Recent Developments in Antennas with Full Ground Planes for Wireless Body Area Networks (Invited Paper)

Syed Muzahir Abbas[*†], Yogesh Ranga[*], Karu P. Esselle[*], Stuart G. Hay[†]

[*]Department of Engineering, Macquarie University, North Ryde, NSW 2109, Australia

[†]CSIRO Digital Productivity Flagship, PO Box 76, Epping, NSW 1710, Australia

syed.abbas@mq.edu.au, yogeshwar.ranga@mq.edu.au, karu.esselle@mq.edu.au, stuart.hay@csiro.au

***Abstract* — This paper highlights recent developments in antennas with full ground planes, which have been designed for Wireless Body Area Networks (WBANs). These antennas are designed to provide single/dual band operation in 2.4GHz industrial, scientific and medical (ISM) band and 4.9GHz public safety wireless local area network (WLAN)/5GHz IEEE 802.11 WLAN bands. They have significant advantages of compactness, wide radiation pattern over the body surface, and less sensitivity to the variation of the gap between the antenna and the human body. These advantages make them suitable for on-body communications and wearable applications.**

***Index Terms* — Printed antenna, Full ground plane, Electromagnetically-coupled feed, On-body communication, Wearable antenna, WLAN, ISM, Wireless body area network, Wireless body centric communication.**

I. Introduction

With the advancements in wireless communications, there is a constant need to develop novel antennas and components to support modern communication systems. Body Centric Wireless Communication (BCWC) is a fast growing research area in modern communication, targeted for applications in personal communication, healthcare, defense, sports and public security [1-3]. The antenna is a vital front end component in any wireless system. Although many narrow- and wide-band antennas have been designed over past decades, still there are several challenges when designing such antennas for modern systems. These challenges include compactness, space constraints, desired radiation characteristics, low cost, light weight, multi-band operation, interference mitigation, reconfigurability, and stable performance under varying conditions.

For wearable antennas intended for on-body communications, the challenge is to achieve a wide beamwidth over the body and around, and to make antenna input matching less sensitive to potentially varying distance between the antenna and the human body [4]. The wide beamwidth helps to provide maximum coverage over the body surface. In addition to wide beamwidth, by confining the radiation over the body surface off-body communication can by reduced thus better on-body communication can take place. Moreover, backward radiation that could go into the human body and possibly can be harmful, needs to be minimized. To meet these challenges, antennas with full ground planes are valuable.

In past, we have reported several narrow-band antennas with full ground planes for wireless body area networks [5-11]. These antennas provide single- and dual-band operation for the 2.45GHz ISM band and for 4.9GHz public safety WLAN/5GHz IEEE 802.11 WLAN. These antennas have significant advantages of compactness (only 14mm wide), full ground plane that reduces radiation towards the body, a wide radiation pattern over the body surface to provide maximum coverage, and less sensitivity to the variation of the gap between the antenna and the human body. These advantages make them suitable for on-body communications and wearable applications.

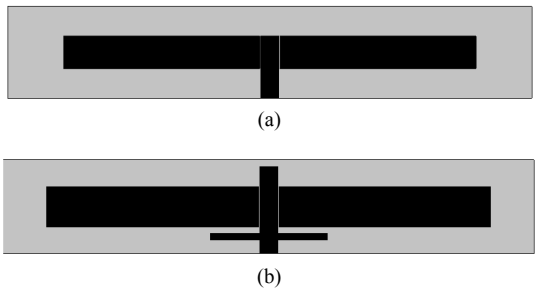

Fig. 1. Single band antennas with a full ground plane and (a) electromagnetically-coupled feed (b) electromagnetically-coupled feed with stub loading.

II. Single-Band Antennas

A printed antenna with full ground plane and electromagnetically-coupled feed to operate in 2.4GHz ISM band has been presented in [5]. The electromagnetically-coupled feed is used to achieve in-phase current in two radiating elements and the full ground plane is used to minimize the backward radiations that could potentially be

harmful for human body tissues. This antenna has a wide radiation pattern over the body surface, and is less sensitive to the gap variation between the antenna and the human body. It has a null at the feed that needs to be filled. For this purpose, the feed has been modified and is extended in length [6]. A stub has also been introduced in the feed to have better impedance matching as shown in Fig. 1(b). The antenna with modified feed has wide radiation pattern over the body surface that has a partially filled null along the feed line. By applying bending to the design, omni-directional radiation pattern in the plane parallel to the human body is noted. The modified design is also less sensitive to the gap variation between the antenna and the human body, and the wide radiation pattern helps to provide maximum coverage.

III. Dual-Band Antennas

In [7], a printed dual band antenna for 2.45GHz ISM band and 4.9GHz public safety WLAN has been reported and is shown in Fig. 2. This antenna also takes advantage of full ground plane to minimize backward radiations towards the human body, in addition to electromagnetically-coupled feed to achieve in-phase current in radiating elements. By inserting a slit in one radiating element, dual band characteristics are obtained. By variation of the length of slit, the higher frequency band can be moved. The antenna exhibits wide radiation patterns over the body surface and is less sensitive to the gap variation between the antenna and the human body.

Fig. 2. Dual band antenna with a full ground plane and electromagnetically-coupled feed.

IV. Conformal Antennas

A printed antenna for wearable armband and other such applications, shown in Fig. 3, has been reported in [8]. The antenna is designed for a flexible substrate and to operate in 2.45GHz ISM band. It also makes use of a full ground plane and electromagnetically-coupled feed. This antenna has been analyzed in close proximity to human arm when conformal bending is applied. Results show that the antenna exhibits a wide radiation pattern and is highly insensitive to the conformal separation between the antenna and the human arm.

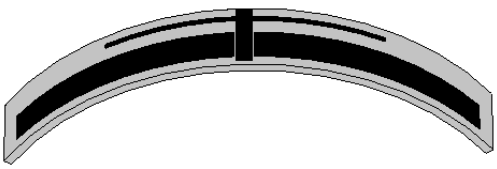

Fig. 3. Conformal antenna with a full ground plane and electromagnetically-coupled feed with stub loading.

Fig. 4. Switchable antenna with a full ground plane and stub loading.

V. Switchable Antennas

A printed antenna with full ground plane for 2.45GHz ISM band and 5GHz IEEE 802.11 WLAN has been presented [9]. It uses several switches to add reconfigurability to the design and is capable of switching between the above mentioned two frequency bands. This antenna also exhibits a wide beam radiation pattern to provide maximum coverage along the body surface that makes its suitable for on-body applications. In [10], a partial ground plane has been used and the performance has been compared with the antenna having a full ground plane. This analysis and findings on antenna gain and bandwidth trade-off are helpful for antenna selection.

VI. Near Body Analysis

The antenna reported in [8] has been investigated in close proximity to different human arm models when no bending is applied to it [11]. The investigation shows that by placing antenna along the length of the human arm, bending can be avoided. An inherent shift in resonance frequency has been noted when bending is applied but it can be retuned using the design parameters. However, under bending, retuned antenna is less sensitive to the conformal gap between the antenna and the human arm. Results illustrate that placement of antenna along the arm length helps to provide better coverage and also avoids bending. Furthermore, it is also insensitive the gap variation between the antenna and the human body. These reasons make is suitable for wearable applications.

VII. Conclusion

We have discussed several antennas that have utilized full ground planes to minimize backward radiation, which can potentially be harmful to the human body. These antennas include single-band, dual-band, conformal and switchable antennas. Their performance in near body scenario has been discussed. These antennas have significant advantages of narrow width, less sensitivity to gap variation between the antenna and the human body, a full ground plane, and wide beam radiation over the body surface for maximum coverage. These advantages make them suitable for on-body applications.

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