(12) UK Patent Application (19) GB (11) 2 039 690 A

(21) Application No **7939261**
(22) Date of filing **13 Nov 1979**
(30) Priority data
(31) **53/139713**
(32) **13 Nov 1978**
(33) **Japan (JP)**
(43) Application published
13 Aug 1980
(51) **INT CL[3]**
H01P 1/203
(52) Domestic classification
H1W 7 BA
(56) Documents cited
GB 1421311
GB 690684
(58) Field of search
H1W
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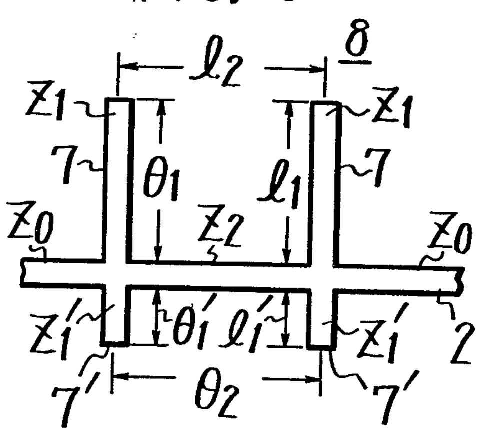
(54) **Microwave circuits**

(57) A microwave filter circuit realized in stripline form, comprises a transmission line 2 and stubs 7, 7′ at two or more positions, at least one of the stubs 7, 7′ extending across the transmission line 2 and projecting by different lengths 1_1 and $1_1'$, the distance 1_2 between adjacent stubs 7, 7′ and the lengths 1_1 and $1_1'$ being selected to produce desired frequency band and attenuation characteristics.

FIG. 6



The drawings originally filed were informal and the print here reproduced is taken from a later filed formal copy.

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FIG. 1

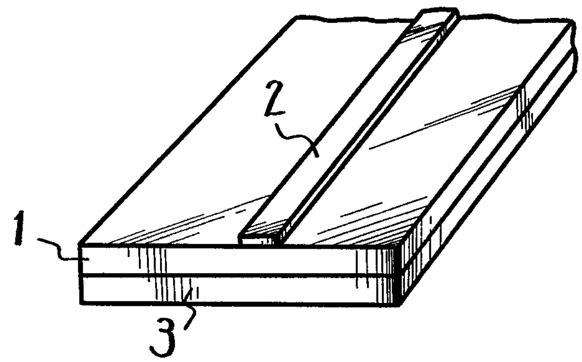


FIG. 2

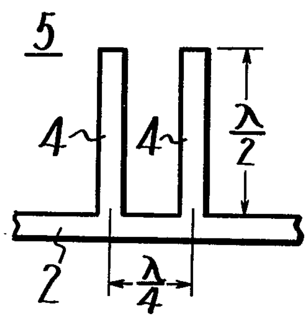


FIG. 3

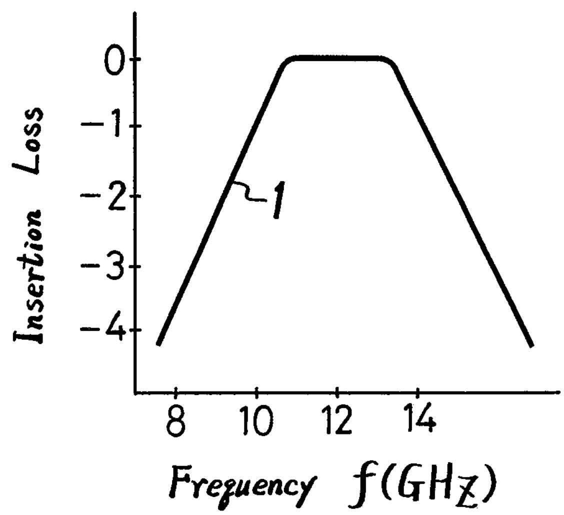


FIG. 4

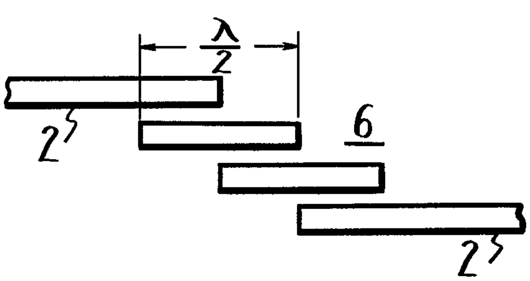


FIG. 5

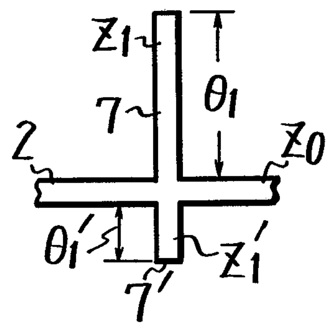


FIG. 6

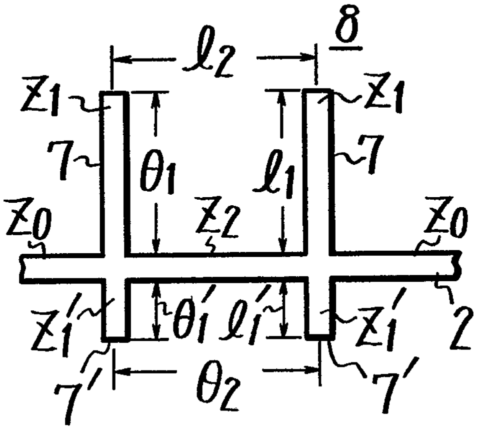


FIG. 8

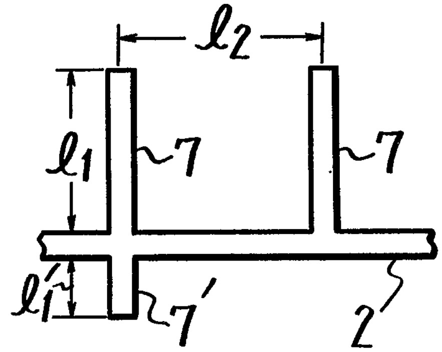
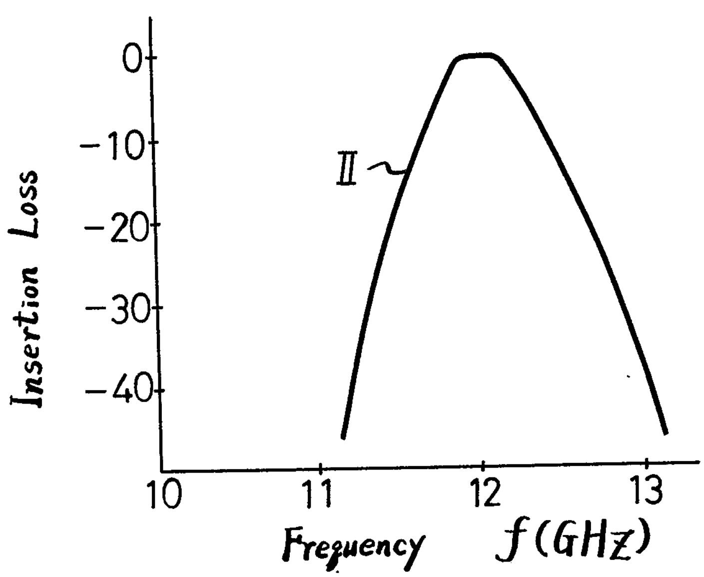


FIG. 7



SPECIFICATION

Microwave circuits

This invention relates to microwave circuits.

In a prior art microwave circuit shown in Figure 1 of the accompanying drawings, on a dielectric such as ceramic dielectric substrate 1 made, for example, of alumina or the like, there is formed a microwave conductor, that is a transmission line 2, while on the back surface of the substrate 1 there is formed a conductor 3 which may be grounded. This is known as a micro strip line. In a so-called strip line the structure is in the form conductor-dielectric-transmission line and is symmetrical with respect to the transmission line.

In a micro strip line band-pass filter 5 as shown in Figure 2 of the accompanying drawings, in which at two positions of the main transmission line 2 there are provided parallel stub lines or stubs 4 of $\lambda/2$ length (λ being the wavelength) spaced by $\lambda/4$, the frequency characteristic of the insertion loss is as shown by a curve I in the graph of Figure 3 of the accompanying drawings and the attenuation characteristic thereof is very gently sloped.

Moreover, in a band-pass filter 6 with the pattern shown in Figure 4 of the accompanying drawings, if the number of elements, which form the band-pass filter 6, is increased somewhat, the attentuation characteristic can be sharpened to some extent. In this case, however, the insertion loss of the pass band increases.

According to the present invention there is provided a microwave circuit comprising:
a dielectric;
a transmission line on one surface of said dielectric;
a conductor on the other surface of said dielectric; and
at least two stubs provided on said transmission line at different positions thereof;
at least one of said stubs extending across said transmission line so as to project by different lengths from the two sides of said transmission line, the lengths of said stubs and the distance between adjacent stubs being so selected that said transmission line has predetermined frequency band and attenuation characteristics.

The invention will now be described by way of example with reference to the accompanying drawings, throughout which like reference numerals designate like elements, and in which:

Figure 1 is a perspective view showing a microstrip line to which the invention can be applied;

Figure 2 is a diagram showing the transmission line pattern of a prior art band-pass filter;

Figure 3 is a graph showing the frequency characteristic of the insertion loss of the band-pass filter of Figure 2;

Figure 4 is a diagram showing the transmission line pattern of another prior art band-pass filter;

Figure 5 is a diagram showing the transmission line pattern of a microwave circuit for explaining the invention;

Figure 6 is a diagram showing the transmission line pattern of an embodiment of filter circuit according to the invention;

Figure 7 is a graph showing a typical example of the insertion loss of frequency characteristics of the filter circuit of Figure 6; and

Figure 8 is a diagram showing the transmission line pattern of another embodiment of filter circuit according to the invention.

First, a circuit will be considered which is formed by a main transmission line 2 and two stub lines or stubs 7 and 7′ projecting on opposite sides of the main transmission line 2 and differing in length as shown in Figure 5. In the Figure, Z (namely Z_0, Z_1 and Z_1') and θ (namely θ_1, and θ_1') represent an impedance and electrical angle of the respective lines 2, 7 and 7′. In Figure 5, only the pattern of the transmission line 2, 7 and 7′ of the circuit is shown, but the circuit may be formed as a strip line or as a microstrip line.

The F matrix of the circuit shown in Figure 5 can be expressed as follows:

$$F = \begin{pmatrix} 1 & 0 \\ Y & 1 \end{pmatrix}, \quad Y = j\frac{\tan\theta_1}{Z_1} + j\frac{\tan\theta_1'}{Z_1'} \quad \cdots (1)$$

Next, a circuit 8 which can be considered as being formed of two circuits, each the same as that shown in Figure 5 and connected in cascade as shown in Figure 6 will be considered, this being an embodiment of the invention. The F matrix of the circuit 8 can be expressed as follows:

$$F = \begin{pmatrix} 1 & 0 \\ Y & 1 \end{pmatrix} \begin{pmatrix} \cos\theta_2 & jZ_2\sin\theta_2 \\ \frac{j\sin\theta_2}{Z_2} & \cos\theta_2 \end{pmatrix} \begin{pmatrix} 1 & 0 \\ Y & 1 \end{pmatrix}$$

$$= \begin{pmatrix} A & B \\ C & D \end{pmatrix} \quad \cdots (2)$$

The transmission coefficient S_{21} of a signal from the input to the output of the circuit 8 is expressed as follows:

$$S_{21} = \frac{2}{A + \frac{B}{Z_0} + CZ_0 + D} \quad \cdots (3)$$

If it is assumed that $Z_1=Z_1'=Z_2=Z_0$ for the sake of simplicity, the above transmission coefficient S_{21} can be expressed as follows:

$$S_{21} = \frac{1 + \tan^2\theta_2}{1-(\tan\theta_1+\tan\theta_1')\tan\theta_2 + j\{\tan\theta_1+\tan\theta_1'+\tan\theta_2-\frac{1}{2}(\tan\theta_1+\tan\theta_1')^2\tan\theta_2\}} \quad \cdots (4)$$

The frequency condition for complete transmission through the circuit 8 or filter is as follows:

$$|S_{21}|^2 = 1 \quad \cdots (5)$$

From equation (5), the following equation (6) is obtained:

$$(\tan\theta_1 + \tan\theta_1')\tan\theta_2 = 2 \quad \cdots (6)$$

For the frequencies f_A and f_A' where maximum attenuation is presented in the attentuation region (generally, f_A is a frequency lower than the pass band and f_A' is a frequency higher than the pass band), the following equations are established:

$$\left.\begin{aligned} \tan\theta_1 &= \tan\frac{2\pi}{\lambda A}\ell_1 = \infty \\ \tan\theta_1' &= \tan\frac{2\pi}{\lambda' A}\ell_1' = \infty \end{aligned}\right\} \quad \cdots (7)$$

From equation (7), the lengths l_1 and l_1' of the stubs 7 and 7' are determined. When the values of the lengths l_1 and l_1' and that of the centre frequency f_S in the pass band are substituted into equation (6), a distance l_2 between the stubs 7 and 7' can be obtained. In other words, if the centre frequency in the pass band and the attenuation polar freqencies each side of the centre frequency are given in the circuit 8 of Figure 6, a band-pass filter can be designed. In this case, since the attenuation polar frequency can be selected desirably, if it is selected close to the pass band, a sharply rising and falling characteristic can be realised. The frequency characteristics of the insertion loss in the circuit 8 of Figure 6 is typically shown in the graph of Figure 7 by a curve II.

In the above example, it is assumed that $Z_1=Z_1'=Z_2=Z_0$ is satisfied and then equations (4) onwards are calculated. However, when Z_1 and Z_1' are selected as values other than Z_0, if the condition making the following input reflection coefficient S_{11} of the circuit zero, that is the condition for making the input voltage stationary wave rate a minimum is added, Z_2 can be determined and then a procedure the same as that above can be followed:

$$S_{11} = \frac{A + \frac{B}{Z_0} - CZ_0 - D}{A + \frac{B}{Z_0} + CZ_0 + D} \quad \cdots (8)$$

In the above embodiment, the stubs 7 and 7' are open at their free ends. However, it is possible for a substantially similar filter circuit to be designed by using stubs the ends of which are short-circuited, or the combination of a stub having an open end with a stub having a short-circuited end.

Figure 8 shows another embodiment of the invention. In this embodiment, two stubs 7 are provided on a main transmission line 2 at two positions with a predetermined distance therebetween, and one of the stubs 7 is extended through the main transmission line 2 to the other side, or a stub 7' is provided on the main transmission line 2 at the same position as one of the stubs 7 but on the opposite side and has a length l_1' different from the length l_1 of the stub 7. In this case, by suitably selecting the lengths l_1, l_1' of the stubs 7 and 7' and the distance l_2 between the two stubs 7, a filter circuit a having sharply rising and falling characteristic can be provided.

In the embodiments of Figure 6 and 8, the stubs are provided on the main transmission line at two positions, but the invention can be applied to cases in which the stubs are provided on the main transmission line at more than two positions. In the latter case, at least one stub is formed such that it extends through the main transmission line and projects by different lengths.

As described above, two frequencies which are very close can be separated by a simple circuit construction. In a case where a signal frequency, a local oscillation frequency and an image frequency, for example, are close to one another and are applied to a mixer circuit, an embodiment of filter circuit according to the invention may be provided at the signal input side of the mixer circuit, so that leakage of the local oscillation signal can be avoided and also trap operation for the image frequency signal can be achieved.

CLAIMS

1. According to the present invention there is provided a microwave circuit comprising:
a dielectric;
a transmission line on one surface of said dielectric;
a conductor on the outer surface of said dielectric; and
at least two stubs provided on said transmission line at different positions thereof;
at least one of said stubs extending across said transmission line so as to project by different lengths from the two sides of said transmission line, the lengths of said stubs and the distance between adjacent stubs being so selected that said transmission line has predetermined frequency band and attenuation characteristics.

2. A microwave circuit substantially as hereinbefore described with reference to Figure 6 of the accompanying drawings.

3. A microwave circuit substantially as hereinbefore described with reference to Figure 8 of the accompanying drawings.

Printed for Her Majesty's Stationery Office, by Croydon Printing Company Limited, Croydon Surrey, 1980.
Published by the Patent Office, 25 Southampton Buildings, London, WC2A 1AY, from which copies may be obtained.