A MINIATURIZED 6.5 - 16 GHz MONOLITHIC POWER AMPLIFIER MODULE

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ABSTRACT

A miniaturized 6.5 - 16 GHz power amplifier module, which includes T/R switch, dual polarity power supply, switch driver and gate functions was designed using two types of broadband MMIC amplifiers. The two cascade designs were a 900 μm - 1200 μm FET amplifier and a 300 μm - 300 μm feedback amplifier which were used to provide large and small gain functions respectively. The module exhibits 35 dB of gain, 1 watt power output and 55 dB T/R switch isolation.

INTRODUCTION

The ever increasing demand for reliable, inexpensive, miniaturized components is driving the microwave industry to incorporate MMIC (microwave monolithic integrated circuits) technology into current and future systems. Some of the next generation of EW systems being developed require quantities of modules that are several orders of magnitude greater than the current production capacity and experience of the industry. Present approaches for building microwave broadband power amplifiers using MIC techniques are extremely labor intensive and sensitive to variations in assembly methods. However, MMIC technology has the advantages of reducing labor intensive activities and circuit sensitivity to critical tuning elements; thus, improving reproducibility and module yield. This paper describes the use of two types of MMIC amplifiers in the development of a miniature power amplifier module targeted for future high volume production. The first amplifier type is a cascade two stage feedback amplifier used to develop small signal gain, while the second amplifier type is a cascade design used for driver and output stage applications.

CIRCUIT DESCRIPTION

The use of controlled feedback in the design of microwave amplifiers is well established, and is used extensively in amplifier designs. Some of the advantages of using feedback are improved gain flatness, reduced input/output port VSWR, increased stability, and reduced device count. The performance goals for the feedback amplifier were to achieve a gain of 10 ± 0.7 dB per chip, and a VSWR of less than 2.0:1 on both input and output ports. The amplifier design approach consisted of accurately modeling a feedback loop for maximum available gain across the desired band. Figure 1 shows the power and gain performance of the feedback amplifier at the 1 dB gain compression point.

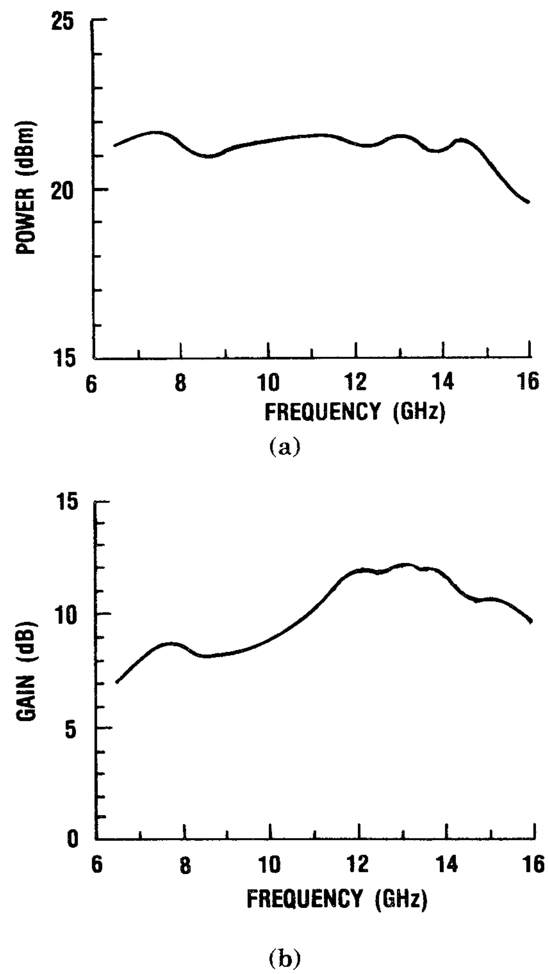

Figure 1 Feedback amplifier MMIC (a) power and (b) gain at 1dB gain compression.

The 900 μm-1200 μm monolithic amplifier (power amplifier) was designed for optimum power performance throughout the 6.5-16 GHz frequency range. Since the FET's will operate in a nonlinear mode, an analysis was performed to determine the optimum power termination impedance. From this model, the output matching networks were designed to present the optimum load to the FET. The input networks were designed to maintain a flat gain response using mismatching and equalization techniques. Both the input and output matching networks were of the high-pass form, which allowed for an easy method of biasing the amplifier. Power performance of the 900 μm-1200 μm FET amplifier at the 1 dB gain compression point is shown in Figure 2.

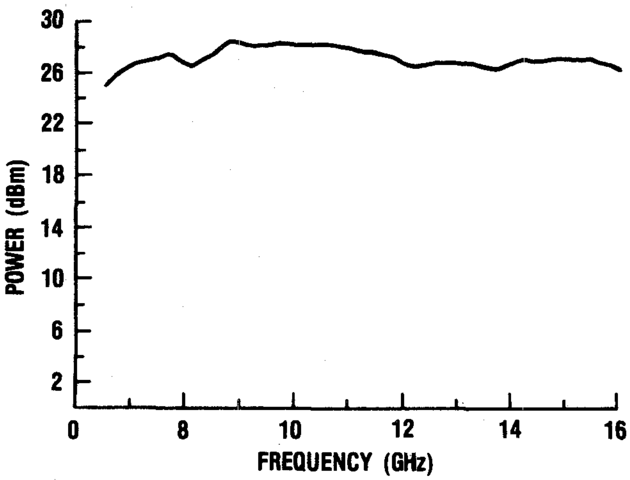

Figure 2 Power amplifier MMIC power at 1dB gain compression.

Both the feedback and power amplifiers were fabricated using similar techniques. The amplifiers were constructed on a .1 mm thick semi-insulating GaAs substrate, with the active layers being formed by ion implantation techniques. Via hole processing was accomplished using reactive ion etching. The MIM capacitors are of the metal/silicon-nitride/metal type, which have approximately 2000 Å of dielectric thickness. Resistors for the feedback amplifier were formed using the Mesa layer, while the power amplifier used germanium type resistors.

A four stage power amplifier module, shown in Figure 3, was designed using two feedback and six power amplifier MMICs. The first two stages of the module were used to developed small signal gain and consisted of two cascaded feedback amplifier MMICs. This section developed over 20 dB of small signal gain and 19 dBm of saturated power. The feedback amplifiers were followed by a pair of balanced power monolithics. The balanced amplifier pair had a saturated output power of 25-27 dBm and was used to drive the modules final amplifier stage, an output amplifier. The output amplifier had a saturated output power of 31 to 33 dBm which was achieved by employing balancing and Wilkerson combining techniques with four power MMICs. Close phase and amplitude tracking by each of the monolithic amplifiers resulted in excellent power combining efficiency. Figure 4 illustrates the functional block diagram of the power amplifier module.

The power amplifier module was designed to operate in two modes: transmit and receive. In the transmit mode all the amplifiers are turned on and the T/R switch connects the output amplifier to the output port. In the receive mode, the T/R switch connects the output port to the receive port, while the transmitted signal is blocked by shorting the output amplifier and turning off the feedback amplifiers.

The performance of the T/R switch is critical to the performance of the module. In the transmit mode, the T/R switch must have very low loss to avoid attenuating the transmitted signal while maintaining 55 dB isolation between the output and receiver port. The required performance is achieved by using a combination of series and shunt PIN diodes as shown in Figure 5. RF energy radiating to the receiver port from the output port is blocked by bridging the receiver arm of the T/R switch with a small, brass block. The negative supply available in the module does not have adequate current to drive the pin diodes. As a result, a diode biasing network is used in which the diodes are connected in series between two

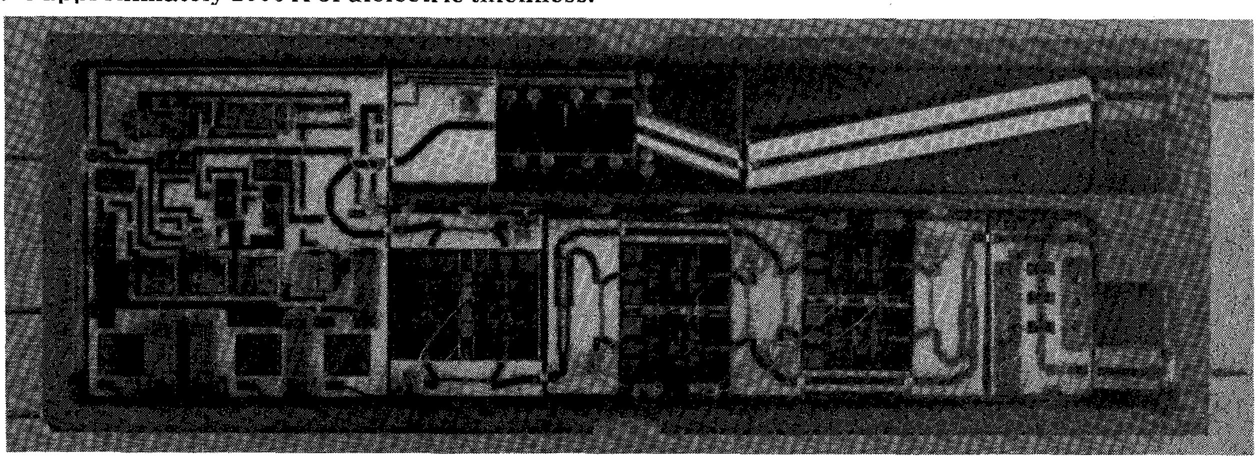

Figure 3 Power amplifier module.

positive switch drivers. The switch drivers, controlled by a TTL signal, switch inversely from one another between 0 and +1 volt, driving the diodes on and off. To facilitate biasing, the shunt PIN diodes were mounted on chip ceramic capacitors, which were placed in vias cut in the alumina substrate.

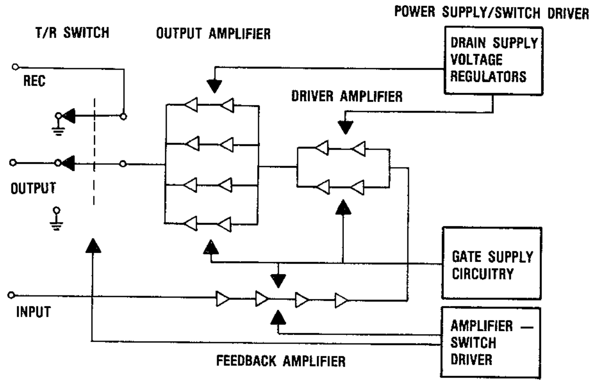

Figure 4 Power amplifier module block diagram.

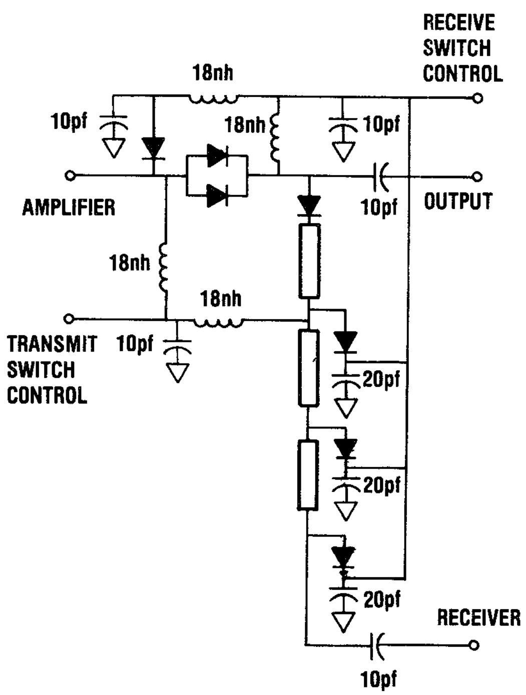

Figure 5 Circuit schematic of transmit-receive switch.

The amplifier module requires adequate heat dissipation to prevent failure of the amplifiers. Considerable attention was paid to the materials and assembly techniques used to build the amplifier module. The module housing is made of KOVAR with several copper inserts placed in the floor of the package beneath the areas of high power dissipation. Each of the module components are assembled on molybdenum carrier plates, and then epoxied to the module floor. For extended operation, the amplifier module is mounted on an aluminum plate to provide a heat sink.

The small size of the module presented special problems in making adequate RF connection to the RF ports and in maintaining good isolation to prevent oscillations during testing. Two special connectors were developed to test the module. The receiver and input ports used a connector with a compressible, conductive gasket, which made a pressure contact fit, for ground, and a slip-in pin for RF. The output port used a slip-in connector which was inserted into a recess in the module housing.

MODULE PERFORMANCE

Performance of the module was measured at room temperature with the module mounted in its test fixture. Cable losses in the test setup were removed through calibration. The saturated output power and small signal gain, which were measured while the module was in the CW transmit mode, are shown in Figures 6 and 7. Receiver isolation was determined by measuring the RF leakage at the receiver port during the transmit mode. The measured isolation was greater than 60 dB through the entire frequency range. Switching speeds, for the module changing between the receive and transmit modes, were less than 100 nsec.

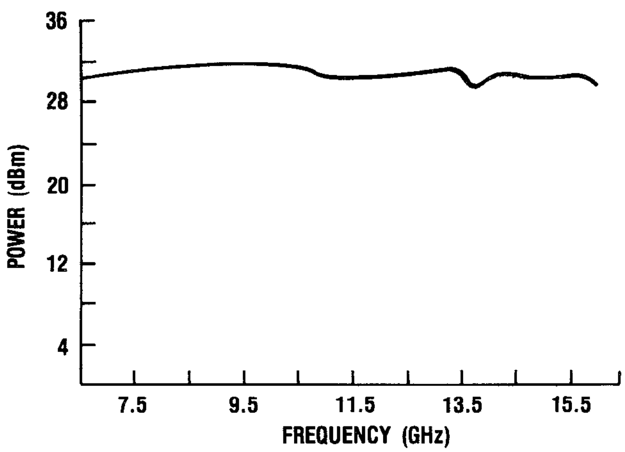

Figure 6 Saturated output power of power amplifier module.

CONCLUSION

This paper has described the development of a miniaturized power amplifier module using several microwave monolithic circuits; demonstrating that monolithic technology can reduce the size and cost of producing difficult microwave designs. The MMIC circuits proved to be simpler and smaller than their MIC counterparts, and are well suited for high volume production. The resultingmodule design demonstrates the promise that monolithic technology is a step closer to meeting the demands of the growing microwave industry.

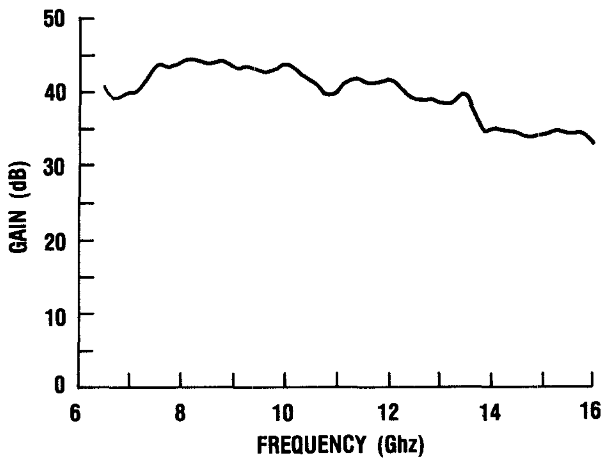

Figure 7 Small signal gain of power amplifier module.

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