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RADIALLY COMBINED 30 W, 14-16 GHz AMPLIFIER

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ABSTRACT

The paper describes a highly integrated 30 W power amplifier for a Synthetic Aperture Radar, operating in the 14-16 GHz band. The use of a waveguide radial combiner, a microstrip power divider and direct microstrip to waveguide transitions, in combination with a miniaturized ceramic technology, leads to an unusually compact and accessible structure, well suited for commercial production.

INTRODUCTION

One of the main advantages of the highly integrated monolithic or semi-monolithic technologies which have emerged in the last few years is the ability to maintain phase correlation complex structures such as phased arrays and high power combiners. This is due both to the compact physical dimensions of the amplifying modules and to the high degree of reproducibility achievable with batch fabrication.

In this paper we describe a broadband high power amplifier for a Synthetic Aperture Radar (SAR) where the low-loss characteristics of radial combiners [1,2,3,4,5], together with the high level of integration achievable with miniature ceramic technologies, leads to an unusually compact and efficient design.

AMPLIFIER DESCRIPTION AND PERFORMANCE

The complete amplifier is designed to provide an output power of 30 W with a gain of 50 dB over the frequency band from 14 to 16 GHz. This is achieved by combining the output power of 16 identical pallets, which in turn comprise three balanced stages of amplification, with two amplifying modules in parallel in each stage.

Three different amplifying modules are used for the three stages. One more identical pallet is used as a driver. A general schematic of the complete amplifier is shown in Fig. 1.

Fig. 1. Electrical schematic.

All the amplifying modules are fabricated in large batches on 3" x 3" ceramic substrates with solid gold vias, using MPI's proprietary Microwave Monolithic Ceramic Circuit (MMCC) technology [6,7], thereby achieving the high level of reproducibility required for efficient power combination in phase. All couplers are also fabricated on alumina or quartz using the same technology.

The low and medium power modules are slightly modified versions of the two modules already described in [6]. They are capable of very broad band operation, so that the bandwidth is limited only by the newly designed high power module, which is shown in Fig. 2.

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Fig. 2. Ku-Band Power module.

Fig. 3. Three stage amplifier pallet.

Fig. 4. Pallet gain and power output.

The two active devices are Fujitsu FLK-102 and FLK202. The output power of this module is in excess of 1 W over a 2 GHz band, while the gain is of the order of 10 dB. Shown in Fig. 3 is a photograph of the assembled pallet, whose performance is summarized in Fig. 4.

The output power of each pallet is fed into the radial combiner by means of a direct microstrip-to-waveguide transition specifically designed for this

application. The transition is designed using a linear taper single ridge waveguide as an impedance matching network between the microstrip and the WR62 waveguide. The length of the taper is a fraction 0.815 of the wavelength. A quarter of a wavelength backshort is included to reduce radiation losses, as shown in Fig. 5. The simultaneous transcendental characteristic equations relating the ridge waveguide geometry, to the cutoff wavelength, susceptance and characteristic impedance are outlined in Marcuvitz [8] and Hopfer [9]. The length of the linear taper for optimum return loss is given in Collin [10]. The transition is fabricated in 6061 aluminum and then gold plated. The linear taper ridge waveguide section is fabricated using a numerically controlled wire EDM. The transition from microstrip to ridge is accomplished using a 2 x 10 mil gold ribbon soldered to the ridge with 80/20 Au/Sn solder and ultrasonically bonded to the 50 ohm microstrip line.

Fig. 5. Waveguide to microstrip transition.

The performance of the transition is shown in Fig. 6. A 3.5 mm launcher is included in these data. The insertion loss of the transition is typically less than 0.25dB and the return loss is better than 17 dB over the 14-16 GHz band.

The outputs of the 16 WR62 waveguides, arranged side to side, define the outer periphery of the radial combiner. This is a radial waveguide of uniform height,

designed as a non-resonant waveguide terminated at the periphery and the center port. The structure can be viewed as a phased-array space-combiner, where the radiating elements, located around the circular periphery, focalize the energy onto the center port. This type of radial combiner operates over a broad band (e.g. an octave), with a bandwidth substantially independent on the number of ports, an important characteristic of space combiners. The combiner performance is summarized in Fig. 7. The unusually wide band is obtained by optimizing the matching of the radial waveguide at both the periphery and the center port.

Fig. 6. Insertion loss and return loss of the transition.

Fig. 7. Insertion loss and return loss of the combiner.

A photograph of the overall amplifier is shown in Fig. 8. Clearly visible are the seventeen identical pallets, sixteen of them arranged radially around the central structure and the last one (the driver) located in the front left

corner. All pallets are protected by metallic covers. Next to each pallet one can see the individual pulsing circuits, each with its own energy storage capacitor. The input TTL control signal is buffered and then distributed to all the pulsers. Also visible near the center of Fig. 8 is the microstrip divider, which feeds the pallets by means of thin coaxial cables. The radial combiner is located under the divider and is accessed on one side through the central connector, on the other through the microstrip to waveguide transitions whose front openings are identifiable by the presence of the characteristic ridge. The use of a microstrip divider in combination with a waveguide radial combiner results in an unusually compact, easily accessible and flat structure, with excellent heat dissipation characteristics. The ease of access facilitates maintenance and minimizes downtime.

Fig. 8. The 30 W amplifier assembled. The radius is approximately 11 1/2" and the height 1 1/2"

Fig. 9. Amplifier gain and power output.

The performance of the amplifier is summarized in Fig. 9. For most of the band the power is well in excess of the 30 W target. The gain is 50 dB. With a 10% duty cycle, the current consumption is 3.2 A at 10.5 V, yielding an efficiency of 8.9%.

Considerable attention was dedicated to the mechanical design and to the details of the assembly sequence in order to achieve a producible and repairable unit in spite of its compactness. The task was especially challenging in view of the constraints imposed by the overall SAR system, of which this amplifier is the central core. Shown in Fig. 10 is a cut-off view of the SAR RF assembly with the amplifier clearly identifiable in the lower portion of the picture.

CONCLUSIONS

A highly integrated 30 W amplifier in the 14-16 GHz frequency band has been designed and built specifically for a new Synthetic Aperture Radar under development at the Sandia National Laboratories. The high power output and wide band have been achieved by the use of a radial combiner associated with a modular and highly integrated structure. The modular design combined with the intrinsic wide band properties of most of the components as well as the tunability of the high power modules, leads to a whole family of high power wide band amplifiers based on the same approach.

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Fig. 10. Cut-out view of the SAR RF assembly, showing the amplifier at the bottom.

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