Design and Performance Analysis of Compact Corner Notched Printed Rectangular Monopole Antenna (PRMA) for Ultra-Wideband (UWB) Communications

Mohammad Tareq*  
Asst. Professor, Dept. of EETE, Dhaka International University, Bangladesh  

Zeenat Afroze  
Asst. Professor, Dept. of EEE, American International University, Bangladesh  

Sajjad Ur Rahman  
Dept. of EEE, American International University, Bangladesh  

Abstract— In this paper a compact corner notched Rectangular Monopole Patch Antenna (RMPA) has been proposed for Ultra-Wideband communications. Based on a reference RMPA, multiple antennas have been designed and performance parameters have been analysed. As performance parameters return losses, impedance bandwidth, Voltage Standing Wave Ratio (VSWR), gain, radiation pattern and efficiencies have been studied. Comparisons of antennas have been tabulated and most suitable antenna has been proposed for UWB communications. All of the simulations have been carried out by Computer Simulation Technology Microwave Studio (CST-MWS) v. 2013.

Keywords — RMPA, UWB, return loss, VSWR, CST-MWS

I. INTRODUCTION

Wireless technology is one of the major achievements of the 20th century. From the early times scientists were trying to develop this technology. Invention of cellular technology brought wonderful advancement in the life of peoples. Advance Mobile Phone System (AMPS) to Global System for Mobile Communications (GSM) changed the way of communication in 1970’s to 1990’s. Later other systems like Code Division Multiple Access (CDMA), Wireless-Fidelity (Wi-Fi), Bluetooth, Worldwide Interoperability for Microwave Access (WiMAX) have been introduced [1]. For utilizing these protocols antenna plays a critical role. Printed antennas became most demanding for achieving requirements of these wireless protocols. Several printed antennas such as patch antenna, printed monopole antenna, printed dipole antenna, Planar Inverted-F Antenna (PIFA) were introduced by the researchers [2-3]. All of the protocols discussed above have narrow bandwidth. In recent past for communicating within short ranges with higher bandwidth, Ultra-Wideband (UWB) technology has been defined by FCC in 2002 as 3.1 GHz to 10.6 GHz [4-7]. On the other frequency regions it has to cover 1.5 GHz for being called as UWB technology [8]. In the UWB system, bandwidth has to be 25% of the resonance frequencies. As an example for a system which resonates at 5 GHz would have impedance bandwidth of 1.5 GHz.

Main objective of this paper is to design a compact PRMA which would have impedance bandwidth on entire ultra-wideband (3.1 GHz to 10.6 GHz) spectrum. Not only this but also return losses, radiation pattern, VSWR, efficiencies and gain needed to be fulfilled UWB antenna requirements. Antenna design and simulations have been executed by CST MWS v. 2013. In this paper antenna design and specifications have been given in the section II. Simulations and discussions have been given in the section III. At the section IV conclusion of the paper has been drawn by proposing well suited antenna from the analysis.

II. ANTENNA DESIGN

In this [9] journal paper several microstrip-fed rectangular monopole antenna have been designed and analysed for wideband applications. Based on these another microstrip-fed rectangular monopole antenna has been designed by imposing slot on the centre of the patch. All four antennas have been excited with the waveguide port. Dimensions of the centre slot have been modified after carried out multiple parametric sweeps.

Antenna types have been given in the Table I.

<table>
<thead>
<tr>
<th>Antenna Name</th>
<th>Notches</th>
<th>Slots</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reference Antenna</td>
<td>2 (lower corner on the patch)</td>
<td>None</td>
</tr>
<tr>
<td>First Proposed Antenna</td>
<td>4 (2 upper and 2 lower)</td>
<td>None</td>
</tr>
<tr>
<td>Second Proposed Antenna</td>
<td>6 (2 Upper, 2 middle and 2 lower)</td>
<td>None</td>
</tr>
<tr>
<td>Third Proposed Antenna</td>
<td>6 (2 Upper, 2 middle and 2 lower)</td>
<td>1 (Center)</td>
</tr>
</tbody>
</table>
Fig. 1: Front view of (a) Reference antenna, (b) First Proposed Antenna (two extra notches), (c) Second Proposed Antenna (four notches) and (d) Third Proposed Antenna (center slot)

Fig. 1(a) represents the front view of the reference antenna used in [9]. Fig. 1(b) shows the front view of the First proposed antenna which has been designed by cutting two upper corner notches. Fig. 1(c) shows the Second Proposed Antenna with two extra notches on the patch. Fig. 1(d) shows the centre slotted antenna which named as Third Proposed Antenna. As substrate material FR-4 has been selected which has relative permittivity (\(\varepsilon_r\)) of 4.3 where patch on the substrate has been designed using Perfect Electrical Conductor (PEC). Ground also been designed by using PEC. All design specifications of antennas have been given in the Table II. Width of the centre notch has been selected as 1 mm at the beginning but it has been modified after some parametric sweeps.

### Table III: Antenna Design Specifications

<table>
<thead>
<tr>
<th>(\varepsilon_r)</th>
<th>Substrate Material</th>
<th>Patch Material</th>
<th>Substrate Width</th>
<th>Substrate Length</th>
<th>Substrate Height</th>
<th>Patch Width</th>
<th>Patch Length</th>
<th>Patch Height</th>
<th>Feedline Width</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.3</td>
<td>FR-4</td>
<td>PEC</td>
<td>16 mm</td>
<td>18 mm</td>
<td>1.6 mm</td>
<td>7 mm</td>
<td>11 mm</td>
<td>0.035 mm</td>
<td>2 mm</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Patch Notch Width</th>
<th>Patch Notch Length</th>
<th>Centre Notch Width</th>
<th>Centre Notch Length</th>
<th>Ground Notch Width</th>
<th>Ground Notch Length</th>
<th>Ground Width</th>
<th>Ground Length</th>
<th>Ground Thickness</th>
<th>Feedline Length</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 mm</td>
<td>2 mm</td>
<td>1.5 mm</td>
<td>2.5 mm</td>
<td>7 mm</td>
<td>1 mm</td>
<td>16 mm</td>
<td>4 mm</td>
<td>0.035 mm</td>
<td>6 mm</td>
</tr>
</tbody>
</table>

Reference antenna has two notches on the lower corner of the patch. Two more identical notches have been imposed on the patch in the First proposed antenna. Second proposed antenna has two more notches and Third proposed antenna contains a slot with the notches around the patch. Ground plane have a notch which has 7 mm width and 1 mm length. Microstrip-feed line is 6 mm long and width is 2 mm. All four antennas have been designed based on the design specifications given in the Table I.

### III. Simulations & Results

All of the simulations have been executed after designing the antennas by taking dimensions discussed in the Table I. At first the Reference antenna, then First proposed antenna, after that Second proposed antenna and finally Third proposed antenna has been designed and simulations have been carried out on CST MWS v. 2013.

(a) ![Reference Antenna](image)

(b) ![Reference Antenna Simulation](image)

(c) ![Second Proposed Antenna](image)

(d) ![Second Proposed Antenna Simulation](image)
Fig. 2(a) shows the return loss plot of the reference antenna. Reference antenna resonates at two frequencies near at 3.5 GHz and 9 GHz respectively. Total impedance bandwidths have been seen on -10 dB return losses are 1.75 GHz and 5.53 GHz. Both of the impedance bandwidth indicates wideband characteristics. Fig. 2(b) shows the VSWR plot of the reference antenna. Magnitudes of VSWR have been seen fewer than 2 on entire ultra-wideband spectrum. Fig. 2(c) shows the radiation pattern on the E-plane and Fig. 2(d) shows the radiation pattern on the H-plane. At lower frequencies both of them obtained nearly omnidirectional pattern. At higher frequencies radiation pattern becomes directional. Fig. 2(e) shows the gain plot of the reference antenna. Gain curve does not shows massive variations on entire UWB spectrum. Maximum gain has been seen around 10 GHz. Fig. 2(f) shows the efficiency plot of the reference antenna. Maximum radiation and total efficiencies have been seen near at 9.5 GHz.

Fig. 3(a) shows the return loss plot of the First Proposed antenna. First Proposed antenna resonates at two frequencies near at 3.7 GHz and 9 GHz respectively. Impedance bandwidth has been seen on -10 dB return losses as 8 GHz. Fig. 3(b) shows the VSWR plot of the reference antenna which lies below 2 on entire UWB spectrum. Fig. 3(c) shows the radiation pattern on the E-plane and Fig. 3(d) shows the radiation pattern on the H-plane. Fig. 3(e) shows the gain plot of the reference antenna. Gain curve does not shows massive variations on entire UWB spectrum. Maximum gain has been seen around 10 GHz. Fig. 3(f) shows the efficiency plot of the reference antenna. Maximum radiation and total efficiencies have been seen near at 9.5 GHz.
radiation pattern on the E-plane and Fig. 3(d) shows the radiation pattern on the H-plane. At lower frequencies both of them obtained nearly omnidirectional pattern. At higher frequencies radiation pattern becomes directional on the E-plane and on the H-plane radiation pattern follows nearly donut shape. Fig. 3(e) shows the gain plot of the First Proposed antenna. Gain curve does not shows massive variations on entire UWB spectrum. Maximum gain has been seen around 10.5 GHz. Fig. 3(f) shows the efficiency plot of the reference antenna. Maximum radiation and total efficiencies have been seen near at 9.5 GHz.

Fig. 4 (a) Return loss plots, (b) VSWR plots, (c) radiation pattern plots on E-plane and (d) radiation pattern plots on H-plane, (e) gain plot and (f) efficiency plot of the second proposed antenna

Fig. 4(a) shows the return loss plot of the Second Proposed Antenna. Second Proposed Antenna resonates at two frequencies 3.73 GHz and 8.8 GHz. At resonate frequencies impedance bandwidths have been seen on -10 dB return losses are 1.78 GHz and 4.73 GHz. Both of the impedance bandwidth indicates wideband characteristics. Fig. 4(b) shows the VSWR plot of the reference antenna. Magnitudes of VSWR have been seen fewer than 2 on entire ultra-wideband spectrum. Fig. 4(c) shows the radiation pattern on the E-plane and Fig. 4(d) shows the radiation pattern on the H-plane. At lower frequencies both of them obtained nearly omnidirectional pattern. At higher frequencies radiation pattern becomes more directional on E-plane and on the H-plane it becomes donut like shape. Fig. 4(e) shows the gain plot of the reference antenna. Gain curve does not shows massive variations on entire UWB spectrum. Maximum gain has been seen around 9.5 GHz. Fig. 4(f) shows the efficiency plot of the reference antenna. Maximum radiation and total efficiencies have been seen near at 9 GHz.
Fig. 5(a) shows the return loss plot of the Second Proposed Antenna. Second Proposed Antenna resonates at two frequencies 3.73 GHz and 8.83 GHz. At resonate frequencies impedance bandwidths have been seen on -10 dB return losses are 1.64 GHz and 4.73 GHz. Both of the impedance bandwidth indicates wideband characteristics. Fig. 5(b) shows the VSWR plot of the reference antenna. Magnitudes of VSWR have been seen fewer than 2 on entire ultra-wideband spectrum. Fig. 5(c) shows the radiation pattern on the E-plane and Fig. 5(d) shows the radiation pattern on the H-plane. At lower frequencies both of them obtained nearly omnidirectional pattern. At higher frequencies radiation pattern becomes more directional on E-plane and on the H-plane it follows donut like shape. Fig. 5(e) shows the gain plot of the reference antenna. Gain curve does not shows massive variations on entire UWB spectrum. Maximum gain has been seen around 9.5 GHz. Fig. 5(f) shows the efficiency plot of the reference antenna. Maximum radiation and total efficiencies have been seen near at 9 GHz. Results of all performance parameters have been given in the Table II.

<table>
<thead>
<tr>
<th>Antenna</th>
<th>Resonate Frequency</th>
<th>Return Losses at Resonate Frequency</th>
<th>Bandwidth (≤-10 dB)</th>
<th>VSWR Range (≤ 2)</th>
<th>Radiation Efficiency</th>
<th>Total Efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reference Antenna</td>
<td>3.68 GHz, 9.04 GHz</td>
<td>-16.55 dB, -21.03 dB</td>
<td>1.75 GHz, 5.53 GHz</td>
<td>3.1701 GHz to 11.266 GHz</td>
<td>85.3%</td>
<td>84.6%</td>
</tr>
<tr>
<td>First Proposed Antenna</td>
<td>3.76 GHz, 9.22 GHz</td>
<td>-17.39 dB, -24.37 dB</td>
<td>8.0952 GHz</td>
<td>3.1966 GHz to 11.483 GHz</td>
<td>84.47%</td>
<td>84.07%</td>
</tr>
<tr>
<td>Second Proposed Antenna</td>
<td>3.73 GHz, 8.8 GHz</td>
<td>-16.85 dB, -16.08 dB</td>
<td>1.787 GHz, 4.7295 GHz</td>
<td>3.212 GHz to 10.569 GHz</td>
<td>85.734%</td>
<td>82.626%</td>
</tr>
<tr>
<td>Third Proposed Antenna</td>
<td>3.73 GHz, 8.83 GHz</td>
<td>-17.27 dB, -15.45 dB</td>
<td>1.6441 GHz, 4.6276 GHz</td>
<td>3.1928 GHz to 10.567 GHz</td>
<td>85.836%</td>
<td>82.234%</td>
</tr>
</tbody>
</table>

From the Table II it has been seen that only first proposed antenna covered entire UWB spectrum under -10 dB return losses. Other antennas also have shown the UWB characteristics but their impedance bandwidth have been found in discontinuity on the -10 dB return losses. Reference antenna, Second proposed antenna and Third proposed antenna have dual band characteristics. All of the antennas have shown two resonant frequencies and magnitudes of return losses at resonant frequencies have been seen almost identical except First Proposed Antenna. Radiation efficiencies have been
seen more than 80% for all of the antennas. Total efficiency has been found comparatively better for first proposed antenna. By considering all parameters, giving impedance bandwidth most priority first proposed antenna can be consider for UWB communications.

IV. CONCLUSIONS

Multiple corner notched antenna has been designed and analyzed in this paper. Performance parameters such as return losses, Voltage Standing Wave Ratio (VSWR), radiation pattern, gain and efficiencies have been analyzed. By comparing all results First Proposed Antenna has been found most acceptable among all antennas. First Proposed Antenna covered almost entire ultra-wideband spectrum (3.1 GHz to 10.6 GHz) which satisfies the requirement of this paper. Radiation pattern follows nearly omnidirectional shape on the azimuthal plane and VSWR has been seen fewer than 2 for First Proposed Antenna on entire UWB spectrum. In terms of impedance bandwidth and VSWR, First Proposed Antenna has been proposed for UWB communications.

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