Bulletin of Electrical Engineering and Informatics
Vol. 11, No. 4, August 2022, pp. 2071~2078
ISSN: 2302-9285, DOI: 10.11591/eei.v11i4.3648

The effects of material's features and feeding mechanism on high-gain antenna construction

Hamed A. Al-Falahi[1], Drai Ahmed Smait[2], Sami Abduljabbar Rashid[3], Sarmad Nozad Mahmood[4], Sameer Alani[2]
[1]Department of Chemical, College of Engineering, University of Anbar, Iraq
[2]Department of Law, College of Law, University of Mashreq, Baghdad, Iraq
[3]Deparment of Computer Engineering Technology, Al-Maarif University College, Al-Anbar, Iraq
[4]Computer Technology Engineering, College of Engineering Technology, Al-Kitab University, Kirkuk Iraq

Article Info

Article history:

Received Jan 25, 2022
Revised Mar 4, 2022
Accepted Jun 15, 2022

Keywords:

Flexible wearable antenna
High gain antenna
Microstrip antenna
Multi-wideband antenna
WBAN applications

ABSTRACT

This study investigates the performance of flexible, wideband antennas with high gain properties. The high gain feature can often be obtained by positioning a reflector in the same planes as the adjacent radiator. For flexibility, this survey discusses the antennas that were printed on the flexible substrate materials. Based on these properties, the antenna can be recognized in a variety of wireless applications, including wireless local-area-network (WLAN), Worldwide Interoperability for microwave access (WI-Max), wireless body area network (WBAN), and radio frequency identification (RFID), as well as wearable applications. The high-gain antennas are compact radio wave-based antennas that provide precise radio transmission management. Such antennas deliver more energy to the receiver, increasing the frequency of the received signal. By gathering more power, high-gain antennas may emit signals quicker. Furthermore, because directional antennas broadcast fewer signals from the main wave, interference may be greatly minimized. Finally, this article identifies the role of lightweight high gain flexible antennas in terms of their size, substrate materials, design, and feeding mechanisms, all of which can affect bandwidth, gain, radiation efficiency, and other important factors.

Corresponding Author:

Sameer Alani
Department of Law, College of Law, the University of Mashreq
Airport St, 11001, Baghdad Iraq
Email: itsamhus@gmail.com

1. INTRODUCTION

The high gain antennas are essential for data transmission, and optimizing performance becomes necessary when either the transmitter or the receiver is portable. Reflectors or planar antenna arrays have traditionally been used to produce high gain. Reflectors are physically adjusted across many axes to guide the beam, whereas phase shifters are used for electrical beam steering in antenna arrays [1]-[5]. The electromagnetic band gap (EBG) or photonic band gap (PBG) constructions have sparked a lot of activity in the antenna sector because of their opportunity to add antenna parameters including size, gain, and radiation efficiency, among other things [6]. EBG resonator antennas, for instance, are a viable way to increase the gain of a planar antenna and are simple to build [7]-[12]. An EBG material is put atop a metallic ground plane holding a tiny antenna to generate a resonant cavity, allowing the tiny antenna's gain to be increased. The gain of the EBG reflector is observed to rise with the quality factor of the resonating cavity. Furthermore, phased array schemes, stacked patch antennas, EBG resonator antennas, and zero-index metamaterials can all be used to create high gain antennas. The antipodal vivaldi antenna (AVA) is a metamaterial-based antenna that improves gain by reducing radiation in unwanted directions [13], [14]. The design is complicated, but it can demonstrate wideband and low return losses by lowering the lower cut-off frequency. The AVA design and performance are improved in this survey work by incorporating unit cells based on metamaterials [15]-[17]. Wideband high-gain array antenna systems with required matching, steady radiation pattern, high beam scanning capabilities with low side lobe level (SLL), and the directed radiating beam [18] have been accomplished. High gain [19], [20], multi-band structures [20]-[23], and beam steering [24], [25] are only a few of the metamaterial-based approaches that have been thoroughly investigated to improve antenna performance. A new approach for mm-wave telecommunication is provided in order to construct a high gain planar bowtie antenna with twin beams that are homogeneous in nature [26]. In the frequency band of 24.04–40.85 GHz, an antipodal Vivaldi transmission line with curved construction is constructed, with a maximum gain of 13.2 dB [27]. Constructing high gain antennas help to construct a clear and effective image for certain special samples particularly when dealing with risky disease detection such as the cancerous tumors in the human breast, which is considered a growing source of disease in millions of women throughout the world, with a high mortality rate [28], [29]. Consequently, studies are being conducted to create a low-cost, simple-to-implement alternative method for identifying breast tumor cells quickly and effectively that is also comfortable for the patient. In comparison to other body parts such as the thorax, limbs, and abdomen, the human breast is built in a more modest style. Surprisingly, the dielectric characteristics of normal and cancerous breast tissue are very equal. The reason that ordinary breast tissue spreads the microwave signal smoothly in a lossy and fatty environment instead of lesions that store much liquid in the reaction of blood and water explains this variation in electrical qualities linked to conductivity and permittivity. As a result, from the dispersed signals, any undesirable cell cluster or cyst may be recognized. Owing to their larger bandwidth, high gain, and high data transmission rate, vivaldi and ultra-wideband (UWB) antennas are suitable candidates for microwave imaging. As a result, using UWB antennas to obtain high-resolution photos is recommended [28], [30]-[35]. Besides, for lightweight high-gain antennas devoted to portable and wearable devices [36], there is a significant basic necessity and high demand. Given their compact sizes and the high gain values that influence the efficiency of the realized signal, this study is organized to describe and differentiate several types of flexible antennas.

This paper studies the performance of multi-wideband and high gain antennas with respect to their size, substrate materials, feeding techniques that can impact the operating frequency bands. The rest of the paper is organized as follows: a brief introduction was given in Section 1 on the importance of the high gain antennas concerning the types of antenna and the techniques that feed the antenna. In section 2, a comprehensive investigation was presented on the antennas that generate high gain signals and their use in various applications as presented in Table 1. Finally, the review article is discussed and concluded in section 3.

2. HIGH GAIN FLEXIBLE ANTENNAS

In contrast with an isotropic antenna, antenna gain informs us of the strength transmitted by an antenna in a particular direction. This definition specifies how powerful a signal an antenna is capable of transmitting or receiving in a given direction. Antenna Gain is a more relevant criterion than directivity as it takes all the losses into account. Antenna Gain is technically the product of directness and efficiency. Whereas directivity is the distribution calculation of the radiated signal of an antenna in a specific direction and output accounts for antenna failure due to defects in processing, surface coating abnormalities, dielectric, resistance, and voltage standing wave ratio (VSWR). Dual or multifunction integrated modules are becoming increasingly common in wireless communication systems for their miniature circuit size and overall output [37], [38]. Hu *et al.* [39] presented a rectangular dielectric resonator (FDRA) filtering antenna with a low profile, wide bandwidth, and high gain. Within the current FDRA, three resonant phases are activated, the (10) dB impedance frequency is approximately 20.4%. To improve the antenna's gain, a dielectric resonator antenna (DRA) fed by a pair of separate slots is proposed such that the model shown in Figure 1 has a similar 20.3% impedance bandwidth, nevertheless with an improved overall passband gain.

As radiation nulls advantages, an out-of-band elimination of higher than (25) dB is obtained in the range of (0–8) GHz is a quite large stopband. Moreover, in situations where the filtering constraint is not too stringent, the filtering DRA can be helpful, as well as it can theoretically minimize the restrictions on additional filters that would follow in the program. As constraints, the input impedance of the first antenna is severely mismatched leading to a very low passband gain, the azimuth gain drops rapidly, and the low gain-based DRA antenna was comparatively restricted for certain applications.

The production of wearable systems through the use of textile materials has taken place owing to the recent miniaturization of wireless devices [40]. The modernistic wireless systems provide the human community with cost-effectiveness and portability [41]. In light of this, Oshin and Amit [42] proposed a unique

UWB textile antenna for wearable medical applications. Miniaturization is achieved by identifying constrained measurements, resulting in a perfect fit for the individual wearing it (see Figures 2(a) and (b)). The proposed configuration of the UWB textile antenna, which has the benefit of using less power than 1 mW, is lightweight, dominates a narrow region of a surface, reasonable gain, and 97% radiation efficiency. Hereby, the proposed antenna can be used in the fields of wearable applications in the remote health monitoring system.

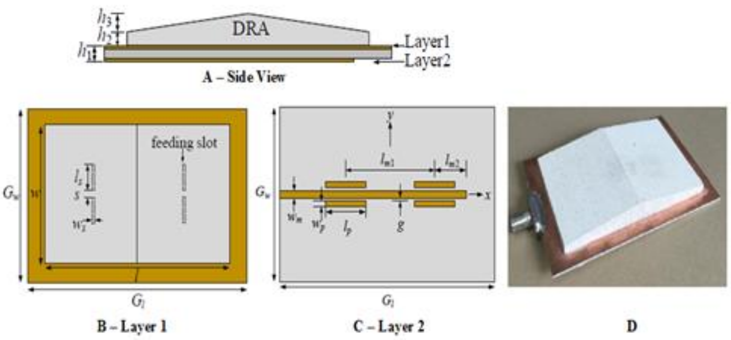


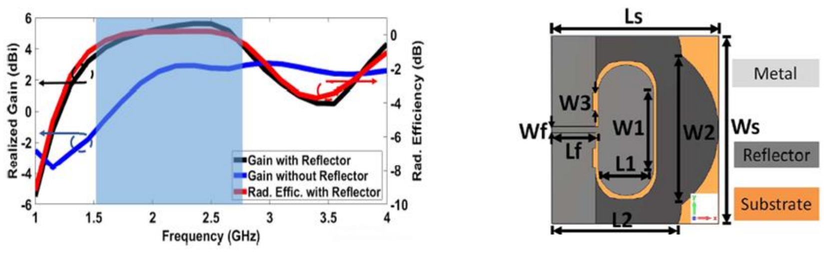
Figure 1. The enhanced FDRA antenna [39]

(a) (b)

Figure 2. The antenna (a) flannel fabric and (b) jeans fabric [42]

Amit and Oshin [43] described a modern principle convergence of UWB technologies, portable textile antenna, and the human phantom with their dielectric properties of each tissue. Based on the design criteria, the offered antenna was made up of three textile substrates. This configuration of the UWB textile antenna achieved several benefits such as less absorbed power, higher gain, realistic impedance matching performance, less volume, lightweight, and 73% radiation efficiency. In addition, the model could function well in the vicinity of the human body and provide an omnidirectional radiation pattern which makes the prototype suitable for wearable applications in the monitoring areas.

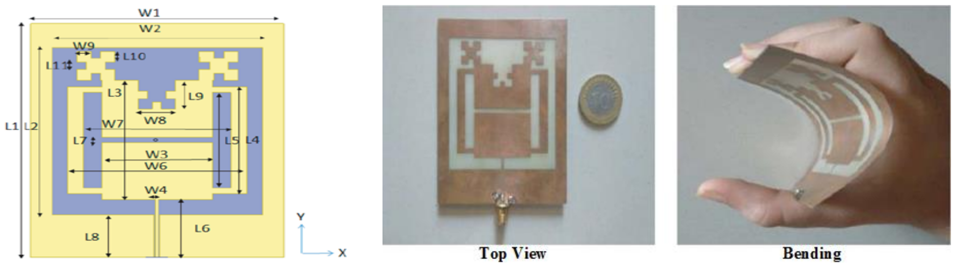
The area of flexible antenna currently observes phenomenal development and advancement in study, architecture, and manufacturing. Wireless device advancements have spawned a slew of intriguing antenna layouts that can be bent and placed on non-planar phenomena [44]-[46]. Hereby, Abdalgalil *et al*. [47] offered an assessment on the performance of a lightweight, high gain wideband antenna (Figure 3(a)). High gain and 100% radiation efficiency were obtained over the broad bandwidth with the use of a special reflector form across the radiator (see Figure 3(b)).



(a) (b)

Figure 3. The antenna (a) 2D design and (b) gain and radiation efficiency [47]

Moreover, in terms of matching, the proposed antenna operated well and maintained the pattern of omnidirectional radiation during bending at (2.45) GHz, knowing that there was a small rotation detected with bent circumstance over the X-Z plane. Hence, the antenna can be a good candidate for wearable and wireless applications. For 2.42 GHz wireless local-area-network (WLAN) and 3.78 GHz worldwide interoperability for microwave access (WiMAX) applications, a dual-band versatile antenna was built by Kantharia *et al*. [48] in which the fractal arrangement utilizing coplanar waveguide (CPW) is proposed (see Figure 4(a)). The application of fractal geometry contributes to enhancing impedance bandwidth and radiation efficiency. The antenna reported greater gain values at (2.39 and 3.77) GHz, with performance efficiency (82.54 and 75.11)% respectively. Noteworthy that the dimension of the antenna is significantly greater than other antennas indicated in [48] knowing that the encouraging results obtained with this model, though, compensate the large scale. In addition, the small difference in S11 value was due to the manufacturing defects, SMA connector errors, and soldering effects (see Figure 4(b)).

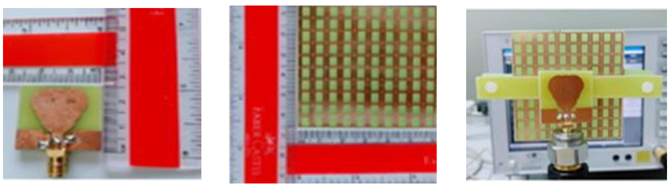


(a) (b)

Figure 4. The antenna (a) dimensions and (b) manufactured [48]

There are two modes of contact by which the knowledge of a user is guided. The first kind is on-body interaction, where it is almost distant wearable nodes connect, and the other kind is off-body communication, where doctors and specialists transmit information to remote devices for review [23], [44], [49]. The interest in WBAN [50] continues to grow through the years owing to the fact that it is an interesting issue to focus on. In view of this, a low profile, CPW-fed slotted triangular monopole antenna for WBAN implementations was introduced by Atrash *et al.* [51]. For WiMAX wireless technology, the designed antenna resonates at 3.5 GHz and the industrial, scientific, and medical (ISM) range at 5.8 GHz, where strong impedance compatibility was obtained. Reasonable findings were achieved at a (15) mm distance from the human body although this would result in a rise in the dimensions. According to the presented results, the antenna can be an optimum candidate for wearable applications particularly for monitoring diabetic patients remotely. However, the dimensions of the antenna alongside the reflector need to be optimized to reach a more miniaturized size with respect to maintaining performance efficiency in order to suit a practical diabetes electronic system and thus retain the features.

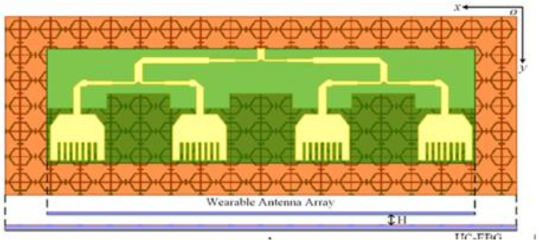
The UWB is a telecommunication system that is used to achieve high-rate bandwidth links utilizing reduced power usage in wireless communications networks (Figures 5(a) and (b)). In view of this, the UWB radio is indeed become a scientific invention utilized in special intelligent devices such as radar, cellular communications, and medical engineering [52], [53]. In [54], Al-Gburi *et al.* introduced a new creative strawberry artistic shaped printed monopole (SAPM) antenna with a single-layer selective frequency surface (FSS) reflector as the metal shield (see Figure 5(c)). This analysis showed the improvement of the FSS benefit potential and achieved around 92 percent of the overall performance. Hereby, the proposed lightweight and low-profile antenna with FSS is favorable for UWB application and ground-penetrating radar (GPR). Nevertheless, owing to the fabrication tolerances, the inconsistencies in the construction have created discrepancies between the theoretical and calculated data.



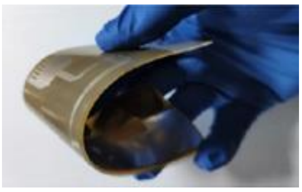
(a) (b) (c)

Figure 5. The antenna (a) SAPM, (b) FSS reflector, and (c) metallic FSS [54]

On-body technologies must meet certain efficiency criteria owing to the demands of the on-body workplace area. Low-profile, high-gain, flexible, and broadband on-body antennas are typically required for portable devices. As a result, Zu *et al.*, [55] proposed an antenna arrangement depending on the use of monopole antennas and uniplanar small EBG (UC-EBG) constructions (see Figure 6(a)). To begin, slots and edge cutting are used to create a broadband versatile monopole antenna. Following that, the UC-EBG construction is created, which serves as a mirror for the monopole antenna. It may improve the antenna's directivity and gain while damping the reverse radiation and lowering the subject access request (SAR) to satisfy general specifications. Lastly, the 4 antenna components and the feeding link are merged to create a portable broadband high-gain antenna structure layout(see Figures 6(b) and (c)). The overall evaluation for the presented high gain antennas is briefly listed in Table 1.



(a)



(b) (c)

Figure 6. The antenna (a) designed, (b) fabricated–flat, and (c) curving [55]

Table 1. Summary of high gain antennas

Ref	Size (mm)	Substrate	Antenna Type	Feeding Technique	Frequency Band (GHz)	Gain (dBi)	Wearable
[39]	60 × 43	Rogers 4003	FDRA	Microstrip	4.40–5.40 4.42–5.42	5.0 and 9.05	No
[42]	30 × 30	Flannel, Jeans	Textile	SMA Port	3–6.5	3.27	Yes
[43]	30 × 30	Jeans, Flannel, Cotton	UWB Slot	Microstrip	3–6	4.3	Yes
[47]	100 × 90	Rogers Ultralam 3850	Monopole	CPW	1.53–2.74	5.63	Yes
[48]	97.48 × 80	FR-4	Fractal	CPW	2.39 and 3.77	1.09 and 4.56	No
[51]	86 × 86	Rogers Ultralam Ro3003	Monopole	CPW	3.5 and 5.8	6.634 and 9.373	Yes
[54]	61 × 61	FR4	Monopole	CPW	3.05–11.9	7.87 and 9.68	No
[55]	27.3 × 20	Copper	Monopole	Monopole & EBG	4.5–6.5	13.6	Yes

3. DISCUSSION

High-gain antennas are small radio wave-based antennas, providing accurate control of radio transmissions. Further energy is transferred to the receiver through high-gain antennas, enhancing the frequency of the received signal. High-gain antennas can emit signals faster by collecting more power. In addition, directional antennas transmit fewer signals from the primary wave as a result the interference can be reduced drastically. Increasing the Q-factor of the resonator is one way to improve the yield of the EBG antenna even more. This can be done by increasing the number of dielectric EBG layers or by utilizing high permittivity EBG material. However, the cost increases in the antenna height or the use of expensive materials. Meanwhile, another way for achieving high gain in EBG antennas is to utilize a metallic grid instead of dielectric EBG layers, which allows the antenna's height to be reduced. Moreover, there exists another popular and efficient technique to construct a high gain antenna is to create an array of antennas with a gain proportionate to the number of components in the array. However, increasing the number of components in the array on purpose is not possible since it will take up more capacity within the cell phone, which is already limited. As a result, there is a tradeoff between the number of components of the array antenna and its gain. In principle, a planar array has been employed to get better benefits. Nevertheless, laboratory investigations have proven that by placing a parasitic element in the dielectric the feeding element at a wavelength interval, the gain of the antenna can be enhanced. Based on this survey, we conclude that CPW is considered the most superior and profitable feeding technique since it offers perfect matching in the air with a stable radiation pattern and enhances the ranges of the operating bandwidth particularly when used with microstrip antenna.

4. CONCLUSION

This paper focused mainly on investigating the performance of compact high gain flexible antennas in terms of their dimension, varieties of substrate materials, the antenna type and feeding methods that can influence operational frequencies, gain, radiation efficiency, and further significant considerations.

REFERENCES

[1] M. Geyikoglu, H. K. Polat, and B. Cavusoglu, "Novel design for differential phase shifter structure by using multi-section coupled lines," *Electronics Letters*, vol. 56, no. 11, pp. 553-556, 2020, doi: 10.1049/el.2020.0316.

[2] J. Warshowsky, C. Kulisan, and D. Vail, "20 GHz phased array antenna for GEO satellite communications," in *MILCOM 2000 Proceedings. 21st Century Military Communications. Architectures and Technologies for Information Superiority (Cat. No. 00CH37155)*, vol. 2, pp. 1187-1191, 2000, doi: 10.1109/MILCOM.2000.904114.

[3] R. J. Mailloux, "Phased array theory and technology," *Proceedings of the IEEE*, vol. 70, no. 30, pp. 246-291, March 1982, doi: 10.1109/PROC.1982.12285.

[4] B. Forman, "Directivity characteristics of scannable planar arrays," *IEEE transactions on antennas and propagation*, vol. 20, no. 3, pp. 245-252, May 1972, doi: 10.1109/TAP.1972.1140209.

[5] M. U. Afzal and K. P. Esselle, "Steering the beam of medium-to-high gain antennas using near-field phase transformation," *IEEE Transactions on Antennas and Propagation*, vol. 65, no. 4, pp. 1680-1690, April 2017, doi: 10.1109/TAP.2017.2670612.

[6] Y. Ge, K. P. Esselle, and Y. Hao, "Design of low-profile high-gain EBG resonator antennas using a genetic algorithm," *IEEE Antennas and Wireless Propagation Letters*, vol. 6, pp. 480-483, 2007, doi: 10.1109/LAWP.2007.907054.

[7] M. Thevenot, C. Cheype, A. Reineix, and B. Jecko, "Directive photonic-bandgap antennas," *IEEE Transactions on microwave theory and techniques*, vol. 47, no. 11, pp. 2115-2122, Nov. 1999, doi: 10.1109/22.798007.

[8] A. R. Weily, K. P. Esselle, B. C. Sanders, and T. S. Bird, "High-gain 1D EBG resonator antenna," *Microwave and Optical Technology Letters*, vol. 47, no. 2, pp. 107-114, 2005, doi: 10.1002/mop.21095.

[9] Y. J. Lee, W. S. Park, J. Yeo, and R. Mittra, "Directivity enhancement of printed antennas using a class of metamaterial superstrates," *Electromagnetics*, vol. 26, no. 3-4, pp. 203-218, 2006, doi: 10.1080/02726340600570294.

[10] S. Wang, A. P. Feresidis, G. Goussetis, and J. Vardaxoglou, "High-gain subwavelength resonant cavity antennas based on metamaterial ground planes," *IEE Proceedings-Microwaves, Antennas and Propagation*, vol. 153, no. 1. pp. 1-6, 2006, doi: 10.1049/ip-map:20050090.

[11] M. Diblanc, E. Rodes, E. Arnaud, M. Thevenot, T. Monediere, and B. Jecko, "Circularly polarized metallic EBG antenna," *IEEE microwave and wireless components letters*, vol. 15, no. 10, pp. 638-640, Oct. 2005, doi: 10.1109/LMWC.2005.856689.

[12] N. Guérin, S. Enoch, G. Tayeb, P. Sabouroux, P. Vincent, and H. Legay, "A metallic Fabry-Perot directive antenna," *IEEE Transactions on Antennas and Propagation*, vol. 54, no. 1, pp. 220-224, Jan. 2006, doi: 10.1109/TAP.2005.861578.

[13] A. S. Dixit and S. Kumar, "A survey of performance enhancement techniques of antipodal Vivaldi antenna," *IEEE Access*, vol. 8, pp. 45774-45796, 2020, doi: 10.1109/ACCESS.2020.2977167.

[14] H. D. Raut, L. Shevada, R. Malekar, and S. Kumar, "High gain wideband antennas for 5G applications: A review," *Inventive Communication and Computational Technologies*, pp. 777-787, 2021, doi: 10.1007/978-981-15-7345-3_67.

[15] B. Tütüncü, H. Torpi, and B. Urul, "A comparative study on different types of metamaterials for enhancement of microstrip patch antenna directivity at the Ku-band (12 GHz)," *Turkish Journal of Electrical Engineering & Computer Sciences*, vol. 26, no. 3, pp. 1171-1179, 2018, doi: 10.3906/elk-1711-50.

[16] A. R. H. Alhawari, A. Ismail, M. A. Mahdi, and R. S. A. R. Abdullah, "Antipodal Vivaldi antenna performance booster exploiting snug-in negative index metamaterial," *Progress In Electromagnetics Research C*, vol. 27, pp. 265-279, 2012, doi: 10.2528/PIERC12012906.

[17] S. Zhu, H. Liu, P. Wen, L. Du, and J. Zhou, "A miniaturized and high gain double-slot Vivaldi antenna using wideband index-near-zero metasurface," *IEEE Access*, vol. 6, pp. 72015-72024, 2018, doi: 10.1109/ACCESS.2018.2883097.

[18] M. Khalily, R. Tafazolli, P. Xiao, and A. A. Kishk, "Broadband mm-wave microstrip array antenna with improved radiation characteristics for different 5G applications," *IEEE Transactions on Antennas and Propagation*, vol. 66, pp. 4641-4647, Sept. 2018, doi: 10.1109/TAP.2018.2845451.

[19] S. Wu, Y. Yi, Z. Yu, X. Huang, and H. Yang, "A zero-index metamaterial for gain and directivity enhancement of tapered slot antenna," *Journal of Electromagnetic Waves and Applications*, vol. 30, no. 15, pp. 1993-2002, 2016, doi: 10.1080/09205071.2016.1236705.

[20] M. Bhaskar, E. Johari, Z. Akhter, and M. Akhtar, "Gain enhancement of the Vivaldi antenna with band notch characteristics using zero-index metamaterial," *Microwave and Optical Technology Letters*, vol. 58, no. 1, pp. 233-238, 2016, doi: 10.1002/mop.29534.

[21] L.-M. Si, W. Zhu, and H.-J. Sun, "A compact, planar, and CPW-fed metamaterial-inspired dual-band antenna," *IEEE Antennas and Wireless Propagation Letters*, vol. 12, pp. 305-308, 2013, doi: 10.1109/LAWP.2013.2249037.

[22] L. -M. Si *et al*., "A Uniplanar Triple-Band Dipole Antenna Using Complementary Capacitively Loaded Loop," *in IEEE Antennas and Wireless Propagation Letters*, vol. 14, pp. 743-746, 2015, doi: 10.1109/LAWP.2015.2396907.

[23] S. N. Mahmood, A. J. Ishak, A. Ismail, A. C. Soh, Z. Zakaria and S. Alani, "ON-OFF Body Ultra-Wideband (UWB) Antenna for Wireless Body Area Networks (WBAN): A Review," *in IEEE Access*, vol. 8, pp. 150844-150863, 2020, doi: 10.1109/ACCESS.2020.3015423.

[24] A. Dadgarpour, B. Zarghooni, B. S. Virdee, and T. A. Denidni, "Single end-fire antenna for dual-beam and broad beamwidth operation at 60 GHz by artificially modifying the permittivity of the antenna substrate," *IEEE Transactions on Antennas and Propagation,* vol. 64, no. 9, pp. 4068-4073, Sept. 2016, doi: 10.1109/TAP.2016.2574881.
[25] J. Li, Q. Zeng, R. Liu, and T. A. Denidni, "Beam-tilting antenna with negative refractive index metamaterial loading," *IEEE Antennas and Wireless Propagation Letters,* vol. 16, pp. 2030-2033, 2017, doi: 10.1109/LAWP.2017.2694400.
[26] H. Jiang, L.-M. Si, W. Hu, and X. Lv, "A symmetrical dual-beam bowtie antenna with gain enhancement using metamaterial for 5G MIMO applications," *IEEE Photonics Journal,* vol. 11, no. 1, pp. 1-9, Feb. 2019, Art no. 4600409, doi: 10.1109/JPHOT.2019.2891003.
[27] A. S. Dixit and S. Kumar, "A miniaturized antipodal Vivaldi antenna for 5G communication applications," in *2020 7th international conference on signal processing and integrated networks (SPIN),* 2020, pp. 800-803, doi: 10.1109/SPIN48934.2020.9071075.
[28] M. Bassi, M. Caruso, M. S. Khan, A. Bevilacqua, A. Capobianco and A. Neviani, "An Integrated Microwave Imaging Radar With Planar Antennas for Breast Cancer Detection," in *IEEE Transactions on Microwave Theory and Techniques*, vol. 61, no. 5, pp. 2108-2118, May 2013, doi: 10.1109/TMTT.2013.2247052.
[29] M. T. Islam, M. Samsuzzaman, I. Yahya, A. E. Kogut, N. Misran and M. T. Islam, "Metamaterial Inspired High Gain Antenna for Microwave Breast Imaging," in *2019 IEEE Asia-Pacific Conference on Applied Electromagnetics (APACE)*, 2019, pp. 1-4, doi: 10.1109/APACE47377.2019.9020819.
[30] A. I. Afifi, A. B. Abdel-Rahman, A. Allam, and A. S. Abd El-Hameed, "A compact ultra-wideband monopole antenna for breast cancer detection," in *2016 IEEE 59th International Midwest Symposium on Circuits and Systems (MWSCAS)*, 2016, pp. 1-4, doi: 10.1109/MWSCAS.2016.7870066.
[31] M. Z. Mahmud, M. T. Islam, M. N. Rahman, T. Alam, and M. Samsuzzaman, "A miniaturized directional antenna for microwave breast imaging applications," *International Journal of Microwave and Wireless Technologies,* vol. 9, pp. 2013-2018, 2017, doi: 10.1017/S1759078717000927.
[32] W. Shao, A. Edalati, T. R. McCollough, and W. J. McCollough, "A time-domain measurement system for UWB microwave imaging," *IEEE Transactions on Microwave Theory and Techniques,* vol. 66, no. 5, pp. 2265-2275, May 2018, doi: 10.1109/TMTT.2018.2801862.
[33] T. Gholipur and M. Nakhkash, "Optimized matching liquid with wide-slot antenna for microwave breast imaging," *AEU-International Journal of Electronics and Communications,* vol. 85, pp. 192-197, 2018, doi: 10.1016/j.aeue.2017.12.037.
[34] M. Islam *et al.*, "A compact disc-shaped super wideband patch antenna with a structure of parasitic element," *International Journal of Applied Electromagnetics and Mechanics,* vol. 50, no. 1, pp. 11-28, 2016, doi: 10.3233/JAE-140188.
[35] M. Mahmud, S. Kibria, M. Samsuzzaman, N. Misran, and M. Islam, "A new high performance hibiscus petal pattern monopole antenna for UWB applications," *The Applied Computational Electromagnetics Society Journal (ACES), vol. 31, no. 4,* pp. 373-380, 2016.
[36] S. N. Mahmood *et al.*, "Recent advances in wearable antenna technologies: a review," *progress in Electromagnetics Research B,* vol. 89, pp. 1-27, 2020, doi: 10.2528/PIERB20071803.
[37] E. H. Lim and K. W. Leung, "Compact multifunctional antennas for wireless systems," in *Wiley Series in Microwave and Optical Engineering*, vol. 215, 2012.
[38] K. W. Leung, E. H. Lim, and X. S. Fang, "Dielectric resonator antennas: From the basic to the aesthetic," in *Proceedings of the IEEE,* vol. 100, no. 7, pp. 2181-2193, July 2012, doi: 10.1109/JPROC.2012.2187872.
[39] P. Hu, Y. Pan, X. Zhang, and S. Zheng, "A compact filtering dielectric resonator antenna with wide bandwidth and high gain," *IEEE Transactions on Antennas and Propagation,* vol. 64, no. 8, pp. 3645-3651, Aug. 2016, doi: 10.1109/TAP.2016.2565733.
[40] J. DicCbshfsE, M. K. Abd Rahim, M. A. Abdullah, N. A. Samsuri, F. Zubir, and K. Kamardin, "Design, implementation and performance of ultra-wideband textile antenna," *Progress In Electromagnetics Research B,* vol. 27, pp. 307-325, 2011, doi:10.2528/PIERB10102005.
[41] S. Amit, "Design of compact bent dipole antenna and its array with high gain performance for GPS application," in *2016 8th International Conference on Communication Systems and Networks (COMSNETS)*, 2016, pp. 1-6, doi: 10.1109/COMSNETS.2016.7439935.
[42] S. Oshin and S. Amit, "Design and analysis of high gain UWB textile antenna for wearable application," in *2017 2nd IEEE International Conference on Recent Trends in Electronics, Information & Communication Technology (RTEICT)*, 2017, pp. 200-204, doi: 10.1109/RTEICT.2017.8256585.
[43] S. Amit and S. Oshin, "Design, implementation and performance analysis of a high gain UWB slot wearable antenna with human phantom for medical application," in *2017 IEEE International Conference on Antenna Innovations & Modern Technologies for Ground, Aircraft and Satellite Applications (iAIM)*, 2017, pp. 1-6, doi: 10.1109/IAIM.2017.8402601.
[44] P. S. Hall and Y. Hao, *Antennas and propagation for body-centric wireless communications*: Artech house, 2012.
[45] H. F. Abutarboush, M. F. Farooqui, and A. Shamim, "Inkjet-printed wideband antenna on resin-coated paper substrate for curved wireless devices," *IEEE Antennas and Wireless Propagation Letters,* vol. 15, pp. 20-23, 2015, doi: 10.1109/LAWP.2015.2425797.
[46] S. R. Zahran, M. A. Abdalla, and A. Gaafar, "Time domain analysis for foldable thin UWB monopole antenna," *AEU-International Journal of Electronics and Communications,* vol. 83, pp. 253-262, 2018, doi: 10.1016/j.aeue.2017.09.006.
[47] O. F. Abdalgalil, M. El Atrash, and M. A. Abdalla, "A flexible high gain wide-band antenna for wireless and wearable applications," in *2018 IEEE International Symposium on Antennas and Propagation & USNC/URSI National Radio Science Meeting*, 2018, pp. 1279-1280, doi: 10.1109/APUSNCURSINRSM.2018.8608830.
[48] M. Kantharia, A. Desai, T. K. Upadhyaya, R. Patel, P. Mankodi, and M. Kantharia, "High gain flexible cpw fed fractal antenna for Bluetooth/WLAN/WPAN/WiMAX applications," *Progress in Electromagnetics Research Letters,* vol. 79, pp. 87-93, 2018, doi:10.2528/PIERL18072702.
[49] G. A. Conway and W. G. Scanlon, "Antennas for over-body-surface communication at 2.45 GHz," *IEEE transactions on antennas and propagation,* vol. 57, no. 4, pp. 844-855, April 2009, doi: 10.1109/TAP.2009.2014525.
[50] S. N. Mahmood *et al.*, "Full Ground Ultra-Wideband Wearable Textile Antenna for Breast Cancer and Wireless Body Area Network Applications," *Micromachines,* vol. 12, no. 3, p. 322, 2021, doi: 10.3390/mi12030322.
[51] M. E. Atrash, M. A. Abdalla, and H. M. Elhennawy, "A wearable dual-band low profile high gain low SAR antenna AMC-backed for WBAN applications," *IEEE Transactions on Antennas and Propagation,* vol. 67, no. 10, pp. 6378-6388, Oct. 2019, doi: 10.1109/TAP.2019.2923058.
[52] W. Yeoh and W. S. Rowe, "An UWB conical monopole antenna for multiservice wireless applications," *IEEE Antennas and Wireless Propagation Letters,* vol. 14, pp. 1085-1088, 2015, doi: 10.1109/LAWP.2015.2394295.
[53] R. R. Krishna and R. Kumar, "A dual-polarized square-ring slot antenna for UWB, imaging, and radar applications," *IEEE Antennas and Wireless Propagation Letters,* vol. 15, pp. 195-198, 2015, doi: 10.1109/LAWP.2015.2438013.

[54] A. J. A. Al-Gburi, I. B. M. Ibrahim, M. Y. Zeain, and Z. Zakaria, "Compact size and high gain of CPW-fed UWB strawberry artistic shaped printed monopole antennas using FSS single layer reflector," *IEEE Access*, vol. 8, pp. 92697-92707, 2020, doi: 10.1109/ACCESS.2020.2995069.
[55] H. Zu, B. Wu, P. Yang, W. Li, and J. Liu, "Wideband and High-Gain Wearable Antenna Array with Specific Absorption Rate Suppression," *Electronics*, vol. 10, no. 17, p. 2056, 2021, doi: 10.3390/electronics10172056.

BIOGRAPHIES OF AUTHORS

Hamed A. Al-Falahi was born in Iraq in 1961. He received the B.Sc. degree in chemical engineering and M.Sc. degree in chemical engineering-improvements of Engineering materials from University of Technology 1994, and Ph.D. degree in modeling of high temperature ablative composites for advanced technology applications from University of Technology 2002. He is currently a professor in chemical and petrochemical engineering, college of engineering, University of Anbar. His research interests include nanomaterials, advanced composites materials and thermal systems engineering. He can be contacted at email: h.alfalahi@uoanbar.edu.iq.

Drai Ahmed Smait was born in Iraq, in 1961. He received B.S. degree in mechanical engineering from MEC in 1985, D.E.A From INPL–France 1990, M.Sc. from MEC in 1995 and Ph.D. degree in applied mechanical engineering in 2003 from University of Technology UOT, Baghdad- Iraq. He can be contacted at email: draialisawi@uom.edu.iq.

Sami Abduljabbar Rashid was born in Iraq, in 1989. He received the He received the B.Eng. degree in computer engineering technology from Al-Maarif University College, Iraq. and the M.Sc. degree in communication and compute engineering from University Kebangsaan Malaysia (UKM), Malaysia. He is currently pursuing the Ph.D. degree in the department of communication engineering, University Tun Hussein Onn Malaysia (UTHM), Malaysia. His research interests include wireless and mobile communications and VANET. He can be contacted at email: sami25.6.1989@gmail.com.

Sarmad Nozad Mahmood was born in Iraq in 1985. He received a B.S. degree in (electronic and control Engineering) from Northern Technical University, Iraq, and an M.Sc. degree in (electronic and communication Engineering) from Cankaya University, Turkey in 2008, and 2014 respectively. He is currently teaching staff in Computer Technology Engineering, College of Engineering Technology, Al-Kitab University, Iraq. He mainly interests in UWB Antennas, Wearable Antennas, antenna applications, image processing, wireless communication, Analog and Digital Communications, and control system designs. He can be contacted at email: sarmadnmahmood@gmail.com.

Sameer Alani was born in Iraq, in 1989. He received the B.S. degree in computer engineering and the M.Sc. degree in wireless communication and Computer networking technology from The National University of Malaysia (UKM), in 2017. He is currently pursuing the Ph.D. degree in wireless communication and networking. His research interests include antenna applications, wireless communication, and networking Technology. He can be contacted at email: itsamhus@gmail.com.