A 5.7 GHz Interpolative VCO Using InGaP/GaAs HBT Technology

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***Abstract*—A 5.7 GHz monolithic interpolative voltage-controlled oscillator using InGaP/GaAs HBT technology is demonstrated for the first time. Frequency tuning is achieved by changing the open loop gain instead of the tank capacitor. The experimental result showed that a 500-MHz tuning range at 5.7 GHz was realized, which can meet the requirement of 5.7 GHz ISM band.**

***Index Terms*—InGaP, interpolative, MBT, oscillators, VCO.**

I. Introduction

RECENTLY, the FCC in the United States has proposed to allocate 300 MHz of spectrum in 5–6 GHz band for ISM use and the wireless LAN is one potential application that can exploit this new spectral allocation [1]. Consequently, an oscillator with a tuning range of 300-MHz at 5.7 GHz is necessary. Most LC oscillators use varactors to vary their oscillating frequencies. However, the tuning range is usually provided by off-chip varactors and not very wide. Nguyen and Meyer [2] proposed and realized an interpolative VCO in which the oscillating frequency is interpolated from two resonant frequencies of two LC resonators, respectively. Hence, wide tuning range can be obtained quite easily and monolithically, and no off-chip varactor is required. In their work, a tuning range of 200-MHz at 1.8 GHz was obtained by using an oxide-isolated BiCMOS IC process with typical f_T $(n\text{-}p\text{-}n) = 10$ GHz. In order to meet the requirements of high operating frequency and wide tuning range for the 5–6 GHz ISM band, we were motivated to use InGaP/GaAs HBT rather than BiCMOS IC process to realize the monolithic interpolative oscillators. The experimental results showed that a 500-MHz tuning range centered at 5.7 GHz, phase noise of -89.74 dBc/Hz measured at 100 kHz offset from the carrier (5.51 GHz) and output power of -13 dBm were obtained.

II. Principles of Circuit Design

The core circuit of the interpolative VCO is depicted in Fig. 1. The detailed analysis of the interpolative oscillator has been given in [2]. The interpolative VCO can be thought of as a cross-coupled differential pair negative resistance (or gm) oscillator composed of Q_5, Q_6, L_1-C_1-R_1 resonator and L_2-C_2-R_2 resonator. The relative contributions of the two resonators in the overall open loop transfer function are controlled by the Gilbert quad (consisting of Q_1, Q_2, Q_3 and Q_4), which is inserted between the cross-coupled differential pair and the two resonators. In the extreme cases where $(V_{b1} - V_{b2})/V_T \gg 1$ or $(V_{b2} - V_{b1})/V_T \gg 1$, the oscillation frequency ω_c is determined only by L_1-C_1-R_1 resonator or L_2-C_2-R_2 resonator, respectively. For intermediate values of $(V_{b1}-V_{b2})/V_T$ or $(V_{b2}-V_{b1})/V_T, \omega_c$ can be interpolated between the resonant frequencies of the two resonators [3].

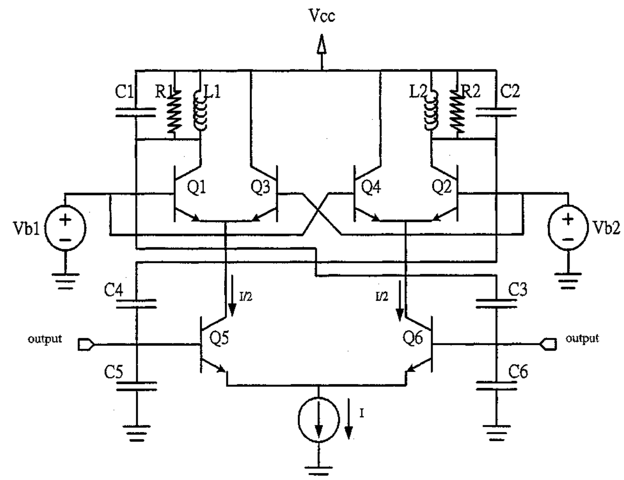

Fig. 1. Core circuit of the interpolative voltage controlled oscillator.

III. Measured Results and Discussion

The complete circuit of the interpolative VCO is shown in Fig. 2. A single-to-differential converting circuit consisting of Q_9 and Q_{10} is used to convert the single-ended control voltage V_{ctrl} to the differential control voltage $V_{b1}-V_{b2}$. The differential output voltage across the base nodes of Q_5 and Q_6 of the core circuit is converted to a single-ended output voltage V_{out} by a differential amplifier composed of Q_{12} and Q_{13}. The simulation result of oscillation frequency versus V_{ctrl} by Star-HSPICE is shown in Fig. 3. InGaP/GaAs HBT IC process with $f_T = 40$ GHz is used to fabricate the VCO, and the die photograph of the finished VCO is shown in Fig. 4. This circuit occupies an area of $300\ \mu$m $\times$ $500\ \mu$m excluding the testing pads.

The measured characteristics of oscillation frequency versus V_{ctrl} exhibit a tuning range of 500 MHz extending from 5.4 GHz to 5.9 GHz, as shown in Fig. 3. For a V_{ctrl} near 2.7 V, the output spectrum of the VCO measured by HP70001A is

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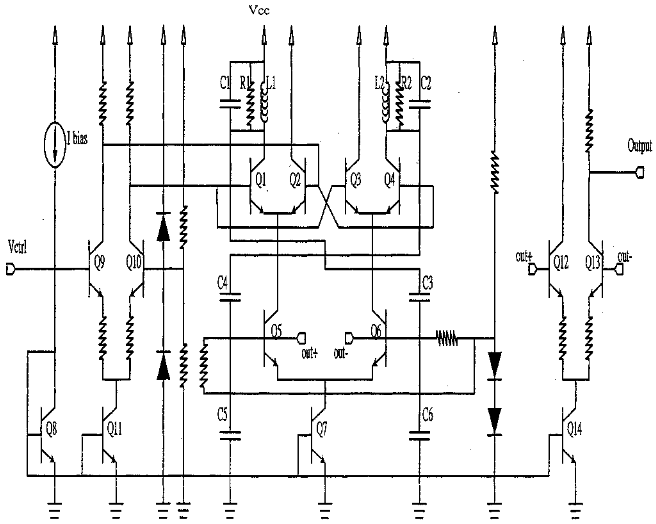

Fig. 2. Complete circuit of the monolithic interpolative VCO.

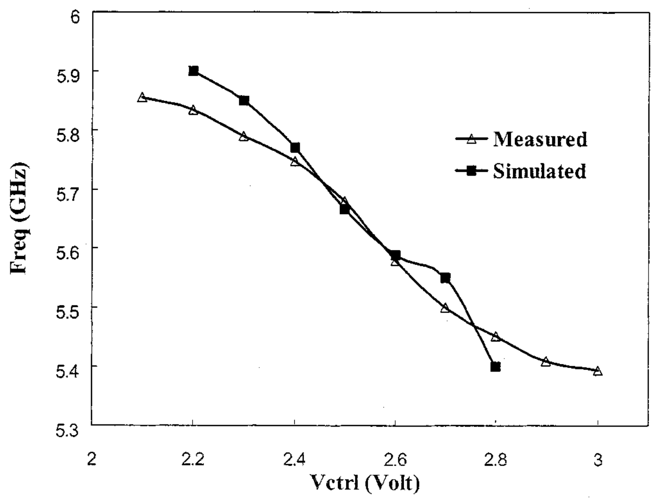

Fig. 3. Simulated and measured characteristics of oscillation frequency versus control voltage.

shown in Fig. 5. A phase noise at 100 kHz offset from the carrier ($f_o = 5.51$ GHz) is calculated to be -89.72 dBc/Hz from the measured spectrum according to the formula used by [4]. This circuit dissipates 84 mW from a 4.2-V supply. An output power level of -13 dBm is also obtained. The low output power is due to nonoptimized design and can be improved by reducing the degenerate emitter resistances of Q_{12}/Q_{13}, replacing the collector resistor of Q_{13} with an inductor, and including a matching network for a 50 Ω load. All the above results are better than the previous reported values of oscillating frequency (1.8 GHz), tuning range (200 MHz), phase noise (-88 dBc/Hz) and the output power (-23 dBm). The reason is attributed to the better technology (InGaP/GaAs HBT) we choose.

IV. Conclusion and Discussion

The first interpolative VCO using InGaP/GaAs HBT technology is reported. A 500-MHz tuning range at 5.7 GHz is

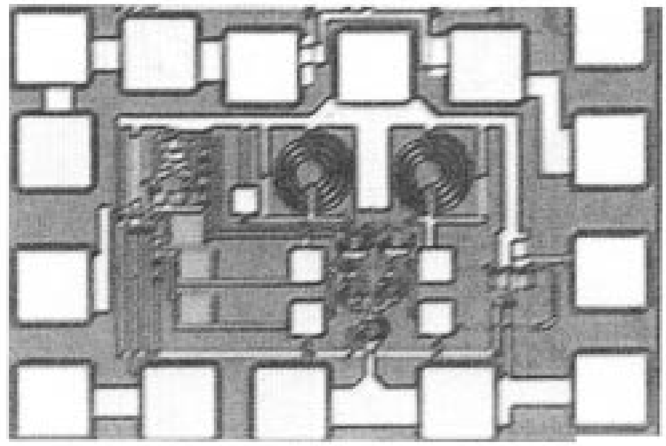

Fig. 4. Die photograph of the monolithic VCO. Two VCOs are included in this chip.

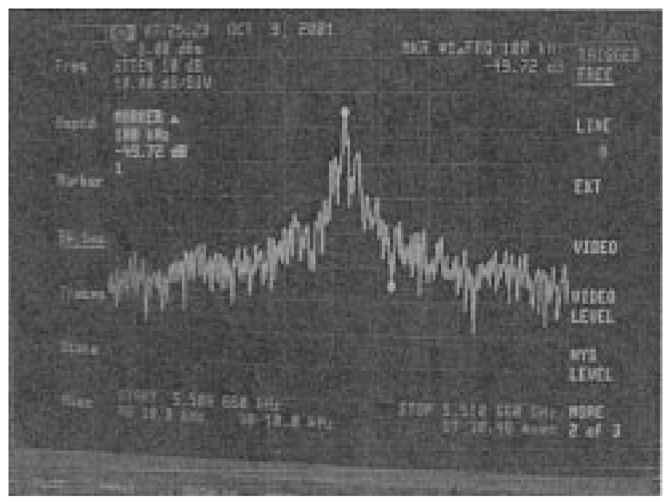

Fig. 5. Output spectrum of the VCO.

achieved, which can meet the requirements of the recent FCC release of 300 MHz spectrum in 5–6 GHZ band for ISM use. The performance of the InGaP/GaAs interpolative VCO is better than that of its BiCMOS version in terms of oscillating frequency, tuning range, phase noise, and output power.

Acknowledgment

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