

A Millimeter Wave Filter for 5G Applications

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Abstract - Bandpass filters, which only transmit frequencies that fall inside the transmission band and reject all other frequencies, are necessary for wireless communication systems. As 5G is set to be implemented, there will be a greater need for filters that operate in new frequency ranges. In 2022, the initial use is anticipated. The two key standards for filters that are used to build mobile applications are size and performance. With a repetition range of 26–28 GHz, the passband channel is designed in this proposal, simulated, and constructed. For downconversion of mmWave signals to microwave frequencies between 2 and 18 GHz, this channel can be employed as the front end of the apparatus. The size and efficiency of channels must be taken into account when planning new portable communications applications. Small, high-performance filters made by merging two components can be used in future mmWave applications like 5G. High-quality channels with minimal imprint are preferred for mmWave applications like 5G.

Keyword : Band pass filter, Millimeter wave, Microwave frequency, High Performance filter.

I. INTRODUCTION

A filter is a device that, in its most basic form, attenuates undesired frequencies while allowing desired frequencies to be transmitted without attenuation. Lowpass, highpass, bandpass, and bandstop are the four subcategories of filters. If a frequency is sent above and below a given stopband, a notch filter attenuates this frequency range[1]. Only noises above the cutoff frequency can pass through a high pass filter, in contrast to a lowpass filter. The bandpass filter only transmits frequencies that are included within the passband; hence it mutes any frequencies above and below the passband[2-5]. Communication systems that normally communicate over a constrained frequency range require the use of bandpass filters. All further frequencies are unnecessary and ought to be lowered.

For the communication we rely on every day, channels are crucial awareness points. Due to its benefits, including a fast information rate, a huge transmission capacity, and a short idle time, millimeter-wave (mm-wave) communication is generating a lot of attention in 5G applications. The

attenuation of undesirable refresh range, LO spill, and noise is frequently anticipated for channels for 5G mmWave front closure[6]. The narrow on-chip channel, however, has a low quality factor (Q), which leads to a large insertion loss, usually greater than 2.5 dB. The 5G mmWave infrastructure struggles to handle the high-Q channel's enormous size[7-8]. Though it is more expensive, mmWave can reach a larger region.

They have a recurrence range of 30 GHz to 300 GHz and are located between microwave (1 to 30 GHz) and infrared (IR) waves. Frequencies for millimetre waves range from 1 to 10 mm. Large receive wire clusters must occupy a smaller area than they really do because of the lower frequencies of mm Wave devices[9-11]. As 5G media delivery frameworks are implemented to satisfy the rising demand, broadcast communications from the past period will continue to function. The fact that 5G signals have a high repetition rate and can't function as well as low repetition signals is a major factor in explaining this. To guarantee signal integrity everywhere, broadcast communication carriers mix high-recurrence and low-recurrence systems.

Since 5G remote systems rely on mm Wave frequencies to operate at high transmission speeds and consequently depend on quicker information rates for consumers distributed across a large geographic area, mm Wave bandpass channels are essential[12]. For tiny cell front-end modules, resolving repetition groups from surrounding obstructions is very crucial. This work offers a new and straightforward planned construction of a wideband route channel with focus repetition from 24 to 26 GHz and a fragmented transmission rate (FBW) of 22% for 5G mm Wave applications[13]. Small and appropriate for 5G mm Wave Massive MIMO applications is the isolated receive cable that is being proposed.

II. FILTER PARAMETER

A. Scattering Parameter

RF device performance is frequently assessed using scattering parameters, also known as S-parameters.

Measurements of the S-parameter can identify devices lacking short or open terminations[14]. For high frequency measurements, this makes things easier. An S-parameter is defined as the ratio between the incident and transmitted or reflected voltages, as shown in Figure 1. From the input and output ports, a total of four parameters are measured. S-parameters expressed as a matrix where each port's voltage is expressed in relation to all other ports.

$$\begin{bmatrix} V1 - \\ V2 - \end{bmatrix} = \begin{bmatrix} S11 & S12 \\ S21 & S22 \end{bmatrix} \begin{bmatrix} V1 + \\ V2 + \end{bmatrix}$$

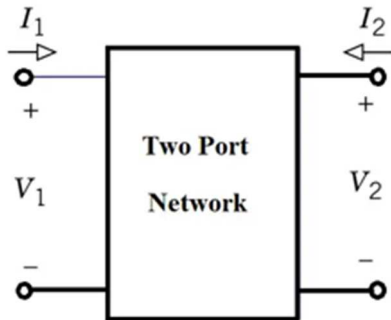


Figure 1: Two-port networks [4]

B. Band Pass Filter Parameter

To assess the effectiveness of the filters, various quality values are used. In order to be used in a specific application, each parameter frequently has predetermined constraints that must be met[15-17]. Frequencies outside the passband or stopband are entirely rejected by a perfect bandpass filter, while frequencies inside the passband are transmitted listlessly. While this is the ideal, bandpass filters sometimes stray from it. A quality value can be used to describe how similar a suggested filter is to a perfect filter.

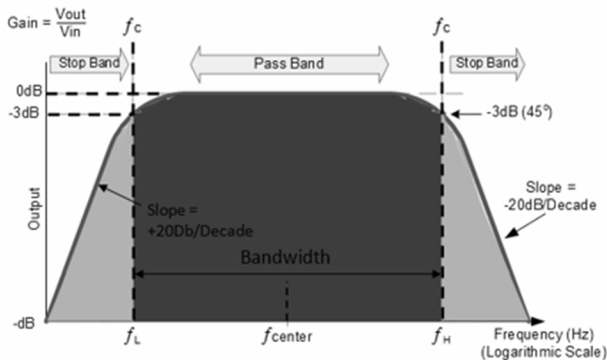


Figure 2: Band pass filter response [2]

The operational frequency is the frequency in the middle of the passband as shown in Figure 2. Because it affects how the filter is made, the centre frequency plays a crucial role in filter design. Low frequencies employ active filters and lumped component filters[18]. Active filters experience

significant losses above 5 GHz, while lumped components are ineffective once they approach the order of the wavelength. Distributed transmission line filters are frequently employed at low mmWave frequencies because of their comparatively simple manufacturing process. Due to space restrictions in conventional PCB fabrication, distributed filters also become useless at higher frequencies. When other filters are not usable at these higher mmWave frequencies, waveguide and SIW filters are employed as a workaround.

C. Insertion Loss

Insertion loss is one of the most crucial performance indicators for bandpass filters. Particularly in the case of receiver chain-related filters, this is true[19-20]. Since the filter is frequently the first link in the receiver chain, losses at this level spread throughout the system and have a negative impact on the noise figure at all later links. The passband's minimum or maximum value corresponds to the insertion loss that is given. S21 can be used to compute insertion loss, which is often reported in decibels (dB). Out-of-band rejection is the term used to describe insertion loss that happens outside the passband. The maximum amount that does not exceed the defined offset of the bandwidth is the denial that is displayed. It's crucial to suppress undesirable frequencies effectively.

$$1L = -20 \log(|S21|) \quad (1)$$

D. Bandwidth

In filters, a 3 dB bandwidth is most frequently employed[21-22]. The 3 dB bandwidth includes frequencies that are within 3 dB of the maximum insertion loss. The filter's design may cause a ripple before the passband rolls off. Characterizing and, if possible, reducing the passband ripple is important. It is advantageous to have a flat passband since it gets closer to a perfect filter.

E. Return Loss

The return loss is the amount of signal reflected back. In other words, it is the in-band rejection from S11. The filter's matching bandwidth will match those frequencies if the return loss is less than -10dB[22-24]. The reported return loss is the highest value of S11 within the 3 dB bandwidth if the 3 dB bandwidth is narrower than the adjusted bandwidth.

$$RL = -20 \text{Log}(|S11|) \quad (2)$$

F. Roll Off

Roll off quantifies the speed at which the filter transitions from the passband to the stopband. According to the definition given in the Insertion Loss section, out-of-band rejection is a peak that starts at a specific offset from the

passband[25]. Roll off will immediately apply to this departure from the passband. Between the passband and the stopband, there is a transition band where signals are neither entirely transferred nor entirely inhibited. Due to the abrupt roll off, the transition band is narrower, bringing the required rejection closer to the passband[26]. However, even though they are outside the passband, progressive roll off has a sizable number of frequencies that are not muted by the filter [27-28].

III. FILTER DESIGN

Primary-fed antenna designs are based on WHEMS. The WHEMS canal infill is made up of metallic canals and has a metallic structure. Two balanced polygonal openings make up the feed point, which is located in the base WHEMS's centre hole. The thick line with arrows denotes typical current conduction, and the dotted line depicts the current that has been harmed by the gradient current. The pitch dispersion of the receive wires in the H-plane is consistent since different rivers are stacked vertically and frequently overlap in a flat manner. The channel is scribed on a 1 mm thick Fs4b substrate with a typical dielectric constant of 2.2. The distance between the receiving and sending radio cables, called the intermediate distance, is 27 mm. The red boxes show where SMP connector locations were preserved for unconnected testing that weren't supported by the present framework. Position B is grounded while position A is aligned with the drawing line of the actual frame. Figure 3 illustrates the front view of the WHEMS filter [29-30].

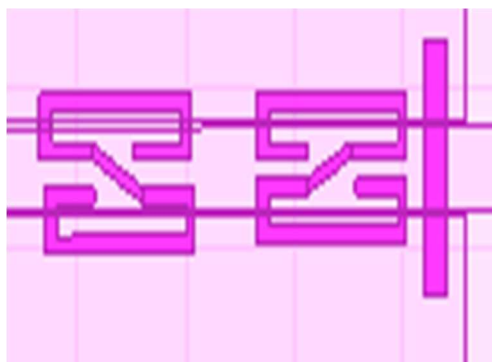


Figure. 3 Front View of WHEMS filter

The receiving cable and RF circuit are connected using this maintenance method, negating the need for additional plugs. Because it is different from the SMP port used by the actual framework, the SMP port is solely employed for isolation testing to confirm the accuracy of the plan. When the receive wire is employed in the system, the framework port mapping mode needs to modify the boundary to achieve impedance adjustment. By placing substantial ground bushings around the current routes, receive wire systems can be transformed into pit structures[31]. The receiving line field is connected with holes in order to lower the pitch of the MMW band. components of a proprietary wireless cable [32]. The normal C shape structure is shown in Figure 4.

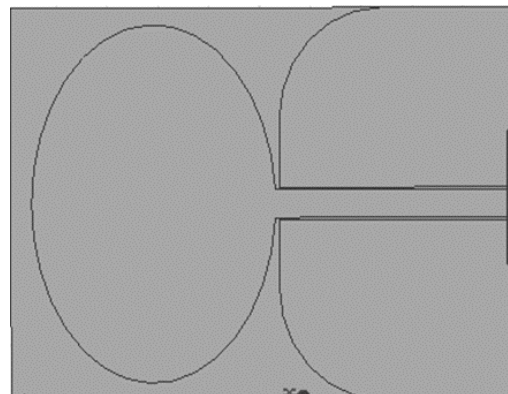


Figure. 4 C-Shape Structure

On a FR-4 substrate, a millimeter-wave filter structure is constructed and simulated as shown in Figure 5. The results are given after scoring for the top and bottom C-shaped slots. Frequency range, gain, return loss, and radiation pattern are among the variables that are measured [33].

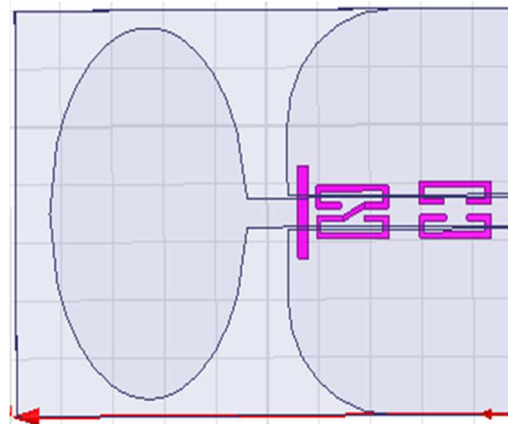


Figure 5. Millimeter wave filter (A slot added with lower C shape)

IV. RESULT AND SIMULATION

A mm-wave filter structure is constructed and simulated on a FR-4 substrate. The top and bottom C-shaped slots have been examined, and the results are displayed. The following elements are measured: radiation pattern, gain, and frequency range. As shown in Table:1, the proposed filter constraint is as follows:

TABLE I. THE PROPOSED FILTER CONSTRAINT

Size	1 mm thick Fs4b substrate with a typical dielectric constant of 2.2
Substrate	Rogers RT base substrate
Bandwidth	3.5GHz
Insertion Loss	-15.5 dB
Return Loss	-0.9 dB
Q Factor	1.2
Gain	4.7 dB

Resonant Frequency	5.2 GHz
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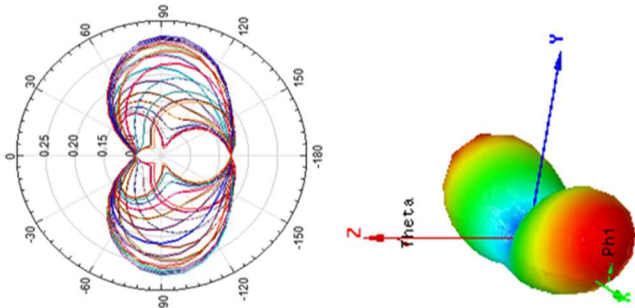


Figure 6. Radiation pattern of Millimeter wave Filter

With a notch added to the lower C shaped slot, 4.7 dB gain was achieved for the millimeter wave filter structure. A millimeter wave filter radiation pattern is shown in figure 6. Using figure 7, it can be seen that the resonant frequency is 5.2 GHz with a return loss of -0.9 dB.

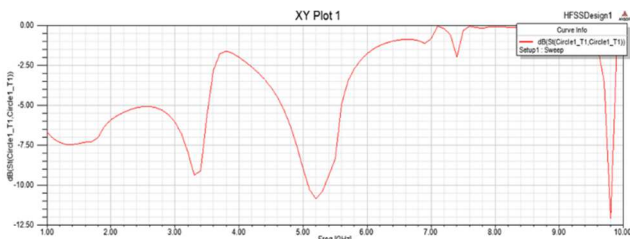


Figure 7. Frequency response of Millimeter wave Filter

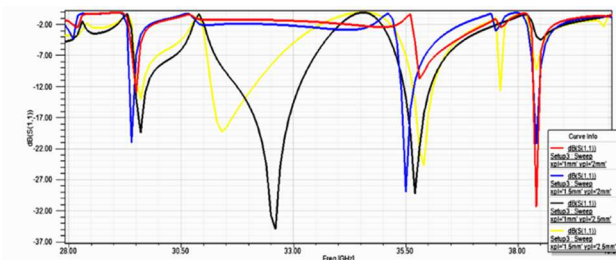


Figure 8. S11 Parametric analysis of Millimeter wave Filter

Figures 8 and 9 show the parametric analysis of a millimeter wave filter based on S11 and S21. A parametric analysis of the S parameter is illustrated in Figure 10.

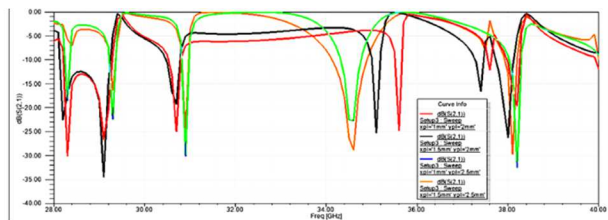


Figure 9. S21 Parametric analysis of Millimeter wave Filter

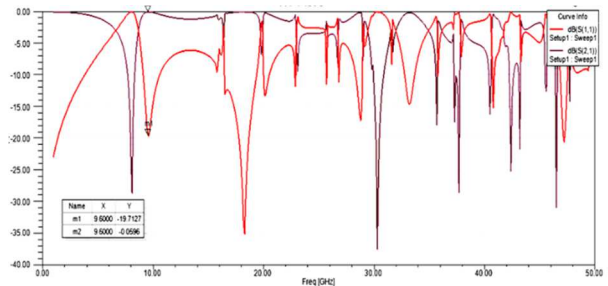


Figure 10. S parameter analysis of Millimeter wave Filter

V. CONCLUSION

In the frequency range of 26 to 28 GHz, millimeter-wave filters are constructed. The High Frequency Structure Simulator (HFSS) software's simulation, optimization, and testing features are used to implement a specific filter design. The proposed filter has a Rogers RT base substrate and an elliptical patch. Filter performance is influenced by a variety of elements, including size, shape, slot, feeding strategy, substrate, and many more. The millimeter wave filter structure achieved 4.7 dB gain by adding a notch to the lower C-shaped slot. Millimeter wave filters have a resonant frequency of 5.2 GHz with a return loss of -0.9 dB. They are utilized in a variety of 5G, telephony, and satellite communications applications.

REFERENCES

- [1] A. Gupta and R. Jha, "A Survey of 5G Network: Architecture and Emerging Technologies", IEEE Access, vol. 3, pp. 1206-1232, 2015.
- [2] M. Agiwal, A. Roy and N. Saxena, "Next Generation 5G Wireless Networks: A Comprehensive Survey", IEEE Communications Surveys & Tutorials, vol. 18, no. 3, pp. 1617-1655, 2016.
- [3] Qualcomm, "Spectrum for 4G and 5G", 2018.
- [4] A. Nordrum, "Popular Internet of Things Forecast of 50 Billion Devices by 2020 Is Outdated", IEEE Spectrum: Technology, Engineering, and Science News, 2018.
- [5] K. Chin, C. Chen and C. Chang, "LTCC Vertically-Stacked Cross-Coupled Bandpass Filter For LMDS Band Applications", Progress In Electromagnetics Research C, vol. 22, pp. 123-135, 2011.
- [6] B. Yuan, W. Yu, H. Sun and X. Lv, "A bandpass filter using LTCC system-on-package (SOP) technology", 2009 International Conference on Microwave Technology and Computational Electromagnetics (ICMTC 2009), 2009.
- [7] E. Arabi, M. Lahti, T. Vaha-Heikkila and A. Shamim, "A 3-D Miniaturized High Selectivity Bandpass Filter in LTCC Technology", IEEE Microwave and Wireless Components Letters, vol. 24, no. 1, pp. 8-10, 2014.
- [8] Optoplex Corporation, Bandpass filter response. 2018.
- [9] V. Egorov, V. Masalov, Y. Nefyodov, A. Shevchun, M. Trunin, V. Zhitomirsky and M. McLean, "Dielectric constant, loss tangent, and surface resistance of PCB materials at K-band frequencies", IEEE Transactions on Microwave Theory and Techniques, vol. 53, no. 2, pp. 627-635, 2005.
- [10] S. Wang and K. Cho, "CMOS/IPD switchable bandpass circuit for 28/39 GHz fifth generation applications", IET Microwaves, Antennas & Propagation, vol. 10, no. 14, pp. 1461-1466, 2016.
- [11] I. Halkhams, S. Mazer, M. El Bekkali, W. El Hamdani, M. Mehdi and F. Temcamani, "A selective active filter for the 5G in the mm-wave band in pHEMT technology", Contemporary Engineering Sciences, vol. 10, pp. 193-202, 2017.
- [12] N. N. Al-Areqi, N. Seman and T. A. Rahman, "Parallel-coupled line bandpass filter design using different substrates for fifth generation

- wireless communication applications," 2015 International Symposium on Antennas and Propagation (ISAP), Hobart, TAS, 2015, pp. 1-4. 65
- [13] W. Wen-qiang Jia and H. Hong-xi Yu, "A 27.5-29Ghz SIW cross-coupling filter in LTCC", IET International Radar Conference 2015, 2015.
- [14] Jong-Hoon Lee, S. Pinel, J. Papapolymerou, J. Laskar and M. Tentzeris, "Low-loss LTCC cavity filters using system-on-package technology at 60 GHz", IEEE Transactions on Microwave Theory and Techniques, vol. 53, no. 12, pp. 3817-3824, 2005.
- [15] B. Yuan, J. Mou, W. Yu and X. Lv, "Five-pole LTCC cavity filter for wireless applications at 34GHz.", in 2011 IEEE International Conference on Microwave Technology & Computational Electromagnetics (ICMTCE), 2011, pp. 193-195.
- [16] G. Chen and T. Chu, "A 30GHz LTCC Bandpass Filter.
- [17] Y. Wu, Y. Chen, L. Jiao, Y. Liu and Z. Ghassemlooy, "Dual-Band Dual-Mode Substrate Integrated Waveguide Filters with Independently Reconfigurable TE₁₀₁ Resonant Mode", Scientific Reports, vol. 6, no. 1, 2016.
- [18] J. Lee, S. Pinel, J. Papapolymerou, J. Laskar and M. Tentzeris, "Comparative Study of Feeding Techniques for Three-Dimensional Cavity Resonators at 60 GHz", IEEE Transactions on Advanced Packaging, vol. 30, no. 1, pp. 115-123, 2007.
- [19] R. Collin, Foundations for microwave engineering. New York [etc.]: McGrawHill, 1992.
- [20] K. Chin, C. Chang, C. Chen, Z. Guo, D. Wang and W. Che, "LTCC Multilayered Substrate-Integrated Waveguide Filter With Enhanced Frequency Selectivity for System-in-Package Applications", IEEE Transactions on Components, Packaging and Manufacturing Technology, vol. 4, no. 4, pp. 664-672, 2014.
- [21] Y. Tao, W. Hong and H. Tang, "Design of A Ka-Band Bandpass Filter Based on High Order Mode SIW Resonator", 2006 7th International Symposium on Antennas, Propagation & EM Theory, 2006.
- [22] Anurag Shrivastava; Ali Rizwan; Neelam Sanjeev Kumar; R. Saravanakumar; Inderjit Singh Dhanoa; Pankaj Bhambri; Bhupesh Kumar Singh; Samarendra Nath Sur, VLSI Implementation of Green Computing Control Unit on Zynq FPGA for Green Communication, Wireless Communications and Mobile Computing 2021-11-30, DOI: 10.1155/2021/4655400
- [23] D. Haripriya; Keshav Kumar; Anurag Shrivastava; Hamza Mohammed Ridha Al-Khafaji; Vishal Moyai; Sitesh Kumar Singh; Mohammad R Khosravi, Energy-Efficient UART Design on FPGA Using Dynamic Voltage Scaling for Green Communication in Industrial Sector, Wireless Communications and Mobile Computing, 2022-05-05, DOI: 10.1155/2022/4336647
- [24] Anurag Shrivastava; D. Haripriya; Yogini Dilip Borole; Archana Nanoty; Charanjeet Singh; Divyansh Chauhan, High performance FPGA based secured hardware model for IoT devices, International Journal of System Assurance Engineering and Management, 2022-03, DOI: 10.1007/s13198-021-01605-x
- [25] Suresh Kumar; S. Jerald Nirmal Kumar; Subhash Chandra Gupta; Anurag Shrivastava; Keshav Kumar; Rituraj Jain; Punit Gupta, IoT Communication for Grid-Tie Matrix Converter with Power Factor Control Using the Adaptive Fuzzy Sliding (AFS) Method, Scientific Programming, 2022-03-29, DOI: 10.1155/2022/5649363
- [26] K. Murali Krishna; Amit Jain; Hardeep Singh Kang; Mithra Venkatesan; Anurag Shrivastava; Sitesh Kumar Singh; Muhammad Arif, Development of the Broadband Multilayer Absorption Materials with Genetic Algorithm up to 8 GHz Frequency, Security and Communication Networks, 2022-02-17, DOI: 10.1155/2022/4400412.
- [27] M. S. Raghavendra, P. Chawla and A. Rana, "A Survey of Optimization Algorithms for Fog Computing Service Placement," 2020 8th International Conference on Reliability, Infocom Technologies and Optimization (Trends and Future Directions) (ICRITO), Noida, India, 2020, pp. 259-262, doi: 10.1109/ICRITO48877.2020.9197885.
- [28] Gupta, S., Rana, A., Kansal, V. (2020). Optimization in Wireless Sensor Network Using Soft Computing. In: Raju, K., Govardhan, A., Rani, B., Sridevi, R., Murty, M. (eds) Proceedings of the Third International Conference on Computational Intelligence and Informatics . Advances in Intelligent Systems and Computing, vol 1090. Springer, Singapore. https://doi.org/10.1007/978-981-15-1480-7_74
- [29] S. V. Singh, J. Pratap, A. Singh, S. Sharma and S. Gupta, "Isolation Enhancement of MIMO Antenna for Millimeter wave Applications," 2021 2nd International Conference on Intelligent Engineering and Management (ICIEM), London, United Kingdom, 2021, pp. 466-470, doi: 10.1109/ICIEM51511.2021.9445333.
- [30] S. Sharma, J. Pratap, P. Chaturvedi, A. Kumar Jain and R. Gupta, "Circularly Polarized Magneto-Electric Dipole Antennas: Review Article," 2021 2nd International Conference on Intelligent Engineering and Management (ICIEM), London, United Kingdom, 2021, pp. 530-533, doi: 10.1109/ICIEM51511.2021.9445325.
- [31] Z. Alam, A. Khursheed and S. V. Singh, "Modeling of Power Line for Home-Building Automation," 2019 International Conference on Automation, Computational and Technology Management (ICACTM), London, UK, 2019, pp. 111-115, doi: 10.1109/ICACTM.2019.8776816.
- [32] Singh, S. Vikram, Aizad Khursheed, and Zahoor Alam. "Wired Communication Technologies and Networks for Smart Grid—A Review." Cyber Security in Intelligent Computing and Communications (2022): 183-195.
- [33] P. Chaturvedi, P. Pachauri, R. Srivastava and A. Thakur, "Hazard Warning & Turn Signal Indication Technologies and Acquisition in Automotive Sector," 2021 2nd International Conference on Intelligent Engineering and Management (ICIEM), London, United Kingdom, 2021, pp. 625-630, doi: 10.1109/ICIEM51511.2021.9445299.