Design of defective ground plane modified microstrip patch antenna for ultra-wideband applications

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ABSTRACT

This study proposes a modified ultra-wideband (UWB) patch antenna with defective ground plane layout on FR-4 substrate material has dielectric constant ε_r equals to 4.3. An altered feed line has been employed to considerably enhance the antennas performance. Starting from 4 GHz to 13 GHz, upper, and lower frequency ranges can produce UWB antenna capabilities. The proposed antenna has a good bandwidth, making it practical to use in a variety of applications. Over the operational band, the reflection coefficient is decreased to less than -10 dB. The finite integral approach of fit is used to construct and analyze the antenna utilizing the computer simulation technology CST package simulator. In this study, an UWB antenna is demonstrated that may offer notches in the lower UWB band (3.1-4 GHz). The performance of the antenna has been enhanced by using the flawed ground structure. The return losses and radiation characterstic confirm that the intended notched frequency has been suppressed. The proposed antenna was designed and simulated using computer simulation technology (CST 2020).

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1. INTRODUCTION

According to the FCC, the ultra-wideband (UWB) spectrum cover range from 3.1 GHz to 10.6 GHz [1] for commercial use. Any communication method that exceeds the operational center frequency by more than 25%, or 500 MHz, is referred to be ultra-wideband [1]. A spectral density of -41.3 dBm/MHz was permitted across the whole UWB frequency band according to the definition of the UWB spectral [2]. Because of low power spectral density UWB has no effect on the licensed system and the propagation like same as the noise. The receiver must have decoder to receive and collect low power signal. Be prompt and efficient despite UWBs extensive operational bandwidth [3], [4].

When attempting to create an antenna with a wide impedance bandwidth, broad radiation patterns, and the ability to fit into a small space, antenna designers encountered many difficulties. Additionally, because the UWB systems use a lot of operating bands, there is interference between them. Solving this issue could lead to additional issues with the UWB systems size, production costs, and insertion loss in extremely narrow bands such as (worldwide microwave access interoperability) WiMAX (from 3.3 to 3.7 GHz) [1], [5]. UWB antennas must be created taking into account the possibility of interference between narrow bands. For portable devices, it is necessary to use antennas that use less power, are smaller, lighter, easier to build, and have a simpler design [6]–[9]. Antennas that can prevent interference should also be considered into account in addition to the aforementioned characteristics [10]. Many academics have suggested creating antennas that has bands reject at certain frequency band by changing the ground plan, patch, or doing both, utilizing splite ring resonator metamaterial SSR [11], [12] using frequency selective surface (FSS), or by using electromagnetic band gap structure (EGB) [13].

Several methods have been used in various antennas to get band notches. Few antennas have had narrow slots patch etching or ground plane to generate multiband antennas with lower frequency notches [14]. This was done to avoid raising system costs or size while also preventing interference between other narrowband systems and UWB. a number of modified design configurations to the both the ground and the radiating patch, or one of them have been suggested to avoid interferences. Numerous studies have also suggested using L-shaped, S-shaped, F-shaped, arc-shaped, or by circular slots in their antenna to obtain demand properties.

Many technique used to control the notch location such as reconfigurable antenna [15]–[18] and a meta-material in feed line of the micostrip patch antenna [19] multiple input multiple output. MIMO antenna used used to increase the channel capacity [20], [21]. Also UWB antenna can be used in nano-scale for medical applications [16], [22] and in 5G applications [23]–[25].

Those who have employed mechanical and electrical methods are very rarer. Variable ground plans and modified UWB patch antennas have been created using the active filtering elements varactor diodes and p-i-n diodes to give reconfigurable antennas in terms of polarization, radiation pattern, and ground plan, and operation frequency. The antennas electromagnetic (EM) properties, however, have been weakened as a result of the systems increased complexity, losses, and geometric requirements that demand more operational power. Therefore, etching, putting slots, and adding studs seem to be preferable and cost-effective when building a UWB antenna with band rejection properties. It is common practice when In order to alter the current distribution on the radiating surface, reduce the antennas size, and boost its bandwidth, antennas are constructed by adding slots and studs to the patch.

High frequency radio waves are used by UWB systems for short-range communications. Due to the benefit of dispersing RF radiation with an extremely broad bandwidth, they have grown to be particularly alluring for high data rate transmission. So that they can link to low-power spectral density signals, UWB systems are immune to the effects of multipath. There has been a resurgence in UWB antenna research in recent years as a result of the availability of affordable yet need for precise position tracking and range in the market and powerful processing SoCs apidly developing technological landscape. Planar monopole UWB antennas are one of the several forms of UWB antennas that have been suggested, due to its tiny size, low cost, and simplicity of integration with other circuit components, has attracted the most interest. UWB antenna design does provide certain difficulties, interference being the main one. Numerous narrowband wireless systems, such as wireless local area network (WLAN: 5.15–5.35 GHz, 5.725–5.7825 GHz) and (WiMAX: 3.3–3.6 GHz), share parts of the spectrum in the defined UWB operating band. Mahdi and Jawad [16] In order to avoid the requirement for an extra band-stop filter in the receiver electronics, a UWB antenna must be able to reject the working frequencies of these systems natively on the antenna.

Several techniques have been put forth to generate band-notched performance in the UWB antenna. The most widely used tactics make use of slots, such as a u-shape another approach is to employ parasitic elements near the monopole [12], or near the feedline [14], in addition to square slots, quarter wavelength open-ended slots on the monopole, and ground plane. Other methods use defective ground structures (DGS) and electromagnetic band gap structures (EBGs) [10]. To achieve band notched functionality, split ring resonators (SRR) have also recently been invented. In a single band notched inside the UWB band is realized by coupling a pair of split ring resonators to a coplanar waveguide fed monopole antenna. Despite the fact that this method generated high gain suppression of -11dB, a 50×50 mm^2 antenna is needed. According to a multiband notched antenna is created by adding three split ring resonators with various sizes to the antennas feedline. At the notched frequencies, good gain suppression of -9.6, -12.7, and -4.3 dBi was achieved. But a substantial antenna, measuring 50×70 mm^2, was needed. There have also been proposed methods using reconfigurable antenna and meandering lines.

According to Abbosh *et al*. [6], band-notched switching is carried out by adjusting the slot length using a switch located inside the radiator of the antenna. The detected radiation patterns are altered by the slots switch and length variations. Four pairs of meandering lines are used in to realize a number of band-notched features. The antennas emission patterns are modified while a high gain suppression of about 9 dB is achieved.

The majority of the aforementioned techniques struggle with three fundamental problems: it is not feasible to utilize the same method on the same antenna to produce several band notches for the following reasons: using these techniques results in band notches with wide notch-widths, some of which surpass a bandwidth of 2 GHz, rejecting some useful frequencies in the process. More importantly, 3 circuit analysis is rarely used to describe the filtering process. If there are, the circuits that are drawn have little to no justification. This research proposes a strategy to design a dual-band notched antenna that solves all the aforementioned problems.

The filtering technique is explained in depth, and the procedure can be used with other designs. To provide band notched performances, vertical quarter wave length use is made of the stub (s) inserted in the feedlines closed slot. Two antennas are recommended in this instance: i) a single stub for a tiny band-notch between 3.3 and 3.6 GHz, and ii) two stubs placed closely together on a closed slot on the feedline for dual band-notched qualities, i.e., a narrow band (3.3-3.6 GHz) and a broader band-notch between (5.15 and 6 GHz). The suggested antennas achieve their wide range of band notches and rather precise band rejection. The majority of the methods discussed above suffer from three common in comparison to prior designs without using a ground plane or radiator. The suggested method also accomplishes twin notch bands while utilizing the very little area.

This study suggests a straightforward method for creating a frequency-notched UWB antenna by modifying patch and ground plane and insert slot in ground plane to get notch in the lower part of UWB spectrum. By adjusting the studs length and the space between them, the notched frequency can be changed. The presented antenna has a large radiation pattern up to 15 GHz and a high rejection (VSWR > 15). The rejected band can be configured between 3 GHz and 6 GHz to reduce potential interference from specialized UWB communication systems and filter the unwanted frequency. A 50 CPW feed line is connected to the antenna, which is built on a Taconic substrate. The item is 22 mm by 30 mm by 1.62 mm in size. On the commercial electromagnetic simulator CST numerous simulations are run to examine the properties of the suggested antenna.

2. UWB ANTENNA SYSTEM

UWB uses a bandwidth of several GHz, in contrast to traditional narrowband communication systems. The design of UWB systems is far more difficult than that of traditional narrowband systems. Rectangular microstrip patch antenna microstrip patch antenna (MPA) shown in Figure 1.

Table 1 summarizes the measurements for the simulated MPAs antenna radiated patch, ground plane, substrate, and feeding line. These measurements were acquired using the MATLAB software and the accompanying equations [1]:

$$W_p = \frac{c}{2f_r\sqrt{\frac{(\varepsilon_r+1)}{2}}} \tag{1}$$

$$\varepsilon_{reff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left[1+12(\frac{h}{W})\right]^{\frac{-1}{2}} \tag{2}$$

$$\Delta L = 0.412h\frac{(\varepsilon_{reff}+0.3)\left[\frac{W_p}{h}+0.264\right]}{(\varepsilon_{reff}-0.258)\left[\frac{W_p}{h}+0.8\right]} \tag{3}$$

$$L_{eff=}\frac{c}{2f_r\sqrt{\varepsilon_{reff}}} \tag{4}$$

$$L_p = L_{eff} - 2\Delta L \tag{5}$$

$$W_s = 2 \times W_P \tag{6}$$

$$L_s = 2 \times L_P \tag{7}$$

Where W_p is the antenna patchs width, L_{eff} related to the length, L_p is the patchs real length, and L is the length protraction due to the fringing effect. Where ε_{reff} is referred to as the effective permittivity, ε_r is referred as the permittivity of the substrate, h is referred to the dielectric thickness, W_p is referred to as the width of the antenna patch, L_p is the first step in calculating the feed line can be summarized by determining the size of the 50 Ω line.

The planned antennas geometry and dimensions are shown in Figures 2(a) and (b). Microstrip feedline width is set at 2.5 mm, and the thickness of the antenna substrate is maintained at 1.62 mm. The ground is lengthened to 7.7 mm and given a 3×1.4 mm slit to achieve 50 characteristics impedance. The patch is 22×30 mm overall. Then, two studs are positioned directly in the center of the slot on the circular patch surface, each measuring 3 mm in length and 0.1 mm in width and being spaced apart by 6 mm. The dimensions of the proposed antenna in millimeter are mentioned in Table 1.

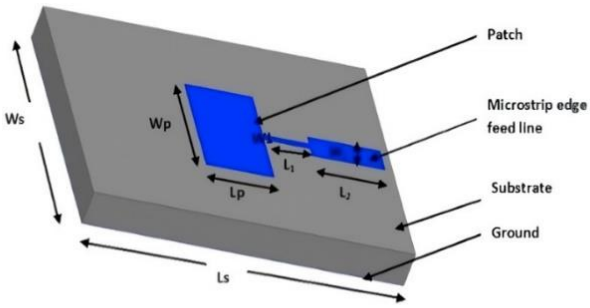
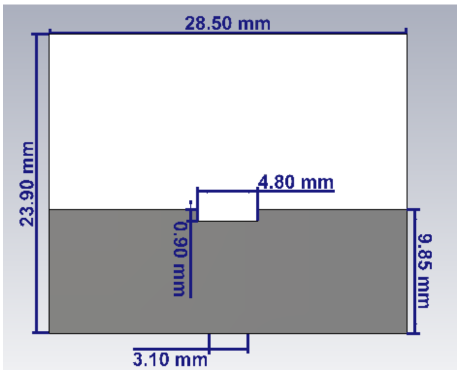
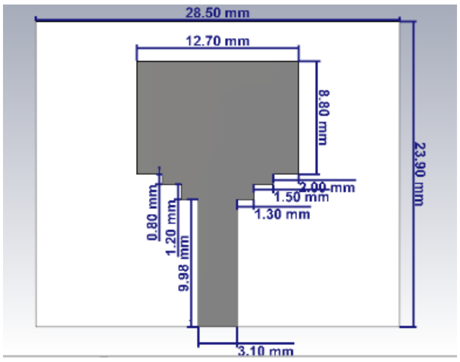


Figure 1. Rectangular MPA



(a)



(b)

Figure 2. The proposed antenna (a) front view and (b) back view

Table 1. Dimensions of the proposed antenna

ws	ls	wp	lf	lg	lp	$W1$	$W2$	$wslot$	wf	h	$L2$	$lslot$	$L1$	t
28.5	23.9	12.7	9.98	9.85	8.8	8.7	5.7	4.8	3.1	1.6	1.2	0.9	0.8	0.035

3. RESULT AND DISCUSSION

The return losses S_{11} of the antenna shown in Figure 3. The return losses of the antenna at frequency 4 to 13.5, less than -10 Db, while the return losses more than -10 dB at frequency 0-3.8 to reject WiFi band. The return losses are minimum at frequency 10.2 GHz approach to -35 Db. Figure 4 shows the voltage standing wave ration VSWR which is less than 2 at the operating frequency band and it has minimum value at frequency 10.2 GHz. The gain of the antenna is shown in Figure 5 the antenna has a good gain (2-5.5) dB at the operating frequency band the gain has maximum value at 12 GHz equals to 5.5 Db and has minimum value at frequency 6 GHz equals to 1.5 dB. Figures 6 to 9 shows the radiation pattern of the antenna at frequencies (2, 4, 6, 8, and 10) GHz respectively. Maximum directivity is 2.98 at frequency and 1.83 at frequency 6 GHz and 3.56 at frequency 8 GHz and 5.19 at frequency 10 GHz. Figures 10 and 11 shoes the radiation and total efficiencies. It is clear from the figures that the antenna has good efficiency.

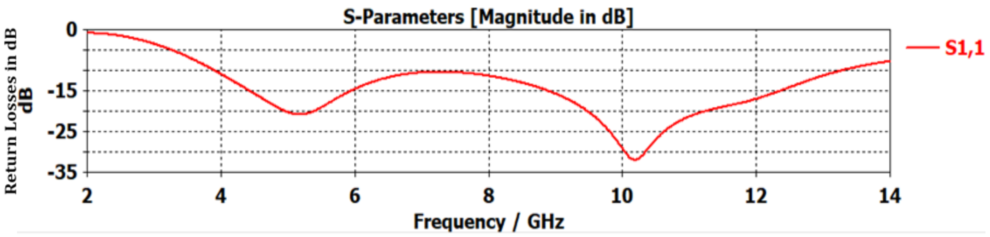


Figure 3. Return loss (S_{11}) for the proposed rectangular MPA

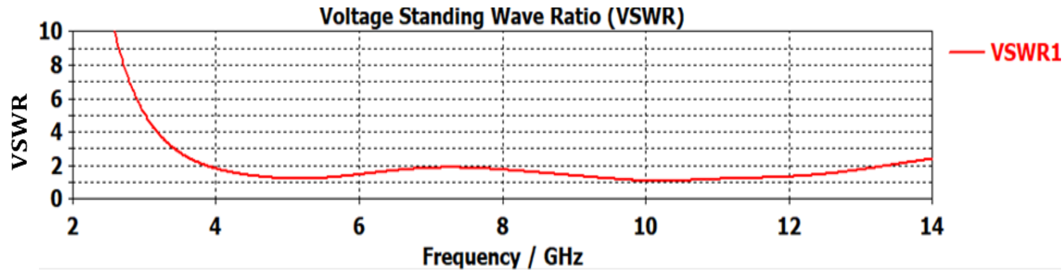


Figure 4. Voltage standing wave ratio for the proposed rectangular MPA

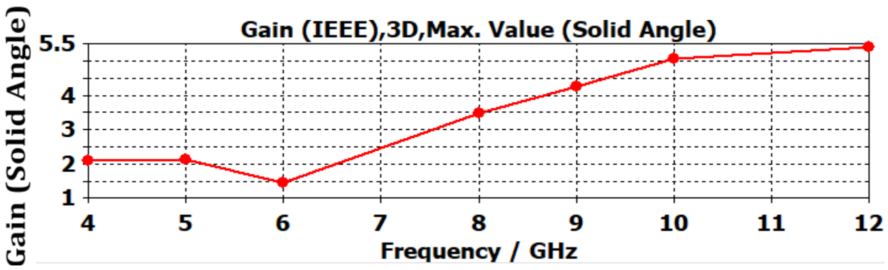


Figure 5. Gain of the antenna

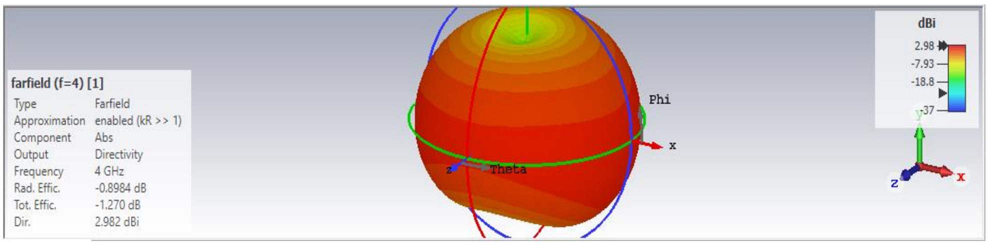


Figure 6. Far field at frequency 4 GHz

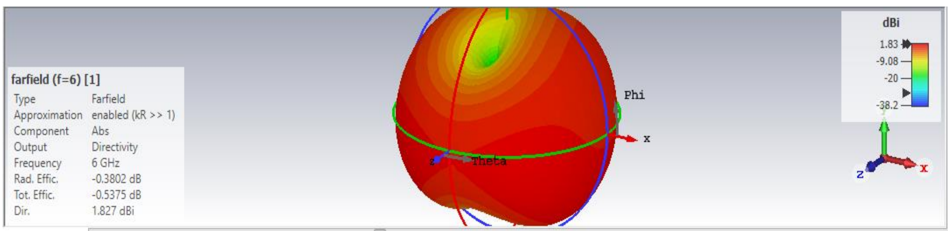


Figure 7. Far field at frequency 6 GHz

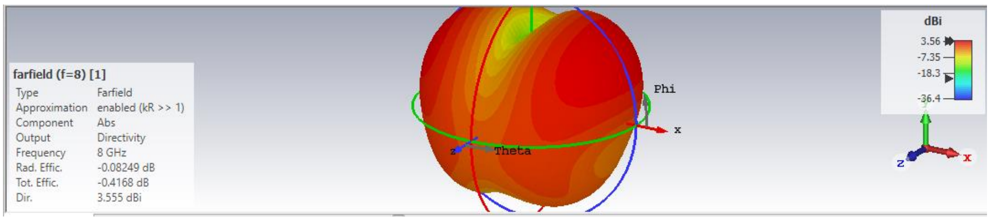


Figure 8. Far field at frequency 8 GHz

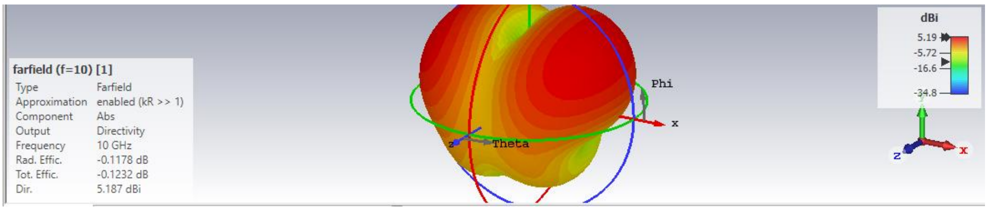


Figure 9. Far field at frequency 10 GHz

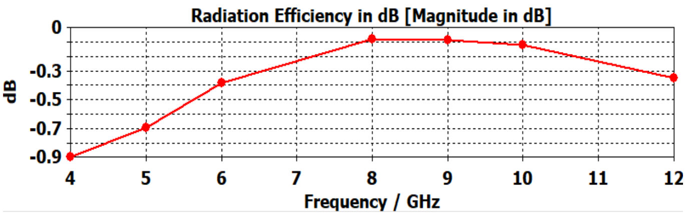


Figure 10. Radiation efficiency

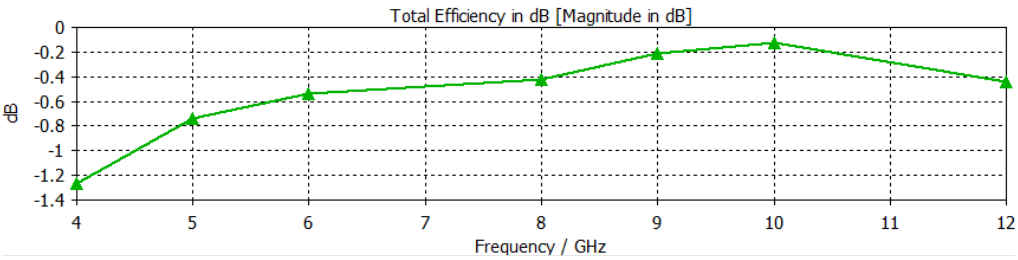


Figure 11. Total efficiency

4. CONCLUSION

The fundamental component of future wireless and mobile communication systems will be UWB technology. This is as a result of its capacity to deliver an extremely high data rate, which comes from the wide frequency range inhabited. This study uses a microstrip antenna with a defective ground plane and a stair-step feed line for use in UWB applications. The outcome indicates that the antenna has good efficiency at the operating frequency band, high gain, and low return loss. The CST -2020 software package was used to simulate the antenna.

The filtering method is thoroughly described, and the process can be applied to various designs. Vertical quarter wavelength stubs implanted in a closed slot on the feedline are utilized to produce band notched performances. Two antennas are recommended in this instance: i) a single stub for a narrow band-notch from 3.3 to 3.6 GHz, and ii) two stubs positioned closely together on a closed slot on the feedline for dual band-notched characteristics, i.e., one narro. The anticipated and actual results show that the suggested technique takes care of the band-notch modules space reduction and precise narrow band rejection problems. More importantly, a methodical methodology to circuit analysis has been presented in the ethology.

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