SAW STABILIZED MICROWAVE GENERATOR ELABORATION

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In order to investigate parameters and design methods of SAW stabilized microwave generators a methodology is elaborated. The generator is divided into four different blocks: SAW resonator, power divider, attenuator, and amplifier. This solution allows each block to be measured and analyzed separately. The amplitude and phase condition for generation can be calculated and the resonant frequency of the oscillator can be predicted. The measurements of the microwave oscillator are done in time and frequency domain by frequency meter and spectrum analyzer. The jitter and the spectrum are observed. The output signal is analyzed, observing the frequency, phase noise (at given offset) and power of the main harmonic and the magnitude and frequency of the other harmonics.

Keywords: SAW, microwave generator, oscillator

1. INTRODUCTION

Surface Acoustic Wave (SAW) devices are used widely in the housekeeping, industrial and military areas [1]. This is due to their unique properties – small size and weight, low price, high reliability and stability in the time. In certain applications they cannot be replaced by other elements because of their unique properties. SAW resonator utilizes SAW, and is able to be applied to high frequency circuit where conventional crystal, ceramic resonators are not available, as SAW resonator oscillates stably with its fundamental mode over frequency range from 50 MHz to around 1,5 GHz. SAW one port resonators have been widely used in oscillators for keyless entry systems [2] These SAW resonators show a very sharp admittance character- ristic due to their high Q-factor.

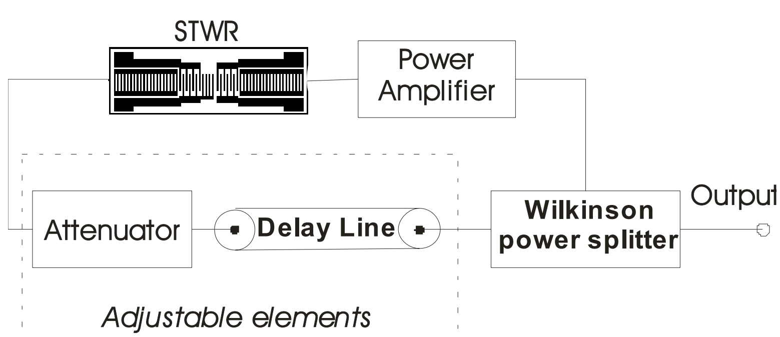

fig. 1. Schematic of the SAW oscillator

2. PROBLEMS

SAW usage requires their characteristics to be known, but suitable design kits by which they will be studied, are still missing. The development of a design kit is presented in this article. It is a SAW-based oscillator (фиг.1) [3]. The design kit allows the different modules to be disconnected. By this way the modules can be analyzed separately each other.

SAW resonators has generally two types of one-port type and two-port type. One-port SAW resonator is a kind of two terminal resonant device utilizing piezoelectricity, like quartz crystal bulk wave resonator or ceramic resonator. The equivalent circuit of one-port SAW resonator is same to that of quartz or ceramic resonator, and therefore, equivalent circuit, basic structure and temperature characteristics of the SAW resonator is as shown in fig.2. This type of SAW resonator has high oscillation frequency stability, good temperature characteristics and is developed with SAW technology. It is also stable against peripheral circuit or supply voltage fluctuation, and is basically free from adjustment. It can be applied to many types of high frequency devices including RF remote controls, demodulators and oscillators [4]. Two-port SAW resonator is a kind of very narrow, low loss band-pass filter. Oscillation circuit is mostly like a RF amplifier with feedback loop.

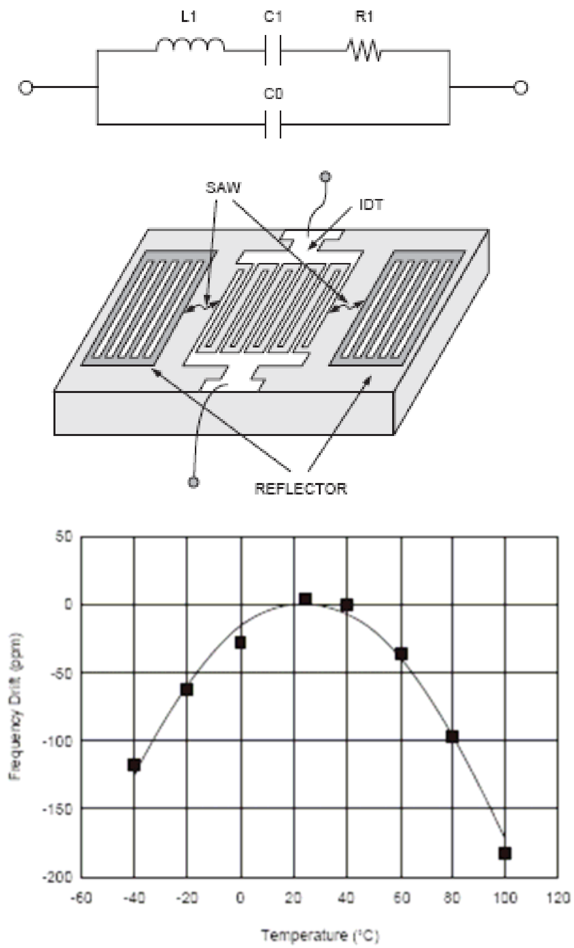

fig. 2. SAW resonator

3. RESULTS

The exercise is divided into two parts and starts with measurement and characterization of the parameters of the built-up blocks, and after that starts the measurement and analyses of the oscillator.

3.1. Measurement and characterization of the parameters of the built-up blocks

The design kit is divided into four modules, and each of them is basic a RF component. Those are: broadband amplifier – it serves to ensure the necessary gain, SAW module – the object under test, attenuator – serves to limit the amplitude of the oscillations, and Wilkinson power divider – serves to carry out a part of the power in the oscillator to external devices, and it preserves the oscillator from load variance. The RF signals are transmitted between the modules by coaxial cables and for this purpose SMA connectors are provided. The overall view is shown on fig. 3. Thanks to the modulus structure, the students will be able to know in details how each module works. This will enlarge their knowledge in the RF field.

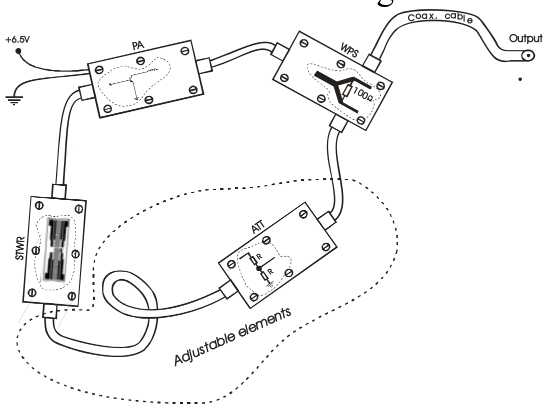

fig. 3. Overall picture of the design kit

In order to start oscillation in a feedback circuit, two conditions must be satisfied – the gain and the phase condition. The first one states that the sum of the gain coefficients of all elements in the chain must be greater than one, and the second condition says that the overall phase delay must be multiple of 360^0. In mathematical expression those conditions are (1), (2):

$$(1)\, G_{PA} + G_{PS} + G_{SAW} \geq 0$$

$$(2)\, \varphi_{PA} + \varphi_{PS} + \varphi_{SAW} \geq 2.\pi.n$$, where

G_i - the gain coefficients of the different blocks,

φ_i - the phase distortion in the different blocks.

The exercise starts with measurement of the amplitude and phase characteristics of the SAW resonator. The purpose is that the students have to extract the resonant frequency, the attenuation at the resonant frequency, the phase distortions, the parasitic capacitance and the quality factor (Q) of the resonator, from the measurements. The amplitude and phase characteristics of the resonator are shown on fig. 4. The quality factor can be determined by three different ways, and the students will have to decide the disadvantages which method is better. The calculation of Q by the amplitude characteristics is performed by determination of the bandwidth at -3dB gain (3):

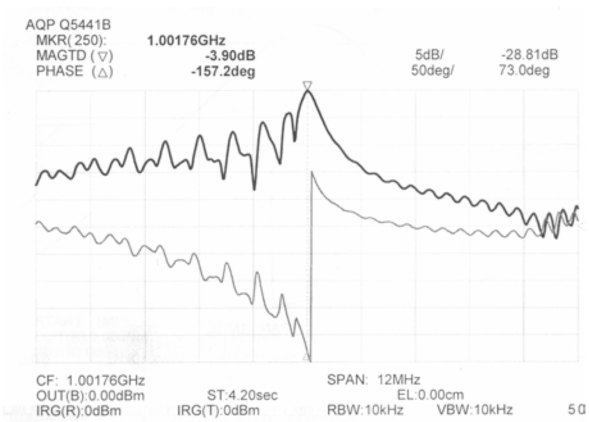

fig. 4. Gain and phase characteristics of the SAW resonator

$$(3)\, Q = \frac{f_{res}}{f_{+3dB} - f_{-3dB}} = \frac{f_{res}}{\Delta f}$$

Q can be also determined measuring the change of the phase at a given frequency change(4):

$$(4)\, Q = \frac{f_{res}}{2}.\left|\frac{\Delta\varphi}{\Delta f}\right|$$

But the change of the phase is nonlinear and that will lead to errors in the Q determination. That is why the time delay of the signal is measured and by that Q is calculated (5) [3]:

$$(5)\ Q = \pi f \tau$$

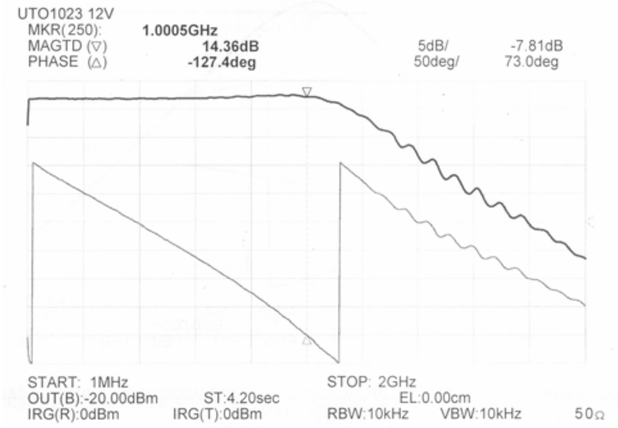

fig. 5. Gain and phase characteristics of the broadband amplifier

The exercise proceeds with examination of the gain and phase distortion of the broadband amplifier. From the shown diagrams (fig.5) the gain and the phase at the resonant frequency are read. This measurement has to be done very carefully, in order to save the equipment. That is why at the input of the amplifier a very low amplitude has to be applied, so the output signal to be less than the maxi-um permissible for the measurement tool.

A measurement of the Wilkinson power divider follows [2,3]. Measurement between the input and Output2 and Output3 is done. After that a measurements between Output2 and Output3. The results are shown on fig.6 and 7.

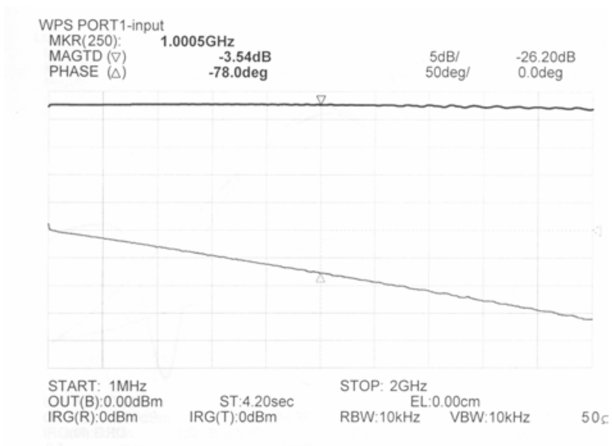

fig. 6. Amplitude characteristic of the Wilkinson power divider – input-Output1

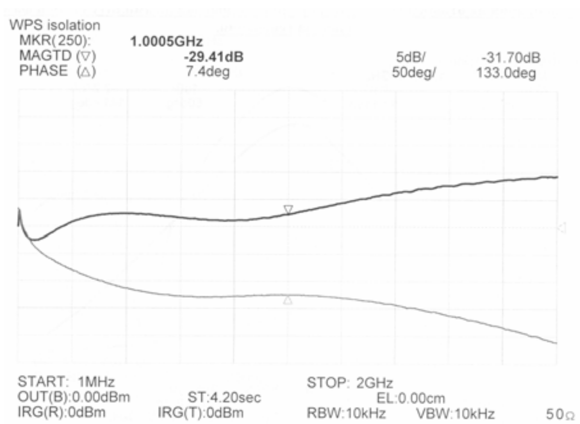

fig. 7. Amplitude characteristic of the Wilkinson power divider –Output1-Output2

After the measurements are finished, a verification of the condition (1) follows. In case that the overall gain is significant, an attenuator in series must be connected, so that the gain decreases up to 1-2dB. After that the modules must be connected in series and the overall gain and phase must be measured (fig.8). In case that the phase condition is not met, additional phase delay or advance must be added. This can be done with minimal efforts by selecting the correct the overall phase. The cable length calculation must be performed by the students. After that the loop is closed and the observing of the oscillations at the output pf the oscillator starts.

3.2 Measurement and analyses of the oscillator.

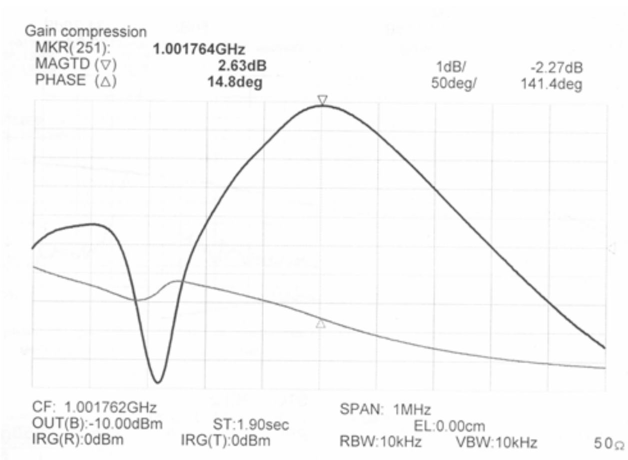

fig. 8. Overall gain and phase characteristic

The oscillator measurement is done in time and frequency domain. Its purpose is to show the students the main techniques for measurement of high-frequency signals.

3.2. Measurement of the phase noise and the spectral purity

Those measurements are done in frequency domain [4, 5]. The output of the oscillator must be connected to spectrum analyzer and the behavior of the spectrum near the resonant frequency must be observed. (fig. 9). The spectral purity can be determined by measuring the amplitude of the harmonics, which originate from the non-sinusoidal form of generated signal (fig.10).

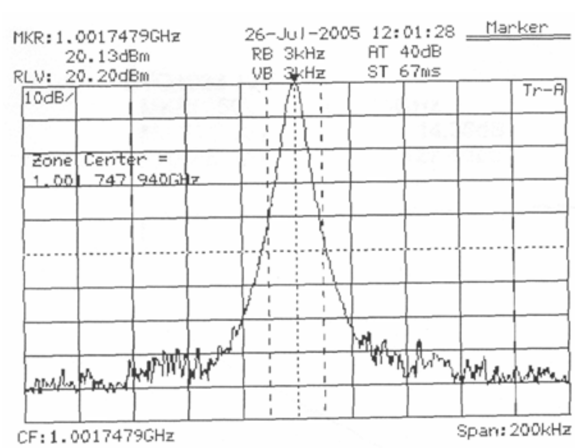

fig. 9. Phase noise measurement

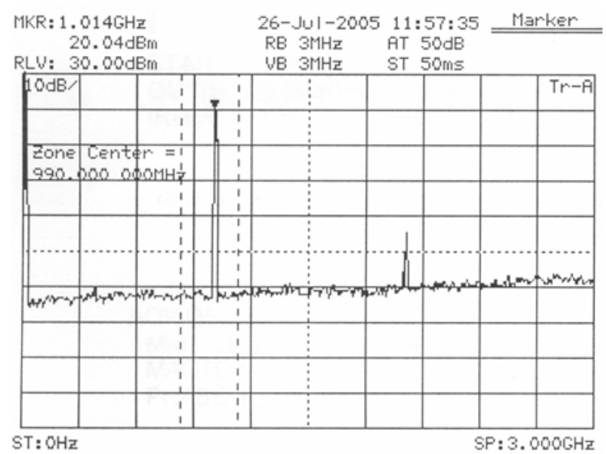

fig. 10. Spectral purity measurement

3.3. Time domain measurement

At this measurement the short time instability of the output signal is calculated. The output of the oscillator is connected to high frequency counter. The measurements must be performed according the recommendations of the IEEE subcommittee for frequency stability [6]. They state, that M samples of the frequency have to be taken for interval τ. To simplify the calculations, τ is 1 sec. After that the short-term instability can be calculated by (6):

$$(6)\,\sigma_y(\tau) = \left[\frac{1}{2(M-1)}.\sum_{i=1}^{M-1}(y_{i+1}-y)^2\right]^{\frac{1}{2}}, \text{ where}$$

y_i is the value of the measured frequency. In fact this is the mean value of the frequency averaged for τ seconds.

Equation (6) is known as the Allan variance.

4. Conclusion

In this article, the development of design kit for analyses of SAW resonators is shown. The block scheme of the kit, its built-up modules and method of work with them are shown. The sequence of the exercise and the different methods for measurement of the characteristics of the modules are described. The methods for phase noise measurement are shown as well as the main equations by which it can be calculated. The made sample of high-stabilized generator with SAW resonator is useful for designing of integrated SAW based oscillators.

5. References

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