

Research Article

# Design and Simulation of Hybrid Tee and 180° Ring Hybrid Coupler for S Band

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## Abstract

Hybrid tee is widely used component in microwave system, the four arms of a conventional Hybrid tee direct at four directions, which occupy much space and give inconvenience to the assemblage of a system. In this paper a design of waveguide having width =50.0 mm, Height =20.0 mm, Length=75.0 mm as well as solution frequency =4.0 GHz. Material assign for Hybrid tee is vacuum which relative permittivity =1 as well as relative permeability =1. We make four arms at different position, such as first arms located at position -25.0,-10.0, 0.0, second arms locate at position -25.0,-10.0, 0.0, third and fourth arms locate at position -25.0,-10.0, and 0.0. Each arm is 900 positions from each other's. 180° ring hybrid coupler a type of coupler used in RF and Microwave system. Its simplest form it is a 3dB coupler and is thus an alternative to a Hybrid tee. Rogers RT/duroid 5870™ is used which relative permittivity 2.33 used. HFSS is a high performance full wave electromagnetic (EM) field simulator for arbitrary 3D volumetric passive device Modeling. It employs the finite Element Method (FEM), adaptive Meshing and brilliant graphics. This paper reports for Hybrid Tee for S band that a signal incident on the different port split equally between port 2 and 3, but the resulting signal are 180° out of phase. Also 180° Ring Hybrid Coupler for S band is a four port networks with a 180° phase shift between two output ports but it can also be operated so that output port are in phase. Both the Structures are first designed using HFSS and then Simulated.

**Keywords:** Microwave system, waveguide, hybrid coupler.

## 1. Introduction

Waveguide E-plane tee is an important passive element in microwave and millimetre 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 junction will help to analyse the power distribution between different ports along with phase of transmission coefficient. Several works already made significant contributions in this field. [1] Made a comparative analysis of planar SIW magic tee with traditional rectangular tee. Novel four planar magic tee was proposed by [2] for networking applications using waveguide 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 finding of others [4]. Experimental results [5] are well fitted with the recently available numerical studies. She first presented the detailed analytical model [6] for tee structures using hybrid finite-element model-expansion method.

As HFSS is an interactive software package for calculating the electromagnetic behaviour 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 high-performance full wave electromagnetic field simulators for arbitrary 3D volumetric passive device Modelling Proper material are always chosen prior to the simulation for future experimental works.

## 2. Designing

### A. Construction

Let us design Hybrid Tee and 180° Ring Hybrid Coupler as Shown in fig and fig

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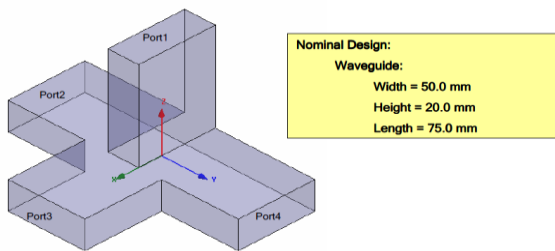
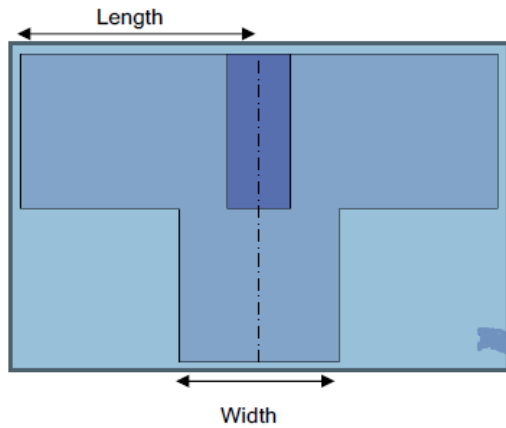


Fig.1 Construction Details of Hybrid Tee

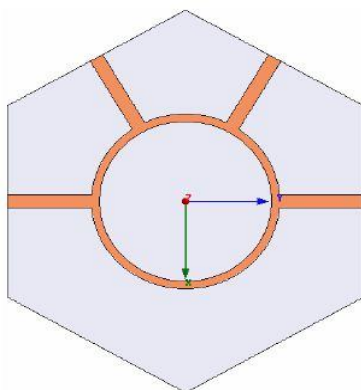


Fig.2 Construction Details Of Ring Hybrid Coupler

B. Principle of operation

- 1) A hybrid tee is a four-port, 180 degree hybrid splitter, realized in waveguide as shown in Fig.3. Like all of the coupler and splitter structures, the hybrid tee can be used as a power combiner, or a divider. It is ideally lossless, so that all power into one port can be assumed to exit the remaining ports. Port 1 is the (sum) port, and is sometimes called the H-plane port, and sometimes called the P-port for “parallel”. A signal incident on port 1 equally splits between ports 2 and 3, and the resulting signals are in phase. Ports 2 and 3 are sometimes called the co-linear ports, because they are the only two that are in line with each other. Port 4 is the (difference or delta) port, and is sometimes called the E-plane port, or The S-port for “series”. A signal incident on the difference port splits equally between ports 2 and 3, but the resulting signals are 180 degrees out of phase.

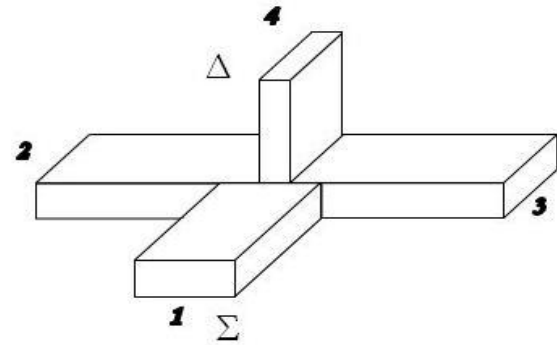


Fig.3 Hybrid Tee

1. Ring Hybrid junction is a four-port network with a 180 degree phase shift between two output ports but it can also be operated so that output ports are in phase. The 180 degree ring hybrid can be constructed in several forms such as planar form or other forms like wave guide forms.

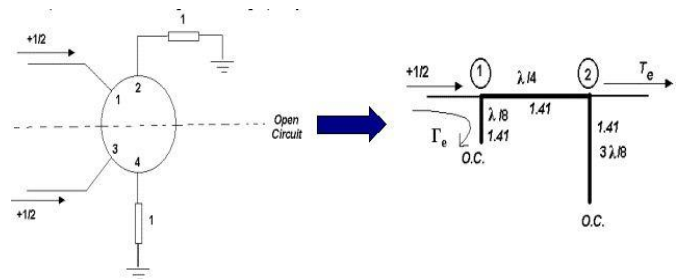


Fig.4 For even-mode excitation

Now consider a unity amplitude wave incident at port 4 (difference port), as in Fig.3 of the ring hybrid junction. The two wave components on the ring will arrive in phase at ports 2 and 3, with a net phase difference of 180 degree between these ports. The two wave components will be 180 degree out of phase at port 1.

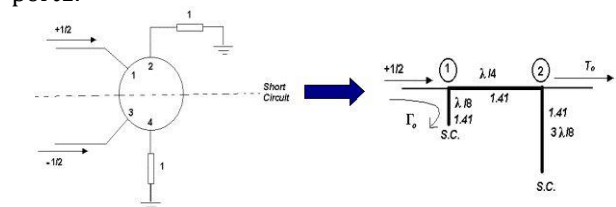


Fig. 5 For odd-mode Excitation

First consider a unit amplitude wave incident at port 1, the sum port, of the ring hybrid. at the ring junction this unit wave will divide into two components, which both arrive in phase at ports 2 and 3, and 180 degree out of phase at port 4. Using the even-odd mode analysis technique we can decompose this case into a superposition of two simpler circuits which are considerably easy to analyze.

C. Steps of construction

Hybrid tee

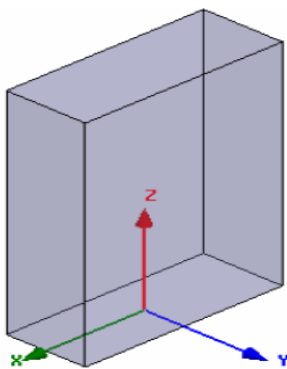


Fig.6 Hybrid Tee Top Arm

Create top arm 1

- Select the menu item Draw> Box
- Using the co-ordinate entry field, enter the box position X= -25.0,Y= -10.0 ,Z= 0.0
- Using the co-ordinate entry field, enter the opposite corner of the base rectangle dX= -50.0 , dY= 20.0 dZ= 75.0

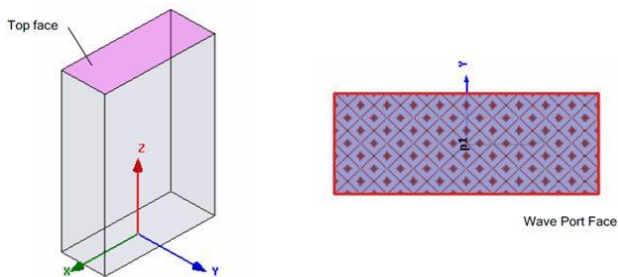


Fig.7 Hybrid Tee Waveport Excitation

Create wave port excitation 1

- Select the menu item edit> select > faces
- Graphically select the top face of the arm at Z= 75 mm

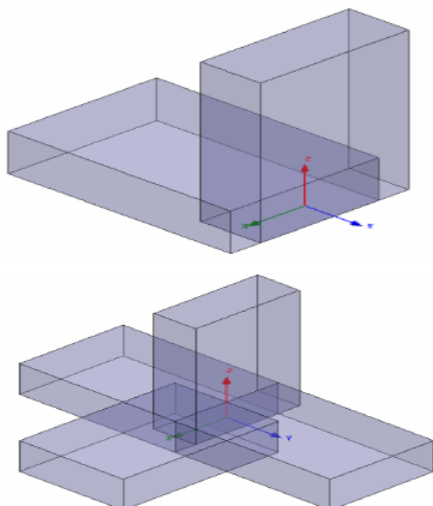


Fig.8 Hybrid Tee Create Arm 2 and Arm 3& 4

- I. Create arm 2
- II.
  - Select the menu item edit> duplicate > around axis
  - Axis – X
  - Angle- 90
  - Total Number- 2
- III.
- IV. Create arm 3& 4
- V.
  - Select the Menu item , Edit > Duplicate > Around Axis
  - Axis – Z
  - Angle- 90
  - Total no- 3
- VI.
- VII. Creating an analysis setup
- VIII.
  - Select the menu item HFSS> Analysis Setup> Add Solution Setup
  - Solution setup window
  - Solution frequency= 4.0 GHz
  - Maximum No. of Passes= 5
  - Maximum delta S per pass= 0.02
  - Adding a frequency sweep
- IX.
- X.

- Select the menu item HFSS > Analysis Setup> Add frequency sweep
- Edit Sweep Window
- Frequency setup – Linear count
- Start – 3.4Ghz
- Stop – 4.0 GHz
- Count – 1001

Ring Hybrid Coupler

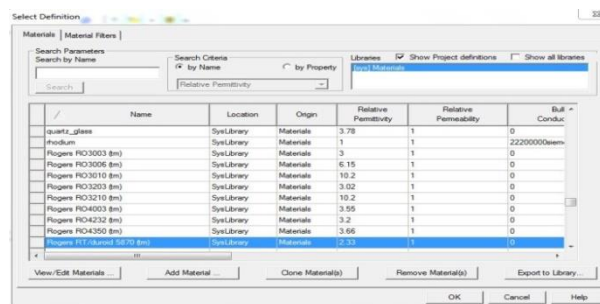


Fig.9 180° ring hybrid Coupler Material

Set Default Material

- Material name-RogersRT/duroid 5870™
- Relative permittivity type- 2.33

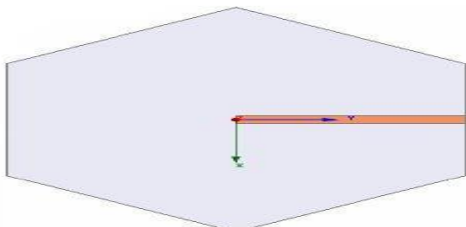
Create Substrate

- Select the menu item Draw > Regular Polyhedron
- Using the co- ordinate entry fields , enter the radius X= 0.0 , Y= 0.0 , Z= -1.43
- Using the co- ordinate entry fields , enter the radius dX = 22.57 , dY= 0.0 , dZ= 0.0

- Using the co- ordinate entry fields , enter the height  $dX= 0.0$  , $dY= 0.0$  , $dZ= 2.286$

Create trace

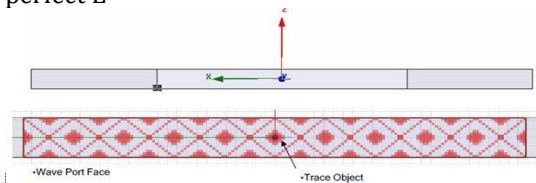
- Select the Menu item Draw > Rectangle
- Using the co- ordinate entry field, enter the rectangle position  $X= - 0.89154$  , $Y= 0.0$  , $Z= 0.0$
- Using the co- ordinate entry field enter the opposite corner of the rectangle  $dX= 1.78308$  ,  $dY= 22.345$  , $dZ= 0.0$



**Fig.10** Assign the Perfect E boundary and Create Wave Port Excitation of 180° ring hybrid Coupler Material

Assign a perfect E boundary to the trace

- Select the menu items HFSS> Boundaries > Assign> perfect E

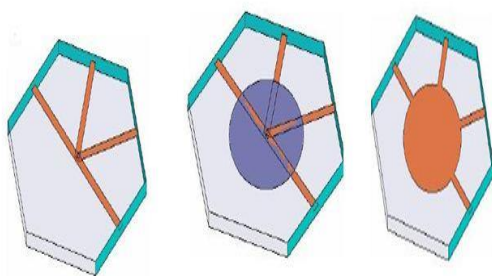


**Fig.11** Perfect E boundary and Create Wave Port Excitation of 180° ring hybrid Coupler Material

Create wave port Excitation 1

- Select the menu item view > modify Attributes >orientations
- Select the menu item Draw > rectangle

Create the remaining traces and wave ports



**Fig.12** Create Substrate of 180° ring hybrid Coupler Material

- Select the menu item Edit > Select > By name

- Select object dialog

Select the objects named : Trace , port

To duplicate the objects

- Select the menu item Edit > Duplicate > Around Axis
- Duplicate Around Axis Window
- Axis – Z
- Angle- 60 deg

Create Outer Ring

- To set grid plane

Select the menu item Modeler > Grid Plane >XY

- To create the ring
- Select the menu item Draw > Circle
- Using the co-ordinate entry fields, enter the position  $X= 0.0$  ,  $Y= 0.0$  ,  $Z= 0.0$
- Using the co-ordinate entry field  $dX= 11.795$  ,  $dY= 0.0$  ,  $dZ=0.0$

Group the conductors

- To group the conductors

Deselect all objects by selecting the Menu item Edit > Deselect All  
Using the Model tree , while holding down the CTRL , key select the following objects in this order Trace, Trace\_1, Trace\_2, Trace\_3  
Select the menu item Modeler > Boolean > Unite

- Create inner ring

Select the menu item Draw > Circle  
Using the co-ordinate entry field , enter the position  $X= 0.0$  , $Y=0.0$  ,  $Z= 0.0$   
Using the co-ordinate entry field , entre the radius  $dX= 10.795$  , $dY=0.0$  ,  $dZ= 0.0$

- Anaysis setup

Select the menu item HFSS >Analysis setup > Add solution setup

- Solution setup window

Solution frequency : 4.0 GHz  
Maximum number of passes :20  
Maximum deltas : 0.01

- Adding a frequency sweep

Select the menu tem HFSS > Analysis setup> Add frequency Sweep

- Edit sweep window

Sweep type: fast

- Frequency set up type: linear setup

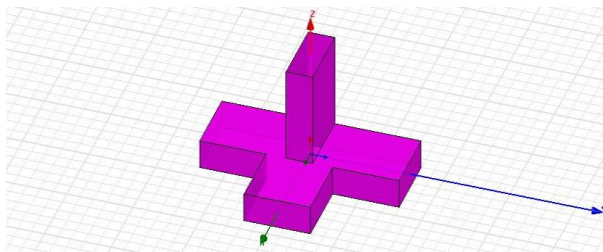
Start : 2.0 GHz

Stop : 7.0 GHz

Step : 0.05 GHz

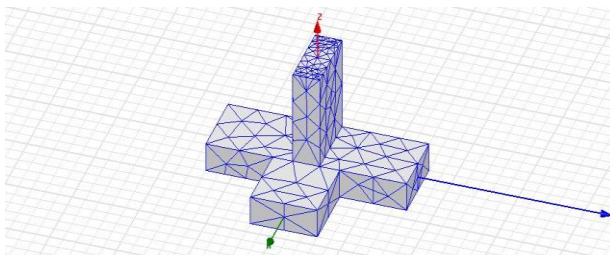
## 2. Analysis Results

### Analysis of Hybrid Tee



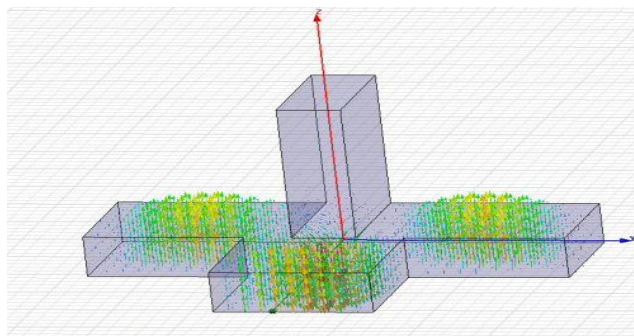
**Fig.13** Schematic Picture of Hybrid Tee in Simulation Software

In above fig.13 the E-field of a signal entering the sum port remains in the same up-and-down direction and polarity as it splits to ports 2 and 3, while the E-field of a signal entering the delta port wraps around into two opposing polarities as it splits between ports 2 and 3.

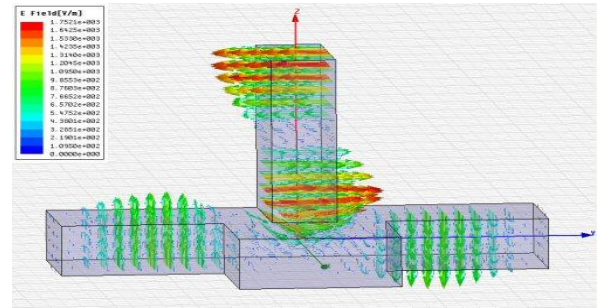


**Fig.14** Schematic Picture of Mesh Plot of Hybrid Tee in Simulation Software

In above fig.14 we will achieve Mesh plot of the Hybrid Tee.



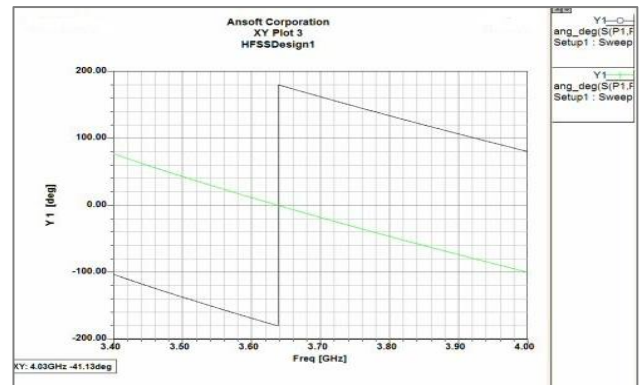
**Fig.15** Shows the E-field vector for signals entering the sum port



**Fig.16** Shows Electric field vector Variation when signal entering Port 1

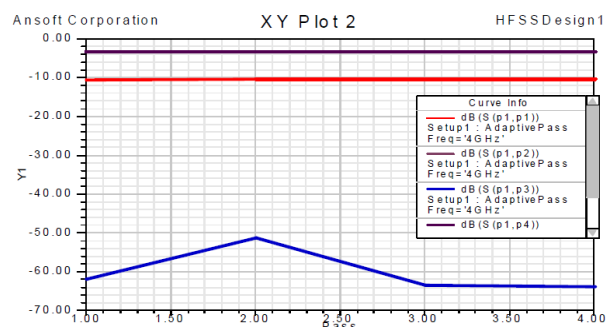
In above fig.16 we will find how the delta port excited opposing phases in the Co-linear arms.

Then we can say that two pictures (fig.15 and fig.16) show the E-field vectors for signals entering the sum port, then the delta port. Now we can see how the delta port excites opposing phases in the CO-linear arms.



**Fig.17** Phase of the Transmission Coefficient out the CO-linear ports

In above fig.17 the S-parameters of the four ports network, including the transmission coefficient between sum and delta ports, which is better than -50 dB. The input match S11 could be better, which would require some tuning.



**Fig.18** S-Parameter Plot vs. Adaptive Pass

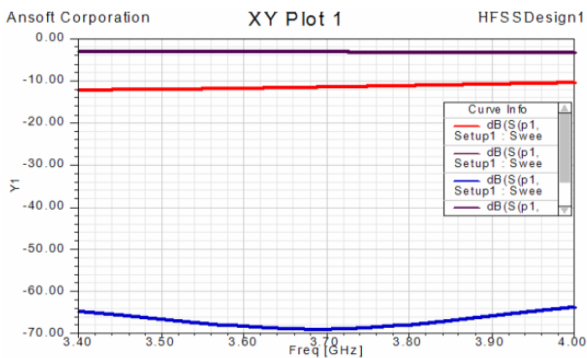


Fig.19 S-Parameter Plot vs. Freq

In above fig.18 we will find s-parameter and Adaptive pass as well as in fig.19 we will find s-parameter and frequency plot.

In both (fig.18 and fig.19) figures the scattering power variation of frequency transmitted power is given at port 1. It can easily be stated from figure that when signal entering port 1, it will equally divide and appear at port 2 and port 3 with opposite phase. As we may say that when the wave fed into port 1, the waves appearing at port 2 and port 3 will be in opposite phase and in the same magnitude. Therefore  $S_{12} = -S_{13}$ .

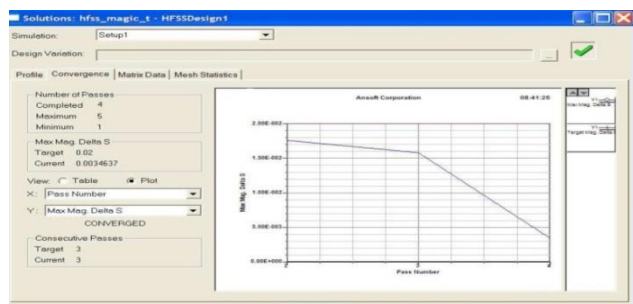


Fig.20 maximum magnitude delta S Vs pass number

In above figure (fig.20) we will find the maximum magnitude delta S and varies to the pass number of Hybrid Tee.

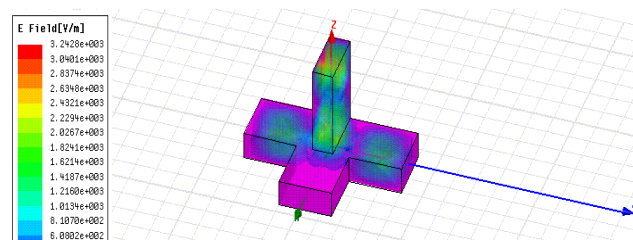


Fig.21 Hybrid tee all objects animation

In above fig.21 we will find animation at frame 9 and phase 180 deg.

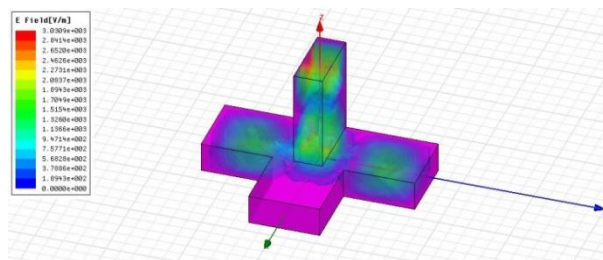


Fig.22 Hybrid tee E-field for all objects

In above fig.22 we can see magnitude of field variation when signal entering at port 1.

In fig.22 it is observed that a wave incident at port 1 (E-Arm) divided equally between port 2 and port 3 in opposite phase. However power fed in arm 2 and arm 3 are subtracted in arm 1.

Analysis of 180° Ring Hybrid Coupler

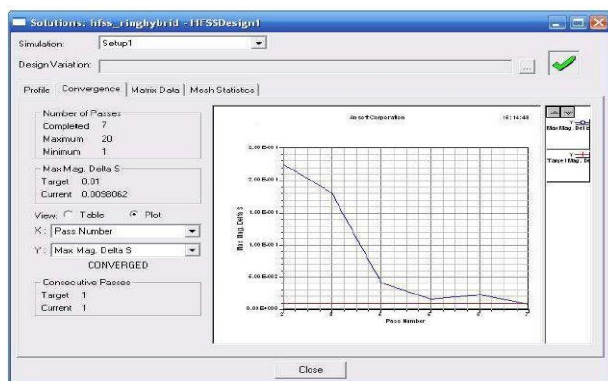


Fig.23 Maximum magnitude delta S and Pass number of 180° ring hybrid coupler

In above fig.23 we achieved the variation of magnitude of delta S with respect to pass number.

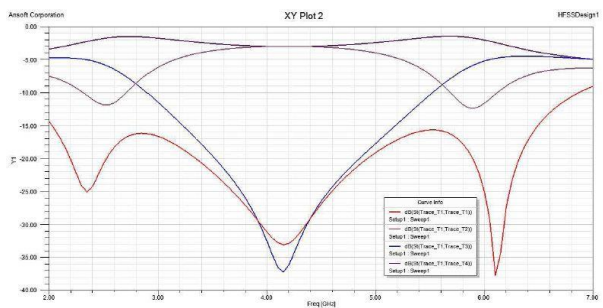
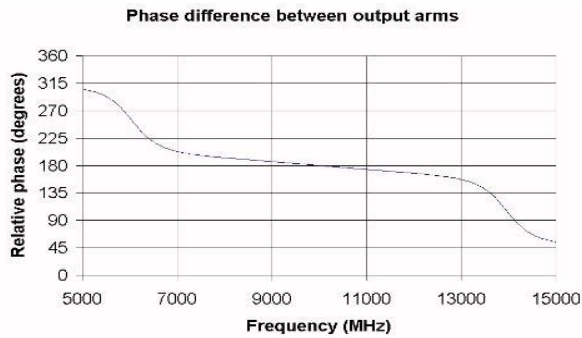


Fig.24 S-Parameter Plot - Magnitude of 180° ring hybrid coupler

In above fig.24 the impedance match of the same 180° Ring hybrid coupler at port 1 and 4 by symmetry, the impedance match at port 3 is the same as at port 1.

Then we may say that the device is perfectly matched equal power division perfectly isolated port.



**Fig.25** Phase difference between output arms of 180° ring hybrid coupler

In above fig.25 we will observe the phase difference between arms 2 and arms 4 is plotted. At the centre frequency a perfect 180 degree difference is observed.

### Conclusions

Hybrid Tee and 180° Ring Hybrid coupler at S-band is analyzed by HFSS Software. Hybrid tee is divided the power among various ports. A signal injected into the E-plane port will also be divided equally between port 1 and port 2 but will be 180 degree out of phase. The E-plane port is also matched then half power will leave by the E-plane port. In this circumstance there is no power 'left over' either to be reflected out of the first collinear port or to be transmitted to the other collinear port. 180 degree hybrid coupler is perfectly matched equal power division perfectly isolated port as well as 180 degree phase difference between output arms achieved.

Therefore the designed Hybrid Tee and 180 degree ring hybrid coupler has a structure that is convenient for S-band.

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