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Design, Development and Simulation of a 2.4 GHz Yagi Uda Antenna

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ABSTRACT: *This paper presents the design and analysis of a 10- element 2.4 GHz Yagi antenna using the Method of Moment inculcated in an electromagnetic simulation software called SuperNec v2.9. The Yagi antenna is an example of a directional antenna. The antenna propagates electromagnetic field energy in the direction running from the driven element toward the director(s), and is most sensitive to incoming electromagnetic field energy in the same direction. Antenna characteristics that will be obtained in this work include current distributions, input impedance, input power and radiated power, efficiency and far-field radiation patterns in polar planes. It can be deduced that once the array geometry and positions of any feed are specified, both the radiation and scattering problem pertaining to Yagi-Uda array can be solved via the Method of Moment technique. Using the simulation software, SuperNEC, simulations are done within the frequency range of 1800MHz and 2400MHz at frequency interval of 100MHz for the Method of Moments analysis. The results of simulation will be displayed in polar and forms from the expressions established for the current distributions and far-field patterns using a ten element array.*

Keywords: *Yagi, Antenna, Method of Moments, Far-Field Patterns, Simulation*

I. INTRODUCTION

A Yagi antenna is commonly used in communication when a frequency is above 10MHz.It is used at some surface installations in satellite communications systems and also used in a wide variety of applications where an antenna with gain and directivity is required. Moreso, it has become particularly popular for television receiving applications, where the Yagi antenna is directed towards the broadcast transmitter to give sufficient signal to provide a high quality picture.[1]

In this paper, the Yagi antenna studied provides an impedance bandwidth from 1.8GHz to 2.4GHz, which can be used for WLANs. Various design parameters of the Yagi antenna are directivity, gain, input power and impedance, polarization, and radiation pattern. [2] are considered in this work.

The geometry of the Yagi antenna is shown in Fig. 1, A basic Yagi consists of two or three straight elements, each measuring approximately ½ electrical wavelengths. It consists of single **DRIVEN ELEMENT** and a number of parasitic element; made up of REFLECTOR and a set of **DIRECTORS** .[3]

The Yagi is a balanced antenna[4], but it can be fed with coaxial cable and a matching system called Gamma matching at the point where the feed line joins the driven element .The REFLECTOR is placed behind the DRIVEN element for maximum gain and directivity, while the DIRECTORS are placed in front of the DRIVEN element for maximum gain and directivity. The dimensions of the elements are:
Yagi element spacing :(0.013, 0.036, 0.045, 0.068, 0.094, 0.125, 0.159, 0.197, 0.235, 0.276).
Yagi element lengths :(0.064, 0.058, 0.055, 0.054, 0.053, 0.052, 0.051, 0.051, 0.05, 0.05)
Yagi element radii (0.141, 0.141, 0.141, 0.141, 0.141, 0.141, 0.141, 0.141, 0.141, 0.141).
A load impedance of 75 ohms and gain of 13dBi were obtained.

Fig .1 10-element Yagi antenna.

II. GAMMA FEED

The antenna is fed with as shown in Figure 1 with a Gamma matching feed. The advantage of matching feed is that the Voltage Standing Wave Ratio (VSWR) is lesser than 1. The gamma matching feed [5] is a symmetrical feed that increases the input resistance with distance from the centre point of the Yagi antenna. In this case the current is balanced on the transmission line, that is, the currents are equal in magnitude and opposite in direction which yields very small radiation from the transmission line.

The antenna has been constructed with the dimensions stated earlier using copper tube as the Yagi elements and Aluminium square tube as the boom .The transmission line is made up of a 75 ohm coaxial cable to align with the matching system.

Mathematical Analysis of a (1.8 GHz – 2.4GHz) Yagi - Uda Antenna

$\frac{D_2}{D_1} = \frac{D_3}{D_2} = \frac{D_4}{D_3} = \frac{D_N}{D_{N-1}} \ldots = \frac{l_2}{l_1} = \frac{l_3}{l_2} = \frac{l_4}{l_3}$ (1)

Where DN is the distance of the pole n from the vertex termed near the feed point of formed near feed point. Also, l_n is equal length in dipole n in metres. The inverse or reciprocal of these ratios in equation (1) is design factor represented as K

Equation (1) becomes

$K = \frac{D_1}{D_2} = \frac{D_2}{D_3} = \frac{D_3}{D_4} = \cdots = \frac{l_1}{l_2} = \frac{l_2}{l_3} = \frac{l_3}{l_4}$ (2)

For each dipole, spacing = D, length = l. these are design parameters.

In the design of a (1.8GHz – 2.4GHz) antenna, constant ratio, design factor (K) and vertex must be known and taking K = 0.97

Since the antenna length and its frequency are inversely related, the highest cut-off frequency is found mathematically as follows.

The smallest dipole has a length l_1 which is related is the wavelength of the antenna as

$l_1 = {}^{\lambda}/_{2}$ (3)

$\lambda = 2l_1$ (4)

Using equation (4), the wavelength can be obtained as $\lambda = 2 \times 0.064 = 0.128m$

Therefore, the upper cut-off frequency can be calculated using

$V = f\lambda$ (5)

$f = \frac{V}{\lambda}$ (6)

$f_{max} = \frac{3\times10^8}{0.128} \equiv 2.4GHz$

To obtain the lowest cut-off frequency, applying equation (2)

Thus,

$\frac{l_1}{l_2} = \frac{l_2}{l_3} = \frac{l_3}{l_4} = \cdots \frac{l_9}{l_{10}} = K = 0.97$ (7)

$l_1 = 0.064m$ (8)

$l_{10} = 0.084m$ (9)

Then,

$\lambda = 2l_{10} = 2 \times 0.084$

$\lambda = 0.168m$

$f_{low} = \frac{3\times10^8 m/s}{0.168m} = 1.82GHz \cong 1.8GHz$

Therefore, the resulting pass band is the difference between the upper and lower frequency.

$Passband = Maximum\ frequency - Minimum\ frequency$ (10)
$Passband = 2.4GHz - 1.8GHz$
$Passband = 0.6GHz$

III. SIMULATION RESULTS AND DISCUSSION

The Yagi antenna was analysed and optimised using the Method of Moments.[6]

Inculcated in electromagnetic simulation software called SuperNEC v2.9, between the frequencies of 1.8 GHz and 2.4 GHz. The results obtained show a high correlation (positive) to what is obtained in practice. The 3-D pattern is shown for various characteristic plot of the antenna. The antenna has been tested with using a 2.4GHz mikrotik radios for point-to-point communication. The transmit rate and the receive rate of the mikrotik radio using the 2.4GHz Yagi antenna is shown. The traffic log is also shown in kbps. The simulation also shows the various gains of the antenna at frequency interval of 100MHz. The reduction in the size of the antenna is as a result of high model frequency (2.4GHz) [7].

IV. RADIATION PATTERN

The radiation patterns of the Yagi antenna have been measured using the SuperNECv2.9 software. The measurements have been taken over a range of frequencies. The 3-D radiation pattern of the antenna have been shown in Figure 2to 8 at frequencies 1.8GHz, 1.9GHz, 2.0GHz, 2.1GHz, 2.2GHz,and 2.3GHz. The radiation patterns have been observed well at all the frequencies.

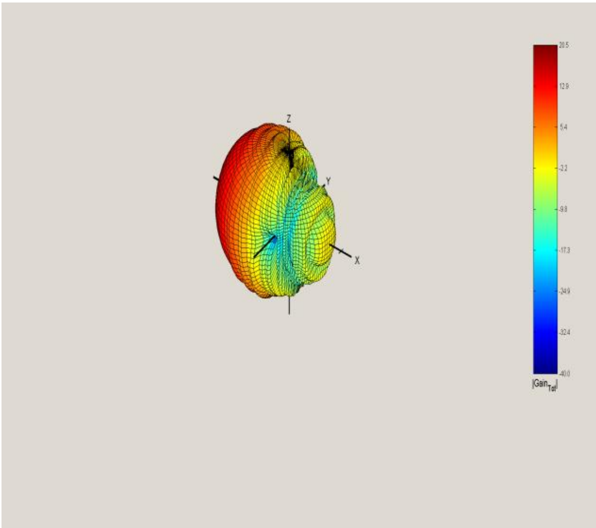

Figure 2. 3-D Radiation pattern of Yagi antenna at 1.8GHz

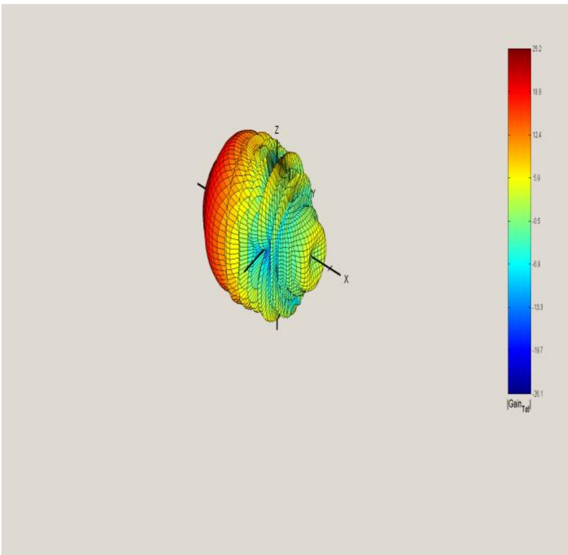

Figure 3. 3-D Radiation pattern of Yagi antenna at 1.9GHz

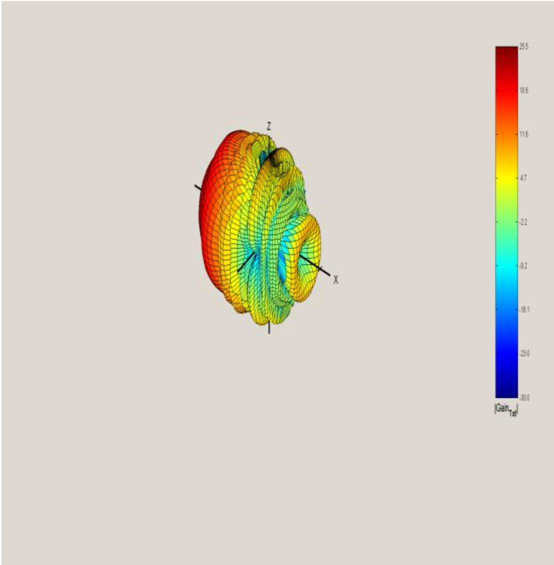

Figure 4. 3-D Radiation pattern of Yagi antenna at 2.0GHz

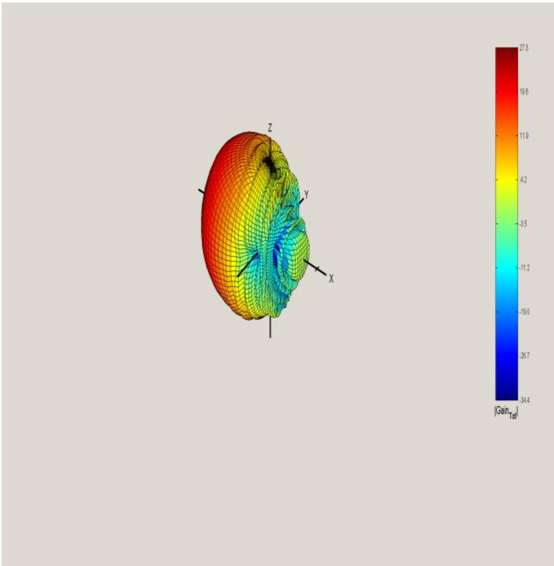

Figure 5. 3-D Radiation pattern of Yagi antenna at 2.1GHz

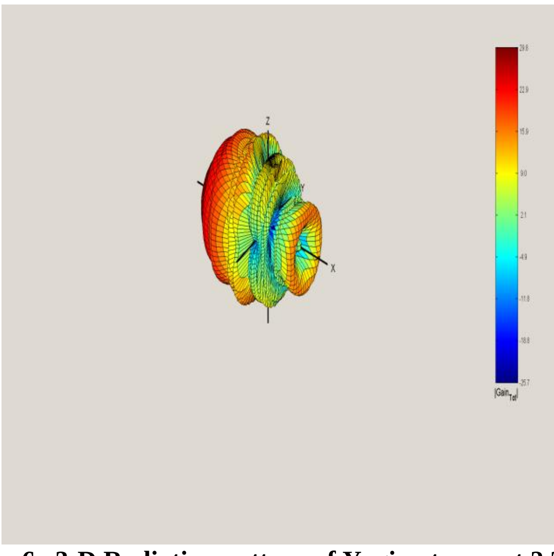

Figure 6 3-D Radiation pattern of Yagi antenna at 2.2GHz

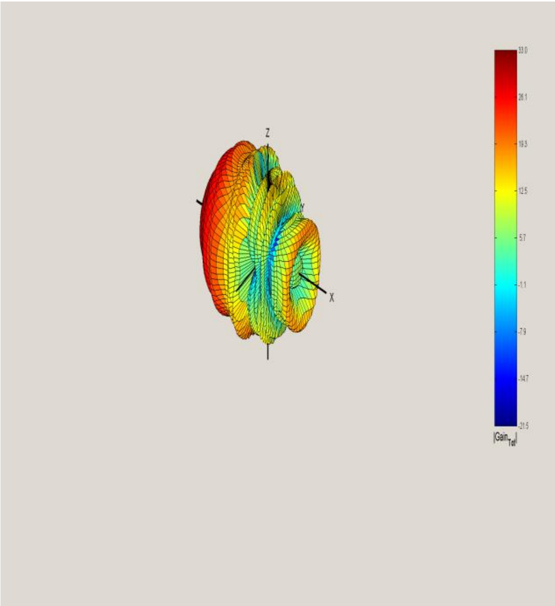

Figure 7 3-D Radiation pattern of Yagi antenna at 2.3GHz

V. CURRENT DISTRIBUTION

The near field current distributions of the Yagi antenna have been shown in Figure 8 to 13. The current distributions have also been measured at various frequencies between 1.9GHz and 2.3GHz at a frequency interval of 0.1GHz using the simulation software. The variations of current at different frequencies have been shown in the figures.

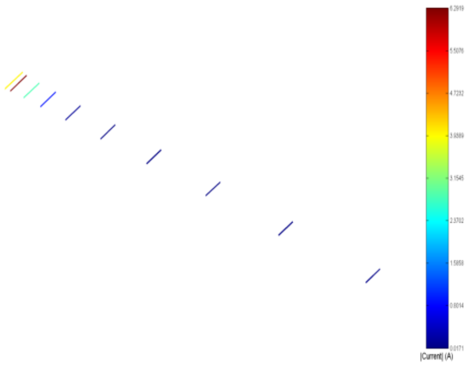

Figure 8. Current Distribution at 1.8GHz

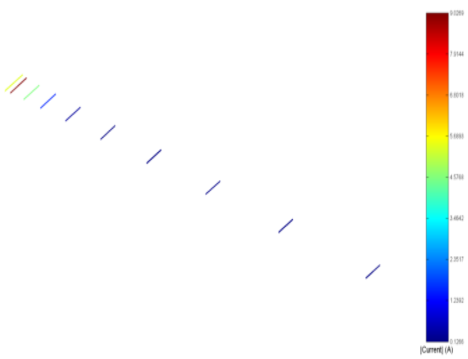

Figure 9. Current Distribution 1.9GHz

Figure 10. Current Distribution 2.0GHz

Figure 11.Current Distribution 2.1GHz

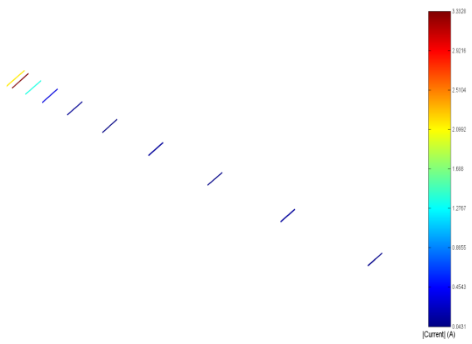

Figure 12. Current Distribution 2.2GHz

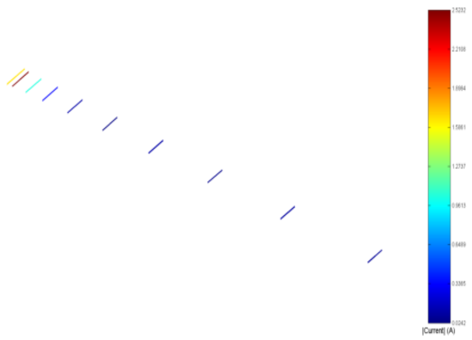

Figure 13. Current Distribution at 2.3GHz

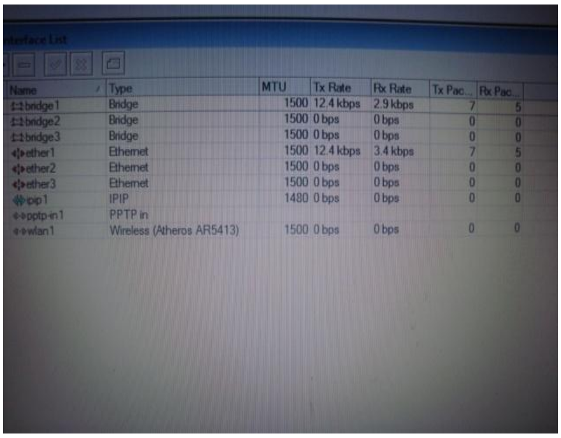

Figure 14. Transmit and Receive Rate of Mikrotik Radio using 2.4GHz Yagi Antenna

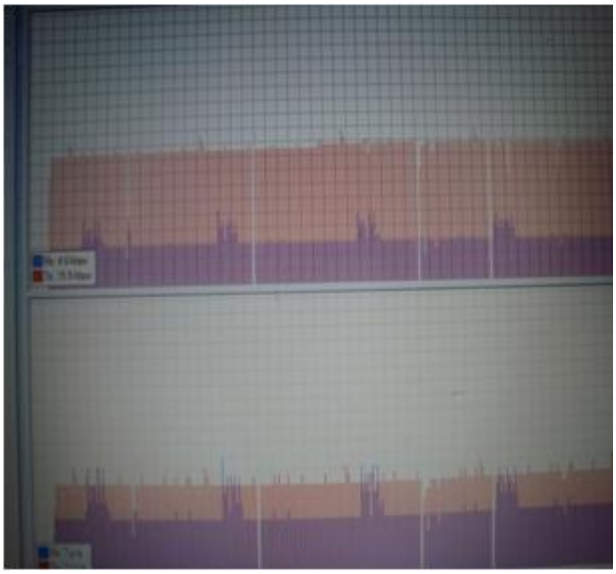

Figure 15. Traffic Log of Mikrotik Radio with 2.4GHz Yagi Antenna.

VII. CONCLUSION

The 2.4GHz Yagi antenna has been fabricated and tested for performance. The number of directors used is eight to increase the forward gain of the antenna. The antenna has good radiation patterns at higher frequencies. The results shows that increase in frequency beyond the centre feed point, reduces the amplitude of currents. Also, it was established that as the frequency is increased beyond optimum level, the advantages of reduced beam width and few side lobes earlier gained will become insignificant. The Method of Moments has been used in the analysis of the problem. This method requires that only the array geometry and feed point be specified for determination of current distribution and radiation pattern. From the test, it is established that the Yagi antenna is highly suitable for point-to-point communication because of the high forward gain of the antenna.

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