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Reflection method of reading acoustoelectronic sensors parameters

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Summary:
The acoustoelectronic sensos change their resonant parameters under influence of the environmental conditions. Usually, the parameters are measured in the self-oscillating circuits or, less frequently, in the systems with an external sweeping generator. Both methods analyze the signal transmitted through the sensor.
The development of modern miniaturized digital systems creates the possibility to apply another measurement method: reflectometry. This method uses signal reflection phenomena from input impedance of the device. The numerous measurements of the quartz crystal microbalances and surface acoustic wave sensors show that the reflectometry is not only applicable to the sensors but also offers some advantages compared to habitual methods. The paper describes a reflection measurement result obtained with miniaturized vector network analyzer.

Keywords: acoustoelectronic sensors, quartz crystal microbalance, sensors redout systems, reflection coefficient measurement, miniaturized vector network analyzers

Introduction

The acoustoelectronic sensors, like quartz crystal microbalances (QCM) or surface wave devices (SAW), change their mechanical and electrical parameters under the influence of physical conditions of environment. The changes may be observed using two methods. The first one is based on frequency change measurements of self-oscillating electronic circuits stabilized with the acoustoelectronic device [1 - 3]. In the second method, the signal is generated by an external sweeping generator, that also allows measurements of amplitude and phase of the signal [4]. Both methods are based on analysis of the signal transmitted through the device. It is worth noting that most papers devoted to the acoustoelectronic sensors set out just such a measurement technique.
Numerous theoretical analyses show that application of reflectometry offers in many cases even better results than the transmission measurements. This principle also applies to acoustoelectronic sensors. The environmental influence on the acoustoelectronic sensors changes not only their resonant characteristics but also their reflectivity by changing the input impedance. Moreover, excessive loading can damp the transmission coefficient of the devices to an unmeasured level, but measuring the reflection coefficient is still possible in this case.

The methods mentioned above are illustrated in Fig. 1.

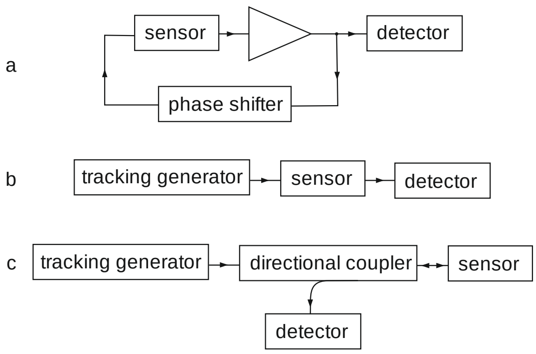

Fig. 1. Three different systems for reading out of acoustoelectronic sensors parameters changes; a – self-oscillating circuit, b – system with an external tracking generator, c – reflectometric system

The system for reflectometric measurements may seem to be overly complex but such kind of measurements is easy to realize using low costs miniaturized digital vector network analyzers (mVNA) [5, 6]. Such a measurement systems are becoming increasingly popular lately.
This kind of electronic circuits analysis was so far reserved rather to the microwave devices. However, the extensive development of modern miniaturized digital measurement systems can change the perception of reflectometry methods including testing of low frequency acoustoelectronic sensors like QCMs and SAWs.

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Measurement set

The block diagram of the exemplary measurement set is illustrated in Fig. 2.

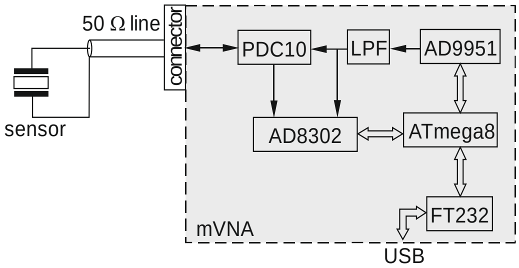

Fig. 2. The configuration of measurement set with internal structure of the mVNA reflectometer

The exemplary reflectometer consists of broadband microwave integrated circuits working from about 1 to 2700 MHz. It consists of broadband directional coupler PDC10, low pass filter LPF, 14-bit direct digital signal synthesizer AD9951, amplitude and phase detector AD8302 and microcontroller ATmega8 to drive the synthesis and detection of the signals as well as to preliminary process the data of the measurements. The data is sent to the external computer via USART/USB converter FT232. The connector (SMA or BNC) allows for connecting the calibration set of the system and then the device under test (DUT). Such a structure allows to measure in the reflection mode: amplitude and phase of return loss, standing wave ratio and complex impedance of the DUT. Some versions of the mVNA have open-source software that allows modifying the internal features of the systems as well as PC user interface.

Exemplary measurement results

The various kinds of sensors were evaluated starting from low frequency QCMs up to SAW devices working on microwave range. In Fig. 3. the resistance and reactance changes of exemplary free and mass-loaded QCM are illustrated.

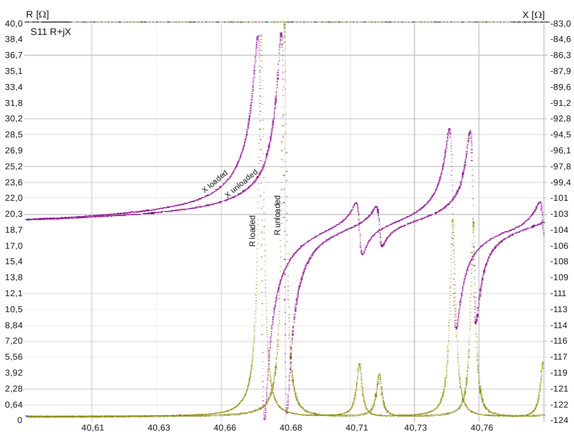

Fig. 3. An exemplary results of 40 MHz QCM measurements using reflectometric mode of mVNA [5]

SAW sensors can be evaluated in a similar way, but some of the devices (like delay lines) may require additional treatment (e.g. short-circuiting of appropriate ports). An exemplary result for Rayleigh wave SAW synchronous resonator is illustrated in Fig. 4.

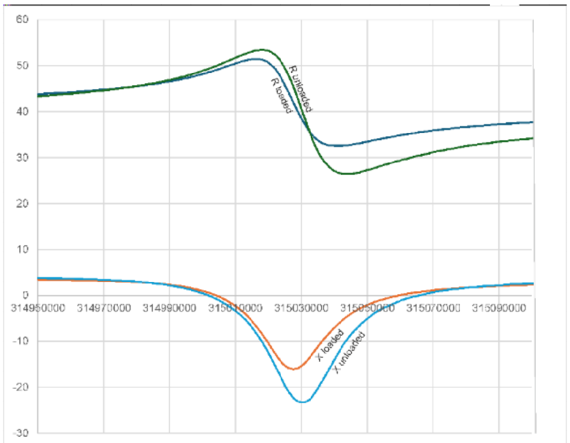

Fig. 4. Characteristic for unloaded and mass-loaded 315 MHz SAW resonator measured using reflection mode of mVNA [6]

The system allows to achieve the frequency resolution of the order 1 Hz.

Conclusions

The reflectometry gives comparable results to transmissive methods but has two important advantages. It allows to measure the sensors with extensive loadings and can requires only one measurement line. This feature may be especially important in applications involving numerous sensors.

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