International Journal of Emerging Technology and Advanced Engineering
Website: www.ijetae.com (ISSN 2250-2459, Volume 2, Issue 5, May 2012)

An Analysis of Wave Guide Magic Tee at X Band Using HFSS

Pampa Debnath[1], Snehasis Roy[2]

[1]*Assistant Professor, RCCIIT, C.S.Road, Kolkata-700015*
[2]*Junior Telecom Officer, BSNL, Saltlake, Kolkata-700064*
[1]poonam.4feb@gmail.com
[2]snehasis@bsnl.co.in

***Abstract*— Wave guide Tee junctions are used to split the line power into two lines or combine the power from two lines with proper consideration of phase. Waveguide magic tee is an important element in microwave and millimeter wave applications. HFSS is a high-performance full-wave electromagnetic (EM) field simulator for arbitrary 3D volumetric passive device modeling. In this paper HFSS simulation software has been used to design X band Magic Tee which shows the isolation between port 1 and port 4 below -60dB and phase of transmission coefficient between collinear arms is 180 deg. Simulation results also show the field analysis in collinear arm, Harm and E arm.**

***Keywords*—Magic Tee, HFSS, 3 dB Hybrid, Coplanar Arm, E plane Tee, H plane Tee, X band.**

I. Introduction

Waveguide magic tee is an important element in microwave and millimeter wave engineering especially in monopulse antenna systems. However, because of the complicated structure and small size, good performance magic tees at microwave frequencies such as at X band or higher frequencies is very difficult to realize. On the other hand, a precise field analysis on waveguide magic tee is also difficult. 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. HFSS is a special type of software precisely designed for extracting modal parameters by simulating passive devices and also antennas having specified geometries, material properties at desired range of solution frequencies using finite element method [7]. A Hybrid Junction is a four port network in which a signal incident on any one of the ports divides between two output ports with the remaining port being isolated.

The assumption is that all output ports are terminated in a perfect match. Under these conditions, the input to any port is perfectly matched. This section describes hybrids in which the power is divided equally between the output ports. These are known as 3 dB Hybrids.

II. Analysis

One method of realizing a 3dB hybrid is to combine an E plane and H plane Tee is shown in the figure1. By virtue of the orientation of E and H arms, ports 3 and 4 are decoupled. Assuming single mode propagation, a TE_{10} wave entering the E arm cannot couple to the H arm since the electric field vector would be parallel to the broad wall of the H arm and hence below cut off. The following argument shows that if the E and H arms are matched, the four port junction forms a 3 dB hybrid, commonly known as a magic tee [4, 6]. Common arms 2 and 3 are called collinear arms side arms. The signal entering the H arm splits equally between the coplanar arms. If the lengths of the coplanar arms are equal, the output signals at port 2 and 3 are in phase. The signal entering the E arm also splits equally, but in this case the output signals at ports 2 and 3 are 180 degree out of phase [8, 9, 10, 11]. If both E and H arms are matched, the amplitude of all four output phasors is the same. Thus assuming equal line lengths, the signals add at port 4 and cancel at port 1. Since the network is reciprocal, this means that an input signal at port 1 splits equally between the E and H arms with none appearing at the other coplanar arm.

Similarly an input signal at port 2 splits equally between ports 1 and 4 with none appearing at port 3. Therefore with E and H arms matched and decoupled, the coplanar arms are also matched and decoupled. Power into any port produces an equal power split between the two output ports, which means a magic Tee is a 3 dB hybrid.

International Journal of Emerging Technology and Advanced Engineering
Website: www.ijetae.com (ISSN 2250-2459, Volume 2, Issue 5, May 2012)

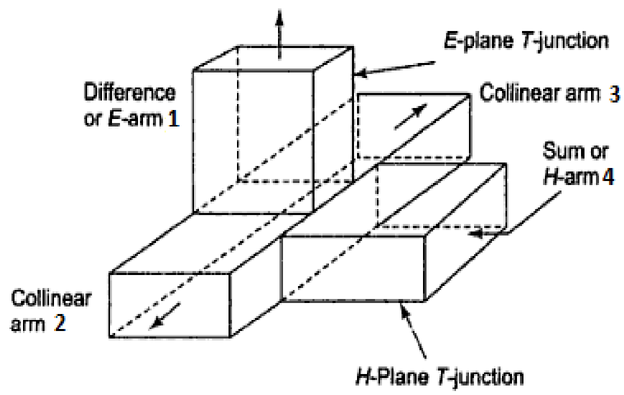

Figure 1: Schematic diagram of Magic Tee

III. Numerical Results

Magic Tee in X band has been designed using HFSS software (fig. 2) in which port 2 and port 3 has been assigned to two collinear arms, whereas port 1 and port 4 for E and H arm respectively.

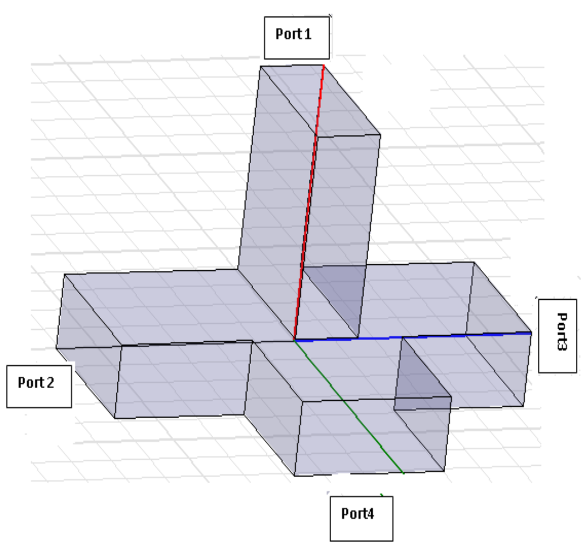

Figure 2: Diagram of Magic Tee using HFSS

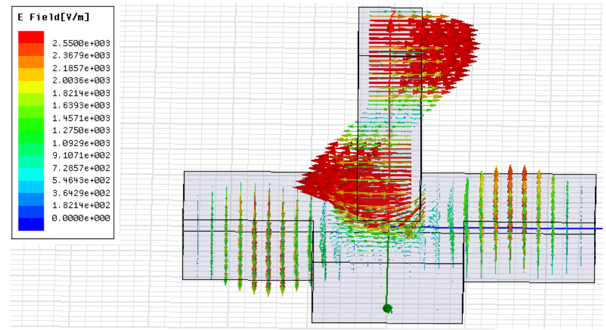

Figure 3: Shows the E-field vectors for signals entering the difference port

As shown 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 with no coupling to port 4(H arm). Therefore E arm is decoupled to the H arm since the electric field vector would be parallel to the broad wall of the H arm. However powers fed in arms 2 and 3 are subtracted in arm 1. This follows the behavior of E plane tees.

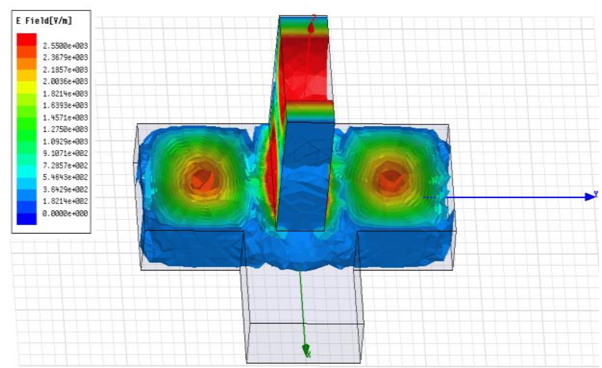

Figure 4: Magnitude of field variation when signal entering at port 1

Simultaneously the one entering the H arm splits equally between the coplanar arms. If the lengths of the coplanar arms are equal, the output signals at port 2 and 3 are in phase. The vector phasors are indicated by solid arrows in fig 5, also the magnitude of field variation is shown in fig.6. However powers fed in arms 2 and 3 are added in arm 4. This follows the behavior of H plane tees [5, 12].

IJETAE
EXPLORING RESEARCH AND INNOVATIONS

International Journal of Emerging Technology and Advanced Engineering
Website: www.ijetae.com (ISSN 2250-2459, Volume 2, Issue 5, May 2012)

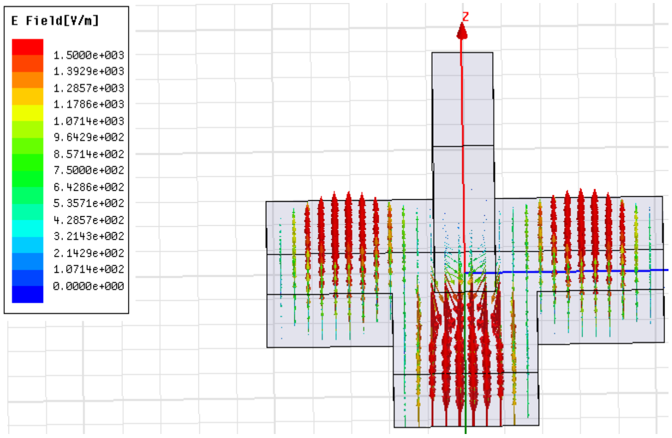

Figure 5: Electric field vector variation when signal entering at port 4

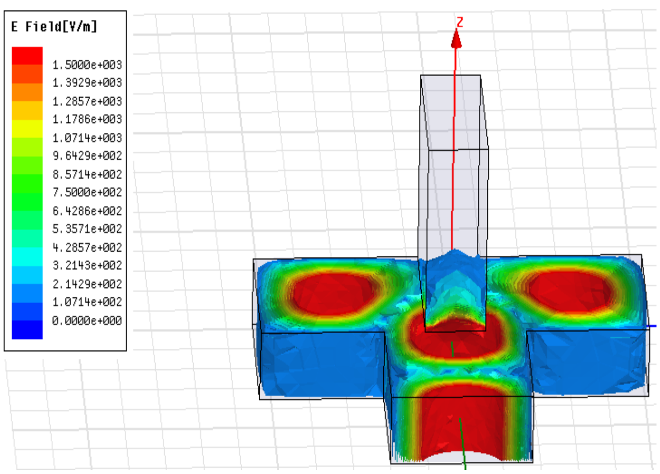

Figure 6: Magnitude of field variation when signal entering at port 4

Without any matching components placed in the waveguide port of the magic tee, the return losses for each port of the magic tee has been observed in HFSS simulation software. The return loss for only port 1 is shown in fig.7. It can also be found that for other ports also return losses are below -10 dB.

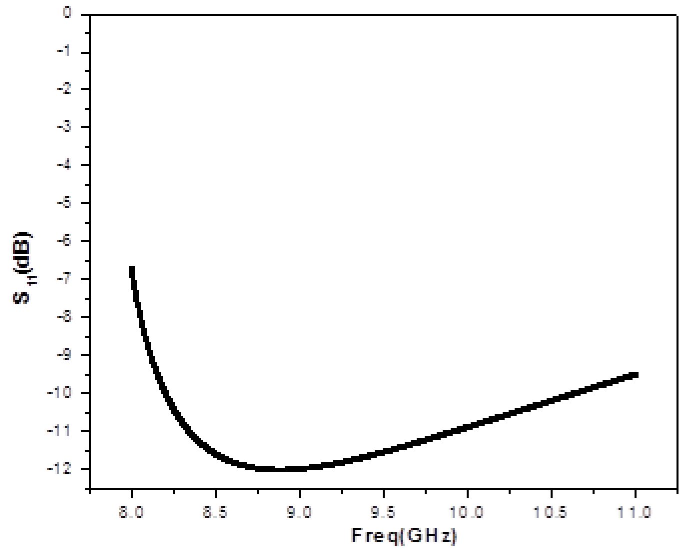

Figure 7: Return loss at port 1

The signal entering the port 1 will not appear at port 4, whereas the signal entering the port 4 will not appear at port 1, so port 1 and 4 is decoupled to each other. The isolation between port 1 and port 4 is below −60 dB in the band from 8 GHz to 11 GHz as shown in fig.8 [2].

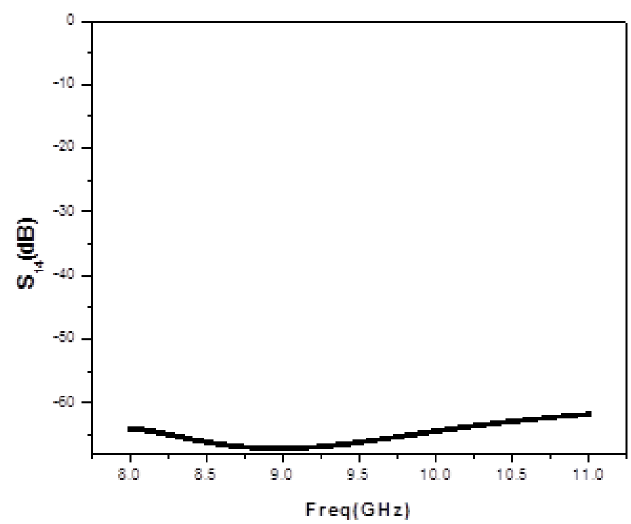

Figure 8: Isolation between port 1 and 4 (ie. S_{14}) or port 4 and 1 (ie. S_{41})

International Journal of Emerging Technology and Advanced Engineering
Website: www.ijetae.com (ISSN 2250-2459, Volume 2, Issue 5, May 2012)

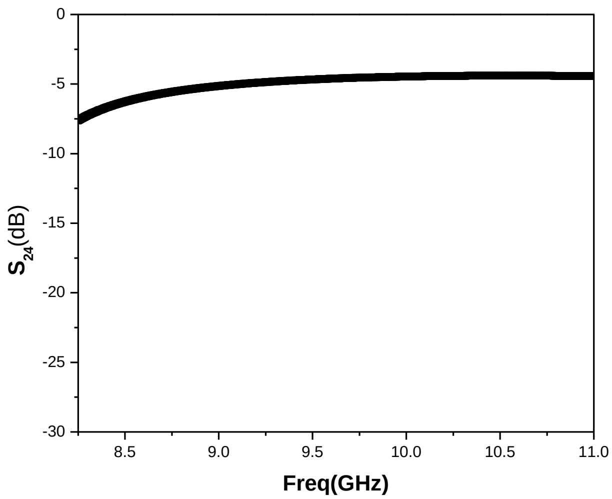

Figure 9: S24/S42

Fig. 10 shows the phase of transmission coefficient between port 2 and 3 when signal entering at port 1. 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.

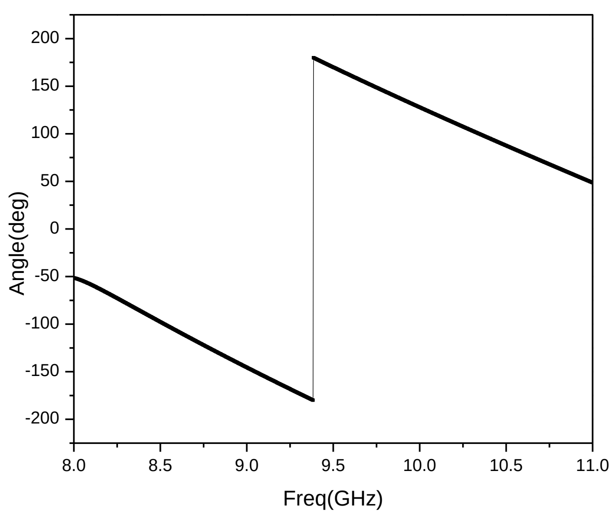

Figure 10: Phase of the transmission coefficients out the Co-linear ports

IV. Conclusion

Waveguide magic tee at X band is analysed by HFSS software. The performance of isolation between E and H port is quite high to use in different microwave systems. The phase of transmission coefficient which is 180 opposite has been observed in this work. Therefore the magic tee designed has a structure that is convenient for manufacture and its good performance can meet the requirement of practical system such as microwave impedance bridges, antenna duplexer, balance microwave mixer, balanced phase detector, frequency discriminator, single side band and double side band suppressed carrier modulators and microwave antenna systems.

References

[1] Liu, M., Feng, Z., 2008, "A novel hybrid planar SIW magic Tee", APMC 2008, pp. 1-4.

[2] You, L.Z., Dou, W.B., 2007, "Design and Optimization of Planar Waveguide Magic Tee at W-band", ICMMT-2007 pp. 1- 4.

[3] Beyer, R., Rosenberg, U., 2003, "CAD of magic tee with interior stepped post for high performance designs", Microwave Symposium Digest, IEEE MTT-S 2003, pp.1207 - 1210 Vol. 2.

[4] Cassivi, Yves., Wu, Ke., 2001, "Magic Tee Junction Based on Hybrid Architecture of Microstrip Line and Non-Radiative Dielectric Waveguide", Microwave Conference, pp. 1 – 4.

[5] Sieverding, T., and F. Arndt., 1993 "Modal analysis of the magic tee", IEEE Microwave Guided Wave Lett., Vol. 3,150–152.

[6] Shen, Z. X., Law.C. L. and Qian.C. 2002, "Hybrid finite-element-modal-expansion method for matched magic T-junction", IEEE Trans. Magnetics, Vol. 38,385–388.

[7] HFSS: High Frequency Structure Simulator based on the Finite Element Method, v. 9.2.1, Ansoft Corporation, 2004.

[8] Das, A. and Das, S. K, 2009, Microwave Engineering, New Delhi: Tata McGraw Hill.

[9] Pozar, D. M., 1998, Microwave Engineering, 2nd Edition, and New York: John Wiley &sons Inc.

[10] Collin, R. E., 1966, Foundation of Microwave Engineering, 2nd Edition McGraw-Hill Book Co, New York.

[11] Sisodia.M.L., Raghuvanshi.G.S., 2003, Microwave circuits and Passive Devices.

[12] Dawar. P., 2011, Design and Simulation of Magic Tee and Ring Hybrid Coupler using Ansoft HFSS, IJCST, vol 2, issue1.