Wearable Microstrip Patch Antenna: Design and Simulation

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Abstract – Vast researches have been done in the field of RF devices and their optimization to suit the needs of human race in the current scenario. Information exchange between devices plays a major role in making human life more comfy. Antennas are used for information exchange in form of electromagnetic waves. The objective of this paper is to design such a microstrip patch antenna which takes a wearable material – in this case a strip of jeans, as the substrate and is small enough to be integrated on human clothing to work as a transmitter. The antenna transmits in the ISM band utilizing the Bluetooth frequency range to provide a free channel and hence is cost effective. Further, results of the S11 parameter and VSWR have been included at the end of the paper.

Keywords: Wearable, Microstrip patch antenna, Bluetooth frequency, Reflection loss, Monopole

1. Introduction
Antenna can be considered as a transducer that converts electrical signal into electromagnetic waves and radiates it into the atmosphere [1]. The traditional antennas designed were bulky and rigid but the communication system in the present era calls for the need of a high gain, high bandwidth, light weight and a small sized antenna.

The general purpose antenna design requires wide bandwidth but if the need is to design an antenna for specific purpose, operating at a certain frequency requires a narrow bandwidth. In the forthcoming discussion the frequency of interest is 2.5 GHz which is the standard Bluetooth frequency [2]. This allows the antenna to gain access to a free channel which reduces the effective cost of the antenna.

Today when communication devices work in close proximity with human body, it is important to address their size. Practically, the traditional bulky antennas cannot find their use in wearable technology. This calls for the need of compact and small microstrip patch antennas. In general a microstrip patch antenna is just a radiating metal patch mounted on a dielectric substrate with a ground plane on the opposite face [3]. In wearable technology the substrate is a piece of cloth which can then be easily integrated into clothing or a hat or any other accessories like the nike+ sensors and the go-pro action cameras [4].

2. Design Specification
The Microstrip patch antenna is designed to work at 2.7 GHz. The geometry of the antenna comprises of a thin conducting copper patch on an insulating fabric substrate backed by a copper ground plane [5].

2.1. Selection of the substrate
The substrate is carefully chosen so as to maintain the value of S11 parameter (Reflection loss) within the accepted range. In this particular design a jeans fabric is used as the substrate. The electrical properties of the jeans material are adopted from the previous research done on the subject. The specifications of the substrate are mentioned in Table 1.

<table>
<thead>
<tr>
<th>Substrate Length</th>
<th>55 mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Substrate Width</td>
<td>60 mm</td>
</tr>
<tr>
<td>Substrate Thickness</td>
<td>1 mm</td>
</tr>
<tr>
<td>Dielectric constant</td>
<td>1.6</td>
</tr>
</tbody>
</table>

Table 1

2.2. Dimension of the patch
A series of designs were carried out iteratively, simulations for which were performed in HFSS (High Frequency Simulation Software). It was done in order to obtain an optimum design which could further be fabricated and tested. The first few designs consisting of a rectangular patch of large
dimension encouraged some adjustments to reduce the size of the patch. Finally, the optimized design (Figure 1) consisting of a circular patch with microstrip line feeding was designed and it carried the following specification that are mentioned below in the table. Table 2 shows the specifications of antennas designed in few of the iterations leading unto the optimized design. Figure 1, 2, 3 show the structures of the antennas whose dimensions are mentioned in Table 2.

<table>
<thead>
<tr>
<th>Antenna Design</th>
<th>Design 1</th>
<th>Design 2</th>
<th>Design 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patch radius</td>
<td>20 mm</td>
<td>20 mm</td>
<td>20 mm</td>
</tr>
<tr>
<td>Up right square DMS</td>
<td>-</td>
<td>-</td>
<td>6 x 6 (mm x mm)</td>
</tr>
<tr>
<td>Diamond DMS</td>
<td>-</td>
<td>6 x 6 (mm x mm)</td>
<td>8 x 8 (mm x mm)</td>
</tr>
<tr>
<td>Microstrip Feed Width</td>
<td>1 mm</td>
<td>1 mm</td>
<td>1 mm</td>
</tr>
<tr>
<td>Microstrip Feed Length</td>
<td>13 mm</td>
<td>13 mm</td>
<td>13 mm</td>
</tr>
<tr>
<td>Feed Line Symmetry</td>
<td>Symmetrical</td>
<td>Symmetrical</td>
<td>Symmetrical</td>
</tr>
<tr>
<td>Operating Frequency</td>
<td>4.5 GHz</td>
<td>4.2 GHz</td>
<td>2.7 GHz 5.1 GHz</td>
</tr>
</tbody>
</table>

Table 2

3. Simulation in HFSS

3.1. Radiation Pattern

The patch’s radiation at the fringing fields results in a certain far field radiation pattern. This radiation pattern shows that the antenna radiates more power in a certain direction than in other direction [6]. The simulated radiation pattern for Figure 3 antenna is shown in Figure 4.
The above figure depicts the radiation pattern of the antenna at two operating frequencies. The pattern in red corresponds to 2.7 GHz and the pattern in violet corresponds to 5.1 GHz. The radiation pattern in the above figure and the $S_{11}$ parameter in Figure 5 convey that the designed antenna works as a Dual band antenna.

3.2. $S_{11}$ parameter (Reflection Loss)

$S_{11}$ indicates the return loss i.e. the loss of power in the signal returned/ reflected by discontinuity in the transmission line [1]. In simple words if there is a mismatch of the antenna with the terminating loads or with the device inserted in the line, $S_{11}$ represents the loss due to reflected wave. The simulated $S_{11}$ parameter for solution frequency in the ISM range is shown in Figure 5.

4. Fabrication and Testing

After the simulation of the antennas, the final optimized antenna, shown in Figure 3 has been fabricated on a Denim (jeans) fabric, with a copper sheet as the ground plane and the radiating patch. Manual designing of the antenna was cumbersome as the dimensions of slot to be cut were to be very accurate. Precision has been maintained by as far as possible. The fabricated antenna is shown in figure 6.

The antenna was tested using a Vector Network Analyzer (VNA). Figure 7 shows the setup of the VNA. Further a comparison is made between the simulated $S_{11}$ parameter of antenna in Figure 3 and the experimented result of $S_{11}$ parameter for the antenna in Figure 6 and is shown graphically in Figure 8.
5. Conclusion

The performance of all antennas were analyzed and investigated by using simulation. The measured result for Antenna 3 agrees with the simulated result in terms of return loss. The design of wearable computing devices demands efficient, reliable and compact size antenna. Important features of this antenna are small size, inexpensive, light weight, simple fabrication and easy integration within the clothing. This antenna can thus find its applications in the clothing of military, sportsmen and police personnel as it can be designed using fabric substrate materials.

6. References