Design and Development of Conformal Body Centric Antenna for WBAN Application

B. Alekhya\textsuperscript{1*}, L. Anjaneyulu\textsuperscript{2}, A. Hrushitha Reddy\textsuperscript{3}, K. Suman\textsuperscript{4}, T. Vikram\textsuperscript{5}

\textsuperscript{1,3,4,5} Department of Electronics and Communication Engineering, VNR Vignana Jyothi Institute of Engineering and Technology, Hyderabad, Telangana, India.
\textsuperscript{2} Department of Electronics and Communication Engineering, National Institute of Technology, Warangal, Telangana, India.

\textbf{Received: 23.03.2024} \hspace{1cm} \textbf{Accepted: 26.03.2024} \hspace{1cm} \textbf{Published Online: 29.03.2024}

\textbf{Abstract:} In this paper, a conformal body centric antenna for wireless body area network (WBAN) applications is discussed. These designs are low-cost, low-profile circular and ring-shaped monopole antennas. Operational frequency of antenna is range from 2.5–10.6 GHz to meet the requirements of WBAN systems. The antenna is intended to be body-centric and conformal, which means for best performance, it is placed close to the body and conforms to the shape of the human body. The radiation patterns are measured at 2.5 GHz frequency. The substrate used for design is FR-4. The simulation results show that the proposed antenna has good impedance matching, a broad bandwidth of 122 MHz, and a gain of 4.8 db. The radiation pattern of the antenna is omnidirectional, which is desirable for wireless communication applications. Monopole antenna is designed and simulated using the Ansys EDT (HFSS) software. The monopole antennas are also fabricated in real time with proposed specifications. The proposed antenna can be used in various wireless communication systems such as WLAN, RFID, and Bluetooth, where low cost, compact size and critical design are considered.

\textsuperscript{*} Correspondence: Assistant Professor, Department of Electronics and Communication Engineering, VNR Vignana Jyothi Institute of Engineering and Technology, Hyderabad, Telangana, India. Email: alekhya_v@vnrvjiet.in

\textbf{https://doi.org/10.58599/IJSMEM.2024.2301}

Volume-2, Issue-3, PP:1-10 (2024)

This work is licensed under a Creative Commons Attribution 4.0 International License CC BY-NC-ND 4.0.
Key words: Wireless body area network, Monopole antenna, Radiation patterns, Impedance matching.

1. INTRODUCTION

It is possible to monitor and gather physiological data from the human body using a wireless body area network (WBAN), which is a rapidly growing topic in the wireless communication industry [1]. The creation of compact, lightweight, and low-power antennas that can be integrated into wearable technology is necessary for the adoption of WBAN [2]. The interaction of these antennas with the human body, which might impact how well they work, is one of the design challenges [3]. Body-centric and conformal antennas, which fit the human body's shape and are placed close to the body for best performance, have been offered as a solution to this problem [4]. Due to its unique qualities, UWB technology received a lot of interest and saw significant growth a few years ago [5, 6]. WBAN, where wireless communication between body-centric units is provided by the deployment of lightweight and compact WBAN antennas, constitutes one of the most promising areas of UWB applications [7, 8]. In this paper, design of a unique Circular monopole antenna and Circular ring antenna with FR-4 as substrate is suitable for WBAN applications [9]. It has a good gain and impedance bandwidth. Optimizing the radiating patch into a circular-shaped structure and inserting ring-shaped slot on the front radiating patch results in the WBAN response [10]. A square-shaped slot is put into the ground plane, and it is geometric modified to look for a WBAN resonance [11, 12].

2. METHODOLOGY

In the world of microstrip configurations, circular designs have a distinct advantage over rectangular ones when it comes to conserving physical space. Even when both designs have identical specifications, the circular disk takes up less area, making it a popular choice for applications that require arrays or other compact configurations. This is because circular geometries can be packed more tightly together, allowing for more efficient use of available space. Another advantage of circular configurations is that they have less coupling loss than their rectangular counterparts. This means that circular-based antennas have higher gain as compared to rectangular ones. For designing an antenna, the parameters required need to be accurate to generate favorable results. The height of the substrate, the permittivity of the substrate, and the antenna's resonance frequency are the first parameters needed to find the radius of circular patch, feed line width [13, 14].

2.1. Design equations for circular Patch

Calculation of Radius for circular patch:

\[
r = \frac{c}{2f}\sqrt{\frac{2}{\pi}}
\]
\[ a = \frac{F}{\left\{ 1 + \frac{2h}{\pi \varepsilon_r F} \left[ \ln \left( \frac{\pi F}{2h} \right) + 1.7726 \right] \right\}^{1/2}} \]

where, \( h \) = thickness of the substrate \( \varepsilon_r \) = relative permittivity of the substrate, \( f_r \) = resonant frequency, and \( a \) = radius of the patch

\[ F = \frac{8.791 \times 10^9}{f_r \sqrt{\varepsilon_r}} \]

\[ a_e = a \left\{ 1 + \frac{2h}{\pi a \varepsilon_r} \left[ \ln \left( \frac{\pi a}{2h} \right) + 1.7726 \right] \right\}^{1/2} \]

Where, \( a_e \) = Effective radius of patch From the above formula the radius is calculated. The width of the feedline is also calculated with respect to the radius to achieve the impedance matching. The length and width of the substrate are set to maximize output. The ground plane width is changed to various values to enhance the bandwidth and the best width is set.

3. PROPOSED ANTENNA DESIGN

The proposed antenna for WBAN applications is provided in the following sub-sections.

3.1. Circular Monopole Design

For better results the radius of the patch calculated by using the above formula and the dimension of the antenna are present in the below Table 1. Thickness of the substrate is given as 1.6mm.

<table>
<thead>
<tr>
<th>Dimensions</th>
<th>Measurements(mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ls</td>
<td>56</td>
</tr>
<tr>
<td>Ws</td>
<td>42</td>
</tr>
<tr>
<td>R</td>
<td>13.95</td>
</tr>
<tr>
<td>FL</td>
<td>2.1</td>
</tr>
<tr>
<td>Lg</td>
<td>56</td>
</tr>
<tr>
<td>Wg</td>
<td>7</td>
</tr>
<tr>
<td>Hs</td>
<td>1.6</td>
</tr>
</tbody>
</table>

Proposed design of circular monopole antenna is shown in Figure 1.
3.2. Circular Ring Design

To improve the performance, design has few modifications. Circular antenna is converted into circular ring antenna. Circular ring antenna is designed with the below dimensions. There are two designs made with different substrates. The radius of inner and outer circle is calculated to match the impedance of 50Ω. The dimension of the circular ring antenna are present in the below Table 2.

Table 2. Dimensions of Circular Ring Antenna

<table>
<thead>
<tr>
<th>Dimensions</th>
<th>Measurements (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ls</td>
<td>56</td>
</tr>
<tr>
<td>Ws</td>
<td>42</td>
</tr>
<tr>
<td>R1</td>
<td>13.95</td>
</tr>
<tr>
<td>R2</td>
<td>11.23</td>
</tr>
<tr>
<td>FL</td>
<td>2.1</td>
</tr>
<tr>
<td>Lg</td>
<td>56</td>
</tr>
<tr>
<td>Wg</td>
<td>7</td>
</tr>
<tr>
<td>HS</td>
<td>1.6</td>
</tr>
</tbody>
</table>

Proposed design of circular ring antenna is shown in Figure 2.

3.3. Fabrication

The antennas of the design are fabricated using the substrate as FR-4 and conducting material as the Copper. The properties of the FR-4 substrate are shown Table 3.

Table 3. Properties of Substrate used in the design

<table>
<thead>
<tr>
<th>Substrate Material</th>
<th>Fr-4 Material</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dielectric Constant</td>
<td>4.44</td>
</tr>
<tr>
<td>Loss tangent</td>
<td>0.03</td>
</tr>
<tr>
<td>Thermal Conductivity</td>
<td>0.10 W m⁻¹ K⁻¹</td>
</tr>
</tbody>
</table>

Substrate selection plays a major role in the performance of the antenna. Having dielectric
constant high helps the antenna to become less in dimensions. It also helps to have high directivity and good bandwidth. Copper is selected as the conducting material because it has high electrical conductivity and is easy to fabricate. It has high thermal resistance which helps to operate at any temperature. The antenna is connected via SMA connector which is soldered to the patch feedline and to the ground plane. The circular monopole antenna top view and bottom view are shown in Figure 3 and Figure 4.

The top view circular ring monopole antenna is shown in Figure 5.
4. RESULTS
The return loss, gain and radiation patterns are discussed in this section.

4.1. Return Loss (S11) of Circular Monopole Antenna
The designs are generated in the HFSS tool with the calculated dimensions and results are generated below. S-parameters of Circular monopole antenna. It is observed that multiband frequency is seen in antenna with antenna having substrate as FR-4. Various resonant frequencies are observed at 2.8ghz, 6.93ghz, 8.93Ghz which are compatible for WBAN applications. The bandwidth of the antenna at various frequencies are 122Mhz (6.63Ghz), 87Mhz(8.92Ghz). The S-Parameters of Circular Antenna is shown in Figure 6.
4.2. Return Loss (S11) of Circular Monopole Antenna

The Fr-4 substrate antenna supports multiband frequency which is suitable for WBAN applications. The resonant frequency is observed at 2.5Ghz, 4.7Ghz, 7.2Ghz, 9.8Ghz. The bandwidth of antenna is maximum observed at 156Mhz which is sufficient for data transfer. The S-Parameters of Circular Ring monopole Antenna is shown in Figure 7.

4.3. Gain Plot (E-plane and H-plane Patterns) of Circular Monopole Antenna

The E-plane, H-plane pattern of the circular monopole antenna is shown below. A circular monopole antenna’s gain is normally proportional to the antenna’s physical height above the ground plane. This antenna shows an omnidirectional pattern as shown below. The radiation pattern is shown at the frequency of 2.5ghz. The Gain plot of Circular Monopole Antenna is shown in Figure 8.

4.4. Gain Plot (E-plane and H-plane Patterns) of Circular Monopole Antenna

The Gain Plot (E-plane and H-plane Patterns) of Circular Monopole Antenna is shown in Figure 9.
4.5. Radiation Pattern (3-D Plot)

3-D plots of the circular monopole and circular ring monopole antennas are shown below. The directivity of the antennas is shown below. These plots show that the antennas are omnidirectional and have good directivity. The radiation pattern of Circular Monopole Antenna is shown in Figure 10 and the radiation pattern of circular ring antenna is shown in Figure 11.
5. CONCLUSION AND FUTURE SCOPE

The antenna designs generated results show that they are suitable for WBAN applications. The small size and low power consumption are key features which can be observed in these designs. Both designs have good bandwidth. Circular ring design has more bandwidth along with more resonating frequencies than the circular monopole antenna. These antennas can be used to operate in various
frequencies. These antennas can be used in various fields like military and Biomedical applications. In the field of biomedicine these antennas can be used for patients by sending the vitals continuously. In military they can be used in combat by knowing actual position of the soldiers having the antenna. The design can be further improvised by using can changing the substrate to textile based to make it more flexible and easier to design. Using textile cloth as substrate can also be an option. Further research can be done in those areas and to improve the bandwidth.

References


