500 MHz, 100 W X-BAND SOLID STATE AMPLIFIER

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ABSTRACT

This paper describes advances made in developing a wideband, high power solid state amplifier at X-band. Presently a bandwidth of 500 MHz with peak power levels of 100 W at 30% duty have been obtained by combining only four GaAs IMPATT diodes in a spatial field type of power combiner/amplifier. Key features of this device are its high combining efficiency (~ 95%), a high degree of isolation (>30 dB) between elemental amplifier modules and a 10 dB stable dynamic range.

INTRODUCTION

The amplifier described in this paper represents advances made in developing a wideband, high power solid state amplifier at X-band. The effort was part of a Navy funded contract (Contract No. N00014-82-C2497, Naval Research Laboratory, Washington, D.C. 20375) to develop a 100 W amplifier for the band 9.5-10.0 GHz with GaAs IMPATT diodes.

Significant power levels have been achieved over the past six years from four-mesa X-Band GaAs Read double drift IMPATT diodes, produced by Raytheon.[1] Production diodes yielding 25-32 W have been used in this program but selected laboratory diodes have shown output as high as 50 W. The diode structure consists of four separate diode mesas formed on a common plated-gold heat sink mounted in a ceramic-metal microwave package.

In this program the emphasis has been on extending the bandwidth performance of IMPATT amplifiers/ combiners and, in particular, at the 100 W level at X-band. Initially the bandwidth capability of a single IMPATT amplifier module was improved to 500 MHz with 25 W min. output. Four such elemental amplifier modules were combined in a spatial field type of combining circuit to achieve 100 W peak at 30% duty with a -1 dB bandwidth of 500 MHz. Factors contributing to this performance from the device are inherent properties of the combiner, such as its high combining efficiency (~ 95%) and a high degree of isolation between elemental amplifier modules.

Combiner/Amplifier Operation

Broadband elemental amplifier modules are combined in a spatial field power combiner circuit, a device with multi-octave bandwidth properties. It has a common rf input/output connected to balanced transmission lines through combining/dividing networks, as illustrated in Figure 1, which shows a four-way 100 W peak spatial field power combiner/ amplifier. The combiner is 8.0 cm long and varies in diameter from 2.5 to 5.5 cm. Each of the amplifier modules is mounted radially on the spatial field combiner circuit and is magnetically coupled to the parallel plane lines of the combiner. Easy access to the diode mount is provided. The dividing/combining network consists of coaxial transformers with quarter-wave binomial steps to provide a maximally flat impedance match covering the operating region of 9.5-10.0 GHz and also the IMPATT sub-harmonic frequency band of 4.75-5.0 GHz. Transmission data on a 10-way spatial field power combiner taken over the band 4.0 to 12.4 GHz (Figure 2) illustrates the broadband nature of the device. A balanced TEM mode propagates in each of the parallel plane lines of the combiner and unwanted modes are damped by matched terminations external to the divider/combiner. This ensures that a high degree of isolation is maintained between individual amplifiers.

Because of its inherent circuit properties the bandwidth and dynamic range performance of the spatial field power combiner follow from that of the single IMPATT amplifier. The matching technique employed to obtain a broadband match from the elemental amplifier is shown in the Smith chart

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plots of Figures 3a and 3b. The low and high values of the IMPATT negative resistance, gain loci and the circuit impedance are shown versus the frequency. Because of a reactance that was added to the matching network, the circuit impedance follows the negative resistance of the device over the operating band of 9.5-10.0 GHz. In practice this translates to refinements made to the output port, coax to waveguide/parallel plane coupling and the matching transformer of the single amplifier module.

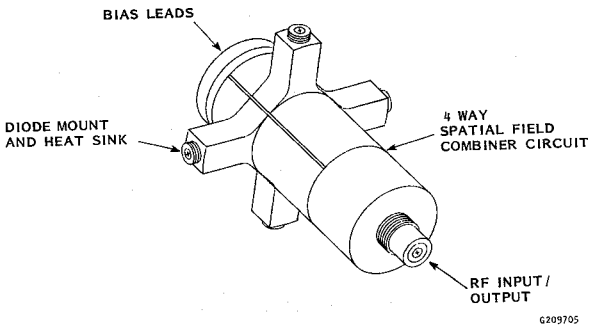


Fig. 1. 100 W, Four-Way Spatial Field Combiner/ Amplifier.

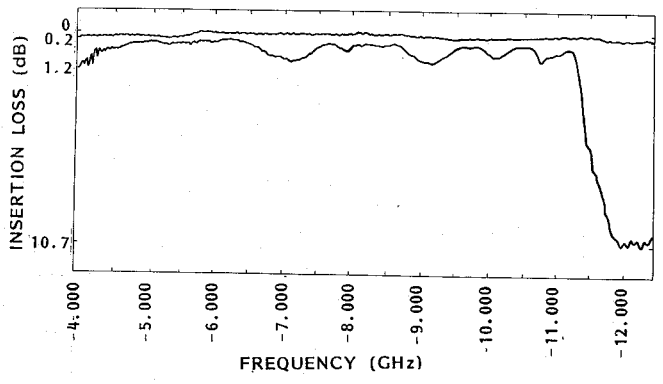
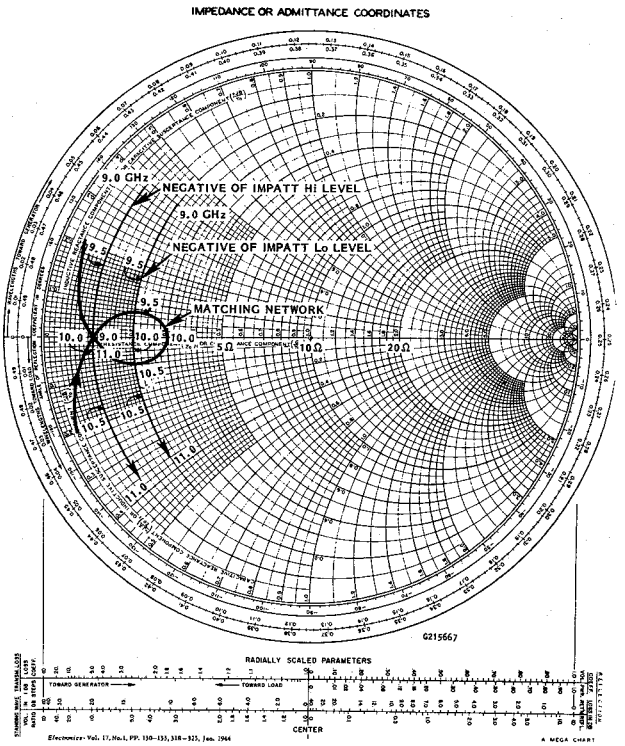
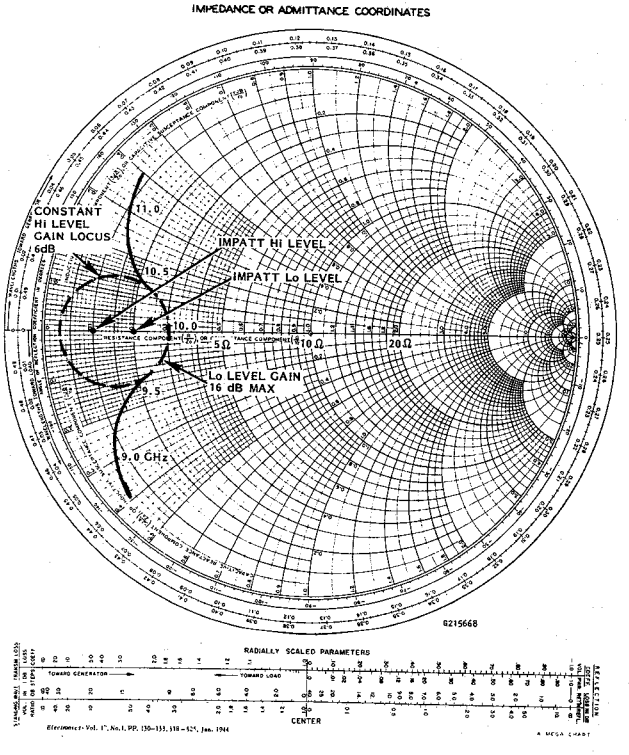


Fig. 2. Transmission Characteristics of the 10-Way Spatial Field Power Combiner 4.0 to 12.42 GHz.



(a)



(b)

Fig. 3. Illustration of Broadband Matching Technique Employed in IMPATT Amplifier Module.

100 W Amplifier Performance

Four single GaAs IMPATT amplifier modules were combined in a laboratory breadboard model of the spatial field power combiner. Typical data obtained on a single IMPATT amplifier module is illustrated in Figure 4 for 300 ns/30% duty. The device operates over a 500 MHz band with a 4 dB min. gain at 25 W min. level. At the band center the device produces 30 W at 5 to 6 dB gain. The amplifier has a large, stable dynamic range in which the output can be varied over a 10 dB range from 3 to 30 W. Similar wideband performance has been obtained at 600 ns/30% duty and 600 ns/0.1% duty.

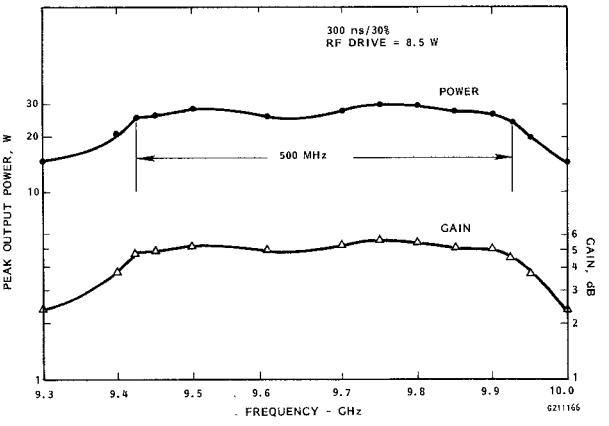


Fig. 4. Single IMPATT Amplifier, Bandwidth Performance.

Performance data on the 100 W combiner/amplifier, consisting of only four single GaAs IMPATT amplifier modules, is illustrated in Figures 5, 6 and 7. Peak output power vs rf drive data (shown in Figure 5) indicates that the device attains a saturated peak power level of over 100 W. The operation of the amplifier is stable with a large dynamic response in which the output power can be varied from 8 to over 100 W peak. The combining efficiency of the 100 watt amplifier was demonstrated to be in the order of 95%. Bandwidth performance (Figure 6) of the device shows a -1 dB band of 500 MHz with the peak power at the band center (9.75 GHz) being in excess of 100 W with a gain of 4.2 dB. Detected rf pulses taken at various frequencies in the 500 MHz operating band of the 100 W amplifier are shown in Figure 7.

The 10 dB dynamic range performance of the 100 W amplifier parallels that of the single IMPATT amplifier. In the 100 W amplifier, each of the single amplifier modules is independently tested and then inserted into the combiner circuit. The interaction between the individual amplifiers is minimal and the stable performance results from the high degree of isolation that is maintained between them.

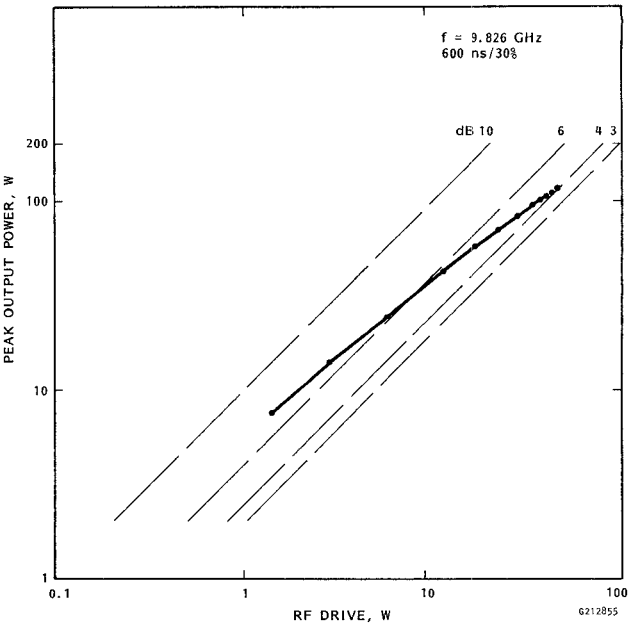


Fig. 5. Four-Way 100 W IMPATT Combiner/Amplifier Peak Output Power vs RF Drive.

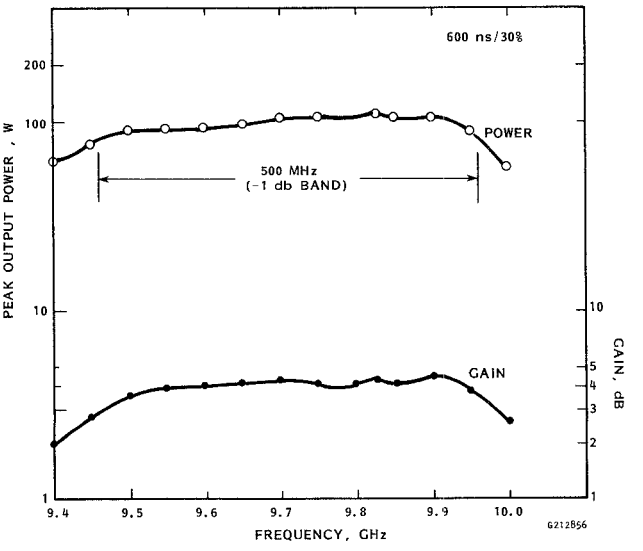


Fig. 6. Four-Way 100 W IMPATT Combiner/Amplifier Bandwidth Performance.

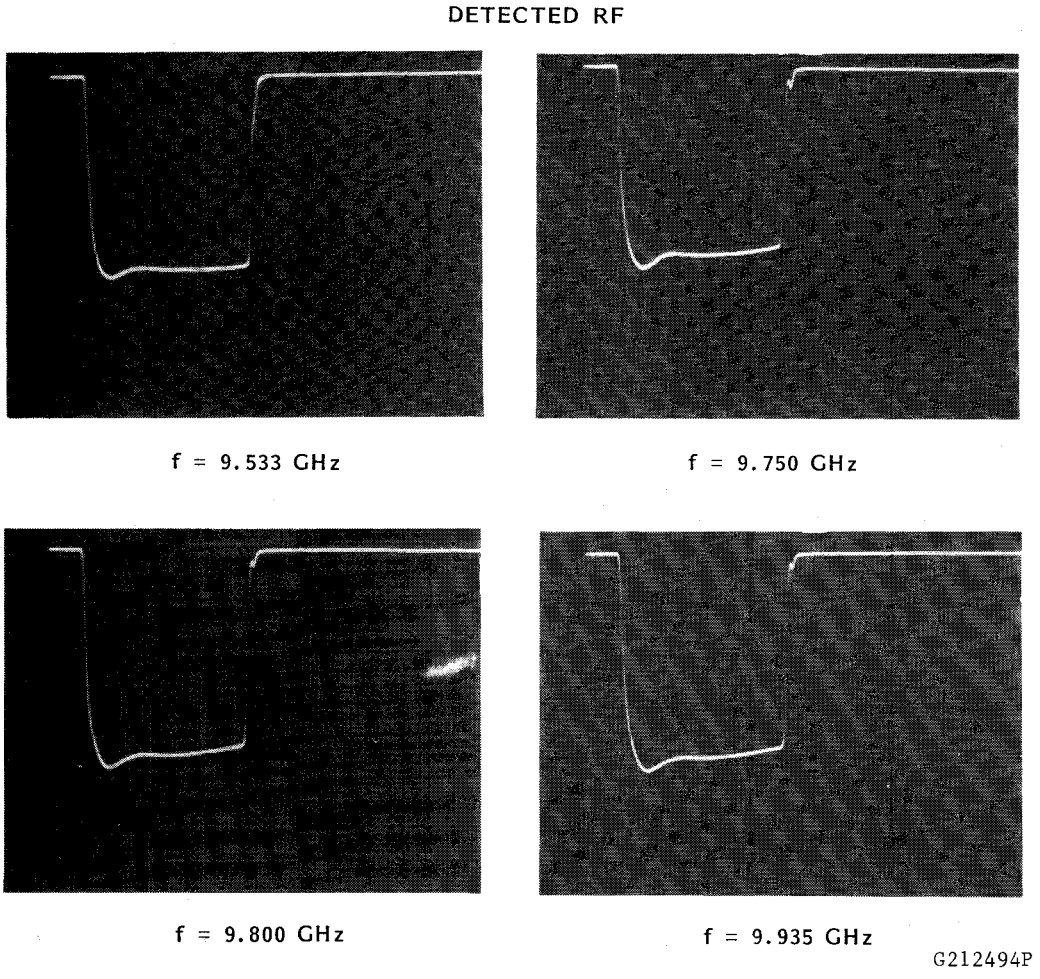


Fig. 7. Four-Way 100 W IMPATT Combiner/Amplifier Detected RF. 600 ns/30% Duty.

CONCLUSION

Presently a bandwidth of 500 MHz at X-band with peak power levels of 100 W at 30% duty has been obtained by combining only four GaAs IMPATT diodes in a spatial field type of power combiner/amplifier. Key features of the combining circuit contributing to this performance are its high combining efficiency (~ 95%) and a high degree of isolation (>30 dB) between elemental amplifier modules. The stable 10 dB dynamic range and bandwidth performance of the 100 W amplifier parallel those of the single IMPATT amplifier module.

REFERENCES

1. R.N. Wallace, S.R. Steele and H.G. Adlerstein, "Performance of GaAs DoubleDrift Avalanche Diodes", Proceedings of the Sixth Biennial Cornell Electrical Engineering Conference, Ithaca, New York, August 16-18m 197, pp. 195-202.