COAXIALLY COUPLED RIDGE WAVEGUIDE TUNABLE OSCILLATOR

R. S. Robertson, R. L. Eisenhart

HUGHES AIRCRAFT COMPANY
Advanced Missile Systems Division
Canoga Park, CA. 91304

ABSTRACT

A coaxially coupled ridged waveguide oscillator circuit using a pulsed IMPATT diode is described. Mechanical tuning bandwidths of 800 MHz (8%) at X-band, instantaneous locking bandwidths greater than 5 percent at 10 dB gain, and a circuit efficiency of 95 to 100 percent have been realized with a silicon pulsed double drift IMPATT diode under large signal conditions.

Introduction

RF driver circuits for solid state transmitters require broad instantaneous locking and mechanically tunable bandwidths. The objective was to develop an alternative circuit to replace conventional coaxial IMPATT diode oscillators for solid state transmitter applications which are not easily tuned over broad bandwidths. Custom tailoring of coaxial oscillator circuits is often necessary to compensate for variations in diode parameters which cause a shift in the oscillator's free running frequency and the frequency range of the instantaneous locking bandwidth. An oscillator with broad mechanical tunability without performance degradation is desirable to compensate for these parameter variations. The oscillator should also demonstrate flat output RF power ($\leq$1.0 dB) over this broad locking range and with maximum diode efficiency. The coaxially coupled ridged waveguide oscillator has demonstrated these characteristics.

Design Approach

In previous work some success[1,2] has been reported in the use of ridged waveguide with low power active microwave devices. Coaxially coupling of diode modules to waveguide transmission media has been demonstrated by Harkless[3], Kenyon[4], Kurokawa[5], and Harp[6]. This coupling technique was applied to the broadband transmission medium of ridged waveguide. This coupling method allowed optimal transformation of ridged waveguide impedance levels to pulsed IMPATT impedance values.

The ridged waveguide was selected as the propagation media since the guide has a wide frequency propagation band and a lower waveguide impedance as defined by Hopfer[7]. Calculations showed that X-band propagation could be achieved by ridging standard Ku-band waveguide whose aspect ratio, b/a, is 0.50. A picture of the disassembled oscillator is shown in Figure 1. A cross section of the oscillator is given in Figure 2. The ridged waveguide was designed for a characteristic wave impedance[7] of 50Ω at 10 GHz. The frequency range of propagation for the TE_{10}, dominant mode, is 4.72 to 12.46 GHz.

The coaxial to ridged waveguide transition was designed to provide a broadband match. Several transitions were fabricated varying the parameter, D, and measured on an automatic network analyzer for the condition when both arms of the ridged guide were matched. An input impedance of approximately 24 ohms real plus a small residual reactance was measured for each transition. The final design was selected to minimize the above post reactance. A short circuit was then placed in one arm of the waveguide, behind the transition, and the input impedance was again measured with the other waveguide arm matched. The resistive part of this impedance was approximately 45Ω from 8 to 12 GHz. The input resistance and reactance is given in Figure 3.

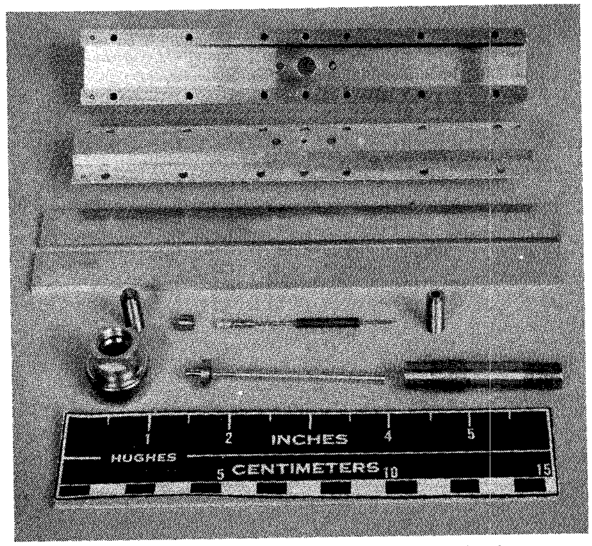

Figure 1. X-Band Coaxially Coupled Ridged Waveguide Oscillator

A coaxial diode module with matching transformer was positioned at the center of the guide. A single section filter network was designed into the load section of the module to enhance the circuits combining efficiency. A piece of ferrite loaded epoxy was used as the RF load material for insuring diode stability. Diode data obtained in the ridged waveguide was compared to data obtained from the same device in a standard coaxial test fixture tuned for maximum power and efficiency. These results showed the ridged waveguide circuit efficiency to be 95-100 percent.

Once a transformer matching network was selected, variations device to device could be compensated by adjustments in the waveguide shorts.

Experimental Results

Oscillator tuning was achieved by adjusting the waveguide shorts. An example of the injection bandwidth achieved with a silicon double drift diode operated at full pulsed power for five tuning conditions is given in Figure 4 at an 11.5 dB gain level. The combined mechanical and instantaneous bandwidth

0149-645X/81/0000-0235$00.75

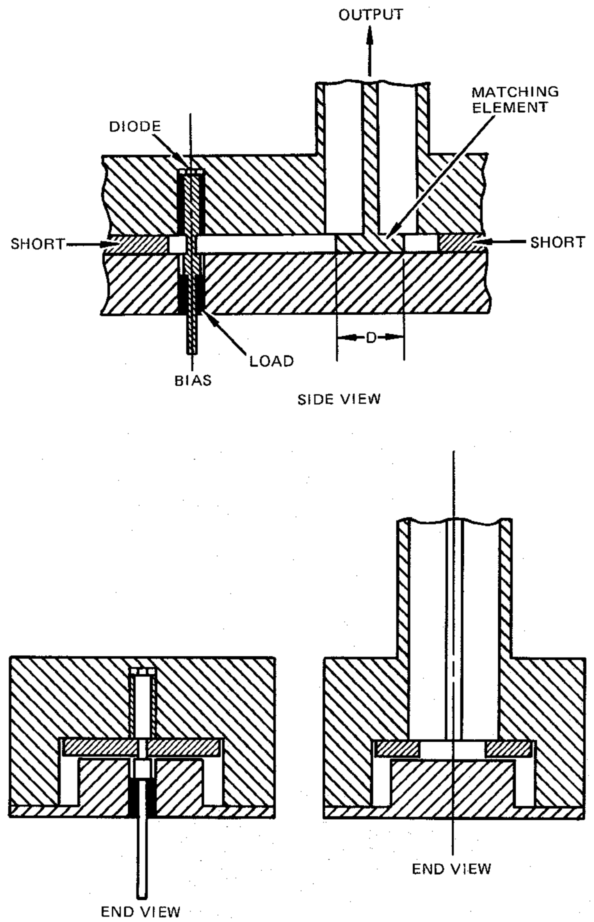

Figure 2. Cross Section of the Ridged Waveguide Coaxially Coupled Oscillator

total and for 1 dB of power variation is 800 MHz and 680 MHz respectively.

With the unit fixed tuned the locking bandwidth was measured as a function of injection gain. The performance is given in Figure 5. One dB power variation bandwidths from 165 MHz to 480 MHz were measured for gain variations of 14 to 8 dB respectively. The bandwidth performance in the fixed tuned condition varies with the type of device and waveform. Tests were also performed to evaluate a Gallium Arsenide single drift IMPATT's performance in the oscillator. The diode was operated at a 250 KHz pulse repetition frequency, a peak operating current of 1.0 amps and 10 dB gain. A graph of the results of tests are given in Figure 6. The conditions of the test were a fixed coaxial matching network and filter. Mechanical tuning of the free running frequency and power was performed with the waveguide shorts. The key point to notice is that although the absolute bandwidth of the diode was not as large as that for the silicon device, the operating range of the oscillator is greater than 1.0 GHz.

Summary

A coaxially coupled ridged waveguide oscillator circuit has been developed for use with pulsed IMPATT diodes. The circuit has demonstrated mechanical tuning bandwidths of 800 MHz at X-band, instantaneous locking bandwidths of 5 percent at 10 dB gain and

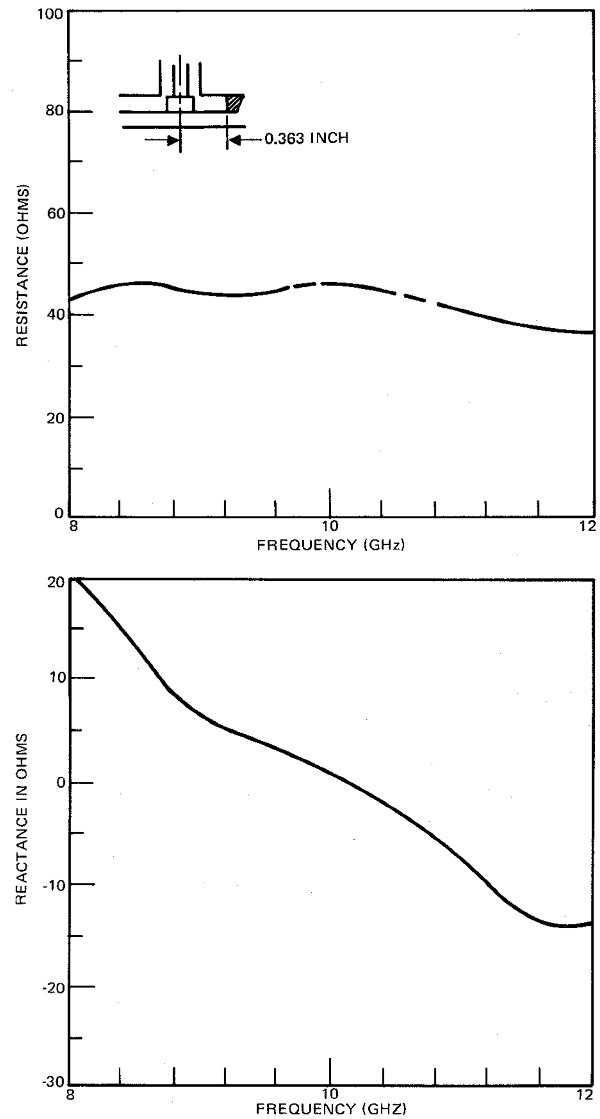

Figure 3. Input Impedance at the Coax to Waveguide Transition

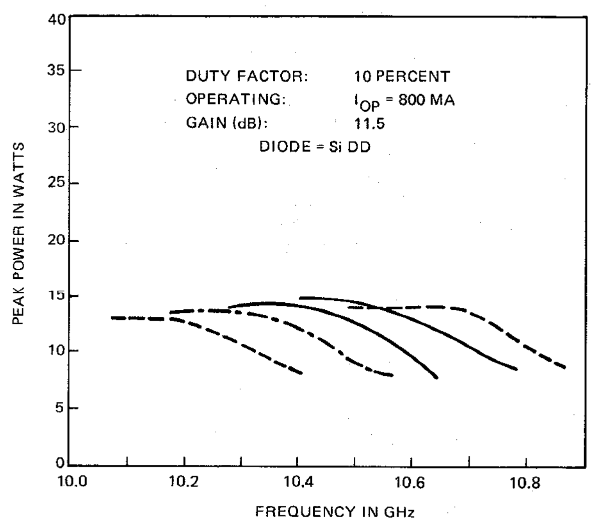

Figure 4. Power Versus Frequency for Five Tuning Conditions. Each curve represents the instantaneous locking bandwidth.

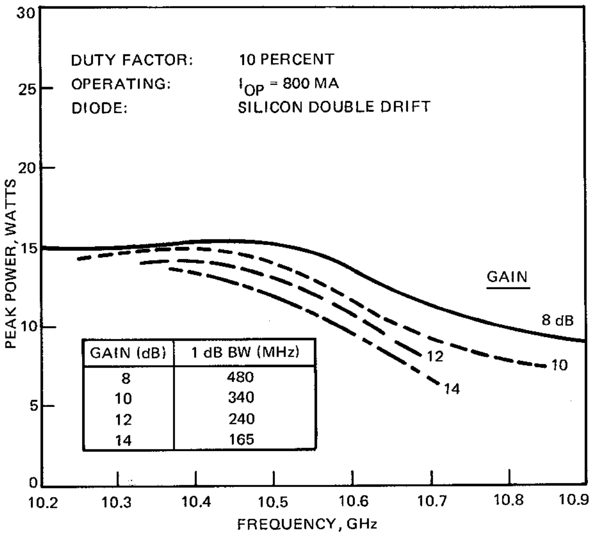

Figure 5. Power Versus Frequency for Four Gain Levels Each curve represents the instantaneous locking bandwidth.

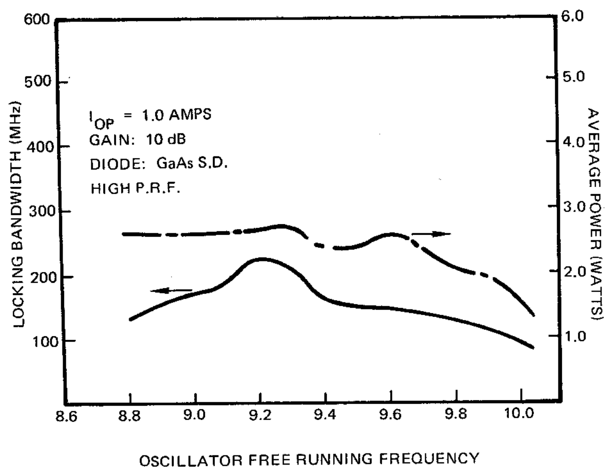

Figure 6. Injection Locking Bandwidth and Average Power Versus Free Running Oscillator Frequency

circuit efficiencies of 95 to 100 percent. This oscillator is an alternative to standard coaxial driver circuits in solid state transmitter applications.

Acknowledgement

The authors would like to thank Mr. Roy Monzello for his help in making the experimental measurements on the oscillator.

References

(1) S. Mizushina and T. Ohsuka, "The Ridged-Waveguide-Cavity Gunn Oscillator for Wideband Tuning," IEEE Trans. Microwave Theory Tech., Vol. MTT-24, pp. 257-259, May 1976.

(2) H. Kondoh, "A 14-27.8 GHz Ridged-Waveguide-Cavity IMPATT Oscillator," Proc. 6th Cornell Elect. Eng. Conf., 85-89 (1977).

(3) E. T. Harkless, "Oscillator Circuit", United States Patent Office, No. 3534293, Filed Oct. 13, 1970.

(4) N. D. Kenyon, "A Circuit Design for MM-Wave IMPATT Oscillators," 1970 G-MTT Symp. Digest, pp. 300-303.

(5) K. Kurokawa, "The Single-Cavity Multiple-Device Oscillator," IEEE Trans. Microwave Theory and Tech., Vol. MTT-19, No. 10, pp. 793-801, October 1971.

(6) Harp, R. S. and Stoger, H. L., "Power Combining of X-band IMPATT Circuit Modules," 1973 IEEE International Solid State Circuits Conference Digest, pp. 118-119.

(7) S. Hopfer, "The Design of Ridged Waveguides," IRE Transactions Microwave Theory and Tech., Vol. MTT-3, Oct. 1955, pp. 20-29.