A VARACTOR-TUNED, ACTIVE MICROWAVE BAND-PASS FILTER

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ABSTRACT

A new microwave tunable high-Q active band-pass filter was developed using a varactor diode for tuning, and a MESFET to provide negative resistance for increasing the tank circuit Q-value. Tuning ranges of 500 MHz for the one-pole filter and 430 MHz for the two-pole filter are achieved with the center frequency of 10 GHz. A 3-dB bandwidth of 20 MHz for the one-pole filter and 80 MHz for the two-pole filter are obtained. The pass-band insertion loss is typically 0 ± 1 dB.

INTRODUCTION

A varactor diode is a good device for microwave tunable filters because of its small size and fast tuning speed compared to the YIG-tuned filter. However, placing a varactor diode into the tank circuit causes the tank circuit Q to degrade significantly. Therefore, the performance of a narrow band tunable filter is usually not acceptable. To overcome this problem, an active filter design is adopted here. There are many microwave active filter designs suitable for different situations [1-6]. For example, the transversal design [1] is suitable for the broad-band case. For a narrow-band situation, using an active device such as transistor or MESFET to compensate the tank circuit loss is the most effective way [2-6]. In this paper, the coupled negative resistance method [6] for the narrow-band filter design is applied to a tunable filter configuration due to the following considerations:

(1) The planar and distributed circuit structure is suitable for integrated circuit fabrication.

(2) It only employs the simple design scheme of the microstrip end-coupled filter design [7] to obtain desired filter parameters.

(3) The active device (MESFET) is not placed directly in the tank circuit. Therefore, the parameter variations of the active device have less effect on the tank circuit parameters.

FILTER DESIGN CONCEPT

The basic structure of the one-pole varactor tuned active filter is shown in Fig. 1. This is an end-coupled microstrip band-pass filter, and half of the half-wavelength resonator is modified by a coupling circuit. Therefore, the design begins with the end-coupled filter design [7]. Then, the half wavelength resonator is divided into a quarter wavelength coupled line section and a quarter wavelength uncoupled line section. A varactor diode is placed in series between these two line sections. The filter may be represented by the equivalent circuit shown in Fig. 2. All of the losses such as conductor loss, dielectric loss, radiation loss, and varactor loss can be represented by a dissipating resistor R_p in the tank circuit. The quarter wavelength coupler couples the negative resistance R_n to the tank circuit. If circuit parameters are appropriately adjusted, the R_p can be canceled out by the coupled negative resistance R_n; therefore, a lossless tank circuit may be obtained.

In the real circuit, the negative resistance is realized by a MESFET and feed-back networks. The input impedance looking into the drain of the MESFET contains a negative real component from 8.5 GHz to 15.5 GHz. If the negative resistance value and coupling values are properly adjusted, all loss terms in the tank circuit can be compensated for by this coupled negative resistance.

A multi-pole filter may be obtained by repeating the same tank circuit as shown in Fig. 3.

FILTER EXAMPLES

Based on the design concept outlined above, one-pole and two-pole tunable filters are realized. A fixed frequency two-pole filter is also realized in the passive and the active forms to show the improvement using the active configuration. The design parameters for each filter are as follows:

(1) For the one-pole tunable filter, the center frequency is between 9.8 GHz and 10.3 GHz, the 3-dB bandwidth is 15 MHz at 9.8 GHz and 23.5 MHz at 10.3 GHz. The corresponding loaded Q-value is 660 at 9.8 GHz and 480 at 10.3 GHz.

(2) For the two-pole tunable filter, the center frequency is between 9.8 GHz and 10.23 GHz, the 3-dB band width is 80 MHz at 9.8 GHz and 75 MHz at 10.23 GHz.

(3) For the two-pole fixed frequency filters, the center frequency is 10.4 GHz and the 3-dB bandwidth is 180 MHz for both the active and the passive filters.

The active devices used in all filters are NEC NE-71083 packaged MESFETs. The varactors are Alpha DVE-6955-G devices in an Alpha 30 mil 290-001 package. The varactor chip shows 2.5-3.0 pF at 0 volts and 4.25 to 1 tuning ratio. The filters are fabricated on a woven PTFE substrate with thickness of 30 mil and the dielectric constant 2.55. The filters are designed with a characteristic impedance of 82 ohms for better aspect ratio of the couped line section. The input and output of the filters are transformed to the characteristic impedance of 50 ohms by microstrip tapered lines. Fig. 4 shows the photographs of the one-pole and two-pole tunable filter.

The measured one-pole and two-pole tunable filter performance are shown in the Fig. 5. The measured fixed frequency passive and active two-pole filter performance are shown in the Fig. 6. In Fig. 6, it is apparent that the pass-band performance improvement is significant.

CONCLUSIONS

The new active filter design concept has been successfully applied to the design of a varactor-tunable filter. This method uses the well developed end-coupled filter design approach and simple computer optimization procedures. It is easy to design a multi-pole filter with desired pass-band and skirt response using this method. The active filter shows a significant improvement on the filter Q-value, the pass-band insertion loss, and the pass-band corner rounding effect.

ACKNOWLEDGEMENT

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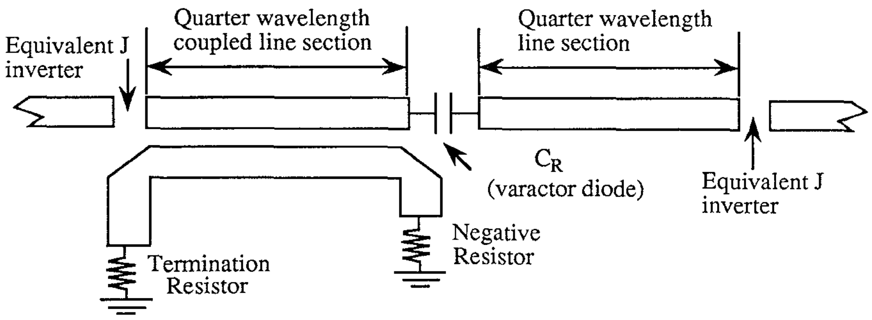


Fig. 1 The basic structure of a one-pole active tunable filter.

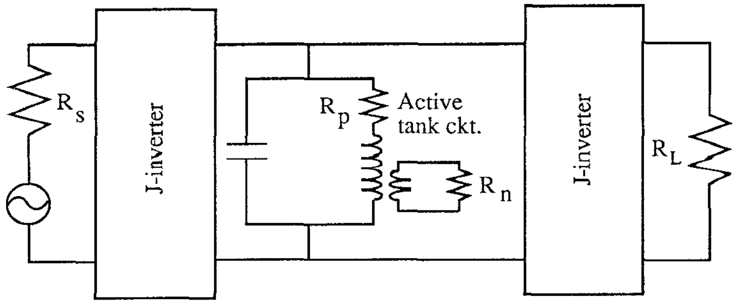


Fig. 2 The equivalent circuit of a one-pole active filter. The negative resistor is represented by R_n and the tank circuit loss is equivalent to a dissipating resistor R_p.

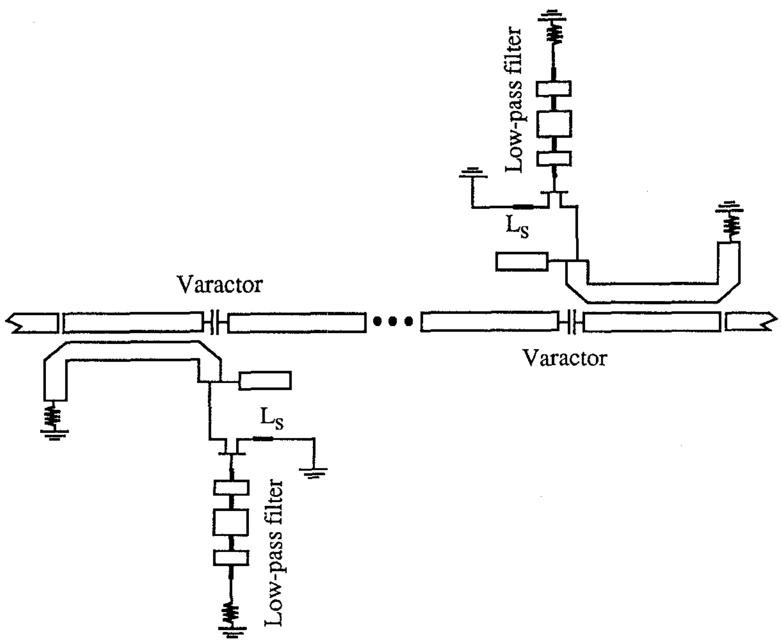
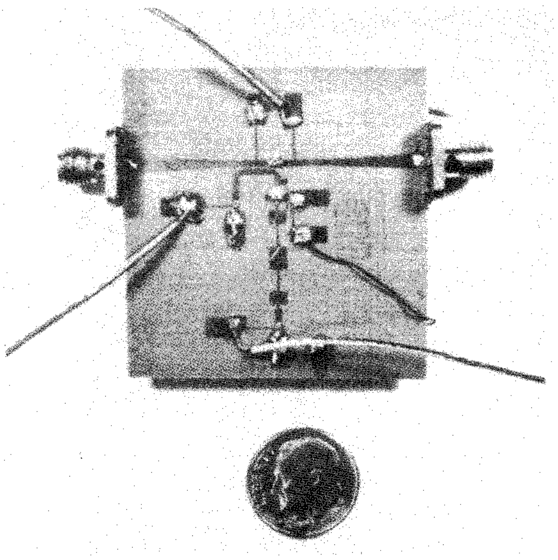
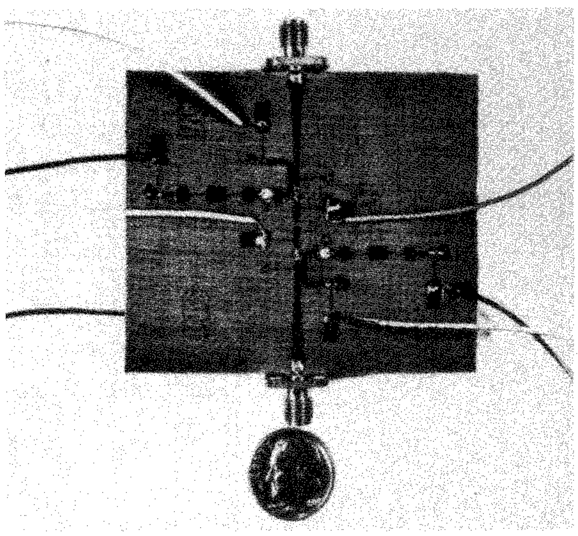


Fig. 3 The multi-pole active tunable filter. The negative resistance is realized by a MESFET circuit.

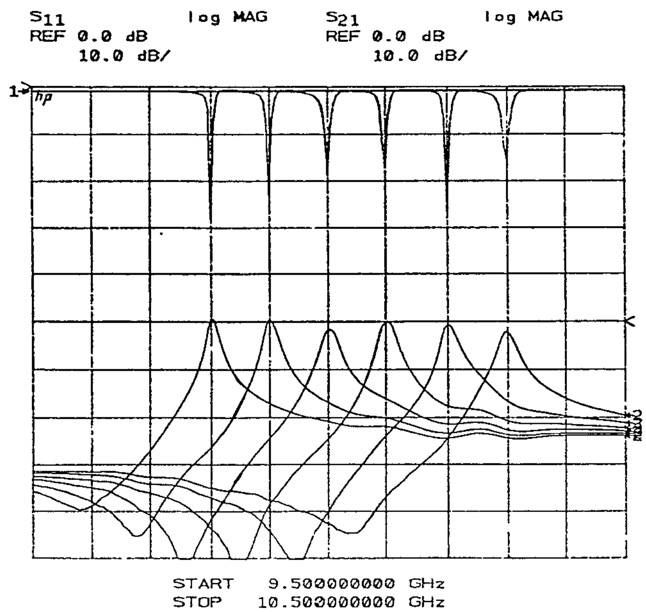


(a) The one-pole active tunable filter.

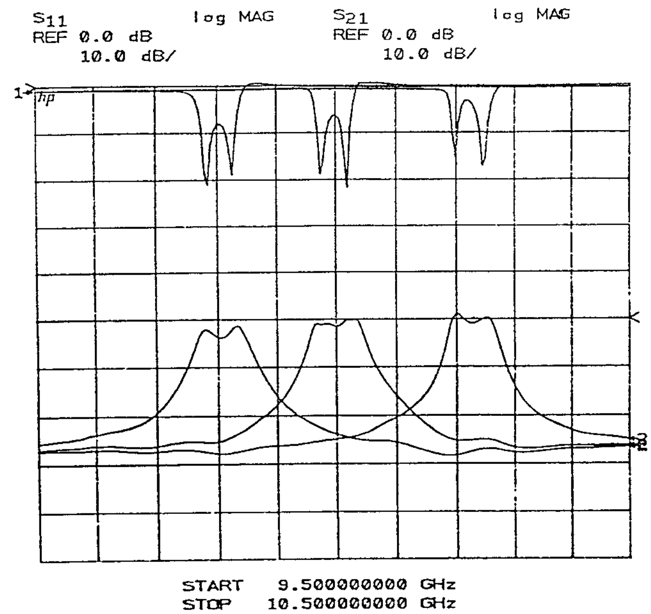


(b) The two-pole active tunable filter.

Fig. 4 The photograph of a one-pole and a two-pole active tunable filter.



(a) The measured one-pole active tunable filter response.



(b) The measured two-pole active tunable filter response.

Fig. 5 The measured one-pole and two-pole active tunable filter responses.

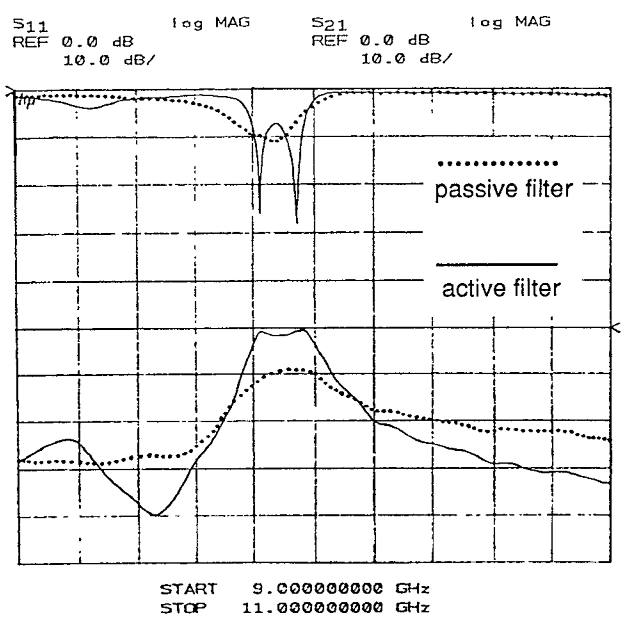


Fig. 6 The measured responses of the active and the passive two-pole filters.