Low-Phase Noise AlGaN/GaN FET-Based Voltage Controlled Oscillators (VCOs)

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***Abstract*—The first report of AlGaN/GaN HEMT-based voltage controlled oscillators (VCOs) is presented. Varactor-tuned oscillators implemented using distributed networks oscillate at 6 GHz with high output power (0.5 W), low-phase noise (−92 dBc/Hz SSB noise at 100 KHz offset), and high-tuning bandwidth (10%). The measured phase noise of AlGaN/GaN FETs is compared to the phase noise of GaAs FET and GaAs HBTs at 6 GHz, indicating the AlGaN/GaN FET exhibits equivalent SSB noise to GaAs FETs. These results indicate high power AlGaN/GaN-based VCOs may be used to simplify the line up in a communication radio, while improving the overall efficiency of the radio.**

***Index Terms*—Gallium nitride, oscillator, solid state.**

I. Introduction

GaAs-BASED voltage controlled oscillators (VCOs) may be utilized in commercial communication radios either as upconverters [1] or local oscillator (LO) sources [2]. For either application, driver amplifiers and MMICs are typically required to amplify the output of the phase-locked oscillator at the expense of additional power consumption and size. Hence, a family of medium and high power oscillators are advantageous, assuming other parameters (including phase noise, and tunability) are not degraded.

GaN is an ideal candidate for the amplifier element in a power oscillator as it enables high power and high efficiency from a single, small transistor die. AlGaN/GaN FETs have demonstrated incredible power densities up to 26 GHz from various organizations [3]–[6]. However, the potential of GaN for oscillator applications has not been explored to date.

II. Oscillator Design

The common-gate configuration is an ideal vehicle for high-power oscillators as it oscillates readily and is easily tuned. Common-gate configuration oscillators using GaAs FETs have been around for over 20 years [7]. Other oscillator configurations [8]–[10], such as common-source, common-drain, and reverse-channel, have previously been demonstrated for GaAs FET oscillators.

A schematic representation of the common-gate circuit used is provided in Fig. 1. The frequency determining network was placed in the source of the device along with the varactor circuit. The output power is coupled through a series dc-block capacitors. The circuit is biased using the source resistor, Rs, to establish the gate-to-source voltage. RF chokes are utilized to minimize the losses on the bias lines. The advantage of this bias circuit is the circuit only requires one positive supply (other than the control voltage). The disadvantage of locating the bias circuit in the source region is the I^2R losses in the source resistance, which degrade the overall circuit efficiency.

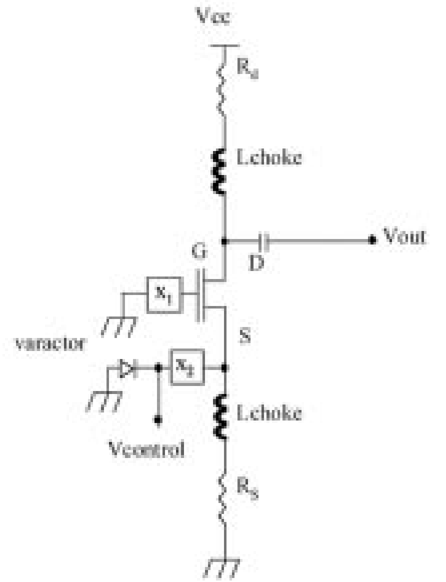

Fig. 1. Schematic of the common gate high-power configuration.

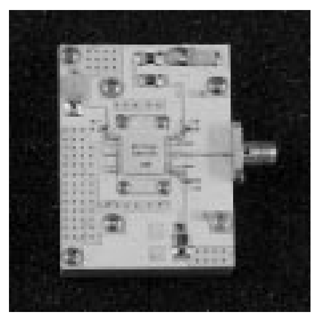

Fig. 2. Picture of AlGaN/GaN FET-based VCO in test fixture.

The circuit was constructed in an industry standard metal-ceramic package. The packaged component was mounted in a test fixture for convenience. A picture of the completed assembly is shown in Fig. 2.

III. Test Results

A supply voltage of +20 V (Vcc) was selected, which provided +15 V across the drain-source of the AlGaN/GaN FET.

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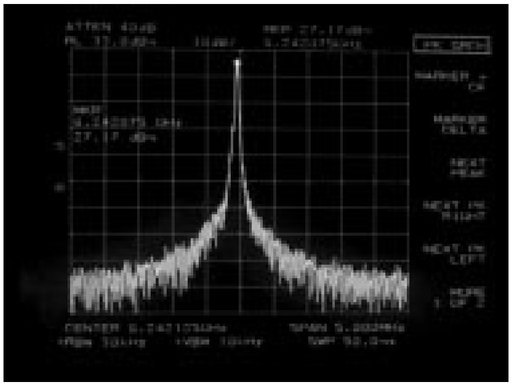

Fig. 3. Spectrum of free-running AlGaN/GaN VCO.

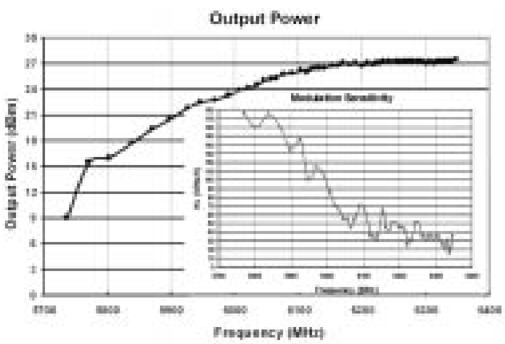

Fig. 4. Modulation sensitivity and output power of 6 GHz AlGaN/GaN FET-based VCO ($Vcc = 20$ V).

The measured bias current was 179 mA (Icc). A plot showing the free running VCO (at Vcontrol $= +10$ V) is provided in Fig. 3. The measured second harmonic was -22 dBc. The control voltage range was 10 V. A plot of the modulation sensitivity (Kv) and associated output power is shown in Fig. 4. The Kv slopes from 150 MHz/V (at the low end of the band) to 40 MHz/V (at the high end of the band). The tuning range was 600 MHz, or 10% bandwidth. The output power exceeded 0.5 W at the high end of the band. The output power was measured at the output of the fixture and does not include losses due to the dc blocking capacitor, as well as transition losses from the package-to-microstrip transition, and the microstrip-to-connector transition.

IV. Phase Noise Performance

The single-sideband noise was tested at 6 GHz (Vcc $= 20$ V, Vcon$= +12$) and the results are plotted in Fig. 5. The phase noise was evaluated utilizing an NTS-1000B-AM phase noise analysis system and DCR-14 000A frequency downconverter manufactured by RDL Inc. At 100 kHz offset, the circuit achieves a single-sideband phase noise of -92 dBc/Hz. The phase noise was tested as a function of control voltage. The phase noise of the GaN oscillator was compared to the phase noise of both GaAs FET and GaAs HBT-based VCO's previously published [2]. The GaAs VCO's have comparable tuning networks, tuning bandwidth, but exhibit 5 mW of output power compared the 0.5 W output power of the GaN VCO presented here. The GaN FET VCO exhibits -30 dB/decade out to 1 MHz and is dominated by the $1/f$ noise of the GaN Transistor.

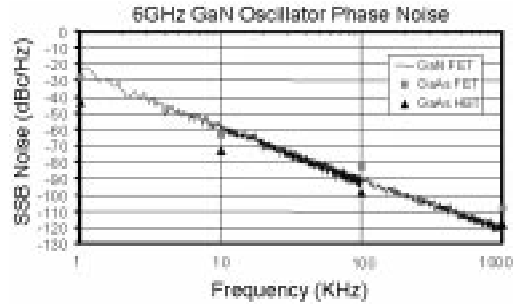

Fig. 5. Phase noise of AlGaN/GaN FET-based VCO at 6 GHz compared to measured phase noise from GaAs FET and GaAs HBT VCOs [2]. At 100 kHz offset, the phase noise is -92 dBc/Hz.

The GaAs FET VCO tested maintains -30 dB/decade out to 10 kHz where it changes to -20 dB/decade thereafter due to the Q of the resonator. The GaAs HBT design maintains -30 dB/decade farther out than the GaAs FET VCO due to its improved resonator Q. The dielectric constant of the selected substrates (on which the resonators were designed) increased in order from the GaAs FET, GaAs HBT, to the GaN FET. Hence, the single-sideband noise of the GaN is better than both the GaAs FET and GaAs HBT at high offset frequency.

V. Conclusion

GaN FET-based VCOs have been reported for the first time. These results indicate that the single-sideband noise (at microwave frequency) of a GaN FET-based oscillator is equivalent to the single-sideband noise of a GaAs FET-based oscillator. Subsequently, these results suggest that a family of medium and high power VCOs may be developed to achieve more efficient communication radios.

Acknowledgment

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