

Design Of Compact Broadband Microstrip Ring Antenna For High-Speed Data Transmission

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Abstract: In modern wireless communication, microstrip antennas are indispensable. This paper focuses on designing 2GHz miniaturized width 4mm rectangular ring antenna optimized for enhanced bandwidth performance. Antenna fabricated on FR-4 platform with permittivity of 4.4 and width of 1.6 mm. Compact 4 mm-wide ring structure achieves a wide impedance bandwidth of 1.14 GHz, providing a fractional bandwidth more than 50% of antenna resonating frequency 2GHz, making it suitable for high-speed wireless applications such as high-speed data transmission and L band applications. The antenna performance parameters carried out through simulation using high frequency simulation software (HFSS) and measurements are discussed in this paper.

Key words: Microstrip Antenna, Impedance, Bandwidth, Ring Structure, Wireless Communication.

INTRODUCTION: We cannot predict wireless communication technology without microstrip antenna. Microstrip antennas are the backbone of modern wireless communication system. Almost all the applications of wireless communication systems get smart, effective solutions with the help of technology. Lot of research work is going on microstrip antenna many researchers are working on ring microstrip antenna, because of its larger bandwidth compared to conventional antenna of ring and rectangular shape patch. Rectangular ring antennas are kind of flat antenna distinguished by its ring shaped element. Electromagnetic waves generated by a proposed shaped structure, by the functioning of ring antenna. The perimeter of an antenna much more effects on its primary working frequency, which is normally equal to its wavelength of operating frequency of, suggested antenna. We consider several parameters of an antenna like feeding technique, dielectric constant with other main parameters while designing microstrip antenna.[3]-[7]

As per Moor's law, miniaturization in device is inevitable, in this way miniaturized microstrip ring antennas stands first in future wireless, sensing technology. They functions in emerged areas of communication. Such antennas have benefited with low profile structure, suitable for less spaced applications. Antenna provides accurate radiation patterns designed for focused communication.[8][10].The inner and outer radii of a ring antenna mainly determines its resonating frequency. Different feeding techniques like co-axial feed, microstrip line feed, quarter wave feed, proximity feed have made effect on impedance matching and on the efficiency of the antenna. The substrate material, dielectric constant ie permittivity and loss tangent values made notable effect on efficiency and bandwidth of a rectangular ring antenna.

In recent years microstrip ring antennas are promising, with advancements in materials, miniaturization, and reconfigurable novel designs enhancing their performance. They will play a vital role in modern communication applications such as 5G, IoT, and biomedical fields, offering high efficiency, wideband capabilities, and integration with flexible electronics for next-generation wireless communication and sensing technologies.[11][18].

In the present work, we have endeavored to design thin lightweight rectangular ring microstrip antenna. The main objective is to design and enhance the gain of rectangular ring microstrip antenna and observed the various parameters like return loss, directivity, VSWR, Gain of an antenna. Designed antennas finds application in highly integrated CMOS transmitters and L band applications. The simulation is carried out by HFSS software.

In this manuscript, we set out designed a slim lightweight rectangular ring antenna, with focus on high performance. Our primary goal is to enhance the antenna gain, while analyzing the key parameters of an antenna like return loss, VSWR, Gain, bandwidth, directivity. These cutting edge design holds great potential for highly integrated CMOS transmitters, and L band applications. To verify precession with reliability of proposed ring antenna. All simulation work carried out by using HFSS software, which helps to modernize the communication system with new advancements.

ANTENNA GEOMETRY: Proposed ring antenna shown in fig.1 uses FR4 platform having measurements of 70.88(L)x91.28(W)mm²,dissipation factor (tanδ) of 0.02, relative permittivity $\epsilon=4.4$.Ring antenna parch which is rectangular in shape forms top layer on FR4 platform. Which is formed by subtracting dimensions of patch 31.44mmX41.64mm in to 35.44mmX45.64mm.Thickness $t=1.6$ mm.The length and width of conducting patch are $L=35.44$ mm, $W=45.64$ mm Feed line length $F_L=18$ mm Feed width $F_W=3$ mm.Quarter wavelength $L_q=2.56$ mm, quarter wave width $Q_w=0.2$ mm constitutes compact ring antenna of suggested shape vibrating at 2GHz frequency as per mathematical analysis.

The antenna measurements provided in Table 1, while the ring antenna configuration is illustrated in Fig.1 and bottom view in fig .a. S11, VSWR, total gain plots are respectively given in fig 1 figures b, c, and f. The S11 plot states that due to the DGS on a ground plane resonating frequency slight shift toward a higher side, indicating a dominant inductive component influencing the capacitance, thereby tuning the response to a higher frequency. The antenna achieves a total gain of 2.1916 dB with a bandwidth of 1.14 GHz.

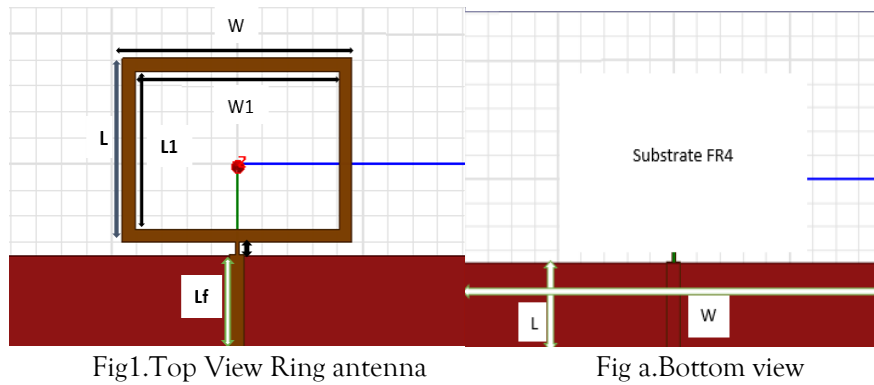


Table 1

| Ring-antenna parameters | Dimensions in mm |
|-------------------------|------------------|
| Length -L | 35.44 |
| Width-W | 45.64 |
| Length-L1 | 31.44 |
| Width-W1 | 41.64 |
| Feed Length Lf | 18 |
| Wf | 3 |
| Quarter wave length | 2.56 |
| Width | 0.2 |
| Ground -L | 17.72 |
| W | 91.28 |

3. SIMULATED RESULTS

The simulated antenna resonates at 2GHz frequency, with return loss -16.79dB. Produces bandwidth of 1.14GHz .Fig 3 shows S11 graph of suggested antenna.

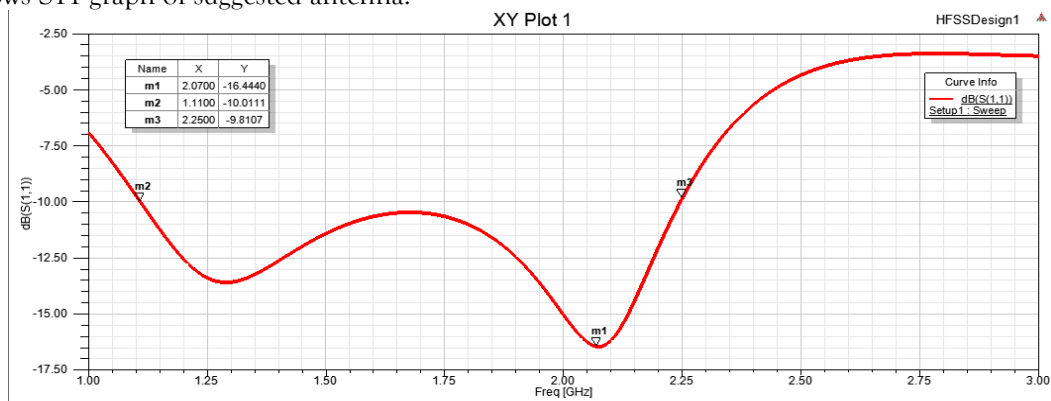


Fig b.s11 plot

Fig 3. Shows the S11 plot of the rectangular ring microstrip antenna shows return loss across frequencies from 1.0 GHz to 2.87 GHz. The lowest return loss (-16.4440 dB) occurs at 2.07 GHz, indicating optimal impedance matching and maximum power transfer. The antenna is well tuned for operation near 2.0 GHz. Antenna finds suitability for applications in the S-band, such as Wi-Fi, radar, and mobile communications.

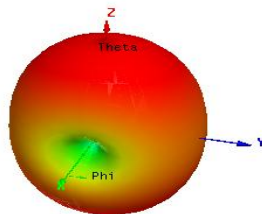
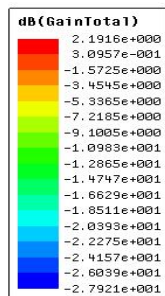


Fig c.Total gain

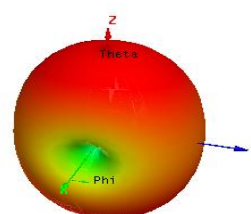
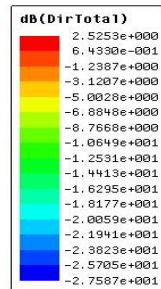


Fig d.Directivity.

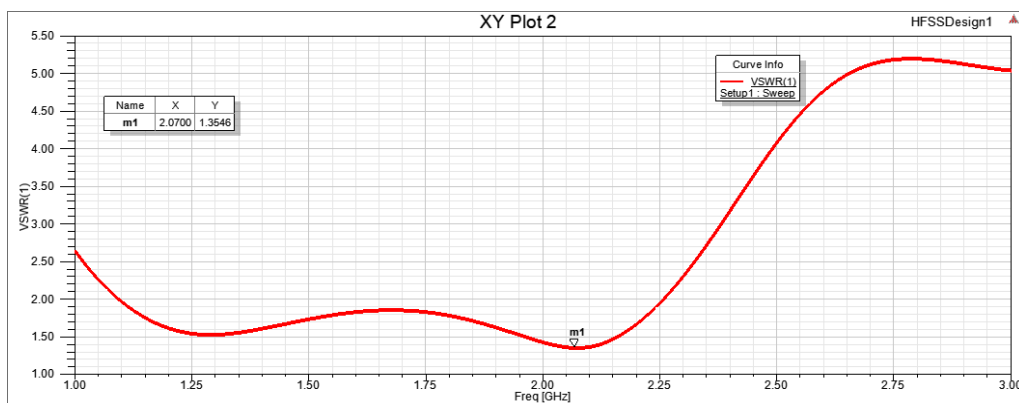


Fig e. VSWR

Fig 6. Shows how the voltage standing wave ratio varies across the 2.07GHz frequency. At resonating frequency the VSWR reaches low value 1.35, ie close to 1, indicates minimum reflection and maximum power transfer. Plot indicates antenna performs efficiently at resonant frequency.

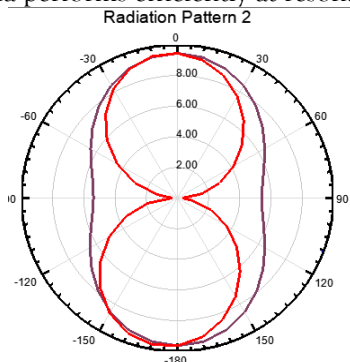


Fig.f.Radiation pattern

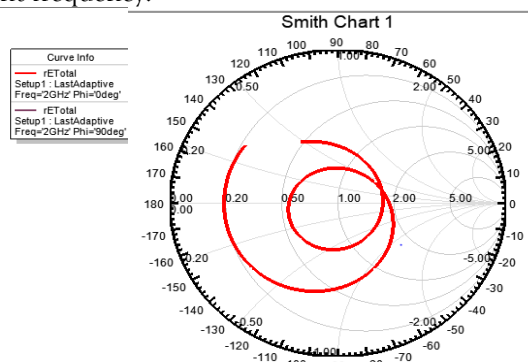


Fig g.Smith Chart

Fig f.shows the radiation pattern of the microstrip ring antenna shows a bidirectional in nature. The pattern exhibits good directivity, with strong radiation at broadside and minimal radiation at the nulls. The E-plane pattern exhibits danish-like behaviour, while the H-plane is nearly omnidirectional response. Such antennas finds in RFID, WLAN, and IoT applications.

To find input impedance, VSWR, reflection coefficient of an antenna we make use of smith chart shown in Fig g. impedance value close to the centre ($Z=50.575+j15.645\Omega$), means antenna matched with input impedance of 50Ω. At resonance the reflection coefficient is 0.1538, low reflection good matching. VSWR value 1.364 value is close to 1, good impedance matching.

VSWR: (Voltage Standing Wave Ratio) should be near 1:1 if impedance is perfectly matched

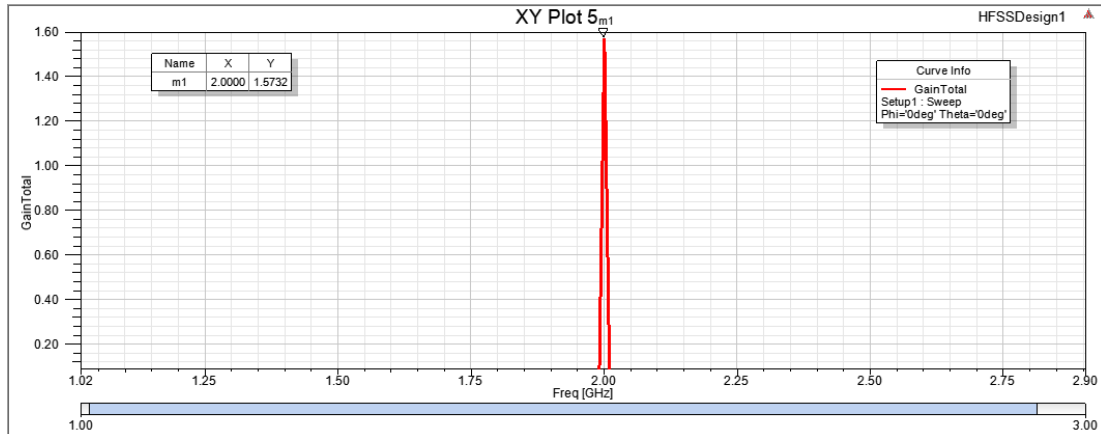


Fig h.Frequency Vs Gain plot

Fig h shows plot frequency versus gain, which depicts maximum gain at $\Phi = 0^\circ$ and $\Theta = 0^\circ$, is 1.6dB, occurs at expected 2 GHz frequency indicates boresight gain. Antenna offers narrow bandwidth .Gain increases abruptly after 2 GHz frequency. The plot shows a peak at 2.00 GHz, aligning well with the expected operating frequency.

Current distribution:

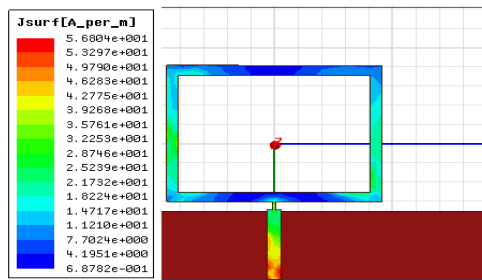
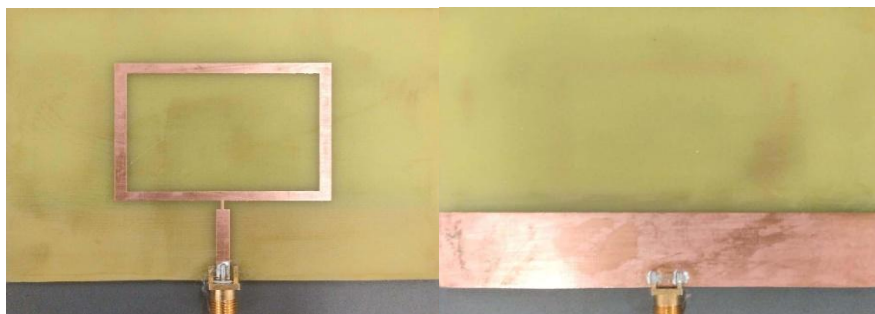


Fig I. Surface current distribution

Common fact, in micro strip antenna radiations caused by edge currents. In the suggested ring antenna, the surface current circulation along the edges of rectangular ring mainly at corners. Low surface current density observed at centre of ring antenna because of less current distribution, behaves like resonant cavity. At the feed point and at edges, the current density increases and gradually decreases towards centre. The ground below the ring also shows some current circulations. Antenna and ground plane together affects impedance characteristics.



Figj.Top view of fabricated antenna

fig k,Bottam view of an antenna

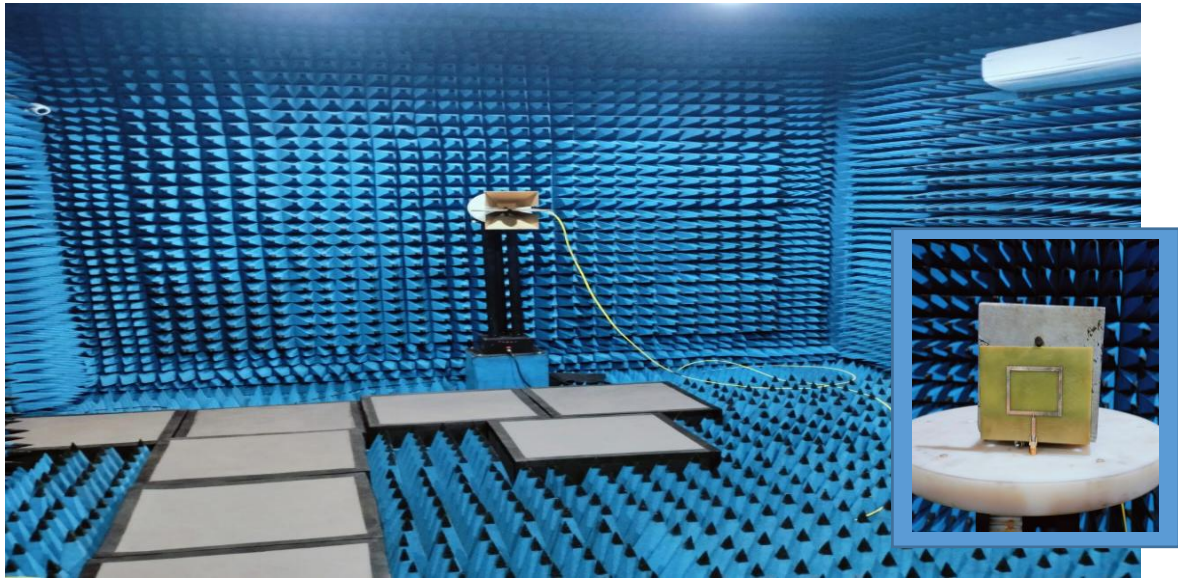


Fig 1 Antenna measurement setup

Table2.Parameters of suggested slim antenna.

| Antenna type | Radiating frequency in GHz | Return loss in dB | VSWR | BW In GHz | Directivity in dB | Gain in dB | Area In mm ² | Patch antenna Area In mm ² |
|-----------------------------|----------------------------|-------------------|------|-----------|-------------------|------------|-------------------------|---------------------------------------|
| Simulated Results | | | | | | | 308.32 | 1,617.48 |
| 4mm ring | 2.07 | -16.44 | 1.35 | 1.14 | 2.1916 | 2.5253 | | |
| Experimental Results | | | | | | | 308.32 | 1,617.48 |
| 4mm ring | 2.02 | -23.089 | 1.34 | 1. | 3.0216 | 3.1483 | | |

Table3.Compact antennas reported in literature compared with suggested antenna.

| Ref papers | Res-freq (GHz) | Antenna size in mm ² | Patch size in mm ² | Max gain in dB | BW in % | Structure type | Polarization |
|----------------------------|------------------|---------------------------------|-------------------------------|----------------|------------|----------------------------------|--------------|
| G.Singh.et al [21] | 2.48, 3.16 | 1,050 | 372 | 1.09 | 6.04, 1.94 | D- Shaped CSRR | CP LP |
| Parvathi. et al.[19] | 2.45 | 2,520 | 1250 | 3.8 | 10.48 | SQ-Splitting | CP |
| S.K.Pandey et. Al.[22] | 2.40 | 3,844 | 784 | 4.62 | 4.52 | Modified FTDGS | CP |
| M.Jafar | 2.05 | 11025 | R=38 | 1.149 | 38.23 | Slit on patch | CP |
| G.Samanta et. al.[23] | 3.7 | 1.600 | Slide length=10 | 3.24 | 9.89 | Hexa-RIS | CP |
| D.Catano-Ochoda et al.[24] | 1.997 | 3,618 | 1,516.06 | - | - | Hexagonal CSRR | LP |
| H Umair et al[25] | UWB (4-16) | 820.8 | 192 | 8.2 | 120 | Star, Square shaped slots | LP |
| Maroli S.Rao et. Al.[26] | 2.48.2.66 | 1,672.5 | 557.5 | 2.476 | 12.9 | CSISRR | CP,LP |
| Proposed antenna | 1.28 2.07 | 1,617 | 308.32 | 3.1483 | 57 | Rectangular ring with DGS | CP,LP |

RESULT DISCUSSION: In this section, we discussed various parametric analysis of proposed compact antenna of suggested shape constructed with the given specifications achieved multiple frequencies. The antenna modelled with HFSS tool. The modelled and experimental results, such as return loss (S_{11} plot), Voltage standing wave ratio (VSWR), Total gain, current distribution are tabulated in table 2. The simulated resonating frequency 2.07GHz is slightly higher than practical 2.02GHz due to some fabrication or tolerance facts. Experimental (-23.089dB) return loss is high compared to (-16.0004dB) simulated values. Achieved better impedance matching in real time applications. VSWR values matched closely. Simulated 1.14GHz bandwidth, slightly higher than experimental 1.02GHz. Directivity with gain results are higher than practically, means good real time applications,.

CONCLUSION: Good agreement between practical and simulated results of proposed 4mm ring antenna. Enhancement in Gain and return loss of fabricated antenna compared to simulated antenna. Suggesting better real-time efficiency. The compact size (308.32 mm²) makes it a space-efficient alternative to larger patch/ring antennas, while maintaining good performance. Such ring antennas finds applications in L and S band applications.

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