Efficient Printed Antenna for Body Wearable UWB Applications

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***Abstract*—A wideband antenna suitable for body area networks is presented. The antenna ensemble consists of a wideband dipole, a spacer element and a back patch. The back patch helps direct the energy efficiently into the forward hemisphere. The low profile antenna displays a VSWR < 2:1 over 3 – 10 GHz. The front-to-back ratio is greater than 3 dB over this frequency range. Both theoretical and experimental investigations of the proposed antenna are presented.**

***Index Terms*—UWB Antennas, Printed Antennas, Body Area Networks, BANs**

I. Introduction

RECENTLY there has been substantial research and development efforts into Body Area Networks (BANs) [1, 2]. Applications range from health care [3], to military (for example, heads-up displays [4]) to consumer electronics (such as Google Glass [5]). All these applications share common themes of being required to operate over short distances (2 to 5 meters), consume low power, potentially supply high date rates and provide highly reliable wireless communications in close proximity to the human body. There are several wireless standards used in BANs [6] and the radio technology incorporated typically will be set by the required data rate for the application. Ultra-Wideband (UWB) is utilized when large transmission bandwidths are required, for example to deliver high definition video. UWB can be referred to as any radio technology with a transmission bandwidth larger than 500 MHz or 20% of the center frequency [7]. FCC regulates the use of UWB in a license-free band within the frequency range of 3.1 – 10.6 GHz.

As is well known, the human body is a very challenging electromagnetic (EM) environment for an antenna to be in close proximity to, as the body will impact the performance (reflection coefficient and efficiency). Naturally, user safety is also an issue. For UWB applications, this latter point is not a concern due to the low transmit power levels [7], however to ensure the EM performance of the antenna is optimum, some form of isolation is required between the antenna and the body. For these reasons there has been a lot of R&D conducted on body wearable antennas and technologies (for example, [8 – 13]).

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In this paper we present a new UWB antenna that can be incorporated in BANs. The antenna is based on a wideband printed dipole and incorporates a back-patch concept [14] to ensure that power is radiated from the user and also allow the antenna to be mounted on the body without impacting its efficiency and reflection coefficient. The antenna displays good reflection coefficient performance, efficiency, and radiation patterns over the entire UWB frequency band.

This paper is organized as follows. Section II provides a theoretical investigation of the proposed body wearable (BW) UWB antenna and also presents a design guide. Section III presents the experimental results for the antenna. In Section IV a theoretical investigation of the antenna when used in a BAN application is given; here the antenna is mounted on a helmet to be used in conjunction with wireless delivery of a video signal. Finally, conclusions of this effort are provided in Section V.

II. Theoretical Investigation of BW UWB Antenna

Fig. 1 shows a general schematic of the proposed BW UWB Antenna. The antenna consists of a wideband printed dipole, a ‘back patch’ [14] and a spacer material separating the two radiators. The design procedures for wideband printed dipoles are well-known (see for example, [15]) and so for the sake of brevity the process will not be repeated here. The concept of incorporating a back patch to reduce the radiation from an antenna in a particular direction was first introduced in [14] and subsequently applied to different antenna configurations in [16 – 18]. In [14, 16 – 18] the principle was applied to slot-based antennas however it can be readily applied to any form of radiator. More recently, this procedure of radiation cancellation using a parasitic radiator has been referred to as a form of ‘complementary’ antenna.

The design procedure for a back patch is relatively simple and details were provided in [16]. Importantly, the back patch concept provides a lower profile solution than a radiator backed by a ground-plane; of the order of 0.1 λ_0, where λ_0 is the lowest frequency of operation, as opposed to 0.25 λ_0. In addition, the back patch has minimal impact on the impedance properties of the primary radiator, thereby simplifying the overall design procedure. In general, the back patch is typically longer in length than the primary radiator. Naturally this length will influence the level of backward directed energy and for a space constrained environment, a compromise between overall size and FBR (front-to-back ratio) will occur.

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The design procedure for the antenna presented in Fig. 1 was carried out using a full-wave EM simulation tool (CST™). The wideband printed dipole was dimensioned to give a good impedance response over 3 – 10 GHz; here we chose a VSWR (Voltage Standing Wave Ratio) of less than 3:1. The back patch was then spaced approximately 0.1 λ_0 from the wideband radiator and the front-to-back ratio was observed. An overall size constraint for the antenna to be no longer than 40 mm was implemented which limited the FBR to be better than 3 dB over the entire 3 – 10 GHz. It should be noted that the designs in [14 – 16] achieved FBRs significantly better than 3 dB as the size of the back patch was not constrained. The dimensions of the radiator presented in Fig. 1 are given in the caption. To etch the conductors for this antenna, 0.5 mm thick Arlon 450 was used.

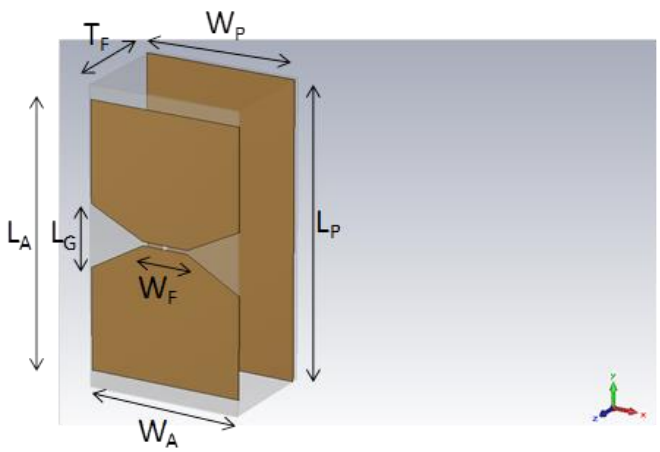

Fig. 1. Schematic of wideband antenna. Dimensions: L_A = 34 mm, W_A = 20 mm, L_P = 38 mm, W_P = 20 mm, T_F = 14 mm, W_F = 7 mm, L_G = 8 mm

Fig. 2 shows the predicted VSWR of the proposed UWB antenna. As can be seen from this plot, the antenna displays a well behaved impedance response over a wide bandwidth. Note that in the simulation, the antenna is excited by a delta function across the two arms of the dipole.

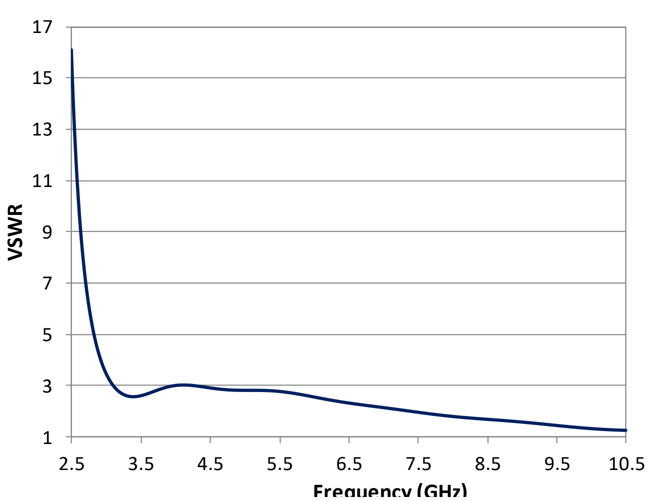

Fig. 2. Predicted VSWR of BW UWB Antenna.

Figs. 3 – 5 summarize the predicted radiation performance of the wideband antenna incorporating a back patch over the UWB frequency range. The antenna displays a relatively stable hemispherical pattern over 3 – 10 GHz with a FBR of greater than 3 dB over this entire frequency range.

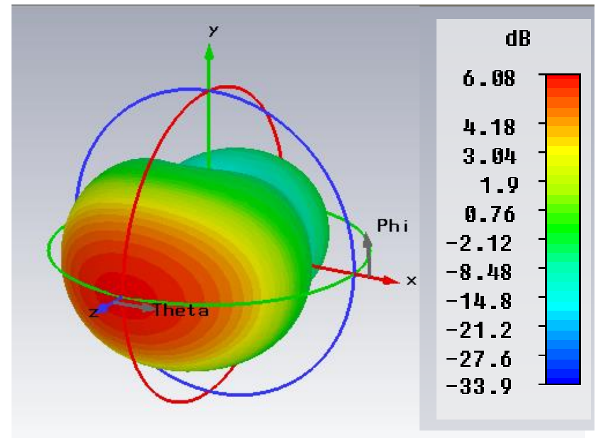

Fig. 3. Predicted radiation performance of BW UWB antenna at 3 GHz.

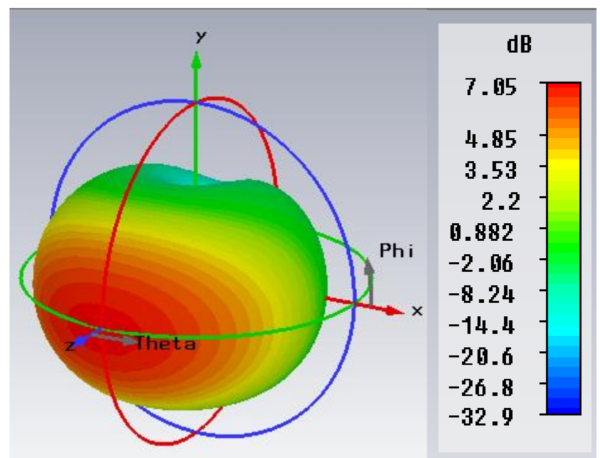

Fig. 4. Predicted radiation performance of BW UWB antenna at 6 GHz.

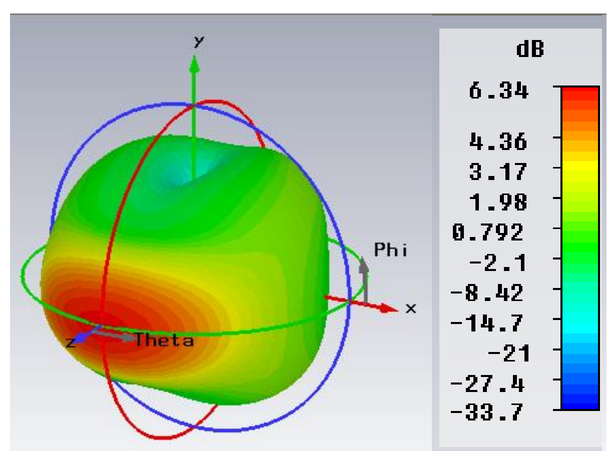

Fig. 5. Predicted radiation performance of BW UWB antenna at 10 GHz.

III. Experimental Investigation of BW UWB Antenna

A prototype of the proposed antenna was developed and a photograph of the assembly is shown in Fig. 6(a). The spacer for the antenna was a soft packing foam and the antenna is fed by an RG316 cable across the dipole. Fig. 6(b) highlights how the RF cable was soldered to the wideband dipole. A small bracket was used to clamp the cable to the radiator, thereby providing a more robust solution. Interestingly a balun was not included in our solution. Originally we did consider one however we found that the added complexity associated with such a structure was not warranted, especially given the results achieved with the simplified feeding approach.

(a)

(b)

Fig. 6. Photograph of: (a) BW UWB antenna; (b) cable feed.

Fig. 7 presents the measured VSWR of the antenna (the predicted results are also included). As can be seen when comparing this plot to the predicted results, the measured performance is actually slightly better than the theoretical predictions with the VSWR < 2:1 over 3 – 10 GHz. This can be attributed to several factors including the simplified feed model used in the simulation (and its location), the 6-inch cable used to feed the antenna in the experiment, and the losses in the spacer which were not taken into consideration. Despite the discrepancy the results are in good agreement.

The measured azimuth (X-Z) radiation patterns of the antenna are shown in Fig. 8. Once again, comparing these plots to those presented in Figs. 3 – 5, we can see that the measured results are in good agreement with the simulations. The measured FBR is greater than 3 dB and the measured gain was within 1 dB of the results presented in Figs. 3 – 5.

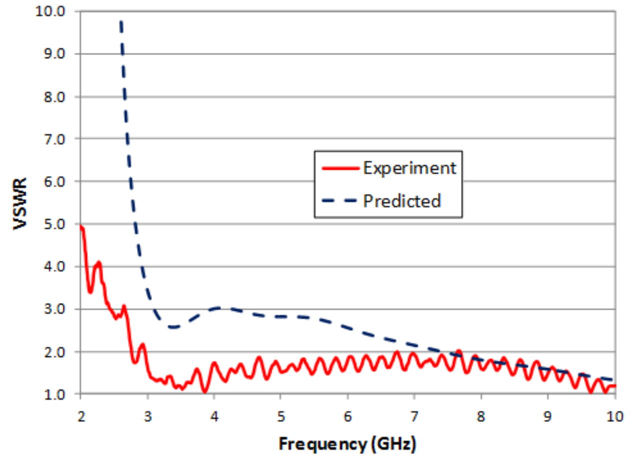

Fig. 7. VSWR of BW UWB antenna.

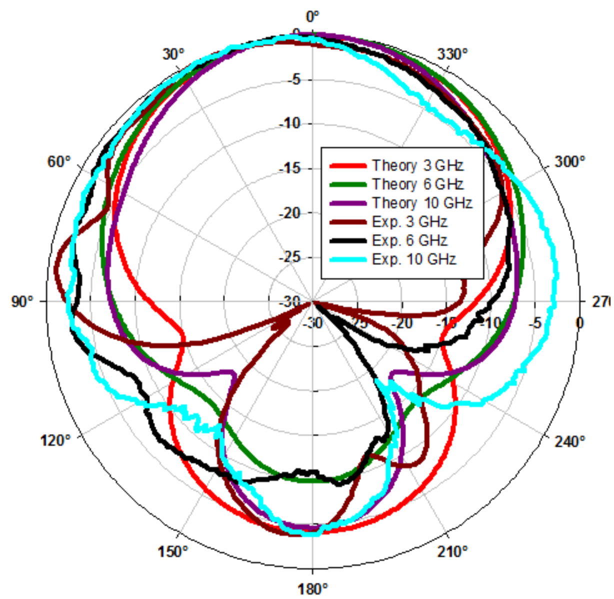

Fig. 8. Measured azimuth radiation patterns of BW UWB antenna.

IV. Application of UWB Antenna

As discussed in Section I there are many BAN applications that could utilize the proposed BW UWB antenna. One such military application is for a soldier communication system [4]. Here video data is sent to the user via a UWB link and is viewed on the soldier's heads-up display. In this scenario the antenna would be mounted on the soldier's helmet. Fig. 9 shows the predicted VSWR of the antenna when mounted on the front of a helmet (made of Kevlar). The results are very similar to that presented in Fig. 2 highlighting that the antenna is not impacted by its mounting environment. An example of the radiation performance is shown in Fig. 10 which is very similar to the performance when no helmet is present.

Fig. 11 shows the predicted radiation performance of the UWB antenna when the viewer (assumed to be metallic) and its horn (to attach the viewer to the helmet) are included in the model. The antenna is located next to the horn. Although the presence of the viewer does impact the radiation performance, the antenna still radiates in the desired direction.

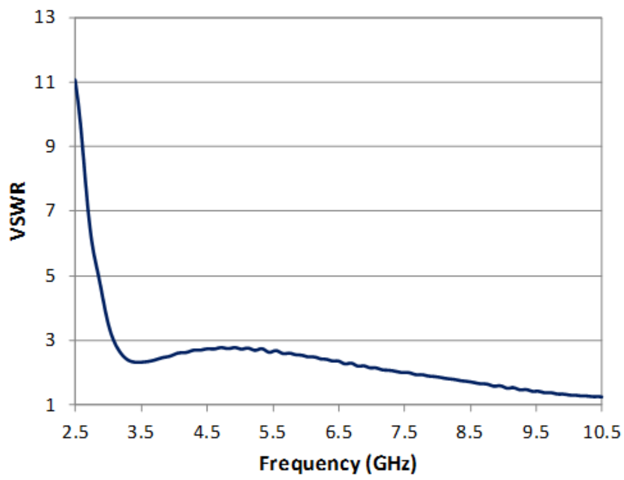

Fig. 9. Predicted VSWR of BW UWB antenna when mounted on a helmet.

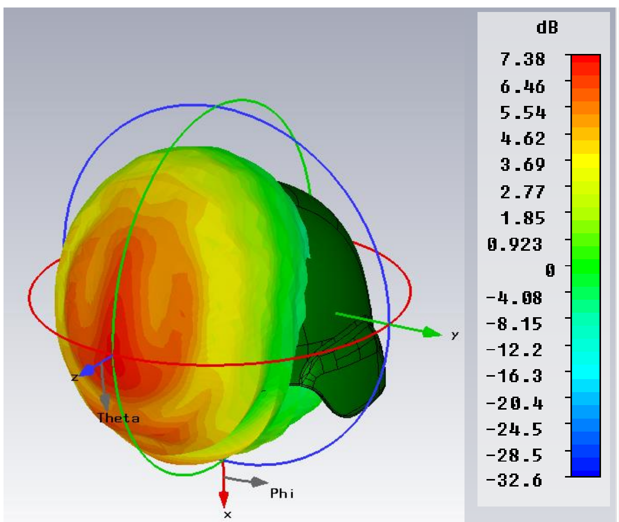

Fig. 10. Predicted radiation performance of BW UWB antenna on helmet at 6 GHz.

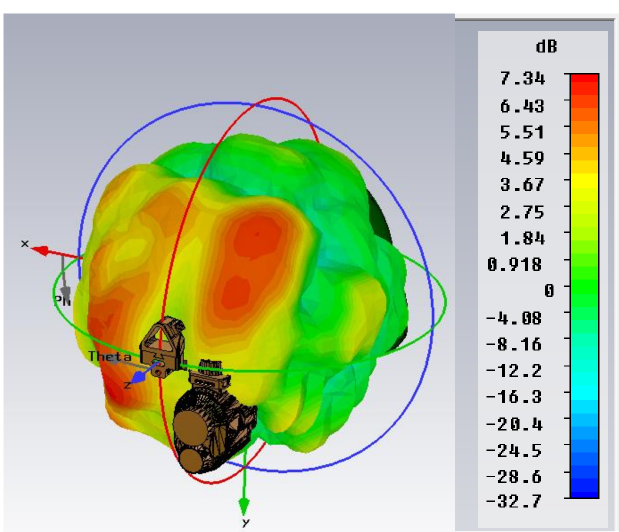

Fig. 11. Predicted radiation performance of BW UWB antenna on helmet in presence of viewer and horn at 6 GHz.

V. CONCLUSION

We have presented a UWB antenna suitable for body area networks. The antenna consists of a wideband dipole and a back patch that helps control the radiation performance of the antenna. The 38 mm × 20 mm × 14 mm antenna has a VSWR less than 2:1 and a FBR greater than 3 dB over the 3 – 10 GHz frequency range. The proposed design offers an efficient UWB solution that can operate relatively independent of the mounting environment thereby increasing its utility. The proposed UWB antenna can be incorporated in a variety of applications and is particularly useful for body area networks.

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