Improved BAW Resonators for RF Applications

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Portable devices like cellular phones for example require the lowest possible power consumption. Significant efforts were made recently to improve the quality factor of the BAW resonators in order to satisfy the specifications in this application field. Q-factors above 800 were achieved.

The driving force for the development of the Bulk Acoustic Wave (BAW) technology is the replacement of the Surface Acoustic Wave (SAW) components in the high frequency telecom applications. A key parameter in this field, and in general in any application dealing with portable devices, is the power consumption. The power consumption of a component is directly linked to its Q-factor (quality factor). Development of BAW resonators with high Q-factors is thus mandatory.

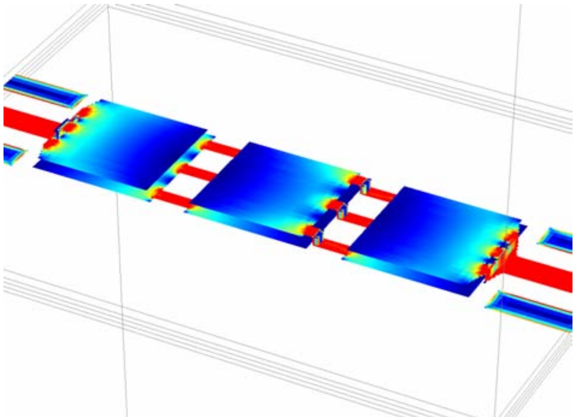

Figure 1: EM current simulation in a structure composed of 3 square BAW resonators in series

Besides low power consumption, a high Q-factor also allows fabricating high precision time references in the form of oscillators [1] . AlN BAW resonators with high Q-factors can advantageously replace high frequency LC-based oscillators by reducing the power consumption by a typical factor 3. Additionally, they present a much lower phase noise.

The early technology developed at CSEM for the fabrication of BAW resonators realized Q-factors in the range of 100 to 400. Significant efforts have been made in the last 2 years to improve these Q-factors. The use of the EM (electromagnetic) simulator Sonnet has given a better understanding of the current distribution in the BAW devices (Figure 1). Consequently, an appropriate design in terms of shape and interconnections was drawn up, leading to an improvement of 40% of the series Q-factor.

Figure 2 shows the magnitude of the impedance versus frequency for a resonator such as the one shown in Figure 3. To analyze the performance of this type of device, it is necessary to fit the measurements with an equivalent circuit. However, since the number of lumped elements in the equivalent circuit is large, too many degrees of freedom exist for the fitting procedure. Therefore EM simulation results are used to set the series resistance and inductance in the equivalent circuit with a good accuracy, and the other elements are then used as fitting parameters. Depending on the value of each lumped element and on its physical meaning, it is then possible to determine how to improve the technology.

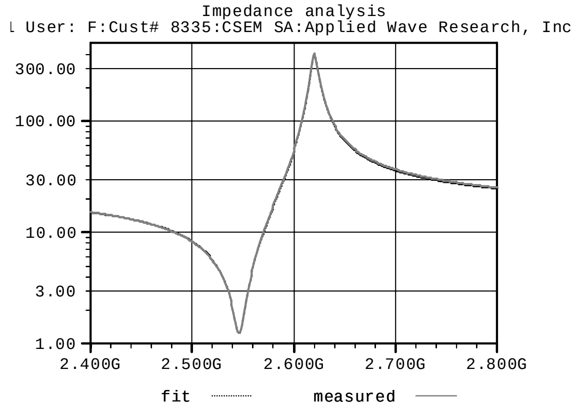

Figure 2: Magnitude of the impedance as a function of the frequency for a resonator @ 2.6 GHz. The measured and fitted curves are perfectly superimposed.

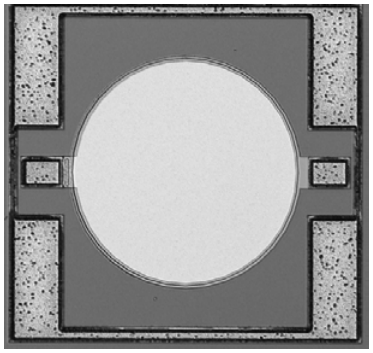

Figure 3: 2-port circular BAW resonator with GSG pads and ground ring

In this particular study, improvement came not only from simulation. Technologywise, the introduction of tungsten, which has excellent acoustic properties, instead of materials with weaker properties led to a substantial increase of the performance of the BAW resonators. Parallel to that, techniques to confine energy in the resonator by minimising the lateral losses were also implemented. Altogether these improvements archieved Q-factors above 800.

The process was realized at CMI-EPFL.

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[1] D. Ruffieux, et al., “An Agile 2.4 GHz MEMS-Based Digital Frequency Synthesizer”, CSEM Scientific and Technical Report 2006