FET DROs AT V-BAND

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ABSTRACT

MESFET DROs have been demonstrated at V-band. The first unit operates at 51.2 GHz with an output power as high as 9 dBm. The second unit operates at 65.6 GHz with an output power of 7.6 dBm. Dc to RF efficiencies were 18 percent and 14 percent, respectively. Power variation is less than ±0.25 dB over a temperature from 0 to 50°C. The high output power associated with the dc-to-RF efficiency is believed to be the highest ever reported.

INTRODUCTION

Advances in GaAs technology have made possible for FET devices to work well into millimeter-wave frequency (e.g., V-band and W-band). While emphasis has been placed on low noise and power amplifiers, relatively little work have been reported for FET oscillator at V-band.

Oscillators at V- and W-bands typically are dominated by two terminal devices such as Gunn and IMPATT diodes. These devices are capable of high output power; however, they suffer from poor dc-to-RF efficiency. In addition, these devices often experience frequency drift and power fluctuation over temperature.

This paper presents measured data from a couple of DROs at V-band. The circuit simplicity, high output power, attractive dc to RF efficiency, and small circuit sizes are desirable features for receivers in space applications.

CRITICAL COMPONENTS

The success of a DRO lies in its ability to obtain two key components: a high quality factor (Q-factor) dielectric resonator as well as a high gain FET at the operating frequency.

A. Resonator Development

Currently, commercially available dielectric resonators operate at relatively lower frequencies. Although high Q is available at low frequency, it tends to degrade rapidly as frequency increases. To obtain V-band resonators, dimensions [1,2] must be provided to manufacturers, and special high Q materials are needed.

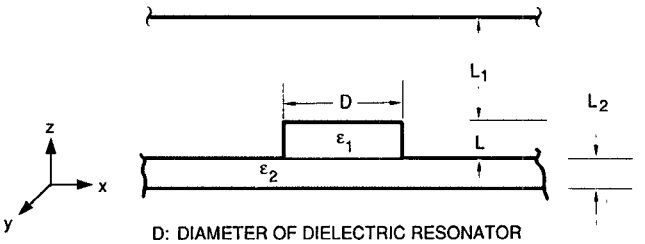
To design dielectric resonator accurately, environmental conditions in which the resonator is to be placed must be considered carefully. Figure 1 shows the condition of the resonator in our model [3,4]. The model includes circuit substrate thickness, circuit substrate dielectric constant, dielectric constant of resonator, as well as the height of the top cover on top of the resonator. The housing is modelled as a parallel-plate waveguide extended infinitely in both X and Y directions.

B. Low Noise MESFET

A low noise GaAs MESFET is employed in this DRO application. The device consists of two 0.25 μm gate fingers that are E-beam written and are placed inside a 2.5 μm source-drain channel. The channel material is doped VPE layers, with N = 3 to 4 x 10^{17} cm^{-3} and a = 1500 Å. A typical device of this type has an I_{dss} of 15 to 20 mA and a G_m of between 9 to 15 mS. Maximum gain is as high as 8 dB. A typical small signal equivalent circuit model of this MESFET is shown in Figure 2.

Resonator Evaluation

Several batches of resonators from different manufacturers were empirically evaluated. These resonators, coupled to a set of microstrip-to-waveguide transitions [5], connected back to back with a 50-ohm microstrip transmission line, were



D: DIAMETER OF DIELECTRIC RESONATOR
ε_1: DIELECTRIC CONSTANT OF RESONATOR
ε_2: DIELECTRIC CONSTANT OF SUBSTRATE
L: HEIGHT OF RESONATOR
L_1: HEIGHT OF TOP COVER
L_2: THICKNESS OF SUBSTRATE

Figure 1 Environmental conditions of the dielectric resonator in our model.

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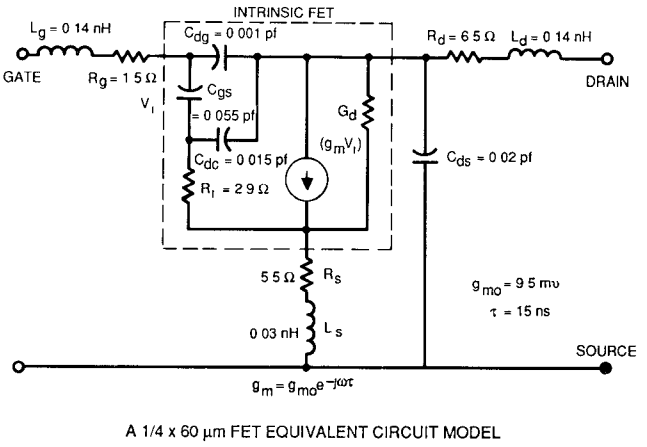

Figure 2 A typical small signal equivalent circuit model of a MESFET.

evaluated in a waveguide housing. Both transmission and reflection coefficient measurement were made to determine load quality (Q_l) and coupling factor (β), from which other parameters such as unloaded Q, external Q, and resonator coupled resistance (R) were determined.

Unloaded Q of resonators as high as 1400 was measured. Other measured resonators parameters are shown in Table 1.

Circuit Topology

A common gate configuration was chosen over other circuit topologies due to circuit simplicity and ease of implementation. The circuit consists of a 0.25 x 60 μm MESFET, an open circuit stub at the gate, a dielectric resonator coupled at the source, and output matching circuit. A microstrip transmission line is connected at the source and terminated with a 50-ohm resistor. The resonator is coupled to the transmission line to provide optimum oscillation conditions. The output circuit is connected between the drain of the MESFET and a microstrip to waveguide transition. The entire circuit is fabricated on a 4 mil thick quartz (ϵ_r = 3.78) substrate. The circuit diagram is shown in Figure 3a and the circuit implementation is shown in Figure 3b.

Oscillator Housing Development

The oscillator housing is made out of an aluminum splitblock configuration. It consists of WR-15 waveguide with a tunable backshort, a below waveguide cutoff channel for the microstrip circuitry, and a 150 x 150 square mil cavity for the

TABLE 1
MEASUREMENTS OF RESONATORS PARAMETERS

	MANUFACTURER 1			MANUFACTURER 2		
	BATCH NO. 1*	BATCH NO. 2				
		NO. 3	NO. 4	NO. 1	NO. 2	NO. 3
UNLOADED Q	600-996	945-1465	942-1334	827	903	840
LOADED Q	164-470	102-346	132-434	151	160	136
EXTERNAL Q	225-837	114-453	153-642	185	195	162
COUPLING COEFFICIENT	2.66-1.19	8.3-3.24	6.2-2.07	4.46	4.64	5.19
COUPLED RESISTANCE	266-119	828-324	616-207	446	463	519

*TYPICAL VALUES OF FIVE SAMPLES.

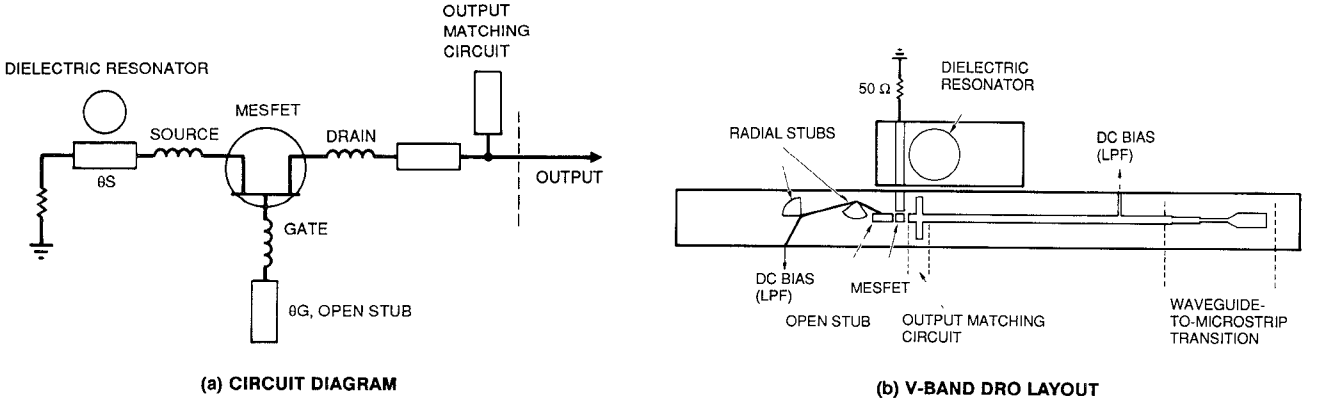

Figure 3 Schematic circuit diagram of a V-band DRO.

placement of the resonator. The overall dimensions of the entire housing are 1.2 x 1.0 x 0.8 inches. A photograph showing the inside view of the circuits, with the top split-block removed, is shown in Figure 4.

Oscillator Performance

A couple of V-band DROs were developed. The first unit (unit 1) demonstrated an oscillation frequency of 65.6 GHz, with an output power of 7.6 dBm, as shown in Figure 5. The oscillator was biased at a drain voltage of 3.2 V with a drain current of 10 mA which yields a dc-to-RF efficiency of approximately 18 percent.

The second unit using a different dielectric resonator demonstrated an oscillation frequency of 51.2 GHz, with an output power as high as 9 dBm. The output power, corresponding with dc bias conditions, and dc to RF efficiencies are shown in Table 2.

Temperature tests were also performed on the second unit (unit 2). The tests were conducted, with 10-degree temperature increments, from 0 to 50°C. A total frequency drift of 49 MHz was obtained. The output power of the oscillator varied by less than ±0.25 dB over the temperature range. The oscillator frequency output spectrums, during temperature test, are shown in Figure 6.

CONCLUSION

Dielectric resonator oscillators at V-band have been demonstrated. Output power as high as 9 dBm can be obtained using MESFET. The 18 percent dc-to-RF efficiency makes the FET DRO attractive for millimeter-wave frequency operation, especially for space applications where efficiency is of a prime concern. Stable output power over temperature makes this FET oscillator attractive over its diode counterpart. Finally, the planar circuit structure employed in this oscillator can be implemented monolithically.

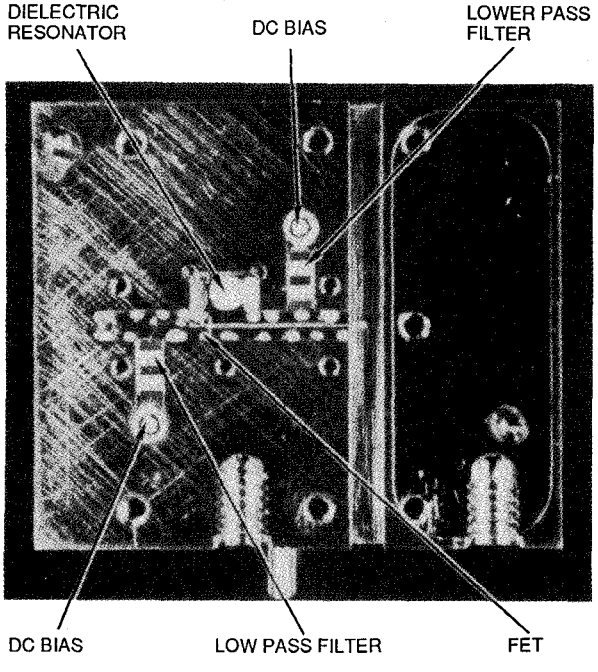

Figure 4 A photograph of V-band DRO with top split-block removed.

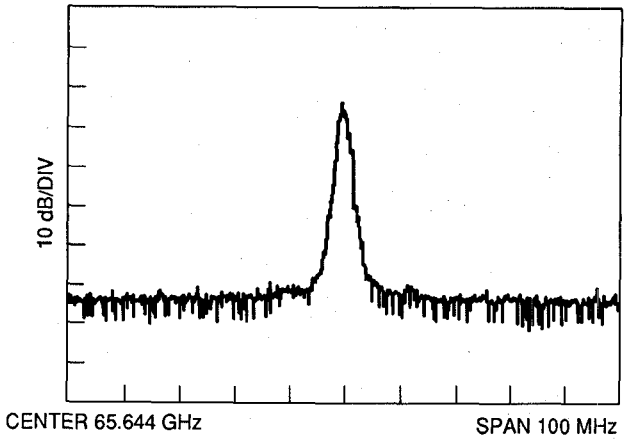

Figure 5 Output spectrum of V-band DRO (unit 1).

ACKNOWLEDGEMENT

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TABLE 2
PERFORMANCE OF V-BAND DRO (UNIT 2) (OUTPUT POWER VS EFFICIENCY)

BIAS CONDITION	V_G (V)	V_G (V)	I_{DS} (mA)	P_{OUT} (dBm)	EFFICIENCY (%)
1	-0.3	3.0	13.5	6.2	10.30
2	-0.685	3.0	11.5	6.2	12.08
3	-0.685	3.66	12.5	8.0	13.80
4	-0.1	4.0	16.1	9.0	12.33

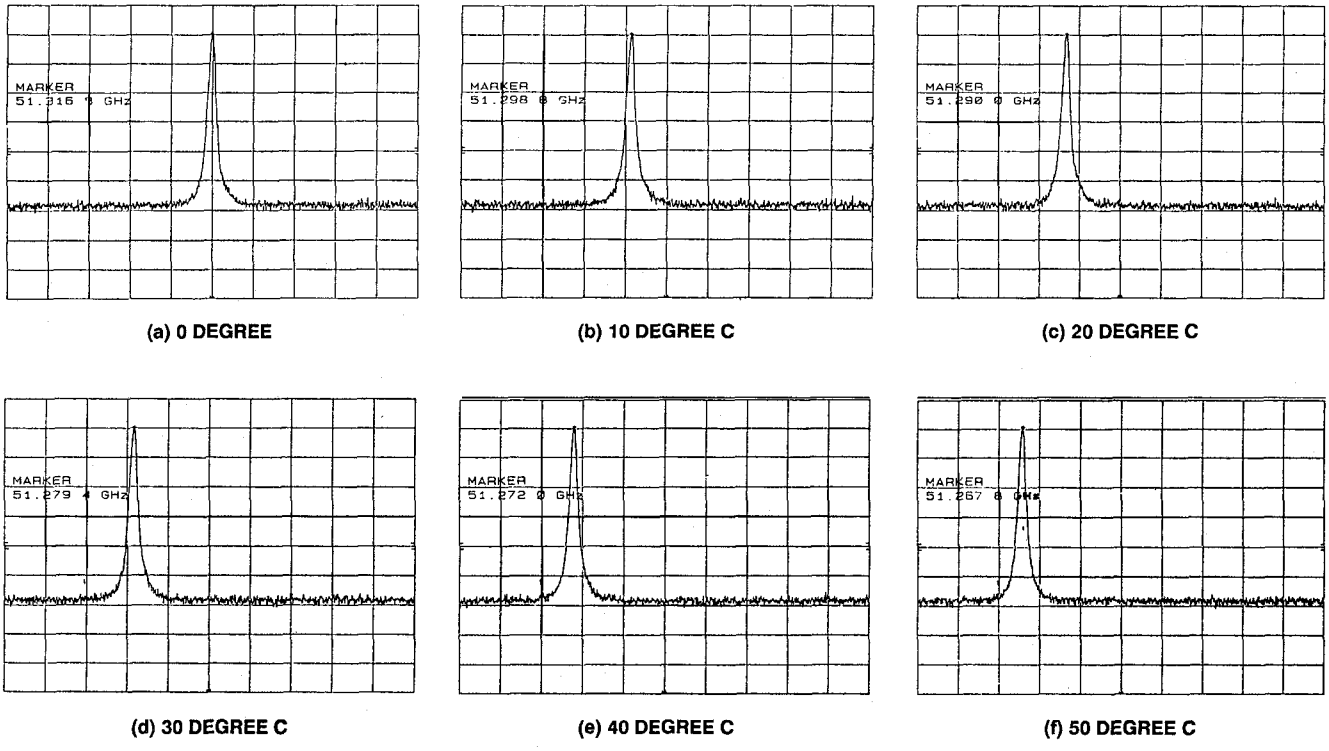

Figure 6 Output frequency spectrum of V-band DRO (unit 2) during temperature test (0 to 50°C). (Frequency span is 200 MHz.)

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