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MILLIMETER WAVE IMPATT MICROSTRIP OSCILLATORS

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ABSTRACT

Low cost, rugged, light weight microstrip IMPATT oscillators with a very simple structure have been developed. A Q-band (45 GHz) oscillator provides a CW output power of 200 mW. A W-band (94 GHz) oscillator provides 25 mW of CW output power and a pulsed output power of 3 watts.

Introduction

Significant progress has been made in the development of millimeter wave integrated circuit components for advanced military electronics hardware. The aim has been to provide MIC components that can be combined on a single substrate. One area, however, that has received very little development attention has been the MIC IMPATT oscillator.[1,2] This paper describes the design and performance of a simple, low cost microstrip oscillator built with a double-drift IMPATT diode. It delivers an output power of over 200 mW CW at 45 GHz. The same approach has been applied to a W-band oscillator which provides 25 mW of CW output power and 3 W of peak pulsed power at 94 GHz.

Circuit Design

The millimeter wave microstrip oscillator consists of a microstrip circuit pattern fabricated on a Duroid substrate which is enclosed in a rectangular channel, and an IMPATT diode in a pill package. The channel dimensions are chosen to be sufficiently small to prevent propagation of the higher order modes and the channel is covered by a conducting plate to eliminate any radiation loss. The tolerances of the housing are not critical and it can be produced at very low cost. The Duroid material has a low dielectric constant ($\varepsilon_r = 2.2$) and a low loss tangent which yields small attenuation, good mechanical tolerance, and resistance to mismatching.

The circuit pattern on the substrate includes a diode impedance matching network and a dc current bias circuit. The connection between the diode and the circuit board is completed by a gold ribbon across the diode cap and the microstrip. The ribbon itself forms a part of the matching structure. The IMPATT diode is produced at TRW.

A microstrip-to-waveguide transition was used to measure the performance of the oscillator. This can be eliminated if the oscillator is integrated with other integrated circuit components.

The substrate and channel dimensions and the diode parameters used in the Q-band oscillator are listed in Table 1.

Performance

Figure 1 is a photograph of the complete Q-band oscillator. Figure 2 shows the output power and frequency of the microstrip oscillator measured as a function of bias current. The maximum dc to RF efficiency of the oscillator is 2 percent for an output power of 200 mW. It was found that the oscillator frequency can be readily tuned by using a metal cap attached to the end of a screw above the diode. The cap loads the RF field around the diode and allows tuning over a bandwidth of 20 percent with a power variation of about 3 dB, as shown in Figure 3. An injection-locked experiment was also conducted and Figure 4 shows the locking frequency range with different injection power levels. The external Q of the oscillator is estimated to be 14.[3]

The same circuit configuration was scaled up to W-band. As given in Figures 5 and 6, preliminary results at 94 GHz show 25 mW of output power for CW operation and 3 W of peak output power for pulsed operation. Further optimization is underway to improve the oscillator performance.

Conclusions

The MIC technology applied to the design of millimeter wave oscillators provides performance adequate for many system applications and offers the advantages of low cost, light weight, a compact rugged structure, and ease of large scale integration.

Acknowledgements

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References

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Table 1. Q-Band Microstrip Oscillator Parameters

PARAMETER	DESCRIPTION
IMPATT DIODE	DOUBLE-DRIFT SILICON
	P+PNN+
	$N_A = 6.8 \times 10^{16}/CM^3$ $L_A = 1 \mu m$
	$N_D = 6 \times 10^{16}/CM^3$ $L_D = 0.8 \mu m$
DIODE CAPACITANCE AT ZERO VOLT	2 pF
DIODE BREAKDOWN AT 1 mA	27 V
DUROID THICKNESS	10 MILS
CHANNEL WIDTH	120 MILS
CHANNEL HEIGHT	80 MILS

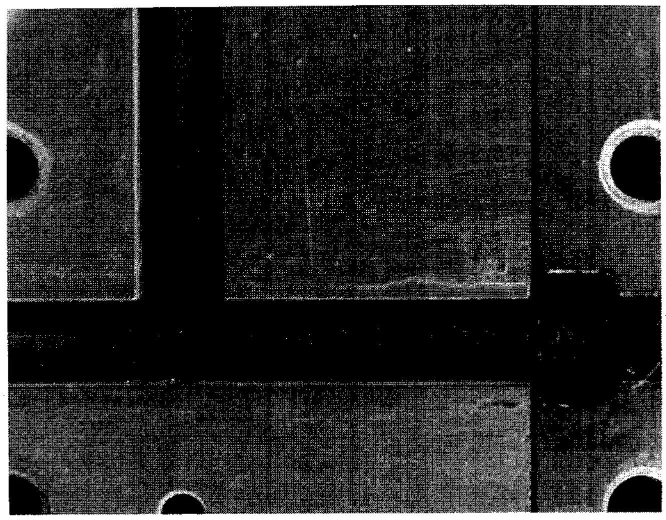

Figure 1. Circuit Layout of Q-Band Microstrip Oscillator

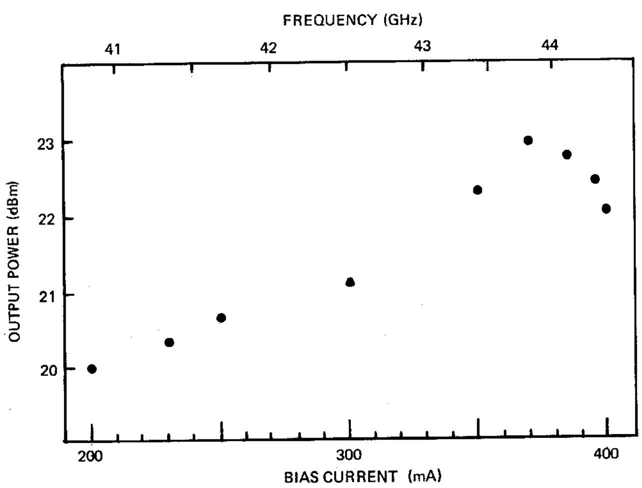

Figure 2. Output Power and Frequency of Q-Band Microstrip Oscillator as a Function of Bias Current

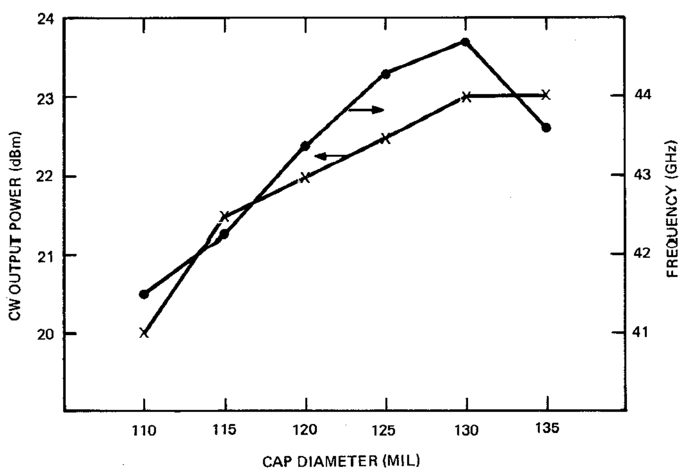

Figure 3. Power and Frequency Variation vs Cap Size

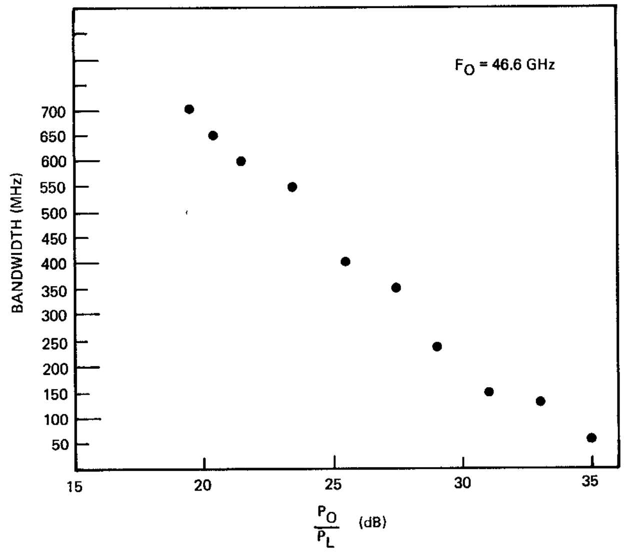

Figure 4. Injection-Locking Bandwidth as a Function of Power Gain

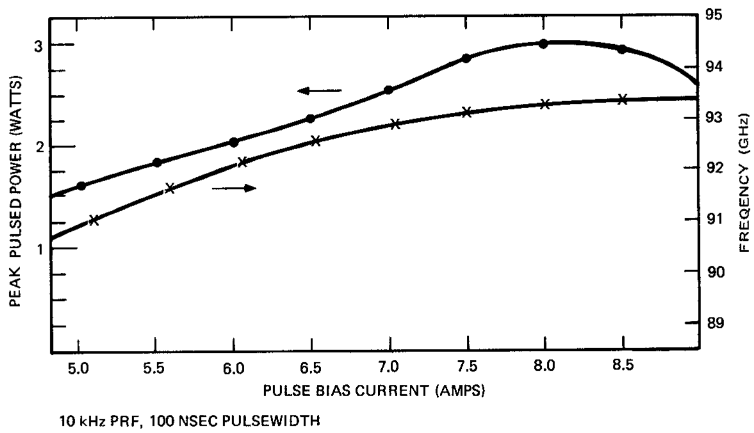

Figure 5. Output Power and Frequency of 94 GHz Microstrip Pulsed Oscillator

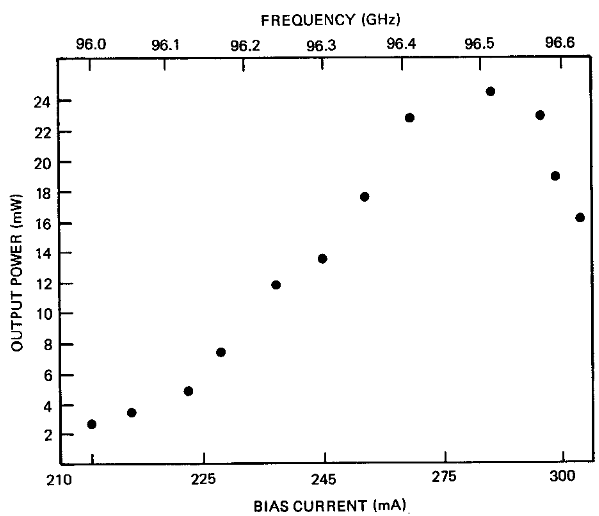

Figure 6. Output Power and Frequency of 94 GHz CW Oscillator