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VARACTOR TUNED BANDPASS FILTERS USING MICROSTRIP-LINE RING RESONATORS

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ABSTRACT

This paper describes the fundamental characteristics and experimental results of newly developed tunable bandpass filters using microstrip-line ring resonators. The experimental filter has a steeper attenuation slope and less circuit instability than conventional filters, and it seems to be a suitable filter for MICs or MMICs.

INTRODUCTION

Conventional varactor tuned bandpass filters utilize a half or quarter wave-length resonator as the filter element. Circuit losses and resonance frequencies of these filters are apt to be influenced by parasitic components generated at short circuited points in the resonators. It is not practical to use these filters for MICs or MMICs because of this instability.

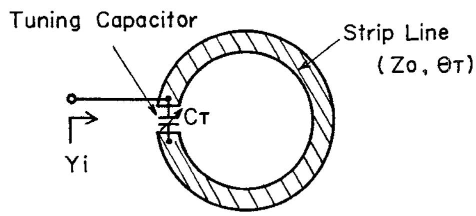
To overcome this problem, the authors have introduced a ring resonator for the filter element which has no RF short circuited points and less radiation loss. It is well known that a ring resonator has a suitable structure for measuring microstrip-line characteristics. Several applications of ring resonators in bandpass filters with a fixed center frequency were reported[1),2),3)], but it seems that there has been no study about a tunable ring resonator and its applications.

For designing bandpass filters using ring resonators, tight coupling circuits are necessary and two coupling methods of parallel coupled lines for inter-stage and coupling capacitors for input and output have been introduced. However, it is inevitable that, in order to expand the tuning range, the coupling capacitance value must be changed in accordance with variations of the center frequency, because coupling parameters (i.e. external Q) of capacitors are strongly frequency dependent.

Computer simulations and experimental results have made it clear that ring resonator filters have two attenuation points in the stopband and have a steeper attenuation slope compared with conventional capacitively coupled resonator filters.

RESONATOR STRUCTURE

The resonator structure to be considered here is shown in Fig. 1. The ring resonator is composed of one transmission line and one capacitor which connect both ends of a line. It should be noted that this resonator structure has no RF short circuited point.



Z_o (= $1/Y_o$) : Characteristic Impedance of the Line

θ_T : Total Electrical Length of the Line

C_T : Tuning Capacitance

Y_i : Input Admittance of the Resonator

Fig. 1 Structure of ring resonator

The input admittance of the resonator from one end of the line, Y_i is given as

$$Y_i = jY_0 \frac{Y_0 \sin\theta_T - 2\omega C_T (1-\cos\theta_T)}{Y_0 \cos\theta_T - \omega C_T \sin\theta_T} \quad (1)$$

where Y_0 : characteristic admittance of the line
θ_T : total electrical length of the line
C_T : tuning capacitance

The input impedance can be calculated by using equation (1), and one of the results is shown in Fig. 2. It can be seen from this figure that a ring resonator has a serial and parallel resonance point and the frequency span between these resonance points is very close.

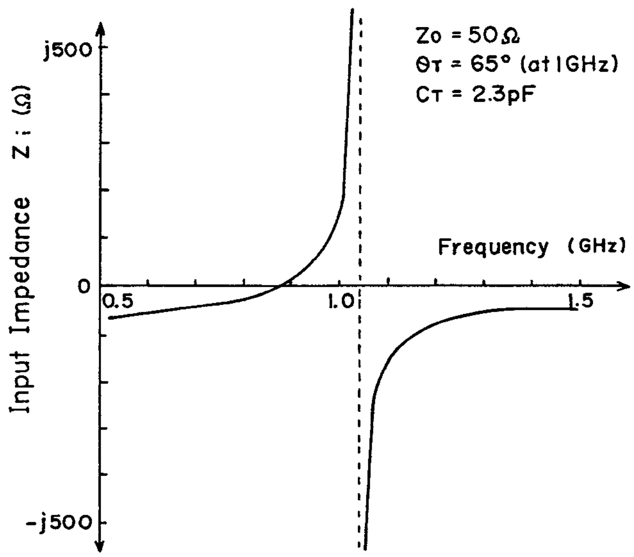


Fig. 2 Input impedance of ring resonator

The parallel resonance condition can be obtained from the following:

$$Y_0 \sin\theta_T - 2\omega C_T (1-\cos\theta_T) = 0 \quad (2)$$

The resonance frequency can be calculated by solving the above equation, and the results are shown in Fig. 3 as a function of the resonator length.

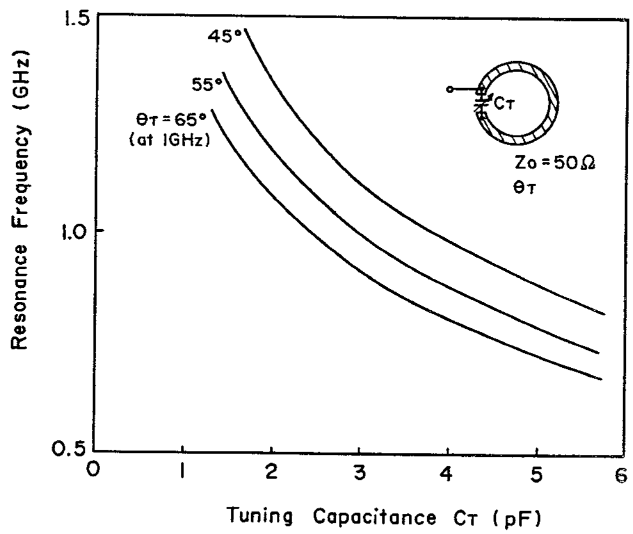


Fig. 3 Resonance frequency

COMPUTER SIMULATION OF TUNABLE BANDPASS FILTERS

Fig. 4 shows the configuration of a 2-stage tunable band-pass filter using ring resonators. The interstage coupling is parallel coupled lines whose electrical parameters are expressed as even and odd mode impedance (Z_{oe} and Z_{oo}), and coupling length θ_C. A capacitor of value Cs is used for input and output coupling.

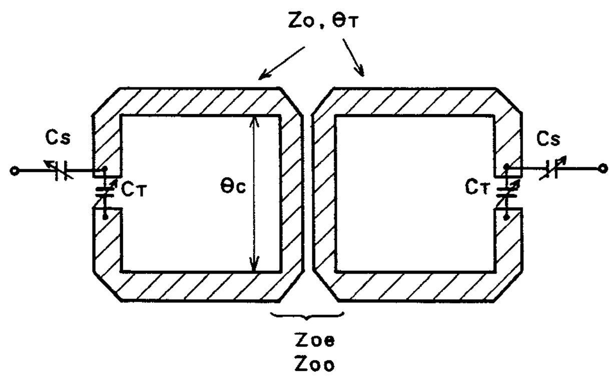


Fig. 4 Arrangement of 2-stage tunable BPF

It has been shown from theoretical analysis that interstage coupling strength is approximately constant over the octave frequency band, but capacitive couplings of input and output have a strong frequency dependence. Thus, coupling capacitance C_S should be changed in accordance with the center frequency of the bandpass filter as well as tuning capacitor C_T.

The frequency response of tunable bandpass filter when analyzed by computer simulation are shown in Fig. 5.

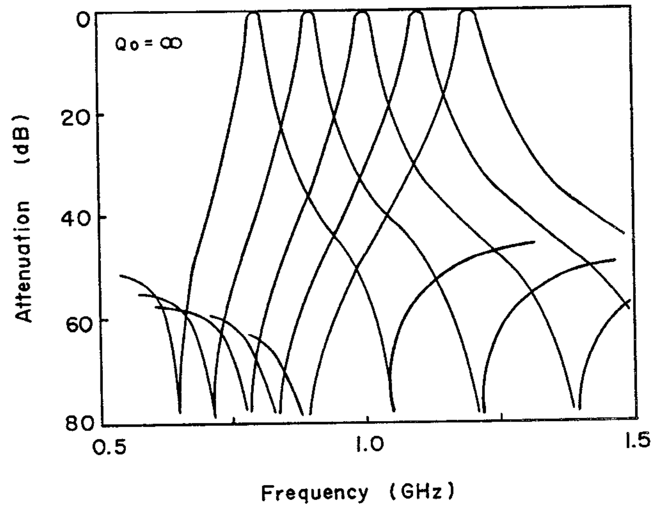


Fig. 5 Calculated response of tunable BPF

The responses have two attenuation points in the stop-band as understood from these results. Therefore, the attenuation slopes seem to be steeper than that of a conventional resonator filter.

Fig. 6 shows the frequency response of a 2-stage conventional resonator filter and the ring resonator filter. The dotted and solid lines indicate the frequency response of a 2-stage conventional resonator filter and the ring resonator filter, respectively. These calculated results have made it clear that the ring resonator filter has a steeper attenuation slopes than conventional capacitively coupled resonator filters.

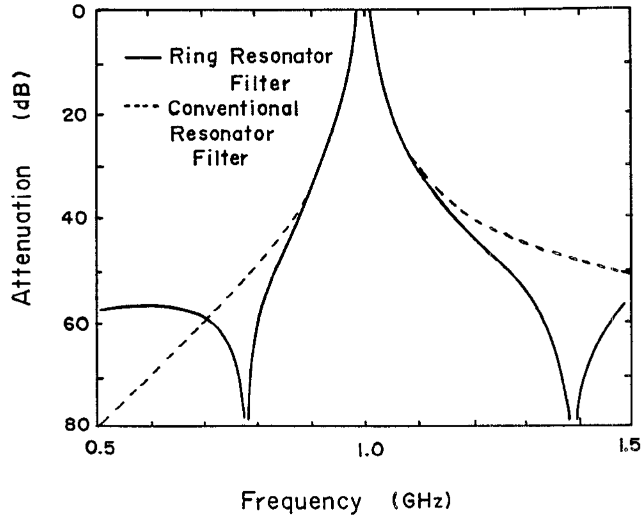


Fig. 6 Calculated response of a conventional resonator filter and a ring resonator filter

PERFORMANCE OF THE EXPERIMENTAL FILTER

On the basis of above discussion, an experimental tunable filter was designed using the following parameters:

Number of resonators	N = 2
Relative bandwidth	w = 2%
Tuning range	0.8 GHz – 1.2 GHz

The filter was fabricated with a substrate having dielectric constant of ε_r = 2.6 and thickness of 0.8mm. The layout and photograph of the experimental filter are shown in Fig. 7 and Fig. 8 respectively, and Fig. 9 shows the measured response of this filter.

Insertion losses of filters were determined by the unloaded-Q of the resonator. The loss in this device was not so good but it can be improved by applying high-Q varactor diodes. The highest tuning frequency was 1.15 GHz and this was slightly lower than the expected value. This is because, in the design process, stray diode inductance was neglected. The tuning range can be expanded to the octave band by optimizing the circuit parameters.

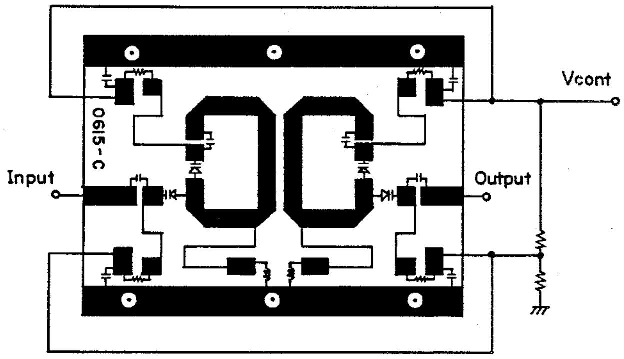


Fig. 7 Layout of the experimental tunable BPF

CONCLUSIONS

Electrically tunable bandpass filters using microstrip-line ring resonators were proposed and theoretically analyzed. The experimental filter was designed and the fabricated filter performance showed steep attenuation and a wide tuning range.

ACKNOWLEDGEMENT

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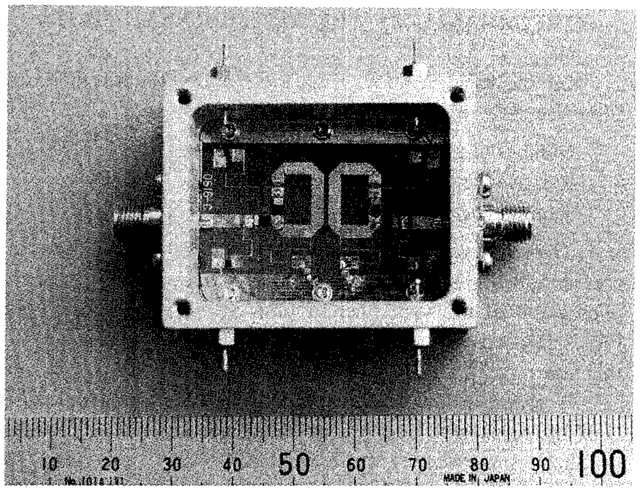

Fig. 8 Photograph of the experimental tunable BPF

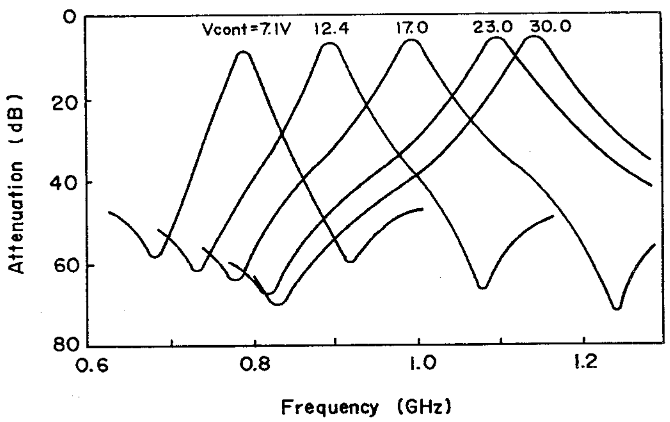

Fig. 9 Measured response of the experimental BPF