Dual-Band Slot Antenna with Metal Surroundings for WBAN Applications

Wonseok Lee and Jaehoon Choi
Department of Electronics and Computer Engineering
Hanyang University
Seoul, Republic of Korea
E-mail: choijh@hanyang.ac.kr (corresponding author)

***Abstract*— A dual-band slot antenna with metal back-cover and metal rim for WBAN applications is proposed. A T-shaped coupled feed structure on FR4 substrate is placed under the metal back-cover and surrounded by an unbroken metal rim. A slot antenna operating at 2.45 GHz is designed first on the metal back-cover and two parasitic elements nearby the feed structure are added to enhance the bandwidth in 2.45 GHz ISM band by exciting TM_{11} mode on the ground plane. Another parasitic element nearby the feed structure is used to cover 5.8 GHz ISM band. Then, additional two shorting strips between the metal back-cover and the surrounding metal rim are applied to control current flows properly in 2.45 GHz and 5.8 GHz ISM bands. The proposed antenna satisfies required bandwidths in 2.45 GHz and 5.8 GHz ISM bands. In addition, the radiation pattern of the proposed antenna is outward directional on the human equivalent flat body phantom, which is desirable for WBAN applications.**

Keywords*— Dual-band, metal surroundings, metal back-cover, metal rim, Wireless body area network (WBAN)

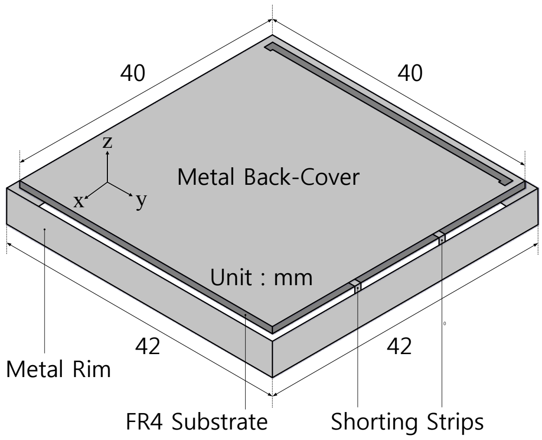
I. Introduction

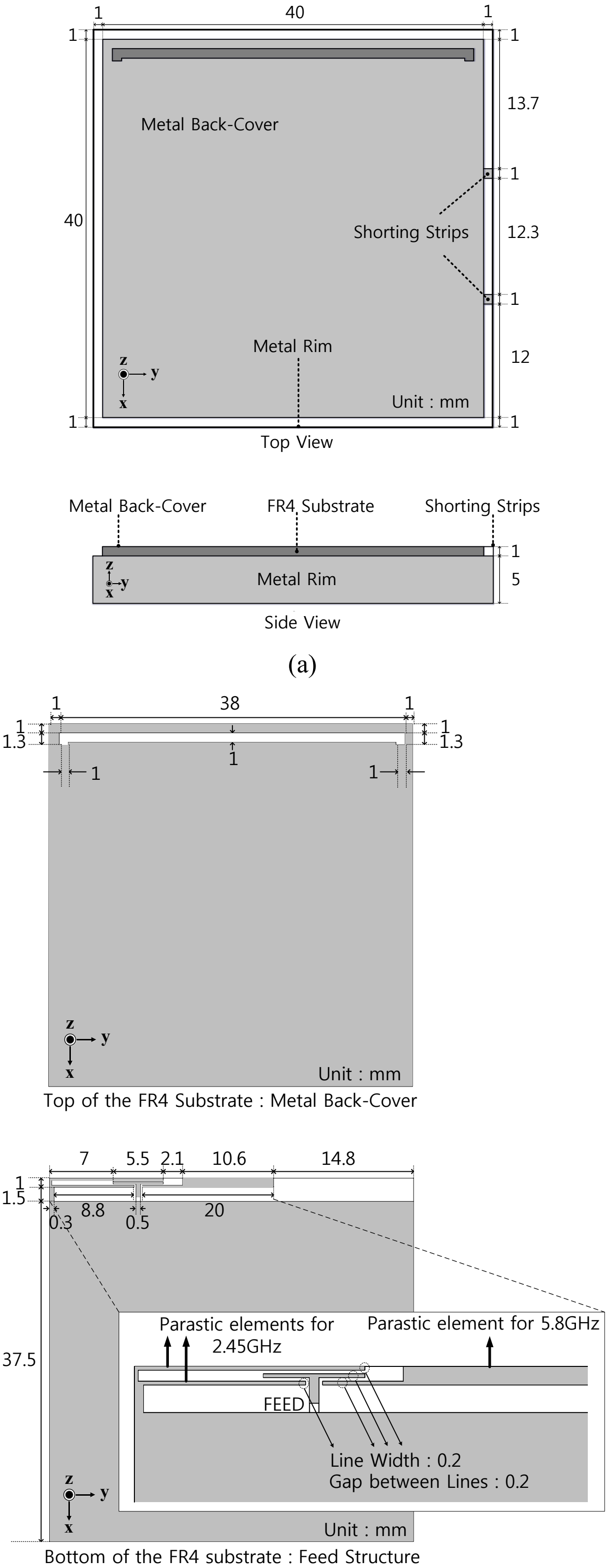
In recent years, a wearable device has become a major communication tool for checking a personal body condition or providing audiovisual pleasure. Therefore, wireless body area network (WBAN) has received great attention because it can be potentially applied to a number of markets such as health, medical, or entertainment services [1]. With the innovative design trend of applying metal surroundings to a wireless device, the antenna design technique with metal surroundings is consistently improving. Though current researches on antenna design with metal areas show steady improvements, there still remain many limitations since the antenna is significantly affected by the presence of surrounding metal area. Metal surrounding parts of the WBAN device interfere the signal radiation from the antenna located in the device and consequently deteriorate the antenna performance. Nevertheless, effective radiation performance can be obtained if the metal surrounding part itself can be used as a radiator. A metal back-cover with slots can be a good radiator if feeding structures are properly placed under the metal back-cover [2]. In [3], it is shown how the metal rim of the mobile device can be used as a good antenna. These promising solutions, however, are targeted for mobile phone antenna which usually optimized for 6-dB return loss bandwidth and leave a possibility of improvement.

In this paper, a dual-band slot antenna with metal back-cover and metal rim for WBAN applications operating in 2.45 GHz and 5.8 GHz industrial, scientific, and medical (ISM) bands is proposed. First, a slot on the metal back-cover is excited by a T-shaped coupled feed, and the ground plane is fed by parasitic elements nearby the feed structure for 2.45 GHz ISM band. Then, another parasitic element is added and two shorting strips are applied between the metal back-cover and the metal rim for 5.8 GHz ISM band. Finally, a human equivalent body phantom is used to analyze the antenna performance on the human body.

II. Antenna Design And Result

Fig. 1 shows the geometry of the proposed antenna. The dimension of the antenna is 42 mm × 42 mm× 6 mm, and the device is enclosed by metal surroundings : a metal back-cover and a metal rim. The metal rim is connected to the metal back-cover with two shorting strips as shown in Fig. 1 (a). A slot is located on the metal back-cover and a FR4 substrate (ε_r = 4.4, tanδ = 0.02) is placed under the metal back-cover. The feed structure consists of a T-shaped coupled feed and three parasitic elements as shown in Fig. 1 (b).





(a)

(b)

Fig. 1. Geometry of the proposed antenna (a) Metal back-cover and metal rim, (b) Top and bottom views of the FR4 substrate

Fig. 2 shows the simulated return loss characteristics of the proposed antenna in free space and on the phantom. The proposed antenna is placed 1 mm away from the surface of a two-thirds muscle-equivalent phantom (ε_r = 35.7, σ = 1.5 S/m at 2.45 GHz and ε_r = 32.66, σ = 3.47 S/m at 5.8 GHz) to analyze the antenna performance on the human body [3]. The dimension of the phantom is 200 mm × 270 mm × 60 mm. The required 10-dB return loss bandwidths are 4.08 % (0.1 GHz, ranging from 2.4 GHz to 2.5 GHz) in the 2.45 GHz ISM band and 2.59 % (0.15 GHz, ranging from 5.725 GHz to 5.875 GHz) in the 5.8 GHz ISM band. The simulated 10-dB return loss bandwidths of the proposed antenna in free space are 6.94 % (0.17 GHz, ranging from 2.39 GHz to 2.56 GHz) in the 2.45 GHz ISM band and 3.45% (0.2 GHz, ranging from 5.68 GHz to 5.88 GHz) in the 5.8 GHz ISM band, respectively. Finally, the human body effect is analyzed with the phantom and the result shows that bandwidths increase in both ISM bands. The bandwidths increase to 8.57 % (0.21 GHz, ranging from 2.34 GHz to 2.55 GHz) in the 2.45 GHz ISM band and 4.82 % (0.28 GHz, ranging from 5.62 GHz to 5.9 GHz) in the 5.8 GHz ISM band. As we can see, the 10-dB return loss bandwidths are wide enough to cover the required bandwidths in free space and on the phantom, which means that the proposed antenna is suitable for WBAN applications.

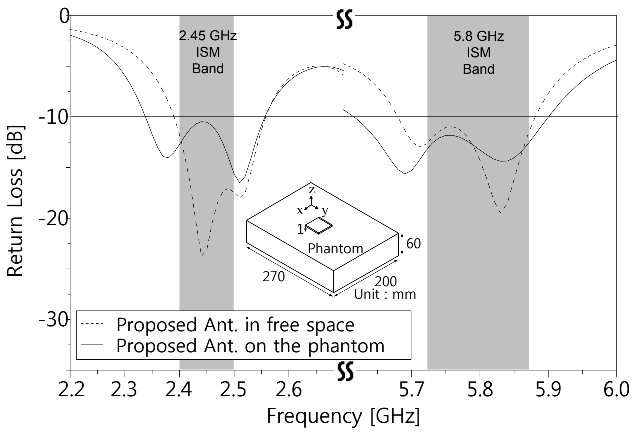
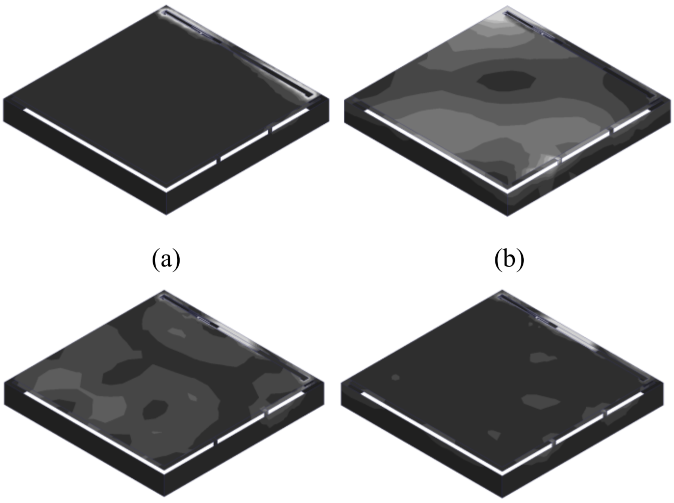


Fig. 2. Simulated return loss characteristics of the proposed antenna in free space and on the phantom

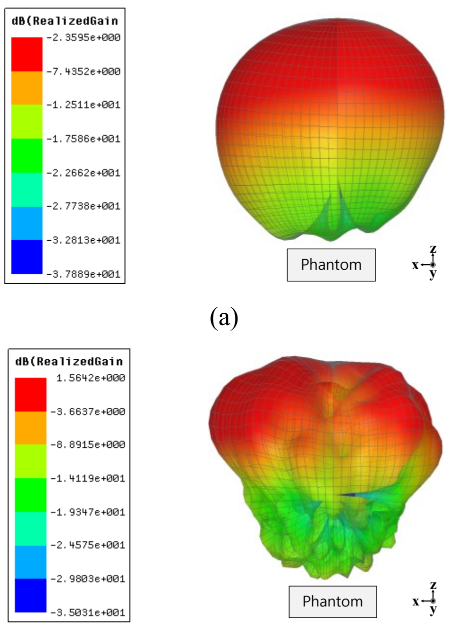
Fig. 3 shows the simulated current distributions of the proposed antenna. The slot on the metal back-cover is excited by the coupled feed and generates a resonance at 2.44 GHz as shown in Fig. 3 (a). Then, two parasitic elements connected to the ground excite TM_{11} mode at 2.51 GHz as shown in Fig. 3 (b). Another parasitic element and two shorting strips are used for 5.8 GHz ISM band. The resonance at 5.71 GHz is generated along the feed structure as shown in Fig. 3 (c). The induced current on the parasitic element generates the resonance at 5.83 GHz as shown in Fig. 3 (d). Two shorting strips control the current flows between the metal back-cover and the metal rim in both 2.45 GHz ISM band and 5.8 GHz ISM band. These dual resonances in both ISM bands widen the practical bandwidths and possibly compensate for the frequency shifts due to the human body effect.



(a) (b) (c) (d)

Fig. 3. Simulated current distribution at each resonance frequency (a) 2.44 GHz, (b) 2.51 GHz, (c) 5.71 GHz, (d) 5.83 GHz

Fig. 4 shows the simulated 3D radiation patterns of the proposed antenna on the phantom. The peak gains of the proposed antenna are -2.35 dBi at 2.4 GHz and 1.56 dBi at 5.8 GHz. Since the direction of the maximum radiation is toward outside in both 2.45 GHz and 5.8 GHz ISM bands, it is expected that the WBAN applications can communicate with external devices effectively.



(a)

(b)

Fig. 4. Simulated far-field radiation patterns of the proposed antenna (a) 2.4 GHz, (b) 5.8GHz

III. Conclusion

In this paper, a dual-band slot antenna with metal back-cover and metal rim for WBAN applications is proposed. In our design, the human body effect was considered and verified on the human equivalent flat body phantom while the previous antenna researches about metal surroundings did not consider the human body effect. The proposed antenna has enough 10-dB return loss bandwidths to cover 2.45 GHz and 5.8 GHz ISM bands in free space and on the phantom. In addition, the radiation patterns of the antenna are outward directional on the phantom. Therefore, all results imply that the proposed antenna with metal surroundings is applicable for WBAN applications.

Acknowledgment

This work was supported by Samsung Electronics.

References

[1] P. S. Hall and Y. Hao, Antennas and propagation for body-centric wireless communications, Artech House, Norwood, Mass, USA, 2006.

[2] J. Zhong, R. M. Edwards, L. Ma, and X.-W. Sun, "Multiband slot antennas for metal back cover mobile handsets," Progress In Electromagnetics Research Letters, Vol. 39, 115-126, 2013.

[3] Yong-Ling Ban; Yun-Fei Qiang; Zhi Chen; Kai Kang; Jin-Hong Guo, "A Dual-Loop Antenna Design for Hepta-Band WWAN/LTE Metal-Rimmed Smartphone Applications," *Antennas and Propagation, IEEE Transactions on* , vol.63, no.1, pp.48,58, Jan. 2015

[4] Gabriel C 1996 Compilation of the dielectric properties of body tissues at RF and microwave frequencies Armstrong Laboratory, Brooks Air Force Base, Tech. Rep. AL/OE-TR-1996-0037.