Firefighters communicating through textiles

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Abstract— **With the introduction of intelligent textile systems, the functionality of personal protective clothing is further enhanced. High tech fabrics protect the wearer from harsh environmental conditions, while monitoring systems provide information about his physical state during operation. Thus, a wireless communication device between the wearable system and an external base station is required. In order to allow maximum integration of this antenna into a garment, flexible textile antennas have been introduced. In this work, a protective foam-based antenna for integration into a firefighter jacket is developed .**

Keywords— **Wearable antennas, off-body communication, protective clothing, firefighters.**

I. INTRODUCTION

Within the framework of the European project *"Proetex"*, research is performed to improve the safety of rescue workers and firefighters by incorporating a sensor network system into their garment. Sensors to measure e.g. heart rate and respiration are integrated into the inner garment because they require a close contact to the skin. Other sensors operate to measure environmental characteristics such as temperature and the presence of toxic gases and are therefore incorporated into the outer garment. The data is processed in a wearable electronic box and transmitted to a base station. This off-body communication is achieved by wearable antennas integrated into the outer garment. The antennas need to be flexible, to guarantee wear comfort on the one hand and sufficiently robust to ensure a good communication link on the other hand.

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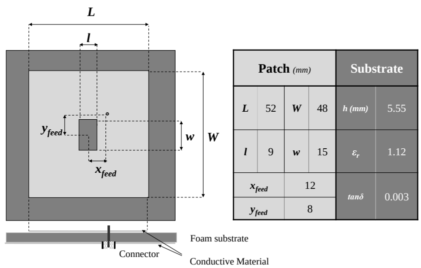

Patch (mm)				Substrate	
L	52	W	48	h (mm)	5.55
l	9	w	15	ε_r	1.12
x_{feed}	12			tanδ	0.003
y_{feed}	8				

Figure 1. Topology and characteristics of the antenna

II. ANTENNA SPECIFICATIONS

The antenna is designed to operate in the 2.45 GHz ISM band where a bandwidth of at least 83.5 MHz is to be obtained. Furthermore the antenna has to radiate 90% of the incoming power in this frequency range. The rectangular ring topology has proven to be suitable [1] and is thus maintained. As antenna substrate material, flexible pad foam was selected. Pad foam is commonly available in protective clothing; it has a protective function without hindering the wearer in his movements. Furthermore, its uniform, stable and sufficient thickness is a beneficial property for antenna design. This foam is 5.5 mm thick and its electromagnetic properties were determined as presented in [2]. All details of the antenna characteristics are given in Figure 1. On the backside of the antenna, a ground plane is placed in order to prevent radiation towards the body. Antenna patch and ground plane our manufactured out off *e-textiles*. To improve overall flexibility, the antenna is fed with a coax cable that is attached with a conductive glue.

III. ANTENNA PERFORMANCE

A. Reflection characteristics

Figure 2 shows that the design criterion of reaching a return loss of less than -10 dB (90 % radiation) in the entire ISM band is largely fulfilled. Moreover a bandwidth of over 280 MHz is achieved. This contributes to the robustness of the antenna since it becomes less vulnerable to frequency shifts due to e.g. manufacturing inaccuracies or bending.

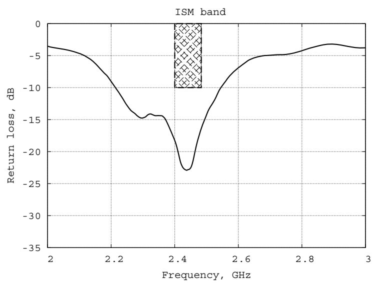

Figure 2. The entire 2.45 GHz ISM band is covered

B. Transmission characteristics

In a transmission measurement set-up, the textile antenna is applied as receiving antenna with a standard gain horn as transmitting antenna. This operation is performed in an anechoic chamber so that interfering and reflecting radiation is absorbed by the walls. An antenna gain of 6.7 dBi was found, which guarantees a good communication link during real-life operation.

C. Moisture influence

When designing an antenna to be applied in a protective garment, sensitivity to humidity has to taken into account. To do so, a foam material with a very low moisture regain of 0.84 % was chosen. To examine the influence of humidity changes, the antenna was conditioned in a climatic test cabinet for 24 hours in a temperature of 23°C and a relative humidity of 30, 50, 70 and 90 % respectively. Figure 3 shows that for this kind of material the frequency shift is only limited, especially when compared to natural fibre based materials that have a much higher moisture regain (up to 8 %) as analysed in [3].

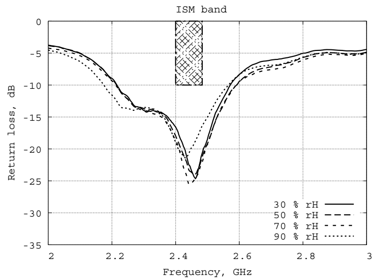

Figure 3. Changing humidity conditions in the environment only slightly influences the return loss characteristic

IV. CONCLUSIONS

A flexible pad foam material was applied to design and manufacture a robust antenna for integration into firefighter garments. The proposed antenna has a sufficiently large bandwidth of 280 MHz and a high gain of 6.7 dBi to establish a good off-body communication link. Given the small moisture regain of the foam material (0.84%), the antenna provides a stable return loss characteristic in changing environmental conditions.

ACKNOWLEDGMENTS

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