A Capacitive Load Double-Ridge Waveguide Evanescent Mode Low-pass Filter

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Keywords: evanescent mode ;capacitive loading ; double-ridge waveguide;filter

Abstract. In this paper, a capacitive load double-ridge waveguide evanescent mode low-pass filteris is presented. Combining electromagnetic simulation software to design ,the test results are: The filter return loss＜-20dB, insertion loss＞-0.6dB, out-band suppression≥40dBc at 5.5GHz and≥20dBc at 13GHz to 26 GHz, parasitic passband appears in multiples of five frequency, improving filter performance greatly.

Introduction

As we know waveguide,a kind of passive component, has been used widely in the field of Microwave. However, we take it as a transmission line where we are used to pay more attention to its transmission mode with avoiding cutoff state usually. With study on the waveguide cutoff mode deeply found an important application value containing evanescent mode filter which is a significant reflection.Compared traditional filter evanescent mode filter is advantage of smaller size, higher clutter suppression and farther parasitic passband preferred by engineer in practical application. Meanwhile, The capacitive loading effect refined the filter size further increating designing flexibility.

Theory

A transmission line will behave shortened effect when paralleled capacitor. load capacitance transmission line can use T-type or π-type equivalent circuit. [1]We assumed there is a transmission line with characteristic impedance of Z and length of L. For the T-type circuit , (As shown in Fig. 1). Assuming centering capacitive loading transmission line is loading capacity of B, each segment length of L_0 and characteristic impedance of Z_0
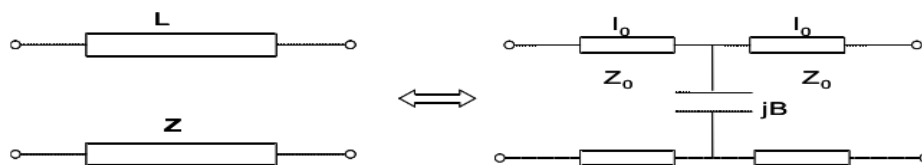

Fig.1 T-type equivalent circuit

Lossless transmission line $[A]$ matrix

$$[A]=\begin{bmatrix} \cosh(\beta L) & Z\sinh(\beta L) \\ \sinh(\beta L)/Z & \cosh(\beta L) \end{bmatrix} \quad (1)$$

Lossless T-type equivalent circuit $[A']$ matrix

$$[A']=\begin{bmatrix} \cosh(\beta_0 L_0) & Z\sinh(\beta_0 L_0) \\ \sinh(\beta_0 L_0)/Z_0 & \cosh(\beta_0 L_0) \end{bmatrix}\begin{bmatrix} 1 & 0 \\ jB & 1 \end{bmatrix}\begin{bmatrix} \cosh(\beta_0 L_0) & Z\sinh(\beta_0 L_0) \\ \sinh(\beta_0 L_0)/Z_0 & \cosh(\beta_0 L_0) \end{bmatrix} \tag{2}$$

Assuming $[A]=[A']$,we will get the following equation

$$Z = Z_0\sqrt{\frac{2\sin(2\beta_0 L_0)-BZ_0+BZ_0\cos(2\beta_0 L_0)}{2\sin(2\beta_0 L_0)+BZ_0+BZ_0\cos(2\beta_0 L_0)}} \tag{3}$$

$$\cos(\beta L)=2\cos(2\beta_0 L_0)-BZ_0\sin(2\beta_0 L_0)/2 \tag{4}$$

$$\tan(\beta L)=\frac{Z_0}{Z}\frac{2\sin(2\beta_0 L_0)-BZ_0[1-\cos(2\beta_0 L_0)]}{2\cos(2\beta_0 L_0)-BZ_0\sin(2\beta_0 L_0)} \tag{5}$$

As is shown above ,we can get the conclusion that transmission line of capacitive loading line will shorten comparing with original transmission where the more capacitive loading resulting shorter length and greater impedance. Remaining the resonance frequency is unchanged, the capacitive load filter has smaller size to meet the requirements of miniaturization.Lumped capacitance is no longer applicable in microwave frequencies, so we usually use it as a slug load capacitance, which is the cylinder chosen length of 1/4 λ normaly.

Signal (f＜fc)can not transmit the form of traveling wave along the waveguide , It is attenuation wave in exponential decay form. The actual inner wall of the waveguide is not a perfect conductor, there is a certain loss, then the propagation constant exist a small traveling wave component β.The size of waveguide is small usually,so there is a small loss of amplitude through it. The wave impedance is inductive, when the transmission waveguide is TE wave.TM wave impedance is capacitive. It will form a resonator thougth adding the corresponding capacitive or inductive patch[2,3].

Ridge waveguide , a modified rectangular waveguide, has better properties in some aspects. There is a salient in rectangular waveguide broadside equivalent to increasing the length of the broadside with smaller size in transmitting the same frequency electromagnetic wave, The cross section is shown in Fig .2.
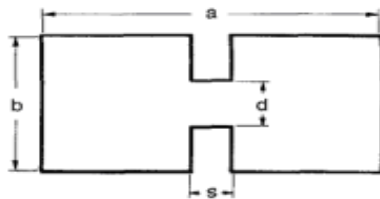

Fig. 2   structure of cross section

We calculate the cutoff wavelength λ_{rc} by the following formula

$$\frac{b}{\lambda_{cr}}=\frac{b}{2(a-s)}[1+\frac{4}{\pi}(1+0.2\sqrt{\frac{b}{a-s}})\frac{b}{a-s}\ln\csc\frac{\pi}{2}\frac{d}{b}+(2.45+0.2\frac{s}{a})\frac{sb}{d(a-s)}]^{-0.5} \tag{6}$$

Finally,the guided wavelength for any frequency is related to the cutoff wavelength by

$$\lambda_g=[1-(\lambda/\lambda_{cr})^2]^{0.5} \tag{7}$$

We combine electromagnetic simulation software mainly to help us to design. For the normal ridge waveguide filter, the capacitance will increase and resonant frequency will reduce with the length of ridge increasing because of the increasing the effective area to addition of capacitance and electric field energy. Increasing the ridge width of the resonance will be reduce resonance frequency and increase when it gets to a certain value.The reason is double-ridged edge inductance effect increasing the magnetic field energy faster than electric field energy to net electric field will decrease. The height between double ridges plays the most important role in resocrnant frequency

sensitive,where increasing the height of double ridges will reduce the capacitance to decrease the electric field energy,the resonant frequency will increase.

Result and Discussions

In this paper we have designed a six ordercapacitive load double-ridge waveguide evanescent mode low-pass filter through above theory.The simulation structure of this filter is in Fig 3.The result of simulation is in Fig 4.
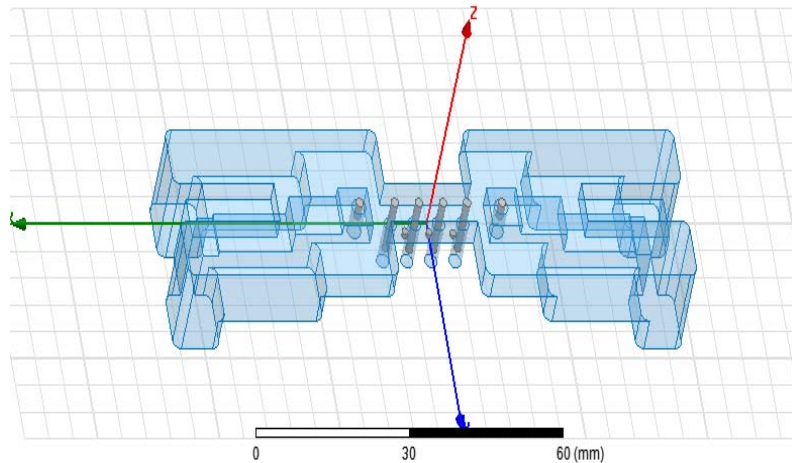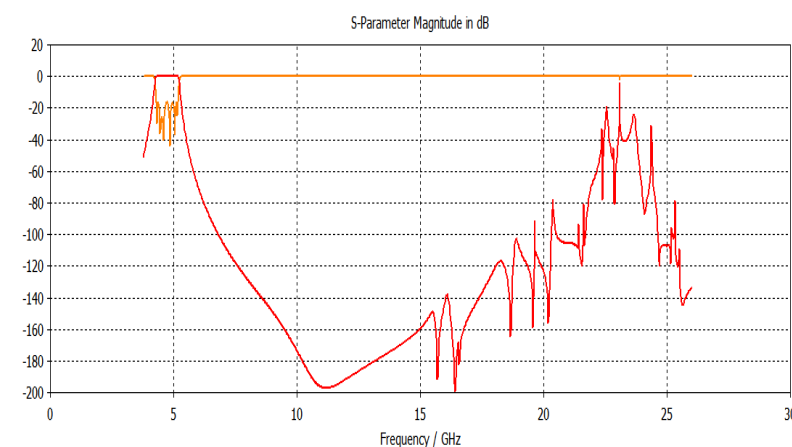

Fig. 3 simulated structure

Fig. 4 simulated result
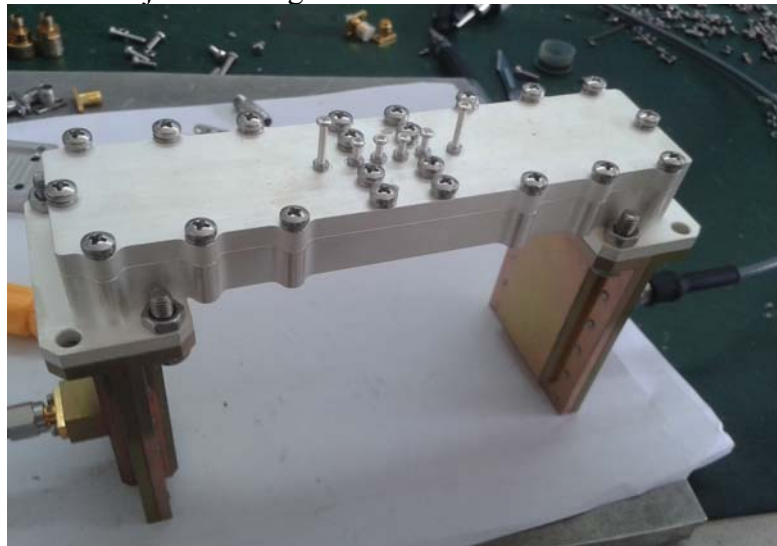
The picture of the actual object is in Fig. 5

Fig. 5 actual object
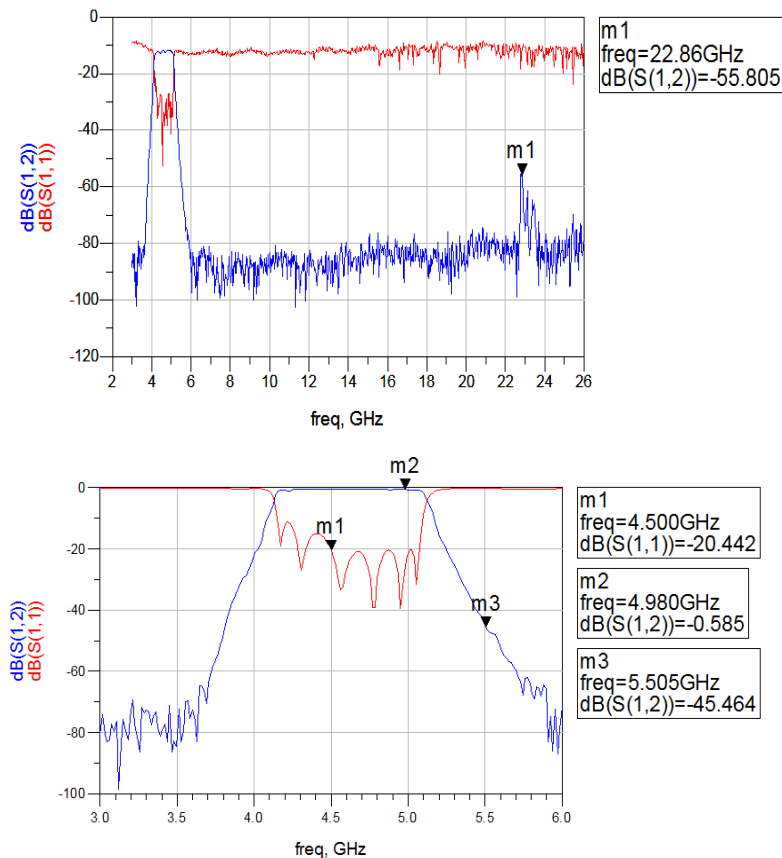
The measured result is showed in Fig.6

Fig. 6 measured result

Because of the frequency scanning range of the vector network is 3GHz-26GHz, the result of the band is not accurate enough.

Conclusions

By comparing with the simulation results and the test results，we take the correctness of the proposed model verify.It has a value of project of the filter where the parasitic passband has been pushing five frequency multiplier successfully.

Acknowledgements

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