Microwave Laboratory
Experiment-2A
Simulation-2A
Studies on Microstrip

Name: Harshavardhan Alimi
Roll No: 18EC10021

<u>Aim</u>

● Study electric and magnetic field distributions on a cross-sectional plane of a microstrip line.
● Study different sources of loss.

Theory:

Microstrip line is one of the most popular planar guiding structures. It consists of a conducting strip separated from the ground plane by a dielectric layer known as substrate. The microstrip line is always used in TEM mode excitation. Thus, it does not have any cut-off frequency and can be described by a characteristic impedance Z of which mainly depends on the thickness of the substrate and dielectric constant of the substrate. The microstrip line is associated with metal losses,dielectric loss, radiation loss and loss due to power lost into surface waves. Group delay is a measure of phase distortion.It is the actual transit time of a signal through a device under test and is a function of frequency. The lossless transmission line model can be used to calculate the electrical parameters of a quarter-wave transformer. The input impedance of this microstrip line implementation should be equal to the characteristic impedance in order to make the reflection coefficient 0.

Group delay is a measure of phase distortion. It is the actual transit time of a signal through a device under test and is a function of frequency.

$$\frac{W}{d} = \frac{8e^{A}}{e^{2A}-2} \qquad \text{for } W/d < 2,$$

$$= \frac{2}{\pi}\left[B - 1 - \ln(2B-1) + \frac{\varepsilon_r - 1}{2\varepsilon_r}\left\{\ln(B-1) + 0.39 - \frac{0.61}{\varepsilon_r}\right\}\right] \qquad \text{for } W/d < 2,$$

where

$$A = \frac{Z_0}{60}\sqrt{\frac{\varepsilon_r + 1}{2}} + \frac{\varepsilon_r - 1}{\varepsilon_r + 1}\left(0.23 + \frac{0.11}{\varepsilon_r}\right),$$

$$B = \frac{377\pi}{2Z_0\sqrt{\varepsilon_r}}.$$

- **<u>Microstrip-line:</u>**

<u>schematic:</u>

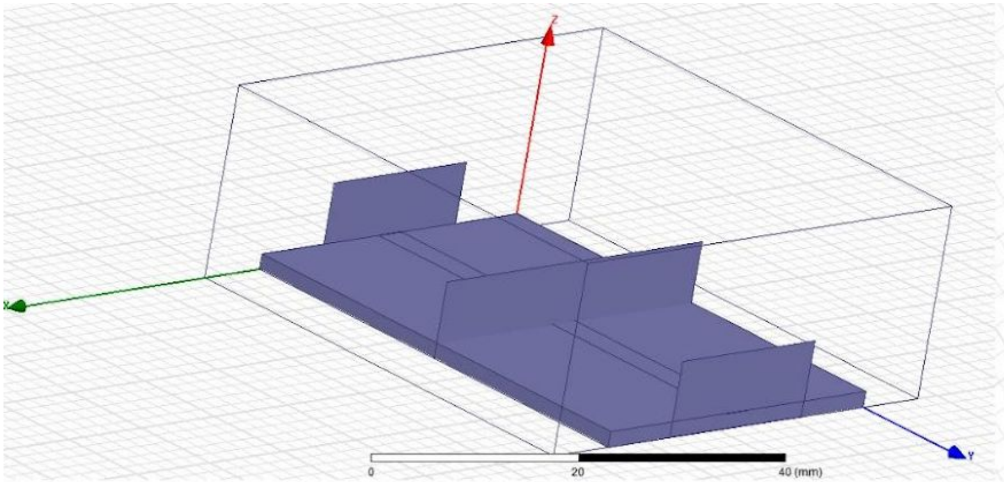


Fig.1

Link for the microstrip line simulated HFSS file:
https://drive.google.com/file/d/1doIdZEZyFyq1VeTUex1Qvrby81i9oQvU/view?usp=sharing

<u>Fields:</u>

A:vector_Electric Field:

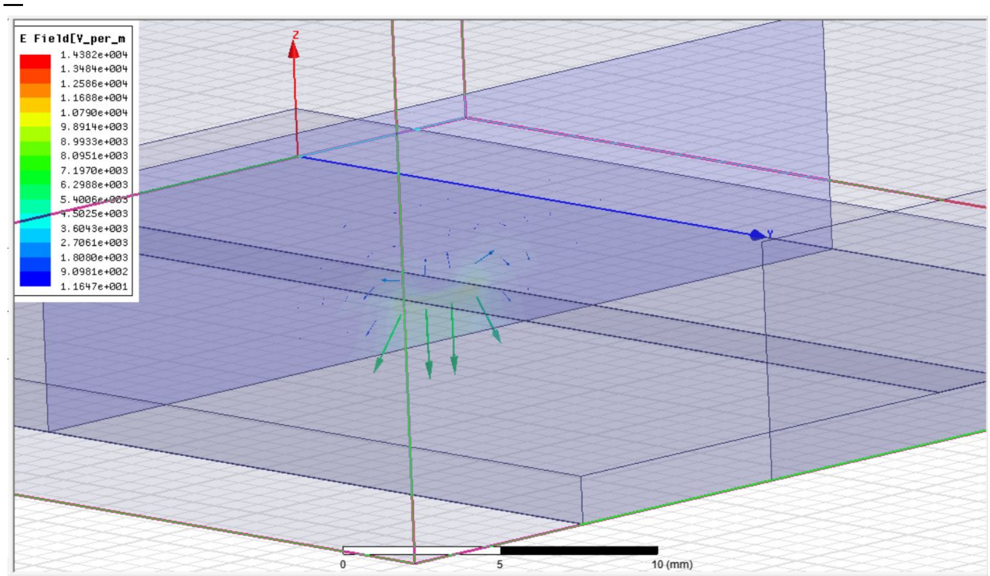


Fig.2

B:mag_Electric Field:

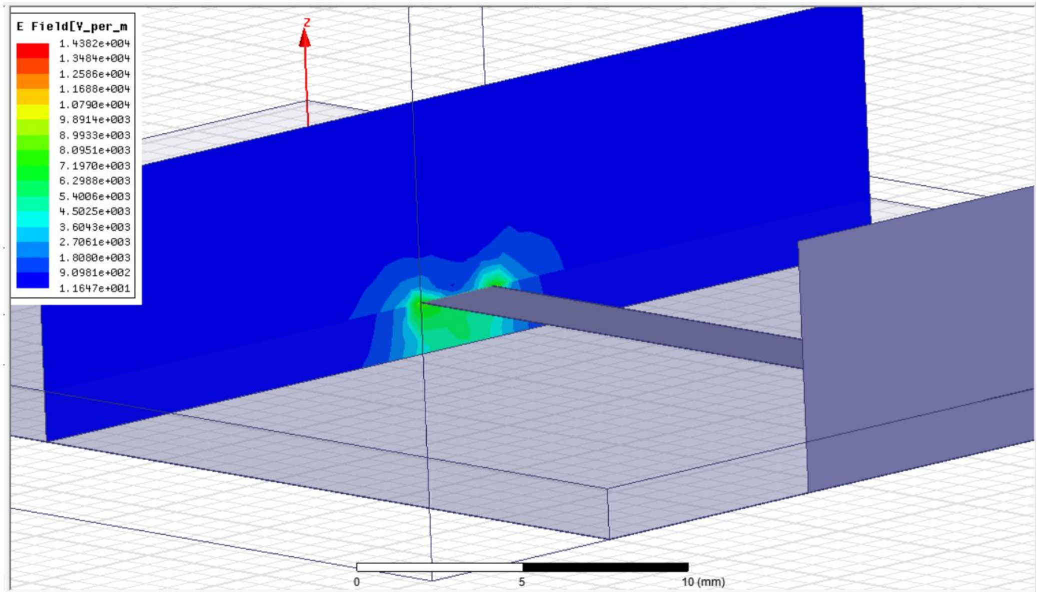


Fig.3

C:vector_Magnetic Field:

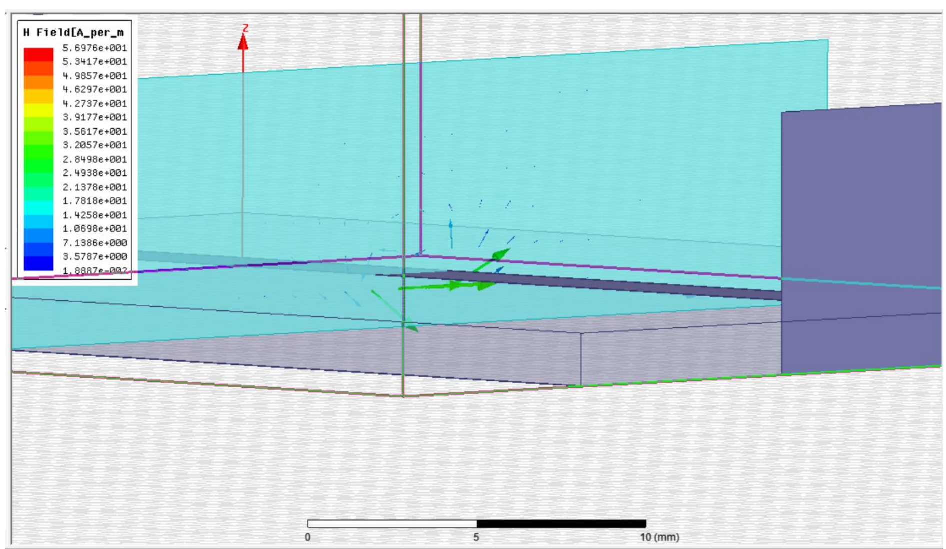


Fig.4

D:mag_Magnetic Field:

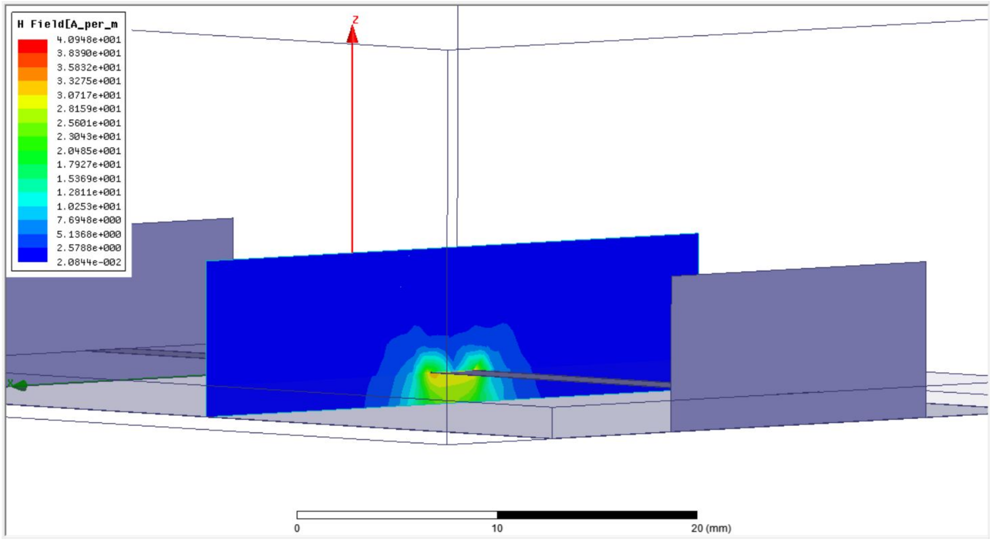


Fig.5

Link for simulations when metal is PEC & tan(delta)=0:
https://drive.google.com/file/d/1AkXbSeuJZxDbtjnQQbxxnjSzjyvHpg0q/view?usp=sharing

Link for simulation when metal is PEC=0:
https://drive.google.com/file/d/1LaBf_x4kCF823mQAX07ZPUXzR2jlzWJZ/view?usp=sharing

Plots:

1.S(1,1) in dB vs Freq:-

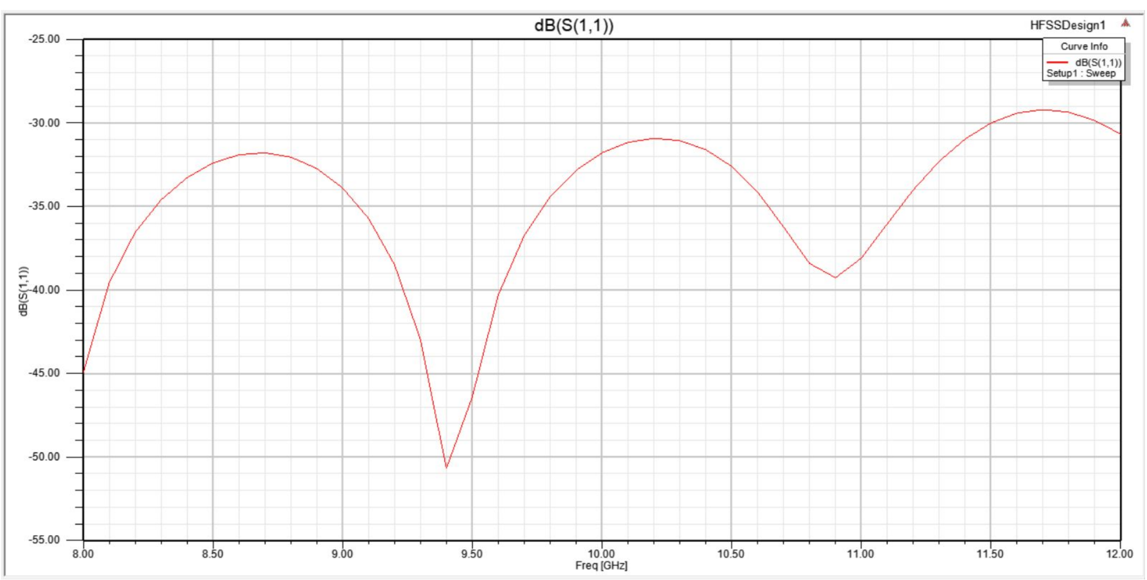


Fig.6

2.S(2,1) in dB vs Freq:-

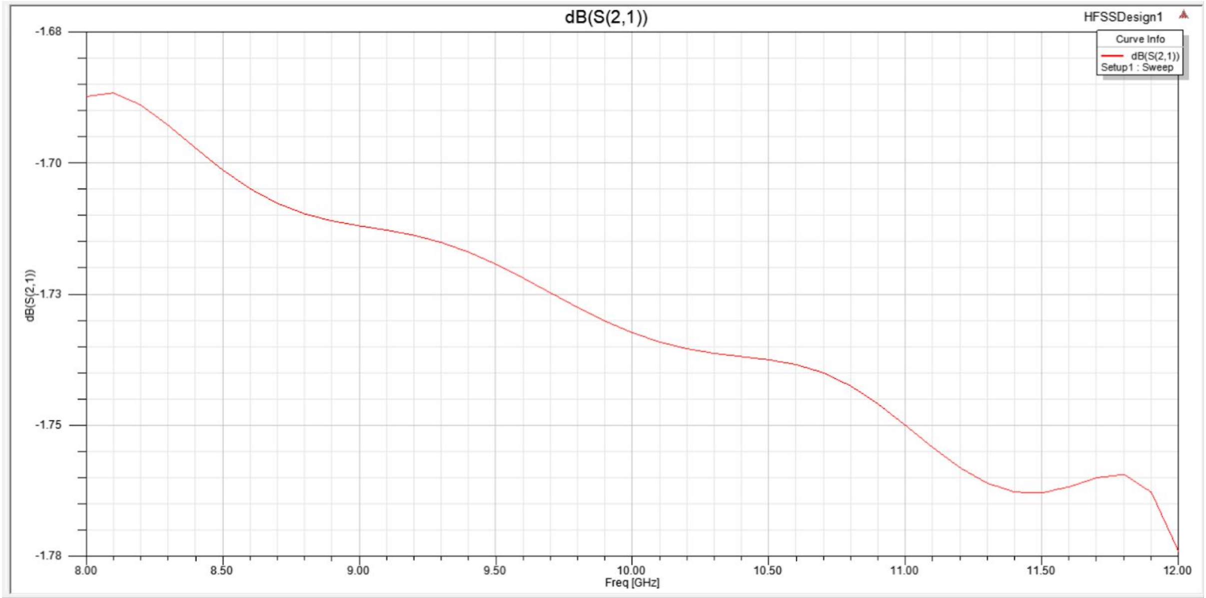


Fig.7

3.ang(S(2,1)) in rad vs Freq:-

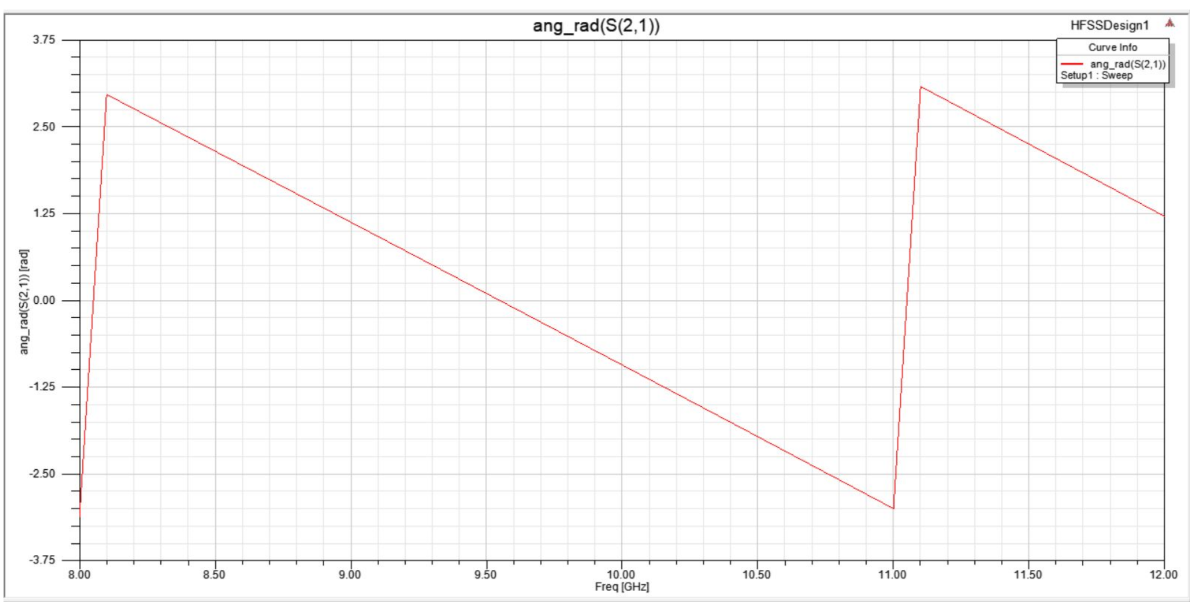
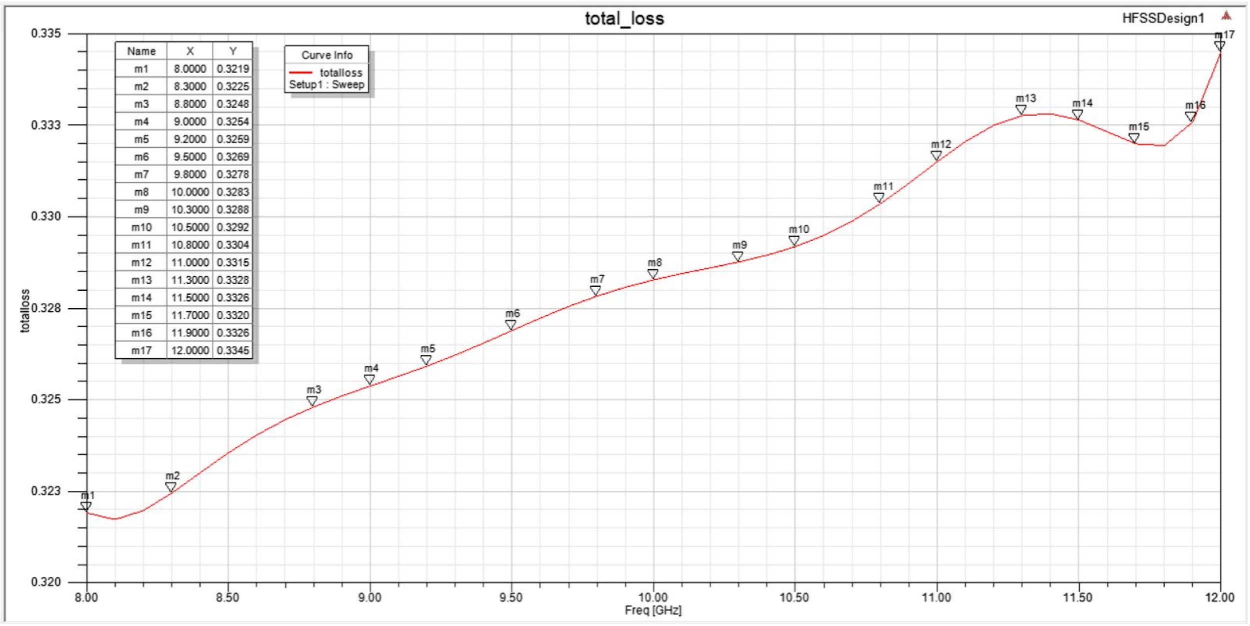


Fig.8

4.Total loss vs Freq:-

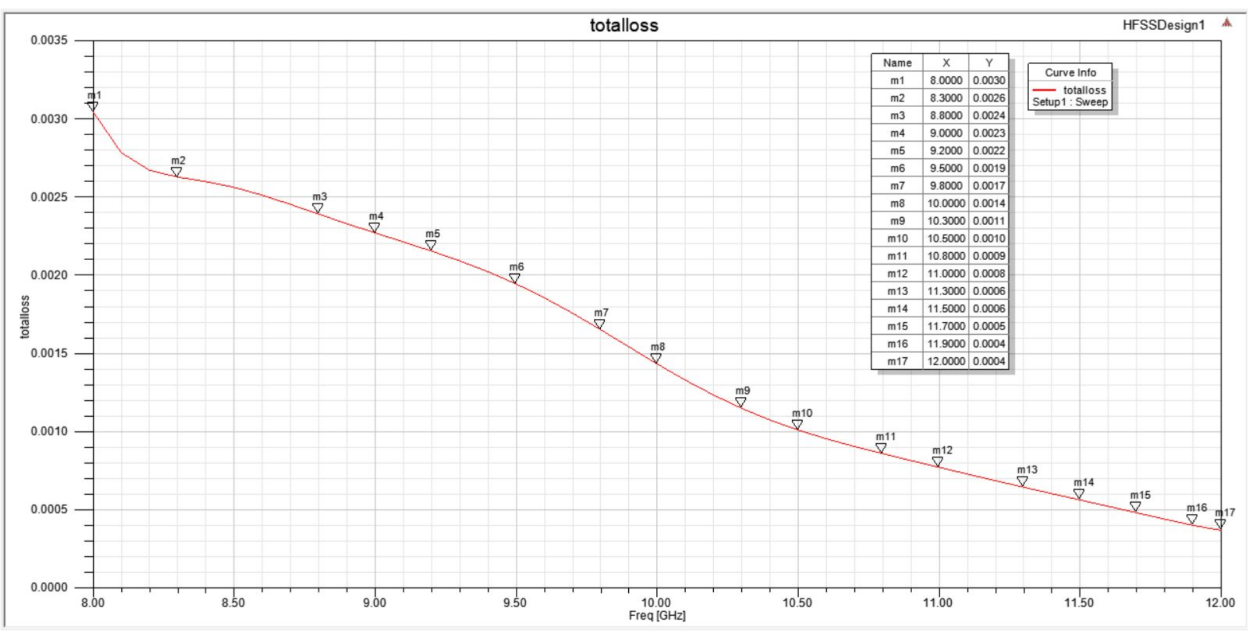
Total loss=Metal loss+Dielectric loss+Radiation loss+Surface loss



Name	X	Y
m1	8.0000	0.3219
m2	8.3000	0.3225
m3	8.8000	0.3248
m4	9.0000	0.3254
m5	9.2000	0.3259
m6	9.5000	0.3269
m7	9.8000	0.3278
m8	10.0000	0.3283
m9	10.3000	0.3288
m10	10.5000	0.3292
m11	10.8000	0.3304
m12	11.0000	0.3315
m13	11.3000	0.3328
m14	11.5000	0.3326
m15	11.7000	0.3320
m16	11.9000	0.3326
m17	12.0000	0.3345

Fig.9

5.Radiation loss+Surface loss vs Freq:-



Name	X	Y
m1	8.0000	0.0030
m2	8.3000	0.0026
m3	8.8000	0.0024
m4	9.0000	0.0023
m5	9.2000	0.0022
m6	9.5000	0.0019
m7	9.8000	0.0017
m8	10.0000	0.0014
m9	10.3000	0.0011
m10	10.5000	0.0010
m11	10.8000	0.0009
m12	11.0000	0.0008
m13	11.3000	0.0006
m14	11.5000	0.0006
m15	11.7000	0.0005
m16	11.9000	0.0004
m17	12.0000	0.0004

Fig.10

6.dielectric loss+Radiation loss+Surface loss vs Freq:-

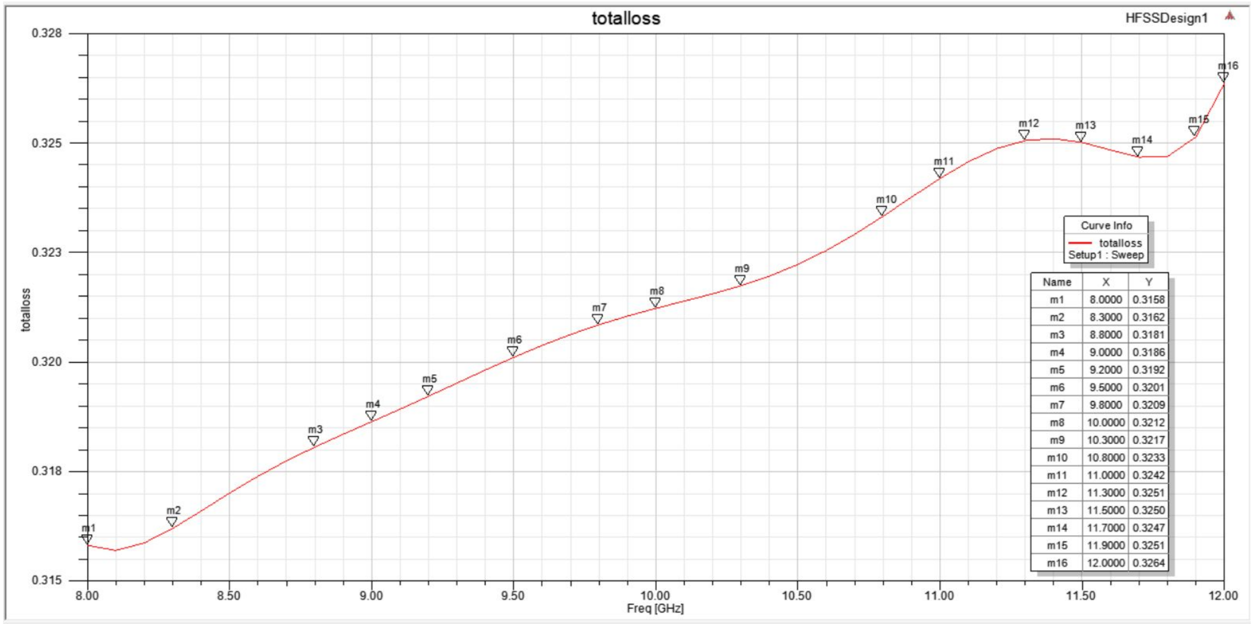


Fig.11

7.Dielectric loss vs Freq:-

Fig.12

8.Metal loss vs Freq :-

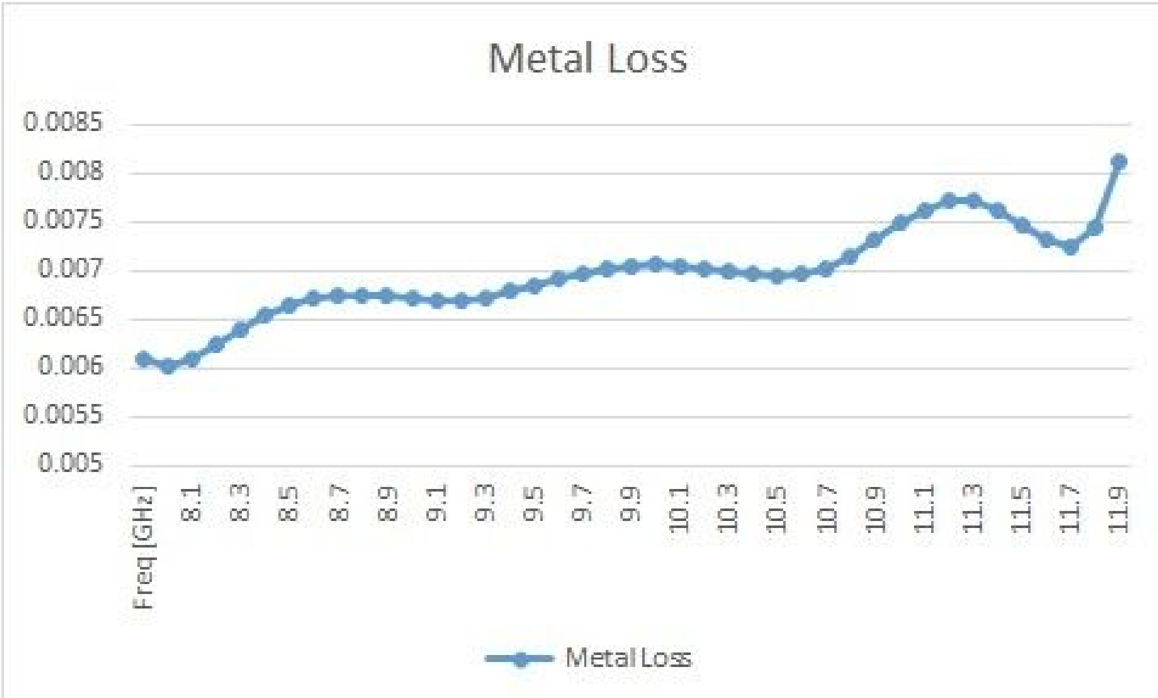


Fig.13

9.beta vs Freq:-Dispersion Diagram

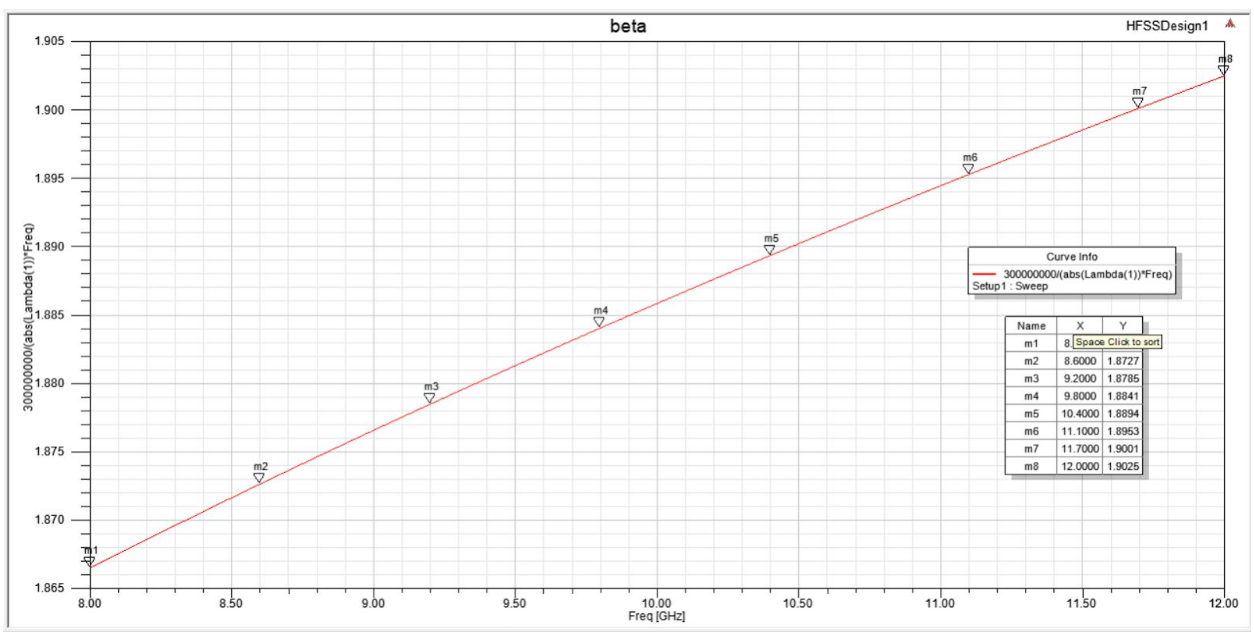


Fig.14

10.Group delay vs Freq:-

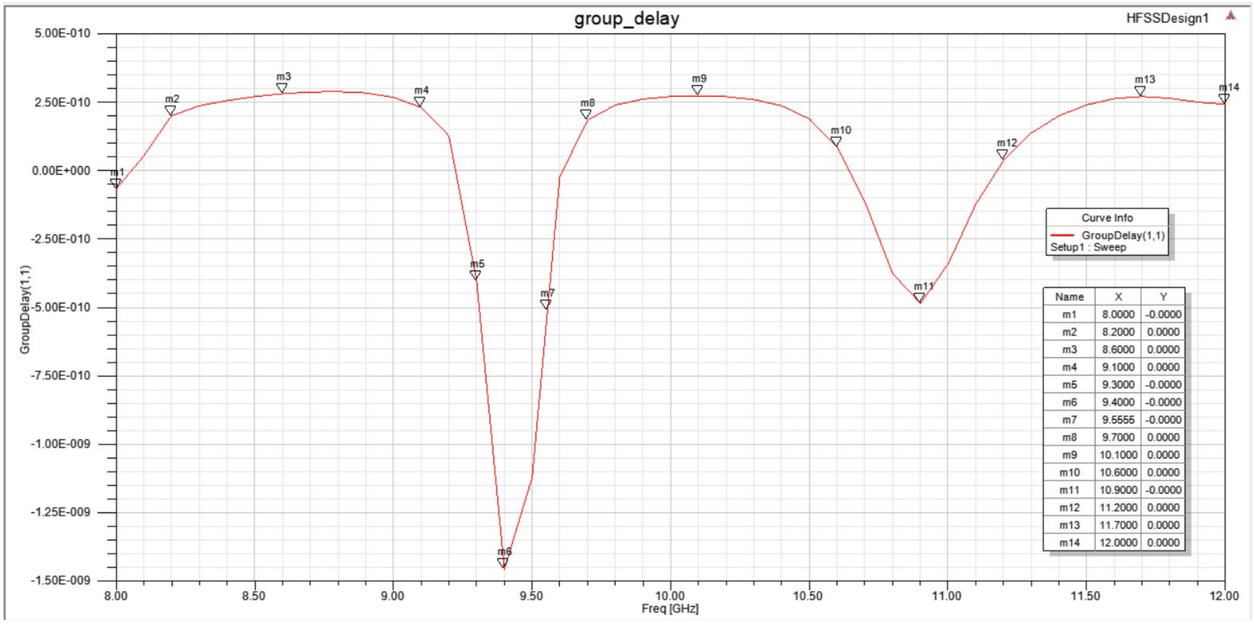


Fig.15

Calculations:

Total loss=Metal loss+Dielectric loss+Radiation loss+Surface loss

Freq [GHz]	Dielectric loss+rad	Radiation loss	total loss	Metal Loss	Dielectric loss
8	0.315820336	0.003043901	0.32191612	0.006095784	0.312776434
8.1	0.315703809	0.00278223	0.32173324	0.006029429	0.312921579
8.2	0.315874807	0.00267015	0.3219781	0.006103294	0.313204657
8.3	0.3162047	0.002626424	0.32245196	0.006247263	0.313578275
8.4	0.316602838	0.002597795	0.32300755	0.006404707	0.314005044
8.5	0.317010879	0.002560716	0.32355259	0.006541709	0.314450162
8.6	0.317396039	0.002510646	0.32404019	0.006644147	0.314885393
8.7	0.317745574	0.002451635	0.32445566	0.006710082	0.315293939
8.8	0.318061635	0.002389566	0.32480477	0.006743131	0.315672069

8.9	0.318355287	0.002328536	0.32510449	0.006749202	0.316026751
9	0.318640139	0.002269744	0.32537627	0.006736132	0.316370395
9.1	0.318927046	0.002212109	0.32564166	0.006714619	0.316714937
9.2	0.319221011	0.002153377	0.3259193	0.006698293	0.317067633
9.3	0.319520607	0.002090839	0.32622126	0.006700655	0.317429768
9.4	0.319819517	0.002021688	0.32654889	0.006729371	0.317797829
9.5	0.320109194	0.00194351	0.32689158	0.006782389	0.318165683
9.6	0.320381471	0.001855015	0.32723108	0.006849612	0.318526455
9.7	0.320630322	0.001756652	0.32754876	0.006918434	0.318873669
9.8	0.320852816	0.001650779	0.32783128	0.006978465	0.319202038
9.9	0.321049742	0.001541248	0.32807287	0.007023132	0.319508494
10	0.321226116	0.001432573	0.32827534	0.007049221	0.319793543
10.1	0.321391372	0.001328989	0.32844741	0.007056042	0.320062383
10.2	0.321558831	0.001233727	0.32860383	0.007045001	0.320325104
10.3	0.321744215	0.001148679	0.3287639	0.007019684	0.320595535
10.4	0.321963267	0.001074389	0.32894976	0.006986497	0.320888878
10.5	0.322228813	0.001010197	0.32918448	0.006955669	0.321218616
10.6	0.32254784	0.000954479	0.32948945	0.006941613	0.321593362
10.7	0.322919193	0.00090499	0.32987996	0.006960765	0.322014202
10.8	0.323332243	0.000859342	0.33035953	0.00702729	0.322472901
10.9	0.323766573	0.000815529	0.3309141	0.007147531	0.322951044
11	0.324192712	0.000772335	0.33150281	0.007310098	0.323420376
11.1	0.324574341	0.000729405	0.33205742	0.007483084	0.323844937
11.2	0.324872654	0.000686942	0.33250001	0.007627356	0.324185712
11.3	0.325053353	0.000645237	0.33276317	0.007709817	0.324408116
11.4	0.325096367	0.000604292	0.33280641	0.007710047	0.324492075
11.5	0.325007947	0.000563772	0.332633	0.007625056	0.324444175
11.6	0.324834077	0.000523206	0.33230886	0.007474786	0.32431087

11.7	0.324673693	0.000482301	0.33198692	0.007313228	0.324191392
11.8	0.324692476	0.000441269	0.33193962	0.00724714	0.324251208
11.9	0.3251404	0.000401741	0.33258468	0.00744428	0.324738659
12	0.326368045	0.000369826	0.33449425	0.008126206	0.325998219

Discussion:-

Microstrip line:

- In this experiment, we simulated a segment of microstrip line and studied the various field distributions and different losses associated with a microstrip line.
- A microstrip line is always used in TEM mode excitation. More accurately it can be said to be operated in quasi-TEM mode as it has infinitesimal components of E and H fields in the direction of propagation.
- As it operates in TEM mode it has zero cutoff frequency and can be characterized by its characteristic impedance.
- The E and H field distribution is mainly confined between the metal line and the ground plane with can be observed from the fig.2 and fig.4
- The magnitude of E and H fields is also maximum in the region between the metal line and the ground plane.From fig.2 we can see that the E field lines are perpendicular to metal line and the ground plane and fringing of field line at the edges of the metal line can also be observed.
- The H fields are concentric and encircle the metal line and are perpendicular to the E field lines as observed in fig.4.
- An imaginary plane bisecting the metal line can be considered as a perfect magnetic wall as the $H_{tangential} = 0$ along this plane.
- The microstrip line has three main sources of loss which are:
    - Metal loss: Due to finite conductivity of the metal line.
    - Dielectric loss: Due to non-zero conductivity of the dielectric substrate.
    - Radiation Loss: Due to the open structure of the microstrip line.
- .In fig.9 we plotted the total loss. Then we made the metal lines as PEC and made conductivity of the dielectric as 0 thereby making metal loss and dielectric loss equal to 0 and plotted the radiation loss in fig.10.
- Then we calculated dielectric+radiation loss by keeping metal lines as PEC(Fig.11). Subtracting radiation loss from it we got dielectric loss in fig.12.
- Subtracting dielectric+radiation losses from total loss we got metal loss as plotted in fig.13.
- We observed all components of the losses to increase with frequency except radiation losses.
- Finally we plotted a dispersion diagram in fig.14 which can be seen as a straight line with positive slope. We also plotted the group delay as a function of frequency in fig.15.