MMIC Lumped and Transversal Filter with LC Tuned Amplifiers

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Abstract — **This paper presents a modular approach for the design of MMIC lumped and transversal filter with LC tuned amplifiers. The filtering improvement due to the introduction of LC tuned amplifier modules (LCTAM) as the transversal element on the conventional lumped and transversal structure is illustrated by comparing the performances of a single LCTAM and double LCTAM filters with a conventional one. In order to demonstrate the novel filter usefulness three filters with two transversal sections were implemented with the same typical 0.5μm GaAs MMIC technology (a conventional, a single and a double LCTAM). It is shown that when we increase the number of LCTAM the rejection increases, however the chip area and complexity also increase. For a 1.54GHz centre frequency filter, a good compromise is the double LCTAM. This solution on the lower stop band (-250MHz) has 15dB more attenuation than the other two filters and on the upper stop band (+250MHz) has 17dB and 20dB more attenuation than the single LCTAM or conventional filter topology, respectively.**

I. INTRODUCTION

Microwave lumped and transversal bandpass filtering technique has been introduced more than twenty years ago [1]. MMIC implementations were already presented [2]. The main drawback of this filter, to be used in the modern communication systems, is its intrinsic wide bandwidth characteristics [3]. To increase its selectivity a higher order transfer function should be obtained. Increasing the number of sections is cumbersome and increases the power consumption. Accordingly, an alternative solution is the introduction of an LC tuned feedback circuit in the filter amplifiers [4].

In this paper, three MMIC filters were designed for a 0.5μm MESFET technology [5]. The first filter was a simple 2 sections lumped and transversal bandpass filter, which will be used as a reference. The other two are obtained from this one introducing the mentioned above LC feedback network in one or two of the filter transversal element amplifiers.

II. LCTAM FILTERS DESIGN

The circuit diagram of the three filters is presented in Figs. 1 to 3. The bias networks (choke inductors and AC coupling capacitors) are also introduced. The filters were designed in three steps.

Firstly, the conventional lumped and transversal bandpass filter (Fig. 1) for 1.54GHz was designed. In order to ease the filter design, a modular approach was adopted. The same MESFET was used in both amplifiers with V_{GS}=0V and V_{DS}=3V. The second order LC low pass and high pass networks were designed for 1.54GHz. Standard spiral inductors and polymide capacitors were used. The complete filter was optimised changing the capacitors, inductors and termination resistances. Special attention was given not only to the gain (s_{21}) but also to the matching (s_{11} and s_{22}).

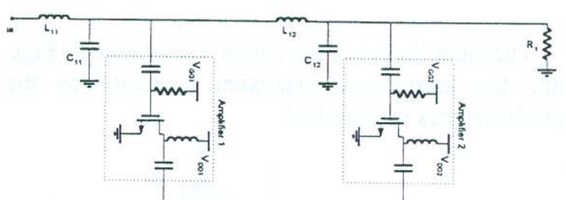

Fig. 1 - Conventional lumped and transversal bandpass filter circuit

Secondly, the LC feedback network was introduced on the second MESFET (single LCTAM filter - Fig. 2) and a similar optimisation process was followed. On this filter the stability was improved introducing a parallel feedback resistor on the second MESFET.

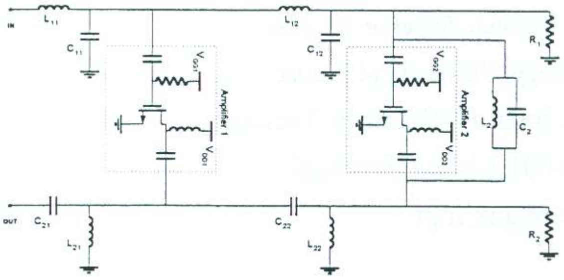

Fig. 2 - Single LCTAM filter circuit

Finally, the LC feedback network was introduced on both MESFETs (double LCTAM filter - Fig. 3) and a similar optimisation process was followed. To improve the stability, small resistors in series with the capacitors of the LC tunned circuits and short transmission lines in series with the first MESFET sources, were introduced.

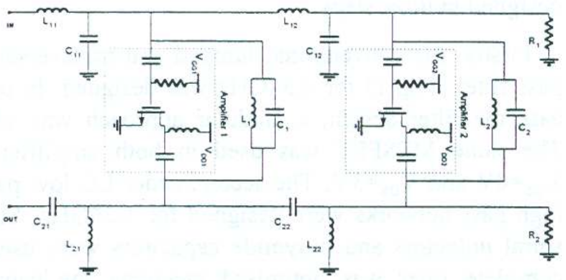

Fig. 3 - Double LCTAM filter circuit

The final layout of the filters was obtained (Figs. 4 to 6) and the fabrication dispersion influence on the filters performances was studied.

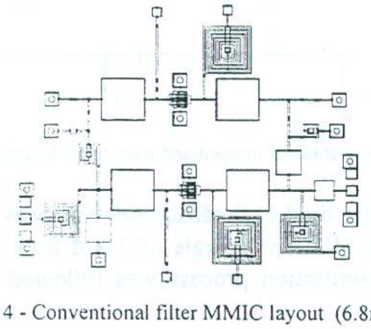

Fig. 4 - Conventional filter MMIC layout (6.8mm^2)

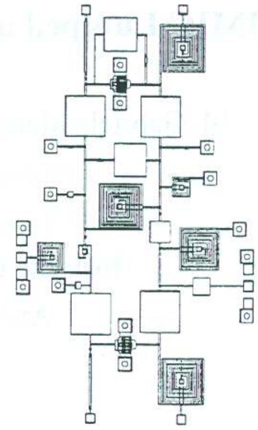

Fig. 5 - Single LCTAM filter MMIC layout (7.9mm^2)

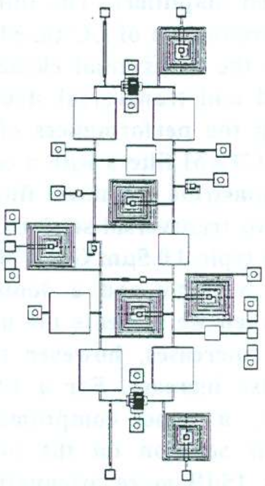

Fig. 6 - Double LCTAM filter MMIC layout (9.0mm^2)

III. FILTERS COMPARISON

In order to illustrate the usefulness of the tuned amplifier on the transversal filter response, Figs. 7 and 8 show the gain versus frequency of the three filters. Obviously, the filter with both MESFETs tuned presents better filtering performance: 3dB bandwidth of 35MHz and more than 20dB attenuation at ±250MHz. From Fig.7, the advantage of tuning only one MESFET is not very significant. Only at the upper stop band an attenuation increase lower than 5dB was obtained. A 3dB bandwidth of 240MHz and 340MHz was obtained for the single LCTAM and conventional filters, respectively.

On a wider band (Fig. 8) also the double LCTAM filter presents better performance. A second resonance is presented only at 15GHz and with a 15dB attenuation. The worse response on a wide band is presented by the single

LCTAM filter. This configuration is also the one with the lowest stability factor. The filter doesn't presents much narrower bandwidth than the conventional filter due to the need of a resistive feedback to increase the stability.

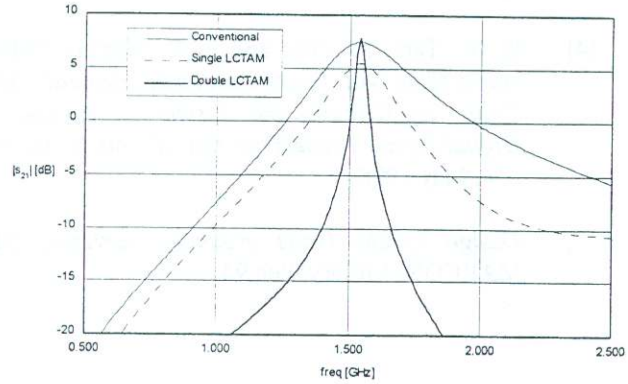

Fig. 7 – Filter gain versus frequency at 1.5GHz±1GHz

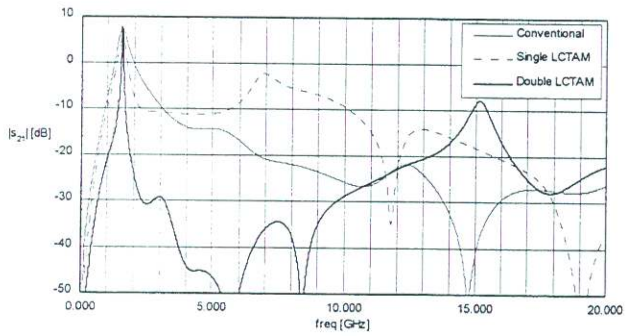

Fig. 8 – Filter gain versus frequency up to 20GHz

When we compare the input and output matching characteristics of the three filters (Figs. 9 and 10), we noticed that the results are not very good, which is one drawback of this type of filters. The circuit with both MESFETs tuned has also the best performance, however on a narrower bandwidth. The input matching is better than the output one.

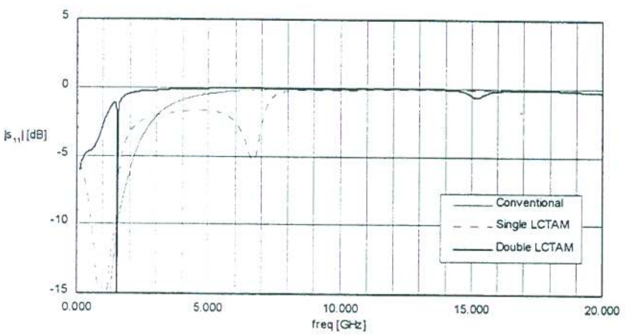

Fig. 9 – Filters input return losses versus frequency (s_{11})

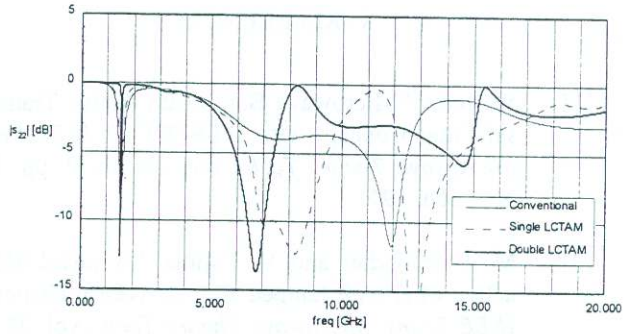

Fig. 10 – Filters output return losses versus frequency (s_{22})

At the input return losses higher than 10dB were obtained for all filters. However, output return losses better than 10dB were only obtained with the double LCTAM filter.

The main disadvantage of the filter with both amplifiers tuned is a higher layout area (Figs. 4 to 6): 30% increase over the conventional and 14% over the single LCTAM.

Another disadvantage is the sensitivity to technology parameters dispersion. Analysing the dependence on the fabrication dispersion, it was noticed that for a ±12% change on the capacitors (foundry specification) a centre frequency maximum variation of 80MHz is expected for the conventional and for the single LCTAM filters, and 90MHz for the double LCTAM filter. Assuming an additional variation of the MESFETs threshold voltage V_T of ±0.2V an increase of 20MHz on the centre frequency was noticed for all filters.

IV. CONCLUSIONS

The study of a modified lumped and transversal passband filter with one or two tuned amplifiers on the transversal elements was presented. It was noticed that, for a two transversal sections filter, the improvement of the frequency response when only one tuned transversal element is introduced is not very significant. This can be due to the introduction of a resistive feedback network to avoid stability problems.

The two tuned transversal elements filter presents not only a better frequency response but also better return losses. In spite of a larger number of components, this filter presents similar fabrication dispersion.

All MMICs are biased with V_{DD}=3V and V_{GG}=0V. For this nominal bias each MMIC has a current consumption of 94mA (282mW power consumption).

V. REFERENCES

[1] W. Jutzi, "Microwave Bandwidth Active Transversal Filter Concept with MESFET's," *IEEE Trans. Microwave Theory Tech.*, vol. 29, no. 9, pp. 760-767, Sep. 1971.

[2] M. J. Schindler and Y. Tajima, "A novel MMIC active filter with lumped and transversal elements," *IEEE Trans. Microwave Theory Tech.*, vol. 37, no. 12, pp. 2148-2153, Dec. 1989.

[3] C. Rauscher, "Microwave channelized active filters – a new modular approach to achieving compactness and high selectivity," *IEEE Trans. Microwave Theory Tech.*, vol. 44, no. 1, pp. 122-132, Jan. 1996.

[4] K. W. Tam, P. Vitor and R. P. Martins, "MMIC active filter with tuned transversal element", *IEEE Trans. on Circuits and System II: Analog and Digital Signal Processing,* vol. 45, no. 5, pp. 632-634, May 1998.

[5] *Design Guide GaAs Foundry services*, GEC-MARCONI Library, Feb 95.