New Type of Push-push Oscipliers for The Frequency Synthesizer

Hiroyuki Yabuki, Morikazu Sagawa, Mitsuo Makimoto

Tokyo Information and Communications Research Laboratory
Matsushita Electric Industrial Co., Ltd., Kawasaki, Japan

ABSTRACT

This paper describes the fundamental principle of novel voltage controlled push-push oscipliers (oscillator/doubler) and shows their application to a frequency synthesizer for L-band operation. The experimental frequency synthesizer made it clear that they have the advantages of high frequency operation, compact size and low power consumption.

INTRODUCTION

The increasing demand for mobile radio communication has caused a lack of frequency resources lower than 1 GHz. The time is now ripe to fully utilize the L-band. This technology trend requires the development of compact, low power consumption frequency synthesizer circuits in the L-band.

Push-push oscillators are useful in many applications(1) because of their good performance in areas such as high frequency operation and high output power. However, as the operating frequency of an oscillator and a prescaler, which are the essential devices for a frequency synthesizer, become higher, the power consumption of these devices increases remarkably. It is desirable to adopt a frequency multiplier for the reduction of power consumption, but it generates many spurious components and requires filters to suppress them. To overcome these problems, new types of oscipliers have been devised for this application.

The authors previously introduced voltage controlled push-push oscillators(2),(3) using miniaturized hairpin shaped stepped impedance split-ring resonators(4) (SISR's). SISR's have a suitable structure for use in microwave integrated circuits(5),(6) (MIC's), and have useful features desirable in RF oscillator circuits, that is, low phase noise and a wide tuning range.

It is well known that push-push oscillators have two oscillating circuits operating at the same frequency and 180° out of phase. Therefore, the fundamental frequency component can be combined using 180° hybrid, and the second harmonics can be obtained by 0° hybrid. This is a special and important feature of push-push oscipliers to be considered when they are applied to the low power frequency synthesizer.

The frequency synthesizer employing these push-push oscipliers is expected to have high frequency operation,compact size and low power consumption. Furthermore, filters connected to the output of the frequency synthesizer can be removed because the fundamental frequency component is suppressed by the combined circuits.

FUNDAMENTAL PRINCIPLE OF THE FREQUENCY SYNTHESIZER

Fig.1 shows a block diagram of the frequency synthesizer. The frequency synthesizer consists of voltage controlled push-push oscipliers which have 2 output ports, a buffer amplifier and a Bi-CMOS PLL LSI containing a prescaler, a programmable

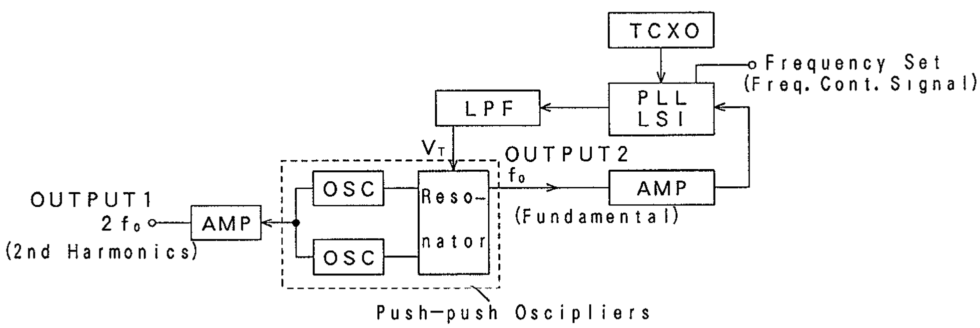

Fig.1 A block diagram of the frequency synthesizer

 1992 IEEE MTT-S Digest

counter, a phase detector and a charge pump.

Fig.2 shows a circuit diagram of the voltage controlled push-push oscipliers which have 2 output ports. These oscipliers have two identical oscillator circuits built up from the SISR's and the combined output circuits. Fig.3 shows the SISR's with a varactor diode. By connecting a varactor diode between the parallel coupled lines of the SISR's, wide band voltage controlled oscipliers can be easily constructed. One part of the circuits oscillates at the fundamental resonance frequency, dependent on the SISR's. The other oscillates at the same frequency, but 180° out of phase. However, both of the circuits are in phase for the second harmonics.

The combined outputs for the fundamental frequency can be obtained using a balun consisting of asymmetrical parallel coupled lines, as shown in Fig.2. The combined outputs, therefore, have twice the output power of a single oscillator. By applying these outputs to a prescaler of a phase locked loop, it is possible to reduce the RF input power and the DC power consumption of the frequency synthesizer.

The combined outputs of the second harmonics can be obtained by connecting two oscillating circuits directly with capacitors, as shown in Fig.2. The combined outputs, therefore, have twice the output power of a single oscillator. Furthermore, the fundamental frequency is suppressed by the combined circuits as mentioned before, so filters connected to the output of the frequency synthesizer can be removed or be replaced by a simple one.

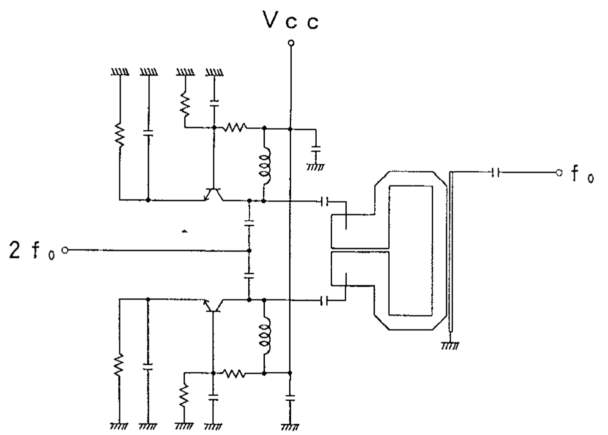

Fig.2 A circuit diagram of the push-push oscipliers

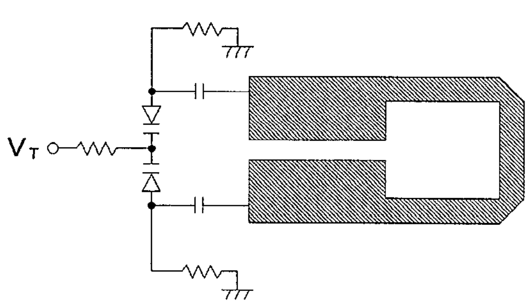

Fig.3 The SISR's with a varactor diode

CHARACTERISTICS OF THE EXPERIMENTAL FREQUENCY SYNTHESIZER

On the basis of the above discussion, a frequency synthesizer employing voltage controlled push-push oscipliers for L-band operation was experimentally designed and fabricated.

A. Voltage Controlled Push-push Oscipliers

Design parameters of SISR's are shown below.

$Zs = 62.6\Omega$, $\theta s = 50°$

$Zpe = 39.4\Omega$, $Zpo = 24.9\Omega$, $\theta p = 20°$ (f_0=1GHz).

Small package Si bipolar transistors and Si varactor diodes were adopted for oscillator and tunable resonators, respectively.

Fig.4 shows the spectrum of experimental voltage controlled push-push oscipliers for output 2. Output power of the fundamental frequency was above -5dBm which is enough to operate PLL LSI. The second harmonics suppression was measured to be about -50dBc across the band.

Fig.5 shows the spectrum of experimental voltage controlled push-push oscipliers for output 1. The fundamental frequency suppression was measured to be about -25 dBc across the band. It should be noted that these suppression values are obtained by the circuit balance. This means that spurious components can be easily eliminated, using simple filters.

Fig.6 shows the tuning characteristics versus control voltages. Oscillation frequency varies 5MHz/V with the change of control voltages from 0.5V to 4V. Output power of the second harmonics is about -9dBm which is constant in the tuning ranges.

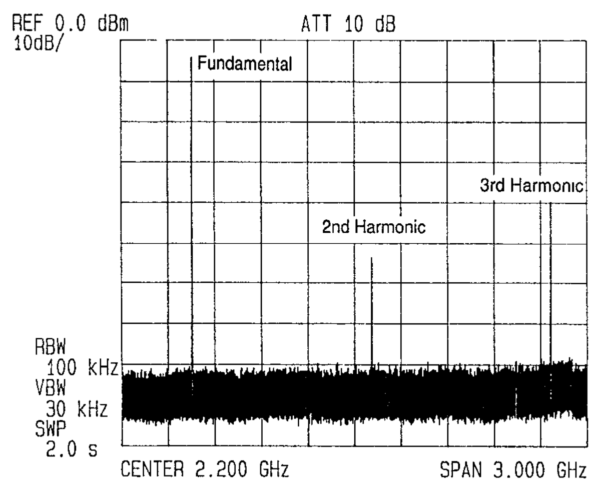

Fig.4 The spectrum of push-push oscipliers for output 2

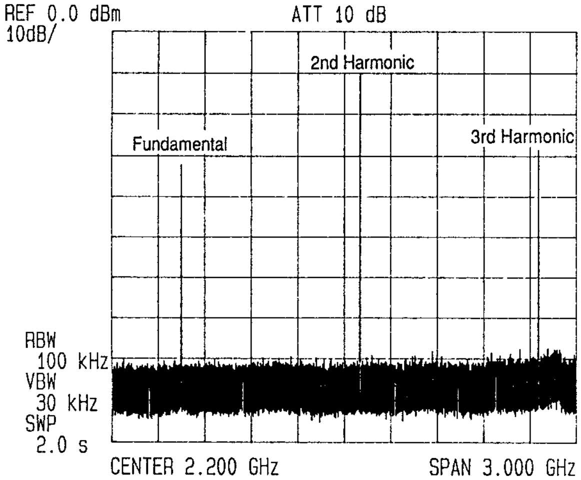

Fig.5 The spectrum of push-push oscipliers for output 1

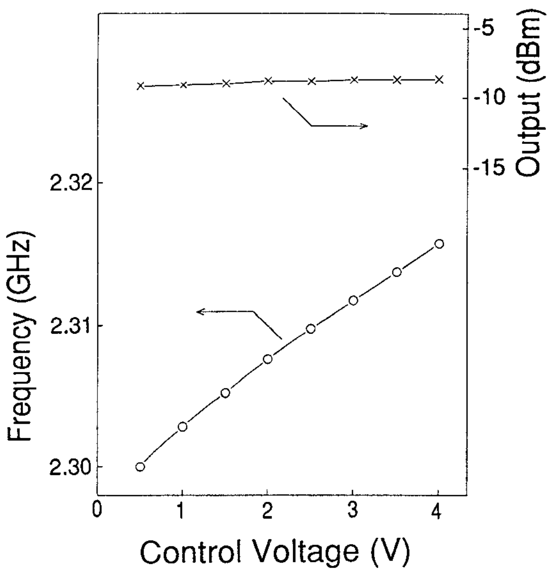

Fig.6 The tuning characteristics versus control voltages

B. Frequency synthesizer

A frequency synthesizer employing voltage controlled push-push oscipliers for L-band operation was made.

Owing to the realization of low frequency operation, the power consumption of this system is about 100mW which is much smaller (approximately less than 1/2) than that of the conventional direct division frequency synthesizer system.

The spectrum of experimental frequency synthesizer nearby the oscillation frequency is shown in Fig.7. The output frequency of the frequency synthesizer was approximately 2.3GHz. The reference leak (Fr=100KHz) was suppressed below -80dBc.

Fig.8 shows single-side-band (SSB) phase noise characteristics. Phase noise level was about -103dBc/Hz at offset frequency 10KHz and about -123dBc/Hz at offset frequency 100KHz.

These characteristics can be improved by replacing Si varactor diodes with GaAs type, which have lower series resistances than those of Si type and enhance the Q-factor of tunable split-ring resonators.

The frequency switching response of the frequency synthesizer is shown in Fig.9. The output frequency was changed from 2.30GHz to 2.31GHz. Frequency switching time was less than 2msec.

Table.1 shows the fundamental characteristics of the frequency synthesizer. These results indicate that this frequency synthesizer can be applied to mobile communication equipment.

Fig.10 shows a photograph of the experimental frequency synthesizer employing voltage controlled push-push oscipliers. The size of the frequency synthesizer is $44 \times 28 \times 2$ mm^3.

The performance of the frequency synthesizer using voltage controlled push-push oscipliers having 2 output ports is expected to be superior to those using a conventional oscillator.

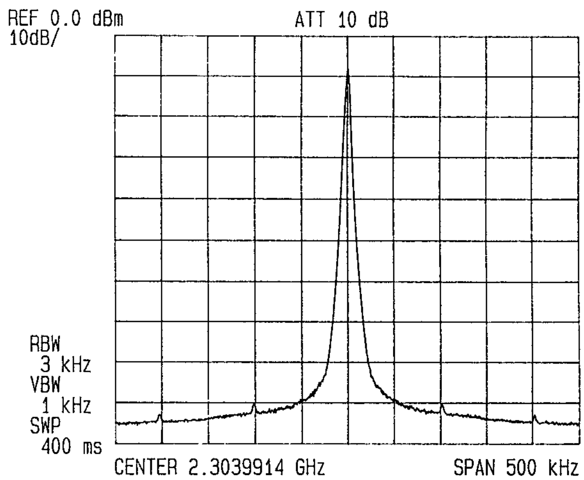

Fig.7 The spectrum of experimental frequency synthesizer

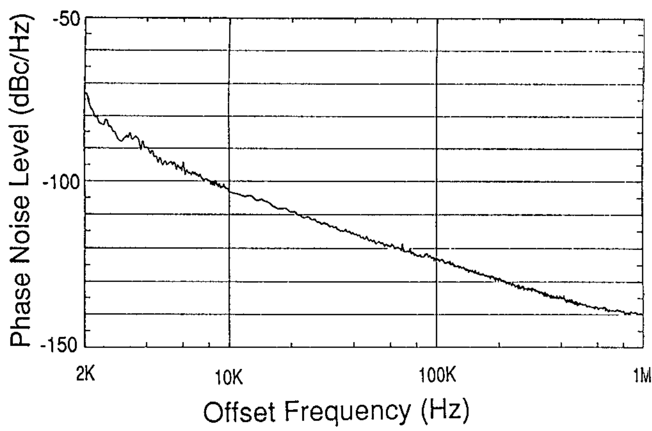

Fig.8 SSB phase noise characteristics

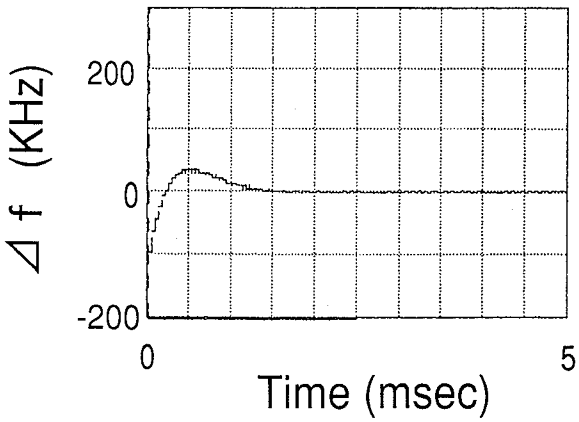

Fig.9 The frequency switching response

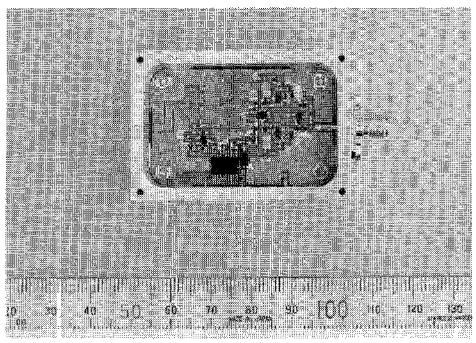

Fig.10 A photograph of the experimental frequency synthesizer employing push-push oscipliers

Frequency	2.3 GHz
Output Power	−9 dBm
Current	21 mA
S/N*	44 dB
C/N**	−123 dBc/Hz
Kv	5 MHz/V
fREF	100 KHz
Switching Time	2 msec

* : 1KHz tone, 3.5KHz dev.
** : 100KHz offset

Table.1 The fundamental characteristics of the frequency synthesizer

CONCLUSION

A new type of voltage controlled push-push oscipliers which have 2 output ports has been developed and applied to a frequency synthesizer which operates in the L-band.

By means of a 0° hybrid circuit, the external output power is obtained and the fundamental frequency is adequately suppressed at the same time. Furthermore, by applying fundamental frequency, which is derived from 180° hybrid, to a prescaler of a phase locked loop, the RF input power and the DC power consumption of the frequency synthesizer is reduced.

This type of a frequency synthesizer is verified to be compact with simple circuit configuration, high frequency operation and low power consumption.

In this paper an L-band synthesizer has been demonstrated, but it seems that this synthesizer system can be applicable at much higher frequencies than L-band by introducing MMIC technology. Hereafter, we intend to make injection locked multiple chain employing voltage controlled push-push oscipliers.

ACKNOWLEDGEMENT

The authors are grateful to Tomoki Tsumura for his continuous encouragement

REFERENCE

(1) A.Pavio and M.Smith, " Push-push dielectric resonator oscillator," in IEEE MTT-S Int. Microwave Symp. Dig., June 1985, pp.266-269.
(2) H.Yabuki, M.Sagawa and M.Makimoto, " Voltage controlled oscillators using miniaturized hairpin resonators, " in IEICE Japan, MW90-153, Feb. 1991, pp.59-64.
(3) H.Yabuki, M.Sagawa and M.Makimoto, " Voltage controlled push-push oscillators using miniaturized hairpin resonators, " in IEEE MTT-S Int. Microwave Symp. Dig., June 1991, pp.1175-1178.
(4) M.Sagawa, K.Takahashi and M.Makimoto " Miniaturized hairpin resonator filters and their application to receiver front-end MIC's, " in IEEE Trans. Microwave Theory Tech., vol.37, No.12, Dec. 1989, pp.1991-1997.
(5) M.Makimoto and M.Sagawa, " Varactor tuned bandpass filters using microstrip-line ring resonators, " in IEEE MTT-S Int. Microwave Symp. Dig., May 1986 pp.411-414.
(6) M.Makimoto, " Microstrip-line split-ring resonators and their application to bandpass filters," Trans. IEICE Japan, vol. J71-C, No.7, pp.1063-1070, July 1988.