

Gain Enhancement of Small Antenna Using Meander Line Concept

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Abstract

In view with the latest technologies, compact device sizes had become a greater focus in industry because of which the demand for small antenna escalates. But electrically small antennas have high quality factor because of which the gain decreases. Therefore, an antenna was designed to improve the gain using the meander line concept based on the ground plane effect. A finite ground plane affects the resonant frequency and as the ground plane size increases, the resonant frequency decreases. By using a truncated ground plane, the antenna efficiency, gain and radiation pattern are improved. The antenna design had been modified based on another important concept of efficiently occupying the available volume. The antenna was designed on a cubic configuration and by using the two general techniques of modifying the geometry and truncating the ground plane, the gain of the antenna had been improved from 7.05dB to 8.03dB.

Keywords: Electrically small Antenna; Meander concept; Miniaturization techniques; HFSS v13; Quality factor.

1. Introduction

Electronics as we know it today is characterized by extremely low weight and volume. However, there are some parameters involved in the design, for example, power consumption and sensor node size [1]. In order to maintain the size of the antenna small, high frequencies are used. Path loss and power consumption comes into picture because of high frequencies. So, to eliminate these negative effects the gain of the antenna should be significantly high [1]. The effect of noise and unwanted signals from the surrounding can also be reduced by maintaining the gain of the antenna as high as possible. As the gain of the antenna indicates the efficiency with which the antenna can transform the input power from source to the radio waves, having high gain results in high directivity.

Antenna is one of the most significant elements in wireless system that can either enhance or constrain the system performance. Depending on the type of application, the antenna can be directional or Omni-directional [2]. Directional antennas reduce the effect of interference and extend the communication range of the system whereas Omni-directional antennas enable coverage area in all directions equally.

Wireless Local Area Network (WLAN) allows the users in a particular area for example, university, college or library to form a network and gain access with the internet. Wireless Local Area Network connects two or more devices in a local area with a wireless communication method.

The main objective of this project is to design low cost, high gain electrically small antenna which is used for wireless local area networks (WLAN) applications and also to study various antenna parameters [3] such as return loss, VSWR, gain, radiation pattern, quality factor for the antennas.

2. Small antennas analysis

An antenna is a device that can be defined as a transducer to transmit and receive electromagnetic waves. It can also be defined as device that converts between electric power and radiated power of electromagnetic wave [4]. Since the antenna has radiation characteristics for receiving and transmitting, they are usually termed as reciprocal devices. Since small is the relative term, for the purpose of comparison there must be demand for the existence of reference standard. Moreover, it is important that there must be difference between the electrical size and physical size of the antenna. The interest for the electrical engineers who are managing inside the domain of wireless technologies is the free-space wavelength at the operating frequency. An antenna is termed to be an electrically small antenna if it fits in a radian sphere of radius $(\lambda/2\pi)$ which is the boundary between the near field and far field dimensions of the antenna [5]. If there are no size constraints, most of the antennas would be measured at the resonant length i.e., multiples of $\lambda/4$ because the load impedance of the antenna can be easily matched with the transmission line connected to it. Moreover minimizing the size of the antenna is of interest for wireless communication devices, but it may lead many limitations which will directly affect the radiation properties of the antenna. Generally an antenna can also be considered as an electrically small whose $k*a$ value is less than 1 where a is the radius of the imaginary sphere and k is the free-space wave number i.e., $(2\pi/\lambda)$ [7]. Electrically small antenna will have low gain, high quality factor and low bandwidth.

The minimum quality factor expression for electrically small antenna is given by

$$Q = 1/(Ka)^3 \quad (1)$$

The quality factor expression for the electrically small antennas is given by

$$Q = 1/(Ka)^3 + 1/(Ka) \tag{2}$$

Wheeler described electrically small antenna as the one whose dimension is less than $\lambda/2\pi$ and expressed the relation as $Ka < 1$ Where k is the wave number ($2\pi/\lambda$) and a is the radius of the imaginary sphere.

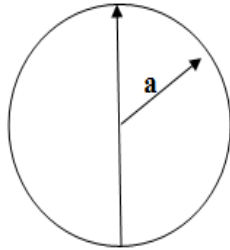


Fig.1: Electrically small antenna in free space

An antenna which is considered to be electrically small with $k*a$ value less than 1 are subjected to many limitations. An antenna with small size behaves as a lumped inductance and capacitance. But if the electrically small antenna is free of losses it can transmit and receive the maximum amount of power without depending upon its size. For this purpose the antenna must be operated at single resonant frequency and without adding of any losses. As the radiation resistance of the small antenna depends on the physical laws, the antenna radiation resistance decreases significantly with its size. There are some miniaturization techniques that are used to decrease the size of an antenna which effect the radiation characteristics of an antenna are antenna loading with materials, modifying the geometry, using the antenna environment and antenna loading with lumped components [8].

3. Design procedure

3D antennas are used for the applications that require high efficiency concurrently with small size because such types of antennas use maximum extent of the available volume by realizing the long length antennas. There are other benefits with the use of dipole antennas such as opening up of internal volume for different purposes, for example, storage room for batteries or other circuit elements.

Dipole antennas can be easily designed and fabricated into required shapes and configuration. Dipole antenna which is fabricated on a pyramid configuration provided low gain although the antenna exhibits maximum electrical size. It has provided low gain because of the cancellation of radiated fields. The antenna fabricated on spherical configuration yields very good performance in occupying the entire volume to a greater extent.

In this paper a high gain dipole antenna operating at 2.4GHz is designed on a cube configuration. Rogers/RT Duroid 6010 possessing a dielectric constant of 10.2 is used as a substrate material [9].

3.1. Antenna with rectangular ground plane

The design consists of two rectangular strips whose width is much greater than the gap between them in order to reduce the fringing fields [11]. Generally a dipole antenna is defined as a two wired transmission line in which the radiated fields do not cancel with each other because of the separation between the wires. Dipole antenna is termed as a standing wave antennas, as their radiation is due to the result of standing wave electric current. Since the symmetric dipole antenna requires a balanced feed, the connection of signal source is unbalanced for example, a coaxial feed. Therefore a parallel plate balun is required to transform the unbalanced feed

(such as coaxial or micro strip line feed) to a balanced dipole antenna [12].

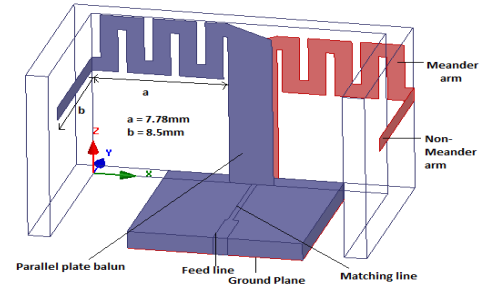


Fig.2: Geometry of proposed rectangular ground plane antenna at 2.4GHz

3.2. Antenna with circular ground plane with slots

In addition to the existing antenna to improve the gain and various radiation properties the geometry of the antenna is modified. As ground plane is significant for current distribution the proposed antenna is designed with circular ground plane. Each rectangular strip is loaded with 4 slots of dimensions 0.6mm length and 0.6mm width. Slot loading shifts the resonance to lower frequency. The ground plane size and shape have a significant impact on the resonant frequency of the antenna. The circular ground plane with a diameter greater than 1.25 times the wavelength gives reasonable impedance and radiation characteristics than that of a rectangular ground plane [10].

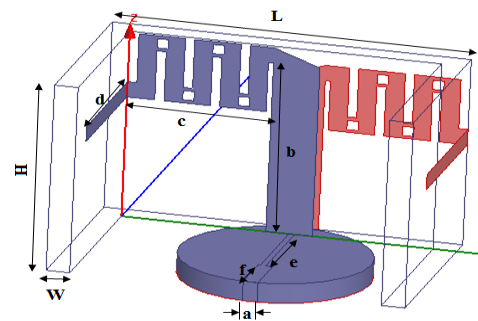


Fig.3: Geometry of proposed circular ground plane antenna at 2.4GHz
 Length of the substrate, $L = 18.06\text{mm}$
 Height of the substrate, $H=12.1\text{mm}$
 Width of the substrate, $W=1.27\text{mm}$
 Length of the parallel plate balun, $b=11\text{mm}$
 Length of the matching line, $e=6\text{mm}$

4. Results and Discussions:

4.1.1 Return loss of an antenna with rectangular ground plane

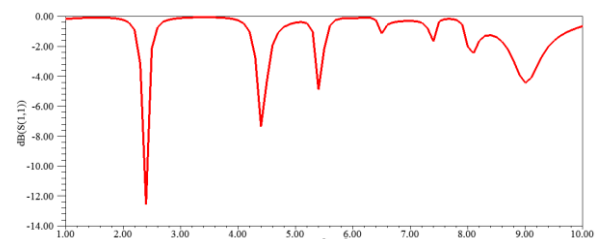


Figure. 4: Return loss of an antenna with rectangular ground plane

4.1.2 Returnloss of an antenna with circular ground plane with slots

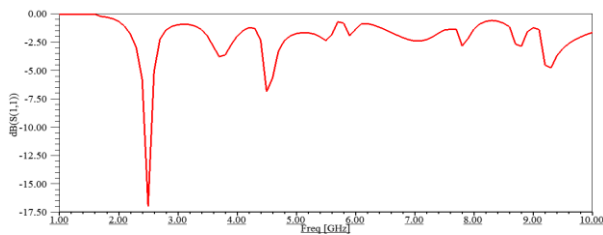


Figure.5: Return loss of circular ground antenna with slots

The returnloss plot indicates the ratio of the amount of power reflected back to the amount of power incident into the free space by an antenna. The returnloss of initial antenna is -13dB which indicates that 94.98% of the power is transmitted and 5.02% of the signal power is dissipated in the form of heat. The designed antenna had a returnloss of -17.25dB which indicates that 98.11% of the power is transmitted and 1.89% part of the signal power is dissipated in the form of heat.

4.2.1 Gain of rectangular ground plane antenna

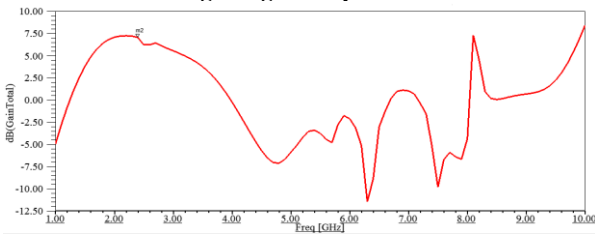


Figure.6: Gain of an antenna with rectangular ground plane

4.2.2 Gain of circular ground plane antenna with slots

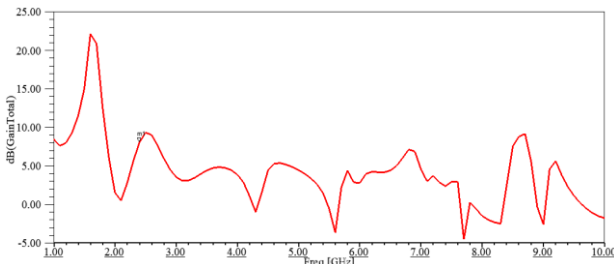


Figure. 7: Gain of a circular ground plane antenna with slots

Gain of the antenna indicates the antenna efficiency and its direction capabilities. The gain is usually measured at an angle where the maximum radiation occurs. The gain of the initially designed antenna is 7.05dB and the gain of proposed antenna is 8.03dB. The gain had been improved by using the miniaturization techniques.

4.3.1 Radiation pattern of rectangular ground plane antenna

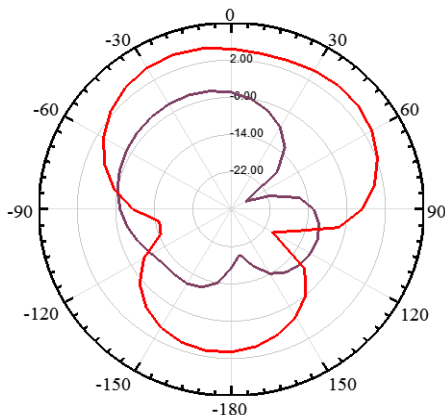


Figure. 8: Radiation pattern of a rectangular ground plane antenna in E plane.

4.3.2 Radiation pattern of circular ground plane antenna with slots

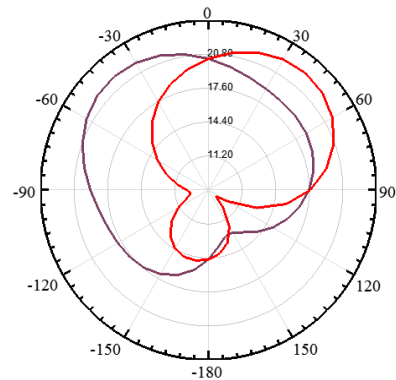


Figure. 9: Radiation pattern of a circular ground plane antenna in E plane.

Figure 8 represents the radiation pattern in E plane for the rectangular ground plane antenna. The radiation pattern represents the radiation properties of the antenna as a function of space coordinates. It describes how the antenna radiates energy out into the space or how it receives the energy. For the designed antenna the maximum radiation occurs at $\theta = -20$ degrees. Figure 9 represents the radiation pattern in E plane for the circular ground plane antenna. For the proposed antenna the maximum radiation occurs at $\theta = 35$ degrees and in that particular direction the antenna possess maximum directivity.

4.4 3D Polar plot of circular ground plane antenna with slots:

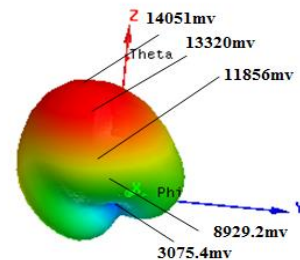


Figure.10: 3D polar plot of a circular ground plane antenna with slots

In the above figure, red colour on the lobe indicates the direction of maximum radiation of the antenna with a voltage of 14051mV. The least radiation is represented by blue colour with a voltage of 3075.4mV

5. Comparison

Dipole antenna on cube configuration with rectangular ground plane is modified as an antenna with circular ground plane with slots. The radiation characteristics of the proposed antenna are compared with the antenna with rectangular ground plane. The return loss of the antenna with rectangular ground plane is -13db whereas the return loss of the proposed antenna i.e., antenna with circular ground plane with slots is -17.25db. The gain of the proposed antenna and initial antenna are 8.03dB and 7.05dB respectively. Modifying the geometry is the major factor to improve the return loss and gain. The gain of circular ground plane antenna with slots is high than the rectangular ground plane antenna, from which we can say that the ground plane has major impact on the gain.

6. Conclusion

A simple and novel method for improving the gain of electrically small dipole antennas that uses the available volume effectively is presented. High gain of 7.05dB and 8.03dB are achieved and radiation pattern for E plane and H plane are plotted for the designed antennas. The meander line concept is used for making the antenna electrically small. Various parameters like return losses, VSWR, gain are measured. The designed antenna works for wireless applications.

Acknowledgement

We express our sincere gratitude to K.L University for encouraging and guiding us to undertake this project work and for providing required facilities to carry out the project work successfully.

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