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A Wideband Push-Push VCO Using Common Phase shifter

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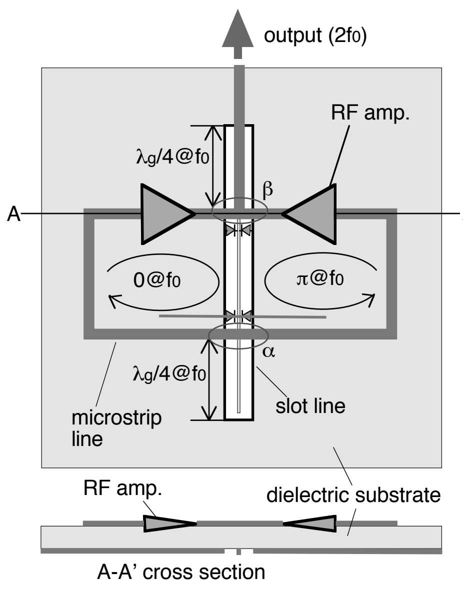
1. Introduction

Microwave and millimeter wave oscillators are extensively required for the modern wireless systems. However, there are still a lot of practical issues such as phase noise, cost reduction, high stability, output power in high frequency bands. A push-push oscillator is very effective for these solutions [1]-[4]. For a wideband VCO, a feedback type oscillator is much more suitable as compared with a negative resistance type one because the electrical length of the feedback loop can be changed easily and widely. The positive feedback push-push oscillators using the double-sided MIC technology [5] have been proposed by the authors [6],[7]. Moreover, a push-push VCO using the double-sided MIC technology was also proposed by the authors[8].

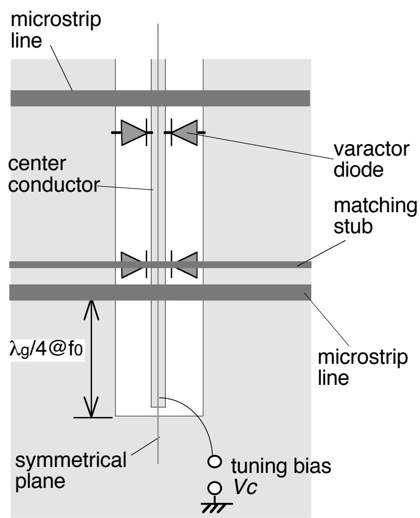
In this paper, a novel push-push VCO using one phase shifter with varactor diodes in the common part of the positive feed back loops is proposed. The structure is very simple and compact because the circuit need only one phase shifter embedded on the common part of the feedback loops. The oscillation frequency is widely tuned by the varactor diodes. The developed push-push VCO provides a wide tuning range of 1.35 GHz (7.6 %) and the phase noise of -103.7 dBc/Hz at the offset frequency of 1 MHz in 18 GHz band.

2. Push-Push VCO

Fig. 1 shows the circuit configuration of the proposed push-push VCO. The microstrip lines are arranged on a dielectric substrate, and a slot line on the reverse side. The oscillating frequency is determined by the electrical length of the slot line, microstrip lines and the RF



(a) upper side of structure



(b) phase shifter on the feedback loop

Figure 1: Circuit Configuration of The Push-Push VCO .

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amplifiers, which is designed to be 2π x n (n : integer) at the fundamental frequency (f_0). The oscillation signal on the common part (slot line) of the two positive feedback circuits is divided out of phase on the slot-strip T- junction (part α in Fig. 1(a)). Since the slot line is a kind of a balanced transmission line, the slot-strip T-junction acts as an out of phase power divider. Therefore, the fundamental signals and the odd harmonics from the two RF amplifiers are out of phase and the even harmonics are in-phase in principle due to the non-linearity of the RF amplifiers. The strip-slot T-junction (part β in Fig. 1(a)) is in-phase coupling circuit for the even harmonic signals. Therefore, the in-phase harmonic signals (even harmonics) are transmitted to the output port. On the other hand, the out of phase harmonic signals such as the fundamental signal and odd harmonics are transmitted to the part α in Fig. 1(a). A high frequency signal of good quality can be generated due to the superior suppression of undesired odd harmonic signals.

The push-push VCO has a phase shifter with varactor diodes in the common part slot line of the positive feed back loops as shown in Fig. 1 (b) . On a part of the phase shifter, a microstrip line stub is formed for impedance matching. By adjusting the reactance of the matching stub, the transmission characteristics of the phase shifter is improved. The symmetrical plane of the slot line is null plane for the electric field. A very narrow width center conductor is formed on the symmetrical plane. The line is designed so as not to disturb the RF transmission of the slot line mode. The varactor diodes are mounted on the coplanar waveguide of the positive feedback loop on the reverse side. Beam-lead varactor diodes are easily mounted on the line. Therefore, the oscillation frequency can be effectively controlled by the tuning voltage V_c supplied to the varactor diodes in the phase shifter. The proposed push-push VCO has the phase shifter on the common part of the positive feedback loops and the structure of phase shifter is very simple and compact. So the circuit is very simple and compact. A wire to supply the tuning voltage V_c is bonded on the center conductor. The distance between the tuning bias point and the edge of feedback loop is a quarter wavelength at the fundamental frequency (f_0) as shown in Fig. 1 (b). The slot line of the bias point is then a short circuited for the slot line mode. The oscillation frequency signal transferred to the tuning bias point can be suppressed in principle. The positive feedback type push-push oscillator is suitable for a wideband VCO in high frequency bands as compared with the negative resistance type one.

3. Experimental Result

The proposed push-push VCO is fabricated and the oscillating output signal is measured. The dielectric substrate is Teflon grass fiber with the relative dielectric constant ε_r of 2.15. The substrate thickness is 0.8 mm. Table 1 shows parameters of the dielectric substrate used here. As for the active devices, HEMTs (Fujitsu FHX35LG) are used. The drain bias voltage is 4.0 V and the drain bias current is 120 mA with the gate bias voltage of 0.0 V. The varactor diodes are MA46580-1209 (M/A COM). The output power spectrum, the phase noise and the output frequency of the output signal are measured with a spectrum analyzer (Agilent HP8565EC), and the output power is measured with a power meter (Agilent 53152A). The measured output power spectrum in the full range of 50 GHz is shown in Fig. 2. The power spectrum for estimating the phase noise is also shown in Fig. 3. Fig. 4 shows the output frequency and the power *vs*. tuning voltage V_c. The frequency range of the desired second harmonic signal is 17.04 ~ 18.39 GHz (bandwidth =1.35 GHz, relative bandwidth = 7.6 %), and the output power is +3.5 ~ +10.8 dBm for the tuning voltage V_c = 4.8 ~ 20 V. The phase noise *vs*. tuning voltage V_c is shown in Fig. 5 as well. The phase noise is -91.7 to -103.7 dBc/Hz at 1 MHz offset and -67.8 to -75.0 dBc/Hz at 100 kHz offset. Table 2 shows the comparison of the push-push VCO characteristics which have almost same frequency band. The proposed VCO achieves very wideband oscillating frequency tuning range successfully.

Table 1: Substrate Parameters

Substrate thickness [mm]	0.8
Metal thickness [mm]	0.018
Relative dielectric constant (ε_r)	2.15
Loss tangent (tan δ)	0.001

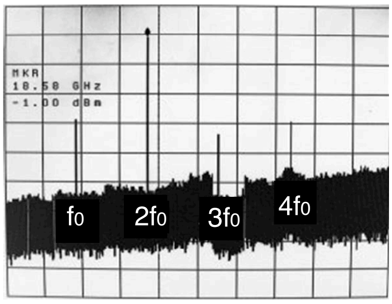

Figure 2: Output Power Spectrum in a Full Range of 50 GHz (Tuning Voltage *Vc* is 20 V)

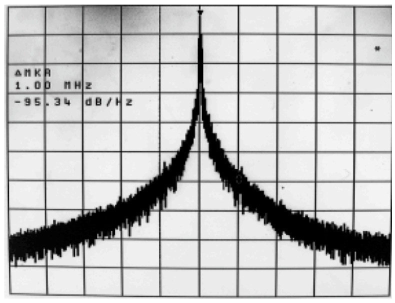

Figure 3: Power Spectrum for Estimating Phase Noise (Tuning Voltage *Vc* is 20 V)

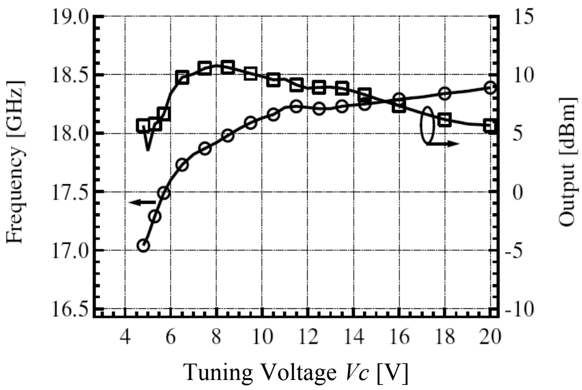

Figure 4: Oscillation Frequency and Output Power *vs.* Tuning Voltage *Vc*

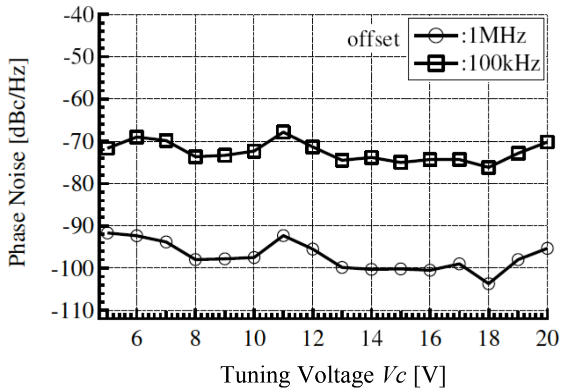

Figure 5: Phase Noise *vs.* Tuning Voltage *Vc*

Table 2: Comparison of VCO Performance

Ref.	Device/ Technology	Freq. [GHz]	Tuning range [MHz]	Output power [dBm]	P/N@ 100 kHz offset [dBc/Hz]	P/N@ 1 MHz offset [dBc/Hz]
[8]	HEMT	15	390 (2.6%)	-1.17 ~ +0.17	-77.2	-100.2
[9]	Silicon bipolar	18	360 (2 %)	+0.4 ~ +3.1	-108	-124
[10]	HEMT (MMIC)	21	1600 (7.5 %)	+10.0 ~ +13.7	-80.3	-
[11]	HBT (MMIC)	22	430 (1.9 %)	-1.5 ~ -0.3	-	-108.2
[12]	RTD/HBT (MMIC)	18	370 (2.1%)	-9.8~ -9.0	-	-112
[13]	Silicon bipolar	18.5	4100 (22 %)	-	-	-109.1
This work	HEMT	18	1350 (7.6 %)	+3.5 ~ +10.8	-75.0	-103.7

Note: [8], [9], and this work are push-push VCOs

5. Conclusion

In this paper, a very wideband push-push VCO with a compact phase shifter embedded on the common part of the positive feed back loops is proposed. The structure is very simple and compact because the circuit has only one phase shifter on the common part of the positive feedback loops. This push-push VCO demonstrated a wide tuning range of 1.35 GHz (7.6%) with a maximum output power of +10.8 dBm. The phase noise is -91.7 to -103.7 dBc/Hz at the offset frequency of 1 MHz for the tuning voltage Vc = 4.8 ~ 20 V in 18 GHz band.

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