An Analysis of Wave Guide E-Plane Tee as 3dB splitter at X Band Using HFSS Software

Pampa Debnath, Snehasis Roy

Abstract— ***In this paper, HFSS simulation software has been used to design X band E-plane Tee to study the power distribution between port 1 and 2 along with distribution of electric and magnetic fields. Phase of transmission coefficient between collinear arms is observed 180 degree and the power at collinear arms reflect the nature of 3 dB splitter of E plane tee. Simulation results also show the field analysis in collinear, and side arm. The analysis is helpful for designing magic tee and waveguide components using tee structure.***

Keywords— ***HFSS, E Plane TEE, E-port, Collinear arm, Transmission coefficient, X band.***

I. INTRODUCTION

Waveguide E plane tee is an important passive element in microwave and millimeter wave engineering. Tee junctions are generally used to split the line power into two or combine the power from two lines with proper consideration of phase. However, because of the complicated structure and small size, good performance E plane tee at microwave frequencies such as at X band or higher frequencies is difficult to realize. On the other hand, a precise field analysis on waveguide E plane tee is also difficult. So proper numerical analysis of waveguide tee junctions will help to analyze the power distributions between different ports along with phase of transmission coefficient.

Several workers already made significant contributions in this field. Liu [1] made a comparative analysis of planar SIW magic tee with traditional rectangular tee. Novel four planar magic tee was proposed by You *et. al.* [2] for networking applications using waveguide side-wall slot directional coupler and a double dielectric slab filled waveguide phase shifter. The present author [3] also analyzed magic tee structure in X-band for useful practical applications, which is matched with findings of others [4]. Experimental results [5] are well fitted with the recently available numerical studies. Shen first presented the detailed analytical model [6] for tee structures using hybrid finite-element-modal-expansion method. As HFSS is an interactive software package for calculating the electromagnetic behavior of a structure, so one can compute basic electromagnetic field quantities, generalized S-parameters and S-parameters renormalized to specific port impedances, the eigenmodes, or resonances, of a structure [7]. HFSS is a high-performance full-wave electromagnetic field simulator for arbitrary 3D volumetric passive device modeling. Proper materials are always chosen prior to the simulation for future experimental works.

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Pampa Debnath is an Assistant Professor in the Department of Electronics & Communication Engineering, RCC Institute of Information Technology, Kolkata, and West Bengal, India.

Snehasis Roy is a Junior Telecom Officer in IT Project Circle of Bharat Sanchar Nigam Limited, Kolkata, and West Bengal, India.

For a linearly-polarized antenna, the plane containing electric field vector is the E-plane, and is in the direction of maximum radiation. The electric field determines the polarization or orientation of the radio wave. For a vertically-polarized antenna, the E-plane usually coincides with the vertical/elevation plane. For a horizontally-polarized antenna, the E-Plane usually coincides with the horizontal/azimuth plane.

II. DESIGN

An E plane Tee is a wave guide tee in which the axis of its side arms is parallel to the E field of the main guide. When the waves are fed into the side arm (port 3), the waves appearing at port1 and port 2 of the collinear arm will be in opposite phase and in the same magnitude [9-11]. Fig 1 shows the schematic structure of a E-plane tee. It is called an E type junction because the junction arm extends from the main waveguide in the same direction as the E field in the waveguide.

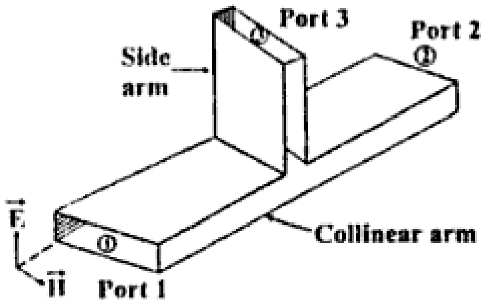

Fig: 1(a) Schematic diagram of E plane Tee

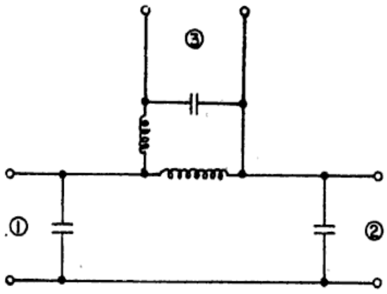

Fig: 1(b) Equivalent circuit of E plane Tee

From fig 1(a) and 1(b) it is clear that it causes load connected to its branches to appear in series. So it is often referred to as a series tee. In the design of E plane tee using HFSS software length is to be taken as 9.5 mm and width is 8 mm.

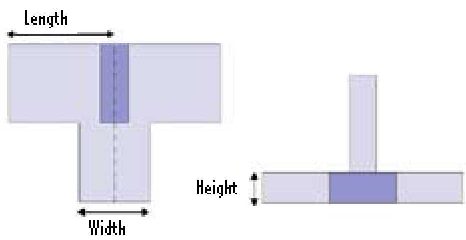

Fig:1(c) Constructional details of E plane Tee

III. NUMERICAL RESULTS

An E plane Tee in X band has been designed using HFSS software as shown in Fig. 2, in which port 2 and port 3 has been assigned to two collinear arms, whereas port 1has been assigned for side arm .

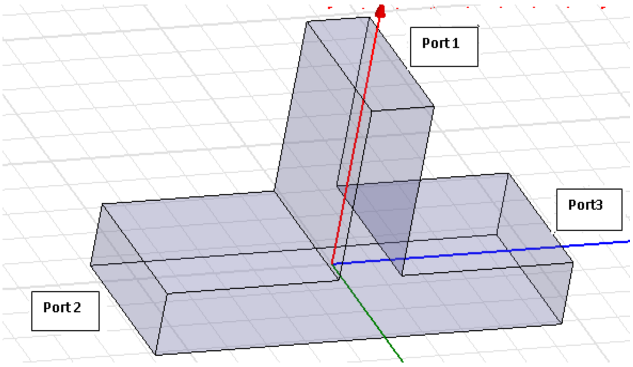

Fig 2: Schematic picture of E plane tee in simulation software

In Fig.3 and Fig. 4, it is observed that a wave incident at port 1 (E arm) divides equally between ports 2 and 3 in opposite phase. However powers fed in arms 2 and 3 are subtracted in arm 1

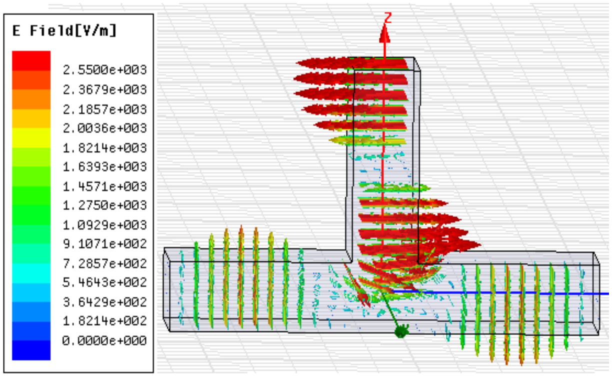

Fig 3: Electric field vector variation when signal entering at port 1

Fig 5 shows the scattering power variation between port 1, 2 and port1, 3 which shows that with variation of frequency transmitted power in port 2 and port 3 is equally distributed when power is given at port 1 whereas Fig 6 shows the phase of the transmission coefficients out the Co-linear ports. It can easily be stated from the figure that when signal entering port 1, it will equally divide and appear at port 2 and 3 with opposite phase.

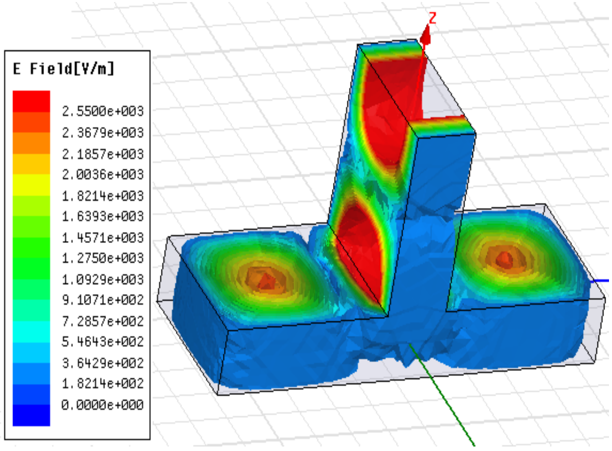

Fig4: Magnitude of field variation when signal entering at port 1

As described earlier when the waves are fed into port 1, the waves appearing at port 2 and port 3 will be in opposite phase and in the same magnitude. Therefore $S_{12}= - S_{13}$.

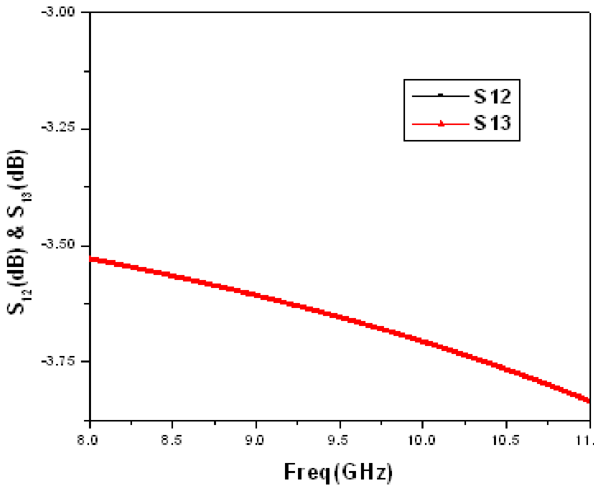

Fig5: S_{12} and S_{13}

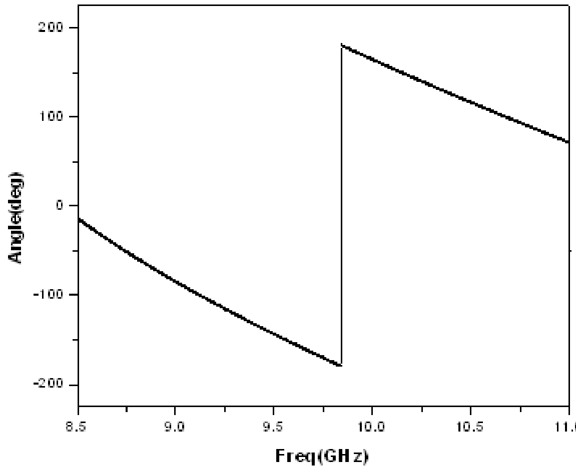

Fig 6: Phase of the transmission coefficients out the Co-linear ports

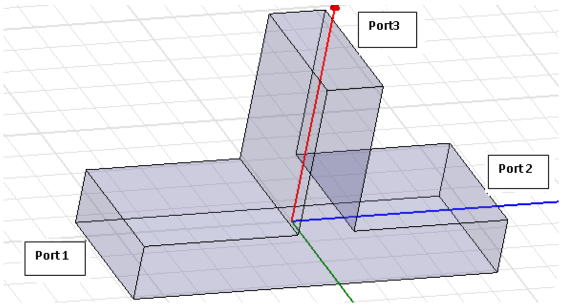

Fig 7: Port 3assigned to E arm

From the simulation results it has been observed at 9.7 GHz frequency the S matrix of E plane tee (where port 3 has been assigned to the side arm and port 1 and 2 to the collinear arms as shown in fig 7) is

$$\begin{bmatrix} S_{11} & S_{12} & S_{13} \\ S_{21} & S_{22} & S_{23} \\ S_{31} & S_{32} & S_{33} \end{bmatrix} = \begin{bmatrix} 0.14423 & 0.40836 & 0.40924 \\ 0.40836 & 0.25154 & -0.55261 \\ 0.40924 & -0.55261 & 0.05233 \end{bmatrix}$$

For S matrix, it is known that, $[b] = [s][a]$.
If $a_1 = a_2 = 0$ and $a_3 \neq 0$, then simulation gives,
$b_1 = 0.40924\, a_3$,

b_2 = -0.55261 a_3 and
b_3 = 0.05233 a_3 (indicates almost zero power)

i.e. an input at port 3, is equally divided between port 1 and 2, but introduces a phase shift of 180° between the two outputs. Hence E plane Tee acts as a 3dB splitter.

IV. CONCLUSION

Waveguide E plane tee at X band is analyzed by HFSS software. The performance of transmission coefficient is examined and the phase of transmission coefficient which is 180º opposite has been observed in this work. Transmission coefficients vs frequency has been plotted and also numerically calculated from the simulation. The S matrix calculation reflects the nature of 3 dB splitter of E plane tee. Therefore the designed E plane tee has a structure that is convenient for manufacture and its good performance can meet the requirement for designing a Magic tee for practical system such as microwave impedance bridges, antenna duplexer, balance microwave mixer and microwave antenna systems.

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Pampa Debnath received her B.Tech. Degree in Electronics & Communication Engineering from the University of Burdwan in 2004 and she recieved M.Tech. In RF & Microwave Engg. From the University of Burdwan in 2006. She is presently working as an Assistant Professor in RCC Institute of Information Technology, Kolkata. Her research interests are in Microwave Engineering, Antenna and Microcontroller.

Snehasis Roy received his B.Tech. Degree in Electronics & Instrumentation Engineering from the University of Kalyani in 2005 and he recieved M.Tech. In Instrument technology from Indian Institute of Technology, Delhi in 2009. He served as a visiting lecturer in RCC Institute of Information Technology, Kolkata. He is presently working as a Junior Telecom officer in Bharat Sanchar Nigam ltd. His research interest are in Microwave Engineering, Microcontroller and communication Engineering.