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8 GHz Tunable Gunn Oscillator in WR-137 Waveguide

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Abstract. The conventional technique of realising waveguide resonators for Gunn diode oscillators to operate at the band edge of the waveguide fails owing to the excitation of a coaxial mode resonance formed by the post and the side walls of the waveguide. One of the solutions to the problem is to mount the diode in a ridged waveguide resonator. This has been demonstrated by constructing an 8 GHz Gunn oscillator using a single ridge in WR-137 waveguide. The steps in designing the oscillator system are also presented.

1. Introduction

The conventional technique of realising a Gunn diode microwave oscillator in waveguide systems is to mount the diode in a shorted half-wavelength waveguide cavity resonator by an inductive post. This technique, however, fails when an oscillator is required to operate at the upper band-edge of the waveguide because of the coaxial-mode resonance occurring just above the top of the band (1). The effect of this coaxial resonant mode becomes very pronounced and difficult to eliminate in lower microwave bands particularly below X-band, where the separation between the band edge and the saturation frequency becomes smaller A solution to the problem may be obtained by using a ridge structure for mounting the diode. The ridge structure not only increases the saturation frequency but also gives wide-band tuning capability of the oscillator (2).

In this paper, the design of a resonator using a single-ridge has been described. The power output performance of a commercially available Gunn diode in three different resonator configurations including a full-height waveguide cavity has been studied and the result of a prototype 8 GHz Gunn oscillator using a single ridge mounting structure is presented.

2. Resonator Design Considerations

Resonators can be designed using either a single ridge or a double ridge. However, single ridge mounting is preferred because it is easily fabricated and such a structure has not been exploited for Gunn diode oscillator construction. The structure of the oscillator that employs a single ridge where the packaged diode is mounted in the gap between the ridge and the top wall of the waveguide (WR-137) is shown in Fig 1. The ridge of height 0.510 in. extends uniformly all the way to the shorting plate which is located at a distance of $\lambda g/2$ from the diode plane, λg being the guide wavelength at the design frequency. The width of the ridge is determined primarily from the impedance and the bandwidth requirements set by the active device for the dominant mode since Gunn diodes are capable of oscillating over a wide band and the performance of the diodes is highly influenced by the operating load impedance. The load impedance for Gunn diodes to deliver power to the load circuit with maximum efficiency should be around 3OR_0 (3), where R_0 is the low-field resistance of the Gunn diode. Neglecting the effects of the package parasitics, the load impedance in case of the resonator of Fig. 1 is determined by the characteristic impedance of the ridged waveguide. Since the ridge height is fixed by the length of the packaged diode, the only parameter available for adjustment, to obtain the required value of the characteristic impedance and bandwidth, is the ridge width. For a WR-137 waveguide resonator and a S4 packaged Gunn diode, the normalised value of the gap length, d/b, is O.15. Considering Fig.9 of reference 4, the maximum bandwidth is obtained when the normalised value of the ridge width (s/a) is about 0.2 for the above value of d/b and is almost independent of d/b. The guide impedance calculated theoretically for the above values of the ridge width and height is 68Ω at infinite frequency. The variation of the ridged guide impedance with ridge height for a ridge width of 0.275 inch in WR-137 waveguide is shown in Fig. 2. The low-field resistance of the Gunn diode (Microwave Associates, Type MA 49151) used in our experiments was around 6Ω. For this value of R_0, the guide impedance should be about 200Ω for maximum power delivery to the load. However, this value is much larger than that obtained from the resonator configuration of Fig. 1. An increase in the guide impedance may be obtained by decreasing the height of the ridge but this necessitates the use of a

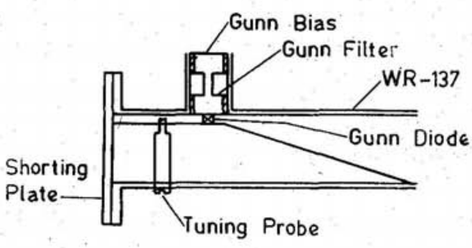

Figure 1. Ridged-waveguide oscillator structure in WR-137.

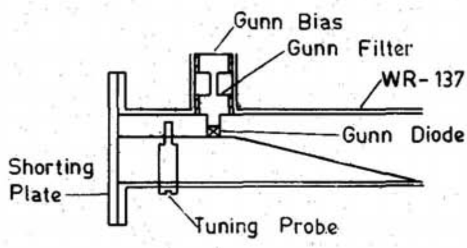

Figure 2. Reduced-ridge mounting structure in WR-137 resonator

short length of a post for mounting the Gunn diode as can be seen from Fig. 2. For this particular configuration of a reduced ridge structure the load impedance at the device terminals will be the impedance of the ridged structure modified by the reactances of the post and the package. The load impedance of such a structure for optimum power coupling may be evaluated theoretically but a more convenient method would be to determine experimentally the diameter of the post for maximum power output.

3. Resonator Structures

Three resonator structures using WR-137 waveguide were designed and fabricated for operation at 8 GHz : (i) a full height waveguide resonator where the diode is bottom mounted by means of a metallic post in a shorted half-wavelength waveguide cavity, (ii) a single-ridged waveguide resonator (Fig. 1) where the packaged diode fits in the gap between the ridge and the top wall of the waveguide and (iii) a single ridge structure (Fig. 3) where the diode is mounted by means of a short post above the ridge.

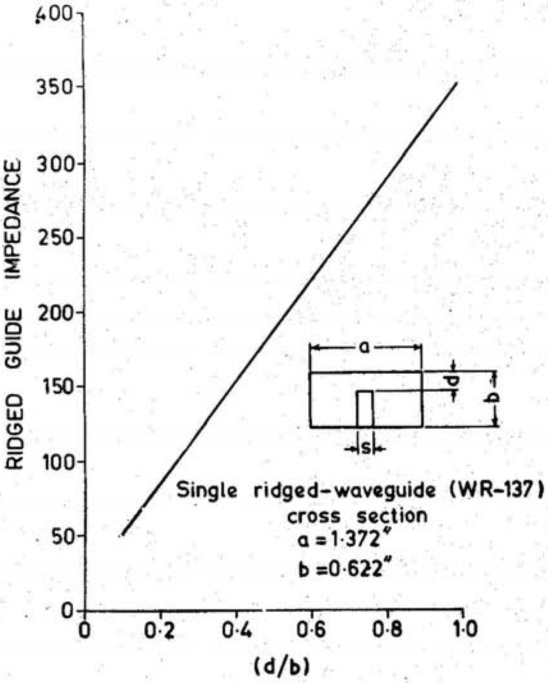

Figure 3. Variation of guide impedance with normalised gap length (d/b)

The diameter of the short post has been determined experimentally for optimum power delivery to the load circuit. In the case of ridge structures, mechanical tuning of the oscillators is easily accomplished by inserting a cylindrical metallic probe midway between the diode and the shorting plate. Bias was applied to the diode through a coaxial low-pass filter.

4. Experiments and Results

The performance of the resonators were studied using a Microwave Associates Gunn diode (Type MA 49151). The diode is capable of delivering an output power of about 64mW at 8 GHz (Manufacturer's specification). In our experiments, the bias voltage to the diode was kept fixed at 10 volts. With the diode post mounted in the full height waveguide resonator, the oscillator was found to generate a fixed frequency signal of 9.2 GHz with negligible power output. The frequency was primarily determined by the height of the waveguide and was very little affected by the change in diameter of the post. Further investigations led us to conclude that this was due to the coaxial mode resonance formed by the post and the side walls of the waveguide. Theoretically it is possible to eliminate this coaxial resonant frequency of oscillation by placing the diode at the centre of the post (1). But in practice, this technique could not be adopted because the position of the diode was very critical and a slight disturbance made the cavity oscillate at two frequencies, one at the co-axial resonant frequency of 9.2 GHz and the other at the cavity resonant frequency of 8 GHz, but the former is much more stable than the latter. To overcome this coaxial resonance occurring above the band edge, the diode was mounted in the ridged waveguide resonator of Fig. 1. The frequency of oscillation with the tuning probe flushed with the ridge surface was 8.2 GHz. The length of the cavity was found to correspond to $\lambda g/2$ at this frequency. Fig. 4 (a) depicts the power-frequency characteristic of the oscillator tuned mechanically by means of the probe. The oscillator was continuously tunable from 7.1 GHz to 8.2 GHz. The power output performance of the oscillator is seen

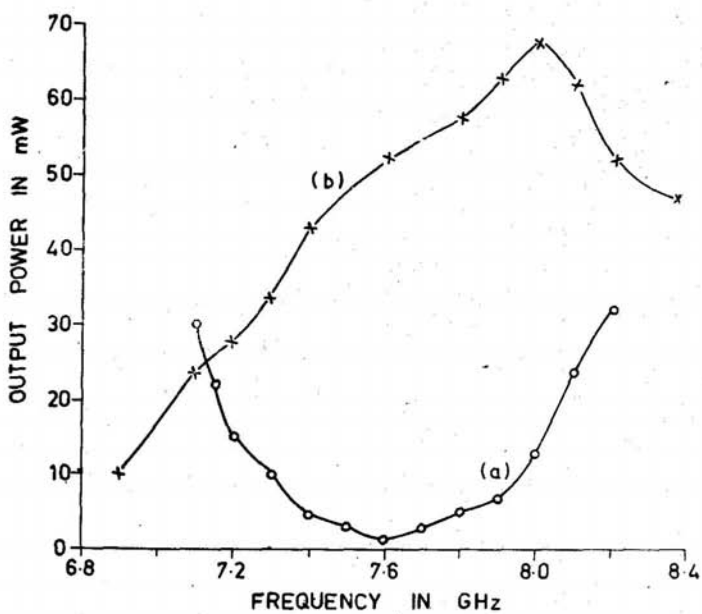

Figure 4. Power-frequency characteristics.

to be very poor being less than 10mW over most of the tuning range. The power frequency profile of the same diode mounted in the resonator of Fig. 3 is shown in Fig. 4 (b). It is evident from the characteristics that this resonator gives significant improvement in performance over the cavity of Fig. 1. The output power was more than 25mW above 7.2 GHz with a maximum value of 68mW occurring at 8.0 GHz using a post diameter of 0.125 in. This diameter was found to give the optimum performance with regard to power output and tunability of the oscillator. In this case the oscillator is tunable from 6.9 GHz to 8.35 GHz and the tunability could be increased further by decreasing the diameter of the probe.

5. Conclusion

A technique for realising Gunn oscillators for operation at or near the upper band edge of a waveguide system has been developed. Using this technique a prototype 8 GHz tunable oscillator with a Gunn diode ridge mounted in a WR-137 waveguide resonator has been successfully fabricated and tested. By properly designing the ridge structure and incorporating a cylindrical post for mounting the diode in the ridge gap, the oscillator system has been optimised for maximum power output to the load.

Acknowledgement

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