A MONOLITHIC ACTIVE NOTCH TUNABLE FILTER BASED ON THE GYRATOR PRINCIPLE

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ABSTRACT

A monolithic bandstop active tunable filter has been designed and realised. The filter is based on a gyrator-type active resonator, implemented using only three active devices. The center frequency of the realised notch filter is around 1.9 Ghz, with a tuning range of more than 400 MHz. Measured performances include a typical in-band rejection of more than 30 dB all over the operating bandwidth, a stopband span of less than 50 MHz, together with input/output match better than 12 dB. Positive supply only has been employed.

INTRODUCTION

The increasing complexity and functionality of modern communication systems require the availability of subsystem components featuring high performances, high degree of possible reuse and modularity. All of such requirements have obviously to be weighted with the counteractive features of low cost, low dissipation and low size, if a portable equipment is concerned. In such a scenario, filters represent a key component for most applications and not only in the communication market. The tight requirement of a cheap realisation together with size and weight considerations, makes the monolithic approach a natural choice for filtering structures. In this case a distributed design approach is not advisable, above all in the low microwave frequency range, due to the unpractical resulting size. Moreover, performance limitations, dictated by the losses of monolithic lumped passive elements (like spiral inductors and MIM capacitors), suggest an active design approach. On the other hand, such a choice has the major avantage of allowing a voltage-controlled tuning of the filtering properties.

According to the above considerations, an active bandstop filter of the notch type has been designed. The core of the design strategy is in the realisation of a variable-frequency active resonator, in which the tuning element is an active inductor realised loading a gyrator with a fixed capacitive impedance. The tuning property is obtained electronically controlling the coupling factor of the gyrator. A design example, realised utilising a standard 0.5μm MESFET monolithic technology by Alenia on a low-noise substrate, has been carried out. In the following, together with the description of the notch filter design principles, measured performances will be presented. Major measured performances include a voltage tuning range of more than 400 MHz around a center frequency of about 1.9 GHz. A rejection of more

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than 30 dB all over the tuning band has been obtained with a resulting rejection bandwidth of less than 50 MHz. Input / output return loss is better than 12 dB and it is independent of the tuning voltage.

DESIGN APPROACH

As already mentioned, the active notch filter is based on the gyrator principle [1]. The well-known property of this two-port component is in inverting the impedance on which one of its ports is terminated: in this way , if we impose a capacitive termination on one of the ports of the gyrator, the impedance obtained looking into the other one is inductive. If the remaining port of the device is terminated again with a capacitive impedance, the resulting circuit is a parallel ***LC*** resonator. The main problem is therefore in the high-frequency realisation of the gyrator. The basic topology for this device is shown in fig.1. The inverted back-to-back connection of the two active devices gives the basic gyrator behaviour, while the feedback resistor ***R*** modifies the coupling factor of the device. It is possible to demonstrate, making some simplifying assumptions on FET models and after some algebra, that the resulting gyrator loaded with a capacitor ***C*** exhibits an inductive impedance depending on the coupling factor (***R***), on the capacitor's value and on FETs' transconductance. Since the inductor's value directly depends on the coupling factor, a possible tuning can be obtained varying the feedback resistor: this one can be realised by means of a third FET acting as a VVR, controlled by the gate bias voltage. It is to note that the quality factor of the resonant ***LC*** circuit is a strong function of the capacitor's losses and a weak function of the gyrator coupling factor: this dependence suggests not to use a varactor diode as a tuning element, thus employing a fixed MIM capacitor.

The parallel ***LC*** resonator exhibits obviously a bandpass frequency response: to obtain a bandstop behaviour, it is necessary to invert such response. This can be accomplished by means of the arrangement shown in fig.2, in which the gyrator-based resonator is inserted between two inverting stages and the resulting output is summed to the response of another inverting stage. It is to note that the same principle can be applied, with the same (or even better) performances to the design of active bandpass filters, that can be obtained with a much simpler arrangement. A great care must be posed on the design of bias networks for the active devices: unproper filtering or RF leakage may degrade or even obscure the desired performances. The complete schematic of the filter is shown in fig.3: three bias voltages are included in this design: one for inverting stages bias (to be kept fixed), one for the bias of the FETs composing the gyrator, and a last one for the tuning of the gyrator's coupling factor. It is to note that no negative supply is employed, since all stages are of the self-biased type, so greatly simplifying external DC circuitry.

FILTER REALISATION

The designed active bandstop filter has been implemented in monolithic technology using a standard and consolidated 0.5μm MESFET low-noise process, as supplied by ALENIA. The layout of the resulting notch filter chip is shown in fig.4. Chip dimensions are 1.2 x 1.2 mm^2 including coplanar RF test pads, and all the bias circuitry, including DC filtering, is implemented on-chip. Typical measured transmission performances of the filter are plotted in fig.5: a center frequency of about 1.8 GHz with more than 30 dB rejection is obtained; the rejection bandwidth of the filter is less than 50 MHz, resulting in a quality factor for the filter higher than 40. The input and output return loss of the filter are also shown in fig.5, exhibiting a good performance all over the tuning bandwidth. If the coupling factor of the gyrator is changed by means of the applied voltage, a variable center frequency can be easily obtained: in fig.6 the forward transmission of the filter is plotted against frequency with the tuning voltage as a parameter. As it is possible to note, filter's performances remain almost constant within a bandwidth of more than 400 MHz. This behaviour can be obtained simply varying the external control voltage in the range 0.8÷2.0 V, with a almost linear voltage / frequency control law.

CONCLUSIONS

The gyrator principle has been applied to the design and realisation of an active notch filter with tunable center frequency. The realised filter operates in L- and S-bands, featuring a rejection of more than 30 dB all over the 400 MHz tuning bandwidth, with a rejection bandwidth of less than 50 MHz around the center frequency. The simplicity of the principle and the versatility of the realisation makes it attractive for a broad class of applications; the same approach can be also applied to other filter classes.

AKNOWLEDGEMENTS

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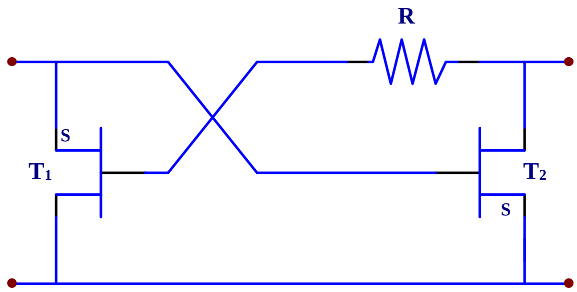

Fig.1: Basic topology for gyrator implementation

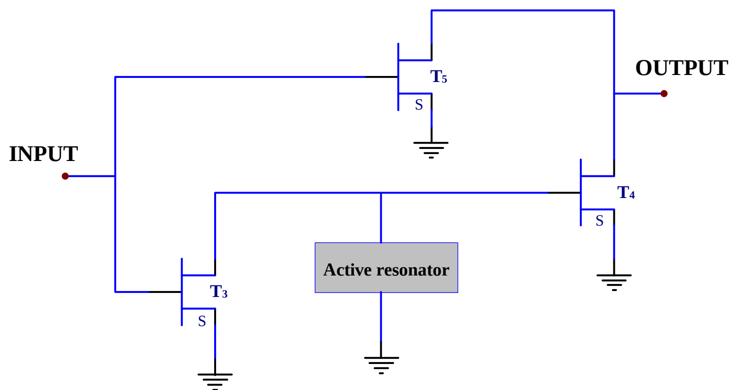

Fig.2: Basic topology inverting the parallel **LC** resonator frequency response

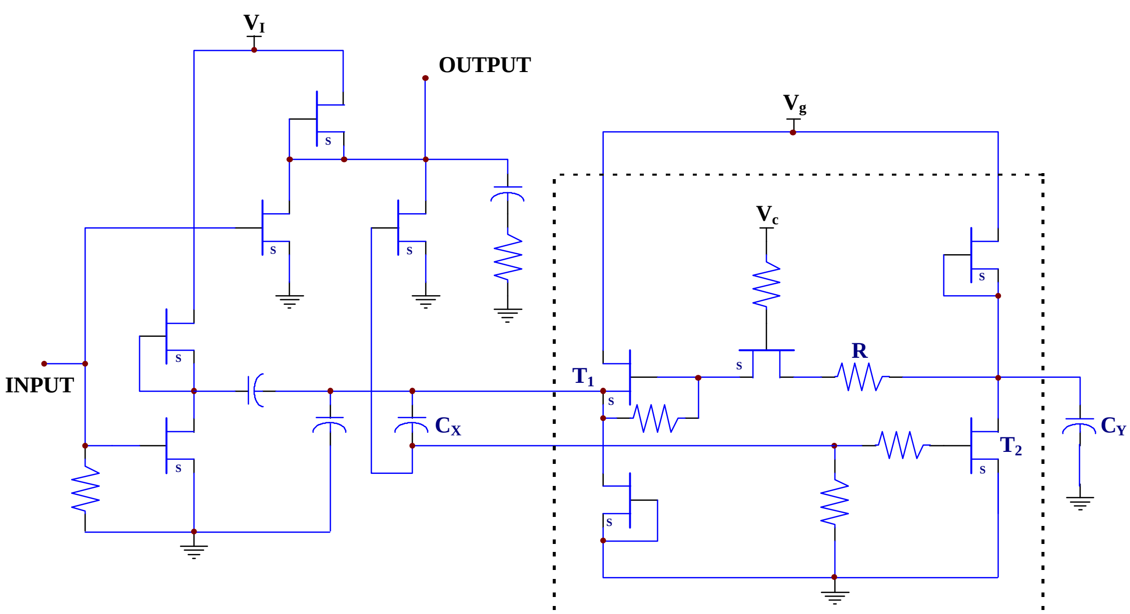

Fig.3: Complete circuit schematic diagram of the bandstop filter (gyrator is boxed)

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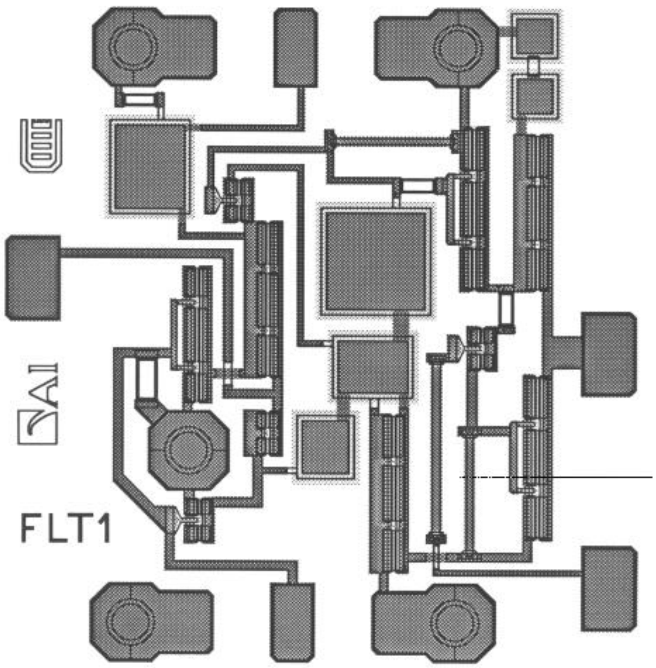

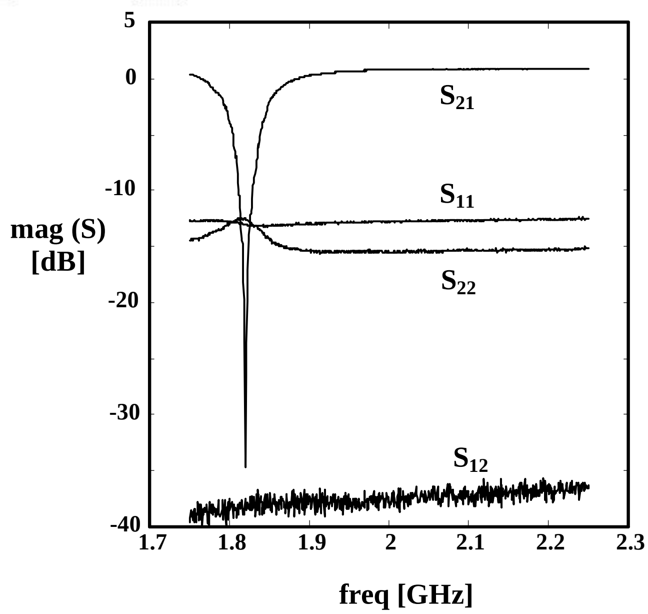

Fig.4: Layout of the realised filter

Fig.5: Typical filter response: transmission loss, input and output return loss.

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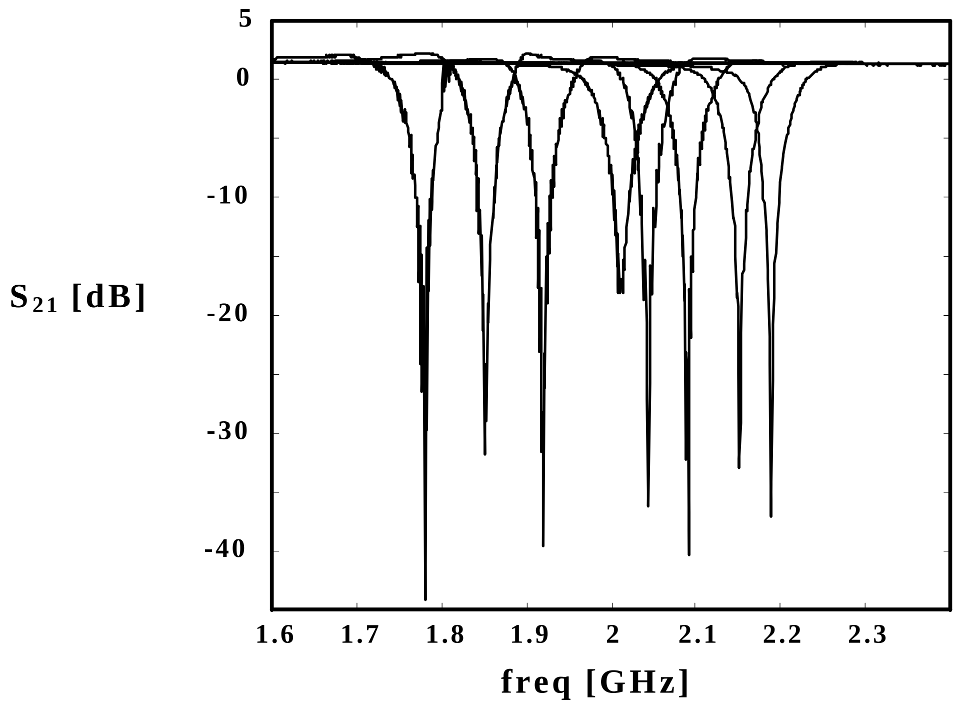

Fig.6: Transmission performances of the bandstop filter with tuning voltage as a parameter