PULSED CHARACTERIZATION OF X-BAND GaAs DDR IMPATT DIODES

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ABSTRACT

A method, and the resulting data, for measurement of transient impedance behavior of pulsed X-band GaAs IMPATT diodes is described.

INTRODUCTION

The design of IMPATT Diode Power Combiners for high peak power injection locked amplification of pulsed RF waveforms requires detailed knowledge of the behavior of the diode's large signal impedance, as a function of time across the pulse, for the expected range of variation of the operating parameters. These parameters can include pulse width, duty cycle, frequency, diode current, temperature, and power levels. Although automatic network analyzer techniques have been used for measurements of active impedances on a CW basis, they do not work for short pulse waveforms, and would not, in any case, reveal impedance variations with time across the pulse. This same shortcoming limits the usefulness of measurements made according to the so called "oscillator or conjugate-matched method", in which diodes are tuned to oscillate in a pulsed mode, and then fixtures are taken apart and the diode impedance set equal to the conjugate match to the terminating impedance "seen" by the diode, as measured at the frequency of the observed oscillation. This paper describes a method of measuring the impedance of active microwave diodes operated as pulsed, injection locked oscillators, as a function of time across the pulse and input power, and presents results of such measurements on Raytheon X-band GaAs Double Drift READ IMPATT diodes.

MEASUREMENT SYSTEM

Measurements of diode impedance have been made using a phase-gain bridge technique. Figure 1 is a block diagram of the measurement instrumentation. The bridge is calibrated with a reference short replacing the IMPATT diode in the coaxial test fixture connected to the test port. Then, the device to be characterized is placed in the fixture and tuned to operate as a high gain, pulsed, injection locked amplifier by means of one or more quarter wave transformers, whose position may be adjusted through a slot in the fixture. Once the desired tuning condition has been obtained, transformer lengths, positions, and characteristic impedances are recorded and used with the previously measured test port impedance, to compute the complex circuit impedance, Z_C, presented to the diode. Measurements of phase and magnitude of the amplifiers's reflection gain are then made as a function of frequency, input power, bias conditions, pulse length and duty cycle, and junction temperature. The diode impedance and RF current may then be quickly computed by means of the relationships:

$$\text{Power Gain} = |\Gamma|^2 = \left|\frac{Z_D - Z_c^*}{Z_D + Z_c}\right|^{1}$$

$$\text{Phase Shift} = \angle\Gamma = \angle\,\frac{Z_D - Z_c}{Z_D + Z_c}$$

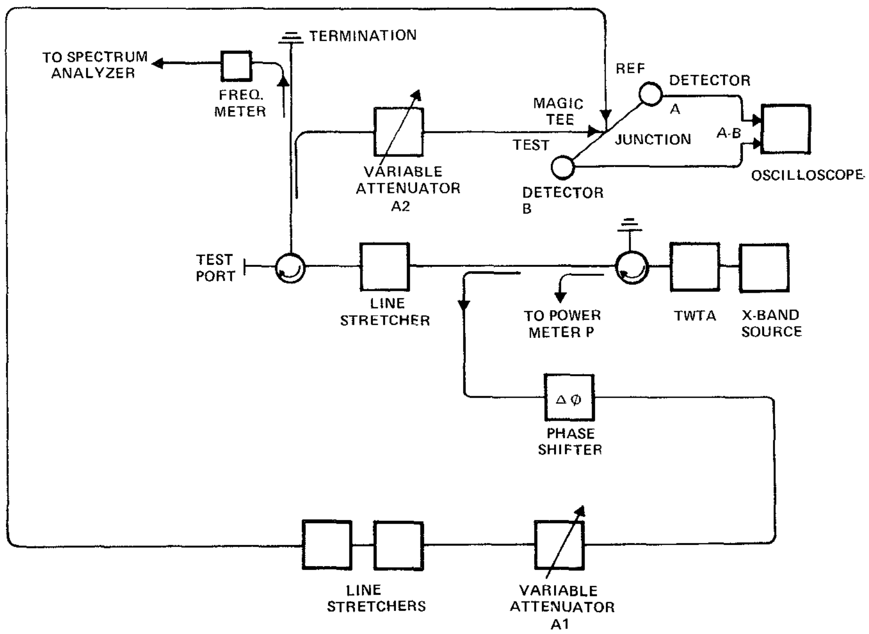

Figure 1 - Manual Phase Bridge

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$$\left|i_d\right|^2_{rms} = \frac{P_{in}\,[|\Gamma|^2 - 1]}{R_c\,(Z_D)}$$

where Z_D, and Z_c are complex and are the diode and circuit impedances, respectively. P_{in} is the input power and i_d is the diode RF current.

Large amounts of data are generated quickly by this method, and conveniently reduced by computer to reveal diode impedance. It is emphasized that no physical disturbance of the diode, fixture, or tuning transformers is necessary following the initial tuning in order to generate a complete family of characteristics within the injection locking bandwidth for given diode, and that changes of these characteristics within the pulse are readily obtained using this method.

RESULTS

Figures 2 through 4 provide representatiave data showing, respectively, the variation of diode impedance with time, with duty cycle, and with bias current, for 300 nsec pulsewidth operation at 10 GHz. In Figure 2, most of the variation occurs in the first 100 nsec, after which the impedance stays constant. In spite of this impedance transient, the diode is injection locked at turn-on and remains so for the pulse duration, as evidenced by a clean detected RF pulse and spectrum. Figures 3 and 4 both show that, at 150 nsec into the 300 nsec pulse, the RF current decreases with increasing RF input power, and that at a given duty cycle and bias current, several values of RF current and therefore input and output power can produce the same diode resistance, albeit at differing reactance values. This is quite significant, as most existing models upon which the design of IMPATT amplifiers and oscillators is based assume single valued impedance functions for a given RF amplitude. Additional data for long pulses up to 12 μsec exists and shows heating effects rather than turn on effects, but is not included in this summary because of space limitations. It will be presented at the conference.

CONCLUSIONS

The impedance of IMPATT diodes operating in a pulsed mode depends upon time into the pulse, duty cycle, bias current, and input power. Measurements of such impedance variations are necessary to permit efficient designs for oscillators and amplifiers which use such devices.

ACKNOWLEDGEMENT

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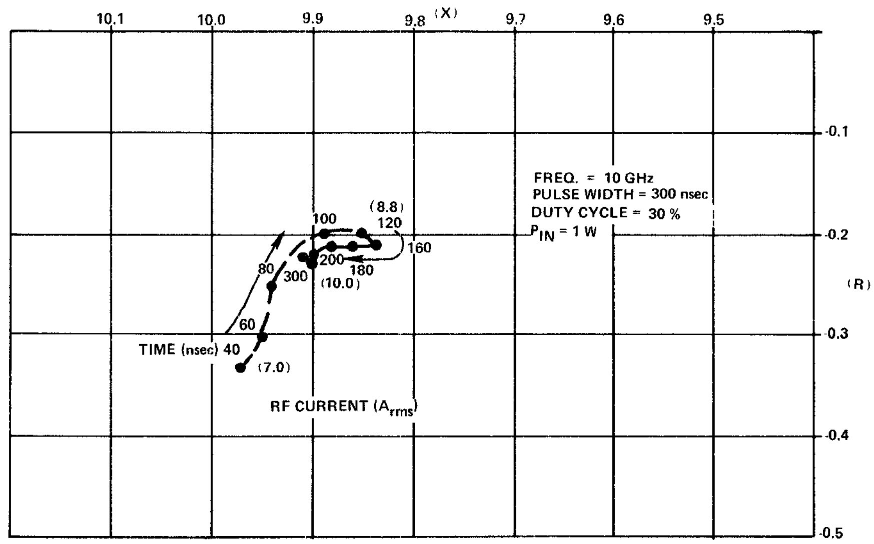

Figure 2 - Variation of Z_D with Time Across Pulse (Short Pulse)

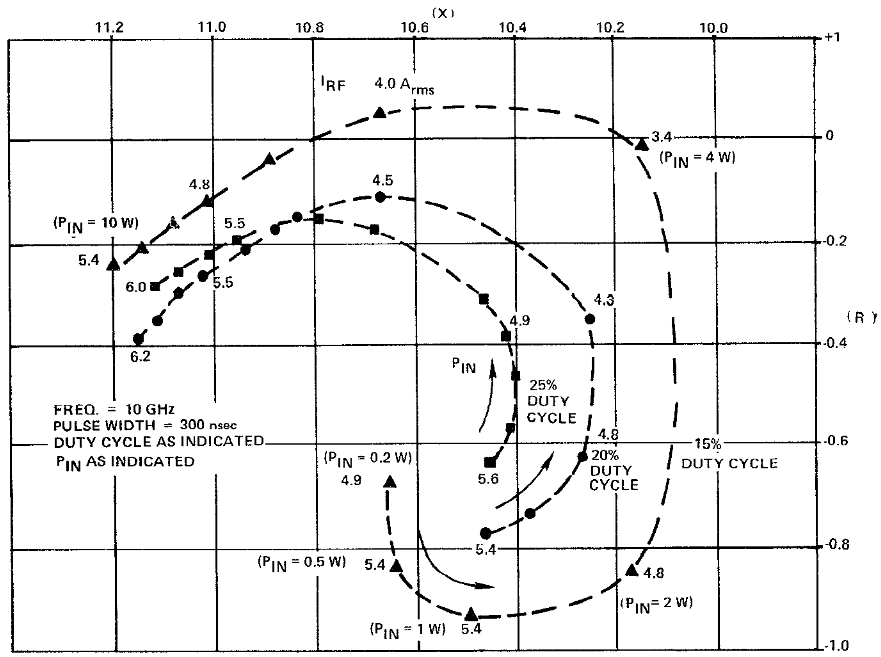

Figure 3 - Variation of Z_D with Duty Cycle (All Measurements taken at 150 ns into Pulse)

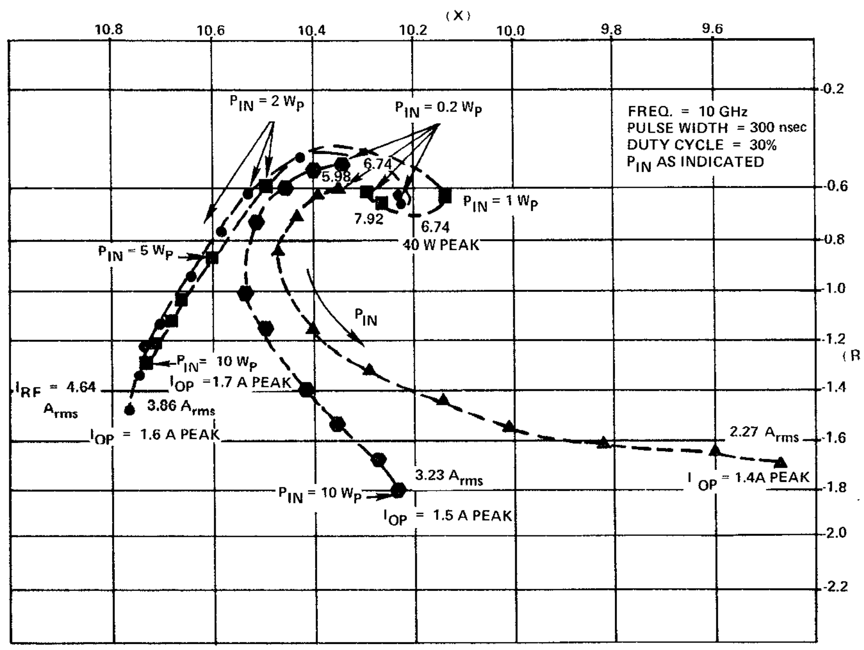

Figure 4 - Variation of Z_D with Bias Current (All Measurements taken at 150 ns into Pulse)