces of a substrate is a constituent of many acoustic surface wave components such as prisms, lenses, filters and waveguides, as shown in Fig. 1, and, the properties of this junction are therefore of interest.

The specific properties of interest are the scattering coefficients of the junction. In calculating these coefficients, we assume the plating to be sufficiently thin so that the modified Rayleigh wave and Love wave are the only propagating waves in the plated region. The inclusion of the Love wave is essential if the theoretical model is to yield certain detailed features of the scattering behavior which are of much interest because they form the basis for some potentially useful components and devices.

The scattering coefficients are computed with the aid of the equivalent network[1] shown in Fig. 2, in which the mode coupling at the junction is represented by a pair of ideal transformers whose turns ratios are functions of frequency and the angle of incidence. The shunt element Y can in general possess both conductive and susceptive contributions, which respectively represent bulk-wave radiation into the substrate and stored bulk-wave energy in the vicinity of the junction. The explicit expression for Y has not yet been derived, but the influence of this element on the interesting properties to be described below can be shown to be quite small. The modal fields in the two regions are normalized in a fashion such that the x-component of power carried in each mode is given by the power flow along its equivalent transmission line, and such that the characteristic impedance of the latter is given by

$$Z_R = \omega\rho/k_{XR},\ Z'_R = \omega\rho/k'_{XR},\ Z_L = \mu k_{XL}/\omega$$

where ω is the angular frequency, ρ is the substrate density, μ is the substrate rigidity, k_{XR}, k'_{XR} and k_{XL} are the x-components of the Rayleigh, modified Rayleigh and Love wave wavenumbers, respectively.

In Figs. 3 and 4 are shown the angular dependence of two of the three scattering coefficients pertinent to the scattering of a Rayleigh wave incident on the junction from the free-surface side. Two cases are considered, namely $k_s t = 0.03$ and 0.12, where $k_s = 2\pi/\lambda_s$ is the shear wave wavenumber in the substrate, and t is the plating thickness. The numerical values correspond to a gold plating on a fused quartz substrate. Two main points of interest should be observed in these curves.

First, one notes from Fig. 3 that the reflection coefficient vanishes at a specific angle of incidence which is slightly less than 30° and which varies with the plating thickness. Such a condition of total transmission is analogous to the Brewster's angle in optics, and may be utilized to eliminate or minimize unwanted reflections from such junctions.

Second, one notes from Fig. 4 that, for sufficiently thin platings, the Love wave becomes cut off in the direction transverse to the junction for angles of incidence above a critical angle, θ_c ($\theta_c \simeq 64°$ for $k_s t = .03$). This cutoff condition is characterized by $k_{XL} = 0$ and $Z_L = \mu k_{XL}/\omega = 0$, so that a short-circuit condition effectively exists across the shunt network of Fig. 2 at $\theta = \theta_c$. As a result, the incident Rayleigh wave must be totally reflected and no energy is transmitted into the modified Rayleigh wave or the Love wave. For $\theta > \theta_c$, $k_{XL} \neq 0$, and the short-circuit condition is removed.

It is important to point out that this particular effect is a direct result of the Love-wave cutoff condition, so that any theory which neglects the existence of the Love wave in the plated region will not yield the interesting behavior associated with the effect. It should also be noted that the effect is very sharp and narrow band, both in terms of angle of incidence and also in terms of frequency. The sharpness of the effect then suggests several useful devices, as shown in Fig. 5.

Figure 5(a) shows the use of the junction as a passive perfect reflector which does not require any type of external tuning. If more than one reflector is employed, the final beam can be made to emerge at any given angle, but it must be recognized that this perfect reflection occurs over a very narrow frequency band.

In Fig. 5(b) is shown an in-line filter which makes use of a sequence of two total reflections, at the critical angle, θ_c, from a pair of junctions of the same thickness t. Such a filter ideally selects and passes the single frequency component for which the incidence angle θ equals the critical angle θ_c. The frequency response curve for such a two-reflector filter employing a gold layer, for which $k_s t = 0.03$, on a fused quartz substrate, is shown in Fig. 6.

Finally, Fig. 5(c) shows a device for multiple frequency selection. From a sequence of incoming signals at different frequencies, certain selected frequencies can be separated out for individual processing. In order to minimize reflections at the back edges of the plated regions, the angle of the back edges can be chosen to correspond to the Brewster-type angle.

Reference

1. A.A. Oliner, H.L. Bertoni and R.C.M. Li, "Equivalent Networks for Acoustic Wave Junctions, with Application to the Junction Between Plated and Unplated Surfaces," IEEE Ultrasonics Symp., San Francisco, Calif.; Oct. 1970.

Acknowledgement

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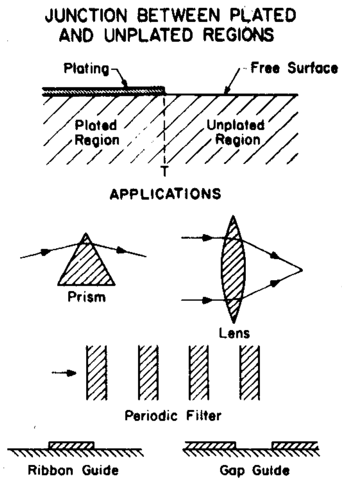

Fig 1

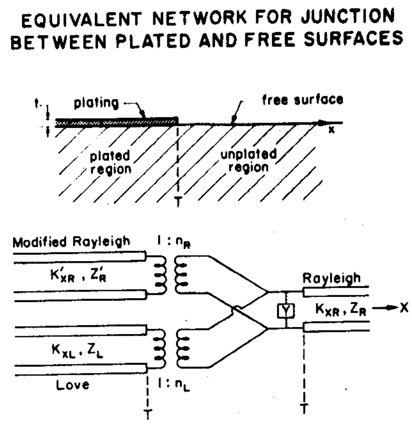

Fig 2

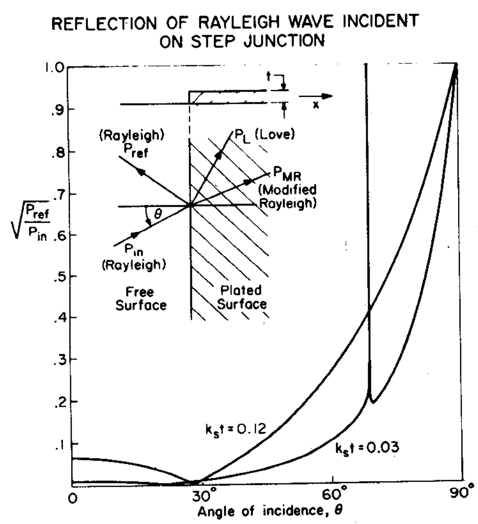

Fig 3

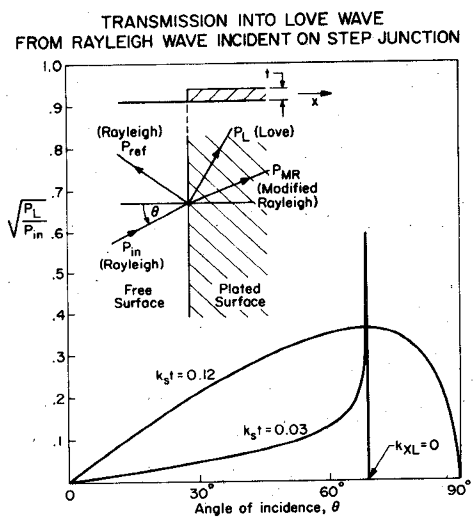

Fig 4

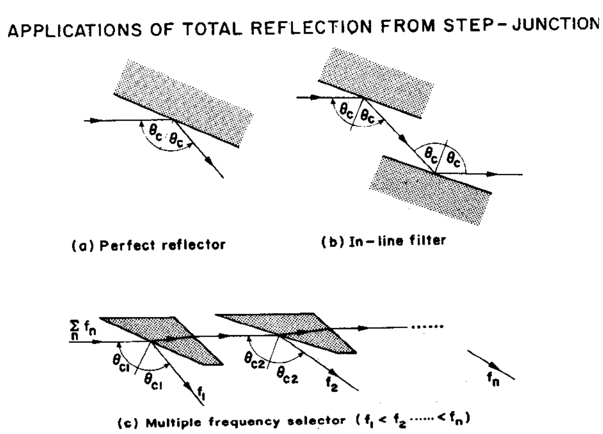

Fig 5

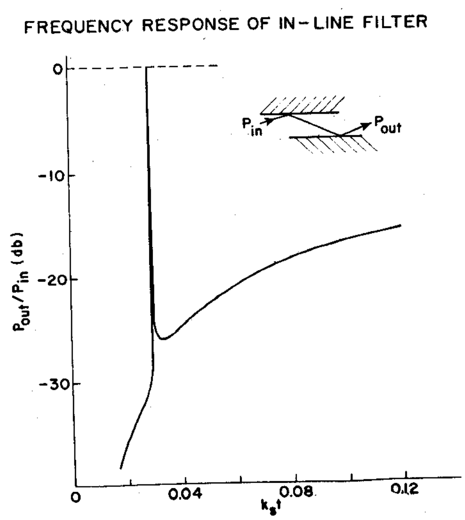

Fig 6