TIME VARYING IMPATT IMPEDANCE MEASUREMENTS

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Abstract

A technique has been developed that measures the dynamic impedance characteristics of an IMPATT diode while it is being operated in the pulsed mode. Time plots are discussed for a variety of diodes.

Introduction

When an amplifier is designed around an IMPATT diode, it is necessary to know the diode's impedance characteristics for the required operating conditions. This information is generally desired as a function of bias, power level, circuit impedance, and frequency. Continuous-wave (CW) impedance information can be measured with a network analyzer at those parameter levels of interest and represents a time invarient or steady-state condition. When pulsed operation is required, the device must go through a transition from a relatively cold off state to a hot on state, approaching the CW condition for long pulses. This temperature variation results in an impedance variation for the transition period that is a function of the pulse length and duty cycle. For a full understanding of the operation of a pulsed IMPATT amplifier, this transient impedance behavior must be determined.

Discussion

A measurement technique has been developed that accomplishes this determination. The technique was used for measurement of a variety of diodes. The procedure is based on determination of the complex reflection coefficient for the device by precise phase and gain measurements as a function of time across the pulse. From this data the impedance changes within a pulse can be determined. The measurement circuit is shown in Figure 1. It consists of a bridge circuit for phase measurement and a detector for amplitude measurement, with both parameters displayed simultaneously on scopes for time correlation. Precise calibration is of utmost importance to produce meaningful data, requiring various attenuators and meters for setting and maintaining constant power levels throughout the measurement procedure. In this way the detector output variation as a function of power is eliminated as a source of error.

A typical presentation seen for a 20-microsecond pulse with the phase shifters and attenuators properly adjusted is shown on the sketch of Figure 2. Gain is determined from the attenuator reading by comparison of the pulse magnitude with the calibrated value when

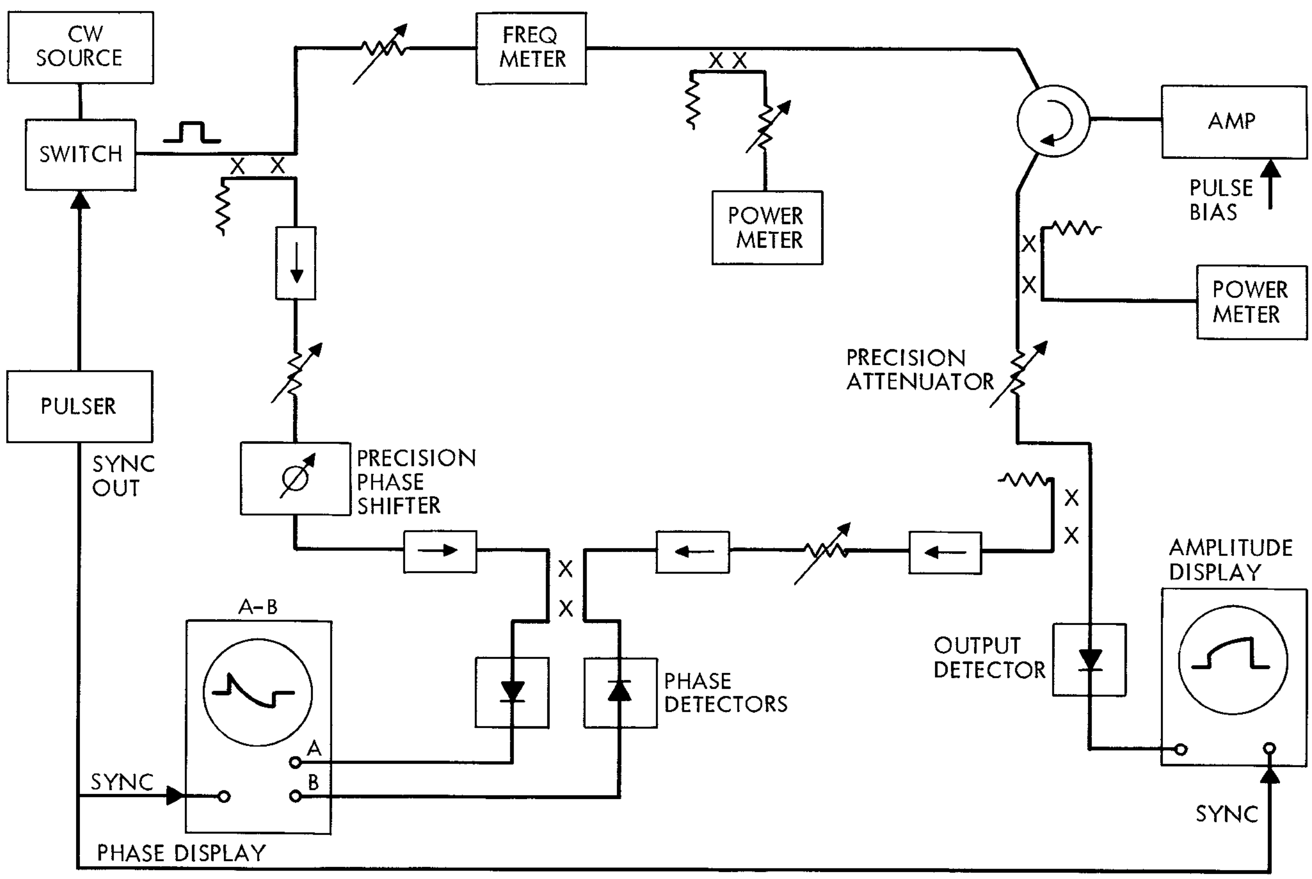

FIG. 1. Measurement Circuit Diagram for Pulsed Device Characterization.

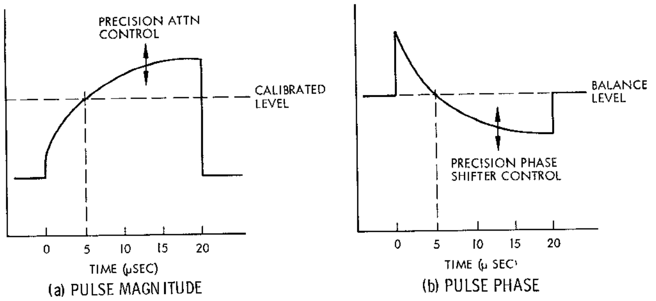

FIG. 2. Typical Magnitude and Phase Time Displays for Pulsed Device Characterization; Phase Shifter and Attenuator Adjusted for 5-μsec Reading.

displayed as shown on Figure 2. Phase measurements are made by adjusting the precision phase shifter and observing the response relative to the balance level as indicated on Figure 2b.

Phase and magnitude calibration are accomplished with a well-established short circuit reference placed in the amplifier circuit. Measured phase and gain can then be interpreted relative to this short to give the desired impedance information using accurately modeled equivalent circuits for the amplifier elements.

The devices under test were GaAs Read IMPATTs from Raytheon and Texas Instruments, supplied for study on a Pulsed Read Diode Amplifier Evaluation Program for the Air Force Avionics Laboratory, Wright-Patterson Air Force Base, Ohio.

Results

A result of this measurement technique is shown in Figure 3. The device impedance as a function of time within the pulse is plotted in Figure 3a, with the corresponding detected output pulse shown in 3b. During the first 2 μsec, the device real part is positive and the input power is absorbed. Following a warm-up delay, negative resistance appears, the device turns on, and the output increases. At 25-percent duty, the 60-μsec off time is sufficient for the device to cool considerably between pulses to start again cold.

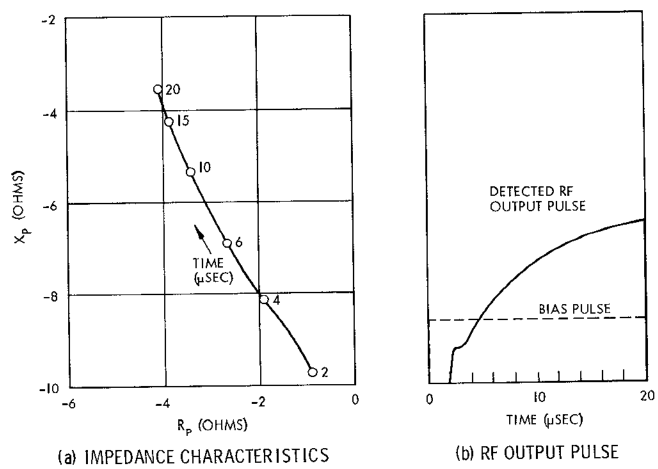

FIG. 3. Pulsed Device Characteristics (bias current, 580 ma; bias voltage, 53 V; frequency, 9.3 GHz; duty, 25 percent; pulse width, 20 μsec; peak P_{IN}, 1.0 watt; Raytheon Diode BSX 605CRB-8.

Some further results are shown on Figure 4 where a family of curves for various duty factors has been developed to show the wide variation in device behavior. In Figure 4a, the plots are for 60-μsec pulses with the 15- and 25-percent duty curves exhibiting delays of 6 and 2 μsec, respectively, and the other four curves indicating immediate turn-on. It was necessary to increase the bias current from 380 ma at 75-percent duty up to 500 ma at 15-percent duty to maintain a measurable pulse shape while the input power was kept at 1 watt for both sets of curves. The diode measured in Figure 4a was the same as that used in Figure 3. Another Raytheon device, No. 6-11-75-81447-10 from a different batch, was measured with the results shown in Figure 4b. Here the pulse width and duty are constant (10 μsec, 10 percent), but two different frequencies are used. The device now turns on quickly and maintains a flat output shape but the performance drops off rapidly above 8.7 GHz. The drop in negative resistance for the 9.0-GHz pulse as the device warms up produces a pronounced pulse droop. A moderate amount of phase shift (approximately 25 degrees) is also present, primarily occurring during the first half of the pulse.

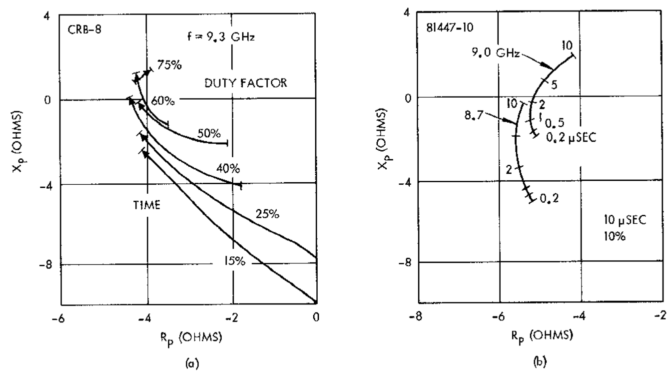

FIG. 4. Pulsed Raytheon Diode Characteristics.

In sharp contrast to the results of Figure 4 are those of Figure 5a. A different diode, Texas Instruments 74-1009, turned on quickly and operated well even at very low duty factors. The negative resistance held constant within each pulse, which resulted in a flat top or constant output pulse. The resistance change shown between duty conditions is due to the increase in bias current applied as the duty was reduced. A slight phase shift is noted due to the reactance change, but this reduces to a negligible amount for 25-percent duty factors and above.

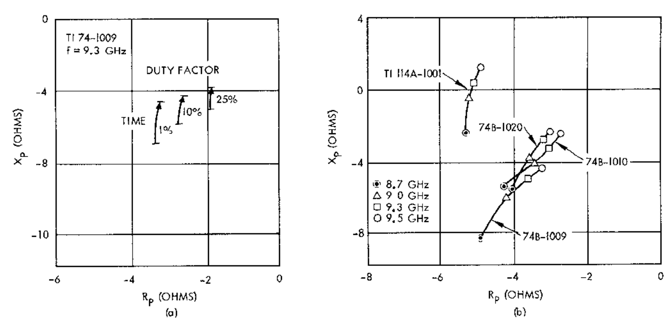

FIG. 5. Pulsed Texas Instruments Diode Characteristics.

Four additional Texas Instruments diodes were measured in this manner and found to have excellent pulse responses. Although these were only operated at 10-percent duty with a 10-μsec pulse width, the impedance had achieved steady-state conditions at the end of the pulse and threfore represented a large signal (P_{in} = 1 watt) CW characteristic. The results for these devices are shown in Figure 5b.

The physical mechanisms giving rise to the differences in intrapulse performance are not completely understood at this time but are undoubtedly related to thermal effects. Heating of the device and temporal redistribution of the thermal energy within the diode junction causes the impedance to vary during the pulses.

Summary and Conclusions

A measurement technique has been presented that allows measurement of the time varying impedance of an IMPATT diode. This resulting information is very useful in the optimization of design and understanding of the operation of pulsed IMPATT amplifier circuits. Characterization of other one-port devices could as easily be accomplished with only minor changes for the modeling of the associated circuitry.