
A Square Tri Slit Slip Ring Resonator Integrating Novel RDRA for C-band Applications

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Abstract:- This paper proposes a square tri-slit slip ring resonator (STSSRR) integrated with a novel RDRA excited by a square ring with conformal strips. The proposed antenna is constructed on an FR4 substrate of 4.4 with overall dimensions of 46 x 46 x 1.6 mm^3.The square ring is placed on the STSSRR-integrated RDRA, and three conformal strips are placed in the proposed design to enhance the impedance bandwidth. The proposed antenna operating band is 5.85 GHz to 7.3 GHz, with an impedance bandwidth of 22.05%. The antenna provides a high gain of 10.9 dB and an Radiation efficiency of 92% in the operating band. A perfect correlation was found between the Anritsu combinational network analyzer MS2037C measured and HFSS simulated results. The proposed antenna is used for communication, AMSAT, and defense satellite and C-band applications.

Keywords*: Conformal Strips, C-band Applications. Rectangular DRA, Square Trislit Slip Ring Resonator*

1. Introduction

Modern 5G wireless communications require compact, wideband, high-data-rate, and high-efficiency antennas. Dielectric resonator antennas, which reduce complexity and have low fabrication costs, were proposed by Long et al. in 1980 as the best potential radiator over a microstrip patch and dipole antenna [1]. Amir Altaf and Munkyo Seo proposed hexagonal DRA [2] with a microstrip square ring operated in triple band impedance bandwidths of 17.4%, 28.13%, and 2.977% with peak gains of 5 dB, 5.28 dB, and 2.36 dB. A dual-band hybrid DRA [3] operating at 3.6 GHz and 5.25 GHz, with 3.9% and 3.24% impedance bandwidths, is utilized in WIMAX and WLAN systems for peak gains. A novel ultra-wideband planar antenna [4] achieves band-notched characteristics by loading a pair of metamaterials in RDRA used for WIMAX. The dual-band vertical polarized antenna [5] obtained peak gains of 6.08 dB and 5.85 dB, with radiation efficiencies of 71.3% and 64.83%, respectively. A hemispherical DRA [6] with complementary split rings obtained an impedance bandwidth of 27% and a peak gain of 6 dBi when used for wideband applications. A dual-segment RDRA with metamaterial [7] as the superstate achieved an impedance bandwidth of 32.8% and a peak gain of 10.22 dB, while a dual-band circularly polarized microstrip line-fed slot antenna [8] achieved a peak gain of 5.9 dB. The RDRA excited higher-order radiating modes [9] demonstrated high gains of 6.90 dBi, 10.2 dBi, and 9.45 dBi, suitable for various communication applications in C-band. The dual-segment [10] RDRA array, excited with a conformal strip, offers high gain and wide bandwidth for satellite applications. A circularly polarized RDRA [11] with a cross-aperture-coupled spiral microstrip line achieved an impedance bandwidth of 31.74% and a total gain of 4.8 dB for WIMAX applications. A new meandered-line inductor fed wideband circularly polarized RDRA [12] with partial ground plane offer impedance bandwidth of 20.67% and 3-dB axial ratio bandwidth of 27.95% in broadside direction., gain 6.4 dB. Wideband circularly polarized RDRA [13] offers an impedance bandwidth of 36.8% at 4.26 GHz and a high gain of 6.4 dB.A circularly polarized compact wearable DRA [14] with an IMBW of 21.7% and gains of 5 dB was used for a wireless body area network (WBAN), with a 2 x 2 array efficiency of 39%.A wideband bi-cone-shaped DRA [15] with an impedance bandwidth of 93.1% (2.8 GHz–7.38 GHz), gain of 7.5 dB, and an efficiency of 80% is used for ultra-wideband applications. The DRA [16] with a single element obtained an impedance bandwidth of 12.5%, a gain of 5.51 dB, and a radiation efficiency of 95%.A split ring resonator with integrated electromagnetic band gap [17] structure achieved 41.40% impedance bandwidth and 8 dB peak gain at 4.0 GHz, while a dual-sense circularly polarized hybrid RDRA [18] achieved 55.18% fractional bandwidth over 3.28 GHz–5.78 GHz.RDRA using a metallic circular patch [19] with a rectangular slot obtained gains of 6.8 dB and 8.04 dB, respectively, used for millimeter applications.

The proposed antenna impedance bandwidth is enhanced by three conformal strips, enhancing high gain and efficiency compared to a previous study on C-band RDRA [20] with defective ground structure. This high-gain Square Tri-slit slip ring resonator (STSSRR) antenna has potential for communication, AMSAT, and defence satellite applications.

2. Design and Configuration of an Antenna

The proposed Square Tri slit slip ring resonator (STSSRR) integrates novel RDRA excited by a square ring with conformal strips, described in two stages. In first stage, an E-shaped microstrip feed line is designed on the ground plane with a conformal strip (C_1) as presented in Fig. 1 (a). The second Square Tri slit slip ring resonator (STSSRR) integrates novel RDRA and its geometry, as presented in Fig. 1. (b). Further gain enhancement is carried out by introducing the right vertical conformal strip (C_2) and left conformal strip (C_3) at an optimal location nearer to the rectangular DRA. The substrate (ϵ_r= 4.4, loss tangent (0.02) has a thickness of S_t = 1.6 mm and dimensions Sx X Sy. The length (Sx) and breadth (Sy) are 46 mm. The feed vertical conformal strip (C_1) is L1 = 7 mm and W1 = 2 mm. The right vertical conformal strip C_2 and left vertical conformal strip C_3 lengths are (L_2 = L_3 = 8 mm) and widths are (W_2 = W3 = 3 mm), sides of the STSSRR, SL = SW = 16 mm, and thickness is 2 mm. Length of feed is 29 mm, and width of feed is 2 mm. The side of the square, RL = RW = 13 mm, has a thickness of 0.3 mm. The wide aperture slot dimensions are length, L = 10 mm & width, W = 6 mm. The height of the proposed RDRA is Ht = 15 mm and the diameter is 2R = 14 mm. Table 1 shows the parameters of STSSRR.

3. Principle of Working

The Square tri-slit slip ring resonator (STSSRR) integrating RDRA whose substrate made by FR4 glass epoxy on the ground of length Sx and breadth Sy as shown in Fig. 1. Wideband characteristics are observed in RDR, with a length-to-height ratio greater than 2. Because of the microstrip feed line's weak coupling matching, 90% of the power is transmitted and 10% is reflected. The feed vertical conformal strip (C1) is placed in the middle of the feed line to provide strong coupling to overcome the improper matching problem. To enhance impedance bandwidth, the conformal strips (C2 and C3) were placed on the right and left sides of the DRA, and gain was enhanced by the square ring placed on the RDRA. The resonant frequency of RDRA depends on the dielectric material's shape, dielectric constant and size.

The STSSRR Resonant frequency modified with its proposed dimensions as

$$F_r = \frac{30}{2\pi r}(c_{o^r}) \qquad (1)$$

$$c_{0R} = \frac{1.6+0.513k+1.392k^2-0.575k^3+0.088k^4}{\epsilon_{sd_R}^{0.42}}$$

$$k = \frac{R}{2 * \mathrm{Ht}}$$

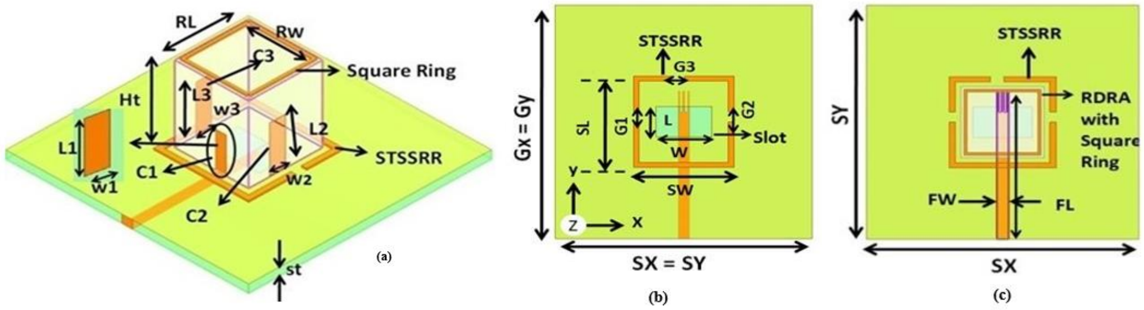

Fig.1.The construction View of STSSRR (a) Isometric view (b) Top View without RDRA (c) Top view with RDRA and square ring

Tab.1. Parameters of the proposed Antenna STSSRR

Name of the Parameter	Parameter	Value (mm)
RDRA height, Width/length	Ht,2R	15&14
Slot width, Slot Length	W, L	6,10
Substrate Length, Width thickness Ground plane length	Sx= Sy Gx = Gy	46,1.6 46
Microstrip feed Length& Width	FL &FW	29& 2
Side of STSSRR Rectangle	SL = SW	16
Side of Square ring	RL = RW	13
The thickness of the STSSRR Rectangle	Ws	3
Height & width of the strip (C1)	L1& W1	7 & 2
Height & width of the strips (C2 &C3)	L2 = L3 W2 = W3	8 3
Gap 1 and Gap 2 & Gap 3	G1, G2 & G3	2,2 &2.2

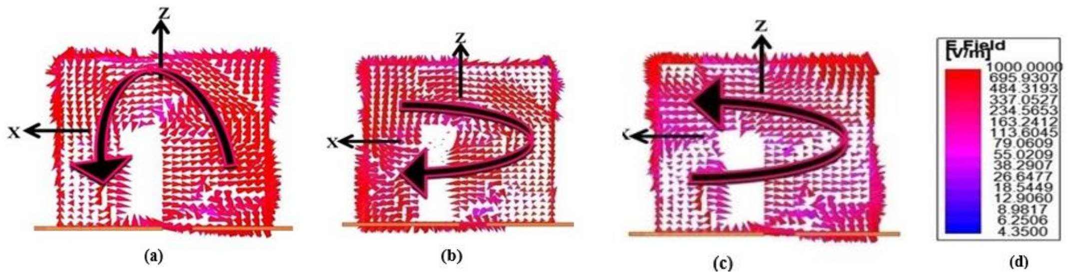

Fig.2 RDRA E-Field Distribution right side view (a) Phi = 0^0 (b) Phi = 90^0 (c) Phi = 180^0(d) scale for a, b, & c at 6.2 GHz

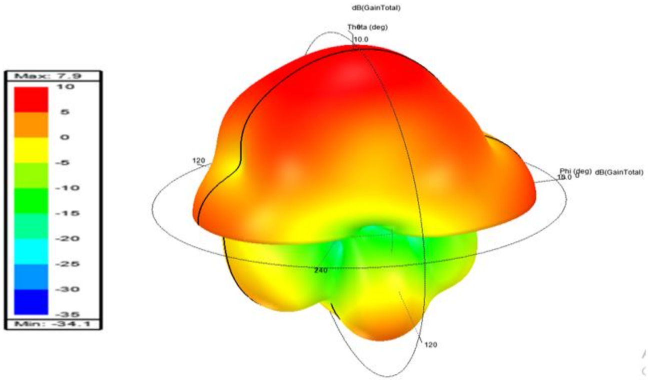

Fig. 3.3D radiation pattern (Directivity) of RDRA at 6.2 GHz

Figure 2 gives RDRA E-field distribution of the wide aperture slot with a square tri-slit slip ring resonator (STSSRR) in the ground plane right side view at 6.2 GHz. Figs. (a), (b), and (c) describe a phase difference of 90^0 between them. By placing conformal strips on the left, right, and front sides of the DRA, the E-fields are circulating in clockwise and anti-clockwise directions, which results in broadening the impedance bandwidth. Fig. 3 shows the three-dimensional radiation pattern of the RDRA simulated by Ansoft HFSS at resonant frequency 6.2 GHz.

4. RDRA Analysis

The RDRA has three conformal strips, a square ring, and a wide aperture slot. It generates spurious radiation due to the wide aperture slot acts as a current monopole element. The antenna's parameters are influenced by width height, dielectric material and length.The parameters of the antenna are influenced by the height, length, width, and nature of the dielectric material of the DR. Parametric analysis is essential for optimizing the dimensions. It is fractional to note that the observed return loss value at RDRA height of 15 mm is high, according to the parametric analysis at resonant frequency 6.2 GHz. Fig.4 shows the fabricated proposed STSSRR antenna; Fig. 4 (a) gives the top of STSSRR without RDRA Fig. 4 (b) shows the Isometric view of STSSRR with RDRA and square ring.

The simulated and measured antenna parameters are presented in Table 2 and 3 the results are depicted in Figures 6-12.

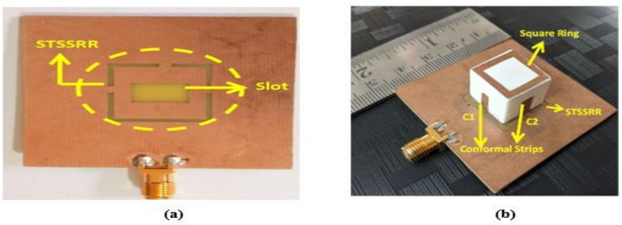

Fig.4. (a) Top view STSSRR without RDRA g (b) Isometric view of STSSRR with RDRA and square ring

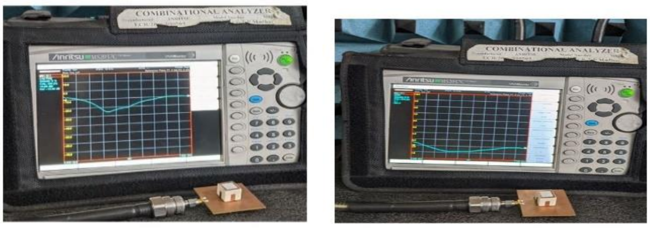

Fig.5. STSSRR with RDRA (a) Measurement setup for Reflection co efficient (b) Measurement setup for VSWR

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Tab. 2. Comparison of Impedance bandwidth of proposed antenna simulated and measured

Simulated & Measured	Resonant frequency Fr (GHz)	Frequency Range (GHz)	Impedance Bandwidth (%)
HFSS	6.2	5.85 – 7.3	22.05 %
Measured	6.15	5.82 – 7.3	22.9 %

Tab.3. parameters of proposed antenna simulated and measured

Antenna Parameters	Simulated STSSRR	Measured STSSRR
S11 (dB)	48	46
VSWR	0.98	1.2
E-plane co-polarization 3 dB beam width (dB) E-plane cross-polarization 3 dB beam width (dB)	89.930 80.460	-
H-plane co-polarization 3 dB beam width (dB) H-plane cross-polarization 3 dB beam width (dB)	46.620 42.910	-
Peak Gain (dB)	10.9	-
Radiation Efficiency (%)	92	-

5. Results and Discussion

This paper proposes a square tri-slit slip ring resonator (STSSRR) integrated with a novel RDRA excited by a square ring with conformal strips. The STSSRR integrates RDRA. The RDRA, excited with conformal strips C1 and C2, and the RDRA with square ring technique with a designed E-shape microstrip feed, improved gain. The measured results and simulated results of the proposed STSSRR integrating an RDR square tri-slit slip square ring resonator with RDRA parameters are presented in Fig. (6) - Fig. (11). Fig. 6 shows the impedance bandwidth and reflection coefficients of conformal strip C1, conformal strips C1 and C2 and C3 and proposed antenna. The simulated and measured results of STSSRR with RDRA parameters are presented in Fig. (8) -Fig. (11). From Table 2, the proposed STSSRR with an integrated RDRA structure covered a single frequency band, i.e., simulated (5.85 GHz–7.3 GHz) with a fractional bandwidth of 22.05% and measured (5.82 GHz–7.3 GHz) with a fractional bandwidth of 22.56 %. Figs. 7 and 8 show the reflection coefficient and voltage standing wave ratio simulated and measured. Fig. 9 shows the far-field 2D pattern (2D E-Plane). The 3 dB co-polarization beam width simulated is $89.83^0$and 3 dB cross-polarization beam width simulated is 80.46^0. Fig. 10 shows the 2D far-field pattern in the H-plane the 3 dB co-polarization beam width simulated is 46.62^0 and 3 dB cross-polarization beam width simulated is 42.91^0 respectively. Fig. 11 shows the proposed antenna's simulated gain is 9.4 dBi–10.9 dBi in the frequency band (5.85 GHz–7.3 GHz). The proposed STSSRR antenna operated in the C band and offered wide impedance bandwidth, high gain, and low cross polarization levels with all the reported antennas, making it suitable for various defense satellite and C band applications.

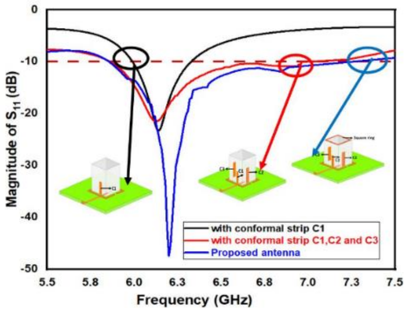

Fig.6 S_{11} versus frequency of with conformal strip C1, with conformal strips C1, C2 and C3 and proposed antenna

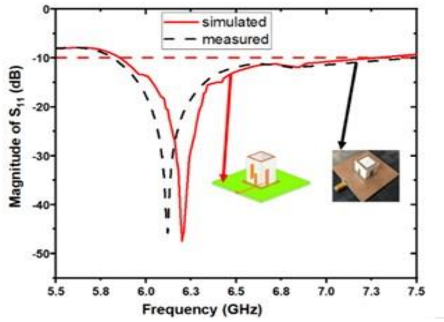

Fig.7. Reflection Coefficient versus frequency

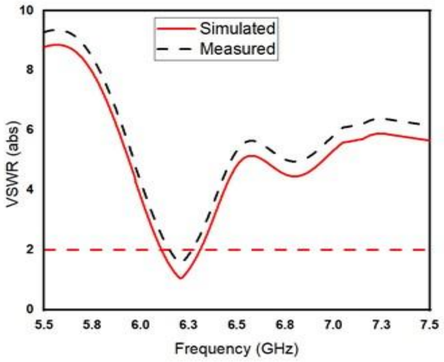

Fig.8. VSWR versus frequency

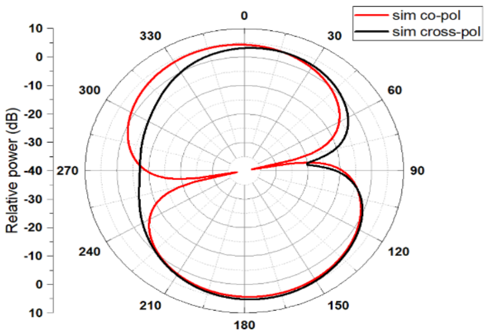

Fig. 9. Radiation 2D pattern E-plane

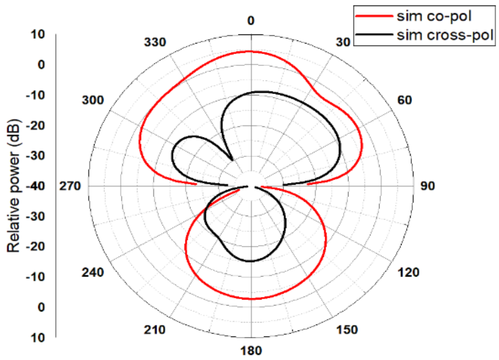

Fig. 10. Radiation 2D pattern H-plane

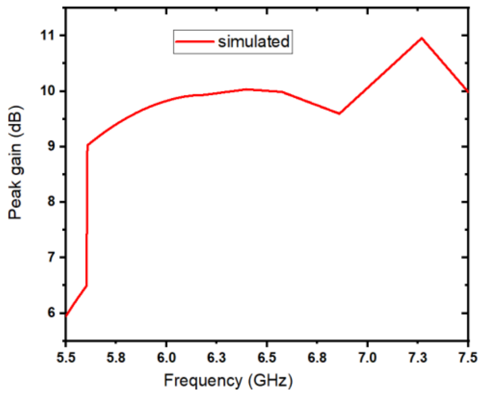

Fig.11. Gain versus frequency

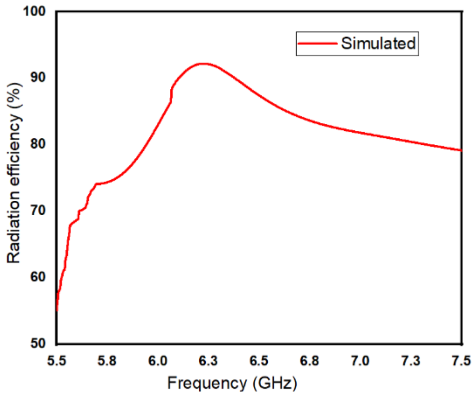

Fig.12. Radiation efficiency versus frequency

6. Conclusions

This paper proposes a Square Tri slit slip ring resonator (STSSRR) integrated with novel RDRA excited by a square ring with conformal strips. It is known that there is the proximity of measured results with the simulated results. It is found that the proposed STSSRR integrating RDRA operated in a frequency band (5.85 – 7.3GHz) with impedance bandwidth of 22.9 %, and 3dB beam width co- polarization of E plane $91.95^0$is and 3dB beam width of H plane is 46.62^0. The designed RDRA is a good choice AMSAT, defense, satellite communication and C-band applications.

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