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GPS HELIX ANTENNA DESIGN

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ABSTRACT

The Ground positioning through GPS-Global Positioning System has earned extreme significance in the recent years and has various applications. GPS is well-developed system which was initially established for military objectives and later showed itself in civil applications. It consists of three parts as control, space and user. Receiver antennas are one of most important mechanism which is used on the user side. These antennas have specific central frequency with narrow reception bandwidth and a beam width must be capable of receiving signals coming from low horizontal angles and also the structure should be sensitive to right-hand circular polarized waves.

In this study, a receiver antenna which is designed in helix form has been implemented for civil GPS applications. In the case when the designed antenna did not meet the required criteria, it was observed that the problem arose from impedance mismatching between the antenna and transmission line and a passive impedance matching circuit has been used in order to eliminate this problem.

Keywords: *Global Positioning Systems, Helix Antenna*

1. INTRODUCTION

For years, people have been interested in accurately localization of their positions accurately on the earth and tracing their movements. One of the oldest techniques that they used for obtaining this information was to leave stone pieces on their route to return. Later, maps provided better solution for this problem. Maps which began to be used nearly 5000 years ago in Mesopotamia have been an important tool for tracking position information. Recently, accuracy of positioning has a great significance, and the information of where we are and to where we are going has become more accurate and reliable. Staggering accuracy became possible by scientific researches. This is provided by Global Positioning System (GPS) [1]. Generally GPS has two application areas: Military and civil. Objective of this study is to design a receiver antenna for GPS used civil applications.

Most important property of this antenna which does not require broadband operation is the center frequency at 1575.42MHz which is known as L1. A bandwidth up to 20MHZ is acceptable. Several examples of designs can be provided for this objective. One of those is GPS patch antenna [2]. These antennas have several advantages such as being cheaper,

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small size and easy implementation. However, this antenna cannot track satellites good enough while they become closer to horizontal side in lower angles. GPS civil applications should perform tracking process up to 5^{o} from the horizontal side of the receiver antenna. In other words, the beam width should cover up to these angles. Therefore, various designs were experimented. One of those antennas used in practice is the helix antenna. GPS satellites transmit Right-Hand Circular Polarization (RHCP) signals.

In this work, it is aimed to design and analysis of the helix antenna for GPS civil applications by simulation programs, HFSS and MWO-Microwave Office. Designed antenna is also fabricated and then measurements are performed to confirm these design parameters which is chosen to satisfy desired properties for GPS applications. It is observed that very close relations exist between the theoretical and practical results.

2. GPS HELIX ANTENNA DESIGN

One of the features which is demanded from receiver antennas used in GPS civil applications is to provide the sustained continuity of the satellite tracking process when it becomes closer to horizontal side in lower angles. The antenna structure which suits to obtain this property is the helix antenna. The information about this antenna is extensively given in this study. Besides, other properties which would be expected from this antenna are to provide specific central frequency, narrow bandwidth, and having the reception of the right-hand circular polarized waves.

2.1.HELIX ANTENNA

Helix antenna which is formed by wrapping a wire around a cylinder has a three dimensional structure. Those three dimensional geometry has a line, a circle and a cylinder [3].

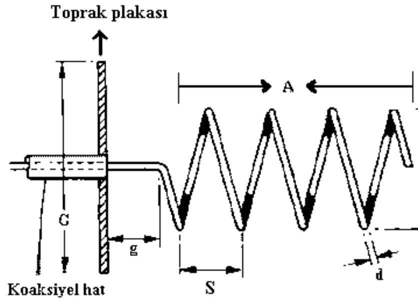

Figure 1. The geometry of helix antenna

Dimensions related with helix antenna and its ground plane are symbolically given in Figure 1. Symbols defined in figure are as follows:
D: Diameter of helix antenna
S: Interval between turns (center to center)
A: Axial length (*nS*)
d: Diameter of conductor of helix antenna
g: Distance between ground plane and helix antenna
G: Diameter of ground plane
The number of turns is shown with number *n*.

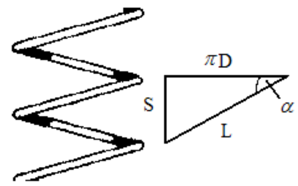

Figure 2. A cross section view of the helix antenna

Cross section of the antenna is given in Figure 2. Here, α is wrap angle and L is the length of wire for one turn. The parameters D and S which mostly affect the receiving frequency change and α stays generally constant. Dimensions for the design applications can be given in terms of wavelength in central frequency in the operation region. These dimensions are given as [4];

$$D = 0.32\lambda \text{ , } S = 0.22\lambda \text{ , } G \geq 0.8\lambda \text{ , } d = 0.02\lambda \text{ , } g = S/2 = 0{,}12\lambda \quad (1)$$

Radiation pattern of the helix antenna depends on radiation mode. Azimuth and elevation diagrams for axial-mode helix antenna are the same and they are different for normal mode antenna. Maximum radiation for axial-mode helix antenna is among the direction of helix antenna extension.

2.2.DESIGN STEPS

An axial-mode helix antenna for GPS civil applications is designed by using the parameters given in (1). Antenna is designed to radiate at 1575.42MHz. All dimensions are given in terms of wavelength related with this central frequency. Simulation of the axial-mode helix antenna is done by HFSS simulation program.

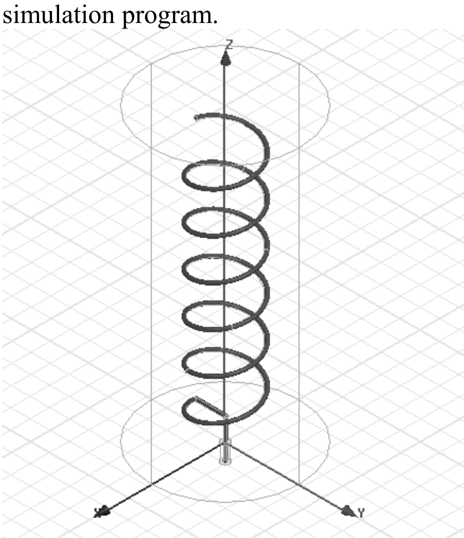

Figure 3. Helix antenna, ground plane and coaxial line

Designed axial-mode helix antenna is given in Figure 3. Dimensions which are given by (1) are used as the initial parameters of the HFSS simulation program. Then the appropriate ground plane and a coaxial line are added to design. The wire which is used to form the helix antenna is chosen as perfect conductor. Antenna is fed by a coaxial line having 50Ω characteristic impedance. Dimensions of this line are calculated by using the formula of coaxial line characteristic impedance [5];

$$Z_0 \approx \frac{138}{\sqrt{\varepsilon_r}} \log\left(\frac{R}{r}\right) \tag{2}$$

Here, Z_0 is the characteristic impedance of coaxial line, ε_r is relative dielectric constant, R is the diameter of external cross section area of the line, r is the diameter of internal conductor of the line.

2.3.ANALYSIS

First parameter which is examined during analysis is reflection coefficient (S_{11}) at the input of the antenna. In this stage, radiation of antenna at 1575.42MHz is investigated. However, sufficient small value of $|S_{11}|$ which is needed for radiation could not be obtained at first. The reason for this situation is the impedance mismatch between input terminal and the transmission line. The impedance observed at the antenna input can be calculated from the input reflection coefficient;

$$S_{11} = \frac{Z_L - Z_0}{Z_L + Z_0} \tag{3}$$

Where, Z_0, Z_L are the characteristic impedance of the cable and the input impedance of the antenna, respectively. Since, the proper matching between the antenna and the standard cable cannot be obtained by direct connection; an impedance matching circuit should be designed and inserted between the antenna and the cable in order to eliminate the matching problem. Input impedance of antenna is generally different than 50Ω characteristic impedance of the cable. A simple L type impedance matching structure composed of serial inductance and a shunt capacitance in Figure 4 is generally sufficient to solve this problem. Capacitance and the inductance values are obtained by the simulation results at the operating frequency.

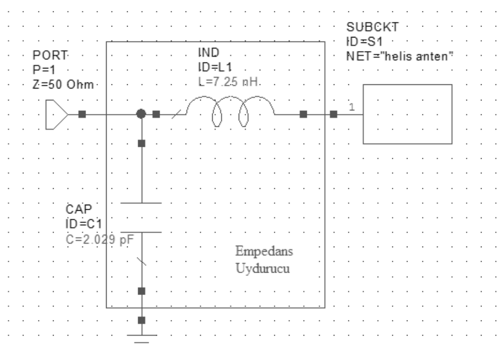

Figure 4. Helix antenna with impedance matching circuit

The variation of the input reflection coefficient is shown in Figure 5. As it is clearly observed from this figure, input reflection coefficient is approximately -37.4dB at the operating frequency of 1575.42MHz. This result clearly shows that the antenna properly radiates at this frequency. Generally, the range $|S_{11}|$ values remain below -14dB is regarded as the bandwidth of the antenna. The results in Figure 5 show that the bandwidth of the antenna is approximately 50MHz which is broad enough to meet the required limits.

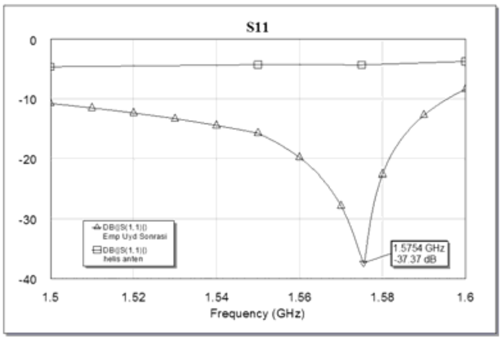

Figure 5. Reflection coefficient measured at the input of the impedance matching structure

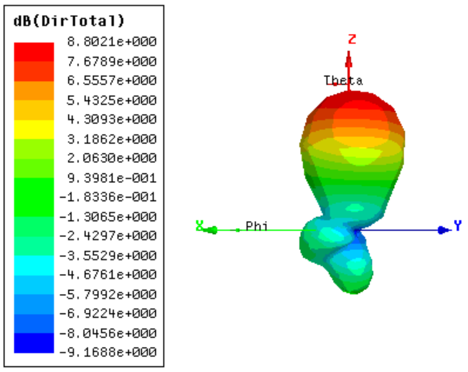

Figure 6. Three dimensional radiation pattern

Three dimensional radiation diagram of the designed antenna is given in Figure 6. As it is clearly observed from this pattern the antenna makes maximum radiation in the direction of its main axis *z*.

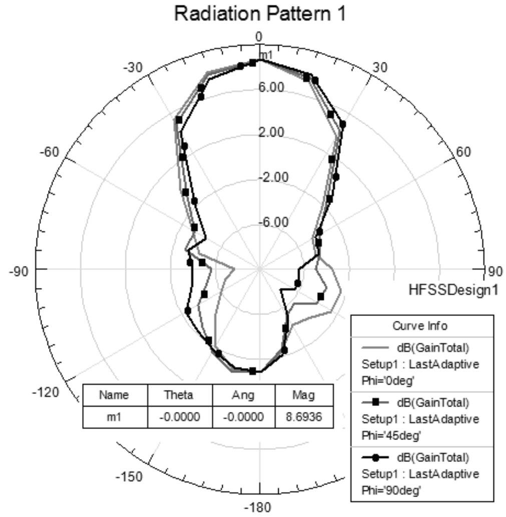

Figure 7. Radiation patterns

In the Figure 7, the radiation diagrams are obtained by scanning for three different angles $\varphi=0^{o}$, 45^{o}, 90^{o} in the spherical coordinates. As it is clearly observed from the figure the radiation diagrams are almost the same for each three different angle values. All lobes other than the main lobe which is known as the lobe covering the maximum radiation direction are called minor lobes [6]. Here, the differences only appear on the minor lobes. As it is also seen in Figure 7, the antenna has the directional main lobe with approximately 8.7dB gain.

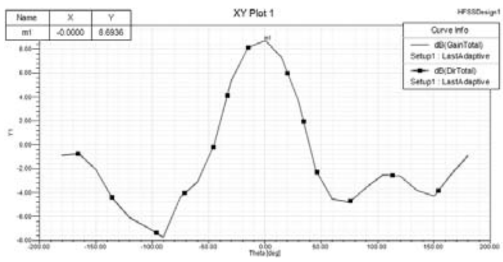

Figure 8. The directivity and gain

Two dimensional directivity and gain variations of the antenna with respect to direction angle are given in Figure 8. While the θ angles are scanned at φ = 0, the diagrams of directivity and gain are found to be the same. As it is known the directivity and the gain are related with the radiation power and the input driving power of the antenna, respectively. As it is also clearly seen on Figure 8, after the impedance matching is provided at the input, the antenna is not influenced by the losses originating from the thermal and mismatch losses.

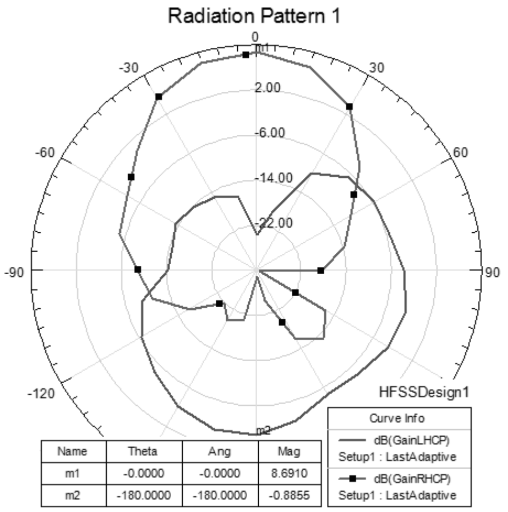

Figure 9. Radiation patterns for Right-Hand and Left-Hand Circular Polarizations

The variations of the radiation patterns for Right-Hand (RHCP) and Left-Hand Circular Polarizations (LHCP) are shown in Figure 9. The maximum gains on the radiation patterns for both types of polarization are given in the table on Figure 9. The maximum gain for RHPC is approximately 8.7dB. This result clearly shows that the antenna radiation is mainly the RHCP waves.

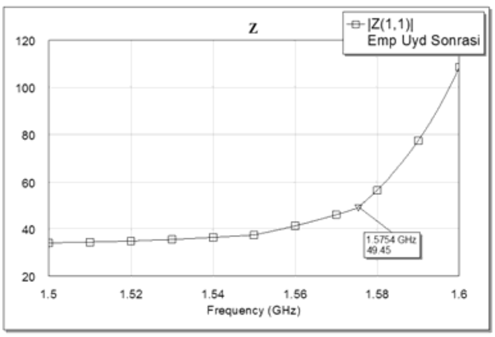

Figure 10. Input impedance variation of the antenna with respect to the frequency

Variation of the antenna input impedance with respect to the frequency is given in Figure 10. It is clearly seen that with the insertion of a passive impedance matching structure at the input 50Ω input impedance at the operating frequency is obtained.

2.4.PRACTICAL REALIZATION

After obtaining the proper simulation results the antenna is realized by using a copper wire. The $|S_{11}|$ parameter of the antenna is measured with spectrum analyzer and it is observed that the antenna does not provide the required input reflection coefficient. The impedance matching structure is formed by using the simulated element values and the structure is inserted between the antenna and cable. Instead of using an additional serial inductance at the matching circuit, the inductance is realized by using the proper length of the wire at the input of the antenna Figure 11.

Figure 11. Helix antenna

The capacitance of the matching circuit is directly connected between the antenna input and the ground plane. Although six turns of the helix antenna is chosen during the simulation analysis, the number of turns is decreased to five to ensure the proper radiation at the desired frequency by considering effect of the inductance which was ignored during the simulation analysis.

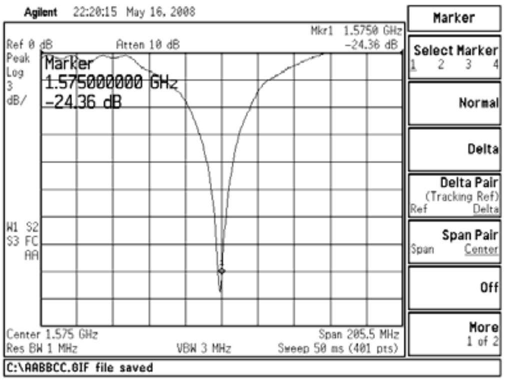

Figure 12. Reflection coefficient of helix antenna

The measured results of the input reflection coefficient of the antenna are shown in Figure 12. As it is seen $|S_{11}|$ at 1575MHz is measured as –24.36dB. The bandwidth is approximately 20MHz. The shrinkage of the bandwidth is mainly due to the narrow bandwidth of the impedance matching structure. Despite this reduction the bandwidth is still sufficient to meat the required value for this type of applications.

As it was shown in Figure 5 the simulation results for the reflection coefficient at the operating frequency was found as approximately –37.4dB. As it is seen from Figure 12 the measured results are slightly different than simulation outputs. The main reason for this difference is the change of dimension of the helix antenna due to using a certain length of the wire as the inductance during the impedance matching circuit. Another reason is that the required symmetry during the implementation of the antenna cannot be completely provided. The most important reason is that each parameter, mainly the conducting wire is not an ideal conductor as assumed during the simulation.

Figure 13. The measurement setup

In the Figure 13, the measurement setup regarding the antenna is given.

3. CONCLUSION

In this research, the design of a helix receiver antenna is realized to be used in GPS civil applications.

In the early stage of the design required features of a GPS antenna are determined and the design of a helix antenna which is thought to be appropriate to meet these features is considered. As a result of the initial analysis the impedance mismatch is observed between the input impedance of the helix antenna and the characteristic impedance of the transmission line. This problem is solved by the way of inserting an impedance matching circuit at the input. It is found that an adequate beam width and right-hand circular polarization required by a GPS receiver antenna are provided by using a helix antenna. It is also be found that the serial inductance which is used in impedance matching circuit could be realized by using a short length of the wire at the input of the antenna. As a result of the connecting the capacitance to the antenna and the changing of the antenna sizes, the specific central frequency and bandwidth values are obtained.

4. LITERATURE

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