# Design of a Small Antenna with Folded Ground and U-shaped Slot for Body-Centric Wireless Communications

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## Abstract

In the paper, a small antenna for 2.4 GHz body-centric wireless communications is proposed. With the folded ground and U-shaped slot, the antenna has an improved efficiency of 56.5% when it is very close to human body. In addition, the antenna has attractive radiation patterns for body-centric wireless communications.

**Keywords :** Body-centric wireless communications Planar inverted-F antenna Folded ground U-shaped slot

## 1. Introduction

The miniaturization of electronic devices is leading to the creation of body-centric wireless communications (BCWCs), in which wireless devices are attached to human body or implanted in human body [1]. With these wireless devices, mobile health monitoring will become real, which reduces the pressure on overburdened healthcare systems by improving daily disease management, and facilitating self-healthcare. Besides, several other applications could also be enhanced, such as smart home, personal entertainment, and identification systems. Although the study on BCWCs is very active, the human body environment is often hostile for wireless signals owing to the mutual influence between antennas and the human body [2]. As a result, antenna efficiency is reduced, and meanwhile, specific absorption rate (SAR) will increase. In addition, wireless devices should be easily equipped on or in the human body so antennas should be of small size and low profile. Maintaining small size and high efficiency simultaneously is a big challenge for antenna researchers. Electromagnetic band gap (EBG) materials were used to improve antenna efficiency [3]. However, in order to maintain small size, limited units of EBG will degrade the performance. Patch antenna is also a suitable candidate because of low profile, in which a relatively large ground plane is used to realize low SAR [4-5]. However, large ground plane means relatively large size.

In [6], a small planar inverted-F antenna was introduced for BCWCs. By adding a small L-shaped ground shield, the antenna has an efficiency of 50.5% even when it is very close to human body. Therefore, in this paper, in order to further improve antenna efficiency, we propose a small antenna with folded ground and U-shaped slot. The antenna operates at 2.4 GHz and has an improved efficiency of 56.5% when it is very close to human body.

## 2. Antenna Design and Human Phantom

As illustrated in Fig. 1, the proposed antenna is a planar inverted-F antenna. The antenna height is 4 mm, and no dielectric material is used between folded ground and top patch. The folded ground includes two parts: a main ground plate (25.5 mm × 30 mm), and an L-shaped ground plate. The vertical portion and horizontal portion of the L-shaped ground plate have the same dimensions of 4 mm × 30 mm. The L-shaped ground plate is used to improve antenna efficiency, which is similar to the L-shaped ground shield's effect in [6]. The top patch has dimensions of $L$ mm × 30 mm, and a U-shaped slot is embedded in it, which is also for efficiency enhancement. The feeding pin is in the center line of the top patch and the folded ground, and $F$ mm away from a shorting plate of *W* mm in width. It should be noted that these parameters, *L*, *W*, and *F*, are used to adjust matching.

Since the antenna is proposed for BCWCs, we should evaluate it with human body. As shown in Fig. 2, the antenna is located close to a 2/3 muscle-equivalent human phantom (dimensions, 200 mm × 200 mm × 50 mm; relative permittivity, $\varepsilon_r$ = 35.2; conductivity, $\sigma$ = 1.16 S/m [7]). The distance between the antenna and the human phantom is set at 2 mm to simplify equipment packaging.

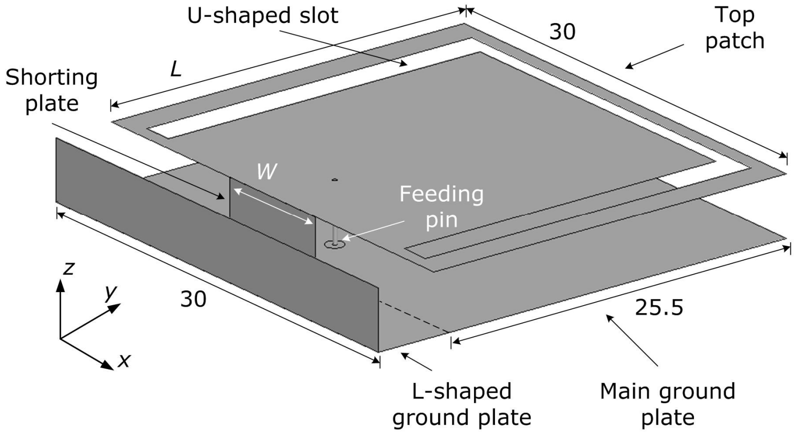
## 3. Calculated Results and Discussion

The proposed antenna is simulated by Remcom XFDTD 7.0, and in the simulation the diameter of the feed pin is not considered for simplicity. Owing to the human phantom's impact, we need to tune the antenna by adjusting parameters of *L*, *W*, and *F*. After conducting a parametric study, the optimized values are acquired (*L* = 25.5 mm, *W* = 8.5 mm, and *F* = 4.5 mm). The simulated reflection coefficient is given in Fig. 3. From the figure, the -7.5-dB bandwidth (VSWR < 2.5) is about 92 MHz (2.395-2.487 GHz). Furthermore, the antenna efficiency reaches 56.5% even when it is close to the human body (human phantom). Another important finding is that the radiation patterns are relatively non-directional in the half-sphere above the human body, which is shown in Fig 4. As a result, the antenna is relatively immune to fading during human body's moving [8], and also able to be applied both in on-body and off-body systems because of wide beam [9].

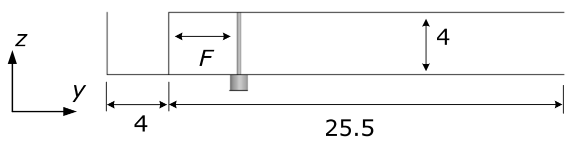
In the design, two components are used to improve antenna efficiency: one is the L-shaped ground plate, and the other is the U-shaped slot. As a comparison, we removed the two components separately (Antenna I: the antenna without the L-shaped ground plate; Antenna II: the antenna without the U-shaped slot), and summarized the calculated results in Table 1, including operation bandwidth, center frequency, antenna gain, and antenna efficiency. Based on the results, by adding the L-shaped ground plate the antenna efficiency is improved from 51.4% to 56.5%. In addition, with the U-shaped slot embedded in the top patch, the antenna efficiency is improved from 44.5% to 56.5%. The two components reduce the electric field distributions in the human body so higher antenna efficiency is achieved.

## 4. Conclusions

In the paper, a small antenna with folded ground and U-shaped slot is proposed for 2.4 GHz BCWCs. By adding the L-shaped ground plate and U-shaped slot, the antenna has an improved efficiency of 56.5% even when it is very close to human body. It is also found that the antenna has attractive radiation patterns for BCWCs. Now, we are fabricating the antenna to validate the design, and will further optimize the antenna.




(a)




(b)

Figure 1: Geometry of the Proposed Antenna (unit: mm): (a) 3D view; (b) Side view.

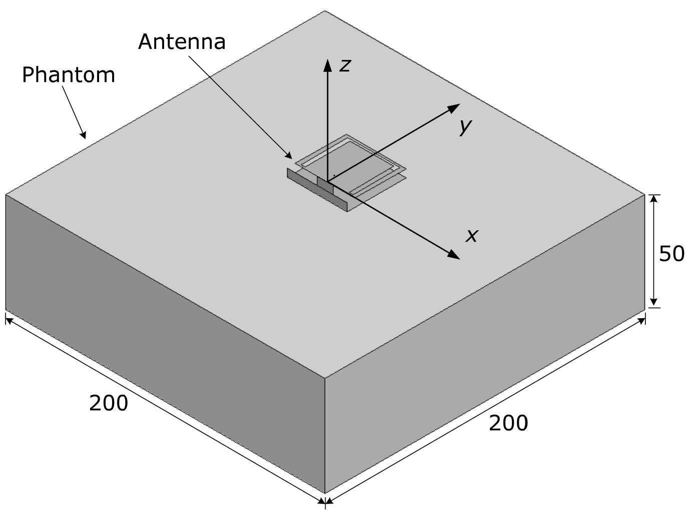



Figure 2: Antenna and 2/3 Muscle-equivalent Human Phantom (unit: mm).

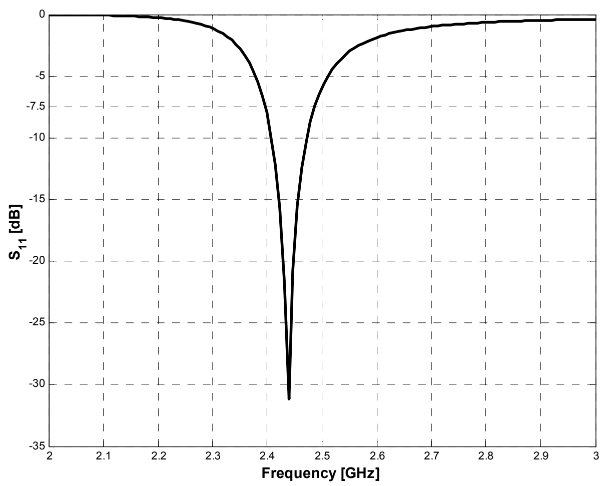



Figure 3: Reflection Coefficient.

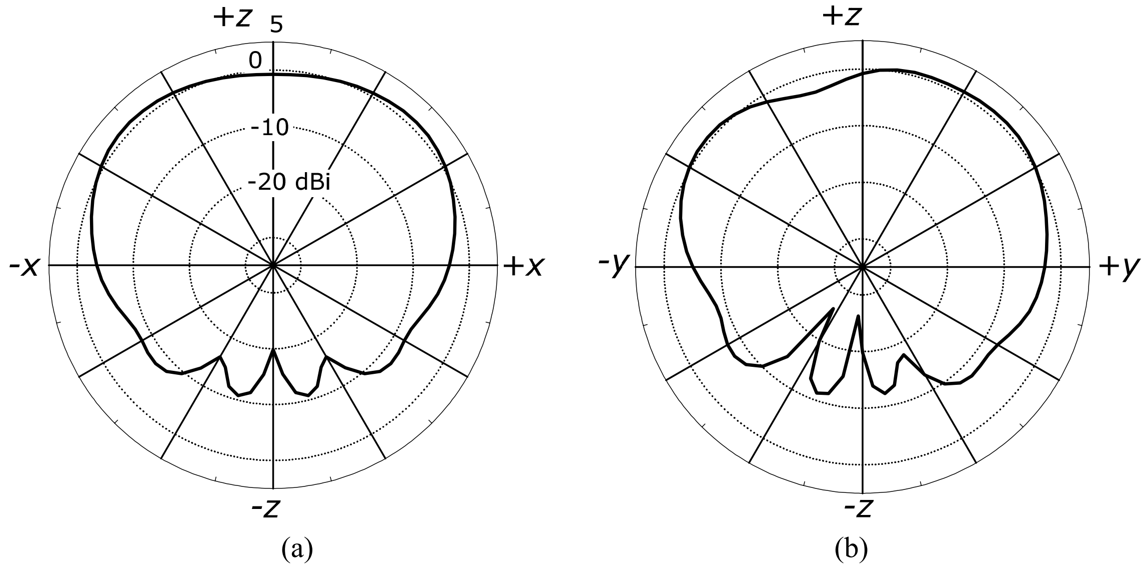


Figure 4: Radiation Patterns: (a) x-z plane; (b) y-z plane.

Table 1: Performance of the Proposed Antenna and Two Other Antennas

| Antenna type | Bandwidth (GHz) | Center frequency (GHz) | Gain (dBi) | Antenna efficiency |
|---|---|---|---|---|
| The proposed antenna | 2.395-2.487 | 2.44 | 1.58 | 56.5% |
| Antenna I (without L-shaped ground plate) | 2.372-2.462 | 2.415 | 1.26 | 51.4% |
| Antenna II (without U-shaped slot) | 2.009-2.118 | 2.06 | 0.81 | 44.5% |

## References


[1] P. Hall, Y. Hao, Antennas and propagation for body-centric wireless communications, Artech House, Boston, MA, 2006.

[2] P. Hall, Y. Hao, K. Ito, "Guest editorial for the special issue on antennas and propagation on body-centric wireless communications," IEEE Transactions on Antennas and Propagation, vol. 57, no. 4, pp. 834-836, 2009.

[3] J. Vicente, A. A. Moreira, "Electro-textile printed slot antenna over finite EBG structure," Proc. iWAT2010, Lisbon, Portugal, pp.1-4, 2010.

[4] S. Sankaralingam, B. Gupta, "A bluetooth antenna for on-body communications," Proc. EuCAP2010, Barcelona, Spain, pp. 1-4, 2010.

[5] C. Hertleer, H. Rogier, L. Vallozzi, L. Van Langenhove, "A textile antenna for off-body communication integrated into protective clothing for firefighters," IEEE Transactions on Antennas and Propagation, vol. 57, no. 4, pp. 919-925, 2009.

[6] Z. Li, K. Saito, M. Takahashi, K. Ito, Y. Huang, "A small planar inverted-F antenna for body-centric wireless communications," Proc. ISAP2010, Macau, China, pp.1-4, 2010.

[7] S. Gabriel, R. W. Lau, C. Gabriel, "The dielectric properties of biological tissues: II. measurements in the frequency range 10 Hz to 20 GHz," Physics in Medicine and Biology, vol. 41, pp. 2251–2269, 1996.

[8] P. Hall, "Antennas and propagation for body centric communications," Proc. IET Seminar Antennas and Propagation Body-Centric Wireless Communications, London, UK, pp. 1–4, 2007.

[9] N. Haga, K. Saito, M. Takahashi, K. Ito, "Characteristics of cavity slot antenna for body-area networks," IEEE Transactions on Antennas and Propagation, vol. 57, no. 4, pp. 837-843, 2009.