Presentation on

# Antenna Simulation for 21cm H line

Ashmita Panda
1811042
4th Year Integrated M.Sc.
SPS, NISER

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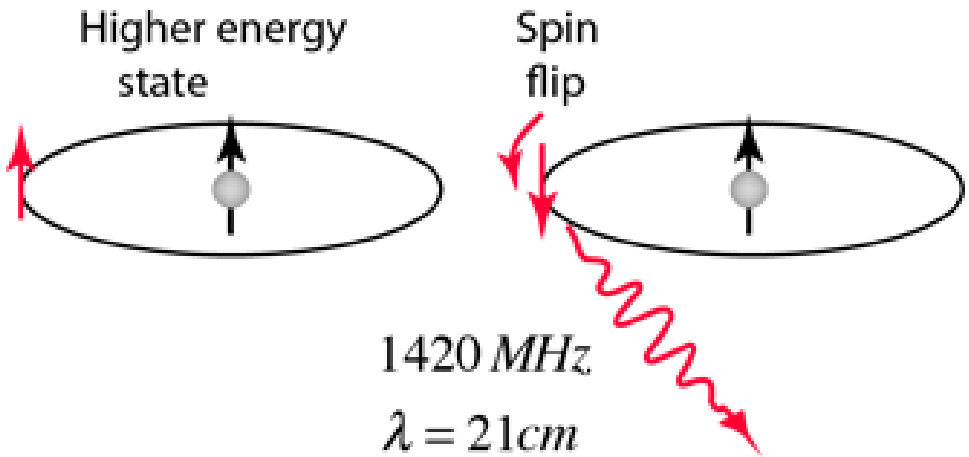
# Outline

# What is the 21cm Hydrogen Line?

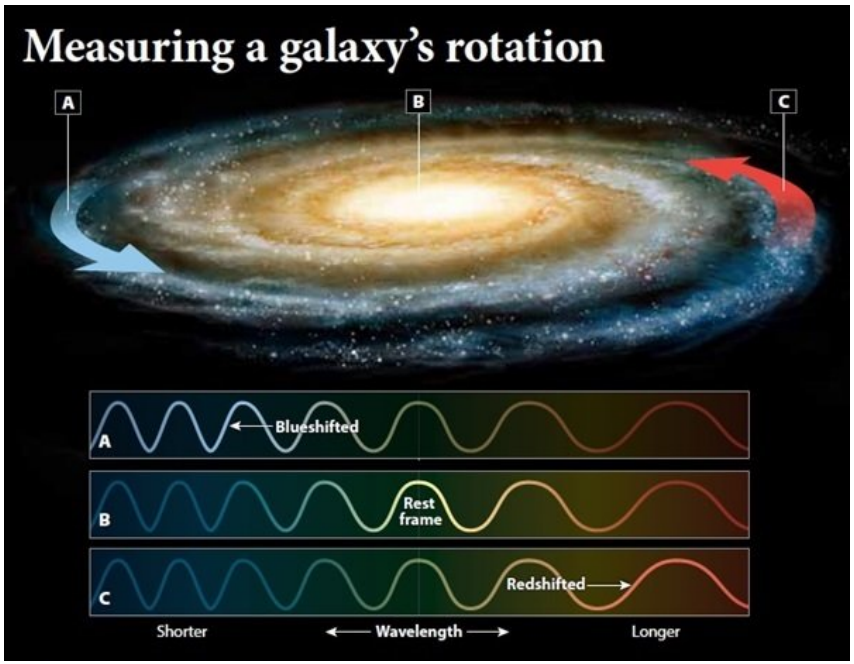
- Neutral hydrogen is made up of an electron and a proton.
- The electron and proton both have half-integer spins.
- Neutral hydrogen can exist in two energy states, one with electron and proton spins parallel, and one with antiparallel.




Source : http://hyperphysics.phy-astr.gsu.edu/hbase/quantum/h21.html

# Importance of the 21cm line

- In Radio Astronomy : The rotation curve of galaxy can be measured by observing the 21cm line received from each line of sight.
- In Cosmology : The "dark ages" of the Universe can be probed by using 21cm line.

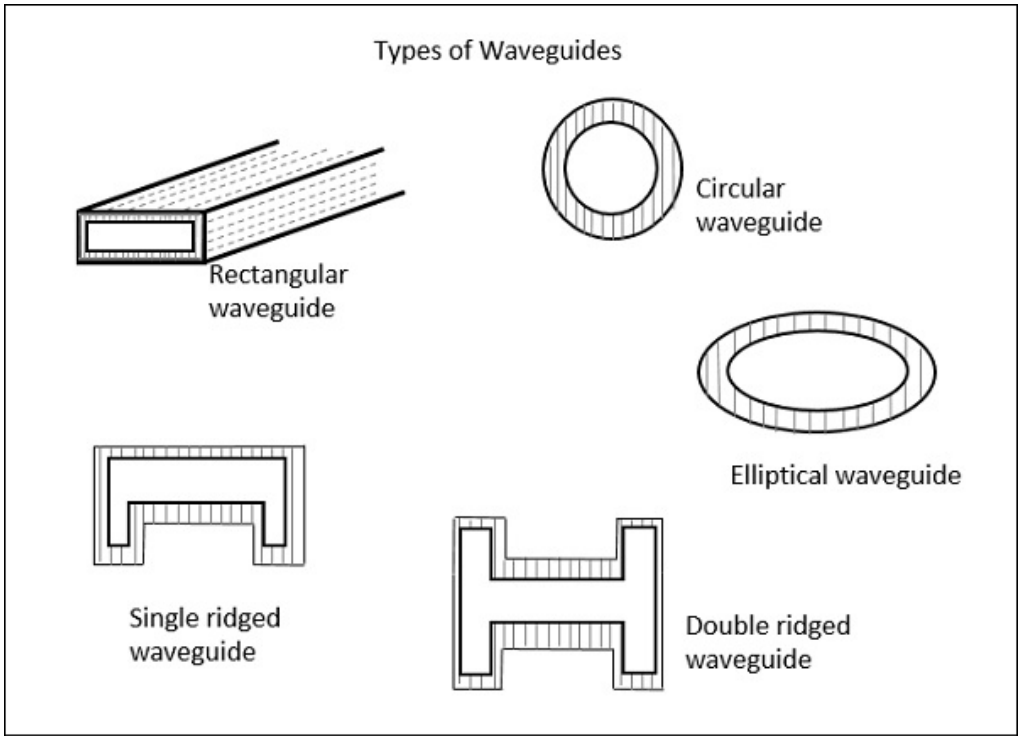



Source : https://physicsopenlab.org/2020/09/08/measurement-of-the-milky-way-rotation/

# Outline

# What are Waveguides?

- A waveguide is a structure which guides waves (like EM and sound waves) in a particular direction with minimal energy loss.
- A hollow metallic tube is used for guiding EM waves.

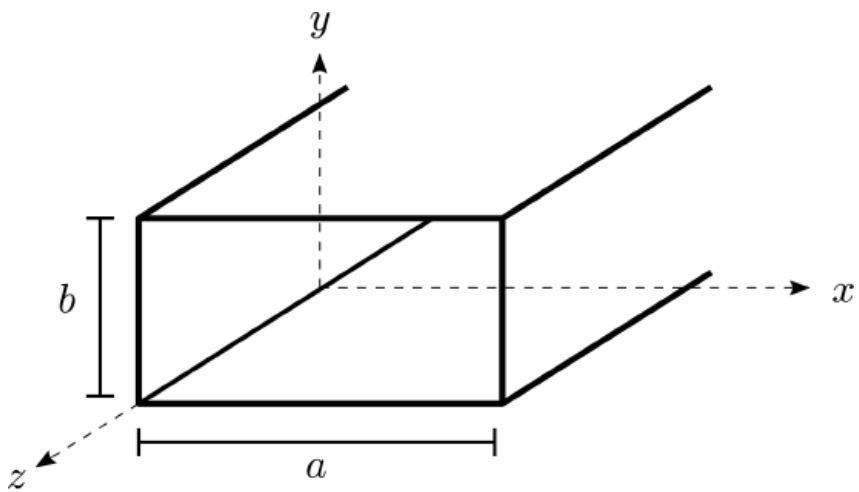



Source :
https://www.tutorialspoint.com/microwave_engineering/microwave_engineering_waveguides.htm

# Rectangular Waveguides

- Rectangular waveguide is one type of waveguide.
- The EM waves will be travelling along the z-direction.
- Thus, the EM wave solutions for Maxwell equations can be separated into longitudinal and transverse waves.

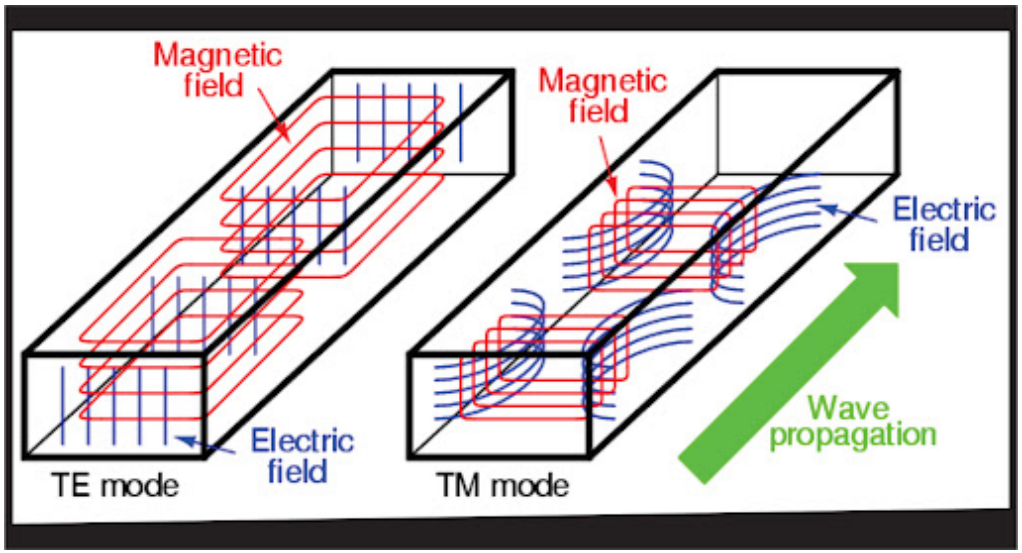
$$E(x, y, z) = E(x, y) \exp(-i\beta z)$$
$$B(x, y, z) = B(x, y) \exp(-i\beta z)$$




Source :
https://www.tutorialspoint.com/microwave_engineering/microwave_engineering_waveguides.htm

# Modes and Field Patterns

- The TE and TM are the two modes which can exist in a rectangular waveguide.
- The TEM mode does not exist.
- The dominant mode of a rectangular waveguide is $TE_{10}$ mode. This mode has the lowest cut-off frequency.




Source : http://www.engineeringdone.com/te-tm-modes/te-tm-modes/

# Outline

# Antenna Parameters

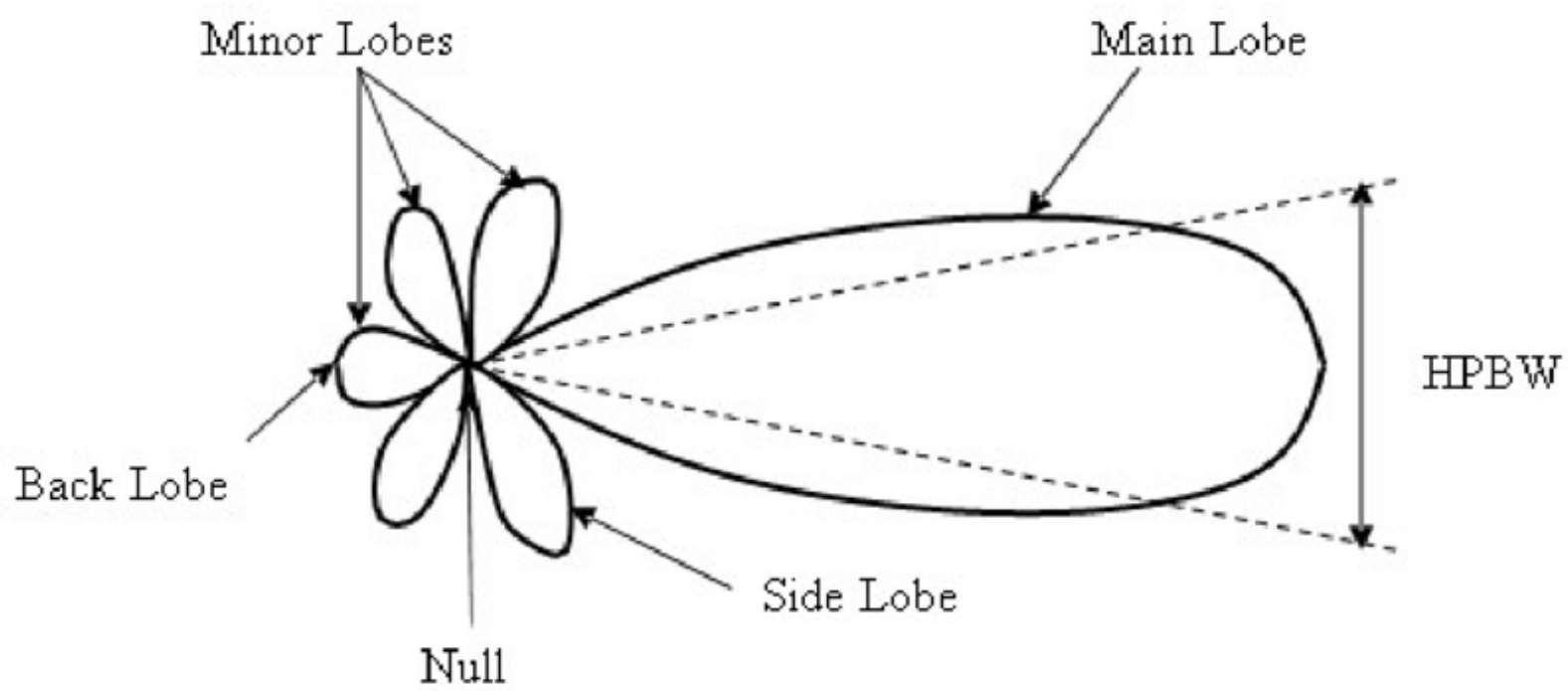
- Bandwidth : It is frequency range over which an antenna functions. Usually, antennas have a lower cut-off frequency, $\omega_c$. For an antenna to function, the frequency of the wave must be greater than the cut-off frequency.
- Radiation Pattern : It is the power radiated by an antenna as a function to angles $\theta$ and $\phi$.
- Three classifications of antennas as per their radiation pattern :
  1. Isotropic : Same power radiated in all directions
  2. Omni-directional : Isotropic in a single plane
  3. Directional : No symmtery, usually a single peak direction

# Antenna Parameters (contd.)

- Field Regions : Fields surrounding an antenna can be divided into three parts.
  1. Far fields : In the region far away from the antenna, the E and B fields donot change shape with distance.
  2. Reactive Near Field : Fields in the immediate vicinity of the antenna. E and B fields are out of phase by 90 degrees.
  3. Radiative Near Field : Fields in the region between reactive near and far fields.
- Directivity : It is a fundamental parameter. It tells us how directed the radiation pattern of an antenna is.
- Gain : It descibes how much power is transmitted by the antenna in the peak directivity direction when compared to an isotropic source.

# Antenna Parameters (contd.)

- Main Lobes, Side Lobes, Null and HPBW :

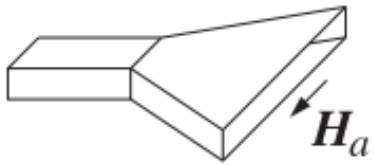



Source : https://www.researchgate.net/figure/Radiation-pattern-of-a-generic-directional-antenna_fig3_335970378

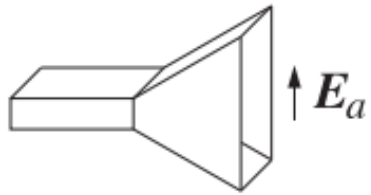
# Outline

# Horn Antenna and its Types

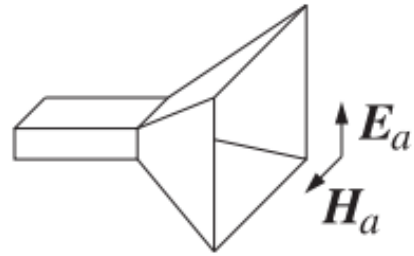
- Horn Antenna is an antenna which consists of a rectangular waveguide which flares out at one end.
- It is a directional antenna.
- There can be different kinds of horn antennas :
  1. H-plane sectoral horn : a side is flared
  2. E-plane sectoral horn : b side is flared
  3. Pyramidal horn : both a and b sides are flared




*H*-plane sectoral horn




*E*-plane sectoral horn

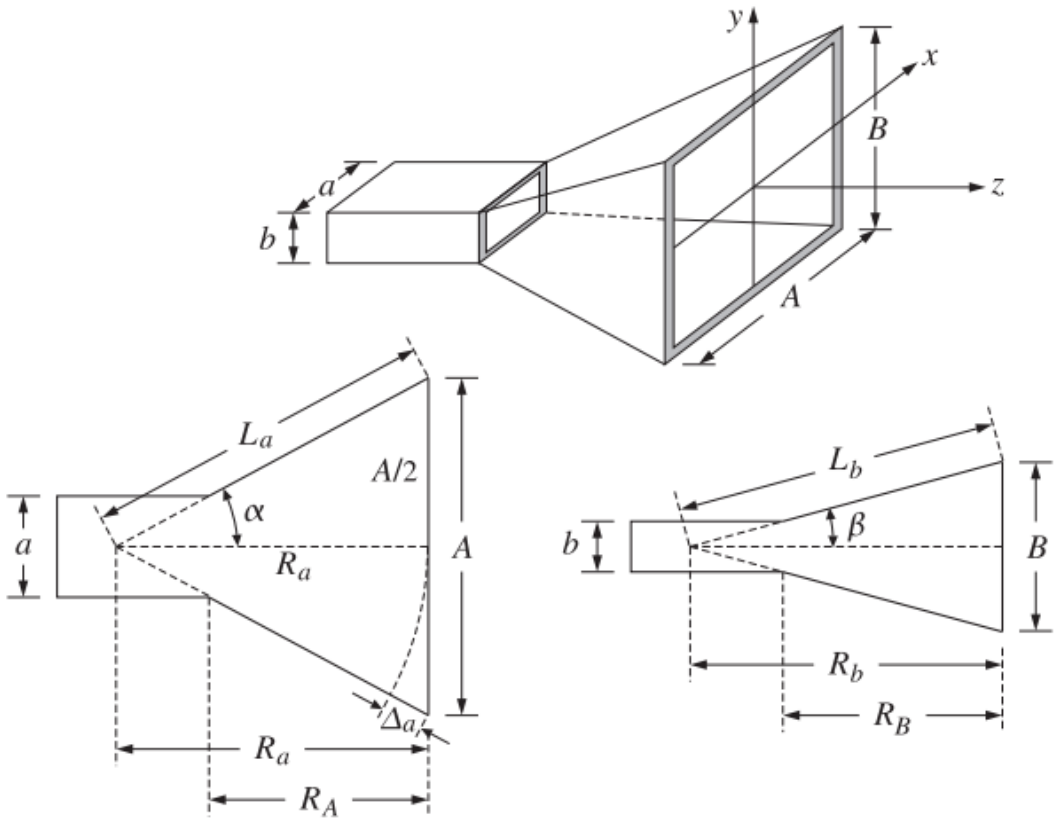



pyramidal horn

Source : `https://www.ece.rutgers.edu/~orfanidi/ewa/ch21.pdf`

# Pyramidal Horn Antenna

- For our setup, we are using a pyramidal horn antenna.
- We power it with a quarter wavelength monopole antenna.




Source : https://www.ece.rutgers.edu/~orfanidi/ewa/ch21.pdf

# Horn Parameters

- The frequency (and wavelegth) we wish to detect :

$$f = 1.4204GHz \qquad \Longrightarrow \quad \lambda = 21cm$$

- Choosing cut-off frequency for dominant $TE_{10}$ mode :

$$f_c = 1.0GHz \qquad \Longrightarrow \quad \lambda_c = 30cm$$

- This gives us the value of $a = \frac{\lambda_c}{2} = 15cm$ and we choose $b = \frac{a}{2} = 7.5cm$.
- The optimum parameters of the flare are calculated using *hopt* function in Octave/Matlab library.

# Horn Parameters (contd.)

- To find the parameters of the flare, we define two parameters :

$$\sigma_a^2 = \frac{A^2}{2\lambda R_a}$$
$$\sigma_b^2 = \frac{B^2}{2\lambda R_b}$$

- By taking different values of $\sigma_a$ and $\sigma_b$ we can find the corresponding flare parameters.
- Using these values along with the waveguide dimensions and required gain, we can obtain the dimensions of the flare.

[A,B,R,err]=*hopt*[G,a,b,$\sigma_a$,$\sigma_b$,N]

# Outline

# Antenna 1

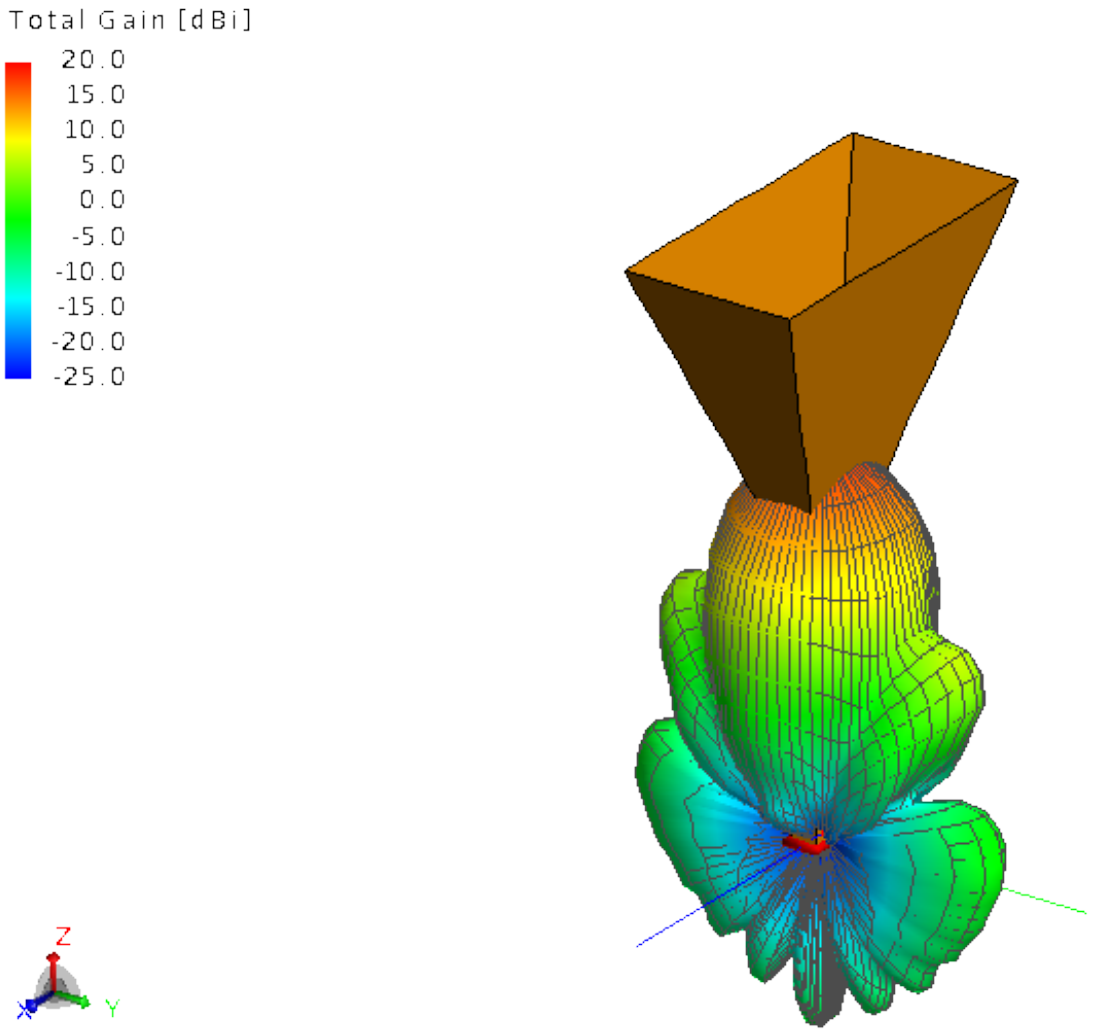
- For this antenna I chose :

$$G = 18dB \qquad \sigma_a = 1.475 \qquad \sigma_b = 0.74$$

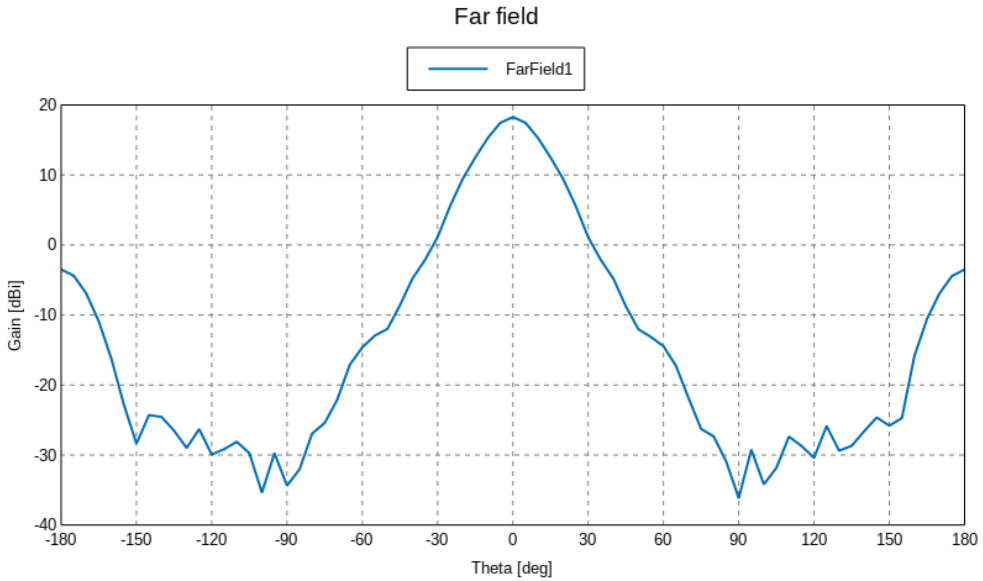
- Putting these values in and using the *hopt* function, I obtain the dimension of flare as :

$$A = 0.96m \qquad B = 0.484m \qquad R = 0.861m$$

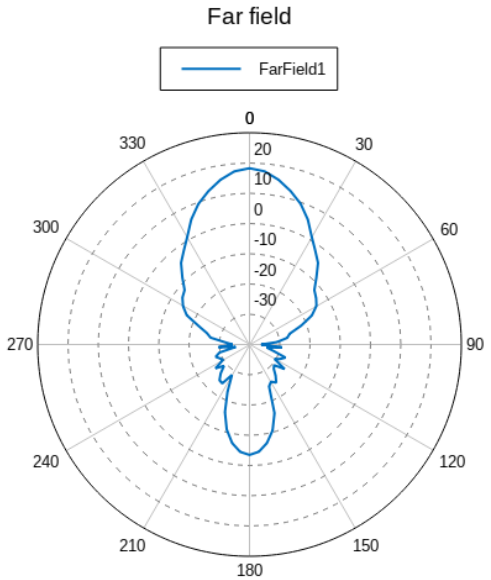
# Antenna 1 (Far Field)



# Antenna 1 (Far Field)

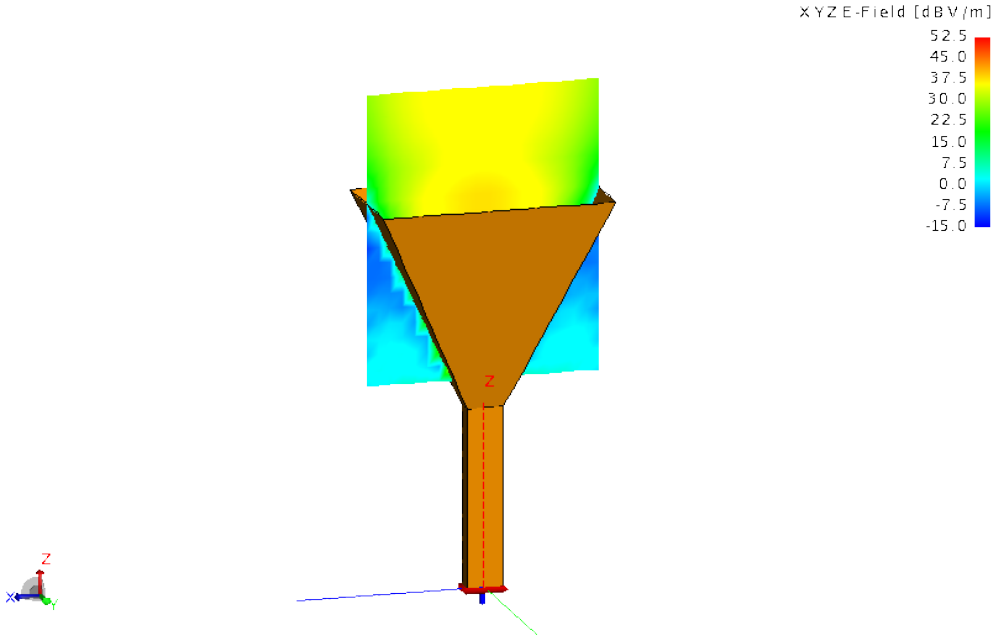


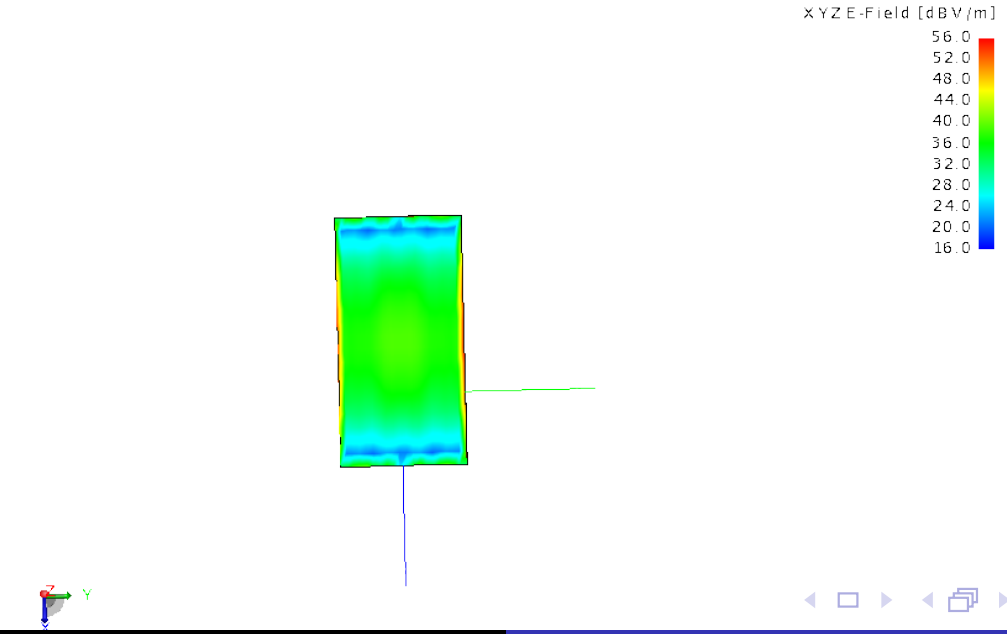

Total Gain [dBi] (Frequency = 1.4204 GHz; Phi = 0 deg) - horn_antenna1




Total Gain [dBi] (Frequency = 1.4204 GHz; Phi = 0 deg) - horn_antenna1

# Antenna 1 (Near Fields)



# Antenna 2

- For this antenna, I changed the a and b values, which affects the cut-off frequency.

$$a = 13.6cm \qquad f_c(TE_{10}) = 1.1GHz$$
$$b = 10cm \qquad f_c(TE_{01}) = 1.5GHz$$

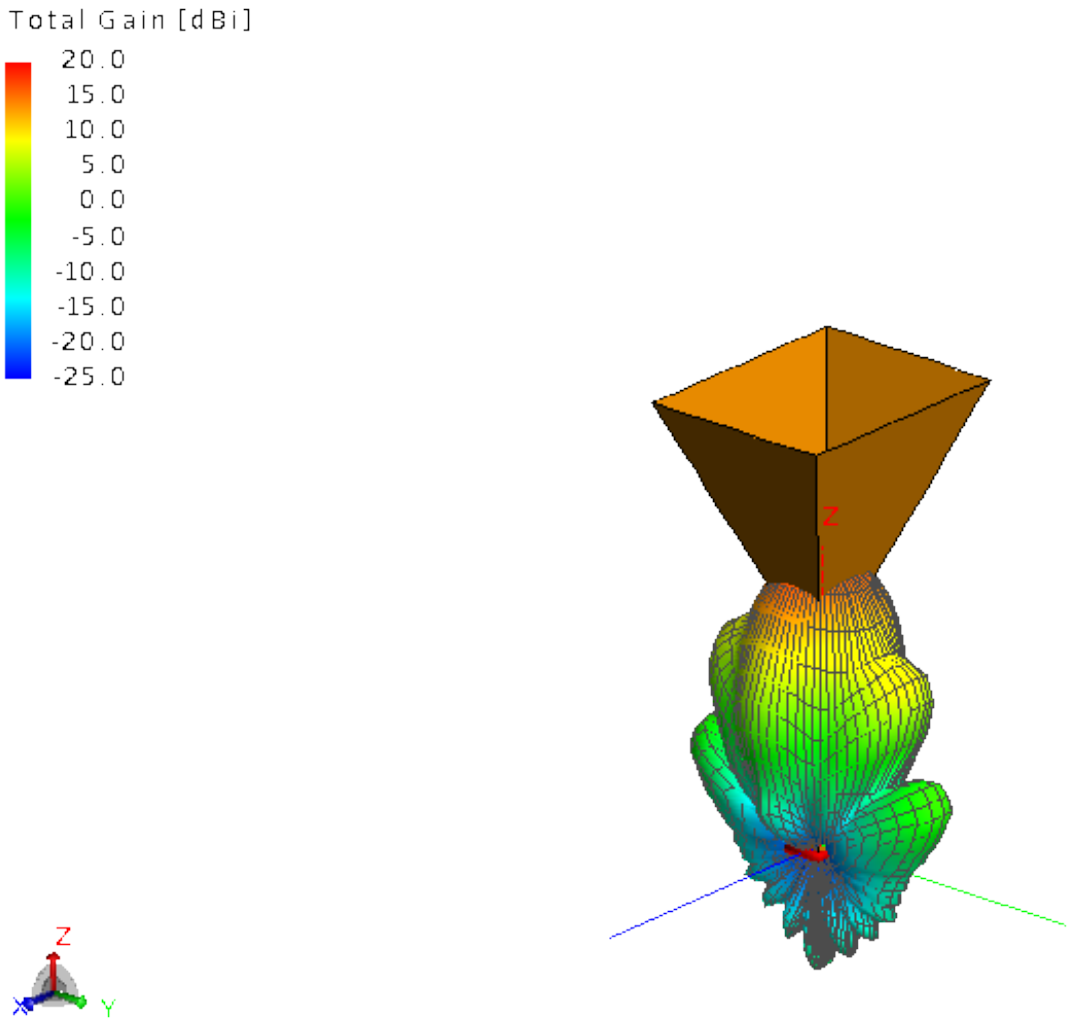
- I kept the gain as 18dB and changed the sigma parameters.

$$G = 18dB \qquad \sigma_a = 1.2593 \qquad \sigma_b = 1.0246$$

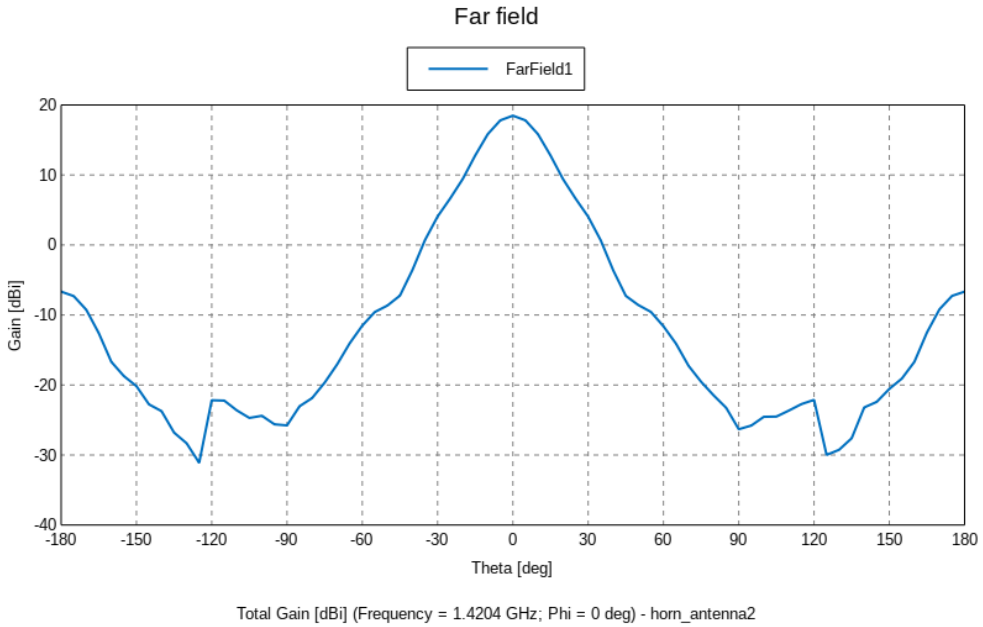
- We get the dimensions of flare as :

$$A = 0.749m \qquad B = 0.60375m \qquad R = 0.69m$$

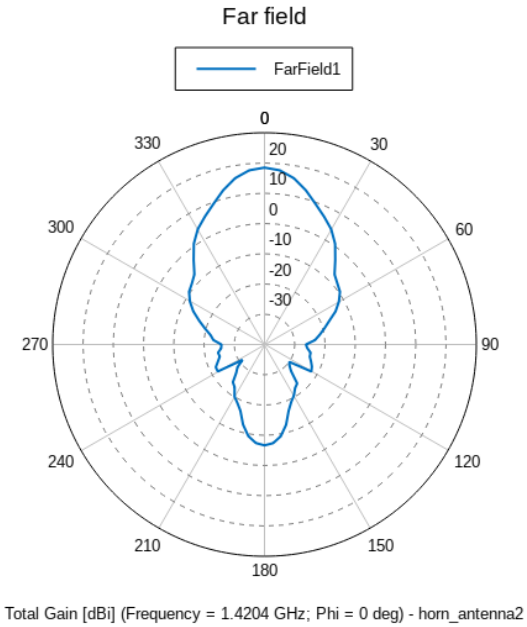
# Antenna 2 (Far Field)



# Antenna 2 (Far Field)

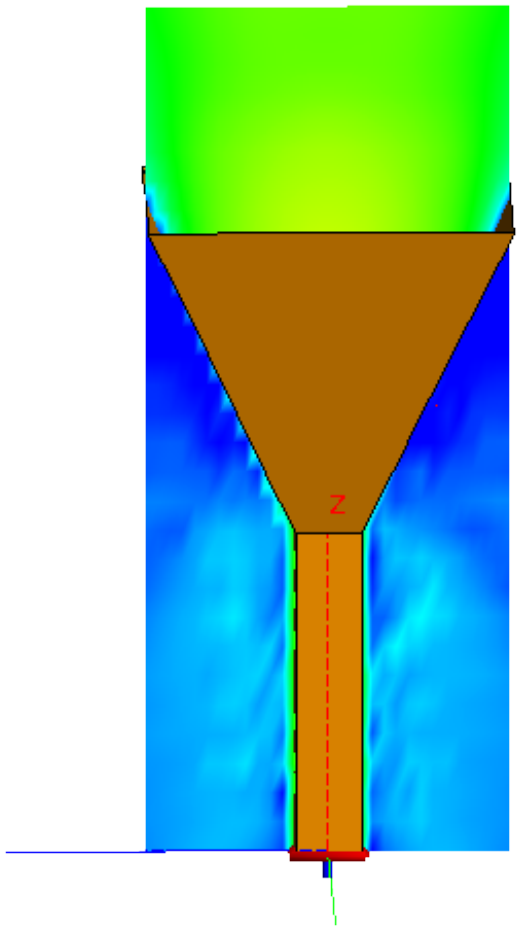


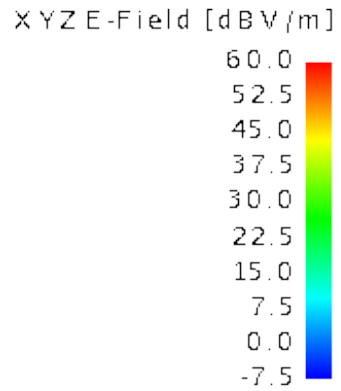

Total Gain [dBi] (Frequency = 1.4204 GHz; Phi = 0 deg) - horn_antenna2




Total Gain [dBi] (Frequency = 1.4204 GHz; Phi = 0 deg) - horn_antenna2

# Antenna 2 (Near Fields)




# Thank You!