Design Procedure for Loss Compensation of Planar Microwave Filters Using Negative Resistances For Tuneable Bandstop and Bandpass Applications

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***Abstract* - In this paper, we present a method to synthesise microwave active bandpass and bandstop filters using negative resistance circuits and/or active inductance circuits realised in MMIC technology. We show measurements of a negative resistance circuit which is after associated with passive lumped elements to realise an active bandstop filter, tuneable in frequency. We also present the synthesis of an adjustable active inductance close to an ideal element over the 3.8-4.2 GHz band. This element is introduced in a passive bandpass filter to compensate its losses and realise a high-Q selective structure.**

I. INTRODUCTION

Recently, there has been an increasing interest in the development of monolithic or hybrid active filters at the lower microwave frequencies for many commercial wireless as well as established military applications. At these frequencies, the classical planar passive filters suffer from metal conductor losses as well as losses through substrate. These prevent passive MMIC or hybrid filters from achieving low insertion loss performance and high Q-factors required to obtain reasonable frequency selectivity. Consequently, active filter approaches involve the use of negative impedances to compensate these passive losses and can provide a compact filter design solution [1].

In our work, we synthesise negative resistance circuits derived from NICs and gyrators at low frequencies [2] and present several applications to filtering by compensating for the losses of passive structures. Then, we present the theoretical principle and the measurements of a negative resistance topology using two transistors. We use this circuit for a bandstop filter application validated with measurements. Using this negative resistance circuit, we describe also the measured results of an active inductance and one of its specific applications to bandpass filtering functions for high-Q selective responses.

II. BANDSTOP FILTER USING A 2-FET NEGATIVE RESISTANCE CIRCUIT

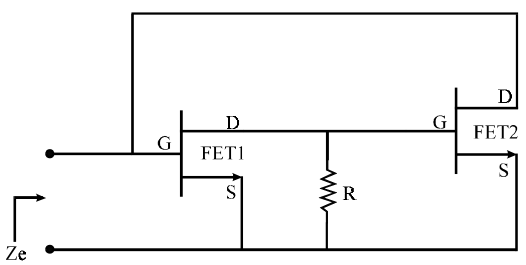
A. Negative resistance topology

The simplified representation of a possible negative resistance topology is illustrated in the principle schematic of Fig. 1. In a simplify approach, if we consider transistors as ideal current sources, the negative resistance is given by:

$$Z_{in} = \frac{-1}{g_1 \cdot g_2 \cdot R}$$

This value can be adjusted by tuning R (load impedance) or by adjusting the voltage bias as shown below.

Fig. 1: SCHEMATIC OF THE MMIC NEGATIVE RESISTANCE CIRCUIT



We present here the synthesis of a negative resistance circuit which works at a frequency band around 2 GHz. The different elements in the circuit are optimised to obtain a negative real input impedance around 2 GHz.

The circuit is realised using GaAs PHEMT technology [3]. Fig. 2 presents layout (2-a) and measurements (2-b) of the chip in the 1.8-2.4 GHz band.

Note on the graph that important negative values (beyond –30 Ω) can be performed for the real part of the input impedance around 2 GHz by simply adjusting the bias values. Great advantages can be derived from this capability of adjusting the real and/or imaginary part of the input impedance to compensate for the sensitivity of the passive parts after the physical implementation step. In the next paragraph, we use this circuit to compensate for the losses of a tuneable bandstop filter, working around 2 GHz.

Fig. 2-a: LAYOUT OF THE MMICNEGATIVE RESISTANCE CIRCUIT

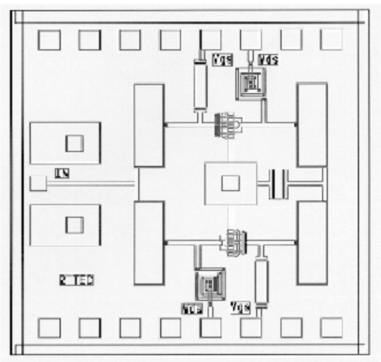
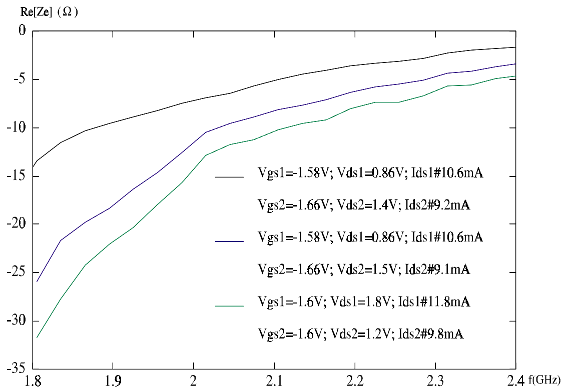


Fig. 2-b: MEASUREMENTS OF THE MMIC NEGATIVE RESISTANCE CIRCUIT



B. Active tuneable bandstop filter using a MMIC negative resistance

In this part, we realise an active tuneable bandstop filter using lumped elements. We use here pseudo-lumped inductors built and synthesised in microstrip technology. Centre frequency is optimised at 2 GHz. This filter can be tuned in frequency by using a varactor diode. The losses of the microstrip inductors and of the varactor diode are compensated by our negative resistance circuit presented above.

In a first step, the characteristics of lumped inductors are studied according to the different geometrical dimensions to determine an electrical equivalent schematic. This study is realised thanks to classical EM-CAD softwares. We use here an alumina substrate (ε_r=9.8; h_s=635µm).

For this filter, the inductor chosen is realised with one meander which has the following characteristics : length : 1mm; gap : 30µm; strip width : 255µm. The layout of the filter with the MMIC circuit is shown in Fig. 3-a and measurements are shown in Fig. 3-b. We note that this bandstop filter is tuneable in frequency over a wide band (nearly one octave) and that the losses are well compensated. The tuning range varies from 1.3 GHz to 2.6 GHz (66% of center frequency).

Fig. 3-a: SCHEMATIC OF THE BANDSTOP FILTER

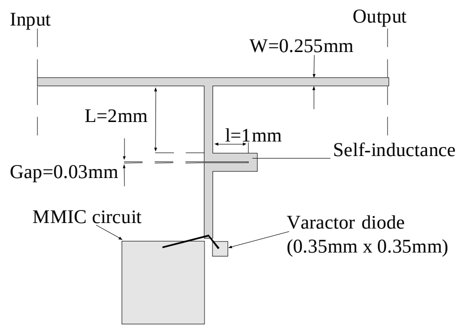
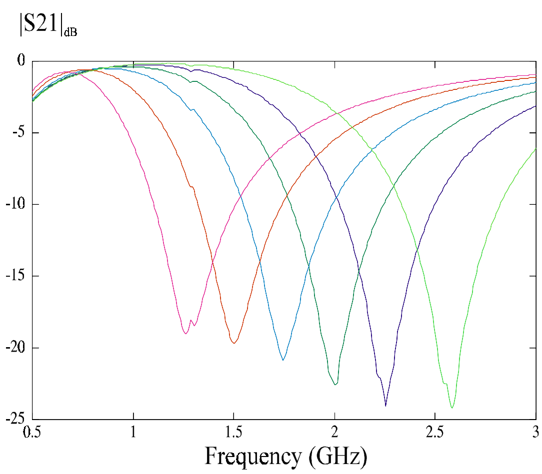


Fig. 3-b: MEASUREMENTS OF THE BANDSTOP FILTER



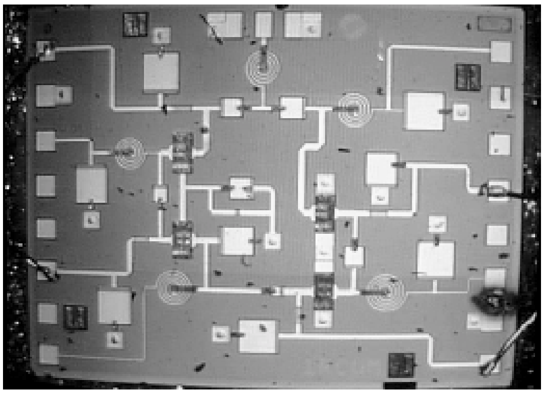
III. BANDPASS FILTER APPLICATION

A. NIC-based active inductance synthesis

The objective of this part is to show the feasibility of an adjustable active inductance over the 3.8-4.2 GHz band by using of the negative resistance. A MMIC inductance of 1.5 nH is cascaded with a negative impedance converter to compensate for the losses of the passive inductor.

Fig. 4-a shows the photograph of the inductance layout designed with the elements of a UMS process[4]. Note that the L value can be adjusted thanks to the biasing conditions of the transistors between 0.66 nH and 1.49 nH. The cascade topology of transistors permits to realise quasi-ideal transconductances. Base biasings are achieved with resistances and collector biasings with inductances which are connected to ground at high frequency thanks to high value capacitors. Considering all the elements, the size of the MMIC chip is about 2.2x1.8mm^2.

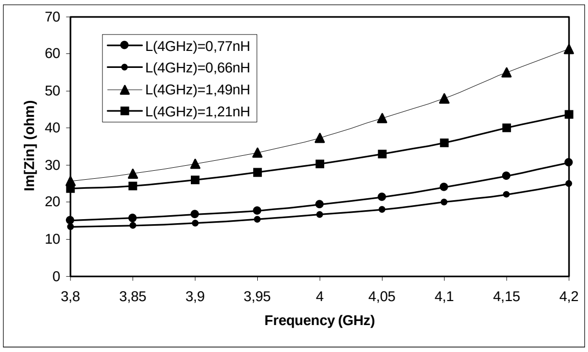
Fig. 4-a: PHOTOGRAPH OF THE ACTIVE INDUCTANCE



In Fig. 4-b, we do not present the measured results obtained for the real part of the input impedance : losses of the input inductor are perfectly compensated in the 3.8-4.2 GHz. Experimental measurements in figure 4 prove the capability to obtain an active inductance around 4 GHz.

Then, note that with the active circuit mentioned above, the adjustable L value can enable to simultaneously match a given centre frequency and a given Q value of the filter.

Fig. 4-b: MEASUREMENTS OF THE ACTIVE INDUCTANCE



B. Active bandpass filter using a MMIC chip at 4 GHz

For the filter implementation [5], we can associate our compensated inductor in parallel with a varactor (Fig. 5-a) to make the filter tuneable. In the case presented here, for a fixed frequency, a classical MMIC capacitor is used. With this topology, we compensate for the losses of the global filter through the compensation operated initially just on the MMIC inductor. Decoupling of the L-C resonator from the input/output ports is achieved through input/output low value capacitances. By choosing the coupling value achieved by the input/output capacitances, the Q factor of the filter can be adjusted. Depending on the desired Q value for the filter, the decoupling can be realised thanks to coupled line sections instead of capacitances, or with microstrip gaps for very high Q.

We present, in Fig. 5-b, the simulated results of a filter with a quality factor of about 1000. We present also in Fig. 5-c the photograph of the filter layout.

Fig. 5-a: SCHEMATIC OF THE BANDPASS FILTER

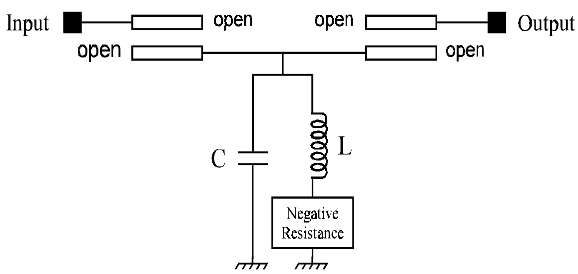


Fig. 5-b: SIMULATION OF THE BANDPASS FILTER

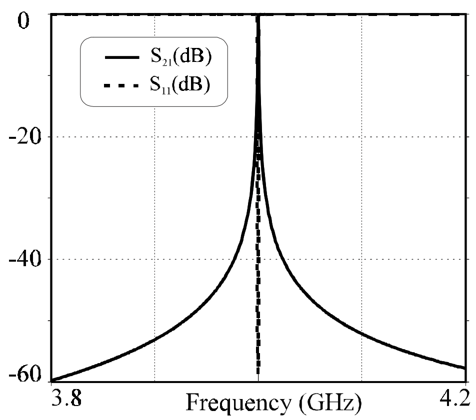
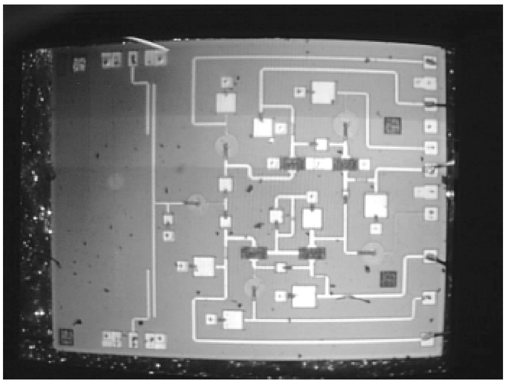


Fig. 5-c: PHOTOGRAPH OF THE BANDPASS FILTER



IV. CONCLUSIONS

In this paper, we have presented a design procedure, verified with computer simulations and measurements. We have shown the capability of associating MMIC negative resistances with passive elements synthesised in microstrip technology or classical MMIC elements to compensate for their parasitic effects both for bandstop and bandpass filtering applications.

In a first part, we have compensated for the losses of a filter with the implementation of an active bandstop filter tuneable over one octave. With the second approach, we have realised a given high-Q filter response by compensating for the parasitics of a lossy inductor in order to obtain a more ideal component. An example is given for a Q of 1000. Our approach can be extended for several filter structures.

V. REFERENCES

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