GaAs MMICs for use in Upconverter module for Ka-band OBS Satellite Transponders

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***Abstract* — GaAs MMICs has been developed for use in the Upconverter module for On-Board Switching Ka-band Satellite Transponders. There are four kinds of MMICs: an S-band Medium power amplifier, a K-band Medium power amplifier, an S to K-band Mixer, and X to Ku-band frequency doubler. The four chips have been fabricated on a wafer using 0.15um GaAs p-HEMT technologies. A Upconverter module using the MMICs with a function of the frequency conversion from 3GHz to 20GHz has been developed and showed the RF performance of the 17.1±0.2dB conversion gain, the 0.2nsp-p group delay, the 46.67dBc C/IM$_3$, and 1.15:1 In/Out VSWR.**

I. INTRODUCTION

The development of MMIC family on a wafer for satellite transponders can provide several advantages [1] including a reduction of the cost for the up-screen process. In this paper presents the development of four kinds of MMICs. MMIC chip sets of an S-band medium power amplifier, a K-band medium power amplifier, an S to K-band Mixer, and X to Ku-band doubler for the Upconverter module have been designed and fabricated on a wafer using 0.15um GaAs p-HEMT technologies. Each MMIC has been performed on-wafer tests.

A high-capacity satellite communication system requires onboard signal processing [2] which includes switching of RF signals between multiple antennas to provide interconnection between the uplink and downlink beams [3]. This paper also presents the development of the Upconverter module for the On-Board Switching Ka-band Satellite transponders using the four kinds of MMICs. Its main function is the frequency conversion from 3.2~3.6GHz of operating band of a Microwave Switch Matrix to 19.8~20.2GHz of downlink band of the transponders.

The Upconverter is 2 for 1 internally redundant. Fig. 1. is a functional block diagram of the Upconverter module. It spatially involves an S to K-band frequency converting block including a LO doubling block. Internal frequency doublers in the upconverter module can simplify a local oscillator (LO) module. Main RF performances of the upconverter module have been measured to the conversion gain of 17.1±0.2dB, the group delay of 0.2 ns p-p, the C/IM3 of 46.67dBc with two carriers each at input level of -29dBm, and In/Out VSWR of 1.15:1.

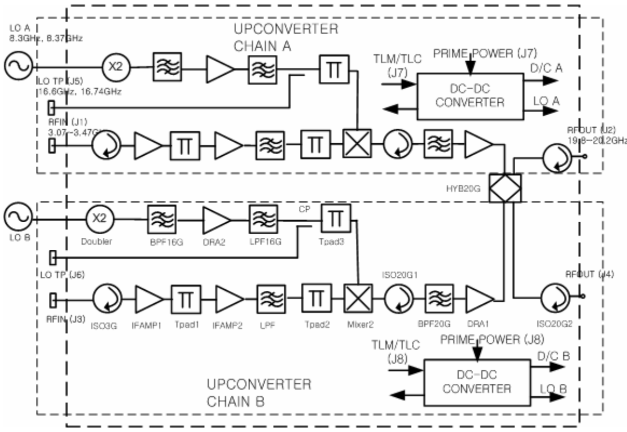
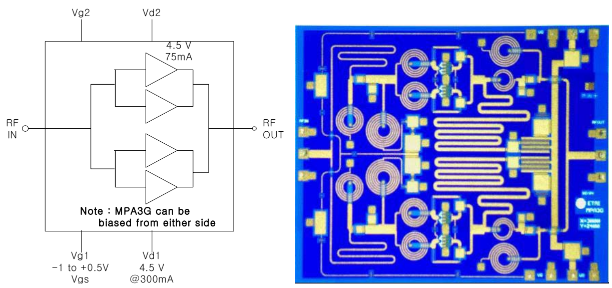


Fig. 1. Functional block diagram of the Upconverter module.

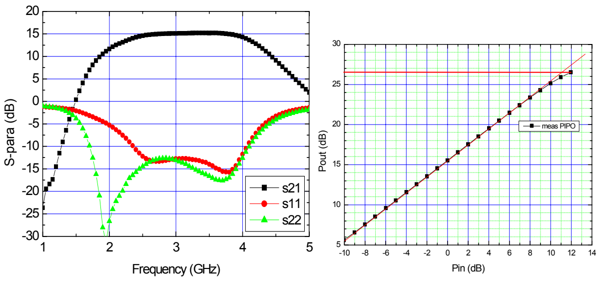
II. MMIC DESIGN

Four kinds of MMICs have been designed and fabricated on a wafer using a 0.15um GaAs p-HEMT technology. The individual circuit designs and performance are described as follows.

A drop-in isolator places on RF input ports for improving the input VSWR of the upconverter module. Following the isolator is two MMIC S-band medium power amplifiers (MPA3G). This MMIC employs a power matched single stage configuration using an R-C shunt feedback to get a wide band performance. The chip size was 3.0mm x 2.4mm. Its nominal gain and P1dB were 15dB with the gain flatness of 0.1dBp-p at 2.5~3.9 GHz and 26.5dBm at 3.4GHz, respectively. The block diagram, the photograph, and on-wafer test results of S-parameter and P1dB are shown in Fig. 2.



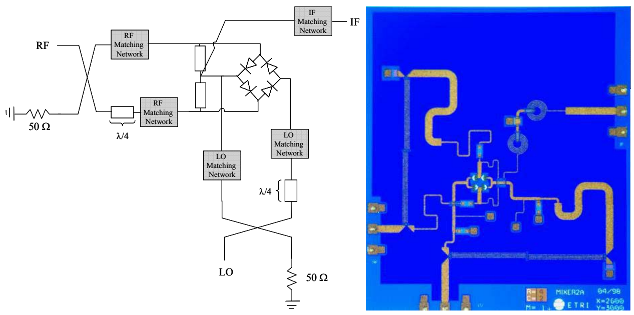
(a) Block diagram (b) Photograph



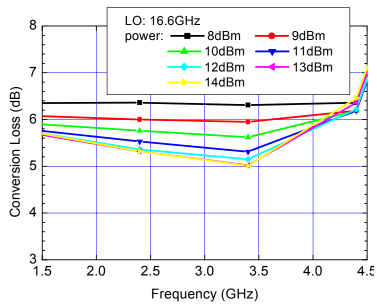
(c) S-parameter (d) P1dB

Fig. 2. Performance of the S-band medium power amplifier (MPA3G)

An S to K-band upconverting mixer has been designed with the configuration of double balanced type using p-HEMT diodes. For the design of the RF and LO baluns, the configuration of the Lange couplers followed by 90 degree line were adapted. The chip size was 2.6mm x 3.0mm. Fig. 3. shows the block diagram, the photograph, and on-wafer test results. The conversion loss was achieved 6dB on the frequency conditions of 16.6GHz LO and S-band RF. This MMIC was placed between a ThermoPad® and a K-band drop-in isolator. Gain temperature compensation has been achieved using two thermal attenuators (ThermoPad®). The K-band drip-in isolator was used for improving gain flatness of the upconverter module.



(a) Block diagram (b) Photograph

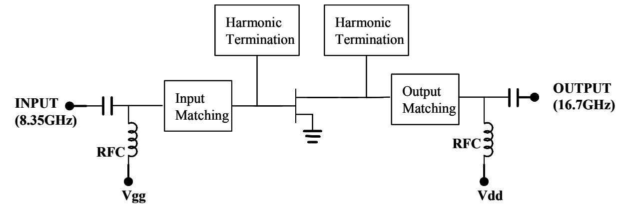


(c) Conversion loss

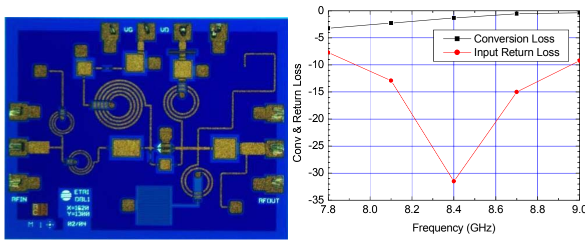
Fig. 3. Performance of the S to K-band upconverting mixer (Mixer2)

An X to Ku-band doubler has been designed with the configuration of an active multiplier to minimize power dissipation. The chip size was 1.62mm x 1.3mm. The block diagram, the photograph, and on-wafer test results are shown in Fig. 4. The conversion loss of doubler was 1.5 dB at the 8.3 GHz input frequency and 8 dBm input power. The 3 dB bandwidth was from 16 to 20 GHz which corresponds to 22%. Fundamental suppression was over 15 dBc and 3rd harmonic suppression was over 25 dBc at 16.6 GHz output frequency for 8 dBm input power.

This MMIC was placed on the LO input port of the upconverter module.



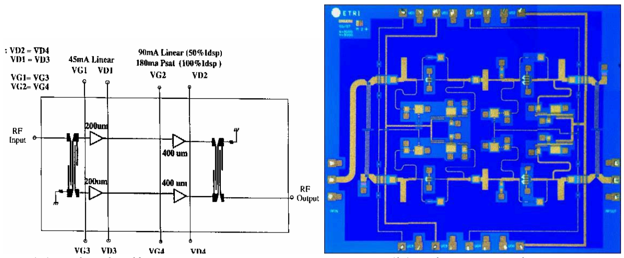
(a) Block diagram



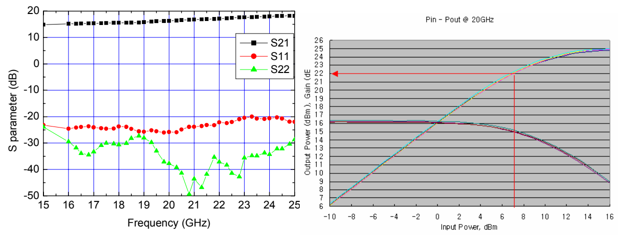
(b) Photograph (c) Conversion loss and Return loss

Fig. 4. Performance of the X to Ku-band Doulber (DBL1)

A K-band medium power amplifier has been designed. This MMIC employs a power matched two-stage configuration. The chip size was 3.6mm x 3.0mm. Fig. 5. shows the block diagram, the photograph, and on-wafer test results. The small signal gain and P1dB were 15dB and 22dBm, respectively, at the operating frequency of 16.6GHz to 20GHz. The MMIC was used in two sites. The output signal of the MMIC doubler is passed through a microstrip band pass filter with the pass band of 16GHz and this K-band medium power amplifier. Also upconverted signal of MMIC Mixer is passed through a microstrip band pass filter with the pass band of 20GHz and this MMIC amplifier.



(a) Block diagram (b) Photograph



(c) S-parameter (d) P1dB

Fig. 5. Performance of the K-band medium power amplifier (DRA)

III. Assembly and Measurement of Upconverter

Fig. 6. shows the picture of the one chain assembled upconverter module. It consists of four kinds of MMICs, two types of drop-in isolators for improving the performance of VSWR and gain flatness, three ThermoPads® for temperature compensation, and thin-film components for a signal filtering and a connection between adjacent components. The thin-film components were fabricated with 15mil Alumina substrates. Kovar carriers were used for assembly of the MMICs. The MMIC carriers were assembled with screws in the module. Thin-film components were fixed using a silver epoxy process. The DC bias board on the rear side of the module and active RF components on the front side were connected through EMI filters. Three kind covers of an inner cover for RF isolation, an outer cover for laser sealing at the RF side, and a DC cover for epoxy sealing at the DC side were used. The total mass including three covers was 480g. The assembly process and performance test was accomplished on the basis of the rules related to the production of space components [4], [5].

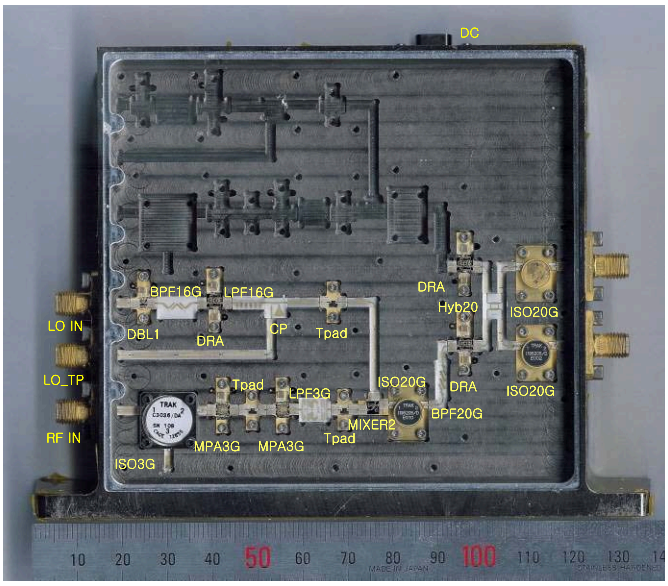


Fig. 6. Picture of the Upconverter module (Redundancy chain except K-band medium power amplifier at the output was not assembled in this module)

Fig. 7. shows the measured conversion gain performance of the upconverter. The conversion gain over the operating frequency range was 17.1 dB ± 0.2dB at ambient temperature. Over any 100 MHz band, the gain did not vary more than 0.3 dB. The gain slope at any operating frequency did not exceed 0.01 dB/MHz. Fig. 8. shows the group delay performance. The group delay variation in any 100 MHz band within the range of the operating frequency did not exceed 0.2 ns p-p. The group delay ripple for any 100 MHz band did not exceed 0.05 ns p-p. With two carriers each at input level of -29 dBm and 4MHz separation, the carrier to the third order Intermodulation ratio (C/IM_3) was 46.67dBc. Fig. 9. shows the IMD3 performance of the upconverter. Fig. 10 shows the input and output VSWR of 1.15:1.

IV. Conclusion

This paper describes the development of the GaAs MMICs used in Upconverter module for On-Board Switching Ka-band Satellite Transponders. MMIC chip sets of an S-band medium power amplifier, a K-band medium power amplifier, an S to K-band mixer, and X to Ku-band doubler for the Upconverter module have been designed and fabricated on a wafer using GaAs p-HEMT technologies. Using the MMICs with the good on-wafer test results the Upconverter module has been developed. The Upconverter module has internal redundancy and LO doubling block. All measured results comply with the requirements of the Upconverter for Satellite transponders.

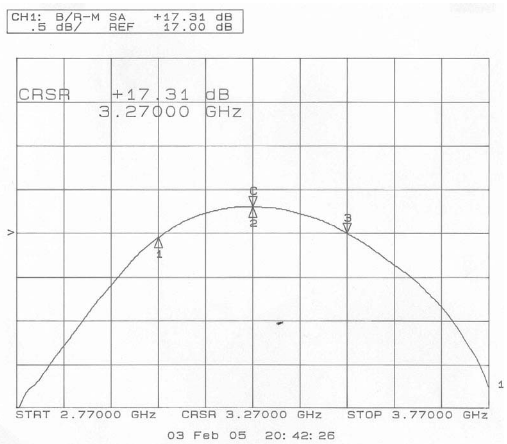


Fig. 7. Conversion gain performance

Fig. 8. Group delay performance

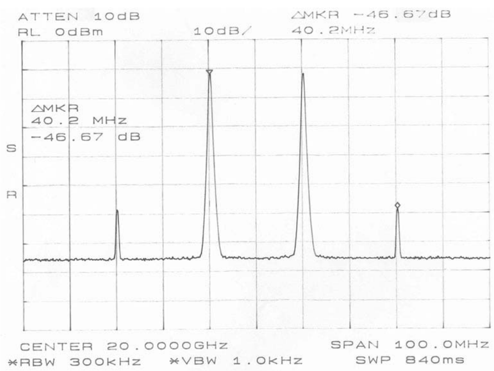


Fig. 9. Third order Inter-modulation ratio (IMD3)

(a) Input VSWR

(b) Output VSWR

Fig. 10. VSWR performance

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