BROADBAND AND TUNABLE NEGATIVE MONOLITHIC CIRCUITS FOR MICROWAVE ACTIVE FILTERS COMPENSATION

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ABSTRACT

In this article, GaAs MMIC negative resistance chips are presented. These devices are used to improve the performances of planar microstrip resonators structures [1][2]. The broadband capabilities of these negative resistance circuits are illustrated with their use to compensate for the losses of two 4-pole bandpass microstrip half wave filters designed with alumina substrate and centered respectively at 1.5 GHz and 4 GHz. Finally, experimental results of bandstop active filters built on lossy high permittivity dielectric substrate (ε_r=36) and also compensated for with these monolithic circuits confirm their great interest.

INTRODUCTION

GaAs MMIC technology has already been employed to great advantage in the design of various active circuits, such as matching networks, multipliers, circulators and phase shifters. Because of the low Q of the inductors and the capacitors in this technology (Q's are usually lower than 25), MMIC filters structures employ active components such as GaAs FET's to compensate for the parasitics of both the passive components and GaAs FET's themselves. The purpose of this paper is to present theoretical and experimental results on MMIC negative resistance to compensate for passive element losses. In the case of microwave filters, the first part of this paper focuses on the various possible ways to place the MMIC negative resistance and the advantages of each one. Then, theory, simulation and measurement of all MMIC negative resistance chips, are discussed. Finally, various applications of these MMIC circuits are presented, such as a 1-pole bandstop filter designed with high permittivity substrate (ε_r=36) which resonant frequency is 1.5 GHz and two other 4-pole bandpass planar resonators filters realised on an alumina substrate which resonant frequencies are 1.5 GHz and 4 GHz.

I - Influence of the position and number of compensation circuits on a planar microstrip resonator

The planar microstrip resonators which we study, perform bandpass or bandstop responses. The filter topologies are presented in figure 1, according to the type of the desired response.

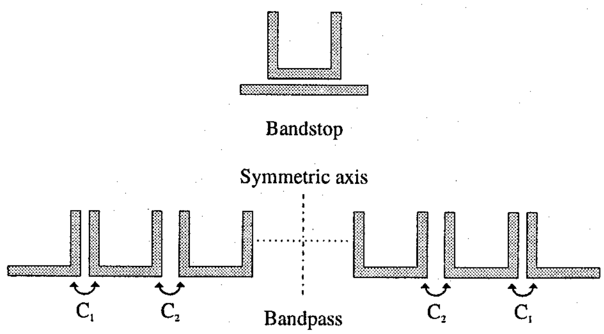

Figure 1 : Bandstop or bandpass planar microstrip resonator filter topologies

In the case of the two-port negative resistance chip, we can only insert this chip at the center of a bandstop resonator. For an optimal losses compensation, we need one active circuit per resonator. In addition to that, this topology allows the use of open-ended resonators, easier to realise physically than short-ended structures. Also, this leads to smaller devices using only $\lambda o/4$ resonators. At the opposite, a 1-port negative resistance can be placed only at the resonator ends. In this case, the number of compensation circuits used, depends on the considered filter type (bandpass or bandstop) considered. For the design of a bandstop filter, only one negative resistance per resonator is necessary, whereas, in the bandpass filter case, the negative resistance located at the resonator end, loads directly the coupled lines between resonators and influences the filter response. To obtain a symmetric response, both the coupling values Ci and the negative resistance must be placed in respect to the filter symmetry.

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In conclusion, to compensate an n-pole bandpass (n even), we need n active circuits and for a n-pole (n odd), n+1 active circuits are required (figure 2).

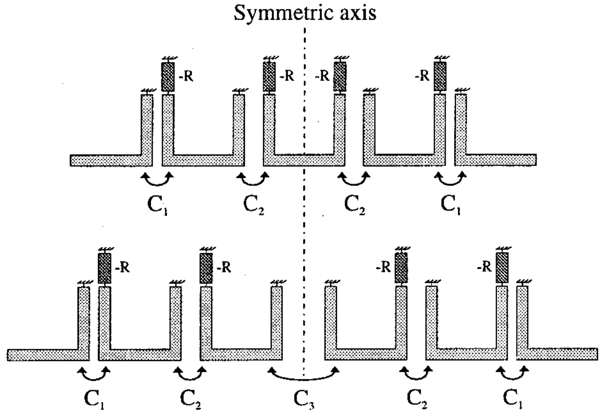

Figure 2 : Losses compensation circuit position on planar microstrip resonator filters

II - MMIC negative resistance chips

This second part focuses on MMIC negative resistances employed to compensate for intrinsic losses of planar microstrip resonators structures.

II-1- Negative resistance based planar filter

In comparison to narrow band applications such as oscillators, compensation of planar resonator losses requires a low negative resistance value over a wide frequency band. In this paragraph, we present the theory, schematic, simulated and measured results and the layout for these MMIC chips implemented on a 100 µm-thick GaAs substrate (ε_r= 12.9) of the PHILIPS GaAs foundry (FRANCE). The first of them is a one-port one-FET negative resistance. This device is based upon the serial feedback of a single FET. The corresponding circuit is shown in figure 3. Simulated results of Re(Zin) are given in figure 4. These results can be clearly compared with measurements presented in figure 5. Dimensions of the final circuit, which layout is shown in figure 6, are 1.5mm x 1.0mm. Based on the same principles, and using the same design process, 3 other MMIC chips have been realised :

- one-port two-FET negative resistance,
- new simplified one-port one-FET negative resistance,
- two-port two-FET negative resistance.

Measured results for these circuits are available but are not presented here in order not to exceed the length limit of this summary.

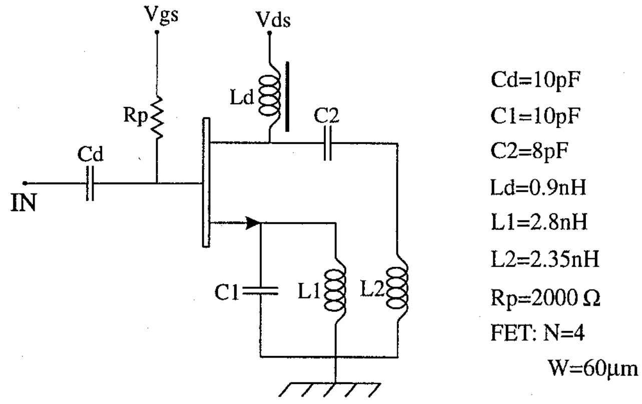

Figure 3 : Schematic of the one-port one-FET negative resistance

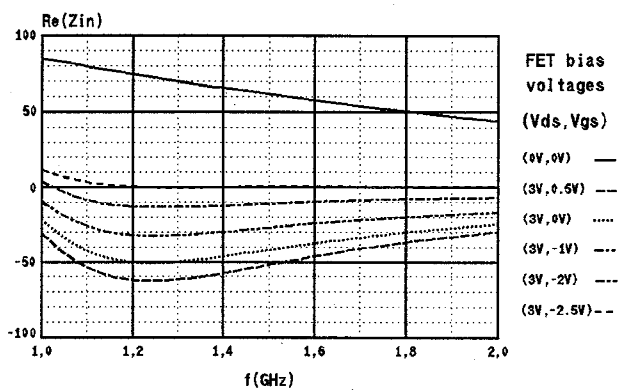

Figure 4 : Simulated real part of Z_{in} of the one-port one-FET negative resistance

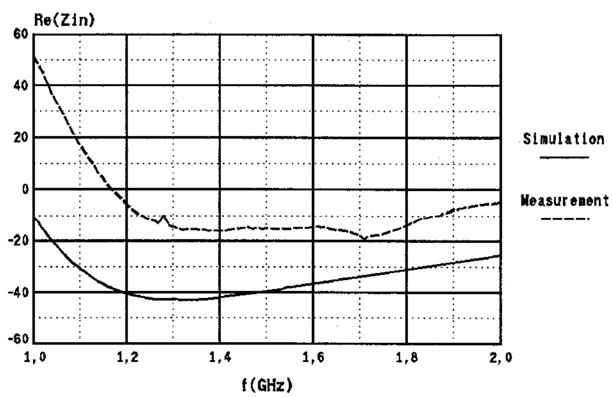

Figure 5 : Simulated and measured real part of Z_{in} of the one-port one-FET negative resistance

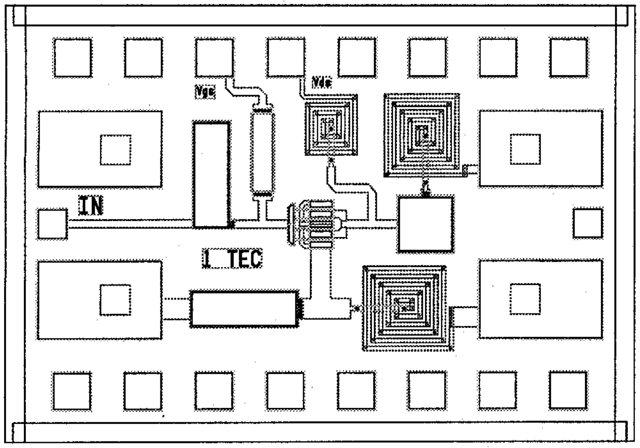

Figure 6 : Layout of the final one-port one-FET negative resistance chip

II-2 - Conclusion

For all the circuits, a broadband negative resistance value is obtained. The shift of this parameter between simulated and experimental responses is due to the voltage drop into the intrinsic parasitic resistance of the bias elements. Note furthermore that a non negligible imaginary part of the input impedance, will have to be taken into account in the planar resonator synthesis.

III - Broadband applications

In this part, we present a one-pole bandstop filter implemented on high permittivity substrate (ε_r=36) and two 4-pole bandpass filters (1.5 GHz and 4 GHz) implemented on an alumina substrate (ε_r=9.6). The same negative resistance circuit is used to compensate for the resonator intrinsic losses in each filter. The one-port one-FET negative resistance circuit which is used now, present a negative input resistance from 1 GHz to 5 GHz. So the compensation of different filters is possible in this broadbandwidth with this circuit.

III-1 - One-pole planar microstrip bandstop filter centered on 1.5 GHz

The device is shown in figure 7 where two similar $\lambda o/4$ resonators at 1.5 GHz are coupled to a 50Ω line. The resonator (b) is strictly passive when the resonator (a) losses are compensated for with the monolithic negative resistance chip.

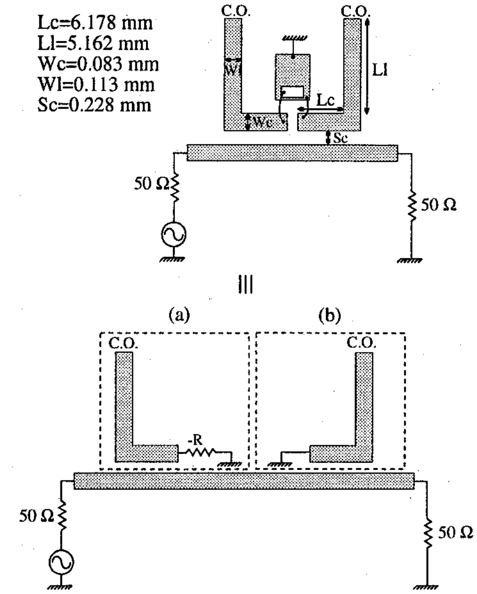

Figure 7 : Schematic of one-pole planar microstrip bandstop filters

The planar microstrip resonator filter is implemented on a high permittivity substrate (ε_r=36) to reduce the final circuit size. We note a good agreement (figure 8) between passive filter simulated and measured results but with more important losses in the last case. To compensate them, the MMIC negative resistance chip is inserted between the resonator end and the ground. We can observe in figure 9, the tunable losses compensation and the associated central frequency shift due to the variable imaginary part of the input impedance of the monolithic circuit.

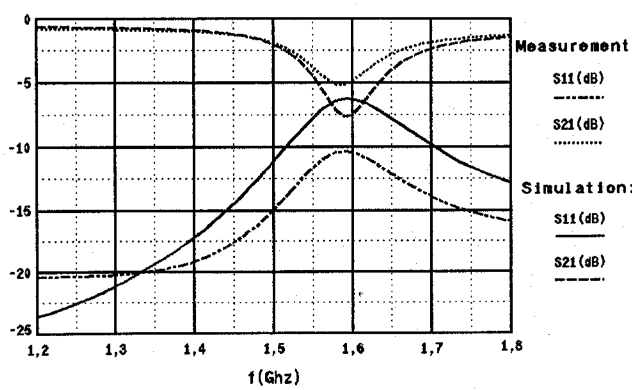

Figure 8 : Simulated and measured response of the passive one-pole bandstop filter

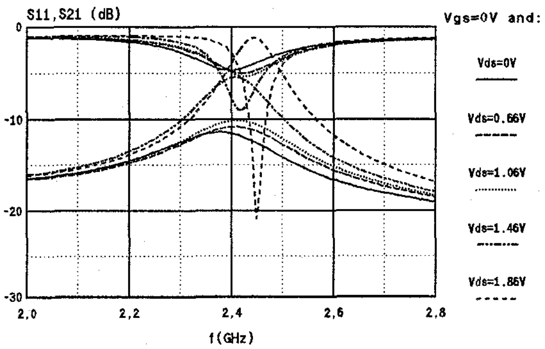

Figure 9 : Measured responses of the active one-pole bandstop filter

III-2 - Four-pole planar half wave microstrip bandpass active filter centered on 1.5 GHz

For this filter, we have taken into account the non negligible imaginary part of the input impedance in the filter synthesis. In figure 10, we present at 1.5 GHz the 4-pole losseless bandpass filter response designed with an alumina substrate (ε_r=9.6) and obtained with the following MMIC FET bias voltage values : Vds = 3V , Vgs = -2.45V.
For this bias values and at 1.5 GHz, active circuit performs an input impedance: Zin = -1.15 Ω - j 252 Ω.

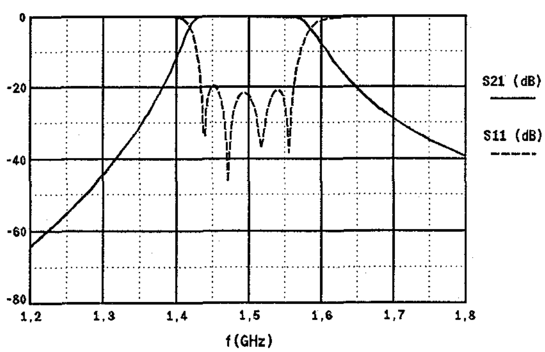

Figure 10 : Simulated response of the active 4-pole bandpass filter at 1.5 GHz

III-3 - Four-pole planar microstrip bandpass active filter centered on 4 GHz

In the same way, and in the same conditions, an other filter centered on 4 GHz is synthesised. In figure 11, we present the filter response obtained with MMIC FET bias voltage values : Vds = 3V , Vgs = -2.82V. For this bias values and at 4 GHz, the active circuit input impedance is : Zin = -0.116 Ω - j 90 Ω.

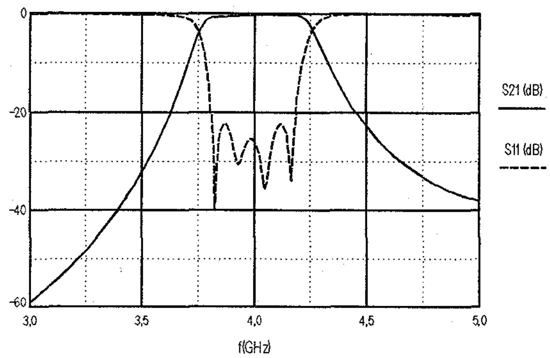

Figure 11 : Simulated response of the active 4-pole bandpass filter at 4 GHz

These two last active bandpass filters with respectively 1.5 GHz and 4 GHz as bandpass central frequency, clearly show the broadband capabilities of the monolithic negative resistance circuits.

CONCLUSION

In this paper, we have presented various MMIC negative resistances, and the advantages of their use in different planar resonator topologies. We show that these MMIC negative resistance circuits can be used for broadband applications and perform losses compensation on two octaves bandwidth.

ACKNOWLEDGMENTS

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