A Broadband High Gain Planar Vivaldi Antenna for Medical Internet of Things (M-IoT) Healthcare Applications

Permanand Soothar[1, 2*], Hao Wang[1*], Zaheer Ahmed Dayo[3], Falak Naz[2], Badar Muneer[2], and Muhammad Aamir[3]

[1]School of Electronic and Optical Engineering, Nanjing University of Science & Technology, Nanjing 210094 China. permanand.soothar@njust.edu.cn haowang@njust.edu.cn

[2]Mehran University of Engineering & Technology, Jamshoro, 76062, Sindh, Pakistan.

[3]College of Computer Science, Huanggang Normal University, Huangzhou 438000, China.

Summary

In this paper, a high gain, broadband planar vivaldi antenna (PVA) by utilizing a broadband stripline feed is developed for wireless communication for IoT systems. The suggested antenna is designed by attaching a tapered-slot construction to a typical vivaldi antenna, which improves the antenna's radiation properties. The PVA is constructed on a low-cost FR4 substrate. The dimensions of the patch are $1.886\lambda_0\times1.42\lambda_0\times0.026\lambda_0$, dielectric constant ε_r=4.4, and loss tangent δ=0.02. The width of the feed line is reduced to improve the impedance bandwidth of the antenna. The computed reflection coefficient findings show that the suggested antenna has a 46.2% wider relative bandwidth calculated at a 10 dB return loss. At the resonance frequencies of 6.5 GHz, the studied results show an optimal gain of 5.82 dBi and 85% optimal radiation efficiency at the operable band. The optometric analysis of the proposed structure shows that the proposed antenna can achieve wide enough bandwidth at the desired frequency and hence make the designed antenna appropriate to work in satellite communication and medical internet of things (M-IoT) healthcare applications.

Keywords:

IoT, Medical healthcare, Planar vivaldi antenna, Slot, Broadband, Bandwidth, Radiation efficient, and High gain.

1. Introduction

With the evolution of wireless communication, many applications are developing periodically that are mostly based on microstrip-type structures due to their added advantages [1-3]. One of the most significant parts of the wireless communication system is an antenna used for transmitting or receiving radio signals. Furthermore, various types of antennas have already been developed [4-8]. The most common type of antenna is the planar vivaldi antenna, also referred to as the vivaldi notch antenna or PVA. This type of antenna has a simple feed structure, compact, conformal, easy to fabricate on a circuit board, and can provide broad bandwidth and high gain [9-10]. A planar vivaldi antenna (PVA) consists of a gradually widening slot in a metallic plate printed on the top surface of the substrate [11]. For designing a vivaldi antenna, full-wave simulation software has been used to calculate the antenna's far-field modes and impedance bandwidth [12-15]. The stripline feed PVA has achieved importance because of its ability to produce large impedance bandwidth (IBW).

The PVA has been considered a microstrip antenna having a coplanar structure with a conical slot imprinted on the top surface of the dielectric substrate. A PVA used a flared strip line etched on the substrate to produce an end-fire radiation pattern from a surface wave. The narrow end of the tapered slot profile is connected to the radial stub. Moreover, the broad end of the tapered slot has been used to capture or radiate the radio waves in the end-fire direction. PVA is able to achieve wide IBW, stable radiation pattern, and high gain characteristics [16-17]. It may take on several geometrical shapes, such as linear taper (LT), exponential taper (ET or vivaldi), constant width taper (CWT), etc. [18]. In the last decade, different structures of compact planar antennas were investigated to enhance the antenna IBW, gain performance, and radiation characteristics [19-26]. However, very few antenna designs have good radiation efficient and compact sizes with a tapered profile and can attain the antenna's optimal key characteristics.

Designing a PVA with stable end-fire radiation patterns, IBW, and high gain remains a big challenge for active researchers. These types of antennas have been used in many applications such as satellite communication, large ships, radio detection & ranging (RADAR), and ultra-wideband (UWB) communication systems [27]. Moreover, the IoT and healthcare applications and their slight variations contain different frequency bands used for satellite communication, Medical Internet of things (M-IoT), cordless telephones, Wi-Fi devices, and weather forecasting [28-31].

Using the high-frequency structure simulator (HFSS. 17.2) program, a broadband PVA is built and constructed in this research. The suggested antenna radiation pattern properties and impedance have been enhanced by etching the feed line just on the upper surface of a dielectric material and ground plane. Moreover, the proposed antenna has a fractional bandwidth of 46.2% with an optimum gain of 5.82 dBi and an excellent radiation efficiency of 85% at the resonant frequency of 6.5 GHz. The designed antenna is used for (M-IoT) systems, satellite communication systems, weather forecasting, radio altimeters, etc.

Manuscript received December 5, 2022
Manuscript revised December 20, 2022
https://doi.org/10.22937/IJCSNS.2022.22.12.31

This paper is organized mainly into five sections. The first section focuses on the introduction of the planar vivaldi antenna. The second section contains the design methodology. The third section focuses on the parametric analysis of the proposed antenna structure. Sections fourth and fifth cover the simulation results and conclusion.

2. Design Methodology

The proposed structure of the antenna is shown in Figure 1. The feeding strip line is placed above the substrate and ground plane with relative permittivity $\varepsilon_r = 4.4$, thickness $h_{sub} = 1.2$mm, and loss tangent $\delta = 0.02$. The patch's width (W) and length (L) can be approximated by equations 1 to 5. For an efficient radiation pattern, width W is given by

$$W = \frac{c}{2 f_r \sqrt{\frac{\varepsilon_r + 1}{2}}} \quad (1)$$

Where c, f_r, ε_r represents in free space the speed of light, resonant frequency, and relative permittivity of the substrate, respectively [32]. The fields recognized in the patch are not limited to the dimension of the patch only. However, it slightly extends outside the patch which is called the fringing field ε_{reff} [33].

$$\varepsilon_{reff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2} \times \left[1 + 12\frac{h}{w}\right]^{-\frac{1}{2}} \quad (2)$$

$$\frac{\Delta L_{eff}}{h} = 0.412 \times \frac{(\varepsilon_{reff} + 0.3) \times (\frac{W}{h} + 0.264)}{(\varepsilon_{reff} - 0.258) \times (\frac{W}{h} + 0.8)} \quad (3)$$

The effective length is given by

$$L_{eff} = \left(L + 2\Delta L_{eff}\right) \quad (4)$$

The resonant frequency is expressed as:

$$f_r = \frac{c}{2L_{eff}\sqrt{\varepsilon_{eff}}} \quad (5)$$

Divided into the stripline/slotline transitions, the tapering slot, and the diameter of the round hollow stubs, the PVA network model may be classified into substrates characteristics and antenna structure variables. W_{FL} (stripline width) and w_{sl} (slotline length) define the stripline/slotline changeover (slotline width). The opening rate R, along with two points, represents the exponential taper profile $P_1(x_1, y_1)$ and $P_2(x_2, y_2)$ [13].

Where,

$$y = c_1 e^{Rx} + c_2 \quad (6)$$

$$c_1 = \frac{y_2 - y_1}{e^{Rx_2} - e^{Rx_1}}$$

$$c_2 = \frac{y_1 e^{Rx_2} - y_2 e^{Rx_1}}{e^{Rx_2} - e^{Rx_1}}$$

T_{sl} is (x_2-x_1), and aperture height H is 2(y_2-y_1) +w_{sl} for vivaldi. When the reopening frequency R reaches zero, the exponential taper produces a PVA whose tapering gradient is continuous and given by $s_0 = (y_2-y_1) / (x_2-x_1)$. The tapering gradient s changes constantly between s_1 to s_2 for the exponentially taper specified by (6), where s_1 and s_2 are indeed the tapering slopes at $x=x_1$ and $x=x_2$, correspondingly, and $s_1 < s < s_2$ for $R > 0$. The height of the taper flare is determined by =$\tan^{-1}$ s. The flaring angles, on the other hand, are linked to and specified by the H, T_{sl}, R, and w_{sl} variables. The following are the variables for available for all types of feeding and circular slotline cavity depicted in Fig.1.

The side and top view geometries of the PVA are shown in the accompanying figures. The parametric analysis of the suggested antenna structure is also discussed in the following section.

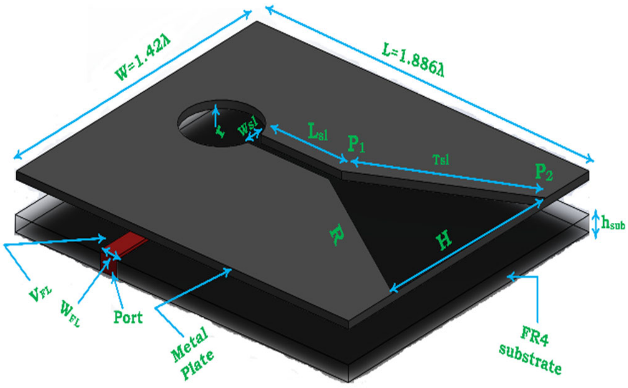


Fig. 1 Geometry of the proposed antenna

3. Parametric Analysis of Proposed Antenna Structure

3.1 Influence of V_{FL}

The PVA is excited by the stripline feed through a slot line transition. The changeover design takes advantage of the broadband properties of a microstrip radial stub that serves as a simulated broadband. Figure 2. illustrates the feedline length variation from 31mm – 33mm. The optimum result of feedline length has been achieved at 32mm.

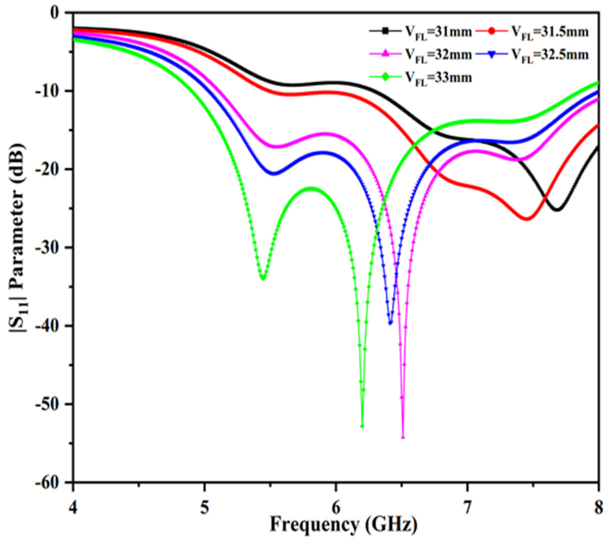


Fig. 2 Influence of parameter of vertical feedline length (V_{FL}) of the proposed antenna

3.2 Influence of W_{FL}

Using the width of the feedline (W_{FL}) as a variable, the best results were obtained at 2.4mm, as shown. Figure 3. Moreover, in order to get improved results, the desired wider band is achieved at 2.4mm. The IBW of the suggested antenna has grown with the adjustment of captured the essence length and width, according to the simulation findings

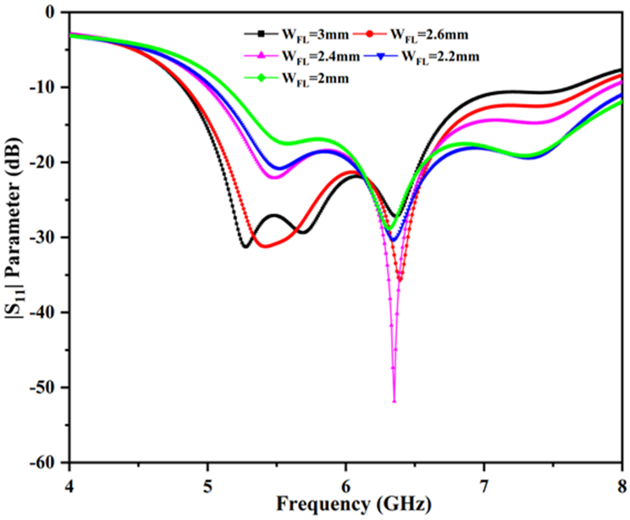


Fig. 3 Influence of parameter of feedline width (W_{FL}) across the operable frequency

3.3 Influence of C_S

The effect of the PVA radial cavity stub (C_S) on antenna performance is analyzed by varying antenna dimensions, i.e., length (L), width (W), and stripline feeding. Fig. 4 gives the results of radial stub variation against frequency. The optimum results are achieved at 10.4mm; the parameterized results have been analyzed and suggested to accomplish the optimum results for the designed antenna geometry.

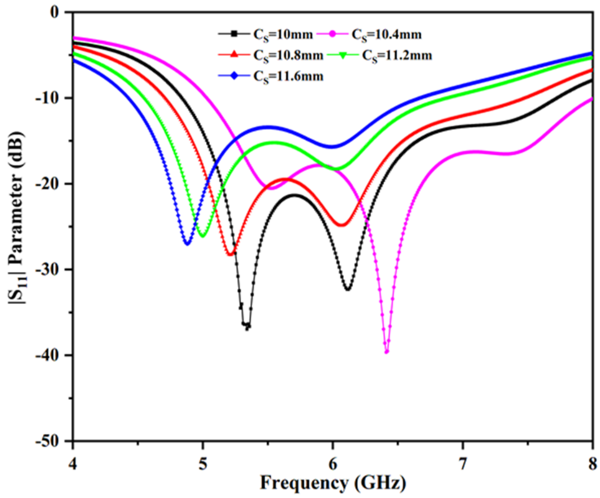


Fig. 4 Influence of parameter of the cavity stub (C_S) across the frequency span

Table 1 shows the dimensions of the proposed antenna with their optimal values. Again for the planned antenna, the width (W), length (L), and thickness (h_{sub}) of the base and patches stay the same.

Table 1: Geometric parameter

PVA Parameters	*PVA Variables*	*Optimized Values (mm)*
Vertical feedline length	V_{FL}	32
Feedline width	W_{FL}	2.4
Cavity stub	C_S	10.4
Slotline width	W_{sl}	3
Slotline length	L_{sl}	9.75
Taper aperture	H	25.5
Taper slotline	T_{sl}	47
Substrate thickness	h_{sub}	1.2

4. Results and Analysis

4.1 Return loss, S_{11}

The Ansys HFSS 17.2 was used to create the simulated results. According to the simulation findings, the comparative bandwidth for minimal return losses of 10 dB, 15 dB, and 20 dB is 46.2%, 40.60%, and 19.08%, respectively. Furthermore, at the resonance frequency of 6.5 GHz, the maximum return loss is 46.3 dB. The fractional BW of 46.2% has been attained at 10 dB path loss, as shown in Fig. 5. Furthermore, at the resonant frequency of 6.5 GHz, the maximum gain of 5.82 dBi is reached. The surface current field at 4.18 GHz with no phase shift is simulated at the surface in Figure 6, which exhibits the top distribution of PVA and a 3-dimensional (3D) pattern.

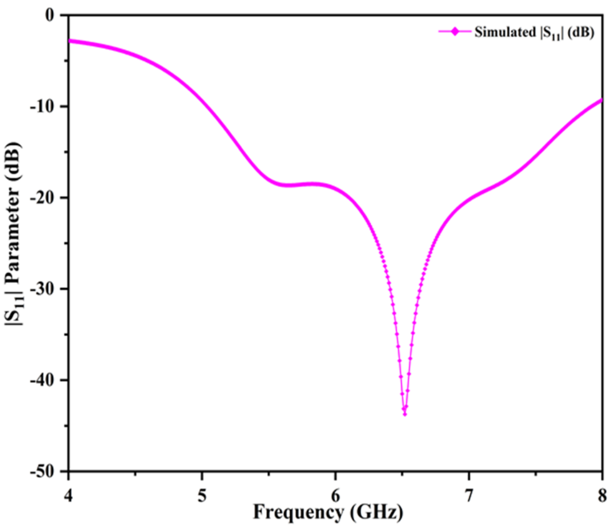
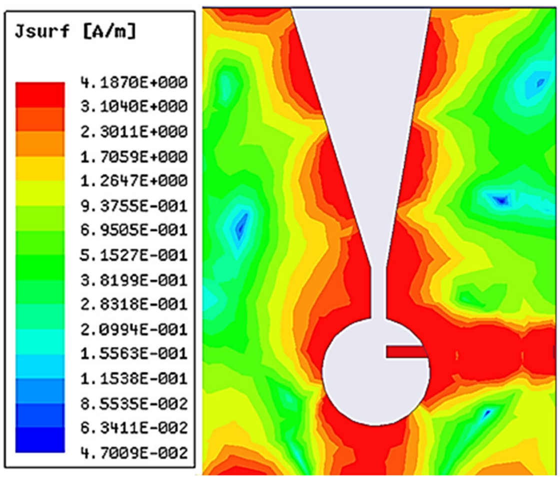
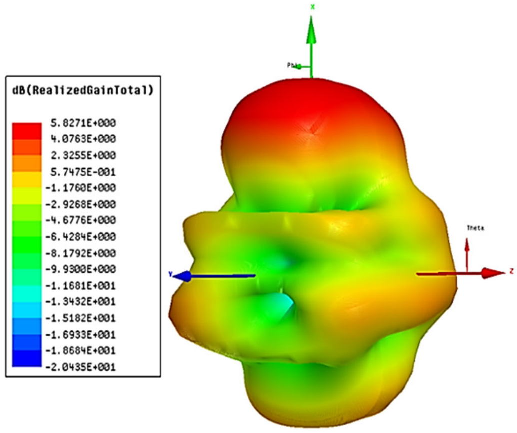


Fig. 5 Variation of return loss with the frequency of the proposed slot antenna



(a)



(b)

Fig. 6 (a) $J_{surface}$ current distribution, and (b) 3D pattern of proposed PVA

4.2 Peak realized gain, efficiency, and radiation pattern

The proposed structure's peak realized gain and efficiency are presented in Figure 7. From Figure, the peak realized gain has occurred at 5.82 dBi. Moreover, 85% efficiency is observed across the operating frequency, as shown in Figure 7.

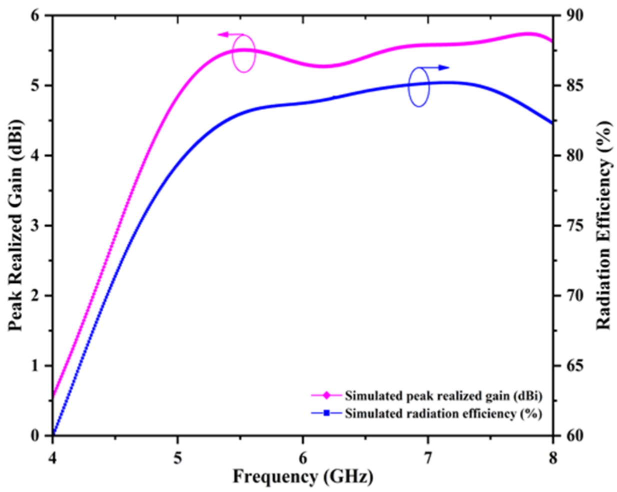


Fig. 7 Simulated peak realized gain and radiation efficiency over an operable frequency span

Figure 8 shows the 2-dimensional (2D) radiation pattern plots in both azimuth and elevation planes. The suggested antenna gain at the resonance frequency of 6.5 GHz is 5.82 dBi, as shown in the diagram. The antenna beam is going in the direction of 90°, as one would anticipate from an endfire antenna. In another sector, the antenna radiates almost evenly.

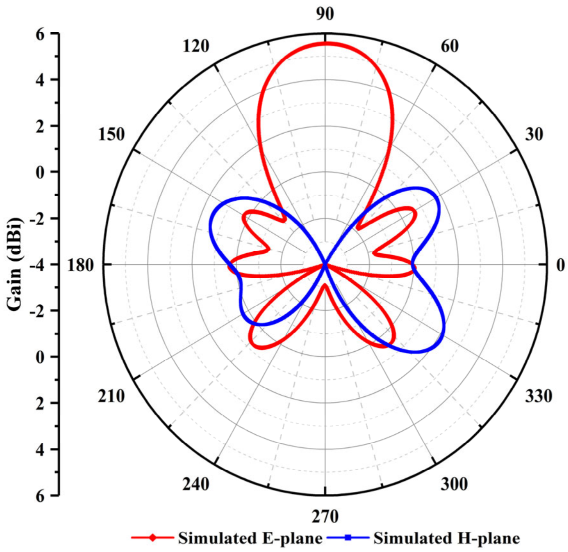


Fig. 8 The isotropic radiation pattern of proposed antenna

5. Conclusion

The authors proposed and constructed a planar vivaldi antenna (PVA) in this study. The antenna's planned structure comprises the substrate, patch, ground plane, and feed line. At a resonant frequency of 6.5 GHz, an efficient feed strategy, microstrip line feeding, does have an increased fractional bandwidth of 46.2% and an optimal gain of 5.82 dBi. Using the modeling program Ansys HFSS 17.2, the parametric and simulation data were examined and confirmed. The optimal outcomes of the s-parameter, yield, and economy have been effectively reached based on the analysis and discussion offered in the study. It has been concluded that the designed antenna is suitable for medical internet of things (M-IoT) healthcare systems and satellite communication applications. This work may be further extendable by utilizing the efficient Wilkinson power divider.

References

[1] Muneer, B., Qi, Z., & Xu, S. A digital SIW phase shifter implemented by switching transverse slots via PIN diodes. Frequenz, vol. 69(9-10), pp. 383-387 (2015).

[2] Muneer, B., Qi, Z., & Shanjia, X. A broadband tunable multilayer substrate integrated waveguide phase shifter. IEEE Microwave and Wireless Components Letters, 25(4), pp. 220-222 (2015).

[3] Godara, L. C. (Ed.). Handbook of antennas in wireless communications. CRC press (2018).

[4] Dayo, Z. A., Cao, Q., Wang, Y., Soothar, P., Muneer, B., & Chowdhry, B. S. A compact broadband high gain antenna using slotted inverted omega shape ground plane and tuning stub loaded radiator. Wireless Personal Comm., 113(1), pp. 499-518 (2020).

[5] Muneer, B., Shabir, W., Shaikh, F. K., & Qi, Z. Plate-laminated slotted-waveguide fed 2×3 planar inverted f antenna array. In 2017 IEEE International Symposium on Antennas and Propagation & USNC/URSI National Radio Science Meeting pp. 2101-2102. IEEE, (2017).

[6] Xu, C., Soothar, P., Quan, S., Liang, G., & Wang, H. The design of crossover based on microstrip ridge gap waveguide of dual-layer medium, (2021).

[7] Cao, J., Wang, H., Mou, S., Soothar, P., & Zhou, J. An air cavity-fed circularly polarized magneto-electric dipole antenna array with gap waveguide technology for mm-wave applications. IEEE Transactions on Antennas and Propagation, 67(9), pp. 6211-6216 (2019).

[8] Schaubert, D. H. Wide-band phased arrays of Vivaldi notch antennas. In Tenth International Conference on Antennas and Propagation (Conf. Publ. No. 436) Vol. 1, pp. 6-12. IET. (1997).

[9] Soothar, P., Wang, H., Xu, C., Dayo, Z. A., Muneer, B., & Kanwar, K. A compact broadband and high gain tapered slot antenna with stripline feeding network for H, X, Ku and K band applications. International Journal of Advanced Computer Science and Applications, vol. 11(7), (2020).

[10] Soothar, P., Wang, H., Xu, C., Quan, Y., Dayo, Z. A., Aamir, M., & Muneer, B., A Miniaturized Broadband and High Gain Planar Vivaldi Antenna for Future Wireless Communication Applications. International Journal of Antennas and Propagation, vol. 2021, (2021).

[11] Lekshmi, B. S. K., & Raglend, I. J. Parametric study of tapered slot antenna for wideband applications. In 2015 International Conference on Computation of Power, Energy, Information and Communication (ICCPEIC) pp. 0071-0077. IEEE, (2015).

[12] Chio, T. H., & Schaubert, D. H. Parameter study and design of wide-band widescan dual-polarized tapered slot antenna arrays. IEEE Transactions on Antennas and Propagation, vol. 48(6), pp. 879-886 (2000).

[13] Shin, J., & Schaubert, D. H. A parameter study of stripline-fed Vivaldi notch-antenna arrays. IEEE Transactions on Antennas and Propagation, vol. 47(5), pp. 879-886 (1999).

[14] Ansoft, H. F. S. S. "V11 User's Guide, 2009." HFSS, Ansoft Corporation, Pittsburgh, USA. 2009.

[15] Dardeer, O. M., Abouelnaga, T. G., Mohra, A. S., & El-Hennawy, H. M. A novel UWB Vivaldi antenna array for radar applications. International Journal of Scientific & Engineering Research, vol. 7(5), pp. 1169-1174 (2016).

[16] Lewis, L., Fassett, M., & Hunt, J. A broadband stripline array element. In 1974 Antennas and Propagation Society International Symposium Vol. 12, pp. 335-337. IEEE. (1974).

[17] Oreyzi, H., & Jam, S. Analysis of the tapered slot antenna by the method of least squares, (2005).

[18] Kedar, A., & Beenamole, K. Wide beam tapered slot antenna for wide angle scanning phased array antenna. Progress In Electromagnetics Research B, 27, pp. 235-251 (2011).

[19] Kishore, M. R., Janardhana, A., & Krishna, B. M. Design and Simulation of Dual Band T-Shaped Slot Microstrip Antenna for C-Band Applications. Int. Journal of Engineering Research and Technology, vol. 4(09), (2015).

[20] Soothar, P., Wang, H., Muneer, B., Dayo, Z. A., & Chowdhry, B. S. A broadband high gain tapered slot antenna for underwater communication in microwave band. Wireless Personal Communications, vol. 116(2) pp.1025-1042 (2021).

[21] Dayo, Z. A., Cao, Q., Wang, Y., Soothar, P., Khoso, I. A., Shah, G., & Aamir, M. A compact high gain multiband bowtie slot antenna with miniaturized triangular shaped metallic ground plane. The Applied Computational Electromagnetics Society Journal (ACES), pp.935-945 (2021).

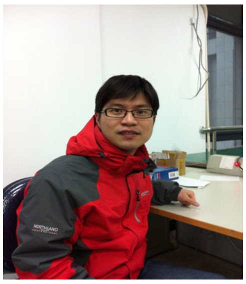
[22] Wu, B., Wang, H., Liu, X., Ding, Z., Quan, S., Cao, J., & Soothar, P. Optimization to the scan blindness of vivaldi array with metallic T-shaped structure. In 2019 IEEE MTT-S International Wireless Symposium (IWS) pp. 1-3. IEEE. (2019).

[23] Liu, X., Wang, H., Wu, B., Quan, S., Cao, J., & Soothar, P. A novel wide bandwidth antenna design and application in wide beam scanning phased array. In 2019 IEEE MTT-S International Wireless Symposium (IWS) pp. 1-3. IEEE. (2019).

[24] Dayo, Z. A., Cao, Q., Wang, Y., Rahman, S. U., & Soothar, P. A compact broadband antenna for civil and military wireless

communication applications. International Journal of Advanced Computer Science and Applications, vol. 10(9). (2019).
[25] Dayo, Z. A., Cao, Q., Soothar, P., Lodro, M. M., & Li, Y. A compact coplanar waveguide feed bow-tie slot antenna for WIMAX, C and X band applications. In 2019 IEEE international conference on computational electromagnetics (ICCEM) pp. 1-3. IEEE, (2019).
[26] Chandio M., Jamali A. A., Jokhio F. A., Anjum M. R., Arain Z. A., Soothar P.; Triangular Nanoparticle Based Plasmonic Biosensor; Sindh University Research Journal (Science Series) SURJ. Vol 52(2), (2020).
[27] Keerthi, V. H. R., Khan, D. H., & Srinivasulu, D. P. Design of C-band microstrip patch antenna for radar applications using IE3D. IOSR Journal of Electronics and Communication Engineering, 5(3), pp. 49-58 (2013).
[28] Guha, D., & Antar, Y. M. (Eds.). Microstrip and printed antennas: new trends, techniques and applications. John Wiley & Sons., (2011).
[29] Bhalla, D., & Bansal, K. Design of a rectangular microstrip patch antenna using inset feed technique. IOSR Journal of Electronics and Communication Engineering, vol. 7(4), pp. 08-13 (2013).
[30] Xiaoxing Y., et al. "An ultra-wideband tapered slot antenna." Antennas and Propagation Society International Symposium, 2005 IEEE. Vol. 2. IEEE, 2005.
[31] Dayo, Z. A., Aamir, M., Dayo, S. A., Khoso, I. A., Soothar, P., Sahito, F., ... & Guan, Y. A novel compact broadband and radiation efficient antenna design for medical IoT healthcare system. Mathematical Biosciences and Engineering, vol. 19(4), pp. 3909-3927 (2022).
[32] Constantine A. B., "Antenna theory analysis and design." John Willey and Son's Inc., New York (1997).
[33] Rahman, M. M., & Islam, M. F. Double U-slot microstrip patch antenna for WLAN and WiMAX applications. Int. J. Comput. Appl, pp. 0975-8887 (2017).

Permanand Soothar was born in Hyderabad, Sindh, Pakistan. He received the Master's Engineering (M.E.) degree in Electronic & Telecommunication Engineering from Mehran University of Engineering and Technology (MUET) Jamshoro, Sindh, Pakistan, in the year 2012. During his Master's program, he was awarded European Commission Scholarship under the ERASMUS Mundus "Mobility for Life" project in the Telecommunication and Wireless Technologies, Innovative Communication Technologies and Entrepreneurship (ICTE) at the Centre of Tele Infrastructure Aalborg University, Copenhagen, Denmark since 2010 to 2011. Besides, Mr. Soothar has been working at MUET, Jamshoro since 2015. Currently, he is pursuing a Ph.D. from the School of Electronic and Optical Engineering, Nanjing University of Science and Technology (NJUST), Nanjing, P.R. China. His current research interests in Electromagnetic field and Microwave Technology include compact planar antennas, Ultra-wideband antennas, Array topology, Millimetre-wave antennas, 5G wireless communication antennas, Gap waveguide technology, SIW technology, dual polarization slotted waveguide antennas and Arrays.



Prof. Dr. Hao Wang was born in Nanjing, China. He received the B.S. and a Ph.D. degree in Electrical and Electronic Engineering from the Nanjing University of Science and Technology (NJUST), Nanjing, in 2002 and 2009, respectively. Currently, Dr. Wang is an Associate Professor and Doctoral Supervisor at the School of Electronic and Optical Engineering, NJUST. His research interests include anti-jamming technology for Chinese navigation, Satellite communication system, Phased and digital beam-forming radar technology, Gap waveguide technology, Millimetre-wave antennas, and Ultra-wideband antennas. In 2011, his doctoral thesis, "Research on Microstrip Antennas," was nominated for National Excellent 100 Doctoral Thesis. In recent years, more than 30 research papers have been published in IEEE Transactions in antenna and propagation and IEEE transaction microwave technology. More than 60 research papers have been published at international conferences.

Zaheer Ahmed Dayo was born in Shikarpur, Sindh, Pakistan. He received the M.E. degree in Telecommunication Engineering and Management from Mehran University of Engineering & Technology (MUET) Jamshoro, Sindh Pakistan, in the year 2014 and a Ph.D. degree in Communication Information Systems at College of Electronic and Information Engineering, Nanjing University of Aeronautics and Astronautics (NUAA), P.R China in the year 2021. Mr. Dayo has published several articles in international journals and conference proceedings. He served as a reviewer and TPC member in international journal and conference. He has a vast research experience of more than 5 years. He is currently working in Electromagnetics, mainly focused on Microwave and R.F Engineering and Measurement. His current research interests include designing Compact, Broadband, High gain Antennas, Array topology and Optimization schemes, Multiband and Slot antennas, Reconfigurable and Metamaterial inspired antennas, and Active and Passive Frequency Selective Surfaces.

Falak Naz was born in the district of Jacobabad, Sindh, Pakistan. She received the B.E. degree in Telecommunication Engineering from Mehran University of Engineering & Technology (MUET), Jamshoro, Sindh, Pakistan, in the year 2021. Ms. Naz is presently pursuing a Master's degree under the ERASMUS Mundus Joint Program in Electronics, Microwave, and Optics in France, Italy, Spain, and the United Kingdom. Falak Naz secured 1st position in Pakistan and 2nd globally during the initial assessment of this program. Her research interest is inclined toward Radio Frequency, Microwave, and Antenna designing for health-related applications. Currently, she is working on an antenna applicator for Hyperthermia.

Badar Muneer was born in Mirpurkhas, Sindh Pakistan. He received the B.S. degree in Communication Systems Engineering from the Institute of Space Technology (IST), Islamabad, Pakistan, in 2008 and the M.E. degree in Telecommunication Engineering from the NED University of Engineering and Technology, Karachi, Pakistan, in 2012, and the Ph.D. degree in Electromagnetism field and Microwave Technology from the University of Science and Technology of China, Hefei, China. From 2008 to 2011, he was with a Satellite Broadcasting Company as a Satellite Engineer. He was involved in VSAT, CATV, and many modern broadcast equipment. His current research includes microwave and millimetre-wave technology, SIW based power dividers, phase shifters and antennas. He is also senior member of IEEE and faculty advisor of IEEE MTTs Chapter. He is currently an Assistant Professor with the Department of Telecommunication Engineering, Mehran UET, Jamshoro, Pakistan.

Muhammad Aamir received the B.E. degree in Computer Systems Engineering from Mehran University of Engineering & Technology (MUET), Jamshoro, Sindh, Pakistan, in 2008, the M.E. degree in Software Engineering from Chongqing University, China, in 2014, and the Ph.D. degree in Computer Science and Technology from Sichuan University, Chengdu, China, in 2019. He is currently an Associate Professor at the Department of Computer, Huanggang Normal University, Huanggang, China. His main research interests include pattern recognition, computer vision, image processing, deep learning, wireless communication, and fractional calculus.