A Ka-band GaInP/GaAs HBT Double Balanced Upconvert Mixer using Lumped Element Balun

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ABSTRACT

A Ka-band GaInP/GaAs HBT double balanced upconvert mixer has been designed and fabricated. This circuit is to be used in a multifunction T/R module for local multipoint distribution systems (LMDS) which include both analog and digital transmission. A conversion gain of 1 dB, and an output power of -10 dBm from 27 GHz to 30 GHz for an LO input power of 10 dBm at 26 GHz were measured. The LO isolation to the output was measured to be 20 dB. These results are the best reported at Ka-band for a mixer using transistors from digital HBT library.

INTRODUCTION

Recently, there has been much interest in providing broadband wireless access to fixed networks via millimeter wave radio transmission in the frequency band 27.5-29.5 GHz. Local Multipoint Distribution Service (LMDS) could be used to provide wireless access to services ranging from one-way view distribution and telephony to fully-interactive switched broadband multimedia applications. GaInP/GaAs heterojunction bipolar transistors (HBT's) are prime candidates for such applications due to their high peak power density and their usefulness for a variety of circuit types. To demonstrate the HBT's potential for mixer applications, a Ka-band HBT double balanced upconvert mixer has been developed using the same material and fabrication process as used for other digital HBT components [1].

From DC to ultra-high frequency Gilbert cell analog multipliers can be used for double balanced active mixers in microwave applications. Compared with conventional diode double balanced mixers, the advantage of the active double balanced mixers are low LO drive power, the ability to provide positive conversion gain, and eliminate the need for bulky balun circuitry. Si bipolar transistor double balanced active mixers [2] and HBT up-converters [3] up to 6 GHz were developed. Recently, GaAs MESFET double balanced active mixers up to 10 GHz [4] and the HBT double balanced active mixer up to 20 GHz [5] have been reported. The analog mixer performance rapidly deteriorates at high frequencies due to a decrease in the common mode rejection ratio. To eliminate the common mode signal and yet keep the chip size small a lumped element balun is used.

The use of lumped elements in microwave monolithic circuit design is becoming a well established technique. Careful measurement, de-embedding and numerical modelling of spiral inductors, interdigital capacitors, MIM capacitors and nichrome resistors have resulted in circuits which perform as well as distributed circuits, while allowing substantial reduction in the GaAs substrate area. In this paper, the development of a GaInP/GaAs HBT Ka-band double balanced upconvert

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mixer is described which incorporates lumped element baluns and an analog Gilbert cell.

CIRCUIT DESIGN

Fig. 1 shows a double balanced mixer with lumped element baluns. An active IF balun is used at an IF of 2 to 4 GHz because the lumped element circuit becomes unpractically large. At these frequencies, the CMRR of the differential amplifier is not a problem. The RF and LO baluns operate in the frequency range of 26 to 30 GHz. Thus it is feasible to make a passive lumped element 180° hybrid [6] balun for both. The 15% bandwidth of these structure is actually slightly broader than that of the simple ring hybrid and is therefore sufficient for this application.

MMIC FABRICATION

The Nortel self-aligned HBT process [1] has standard transistors, 2x2 μm^2, 3x3 μm^2 and 3x6.5 μm^2, that are primarily used for digital applications. Using an array of four transistors of size 3 x 6.5 μm^2 , the transistor was laid out to make one transistor that is used in the differential pair of the Gilbert cell. The balun was modelled using IE3D by Zeland Software. The active IF balun is made of transistors made of two 3x6.5 μm^2. The substrate thickness was four mils and substrate vias were available in the process. Test devices demonstrate typical dc current gains of 70 at a collector current density of 0.5 mA/μm^2. The die size is 2400 x 2400 μm^2. A layout of the chip is shown in Fig. 2.

MEASURED MIXER PERFORMANCE

Fig. 3 is the measured and modelled LO, RF and IF return loss of the mixer biased using a single supply of Vcc = 5.5V which had a power dissipation of 300 mW. Fig. 4 shows a plot of the RF output power and its third order product versus IF input power. From this, the third order intercept was obtained to be 3 dBm. Measured conversion gain is 1 dB from 27 to 30 GHz and is shown in Fig. 5.

CONCLUSION

In conclusion, a Ka-band HBT double balanced upconvert mixer utilizing GaInP/GaAs HBT's has been developed. A conversion gain of 1 dB, and an output power of -10 dBm from 27 GHz to 30 GHz for an LO input power of 10 dBm at 26 GHz were measured. The LO isolation to the output was measured to be 20 dB. These circuits are process-compatible with the other functional components in the HBT T/R module. While not best reported at Ka-band compared to PHEMTs, it is best reported for a HBT process optimized for digital circuits. The success of this work has paved way for the development of future LMDS circuits.

ACKNOWLEDGEMENTS

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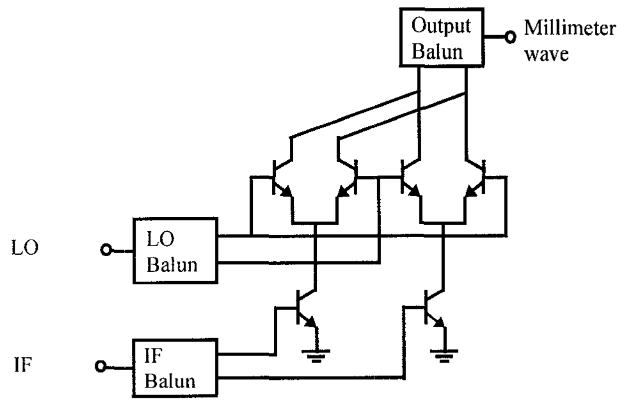


Fig. 1 a) Double balanced upconvert mixer

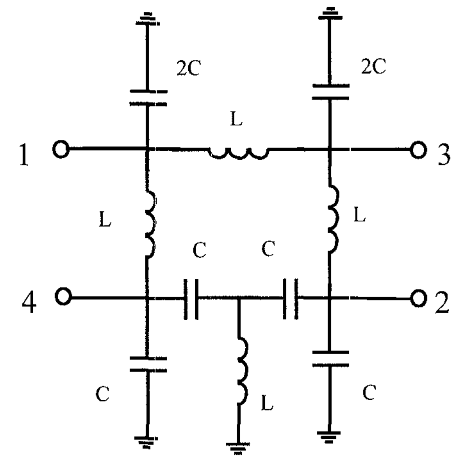


Fig. 1 b) LO and RF 180° hybrid balun for the upconvert mixer

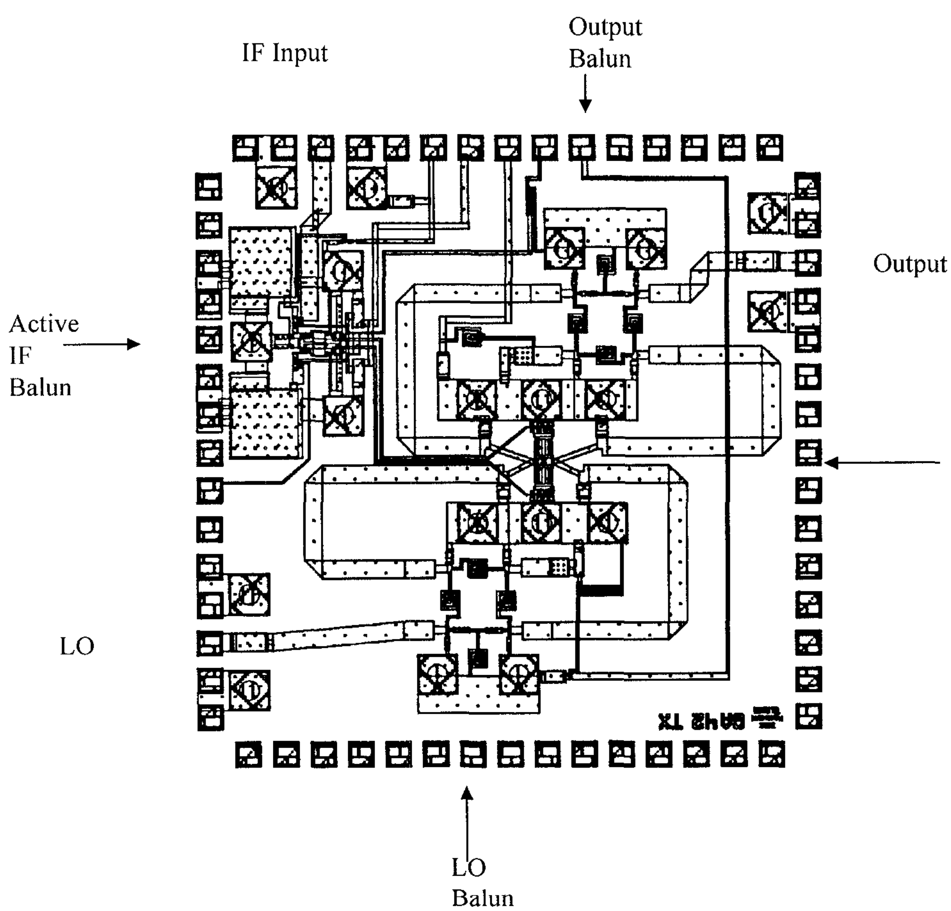
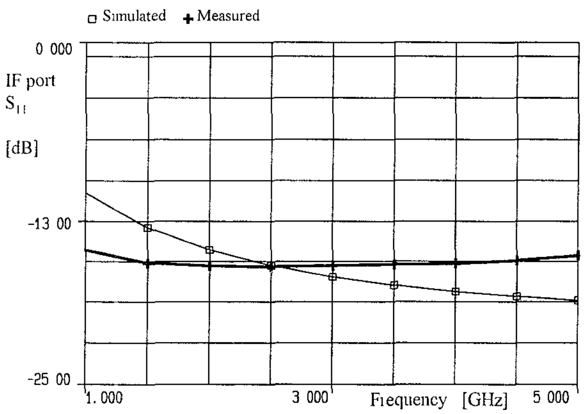
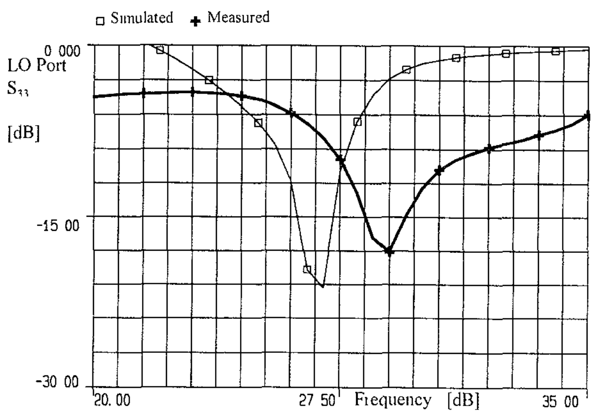


Fig. 2 Ka-band double balanced mixer with lumped element balun





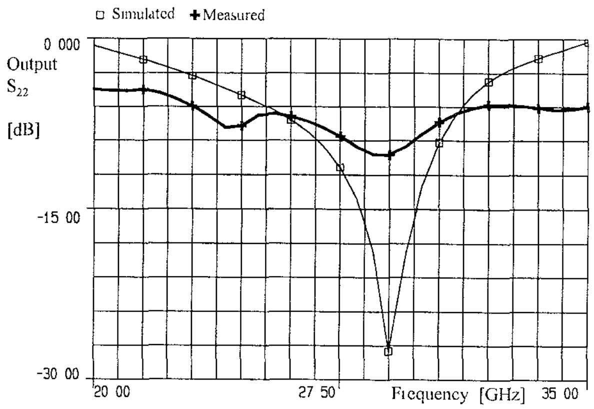


Fig. 3 The simulated and measured reflection coefficients at the IF, LO and millimeter wave output port of the mixer

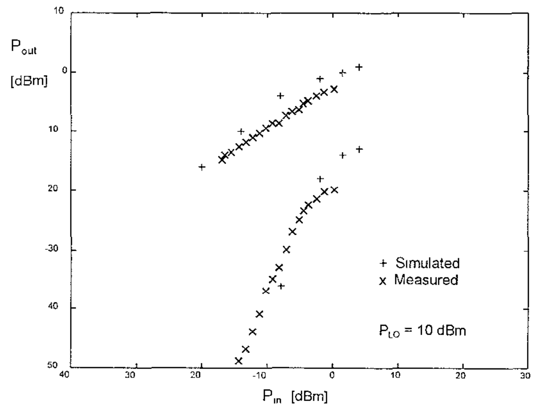


Fig. 4 First order and third order output powers versus IF input power

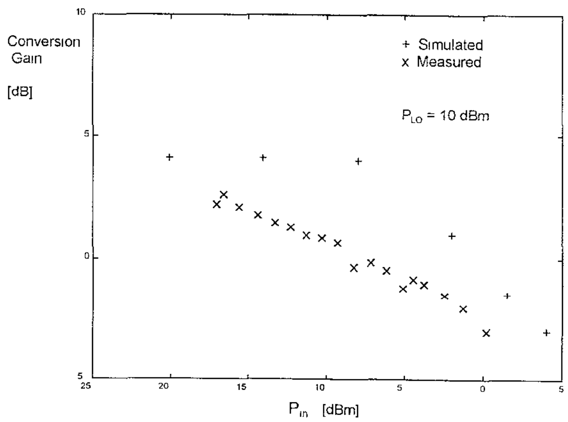


Fig. 5 Conversion gain versus IF input power