DESIGN AND TESTING OF AN 8.5-GHz POLARIZATION-SENSITIVE GRID POWER COMBINER AT 500-kW CW

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Abstract

A power combiner using a polarization-sensitive quasi-optical grid has been designed to operate at 8.5-GHz and 1-MW CW. The combiner has been successfully tested at 500-kW CW. The design and operating principle are discussed, and the evaluation facilities and instrumentation used in high-power testing are presented.

Introduction

A CW radar at 8.5 GHz is presently operated by NASA's Jet Propulsion Laboratory at Goldstone, California for imaging planets and asteroids. The radar system has been upgraded to 500-kW operation, and a conceptual design for a 1-MW system has been completed using four klystron amplifiers [1]. A key component of this design is a polarization-sensitive grid combiner used to add two 500-kW signals to produce a 1-MW output signal.

The quasi-optical combiner consists of a grid formed of aluminum slats and two orthogonal feedhorns, with the grid bisecting the angle formed by the feedhorns (see Fig. 1). The

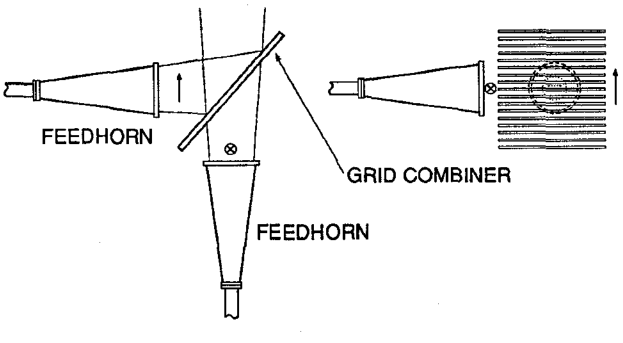

Figure 1. Polarization-Sensitive Grid Power Combiner

feedhorns are rotated so as to orient the electric field vectors of their output signals parallel and perpendicular, respectively, to the slats comprising the grid. It is shown below that given the correct grid dimensions, the combiner is transparent to the signal with the perpendicular electric field vector, and reflective to the signal with the parallel electric field vector. By adjusting the relative phase of the signals applied to the feedhorns, a circular or linearly polarized summed output is obtained. This design offers the advantage of lower power densities over waveguide power combiners, thus reducing the possibility of arcing.

Design

The grid is designed to transmit fields with polarization perpendicular to the slats, while reflecting fields polarized parallel to the slats. This dictates that the spacing of the slats be less than one-half wavelength at the highest frequency of operation. The thickness of the grid is adjusted in order to cancel any power which is reflected at the front end of the grid with that reflected at the back. To determine the required thickness, a mode-matching solution was employed. The fields in the two free-space regions outside the grid are expressed as Floquet harmonics, and the field inside the grid is represented as a set of parallel plate waveguide modes. Matching the electric and magnetic fields at the interfaces completes the solution. The computed reflection coefficient for the polarization-sensitive grid is shown in Figure 2. Note that the grid is well matched near the

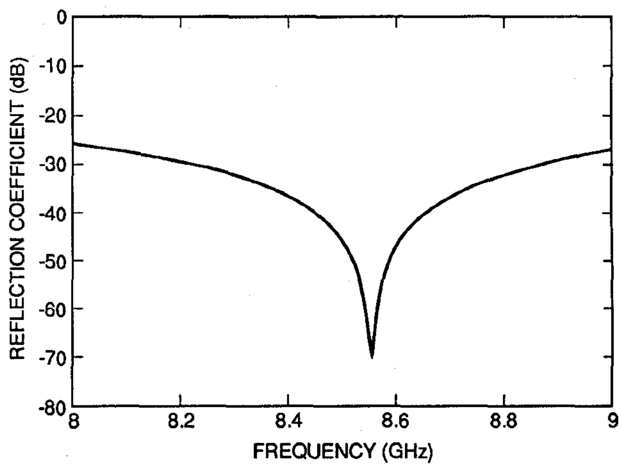

Figure 2. Polarization-Sensitive Grid Reflection Coefficient

center frequency of 8.51 GHz and over the modest ±0.12% bandwidth required. The dimensions of the grid combiner are shown in Figure 3.

Test Configuration

Prior low-power radiation pattern measurements established the proper performance of the grid combiner, however, testing at

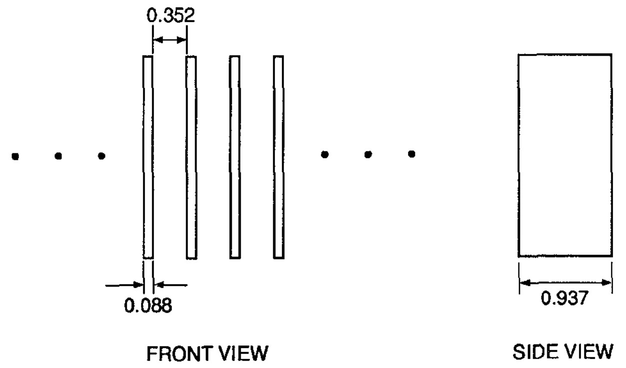

Figure 3. Grid Combiner Dimensions

high power levels remained to be performed to ensure freedom from breakdown. The delivery of the Varian VKX-7864A prototype klystron used in the radar upgrade provided the capability for component testing at a 250-kW power level. A test stand was fabricated on the roof of the building housing the transmitter (Fig. 4), supporting the grid combiner and a 1.8 x 3-meter aluminum reflector. This stand allowed the operation of the combiner in either the transparent mode or the reflective mode, depending on the orientation of the feedhorn.

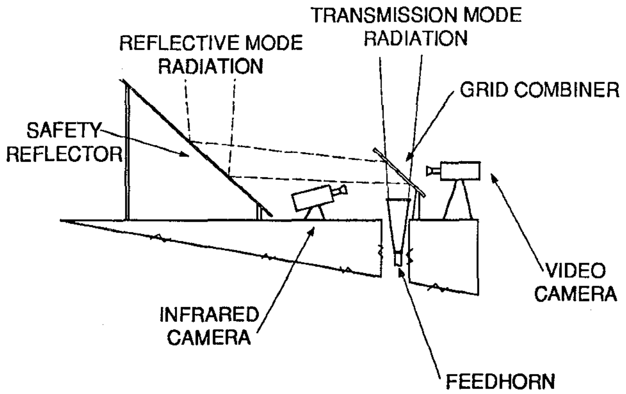

Figure 4. Combiner High-Power Test System

The level of heating of the combiner by the intense RF beam was a concern, along with the possibility of arcing. A high-resolution infrared imaging camera (Inframetrics 600) was installed nearby to provide temperature measurement of the grid surface. This technique has been previously used to remotely measure the temperature of objects in a microwave beam [2]. A video camera was also added to detect any arcing in the grid. Additional indication of arcs was also provided by the transmitter's reflected power protection system.

High Power Operation

Initial operation of the grid combiner took place in the reflective mode, with a transmitter output power of 50 kW. Testing was conducted at night so that any arcing would be easily detected by the video camera. It was found that the infrared camera was providing erratic indications of the combiner temperature due to the poor emissivity of the polished aluminum surface of the slats. The combiner was removed, and the rear face was painted with flat black lacquer to provide a surface with higher emissivity. This dramatically improved the operation of the infrared camera. The transmitter output power was then gradually raised to its maximum of 250 kW and operated at this level for 30 minutes. No arcing was apparent, and the temperature at the center of the combiner stabilized at 70.5°C with a 9.3°C ambient temperature.

The feedhorn was rotated 90 degrees using a waveguide twist to operate the combiner in the transmission mode. Operation was again begun at a 50-kW power level, which was subsequently raised. After 3 minutes of operation at 200 kW, audible and reflected power indications of arcing in the combiner were detected. Examination of the videotape showed a gradual bowing deformation of the combiner slats in the center section, continuing until no gap was visible between the slats (see Fig. 5). This deformation was attributed to a combination of thermal expansion in the center slats (the region with the peak RF field) and the rigid mounting of the end of the slats in the grid frame. The combiner was then removed, and the slat mounting bolts somewhat loosened to allow for some movement. With this modification the combiner was operated at 250 kW for 30 minutes with no indications of arcing—the center section reaching a steady temperature of 49.1°C at 200 kW.

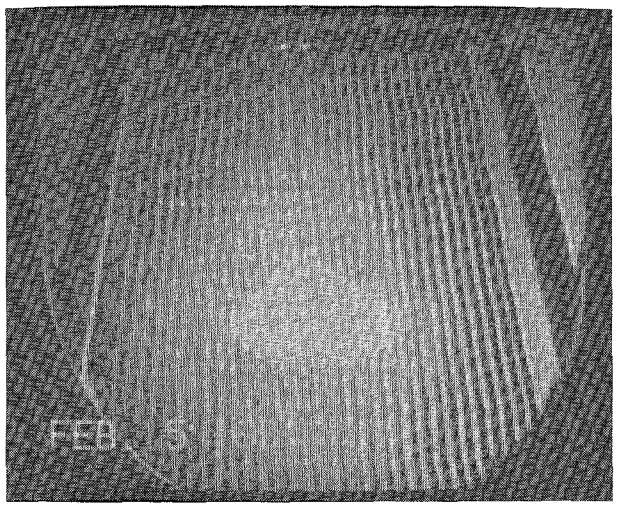

Figure 5. RF Arc in Grid Combiner

With the delivery of the second VKX-7864A klystron, over 500 kW of RF power was available for testing. Due to time constraints, the combiner was tested only in the transmission mode, achieving 30 minutes of operation at 510 kW. No arcing was detected at any time. Temperature data of the combiner surface at this power level were not measured.

Conclusion

A polarization-sensitive grid power combiner was operated successfully in the transmission mode at 510 kW CW and to 250 kW in the reflective mode. While not a full-power test at the required 1-MW CW operation level of this component, the low operating temperatures of the combiner, along with the absence of arcing, give a degree of confidence in the operation of this part at its design value.

Acknowledgment

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References

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