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A Textile RFID Meander Antenna for Military Applications

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ABSTRACT

This study is focused on the construction of a dipole meander textile antenna that exhibits a stable communication system in military applications. The geometric shape of the antenna was calculated and determined based on the fact that dipole antennas geometry shows the highest performance at the Radio Frequency Identification (RFID) frequency band. The High Frequency Simulator Structure (HFSS) program was used for stimulation of the proposed antenna. The fabrication method chosen for the realization of this antenna is the automatic embroidery method, as this method offers high durability in use. The paper aimed to have a textile antenna to operate in the frequency band 868-970 MHz (frequency band defined by NATO), and this was achieved by the proposed textile antenna.

***Keywords**:* Textile antenna, military communication, geometric design.

1. INTRODUCTION

In recent years, textile antennas are being developed as an important element of the smart textile system and the unconventional communication system in the military field [1]. Military wearable antennas must be lightweight, durable, comfortable, and must be easily incorporated into soldiers' uniforms, therefore they should be constructed with flexible materials. These must be cheap, light, comfortable, and durable, and these requirements are met by textile and e-textile materials [2]. The use of conductive textile materials greatly helps in the development and improvement of the properties of wearable antennas [3]. In addition to the selection of materials, it is important to build the geometric model and select the communication system, it must ensure the transmission of information in adverse conditions or indoors and must also not allow information to be blocked by opposing forces [4-6]. Geometric models that have sufficiently high performance in the military field are Dipole antennas and fractal antennas intertwined with communication technologies such as Anti-jam Geographical Position System (GPS) and Radio Frequency Identification (RFID) [7, 8]. Production methodology is also another important process in the development of wearable antennas. Production methods are manual and automatic, but in the military field it is necessary to produce in large quantities, therefore automatic fabrication is more widespread [9]. RFID communication technology allows several advantages for applications in the military. In our work, the following stages were followed for the realization, development, and construction of textile antennas; concept, design, modelling, manufacture, and testing, and they are thoroughly discussed throughout the following sections.

2. MEANDER FRACTAL DIPOLE ANTENNA

2.1 Concept

Dipole antennas are used as a reference for measuring purposes and as a starting design point for new antennas. The dipole antenna has intrinsic resonance and narrowband behavior. The scientific literatures have presented many techniques to increase the antenna bandwidth, and one of the most prominent is the use of fractal structures. Using a fractal structure can permit an overall antenna size reduction and bandwidth increment. Because this geometry plays an important role in reducing the size of a wearable antenna, researchers adapted it to this technology in the development of wearable antennas in the military. In this work, the knowledge from dipole antenna and fractal structures are combined to design the proposed meander antenna.

2.2 Design

Determining the geometric shape of the conductive part is one of the basic stages of textile antenna design. Based on the basic dipole antenna design, the antenna arms must be a quarter of the wavelength of the designed frequency. In this project, the operating frequency chosen is 868 MHz, witch relative free-space wavelength is as by below by quation (1);

$$\lambda = \frac{v}{f} = \frac{velocity\ of\ light}{frequency} = \frac{299792458\ m/s}{868\ MHz} = 0.345m = 345mm \qquad (1)$$

Designing a free space dipole antenna will result in each arm with relative length as by below by equation (2);

$$l_1 = l_2 = \frac{\lambda}{4} = \frac{345}{4} = 86.25 \text{ mm} \qquad (2)$$

The overall dipole antenna length is $l_1 + l_2 = 172.5$ mm (l/2). It is worth to notice, that the dipole antenna by its intrinsic design is a narrow band resonator. The use of the narrowband resonator directly as a textile antenna has its drawback as the operational environment is not controlled. The presence of the closed human body, the possibility of the antenna to be bent or follow a curved shape of the clothes where it has been manufactured, will result in frequency band shift [2, 5]. To improve the overall antenna bandwidth and to be less dependent on the operational environment, a mixing of the dipole antenna and the fractal antenna is being analysed in this work. One of the goals is also to design an antenna geometry that minimizes the final dimensions of the overall radiating element. In Figure 1 is shown the analysed antenna geometry measuring 60 x 120 x 0.4 mm. This final design follows a preliminary phase of antenna design using radiofrequency modelling tools as shown in the next section.

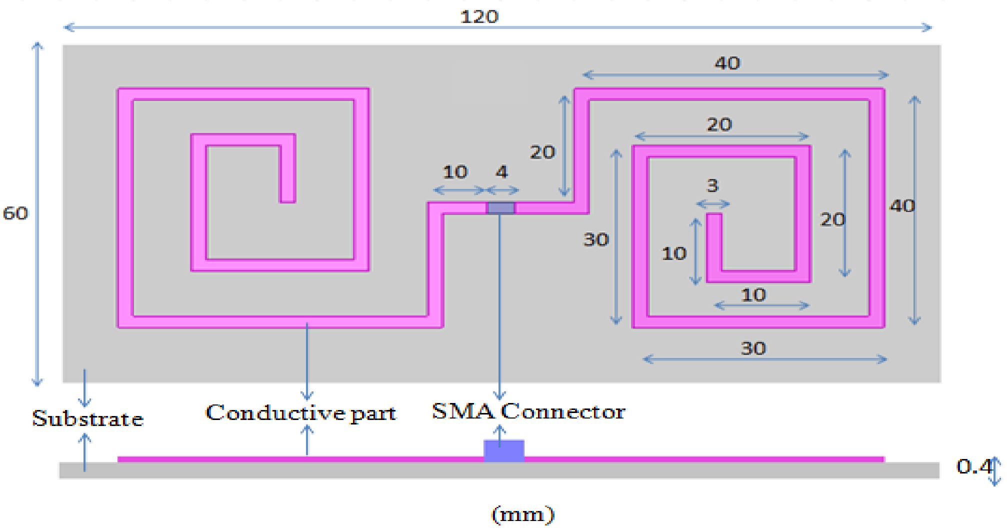


Figure 1. Presentation of the proposed meander dipole antenna geometry

2.3 Modelling

Designing a textile antenna element requires both understanding of radiofrequency antenna theory, textile materials characteristics, and manufacturing capacities and limits. The antenna design, starting from the simple dipole geometry to the actual shape shown in figure 1 has been carried using the HFSS simulation tool [10]. In Figure 2 is shown the Ansys HFSS modelling environment where the design parameters are being analysed. The mechanical and electromagnetic parameters of the textile substrate following actual textile materials used to physically fabricate the designed antenna.

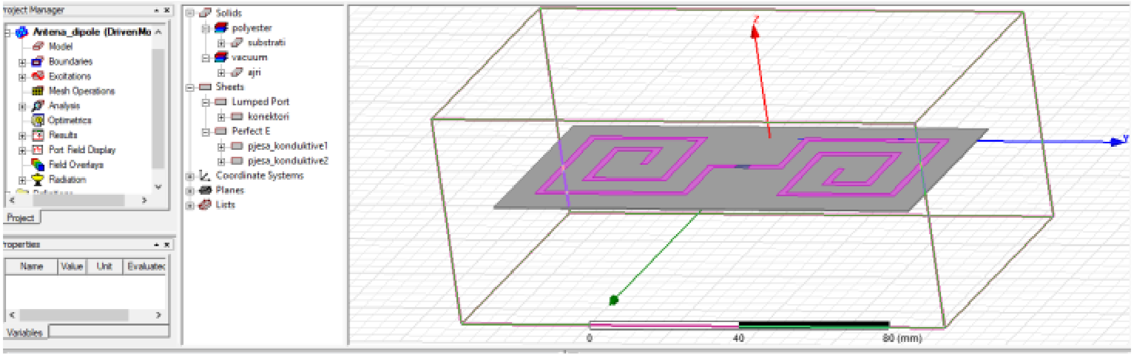
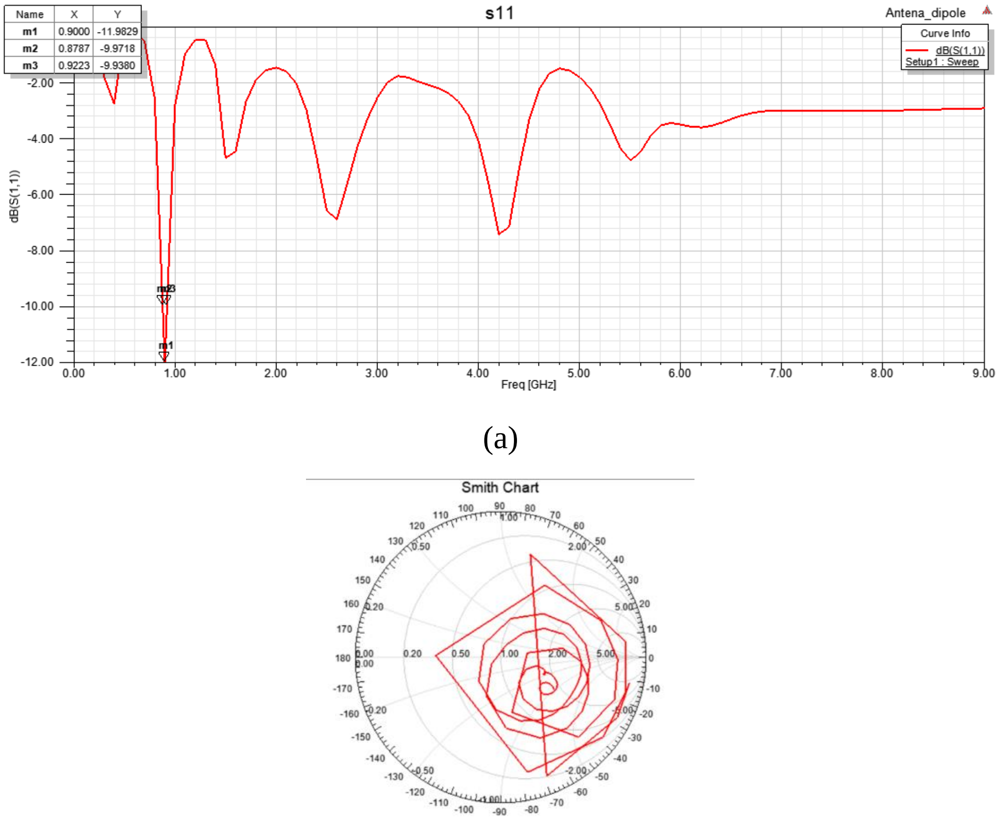


Figure 2. Ansys HFSS designing tool and relative antenna model

In this design, the antenna feed is a 50-ohms coaxial connector to be closer to the real Sub-Miniature Version A (SMA) antenna connector used to test the antenna prototype as will be shown in the next section. For these purposes, antenna reflection coefficient or S11 parameter is crucial to be monitored as antenna operation frequency bandwidth is defined by this parameter. In Figure 3 (a) is presented the simulated antenna reflection coefficient with its best performance in the designed frequency with reflections better than -10 dB. The antenna reflection coefficient parameter is crucial for antenna usage but is not useful to understand the behaviour in the design phase. For these purposes, is better to analyse the antenna impedance in all frequency bands as by the Smith chart presented in Figure 3 (b). The Smith chart has a better insight into antenna design electrical parameters and can be useful to designers to intelligently modify the antenna shape to better feet to the required bandwidth.



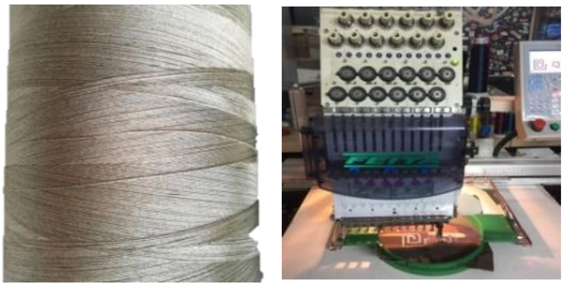
(a)

(b)

Figure 3. Results from HFSS simulation: (a) Reflection coefficient of the proposed antenna in dB; (b) Smith Chart

2.4 Manufacturing

The manufacturing technique used for the realization of antennas is the automatic embroidery method, as shown in Figure 4 (b). The dielectric part of the antenna is made by a textile substrate (50% cotton-50% nylon). The conductive part is made by conductive thread 82% nylon, coated with a thin silver film, as shown in Figure 4 (a), defined geometry. In the next step, the SMA connector was incorporated with the help of an SMA cable.



(a) (b)

Figure 4. (a) Presentation of the conductive thread, (b) The embroidery process in the machine

Figure 5. The implemented meander textile presenting the connected 50-ohm coaxial cable

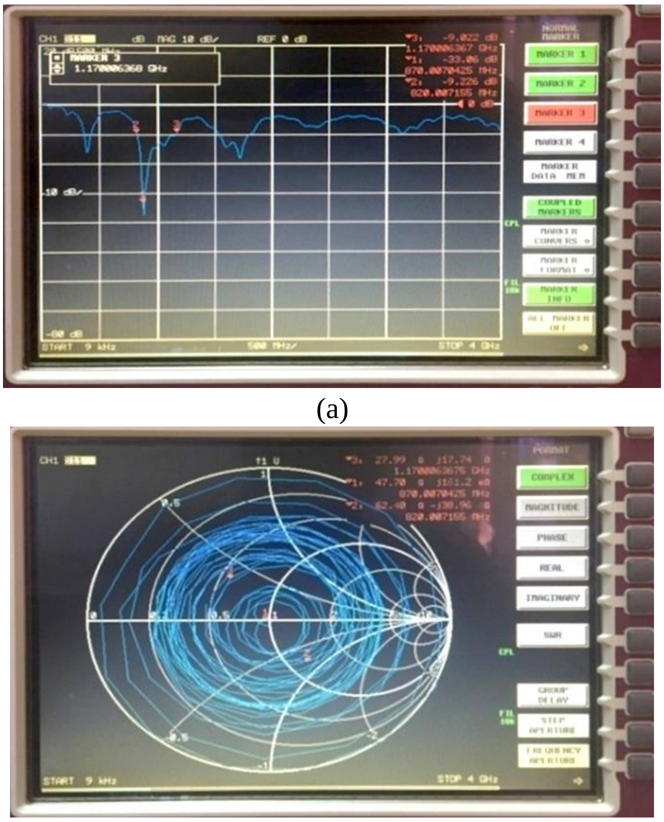
2.5 Testing

The antenna prototype has been manufactured following the designed shape geometry and manufacturing process briefly described in the previous sections. To test the antenna electromagnetic bandwidth performance, a Vector Network Analyses from Rohde & Schwartz has been used as presented in Figure 6.

Figure 6. Measurements of the proposed antenna using a Rohde & Schwartz ZVRE Vector Network Analyzer

Measuring the reflection coefficient, as shown in Figure 7, a very good match with the simulated parameter is observed. The reflection coefficient parameter has the same behaviour as the simulated one (compare Figure 3a with 7a). The designed antenna prototype presents three operational frequency bandwidths with a reflection coefficient better than -10 dB (set as a required reference for mobile, handheld, and portable antennas). The first operational bandwidth is in the range 370 – 430 MHz, with the smallest reflection of -15.96 dB. The second band is in the range of 820-1170 MHz, with the smallest reflection coefficient of -33.06 dB. This band of frequencies is the best one obtained which includes the designed frequency band. The third band is in the range of 1530-1780 MHz, with the smallest reflection of -18.03 dB.

Also, to have a better insight of the antenna electrical behaviour, a Smith chart has been measured and relative input impedance at some sample frequencies. As a reference, the manufactured antenna presents an input impedance of $Z_{in} = 47.7 + j\ 0.161$ ohm at 870 MHz frequency. Input impedance that is very close to the 50 ohms of the required coaxial connector.



(a)

(b)

Figure 7. Results from laboratory measurements: (a) Reflection coefficient of the proposed antenna in dB; (b) Smith Chart

2.5 Results

Table 1 depict laboratory reflection coefficient measurements (LAB) and their comparison with the obtained in the designing phase from the Ansys HFSS tool. Despite the differences between the frequency band, the manufactured prototype has a very good frequency bandwidth as by requirements in the RFID communication technology.

Table 1. Simulated and laboratory measurements of antenna operational bandwidths.

HFSS		**LAB**	
Frequency Bands (MHz)	**Return Loss (dB)**	**Frequency Bands (MHz)**	**Return Loss (dB)**
878.7-922.3	-11.9829	370-430	-15.96
		820-1170	-33.06
		1530-1780	-18.03

3. DISCUSSION AND CONCLUSION

This paper has presented the process of designing, manufacturing, and measuring the textile antenna. The design process using the Ansys HFSS tool with textile material know-how is crucial to obtain the best from the designing and simulation tools. The manufacturer method was chosen for the realization of the textile antenna is suitable for antenna design, as shown from the measured prototype performance.

Despite there is not a perfect match between the simulated and designed antenna reflection coefficient, the behaviour is the same. The differences are due to the roughness of the manufactured conductor which in the design tool has been set as a continuous material. With this knowledge and the analysis from the Smith chart in the designing phase, is possible to modify the antenna shape to acknowledge the manufacturing capabilities.

Since the intended purpose was the operation of antennas in the frequency band 868-970 MHz (frequency band defined by NATO), it follows that our proposed antenna has achieved the required specification with silver-coated nylon thread.

CONFLICT OF INTEREST

The authors confirm that there is no conflict of interests associated with this publication and there is no financial fund for this work that can affect the research outcomes.

REFERENCES

[1] Ali S.M., Sovuthy C., Imran M.A., Socheatra S. and Abidin Q. H. A. a. Z. Z. Recent Advances of Wearable Antennas in Materials, Fabrication Methods, Designs, and Their Applications: State-of-the-Art, *Micromachines*, 2020; 11(10), 1-41.

[2] Poonkuzhali R. and Balakrishna Z. C. A. a. T. Miniaturized Wearable Fractal Antenna for Military Applications at VHF Band, *Progress In Electromagnetics Research C*, 2016; 62(1); 179-190.

[3] Salvado R., Loss C., Gonçalves R. and Pinho P. Textile Materials for the Design of Wearable Antennas: A Survey," *Sensor*, 2012; 12(1); 15841-15857.

[4] Singh A. and Pandey R. M. M. a. V. K. Design and Optimization of Microstrip Patch Antenna for UWB Applications Using Moth–Flame Optimization Algorithm," *Wireless Personal Communicatio*, 2020; 112(1); 2485-2502.

[5] Monne M.A. and Chen X. L. a. M. Y. Material Selection and Fabrication Processes for Flexible Conformal Antennas," *International Journal of Antennas and Propagation*, 2018; 2018(1), 1-14.

[6] Keller S., Weiss S., Maloney J., Kwon D.-H., Janaswamy R. and Morley J. "Design Considerations for a Wearable Anti-Jam GPS Antenna," in *2nd URSI Atlantic Radio*

Science Meeting (AT-RASC), Gran Canaria, Spain, 2018, p. 1-4.

[7] Keller S. Anti-Jam GPS Antennas for Wearable Dismounted Soldier Navigation Systems, Adelphi, United States, 2016. https://apps.dtic.mil/sti/pdfs/AD1011921.pdf

[8] Kumar R. and Chaubey P.N. "On the design of tree-type ultra wideband fractal Antenna for DS-CDMA system," *Journal of Microwaves, Optoelectronics and Electromagnetic Applications,* 2012; 11(1); 107-121.

[9] Santas J., Alomainy A. and Hao Y. "Textile Antennas for On-Body Communications: Techniques and Properties," in *Second European Conference on Antennas and Propagation (EuCAP)*, Edinburgh, 2007, p. 1-4.

[10] Ansys, *Ansys Electronics Desktop Student - HFSS*, 2021.

https://www.ansys.com/products/electronics/ansys-hfss