A HIGHLY COMPACT, WIDEBAND GaAs HEMT X - Ku BAND IMAGE-REJECT RECEIVER MMIC

R. Katz, M. V. Aust, R. Kasody, H. Wang, B. Allen,
G. S. Dow, K. Tan, S. Lin, R. Myers

TRW
Electronics Technology Division
One Space Park, Redondo Beach, CA. 90278

ABSTRACT

A fully integrated MMIC receiver was designed and fabricated using the 0.2μm pseudomorphic InGaAs/GaAs HEMT process technology. This MMIC receiver incorporates a single-stage RF amplifier, a two-staged balanced LO amplifier, a single-stage IF amplifier, an IF switch and an image-reject diode mixer.

Results from these receiver chips showed good conversion gain and image rejection in a single small chip over multi-octave frequencies. This chip operates from a single +5 Vdc and draws 280 mA. Total chip size is 5.5mm x 4.5mm.

INTRODUCTION

As shown in the past, advances in monolithic integrated circuit technology has made it possible to develop very complex MMIC circuits in a single small sized chip. These advances allow the integration of a number of smaller microcells to form a multiple function macrocell.

This paper presents the successful design, fabrication, and test of X and Ku band Image Reject receiver chip. The receiver downconverts and input X- to Ku-band frequency to an S-band IF frequency, while rejecting the image of the input RF frequency [1]. The operating RF frequency range is 10 to 18 GHz with low side LO injection and measured conversion gain of 7 to 10 dB and image rejection of 16 to 40 dB. The other RF frequency range is 8 to 12 GHz with high side LO injection and measured conversion gain of 9 to 10.5 db and image rejection of 13 to 25 dB.

RECEIVER DESIGN

The receiver consists of five single-function microcells: RF amplifier, IF amplifier, LO amplifier , IF switch and Image Rejection diode mixer using 0.2 mm T-gate pseudomorphic InGaAs HEMT device technology. Figure 1 shows the Image Reject Receiver circuit functional block diagram. Figure 2 shows a photograph of the chip. All active circuits require +5Vdc to operate. The macrocell's dimensions are 5.5mm by 4.5mm.

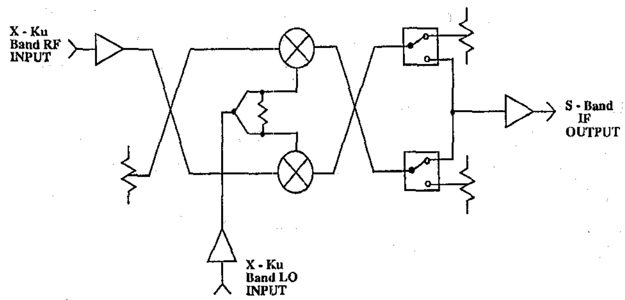

Figure 1 : Block diagram of MMIC image rejection receiver chip

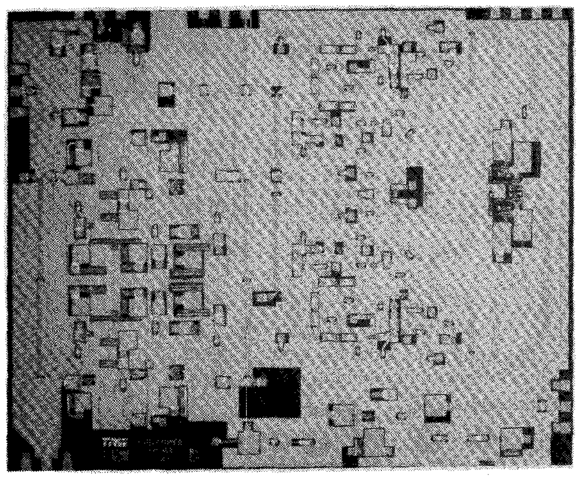

Figure 2 : Fabricated MMIC image rejection receiver chip

RF AMPLIFIER

Figure 3 shows the circuit schematic of the RF amplifier. It is a single-stage amplifier with a 200-μm 0.2μm HEMT. The FET is biased at 75% gmpk , Id=37mA. The amplifier uses a feedback topology and is self-biased. The RF amplifier operates 8 to 18 GHz with a gain of 8dB and noise figure of 3 dB at 18 GHz.

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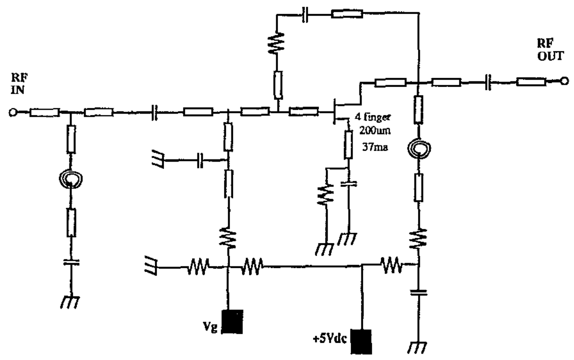

Figure 3 : RF amplifier schematic

LO AMPLIFIER

The LO amplifier operates over a range of 7 to 18 GHz with a gain of 15dB at 13 GHz and is self-biased. As seen in Figure 4, the LO amplifier is a balanced two-stage amplifier with 200µm and 400µm 0.2µm HEMT respectively. The stages are biased at 75% gmpk, Id = 37.5mA and 70mA respectively. The amplifier uses a lossy match to assure a flat wideband frequency response. The LO amplifier has an external tuning port for modification of the bias currents.

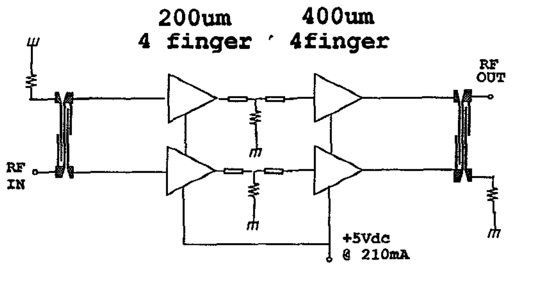

Figure 4 : Balanced LO amplifier block diagram

IMAGE-REJECT MIXER

The image rejection mixer consists of two 8 to 18 GHz single balanced diode mixers, with RF and IF ports connected by lange couplers [2-3], as seen in Figure 5. The LO is supplied through a lumped element Wilkenson power divider. The single balanced mixer consists of a lumped element 180^{o}-balun, shared by the RF and LO, and appropriate high pass matching networks [4-5]. The IF is extracted through a low pass IF filter. The mixer uses 36µm 0.2µm HEMT Schottky diodes as mixing elements. The balun, Wilkenson power divider, and matching networks/filters were realized as combinations of transmission lines, spiral inductors and MIM capacitors. A meandered Lange coupler was used at the IF outputs to minimize the chip dimensions. The mixer has conversion loss of 10dB.

IF SWITCH

The IF switch, shown in Figure 6, consist of two single-pole double throw (SP2T) switches, using

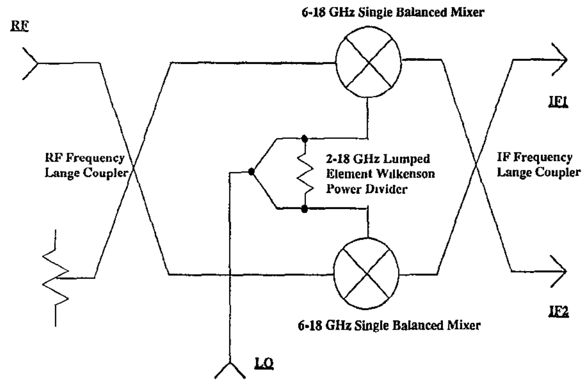

Figure 5 : Image reject mixer block diagram

200µm 0.2µm HEMT. The switches operate from 2.5 to 4 GHz (S-band) and has conversion loss of 1.5 dB.

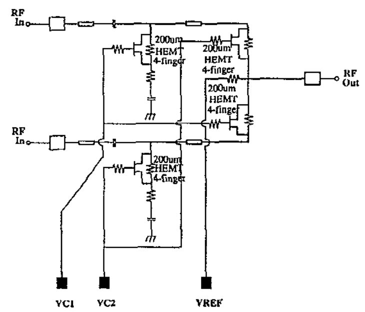

Figure 6 : IF switch schematic

IF AMPLIFIER

Figure 7 shows the IF amplifier. It is a single-stage feedback amplifier, which operates from 2 to 6 GHz with gain of 10 dB at 4GHz and is self biased. The amplifier uses a 200µm 0.2um HEMT, and is biased at 75% gmpk, ID=37.5mA.

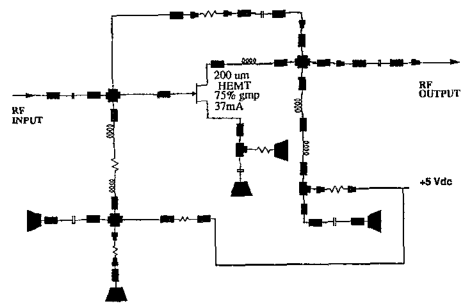

Figure 7 : IF Amplifier schematic

FABRICATION

The receiver was fabricated using one of TRW's readily available FOUNDRY processes for 0.2µm Low Noise HEMT. TRW's processes include Low Noise, High Linearity and Power processes for variations of 0.1mm, 0.15µm and 0.2µm HEMT; 0.25µm and 0.5µm MESFET and 1µm, 2µm and 3µm HBT.

RF PERFORMANCES

On-Wafer RF-tests were done for the receiver from 1 wafer. The parameters tested include conversion gain and image rejection for both Ku and X band inputs. Figure 8 shows the conversion gain of one site with the RF input of 10-17 GHz and an IF of 2.5 GHz. The measured conversion gain is 6.8-10.2 dB. Figure 9 shows the measured image frequency (5-12 GHz) rejection performance. A minimum image rejection of 15.5 dB is achieved, with typical performance greater than 18-22 dB. Figure 10 shows the conversion gain with the RF input of 8-12 GHz and an IF of 2.5 GHz. The measured conversion gain is 9.4 - 10.5 dB. Figure 11 shows the measured image frequency (13-17 GHz) rejection performance. A minimum image rejection of 13 dB is achieved, with typical performance greater than 20 dB.

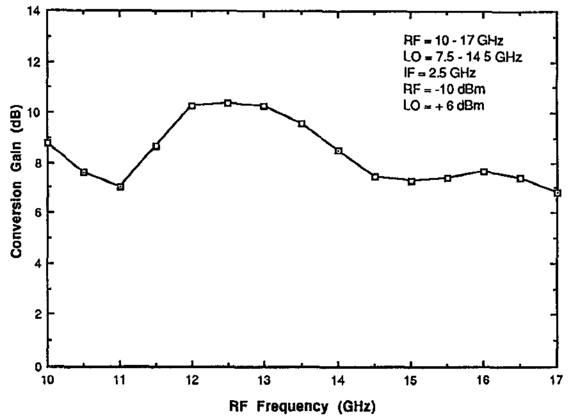

Figure 8 : Receiver conversion gain band 1

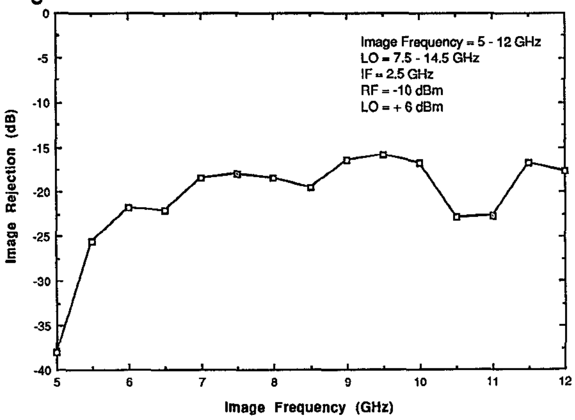

Figure 9 : Receiver image rejection band 1

Significant microcell data for the 6-18 GHz single balanced mixer is shown in Figures 12 and 13. Conversion loss with RF frequencies of 10-18 GHz, LO of 7.5-15.5 GHz and IF=2.5 GHz is 8.5-12 dB. For the second frequency band, RF of 8-13 GHz, LO of 10.5-15.5 and IF=2.5 the conversion loss is 9.1-11.2 dB.

The Image Reject Receiver uses an 8-18 GHz low noise amplifier at its front end. This amplifier is actually a two-staged balanced amplifier with a switch determining usage of amplifier or thru path. Figure 14 shows the circuit block diagram. This amplifier was

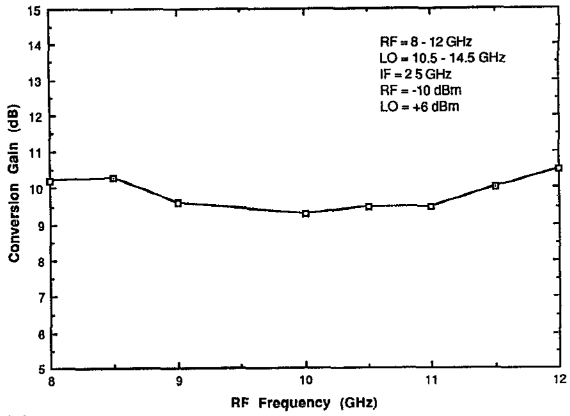

Figure 10 : Receiver conversion gain band 2

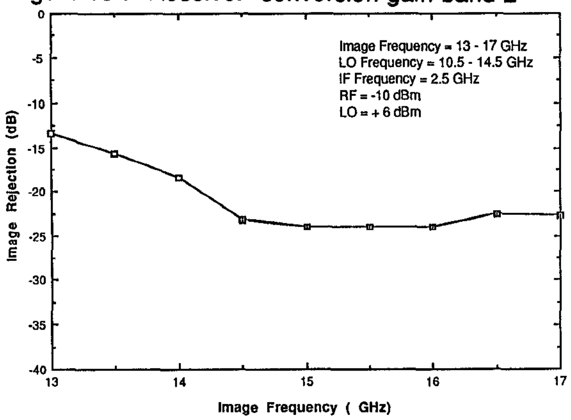

Figure 11 : Receiver image rejection band 2

RF=-10 dBm LO=14 dBm IF=2.5 GHz

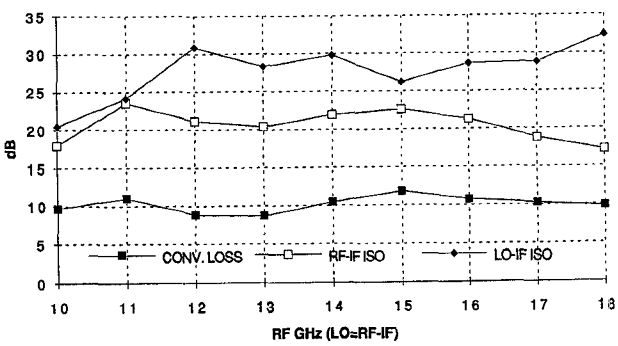

Figure 12 : Single balanced mixer conversion gain band 1

processed on the same wafer as the receiver chip. Figure 15 shows the chip layout. It had excellent measured performance of 16.5-20.5 db gain and less than 1.7 dB noise figure over the required frequency range (Figure 16).

CONCLUSIONS

A highly compact GaAs HEMT X-Ku-band image rejection receiver has been demonstrated. Good to excellent image rejection has been demonstrated in a very densely packed MMIC. These

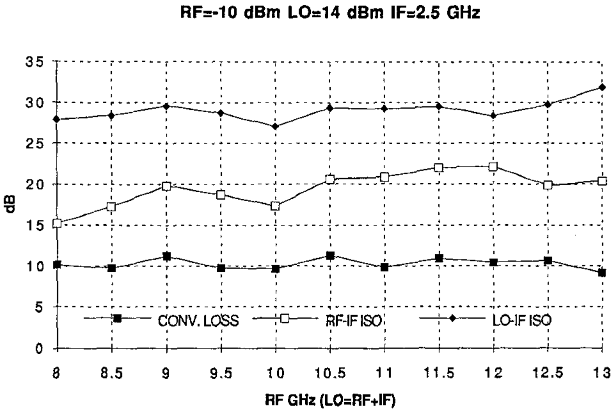

Figure 13 : Single balanced mixer conversion gain band 2

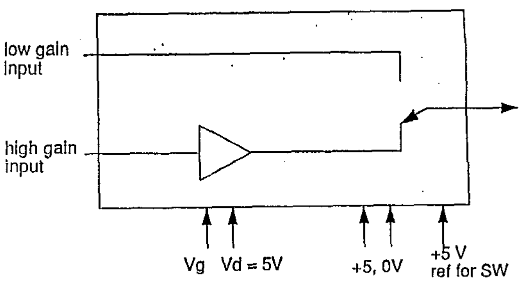

Figure 14 : 8-18 Low noise amplifier schematic

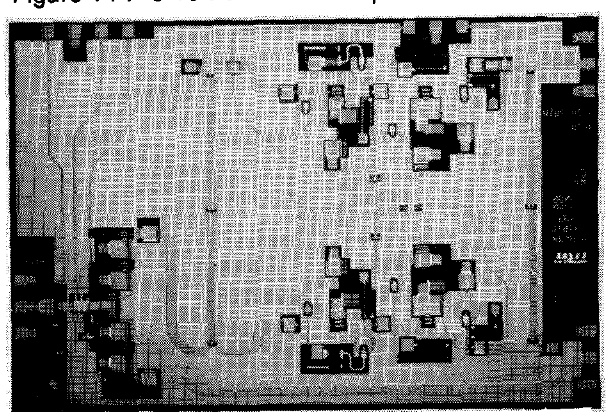

Figure 15 : Fabricated MMIC 8-18 Low noise amplifier

results demonstrate the ability to produce small and complex multifunctional MMIC components.

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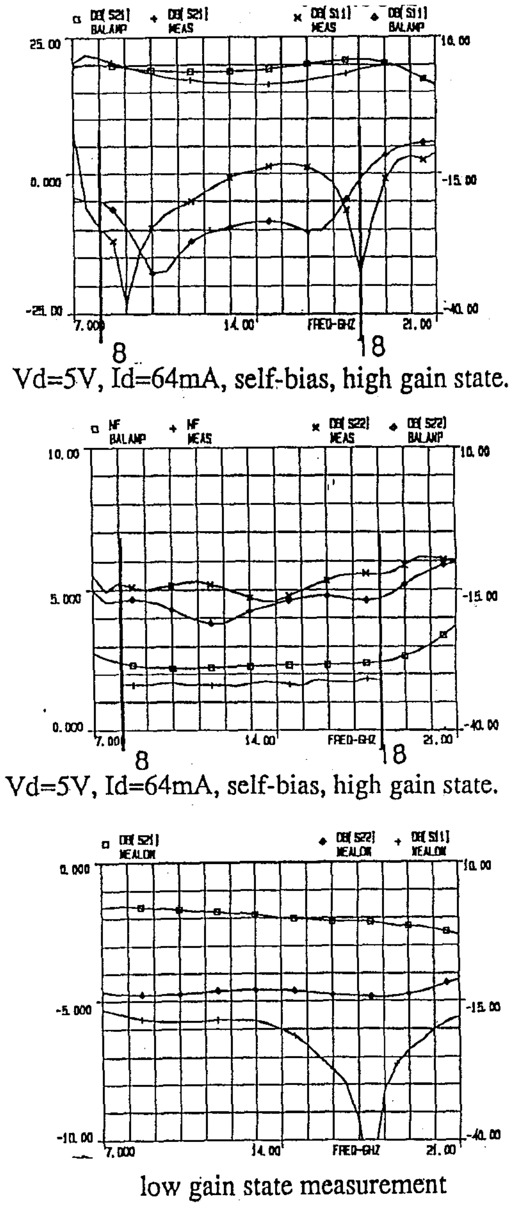

Figure 16 : 8-18 Low noise amplifier performance

REFERENCES

[1] M. V. Aust, et al, 'A Highly Compact, Wideband GaAs MESFET X - Ku Band Receiver MMIC', IEEE MTT Symp dig.,1991, pp. 529-532.
[2] S. Maas, Microwave Mixers, Artech House, 1986., pp248-251.
[3] B. C. Henderson and J. A. Cook, Image-Reject and Single Balanced Mixers, Microwave System News & Communication Technology, August 1987, pp75-83.
[4] T. N. Ton, 'A Wideband GaAs MESFET Monolithic Single-Balanced Mixer', GOMAC, 1991.
[5] S. J. Parisi, '180° Lumped Element Hybrid', IEEE MTT Symp dig.,1989, pp. 1243-1246.