Microstrip Patch Antenna for GPS application

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Abstract

A low profile patch antenna for GPS application is here proposed and analyzed. The radiating structure consists on a square patch with 8 slits introduced on each side and on the corners to reduce the overall dimensions. The circular polarization is obtained by quadrature feeding the patch with two pins placed symmetrically on the two main axis. The 90° phase shift is obtained by a 90° microstrip hybrid junction integrated on the back side of the antenna ground plane. The proposed patch antenna is suitable for implementing low cost, high stable and well circular polarized GPS antenna, as demonstrated by numerical simulations and experimental results.

1 - INTRODUCTION

Nowadays patch antennas with high permittivity sintered material substrates are used for GPS automotive application. These very compact antennas are quite expensive and enough prone to circular polarization degradation due to the positioning of the antenna on the car body, as a rule near the scattering edge of the metallic roof. The aim of this paper is to realize a robust circular polarization antenna for GPS application using low-cost microstrip substrates where the low noise amplifier (LNA) may be easily integrated.

Section 2 describes the GPS microstrip patch antenna design and simulation results, while section 3 presents the results of measurements performed on the antenna prototype.

2 - SIMULATED GPS MICROSTRIP PATCH ANTENNA

The first simulation was done considering an 1.6mm thick FR4 substrate (ε_r=4.48, tanδ=1.48E–2, thickness=1.6mm) for patch design. To reduce patch dimension, 8 slits have been introduced (4 on each middle side of the squared patch and 4 on each corner) [1,2].

In order to get circular polarization, a double feed is used (see inputs 1 and 2 in Fig 1) which allows to excite two orthogonal TM01 mode on the square patch by feeding the two inputs 90° out of phase.

Fig. 2 shows the reflection coefficient and the realized gain on port 1 with quadrature feeding, while Fig. 3 depicts the left and right circular polarized far field patterns of the antenna. It is worth noting that an high degree of polarization purity is maintained also for low incidence angles and the sensitivity to nearby scattering structures is highly reduced because the two exciting quadrature TM01 modes are strongly decoupled. All the simulations were done with the patch put at 5 mm distance from the windscreen of the car.

It must be noticed that, to get circular polarization, slits length and width should be identical and symmetric with respect to orthogonal axes; a slight asymmetry can produce strong degradation of the polarization purity because the two principal axes modes can go to resonate on different frequencies.

A 90° hybrid junction on a 0,8 mm thick FR4 substrate was designed to provide 90° out of phase double feeding point as shown in Fig. 4. Port 1 is the antenna input (receiver) and port 2 and 4 are the two quadrature outputs to be connected to the corresponding patch feeding points. To avoid spurious reflections, port 3 is terminated on a matched load (50 Ohm). In Fig. 5 the scattering parameters of the isolated hybrid junction are presented, while in Fig. 6 shows the results of the whole structure (feeding circuit + antenna).

To increase antenna efficiency and gain, a low loss material should be used to fabricate the patch: a new design has been realized employing Taconic TLC-32-0620" substrate (ε_r=3.2, tanδ=0.002, thickness=1.574mm). Using this lower permittivity dielectric the patch dimensions exceed that of the corresponding patch on FR4 substrate, increasing from 36mm to 46mm. To get an effective increase of antenna gain, the ground plane under the patch should increase proportionally with patch dimensions: changing from 60mm to 80mm square ground plane, results in a gain increasing from –0,6 dB to +1dB, due to the lower back radiation.

3 - REALIZED GPS MICROSTRIP PATCH ANTENNA

The first prototype of the antenna was built using a low-cost FR4 dielectric substrate. As expected from the simulations, measurements show that gain is strongly deteriorated by the high FR4 substrate losses (almost 3 dB).

Following simulations results, a second prototype was built on Taconic TLC-32-0620" substrate in order to increase the efficiency. The square patch, of 46 mm side was printed on a 60mm x 60mm circuit board. Hybrid junction feeding circuit was realized on a 80mm x 80mm FR4 substrate (1.6mm thickness) with microstrip technology. Patch board and hybrid circuit board was stuck together with epoxy glue, in such a way a common ground plane separates the two layers. The feeding points of the patch were connected through via holes to the corresponding hybrid circuit outputs.

Measurements were done in anechoic chamber and are presented in Figs. 9 and 10. To get the real gain value, 31 dB must be added to the measure to compensate for anechoic chamber free space attenuation. A 2dB gain has been achieved at 1550 MHz by positioning the antenna 5mm under the windscreen of the vehicle, while the free space maximum gain is 3.8dB at 1570MHz. The center frequency error from the specified operative frequency of 1575.42MHz is due to unpredictable differences from simulations and practical antenna; in both cases to get correct GPS center frequency it is enough to shorten the slits: this tuning operation will not influence circular polarization purity if all slits are adjusted in the same way.

If the antenna works without the windscreen (for example on the car roof) a frequency shift and a gain increase is expected.

It is also interesting to consider gain difference between a commercial high permittivity ceramic patch and the current microstrip patch (ceramic patch operating in free space is centered on 1584MHz and measured was made using a 70x70mm ground plane). From the measures we derived that the microstrip patch maximum gain is 3.8dB at 1570MHz, while ceramic patch maximum gain is 5.2dB at its nominal operating frequency. The difference can be ascribed to the larger extension of the ground plane used to characterize the performances of the commercial patch and to the slightly higher efficiency of the ceramic radiating element.

4 - CONCLUSION

In this paper a microstrip patch GPS antenna thinner and cheaper than the thick ceramic patch antenna usually employed for automotive applications was proposed and analyzed.

This configuration allows to easily integrate a low noise amplifier on the substrate used for the feeding circuitry. Comparing microstrip patch GPS antenna to the thicker high permittivity ceramic patch solution, a gain reduction of about 1.5 dB is observed. The use of the quadrature feeding permits a better purity of the circular polarization and a wider impedance bandwidth allowing to reduce the environment dependence with respect to ceramic antennas. On the other hand ceramic patch is less sensitive to the windscreen closeness because of its high permittivity substrate and consequently its smaller dimensions.

REFERENCE

[1] Kin Lu Wong , Jian-Yi Wu , “Single- feed small circularly polarised square microstrip antenna” , ELECTRONICS LETTERS , Vol 33 n° 22, 23 oct 1997, p1833

[2] Wen-Shyang Chen, Chun-Kun Wu, Kin-Lu Wong, “Novel Compact Circulary polarized Square microstrip Antenna” , IEEE TRANSACTIONS ON ANTENNAS AND PROPAGATION , Vol 49, N° 3, 3 march 2001.

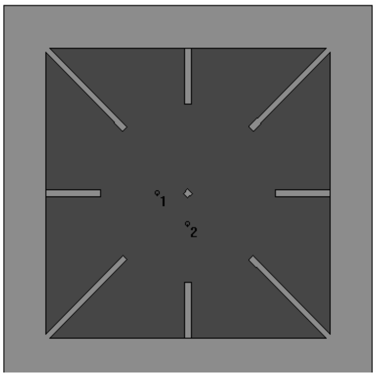

Fig 1- Layout of the proposed patch antenna (first layer).

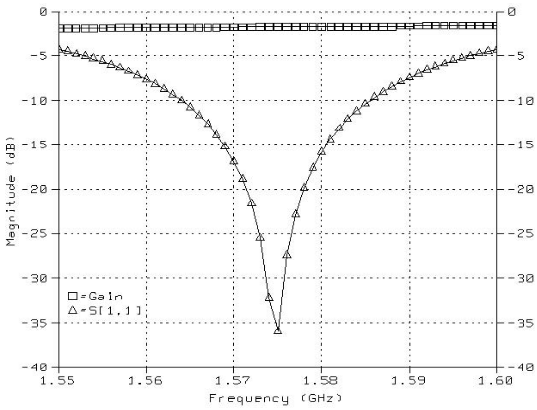

Fig 2 - Reflection and gain (G = -2dB) on port 1of GPS microstrip patch antenna with ideal feeding.

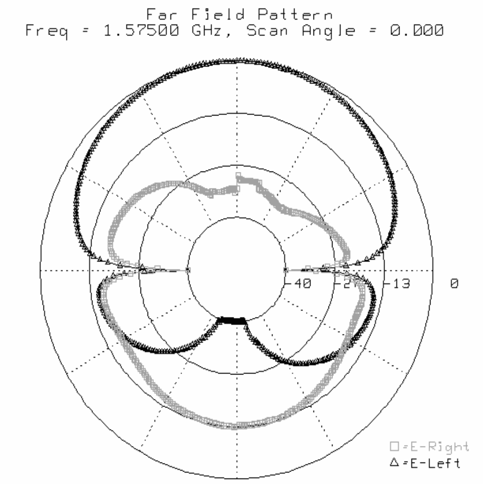

Fig 3 – Left and right polarization far field patterns of the proposed antenna.

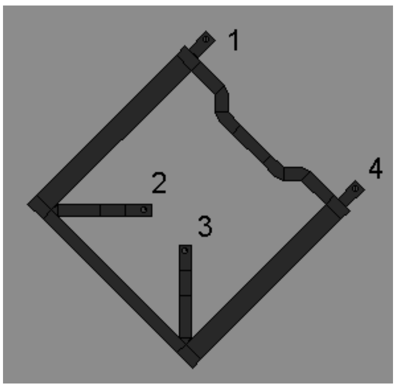

Fig 4 – Layout of the 90° hybrid used as quadrature feeding network (second layer).

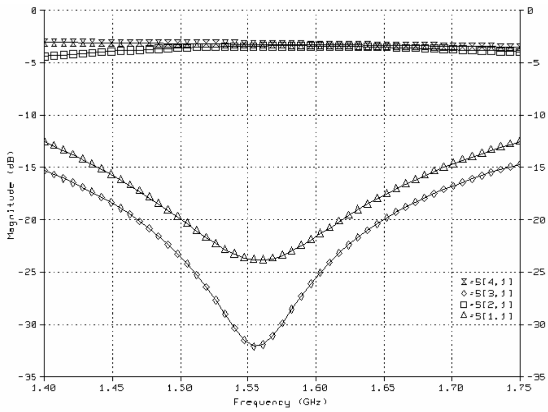

Fig 5 – Scattering parameters of the feeling network.

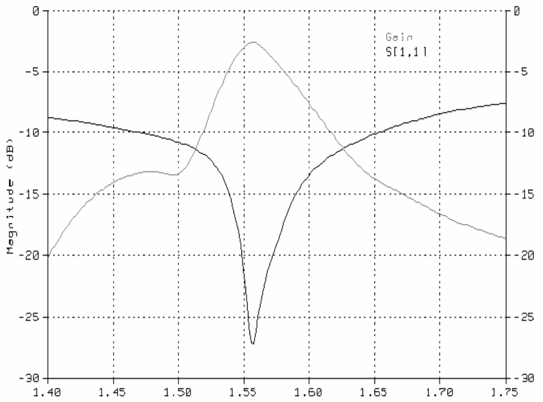

Fig 6 - Reflection and gain (G = -2.5 dB) at the input port of the proposed antenna.

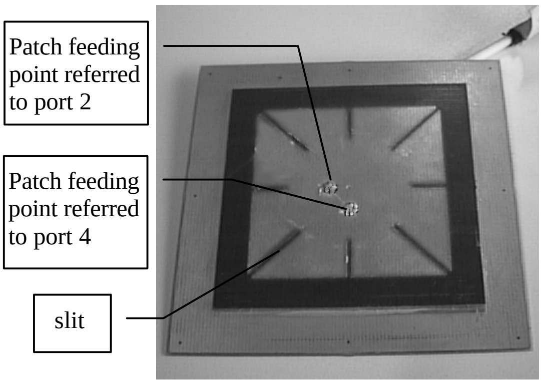

Fig 7 - Realized patch antenna, patch side.

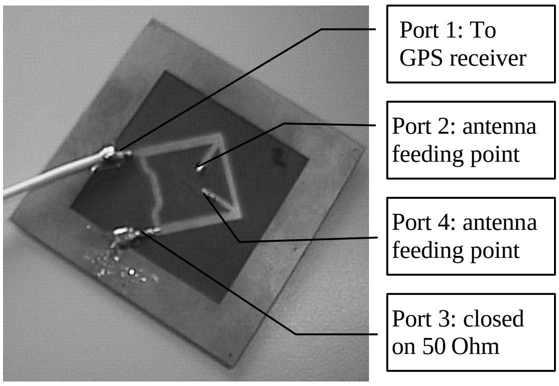

Fig 8 - Realized patch antenna , 90° hybrid side.

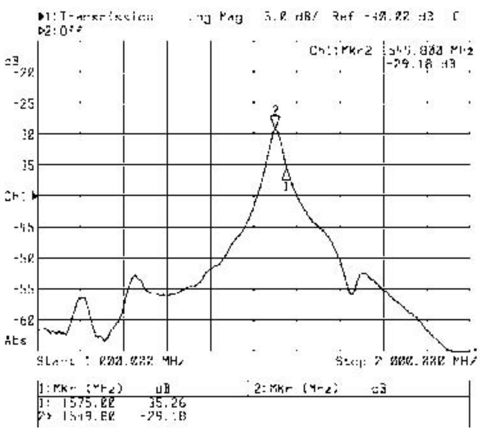

Fig 9 - Gain of the GPS microstrip patch antenna prototype in presence of the windscreen.

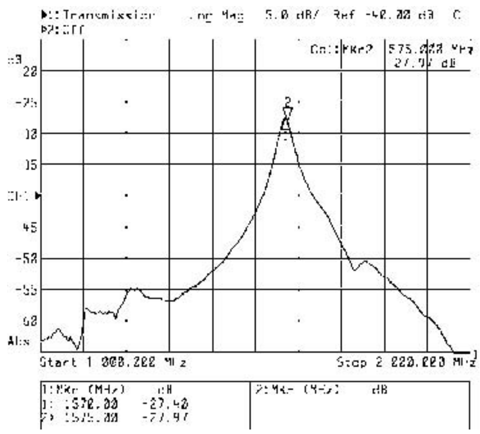

Fig 10 - Gain of the GPS microstrip patch antenna in absence of the windscreen.