Wearable GPS patch ANTENNA on jeans fabric

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Abstract- In this work a wearable GPS adhesive copper sheet patch antenna on jeans fabric is designed, simulated and tested including the human body impact and specific absorption rate (SAR). The proposed textile antenna operates at the GPS L1 band (1575.42 MHz) and it has been designed by means of the commercial full 3D electromagnetic *CST Microwave Studio* simulator. The original textile antenna presents a -13.6 dB return loss at the GPS L1 frequency band with a fractional bandwidth of BW=3% (at S11=-10 dB), with a gain G= 1.7 dBi and efficiency η =23.1%. A homogeneous phantom has been considered in order to simulate the SAR in the leg of an average human body. The impact of the human body on the antenna performance implies a detuning frequency of 1.6% and G= 1.2 dBi; η =19% at the GPS operation frequency. In addition, several bending scenarios have been simulated to determine the degradation of the return loss, realized gain and efficiency. The proposed antenna is compliant with specific absorption rate (SAR) requirements from the IEEE C95.3 standard.

1. INTRODUCTION

Recently, a strong impact of textile or wearable electronics on fields such as health monitoring, physical training, emergency rescue service and law-enforcement has been produced. Among such electronic elements, body-worn antennas are key devices in order to wirelessly transfer the data from on-body sensors to the central database/computing facilities [1-3]. Since the human body is composed of a large variety of tissues types (with different dielectric properties) the substrate design of the wearable antennas must include their effects, specifically to take into account the overall dielectric constant of the device and losses. Moreover, specific absorption rate (SAR) impact analysis is required for body area network (BAN) antennas as they operate near human tissues.

The integration of flexible and lightweight wireless antennas into clothing is a potential solution for many applications such as Global Positioning System (GPS) [4]. In this work a wearable GPS patch antenna is designed, simulated and tested including the human body impact and SAR. The remainder of the paper is organised as follows. Section 2 describes the original wearable patch antenna as well as its performance. Bending impact is also considered. In Section 3 the human body impact on the antenna parameters and the SAR simulation are evaluated. Finally, section 4 summarizes the main conclusions.

2. WEARABLE ANTENNA DESIGN AND PERFORMANCE

The proposed patch antenna operates at the GPS L1 band (1575.42 MHz) and it has been designed by means of the commercial full 3D electromagnetic *CST Microwave Studio* simulator. Fig. 1 shows the GPS patch antenna (dimensions: width W=72 mm; length L=71 mm; feed input Lf=25 mm) which is implemented on a jean textile substrate (dielectric constant εr=1.7, thickness h=1 mm, loss tangent tan δ=0.025). The metal layer corresponds to a commercial WE-CF adhesive copper sheet (thickness t=70 μm). The measured antenna return loss is illustrated in Fig. 2. An experimental S11=-13.6 dB is obtained at the GPS L1 frequency band with a fractional bandwidth of BW=3% (at S11=-10 dB). Fig. 3a depicts the GPS wearable antenna patch far-field radiation pattern. The original antenna gain and efficiency performance correspond to: G= 1.7 dBi; η =23.1%. In addition, several bending scenarios (from moderate to severe cases) have been simulated to determine the degradation of S11, realized gain and efficiency. In particular bending radii from 100 mm<R<1000 mm have been evaluated. As an example, Fig. 3b shows the radiation pattern for the R=100 mm case. Fig. 4 illustrates a graphical comparison for the return losses and realized gain antenna for the following cases: R=100 mm; 250 mm; 500 mm and 1000 mm.

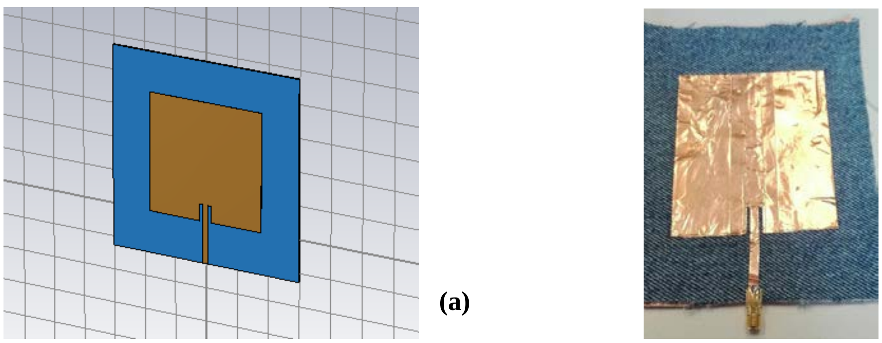
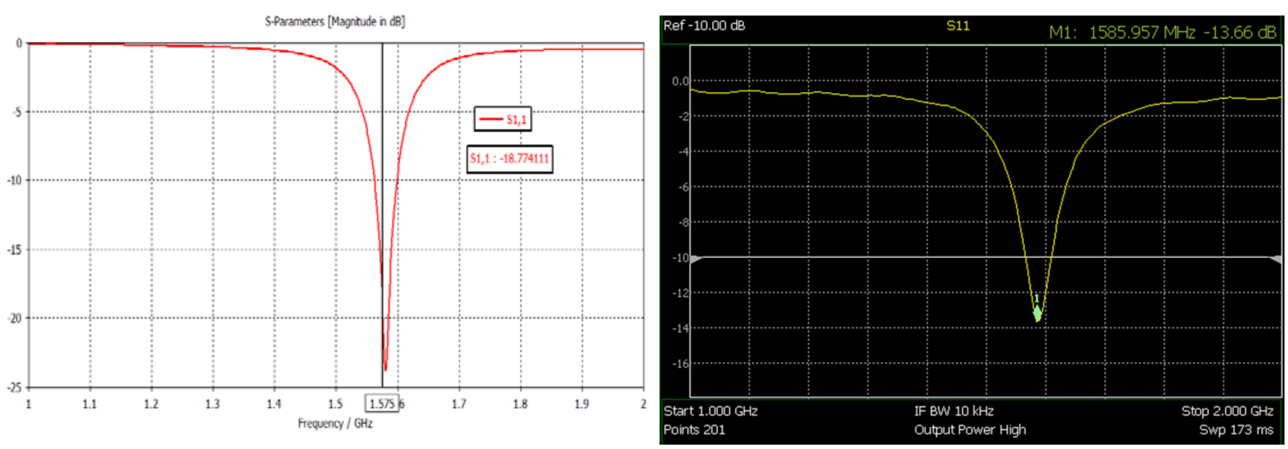
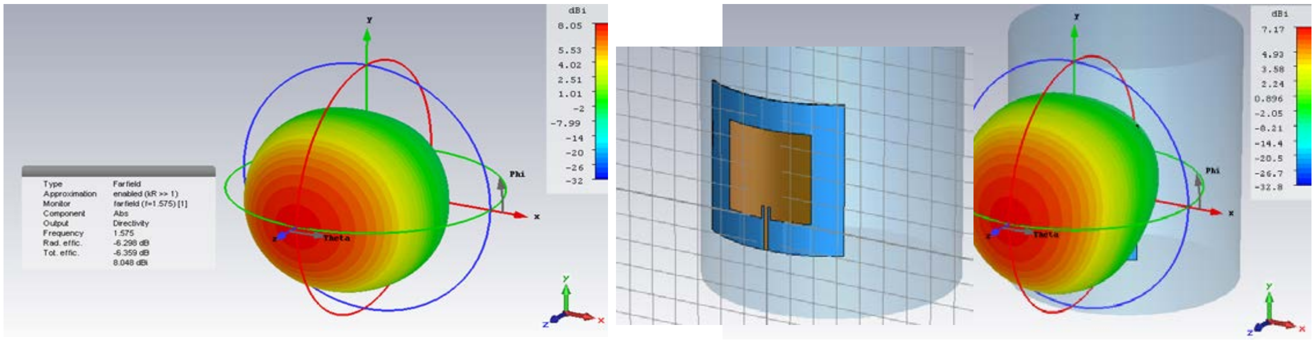


Fig. 1. GPS wearable antenna patch on jeans fabric. (a) 3D layout model in *CST Microwave Studio*. (b) Manufactured antenna.



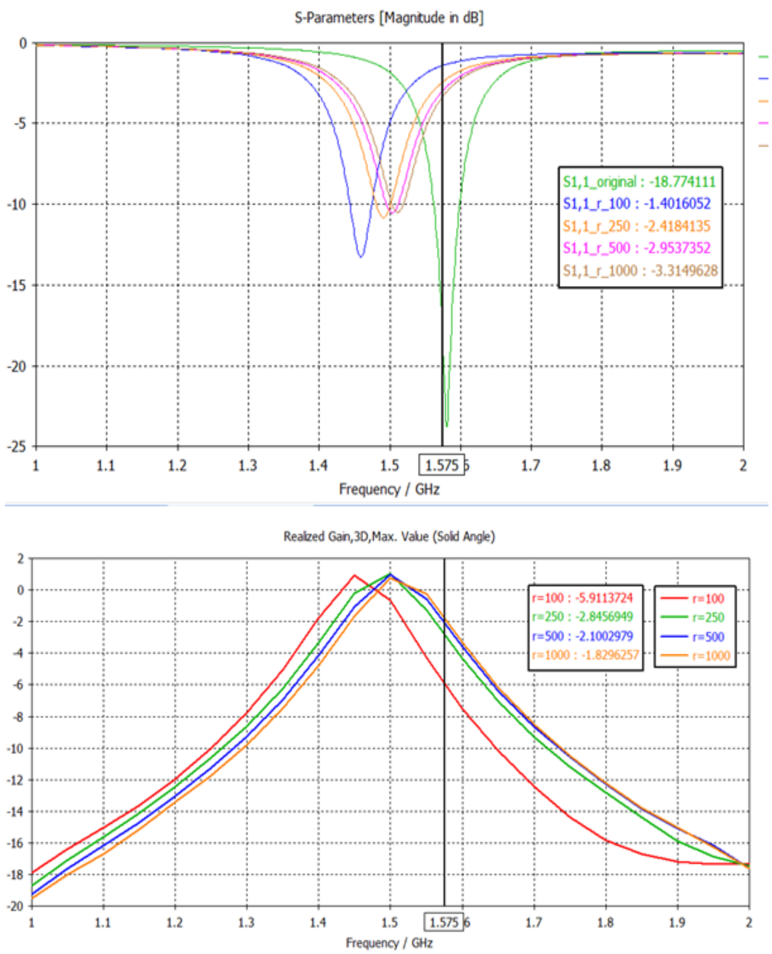
(a) (b)

Fig. 2. GPS wearable antenna patch return losses, S11. Simulated (a) and experimental results (b).



(a) (b)

Fig. 3. (a) Original GPS wearable antenna far-field radiation pattern. (b) Bending case with R=100 mm and corresponding radiation pattern.



(a)

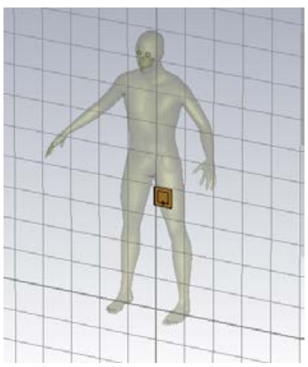
(b)

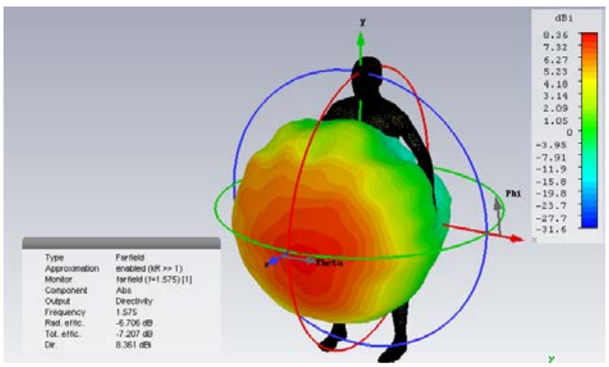
Fig. 4. Return losses, S11 (a) and realized antenna gain (b) for different bending radii: R=100 mm; 250 mm; 500 mm and 1000 mm.

3. HUMAN BODY IMPACT AND SAR EVALUATION

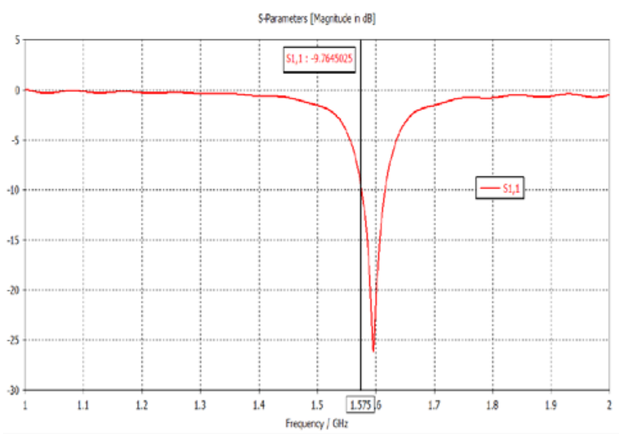
A homogeneous phantom has been considered in order to simulate the antenna performance impact and the SAR in the leg of an average human body (dielectric constant ε_r=42, conductivity σ=1 S/m). The impact of the human body on the antenna performance implies a detuning frequency of 1.6% and G= 1.2 dBi; η =19% at the GPS operation frequency (Fig. 5).

The SAR of the on-body wearable patch antenna must be validated in the design stage to guarantee conformance with regard to safety regulations. SAR is a measure for the electromagnetic energy absorbed by biological human tissue mass when exposed to a radiating device (*i.e.* the antenna). It is normally spatially averaged over a certain amount of exposed biological tissue (typically 1g or 10g). The mass averaging SAR procedure is based on determining a point of averaged SAR calculation, searching for a 1g/10g cube (iteratively) and integrating losses in the cube. In this work, the numerical SAR investigation has been performed by using *CST Microwave Studio*. The proposed antenna is compliant with specific absorption rate (SAR) requirements from the IEEE C95.3 standard [5]. Indeed, the maximum values corresponding to the mass averaged SAR are $9.3\cdot10^{-3}$<1.6 W/Kg over 1g (US standard) and $2.5\cdot10^{-2}$<2.0 W/Kg averaged over 10g of tissue (EU standard), as illustrated in Fig. 6.





(a) **(b)**



(c)

Fig. 5. (a) Human phantom model and wearable antenna location. (b) GPS radiation pattern including the human body impact. (c) On-body antenna patch return losses, S11

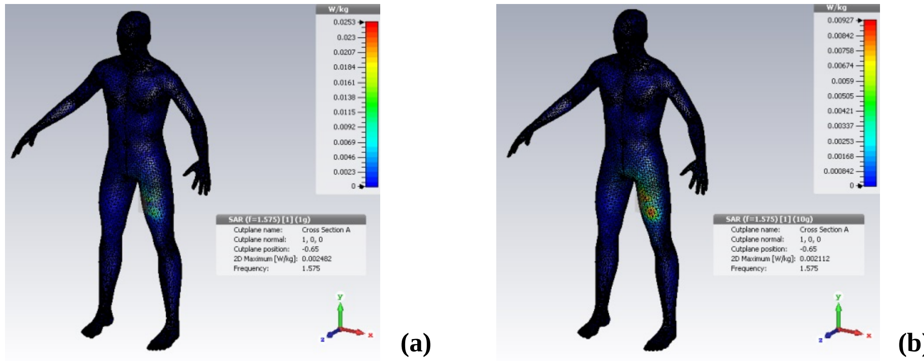


Fig. 6. Simulated mass averaged SAR at GPS frequency: (a) 1 g and (b) 10 g.

4. CONCLUSIONS

A wearable GPS L1 band adhesive copper sheet patch antenna on jeans fabric has been designed, simulated and tested including the human body impact and specific absorption rate (SAR). The textile and human body effects have been studied in terms of the antenna operation frequency, radiation pattern, gain and SAR. The human body proximity as well as bending effects provoke certain degradation in the antenna performance (reduction of the efficiency and gain), as expected. Research is in progress in order to confirm experimentally all the previous simulated results, and to extend the analysis to other kind of microstrip and coplanar wearable antennas.

ACKNOWLEDGEMENT

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