A Low-Noise Active Bandpass Filter

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***Abstract*— The design of narrow-band active bandpass filters with high-gain and low-noise figure is described. The filter configuration is a combination of low-loss suspended stripline resonators and active microstrip circuits with FET devices. Measured results of this filter configuration with two resonators and one active circuit are presented.**

I. Introduction

IN MICROWAVE RECEIVERS, low-noise amplifiers are used to improve system sensitivity. Placed at the receiver input, the amplifier reduces the noise contributions of all following receiver components like mixers, filters and IF amplifiers.

On the other hand, to avoid intermodulation products by strong signals outside the desired frequency band, a bandpass filter at the receiver input is desired; this, however, introduces additional losses affecting directly the overall noise figure.

One way to overcome this problem are active bandpass filters with high-gain and low-noise figure, rejecting spurious frequencies at the input and reducing the noise contribution of all following stages. A further advantage is the integration of bandpass filter and low-noise amplifier into one circuit.

Many active bandpass filters have been published, but only a few have investigated the noise properties, e.g., [1], partly with poor results concerning the noise figure [2].

In this letter, an active bandpass filter configuration with narrow-band characteristic, high-gain and low-noise figure is described. It combines the advantages of suspended stripline and microstrip. In this way, active bandpass filters up to millimeter-wave frequencies can be designed.

II. Design

The bandpass filter configuration is a chain network of transmission line resonators, inverters, and active FET circuits. At the center frequency of the passband, the input terminal impedance Z_{in} is matched to the input impedance Z_a of the active circuit by a resonance transformation (Fig. 1). In contrast to [3], impedance matching is chosen to get maximum insertion gain. The resonator length is

$$l_{\text{res}} = \frac{\arg(r_{\text{in}}) - \arg(r_a^*)}{2\beta} \quad , \tag{1}$$

where β is the propagation constant of the transmission line resonator, and r_{in} and r_a are the corresponding reflection coefficients. With the inverter constant K, the desired 3-dB

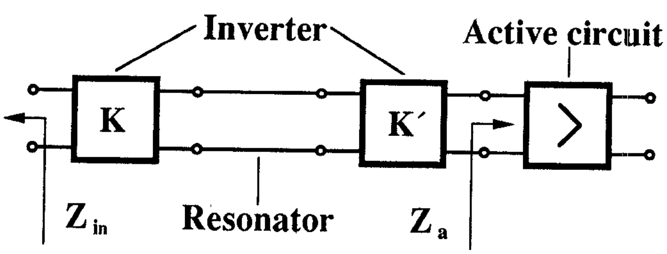

Fig. 1. Block diagram of an active stage with input filter network.

bandwidth can be adjusted. The second inverter constant is calculated as function of K to

$$K' = \sqrt{|Z_a| \cdot |Z_0 \frac{\frac{K^2}{Z_{\text{in}}} + jZ_0 \tan(\beta\, l_{\text{res}})}{Z_0 + j\frac{K^2}{Z_{\text{in}}} \tan(\beta\, l_{\text{res}})}|} \quad . \tag{2}$$

Z_0 is the characteristic impedance of the transmission line resonator. In the same way, the output impedance of the active circuit is matched to the output terminal impedance.

This filter configuration can be extended by additional resonators and active stages. In that case, the respective output impedance is matched to the input impedances of the following element.

The design procedure is valid for all kinds of transmission lines. For the first design, a filter configuration employing suspended stripline and microstrip technique was chosen combining the advantages of both transmission line types. Suspended stripline has considerably small losses and is well suited for high-Q resonators. On the other hand, microstrip offers advantages concerning the ground connection of FET's and the better availability of CAD-tools for bias network design.

Fig. 2 shows the filter set-up with one active circuit, two resonators and 50-Ω suspended striplines for input and output connection. The active circuit is a FET in common-source configuration with short sections of 50-Ω input and output lines and bias networks for gate and drain in microstrip technique. The resonators are 100-Ω suspended stripline sections. The measured losses of these suspended striplines are four times smaller than those of the microstrip lines. The inverters are formed by the transitions from the connection lines to the resonators, placed on different sides of the substrate, and by the transitions from the resonators to the microstrip circuit [4]. Additionally, these transitions provide the necessary dc stops. In such a capacitive configuration, FET's normally are stable even at low frequencies, and no additional resistive network is necessary which would reduce gain and increase noise figure.

In the first design step, the S-parameters of the FET are measured on a microstrip substrate with the same configuration

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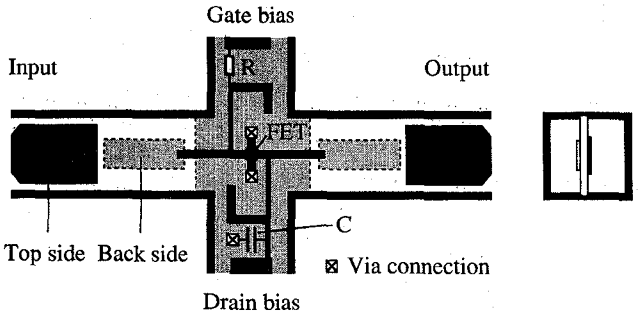

Fig. 2. Set-up of active filter employing suspended stripline and microstrip technique.

as in the filter. Next, the resonator lengths and inverter constants are calculated as shown before. The required transition dimensions of both transition types are calculated with a full-wave spectral-domain method [5]. Finally, the resonator lengths have to be corrected according to the S-parameter phase angles of the transitions.

III. Results

Two active filters for a center frequency of 10 GHz with a 3-db bandwidth of 420 MHz (#1) and 535 MHz (#2) were fabricated and tested. As FET devices, SIEMENS CFY25 MESFET's with 0.5-μm gate length and 6×40-μm gate width were taken. The measured minimum noise figures for several devices were in the range from 1.9 dB to 2.2 dB. The filters were fabricated on RT/Duroid 5880 substrate with 254-μm height and fixed in a brass housing with SMA coaxial connectors.

Fig. 3 shows the magnitudes of the S-parameters versus frequency of filter #1 measured at the corresponding bias point (U_{DS} = 3.0 V, I_{DSS} = 35.7 mA, I_{DS} = 30% I_{DSS}) with minimum noise figure. The small shift of the center frequency is due to tolerances in the fabrication process, deviations of the FET parameters and the accuracy of the S-parameter measurements.

In Table I, the measured results of noise figure and associated gain at center frequency are presented for both filters. The achieved noise figures are extremely low according to the measured minimum noise figures of the single MESFET's.

IV. Conclusion

A concept for narrow-band active bandpass filters with high-gain and low-noise figure has been described. The design procedure can be applied up to millimeter-wave frequencies.

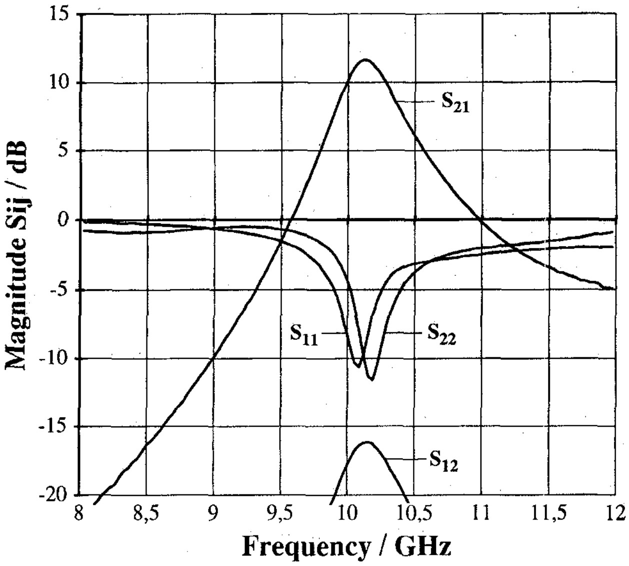

Fig. 3. Measured magnitudes of the S-parameters versus frequency of filter #1.

TABLE I
Measured Noise Figure and Associated Gain at Center Frequency

Filter	NF / dB	G_{assoc} / dB
# 1	2.3	11.9
# 2	2.0	10.7

In a first step, filters with a single active device were designed, fabricated and tested. The filters show very good results concerning insertion gain and noise figure. Further work will be the design of filters with more active stages at higher frequencies.

References

[1] R. R. Bonetti and A. E. Williams, "An octave-band MMIC active filter," *IEEE Int. Microwave Symp. Dig.*, Dallas, TX, 1990, pp. 823–826.
[2] H. Trabelsi and C. Cruchon, "A varactor-tuned active microwave band-pass filter," *IEEE Microwave Guided Wave Lett.*, vol. 2, pp. 231–232, June 1992.
[3] M. R. Moazzam and A. H. Aghvami, "Design concepts of a novel microwave active filter," *Int. J. Microwave Millimeter-Wave Comput.-Aided Eng.*, vol. 2, no. 1, pp. 28–33, 1992.
[4] W. Schwab and W. Menzel, "A suspended stripline to microstrip transition using multilayer technique," in *22th European Microwave Conf. Proc.*, Session A10.5, Helsinki, Finland, 1992, pp. 1181–1186.
[5] ——, "On the design of planar microwave components using multilayer structures,"*IEEE Trans. Microwave Theory Tech.*, vol. 40, pp. 67–72, Jan. 1992.