ADVANCED RF CIRCUIT MINIATURIZATION FOR 800 MHz LAND MOBILE RADIO UNIT

Seizo Seki, Noboru Kanmuri and Shuomi Yuki
Yokosuka Electrical Communication Laboratory
Nippon Telegragh and Telephone Public Corporation
1-2356 Take, Yokosuka-shi, 238-03 Japan

ABSTRACT

Advanced RF circuits for a mobile radio unit are presented. A new compact mobile radio unit has been successfully developed having an 800MHz frequency synthesizer, a thick-film MIC up to 900MHz frequency region and a SAW device. The size and weight of this unit are 1,500 cm^3 and 2.4 kg, respectively, and it possesses 1,000 radio channels.

Introduction

The high capacity 800 MHz land mobile telephone system[1] was put into commercial service in Tokyo in 1979.[2] Since then, this mobile telephone service has gained a good reputation for its quality and convenience. This service was also opened to the public in Osaka last autumn. It is expected that it will be extended nation-wide in the future.

The current mobile radio unit has a relatively large volume and weight. This is because the circuit structure is very complicated employing a large number of electronic parts. Circuit simplification and miniaturization are needed for reducing the unit size and weight as well as the production cost.

This paper describes advanced RF circuit technology for realizing circuit simplification and miniaturization.

RF Circuit construction

Figure 1 shows a block diagram of the RF section of the current mobile radio unit[3]. The section consists of a double heterodyne receiver, a FM transmitter and a frequency synthesizer. The receiving frequency is 870 MHz to 885 MHz and the transmitting frequency is 925 MHz to 940 MHz. There are 600 radio channels. Each channel is allocated a 25 kHz channel spacing. The frequency synthesizer sets up these radio channels. It generates 150 MHz frequencies. Therefore, a number of frequency multipliers and complicated filtering circuits for rejecting spurious outputs are needed in order to produce 800 MHz and 900 MHz frequencies. These RF circuits are mainly composed of various descrete components, such as transistors, inductors, variable capacitors and resistors.

In order to realize a compact RF section, three technical targets should be achieved. (1) Circuit construction simplification; Realizing an 800 MHz frequency synthesizer is very effective in eliminating frequency multipliers and complicated filtering circuits.[4] (2) RF circuit miniaturization: Microwave IC (MIC) technology utilizing a microstripline makes the circuit structure flat and small. Thick-film MICs are effective in reducing fabrication costs. (3) Small size component development; SAW components are extremely small. LSIs are most effective in reducing the number of electronic components.

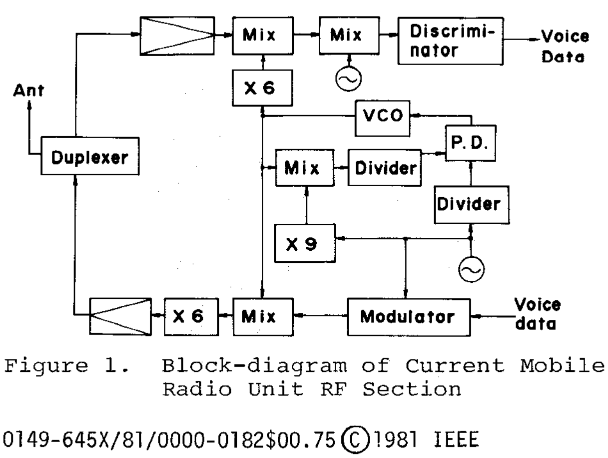


Figure 1. Block-diagram of Current Mobile Radio Unit RF Section

Thick-film MICs

Figure 2 shows the measured microstripline transmission losses.[5] The solid line shows transmission loss of thin-film and the dotted line that of thick-film. The thin-film microstripline is fabricated on 99.99% almina-ceramic substrates, and thick-film on 96% almina-ceramic substrates. The length of both measured microstriplines is 26 cm. Figure 2 shows that thick-film loss is only slightly more than thin-film loss, and doesn't show any abrupt change in the 200 MHz to 10 GHz range. This measured value indicates that thick-film is sufficiently applicable in 900 MHz circuits.

Figure 3 shows the 800 MHz voltage-controlled oscillator (VCO) circuit for the frequency synthesizer.[4] It consists of a Colpitts oscillator and is fabricated on a substrate[6] with a high dielectric-constant of 39. This VCO must have a high spectral purity for rejecting blocking effects in the receiver

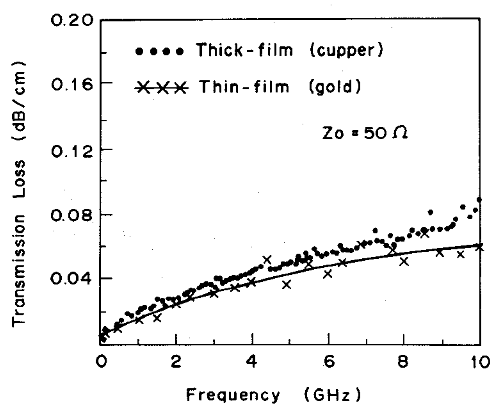


Figure 2. Measured Microstripline Transmission Loss

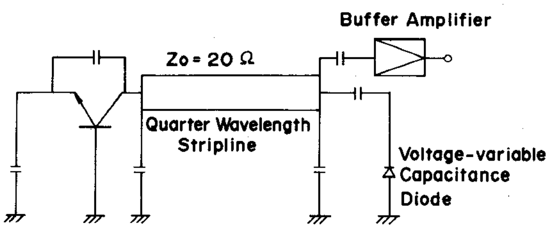


Figure 3. 800 MHz Voltage-Controlled Oscillator for the Frequency Synthesizer

0149-645X/81/0000-0182$00.75

caused by external signals from adjacent channels. To obtain a high spectral purity, the inductor in the oscillator resonance circuit should have a high quality factor. It is formed with a quarter wavelength stripline whose characteristic impedance is chosen to be about 20Ω for reducing the conductive loss of the stripline. Figure 4 shows the obtained performance curves of the 800 MHz VCO. A C/N of more than 77 dB is obtained over a 35 MHz oscillation frequency range (25 kHz offset from the carrier, 15 kHz bandwidth).

Table 1 shows other RF circuits applying thick-film technology. An up-converter, down-converter and transmitter power amplifier are fabricated without troublesome adjustments and show excellent performances using this thick-film technology.

800 MHz frequency synthesizer

Figure 5 shows a block-diagram of the new frequency synthesizer.[7] Besides an 800 MHz VCO, two new LSIs have been developed.[8~9] One is a bipolar two-modulo prescalar which directly divides an 800 MHz frequency. Its divisors are 128 and 129. The other LSI is a C-MOS programmable counter. In addition to the programmable counter it contains a phase detector and a charge-pump. The new synthesizer primarily consists of 4 elements; a temperature compensated crystal oscillator (TCXO), an 800 MHz VCO and two LSIs. The new frequency synthesizer posseses 1,000 channels. Its volume is about 80 cm^3.

SAW application

A 900 MHz SAW filter and a 145 MHz SAW resonator have been developed[10~11]. The SAW band pass filter is used at the up-converter output for rejecting unwanted images and other spurious signals. The SAW resonator

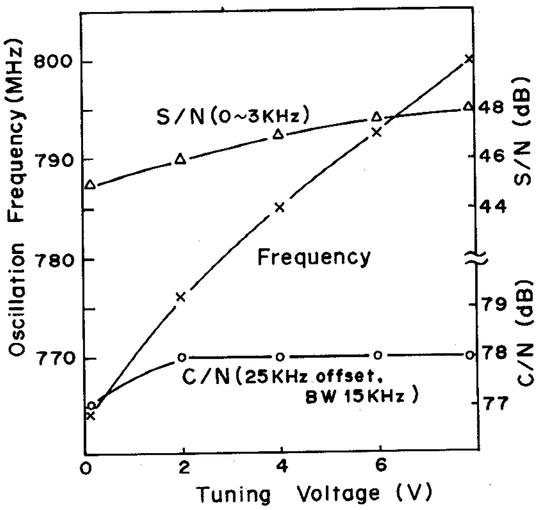


Figure 4. Oscillation Performance Curve for 800 MHz VCO

Table 1. Other RF Circuits Fabricated by Thick-film Microstripline Technology

Circuit	Performance	Remark
Down converter	NF: 4 dB Conversion gain: 11 dB	Transistor mixer
Up converter	Conversion gain: 17dB Carrier suppression: 12 dB	Transistor single-balanced mixer
Transmitter power amplifier	Output power: 39 dBm Gain: 21 dB Power-added efficiency: 45 %	3-stage amplifier using Stepped-electrode-transistor

is used in a 145 MHz FM modulator circuit.

The SAW filter is a three-transducer structure composed of 0.5μm double electrodes, and the chip size of this filter is 1.5 mm^2. The filter is encapsulated in a 6 mm diameter ceramic package (Figure 6). Table 2 shows obtained performances. An insertion loss of 5 dB, pass-bandwidth of 35 MHz and stopband attenuation of more than 40 dB are obtained.

Figure 7 shows a 145 MHz modulator circuit. The modulator consists of a SAW oscillator and a PLL circuit. The reason for applying on SAW device is that; (1) A 145 MHz oscillation frequency cannot be obtained with a 3rd over-tone crystal oscillator, and (2) frequency modulation with ±5 kHz deviation cannot be obtained by using a 5th over-tone crystal oscillator. The SAW oscillator can generate a 145 MHz frequency in the fundamental oscillation mode and it can be modulated with sufficient frequency deviation. The SAW is a cavity type resonator and it is fabricated on a ST-cut quarts substrate. The unloaded quality factor is about 20,000. Table 3 shows performances of the FM modulator. A C/N of 86 dB and a S/N of 57 dB are obtained. Even when mechanical vibrations are applied, a S/N of more than 43 dB is obtained, where S is a 1 kHz tone whose level is set to excite a ±3.5 kHz deviation, and noise level is a phase noise on the carrier in the 0 to 3 kHz frequency range which corresponds to data or voice transmission bandwidths. Distortion at a ±4.5 kHz deviation is less than -30 dB, and an input level variation to cause a ±4.5 kHz deviation is whithin 1dB in the temperature fluctuation range of from -20°C to 60°C. These performances satisfy the design objectives of the FM modulator.

Improved new mobile radio unit

Figure 8 shows the block-diagram of the RF section of the new mobile radio unit. Employing the 800 MHz frequency synthesizer and the 145 MHz SAW modulator, the new unit is composed without any frequency multipliers. The new unit has 1,000 radio channels. The transmitting frequency of this new unit is 915 MHz to 940 MHz and the receiving frequency is 860 MHz to 885 MHz. These are converted from the frequency synthesizer oscillation frequency of 770 MHz to 795 MHz.

Figure 9 shows two types of mobile radio units.

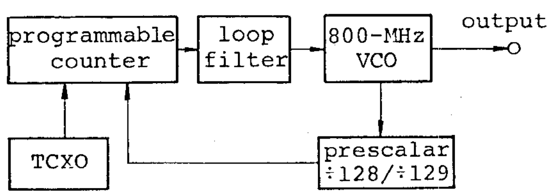


Figure 5. New 800 MHz Frequency Synthesizer

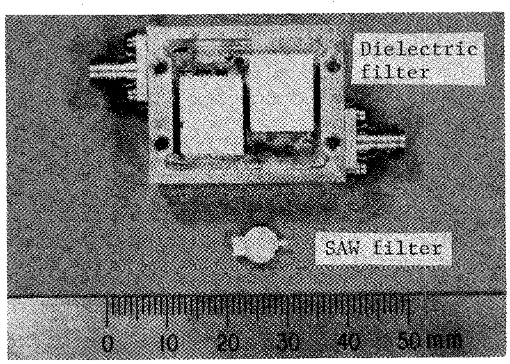


Figure 6. SAW Filter and Conventional Dielectric Filter

The left one is the current mobile radio unit and the one on the right is the improved new unit. Applying the above mentioned technologies, the size of the new mobile radio unit is reduced from the current unit size of 6,600 cm^3 to 1,500 cm^3, and the weight is lightened from 7 kg to 2.4 kg.

Conclusion

By applying wideband microwave technology and small microwave components, circuit simplification and miniaturization have been achieved. The thick-film microstripline composed of copper material is suitable for fabricating microwave circuits. Its transmission loss is nearly the same as that of thin-film in the 200 MHz to 10 GHz range. Thick-film MICs are effective in reducing circuit structure size and production costs. SAW components are extremely small in comparison with conventional circuits such as dielectric filters. A 900 MHz SAW filter and a 145 MHz SAW resonator have been developed. A SAW filter insertion-loss of 5 dB has been obtained. The FM modulator utilizing the SAW resonator has shown good modulation characteristics. By applying thick-film technology and developing two LSIs, an 800 MHz frequency synthesizer has been realized. Since a number of frequency multipliers and complicated filtering circuits are unnecessary, the 800 MHz frequency synthesizer greatly contributes to reducing the size of the mobile radio unit and to saving troublesome RF circuit adjustment.

Table 2. Structure and Performance of 900 MHz SAW Filter

Structure	3-transducer with 0.5μm double electrode
Substrate	$LiNbO_3$
Center frequency	928 MHz
Bandwidth	35 MHz
Insertion loss	5 dB (Pass-band ripple ± 1.5 dB)
Stop-band attenuation	40 dB

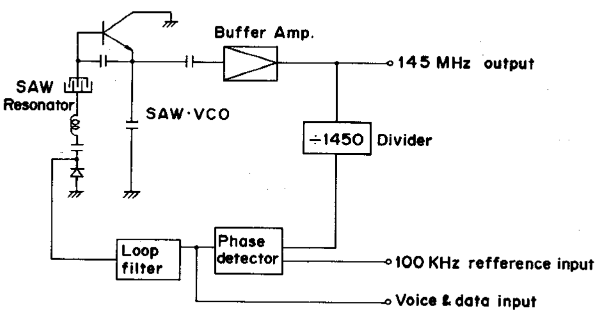


Figure 7. FM Modulator Circuit

Table 3. Modulator Performance

Item	Objective value	Measured value	Remark
C/N	60 dB	86 dB	25KHz offset, 15KHz bandwidth
S/N	45 dB	57 dB	S: 1KHz tone, 3.5 KHz deviation
	40 dB	43 dB	Adding vibration, 2G(0~100Hz)
Distortion	-20 dB	-30 dB	4.5KHz deviation
Sensitivity variation		less than 1dB	-20°C ~ +60°C

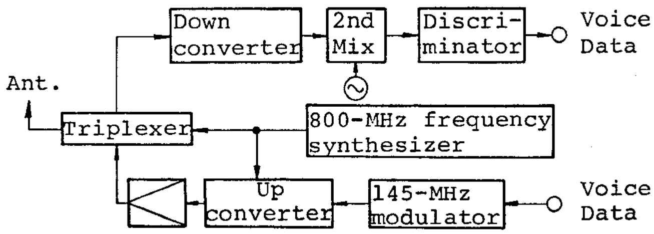
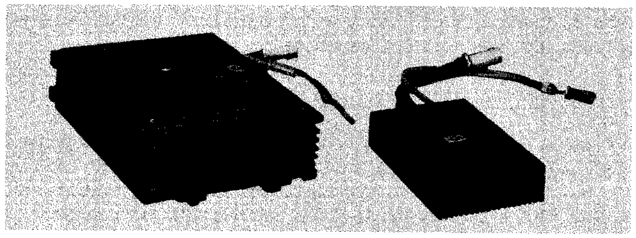


Figure 8. Block-diagram of New RF Section



Current mobile radio unit	New mobile radio unit
6,600 cm^3	1,500 cm^3
7 kg	2.4 kg
600 channels	1,000 channels

Figure 9. Mobile Radio Unit

Acknowledgements

The authors wish to express their thanks to Dr. K. Miyauchi and K. Izumi for their encouragement and guidance, other staff members of Yokosuka Electrical Communication Laboratory for fruitful discussions and A. Iwata for developing the LSIs.

References

(1) M.Watanabe and K.Miyauchi,"Research and Development on Land Mobile Telephone System," Review of the E.C.L.,NTT.,Jap.,25,11-12,1977.

(2) T.Ooi, T.Kikuchi and S.Kimura,"High Capacity Automobile Telephone Service,"IEEE,VT,30th Annual Conf. Rec.,1980.

(3) M.Sakamoto and K.Kinoshita,"Mobile Unit for 800MHz Band Land Mobile Telephone System,"Reviw of the E.C.L.,NTT.,Jap.,25,11-12,P.1231.

(4) S.Yuki, T.Matsuura and Kouji Nakabe,"New 800-MHz Frequency Synthesizer for Cellular Land Mobile Telephone Equipment,"Proc.IEEE,Vol.67,No.10,1979.

(5) S.Nishiki and S.Yuki,"Thick-film Transmission Loss in Microwave Region,"Inst.Electron,Eng.Jap.,Rep. Tech.Group on Microwaves,1980,MW79-133,P.43.

(6) Y.Kajiwara, T.Noguchi, T.Sugiura, H.Takamizawa K.Hirakawa and K.Sasaki,"UHF High-Power Low-distortion Transistor Amplifier with High dielectric Substrate," 1979IEEE,MTT-S,Int.Microwave Symp. Dig.

(7) T.Matsuura, Y.Noda, T.Nishihara and S.Nishiki,"An 800-MHz 1,000 Channel Frequency Synthesizer,"1980 National Conf.on Comm.,IECE.Jap.,No.463.

(8) H.Kikuchi, A.Iwata, T.Matsuura, T.Nishihara and Y.Katoh,"C-MOS-LSI for Frequency Synthesizer," National Conv.of IECE Jap.,No.387,1980.

(9) Y.Akazawa, A.Iwata, T.Takahashi, K.Yamada and H.Kimura,"1-GHz Low Power 2-modulo Prescalar," 1980 National Conf.on Comm.,IECE.Jap.,No.74.

(10) S.Urabe, K.Asakawa, M.Itoh, H.Gokan, S.Esho and K.Nishikawa,"Low Loss 0.9-1.9GHz SAW Filters", 1980 IEEE Ultrasonic Simp.

(11) S.Ashida, T.Matsuura, T.Nishihara, T.Habuka and S.Yuki,"A 145-MHz SAW Modulator for Mobile Radio Unit,"National Conv.of IECE Jap.,No.2082,1980.