NEW COMPACT DOUBLE BALANCED MONOLITHIC DOWN-CONVERTER APPLICATION TO A SINGLE CHIP MMIC RECEIVER FOR SATELLITE EQUIPMENT

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ABSTRACT

This paper proposes a new compact double balanced mixer architecture suitable for satellite repeater. The size of the proposed mixer has been divided by more than 5 compared to the previous generation currently used in the 14/12GHz satellite repeaters. Thanks to its small size, about 1mm², this mixer was integrated in a single chip MMIC receiver, including 5 different functions.

INTRODUCTION

A constant trend in satellite equipment is the weight and size reduction. MMIC led to an important improvement in the present microwave subsystems for satellites for few years. The last step is nowadays the increase of the number of functions on the same MMIC. This trend is directly correlated with the size reduction of main microwave monolithic functions. The proposed paper shows a new compact double balanced mixer which allowed us to design a 14 to 12GHz single chip MMIC receiver for the new generation of telecommunications satellite payloads, in particular, for SKYBRIDGE project which will provide interactive multimedia services by satellite. Thanks to its small size, the studied mixer was able to be associated with RF, IF and LO amplifiers and a LO attenuator on the same MMIC.

Satellite repeaters need down-converters allowing to convert a up link RF frequency into a down link IF frequency which is usually quite close from the first one (for example 14 to 12GHz, 6 to 4GHz...). To our knowledge, the proposed mixing cell is the smallest double balanced mixer directly applicable on a standard MMIC process in microstrip technology which achieves this kind of frequency conversion. For a 14 to 12GHz down conversion, the mixer sizes are 1mm x 1.1mm.

NEW MIXER DESIGN

The proposed mixer includes a quad of cold PHEMTs associated with RF and IF 180° couplers Fig1. These couplers are 3 coupled line structures which were designed using electromagnetic simulations. Their lengths, about $\lambda/16$ (with λ wavelength), make the mixer much more compact than the standard mixers using couplers based on one or several $\lambda/4$ structures Fig2.

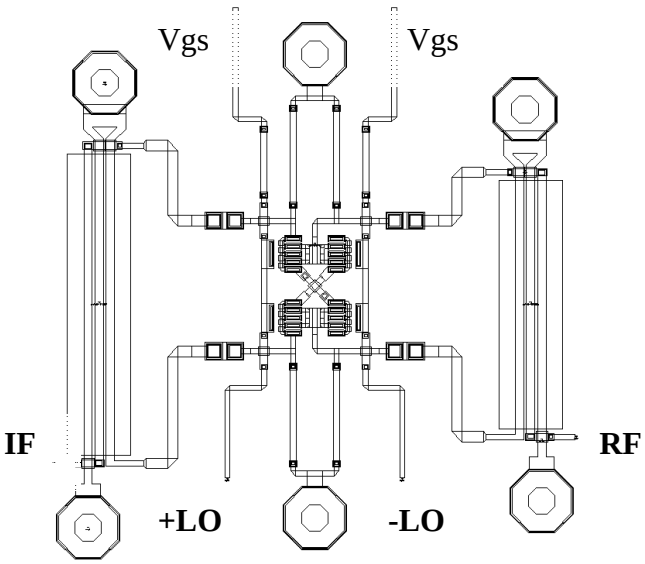

Fig1. Proposed double balanced mixer 1mm x 1.1mm

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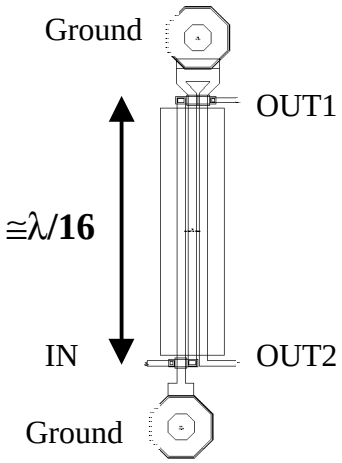


Fig2. Proposed 3 line coupler

A main feature of the 3 line couplers is that their terminations are very different from 50Ω. We developed a new mixer optimization method, the Statistical Load Pull [1]. The principle is to make vary at random the loads at the main mixing frequencies at the nonlinear component ports. Statistics are computed on the conversion losses corresponding to all the embedding cases to find what are the best operating conditions (loads at all the important mixing frequencies, bias, LO pump signal ...) to reach low losses Fig3.

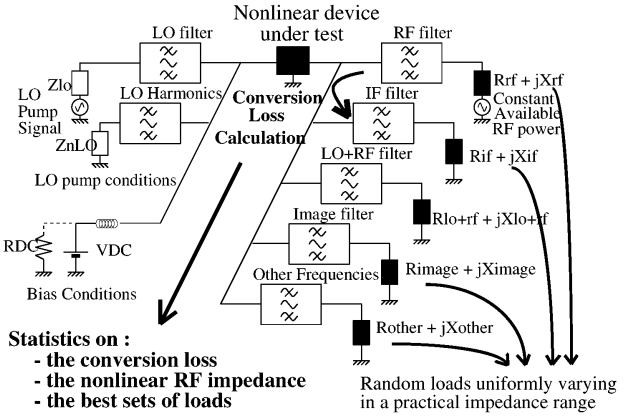


Fig3. Principle of the statistical load pull

The Statistical Load Pull showed us that the optimal RF and IF loads of the cold PHEMT quad were compatible with the termination impedances of the 3 line couplers. Then, optimizing on the one hand the gate size and the gate bias of the PHEMT with the Statistical Load Pull and on the other hand the coupler sizes with MOMENTUM from HP-EEsof, the quad and the couplers can be directly connected without any matching network. This property reduces once more the mixer size.

RECEIVER DESIGN

The complete single chip MMIC receiver includes 5 different microwave functions : the 14 to 12GHz double balanced mixer associated with a 2 stage RF LNA, a 2 stage IF amplifier, a 4 stage LO differential amplifier and a LO voltage controlled attenuator Fig4. The resulting MMIC contains 22 PHEMT. The chip, fabricated using a 0.2µm PHEMT process from Philips Microwave Limeil, France, was successful at the first pass Fig5.

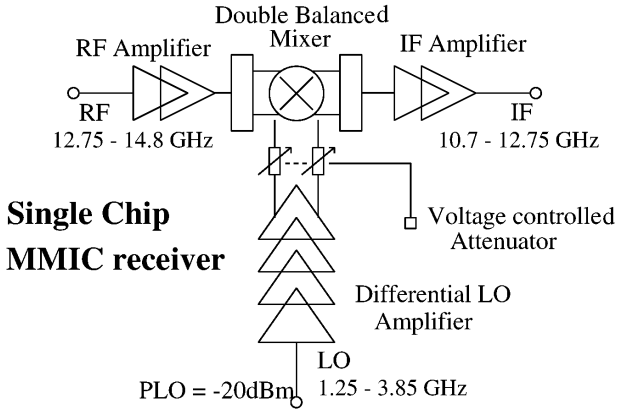


Fig4. Block diagram of the single chip MMIC receiver

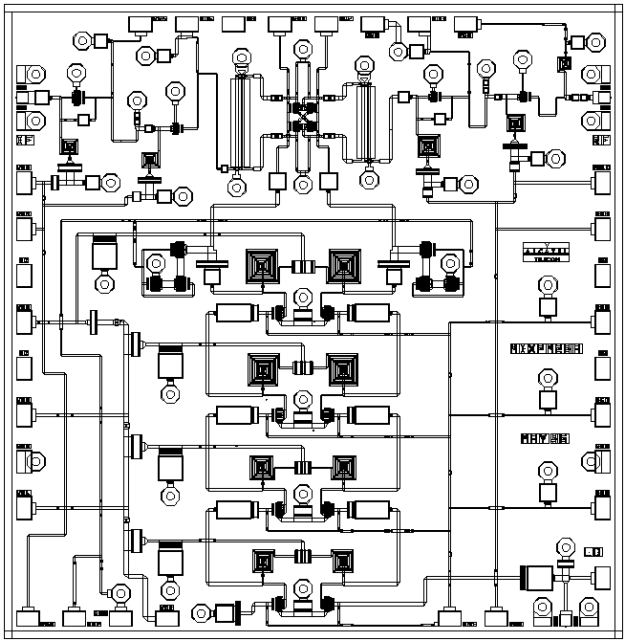


Fig5. The single chip MMIC receiver 4mm x 4.1mm

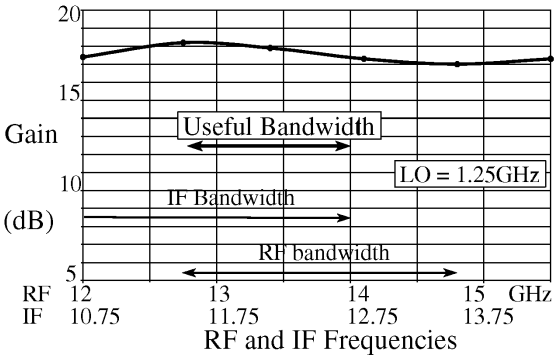


Fig6

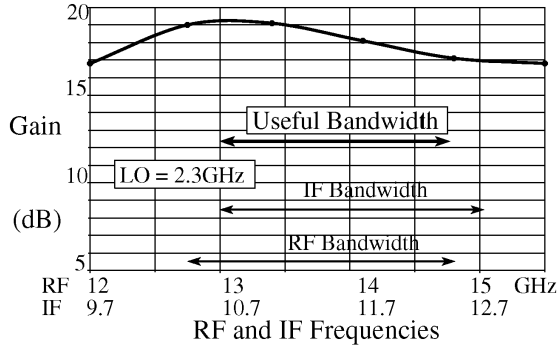


Fig7

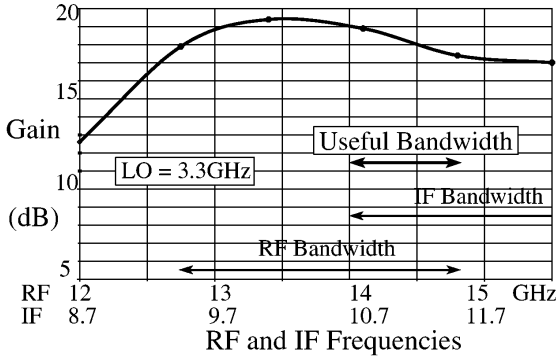


Fig8

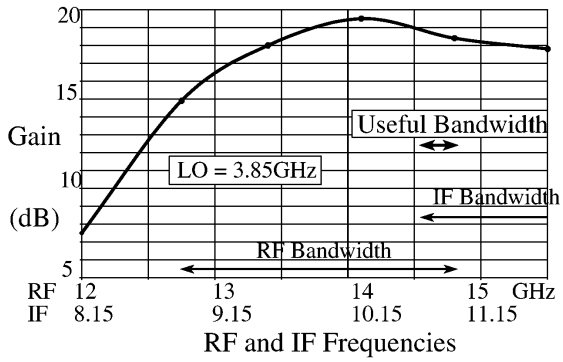


Fig9

Fig 6, 7, 8 and 9. Conversion gain versus RF frequency for a LO at 1.25, 2.3, 3.3 and 3.85GHz, -20dBm and a middle LO attenuation

MEASUREMENT

For -20dBm LO power and an attenuation in the middle of the LO attenuator caracteristic, the receiver conversion gain is higher than 17dB, the RF, IF and LO return losses are respectively lower than -10dB, -17dB and -12dB. The output P1dB is always higher than +4dBm. Figures 6 to 11 show few measurement curves for different LO frequencies.

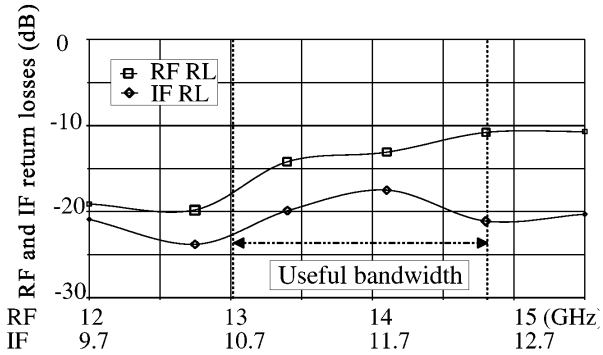


Fig10. RF and IF return losses versus RF and IF frequencies for a 2.3 Ghz LO frequency, a LO power at -20dBm and a middle LO attenuation

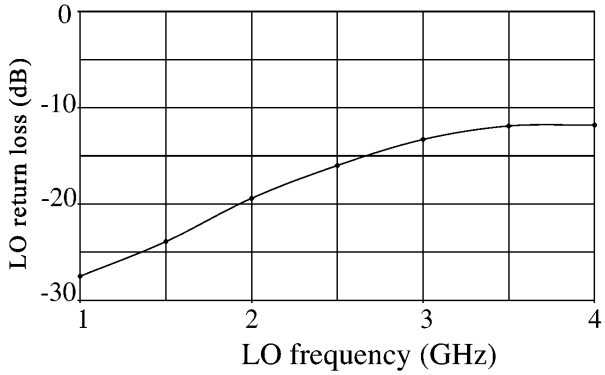


Fig11. LO return loss versus LO frequency for a LO power at -20dBm

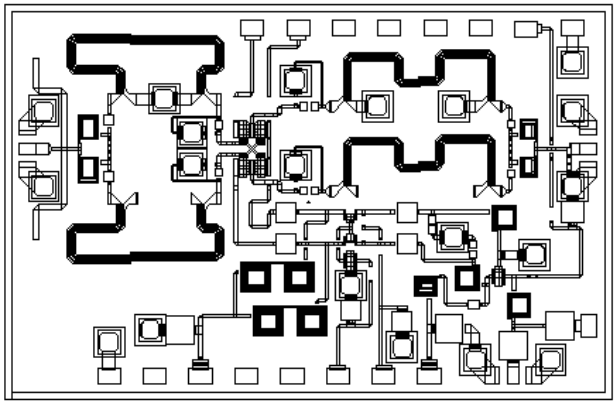
CONCLUSION

The use of MMIC allowed an important size reduction of satellite microwave equipments for few years. The next step is nowadays the integration of a increasing number of functions on the same MMIC. This trend leads to the size reduction of main microwave monolithic functions. This paper proposes a new small double balanced mixer architecture suitable for satellite repeaters. The

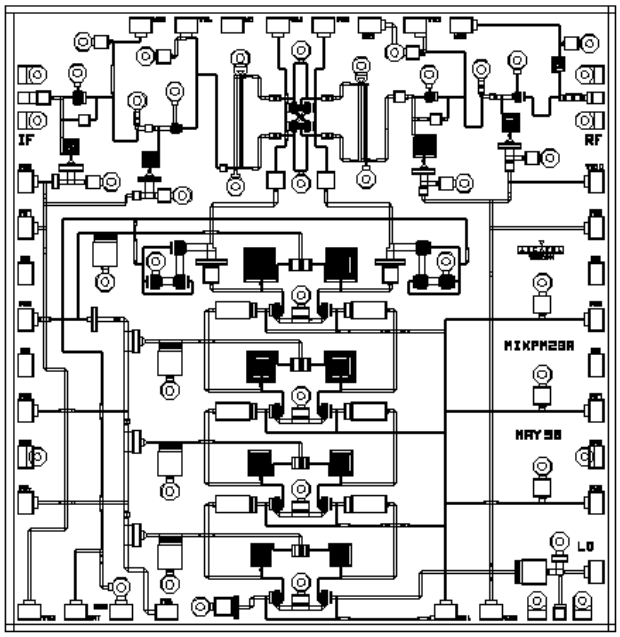
mixer is based on RF and IF 3 line couplers directly connected to a cold PHEMT quad. The new mixer area is divided by more than 5 compared with the previous version of the mixer Fig12. Thanks to its small size, about 1mm², the studied mixer was able to be associated with RF, IF and LO amplifiers and a LO attenuator. The resulting single chip MMIC receiver, including 5 different functions, was successful at the first pass and will be used in the new generation of telecommunications satellite equipments of ALCATEL ESPACE and in particular, in SKYBRIDGE payloads for multimedia services by satellite.

REFERENCES

[1] JF. VILLEMAZET, M. SOULARD "A Statistical Load Pull for mixer design using a commercial circuit simulator" IEEE MTT-S Digest, pp 757-760, 1996



4mm x 2.6mm



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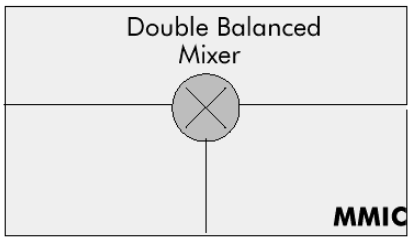

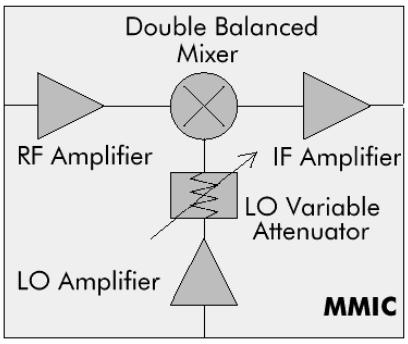

Fig12. MMIC size comparison between the previous generation and the new generation of the 14 to 12GHz receiver (the scale is the same for the 2 layouts). The double balanced mixer size is divided by more than 5