# A Textile RFID Antenna for Wearable Applications

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**Abstract**

*In this paper, we present a configuration of a textile antenna for wearable applications of Radio Frequency Identification (RFID) technology. This antenna operates at a frequency of 2.45 GHz and it is implemented on a single layer dielectric. The dielectric used in this research is a Kevlar substrate having a dielectric constant of Ɛr= 3.58 and a thickness of h=0.254 mm. This material satisfies the requirements of flexibility of the wearable antenna. The radiating element designed in the form of text is the abbreviation of the Hanoi University of Science and Technology (HUST), HUST. The substrate has the dimension L=45 mm and W=16 mm. The radiation element is made of copper. This antenna is designed and simulated by using the commercial software CST Microwave Studio. The simulated reflection coefficient S11 is -18.26 dB and the gain of 2.2 dBi at the frequency of 2.45 GHz.*

Keywords: Textile antenna, wearable antenna, RFID antenna

## 1. Introduction

The RFID technology is applied in many areas especially in the access control tracking, navigation and logistic [1, 2]. This technique was proposed in the 1950s but most of its applications were employed since the 2000s. In recent years, utilization of RFID systems has been on the rise due to the low cost of tags. A tag is considered to be a part of the object used for communication purposes. As a part of RFID systems, the wearable antennas have been developed. These antennas are intergrated into the clothes with regards to size reduction and cost effectiveness, so the wearer will do not feel inconvenience with the existence of these antennas. Requirements of wearable antennas are light weight, flexible and durable. Therefore it is necessary to research in properties of materials used for antenna fabrication. The effect of the human body on the operation of antennas located in close proximity has been described in detail in [3-5]. A dual-band textile antenna for wearable applications in was introduced by Salonen *et al* in [6]. Fleece fabric was used to design antenna for GSM and WLAN bands. The study indicates that the sensitivity of dielectric constant of textile materials greatly affect to the characteristics of the antenna. Elias has adressed a single band 2.4GHz textile antenna in [7]. The effects of bending and different distances from the body are also considered in this study. Results have clearly indicated that the human body has notably shifts the antenna resonant frequency and modifies the radiation pattern at the frequencies operated.

This paper intends to present a configuration of a RFID textile antenna for wearable applications. The radiation element using copper fiber is embroidered on the textile sustrate. This antenna operates at a frequency of 2.45 GHz . The paper is organized as follows. Section 2 provides a description of wearable antenna design. Section 3 discusses the simulation results of the proposed antenna. Finally, section 4 presents a brief summary of this study.

## 2. Design of the antenna

### *2.1 Material Selection*

The materials of radiation elements and substrate of antenna are selected to suit the specific applications. Textile material was desired to have flexibility and durability so that the antenna can be deformed. The conductive material requires a low and stable electrical resistance [≤1Ω/square] to minimize losses. The non-conductive textile such as polydimethylsiloxane (PDMS), fleece fabric, felt is used as substrates [8]. In this study, Kevlar is selected for the substrate with a dielectric constant of Ɛr= 3.58, a loss tangent of tgδ=0.019 and a thickness of h=0.254 mm. The copper wire with a diameter of t=0.4 mm is selected for the radiating element.

### *2.2 Antenna configuration*

In this study, we introduce a textile antenna for tracking and navigation applications by using RFID technology. The antenna is designed as a logo for human resource management applications and has the structure of a dipole antenna. The selected frequency

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of antenna is 2.45 GHz so the length of antenna is calculated as follows:

$$\lambda = \frac{c}{f} = \frac{3.10^8}{2,45.10^6} \approx 122\,(mm)$$

$$L = \frac{\lambda}{2} \approx 61\,(mm)$$

In which λ is the wave length, L is the length of antenna.

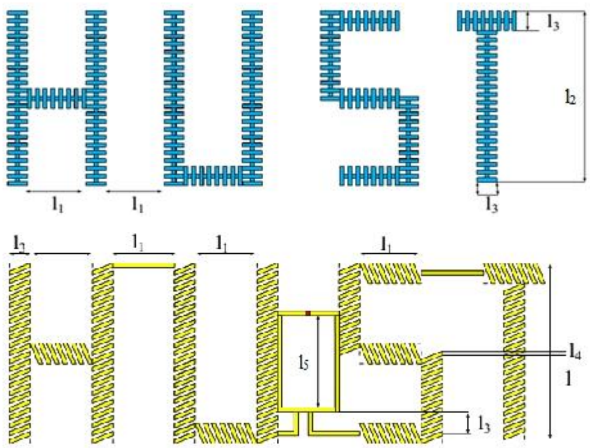



**Fig.1.** The geometry of the front and back of the proposed antenna

The word elements are connected together and arranged so that the two branches of the antenna length roughly equal at the same time the total length of two branches is half of the wavelength. The radiation element designed in the form of text is the abbreviation of the Hanoi University of Science and Technology (HUST). Meander-lines structure is used in order to miniaturize antenna dimension. The geometry of the front and back of the proposed antenna is shown in Fig.1. The dimension of the substrate is L=45 mm and W=16 mm. The radiation element has dimension l1=4.1 mm, l2=14.35 mm, l3=2.05 mm, l4=0.4 mm, l5=2.4 mm. Copper wire is embroidered from the front to the back of the fabric substrate. The antenna is matched with integrated chip by using T matching network [9]. The integrated chip has impedance of 50 Ohm.

### 3. Simulation Results

The characteristics of proposed antenna depend considerably on the material of substrate and radiation element. Hence it is necessary to research in properties of materials before the antenna fabrication.

#### *3.1 Results for Various Values of Substrate Thickness*

The first step in modeling the antenna in this paper is to determine the characteristics of the layout in Fig.2 for various values of substrate thickness. The results from these simulations are shown in Figures.2, 3 for various values of substrate thickness which are 0.076 mm, 0.101 mm and 0.254 mm.

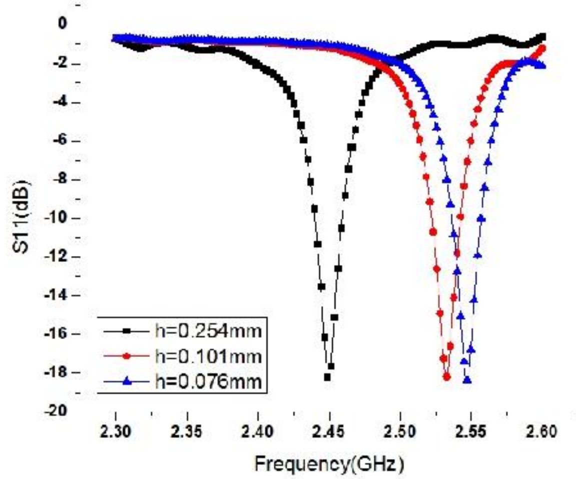



**Fig.2.** Simulation of the reflection coefficient S11 of the proposed antenna for various values of substrate thickness

The results in Fig.2 show that the greater the thickness of the substrate is, the smaller the resonance frequency is. Fig.3 shows that the gain is only slightly reduced for higher values of h. This is very important information to have, especially if it is anticipated that the RFID tag will be placed on many different types of materials and thick substrates.

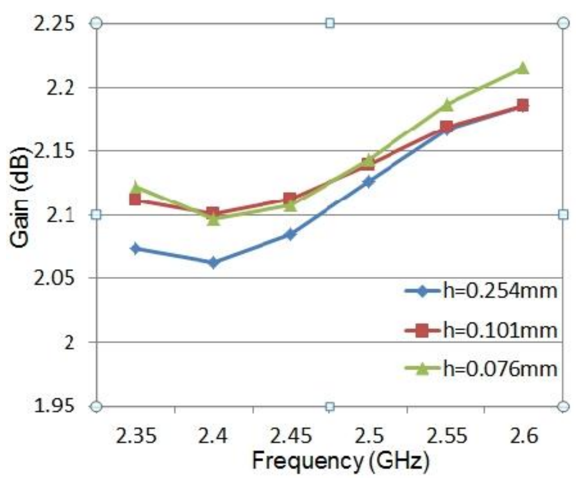



**Fig.3.** Simulation of the gain of the proposed antenna for various values of substrate thickness

#### *3.2 Results for Various Values of Substrate Permittivity*

The next step is to determine the characteristics of the antenna for various values of substrate permittivity. Three different substrate materials are used in this study: felt, fleece and woolen. The felt fabric has a relative dielectric permittivity εr = 1.22, thickness of 2 mm and loss tangent, tgδ = 0.016 [10]. The second substrate, fleece, is a thick fabric that has a relative dielectric permittivity εr = 1.04, thickness of 3 mm and loss tangent, tgδ = 0.024. The third selected substrate, woolen felt has a relative dielectric permittivity εr = 3.5, thickness of 1.45 mm and loss tangent, tgδ = 0.02 [11].

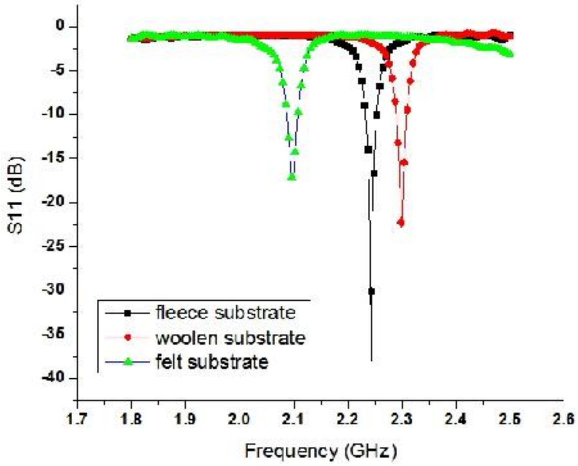



**Fig.4.** Simulation of the return loss S11 of the proposed antenna for various values of substrate permittivity

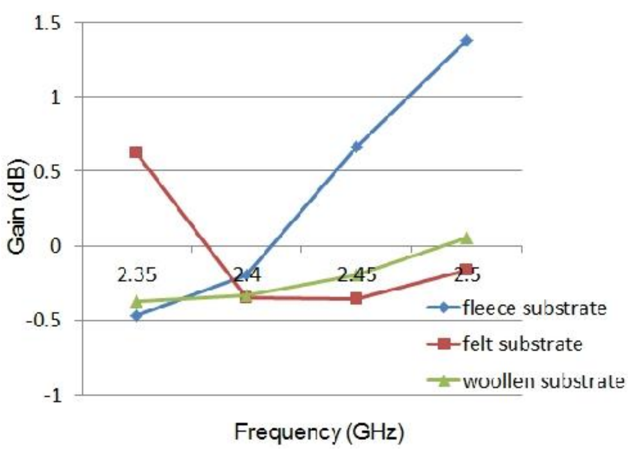



**Fig.5.** Simulation of the gain of the proposed antenna for various values of substrate permittivity

The results from these simulations are shown in Figures.4, 5 for various values of substrate permittivity. The results in Fig.4 show that the greater the dielectric permittivity of the substrate is, the smaller the resonance frequency is. Fig.5 shows that the gain is changed significantly for various values of substrate permittivity.

### *3.3 Results for Various Values of Copper wire Diameter*

The last step is to determine the characteristics of the antenna for various values of copper wire diameter. The results from these simulations are shown in Figures.6, 7. These copper wires have diameters of 0.3 mm, 0.4 mm and 0.5 mm.

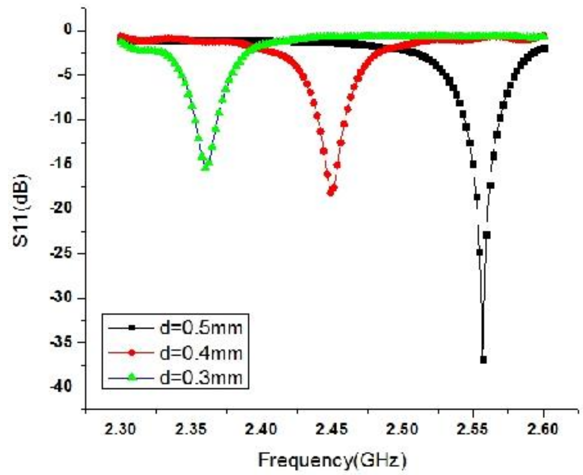



**Fig.6.** Simulation of the reflection coefficient S11 of the proposed antenna for various values of copper wire diameter

The result in Fig.8 shows that the smaller the copper wire diameter is, the smaller the resonance frequency of the antenna is.

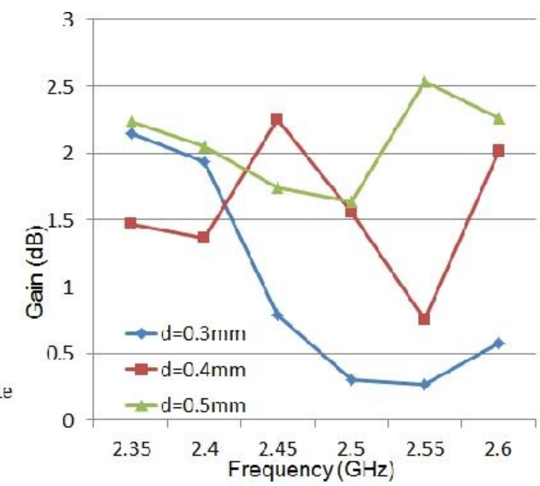



**Fig.7.** Simulation of the gain of the proposed antenna for various values of copper wire diameter

## 4. Fabrication Results

Based on the simulation results above, the proposed antenna was designed using the Kevlar substrate with a dielectric constant of Ɛr= 3.58, a loss tangent of tgδ=0.019, a thickness of h=0.254 mm and the copper wire with a diameter of 0.4 mm. The structure of antenna is shown in the Fig. 1. The dimension of the substrate is L=45 mm and W=16 mm. The radiation element has dimension l1=4.1mm, l2=14.35 mm, l3=2.05 mm, l4=0.4 mm, l5=2.4 mm.

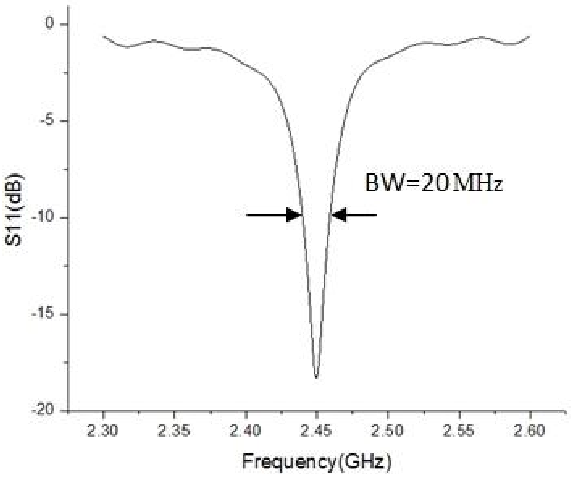
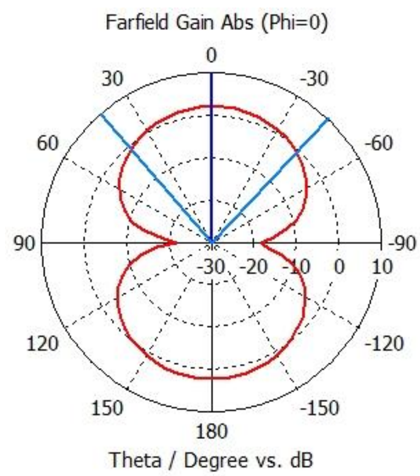
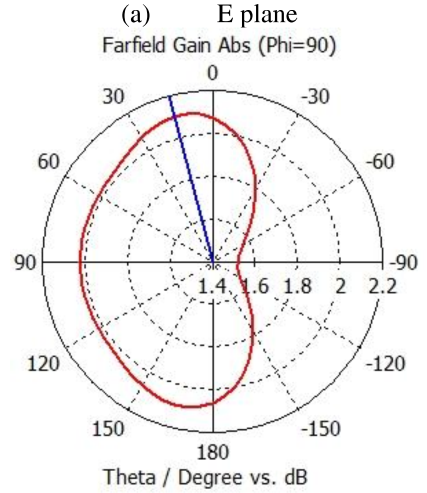



**Fig.8.** Simulation of the reflection coefficient S11 of the proposed antenna




(a) E plane




(b) H plane

**Fig.9**. Radiation patterns of the proposed antenna in the E-plane (a) and H-plane (b).

Simulated reflection coefficient S11 shown in Fig.8 is of -18.26 dB. The Fig.9 shows the radiation patterns of the proposed antenna in the E-plane and H-plane. The antenna has the gain of 2.2 dBi and the bandwidth of 20 MHz at frequency 2.45 GHz.

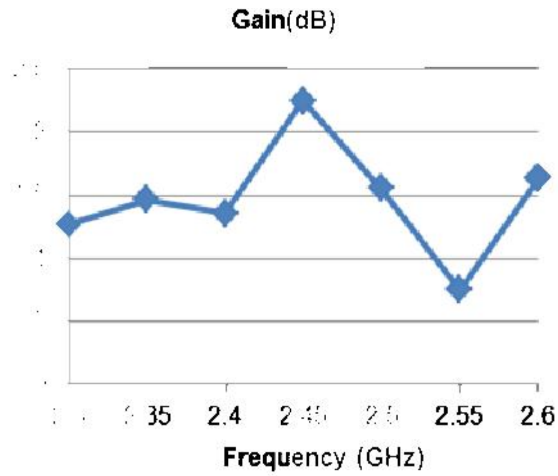



**Fig.10**. The surface current density of proposed antenna at 2.45 GHz

The gain of the proposed antenna in the frequency range from 2.3 GHz to 2.6 GHz is illustrated in the Fig.10. The Fig.11 illustrates the surface current density of proposed antenna. At 2.45 GHz , maximum current distribution is observed at the peak of the abbreviations so the radiation efficiency can be improved when the density of copper fiber in that area is increased.

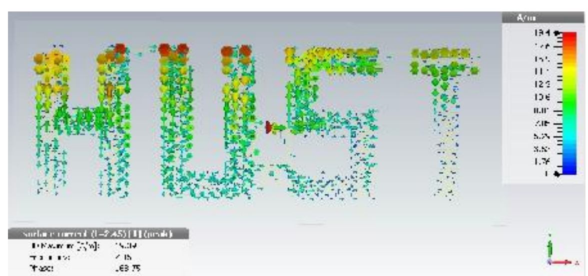


**Fig.11**. Surface current density of the proposed antenna at 2.45 GHz

Finally, the proposed antenna is fabricated by hand using copper fiber and textile. The measurement is performed by the PNA-X network analyzer.

The Fig.12 introduces fabricated antenna. The measured result of the reflection coefficient S11, illustrated in the Fig.13, is -13.3 dB at the frequency of 2.45 GHz .

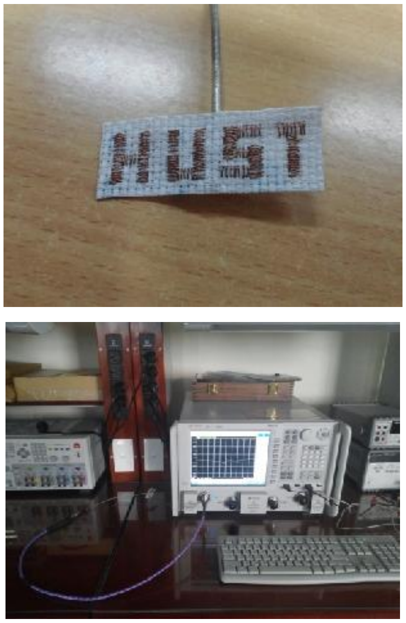


**Fig.12.** Fabricated antenna and the setup of measurement

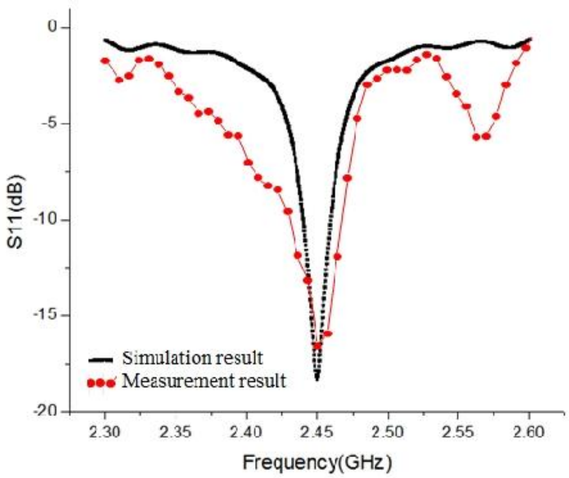



**Fig.13.** Simulated and measured results of the return loss S11

## 4. Conclusion

In this paper, we presented a textile antenna for wearable applications with RFID technology. The prototype has been designed and simulated to have the bandwidth and gain of respectively 20 MHz and 2.2 dBi. The radiation pattern at resonance in the H-plane has the angular width of 83.7 degrees. This design is has a straightforward fabrication and applicable to wearable applications. However the dimension of antenna is still large. It is necessary to minimize this antenna as small as possible.

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