ADVANCES IN PRINTED MILLIMETER-WAVE OSCILLATOR CIRCUITS

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Summary

Millimeter-wave Gunn oscillators and VCO's which use a printed fin-line oscillator circuit in the 55 to 100 GHz range are described. Demonstrated technological advances include the use of printed oscillator circuits to 100 GHz, wideband mechanical tunability (to 8 GHz), and varactor tuning.

Introduction

Single ridge fin line[1] is a printable transmission line for the 10 to 100 GHz range which has proven useful in the construction of a variety of components[2, 3, 4, 5]. The advances in Gunn oscillator technology and performance to be reported include the use of printed oscillator circuits to 100 GHz, wideband mechanical tuning (to 8 GHz), and varactor tuning for FM capability.

Oscillator Description

The basic form of a fin-line Gunn oscillator with both mechanical and varactor tuning is shown in Figure 1. The rectangular waveguide housing is split along the E-plane to accommodate a printed 0.005-inch thick copper-clad dielectric board (Duroid 5880) and a 0.005-inch insulator board, which are aligned by the dielectric dowels. The printed board is fabricated by standard photo-etching techniques. The printed pattern contains the oscillator circuit, chokes, and dc blocks for the Gunn and varactor biases, and a tapered fin which couples the oscillator to standard WR-12 (or WR-10) waveguide. The insulator board insulates the printed board from the housing, thereby allowing bias to be applied, via the printed pattern and a ribbon bond, to a packaged Gunn diode and a chip varactor. The dc blocks are two vertical gaps across the metal fin which are spaced a nominal quarter-wavelength apart. RF grounding of the fin at the upper wall of the housing is accomplished by the printed serrated choke pattern within the broad wall. The serrations in the choke prevent longitudinal current, and thereby ensure single-mode operation. Mechanical tuning is provided by a micrometer driven, noncontacting short circuit which spans the printed and insulator boards, and reactively terminates the packaged Gunn diode.

Printed oscillator circuits, with and without provision for varactor tuning, are shown in Figure 2. The notch in the output end of the dielectric board is a quarter-wave transformer that provides an impedance match between the air-filled and slab-loaded waveguide.

The component parts of an oscillator and an assembled unit are shown in Figures 3 and 4, respectively. The SMA connector on the top surface is the tuning (varactor) port.

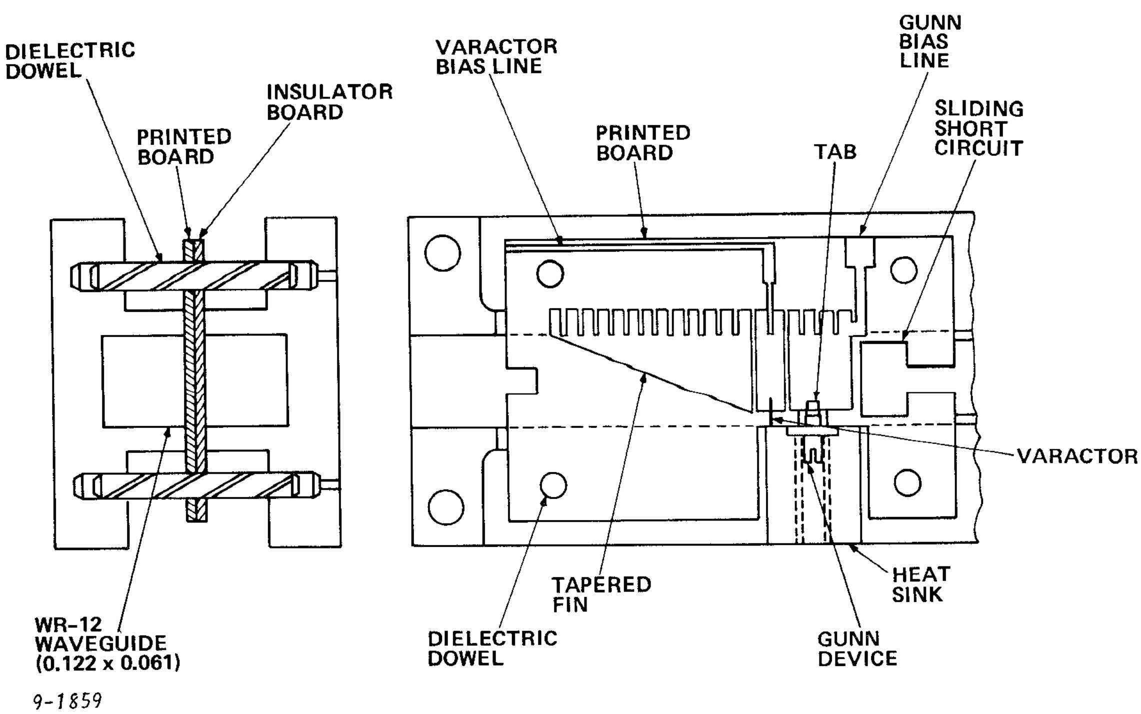

Figure 1. Cross Section of Fin-Line Oscillator With Mechanical and Varactor Tuning

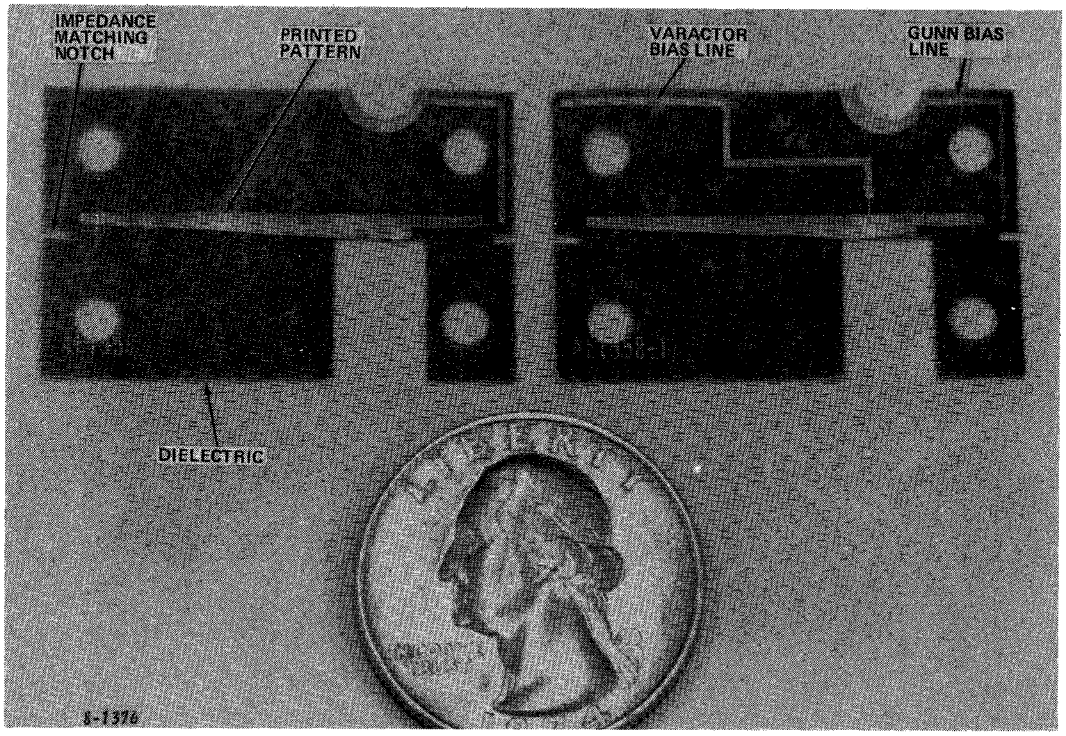

Figure 2. Printed Fin-Line Oscillator Circuits

Oscillator Performance

The performance of a GaAs Gunn diode-oscillator, incorporating both mechanical and varactor tuning, is shown in Figure 5. The measurements are referenced at the output of an isolator having a forward loss of 0.4 to 0.5 dB. As the short circuit was moved, the oscillator tuned continuously and smoothly from 55.6 to 62.4 GHz, a 6.8 GHz tuning range. The tuning characteristic repeats at half-wavelength intervals on the range of the micrometer, and two such intervals are shown. Electronic tuning to 100 MHz with 0 to 10-volt varactor control provided FM capability at each frequency on the tunable range, with an insignificant change in output power. Correcting for isolator loss, the power output was 28 mW (14.5 dBm) at the center of the band.

A moderate increase in tuning range and output power was observed from mechanically tuned oscillators which did not additionally incorporate varactor tuning. The performance of such an oscillator is shown in Figure 6. As the tuning short was moved through 0.150 inch, the oscillator tuned across an 8-GHz range centered at 66.4 GHz. The output power characteristic was centered on the band and was 35 mW (15.4 dBm) at midband.

These results represent an advance in millimeter-wave oscillator technology in terms of mechanical tuning capability with a printed oscillator circuit, both with and without varactor tuning.

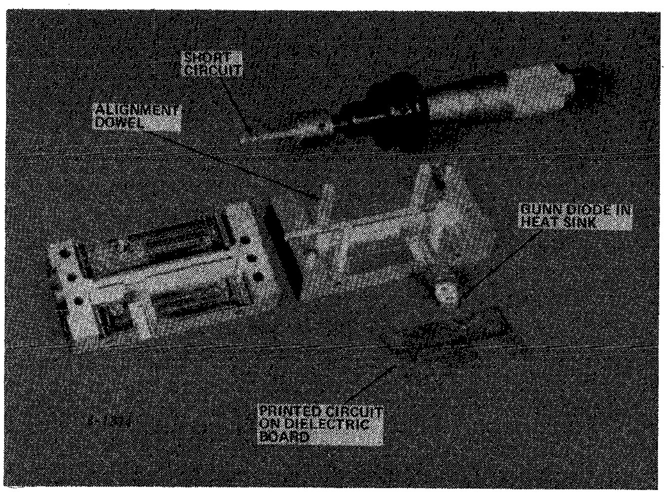

Figure 3. Fin-Line Oscillator Component Parts

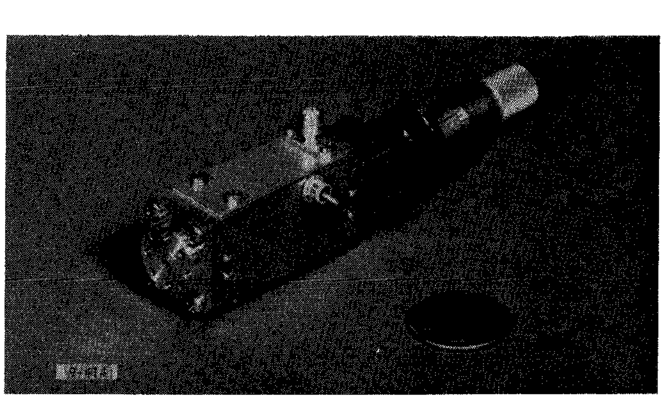

Figure 4. Fin-Line Gunn Oscillator With Mechanical and Varactor Tunability

The same basic form of fin-line oscillator circuit has been used up to 100 GHz. Above 80 GHz, a disc was used between the printed fin and the top of the 0.030-inch diameter Gunn diode package. The disc was required to eliminate a frequency limit on oscillator performance due to the packaged Gunn diode. Typical oscillator performance in the 85 to 94 GHz range is 5 mW output and 2 GHz mechanical tuning. Power at the 10 mW level at 94 GHz has been obtained with selected Gunn diodes. These results represent an advance in the frequency range of use of printed oscillator circuits.

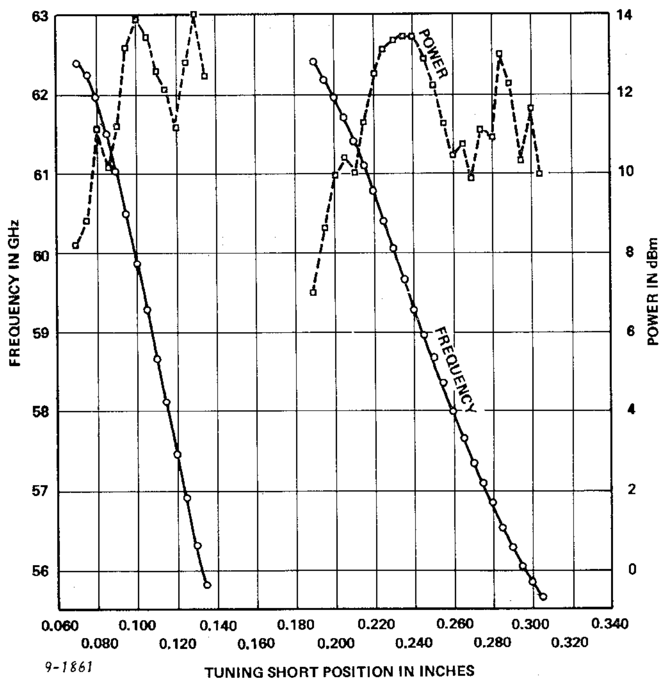

Figure 5. Fin-Line Gunn Oscillator With Mechanical and Varactor Tunability - Frequency and Power Characteristics

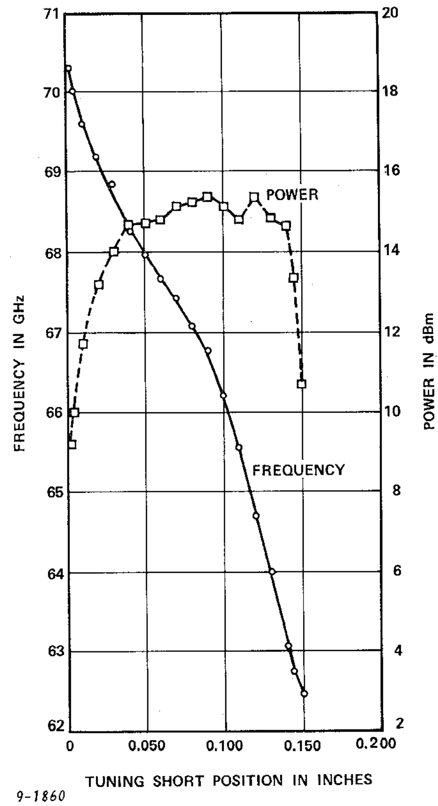

Figure 6. Mechanically Tunable Fin-Line Gunn Oscillator - Frequency and Power Characteristics

References

1. Meier, P.J., "Millimeter Integrated Circuits Suspended in the E-Plane of Rectangular Waveguide," IEEE Trans on Microwave Theory and Techniques, Vol MTT-26, No. 10, p 726-733, October 1978.

2. Fleri, D.A., Taub, J.J., Whelehan, J.J., & Wolczok, J.M., "Low Cost X-Band MIC Parametric Amplifier," Digest of 1974 IEEE International Microwave Symposium, p 210-212, June 1974.

3. Cohen, L.D., and Meier, P.J., "Advances in E-Plane Printed Millimeter Wave Circuits," 1978 IEEE MTT-S International Microwave Symposium Digest, p 27-29, June 1978.

4. Hofmann, H., et al, "New Integrated MM-Wave Components using Fin Lines," 1978 IEEE MTT-S International Microwave Symposium Digest, p 21-23, June 1978.

5. Knochel, R., "Design and Performance of Microwave Oscillators in Integrated Fin-Line Techniques," IEEE Journal on Microwaves, Optics and Acoustics (England) Vol 3, No. 3, p 115-120, May 1979.