NARROW X-BAND TUNABLE MMIC FILTERS EMPLOYING ACTIVE RESONATORS AS LOCAL FEEDBACK

F.E. van Vliet[1], J.L. Tauritz[2], F.L.M. van den Bogaart[1] and R.G.F. Baets[3]

1: TNO Physics and Electronics Laboratory
P.O. Box 96864, 2509 JG, The Hague, The Netherlands

2: Delft University of Technology, Faculty of Electrical Engineering
P.O. Box 5031, 2600 GA, Delft, The Netherlands

3: University of Gent, Department of Information Technology
Sint-Pietersnieuwstraat 41, B-9000 Gent, Belgium

ABSTRACT

Monolithic microwave active inductors have been used to realize very narrow X-band tunable filters. The active inductors were used in local feedback configurations. This results in simple structures that make optimal use of the unloaded resonator quality factor. MMIC band pass and band stop filters were designed, realized and fully characterized.

INTRODUCTION

The integration of narrow microwave tunable band filters is of paramount importance for the reduction of cost and size of high-performance microwave front-ends. Specific problems associated with monolithic filters include low component quality factors and a low capacitance ratio of the varactors.

A promising solution for the component quality factors is the use of microwave active inductors, as has been widely reported [1-6]. Most reported filters with these inductors, however, are either limited to moderate bandwidth filters or to the communication bands at 0.9 and 1.8 GHz. This paper presents filter designs at X-band with very narrow responses. The tunable filters are fully characterized for small signal, large signal and noise behavior. Also the temperature dependence has been measured.

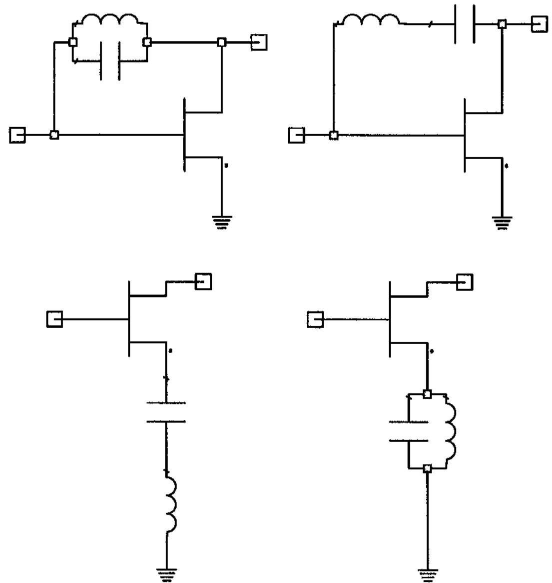

Figure 1: Different ways to use high-Q resonators as local feedback. Shown are the possibilities for a single transistor configured in a common-source topology.

METHODOLOGY

The design of monolithic narrow band passive filters is hindered by the low quality factor of integrated active inductors. The maximum quality factor is at 10 GHz limited to approximately 20, even for high-performance microwave GaAs processes. We have therefore chosen to use *active* inductors, that were synthesized according to [7].

There are different ways to use the active inductors to realize actual filters. In the first place, we can use them to replace passive inductors in conventional ladder-type filters, such as demonstrated in for example [8]. The design of those filters is easy and their sensitivity low, but noise properties are generally not so good and the design has no gain. To overcome the gain problem, we may realize resonators and couple them with amplifiers. Still, the noise figure is not very good. Furthermore, the resonator is loaded by the output impedance of the amplifier.

We propose to use the resonators as local feedback and couple them to the amplifier as a tapped resonator. The quality factor of the resonator is then only slightly lowered and we can fully take advantage of its high Q. Also, gain may be present.

When a single resonator is used as feedback, shunt- or series-feedback may be chosen and the resonator can either be a series or a parallel resonator. Hence, four combinations result, as shown in Figure 1. Microwave active inductors are most easily designed as grounded inductors. As can be seen, series feedback offers the best opportunities.

We realized both band stop and band pass filters. The band stop filters were realized as a common-source stage with series feedback. Due to the limited tuning range of the varactors, two resonators were realized, biasing determined which resonator was active. For the band pass filter, we combined a band stop filter together with a matched all-pass filter. This kind of realizations can be considered as an implementation of [9]. Active splitters and combiners (in the form of a differential-to-single-ended amplifier) were employed on the same IC.

RESULTS

Two chips have resulted from the work described, photographs are shown in Figure 2 and Figure 8, both employing similar active inductors. With the design of the active inductor, special care was taken to make sure that stability was guaranteed, regardless of the signal power.

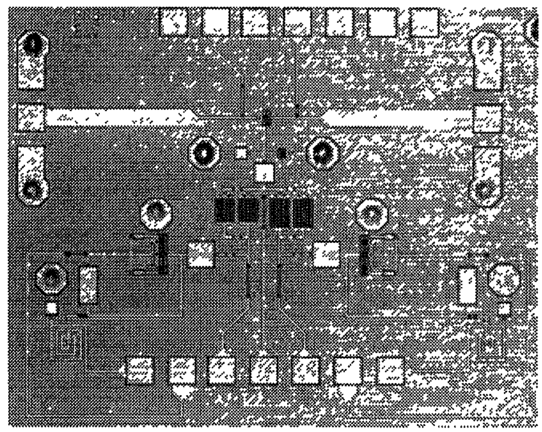

Figure 2: Layout of a band stop filter with two resonators used as series feedback.

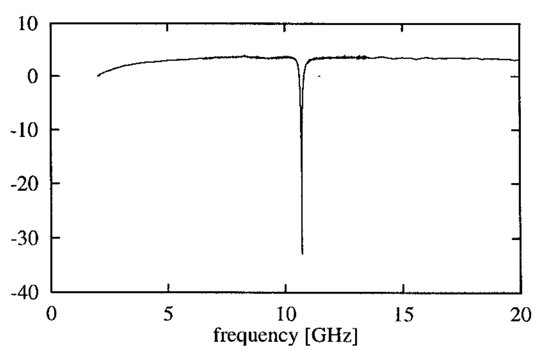

Figure 3: Measured S_{21} for the band stop filter.

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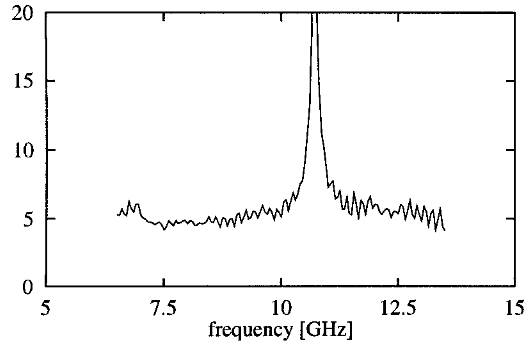

Figure 4: Measured noise figure for the band stop filter.

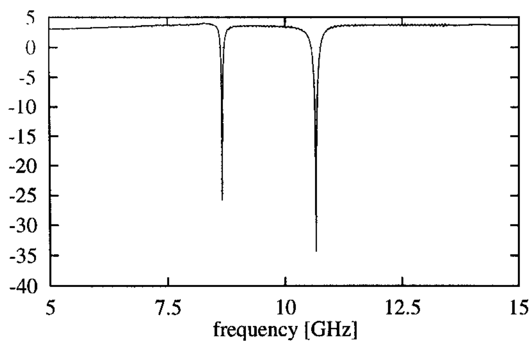

Figure 5: S_{21} measured when both resonators are actively biased.

Small signal measurements and the noise figure of the band stop filter are shown for a particular notch frequency in Figure 3. The notch frequency could be tuned from 8.5 to 11 GHz, with a narrow gap around 10 GHz. The notch depth remained more than 25 dB for input signals up to -18 dBm.

Although the tuning was difficult, the filter could be shown to have two notches simultaneously, as is illustrated by Figure 5. The filter was also measured at different temperatures. The results of measurements with and without manual temperature compensation are shown in Figure 6 and Figure 7

For the band pass filters, noise and small signal parameters are shown in Figure 9 and Figure 10. Tuning was achieved from 9 to 11 GHz. The 1-dB compression point was measured at -25 dBm, referred to the input. Especially the noise figure is very good as compared to other designs with equal relative bandwidth.

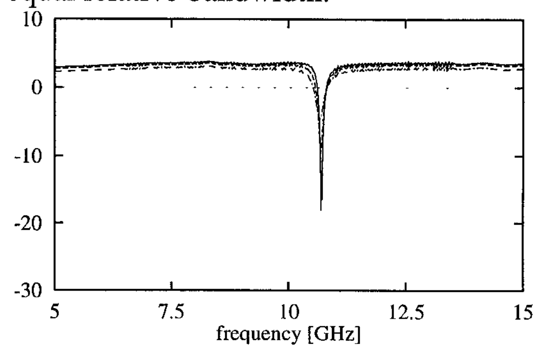

Figure 6: Measured S_{21} for 20, 40 and 60 degrees Celcius.

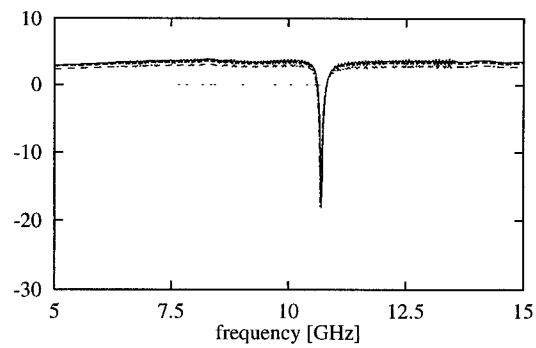

Figure 7: Measured S_{21} for 20, 40 and 60 degrees Celcius. Bias current of the active inductor was manually adjusted.

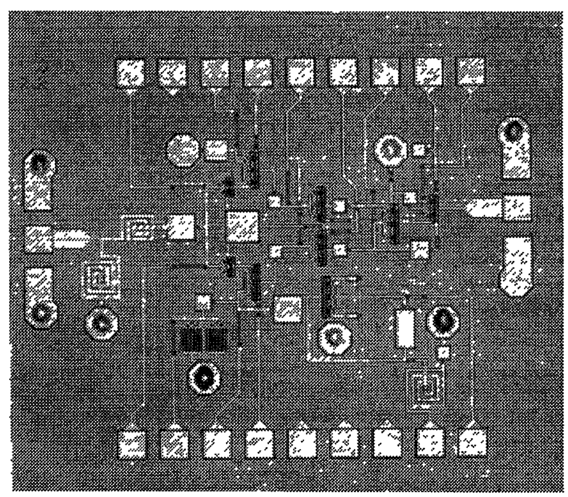

Figure 8: Layout of the band pass filter. The filter uses a notch filter in parallel to a matched all-pass filter. The notch filter is realized by applying a resonator as series

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feedback to a common-gate amplifier.

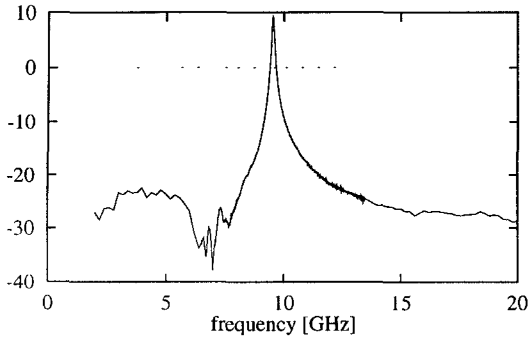

Figure 9: Measured S_{21} for the band pass filter.

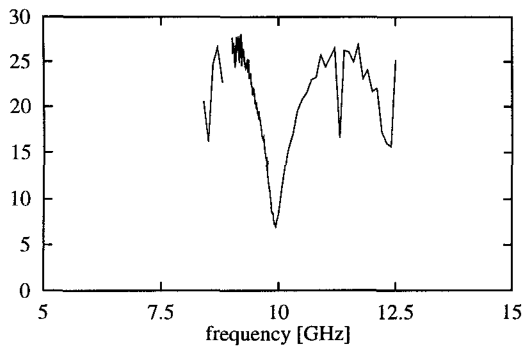

Figure 10: Measured noise figure for the band pass filter.

CONCLUSION

Single-chip narrow X-band tunable filters were demonstrated. With the low noise-figure, small size and state-of-the-art performance, a valuable contribution to the monolithic microwave filter area was made. Measurements over temperature indicate that a more advanced bias network, such as proposed by [10] may solve problems arising from their temperature dependency in a design which is currently investigated.

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