Simple Analysis of Insertion-Loss and Triple-Transit-Echo in SAW Unidirectional Transducers

Jun Yamada

Semiconductors & Integrated Circuits Group, Hitachi Ltd.

Nippon Bildg., 6-2, Otemachi 2-Chome, Chiyoda-ku, Tokyo, 100-0004 Japan

Tel:+81-3-5201-5070 Fax:+81-3-3270-5210

E-Mail:yamada-jun@sic.hitachi.co.jp

Abstract: The scattering matrix of SAW unidirectional transducers is calculated on the assumption that is passive, reversible and lossless. Then the insetion loss and the triple transit echo are obtained as a function of the normalized radiation conductance. The propriety of the theoretical results is verified by experiments.

INTRODUCTION

Much research and development of Surface Acoustic Wave (SAW) filters has been performed to obtain good performance and cost/size reduction of their electric circuits. This paper describes a simple analysis of the scattering matrix in SAW unidirectional transducers and the experimental results when external electrical load changes.

A detailed knowledge of the reflection and transmission characteristics of the unidirectional transducers is necessary in the design of the low loss filters for the signal processing applications. We consider the transducers as taps whose scattering characteristics vary as a function of the electrical termination, and then obtain the insetion loss and the triple transit echo of the filter.

SCATTERING MATRIX

Unidirectional transducers can be indicated as the three pair ported network shown in Fig. 1, which is identical with bidirectional transducers. In the network, an acoustic wave is incident at port 1, port 2 is acoustically terminated, and port 3 is electrically terminated in load conductance *Gl*. An electical 90 degree phase shifter is included in the network.

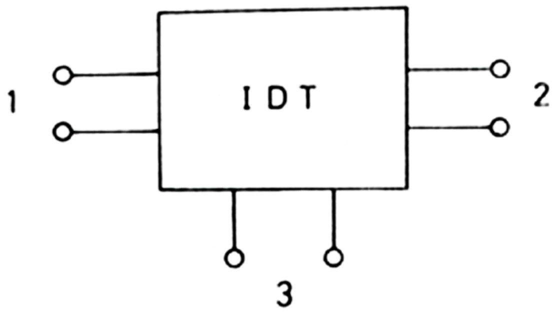

Fig.1. Schematic of an interdigital transducer with three pair of ports.

The scattering matrix of the transducer is expressed as *(S)*. The matrix is symmetric and the therefore the network is reversible.

$$S_{ij} = S_{ji} \quad , \quad i,j = \quad 1,2,3 \tag{1}$$

The following equation would hold true the conservation theory of energy if the network is passive and lossless.

$$(S^*)(S) = (E) \tag{2}$$

where * and *(E)* indicate the complex conjugation and a unit matrix respecrtively. We assume for purposes of simple treatment that S_{ij} is real.

$$(S^*) = (S) \tag{3}$$

The each element of the matrix is replaced as follows.

$$S_{31} = S_{13} = p \tag{4}$$
$$S_{32} = S_{23} = q \tag{5}$$
$$S_{33} = r \tag{6}$$

The following relations are found to be

$$p^2 + q^2 = 4GaGl / (Ga+Gl)^2 = 4b / (1+b)^2 \tag{7}$$
$$r^2 = (Gl-Ga)^2 / (Ga+Gl)^2 = (b-1)^2 / (b+1)^2 \tag{8}$$

where *Ga* , *Gl* and the quantity *b* are defined as the radiation conductance of the transducers, electrical conductance of applied load and the normalized conductance (=*Gl / Ga*).

INSERTION LOSS AND TRIPLE TRANSIT ECHO

The insertion loss L_{31} and the triple transit echo (TTE) L_{11} are defined in dB by the scattering matrix of the transducers.

$$L_{31} = -10 \log (S_{31})^2 \tag{9}$$
$$L_{11} = -10 \log (S_{11})^2 \tag{10}$$

The reflection S_{11} can be calculated by the above equations.

$$(S_{11})^2 = (q^2 \pm p^2 r)^2 / (p^2+q^2)^2 \tag{11}$$

Here, an index *a* is introduced for the directivity of the surface wave propagation.

$$q^2 = a\, p^2 \tag{12}$$

The definition means the transducers are unidirectional or bidirectional when the index a is zero or one respectively. Thus the reflection S_{11} and transmission S_{31} are expressed as a function of the index at synchronism.

$$(S_{11})^2 = (a-r)^2 / (a+1)^2 \qquad (13)$$

$$(S_{31})^2 = 4b / (1+a)(1+b)^2 \qquad (14)$$

The negative sign of the reflection r in the electrical port is elected in accordance with ref.2 in the crossed field model, which is true in case of bidirectional transducers.

The insertion loss and the triple transit echo are obtained in Fig.2 as a function of normalized conductance for shunt resonant electrical load when the index changes.

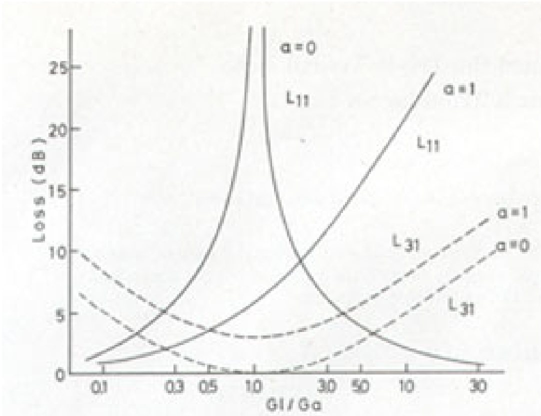

Fig.2. Acoustic reflection and conversion loss as a function of normalized conductance.

Caluculated results are put in order as follows.

(1) $a = 0$ (unidirectional)

$$(S_{11})^2 = (b-1)^2 / (b+1)^2 \qquad (15)$$

$$(S_{31})^2 = 4b / (1+b)^2 \qquad (16)$$

(2) $a = 1$ (bidirectional)

$$(S_{11})^2 = 1 / (1+b)^2 \qquad (17)$$

$$(S_{31})^2 = 2b / (1+b)^2 \qquad (18)$$

EXPERIMENTAL RESULTS

Electrode pattern of interdigital transducer is shown in Fig.3. Apodized electrode is bidirectional transduces, which is designed for the low loss TV-IF filter application by using an impulse model. And a 128 degree rotated Y cut and X propagation $LiNbO_3$ is used as a piezoelectric substrate.

Non-apodized transduder are four pair and three group electrodes. Apodized transducers are 50 pairs and varying pitch electrodes. A Bessel type 90^o phase shifter is used (L= 1.8 H and r =130 ohms) in unidirectional transducers.

The insertion loss and triple transit echo are measured when the source conductance Gl changes with bidirectional transducers tuned for a conjugate matched condition. The experimental results are shown in Fig.4.

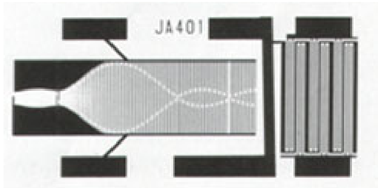

Fig .3. Electrode pattern of interdigital transducers.

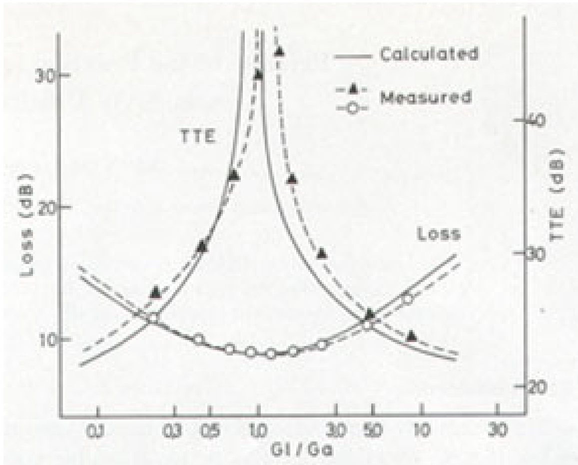

Fig.4. Measured data and calculated curves of insertion loss and triple transit echo.

CONCLUSION

The reflection and conversion losses of SAW unidirectional transducers are obtained as a function of the normalized radiation conductance from the scattering matrix, which is calculated on the assumption that it is passive, reversible and lossless. Then the propriety of the theoretical results is verified by measuring the insertion loss and triple transit echo when the electrical load changes.

REFERENCES

(1) K.Yamanouchi, N.Nyffeler and K.Shibayama:*Proc. IEEE Ultrasonics Symposium* (1975), p.317.

(2) W.R.Smith,H.M.Gerard,J.H.Collins,T.M.Reeder and H.J.Shaw:IEEE Trans.,**MTT-17**(1969)856.