Paper II

Anomalous asymmetric acoustic radiation in low-loss SAW filters

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Anomalous asymmetric acoustic radiation in low-loss SAW filters

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The experimental discovery of a novel acoustic loss mechanism in SAW filters at RF frequencies is reported. The phenomenon is characterised by an unexpected spatial distribution of the surface-acoustic wave field. The observation and measurements were performed with a specially constructed scanning laser-interferometric probe. Current simulation methods and known phenomenological models applied to SAW resonators have no predictive ability to describe the discovered effect.

Introduction: Surface acoustic wave (SAW) devices are widely employed in the RF circuits of cordless and cellular phones. Recently, significant improvements in the power durability of RF-band SAW filters were reported [1]. In addition to the high power tolerance, low insertion loss (IL) is also critical for achieving acceptable performance in cellular phones. SAW impedance element filters (IEFs), based on interdigital transducer (IDT) resonators, have proven to be the best SAW device for achieving low losses and high power durability. In this Letter we report a novel acoustic loss mechanism in IEF devices.

We have investigated the acoustic operation of IDT resonators as used in SAW impedance element filters designed for mobile-communication applications. A scanning laser interferometer was used to perform non-contact high-resolution two-dimensional probing of the surface acoustic wave field. Our Michelson interferometer features a high sensitivity of 10^{-4} Å/√Hz, sufficient for probing leaky waves at GSM frequencies (~1 GHz). The lateral resolution of the measured field image is better than 1 µm. An optical image of the scanned area is obtained simultaneously with the amplitude image; a detailed description of the setup can be found in [2].

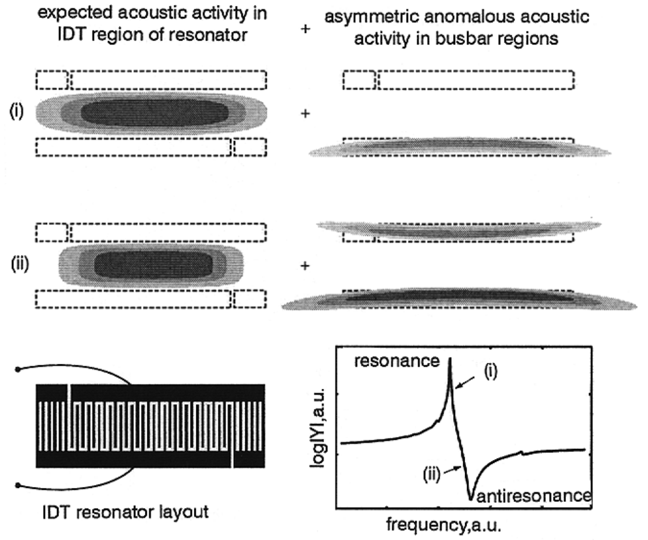

Fig. 1 *Observed acoustic activity is sum total of expected symmetric activity in IDT region plus anomalous asymmetric activity in busbar regions*

First and second rows illustrate observed activity near resonance and antiresonance, respectively
Bottom row illustrates structure and admittance properties of typical resonator

Results: Several SAW filters from different manufacturers have been probed. The devices apply the IEF scheme and utilise leaky waves on $LiTaO_3$. The unexpected acoustic radiation was discovered in all of the samples probed. Fig. 1 gives a schematic illustration of the observed effect. The expected acoustic activity on top of the active finger structure is displayed on the LHS at the two frequency points (i) and (ii) between the resonance and antiresonance frequencies of the filter. The RHS shows the additional spatially asymmetric acoustic radiation observed on top of the inactive busbar area.

Probed images from a series resonator of an IEF duplexer are displayed in Fig. 2. The substrate is 36°YX-cut $LiTaO_3$ where the SAW mode used is a leaky wave. Fig. 2*a* displays the scanning area. The number of scanning points is 120 000. At the series resonance frequency of the IDT (Fig. 2*b*), the asymmetric radiation, though possessing weak amplitudes, can be detected on top of the lower busbar metallisation. As expected, the highest acoustic amplitudes are concentrated on top of the active IDT area. However, above the series resonance (Fig. 2*c*) the asymmetric radiation is evident and results in a manifest leakage of acoustic energy past the reflector grating. Close to the antiresonance frequency of the IDT (Fig. 2*d*), the radiation is most dominant and in addition there appears radiation on the upper edge of the IDT. However, the radiation is still stronger at the lower edge. Finally, at the antiresonance frequency of the IDT (Fig. 2*e*), the radiation appears almost equally intensive at both edges of the IDT.

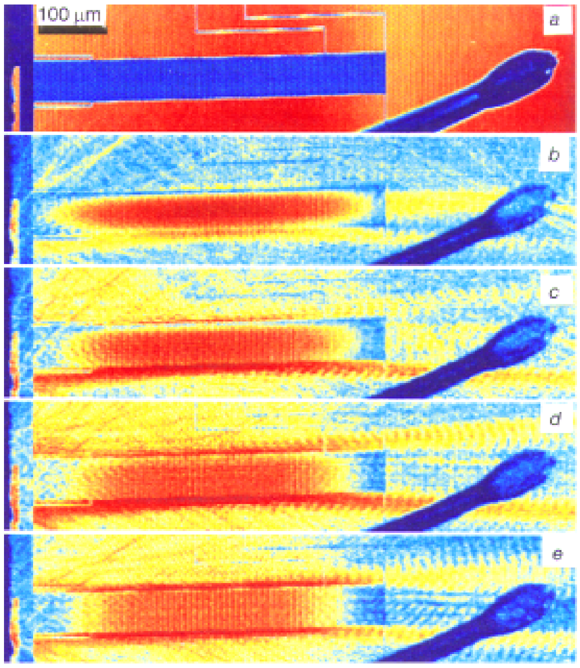

Fig. 2 *Series resonator of low-loss IEF filter*

a Light reflection data plotted for each scanning point
LHS: vertical edge of the substrate is visible
Middle: IDT resonator
RHS: bond wire is shown (diameter 30 µm)
b Acoustic field; 925 MHz (at resonance)
c Acoustic field; 927 MHz (above resonance)
d Acoustic field; 929 MHz (below antiresonance)
e Acoustic field; 933 MHz (at antiresonance)

Several measurements have confirmed that the asymmetry of the radiation is not affected by reversing the polarity of the drive voltage. The asymmetry is also independent of the symmetry of the IDT structure. For a given substrate, the asymmetry of the radiation is invariant, i.e. independent of the electrical conditions or device layout.

Conclusion: We have discovered a novel acoustic two-dimensional radiation mechanism in high-frequency SAW resonators featuring leaky SAWs in $LiTaO_3$ substrates. Currently, no model exists for describing the detected radiation. We assert that the source of this acoustic radiation needs to be identified and addressed in the design of high-performance low-loss SAW filters if the best possible performance is to be achieved.

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