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BROADBAND POWER AMPLIFIERS BASED ON A NEW MONOLITHIC CERAMIC TECHNOLOGY

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ABSTRACT

A new monolithic ceramic technology especially developed for high power applications is proposed. Broadband power amplifiers based on this technology have demonstrated output powers in the range of one to two watts over the 6-18 GHz frequency band, with good efficiency and high reproducibility.

INTRODUCTION

The performance of power amplifiers is critically dependent on the ability to dissipate the heat generated by the active devices and to provide low inductance connections to ground. It has been recognized for some time (1-5) that the GaAs monolithic technology (MMIC) is not ideally suited for this purpose and it often forces the designer to unacceptable tradeoffs. This paper describes a new monolithic ceramic technology especially developed to address the requirements of high power circuits and the application of this technology to broadband amplifiers.

MONOLITHIC CERAMIC TECHNOLOGY

The newly developed technology combines some of the features of GaAs MMIC's such as high circuit density, high level of integration, batch production, good high frequency performance, with an excellent heat dissipation and the freedom to select the optimum substrate material according to specific requirements.

One of the main characteristics of this technology is the presence of solid gold vias through the ceramic substrate, providing both heat dissipation and low inductance connections to ground. Holes are drilled by laser and filled by plating prior to the circuit processing. The excellent surface planarization allows the definition of fine circuit details, with geometries of the order of few microns, as close as desired to the gold vias. Conductive and resistive materials are deposited and etched by sputtering, dielectrics by plasma. As compared to GaAs, ceramic substrates withstand much higher energies and temperatures during dry processing, leading to excellent adherence, fast deposition and etching rates and high quality dielectrics. Circuit yields are typically 70-80% and fabrication cycles average one week, leading to low cost and fast turn around of new designs. A typical cross-section for a circuit including conductive, resistive and capacitive elements is sketched in Fig.1. A 3" x 3" alumina substrate with 153 two-stages amplifier modules is shown in Fig.2. The only elements missing are the two GaAs FET's, which are die-attached on the solid gold vias after the substrate is sawed and tested. Since the devices have via holes under the sources, only two bond wires are required for the first device and four for the second.

BROADBAND POWER AMPLIFIERS

Based on this technology, several high power amplifiers, both narrow and broadband, have been designed so far. This paper describes a family of broadband amplifiers built by combining two basic two-stages amplifier modules, providing an output power of +21 dBm and +26 dBm, respectively, over the 6 to 18 GHz frequency range. The low power module (WA), 118x280 mils in size, is shown in Fig.3. and the high power one (WB), 146x280 mils in size, is shown in Fig.4. Visible in the pictures are several large bias or bypass capacitors and some smaller tuning capacitors. These were designed in the shape of thin parallel fingers to allow some degree of tuning by cutting one or more fingers. Some additional flexibility is obtained by providing alternative paths for the inductive elements, as exemplified in Fig.4 by the shortening of the output bias inductor. In the same figure, the interstage resonator can be also slightly modified by connecting the additional metallized areas surrounding the central body. In both circuits, biases can be optimized with the help of the modular resistor network visible in the lower portion of the modules. This flexibility in the circuit

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elements compensates for small variations in device parameters and allows to adapt the same basic modules to slightly different customer requirements. Since the fabrication process for the modules is extremely uniform and repeatable, once the performance is optimized for a given application the same tuning is applied to all modules involved, and no additional tweeking is needed. The typical gain, for both modules, ranges from approximately 7 to 10 dB depending on biases. The output power of the WB module is plotted as a function of frequency in Fig.5. This compares favorably with a rated power of 27 dBm at 14.5 GHz for the output device, a Fujitsu FLK-052XV, testifying to the efficient heat dissipation and the low-loss of the tuning elements.

A complete output pallet using four WB and four WA modules is shown in Fig.6. This pallet provides an output power in excess of 1 W with a power consumption of about 12 W and can be used in a variety of systems. Its output power and small signal gain as a function of frequency are plotted in Fig.7.

A complete amplifier incorporating one output pallet of the type shown in Fig.6 and one driver pallet with four WA modules is shown in Fig.8. Visible in the lower half is a power conditioner which includes bias sequencing and thermal protection. The dc power requirement is 2 A at +12 V (regulated down to 10 V for the FET's) and 0.1 A at -6 V. This amplifier configuration provides an output power in excess of 1 W over the 6 to 18 GHz frequency range, with a minimum gain of 30 dB. Higher gains can be obtained by adding one or more driving stages in the space available in the upper left corner. Plotted in Fig.9 is the output power as a function of frequency for case temperatures ranging from 0 to 85 deg C. By combining six WB modules at the output, driven by a combination of WA's and WB's, the saturated output power is increased to 1.5 W , again with a wide range of gains depending on the number of driving stages.

CONCLUSIONS

The new technology described in this paper offers an attractive alternative for microwave power applications. The fast turn around, high yield and batch production result in low fabrication costs and the ability to respond quickly to customer needs. The excellent heat dissipation, low circuit losses and fine photolithograghy lead to state of the art performances, as exemplified by the broadband power amplifiers described in this paper.

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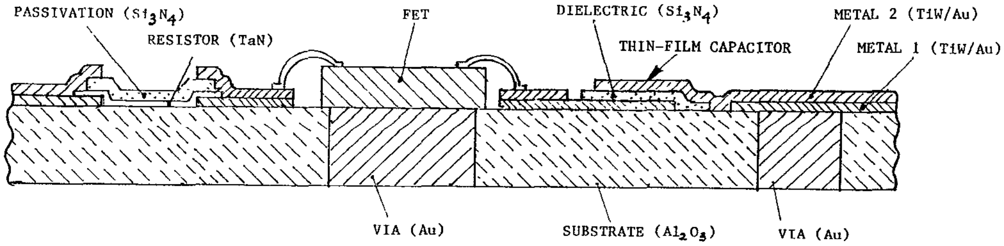

FIG.1. CROSS SECTION OF A MONOLITHIC CERAMIC CIRCUIT

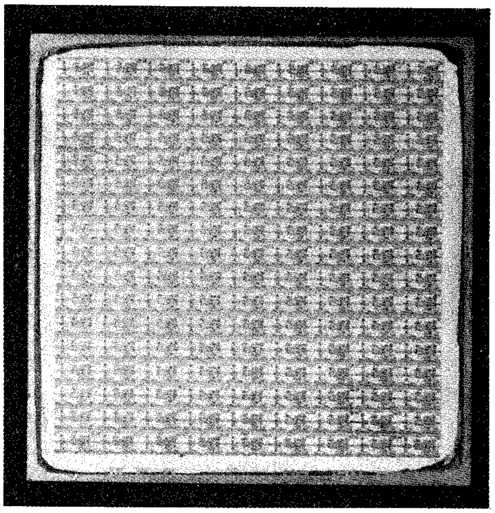

FIG.2. BATCH PORCESSED MODULES ON 3" X 3" SUBSTRATE

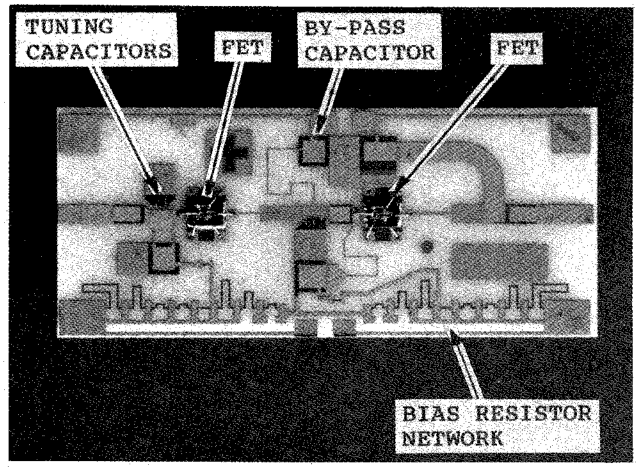

FIG.3. PHOTOGRAPH OF A LOW POWER MODULE

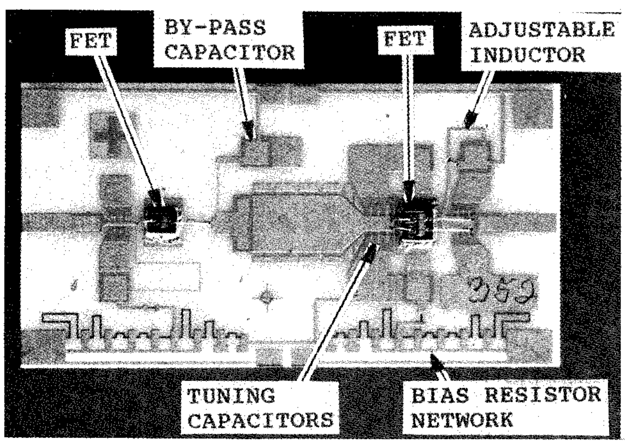

FIG.4. PHOTOGRAPH OF A HIGH POWER MODULE

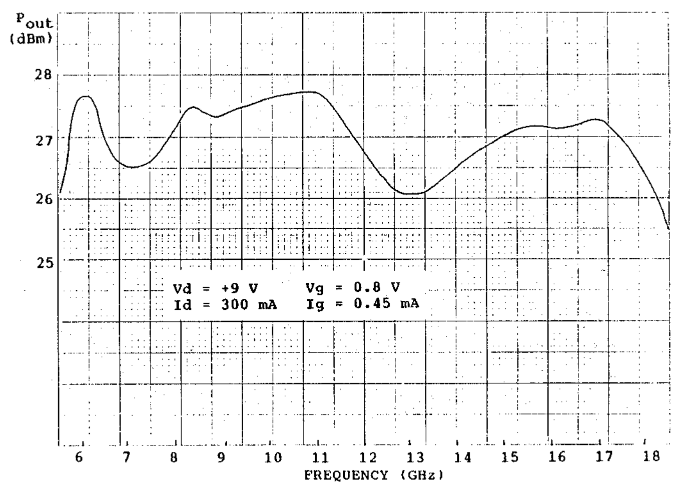

FIG.5. **OUTPUT POWER OF A HIGH POWER MODULE**

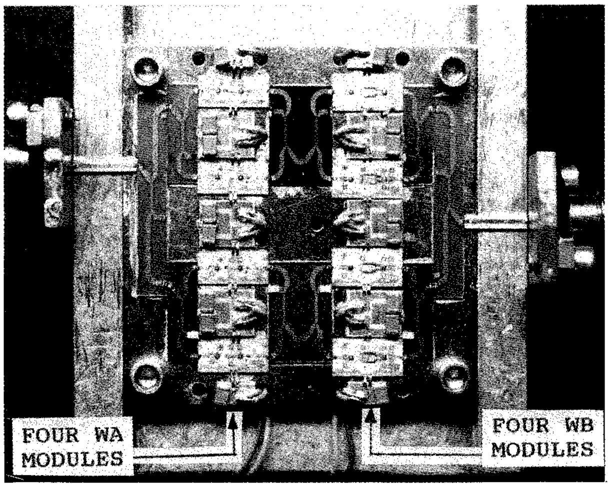

FIG.6. PHOTOGRAPH OF A POWER PALLET

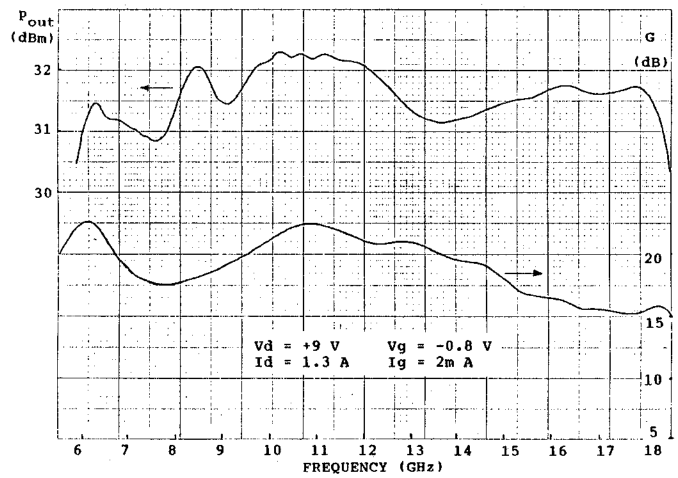

FIG.7. OUTPUT POWER AND SMALL SIGNAL GAIN FOR A POWER PALLET

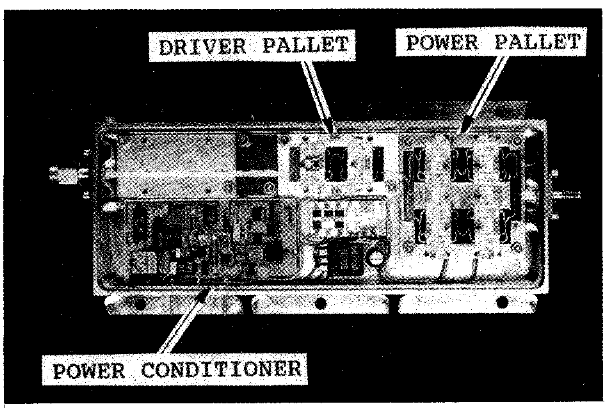

FIG.8. PHOTOGRAPH OF A COMPLETE BROADBAND POWER AMPLIFIER

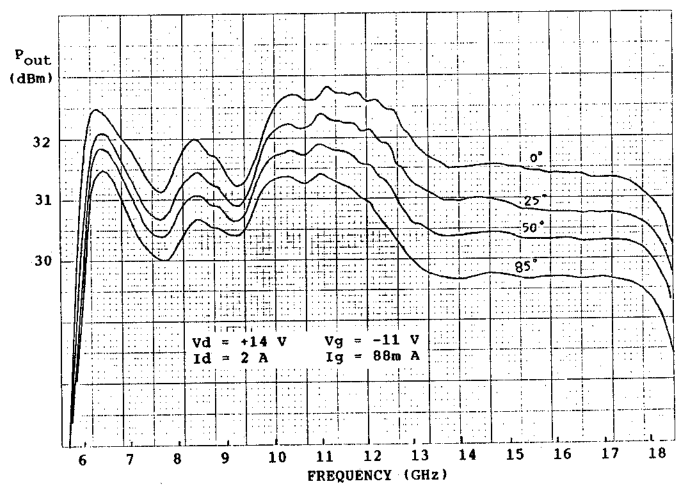

FIG.9. OUTPUT POWER OF A BROADBAND POWER AMPLIFIER AS A FUNCTION OF THE CASE TEMPERATURE