Journal of Physics: Conference Series

PAPER • OPEN ACCESS

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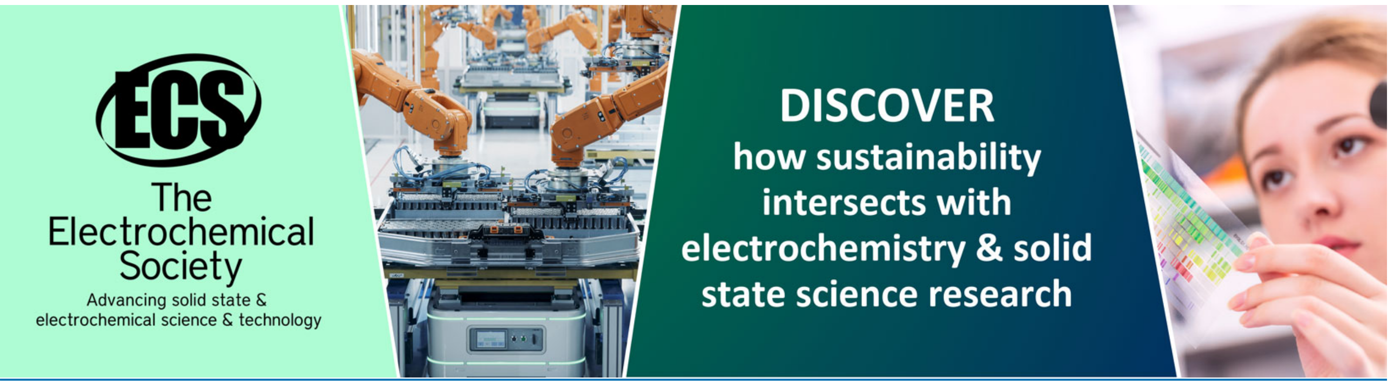
To cite this article: Ashraful Haque *et al* 2023 *J. Phys.: Conf. Ser.* **2550** 012015



Design and Analysis of Sphere Yagi antenna at 915 MHz Band for LoRaWAN Application

Md. Ashraful Haque[12], M Azman Zakariya[3], Hisham Mohamad[3], M. H. Md Khir[3], Md. Afzalur Rahman[2], Dipon Saha[2], M Aiman Muazzam[3], Eryana Eiyda Hussin[3], M Faizairi M Nor[4], Aizat Akmal Bin A.mohamad Beddelee[3]

[1] Department of Electrical & Electronics Engineering (EEE), Universiti Teknologi PETRONAS, Seri Iskandar, Malaysia
[2] Department of Electrical & Electronics Engineering (EEE), Daffodil International University, Dhaka, Bangladesh
[3] Smart Infrastructure Modelling and Monitoring (SIMM) Research Group, Institute of Transportation and Infrastructure, UniversitiTeknologi PETRONAS, Seri Iskandar, Malaysia
[4] Department of Mechanical Engineering, Universiti Teknologi PETRONAS, Seri Iskandar, Malaysia

Email: md_21000832@utp.edu.my

Abstract. Using a frequency of 915 MHz as an operating point, this project has analyzed and refined the design of a Sphere Yagi antenna. In CST, we have begun the research phase and created a preliminary design for an antenna. The simulation results have been analyzed, and then fabrication, testing, and measurement have been carried out. To begin the manufacturing process, a single-sided copper board is cut into sphere shapes, with the length of each plate varying depending on the size of the sphere. Drilling machines are then used to create a hole in each of the plates. As a result, everything is coming together nicely. In addition, both indoor and outdoor settings have been used for testing and experiments. Therefore, the antenna design works well in 915MHz frequency, but the signal weakens when it travels more than 100 meters away. An improved antenna transmitter's power output can fix this. This project can be extended to cover the 2.4 GHz and 5 GHz frequencies. So, the antenna layout can be employed to improve the wireless connection of communication devices that need extensive range.

1. Introduction

Both humans and artificial machines are becoming increasingly interconnected in today's modern world. This trend has prompted the Internet of Things (IoT) innovation in niche network infrastructure. Connecting things requires a means of communication just like that used to link individuals together [1]. Sensors connected to the Internet of Things (IOT) that do not require direct human interaction are typically deployed in inhospitable or otherwise hard-to-reach locations [2]. Many of these wireless sensors lack the processing power and data storage capacity to use Wi-Fi or conventional cellular networks for long-distance data transmission. A Low Power Wide Area Network (LPWAN) specification, Lora aims to facilitate IoT across wide areas, while the Lorawan concept is well-suited to endeavors requiring extensive in-building communication between numerous low-power devices that collect only modest amounts of data [3, 4]. Figure 1 displays the varying connection ranges between various wireless communication mediums. Semtech's proprietary spread spectrum modulation scheme outperforms standard mechanisms in a number of respects, such as power consumption, robustness, range, and so on [5-7].

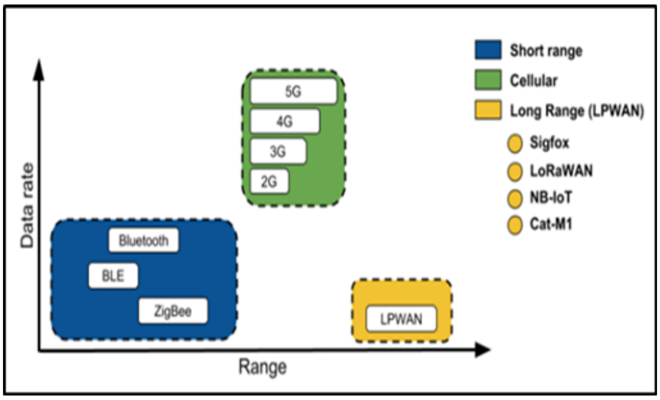


Figure 1. Wireless communication platform range.

Lora can operate on 433MHz, 868MHz in Europe, and 915MHz in the United States [8, 9]. Due to its many benefits, microstrip antennas are now widely used in the field of wireless communication. Antennas play a crucial role in the transmission and reception of signals within a system, making them essential for the effective operation of any wireless network. An antenna that operates at 915 MHz is needed for this project. The primary purpose of this antenna is to establish a link between two signal-sending Arduino Microcontrollers.

The Yagi antenna was developed by Shintaro Uda and his coworker Hidetsugu Yagi in 1926. All over the United States, you can find a log-periodic antenna, which is very similar to the Yagi antenna [10]. A Yagi antenna consists of a small number of straight antenna elements, each of which is tuned to a length equal to nearly half the electromagnetic wavelength it is designed to support. True, it's a symmetrical type, but it can be unbalanced if a balun isn't used at the transmission junction where the driving element of the directional antenna is connected. Yagi antennas, in comparison to other directional antennas and configurations [11, 12], have a respectable range and appear to be simple to aim. Since a directional antenna only radiates in one direction, all of the signal is focused in one spot. This improves performance in comparison to the omni-directional antenna, which disperses radiation in a 360° arc. Figure 2 depicts the Yagi Antenna's fundamental structure.

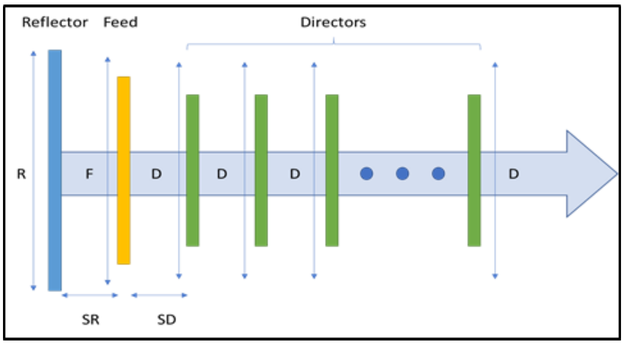


Figure 2. Basic design of Yagi antenna.

2. DESIGN OF PROPOSED ANTENNA

The proposed antenna was created with the help of the CST software simulation, a simulated 3D program. When the optimal design parameters are obtained through CST software simulation, the prototype antennas would be manufactured. Ultimately, the system will be tested and evaluated for long-range (Lorawan) communication using a wider bandwidth and a 915MHz frequency range. Total resolution is attained, along with a comparison of simulated and measured results. The Yagi Sphere antenna parameters are entered into the CST software, and a simulated result is obtained. For electromagnetic frequency range simulation in three dimensions, The platform CST offered was really intuitive. For high-frequency components like antennas, filters, couplers, and planar and multilayer systems, this allows for rapid and precise evaluation. CST model of a spherical Yagi antenna with 7 copper plates. Table 1 lists all of the available plate dimensions. To prevent a short circuit in the antenna, the rod used in this CST design was crafted from a lossy material with an epsilon of 2.22.

The five directors and ground plate (which also acts as a reflector) make up this configuration. The Sphere Yagi antenna structure was created using CST software. The fabrication section of this design presented the hardware configuration. Figure 3 depicts the antenna geometry used in the design. All of the parameters and dimensions of the antenna's design that have been implemented in CST are listed in Table 1.

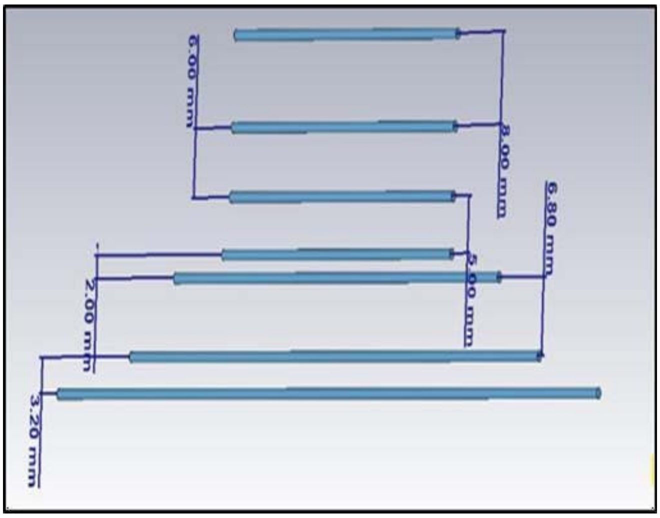


Figure 3. Geometry of Sphere Yagi antenna with gap distances dimension.

Table 1. All design parameters of the proposed antenna design.

Design parameters	Material	Length(mm)
Ground(Reflector)	Copper(annealed)	90
Feeder	Copper(annealed)	68
Director 1	Copper(annealed)	54
Director 2	Copper(annealed)	38
Director 3	Copper(annealed)	37
Director 4	Copper(annealed)	37
Director 5	Copper(annealed)	37
Sphere radius thickness (all plates)	-	0.5
Gap Ground and Feeder	-	3.2
Gap Feeder and Director 1	-	6.8
Gap Director 1 and Director 2	-	2.0

Gap Director 2 and Director 3	-	5
Gap Director 3 and Director 4	-	6
Gap Director 4 and Director 5	-	8
Rod	PEC	40

The first proposed designs require minimal assembly and simple connectivity methods like soldering. Copper plates, the main conductivity material in this design, ensure that the antenna is connected. The next step involves shaping the copper plates into balls; the diameter of each ball may vary depending on its intended use. Table 1 summarizes key characteristics of the antenna's individual parts. After that, a metal rod and screws were used to hold all the copper plates together in their designated places, as shown in Figure 4.

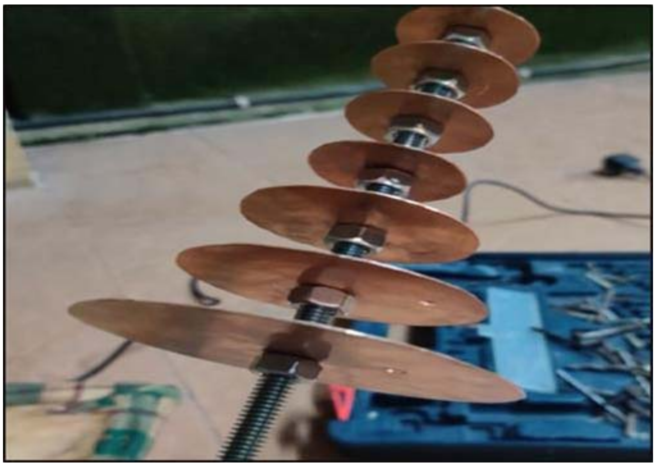


Figure 4. Coaxial cable to feeder.

3. RESULT ANALYSIS OF PROPOSED ANTENNA

Here, we go over the simulation results for the proposed antenna. A comparison is made between the CST-simulated S11 and the measured value.

3.1. Simulation result

The 915MHz operating frequency was chosen as a starting point for this antenna's construction, but it may eventually be able to handle the 2.4GHz range as well. This section will show how we boosted the antenna's performance at 915MHz, including its return loss or s11 parameter, 2D and 3D radiation pattern of gain and directivity. Typically used in agricultural, utility metering, inventory monitoring, automotive, and ecological surveillance, 915MHz could support the Long-Range Wireless for Internet of Things (Lora). A plot of the s11 reflection coefficient represents the amount of power reflected by the antenna. An antenna's Return Loss is a measurement of how much of the radio waves it receives at its input are reflected out rather than received. Figure 4.2 shows the s11 return loss at 915MHz for the suggested antenna configuration. Figure 5 depicts the manufactured measured result for s11 return loss.

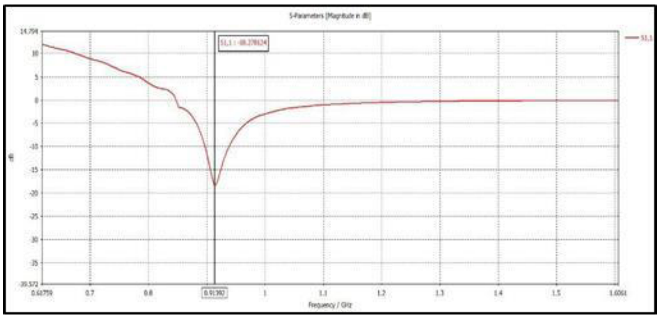


Figure 5. S11 return loss at 915MHz.

Analyzing the antenna's 2D radiation pattern can shed light on its 3D radiation behavior. Figure 6 depicts the polar 2D radiation pattern of the antenna's gain and directivity.

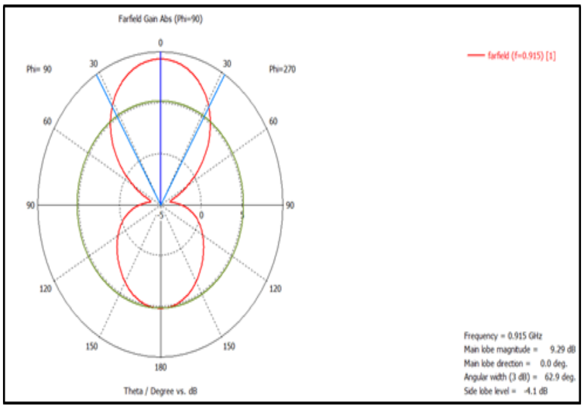


Figure 6. 2D Simulated radiation pattern of antenna gain polar shape at 915MHz.

A good antenna's radiation pattern should remain stable across the entire frequency range it needs to support. The antenna has a strong and respectable gain of 9.29dB, measured by the magnitude of the main lobe that has been stimulated. Figure 4.23 and Figure 7 then show the gain radiation pattern of the 2D antenna. Analysis of the antenna's power radiation patterns is made possible with the help of CST software's 3D modeling output. Figure 8 displayed the antenna gain's 3D radiation pattern [13].

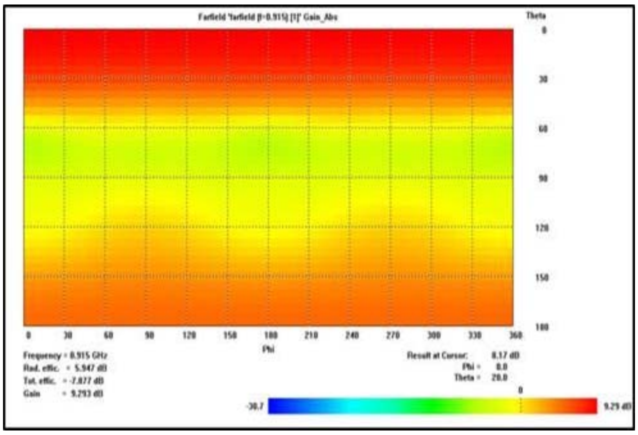


Figure 7. Simulated result for 2D Radiation pattern of the antenna’s gain at 915MHz.

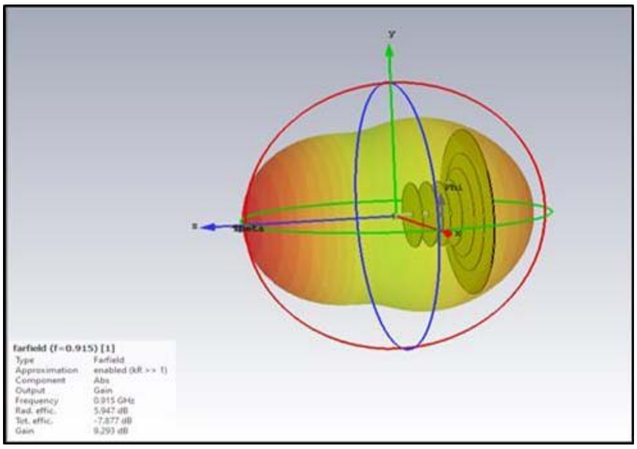


Figure 8. 3D radiation pattern of antenna's gain an directivity at 915MHz.

3.2. *Simulation result*

Using a resonance frequency of 915 MHz and a return loss of -18.299161 dB, the simulation results illustrated in Figure 9 demonstrate the effectiveness of the proposed design of antenna. A lower reflection coefficient and better VSWR can be achieved using an antenna that has a larger return loss value. The manufactured s11 return loss antenna (shown in Figure 10) has a return loss of -8.323 db when operating at 915MHz.An analysis was performed based on the observed s11 return loss results from both the fabricated and simulated antenna design. Figure 10 displays the s11 return loss graph that was created to facilitate such a comparison.

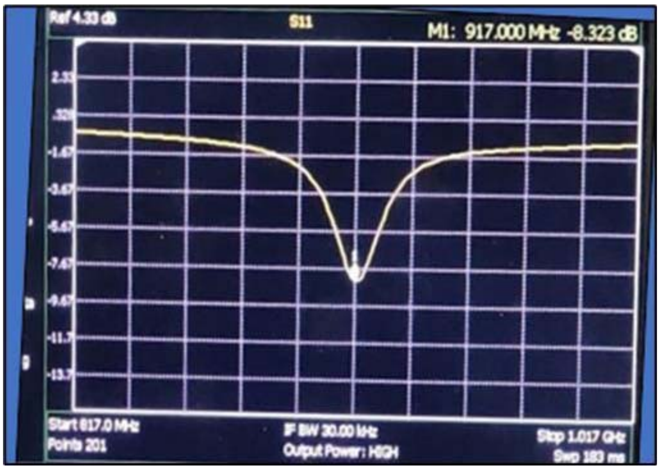


Figure 9. S11 return loss fabricated antenna.

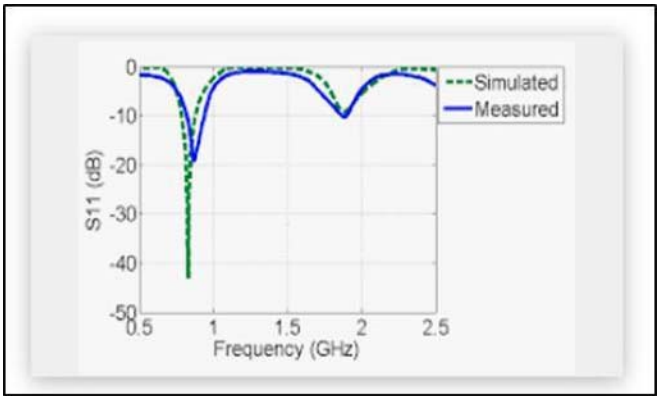


Figure 10. Graph plot of simulated and measured results.

3.3. Hardware results
Antennas of the suggested design were tested in both indoor and outdoor environments, and the collected data and subsequent experimental findings are presented here. Indoor evaluations had been conducted at the UTP satellite lab, as shown in Figure 11 and Figure 12 displays the results of the test with the antenna's transmitter and receiver fixed at separate nodes separated by a distance of 15 meters; Figure 13 displays the results of the test with the antenna's receiver tuned in to 915MHz.

Figure 11. UTP satellite lab.

Two antennas, one acting as a receiver and the other as a transmitter, were set up in an indoor testing and experimental setup, with a separation of about 5 meters between them.

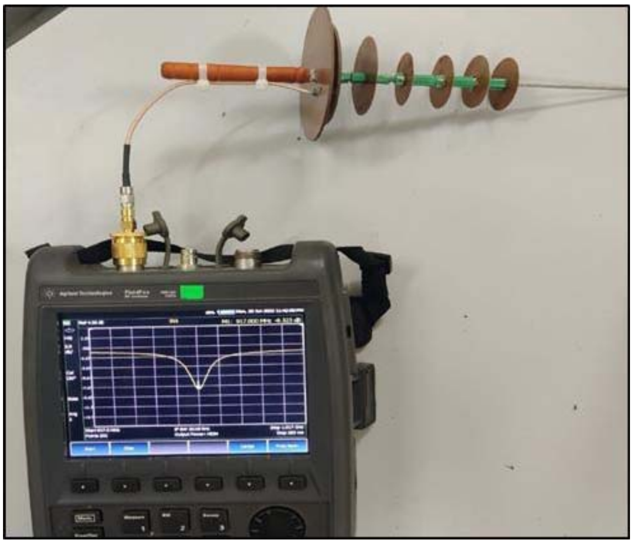


Figure 12. Antenna's receiver captured 915 MHz signal.

Impressively, the antenna performed splendidly at 915MHz from a distance of 15 meters in indoor testing. The 915MHz signal, which was a strong -33.77 dBm, was successfully recorded.

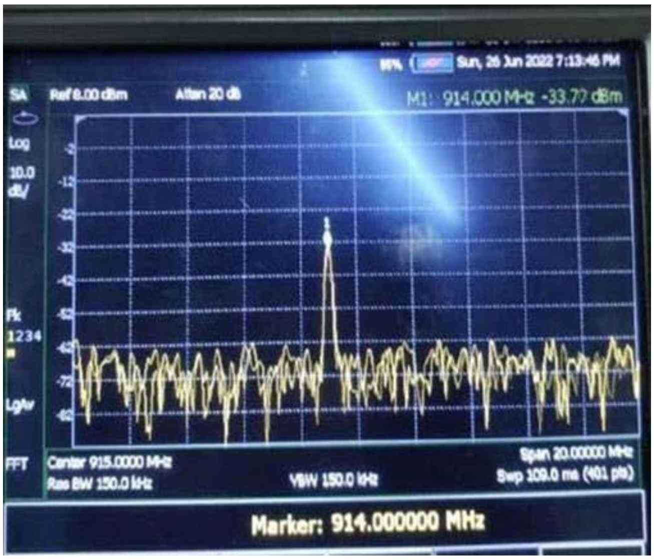


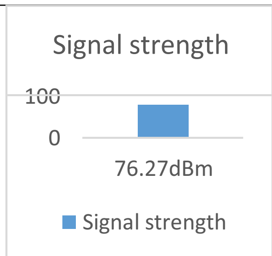
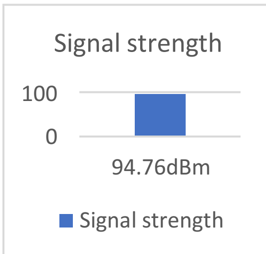
Figure 13. Result of indoor testing for 5 meters distance with signal strength of -33.77 dBm.

The outcomes of tests conducted in the UTP field are presented here. There will be 10 checkpoints spread out over a distance of 10 meters for this examination. Figure 14 depicts the testing setup, which consists of an antenna transmitter stationed in front of a rest port leading to a UTP field. A canopy and a table are brought along and set up nicely to block the sun, allowing for better image quality to be captured of the signal strength results.

Figure 14. Checkpoints of outdoor test at UTP field.

There are ten different signal intensities for 915MHz displayed in Table 2 for each measurement point: 10m, 20m, 30m, 40m, 50m, 60m, 70m, 80m, 90m, and 100m. Figure 15: A data plot of signal strength against distance. Table 2 displays graphs of signal strength at each checkpoint every 10 meters. The antenna has a signal strength of 76.27 dBm from 0 to 10 meters and 76.80 dBm from 0 to 20 meters. The antenna has a 77.56 dBm signal strength between 0 and 30 meters. The antenna has a 78.39 dBm signal strength between 0 and 40 meters. Results from the remaining checkpoints are shown in the table below.

Table 2. Graph of signal strength.

CHEKPOINT	Result of Signal strength	RESULT
1.0 – 10 metres	76.27 dB	
10.0 – 100 metres	94.76 dB	

4. CONCLUSION

By reviewing the acquired data, we can conclude that our objectives of designing and analyzing the Sphere Yagi antenna at the 915 MHz band for Lorawan application have been successful. As a bonus, this antenna works with 2.4 GHz Wi-Fi modules and other communication equipment. Most likely, we are not making the most of this antenna's possibilities because more research needs to be done. Moreover, the simulated result from the software part is consistent with the result from the hardware part in terms of the signal they could operate, but the s11 return loss both parts generated is different, with the simulated result being superior to the fabricated antenna result, which occurred due to the fabrication error during the fabrication process. The maximal gain of the built antenna is lower than that of the simulated antenna, but that is the only significant change. This could have resulted from a manufacturing flaw that was difficult to spot and fix. You can get more reliable results from field testing this design if you increase the output strength of the signal generator in the antenna's transmitter. The proposed antenna also performs admirably at receiving signals at the 915MHz frequency. If the ground plane antenna is to cover a greater spectrum of frequencies, it must be physically expanded. This antenna's potential for use with radio and television broadcasts therefore improves.

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