International Journal of Scientific Engineering and Technology(ISSN:Applied)

Volume No.1,Issue No.1 pg:16-22 Dec.2011

SAW Filter Performance Improvement

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Abstract: **Surface acoustic wave (SAW) filters have a wide range of applications, including, for example, in mobile/wireless transceivers, radio frequency (RF) filters, intermediate frequency (IF) filters, resonator-filters, filters for mobile and wireless circuits, IF filters in a base transceiver station (BTS), RF front-end filters for mobile/wireless circuitry, multimode frequency-agile oscillators for spread-spectrum secure communications, nyquist filters for microwave digital radio, voltage controlled oscillators for first or second stage mixing in mobile transceivers, delay lines for low power time-diversity wireless receivers, pseudo-noise-coded delay lines for combined code division multiple access/time division multiple access (CDMA/TDMA) access, clock recovery filters for fiber-optics communication repeater stages, synchronous, spread-spectrum communications, televisions, video recorders, and many other applications. SAW filters are also finding increasing use as picture-signal intermediate-frequency (PIF) filters, vestigial sideband (VSB) filters, and other types of communication filters, and as filters for digital signal processing [1]. It is, however, supported and lead by various technologies of public communication systems such as fiber optics, digital microwave and satellites. Various custom SAW devices for public communication systems have been already widely used and still progress [2].**

This paper describes various methods to minimize some of the distortions in SAW filter. It includes bulk wave distortion and feed through distortion.

I. Introduction

Surface acoustic waves are mechanical waves that can be generated on the surface of piezo-electric substrates. A SAW filter consists of aluminum input and output interdigital transducers (IDT) on top of a piezoelectric substrate (Fig. 1**),** which are connected by bond wires to the pins of a hermetically sealed package. SAW devices allow the design of transversal filters in the range from 20MHz to more than 2.5GHz. Time lengths are limited by 16 ps. Within these limitations the amplitude and phase can be designed independently of each other. Precise simulation tools for SAW devices are available. Simulation and measurement are in good agreement. Thus it is possible to optimize the SAW devices on a computer before fabrication of the first samples**.** Very accurate SAW devices performing complex signal processing in communication systems may be designed [3]. This paper explains the some of the possible ways to improve the performance so that Simulation and measurement remains in good agreement. Small amount of performance improvement can be very useful in order to improve whole system performance.

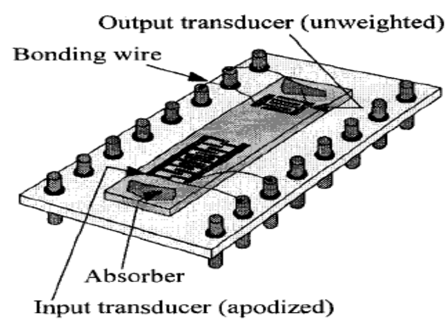

Figure1: Schematic drawing of a SAW filter. [3] II.

BULK WAVE

Widely used piezo-electric substrate for SAW filter is quartz, LiNbO3, LiNTaO3. Selection of the substrate material depends on the design requirement. Substrate with different directional cut offers different characteristic.

Bulk wave transmission is a serious problem in SAW transversal filters. Generally, both direct and indirect bulk wave transmission is possible in SAW filters (Fig.2). In the first case the waves are transmitted directly along the crystal surface and in the second one their path includes one or more bounce off the bottom of the crystal. This transmission degrades filter stop band especially on the high frequency side of the pass band. One way to cope with the problem is the use of a multistrip coupler (MSC). However, this solution leads to the increase of both the size and the cost of the device [3]. Fig. 3 (a) & (b) shows the some of the possible configuration of inserting MSC. MSC is connected to common ground plane.

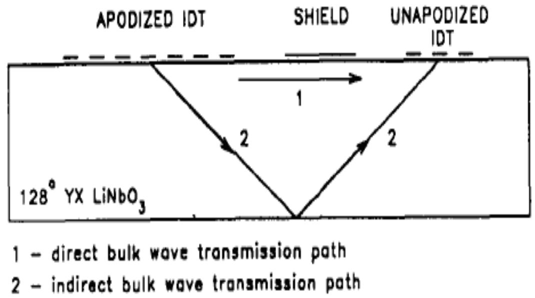

Fig.

Figure 2: Schematic outline of the SAW filter [4] We do not

have much control over directly transmitted shear waves, how ever their effect is relatively small (within some specified range) if appropriate directional cut of a wafer is selected. Substantial amounts of bulk wave energy in the filter were transmitted within the time window corresponding to Rayleigh wave propagation and/or within the frequency range of the filter pass band. To suppress Rayleigh wave propagation the upper surfaces of some filter chips were covered with an acoustic absorber (epoxy resin).

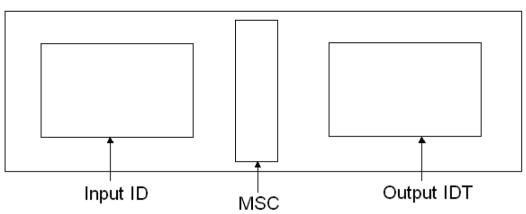

Figure 3(a): SAW filter with MSC

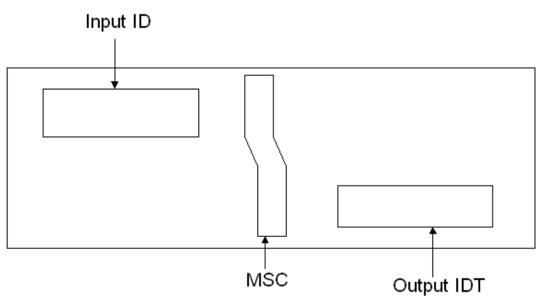

Figure 3(b): SAW filter with MSC

Effect of Indirect bulk wave can be substantially reduced by an appropriate roughening of the crystal backside. Two possible ways of roughening the crystal backside are A) Backside grooving and B) Sandblasting.

A) Backside grooving

- It can be done in two different ways as shown in Fig.4 (a) and (b).
- Size and spacing between two grooves generally depends on the operating frequency of the device.
- Selecting the angle of the grooves with respect to the direction of propagation is very important factor.
- This technique can be used for mass production of commercial devices.

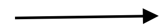

Figure 4(a): Backside grooving

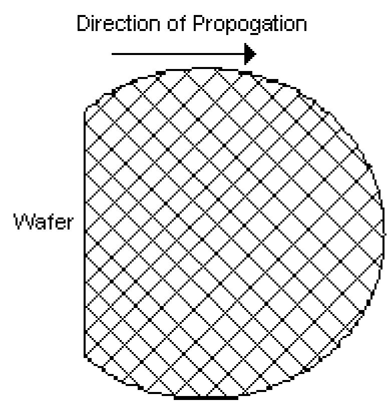

Figure 4(b): Backside grooving

B) Sandblasting (Fig.5)

- Sandblasting is a random process, carried out for some fixed time duration (Based on experimental results).
- Selecting the size of sand particles, exposure time and the flow rate is very important.
- Sandblasting is a random process so it requires lots of R&D work to achieve desired response. It is not suited for mass production (with good accuracy). However it is used in some military and space applications.

Selection of the roughening technique totally depends on the system requirements and the results produced by particular technique.

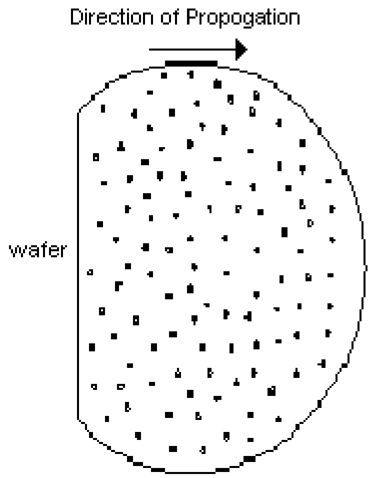

Figure 5: Backside Sandblasting

For 128 YX LiNbO3 the effect of grooving on the filter amplitude response can be evaluated by comparison of Figs. 6 and 7. Application of grooving substantially improves stop band rejection of the filter. At some frequencies the improvement is greater than 20 dB. The improvement is observed on both sides of the pass band [4].

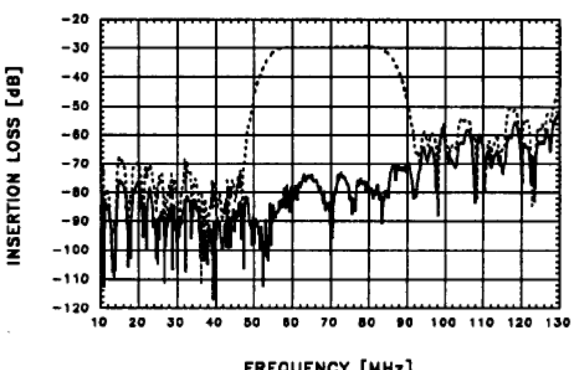

Figure 6: Measured amplitude responses of the ungrooved filter

- - - - before covering the chip with epoxy resin
________after covering the chip with epoxy resin [4]

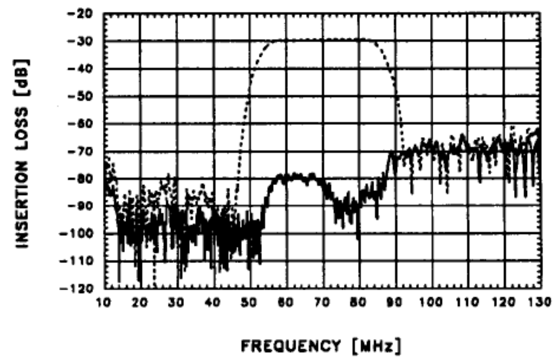

Figure 7: Measured amplitude responses of the grooved filter

- - - - - before covering the chip with epoxy resin
________after covering the chip with epoxy resin [4]

Improvement varies depending on the substrate type and its directional cut.

III. FEEDTHROUGH

After SAW device is placed in packages and secured by adhesive. Bond wires are attached between pads on the device and the package, giving connections to the external terminals. The packages are sealed. The next step is mounting this package on printed circuit board (PCB). To match the impedance of the device with the system, external impedance matching components are needed, and these are usually added on PCB. At this stage, it is important to minimize feedthrough, which can degrade the stop-band rejection by generating spikes in the stop-band. Feedthrough can be caused by inductive or capacitive coupling between the input and output, or by a ground loop [5].

The SAW matched filters can be realized with the structure called tapped delay line. It has one input and several output taps with different delay times. Figure 2 illustrates a basic configuration of the conventional SAW matched filter [6].

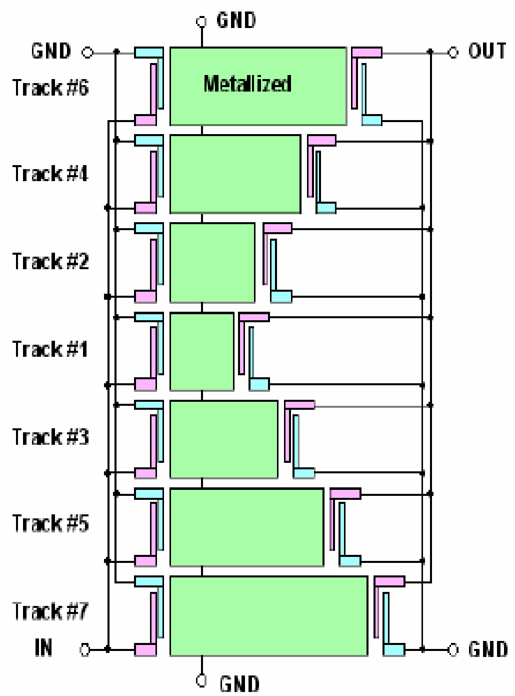

Figure 8: Conventional SAW matched filter consisting of multi-track tapped delay lines.

Figure 8 shows an impulse response of the fabricated device. We can hardly observe the main response of SAW, as shown in Fig. 9(a). In Fig. 9(b), the feed-through response is much larger than the desired time response. It is found that the parasitic elements degrade the performance of the SAW matched filter in the high frequency range. In Fig. 10, the correlation properties are awfully degraded by the spurious response related to the feed-through. The D/U ratio is getting worse to 1.6 [6].

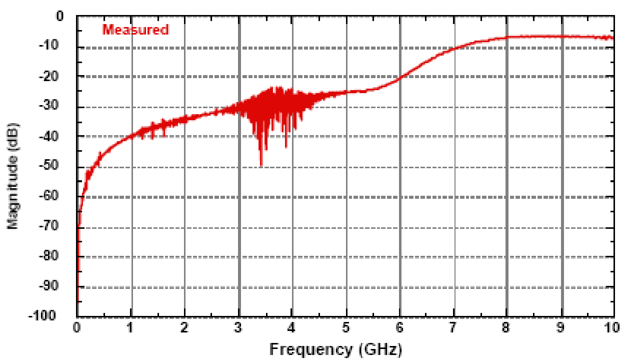

Figure 9 (a): Impulse responses of the conventional SAW matched filter. (Frequency domain)[6]

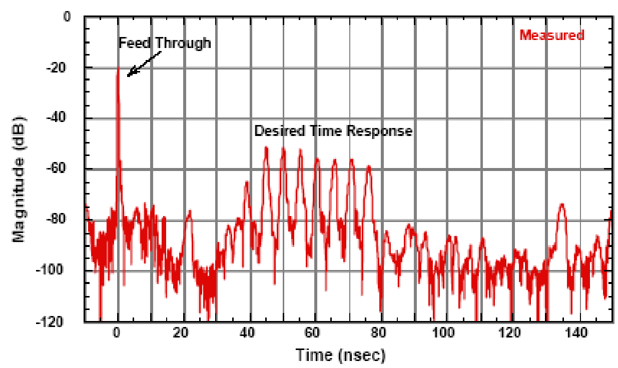

Figure 9 (b): Impulse responses of the conventional SAW matched filter. (Time domain) [6]

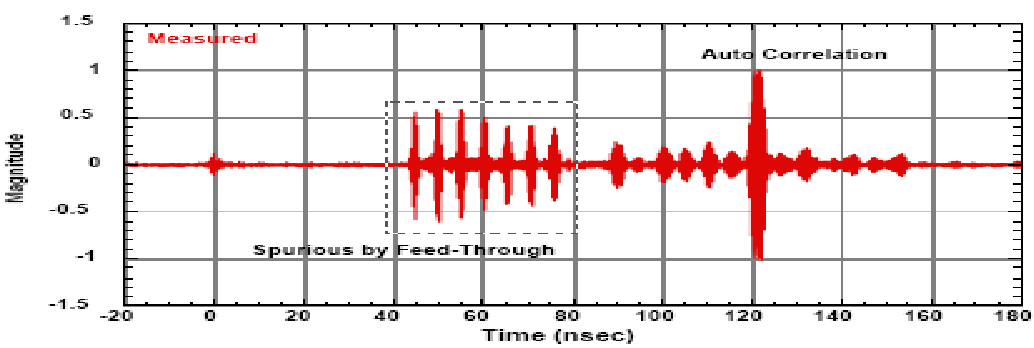

Figure 10: Correlation properties of the conventional SAW matched filter.

Proposed new configuration of SAW matched filters as illustrated in Fig. 11, in order to solve the feed-through problem. The new configuration has a single-ended input and balanced outputs. The input-output1 and input-output2 patterns are designed to be symmetrical. The individual feed-through signals of output1 and output2 are in phase and the same magnitude, because of the symmetrical device pattern. On the contrary, the SAW IDT structures are designed as both desired output signals are out of phase. Consequently, the feed-through signals can be canceled and only the desired signal can be detected by using a balun [6].

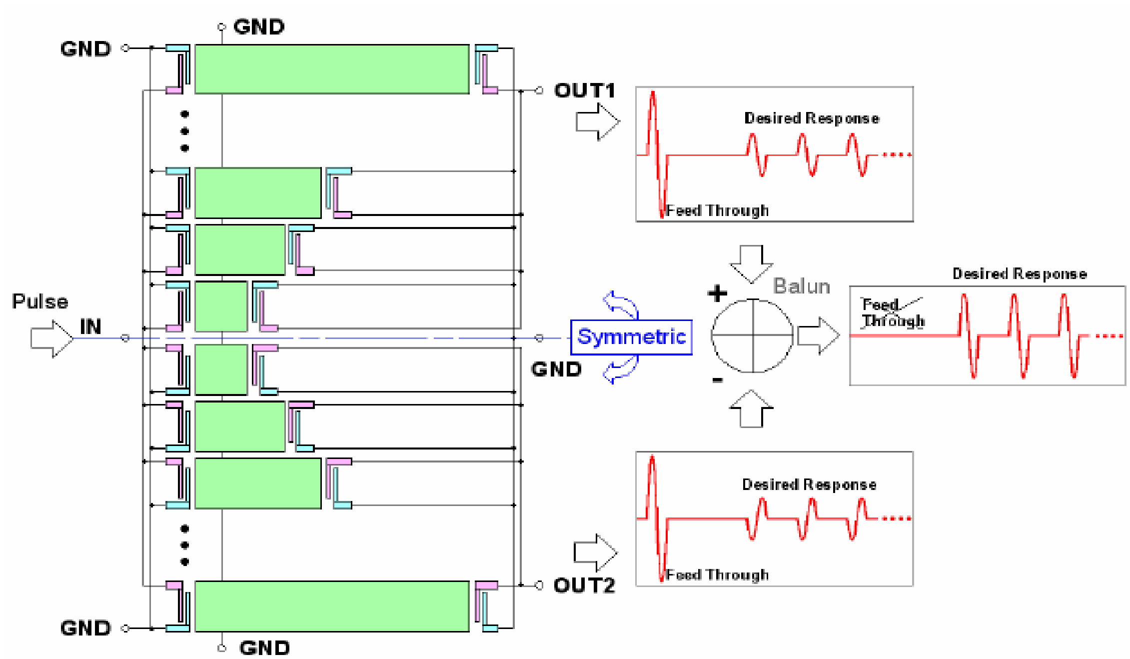

Figure 11: Feed-through cancellation concept by symmetrical configuration. [6]

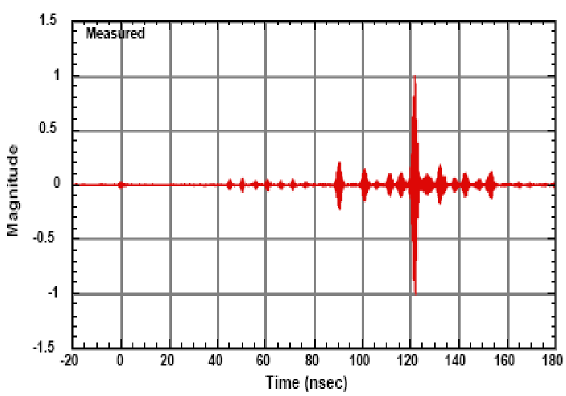

Figure 12: Correlation properties of the new SAW matched filter with symmetrical configuration.

To reduce the feedthrough effect some modifications can also be done at PCB level. Inserting cuts/slots on PCB (Fig. 13) can help to improve the overall filter performance.

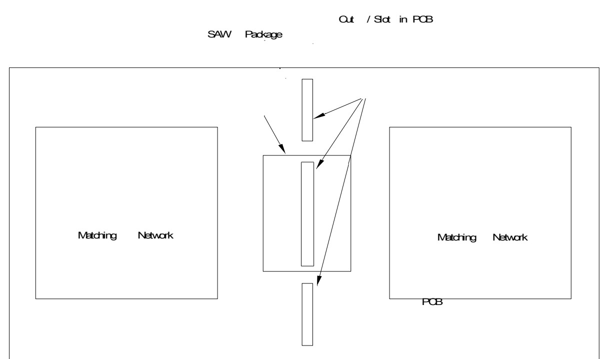

Figure 13: Modification in PCB III.

CONCLUSION

Paper presented the performance improvement in SAW filter stop band response by using MSC, backside surface roughening, symmetric configuration and some modification in PCB. Typically 7 to 20 dB improvement in stop band is achievable. This can be very useful in achieving desired specifications.

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