Tuning of Yagi Uda Antenna with Gain Enhancement at 300 Mhz and 2.4 Ghz Bands For Wi-Fi Application

Bevek Subba, Tashi Tenzin, Sangay Norbu, Thinley Tobgay, Tandin Zangmo

Abstract: In this paper, a tuning of several Yagi-Uda antennas in the frequency range of 300 MHz and 2.4 GHz band for uniform and non-uniform spacing between directors and maintaining this spacing between the elements to enhance the gain is discussed. A Yagi-Uda antenna with closely spaced directors is proposed for achieving appreciable gain as reducing the spacing results in physically compact size. Further, we seek other techniques such as folded dipole Yagi-Uda antenna and increasing the radius of reflector. The computer simulation was performed and results were compared with traditional Yagi-Uda antenna with the aim at tuning it for Wi-Fi application.

Keywords: Yagi-Uda antenna, Dipole antenna, Closely spaced, Gain.

I. INTRODUCTION

In application such as HF RFID (radio frequency identification reader) antenna and HF ground wave antennas, the spacing between the elements is reduced to achieve high gain to enhance compactivity [1]. In order to communicate over a rugged mountain terrain and hills where the cables are difficult to connect and expensive to construct the telecommunication infrastructures, the antennas are used. These antennas are categorized based on frequency, aperture, and polarization and pattern of radiation. The frequency of Yagi-Uda antenna ranges between 3 MHz to 300 GHz. Frequencies ranging between 3 MHz and 300 GHz are categorized into VHF, LF, UHF, HF, SHF and EHF [1-6]. Antennas can be used for various applications such as for wireless ccommunications, satellite communication, astronomical antenna etc. and choice of these applications are affected by the factors such as gain, impedance, bandwidth, frequency, side lobe level etc. of the antenna [2].

Wi-Fi has emerged as one of the successful and popular wireless network technologies due to its high-speed data transfer and internet access. Various types of patch antennas Were proposed in [1-3], for such Wi-Fi communication. But the problem is that they have low gain.

II. CONVENTIONAL YAGI UDA ANTENNAS

The Yagi-Uda antenna was used for domestic application that is for receiving signal for televisions and in wireless system [1]. Yagi-Uda is designed at VHF (30-300MHz) and UHF (300-3000MHz) due to its high forward gain capability, low cost and ease of construction [6]. Basically, Yagi-Uda antennas consist of three different types of linear dipole elements as shown in the figure 1.

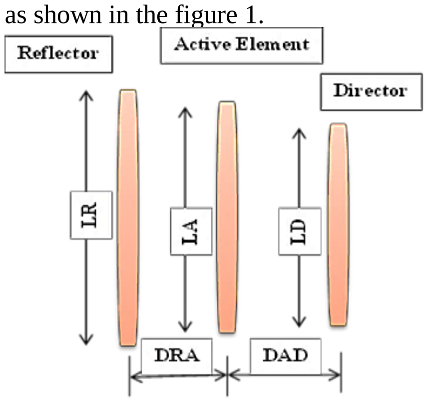

Figure 1 Three Elements Of Yagi Uda Antenna

The elements are active element, reflectors and directors [4]. An active element is the one to which the source or excitation is applied. Generally, length of active elements (L_A) is slightly less than 0.5λ. The length of reflector (L_R) is 5% greater than that of active element. Having L_R length greater than the active element causes a good reflection in forward direction. A reflector is located behind the active element. In the design of Yagi-Uda antennas, directors play an important role in achieving better gain and directivity. and directivity. Generally, gain and directivity is enhanced by adding numbers of directors as well as by optimizing the space between them [5-10]. Spacing between the elements varies between 0.35λ to 0.4λ. The radius of teach element is 0.4λ.

III. DESIGN AND ANALYSIS OF YAGI UDA ANTENNA

For designing the Yagi Uda antenna, Friss equation [3] is used to design and simulate for 300 MHz and 2.4 GHz bands.

- For 300MHz.

Using Friis equation:

$$\lambda = \frac{c}{f}$$

Where

C= the speed of light ($3x10^8$ ms^{-1})

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F= the resonant frequency (300 MHz /2.4 GHz)
λ= the wavelength

$$\lambda = \frac{3 \times 10^8}{300 \times 10^6} = 1\,m$$

As the dipole length is λ/2, the length of the active element (L_A) which is equal to dipole is calculated as 0.5 m.

$$\therefore L_A = \frac{\lambda}{2} = 0.5\,m$$

Length of the reflector is 5% greater than the length of the active element.

$$\therefore L_R = \frac{\lambda}{2} + (\frac{\lambda}{2} \times 0.05) = 0.525\,m$$

Length of the director is 5% less than the length of the active element. So, therefore

$$\therefore L_D = \frac{\lambda}{2} - (\frac{\lambda}{2} \times 0.05) = 0.475\,m$$

TABLE I: THE LENGTH OF ELEMENTS FOR 300 MHZ

Elements	Lengths (m)
Active, L_A	0.5
Reflector L_B	0.525
Director L_D	0.475

- For 2.4 GHz

Similar calculations by considering operating frequency of antenna as 2.4 GHz was made and the lengths of elements as shown in Table II were obtained.

TABLE II: THE LENGTH OF ELEMENTS FOR 2.4 GHZ

Elements	Lengths (m)
Active, L_A	0.0625
Reflector, L_B	0.09375
Director, L_D	0.059375

A. Closely spaced Yagi-Uda antenna

The results obtained by varying spacing between the active element i.e. Director, driven element and reflector in the Yagi-Uda antenna design section were compared. The spacing between the elements were varied from 0.1 m to 0.4 m and from 0.0125 m to 0.0500 m for operating frequency of 300 MHz and 2.4 GHz respectively.

B. Increasing number of directors

A simulation was performed by varying the number of directors in the Yagi-Uda antenna design section for 300 MHz and 2.4 GHz. Considering increased in the number of directors from 1 to 5 for 2.4 GHz and 300 MHz Generally every director will provide a 1dB gain in the forward direction [8].

C. Folded dipole active element

The modified Yagi-Uda antenna was design by selecting the highest gain from previous design and only changed the active elements as folded active element keeping all parameter same. Both the antenna for 300 MHz and 2.4 GHz are modified.

D. Increased reflector radius

Yagi-Uda antenna for 2.4 GHz and 300 MHz were modified by increasing the radius of reflector and maintaining radius of other elements as 0.4 m. The antenna with high gain was selected for modification.

IV. SIMULATION AND PARAMETER

- For 300 MHz

A. Decreasing the space between elements

Compared the results obtained by varying space between the director, driven and reflector of the Yagi-Uda antenna design section. Simulated to have high gain and compact size because most users prefer this specification in the antenna.

Therefore, analyzing the designs, the increasing number of directors increases the gain of antenna and when we decrease the spaced between the elements, the gain also gets increase till certain value as shown in Table III and Table IV. Whereas both uniform and non-uniform does not give appropriate result because gain gets decrease and increase without appropriate pattern.

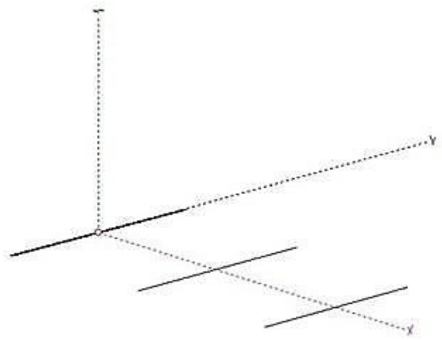

Figure 2 Closely spaced Yagi-Uda for 300 MHz

Simulation of Yagi Uda antennas were performed using MMANA-Gal software with a variation in closely spaced are given in Table III, by keeping the length and number of director same.

TABLE III: SPACING AND GAIN OF CLOSELY SPACED YAGI-UDA

Space between Elements (m)	Antenna gain (dB)
0.4	8.66
0.3	10.52
0.2	11.80
0.1	12.32

From the result of simulation, it was observed that the gain of antenna increases as space between element decreases [4]. Yagi Uda antenna with 0.4λ space between elements gives the least gain while 0.1 λ space between the elements give maximum gain of 12.32 dB. The graph in figure 3 shows the graphical representation between Yagi-Uda antennas with gain verses space between the elements, ranges from (0.1 - 0.4) λ.

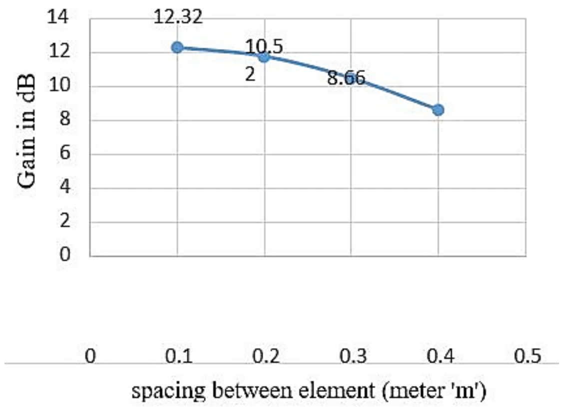

Figure 3 Gain spacing curve for closely spaced Yagi-Uda

From this graph, we can conclude that as the spacing between the elements increases, the value of gain decreases. The length, spacing and diameter of this element have larger effect on radiation parameter like forward gain, backward gain ratio and input space between the elements in meter impedance [2]. Referring figure 5 and 6, the radiation pattern is more streamlined and narrower when the spacing between the elements is 0.1λ compared to the radiation pattern when spacing is 0.4λ. This means that the narrower radiation pattern has more directivity and gain. [5].

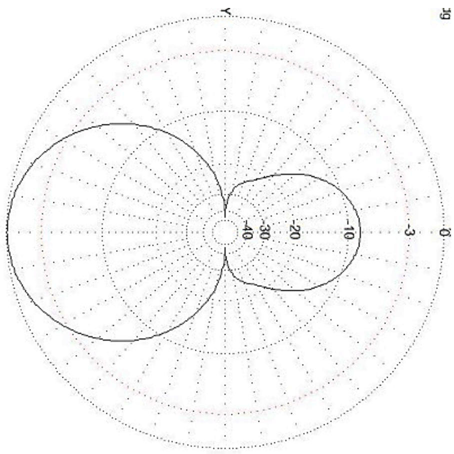

Figure 4 Radiation pattern of 0.4 m spacing

B. Increasing number of directors

The results obtained by varying the number of directors in the Yagi-Uda antenna design are shown in figure 5 and observed that the gain of the antenna is varied according to the increasing number of directors. Figure 5 shows the 7 element Yagi antenna with 5 number of directors.

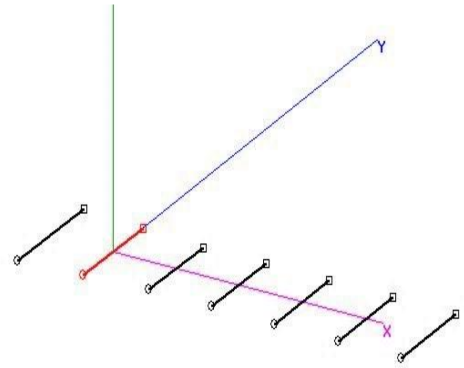

Figure 5 Increasing Number of Directors

Result of the antennas with a variation in number of directors are given in table IV. 'LR'=0.525 m, 'LA'=0.50 m, 'LD'=0.475 m, 'DRA'=-0.3 m, 'DAD'=0.3 m, R=0.4 mm where the number of directors is varying but keeping the length of elements and spacing between them same.

TABLE IV: GAIN FOR CORRESPONDING NUMBER OF DIRECTORS

Number of directors	Antenna gain (dB)
1	11.98
2	14.91
3	15.99
4	15.43
5	16.03

Form Table IV it can be concluded that the gain with one director is less compared to that of five directors which means that as the number of director increases, gain also increased [11]. The graph in the figure 6 shows the gain versus number of directors

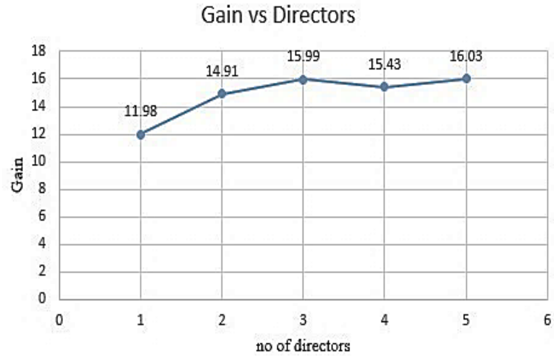

Figure 6 Gain Vs No. Of Directors

Obtained results in these cases are better with the Yagi-Uda antenna element in terms of gain with more no of directors. Yagi-Uda antenna with 5 directors is yielding improved and maximum gain than all other cases as shown in the figure 6. From the observation, as we increase number of directors, gain as well as size of the antenna increases which means directivity also increases. Our focus here is to enhance the gain by keeping same length and the spacing between the elements maintaining the same frequency.

Far field radiation pattern of 5 directors with the gain 16.03 dB and 1 director with gain 11.98 dB is shown below in figure 7; here the directivity is high as the gain is maximum. Since the gain is high, radiation pattern is narrower which indicates the high directivity but back loop is more [11].
More number of directors shows the high streamline of radiation pattern than the other where by indicating the high directivity of the Yagi antenna as shown figure 7.

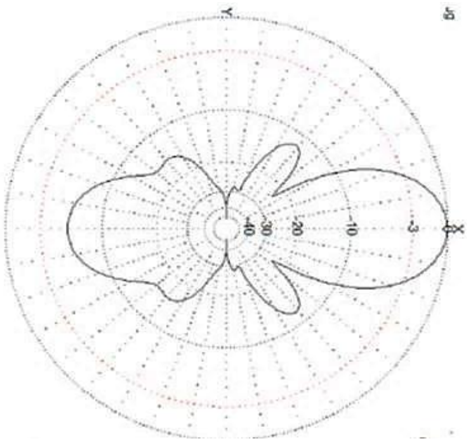

Figure 7 Radiation pattern for 7 elements

C. Folded dipole active element

Keeping the same parameters, the active elements as folded and observed its gain and directivity.

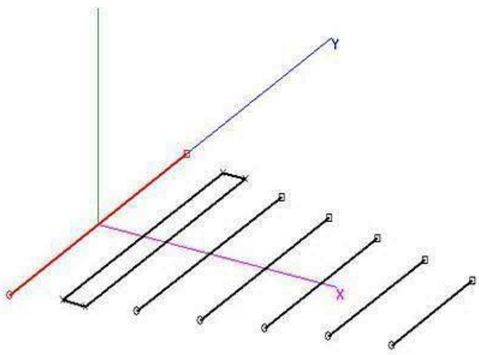

Figure 9 Folded Dipole Active elements

The gain of antenna increased to 15.32dB changing the active element as folded active element.

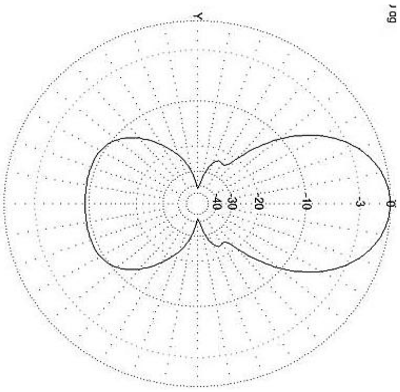

Figure 10 Radiation pattern of folded Yagi-Uda antenna

Now we conclude that closely spaced folded Yagi Uda antenna with increasing number of directors are going to be implement for 300MHz which gives the maximum gain of 15.32dB and high gain compare to other designs of Yagi-Uda antenna.

- For 2.4 GHz

D. Closely spaced of Yagi Uda antenna

We choose to simulate Yagi-Uda antenna for high gain, directional antenna for Wi-Fi frequencies (2.4 - 2.4GHz) by varying the space between the elements. We have kept the length of active elements equals to 0.0625m, reflector length=0.0937m and director length=0.05937m.

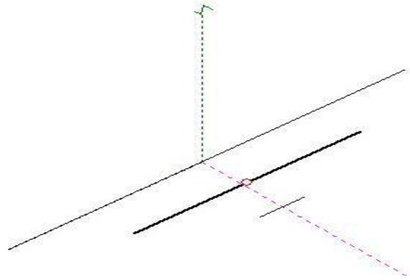

Figure 8 Closely Spaced Yagi Uda For 2.4 Ghz

Simulation was done for 2.4 GHz Wi-Fi with a variation in closely space, by keeping the length and number of director same. Results of designs having different possible lengths are shown in Table V.

TABLE V: SPACING AND GAIN BETWEEN THE ELEMENTS FOR 2.4 GHZ

Separation between elements (m)	Antenna gain (dB)
0.0125	9.77
0.0250	12.63
0.0325	11.52
0.0500	9.52

Looking at the Table V as spacing between the elements decreases, the gain of Yagi antenna increases but in case of spacing between 0.0125 m and 0.0250 m the gain decreases because minimum space for 2.4 GHz frequency is 0.2. Yagi-Uda antenna with 0.0500m space between the element gives the least gain while 0.0250 m space between the element give maximum gain of 12.63 dB

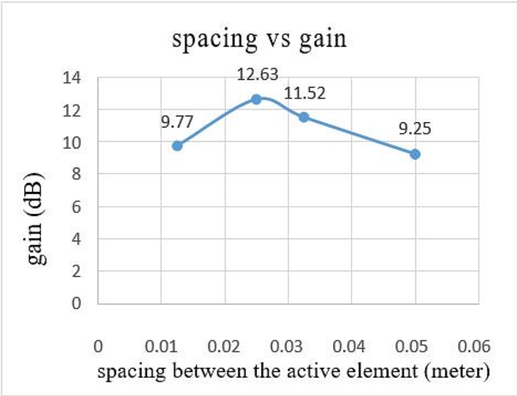

Figure 11 Spacing Vs Gain graph

E. Increasing number of directors

The gain of the antenna is varied according to the increasing number of directors. As the number of directors increases the gain of director gets increases as shown in Table VI. In case of 2.4 GHz, figure 13 below shows the 6 element Yagi antenna with 4 numbers of directors.

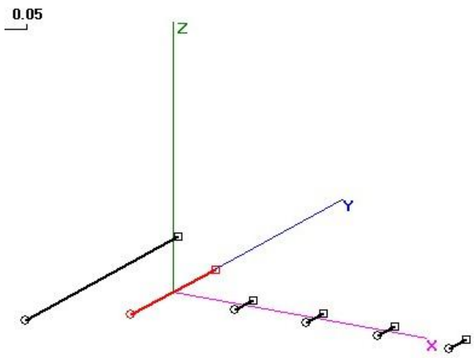

Figure 13 Yagi-Uda with increased number of directors

Design results of the antennas with a variation in number of directors are given in Table VI. 'LR'=0.0625 m, 'LA'=0.0625 m, 'LD'=0.05937 m, 'DRA'=-0.3 m, 'DAD'=0.3 m, R=0.4 mm. The number of directors is varied by keeping the length of elements and spacing between them same.

TABLE VI ASSOCIATED GAIN FOR CORRESPONDING NUMBER OF DIRECTORS

Number of directors	Antenna gain (dB)
1	4.39
2	9.68
3	9.7
4	9.71
5	9.7

The results of designing, different cases of number of directors are shown in Table VI. Here Yagi-Uda antenna with 1 director is giving low gain of 4.39 dB while antenna with 4 directors is giving a maximum gain of 9.71 dB which shows that as the number of director increases gain increases. Various plots of Yagi-Uda antenna with gain versus no of director which ranges from 1 to 5 are presented in figure 13. Obtained results in this case shows that the gain of antenna is improved and have maximum gain as the number of directors is increased. Far field radiation pattern of 1 director with the gain 4.39dB and 4 directors with gain 9.71dB is shown in figure 14 since

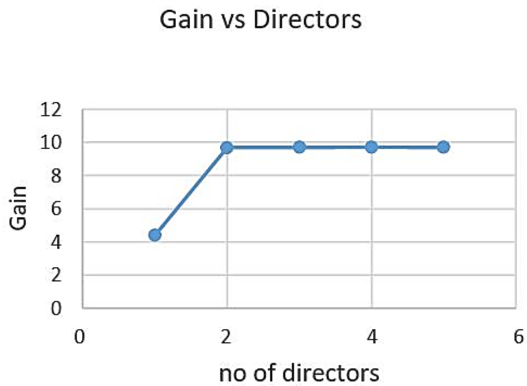

Figure 14 Gain Vs Number of directors

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the gain is high; radiation pattern is narrower which indicates the high directivity but back loop is more.

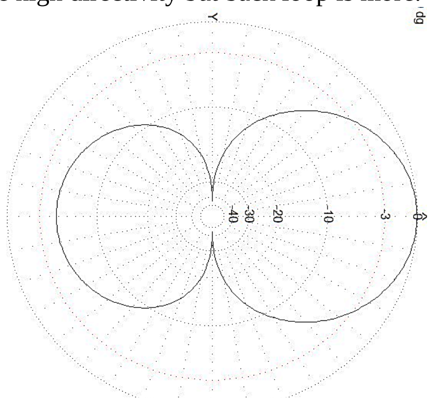

Figure 12 Radiation pattern for 6 elements

F. Increase in the radius of reflector

As we observed that the size of the antenna decreases as the operation of antenna increases and for 2.4GHz we could design only with three elements since length of element should decrease 5% from every element. Therefore, we cannot increase numbers of directors to increase the gain but however we have considered closely spaced as 0.2λ.

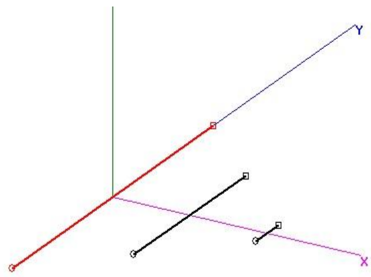

Figure 15 2.4 GHz modified Yagi-Uda antenna

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However, to modify the 2.4GHz Yagi Uda antenna we considered the closely spaced and increasing the radius of reflectors as shown below

TABLE VII GAIN AND RADIUS OF REFLECTOR

Radius (mm)	Antenna gain (dB)
0.4	12.50
1	12.52
1.5	12.53
3	12.54
5	12.54
6	12.54
8	12.51

As we increase the radius of reflector the gain increases at certain instant as shown below in graph and after crossing 6mm the gain tends to decrease.

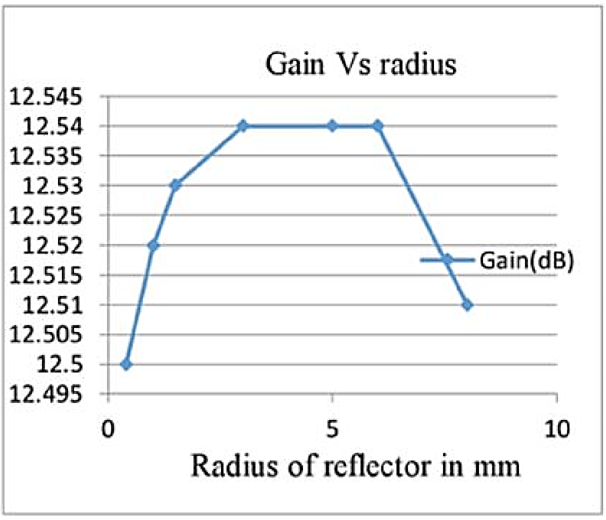

Figure 16 Gain Vs Radius

Therefore, modification was made with increasing radius of reflector with closely spaced and compact size. The radiation pattern of 2.4GHz is shown in figure 17 and it gives gain of 12.54dB

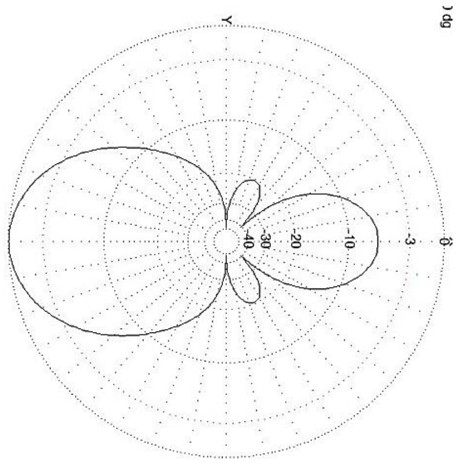

Figure 17 Radiation pattern of modified Yagi-Uda antenna for 2.4 GHz

The design specification used for designing the Yagi-Uda Antenna for 300 MHz and 2.4 GHz are as shown in Table VIII

TABLE VIII DESIGN PARAMETERS

Frequency	300 MHz	2.4 GHz
Height	4 m	4 m
Radius	0.4 mm	0.4 mm
Material	Cu wire	Cu wire
Ground Setup	Dry field	Dry field
Wavelength	1 m	0.125 m

V. CONCLUSION

In this paper, the design of Yagi-Uda antenna with gain enhancement for 300MHz and 2.4GHz for Wi- Fi application had been presented.

The paper presented the tuning of Yagi-Uda Antenna with gain enhancement of 300 MHZ and 2.4 GHz for Wi-Fi application. The antenna designs are carried out with a view to increase the gain and directivity by varying the spacing between the elements and by increasing the number of director's Yagi-Uda antenna [6]. This paper contents the outcomes of our various researches with the frequency of 300MHz and 2.4GHz. we discussed about the conventional Yagi-Uda antennas by considering its gain with number of directors, with uniform and non-uniform spacing between reflector and directors with respect to driven and with closely spaced. Accordingly, the directive radiation pattern was observed in almost all the simulation using MMANA-GAL basic software [12]. It was observed that no uniform gain increase owing to various factors. The gain and directivity of the antenna is increased by the numbers of directors and by varying the spacing between the elements.

The entire antennas designed in this paper are for the betterment of gain and directivity of Yagi antenna. The objectives of this research work were achieved successfully.

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