A TEXTILE ANTENNA FOR FIRE FIGHTER GARMENTS

C. Hertleer, L. Van Langenhove
Ghent University, Department of Textiles, Zwijnaarde, Belgium

H. Rogier, L. Vallozzi
Ghent University, Department of Information Technology, Ghent, Belgium

ABSTRACT

The trend of further exploiting the potential of ubiquitous garments by integrating more functionality, together with the availability of a new generation of materials, has led to the concept of *wearable intelligent textile systems*. These are garments able to monitor the wearer's vital signs and activity and capable of observing environmental conditions, in a comfortable and unobtrusive way. In order to transfer the obtained sensor data, these wearable systems require wireless communication tools. To preserve textile properties such as flexibility and comfort, the antennas should be fully integratable into the garments. The availability of electrotextiles allows manufacturing these antennas entirely out of textile materials. A lead application area for these wearable textile systems is undoubtedly protective clothing for workwear such as fire fighter garments.

This paper introduces a textile antenna designed on an aramid fabric for integration in a fire fighter outer garment. A multilayer microstrip patch antenna is designed for operation in the 2.45 GHz Industrial Scientific Medical (ISM) frequency band for short range communication to transmit the fire fighter's life signs to a nearby base station. When integrated into the garment, the antenna requires a finite ground plane and operates in the presence of the body, a condition which may result in changing antenna characteristics. Furthermore, the antenna plane is covered with several layers of textile material when it is placed in the fire fighter garment. The proposed antenna provides enough robustness to preserve its characteristics under these circumstances. This research paves the way for a new generation of fire fighter garments.

1 INTRODUCTION

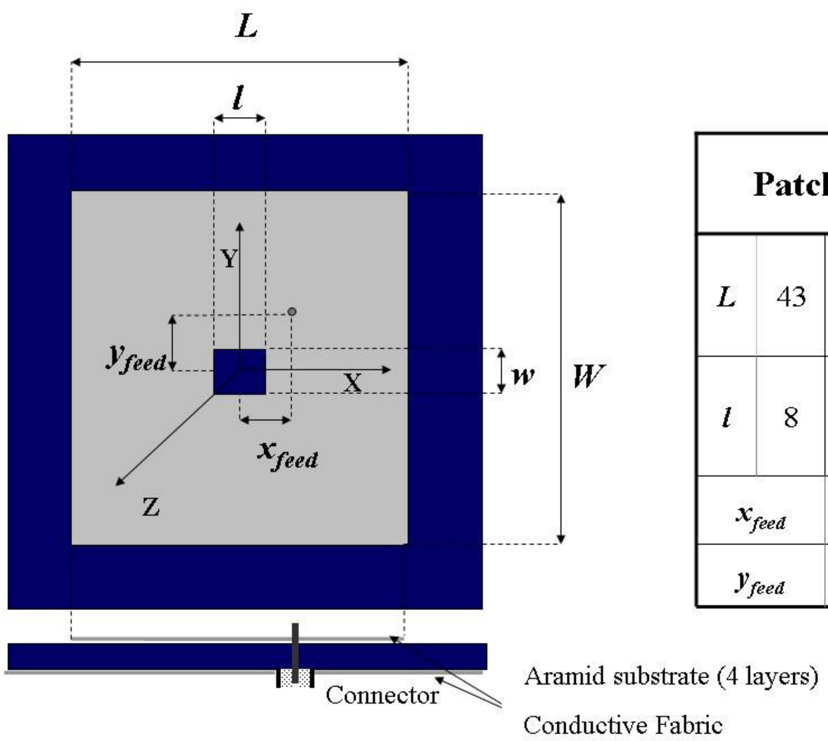
The main purpose of clothing is protecting the human body against environmental conditions. Professional workers benefit to a large extent from the scientific developments such as the introduction of high performance fibres that have been achieved in the previous century. The 9-11 events in the US raised the awareness of the importance of equipping firefighters, paramedics and other rescue workers with the most advanced materials. Additionally monitoring their vital signs will be enabled in the next generation of professional protective clothing. Wireless communication infrastructure allows transmitting substantial amount of data to a supporting base station. Implementing the antenna in the clothing [1, 2] will maintain wearing comfort while supporting the operability. In that perspective, a textile antenna based on specialty fabrics is required and will be presented in this paper. This research is produced in the framework of the European Integrated Project Proetex [3] that enhances the development of wearable textile systems to support the work of emergency worker and firemen.

2 ANTENNA DESIGN

Our point of departure was a microstrip patch antenna built up as a multilayer textile structure and applied for off-body short range communication. These Wireless Local Area Networks (WLAN) operate in the 2.45 GHz ISM band and are based on protocols such as Zigbee, Bluetooth, WiFi and Wireless USB. An antenna with a -10dB return loss in this 2.4 – 2.4835 GHz band had to be obtained. Next to a specific antenna topology, an antenna substrate with a sufficient thickness is required. A firefighters' turnout coat for structural fire consists of an assembly of textile layers that are suitable as substrate material. These layers are a flame-resistant outer shell, a moisture barrier, an inner thermal barrier and a liner. In order to obtain an adequate thickness we chose to adhere four layers of outer shell aramid fabric, resulting in a substrate thickness of 1.73 mm. By doing so, the flexibility of the antenna was reduced but it is still sufficient to provide wear comfort. Commercially available electrotextiles were applied for manufacturing the antenna patch and the ground plane.

A rectangular ring shaped textile antenna has been formerly presented [4] and has proven its suitability as textile antenna, mainly because it provides an antenna with a sufficiently broad bandwidth (83.5 MHz is required). Furthermore, the simple shape allows easy cutting out of textile material.

A 2.5-D field simulator Advanced Design System (ADS)-Momentum® from Agilent Technologies was used to design and optimize the antenna's dimensions according to the properties of the substrate (see Figure 1). A ground plane of 10 to 10 cm was provided.



Patch (mm)				Substrate	
L	43	W	41	h (mm)	1.73
l	8	w	7	ε_r	1.85
x_{feed}	7			$tan\delta$	0.015
y_{feed}	6				

Figure 1 – Dimensions of the rectangular ring textile antenna

3 ANTENNA POSITIONING IN THE GARMENT

The proposed antenna is designed for integration into the outer fire fighter garment. Since this is a multilayer assembly, two types of positioning have to be determined: between what layers and where on the garment.

The antenna will be wired to the monitoring system within the garment; therefore it was decided to locate it underneath the moisture barrier and the thermal barrier layer. Underneath the antennas' ground plane is the inner lining of the garment, as shown in Figure 2.

Figure 2 – Positioning of the antenna with regard to the assembly of the garment

The antenna placement on the garment was preferred in the area of the shoulders or the upper arm because of the minimal risk of creasing and wrinkling in these areas.

Figure 3 – Possible location of the antenna on the garment

4 ANTENNA CHARACTERISTICS

For the reflection measurements an Agilent 8714 ET Network Analyzer was used. Return loss measurements from the antenna in planar and in bent state were performed. For the bent state, the antenna was wrapped around a plastic tube with a diameter of 8 cm, simulating e.g. the arm. Figure 4 shows that both antenna characteristic are comparable to the simulation. Even in bent state, the entire ISM band remains covered.

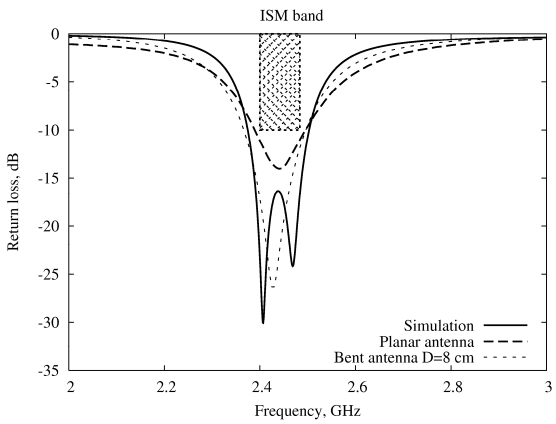


Figure 4 – Return loss simulation and measurements.

For the transmission measurements an HP 8510 Network Analyser was applied. The set- up in the anechoic room had a standard gain horn antenna as transmitting antenna and the textile antenna, mounted on an Orbit/Fr positioning system [5], as receiving antenna, as illustrated in Figure 5.

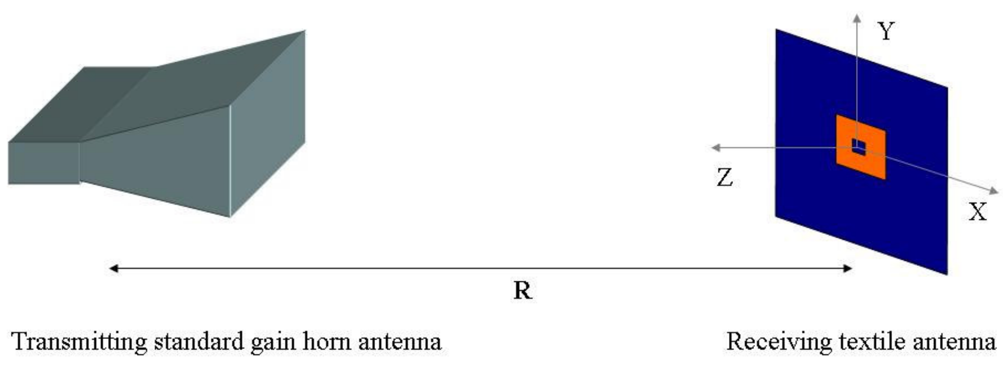


Figure 5 – Antenna configuration for the transmission measurements

In order to evaluate the presence of the additional textile layers covering the antenna in real-life application, the transmission parameters were consecutively measured without and with the extra layers. This resulted in four types of measurements: uncovered and covered antenna both when the antenna was in planar and bent state. For each line-up, transmission measurements were executed both in the XZ- and the YZ plane. The antenna gain resulting from these data is presented in Figure 6. The gain pattern visualises how the antenna redistributes the radiated power in all directions. Most of the power is transmitted in the direction perpendicular to the antenna (Z-direction), yet, when the antenna is bent, the radiated energy is distributed more evenly in the hemisphere ranging from -90° to 90°. This however, will not diminish the quality of the communication link.

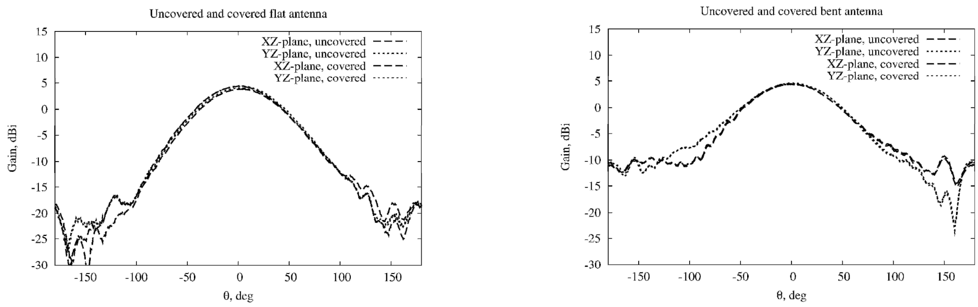


Figure 6 – Measured antenna gain of the uncovered and covered antenna at 2.45 GHz

Figure 7 compares the simulated and measured antenna gain of the uncovered planar antenna and reveals that there is a good agreement.

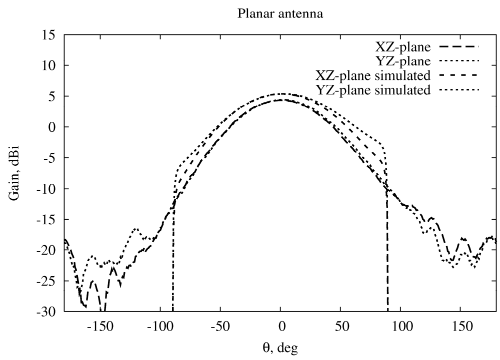


Figure 7 – Simulated versus measured gain of the uncovered planar antenna at 2.45 GHz

The following table resumes the maximum gain and the -3 dB lobe width in all different situations.

	Maximum gain (dB)		**-3 dB main lobe width** (deg)	
	XZ-plane	YZ-plane	XZ-plane	YZ-plane
Planar – uncovered	4.36	4.45	71.1	70.2
Planar – covered	3.83	4.04	70.2	70.2
Bent – uncovered	4.49	4.61	76.5	78.3
Bent - covered	4.37	4.50	76.5	79.2

We conclude that neither covering nor bending the antenna has a significant influence on its gain, since the differences in antenna gain are beneath the measurement error. There is however a considerable increase of the -3 dB main lobe width, which means that the antenna becomes less directive and implies that the antenna is capable of detecting a broader range of incoming rays.

Finally, on-body measurements were performed as shown in Figure 8. The antenna gain decreases but remains over 3 dB in the entire ISM band.

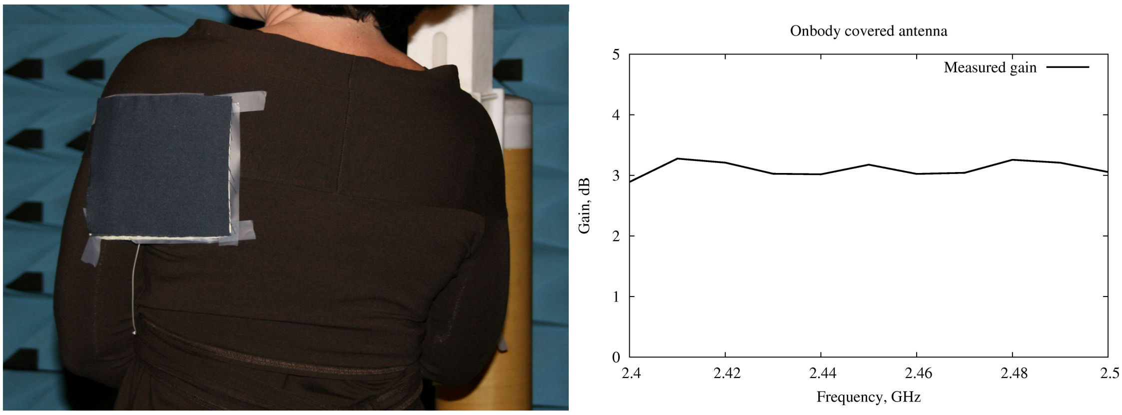


Figure 8 – On-body measurements and resulting antenna gain.

5 CONCLUSIONS

The proposed rectangular-ring antenna based on a flame-resistant aramid fabric provides sufficient gain to operate from an inner layer of a fire fighters' outer garment. Assembling four layers of this fabric provides an antenna substrate with a sufficient thickness rigidity without harming the wear comfort. Even in bent state, this antenna will guarantee the wireless communication link between the wearer and the base station.

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