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Design And Optimization of Stepped U-Shaped Microstrip Patch Antenna For Uwb Applications

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Abstract: This is a presentation of a stepped U-Shaped microstrip patch antenna with microstrip-fed monopole for ultra wide band (UWB) application. The monopole is composed of an U-Shaped patch cut on a rectangular patch. The radiator patch is attached to a 50- microstrip feed line by a smoothly tapered line to enhance the wideband matching. A E-shaped slot is etched on a rectangular plane placed on the one side of the substrate. The antenna has compact physical structure and is designed on standard FR4 substrate with an operating frequency of 9.5Ghz. Simulation and optimization with Ansoft HFSS and CST Microwave Studio software indicate 145% fractional impedance bandwidth varying from 3.1 to 10.6 GHz for VSWR with -60dB and filtering 5-6GHz for eliminating the interference effect due to WiFi and Wimax. The antenna is successfully fabricated and characterized by measuring VSWR, radiation pattern, and gain. Comparison between simulated and practical results exhibits the near agreement in the operating band. Besides, it yields an average gain of several decibels with low tolerance and reasonable stable radiation characteristics. The effects of significant parameters on antenna performance and some other details are analyzed and discussed as well.

Index Terms: Planar monopole, radiator patch, slot and patch antenna tapered line, ultrawideband (UWB) antenna.

I. INTRODUCTION

There has a rapid development in ultrawideband (UWB) wireless communication technology, and hence UWB antennas, especially in the last decade. Thus, UWB antenna designing has become a hot topic to attract researchers' attention, both in academic and industrial points of view worldwide. The Federal Communications Commission (FCC) prescribed the frequency spectrum of 7.5 GHz (3.1–10.6 GHz) for commercial ultrawideband applications in 2002 [1]. Since then, UWB technology is expected to revolutionize prevalent communication systems. Meanwhile, low cost, low weight, small shape, low transmission power, and omni directional radiation pattern should also be considered, particularly in portable cases. Among various types of microstrip antennas, planar monopole does not require balanced feeding structure and can be implemented in a smaller area compared to equivalent planar dipole; hence it would be a competitive choice to be handled in UWB systems if we could overcome its inherent drawback of narrow bandwidth. Some researchers suggested common alternatives such as using a large ground plane and thick substrate to widen the bandwidth. Using planar wide slot would be another feasible and effective technique duo to its likely benefits such as wideband radiation performance, easy fabrication, and bidirectional radiation.

In addition, a larger near magnetic field component rather than an electric one in wide slots results in reducing coupling to adjacent slabs if not desired. The substrate used is FR4 lossy material with standard thickness of 1.575mm.The ground plane made up of Copper material with 0.035mm thickness. The rectangular and circular patch with 10 x 20mm and 10mm radius respectively is designed to produce U-shaped patch by using Boolean healing techniques. In this letter, we present a new wideband planar geometry for UWB antennas. First, smoothly tapered transition is employed to effectively obtain impedance matching over the band of interest. By choosing a proper wide size for the slot, we realized the optimal design with successful increment of 10 dB measured bandwidth up to 145% from 3.1 to 10.6 GHz. The substrate area is only 50 x 42.8 mm, which can be considered as a compact antenna with respect to most of the others. Although supporting the lower UWB range is commonly obtained with larger dimensions, the advantage of this structure is the ability of supporting both lower range and higher range functions, despite a small size. Furthermore, simulation and measurement show fairly constant radiation properties and low gain variation throughout the operating frequency range. This letter discusses results, parameter sweeps, and some details as well.

II. DESIGN PARAMETERS AND CONSIDERATIONS

The geometry of the proposed patch antenna, as depicted in Fig.1, consists of a patch mounted on the top layer of a famous FR4 lossy epoxy substrate with dielectric relative permittivity of 4.3 with thickness of 1.575 mm and a E-shaped slot etched from a square conducting ground plane on the side. The ground plane is located in the plane in 9.5 x 42.8 surface. The top-layer patch itself includes a main radiator patch, feed line, and wideband matching. The radiator patch acts as an open-circuit load at the end of the transmission line. The structure is fed by a centered 50-microstrip line by way of another narrow smoothly tapered matching line.

The various design parameters used in this design are length, dielectric constant (ε_r), resonant frequency fr,

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thickness h, input impedance etc..,and some of the considerations are Bandwidth, Directivity, Polarization, Antenna temperature, Gain, VSWR, Radiation efficiency.

- Input impedance can be optimum if the patch is centre-fed. A 50-Ω input impedance microstrip line is centre-fed to the patch inorder to improve the radiation in edge of the patch.
- Permittivity or dielectric constant (ε_r) of the substrate is the most important parameter used to design patch antenna. Low ε_r is preferred to produce better results. FR4 lossy material with 4.3 dielectric constant is used.
- Thickness (or) height of the substrate h, decides the bandwidth of the antenna. High thickness leads to wider bandwidth and low thickness leads to narrow bandwidth. Increase in thickness also leads to unwanted radiations. So a standard thickness of roger's substrate which is 1.575mm is used in this design.
- Fringing fields are responsible for radiation and it is determined by permittivity value. Lower the permittivity leads to higher fringing fields and better radiation.
- Higher permittivity is needed where there should be no radiation like in transmission line and it leads to tight coupling with less fringing fields and less radiation.
- It's a trade-off in patch design. So optimum values are considered.
- When the thickness h, is decreased, less energy is radiated and more energy is stored in patch capacitance and inductance.
- Some of the other considerations are Gain, VSWR, Radiation pattern, Polarization.\
- Circular polarization is achieved in this design and better VSWR with -16dB is produced.

III. EXISTING METHODOLOGY

This antenna designed in existing methodology is rectangular shaped microstrip patch antenna in which the FR4 lossy substrate material with dielectric constant ε_r =4.3, and standard thickness h=1.575mm of size 50 X 42.8mm is sandwiched in between ground plane made up of cavity backing material with good conductivity, on one side and a rectangular patch made up of copper material with 10 x 20mm size.

This antenna is fed with input impedance of 50-Ω and it is fed with microstrip line feed on the edge centre of the patch which is also called as centre-fed line feed. The design values are given in table 1.

TABLE I
DESIGN PARAMETERS

COMPONENTS	Values in (mm)			
	Length	*Width*	*Thickness*	*Material*
Substrate	18	16	1.575	FR4 lossy
Ground plane	4	16	0.1	Copper
Patch	11	7	0.035	Copper
Feed line(centre-fed)	3	2	-	Copper

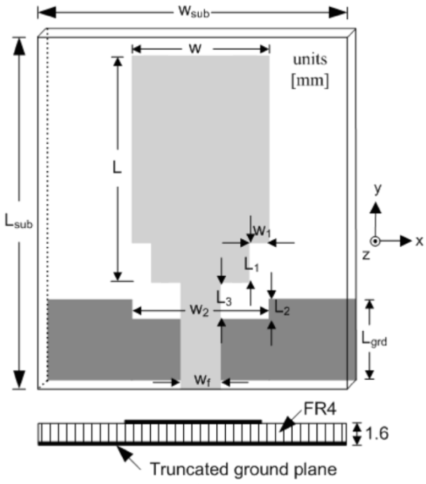

Fig 1.Microstrip-fed monopole antenna

In this existing methodology, the bandwidth obtained is narrow and gain is better. The gain about 6dB is enough for mobile communication but for medical application like EMI scanning, tumour detection need wide bandwidth and accurate results. So this method doesn't support for medical applications since it has narrow bandwidth and also it has a negative effect on cancer or bran tumour detection. While detecting, it detects as well as increases the tumour cells. Its radiation in terms of magnet field also causes a feeling of nausea or a slight uncomfortableness. Research has been going on to reduce this effect. So slots have been cut inorder to filter the unwanted harmonics thus reducing the side effects.

IV. PROPOSED METHODOLOGY

The existing methodology produces narrow bandwidth with better gain. But antennas in medical applications need wide bandwidth so that accuracy can be improved. So a E-shaped design is made by cutting two slots are cut in the rectangular patch. As far the microstrip antenna is concerned, the slots act as filter itself. This will filter out the unwanted harmonics and widen the bandwidth in the region around resonant frequency and thus improving gain and polarization too.

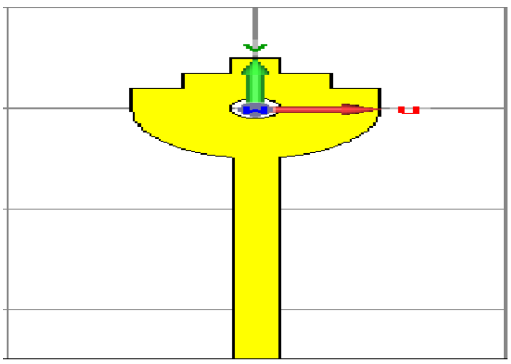
Fig 2. Modified U-patch antenna with steps

This antenna is further modified to design a band-notch filter inorder to eliminate 5-6GHz which performs communication for WiFi and Wimax respectively. This wil improve the UWB performance and results in optimum usage of spectrum. The modified design is given below.

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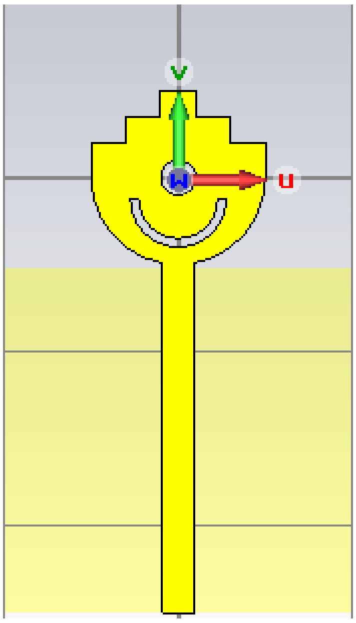

Fig 3. Modified U-patch antenna with filter design

The design parameters and values are shown in table given below.

TABLE 2
DESIGN PARAMETERS

COMPONENTS	Values in (mm)			
	Length	*Width*	*Thickness*	*Material*
Substrate	50	42.8	1.575	FR4 lossy
Ground plane	9.5	42.8	0.035	Copper
Patch	11	7	0.035	Copper
Feed line(Inset feed)	3	3.2	-	Copper

V. IMPLEMENTATION

The design is designed using various equations related to electromagnetic waves. The frequency is considered as soul parameter to design a microstrip patch antenna. The various equations are given as follows.

Resonancefrequency

$$f_r=2\pi f_0=\frac{1}{\sqrt{LC}} \quad (1)$$

where L and C are inductance and capacitance respectively.

Width of the patch, $W=\frac{1}{2f_r\sqrt{(\mu_0\varepsilon_0)}}\sqrt{\frac{2}{\varepsilon_r+1}}$ (2)

where μ_0 and ε_0 and $\varepsilon_r$are freespace permeability and permittivity and relative permittivity respectively.

Effective length of the patch,

$$Le=L+2\Delta L \quad (3)$$

where ΔL is the edge extension or fringing length

$$\Delta L = 0.412h\frac{(\varepsilon_{reff}+0.3)\left(\frac{W}{h}+0.2645\right)}{(\varepsilon_{reff}-0.258)\left(\frac{W}{h}+0.8\right)} \quad (4)$$

where h is the thickness and ε_{reff} is effective dielectric constant

$$\varepsilon_{reff}=\frac{\varepsilon_r+1}{2}+\frac{\varepsilon_r-1}{2}\left(1+\frac{12h}{W}\right)^{-0.5} \quad (5)$$

Effective length, L_e

$$=\frac{1}{2f_r\sqrt{\varepsilon_{reff}}\sqrt{\mu_0\varepsilon_0}} \quad (6)$$

The design is implemented using a tool called CST Microwave studio. Computational electromagnetics, computational electrodynamics or electromagnetic modeling is the process of modeling the interaction of electromagnetic fields with physical objects and the environment. It typically involves using computationally efficient approximations to Maxwell's equations and is used to calculate performance of antenna, electromagnetic compatibility, radar cross section and electromagnetic wave propagation when not in free space.

Finite Difference Time Domain(FDTD) is the method used to implement full wave solver. It is better than FEM and MOM solver. It is time-domain and so it can cover wide range of frequency with single simulation run. It provides time-steps which is enough to satisfy Nyquist criterion for desired higher frequency.

VI. RESULT AND CONCLUSION

The antenna is mainly designed to perform biomedical applications. The bandwidth required to perform those applications range from 300MHz to 1 GHz. The output of existing terminology achieves around -10dB in most of the areas as shown in figure.

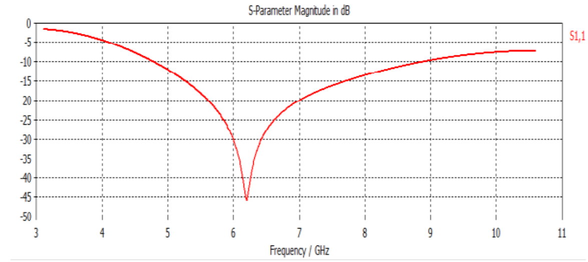

Fig. 4. Output of basic UWB application based antenna

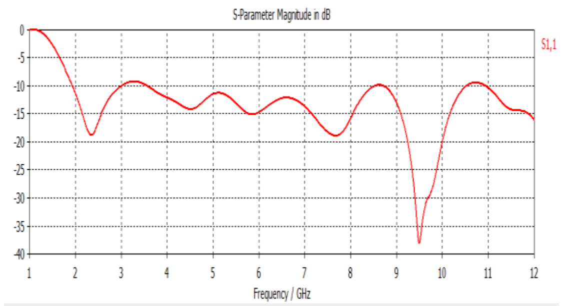

Fig. 4. Output of existing method

The proposed antenna achieves multiple resonant frequency and better bandwidth and less interference when compared to existing terminology. The output of the proposed method is given in figure 3.

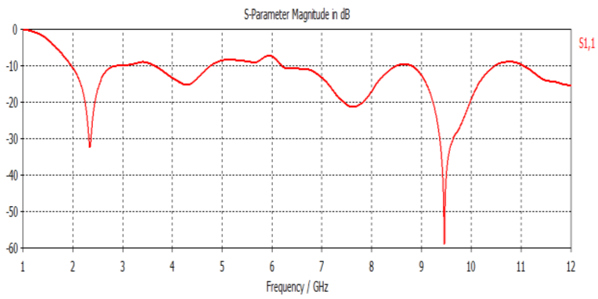

Fig 5. Output of proposed methodology

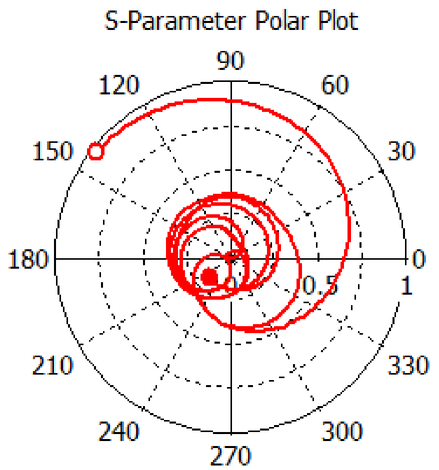

Fig 7. S-polar plot of proposed design

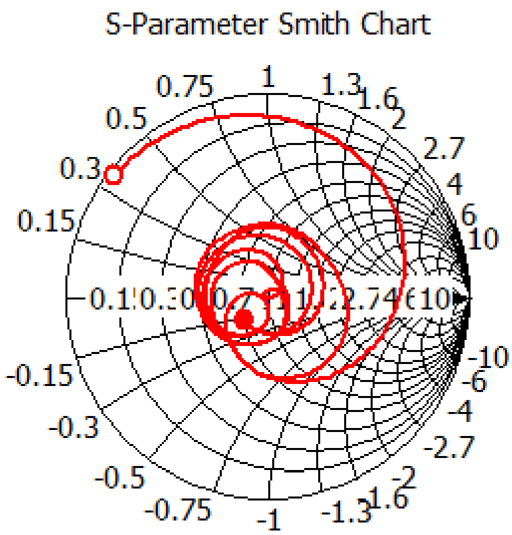

Fig 8. Smith chart of proposed antenna

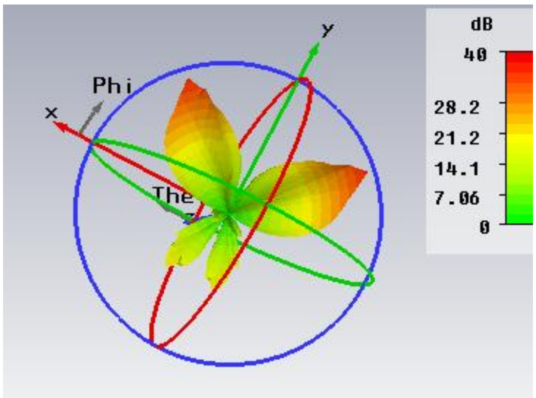

Fig 9. Directivity of proposed design

Bandwidth of more than 5GHz with better response is obtained and -58dB is achieved in one of the resonant frequency. Thus it is reliable for biomedical and other UWB applications.

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