Low Profile Dual-Polarized Antenna for SDARS Application

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Abstract

This paper presents low form factor dual polarized antenna incorporating low profile annular ring patch antenna having 90° phase delay element for circular polarization(CP) and a reactive-loaded monopole linear polarized(LP) antenna. Both types of receiving antennas operate in the same frequency region from 2.320 GHz to 2.345 GHz, while different polarizations are used to take advantage of polarization diversity. The proposed CP antenna has good broadside radiation patterns, while the LP antenna reveals monopole-like radiation patterns. The gains of the antennas are measured to be 1.93 dBi and 2.24 dBi for CP and LP, respectively.

Key words : SDARS Antenna, Roof Antenna, Circular Polarization, Linear Polarized Antenna, Reactive Loaded Monopole.

Ⅰ. Introduction

Due to the increasing need of antenna for use in mobile satellite as well as terrestrial digital multimedia broadcasting applications at 2.3 GHz, the various kinds of vehicular antennas have been developed recently. Automotive radios, especially the SDARS(Satellite Digital Audio Radio System) provides compact disk quality audio service to users[1]. SDARS service utilizes a dual transmission broadcasting format in which signals are provided in either through direct satellite channel or via terrestrial-based transmitters so called gap filler to accommodate dynamic RF mobile environment. The satellite transmission covers most open areas, however, terrestrial transmitters are used when satellite is positioned at out of line-of-sight(LOS) position. Among the many design parameters the minimization of the radiation interference between two different antennas, easy and low cost fabrication, and compact volume would be some of the key issues in successful deployment of the system.

Many kinds of satellite and terrestrial antenna combination have been proposed in the literature[2]~[4]. The main drawback of these antennas[2] lies within the complex feed matching network design and degradation of the radiation pattern with improper placement of the monopole within the quadrifilar helix. Also, the combination of crossed dipoles and monopole array antennas requires complex three dimensional topology and large overall volume[3]. Wu presented dual-band microstrip patch antenna which meets the requirements of DCS(digital communication system) and GPS(global positioning system). However, the proposed configuration, with a monopole is integrated in the free space and foam substrate, is difficult to achieve easy fabrication and mass production[4]. Also, relative larger size makes it less attractive for mounting on a vehicle. In this paper, the dual-polarized antenna has many advantages for automotive multi-media applications, such as low cost, simple structure, compact size, wide bandwidth, and acceptable radiation efficiency.

Ⅱ. Antenna Design

A simulation is performed which is a full wave analysis software based on the Finite Element Method (FEM). In the design process, both of the annular ring patch for CP operation and the monopole antenna loaded with a shorted circular patch for LP operation have been first designed independently and integrated together later. For compact volume CP antenna, annular ring microstrip patch antenna is used[5]. As illustrated in Fig. 1, the annular ring antenna is combined with monopole antenna. Both antenna elements share common ground plane as well as substrate, while the feeding ports are placed at different positions. It is desirable that the radiation patterns of two antennas cause minimum interference each other. The method of incorporating two feed points exciting a pair of orthogonal linear polarizations in a microstrip patch based on 90° phase shift is a well known technique[6]. With two feeding network for two different polarizations, the entire volume of the antenna is miniaturized compared to conventional antennas for low cost fabrication.

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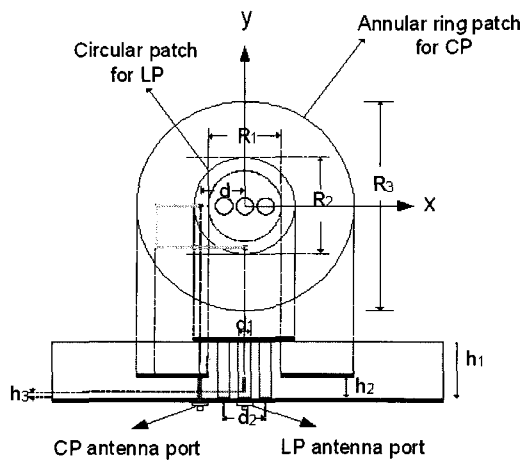


Fig. 1. Structure of studied antenna.

The circular polarized antenna, operating at 2.32 GHz, is composed of an annular ring placed in a FR4 substrate(dielectric constant = 4.4, tangent loss = 0.01) of 3 mm thick(h_2). The inner and outer diameter of the annular ring is 8 mm(R_1) and 30.6 mm(R_3), respectively. The feed positions of the annular ring antenna are situated on the x- and y-axis realizing 90° phase difference. The cylindrical monopole has a diameter of 1 mm(d_1) and has been loaded with a shorted circular patch on top. The circular patch has a diameter of 13.4 mm(R_2), and it is short-circuited to the antenna ground by using two identical conducting cylinders of diameter 1 mm and length 6 mm(h_1). For good matching performance the spacing between two shorting pins is chosen as 4.9 mm(d_2), while the height of the orthogonal feeder is 0.5 mm(h_3). The proposed antenna is composed of three layers of same substrate. The ground plane has a dimension of 100 mm × 100 mm, which is considered to be the much smaller size than practical test environment(1 meter diameter ground plane).

III. Numerical Results

The resonant properties of the antenna have been simulated and measured. Fig. 2 depicts the simulated return losses of the proposed antennas revealing much larger bandwidth than the required bandwidth specification of SDARS receiving antenna(25 MHz). From Fig. 3, phase difference of a quarter-wavelength section of transmission line is tested to create the 90° phase difference required for circularly polarization at resonant frequency. The simulated axial ratio is well below 3 dB as plotted in Fig. 4. Fig. 5 shows the simulated radiation patterns at the resonant frequency. The proposed CP antenna has good broadside radiation patterns, while the LP antenna reveals monopole-like radiation patterns.

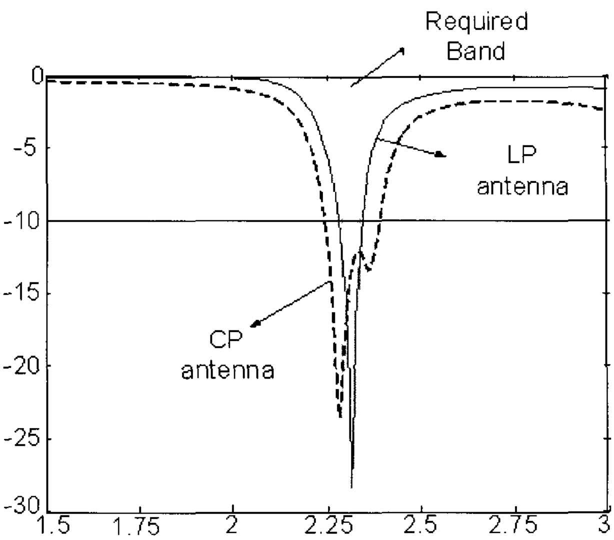


Fig. 2. Simulated return loss of SDARS antenna.

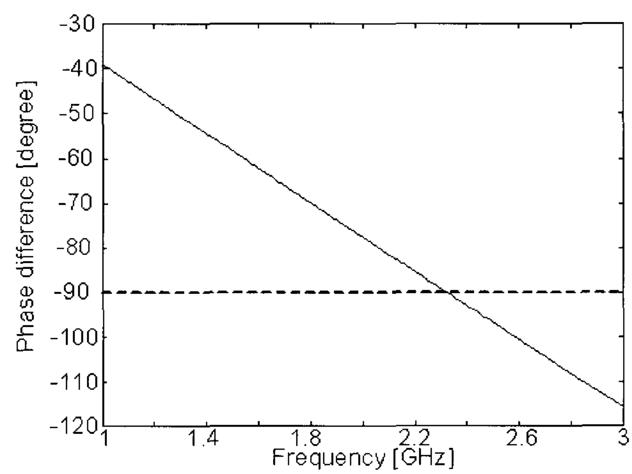


Fig. 3. Phase difference between two ports for CP antenna.

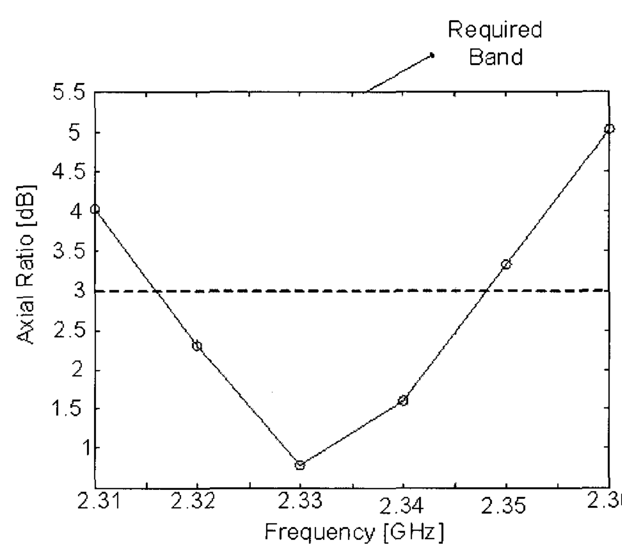
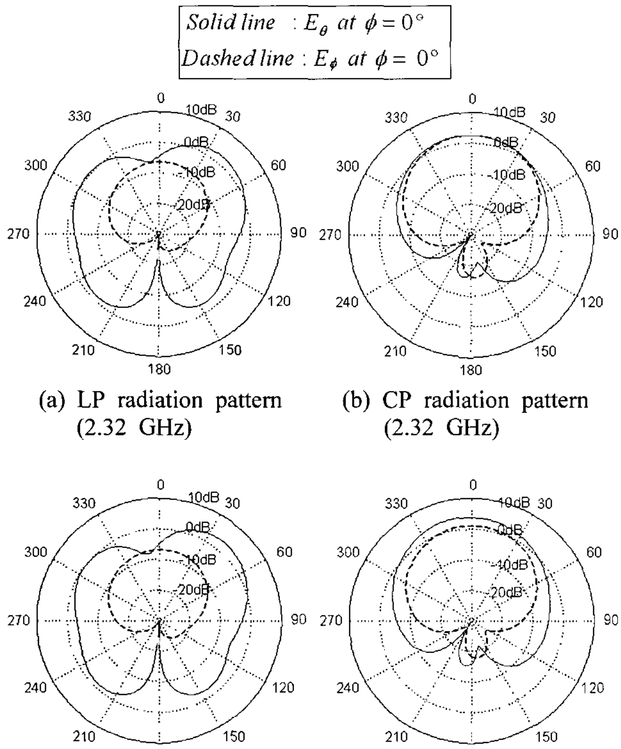


Fig. 4. Simulated axial ratio of CP antenna.



(a) LP radiation pattern (2.32 GHz)
(b) CP radiation pattern (2.32 GHz)
(c) LP radiation pattern (2.345 GHz)
(d) CP radiation pattern (2.345 GHz)

Fig. 5. Simulated radiation pattern of SDARS antenna.

The simulated gain of the CP and LP antennas are measured to be 1.86 dBi and 3.74 dBi, respectively. The radiation pattern at 2.345 is very similar with resonant frequency(2.32 GHz).

Ⅳ. Experimental Results

The resonant properties of the antenna have been simulated and measured. Fig. 6 describes the measured return losses which satisfies the required bandwidth. The measured axial ratio is well below 3.5 dB as plotted in Fig. 7 and it is clear that the CP antenna is successfully implemented. It is found also that the axial ratio is varying significantly with as a function of the diameter of the short-circuit via holes for exciting annular ring. As a result, the axial ratio bandwidth is shifted due to the difference in diameter between the simulated and actually fabricated one. The specific values of resonant

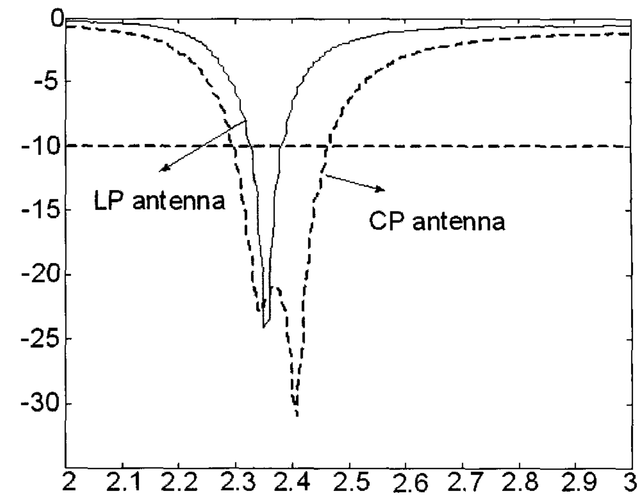


Fig. 6. Measured return loss of SDARS antenna.

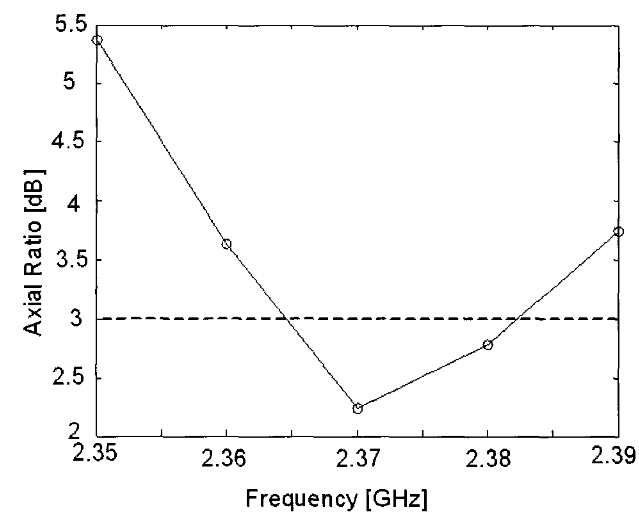
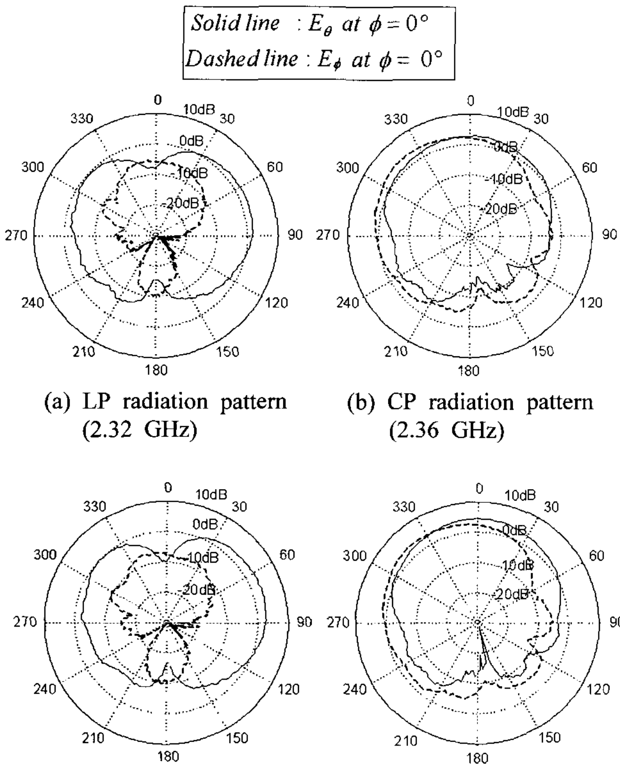


Fig. 7. Measured axial ratio of CP antenna.

frequencies, bandwidths, and gains are summarized in Table 1. Fig. 8 depicts the measured radiation patterns at the resonant frequencies. The ripples in the measured radiation pattern are due to the effect of the feeding cable. It is seen that the radiation pattern both at 2.32 and 2.345 GHz are approximately omnidirectional and similar to those of electric monopole placed on a finite ground plane. The proposed CP antenna has good broadside radiation patterns, while the LP antenna reveals monopole-like radiation patterns. The gain of the

Table 1. Simulated and measured results of the proposed antenna.

	LP antenna		CP antenna	
	Simulation	Measurement	Simulation	Measurement
BW(GHz)	2.32~2.38 [2.5 %]	2.32~2.38 [2.5 %]	2.24~2.37 [5.6 %]	2.29~2.47 [7.5 %]
Gain(dBi)	1.86	2.24	3.74	1.93



(a) LP radiation pattern (2.32 GHz)
(b) CP radiation pattern (2.36 GHz)
(c) LP radiation pattern (2.345 GHz)
(d) CP radiation pattern (2.385 GHz)

Fig. 8. Simulated radiation pattern of SDARS antenna.

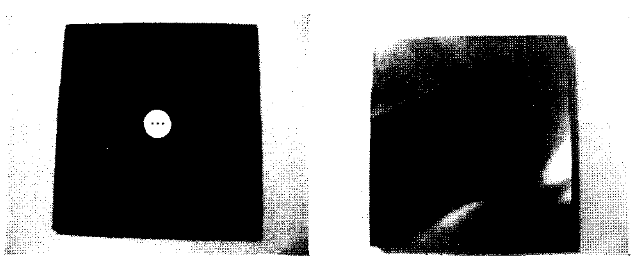


Fig. 9. Fabricated antennas for SDARS system.

CP and LP antennas are measured to be 1.93 dBi and 2.24 dBi, respectively. Fig. 9 shows the fabricated antenna for SDARS system. Isolation between the CP and LP antennas is not concerned due to the fact that the SDARS utilizes switching element for best reception performance.

V. Conclusion

In this work, combination of an annular ring and monopole antennas for S band operation has been successfully implemented. The dual-polarized antenna proposed herein is important for at least two reasons. First, the annular ring patch antenna incorporating 90 degree phasing element is embedded in the relatively high permittivity substrate to realize circular polarization, thus with two orthogonal feed connections more than 50 % volume reduction could be possible compared to conventional antennas. Second, mass production can be obtained with easy and low cost PCB(Printed Circuit Board) manufacturing process, because a low profile reactive loaded monopole antenna is integrated on the same substrate. Also, the length of the monopole antenna is only 0.0464 free-space wavelengths at 2.32 GHz. Therefore, a low profile configuration for two patch antennas integrated on the same microwave substrate is implemented and a prototype for SDARS operation has also been successfully fabricated and tested. The proposed CP antenna has good broadside radiation patterns, while the LP antenna reveals desirable monopole-like radiation patterns. The gain of the CP and LP antennas are measured to be 1.93 dBi and 2.24 dBi, respectively. The results show good performances of the proposed antenna operating in the S band. This proposed combined antenna topology is suitable for SDARS(Satellite Digital Audio Radio System).

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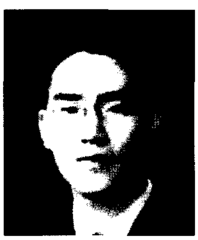

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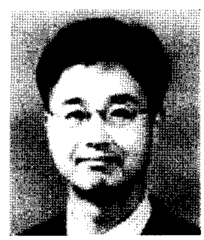

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