

Design of an All-textile Antenna Integrated in Military Beret for GPS/RFID Applications

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Abstract – In this paper, an all-textile antenna integrated in military beret for global positioning system (GPS) and radio frequency identification (RFID) applications is proposed. The proposed antenna consists of a left handed circular polarization (LHCP) GPS patch antenna and a circular ring patch antenna with conductive threads to operate as RFID in 915 MHz Industrial, science and medical (ISM) band. The circular ring patch with four shorting pins has TM₄₁ higher order resonance mode at 915 MHz for a monopole-like radiation characteristic. Considering the military beret, the antenna is designed by using only textile materials such as conductive textiles, conductive thread, and a felt substrate. The performance comparisons under bending condition and human body (head) effect are conducted.

Index Terms —Wearable antenna, textile antenna, GPS, RFID, military beret.

1. Introduction

As the demand for various wearable devices such as smart watches, glasses and clothes increases, wireless body area networks (WBANs) have received a great deal of attention [1]. A conformal antenna is required for WBAN application. To satisfy this requirement, a compact low-profile IR-UWB antenna and an all-textile higher order mode circular patch antenna for omnidirectional radiation characteristics have been studied [2], [3].

Global positioning system (GPS) is a space-based navigation system that provides the position and time information at outdoor location. However, GPS communication cannot provide service directly at indoor location. Thus, RFID communication needs to be used to provide GPS information at the indoor locations.

In this paper, an all-textile antenna integrated in military beret for GPS and RFID applications is proposed. The proposed all-textile antenna utilizes dual modes by using two ports. A ring patch with four shoring pins is designed for a monopole-like radiation characteristic at 915MHz for RFID, while a truncated patch is designed for a broadside radiation pattern with LHCP at 1.575GHz for GPS applications.

2. Antenna Design and Simulated Results

Fig. 1 (a) shows the geometry of the proposed antenna. The antenna is designed on a felt substrate ($\epsilon_r = 1.2$, $\tan \delta = 0.02$) with a thickness of 5 mm. The antenna consists of a circular ring patch with feed 1 and a truncated rectangular patch with feed 2. The conductive patches on the top plane and the ground on the bottom plane are designed by Shieldex

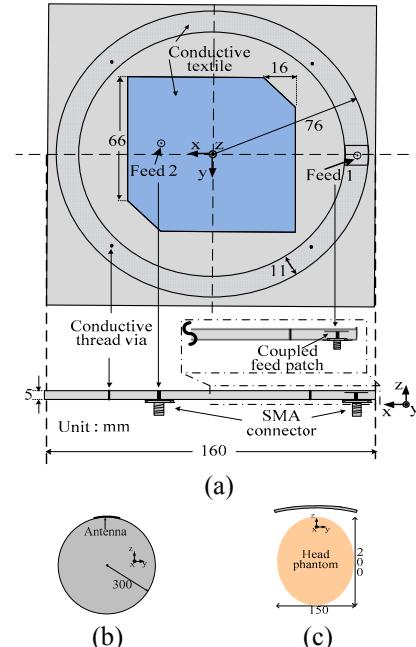


Fig. 1. Geometry of the proposed antenna under the bending and human body proximity conditions: (a) geometry of the proposed textile antenna, (b) bending setup of the proposed antenna, (c) the antenna above the head phantom.

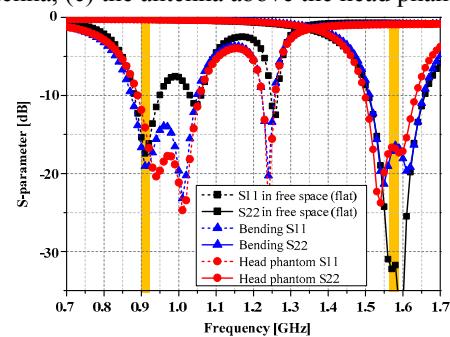


Fig. 2. Simulated S-parameter under three conditions for bending and human body effect.

conductive metallized nylon fabric (Zell) with a thickness of 0.1 mm (surface resistance=0.02 Ω/square). The truncated rectangular patch has a dimension of 82 mm × 82 mm × 0.1mm. The circular ring patch antenna has four conductive threads (Resistivity=0.0025 Ω/square·cm) with a radius of 0.2 mm. Fig. 1(b) shows the proposed antenna attached on a cylinder with a radius of 300 mm to account for the bending condition. Fig. 1(c) shows the bent antenna located at 20 mm above the head phantom ($\epsilon_r=44.8$, $\sigma=0.88$ S/m) to take into account the human body effect.

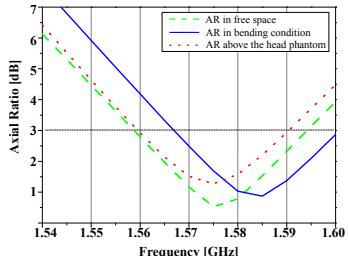


Fig. 3. Simulated axial ratio under three conditions.

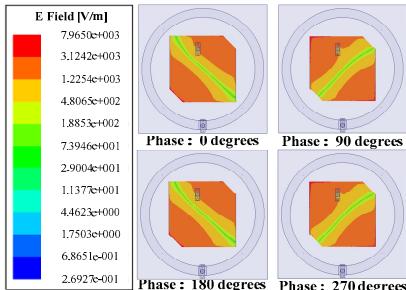


Fig. 4. Simulated E-field distributions of the GPS CP antenna at four phases (at 1.575GHz).

Fig. 2 shows the simulated s-parameter characteristics for three different conditions. The resonant frequency of the circular ring patch is 915 MHz and the simulated -10-dB return loss bandwidth is enough to cover the 915 MHz ISM band (902 MHz – 928 MHz). The simulated -10-dB return loss bandwidth of the truncated rectangular patch covers L1 GPS band (1.563 GHz – 1.587 GHz). It is observed that both the simulated -10-dB return loss bandwidths fully cover the required bandwidth when the antenna is located above the head phantom and is bent.

The functionality and polarization quality of GPS antenna can be determined by the axial ratio (AR) parameter. Any antenna can be considered as a circular polarized (CP) antenna when it has an axial ratio (AR) less than 3-dB over the desired frequency band. The simulated AR results of the proposed rectangular patch under three different conditions are shown in Fig. 3. The simulated 3-dB AR bandwidth of the proposed antenna above the head phantom is 30 MHz (1.56 GHz – 1.59 GHz).

Fig. 4 illustrates the simulated electric field magnitude distributions of the proposed antenna placed above the head phantom at 1.575GHz in order to verify the CP characteristic. In four different phase states (0° , 90° , 180° , and 270°), the E-field is rotated in a counterclockwise when the antenna is observed from the backward. It shows that the antenna indeed operates with left handed CP (LHCP) at GPS band.

Fig. 5 shows the simulated surface current distribution on the circular ring patch of the proposed antenna at 915MHz. The fact that the current varies by four cycles along the circumferential direction and by one cycle along the radial direction shows that the antenna is excited by the TM₄₁ higher order mode.

Fig. 6 illustrates the far-field radiation patterns of the proposed antenna located above the phantom at 915 MHz and 1.575 GHz. The proposed antenna has a monopole-like radiation pattern at 915 MHz and a broadside radiation

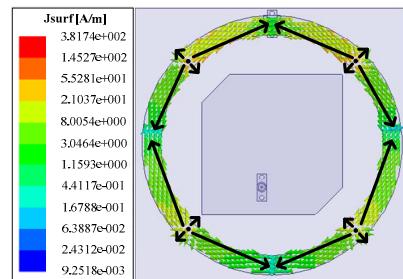


Fig. 5. Simulated surface current distribution on the circular ring patch at 915MHz.

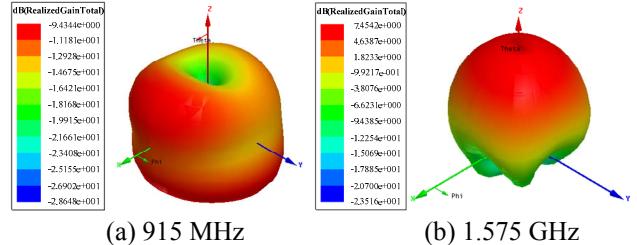


Fig. 6. Simulated 3-D radiation pattern for antenna above the head phantom.

pattern at 1.575 GHz. The simulated peak gains and radiation efficiencies of the proposed antenna above the head phantom are -9.43 dBi and 6.2 % at 915 MHz and 7.45 dBi and 71% at 1.575 GHz, respectively.

3. Conclusion

In this paper, an all-textile antenna integrated in military beret for GPS/RFID applications was proposed. All components of the proposed antenna are designed by textile materials including conductive fabric, conductive thread and felt. The bending condition and the effect of the human head were simulated. The characteristics of the proposed antenna were not critically affected by adding the head phantom. The -10-dB return loss bandwidth of the proposed antenna on the phantom fully covers the 915 MHz ISM band (902 – 928 MHz) and GPS L1 band (1.563 – 1.587 GHz). Thus, the proposed antenna is a good candidate for WBAN applications, and can be used directly in military beret products.

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