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Abstract— The filter described in this paper is composed of rectangular irises of finite thickness as a junction between cylindrical cavities. Mode Matching Method (MMM) has been used to analyze the discontinuities present in the filter and obtain the performance of the filter. The filter has been further optimized to obtain the desired performance.

1. INTRODUCTION

Filters in rectangular and circular waveguides can be designed based on equivalent network theory approach using closed form approximation for susceptance of the apertures [1–3]. Mode matching method to design waveguide filters is a preferred option as accurate design for the desired performance is easily obtained using this approach. A circular waveguide coupled cavity filter with input and output guides that are circular and resonant irises that are also circular has been presented in [4]. This paper presents the design of rectangular irises as coupling elements between cylindrical cavities. The input and output to the filter are rectangular waveguides.

2. THEORY

The input and output to the filter are rectangular waveguides as shown in Figure 1. The irises that couple the input and output rectangular waveguides and the cylindrical cavities are rectangular irises of finite thickness as shown in Figure 2. The axes of all the irises in the filter are concentric with that of the input and output guides. The filter presented here is composed of discontinuities that are from smaller rectangular to larger circular waveguide and, larger rectangular to smaller rectangular waveguide or vice-versa.

The first discontinuity in the filter is from a larger rectangular waveguide to a smaller rectangular waveguide which forms the first iris. This type of discontinuity is easily analyzed using mode matching method. The fields in the rectangular waveguide of this discontinuity are expressed in terms of the fundamental and higher order TE and TM modes of incident and reflected waves with unknown coefficients. The magnitude of power carried by each of these modes is set to unity. The continuity conditions for the tangential components of electric and magnetic fields are imposed at the interface of the discontinuity. Using the principle of orthogonality of modes, the equations of continuity conditions are transformed into matrices relating the unknown coefficients of incident and reflected waves at the discontinuity. The matrices are rearranged and inverted suitably to obtain the generalized scattering matrix which describes the discontinuity in terms of the dominant and higher order modes. Theoretically the generalized scattering matrix is of infinite dimension corresponding to the infinite number of modes. The matrix is truncated to a finite size for numerical computations after testing the convergence of the S-parameters. The method of the analysis for such a discontinuity is available in [5] and a program has been written for the analysis of this discontinuity in the filter.

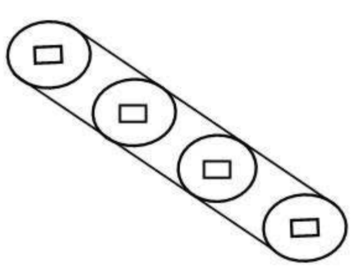

Figure 1: Filter structure — Longitudinal configuration.

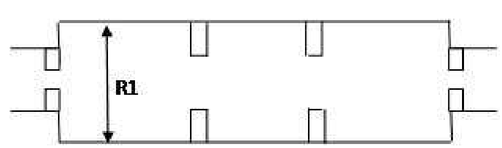

Figure 2: Filter structure showing irises of finite thicknesses.

The next discontinuity in the filter is from the smaller rectangular waveguide to a larger circular waveguide which forms the cylindrical cavity. Mode matching method begins with writing the potential functions on both the sides of the discontinuity. In the circular waveguide the potential functions ψ^h and ψ^e for TE and TM modes are written as,

$$\begin{aligned}\psi^h(\rho,\varphi) &= P_{n,m}J(k^h_{cn,m}\rho)\sin n\varphi\\ \psi^e(\rho,\varphi) &= P_{n,m}J(k^e_{cn,m}\rho)\cos n\varphi\end{aligned}$$

The coefficients P in the above equations are the power normalization constants that set the power carried in each of the modes to a watt. The cutoff wave numbers of the TE_{nm} and TM_{nm} modes are $k^h_{cn,m}$ and $k^e_{cn,m}$.

The potential functions in the rectangular waveguide for TE and TM modes are as follows:

$$\begin{aligned}\Psi^{(h)}_{(m,n)}(x,y) &= T^h_{m,n}\cos(k_{xm}x)\cos(k_{yn}y)\\ \Psi^{(e)}_{(p,q)}(x,y) &= T^e_{p,q}\sin(k_{xp}x)\sin(k_{yq}y)\end{aligned}$$

where, $k_{xm} = m\pi/a$, $k_{yn} = n\pi/b$, $k_{xp} = p\pi/a$ and $k_{yq} = q\pi/b$ are the cut of wave numbers in the rectangular waveguide with dimension of sides being a and b. The values of m and n in the potentials functions correspond to that of various modes. The electric and magnetic field of Transverse Electric (TE) and Transverse Magnetic (TM) for various modes in the region are obtained from these functions.

The discontinuity is symmetric as the longitudinal axes of all the guides are concentric. Due to symmetry it is sufficient to consider only modes that have m and p odd and n and q even for dominant mode namely TE_{10} excitation in the rectangular waveguide. This means that modes that form magnetic wall along y-axis and electric wall along x-axis are alone considered in the analysis.

The symmetry condition in the circular waveguide translate into choosing waveguide modes that have n values that are odd starting from 1 and continuous values of m starting from 1 in determining the values of $k^h_{cn,m}$ and $k^e_{cn,m}$.

The next step in MMM involves writing the continuity condition for the electric and magnetic fields at the interface of the discontinuity. The electric and magnetic fields in circular waveguide are a function of Bessel function in the radial direction and sinusoidal in the angular direction while those in the rectangular waveguide are in Cartesian co-ordinate system. Matching of the fields is done in Cartesian co-ordinate system as the iris is rectangular. In order to transform the continuity condition into linear algebraic equations using the principle of orthogonality of modes, the fields in the circular waveguide are converted as a sum of complex exponential in x and y co-ordinates

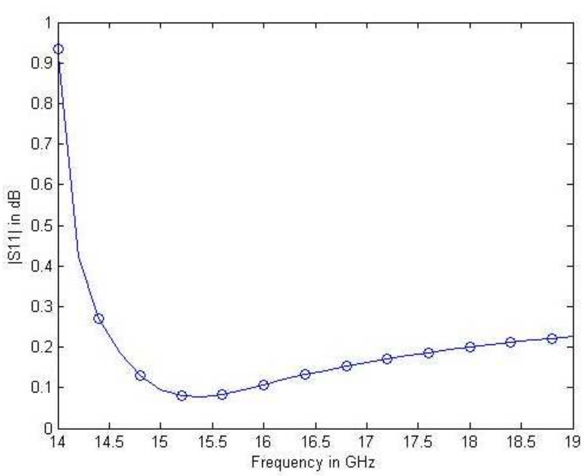

Figure 3: Magnitude of reflection coefficient from rectangular waveguide 10.7 mm × 4.32 mm to a rectangular waveguide of dimension 15.8 mm × 7.9 mm — computed, o [5].

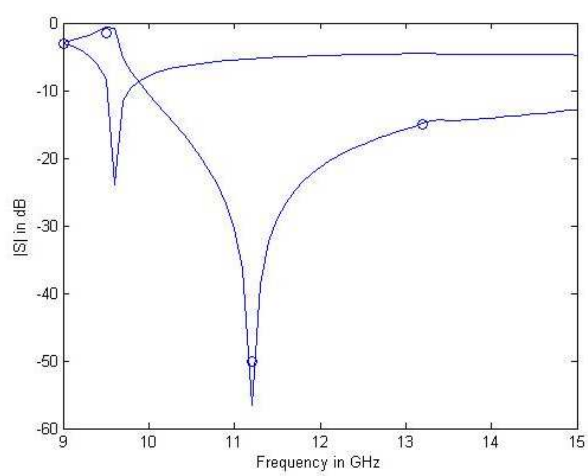

Figure 4: Magnitude of S parameters from WR75 rectangular to circular waveguide with $a = 2b = 0.75''$ = radius of circular waveguide — computed, o [6].

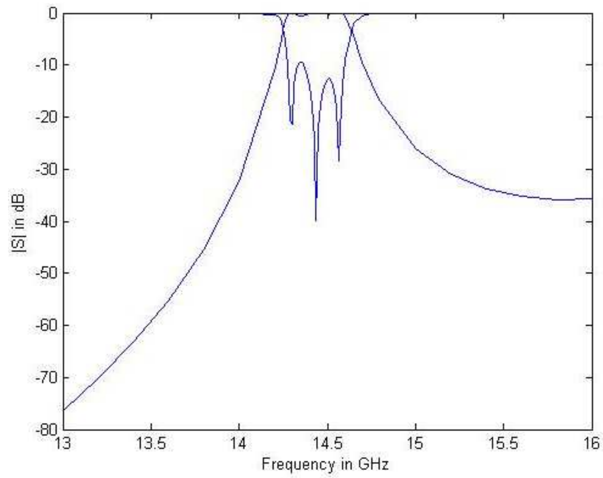

Figure 5: Response of the filter. Input and output rectangular waveguide of dimension 1.58×0.79 cm, Cavity radius = 0.6985 cm, Iris thickness = 0.127 mm, cavity lengths = 1.91, 1.97, 1.91 cm.

using the equations described in the appendix of [6] and given as,

$$J_q(h\rho)e^{jq\varphi} \cong \frac{j^q}{N}\sum_{l=0}^{N-1} e^{j\frac{2lq\pi}{N}} e^{-jh(C_l x+S_l y)}$$

where, $x = \rho\cos\varphi$, $y = \rho\sin\varphi$, $C_l = \cos(\frac{2l\pi}{N}), S_l = \sin(\frac{2l\pi}{N})$ and $N-1 > h\rho + M$, with M being a small integer. Using these equations the fields in circular waveguide which are expressed in cylindrical co-ordinate system are transformed to Cartesian co-ordinate system.

The linear algebraic equations obtained by application of principle of orthogonality are rearranged and manipulated to obtain the generalized scattering matrix of the discontinuity. The generalized scattering matrices of all the discontinuities in the filter are cascaded to obtain the characteristic of the filter. Sufficient higher order modes have been used in the analysis of the discontinuity by testing for convergence of the scattering parameters. The filter has been designed and optimized using a practical quasi-Newton algorithm as described in [7] to obtain the desired performance.

3. RESULTS

The discontinuity from a larger rectangular waveguide to smaller rectangular waveguide was analyzed with 40 TE and TM in larger waveguide. The ratio of the modes from larger to smaller guide was set close to the ratio of the dimensions of the two guides. Convergence of the S-parameters has been observed and the results have been verified with [5] as shown in Figure 3. The analysis of a smaller rectangular to larger circular guide was also performed and a good agreement has been found with [6] as shown in Figure 4. A filter using cylindrical cavities and rectangular coupling irises of finite thickness has been analyzed, designed and optimized further for the desired specifications. The performance and the dimension of the filter are as shown in Figure 5. In comparison to the filter with circular irises as presented in [4] this filter offers improved stop band performance.

4. CONCLUSIONS

The Mode Matching Method has been used for the analysis and design of circular waveguide filters with rectangular irises. The design has been optimized in order to obtaining the desired performance. However further optimization may be necessary to improve the performance to obtain a return loss better than 20 dB.

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