Design of GPS Antenna using Dielectric Resonator

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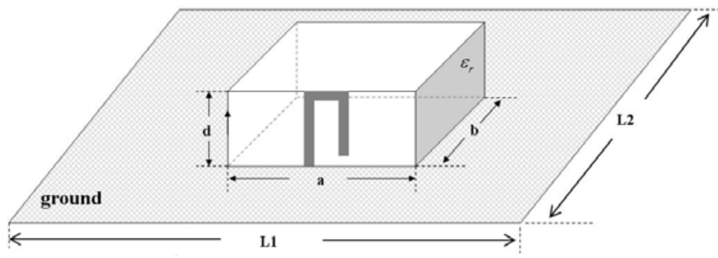
Abstract : In this paper, the design of the RHCP (right hand circular polarization) dielectric resonator antenna for GPS (Global Positioning Systems) is proposed. For the miniaturization size of antenna, high-permittivity dielectric (ε_r =30) is used. Also in order to obtain circular polarization of low-profile rectangular dielectric resonator antenna, the proposed antenna is simply excited by single strip line. The proposed single feeding method consisting of a loop shape can easily excite two orthogonal modes ($TE^x_{\delta 11}$, $TE^y_{\delta 11}$) within the single resonator and easily achieve circular polarization. Using EM simulation, antenna characteristic parameters are found. Based on these results, antenna is manufactured. The simulated and measured results of proposed design are presented.

1. Introduction

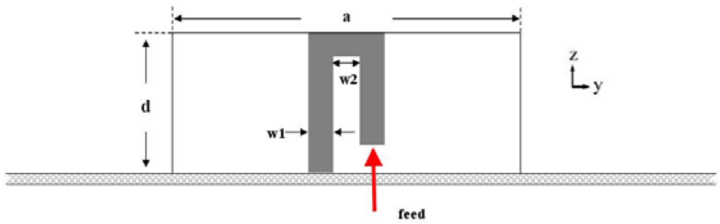
The satellite-based GPS initiated thirty years ago for military missions. It has twenty-four satellites circling the Earth every twelve hours at an altitude of 20,200 km. At any time, four of these satellites can together help a user on the ground to determine his precise position with an accuracy of 15m and the time to an accuracy of 100nsec [1]. The GPS demand in navigation system, LBS (Location Based Service) and personal mobile devices may increase rapidly and at future, more so. In this paper, a dielectric resonator antenna is used for the GPS. The best advantage of dielectric resonator antenna (DRA) is the high radiation efficiency due to no conductor loss. And a DRA has other attractions including its small size, lightweight, low cost, and easy excitation [2, 3]. By these reasons, recently, DRAs for a number of applications at communication system are investigated [4, 5]. Former studies of DRA concentrated on linear polarization (LP). However, the interest of circular polarized DRA has increased recently. To achieve circular polarization of DRA, various methods of exciting a DRA were used, such as using quadrature feeds, dual conformal strip feed methods, and using parasitic patches [6]-[8]. Good circular polarization is obtained when two orthogonal modes of equal amplitude are excited with a 90 degree phase difference between two modes. This paper introduces new single feed method consisting of loop shape for achieving circular polarization radiation. The simple strip line shorted with ground plane can excite two orthogonal modes. The $TE^x_{\delta 11}$ mode is excited by the strip loop which generates a magnetic current source (M_x), and the other is $TE^y_{\delta 11}$ which is excited by electric current (J_z) on the surface of the strip line. To find the effects of antenna parameters at the proposed DRA, HFSS, commercial 3D EM simulator, is used in this paper. Also the far-field radiation pattern of the proposed antenna is measured at anechoic chamber. From those data, one can see that the measured data is in agreement with simulation data.

2. Antenna Structure

The proposed design has been applied to a rectangular DRA with a high-permittivity ε_r=30. Figure 1(a) shows the geometry of the proposed circular polarization DRA.



(a)



(b)

Figure 1. Structure of the proposed antenna. (a) entire structure (b) front of antenna

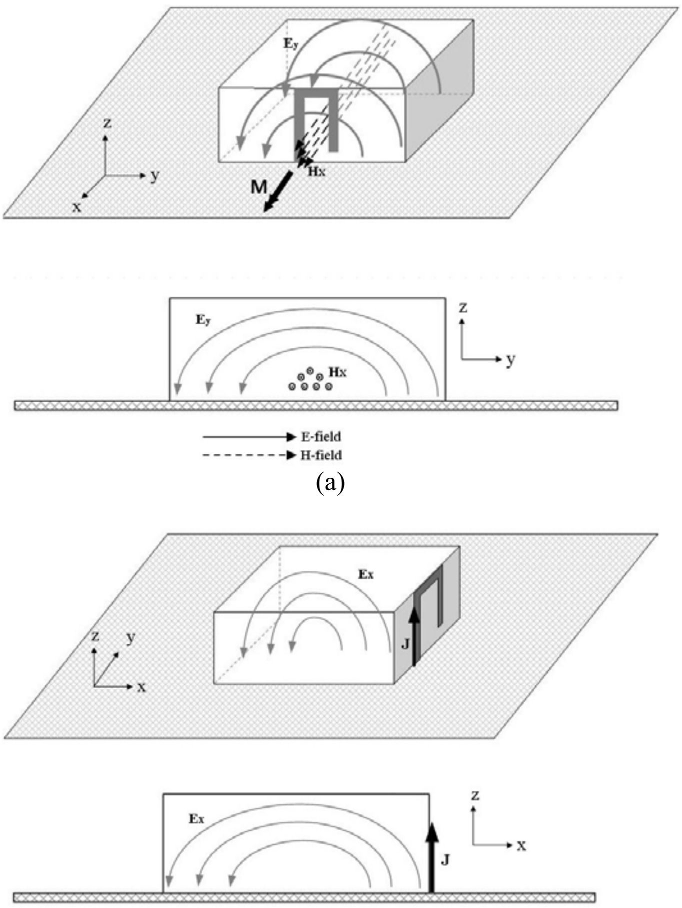
The dimensions of proposed rectangular DRA are a=34 mm, b=34 mm and d=12 mm which is placed in center of ground plane. The volume of ground plane is 68 × 68 × 1.6 mm^3. The feeding strip consisting of line width w1 and distance w2 between strips is placed in the middle of the front wall. The proposed DRA is fed by a strip line with a 50Ω coaxial cable. To show the detailed structure of the antenna, a entire structure and front of antenna is depicted in Figure 1 (a) and (b).

3. Design of Antenna

As above mentioned, in order to get circular polarization, E_x and E_y which are orthogonal each other in the far field should have the same amplitude but 90 degree phase difference. Classifications of wave polarization are listed in Table 1 [2]. The proposed antenna generates the orthogonal two E-fields ($TE^x_{\delta 11}$, $TE^y_{\delta 11}$). The $TE^x_{\delta 11}$ mode is excited by the strip loop which generates a magnetic current source (M_x), and the other is $TE^{y}_{\delta 11}$ which is excited by electric current (J_z) on the surface of the strip line. The distributions of the electric and magnetic fields of proposed antenna are shown in Figure 2. As shown in Figure 2(a), the dominant magnetic fields to the x-direction are produced along the center of the DRA, while the electric fields circulate around these fields. These fields are similar to those produced by a short magnetic dipole. And the shorted point of strip line exited by probe can be considered as a vertical electric dipole, as shown in Figure 2(b).

Table 1. Classifications of wave polarization

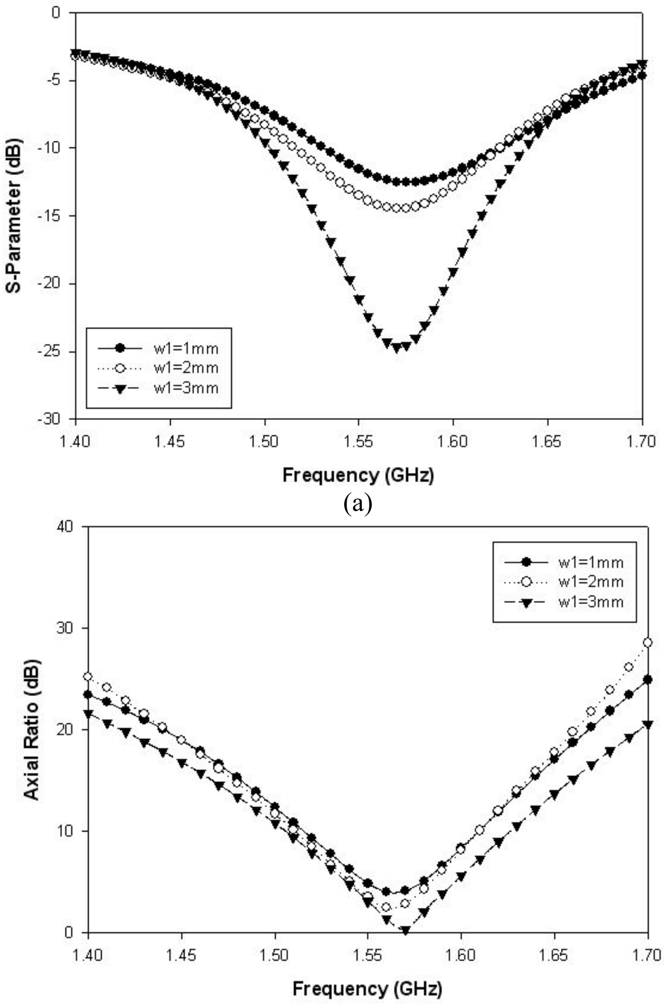
E_X / E_Y	δ (degree)	Polarization	Rotation
0,∞	n.a.	Linear	n.a.
Any	0,180	Linear	n.a.
1	90	Circular	RHCP
1	-90	Circular	LHCP
1	0< δ<180, ≠90	Ellipse	RHCP
1	0< δ<180, ≠90	Ellipse	LHCP
≠0,1, ∞	0< δ<180, ≠90	Ellipse	RHCP
≠0,1, ∞	0< δ<180, ≠90	Ellipse	LHCP



(a)

(b)

Figure 2. Electric and Magnetic fields distribution of DRA .

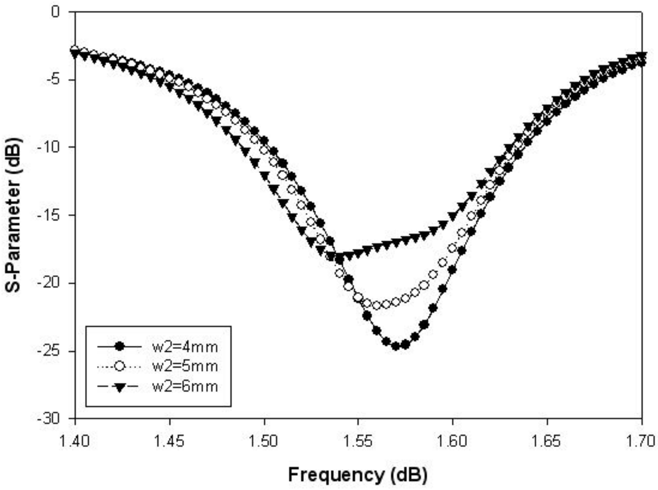


(a)

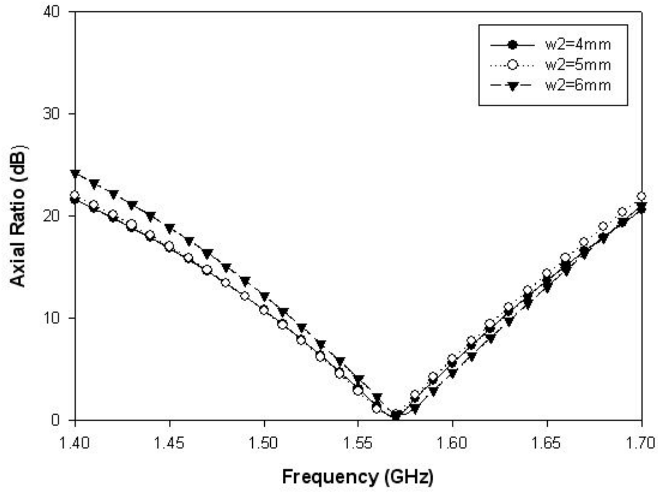
(b)

Figure 3. Simulated return loss of the DRA for different strip width w1:a=34 mm, b=34 mm, d=12 mm, w2=4 mm, ε_r=30. (a) return loss. (b) axial ratio.

Figure 3 shows the variation of the simulated return loss and simulated axial ratio versus frequency for w1=1, 2 and 3 mm. The strip width w1 is important design parameter to adjust return loss of the DRA. As shown in the Figure 3, strip line width w1 influences both the return loss and axial ratio. It is found that when the proposed antenna has the optimization of return loss, axial ratio characteristic of it also is optimized. The effect of return loss for different distance w2 between strips was also studied. The simulated return loss and simulated axial ratio versus frequency for w2=4, 5 and 6 mm are shown in Figure 4. The return loss is changed with distance between strips width w2 whereas the axial ratio does be not changed hardly at resonant frequency (GPS band). Consequently, it can be used to only impedance matching parameter because the axial ratio is nearly fixed. We can observe that optimizations of return loss and axial ratio are achieved near the w1=3 mm and w2=4 mm. Figure 5 shows the simulation result of phase both E_x and E_y in the far-field as a function of the frequency. It is found that phase difference is about 88 degree.



(a)



(b)

Figure 4. Simulated return loss of the DRA for different distance between strips w2 : a=34 mm , b=34 mm , d=12 mm , w1=3 mm , ε_r =30. (a) return loss. (b) axial ratio.

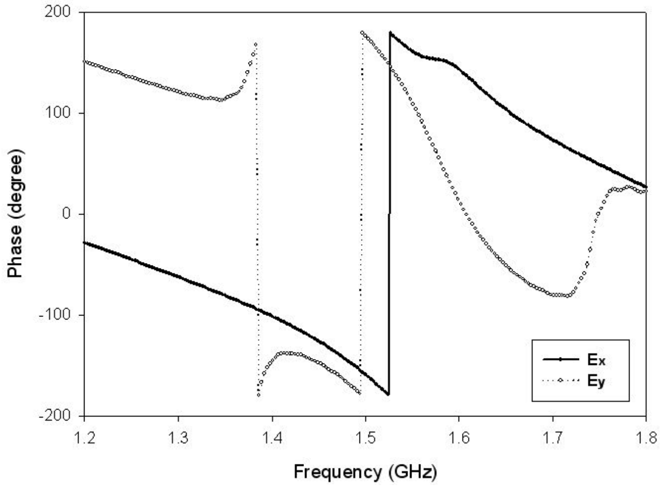
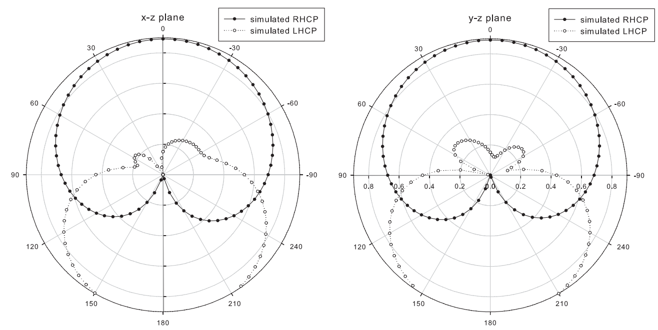


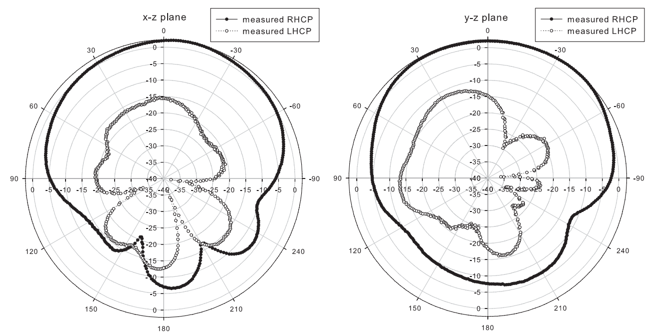
Figure 5. Result of simulated phase both E_x and E_y in the far-field as a function of the frequency: a=34 mm, b=34 mm, d=12 mm, w1=3 mm, w2=4 mm, ε_r =30.

4. Results and Discussions

The simulated and measured radiation patterns in x-z and y-z plane at resonance frequency (1.57GHz) are shown in Figure 6(a) and (b). It shows both a RHCP and a LHCP fields each plane. It is found that reasonable agreement between simulation and measurement is obtained and good RHCP radiation is obtained. As observed from Figure 6, the LHCP level is about 15 dB lower than RHCP level. The proposed antenna is operating in a RHCP for GPS, however if need, it is available in a LHCP by reversing feed point of strip line of DRA. Figure 7 shows the simulated and measured return loss of the proposed the rectangular DRA. The simulation and measurement results exhibit impedance bandwidth (S_{11}<-10dB) of 8.5% and 5.4%, respectively. The measured resonant frequency is 1.565GHz, which is closely located simulated resonant frequency 1.57GHz. The simulated and measured 3dB axial ratio bandwidth is shown in Figure 8, in which axial ratio bandwidth is found to be 2.3% relative to the center frequency 1.57GHz and 1.95% relative to the center frequency 1.565GHz respectively. It is found that the 3dB axial ratio of generally single-fed CP DRA is obtained. It is observed that reasonable agreement between simulation and measurement is obtained. The gain of proposed antenna including the operating frequencies within GPS band was measured and results are shown in Figure 9. The peak of obtained antenna gain is about 2.5dBi for GPS band.



(a)



(b)

Figure 6. Simulated and measured radiation patterns of the proposed DRA.

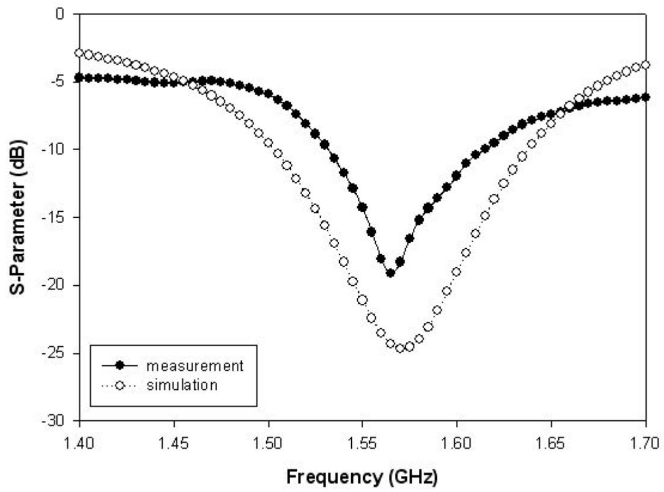


Figure 7. Simulated and measured return loss of the DRA.

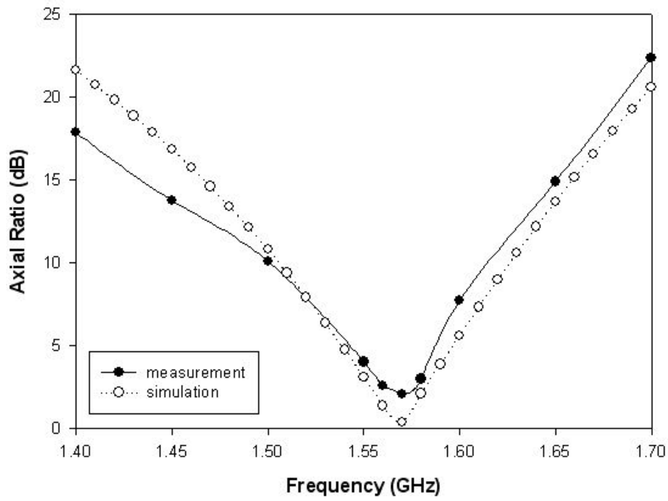


Figure 8. Simulated and measured axial ratio of the DRA.

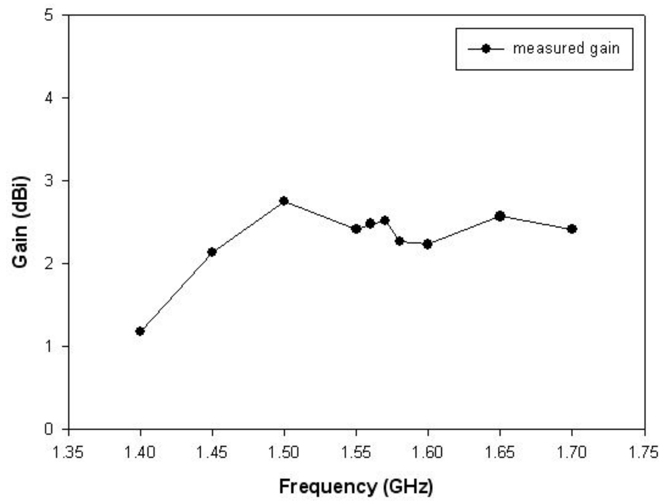


Figure 9. Measured antenna gain of the proposed antenna.

5. Conclusion

In this paper, we introduced strip single feed method consisting of loop shape to achieve circular polarization for GPS. A low profile rectangular dielectric resonator is excited by strip line with a 50Ω coaxial cable which is located in the middle at the front wall of DRA. This method generates two orthogonal electric fields ($TE^{x}_{\delta 11}$, $TE^{y}_{\delta 11}$) within the single resonator. The advantage of proposed antenna is easy conversion between RHCP and LHCP by reversing feed point of strip line of DRA. The proposed antenna is made of high-permittivity dielectric material (ε_r=30) for small receiver GPS antenna. Using a computer simulation, an optimization of antenna characteristic is found as parameters analysis. And reasonable agreement between simulation and measurement has been obtained. Since the proposed design of DRA is considerably simple moreover tuning parameters can almost independently adjust the return loss or axial ratio, we expect that the proposed antenna may apply in various field.

Acknowledgements

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