Comparative Analysis of Yagi Uda Antenna of Different Loop Arrays

Kartik Goyal[1], Anvita Srivastava[2] , Vishumendra Thakur[3]

[1,2,3]*Department of Electronics & Communication Engineering, SRMS College of Engg. & Tech. Ram Murti Puram, Bareilly.*

Email: [1] kartikgoyal21@gmail.com, [2]anvitasrivastava18@gmail.com, visuaryan22@gmail.com

Abstract: An antenna is a metallic device for radiating and receiving radio waves. The parameters that can affect the characteristics of an antenna are the material chosen, the shape, the size and the feed used for the activation of the antenna. Different characteristics that get affected with design are the gain, input impedance, radiation pattern, etc. This paper concentrates on Yagi-Uda loop array antenna. This paper reviews and compares the characteristics of circular loop arrays and square loop arrays with an objective to find suitability of both for IEEE 802.11 Wi-Fi standard.

Keywords: Yagi-Uda antenna, input impedance and gain.

I. INTRODUCTION

Yagi-Uda antenna is familiar as the common kind of terrestrial TV antenna to be found of the roofs top of houses used at frequency between 30Mhz to 3Ghz & covers 40 to 60Km. Yagi-Uda array of linear dipoles possess a particular gain at particular frequency. On the other hand, yagi-uda array of loop array provides a better gain and input impedance compared to the array of linear dipoles. The general performance of a loop yagi-uda array is controlled by the same geometrical parameters (reflector, feeder & director sizes and the spacing between the elements) & it is influenced in the same manner as an array of linear dipoles.

2. DESIGN OF YAGI-UDA ARRAY OF CIRCULAR LOOPS

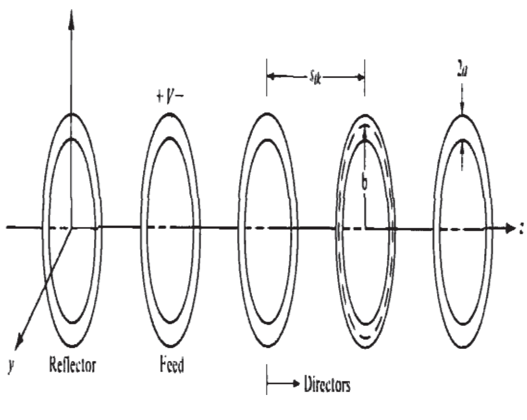

Fig. 1. - Element Yagi array of Circular loops

The circular Yagi-Uda antenna geometry is started from the conventional linear element Yagi-Uda antenna geometry and by rotating of the elements we form a low profile omni directional antenna. In the center of the rotational symmetric, geometry is placed the driven dipole. Antenna is optimized by varying the lengths and spacing of the circular elements. In a numerical parametric study of coaxial Yagi-Uda arrays of circular loops, it has been found that the optimum parameters for maximum forward gain were-

1. Circumference of feeder $2\pi b_2=1.1\lambda$, where b_2 is its radius. This radius was chosen so that the input impedance for an isolated element is purely resistive.
2. Circumference of the reflector $2\pi b_1=1.05\lambda$, where b_1 is its radius. The size of the reflector does not strongly influence the forward gain but has a major effect on the backward gain and input impedance.
3. Circumference of the director $2\pi b=0.7\lambda$, where b is the radius of the director and it was chosen to be the same for all. When the circumference approached a value of one wavelength, the array exhibited its cut-off properties.

Feeder-reflector spacing of about 0.1λ. Because it has negligible effect on the forward gain, it can be used to control the backward gain or the input impedance

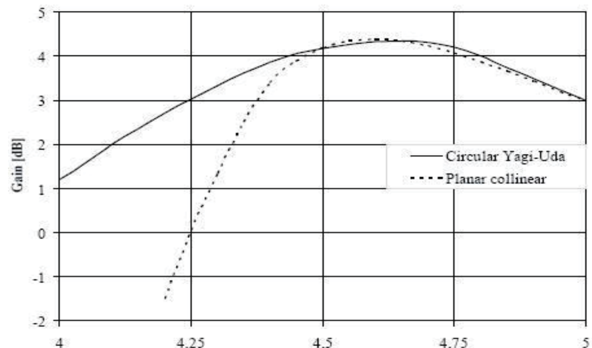

Fig. 2. - Gain of Yagi-Uda Array of Circular Loops

3. MATHEMATICAL INTERPRETATION

The N-element 2YSCLA and the coordinate system for the analysis are illustrated in Fig. 3. The array elements are arranged parallel to each other with centers on the axes stacked with spacing D in the Z direction, and the antenna is fed at the center of the driven two-stacked circular loops (# 2 and #2‘ in the figure) connected with the twin conductive wires. The reflector and director loops are parasitic.

As shown in Fig. 2, this antenna can be represented by an analytical model composed of loop elements and feeder sections.At first, as shown in Fig. l(b), the loop-element sections are considered as follows.

The radii of the loops and conductive wires are expressed by *bj* and *a,* respectively, where *a* < *bj,* A, Hjj, and D is assumed, Hjj is the distance between the centers of elements ***i*** and *j* . *V,* is

the driving point voltage of the ith loop. The gap width of the driving point is not infinitesimal but equal to
bj63;. and the current *Zi(S;.)* on the ith loop is assumed to flow along the direction of the wire and have uniform distribution in the circumferential direction on the wire. Then the integral equations for the current on the conducting wires are derived from the boundary condition on the surfaces of the wires as follows:

$$-\frac{(V_i}{b_i\delta\zeta_i}U_j(\zeta_i) = \sum_{j=1}^{N'}\int_{\theta}^{2\pi}[F_{ij}.I_j\left(\zeta'_j\right)]\ d\zeta'_{j,} \qquad i = 1, 2, \dots N'.$$

Where $U_j(\zeta_i)$ a function equal to unity at the driving point and zero elsewhere, ***Fij*** is the Green's function which is proportional to the electric field that is induced on the surface of the ith loop by the current on the ith or jth loop.
As a result of using the method of Fourier series expansion in order to solve the integral equation , we obtain the following simultaneous equation which contains Fourier components of the unknown currents I_j on the loop surface after some straightforward manipulations.

$$[Z_{ij}^{m.n}][I_j^n] = [M_j^n], \qquad i, j = 1, 2, \dots N' \quad m, n = 0, \pm 1, \pm 2, \dots$$

where $Z_{ij}^{m.n}$ is the self -($\boldsymbol{i = j}$) and mutual l-($\boldsymbol{i \neq j}$) impedances for the nth mode current calculated from the Fourier expansion coefficients of the integral including Green's functions, and M_j^n is the driving point-
voltage function defined as

$$\mathrm{M}_{\boldsymbol{j}}^{\boldsymbol{n}} = S_j^n V_j$$

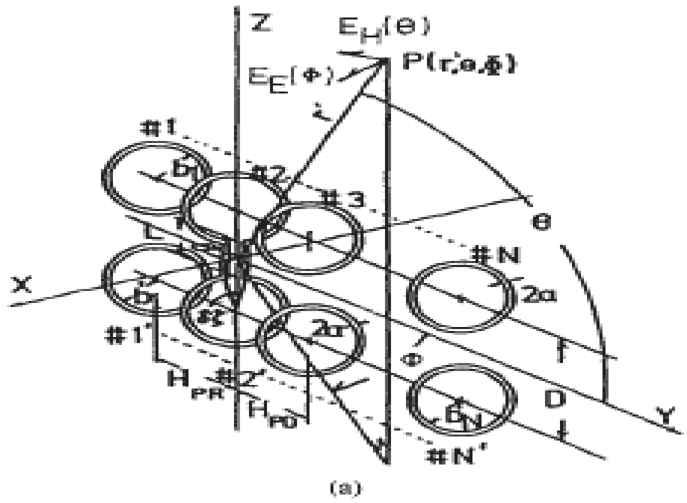

Fig. 3. - N-element 2YSCLA

Where S_j^n is given by

$$S_j^n = [\mathbf{sin}(\frac{\boldsymbol{n\delta\zeta_j}}{\mathbf{2}})/(\frac{\boldsymbol{n\delta\zeta_j}}{\mathbf{2}})]\ \boldsymbol{exp(jn\pi\delta_j)}$$

$$\boldsymbol{\delta_j = 0}, \qquad (\boldsymbol{j = 1, 2, \dots\ N})$$

$$\boldsymbol{\delta_J = 1}, \qquad (\mathbf{1', 2', \ldots N'})$$

The driving point impedance ***Z,*** of element **#2** can be obtained as follows:

$$\boldsymbol{Z_2 = \frac{V_2}{I_2} = \{ \sum_{n=-\infty}^{\infty} (\sum_{j=1}^{N'} Y_{2j}^{m.n}\ S_j^n)\}^{-1}}$$

Since the loop elements are arranged symmetrically with respect to the Y-axis, we get the input impedance ***Z***

$$Z_{in} = \left(\frac{Z_0}{2}\right) . \left\{Z_2 + jZ_0 \tan\left(\frac{kL}{2}\right)\right\} / \{Z_0 + jZ_2 \tan\left(\frac{\mathrm{kL}}{2}\right)\}$$

where *Z,* and ***k*** are the characteristic impedance and the phase constant of the feeder line, respectively.

4. DESIGN OF YAGI-UDA ARRAY OF SQUARE LOOPS

A 3-element Yagi array of square loops is designed for use in an 802.11 wireless network which operates in the frequency band of 2.400 GHz to 2.484 GHz. The table below specifies the values of designed parameters, where-

C_r – circumference of the reflector loop
C_s – circumference of the driven loop
C_d – circumference of the driven loop
S_r – spacing between the reflector and the driven loop
S_d – spacing between the director and the driven loop.

The drawing of the antenna structure is shown below. Each side of the square loop is divided into 21 segments. The feed is located at the center segment on wire

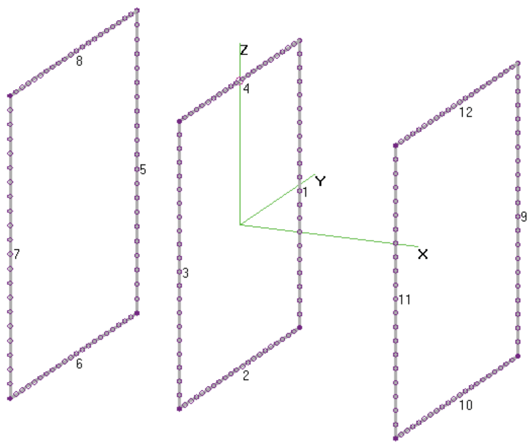

Fig. 4. – Element Yagi Array of Square Loops

The impedance of the antenna is graphed below in the frequency range of 2.3 to 2.6 GHz, where the blue line is the real part of the input impedance, and the red line is the imaginary part of the input impedance.

TABLE I

DIFFERENT PARAMETERS AT DIFFERENT FREQUENCY

Frequency (GHz)	Gain on bore site (dB)	Impedance (Real Part in Ohms)	Impedance (Imaginary Part in Ohms)
2.4	**10.05**	**10.52**	**-46.6**
2.442	**10.63**	**9.84**	**-9.4**
2.484	**10.04**	**11.2**	**37.9**

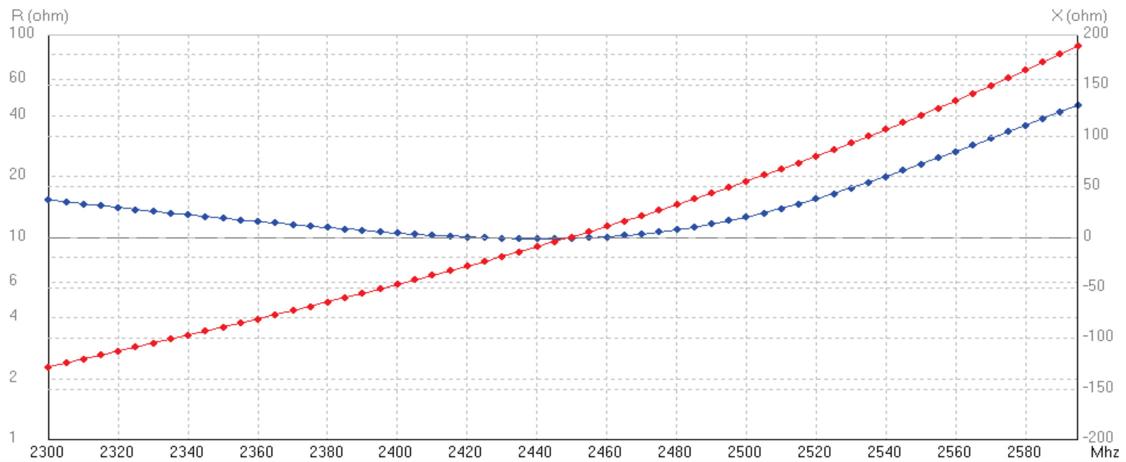

Fig. 5 - Input Impedance of 3-element Yagi array of square loops

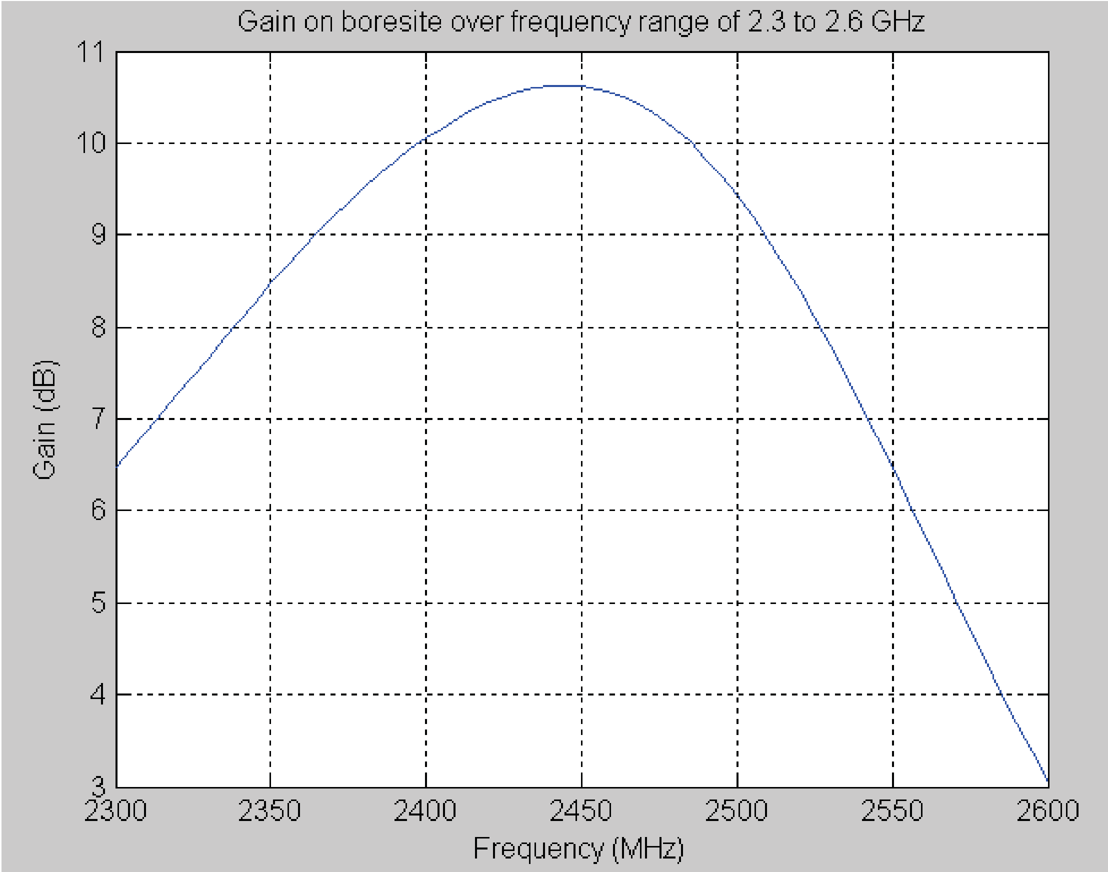

Fig. 6 - Gain on boresite over frequency range 2.3GHz to 2.6GHZ

5. DISCUSSION

Yagi-Uda array of loops is suitable for 802.11 wireless networks since 802.11b operates at the range of 2.4GHz. The circular loop array has a fairly broadband of 4.45GHz-4.76GHz at 4dB. On the other hand, the square loop array has a fairly broadband of 2360MHz-2510MHz at 9dB which can easily support high quality and variety for video channels. The circular loop Yagi-Uda array designed here has 1.8dB higher in gain and square loop Yagi-Uda array has 1dB higher in gain compared to three element Yagi arrays of linear dipoles. In terms of dimensions, the square loop antenna is again better out of the two as the circumference of the element of the circular loops antenna is assumed to be 1.1λ whereas the circumference of the square loop antenna is considered as λ.

6. CONCLUSION

The Yagi-Uda array of square loops is better than the circular loops in dimensions; input impedance nut has a little drawback in gain.

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