Directional GPS Antenna for Indoor Positioning Applications

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Abstract- In this paper, a directional GPS antenna for L1 frequency - 1575 MHz - with RHCP and a high directive gain is proposed for indoor positioning applications. The proposed antenna is made of a standard off the shelf GPS patch antenna with an additional conical reflector to enhance the gain and the beamwidth of the antenna. The angle of the cone reflector is optimized by HFSS 11 software. Finally, the cone is fabricated, integrated with the patch antenna and measured. The measurement results show that the antenna with the reflector has a 9 dBi gain and a beamwidth of 60 degrees with an axial ratio of 1 dB which agrees well with simulation results.

I. INTRODUCTION

Civil Global Positioning System (GPS) has become very popular in recent years and it has wide usage in many areas. With the latest technological advances such as Differential GPS (DGPS), Assisted GPS (AGPS), civil GPS receivers are able to locate themselves with an error of 1-3 meters outdoors [1]. Although GPS is very successful in outdoor areas, it is hard to decode GPS signals indoors due to the additional signal loss caused by the buildings. GPS signals are transmitted from the satellites orbiting around 20.000 km in the sky. When these signals reach the earth surface, the strength of the signals is very low due to free space loss. For indoors, signals go through additional loss of 10-30 dB [2], in which case, signal levels are too low for an off-the shelf GPS receiver to detect the satellite signals. In order to solve indoor coverage problem, we plan to build an indoor positioning system that uses the GPS infrastructure. This indoor positioning system consists of GPS pseudo-satellites (pseudolite) and a GPS receiver with improved positioning algorithms. A GPS pseudolite works like an RF repeater, i.e.; it picks up a satellite signal, amplifies and then retransmits into the building in which there is no GPS signal coverage. It is crucial to have directional receive and transmit antennas for our indoor positioning system. A pseudolite should be able to pick up the satellite signal only from a given direction in the sky and transmit the amplified signals to an indoor area. There are several ways to design directional antennas such as Yagi-Uda, horn, log periodic, reflector and parabolic antenna or phased array systems [3]. Along these antennas, we choose the reflector antenna type since it is simple to manufacture, and also compact and robust in performance and low cost.

In this paper, we propose a directional GPS antenna for L1 frequency - 1575 MHz - with RHCP and a high directive gain. A standard off the shelf GPS patch antenna is used in the design, and the directivity increase is achieved through the use of a conical reflector. The cone is fabricated and integrated with the standard GPS patch antenna and finally directional GPS antenna is measured. The organization of the rest of the paper will be as follows: in Section II, the design procedure of the antenna is given. In Section III, measurement results will be presented, and finally the paper will be concluded.

II. ANTENNA DESIGN

The proposed antenna is comprised of a standard of the shelf GPS antenna and a conical reflector as illustrated in figure 1. Standard GPS antenna is a circularly polarized patch antenna operating at the frequency of 1575 MHz. The circular polarization is provided by truncation of the two diagonal corners and feeding the antenna asymmetrically with a coaxial probe under the patch [3]. The dimensions of the GPS patch antenna - 25 mm x 25 mm - are kept small by using high electrical permittivity (e_r = 25). Microstrip patch antennas are medium gain antennas. In order to further increase the directivity of the patch antenna, either a phased array system consisting of multiple radiating elements or a parasitic reflector system can be utilized. In our approach, we choose a simple reflector system over other directional antennas. The conical reflector is simple, compact, robust in performance and low cost. Most importantly, as opposed to phase array antenna, reflector antenna does not need a beam forming network which decreases the received power and increases the noise figure of the overall system. Therefore, a reflector is designed to increase the directivity of the antenna.

The design of conical reflector together with the patch antenna is performed using Ansoft's High Frequency Structure Simulator (HFSS). First, off the shelf GPS patch antenna is simulated and parameters of the antenna are adjusted such that the specifications in the datasheet are obtained with good accuracy. Then, the GPS patch antenna is placed in the middle of cone reflector. The reflector is left as floating reflector, i.e., it is not grounded. Optimizations are done iteratively by the simulation tool and more emphasis is given to three parameters of the conical reflector namely height of the cone, angle between the cone and the ground plane and the distance of cone to the patch antenna. The distance between the cone and the standard patch antenna basically affects the all parameters. However, most importantly, it affects the return loss of the antenna. The height of the cone changes the beamwidth and the gain of the antenna. The cone angle mostly affects the radiation pattern of the antenna. In figure 2, one can observe the effect of the cone angle to the radiation pattern of the antenna with the other parameters set to optimum values.

After simulation results, thickness of the conical reflector is chosen as 1 mm, the two of the three parameters are fixed with the best results acquired in simulations and the other parameters are optimized. The summary of the dimensions of the proposed antenna after the optimizations are given in Table 1.

III. SIMULATION AND MEASUREMENT RESULTS

Simulation results of the stand alone GPS patch antenna shows that the antenna has 4 dBi maximum directive gain and 120^{o} half power beam width. Antenna is matched at GPS L1 frequency. These simulation results agree with the datasheet of the GPS patch antenna. After the design of the cone and the integration of the cone with the GPS patch antenna, measurements are done in an anechoic chamber. The results show that the gain of the antenna is increased and the center resonant frequency of the overall system slightly changed which does not affect the overall performance. The simulated and the measured return loss of the directional antenna with the measured return loss of the stand alone GPS patch antenna can be seen in figure 3. As seen in the figure, cone changes the input impedance slightly. However, directional antenna still matches at GPS L1 frequency. The measured and simulated radiation pattern of the directional antenna can be seen in figure 4 and 5 with the phi angles 0 and 90 degree respectively. The beamwidth of the directional GPS antenna is 60 degrees. Decrease in the beamwidth angle can be seen in figure 6 in which the measured radiation pattern of the directional antenna and the simulated radiation pattern of the GPS patch antenna are shown. Measured radiation patterns of the two orthogonal phi angles can be seen in figure 7. As seen in the figure, axial ratio of the directional antenna is 1 dB which indicates that the antenna is circularly polarized. Simulated directional gain of the antenna is 10 dB and the measured maximum directional gain of the overall system is 9 dB. Cone brings an additional 5 dB gain to the patch antenna. The measurement results of the return loss, gain and the radiation patterns fit well with the simulation results.

IV. CONCLUSION

In the proposed paper, a directional GPS L1 frequency antenna is designed for indoor GPS applications and repeaters by using an off the shelf GPS patch antenna and a conical reflector. Directionality is achieved through the conical reflector. The measurement results show that the overall gain of the antenna is 9 dB and the beam width of the antenna is 60 degree which is highly satisfactory results. The conical reflector is optimized with the simulator tool and the optimization results are demonstrated in the paper. Our design shows that conical reflector can be used to increase the directivity and decrease the beam widths of the patch antennas. In different applications same method can be used to simply increase directivity of the antenna for different aims.

REFERENCES

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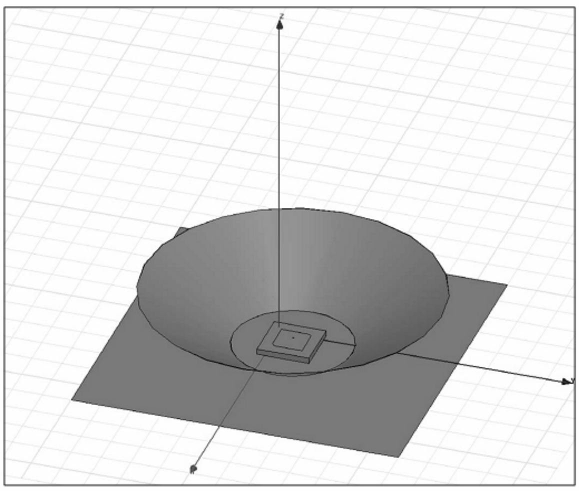


Fig 1 - GPS Patch Antenna with the conical reflector

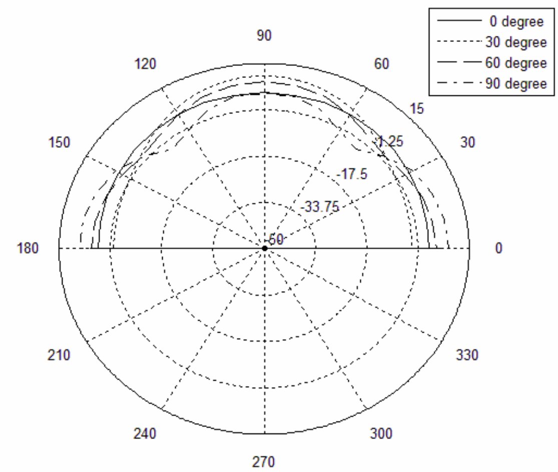


Fig 2 – Radiation Patterns with Different Cone angles

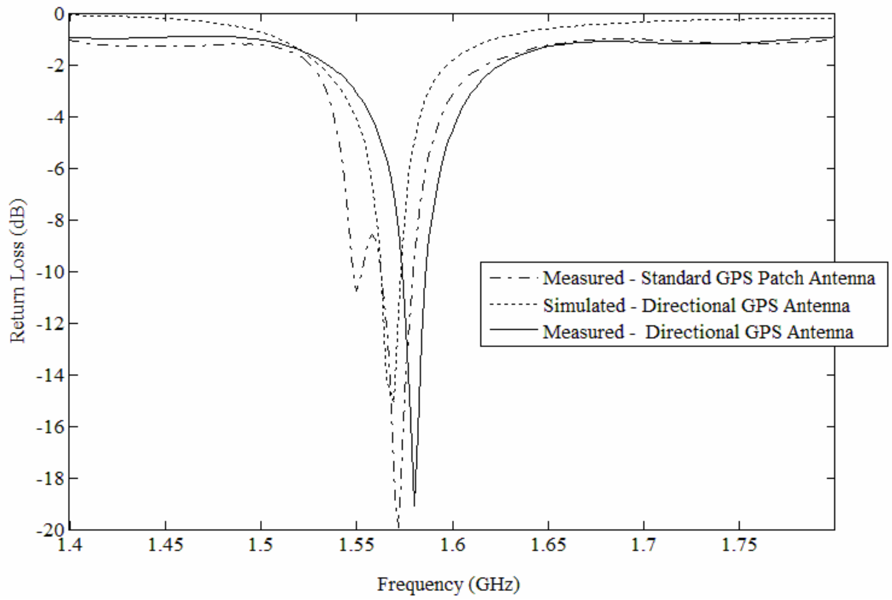
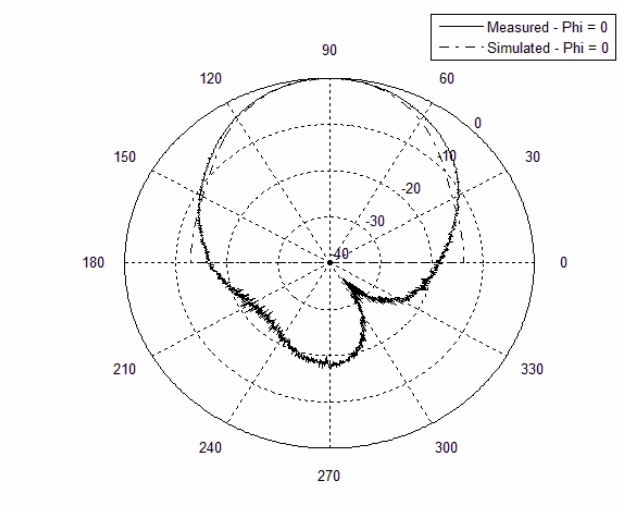


Fig 3 – Measured Return Loss of the Standard GPS Patch Antenna and Directional Antenna. Simulated Return Loss of the Directional Antenna.



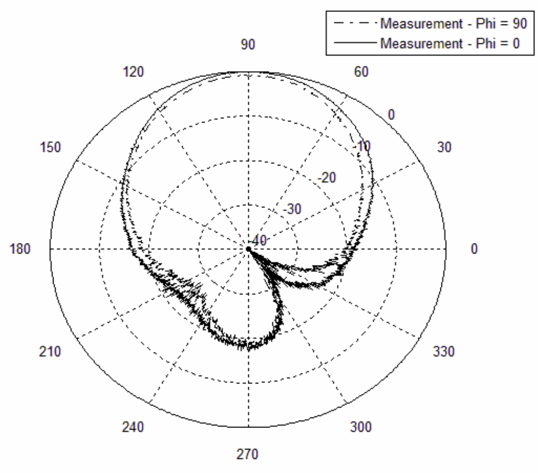


Fig 4 – Measured and Simulated Radiation Patterns $f = 0^{0}$.

Fig 5 - Measured Radiation Patterns at $f = 0^{0}$ and $f = 90^{0}$.

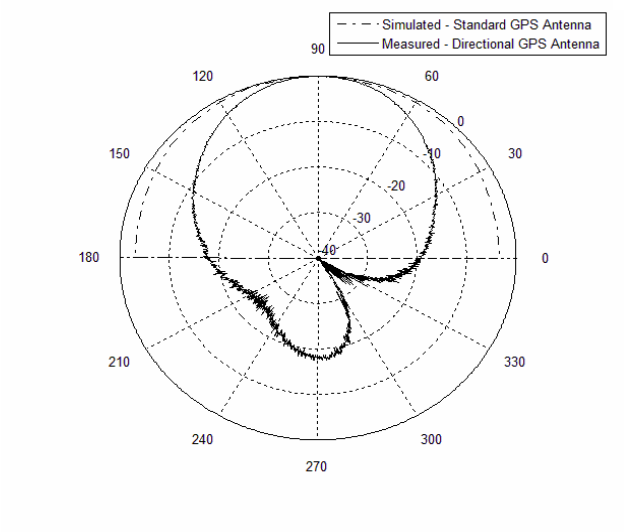


Fig 6 - Measured and Simulated Radiation Patterns at $f = 0^0$.

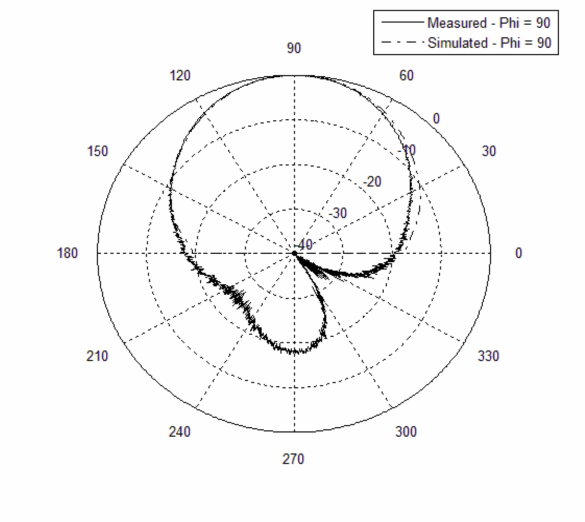


Fig 7 - Measured and Simulated Radiation Patterns at $f = 90^0$.

Table 1 – Optimized parameters

Distance of the cone to the standard patch antenna	4 cm
Height of the cone	4 cm
Angle between the cone and the ground plane	30^0