# A 2 - 18 GHz Wideband High Dynamic Range Receiver MMIC

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***Abstract*** **In this paper, a 2 to 18 GHz wideband receiver MMIC for EW applications is presented. The receiver comprises a balanced cascode travelling wave LNA, a wideband active balun and a cold-FET ring mixer. The MMIC was fabricated using the TriQuint GaAs pHEMT process, using 0.25 μm gate length devices. The measured conversion gain is greater than 7.8 dB between 3 GHz and 20 GHz. The RF input return loss is better than 10 dB between 3 GHz and 21.5 GHz. The receiver requires a drain bias voltage of 5 V and draws a drain current of approximately 260 mA. This wideband receiver is believed to be the first fully integrated single-chip receiver MMIC covering the 2 to 18 GHz frequency band.**

## I. Introduction

The 2 to 18 GHz frequency band is used by many military and commercial, RADAR and communication systems. This band is of particular interest to the EW community. Many EW receivers operate over 2 to 18 GHz by splitting the band into a number of sub-bands. This leads to complex and expensive receiver system architectures. The aim of this work is to produce a compact and inexpensive single-chip EW receiver MMIC operating over 2 to 18 GHz using GaAs integrated circuit technology. The ease of construction of a receiver incorporating such a circuit is improved, due to a reduced number of components and bond-wires. The use of GaAs MMIC technology thereby introduces a high level of repeatability between receivers. This is particularly important for applications requiring several identical receiver channels.

In this paper, a 2 to 18 GHz wideband receiver MMIC for EW applications is presented. The receiver comprises a balanced cascode travelling wave LNA, a wideband active balun and a cold-FET ring mixer. The MMIC was fabricated using the TriQuint GaAs pHEMT process using 0.25 μm gate length device technology.

The measured conversion gain is greater than 7.8 dB between 3 GHz and 20 GHz. The RF input return loss was measured to be better than 10 dB between 3 GHz and 21.5 GHz. The receiver requires a drain bias voltage of 5 V and has a drain current of 257 mA.

Other wideband integrated receiver MMICs have been published, [1], [2]. However, this is believed *to be the first* single-chip receiver front-end MMIC covering the 2 to 18 GHz RF band. Furthermore, using an IF bandwidth of 200 MHz, the MMIC has a spurious-free dynamic range in excess of 55 dB.

## II. Fabrication Process

The circuits were fabricated using a GaAs pHEMT process, with a 0.25 μm gate length. The substrate height is 100 μm after thinning. The design makes use of both TAN and EPI resistors. The gate to drain breakdown voltage of the active device is approximately 20 V. The device $f_T$ is around 42 GHz. The device Idss is 285 mA/mm. Therefore, this fabrication process lends itself well to the fabrication of high dynamic range microwave receivers.

## III. Circuit Design

The receiver comprises 3 basic building blocks; a balanced travelling wave amplifier at the RF input, which acts as an LNA, a cold-FET ring mixer and an active travelling wave balun which provides the mixer with a balanced LO from a single-ended input. This block diagram of the receiver is shown in Figure 1. The travelling wave amplifier structure has five stages, each using two transistors connected in a cascode configuration. Both the gate lines and drain lines are terminated in 50 Ohm resistors, which in turn, are connected to the bias lines via large de-coupling capacitors and an RF choke on the drain line.

The balanced LNA outputs feed directly into a FET ring mixer, which has very high linearity compared with other mixer types [3]. The mixer in turn is connected to a balanced IF output port. The FET devices in the mixer are biased at pinch-off, and with zero drain bias, to ensure optimum intermodulation performance. The mixer is provided with a balanced LO drive signal from an active on-chip balun. The balun has a travelling wave structure, in which the input signal is fed onto an artificial transmission line, which is connected to both common source and common gate transistors. The drain connections of these devices are connected onto two further artificial transmission line structures to form the 0 and 180 degree outputs.



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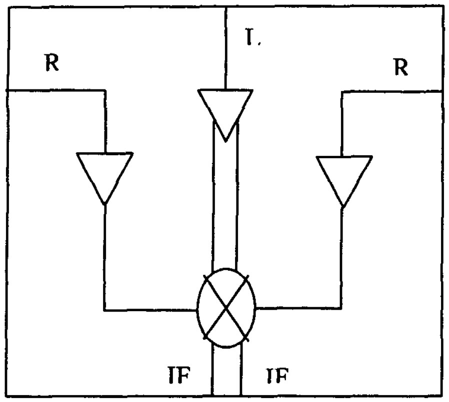


Figure 1. Block diagram of the wideband receiver

The circuit was designed and simulated with bond-wire models attached to the circuit. This ensures that a good match can be achieved when the circuit is placed in a microwave package. During circuit layout, care was taken to minimise unwanted coupling between adjacent microwave structures. Figure 2 shows a chip photograph of the MMIC, which measures 5.7 mm x 4.2 mm.

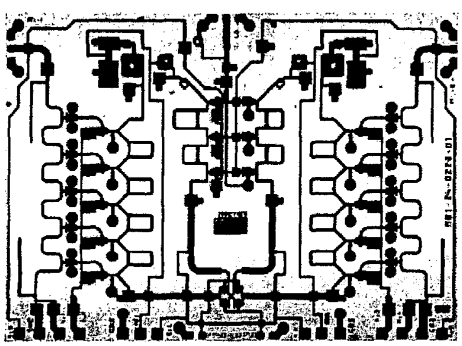

Figure 2. Wideband high dynamic range receiver MMIC

## IV. MEASUREMENTS

The fabricated wideband receiver MMICs were measured on-wafer up to 50 GHz. An IF of 100 MHz was used so that measurements could be made on wafer, using low frequency probes. The following three figures show the results of these measurements.

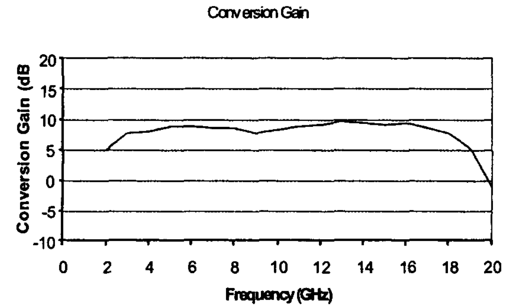


Figure 3. Conversion gain of wideband receiver MMIC.

The conversion gain performance of the wideband receiver is presented in Figure 3. The conversion gain is greater than 7.8 dB from 3 GHz to 18 GHz. The gain at 2 GHz is 5.1 dB.

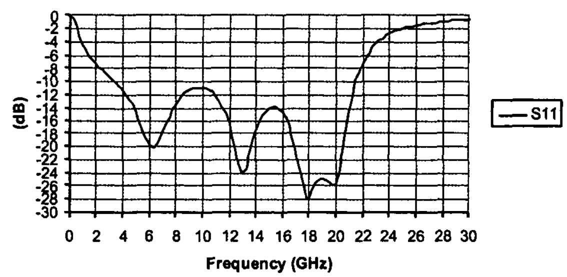


Figure 4. RF input return loss performance of wideband receiver MMIC.

The RF input return loss, shown in figure 4, is better than 10 dB between 3 GHz and 21.5 GHz. At 2 GHz the RF input return loss is approximately 7.5 dB.

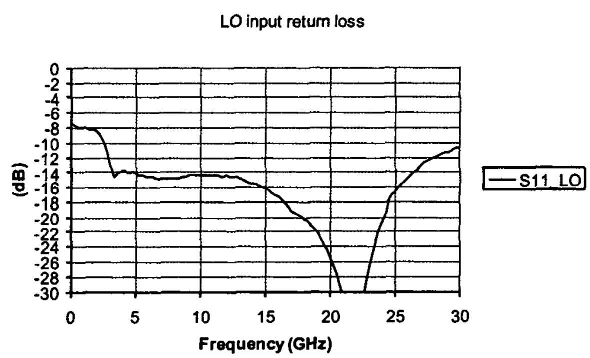


Figure 5. LO input return loss performance of wideband receiver MMIC.

The LO input return loss, shown in figure 5. is better than 10 dB from 2.5 GHz to 30 GHz.

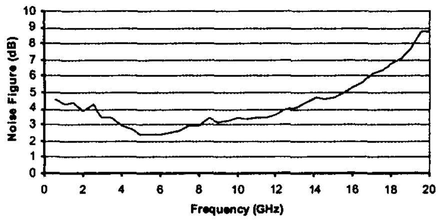


Figure 6. Noise Figure performance of wideband receiver MMIC

The measured noise figure of the wideband receiver MMIC is presented in Figure 6 and has a minimum value of 2.3 dB at 5.5 GHz, rising to approximately 7 dB at 18 GHz.

The second order and third order intermodulation performance of the receiver was also measured across the operating band. Typically, the input IP2 intercept point was found to be greater than 25 dBm and the input IP3 intercept point was found to be greater than 0 dBm. Assuming an IF bandwidth of 200 MHz, these figures imply a spurious free dynamic range in excess of 55 dB.

The receiver draws a total current of 257 mA, giving it a DC power requirement of approximately 1300 mW. The RF functional yield of the wideband receiver MMIC was found to be approximately 97%. This yield figure was derived from 94 receivers, measured on two wafers from the same batch.

All on-wafer measurements were repeated, with the MMIC mounted in a five-port package. The results of measurements of conversion gain, noise figure IP2 and IP3 made in this environment agree very well with the corresponding RF on wafer results. This indicates that the MMIC is suitable for use in a packaged receiver. The packaged MMIC is shown in figure 7.

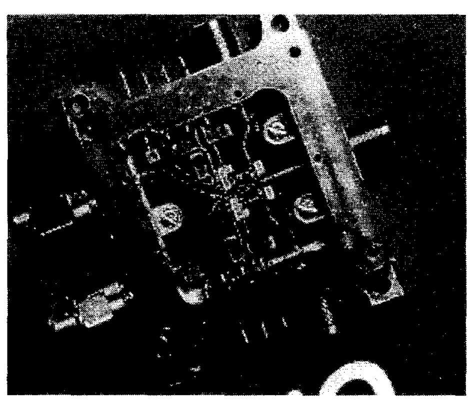

Figure 7. Packaged MMIC

On the basis of these results, the MMIC is intended for use in a series of receiver technology demonstrators, with the aim of demonstrating further, the applicability of highly integrated MMICs in wideband microwave receivers.

## V. Conclusions

In this paper a 2 to 18 GHz single-chip receiver MMIC is presented. The receiver comprises a balanced cascode travelling wave LNA, a wideband active balun and a cold FET ring mixer. The MMIC was fabricated using the TriQuint GaAs pHEMT process using a 0.25 μm gate length device technology. The measured conversion gain is greater than 7.8 dB between 3 GHz and 18 GHz, and is greater than 5 dB between 2 GHz and 18 GHz. The RF input return loss was measured to be better than 10 dB between 3 GHz and 21.5 GHz. The spurious free dynamic range of the receiver, assuming an IF bandwidth of 200 MHz, is in excess of 55 dB. The receiver requires a drain bias voltage of 5 V and has a drain current of 257 mA. This is believed to be the first single-chip integrated receiver MMIC covering the 2-18 GHz band. Furthermore, measurements taken on-wafer have been repeated and corroborated, with the MMIC mounted in a five-port package.

Both the on-wafer results, and the success in packaging the MMIC, will have implications for the introduction of compact and inexpensive wideband receiver systems for both military and commercial applications.


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