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Circularly Polarized Compact GPS and SDARS Integrated Antenna

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Abstract: **-**This paper presents a compact integrated dual service antenna, which is suitable for ultra-wideband communication in automobile applications. The antenna design merges two antennas for Global Positioning System (GPS) and Satellite Digital Audio Radio Service (SDARS) into a single integrated antenna structure. The GPS antenna is a classic small commercial ceramic patch, and the SDARS antenna is designed in order to fit in the reduced space without affecting radiation and band performance of the GPS antenna. The proposed design has a square ring micro strip antenna for SDARS service operating in the frequency range 2.320-2.345 GHz with left hand circular polarization (LHCP), and it is wrapped around the GPS patch, which receives the right hand circular polarization (RHCP) at 1.575 GHz. The entire compact solution resides in the total volume of 30x30x7.6 mm^3 making it space saving-efficient and attractive to automobile industry.

Keywords: Patch Antenna, Integrated Antenna, SDARS, GPS Service.

I. Introduction

In the past few years the demand for integrated services within the cars requires light weight compact automotive antennas in the customer's desired mounting position, which has brought a challenge for the automotive antenna developers. Due to the high demands for the accuracy and compactness it became very difficult to develop antenna elements which fulfil all the strict requirements. Integrated SDARS (Satellite Digital Audio Radio Service) and GPS antenna element is one of such tasks which require strong gain requirements at particular elevation angles for the best reception of the satellite signals along with the car manufacturer's desired mounting positions.

SDARS employs a dual-transmission broadcast format, in which signals are provided both by satellite and terrestrial transmitters in the 2.320–2.345 GHz band. The satellite signal reaches the users in the open areas, whereas the terrestrial transmitters provide the necessary coverage in the urban environment where the satellite service is obstructed.

Antennas for SDARS application must be able to handle both types of transmission; namely, left-hand circular polarization (LHCP) signals coming from the satellites and linear polarization (LP) signals radiated by terrestrial stations.
Currently, the majority of SDARS antennas realize a dual-polarized system consisting of two separate antennas, one optimized for the LP terrestrial reception and the other for the LHCP satellite one (switches are used to select the polarization of operation).

The basic antenna pattern for the satellite reception must provide a LHCP, zenith-pointed, wide beam with a constant gain for elevation angles greater than 20 and circular symmetry with respect to the azimuth. The typical LP pattern for terrestrial signal is a monopole-like pattern with Omni directionality in the azimuth.

In this letter, we present an integrated antenna solution for GPS and SDARS services whose design was constrained within a volume of 30x30x7.6 mm^3, in compliance with the space limitation requirements of the automotivemarket. Regarding the GPS, we are interested in the RHCP signal at 1.575 GHz (L1 Band).

Placing two antennas in an extremely reduced space, working with either LHCP or RHCP at SDARS or GPS frequency bandwidth, renders the design superconstrained. In particular, the axial ratio (AR) bandwidth of SDARS is extremely hard to achieve. Different types of antenna elements such as micro strip patch, probe feed patch and ceramic patch antennas are in the market for automotive applications. . For the time being there are strong recommendations for a top roof mounting location of a SDARS and GPS-antenna in order to meet the required radiation pattern on a vehicle.

The constraints of the design considerations of the compact integrated module demands the reception of the terrestrial LP signal at low-elevation aspects from the same LHCP antenna for satellite reception without using an additional specific LP antenna. This seems to be reasonable because the degradation of the CP pattern at grazing aspects results in an almost vertical LP there.

II. Antenna Design

The proposed design consists of the two integrated antennas depicted in Fig. 1. The GPS antenna is constituted by a commercial square patch with truncated corners printed on a circularly shaped high-dielectric-constant ceramic material operating in RHCP polarization at 1.575 GHz. The SDARS antenna is realized by a probe-feed square-ring micro strip antenna printed on low-cost substrate (FR4) operating at 2.330 GHz with 25 MHz bandwidth.For the GPS antenna, we selected a commercial standard patch antenna printed on a ceramic substrate with high dielectric constant ($\varepsilon_r = 45$) that leads to an overall volume of $3.14x10.16^2x3.6$ mm^3. The probe-feed square-ring micro strip SDARS antenna is etched on an FR4 substrate (thickness 1.6 mm and permittivity 4.4) suspended at 5 mm from the ground plane. To achieve circular polarization, the square-ring antenna has truncated corners of equal side length ΔL.In order to avoid

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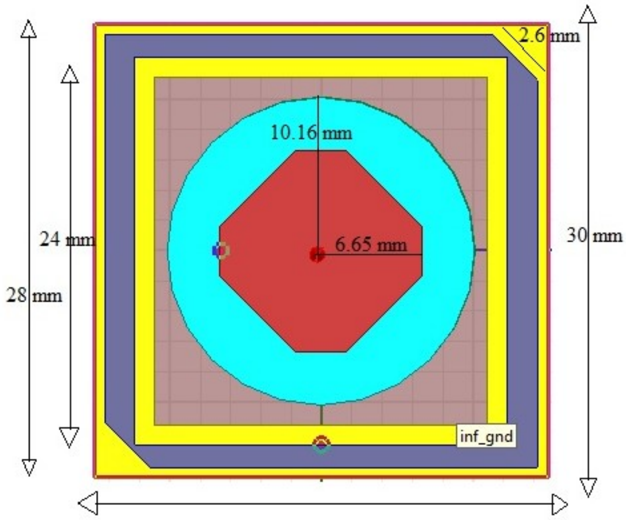

Fig. 1

The SDARS antenna affecting the operation of the GPS antenna, the latter is located on a top of metallic raised base to keep the GPS patch at a higher level with respect to the SDARS antenna, thus preserving its radiation and bandwidth properties. This metallic base with height 4 mm is soldered to the ground plane and hosts a coaxial via a circular hole to excite the GPS patch antenna.

STEPWISE ANALYSIS USING TRANSMISSION LINE MODEL FOR THE GPS RECTANGULAR PATCH

1. For an efficient radiator, the practical width that leads to good radiation efficiencies is–

$$W = \frac{1}{2fr\sqrt{\mu o \varepsilon}}\sqrt{\frac{2}{\varepsilon + 1}} = \frac{vo}{2fr}\sqrt{\frac{2}{\varepsilon + 1}}$$

So, the width of GPS patch W is equal to 13.3 mm for εr = 45 and at the centre frequency f_r = 2.33 GHz.

2. Determination of the effective dielectric constant of the micro-strip antenna from the basic concept of fringing effect.

Formula of Effective Dielectric Constant of Antenna is –

$$\varepsilon ff = \frac{(\varepsilon + 1)}{2} + \frac{(\varepsilon - 1)}{2}\frac{1}{\sqrt{\left(1 + \frac{12W}{H}\right)}}$$

Here, W=13.3 mm, H= 3.6 mm, εr = 45 therefore W/H = 3.69

Hence, effective dielectric constant

εeff = 33.7

3. Determination of extended incremental length of GPS patch (ΔL).

Formula for the normalised Extension of length of Antenna is –

$$\Delta L = 0.412H\left(\frac{\varepsilon ff + 0.3}{\varepsilon ff - 0.258}\right)\left(\frac{(W/H) + 0.264}{(W/H) + 0.8}\right)$$

Here, h = 3.6 mm, εeff = 33.7, W = 13.3mm therefore –

Extended incremental length ΔL is equal to 1.3 mm.

4. The actual length formula of the patch is-

$$L = \left(\frac{c}{2fr\sqrt{\varepsilon ff}}\right) - 2\Delta L$$

From here, actual length of the patch is equal to 8.44 mm.

But for this compact integrated GPS – SDARS Antenna a 'square GPS patch' is used, hence here we are taking equal length and width of the patch equals to *13.3 mm.*

Resultant Dimensions of Patch
Width = Length = 13.3 mm.

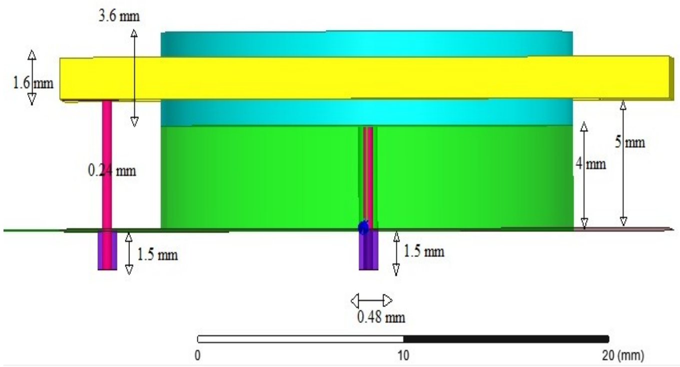

Fig.2

ANTENNA DESIGN PROCEDURE

Using the above equations and geometrical parameters dimensions of antenna is calculated. In the design of antenna first the dimensions of patch are calculated and then antenna is designed by using the calculated dimensions after that slots cut into the micro strip patch.

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Name of the structure parts	**Length(L) in mm**	**Breadth(B) in mm**	**Height(H) in mm**	**Radius(R) in mm**
Ceramic substrate	**-**	**-**	**3.6**	**10.16**
Metal	**-**	**-**	**4**	**10.16**
SDARS substrate outer ring	**30**	**30**	**1.6**	**-**
SDARS substrate inner ring	**23**	**22**	**1.6**	**-**
SDAR patch outer ring	**28.6**	**28.6**	**-**	**-**
SDAR patch inner ring	**25.6**	**24.6**	**-**	**-**
GPS square patch	**13.3**	**13.3**	**-**	**-**
Ground	**30**	**30**	**-**	**-**

Table.1

III. Simulated and Measured Results

All simulations were performed with the help of High-Frequency Structure Simulator (HFSS), the Ansoft full-wave solver based on the Finite Element Method (FEM). All the simulated results are performed using an infinite ground plane. The SDARS antenna performances, being at higher frequency, are much more critical with respect to those of the GPS antenna; we will focus therefore on SDARS antenna. The SDARS antenna measurements discussed below were carried out with a GPS port that was 50 Ώ terminated.

1. The reflection coefficient versus frequency graph (Fig. 3) depicts the simulated and measured return loss of the SDARS integrated with GPS. The graph plot of return loss Vs frequency is taken at the maximum frequency of 2.345 GHz. The impedance bandwidth 25MHz of design antenna is obtained at calculated resonant frequency of 2.567GHz.

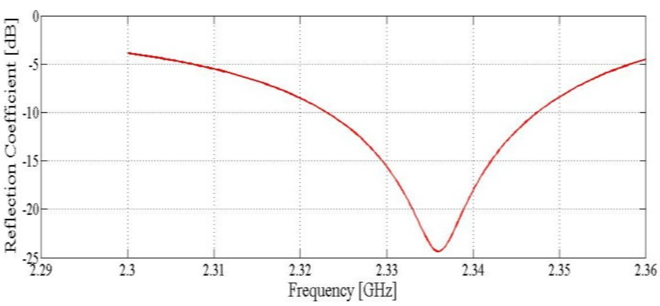

Fig. 3 Reflection Coefficient v/s frequency

2. The Axial Ratio versus Frequency graph shown in Fig 4.shows the measured and simulated AR for the square-ring antenna. The measured AR has the same behavior as the simulated one with 0.21 %shift that could mainly be attributed to the tolerance in the dimensions of fabrication

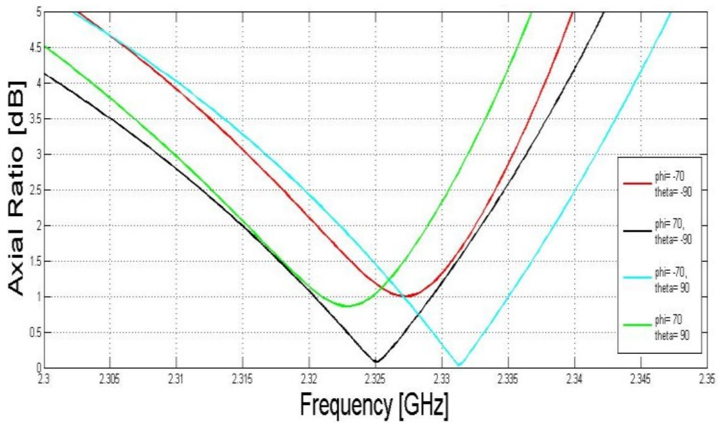

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Fig. 4 Axial Ratio v/s Frequency

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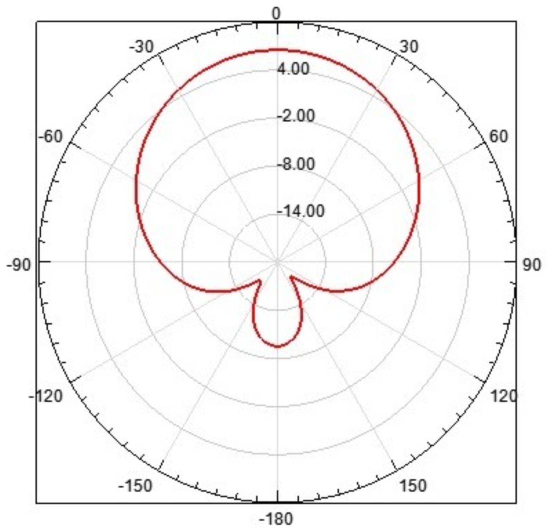

Fig. 5 Radiation Pattern X-Z Plane

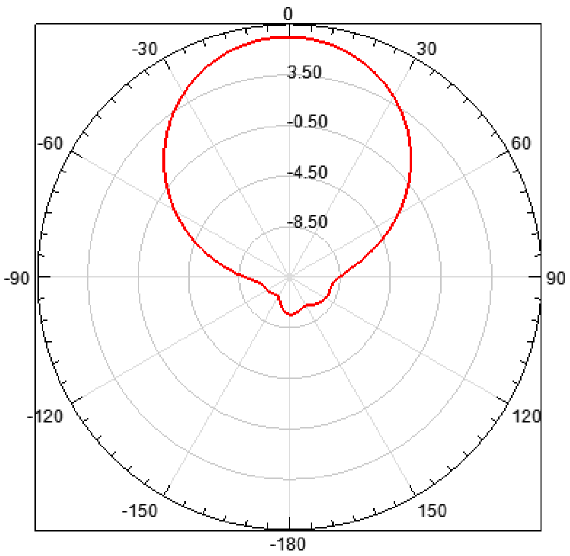

Fig. 6 Radiation Pattern Y-Z Plane

IV. Conclusion

This paper presents the research and development of the antenna element for the GPS and SDARS applications. The proposed design is a good solution for both the applications on a big ground plane such as top roof position whereas for the use on a non-smooth ground planes and the antenna elements should be optimized further.

The performance parameters such as high gain of more than 6.5 dBi with an Axial Ratio of less than 3dB at the peak gain position, Return loss equal to -43 dB are in good compliant with the market requirement. The parasitic element helps to tune the resonating frequency of the antenna without changing the dimensions of the antenna.

V. References

[1] C. D. McCarrick, "A combination monopole/quadrifilar helix antenna for S-band terrestrial/satellite application," IEEE Trans. Antennas Propag., vol. 44, no. 5, pp. 330–334, May 2001.

[2] Y.-P. Hong, J.-M. Kim, S.-C. Jeong, D.-H. Kim, and J.-G. Yook, "Low profile S-band dual polarized antenna for SDARS application," in Proc. Eur. Microw. Conf., Oct. 2005, pp. 1851–1854.

[3] Y.-P. Hong, J.-M. Kim, S.-C. Jeong, D.-H. Kim, and J.-G. Yook, "Low profile S-band dual polarized antenna for SDARS application," IEEE Antenna Wireless Propag. Lett., vol. 4, pp. 475–477, 2005.

[4] H. Lindenmeier, J. Hopf, and L. Reiter, "Low profile SDARS-antenna with diversity functionality," in Proc. IEEE Antennas Propag. Symp., 2002, vol. 4, pp. 744–747.

[5] D.-C. Chang and J.-H. Cheng, "2.3 GHz antenna with both LHCP and LP for SDARS," in Proc. IEEE Antennas Propag. Symp., Jun. 2003, vol. 3, pp. 874–877.

[6] Ram Singh Kushwaha, D.K. Srivastava, J.P. Saini," A Design of H-shape Slot loadedWideband Micro-strip Patch Antenna".

[7] Kawai Qian and Xiaohong Tang, " compact LTCC dual-band circularly polarized perturbed hexagonal micro -strip antenna" *IEEE Antennas and Wireless Propogation Letters, Vol. 10, pp. 1212-2011.*

[8] V. Rabinovich, L-band active receiving antenna for automotive applications,Microwave Opt Technol Lett 39 (2003), 319–323.

[9] M. Daginnus, R. Kronberger, A. Stephan, J. Hopf, and H. Lindenmeier,SDARS antennas: Environmental influences, measurement, vehicleapplication investigations and field experiences, SAE 2002World Congress, Society of Automotive Engineers, Detroit, MI, 2002,2002-01-0120.

[10] K. Allsebrook and J.D. Parson, Mobile radiopropagation in Britishcities at frequencies in the VHF and UHF bands, IEEE Trans VehicTechnol VT-27 (1978), 313–322.

Books-

[1] Antenna theory analysis and design, 3rd edition, Constantine A. BALANIS, WILEY PUBLICATIONS.

[2] Antenna and wave propagation, A.K GAUTAM, KATSON PUBLICATION.

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