THE SURFACE ACOUSTIC WAVE REFLECTIVE DOT ARRAY (RDA)

Leland P. Solie
Sperry Research Center
Sudbury, Massachusetts 01776

Abstract

A new type of reflective array device is described in which the array of reflecting grooves is replaced by an array of reflecting metallic dots. This Reflective Dot Array or RDA has the principal advantage of being part of the same mask and metalization as the transducers allowing single step fabrication. A bandpass filter operating at 213 MHz with a bandwidth of 6 MHz, which was fabricated using this technique, has a passband to sidelobe ratio of over 50 dB.

Introduction

Passive surface acoustic wave (SAW) devices are capable of performing a number of signal processing functions. The most common technique has been to design the surface wave transducer to perform the signal processing operation. The type of operation which could be performed is determined by the geometrical layout of the interdigital electrodes that excite or detect the surface wave. Another class of SAW devices developed which used etched grooves to reflect the SAW into another acoustic track where it could be detected. In these devices the layout and reflective properties of the grooves determine the signal processing operation to be performed. The most common reflecting groove device is the reflective array compressor (RAC) with which time bandwidth products as high as 10,000 have been realized.[1-4] The reflective groove arrays have also been used very successfully to fabricate bandpass filters.[5,6]

There are several reasons why these devices perform so well. (1) Spurious bulk modes and pseudo surface modes are reflected at different angles and thus will not be detected by the output transducer. (2) The structure is quite defect tolerant. (3) There is no effect equivalent to regeneration in a reflective array. (4) Resolution requirements are relaxed. (5) Another advantage of a reflective groove device is that the reflections are not dependent upon the piezoelectric coupling factor $\Delta v/v$. (6) Finally, in contrast to apodized transducers, the grooves achieve true amplitude weighting uniformly across the beam and thus diffraction is not a problem.

A major limitation to the reflecting groove devices is the cost and complexity of fabricating them. There are (1) the initial cost of the ion beam etching equipment and (2) the time and cost of serial etching; i.e., each substrate must be precisely aligned with respect to a movable mechanical mask in which the groove depth (tap weight) is proportional to the total time that the mask exposes the groove to the ion beam. Finally, there is the cost and time of the two-step fabrication. The etched grooves require one mask and the metalized transducers a second. The two patterns must be aligned very precisely with respect to each other.

The high cost of the reflecting groove devices is no problem for one-of-a-kind radar system applications where there may not be a satisfactory alternative to the RAC at any price, but this is not true for high volume devices. What is needed is a metalized RAC. Then the entire device could be fabricated in a single metalization step and the cost and time limitations listed above could be avoided.

The Relfective Dot Array

The need for a metalized RAC can be met with a device which we shall call a Reflective Dot Array or RDA (for the purposes of this discussion we shall refer to any reflecting groove device as an RAC devices regardless of whether it is a pulse compression filter, expansion filter, bandpass filter, etc.).

The RDA device may be described as a RAC device in which each reflecting groove has been replaced by a row of metallic dots. The reflections from each dot create a nearly circularly symmetric wavefront, part of which intersects an interdigital transducer. The response detected by a transducer from a single dot is somewhat complicated to calculate, but it is reasonable to assume that, whatever its response, it will be the same for each dot (neglecting a possible phase shift due to the relative position of the dots) if the dots are identical in shape and size. For a row of N dots at the appropriate angle the responses will be in identical phase with one another so that the total response from the row as measured at the output transducer is N times the response of a single dot. Thus the number of dots in a row is proportional to its desired tap weight provided the dots are far enough apart so that the strain fields not not interact with each other and alter the reflectivity of each dot. All the dots are the same size and shape; they may be round, square, rectangular, etc., but should not be much larger than $\lambda/4$. Since the dots are small compared to a wavelength, they do not short out the electric fields at the surface as would a continuous metal film. The potential at each dot is floating at the potential induced by the piezoelectric surface wave.

The relative weighting between taps is fixed by the number of dots in each row while the overall weighting may be controlled by varying the metal thickness (which is uniform across the sample). Generally a metal thickness is desired which yields the lowest insertion loss without introducing significant second order distortion effects.

The advantages of an RDA device over a filter using interdigital transducers are exactly the same as listed earlier for a RAC device. In addition, the RDA has the advantage over the RAC in that multiple reflections within the RDA are not coherent and thus do not distort the device response. Thus the advantages of a metalized RAC have been achieved, i.e., single step fabrication, no critical mask alignments and no serial etching.

Experimental Results

A bandpass filter has been designed and fabricated on Y cut $LiNbO_3$ using an RDA. The center frequency was 213 MHz with a 3 dB bandwidth of 6 MHz. The results shown in Fig. 1(a) show an out of band rejection of over 50 dB below the passband. The passband is shown in more detail in Fig. 1(b) where the ripple is seen to be less than 0.2 dB. The insertion loss with both transducers untuned was 42 dB. The Z and X propagating transducers accounted for 10 dB and 14 dB, respectively,

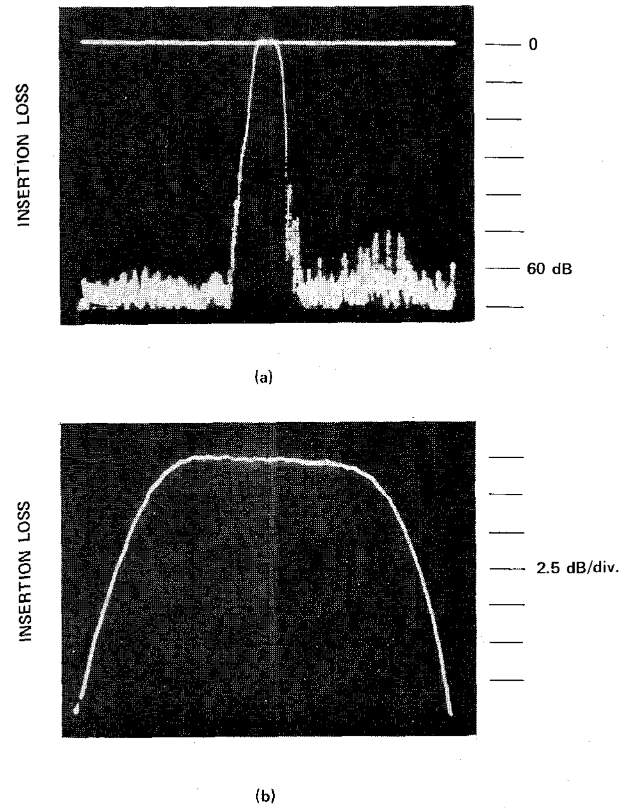

FIG. 1 Relative insertion loss for the RDA bandpass filter, f_c = 213 MHz.
(a) 10 MHz/horizontal div, 10 dB/vertical div;
(b) 1 MHz/horizontal div, 2.5 dB/vertical div.

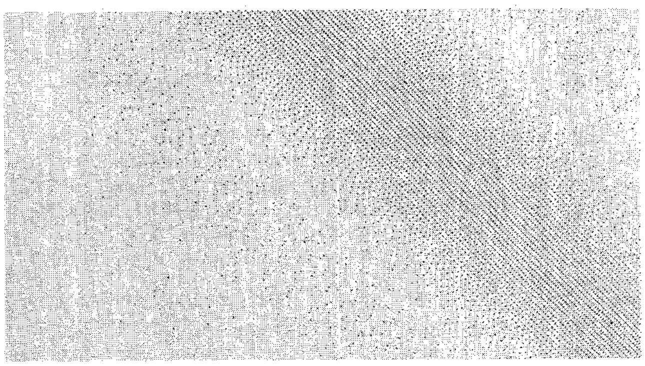

FIG. 2 A section of the RDA pattern.

leaving a reflection loss of 18 dB in the RDA. The metalization consisted of 200 Å of Cr followed by 4000 Å of Aℓ. A section of the dot array showing part of the main lobe and the first sidelobe is shown in Fig. 2. The dots are evenly spaced within a given row. The center line of the main lobe has 300 dots and all others proportionately less depending upon their relative tap weights.

The reflectivity loss can be reduced by increasing the metal film thickness. However, this introduces a phase error in the response because the film thickness become sufficiently large to decrease the surface wave velocity in the area of the dot array with a high density of dots (e.g., in the center of the main lobe). It is possible to compensate for this phase error in the design of the mask by assuming that the reduction in the localized surface wave velocity is proportional to the density of dots. This has been done with the result that the phase error is removed and with a film thickness of 5500 Å the reflection loss has been reduced to under 10 dB.

References

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