A 16.5 WATT, 20 GHZ IMPATT DIODE POWER COMBINER

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ABSTRACT

Progress in the development of a 20 watt, 20 GHz power combiner with 5 percent bandwidth will be discussed. Six Raytheon high power GaAs double-drift diodes are used. Each diode has four mesas which are TC bonded to the heatsink to achieve very low thermal resistance. A set of characterization data for the diodes and the combiner will be presented to demonstrate Raytheon's method for designing power combiners with large bandwidth.

INTRODUCTION

The Research Division of Raytheon Company has been developing 20 GHz high power GaAs IMPATT diodes for 2 years under contract from the Air Force Avionics Laboratory*. Midway in this contract, the task of building a 20 GHz, 20 watt power combiner using these diodes was phased in. This paper will present the progress achieved to date on the diodes and the combiner.

The IMPATT diodes that are used in the combiner are GaAs double-drift Read devices using material grown by vapor phase epitaxy. The wafers are processed into quadrimesa chips which can be attached to diamond heatsinks by thermocompression bonding rather than soldering[1]. A diamond heatsink package is in development but the interim power combiner results presented in this paper were obtained with copper heatsink packages. Our diodes with copper heatsink packages fall in the 4.5 to 5.5 watt range with over 20 percent efficiency and junction temperatures of about 250°C. The best oscillator result obtained to date from a diode with a diamond heatsink is 7.25 watts and 21.1 percent efficiency with a junction temperature of about 260°C.

The high power, solid-state amplifier stage combines diodes in a waveguide Kurokawa circuit with a special matching circuit at the waveguide port. A maximum output power of 16.5 watts with 4.4 dB gain has been achieved, and the output power is greater than 13.1 watts (-1 dB) over a 1 GHz band for a constant input power level. An automatic network analyzer with special software to characterize the power combiner has played an important role in the combiner development. Higher gain with the same 1 dB bandwidth will be attained as the circuit is optimized. Diodes with diamond heatsinks will be employed in the near future, and these diodes will raise the output power of the combiner to over 20 watts.

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DIODE DEVELOPMENT

An electron micrograph of our quadrimesa chip is shown in Fig. 1. Each mesa incorporates a 2-micron thick gold pad which allows thermocompression bonding to the heatsink surface. Figure 2 shows our diamond heatsink package. A ceramic barrel is mounted to enclose the diamond and the chip. The barrels are fabricated to our specifications to achieve the desired values of the package and mount parasitics.

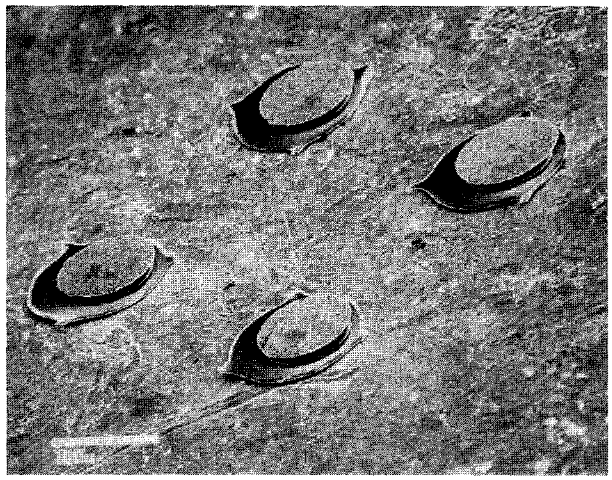

Figure 1. Web quad chip design allows four mesas to be thermocompression-bonded directly to the diamond heat spreader.

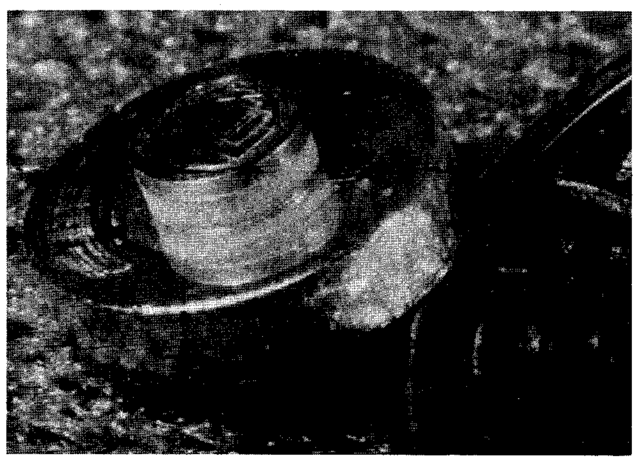

Figure 2. Diamond heatsink package.

The quadrimesa chip has a thermal resistance that is about 30 percent lower than a single mesa chip of equal total area, and a diamond heatsink also reduces the thermal resistance by another 30 percent as compared to a copper heatsink. Conversion efficiencies between 20 and 23 percent are typical of the diodes produced now. The quadrimesa chip mounted on a diamond heatsink is by far the best choice of the present processing and packaging technologies. The single diode oscillator and six-diode power combiner results that have been obtained with quadrimesa diodes demonstrate the absence of any adverse effects of parasitic reactances in the quadrimesa chip or associated package[1].

COMBINER DEVELOPMENT

Figure 3 is a simplified drawing of a conventional waveguide Kurokawa combiner. The cavity is coupled to the external load through an iris, and the diodes (placed in the coaxial lines) are matched with simple, single step transformers. The bandwidth of the combining circuit can be improved significantly by replacing these narrow band matching structures with broadband ones.

Figure 4 shows the calculated 20 GHz device impedance locus and the measured load impedance line for a conventional combiner referred to the plane of the diode chip. Special network analyzer techniques were used to obtain the load line. The gain of the amplifier is inversely related to the distance from the load line to the high power region of the device line. To make the circuit broadband, the frequency dependence of the load line must be reduced so that the distance from the high power region of the device line to any point on the load line is nearly constant over the frequency range of interest[2]. This is accomplished by broadband matching.

Figure 5 shows the effect of replacing the waveguide coupling iris with a broadband matching network. The distance from the high

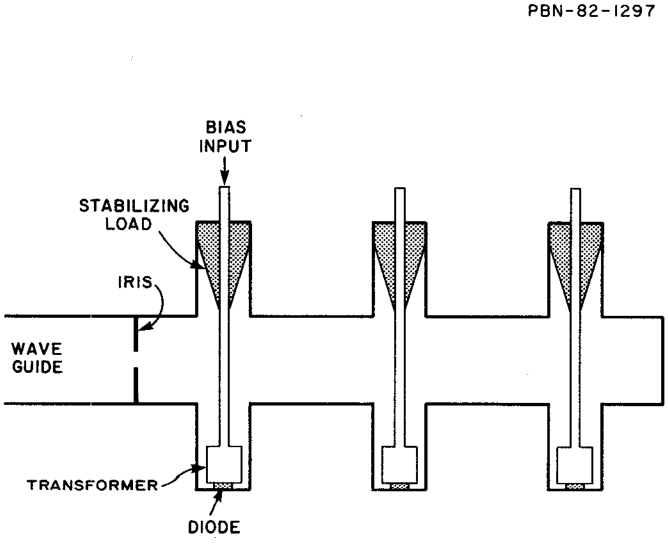

Figure 3. Simplified drawing of a conventional waveguide Kurokawa power combiner.

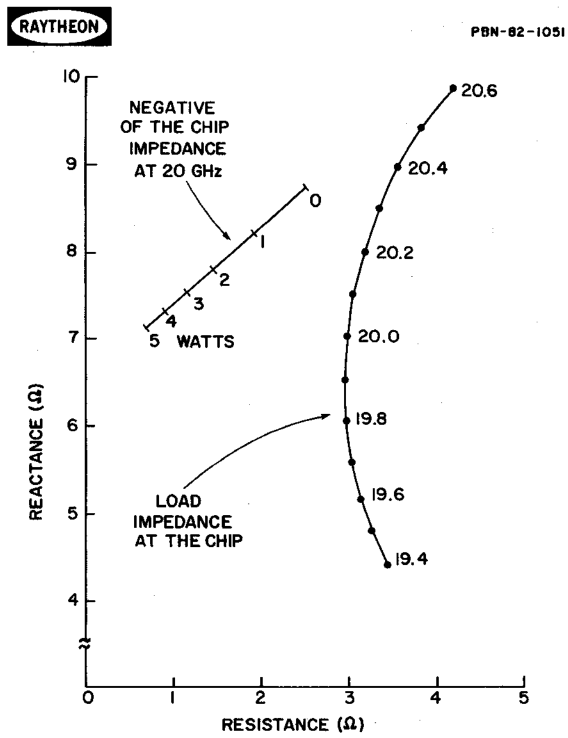

Figure 4. Calculated device line and the measured load line for a six-diode combiner having conventional matching networks.

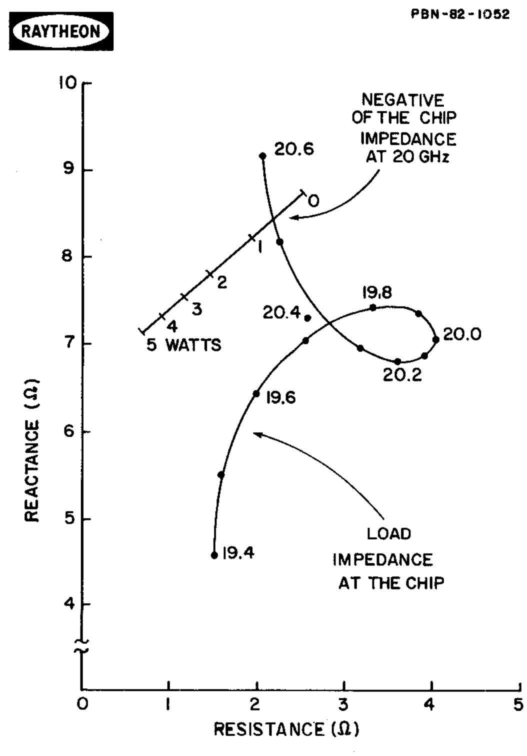

Figure 5. Calculated device line and the measured load line for a six-diode combiner having broadband matching at the waveguide port.

power region of the device line to the load line is now more constant over the desired band. The combiner performance data which is reported below was taken for this case. The frequency dependence of the load line will be reduced even more when broadband matching at the diode is added.

Figure 6 shows the measured six-diode power combiner data: 16.5 watts of output power was achieved, and the broadband matching

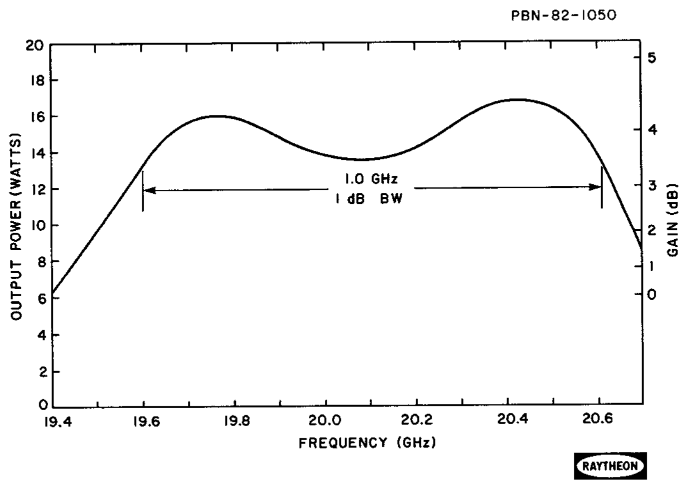

Figure 6. Performance of the 20 GHz combiner that has broadband matching on the waveguide port. Web quad diodes in copper puck packages were used.

between the cavity and the circulator resulted in a very flat frequency response. The 1 dB bandwidth was 1 GHz.

CONCLUSION

We have demonstrated a state-of-the-art 20 GHz high power amplifier stage using high efficiency GaAs IMPATT diodes. Our plans are to optimize the coupling networks to increase the gain and to obtain more than 20 watts output by using improved diodes. Our unique automatic network analyzer techniques make it possible to systematically evaluate each change that is made in the complex power combiner circuit so that the performance of the combiner is improved predictably.

ACKOWLEDGEMENTS

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