Microstrip Variable Band-pass Filters Using Varactor-Diodes

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Abstract

Two microstrip variable band-pass filters for 6 GHz and 4 GHz bands are proposed and tested. The pass-band width varies from 310 MHz to 1.24 GHz for the varactor-diode coupled filter, and it varies from 380 MHz to 2.18 GHz for the filter which is composed of low-pass and high-pass filters connected in series. The center frequency of the both filters can be changed arbitrarily.

Introduction

Many studies of the microwave filter using a rectangular waveguide and coaxial line or strip line have been reported. However, the pass-band width of microwave filter mentioned above is fixed and cannot be varied.

The pass-band width of the band-pass filter can be varied mechanically or electrically. These methods of changing the pass-band width have been already reported[1]. In this paper, the author proposes new microstrip variable band-pass filters using varactor-diode. Two types of the filters are considered.

The first one is the varactor-diode coupled variable band-pass filter which is composed of three parallel resonance circuits connected with varactor-diodes and short transmission lines. The pass-band width is varied by changing the capacitances of the varactor-diodes.

The second one is composed of low-pass and high-pass filters conncted in series. The low pass filter is constructed by mounting three varactor-diodes in a microstrip line at a certain interval. By changing the capacitances of the varactor-diodes, the cut off frequency of the low-pass filter is varied. The high-pass filter is constructed by placing three condensers on a microstrip line, and between them, open transmission lines terminated by varactor diodes are connected as inductances. The cut off frequency of the filter is varied by changing the capacitances of the varactor-diodes. The pass-band width of the band-pass filter can be varied by changing the capacitances of the varactor-diodes in both low-pass and high-pass filters.

The experiments were carried out at the 4 GHz band. For the second filter, the pass-band width was varied from 380 MHz to 2.18 GHz.

Varactor-diode coupled variable band-pass filter

The structure of the varactor-diode coupled variable band-pass filter is show in Fig. 1.

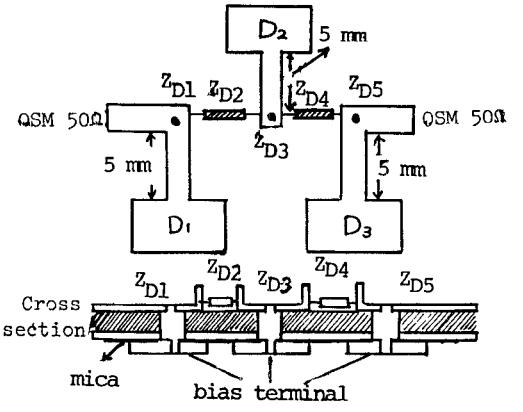

Fig. 1. Construction of varactor-diode coupled variable band-pass filter

The filter is composed of the three resonance circuits connected with the varactor-diodes and the short transmission lines. The center frequencies in the pass-band of the three resonance circuits are equal, and they are varied by changing the junction capacitance of the D5047 varactor-diodes Z_{D1}, Z_{D3}, Z_{D5}. The lengths of the short transmission lines are all 5mm.

The experiments were carried out at the 6 GHz band. The measured attenution characteristics of the filter is shown in Fig. 2. The capacitances of varactor-diodes Z_{D1}, Z_{D2} and Z_{D3}, Z_{D4}, Z_{D5} shown in Fig. 2 will be denoted simply as C_1, C_2 and C_3, C_4, C_5 in the following. As shown in Fig. 2, the pass-band width varied from 310 MHz to 1.24 GHz when the bias

voltage of the diodes Z_{D2} and Z_{D4} was changed from 0(V) to -9.5(V)(constant bias voltage -25 (V) was applied to the diode Z_{D1}, Z_{D3}, Z_{D5}). The center frequency is 6.8 GHz. When the junction capacitances of Z_{D2} and Z_{D4} become large, the coupling between three resonance circuits increases. As a result, the center freqency is shifted 45 MHz to lower frequency.

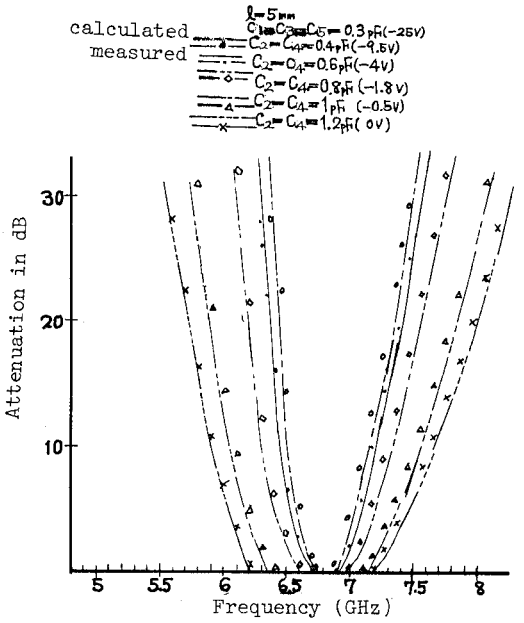

Fig. 2. Attenuation characteristics of the filter shown in Fig. 1.

The pass-band width varied from 140 MHz to 840 MHz when the bias voltage of the diodes Z_{D2} and Z_{D4} was changed from 0(V) to -9.5 (V) (constant bias voltage -6.2 (V) was applied to the diodes Z_{D1}, Z_{D3} and Z_{D5}). The center frequency is 5.85 GHz. If we want to move the center frequency of the filter to around 4 GHz, the varactor-diodes Z_{D1}, Z_{D3} and Z_{D5} with larger junction capacitances should be used.

The experimental results are compared with the theoritical results Fig. 2, and good agreement between them is observed. Moreover, the measured insertion loss in the pass-band was less than 1 dB.

Variable band-pass filter composed of low-pass and high-pass filters connected in series

(1) Low-pass filter

The structure of the variable cut off frequency low-pass filter is shown in Fig. 3. An interval ℓ between D5047 varactor-diodes Z_{D6}, Z_{D7} and Z_{D8} is 6 mm, and the varactor-diodes are mounted in the microstrip line. The input and output impedances of the low-pass filter are 50 Ω, and Z_{01} is 75 Ω. The cut off frequency in the low-pass filter is varied by changing capacitances of the varactor-diodes.

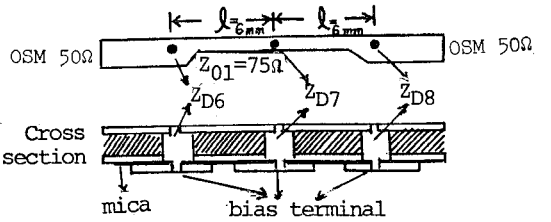

Fig. 3. construction of low-pass filter

The experiments were carried out from 3 GHz to 5 GHz bands. The measured attenuation characteristics of the filter is shown in Fig. 4. The junction capacitances of varactor-diodes Z_{D6}, Z_{D7} and Z_{D8} shown in Fig. 4 will be denoted simply as C_6, C_7 and C_8 in following. The cut off frequency varied from 3.25 GHz to 5.37 GHz when the bias voltage of the diodes Z_{D6} and Z_{D7} was changed from 0(V) to -25 (V)(constant bias voltage -25(V) was applied to the diode Z_{D8}).

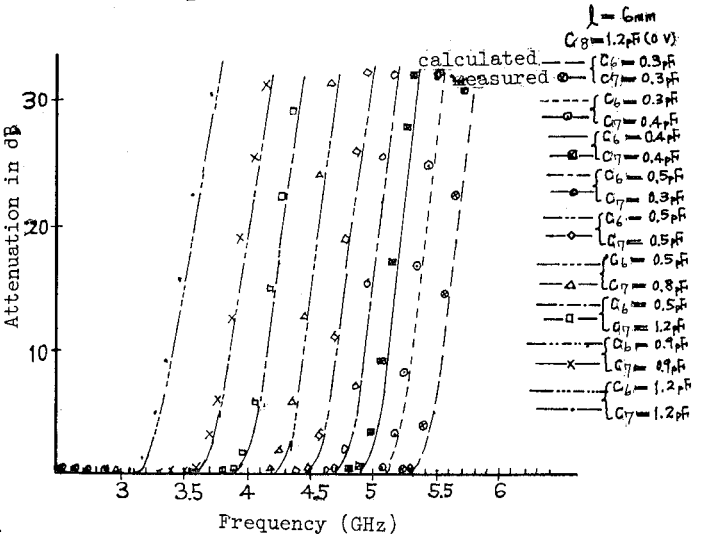

Fig. 4. Variable cut off frequency low-pass filter shown in Fig. 3.

(2) High-pass filter

The structure of the variable cut off frequency high-pass filter is shown in Fig. 5. The D5047 varactor-diodes Z_{D9} and Z_{D10} are mounted at the ends of the open transmission line. The characterististics impedance of the open transmission line is 100 Ω, and the length was 10 mm. In order to supply the voltage to the varactor-diodes, the transmission lines shorted by condensers D_1 and D_2 are connected

to the strip line. The condenser C_a, C_b, C_c are formed by sandowiching mica plates between the upper and lower plates of the microstrip. The cut off frequency is varied by changing capacitances of the varactor-dioeds.

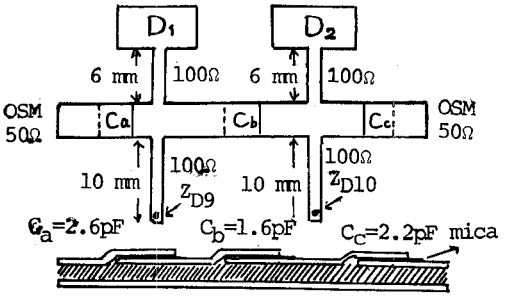

Fig. 5. Construction of high-pass filter

The experiments were carried out from 3 GHz to 5 GHz bands. The measured attenuation characteristics of the filter is shown in Fig. 6. The junction capacitances of the varactor-diodes Z_{D9} and Z_{D10} shown in Fig. 6 will be denoted simply as C_9 and C_{10} in the following.

The cut off frequency varied from 2.86 GHz to 4.05 GHz when the bias voltage of the diode Z_{D10} was changed from 0(V) to -25 (V) (constant bias voltage -0.4 (V) was applied to the diode Z_{D9}).

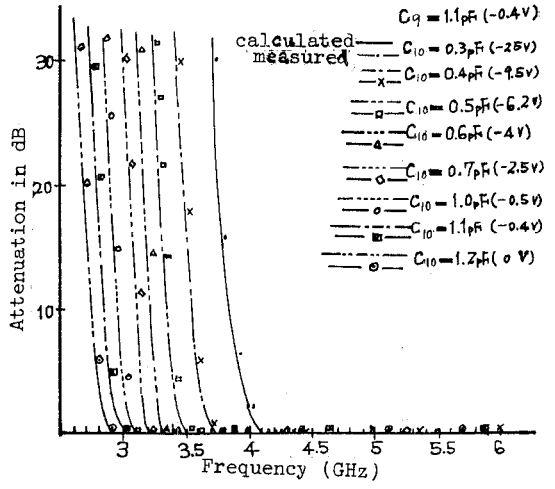

Fig. 6. Variable cut off frequency high-pass filter shown in Fig. 5.

The measured insertion loss of the filter was less than 1 dB.

(3) Variable band-pass filter composed of low-pass and high-pass filters

The measured attenuation characteristics of the variable band-pass filter are shown in Fig. 7. The pass-band width varied 320 MHz to 1.805 MHz when the bias voltage of the diode Z_{D6} was changed from -6.2 (V) to -9.7 (V) and Z_{D7} was changed from -1.8 (V) to -9.7 (V) (constant bias voltage 0 (V) was applied to the diode Z_{D8}), and Z_{D10} was changed from -2.6 (V) -25 (V) (constant bias voltage -0.4 (V) was applied to the diode Z_{D9}). The center frequency is 4.15 GHz.

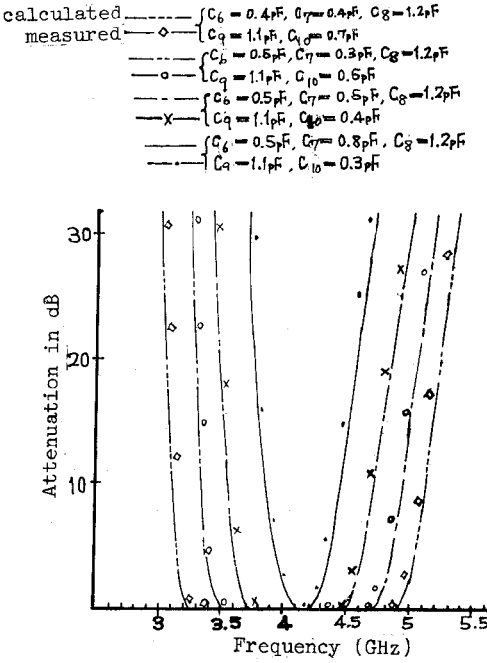

Fig. 7. Variable band-pass filter composed of low-pass and high-pass filters connected in series

The experimental results are compared with the theoritical results in Fig. 7, and good agreement between them is observed. Moreover, the measured insertion loss in the pass-band was less than 1 dB. This type of band-pass filter has several advantages over the varactor diode compled band-pass filter. Namely, the center frequency of the pass-band can be selected more easily, and the pass-band width be varied more widely.

References

1) S.Toyoda "Rectangular Waveguide-Type Variable Band-Pass Filters" IEEE MTT-S 1979 International Microwave Symposium digest pp 281/284.