TYPICAL APPLICATIONS

Gunn diode oscillators are used for many purposes and typical applications include local oscillators, klystron replacement, transmit and receive oscillators for radio communications, military and commercial radar sources, police radar, sensors for detecting: velocity, direction, proximity, or fluid levels, alarms, pumps for parametric amplifiers, wireless Lans, collision avoidance and intelligent cruise control, and others.

THEORY OF OPERATION

Gunn oscillators are categorized as transferred electron oscillators (TED) using the negative resistance property of bulk Gallium Arsenide. When an electric field of 3.2 KV/cm is present, the electrons in N type GaAs move from a high mobility to another lower mobility valley. Consequently, the net electron velocity is lower. This "negative resistance" phenomenon is used for converting DC into microwave power.

Figure 1 shows a typical voltage vs current characteristics of a Gunn diode. As the bias across the Gunn diode is increased, the current proportionately increases. However, at a bias voltage called the threshold voltage- corresponding to the threshold electric field of 3.2 Kv/cm - the current reaches a maximum known as the threshold current. As the bias across the Gunn diode is increased further, the current begins to decrease due to the negative resistance property. The current will continue to fall as the voltage is increased till a condition known as the breakdown voltage is reached. The diode will be catastrophically destroyed as the voltage in increased beyond the breakdown. The operating voltage is usually about 3 times the threshold voltage for cw operation and about 10 times the threshold voltage for pulsed operation

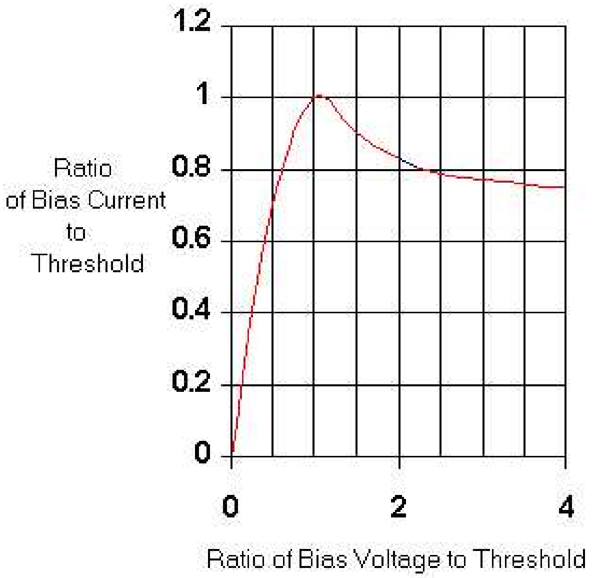
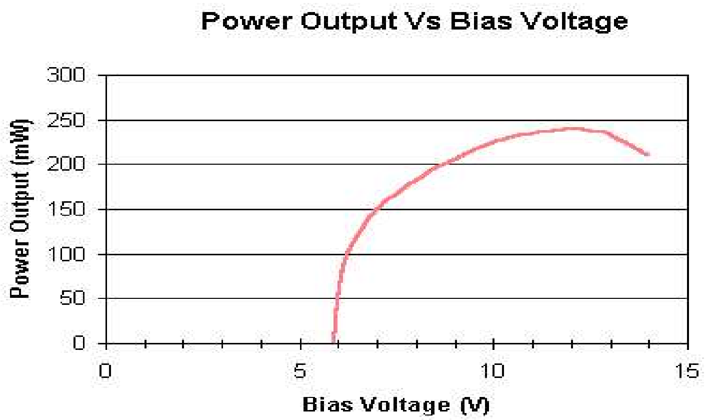


Figure 1.Typical voltage vs current characteristics of a Gunn diode.



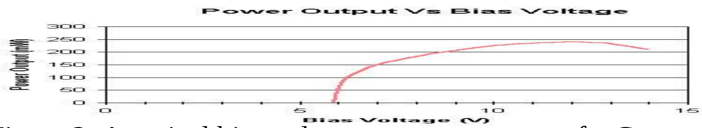


Figure 2. A typical bias voltage vs power output of a Gunn oscillator

Figure 2 shows a typical bias voltage vs power output of a Gunn oscillator. As bias is first applied to the Gunn diode no output in the desired band is seen, then low power random noise is generated. These low level, low frequency signals interfere with the proper operation of the oscillator and can cause damage to the diode so suppression networks are used to minimize them. When the "turn on" voltage level is reached, the desired frequency is generated with low levels of power rising with increased voltage until " voltage power peak" or VPP is reached. Voltage power peak is the bias level at which maximum RF power is generated. Best performance over operating temperature for power, turn on, and phase noise is usually obtained at a bias level 10 - 20 % . below the room temperature power peak. As an example , a 23 GHZ oscillator may "turn on" at 3.5 V. , be operated at 7.0 V. and have a power peak of 8 V.

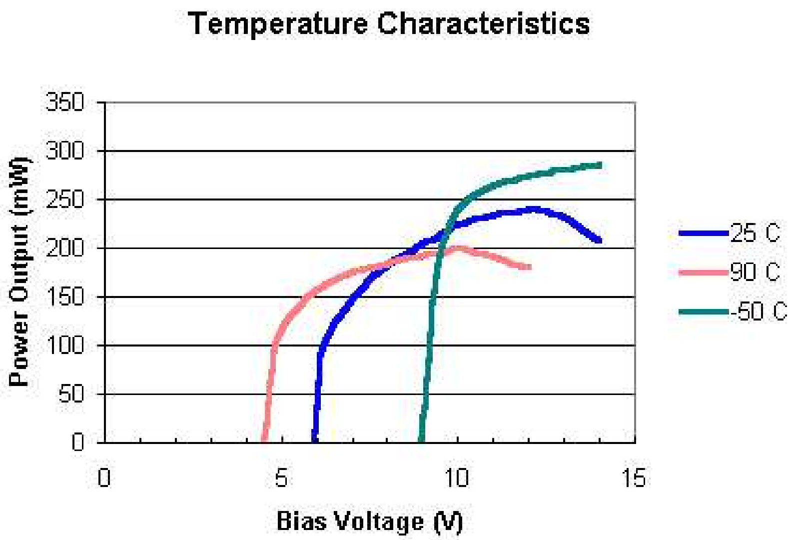


Figure 3. A typical turn on temperature characteristics

Figure 3 shows the temperature characteristics of turn on, power peak and breakdown voltages of a Gunn diode. In general, the turn on voltage and the power peak voltage decrease with increasing temperature while the breakdown voltage increases with increasing temperature. At lower temperatures, the turn on and the power peak voltages are higher than at room temperature. Conversely, the turn on and the power peak voltages are lower at higher temperatures. As an example, the turn on and the power peak voltages at room temperature may be 3.5 V and 7.0 V. At - 30 C, the turn on and the power peak voltages will be 5.0 V and 8.5 V while at + 70 C turn on and the power peak voltages will be 2.5 V and 7.0 V. The choice of the operating voltage, for a single voltage operation , becomes crucial and has to be between the turn on voltage at the coldest temperature and the power peak voltage at the highest temperature. In the case of the pulsed operation, the operating voltage has to be lower than the breakdown voltage at the lowest temperature.

GENERAL OSCILLATOR DESIGNS

In general, there are 3 types of oscillator designs that are used in microwave and millimeter frequencies.
These are:

- Coaxial
- Waveguide
- Microstrip or planar

The output circuits of these 3 types may be either coaxial or waveguide. Oscillators of all these types are manufactured in MDT covering the frequency range 5 to 140 GHZ for cw and pulsed operation. Our own GaAs diodes are used in these designs.

The choice of a particular design for a given application depends on several factors such as : power, frequency, frequency stability, power, power stability, mechanical tuning, voltage tuning, cavity material, size, weight and cost. The design considerations for these oscillator types are discussed below.

In general, simple coaxial and planar circuits have a low Q. Consequently, the active device dominates the performance. Consequently, stabilization with temperature is difficult. However, high stability may be achieved by fabricating the cavity with low temperature coefficient Invar and the proper choice of the diode. On the other hand, waveguide and dielectric resonator stabilized circuits have higher Q and hence temperature stabilization may be relatively easier.

Again in general, coaxial designs are preferred in the frequency range 5 - 65 GHZ because of the ease of mechanical tuning over a 10 - 20 % range.

COAXIAL CAVITY:

A coax cavity with coax output is often the cavity of choice below about 15 GHZ.. A typical coax cavity with coax output, coax coupling is shown in Figure 4. Coax oscillators have lower Q than waveguide cavity oscillators making them easier to tune. This type of cavity is mechanically tuned 10 - 20 % and can be electrically tuned with bias pushing of the Gunn diode or with varactor tuning. This lower Q results in lower stability and higher frequency drift. The Gunn diode dominates the cavity preventing cavity stabilization efforts typically used in waveguide cavities from being effective. Typical frequency stability with temperature @ 15 GHZ would be 1.0 MHZ/ ^{0}C with aluminum as the body material.

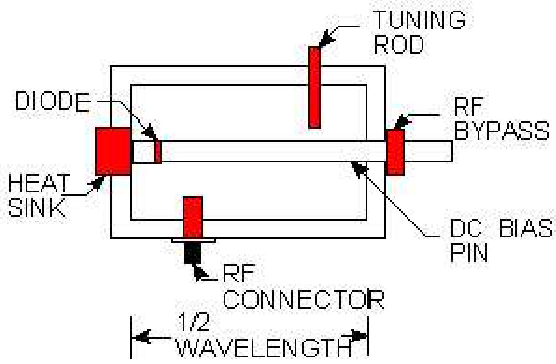


Figure 4 Coax Cavity with Coax output

A variation on this design is the waveguide slot coupled coax cavity which is typically used at frequencies between 15 and 65 GHZ. This design is used for varactor tuning where large tuning bandwidths are needed and stability is not as critical. Figure 5 shows an example of this design. These are the most efficient cavities at millimeter wave frequencies for power generation. Typical stability @ 35 GHZ would be 1.8 MHZ/ ^{0}C with aluminum.

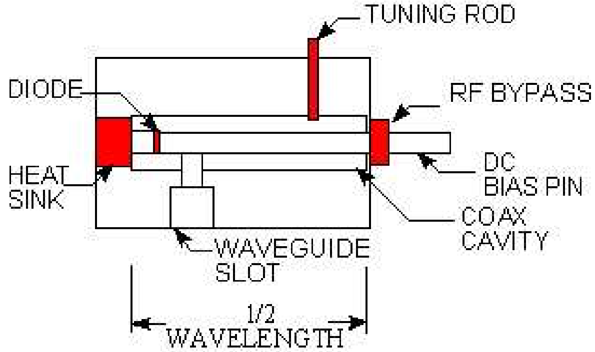


Figure 5 Coax cavity with waveguide slot

Waveguide Cavity:

Waveguide iris coupled cavities are the most common types used at microwave thru millimeter wave frequencies. These are simple to fabricate and are the cavity of choice for CW and Pulsed oscillators. Iris coupled cavities have the highest Q and best frequency stability. They can be bias tuned or varactor tuned but over a much smaller bandwidth than a coax cavity. Waveguide cavities can be stabilized

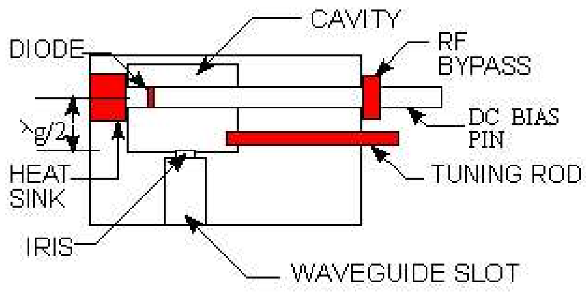


Figure 6 Iris Coupled Waveguide Cavity

with the use of chimney or differential material expansion methods or by using a family of ceramics. Typical stability @ 35 GHZ would be 1.0 MHZ/ ^{0}C in an unstabilized cavity. An example of an iris coupled cavity is shown in Fig. 6. With ceramic rod temperature compensation, stability of 200 Khz/ ^{0}C @ 35 GHZ are easily realizable.

Waveguide iris coupled cavities are used typically to 50 GHZ. Above this, coax or 2nd harmonic cavities are commonly used. One type of 2nd harmonic cavity design is the resonate top hat structure. This circuit is used for CW and Pulsed oscillators as well as vco tuned oscillators of moderate bandwidth at frequencies up to 110 GHZ. Typical stability @ 95 GHZ would be 6.0 MHZ/ ^{0}C. An example of this circuit is shown in Fig.7.

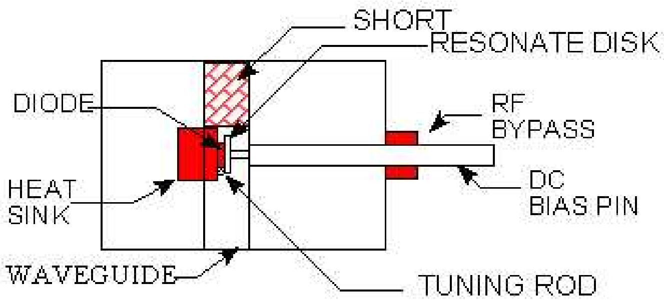
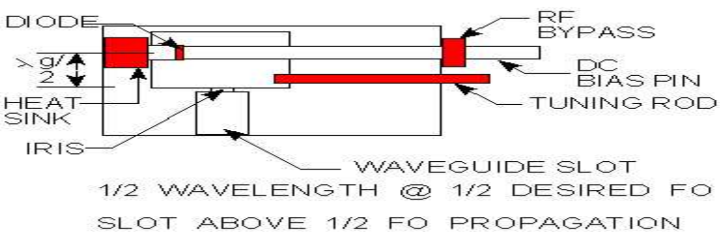


Figure 7 2nd Harmonic Waveguide Cavity

A different type of 2nd harmonic cavity is used when frequency stability or increased varactor tuning is needed. This is a 2nd harmonic cutoff cavity where 1/2 the desired fo is generated in the cavity and is filtered out to enhance the 2nd harmonic. An example of this cavity is shown in fig 8. Typical stability or FS @ 77 GHZ would be 3.0 MHZ/ ^{0}C.



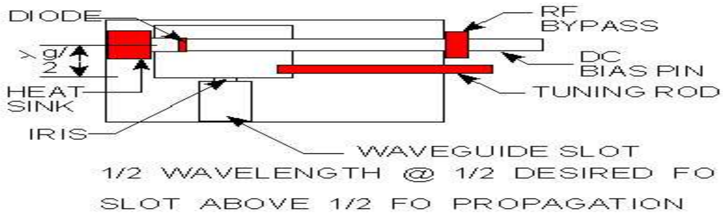


Figure 8 2nd Harmonic Cut-Off Waveguide Cavity

Planar microstrip oscillators

Planar microstrip oscillators are now developed to operate at millimeter wave frequencies. These have an advantage of small size and low cost at production quantities since no cavity is required. Designs include a DRO (or dielectric resonator oscillator) and a planar microstrip Gunn oscillator. An example is shown in Fig. 9.

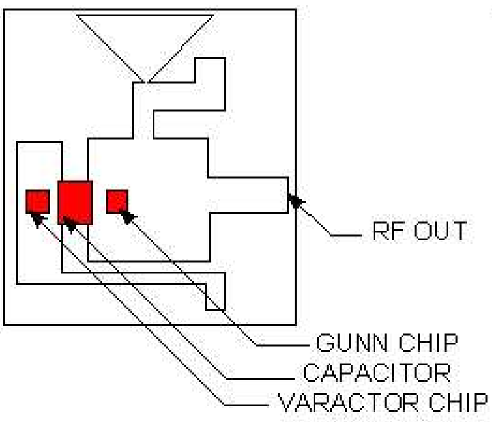


Figure 9 Planar Gunn Oscillator

Conclusions:

The Gunn cavity is chosen to match the customer requirements with higher Q cavities selected when stability is most important and lower Q when maximum tuning is required. Waveguide cavities can be stabilized with the use of chimney or differential material expansion methods or by using a family of ceramics. Typical frequency stability @ 35 GHZ would be 1.0 MHZ/ ^{0}C for an unstabilized cavity. This can be improved to 0 .1 MHZ / 0C with the combination of chimney or differential material expansion methods and ceramic compensation. Hybrid heaters can be used to hold the operating temperature to a 10 ^{0}C window further improving frequency stability and can be used alone or in combination with the above methods. Voltage regulators can be used to protect the oscillator from line variations and minimize bias pushing. Many options can be combined to meet a variety of performance specifications. The following data and charts are only a representation of available oscillators manufactured at MDT,

Request more information

Email: mdt@mdtcorp.com