Environmental Effects on Short Dipole Antenna and RFID UHF Passive Tags

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***Abstract*— The use of RFID systems as sensing and identification systems is increasing in the last years. Along the reduction of costs, the study of RFID technology needs more research about the effects of temperature, humidity, altitude, vibration and some materials on its readability and operability. The effects of temperature and some materials in the performance of short dipole antennas and RFID UHF passive tags are presented in this paper, using simulations and measurements. It has been found that all the materials affected the antenna's performance. The effects of the temperature in the read range of five RFID UHF passive tags were measured with different temperatures and the relation between read range and temperature was verified.**

Keywords*— *short dipole antenna, RFID tag, performance, materials, temperature.

I. Introduction

A basic radio frequency identification (RFID) system consists of three main components: tags or transponders, which contains the identification code; a reader or transceiver, which transmits a signal to interrogate the tag and receives the reflected wave and the software where the application is implemented [1].

RFID is a well-developed technology with various interesting functionalities and applications [2]. In addition to the high monetary value, RFID technology has other difficulties, such as the influence of the environment on its operation. Although multinationals have conducted and encouraged studies on such systems, the influence of certain materials and adverse environmental conditions on the behavior of RFID systems needs further study. Any disturbance in the operation of an RFID system caused by an adverse environmental condition results in reducing the reliability of these systems and consequently reduces the competitiveness of this technology.

In [3], measurements in an anechoic chamber were performed to determine the radiation pattern of some omnidirectional antennas in the presence of several objects in order to demonstrate the degradation that the objects cause in these antennas.

It was verified in [4] the effects of an aluminum piece on the parameters of a folded dipole antenna. The dependence of the antenna parameters on the aluminum piece's size and the distance between the piece and the antenna were analyzed. The radiation pattern of the antenna was changed and the resonance frequency increased as the aluminum piece's area increased.

In [5], the effects of near objects on RFID tags were studied, as well as the effects of these objects on the impedance and radiation pattern of antennas that emulate the structure of the tags using measurements and simulations.

In [6], it was obtained the far-field radiation diagram and the gain variations for thin and flexible antennas attached in wood, acrylic, cardboard, deionized water, ethylene glycol, ground beef, and an aluminum plate. The changes in the radiation diagram are due to several phenomena, such as surface waves, diffraction and the loss tangent of each material.

In [7], the effects of temperature, humidity, altitude and vibration were investigated on the reading and operation of SAW RFID systems. This study was performed in a temperature chamber and both tests showed that the readability of the tags was affected at certain temperatures.

In [8], an investigation of the impact of temperature and humidity on changes in the resonance frequency of a passive UHF RFID system was presented. The results of this study indicate that the frequency and return losses are independent of each other and are good indicators for monitoring temperature and humidity.

This paper presents the influence of some environmental conditions, such as temperature, on the performance of RFID tags, as well as the influence of the presence of some materials on the radiation diagram of a planar antenna, the type of antenna commonly used in RFID tag designs.

II. THE EFFECTS OF SOME MATERIALS IN THE PERFORMANCE OF SHORT DIPOLE ANTENNAS

An electrically short dipole antenna was chosen for measurements because this is one of the most common types of antennas used in RFID tags. Reference [6], for example, also used a dipole antenna, but a dipole antenna folded. Several factors influence the radiation pattern of an electrically short antenna, such as some ambient conditions, temperature and humidity.

A. Short Dipole Antenna

The electrically short dipole antennas used for the measurements were designed with @CST Microwave Studio and made on phenolite substrate, as seen in Fig. 1. If the cross-section of one of the antenna arms is used to calculate the antenna resonant frequency, the result obtained is a frequency of 890 MHz. If one of the meander arms of the antenna is stretched and the distance of the antenna stretched is used in the calculations, the resonance frequency is 300 MHz [9].

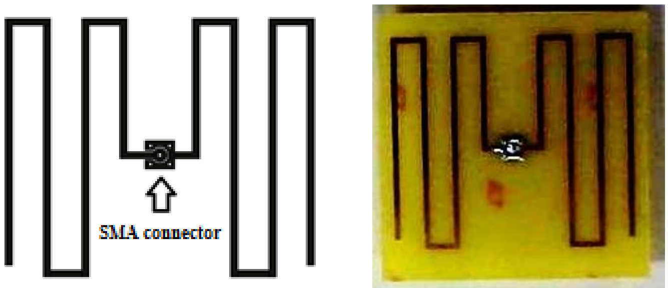


Fig. 1. Electrically short dipole antenna built in the LEMA/DEE/CEEI/UFCG.

TABLE I. ELECTROMAGNETIC PARAMETERS OF THE MATERIALS USED

Materials	**Electromagnetic Parameters**		
	Conductivity (S/m)	***Dielectric constant***	***Loss tangent***
Large Aluminum Piece	$3.96*10^{-7}$	8.8	$6.1*10^{-4}$
Small Aluminum Piece	$3.96*10^{-7}$	8.8	$6.1*10^{-4}$
Plastic Bottle with Water	$1*10^{-2}$	81	0.048
Ground Beef	-	50	0.7
Plaster	$8{,}25*10^{-15}$	4	0.005

B. Electromagnetic Parameters of Materials

The electromagnetic parameters of the materials used in the measurements are described in Table I [6], [10], [11], [12], [13]. These materials were chosen because they were used in similar research and they have electromagnetic parameters discussed in other works in the area. The magnetic permeability values of all materials are very close and approximately equal to 1. For the ground beef, only the values of the loss tangent and the dielectric constant were found.

C. Simulated results

Simulations were performed in order to investigate the effects of materials (a small aluminum piece, a large aluminum piece, a plastic bottle with water, a plaster piece and a ground beef piece) near an electrically short planar dipole antenna in the free space.

The electrically short planar dipole antenna was simulated in the CST Microwave Studio software in free space, and the radiation pattern of the antenna was obtained. The antenna substrate was designed 10 cm wide by 10 cm long and 0.1 cm thick and was projected with a permittivity of 4.6 and permeability of 1.0. The meander arms were constructed with PEC (perfect electric conductor) material. Then, each material was placed 1.5 cm away from the antenna and the radiation diagram for each case was obtained.

The antennas' radiation diagram in the resonance frequency were obtained, as seen in Figures 2, 3, 4. The blue lines in these graphs indicate the direction of the main lobe.

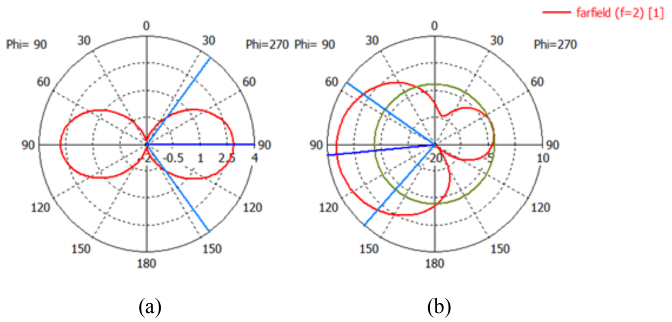


Fig. 2. Comparison of simulated antenna radiation gain diagrams (elevation plane): with (a) and without (b) the small aluminum piece (12 X 10.5 cm).

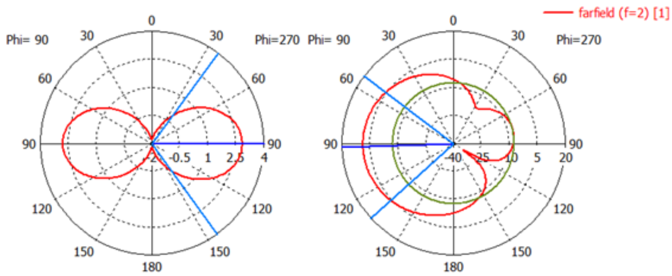


Fig. 3. Comparison of simulated antenna radiation gain diagrams (elevation plane): with (a) and without (b) the large aluminum piece (16 X 13 cm).

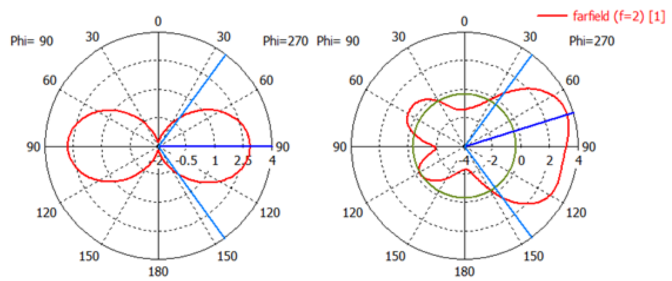


Fig. 4. Comparison of simulated antenna radiation gain diagrams (elevation plane): with (a) and without (b) the plastic bottle with water (the radius is equal to 3 cm and the height is equal to 23 cm).

The simulations showed that the aluminum plates caused less distortion in the antenna's radiation pattern of gain than the other materials due to the low tangent of losses of this metal. The plastic bottle with water and the ground beef causes an increase in the beam width of the main lobe of the radiation pattern of the dipole antenna.

D. Measurement results

In experiments to measure the influence of objects, Fig. 5, on the electrically short dipole antenna radiation pattern, it is necessary to use another identical antenna for measurement. The latter antenna was connected to a GA4063 GRATTEN spectrum analyzer using a coaxial cable and the antenna under test was fed by an ATTEN AT8010D radio frequency generator through another coaxial cable, as shown in Fig. 6. This experiment was done in the Control Laboratory of the Electrical Engineering Course/CT/UFPI.

Initially, the dipole antenna radiation gain diagram was determined without the presence of materials, with the antennas distant each other by 36 cm. Then, the radiation patterns were obtained for the dipole in the presence of five different materials, and the results were compared, as seen in Fig. 7. The material were placed roughly 2 cm away from the short dipole antenna.

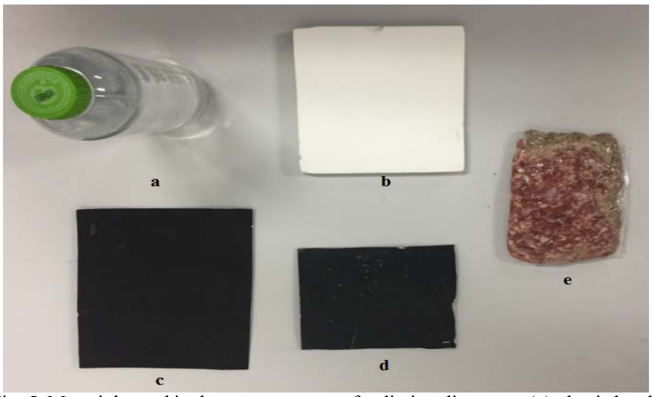
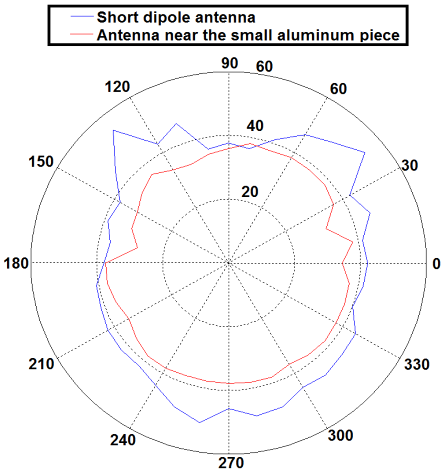
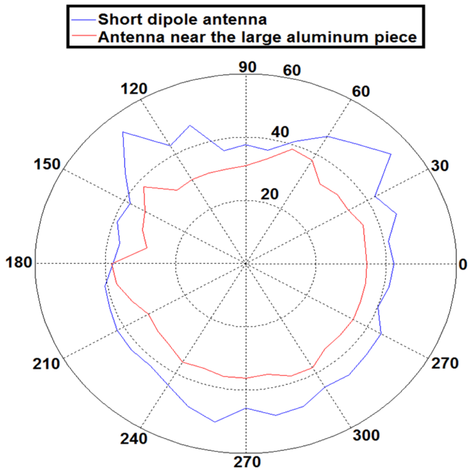


Fig. 5. Materials used in the measurement of radiation diagrams: (a) plastic bottle with water, (b) plaster piece, (c) large aluminum piece, (d) small aluminum piece and (e) ground beef.

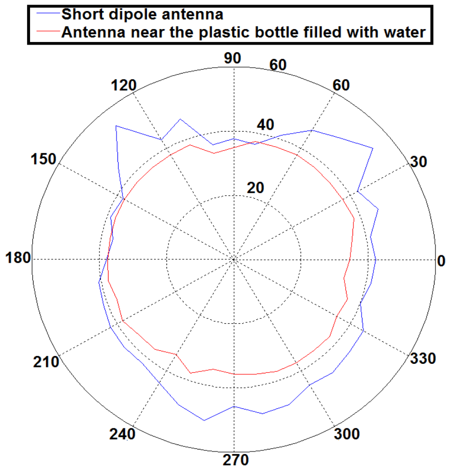
Fig. 6. Measurement setup of antenna radiation diagram: a) signal generator, (b) spectrum analyzer, (c) connector cable, (d) short dipole antenna.



(a)



(b)



(c)

Fig. 7. Comparison of antenna power radiation patterns (azimuth plane) with and without: (a) the small aluminum piece, (b) the large aluminum piece, (c) the plastic bottle with water.

The size of the aluminum plate placed close to the antenna causes small change in the power radiation diagram of the antenna. In addition, all the materials caused some kind of distortion in the performance of the antenna. Moreover, for the ground beef and the bottle with water [6] also showed these results.

The plastic bottle with water did not cause significant interference in the radiation diagram of the dipole antenna due to its low loss tangent.

The changes in the gain irradiation diagram of the electrically short dipole antenna near the bottle with water are caused by the bottle's water molecules, which act as tiny dipole antennas that align with the oscillate electromagnetic fields.

The water molecules produce heat in this process, so the antenna near the bottle with water loses energy due to the vibration of water molecules because these molecules form the path of fewer impedance to the absorption of electromagnetic energy.

III. The Effects of Temperature in the Performance of RFID UHF Passive Tags

A. *The RFID UHF Passive Tags*

The five passive UHF RFID tags used to perform the experiments with temperature and aluminum are shown in Fig. 8.

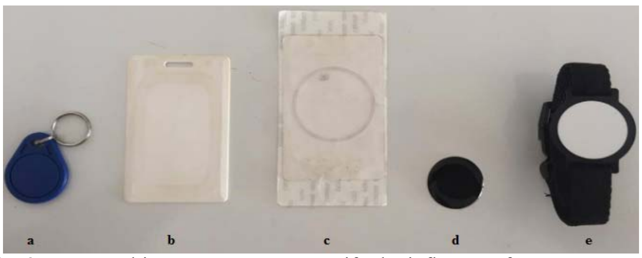


Fig. 8. Tags used in measurements to verify the influence of temperature and aluminum on their operation.

The setup of the experiment is set out in Fig. 9 and shows the Phidget reader model P/N 1023 and a laptop computer used to display the information collected by the reader.

Fig. 9. Setup of measurements for the verification of the influence of temperature and aluminum on the performance of passive UHF RFID tags.

B. *Results*

The first part of this step of measurements consisted in the identification of each tag by the reader with the placement of the tags next to it.

Following the nomenclature shown in Fig. 8, the blue tag "a" was identified by the reader as 1f00be131b, "b" was identified as 2100681163, the tag "c" as 1f00d9c251, the adhesive tag "d "Received the code 1f0074d439 and " e " was named 2100453780.

After identifying the antennas, the range of each of the tags was measured at the following temperatures: 21 ° C and 31 ° C, as seen in Table 2.

Reference [8] showed that an RFID tag attached to a piece of aluminum is not detected by the reader at distances smaller than 500 cm. In order to verify this information, the tag "e" code 2100453780 with approximately 1 cm radius was attached to an aluminum plate of approximately 15 cm radius and its range was measured. The result found is equal to the result of [8].

TABLE II. Range of RFID passive UHF tags

Tags	**Range (cm)**	
	Temperature	
	21º	**31º**
a (1f00be131b)	9,8	9,2
b (2100681163)	12,8	11,7
c (1f00d9c251)	6,8	5,8
d (1f0074d439)	10,7	10,3
e (2100453780)	10,2	9,8

The observation in Table II shows that the increase in temperature by 10 ° C caused a reduction in the range of all tags.

IV. Conclusion

The simulations in the CST software to obtain the influence of some materials on the performance of the dipole antenna showed that the aluminum plates caused fewer distortions in the radiation pattern of gain of the antenna than the other materials due to the low tangent of losses of this metal. Moreover, the plastic bottle with water and the ground beef made the radiation diagrams of the dipole antenna increase the beam width of the main lobe. These results were also demonstrated by Griffin et al. (2005).

The laboratory measurements on the influence of the materials discussed in Table 3.1 on a dipole antenna showed that the size of the aluminum plate placed near the antenna causes irrelevant change in the power radiation diagram of the antenna. In addition, all the materials caused some kind of distortion in the performance of the antenna, and for the ground beef and the bottle with water these results were also shown by Griffin et al. (2005). Greater distortion of the irradiation diagram was observed for the range of angles between 280 ° and 330 ° probably caused by the presence of a plastic metal near the place where the antenna and the materials were placed.

Measurements with RFID tags demonstrated that the increase of the temperature by 10 ° C caused a reduction in the tag's range. Moreover, Mo & Zhang (2007) demonstrated that an adhesive tag placed on an aluminum plate reduces the tag's range to zero. The same result was verified in the experiment because the tags were not recognized by the reader when they were attached to the aluminum and close to the reader.

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