COMPARISON OF GNSS PATCH VERSUS GPS L1 PATCH ANTENNA PERFORMANCE CHARACTERISTIC

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ABSTRACT

Antenna module is a vital component of automated driving systems, it should function as needed in dGPS, HD map correction services, and radio and navigation systems. The proposed antenna model for GPS only patch antenna operating at 1.57542 GHz and the GNSS patch antenna resonating at 1.5925 GHz are developed. This work presents the design, modelling, determining passive gain of the GPS patch vs. GNSS antenna with intended targeted applications within the automotive system. Simulation are undertaken to evaluate the performance of the proposed GNSS antenna. Simulation conducted in FEKO software rather than mathematical modelling. The two antennas are also compared from the size standpoint. The goal of this paper is to test, measure and evaluate the performance of GPS against GNSS antennas. Another emphasis of this paper is how to obtain the equivalent amount of total passive gain in a GPS vs. that of GNSS antenna.

KEYWORDS

Differential Global Position System (dGPS), Global Navigation Satellite System (GNSS), Globalnaya Navigazionnaya Sputnikovaya Sistema (GLONASS), Advanced Driver Assistance Systems (ADAS), Automated Driving (AD), Modelling, comparison, measurements, analysis

1. INTRODUCTION

An antenna could be defined as a wireless communication device or module such as a piece of wire for radiating or receiving electromagnetic wave propagating in a communication channel, such as guided structure transmission line and then getting transmitted into a free space and/or vice versa in the receiving mode. We present the passive gain of the GPS only patch and GNSS (GPS/GLONASS) antenna structure using FEKO electromagnetic simulation software package, in order to support automotive applications. This study describes the modelling, design, simulation and analysis of GPS only (L1) patch and GNSS (GPS/GLONASS) patch antenna. According to Constantine A. Balanis, the antenna is the transitional structure between free-space and a guiding device, for wireless communication systems, the antenna is one of the most critical components. For the past few decade Microstrip Patch Antenna were used heavily in high performance aircraft, spacecraft, satellite and missile where size, weight, cost, performance, ease

David C. Wyld et al. (Eds): ICAITA, CDKP, SAI, NCO, CMC, SOFT, MLT, AdNLP - 2020
pp. 01-12, 2020. CS & IT - CSCP 2020 DOI: 10.5121/csit.2020.100901

of installation, and aerodynamic profile are constraints. Low profile antennas maybe required [1] for packaging and/or aesthetic constraints. The GNSS (GPS/GLONASS) antennas play a significant role in today's modern communications, i.e. they nicely meet automotive specification requirements, most antenna designers and OEMs mainly preferred and select this rectangular/square GNSS (GPS/GLONASS) patch antenna, in order to mount, install, place and position it on their production vehicles.

2. ANTENNA PERFORMANCE CHARACTERISTICS

In the following below are illustration of mathematical model/equations that define the antenna gain, efficiency, directivity and input impedance.

Equation 1 Expresses, the antenna gain as:

Gain G =4(π)(radiation intensity)/total input(accepted) power=4(π)*(U((Elevation Angle, Azimuth Angle)))/Pin (dimensionless) [1] (1)

Also, Antenna Gain (G) = Antenna Efficiency (€)*Antenna Directivity (D) [2]

Equation 2 Expresses the antenna Radiation efficiency:

€ = Prad/Pt (dimensionless) (2)

Where Prad = Radiated Power, Pt = Transmitter Power [2]

In general, the overall antenna efficiency can be express as below

$e_O = e_r \, e_c \, e_d$

Where e_O is the total efficiency (dimensionless)

e_r= reflection (mismatch) efficiency = (1-|voltage reflection coefficient at the input terminals of the antenna|^2) (dimensionless)

e_c = conduction efficiency (dimensionless)

e_d = dielectric efficiency (dimensionless) [1]

Equation 3 Expresses, the antenna directivity

D=4(π)/Ω (3)

Where Ω=Pattern Solid Angle= $\int\int_{4*Pie}$ F(Elevation Angle, Azimuth Angle)(d Ω)
F (Elevation Angle, Azimuth Angle) =Normalized Radiation Intensity [2]

Equation 4 Highlights, the antenna input impedance, defined as:

Input Impedance = $Z_A = R_A + jX_A$ (ohms) [1] (4)

Where

Z_A = antenna impedance at the input terminals of an antenna when it operates in transmitting mode (ohms)

R_A = antenna resistance at the input terminals of an antenna when it operates in transmitting mode (ohms)

X_A = antenna reactance at the input terminals of an antenna when it operates in transmitting mode (ohms)

In general, the R_A parameter from
Equation 5 is mainly made up of two resistances (R_r and R_L) of the antenna
Resistive component = $R_A = R_r + R_L$ (ohms) [1] (5)

Where

R_r = Represents the radiation resistance of the antenna (ohms)

R_L = Represents the loss resistance of the antenna (ohms)

If we assume that the antenna is connected/attached to a signal/function generator/source with internal impedance, when the antenna is used in the transmitting mode of operation then internal impedance is defines as listed below:
Internal impedance (Z_g) = $R_g + jX_g$ (ohms) [1] (6)

Where

R_g = Represents the resistance of signal source/generator impedance (ohms)

X_g = Represents the reactance of signal source/generator impedance (ohms)

Solving these equations at high level will allow to obtain the some of the antenna characteristics. Where on the other hand FEKO simulator/simulation software package is based on the Method of Moments (MoM) integral formulation of James Maxwell's equations, in order to solve for antenna characteristics, such as antenna gain, antenna input impedance, etc.

3. ANTENNA DESIGN STRUCTURE AND ANTENNA EVALUATION

The testing, experimental, comparison and evaluation of the square GPS only patch and GNSS (GPS/GLONASS) patch antenna design and simulation of the proposed two antennas is performed using FEKO which has not been previously investigated and/or studied at the FEKO simulation level. The GPS only patch and GNSS (GPS/GLONASS) patch antenna will be compared and contrasted mostly from the total passive gain in FEKO simulation environment viewpoint. The photo of each of the respective two test and presented antennas under evaluation and assessment are outlined and shown in Figure 1, Figure 2, Figure 3, and Figure 4. Figure 1 depicts the front view of the dual band GNSS (GPS/GLONASS) antenna. From the Figure 2 we can see the top view of the dual band GNSS (GPS/GLONASS) antenna. Figure 3 depicts the front view of the GPS only L1 square/rectangular patch antenna. From the Figure 4 we can see the top view of the GPS only L1 square/rectangular patch antenna.

3.1. GNSS (GPS/GLONASS) Patch Antenna Front View Photo

Figure 1. Dual Band Constellation GNSS Patch Antenna

3.2. GNSS (GPS/GLONASS) Patch Antenna Top View Photo

Figure 2. Dual Band Constellation GNSS Patch Antenna

3.3. GPS Only Passive Patch Antenna Front View Photo

Figure 3. GPS Only Patch Antenna

3.4. GPS Only Passive Patch Antenna Top View Photo

Figure 4. GPS Only Patch Antenna

3.5. GPS Antenna Samples Consideration for the Evaluation

Table 1. One sample of each antenna used for the model simulation in the FEKO environment

Dual-Band GNSS (GPS/GLONASS) Patch Antenna	1
GPS Only Passive Patch Antenna	1

3.6. Range of Operating and Simulation Frequency Requirements

The GNSS (GPS/GLONASS), GPS Only L1 frequencies were used for the purpose of this paper test and simulation activities:

- GPS Only L1 Frequency, GPS (L1): 1.57542 GHz

- GNSS (GPS/GLONASS): 1575 to 1610 MHz, Center Frequency (fc)= 1.5925 GHz)

The proposed antennas [GPS Passive Patch and GNSS (GPS/GLONASS)] characteristic was simulated by using FEKO simulation software package. An analysis was conducted next and finally total gain for each of the sample antenna were observed from the POSTFEKO environment.

4. FEKO DESIGN PARAMETERS AND SIMULATION RESULTS

4.1. Antenna Samples for FEKO Simulation

Table 2. Antenna substrate and radiating element dimensions

Patch Size & Application	**Reference & Device Under Test (DUT) Antenna**
GPS Only Single Passive Patch Antenna (L1-, 1.57542 GHz) • Substrate Size: 24.9 x 24.8 x 4.5 mm • Radiating Element Size: 12.25 x 12.25 mm	Reference
Dual Band GPS/GLONASS Antenna (GNSS-1.5925 GHz) • Substrate Size: 24.7 x 24.7 x 4.5 mm • Radiating Element Size: 12.25 x 12.25 mm	DUT

4.2. Design Parameters within FEKO Simulation Environment

Table 3. FEKO Mesh and Loss Tangent Parameters for GPS only Patch and GNSS Patch Antenna

GPS and GNSS Antenna Component	**Parameter**	**Value**
GPS only Patch Antenna Operating at , 1.57542 GHz	Mesh-Wire Segment Radius	1.587e-3 mm
	Dielectric Loss Tangent for Porcelain Material	2.1e-14 mm
GNSS (GPS/GLONASS) Patch Antenna Operating at 1.5925 GHz	Mesh-Wire Segment Radius	1.569e-3 mm
	Dielectric Loss Tangent for Porcelain Material	2.0e-14 mm

4.3. Reference GPS only L1 Patch Antenna

Modelling, design, and simulation based on the following design parameters listed in Table 4 below.

Table 4. Design Parameters of Reference GPS only Structure Antenna

Parameter	**Value**
Feed Length	0.5 mm
Operating Frequency	1.57542 GHz
Ground Plane Length	95 mm
Ground Plane Width	95 mm
Radiating Element Length	12.25 mm
Radiating Element Width	12.25 mm
Substrate Length	24.8 mm
Substrate Width	24.9 mm
Substrate Thickness	4.5 mm
Substrate Dielectric Constant (Relative Permittivity) for Ceramic/Porcelain Material	5.5 mm

Figure 5 plot below shows graphic representation of a pin fed voltage source of excitation. The Top View of the GPS only (L1 frequency, 1.57542 GHz) passive patch antenna on a finite square/rectangular orange color ground plane, square purple color substrate with dielectric constant value of 5.5 mm and a square dark blue color radiating element. Figure 6 depict the Side View of the GPS only patch antenna.

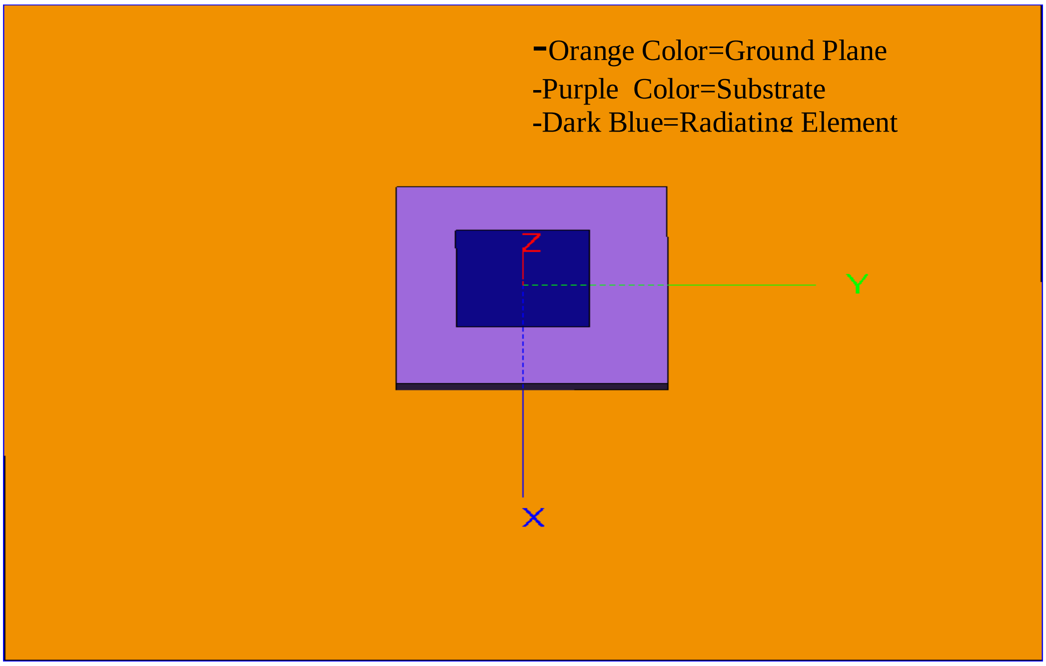

Figure 5. GPS Patch antenna operating at 1.57542 GHz (Top View/Cross Section Image)

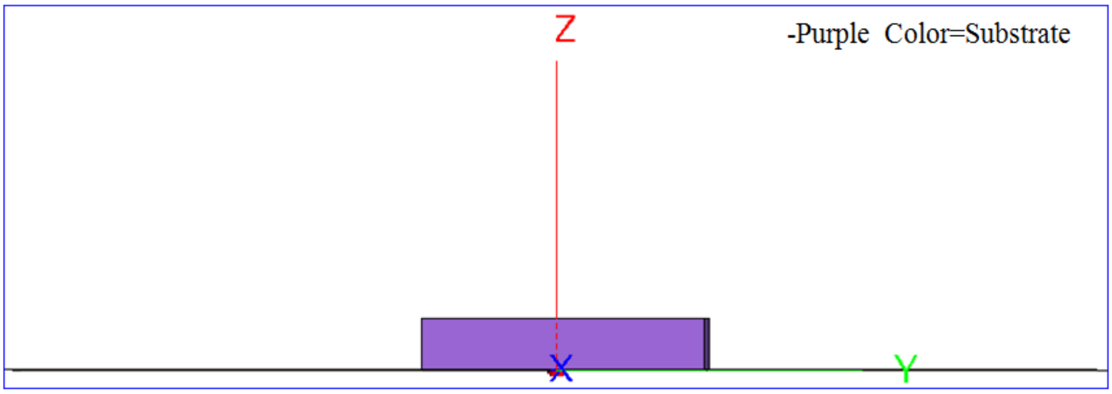

Figure 6. GPS Patch antenna operating at 1.57542 GHz (Side View)

4.4. Simulated Far Field of Reference GPS only Structure Patch Antenna

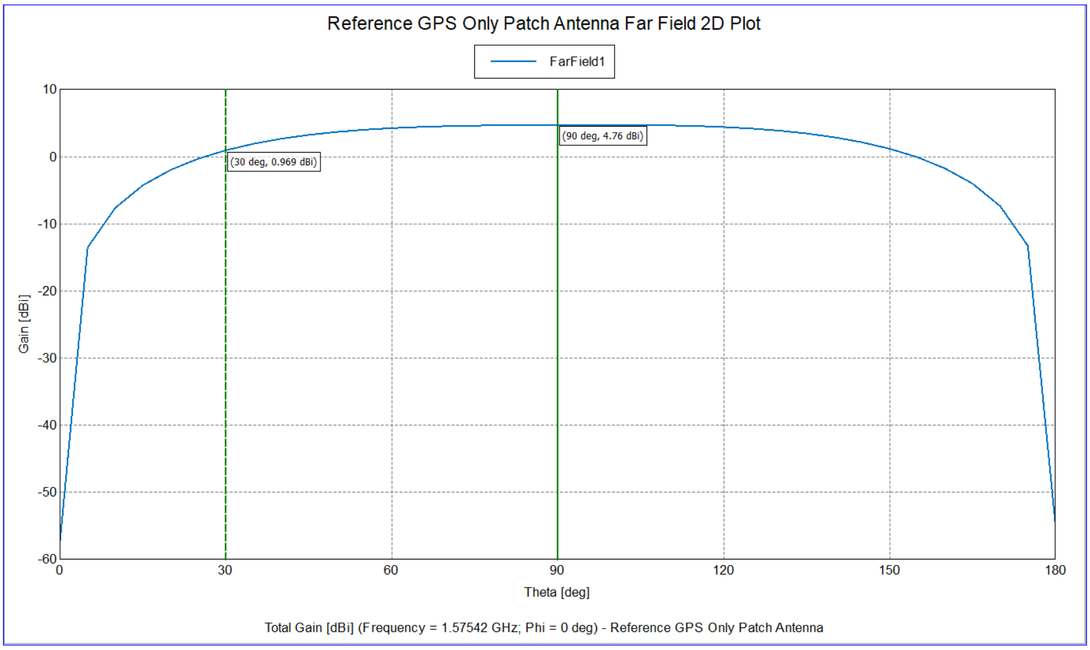

Figure 7. Patch antenna operating at 1.57542 GHz

Using Figure 7, the passive gain is approximately 3.791 dBi of the presented antenna and it can be determined by taking the difference in gain angle/delta between 30 and 90 degree angles in the 2D plot graphic.

Figure 7 shows the simulated passive gain of the proposed antenna and I selected substrate material to be Ceramic/Porcelain with dielectric constant/relative permittivity=5.5 mm to model, design, and simulate the presented GPS (L1) only patch antenna.

4.5. Device Under Test (DUT) GNSS Patch Antenna

Modelling, design, and simulation based on the following design parameters listed in table 5 below.

Table 5. Design Parameters of Device Under Test (DUT) GNSS (GPS/GLONASS) Structure Patch Antenna

Parameter	**Value**
Feed Length	0.5 mm
Operating Frequency	1.5925 GHz
Ground Plane Length	95 mm
Ground Plane Width	95 mm
Radiating Element Length	12.25 mm
Radiating Element Width	12.25 mm
Substrate Length	24.7 mm
Substrate Width	24.7 mm
Substrate Thickness	4.5 mm
Substrate Dielectric Constant (Relative Permittivity) for Ceramic/Porcelain Material	5.5 mm

Figure 8 plot shows the Top View of the GNSS (GPS/GLONASS) patch antenna with a square/rectangular orange color ground plane, square purple color substrate with dielectric constant value of 5.5 mm and a square dark blue color radiating element. Fig 9 depict the Side View of the GNSS (GPS/GLONASS) patch antenna.

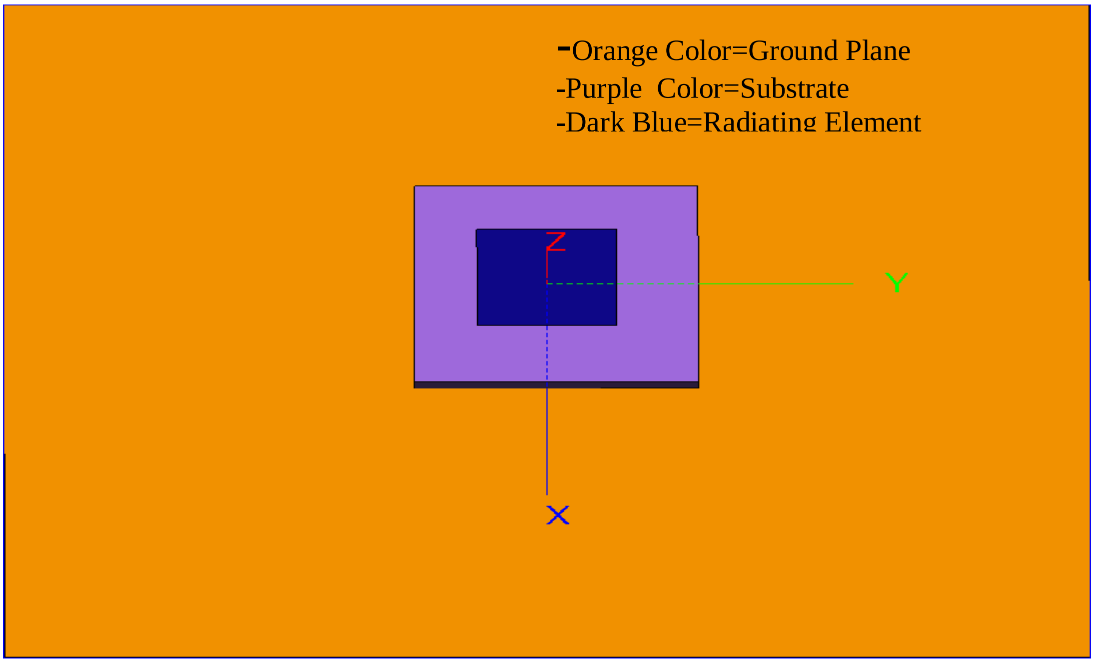

Figure 8. DUT GNSS Patch antenna operating at 1.5925 GHz (Top View/Cross Section Image)

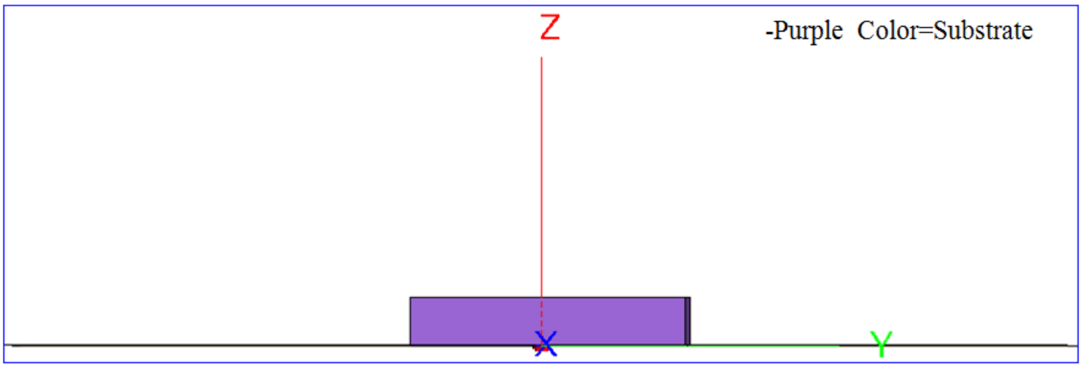

Figure 9. DUT GNSS Patch antenna operating at 1.5925 GHz (Side View)

4.6. Simulated Far Field of DUT GNSS Structure Patch Antenna

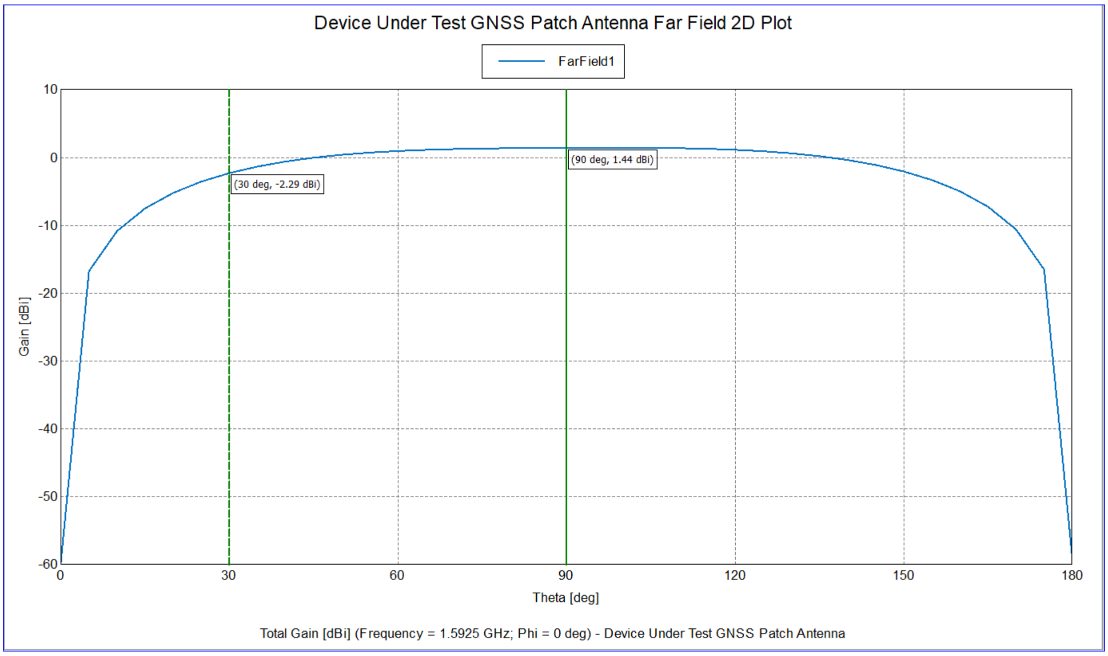

Figure 10. Patch antenna passive gain at 1.5925 GHz

In the 2D model plot from figure 10, we can see about 0.85 dBi passive gain, by taking the difference in gain between 30 and 90 degrees.

Figure 10 simulated the passive gain of the proposed antenna and we selected substrate material to be Ceramic/Porcelain with dielectric constant/relative permittivity=5.5 mm to model, design, and simulate the presented GNSS (GPS/GLONASS) patch antenna.

5. CONCLUSIONS

This paper describes the GPS (L1 1.57542 GHz) frequency) patch antenna performance and compares it to that of GNSS patch antenna with ceramic/porcelain substrate material. These two antennas can be used in modern automotive applications. The models for each antenna were developed and then simulated on FEKO. The performance characteristic, such as passive gain in dBi were found, 3.791 dBi for GPS and 0.85 dBi for GNSS delta between 30 and 90 degrees. The simulated results show an improved passive gain for the antenna. Thus, the proposed GNSS will meet the needs of future automotive applications in robust way. Furthermore, other characteristics such as wide band width and efficiency are examined.

6. FUTURE WORK SUGGESTIONS

In future work this presented antenna can be modified, further studied and simulated in each of the following manners:

- The substrate material type can be changed from ceramic/porcelain to non-ceramic version/variant.

- The proposed antenna performance can be further improved by selecting a thick substrate whose relative permittivity is in the lower/smaller value than the presented dielectric constant of 5.5 mm.

- The mechanical dimensions of each antenna can be altered and simulated enhance antenna major performance parameters, such as Directivity, Impedance, Current and Polarization.

- The verification, validation and testing of the proposed GPS only patch and GNSS patch antenna component can also be conducted at the system vehicle level, where each of the presented antenna can be installed and mounted on an optimal vehicle roof location area prior to the start of the testing and antenna performance parameters experimental measurement can be ascertained.

- The testing, assessment and evaluation of the presented GPS only (L1 1575.42 MHz frequency) and GNSS (GPS/GLONASS) patch antenna can be carried out in anechoic chamber and/or indoor antenna range, in order to measure the basic antenna performance parameters and/or characteristics, such as radiation pattern, radiation efficiency, directivity, impedance, polarization and current draw.

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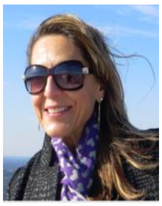

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