RESEARCH ARTICLE OPEN ACCESS

Design Analysis of Ultrawideband Antenna with Enhanced Bandwidth

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Abstract—
In this paper, a novel ultrawideband antenna with enhanced bandwidth is presented. Experimental results show that the antenna achieves good impedance match from 2 to 14 GHz with the voltage standing wave ratio (VSWR) less than 2. From HFSS13 simulations, dimensions of antennas are chosen for better performance. It is shown that return loss of the antenna at solution frequency 7 GHz is less than -10 dB. The antenna is designed on Epoxy FR4 substrate. It covers nearly UWB band 3.1 to 10.6 GHz which is FCC decided. The proposed microstrip antenna is highly suitable for applications of wideband systems.
Keywords- return loss, VSWR and ultra-wideband antenna

I. INTRODUCTION

The trend of communications systems has lead designers to require light weight, robustness, and easy integration of antenna. In 2002, Federal Communication Commission (FCC) authorized unlicensed use of UWB band ranging from 3.1 GHz to 10.6 GHz. Since then, the design of broadband antennas has become an attractive and challenging area in the research of the system design. In general, the antennas for UWB systems should have sufficiently broad operating bandwidth for impedance matching and high-gain radiation in desired directions. Among the UWB antenna design in the recent literature, the monopole planar antenna type is widely used due to its wide bandwidth, simple structure and low cost. It has become one of the most considerable candidates for UWB application. Several designs of monopole planar UWB antenna have been proposed. However, some of these antennas involve complex calculation and sophisticated fabrication process. Therefore, we propose a simpler method to design the UWB antenna based on microstrip rectangular patch calculation using simple transmission line model.

This paper is organized as follows. In Section II ,review of the state of art Antennas is presented. The proposed antenna design geometry is presented in section 3. Simulation results in three parts, namely, parametric study, time domain analysis and experimental results and discussion is presented in section 4 and 5 .Section 6 summarizes and concludes the study.

II Review of the Art

The UWB technology has undergone remarkable achievements during the past few years. In spite of all the promising prospects featured by UWB, there are still

challenges in making this technology live up to its full potential. One particular challenge is the UWB antenna. In recent years, many varieties of UWB antennas have been proposed and investigated. They present a simple structure and UWB characteristics with nearly omni directional radiation patterns. Several factors need to be considered while designing the antenna, including bandwidth,

directivity, polarization, power gain, radiation pattern and return loss. For successful transmission and reception of an Ultra Wideband signals, an antenna should fulfill following requirement. The antenna

- covers an extremely wide band, (3.1 to 10.6GHz)
- has a high radiation efficiency
- has linear phase
- offers low dispersion
- has a VSWR < 2 for entire band
- has minimum power loss due to dielectric and Conductor losses
- has electrically small size
- holds a reasonable impedance match over the band for high efficiency
- has a non-dispersive characteristic in time and Frequency, to provide a narrow pulse duration to

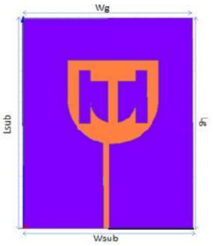
Enhance a high data rate
• has the reflected power < -10db
There are several types of microstrip antennas , the most common of which is the microstrip patch antenna antenna. A patch antenna is a narrowband, wide-beam antenna fabricated by etching the antenna element pattern in metal trace bonded to an insulating dielectric substrate with a continuous metal layer bonded to the opposite side of the substrate which forms a ground plane. Common microstrip antenna radiator shapes are square, rectangular, circular and elliptical, but any continuous shape is possible. Some patch antennas eschew a dielectric substrate and suspend a metal patch in air above a ground plane using dielectric spacers; the resulting structure is less robust but provides better bandwidth. Because such antennas have a very low profile, are mechanically rugged and can be conformable, they are often mounted on the exterior of aircraft and spacecraft, or are incorporated into mobile radio communications devices.
A new approach for design of the planar monopole UWB antenna was proposed in [uwb3] to achieve a good impedance matching and stable omnidirectional radiation pattern.Two compact antennas with circular ground and fractal ground were proposed in which drawbacks of conventional antennas were alleviated. Simulation and measured results show that in the proposed antennas, the radiation pattern has been improved noticeably.
A compact eye-shaped UWB is proposed in[uwbantenna] . A novel miniature technology for UWB antenna design is proposed by applying the eye-shape and the feeding part modification. The operating band (1.2-4.5 GHz) can reach as high as 142%. this antenna exhibited nearly constant group delay over a wide range of bands to reduce the distortion of the UWB pulse shapes.

III. THE PROPOSED ANTENNA DESIGN GEOMETRY

The three essential parameters for the design of a Microstrip Antenna are:
• Frequency of operation (*fo*): The resonant frequency of the antenna must be selected appropriately. The ultrawideband antenna uses frequency band of 3.1 to 10.6GHz. Hence the antenna designed must be able to operate in this frequency range. The resonant frequency selected for this design is 7.0 GHz.
• Dielectric constant of the substrate (*εr*): The dielectric material selected is Epoxy FR4 which has a dielectric constant of 4.4. A substrate with a high dielectric constant has been selected since it reduces the dimensions of the antenna.
• Height of dielectric substrate (*h*): For the microstrip patch antenna to be used in many application where size and weight matters, so it is essential that the antenna is not bulky. Hence, the height of the dielectric substrate is selected as 1.6 mm.

The antenna is designed from the basic rectangular microsrtip antenna and circular microstrip antenna. Some modification is done by using this two basic antennas to get the desired results. Step by step designing of the microstrip antennas is explained below.

The proposed microstrip antenna is illustrated in Figure 3.1. This antenna has a modified combination of rectangular and circular patch antenna fed by a microstrip line, with rectangular feedline and infinite ground.



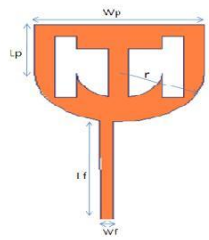


Figure 3.1 Antenna structure Figure 3.2 Top view

The most important design parameters that affect the performance of the modified patch antenna are the dimensions of the patch and the height of the branches. Thus those parameters must be investigated to reach the optimum design. Before reaching the optimum design, we passed through many steps of simulation. We started with the design and the thickness of the substrate (t) is 1.6 mm.
The patch printed on one side of the substrate and ground on the other side of substrate. It is etched on a rectangular (LxW) FR4 substrate with thickness t=1.6 mm and a relative dielectric constant ε_r=4.4 with dimensions 100 X 75 mm. The two slots are symmetrical in shape having same height and width of the two symmetrical identical branches. The width of the microstrip feed line is fixed at Wf = 3mm to achieve 50Ω impedance.

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The simulations are performed using the Ansoft HFSS 13 which utilizes the finite integration technique for electromagnetic computation.

IV. PARAMETRIC STUDY

4.1 Bandwidth

The main characteristic of UWB antenna is bandwidth. There are two ways to express bandwidth:

(1) The ratio of the upper frequency fH and lower frequency, fL. The UWB has approximately fH : fL=3:1. (2) The fractional bandwidth (fbw) of a system is the ratio of the bandwidth BW to the center frequency fc.

The bandwidth of the system is often described relatively to the center frequency, which is calculated in formula (2).

.... (1)

= ——...(2)

The Federal Communications Commission (FCC) issued are port and order to define a UWB systems in terms of -10dB power bandwidth meaning that upper and lower frequencies are those where the radiated spectral power density is -10dB down from the center frequency. According to FCC definition of UWB system, UWB antenna has bandwidth greater than 500MHz or a fractional bandwidth greater than 0.2 where fractional bandwidth is defined as in formula (1).

4.2. Impedance Matching

Impedance is the ratio of the electric and magnetic fields. Impedance is complex value since the electric and magnetic fields are not necessarily in phase. If an impedance of a transmission line (Z0) and the antenna impedance (ZA) are not identical then there will be a mismatch to the antenna terminals and some of the incident signal will be reflected back to the source. This reflection is characterized with reflection coefficient (Γ) which is ratio of the reflected voltage (−V0) to the transmitted voltage (+V0).

$$= \frac{-}{+} = \frac{- \ 0}{+ \ 0}$$

The other parameter frequently used to characterize Impedance matching is Voltage Standing Wave Ratio (VSWR). The VSWR is defined as the ratio of the peak Voltage maximum to peak voltage minimum.

$$= \frac{1 + |\ |}{1 - |\ |}$$

For the perfect matching VSWR = 1, there is no reflection and return loss. In the real UWB system it is very hard to achieve a perfect match over a wide frequency match so it is define that have VSWR < 2 is still good matching system.

4.3 Effect of change of ground size

Size and shape of the ground affect the antenna parameter according to it. Following some Fig shows the effect on parameter of the antenna when ground dimension is 100 * 75mm and when ground is 40 * 75mm.

4.3.1. Effect on s11 parameter

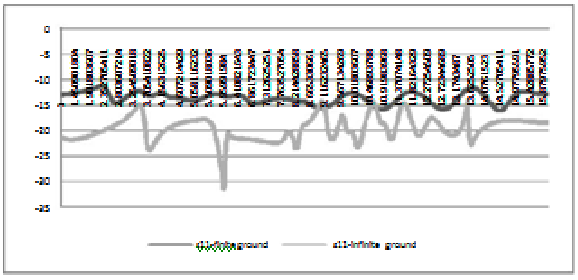

Figure 4.1 s11 for change in size of ground

4.3.2. Effect on VSWR parameter

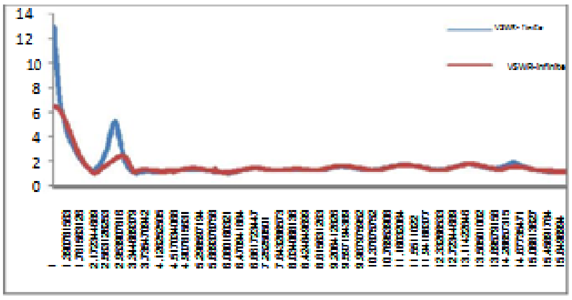

Figure 4.2 VSWR for change in size of ground

4.3.3. Effect on Radiation Pattern

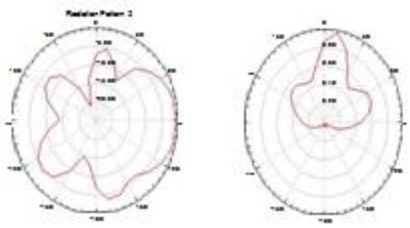

Figure 4.3.3.a. and Figure 4.3.3.b. VSWR for a) 40*75mm ground b) 100*75mm ground

V SIMULATED AND MEASURED RESULT

Figure 5.1 shows the simulated and measured return loss curves and figure 5.2 shows the simulated and measured VSWR curve at 7.5GHz.

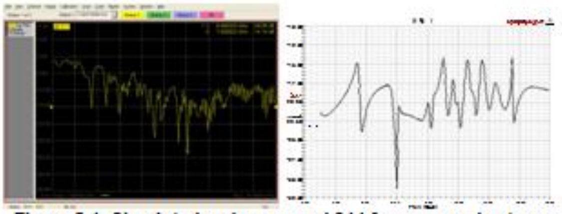

Figure 5.1. Simulated and measured S11 for proposed antenna

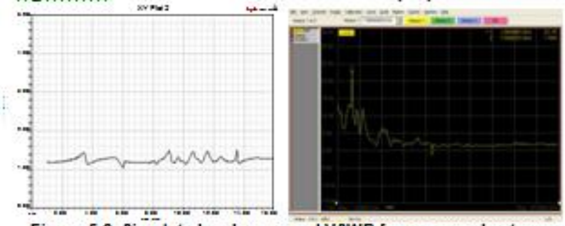

Figure 5.2. Simulated and measured VSWR for proposed antenna

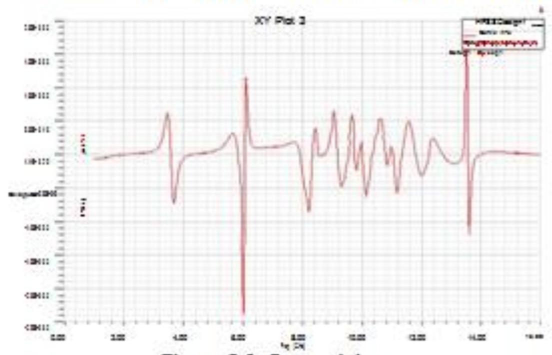

Figure 5.3. Group delay

The figure 5.3 shows the group delay for the proposed design at centre frequency 7.5 GHz, which comes less than 1ns for the UWB band. The figure 5.4 shows the simulated 3D polar plot for the proposed design showing more gain in z direction, and the figure 5.5 shows the simulated radiation pattern having directivity in 0 deg.

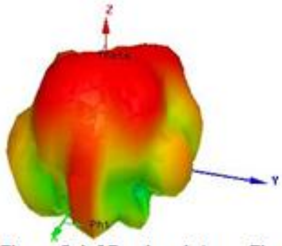

Figure 5.4. 3D polar plot

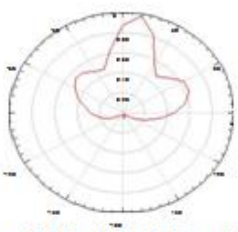

Figure 5.5 Radiation Pattern at 0 deg

These simulations were performed using the Ansoft High Frequency Structure Simulation (HFSS). Figure 5.1 shows the simulated return loss curve with the optimal design, i.e. The simulated return loss bandwidth is from 1.8 to 14.3 GHz for which s11 is less than -10 dB and SWR is also less than 2 in this range as shown in the simulated result in figure 5.2, which confirms to the UWB standards. Moreover a considerable increase in bandwidth is obtained relative to the design. This permits to use the antenna in more applications operating under UWB band.

VI. CONCLUSION

In this paper, an antenna is proposed having a wide bandwidth from 1.8 GHz to more than 16 GHz. The designed antenna has simple configurations and is easy to fabricate. It has been shown that the performance of this antenna in terms of its frequency domain characteristics is mostly dependent on dimensions and the height of substrate. It is demonstrated by simulation and measurement that the proposed antenna can yield an ultra wide bandwidth, and that the radiation patterns are slightly omni-directional over the entire -10 dB return loss bandwidth having VSWR less than 2 over that range of bandwidth.

This antenna can be used for many applications including 3G, Wi-Fi, WiMAX, as well as UWB applications due to its wide bandwidth and simple structure.

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