AN X-BAND DUAL GATE MESFET IMAGE REJECTION MIXER

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ABSTRACT

An X-band image rejection mixer circuit using 1 micron dual gate GaAs FETs will be described. Conversion gains up to 15dB and simultaneous image rejection of at least 20dB have been obtained for IF outputs in the 10 - 100 MHz range, in a simple circuit which uses only 2 R.F. hybrids.

Introduction

A mixer which provides rejection of signals on the image channel has important applications in microwave systems, especially where low intermediate frequencies are used and the image signals are in-band. With the increasing use of GaAs FET pre-amplifiers image rejection has gained in importance, since not only interfering signals but amplifier noise must be rejected.

This paper describes the design and realisation of an X-band image rejection mixer circuit using a balanced pair of dual gate GaAs FETs. The circuit is shown to combine the advantages of image rejection with the high conversion gain of the GaAs FET devices, whilst maintaining adequate noise performance. Up to 15dB conversion gain, with simultaneous image rejection greater than 20dB have been observed for R.F. signal inputs in the 8 - 12 GHz range, and I.F. outputs in the 10 - 100 MHz range. The circuit uses in-house fabricated 1 micron dual gate devices which have given mixer noise figures better than 10dB. The circuit uses only two active devices and two microwave power splitters and is a potentially compact arrangement for an all-FET front end.

Dual Gate FET Mixer

The dual gate FET has been shown to be a simple and effective microwave mixer.[1] The local oscillator signal is applied to the second gate via a suitable matching network, and causes the transconductance measured at gate 1 to vary at the local oscillator frequency. Mixing action can therefore be obtained, with the signal applied to gate 1 and the I.F. output extracted via a low pass filter from the drain (Figure 1). Conversion gains in excess of 12dB, with associated SSB noise figures of 8.5dB have been obtained with this mixer circuit, which has the advantage of requiring no external couplers or hybrids in the R.F. circuitry. More recently, it has been shown that the dual gate GaAs FET mixer can give high conversion gains with very low local oscillator drive if forward bias is applied to the second gate. Figure 2 shows typical conversion gain as a function of L.O. drive for a single ended dual gate GaAs FET operated in this condition, and it can be seen that 10dB gain can be obtained with as little as 100 μW L.O. power

Image Rejection Circuit

The development of the single ended mixer into an image rejection configuration is shown in Figure 3. A simple balanced arrangement is used, in which the two signal gates (i.e. gate 1's) are fed from a broadband 90° hybrid, and the two local oscillator gates (gate 2's) are excited in phase by a straight power splitter. It can be readily shown that the I.F. output at the drain of device A either lags or leads that at B by 90° depending on whether the R.F. input is on the signal or image channel. Consequently signal and image channels appear on separate output ports of the 90° I.F. hybrid.

In addition to providing image rejection, the circuit of Figure 3 has advantages over the simple single ended circuit. In particular, the signal input will always have a good VSWR due to the action of the 90° coupler, as in a balanced amplifier. Thus the gate 1 inputs may be matched for optimum noise figure and provided symmetry is maintained the input match will be good. The balanced arrangement also improves the power handling capability by 3dB, although of course the L.O. drive requirement will increase by a similar amount.

Experimental Circuit

The circuit of Figure 3 has been realised in an experimental form on a single alumina substrate. This circuit has been designed for maximum experimental flexibility and could be made much smaller if necessary. The input quadrature coupler was of the interdigital Lange type with an integrated load. The local oscillator inputs were fed from an in-phase Wilkinson coupler, and the dual gate devices themselves mounted in chip form and coupled to the circuit via 50 ohm microstrip lines (Figure 4). The intention was to evaluate the circuit initially with no tuning on the R.F. ports, which would allow a direct measure of typical operating bandwidth for adequate phase balance. Improved performance could then be obtained by on-circuit tuning with metal discs. Bias and I.F. output networks were low-pass filter structures incorporating resistive elements to aid stability. The I.F. used for these measurements was 30 MHz, so that gain and automatic noise measurement equipment could be used directly. Each drain circuit was matched to 50 ohm using a tapped parallel tuned circuit, and the two outputs were combined using a commercial TO-5 packaged 90° I.F. hybrid. The bias and 30 MHz circuitry was assembled off the MIC on an adjoining P.C. board.

Experimental Results

Circuit R.F. Ports Untuned

Figure 5 shows a typical gain vs. frequency response for a L.O. frequency drive at 9.5 GHz. The two responses correspond to upper and lower sideband outputs from the I.F. hybrid, and can be seen to be nearly symmetrical. Image rejection is well over 20dB for both channels, and 0dB conversion gain is obtained in this completely untuned circuit for a L.O.

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drive of +10dBm. The noise figure measured on this circuit was 12dB, which agrees well with the figures measured on single ended mixer circuits in the untuned condition, and indicates that at least 3dB of improvement is possible by matching the input gate circuits. VSWR was better than 2:1 over 8 - 12 GHz and the gain and image rejection could be maintained over at least a 500 MHz bandwidth, without any special effort to optimise the bandwidth.

Tuned Circuit

The above results were for an untuned circuit, where both devices input ports were being fed directly from 50 ohms. Results from single ended dual gate mixers have shown similar performance in the untuned state, with the gain being increased by at least 10dB, and noise figure 3dB, by simple 'disc' tuning on the gate inputs. In the image rejection circuit, such tuning is more difficult to perform because both arms must be tuned simultaneously in order to retain the balanced circuit operation. Figure 6 shows a typical gain response for a tuned circuit, showing 10dB of conversion gain and 20dB image rejection. Up to 15dB conversion gain has been observed with this circuit, with at least 20dB image rejection, although at this level of gain the noise figure was significantly away from optimum (15dB). Optimisation of the circuit for minimum noise is difficult, because any degradation of the image rejection causes an apparent improvement in mixer noise figure. Consequently presently available noise figure results are considered not to represent the best achievable values, which will be close to the SSB values of those obtained in a single ended mixer circuits, i.e. 8.5dB optimum.

Conclusions

The feasibility of realising an image rejection mixer with GaAs FETs has been demonstrated. The circuit is simpler than equivalent circuits using Schottky diodes, in that only two active devices and two microwave hybrids are used. The circuit has demonstrated good conversion gain simultaneously with high image rejection, and an adequate noise figure for many applications. The use of improved sub-micron dual gate FETs and on-circuit noise matching is expected to give a significant improvement in noise performance, and this forms part of the ongoing experimental programme.

Acknowledgements

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Reference

1. 'An X-Band Dual Gate FET Mixer', S.C. Cripps, et al., Proc. 1977 European Microwave Conference.

FIG. 1
DUAL-GATE F.E.T MIXER

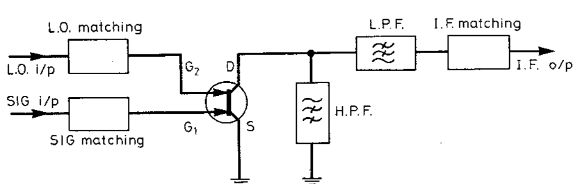

FIG. 2
CONVERSION GAIN Vs. L.O. DRIVE (Single ended mixer, f = 9·5 GHz)

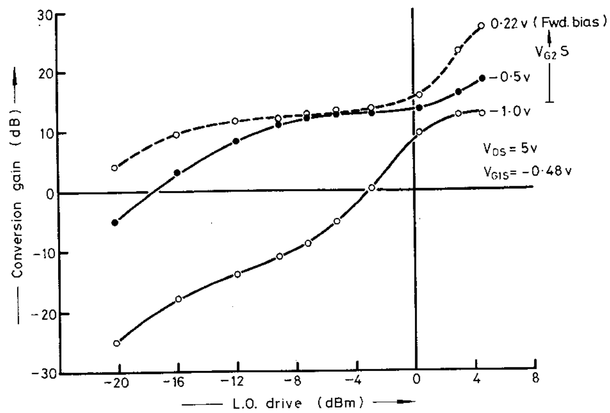

FIG. 3
DUAL-GATE IMAGE REJECTION MIXER

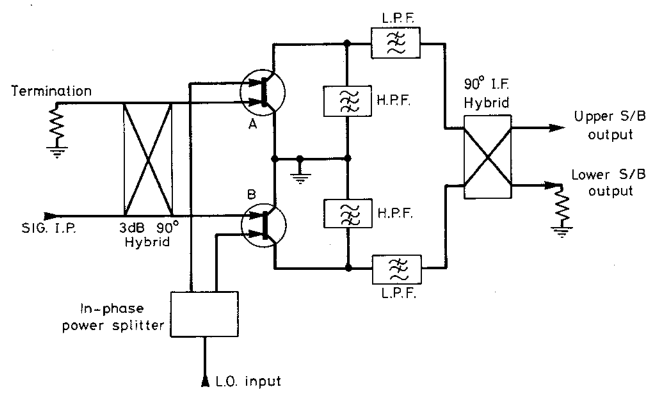

FIG. 4
IMAGE REJECTION F.E.T. MIXER

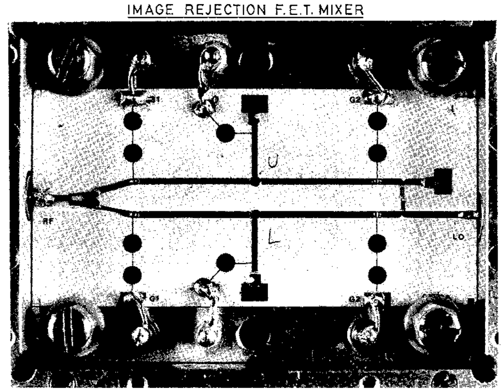

FIG 5

IMAGE REJECTION MIXER RESPONSE (NO RF TUNING)

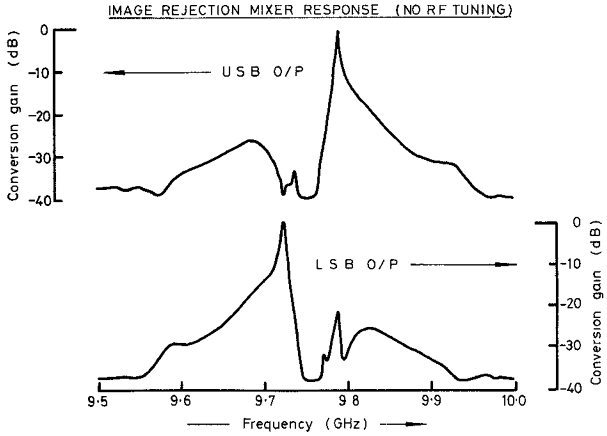

FIG 6

IMAGE REJECTION MIXER RESPONSE (WITH TUNING)