International Journal of Scientific Research Engineering & Technology (IJSRET)
Volume 2 Issue 12 pp 837-839 March 2014 www.ijsret.org ISSN 2278 – 0882

A Step by Step Synthesis of Planar Monopole Ultra Wideband Antenna

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ABSTRACT

An antenna design is presented for Ultra Wideband (UWB) applications. Initially a rough design is made on the basis of lower frequency band of proposed design. The Transmission line modeling of the prototype is done and a staircase profile is introduced to obtain the upper frequency limit. To increase the impedance bandwidth slot etching has been employed. The antenna was designed using CST Microwave Studio simulator and the final results meet the requirements of UWB.

Keywords- *Planar Monopole Antenna; Ringing Effect; Slot Etching; Transmission Line Modeling; UWB.*

1. INTRODUCTION

The basic requirement of any UWB antenna is its fractional bandwidth, which should be greater than 20% [1]. The UWB antenna deforms the transmitted signal. The response of an antenna to a pulse of very short duration (common in UWB systems) is seen as a ripple after the pulse [2], which is called the ringing effect. Planar monopole antenna (PMA) have a much more constant phase center and also use the same area of the radiating element at all frequencies. This reduces the ringing effect. Planar monopoles consist of a metal patch on one face of a dielectric, with the ground plane parallel to it, usually on the other face of the printed circuit board.

2. ANTENNA DESIGN

A systematic procedure was employed in the design of the UWB antenna starting from a simple rectangular patch antenna. A substrate of size 45mm$\times$ 24mm with $\varepsilon_r = 4.3$ (FR4) was used. The dimensions of the ground were taken 24mm$\times$5mm. The steps are as follows:

2.1. Defining the lower frequency limit of the frequency band

To determine the lower frequency limit of PMA to have VSWR < 2, the following closed form formulae stated in [3] for circular cross section (radius ***r***) monopole was used.

$$\boldsymbol{L} = 0.24 \times ^{a} \times \boldsymbol{F} \tag{1}$$

where the factor F reflects the widening of the antenna due to the radius r.

$$\boldsymbol{F} = \frac{\boldsymbol{L}}{\boldsymbol{L} + \boldsymbol{r}} \tag{2}$$

By equating the area of the rectangular PMA with that of the cylindrical monopole the effective radius ($\boldsymbol{r_e}$) for the PMA was found. On the basis of this the lower frequency of the antenna including the feed length without ground plane ($\boldsymbol{p}$) was found as

$$\boldsymbol{f_m} = \frac{0.24 \times \boldsymbol{c}}{\boldsymbol{L} + \boldsymbol{r_e} + \boldsymbol{p}} \tag{3}$$

In the present work $\boldsymbol{L}$ = 45mm, $\boldsymbol{W}$ = 24mm, and $\boldsymbol{p}$ = 3mm was chosen. Hence $\boldsymbol{r_e}$ = 7.6mm. These values gives rise to the value of $\boldsymbol{f_m}$ = 1.3GHz. Simulation of this structure with those dimensions were made in CST Microwave Studio 12 [4] and the response is shown in Fig. 2a. From Fig. 2a the lower frequency limit of operation can be observed sa 1.5GHz which is very close to the calculated value.

2.2 Size reduction of the patch

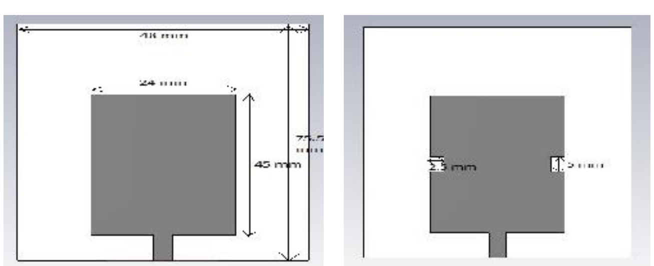
It has been observed that the current distribution is concentrated on top and bottom edges. So removal of portions of the patch from the left and right edges along the center should not significantly alter antenna response in terms of impedance bandwidth. It comes from the fact that radiation from an antenna depends on current distribution and current path along the surface of antenna. So this principle has been utilized to reduce the antenna size which improves factors such as weight, wind resistance and cost. After making necessary modification the new design and its response are shown in Fig. 1.b and Fig. 2.b respectively. It can be clearly marked from response of Fig. 2a & Fig. 2b that there is no significant change in the impedance bandwidth. The percentage decrease in antenna size is 2%.

2.3 Obtaining the upper frequency with staircase profile using transmission line modeling

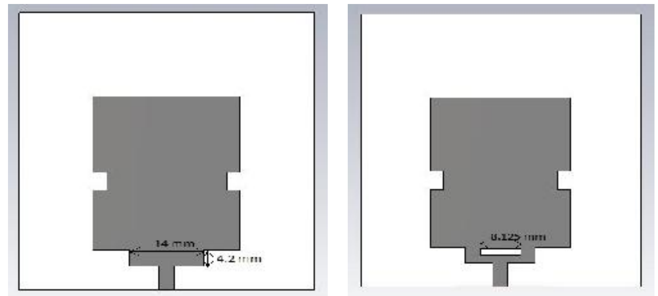
A descriptive model is defined for the behavior of a conventional monopole antenna over a specified range of frequencies, based on transmission line theory [5]. The following approximate formulae [5] can be used for finding the upper limit of the frequency band for PMA with staircase profile to get VSWR<2.

$$f_u \approx \frac{0.3 \times N}{2 \times W} \tag{4}$$

where f_u is the upper frequency of the band, in GHz, N is the number of pair of notches or steps and W is half the width of the monopole, (in meters). As a general rule, for a given width, greater the number of notches or steps, greater is the bandwidth.

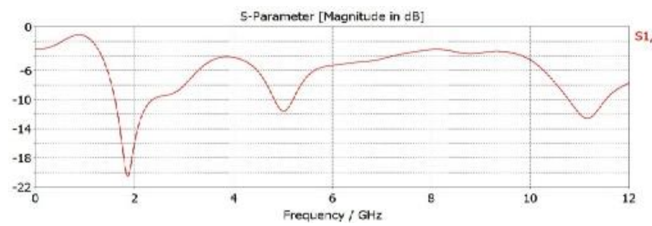


(a) (b)

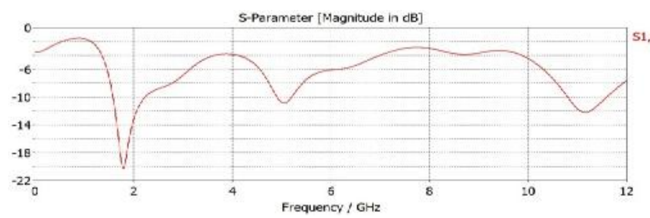


(c) (d)

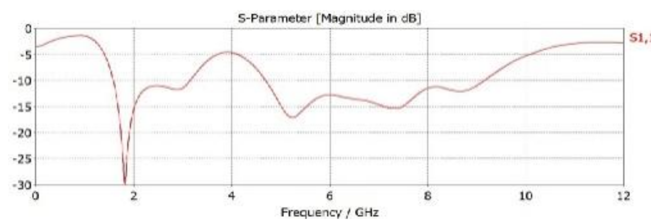
Fig. 1. Steps in Antenna design



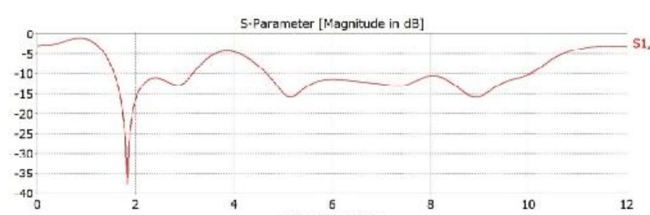
(a)



(b)



(c)



(d)

Fig. 2. Return Loss vs. Frequency Plots

To increase the upper (-10dB) cut off frequency the staircase profile is introduced with one step i.e. $N = 1$. So the calculated value of upper cut off frequency according to Eqn. (4) comes out to be roughly around 10 GHz. The design of the staircase profile is done as shown in Fig 1.c and as expected the upper frequency band has increased up to 9.5 GHz (calculated value is 10 GHz).

2.4 Increasing the bandwidth through slot etching

When a slot was introduced in the patch a high density current patch was formed along the length of the slot. So it can be considered as a radiating element with resonance condition as

$$l_s = {}^{a}/2 \qquad (5)$$

where l_s is the length of the slot. To meet the UWB specifications the upper frequency band needs to extend up to 10GHz. So a slot of corresponding length (8.25mm approx.) is introduced to create resonance at 10 GHz. As evident in Fig.1.d and Fig. 2.d the bandwidth has increased up to 10GHz mark due to the resonance slot created in the structure.

3. RESULTS AND DISCUSSION

The final design has a dual band response. The lower frequency band extends from 1.5 GHz to 3 GHz. This has its application in GSM, GPS etc. The upper frequency band extends from 4.5 GHz to 10 GHz. Its fractional bandwidth is

$$BW = \frac{2(f_h - f_l)}{(f_h + f_l)} \qquad (6)$$

$$= 0.7586$$

$$= 75.86\%$$

Clearly it meets the UWB specifications [1]. So this antenna can be used for various UWB applications like medical imaging, through wall imaging etc. There is a large band separation between the lower frequency band and the upper UWB band. So the designed antenna can be effectively used for application of both bands without any interference between them.

4. CONCLUSION AND FUTURE SCOPE OF WORK

A systematic procedure for design of a planar monopole UWB antenna was discussed in this paper. The return loss of the final design is very close to -10 dB in some regions (around 8 GHz) of the entire UWB frequency range. So there is a need to design a better feeding network to decrease the return loss. The control over polarization form and radiation pattern of this design is a topic of future work. Also another important aspect is the study the response of this structure to the UWB pulses fed to it.

5. REFERENCES

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