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MULTIDIODE WAVEGUIDE POWER COMBINERS

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ABSTRACT

An approach for increasing the density of IMPATT diodes in a waveguide power combiner is introduced. Design concepts and performance characteristics of three configurations are presented. These demonstrate the versatility of the waveguide power combiner.

Introduction

The waveguide type IMPATT diode power combiner developed by Kurokawa (1) has many advantages over the cylindrical cavity combiners as presented by Harp and Stover (2). Principally, the waveguide design is inexpensive to manufacture, has superior thermal management, inherent high power handling capability and can combine large quantities of diodes. The main disadvantage of this design has been its size. The cylindrical cavity is much smaller and for applications is a desirable characteristic.

In combining large numbers of diodes, the user of the cylindrical cavity combiner must resort to using higher order mode cavities or exotic manufacturing techniques (3,4). This further increases the cost to manufacture these units. Recently an extension to the Kurokawa circuit, HIPAC I (5,6), was presented which doubled the diode density of the original design. This was accomplished by placing the coaxial transmission lines (modules) symmetrically about a standing wave field within the cavity. A module contains a diode and its associated bias and matching network. Energy is coupled from the diode to the cavity through the magnetic field.

The versatility of the HIPAC design for increasing the diode density will be presented using three configurations. These designs double and triple the diode density of HIPAC I. In addition, the performance of these combiners will be compared along with a brief discussion of the design philosophy.

Design

The Kurokawa circuit and HIPAC I, shown in Figure 1, position the modules on both sides of the waveguide cavity and periodically along its length. Figure 2 illustrates the location of the module relative to the standing wave field within the cavity. The Kurokawa module is located at the peak of the magnetic field whereas the HIPAC I modules are located symmetrically about the peak of the field. Within a design, the same impedance is presented to each module. However, the impedance differs between the Kurokawa and HIPAC circuit.

The diode density of a given cavity may be increased by using one of two design techniques. Both techniques will present the same or approximately the same impedance to each module within a set. A set is defined to be a group of modules located on the side of the waveguide centerline and locally near the peak of the magnetic field. These details are shown in Figure 3a.

The first design technique minimizes the magnetic field variation in the region of a set of modules. The basis of the design is to operate with a wavelength that is much longer than the distance over which a set of modules are spread. Experimentally it has been determined that the length of a set of modules should be less than 18% of the wavelength. With this criteria satisfied, the modules may be positioned the same distance off of the waveguide sidewall, as shown in Figure 3a. This approach yields approximately the same impedance to each module within a set. The outboard modules will be presented a slightly lower impedance than the center modules. The difference in impedance levels is small, therefore the same diode matching structure can be used for all modules.

The second design approach is to position the modules such that the same impedance is maintained for all modules within a set. This is accomplished by placing modules on lines of constant impedance. The impedance is established by the location of the center modules within a set. To maintain lines of constant impedance the outboard modules must taper away from the sidewall of the cavity. Figure 3b shows the positioning of modules using this approach.

Using the aforementioned design techniques, three combiner configurations were developed, as described in Table I.

TABLE I

COMBINER	DIODES PER SET	DESIGN TECH
HIPAC I	2	CONST. IMPED.
HIPAC II	4	APPROX. IMPED.
HIPAC III	6	CONST IMPED.

The IMPATT diodes used in testing the various configurations were developed by Microwave Associates, MA-46072. These were lo-hi-lo profile GaAs single drift diodes. The tests were conducted at 1/3 duty, 250 KHz prf. At this waveform the diodes produce approximately 3.5 watts of average power with 18% D.C. to RF efficiency.

GaAs diodes were selected to run in the HIPAC combiners because of their unique voltage characteristics. The operating voltage of this device is sensitive to small changes in load impedance. This characteristic was used to verify that the same impedance was being presented to all the modules.

The HIPAC combiners, shown in Figure 4, were all tested as free running oscillators. Table II describes the performance characteristics of the three oscillators. The voltage variation across a set of modules in HIPAC I and III was negligible. The variation across the set of modules in HIPAC II was 1.0 volt which corresponds to an impedance difference of approximately 3%.

TABLE II

COMBINER	DIODES COMBINED	AVERAGE POWER	COMBINING EFFICIENCY
HIPAC I	4	11.5 W	82.1%
HIPAC II	8	23.1 W	82.4%
HIPAC III	12	34.8 W	82.9%

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To demonstrate the full capability of the HIPAC technique, two 32 diode combiners were designed, as shown in Figure 5. The HIPAC I and II designs produced 109.8 and 105.2 watts of average power respectively. Both designs had combining efficiencies over 82%. The voltage variation over all sets of modules, in both configurations, was the same as the cases previously described.

Summary

The HIPAC designs have demonstrated the versatility of the waveguide power combiner. The design offers efficient combining of large quantities of diodes. The inherent characteristics which highlight this technique are, low cost fabrication, thermal isolation, and suppression of parametric instabilities. The size reduction of the waveguide power combiner will allow this type of combiner to compete with its cylindrical counterpart. An additional feature of this design is that the number of diodes to be combined does not affect the design of the matching structure used in the module. Thus the lower power driver stages in a transmitter chain will use the same components as the high power combiner. The only difference is the length of the combiner and consequently the number of diodes combined.

References

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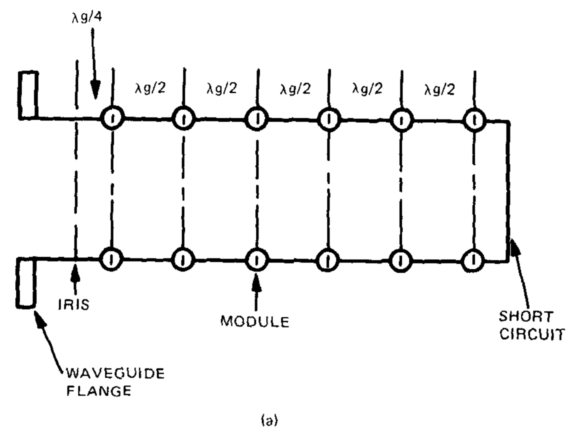

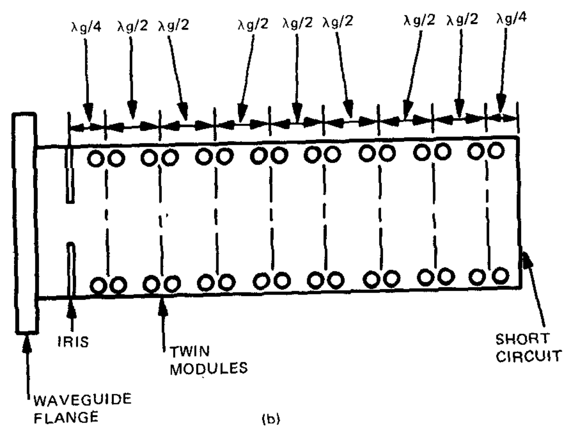

Figure 1. (a) Kurokawa CKT
(b) HIPAC I

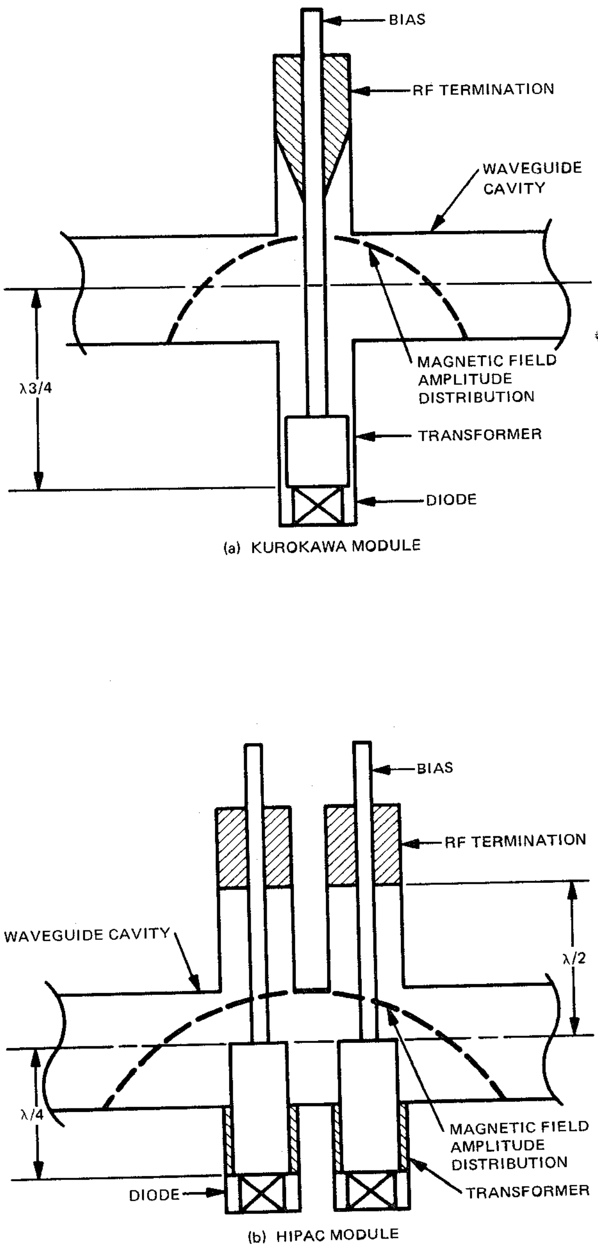

Figure 2. Module Configuration

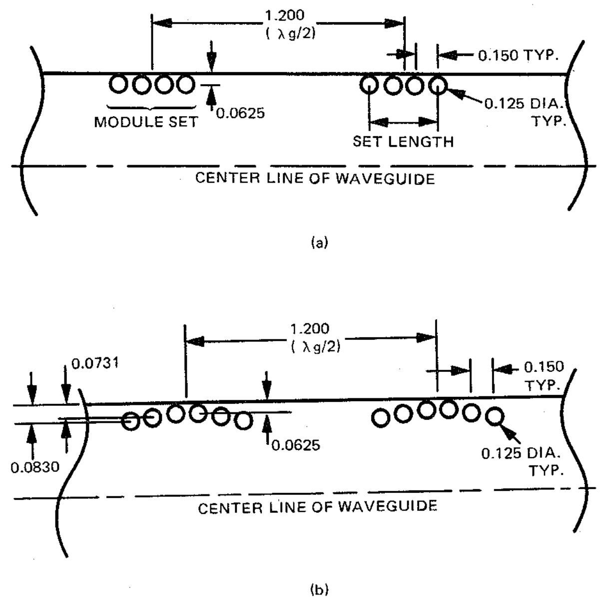

Figure 3. (a) HIPAC II Module Placement
(b) HIPAC III Module Placement

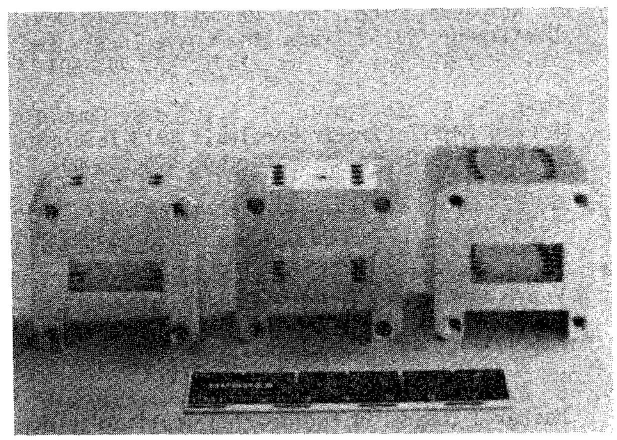

Figure 4. HIPAC I, II & III Combiner Configurations.

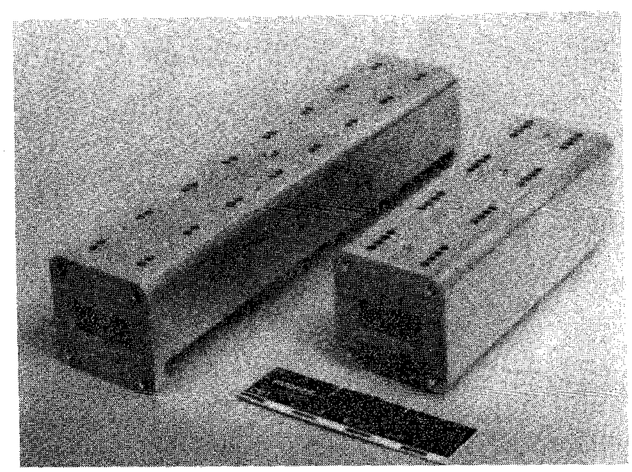

Figure 5. HIPAC I & II