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Design of Compact High Frequency Micro-Strip Antenna

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Abstract: In this paper a method of designing high frequency micro-strip antenna is presented. The proposed method is very simple than transmission line model or resonant cavity model of the micro-strip antenna design. In this paper the concepts of linear dipole antenna is implemented to design the high frequency micro-strip antenna. The results of proposed antenna are compared with different substrate thickness and transmission line method. Proposed antenna is designed for 10 GHz frequency and simulated using HFSS. The substrate used for the antenna is FR4 Epoxy having dielectric constant 4.4 and dielectric loss tangent 0.02. The proposed antenna is compact than the conventional design.

Index Terms: Dipole antenna; High Frequency Antennas; Miniature Antenna.

I. INTRODUCTION

Recent trends in mobile wireless devices has to provide faster access, high resolution, brighter screen, additional connectivity, all with longer battery life and compact size [1]. This can be achieved only when the size of the individual components is reduced. Antenna is one of the important component of the wireless communication systems whose performance completely depends on the dimensions and size of the antenna. So to reduce the size of the wireless devices we need to focus on the miniaturization of the antennas. Various techniques have been presented for the miniaturization of the micro-strip antenna. Amit A. Deshmukh and Dr. K. P. Ray have presented a half U-slot slotted micro-strip antenna which is compact as well as broad band response [2]. Keyvan Bahadori and Yahya Rahmat Sammi have presented an Elliptical-card antenna [3]. Nasimuddin, Zhi Ning Chen, and Xianming Qing have presented a cross shaped slotted micro-strip antenna in their literature [4]. Kun Qin, Minquan Li, Huimin Xia, and Jun Wang have presented Corrugated Ground Plane micro-strip antenna in their literature [5]. In all above literature the designing process is very complicated.

In this paper a micro-strip dipole antenna is presented. The dipole is a simple antenna to construct and use, and many calculations are quite straightforward. Dipole antenna consists of two terminals or “poles” into which radio frequency current flows. This current and associated voltage causes an electromagnetic or radio signal to be radiated.

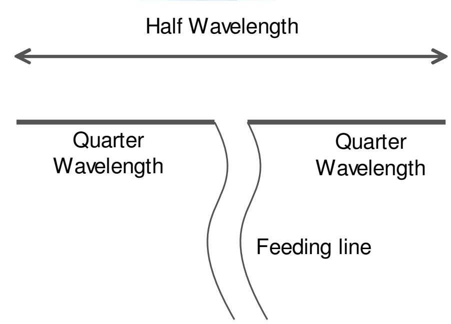

Figure.1: Basic Half Wave Dipole Antenna

The length of the radiating element determines many of the properties of the dipole antenna from its impedance, centre operating frequency, etc. As such this is an important feature of the antenna. Often the term dipole antenna tends to indicate a half wave dipole. This is by far the most widely used length for a dipole. It forms a resonant circuit which resonates where the electrical length is half a wavelength long - the electrical length differs from the wavelength of the signal in free space because of a number of the effects of the radiating element on the signal and it is very slightly shorter than the signal e/m wavelength in free space. Although the half wavelength dipole antenna is the most popular, a variety of other formats are also available.

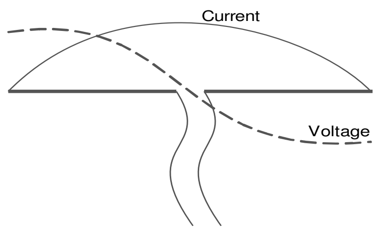

Figure. 2: Voltage and current distribution on half wave dipole antenna

The current and voltage on a radiating element vary along the length of the dipole. This occurs because standing waves are set up along the length of the radiating element and as a result peaks and troughs are found along the length. The current falls to zero at the end and rises towards the middle. Conversely, the voltage peaks at the end and falls as the distance from the end increases. Both the current and voltage on the dipole antenna vary in a sinusoidal manner, meaning that there may be other peaks and troughs along the length of the radiating sections dependent upon their length. The most popular form of dipole antenna is the half wave and for this, the current is at a minimum at the ends and rises to a maximum in the middle where the feed is applied. Conversely the voltage is low at the middle and rises to a maximum at the ends. It is generally fed at the centre, at the point where the current is at a maximum and the voltage a minimum. This provides a low impedance feed point which is convenient to handle. High voltage feed points are far less convenient and more difficult to use. When multiple half wavelength dipoles are used, they are similarly normally fed in the centre. Here again the voltage is at a minimum and the current at a maximum. Theoretically any of the current maximum nodes could be used. In this paper the above theory is used to design a Half Wave Micro-strip Dipole antenna.

II. DESIGN OF HALF WAVE MICRO-STRIP ANTENNA

For designing the micro-strip antenna different analytical models have been presented as Transmission line model, Resonant Cavity model. In transmission line model the micro-strip antenna can be designed by using the following Equations [7]:

$$f_{mn} = \frac{c}{2\pi\sqrt{\varepsilon r}} \sqrt{\left(\frac{m\pi}{L}\right)^2 + \left(\frac{n\pi}{W}\right)^2} \qquad (2.1)$$

$$W = \frac{c}{2fr}\sqrt{\frac{2}{\varepsilon r+1}} \qquad (2.2)$$

$$\varepsilon reff = \frac{\varepsilon r+1}{2} + \frac{\varepsilon r-1}{2}\left[1 + 12\frac{h}{w}\right]^{-\frac{1}{2}} \qquad (2.3)$$

$$\Delta L = hx0.412\frac{(\varepsilon reff+0.3)(\frac{w}{h}+0.264)}{(\varepsilon reff-0.258)(\frac{w}{h}+0.264)} \qquad (2.4)$$

$$L = \frac{c}{2fr\sqrt{\varepsilon reff}} - 2\,\Delta L \qquad (2.5)$$

For better radiation properties the aspect ratio should be: $1 \leq \bar{} \leq 1.5$

The ground plane of an ideal patch antenna should be infinite. Practically it is not possible to implement infinite ground plane so approximate formula of length and width of ground plane is given as:

$$L_g \geq L+6h \qquad (2.6)$$

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$$W_g \geq W + 6h \tag{2.7}$$

For both the design methods FR4 Epoxy substrate of thickness 1.6 mm is used. The dielectric constant of FR4 Epoxy is 4.4. From the above equations the dimensions of a 10 GHz antenna for FR4 Epoxy substrate with thickness 1.6 mm are:

Table No.1 Dimensions of 10 GHz conventional rectangular patch antenna

Parameters	Dimensions
Width of Patch	9.12 mm
Length of Patch	6.43 mm
Width of Ground/Substrate	18.72 mm
Length of Ground/Substrate	16. 03mm
Overall Volume of antenna	480.13 mm^3

In the proposed antenna a half wave rectangular patch and conventional ground plane is implemented. For 10 GHz operating frequency the wavelength is 30mm. Patch of length λ/2, 15 mm and width λ/8, 3.75 mm is taken. The structure of proposed antenna is depicted in Figure.3.

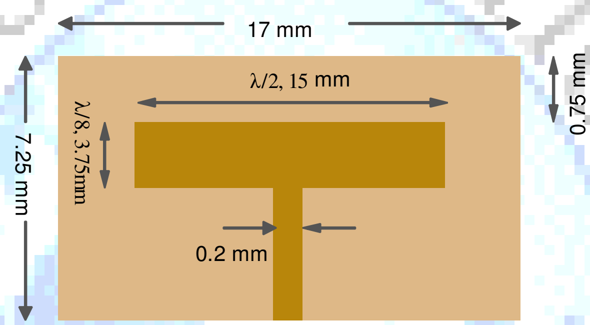

Figure. 3: Structure of proposed antenna

The ground of the proposed antenna is same as a conventional antenna. The comparative dimensions of conventional and proposed antenna are given in Table No. 2.

Table No.1: Dimensions of 10 GHz conventional rectangular patch antenna

Parameters	Dimensions of Conventional Antenna	Dimensions of proposed Antenna
Width of Patch	9.12 mm	15 mm
Length of Patch	6.43 mm	3.75 mm
Width of Ground/Substrate	18.72 mm	17 mm
Length of Ground/Substrate	16. 03mm	7.25 mm
Overall Volume of antenna	480.13 mm^3	123.25 mm^3

III. RESULTS AND DISCUSSIONS

The results of proposed antenna are depicted in Figure.4 to Figure.8. The proposed antenna performs as a Half Wave Dipole antenna and resonates at 10 GHz frequency for antenna element of length λ/2, 15 mm. In the simulation the return loss of the antenna is -14.95 dB. The antenna performance can be further enhanced by using proper matching network. The co-plane and cross-plane radiation pattern of the antenna is depicted in Figure.7 and Figure.8. The current and voltage on a radiating patch vary along the length of the patch. This occurs because standing waves are set up along the length of the radiating patch and as a result peaks and troughs are found along the length. The current falls to zero at the end and rises towards the middle. Conversely, the voltage peaks at the end and falls as the distance from the end increases. Both the current and voltage on the dipole patch antenna vary in a sinusoidal manner, meaning that there may be other peaks and troughs along the length of the radiating sections dependent upon their length.

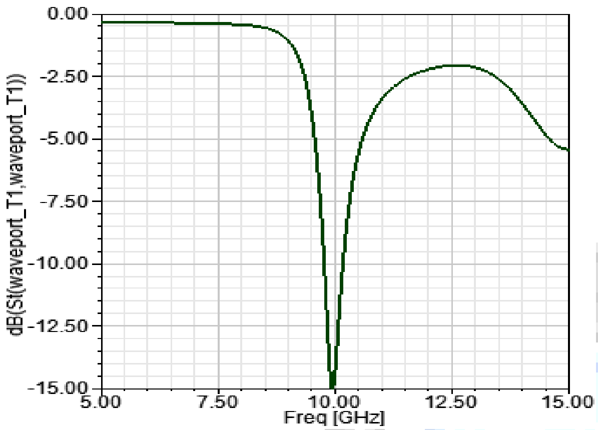

Figure. 4 Return Loss of Proposed Antenna

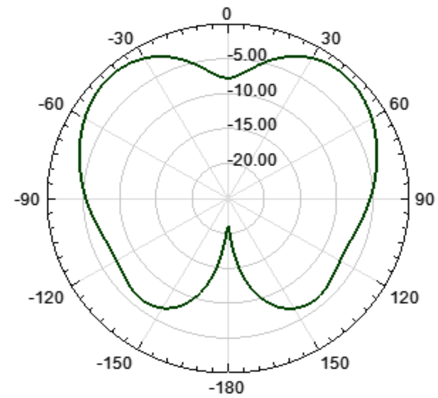

Figure. 6 Co-plane Radiation Pattern of Proposed Antenna

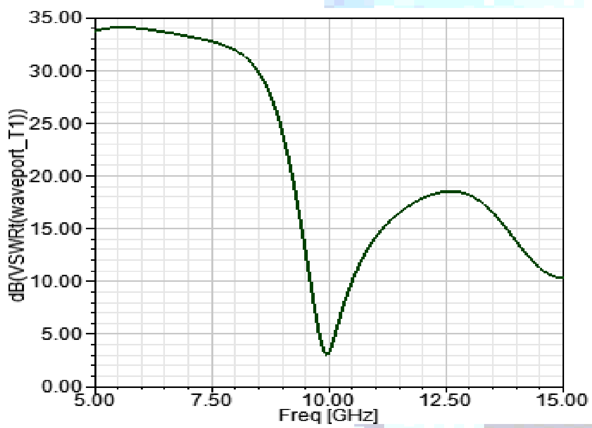

Figure. 5 VSWR of Proposed Antenna

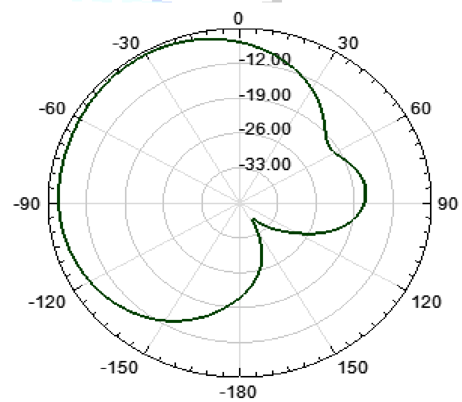

Figure. 7 Cross-plane Radiation Pattern of Proposed Antenna

CONCLUSION

A half wave patch dipole antenna is presented. The resonant frequency and the other performance parameter of the antenna depend on the length of the antenna. The results of the proposed antenna are satisfactory. By using proper feeding technique or suitable impedance matching network the performance of the antenna can be further improved.

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