TRANSDUCER-COUPLED SURFACE ACOUSTIC WAVE AMPLIFIERS

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Abstract

A review is made of various transducer-coupled surface acoustic wave amplifiers which are by nature bilateral. A unilateral transducer-coupled parametric amplifier is described. Unilateral operation is achieved by the cancellation of excitation in the common idler circuit.

Recent interest in microwave acoustic circuitry and extremely large time-bandwidth delay devices has accentuated the need for surface acoustic wave amplifiers. This paper discusses the amplification of surface waves by coupling negative resistance amplifiers to the propagating surface wave.

The coupling of a single negative resistance amplifier to a propagating acoustic wave by an interdigital electroacoustic transducer has been discussed in the literature.[1,2] Such an arrangement was found to have reflection gain as well as transmission gain. By coupling two amplifiers with transducers separated by the correct phase relationship along the propagation path, a surface wave amplifier may be constructed with no reflection gain.[3] The amplifier remains bilateral, however, and would be highly sensitive to output loading.

A unilateral, nonreflecting amplifier may be constructed by coupling to the propagating acoustic wave two parametric amplifiers sharing an idler circuit, FIG.1. The transducers used must be separated by an odd multiple of a quarter wavelength of the propagating surface wave as in the case of the transducers described.[3] The amplifier is unilateral because the nonlinear mixing of the signals in the varactor diodes results in the reinforcing of idler excitation when the signal is propagating in the desired direction and a cancellation of idler excitation when the signal is propagating in the reverse direction.

In the conventional analysis of varactor parametric amplifiers, it is shown that the idler voltage is a function of the relative phases of the pump and the signal.[4]

$$V_{idler} = k_1 \, e^{j(\theta_p + \theta_s)} \tag{1}$$

where k_1 is a proportionality factor and θ_p and θ_s are the relative phases of the pump and signal respectively. If we consider a wave propagating to the right under the center transducer of FIG.1, we see that the idler voltage generated by the varactor on the left (which is pumped with zero relative phase) has a total phase

$$\theta_p + \theta_s = \varphi , \tag{2}$$

since

$$\theta_p = 0$$

and

$$\theta_s = \varphi .$$

φ is the initial phase of the signal relative to the pump. The idler voltage generated by the varactor at the right (which is pumped with a $-\pi/2$ phase) also has the total phase

$$\theta_p + \theta_s = \varphi \ ,$$

since

$$\theta_p = -\pi/2$$

and (3)

$$\theta_s = (\varphi+\pi/2)$$

The two idler voltages are then in phase, and amplification takes place.

If the wave is propagating to the left, however, the idler voltage due to the right varactor has the phase

$$\theta_p + \theta_s = (-\pi/2) + (\varphi) \ , \tag{4}$$

while that due to the left varactor has the phase

$$\theta_p + \theta_s = (0) + (\varphi+\pi/2) \ , \tag{5}$$

and the two contributions cancel resulting in no amplification of the surface wave. Equal idler amplitude contributions from both varactors are assumed. Similar phase considerations may be made at the acoustical ports of the transducers to verify that there is no reflection gain for either propagation direction.

Experimental results will be presented for amplifiers on $LiNbO_3$ and $Bi_{12}GeO_{20}$ at 50 and 100 MHz.

References

1. A.J.Bahr, "Reflection and Amplification of Acoustic Surface Waves by Interdigital Transducers with Active Circuit Loading," IEEE Trans, MTT-18, No.9,

2. G.Chao, "Parametric Amplification of Surface Acoustic Waves," App.Phys.Ltrs., 16, No.10, pg.399 (15 May 1970)

3. R.Krimholtz and G.L.Matthaei, "Amplification of Acoustic Surface Waves by Means of a Broadband Hybrid-Junction Transducer and Negative-Resistance Circuit," Elec.Ltrs., 7, No.9, pg.233 (6 May 1971). The transducer described by Collins et al, "Unidirectional Surface Wave Transducer," Proc.IEEE, 57,

pg.833 (May 1969) may also be used if it is used as a four-port. These two transducers are similar since they rely on a quarter-wave phasing between two like transducers. In the case of Krimholtz and Matthaei, the two like transducers are interleaved.

4. L.A.Blackwell and K.L.Kotzebue, Semiconductor-Diode Parametric Amplifiers, Prentice-Hall, Inc. Englewood Cliffs, New Jersey (1961).

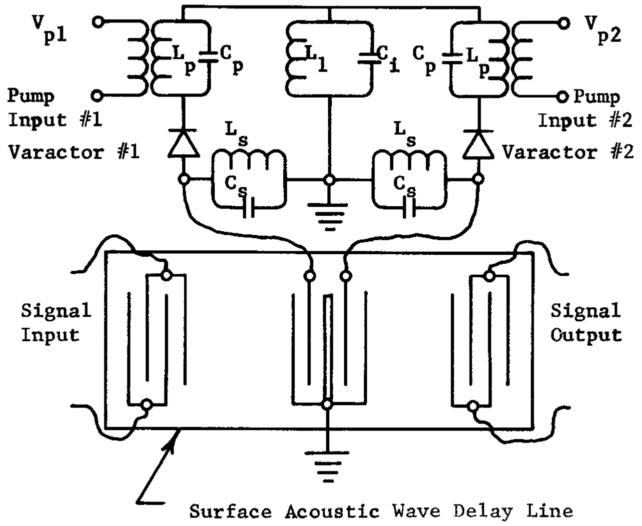

Figure Caption

FIG.1: Unilateral surface wave parametric amplifier. Subscript designations:

s = signal,

p = pump,

i = idler,

$V_{p1} = A\ e^{j\omega_p t}$

$V_{p2} = A\ e^{j(\omega_p t\ -\ \pi/2)}$

The two like transducers making up the center transducer are separated by a quarter wavelength, denoted by the wide line in the center.