MINIATURE CERAMIC CIRCUIT COMPONENTS FOR Ku BAND RECEIVERS*

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ABSTRACT

Components for a 14 GHz receiver were developed using the Miniature Ceramic Circuit (MCC) technology. These components are remarkable for their small size and high level of integration. MCC technology combines many of the desirable characteristics of the monolithic approach and with the flexibility of the hybrid approach.

I. INTRODUCTION

Microwave technology is presently oriented toward the development of circuits that are small and highly integrated. Thus complex functions and broadband operation can be obtained in a small size, with high reliability, and ultimately at low cost. Achieving these objectives has been the driving force toward the development of monolithic microwave integrated circuits (MMIC) and in general, of miniature circuits. Along this line we have developed miniature circuit technologies, initially the Miniature Beryllia Circuit (MBC) technology with surface-mounted FETs on beryllia. More recently we have expanded the technology to alumina substrate. This Miniature Ceramic Circuit (MCC) technology, either with beryllia or alumina substrate material, combines many of the advantages of the MMIC technology - batch fabrication, small size and weight - with the flexibility of the hybrid technology that uses separately attached active devices. The fabrication and assembly of these miniature components are highly reproducible and are suitable for low-cost production at frequencies ranging from UHF to K band. In this paper, we report for the first time on MCC components on alumina, with FETs recessed into the substrate. They have been developed for integration in a miniature low noise receiver operating at 14 GHz.

II. MCC COMPONENTS

The main characteristics of the MCC technology, is the fabrication of passive circuits in monolithic form on Al_2O_3 substrates. These circuits include thin-film Si_3N_4 capacitors, lumped inductors, bridges supported by polyimide, and short sections of transmission lines for input and output interconnections. In the amplifiers, low parasitic ground connections are achieved by means of films of metal (septa) embedded in the substrate and forming an integral part with the ceramic material. The active devices, in this case GaAs low-noise FETs, are added to the circuits as discrete components in pallet form and are connected to the circuit through very short bond wires.

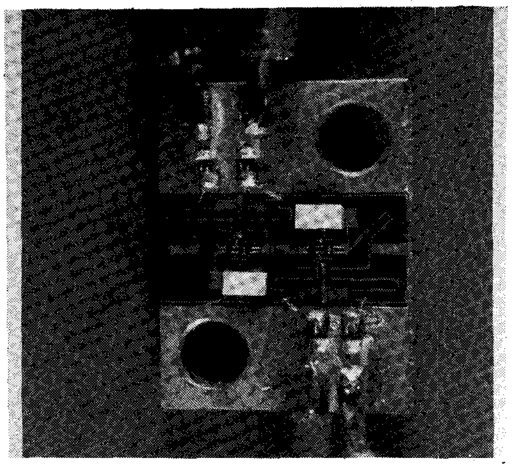

Figure 1. Photo of the Dual-Stage 4 GHz Amplifier.

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A. 4 GHz Amplifier

This amplifier was designed to operate at C band, in the 3.7-4.2 GHz frequency range allocated for broadband communication. In this particular application this frequency is the IF for a 14 GHz receiver. A photograph of the dual-stage amplifier is shown in Fig. 1. Clearly visible are the FET pellets, type NE710 made by NEC, placed into 25-mil diameter holes drilled into the substrates. The matching and bias circuits are formed by the 2-mil wide inductive lines and thin film Si_3N_4 capacitors printed on 10-mil thick Al_2O_3 substrates smoothed by polyimide.[3] The amplifier, shown here mounted on a test block, is very small, only 0.1 x 0.23 in^2. Two 1200 ohm chip resistors, used for negative feedback, are presently added as discrete components, and will be later integrated monolithically in the circuit. Figure 2 is a photograph of a 0.275 x 1.000 in. substrate with batch-fabricated amplifiers prior to drilling holes for the FET pellets. The

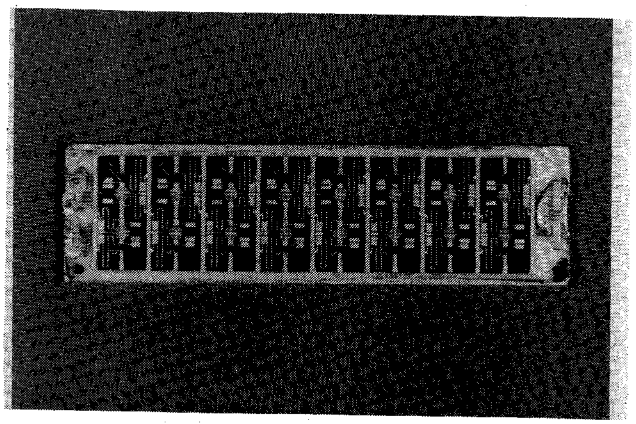

Figure 2. Photo of the Batch-Fabricated 4 GHz Amplifiers.

substrate incorporates two septa for grounding of the two stages.

The gain vs. frequency, plotted in Fig. 3, was measured without any circuit trimming or any external tuning. The gain varies only 1 dB, from 21.5 to 22.5 dB, over the 3.7-4.2 GHz operating band. The 3-dB bandwidth exceeds 1 GHz. Two of these dual stages were cascaded directly without trimming or external tuning as shown in Figure 4. The measured gain was 45.0 to 49.0 dB across the 3.7-4.2 GHz band. The physical size of the amplifier is very small, only 0.10 x 0.46 in^2.

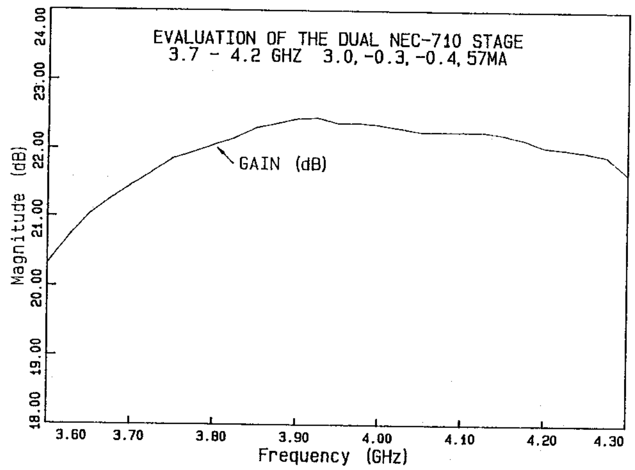

Figure 3. Gain vs. Frequency response for the Dual- Stage 4 GHz Amplifier.

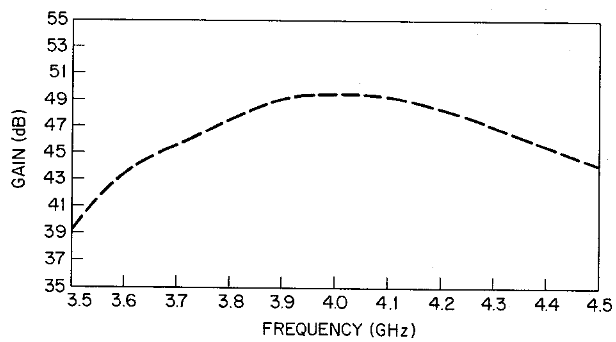

Figure 4. Gain vs. Frequency response for two Dual-Stage Amplifiers cascaded.

The output stage for the 4 GHz IF amplifier has been designed and fabricated. The active device is a low-power GaAs FET type NE694 made by NEC. This device is capable of an output power of 100 mW at the 1 dB gain compression point. The physical size of the amplifier is very small, only 0.10 x 0.20 in^2.

The test results for the stage are plotted in Figure 5. Figure 5 shows the output power and power-added efficiency vs. input power for this device. It can be seen that the amplifier provides the

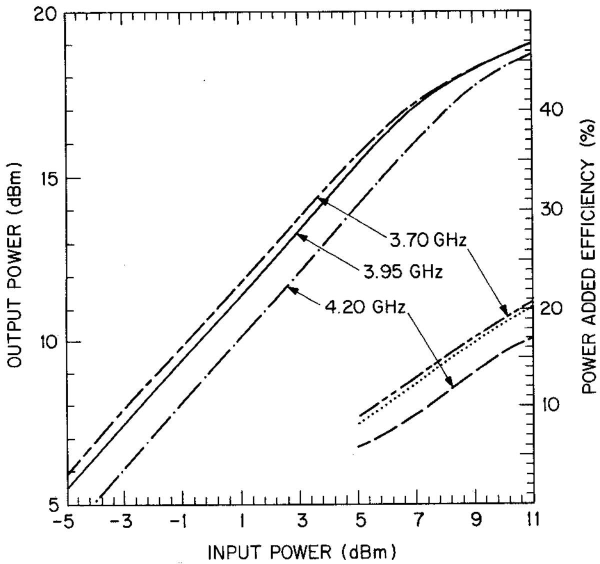

Figure 5. Input Power vs. Output Power and Power Added Efficiency for the NE694 stage.

required +10 dBm output power while remaining quite linear. The linear gain for this stage was 9.7 ± 0.8 dB without external tuning or trimming. The third-order intermodulation (IMD) performance for this amplifier indicates that for an input drive providing the required +10 dBm output power the IMD was smaller than -50 dBc.

B. 14 GHz Preamplifier

This unit was designed to preamplify the receiver input signal in the frequency range from 14.0 to 14.5 GHz. In addition to the septum, the substrate was equipped with via holes for additional grounding of the metal pattern to avoid transmission line effects in the ground connection. The circuits were batch fabricated on a 10-mil thick Al_2O_3 substrate 1.0 x 0.2 in. in size. The area of each circuit is only 0.1 x 0.2 in^2. The measured performance shows a gain of 6 dB, approximately constant over the 14.0-14.5 GHz operating bandwidth. The noise figure is 3 dB, also approximately constant over the bandwidth.

Figure 6 shows the photograph of a dual-stage amplifier with two FETs directly cascaded. The amplifier is very small, only 0.1 x 0.275 in^2. The gain performance, as shown in Figure 7 was measured without any circuit trimming or

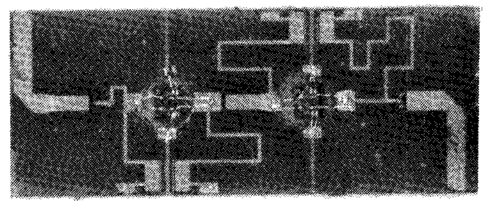

Figure 6. Photo of the Dual-Stage 14 GHz PreAmplifier.

any external tuning. The gain varies only 0.35 dB, from 13.65 to 14 dB, over the 14.0-14.5 GHz operating bandwidth. The noise figure is 3.25 dB, approximately constant over the bandwidth.

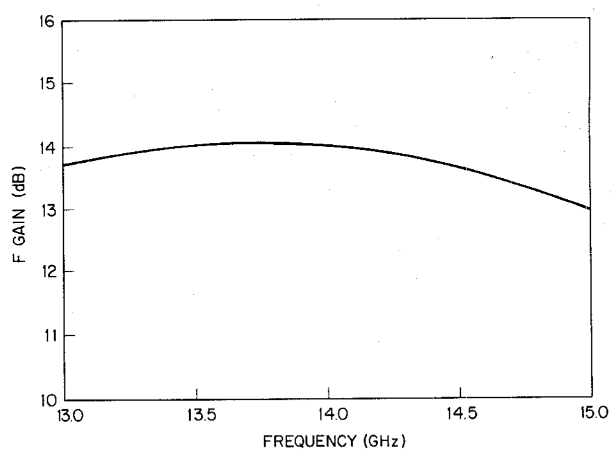

Figure 7. Gain vs. frequency response for the Dual-Stage 14 GHz PreAmplifier.

C. Lumped Element Quadrature Coupler

Another circuit realized with MCC technology was a 3.7-4.2 GHz miniature lumped element coupler - electrically equivalent to a distributed branch-line coupler. The 50 ohm and 35.4 ohm quarter-wave lines were simulated by networks of short inductive lines and discrete thin-film capacitors. Figure 8 is a photograph of the couplers batch-fabricated on an alumina substrate 10-mil thick and coated with polyimide as a smoothing agent. Clearly visible is a circular line 136 mil in diameter and 2 mil wide with four 1.6 pF thin-film capacitors distributed along the periphery. A through-hole at the center of the circular line provides the ground connection for the thin film capacitors.

The measured power splitting performance of the coupler, as shown in Figure 9, indicated that the difference of power coupling into the two output ports was less than 0.4 dB over the passband with a relative phase shift of 90^{o} to 100^{o}. The isolation was greater than 15 dB over the passband.

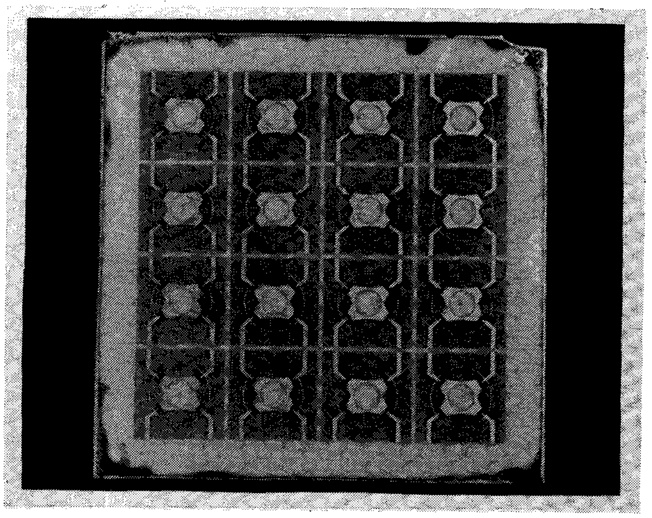

Figure 8. Photo of batch- fabricated lumped element quadrature coupler on a 1.0 x 1.0 inch substrate.

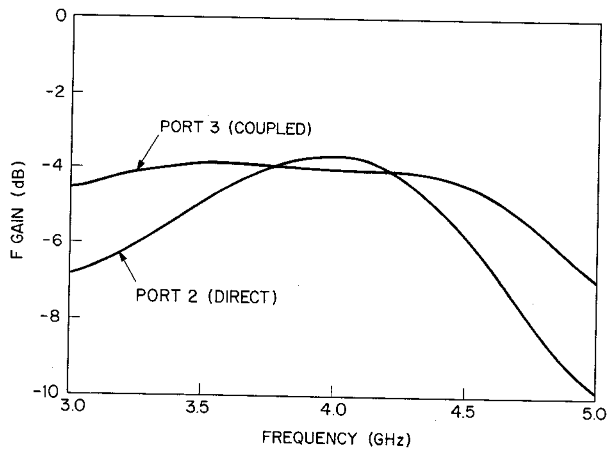

Figure 9. Test results of lumped element quadrature coupler.

III. CONCLUSIONS

The MCC components that have been described are remarkable for their small size and high level of integration. The circuits, fabricated in a batch mode, are highly reproducible, reliable because of the few interconnections, and ultimately low cost. The MCC technology that extends to the limit the monolithic integration of the passive circuit, combines many of the desirable characteristics of the monolithic approach with the flexibility of the hybrid approach.