Design and Performance Analysis of a Flexible UWB Wearable Textile Antenna on Jeans Substrate

Mustafa Turkmen and Husnu Yalduz

***Abstract*—This paper presents the design and analysis of a compact and flexible textile antenna for wireless body-area network systems. The presented antenna operates at a frequency range of 2.2 GHz to 17 GHz and covers the UWB frequency band. The antenna is designed from a jeans textile substrate with attractive features such as flexible and low dielectric properties. Copper tape was used for the radiator patch and ground plane of the antenna. The dimensions of antenna are 45 mm x 60 mm x 1 mm. In this study, the UWB antenna successfully evaluated the return loss (S11) and radiation pattern parameters under the planar condition and various bending conditions. It has been observed that the simulation result values of the antenna are suitable for UWB WBAN applications under planar condition and different bend conditions.**

***Index Terms*—Bend effect, textile antenna, wearable antenna.**

I. Introduction

In recent years, wireless body-area network (WBAN) systems are getting more attention due to their great potential applications such as health monitoring, sport, navigation, military and so on [1], [2]. As one of the vital components in the WBAN system for wireless communication with other devices on or off the human body, wearable antennas are important research works in both academia and industry [3], [4]. A microstrip patch antenna is commonly preferred in WBAN applications, but bandwidth limitation of conventional microstrip antennas is a main problem [5].

In conjunction with advances in the wireless communication systems, ultra-wide band (UWB) technology is becoming increasingly a very popular short-range wireless communication system with various attractive features which are large bandwidth, low power consumption and high data rate compared to other conventional narrowband communication systems. In 2002, the FCC identified a broad bandwidth 7.5 GHz bandwidth in the 3.1 - 10.6 GHz frequency range with low power spectral density (-41.3 dBm / MHz) and high data transmission as the UWB frequency band for commercial unlicensed use [6]-[13].

The antenna design for WBAN applications should be low cost, low profile, compact, flexible and easy to fabricate for the comfort of the user and modern wireless communication [9], [14]-[16]. As a consequence these WBAN requirements led to the combination of UWB technology and textile technology [6]. UWB textile antennas can be easily integrated into the garment, due to their small size and flexible construction. Textile materials are used as non-conductive substrate material or metallic radiating element for wearable antenna [17]. The use of non-conductive textile fabric as a substrate material helps to reduce antenna surface wave losses and increases band width with low dielectric constant [18]. Recently, many researchers have designed (studied) textile substrate antenna made of jeans [18], [19], felt [6], fleece [5] and Dacron [20]-[22]. Due to the flexibility of these textile material antennas, they are easily bendable according to the human body to provide comfort for the user, but the antenna should be kept to its maximum performance in the bending conditions. Therefore, flexible wearable antenna performance parameters should be analyzed under various bending conditions [23]. In [21] and [22], flexible antenna performance is investigated for return loss and radiation pattern parameters.

In this paper, the design of the UWB textile antenna for WBAN applications and the comparison of performance analysis simulation results of reflection loss and radiation pattern parameters between planar and various bending conditions are presented. The article, the results of simulation of the antenna, was obtained by simulation software of CST Microwave Studio (MWS).

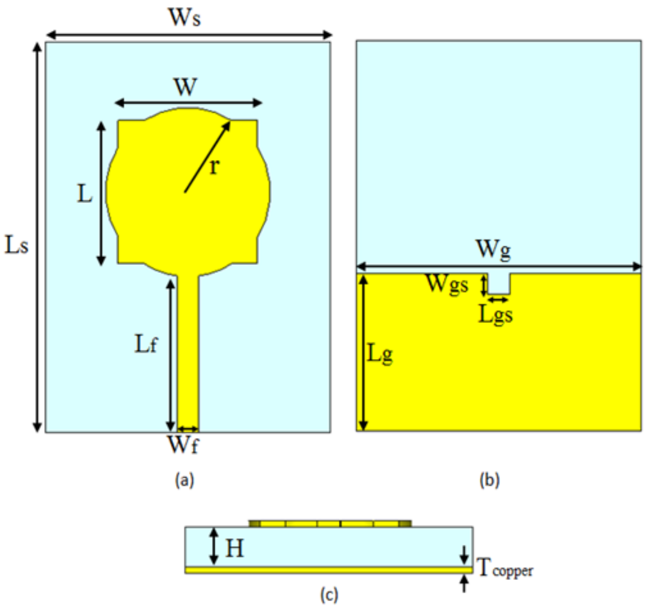

Fig. 1. Geometry of proposed antenna a) Front view, b) Back view, c) Bottom side view.

II. Antenna Design

The geometry front, back and bottom side views of the designed antenna with detailed dimensions in mm are shown

Manuscript received March 9, 2018; revised June 1, 2018.

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doi: 10.18178/ijiee.2018.8.2.687

in Fig. 1. Jeans textile material was chosen as a substrate with low dielectric constant (ε_r) of 1.68, tangent loss (tanδ) of 0.01and thickness of 1mm. The conductive component of the antenna (the radiator patch and ground plane) were used copper which has a thickness 0.02 mm. Fig. 1a shows the radiator patch and feedline structure in the front view of the antenna. The antenna is fed by a microstrip feedline dimensions of W_f x L_f (3.5 mm x 24.25 mm) for the 50 ohm impedance with SMA port. Radiator patch has a geometric structure that combines square and circular patches. Fig. 1b shows the ground plane with dimensions of W_g x L_g in the back plane of the antenna. A slot W_{gs} x L_{gs} was created on the ground plane. Detailed parameters of the final Antenna are given in Table I.

TABLE I: THE PARAMETER OF ANTENNA

Parameter	Value	Parameter	Value
Ws	45 mm	Wf	3.5 mm
Ls	60 mm	Lf	24 mm
H	1 mm	Wg	45 mm
W	22 mm	Lg	24.25 mm
L	22 mm	Wgs	3.6 mm
r	13 mm	Lgs	3.25 mm

III. PERFORMANCE OF SIMULATED TEXTILE ANTENNA

Flexible UWB Antenna design and simulation were performed using the CST MWS software simulation program. The return loss parameter of the antenna performance parameters is considered as the priority parameter for the design and the antenna is designed for planar conditions. After this parameter was successfully obtained, the performance of the other parameters was evaluated. Due to the flexibility of the antenna, antenna performance parameters (return loss and radiation pattern parameters) have been investigated in the free space for planar and bending conditions.

A. *Return Loss (S11) Parameter Analysis of Antenna Planar Configuration*

Fig. 2 shows the return loss frequency graph obtained for the antenna as a result of the simulation for planar conditions. This graph shows that the presented antenna operates over a wide band between 2.2 GHz and 17 GHz frequency, covering the UWB (3.1-10.6 GHz) frequency range.

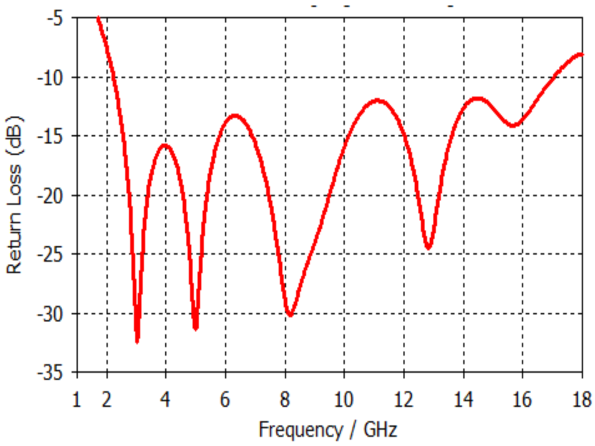


Fig. 2. Retun loss (S11) parameter graph of plannar antenna.

B. *Return Loss (S11) Parameter Analysis of Antenna Bending Configuration*

Because the wearable textile antennas are flexible, the human body can bend to different shapes on different diameters, but it is important that the antenna maintains its maximum performance in these bending conditions. In this study, the bending performance around the X axis and Y axis of the antenna for 30 mm, 40 mm and 50 mm radius values was analyzed by simulation.

Fig. 3 shows the structure of a flexible textile antenna bent around the X-axis. Fig. 4 comparatively shows the return loss versus frequency graph for planar (no Bend) and 30 mm, 40 mm, 50 mm bending radii of the antenna in the single graph. According to the graph, the antenna operation frequency band width is reduced from the upper frequency region around 1 - 1.5 GHz, in response to the increase in antenna bend level. However the antenna has a very wide operating frequency bandwidth covering the UWB frequency band.

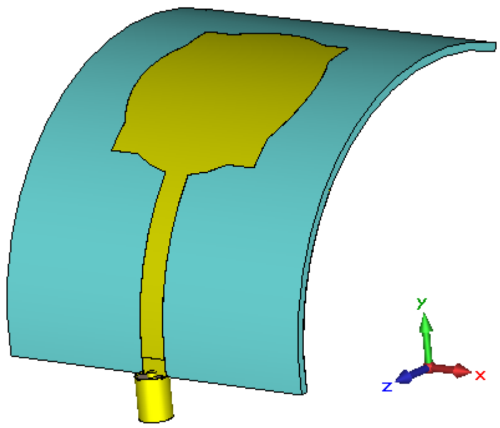


Fig. 3. Bending around X-axis of antenna.

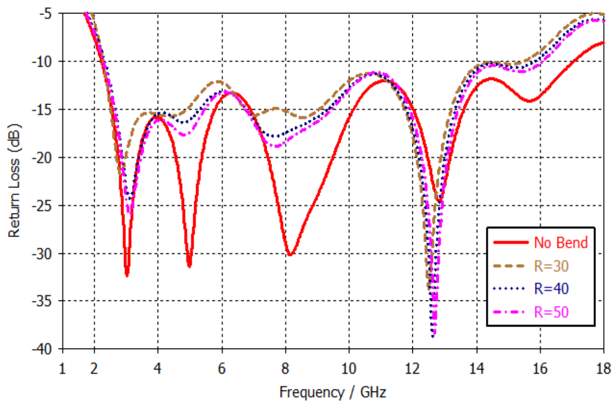


Fig. 4. Comparison of return loss graphs of antenna for different radii bending around X-axis.

Fig. 5 shows the structure of a flexible textile antenna bent around the Y-axis. Fig. 6 comparatively shows the return loss versus frequency graph for planar (no Bend) and 30 mm, 40 mm, 50 mm bending radii of the antenna in the single graph. According to the graph, the antenna substantially keeps the working frequency band and its width, in response to the increase in antenna bend level. According to these results, the UWB frequency band has a very wide working frequency bandwidth even in antenna X-axis or Y-axis bending conditions.

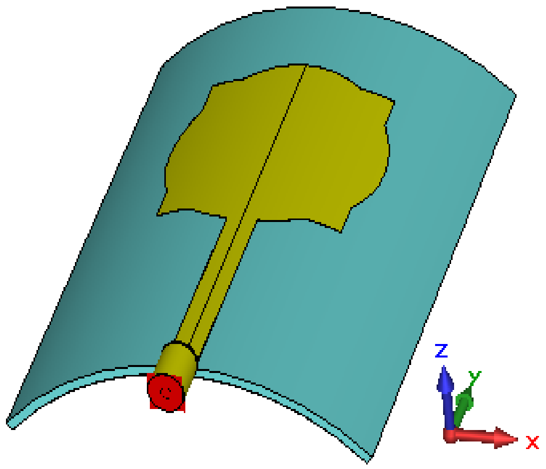


Fig. 5. Bending around Y-axis of antenna.

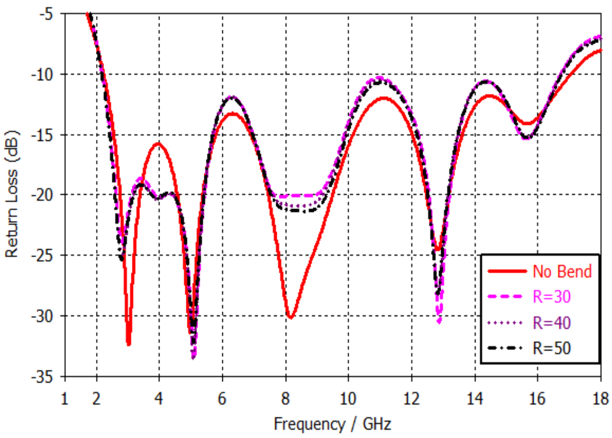
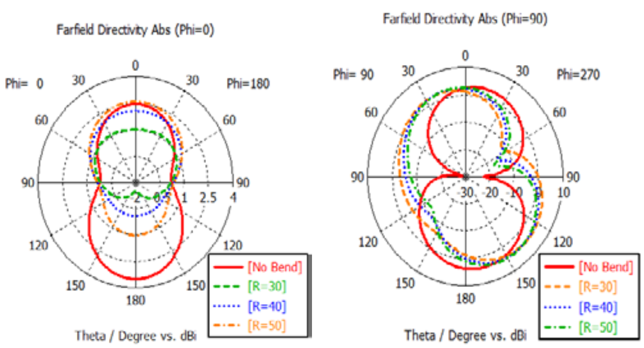


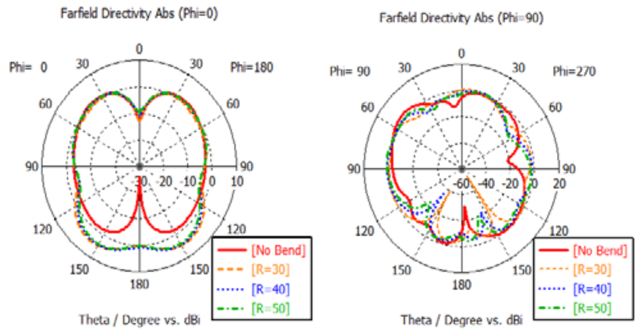
Fig. 6. Comparison of return loss graphs of antenna for different radii bending around Y-axis.

C. *Radiation Pattern Parameter Analysis of Antenna Planar and Bending Configuration*

The radiation pattern shows how the antenna directs the energy. Fig. 7 compares 2D radiation models (phi: 0 and Phi: 90) for different frequencies with respect to planar and X-axis bend states of the simulated antenna. Fig. 8 compares 2D radiation models (phi: 0 and Phi: 90) for different frequencies with respect to planar and Y-axis bend states of the simulated antenna. There is a change in the twist states of the antenna in both bent directions according to the planar situation. However, this change does not have a great influence on the radiation performance of the antenna. On the other hand, the bending radiation pattern around the antenna Y-axis is more stable than the bending radiation pattern around the X-axis.



(a)



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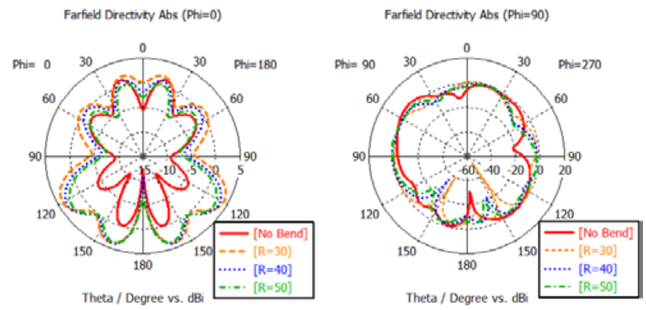
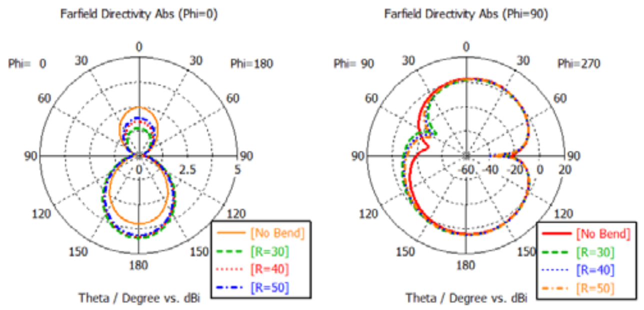
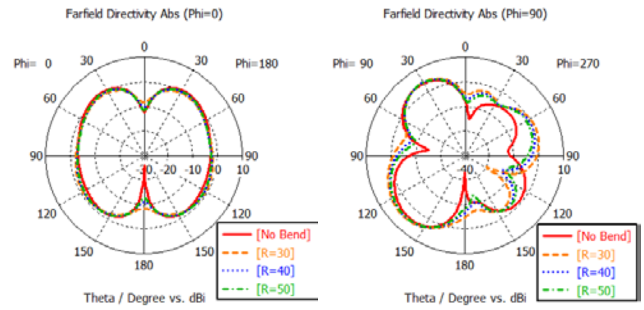


(c)

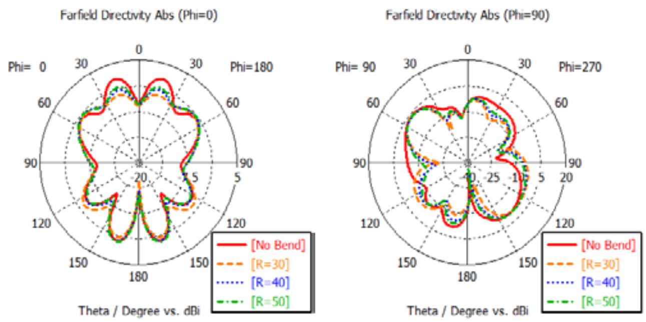
Fig. 7. Comparison of radiation pattern (Phi: 0 and Phi:90) for the X-axis bended textile antenna at different frequencies (a)3.5 GHz (b) 8 GHz (c) 13GH$_Z$.



(a)



(b)



(c)

Fig. 8. Comparison of radiation pattern (Phi: 0 and Phi:90) for the Y-axis bended textile antenna at different frequencies (a)3.5 GHz (b) 8 GHz (c) 13GH$_Z$.

IV. Conclusion

In this study, a flexible textile UWB microstrip antenna which can be used in WBAN applications is designed and its performance is obtained by CST MWS simulation software program when antenna is planar and bending about X and Y axes. Simulation results show that the antenna operates on a wide band in the frequency range of 2.2 and 17 GHz, covering the UWB (3.1-10.6 GHz) frequency range in the planar space. It is also observed that return loss (S_{11}) and radiation pattern performance parameters for the antenna bending position are optimum. Especially when the antenna is bent in the Y-axis, the antenna performance is better than X-axis. In future works, we plan to use these values in WBAN antenna production and measurement.

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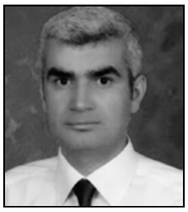

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