Available online at www.worldscientificnews.com

World Scientific News

WSN 44 (2016) 35-49 EISSN 2392-2192

Antenna Design based on Meander Line Technique to be applied to RFID tag

Ricardo Meneses González*, Laura Montes Peralta

Instituto Politécnico Nacional Escuela Superior de Ingeniería Mecánica y Eléctrica, Unidad Zacatenco, Ingeniería en Comunicaciones y Electrónica, Col. Lindavista, C. P. 07738, México, D. F.

*E-mail address: rmenesesg@ipn.mx

ABSTRACT

This work describes the design and implementation of an antenna based on meander line technique and ended in circular structures and two parasitic element acting as reflectors, in order to be applied as 915 MHz UHF RFID tag antenna. In order to determine the performance of varying design parameters on impedance, resonance frequency, radiation pattern, etc., HFSS simulation software has been used and experimental tests under an anechoic chamber have been applied. The achieved results show the feasibility of the designed antenna.

***Keywords*:** RFID tag antenna; loop antenna; meander line technique; resonance frequency; parasitic elements

1. INTRODUCTION

Radio Frequency Identification System, a wireless communication system, consists of a wireless communication link between a remote transponder (antenna and integrated circuit), known as the tag, containing the information into the memory block, and an interrogator or reader, which emit radio waves and collect part of them reflected back by the RFID tag, as shown in Figure 1.

RFID enables healthcare facilities improve overall safety and operational efficiency because it operates without line-of-sight while providing read/write capabilities for dynamic item tracking, used to identify objects or people with no physical contact or visual supervision. Even so numerous RFID applications come out for instance: consumer packaged goods, animal identification, waste management systems, hospitals, libraries, vehicular identification and even humans tagged with RFID chips [1,2], etc.

Relative to the public health system, hospitals have been victims of babies' robberies, according to the newspapers information, some newborns babies have been taken out from them, RFID technology offers advantages and solutions, reinforcing the control and security into the hospital building in order to prevent baby kidnapping attempts, as well as, it is an aid tool for the hospital administrative staff to control the patient medical history, drugs robbery, and patient identification [3].

Actually, the UHF RFID Wristband is used for Personnel Tracking, such as patient tracking, ticket management and amusement park. By using silicone material, it is waterproof and heat-resistant, and it can be reusable after high-temperature sterilization, and it is ideal for unlimited access control applications, such as hospitals [4], as shown in Figure 2. Nevertheless, the most of the manufacturers inform some limitations, for instance, a Read / Write Range approx. to 1-3 m, line of sight (LOS), due to patient position, low antenna gain, unsuitable antenna polarization, etc.

When RFID technology is applied to vehicular Identification the tag installed in the windshield motorcar, the memory tag contains important information for instance owner name, driving license, fines, etc., as shown in Figure 3.

Figure 4 shows an important application, the information data contained into the tag allow to the doctor in charge from anywhere through a mobile device, patient remote supervision, to know, in real time, a particular patient´s health state.

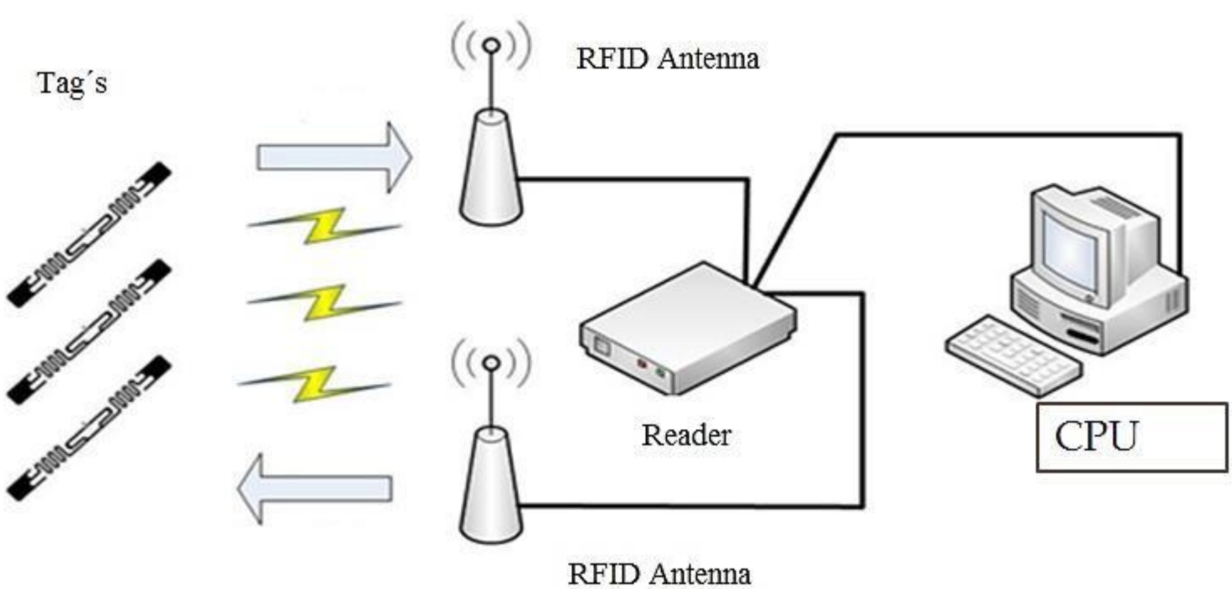


Figure 1. RFID System.

Figure 2. RFID applied to patient identification.

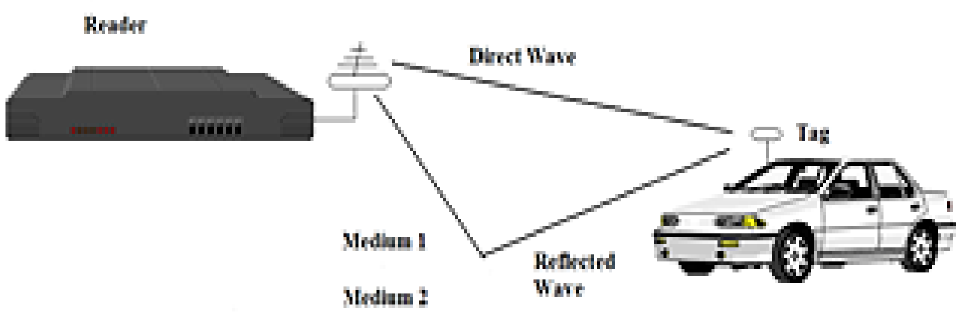


Figure 3. RFID technology applied to vehicular Identification.

Design this kind of antenna is a challenge since it is necessary to design a RFID tag antenna which dimensions must be enough small size for be installed as a bracelet on the wrist of the patient, moreover, it should satisfy gain, resonance frequency, impedance requirements, circular polarization, bandwidth requirements (ten of MHz) and low cost. To determine the performance of design parameter, as impedance, resonance frequency, radiation pattern, polarization, HFSS simulation software has been used and experimental tests under an anechoic chamber have been applied.

The paper is organized as follows: section 2 describes a brief tag antenna design foundation, section 3 discusses simulation and measurements results, and conclusions and references are described in section 4.

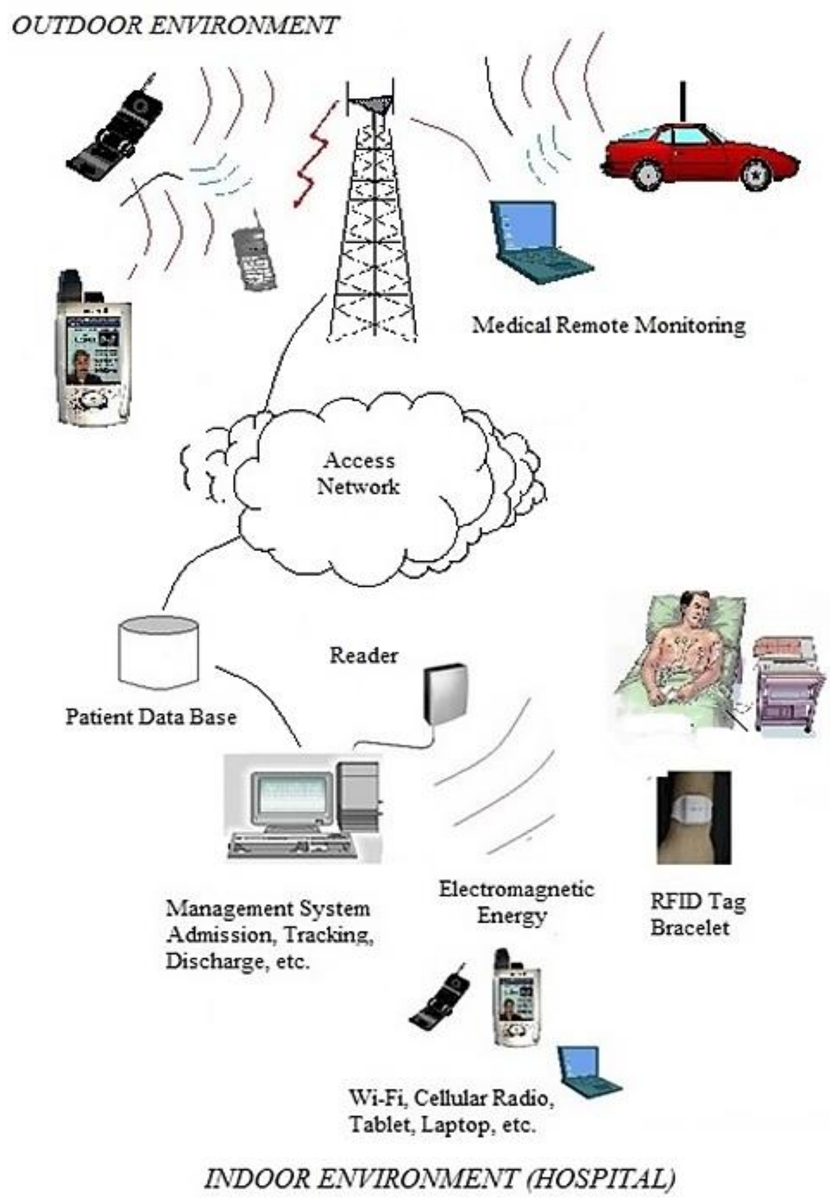


Figure 4. RFID applied to patient remote supervision.

2. TAG ANTENNA DESIGN FOUNDATION

2. 1. Design Foundation

An appropriate RFID tag as bracelet wrist applied to tracking and location assistance and identification must satisfy small size, gain, resonance frequency, and impedance requirements, in order to match to the passive RFID integrated circuit (IC), to have the maximum matching and achieve maximum efficiency and minimal effects of the electromagnetic environment, as well as bandwidth requirements (ten of MHz) and low cost. Uniform Meander Line Antennas, UMLA [5], are designed by a loop antenna or bending the arms of a printed dipole at right angles to create an electrically larger antenna in a smaller area and a set of symmetric rectangular jointly connected, forming a parasitic element, as shown in Figure 3, where N is number of turns, h_{ni} and v_{ni} are horizontal and vertical segments of the n^{th} turn.

The currents on the symmetric and adjacent horizontal segments have opposite phase, meanwhile N increases, the antenna shows a smaller resonant width due to the wire is folded along a great number of turns within a small area, this way, the optimum gain is achieved with highest radiation resistance when the total wire length is smallest [6]. On the other hand, the radiation resistance is affected by the vertical segments, therefore, this kind of antenna exhibits low radiation resistance due to portion of the wire is bent along horizontal segments, and this one could be improved if the central segment h_0 is increased, in this case the wire resonant length increases and consequently also the loss resistance. In order to radiate the maximum energy, the dimensions of the antenna must be on the same order as the radiated wavelength.

To obtain the maximum gain having the maximum size (V_{max}, H_{max}), each horizontal and vertical segments need to be properly adjusted to maximize the radiation resistance, minimize the loss resistance and obtain the resonance frequency, 915 MHz, due to the chips are made to cover three UHF RFID frequency ranges for different regions: Europe (866.5 MHz), and Asia (953 MHz), in our case North America (915 MHz). These chips have typically input impedances with a real part of one order of magnitude, smaller than imaginary part [7].

The inductance *L* results of the current flowing along the microstrip line, and the capacitance *C* results of the gap between the two adjacent vertical conductors as shown in figure 5. Hence the center frequency of the bandgap, LC circuit is given by [8,9]:

$$f_c = \frac{1}{2\pi\sqrt{LC}} \tag{1}$$

And the bandwidth of the bandgap frequency is given by:

$$BW = \frac{1}{\eta_0}\sqrt{\frac{L}{C}} \tag{2}$$

where: η_0, free space intrinsic impedance

It is easily noted from (1) that the equivalent circuit LC should be increased in order to decrease the bandgap frequency center, and the capacitance (2) should be decreased in order to increase the bandwidth.

On the other hand, maximum power transfer is one of the basic problems on antennas design., it is clear that the maximum power transfer to RFID tag is achieved when the impedance of the antenna is equal to the conjugate complex of the chip impedance, this way, inductive-match feed structure for wideband impedance between antenna-chip of the RFID tag without additional matching networks was proposed by [10], as shown in figure 6, which input impedance is given by (3). This structure matching is used to compensate the large capacitive reactance of tag chip.

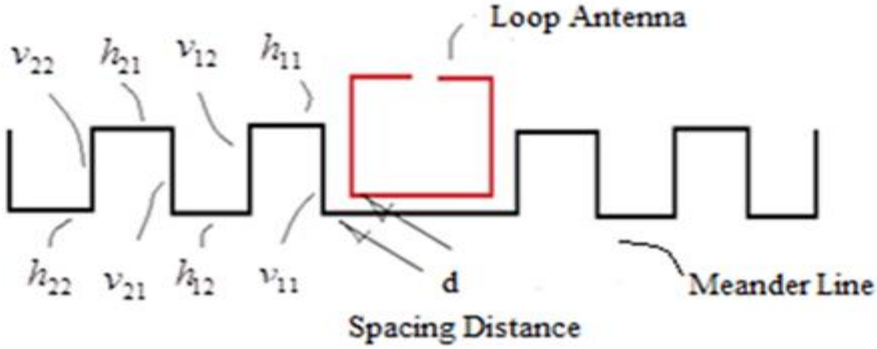


Figure 5(a). Uniform Meander Line Antenna.

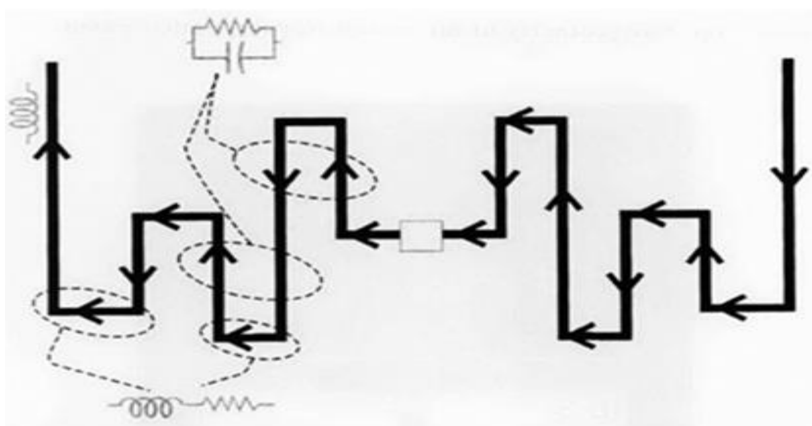


Figure 5(b). Uniform Meander Line Antenna.

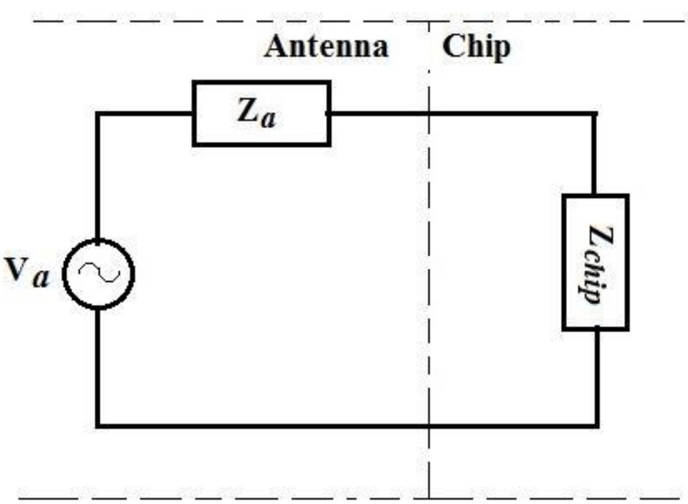


Figure 6(a). Inductive Match Feed Loop.

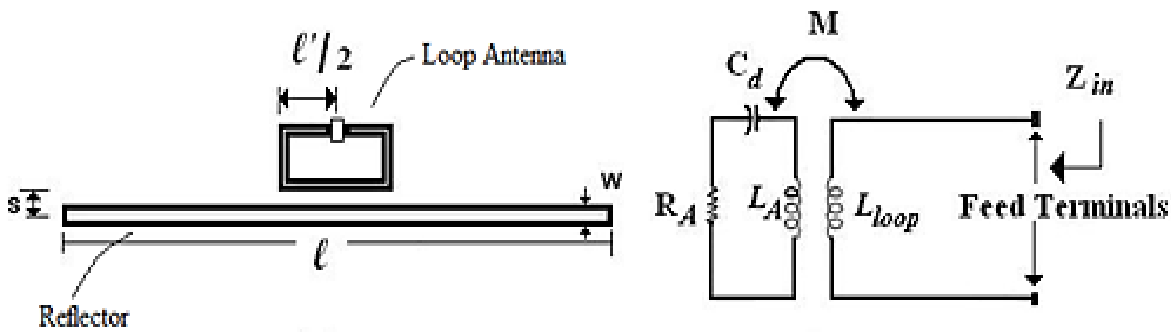


Figure 6(b). Inductive Match Feed Loop.

$$Z_{in} = R_{in} + jX_{in} = Z_{loop} + \frac{(\omega M)^2}{Z_A} \tag{3}$$

where:
Z_{loop}, loop impedance
Z_A, radiation impedance
M, mutual impedance

3. SIMULATION AND MEASUREMENT

The designed antenna for passive RFID tag is printed on a single conducting plane with a single dielectric substrate, Epoxy glass fiber FR-4, electric permittivity, $\varepsilon_r = 4.4$, fed with an SMA connector through the loop antenna.

HFSS software [11] has been used to simulate the designed antenna, satisfying the following requirements:

- Operation Frequency: 915 MHz
- Dimensions: Length: 8 cm (λ/4), Wide: 2 cm (λ/8)
- Loop Antenna Perimeter: 3.2 cm
- Material: Copper
- Coupling: Inductive
- Spacing distance between adjacent horizontal segments: 10 mm
- Spacing distance between loop antenna and MLA: 0.1 mm
- Number of turns: 3

A Vector Network Analyzer ZVB 40 calibrated in the band 500 MHz – 2 GHz, as shown in Figure 7, has been used to measure the resonance frequency of the designed antenna.

Figure 7. Measurement equipment.

Fig. 8 shows Magnitude vs. Frequency graphic, parameter S_{11}, that is, reflection coefficient vs. frequency, which represents how much power is reflected from the antenna, and hence is known as the reflection coefficient, or return loss. It is possible to observe that the operation frequency is equal to 915 MHz and the radiation pattern geometry shown is similar to dipole antenna λ/2 radiation pattern [12,13].

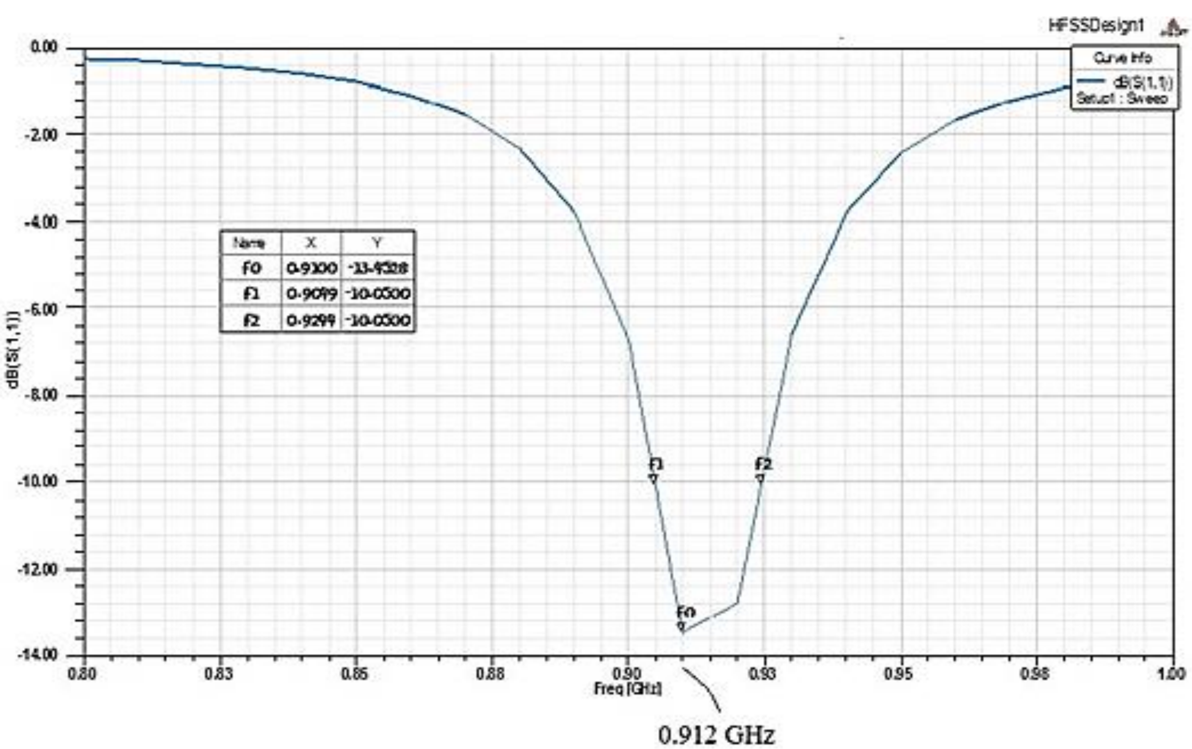


Figure 8(a). Magnitude vs. Frequency graphic and radiation pattern (Simulation).

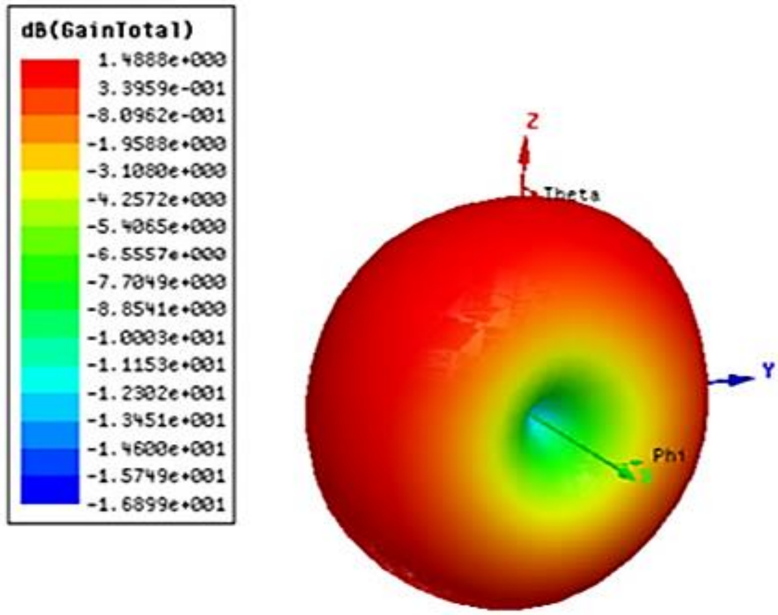


Figure 8(b). Magnitude vs. Frequency graphic and radiation pattern (Simulation).

Figure 9 shows the prototype antenna under test, inside of the anechoic chamber, and Figure 10, shows measurement results, that is, Magnitude vs. Frequency graphic and radiation pattern Plane E and Plane H, respectively.

Figure 9. Prototype antenna under test (anechoic chamber).

In accordance with the achieved measurement results, the resonance frequency of the designed antenna is approximately to 915 MHz (915.4 MHz), however, the radiation pattern Plane E shows low coverage along the horizontal axe (0° - 180°).

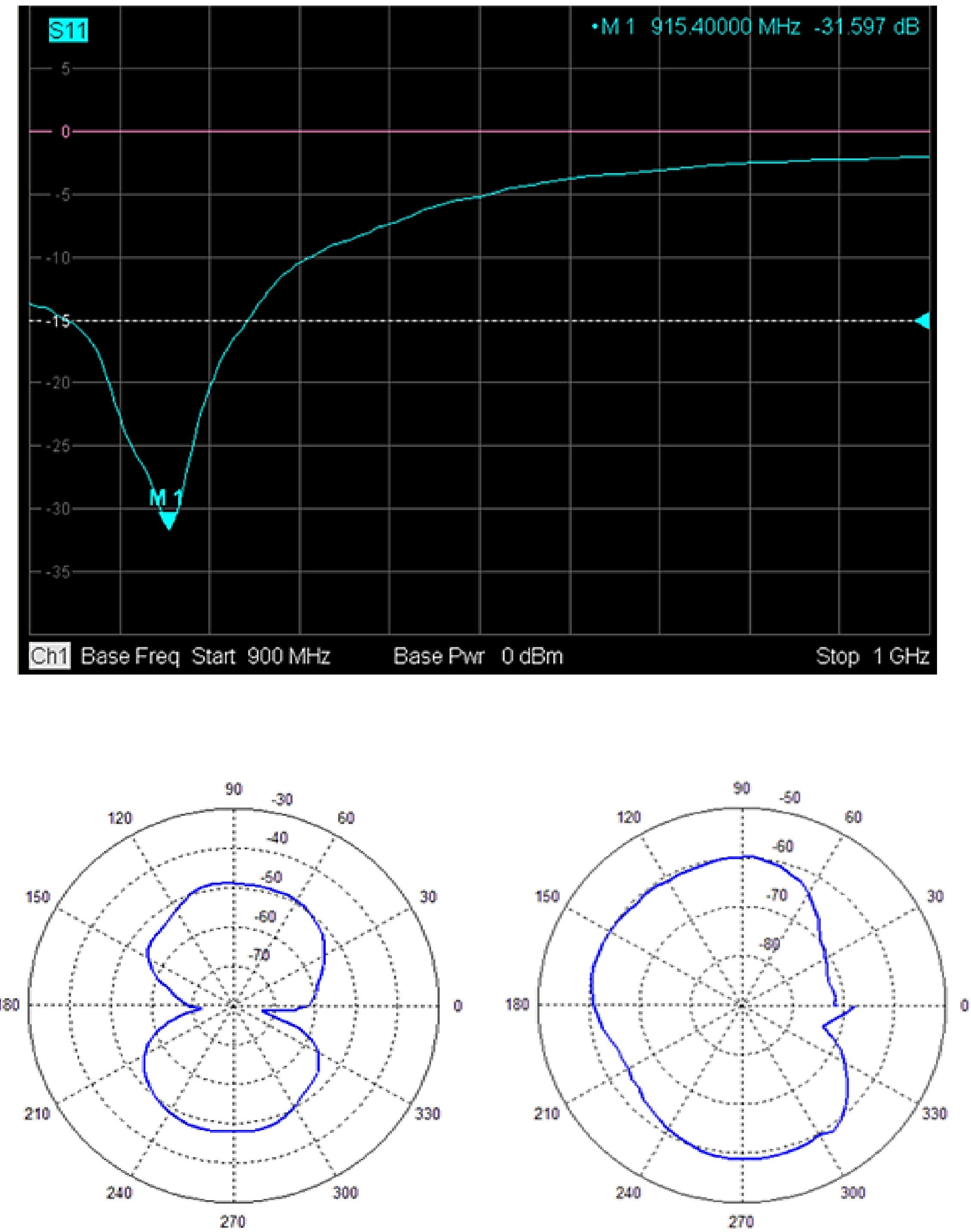


Figure 10. Magnitude vs. Frequency graphic and radiation pattern Plane E, Plane H (Measurement).

In the case of the RFID tag is installed as a bracelet around the wrist of the patient, this one moves in accordance with the arm movement, as a consequence, the antenna position changes continuously, or in the case of RFID applied to vehicular identification, etc., that is, when the tag is installed on a mobile object, the distance between the reader and the tag is variable, this way, the communication link quality decreases, as well as, possibly physical obstacles between them, creating non line of sight (NLOS). Under these conditions, the RFID tag antenna must be capable to collect the maximum electromagnetic energy, in order to energize the chip. With this aim, circular structures and parasitic element acting as reflectors are added to the designed antenna in order to increase gain and absorption area [14], as shown in Figure 11.

Figure 11. Prototype antenna under test (anechoic chamber).

The prototype antenna 2 is built using Epoxy glass fiber FR-4, ε_r = 4.4, electric permittivity, a SMA connector is used, and the parasitic elements consists of reflector line close to the excited element, a reflector line along the meander structure and circular structures mounted at the end of the meander line. A small frequency difference respect to the resonance frequency demanded is observed, Figure 12, however, the reader´s wideband is wider than this small deviation frequency, capable to detect and recover the signal transmitted from the tag. In the same figure is shown the radiation pattern, Plane E and Plane H, respectively, and it is notorious various semi nulls in the Plane H.

In accordance with the achieved measurement results, the resonance frequency of the designed antenna is approximately to 915 MHz, however, the radiation pattern Plane E shows a null along the 30° position, because of the wave interference phenomena that occur between the radiation from the different elements of the antenna, that is, the mutual coupling between them can lead to different problems that will degrade the overall performance of the antenna array, in this case, this one is minimum.

On the other hand, the measured impedance value of the antenna is shown in the Smith Chart in Figure 13, equal to Z_{in} = 106.25 + j6.95 Ω, and inductive reactance L = 1.205 ηH, having the desired effect to reduce a little the large capacitive reactance of tag chip to obtain a high matching.

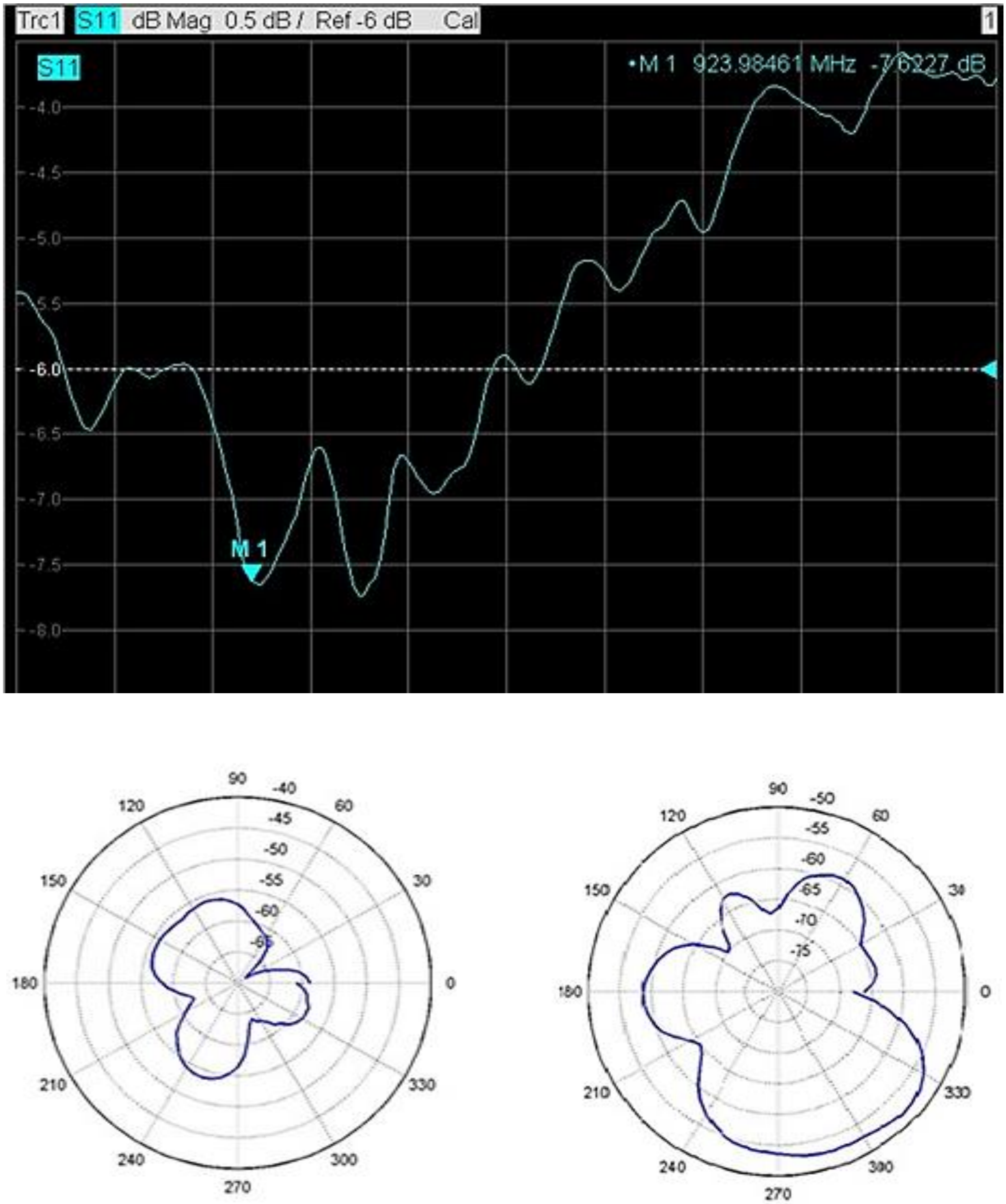


Figure 12. Magnitude vs. Frequency graphic and radiation pattern plane E, plane H (Measurement).

Finally, in order to measure and calculate the gain antenna, a second antenna was built, placing both antennas into the anechoic chamber, spaced 2.5 m apart, this way, considering the overall transmission loss (free space and cable loss), the resultant antenna gain is equal approximately to 3 dB. This antenna shows an increase in gain in comparison with the single dipole, due to the added structure elements.

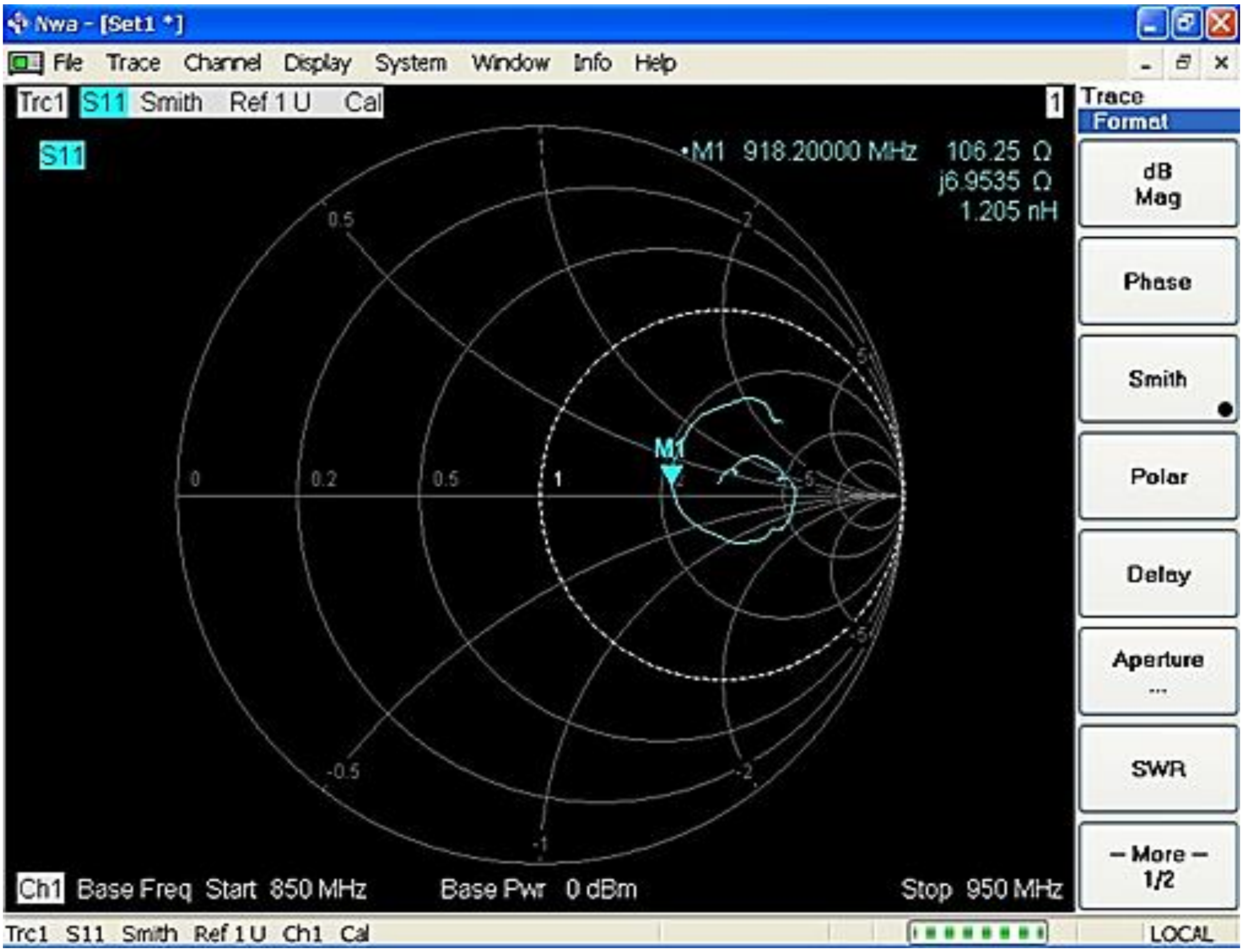


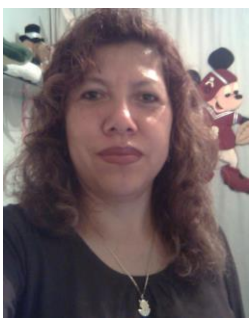
Figure 13. Antenna Impedance (Measurement).

4. CONCLUSION

RFID tag antenna has been designed, based on uniform meander line technique, the designed prototype antenna, meets the fundamental resonance frequency, input impedance requirement, an appropriate geometry of the achieved radiation pattern, and a Read / Write Range suitable. It is also found that increasing slot length, the fundamental resonant frequency of the meandered microstrip antenna decreases. As well as, the parasitic structure added to the meander antenna improved the gain value. Therefore, the proposed antenna can be feasible employed as a RFID tag antenna to enhance the performance of the RFID Technology.

Biography

Salvador Ricardo Meneses González. P.H.D., ESIME Culhuacán. Instituto Politécnico Nacional, I.P.N.., M.S.E. Centro de Investigación y de Estudios Avanzados del IPN (CINVESTAV IPN). He is actually professor of Communications and Electronic Engineering Department of Escuela Superior de Ingeniería Mecánica y Eléctrica, Unidad Zacatenco, IPN. México



Laura Leticia Montes Peralta. Electronic and Communication Engineer. She is actually professor of Communications and Electronic Engineering Department of Escuela Superior de Ingeniería Mecánica y Eléctrica, Unidad Zacatenco, ESIME Zacatenco, IPN

References

[1] N. Ch. Karmakar, "Advanced RFID Systems, Security, and Applications", 2013, IGI Global.

[2] K. Finkenzeller, RFID Handbook: Radio-Frequency Identification Fundamentals and Applications, 2nd Edition. New York: John Wiley & Son, 2003.

[3] Feig Electronics, "Innovative, New Payment Devices Revolutionizing Contactless Payment Market", July 24, 2015.

[4] http://www.alibaba.com/showroom/rfid-wristband.html

[5] Marrocco G. Gain-optimized self-resonant meander line antennas for RFID applications. *IEEE Antennas Wireless Propagation. Letters,* 2 (2013) 302-305.

[6] A. Jahanbakhshi, Gh. Moradi, and R. Sarraf Shirazi, "Design and simulation of different types of meander line Antennas with improved efficiency", *PIERS Proceedings*, Moscow, Russia, August 19-23, 2012.

[7] N. Popovic, "UHF RFID Antenna: Printed Dipole Antenna with a CPS Matching Circuit and Inductively Coupled Feed", *International Journal of Radio Frequency Identification and Wireless Sensor Networks,* 1(1) (2011) 28-33.

[8] D. Sievenpiper, L. Shang, R. F. J. Broas, N. G. Alexopolous, and E. Yanoblovitch, "High impedance electromagnetic surface with a forbidden frequency band", *IEEE, Trans., Microw Theory Tech*., 47(11)(1999).

[9] Kin Lu-Wong, "Compact and Broadband Microstrip Antennas", John Wiley and Sons, 2002.

[10] Son, H. W. & Pyo C. "Design of RFID tag antenna using an inductively coupled feed", *Electronic Letters*, 41(18) (2005) 994-996.

[11] Ansoft Corporation HFSS [Online], http:// www.ansoft.com/products/hf/hfss/.

[12] E. C. Jordan and K. G. Balmain, "Electromagnetic Waves and Radiating Systems", 1968, Prentice Hall.

[13] J. D. Krauss and R. J. Marhefka, "Antennas for all applications", 2002, McGraw Hill.

[14] C. A. Balanis, "Antenna Theory, Analysis and Design", 1982, John Wiley & Sons, Inc. P. Kolodzy et al, "Next generation communications: *Kickoff meeting"*, in Proc. DARPA". Oct 17, 2001.

(Received 18 February 2016; accepted 02 March 2016)