A 20 GHz MMIC POWER MODULE FOR TRANSMIT PHASED ARRAY APPLICATIONS

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ABSTRACT

A novel high gain, high power, high efficiency and high linearity MMIC power module is developed for a 20 GHz transmit phased array for future communication satellite application. This MMIC module has a maximum gain of 50 dB, a gain range more than 30 dB, an output power of 1 1 Watt, an efficiency of 18% and a third-order Intermodulation of 17 dBc at 19 GHz. It has a size of 4 5x1.75x0.5", a mass of 100 gm and a DC power consumption of 6.3 Watt.

INTRODUCTION

Implementation of MMICs into future communication satellites has the potential for providing significant reductions in cost, size and mass while offering good uniformity and reproducibility, and higher reliability than the discrete circuits being used today [1-2]. However MMIC insertion has high initial development costs, longer design cycles and almost no adjustability after manufacturing. The current use of MMICs in space applications has been mainly in the area of large volume active phased array antennas.

Future communication satellites will require multiple reconfigurable antenna beams to achieve competitiveness and adaptability in the international marketplace. A preferred method for achieving this is by multibeam active arrays, using separate control MMICs for each beam and common power amplifiers, on transmit. To study the feasibility of this approach, we have designed and are building a 37-element dual-beam active transmit array operating at 20 GHz.

A MMIC power module is the basic building block of each element for the 20 GHz transmit phased array. The MMIC module consists of two RF chains (for two beams) which are combined and then amplified by a driver amplifier. These are followed by a power amplifier and an isolator, as shown in Figure 1

This MMIC module has a designed operation gain range from 35 to 50 dB, an output power of 1.1 Watt, an efficiency of 18% and a third-order intermodulation of 17 dBc at 19 GHz. The phase adjustment range is 360 degrees, with a 5 6 degrees step size, and a continuous gain adjustment range of more than 30 dB for each beam. It has a size of 4.5x1.75x0.5", a mass of 100 gm and a DC power consumption of 6.3 Watt.

20 GHz POWER MMIC MODULE DEVELOPMENT

Figure 2 shows the block diagram of the 20 GHz power MMIC module. Each RF chain consists of a 20 GHz MMIC amplifier, a 20 GHz MMIC phase shifter, two sets of 20 GHz MMIC amplifier and MIC PIN diode attenuator pairs. The two RF chains are then combined and amplified by a driver amplifier and a power amplifier, then passed through a 20 GHz detector coupler, an isolator and then exited the MMIC module into the filter, polarizer and horn antenna. Figure 3 shows the photograph of the assembly of the 20 GHz MMIC module, filter, polarizer, and horn for the transmit phased array.

Three MMIC chips are utilized in this module. the 20 GHz 6-bit MMIC phase shifter, the 20 GHz PHEMT MMIC driver amplifier and the 20 GHz PHEMT MMIC power amplifier. A 20 GHz MIC PIN attenuator is used in the module. Both MMIC and MIC circuits are mounted on the Silvar carriers (except for the power amplifier which is mounted on the CuW carrier) for ease of insertion.

The 6-bit MMIC phase shifter utilizes the true time delay approach with modified MESFETs as the high isolation RF switches The phase adjustment range is 360 degree, with a 5.6 deg step size. Figure 4 shows the MMIC layout of the 6-bit phase shifter The absolute insertion loss is ~ 16.5 dB from 19 to 21 GHz. The relative insertion loss and relative phase for all 6 bits over temperature are less than +/- 0.5 dB and less than +/- 1 degree, respectively.

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Both the MMIC driver and power amplifiers utilize power PHEMT technology. The driver amplifier has a linear gain of 17 dB, a 1-dB compression power of 20 dBm, and an efficiency of 35% at 19 GHz. The power amplifier has a linear gain of 14 dB, a 1-dB compression power of 31.5 dBm, an efficiency of 30-40%, and a third-order intermodulation of 18 dBc at 19 GHz, which is state-of-the-art performance [3]. Figure 5 shows the layout of the 20 GHz power amplifier. The power transfer curve, gain compression and efficiency for the power amplifier at 19 GHz are shown in Figure 6. The center frequency for both driver and power amplifiers are lower than the designed value by ~ 1 GHz. On-chip tuning has demonstrated that the center frequency can be tuned up to 20 GHz which will be implemented in second iteration.

The MIC PIN diode attenuator has a minimum insertion loss of 2 dB and a continuous amplitude adjustment range of more than 15 dB with gain flatness within +/- 0.5 dB from 18.5 to 21.5 GHz.

A multi-layer control circuit which consists of two ASIC chips, bias circuitry, filters and voltage regulators is under evaluation (Figure 7). This control circuit provides the proper bias voltages or currents to the amplifiers, phase shifters and attenuators, controls the output power level through the ALC loop, compensates the gain and phase variations over temperatures, and sets the desired gain and phase of each beam in the MMIC module according to the command.

20 GHz POWER MMIC MODULE PERFORMANCE

A prototype MMIC module has been built up and tested (Figure 8). This MMIC module has 50 +/- 1 dB gain with greater than 30 dB gain range from 18.5 to 19.5 GHz (as shown in Figure 9) and input/output return losses less than -10 dB. It has a 1 dB compression power of 1.1 Watt (Figure 10) and a third-order intermodulation of 17 dBc at 19 GHz. The measured power added efficiency is around 18% at 19 GHz.

CONCLUSION

In conclusion, we have designed and are evaluating a high gain, high power, high efficiency and high linearity MMIC power module for a 20 GHz transmit phased array for future satellite communication applications.

This MMIC module has a designed operation gain range from 35 to 50 dB, an output power of 1.1 Watt, an efficiency of 18% and a third-order intermodulation of 17 dBc at 19 GHz. The phase adjustment range is 360 degrees, with a 5.6 degrees step size, and a continuous amplitude adjustment range of more than 30 dB for each beam. It has a size of 4.5x1.75x0.5", a mass of 100 gm and a DC power consumption of 6.3 Watt.

After all 37 MMIC modules being assembled and evaluated, they will be integrated with other parts into a 20 GHz transmit phased array antenna and tested in the compact test range.

ACKNOWLEDGMENT

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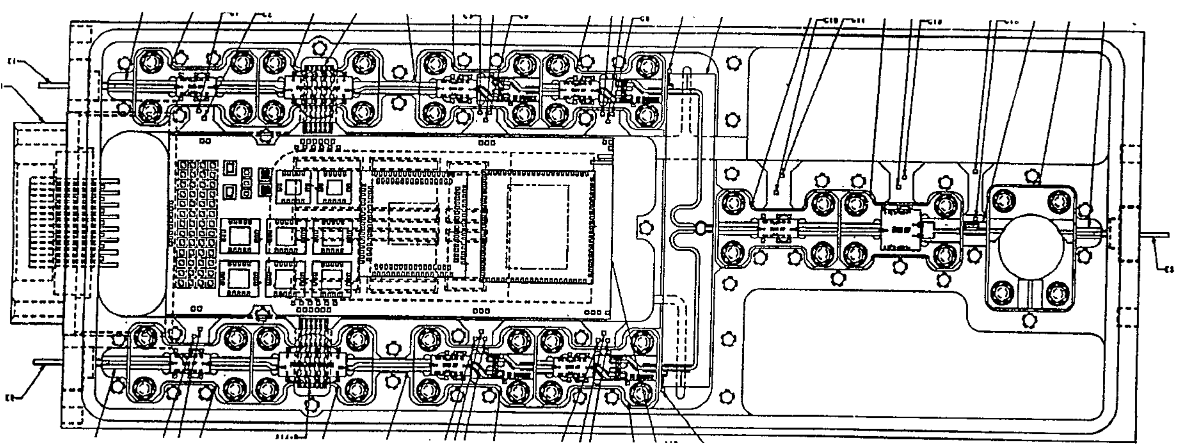

Figure 1. 20 GHz Power MMIC Module Assembly Drawing

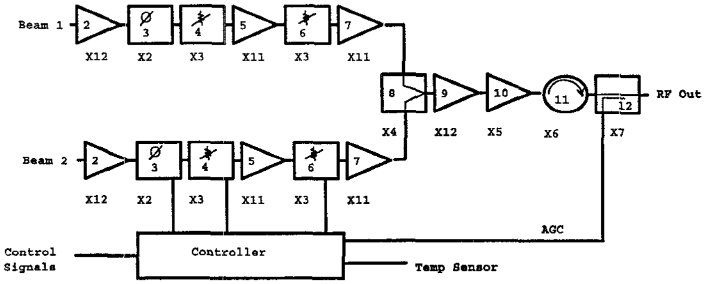

Figure 2. Block Diagram for 20 GHz Power MMIC Module

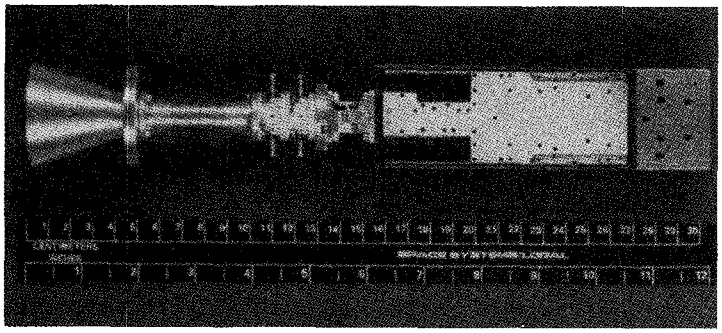

Figure 3. Photograph of Assembly of MMIC Module, Filter, Polarizer and Horn

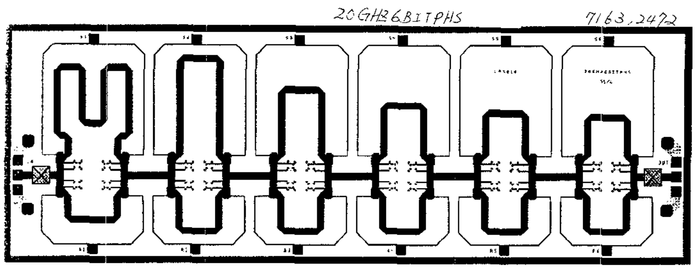

Figure 4. Layout for 20 GHz 6-bit MMIC Phase Shifter

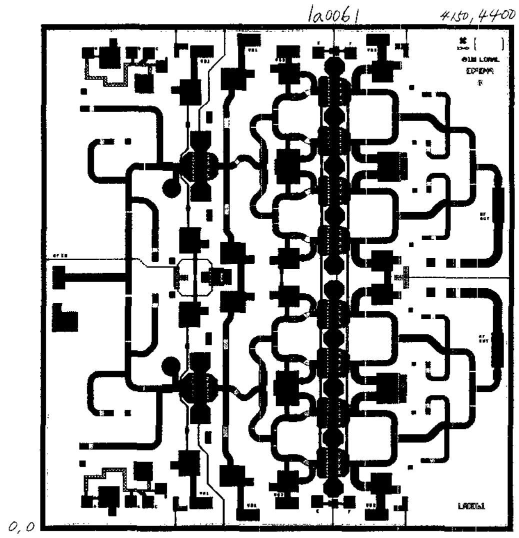

Figure 5. Layout for 20 GHz MMIC Power Amplifier

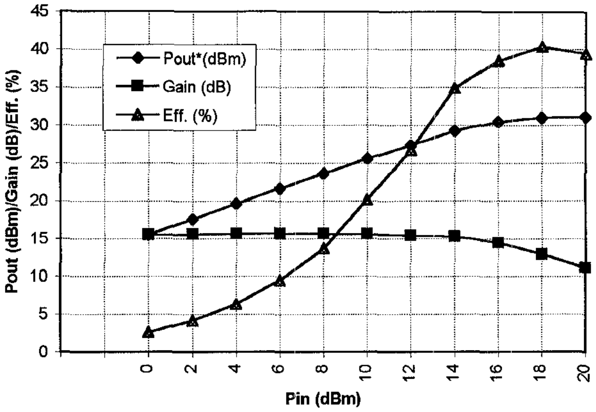

Figure 6. Measured Gain, Output Power and Efficiency for MMIC Power Amplifier

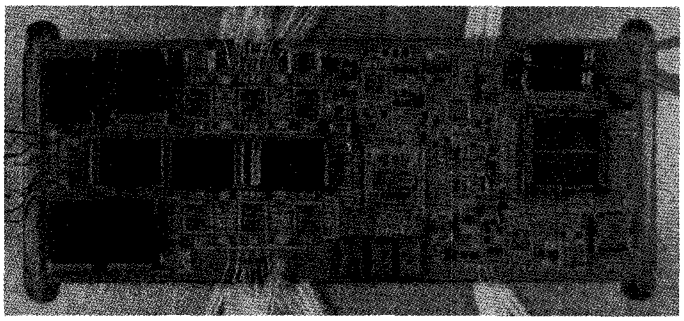

Figure 7. Photograph of Prototype Control Circuit

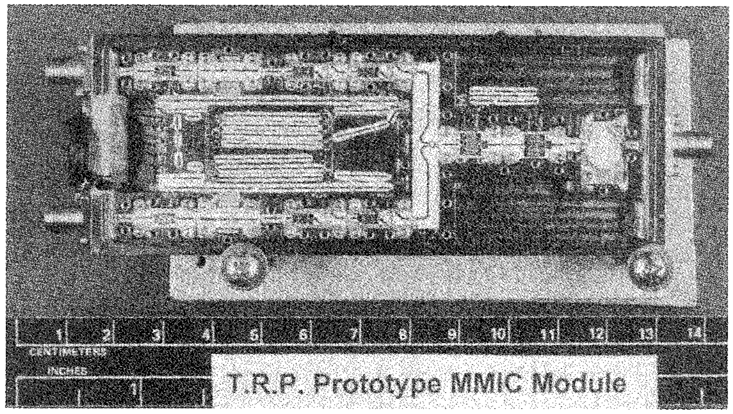

Figure 8. Photograph of Prototype Power MMIC Module

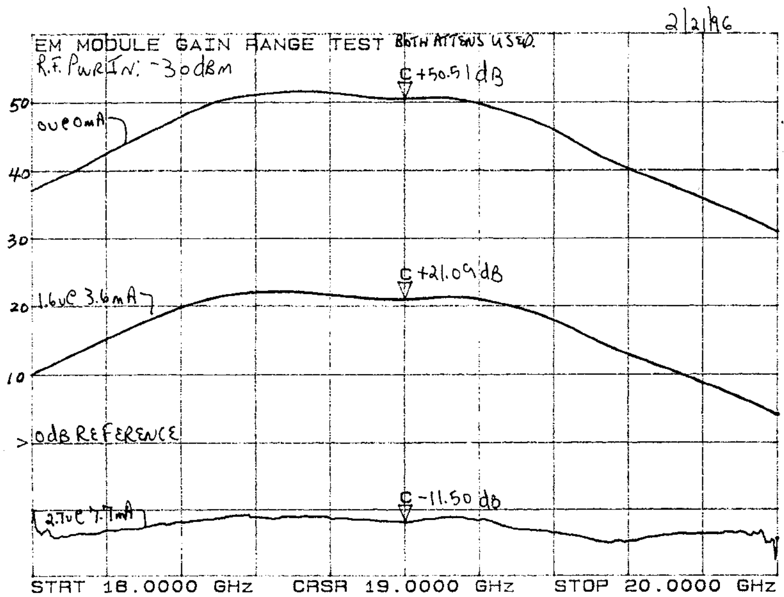

Figure 9. Measured Gain for Power MMIC Module

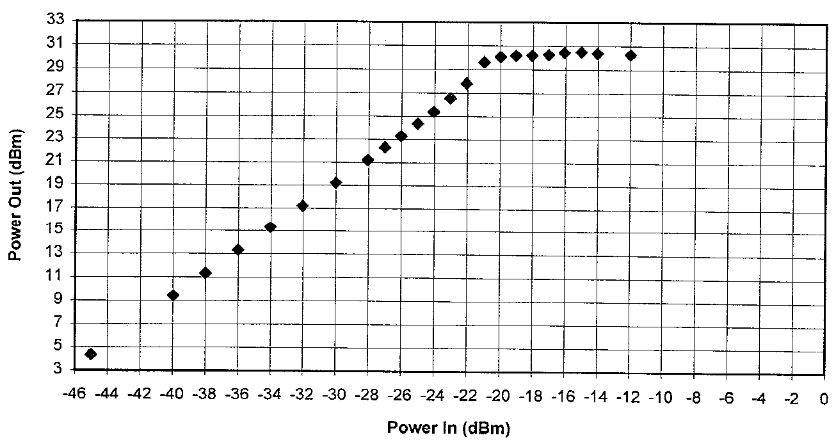

Figure 10. Measured Power Transfer Curve for Power MMIC Module