NEW SAW OSCILLATORS FOR LAND MOBILE TELEPHONE RADIO UNIT

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Abstract

New SAW frequency variable oscillators for a mobile radio unit are presented. A 145-MHz SAW-resonator -oscillator has been developed for the FM modulator. An 800-MHz SAW delay-line oscillator without an external phase shifter is proposed for the frequency synthesizer.

1. Introduction

For establishing a high-capacity land mobile telephone system, high-purity oscillators are essential. Furthermore, the radio unit for the system must be small and light weight, especially when it is used as a portable unit.

SAW (Surface Acoustic Wave) oscillators, which are small and light weight and are operated in the fundamental mode at VHF and UHF frequencies, have stable, high-purity oscillation characteristics.

Two new SAW frequency variable oscillators for a land mobile telephone radio unit are presented. A 145-MHz FM modulator oscillator using a SAW resonator has recently been developed and it satisfactorily meets the system's requirements. In addition, an 800-MHz SAW delay-line oscillator without an external phase shifter is proposed and is shown to be suitable for fabricating a monolithic frequency synthesizer oscillator.

2. RF Circuit for Mobile Radio Unit

Figure 1 shows a block diagram of the RF circuit for the mobile radio unit(1). The RF circuit consists of an 800-MHz frequency synthesizer employed as a radio channel selection local oscillator, a transmitting circuit which includes a 145-MHz modulator, and a receiving circuit.

The oscillators in the unit are required to have high-purity oscillation characteristics because the system adopts a narrow 25-kHz radio-channel separation at 800-MHz band. The application of SAW devices for the fabrication of frequency variable oscillators for the 145-MHz modulator and the 800 MHz synthesizer is proposed. This is because they will significantly improve the oscillators.

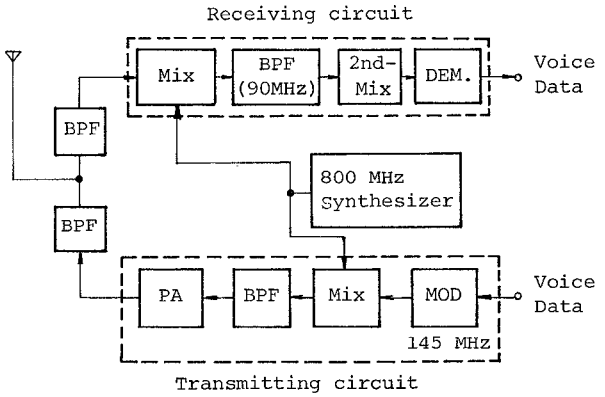

Fig.1 Block diagram of RF circuit for mobile radio unit

3. A 145-MHz SAW Resonator Stabilized Voltage-Controlled-Oscillator (SAWR-VCO)

In the mobile radio unit, the 145-MHz modulator is required to have high-purity and low-distortion characteristics.

In order to obtain a high-purity modulation signal, a VCXO (Voltage-Controlled-X'tal-Oscillator) is usually employed. For the 145-MHz operation, however, it is necessary to employ the 5th overtone oscillation mode. Therefore, it is difficult to achieve good FM modulator performance with low harmonic distortion.

The SAW oscillator operates in the fundamental mode at 145-MHz and a modulator having low harmonic distortion can be fabricated without frequency multiplication. A resonator-oscillator is preferable to a delay-line-oscillator for modulation because of a resonator oscillator's low electrical power dissipation. Figure 2 shows a SAW resonator stabilized voltage-controlled-oscillator (SAWR-VCO). The SAWR is a cavity type resonator with alminum strip grating reflectors, and its substrate is an ST-cut quartz. The unloaded Q is about 20,000. Resonance resistance and capacitance ratio is 42 Ω

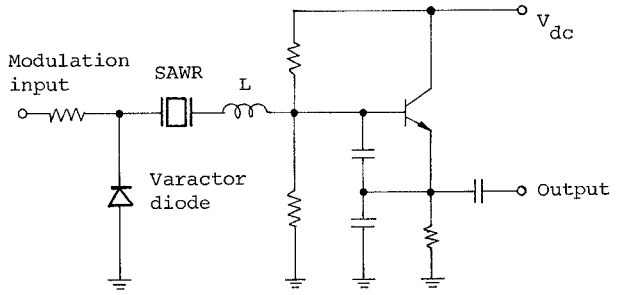

Fig.2 SAW resonator stabilized VCO (SAWR-VCO)

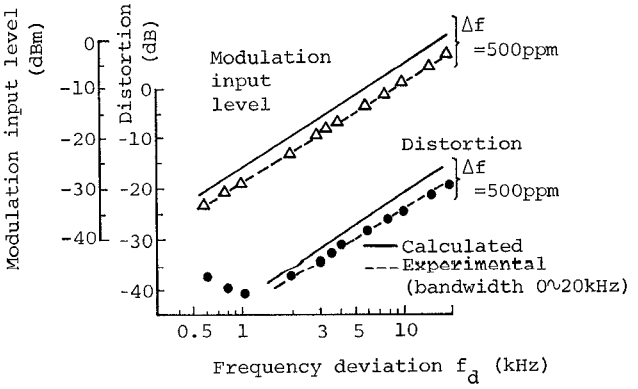

Fig.3 SAWR-VCO modulation characteristics

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and 3,000, respectively. To reduce the modulation distortion and modulation sensitivity fluctuation, the central VCO oscillation frequency is set at a frequency that is about 500-ppm lower than the resonator resonance frequency using a series inductance L(2).

Figure 3 shows 145-MHz SAWR-VCO modulation characteristics. Good modulation linearity and distortion less than -30 dB at 5-kHz deviation are obtained. S/N (S: 1-kHz modulation with 3.5-kHz deviation, N: bandwidth 0~3-kHz) is more than 58 dB, and C/N (C: carrier, N: 25-kHz offset from carrier and bandwidth 15-kHz) is more than 87 dB. The mobile radio unit must operate under vibration. When a VCO is mechanically vibrated, however, the VCO FM noise increases. S/N degradation due to mechanical vibration was measured and is shown in Fig.4. Good S/N value of more than 43 dB was obtained.

Furthermore, this VCO has been confirmed to be stable after the vibration test(10-G, 10 500-Hz),the mechanical shock test(50-G), and the thermal shock test(abrupt change from -20°C to 75°C).

This SAWR-VCO meets all of the requirements for the 800-MHz land mobile telephone system. The modulator using this SAWR-VCO is about half the size of a conventional modulator which is composed of 20-MHz VCXO and frequency multiplier chain. This SAWR-VCO is being used in NTT's new compact mobile radio unit.

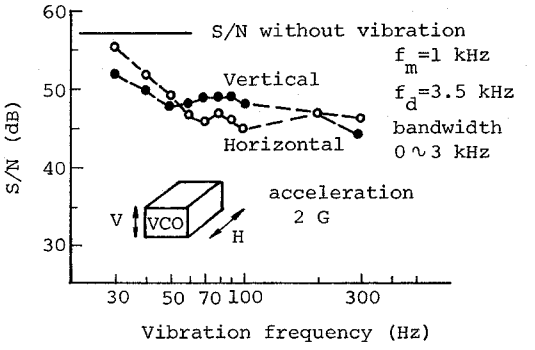

Fig.4 Degradation of S/N due to vibration

4. An 800-MHz SAW Frequency Variable Oscillator

For fabricating an 800-MHz frequency synthesizer, a frequency variable oscillator with high-purity and a tuning range of several-MHz at 800-MHz band is required.

A high-purity 800-MHz frequency variable oscillator using stripline or coaxial-cable inductance is conventionally used for a frequency synthesizer. Oscillator size, however, is limited to the size of an inductance element whose length is about $\lambda/4$ (λ: wavelength) in this case. With SAW technology, on the other hand, substantial progress can be made in reducing the size of the oscillator.

A SAW frequency-variable-oscillator without an external phase shifter is proposed here. An ordinary SAW frequency-variable-oscillator with a tuning range of several-MHz is composed of a SAW delay line, amplifier, and an external phase shifter. This phase shifter, however, is difficult to miniaturize or monolithically integrate because lumped elements such as L's and C's are inevitable.

Figure 5(a) shows a fundamental circuit configuration for the proposed SAW oscillator.

The circuit between P and P' in Fig.5(a) is a new SAW delay-line phase shifter, which is fabricated by adopting a microwave phase shifter configuration having a quadrature hybrid(3). The phase

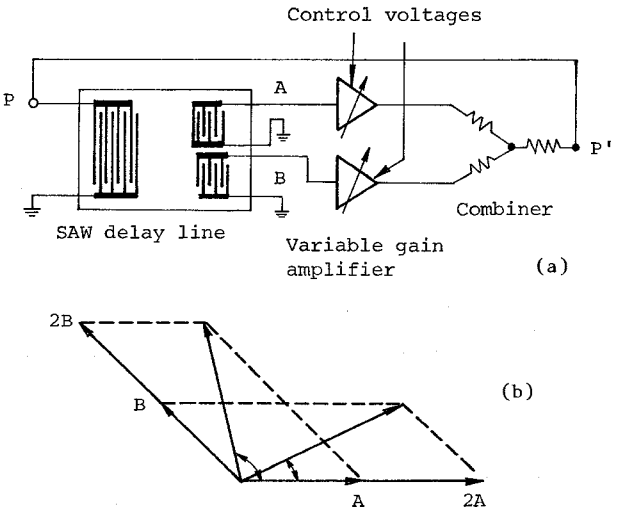

Fig.5 SAW-VCO without external phase shifter
(a) Block diagram (b) Operation principle

Table I 800 MHz SAW delay line design

Center frequency	785 MHz
Electrode structure	three-transducer
	60 pairs(center) 42 pairs(each side)
Electrode finger	Split type, 0.66μm width
Overlap length	95μm (18λ)
Propagation length	80λ (left) (80+$\frac{1}{3}$)λ (right)
Substrate	36°rotY-Xprop. $LiTaO_3$
Chip size	2mm X 2mm

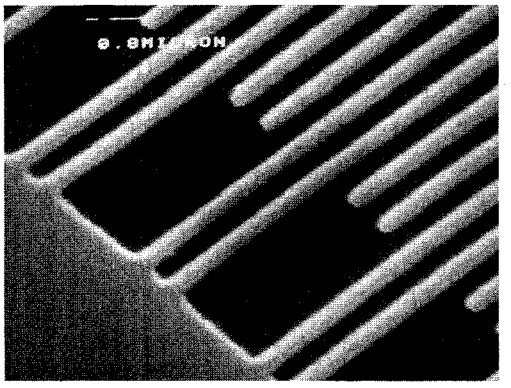

Fig.6 Fabricated interdigital transducer finger pattern (finger width 0.66μm, electrode thickness Al 400Å)

shifter operation is obtained by the vector sum of two signals (A and B) which are not the same phases from the SAW delay-line, when each signal amplitude is changed by varying the amplifier gain, as shown in Fig.5(b). When the loop is closed, the frequency variable oscillator operation is achieved.

The parameters of the SAW delay line used here ,summarized in Table I, were designed to construct the oscillator to have a C/N value of more than 70dB. (The value of C/N was calculated by the published theoretical equation (4)). Figure 6 shows a interdigital-transducer finger pattern of the 800 MHz SAW delay-line. The finger width of 0.66μm is successfully fabricated on the $LiTaO_3$ substrate. Measured transmission characteristics of the SAW delay line is shown in Fig.7. The phase difference of the two outputs is nearly 120°, and insertion loss is 15dB.

The phase shifter experiment was carried out at 783 MHz by using the SAW delay line, amplifier,

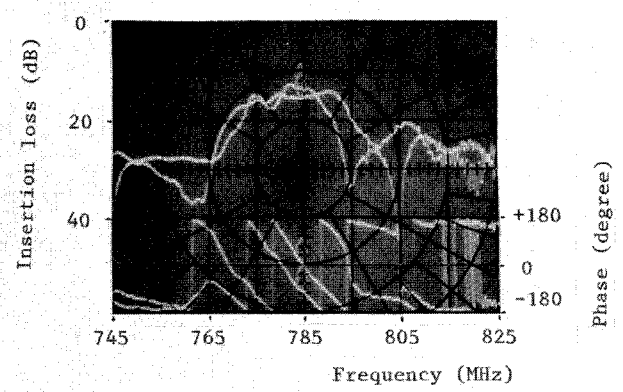

Fig.7 Transmission characteristics of the 800 MHz SAW delay line

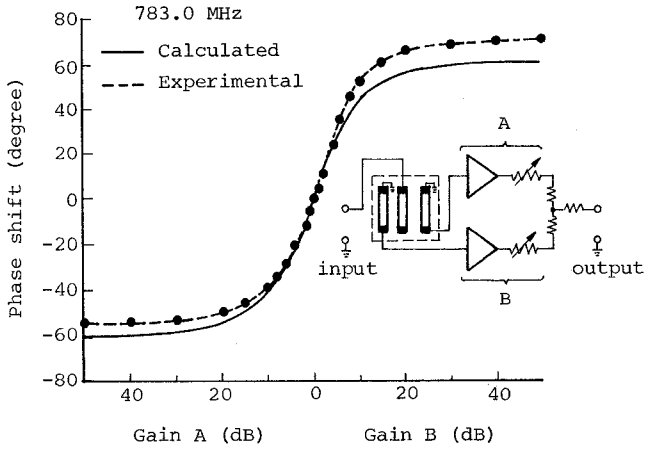

Fig.8 Experimental results of variable phase shifter

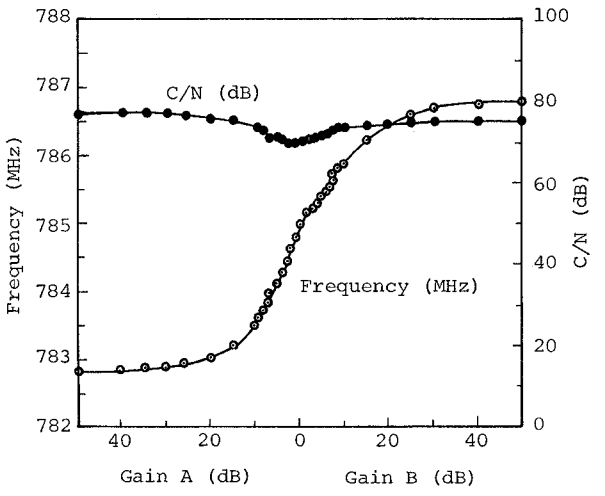

Fig.9 800MHz SAW frequency variable oscillator performance

variable attenuators, and a combiner. Figure 8 shows experimental results and calculated values of the variable phase shift.

Figure 9 shows experimental results of this SAW frequency variable oscillator. A tuning range of 3.9 MHz and a high C/N ratio (C:carrier, N: 25-kHz offset from carrier and bandwidth 15-kHz) of more than 70 dB was successfully obtained. Slight C/N degradation near the center of Fig.9 is believed to be caused by the distortion of the combined signals A and B. This is due to the SAW delay line transmission amplitude ripples across the operation frequency range. This can be refined by suppressing the inband amplitude ripples.

By applying a multiple SAW delay-line, as shown in Fig.10, it is possible to achieve a large tuning range with high-purity oscillation. Using this proposed configuration, a SAW frequency variable oscillator can be monolithically integrated in a multi-chip (SAW chip and amplifier chip) or a single chip IC without an external phase shifter.

5. Conclusion

Two new SAW frequency variable oscillators have been presented for use as the 145-MHz modulator oscillator and the 800-MHz synthesizer oscillator. High modulation performance was obtained with the 145-MHz SAWR-VCO which contributes to the reduction of the mobile radio unit's size. An 800-MHz SAW oscillator with high-purity and wide tuning range was demonstrated without an external phase shifter. The frequency variable oscillator with a multi-chip or a single chip IC can be fabricated using this circuit configuration. This will make possible the substantial miniaturization of the mobile radio unit and possibly lead to a pocket-size one.

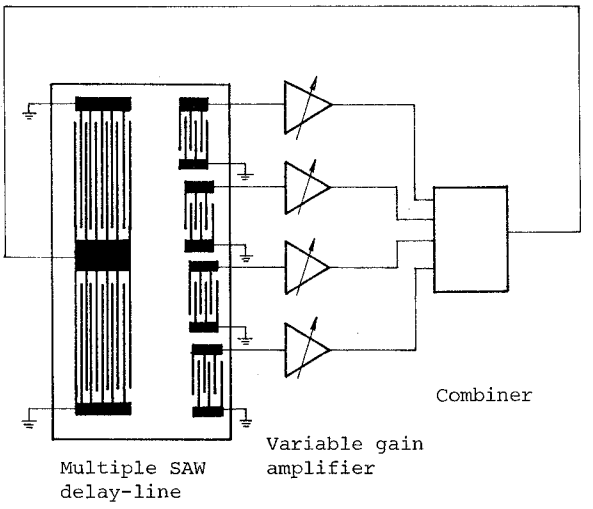

Fig.10 SAW-VCO with large tuning range

Acknowledgement

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