# 32 DIODE WAVEGUIDE POWER COMBINER

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## ABSTRACT

An extension to a previously developed IMPATT diode power combining scheme is presented. The new design doubles the diode capacity over the previously presented scheme. The design concept and performance of the combiner using 32 GaAs IMPATT diodes is also described.

## Introduction

Many combining circuits have been reported[1,2] which sum the power produced by 32 IMPATT diodes. Basically the circuits are of the cylindrical cavity type operating in a $TM_{0N0}$ mode, consequently their characteristics are similar. While they are capable of combining may diodes this type of circuit has several disadvantages, a few of which are: (1) high fabrication cost, (2) reduced combining efficiency over $TM_{010}$ combiners and (3) reduced reliability due to thermal limitations.

The high fabrication cost of these circuits is due to the tolerance requirements and amount of machining necessary. The reduced efficiency of these circuits is caused by the effect of higher order mode suppression. This suppression is required to reduce the effect of modes that do not couple to the output. The reliability of these circuits is reduced because of the large amount of power dissipated by the diodes in a small area. If one uses a diode with 20% efficiency that produces 4.0 watts of average power it will dissipate 16 watts. When combining 32 of these diodes on a 2.0 inch diameter the power dissipated per unit area will be 163 watts/in$^2$. The reliability of IMPATT diodes is inversely proportional to junction temperature. Therefore particular attention must be paid to the thermal design. Most of the present use of high power solid state combiners is found in missile systems with restricted volume requirements. Hence the use of bulky thermal conditioning systems is restricted and thermal control difficult.

In order to maximize the advantages of high power solid state sources a new combiner, called HiPac[3], was developed. It offers low fabrication costs, high combining efficiency and improved reliability over present circuits.

## Configuration

HiPac is an extension of the Kurokawa multiple diode oscillator[4]. Kurokawa positioned a TEM line (module) every half wavelength along the length of a waveguide cavity. These modules were located against the cavity sidewall and on each side of the cavity as shown in Figure 1. In each module there was an IMPATT diode, matching circuit and bias port as shown in Figure 2a. The modules were positioned at the peak of the magnetic field which existed against the side wall of the cavity. A short circuit was placed at one end of the cavity to establish the required field pattern within the cavity. At the other end of the cavity there was an iris which provided the coupling from the cavity to the load.

The difference between the Kurokawa circuit and HiPac is illustrated in Figure 2b. The HiPac modules are positioned on either side of the peak magnetic field as shown in the figure. This essentially doubles the diode capacity for a given size cavity. Using this concept a 32 diode combiner was designed as shown in Figure 3.

## Design

The first HiPac was designed to operate at 9.25 GHz. The unit was fabricated from extruded X-band waveguide. Based on the frequency and waveguide size the module pair spacing was set at $\lambda g/2$ as shown in Figure 4. The individual module spacing was based on mechanical design. A short circuit was positioned approximately $\lambda g/4$ from the last module pair. The inductive iris was positioned $\lambda g/4$ in front of the first module pair. The length of the total oscillator was 7.2 inches.

The diode used for this design was an MA-46072 developed by Microwave Associates. This is a GaAs single drift lo-hi-lo profile IMPATT diode. Typically the diodes produced 4.0 watts average at 1/3 duty with an efficiency of 18.0%. The matching circuit for HiPac was based on the characteristic impedance of the diode.

## Performance

HiPac was first operated as a free running oscillator with 32 diodes at optimum current shown in Figure 5. The unit produced 109.8 watts of average power at 9.48 GHz. The combining efficiency was 82%. The power vs. peak current characteristic is illustrated by Figure 6. With the fixed short replace with a sliding short the unit was tuned over 200 MHz with 0.5 dB power variation.

The total power dissipation in the diode heat sinks was 512 watts average. Since the didoes are separated by $\lambda g/2$ the total surface area of the diode heat sink was 7.0 square inches. The power dissipated unit area was 44.7 watts/in$^2$. Due to the thermal isolation of the diodes from each other, relative to the cylindrical cavity combiner, HiPac was operated for 1.0 minutes without coolant flow. The performance of the combiner did not degrade during this time. The junction temperature of the diodes was less than 250$^o$C at the end of the test.

The final test conducted on HiPac was to measure the injection locked bandwidth. The resulting bandwidth was 40 MHz at a gain of 15 dB.

## Summary

The advantages of the HiPac design concept has been demonstrated. The design offers low cost construction, good combining efficiency, inherent mode suppression and outstanding thermal characteristics. The unit presently does not have adequate injection bandwidth over other designs. Increased bandwidth may be obtained by reducing the cavity height. The characteristic is presently being studied.

## Acknowledgement

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## References


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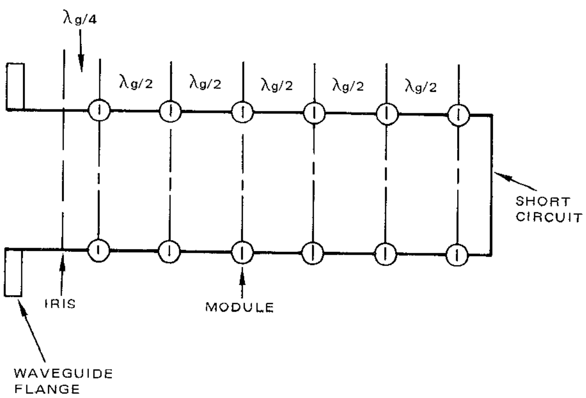


Figure 1. Kurokawa Waveguide Oscillator Top View

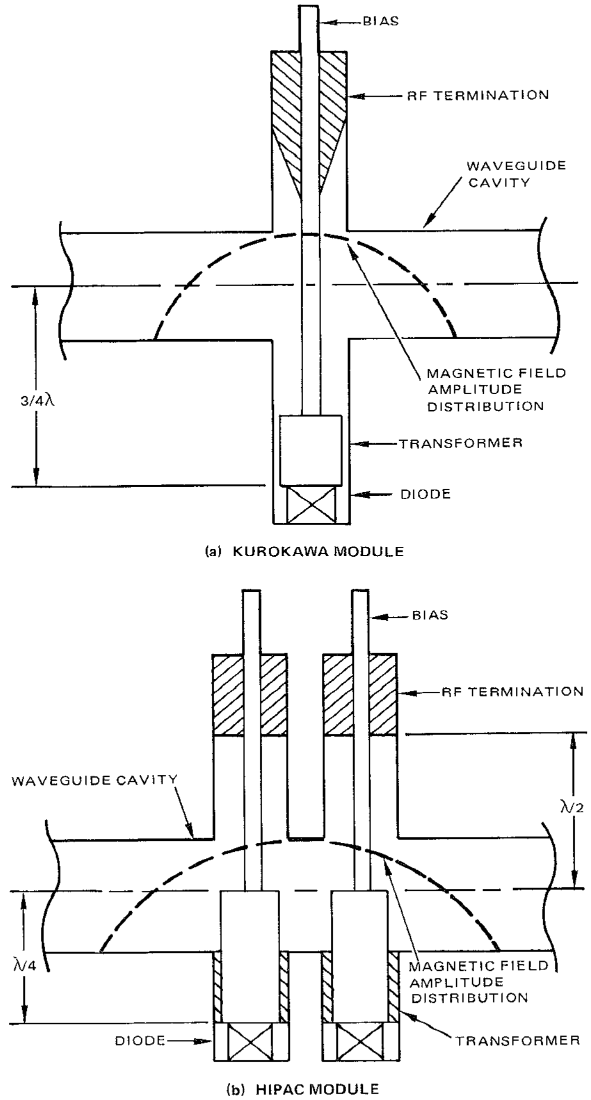


Figure 2. Module Configuration

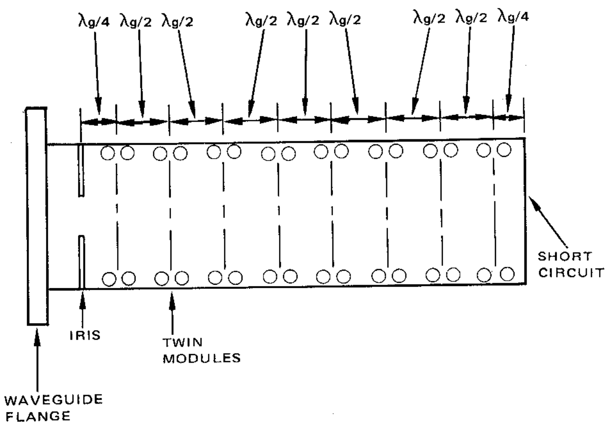


Figure 3. 32 Diode Hi Pac I

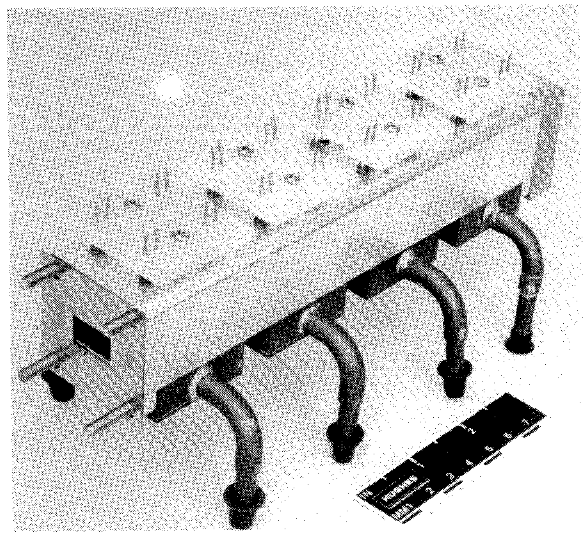

Figure 5. 32 Diode Hi Pac I.

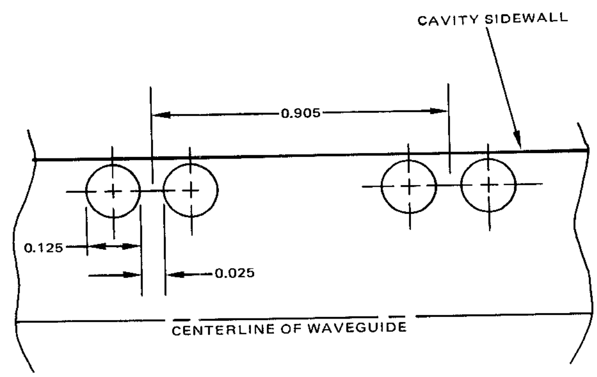


Figure 4. Module Location

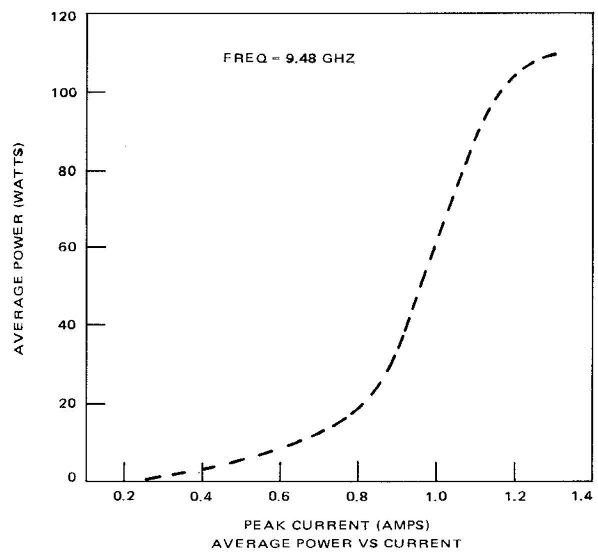


FIGURE 6