X-BAND MICROWAVE GUNN OSCILLATOR FOR EDUCATIONAL PURPOSES

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Abstract. *A low cost, high performance Gunn X Band oscillator for educational and research purposes has been developed. The cavity has been manufactured on standard waveguide WR90, with UBR100 flange, in order to make it compatible with the rest of waveguide circuitry available in a basic microwave laboratory. The ability to sweep the whole X Band (8-12 GHz) with constant output power and low phase noise, added to its low cost makes this oscillator an interesting tool for users at any level.*

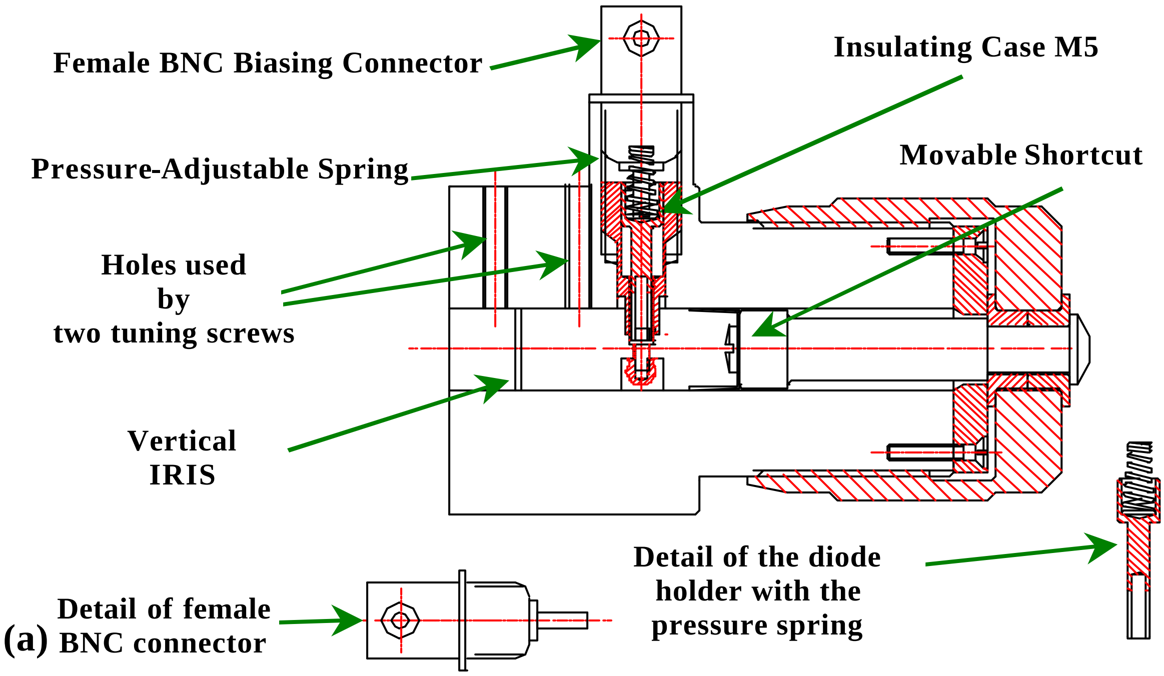
1 INTRODUCTION

Since the end of the1940s, solid–state devices have replaced tubes in most microwave amplifier and oscillator applications. This class of devices are preferred because their performance and low cost. In the 1960s and 1970s, avalanche and Gunn diodes were extensively used for the generation of microwave power [1-4] and more recently, junction and field-effect transistors have been increasingly used in microwave amplifiers and oscillators. GaAs FETs, and Heterojunction devices have replaced other solid-state devices in many microwave applications; however Gunn and IMPATT diodes are still commonly used at frequencies up to Ka band frequencies (26-40 GHz) and beyond. Given the usually limited resources of universities to endow the basic instrumentation required in educational microwave laboratories, a low cost, high performance Gunn X Band oscillator for educational and research purposes has been developed. The cavity has been manufactured on standard waveguide WR90, with UBR100 flange, in order to make it compatible with the rest of waveguide circuitry available in a basic microwave laboratory. The oscillator may also be used as a microwave source in a wide type of experiments. For these reasons, and taking into account the fragility of Gunn diodes regarding their biasing [5], we have designed an external protection circuit for the device. This robust circuit allows to bias the Gunn diode in a wide range of conditions, so that if the user inverts the biasing polarities or exceeds the maximum working voltage, the Gunn diode will not be damaged.

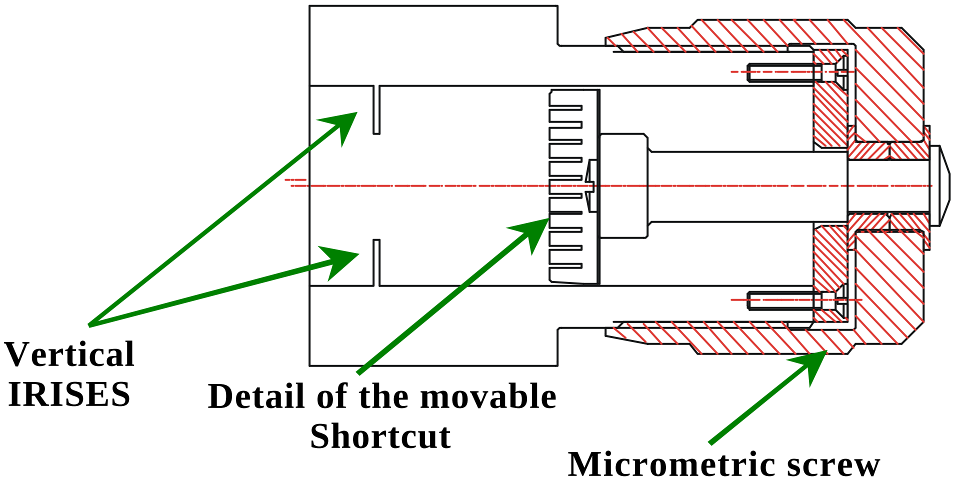
2 GUNN OSCILLATOR

Gunn oscillator properties depend on the internal negative resistance due to carrier motion in the semiconductor at high electric fields. When the Gunn diode is biased above the critical threshold field, a negative dielectric relaxation time is exhibited, which results in amplification of any carrier concentration fluctuations, causing a deviation from space-charge neutrality. The resultant domain drifts toward the anode and is extinguished, and a new domain is formed at the cathode. The current through the device consists of a series of narrow spikes with a period equal to the transit time of the domain. When, in a given period of time an RF voltage is superimposed to DC bias, the terminal voltage can be below that of both the threshold voltage and the domain-sustaining voltage. The frequency of oscillation is determined by the resonant circuit, including the impedance of the device. Experimental results and computer simulation [4-7] have shown that the device can be tuned over more than an octave bandwidth by an external cavity.

A Gunn diode type MA49156 was chosen for this purpose, because of its availability, good performance and low cost [8]. The bias voltage is applied to the cavity interior via a BNC connector directly attached to the external part, as shown in Figure 3a. Inside the resonant cavity, and in order to optimize its operation, the oscillator includes a sliding short circuit, an iris which acts as a filter, and tuning screws which act as reactive elements, as shown in Figure 1(a). It can also be appreciated in the figure that a threaded drum machined in plastic is included in order to move the short circuit, so the oscillating frequency can be accurately varied. Figure 1(b) shows a photograph of the oscillator, completely mounted and ready for use. To assess the correct operation of the diode inside the resonant cavity, three types of measurements have been performed: output power, frequency spectrum and phase noise of the oscillator. Previously, the matching of the cavity-diode assembly is verified by measuring the scattering parameters of the oscillator without biasing the diode. The matching was found better that 20 dB in the whole band.



(b)



(c)

Figure 1: (a) Transversal view.
(b) Top view.
(b) Photograph of the Oscillator.

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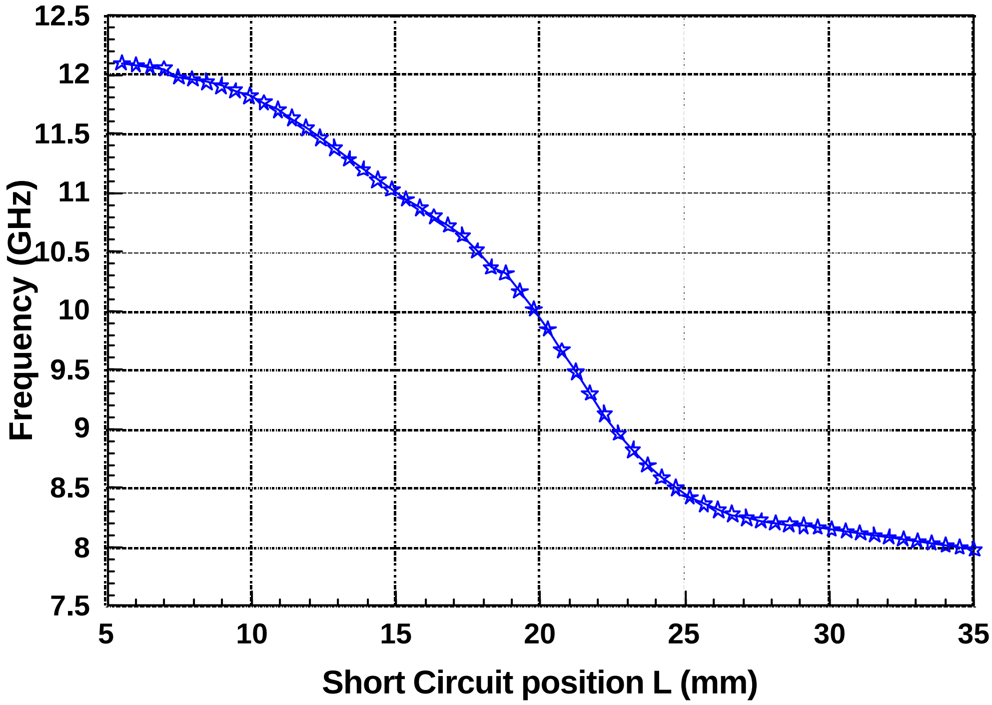
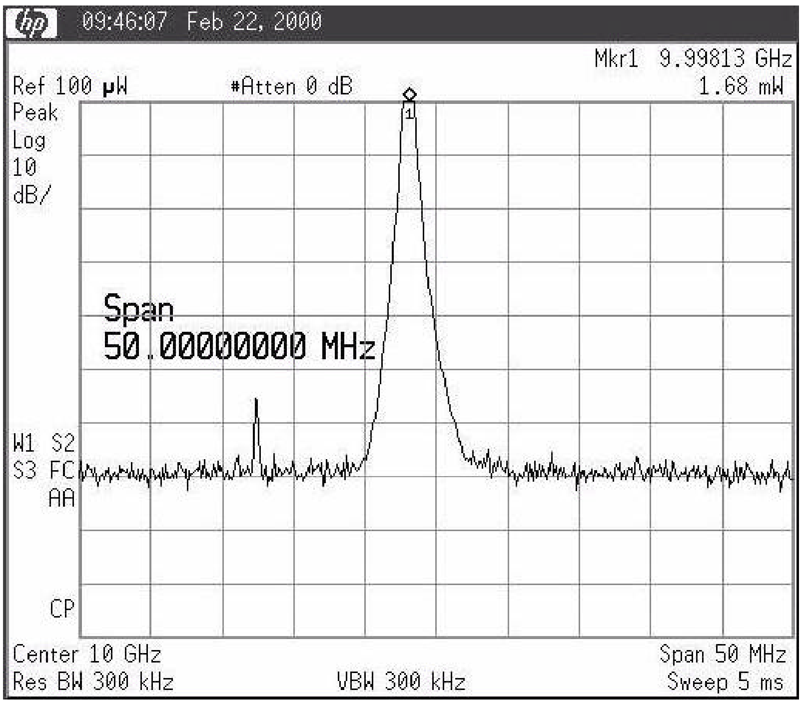
Figure 2(a) it shows the mechanical tuning characteristics of the Gunn oscillator at in the whole X band. This measure has been performed during the characterization of one of the ten devices manufactured for our RF and microwave laboratory. Figure 2(b) shows the spectrum of the oscillator at 9.98 GHz As can be observed in the figure, the power exceeds 1.5 mW, which is sufficient for most of the laboratory experiments. Also, it can be appreciated there are no in-band spurious, except one, 55 dB below the output power level at the oscillating frequency.



(a)



(b)

Figure 2: (a) Mechanical tuning characteristics of the Gunn oscillator.
(b) Frequency response @ 9.98 GHz.

In Figure 3 the SSB (single side band) phase noise of the oscillator measured at 10 GHz is shown.

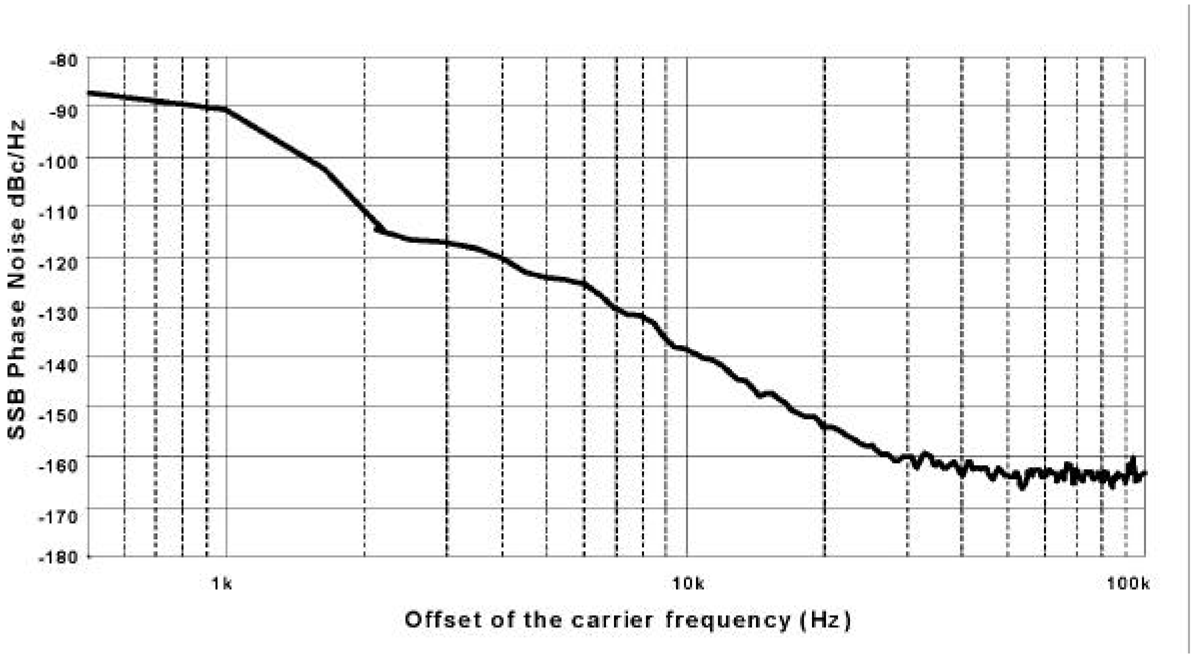


Figure 3: Phase noise plot of the Gunn oscillator @ 9.98 GHz.

3 PROTECTION CIRCUIT

The diagram for the external protection circuit is shown in figure 4.

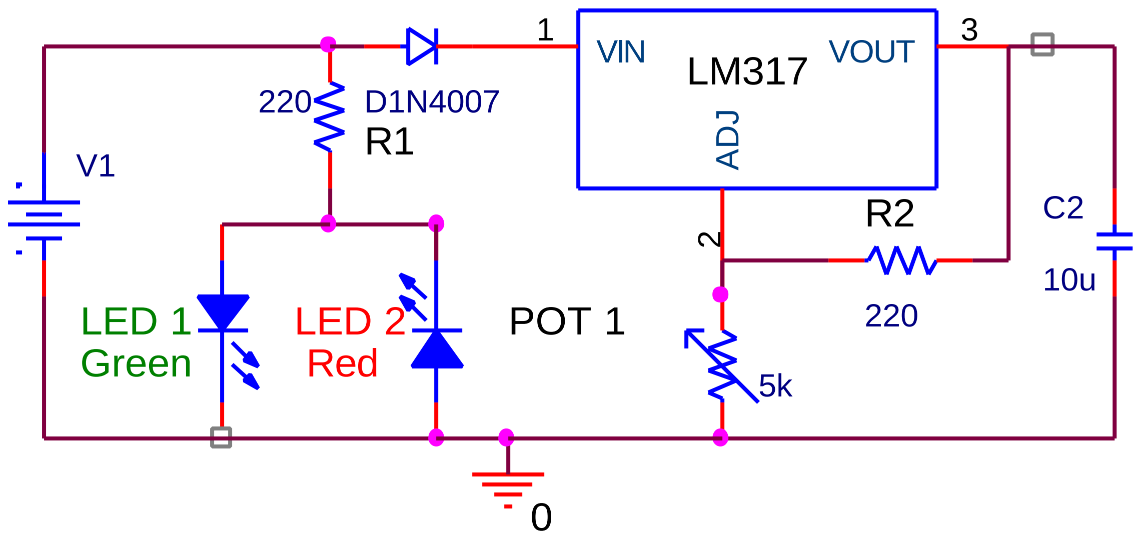


Figure 4: Diagram of the protection circuit.

This circuit allows the biasing of the Gunn diode in a wide range of conditions. If the biasing polarity is reversed, the power diode D1N4007 does not conduct and the output voltage is zero. The programmable linear regulator LM317 is set to the best bias voltage (14V) for the Gunn diode, by varying the value of the potentiometer POT1. If the input bias range exceeds the maximum operation voltage of the Gunn diode, the linear regulator fixes the output voltage at 14 volts (or the maximum voltage set by POT1). Even if the DC supply voltage is increased to up to 40V, the maximum permissible voltage at the input of the LM317, the Gunn diode will not be damaged.

4 CONCLUSIONS

A very low-cost and good performance X-Band Gunn cavity oscillator for use with waveguide WR-90 has been developed and tested. This oscillator is capable to sweep all the X-Band (8-12 GHz) with constant output power and low phase noise. Additionally, an external protection circuitry has been designed, to protect the oscillator against polarity inversion or excess voltage when biasing the Gunn diode. Future lines of work contemplate the extension of this cavity for higher power diodes.

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