Wideband Colpitts Voltage Controlled Oscillator with Nanosecond Start-up Time for Bubble-Type Motion Detector

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Abstract — **This paper presents a wideband Colpitts voltage controlled oscillator (VCO) with a center frequency of 8.35GHz and nanosecond start-up time for a new bubble-type motion detector that has a bubble layer of detection zone at the specific distance from itself. Combined with the varactor diode, the shunt microstrip line resonating at 6.8GHz is proposed to compensate the input reactance of the transistor that changes from capacitive values to inductive values at 8.1GHz. The measured VCO shows the tunable bandwidth of 2.3GHz, the output power of 4~7dBm and the start-up time of less than 2nsec. It will be utilized for the novel bubble-type motion detector later.**

Index Terms — **Colpitts, Voltage Controlled Oscillator, Motion Detector, Wideband, Start-up Time.**

I. Introduction

There has been a growing demand for wireless security systems, resulting in 60% increase of the relevant market annually, especially since the 9/11 terrorism. In this context, we proposed a novel bubble-type motion detector shown in Fig. 1 [1].

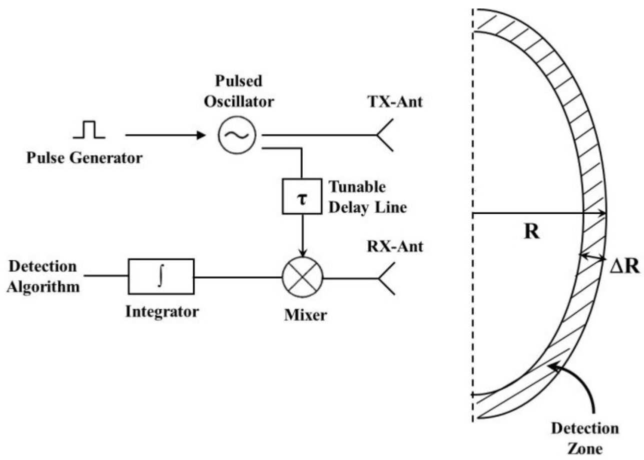

Fig. 1. Bubble-type motion detector.

In this paper, we present a wideband Colpitts voltage controlled oscillator (VCO) with a center frequency of 8.35GHz and nanosecond start-up time for the bubble-type motion detector. The VCO should have a fast start-up for pulsed-mode operation, and a wide tuning range to utilize different group delay time of a tunable delay line used for splitting transmitting signals into a receiving path. The VCO is fabricated using a HEMT and Si hyperabrupt junction varactor diode on a PCB substrate. It shows the frequency tuning range of 7.2~9.5GHz, corresponding to the tuning bandwidth of about 28%, and the output power of 4~7dBm with the start-up time of less than 2nsec.

II. Circuit Design and Fabrication

A VCO is typically composed of a negative resistance part of active devices and a resonator part of inductors and capacitors [2]. For pulsed-mode operation, a hybrid Colpitts VCO is designed using a NEC HEMT (NE33284A) and its output signal is filtered out through a low pass filter (LFCN-113+), as shown in Fig. 2.

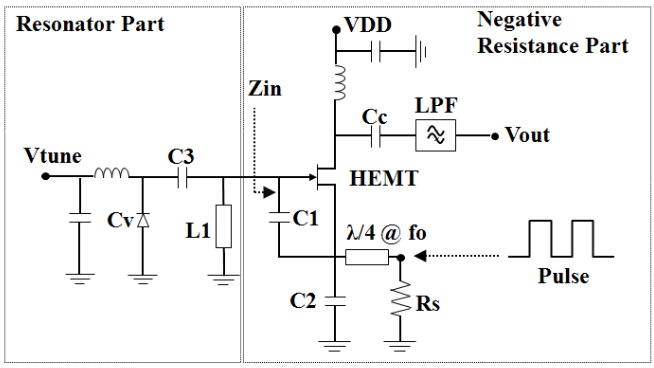

Fig. 2. Schematic circuit of the designed VCO.

Negative resistance (real part of Zin) is implemented using positive feedback of a gate-source capacitor C1 and source-ground capacitor C2 and its magnitude is determined by the ratio of C1 and C2 [3]. To facilitate oscillation, negative resistance needs to be maximized, and we found the optimal ratio of C1 and C2 by circuit simulations when C1=0.1pF and C2=0.2pF. The transistor is self-biased through a source resistor Rs and a quarter wavelength transmission line which makes the path to the source resistor open at RF frequencies.

The resonator part consists of a Skyworks varactor diode (SMV2019) Cv, a series capacitor C3 and a shunt inductor L1. The total reactance sum of the negative resistance part and resonator part should be 0 for the circuit oscillation. As shown in Fig. 3, input impedance at the gate of the negative resistance part shows negative resistance up to 9.9GHz, but

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the polarity of the reactance changes from negative values (capacitance) to positive values (inductance) at 8.1GHz. To compensate this reactance change, we propose a shorted shunt microstrip line whose reactance changes from inductive values to capacitive values at a specified frequency (here 6.8GHz) and could make the VCO widely tunable, together with the varator diode. The shorted shunt microstrip also plays a role to bias the gate terminal to 0V, which makes the gate-source voltage negative so that the transistor has enough transconductance.

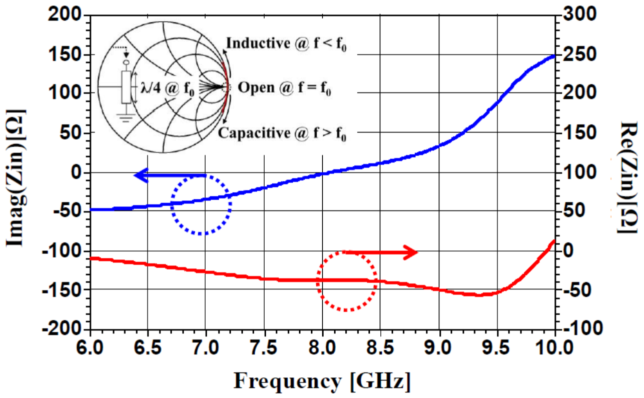

Fig. 3. Input impedance at the gate of the negative resistance part.

The varactor diode has capacitance values of 2.2 to 0.3pF with the reverse bias voltages of 0 to 20V. However, the reactance from parasitic inductive elements is dominant at high GHz region; for example, the varactor diode is inductive at 8GHz under the reverse bias conditions of 0 to 6V. So the series capacitor C3 is intentionally inserted to eliminate the inductance effect of the varactor diode and decouple the gate and varactor control voltages.

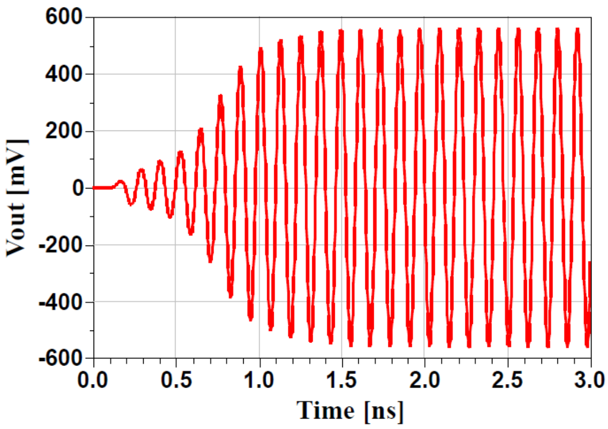

Fig. 4. Simulated transient response of the designed VCO.

The final VCO is designed using ADS harmonic balance simulations and then momentum simulations for consideration of layout effects, and shows the output power of about 5.3dBm at 8GHz and the start-up time of less than 1.5nsec as shown in Fig. 4. The designed VCO is fabricated on the low-loss substrate (RO4003) which is shown in Fig. 5. The PCB is 23×21mm^2 in area.

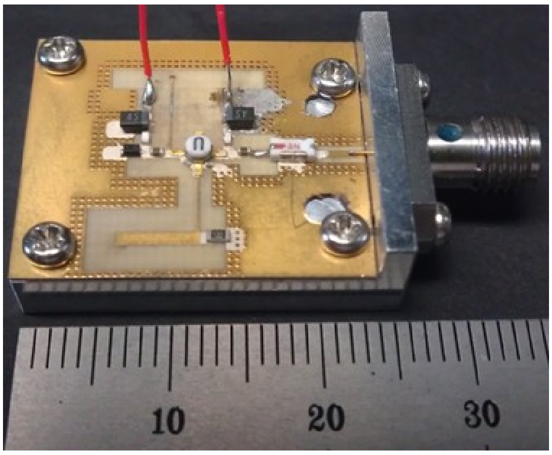

Fig. 5. The fabricated VCO on the PCB substrate.

III. MEASUREMENT RESULTS

To drive the fabricated VCO in a pulsed mode, pulse signals are applied to the source of the transistor as shown in Fig. 2. Since the transistor operates at the gate-source voltage of 0V and is off at the gate-source voltage of -0.7V, the input driving pulse signals have the peak-to-peak amplitude of 0 (ON) to 0.7V (OFF). Also they have very fast rise/fall times of 100psec not to affect the transient response of the VCO which are obtained from an Agilent pulse pattern generator 81133A.

Figure 6 shows the output power and oscillation frequency of the fabricated VCO with the reverse bias voltages of 0 to 20V. As shown in Fig. 6, the output signal has the oscillation frequency of 7.2~9.5GHz and the output power of 4~7dBm with the tuning voltages. The measured results are in good agreement with the simulated results (see Table I).

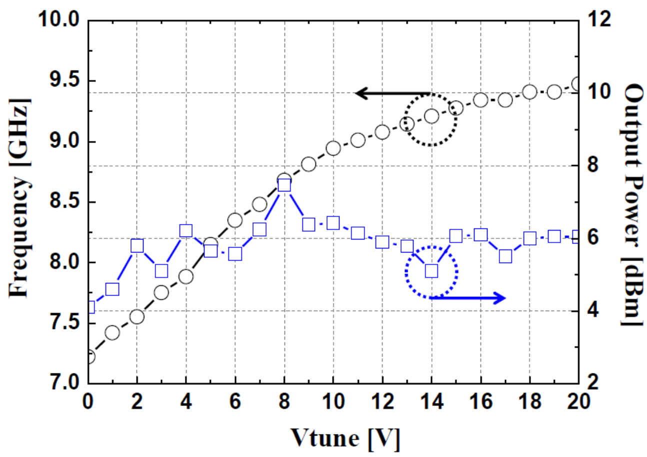

Fig. 6. Measured oscillation frequency and output power of the VCO with the tuning voltages.

TABLE I
COMPARISON OF SIMULATED AND MEASURED RESULTS OF THE DESIGNED PULSED-MODE VCO

	Simulation	Measurement
Tuning Range [GHz]	7.0~9.0	7.2~9.5
Start-up Time [nsec]	1.4~1.5	1.5~2.0
Output Power [dBm]	3.0~7.0	4.0~7.0

Figure 7 shows the measured phase noise performance of the VCO. The VCO shows the phase noise of less than -120dBc/Hz at the offset frequency of 1MHz which is emough for our target application. The bubble-type motion detector is based on coherent detection which mixes received signals with its own transmitting signals, and so requires relatively loose phase noise performance.

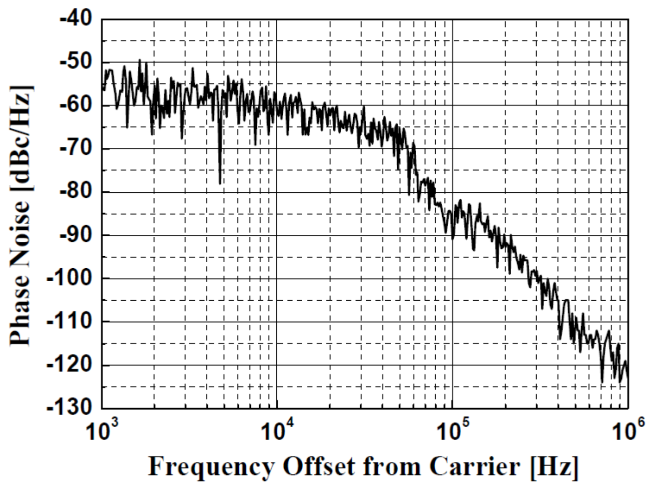

Fig. 7. Measured phase noise of the VCO at 8GHz.

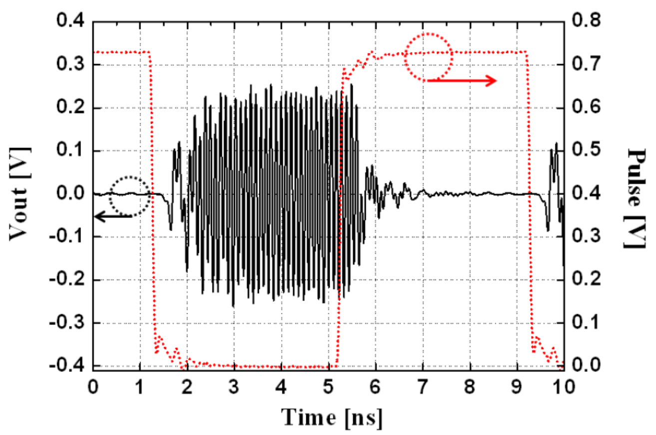

Fig. 8. Measured oscillation waveforms of the VCO when the input pulses with 4nsec pulse width are applied.

Figure 8 shows the output waveforms of the VCO driven by the input pulses with 4nsec pulse width and 100psec rise/fall times. The waveform measurement is done with an Agilent wide-bandwidth oscilloscope 86100A. According to the measured waveforms, the pulsed output signals are estimated to have the start-up time of 1.5~2.0nsec although their steady state waveforms are still slightly fluctuated. The measured start-up time is about 0.5nsec larger than the simulated one and could be improved by the resonator with lower Q which is currently under study [4]. The reason of the steady-state signal amplitude fluctuation is not clearly analyzed at the moment. The small delay before the oscillation pulse is thought to be due to the charging process of bypass capacitors for the supply voltage and the damped ringings after the pulse is due to the discharging process and inductor effect.

IV. CONCLUSIONS

The hybrid Colpitts VCO with the center frequency of 8.35GHz was fabricated and measured for the application of the novel bubble-type motion detector. It utilized a HEMT device for negative resistance and a Si hyperabrupt varactor diode for controlling the oscillation frequency. The shorted shunt microstrip line was also used for compensating the reactance change of the input impedance due to the parasitic inductance of the packaged transistor. The measurement showed that it had the output power of 4~7dBm, the start-up time of less than 2nsec and wide tuning range of 2.3GHz, corresponding to a relatively large tuning bandwidth of about 28%. The fabricated VCO will be utilized for a new VCO design with sub-nsec start-up time and will be integrated with a tunable delay line into the bubble-type motion detector for wireless security systems.

ACKNOWLEDGEMENT

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