RESISTIVE GAAS HEMT MIXER DESIGNS FOR SATELLITE PAYLOADS

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ABSTRACT.

This paper focuses on design of resistive HEMT mixers suited for satellite repeaters where conversions from uplink to downlink frequencies, both higher than the LO frequency, is required with suppression of spurious mixing products and local oscillator harmonics which may fall inside or close to the transmit frequency range. Results are shown indicating clear advantages over conventional Schottky diode mixing.

INTRODUCTION.

In 14/12 GHz converters, typical of Fixed Satellite Services, a Local Oscillator (fixed) frequency of 1.2 to 3.5 GHz may be required by the frequency plan: depending on the latter, harmonics of the LO may fall in or close to the useful transmit band (with levels comparable to IF signal if not rejected) so that filtering them out is impossible or troublesome. The same holds for possible mixing products involving high-order LO harmonics. Similarly, in 18/12 GHz and 30/20 GHz converters, the second harmonic of the LO signal needs to be highly suppressed.

In [1] it was shown that a single balanced mixer design allows rejection of the most important products when properly selecting RF and IF orts, and that a double balancing does not in principle yield an advantage. Schottky diode mixer designsd suffer from the need of a relatively high LO power which in turn causes high generation of harmonics: HEMT resistive mixing is preferable in this respect and, when combined with a singly balanced configuration, allows the best performance in these transponder-type mixers.

14/12 GHz HEMT RESISTIVE MIXER DESIGN

Single balaced resistive HEMT mixers may be effectively realised with the configurations shown in fig. 1a. and 1b, based on a uniplanar balun derived from [2] and here applied to FET mixing rather than diode. The balun is composed of phase inverting lines cascaded at quarter wavelength intervals. its operating band should cover RF and IF bands altogether. In 1a. the FET source ground is virtual for LO and RF. In 1b. the physical source grounding makes the solution more easily implementable in hybrid technology: if a single phase inverting line is used (1st order balun) this scheme coincides with a ratrace hybrid.

A design based on 1b. was completed for the 14/12 GHz receiver (fig. 2,3). The devices selected were discrete low noise HEMTs with 0.25 um gate length by Mitsubishi, preferred to MESFETs because of the more sharply nonlinear Rds versus Vgs characteristics.

When compared to diode mixer designs, further to similar rejection properties, the possibility to use lower LO power (+3 dBm versus +9 dBm) while maintaining similar linearity performance, causes the high-order mixing products to have a much lower conversion efficiency, which enhances the spurious outputs' suppression obtained by balancing.

The LO frequency band is limited by the operating band of the 2.3 GHz coupler. In this realization it is a simple 180° delay line with selectable pads, leading to a narrow band (10%) which however may be centerd (by hardwiring) in a wide frequency range. This was completely acceptable in our narrowband, modest volume application. To increase the LO band while maintaining layout size acceptable, the LO balun can be designed as a 2nd or 3rd order balun with the same principle as for the RF and IF circuit portion, but with a lumped or semilumped-element approach. this is currently being attempted in monolithic technology, obviously more suited for a lumped-element microwave design.

EXPERIMENTAL RESULTS

The 5th LO harmonic, close to the IF band for a receiver with LO frequency of 2.3 GHz, was measured to be -61 dBm at the IF port (fig. 4), which is 10 dB below the perforamnce presented in [1] for a balanced diode mixer. Conversion loss and noise figure performance are a typical 7 to 9 dB. The RF/IF isolation, of importance in a satellite repeater to minimize stray feedback at IF (as on board gain may exceed 130 dB) was measured better than 28 db throughout RF and IF bands (fig. 5).

Gate bias may be adjusted to enhance the third order intermodulation rejection: the measured C/I at -10 dBm input per carrier was 43 dBc, i.e. +11.5 dBm/carrier input intercept point, for +3 dBm LO power and -0.2V gate bias. This result is comparable to what obtained with Schottky diodes at +9 dBm LO power.

30/20 GHZ MMIC PHEMT RESISTIVE MIXER DESIGN

The general schematic shown in fig. 1a has been implemented in a MMIC design for 30/20 GHz repeaters. To overcome the LO band limitations previously pointed out, the 10 GHz LO is fed via a 2nd order balun realized with lumped elements, allowing a simulated 40% bandwidth. Figures 6 shows the schematic of this balun. The 30 Ghz RF and the 20 Ghz IF are fed via a 2nd order balun, which in this case is realized with distributed elements.

The balanced structure allows to rejects the second harmonic ot the L.O., which is fully in band. The predicted conversion loss is a typical 8 to 9 dB for a swept L.O. from 9 to 12 Ghz and it doesn't change significantly for a swept L.O. input power from +9 to +2 dbm (fig.8). The second harmonic of the L.O. is below -40 dBm for a swept L.O. from 8.5 to 12 Ghz, with +2 dBm L.O. input power. Figures 9,10 and 11 show respectively the predicted L.O., R.F. and I.F. Return Loss [dB].

The MMIC is to be manufactured using a 0.25 um PHEMT process by a European foundry and the layout is shown in fig.7.

CONCLUSIONS

Resistive mixer designs were shown specific for satellite repeater applications, where the LO frequency is low compared to the RF and IF frequencies and peculiar spurious intermodulation problems are faced. Hybrid and monolithic designs were illustrated, with experimental evidence of improvement with respect to Schottky diode mixers in terms of single carrier intermodulation and harmonics.

REFERENCES.

[1] A.Suriani, P.Montanucci, P. Ranieri, "Design of microstrip balanced mixers for spurious outputs suppression in Ku band satellite repeaters", 27th European Microwave Conference, Jerusalem, 1997.

[2] R.Knochel, B.Mayer, U.Goebel, "Unilateral microstrip balanced and doubly balanced mixers", IEEE MTT Symposium Digest, 1989, page 1247.

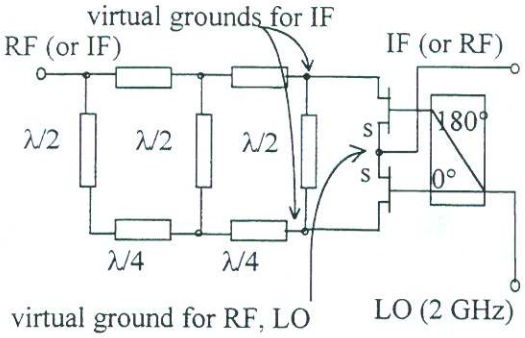


fig. 1a: balanced resistive mixer principle schematic

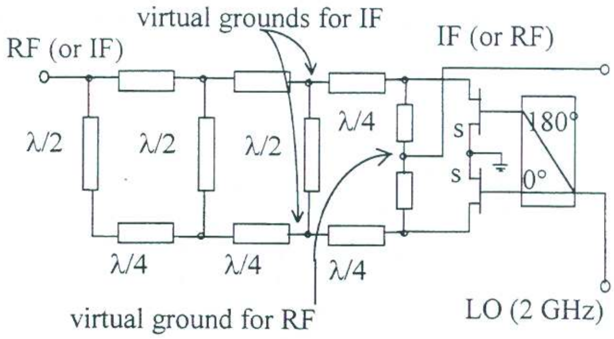


fig. 1b: alternate principle schematic (sources grounded)

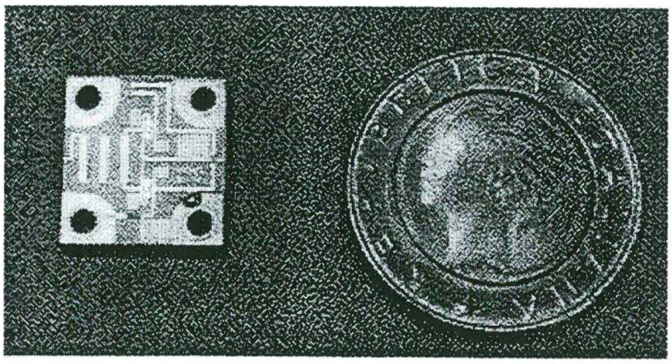


fig. 2: 14/12 GHz mixer (hybrid MIC)

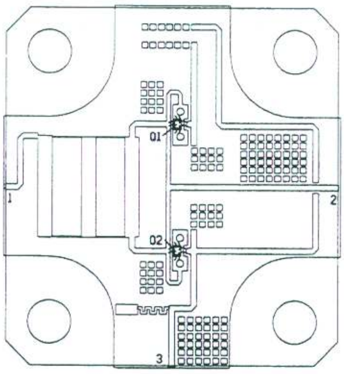
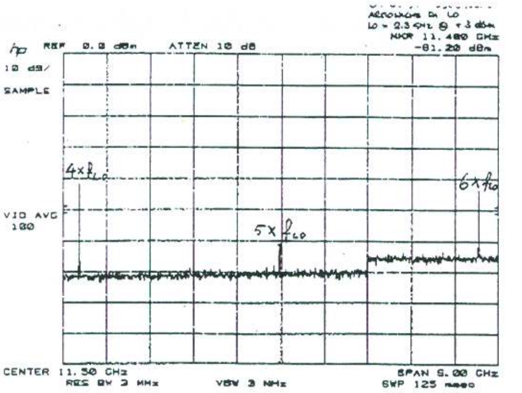


fig. 3: 14/12 GHz mixer layout



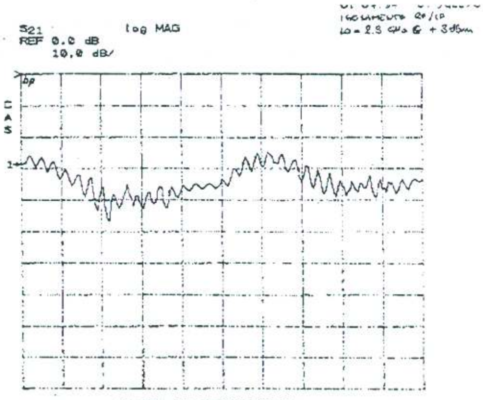


fig. 4: output spectrum showing odd harmonics suppression

fig. 5: measured RF/IF isolation

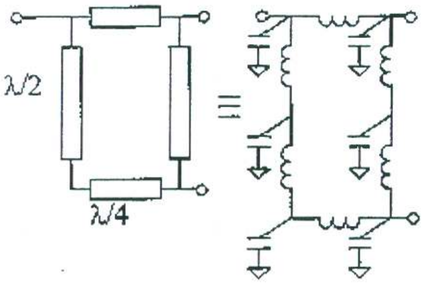


fig.6: second order balun schematic

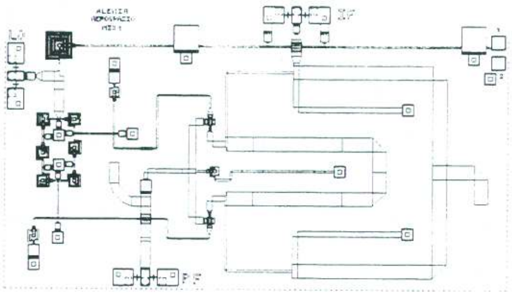


fig. 7 MMIC resistive mixer layout

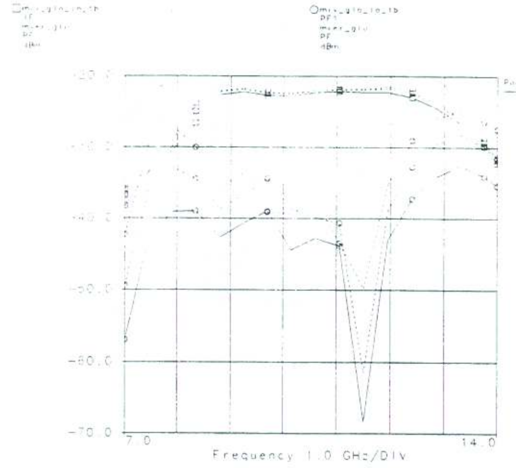


fig.8 : predicted IF and $2xf_{LO}$ output for swept LO and differents LO input power values (2 to 9 dBm)

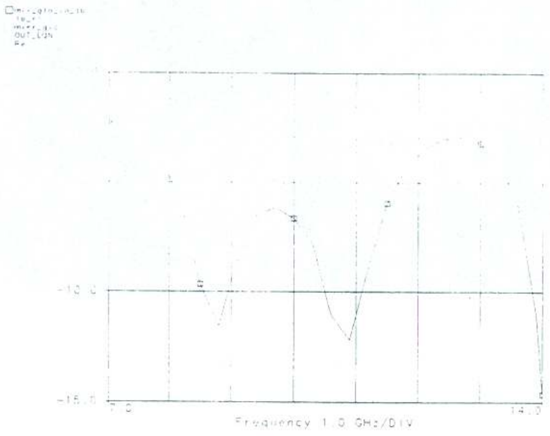


fig. 9: predicted L.O. Ret. Loss[dB] for swept LO

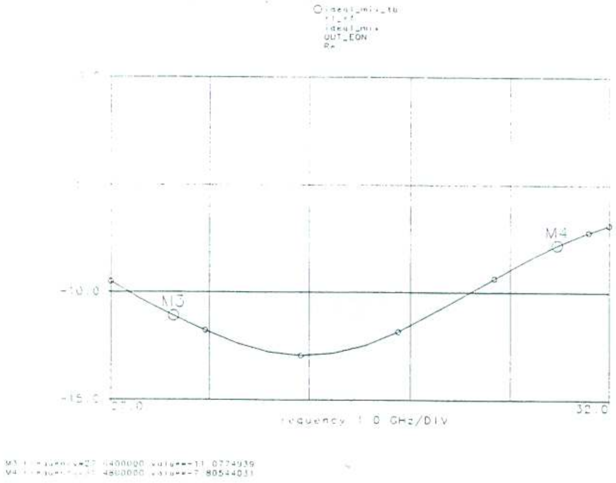


fig.10: predicted R.F. Return Loss [dB] for swept R.F.

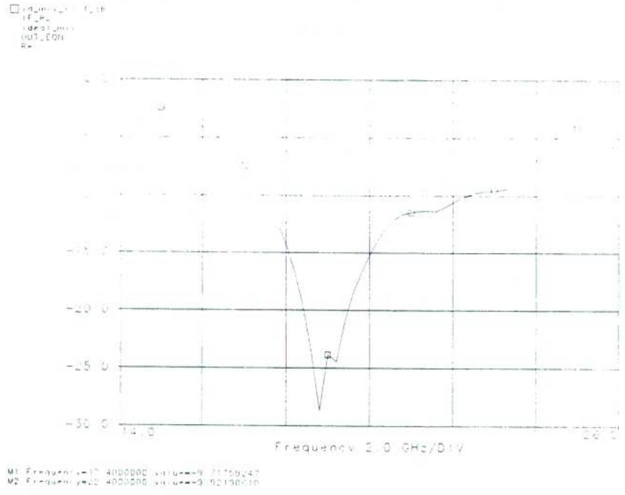


fig.11: predicted I.F. Return Loss [dB] for swept I.F.