www.ijecs.in
International Journal Of Engineering And Computer Science
Volume 11 Issue 09September 2022, Page No.25612-25619
ISSN: 2319-7242 DOI: 10.18535/ijecs/v11i11.4671

Miniaturized Helical Antenna Design For Network With Lora Technology

Carlos Soria
[1]facultad De Ingeniería, Universidad Nacional Autónoma De México, Edificio Q-Valdés Vallejo, C.P. 04510, Cdmx México.
Rcanos02@Hotmail.Com

Víctor Rangel R
; Victor@Fib.Unam.Mx

,. M. Edwards
[2]school Of Mechanical, Electrical And Manufacturing Engineering, Loughborough University, Wolfson Building, Ashby Rd, Loughborough Le11 3tu, Uk; (R.M.E.).

R.M.Edwards@Lboro.Ac.Uk

Abstract— This article presents the analysis, design and optimization of a normal radiation helical antenna with medium gain (2db) and circular polarization as a proposal for use in a network with lora technology. The diameter of this antenna for the UHF frequency band would be 10.5cm, for which a parametric study is carried out to miniaturize the dimensions of the helix without losing its characteristics. The parameters and simulation results for a frequency of 915 mhz are presented.

***Keywords*— Lora; Antenna Theory; Helical Antennas; UHF Antennas, Miniaturized Antenna.**

I. Introduction

LoRa technology is a wireless communications protocol designed for the Internet of Things (IoT), with secure connectivity through encryption and bidirectional data transmission. Its performance is based on two elements: the RF modulation protocol to define the physical layer, and LoRa WAN to define the network layer, which contains a MAC protocol and allows a node to be connected to a gateway to send the information collected to a server [1].The word LoRa comes from longrange. The low power sender transmits small data packets in the order of 10 to 256 bytes approximately. A rate that goes from 0.3 kbps to 20 kbps to a receiver. By not using license frequencies, connectivity costs are considerably lower. LoRa modulation allows long distance communications (10m-10km) with low current consumption. In order to achieve satisfactory communications over long distances, it is recommended, and sometimes necessary, to meet the following requirements:

Line of sight: from the nodes to the base station

there must be a free line of sight or with few obstacles [2].
Power: it is recommended to use the maximum legal power available, +20 dbm [2].
High spreading factor: a high value of SF (10-12) allows potentially more messages to reach the destination at the cost of reducing speed [2].
In the case of the antennas used, an analysis and optimization of their parameters must be carried out to obtain an average gain of 2dB, circular polarization and reduced size.

II. Helical Antenna

Of course, miniaturization brings with it problems that need to be resolved. One of the challenges is represented by the antennas, whose dimensions must be adapted to those of the LoRa device, but complying with the necessary conditions of gain and radiation pattern; today more than ever small antennas with medium gain are necessary. This work presents the design and simulated results of a normal radiation miniaturized helical antenna for the UHF band. Due to its application, the antenna must present a radiation pattern in the form of a dipole perpendicular to the axis of the helix, it must also be self-contained in a volume no greater than a few millimeters in height.
The helical antenna was invented by John Kraus more than 50 years ago [3], who considered that it represented any wire antenna, because the extended helix is straight and the collapsed one is circular.
Helical antennas have been widely used for their bandwidth and convenient radiating elements. It has two features that make it useful in various applications. In the first place, it has circular polarization, which is decisive for a network with low stability LoRa technology. Circular polarization is widely used in telecommunications because the atmosphere causes the so-called Faraday rotation [4], the direction of the winding defines whether the polarization is right or left. On the other hand, its "poorly tuned" response allows relatively wide band applications in both gain and impedance [5].
The helical antenna has several radiation modes (figure 1). The normal radiation mode occurs when the wavelength is much greater than the dimensions of the antenna, producing a maximum radiation field in the plane perpendicular to the axis and a minimum in the axis of the antenna.

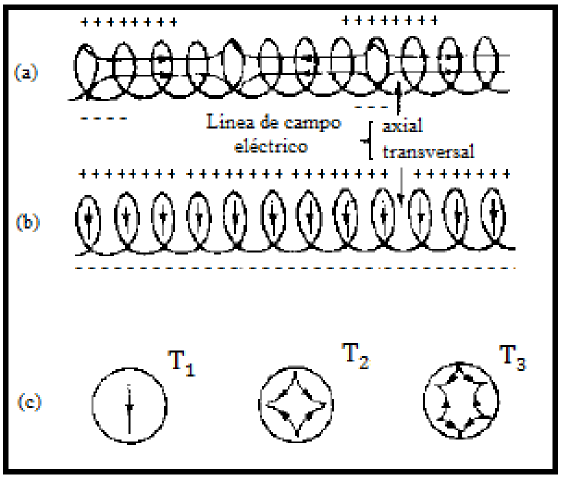

Fig. 1. Radiation modes

The helical antenna can radiate in the axial mode, if the wavelength of the operating frequency is approximately equal to the circumference of the helix. Unlike the normal mode, it is characterized in that the maximum radiation is in the direction of the axis and produces lateral secondary lobes. The axial radiation antenna ($C=\lambda$) is used to concentrate the radiation in one direction and has medium gain, depending on the number of turns, and is mainly used for satellite links due to its high directivity. The helix antenna can be used as a dipole or monopole when mounted on a ground plane, this form is the most widely used since its invention. For the case at hand, the monofilar helical antenna with normal radiation mode [6] has been chosen.

III. Helical antenna design:

For the analysis and design of the antenna, Kraus constructed a chart that relates the dimensions of the antenna (diameter, spacing between turns and pitch angle) with the radiation mode (Figure 2). Dimensions are expressed both in rectangular form for spacing S_λ($S_\lambda = S/\lambda$) and the circumference C_λ ($C_\lambda=C/\lambda$) and in polar coordinates times the length of one lap L_λ ($L_\lambda=L/\lambda$) and the pitch angle α. The ordinates represent the turns because the spacing is zero (α=0), while the abscissa indicates a diameter of zero (α=90) which makes the antenna a straight conductor [7]. The shaded areas they mark the way in which the antenna radiates, for the axial mode the area
T_1R_1.

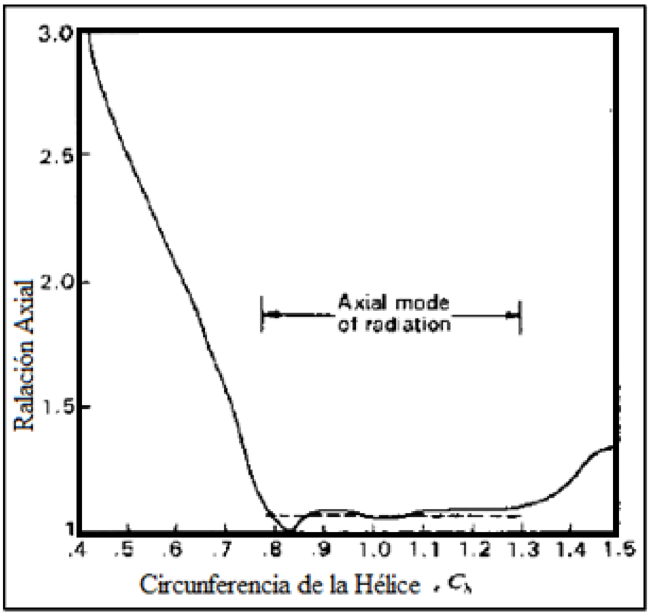

Fig. 2. Axial relationship

As the frequency varies, the diameter of the helix D_λ and the wavelength spacing S_λ in free space change, but the pitch angle remains constant. The relationship of D_λ, S_λ and α as a function of frequency is conveniently illustrated by figure 3. The dimensions of any uniform helix are defined by a point on the chart. The lower and upper design frequency limit of a normal mode frequency range are F_1 and F_2 respectively, the corresponding range in diameter and spacing is given by a line between points F_1 and F_2. The center frequency of this range is F_0 and it is arbitrarily taken such that $F_0 = (F_1+F_2)/2$ or $F_0 - F_1 = F_2 - F_0$. The dimensions of the helix are designed in wavelength in free space at the center frequency [8].

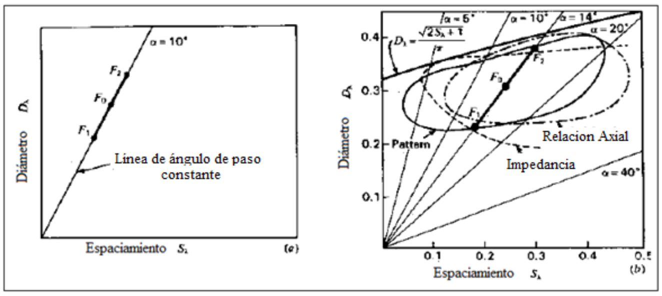

Fig. 3 Diameter-spacing chart

IV. Proposed Antenna:

The antenna that is proposed for the network with LoRA technology, which has an approximate area of 10 cm2 for the antenna and the LoRa device is a 5-turn helix on a ground plane, which works in the UHF band, it is expected to have an average gain of 3 dB. Using the chart in Figure 2, a circumference of 0.4λ and a spacing of 0.2λ are selected, the other dimensions are obtained from those parameters and are shown in table I, the antenna layout is as shown in figure 4.

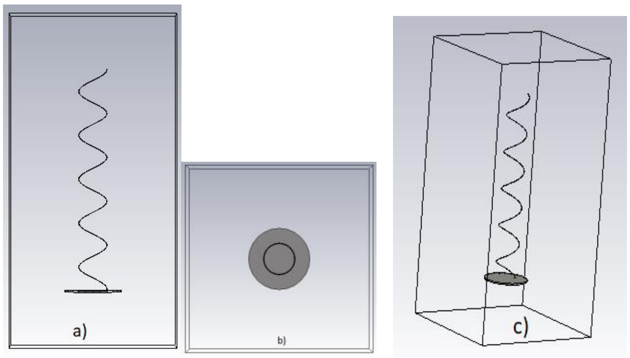

Fig. 4 Helicoidal antenna normal mode. a) front view, b) top view, c) profile view.

Table I. Dimensions Of The Helical Antenna

Dimension	Symbol	Value
Frequency	F(MHz)	915
Wavelength	λ (cm)	32.78
Circumference	C	1λ
Spacing	S(cm)	6.55
Diameter	D(cm)	4.17
Pitch angle	α	27°
Number of turns	N	5
Length	L(cm)	32.78
Ground plane diameter	Dpt(cm)	8

A simulation stage is developed for the calculated antenna based on the Kraus design. The design results are obtained by simulating the antenna through the (CST) program, the analysis is done over a bandwidth between 900MHz and 930MHz, for coupling using parameter S11 (a suitable value is -10 dB or less), the pattern radiation and gain. Figure 5 shows the result of the simulation of the dispersion parameter S11.

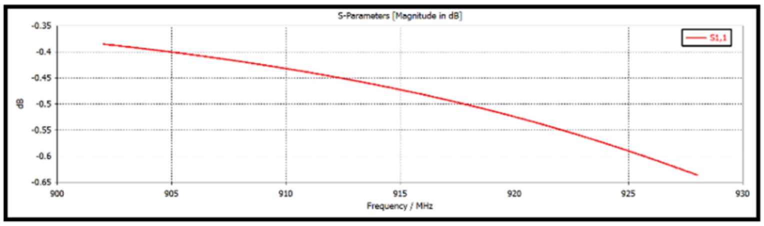

Fig 5 Simulated S11 Parameters

The radiation pattern, both volumetric and Ө-plane, is shown in Figures 6(a) and 6(b). The simulation shows a gain of 2.9 dB for 915MHz.

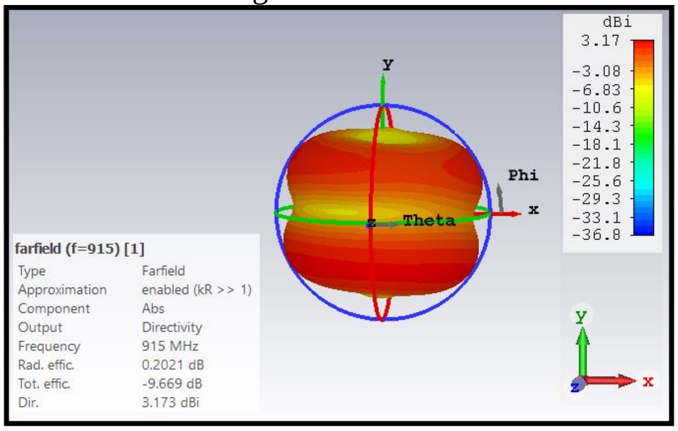

Fig 6(a) Volumetric Radiation Pattern.

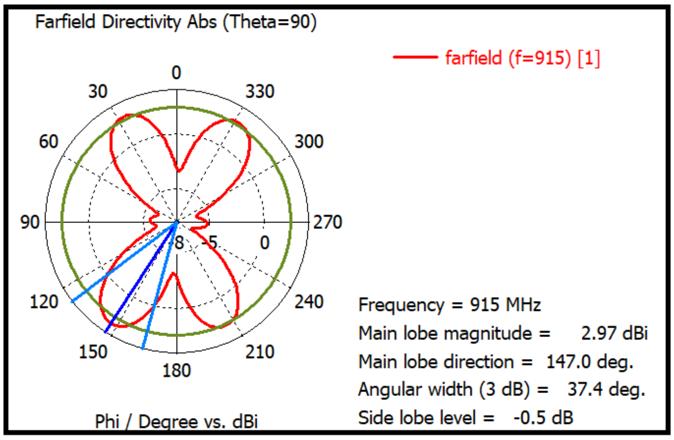

Figure 6(b) Radiation Pattern in Polar Form.

The simulated antenna with the results obtained cannot be used for the network with LoRa technology due to its large dimensions (32.78 cm axial length) and its clover-shaped radiation pattern, a dipole radiation pattern perpendicular to the axis is needed. of the helix (radiation lobes at 0° and 180°).

V. Miniaturization

Based on the parameters obtained in the design of the proposed antenna, a parametric study is carried out to optimize the parameters, radiation pattern and gain of the helix.

The parametric study will help us analyze the behavior of the antenna by observing the effects of each geometric parameter that is modified, with the aim of obtaining the best performance of said antenna. The fundamental parts of the parametric analysis for a helical antenna are: the determination of the distance between the antenna and the ground plane, separation between turns, diameter of the antenna, diameter of the conductor and number of turns as shown in figure 7.

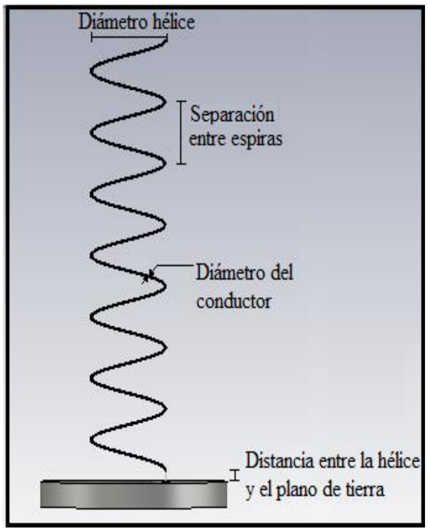

Fig 7 Helical antenna structure.

The parametric analysis will start from the design chart in figure 2. In which the normally shaded area is the one to work on.

The antenna is designed with the dimensions of table 1, gradually varying the separation between turns. In the design chart of figure 2 it is observed that the separation between turns or spacing can vary from 0.01λ to 0.5λ, to be within the normal radiation area. Figure 8 shows the results obtained.

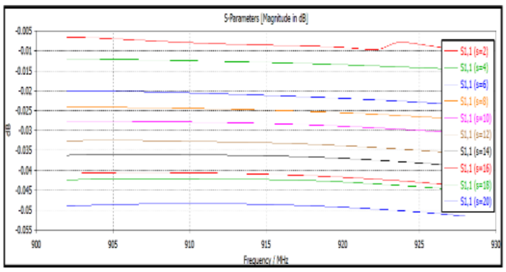

Fig 8 (a) Parameter S11 for different spacing between turns.

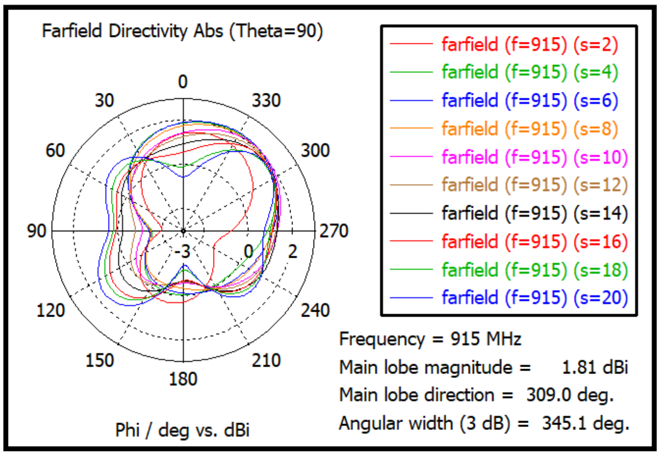

Fig 8 (b) Radiation pattern in polar form for different separation between turns.

The parametric analysis for the diameter of the helix is based on the design chart in figure 2, where the circumference of the helix can vary between 0.01λ and 0.5λ corresponding to normal radiation. Figure 9 shows the results obtained.

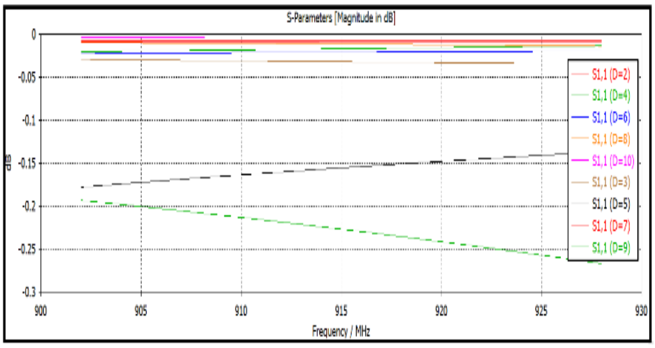

Fig 9 (a) Parameter S11 for different diameter of the helix.

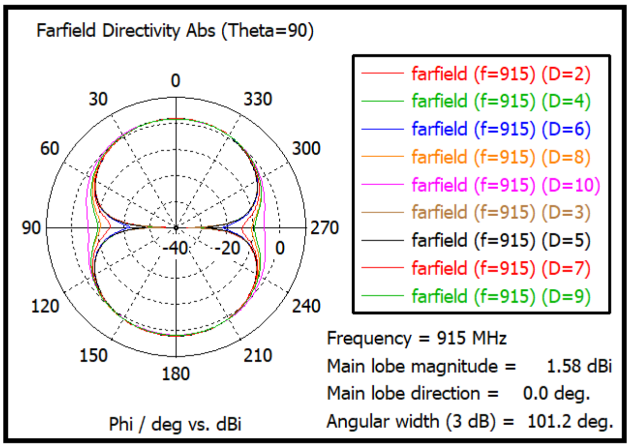

Fig 9 (b) Radiation pattern in polar form for different diameter of the helix.

To optimize the distance from the propeller to the ground plane, a propeller diameter of 12mm (optimized parameter), separation between turns of 4mm (optimized parameter) and 5 turns of the propeller will be taken, simulations are made from 0.5mm to 5mm of diameter. clearance of the propeller to the ground plane. Figure 10 shows the results obtained.

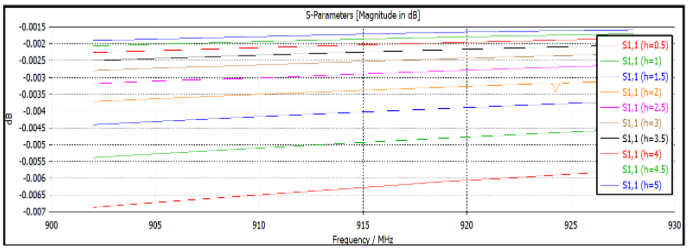

Fig 10 (a) Parameter S11 for different distance from the propeller to the ground plane.

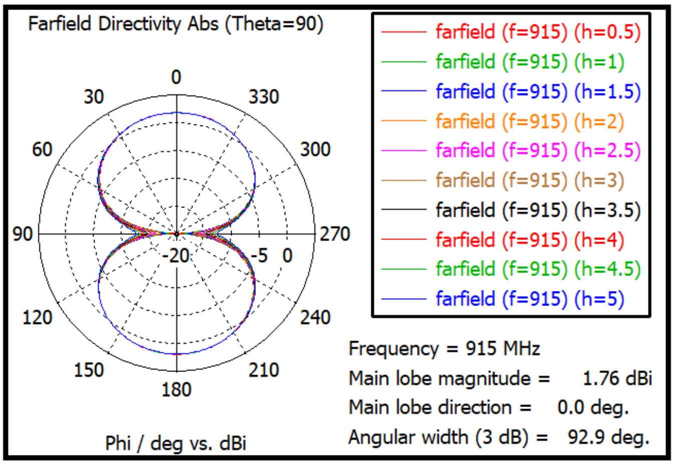

Fig 10 (b) Radiation pattern in polar form for different distance from the propeller to the ground plane.

The parametric analysis for the diameter of the conductor is performed with the optimized parameters of diameter (12mm), separation between turns (4mm) and distance from the helix to the ground plane (2mm). The size of the conductor is not critical and can vary from 0.005λ to 0.05λ. Figure 11 shows the results obtained.

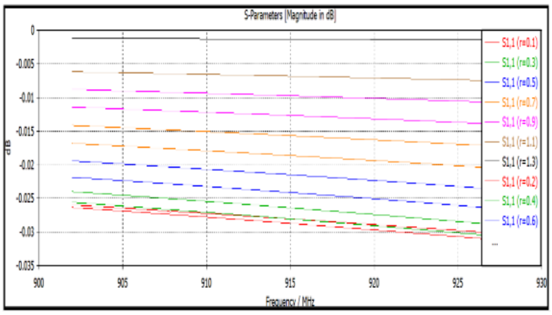

Fig 11 (a) Parameter S11 for different conductor diameter.

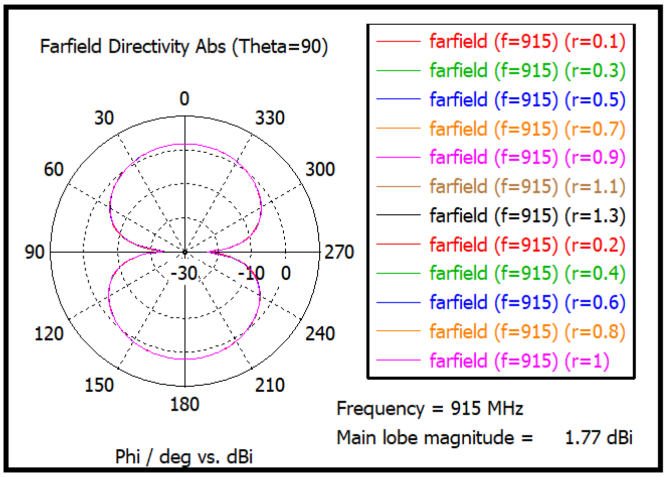

Figure 11 (b) Radiation pattern in polar form for different conductor diameters.

The parametric analysis for the number of turns is performed with the optimized parameters of diameter (12mm), separation between turns (4mm) and distance from the helix to the ground plane (2mm) and conductor diameter (0.55mm). Simulations are carried out from 2 to 20 turns. Figure 12 shows the results obtained.

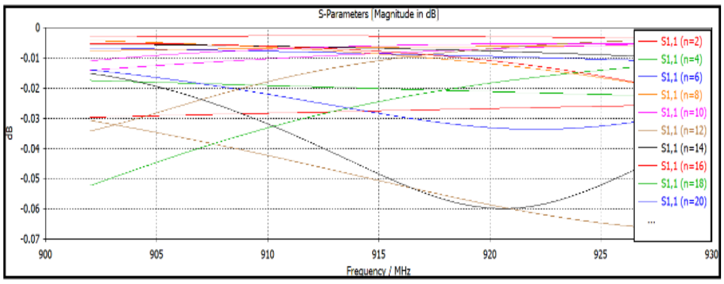

Fig 12 (a) Parameter S11 for different number of turns.

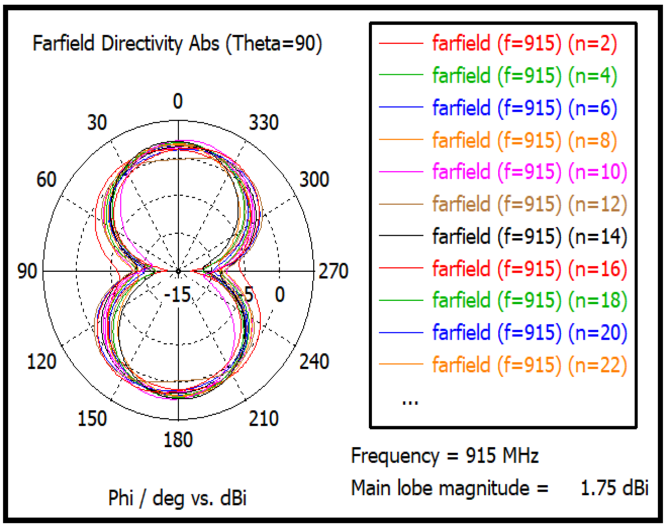

Fig 12 (b) Radiation pattern in polar form for different number of turns.

Multiple analyzes have been carried out varying different parameters of the helix, trying to optimize its structure, with the aim of determining the best geometric configuration as well as the effects that occur in the radiation pattern, gain and coupling. The dimensions of the miniaturized proposed antenna (figure 13) are shown in table II.

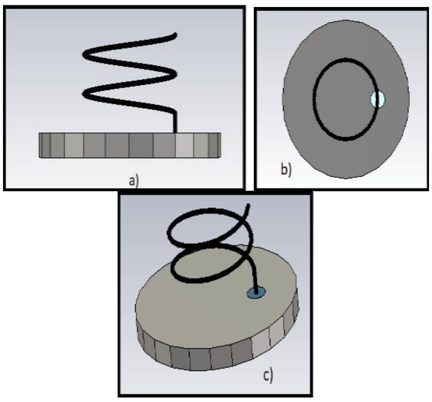

Fig 13 Helicoidal antenna normal mode. a) front view, b) top view, c) profile view.

Table Ii. Dimensions Of The Miniaturized Helical Antenna

Dimension	**Symbol**	**Value**
Frequency	F(MHz)	915
Wavelength	λ (cm)	32.78
Circumference	C	1λ
Spacing	S(cm)	0.4
Diameter	D(cm)	1.2
Pitch angle	α	7°
Number of turns	N	2
Length	L(cm)	1
Ground plane diameter	Dpt(cm)	1.5

In table III a comparison is made between the dimensions of the designed antenna and the miniaturized optimized antenna. It is observed that it was reduced from an antenna of 32.78cm high by 8cm wide to a miniaturized antenna of 1cm high by 1.5 wide. Losing less than 1dB of gain and obtaining the desired radiation pattern in the form of a dipole.

Table Iii. Comparison Of Engineered And Miniaturized Helical Antenna

Símbolo	Value designed antenna	Value miniaturized antenna
F(MHz)	915	915
λ (cm)	32.78	32.78
S(cm)	6.55	0.4
D(cm)	4.17	1.2
α	27°	2°
N	5	2
L(cm)	32.78	1
Dpt(cm)	8	1.5
G	2.9	2.1
Radiation pattern	clover	dipole

Figure 14 shows the simulated results of the normal mode miniaturized helical antenna with a resonance frequency of 915MHz proposed for the network with LoRa technology.

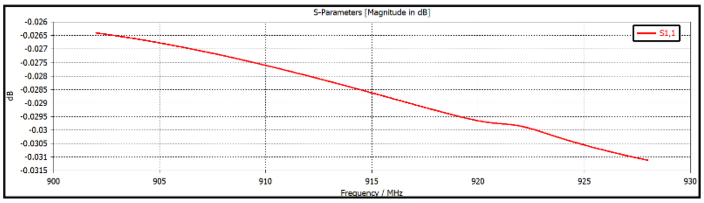

Figure 14 (a) Parameter S11 of miniaturized optimized antenna.

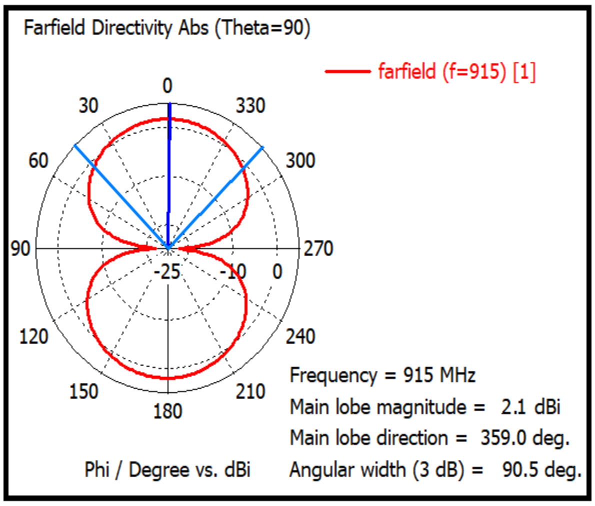

Figure 14 (b) Radiation pattern in polar form of miniaturized optimized antenna.

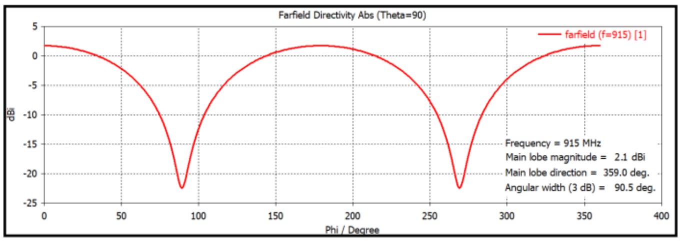

Fig 14(c) Miniaturized optimized antenna Cartesian-shaped radiation pattern.

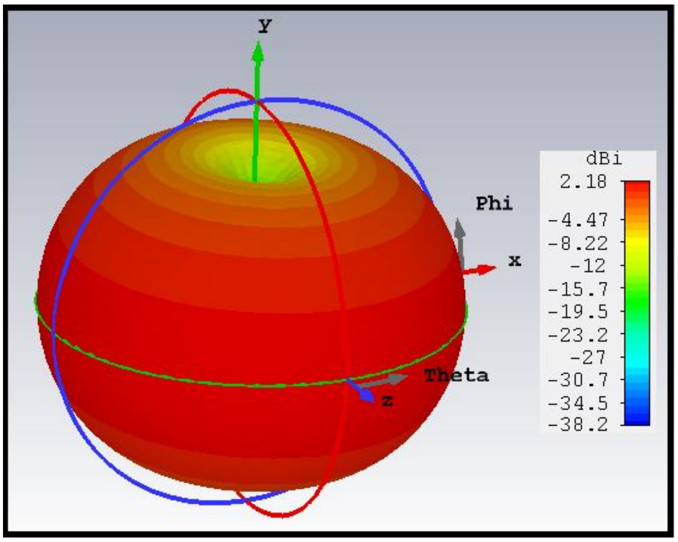

Figure 14(c) Miniaturized optimized antenna volumetric radiation pattern.

VI. CONCLUSIONS:

Due to the application of the helical antenna (network with LoRa technology), the dimensions of the antenna are a limitation both transversely and longitudinally. The antenna designed in the 915MHz resonance frequency is large, 33 cm high by 8 cm wide, so it cannot be used for the network, therefore the helical antenna is miniaturized, reaching dimensions of 1.5 cm wide. by 1cm high.

Multiple analyzes have been carried out, varying different parameters of the helix, trying to optimize its structure, with the aim of minimizing its dimensions and determining the best geometric configuration, as well as the effects that occur in the radiation pattern, gain and coupling.

- By optimizing the separation between turns, greater gain is obtained at greater separation, but the radiation pattern is deformed.

• By optimizing the diameter of the helix, the larger the diameter the radiation pattern deforms, the gain remains constant.

• By optimizing the diameter of the conductor, the results remain stable.

• By optimizing the separation of the propeller to the ground plane, the smaller the separation, the greater the gain, the radiation pattern is maintained.

• When optimizing the number of turns, the greater the number of turns, the greater the gain, the increase is not linear.

With the miniaturized antenna, it has a circular polarization and a gain of 2dB, as well as a dipole-shaped radiation pattern. This antenna is easy to build and low cost, it can be successfully implemented in the network with LoRa technology, the bandwidth will be determined once the antenna is coupled in the parameters S11 (-10dB). The dimensions of the antenna even allow the use of arrays, to reduce side lobes and increase gain. To couple the antenna to the operating frequency, an impedance matching method (STUB) is used, with which the antenna can be coupled to the operating frequency (915MHz) and obtain a higher gain. The miniaturized helical antenna has been built and is currently in the docking process.

CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest.

ACKNOWLEDGEMENTS

Universidad Nacional Autónoma de México
Secretaría General
Dirección General de Asuntos del Personal Académico
Programa de Becas Posdoctorales en la UNAM

This research was also funded by the Engineering and Physical Sciences Research Council (EPSRC) under Grant No. EP/P029221/1

REFERENCES

[1] M. A. Erturk, M. A. Aydin, M. T. Buyukakkaslar, and H. Evirgen, "A Survey on LoRaWAN Architecture, Protocol and Technologies, "*Future Internet*, vol. 11, no. 10, pp. 1–34, Oct. 2019, doi: 10.3390/fi11100216.

[2] J. C. Liando, A. Gamage, A. W. Tengourtius, and M. Li, "Known and Unknown Facts of LoRa: Experiences from a Large-scale Measurement Study," *ACM Trans. Sens. Netw.*, vol. 15, no. 2, pp. 1–35, Apr. 2019, doi: 10.1145/3293534.

[3] J.D. Kraus y D.A. Fleish, "Electromagnetismo con Aplicaciones", Ed.McGraw-Hill Interamericana, 1999.

[4] Chapter 2. Some Basic Technical Issues. Handbook on satellite communications 3rd ed. Willey. USA, 1995.

[5] J.D. Kraus, *"Antennas",* Ed.McGraw-Hill, New York, 1950

[6] J. D. Kraus, *"Helical beam antennas,"* Electronics, vol. 20, pp. 109-111, April 1947

[7] T. E. Tice and J. D. Kraus, *"The influence of conductor size on the properties of helical beam antennas,"* Proc. IRE, vol. 27, p. 1296, November 1949.

D. J. Angelakos and D. Kajfez, "Modifications on the axial-mode helical antenna," Proc. IEEE, vol. 55, no. 4, pp. 558-559, April 1967.

[8] D. J. Angelakos and D. Kajfez, *"Modifications on the helical antenna,"* Proc. IEEE, vol. 55, no. 4, pp. 558-559, April 1967.