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WIDEBAND GaAs MMIC RECEIVER

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ABSTRACT

A wideband GaAs MMIC receiver module has been developed using half-micron gate MESFET technology. The fabrication process used is optical lithography with ion-implanted undoped LEC GaAs wafers. The module consists of three generic monolithic chips: an RF amplifier, an IF amplifier, and an image rejection filter which is integrated on a dual-gate MESFET mixer chip. The RF input frequency is 6 to 10 GHz and the IF output is at 3 GHz. Test results have shown an overall conversion gain of more than 20 dB, and less than a 5.5 dB noise figure. The isolation between RF and IF ports is better than 22 dB, between LO and IF is more than 30 dB, and between LO and RF isolation is 20 dB. The DC functional yield of more than 70-80% has also been achieved for each chip type.

INTRODUCTION

GaAs Microwave Monolithic Integrated Circuits (MMICs) have promised high potential for reducing system cost. The objective of the receiver design is to develop a low cost module using generic circuits for wide-band operation covering X-band frequencies. The design is aimed toward communication and EW high volume applications.

In this paper the reported receiver module uses identical material and fabrication for processing all three chips. The module development is discussed. The design, fabrication, and test results of each submodule chip, as well as the complete receiver module, will be described. This is the first wide-band receiver module using all GaAs MMIC chips reported at X-band frequencies. This work is the first step toward the integration of a complete receiver module on a single chip.

RECEIVER MODULE DESIGN

A block diagram of the module is illustrated in Figure 1. The RF amplifier at the front end receives the signal from 6 to 10 GHz, a dual-gate MESFET mixer down-converts the RF signal to an IF frequency of 3 GHz by using a 9 to 13 GHz local oscillator. The image-rejection low-pass filter uses passive L-C components to suppress unwanted signals at the mixer output port. The IF amplifier is used to provide proper signal level. The design goal is 20 dB conversion gain.

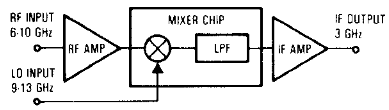

Figure 1. Block Diagram of MMIC Receiver Module

All three monolithic chips have been successfully developed, fabricated, and directly integrated into a receiver module as shown in Figure 2. The design, process techniques, and test results of each chip, and the integration of a receiver are reported separately as follows.

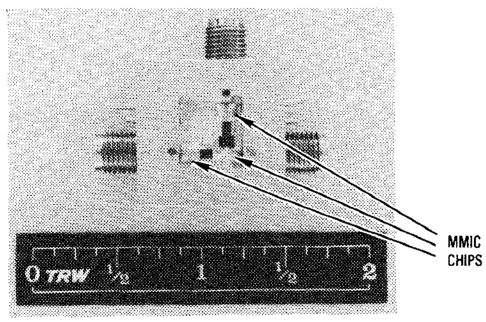

Figure 2. Photograph of Receiver Module

RF AMPLIFIER

The RF amplifier uses two 0.5 X 300 micron MESFETs. The process uses optical lithography on silicon ion-implanted LEC substrate. A photograph of the chip is shown in Figure 3. MIM capacitors with plated air-bridge crossover were used in both DC blocking and RF by-pass applications. Spiral inductors and via-hole ground were used to provide self-bias for the amplifier. The input and output pads were formatted to provide access for on-wafer RF probing. Feedback was used in the circuit design to improve match and reduce sensitivity due to process variations. The amplifier test result is depicted in Figure 4. It has a typical gain of 12 dB from 6 to 10 GHz and better than 10 dB return loss at both input and output ports. The same processing technique and material is used to fabricate the mixer and the IF amplifier.

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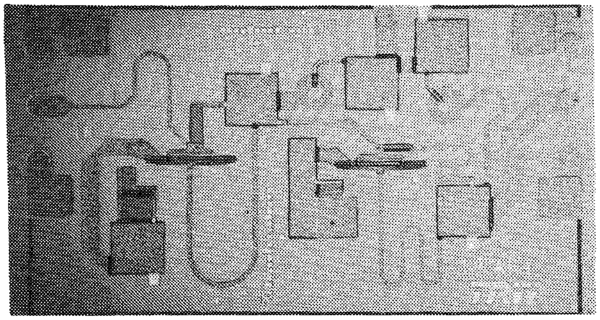

Figure 3. Photograph of RF Amplifier

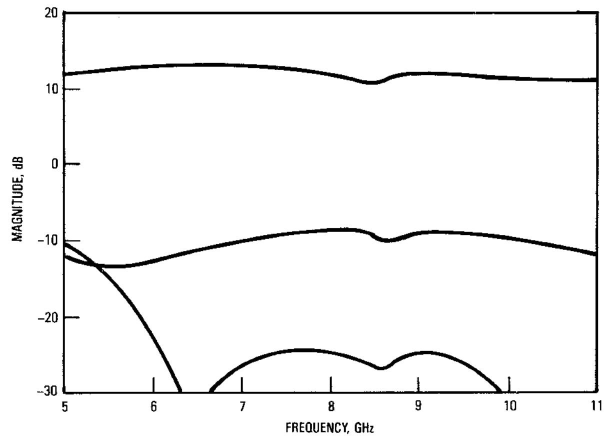

Figure 4. RF Amplifier Test Results

DUAL-GATE MESFET MIXER

The MMIC mixer consists of both lumped and distributed RF, LO, and IF matching circuits and low-pass filter. It uses a dual-gate 0.5 X 300 micron MESFET, and is shown in Figure 5. A low-pass filter circuit was incorporated at the output port to suppress RF and LO signals by using MIM capacitors and spiral inductors. Via-hole ground is also used to reduce source grounding inductance and parasitics. The mixer has an RF frequency range of 6 to 10 GHz and uses LO from 9 to 13 GHz to produce 3 GHz IF signals. The average conversion loss is 7 ± 1.5 dB across band. Figure 6 shows the measured mixer conversion loss. The measured isolation is depicted in Figure 7. Figure 8 shows the RF input power versus the IF output power.

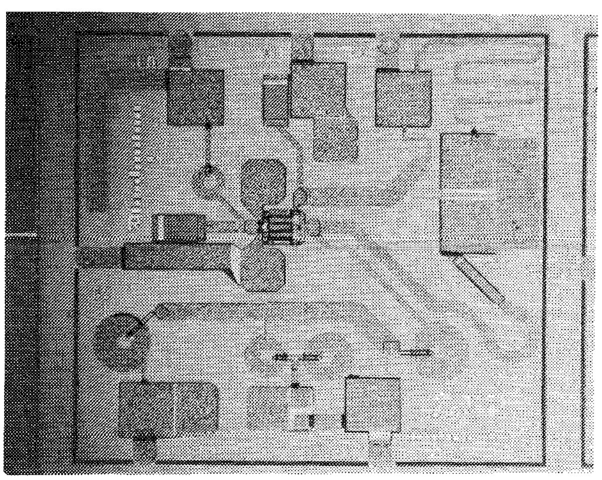

Figure 5. Photograph of Dual-gate MESFET Mixer

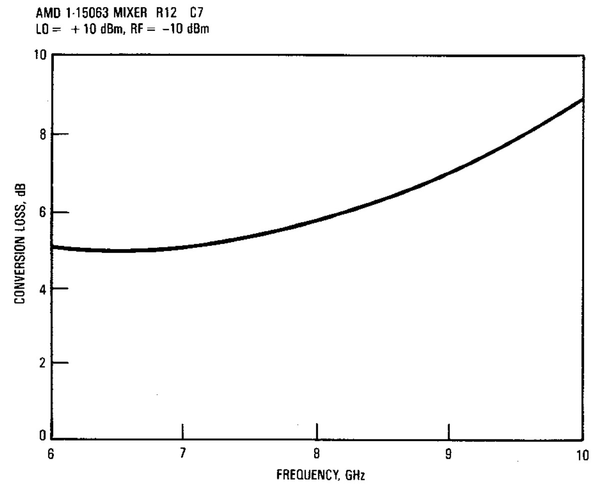

Figure 6. Mixer Conversion Loss Vs. RF Frequency

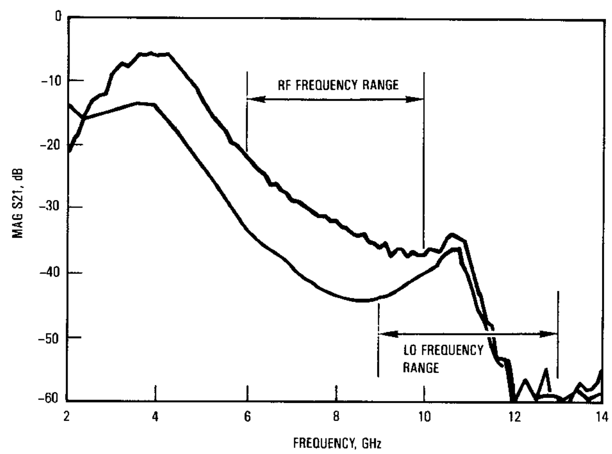

Figure 7. Mixer RF and LO to IF Isolation

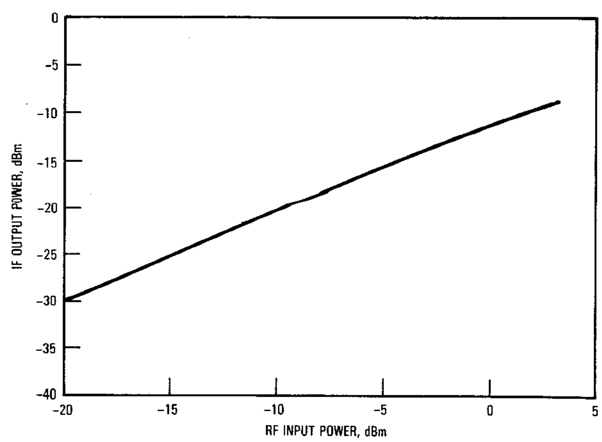

Figure 8. Mixer IF Output Vs. RF Input Power

IF AMPLIFIER

A two-stage feedback amplifier was designed to operate from 1.5 to 5 GHz. The chip photograph is shown in Figure 9. The amplifier uses two 0.5 X 600 micron gate MESFET. Square spiral inductors were used to provide the high inductance required at low frequencies with minimum area. MIM capacitors were used for RF bypass and DC blocking. Self-bias circuit design was used to reduce the complexity of testing and assembly into receiver modules. RF on-wafer probing pads were also provided for RF screening before inserting parts into module. Via-hole grounding though 0.1 mm substrate was used to aid layout flexibility and reduce parasitic grounding inductance. Test results have indicated that the IF amplifier has an average gain of 15 dB, and better than 10 dB return loss at both input and output ports across band, as shown in Figure 10.

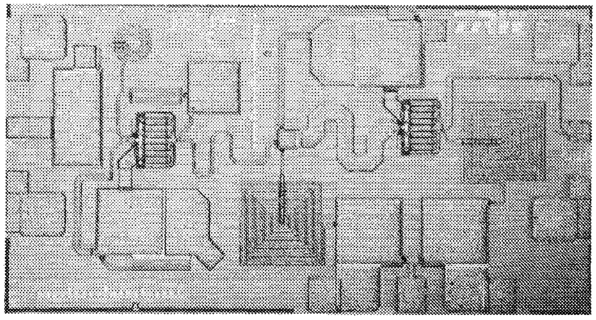

Figure 9. Photograph of IF Amplifier

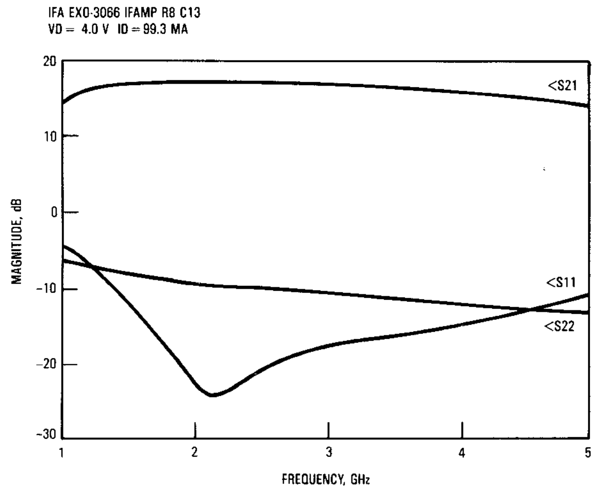

Figure 10. IF Amplifier Test Result

RECEIVER MODULE INTEGRATION

All three MMIC chips were integrated into a hybrid module for testing. A photograph of module chip assembly is shown in Figure 2. The test results are shown in Figure 11. The overall conversion gain is 20 ± 2 dB, and the match at all three ports is better than 2:1 VSWR. All chips have DC blocking capacitors for direct wire bonding. A new module fixture is being designed to eliminate the hybrid connecting lines and further reduce the module size. Both the RF and IF amplifier chips have the RF on-wafer test pads and were 100 percent screened before insertion into the module to enhance the module yield. A three-port RF on-wafer test system is being developed and will be used to perform the same screening on mixers.

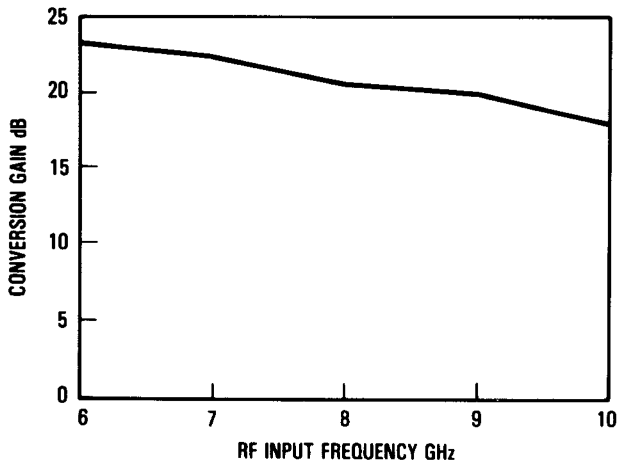

Figure 11. Communication Receiver Module Conversion Gain Vs. RF Frequency

CONCLUSION

Three MMIC chips have been developed for the wide-band monolithic module. This is the first wide band receiver module using all GaAs MMIC chips at X-band frequencies. The module demonstrated more than 20 dB conversion gain. The chips were designed to use the same processing technology and ion-implanted material so that they can easily be integrated into one chip for the entire receiver module. The DC functional yield of all three chips averaged from 70 to 80 percent which includes MIM capacitors, spiral inductors, and thin film resistors. With the integration and testing considerations incorporated into the circuit design, this reported work has enhanced the potential for high volume, low cost production of the GaAs MMIC.