

Axial Mode Helix Antenna to Amplify 4G LTE Signal in Rural Area

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ABSTRACT

Rural areas that may still be difficult to get 4G signals are caused by the diverse topography of the region and uneven landscapes, especially in mountainous areas which result in weakness in signal reception in the area. To get 4G signal coverage in this area, it is necessary to have a repeater in the form of an antenna that functions as a signal booster in the area. In this study, a helix antenna consisting of ten windings at the uplink (1710-1785 Mhz) and downlink (1805-1880 Mhz) 4G LTE frequencies was designed. It is hoped that this antenna can produce higher gain and a more focused beam, with the aim of strengthening 4G signals in rural areas. The antenna design was tested through the use of CST Studio Suite software. The antenna design has been simulated using CST Studio Suite software. After optimizing the simulation results, a return loss of -14 dB, VSWR of 1.49, a gain of 12.47 dBi, and HPBW of 50° were obtained. From the measurement results obtained, the helix antenna with ten turns shows good performance at a frequency of 1880 Mhz with a return loss of -17.75 dB, VSWR of 1.32, gain of 12.15 dBi, HPBW of 44°, and unidirectional polarization.

INTRODUCTION

Rural areas refer to rural areas or areas outside of urban areas. This type of area tends to have low signal reception because there are many rice fields, hills, or forests with large trees. (Dhaifina et al., 2019). In rural areas, the number of buildings is also limited, and there are often open areas. This type of propagation path in these areas has few obstructions, such as rice paddies, fields, and less populated areas (Dhaifina et al., 2019). Therefore, signals received in rural areas tend to be stronger compared to hilly and forested areas that have many obstructions. Previous research has shown that topographical conditions and long distances between residents affect signal reception in rural areas. (Ulfah, 2019). The main cause of poor signal in rural areas is the distance between the transmitter and receiver. The greater the distance between the Mobile Station (MS) or mobile device and the eNodeB or base station, the greater the path loss (Ulfah, 2019). Pathloss is the phenomenon of reducing the power of the information signal emitted by the signal-sending antenna (Tx) when heading to the receiver (Rx) (Yansah & Reza, 2022). Topographical conditions, such as hills or large trees in rural areas, can also affect signal propagation and cause additional path loss that contributes to signal weakness (Yansah & Reza, 2022).

To overcome the problem of poor signal in rural areas, devices such as antennas specifically designed to improve performance strengthen 4G LTE signals, and expand signal coverage areas in rural areas are needed (Theiconomics, 2020). One type of antenna that can be used to communicate over long distances is the Helix antenna (Theiconomics, 2020). Helix antennas have a shape that resembles a spring wire with a specified diameter and wire coil spacing. This type can be a good choice to maximize the communication process in 4G LTE networks (Theiconomics, 2020). Helix antennas, especially the axial mode, are characterized by good gain and fairly large dimensions. This antenna also has a unidirectional radiation pattern, which means that the signal power it emits is more focused in a particular direction. Due to its directional radiation pattern, axial-mode Helix antennas are often used in satellite communications as they provide high signal gain and are suitable for transmitting signals over long distances (Balanis, 2015). With the implementation of the Helix antenna, it is expected that the 4G LTE network in rural areas can be strengthened, improving network quality and coverage to provide the best service for customers in rural areas (Balanis, 2015).

LITERATURE REVIEW

Research related to helix antennas to strengthen 4G signals has been carried out, namely the Design of 1.8 GHz Helix Antenna to strengthen GSM signal reception by (Yansah & Reza, 2022). this antenna produces directional polaradiation, antenna gain of 9.4 dB and HPBW 35°. further research on the design and simulation of helix antennas at a frequency of 2.4 GHz using eight copper windings by (Mughtar & Firmansyah, n.d.). This antenna produces a unidirectional radiation pattern with a bandwidth of 1.5 GHz at a return loss of -10.88 dBi and a resulting gain of 9.70 dB.



METHOD

The flowchart illustrates several phases in the antenna design. Namely, the phase that adds up the operating frequency, antenna dimensions, VSWR, gain, and mathematical calculations for return loss, then the second phase calculates the width and length of the wire, ground plate diameter, pitch angle, and number of wire coils. Furthermore, in the first and third steps, the dimensions of the axial mode helical antenna are designed using CST 2019 software. If the design process is good, we make the helical antenna in axial mode, and then carry out the measurement step in the antenna laboratory and antenna simulation and analyze the measurement characteristics.

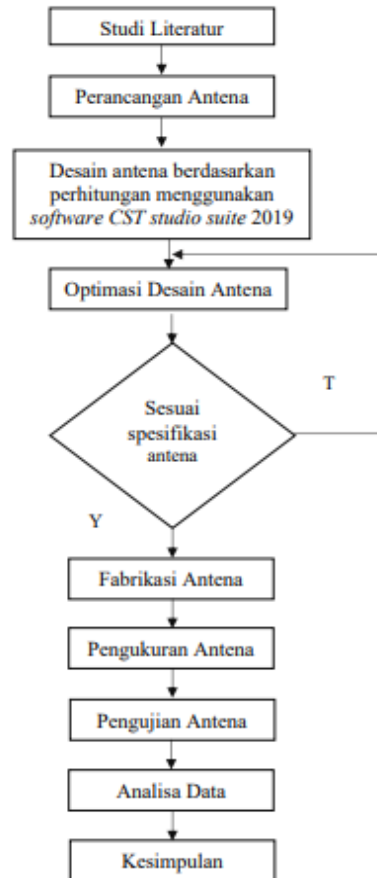


Figure 1. Flowchart

RESULT

Dimensions of Axial Mode Helical Antenna

After determining the working frequency of the design, the formula for the helix antenna is developed. To calculate the wavelength:

$$\lambda = \frac{C \ 3 \times 10^8 \ m/s}{f \ 1.8 \times 10^9 \ Hz}$$

$$\lambda = 1.6767 \ m = 16.767 \ cm = 167.67 \ mm$$

where C = (3x108 m/s) and f is the center frequency. (D) is the diameter of the helical antenna, use the following formula:

$$D = \frac{\lambda}{\pi} = 53.39 \ mm$$

$$D = 5.3 \ cm$$

Furthermore, the circumference used for axial mode helical antennas using the following formula:

$$C = \pi x D$$

$$C = 3.14 x 53.39 mm$$

$$C = 167.67 mm$$

The following formula applies to the distance between the turns (S) of a helical antenna:

$$S = 0.25 x C$$

$$S = 0.25 x 167.67$$

$$S = 41.917 mm$$

Then the overall length of the axial mode helix antenna is calculated using the formula:

$$A = n x S$$

$$A = 10 x 41.917$$

$$A = 419.17 mm$$

Then measure the diameter of the helical antenna ground plan using the following equation:

$$Rgp = \frac{3}{4} \lambda$$

$$Rgp = \frac{3}{4} 167.67$$

$$Rgp = 125.75 mm$$

Next, calculate how much the angle of the helix antenna winding is using the following equation:

$$\alpha = \tan^{-1} \left(\frac{S}{\lambda} \right)$$

$$\alpha = \tan^{-1} \left(\frac{41.917}{167.67} \right)$$

$$\alpha = 14.03^\circ$$

Calculate the length of one coil of the helix antenna using the following equation:

$$\cos \alpha = \frac{C}{L}$$

$$L = \frac{C}{\cos \alpha}$$

$$L = \frac{167.67}{\cos 14^\circ}$$

$$L = \frac{167.67}{0.97} = 172.85 mm$$

Axial Mode Helical Antenna Impedance Matching Dimension

When designing an axial-mode helical antenna, impedance matching is required to achieve maximum and accurate calculations. Getting good results will affect the quality of the antenna whether it is suitable for signal amplification or not. Helical antennas with impedance use peripheral feeds, so helical antennas use the following impedance formula:

$$Z_a = 150 \frac{C}{\lambda}$$

$$Z_a = 150 \frac{16.67}{16.67}$$

$$Z_a = 150$$

In this case the helical antenna has an impedance (Z_a) of about 100-200 ohms with the coaxial cable having an impedance of 50 ohms. Therefore, it is necessary to adjust the numbers with the following helical antenna parameters:

Table 1. Specifications of Helical Antenna

No	Antenna Parameters	
1	Working Frequency	1800 MHz
2	Return loss	≤ 10 dBm
3	VSWR	$1 \leq \text{VSWR} \leq 2$
4	Impedance Input	50ohm
5	Gain	>10 dBi
6	Polaradiation	Unidirectional

2. Dimensions of Helical Antenna

No	Name	symbol	Size
1	Wave Length	λ	167,67 mm
2	Helical antenna diameter	D	53.39 mm
3	Helical antenna circumference	C	167,67 mm
4	Pitch Angle	α	14,03°
5	Distance between windings	S	41.917 mm
6	Total length of antenna	A	419.17 mm
7	Ground Plate Diameter	Dgp	125.75 mm

The calculation used to determine the impedance matching of the axial mode helical antenna uses the following equation:

$$Z_{MI} = \sqrt{Z_c Z_a}$$

$$Z_{MI} = \sqrt{50 \times 150}$$

$$Z_{MI} = 86.602 \Omega$$

The process of making an impedance matching antenna is determined by three things: plate width (w), plate thickness (t), plate length (l) = $1/4 \lambda$. Use the following formula to calculate the space above the ground (h):

$$h = \frac{(w + t) \ln^{-1} \left(\frac{Z_{MI}}{56} \right)}{7,5}$$

$$h = \frac{(125.75 + 2) 41.917 (10)^{-1} \left(\frac{86.602}{56} \right)}{7.5} = 1.10 \text{ mm}$$

Table 3. Matching Impedance of Helical Antenna

No	Name	Symbol	Size
1	Impedance	Z_c	50 Ω
2	Antenna impedance	Z_a	150 Ω
3	Matching impedance	ZMI	88,5 Ω
4	Conductor width	W	5 mm
5	Conductor thickness	T	0,5 mm
6	Conductor length	L	101,334 mm
7	Distance above plate plane	H	1.10 mm

Design of Axial Mode Helical Antenna

The axial mode helical antenna is designed to operate at 1800MHz LTE frequency. This time, the author hopes to achieve results that exceed previous research according to the parameters in Table 1. When designing, you can find based on the working frequency of the helical antenna. Table 2 shows the design dimensions of the axial-mode helical antenna. As well as the antenna manufacturing process on impedance matching.

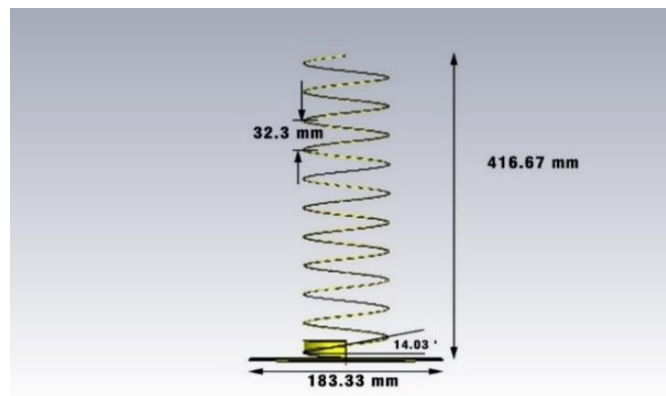


Figure 2. Design of Helical Antenna

For peripherally fed helical antennas, the input impedance does not cook with the 50-ohm coaxial cable, which is used to feed the antenna. Therefore, impedance matching is required to minimize the impedance mismatch.

Replacing the helical wire near the feed point with a triangular copper strip, the same length as the replaced helical wire, can help reduce the impedance mismatch(IEEE Staff & IEEE Staff, n.d.), (Mardani et al., 2021)- This technique is attractive compared to others because it is simple and easy to implement. A detailed sketch of this technique is shown in Figure 1. A triangular copper strip is wrapped around the pipe, replacing the initial section of helical wire near the feed point. The corners of the strip are soldered to the inner conductor of the connector while the ends of the strip are soldered to the ends of the helical wire. The length of the triangular copper strip is exactly equal to the length of the helical wire it replaces.

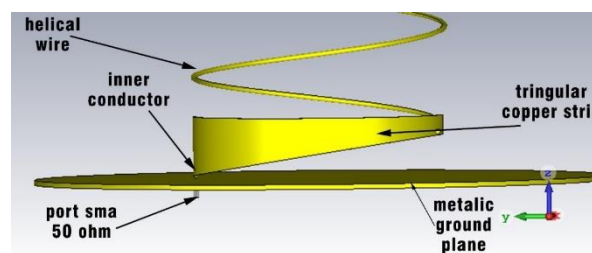


Figure 3. Triangular Strip Matching Impedance Helical Antenna

DISCUSSION

Parametric Study

The parameter study was conducted to obtain the best antenna parameter values in the simulation. At this stage, it is done by modifying the number of turns, distance, and angle of the image on the antenna. The results of the antenna return loss parameters are displayed in the form of images. The return loss value seen at 1800 Mhz frequency reaches -13.73 dB, which is not optimal. Optimizing the simulation results was done by reducing the winding size from 20 mm to only 32 mm, and resulted in a return loss value of -21.46 dB.

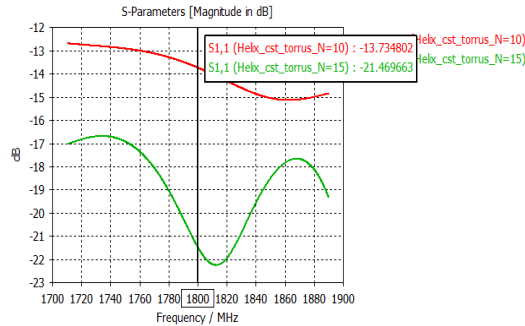


Figure 4. Axial Mode Helical Antenna Return loss results

By extending the helix winding length from 20 mm to 32 mm and reducing the diameter from 40 mm to 53.2 mm, there is a more optimal increase in the return loss value, which is -21.46 dB compared to before. The initial VSWR figure of 1.51 now changes to 1.18 as shown in the figure.

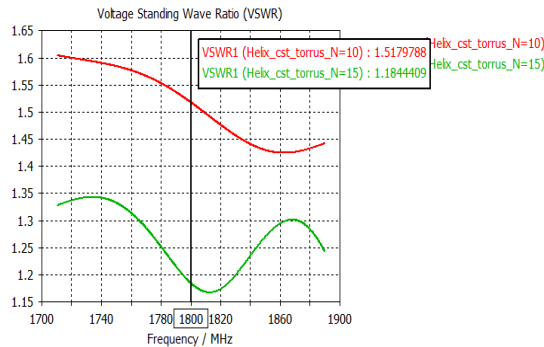


Figure 5. VSWR Results of Helical Antenna Axial mode

After optimizing the image above, the optimal design is obtained which has results that are in accordance with the required antenna specifications as shown below.

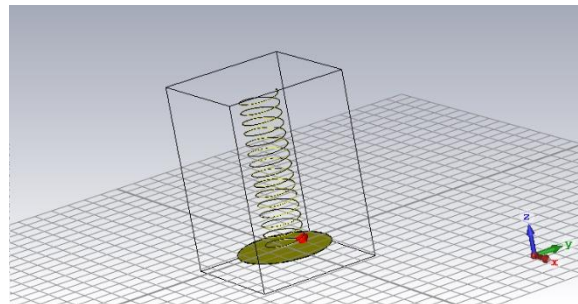


Figure 6. Axial Mode Helical Antenna Design in CST 2019 Software Before Modification

The design of the helix antenna above with no triangular strip slot acts as an impedance matching which makes the return loss value -21.46 dB at 1800 MHz frequency and makes the antenna have a directional or unidirectional working

frequency. but there are still shortcomings, namely the return loss value produced during fabrication does not match the optimization measurement at 1800 MHz frequency. For optimum design at 1800 MHz frequency, optimization is done by adding a triangular strip at the corner of the strip soldered to the inner conductor of the connector while the end of the strip is soldered to the end of the helical wire. The length of the triangular copper strip is exactly the same as the length of the replaced helical wire. With this method, the results obtained during optimization and fabrication obtained a return loss value of -14.00 dB and VSWR 1.497 and produced a good antenna at 1800MHz frequency.

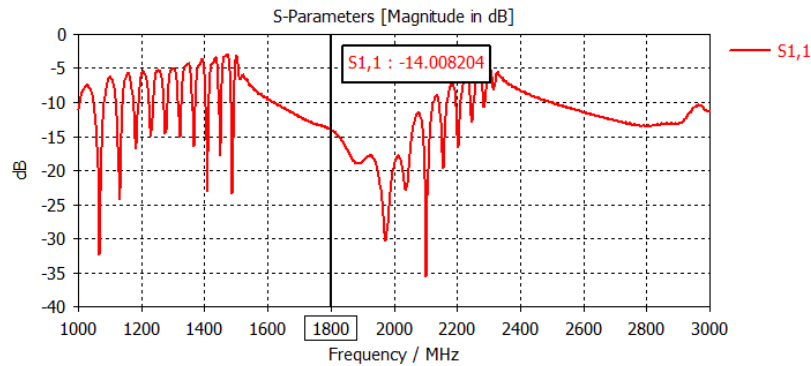


Figure 7. Return loss results of Modified Axial Mode Helical Antenna

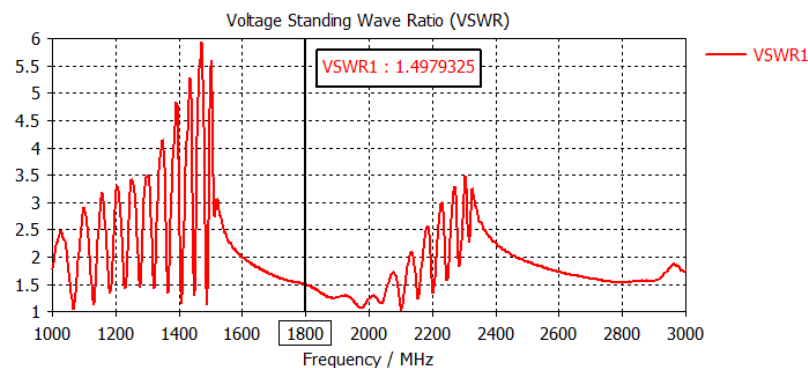


Figure 8. Modified Axial Mode Helical Antenna VSWR Results

Fabricated Antenna

After obtaining the optimum antenna design, next is the fabrication of the antenna, the plate used is aluminum with a thickness of 2 mm. The antenna uses a 50 Ω SMA port, the fabrication results are shown in Figure 9.

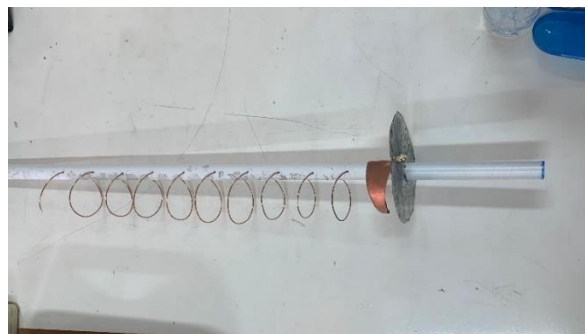


Figure 9. Fabrication results of Modified Axial Mode Helical Antenna

At the return loss and VSWR measurement stage using the Keysight E5071C Vector Network Analyzer (VNA) for the return loss measurement results can be seen in Figure 10 and VSWR (Voltage Standing Wave Ratio) values in

Figure 11. Radition pattern measurements using RF-Generator as a signal generator and using a yagi antenna as a transmitter.

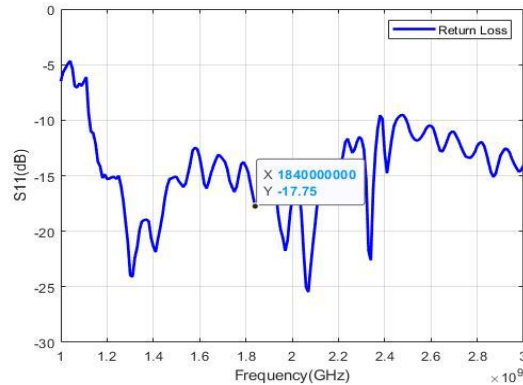


Figure 10. Return Loss Results of Fabricated Axial Mode Helical Antenna

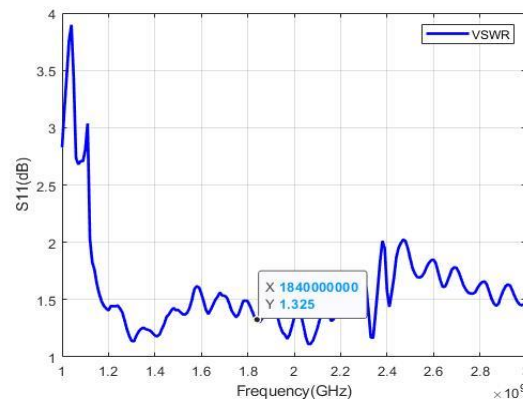


Figure 11. VSWR Results of Fabricated Axial Mode Helical Antenna

Figure 10 displays the return loss value where there is a difference caused during fabrication. Return loss value at frequency during simulation is -14.00 dB while during measurement is -17.75 dB. As well as the VSWR value at the time of simulation 1.497 and when the measurement becomes 1.325 in Figure 11. despite changes in parameter values still meet the specifications of the helix antenna

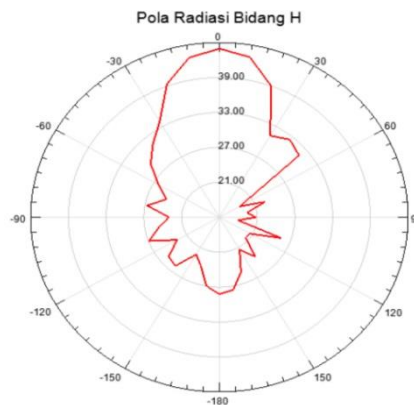


Figure 12. Polarization Results of Horizontal Helical Antenna

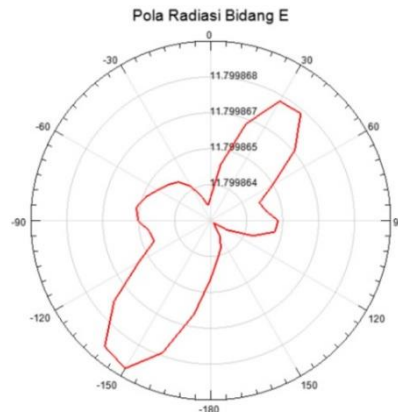


Figure 13. Polarization Results of Vertical Helical Antenna

Table 4. Comparison of Helical Antenna Modification and Fabrication

No	Antenna Parameters	Modified Antenna Results	Fabricated Antenna Results
1	Frequencies	1800	1880
2	Return loss	-14.00	-17.75
3	VSWR	-1.49	-1.32
4	HPBW	50 ⁰	44 ⁰

Testing and Analysis

Selection of test locations in locations where there are no or few obstacles in order to receive 4G LTE signals from sites located in rural areas there are no barriers or that interfere with signal reception. The location taken for this research is in Alahan Panjang, Gumanti Valley District, Solok Regency, West Sumatra. The Alahan Panjang area is a rural area where there are mountains and large trees. With coordinates latitude = -1.030556, longitude = 100.678905 and has a wide viewing angle.

Recording of test results is done using Network Cell Info Lite and Speed Test software. Measurement data collection is carried out when the process of sending internet signals from BTS to the receiving antenna is in progress. The recording of each experiment in each measurement is carried out with a duration of ± 5 to 10 minutes. Then it can be done recording the measurement results for each parameter

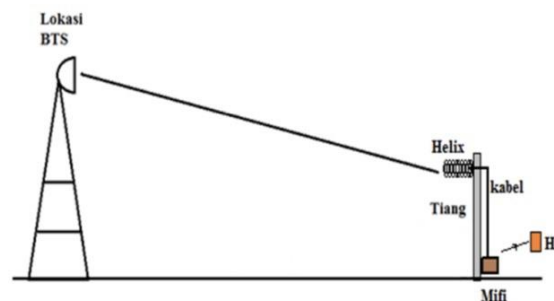


Figure 14. Schematic of Modem Signal Measurement on Helix Antenna

Internet connectivity measurement is conducted by measuring internet speed, both before and after using the Helix antenna, using the Network Cell Info Lite application installed on an Android smartphone. The testing is performed using the "speed" command, which is used to measure internet connectivity speed on the smartphone and compare it to the desired expectations (Imansyah et al., 2022). The "speed" command will measure internet speed at that location and display parameters such as jitter, download, and upload on the smartphone, as shown in Table 5 below.

Table 5. Comparison of Helical Antenna Network Quality

No	Without Helix Antenna		Using the Helix Antenna		Distance
	downlink	uplink	downlink	uplink	
1	33,9 mbps	31,0 mbps	36,4 mbps	30,0 mbps	100 m
2	45,0 mbps	30,8 mbps	47,1 mbps	31,7 mbps	500 m
3	44,1 mbps	30,5 mbps	50,1 mbps	32,6 mbps	900 m

CONCLUSION

The helical antenna with ten turns can operate well at a frequency of 1800 Mhz with a return loss level of -17.75 dB, VSWR 1.325, gain 12.47 dBi, and has a unidirectional radiation pattern. The connectivity value or network quality produced by the axial mode helix antenna is good.

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