Assignment 1: EE3089F (2024)

Yagi-Uda Antenna

Ntsako Phiri PHRANN001 • Mukundi Mangena • MNGBLE005•Zolile Zoko ZKXZOL001 • Tohlang Rakhapu RKHTOH001

Introduction:

The aim of this project is to construct a Yagi-Uda antenna. We will use software, i.e. FEKO, to optimise antenna dimensions based on desired performance. Following simulation, a real prototype will be built and evaluated to ensure the accuracy of the design. Yagi-Uda antennas are excellent in directed transmission and reception of electromagnetic waves in both radio and optical regimes. This project focuses on traditional radio frequency (RF) applications. Yagi antennas improve signal strength and filter out interference, making them excellent for use in television reception, point-to-point communication, and wireless networks.

Construction:

Materials: Copper wire (2mm diameter) ,Veroboard (small section), BNC through-hole connectorPerspex sheet (40 cm length), Tape or glue for assembly.

Tools: Soldering iron and solder, Wire cutter, Ruler, Marker, Drill

Assembly Process

1. Element Preparation: The 2 mm copper wire is cut into predefined lengths for the following antenna components: reflector, driven element, and four directors. To ensure accurate lengths, make measurement lines on the wire before cutting with a wire cutter.
2. Boom markings: A ruler is used to mark the exact placements of each copper component on the Perspex which serves as the antenna boom. These markings will determine the space between the reflector, driven element, and director-to-director spacing.
3. Connector assembly: BNC Connector and Holes are drilled into the Veroboard to fit the BNC through-hole connector. The connector is then soldered securely to the Veroboard.
4. Feed Point Assembly: The driven element wire is connected to the Veroboard, making a power connection with the BNC connector, the connector will function as the antenna's feed point.
5. Component attachment: At the previously designated locations on the Perspex boom, firmly attach the reflector, driving element, and all four directors using tape or glue. This ensures that the elements are properly positioned for peak antenna performance.

Design and Simulations

The following are specifications from the assignment manual and the chosen operating frequency for the group's yagi uda antenna.

Specifications:

- Operating frequency: 1.3 GHz
- Yagi antenna elements: 6 (1 reflector, 1 driven element , 4 directors)
- Gain: 12.35dBi = 10.2dB
- Bandwidth <= 2% (about centre frequency)

Given the operating frequency of the antenna is 1.3 GHz and after following all the steps detailed in the yagi uda design document for EE3089F the following Antenna dimensions were calculated.

Table 1 below shows the dimensions of the different elements of the yagi antenna. The initial lengths column are based off the theoretical design and design curves. These were then simulated and then improvements were made on these dimensions through optimisation using the FEKO simulations. The new optimised lengths are depicted in the rightmost column labelled length on Table 1.

Element	Schematic Element	Initial length(mm)	length(mm)
Reflector	l1	111.15	112.5
Driven element	l2	104.9	106.2
Director 1	l3	98.7	99.9
Director 2	l4	96.8	98.03
Director 3	l5	96.8	98.0
Director 4	l6	98.7	99.9
Spacing between reflector and driven element	s12	46.1	46.1
Spacing between Directors	Sij	57.6	57.6

Table 1 : Lengths of the directors, dipole and reflector

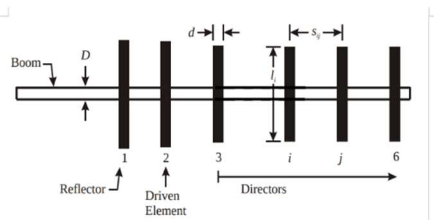

Figure 1 Schematic of the Antenna

2 Simulations

Figure 2 below shows the reflection coefficients of the designed antenna. The minimum value should be at the designed frequency (1.3GHz). This is achieved on the left subfigure of figure 2 where lengths have been optimised.

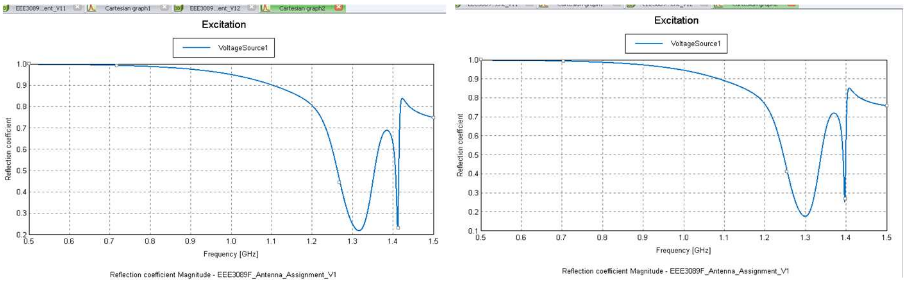

Figure 2 The left figure shows the results for initial calculations and on the right are the results for the optimised design.

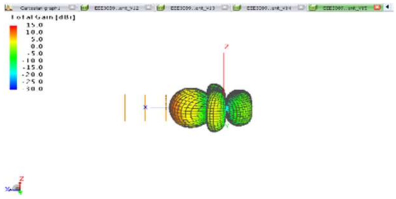

Figure 3 field pattern of optimised design

Figure 3 shows the gain variation of the gain of the antenna in the direction of radiation. The maximum gain is 15dBi > 12.35dBi. Therefore, the antenna meets the gain specifications.

Testing & Results

Figure 5 below shows the Reflection coefficient vs frequency curve of the antenna in transmission mode. This was achieved by exciting the Driven element and measuring the reflection coefficient.

Figure 6 shows the gain of the antenna when used as a receiver. This was achieved by sending a signal from a reference antenna of a known gain, and measuring the gain of the received signal.

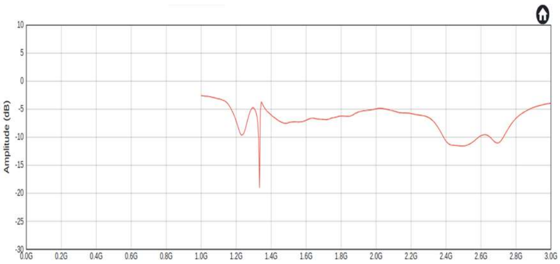

Figure 5 Transmitter amplitude test results

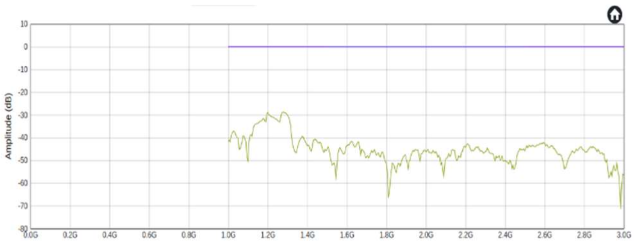

Figure 6 Antenna as a receiver results

Looking at Figure 5, the reflection coefficient at 1.3GHz is -4.8dB = 0.33. This value is greater than the simulated value by 0.15. Also, the minimum value of the reflection coefficient from the graph is -9.34dB = 0.116, which occurs at 1.24GHz. It is therefore evident that the antenna best performs at 1.24GHz, which is 5% lower than the designed value.

Looking at Figure 6, At the 1.3GHz the gain of the antenna is -30.12dB = 0.000973. But the peak value for the gain is at 1.28GHz, with a value of -28.83dB = 0.0013. Thus the antenna performs best at 1.28GHz which is 2% off the designed value (within the design bandwidth). The antenna was placed 2m from a transmitting HyperLog antenna. The gain of the transmission antenna is 2.35dB = 1.72 at 1.3GHz and 2.45dB = 1.76 at 1.28GHz. Using the Friis Transmission equation the gain of the antenna can be calculated as follows:

$$\frac{P_{rec}}{P_r} = G_t G_r \left(\frac{\lambda}{4\pi R}\right)^2 \Rightarrow G_r = \frac{P_{rec}}{P_r} \times \left(\frac{4\pi R}{\lambda}\right)^2 \times \frac{1}{G_t}$$

At 1.3GHz	At 1.28GHz
Gr = 8.267dB This is 1.933dB below the design specification.	Gr = 9.425dB This is 0.775dB below the design specification.

In conclusion: The physical design is performing poorer than the specifications at the design frequency of 1.3GHz. This is likely due to unmatched impedances, and imperfections in the dimensions of elements used.

Picture of The Antenna: