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21 cm H-Line using Radio Telescope

Sunil Kumar[1], Prem Singh[2], Md. Suhaib[3], Manoj Kumar Saini[4], Nikhil Sharma[5]
[1, 2, 3, 4, 5]Department of Mechanical Engineering, Swami Keshvanand Institute of Technology, Management & Gramothan, Jaipur

Abstract: The value of the horn antenna has been demonstrated in radio astronomy applications. The usage of horn antennas is restricted to professional applications solely due to expensive and complicated technology. A low-cost, simple-to-build horn antenna for 21cm H-line applications has been designed. It can be used for outreach and popularization efforts in science at the high school and college levels as well as for educational purposes. The horn has an aperture measuring 75.4 x 58.7 cm^2 and a gain of roughly 20 dB. The LNA and BPF, SDR, and signal processing software make up the receiver system. The project can be advanced to test out the rotation curve discovery for applications such as charting our galaxy and interferometry.
Keywords: H-line, radio telescope, antenna, frequency, Horn

I. INTRODUCTION

Radio Astronomy is the study of celestial objects that emits radiation in radio frequency of electromagnetic spectrum. Radio Astronomy is important radio waves are not blocked by the interstellar medium but the electromagnetic waves of optical frequency are opaque to the medium. Radio telescopes are antennas which are used for detection of radio waves coming from an astronomical source.

II. 21CM H-LINE

Since hydrogen is the most common element, it is easy to find neutral hydrogen atoms across the cosmos. They are common in the Interstellar Medium's low density zones (ISM). These H1 or the 21cm line is a spectral line where hydrogen atoms can be seen. It radiates at 1420.4 MHz in frequency. The magnetic interaction between the quantized spins of the proton and electron in the hydrogen atom, which occurs because anti-parallel spin has less energy than parallel spin, results in the 21 cm line

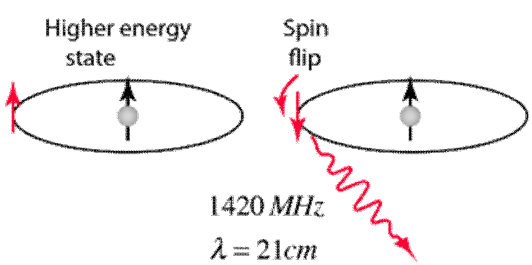

Figure 1 Formation of 21cm line ofNeutral Hydrogen

Due to the fact that molecular hydrogen lacks a persistent dipole moment, we are unable to identify any spectral lines at RF. A particularly helpful tool for studying galaxy formation in the early cosmos is the red-shifted 21cm line. The universe is expanding, which causes the redshift. Our galaxy's hydrogen distribution is mapped using the 21cm.

III.HORN DESIGN

Due to their directional radiation pattern, high gain, directivity, slowly increasing input impedance, and simplicity of manufacture, rectangular horn antenna was chosen for the design. The following restrictions applied to the horn antenna that we created:

1) Operating Frequency = 1420 MHz
2) Horn Antenna's Gain = 20 dB
3) High directivity

The skin depth is determined to make sure the material being used in construction is thick enough for a 1420 MHz electromagnetic wave to propagate with the least amount of attenuation:

f = frequency of electromagnetic waves = 1420 MHz

$\Rightarrow \quad \delta = 2.198\ \mu m$

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This cut-off frequency allows the waveguide to work as a high pass filter and removes the lower frequency. For optimum horn design, we take

$$\mathbf{R_E = R_H = R_O = 70.19\ cm}$$

The position and length of the probe is calculated through empirical relations and a very small change in these parameters can affect the reception of signal greatly as shown in Figure 2.

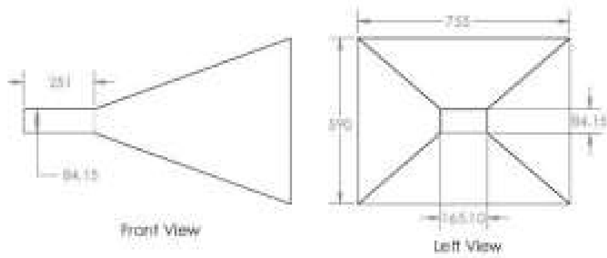

Figure 2 Dimensions of the Horn

IV. FABRICATION

Effective planning was done before starting the fabrication to minimize the time required and utilize the resources - man, machine, material and money – optimally.

Figure 3 Fabricated Horn

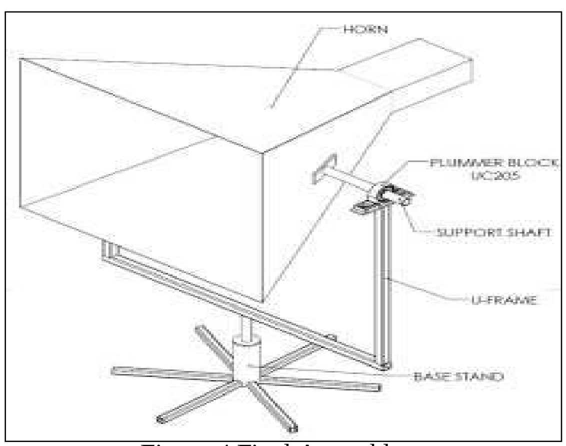

Figure 4 Final Assembly

Fabricated Horn is shown in Figure 3 and Final Assembly is shown in Figure 4.

V. RESULTS AND DISCUSSIONS

The design basis mentioned earlier are simulated after specifying material properties, geometrical specifications, boundary conditions, etc. of the horn designed.

Material used: Aluminium

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Table 1 Material Properties

Property	Value
Thickness	0.71mm (21 gauge)
Density	2.7 g/cm^3
Conductivity	3.77×10^7 S/m

Table 2 Boundary Conditions

Parameter	Value
Center Frequency	1420.4 MHz
Frequency Range	1134-1715 MHz
Step Size	10 MHz
Excitation Port	Lump Port
Dielectric Medium	Air

Certain properties are assigned to the design created in HFSS software to begin with the analysis.
The analysis of the theoretical design is verified by analyzing it using the HFSS software and further observations are made to confirm our findings.
It was found that the frequency sweep plot is variable with different frequencies and the gain at required frequency i.e. 1420.4 MHz, is 20.9741 dB.
The gain of the horn antenna is plotted against the frequency range of 1134 MHz to 1715 MHz.
The gain at the center frequency is found to be 18.7068 dB.
The directivity of the horn at the center frequency is found to be 18.456 dB.
The range of values for VSWR is from 1 to ∞. A VSWR value under 2 is considered suitable for most antenna applications. The Active VSWR value for our horn antenna at the center frequency is 1.625 dB.

VI. CONCLUSIONS

It was discovered that the theoretical design we estimated was very closely in accordance with the findings of the analysis. The 21cm H-line can be received using the planned horn antenna's directivity, which is above the allowed limitations. With a center frequency of 1420.4 MHz, the values of the antenna's parameters are as follows:

Table 3 Antenna Parameters

Parameter	Value (dB)
Gain	18.706
Directivity	18.456
Active VSWR	1.625

Also, the project's cost has been lowered to 50% of what was first anticipated, increasing its cost-effectiveness. Our project is more approachable for students to apply their scientific knowledge with our Radio Telescope thanks to the usage of waste and the simple construction design.

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