A Highly Miniaturised Ultra-Wideband Antenna with a Triple-Band Notch for Wearable Applications

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DR. SHAHARIL BIN MOHD SHAH
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   i. Fundamental UWB Antenna Design and Configuration
   ii. Design and Configuration of UWB Antenna with Notch Bands
   iii. Antenna Simulation in Bending Condition

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   Reflection coefficient, Surface current distribution, Radiation pattern, gain and efficiency, bending investigation, Specific Absorption Rate

4. Conclusion
Requirement of miniaturized wearable UWB device for Wireless Body Area Network (WBAN)

UWB frequency range: 3.1 GHz – 10.6 GHz

Highly compact antenna: 19 × 14 mm²

Support multiple applications

Useful for wearable applications (antenna is to be worn on body)

In this work, UWB antenna is proposed for wearable applications.

Notch bands for WiMAX, WLAN and C-bands are introduced to alleviate electromagnetic interference.

For UWB antenna to work in wearable and indoor applications (IEEE 802.11a), it should avoid:

i. WLAN (5.15 GHz to 5.35 GHz)

ii. C-band (3.2 GHz to 3.6 GHz)

iii. WiMAX (3.7 GHz to 4.2 GHz)

These three bands cause interference with their neighboring channels.

Specific Absorption Rate (SAR) is a significant on-body measurement for wearable antennas

SAR limit:

1.6 W/kg averaged for 1 g tissue (FCC)

2.0 W/kg averaged for 10 g tissue (ICNIRP)

Previous work can only reject one band:

Parasitic strips, T-shaped stubs in elliptical slot, SRR in feeline, C-shaped parasitic structure

Multiple notch structures are needed to notch multiple bands
# Summary of Previous Work

<table>
<thead>
<tr>
<th>Reference</th>
<th>Size of antenna (mm)</th>
<th>Impedance bandwidth</th>
<th>Notch bands</th>
<th>Frequency of notch bands</th>
<th>Substrate</th>
</tr>
</thead>
<tbody>
<tr>
<td>[17]</td>
<td>26 × 16</td>
<td>3.1 GHz to 10.6 GHz</td>
<td>WLAN</td>
<td>5.25 GHz</td>
<td>Ultra-thin liquid crystal polymer (LCP)</td>
</tr>
<tr>
<td>[18]</td>
<td>49 × 34</td>
<td>3.1 GHz to 10.6 GHz</td>
<td>WLAN</td>
<td>5 GHz</td>
<td>PET film</td>
</tr>
<tr>
<td>[24]</td>
<td>27 × 21</td>
<td>3.1 GHz to 10.6 GHz</td>
<td>C-band WLAN</td>
<td>3.7 GHz – 4.2 GHz 5.15 GHz – 5.825 GHz</td>
<td>Ultra-thin liquid crystal polymer (LCP)</td>
</tr>
<tr>
<td>Proposed antenna</td>
<td>19 × 14</td>
<td>3.09 GHz to 11.09 GHz</td>
<td>WiMAX C-band WLAN</td>
<td>3.2 GHz – 3.6 GHz 3.7 GHz – 4.2 GHz 5.15 GHz – 5.35 GHz</td>
<td>Rogers Duroid (RO3003™)</td>
</tr>
</tbody>
</table>
Design of UWB Antenna

Fundamental UWB antenna is the outcome from **optimisation process**

- Partial ground plane to increase the frequency range
- Substrate: Rogers Duroid RO3003™
  - Antenna size: 19 × 14 mm²
- Simulation on software CST MWS
Simulation Design of UWB Antennas

1. UWB antenna for WiMAX and C-bands rejection

First slot (L-inverted slot)

2. UWB antenna for WLAN rejection

Second slot (two inverted-U slots)

3. UWB antenna for WLAN band rejection

WiMAX and C-bands notch

WLAN band notch

The slots’ dimensions have been optimised without increasing the overall size of the antenna
Antenna Simulation in Bending Condition

Vacuum cylinder along y-axis to imitate the human arms

Cylinder with diameters

50 mm, 80 mm and 100 mm

(average approximate size of human arms)
Results, Analysis & Discussion
1. UWB Antenna

Actual UWB band: 3.1 GHz – 10.6 GHz

<table>
<thead>
<tr>
<th>Linear Characteristics</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency (GHz)</td>
<td>3.09 GHz to 11.09 GHz</td>
</tr>
<tr>
<td>Bandwidth</td>
<td>8 GHz</td>
</tr>
</tbody>
</table>

Maximum current at 6.17 GHz
2. UWB Antenna – WiMAX and C- Bands Rejection

Actual WiMAX band : 3.2 GHz – 3.6 GHz

<table>
<thead>
<tr>
<th>Linear Characteristics</th>
<th>Simulation Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency (GHz)</td>
<td>3.20 GHz to 4.30 GHz</td>
</tr>
<tr>
<td>Bandwidth</td>
<td>0.27 GHz</td>
</tr>
</tbody>
</table>
3. UWB Antenna – WLAN Band Rejection

Actual WiMAX band: 5.15 GHz – 5.35 GHz

<table>
<thead>
<tr>
<th>Linear Characteristics</th>
<th>Simulation Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency (GHz)</td>
<td>5.11 GHz and 5.38 GHz</td>
</tr>
<tr>
<td>Bandwidth</td>
<td>0.27 GHz</td>
</tr>
</tbody>
</table>
### 4. UWB Antenna – WiMAX, C- and WLAN Bands Rejection

<table>
<thead>
<tr>
<th>Frequency (GHz)</th>
<th>Simulation Results</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Rejected WiMAX and C- bands</strong></td>
<td></td>
</tr>
<tr>
<td>Actual (3.2 GHz – 3.6 GHz)</td>
<td>3.16 GHz - 4.20 GHz</td>
</tr>
<tr>
<td><strong>Rejected WLAN band</strong></td>
<td></td>
</tr>
<tr>
<td>Actual (5.15 GHz – 5.35 GHz)</td>
<td>5.14 GHz to 5.34 GHz</td>
</tr>
</tbody>
</table>
### 5. Radiation Pattern, Gain and Efficiency

<table>
<thead>
<tr>
<th>Radiating Frequencies (GHz)</th>
<th>Simulated Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.1 GHz</td>
<td>6.85 GHz</td>
</tr>
<tr>
<td>6.85 GHz</td>
<td>10.6 GHz</td>
</tr>
<tr>
<td>Gain (dBi)</td>
<td>Gain (dBi)</td>
</tr>
<tr>
<td>-3.164 dBi</td>
<td>2.780 dBi</td>
</tr>
<tr>
<td>4.989 dBi</td>
<td></td>
</tr>
<tr>
<td>Efficiency (%)</td>
<td>Efficiency (%)</td>
</tr>
<tr>
<td>75.38 %</td>
<td>75.02 %</td>
</tr>
<tr>
<td>74.11 %</td>
<td></td>
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</tbody>
</table>
Return loss is almost keep unchanged
3. Specific Absorption Rate

The simulated SAR values of the antenna at 2 mm away from the tissue model at 1 mW input power

- **SAR at 3.73 GHz**
  - 0.12 W/kg for 1 g
  - 0.04 W/kg for 10 g

- **SAR at 5.26 GHz**
  - 0.25 W/kg for 1 g
  - 0.06 W/kg for 10 g

The 2 mm distance is chosen as the approximate thickness of fabric materials worn by human
Conclusion
A compact UWB antenna with a triple band notch has been designed and simulated on RO3003™

Two slots on the radiating patch have been introduced to achieve notch bands at WiMAX, C- and WLAN bands

Simulation results:
UWB antenna can operate over the UWB frequency band from 2.89 GHz to 10.56 GHz
(actual UWB band: 3.1 GHz to 10.6 GHz)

WiMAX and C- notch bands from 3.16 GHz - 4.20 GHz
(WiMAX actual band: 3.2 GHz to 3.6 GHz;
C-band actual frequency range: 3.7 GHz to 4.2 GHz)

WLAN notch band from 5.14 GHz to 5.34 GHz
(actual WLAN band: 5.15 GHz to 5.35 GHz).

Simulation results on bending condition shows that performance of the UWB antenna is not affected on a vacuum cylinder with varying diameters of 50 mm, 80 mm and 100 mm.

SAR level of the antenna obeys the FCC and ICNIRP guidelines
THANK YOU

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