MILLIMETER-WAVE MICROSTRIP OSCILLATORS

B. S. Glance and M. V. Schneider
Bell Laboratories
Crawford Hill Laboratory
Holmdel, N. J. 07733

Abstract

Hybrid integrated millimeter-wave sources at 30, 60 and 100 GHz have been built using a novel oscillator configuration. The new structure features a planar microstrip circuit in a conducting channel with an IMPATT diode which is inserted into the side wall of the channel RF efficiencies of 5% at an output power of a quarter watt CW have been measured both at 30 and 60 GHz. The ouput power at 100 GHz is 25 mW with an efficiency of 2%. The oscillators can be readily tuned over a 10% bandwidth.

Introduction

Hybrid integrated microstrip oscillators built with a single IMPATT diode and a microstrip conductor pattern on fused silica have been described in a previous paper.[1] These oscillators have given output powers of 100 mW CW at 30 GHz with a corresponding RF efficiency of 2%. The purpose of this paper is to describe a substantially improved microwave source with a higher output power and efficiency at 30 GHz. Since the new circuit can be readily scaled to higher frequencies in the millimeter-wave range it was also built at a frequency of 60 GHz and 100 GHz. The measured output power is 200 mW at 29 GHz, 270 mW at 55 GHz and 25 mW at 108 GHz. The corresponding efficiencies are 5%, 5.7% and 2% respectively. The output power does not follow the 1/f law[2] because different types of diodes were used at these frequencies, e.g. a device with a single-drift region (SDR) was used at 30 GHz and a diode with a double-drift region (DDR) at 60 GHz and 100 GHz.

The improvement in output power and device efficiency is due to a substantially improved biasing network. The output power and the efficiency obtained from diodes from the same batch mounted in a waveguide circuit is approximately the same, e.g. a power of +22.95 ± 0.95 dBm was obtained for six diodes in a waveguide circuit at 56.4 ± 1.1 GHz at a bias current of 130 mA, while an output power of +22.7 dBm at 55.4 GHz was measured for the new hybrid integrated microstrip oscillator under the same conditions. We conclude from these experiments that the maximum available efficiency and output power of the oscillator is determined by the properties of the diode and that the losses in the microstrip circuit are comparable to the losses in a waveguide circuit.

Description of the Oscillator

The millimeter-wave microstrip oscillator consists of a microstrip conductor pattern on a clear fused quartz substrate which is shielded by means of a rectangular channel, and an IMPATT diode on a cylindrical stud which is inserted into one side wall of the channel. The conductor pattern on the substrate is shown in Fig. 1, and the substrate with the IMPATT diode in a channel is shown in Fig. 2. A transition to rectangular waveguide was used to measure the performance of the microstrip oscillator. This transition is not necessary upon further integration of the oscillator.

The conductor pattern in Fig. 1 consists of a wide resonator strip, a capacitive coupling section, a DC biasing network and a 50 ohm output transmission line. The resonator strip is connected to a high impedance DC bias line at a point where the RF voltage reaches a minimum. The length of this bias line is approximately $\lambda g/4$. A second DC bias line which includes a $\lambda g/4$ RF stub connects the DC bias contact to the 50 ohm output line.

The substrate is mounted in the channel as shown in Fig. 2. The substrate and channel dimensions and the diode parameters are listed in Table I. The channel width is sufficiently small to suppress propagation of the first order longitudinal section magnetic mode (LSM mode). The diode is mounted on a cylindrical 0.150" diameter stud which is inserted into the channel wall perpendicular to the metallized silica substrate. A small metal tab soldered to the microstrip resonator is used to contact the diode. This structure minimizes parasitic reactances and allows the easy exchange of diodes without altering the RF circuit. The capacitive transition to rectangular waveguide with a variable short in the waveguide was used to measure the output power and efficiency of the oscillator. The channel is covered by a conducting plate to eliminate radiation losses and to suppress undesired modes.

Performance of the Oscillator

Figure 3 shows the output power and efficiency of a microstrip oscillator at 55 GHz measured as a function of bias current. The maximum efficiency is 5.7% for an output power of 230 mW. A power of 270 mW CW was measured at a slightly reduced efficiency of 5.2%. The power and efficiency obtained in Fig. 4 for an oscillator built at 30 GHz are 230 mW CW and 5.0% respectively. It was found that the 30 GHz oscillator can be readily tuned using a small piece of dielectric material attached at the end of a nylon screw above the microstrip resonator. The material dielectrically loads the RF fringe field of the resonator and allows tuning over a bandwidth of 9% with a power variation of ±1 dB as shown in Fig. 5. A tuning range of the same order can be expected for similar microstrip oscillators built at higher frequencies. Experiments performed on a circuit scaled to 100 GHz have given an output power of 25 mW at 108 GHz with a maximum efficiency of 2% as shown in Fig. 6.

Conclusions

Good performance has been obtained with hybrid integrated microstrip IMPATT oscillators at millimeter-wave frequencies. The oscillators can be easily tuned and readily scaled to the maximum operating frequency of an IMPATT diode. Circuits of this type are inexpensive to manufacture and they can readily be produced in large quantities.

Acknowledgements

The authors thank C. N. Dunn in Dept. 2143 for providing high-quality millimeter-wave IMPATT devices and K. C. Schwarz for precision fabrication.

References

1. Glance, B., "Low-Q Microstrip IMPATT Oscillator at 20 GHz," Proc. IEEE, Vol. 60, Sept. 1972, pp. 1105-1106.

2. Scharfetter, D. L., "Power-Impedance-Frequency Limitations of IMPATT Oscillators Calculated from a Scaling Approximation," IEEE Trans. Electron Devices, Vol. ED-18, Aug. 1971, pp. 536-543.

Table I

Diode and Circuit Parameters

Parameter	Microstrip Oscillator 30 GHz	Microstrip Oscillator 60 GHz	Microstrip Oscillator 100 GHz
IMPATT Diode	Single Drift Silicon p^+-n-n^+	Double Drift Silicon p^+-p-n-n^+	Double Drift Silicon p^+-p-n-n^+
Junction Capacitance	0.25 pF at -21 V	0.22 pF at -14 V	0.11 pF at -12 V
Breakdown Voltage	26 V at 1 mA	23 V at 1 mA	14 V at 1 mA
Quartz Thickness	0.0133"	0.010"	0.004"
Width of Substrate and Channel	0.160"	0.080"	0.040"
Channel Height	0.108"	0.054"	0.027"

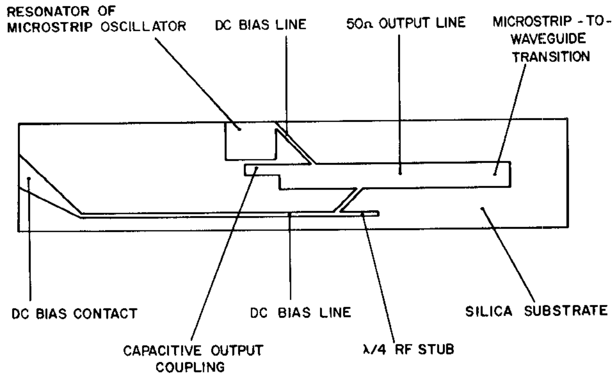

Fig. 1 Microstrip conductor pattern of oscillator on clear fused silica substrate including resonator, biasing network and 50 ohm microstrip transmission line. The substrate thickness for a 60 GHz oscillator is 0.010" and the substrate width is 0.080".

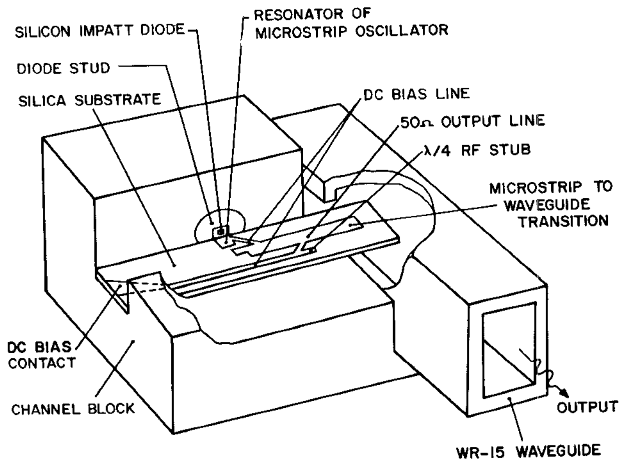

Fig. 2 Microstrip IMPATT oscillator assembly including IMPATT diode, microstrip conductor pattern on substrate, rectangular channel and broadband transition to rectangular waveguide. The transition to rectangular waveguide is used to measure the performance of the circuit. It is not needed upon further integration of the oscillator.

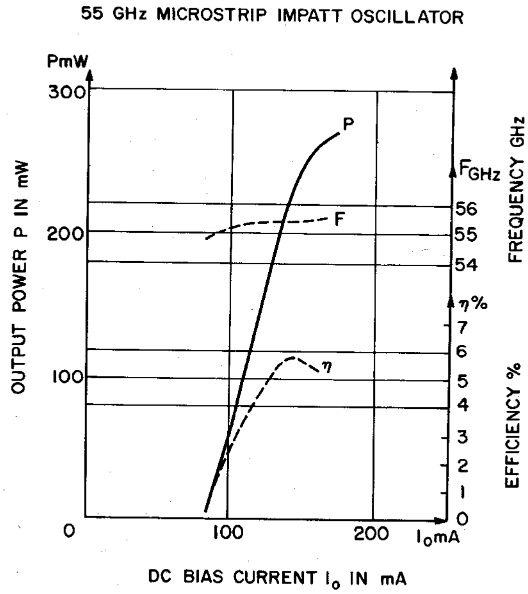

Fig. 3 Output power and efficiency of 55 GHz microstrip oscillator as a function of bias current. An efficiency of 5.7% is obtained for an output power of 230 mW CW.

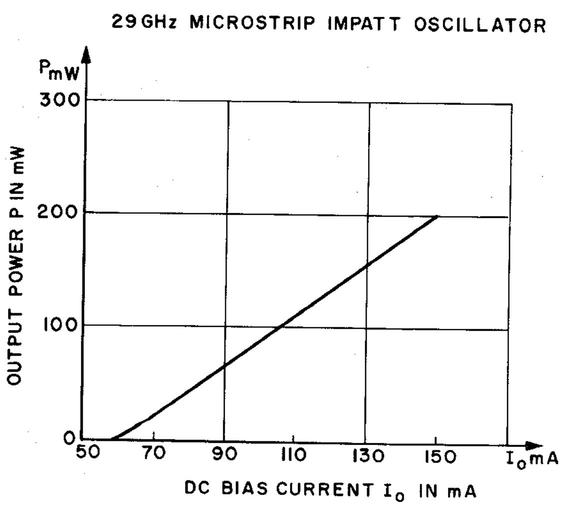

Fig. 4 Output power of 29 GHz microstrip oscillator as a function of bias current. An efficiency of 5% is obtained for an output power of 200 mW.

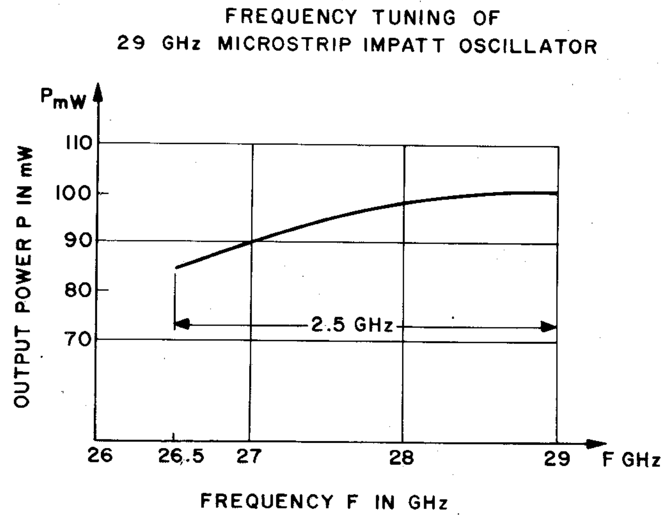

Fig. 5 Tuning range of 29 GHz microstrip oscillator versus output power. The frequency is tuned by means of a small piece of dielectric attached to a nylon screw above the microstrip resonator.

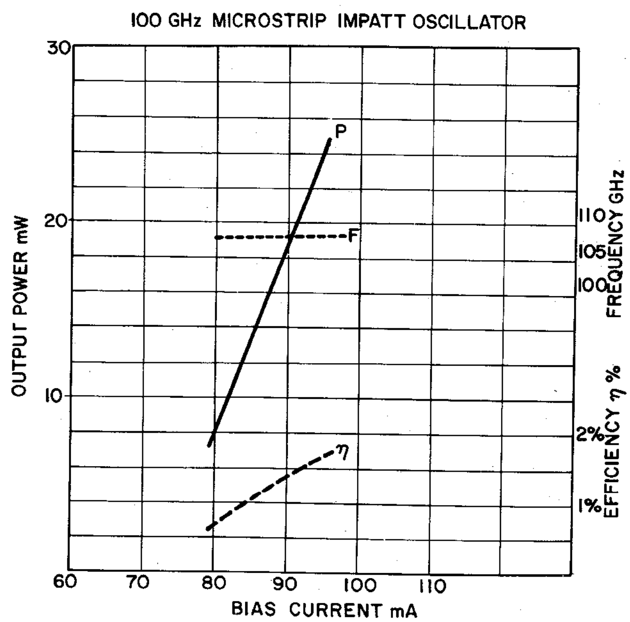

Fig. 6 Output power and efficiency of 108 GHz microstrip oscillator as a function of bias current. An efficiency of 2% is obtained for an output power of 25 mW.