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A novel design of plannar antenna for UWB and WLAN applications with notched bands

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ABSTRACT

A micro strip-fed monopole antenna for ultra-wideband antenna with triple band notched and WLAN antenna is presented and analyzed in detail. In the UWB antenna three different frequencies are notched by means of using E-shaped resonator. The three notched frequencies are 3.6 GHz (WLAN), 5GHz (WLAN) and 10 GHz (X- band) with a reference level of s11 > -10dB. The center frequency of the notched band is 7 GHz. The frequency band of the proposed antenna is 0 GHz-11GHz for voltage standing wave ratio (VSWR) less than 2.Surface current distributions and transmission line models are used to analyze the effect of these slots. The antenna is successfully fabricated and measured, showing broad band matched impedance and good Omni directional radiation pattern. The designed antenna patch has a compact size of 17x13.8 mm^2.

Introduction

The approval and allocation of the frequency band between 3.1–10.6 GHz and 2.4 GHz, the ultra wideband (UWB) and WLAN technology has become one of the most promising technologies for future high-data-rate wireless communication, high-accuracy radar, and imaging systems. As an essential part of the UWB system, the UWB antenna has drawn heavy attention from researchers. It displays desirable characteristics such as compact size, low cost, and good omnidirectional radiation pattern. However, there is an issue of a possible electromagnetic interference, as over the allocated wide bandwidth of the UWB system, some narrow bands for other communication systems exist, such as WiMAX operating in 3.3–3.7 GHz, WLAN operating in 5.15–5.825 GHz, and downlink of X–band satellite communication systems in 7.25–7.75 GHz. Three band stop filters connected to a UWB antenna can be used to reject these bands. However, this increases the complexity of the system. A simpler way to solve this problem is to design the UWB antenna with band-notched characteristics. UWB antennas with band-notched function have been reported mostly with one notched band for WLAN in 5.15–5.825 GHz. Recently, several antennas with dual notched bands or triple notched bands were presented.

It has been demonstrated that the notched band can be achieved by etching a pair of T-shaped stubs inside an elliptic slot cut in the radiating patch or using U-shaped arc-shaped or C-shaped slots embedded in the patch or in the ground plane.

Design And Analysis

Fig. 1 shows the final design of the antenna, along with a photograph of the fabricated prototype. Simulation was performed using the commercial software IE3D. The final design was optimized taking several aspects into consideration such as bandwidth of the antenna, bandwidth of the notched bands, and level of band rejection.

The antenna has a compact volume of 17X13.8 mm^2 on FR4 substrate with a relative dielectric constant of 4.4 and loss tangent of 0.02. It is composed of a 50-Ω micro strip feed line.

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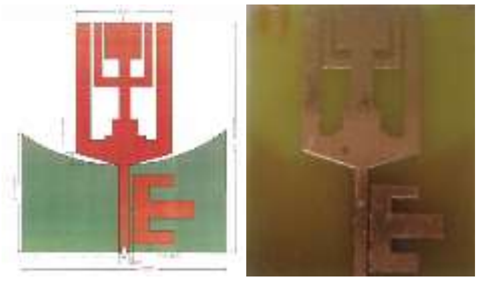

Fig.1 Geometry of the antenna (units in millimeters). (a) Top view. (b) Photograph of the fabricated antenna.

In this design we designed two different antennas and then add the two antennas, finally we get a plannar antenna. Therefore plannar antenna is the combination of 2.4 GHz and UWB antenna.

Ultra Wide Band (UWB) Antenna

Over the past few years Ultra Wideband communication has received much attention. Research and development on UWB communications is gaining momentum mainly because of communication and ranging capabilities of this technology as well as the recognition of significance of UWB technology by the FCC and other regulatory bodies. The major step in the development of UWB technology for wireless communications is the antenna.

Like all wireless devices, the antenna is an essential part of UWB communication systems. Due to huge bandwidth of the UWB system, antenna poses a remarkable challenge to the UWB technology.

In the recent years researchers, engineers and scientist have tried hard to solve UWB antenna problem in different ways and now, six years after the FCC authorized commercial UWB systems, the UWB products are entering the market with a large scale of commercialization. Generally antennas are elements that radiate the electromagnetic energy of a transmission line to the free space.

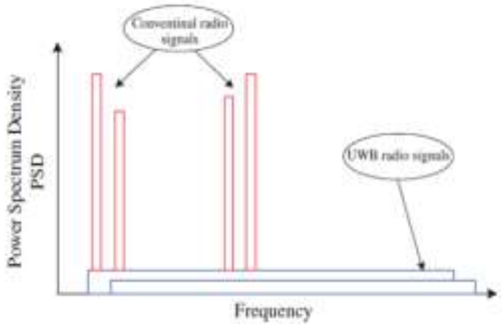

Fig.2 The spectrum of the UWB signal versus conventional signal

Micro strip antenna

A micros trip antenna consists of a metallic pattern on one side of a dielectric substrate and ground plane on the other side of the substrate. In this project I have focused on making a micros trip patch antenna. Figure 3.1.2 shows a micro strip patch on a dielectric substrate.

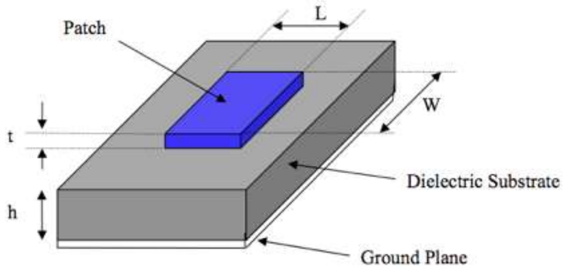

Fig.3 Micro strip antenna

The antenna patch can have different shapes, but is most likely rectangular. In order to make performance predictions the rectangular patch antenna has the following parameters, where $\lambda_0$is the wavelength in vacuum also called the free-space wavelength.

Length (L): 0.3333λ0 <L < 0.5λ0

Height (h): 0.003λ0 ≤ h ≤ 0.05λ0

Thickness (t): t<< λ0

Dielectric constant (ε r) : 2.2 ≤ ε r ≤ 12

In electromagnetic radiation λ is often given instead of $\lambda_0$as the speed of light in vacuum is very close to the speed of light in air. Looking at the parameters of the length, the length is slightly less than λ/2.

Advantages and Disadvantages:

Micro strip antennas are becoming more and more popular every day. And with a more modern world where the internet and Wi-Fi are delivered in many stores, more and more gadgets are using micro strip antennas. Some of the advantages are:

•Light weight.

•Low volume.

•Easy integration with Microwave Integrated Circuits (MIC).

On the other hand, micro strip antennas also features some disadvantages compared to conventional antennas:

•Narrow bandwidth

•Low efficiency

•Low gain

•Extra radiation from feeds and junction

•Surface waves

•Low power handling capacity.

Antenna feed techniques

There are different ways to feed the antenna. It is obvious that one cannot have merely a patch and transmit power through it without actually delivering the power to the patch and vice versa by receiving.

I have been looking at two different feed methods for the patch antenna. They are

1. Micro strip feed techniques
2. Coaxial feed techniques

Micro strip feed techniques

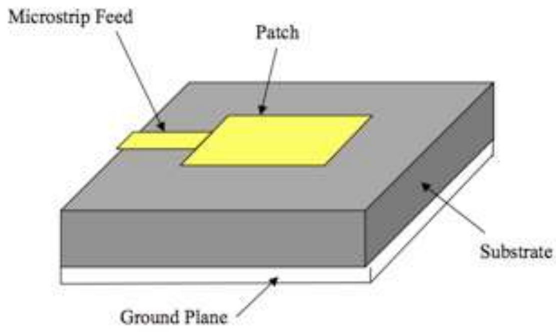

Fig.4 Micro strip feed line technique

The feed line to the patch antenna is in its origin a transmission line and is therefore often referred to as the transmission line feed. The feed line width is smaller than the patch and is etched directly to the edge of the patch so that power is transferred from the source through a coaxial cable, into the feed line and then to the patch. The purpose of the feed line is to match the impedance from the patch without any additional matching component, however because the feed line is a patch itself it can cause radiation interfering with the patch which will decrease the bandwidth of the antenna.

When designing the feed line, this must be along the side of the length, as the current flow is along the direction of the feed wire and at the length is where the maximum radiation of the patch is created.

Coaxial feed techniques

Another way to feed the antenna is to directly connect it to a coaxial cable to avoid radiation from the feed line.

The coaxial feed (also referred to as a probe feed) is a very common way to feed the antenna. As seen from figure 3.1.3.2 the coaxial connector is inserted at the ground plane where the inner conductor extends through the dielectric substrate and is soldered on to the patch.

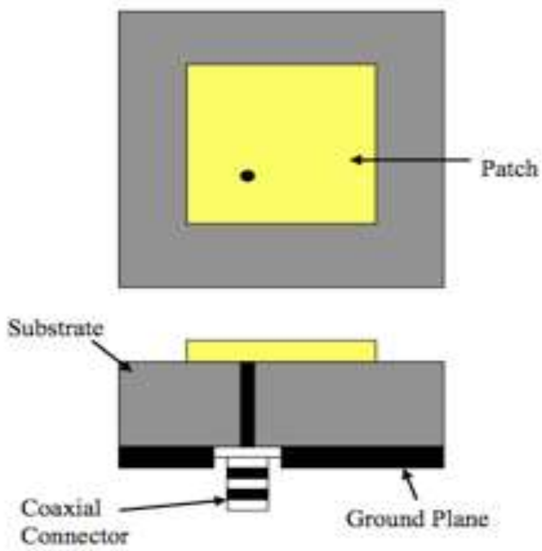

Fig.5 Coaxial feed technique

The advantages of this kind of feed are its lower radiation and the fact that it can be placed any where to match the impedance of the patch (though a calculation of the x, y plan of the patch). The disadvantage is that it provides a narrow bandwidth and is it is difficult to drill through the substrate.

With a fragile dielectric substrate you might end up damaging the substrate or the inner connector might not perfectly fit the drilled hole and thereby create power loss to air conductivity. Another problem is that with a thick substrate the inner coaxial conductor has to belonged leading to higher input inductivity which creates matching problems.

PCB substrate

In today's market there are a lot of different PCB substrate products. Unfortunately there is not only one product that can cover all applications. It all depends on the application itself. Even though your application is simple it is still difficult to meet all requirements. Depending on your application you need to consider your selection of substrate. Properties to be considered includes dielectric constant, loss tangent, and their variation with temperature, frequency, dimensions, stability, thickness, resistance to chemicals, flexibility etc.

Substrate material- FR4 substrate

FR-4 substrate is a very common and by far the most used substrate in consumer electronics market as it has a good quality-to-price ratio. It is mostly used where cost is more efficient than performance.

FR-4 is a standard with many different distributors making many different FR-4 quality and property boards. It is made of woven fiberglass with an epoxy resin binder (binds the copper clad to the dielectric substrate) that is flame resistant. The dielectric constant goes down the more theFR-4 PCB is reinforced with epoxy resin instead of fiberglass as this is not determined as a standardized parameter. 100% epoxy resin boards has a dielectric constant of 3.4 @ 1MHz.

Fig.6 Copper clad FR-4 PCB substrate.

The FR-4 changes its dielectric constant along its area which makes it too unstable to mass produce precise antennas on it. Also, the FR-4 is has a higher loss at frequencies over 3GHz, because of the sensitivity of the cheap substrate. Other products are therefore recommended toper form better than FR-4 in RF applications. A highly recommended distributor is Rogers, who is a little more expensive but performs much better in RF applications. In the cell phone industry, companies uses higher quality FR-4 substrate because it is more cost efficient, but from only one manufacture so they can be sure of the quality and properties when mass producing. The performance is typically around -13 dBm.

Antenna Design

Design of ultra-wide band antenna:

This design consists of a micros trip antenna for UWB short range applications. The frequency ranges between 3.6GHz to 10.6GHz and having a bandwidth of greater than 500MHz. This design can be done in IE3D software. The side two slots are inductive reactance and the center one is a capacitive reactance.

In the end having an E shaped structure and is known as resonant cavity. The resonant cavity allows only a certain frequency is known as resonance frequency.

In the background a large structure having green coloured is the ground plane, used for notching purpose. The notch can be done in many ways like designing a stop band filter, using ground plane,etc...Here we choose ground plane for notching purpose because it reduce the computational complexity.

The length and width of each slot can be designed by using the above calculation. The design can be based on inductive and capacitive reactance.

$$f_r = \frac{1}{2\Pi\sqrt{LC}}$$

Here we notch three different frequencies. The ground plane also designed by the above calculation.

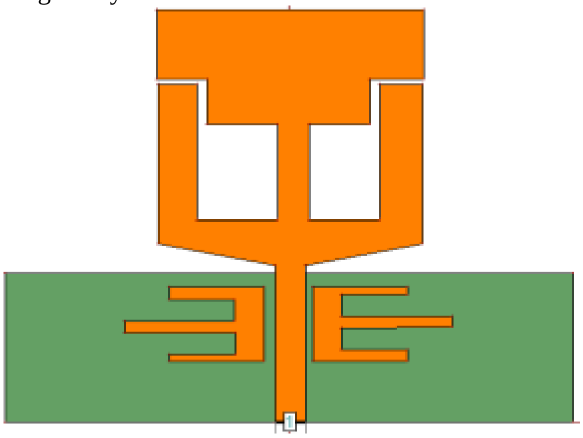

Fig.7 Design of micro strip antenna for UWB applications

The current distribution only shows the designed antenna will be in working condition or not. The red colour in the feed line shows that the current will be spreaded in all the planes.

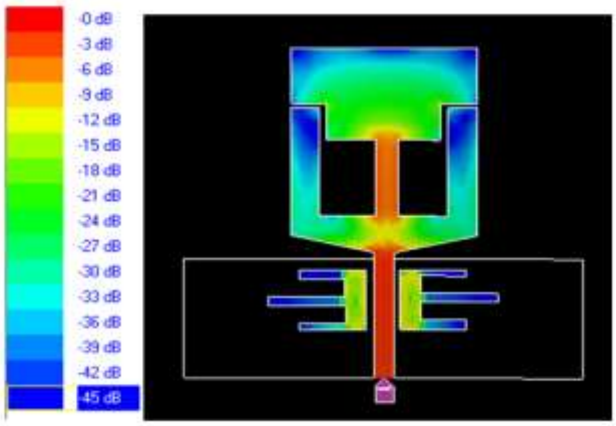

Fig.8 Current distribution of UWB antenna

In this frequency Vs Return loss graph shows that we achieve an output of three different frequencies between the ranges of 3.1GHz-10.6GHz (UWB). The three different frequencies are 3.6 GHz, 5 GHz, 10 GHz.

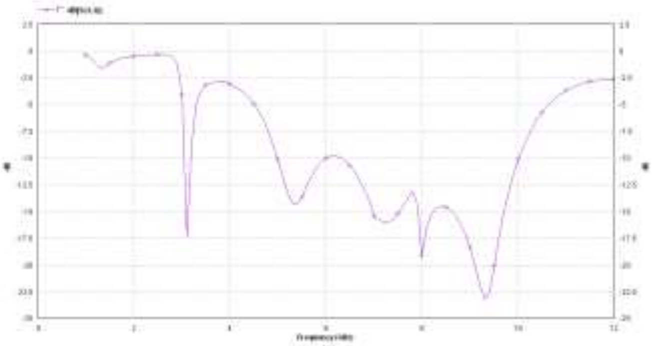

Fig.9 Frequency Vs Return loss response

The below graph shows we get a minimum VSWR(i.e., 1) at our resonant frequency range of 3.1GHz -10.6GHz.

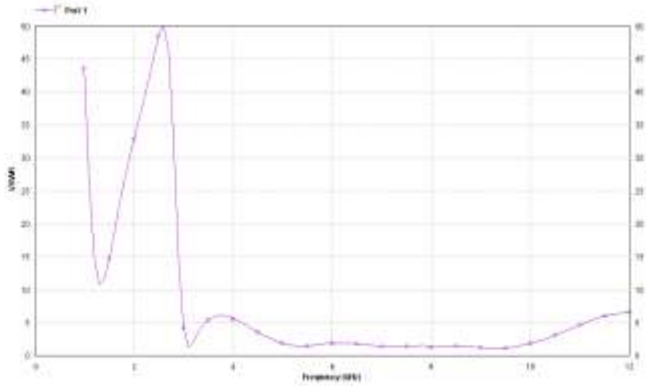

Fig.10 Frequency Vs VSWR response

Design of WLAN antenna

The below design shows that side two slots are inductive reactance and the center one is a capacitive reactance.

In this design can be done with the help of the length and width in the above calculation. We take a resonant frequency of 2.4GHz (WLAN).

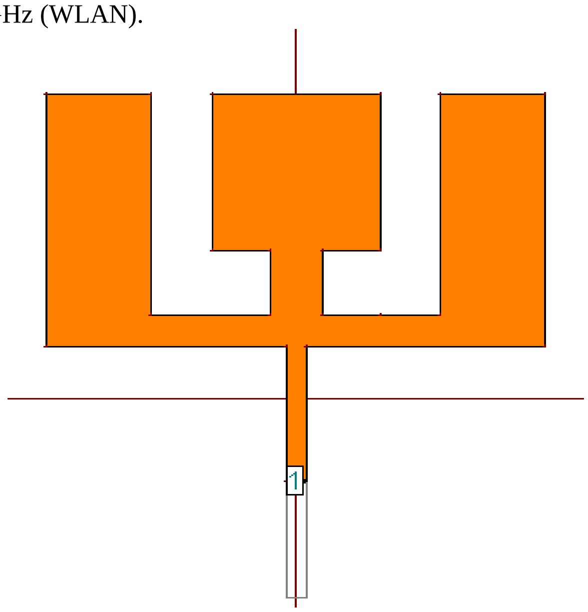

Fig.11 Design of WLAN antenna

The current distribution only shows the designed antenna will be in working condition or not. The red colour in the feed line shows that the current will be spreaded in all the planes otherwise it will not be in good working condition.

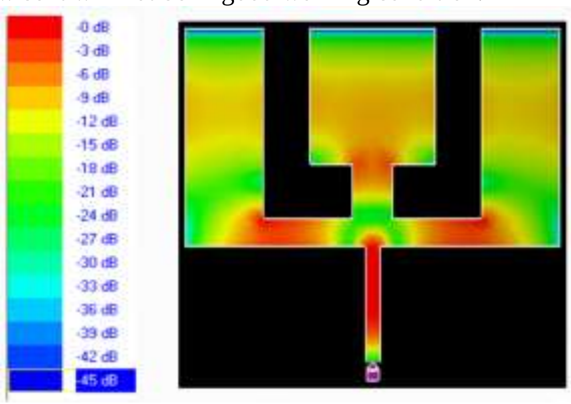

Fig.12 Current distribution of WLAN antenna

In this frequency Vs Return loss graph shows that we achieve an output of 2.4GHz .We achieve a Return loss of -9dB.

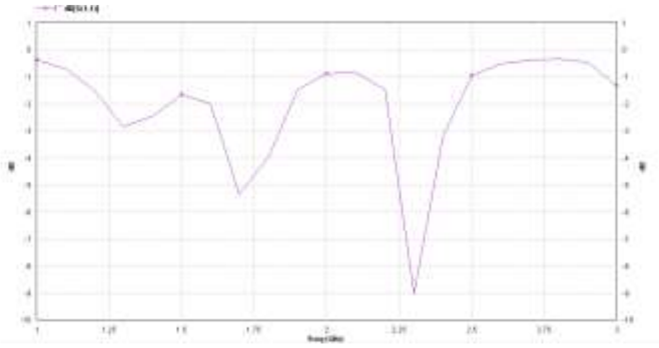

Fig.13 Frequency Vs Return loss response

The below graph shown that we get a minimum VSWR at our resonant frequency of 2.4GHz.

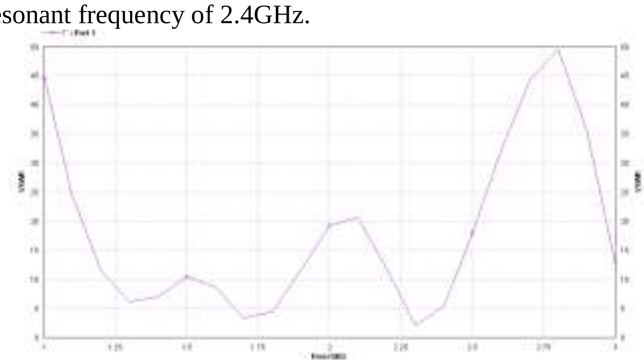

Fig.14 Frequency Vs VSWR response

Design of Plannar Antenna

In this section having the combination of both WLAN and UWB system and providing various applications. This design can be done by using trial and error method. Finally we are getting an output of plannar antenna.

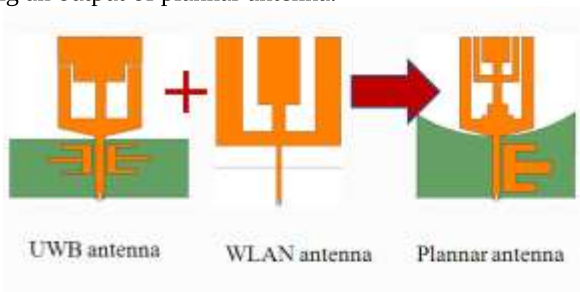

Fig.15 Plannar antenna (UWB+WLAN)

The WLAN antenna having frequency range of 0 to 2.4GHz and the UWB antenna having the frequency range of 3.1GHz to 10.6GHz.

The combination of this two antenna i.e., plannar antenna having a frequency range of 0 to 10.6GHz.

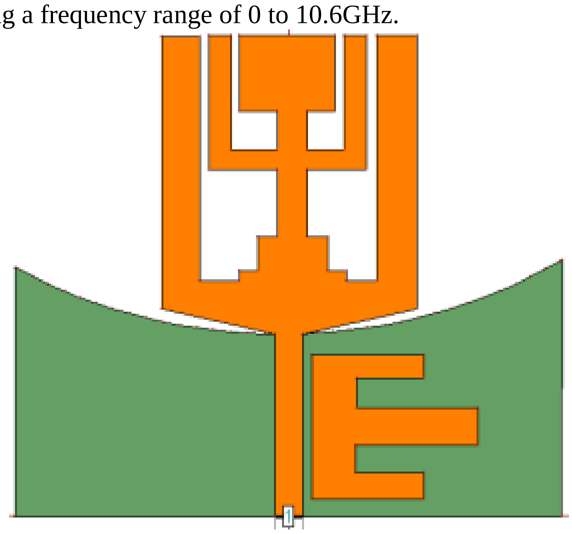

Fig.16 Design of Plannar antenna

The current distribution plannar antenna includes four different frequencies namely & GHz(resonant frequency), 3.6 GHZ, 5 GHz, 10 GHz.

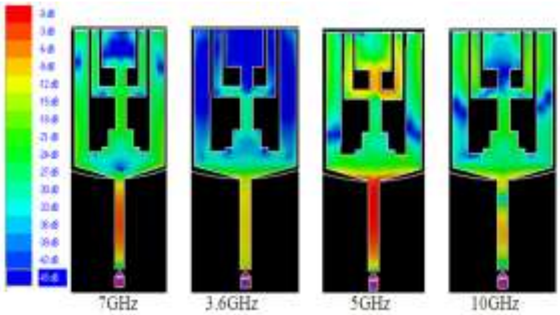

Fig.17 Current distribution of plannar antenna

Here we are getting a return loss of the combination of WLAN and UWB antenna.

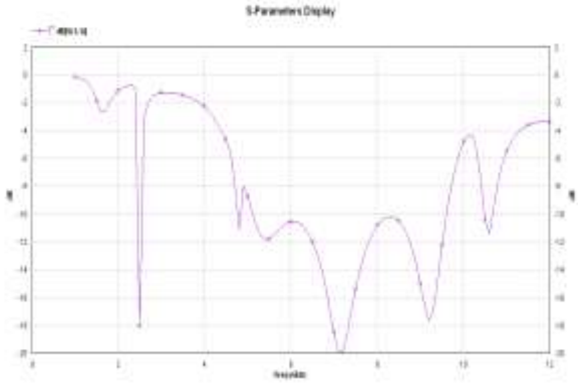

Fig.18 Frequency Vs Return loss response

The graph shows that the two frequencies(i.e., 2.4GHz and 3.1GHz -10.6GHz) having minimum VSWR.

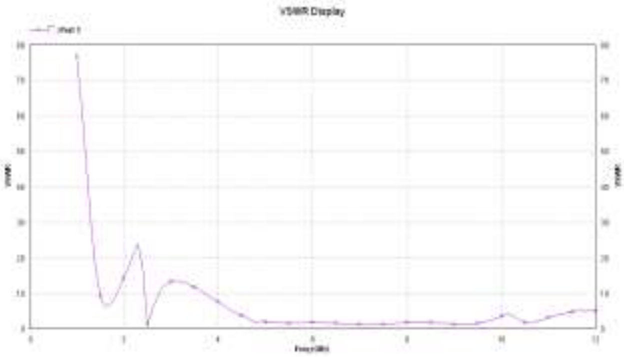

Fig.19 Frequency Vs VSWR response

The designed planar antenna having a higher gain at 2.4GHz and UWB frequency range i.e., 3.1GHz-10.6GHz.

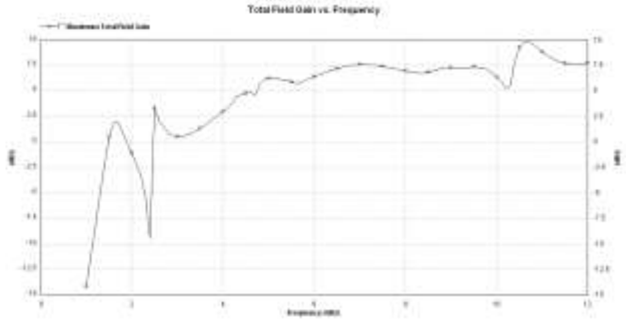

Fig.20 Frequency Vs Gain response

Conclusion

A novel design of plannar antenna for UWB and WLAN applications with notched bands has been presented and analyzed in detail. To obtain three notched bands and WLAN by designing two side slots and one patch present at the center. We introduced new term, an effective length of a slot, and used this concept along with the surface current distributions and transmission line models to analyze the physical effects of these slots generating the band-notched characteristics. The antenna was fabricated and measured, showing broad bandwidth, three designed notched bands, and good Omni directional radiation patterns.

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