Design and Fabrication of Microwave Waveguide Resonator: With Improved Frequency Response

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Abstract

Designing techniques of resonator using the non-planner model that is most preferable among all present for low-cost mass production of microwave and millimetre wave circuits and systems. This paper basically concerned with the improvement characteristics of post coupled designs that have been modelled and it demonstrates the approach to overcome the limitation inherent in hairpin as well as suppression of the odd harmonic which is prominent in the micro strip coupled filter and resonator topology. This has been achieved using the design concept of finite conductive post coupled obstacles into the perfect impedance match rectangular waveguide up to intrinsic impedance 376 ohm. The modified topologies of the post coupled along with the concept of reduced insertion loss and better return loss with improved quality factor has been achieved. Furthermore, presented structures results are sensitive to standard design equations and dimensions of the elements used.

Introduction

Now a day, a resonator having multiple resonances with high selectiveness and low internal losses in pass band is required in most of the communication applications, especially for satellite communication and RADAR system [1, 2]. Substrate integrated waveguide (SIW) extensively used due to the high-power handling capacity compare to patch type in operative circuits (because patch can't handle large power) [3, 4, 5]. Rectangular waveguide has been one of the best candidates to design a high Q and large power handling component in microwave and millimeter wave systems during decades. In this paper dual and multiple posts waveguide resonator design process and simulated data at X- band are presented [7]. Initially we begin with a brief analysis of single post obstacles coupled in rectangular waveguide using moment method solution suggested by PING GUAN LI in section-I [9] and a detailed analysis of rectangular waveguide, in section II and continue in section III by presenting the design process of post coupled waveguide resonator and the finally the physical parameters for implementing the filter are tabled. In section IV we consider the design parameters related post. Also the simulation results are included in section V. In section VI, transformation of post coupled waveguide resonator to large bandwidth bandpass filter is explained using the dual post concept. Here we compare the specification of the resonator in terms of insertion loss, return loss, VSWR (voltage standing wave ratio) and bandwidth for improving performance in microwave application. The proposed designed resonator is simulated in High frequency structure simulator (HFSS) software version. 11.0.

The cylindrical post in a rectangular waveguide was first treated by the well-known and widely referenced various method of Schwinger and supported by Matthaei [8] and the result is given in Marcuvitz's waveguide handbook [9]. If a short circuit is placed at any transverse plane in rectangular waveguide it will result in a complete standing wave pattern of the fields. At the short there will be a voltage minimum and this minimum is repeated at half guide wavelength intervals from the short circuit. If a short circuit is now placed at one of the voltage minima, there will be complete reflection back towards the first short and in phase with the original signal. The resulting configuration is a rectangular cavity or resonator that can support a signal which apparently bounces back and forth between two opposite walls; Figure 1 shows the geometry and a cylindrical coordinate system centered at the post axis. A dominant mode is incident upon the post which is assumed to be a perfect. The post current thus may be represented in terms of Fourier series. Schwinger had taken into account the zeroth and first order terms of the series in his variation solution avoiding higher order terms and derived unknown coefficients. The results were sensible to posts which were moderate inside (taking arbitrary shape), distant from each other and from the waveguide walls (symmetry or asymmetry post) but very accurate within those limitation results were useful in the design of microwave post filters [10, 11, 12, 13].

A Single Post Obstacle into waveguide

In figure 1 show a circular post in a rectangular waveguide, this made up of copper having a finite conductivity. A dominant mode travelling in the z-direction is incident upon the post. A cylindrical coordinate system is centered on the post axis at z=0, y=c [10]. Now the incident electric field I may be expressed as follows

Figure 1. Post coupled rectangular waveguide.

Theory and Design

In rectangular waveguide, the first and foremost criterion is selecting the length of the waveguide. For deciding the length of the waveguide, two conditions are to be taken into consideration:

1. The electric field must be highest at both the end of the waveguide (shown in figure 2, it should be linear and periodic).

2. At the center point of the waveguide, where the middle post is kept, the electric field must be highest for the good coupling (Mode TE10) [7,14, 15].

$$d = \frac{l}{2}\sqrt{\frac{1}{\left(\frac{f}{c}\right)^2 - \left(\frac{n}{2a}\right)^2 - \left(\frac{m}{2b}\right)^2}}$$

Where f stands the frequency of the wave, c is the velocity of light in vacuum (= 3 x 1011 mm/Sec), the l, m and n are number of electromagnetic cycles transmitting through waveguide generally even (here, we take l=8 so that we get higher numbers of mode interaction in compromise with increasing distance end to end), mode index in E- plane and mode index in H-plane respectively [16, 17]. 'a' and 'b' are width (22.86mm) and height (10.16mm) of the waveguide.

Calculating length from the equation (9) and sufficing above two conditions the length of the waveguide came out to be 132.23mm (4λg).

Post Designs

Rectangular waveguide act as a high pass filter. If we introduce posts inside it, the structure react as a band pass filter. Now dimensions of the posts are to be decided depending upon its behavior [8, 9, 18, 19]. Posts and Screws made of conductive material can be used for impedance-changing devices in waveguide. Figure 3 illustrates two basic methods of using posts and screws. A post or screw, which only partially penetrates into the waveguide, acts as a shunt capacitive reactance. When the post or screw extends completely through the waveguide, making contact with the top and bottom walls, it acts as an inductive reactance. Note that when screws are used the amount of reactance can be varied.Where $\lambda 0$ is c/fc (= 26.79mm) for fc is equal to11.2GHz. λc is equal to 2a(= 45.72mm). These values of $\lambda 0$ and λc give the value of λg that is 33.05 mm. varying the distance between two posts either resulted in dual bands or very low return loss. The specifications are tabulated in table-1 for dual band response. And corresponds wired structural model is given in figure 4. Further modification in dual post is given in figure 5a , 5b and 5c, which shows 4 , 8 and modified 4 posts coupled rectangular waveguide resonator. We have also carried out simulations for the resonator with four and eight post respectively (2 post coupled waveguide resonator have been fabricated and tested on VNA (Vector network Analyzer).

Length of waveguide	**Width of Waveguide**	**Height of waveguide**	**Diameter of post 1**
132.23mm	22.86mm	10.16mm	3.313mm
Diameter of post 2	**Distance of 1st post from source**	**Distance of 2nd post from source**	**Height of the post**
3.313mm	76.2mm	101.818mm	5.16mm

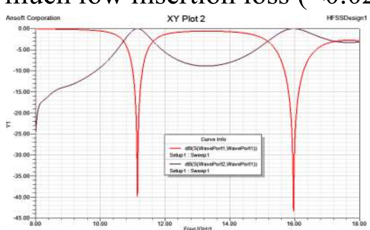
ANSOFT-HFSS is quite accurate simulating software. This software helps in optimization (using quasi newton based techniques) of various specifications, Resonator dimensions and obtaining S-parameters in Figure 4 shows the finalized design and the simulated results. In first design, two posts of diameter 3.313mm ($0.1\lambda g$) and height of 5.16mm were kept at 76.2mm and 101.818mm respectively from the input end of the waveguide and generating capacitive effects(Dimensions of posts are finalized keeping d/a<0.25,where d=diameter of the post and a=width of rectangular waveguide and above which dispersion is increased).

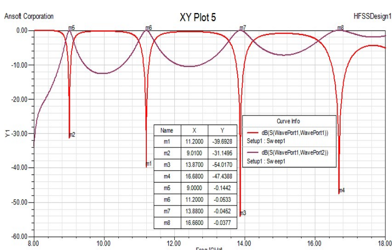
Varying diameter and height of posts (in terms of capacitance), finalized design for getting superior results. The simulated result is shown in figure 6 which gives dual band (X-band and Ku band) resonator with peak at 11.20GHz and 16.02GHz frequency, insertion loss -0.06dB, return loss -40.02dB and VSWR is 1.02 and its electromagnetic field distributions for TE10 mode are given in Figure 6b. If we increase the distance between the two posts while keeping length of waveguide constant, the resonance frequency will be changed and if we decrease the distance between the posts we got the only single resonant frequency at X-band and insertion loss will be increased.

In 2nd proposed design instead of taking two post if take four post and keep posts(modified impedance) as shown in figure 5a then we get dual band and dual frequency , dual band with multi frequencies (increases distance between posts gives opportunity for higher order mode interaction) of resonator filter with narrow bandwidth and improved scattering parameters which is given in figure 7and varying distance between

the posts the resonator frequencies will be changed. It also give better quality factor and low insertion loss compare to two post result in compromise with decreasing bandwidth. The pose of posts and results are tabulated in table-2 (keeping diameter and height remains same as two post design). In 3rd proposed design, modified pose of 4 posts, arrange them as shown in figure 5b (modified impedance structure in terms of mutual coupling). The posts dimensions, position and resonant frequencies are tabulated in table 3. Due to mutual coupling between the posts it will give more resonant frequencies compare to above one design, its Electromagnetic field distribution is shown in figure 8a and simulation result is shown in figure 8b.

Now in 4th proposed design, if we take eight posts and keep at as shown figure 5c then simulated in HFSS so it gives Electromagnetic field distribution as shown in figure 9a and simulation result as shown in figure 9b, the result gives multiband multi resonance frequencies (X, Ku and Ka band) response, more and more narrow bandwidth, high q-factor (it is more than 300 due to waveguide structure) and too much low insertion loss (<0.02dB). It gives





excellent response compare to 4 post coupled waveguide resonator and having superior return loss and high-quality factor as shown figure. It is due to the fact that increase number of post and distance between the post results becomes the higher number of modes are interacting with each other (due to shorter wavelength) and gives a higher number of frequencies resonant. The pose of posts and results are tabulated in table-4

Conclusion

The design of the post-coupled microwave waveguide resonator is such that the mechanical fabrication is feasible in Workshop for industrial and organization application. It gives quite accurate and even better results than the required specifications and also further modification gives a dual band Dual frequency and dual band multi frequencies with narrow bandwidth and improved scattering parameters. It is also possible that scaling of this design will give band pass filter for various bands. It will provide a Q - factor is more than 300 which is better for frequency separation and also gives low insertion loss which is less than 0. 05dB.This type of resonator is capable of handling high power at the cost of larger size compare to planner resonator. In the existing Resonator if we applying layers of gold or silver, which has higher conductivity than copper, can reduce the losses. Moreover, such post-coupled resonators result in lower attenuation compared to iris-coupled filters and hence certain modifications like square shaped posts or flat posts can be tried out for superior results.

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