A HIGH-POWER X-BAND DIODE AMPLIFIER

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Abstract

The requirement for high power solid state amplifiers at X-Band has necessitated a close investigation of diode power combiners for use as reflection amplifiers. A brassboard amplifier incorporating 17 diodes in all and using a 10 diode TM_{010} mode resonant cavity combiner has been fabricated in a 4 inch diameter 10 inch long cylindrical configuration. A power level of 74 watts peak at a 0.33 duty ratio and 34 dB gain has been achieved.

Introduction

Previous programs (1,2) have demonstrated the capability of pulsed silicon double-drift IMPATT diodes to operate as power amplifiers; however, the efficiency of these amplifiers remained below 10%. For high efficiency operation, the GaAs IMPATT diode provides the basis for the design of amplifiers having efficiencies of almost double that of silicon. Furthermore, GaAs single drift diodes offer lower operating voltage thus making them more compatible with missile power systems. The problems of combining GaAs IMPATT diode amplifiers share common features with silicon combining and exhibit some unique features of their own. The achievement of unconditional stability in GaAs diode amplifiers is an example.

The purpose of the described program was to design, fabricate, test, and evaluate an advanced development model of a GaAs FET/GaAs IMPATT diode power amplifier assembly for a missile radar transmitter. The model was to be used to assess the feasibility of a solid-state radar transmitter for tactical/production missile systems.

A major consideration of this program was whether the available GaAs IMPATT diodes could function as amplifiers and could operate with the required waveform. The diode evaluation procedure and results are detailed in this paper. The subsequent use and performance of the IMPATT diodes in several single diode and multiple diode amplifier stages are described. The paper discusses the highlights of the final overall amplifier assembly.

Amplifier Approach

The power amplifier consists of three major units as illustrated in the block diagram of Figure 1: (1) RF Unit which amplifies the RF signal (2) Bias/Modulator Unit which pulse-modulates and regulates the operating current of the IMPATT diodes (3) Power Supply Unit which supplements the dc power input to the RF power amplifier to generate the internal voltages required.

A GaAs FET amplifier is used as the input stage and is followed by four-stages of GaAs IMPATT diode amplifiers. The low-noise property of the GaAs FET minimizes the effect of the higher power IMPATT diode noise contribution in the amplifier output signal.

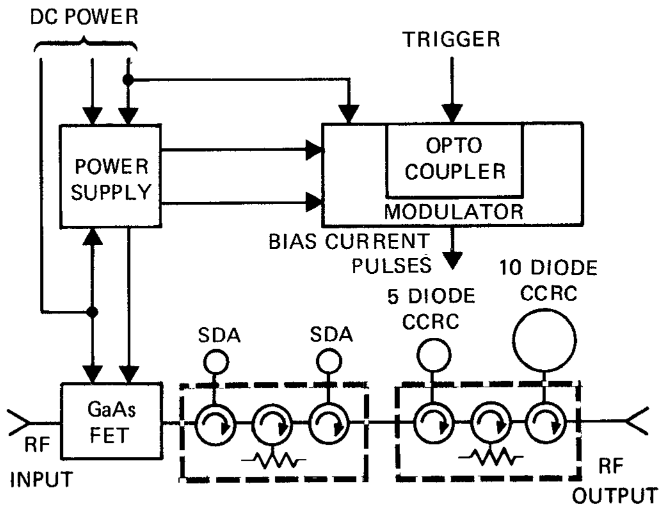

Figure 1. Power Amplifier Block Diagram

Each of the IMPATT diode stages is a circulator-coupled, negative resistance reflection amplifier. The second and third stages are formed by coupling two single IMPATT diode amplifiers to a 5-port ferrite circulator. The fourth and fifth amplifier stages are achieved with a 5-diode and 10-diode CCRC* power combiner, respectively, each operating in the symmetrical TM_{010} mode. The CCRC combiner-amplifiers are also coupled to a 5-port ferrite circulator.

Each IMPATT diode is biased independently. To each diode, a constant current bias pulse is applied which modulates the diode operating voltage between the reverse-biased threshold level and avalanche breakdown. The avalanche current in each IMPATT must be highly regulated during the pulse of the modulating waveform in order to minimize amplitude and phase distortions. A hybrid microelectronic modulator circuit is used to fulfill this requirement.

Diode Evaluation

The design approach uses a GaAs, pulsed single drift, p+ hi-lo IMPATT diode manufactured by Varian Associates, Palo Alto, California. The diode was evaluated at midband and 16.67μs pulsewidth, 33% duty. A minimum power output of 10 watts and 18% efficiency was recorded.

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* Circular Cylindrical Resonant Cavity

The dependence of power-added by the IMPATTs on frequency, RF circuit impedance, and RF input signal power governed the final amplifier design factors of number and types of stages and number of diodes. The diode-circuit impedance behavior was characterized vs. frequency, with RF input power the parameter, using a mount having the construction features shown in Figure 2. Figure 3 shows typical power output vs. frequency produced by a set of six diodes using a single section transmission line transformer with a constant impedance.

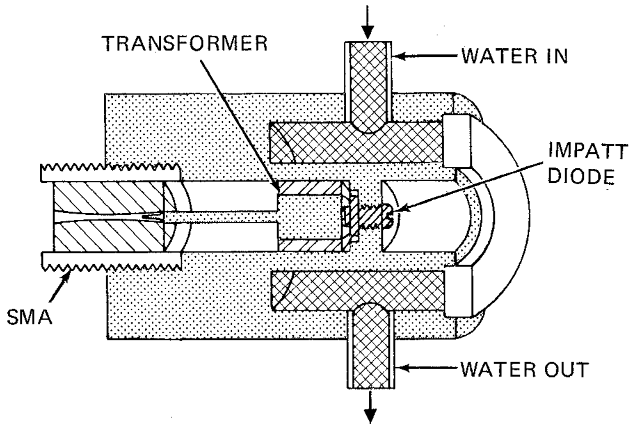

Figure 2. Single Diode Amplifier Construction

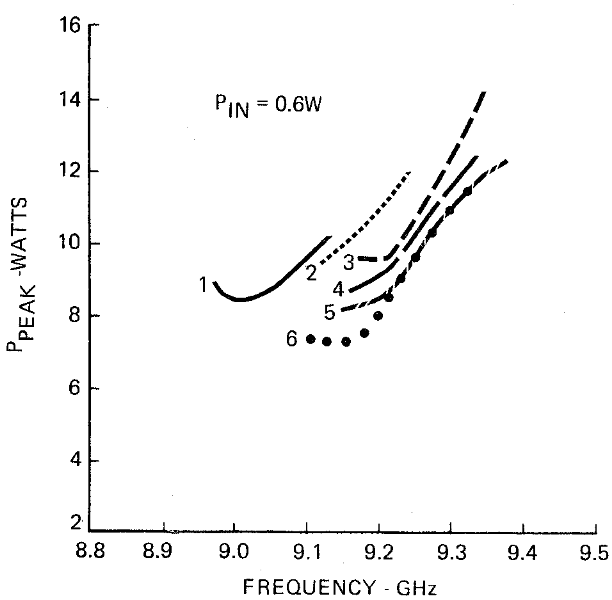

Figure 3. Measured Power Output vs. Frequency for Single Diode Amplifiers

In conjunction with a digital-computer aided design program, diode data were used to design and optimize the four IMPATT diode stages. It was found that the diodes had to be carefully sorted into matched groups to insure that the devices had sufficient phase and amplitude tracking to combine efficiently.

Power Amplifier Stages

The single diode stages (Figure 2) are identical in construction except for unique constant impedance single section transmission line transformers. The power-output vs. frequency responses are similar to those shown in Figure 3.

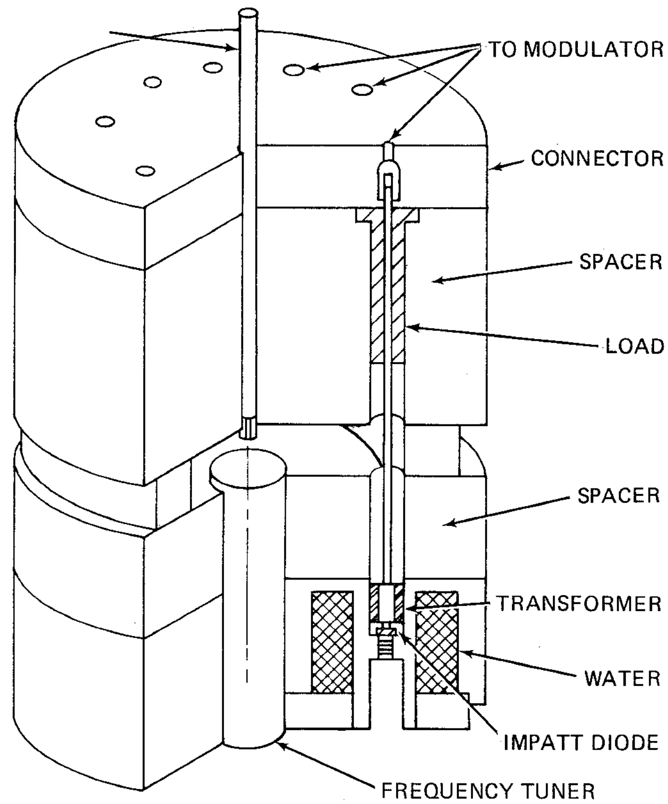

Figure 4. Five and Ten Diode Power Combiner Construction

In the fourth and fifth stage CCRC power combiners, arrays of coaxial circuits, each forming a Kenyon type circuit, are combined. The combined power is coupled to the external load with a centrally located electric field probe. Figure 4 illustrates the key construction features common to both CCRCs. To optimize power output, the diode transformers and the loads must be properly spaced from the cavity. Final optimization was accomplished empirically. Typical results shown in Figure 5 for the 10 diode CCRC illustrate the dependence of power output on the diode to cavity spacing for a transformer of varying length.

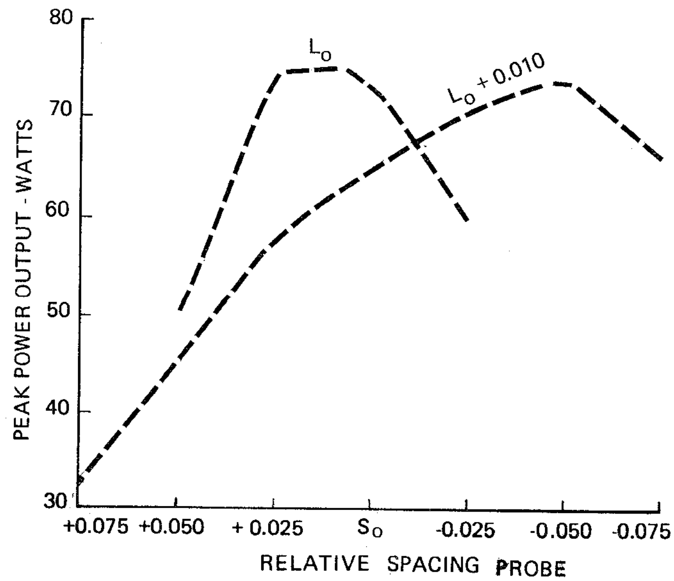

Figure 5. 10 Diode CCRC Measured Power Output vs. Diode to Cavity Spacing

The measured performance of each stage is presented in the table below.

Measured Performance

	GaAs FET	1stSDA	2nd SDA
Pout Peak-W Gain - dB	0.812 14.1	6.4 10.4	8.1 4.3

	CCRC5	CCRC10
Pout Peak-W Gain - dB	33.8 5.8	74.0 4.0

Amplifier Configuration

A single diode amplifier and the five and ten diode combiners are shown in Figure 6. All power amplifiers are made of gold plated, solid tellurium copper. All subassemblies are packaged in a 4 inch diameter, 10 inch long ruggedized housing suitable for flight (Figure 7). Thermal design utilizes flowing water during bench test to cool the IMPATT diodes and hybrid modulators.

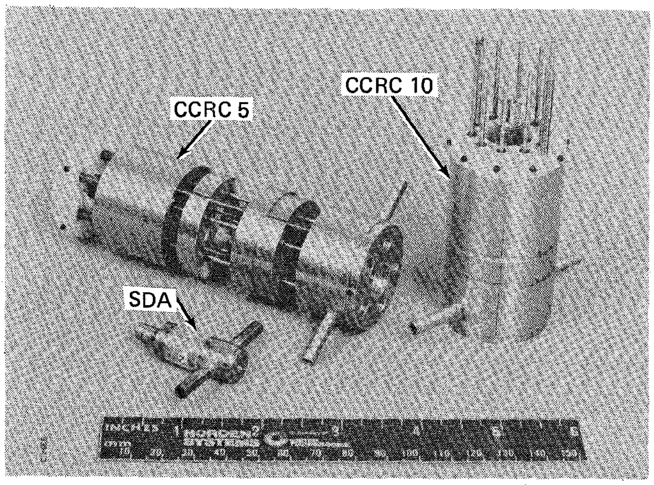

Figure 6. Single Diode Amplifier, Five and Ten Diode Combiners

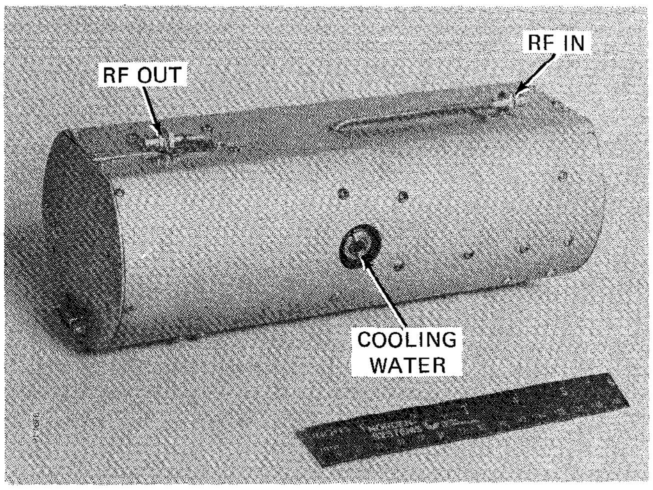

Figure 7. Assembled Power Amplifier

Acknowledgements

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