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Super Wide Band Wearable Antenna: Assessment of the Conformal Characteristics in terms of Impedance Matching and Radiation Properties

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Abstract

This paper illustrates the design and competence investigation of a novel conformal super wide band (SWB) wearable textile antenna. The design of this flexible antenna is employed on a material named Dacron fabric whose substrate permittivity is 3. This antenna occupies a bandwidth of almost 35 GHz and ranges between frequencies from 1.76 GHz to 36.80 GHz. The designed antenna is bended at different angles to study its conformal nature in terms of return loss and radiation characteristics.

Keywords: Super Wide Band, Conformal, Textile antenna

1. Introduction

The appearance of wearable intelligent textile systems revealed the necessity for WBAN (Wireless Body Area Network) system to provide standalone outfit in recent years. This network enables wearable computer devices to interact with each other and exchange digital information using the electrical conductivity of the human body as a data network [1]. The antenna is a fundamental part of wireless body area networks. Textile antenna is one of the most fascinating and cutting edge research areas of modern era. It provides a wearable interface which permits monitoring of the operator life signs and activity, as well as environmental parameters (e.g. temperature, position) [2]. This antenna does not disturb the movement of the wearer as it is light weight and flexible. The radiation efficiency, cost-effectiveness, ease of system integration and immunity to performance degradation are also the factors to consider while designing this antenna [3]. In case of wearable antennas it is quite difficult to have a flat antenna surface. Therefore, the designed antenna should be such that, even if the antenna is bent frequently, it should operate properly [4].

UWB antennas for body-centric wireless communications as well as the bending effect of these antennas have been presented extensively in the open literature recently [5-6]. But very few people have discussed about SWB antennas, especially about the consequences of bending on antenna for SWB body area networks. There are several definitions of bandwidth circulated among the antennas and propagation society; the two definitions, that most frequently used, are the percent bandwidth and the ratio bandwidth. The ratio bandwidth is defined as follows: $BR = BW / f_L$; Where BW is the nominal bandwidth defined by $BW = f_H - f_L$ Here, f_H, f_L are the maximum and minimum frequency at -10 dB, respectively, BR is the ratio bandwidth, commonly noted as BR = R: 1, where R is the ratio defined as R=f_H/f_L. The term SWB is used to indicate a greater bandwidth than a decade bandwidth that is it is often used for describing a ratio bandwidth of 10:1 or larger. [7] The operating frequency of our designed antenna is 1.7 GHz to 36.8 GHz which exhibits a ratio bandwidth of 21.64:1. Therefore this antenna can be considered to be a super wide band (SWB) antenna.

This paper presents a unique design of a wearable Super Wide Band (SWB) textile antenna realized on a Dacron fabric material with substrate permittivity, $\varepsilon_r = 3$. Here, woven copper thread is used as the conductive part of the antenna patch. It mainly focuses to evaluate the designed antenna's performance under different bending conditions. Here, the return loss and resonance frequency variations due to impedance matching as well as the effects of radiation pattern deformation and antenna efficiency are studied. This investigation assesses the competence of the designed antenna to be employed as a conformal wearable super wide band radiator for body centric wireless communication.

2. Antenna Design and Implementation

Here, a circular disc monopole antenna is chosen since it has got a simple structure. It is low profile and light in weight which enables this antenna to integrate fully into the textile materials. In Figure 1, the designed SWB planar antenna is presented with all its dimensions. The antenna is fabricated on a 60x40 mm² substrate with thickness of 1.6 mm. The substrate selected for the designed antenna is hypalon coated Dacron fabric with $\varepsilon_r = 3$. The designed antenna has a circular disc with a radius of 14mm which is fed by a 50 ohm microstrip feed line whose width is 3.2 mm. The main circular patch and the feed is connected through a quarter wavelength section with a width of 2.6 mm. The antenna is designed by cutting a small 6x6 mm^2 slot along with a rectangular portion of 14x2mm^2 vertically. A conductive ground plane with a length of 30mm is placed on the back of the substrate. A rectangular notch with size of 4mm x 4mm on the top of the ground is introduced to improve the impedance matching of the antenna.

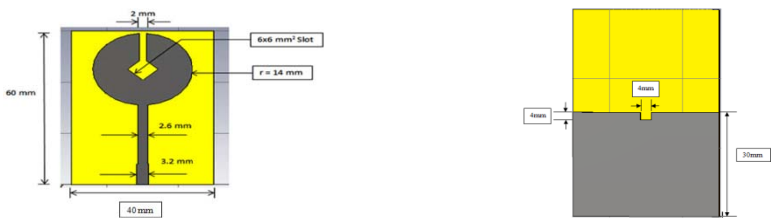


Figure 1: Proposed Antenna (Front and Back View)

To demonstrate the effect of bending on the performance of antenna, seven different bent angles with respect to horizontal plane (i.e. 20^0, 30^0, 40^0, 50^0, 60^0, 70^0, $80^{0)}$ are made as shown in fig. 2.

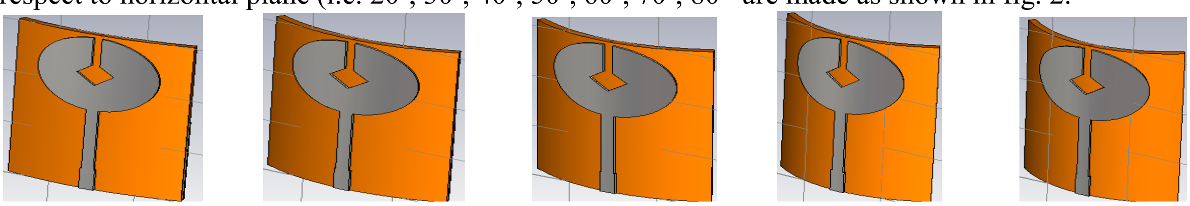


Figure 2: Designed Antenna with different bent angles (i.e. 30^0, 50^0, 60^0, 70^0, 80^0 respectively)

3. Performance Analysis of Super Wide Band Textile Antenna

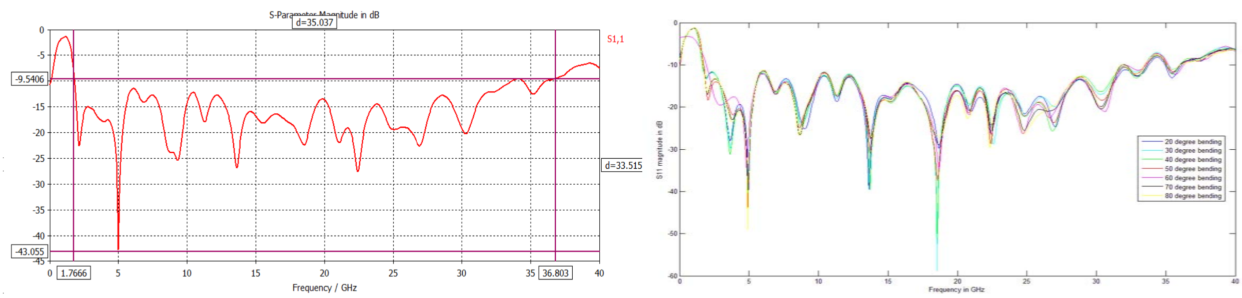


Figure 3: (a) S-parameter for Planar SWB antenna (b) Comparison of S-Parameter for Conformal state

The s-parameter plot of the planar SWB circular disc monopole antenna in Figure 3(a) shows that this occupies a bandwidth of almost 35 GHz starting from 1.76 GHz to 36.80 GHz with a significant resonance in 5GHz. It exhibits a good impedance matching all over its bandwidth with a return loss of -10 dB except at a frequency span of 0.75 GHz starting from 33.69 to 34.44 GHz where it reaches up to a value of a mere -9.54 dB which is quite acceptable [5].

Fig. 3(b) shows the comparison of S-Parameters for conformal SWB textile antenna at seven different bended angles. The designed conformal antenna does not follow any particular trend unlike the conformal UWB and narrowband antenna [3-5]. This antenna occupies at least a bandwidth of 32 GHz for each of the bent angles with a return loss of below -10 dB which exhibits super wideband characteristics with excellent impedance matching. At the lowest angle of bending i.e. 20 degree, the antenna occupies 32.26 GHz bandwidth with two significant resonances at 4.94 and 13.63 GHz with a return loss of -39.81dB and -39.05dB respectively. At high frequencies (above 33.6 GHz) the impedance matching gets relatively poor which causes the return loss to go up to -7dB for a certain amount of frequency span of the functional bandwidth. This span varies with the angle of bending and occupies about 1.09 to 1.59 GHz depending upon impedance matching. If the matching is good, the span is smallest; however, a poor impedance matching causes the span to reach its peak. At 20 degree bending, the matching is relatively better with a maximum return loss of -8.07 dB which ensures the frequency span above -10 dB to be only 1.09 GHz. However, bending of this antenna at 30 degree exhibits the highest frequency span of 1.59 GHz as it has the poorest impedance matching resulting to a maximum return loss of -7.01 dB. This has a noteworthy resonance with a return loss of -52.64 dB at 18.54 GHz. At higher angles of bending the pattern of the S-Parameter is almost similar. In each case, they occupy a total bandwidth of almost 35 GHz approximately from 1.7 GHz to 36.7 GHz irrespective of bending.

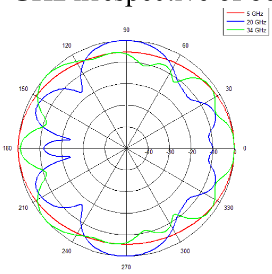
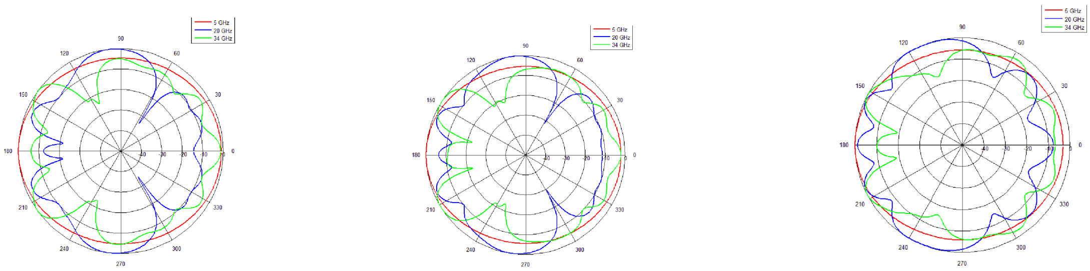


Figure 4: Radiation Pattern of Planar Antenna in Different Frequencies



a) 30 Degree Bending b) 50 Degree Bending c) 80 Degree Bending

Figure 5: Comparison of Radiation Pattern of the Conformal Antenna in Different Frequencies

The azimuth radiation pattern of the planar SWB textile antenna in Fig. 4, shows a fully Omni directional pattern provided by the far-fields at 5 GHz. At 20 GHz, it exhibits a slight distortion from the 5 GHz pattern whereas the far field at 34 GHz has a quite significant deformation from being Omni-directional. The main lobe magnitude does not differ much at comparatively lower frequencies; however, it reaches down to a value of 0 dB at high frequencies and at the same time side lobe magnitude increases significantly.

Fig. 5 shows the comparison of Azimuth pattern at different frequencies for conformal Super Wide Band textile antenna. Here, Fig. 5 (a, b, c) depict the radiation pattern of the antenna at 30, 50 and 80 degree bending respectively. At lower frequencies such as 5 GHz, the pattern is almost Omni-directional for each of the bending angles whereas it gets deviated as we keep increasing the frequency. The radiation pattern at 20 GHz becomes somewhat distorted from that of 5 GHz frequency for every different bending angles. At 34 GHz, we observe a noteworthy deformation of the radiation pattern in comparison to that at the lower frequencies irrespective of bending. Bending does not affect the radiation pattern except a slight variation of the main lobe magnitude. Therefore, conformal characteristics don't seem to have much impact on the radiated power beam. a complete distortion of the radiation patterns at higher frequency helps us to deduce that at increasing frequencies, the radiation pattern of the antenna gets deviated from the Omni-directional characteristics of the circular disc monopole textile antenna. However, bending of the antenna at various angles hasn't got much influence on radiation pattern at any frequency.

4. Conclusion

The primary focus of this paper is to introduce a compact yet conformal antenna for wireless body area network applications and to study the conformal characteristics of the proposed antenna. It has been observed that bending along with increasing frequencies have a great impact on the designed antenna's impedance matching and return loss. From comparison of S-parameter simulated result for different angles of bending, conclusion can be drawn that bending does not hamper the super wideband characteristics of the antenna, however, at higher frequencies, bending causes a little impedance mismatch which results in a fluctuation of the return loss though it does not have much adverse effect on the overall performance of the antenna. From the study of radiation pattern (azimuth) of conformal SWB textile antenna at different frequencies, it is found that the patterns remain unchanged with different angles of bending whereas they get deviated from being Omni directional with increasing frequencies. This indicates that the proposed antenna suits well to demonstrate the super wideband characteristics even at conformal state and is suitable for current /future SWB communication applications.

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