LC-Oscillator for 94 GHz Automotive Radar System Fabricated in SiGe:C BiCMOS Technology

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***Abstract* — This paper presents the design and measurement of a voltage-controlled oscillator (VCO) for the use in a 94 GHz automotive radar system and other applications. The oscillator has been fabricated in a 200 GHz SiGe:C BiCMOS technology with 0.25 µm minimum feature size. The oscillator is fully integrated on a single chip with a chip area of only 0.25 mm2.**

The fabricated oscillator has a tuning range of 2.2 GHz and a supply voltage of -3 Volt.

I. Introduction

High-frequency oscillators are key components in modern low-cost radar systems for automotive and other sensor applications. Most of today's automotive radar systems utilize the frequency bands at 24 and 77 GHz. For future developments, also higher frequency bands at 94 and 140 GHz are under discussion. Reasons for the use of higher frequency bands are the further miniaturization of the radar systems and the better beam forming prospects due to the shorter wavelength. Also other applications such as millimeter-wave holography with high resolution require oscillators at very high frequency [6].

Recently, several monolithic integrated LC oscillators have been presented operating in frequency regions useful for automotive radar [1,2,3].

This paper presents a fundamental mode VCO that is designed for the use in a 94 GHz automotive radar system. The manufactured LC-oscillator works at an oscillation frequency between 95.2 GHz and 97.4 GHz at a supply voltage of -3 V. The device is fabricated in a 0.25 µm SiGe:C BiCMOS technology [4,5].

II. Circuit Design

The circuit diagram of the LC oscillator is shown in Fig.1. The circuit is a common collector Colpitts oscillator in fully differential implementation. With the symmetric circuit, two advantages are reached: First, it gives reduced signal interference via the silicon substrate and, second, the coupling of the high-frequency energy to subsequent building blocks such as integrated amplifiers or mixers is more effective.

The tank is a symmetric circuit of two Inductors L1 and L1' and the MIM capacitors C_1, C2, C_1' and C2'. In parallel to the MIM capacitor C_1 acts the base-emitter capacitor of the bipolar transistor C_{BE}. For explanation, the tank can be divided into two half circuits separated by the symmetry line shown in Fig. 1. In operation, the oscillator-halves are working in the odd mode, such that the outputs are 180ºout of phase. The nodes of the tank indicated by the symmetry line have virtual ground.

The oscillation frequency can then be estimated approximately by the following equation:

$$f = 1/(2\pi\sqrt{L_1\{C_{BC} + [C_2 \cdot (C_{BE} + C_1)/(C_1 + C_2 + C_{BE})]\}})$$

Were C_{BC} is the base-collector capacitance of the transistors.

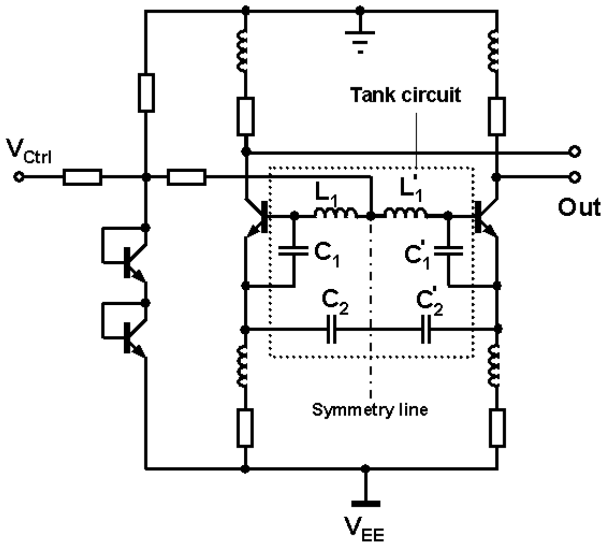

Fig. 1. Circuit diagram of the high frequency oscillator.

III. Experimental Results

The oscillator was fabricated in the IHP 0.25 µm SiGe:C BiCMOS technology. The bipolar transistors of this technology show a maximum transit frequency f_T of 200 GHz and also a maximum frequency of oscillation f_{max} of 200 GHz [4]. In the oscillator only bipolar devices and passive devices were used but no MOS devices. The metal system of the technology provides four layers of aluminum with the fourth layers thickness of 2 µm. High-quality inductors can be designed within this layer. The metal-insulator-metal (MIM) capacitors use the layers metal two and metal three and have a specific capacitance of 1 fF/µm^2.

The oscillator was characterized using an on-wafer test-system with GS-probes. For determination of the output spectrum a Rohde & Schwartz spectrum analyzer

FSEM30 with a mixer unit FS-Z110 was used. The supply voltage of the oscillator is -3V. Fig. 3 shows the measured output spectrum. The output power is –13.7 dBm per output channel. The frequency of oscillation can be tuned by applying a tuning voltage at the Vctrl input thereby changing the current flowing through the oscillator core. With increasing current level the internal transistor capacitances will go up and the frequency of oscillation is reduced. The tuning range is from 97.5 GHz to 95.2 GHz for the control voltage changing from –2.4 V to 0 V (Fig.4). Because the target frequency of 94 GHz was not met in this design a redesign has to be done. The capacitance of C2 and C2' will be reduced by a modest amount to shift the frequency to 94 GHz. The current consumption of the whole oscillator is within the range of 15 mA to 37 mA. Of course, the output power will also undergo a change with varying the current flowing through the oscillator. The maximum measured output power is –11.2 dBm. Within the frequency range from 95.2 GHz to 97.5 GHz the output power is above -20dBm.

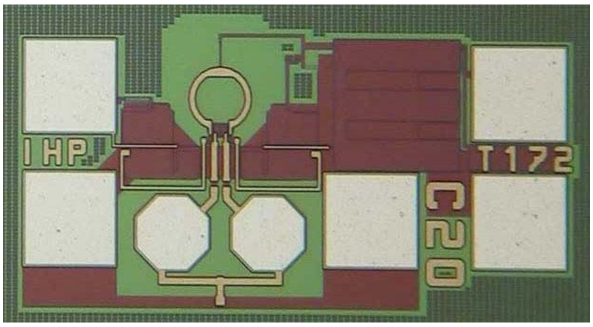

Fig. 2. Photograph of the oscillator chip. It measures 650µm x 350µm.

The phase noise of the oscillator was measured by using the spectrum analyzer with an appropriate mixer unit (Fig. 3). The phase noise is -88 dBc/Hz at 1 MHz offset and -94 dBc/Hz at 2 MHz offset.

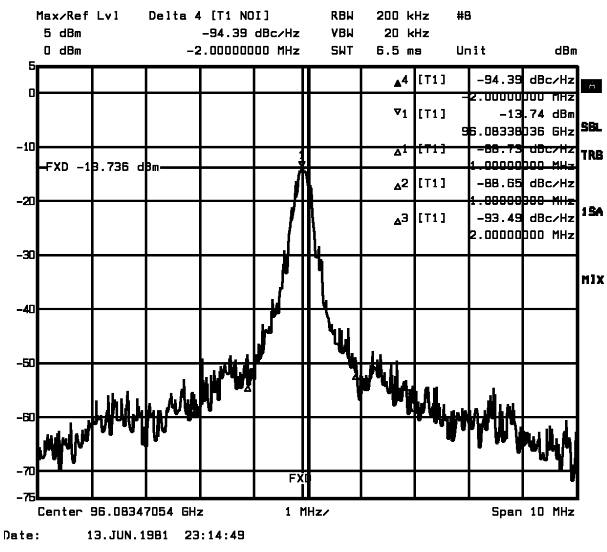

Fig. 3. Spectrum of single-ended output. The center frequency is 96.1 GHz.

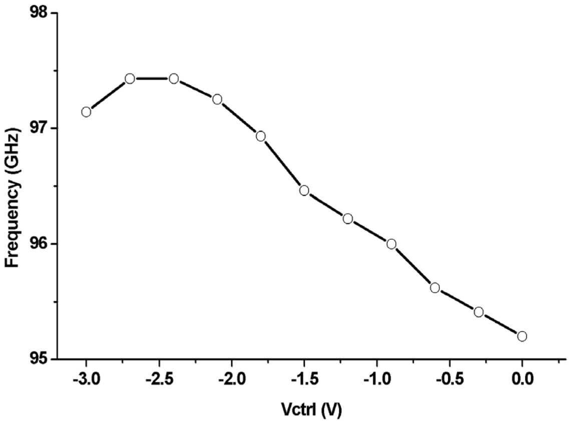

Fig. 4. Tuning curve of the LC oscillator.

IV. CONCLUSIONS

The paper presented an LC oscillator working from 95.2 GHz to 97.5 GHz fabricated in a 0.25 µm SiGe:C BiCMOS technology. The oscillator is intended for the use in automotive radar applications at 94 GHz. In the redesign of the oscillator the oscillation frequency has to be shifted to the target by reducing the value of the MIM capacitors C2 and C2' by a modest amount.

ACKNOWLEDGEMENT

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