DESIGN OF PASSIVE COMPONENTS BASED ON MICROSTRIP LINE

Microstrip Line:

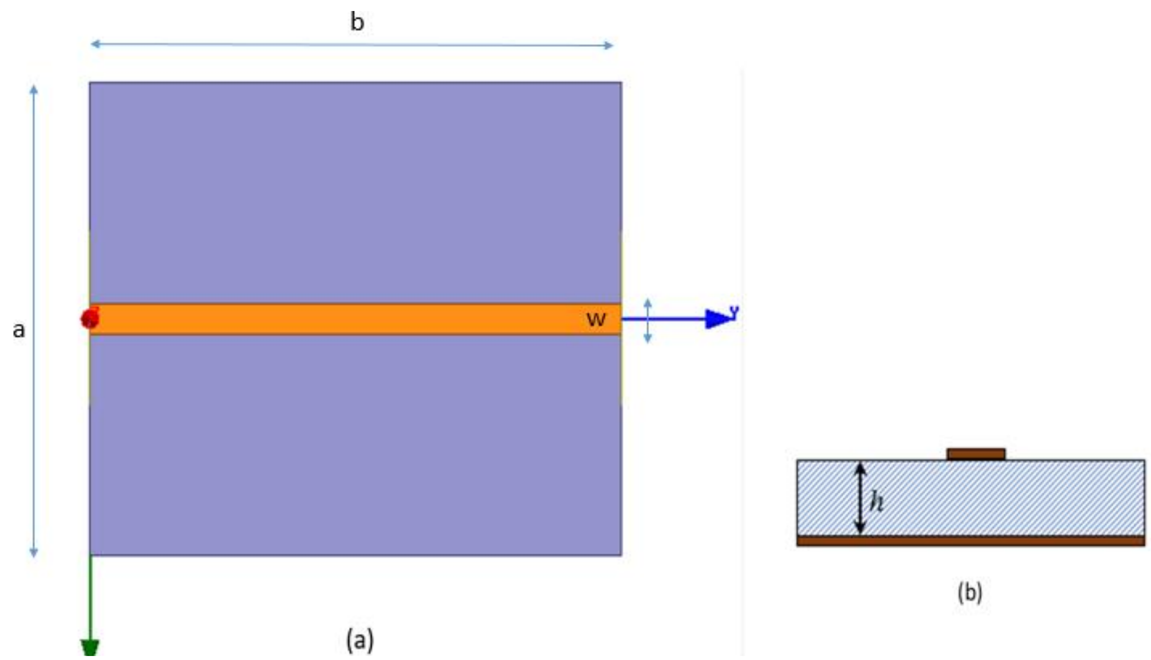

Fig.1 shows the top view of the designed microstrip line. Wave ports are not visible as they are in the orthogonal plane. Radiation box's visibility is turned off. Plots have been plotted with the help of MATLAB

Microstrip Line Designed on FR4_Epoxy Substrate:

- **Components:**
  - Metal: **Copper**
    - Conductivity: 58000000 Siemens/m
    - Relative Permittivity (εr): 1
  - Substrate: **FR4_Epoxy**
    - Relative Permittivity **(**εr): 4.4
    - Dielectric Loss Tangent ($tan\delta$): 0.02

- **Design Specifications:**
  - a = 40mm
  - b = 50mm

- h = 0.8mm (Substrate thickness)
- t = 0.017mm (Metal thickness)
- w = 1.5295mm

Design Criteria:

- Frequency Band: 8-12 GHz

Results:

- **Magnitude Plot of S Parameters**

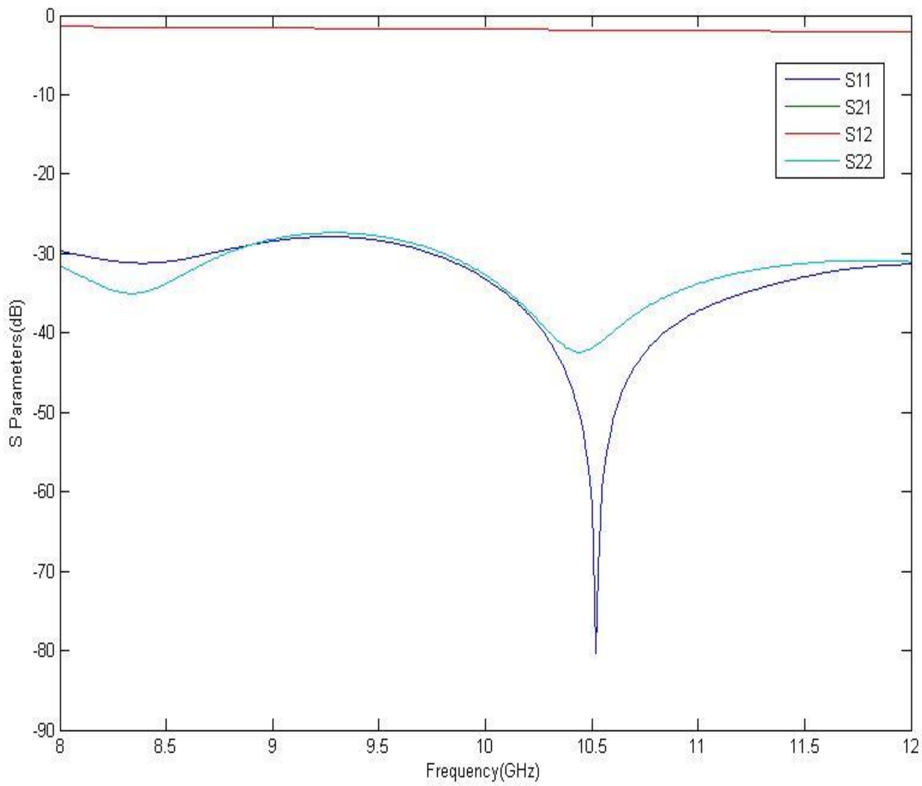

Fig.2. Magnitude Plot of S Parameters

- **Phase Plot of S Parameters**

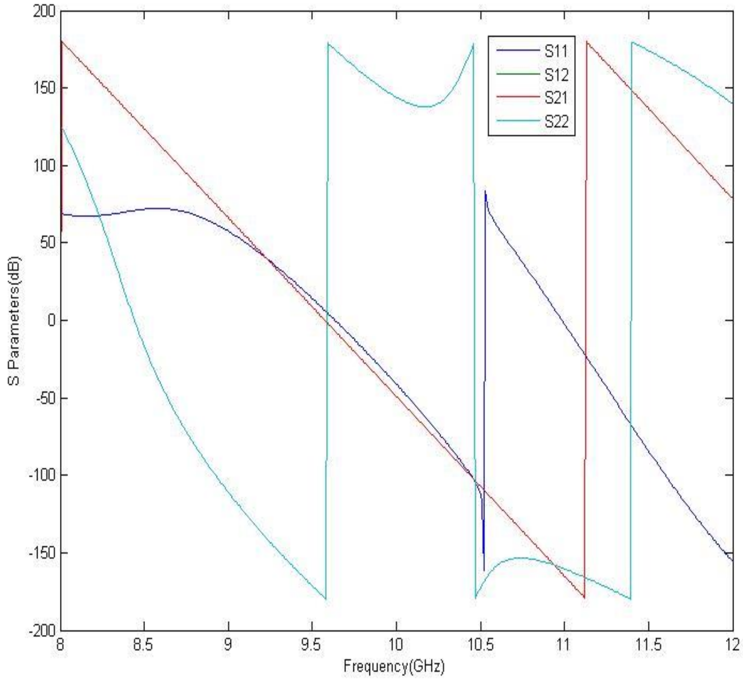

Fig.2. Phase plot for the S parameters

- **Plot of Dispersion diagram over the band**

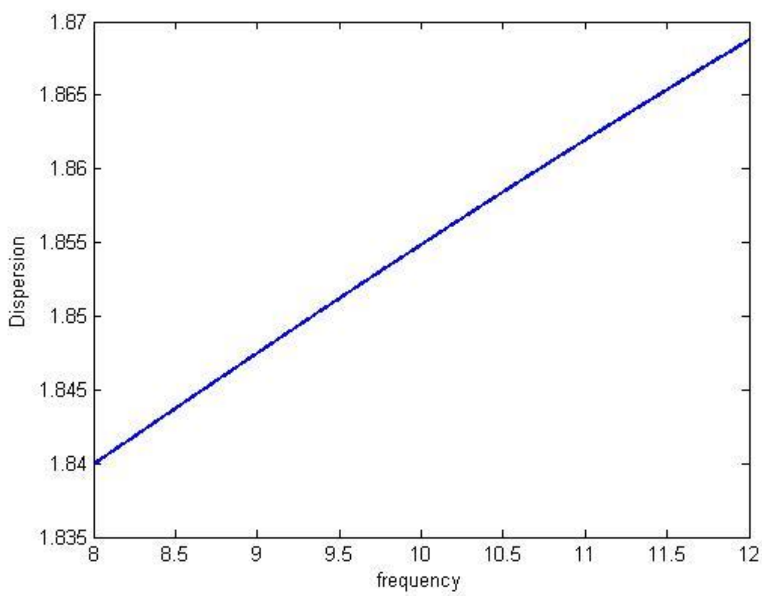

Fig.3. Dispersion diagram for FR4_Epoxy substrate

- **The plot of Total Loss**

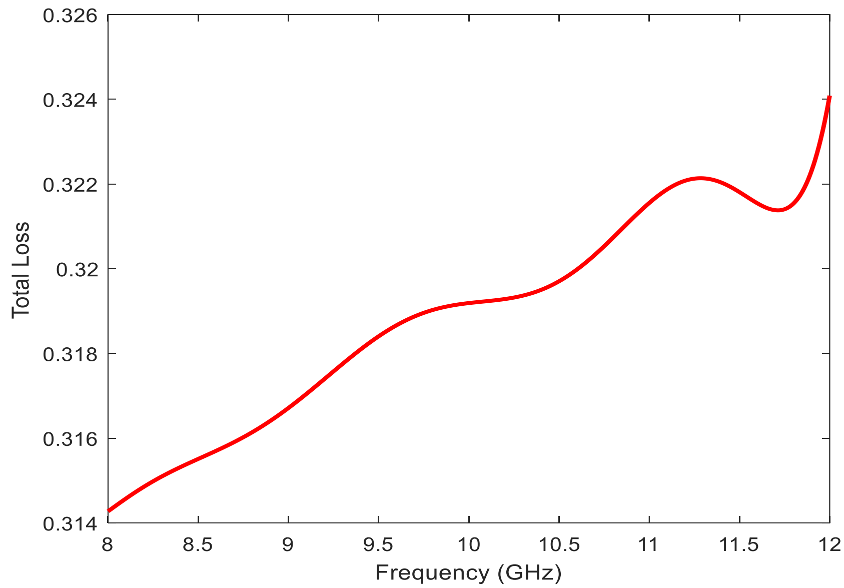

Fig.4. Total loss plot

- **The plot of different types of losses**

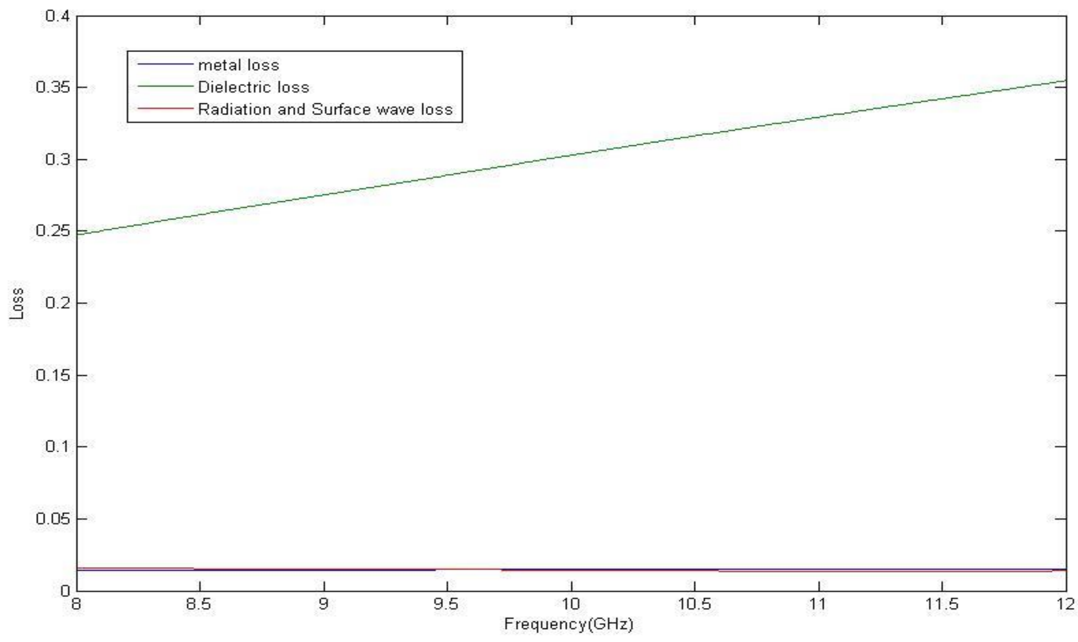

Fig.5.Individual loss plot (i) Metal Loss (ii) Dielectric Loss (iii) Radiation and Surface wave Loss

Vector Electric and Magnetic Field Distribution

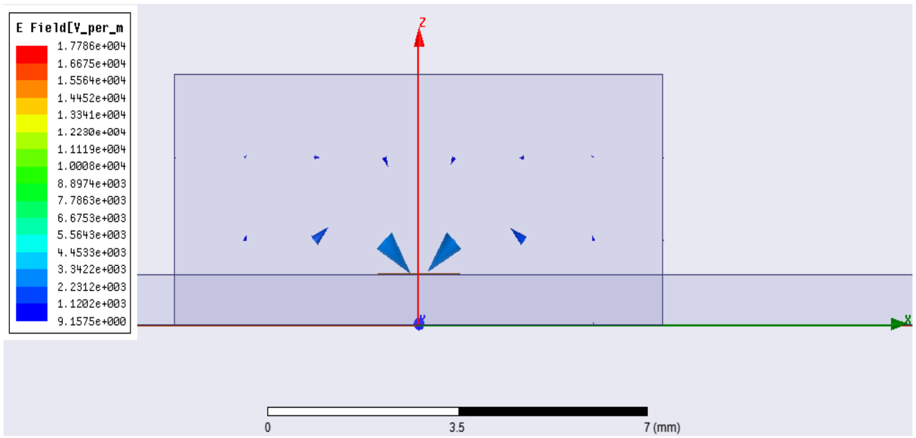

Fig.6. Vector Electric Field at 10 GHz

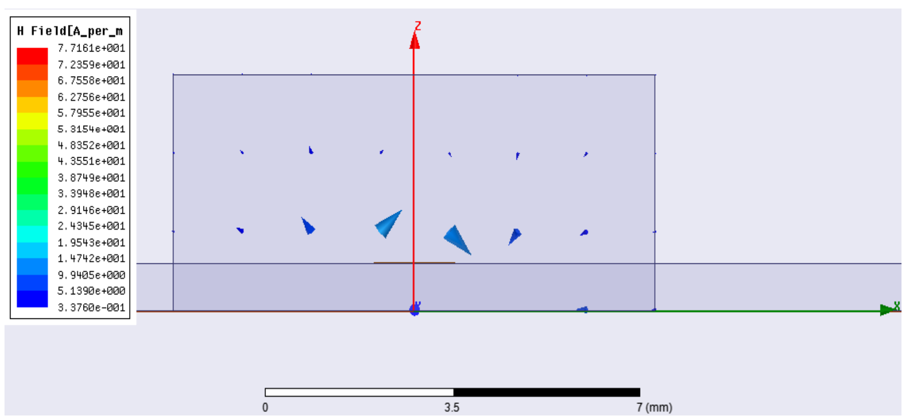

Fig.7. Vector Magnetic Field at 10 GHz

Calculations

For the dispersion diagram, we know it is the relation between *k/β* and frequency. And *k* can be given as

$$\boldsymbol{k = \frac{2\pi}{\lambda_g}} \qquad \textbf{(1)}$$

$$\boldsymbol{\beta = \frac{2\pi}{\lambda_0}} \qquad \textbf{(2)}$$

$$\boldsymbol{\lambda_g = \frac{3\times10\hat{}8}{f\times\sqrt{\varepsilon_{eff}}}} \qquad \textbf{(3)}$$

$$\boldsymbol{\varepsilon_{eff}} = \frac{\boldsymbol{\varepsilon_r+1}}{\mathbf{2}} + \frac{\boldsymbol{\varepsilon_r-1}}{\mathbf{2}}\left[\left(\mathbf{1}+\mathbf{12}\left(\frac{\boldsymbol{H}}{\boldsymbol{W}}\right)\right)^{-\frac{1}{2}} + \mathbf{0.04}\left(\mathbf{1}-\left(\frac{\boldsymbol{W}}{\boldsymbol{H}}\right)\right)^{2}\right], \textbf{ when } \left(\frac{\boldsymbol{W}}{\boldsymbol{H}}\right) < \mathbf{1} \quad \textbf{(4)}$$

$$\boldsymbol{\varepsilon_{eff}} = \frac{\boldsymbol{\varepsilon_r+1}}{\mathbf{2}} + \frac{\boldsymbol{\varepsilon_r-1}}{\mathbf{2}}\left[\left(\mathbf{1}+\mathbf{12}\left(\frac{\boldsymbol{H}}{\boldsymbol{W}}\right)\right)^{-\frac{1}{2}}\right], \textbf{ when}\left(\frac{\boldsymbol{W}}{\boldsymbol{H}}\right) \geq \mathbf{1} \quad \textbf{(5)}$$

Total loss of the medium can be calculated as

$$\boldsymbol{Total\ Loss} = \left(\mathbf{1} - |\boldsymbol{S}(\mathbf{1},\mathbf{1})|^{\mathbf{2}} - |\boldsymbol{S}(\mathbf{2},\mathbf{1})|^{\mathbf{2}}\right) \quad \textbf{(6)}$$

Total loss can be calculated using (6).

The individual losses can be separately calculated as follows.

$$\boldsymbol{Metal\ loss = total\ loss\ \text{-}\ loss\ considering\ metal\ as\ PEC} \quad \textbf{(7)}$$

$$\boldsymbol{Dielectric\ loss = total\ loss\ \text{-}\ losses\ when\ dielectric\ loss\ factor\ (tan\delta)\ is\ 0} \quad \textbf{(8)}$$

$$\boldsymbol{Radiation\ and\ surfacewaveloss = total\ loss\ \text{-}\ metal\ loss\ \text{-}\ dielectric\ loss} \quad \textbf{(9)}$$

- **<u>Conclusion</u>**

- A 50Ω microstrip line is designed on an FR4 substrate having dielectric constant 4.4 and dielectric loss tangent 0.02 using HFSS and its characteristics are studied through the figure. Ideally, the transmission is expected to be very close to 0 dB but due to the high loss tangent of FR4 substrate it exhibits some degree of losses.

- Fig.2 depicts the Magnitude plot of the S-parameters. Fig.3 shows the phase plot with respect to frequency. A linear increase in dispersion with frequency is observed.

- Fig.4 shows the total loss incurred in FR4 substrate and it includes metal loss, dielectric loss and radiation and surface wave loss. The losses are calculated by considering different conditions of 1. Considering the metal of line and ground as PEC and 2. Considering the Loss Tangent of the material of the substrate to be 0.

- Fig. 5 indicates the individual losses. We can see that metal loss and dielectric loss are increasing with frequency and radiation and surface wave loss is decreasing with frequency. Also, dielectric loss is the most dominating loss as seen in the figure.
- Fig.6 shows the vector electric field in the cross-sectional plane. Clear fringing of the electric field is evident. Similarly, Fig. 7 represents the magnetic field vectors in the

cross-sectional plane of the port. As per the simulation magnetic fields forming closed loops are observed clearly.

- We managed to observe a dip at the frequency at 10.5 GHz for the magnitude plot of S11 and S22 parameters. The dispersion diagram shows the linear relation with respect to the frequency.

- By calculating the losses we can infer that the total loss consists of metal loss as the dominant loss as in case of FR4_Epoxy substrate and the dielectric and the surface wave loss and radiation loss that are calculated also contribute to a minor percentage in the total loss of the design.

- The electric and Magnetic field was observed on the cross-section of the plane for the design. We can observe the fringing electric fields and the magnetic fields forming a closed loop around the microstrip line.

❖ <u>Microstrip Line Designed on Rogers RO4003 Substrate:</u>

- **<u>Components:</u>**
  - Metal: **Copper**
    - Conductivity: 58000000 Siemens/m
    - Relative Permittivity (εr): 1
  - Substrate: **Rogers RO4003**
    - Relative Permittivity (εr): 3.55
    - Dielectric Loss Tangent ($tan\delta$): 0.0027

- **<u>Design Specifications:</u>**

  - a = 40mm
  - b = 50mm
  - h = 0.8mm (Substrate thickness)
  - t = 0.017mm (Metal thickness)
  - w = 1.7896mm

- **<u>Design Criteria:</u>**

  - FrequencyBand: 8-12 GHz
- **<u>Results:</u>**

- **Magnitude Plot of S Parameter**

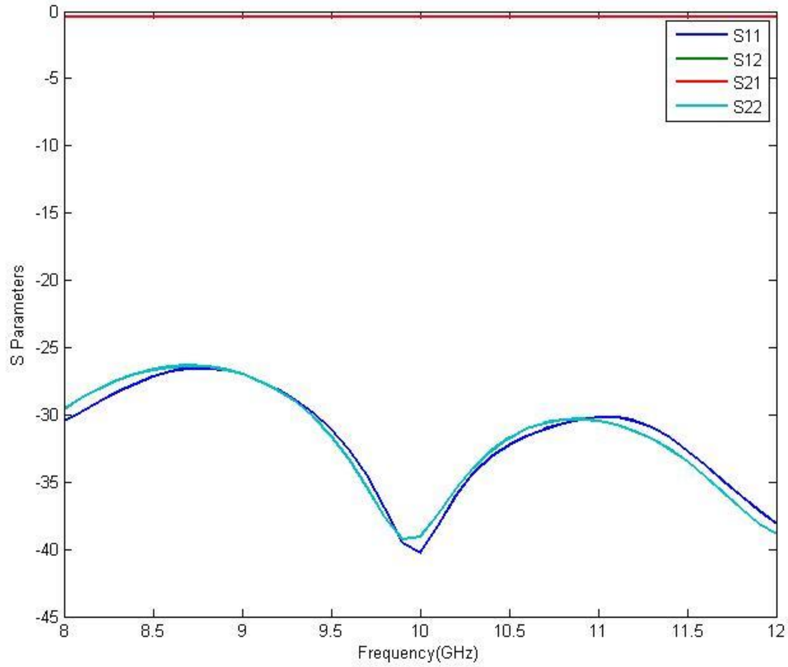

Fig. 8. Magnitude Plot of S Parameters

- **Phase plot of S Parameter**

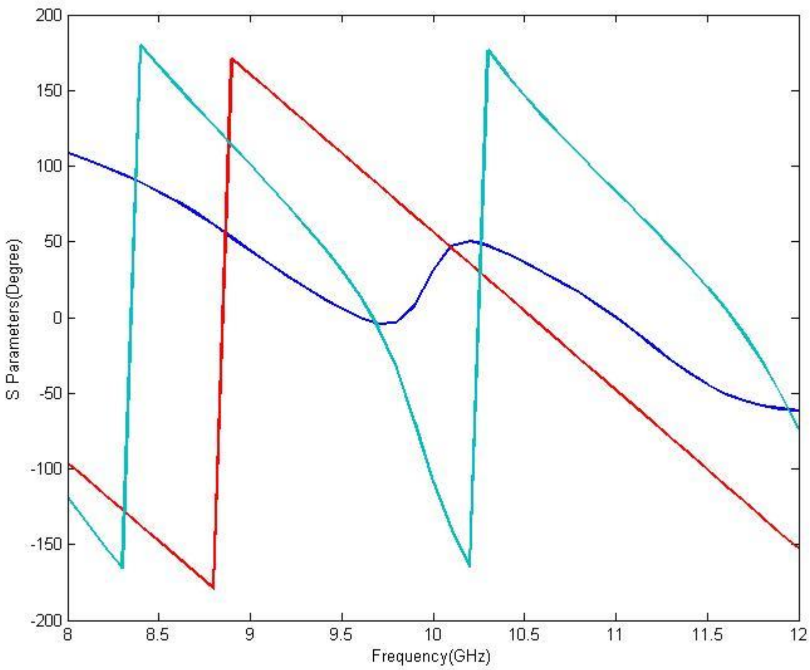

Fig. 9. Magnitude and phase plot for the S parameters

- **Plot of Dispersion Diagram over the band**

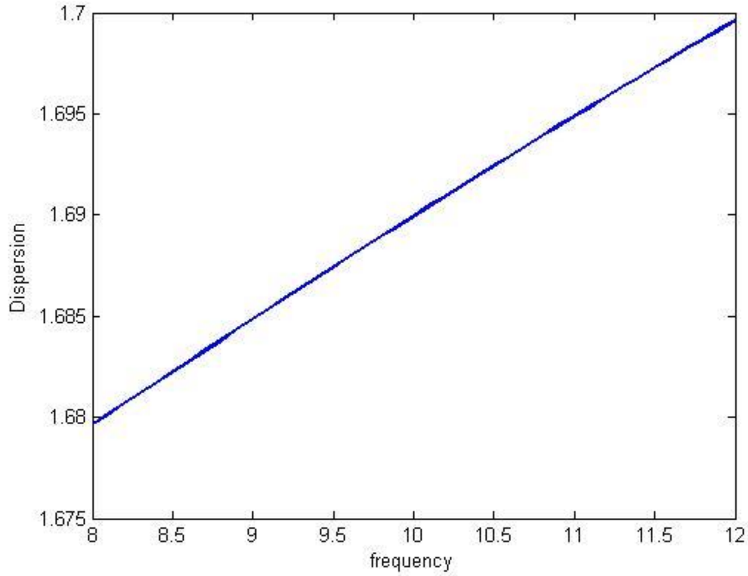

Fig. 10. Dispersion diagram for Rogers RO4003 substrate

- **The plot of Total Loss**

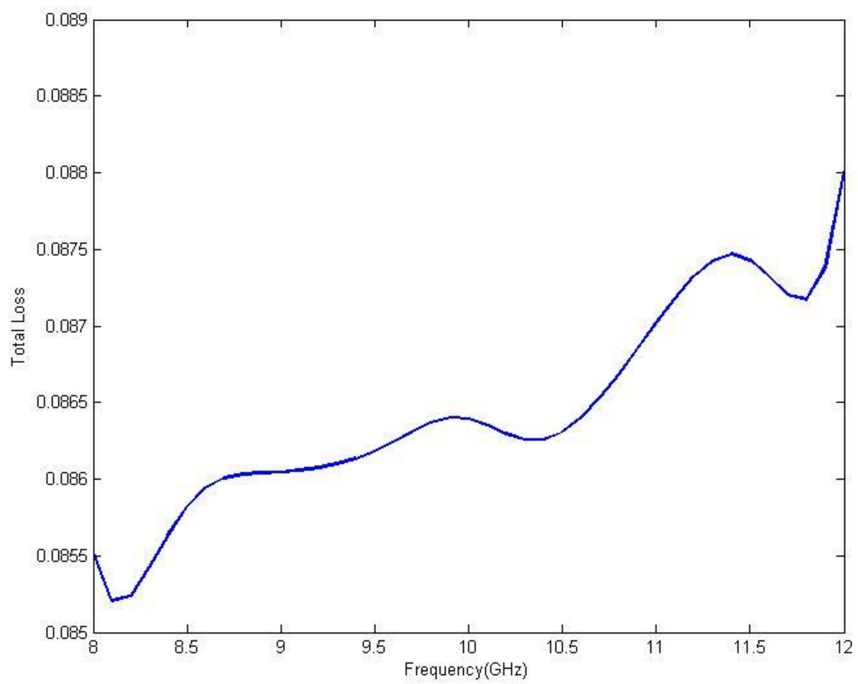

Fig. 11. Total loss plot

- **The plot of different types of losses**

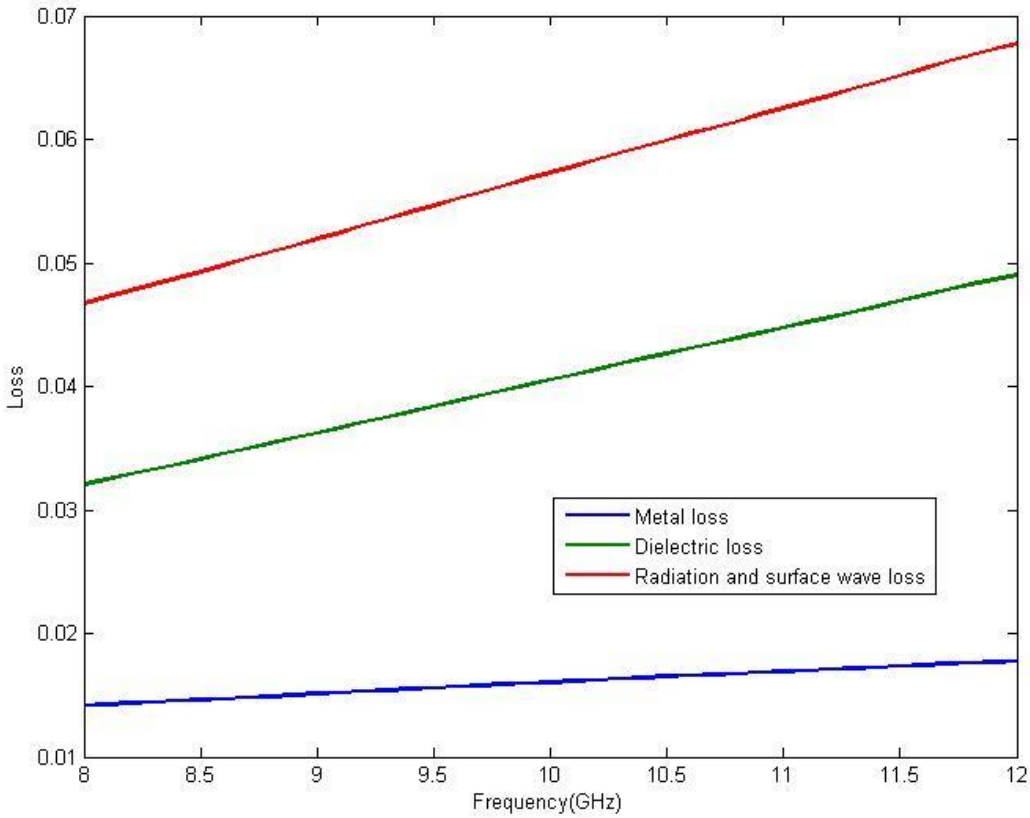

Fig. 12. Individual loss plot (i) Metal Loss (ii) Dielectric Loss (iii) Radiation and Surface wave Loss

- **Vector Electric and Magnetic Field Distribution**

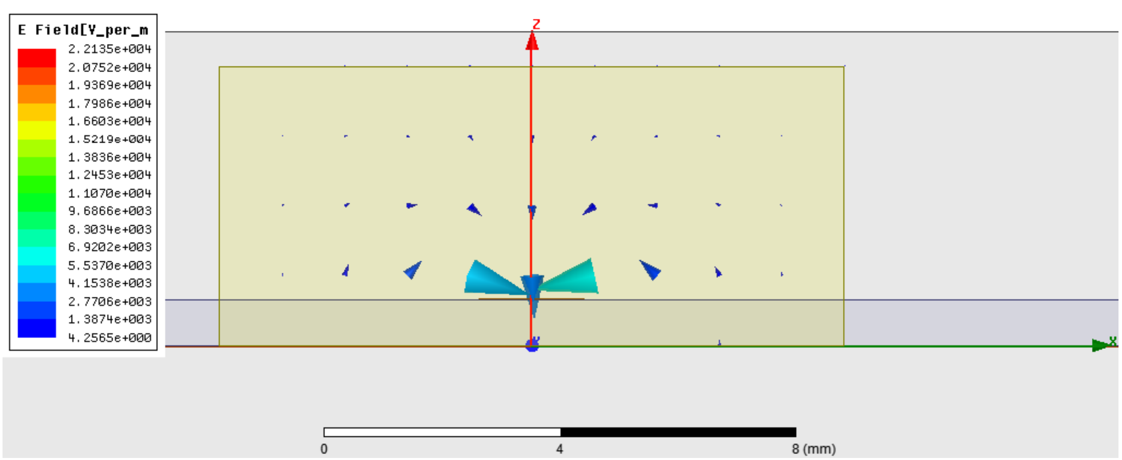

Fig. 13. Vector Electric Field at 10 GHz

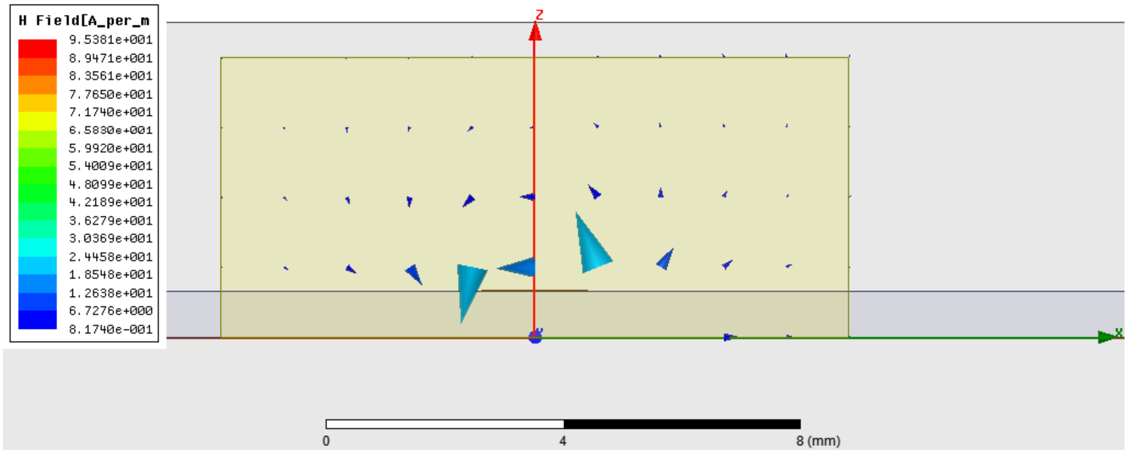

Fig. 14. Vector Magnetic Field at 10 GHz

- **<u>Calculations</u>**

For the dispersion diagram, we know it is the relation between *k/β* and frequency. And *k* can be given as

$$\boldsymbol{k = \frac{2\pi}{\lambda_g}} \qquad \textbf{(from 1)}$$

$$\boldsymbol{\beta = \frac{2\pi}{\lambda_0}} \qquad \textbf{(from 2)}$$

$$\boldsymbol{\lambda_g = \frac{3\times10\text{^}8}{f\times\sqrt{\varepsilon_{eff}}}} \qquad \textbf{(from 3)}$$

$$\boldsymbol{\varepsilon_{eff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left[\left(1+12\left(\frac{H}{W}\right)\right)^{-\frac{1}{2}} + 0.04\left(1-\left(\frac{W}{H}\right)\right)^2\right], \text{when} \left(\frac{W}{H}\right) < 1}$$

$$\boldsymbol{\varepsilon_{eff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left[\left(1+12\left(\frac{H}{W}\right)\right)^{-\frac{1}{2}}\right], \text{when}\left(\frac{W}{H}\right) \geq 1} \qquad \textbf{(from 4 and 5)}$$

Total loss of the medium can be calculated as

$$\textbf{Total Loss} = \boldsymbol{(1 - |S(1,1)|^2 - |S(2,1)|^2)} \qquad \textbf{(from 6)}$$

Total loss can be calculated using (6).

The individual losses can be separately calculated as follows.

$$Metal\ loss = total\ loss\ \text{-}\ loss\ considering\ metal\ as\ PEC \qquad \textbf{(from 7)}$$

$$Dielectric\ loss = total\ loss\ \text{-}\ losses\ when\ dielectric\ loss\ factor\ (tan\delta)\ is\ 0 \qquad \textbf{(from 8)}$$

$$Radiation\ and\ surfacewaveloss = total\ loss\ \text{-}\ metal\ loss\ \text{-}\ dielectric\ loss \qquad \textbf{(from 9)}$$

Conclusion

- A 50Ω microstrip line is designed on a Rogers RO4003 substrate having dielectric constant 3.55 and dielectric loss tangent 0.0027 using HFSS and its characteristics are studied through the figure. Ideally, the transmission is expected to be very close to 0 dB but due to loss tangent of Rogers RO4003 substrate it exhibits some degree of losses.

- Fig.8 depicts the phase plot of the S-parameters and Fig. 9. Shows the Phase plot of the s parameters for the design. Fig.10 shows the dispersion diagram with respect to frequency. A linear increase in dispersion with frequency is evident.

- Fig.11 shows the total loss incurred in Rogers RO4003 substrate and it includes metal loss, dielectric loss and radiation and surface wave loss.

- Fig. 12 indicates the individual losses. We can see that metal loss, dielectric loss and the Radiation and surface wave loss are increasing with frequency. Also, radiation and surface wave loss is the most dominating loss. The metal loss contributes to the least in the losses as seen in the diagram. The loss due to dielectric is also significant in the total loss of the design.
- Fig.13 shows the vector electric field in the cross-sectional plane. Clear fringing of the electric field is evident. Similarly, Fig. 14 represents the magnetic field vectors in the cross-sectional plane of the port. As per the simulation magnetic fields forming closed loops are observed clearly.
- We managed to observe a dip at the frequency at 10 GHz for the magnitude plot of S11 and S22 parameters. The dispersion diagram shows the linear relation with respect to the frequency.

- By calculating the losses we can infer that the total loss consist of radiation and the dielectric losses as the dominant loss as in case of Rogers RO4003 substrate and the metal loss also contribute to a minor percentage in the total loss of the design.

- The electric and Magnetic field was observed on the cross-section of the plane for the design. We can observe the fringing electric fields and the magnetic fields forming a closed loop around the microstrip line using the simulation.