

## Research Article

### Design of an UWB Patch Antenna for Dual Frequency Operations

M.M. Islam, M.T. Islam and M.R.I. Faruque

Institute of Space Science (ANGKASA), Level 2, Faculty of Engineering Building, Universiti  
Kebangsaan Malaysia, 43600 UKM, Bangi, Selangor D.E., Malaysia

**Abstract:** The purpose of this study is to present the development of an Ultra-Wide Band (UWB) patch antenna for dual frequency operations. The size of the proposed antenna is  $40 \times 40 \times 1.6 \text{ mm}^3$  and is excited by microstrip line. The Finite Element Method (FEM) based on high frequency electromagnetic simulation software is used in this investigation. Return loss is obtained below -10 dB from 8.39 to 9.7 GHz. It has achieved stable radiation efficiency 84% with gain 3.81 dB and 4.25 dB in the operating frequency band. The antenna generates two separate resonant frequencies to cover UWB band (3.1-10.6 GHz). Lower resonant mode of the antenna has an impedance bandwidth of 940 MHz (9-8.06 GHz) and the upper resonant mode has a bandwidth of 1 GHz (10.08-9.08 GHz).

**Keywords:** Dual frequency, microstrip patch antenna, microstrip line, UWB

#### INTRODUCTION

Recently, patch antenna is extensively used in Ultra-Wide Band (UWB) applications and is continuing to fulfill the changing demands of new generation antenna technology. Both industries and academia are extensively searching UWB antennas as a key component. The Federal Communications Commission (FCC) released 3.1-10.6 GHz unlicensed band for communication (FCC, 2002). Advances in wireless communications have introduced tremendous demands in the antenna technology. It also paved the way for wide usage of mobile phones in modern society resulting in mounting concerns surrounding its harmful radiation (Faruque *et al.*, 2010, 2011; Islam *et al.*, 2010a, 2011a, b; Misran *et al.*, 2011). Microstrip patch antennas are widely utilized in the present wireless communication system because of their regular facilities of less profile, less weight, conformal design; low cost, easy to fabricate and integrate. Patch is the main component of microstrip antenna and other components are substrate and ground which are two sides of patch (Weng *et al.*, 2008). The principal disadvantages of microstrip patch antenna are narrow bandwidth, low efficiency and small size (Kiminami *et al.*, 2004; Islam *et al.*, 2009a, b). Many researches have been performed to enhance the bandwidth of printed antennas. To overcome this difficulty many methods and techniques are raised in the literature (Lee *et al.*, 1997; Azim *et al.*, 2011; Shakib *et al.*, 2010; Mobashsher *et al.*, 2010; Islam *et al.*, 2010b).

Huang and Chiu (2005) mentioned a dual-band monopole antenna using a microstrip feeding consisted

of a C-shaped radiating component and a modish radiating slice directly shorted to the ground plane. Jan and Tseng (2004) and Wong *et al.* (2005) were also mentioned to operate in 2.4 and 5 GHz WLAN bands. In these designs, the longer slice controls the lower band of the antenna, while both of the shorter slice and the modish slice originate the wide resonant frequency on the upper band at one place. In all the above designs the wide bandwidth is achieved by limiting the monopole or the parasitic patches. Thus, the limiting will decrease the overall antenna gain. The wideband monopole antenna fed by coplanar waveguide with two modish components (Chung *et al.*, 2004) uses the effect of the electromagnetic coupling for obtaining 3.1-11 GHz band operation. The disadvantage of the antenna size is very large. Raj *et al.* (2006), a microstrip-fed line dual-band co-planar antenna has been reported. Although the antenna is compact in size, azimuth (H-plane) patterns do not keep omni-directional. Large cross-polarization levels are also noticed in both E and H plane patterns. In addition, the antenna resonant modes get on more parameters like slot, width length etc. This may conduct to design difficulties.

#### METHODOLOGY

The initial geometry of the proposed antenna was first designed implementing the equations from the Transmission Line Model (TEM) approximation in which patch radiating element is viewed as a transmission line resonator with no transverse field variations.

**Corresponding Author:** M.R.I. Faruque, Institute of Space Science (ANGKASA), Level 2, Faculty of Engineering Building, Universiti Kebangsaan Malaysia, 43600 UKM, Bangi, Selangor D. E., Malaysia

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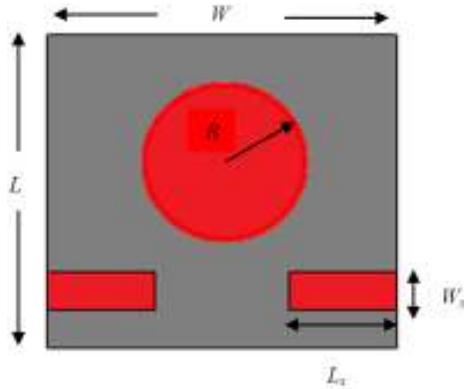


Fig. 1: The proposed patch antenna

Garg *et al.* (1980), the approximation states that the width and length of the patch antenna can be modeled according to the specified central frequency by the following equations:

$$W = \frac{c}{2f_0} \sqrt{\frac{\epsilon_r + 1}{2}} \quad (1)$$

$$L = \frac{c}{2f_0 \sqrt{\epsilon_r}} - 2\Delta l \quad (2)$$

where,

$L$  = The length of the patch

$W$  = The width of the patch

$f_0$  = The target resonant frequency

$c$  = The speed of light in a vacuum and the effective dielectric constant can be calculated by the equation:

$$\epsilon_e = \frac{1}{2}(\epsilon_r + 1) + \frac{1}{2}(\epsilon_r - 1) \sqrt{1 + \frac{10h}{W}} \quad (3)$$

where,

$h$  = The thickness of the substrate

$\epsilon_r$  = The dielectric constant of the substrate

Because of the fringing field around the periphery of the patch, electrically the antenna looks larger than its physical dimensions.  $\Delta l$  takes this effect in account and can be expressed as:

$$\Delta l = 0.412h \frac{(\epsilon_e + 0.3) \left[ \frac{W}{h} + 0.8 \right]}{(\epsilon_e - 0.258) \left[ \frac{W}{h} + 0.8 \right]} \quad (4)$$

As the antenna is fed with the microstrip line, the length of the probe feed is also calculated. The input impedance of the antenna must be matched to the transmission line by choosing the correct position for

the feeding point. After taking account the design requirements such as bandwidth and dielectric constant, the antenna is initially designed to operate in dual frequency at X-band and consequently optimized to obtain the most preferable size of the patch.

The geometry of the proposed antenna is shown in Fig. 1.

The antenna comprises of three conducting slots on patch and the ground plane. A circular slot and two similar lateral rectangular slots are on the patch of proposed the antenna. The two rectangular slots are of equal lengths  $L_s$  and widths  $W_s$ .  $R$  is the radius of the circular slot. The design procedure begins with the radiating patch with substrate, ground plane and a feed line. It is printed on a 1.6 mm thick FR4 substrate that contains relative permittivity 4.55, relative permeability 1 and dielectric loss tangent 0.02. A circular and two rectangular slots are cut from the rectangular copper patch.

Thus, the proposed UWB patch antenna is achieved finally. Two resonant frequencies 8.39 GHz and 9.7 GHz are obtained adjusting length, width and slots of the proposed antenna endlessly. Microstrip line is used to provide feeding to the proposed antenna. The Sub Miniature version A (SMA) connector that contains  $50\Omega$  is conducted at the end of antenna feeding line for input RF signal.

Optimal parameter values of the proposed antenna has been considered such as patch length,  $L = 40$  mm; patch width,  $W = 40$  mm; patch slot length,  $L_s = 12$  mm; patch slot width,  $W_s = 4$  mm; and radius,  $R = 12$  mm.

## NUMERICAL RESULTS AND ANALYSIS

The total calculation has been performed using Finite Element Method (FEM) based high frequency simulation software HFSS to carry out the resonant requirements of the proposed antenna structure. The simulated VSWR of the proposed antenna is shown in Fig. 2. Input impedance has been matched properly as well as Feed line has been well-positioned also. As a result, VSWR (2:1) is obtained at two resonant frequencies 8.39 and 9.7 GHz respectively. Meanwhile, to examine the effects of the embedded slots of the patch to the antenna's matching condition, the simulated results of return loss for the proposed antenna without part of the embedded slots were also studied. A large value of frequency ratio is obtained due to the presence of slots in simulated antenna resonant frequency operation. We achieved 11.2% bandwidth in 1<sup>st</sup> resonant frequency and second resonant frequency 10.3%. This bandwidth covers UWB applications that are mentioned before.

The Gain of the proposed UWB patch antenna is shown in Fig. 3. The obtained gains are 3.81 dB on the lower band and 4.25 dB for the upper band. Cross-polarization level is higher at H-plane at the lower band.

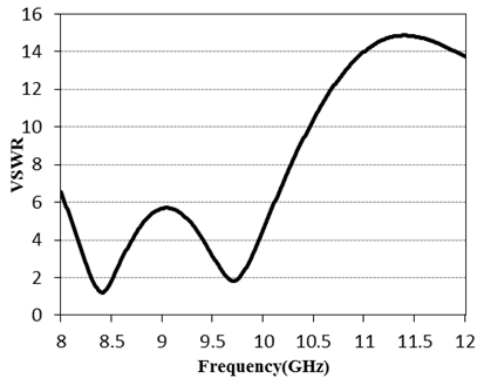


Fig. 2: VSWR of the proposed antenna

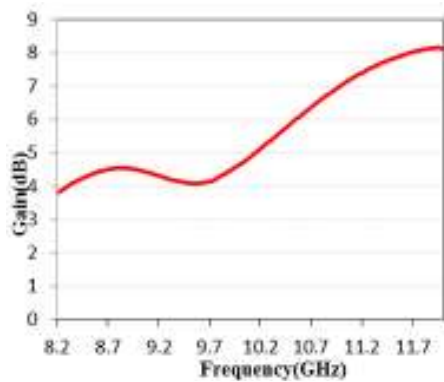


Fig. 3: Gain of the proposed antenna

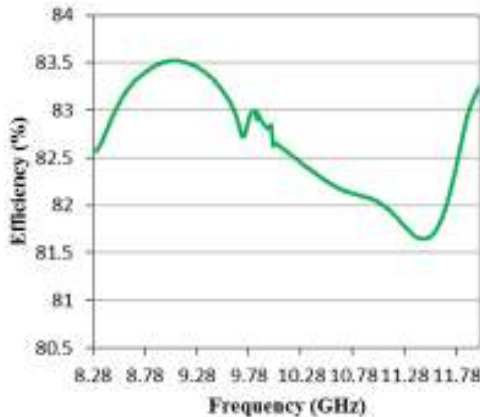


Fig. 4: Radiation Efficiency of the proposed antenna

As a result, the gain at the lower band is lower than that at the higher band. Figure 4 shows that the result of radiation efficiency of the proposed antenna. The radiation efficiency is 83.5% in the proposed antenna. This efficiency is broadly appropriate for UWB band applications.

The radiation patterns of the proposed antenna on the E-plane and H-plane at resonant frequencies of 9.70 GHz are shown in Fig. 5. Good broadside radiation patterns are observed and the two frequencies have the

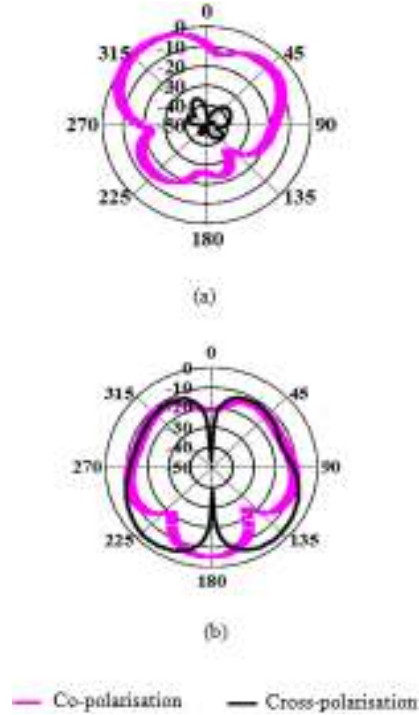


Fig. 5: Radiation pattern of the proposed antenna; (a) E-plane at 9.7 GHz (b) H-plane at 9.7 GHz

same polarization planes. The cross-polarization level in the H -plane at the both band is relatively large, which is expected to be due to the diffractions from the edges of the small ground plane. This cross-polarization level may be decreased by enlarging the ground plane size. It is shown from the results that significant Omni-directional and bidirectional radiation patterns are obtained along the H-plane and E-plane respectively. The E-plane co-polarization patterns are bidirectional and H-plane co-polarization patterns are omnidirectional or nearly omnidirectional at higher frequency. This characteristic is convenient because the propagation condition of wireless communication devices is normally much complicated in practice. As a result, the radiation pattern of the proposed patch antenna is almost durable for UWB applications.

### CONCLUSION

A UWB patch antenna is proposed to increase its bandwidth for dual frequency operations. The antenna is designed on 40×40 mm printed circuit board. The antenna layout is simple and straightforward, so fabrication is easy. VSWR (2:1), gain 3.81 and 4.25 dB, bandwidth 11.2 and 10.3% are obtained at two resonant frequencies 8.39 and 9.7 GHz, respectively. The radiation efficiency of the antenna is 83.5%. These attractive radiation patterns, efficiency with improved bandwidth and higher gain make the proposed antenna compatible for using UWB applications.

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