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Design and implementation of X band Gunn diode oscillator

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Abstract: *Recently, there has been a revolution in the world of microwave, and Gunn diode oscillators have found many applications and are also heavily applied in research and development in laboratories. These devices are often referred to as an oscillator with low and medium power and are used in microwave receivers.**This paper introduces X-band oscillator Gunn diodes and discusses the design and implementation steps that are taken into consideration. The local oscillator of X band, sweeps 8.5 to 9.4 GHz frequency range with a short circuit plate movement across the cavity. Furthermore, change in aperture diameter of diaphragm to achieve maximum output power is examined. We observe that the change in aperture diameter of 8 to 9 mm, leads to 15mW more output power to the amount that can be accounted as outstanding. To prevent damage to the diode, due to current fluctuations of a metal, applying a metal nut with high capacity is also investigated. Phase noise measuring, frequency stability with temperature and time and the second harmonic excitation are also the cases that have been studied. In order to protect Gunn diode in different biases a protection circuit has been designed.*

Keywords: *Gunn oscillator, frequency mechanical adjustments, protection circuit, isolator, diaphragm aperture.*

I. Introduction

Since the late 1940s, in the majority of microwave oscillators and amplifiers, semiconductor devices have replaced light bulbs.

Semiconductor devices are preferred because of their low price and good performance. In the 1960s and 1970s, Gunn and Avalanche diodes were used extensively to produce microwave power [3-1]. Besides, Hybrid and Field-effect transistors, increasingly are used as oscillators, amplifiers, and microwave diodes. However, Impatt and Gunn diodes work at frequencies higher than the Ka frequency band (26-40 GHz) and even beyond it now.

Also in the microwave laboratories, X-band Gunn oscillators are used for low cost and high performance in the educational and research goals.

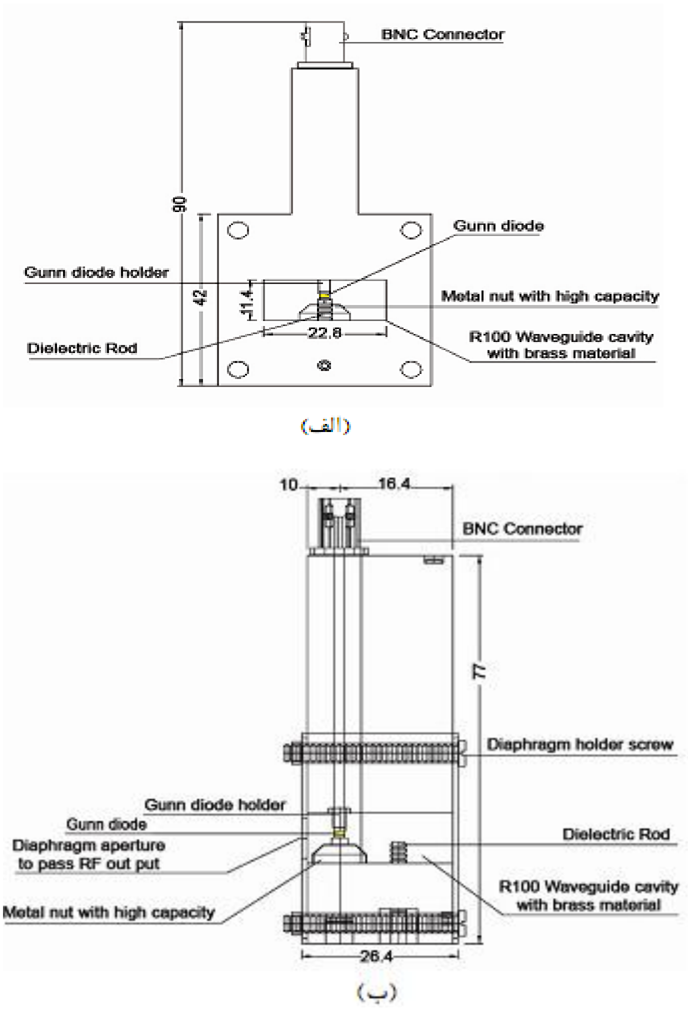
In the cavity, a standard WR100 waveguide and UBR100 flange are used. This oscillator is also used in a wide variety of tests is used as the microwave source. In addition, the Gunn diodes are very fragile in terms of their bias voltage. In order to avoid this problem, an external protection circuit is used.

The resistant circuit will allow the Gunn diodes to be biased in a wide range without any damage.
Therefore, if the user reverses the polarity of bias voltage or maximum working voltage of the Gunn diode exceeds, no danger threatens.

II. Gunn oscillator

In order to make this oscillator, a Gunn diode with a maximum flow of 120mA has been applied. The bias voltage is applied through a BNC interface connected directly to the external field. Inside a resonant cavity, in order to optimize its performance, a short circuit plate, a metal plate as a filter and adjustable screws as the passive elements have been used.

By moving short circuit plate along the waveguide, we can change the oscillation frequency of the band, within X band frequencies (8.5-9.4 GHz) as desired. Figure 1 clearly shows these sectors.



a) Longitudinal cut of band X Gunn oscillator
b) Transverse cut of band X Gunn oscillator

Figure 2 depicts clearly the performance and simple overview of the oscillator. What is also clear in the Figure is the distance between the installation site and diaphragm aperture of Gunn diode. This distance is equal to half of wavelength which is 16 mm in the built oscillator. Since the relevant frequency of 32 mm-wavelength is approximately 9.4 GHz, the frequency response of the test results is the same as the measured value.

Figure 3 shows a photo of this oscillator.

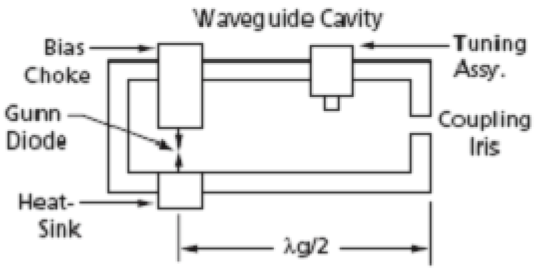


Figure2: The total structure of band X Gunn oscillator [2]

Fig3: A photo of this oscillator

In order to evaluate the performance of the diode in a resonant cavity, we measure the output and examine the oscillator frequency spectrum.It is important to note that for matching the diode with cavity, the measurement of scattering parameters without any bias is required.

Figure 4: shows the frequency spectrum of the oscillator at 9.41387 GHz. It is clear that the received power is about 12 mW.

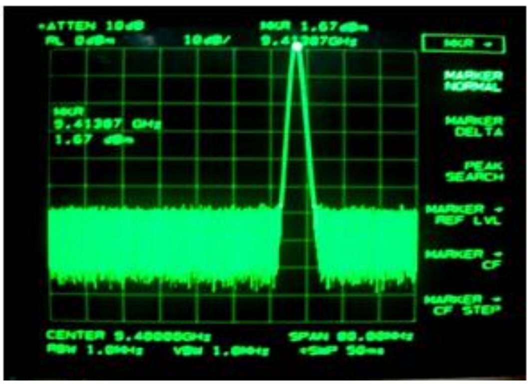
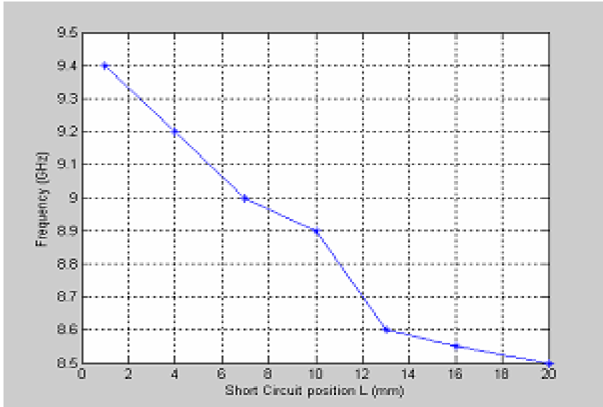


Fig 4: frequency response at 941387 GHz

Also, by connecting a flange into the waveguide mouth and changing the position of short circuit plate inside it, frequency range of 8.5 to 9.4 GHz is covered. In the following figure this is illustrated.



Frequency changes due to moving the short circuit plate

III. Bias circuit Oscillation

Gunn diode inherently shows negative resistance and this negative resistance with the pre-phase inductance and any excess capacity may lead to oscillation.Permanently, the oscillation is so great that it disables the diode.

To reduce or prevent this type of diode malfunction, high-capacitance capacitors near or parallel to diode will be taken advantage. The combined capacitance must have at least a few tens of MHz frequency response.

IV. Adjustment

Mechanical adjustment of frequency is feasible by using an adjustment rod into the cavity. Rod should be preferably made of a low loss dielectric such as Sapphire with a dielectric constant of 9. Adjustment rate is proportional to the diameter of the rod. If the diameter of the rod is too big, it makes different modes of waves propagated. Off wavelength for a rod with diameter D can be calculated as:

$$\lambda_{co} = 1.7 * D * \sqrt{K} \qquad (1)$$

Electronic setup is feasible by using a varactor in the oscillator. Using varactor, regulated bandwidth and oscillator efficiency depend on capacity of connections in chip as well as diode quality coefficient. [4]

V. Protection Circuit

The circuit diagram is shown in Figure 6:

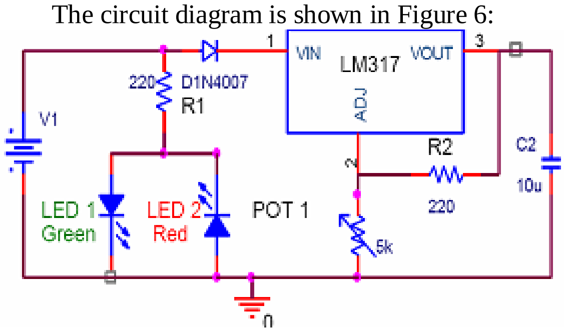


Figure 6: Protection Circuit diagram

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Circuit protection is advantageous to biasing Gunn diode in different conditions without causing any harm. If bias voltage polarity gets inversed, the power diode of D1N4007 does not conduct and the output voltage will be zero.

LM317 which is a linear programmable regulator is set on the best bias voltage (14V) for the Gunn Diode. This setting is enabled by changing the potentiometer POT1.

On the other hand, if the input bias voltage exceeds maximum operating voltage of Gunn diode, the linear regulator sets the output voltage on 14 V (or the maximum regulation voltage by POT1).Therefore, even with an increase of DC supply voltage up to 40 V, which is the maximum voltage at the input of the LM317, the Gunn diode will not be harmed.

VI. Frequency stability with temperature

Generally, the oscillator frequency stability depends on cavity material, reactance stability of diode Gunn and varactor. Frequency stability will improve by 3 methods:

1-Selecting the appropriate cavity material

2- Thermal compensation by incorporating mechanical substances

3- Selecting the appropriate Gunn diode

As for cavity material, It is important to say that using an alloy of iron and nickel called Invar is beneficial which is formed by 64% of iron and 46%.The advantage of this material is its thermal expansion which is zero in the range of -50 to 150ºC. Aluminum and brass are in the second priority due to having more thermal conductivity, thereby less loss compared to the other materials. Although, the loss of aluminum is less than brass, the brass has been used for four reasons:

1-economically inexpensive metal

2-Cheap metal in fabrication

3-Corrosion resistance

4-Easily cut and formed by devices.

VII. Measurement and Laboratory Installation

The module can be seen in figure 7, schematically depicts the RF source. Also, in figure 8, installing structure and measurement result have been shown:

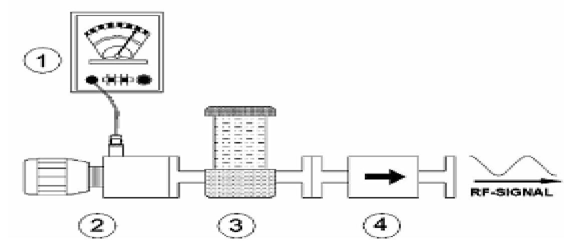


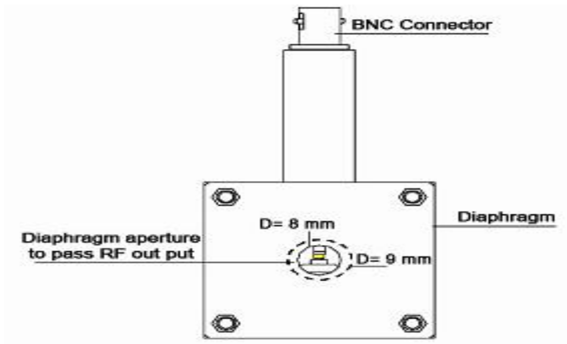
Fig 7: The module Related to RF source and installing and measuring oscillator Gunn

Fig 8: A photo of installing structure and measurement result

In this module a Gunn diode power supply is used to bias the Gunn diod in oscillator. The amount of bias in order to achieve maximum output power is between 8 to 10 volts. The power supply is marked with tag 1. Then, tag 2 is an adjustable cavity of Gunn oscillator. In order to measure the resonant frequency of the cavity, a frequency meter has been used and marked with tag 3. The power reflection from the end of the set is considerable. That is why it may damages the Gunn diode. In order to avoid this issue in section 4, a ferrite isolator is used to make wave passage through one-way and prevent from reflected power passage.

VIII. Output power and diaphragm aperture diameter effect

When the aperture diameter was chosen 8 mm, output power of 12 mW was measured. As it is evident in Figure 9, by changing the aperture diameter to 9 mm, the power increases dramatically and reaches the level of 30 mW. Therefore, we conclude that increasing the aperture diameter increases the output power. However, an excess amount of output power might shorten the life of Gunn diode which is the main part of the oscillator. Passing an excess amount of electrical current through the diode is the reason.



Change in aperture diameter from 8 to 9 mm

IX. Conclusion

In this paper, an X-band Gunn oscillator with WR100 waveguide cavity and the benefits of good performance and low cost have been designed and tested. One of the important points in the design of the oscillator is a metal piece located near the diode that makes a large capacitance. Since the oscillation amplitude is large enough to disrupt the work of the diode, the existence of the metal piece is mandatory in order to avoid any damage.

Otherwise, it will not show the desired results. It should be noted that the frequency response of the combined capacitance must be at least a few tens of MHz. The output power of the oscillator has been evaluated by changes in diaphragm aperture. So, by increasing an aperture diameter from 8 to 9 mm, an increase of 18 mW in output power was observed. The oscillator sweeps the frequency in the range of 8.5 to 9.4 GHz that has many uses. Applications of Gunn oscillator are such as local oscillator in the range of 1 to 100 GHz, microwave amplifiers, radar source, sensors detect the speed, direction, proximity and liquid level, wireless LAN, avoiding colliding vehicles, intelligent traffic control, ABS brake, smart controls of cruise missiles. Also, X band oscillators have been vastly used in research and development especially in labs.

X. Acknowledgement

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