Rectangular Waveguide Type Variable Band-pass Filters

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Abstract

Two rectangular waveguide type variable band-pass filters for 10 GHz and 4 GHz bands have been proposed and tested. The pass-band width varied from 600 MHz to 2.2 GHz in the filter using ridge resonant irises, and it varied 260 MHz to 1.02 GHz in the filter using varactor-diodes. The center frequency of both filters could be changed arbitrarity.

Introduction

Many studies of the microwave filters using a rectangular waveguide and coaxial line or strip line have been reported. Filters used in the waveguide circuit are usually composed of capacitive or inductive irises placed at quarter-wavelength intervals. G.Croven and L.Lewin[1] proposed quarter-wavelength coupled band-pass filter in which three metallic posts in the rectangular waveguide are mounted. The filter mentioned above has narrow-band characteristics. T.S. Chen[2] obtained the wide-band characteristics for the filter composed of resonant irises planced across a rectangular waveguide at quarter-wavelength intervals. However, the pass-band width of the band-pass filters mentioned above is fixed and cannot be varied.

In this paper, two new waveguide type variable band-pass filters are proposed, in which the pass-band width is varied mechanically or electrically.

In case of the mechanical method, the variable band-pass filter is composed of four ridge resonant irises planced across a rectangula waveguide at quater-wavelength intervals. The experiments were carried out at the X-band, and the pass-band width varied from 600 MHz to 2.2 GHz when the width and heigth were changed sligtly.

In case of the electrical methode, two pairs of a diode and a metallic post separeted by a/3 in x direction are mounted in the upper and lower sides of the E-plane bifuracated waveguide, and other two pairs of them are placed apart from the first pairs by $\lambda/4$ in z direction. The experiments were carried out at the 4 GHz band. The pass-band width varied from 260 MHz to 1.02 GHz when the bias voltage of the varactor diode was change from -0.3 (v) to -2.5 (v).

The experimental results agree well with the theoritical results, and the measured insertion losses in the pass-band of both filters were less than 1 dB.

Waveguide variable band-pass filter using ridge resonant irises

The structure of the variable band-pass filter using the ridge resonant irises is shown in Fig. 1. The filter is composed of four ridge resonant irises placed across a rectangular waveguide at quarter-wavelength intervals. The pass-band width was varied by changing the width and heigth of the ridge resonant irises. The thicnesses of the irises which are made of phosphor-bronze sheets are all 0.4 mm.

The experiments were carried out at the X-band. The measured attenuation characteristics of the filter is shown in Fig. 2. Five resonant irises were prepared, and their dimensions are as follows:
(1) a=12mm, b=3.3mm, d=4mm, h=1.98mm
(2) a=7.4mm, h=1.8mm, (3) a=7.8mm, h=1.75mm
(4) a=10.2mm, h=1.47mm (5) a=11.4mm, h=1.3mm
For irises (2)$\sim$(5), b=2mm and d=3mm.
The center frequency of each iris is set to 10 GHz. As showen in Fig. 2, four of these irises were used in the filter. They are separated by l=10mm. The width and height of the ridge resonant iris (1) are fixed, and those of irises (2),(3),(4),(5) are variable.

The pass-band width varied from 600 MHz to 2.2 GHz when the width and height were changed slightly. The measured insertion loss in the pass-band was less than 1 dB.

Waveguide variable band-pass filter using varactor-diode

1) Analysis and equivalent circuit of the filter

The structure of the variable band-pass filter using the varactor-diodes is shown in Fig. 3. Two pairs of a diode and a metallic post separated by a/3 in x direction are mounted in the upper and lower sides of the E-plane bifurcated waveguide, and other two pairs of them are placed apart from the first pairs by $\lambda/4$ in z direction.

As shown in Fig.3, the width and height of the upper or lower waveguide are a and b', respectively. Both the diode and metallic post are assumed to be very thin cylindrical post of radius r, and are mounted at the distance d_1 and d_2 from the wall in the upper waveguide (the structure of the lower waveguide is the same as that of the upper waveguide). It is assumed that filamentary currents denoted by $J_1\delta(z)\delta(x-d_1)$, $J_2\delta(z)\delta(x-d_2)$ flow uniformly in the posts. The currents J_1 and J_2 are determined from the boundary condition. We consider here the special case where the height b' of the waveguide coincides with that of the diode. Since $b' \ll \lambda$ in this case, the electromagnetic fields are almost uniform in y direction, and therefore the electric field is assumed to have only y-component $E_y(x,z)$. With these assumptions, the analysis was carried out, and thus obtained equivalent circuit of the filter is shown in Fig. 4[3]. The equivalent circuit of N_1 in Fig.4a is shown in Fig. 4b. The equivalent circuit of N_2 is obtained by replacing Z_{D1} and Z_{D2} by Z_{D3} and Z_{D4}, respectively. The expressions for reactance $Jx, -Jx_1$ are given in the reference (4).

The impedance shown in Fig. 4b is expressed as

$$Z_s = m^2\left(A_n + \frac{1}{\dfrac{1}{C_n} - \dfrac{4}{Z_{D1}}}\right) \qquad (1)$$

$$A_n = j\frac{\omega\mu_0 b'}{a}\sum_{n=3,5,7\cdots}^{\infty}\frac{1}{T_n}\sin\left(\frac{n\pi d_1}{a}\right)\sin\left\{\frac{n\pi(d_1+r)}{a}\right\}$$
$$= j\frac{\omega\mu_0 b'}{2a}\left[\frac{a}{\pi}\left\{\ln\left(\frac{2a}{\pi r}\sin\frac{\pi d_1}{a}\right) - 2\sin^2\left(\frac{\pi d_1}{a}\right)\right.\right.$$
$$\left.\left. + \left(\frac{a}{\pi}\right)^3\sum_{n=3,5,7\cdots}^{\infty}\frac{1}{n^3}\sin\left(\frac{n\pi d_1}{a}\right)\sin\left\{\frac{n\pi(d_1+r)}{a}\right\}\right\}\right] \qquad (2)$$

$$C_n = j\frac{\omega\mu_0 b'}{2a}\left[\frac{a}{\pi}\left\{\ln\left(\frac{2a}{\pi r}\sin\frac{\pi d_1}{a}\right) - 2\sin^2\left(\frac{\pi d_1}{a}\right)\right.\right.$$
$$\left.\left. + \left(\frac{a}{\pi}\right)^3\sum_{n=2,4,6}^{\infty}\frac{1}{n^3}\sin\left(\frac{n\pi d_1}{a}\right)\sin\left\{\frac{n\pi(d_1+r)}{a}\right\}\right\}\right] \qquad (3)$$

$$m^2 = \frac{a}{2b'}\operatorname{cosec}^2\left(\frac{\pi d_1}{a}\right) \qquad (4)$$

2) Experimental results

The varactor-diodes used in the filter are D5047. The values of a, b' and b of the waveguide are 58mm, 2mm and 5mm, respectively. The thichness of a copper plate is 1mm. Diameter of the metallic post made of copper is 3mm, and radii r are of the varactor-diode and of the metallic post are 0.6mm. The length l_1, l_2, l_3 are all $\lambda g/4$ for the frequency 4 GHz. The input power was 0.01 mW.

The measured attenuation characteristics of the variable band-pass filter are shown in Fig. 5. The junction capacitances of varactor diodes Z_{D1}, Z_{D2}, and Z_{D3}, Z_{D4} showen in Fig. 5 will be denoted simply as C_1, C_2, and C_3, C_4 in the following. As shown in Fig. 5a, the pass-band width varied from 300 MHz to 820 MHz when the bias voltage of the diode Z_{D3} and Z_{D4} was changed from -0.05 (v) to -6 (v) (constant bias voltage -25 (v) was applied to the diodes Z_{D1} and Z_{D2}).

Fig. 5b indicates that the pass-band width varied from 260 MHz to 1.02 GHz when the bias voltage of the diodes Z_{D1} and Z_{D2} was changed from -1 (v) to -2.5 (v) (Z_{D3} and Z_{D4} was varied from -0.3 (v) to -2.5(v).

The experimental results are compared with the theoritical results in Figs 5a and 5b, and good agrement between them is observed. Moreover, the measured insertion loss in the pass-band was less than 1 dB.

It we want to more the center frequency of filter to around 3 GHz the varactor-diodes with larger junction capacitances should be used. According to the analysis, the values of C_1, C_2, and of C_3, C_4 are 1.2pF if the center frequency is 3.4 GHz.

The pass-band with in this case is 350 MHz. When the values of C_1 and C_2, and of C_3, C_4 are 1.2 pF and 1.3pF, respectively, the center frequency is still 3.4 GHz but the pass-band width is 190 MHz.

Conclsion

Two rectangular waveguide type variable band-pass filters for 10 GHz and 4 GHz bands have been constructed and tested. The pass-band width varied from 600 MHz to 2.2 GHz in the filter using ridge resonant irises, and it varied 260 MHz to 1.02 GHz in the filter using varactor-diodes. It was confirmed that the center frequency of both filters could be changed arbitrarily. The experimental results on the attenuation characteristics of both filters agree well with the theoretical result.

References

1) G. Craven and L.Lewin:"Design of microwave filter with quater-wave coupling" Proc IEE Pt, B, 103 p 173 (1956)
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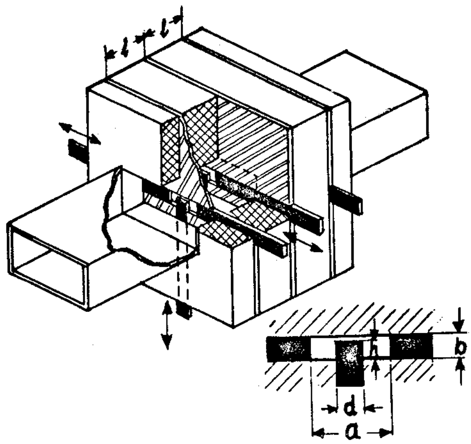

Fig. 1 Construction of variable band-pass filter using ridge resonant irises

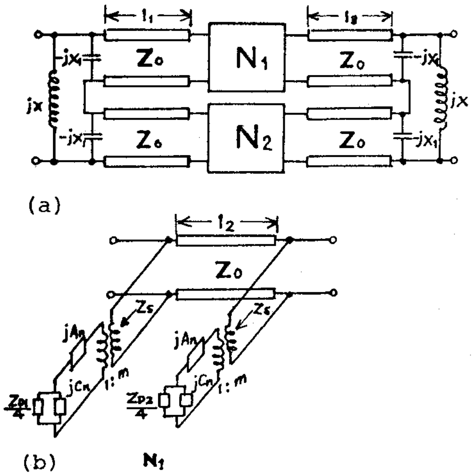

Fig. 4 Equivalent circuit of Fig. 1

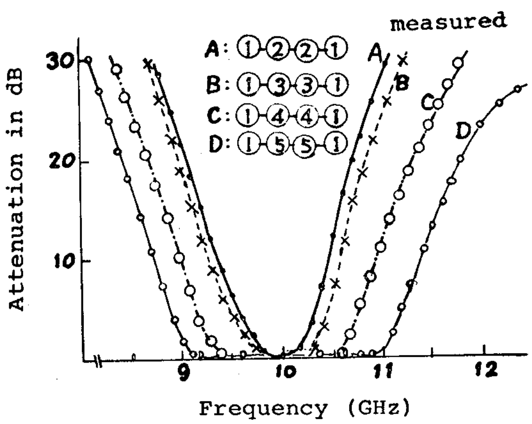

Fig. 2 Attenuation characteristics of variable band-pass filter

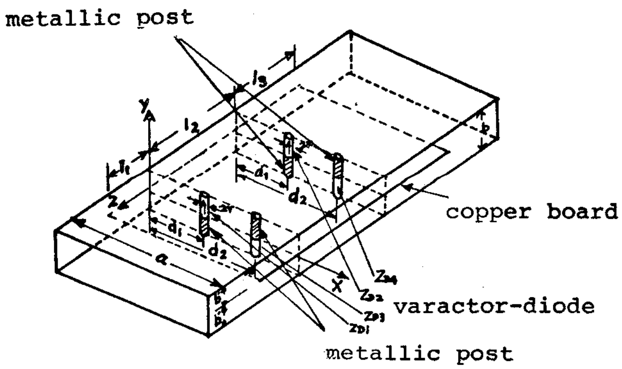

Fig. 3 Variable band-pass filter using varactor-diodes and metallic posts mounted in a E-plane bifurcated waveguides

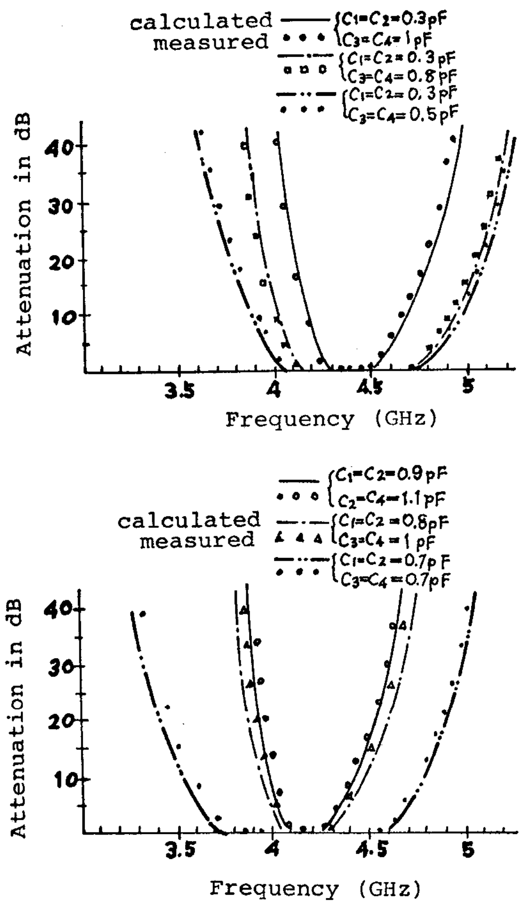

Fig. 5 Attenuation characteristics of the band-pass filter shown in Fig. 1.