Design of reduced dipole yagi – Uda antenna

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Abstract. This work provides design and analysis of a dipole antenna whose height is reduced. Any Dipole antenna can be designed with λ/2 height. A half wave dipole is formed with ‘λ/2’ height to get desirable characteristics of dipole antenna. Minimizing antenna height is always a desirable in antenna design. Hence, an attempt is made in this work to reduce the height of a dipole and as an application, Yagi-Uda antenna is constructed using this reduced dipole and optimized for better gain. The results are discussed in detail.

1. Introduction

The entire world became wireless over the last few decades. Huge technological developments are reported in the field of wireless communication. The communication systems are developed with extremely high SNR, Better throughput and vastly improved encryption techniques. Improvements in the design of antenna technology is really serving a lot in the implementation of effective wireless communication systems.

Varieties of antennas are developed such as Wire antennas, Microstrip antennas and Dielectric Resonator antennas [1]. Wire antennas are the basic antenna types. Lot of variants of Microstrip antennas such as fractal antennas, Reconfigurable antennas, Electromagnetic Bandgap antenna, Wearable antennas are discussed by Balanis [1], Kraus [2], K.D. Prasad [3] and D.M. Pozar [4] [5].

A Dipole antenna is the basic antenna in the development of wire antennas. The height of dipole antenna is the design criterion. The height of the dipole antenna is given as “Half of the wavelength” at the resonant frequency. In the design of microstrip based dipole antenna also the above design is used. If this height of the antenna can be reduced while maintaining the same desirable characteristics, it will be useful in saving the required space, which in turn will produce miniaturized antenna.

The discussion of Microstrip dipole antenna on various ground planed is discussed [6] and design of Microstrip dipole antenna for WLAN is elaborately explained [7]. With the design of reduced dipole, it is possible to design a Yagi – Uda Antenna which is a popularly used antenna for Television reception. The reduction in size of Yagi-Uda antenna by modifying the diameter and spacing of the elements is discussed [8]. Sheldon and Bray pointed out printed Quasi- Yagi antennas with reduced mass [9]. D.I. Savitri compared hollow aluminium Yagi-Uda antenna and Dipole antenna for Indoor Television reception [10].
2. The Problem

The design parameter of a dipole is the height of the antenna which is calculated as half of the wavelength at resonant frequency. For example, a dipole antenna resonating at 300 MHz, should have a height of 0.5 m which is a sizeable dimension. The required space for the development of antenna is also depending on this height.

If it is possible to reduce the height of the antenna, with the same characteristics, the required space for the development of antenna can be reduced. This will help in the development of miniaturized antenna. This work was carried out to design a dipole antenna at 300 MHz with reduced height and a Yagi – Uda antenna is also designed and analyzed using this reduced dipole.

3. Design of dipole antenna

To design a dipole antenna, a freeware MMANA-GAL is used which is a reliable software for the design of wire antennas. The dipole antenna is selected to resonate at 300 MHz. The height of the antenna is calculated as the half of the wavelength. For a 300 MHz frequency, the corresponding wavelength will be 1 m and half wavelength will be 0.5 m. The antenna is resonating in free space condition and is assumed to be made up of loss less material. By employing the tuning mechanisms available in the software, the height of the designed antenna is given as 0.476 m and oriented in ‘z’ axis at 0.238 m on either side. The designed antenna is shown in the figure 1.

![Dipole antenna at 300 MHz](image)

**Figure 1.** Dipole antenna at 300 MHz

4. Dipole antenna and reduced dipole antenna

4.1 Design of Dipole Antenna

The tuned dipole is given in Figure 1 which resonates at 300 MHz. The radiation pattern and VSWR are calculated using the software mentioned.
Figure 2. Radiation pattern of normal dipole antenna

As per the results shown in Figure 2, this dipole antenna has impedance of $72 + j 0.252 \ \Omega$ which is close to the impedance of a dipole which is $73 \ \Omega$. Hence this antenna resonates well which is also evident from the SWR given as 1.4. The gain is given as 2.13 dBi.

Figure 3. 3D Radiation pattern of normal dipole antenna

Figure 3 gives the three dimensional radiation pattern of the dipole antenna at 300 MHz. The radiation pattern obtained is a proper three dimensional pattern.

4.2 Design of Reduced Dipole Antenna

The height of the antenna is to be reduced but with similar characteristics. The antenna which is designed has a height of 0.396 m in the 'Z' direction which is shown in Figure 4. This antenna is designed with four wires with the edge of the dipoles are placed at 0.193 m on either side which gives the overall height of 0.396 m.
Figure 4. Reduced dipole antenna at 300 MHz

The antenna given in Figure 4 is made up of four wire segments. Each wire segment has a length of 0.124 m which gives the overall length of the antenna as 0.496 m. Even though the length of 0.5 m for a dipole antenna is maintained, the height of the antenna is reduced to 0.08 m.

Figure 5. Radiation pattern of reduced dipole antenna.

Figure 6. 3D Radiation pattern of reduced dipole antenna.
From the figure 5, the gain of the antenna is given as 2.03 dBi and the input impedance is given as 52.7 + j 1 \Omega. The SWR is given as 1.1. These characteristics give a good similar result. The three dimensional radiation pattern of the above dipole is given in Figure 6.

5. Design of Yagi-Uda antenna with normal and reduced dipoles

5.1 Design of Yagi-Uda Antenna with normal dipole

As an application with the reduced dipole, design of yagi antenna is considered in this work. Yagi antenna is a directional antenna which is widely used in Television reception in RF range. A yagi antenna has a dipole or folded dipole as an active element with the length of 0.5 m. It has a director whose length is five percent shorter than that of active element and a reflector whose length is five percent longer that of active element. The distance between director and active element is modified as 0.2 m and the distance between active element and the reflector is also fixed as 0.2 m.

![Figure 7. Yagi antenna with normal dipole](image)

The two dimensional radiation pattern of the Yagi antenna at 300 MHz with normal dipole is given in Figure 8 and three dimensional radiation pattern is given in Figure 9.
Figure 9. 3D Radiation pattern of Yagi antenna with normal dipole at 300 MHz.

5.2 Design of Yagi-Uda Antenna with reduced dipole

Now, design of Yagi antenna is carried out with reduced dipole and the reflector and directors are having the same length and spacing as that of Yagi antenna with normal dipole. The structure is shown in Figure 10 at which the active element is the same as shown in Figure 4.

Figure 10. Yagi antenna with reduced dipole

Radiation pattern of Yagi antenna with reduced dipole is shown in Figure 11. The corresponding three dimensional pattern is also given in Figure 12.
Comparing the radiation pattern and directivity of Yagi antenna with normal dipole and reduced dipole, the gain (or) directivity is reduced in reduced dipole for the same dimensions. It is important to improve the gain as much as possible. Hence it is decided to reduce the distance between the active element and reflector. But the gain is reduced even further. Then, the distance between the active element and reflector is increased. The gain is increased compared with Yagi antenna with reduced dipole as given in Figure 11 and 12.

First, the Yagi antenna with reduced dipole is maintaining other dimensions but the spacing between active element and the reflector is increased from 0.2 m to 0.3 m; The structure of the antenna is given in figure 13.
Figure 13. Yagi antenna with reduced dipole and Reflector spacing of 0.3 m.

The radiation pattern of Yagi antenna with reduced dipole for a reflector spacing of 0.3 m is shown in Figure 14. It gives marginal improvement compared to Figure 11. The gain is increased to 4.97 dBi from 3.84 dBi given in Figure 11.

Figure 14. Radiation pattern of Yagi antenna with reduced dipole and reflector spacing as 0.3 m

Hence it is decided to further increase the distance between the active element and the reflector and the same is increased to 0.4. The structure of the Yagi antenna is given as shown in Figure 15.

Figure 15. Yagi antenna with reduced dipole and reflector spacing of 0.4 m.
The radiation pattern of the Yagi antenna with reduced dipole and reflector spacing of 0.4 m is given in the Figure 16. The gain is marginally reduced to 4.9 dBi.

![Figure 16. Radiation pattern of Yagi antenna with reduced dipole and reflector spacing 0.4 m.](image)

Based on the reflector spacing in the previous two cases, it is observed that the spacing between active element and reflector of 0.3 m, has better gain of 4.97 dBi. But this gain is less compared with Yagi antenna with normal dipole which is 8.5 dBi. Hence there are few methods to be tried to increase the gain of Yagi antenna. For a reflector spacing of 0.3m for which the gain is maximum, the length of reflector is increased to 0.5 m and the radiation pattern is found out. The gain is given as 5.26 dBi as shown in Figure 17.

![Figure 17. Radiation pattern of Yagi antenna with reduced dipole and reflector length of 0.5 m.](image)

The reflector length can be varied further to find out the maximum gain from Yagi antenna with reduced dipole. The reflector length is increased to 0.54 m and the gain achieved is 4.34 dBi. When the reflector length is increased to 0.6 m, the gain is reduced to 3.84 dBi. Hence, maximum gain is achieved with the
reflector length of 0.5 m and the active element – reflector spacing of 0.3 m. But keeping the active element - reflector spacing of 0.2 m and reflector length of 0.5 m, gives even better gain of 5.94 dBi. The radiation pattern in shown in Figure 18. Hence the optimum spacing of active element – reflector is considered as 0.2 m for the reflector length of 0.5 m.

![Image of radiation pattern]

**Figure 18.** Radiation pattern of Yagi Antenna for reflector length 0.5 m and spacing 0.2 m

6. Conclusion

The design of a dipole with reduced height is designed and discussed. The height of the dipole is reduced with 0.08 m. But almost same gain is obtained with good standing wave ratio. This design will help in miniaturized dipole antenna. Even though the design was tested in free space condition as wire antenna, the same design may be extended to microstrip antennas also. Hence it is possible to reduce the height of the antenna and in turn the space required for conventional dipole antenna. Using this antenna, an application of Yagi-Uda antenna is considered. The radiation pattern and gain are found out for various conditions. It is found out that reflector length of 0.5 m and active element – reflector spacing of 0.2 m gives maximum gain of 5.94 dBi which is considered as an optimized solution for this reduced dipole.

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