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Q-factor doubling in the acoustoelectronic sensors measurements

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Summary:

Amplitude vary under the influence of environmental factors. Most commonly only frequency shift is measured using self-oscillating circuits with the sensors working in the positive feedback loop. Alternatively, the systems with an external sweeping generator and detector may be applied. Such systems additionally enable tracking of the amplitude and phase of generated signals. All the approaches are well established and allow for the analysis of signals transmitted through the sensors. The investigations of alternative method based on reflection-coefficient measurements brought an unexpected effect of significantly improving Q-factor of the system. The results of comparative measurements show that reflective measurements yield noticeably higher resonance-peak Q-factors than transmissive measurements, while maintaining similar acoustic power. In the experimental systems this coefficient was doubled. As demonstrated by the results, this improvement persists even under substantial mechanical loading of the acoustic parts of the sensors by functional layers. However, this kind of measurement appears to be sensitive to instrumentation-related issues, and its implementation may be challenging but Q-factor doubling increases the accuracy of measurements and allows to apply heavier mass loading.

Keywords: acoustoelectronic sensors, reading parameters system, reflection coefficient measurements

Introduction

The acoustoelectronic sensors with bulk (BAW) and surface wave (SAW) change their mechanical or electrical parameters under the influence of physical factors come from the environment. Commonly to increase the sensitivity and selectivity of the devices, some interface layers are deposited at their acoustically active surfaces. Depending on the layers properties it can be possible to obtain different sensors starting from ultraviolet up to toxic gases and different biological factors.

The acoustoelectronic sensors are parametric and require dedicated electronic circuits for tracking their parameters change under influence of physical factors under measurement.

The changes are commonly observed using two methods. The first one, most popular, is based on self-oscillating electronic circuit with positive feedback loop with acoustoelectronic sensor where the frequency of oscillation is determined by the Barkhausen criterion. The method is simple and operates in analogue form. Alongside the acoustoelectronic device it requires only amplifier and phase shifter in the feedback loop. Such simplicity comes with a limitation to the frequency shift tracking only [e.g.,1, 2].

In the second method, the probing signal with constant amplitude is generated by an external sweeping generator and after passing through the sensor it is received by external detector. As the instantaneous signal is determined, the detection process allows to extract next frequency also phase shift and signal attenuation [e.g.,3, 4].

In some cases, the frequency shift is less informative than the remaining parameters mentioned, so the second method is more versatile. Until recently, the method was not popular due to the availability and precision of measuring equipment. However, the development of modern electronic circuits has changed this situation. Modern vector network analyzers(VNA) have become inexpensive and sufficiently precise measurement tools used, among others, to read changes in acoustoelectronic sensor parameters. They can operate in the frequency range from single kHz

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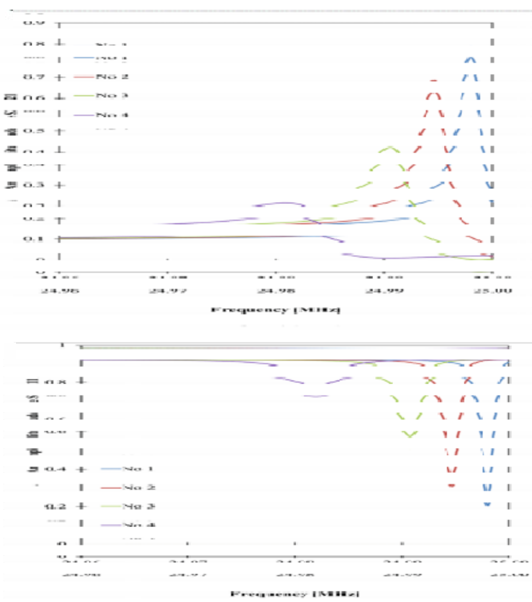
up to GHz, offering a measurement resolution of 1 Hz and additionally the ability to measure signal reflection coefficients from the tested systems. This opens new measurement possibilities. It is worth noting that the methods described above were used exclusively for transmission measurements. Most of the papers devoted to the acoustoelectronic sensors describe one of these two measurement techniques, precisely in the context of transmission measurements.

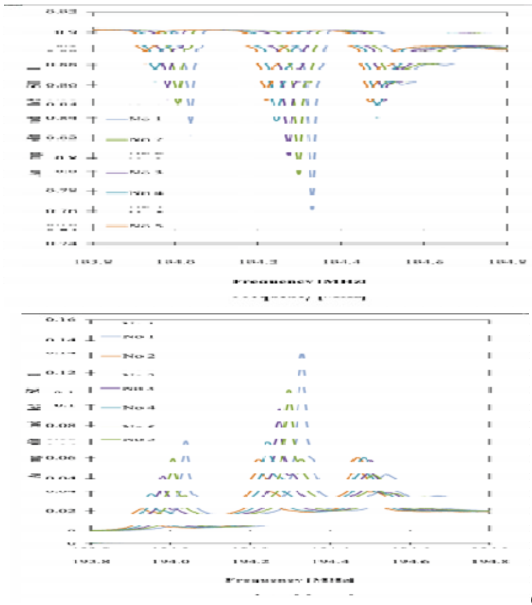
The theoretical analyses show that reflectometry measurements in certain cases offer even more valuable results than the transmission measurements. The difference lies in the configuration of the equivalent circuit, which is revealed after considering the input and output impedances of the measuring device.

Regardless of the topology of the equivalent circuit, in the case of transmission measurements it is always loaded on both sides with the input/output impedances of the measuring device. In reflection measurements, the load is only on one side (second port remains open). This is important because the input and output impedances are typically 50 Ω, thus introducing a significant resistive load on the system being measured. Additional load will always decrease the Q-factor of the system. Due to some symmetry of equivalent circuit this deterioration should be two fold. This is clearly visible in the results of the exemplary measurements (Fig. 1.), which show that this principle applies to both BAW and SAW systems, regardless of their electromechanical load and resonant frequency.



a

b



c

d

Fig. 1. The comparison of the exemplary results of transmission and reflectometry measurements for 25 MHz BAW sensor (a and b respectively) and 194 MHz SAW sensor (c and d). The characteristics are numbered according to the increasing acoustic-mechanical load of the sensor surfaces.

The Q-factor was calculated using Fano resonance model. In most cases the ratio of Q-factor for reflection measurements to Q-factor for transmission measurements was about 1.5. The experimental value is less than 2 due to the systemic shortcomings of the directional couplers and the energy dissipation occurring in them.

Conclusions

The results of measurements show that reflective measurements yield noticeably higher resonance-peak Q-factors than transmissive measurements. In the experimental systems this coefficient was equal to about 1.5. This improvement persists even under substantial mechanical loading of the acoustic parts of the sensors by sensitive layers.

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