

# Robust Wideband Printed Antennas for Body-Centric Communications \*

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## ABSTRACT

A wideband printed antenna designed for body-centric communications is presented. Its very wide bandwidth extending from 4 to 9.5 GHz is obtained by applying several bandwidth enhancement techniques on the radiator while keeping a full ground plane intact on the other side of it. The proposed antenna was simulated in free space and in very close proximity to a frequency dependent homogeneous human muscle-equivalent phantom. The results reveal that the antenna is robust against both human body loading and structural deformation, indicating that it is a very promising candidate for body-worn applications.

## Categories and Subject Descriptors

D.2.8 [Hardware]: Performance and reliability—*general, performance analysis and design aids, miscellaneous*

## General Terms

Design, Performance

## Keywords

Body-centric communications, body-worn antenna, full ground plane, printed antenna, wideband antenna

## 1. INTRODUCTION

In comparison to any other wireless networks, body-centric communications have special requirements of antennas to provide a reliable link. It is due to a well-known fact that the antennas' characteristics such as impedance bandwidth, radiation pattern, gain, and efficiency are significantly affected by close proximity to the lossy human body tissues. Thus, antennas with a higher degree of isolation from human body

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would be advantageous. With a low antenna-body coupling level, not only the antenna performance can be maintained, but also the impact of such wearable antennas on the body tissues e.g. maximum specific absorption rate (SAR) can be reduced. In addition to the high isolation level, antennas are also required to possess low profile, lightweight, and robust characteristics, as many of emerging personal wireless technologies demand for more cost-efficient and smaller devices.

Printed antennas are considered as a promising solution for the above mentioned requirements owing to their favourable characteristics such as planar structure, physical robustness, low cost, and ease of manufacture. Moreover, they can be realized using flexible materials ensuring deformability and good ergonomics, which are also important for body-worn applications. Several wearable printed antennas with a very wide bandwidth have been proposed, including coplanar waveguide (CPW)-fed antennas [8], [9] and antenna with modified ground plane [10]. The motivation of this research is to design a wideband antenna that preserves a full ground plane to suppress backside radiation towards the human body and to reduce the antenna sensitivity to the human body. Previously in [1]–[4] printed antennas with full ground planes have been presented, however, they focus on narrowband designs only.

In this paper, a printed antenna with a very wide bandwidth of 4 – 9.5 GHz is presented for off-body communications. The antenna is designed with a full ground plane, thereby providing insensitivity to the proximity of the human body. The performance of the proposed antenna are verified numerically on direct contact with a frequency dependent homogeneous human muscle-equivalent phantom. It is revealed that the antenna is very stable with respect to the human body loading as well as structural deformation.

## 2. ANTENNA DESIGN AND PERFORMANCE

The configuration of the proposed antenna is shown in Fig. 1(a). It consists of three arc-shaped radiator patches and a ground plane printed on opposite interfaces of a Rogers RO3003 substrate with a dielectric constant of 3 and a thickness of 3 mm. As opposed to the partial ground planes that most wideband printed antennas have, this antenna has a full ground plane. It is well known that a conventional thin patch antenna with a full ground plane configuration is inherently narrowband. Thus, to achieve a very wide band-

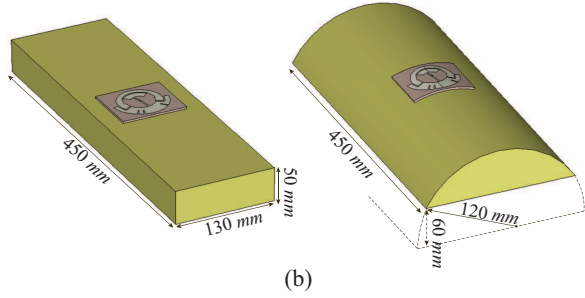
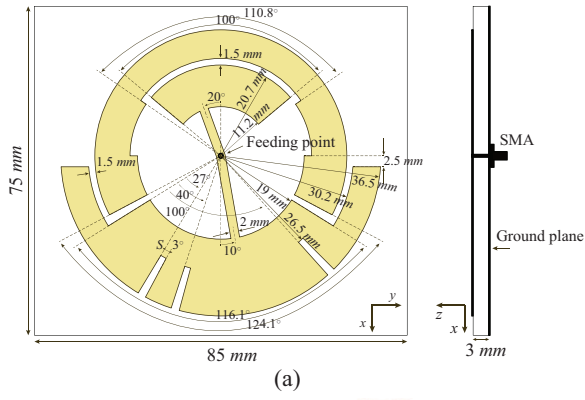


Figure 1: (a) Geometry of the proposed antenna: top view (left) and side view (right). (b) Configuration of the antenna on top of rectangular (left) and cylindrical (right) phantom.

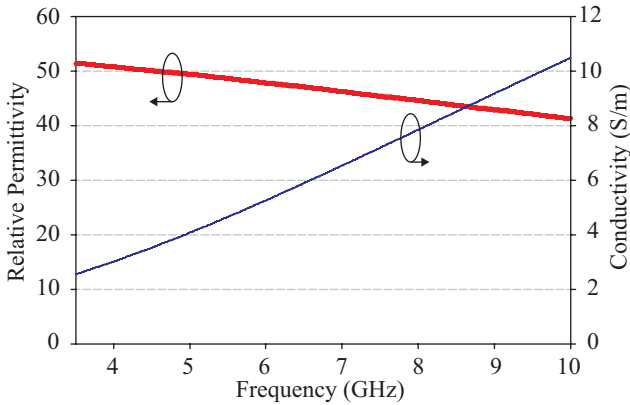


Figure 2: Characteristic of the phantoms.

width, several bandwidth enhancement techniques, such as inclusion of multiple resonators [6], slots [7], and parasitic element [11] are applied. The antenna are designed by firstly combining two arc-shaped patches, each fed by two small transmission lines connected to a coaxial probe on the opposite side of the substrate. The smaller and bigger patches operate in higher and lower bands, respectively. To extend the bandwidth in the low band, three slots with the length of less than a quarter of the effective wavelength at the lowest target frequency operation (4 GHz) are added. Lastly, to improve the impedance matching throughout the bandwidth, therefore enabling a combined wideband resonance for the proposed antenna, an arc-shaped parasitic patch is

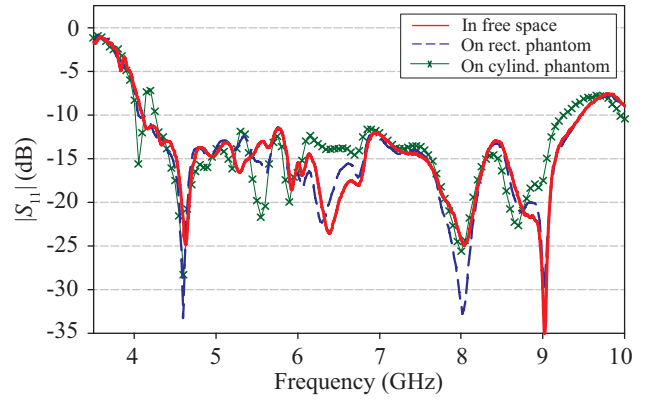


Figure 3: Computed  $|S_{11}|$  of the proposed antenna.

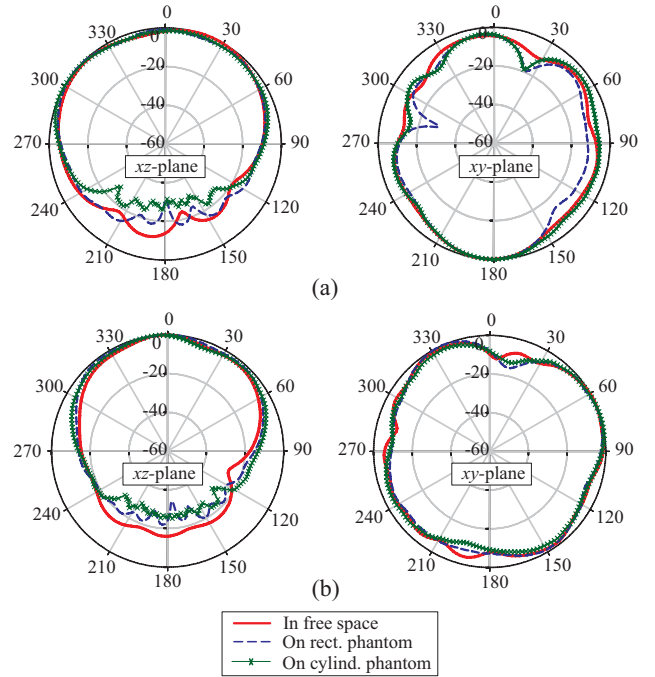
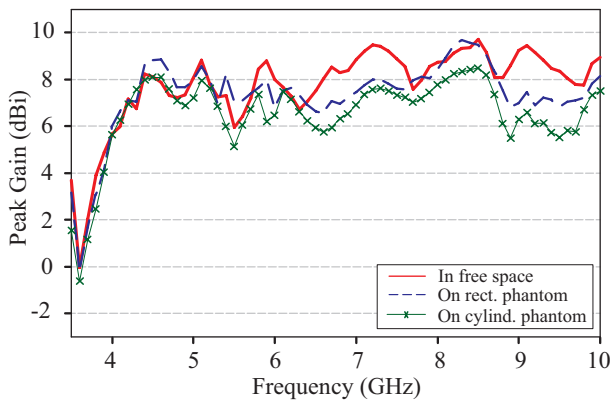


Figure 4: Computed radiation patterns of the proposed antenna at (a) 5 GHz and (b) 7 GHz.

positioned in the proximity of the main patches' radiating edges.

To analyze the performance of the antenna in the presence of human body, two human muscle-equivalent phantoms with Cole-Cole dispersive characteristic shown in Fig.2 were used [5]. The antenna was located directly on the top surface of both rectangular and cylindrical phantoms as depicted in Fig. 1(b). The latter scenario is to mimic the case when the antenna becomes conformal to the human body surface. Thus, the radius of the cylindrical phantom also denotes the bending radius of the antenna. The size of the cylindrical phantom was modified to reduce the computation time.

The comparison between the computed return loss of the proposed antenna in free space and that on the phantoms



**Figure 5: Computed peak gains of the proposed antenna.**

are shown in Fig. 3. As can be seen, the proposed antenna maintains a robust input impedance even when it is placed directly on the surface of both human muscle tissue models. Good matching performance is achieved that maintains the return loss above 10 dB within a very wide bandwidth extending from 4 to 9.5 GHz on the flat surface and from 4.2 to 9.3 GHz on the cylindrical surface.

The stable input impedance indicates a high degree of isolation between the antenna and the phantom. To verify this, the far field patterns of the antenna are shown in Fig. 4. As predicted, due to the full ground plane, the proposed antenna radiates mainly towards its normal direction making it suitable for off-body communications. This characteristic remains stable when the antenna is placed on the phantom as well as when the antenna is conformed. The computed peak gains are given in Fig. 5. They vary between 5.76 dBi and 9.7 dBi over the operating bandwidth. After considering all possible losses, average total efficiency is 92.3% in the free space, 82% with the rectangular phantom, and 80% with the cylindrical phantom.

### 3. CONCLUSION

A wideband printed antenna suitable for off body-centric communications has been presented. Unlike the previous wearable wideband printed antennas, the proposed antenna provides a very wide bandwidth with a full ground plane, which delivers the necessary isolation between the antenna and the human body. The bandwidth of 75% and an average gain of 6.9 dBi with 80% average total efficiency over the operating bandwidth are achieved even in a very close proximity with the cylindrical phantom. The antenna also shows robust performance to structural deformation.

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