A TEXTILE ANTENNA FOR PROTECTIVE CLOTHING

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Abstract

This paper presents a textile antenna designed to be integrated into protective clothing since it is made out of a high performance aramid fabric. A microstrip patch antenna is designed for operating in the 2.45 GHz Industrial, Scientific and Medical (ISM) band for short range communication to transmit the wearer's life signs to a nearby base station. Electrotexiles are used for the antenna patch and ground plane. When integrated into the garment, the antenna requires a finite ground plane and operates in the presence of the body, hence changing its characteristics. Furthermore, when a textile antenna is integrated into a garment the patch might bend. A rectangular ring topology is proposed to preserve the antenna characteristics in real-life applications. This research paves the way for a new generation of protective clothing.

1 Introduction

The development of *wearable intelligent textile systems* has altered the concept of clothing. New generation garments are capable of monitoring the wearer's vital signs and activity as well as the environment [2,3]. The fact that this is done in a – for the wearer- comfortable and unobtrusive way, makes these garments quite exceptional. Additionally, the introduction of these intelligent textiles has uncovered the need for wireless communication systems that are unnoticeably integratable into clothing [1,4]. Clothes always performed a protective function. However, some people require additional protection against occupational hazards during their professional activities. High performance materials are used to make this special class of protective clothing. Fire fighters are a group of professionals that surely require adapted garments. A following step in the development of protective clothing is to equip the garments with additional functions such as for monitoring and communication. The European Integrated Project Proetex (FP-2004-IST-4-026987) carries out research for the development of wearable textile systems to support the work of emergency rescuers and firemen, next to a victim's patch [6]. Data concerning the operator's health status and surrounding environmental risks can be communicated to a nearby base station. Therefore, a wireless link is established where the antenna on the operator's side is a textile antenna to be integrated into the garment. The presented work reveals the design methodology and the measured results of an aramid based textile antenna.

2 Antenna design and construction

The basic assumption of our research was a microstrip patch antenna to be manufactured out of a multilayer textile structure. Our goal was to design an antenna for short range communication, known as the Wireless Local Area Network (WLAN) operating in the 2.45 GHz ISM band and based on the Zigbee, Bluetooth, WiFi and Wireless USB protocols. To obtain an antenna with a -10dB return loss in this 2.4 – 2.483 GHz band and a nonlinear polarisation, a single feed rectangular ring topology was chosen. The geometry of the patch and the location of the feed point were optimised using a 2.5-D field simulator ADS-Momentum[®] from Agilent Technologies. The dimensions of the resulting antenna are given in

Figure 1. Linear polarization is avoided to improve reception in real-life application, where the wearer is mobile and thus continuously changing his orientation with respect to the receiving antenna. In order to achieve circular polarisation, the feed point is placed on a diagonal of the patch, thereby exciting the two orthogonally polarised TM₀₁ and TM₁₀ modes. Because of the slightly different values of the length L and the width W of the antenna patch, a broad bandwidth is achieved. [5] provides more details about the radiation mechanism of a planar rectangular ring antenna. As the antenna is meant to operate in the vicinity of the body, it is provided with a ground plane to shield the body from the radiation. However, this ground plane is kept as small as possible.

Figure 1 : Dimensions of the rectangular-ring textile antenna

Since the antenna was designed for integration into a fire fighter's jacket, the outer shell fabric was chosen as antenna substrate. This is a high performance aramid woven fabric with a thickness of 0.40 mm. However, since we require a bandwidth of over 83.5 MHz, an antenna substrate with a sufficient thickness is needed. Therefore we assembled 4 aramid layers using an adhesive sheet. This results in an overall thickness of 1.67 mm, which still allows discreet integration into a garment. This antenna substrate possesses an ϵ_r of 1.75 and a loss tangent of 0.015. Commercially available electrotexiles with a very high conductivity (surface resistivity $<0.1 \Omega/\text{sq}$) were used for patch and ground plane. The antenna was excited by means of a 50 Ω SMA feed, which was carefully soldered onto the antenna. Several antenna prototypes were built according to the simulation outcome.

3 Simulation and measurement results

The return loss of the prototype is measured using an Agilent 8714ET Network Analyzer, while transmission measurements in combination with a standard gain horn antenna in an anechoic room were performed using an HP 8510 Network Analyser. First, the antenna was measured in planar state in order to compare the simulated and measured return loss. Second, the return loss of the bent antenna was evaluated. Therefore the antenna was curved over a plastic tube with a diameter of 8 cm, which corresponds with an arm or a shoulder. Simulation and measurements are compared in Figure 2 and show first-rate agreement. A robust design is obtained by increasing the bandwidth up to 100 MHz. That is because we expect a shift in frequency in real life application due to bending or manufacturing tolerances of the antenna patch. The measured bandwidth of the textile antenna is found to be slightly over 100 MHz, both in planar and in bent state.

Figure 2 : Measured and simulated return loss

Before measuring the transmission characteristics, the ground plane of the antenna was reduced to 65 to 65 mm. From the radiation patterns in XZ and in YZ plane at a frequency of 2.45 GHz, the gain was obtained. Figure 3 and Figure 4 visualize the measured radiation patterns in two orthogonal planes at 2.45 GHz and reveal that almost the complete upper hemisphere is covered by the antenna. E_ϕ and E_θ are almost

equal which means that the reception will be similar for horizontally and vertically polarized fields.

Figure 3 : Measured normalised radiation pattern in the XZ-plane at 2.45GHz

Figure 4 : Measured normalised radiation pattern in the YZ-plane at 2.45 GHz

It is clear, also from Figure 5 that a back radiation is present due to the limited ground plane. Comparison is made with a 2.5-D simulation of a lossless antenna and reveals good agreement.

Figure 5 : Simulated and measured gain at 2.45 GHz of the planar antenna

Figure 6 displays the simulated and measured antenna gain along broadside (Z-direction, orthogonal to the antenna XY-plane). The measured gain is about 3 dB lower than the simulated gain of a lossless antenna, yielding an antenna efficiency of 50%.

Figure 6 : Simulated and measures antenna gain

Finally, in Figure 7 we compare simulations of the antenna in air (both with an infinite and a finite ground plane) and on a human body in order to simulate real-life operation circumstances. The 2.5-D simulation represents a lossless antenna with an infinite substrate and ground plane, while the 3-D simulation takes a finite substrate with losses (loss $\tan\delta$ of 0.015) and a finite ground plane into account. For this particular simulation the dimensions of substrate and ground plane are 66x63 mm. For the on-body simulation a homogeneous lossy dielectric with an ϵ_r of 42 and a σ of 0.99 S/m (as proposed by CENELEC) was modelled at 8 mm below the finite antenna ground plane. This was done using a CST Microwave Studio® 3-D field simulator. It can be observed that these additional restrictions have only a limited influence on the radiation characteristics of the antenna.

Figure 7 : Simulated antenna gain at 2.45 GHz

4 Conclusion

A rectangular ring antenna based on a high performance aramid fabric, to be integrated into a protective fire fighter garment was presented in this paper. The antenna was designed to operate in the 2.45GHz ISM band for Local Area Networks. Excellent agreement was found between the simulated and measured reflection and transmission characteristics of this textile antenna. A rectangular ring topology guarantees reception of both horizontally and vertically polarised fields. An antenna gain of 5 dBi is found.

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