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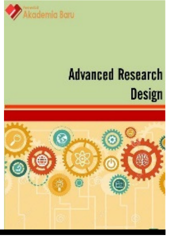

Slotted Flexible UWB Antenna

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ABSTRACT

In this manuscript, a slotted flexible UWB antenna is proposed and presents the simulation results at the free space. The proposed antenna operates from 2.45 GHz to 10.75 GHz providing an impedance bandwidth of 8.3 GHz. The antenna is designed on a flexible textile (jeans) substrate with relative permittivity (ε_r) of 1.75 and loss tangent of 0.078 and a thickness of 1 mm. the overall dimension of the patch is 35*30 mm2 and that of a truncated partial ground is 31*5.8 mm2. The proposed antenna provides VSWR < 2 for the entire impedance bandwidth.

1. Introduction

The recent development in technology and the applaudable success of the commercial wireless personal communications (WPC) do leave its remarkable influence on our day to day lives as the conversion from analog to digital cellular communications and the emerging of the fourth and fifth generation of the radio systems and the removal of the wired communication with Bluetooth and Wi-Fi enabled the users to access the information anytime and anywhere. As with the passage of time the RF spectrum is getting crowded and insufficient for the user to have higher data rate, bandwidth and channel capacity within (WPC) so to cope for the problem FCC in 2002 allocated an unlicensed band from (3.1-10.6) GHz called Ultra Wide Band (UWB) [13] on the grounds that it will not interfere or will have a very minute interference with the existing radio channels. The FCC and ITU-R defines Ultra Wide Band systems as an antenna transmission for which the radiated EM-Wave exceeds the bandwidth of 500 MHz or 20% of the central frequency or whichever is greater. As with the passage of time, new trends in the antenna technology were introduced for the UWB as of today aim for the antennas on the flexible substrate is getting diverse day by day whereas the most basic types of antenna for UWB as mentioned in [1] are

- Variation of dipole/monopole antennas
- Antennas with absorptive loading or with curved geometries
- Frequency independent antennas

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In this manuscript, a slotted dipole antenna is designed on a textile substrate for UWB applications as shown in figure (1) the utilization of the textile as a substrate reduced the gap of the body-worn antennas in WPC systems sometimes referred as "Smart Clothes" which opens up new possibilities [9]. The textile materials offer a new set of properties for the antennas designers as it offers low dielectric constants which reduces the surface wave losses and enhances the bandwidth [9].

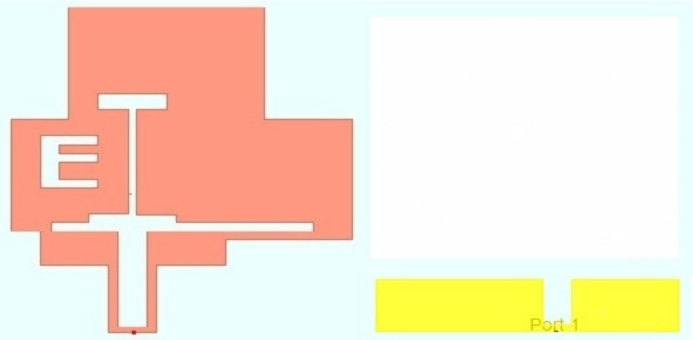


Fig. 1. Proposed flexible antenna design front and back view

This manuscript is organized in the following manner. In Section 2.0, Design of antenna is presented. Section 3.0, presents results discussion and comparison table. Section 4.0, finally concludes the paper.

2. Design of an Antenna

The proposed dipole antenna has been designed for UWB applications. Therefore the material and geometry of the antenna have been considered and following is the summary of the details of the proposed dipole antenna.

2.1 Material and Geometry

The antenna consists of a flexible textile substrate (jeans) in order to confirm the properties of the substrate an experimental study has been conducted in Ashwal *et al.,* [2] to measure the relative permittivity and loss tangent of the substrate. From the figures (2) and (3) relative permittivity (ε_r) and loss tangent averaged to be 1.76 and 0.078 respectively over the UWB spectrum. Whereas height of substrate (h) was set to be 1 mm and conducting material of the antenna is an Adhesive copper tape with the thickness of 0.035 mm.

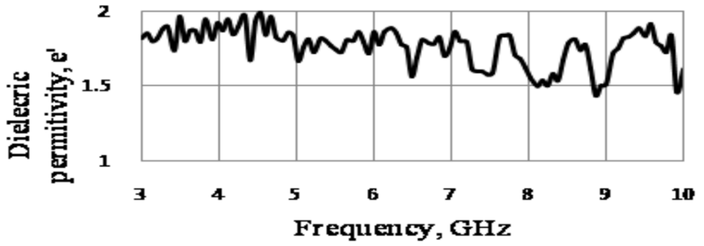


Fig. 2. Jeans dielectric constant with respect to UWB frequency range

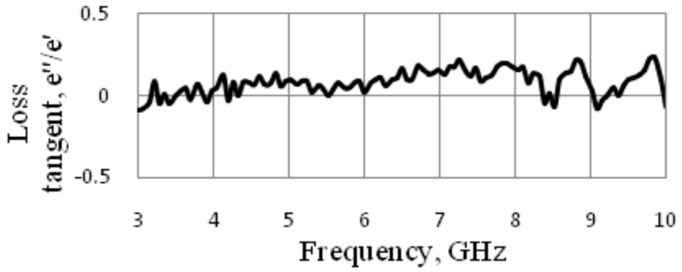


Fig. 3. Jeans loss tangent with respect to UWB frequency range

The initial dimensions of the antenna were calculated with the help transmission line model equations (1) (2) from Balanis [3]. For an initial rectangular patch antenna, the central frequency of the UWB spectrum was taken as the resonate frequency (f_r) for the calculation.

$$W = \frac{v_0}{2f_r}\sqrt{\frac{2}{\epsilon_r+1}} \tag{1}$$

$$L = \frac{1}{2f_r\sqrt{\epsilon_{reff}\sqrt{\mu_0\varepsilon_0}}} \tag{2}$$

where in equation (1) (ϵ_r) is the relative permittivity of the substrate and v_0 is the speed of light in free space which is equal to ($3*10^8$ ms^{-1}). Similarly in equation (2) (ϵ_{reff}) is the equivalent relative permittivity moreover changes that occurred due to the fringing effect were ignored as the ratio (L_p/h) and (W_p/h) are both greater than 1 as mentioned in Balanis [3], where (μ_0) is free space permeability constant and (ε_0) is free space permittivity constant. The overall geometry adjustment of the antenna after the initial design was required to enhance the bandwidth as to achieve UWB frequency spectrum. Slots, truncation of the corners as in Choi et al., Hayouni *et al.*, Gunavathi *et al.*, Hao *et al.* and Ghannoum *et al.,* [4-6,9,14] adjustments of the overall dimensions were done in the patch to achieve the desired UWB impedance bandwidth. For keeping the size of the antenna to minimum on a flexible textile (jeans) substrate the T- shaped slot in the middle of the patch [7] which extend towards the middle of feed transmission line[10] and the truncated partial ground used in the proposed antenna design which helps improve the impedance bandwidth as in Hayouni *et al.*,[5] Rahayu *et al.*, [7] and Rafiqul *et al.*, [11] because the modified truncated ground plane acts as an impedance matching as the truncating creates the effect of capacitive loading which neutralizes the inductive effect of the patch [7]. The finalized designed for the proposed antenna with dimensions is illustrated in the figure (4). The overall dimension of the patch is (L_p* W_p) (35*30) mm whereas ground dimension is reduced to (L_g*W_g) (31*5.8) mm and have a slot of (L_{gs}* W_{gs}) (4.8*3) mm along below the feed transmission line. Feed transmission line is U-Shaped because of T-shaped slot in the middle of the patch which extends through the transmission line total dimension of the feed (L_f * W_f) (7.8*5) mm with the resultant slot of (L_{ts}*W_{ts}) (6.8*3) mm which left the legs of U-shaped feed transmission line with width of 1 mm of conducting material.

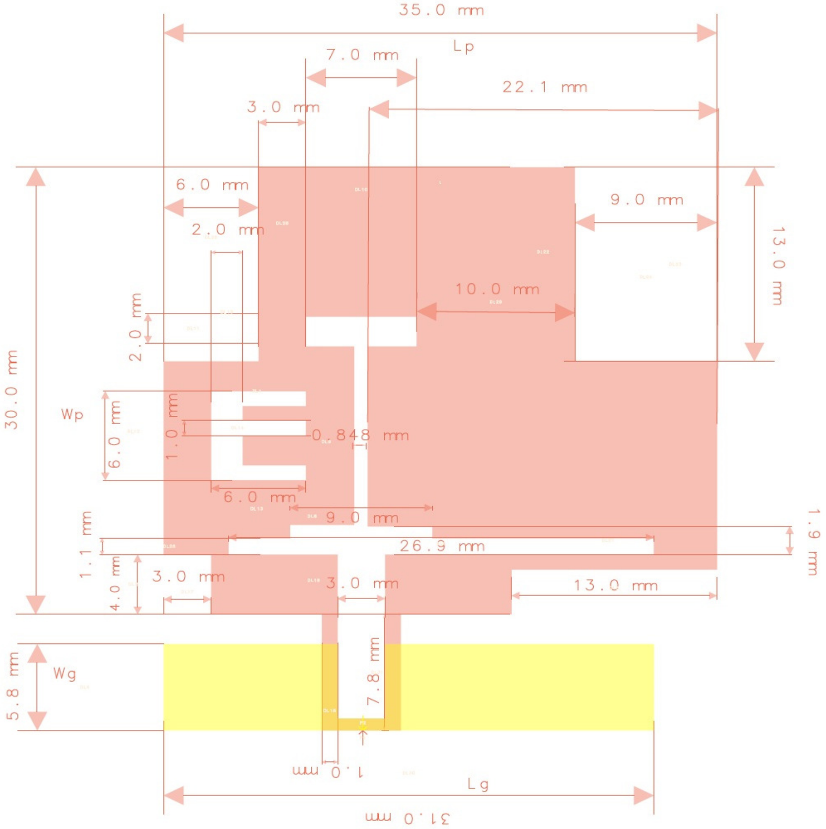


Fig. 4. Dimensions of the proposed flexible antenna design

3. Results and Discussions

The simulation of the proposed dipole antenna is done in ADS 2011.10. The performance variables like return loss (S(1,1)), VSWR, gain, directivity, efficiency, and radiation pattern are carried out over the frequency range of (2.45 – 10.75) GHz. Figure (5) illustrates the plot of the simulated S11 parameter of the antenna which shows that the antenna provides -10 dB bandwidth of 8.3 GHz which ranges from (2.45-10.75) GHz which covers the entire band of UWB spectrum and provides 125.75% fractional bandwidth.

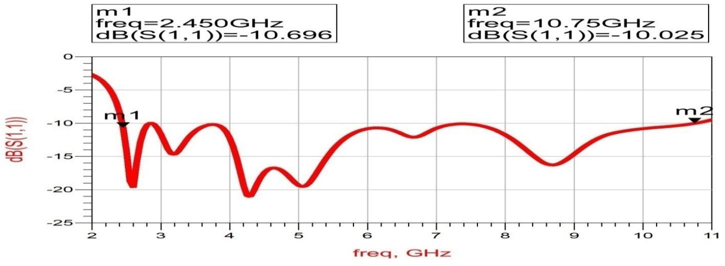


Fig.5. Simulated S(1,1) of the proposed design

From [1], fractional bandwidth can be calculated as.

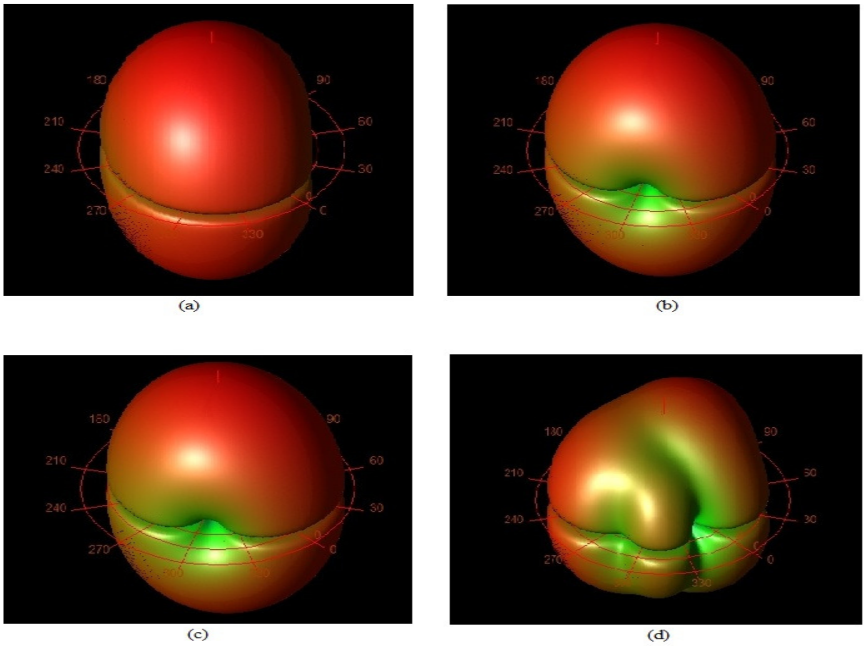
$$Fractionl\_Bandwidth = \frac{F_{high}-F_{low}}{F_{center}} \tag{3}$$

$$F_{center} = \frac{F_{high}+F_{low}}{2} \tag{4}$$

where in equation (3) and (4) (F_{high}) is the higher, (F_{low}) is the lower and (F_{center}) is the center frequency of the impedance bandwidth. Whereas figure (6) illustrate the simulated magnitude of VSWR of the proposed antenna which is < 2 for the entire impedance bandwidth.

Fig. 6. Simulated VSWR of the proposed design

The far-field radiation pattern is computed in 3D mode. The 3D plots in figure (7) indicates the gain and directivity of an antenna varies over the frequency band whereas the efficiency varies inversely to the frequency. Table 1 lists gain, directivity and efficiency of the antenna at few sample points.



(a)
(b)
(c)
(d)

Fig. 7. 3D radiation pattern simulated results of the proposed flexible antenna at (a) 2.6 GHz (b) 3.2 GHz (c) 3.4 GHz (d) 5.8 GHz

Table 1
Gain, directivity, and efficiency simulated results of the proposed flexible antenna

Frequency (GHz)	Gain (dBi)	Directivity (dBi)	Efficiency
2.6	2.62193	2.61859	100.077
3.2	3.29552	3.29138	100.095
3.4	3.59852	3.61603	99.598
5.8	4.01576	5.00476	79.634

3.1 Comparison Table

Table 2 shows the comparison of the antenna parameters of the different research papers.

Table 2
Comparison of different research papers with the proposed antenna design

Antenna Parameter	[2]	[15]	[12]	Proposed
Impedance Bandwidth	7.26 GHz	7.7 GHz	7.7 GHz	8.3 GHz
Operational Frequency Range	(3.04 to 10.3) GHz	300 MHz to 8 GHz	(3.7 to 11.6) GHz	(2.45 to 10.75) GHz
Gain (dBi)	2.74, 3.66, 4.17	Ranges from 1-10	Maximum 2.36	3.29,3.61,4.01
Overall Patch Dimension	25 × 21.6 mm^2	175*105 mm^2	17*22.6 mm^2	35*30 mm^2
Ground Dimension	13.8 × 46 mm^2	160*270 mm^2	17.8*43 mm^2	31*5.8 mm^2
Substrate	Jeans	Jeans	Jeans	Jeans

4. Conclusion

This manuscript present dipole antenna on a textile (jeans) substrate which provides an impedance bandwidth of 8.3 GHz and has a reduced ground and shows very approximated ideal dipole radiation patterns at the lower frequencies.

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