Microwave lab
Simulation:1
STUDIES ON RECTANGULAR WAVEGUIDE

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OBJECTIVE:

- Study standing wave distribution inside a waveguide with short-circuit termination.
- Calculation of guide wavelength λ_g and hence plot of dispersion(ω-β plot).

Components:

- Section of an air-filled WR-90 rectangular waveguide:- Dimension: a= 22.86mm, b= 10.16mm and length= 30cm.
- 1 waveport at one end for TE_{10} mode and 2 waveports for TE_{20} mode.
- Other end is terminated by a short circuit- a metal plate for both the modes.

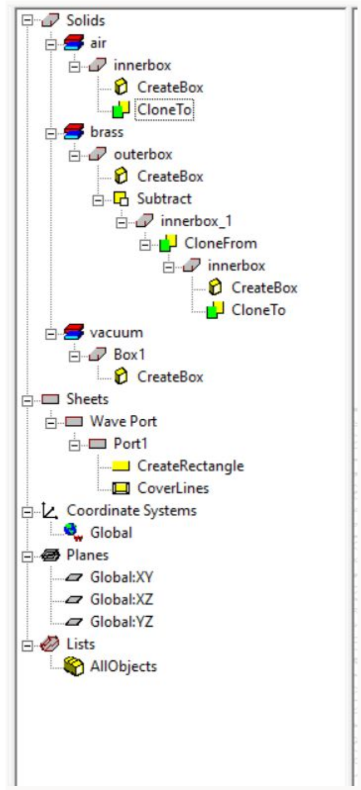
Theory:

A rectangular waveguide is a hollow metal pipe used to carry high power microwave signals. For the TE_{10} mode it has the least attenuation over a given frequency band and behaves as a high pass filter. The cut-off frequency of an air filled waveguide is f_c= c/(2*a), where c= speed of light in air. If we introduce a dielectric material with relative permittivity e_r, cutoff frequency reduces to 1/sqrt(e_r) of its air filled value. The only source of loss in air filled waveguides is conductor loss. If there is a dielectric introduced, there will be additional dielectric losses. If one end of the waveguide is kept open, it will radiate a fraction of the electromagnetic wave from open end.

Simulation:-

TE$_{10}$ mode:

Model description of TE$_{10}$ mode



Link for the simulated model:

Setup-1 in the model:-

https://drive.google.com/drive/folders/1rUK9cYE_sfA0Q5SWWbVH3fT6igNVkQqq?usp=sharing

Fields:

1.vector_Electric field:(TE$_{10}$ mode)

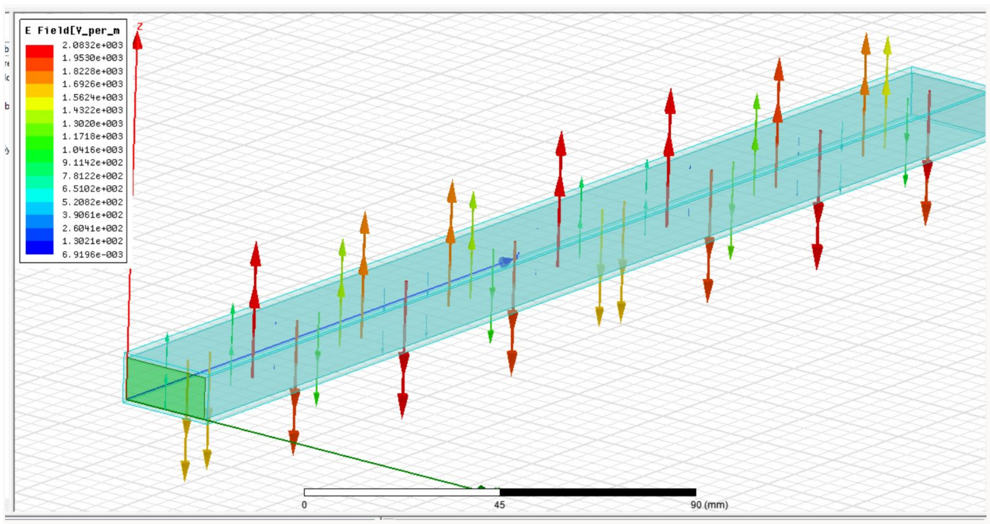


Fig.1

2.vector_Magnetic field:(TE$_{10}$ mode)

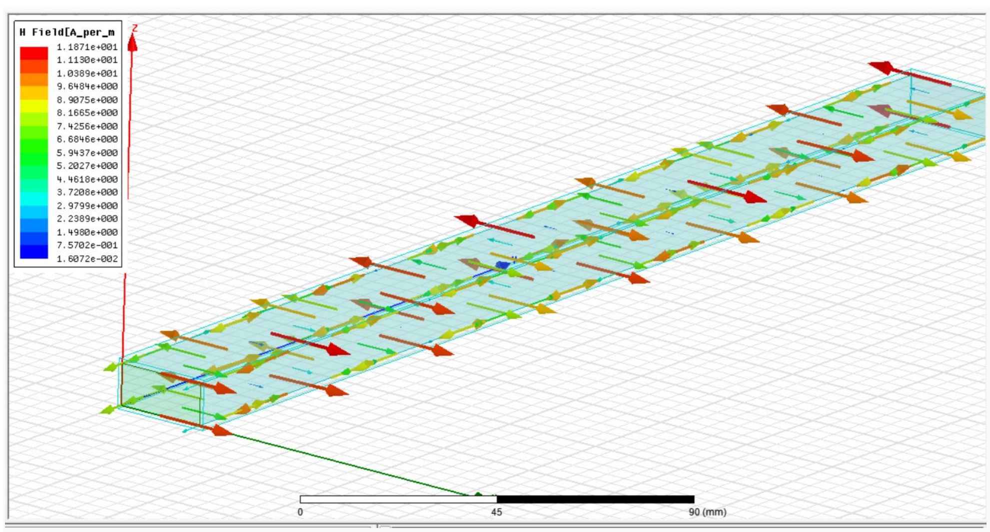


Fig.2

3.magnitude_Electric field:(TE_{10} mode)

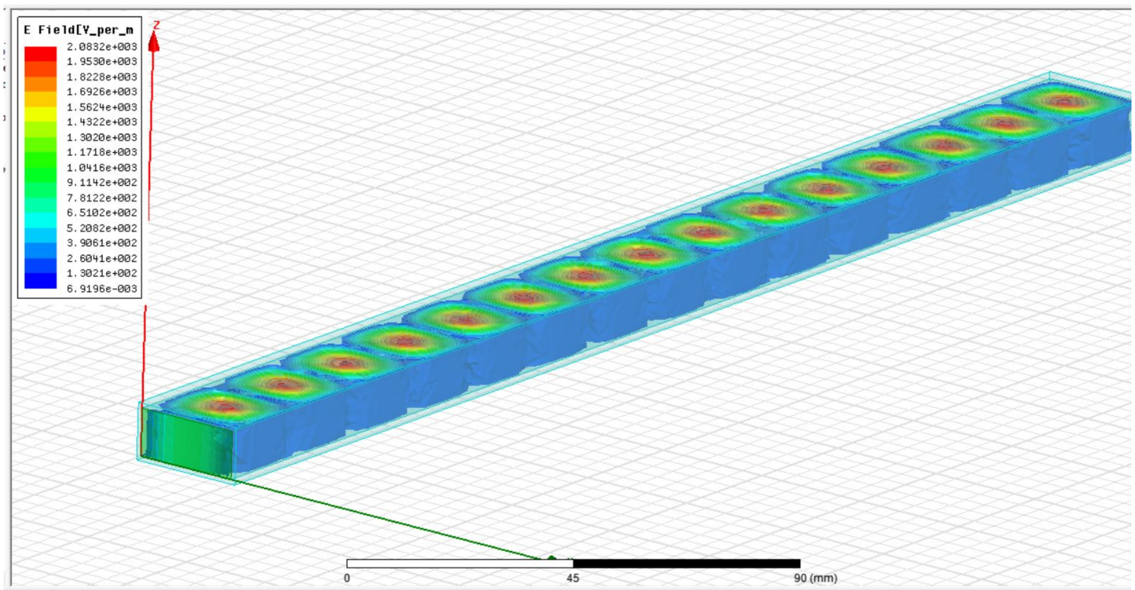


Fig.3

4.magnitude_Magnetic field:(TE_{10} mode)

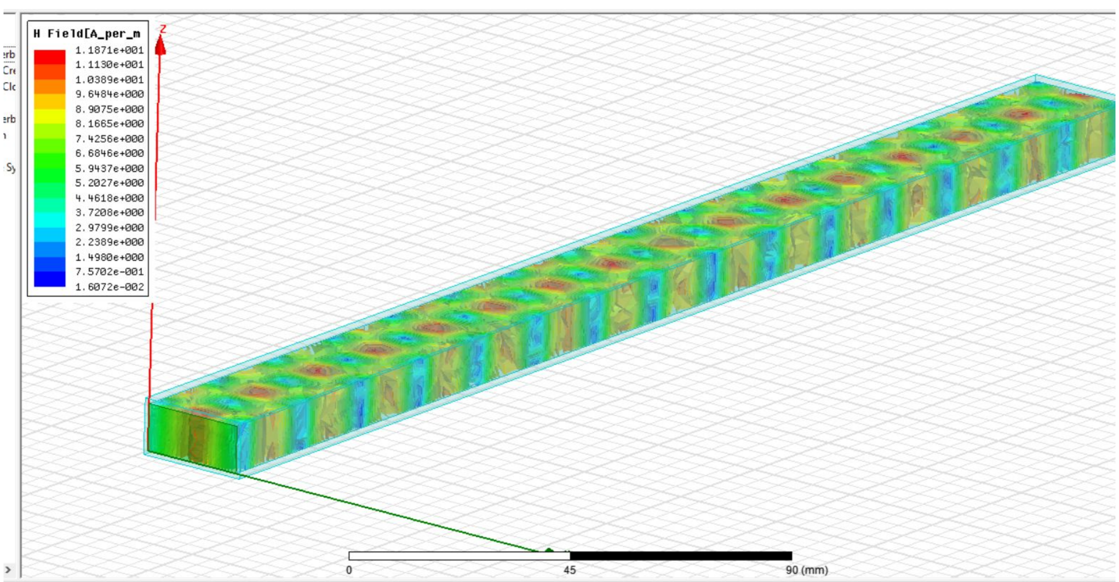


Fig.4

Plots:

1.λ_g VS f_o:(TE_{10} mode)

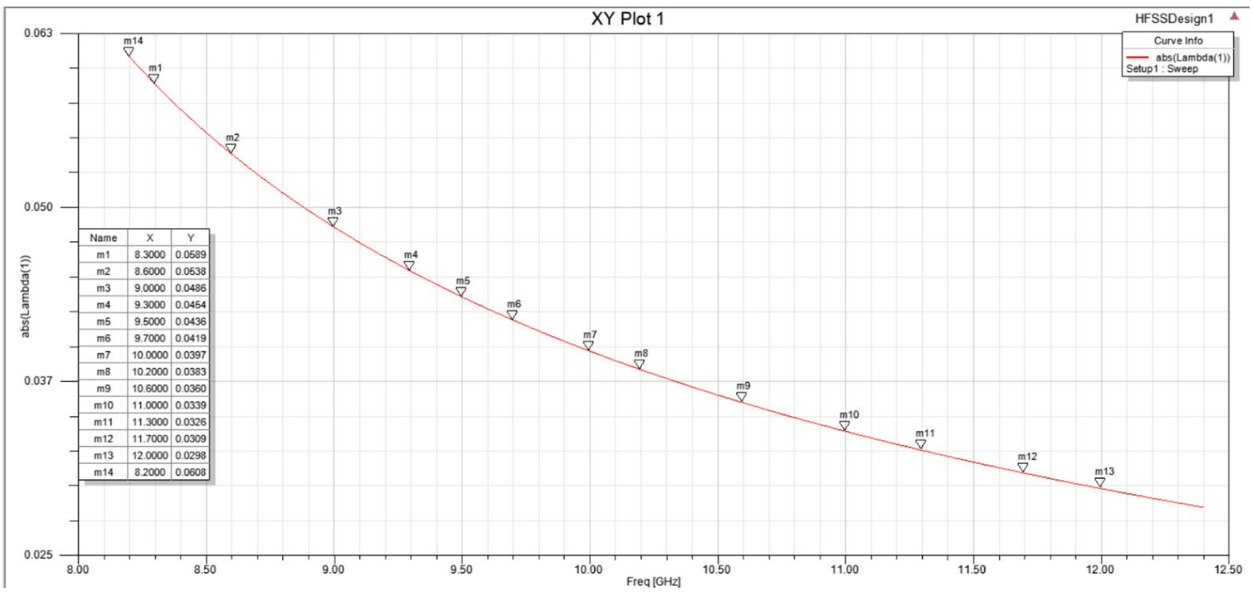


Fig.5

2.β/k_o VS f_o:(TE_{10} mode)-method1

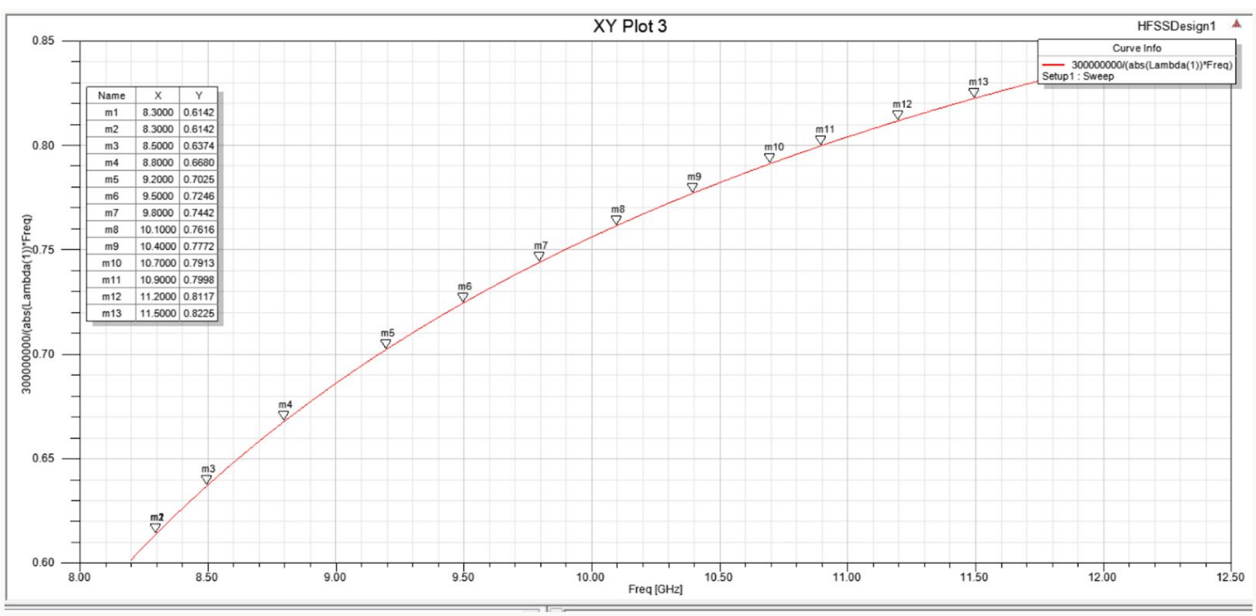


Fig.6

Calculations & result:

Calculations

Plot-1 : λ_g Vs f

TE_{mn} :

$$f_{c_{mn}} = \frac{K_c}{2\pi\sqrt{\mu\epsilon}}\sqrt{\left(\frac{m\pi}{a}\right)^2+\left(\frac{n\pi}{b}\right)^2}$$

Formulae -

$$\lambda_g = \frac{\lambda_0}{\left[1-\left(\frac{\lambda_0}{2a}\right)^2\right]^{1/2}}, \quad \lambda_0 = \frac{c}{f_0}$$

$a = 22.87$ mm

f_0 (GHz)	$\lambda_0 = \frac{c}{f_0}$ (mm)	λ_g (calculated) (mm)	λ_g {simulation} (mm)
8.3	36.143	58.98	58.9
8.6	34.883	53.93	53.8
9.0	33.333	48.68	48.6
9.3	32.258	45.50	45.4
9.5	31.579	43.65	43.6
10	30	39.74	39.7
10.2	29.412	38.40	38.3
10.6	28.302	36.33	36.0
11.0	27.272	33.97	33.9
11.3	26.549	32.60	32.6
11.7	25.641	30.96	30.9
12	25	29.85	29.8

Plot-2 :-

$\left(\frac{\beta}{K_o} \text{ vs } f\right)$

$\lambda_o = \frac{c}{f_o}$

$\boxed{2.a}$ $\Rightarrow k_o = 2\pi/\lambda_o = \frac{2\pi f_o}{c}$

$$\frac{\beta}{K_o} = \frac{2\pi}{\lambda_g} * \frac{\lambda_o}{2\pi} = \frac{\lambda_o}{\lambda_g}$$

$$= \frac{c}{\lambda_g * f_o}$$

(or)

$\boxed{2.b}$

$$\frac{\beta}{K_o} = \frac{im(\gamma)}{2\pi} * \frac{c}{f_o}$$

plot:

3.β/k_o VS f_o:(TE_{10} mode)-method2

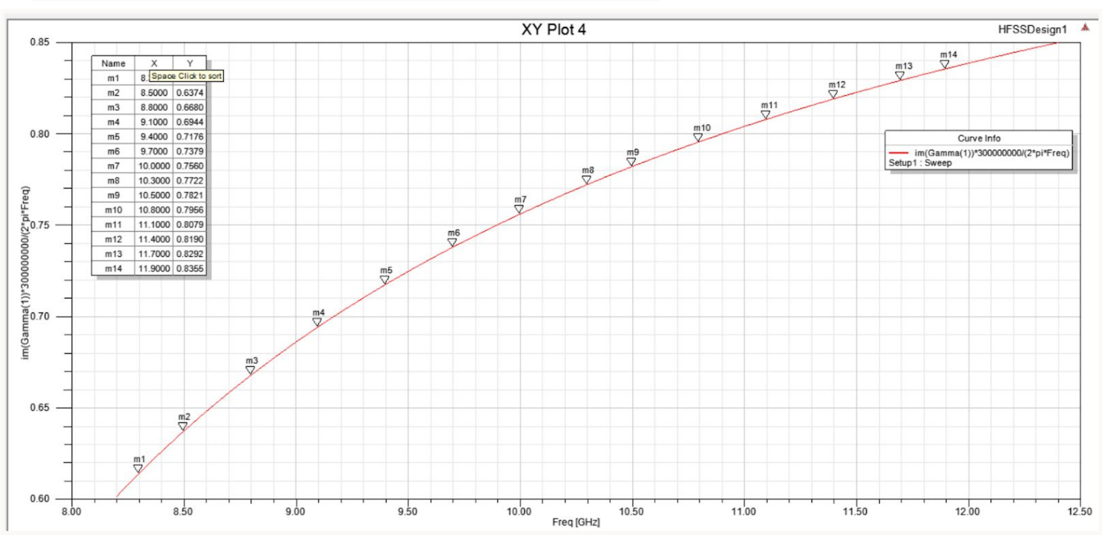
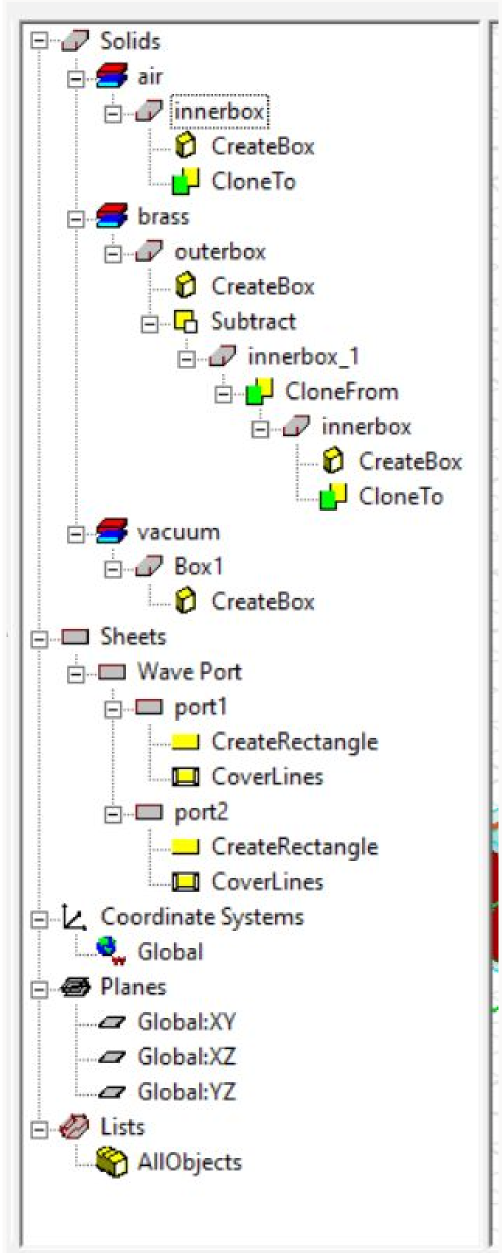


Fig.7

TE_{20} mode:

Model description of TE_{20} mode



Link for the simulated model:

Setup-3 in the model:-

https://drive.google.com/drive/folders/1SOeCV8eLAUE5AX274zmMKjG0E66gQubF?usp=sharing

Fields:

1.vector_Electric field:(TE_{20} mode)

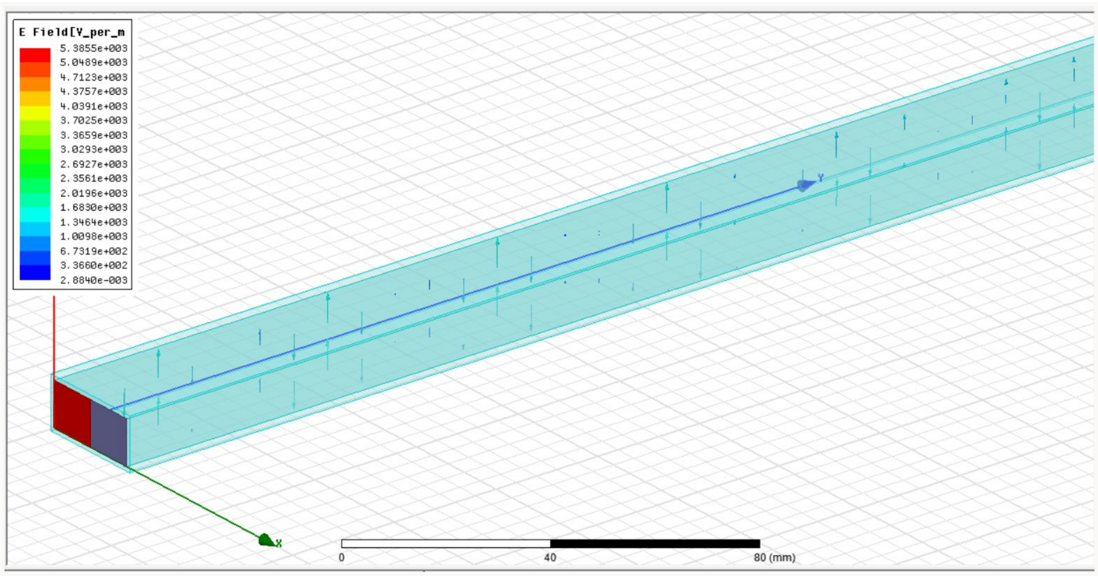


Fig.8

2.vector_Magnetic field:(TE_{20} mode)

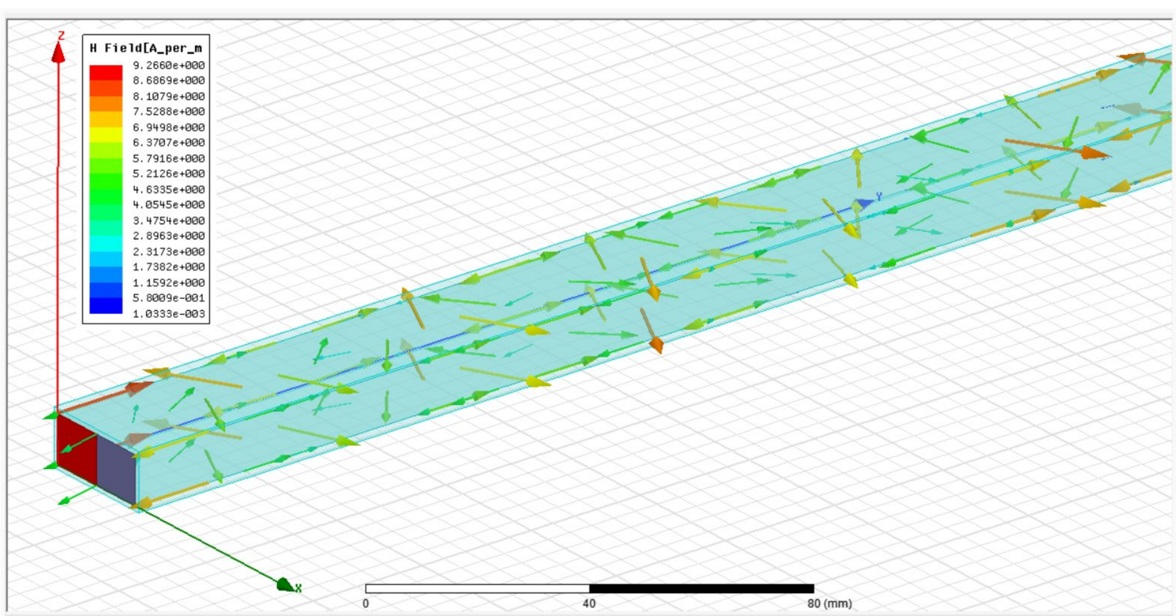


Fig.9

3.mag_Electric field:(TE$_{20}$ mode)

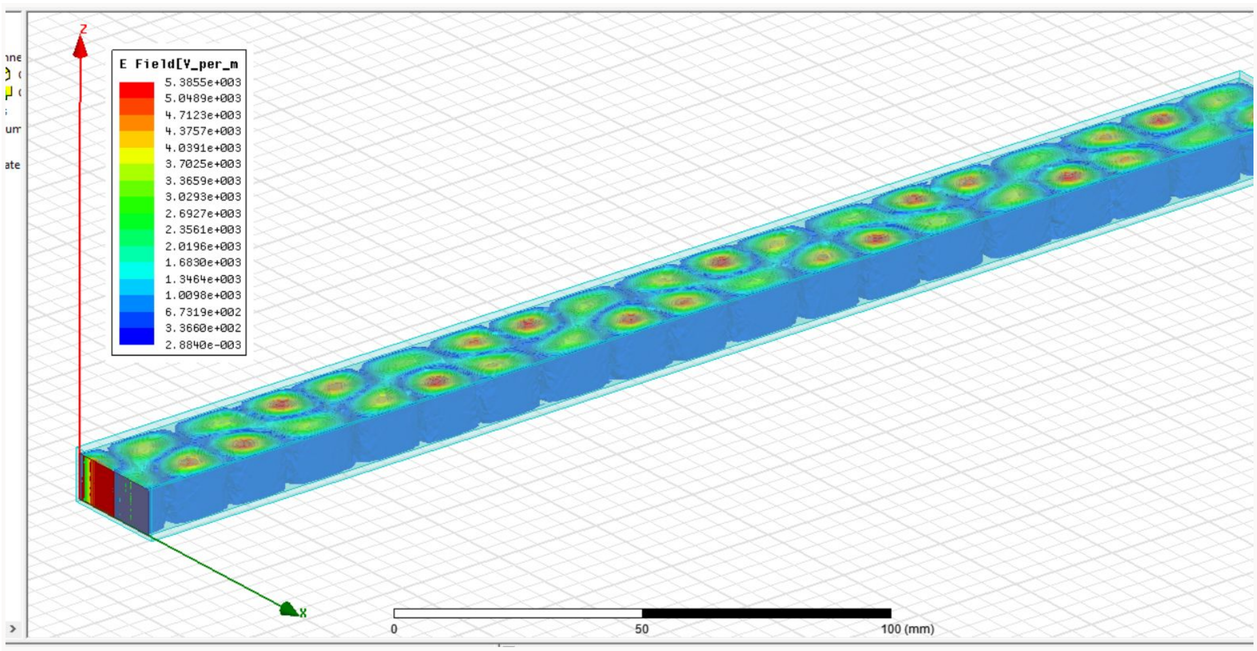


Fig.10

4.mag_Magnetic field:(TE$_{20}$ mode)

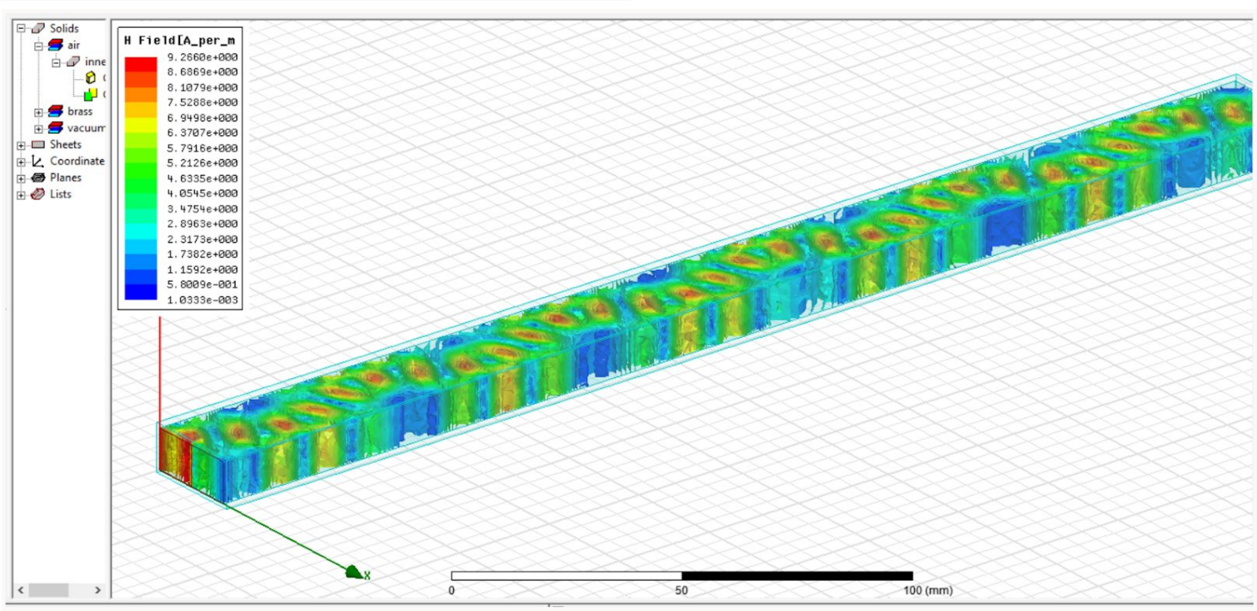


Fig.11

Plots:

1.re(gamma(1)) VS f_o:(TE_{20} mode)

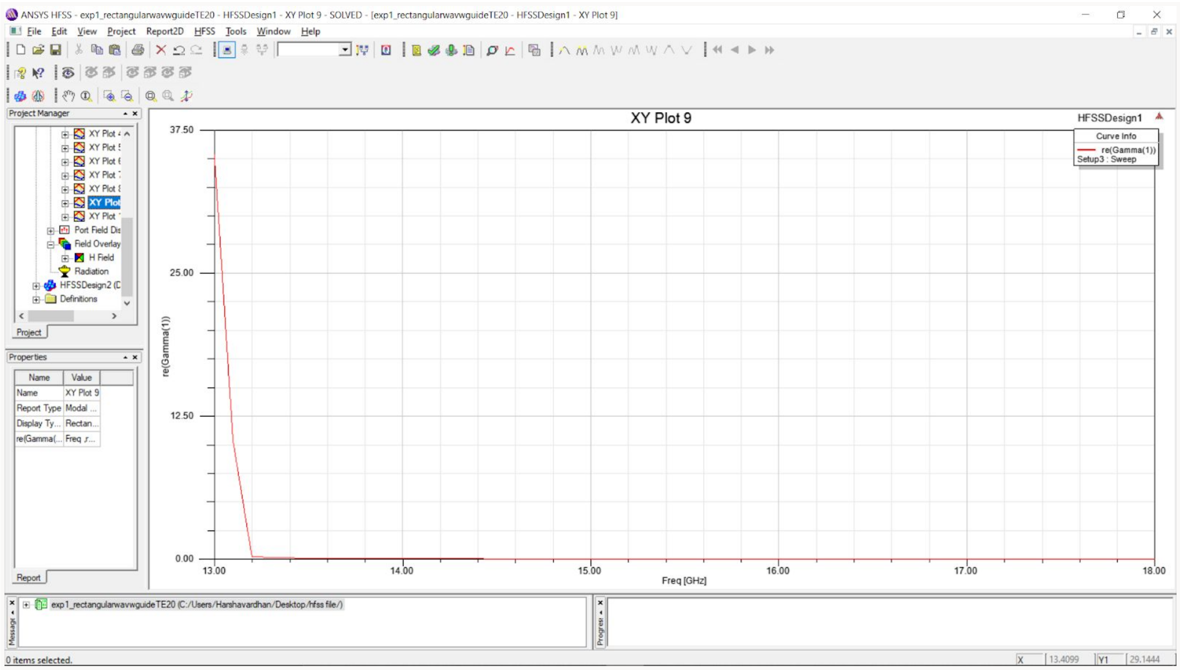


Fig.12

2.re(gamma(2)) VS f_o:(TE_{20} mode)

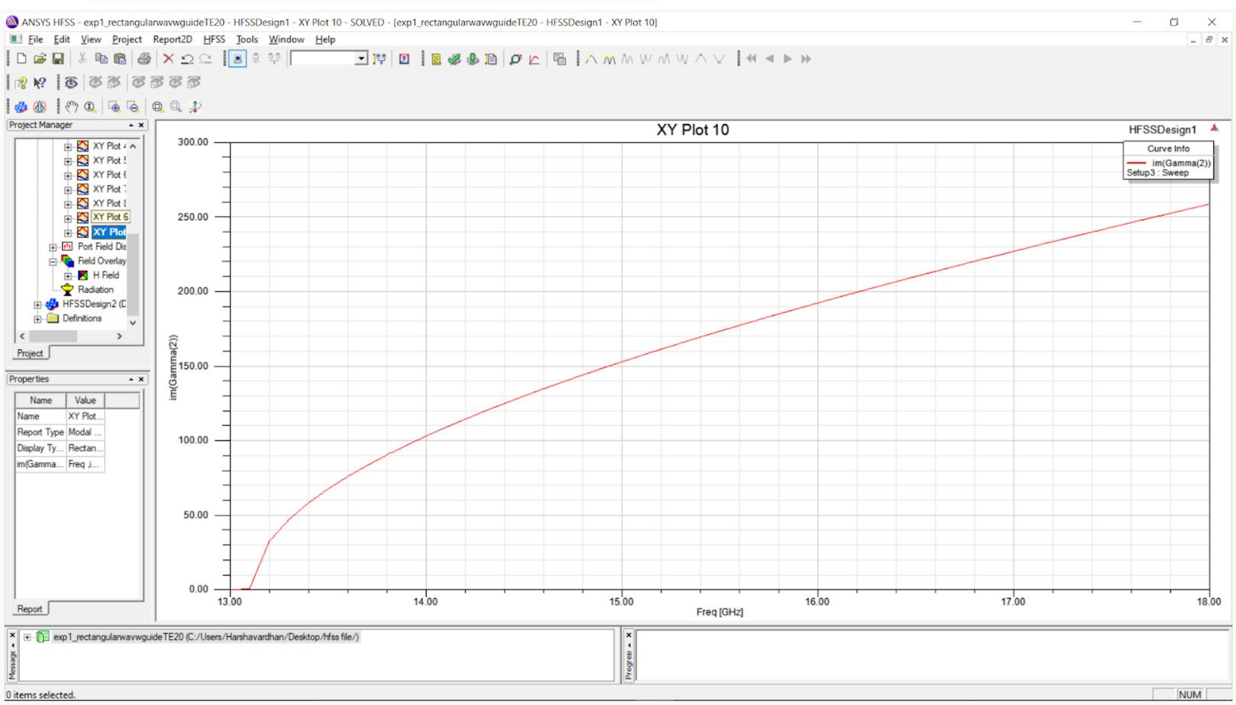


Fig.13

Discussion:

1. In this simulation experiment, we simulated an air-filled segment of closed-ended rectangular waveguide WR-90 and observed the standing wave field distributions pattern inside the waveguide.
2. WR-90 is a rectangular waveguide used in X band transmission having an operating frequency range of 8.2GHz to 12.4GHz.
3. Every rectangular waveguide has a cutoff frequency which depends on the mode of operation and the broadside length of the waveguide.
4. We simulated our waveguide at two different modes, TE10 and TE20 modes.
5. TE10 mode is called the dominant mode and has the lowest cutoff.For WR-90 cutoff frequency of TE10 mode is ($f_c = c/2a$) 6.56 GHz and cutoff frequency for TE20 mode is ($f_c=c/a$) 13.12 GHz.
6. The vector electric field distribution for TE10 mode, as seen in the fig. 1 provided above in the report, we can see that electric field exists only in z-direction which is perpendicular to wave propagation direction which is along the y-direction.(In the fig. 1 provided above electric field is shown only along the middle part of the waveguide because the magnitude of electric field is maximum along this line.)
7. The vector magnetic field distribution is obtained in fig. 2, from which we can see two components of the magnetic field which are Hx and Hy. (y is the direction of propagation of the wave)
8. The maxima in electric field distribution as observed in fig 3. Denoted by red colour are separated by a distance of $\lambda g/2$.
9. We then plotted the dispersion diagram of the waveguide which is a graphical representation of the relationship between frequency and relative wavelength useful in determining the speed of the wave and its dispersion characteristic.
10. From the dispersion diagram, which is provided in fig.6 we can see the ratio of β to ko to be approaching 1 at high frequencies. As for the entire frequency range, the graph is below unity the wave is characterised as a fast wave.11. Then we plotted the field distribution for the TE20 mode, which is available in fig. 8, fig. 9,fig. 10 and fig. 11.
12. The plane passing through the centre of the waveguide in TE20 mode can be assumed as a magnetic wall as normal components of E and H fields and the tangential component of H field is zero. Thus we have just the tangential component of E field.