Design of Compact MIMO Multiband Antenna for Wireless Radio Communication Application

C. Anand

Department of CSE, K.S.R. College of Engineering, Tiruchengode, India

E-mail: anandsione@gmail.com

Abstract

Slot and patch modification for the design of a compact multiband antenna with Multi-Input-Multi-Output (MIMO) functionality is proposed in this paper. At various frequency bands, the antenna performance is obtained by modification and addition of slot and patch shapes in the design of the compact MIMO multiband antenna. Addition of slots or patches is done separately in the already existing multiband antenna designs. Whereas in this work, the addition of slot and patch are combined. Arlon Diclad 880 with a dielectric constant of 2.17 - 2.2 (εr) and height 0.75mm is used for the antenna design. The MIMO multiband antenna with the dimension of 12.5 mm × 7.5 mm is designed. On various millimeter-wave frequency bands ranging from 20 GHz to 40 GHz, the MIMO antenna can function as observed in the results of simulation and evaluation. This work shows that microstrip antennas can be added with slots and patches during their design and development, thereby enabling the antenna to operate under multiple frequency bands.

Keywords: MIMO, Slot Antenna, Multiband antenna, Patch modification, Wireless radio communication

1. Introduction

The multiband antennas are allocated with diverse frequency bands that are far apart from each other [1]. They are essential for the modern-day wireless communication systems due to their

SWS

features and functionalities. In this paper, the design of a compact multiband MIMO (Multiple Input Multiple Output) antenna is presented, and the results are simulated to analyze its efficiency [2]. Despite having a wide bandwidth, a single band antenna cannot accommodate this. The wireless communication system frequency range requirements can be supported by proposing a solution to the bandwidth limitation, by designing a microstrip antenna with limited frequency and bandwidth. In the design and development of antennas for cellular communication systems, meeting the range of frequency bands required for the antenna is challenging [3]. The future wireless communication systems mainly require millimeter-wave frequency range and MIMO system capability. Several frequency bands in the millimeter-wave are required for the fifth-generation technology (5G) cellular communication and modern wireless radio networks. In order to support these frequency ranges, the antennas that support these requirements are essential [4].

At various frequency bands like 26-28 GHz, 24 GHz and 3.5 GHz, the development plans of 5G technology are proposed in Indonesia [5]. The need for developing antennas can be anticipated, for meeting the requirements of 5G technology that can operate on multiple frequency bands [6]. For wireless radio applications, a multiband MIMO antenna is designed and developed that operates in the millimeter-wave frequency range. Various existing literature propose the use of multi-slit regular patch [7], addition of patches to multiband and MIMO antennas [8], addition of slots [9], addition of slit using MIMO technique [10] and so on. The addition of patch and slot is combined in this design for the development of a microstrip antenna. This state of the art design offers improved antenna performance for multiband applications when compared to the existing techniques.

2. Literature Review

Subchannel correlation of the stochastic MIMO channel model is characterized as a joint function of the receive and transmit arrays [11]. Rather than the models, the measured MIMO

SWS

channel capacity is predicted more accurately, and verification of the joint-correlation channel model is presented with independent correlation characterized at the transmit and receive arrays. These models are also called the marginal-correlation channel models [12-15]. On either side of the MIMO link, the correlation of the antenna array is minimized independently based on the joint correlation between the transmit and receive arrays using the MIMO channel capacity function. The available channel capacity, however, cannot be persevered by the MIMO link. In studies related to channel models immersing a single array in rich multipath, such as one-sided-correlation and marginal-correlation channel, the aforementioned subtlety has been overlooked. The received signals at an antenna can be decorrelated by mutual coupling in the antenna array [16]. In MISO and SIMO communications, the diversity gain is observed by this decorrelation by influencing the diversity of the array's angle. In each array, a decorrelating effect is produced independently by simulating a marginal channel model for computing the larger MIMO channel capacity [17]. The channel capacity, however, cannot be restored by the joint decorrelation of general MIMO channels using these conclusions [18].

The multipath interface of the array and its effect are not considered when taking into account the independently constrained interface between the available multipath and each array in the array design paradigms that currently exist [19]. In polarization-space or angle-space, at the radiation pattern of each array, fixed orthogonal division is performed and at each side of the link, decorrelation is achieved independently in the diversity-array paradigm [20]. The multipath perceived alone is matched with the radiation pattern of each array in the smart-array paradigm [21]. In the design of the MIMO array, a different approach is suggested by the MIMO transmitter and receiver based on the joint relationship between the two [22]. Due to the joint-correlation nature of the challenge, perception of the MIMO capacity is not ensured by the diversity-array design constraint [23]. The strongest Eigen channel capacity is achieved by the MIMO link as a result of the smart-antenna constraint. For all minimum Eigen channels, joint and simultaneous

SWS

formation of Eigen beam pairs are permitted, and the eigenvalue distribution or inherent Eigen structure of the MIMO channel is not distributed in order to preserve the available capacity of the MIMO channels by designing a pair of arrays [24]. Using arrays whose elements are omnidirectional and independently interfaced with the multipath realization's joint angular spectra which is a condition that must be satisfied for preserving the channel capacity [25].

3. Proposed Research Methodology

3.1 Microstrip Antenna Design Method

In this paper, a multiband MIMO antenna design is introduced with the help of multipatch multi-frequency technique and loaded multifrequency technique. A U-slot and a patch are included as part of modifying the patch antenna. Miscellaneously loaded or reactively loaded by the addition of reactive load on capacitors, pins, slots and stubs is taken into consideration.
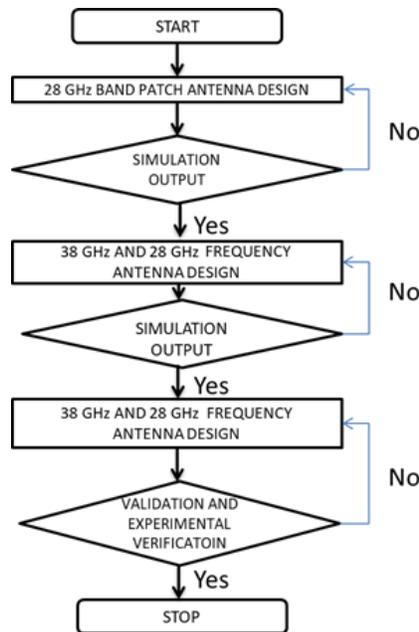
Figure 1. Design of Multiband Antenna

SWS

To produce more than one frequency band, multi-frequency multipatch is used by proper arrangement of the multiple patch antennas. Fig.1 indicates the design methodology that is incorporated in this paper in order to develop the multiband antenna. Here, the patch antenna is initially designed to operate in the 28 GHz frequency and on addition to patches, 38 GHz is attained as the working frequency. Addition of slots will further modify the patch to operate at the 24 GHz frequency.

CST Microwave Studio 2016 is the simulation software that is used in order to obtain the results of design simulation. A Vector Network Analyzer (VNA) is used for measuring the results of antenna fabrication. Radiating elements, substrate material and ground plane are the basic constituents of a typical microstrip patch antenna.
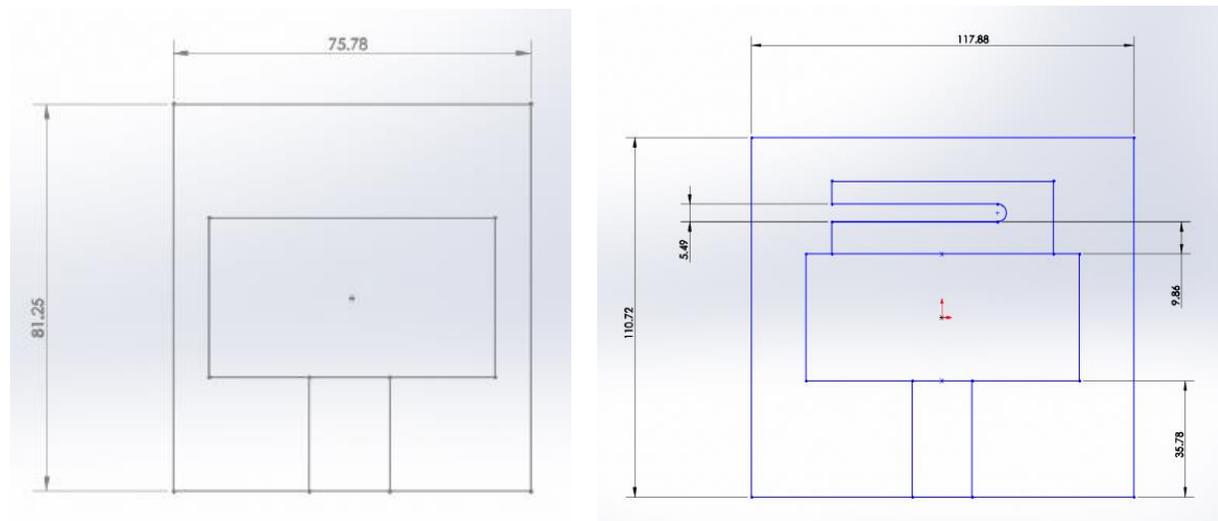
3.2 MIMO Antenna Design

Table 1 is used for designing the MIMO multiband antenna in an efficient manner.

**Table 1.** Specifications of MIMO multiband antenna

Parameters	Specifications
Frequency Band	24 GHz, 28 GHz, 38 GHz
Bandwidth	$\geq$ 1000 MHz
VSWR	$\leq$ 2
Return Loss	≤ -10 dB

SWS

Arlon Diclad 880 is the substrate material that is incorporated in multiband MIMO antenna design. It has a thickness of 0.75 mm and a permittivity of 2.17. According to the proposed work, Fig.2 shows the representation of a millimeter-wave region in which the multiband antenna design operates.

Figure 2. Multiband Antenna (a) 28 GHz Antenna Design, (b) 38 GHz Antenna Design with Patch Antenna

As per the use in wireless radio applications, a better beam width performance is possible with the help of a 2T2R MIMO configuration and 4-element linear array configuration as represented in Fig.3.

175

SWS
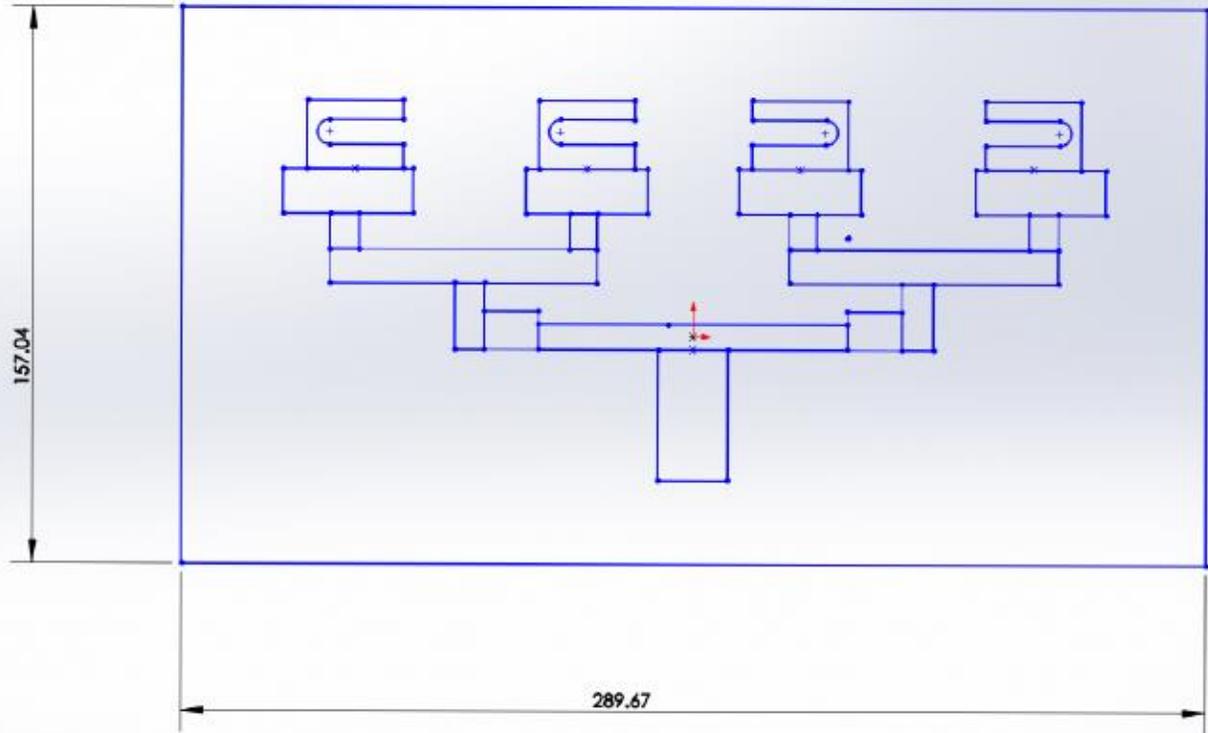
Figure 3. MIMO Multiband Antenna

4.   Results and discussion

Fig.4 indicates the return loss observed at the frequencies 38 GHz, 28 GHz and 24 GHz along with the proposed methodology radiation pattern using multiband array antenna. Based on the observed output in the form of simulation, it is determined that, there are 3 working frequencies for the antenna ranging from 20 to 40 GHz. In 38 GHz, the bandwidth value and return loss value are at 1.2 GHz and -19 dB, while at 28 GHz, the values are 1.324 GHz and -20.4 dB. A bandwidth of 1.23 GHz and return loss of about -21 dB is observed in the 24.6 GHz frequency.

SWS
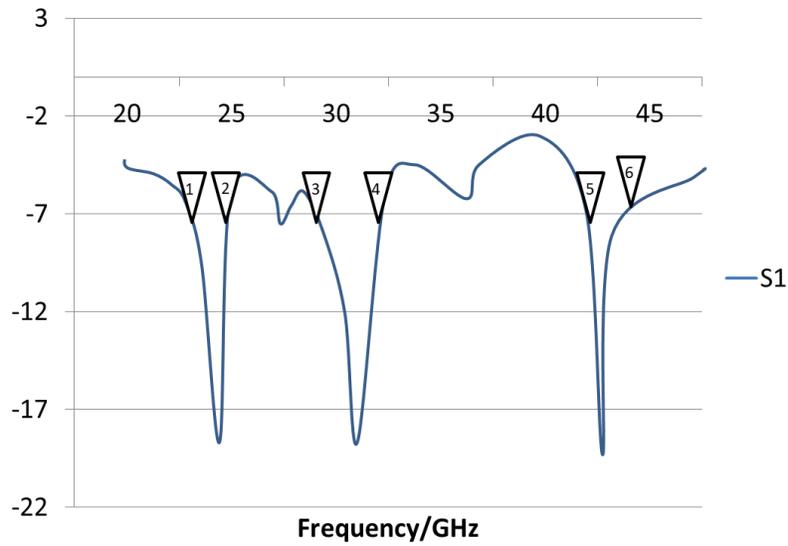
Figure 4. The proposed multiband antenna with S-parameter
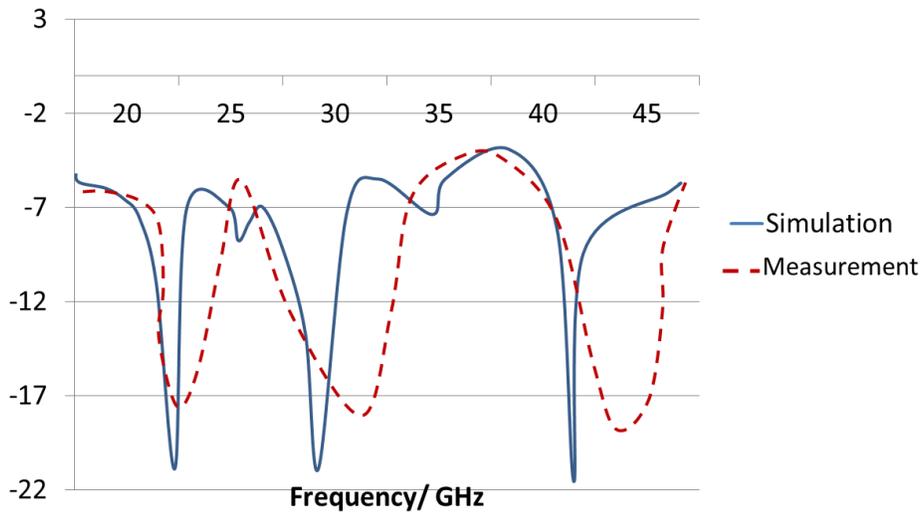
Figure 5. Comparison of Measurement and Simulation

SWS

The output simulations observed in Fig.5. indicates that the multiband antennas perform in a more efficient manner when compared to other traditional methods. This is especially the case in comparing bandwidth performance in every band. Then, average bandwidth considered in prior algorithms is 300 MHz for every band. Figure 5 indicates the way in which measurement, fabrication and simulation results for the multiband antenna takes place. However, it is found that there is a minute difference between the measured and simulated results. This change does not have a significant impact on the performance of the bandwidth in terms of measurement. This observation indicates that the addition of slots and patches as suggested in this work will be able to develop a better bandwidth performance in comparison with other methodologies which are within the 300 MHz band.

5. Conclusion

In this paper, a multiband MIMO antenna is designed such that it operates at millimeter-wave frequencies and is best apt for applications in wireless radio communication. The simulated output indicates that the proposed work and the design process can develop multiband antennas which operate at 20 GHz to 40 GHz wave bands. The observed output indicates a good bandwidth performance with multiple bands of frequency. Moreover, this output can also be incorporated for further development of MIMO antennas based on the need of communication systems.

References

[1] Thummaluru, S. R., Kumar, R., & Chaudhary, R. K. (2019). Isolation and frequency reconfigurable compact MIMO antenna for wireless local area network applications. IET Microwaves, Antennas & Propagation, 13(4), 519-525.

[2] Bashar, A. (2020). Artificial intelligence based LTE MIMO antenna for 5th generation mobile networks. Journal of Artificial Intelligence, 2(03), 155-162.

SWS

[3]   Ramya, P., R. S. Valarmathi, C. Poongodi, and P. Hamsagayathri. "Slotted Microstrip Patch 4× 4 MIMO Antenna for Ultra Wide Band Applications." In International Conference on Inventive Computation Technologies, pp. 11-17. Springer, Cham, 2019.

[4]   Jha, K. R., Bukhari, B., Singh, C., Mishra, G., & Sharma, S. K. (2018). Compact planar multistandard MIMO antenna for IoT applications. IEEE Transactions on Antennas and Propagation, 66(7), 3327-3336.

[5]   Baranidharan, V., N. Praveen Kumar, K. M. Naveen, R. Prathap, and KP Nithish Sriman. "Singular Value Decomposition-Based High-Resolution Channel Estimation Scheme for mmWave Massive MIMO with Hybrid Precoding for 5G Applications." In Inventive Computation and Information Technologies, pp. 365-377. Springer, Singapore, 2021.

[6]   Karuppusamy, D. P. (2019). MIMO BASED HIGH SPEED OPTICAL FIBER COMMUNICATION SYSTEM. Journal of Electronics and Informatics, 1(2), 107-116.

[7]   Yang, Y., Chu, Q., & Mao, C. (2016). Multiband MIMO antenna for GSM, DCS, and LTE indoor applications. IEEE Antennas and Wireless Propagation Letters, 15, 1573-1576.

[8]   Amanuel, Thomas, Amanuel Ghirmay, Huruy Ghebremeskel, Robel Ghebrehiwet, and Weldekidan Bahlibi. "Design of Vibration Frequency Method with Fine-Tuned Factor for Fault Detection of Three Phase Induction Motor." Journal of Innovative Image Processing (JIIP) 3, no. 01 (2021): 52-65.

[9]   Rajkumar, S., Vivek Sivaraman, N., Murali, S., & Selvan, K. T. (2017). Heptaband swastik arm antenna for MIMO applications. IET Microwaves, Antennas & Propagation, 11(9), 1255-1261.

[10]   Valanarasu, M. R., & Christy, A. (2019). Comprehensive survey of wireless cognitive and 5G networks. Journal of Ubiquitous Computing and Communication Technologies (UCCT), 1, 23-32.

SWS

[11] Vijay, A., and K. Umadevi. "Performance Improvement in 6G Networks Using MC-CDMA and mMIMO." In International conference on Computer Networks, Big data and IoT, pp. 112-118. Springer, Cham, 2019.

[12] Patel, R., Desai, A., Upadhyaya, T., Nguyen, T. K., Kaushal, H., & Dhasarathan, V. (2021). Meandered low profile multiband antenna for wireless communication applications. Wireless Networks, 27(1), 1-12.

[13] Shakya, Subarna. "A Self Monitoring and Analyzing System for Solar Power Station using IoT and Data Mining Algorithms." Journal of Soft Computing Paradigm 3, no. 2 (2021): 96-109.

[14] Ihamji, M., Abdelmounim, E., Bennis, H., Hefnawi, M., & Latrach, M. (2017). Design of compact tri-band fractal antenna for RFID readers. International Journal of Electrical and Computer Engineering, 7(4), 2036.

[15] Chen, J. I. Z. (2019). 5G technology and advancements in connected living-comprehensive survey. Journal of Electronics, 1(02), 71-79.

[16] Janisha, R. S., D. Vishnu, and O. Sheeba. "Frequency Reconfigurable Circular Patch Antenna." In Intelligent Data Communication Technologies and Internet of Things: Proceedings of ICICI 2020, pp. 109-118. Springer Singapore, 2021.

[17] Elfergani, I., Iqbal, A., Zebiri, C., Basir, A., Rodriguez, J., Sajedin, M., ... & Ullah, S. (2020). Low-profile and closely spaced four-element MIMO antenna for wireless body area networks. Electronics, 9(2), 258.

[18] Praveenkumar, B., S. Naik, S. Suganya, I. Balaji, A. Amrutha, Jayanth Khot, and Sumit Maheshwari. "FETE: Feedback-Enabled Throughput Evaluation for MIMO Emulated Over 5G Networks." In Computer Networks, Big Data and IoT, pp. 939-952. Springer, Singapore, 2021.

SWS

[19] Jacob, I. Jeena, and P. Ebby Darney. "Artificial Bee Colony Optimization Algorithm for Enhancing Routing in Wireless Networks." Journal of Artificial Intelligence 3, no. 01 (2021): 62-71.

[20] Sujanth Narayan, K. G., Baskaradas, J. A., & Rajesh Kumar, D. (2021). Design of a CPW-Fed Compact MIMO Antenna for Next Generation Vehicle to Everything (V2X) Communication. Wireless Personal Communications, 120(3), 2179-2200.

[21] Suma, V. "Community Based Network Reconstruction for an Evolutionary Algorithm Framework." Journal of Artificial Intelligence 3, no. 01 (2021): 53-61.

[22] Hussain, R., & Sharawi, M. S. (2014). A cognitive radio reconfigurable MIMO and sensing antenna system. IEEE Antennas and Wireless Propagation Letters, 14, 257-260.

[23] Pandian, M. D. (2019). Enhanced network selection and handover schema for heterogeneous wireless networks. Journal of ISMAC, 1(01), 160-171.

[24] Li, H., Sun, S., Wang, B., & Wu, F. (2018). Design of compact single-layer textile MIMO antenna for wearable applications. IEEE Transactions on Antennas and Propagation, 66(6), 3136-3141.

[25] Mugunthan, S. R. "Wireless Rechargeable Sensor Network Fault Modeling and Stability Analysis." Journal of Soft Computing Paradigm (JSCP) 3, no. 01 (2021): 47-54.

Author's biography

C. Anand has completed B.E. in EEE and M.E. in CSE. He has more than 12 years of teaching experience and has published more than five international journals on the field of wireless sensor networks. He has guided about 10 PG students and currently he is working as an Assistant Professor in the department of computer science and Engineering at K.S.R. College of Engineering, Triuchengode, Tamil Nadu, India. He is a lifetime member of ISTE.

SWS