



Wideband Dual Posts Waveguide Band Pass Filter

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Abstract- In This paper the sensitivity analysis and design of the wideband dual post waveguide band pass filter has been described. The design method is based on insertion loss technique and the calculated results are used to design the certain filter. The simulation results have been validated by measurement s.

Index Terms- Waveguide Bandpass Filter, Dual Posts, Sensitivity Analysis, Insertion Loss Technique.

I. INTRODUCTION

At low frequencies the building blocks for filters are ideal inductors and capacitors that their frequency characteristics are known completely and there are known synthesis procedure to design. But the complex frequency behavior of microwave circuit elements makes it impossible to develop a general and complete synthesis procedure. However, in narrowband cases there are useful techniques for microwave filters [1-3]. Waveguide filters have been used for many years in a large variety of applications from 1937 to now and their theory and design in directly coupled resonator arrangements is well known and understood, e.g. [1-5].

The cylindrical post in a rectangular waveguide was first treated by the well-known reference [1]. The complete analysis of multiple post inductive obstacles in rectangular waveguide was presented in some papers [6-7].

This paper explicates design method and then sensitivity analyses of a wideband waveguide bandpass filter with dual posts have been provided.

II. THEORY

The direct coupled cavity waveguide filter is made up of a number of high-Q resonant cavities. Such a cavity is formed by two obstacles nearly half a guide wavelength apart. In general, the obstacle used may be of either the capacitive or inductive type.

Of all conventional inductive obstacles, a single cylindrical post, centrally placed across the waveguide parallel to the electric field of the dominant mode seems to be the most simple way. However, the post size must be changed according to the value of the obstacle susceptances. Normally, the center cavity post is largest and the other posts' sizes are reduced toward both ends of the filter. So, thinnest posts would be located in the two ends as shown in Fig.1. When the number of cavities and the filter band-width increase, these two end posts' diameters become extremely thin and this leads to two major problems; first, higher order modes are generated and, second, it becomes difficult to produce the filter in mass production. Variations in posts' diameters do not allow simple automation, too. An alter to eliminate higher order modes is the use of symmetrical multiple posts, but manufacturing become complex and expensive. Therefore, a trade off is the use of two post cavity waveguide filter. Every pairs have a specific diameter. Separation between every pairs must be varied to compensate for the change of obstacle susceptance.

The extent of higher order modes can be eliminated by using posts that are as thick as possible. In addition, the two posts are symmetrically located in the waveguide as seen in Fig.1.

Because tuning screws are located along the center line, the tuning effect will be strongest. As a consequence, the screw penetration into the



cavity is minimal, the effect of reducing unloaded Q is minimized, and, of course, the insertion loss is also minimal.

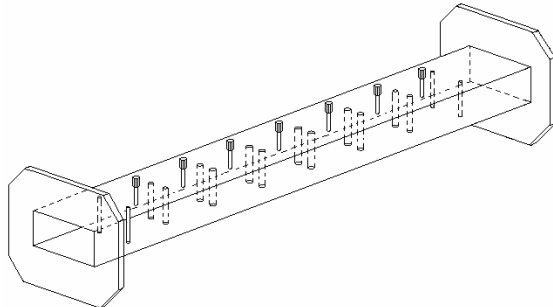


Fig.1. the geometry of waveguide filter with 8 rows of dual post

III. DESIGN

In this section we provide a common step by step design for bandpass waveguide filter with insertion loss method based on chebyshev approximation. The designed filter has an approximate center frequency of 9 GHz, bandpass response is between 8.8-9.2 GHz, cutoff frequencies are 8.6GHz and 9.4GHz, 50dB bandstop attenuation and 0.5dB ripple in the passband. Waveguide filter designs are often met in the descriptions of metal posts, iris or similar discontinuities [1]. We know in case of thickened obstacle in cross section of a waveguide one can not use the approximates' circuits of Fig.2 with no series elements in T circuit and shunt ones in the π circuit, instead, the use of T and π circuits with series and shunt elements, respectively is essential. But from Fig.2, we see that if we use the precise circuits, there is two equations with three unknowns (X_s, X_p, ϕ), so we should find these unknowns. Three methods could be applied:

- 1- Optimize three parameters from the first by the use of some engineering softwares like microwave office.
- 2- Fix one of the parameters and then try to find the others with the use of an optimization algorithm.
- 3- We mentioned that if obstacles be thin enough (e.g. for post across the wave guide $post\ diameter / waveguide\ length = 0.15$ [1])

one can use the approximate circuits of Fig.2, so to use this approximation we should make the posts' diameters thinner in some ways. There are two ways doing this:

- a) Using single post in waveguide as possible, and then use dual posts with smaller diameters.
- b) Only use dual posts in waveguide cross section.

In practice the first two ways are time consuming and not applicable in case of high order filters and so series elements in the T circuits and the shunt ones in the π circuits would be neglected and so we use the third way to achieve the filter characteristics.

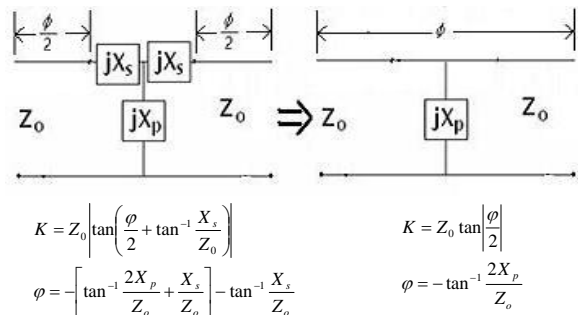


Fig. 2a. Schematic diagram of practical impedance inverter

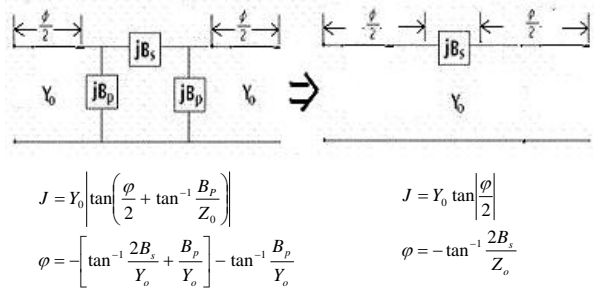


Fig. 2b. Schematic diagram of practical admittance inverter

In step by step procedure in filter design, a WR-90 waveguide (0.9 inches×0.4 inches) is selected as a primary frame for waveguide filter.

$$\lambda_g = \frac{1}{\sqrt{(0.08472 f)^2 - \left(\frac{1}{2a}\right)^2}} \tag{1}$$

Where a is the waveguide input port length and f is the frequency in GHz.

$$\lambda_{g1} = 2.0124 \text{ inches}$$

$$\lambda_{g2} = 1.8301 \text{ inches}$$

Where λ_{g1} and λ_{g2} are the guide wavelengths at two band edges. With respect to chebyshev filter design equations the orders of filter have obtained to $n=7$ and the lumped elements prototype for equivalent low pass filter is shown in Figure.3.

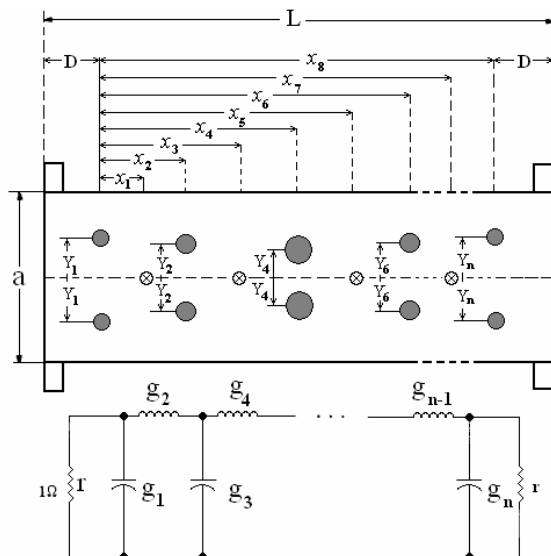


Fig.3. Schematic of equivalence low-pass prototype

Thus, the elements of odd order, i.e., g_1, g_3, \dots are shunt capacitances and their values given by the formulas are in Farad, while the elements of even order g_2, g_4, \dots are series inductances and are in Henry. For $\omega'_1 = 1$ we can get:

$$\frac{K_{01}}{Z_o} = \frac{K_{78}}{Z_o} = \frac{\sqrt{\pi} w_\lambda}{2 g_o g_1 \omega'_1} = 0.3296$$

$$\frac{K_{12}}{Z_o} = \frac{K_{67}}{Z_o} = \frac{\pi w_\lambda}{2 \omega'_1 \sqrt{g_1 g_2}} = 0.1084$$

$$\frac{K_{23}}{Z_o} = \frac{K_{56}}{Z_o} = \frac{\pi w_\lambda}{2 \omega'_1 \sqrt{g_1 g_2}} = 0.0842$$

$$\frac{K_{34}}{Z_o} = \frac{K_{45}}{Z_o} = \frac{\pi w_\lambda}{2 \omega'_1 \sqrt{g_1 g_2}} = 0.0807$$

And:

$$\frac{X_{j,j+1}}{Z_o} = \frac{\frac{K_{j,j+1}}{Z_o}}{1 - \left(\frac{K_{j,j+1}}{Z_o}\right)^2}$$

$$\frac{X_{01}}{Z_o} = \frac{X_{78}}{Z_o} = 0.3698$$

$$\frac{X_{12}}{Z_o} = \frac{X_{67}}{Z_o} = 0.1097$$

$$\frac{X_{23}}{Z_o} = \frac{X_{56}}{Z_o} = 0.0848$$

$$\frac{X_{34}}{Z_o} = \frac{X_{45}}{Z_o} = 0.0812$$

$$\frac{X_{01}}{Z_o} \frac{\lambda_{go}}{a} = \frac{X_{78}}{Z_o} \frac{\lambda_{go}}{a} = 0.7893$$

$$\frac{X_{12}}{Z_o} \frac{\lambda_{go}}{a} = \frac{X_{67}}{Z_o} \frac{\lambda_{go}}{a} = 0.2342$$

$$\frac{X_{23}}{Z_o} \frac{\lambda_{go}}{a} = \frac{X_{56}}{Z_o} \frac{\lambda_{go}}{a} = 0.1810$$

$$\frac{X_{34}}{Z_o} \frac{\lambda_{go}}{a} = \frac{X_{45}}{Z_o} \frac{\lambda_{go}}{a} = 0.1734$$

Where d is the diameter and a is the waveguide input port length. The electrical and physical lengths respects to proportional impedances values are given:

$$\theta_j = \pi - \frac{1}{2} \left[\tan^{-1} \frac{2 X_{j-1,j}}{Z_o} + \tan^{-1} \frac{2 X_{j,j+1}}{Z_o} \right]$$

$$\theta_1 = \theta_7 = 2.7152 \text{ radians}$$

$$\theta_2 = \theta_6 = 2.9496 \text{ radians}$$

$$\theta_3 = \theta_5 = 2.9771 \text{ radians}$$

$$\theta_4 = 2.9806 \text{ radians}$$

And hence, the distances between each pairs of posts can be obtained as:

$$l_1 = l_7 = \frac{\theta_1 \lambda_{go}}{2 \pi} = .8303 \text{ inches}$$

$$l_2 = l_6 = \frac{\theta_2 \lambda_{go}}{2 \pi} = .9019 \text{ inches}$$

$$l_3 = l_5 = \frac{\theta_3 \lambda_{go}}{2 \pi} = .9103 \text{ inches}$$

$$l_4 = .9114 \text{ inches}$$

Note that the posts' diameters must be added to respected values.

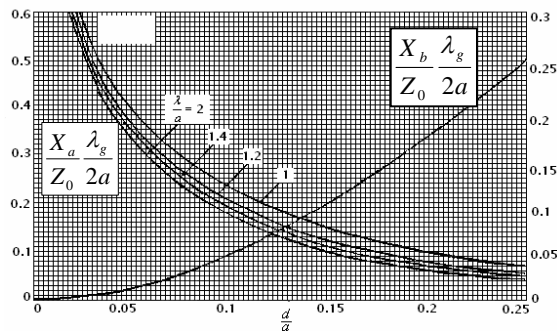
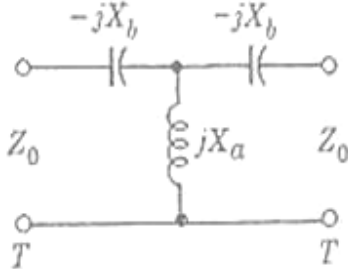


Fig.4. Impedance to post diameter ratio. The left vertical axis is $\frac{X_a \lambda_g}{Z_0 2a}$ and the right vertical axis is related to $\frac{X_b \lambda_g}{Z_0 2a}$.

It is clear from Fig.4 [7] that only first post diameter satisfies the $d \leq 0.15a$ and we have to use only dual posts in waveguide. Hence, with the use of curves that have been calculated for dual posts in waveguide cross sections (with HFSS software) one can determine the d/a and x/a ratios. One of such curves is depicted in Fig.5. In this figure the normalized suseptance of a post doublet structure with post's radius of 0.0315 inches in a WR90 waveguide has been shown. The suseptance has been calculated in two ways: firstly, by solving the achieved series for suseptance [8], and secondly, by numerical FEM method that HFSS software uses. The results are acceptable. It should be noted that this analysis has only been made for validation check of what presented in [8]. So for other diameters and distances we only use the curves presented in [8].

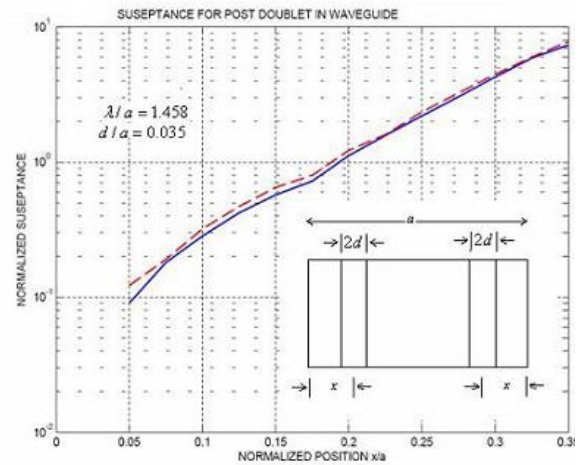


Fig.5. Suseptance for post doublet in WR90 waveguide. $d=0.0315$ inches and $a=0.9$ inches.

- - - series solving [8]
- FEM method(Ansoft_HFSS)

From Fig.5 one can achieve following results for our design:

$$\frac{X_{01}}{Z_o} = \frac{X_{78}}{Z_o} = 0.3698 \rightarrow \frac{d}{a} = 0.0444 \rightarrow \frac{x}{a} = 0.2713$$

$$\frac{X_{12}}{Z_o} = \frac{X_{67}}{Z_o} = 0.1097 \rightarrow \frac{d}{a} = 0.069 \rightarrow \frac{x}{a} = 0.3575$$

$$\frac{X_{23}}{Z_o} = \frac{X_{56}}{Z_o} = 0.0848 \rightarrow \frac{d}{a} = 0.085 \rightarrow \frac{x}{a} = 0.3725$$

$$\frac{X_{34}}{Z_o} = \frac{X_{45}}{Z_o} = 0.0812 \rightarrow \frac{d}{a} = 0.0860 \rightarrow \frac{x}{a} = 0.3738$$

IV. RESULTS

The fabricated filter based on dual post waveguide bandpass filter is shown in Fig.6.



Fig.6. Fabricated waveguide bandpass filter with dual post obstacle

Final Geometry and designed values for posts diameters, positions and separations are shown in Fig.7. These values have used in simulation. It is clear that because of practical limitations, these values can not be used in practice, so some deviation from simulation and manufactured results is occurred.

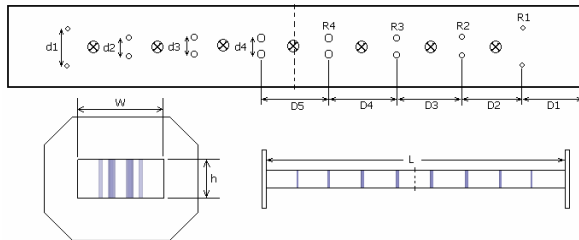


Fig.7. the geometry of waveguide filter with 8 rows of dual post with $d_1=10.4562\text{mm}$, $d_2=6.5151\text{mm}$, $d_3=5.8293\text{mm}$, $d_4=5.7699\text{mm}$, $R_1=0.507\text{mm}$, $R_2=0.7887\text{mm}$, $R_3=.9716\text{mm}$, $R_4=.983\text{mm}$, $D_1=24.4005\text{mm}$, $D_2=21.0896\text{mm}$, $D_3=22.9083\text{mm}$, $D_4=23.1216\text{mm}$, $D_5=23.1496\text{mm}$, $W=22.86\text{mm}$, $h=10.16\text{mm}$, $L=206.1896\text{mm}$

The measured and simulated results of the fabricated filter are shown in Fig.8. The return loss results are presented in Fig.9.

As can be seen there are excellent agreement between measured and simulation. Actually there is a negligible shift between simulated and measured results that can be calculated to have a good design.

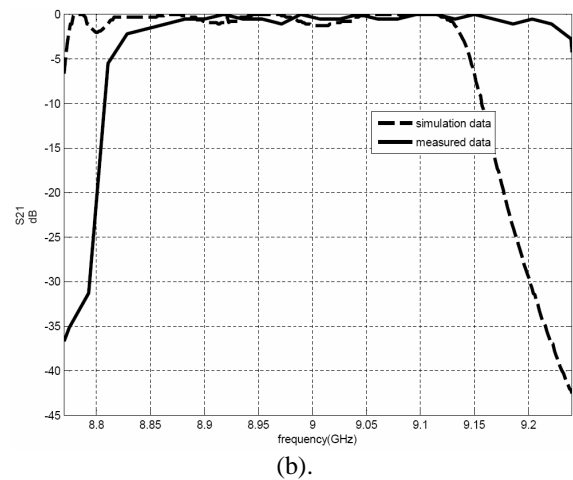
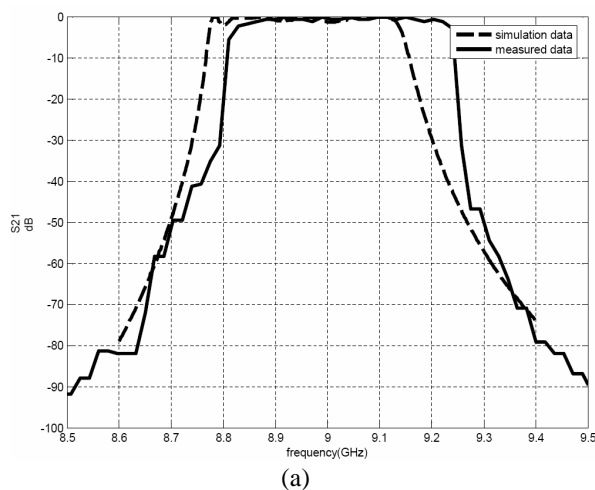


Fig.8. Insertion loss (measured (—), simulation (---))

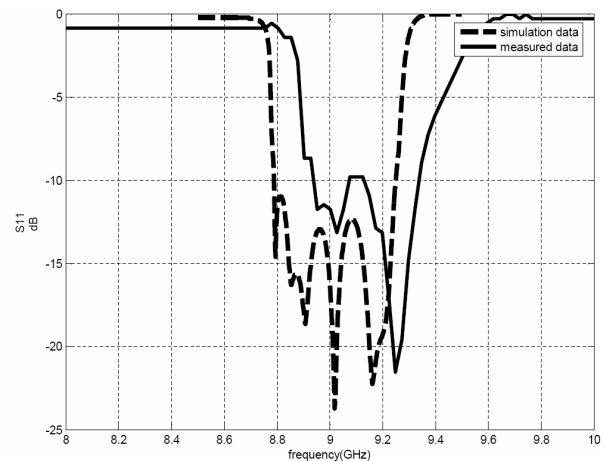


Fig.9. Return loss (measured (—), simulation (---))

IV. SENSITIVITY ANALYSIS

Figure 10, 11, 12 and 13 show the sensitivity analysis of the filter with radius variation of post and distance variation of the two adjacent posts. We achieve these results by changing the post diameters and distance between two adjacent posts. Our design is a filter by eight of pair posts that the diameters and distances are symmetric around the waveguide length cross section, so we have changed these two parameters (diameter and distance between two adjacent posts) for two pairs simultaneously (Fig.7).

In Figures (10-13), by number of posts, we mean the first, second, third and fourth post pairs along



the waveguide from terminals to center, respectively.

Fig.10 shows that the fractional bandwidth will generally be decreased, and variations in posts' radius that are closer to the center of waveguide would affect more, and Fig.11 shows the passband ripple will be enhanced with posts diameters' variations and those are closer to terminals affect more.

From Figure 12 and 13 it could be seen that there is a little bandwidth enhancement until there is a lot variations in distances between posts, but in any way, the ripples are increased.

In general, one can realize that the passband ripple is more sensitive than fractional bandwidth with diameters and distances variations. We should note that by variation of the posts' diameters there is a shift in center frequency.

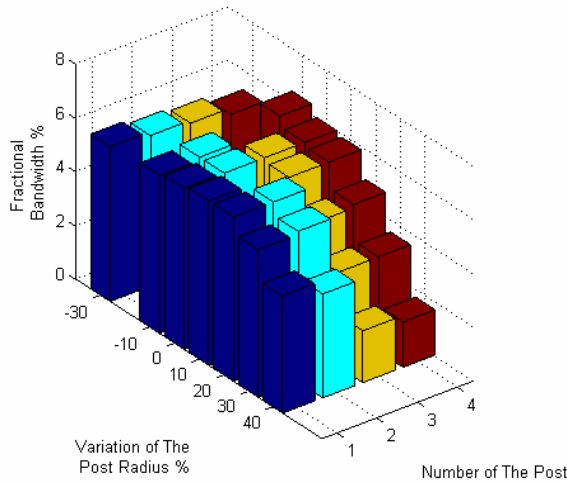


Fig.10. Sensitivity analysis of the fractional bandwidth vs. variation of the post radius

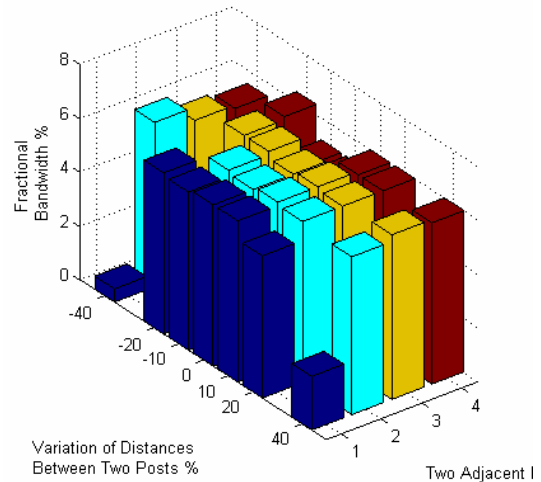


Fig.12. Sensitivity analysis of the fractional bandwidth vs. variation of the distance between two adjacent posts

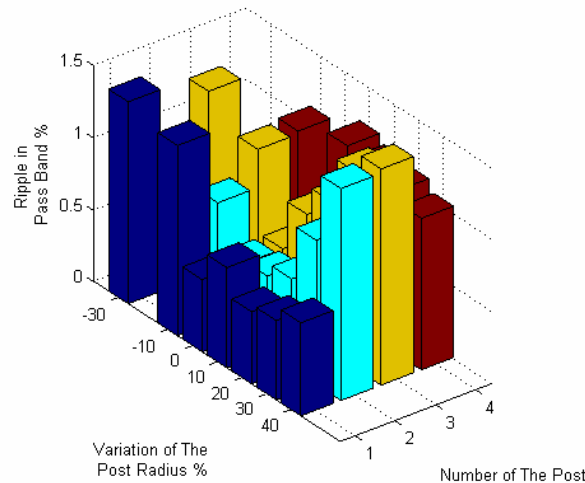


Fig.11. Sensitivity analysis of the ripple in pass band vs. variation of the post radius

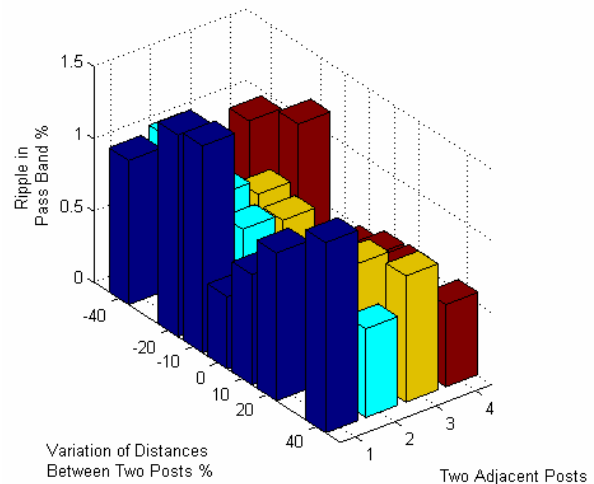


Fig. 13. Sensitivity analysis of ripple in pass band vs. variation of the distance between two adjacent posts



V. CONCLUSION

In this paper sensitivity analysis and design method for a wideband waveguide bandpass filter with dual posts is presented.

The measured and simulated results of the fabricated filter have shown and as can be seen there are excellent agreement between measured and simulated results.

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