GUNN DIODE IMPEDANCE MEASUREMENTS USING A SINGLE-TUNED OSCILLATOR

P. W. Dorman
Bell Telephone Laboratories
Murray Hill, New Jersey 07974

Abstract

Impedance measurements of Gunn diodes indicate that these diodes have higher impedances than ordinary IMPATT diodes and that unusual circuit characteristics are required for self-starting, maximum power, operation at off-transit-time frequencies.

Summary

The output power of microwave solid state devices is limited by the range of impedance levels that a circuit can provide without introducing excessive losses. If this were not the case, it would be possible to increase the output power continuously by simply increasing the cross-sectional area of the active region or paralleling several chips in one package.[1]

We have measured the impedance of Gunn diodes using a single-tuned oscillator circuit and have found that this impedance is considerably higher than that of another important solid state device, the ordinary IMPATT diode. A fair comparison of the output power capability between the two devices can therefore be made only after the total cross-sectional area of Gunn diodes is increased such that the impedance of the two devices is comparable.

The diode impedance measurement is based on the following observation. The negative of the device impedance under oscillating conditions is equal to the circuit impedance which can be measured separately. The oscillator circuit used for this measurement (Fig. 1) is similar to one previously used for IMPATT characterizations[2] except that the coaxial line location has been moved to the side wall of the cavity for improved tunability. Unfortunately, this circuit was not immediately compatible with Gunn diodes. It was found that Gunn diodes oscillated with a much larger range of impedances than IMPATT diodes and thus any spurious circuit resonances that provided the proper impedance anywhere in the vicinity of the primary resonance point resulted in unpredictable frequency jumps and multiple frequency oscillation. To eliminate any high frequency resonances without altering the primary resonance curve, a pair of mode suppressors in the form of waveguide traps with a cutoff of 12.5 GHz were added across the broad walls of the cavity as shown in Fig. 1. The resultant circuit was free from troublesome spurious frequencies below 18 GHz and it was possible to operate Gunn diodes in the vicinity of 9 GHz with very predictable results. The modified circuit thus allowed us to smoothly change the resonant frequency with the waveguide short, the position of the impedance locus around the Smith chart with the variable length coaxial line, and the impedance locus diameter with the rotary iris.

This circuit enabled us to cover nearly all regions of the Smith chart and thus be assured that any circuit impedance required by the diode for oscillation was obtainable. For a given oscillator frequency it was then possible to vary the impedance at the diode position by changing the loading and measure the extent of the impedance change required to stop coherent oscillation. A plot of this impedance variation is actually a device line[3] for the Gunn diode; i.e., a constant frequency locus of the negative of the device impedance as the RF current amplitude varies. The measured device line position as a function of frequency for one typical diode is shown in Fig. 2. The reference plane is located at the top of the diode package. Typical diode dimensions are 125µm × 125µm × 10µm thick with an electron concentration of 4.5×10^{15} cm^{-3}. Typical output power is 100 MW.

By careful measurement of a device line in the region where coherent oscillation stops, a starting point for each line can be determined as shown in Fig. 3. For this measurement the circuit is first adjusted for a given frequency oscillation and the loading is increased until oscillation stops at point A. At this particular loading the circuit impedance locus, the locus of impedance variation versus frequency, is shown by curve B. If the circuit loading is then decreased slightly (increased circle diameter), oscillation will not restart. The circuit must be adjusted to curve C before oscillation will begin. Varying the coaxial length to change the rotational position of the circuit impedance locus and repeating the above adjustments allows us to locate point D, the starting point for that particular device line. The dotted line between points D and A is unstable. If the circuit load line does not intersect or encircle point D, coherent oscillation will not start. Curve E shows such a case.

The diode behavior described above can be explained as follows. When bias voltage is first applied, the negative of the device impedance is located at point D and the RF amplitude is approximately zero. If the circuit load line does not encircle point D as shown by curve E, then the Nyquist stability criterion dictates that the system is stable and oscillation will not build up. On the other hand, if the circuit load line encloses point D, the Nyquist criterion indicates that the system is unstable and the oscillation amplitude will grow. With this amplitude build-up, the device impedance moves along the device line to a stable point such as F where the negative resistance just equals the positive resistance.

There is, in general, only one point along a device line which will provide maximum output power. As the radius of the circuit impedance locus is varied by changing the loading, this maximum power point is well defined. If this intersection is achieved while still enclosing the device line starting point (D), then bias may be removed and reapplied and maximum power will again be present. If, however, in tuning for maximum power the circuit load line no longer encircles the starting point, then bias cannot be removed and reapplied to achieve renewed oscillations. This latter condition generally occurs when a Gunn diode is operated at frequencies well above the transit-time frequency because then the maximum power point is near the end of the device line.

The diode resistance for maximum output power is approximately -10Ω at frequencies close to the transit time frequency. This compares very favorably with the 1-2Ω resistance provided by IMPATT diodes. The magnitude of the Gunn diode resistance indicates that a greatly increased area is a reasonable design objective.

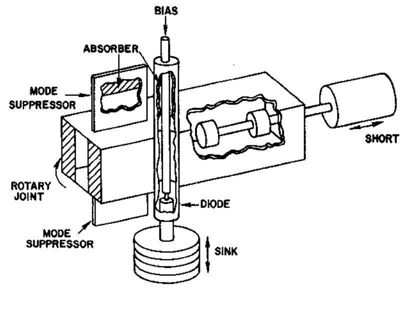

Fig. 1 Oscillator Circuit.

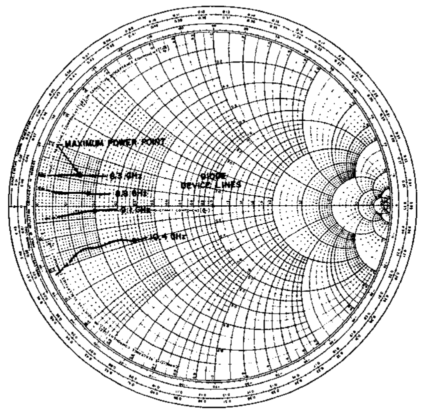

Fig. 2 Diode Device Line Versus Frequency

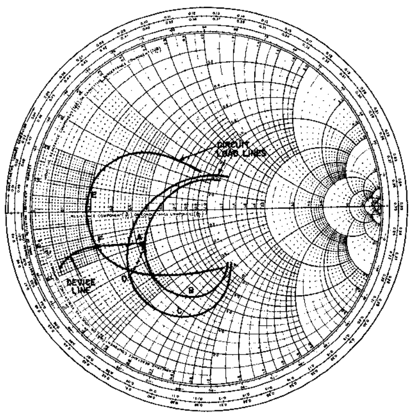

Fig. 3 Device Line and Load Line Interaction.

REFERENCES

1. B. C. Deloach, Jr., "Recent Advances in Solid State Microwave Generators," Advances in Microwaves, Vol. II, Academic Press, 1967.

2. F.M. Magalhaes and K. Kurokawa, "A Single-Tuned Oscillator for IMPATT Characterizations," Proc. IEEE, 58, No. 5, pp. 831-832, May 1970.

3. K, Kurokawa, J. P. Beccone and N. D. Kenyon, "Broadband Negative Resistance Oscillator Circuits", G-MTT Symposium Digest, pp. 281-284, 1969.