Experiment No. 6 DESIGN AND ANALYSIS OF YAGI-UDA ANTENNA (PARASITIC ARRAY)

Date: ________________

Aim:

To understand design and analysis of Yagi-Uda antenna.

Software requirements:

Software- 4nec2 (Numeric Electromagnetic Coder), Operating System- Windows XP, windows 7 and above

Theory:

The typical example of parasitic array is Yagi-Uda antenna The Yagi–Uda antenna (also known as a Yagi) is popular type of end-fire antenna widely used in the VHF and UHF bands (30 MHz to 3 GHz) because of its simplicity, low cost and relatively high gain. The most noticeable application is for home TV reception and these can be found on the rooftops of houses as it provides moderate gain (10-18 dB) at a low cost.

Yagi and Uda were two Japanese professors who invented and studied this antenna in the 1920s. S. Uda made the first Yagi–Uda antenna and published the results in Japanese in 1926 and 1927, and the design was further developed and published in English by his colleague Professor Yagi a year later. Since then a significant amount of work has been done theoretically and experimentally. A lot of data and results are available in the public domain. The main feature of this type of antenna is that it consists of three different elements: the driven element, reflector and director, as shown in Figure 1 below-

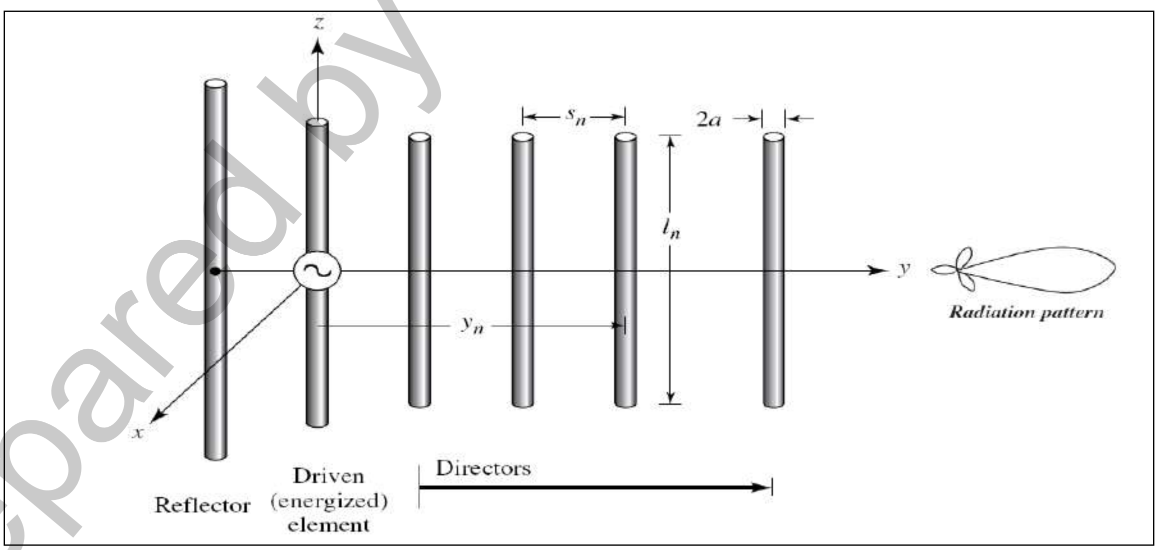

Fig. 1: Geometry of Yagi-Uda Antenna (typical parasitic array configuration)

The Yagi–Uda antenna can also be considered as an array, since it has more than one element. However, it has just one active element and feed port; all the other elements (the reflector and directors) are parasitic. Thus, some people consider it as an element antenna rather than an antenna array. The main characteristics and design recommendations of these elements can be summarized as follows:

- **The driven element (feeder):** the very heart of the antenna. It determines the polarization and central frequency of the antenna. For a dipole, the recommended length is about 0.47λ to ensure good input impedance to a 50 feed line.

- **The reflector:** normally **slightly longer than the driven resonant element** to force the radiated energy towards the front. It **exhibits an inductive reactance**. It has been found that there is not much improvement by adding more reflectors to the antenna, thus there is only one reflector. The optimum spacing between the reflector and the driven element is between 0.15 and 0.25 wavelengths. The length of the reflector has a large effect on the front-to-back ratio and antenna input impedance.

- **The directors:** usually **10 to 20% shorter than the resonant driven element** and appear to direct the radiation towards the front. They are of **capacitive reactance**. The director to director spacing is typically 0.25 to 0.35 wavelengths, with larger spacing for longer arrays and smaller spacing for shorter arrays. The number of directors determines the maximum achievable directivity and gain.

- **Operational Principle**

  The special configuration (long reflector and short directors) has made the Yagi–Uda antennas radiate as an end-fire antenna. The simplest three-element Yagi–Uda antenna (just one director) shows an acceptable end-fire antenna pattern. The radiation towards the back seems to be blocked/reflected by the longer element, but not just by the reflector; the reflector and director produce push-and-pull effects on the radiation. Induced currents are generated on the parasitic elements and form a traveling wave structure at the desired frequency. The performance is determined by the current distribution in each element and the phase velocity of the traveling wave.

- **Current Distribution**

  The current distribution on the driven element is determined by its length, frequency and interaction/coupling with nearby elements (mainly the reflector and first director), while the current distribution in parasitic elements is governed by the boundary condition: the total tangential electric field must be zero on the conducting surface. This results in induced currents and they may be viewed as the second sources of the radiation. Analytical and numerical methods have been employed to obtain the current distribution along each element. Typically past experimentations by researchers show that the current distribution on each element is similar to that of a dipole. As expected, the dominant current is on the driven element; the reflector and the first director carry less current, and the currents on other directors are further reduced and they appear to be of similar amplitude, which is typically less than 40% of that of the driven element.

Radiation Pattern

For a dipole Yagi–Uda antenna, the radiation from element n is given by Equation –

$$E(\theta)_n \approx j\eta \frac{I_n e^{j\beta r}}{2\pi r}\left(\frac{\cos(\beta l_n \cos\theta) - \cos(\beta l_n)}{\sin\theta}\right)$$

where, I_n is the maximum current and l_n is half the length of the n^{th} dipole. Thus, the total radiation pattern is the field superposition from all the elements and may be expressed as-

$$E(\theta) \approx j\eta \frac{e^{j\beta r}}{2\pi r}\sum_{n=1}^{N} I_n\left(\frac{\cos(\beta l_n \cos\theta) - \cos(\beta l_n)}{\sin\theta}\right)\exp(j\beta S_{n-1}\cos\theta)$$

where, r is the center of the reflector to the observation point and spacing S0 = 0. It is apparent that each element length and spacing, weighted by its maximum current, affects the total radiation.

One **important figure of merit in a Yagi–Uda antenna is the front-to-back ratio** of the pattern. It has been found that this is very sensitive to the spacing of the director. It varies from trough to peak and from peak to trough repetitively as a function of the spacing.

Design:

(Students are expected to draw appropriate 2 separate sketches alongwith design in a tabular manner for 3-element and 5-element Yagi-Uda antenna operating at f = _ _ _ _ MHz.)

Observation Table:

Sr. No.	Antenna Configuration	HPBW	Gain
1	3-element Yagi-Uda antenna		
2	5-element Yagi-Uda antenna		

Conclusion:

For Yagi-Uda antenna configuration, as the number of elements goes on increasing, antenna gain increases.