International Journal of Innovative Research in Engineering & Management (IJIREM)
ISSN: 2350-0557, Volume-8, Issue-1, January 2021
https://doi.org/10.55524/ijirem.2021.8.1.2
www.ijirem.org

Negative Indexed Material Inspired Patch Antenna for 5g Communication

S. Vasantha Swamy NathanV
Associate Professor, Department of Electronics and Communications Engineering, PACE Institute of Technology & Sciences, Ongole, AP, India

Vishnuvardhan
Assistant Professor, Department of Electronics and Communications Engineering, PACE Institute of Technology & Sciences, Ongole, AP, India

G. J. Jyothi
UG student, Department of Electronics and Communications Engineering, PACE Institute of Technology & Sciences, Ongole, AP, India

B. Manisha
UG student, Department of Electronics and Communications Engineering, PACE Institute of Technology & Sciences, Ongole, AP, India

M. Sireesha
UG student, Department of Electronics and Communications Engineering, PACE Institute of Technology & Sciences, Ongole, AP, India

B. Venkata Siva
UG student, Department of Electronics and Communications Engineering, PACE Institute of Technology & Sciences, Ongole, AP, India

ABSTRACT
This paper proposes a different info various yield) receiving wire for 5G based vehicular correspondence applications. A planned rectangular antenna reception apparatus comprises of two components T-shaped radio wire with surrendered ground structure (DGS) and split ring resonator (SRR). The presented antenna results a reflection coefficient is less than or equal to 10dB and having a bandwidth of 6.2GHz and 3.97GHz with a frequency range of 26.82 to 33.13 GHZ and 34.17 to 38.14 GHz respectively, achieves a peak gain of 7.11 in operating band and also it results a resonant frequency are 28GHz, 33GHz, and 37GHz in op which are useful for vehicular mm wave communications. The design is fabricated with the dimensions of 12 x 25.4 x0.8 mm with the substrate of Roger RT duriod 5880 with a dielectric constant of 2.2

Keywords
5g Communication, MTM CELLS

1. INTRODUCTION
From the previous few decades, we have experienced four ages of cell correspondence and still there is an immense transmission capacity deficiency around the planet [1]. Mille-metric wave innovation will have immense interest and it will be utilized in wide scope of uses and interest for increment in information rates likewise [2]. Ongoing days there is a tremendous group in the sub-3 GHz range in this way, range between 3-30 GHz range (SHF) and 30-300 GHz range (EHF) is left unutilised and having the frequency going from 1mm-100mm [3]. In any case, a portion of the issues are related in this mille-metric wave range like blurring, weakening and retention [4]. At times concerning environment, there is an ascent of weakening and retentions of the millimetre wave [5].
MIMO (Multiple-input numerous yield) receiving wires are under exploration and they are having properties like huge channel limit due to multi-radio wires and can be utilized to get higher information rates [6]. A few MIMO receiving wires are currently available, and some MIMO radio wires operate in both high and low frequencies for different applications [7]. Designing a MIMO reception system that operates at millimetre wave frequencies allows for greater flexibility, high productivity, and less multipath blurring [8]. Higher addition, greater information speeds, higher throughput, and unwavering quality are all possible with MIMO radio wire. Little shared coupling between neighbouring receiving wires is necessary to achieve the aforementioned features [9]. Firmly dispersed micro strip MIMO reception apparatuses have common coupling issues, so according to the necessity we need low shared coupling between receiving wires in MIMO structure. There are not many endeavours that were made to diminish the common coupling [10-12]. In [13], The writer proposed a flower shaped antenna with a split ring resonator placed at a rectangular patch, in this paper it has observe that multi bands and a peak gain of 4dB and efficiency of radiation is 87%. The main reasons to abandon fixed radio cables are the reduced gain and data transfer, but this can be done by employing a few techniques. One way to enhance the reception apparatus boundaries, such as transfer speed and gain, is through abandoned ground constructions [14]. DGS refers to a configuration of ground plane distortion in the receiving wire. By changing the current dispersion in the ground plane, these flaws can alter boundaries like capacitance and inductance. [15-16]. We can incorporate DGS at various points in the ground plane while planning the reception equipment to obtain the required results [17]. A familiarity with obtain conservatism, high transfer speed, and low plan complexity can be gained through abandoned ground structures [18–19]. The receiving apparatus boundaries can be improved by using abandoned ground structures that combine SRRs and CSRRs [20]. For 5G correspondence applications, scientists anticipated on receiving wire models with smaller DRA models [21–22]. Alhalabi [23] suggests a high proficiency dipole display radio wire for millimetre wave applications. Receiving with low shared coupling MIMO.
In this paper an alternate T-formed MIMO reception apparatus with deserted ground construction and CSRR is intended for vehicular correspondence applications and 5G organizations. The proposed radio wire offers a little data transfer capacity at miller-metric wave frequencies with great execution attributes. Two radio wire components are organized one next to the other straight to frame MIMO structure. Plan and recreation of the MIMO receiving wire is done through ANSYS HFSS and vehicular arrangement is done in ANSYS SAVANT apparatus.

2. RESULT ANALYSIS

The proposed Wideband Rectangular Antenna is carried out into three iterations. The underlying plan of the proposed antenna is displayed in the Fig. 3.1. The basic Rectangular curved CPW Fed antenna is presented.

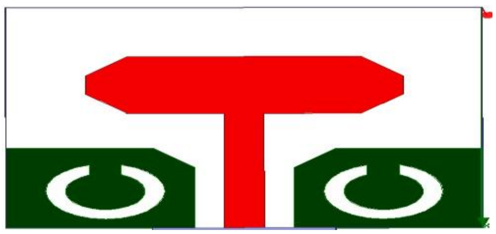


Figure 1: Rectangular CPW Fed antenna

The Elliptical curved CPW Fed antenna is designed on substrate material FR-4 epoxy is uses with loss tangent is 0.02 and εr=4.4. The dimensions are 44×40mm ×1.6mm of the substrate. A pair of ellipse-shape-combined design is employed with the radius of R1 16mm and R2 15mm in dimensions. The feed line is incorporated with the substrate with thickness 1mm. The feed length and width of the substrate are 3×24 mm is utilized. The dimension of the Elliptical curved CPW Fed antenna is shown in the table 3.1.

The attractive reaction in the proposed reception apparatus is because of holes in CSRR. The technique to get identical model of the circuit to put the capacitors and inductors according to the use of rings and seeing if the CSRR is of metal or carved on a metal. We have picked a few estimations of length and expansiveness of the bigger and more modest rings as per the proposed conditions. The same circuit and demonstrating of the CSRR is motivated from [20] and are represented in Fig 1.

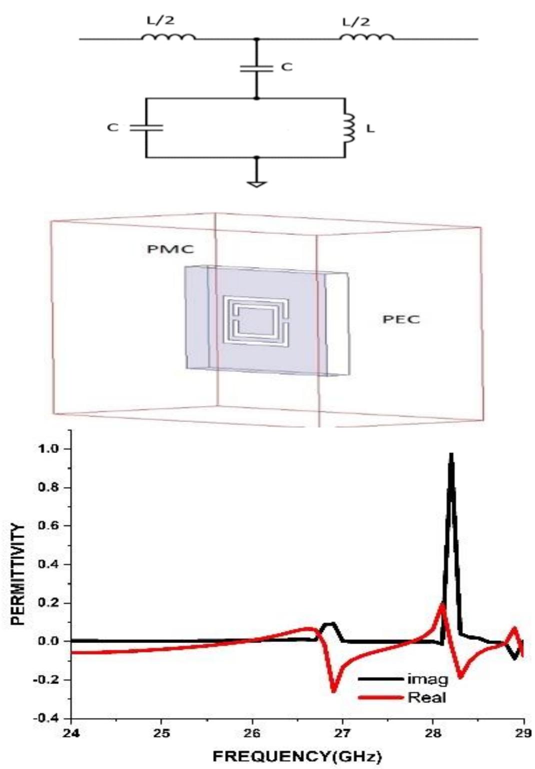


Figure 2: CSRR Equivalent Circuit (a) CSRR (b) Unit cell analysis (c) permittivity vs frequency plot

2.1 Antenna Design

The equations of this design are to calculate the antenna sizes as follows

The operating wavelength $\lambda_0 = c / f_r$

Where 'C' is the speed of the light and 'f_r' is the resonant frequency

Guide wavelength $\lambda_g = \lambda_0 / \sqrt{\varepsilon_r}$

Relative dielectric constant = ε_r

Substrate thickness

$$h_s \le \frac{0.3 * c}{2\pi f_r \sqrt{\varepsilon_r + 1}}$$

Strip width

$$w_s = \frac{c}{2 f_r} \sqrt{\frac{2}{\varepsilon_r + 1}}$$

Effective dielectric constant

$$\varepsilon_{reff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left[\left(1 + \frac{12 h_s}{w_s}\right)^{-\frac{1}{2}} + 0.04\left(1 - \frac{w_s}{h_s}\right)^2\right]$$

(F) Effective length

$$\Delta L = 0.412 * h_s \left\{\frac{\varepsilon_r + 0.3}{\varepsilon_r - 0.258}\right\}\left\{\frac{\frac{w_s}{h_s} + 0.264}{\frac{w_s}{h_s} + 0.813}\right\}$$

(G) patch length

$$L_d = \left\{\frac{c}{2 f_r \sqrt{\varepsilon_{reff}}}\right\} - 2\Delta L$$

Table 1: Dimensions of Antenna in mm

Parameter of Antenna	Dimension in mm
L_s	44
W_s	40
R_1	16
R_2	15
L_f	24
W_f	3
H	1.6

2.2 Analysis and Results

The parameters which are significant to design antenna are, VSWR, reflection coefficient, impedance, radiation pattern, smith chart, gain vs frequency and efficiency, current distribution is simulated, and the parametric analysis of the projection were implemented by HFSS tool.

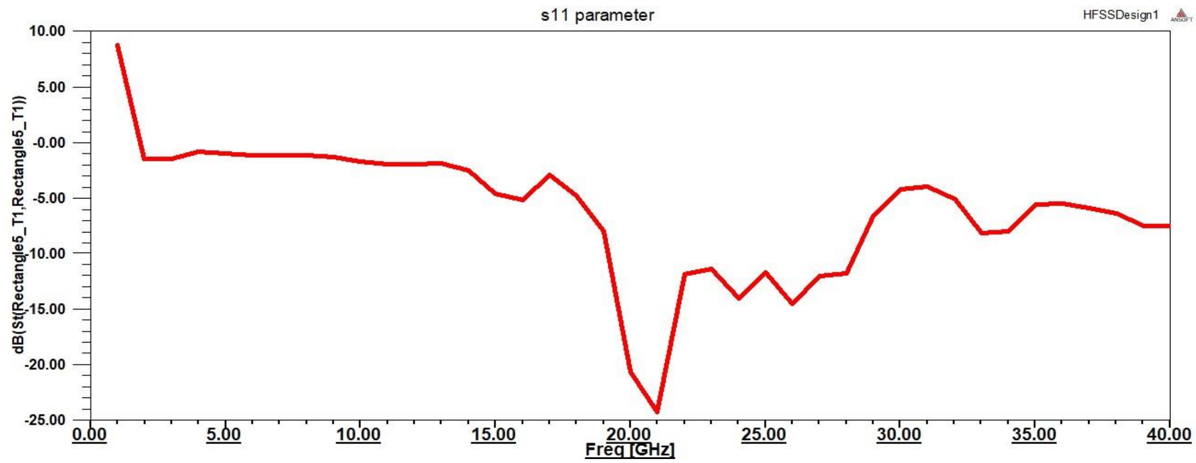


Figure 3: Rectangular CPW Fed Antenna Reflection Coefficient

The Fig 3.2 displays the reflection coefficient of the basic projected antenna Elliptical curved CPW Fed antenna has the resonant frequencies from 2.9 GHz – 13.5 GHz with a bandwidth of -13dB to -23dB. From this the presented antenna has perfect bandwidth for the reflection coefficient less than to -10dB

The reflection coefficient is executed by implementing HFSS (High Frequency Structure Simulator Software). 'Voltage Standing Wave' (VSWR proportion) is commonly utilizes to gauge the impedance crisscross. The Fig 3.3 displays the VSWR which is (1<VSWR<2). The Fig. 3.4 displays the Elliptical curved CPW Fed Antenna Impedance. The impedance of Elliptical curved CPW Fed antenna is not stable and fluctuates in between 30 ohms to 80 ohms. The Fig. 3.5 displays the Elliptical curved CPW Fed antenna smith chart.

S

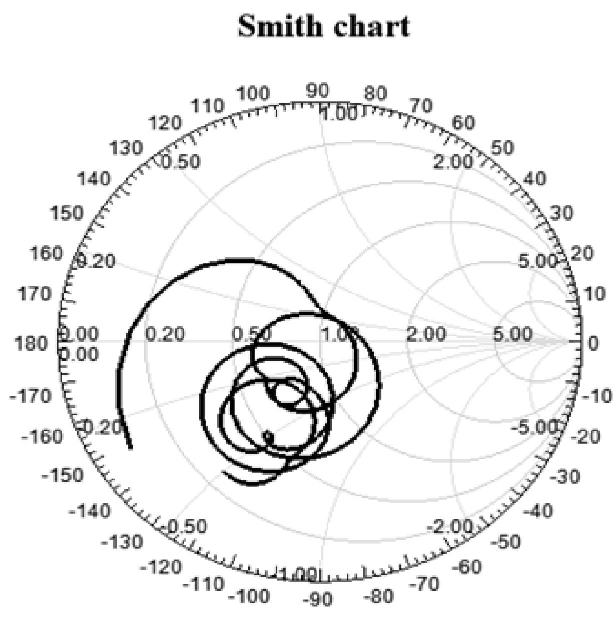
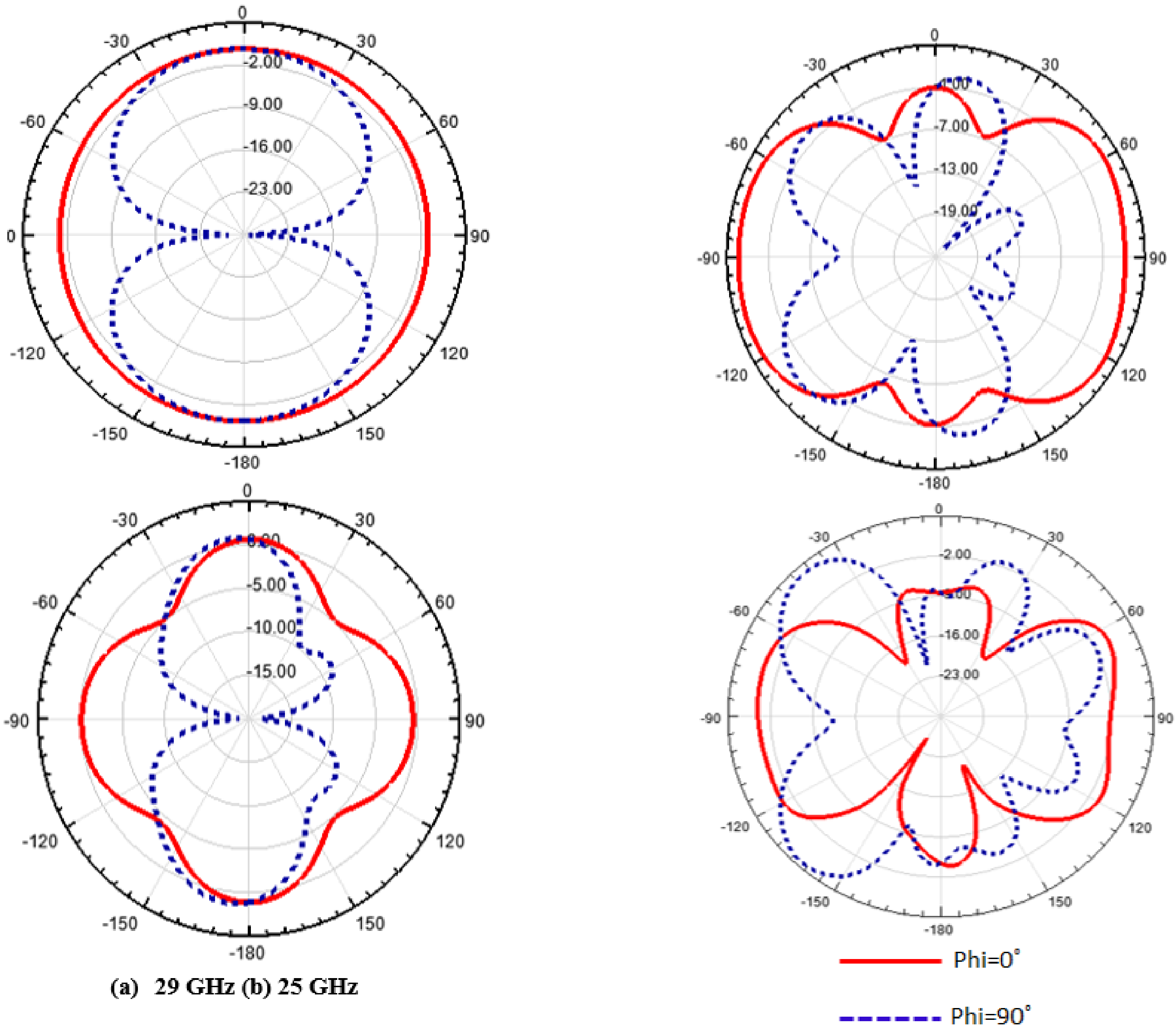


Figure 4: CPW Fed antenna Smith Chart

A curved co-planar wave-guide(CPW) fed antenna in an Elliptical shape radiation patterns has been designed and stimulated in Ansys electronic deskstop-20. To differentiate the power radiated from the antenna radiation patterns has been used. In below figure, the differentiate of the graphs of the radiated power as shown below. 2.9, 6.9, 9.0 and 13.4GHz are resonant frequencies plotted in E-plane and H-plane of the proposed antenna The Fig. 5 demonstrates the 2D radiation designs at the resonant frequencies with phi=0˚ indicates the red colour line and phi=90˚ indicates blue colour line.

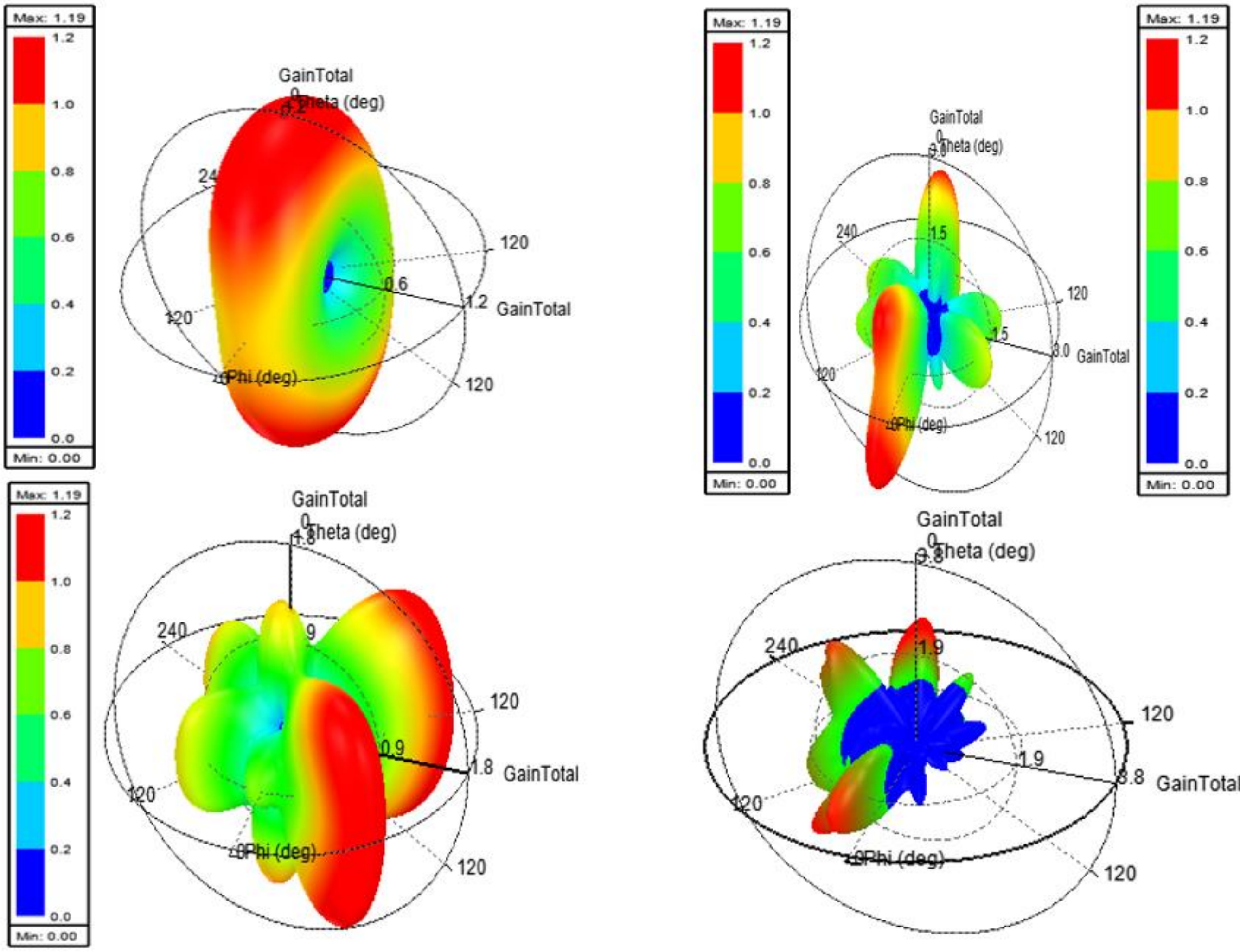


(a) 29 GHz (b) 25 GHz

(c) 35 GHz (d) 33.4 GHz

Figure 5: CPW Fed Antenna Radiation Pattern operating at various frequencies at 2D in E-H plane (a) 29 (b) 25 (c) 35 (d) 33.4 GHz

The above Fig 5 displays the radiation patterns in 2D the antenna radiates in Omni direction which is shown at the resonant frequency 2.9 GHz at phi=0˚ and the antenna radiates in dumbbell shape direction at phi=90˚. At some another resonant frequencies the antenna radiates in classy Omni- directional and in squeezed dumbbell shapes. The Fig 3.7 displays the Elliptical curved CPW Fed Antenna Radiation Pattern operating at various frequencies at 3D in E-H plane (a) 29 (b) 25 (c) 35 (d) 33.4 GHz. The resonant frequency at 2.9GHz the antenna radiates as donut shape or toroidal shape.



(a) 29 (b) 25 (c) 35 (d) 33.4 GHz

Figure 6: CPW Fed Antenna Radiation Pattern operating at various frequencies at 3D in E-H plane (a) 29 (b) 25 (c) 35 (d) 33.4 GHz

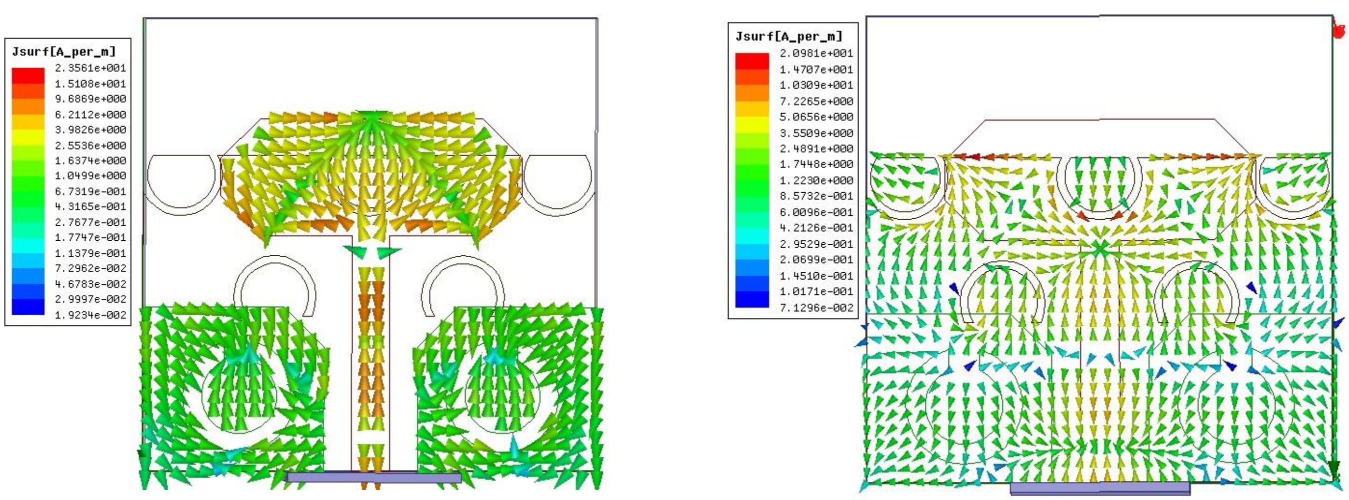


Figure 6: CPW Fed Antenna Radiation Pattern operating at various frequencies at 3D in E-H plane (a) 29

The Fig. 3.8 displays the current distributions of the Elliptical curved CPW Fed antenna different resonant frequencies in electric field is at 2.9, 6.9, 9 and 13.4GHz. The strong surface current shown in Fig 3.8 flows at the feed is more and flows less at the patch of the antenna are appropriately good. The Fig. 3.9 displays current distributions of the Elliptical curved CPW Fed antenna different resonant frequencies in magnetic field is at 2.9, 3.9, 9 and 13.4GHz The Table.3.2 displays the plots of Gain/Radiation Efficiency Vs Frequency. A pinnacle acknowledged gain of more than 5.5 dB has the proficiency of 70%. The Table 3.10 demonstrates the estimations of the gain and productivity of the Elliptical bended CPW Fed antenna at the full frequencies.

3 CONCLUSION

In this paper, we offer a decreased T-molded MIMO radio wire with CSRR for 5G cell organisations and vehicular correspondence applications. The proposed MIMO reception device model reportedly captures 11.7GHz's purportedly wide data transmission. Receiving wire plans with free parting resonators on the front side and symmetric parting resonators as hidden ground structures play a significant role in the improvement of data transmission and gain. The impedance data transfer capability, acquisition, radiation characteristics, ECC, and DG of the proposed MIMO radio wire are all being explored and tested. Using ANSYS SAVAT, the suggested reception device is tested in a vehicle environment at four different locations. The calculated radiation characteristics of the constructed model agree reasonably with the mimicked radiation properties in the vehicle climate. due to its large transmission capacity,

REFERENCES

[1] Venkateswara Rao, M., Madhav, B. T., (2019). CSRR-loaded T-shaped MIMO antenna for 5G cellular networks and vehicular communications. International Journal of RF and Microwave Computer-Aided Engineering, 29(8), e21799.

[2] Rao, M. V., Madhav, B. T. P., (2018). Metamaterial inspired quad band circularly polarized antenna for WLAN/ISM/Bluetooth/WiMAX and satellite communication applications. AEU-International Journal of Electronics and Communications, 97, 229-241.

[3] Venkateswara Rao, Manikonda, et al. "Circularly polarized flexible antenna on liquid crystal polymer substrate material with metamaterial loading." Microwave and Optical Technology Letters.

[4] Madhav, B. T. P., Rao, M. V., (2018). Conformal Band Notched Circular Monopole Antenna Loaded with Split Ring Resonator. Wireless Personal Communications, 103(3), 1965-1976.

[5] Prudhvi Nadh, B., Madhav, B. T. P., & Venkateswara Rao, M. (2019). Circular ring structured ultra-wideband antenna for wearable applications. International Journal of RF and Microwave Computer-Aided Engineering, 29(4), e21580

[6] Madhav, B. T. P., Venkateswara Rao, M., (2018). Asymmetric ground structured circularly polarized antenna for ISM and WLAN band applications. Progress in Electromagnetics Research, 76, 167-175.

[7] Deepak, Bandhakavi Srikanth, Madhav B T P, M Venkateswararao et al. "Design and analysis of hetero triangle linked hybrid web fractal antenna for wide band applications." Progress In Electromagnetics Research 83 (2018): 147-159.

[8] Prudhvi Nadh, B., Madhav, B. T. P., Siva Kumar, M., Anilkumar, T., Venkateswara Rao, M., & Kishore, P. V. V. (2020). Windmill-shaped antenna with artificial magnetic conductor-backed structure for wearable medical applications. International Journal of Numerical Modelling: Electronic Networks, Devices and Fields.

[9] Tilak, G. B. G., Kotamraju, S. K., Madhav, B. T. P., Sri Kavya, K. C., & Venkateswara Rao, M. (2020). Dual sensed high gain heart shaped monopole antenna with planar artificial magnetic conductor. Journal of Engineering Science and Technology, 15(3), 1952–1971.

[10] Anilkumar, T., Madhav, B. T. P., Venkateswara Rao, M., & Prudhvi Nadh, B. (2020). Bandwidth reconfigurable antenna on a liquid crystal polymer substrate for automotive communication applications. AEU - International Journal of Electronics and Communications, 117.

[11] Vinitha, M Sivakumar,B T P Madhav,M Venkateswararao [2020] Srr Based Tri-Mode Resoanant Microstrip Bandpass Filter For Wlan Applications. Journal of Engineering Science and Technology, Article in Press

[12] Venkateswara Rao, M., Madhav, B. T. P., Naveen, T., Sai Prashanth, N., & Niharika, B. (2019). Met material loaded rectangular monopole antenna with ultra-wideband applications. International Journal of Recent Technology and Engineering, 8(1), 1573–1576.

[13] Madhav, B. T. P., Venkateswara Rao, M., (2018). Compact metamaterial inspired periwinkle shaped fractal antenna for multiband applications. International Journal of Engineering and Technology(UAE), 7(1.1), 507–512. https://doi.org/10.14419/ijet.v7i1.1.10157

[14] Madhav, B. T. P., Thirumalarao, K., Rao, M. V., (2018). Metamaterial inspire multiband monopole antenna with defected ground structure. International Journal of Engineering and Technology(UAE), 7(1.5 Special Issue 5), 90–96. https://doi.org/10.14419/ijet.v7i1.5.9128

[15] Priyadharshini, B., Madhav, B. T. P,Venkateswara Rao, M (2019). A compact semi square split ring resonator slotted flag shaped mimo antenna for band notched uwb applications. International Journal of Recent Technology and Engineering, 8(1), 3011–3018.

[16] Kishore, M. P., Madhav, B. T. P., & Rao, M. V. (2019). A CPW-fed elliptically curved antenna design for multiband operation with metamaterial loading. International Journal of Innovative Technology and Exploring Engineering, 8(7), 120–125.

[17] Sanam, N., Madhav, B. T. P., Venkateswara Rao, M. (2019). A flag-like MIMO antenna design for wireless and IoT applications. International Journal of Recent Technology and Engineering, 8(1), 3023–3029.

[18] Naik, D. K., Madhav, B. T. P., Krishna, J., Venkateswara Rao, M., (2019). CSRR loaded miniaturized 5G antenna for vehicular communication appliance. International Journal of Innovative Technology and Exploring Engineering, 8(7), 786–791.

[19] Raghavaendra Rao, P., Madhav, B. T. P., Deepthi, C. H., Venkateswararao, M., (2019). Design and analysis of multi-band met material antenna for wireless and IOT applications. International Journal of Recent Technology and Engineering, 8(1), 334–340.

[20] Anilkumar, T., Madhav, B. T. P., Hawanika, Y. S., Venkateswara Rao, M., & Prudhvi Nadh, B. (2019). Flexible liquid crystal polymer based conformal fractal antenna for Internet of Vehicles (IoV) applications. International Journal of Microwave and Optical Technology, 14(6), 423–430.

[21] Saravanan, R. A., Madhav, B. T. P., Venkateswararao, M., (2019). Frequency and pattern reconfigured multi band cpw

antenna for wimax and x-band applications. International Journal of Innovative Technology and Exploring Engineering, 8(6), 1202–1208.

[22] Sai Sivakumar, B., Pardha Saradhi, P., Madhav, B. T. P., Venkateswara Rao, M., & Kesava Sai, G. (2019). Meta-material inspired monopole antenna for LTE/bluetooth/Wi-max subsystems. International Journal of Recent Technology and Engineering, 8(1), 3019–3022.

[23] Pokkunuri, P., Madhav, B. T. P., Sai, G. K., Venkateswararao, M., (2019). Metamaterial inspired reconfigurable fractal monopole antenna for multiband applications. International Journal of Intelligent Engineering and Systems, 12(2), 53–61. https://doi.org/10.22266/ijies2019.0430.06

[24] Kishore, M. P., Madhav, B. T. P., & Rao, M. V. (2019). Metamaterial loaded elliptical ring structured mimo antenna. International Journal of Engineering and Advanced Technology, 8(6), 1798–1801. https://doi.org/10.35940/ijeat.F8457.088619

[25] Madhav, B. T. P., Babu, M. A., Kumar, P. V. S. P., Rao, M. V., (2018). Cylindrical Structured Multiple-Input Multiple-Output Dielectric Resonator Antenna. In Lecture Notes in Electrical Engineering (Vol. 471, pp. 589–597). Springer Verlag. https://doi.org/10.1007/978-981-10-7329-8_60

[26] Saleem Akram, P., Madhav, B. T. P., Jeevana Sravya, G., Sudhakar, V., Lakshmi Sirisha, G., Mounika, C., & Venkateswara Rao, M. (2018). Design and analysis of square shaped serrated patch antenna for ultra-wideband applications with single rejection band. International Journal of Engineering and Technology(UAE), 7(1.1), 525–529. https://doi.org/10.14419/ijet.v7i1.1.10160

[27] Ajay Babu, M., Madhav, B. T. P., Bhargavi, G., Sai Krishna, V., Hemanth Kumar Reddy, Y., Kalyan, G. V. S., & Venkateswara Rao, M. (2018). Design and analysis of stepped reconfigurable rectangular patch antenna for LTE, vehicular and ultra wideband applications. International Journal of Engineering and Technology(UAE), 7(1.1), 548–553. https://doi.org/10.14419/ijet.v7i1.1.10164

[28] Vasujadevi, M., Madhav, B. T. P., Shiva Skandan, A., Rajeswari, P., Arjun Rao, K., Khyathi Reddy, K., & Vekateswara Rao, M. (2018). Maple leaf shaped array antenna for multiband applications. International Journal of Engineering and Technology(UAE), 7(1.1), 494–499. https://doi.org/10.14419/ijet.v7i1.1.10153

[29] Ramakrishna, T. V., Madhav, B. T. P., Venkateswara Rao, M., Babu Rao, A., Sunaina, A., Avinash, A., & Shivani, B. (2018). SRR loaded half -mode substrate integrated waveguide monopole slot antenna for multband applications. International Journal of Engineering and Technology(UAE), 7(1.1 Special Issue1), 560–564. https://doi.org/10.14419/ijet.v7i1.1.10166

[30] Madhav, B. T. P., Reddy, V. S., Reddy, D. R., Sankar, K. R., Ramanujan, E. V. S. H., Prakash, V. V. S., & Rao, M. V. (2018). Tree shaped fractal antenna with multiband characteristics. International Journal of Engineering and Technology(UAE), 7(1.1 Special Issue1), 333–338. https://doi.org/10.14419/ijet.v7i1.1.9847

[31] Sujatha, M., Madhav, B. T. P., Prakhya, V., Akhila, B., Gowtham, N., Mozammil, S., & Rao, M. V. (2018). Tristrip monopole antenna with split ring resonators for ism band biomedical applications. Indian Journal of Public Health Research and Development, 9(6), 301–305. https://doi.org/10.5958/0976-5506.2018.00568.5

[32] Madhav, B. T. P., Khan, H., Sri Harsha, B., Sai Kumar, P., Lavanya, M., Veena, K., & Venkateshwara Rao, M. (2018). X-Slotted circularly polarized antenna with parasitic patches. International Journal of Engineering and Technology(UAE), 7(1.1), 534–538. https://doi.org/10.14419/ijet.v7i1.1.10162

[33] Madhav, B. T. P., Subbareddy, V., Venkateswara Rao, M., (2017). A high gain metamaterial inspired vivaldi antenna for ultrawide band applications. Journal of Advanced Research in Dynamical and Control Systems, 9(Special Issue 14), 2078–2086

[34] Madhav, B. T. P., Sai Santosh, T., Venkateswara Rao, M., Sai Manikanta, S., Srinivas, K. B. V., & Hanumath Sastry, J. (2017). A novel ultra wideband mimo antenna with wimax band notch characteristics. Journal of Advanced Research in Dynamical and Control Systems, 9(Special Issue 14), 2094–2103.

[35] Subbareddy, V., Madhav, B. T. P., Prathyusha, S., Gopi Janardhan, G., Kalpanath, N., & Venkateswara Rao, M. (2017). A printed staircase serrated CPW antenna for UWB applications. ARPN Journal of Engineering and Applied Sciences, 12(15), 4483–4488.

[36] Pardhasaradhi, P., Madhav, B. T. P., Vineel, M., Meghanadh Sai, K., Sharmada, M. R., Rahul, M., & Venkateshwara Rao, M. (2017). Bow-tie slot antenna for WLAN/WiMAX communication systems. Journal of Advanced Research in Dynamical and Control Systems, 9(Special Issue 14), 1840–1849.

[37] Prakash, B. L., Madhav, B. T. P., Lokesh, T., Sri, Y. R., Aditya, N. V. D. S., & Rao, M. V. (2017). Metamaterial inspired tri-band antenna with SRR and Shorting STUB. ARPN Journal of Engineering and Applied Sciences, 12(21), 6197–6205.

[38] Madhav, B. T. P., Reddy, M. V. K. C., Rao, M. V., Krishna, C. M., Raj, P. C., & Jaya, G. (2017). Quad band filtenna using split ring resonators to notch unwanted frequencies in medical application bands. Journal of Theoretical and Applied Information Technology, 95(9), 2070–2077.

[39] Tilak, G. B. G., Kotamraju, S. K., Madhav, B. T. P., Sri Kavya, C., & Venkateswara Rao, M. (2019). Broken heart shaped monopole antenna for WiMAX applications. International Journal of Recent Technology and Engineering, 8(2), 2333–2337.

[40] Anilkumar, T., Madhav, B. T. P., Venkata Abhiram, R., Nikhil Sai Radhesh, K., Harish, J., & Venkateswara Rao, M. (2021). Analysis of CPW-Fed Modified Z-Shaped Reconfigurable Antenna for Automotive Communications. In Lecture Notes in Electrical Engineering (Vol. 655, pp. 709–717). Springer. https://doi.org/10.1007/978-981-15-3828-5_74

[41] Lakshmi, M. L. S. N. S., Madhav, B. T. P., Khan, H., Venkateswara Rao, M., & Madhumati, G. L. (2020). Triple notch reconfigurable parasitic monopole patch antenna with defected ground structures. International Journal of Microwave and Optical Technology, 15(4), 318–324

