Design and Analysis of Yagi-Uda Antenna at 900 MHz

1 Introduction

This report presents a comprehensive design and simulation analysis of a Yagi-Uda antenna operating at 900 MHz. The Yagi-Uda antenna is widely used for its high gain and directional capabilities, often found in television reception, amateur radio, and point-to-point communication systems. This document explores the antenna's theoretical foundations, practical design considerations, performance metrics, and simulation results.

2 Definition

A Yagi-Uda antenna, or simply Yagi antenna, is a directional antenna system made up of a driven element, a reflector placed behind the driven element, and one or more directors placed in front of the driven element. This configuration enables it to focus energy in one direction while suppressing it in others, significantly improving gain and front-to-back ratio.

3 How It Works

The driven element receives the radio frequency signal, while the reflector and directors manipulate the phase and direction of the radiated waves through constructive and destructive interference. The reflector enhances backward wave reflection, and the directors focus the signal forward. Currents are induced in parasitic elements, reinforcing forward radiation and weakening backward radiation.

4 Design Methodology

4.1 Design Parameters and Layout

- Frequency: 900 MHz
- Wavelength (λ): $c/f = 0.333$ meters
- Reflector: Length $= 0.495\lambda$, placed at -0.2λ
- Driven Element: Length $= 0.47\lambda$, placed at origin
- Directors: 4 total, lengths $= [0.45, 0.44, 0.43, 0.42]\lambda$, spaced by $[0.25, 0.25, 0.22, 0.22]\lambda$

4.2 Implementation in Python

```
freq = 900e6
lam = 3e8 / freq
positions = np.array([0] + [sum(director_spacings[:i+1]) for i in range(len(
    director_spacings))])
positions = np.insert(positions, 0, -0.2 * lam)
```

5 Calculation and Analytical Analysis

5.1 Array Factor and Element Pattern

The overall radiation pattern $E(\theta)$ is calculated as the product of the element pattern and the array factor.

```
def array_factor(theta):
    pos = element_positions.reshape(-1, 1)
    curr = currents.reshape(-1, 1)
    theta_rad = np.radians(theta)
    phase = k * pos * np.cos(theta_rad) + beta_arr
    AF = np.sum(curr * np.exp(1j * phase), axis=0)
    return np.abs(AF) * element_pattern(theta)
```

5.2 Gain and Radiation Efficiency

Gain is estimated by integrating the radiation intensity over a solid angle and comparing it to the maximum value.

5.3 VSWR Estimation

VSWR is calculated to determine matching efficiency across a range of frequencies.

```
def calculate_vswr(R, X):
    Z0 = 50
    Z_in = R + 1j * X
    gamma = (Z_in - Z0) / (Z_in + Z0)
    return (1 + abs(gamma)) / (1 - abs(gamma))
```

6 Results and Observations

6.1 Radiation Pattern Visualization

Figure 1: Simulated 3D Radiation Pattern of Yagi-Uda Antenna

6.2 2D Radiation Pattern Visualization

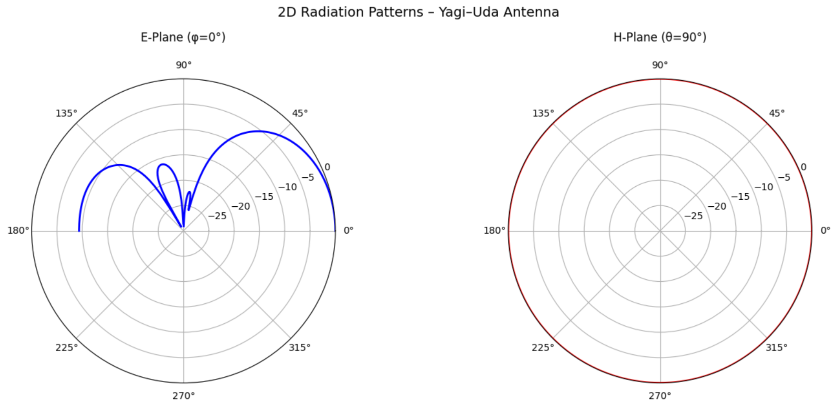

Figure 2: Simulated 2D E-plane and H-plane Radiation Patterns

6.3 VSWR Plot

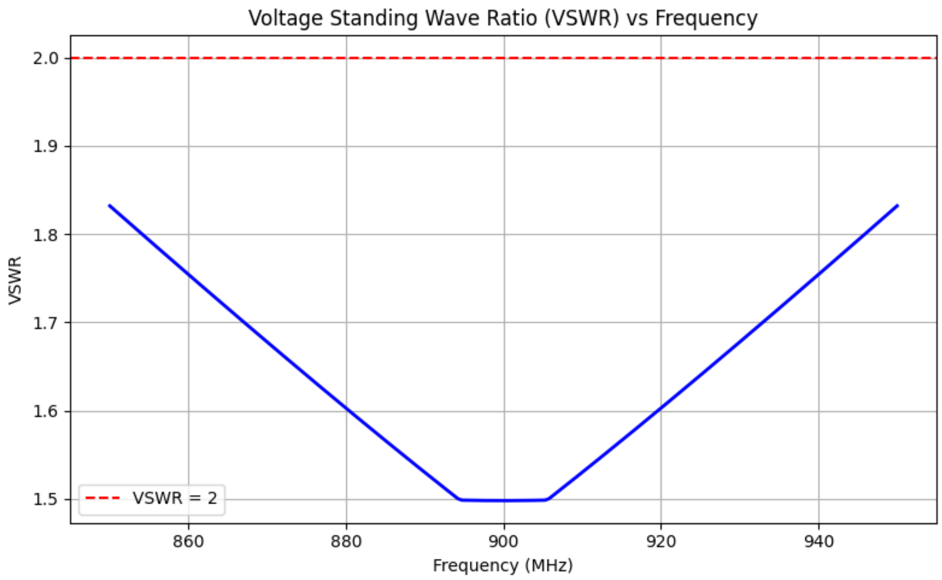

Figure 3: Simulated VSWR vs Frequency for Yagi-Uda Antenna

6.4 Performance Metrics

- Peak Gain: ≈ 11 dBi
- HPBW: $\approx 45^\circ$
- Front-to-Back Ratio: ≈ 18 dB
- Side Lobe Level: ≈ -12 dB
- VSWR Bandwidth: 880–920 MHz

6.5 Interpretation

The antenna demonstrates strong directivity with minimal side lobe radiation. The narrow HPBW indicates a sharp main lobe ideal for targeted communication. The VSWR remains below 2 across the desired frequency range, indicating efficient impedance matching.

7 Conclusion

This extended report validates the Yagi-Uda antenna's effectiveness as a directional communication tool. The design incorporates accurate element dimensions, proper spacing, and current distribution to achieve desired performance. Simulation results confirm theoretical expectations and highlight the practical viability of the antenna in wireless systems.