Ka- and W-Band PM-HFET DRO's

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***Abstract*—Dielectric resonator stabilized oscillators have been designed, fabricated, and investigated. The oscillators consist of microstrip matching and biasing circuits on alumina substrate, a dielectric resonator puck, and a low-noise quarter-micron InGaAs–GaAs pseudomorphic (PM) HFET as the active device. At 37 GHz and 81 GHz, output powers of 10 dBm and 0 dBm have been measured. The phase noise of the Ka-band and W-band oscillators has been determined to be −97 dBc/Hz at 100 kHz and −90 dBc/Hz at 1 MHz off carrier, respectively.**

I. Introduction

The increasing demand for sensor and communication systems in the millimeter-wave frequency range results in the need for efficient and highly stable oscillators. Although MESFET- and HFET-oscillators are known to have phase noise levels which are significantly higher than those of bipolar oscillators, they are able to operate at higher frequencies well above 30 GHz. By using GaAs-MESFET's oscillators have been reported for frequencies up to 115 GHz [1], at 92 GHz 14 dBm output power has been obtained [2]. Voltage controlled oscillators (VCO's) using HFET's as the active device have shown 8.3 dBm output power at 35 GHz [3] and recently an output power of 7.6 dBm has been demonstrated at 92 GHz [4]. To achieve acceptable phase noise in FET-oscillators varactors or high-Q dielectric resonators are often used in voltage controlled oscillators or fixed frequency oscillators, respectively. At 38 GHz, a varactor-tuned 10-dBm VCO based on MESFET's has shown a phase noise of −100 dBc/Hz at 1 MHz off carrier [5]. Published results for low phase noise oscillators which are frequency stabilized by adding a dielectric resonator (DRO) include a monolithic 38 GHz HFET oscillator with 0-dBm output power ($N/C_{FM} = -68$ dBc/Hz @100kHz) [6], a monolithic 57-GHz MESFET oscillator with $P_{out} = 1.2$ mW [7], and a hybrid MESFET DRO at 65.6 GHz with 7.6 dBm output power [8].

In this letter, we describe the development and performance of 0.25 m PM-HFET oscillators with dielectric stabilization for frequencies up to 81 GHz with good output power, efficiency, and excellent phase noise results.

II. Device Description

As the active device for the oscillators low noise multi-gatefinger PM-HFET's fabricated on layer sequencies grown by MBE have been chosen, for the processing the Daimler–Benz low-noise foundry technology has been used. The gate pattern is defined by e-beam direct writing, resulting in a gate length of 0.25 μm, each of the six gate fingers has a width of 20 μm. The PM-HFET's have shown f_T and f_{max} values of at least 90 GHz and 180 GHz, respectively, the transconductance is 600· · ·700 mS/mm, and the maximum drain current is 600 mA/mm. A description of the technology and the noise behavior of the devices has been published recently [9], [10]. Used in a monolithic 60 GHz LNA [11] these devices have demonstrated an output power of 10 dBm.

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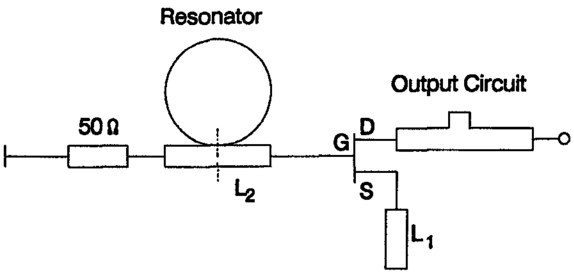
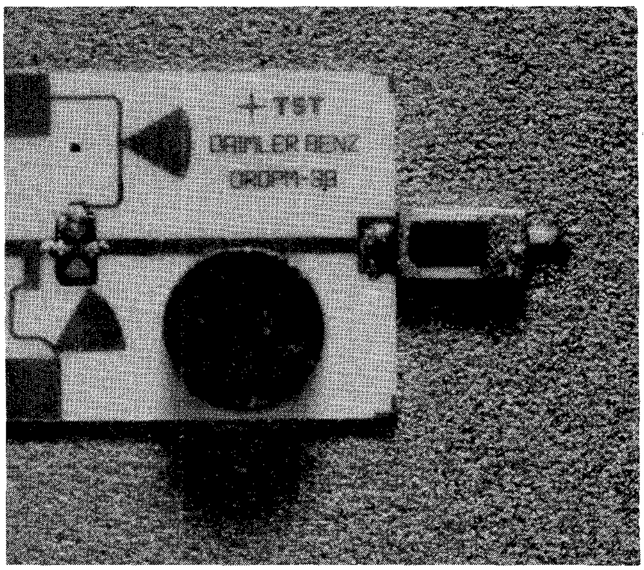


Fig. 1. Equivalent circuit of the dielectric resonator stabilized oscillators.

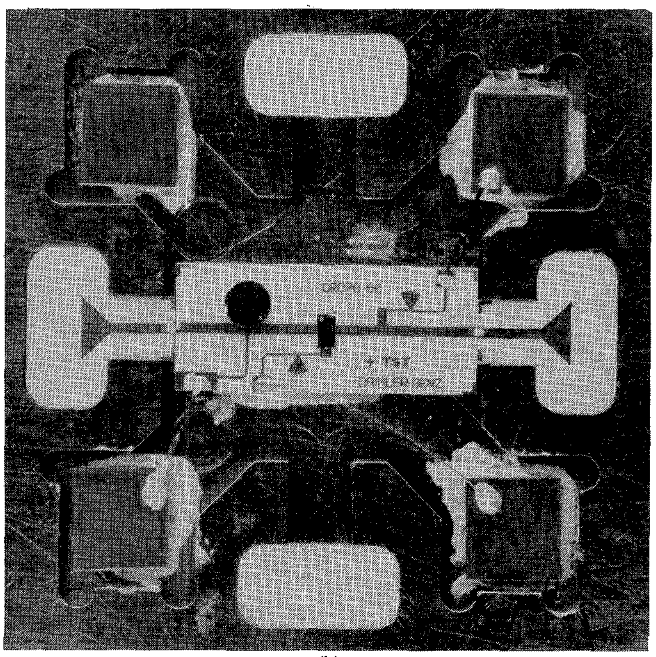
III. Oscillator Configuration and Design

The oscillator circuit consists of a 6-mil alumina substrate with matching and biasing circuits, a dielectric resonator puck, a chip resistor, and a PM-HFET chip inserted into a hole in the substrate. A reflection type oscillator topology with a HFET in common source operation and series feedback has been chosen (Fig. 1). This configuration is known to have low phase noise and excellent frequency stabilization due to its good isolation between the frequency determining element and the RF output port [12]. The dielectric resonator is placed at the gate side of the HFET, while the RF output is at the drain. The design of the microstrip circuit is based on an equivalent circuit derived from small-signal S-parameter data measured up to 40 GHz and uses linear CAD software tools developed at Deutsche Aerospace. The length of the stub at the HFET source L_1 and the distance from the gate port to the resonator coupling locus L_2 have been optimized for maximum negative resistance at the output port of the DRO. At the drain side of the HFET the output circuit matches the oscillator impedance to a 50-Ω load by fulfilling the oscillation condition.

As the dielectric resonator (DR) a commercially available 28-GHz $Ba_2Ti_9O_{20}$-puck with a dielectric constant of 35 was lapped to the desired thickness and diameter. The DR coupled to the stripline at the gate port of the HFET has been modeled as a resonant circuit [13]. The diameters of the 37-GHz and 81-GHz dielectric resonators are 1.44 mm and 0.7 mm with thicknesses of 800 μm and 300 μm, respectively. The temperature coefficient of the resonator is +3 ppm/°C, the unloaded Q has been estimated to be 3000 at 37 GHz and



(a)



(b)

Fig. 2. Photographs of the PM-HFET dielectric resonator oscillators. (a) 37 GHz DRO. (b) 81 GHz DRO.

less than 1000 at 81 GHz. Fig. 2(a) shows the 37 GHz DRO, the chip size is 3*3.6 mm^2. A PM-HFET chip with outer dimensions of 300*560 μm^2 is inserted into an ultrasonically drilled hole in the substrate of the 37 GHz oscillator, the active device of the W-band DRO is flip-chip mounted. The contact pads of the HFET chip and the 50-Ω chip resistor used as a gate termination to quench spurious oscillations are connected to the microstrip lines by using an electrically conductive adhesive, which avoids additional parasitic inductances of bond wires. In case of the 81-GHz DRO the gate termination is realized by using an E-probe transition to a matched W-band WR-10 waveguide (Fig. 2(b)). Biasing networks are realized by using quarter-wavelength 75-Ω lines and 60 radial stubs. To avoid spurious bias oscillations off-chip blocking capacitors are used.

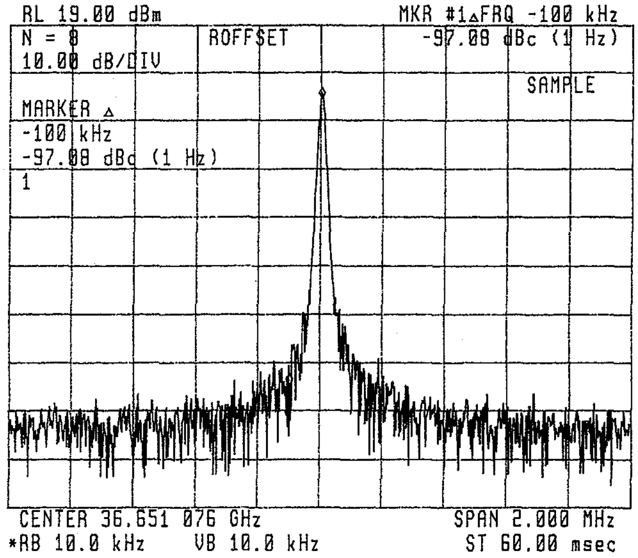


Fig. 3. Output frequency spectrum of the 37-GHz DRO (P_{out} = 10 dBm, N/C$_{FM}$ = −97 dBc/Hz @ 100 kHz).

IV. Oscillator Performance

The RF-performance of the Ka-band DRO has been measured in a test fixture with a microstrip-coaxial transition, the phase noise is determined by using a HP 7000 spectrum analyzer. The measured output frequency spectrum is shown in Fig. 3. At 36.6 GHz an output power of 10 dBm has been obtained when the active device is biased at V_{ds} = 4.4 V and I_{ds} = 40 mA. The dc to RF conversion efficiency is 5.7%. The phase noise N/C$_{FM}$ has been determined to be −97 dBc/Hz at a frequency off carrier of 100 kHz that is similar to data published for HBT-DRO's at 25 GHz [14]. The W-band DRO has been measured in a test fixture with waveguide-to-microstrip transitions. The chip size of the 81 GHz DRO is 4.8*2 mm^2. The low-noise PM-HFET has been biased at V_{ds} = 1.4 V, resulting in a drain current of 15 mA. At 81 GHz an output power of 1 mW at a conversion efficiency of 3.8% has been measured. The phase noise at 1 MHz off carrier is −90 dBc/Hz.

V. Conclusion

State of the art dielectric resonator oscillators (DRO's) have been fabricated by using low-noise 0.25*120 μm^2 PM-HFET's. The circuits have shown good output powers of 10 dBm and 0 dBm at 37 GHz and 81 GHz with excellent phase noise characteristics of −97 dBc/Hz and −90 dBc/Hz at 100 kHz and 1 MHz off carrier, respectively. Monolithic integrated versions of the planar structures are under fabrication. The obtained results make the circuits well suited for local oscillator applications in sensor or digital communication systems at mm-wave frequencies.

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