Triple Band Textile Array Antenna with Enhanced Gain and Low SAR for Off Body Communication Applications

[1]VSD Rekha, [2]M Padmanabharaju, [3]B T P Madhav, [4]S S Mohan Reddy
[1]Assistant Professor, Department of ECE, P V P Siddhartha Institute of Technology, Vijayawada, AP, India
[2]Asst. Professor, Dept of ECE, Shri Vishnu Engineering College for Women, Bhimavaram, India
[2]Professor, Dept. of ECE, Koneru Lakshmaiah Education Foundation, India
[3]Associate Professor, Dept. of ECE, SRKR Engineering, Bhimavaram, India

Abstract: A triple band wearable microstrip patch antenna array has been designed and analyzed in this work. The designed antenna can be operated in ISM, LAES and X-Band with moderate average gain of 4.2 dB. The antenna gain has been improved by constructing array structure of 1X2 and 1X4 with good impedance feeding by quarter wave transformer. The proposed array antennas are providing moderate gain of 5.7 dB (1X2) and 8.3 dB (1X4) with efficiency more than 90% in the operating bands. The antenna model and the array has been constructed on wearable substrate with conductive textile as radiating element in the design for off body wearable communication applications. SAR analysis also providing acceptable values below 1.6 w/kg at triple operating bands with body placement experimentation.

Keywords: Specific Absorption Rate (SAR), Triple Band, Textile Antenna, Wearable Communications

1. Introduction: Recent developments in communication systems antennas plays a vital role to receive and transfer the information. For this antenna with high gain and high data rates with large channel capacity is required [1-2]. For this, antenna arrays plays a vital role to attain above characteristics [3]. In smart textile antennas having high potential for revolutionize life in many aspects. These antennas have wide range of applications like medical monitoring, sports, sensing and in emergency applications [4-5]. To avail this application key component is textile antenna which can wireless transfer the data from on-body communication device. To design the wearable antenna should have robustness and comfort when worn. While designing the textile-based antennas lot of challenges regarding the material selection, conductivity of radiating elements, deformation when washed, crumpling effects, and coupling effects when antenna is placed on the human body [6-8]. All these factors degrade antenna performance while placing antenna on human body. To overcome that array antenna is used to improve the gain and efficiency of antenna to over some of the drawbacks compared to monopole antenna [9-10].

To design the textile based wearable antenna should have conductive textile materials know as electro textiles enables manufacturing of wearable antennas. These electro textiles are designed using conductive threads on embroidery machine or by interpolating non-conductive fabric thread with thin conductive alloys of metals [11-14]. The embroidered textiles give isotropic patterns for which conductivity depends on the current flow direction of pattern and stitching density. In most of the literature gives electrical characterisation of electro textiles. If the conductive threads are placed along the edge surface which keep the conduction losses minimum [15-16]. The electro textile wearable UHF RFID antenna with embroidered patch is presented. The design of wearable array antennas is very in the literature because of complexity and textile-based antenna provides low gains when loaded on human body due to variation of dielectric properties of human layers [17-18]. The textile-based array antenna improves the gain even when loaded to humans. In the available literature microstrip patch array antenna is designed for the cover different wireless applications [19-20]. The paper presents 4 X 4 array patch antenna for communication purpose, and this have 1 x 2, 2 x 2 and 4 x 4 are computed to cover KU-band applications. Choi [21] presented high gain antenna with 2 x 8 array with each element is separated by a distance of $\lambda_g/2$. the 2 X 1 array patch antenna is designed to cover 7.642 GHz with defected ground structure to improve the gain. The 8 x 2 array antenna with 16 elements is presented on

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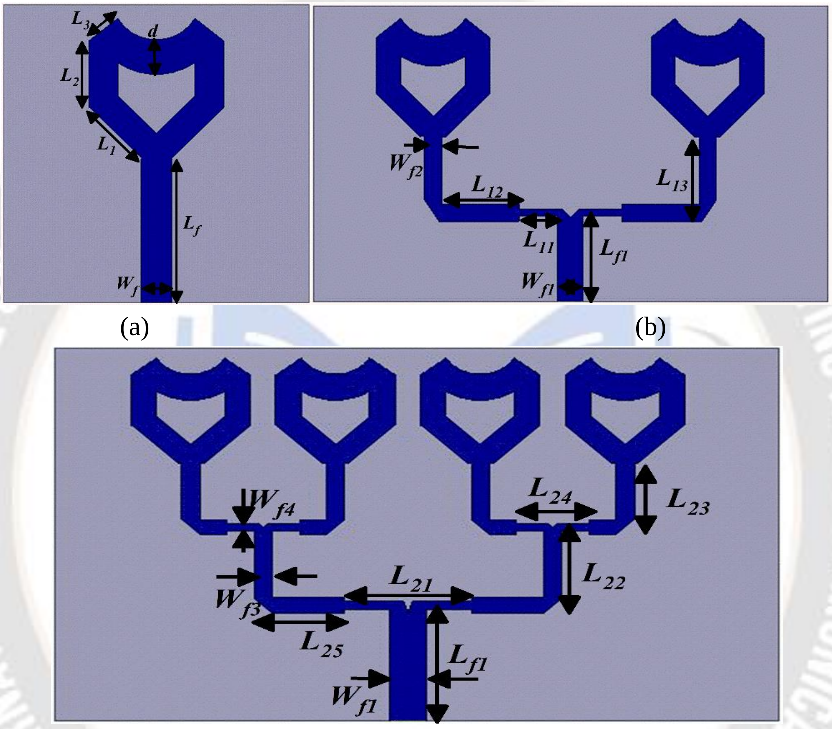
FR4 substrate with overall dimensions 244 x 107 mm^2 with spacing between the elements of $\lambda_g/2$ and covers ISM band applications [22-25].

2. Antenna Design: In this paper the design of wearable textile array antenna with single monopole antenna on the jeans substrate which has dielectric constant of 1.6 and loss tangent of 0.04. The design of feed network is done, to reach signal to array elements in same way. For this, T-junction is used at the feed point which are placed at three discontinuities which are known as a, b, c. the point a is one of the main T-junction, which divides the signal equally in both sides of elements. This type of discontinuity acts as impedance transformer which helps in impedance matching in microstrip line feeds. The point c discontinuity is designed to introduce flexibility in the feed network layout. The cuts at the edges of the feed network is to compensate the losses due to its discontinuity and feed network is calculated using [26-30] presented in literature.



(c)

Fig 1. Wearable Array Antenna Evolution, (a) Single Element, (b) 1X2 Array, (c) 1X4 Array

Tab.1 Antenna dimensions of array antenna

Parameter	L_f	L_{f1}	L_1	L_2	L_3	d_1	L_{21}	L_{23}	L_{24}
Value	14.5	11	7.2	6.7	3.5	3.5	9	9.5	8
Parameter	W_f	W_{f1}	L_{11}	L_{12}	L_{13}, L_{25}	W_{f2}	L_{22}	W_{f3}	W_{f4}
Value	3	3	5	9	10	2	11	2	1

3. Results and Discussions: The simulation characteristics of the designed models are presented in Fig 2. Single element, two elements and four elements-based models S_{11} is analyzed and found triple band characteristics with no variation in the bandwidth except the reflection coefficient level variations. The designed models are working in ISM, LAES and X-band communication applications

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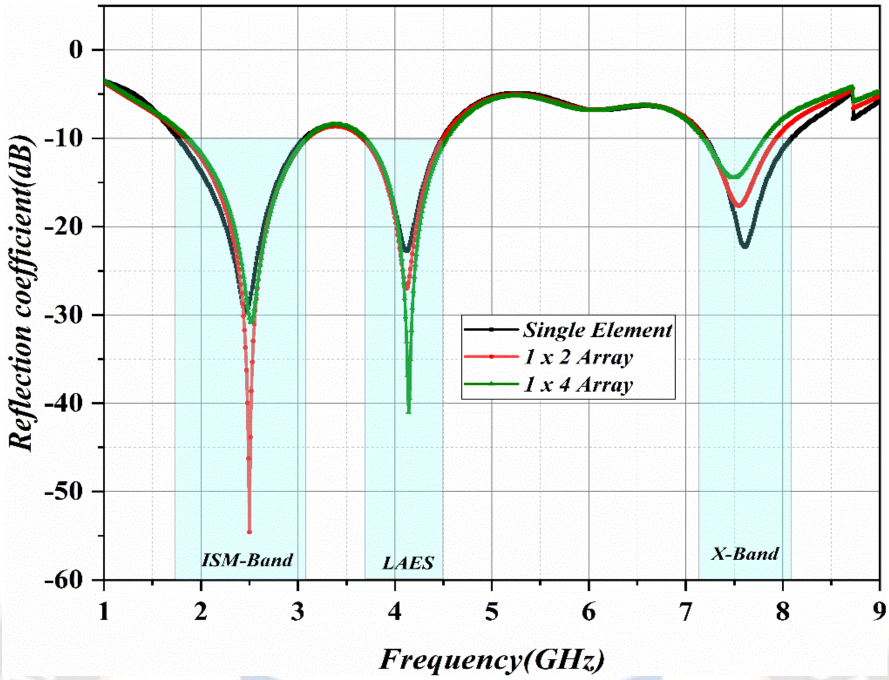
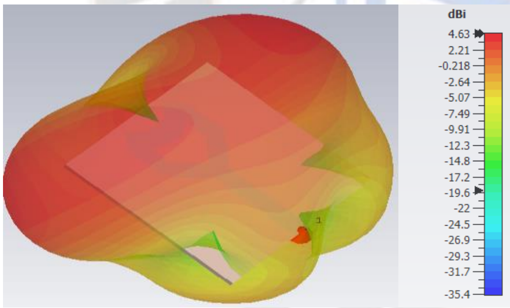
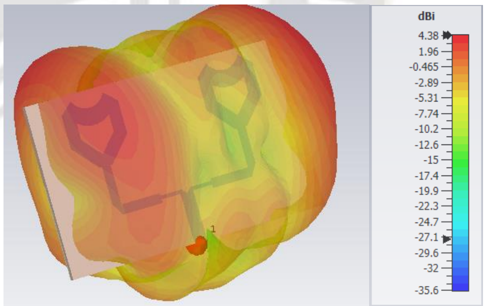


Fig 2. Frequency Vs S_{11} of designed models

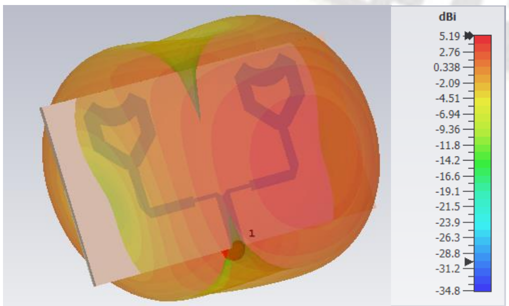
The antenna gain is analyzed at operating bands for the designed models and presented in Fig 3. Single element antenna gain at ISM band of 2.4 GHz is presented in Fig 3(a) and it is showing maximum gain of 4.63 dB. 1X2 array antenna gain at 2.4 GHz, 4.2 GHz and 7.5 GHz is observed as 4.3, 5.1 and 5.7 dB respectively and presented the same in Fig 3(b), 3(c) and 3(d). 1X4 array antenna gain at 2.4 GHz, 4.2 GHz and 7.5 GHz is observed as 7.3, 8.3 and 8.8 dB respectively and presented the same in Fig 3(e), 3(f) and 3(g).



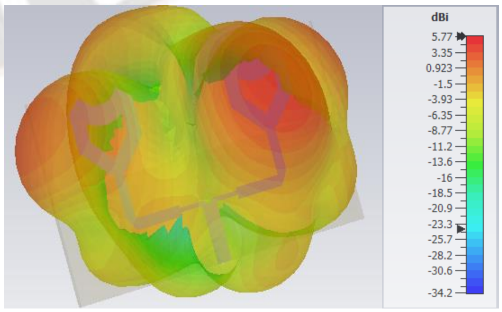
(a)



(b)



(c)



(d)

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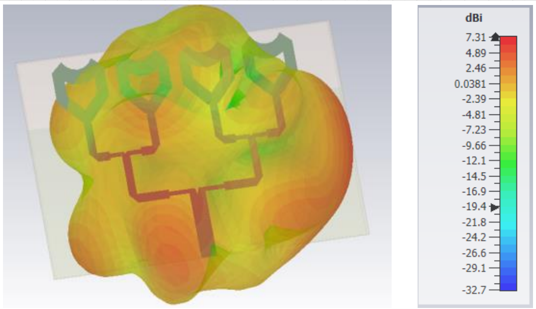
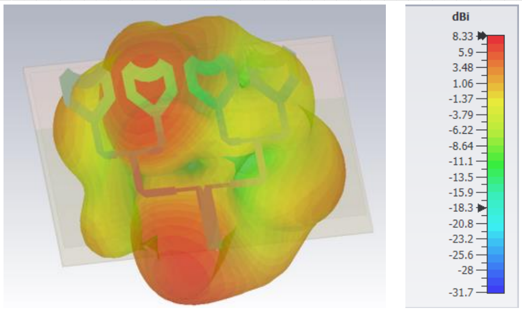
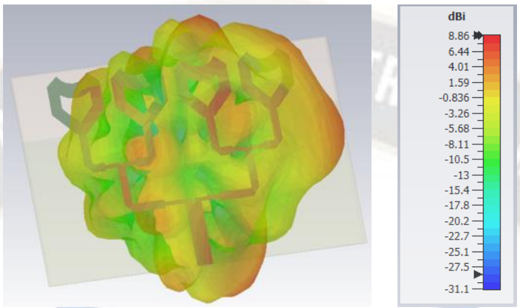


(e)



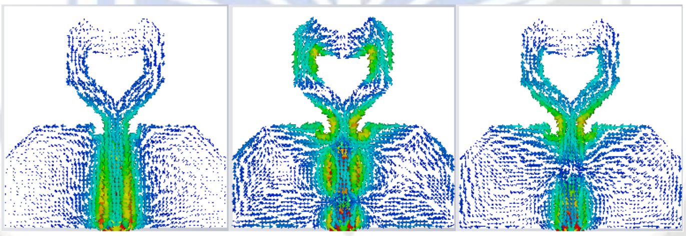
(f)



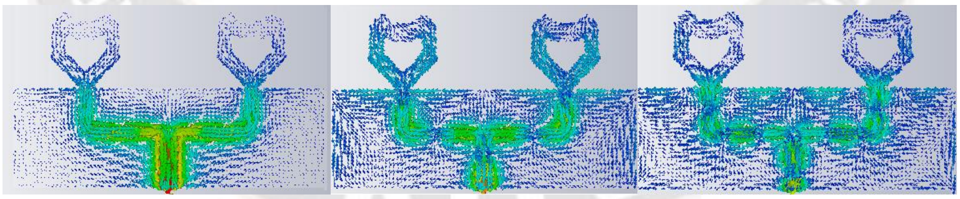
(g)

Fig 3. Three dimensional gain of the models

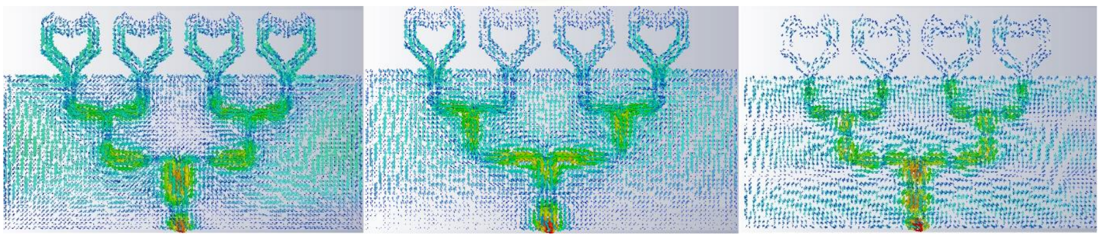
The surface current distribution of the designed models are analyzed and presented in Fig 4. At three operating bands, the concentration of the current intensity is identified for single, dual and four element fabric antenna.



4(a)



4(b)



4(c)

Fig 4. Surface current distribution, (a) Single element at three bands, (b) Dual element array at three bands, (c) Four elements array at three bands

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The flexible behaviour of the designed models in the horizontal position is analyzed and presented in Fig 5. It has been observed that in all the cases the designed antenna models are exhibited the similar patterns in reflection coefficient and radiation. Negligible variations are observed in the bending analysis and the overall performance is almost constant in the conformal testing analysis.

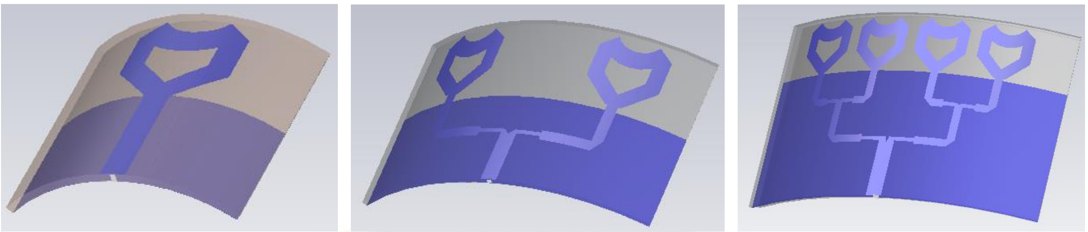
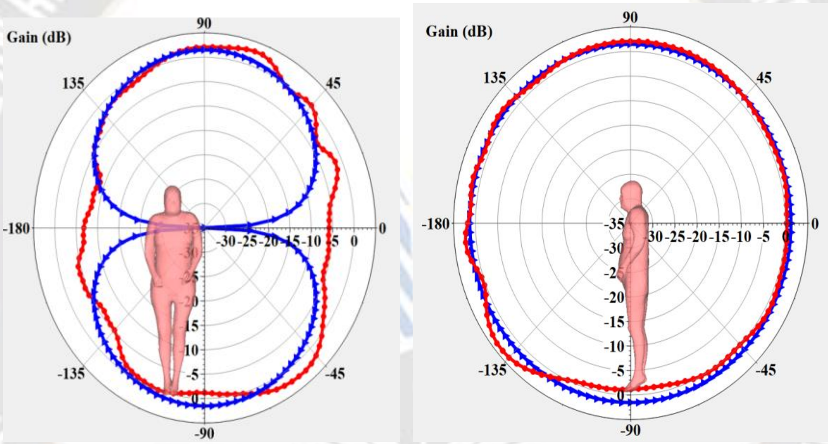
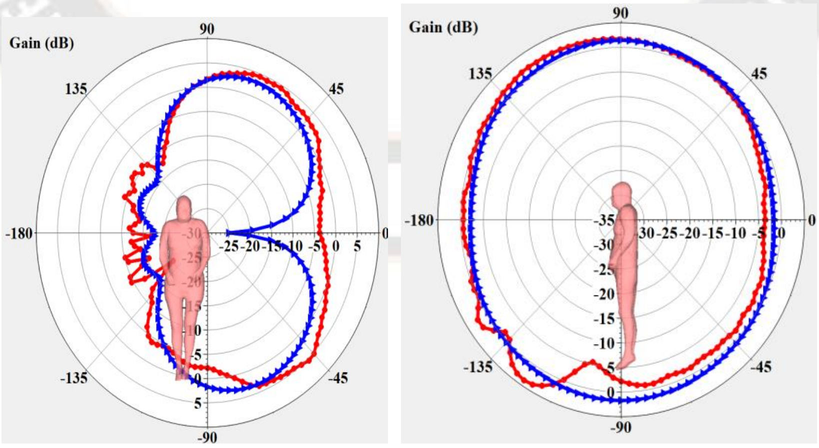


Fig 5. Bending analysis of three models

The radiation pattern analysis for the three models are presented in Fig 6. For single element antenna, the radiation is monopole like in E-plane and omni directional in H-plane. For 1X2 and 1X4 array antenna models the E-plane is slightly disturbed with harmonics due to coupling of elements, but in the H-plane it is almost omni directional with small fraction of distortion.



(a) At 2.4 GHz for single element antenna in E and H-Plane



(b) At 2.4 GHz for 1X2 array antenna in E and H-Plane

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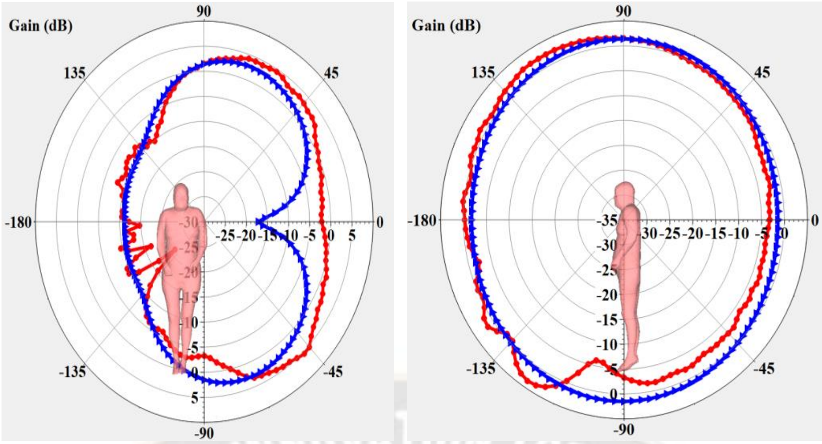

(c) At 2.4 GHz for 1X4 array antenna in E and H-Plane

Fig 6. Body placement radiation analysis

4. Specific Absorption Rate Analysis: The specific absorption rate of the antenna is very much important to identify the applicability of the antenna in the real time when body placement is needed. Antenna should be compatible to human body with respect to low radiation and less harmful and the reading should be in limits of 1.6 w/kg for 10 gm of tissue.

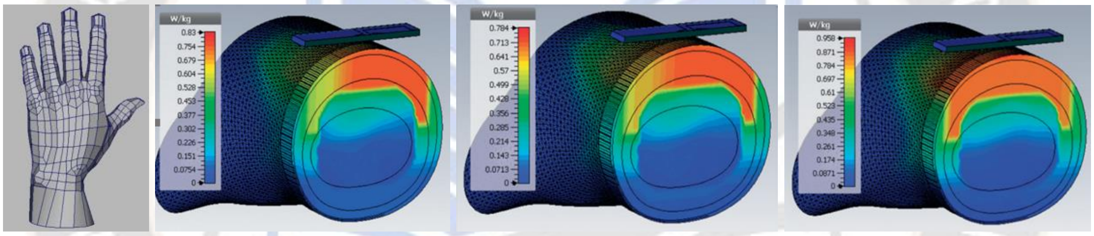

Fig 7. Placement on hand for SAR Analysis

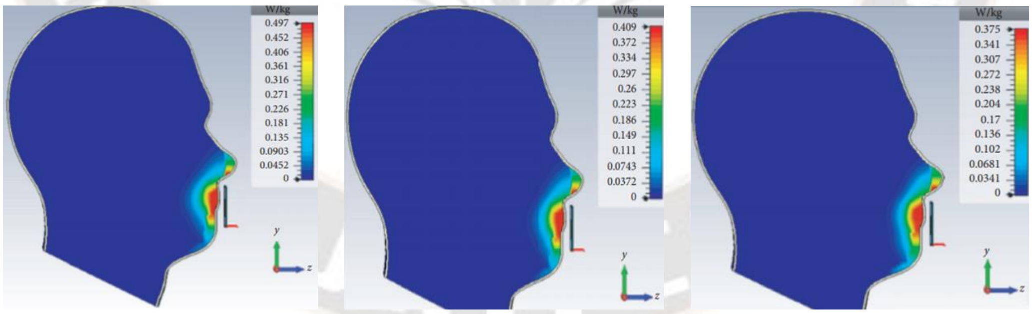

Fig 8. Placement between ear to mouth for SAR Analysis

Fig 7 and 8 sows the SAR analysis of the antenna when it is placed on human arm and nearer to mouth. The SAR at three resonant frequencies when it placed on arm are 0.83, 0.78 and 0.95 w/kg, which are very less as per the standards. The SAR at three resonant frequencies when it placed nearer to mouth are 0.49, 0.40 and 0.37 w/kg respectively.

Conclusion: A triple band conductive fabric-based jeans fabric wearable microstrip patch antenna array has been designed and analyzed its performance characteristics in this work. The designed array antennas are providing moderate gain of 5.7 dB (1X2) and 8.3 dB (1X4) with efficiency more than 90% in the operating bands. The flexible behaviour of the designed models in the horizontal position is analyzed and negligible variations are observed in the bending analysis with constant performance in the conformal testing analysis. The SAR at three resonant frequencies when it placed on arm are 0.83, 0.78 and 0.95 w/kg and when it is placed nearer to mouth are 0.49, 0.40 and 0.37 w/kg respectively. The simulation results are matching to measured results of the prototype and antenna performance is providing satisfactory condition for application is wearable communications.

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References:

[1]. P. Syam Sundar, D. Sri Harsha, P. Manasa, G. Manikanta and K. Brahmaiah, "Fabric Substrate Material Based Multiband Spike Antenna for Wearable Applications", Research Journal of Applied Sciences, Engineering and Technology, ISSN: 2040-7459, Vol 8, Issue 3, pp 429-434, Oct-2014.

[2]. B. Prudhvi Nadh, M. Siva Kumar, M. Venkateswara Rao, T. Anilkumar, Circular ring structured ultra-wideband antenna for wearable applications, International Journal of RF and Microwave Computer-Aided Engineering, Vol 28, No 9, 2018, pp 1-15

[3]. Gill, D. R. . (2022). A Study of Framework of Behavioural Driven Development: Methodologies, Advantages, and Challenges. International Journal on Future Revolution in Computer Science &Amp; Communication Engineering, 8(2), 09–12. https://doi.org/10.17762/ijfrcsce.v8i2.2068

[4]. Mudunuri Padmanabha Raju, D. S. Phani Kishore, CPW Fed T-Shaped Wearable Antenna for ISM Band, Wi-Fi, WiMAX, WLAN and Fixed Satellite Service Applications, Journal of Electromagnetic Engineering and Science, Vol. 19, No. 2, pp 140-146, 2019.

[5]. Prudhvi Nadh B, Siva Kumar M, Anilkumar T, Venkateswara Rao M, Kishore PVV. Windmill-shaped antenna with artificial magnetic conductor-backed structure for wearable medical applications. Int J Numer Model El, 2020, https://doi.org/10.1002/jnm.2757.

[6]. Nouby M. Ghazaly, M. M. A. . (2022). A Review on Engine Fault Diagnosis through Vibration Analysis . International Journal on Recent Technologies in Mechanical and Electrical Engineering, 9(2), 01–06. https://doi.org/10.17762/ijrmee.v9i2.364

[7]. D. Ram Sandeep, N. Prabakaran, K. L. Narayana & P. Rakesh Kumar, Systematic Investigation from Material Characterization to Modeling of Jute Substrate-Based Conformal Circularly Polarized Wearable Antenna, Journal of Electronic Materials, 2020, DOI 10.1007/s11664-020-08536-6

[8]. K Srilatha, B Anil Babu, M Rishikesh Raj, Tulasi Somala, Vyshnavi Nimmaraju, M C Rao, Design and analysis of Jeans based Wearable monopole antenna with enhanced gain using AMC backing, Journal of Physics: Conference Series, 1804 (2021) 012189, doi:10.1088/1742-6596/1804/1/012189

[9]. JayantthReddyK, JVani, R R Priyanka, B Prudhvi Nadh, M C Rao, Concentric Ring Loaded Monopole Antenna with AMC Backed for Wearable Applications, Journal of Physics: Conference Series, 1804 (2021) 012191, doi:10.1088/1742-6596/1804/1/012191.

[10]. D Ram Sandeep, N Prabakaran, D Lokesh Reddy,K Divya Sree, J Pavan Sai Kumar, S Salma, SAR Analysis of Jute Substrate based Tri-band Antenna for Wearable Applications, Journal of Physics: Conference Series, 1804 (2021) 012203, doi:10.1088/1742-6596/1804/1/012203

[11]. K.V.Vineetha, M.Siva Kumar, M.C.Rao, Flexible bandpass filter with silver conductive layer for GPS, ISM, PCS, LTE and WLAN applications, Materials Technology Proceedings, https://doi.org/10.1016/j.matpr.2020.12.1187.

[12]. Shaik Rajiya, Badugu P. Nadh, Munuswami S. Kumar, Frequency reconfigurable monopole antenna with DGS for ISM band applications, Journal of Electrical Engineering, Vol 69, No 4, pp 293–299, 2018

[13]. Venkateswara Rao M, Anil Kumar T, Prudhvi Nadh B, Metamaterial inspired quad band circularly polarized antenna for WLAN/ISM/Bluetooth/WiMAX and satellite communication applications, AEU - International Journal of Electronics and Communications, Vol 97, 2018, pp 229-241

[14]. Badugu P. Nadh, Munuswamy S. Kumar, Manikonda V. Rao, Tirunagari Anilkumar, Asymmetric Ground Structured Circularly Polarized Antenna for ISM and WLAN Band Applications, Progress in Electromagnetics Research M, Vol. 76, 2018, Pp 167–175.

[15]. B Priyadharshini, D Ram Sandeep, B Charishma Nag, G Krishna Sai, M Amulya, K Aravind Swamy, S Salma, M C Rao, Design and Simulation of Multiband Operating Single Element Antenna for Wi-Fi, ISM and X Band Applications, International Journal of Advanced Science and Technology, Vol. 29, No. 4s, 2020, pp. 2011-2021

[16]. S Salma, K R V Narasimha Reddy, D Mahidhar, D Ram Sandeep, M C Rao, Design and Analysis of Circularly Polarized Dual Element MIMO Antenna with DGS for Satellite Communication, Fixed mobile, ISM, and Radio Navigation Applications, International Journal of Advanced Science and Technology, Vol. 29, No. 4s, 2020, pp. 1982-1994

[17]. Habibulla khan, S Salma, K R V Narasimha Reddy, D Mahidhar, D Jayachandra, D Ram Sandeep, M C Rao, Design of Monopole Antenna With L-Shaped Slits for ISM and WiMAX Applications, International Journal of Scientific & Technology Research, Vol 9, Issue 03, March 2020, Pp 5151-5156.

[18]. B Neha Reddy, G Uma Maheswari, K Rama Prathyusha, D Ram Sandeep, M C Rao, Design and Analysis of Monopole Antenna for ISM, C, and X-Band Applications, International Journal of Scientific & Technology Research, Vol 9, Issue 03, March 2020, Pp 5157-5162.

[19]. D. Ram Sandeep, N. Prabakaran, K. L. Narayana, Y. Pratapa Reddy, Semicircular shape hybrid reconfigurable antenna on Jute textile for ISM, Wi-Fi, Wi-MAX, and W-LAN applications, International Journal of RF and

Microwave Computer Aided Engineering, 2020, https://doi.org/10.1002/mmce.22401

[20]. K. V. Vineetha, M. Siva Kumar, Y. Usha Devi, Sudipta Das, Flexible and conformal metamaterial-based microwave absorber for WLAN, Wi-MAX and ISM band applications, Materials Technology, 2021, https://doi.org/10.1080/10667857.2020.1864194, pp 1-17.

[21]. Ram Sandeep D, Prabakaran N, Narayana K L, Circularly Polarized Jute Textile Antenna for Wi-MAX, WLAN and ISM Band Sensing Applications, ACES JOURNAL, Vol. 35, No. 12, December 2020, pp 1493-1499.

[22]. J. . Hermina, N. S. . Karpagam, P. . Deepika, D. S. . Jeslet, and D. Komarasamy, “A Novel Approach to Detect Social Distancing Among People in College Campus”, Int J Intell Syst Appl Eng, vol. 10, no. 2, pp. 153–158, May 2022.

[23]. Ch. Amarnatha Sarma, Syed Inthiyaz, V. Ratna Kumari, Interdigital Filtenna with Bandpass Filter, DGS, and Inset Feed Elliptical Antenna for S-Band & ISM-2.4 GHz Band Applications, Turkish Journal of Physiotherapy and Rehabilitation, Vol 32, Issue 2, 2021, pp 2923-2931

[24]. K.V.Vineetha, M.Siva Kumar, M.C.Rao, Flexible bandpass filter with silver conductive layer for GPS, ISM, PCS, LTE and WLAN applications, Materials Technology Proceedings, https:// doi.org/ 10.1016/ j.matpr.2020.12.1187

[25]. M Padmanabharaju, D S Phani Kishore, P V Datta Prasad, Conductive Fabric Material based Compact Novel Wideband Textile Antenna for Wireless Medical Applications, Materials Research Express, Volume 6, Number 8, 2019, DOI: 10.1088/2053-1591/ab09a1

[26]. Venkateswara Rao M, Anilkumar T, Prudhvinadh B, Circularly polarized flexible antenna on liquid crystal polymer substrate material with metamaterial loading, Microwave and Optical Technology Letters, 2019, pp 1–9, https://doi.org/ 10.1002/mop.32088

[27]. S. Bandi, D.K. Nayak, S.S.M. Reddy, Compact flexible inkjet-printing antenna on paper and transparent PET substrate materials for vehicular instrument communication, Journal of Instrumentation, Vol 14, 2019, https://doi.org/10.1088/1748-0221/14/10/P10022

[28]. T Anilkumar, Yepuri Spoorthi Hawanika, M Venkateswara Rao, B Prudhvi Nadh, Flexible Liquid Crystal Polymer Based Conformal Fractal Antenna for Internet of Vehicles (IoV) Applications, International Journal of Microwave and Optical Technology, Vol 14, No 6, Nov 2019, pp 423-430.