Circularly Polarized Ring-Slotted-Microstrip Antenna

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***Abstract*—A compact square-ring-slotted-microstrip antenna is proposed for circularly polarized (CP) radiation and global navigation satellite systems (GNSS). Four square-ring-shaped slots along the diagonal directions are cut symmetrically onto a square patch radiator for CP radiation and miniaturization. The operating frequency can be tuned by varying the ring width. The measured 3-dB axial-ratio (AR) bandwidth of around 25.0 MHz (1.56–1.585 GHz) and 10-dB return loss bandwidth of 80.0 MHz (1.545–1.625 GHz) are achieved.**

***Keywords—* circularly polarized antenna; GNSS; miniaturization; slotted-microstrip radiator; wide-beamwidth**

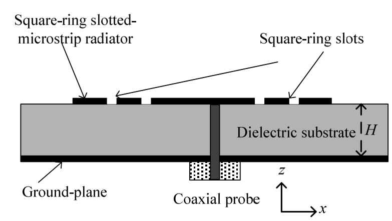
I. INTRODUCTION

Global navigation satellite systems (GNSS) are widely used currently for guidance and navigation. An antenna for a GNSS receiver requires to be compact, right-hand circularly polarized (RHCP) radiation, and a wide CP radiation beamwidth. Due to the limited space in the GNSS receiver, a compact CP antenna design is more preferable [1, 2], wherein the beamwidth and size of the antenna are the main considerations while the antenna gain and bandwidth are not so critical. However, the antenna must cover at least one of the GNSS bands with bandwidth of few MHz and gain of around 5 dBic. Some miniaturized CP microstrip antennas have been reported, however, the performance of the antenna such as gain, beamwidth, AR bandwidth, and impedance bandwidth are not desired [3-5]. In this paper, a compact, wide beamwidth, square-ring-shaped slotted-microstrip antenna is proposed for GNSS applications. The cutting of the four square-ring-shaped slots along the diagonal line of the patch radiator makes the antenna compact and generates the wide-beam CP radiation.

II. ANTENNA DESIGN

The configuration of the proposed square-ring-shaped slotted-microstrip antenna is shown in Fig. 1. The length of the square slotted-microstrip radiator is L (45.2 mm) and the ground-plane size of the antenna is 60.0 mm × 60.0 mm. The x_o is the coaxial feed-location from the slotted-microstrip radiator center. Four unequal square-ring slots are cut in diagonal line directions of the square microstrip radiator to achieve a CP radiation with compact size. The width of the small and large ring-slots is the same and indicted as g.

For CP radiation, the proposed slotted-microstrip radiator has to support two orthogonal resonance modes with a 90° phase shift. The orthogonal modes can be excited by adding the unequal square-ring slots symmetrically along the diagonal lines of microstrip radiator. The locations of the four square-ring slots are located symmetrically at s, $s = L/4$ along the diagonal directions from the origin (0, 0) of the square slotted-microstrip radiator as shown in Fig. 1(b). The coaxial feed location is on the -x-axis. By slightly varying in the length for one of the slots or ring-width in diagonal directions, the CP radiation can be obtained. The length of the square-ring-slots along one diagonal line should be different those along the orthogonal one ($s_1 \neq s_2$). The proposed antenna design dimensions at the operating frequency of 1.575 GHz are: large ring-slot length, s_1 = 13.2 mm; small ring-slot length, s_2 = 8.3 mm; ring-width, g = 0.8 mm; coaxial feed location, x_o = 8.5 mm; substrate height, H = 5.0 mm; substrate dielectric constant = 3.4, and loss tangent = 0.0027.



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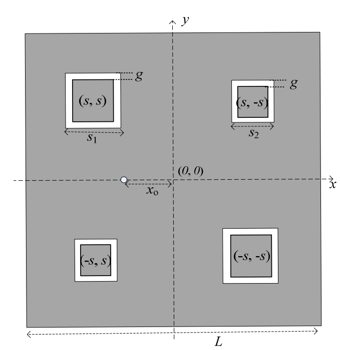
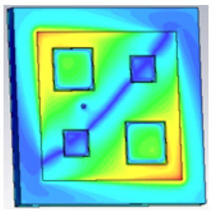


(b)

Fig. 1. Proposed antenna geometry: (a) cross-sectional view and (b) square-ring-shaped slotted-microstrip radiator.

The current distributions of the proposed slotted-microstrip antenna are illustrated in Figs. 2(a)-2(d), respectively, at ωt = 0°, 45°, 90°, and 135°. The strongest current distribution is around the square-ring-slots. The four unequal square-ring-slots on the microstrip radiator can cause meandering of the current paths. Accordingly, the resonance frequency of the antenna is shifted down compared with the square microstrip radiator and thus the electrical size of the antenna is reduced. The rotation of the current distributions with time is just like a circularly rotation, which demonstrates CP radiation fearures of the proposed antenna.



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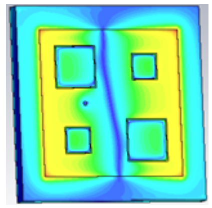

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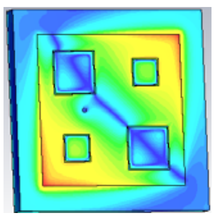

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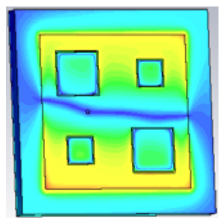


(d)

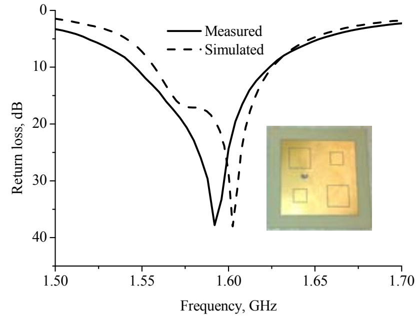
Fig. 2. Current density distribution on patch radiator at 1.578 GHz.

III. Experimental Results and Discussions

The proposed antenna was fabricated and tested to validate the simulations. The measured and simulated results on return loss, AR at the boresight, and gain at the boresight are plotted in Figs. 3(a) and 3(b), respectively. The measured 10-dB return loss bandwidth is 80 MHz (1.545−1.625 GHz) and good agreement is observed between the simulated and measured results. The measured 3-dB AR bandwidth is 25 MHz (1.56–1.585 GHz) and it is within the measured 10-dB return loss bandwidth. The agreement of the simulated and measured 3-dB AR bandwidth is good as well. The measured AR bandwidth is able to cover GPS L1 at centre frequency of 1575.42 MHz and bandwidth of 20.46 MHz. The measured maximum boresight gain is 5.2 dBic at 1.6 GHz and gain is more than 5.0 dBic across the 3-dB AR bandwidth. The radiation patterns were measured with a rotating linear polarized transmitting horn antenna method for the *xz*- and *yz*-planes. Fig. 4 shows the measured and simulated normalized radiation patterns at 1.578 GHz for the *xz*- and *yz*-planes. The 3-dB AR beamwidth is more than 150° for both planes.

IV. Conclusion

A wide-beam CP radiation, compact, square-ring-shaped slotted-microstrip antenna has been proposed for GNSS applications. The square-ring-slot length and width can be used to tune the operating frequency of the antenna. The antenna has RHCP radiation with wide beamwidth of 150°.



(a)

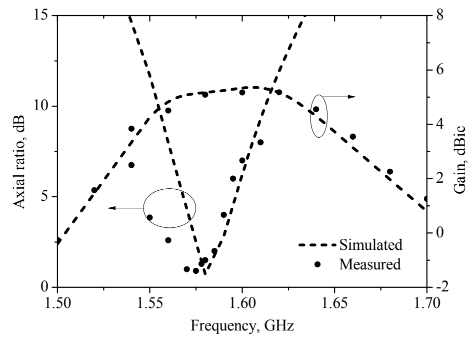


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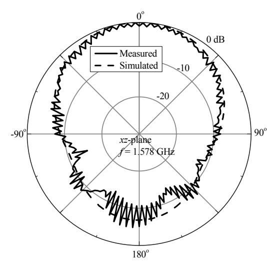
Fig. 3. Simulated and measured results: (a) return loss and (b) AR and gain.



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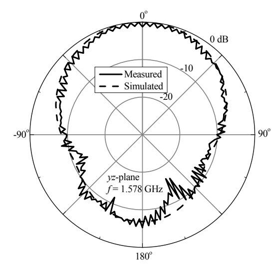

(b)

Fig. 4. Measured and simulated radiation patterns: (a) *xz*- and (b) *yz*-plane.

References

[1] R. Leelaratne, "The GPS to GNSS antenna design challenge," *Antennas Systems & Technology*, Fall 2014. (www.AntennasOnline.com)

[2] J. H. Wang, "Antennas for global navigation satellite system (GNSS)," *Proceeding of the IEEE*, vol. 100, no. 7, pp. 2349–2355, July 2012.

[3] Nasimuddin, X. Qing, and Z. N. Chen, "A compact circularly polarized slotted patch antenna for GNSS applications," *IEEE Trans. Antennas and Propagation*, vol. 62, no. 12, pp. 6506–6509, Dec. 2014.

[4] H. Chung, Y. Lee, and J. Choi, "Miniaturization of an UHF RFID reader antenna using an artificial magneto-dielectric" Microwave and Optical Technology Letters, vol. 52, no. 9, pp. 1926-1930, September 2010.

[5] J. S. Row and C. Y. Ai, "Compact design of single-feed circularly polarized patch antenna," Electronics Letters, vol. 40, no. 18, pp. 1093–1094, 2004.