Design of a Compact UWB Diversity Antenna for WBAN Wrist-Watch Applications

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***Abstract*- This paper presents a compact ultra-wideband diversity antenna for wireless body area network wrist-watch applications. The antenna is designed based on a folded monopole antenna with a stub in order to achieve wideband characteristic. The proposed antenna has a size of 40 mm × 40 mm × 5 mm and operates at a frequency range of 2.9-5.1 GHz. The analysis of the antenna performance was carried out when it was placed on the human body equivalent flat phantom. Simulated results show that S_{11} is lower than -10 dB and the isolation ($|S_{21}|$) is better than 15 dB across the UWB low band (3.1-4.8 GHz).**

Index Terms* — *Ultra-wideband, diversity antenna, wireless body area network, on-body communication

I. Introduction

There has been a lot of interest in wireless body area network (WBAN) applications such as biomedical, military and commercial services. An antenna used for WBAN system is desired to have small size, wideband characteristic and low specific absorption rate (SAR). These applications need high data rate to perform processing much data including high-definition video. At the same time, wearable devices are required to observe small power consumption (~ 1 mW/Mbps) [1]. When an antenna operates near the human body which has high dielectric constant, a high loss tangent and low conductivity, the performance of the antenna can be deteriorated. The multipath fading also is occurred by the movement of body parts, shadowing and scattering over the body. In order to overcome the human body effect and improve the antenna performance, UWB diversity technique is a good candidate for applying to WBAN systems [2].

UWB antennas have been studied for WBAN system especially for on-body applications recently [3-5]. In [3], the loop antenna with high gain characteristic was proposed. However, the antenna is sensitive so that the radiation property may not be maintained if the antenna was installed on a human wrist. The on-body directional antenna was presented in [4]. The antenna size was not adaptable to use for watches. In order to miniaturize the antenna size, a dual-port antenna with pattern diversity was reported in [5]. It had a good isolation property, but the feeding structure of the antenna was complex since the antenna has a central strip that extends vertically from the ground plane.

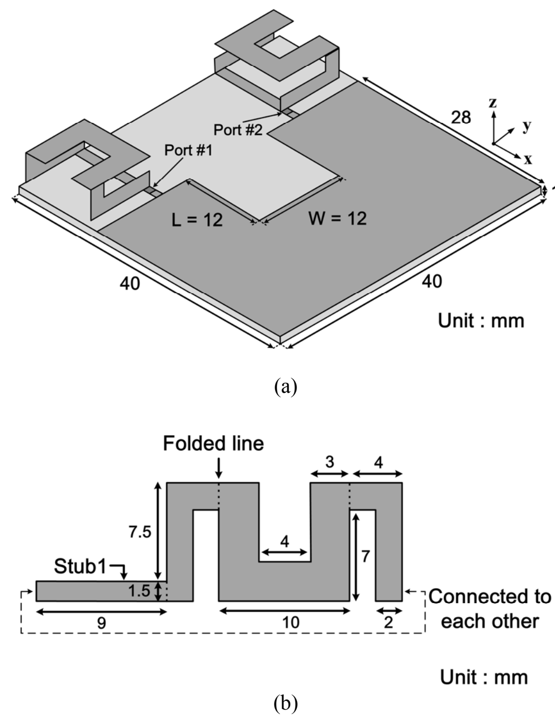


Figure 1. The proposed UWB diversity antenna:
(a) perspective view, (b) radiator structure

In this paper, we proposed a compact UWB diversity antenna for WBAN wrist-watch applications. To achieve a compact size of antenna and ultra-wide bandwidth, a stub1 is connected between side ends of each radiator. For the simulated result, the human equivalent flat phantom was set using dispersive physical properties which varied in terms of frequency [6].

II. Antenna Design

The configuration of the proposed antenna for WBAN applications is shown in Fig. 1. The proposed antenna has a dimension of 40 mm × 40 mm × 5 mm. An FR-4 dielectric with a relative permittivity of 4.4 is used as a substrate. The proposed antenna consists of two radiators which are placed symmetrically on the top corner of the ground plane. Each antenna element has a size of 10 mm × 9 mm × 4 mm and is fed by a 50 Ω coaxial cable.

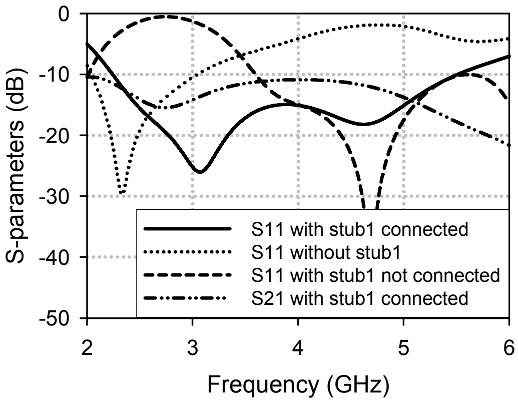


Figure 2. Simulated s-parameters for the variable stub1 in free space (without the slot)

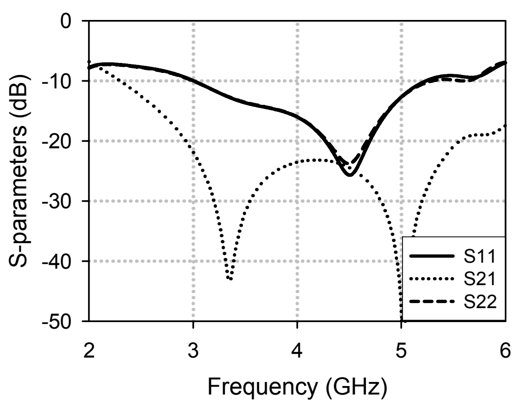


Figure 3. Simulated S-parameters in free space (W=L=12mm)

To analyze the effect of stub1, the s-parameters of the proposed antenna with the variable stub1 is illustrated in Fig. 2. The stub1 which has a dimension of 9 mm × 1.5 mm is connected both each end of the folded line. When the stub1 is absent on the radiator, the antenna is operated as a folded monopole at 2.3 GHz. When the stub1 exist on the radiator, but not connected to port, the resonance frequency is changed to lower than 2.3 GHz. However, when the stub1 is connected to the port, the resonance frequency of lower band becomes higher. Consequently, the wideband characteristic of the antenna can be achieved.

Fig. 3 shows the s-parameter of the proposed antenna in free space. By adding a slot placed on a center between port #1 and #2, the isolation property of the antenna is improved from 10 dB to 23 dB at 4 GHz. The 10dB impedance bandwidth of the proposed antenna is 53% and the isolation is less than 20 dB at the entire UWB low band (3.1 – 4.8 GHz).

III. Analysis of On-body Performance

Fig. 4 shows the human equivalent flat phantom having the dispersive property from [6]. Considering a wrist-watch application, a human wrist phantom (70 mm × 70 mm × 150 mm) is used and placed away from the antenna by a distance of 15 mm.

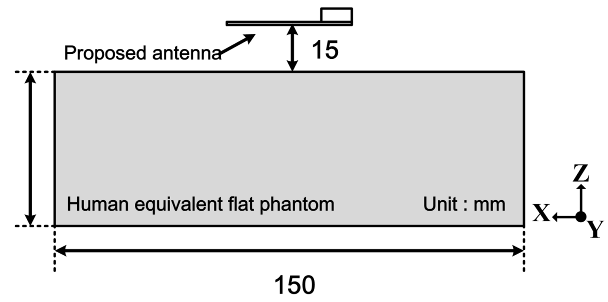
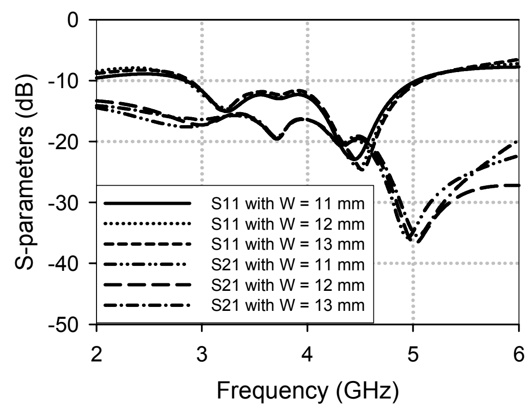
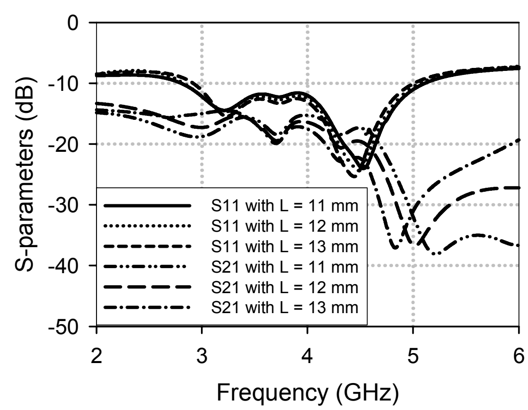


Figure 4. Human equivalent flat phantom for simulation



(a) Various values of width W



(b) Various values of length L

Figure 5. Simulated S-parameter characteristics of the proposed antenna on the flat phantom.

Fig. 5 shows the s-parameters characteristic for various lengths L and width W of the slot. Choosing the proper dimension of the slot is important because the isolation is dependent on the width and the length of the slot. When the length L and the width W were increased, the isolation is improved over the frequency of interest. To obtain optimized isolation characteristic, the proper width W and length L were chosen that of 12 mm and 12 mm, respectively.

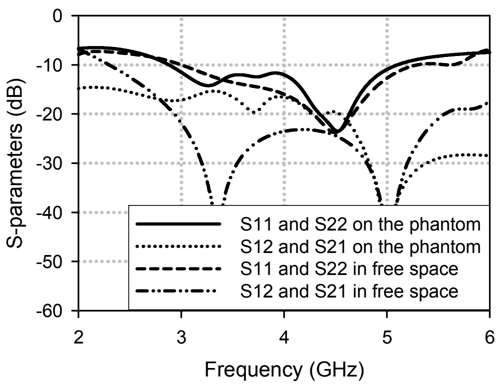


Figure 6. Simulated S-parameters characteristics.

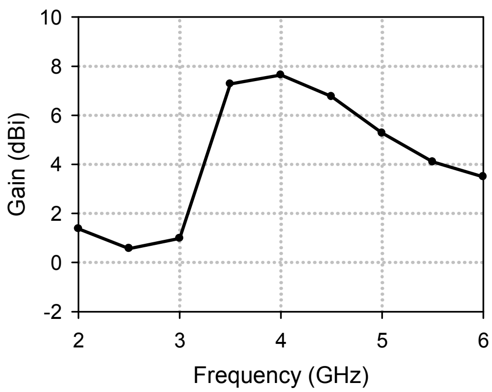
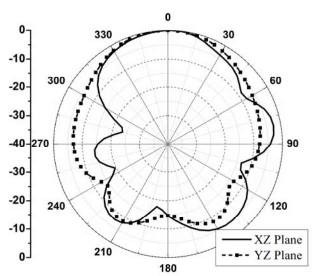
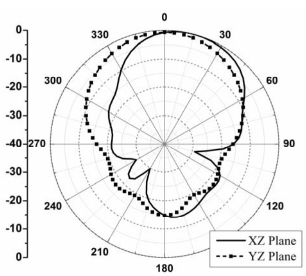


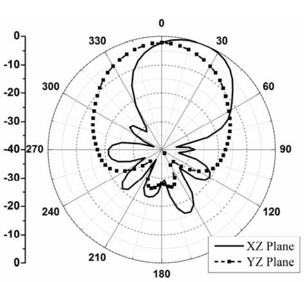
Figure 7. Simulated peak gain and radiation efficiency.



(a) 3 GHz



(b) 4 GHz



(c) 5 GHz

Figure 8. Normalized the radiation patterns.

In Fig. 6, the simulated s-parameters of the proposed antenna when the antenna is placed on the phantom and in free space are shown. 10 dB impedance bandwidth of the antenna is 55 % (2.9-5.1 GHz) and the isolation is greater than 15dB in the required frequency band.

Fig. 7 shows the simulated peak gain of the proposed antenna placed on the flat phantom. At 3 GHz, the peak gain is deteriorated in comparison with at 4 and 5 GHz because the electrical distance between the antenna and the phantom becomes larger as operating frequency decreases.

Fig. 8 shows the normalized radiation pattern of the antenna on flat phantom at 3, 4, and 5 GHz. The maximum power is delivered outward from the body and the front-to-back ratio of the antenna becomes larger as operating frequency increases. The reason of the phenomenon is according to the dispersive property of the phantom since conductivity increases when the frequency becomes higher.

IV. Conclusion

A compact UWB diversity antenna for WBAN wrist-watch applications is proposed in this paper. The proposed antenna was simulated on the wrist-shaped human equivalent flat phantom. S_{11} property satisfies lower than -10 dB and the isolation characteristic is higher than 15 dB over the whole UWB low band of 3.1-4.8 GHz. Radiation patterns of the antenna are toward off-body. Consequently, the proposed antenna can be a good candidate for UWB WBAN wrist-watch applications.

Acknowledgment

This research was funded by the MSIP(Ministry of Science, ICT & Future Planning), Korea in the ICT R&D Program 2013

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