ANALYSIS OF A J-BAND PULSED READ IMPATT OSCILLATOR

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Summary

A computer analysis of a waveguide Impatt oscillator has been undertaken with good agreement between theory and experiment. Using this analysis a new technique has been devised for determining package bond-wire inductance and diode capacitance.

Introduction

Direct measurement of the large-signal impedance of an Impatt diode is extremely difficult, particularly for high-power pulsed diodes. An alternative approach is to measure the impedance presented to the diode by the external circuit under resonant conditions but this is also difficult.

Computer analysis of the circuit based on the work of Williamson[1] was undertaken and experimental results showed it to give accurate values of impedance. This analysis when combined with measurements of power and frequency as a function of diode area enabled a large-signal equivalent circuit for the diode to be derived, and the package inductance and diode votltage modulation to be determined.

Circuit analysis

Williamson[1] has analysed the coax to waveguide transition shown in Figure 1 and has derived an equivalent circuit (shown in Figure 2) when only the TE_{10} mode is present in the waveguide.

The theory was first checked by measuring the impedance at the waveguide port. In order to have a measurable return loss, the Impatt diode was replaced with a PIN diode and the impedance measured on a computer-corrected network analyser as a function of the DC current through the PIN diode. Figure 3 shows typical excellent agreement between theory and experiment. The PIN diode RF resistance was measured (at 400 MHz) as a function of current and this value was used to produce the theoretical curve in Figure 3.

Another check on the theory was achieved by measuring the impedance presented to the Impatt diode and comparing this with the theoretical value. This result is shown in Figure 4 and good agreement is once more obtained, but there is greater uncertainty in the measured values in this case. It should be noted that this measurement was made after the circuit had been adjusted for optimum power output for a pulsed Read Impatt diode at 16.5 GHz.

Determination of package parasitics

The package capacitance was determined by measuring the capacitance of an empty package on a 10 MHz bridge.

The determination of bond wire inductance is more difficult. The usual method is to measure the

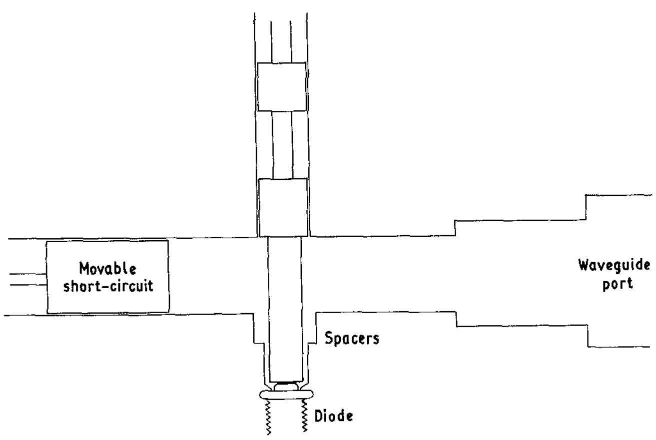

Fig.1 Schematic of waveguide mount

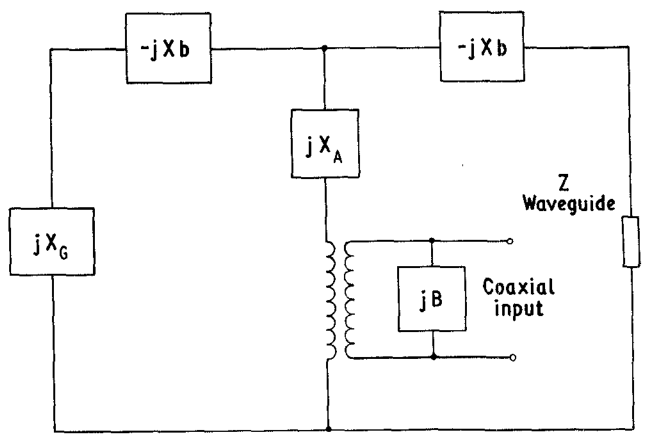

Fig. 2 Williamsons equivalent circuit

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package resonant frequency by inserting the diode into the centre conductor of a coaxial transmission line and then to calculate the inductance knowing the capacitance. This method is very difficult if the resonant frequency is in the millimetre wave frequency region which it is for these diodes. Furthermore, the inductance which is measured is not that of an actual packaged diode as the technique usually requires the semiconductor chip to be eliminated.

A new technique has been developed which enables the inductance of a packaged Impatt or Gunn diode to be evaluated at the frequency of oscillation using Williamson's analysis of the oscillator cavity. The technique consists of inserting a diode into the cavity and adjusting the circuit and bias conditions for optimum power output. This operation is repeated several times with the diode mesa diameter etched down between each measurement. Representing the Impatt diode by a series equivalent circuit as shown in Figure 5, then at the frequency of operation

$$-X = 2\pi f L - \frac{1}{2\pi f C} \qquad (1)$$

where X is calculated from the circuit dimensions, L is the bond wire inductance and C is the diode's equivalent capacitance. Since the Q of the Impatt diode is high, then

$$C = \frac{\varepsilon A}{d} \qquad (2)$$

The 0.2 pF package capacitance has been incorporated into X and r. Equation (1) can be rewritten as

$$-\frac{X}{f} = 2\pi L - \frac{1}{2\pi \varepsilon f^2 A} \qquad (3)$$

and hence a graph of $-\frac{X}{f}$ versus $1/f^2A$ enables the package inductance to be determined from the intercept and the slope gives the time-averaged large-signal depletion width. A typical result is shown in Figure 6. The results of measurements on four diodes gave values for d of 2.6 μm, 4.0 μm, 2.8 μm and 3.3 μm which are reasonable since the doping profiles has a total active region thickness of 4 μm and the corresponding values of bond-wire inductance are 134 pH, 174 pH, 137 pH and 155 pH.

For a typical diode with an area of 2.5×10^{-8} m^2 the large signal model can be represented by a negative RF resistance of 0.9 ohms in series with a capacitance of 0.89 pF or a negative RF resistance of 140 ohm in parallel with 0.88 pF of capacitance.

Diode voltage modulation

From the power output and the value of r one can calculate the peak RF current as $\sqrt{2P/r}$ and hence the peak RF voltage across the diode is

$$\hat{V} = \sqrt{\frac{2P}{r}} \cdot \frac{1}{2\pi f C} \qquad (4)$$

The voltage modulation was surprisingly high with values between 90 and 130%, contrary to the customarily accepted value[2] of 50%. This discrepancy can not be explained by postulating series resistance within the circuit. The

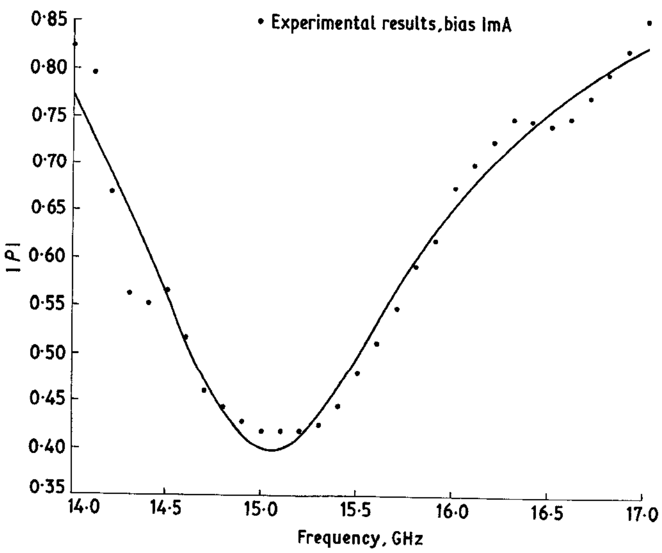

Fig. 3 Impedance of waveguide part with Impatt replaced by PIN diode

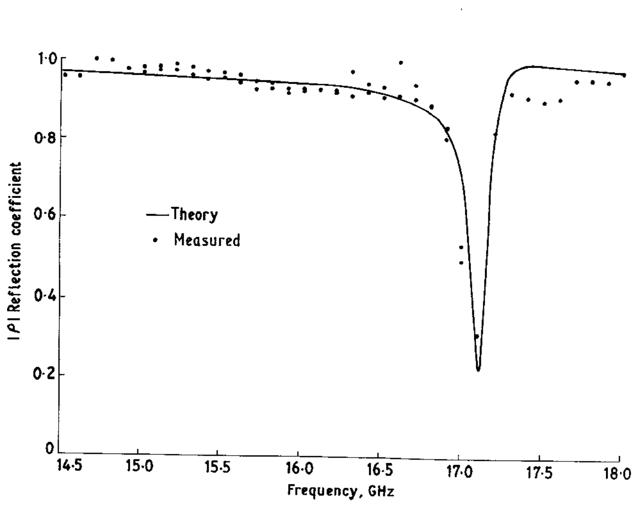

Fig. 4 Impedance presented to Impatt diode

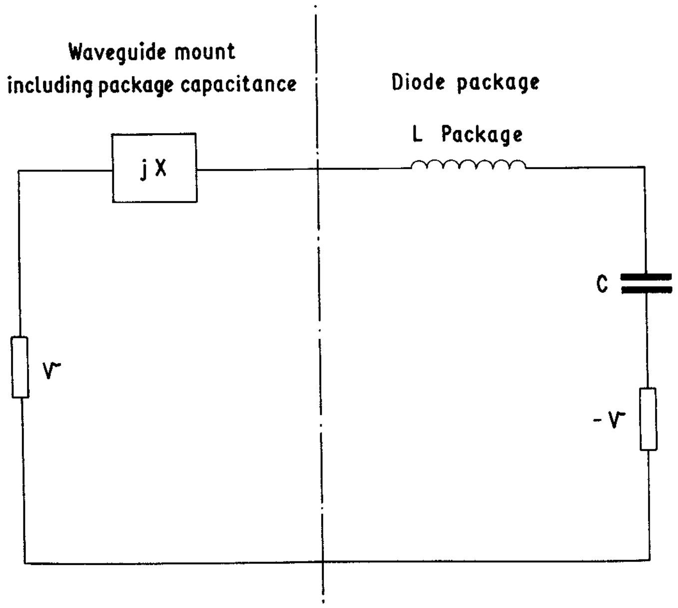

Fig. 5 Equivalent circuit of Impatt diode

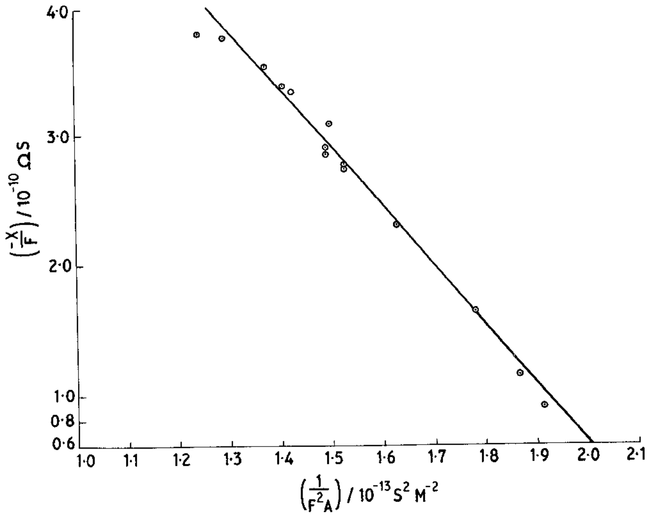

Fig. 6 Determination of bond wire inductance of diode deflection width

effect of back bias[2] on voltage modulation is currently being examined to see if this explains the anomaly. The impedance presented to the diode at the harmonic frequencies is also being determined.

References

1 A G Williamson, 'Analysis and modelling of a single-post waveguide mounting structure', IEE Proc., 129, Pt-H, No 5 pp 271-7, (October 1982).

2 B Culshaw, R A Giblin and P A Blakey, 'Avalanche diode oscillators', Taylor and Francis, London (1978).