OPERATION OF SOLID STATE POWER AMPLIFIERS AT CRYOGENIC TEMPERATURES

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ABSTRACT

A novel approach is presented to the cooling of lightweight transistor amplifier modules for high power operation. 1800 Watts (C.W.) at 425 MHz was obtained from a four transistor amplifier that weighed a mere 13 ounces.

INTRODUCTION

The baseline for this effort was the performance obtained at MMD with miniature pulse amplifiers. Baseline measurements are shown in TABLE I, below for two four-transistor modules.

Amplifier	1	2
Power Output	2KW	1.6KW
Gain	10.0 dB	9.5 dB
Collector Efficiency	65%	59%
Pulse Conditions	350 u Sec, 1% D.C.	1.6 mSec, 20% D.C.
Bias Voltage	45 Volts	40 Volts
Frequency	425 MHz	425 MHz

TABLE I. Baseline Performance

This performance was achieved by the early integration of die design, fabrication, packaging and circuit technique efforts.

AMPLIFIER DESIGN AND CONSTRUCTION

Two circuits were designed, built and tested for this effort. One, was a simple test amplifier utilized to verify the performance of single devices and is shown in Figure 1. The performance of the MC100 (an MMD proprietary bipolar die) was evaluated in this amplifier under different packaging and cooling configurations, with the results shown in Figure 2. It can be seen that the performance of a standard 45 mil thick BeO pill package, where the amplifier was cooled with liquid nitrogen, is similar to the performance obtained with a very expensive chip carrier package that utilizes a diamond insulator insert.

A four-transistor amplifier was then designed that incorporated a matching balun structure for the output and input circuit elements with each device operating in a push-pull arrangement as shown in Figure 3.

A module construction technique was then chosen that optimized the module thermal design and provided a small physical size. The devices were mounted into the standard beryllium oxide (BeO) pill package. The BeO pill package was then placed directly onto a copper base-plate and held in place with a physical clamping device. This method reduced the number of thermal interfaces to the cooling medium yet tolerated the thermal expansion differences between the base-plate and the BeO pill package. A thin coating of thermal compound reduced the thermal interface resistance.

Separate single layer impedance matching launching networks were then connected to both the input and output side of the four transistors. Since grounding of these boards was critical, they were soldered directly to the amplifier base-plate. Parallel stripline "flat pack" transformers, each a composite of several layers of board material, were positioned next to the microstrip launching boards. Located on top of this printed circuit board "sandwich", is a DC distribution board for routing the necessary module bias voltages. The concept is illustrated in Figure 4.

MODULE PERFORMANCE

As mentioned above, single device amplifier measurements were performed in the circuit shown in Figure 1. With the data (summarized in Figure 2) pointing to the fact that cryo-cooling of the base-plate was as effective as utilizing a diamond insert package. Therefore, to obtain high amplifier performance economically; the four-transistor amplifier was developed and tested with cryo-cooling capability. The best RF performance result obtained are shown in Figure 5.

CONCLUSIONS AND RECOMMENDATIONS

We have demonstrated the feasibility of fabricating UHF CW power amplifiers with weight to power output ratios of the order of 0.2 grams/watt and power output approaching 2KW (C.W.).

Major circuit construction, cooling and transistor fabrication problems have been solved with the remaining problems centered mainly in the device optimization area.

The most important areas for future work we feel are:

- Device fabrication optimized for low temperature operation
- Combination of multiple amplifier modules for high power applications
- Continue size and weight reduction
- Improve amplifier test procedures for low temperature operation

ACKNOWLEDGEMENT

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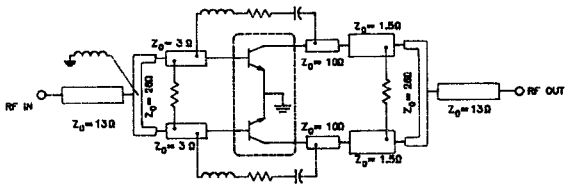

SINGLE DEVICE AMPLIFIER

Figure 1

SINGLE DEVICE AMPLIFIER PERFORMANCE

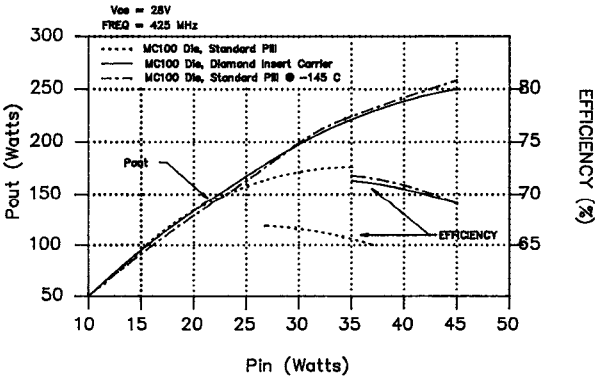

Figure 2

FOUR-TRANSISTOR AMPLIFIER

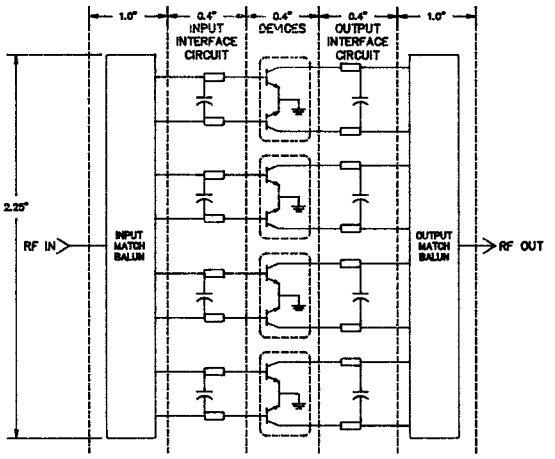

Figure 3

FOUR-TRANSISTOR AMPLIFIER CONSTRUCTION

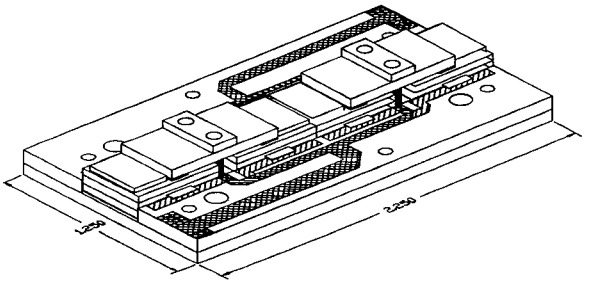

Figure 4

FOUR-TRANSISTOR AMPLIFIER PERFORMANCE

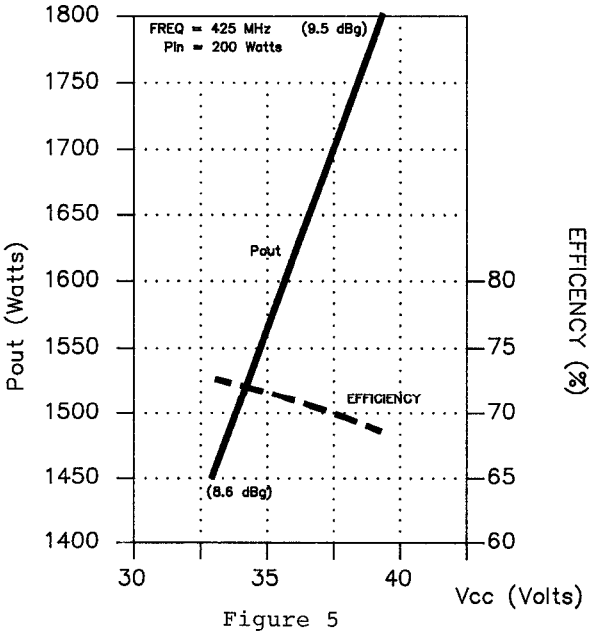

Figure 5