International Journal of
INTELLIGENT SYSTEMS AND APPLICATIONS IN ENGINEERING

ISSN:2147-6799 www.ijisae.org Original Research Paper

Performance Analysis of Smart Antenna for Wireless Communication

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Submitted: 10/09/2022 **Accepted:** 20/12/2022

Abstract: This study offers a compact three-dimensional antenna solution for the automotive sector. To fit in a shark-fin enclosure, a printed circuit board and metal sheet can be used to make the antenna. The antenna system covers LTE, GPS, WLAN, and WAVE bands (850 MHz, 1575 MHz, 2.4 GHz, and 5.9 GHz, respectively). Because of their low-profile design, planar inverted-F antennas (PIFAs) are commonly used as MIMO antennas in the LTE spectrum. Modified planar monopoles are used to produce omni-directional radiation patterns in the WLAN and WAVE bands. Antenna qualities that can be employed in automobiles have been modelled and tested. Using a shark-fin antenna, a novel vehicle-ready MIMO-LTE, GPS, WLAN and WAVE (850/1575 MHz, 2.4 and 5.9 GHz) solution has been shown. It is completely integrated. In addition to the two PIFAs and two modified monopoles, the solution includes a simple and low-cost manufacture method for a separate patch. It is designed to fit in a shark fin case when fitted on a level surface. Despite the lack of matching or decoupling networks, measurements and modeling reveal that this antenna system performs well in terms of return loss, radiation pattern, and isolation.

Keywords: *Microstrip Antennas, Wearable, Wireless, VSWR, Return Loss and Radiation Pattern*

1. Introduction

Low-terahertz (Low-THz, 100 GHz-1.0 THz) technology is expected to enable unprecedented data rates in future wireless systems, such as 6th generation (6G) mobile communication networks. Carriers can be boosted from millimeter wave to THz in order to maintain transmission rates and channel capacity. Because of the large transmission loss of Low-THzwaves in free space, compensating for the extra route loss and exceeding the power restriction of a Low-THz source necessitates the employment of exceptionally high gain antennas. Additive manufacturing (AM) and 3D printing (3DP) technology have lately made it easier and less expensive to build antennas with complicated shapes. As a first start, this study shows a number of innovative techniques to submillimeter wave and Low-THz antenna research and construction. Results from recent wideband and high-gain antennas are also given. A comparison of a variety of previously reported antennas is shown here. It is used to simulate a high-gain 300 GHz broadband antenna using Fabry-Perot cavity (FPC) theory. The proposed FPC antenna for forthcoming THz applications may be manufactured using AM technology at a low cost and great reliability. The precision of an antenna's construction is critical to its performance in the low-THz band. Production of traditional THz devices using these approaches may be both time and money-intensive. Wideband Low-THz antennas are examined here, along with their manufacturing procedures and the many strategies used by researchers to increase the antenna's gain.. A 300 GHz three-switched beam antenna may be constructed using these two antennas [1]-[5].

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The MBJ process, which is substantially faster and less expensive than the prior manufacturing approach, was used to build a 30 GHz scaled antenna element in order to validate that the proposed antenna had good performance. It is possible to agree on the results of a simulated and measured experiment. Comparisons of antenna type, size and frequency range and processing method are presented. Using AM methods, our antenna is the first to provide high gain and multi-beam radiation using a basic all-metal RCA construction in the millimeter-wave and low-THz bands. A high level of dimensional accuracy was found in the components fabricated in this investigation. Due to improvements in AM accuracy, we may soon be able to leverage new printing methods like hybrid 3DP and 4D printing to build our Low-Thz antennas. Phased array systems with low-THz active circuits are the next stage in our study, and they incorporate both active and passive circuits on a single chip. Low-Thz frequency scanning antennas will be studied further. An ultrawide bandwidth (UWB) spread spectrum (IR) short-range communication technology is used. A novel antenna design for wireless capsule endoscope (WCE) communication system signal reception is introduced and tested in this article. Antenna design incorporates three frequency bands (38.5, 48.2 and 57.2MHz operating frequencies). Antenna performance testing is carried out using three in-body transmitting antennas. The reflection and transmission coefficients, electric and magnetic field distributions, and particular absorption rates may all be simulated using a muscle equivalent phantom (SAR). A battery-powered IR transceiver is also used to test transmission performance in a liquid phantom.. Attenuation at 50 mm is 32, 43, and 52 dB at 38.5, 48.2, and 57.6 MHz, respectively. At a total data rate of 3.75 and 2.5 Mbps, WCE pictures may be received less than 50 and 90 mm away from the antenna using the suggested antenna, respectively. In this study, three single-band in-body transmitting antennas for WCE communication system signal reception were built, and their communication performance was tested. Low frequency multiband communications attenuated to 50 MHz, 403.5 MHz, and 2400 MHz, respectively, were measured using a 50-mm muscle phantom. In order to verify the accuracy of their antenna simulation model, the authors constructed a Rx and Tx3 prototype and performed free space reflection tests. Their next step was to simulate how variations in resonant frequency, reflection and transmission coefficients may alter their results [6]-[10].

Transmission coefficient enhancement by the Rx array under the misalignment situation and its implications on the SAR and maximum safe input power are some of the topics covered in this paper. Coupling occurred at 576 MHz, which is substantially equal to what was expected, except for the fact that antenna reflection and transmission coefficients were checked by VNA. Finally, the transmission quality of the battery-powered IR transceiver was tested. Transmission attenuation increases by 10.3, 13.3, and 16.4 dB as compared to simulations when the transmitting antenna frequency is changed. Medical imaging applications may normally expect data speeds of 3.75 Mbps and 2.5 Mbps at 50 and 90 mm [11]-[15].

Each node in an IoT network may fuel self-sustaining wireless communication systems by using a renewable energy source, such as energy harvesting (EH). This study examines WPCN protocols in order to facilitate communication between an access point (AP) and a large number of mobile users (MUs). Full-duplex (FD) functionality of the AP makes use of several antennas. There is just one antenna on a MU, which means it can only communicate in half-duplex mode (HD). MUs connected to the FD-AP fall into two categories: uplink (UL) and downlink (DL), which differ in terms of time allocation and channel access. The channel assignment, time resource, and power resource allocations are examined and adjusted in order to maximize the UL weighted sum-rate. The sum rate optimization problem is non-convex. UL weighted sum rates for the FD-WPCN system are being refined iteratively. HD-WPCN communication between the AP and many MUs is now available after these alterations have been implemented. Our FD-WPCN approach is also compared against the HD-WPCN method in several simulations. It appears that FD-WPCN outperforms HD-WPCN in the low AP transmit SNR range, according to simulation data. High AP transmit SNR leads to the opposite behavior due to an increase in residual self-interference at the FD-AP. Researchers in this study have come up with a whole new antenna design. In the Ultra-Wideband (UWB) frequency range of 3.75-4.25 GHz, the antenna is used for IEEE 802.15.6 Body Area Networks (BAN). The antenna's dimensions are 89 mm long by 60 mm broad and 21 mm high. The antenna's gain is 8 dBi at 4 GHz, which is the central frequency. In order to evaluate the antenna behavior in close proximity to the human body, specifically the small intestine, wireless capsule endoscopy localization must operate. A tissue-layer model, which mimics the dielectric characteristics of real body tissues, was used to replicate the dielectric properties of human body tissues at 4 GHz. This was followed by research into voxel models. Antenna features were first analyzed in relation to the body's own properties, and then the power _ow propagation into tissues was investigated. These techniques are used to test antenna communication with a capsule implanted in the small intestine. After that, the antenna's free-space propagation was tested and found to be accurate. These findings lead to a physical examination of male and female patients. The simulation results were generated by CST Microwave Studio. University of Oulu anechoic chamber measurements corroborated the findings. Frequency readings were converted to time measurements with the application of post-processing. Consequently, both modeling and measurements are in agreement. Antennas for wireless capsule endoscopy communications may be derived using IEEE 802.15.6-compliant UWB signaling. A novel antenna design is introduced in this research [16]-[20].

2. Proposed Antenna Methodology

IEEE 802.15.6-compliant antennas operate in the 3.75-4.25 GHz Low UWB band for BAN applications. Detailed measurements and simulations of the body's back and abdomen were used to generate its characteristics. It has been demonstrated that the antenna is a good candidate for usage in Body Area Networks. This study discusses antenna matching near to the human body. Using frequency and time domain data, a further comparison of the grounded structure is conducted. Antenna propagation efficiency is measured in free-space using models and experiments. These investigations were brought to an end by conducting on-body investigations. Antenna placement on human participants' bellies and backs was evaluated using a variety of antenna layouts, particularly at navel level. It began with computer models, which were followed by real-world measurements and observations. Simulation and measurement results were in excellent agreement in terms of the antenna's performance. Everything that has been learned about antenna operation from this work is useful for BAN applications.

Dual-band and dual-sensor wearable textile antennas are shown in this study. GPS operates at a frequency of 1.575 GHz while WBAN and WLAN applications operate at a frequency of 2.45 GHz. An AMC plane-based antenna backing in the 2.45 GHz band has been introduced to decrease backward radiation and boost antenna gain. Square patch unit cells are three-by-three, with four slits and a square ring built in. Placed on top of the substrate, the radiator looks like a square patch. Each of the radiator's four corners has a rectangular slit incorporated into it, allowing the circular polarization characteristic in the GPS band to be utilized for dual-band use. For the 2.45GHz band, the antenna achieved a realized gain of 1.94dBi, and for the 1.575GHz band, it achieved a realized gain of 1.98dBic. A dual-band and dual-sensing textile antenna was designed to track a person's exact location both inside and outside. The dual band radiator originated as a square patch with truncated corners in order to operate at both 1.575 GHz and 2.45 GHz (with linear polarization). An AMC plane has been designed to decrease the body coupling of wearable antennas.

A 3x3 array of unit cells is hidden below the antenna. Square patches with rectangular slots on either side and square bands make up the AMC unit cells for 2.45 GHz operation. The 1.575 GHz band has an axial ratio bandwidth of 9 percent at 3 dB for these two bands, with a total fractional impedance bandwidth of 27 percent and 7.5 percent. One may expect to see 1.98dBic at 1.575GHz, whereas at 2.45GHz, it has 1.94dBic. An analysis of the antenna under bending uncovered that it was better suited for operation when bent at the y-axis on the body. Antennas incorporated into the AMC aircraft have to have SAR values below 0.12 W/kg in order to be worn on a human's upper arm and shoulder. For wearable applications, it is suitable since its front to back ratio, which is normally above 10 dB, falls under the 2W/kg restriction.

Spectrum precoding negatively impacts overall system performance, especially in high data-rate multiple-input multiple-output (MIMO) systems and orthogonal frequency division multiplexed (OFDM) systems. TxEVM at the receiver may be reduced by using (large) MIMO systems' intrinsic degrees of freedom and thereby increasing systemwide throughput, as demonstrated by two mask-compliant spectral precoding schemes. In addition, we provide TOPADMM, a three-operator consensus alternating direction method of multipliers (ADMM) algorithm that breaks down a big issue into smaller ones that may be addressed more quickly and effectively. Spectral precoding issues are handled using the TOP-ADMM-based approach, which is efficient in terms of calculation time. An important set of numerical results is presented in our third contribution, which makes use of an NR release 15-compliant simulator. Out-of-band emission (OOBE) criteria can be met even if the transmitter possesses perfect channel information, as long as the proposed alternatives give the same block error rate and throughput performance. However, even when the throughput decreases gradually with channel uncertainty, OOBE efficiency is unaltered. Dynamic beamforming algorithms confront considerable challenges in millimeter wave communications in high-speed rail (HSR) networks because of the projected high speed trains (up to 500 km/h). Because HSR cellular networks have a linear structure, the train's path may be anticipated practically perfectly. Fixed beamforming, which uses highly directional antennas with predefined emission directions, is a low-cost alternative to dynamic beamforming. However, in order to justify the use of fixed BF in HSR mmWave communications, the performance difference between dynamic BF and fixed BF must be examined. In order to conduct empirical analyses, this study makes use of raw data obtained through extensive measurement operations. The regular railway station and the high-speed rail tunnel are two of the most often encountered train traffic locations [21]-[25].

Analysis of received signal intensity, power deflection profiles and root-mean squared delays is presented. On the basis of the acquired data, we extend the commonly used close-in freespace (CI). Model in the HSR tunnel to increase generalized model's accuracy in describing the PL there. It is therefore possible to compare dynamic BF to fixed BF by using the extended model and the observed data. We found that even with severe beam misalignment, dynamic BF's throughput was only 4 percent higher than fixed BF's, while the throughput in the train station was 21 percent higher. Energy efficiency, which is crucial in wireless communications, allows for high data rates. Use of D2D under multiple antenna cellular systems as a potential method for producing energy-efficient devices. Cellular users interfere with D2D pairings, while D2D pairs interfere with each other. The BS also interferes with D2D pairs. To support multi-D2D communications via numerous antennas, the BS has developed resource allocation algorithms that are both energy efficient and multi-D2D compatible. Using the Dinkelbach algorithm, the Message Passing Algorithm (MPA), and multi-layer artificial neural networks, we offer a strategy for maximizing global energy efficiency while fulfilling the data rate needs of both cellular users and D2D couples [26]-[30].

3. Results and Discussion of the Methodology

MPA's factor graph for D2D pairings takes interference between D2D pairs and interference at the base station (BS) into account. A combined approach for training a deep neural network off-the-shelf is what makes this possible. In multi-D2D communications, algorithms for optimum resource allocation have been proven to outperform traditional single-D2D communication. Our research focused on a wide range of subjects, including wireless interchip communication between neighboring ICs. Using symmetrical layers, it is suggested that To avoid destructive interference, redirect the emitted energy away from the receiving antenna and into the vacuum of space. In order to focus the emitted energy toward the receiving antenna, substantial research is being done on EBG structures and soft/hard surfaces. Due to the reduction of spherical spreading losses resulting from spherical radiation, the receiving antenna gets greater power. This study presents a millimeter-wave (mmWave) communication system architecture based on quadrature spatial modulation employing a frequency diversity array (FDA) (QSM). Spatial Modulation Techniques employ maximum modulation in order to accomplish their desired results [31]-[35].

At the receiver, the computational complexity of an ML-based detector skyrockets. In addition, phased array (PA) SMT systems are employed, which only permit communication at an angle. For range-angle dependent QSM wireless communications, we propose a standard FDA based on a modest linearly rising frequency set across the array. ‘Vectors transfer data using slightly varied frequencies. We propose in the receiver a suboptimal multiple-stage (MS) detector that first decodes the index bits using matched filtering and then utilizes two most probable estimates to decode associated data bits using a conventional ML approach to decode these data bits. While the MS strategy reduces receiver processing complexity by using FDA-based range and angle-dependent transmission, modeling and numerical results demonstrate that the suggested design is superior to existing SM and QSM based approaches. Silicon technology may be used to produce a high gain on-chip antenna for subterahertz applications, according to research reported in this publication. On top of the polycarbonate layer is an aperture feeding mechanism, which is utilized to link electromagnetic energy from the metal slot-line sandwiched between silicon and polycarbonate substrates to 15-element array made up of circular and rectangular radiation patches. A microstrip line with an open end that is orthogonal to the metal slot line is buried beneath the silicon substrate. An open-ended microstrip line that is stimulated to drive a metal slot line is used to couple and output the signal from patch arrays. There is an efficiency of 70.8 percent for the on-chip antenna, which is below 10dB at 0.290 THz to 0.316 THz based on the results. The antenna's stopband is exceptionally narrow between 0.292 THz and 0.294 THz. The antenna is 20 x 3.5 x 0.126 mm3 in size. We're looking at wireless energy transmission [36]-[40].

With a high number of base station antennas, estimations from orthogonal and shared uplink pilot signaling approaches enable Wireless Energy Transfer (WET) to a large number of sensors. We get new upper limits on the probability of a WET outage if every sensor node fails to gather a specific minimum amount of energy Eu required to deliver uplink pilots and the energy Ep required for its primary operations. Number of base station antennas increases with sensor node count, transmission power, channel estimation errors and the kind of pilot signaling technology utilized. We demonstrate that the outage probability is the same with an orthogonal method as with a shared strategy when the sensor nodes are equidistant from the BS. In situations where the two strategies are positioned at different distances from each other, the orthogonal technique is more effective. In order to overcome this problem, we offer a simple location-dependent clustering and hybrid pilot assignment strategy. Using the proposed technique, an interesting trade-off between outage performance and the resources required for channel estimation is revealed. Antenna arrays are commonly used to locate active communication transmitters and passively reflected radar targets. Quality of localization has slipped, unfortunately [41]-[45].

Time delays and antenna placement inaccuracies, especially in large array systems with many antennas spread across a vast area Cable phase instability and position misalignment cause these flaws to be varied until the array is securely installed. Therefore, the in-situ array calibration is required. Beacons that are sent incoherently can lead to erroneous location. Because the in-situ calibration will be affected by multipath, measurements of the array's reference points that are not uniform. The near field is used to do the calibration. Because of this, the algorithm runs much faster. Path losses might vary wildly owing to unknown causes.

The technique through which physically plausible effects are accomplished using a soundproofed environment additionally, the caliper is Indoor findings can be confirmed using three antennas. Outcomes from the calibration of the arrays indicated in the paper. The purpose of this work is to design and build a compact MIMO antenna (MIMO). Ground-radiation antenna system for the 5G terminal device. Ground radiation is emitted by small loop-type antennas. As portable radiators with tiny, lightweight resonators that can excite the ground plane. Outdoor WLANs benefit from its wind resistance. By merging human body shape and physical layer features, a novel biometric identification feature for wearable communication applications is described in this study Antenna-tissue interactions alter the physical layer characteristics of closely fitting wearable devices in a unique way. In a novel biometric idea, return loss traits may be utilized to identify individuals on a variety of body areas. An upgraded directional coupler design and an optimized antenna for detecting differentiating traits are employed for person identification. It was revealed that classification accuracy for stationary participants was more than 98 percent and for mobile subjects was greater than 93 percent when using a prototype standalone test-bed with sensor circuits running at 2.45 GHz. Authentication and authorization of users can be accomplished by using circuitry already present in wireless wearable communication systems as an indicator of return loss. Future wireless communications will benefit greatly from massive multiple-input multiple-output (MIMO) systems, which may increase spectral efficiency by orders of magnitude. Existing large MIMO systems, on the other hand, use classic phased arrays for beamforming. Electricity consumption is high and expensive hardware is needed for this procedure. Configurable intelligent surface (RIS), a two-dimensional structure with many passive elements, has lately been recognized as one of the revolutionary technologies to enable energy-efficient and intelligent wireless communications.. High-gain and low-cost high-resolution imaging systems are provided in this work. For beamforming, the proposed RIS use PIN diodes to create 2-bit phase shifting using PIN diodes, which combines the effects of phase shift and radiation on an electromagnetic surface. It is because of this groundbreaking design that the world's first wireless communication prototype was built [46]-[50]. The prototype includes all of the following: hosts for parameter setup and data interchange, universal software radio peripherals (USRPs) for baseband signal processing, and receiver-input-output (RIO) for data transmission and reception. Each of these components is present in the prototype. Our findings show that RISs in wireless communications are both practical and effective. At 2.3 GHz, the RIS proposed in this study provides a gain of 21.7 dBi. Antenna gain of 19.1 dBi is achieved at millimeter wave frequency (28.5 GHz) (mmWave).

Power consumption has also been reduced dramatically in this RIS-based wireless communication prototype. Physical layer security (PLS), which has attracted a lot of attention, provides reliable and lightweight secure communications for automobile networks. There is currently no way to keep passive eavesdroppers safe, even if they have many antennae. We propose a physical layer secure MIMO-SVD communication to fill this gap. Any number of antennas against an eavesdropper using a way (SSVD). SSVD-enhanced data frames are used to encrypt sensitive data at the transmitter. In conjunction with activated/non-activated MIMO parallel subchannels of the valid receiver and SSVD precoding integration, the crucial information is then connected and transmitted across the wireless channel.

In order to decode (XOR) the secret data, only the legitimate receiver may view the key information and utilize it in a step-by-step method with an arbitrarily low BER due to the uniqueness and independence of the wireless channel (bit error rate). Regardless matter how many antennas an eavesdropper has, he or she will be unable to gather any essential information from the signals received. Eavesdroppers can't "decrypt" any information connected to the secret material because of the encryption. The validity of security and dependability has been demonstrated mathematically and conceptually. There are various chances to expand mobile capacity due to the large bandwidth available in the millimeter-wave (mmWave) frequency. Propagation channels in the mmWave spectrum were measured and modelled using a wideband sliding correlator channel sounder with steerable directional horn antennas at both transmitter and receiver from 2011 to 2013. A total of more than 15,000 power delay profiles were generated from the mmWave bands, which were then utilized to develop path loss models, channel models, and outage probabilities. These models give side-by-side comparisons of propagation qualities over a number of mmWave bands for upcoming mmWave system development and standardization [51]-[55]. As a result, researchers can compare and standardize path loss parameters for emerging millimeter wave networks by using these models of path loss in real-world environments, including the use of directional antennas is shown in figure 1 and table 1.

Table.1. Performance Analysis of Microstrip Antennas

Frequencies(GHz)	Return Loss (dB)	Gain (dB)	VSWR	Efficiency (%)
2.5	-18.08	3.2	1.2	45

3.5	-20.28	4.2	1.4	55
4.5	-22.45	4.8	1.5	58
5.5	-25.98	5.2	1.4	65
6.5	-32.56	6.8	1.6	70
7.5	-30.85	7.2	1.8	75
8.5	-28.58	8.2	1.7	80

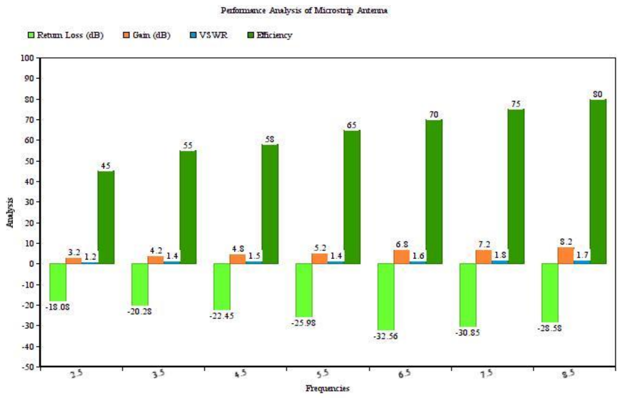

Figure.1. Performance Analysis of Microstrip Antennas

4. Conclusion

A new channel impulse response modeling framework for link-layer simulations is developed based on the observation that spatial lobes contain multipath energy that arrives at various propagation time intervals. The data presented here could be used to study and simulate future mmWave wireless networks that use adaptive antennas and multiple input and multiple output antenna systems (MIMO). Explained is the new double-sided redistribution layer technology used in Fowlp packaging, which has tall copper vertical interconnects. A dual-polarized magnetoelectric (ME) dipole antenna is presented as a result of this new packaging technology. Good impedance matching and steady radiation patterns were established in this investigation using an antenna of 10x10 mm2 area, which covers the majority of millimeter-wave frequencies used in 5G mobile networks in different countries. The antenna's FOWLP compatibility allows it to be utilized in phased-array 5G wireless communication systems.

Author contributions

Jacob Abraham: Design, Conceptualization, Methodology, Software, Field study and Writing

Kannadhasan Suriyan: Analysis, Writing-Original draft preparation, Software, Validation., Field study and Discussion

Conflicts of interest

The authors declare no conflicts of interest.

References

[1]. A. Lai, C. Caloz, and T. Itoh, "Composite right/left-handed transmission line metamaterials," *IEEE Microwave., Mag*., vol. 5, no. 3, pp. 34–50, sept. 2004.

[2]. Laure, H., Koubeissi, M., Mouhamadou, M., *et al.*: 'Compact and multiband dielectric resonator antenna with pattern diversity for multistandard mobile handheld devices', *IEEE Trans. Antennas Propag.*, 201

[3]. Won-Gyu, J., Choi, J.-H.: 'Design of a wide and multiband aperture-stacked patch antenna with reflector', *Microw. Opt. Technol. Lett.*, 2007, **49**, pp. 2822– 2824 (doi: 10.1002/mop.22876)

[4]. Ziolkowski, R.W., Erentok, A.: 'Metamaterial-inspired efficient electrically small antennas', *IEEE Trans. Antennas Propag.*, 2008, **56**, (3), pp. 691–707 (doi: 10.1109/TAP.2008.916949)

[5]. Alibakhshi-Kenari, M.: 'Introducing the new wideband small plate antennas with engraved voids to form new geometries based on CRLH MTM-TLs for wireless applications', *Int. J. Microw. Wirel. Technol.*, 2014, **6**, (6), pp. 629– 637 (doi: 10.1017/S1759078714000099)

[6]. Linda A. Yimdjo Poffelie, Ping Jack Soh, Sen Yan, and Guy A. E. Vandenbosch, A High-Fidelity All-Textile UWB Antenna With Low Back Radiation for Off-Body WBAN Applications, *IEEE Transactions On Antennas And Propagation*, Vol. 64, No. 2, February 2016 pg-757 -760

[7]. Mohammad Alibakhshikenari, Bal S. Virdee, Leyre Azpilicueta, Mohammad Naser-Moghadasi, Mobayode Olusola Akinsolu, Chan Hwang See, Bo Liu, Raed A. Abd-Alhameed, Francisco Falcone, Isabelle Huynen, Tayeb A. Denidni, Ernesto Limiti, A Comprehensive Survey of "Metamaterial Transmission-Line Based Antennas: Design, Challenges, and Applications", *IEEE Access*, 10.1109/ACCESS.2020.3013698, **8**, (144778-144808), (2020)

[8]. Komal Jaiswal, Shekhar Yadav, Nagendra Yadav, Ram Suchit Yadav, Analysis of Different Feeding Techniques of Butterfly-Shaped Patch Antenna with Defected Ground for UWB Application, *IETE Journal of Research*, 10.1080/03772063.2020.1773947, (1-10), (2020).

[9]. G. Geetharamani, T. Aathmanesan, A Metamaterial Inspired Tapered Patch Antenna for WLAN/WiMAX Applications, *Wireless Personal Communications*, 10.1007/s11277-020-07283-5, (2020).

[10]. Sahar Abdi Tazehabadi, Shahrokh Jam, X-band reflectarray antenna with arbitrarily (elliptical) polarization for high-power microwave applications, *Engineering Science and Technology, an International Journal*, 10.1016/j.jestch.2019.08.004, (2019).

[11]. Asimina Kiourti, John L. Volakis, Roy B. V. B. Simorangkir and Syed Muzahir Abbas, UWB Antennas on Conductive Textiles, 2016 *International Symposium on Antennas and Propagation (APSURSI)*, ISSN. 978-1-5090-2886-3,pp. 1941-1942.

[12]. Kawshik Shikder and Farhadur Arifin, Design and Evaluation of a UWB Wearable Textile Antenna for Body Area Network, International Conference on Electrical Information and Communication Technology (EICT 2015),ISSN-978-1-4673-9257-0, pp. 326-330.

[13]. Maciej Klemm, Member, IEEE, and Gerhard Troester, Senior Member, Textile UWB Antennas for Wireless Body Area Networks, IEEE Transactions On Antennas And Propagation, Vol. 54, No. 11, November 2006, pp.3192-3197

[14]. Stephen A. Holland, Dounia Baiya, Essam Elkhouly, A. E. Fathy, Ultra Wideband Textile Antenna Development for Indoor Localization, IEEE MTT-S *International Microwave Symposium Digest(MTT)*, ISSN. 978-1-4673-2141-9,2013.

[15]. Jong Ok Ha, Seung Hwan Jung, Myung Cheol Park, Kyung Hak Lee, and Yun Seong Eo, A fully Integrated 3-5 GHz UWB RF Transceiver for WBAN Applications, *MTT-S International Microwave Workshop Series on RF and Wireless Technologies for Biomedical and Healthcare Applications* (IMWS-BIO) 2013,ISSN. 978-1-4673-6096-8.

[16]. Agrawal, A. ., and G. . Tiwari. "Design Simulation and Assessment of Computer Based Cancer Diagnosis Accuracy Using ART 1.0 Algorithm". International Journal on Recent and Innovation Trends in Computing and Communication, vol. 10, no. 3, Apr. 2022, pp. 25-34, doi:10.17762/ijritcc.v10i3.5522.

[17]. Kawshik Shikder, Farhadur Arifin, A Novel UWB Wearable Icon-Type Textile Antenna for WBAN Applications, *International Conference on Electrical, Computer and Communication Engineering* (ECCE), February 16-18, 2017.

[18]. Lemey, S Declercq, F, Rogier, H 2014, 'Textile antennas as hybrid energy-harvesting platforms, *Proceedings of the IEEE*, vol. 102, no. 11, pp.1833-1857

[19]. Lin, TH, Bito, J, Hester, GD , Kimionis, J, Bahr, RA & Tentzeris, MM 2017, 'On-body long-range wireless backscattering sensing system using Inkjet-/3-D printed flexible ambient RF energy harvesters capable of simultaneous DC and harmonics generation, *IEEE Transactions on Microwave Theory and Techniques*, vol. 65, no. 12, pp. 5389-5400.

[20]. Ravita, R., & Rathi, S. (2022). Inductive Learning Approach in Job Recommendation. International Journal of Intelligent Systems and Applications in Engineering, 10(2), 242–251. Retrieved from https://ijisae.org/index.php/IJISAE/article/view/1829

[21]. Lemey, S, Agneessens, S, Torre, PV, Baes, K, Vanfleteren, J & Rogier, H 2016, 'Wearable flexible lightweight modular RFID tag with integrated energy harvester', *IEEE Transactions on Microwave Theory and Techniques*, vol. 64, no. 7, pp. 2304-2314.

[22]. Louis Wy Liu, Abhishek Kandwal, Hongjian Shi, & Qingsha S. Cheng 2018, 'Wireless Power Transfer Using an RF Plasma', *IEEE Access*, vol.6, pp. 73905-73915.

[23]. Bose Anandhi Meena, Palavesanadar Thiruvalar Selvan, Singaravelu Raghavan, Compact Metamaterial Antenna with High Directivity for Bio-Medical Systems, *Circuits and Systems*, No. 7, pp-4036-4045,2016. http://dx.doi.org/10.4236/cs.2016.712334.

[24]. B. Anandhi Meena, P. Thiruvalar Selvan, B. Nagaraj, S. Raghavan, S. Suganthi and V. Karthiyayini, Novel Splitring Resonator Antennas for Biomedical Application, Journal of Pure And Applied Microbiology *Special Issue on Recent Research Challenges in Bio-Medical Applications*, Aug. 2015. Vol. 9, pp- 235-242.

[25]. Anandhi Meena B, Thiruvalar Selvan P, Raghavan S, Suganthi S, Design of CSRR Embedded Metamaterial Monopole Antenna for WiMAX Applications, *ARPN International Journal of Engineering and Applied Sciences*, Vol 10, No-5, pg-2214-2216, March 2015, ISSN: 1819-6608

[26]. Anandhi Meena B, Thiruvalar Selvan P, Raghavan S, Suganthi S, Sindhiya S, Effect of ground Plane structures in Metamaterial Inspired Monopole Antenna, *International National Journal of Applied Engineering Research*, Vol 10, No-5, pg-4777-4780, 2015 ISSN: 0973- 4562.

[27]. Anandhi Meena B, Thiruvalar Selvan P, Raghavan S, Suganthi S, Sindhiya S, Effect of ground Plane structures in Metamaterial Inspired Monopole Antenna, *International National Journal of Applied Engineering Research*, Vol 10, No-5, pg-4777-4780, 2015 ISSN: 0973- 4562.

[28]. Mohammad Alibakhshi-Kenari,Mohammad Naser-Moghadasi,Ramzan Ali Sadeghzadeh,Bal S. Virdee,Ernesto Limiti, Periodic array of complementary artificial magnetic conductor metamaterials-based multiband antennas for broadband wireless transceivers, https://doi.org/10.1049/iet-map.2016.0069, 01 December 2016

[29]. N. A. Libre. (2021). A Discussion Platform for Enhancing Students Interaction in the Online Education. Journal of Online Engineering Education, 12(2), 07–12. Retrieved from http://onlineengineeringeducation.com/index.php/joee/article/view/49

[30]. Mohammad Alibakhshi-Kenari, Mohammad Naser-Moghadasi, R.A. Sadeghzadeh, Bal S. Virdee, Ernesto Limiti, Bandwidth Extension of Planar Antennas Using Embedded Slits for Reliable Multiband RF Communications", *AEUE Elsevier- International Journal of Electronics and Communications*, Volume 70, Issue 7, July 2016, Pages 910–919, http://dx.doi.org/10.1016/j.aeue.2016.04.003

[31]. Agarwal, D. A. . (2022). Advancing Privacy and Security of Internet of Things to Find Integrated Solutions. International Journal on Future Revolution in Computer Science &Amp; Communication Engineering, 8(2), 05–08. https://doi.org/10.17762/ijfrcsce.v8i2.2067

[32]. Dr.K.Meena alias Jeyanthi, E.Thangaselvi,A.S.Prianga," Simulation of rectangular microstrip antenna using nylon fabric material", *International Journal of Emerging technology and advanced engineering*", vol.3,Issue 1,pp 645-647,Jan 2013

[33]. S. Maria Glammi, K. Meena Alias Jeyanthi, "Design of Wide Band and Rectangular Microstrip Patch Antenna for Breast Tumor Detection", *International Journal of Recent Technology and Engineering (IJRTE)* ISSN: 2277-3878, Volume-7, Issue-5S3, February 2019**.**

[34]. S.Kannadhasan and R.Nagarajan, Development of an H-Shaped Antenna with FR4 for 1-10GHz Wireless Communications, *Textile Research Journal*, DOI: 10.1177/00405175211003167 journals.sagepub.com/home/trj, March 21, 2021, Volume 91, Issue 15-16, August 2021 Impact Factor: 1.926], Sage Publishing

[35]. Mohammad Alibakhshi-Kenari,Mohammad Naser-Moghadasi,Ramazan Ali Sadeghzadeh,Bal Singh Virdee,Ernesto Limiti "New Compact Antenna Based on Simplified CRLH-TL for UWB Wireless Communication

Systems", *International Journal of RF and Microwave Computer-Aided Engineering*, Volume 26, Issue 3, March 2016, pages: 217–225.
[36]. S.Kannadhasan and R,Nagarajan, Performance Improvement of H-Shaped Antenna With Zener Diode for Textile Applications, *The Journal of the Textile Institute*, Taylor & Francis Group, DOI: 10.1080/00405000.2021.1944523
[37]. Mohammad Alibakhshi-Kenari,Jaume Anguera "New Compact Printed Leaky-Wave Antenna with Beam Steering", *Microwave and Optical Technology Letters*, Volume 58, Issue 1, January 2016, Pages: 215–217.
[38]. Mohammad Alibakhshikenari , Mohsen Khalily , Bal Singh Virdee , Chan Hwang See , Raed A. Abd-Alhameed , Ernesto Limiti , "Mutual-Coupling Isolation Using Embedded Metamaterial EM Bandgap Decoupling Slab for Densely Packed Array Antennas", *IEEE Access*, vol. 7, pp. 5182–51840, April 29, 2019
[39]. Zhang J, Yan S, Vandenbosch GAE. Metamaterial-inspired dual-band frequency-reconfigurable antenna with pattern diversity. *Electron Lett*. ,55(10):573-574, 2019.
[40]. A. M. Al-samman, M. H. Bin Azmi, and T. A. Rahman, "A survey of millimeter wave (mm-wave) communications for 5G: channel measurement below and above 6 GHz," in Recent Trends in Data Science and Soft Computing, F. Saeed, N. Gazem, F. Mohammed, and A. Busalim, Eds., vol. 843, *Springer, Berlin*, Germany, 2019.
[41]. B. Almohammed, A. Ismail, and A. Sali, "Electro-textile wearable antennas in wireless body area networks: materials, antenna design, manufacturing techniques, and human body consideration-a review," *Textile Research Journal*, vol. 91, no. 5-6, pp. 646–663, 2020.
[42]. P. M. Potey and K. Tuckley, "Design of wearable textile antenna for low back radiation", *Journal of Electromagnetic Waves and Applications*, pp. 1-11, 2019.
[43]. Chen H, Zhao A. LTE antenna design for mobile phone with metal frame. *IEEE Antennas Wireless Propag Lett* ,5:1462-1465, 2016.
[44]. Kannadhasan S and.Nagarajan R, Performance Improvement of Slot Antenna Using Various Parameters and Band Pass Filter. *IEEE International Conference on Circuits and Systems in Digital Enterprise Technology*, December 21 and 22, 2018, Saintgits College of Engineering, Kottayam, Kerala. ISBN: 978-15-38605-75-2
[45]. S. Surya and R. Ravi, "Concoction Node Fault Discovery (CNFD) on Wireless Sensor Network Using the Neighborhood Density Estimation in SHM ", *Wireless Personal Communication*, Vol.113, No.4, 2020, pp. 2723–2746
[46]. Pérez-Moreno CG, Grajal J. Physical electro-thermal model for the design of Schottky diode-based circuits. *IEEE Trans Terahertz Sci Technol*. 2014;4(5):597-604.
[47]. Caverly RH. Microwave and RF p-i-n diode model for timedomain simulation. *IEEE Trans Microwave Theory Techn*. 2012; 60(7):2158-2164.
[48]. Grajal J, Krozer V, Gonzalez E, Maldonado F, Gismero J. Modeling and design aspects of millimeter-wave and submillimeter-wave Schottky diode varactor frequency multipliers. *IEEE Trans Microwave Theory Tech*. 2000;48(4):700-711.
[49]. Siles JV, Grajal J. Physics-based design and optimization of Schottky diode frequency multipliers for terahertz applications. *IEEE Trans Microwave Theory Tech*. 2010;58(7):1933-1942.
[50]. S. M. Hosseini Varkiani and M. Afsahi, "Grounded CPW multi-band wearable antenna for MBAN and WLAN applications*", Microwave and Optical Technology Letters, vol. 60, no. 3, pp. 561-568, 2018.*
[51]. Ibrahim Tekin, Michael Knox, "Reconfigurable dual band microstrip patch antenna for Software Defined Radio Application", 2010.
[52]. "Enhanced Bandwidth Refelctarray Antenna Using Variable Dual Gap", 2011 Ismail M Y, Sulaiman N H , *International Conference on Instrumentation, Communication, Information Technology and Biomedical Engineering*, Bandung, Indonesia.
[53]. Ismail M Y, Sulaiman N H, "Integration of H-shaped Element with Rectangular Slot for Broadband Reflectarray Antennas", *International Seminar on the Application of Science & Mathematics* 2011.
[54]. Sazegar M, Zheng Y, Maune H, Damm C, Zhou X, Binder J, Jakoby R, "Low-Cost Phased-Array Antenna using Compact Tunable Phase Shifters Based on Ferroelectric Ceramics", *IEEE Trancsations on Microwave Theory and Techniques*, Vol. 59, No. 5, May 2011.
[55]. Ouaddari M, Delprat V, Vidal F., Chaker M., Ke Wu, "Microwave Characterization of Ferroelctric Thin-Film Materials", *IEEE Transactions on Microwave Theory and Techniques*, Vol. 53, No. 4, April 2005.
[56]. R. Tino Merlin and R. Ravi, Novel Trust Based Energy Aware Routing Mechanism for Mitigation of Black Hole Attacks in MANET, *Wireless Personal Communications*, February 2019. IF 1.20. https://doi.org/10.1007/s11277-019-06145-z.
[57]. Haider, N. D, Caratelli, and Yarovoy A.G., "Recent development in reconfigurable and multiband antenna technology*," Int.J.Antennas Propag*, 2013,14 pages, Article ID 869170.
[58]. Majid H., Kama M.l, Rahim A., Rijal M., Ismail M.F.. "A Compact Reconfigurable Narrowband Microstrip Slot Antenna," *IEEE Antennas and Wireless Propagation Letters*, vol.11, 2012.
[59]. Sayem, A.S.M.; Simorangkir, R.B.V.B.; Esselle, K.P.; Hashmi, R.M. Development of Robust Transparent Conformal Antennas Based on Conductive Mesh-Polymer Composite for UnobtrusiveWearable Applications. *IEEE Trans. Antennas Propag*. 2019, 67, 7216–7224