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ANTENNA REPORT

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Design and Implementation of a 2.5 GHz Yagi-Uda 4 Elements Antenna and Dependence of the Antenna Parameters to the Structural Parameters :-

Abstract

This report will define antenna theory and design as it relates to a Yagi-Uda Antenna type. Antenna theory will originate from Electromagnetic field equations, while expected design parameters will be simulated via software and the actual design characteristics will be measured. This Yagi antenna consisted of the driven element, a reflecting element and four directing elements. The material for our design consisted of an copper wire, copper tape, thin plastic, and a large threaded N-connector. The primary requirement for the antenna was that it operated in the 2.5 GHz range. Another objective was to predict its gain and verify the prediction.

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Introduction

The fundamentals of our antenna project are described through basic antenna characteristics. In general this starts with establishing the antenna's radiation pattern, gain and directivity. The radiation pattern is a 2-D or 3D plot which assesses the intensity in which electromagnetic waves propagates as a function of orientation. The gain of an antenna indicates how well the signal power amplifies in one direction, where its directivity characterizes the direction and magnitude of maximum power amplification.

The design of a Yagi (Yagi-Uda) antenna requires proper understanding of how the components are structured and how varying the lengths and position of these components changes the characteristics of the antenna. The components include a driver, reflector(s), and a number of directors. The driver is the single active element which is excited by a signal, while the reflector(s) re-radiate by reflecting the signal and directors re-radiate by directing the signal. For this reason both the reflector(s) and directors are considered as parasitic elements. A common starting point for a design begins with selecting the length of the director such that is it slightly less than one-half of the intended operating wavelength. In the report other general guidelines and specific details showcase the design choices as they relate to antenna performance. In addition to our design we have examined the characteristics of a commercially available Yagi Antenna that being the WSJ-1800 which operates at 2.5 GHz as well.

Theory

Antennas are devices that transmit or receive electromagnetic waves. If an antenna is receiving a signal it converts the incident electromagnetic waves into electrical currents; if it is transmitting it does the opposite. Antennas are designed to radiate (or receive) electromagnetic energy with particular radiation and polarization properties suited for its specific application.

The Yagi antenna is a directional antenna which consists of a dipole and several parasitic elements. The parasitic elements in a Yagi antenna are the reflectors and the directors. A Yagi antenna typically has only one reflector which is slightly longer than the driving element (dipole) and several directors, which are slightly shorter than the driving element. The Yagi antenna is said to be directional because it radiates power in one direction allowing it to transmit and receive signals with less interference in that particular direction. Figure 1 is a diagram of the general configuration of a Yagi antenna.

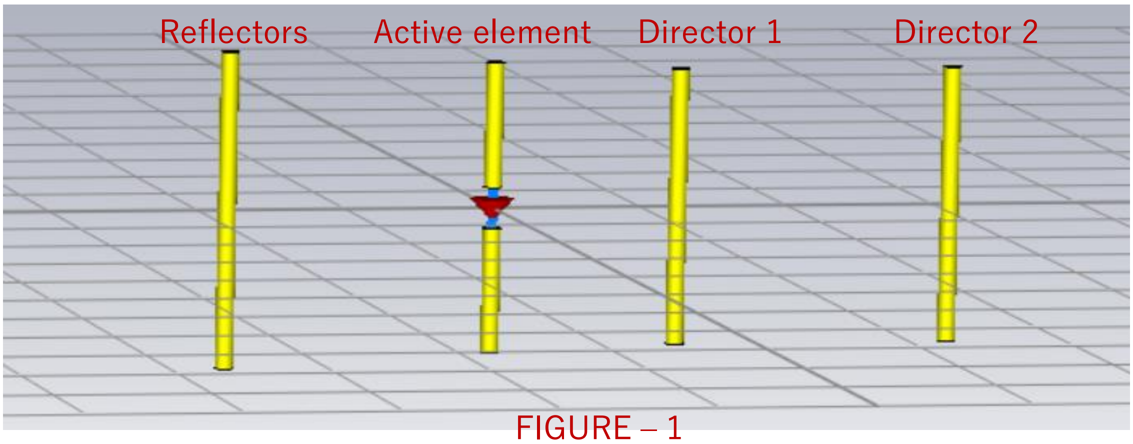


FIGURE – 1

The directionality of an antenna can be determined from the relative distribution characteristics of the radiated power from the antenna; this is known as an antenna's radiation pattern. Given the electric and magnetic field patterns of an antenna, the time * average Poynting vector, also known as the power density equation, can be obtained using the following formula:

$$S_{av} = \frac{1}{2}\Re(\mathbf{E}\times\mathbf{H})$$

Where E and H are the electric and magnetic field equations. The radiation pattern is typically described in terms the normalized radiation intensity, which is given by:

$$F(\theta,\phi) = \frac{S(R,\theta,\phi)}{S_{\max}}$$

Where R is the range, θ is the called the elevation plane which corresponds to a constant value of ϕ . If $\phi = 0$ then the x-z plane is defined. The ϕ angle is referenced through the azimuth plane and specified by $\theta = 90°$ (x-y plane). Figure 2 summarizes these parameters.

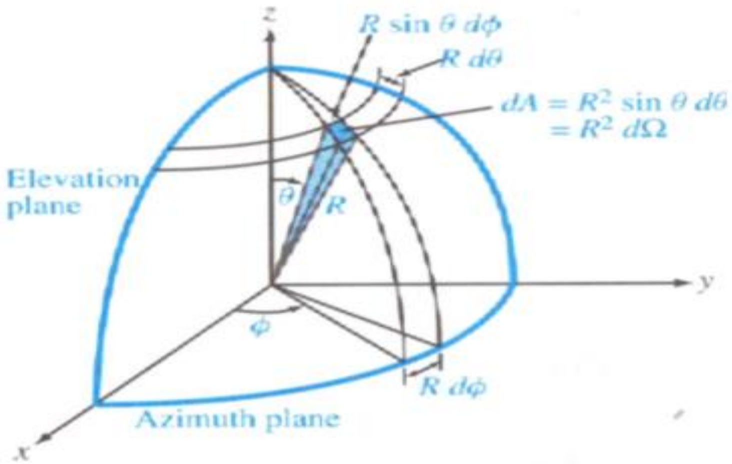
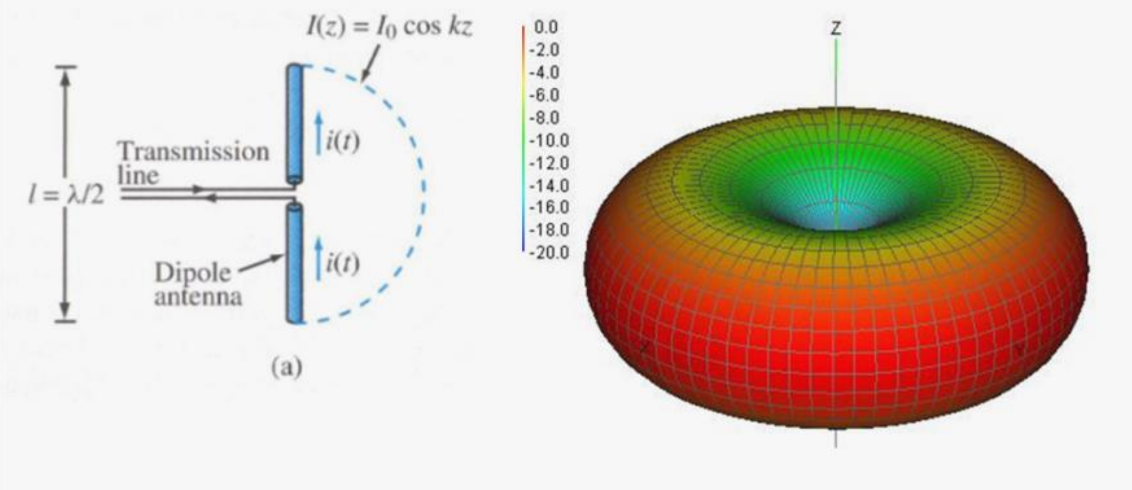


Figure 2. Definition of R, θ , and ϕ .

The radiation pattern of a Half-Wave Dipole Antenna is shown below. Once the electric and magnetic field equations for the Half-Wave Dipole Antenna are solved then a radiation pattern can be calculated. Please refer to the Appendix for the derivation of the electric and magnetic wave equations which lead to the calculation of the radiation pattern.



$$F(\theta) = \frac{S(R,\theta)}{S_0} = \left[\frac{\cos[(\pi/2)\cos\theta]}{\sin\theta}\right]^2$$

Figure 3. Half-Wave Dipole Antenna and Radiation Pattern

Notice that the Half-Wave Dipole Antenna radiates its power equally in a radial fashion, along the x-y plane in Figure 3.

The general guidelines for determining the size and shape of a Yagi antenna include accounting for the reflector length, driver length, director lengths, reflector to driver spacing, driver to first director spacing, and the spacing between the directors. The directional gain of a Yagi antenna is typically 7-9dB per

λ (wavelength) of overall antenna length (given as a multiple of wavelengths). There is little to no gain by the addition of more than one reflector. Adding directors however, does increases the overall directive gain of the antenna, but not indefinitely. Generally the reflector length is slightly greater than $\lambda/2$, the driver and director lengths are slightly less than $\lambda/2$, director lengths are typically between 0.4-0.45λ. The reflector to driver spacing is about $\lambda/4$. The P a g e | 9 spacing between directors can be between n 0.2 to 0.4λ, but be aware when the director spacing is greater than 0.3λ the overall gain of the antenna is decreased by 5-7dB. It is concluded from the table that, the better reflection coefficient values obtained by increasing the spacing between the antenna elements, however, the center frequency shifted a bit to the left.

Procedure

The Yagi antenna that was built for this project was made from a cooper wire. The cooper wire was cut out using pliers and filed down to the specific dimensions.

The driving element was shaped from a thin plastic sheet and then covered with copper tape. The Yagi antenna was built this way for two reasons: the cooper wire and copper tape were cheap and also easy to work with. The drawback of cutting out the Yagi antenna from a cooper wire was that the design became final upon cutting and no further adjustments in length are then possible.

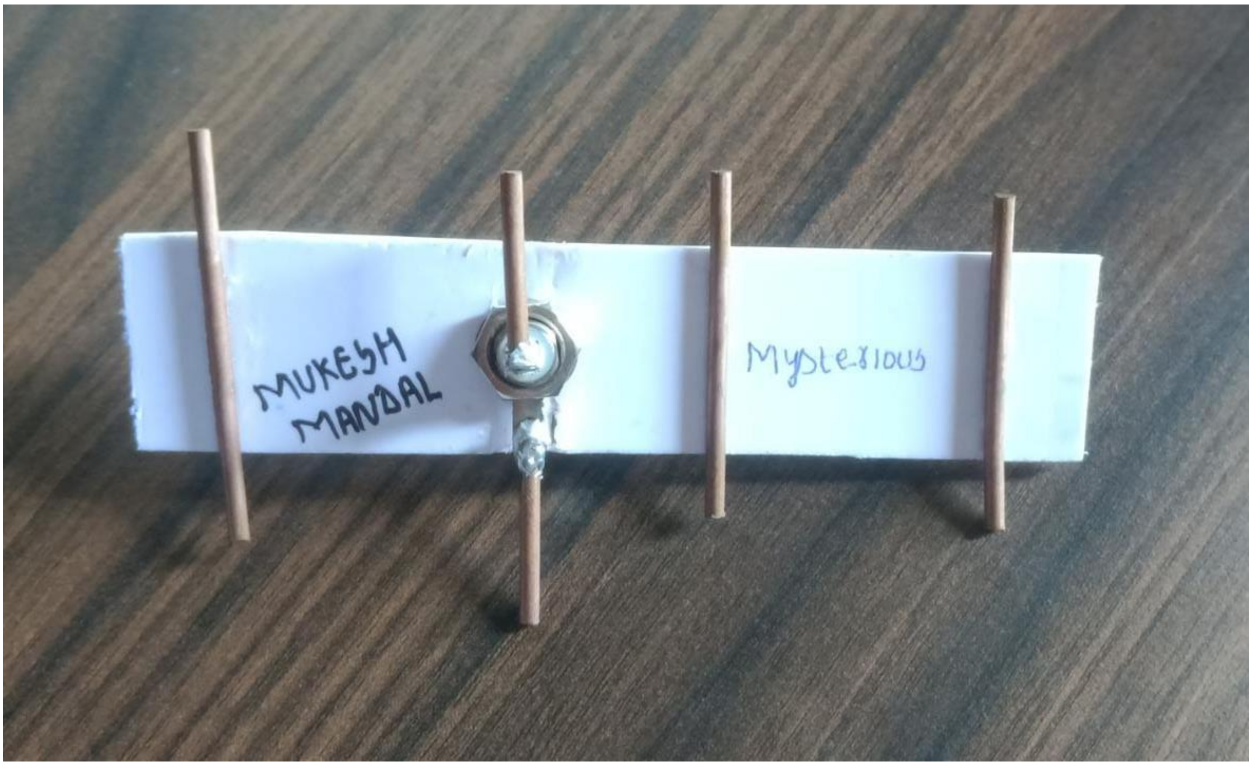


Fig: Yagi-Uda 4 element's antenna

The list below summarizes those lengths.

Name	Expression	Value
freq	2.5*10^9	2500000000
C0	3*10^11	300000000000
lam	C0/freq	120
h	lam*0.39	46.8
r	1.25	1.25
s	6.7	6.7
spacing	lam/4	30

Length of active element = 46.8 mm

Length of reflector = 51.012 mm

Length of director 1 = 44.46 mm

Length of director 2 = 44.46 mm

Spacing between active element and director1= 25.2 mm

Spacing between active element and director2= 62.4mm

Spacing between reflector and active element=36 mm

Results

We verified our design at Palm, Inc. Palm has a calibrated setup for measuring radiation patterns of antennas. The first step that was taken prior to placing the antenna in a chamber for measurements was to verify that the antenna could in fact transmit a signal. With the use of a spectrum analyzer the S11 parameter was measured; if the S11 had been 0dBm this indicates the entire signal that is being put into the antenna is reflected back and not transmitted at all. Ideally we want the S11 to be as low as possible at the desired operating frequency.

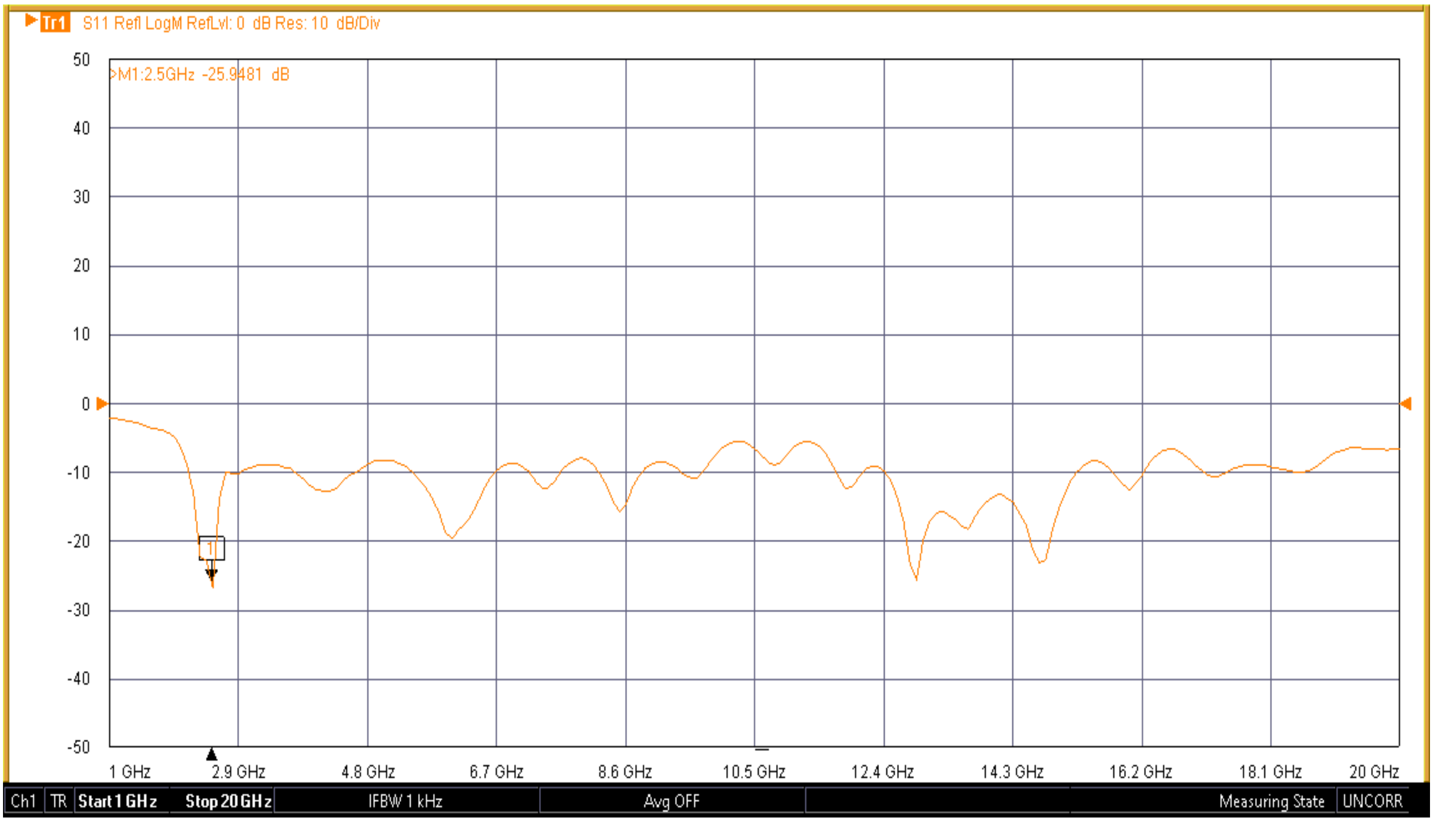


FIGURE: S11 PARAMETER

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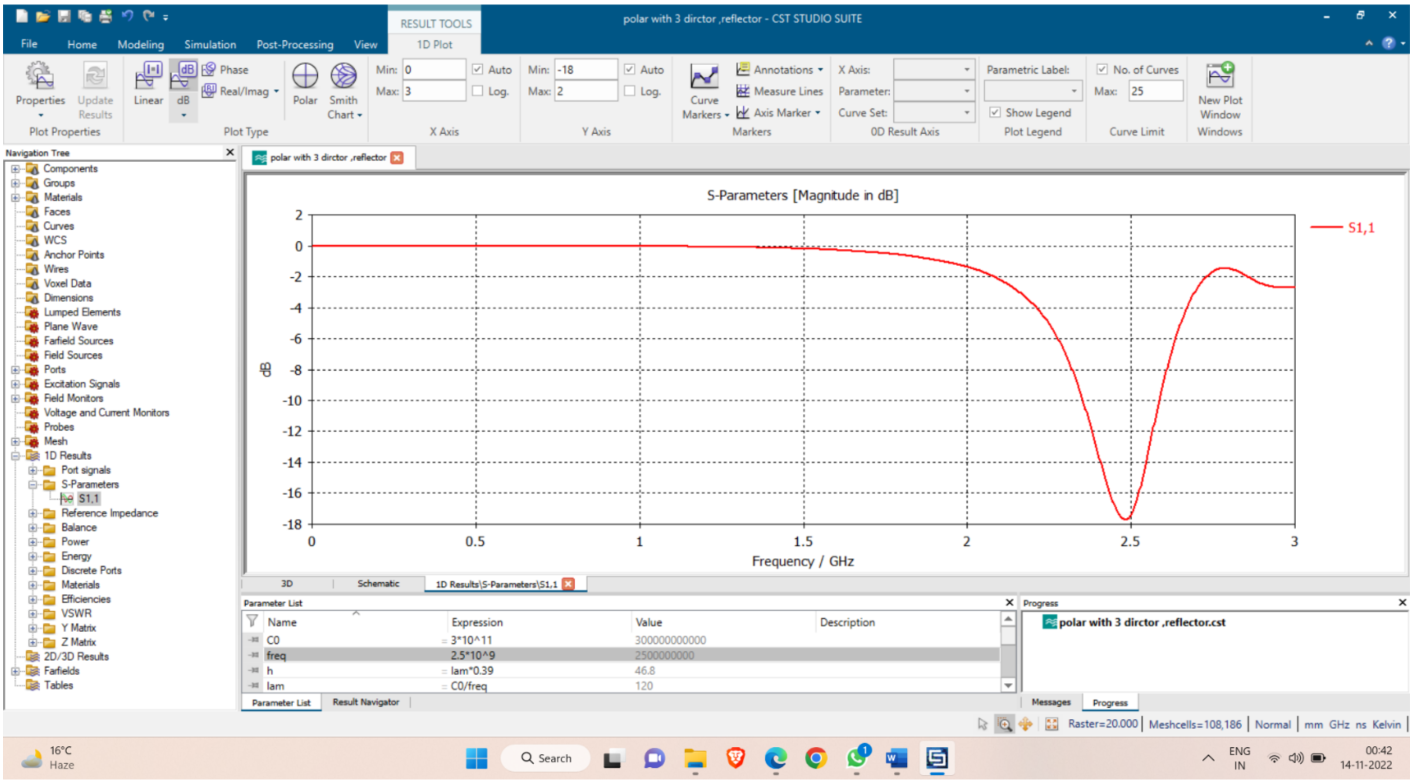

Figure : S-Parameters In CST

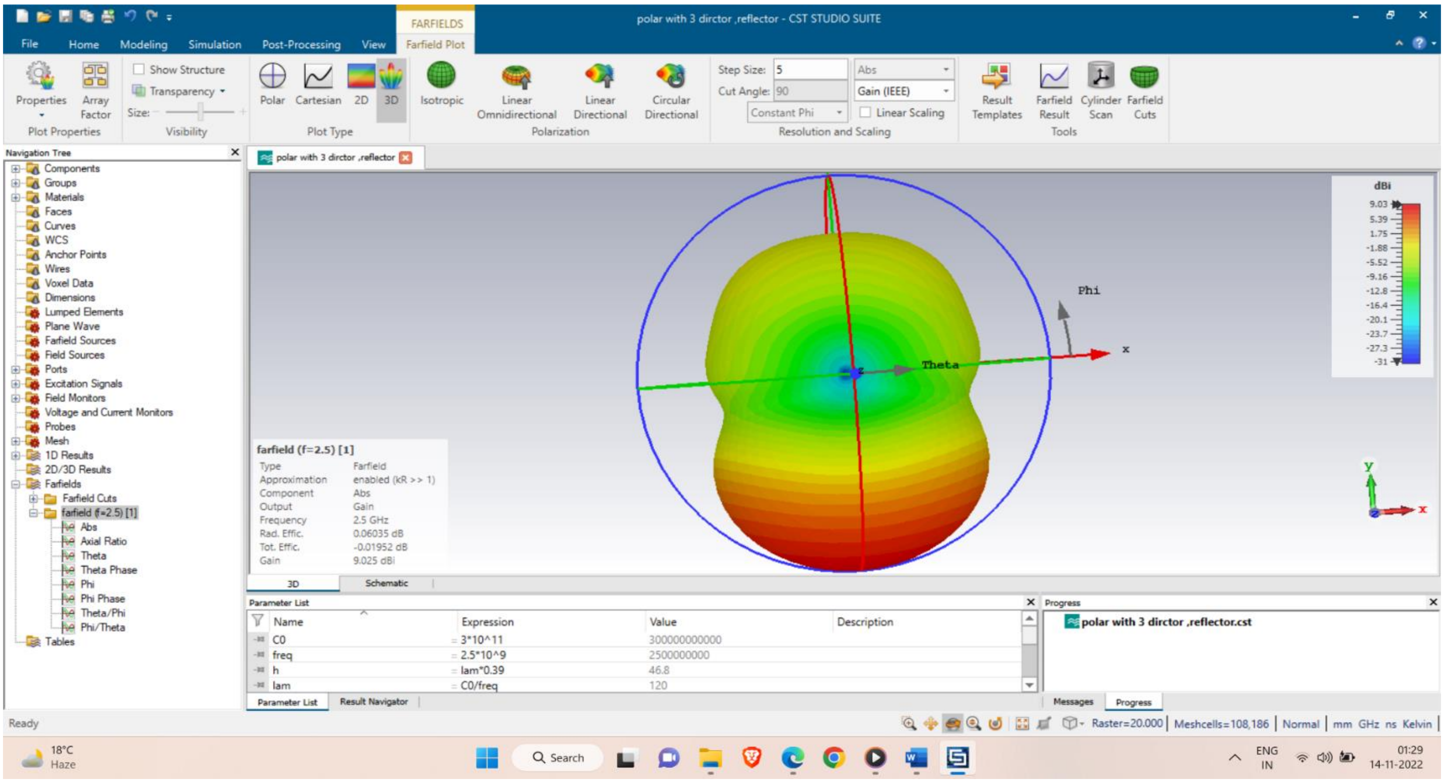

Figure: farfield(f=2.5) in CST

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Discussion

The overall gain closely correlated to the theoretical gain, which came as a surprise to us since we had not performed any matching on the antenna. We simply used 50ohm cable to solder the N-connector to the driving element and counted on it to work from our theory understanding. The relief came to us once we had performed the S11 measurement and verified that it was transmitting. Consequently we were confident that a radiation pattern measurement would be possible.

References

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THANK YOU