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MULTIPLE CAVITY MODELING OF A FEED NETWORK FOR TWO DIMENSIONAL PHASED ARRAY APPLICATION

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Abstract—In this paper a method of moment based analysis of an H-plane 1:3 power divider has been presented using Multi Cavity Modeling Technique (MCMT) in transmitting mode. Finally attempt has been made to improve the frequency response characteristic of the above mentioned waveguide circuit using a sorting post to diversify the power equally in all the ports. Codes have been written for analyzing the frequency response characteristic of the structure, mentioned above. Numerical data have been compared with the data obtained with laboratory measurement, and CST Microwave Studio simulation. In the present analysis global basis function has been used. The existence of cross polarization components of the field inside the waveguide structures if exists, have also been considered to obtain an accurate result. The proposed power divider has good agreement with the theoretical; CST microwave studio simulated data and measured data. The power divider can be used in the input at 9.8 GHz frequency band, over 800 MHz.

1. INTRODUCTION

Modern RADAR systems employ a number of waveguide components and circuit elements, which are commonly used, can be classified as matching networks and beam forming networks. Multi-port Power divider has already found wide applications in l phased array techniques. Basic requirements for the considered class of beam forming networks are, low losses in the operational frequency band, the high accuracy of power splitting (With necessary amplitude and phase distribution at the outputs). Today, a large number of configurations and power divider constructions are known [1–4]. However the problems of theoretical analysis of high quality power divider remain unsolved. Effort has been made to miniaturize (dimensionally) a 1:2 power divider [7] with wide band frequency response.

Present work was performed for analysis of a 1:3 power divider for phased array application using Multi Cavity Modeling Technique (MCMT) [5]. The technique involves in replacing all the apertures and discontinuities of the waveguide structures, with equivalent magnetic current densities so that the given structure can be analyzed using only Magnetic Field Integral Equation (MFIE). To make the MFIE applicable to the generalized waveguide structures problem, the given structure is modeled using rectangular cavities. As a result, it is necessary to use a number of such cavities in order to study this complicated structure. The major reason for using the MCMT for analyzing this problem is the fact that the structure is of rectangular in nature and hence it becomes possible to model the structure using rectangular cavities. Since only the magnetic currents, present in the apertures, are considered the methodology involves only solving simple magnetic integral equation rather than the complex integral equation involving both the electric and magnetic current densities.

2. PROBLEM FORMULATION

The diagram of a basic H-plane 1:3 power divider is shown in Fig. 1 and with its cavity modeling and details of region in Fig. 2 which shows that the structure has 4 waveguide region and 4 cavity region. The interfacing apertures between different regions are replaced by equivalent magnetic current densities.

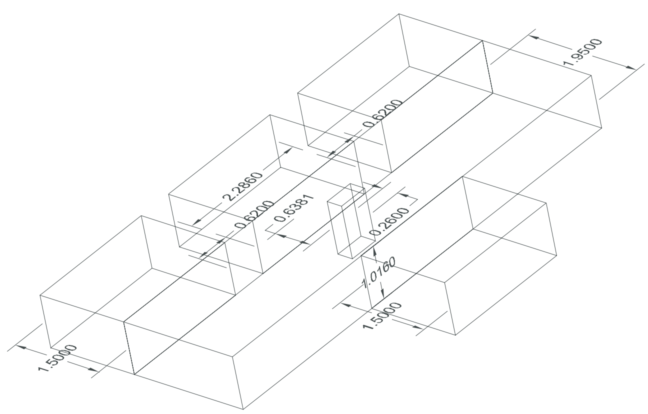

Figure 1. Three dimensional view of an H-plane 1:3 power divider, all dimensions are in cm.

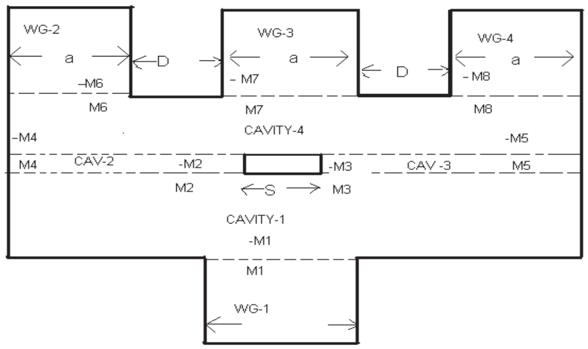

Figure 2. Cavity modeling and details of a basic 1:3 power divider.

The magnetic field scattered inside the cavity region due to this source is determined by using cavity Green's function of the electric vector potential. The cavity Green's function has been derived by solving the Helmholtz equation for the electric vector potential for unit magnetic current source. The tangential components of the cavity scattered fields are derived in [5]. The final form of the tangential components of the cavity scattered field will be same as given in [6], except (a_2, b_2) will be replaced by (L_c, W_c) where L_{cj} is the length and W_{cj} is the height of jth the cavity. L_i and W_i are the half length and half width of ith aperture. The cavity magnetic field, in general form, can be written as

$$H_x^{cav^j}(M_i^x) = -\frac{j\omega\varepsilon}{k^2}\sum_{m=1}^{\infty}\sum_{n=0}^{\infty}\frac{\varepsilon_m\varepsilon_n L_i W_i}{2L_{cj}W_{cj}}\left\{k^2-\left(\frac{m\pi}{2L_c}\right)^2\right\}\sin\left\{\frac{m\pi}{2L_{cj}}(x+L_{cj})\right\}$$
$$\times\cos\left\{\frac{n\pi}{2W_{cj}}(y+W_{cj})\right\}\cos\left\{\frac{n\pi}{2W_{cj}}\,(y_w+W_{cj})\right\}\sin c\left\{\frac{n\pi}{2W_{cj}}W_i\right\}F_x(p)\times$$
$$\frac{(-1)}{\Gamma_{mn}\sin\{2\Gamma_{mn}t_c\}}\left\{\begin{array}{ll}\cos\{\Gamma_{mn}(z-t_c)\}\cos\{\Gamma_{mn}(z_0+t_c)\} & z>z_0\\ \cos\{\Gamma_{mn}(z_0-t_c)\}\cos\{\Gamma_{mn}(z+t_c)\} & z<z_0\end{array}\right.$$

While the general form of scattered field in the waveguide is given by

$$H_x^{wvg}(E_i^y) = H_x^{wvg}(M_i^x) =$$
$$-2LW\sum_m\sum_n\left\{Y_{mn}^e\left(C_{mn}^e\frac{m\pi}{2a_i}\right)^2+Y_{mn}^m\left(C_{mn}^m\frac{n\pi}{2b_i}\right)^2\right\}\times$$
$$\sin\left\{\frac{m\pi}{2a_i}(x+a_i)\right\}\cos\left\{\frac{n\pi}{2b_i}(y+b_i)\right\}\cos\left\{\frac{n\pi}{2b_i}\,(y_w+b_i)\right\}\sin c\left\{\frac{n\pi}{2b_i}W\right\}F_x(p)$$

where,

$$\begin{aligned}
C^e_{mn} &= \frac{1}{\pi}\sqrt{\frac{ab\varepsilon_m\varepsilon_n}{(mb_i)^2+(na_i)^2}}\\
C^m_{mn} &= \frac{2}{\pi}\sqrt{\frac{ab}{(mb)^2+(na)^2}}\\
Y^e_{mn} &= \frac{k_z}{\omega\mu} = \frac{k_z}{k\eta}\\
Y^m_{mn} &= \frac{\omega\varepsilon}{k_z} = \frac{k}{k_z\eta}\\
\varepsilon_i &= \begin{cases} 1, & i=0\\ 2, & i\neq 0\end{cases}
\end{aligned}$$

$$\begin{aligned}
F_x(p) = &\left[\cos\left\{\frac{\pi}{2}\left(-\frac{mx_w}{a_i}+p-m\right)\right\}\sin c\left\{\frac{\pi L}{2}\left(\frac{p}{L}-\frac{m}{a_i}\right)\right\}\right.\\
&\left.-\cos\left\{\frac{\pi}{2}\left(\frac{mx_w}{a_i}+p+m\right)\right\}\sin c\left\{\frac{\pi L}{2}\left(\frac{p}{L}+\frac{m}{a_i}\right)\right\}\right]
\end{aligned}$$

At the region of the window, the tangential component of the magnetic field in the aperture should be identical and applying the proper boundary conditions at the aperture the electric fields can be evaluated [6].

3. SOLVING FOR THE ELECTRIC FIELD

To determine the electric field distribution at the window aperture, it is necessary to determine the basis function coefficients $E_p^{i,x/y}$ at both the apertures. Since the each component of the field is described by M basis functions, $16M$ unknowns are to be determined from the boundary conditions. The Galerkin's specialization of the method of moments [9] is used to obtain $16M$-different equations from the boundary condition to enable determination of $E_p^{i,x/y}$. The weighting function $w_q^{i,x/y}(x,y,z)$ is selected to be of the same form as the basis function $e_p^{i,x/y}$. The weighting function and the moment of the field are defined as follows:

$$w_q^{i,y} = \begin{cases} \sin\left\{\dfrac{q\pi}{2L}(x-x_w+L)\right\} & \text{for } \begin{array}{c} x_w-L\le x\le x_w+L\\ y_w-W\le y\le y_w+W\end{array}\\ 0 & \text{elsewhere}\end{cases}$$

$$w_q^{i,x} = \begin{cases} \sin\left\{\dfrac{q\pi}{2W}(y - y_w + W)\right\} & \text{for } \begin{matrix} x_w - L \leq x \leq x_w + L \\ y_w - W \leq y \leq y_w + W \end{matrix} \\ 0 & \text{elsewhere} \end{cases}$$

The procedure for derivation of reflection and transmission coefficients is given in [12]. Following the same procedure the expressions for Γ and T is given by:

$$\Gamma = \frac{E_y^1 + E_y^2}{E_y^{inc}} = -1 - E_1^{1,y}$$

and

$$T_{21/31/41} = \frac{E_y^{transmitted}}{E_y^{inc}} = -E_1^{2/3/4,y}.$$

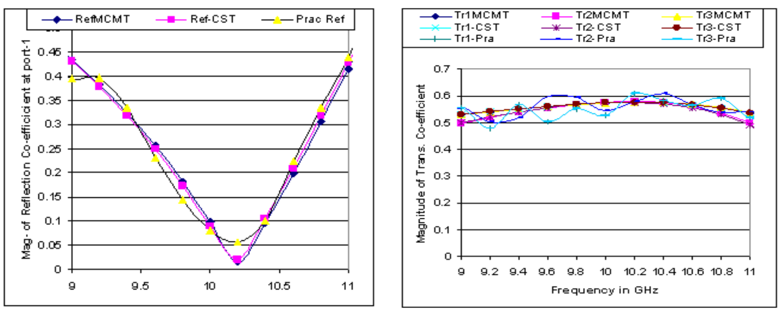

Figure 3. Comparison of theoretical, CST Microwave Studio simulated and measured data for an H-plane 1:3 WR-90 waveguide power divider with $2t = 19.5$ mm.

4. NUMERICAL RESULTS AND DISCUSSION

Theoretical data for the magnitude of scattering parameters for an H-plane 1:3 WR-90 waveguide power divider at X-band has been compared with CST Microwave Studio simulated data in Fig. 3.

The theory has been validated by the excellent agreement with the theoretical, CST Microwave Studio simulated data and Measured Data. The scattering parameters for the circuit, when excited through port-2, port-3 and port-4 have not been presented in this section because these are less important in the study of a power divider.

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