A 14 GHz MMIC VCO FOR HYBRID DEMONSTRATOR APPLICATION

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Abstract

A 14 GHz MMIC voltage controlled oscillator is described and characterized. The MMIC circuit is connected in the hybrid circuit including DC bias pads with blocking capacitances and bias resistance and RF output, which is splitted into two outputs with 12 dB different power levels.

INTRODUCTION

For realizing of more compact and cost - effective radar systems, low cost integration methods can be used. There is increasing interest, focused on the possibility of implementation of monolithic multifunctional microwave integrated circuits in the receiver front end. The VCO appears as a main part of the radar front end. To have the possibility to evaluate the system performances including the MMIC VCO, the chip are intended to be used in radar receiver (e.g. FMCW) where it may easily be employed within a phase-locked loop (PLL). In this report the implementation of the MMIC chip in to shielded area with output K-connectors is described.

14 GHz MMIC VCO

A 14 GHz monolithic voltage controlled oscillator, based on a negative resistance topology has been designed and fabricated. The schematic of the designed VCO is shown in Fig.1.The optimization of oscillator negative resistance over desired frequency is performed using small signal analysis of the circuit on right side from point A. Adjusting the length of the source open stub L_s (feedback component) and gate line L_1 a broad band negative resistance is obtained and spurious oscillation out of the desired band (12 GHz to 16 GHz) are quenched.

The resonator (left side from point A) consists of HEMT2 with double bias circuits for the gate (Vtun) and the drain, capacitance G and inductance L₆. The drain voltage Vdv can be used occasionally for linearization of the tuning and reducing the phase noise [1].Bias networks consists of inductances, optimized to stop RF leakage and bypass capacitors to ignore the low frequency parasitic oscillation. The photograph of the fabricated chip is shown on Fig.2. The chip sizes are 1.5x2 mm.



Fig.1 Schematic of 14 GHz monolithic VCO

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The chip has a gold plated input DC pads and GSG RF output pads with sizes $50x50\mu m$. The MMIC thickness is $100 \ \mu m$.

VCO HYBRID IMPLEMENTATION

The VCO chip is integrated in a hybrid circuit by using a 10 mils (254 μ m) alumina substrate of Reinhardt - Microtech The dielectric constant is 9.9 and loss factor 10⁻⁴. The topology is depicted on Fig.3. It includes the bias pads with drain resistor and halls for blocking capacitors. The RF output provides splitting of the signal into two outputs with 12 dB difference of the output power.



Fig.3 Layout of Al₂O₃ substrate

A broad band directional coupler designed for 8 to 15 GHz bandwidth is realized to ameliorate a supplementary output for PLL connection. The photograph of the implemented circuit with VCO chip included is shown on Fig.4. The chip hall is designed to be appropriate for different chip's size. The metal case is designed with a 120µm high shelf for the MMIC to elevate the chip's surface to the same level as the alumina substrate. This will ensure that the connecting bonds will be as short as possible. Two supplementary alumina substrate plates with 50 ohm lines are used at the RF outputs to fit the circuit to the standard (20x20 mm) shield. The shielded VCO hybrid circuit is shown on Fig.5. The MMIC, the capacitors and the substrates are mounted with silver epoxy adhesive (Epotek H20E). Flange mount Kconnectors (K103M) with standard low-reflection glass beads are used at the RF outputs of the circuit. The Kconnector beads and DC pins are soldered to the shield with standard SnPb eutectic solder using a hot plate. The



Fig.2 Photograph of 14 GHz MMIC VCO. Chip sizes are 1.5x2mm



Fig.4 Photograph of hybrid implementation. Size is 20x20 mm



Fig.5 Photograph of shielded MMIC VCO

A 14 GHz MMIC VCO FOR HYBRID DEMONSTRATOR APPLICATION Rumen Kozhuharov, Camilla Kärnfelt, Herbert Zirath K-connector pins are then connected to the RF path by silver epoxy. 25 μ m gold ball bonding is used to connect the DC pins to the substrate pads. For best high frequency matching, 50 μ m gold ribbon wire is used to connect the MMIC to the substrate microstrip line. The VCO is finally covered with a metal lid to shield it. The assembly method and materials were chosen to make the assembly possible with equipment available at Microwave Electronics Laboratory.

EXPERIMENTAL RESULTS

The shielded VCO is measured using HP8565E spectrum analyzer. The dependence of output power on varactor tuning voltage at four different bias voltage Vd= 1.8; 2.0; 2.5 and 3.0 V is shown on Fig.6(a). The output power is 12 dBm at bias voltage 3 V and the dissipated power is 90 mW. More than 6dB power control is possible by changing the bias voltage. Fairly constant level of the power is obtained . The dissipated power depending on bias voltage (from 1.8 V to 3.0 V.) is from 37 mW to 90 mW. The power levels at the second output are between 0 dBm and -5 dBm.



Fig.6 Output characteristics power (a) and frequency (b) vs. tuning varactor voltage at different bias voltages

Frequency tuning bandwidth of 600 MHz centered at 13.7 GHz is obtained. The output frequency dependence on the tuning voltage at different bias voltages (Vd =2 ;2.5 and 3V) is shown on Fig.6(b). The linearity of tuning characteristics improved with increasing of the bias voltage.

The phase noise characteristic of the VCO is of a main importance in its front end application. Using the shielded MMIC VCO give the possibility to achieve better stability and noise performances. The phase noise measurement is carried out with HP E5500 noise measurement system from Agilent, using frequency discriminator method. The phase noise vs. frequency offset from the carrier at three different bias voltages are depicted on Fig.7 (a) .The oscillator shows 30 dB/decade slope between 100 Hz and 10 kHz, above 10 kHz the slope is 25 dB/decade. Fig.7 (b) shows the phase noise vs. tuning voltage at bias voltage Vd=2 V. The minimum phase noise of -87 dBc at 100 kHz from carrier was obtained, which indicates an improvement of the phase noise daracteristic compare to one from "on-wafer" VCO measurement (-80 dBc at 100 kHz)

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Fig.7 Measured phase noise of shielded VCO vs. frequency offset (a) at different bias voltage, and vs. tuning voltage at Vd= 2 V.

Summary and conclusions

A 14 GHz monolithic VCO is successfully implement in to a hybrid environment for demonstrator application. During the design of MMIC circuit, the bonding wires were modeled by 0.3 nH inductances. The measured oscillation frequency differs less than 1% from the measured one "on wafer. An improvement of 7dB of phase noise is observed due to the shielded circuit and better temperature conditions. All assembly operations were made in the Microwave Electronics Laboratory of Microelectronics department – MC2 at Chalmers University.

The VCO is realized in the frame of "VCO-Topologies suitable for MMIC" project of CHACH.

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