MILITARY INSTITUTE OF SCIENCE AND TECHNOLOGY

COURSE CODE: EECE 434

COURSE NAME: Microwave Engineering Laboratory

PROJECT TITLE:

Yagi-Uda Antenna Design Using CST Studio Suite

GROUP NO: 04

GROUP MEMBERS:

Name	Student ID
Mayan Uddin Sizan	202016069
Mansib Hasan	202116037
Md. Farhan Fuad	202116046
Md. Mostaque Mahbub Tamim	202116050
Nasif Ahmed Rafe	202116072

Table of Contents

1 Contribution Matrix

Student ID	Antenna Design	Parameters Adjustment	Result Analysis	Report Writing	Presentation Slides
202016069		✓	✓		✓
202116037	✓	✓		✓	
202116046	✓		✓	✓	
202116050	✓		✓	✓	
202116072	✓	✓		✓	

2 Abstract

The Yagi-Uda antenna is a widely used directional antenna known for its simple design and high performance in various communication systems. It consists of a driven element, typically a dipole, along with a reflector and one or more director elements, which work together to enhance signal strength in a specific direction while reducing interference from unwanted angles. This design allows for high gain and improved directivity, making the Yagi-Uda antenna highly effective in applications such as television reception, wireless communication, amateur radio, and radar systems. The antenna operates mainly in the VHF and UHF frequency bands, and its performance can be optimized by altering the spacing and quantity of parasitic elements, which enables better control over beamwidth and signal direction. Its ability to achieve reliable, long-range communication with minimal complexity has made the Yagi-Uda antenna a preferred choice in numerous industries.

3 Introduction

The Yagi-Uda antenna is a widely recognized and highly effective directional antenna that has found extensive use in various communication and broadcasting systems. Known for its simplicity and high gain performance, this antenna is composed of a few key components: a driven element, typically a half-wave dipole, and several parasitic elements, which include a reflector and one or more directors. These parasitic elements play a crucial role in shaping the radiation pattern by enhancing signal transmission in the desired direction and minimizing it from other directions, thus providing better directivity. Its design enables the Yagi-Uda antenna to concentrate radio waves into a narrow beam, making it highly efficient for point-to-point communication. The simplicity and effectiveness of the Yagi-Uda design makes it suitable for a wide range of applications, from television reception and amateur radio to satellite communication and even radar systems.

One of the major advantages of the Yagi-Uda antenna is its ability to provide significant gain without complex or bulky structures. The antenna operates primarily in the VHF (30 MHz to 300 MHz) and UHF (300 MHz to 3 GHz) frequency ranges, which are commonly used for a variety of wireless communication services. The high gain and focused radiation pattern make it particularly useful for long-range communication, as it can pick up weak signals from distant sources or transmit signals over extended distances without excessive power loss. This makes the Yagi-Uda antenna a popular choice for applications where signal directionality and strength are critical, such as television broadcasting in rural areas, where it is used to receive signals from distant transmitters.

Moreover, the Yagi-Uda antenna's performance can be fine-tuned by adjusting the number, size, and spacing of its parasitic elements. The reflector, positioned behind the driven element, helps block signals from the rear and reflects energy forward, while the directors, located in front of the driven element, guide the radio waves in the intended direction. By adding more directors, the gain can be further increased, although this also narrows the beamwidth. This flexibility allows users to customize the antenna for specific applications, such as increasing the gain for long-distance communication or widening the beam for broader signal coverage. Despite its simple structure, the Yagi-Uda antenna's ability to deliver high performance across a wide range of frequencies and applications has cemented its place as a reliable and versatile tool in the field of wireless communication.

4 Literature Review

This literature review discusses the fundamental principles of Yagi-Uda antenna design, the role of simulation software, and the latest research trends in using CST for Yagi-Uda antenna optimization. The Yagi-Uda antenna was invented by Shintaro Uda and popularized by Hidetsugu Yagi [1]. The performance of a Yagi-Uda antenna depends on the number of directors, their spacing, and the length of the elements. Research has shown that the gain of the antenna increases with the number of directors, but the additional size can limit the practicality of certain designs, especially in modern compact devices [2].

The Yagi–Uda antenna typically consists of parallel thin rod elements, each about half wave in length. Rarely, the elements are discs rather than rods. Often, they are supported on a perpendicular crossbar or "boom" along their centers. Usually there is a single dipole driven element consisting of two collinear rods each connected to one side of the transmission line, and a variable number of parasitic elements, reflectors on one side and optionally one or more directors on the other side [3]. The parasitic elements are not electrically connected to the transmission line and serve as passive radiators, reradiating the radio waves to modify the radiation pattern. Typical spacings between elements vary from about 1⁄10 to 1⁄4 of a wavelength, depending on the specific design. The directors are slightly shorter than the driven element, while the reflector(s) are slightly longer. [4] demonstrate that varying the lengths of directors can lead to higher gain and improved impedance matching across a wider range of frequencies. It is necessary to have antennas with good directivity for effective signal reception [5].

Yagi Uda antenna's application is huge. Substrate lens Yagi-Uda antenna best suitable for applications in 5G and beyond [6]. This antenna can be implemented with solar cells [7]. Planar compact Yagi-Uda antenna is used for WLAN 2.4GHz band applications [8]. Planar quasi Yagi-Uda antenna based on liquid crystal (LC) technology for millimeter-wave applications [9].

5 Methodology

5.1 Flow chart

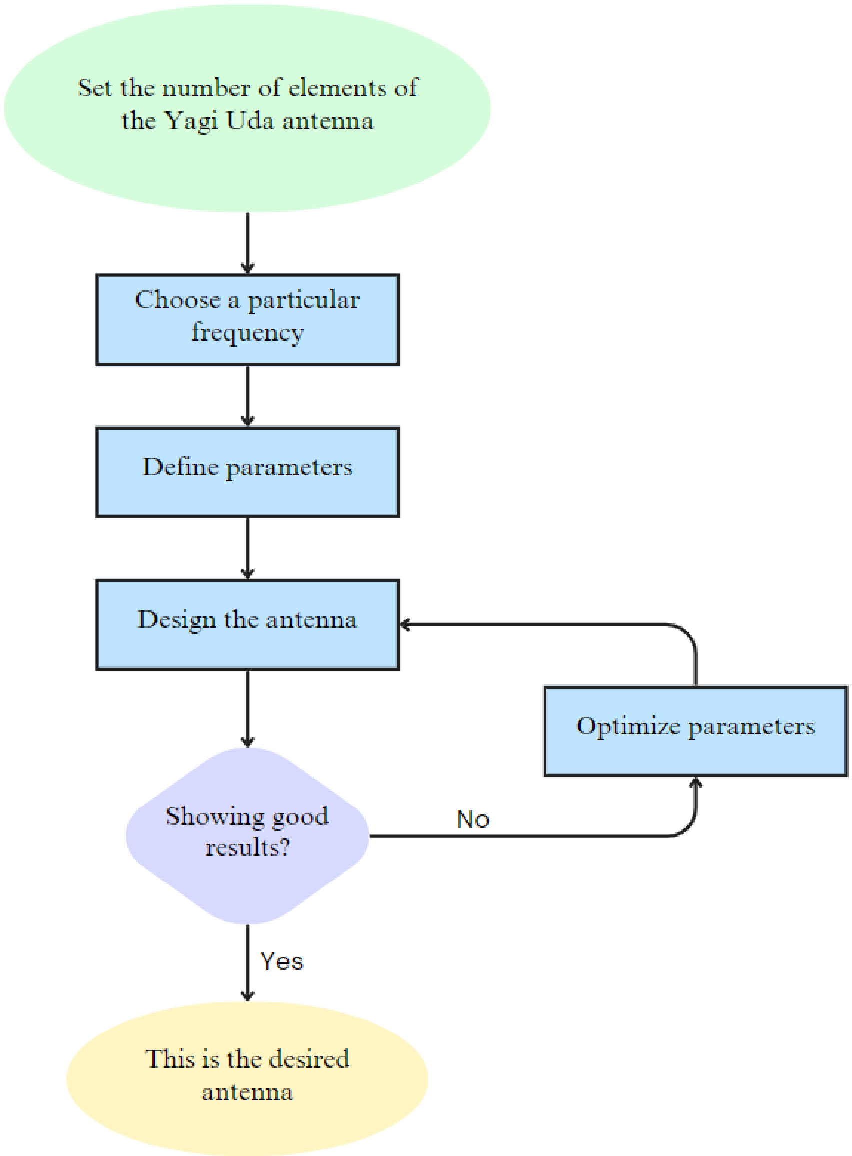

Fig 1: Flow chart of the design

5.2 Design parameters

To design the 3 element and 8 element Yagi Uda antenna, following steps are taken-

- The number of directors for Yagi Uda antenna is taken from the number of elements.
- The operating frequency is chosen to be 2.45 GHz.
- Size of the dipole antenna, reflector and directors, distance among each element is calculated from the operating frequency.
- For 3 elements antenna, 1 dipole antenna with 1 reflector and one director are used. Similarly, for 8 element antenna, 1 dipole antenna with 1 reflector and 6 directors are used.
- A boom is designed for structural support, ease of mounting and maintain spacing of the antenna.

Table-1: Parameter values

Element	3 element Yagi-Uda antenna	8 element Yagi-Uda antenna
Operating frequency	2.45 GHz	2.45 GHz
Wavelength	113.2 mm	113.2 mm
Dipole length	0.5λ	0.5λ
Reflector length	0.55λ	0.55λ
Director 1 length	0.45λ	0.45λ
Director 2 length	-	0.4λ
Director 3 length	-	0.35λ
Director 4 length	-	0.35λ
Director 5 length	-	0.35λ
Director 6 length	-	0.35λ
Dipole to reflector spacing	0.35λ	0.35λ
Dipole to director spacing	0.2λ	0.2λ
Director to director spacing	0.125λ	0.125λ
Boom length	0.75λ	1.125λ

6 Simulation Results

6.1 Three element Yagi-Uda Antenna

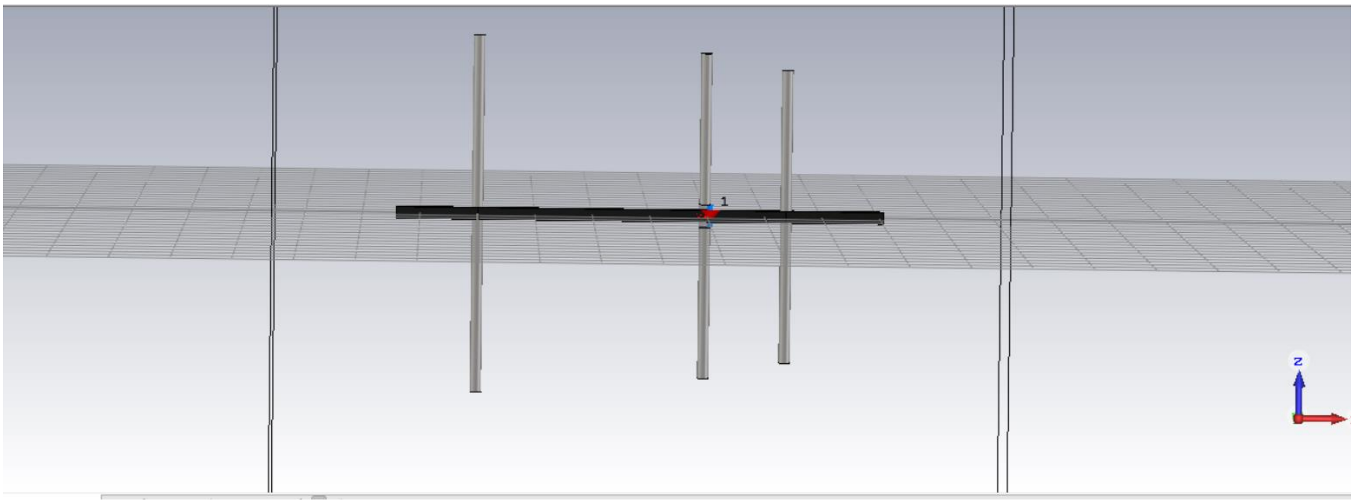

Fig 2: Diagram of three element Yagi-Uda Antenna

6.1.1 S parameter

For the three element Yagi-Uda antenna, the wavelength was primarily selected as 150 lambda. The goal was to build an antenna with a cutoff frequency of 2.45 GHz. But from s parameter, it is evident that the output is slightly shifted from the desired frequency which is needed to be minimum.

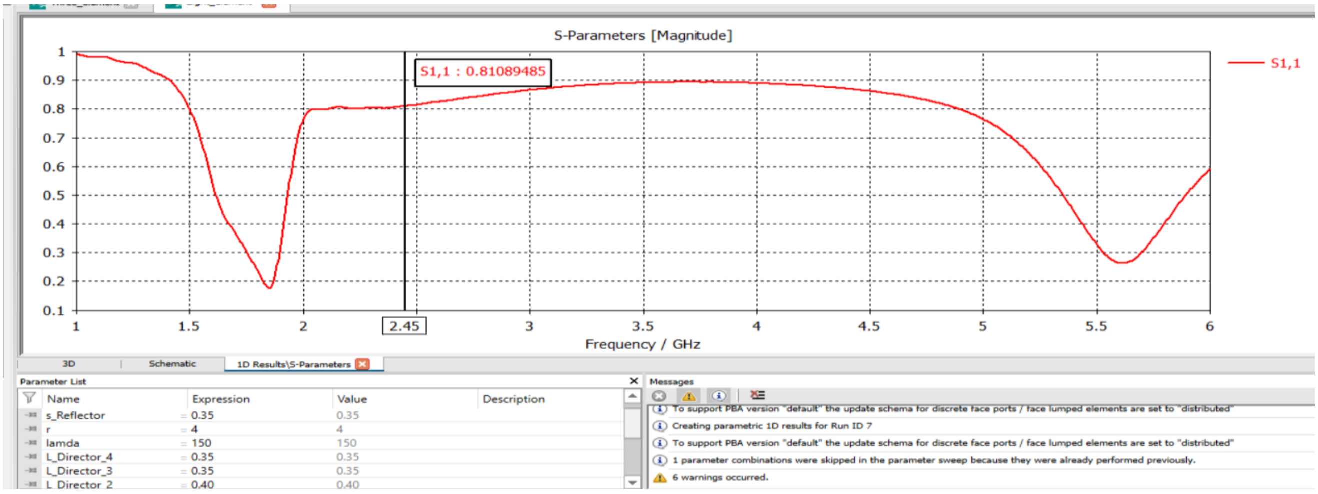

Fig 3: S parameter at lambda value of 150

To understand at what lambda the desired frequency can be obtained is by doing parametric sweeping which is basically running the simulation at different lambda value. The parametric sweeping was done with a range of 90 to 100 lambda having 10 lambda difference each.

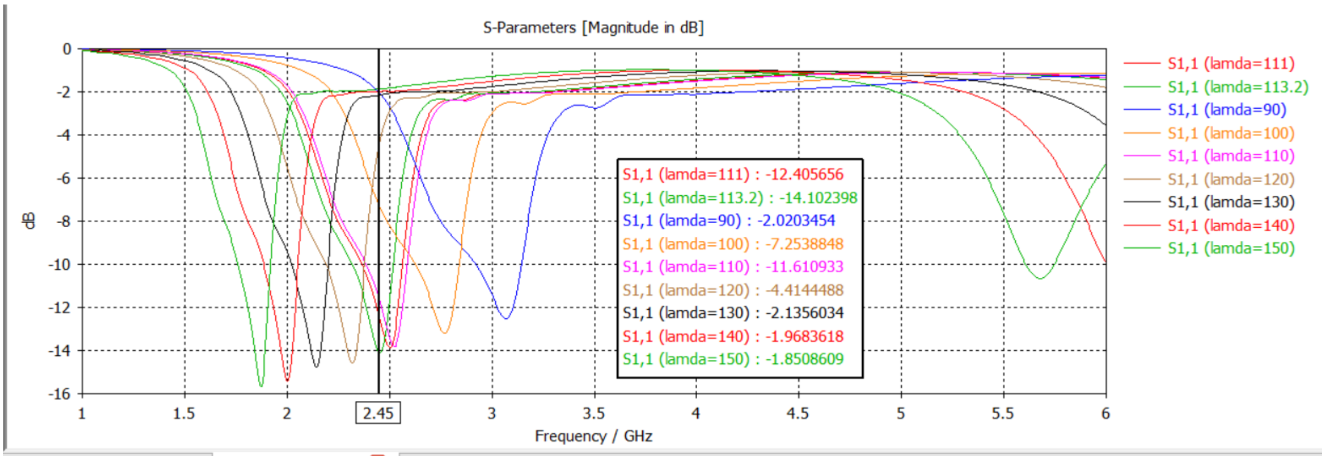

Fig 4: Parametric sweeping result

From the sweeping results it is sure that the value is near the 110 lambda. The final value of lambda is 113.2 for three element Yagi-Uda antenna.

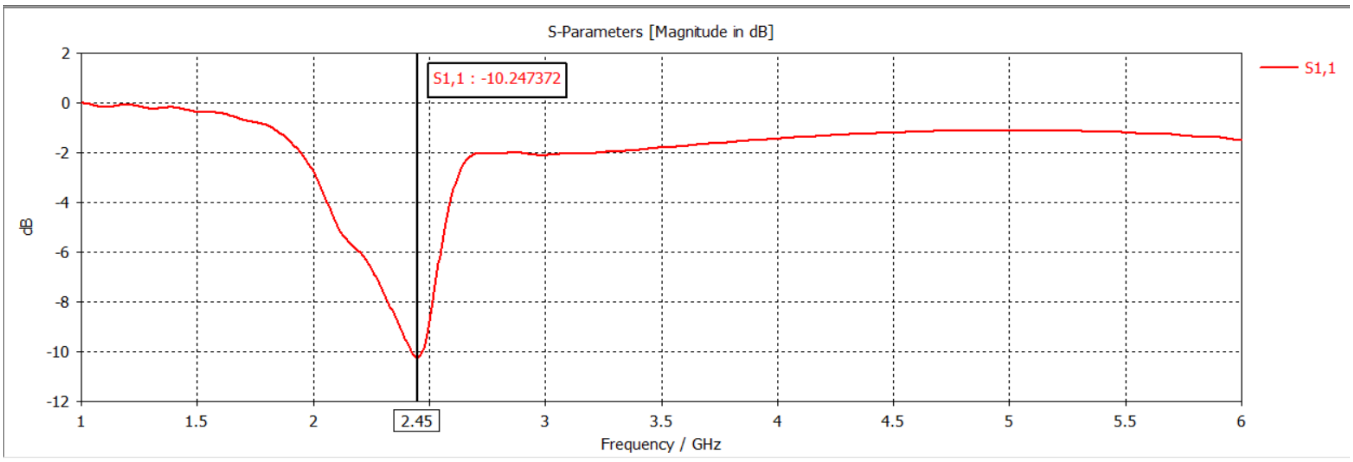

Fig 5: Desired s parameter at 2.45 cutoff frequency

6.1.2 VSWR

The VSWR is near to 1 for three element Yagi-Uda antenna at cutoff frequency.

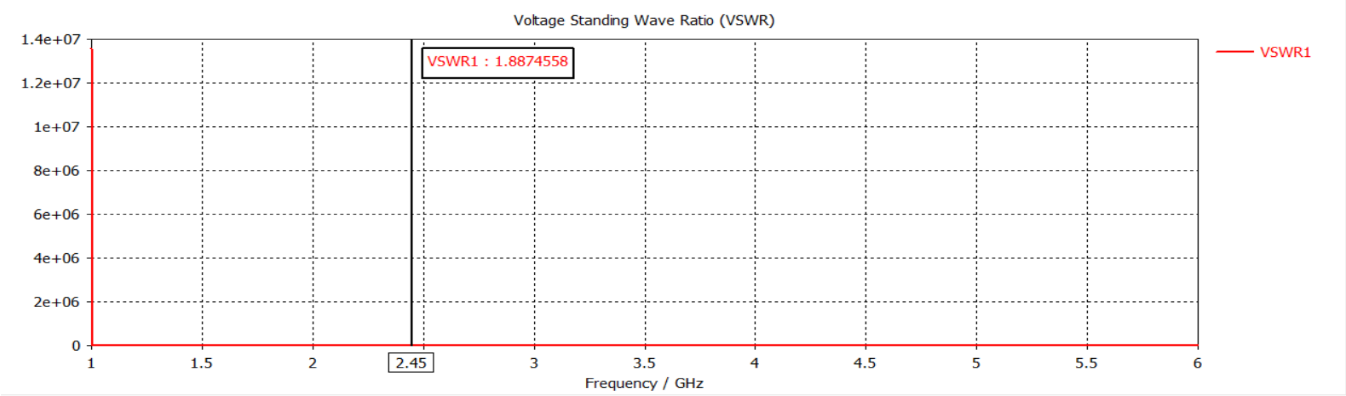

Fig 6: VSWR at 2.45 GHz

6.1.3 Far-field

The maximum far field gain achieved is 7.837 dBi. It is a directive antenna, and the main lobe is directed to x axis. Main lobe direction is at 90 degrees. It has an angular width of 65 degrees and a side lobe level of -20.9 dB which is very small.

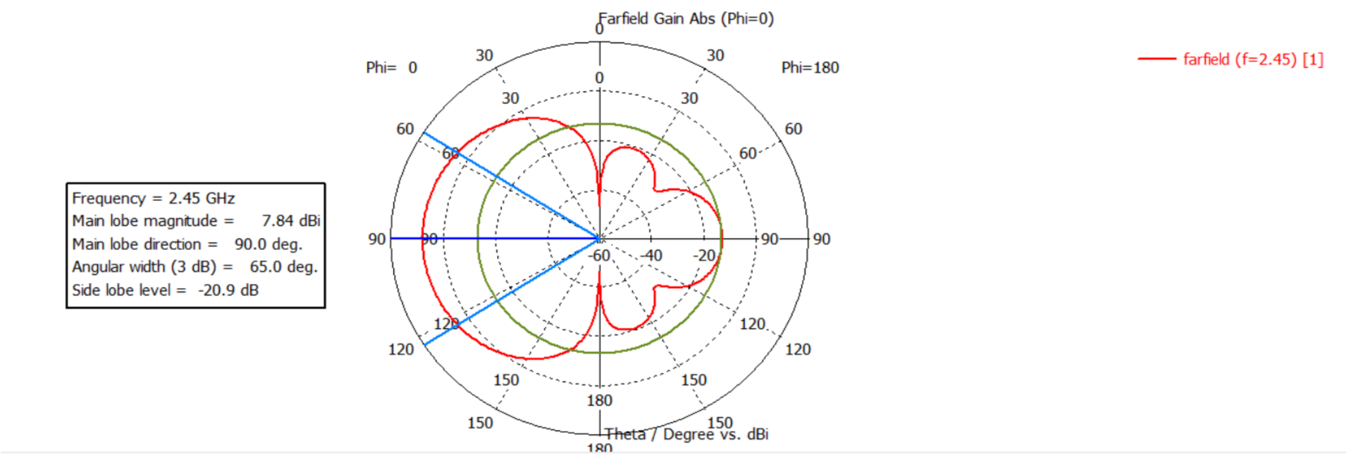

Fig 7: Far-field analysis

6.1.4 Gain vs Frequency

The gain is high at the desired frequency.

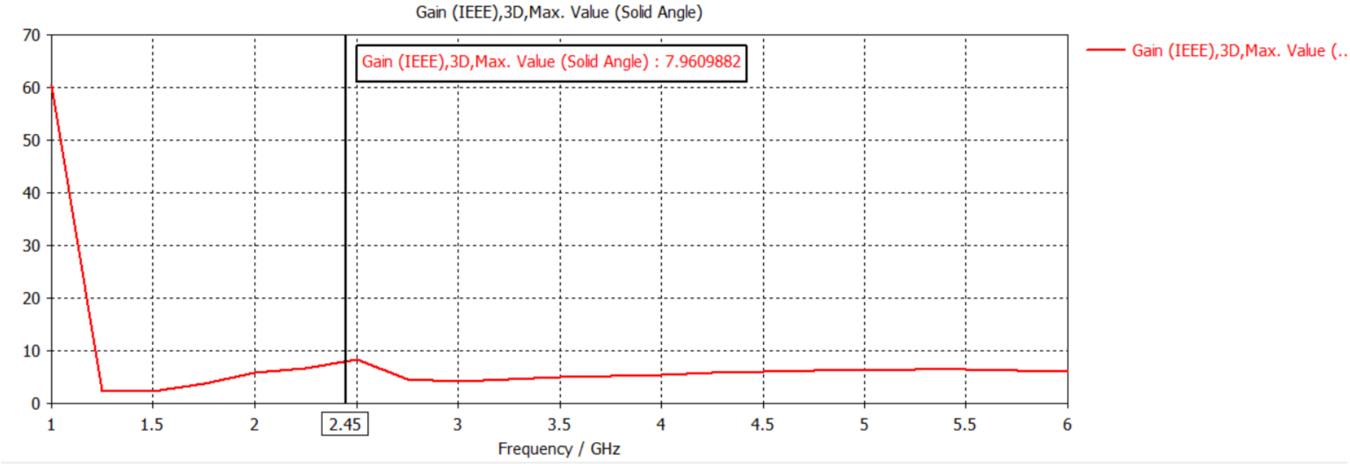

Fig 8: Gain vs Frequency curve

6.2 Eight element Yagi-Uda Antenna

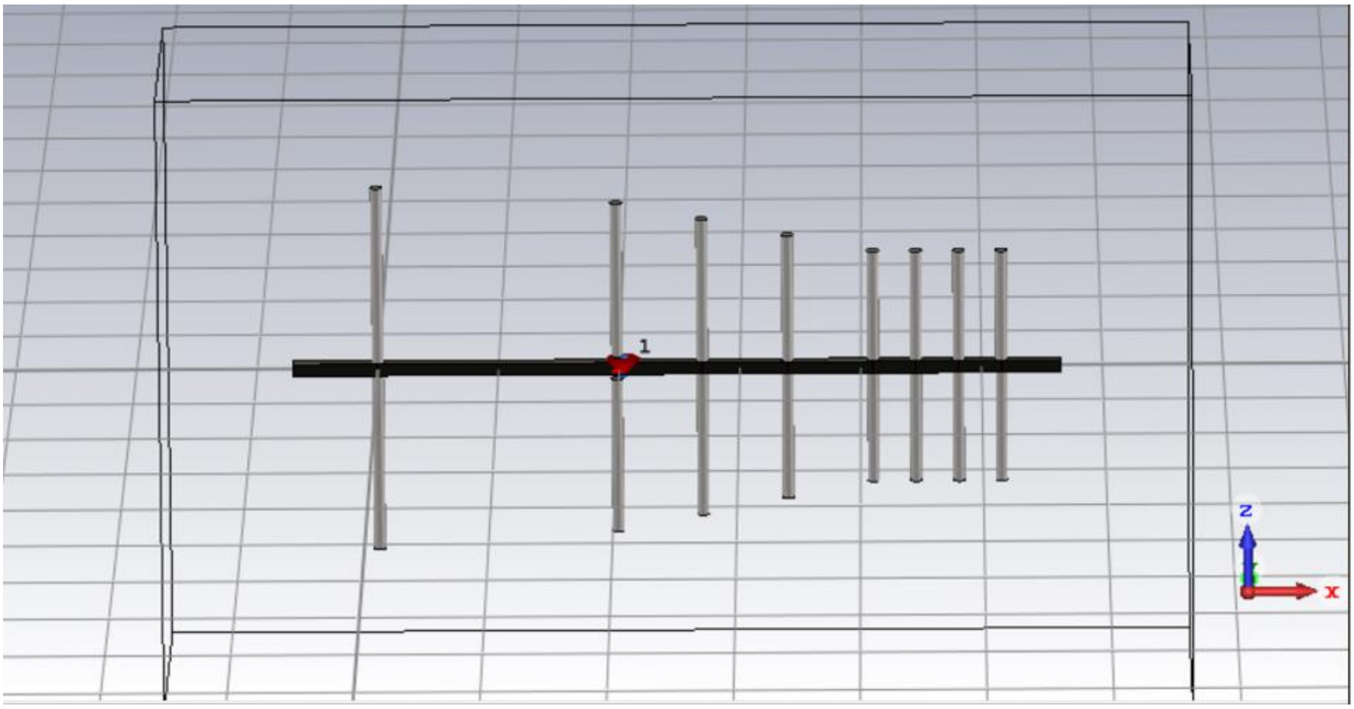

Fig 9: Diagram of Eight element Yagi-Uda Antenna

6.2.1 S parameter

To understand at what lambda the desired frequency can be obtained is by doing parametric sweeping which is basically running the simulation at different lambda value. The parametric sweeping was done with a range of 90 to 100 lambda having 10 lambda difference each.

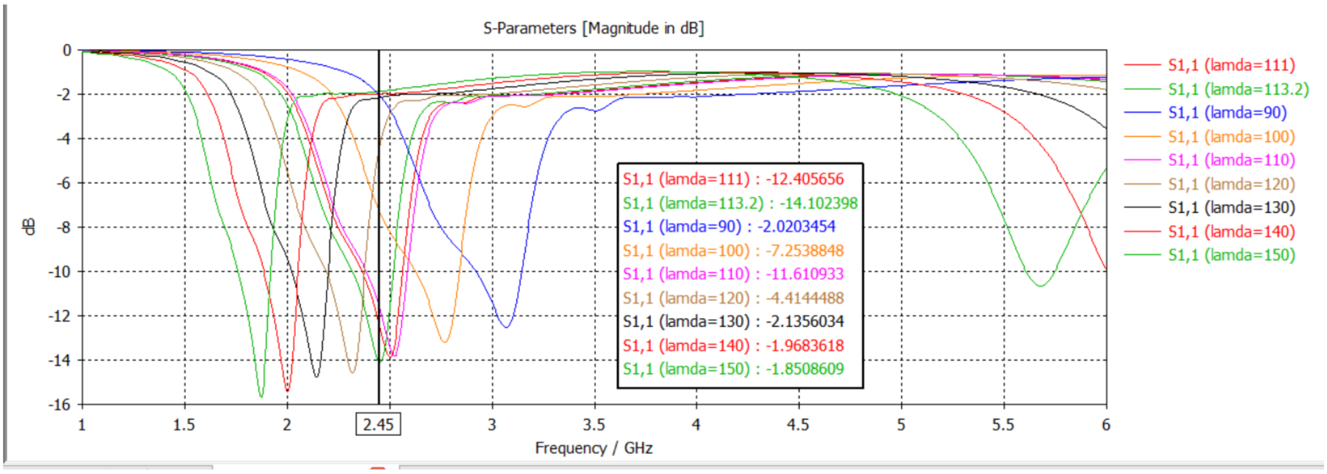

Fig 10: Parametric sweeping for 8 elements

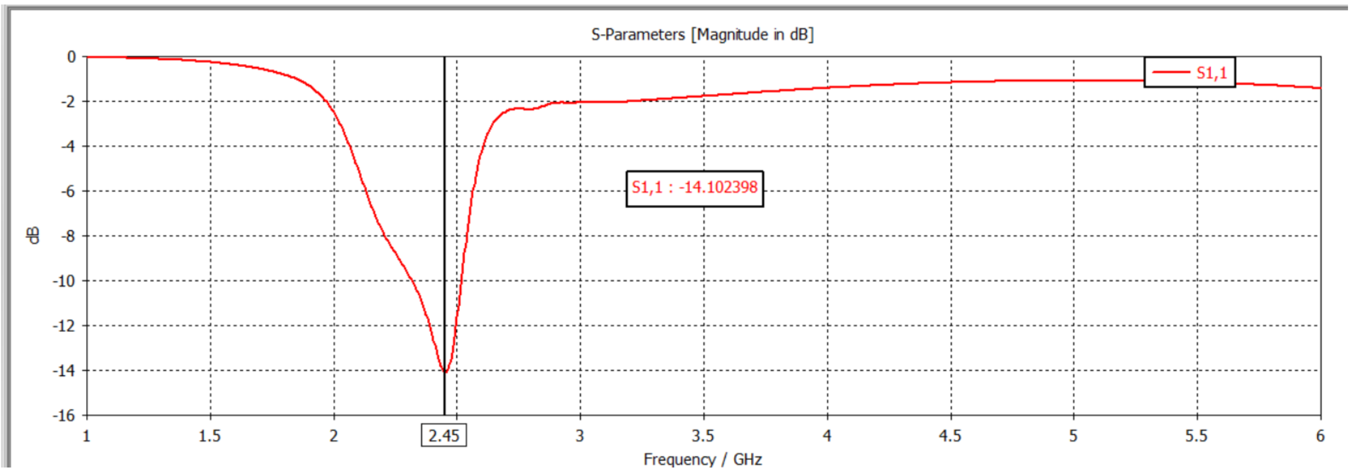

Fig 11: S parameter at 2.45 GHz

6.2.2 Far-field

In the polar plot (Figure 12), the main lobe magnitude is 9.69 dBi with a main lobe direction of 90 degrees. The side lobe level is –22.6 dB, ensuring minimal interference.

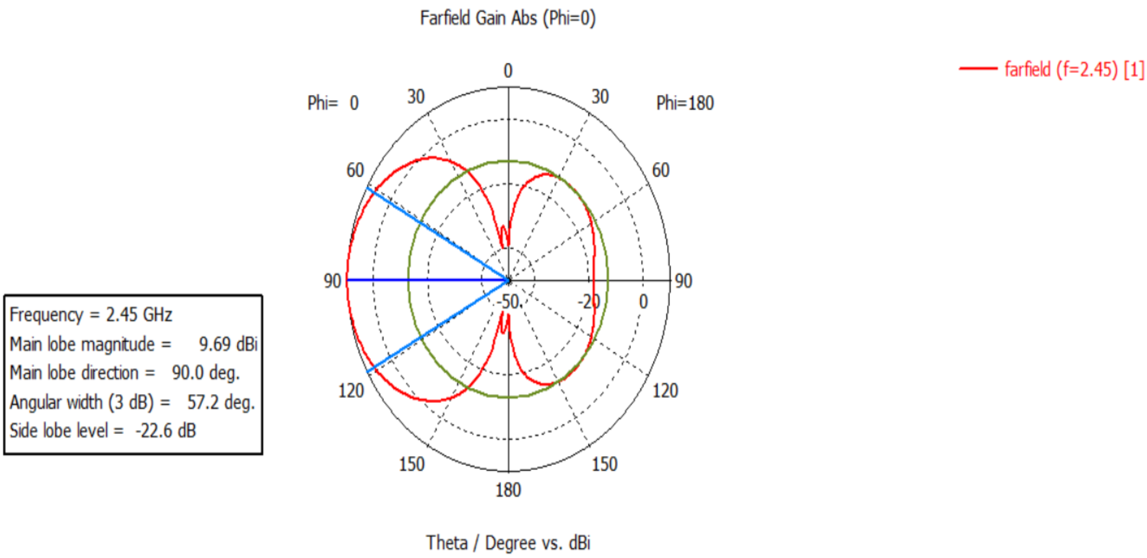

Fig 12: Far field analysis for 8 element Yagi-Uda Antenna

6.2.3 VSWR

Figure 13 presents the VSWR graph. The VSWR reaches a minimum value close to 1 at the resonance frequency of 33 GHz, validating that the antenna is well-matched to the feed line with minimal signal reflection.

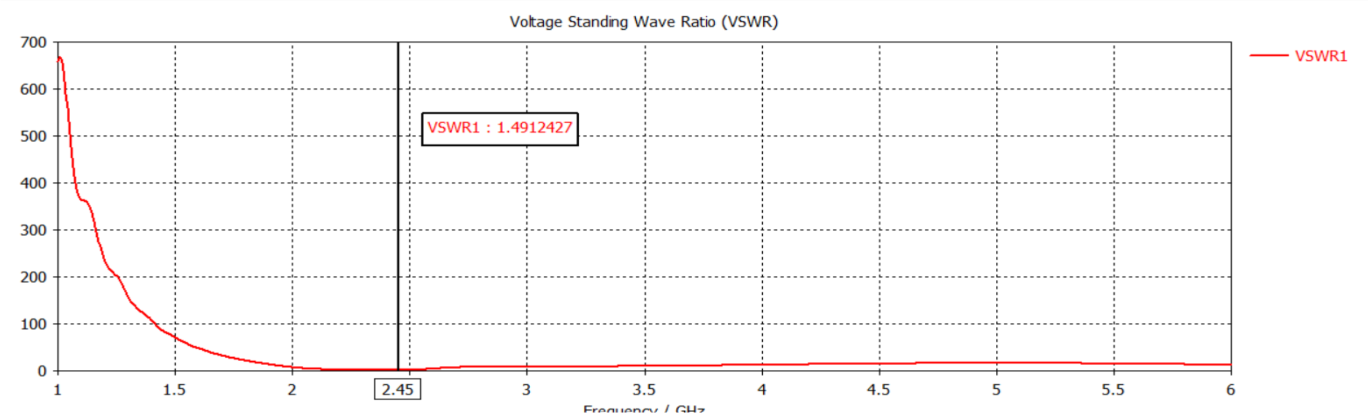

Fig 13: VSWR at 2.45 GHz

6.2.4 Gain vs Frequency

The gain is high at the desired frequency.

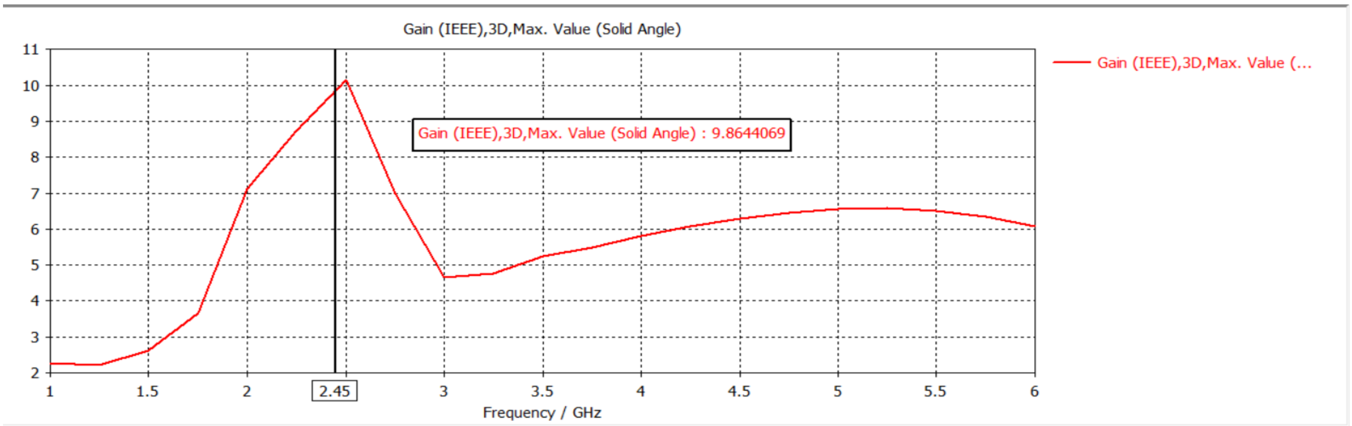

Fig 14: Gain vs Frequency curve

7 Interpretation of Results

The reason for choosing wavelength sweeping is to reduce the antenna size. Smaller antennas are more compact than the large antenna, giving the same output. Both antennas have higher gain and directivity, which is useful for long distance communication. From the simulations, using more directors can give better results.

The output of the simulation indicates that:

- Wavelength value is changed to obtain desired output.
- Parametric sweeping is applied.
- 8 element antenna has higher far field gain.
- By using Boom, results slightly shift from the desired frequency.

8 Application of the Design

The applications of the Yagi-Uda antenna are as follows:

- Television reception, especially for terrestrial TV signals in the VHF and UHF frequency ranges.
- Amateur (ham) radio for long-distance communication due to its high gain and directional properties.
- Radar systems focus signals on a specific direction to improve detection and tracking.
- Satellite communication for signal transmission and reception in ground stations.
- Wireless communication systems, including point-to-point links and remote communication setups.
- FM broadcasting for transmitting or receiving radio signals over long distances.
- Wi-Fi signal enhancement in specific directions to improve coverage and reduce interference.

9 Shortcomings/ Drawbacks of the Design

There are some drawbacks of the design of Yagi-Uda antenna. The drawbacks are as follows:

- The antenna has a narrow bandwidth, meaning it operates effectively over a limited frequency range.
- To achieve high gain, especially at lower frequencies, the antenna requires a large size with a long boom and multiple elements, making it bulky and difficult to install.
- The design can become complex when additional directors are added to increase gain.
- Performance can be affected by environmental factors such as nearby structures or weather conditions.
- The antenna is prone to noise.

10 Conclusion

The Yagi-Uda antenna is a highly effective design in wireless communication, known for its efficiency and directionality. It's simple structure, which includes a driven element and parasitic elements, allows for significant signal enhancement. This makes it a popular choice for applications like television reception, amateur radio, and radar systems. As technology continues to advance, there is great potential to improve the Yagi-Uda antenna's bandwidth and reduce its size for modern communication needs. The growing demand for reliable communication systems may lead to new designs that work well with technologies like 5G. The Yagi-Uda antenna offers exciting possibilities for future developments in the field of electromagnetics.

11 References

[1] H. Yagi and S. Uda, “Projector of the Sharpest Beam of Electric Waves,” *Proc. Imp. Acad.*, vol. 2, no. 2, pp. 49–52, 1926, doi: 10.2183/pjab1912.2.49.

[2] C. A. Balanis, *Antenna theory: analysis and design*, Fourth edition. Hoboken, New Jersey: Wiley, 2016.

[3] C. A. Balanis, *Modern Antenna Handbook*. Somerset: Wiley, 2011.

[4] A. Zeghdoud, M. C. Derbal, and M. Nedil, “Gain Optimization of a Yagi-Uda Antenna using the Genetic Algorithm,” in *2019 IEEE International Symposium on Antennas and Propagation and USNC-URSI Radio Science Meeting*, Atlanta, GA, USA: IEEE, Jul. 2019, pp. 1041–1042. doi: 10.1109/APUSNCURSINRSM.2019.8889003.

[5] R. Reddy and R. Swaminathan, “Directivity Improvement of 9-Element Yagi Uda Antenna by increasing director elements in comparison with 7-Element Yagi Uda Antenna,” in *2022 3rd International Conference on Intelligent Engineering and Management (ICIEM)*, London, United Kingdom: IEEE, Apr. 2022, pp. 561–564. doi: 10.1109/ICIEM54221.2022.9853131.

[6] T. A. Nisamol, P. Abdulla., and K. K. Ansha, “Wideband Sub-THz Substrate lens Yagi- Uda antenna for 5G Communications and beyond,” in *2020 IEEE-HYDCON*, Hyderabad, India: IEEE, Sep. 2020, pp. 1–5. doi: 10.1109/HYDCON48903.2020.9242679.

[7] A. Ali, H. Wang, and I. Park, “A Yagi-Uda Antenna Implemented with Solar Cells,” in *2024 IEEE International Workshop on Antenna Technology (iWAT)*, Sendai, Japan: IEEE, Apr. 2024, pp. 323–325. doi: 10.1109/iWAT57102.2024.10535854.

[8] R. K. Tanti, S. Warathe, and N. Anveshkumar, “Planar Yagi-Uda Antenna with Mirrored Ground Plane for WLAN,” in *2020 11th International Conference on Computing, Communication and Networking Technologies (ICCCNT)*, Kharagpur, India: IEEE, Jul. 2020, pp. 1–5. doi: 10.1109/ICCCNT49239.2020.9225278.

[9] D. Wang *et al.*, “A Planar Quasi Yagi-Uda Antenna Designed For Liquid Crystal Based End-Fire Phased Arrays,” in *2021 IEEE Radio and Wireless Symposium (RWS)*, San Diego, CA, USA: IEEE, Jan. 2021, pp. 164–167. doi: 10.1109/RWS50353.2021.9360363.