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Dual-Band Annular-Ring Microstrip Patch Antenna for Satellite Applications

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ABSTRACT: A dual-band circularly polarized antenna fed by four apertures that covers the bands of GPS, Galileo, is introduced. The ARSAs designed using FR4 substrates in the L and S bands have 3-dB axial-ratio bandwidths (ARBWs) of as large as 37% and 52%, respectively, whereas the one using an RT5880 substrate in the L band, 61%. In these 3-dB axial-ratio bands, impedance matching with VSWR<=1.8 is also achieved. Three wideband planar baluns are used to achieve good axial ratio and VSWR. The results of the annular-ring microstrip antenna show good performance of a dual-band operation, which meets the requirement of Global Navigation Satellite System (GNSS) applications.

INDEX TERMS: Broadband feed network, circularly polarized (CP), Annular Ring Slot Antenna (ARSA), dual-band patch antenna, Global Navigation Satellite System (GNSS).

I. INTRODUCTION

In recent years, antennas have been very intensively used in the satellite communication and Global Navigation Satellite System (GNSS) [1], [2]. For the single-feed circularly polarized (CP) antennas, the measured impedance bandwidth for and 3-dB axial-ratio bandwidths (ARBWs) are less than 3% and 1% [3]. The majority of Global Positioning System (GPS) receivers are requested to cover both 1575 MHz (L1) and 1227 MHz (L2) bands. Though the design bandwidth may be enough to support GPS applications or other navigation system requests, machine tolerances in production are inevitable and could result in bandwidth reductions. CP bandwidth could be enhanced by using the coupled feeding method and the dual-feed or multiple-feeds network. The single-feed CP ring antennas using the coupled feeding method have been investigated in [4], but the 3-dB ARBW is less than 2%. For the dual-feed CP antenna in [5], the ARBW is larger than 2% at both bands. The CP annular-ring patch antenna with two proximity-coupled L-probe feeds [6] obtains a 3-dB ARBW of larger than 30%. The ring microstrip antenna has the advantage of a smaller dimension than that of a circular or rectangular patch when operating in the fundamental mode at a certain frequency [7]. The width of the rings has the most influence to the input impedance of the ring microstrip [8]. Thus, the narrow rings produce higher the input impedance, and good impedance match is therefore more difficult to obtain [9]. In this paper, a dual-band CP antenna based on a concentric annular- rings microstrip fed by four apertures is designed. The broadband feed network based on the broadband phase shifter presented in [10] and [11] is used to obtain the required phase shift, thus allowing improvement of the axial ratio in the direction of maximum radiation. This antenna could be installed on a car or a ship for navigation use.

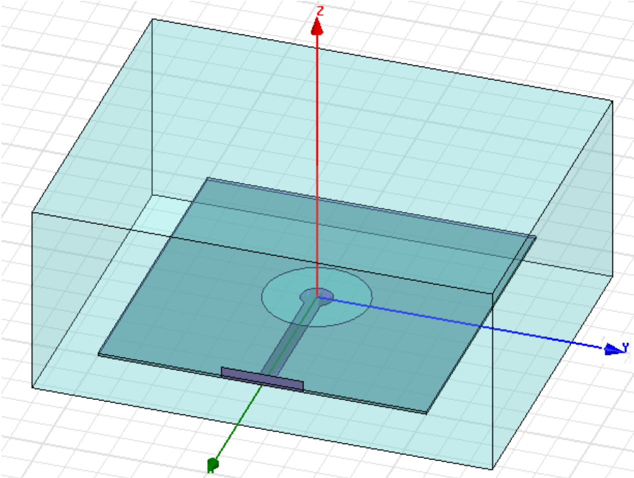

Fig. 1 Proposed annular ring antenna

II. ANTENNA CONFIGURATION

Fig. 1 shows the geometry of the proposed CP ARSA, in which the deformed bent feeding line and the perturbation structure consisting of a pair of grounded hat-shaped patches are redrawn separately for more clarity. The antenna is to be fabricated on a square microwave substrate with side length G, thickness h, dielectric constant ε_r, and loss tangent tanδ. The radiating annular-ring slot of outer radius R1(80mm) and inner radius R2(24mm) is fed from the direction y-by a -wide 50Ω microstrip line printed on the side of the substrate opposite to the slot. On the top of ground plane the substrate is placed and here the substrate is FR4(h=0.8mm) and RTduroid 5880(h=1mm). An SMA connector is used to give input to the antenna through the microstrip feed. If , a bent (or inverted-L) feeding microstrip line is formed, which can broaden the CP band of the CP ARSA fed by a straight feeding line and loaded with grounded rectangular patches. With, the feeding structure is referred to as a deformed bent feeding line, which can improve the impedance matching of the designed antenna in the broadened CP band.

III. CONCEPTS AND PROCEDURE OF ANTENNA DESIGN

The antenna design begins with determining and of a microstrip-line-fed linearly polarized (LP) ARSA, which will be subsequently developed into a CP ARSA. During simulation a wave port is created along the YZ plane to receive the radiation. For good results the entire design is enclosed in a box which must be given perfect E during execution of the antenna. At the center frequency of the fundamental mode of a conventional microstrip line- fed LP ARSA where the width of the ring slot is only 22.2% the average radius of the slot [4], one guided wavelength is estimated to be the average perimeter of the ring slot. However, for a similar LP ARSA in [6] with the ring-slot width being 28.6% the average radius and with a ground-plane size of smaller than that of the antenna in [4], one guided wavelength is modified to be the outer perimeter of the ring slot. In fact, the ground-plane size and slot width complicatedly affect the resonant frequency of the fundamental mode of an LP ARSA. Nevertheless, to more accurately estimate the fundamental-mode resonant frequency of an LP ARSA, extensive simulations using Ansoft HFSS and experimental verifications for the substrates of small dielectric constant and low substrate thickness were performed again in this study. Results show that the fundamental-mode resonant magnetic current of the LP ARSA for one guided wavelength is mainly distributed between the average and outer perimeter of the ring slot at the fundamental resonant-band center frequency. An empirical formula can be found for certain ranges of structural parameters to be described below. The expression of the fundamental-mode resonant frequency of an LP ARSA can be slightly modified from those in [4] and [6] to

$$fr = \frac{c_0}{2.2\pi Rm\sqrt{\varepsilon_{reff}}} \text{----- (1)}$$

$$\varepsilon_{reff} = \frac{2\varepsilon r}{1+\varepsilon r} \text{----- (2)}$$

In this empirical formula, f_r is the resonant frequency of the fundamental mode, $C_0$the speed of light in free space, and ε_{reff} the effective dielectric constant.

IV. RESULTS AND DISCUSSION

Fig 2 shows the total gain of the proposed antenna which is approximately 7.9 dB in both the bands L1 and L2. Fig 3 and 4 shows the return loss and active VSWR of the proposed antenna. Return loss is approximately -19dB and VSWR is 1. Ansoft High Frequency Structure Simulator (HFSS) is utilized to validate the proposed structure. First, for obtaining the good coupling between the radiation patch and feed line and also making a resonance with the patch by the feed and thus increasing the matching bandwidth, we optimize the mentioned parameters of the feed line. On the other hand, the height of the substrate between slot and patch is also an important parameter because it changes the matching bandwidth and gain. The best values of the mentioned parameters for the matching bandwidth and gain enhancement are given above. The proposed antenna can support many existing wireless services, broadband applications over the frequency range of 3, 4, and 5 GHz, and multi standard mobile communication systems.

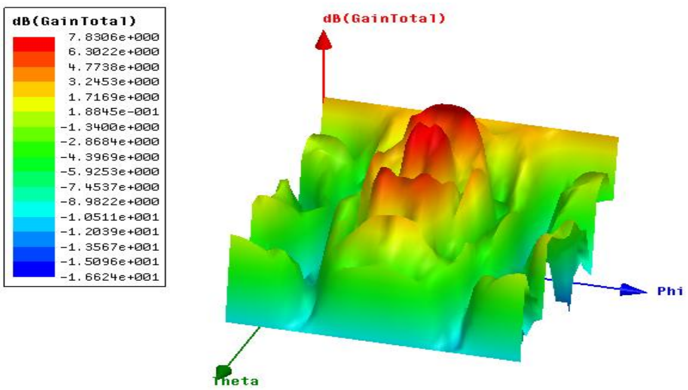

Fig-2. Simulated total gain of the antenna

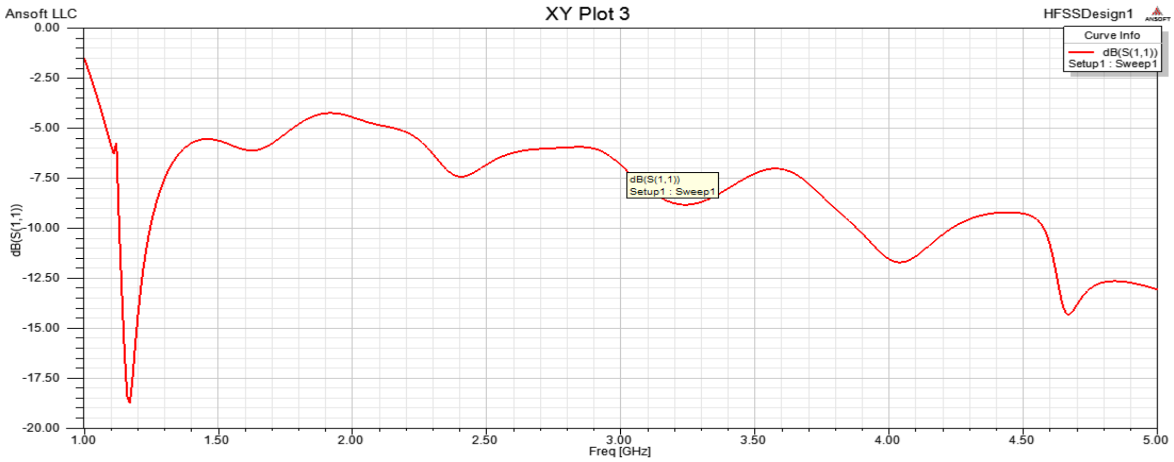

Fig-3. Return loss of the proposed antenna

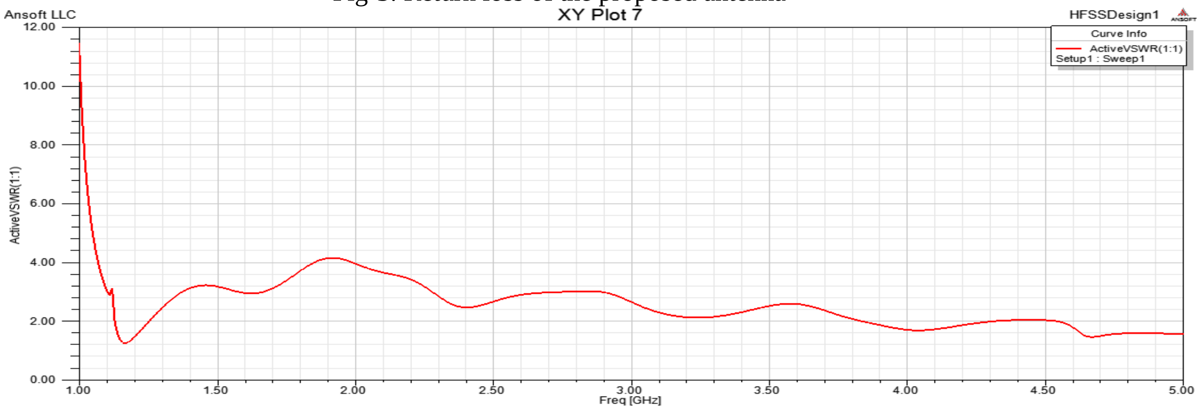

Fig-4. Active VSWR of the proposed antenna

V. CONCLUSION

In this paper we propose an annular ring antenna in which the broadband operation is a result of suitable design of the transmission line, slot, and patch. The shape and size of the patch are main parameters that affect the matching bandwidth and the gain of the antenna, thus we designed them carefully. An annular ring patch satisfied expectations. The measurement results showed a broad matching bandwidth of 61% for VSWR< 1.8. Maximum gain is 7.9dB, and 1-dB gain ripple bandwidth is nearly 37%. Also, the radiation pattern, radiation efficiency, and cross polarization is adequate on the matching bandwidth.

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