

Ultra Small Size X band MMIC T/R Module for Active Phased Array

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Toshiharu Sakai, Norio Takeuchi, Akihito Mizobuchi (*)
Yoshitada Iyama (**), Noriyuki Tanino (***)

MITSUBISHI ELECTRIC CORPORATION

(*) COMMUNICATION EQUIPMENT WORKS, Amagasaki, JAPAN

(**) ELECTRO-OPTICS AND MICROWAVE SYSTEM LABORATORY, Kamakura, JAPAN

(***) OPTOELECTRONIC AND MICROWAVE DEVICES LABORATORY, Itami, JAPAN

ABSTRACT

Ultra small size transmit/receive (T/R) module is reported with application to active phased arrays. By the application of GaAs MMIC technique and two storied stack structure, 130 prototype modules have been built each measuring 13×16.5×8 mm and weighting 10 grams. The average module transmit power is 1 watt and the receive noise figure is less than 4.7 dB in X band.

INTRODUCTION

Active transmit/receive (T/R) modules are the essential elements for the construction of active phased array antennas, with a broad range of applications for radars, communication and EW systems. The desirable attributes for T/R modules include wide band [1], small size and weight, and low cost [2]. The means to achieve these goals include single-chip MMIC [3], wafer integration [4].

What is reported here is an ultra small size T/R module prototype, with an emphasis reduction of array depth, to facilitate independently interchangeable construction when integrated into array antenna structure. A wide use of multi-function GaAs MMIC technique [5] and a two storied stack structure realize the module small enough to be placed parallel to array surface instead of perpendicular, and to enable substantial reduction in depth of the array structure.

T/R MODULE DESIGN

The prototype T/R module is shown in Fig. 1. It is small cubic in shape and measures 13×16.5

× 8 mm (excluding the connectors), and weighs 10 grams.

The block diagram of the T/R module is illustrated in Fig. 2. As shown in Fig. 2, the module consists of two sections, microwave circuit and control circuit, stacked on top of each other in a two storied structure. Each section is shown below.

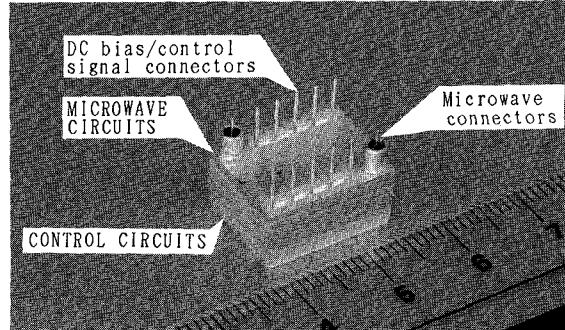


Fig. 1 External View of T/R Module

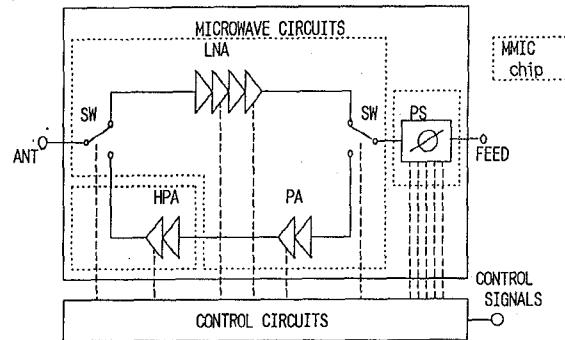


Fig. 2 Block Diagram of T/R Module

Microwave Circuit

Fig. 3 shows the microwave circuit. As shown in Fig. 2 and 3, the microwave circuit comprises the following three chips of MMIC.

- Multi-function MMIC chip
- Four-stage low noise amplifier for reception (LNA), two-stage medium power pre-amplifier for transmission (PA), and two input/output switches (SW).
- Phase shifter chip
- Lumped type five-bit phase shifter (PS)
- Power amplifier
- Two-stage amplifier for transmission (HPA)

Fig. 4 shows the multi-function MMIC chip pattern. The chip, 4.8×4.8 mm in size, has a pad for wafer probing at the I/O terminal, which enables microwave tests on wafer. The bias voltage of low noise amplifier or medium power amplifier in the multi-function MMIC can be set by trimming the resistor network built in the MMIC chip during wafer testing.

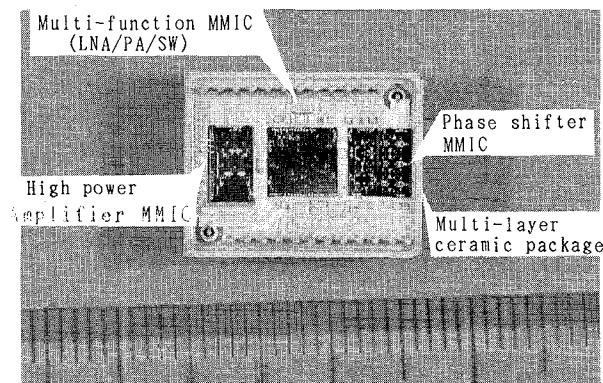


Fig. 3 Internal View of Microwave Circuit

These MMICs are housed in a metal-based multi-layer ceramic package.

On both sides of the package, there are two coaxial connectors for the interface with the antenna and 10 pins for the power supply and control. Also, there are 24 connector pins for the interface with the control circuits.

The microwave circuit measures $13 \times 16.5 \times 3$ mm, and weighs about 6.5 grams.

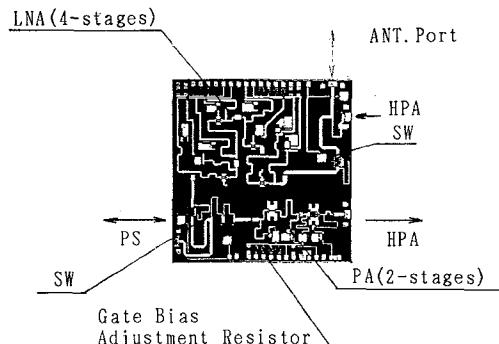


Fig. 4 Multifunction MMIC

Control Circuit

The control circuit has the following functions:

- Receives the control data from the external beam steering circuit.
- Controls the five-bit phase shifter.
- Controls the pulse operation of the transmit/receive amplifier.
- Controls the transmit/receive switching.
- Controls the above timing sequences.

The control circuit consists of a dedicated 6 k gate array LSI, IC for interface, several resistors, and several capacitor chips.

The control circuit is fabricated in a multi-layer ceramic package. Fig. 5 shows its appearance.

The control circuit measures $13 \times 16.5 \times 5$ mm and weighs about 3.5 grams. Control circuits are arranged in such a way that they are stacked under the microwave circuit package. The control of the microwave circuit, and the supply of external control signals and power are performed through the contact with 24 connector pins of the microwave circuit.

Antenna Installation

Fig. 6 illustrates the sectional drawing of antenna installation.

The antenna is made up of the following four layers.

- Antenna element layer
- RF manifold
- DC and control signal manifold
- Cooling manifold

T/R modules are arranged from the rear of the antenna like tilesetting. One coaxial connector of the T/R modules slides and comes in contact with the RF manifold connector to receive microwave signals. The other coaxial connector is joined to the antenna element connector. The control pins are joined to the connectors arranged on the dc and control signal manifold. The T/R module is cooled by bringing the module base plate into contact with the cooling manifold.

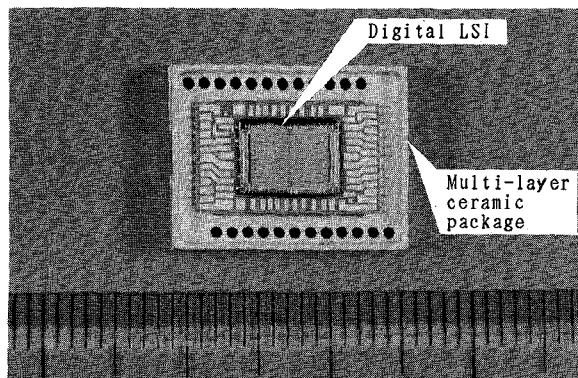


Fig.-5 Internal view of Control Circuit

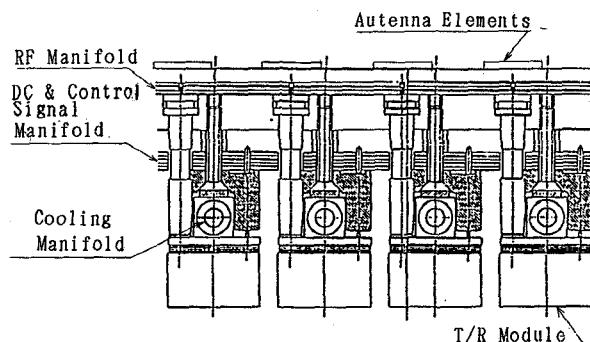


Fig.-6 Structure of Array Aperture

EXPERIMENTAL RESULTS

130 prototype X band T/R modules have been built, and their specifications and experimental results are shown in Table 1.

The characteristics of the average module transmit power are shown in Fig. 7, and the noise figure characteristics in Fig. 8.

The transmit peak power is 1 watt or more

at the 30 % duty. The transmit gain is 20 dB, and the noise figure is less than 4.7 dB. The receive gain is 20 dB. The phase accuracy is 6° rms or less for 32 phase positions in the transmit and receive modes.

Table-1 Module specification and Results

Parameters	Requirements	Results
Frequency	X-band	✓
Transmit Power	> 1 W	> 1 W (saturated)
Noise figure	< 5 dB	< 4.7 dB
VSWR	< 2.5	< 2.2
Transmit Gain	> 18 dB	> 20 dB
Receive Gain	> 15 dB	> 20 dB
Phase sifter	5 bits	✓
Phase accuracy	< 8 deg. rms	< 6 deg. rms
Size	< 13 × 17 × 10 mm	13 × 16.5 × 8 mm
Weight	< 13 g	10 g

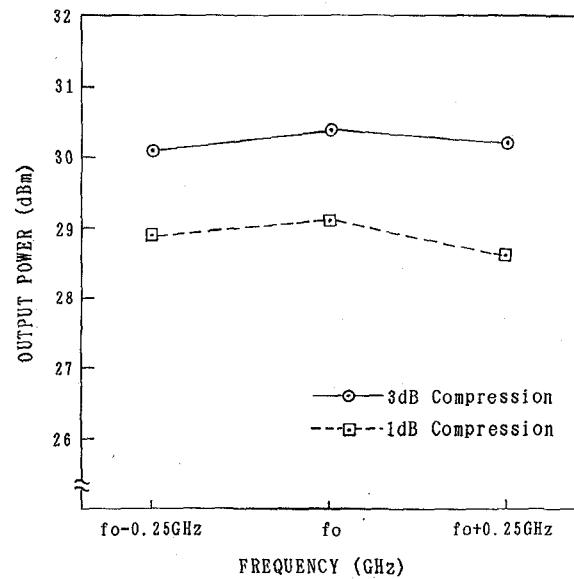


Fig.-7 Output Power of T/R Module

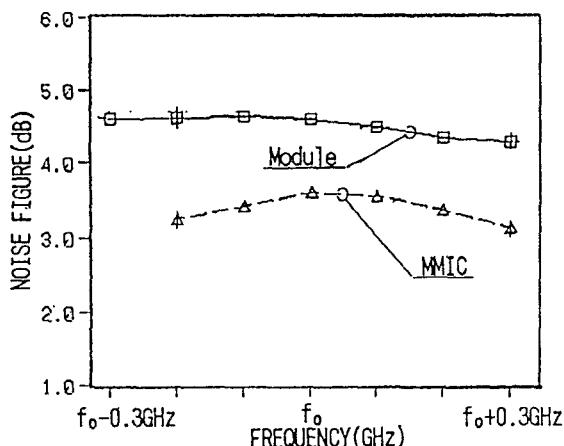


Fig. -8 Noise figure of T/R module

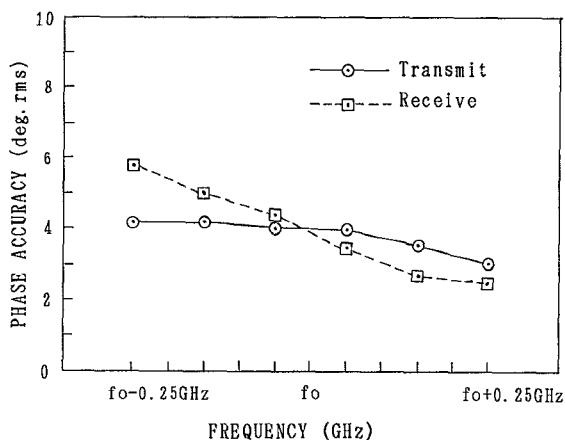


Fig. -9 Phase Accuracy of T/R Module

CONCLUSION

Prototype X band ultra small size T/R module have been built for installation into active phased array with a substantial reduction in depth and of independently interchangeable structure.

Further evaluation of antenna performance using these modules is in planning stage.

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