MONOLITHIC MIXERS WITH MESFETs TECHNOLOGY TO UP AND DOWN CONVERT BETWEEN C AND V BAND

Jorge P. Torres#+, Fernando Fortes#, M. João Rosário#,
J. M. Dieudonné*, J. Costa Freire#

#Instituto de Telecomunicações, Instituto Superior Técnico
Lisboa, Portugal
+Escola Náutica Infante D. Henrique, Lisboa, Portugal
*Daimler Benz Aerospace, Ulm, Germany

ABSTRACT

In this paper the design of singly balanced mixers to convert C to V band signals are presented. A step by step design technique is described, based on harmonic balance simulations. The mixer devices are Schotky diodes compatible with a GaAs MESFET technology. The mixer was optimised for minimum conversion losses on the widest possible bandwidth when used as an up or downconverter in order to be used on a large number of applications. The experiments show a minimum conversion losses on the range of 6 to 8dB for both applications (up and downconverter) and a 3dB bandwidth larger then 6GHz.

INTRODUCTION

To reduce the cost of the RF front end of the transceivers of the emerging millimetre wave civil systems, such as those related to road traffic control and mobile communications, MMICs with the widest bandwidth and modes of operation are needed to increase the range of possible applications per chip. For an easy integration the best choice for the frequency converter is a self biased balanced diode mixer. This topology needs a coupler to separate the LO and RF signals. In order to increase the bandwidth a Lange coupler was used. Due to the mixer sensibility to signals phase on the diodes [1] and the inaccuracies at V band of the passive structures models available on circuit simulation programs [2], test couplers were introduced on the wafer.

In this paper will be described the design and test of C to V band monolithic mixers able to operate as up and down converters with Schotky diodes compatible with a GaAs MESFET technology (MESFET material with n^+ buried layer)[3].

The specific design goals are conversion losses better than 7dB, for Plo<10dBm and return losses better than 10dB with f_{LO}=56.8GHz and at least f_{IF} from 5.2 to 9.2GHz, wich are in agreement with the specifications of a V band mobile system [4]. However, since a wider range of applications is envisaged, the analysis and test of the mixer was performed on a wider f_{IF} bandwidth and for different LO frequencies. To design the mixer an harmonic balance CAD program was used. The diodes models were obtained according to [3]. The design has been realised in 3 main steps based on the technique presented in [5], adapted for diode mixers.

The experiments are in good agreement with the simulations and most of the measured characteristics are better then the design goals.

DESIGN PROCEDURE

The mixers topology is presented on figure 1.

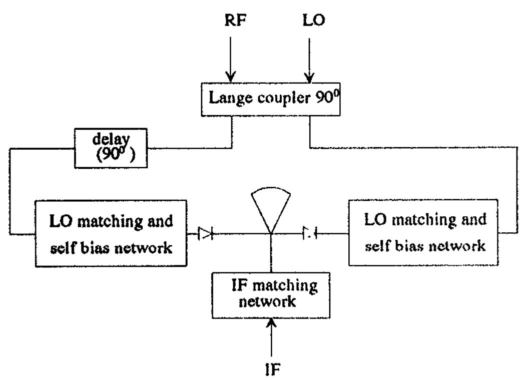

Figure 1 - Mixers topology

To have a wide bandwidth a Lange coupler was used (figure 1). However,

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since it is a 90° coupler, to have low conversion losses as up and down converter an additional delay was introduced on one of the diodes branch [1] (figure 2).

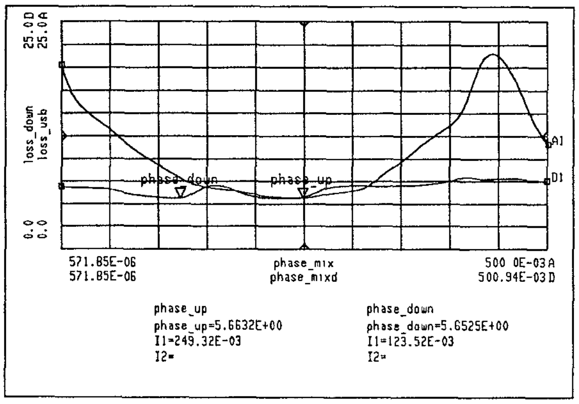


Figure 2 - Mixer conversion losses, as up and down converter, in function of the additional phase shift between the diodes branches.

With the diode self biased its impedance for LO power (P_{LO}) up to +20dBm at a fixed f_{LO}=56.8GHz was obtained. The impedance is almost constant up to +2dBm (Z_D=5-j390Ω at f_{LO}). It was noticed that, as expected, the diode is strongly capacitive, asking for a large inductive circuit to be matched. This is one of the key points on the design. Increasing P_{LO} the diode impedance reaches easier matching values (P_{LO}=+4dBm, Z_D=68-j323Ω at f_{LO}), however still strongly capacitive. The transition between small signal and large signal operation was detected on this range of LO power. At IF the impedance is less capacitive. Accordingly, for P_{LO}=+4dBm several IF and RF/LO matching networks, including elements for self bias, were designed. The best solution for low conversion losses was obtained with an IF network with a radial stub and for the LO with a line-stub network (the bias network acts also as LO matching). However, the stub should be large. Other reasonable solution tested for the LO matching was the λ/4 transformer, that leads to a large step discontinuity, due to the diode capacitive effect above mentioned. Following, both networks were studied.

After an iterative optimisation as down and up converter (upper side band) we notice that: with the λ/4 transformer is not possible to obtain the minimum conversion losses (CL) and the best LO matching for the same P_{LO}; also with the λ/4 transformer and on an IF bandwidth from 5.2 to 9.2GHz, CL_{UP}=6±1dB and CL_{DOWN}=5.9±1.1dB; with the line-stub network CL_{UP}=6.15±0.15dB and CL_{DOWN}=6.4±0.6dB was obtained on the same bandwidth. With the last solution also better return losses are obtained but have the disadvantage of leading to a smaller LO bandwidth. Usually, at the IF side of the diodes a RF short circuit is introduced. However, we have noticed that a reactive radial stub (a short circuit at an higher frequency) reduces the conversion losses.

From figure 3, we can also conclude that the mixers can be used on a much broader bandwidth.

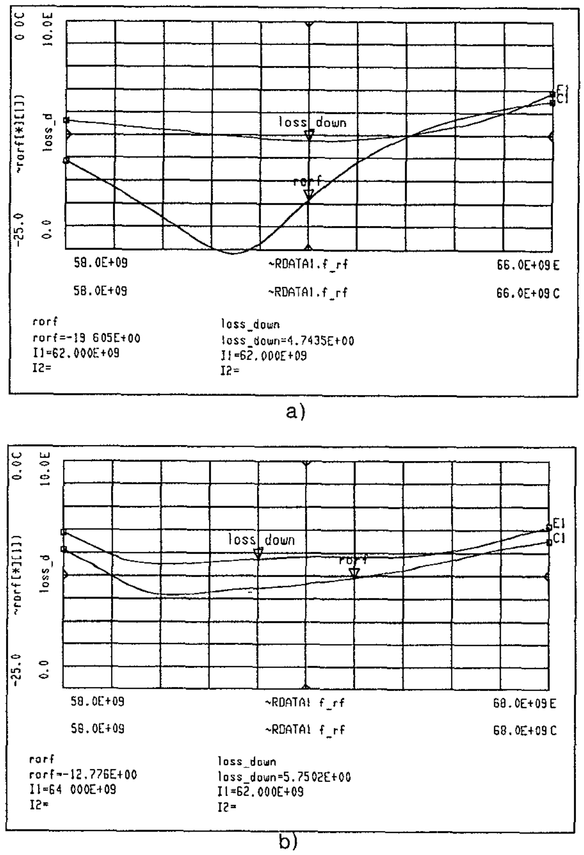
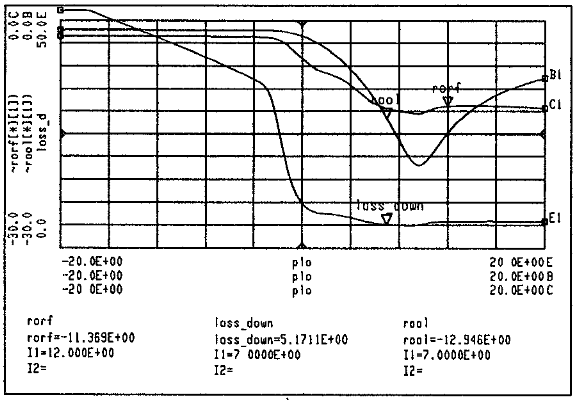


Figure 3 -Single balance mixers simulation results: CL as downconverter and RF return losses vs RF frequency (P_{LO}=7dBm and f_{LO}=56.8GHz): (a)With λ/4 transformer LO matching network; (b)With line-stub LO matching network.

Studying the mixers behaviour for different P_{LO} values we have conclude that increasing P_{LO} over 7dBm no significant improvement on the CL is obtained (figure 4). Furthermore, we don't have a significant degradation of the CL if we decrease P_{LO} down to 4dBm.



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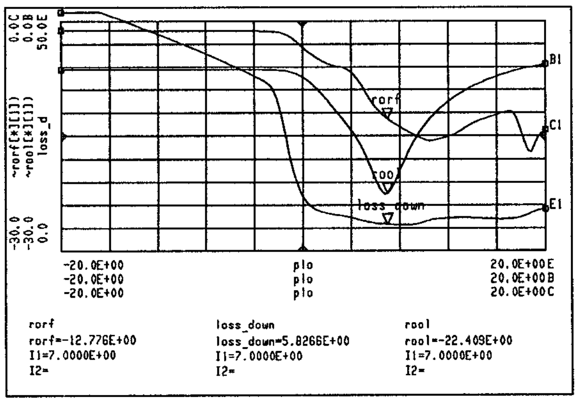
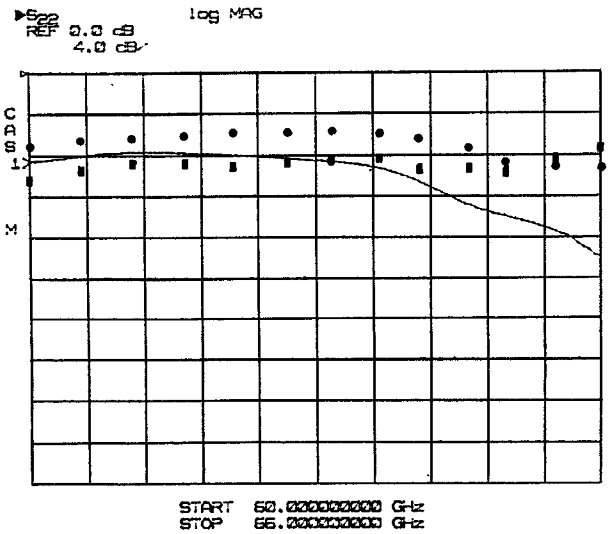


b)

Figure 4 -Single balance mixers simulation results: CL, LO and RF return losses as downconverter vs P_{LO} (f_{LO}=56.8GHz and f_{RF}=64GHz):(a)With $\lambda/4$ transformer LO matching network; (b)With line-stub LO matching network.

MIXERS PERFORMANCES

For both solutions the final layouts were produced and MMICs were fabricated with DB technology [3]. Measurements shown values within specifications and goals and in agreement with the simulations for all topologies processed (SBC1- single balanced with $\lambda/4$ matching network; SBC3 - single balanced with bias matching network). Input return losses at the IF port are better then 9dB and 13dB in the range of 3.4GHz-9.4GHz, for SBC1, SBC3 respectively. The LO-RF isolation is better then 9.8dB over the specified band (62GHz-66GHz) wich is in accordance with the values measured for the Lange coupler with small signals. As downconverter the conversion losses (CL), were 7.2±1.1dB and 7.7±0.7dB in the range of 60GHz-66GHz for SBC1 and SBC3, respectively, wich are in very close agreement with the simulations (figure 5). The minimum CL was achieved with P_{LO}=8.9dBm. For P_{LO}=4dBm and 5dBm the increase of CL is less then 3dB for SBC1 and SBC3 respectively (figure 6).



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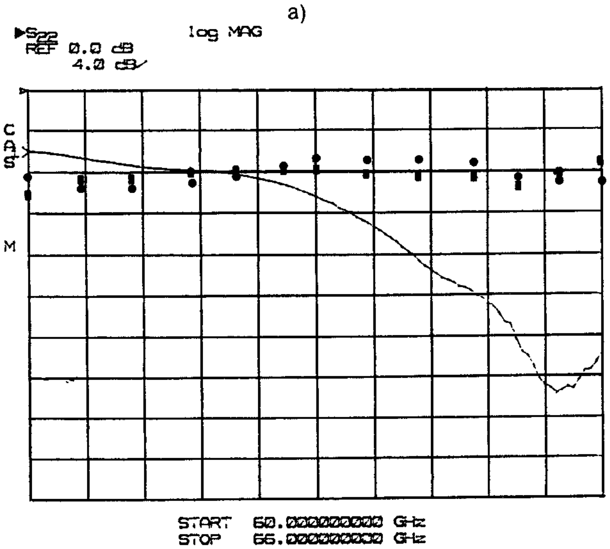
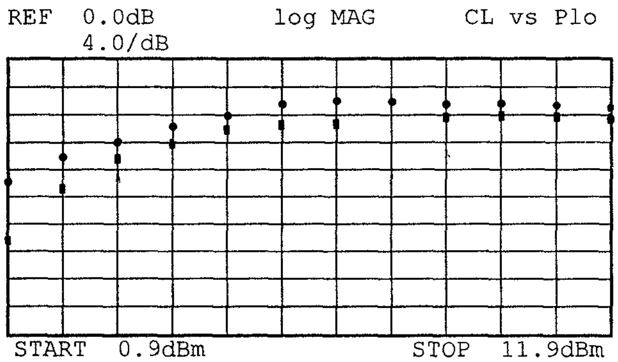


b)

Figure 5 - Single balance mixers experimental CL as up (usb ▮) and down (•) converter and RF return losses (-) vs RF frequency (P_{LO}=7dBm and f_{LO}=56.8GHz): (a)With $\lambda/4$ transformer LO matching network; (b)With line-stub LO matching network.

As upconverter the measured CL are 2dB higher than the simulations (figure 5 and 6). However are only 1dB higher than as downconverter wich confirms that a 90° coupler can be used to obtain a circuit usable as up and down converter, if an additional phase shift (close to 90°) is introduced on one of the diodes branch.



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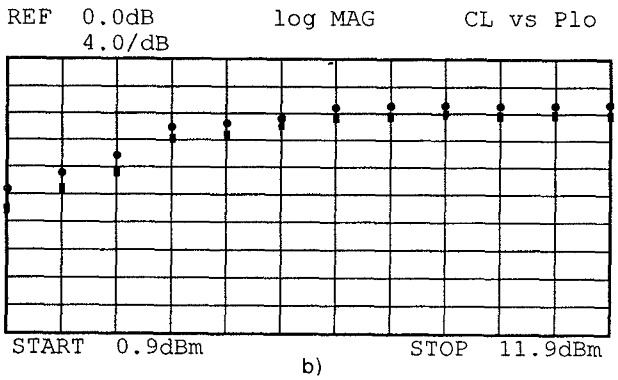

b)

Figure 6 -Single balance mixers experimental CL as up (usb ■) and down (•) converter vs Plo (f_{LO}=56.8GHz and f_{RF}=64GHz):(a) With λ/4 transformer LO matching network; (b) With line-stub LO matching network.

CONCLUSIONS

The design of two monolithic mixers for up and down conversion of signals between C and V band was presented. Several matching networks were studied to obtain the lowest conversion losses on the widest possible IF bandwidth. The two versions of single balance mixers were fabricated to compare two solutions of matching networks in what concern return losses and conversion losses as a function of frequency (available bandwidth) and LO power. Experiments are in close agreement with the design goals and simulation results. Based on a previous study, corrected models for some passive structures were used on the simulations. As far as the authors acknowledgement the experiments shows the lowest conversion losses concerning an up-down MMIC converter for millimeterwave frequency. These experiments and the simulation results proves that the same diode single balanced mixer with a 90° coupler can be used either as up or down converter with similar performances.

ACKNOWLDGEMENTS

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