Fluidically-tuned Reflection Oscillator at C-Band

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***Abstract*—A fluidically-tuned reflection-type oscillator using a substrate-integrated waveguide (SIW) resonator is designed and tested. Frequency tuning is achieved by depositing water droplets along the transmission lines that feed the resonator and the oscillator's load matching network. Experimental measurements show that the oscillator can be tuned over a 110 MHz band from 5.053 GHz to 4.943 GHz while its phase noise degrades by 1.2 dB from −125.2 dBc/Hz to −124 dBc/Hz at 1 MHz offset over the band. To the best of our knowledge, this is the first work to investigate the fluidic tuning of microwave oscillators.**

I. Introduction

There is growing interest in the use of dielectric fluids and liquid metal to tune the response of microwave components and antennas [1]–[4]. Dielectric fluids with high permittivities such as distilled water, $\epsilon = 81\epsilon_0$, can be used to tune the electrical length of transmission lines or resonator structures with only small amounts of liquid. An advantage of using dielectric fluids for tuning of active circuits is that fluids do not add electronic noise nor do they produce distortion to any noticeable extent when compared to semiconductor devices. This paper concerns the design of a 5 GHz fluidically tuned microwave oscillator exhibiting minimal phase-noise (PN) degradation. The oscillator was designed using a packaged pHEMT device on a 1.5-mm thick substrate with $\epsilon_r = 3.5$.

II. Fluidic Tunable Oscillator

The one-port TE_{101} mode SIW cavity resonator depicted in Fig. 1 was designed for the oscillator tank. Full-wave simulations show that the structure resonates at 5.12 GHz and has an unloaded quality factor, Q_0, of 297. Fig. 2 shows the layout of the proposed oscillator circuit. The active device is a pHEMT (ATF-36163) from Broadcom in common-source configuration. The oscillator is designed based on the negative resistance method in which the input impedance to the transistor, Z_{IN}, has a negative real component. TL_1 and TL_2 form a matching network which controls the load impedance $Z_L = R_L + jX_L$ that is presented to the impedance Z_{IN}. As a starting point for oscillator design, the circuit is made to oscillate at the SIW cavity's resonant frequency and the real and imaginary parts of Z_L are designed to satisfy the relationships $R_L = |R_{IN}|/3$ and $X_L = -X_{IN}$ at 5.12 GHz.

TL_6 is connected to the transistor's source terminal to make it unstable. TL_9 and TL_{10} are used for harmonic suppression. TL_4 is a quarter-wavelength transformer at 5.12 GHz used to control the coupling to the cavity and TL_3 is a stub used to suppress spurious oscillations. All dc bypass capacitors (C) have a value of 1.5 pF.

To tune the oscillation frequency, the electrical length of TL_4 is varied by depositing small volume water droplets over its surface. Since it is part of the resonator, the input impedance

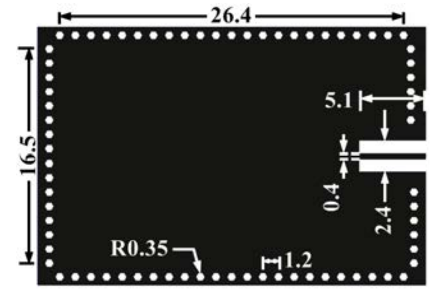
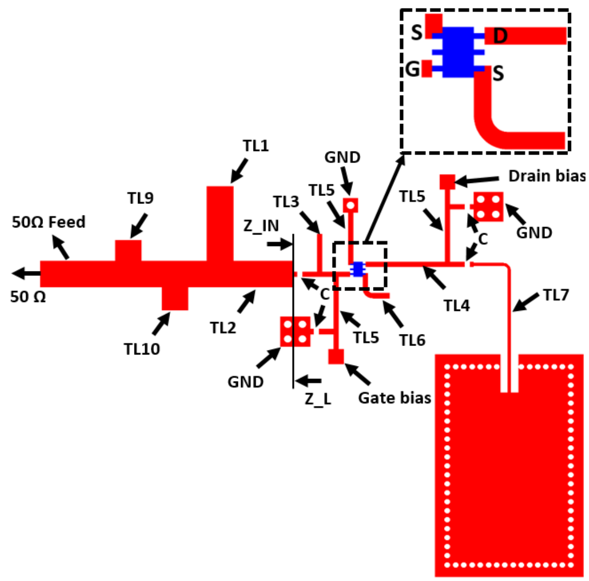


Fig. 1. SIW resonator (all dimensions in mm).



T-line lengths (L) and widths (W) in millimeters:

	TL_1	TL_2	TL_9	TL_{10}	TL_3	TL_4	TL_5	TL_6	TL_7
L	10	8.1	2.8	3.1	5	10.6	7	5.1	17
W	3.5				0.7				0.4

Fig. 2. Reflection oscillator layout

Z_{IN} is expected to change hence causing a variation in the frequency at which the oscillation conditions are satisfied. To simulate this, an HFSS model was created for TL_4 in which water droplets (ϵ_r = 81) of 10 μL volume were deposited on its surface. The electrical delay of the line changes because of the perturbation that water causes over the exposed fields.

III. Experimental Results

A photo of the fabricated oscillator is shown in Fig. 3. The fluidic holes were drilled into the substrate around the matching network and TL_4. These holes act as barriers which

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Fig. 3. Fluidically tuned oscillator photo.

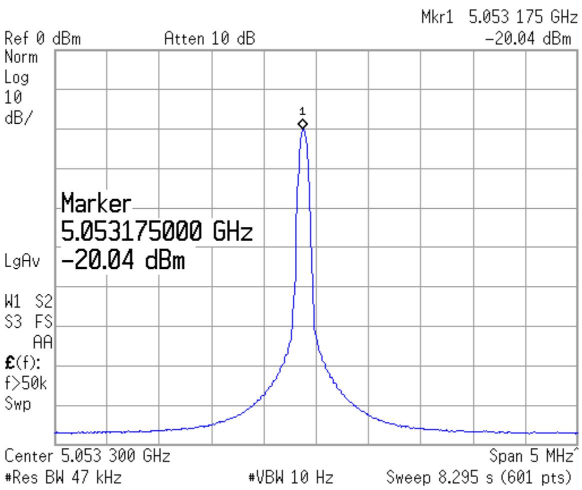

Fig. 4. Output spectrum of the oscillator at 5.053 GHz.

confine the water droplets over the surface of the transmission lines. The oscillator was connected through a 20 dB attenuator to a spectrum analyzer (E4446A from Keysight). Fig. 4 shows the oscillator spectrum which exhibits a free-running frequency of 5.053 GHz, which is only slightly shifted from the simulated free-running output of 5.12 GHz. When water droplets are added, the output frequency is tuned downward in discrete steps to 4.943 GHz−a range of 110 MHz. Meanwhile, the output power remains fixed at 0 dBm. Fig. 6 depicts the change in output frequency versus the number of water droplets added along the resonator and matching network. Fig. 5(a)-(b) shows the measured PN of the oscillator at 5.053 GHz and 4.943 GHz, respectively. At 5.053 GHz, the PN is -125.2 dBc/Hz at 1 MHz offset and at 4.943 GHz it is -124 dBc/Hz at 1 MHz offset.

IV. Conclusion

A fluidically tuned C-band reflection type oscillator was designed, fabricated, and tested. It oscillates at 5.053 GHz and has a PN of -125.2 dBc/Hz at 1 MHz offset. Adding water droplets over the resonator and matching network, progressively shifts the oscillation frequency downward in discrete steps to 4.943 GHz with no observable change in the output power of the oscillator and only a negligible PN degradation of 1.2 dB.

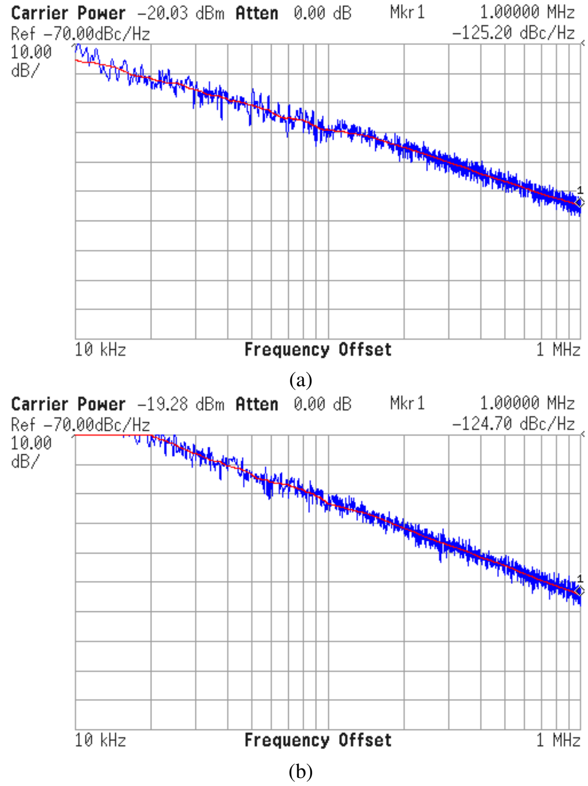

Fig. 5. Phase noise at (a) 5.053 GHz and (b) 4.943 GHz.

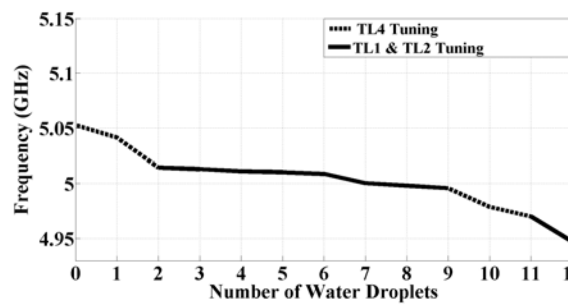

Fig. 6. Output frequency vs. number of water droplets.

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