A Low cost Mixer for Wireless Applications

Jean-Marc Mourant

M/A-COM, Micro-Electronics Division

A new GaAs Integrated Circuit mixer is presented that services wireless communication requirements. Low cost, small size and good electrical performance are achieved through the use of a one balun-one FET scheme, a mature MESFET process and plastic packaging. Measured data is shown for 900 MHz and 1800 MHz parts. This mixer offers the best performance-to-price ratio in the market place.

1. Introduction

The past few years have seen a large demand for parts servicing the growing wireless communication market. The main requirements are low cost , small size (especially in handsets) and good electrical performance. The market for single function IC components can be divided into four families : switches, LNAs, mixers and power amplifiers. Among those, the mixer family is the less developed. Silicon active mixers can be bought inexpensively, but they suffer from poor dynamic range. Double balanced diode mixers do not lack in performance but are expensive and large. The approach presented here, gives the same level of performance as diode mixers, but at the low cost of active ones.

2. Mixer description

Conventional double balanced diode mixers are widely used in the industry because they give good isolation and good spurious rejection. On the other hand, they require two baluns, a diode quad and sometimes an IF diplexer (see fig 1).

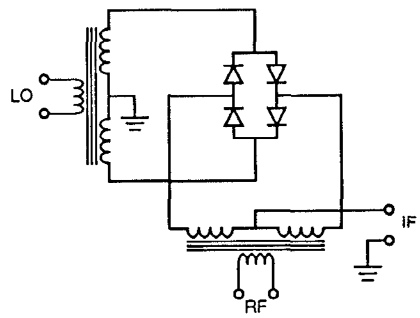

Fig 1: A double balanced diode mixer

If we replace diodes with MESFETs used as switches, we have an inherent advantage. The FET is a three terminal device with good isolation between gate and drain. The scheme presented here was first introduced by C. F. Vasile for various signal processing applications [1]. He called it the "Floating FET". Although Vasile mentions the Floating FET as a mixer, he describes an active scheme that is too complex for our low cost objective. We kept the basic Floating FET cell with no drain bias circuitry. We added to it an efficient diplexing circuit to extract the IF and a self biasing gate element to keep our FET in the pinch off state.

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2.1 Principle of operation

A basic floating FET structure is shown in fig 2. A FET drain and source terminals are floated above ground through a balun. The unbalanced LO voltage is applied between the gate and the balun mid point (ground). It switches the FET on and off. The RF goes through a unbalanced to balanced transformer and is applied, balanced (or floated) between the drain and source terminals.

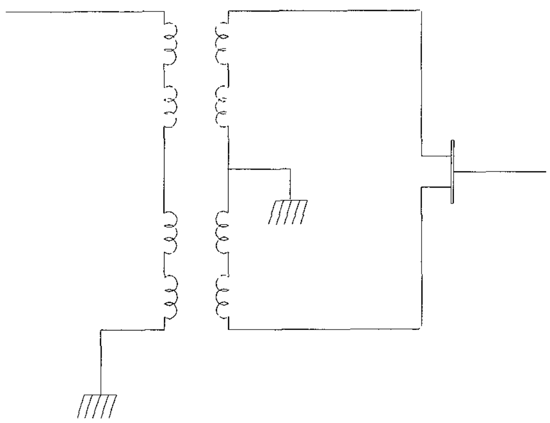


Fig 2 : A Floating FET mixer

One interesting feature of this scheme is the feedback that exists between LO and RF; the FET controlling voltage Vgs is the sum of the LO and RF voltages. At low RF voltages (or low Vds), the FET behaves as a resistor, controlled by the LO. As the RF voltage increases, the current curves would normally saturate. Because of the feedback, however, Vgs decreases and the current can increase. Excellent compression points and IP3 can then be achieved.

Another useful feature of the Floating FET mixer is good LO to RF isolation. The LO is applied on the FET gate and can only couple to the RF side through the low Cgs capacitance. Whatever leaks through is canceled out by the RF balun.

A more detailed schematic is shown in fig 3. The balanced IF created in the FET has to be extracted in an unbalanced manner (to avoid costly IF baluns). It is diplexed efficiently from the RF balun center tap. The series L-C section resonates at the RF frequency and shorts out the two center tap points. At low frequencies, the capacitor is an

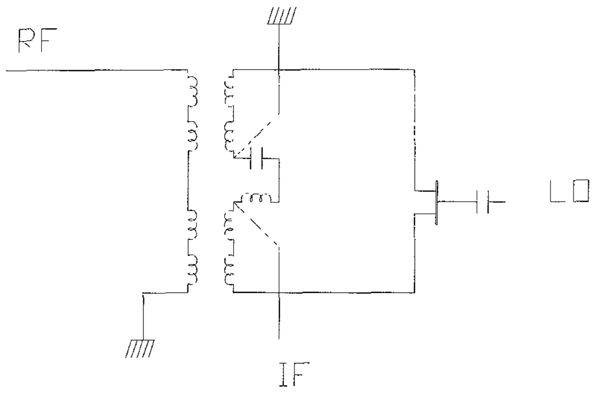


Fig 3 : The complete low cost mixer

open. The IF can be extracted from one end of the resonator. It returns to ground through the FET and the balun.

For proper mixing, the FET gate has to be biased near the pinch off voltage. In this low cost approach, we cannot use an external bias. We use a capacitor that charges up with the LO voltage through the FET Schottky diodes (see fig 4).

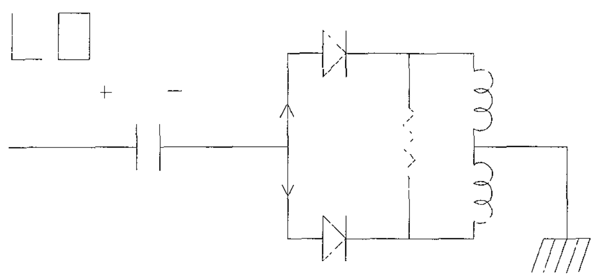


Fig 4 : The gate self biasing scheme

2.2 Design implementation

To meet our low cost objectives, the balun had to be made very compact. There are many ways to implement the balun in an integrated form : lumped element rat race, in phase splitters with lead and lag networks, compensated baluns, etc..The best technique for achieving small size below 6GHz, is to use coupled inductors as shown in fig 5. The inductive behavior can be canceled by parallel resonance at the primary and secondary windings.

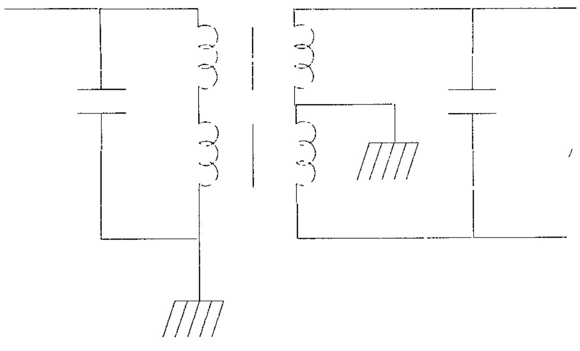


Fig 5 : A coupled inductors lumped element balun

Good bandpass balun performance can be obtained for up to one octave. No matter what balun is used, size can be minimized by avoiding impedance transformations. Since we have a single FET scheme, the IF and RF ports can simultaneously be matched, with no impedance transformation. A four diode mixer would require 4:1 impedance transformation and would use about four times the area.

To meet our low cost goal, the mixers were fabricated on 10 mil GaAs wafers, without via holes and using a well-established, one micron gate, MESFET process. An inexpensive 8 lead surface mount plastic package was also chosen. Two separate designs target two widely used wireless communication bands (800-920 MHz and 1700-2000 MHz). Total die areas are 0.68 mm^2 and 0.5 mm^2. The 1800 MHz mixer layout is shown in fig 6.

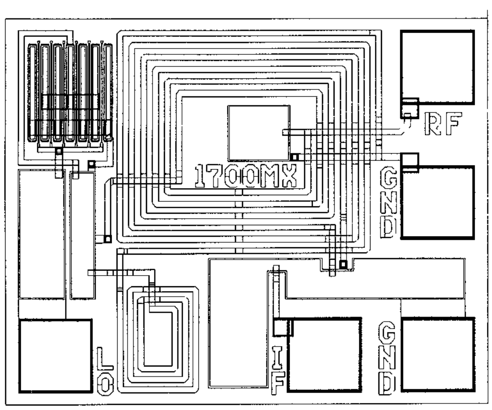


Fig 6 : The 1800 MHz mixer layout

3. Measured performance

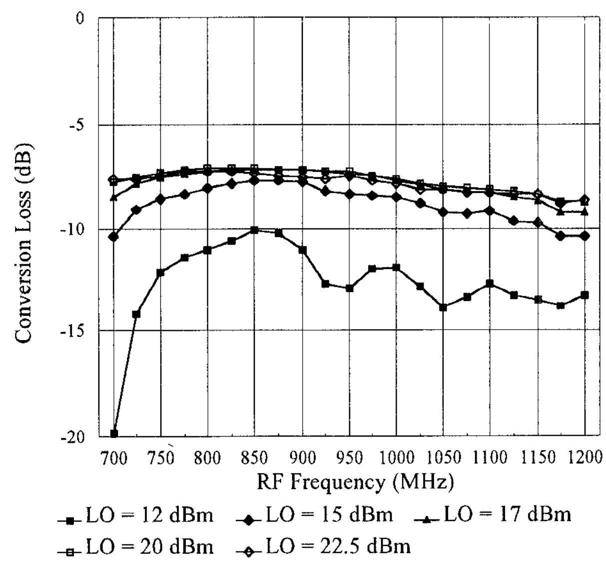
We plastic packaged several hundred chips and measured a few dozens on an engineering test fixture. The mixer requires no external components, but some external matching can be used to improve the following parameters :

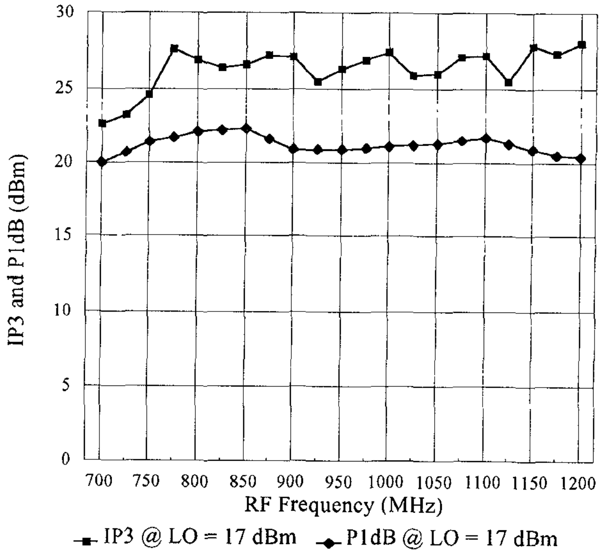
- LO match. Resistive or reactive matching is recommended to improve the poor LO port match. LO drive levels can be dropped by 4 dB if reactive matching is used.
- IF match. IF match is good from DC to 15 % of the RF frequency. Simple reactive matching can double that band.

Typical measured data is shown below. A 100 Ohm shunt resistor was used on the LO port to achieve a 10 dB return loss.

3.1 900 MHz mixer data

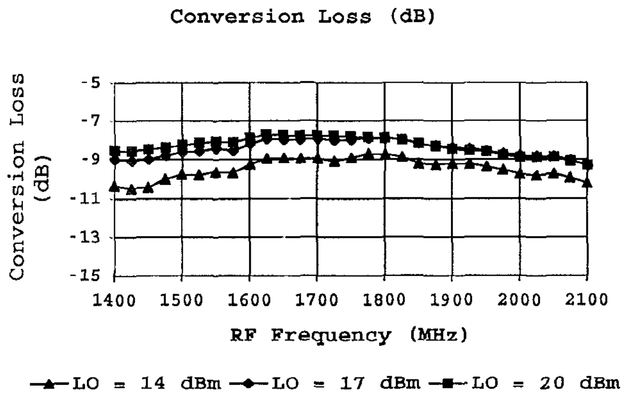
We achieved 7.5dB of conversion loss, 27dBm of input IP3 and 40dB of LO-RF isolation at an LO drive of 17 dBm.

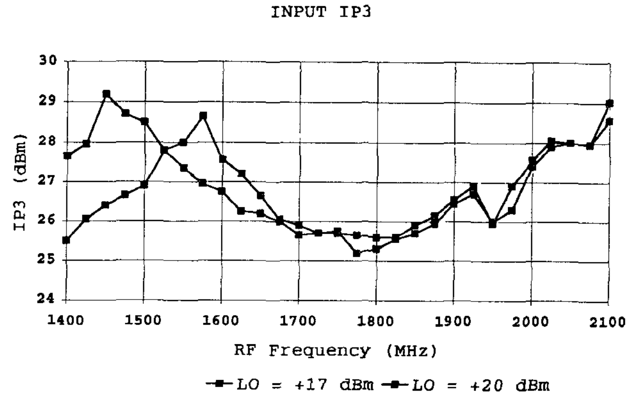




3.2 1800 MHz mixer data

Very similar performance is achieved with the 1800 MHz mixer : 7.5dB of conversion loss, 26 dBm of input IP3 and 30 dB of LO-RF isolation.





4. Conclusion

A MMIC mixer has been designed and characterized for wireless applications. By using a one FET, one balun scheme, along with plastic packaging, we believe we have achieved the best price to performance on the market. The measured data is very good and makes the mixer a direct competitor for double balanced diode mixers. High level products at 900 and 1800 MHz are now offered as standard IC products by M/A-COM. Low level mixers with an even smaller die size and a smaller plastic package are planned for later. This should reduce the cost even further.

Acknowledgments : We are grateful to Christian Kermarrec for sharing the Floating FET mixer idea with us. Also, thanks to Bill Fahey and David Morales for preparing the data graphs.

[1] C F Vasile "Floating GASFET circuits offering unique signal processing from DC-EHF" 1985 GOMAC proceedings pp 305-309