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ANALYSIS AND DESIGN OF HIGH GAIN FLAT PATCH ANTENNA

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Abstract: *This paper demonstrates an enhanced version of a high gain flat patch antenna which provides a gain of 8 dBi. This commercial antenna has a resonant frequency of 1.2 GHz and is considered as a reference antenna in this analysis. The simulations of the reference antenna and the proposed one were carried out using the 3D Full-Wave Finite Element Method (FEM) electromagnetic simulator, Ansys HFSS. The simulation results have a good agreement. The proposed antenna has achieved the main goal of a 1.32 GHz resonant frequency with an increased gain of 9.5 dBi. The effects of the different parameters like SWR, S11 parameter, radiation patterns, bandwidth are analyzed. The proposed antenna is manufactured, measured and tested in real-world conditions. The proposed antenna can be efficiently used in applications such as video signal transmission.*

Keywords: *equivalent model, patch antenna, antenna radiation pattern, directional antenna, HFSS.*

1. INTRODUCTION

For wireless communication systems, the antenna is one of the most critical components. A good design of the antenna can relax system requirements and improve overall system performance [1].

The flat patch antenna is a directional low-profile antenna which belongs to the class of resonant antennas. It is characterized by low manufacturing costs and easy design due to its simple structure, with the drawback of a narrow bandwidth. In essence it is comprised of the upper plate and ground plate with a dielectric substrate in between, as shown in *Figure 1.1*. The ground plane serves as a conductive plate while the upper radiating patch functions as a wave-generating element.

The design outline of the flat patch antenna results in a maximized radiation pattern with a right angle against the upper patch and simultaneously minimized under the lower, ground plate. With this design approach a directional radiation pattern was achieved in the upper half of the sphere, therefore increasing gain.

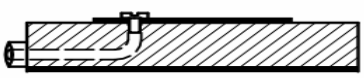

Figure 1.1. Side view of the flat patch antenna

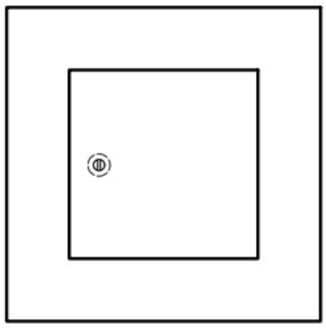

Figure 1.2. Top view of the flat patch antenna

Highly directional antennas are essential for more sophisticated missions, goals, decreased instrument's complexity, large amounts of scientific data handling, higher data rate links, and for better signal to noise ratio [4] [5].

2. REFERENCE ANTENNA ANALYSIS

In this paper we consider a commercial antenna as the reference one with a nominal resonant frequency of 1.14 *GHz*. The simulations of reference antenna were carried out using the 3D Full-Wave Finite Element Method (FEM) electromagnetic simulator, Ansys High Frequency Structure Simulator - HFSS. Ansoft HFSS can be used to calculate parameters such as S-Parameters, Resonant Frequency, and Fields.

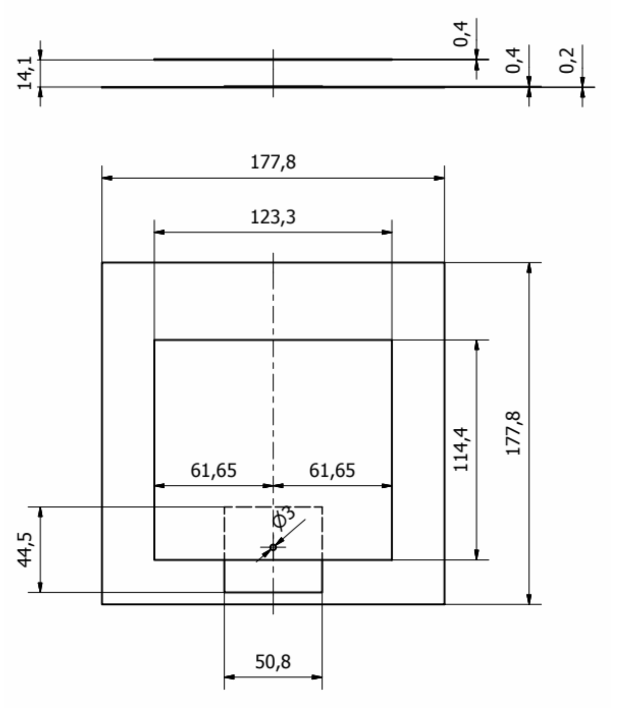

Figure 2.1. Geometry of the reference antenna, side and top view

The geometry of the reference antenna is shown in *Figure 2.1.* and consists of three elements, in contrast to the theoretical antenna described in the introduction. The ground plate is comprised of two elements from different materials, the larger being an aluminum square with dimensions of $a = 177.8\ mm$ and a thickness of $0.2\ mm$, while the smaller brass rectangle measures $a_2 = 44.5\ mm$ and $b_2 = 50{,}8\ mm$, $0{,}4\ mm$ thick. The material used for the upper patch was brass as well, with dimensions $w = 123.3\ mm$ width and $l = 114.4\ mm$ length, $0.4\ mm$ thick. The feed point for the upper plate i.e., the wave emitting element is located $6.5\ mm$ from the edge of the plate, whereas widthwise it is positioned at the value midpoint $w = 123.3\ mm$ which totals $61.65\ mm$. The height between panels equals $h = 14.1\ mm$.

Modeling this data through the HFSS simulation program yields results corresponding to the factory specifications of this reference antenna.

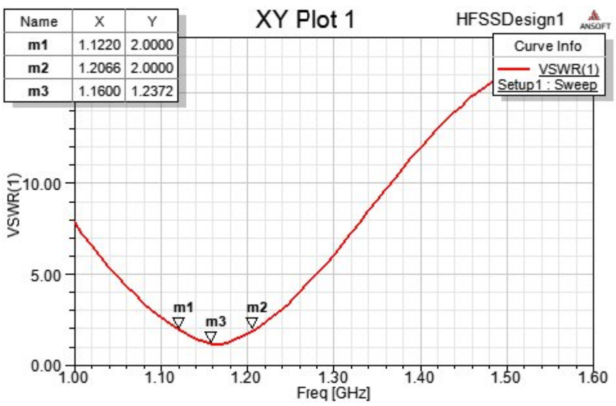

Figure 2.2. Standing Wave Ratio of the reference antenna

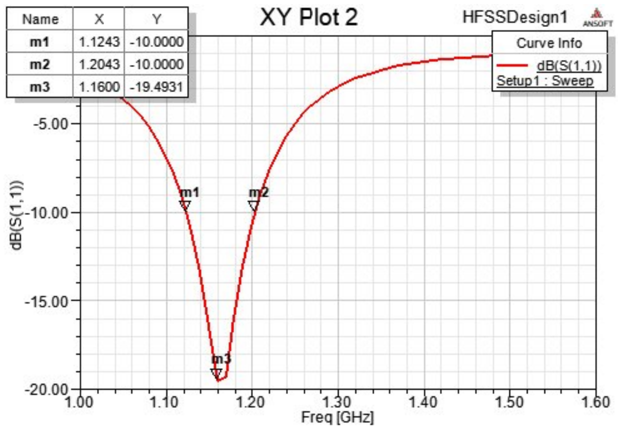

Figure 2.3. S11 – reference antenna parameter

Through a simulation we obtained results for the VSWR shown in *Figure 2.2* and the S11 parameter from *Figure 2.3* from which we can affirm the 1.16 *GHz* resonant frequency of the reference antenna. Examination of the reference antenna factory specifications defines its resonant frequency of 1.14 *GHz*, while its bandwidth ranges from 1.08 *GHz* to 1.2 *GHz*.

The existence of these minor differences between the simulated antenna and its factory specifications may be attributed to approximations done during the simulation setup, as well as potential imperfections in the antenna's manufacturing. In either case we can attest that the simulation data is credible enough for the same simulation principle to be used on our proposed antenna.

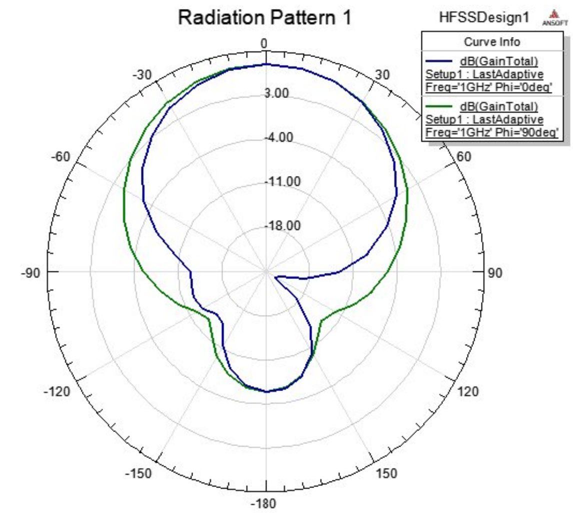

Figure 2.4. Radiation patterns of the *reference* antenna

Radiation patterns of the simulated reference antenna are shown in *Figure 2.4.* Maximum antenna gain at the frequency of 1 *GHz* for $\varphi = 0^{\circ}$ and $\varphi = 90^{\circ}$ is 8.0284 *dBi*, matching factory specifications of 8 *dBi*. *Figure 2.5* displays the 3D simulated reference antenna gain.

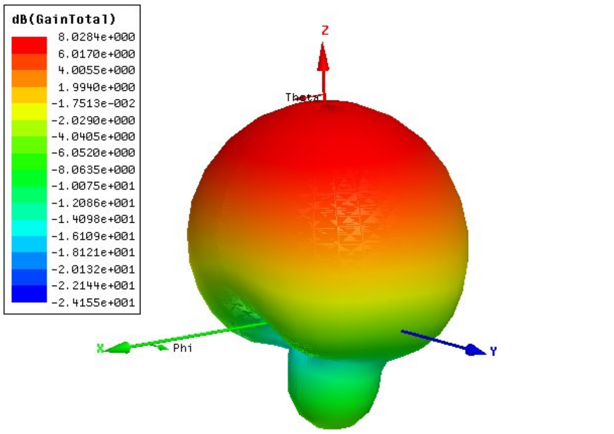

Figure 2.5. 3D Radiation pattern of the *reference* antenna

3. ANALYSIS AND DESIGN OF THE PROPOSED ANTENNA

Starting from the reference antenna analysis, we set forth to create an antenna which would meet our needs for a resonant frequency of 1.32 *GHz*. For a quicker and simpler design all the established elements of the reference antenna were used with the exception of switching from a brass wave-emitting element to a copper one.

Optimized dimensions of the suggested antenna's upper radiating plate, after a number of simulations are as follows: $w = 123.3\ mm$ and $l = 100\ mm$, while the thickness $0.4\ mm$ remains unchanged, with the height decreasing from 14.1 *mm* to $h = 11.3\ mm$.

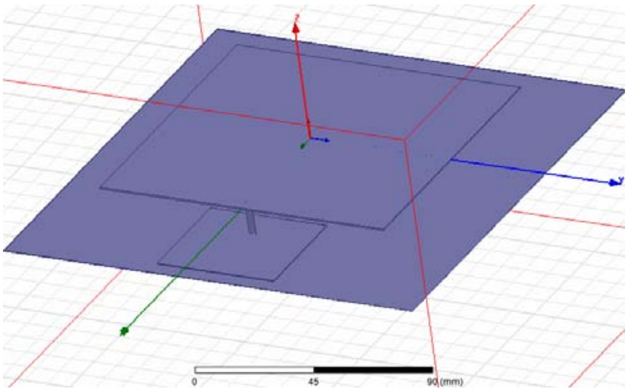

Figure 3.1. Simulation model in Ansys HFSS

The antenna met our goals in various other combinations, e,g, with the retained height of $h = 14.1\ mm$, the dimensions of the transfer plate would be: $w = 118\ mm$ and $l = 98\ mm$, however this solution was dismissed due to a slightly inferior *Standing-wave ratio* (SWR) parameter.

The SWR and S11 parameters of the simulated antenna represented in *Figures 3.2 i 3.3* were defined by the dimensions of the upper antenna plate and height between plates. With the antenna geometry we reached the desired resonant frequency of 1.32 *GHz*.

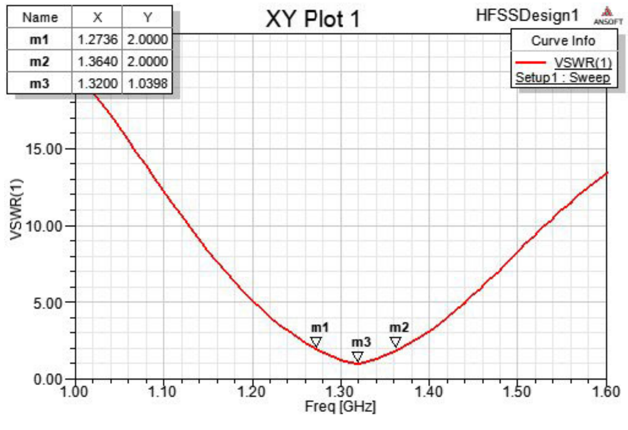

Figure 3.2. Standing Wave Ratio of the proposed antenna

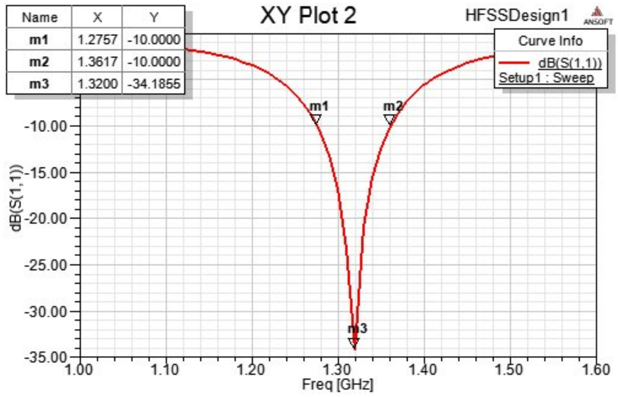

Figure 3.3. S11 – parameter of the proposed antenna

Based on the S11 parameter simulation data bandwidth a range from 1.2757 *GHz* to 1.3617 *GHz* can be infer, we conclude that the proposed antenna has a very wide bandwidth.

The radiation pattern of the simulated proposed antenna is shown in *Figure 3.4.* for $\varphi = 0^{\circ}$ and $\varphi = 90^{\circ}$.

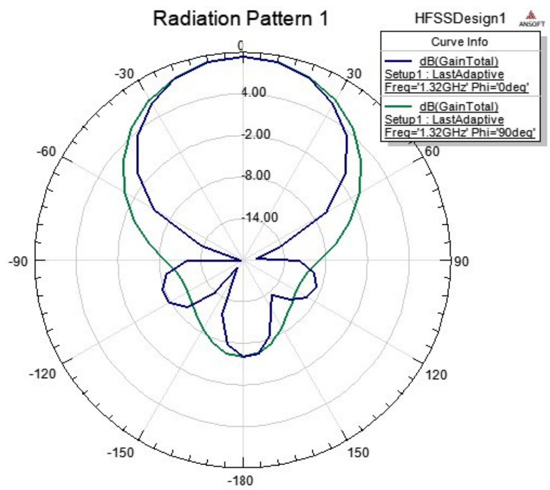

Figure 3.4. Radiation pattern of the proposed antenna

Figure 3.5. represents the 3D simulated gain of the proposed antenna. Gains in the direction of propagation amount to 9.4364 *dBi*.

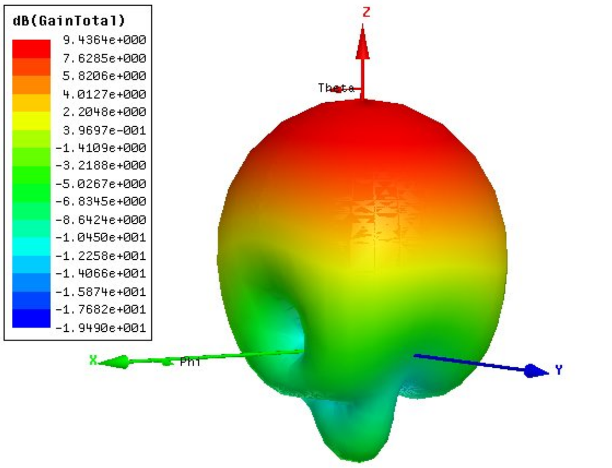

Figure 3.5. 3D radiation pattern of the *proposed* antenna

The results were verified with laboratory measuring in which the prototype of the proposed antenna had a resonant frequency of 1.3154 *GHz*. Agilent HP 8753ES RF Vector Network Analyzer was used during laboratory testing.

Figure 3.6. The result of the proposed antenna laboratory test.

The proposed antenna was subject to real world testing where optical visibility was achieved. With a transmitter strength of $P_t = 5\ W$, a transmission antenna gain of $G_t = 7\ dBi$, receiver sensitivity of $P_r = -70\ dbm$, at a frequency of $f_c = 1.32\ GHz$, the antenna achieved video signal transmission from a distance of $R = 26\ km$. Using the FRIIS equation:

$$P_r = \frac{P_t G_t G_r \lambda^2}{(4\pi R)^2} \quad (1)$$

we can get confirmation of the proposed antenna gain of close 9.5 *dBi*, as predicted by the simulation.

4. CONCLUSION

From the commercial high gain flat patch antenna and the simulation performed using the 3D Full-Wave Finite Element Method (FEM) electromagnetic simulator, Ansys HFSS, we obtained results very similar to the factory specification of a 1.2 *GHz* resonant frequency and an antenna gain of 8 *dBi*. Based on the commercial antenna analysis results, which was used as a reference one, we modeled our own antenna. The manner in which we achieved that involved minimal interventions regarding the reference antenna elements i.e., changing the geometry of the wave-emitting element as well as the height between the elements. This whole process underwent with the help of the HFSS software. Simulations were repeated until a desired result was reached. The parameters of our proposed antenna consist of a 1.32 *GHz* resonant frequency and a gain of 9.5 *dBi* which fully completed the task at hand. This process proved it is possible to achieve a desired result and build a prototype based on a series of simulations. Respectively, laboratory and real-world testing only confirmed the data obtained in the simulation. In the absence of laboratory confirmed antenna characteristics, simulated results can be used with a great degree of certainty in the production of a desired antenna. The proposed antenna can efficiently be used in applications like video signal transmission.

References

[1] BALANIS, C. A.: Antenna Theory: Analysis and Design. Third ed., Hoboken, 2005.

[2] GARG, R., BHARTIA, P., BAHL, I., ITTIPIBOON, A.: Microstrip Antenna Design Handbook, Boston, London, 2001.

[3] MRABET, EL, O.: High Frequency Structure Simulator (HFSS) Tutorial, Rennes, 2005 – 2006.

[4] HEIDT, H., PUIG-SUARI, J., MOORE, A., NAKASUKA, S. and TWIGGS, R.: CubeSat- A new generation of picosatellite for education and industry low-cost space experimentation, 2000.

[5] SAMSUZZAMAN, M., ISLAM, M.T., NAHAR, M.K., MANDEEP, J.S., MANSOR, F., ISLAM, M.M.: Circularly polarized high gain S band antenna for nanosatellite, Amsterdam, 2015.