433 MHz Wide-tunable High Q SAW Oscillator

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Abstract— **In this paper, we have made a 433 MHz dual-T SAW oscillator. The oscillator is made of an amplifier, variable gain amplifiers, phase shifters and dual-T SAW resonator circuit. Oscillation frequency can be changed by controlling the gains of variable gain amplifiers. The effective quality factor of the oscillator is enhanced by adjusting phase shifts of phase shifters. Frequency tunable range is about 1,200 ppm, exceeding the limit restricted by used SAW resonators. The effective quality factor of the oscillator is about 30,000, about three times of the unloaded Q of SAW resonators. Phase noise of the oscillator is estimated from the measured spectrum. Above 6 dB improvement of phase noise is obtained at 1kHz offset frequency compared to that of a colpitts oscillator.**

Keywords—SAW resonator; SAW oscillator; VCSO; VCXO; crystal resonator; crystal oscillator; quality factor; dula-T circuit; resonator; oscillator;

I. INTRODUCTION

Quartz crystal and SAW resonators are widely used in high precision voltage controlled oscillators. Recently, demand for wide tunable range and reduction of phase noise has been increasing for VCOs. But the frequency tunable range is limited by the capacitance ration of a crystal resonator or SAW resonator within a few hundred ppm. And the phase noise is limited by the effective quality factor of a VCO. To overcome these restrictions, a variety of piezoelectric material resonators and oscillator circuits have been developed. But, reported results were not sufficient for recent demands. To attain the demand for wide tunable range, a dual-T quartz crystal resonator circuit was proposed [1]. The resonance frequency of a dual-T crystal resonator circuit can be changed a several thousand ppm exceeding the limit determined by the piezoelectric coupling factor of a crystal resonator. We have been studying the properties of the dual-T crystal resonator circuit[2]-[4]. Omori et al. proposed a widely tunable dual-T SAW band elimination filter and its application to wideband UHF VCO[5].

In this paper, we have investigated a dual-T SAW oscillator. At first, we explain the circuit of a dual-T SAW oscillator. Then we show the simulation and measurement results of a dual-T SAW resonator circuit. Finally, we show the characteristics of the dual-T SAW oscillator.

II. DUAL-T SAW OSCILLATOR CIRCUIT

Fig. 1 shows the schematic diagram of a dual-T SAW oscillator circuit. A dual-T SAW resonator circuit is composed of two T circuits. Each T circuit is composed of an inductor and a capacitor in a series arm and a SAW resonator in a shunt arm. Each SAW resonator has different resonance frequency. The inputs of two T circuits are connected to the output terminal of the amplifier via different variable gain amplifier VGA1 and VGA2. The output terminals of two T circuits are connected and fed back to the amplifier. In order to cancel out the parallel capacitance C_0 of a SAW resonator, the values of L_S and C_S are determined so that the resonance frequency of L_S and $C'_S=C_S+C_0$ is approximately equal to the resonance frequency of a SAW resonator. The same value C_S is used for C_{S1} and C_{S2} because the difference of the resonance frequencies of the two series arms is small. The values of L_{S1} and L_{S2} are set to equal value L_S by the same reason. A phase shifter is inserted in series with each T circuit to improve the effective quality factor.

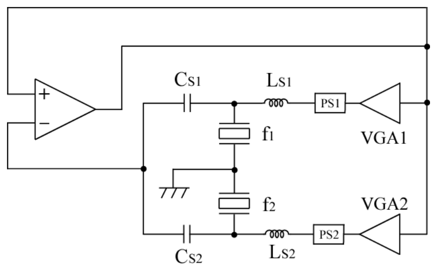

Figure 1 Dual-T SAW oscillator circuit.

III. FREQUENCY RESPONSE OF DUAL-T SAW RESONATOR CIRCUIT

We have made the simulation of frequency response of a dual-T resonator circuit. Table 1 shows the equivalent parameters of SAW resonators. Fig.2 shows the simulated frequency response. The solid line shows the frequency response for 10.6 degree phase shift and the dotted line for 0 degree phase shift. By insertion of phase shift, the notch depth and the slope of phase increase. This result suggests the increase of the effective Q of a dual-T resonator circuit. The notch at 433.59MHz represents the spurious response of lower

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resonance frequency SAW resonator. This response is considered explaining the measured frequency response.

Tabel 1 Equivalent parameters of SAW resonators

Parameters	No.1	No.2
Resonance frequency [MHz]	433.42	433.92
R1 [Ohm]	26.1	16.0
L1 [uH]	101	61.6
C1 [fF]	1.32	2.18
C0 [pF]	2.3	2.2
Q	10600	10500

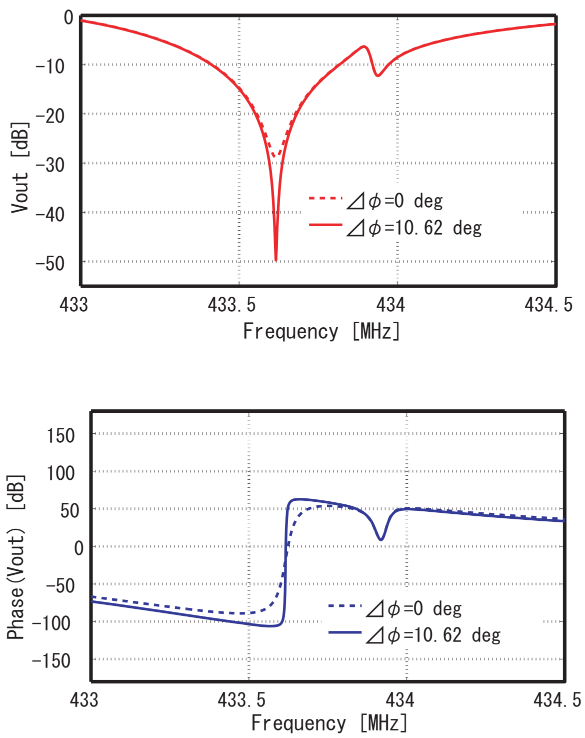

Figure 2. Frequency response of dual-T SAW resonator circuit. (simulation)

Fig.3 shows the measured frequency response. The solid line shows the frequency response for 10 degree phase shift and the dotted line for 0 degree phase shift. The measured result is similar to the simulation result.

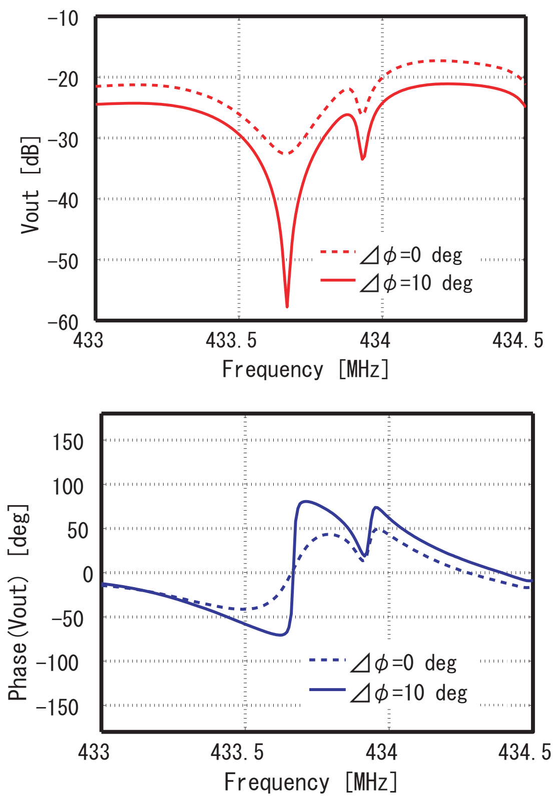

Figure3. Frequency response of Dual-T SAW resonator circuit. (measurement)

IV. OSCILLATOR CHARACTERISTICS

Fig. 4 shows the simulated relation between oscillation frequeny and control voltage of variable gain amplifier. This result suggests about 1200 ppm frequency variation range.

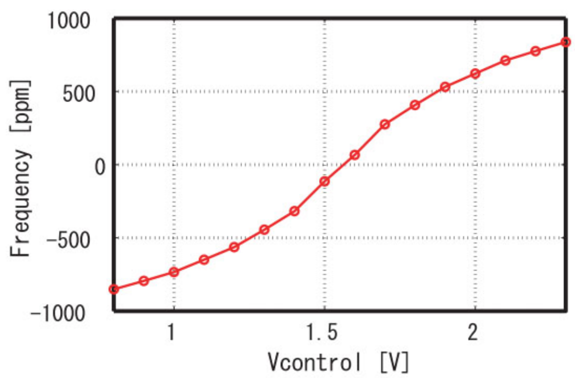

Figure 4. Relation between oscillation frequency and control voltage.

Then, we measured the characteristics of the oscillator. Fig. 5 shows the measured open loop gain of the oscillator when the oscillation frequency is set to be the center of tunable range. Effective Q values evaluated from both the voltage and phase transfer characteristics are about 33,000. These values are around three times of unloaded Q of SAW resonators.

oscillator. The phase noise estimated from measured spectrum supported the effective Q enhancement effect.

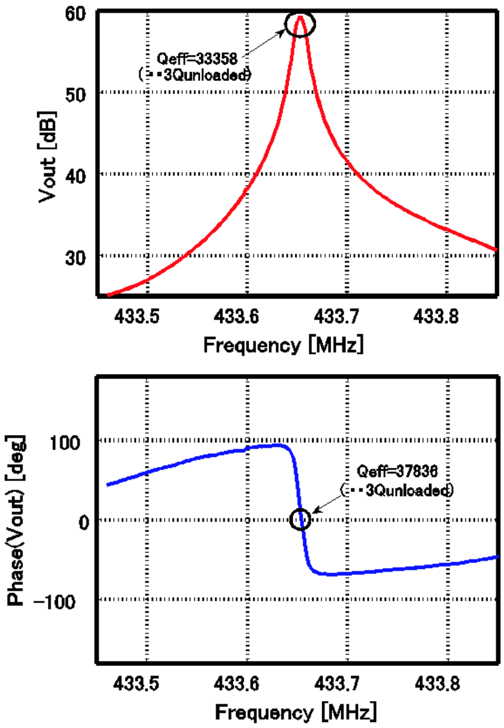

Figure 5. Open loop gain.

Fig. 6 shows the measured spectrum of the output voltage. We estimated the phase noise from the measured spectrum. Fig. 7 is the phase noise at 1kHz offset frequency. The phase noise at the frequency 600ppm higher from the center frequency is -92 [dBc/Hz] The phase noise at the center frequency is -97 [dBc/Hz]. About 6 dB improvement is observed. This value suggests that the effective Q of the oscillator becomes two times of the unloaded Q of a SAW resonator. From this result, we think the Q enhancement method is effective. The evaluated effective Q is small compared to that of the value evaluated from the measured open loop gain of the oscillator. The reason of this difference is the limit of our measurement system. In Fig.7, we shows the measured phase noise of the coplitts oscillator made using the same SAW resonator, for comparison. The phase noise of the colpitts oscillator is almost same with that of the dual-T oscillator at the upper end of frequency tunable range. This means that the effective Q of the dual-T oscillator is almost equal to that of the colpitts oscillator. This fact is reasonable because the dual-T resonator behaves as the single resonator at the upper or lower end of the frequency tunable range.

V. SUMMARY

In this paper, we investigated a dual-T SAW oscillator. It was shown that the frequency tunable range beyond the resonator limited value can be attained. Effective Q enhancement is observed from both the frequency response of the dual-T resonator circuit and the open loop gain of the oscillator. The phase noise estimated from measured spectrum supported the effective Q enhancement effect.

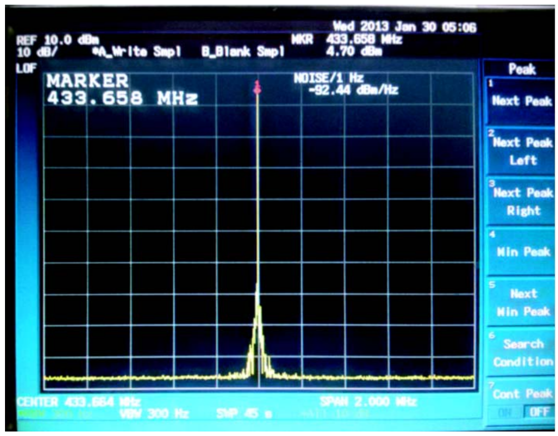

Figure 6. Measured spectrum of oscillator output.

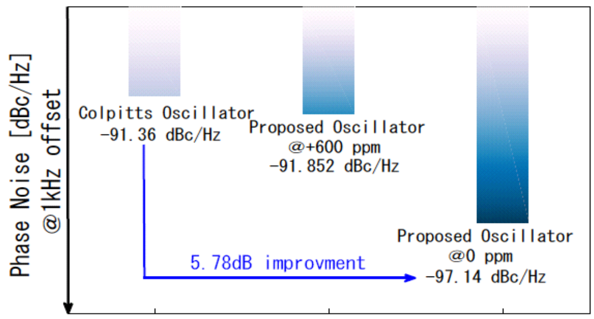

Figure 7. Phase noise estimated from measured spectrum.

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