VI. Discussion and Conclusions

A powerful method of modifying the frequency response of a single, cylindrical TE_{011}-mode, sidewall-coupled resonator has been presented. Increased selectivity is achieved by creating nulls in the transfer characteristics of the cavity. The existence of a null above or below the TE_{011} response steepens the rejection slope on that side. The nulls are created by making use of the TE_{211} and TE_{311} modes which are naturally excited in the cavity resonator along with the TE_{011} mode. Varying the frequency at which the nulls occur requires control of both the relative phase and amplitude of the modes. The relative phase of the modes is determined by the selection of the angular offset of the coupling apertures, while the relative amplitude of the modes is set by both the angular offset of the apertures and the shaping of the cavity.

A lumped constant equivalent circuit has been presented which is shown to accurately represent the response of the resonator. The equivalent circuit representation can be used as an aid in the design of multisection filters.

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Quarter-Wavelength Coupled Variable Bandstop and Bandpass Filters Using Varactor Diodes

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Abstract —**A quarter-wavelength coupled bandstop filter using varactor diodes for the 6-GHz band has been proposed and tested. Frequency giving maximum attenuation varies from 4.4 GHz–7 GHz. A quarter-wavelength coupled variable bandpass filter using varactor diodes for the 4-GHz band is also proposed and tested. The passband width varies from 730 MHz–1.22 GHz. The center frequency of the filter can also be changed.**

I. Introduction

Many works on the bandstop and the bandpass filters using microstrip have been reported. However, the frequency giving the maximum attenuation in the bandstop filter and passband width in the bandpass filter mentioned above are fixed and cannot be varied.

In this paper, the author proposes a new variable quarter-wavelength coupled bandstop and a variable bandpass filters using varactor diodes. The frequency giving the maximum attenuation of the bandstop filter and passband width of the bandpass filter can be varied mechanically or electrically. These methods of changing the frequency giving the maximum attenuation and passband width have already been reported by the author [1]–[3].

Two types of the filters are considered here. The quarter-wavelength coupled variable bandstop filter is constructed with two circuits which are composed of a series and a parallel resonant circuit connected in parallel, and are placed a quarter-wavelength apart. The frequency giving the maximum attenuation is varied by changing the junction capacitances of varactor diodes mounted in those circuits.

The new variable bandpass filter is composed of two quarter-wavelength coupled bandpass filters connected with coaxial power dividers. Each quarter-wavelength coupled bandpass filter is constructed with two parallel resonant circuits, each of which is composed of a short-circuited transmission line connected with a varactor diode, and is placed a quarter-wavelength apart. The passband width is varied by changing the junction capacitance of those varactor diodes on each quarter-wavelength coupled filter. The experiments were carried out at the 6-GHz band. For the bandpass filter, the passband width was varied from 880 MHz–1.44 GHz. This filter may be used for the tuning reception of the respective signals of the channels of the broadcasting satellite, or for the detection of radar frequencies, and so on. For the bandstop filter, the frequency giving the maximum attenuation was varied from 4.4 GHz–7 GHz. This filter also finds application in broad-band receiving systems which must operate near high power radar, etc.

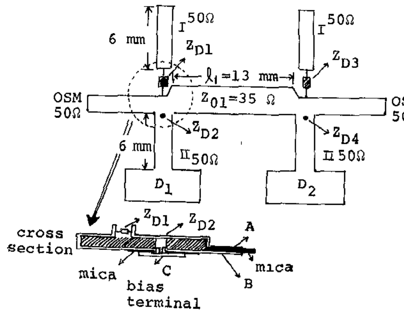

Fig. 1. Quarter-wavelength coupled bandstop filter composed of two composite series and parallel resonant circuits having varactor diodes.

II. Quarter-Wavelength Coupled Variable Bandstop Filter Using Varactor Diodes

The structure of the quarter-wavelength coupled bandstop filter is shown in Fig. 1. A series resonant circuit is structured with a series connection of a short-circuited transmission line I and a varactor diode Z_{D1}, and the parallel resonant circuit is structured with a parallel connection of a short-circuited transmission line II and a varactor diode Z_{D2}. A parallel connection, these two resonant circuits yield a composite series and parallel resonant circuit. Two of the composite resonant circuits are placed a quarter-wavelength apart.

Decreasing in Q-value of the series resonant circuit due to the loading of the varactor diode is recovered by connecting the parallel resonant circuit thereto as shown in Fig. 1, and thereby a narrow bandwidth can be realized.

The bias voltage for Z_{D1} is supplied through terminals A and B, and for Z_{D2} through terminals A and C. The same bias supply

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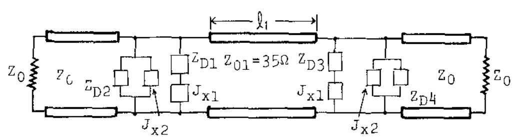

Fig. 2. Equivalent circuit of the filter shown in Fig. 1

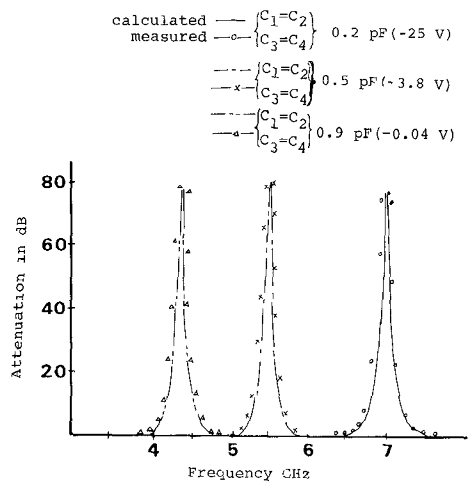

Fig. 3. Attenuation characteristics of the bandstop filter shown in Fig. 1.

connections are applied to Z_{D3} and Z_{D4}. D_1 and D_2 are for short-circuiting the transmission lines II's.

In order to make the resonant frequencies of the series and parallel resonant circuits equal, all the lengths of the short-circuited transmission lines I and II are taken 6 mm.

The characteristics impedance of the short-circuited transmission lines I and II are 50 Ω. The distance l between the composite resonant circuits is 13 mm. As shown in Fig. 1, the input and output impedance of the bandstop filter are 50 Ω, and Z_{01} is 35 Ω.

The frequency giving the maximum attenuation is varied by changing the junction capacitances of the four diodes. The equivalent circuit of the bandstop filter is shown in Fig. 2. J_{x1} and J_{x2} are the inductances of the shorted transmission lines I and II. The junction capacitances of the varactor diodes Z_{D1}, Z_{D2} and Z_{D3}, Z_{D4} will be denoted simply as C_1, C_2 and C_3, C_4 in the following.

The measured attenuation characteristics of the quarter-wavelength coupled variable bandstop filter is shown in Fig. 3. When all the bias voltages of the four diodes were -0.04 V, the frequency giving maximum attenuation was 4.4 GHz, and the stopband width was 460 MHz. The frequency giving maximum attenuation was 7 GHz and the stopband width was 500 MHz when the bias voltage of the four diodes were -25 V.

This resulted from changing the junction capacitance of the varactor diode. The attenuation of the bandstop filter was 80 dB.

The experimental results are compared with the theoretical results in Fig. 3, and good agreement is observed. The measured insertion loss in the passband was 0.55 dB and corresponding VSWR varied in the range between 1.4 and 1.6.

III. Quarter-Wavelength Coupled Variable Bandpass Filter Using Varactor Diodes

The quarter-wavelength coupled variable bandpass filter is composed of two quarter-wavelength coupled bandpass filters N_1 and N_2 connected with coaxial power dividers as shown in Fig. 4(a), each of which includes two parallel resonant circuits. This parallel connection of N_1 and N_2 provides the variable bandwidth characteristic to this bandpass filter. Each parallel resonant circuit is structured with a parallel connection of short-circuited transmission line I and a varactor diode Z_{D5} (or Z_{D6}).

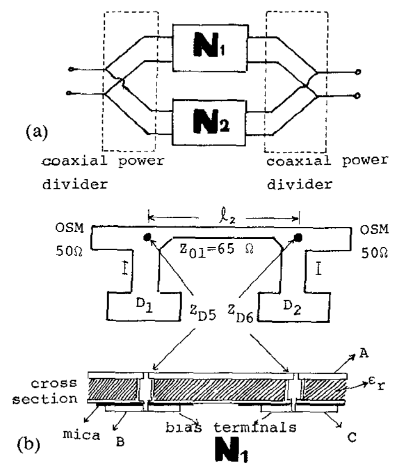

Fig 4. Quarter-wavelength coupled variable bandpass filter composed of two resonant circuits having varactor diodes and short-circuited transmission.

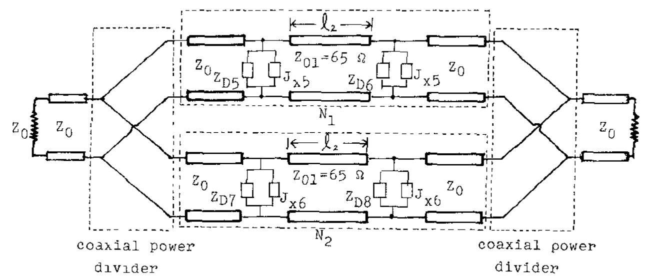

Fig 5 Equivalent circuit of the filter shown in Fig 4.

In filter N_1 the bias voltage for Z_{D5} is supplied through terminals A and B, and for Z_{D6} through terminals A and C as shown in Fig. 4(b). The same bias supply connections are applied to Z_{D7} and Z_{D8} in the filter N_2. D_1 and D_2 in Fig. 4(b) are for short-circuiting the transmission lines I's. All the lengths of the short-circuited transmission lines I's are 5 mm.

The characteristics impedance of the short-circuited transmission line I is 50 Ω. The distance l_2 between the parallel resonant circuit is 18.7 mm. As shown in Fig. 4(b), the input and output impedance of the bandpass filter are 50 Ω, and Z_{01} is 65 Ω.

The passband width is varied by changing the junction capacitances of the varactor diodes Z_{D5}, Z_{D6} and Z_{D7}, Z_{D8} of the quarter-wavelength coupled filters N_1 and N_2.

The equivalent circuit of the bandpass filter is shown in Fig. 5. J_{x5} and J_{x6} are the inductances of the short transmission lines of N_1 and N_2 filters. The junction capacitances of the varactor diodes Z_{D5}, Z_{D6} and Z_{D7}, Z_{D8} will be denoted simply as C_5, C_6 and C_7, C_8 in the following.

The experiments were carried out at the 4-GHz band. The measured attenuation characteristics of the filter are shown in Fig. 6. The input power was 0.01 mW.

As shown in Fig. 6(a), the passband width was 730 MHz when the bias voltages of the varactor diodes were all -0.05 V. The passband width was 1.22 GHz when the bias voltage of Z_{D5} and

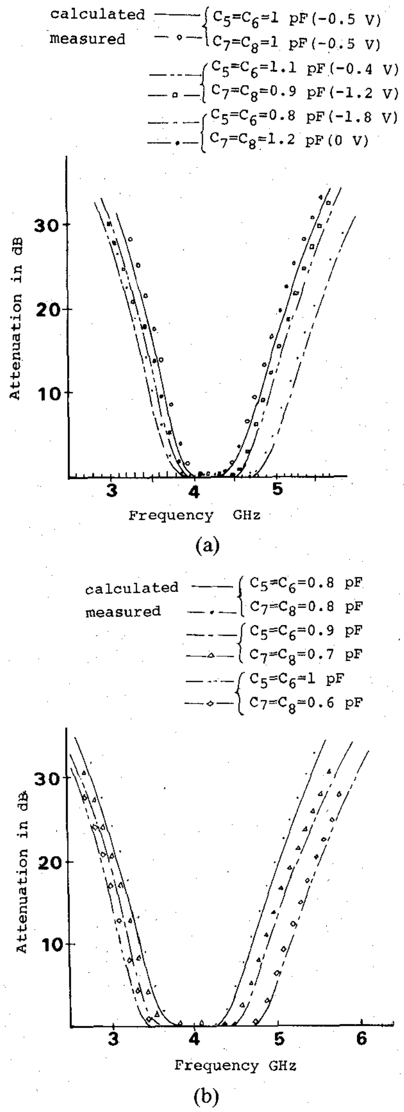

Fig. 6. Attenuation characteristics of the variable bandpass filter shown in Fig. 4.

Z_{D6} was -1.8 V, and that of Z_{D7} and Z_{D8} was 0 V. By changing the junction capacitance of the diodes Z_{D5}, Z_{D6} and Z_{D7}, Z_{D8} the passband width was varied from 730 MHz to 1.22 GHz.

As shown in Fig. 6(b), the passband width is 880 MHz when the bias voltage of Z_{D5}, Z_{D6} and Z_{D7}, Z_{D8} was all -1.8 V. The passband width is 1.44 GHz when the bias voltage of Z_{D5} and Z_{D6} was -0.5 V, that of Z_{D7} and Z_{D8} was -0.4 V. The center frequency of the passband was 4 GHz. By changing the junction capacitance of the varactor diodes Z_{D5}, Z_{D6} and Z_{D7}, Z_{D8} the passband width was varied from 880 MHz to 1.44 GHz.

The experimental results are compared with the theoretical results in Fig. 6, and good agreement between them is observed. The measured insertion loss in the passband was 0.4 dB (the VSWR in the passband varies in the range from 1.25 to 1.35).

If we wish to move the center frequency of the filter to around 7-GHz varactor diodes, smaller junction capacitances should be used.

IV. Conclusion

The quarter-wavelength coupled variable bandpass filter for 4-GHz band has been constructed and tested. By shifting the center frequencies in the quarter-wavelength coupled filters N_1 and N_2, the passband width can be varied widely.

The quarter-wavelength coupled bandstop filter for 6-GHz band has been constructed and tested. By using the composite series and parallel resonant circuits connected in the parallel, the stopband width could be made narrow. By changing the junction capacitances of the varactor diodes, the frequency giving maximum attenuation could be varied widely. The experimental results on the attenuation characteristics of the two filters agree well with the theoretical results.

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