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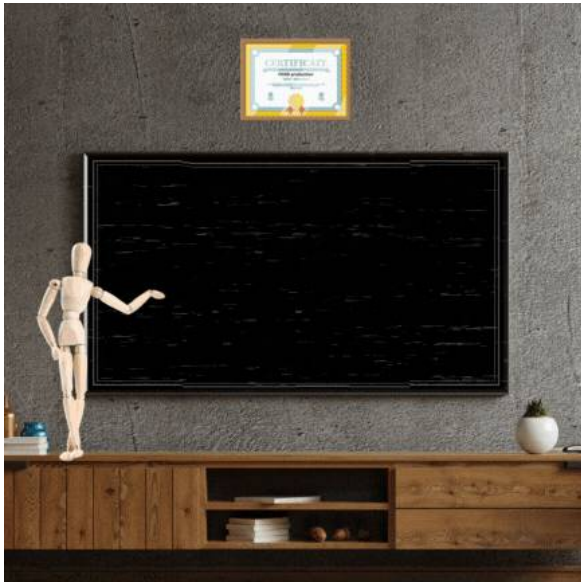
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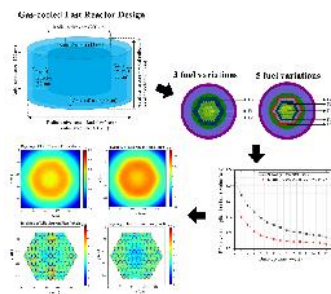
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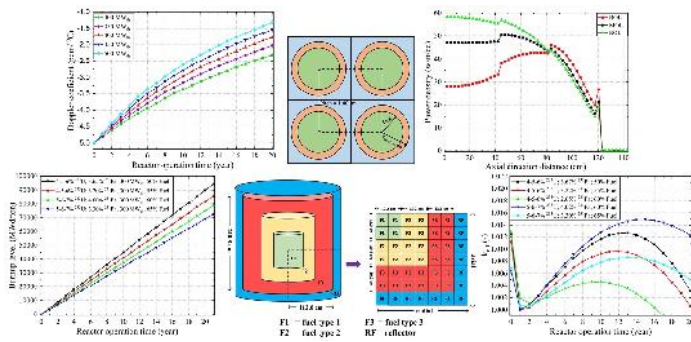


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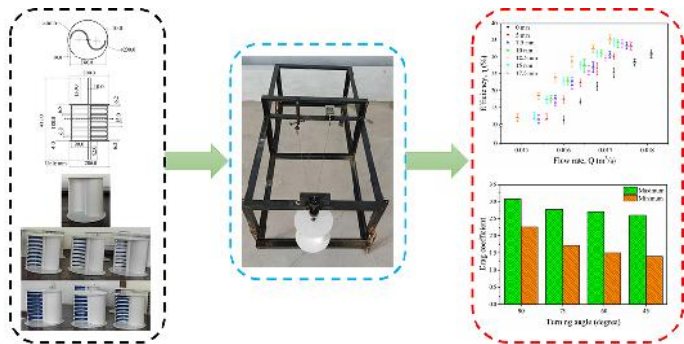
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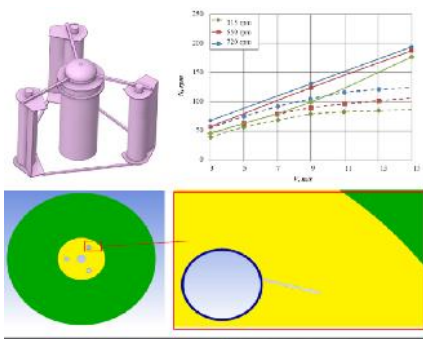
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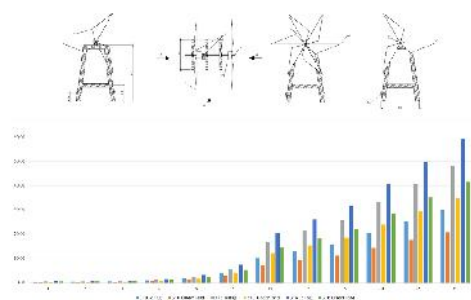
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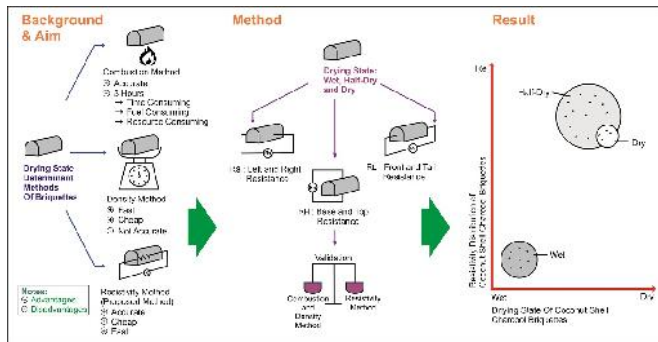
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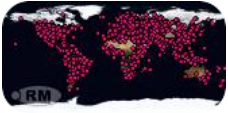
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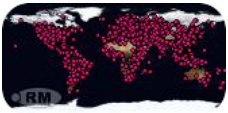
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Wide band and high gain microstrip antenna using planar series array 4×2 element for 5G communication system

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Abstract

The 5G communication system requires an antenna as a receiving device that has high performance including wide bandwidth and high gain. Microstrip antennas have advantages such as low cost, suitable for high frequencies and easy to integrate with other devices. One of the disadvantages of microstrip antennas is their narrow bandwidth and low gain. Therefore, microstrip antennas with wide bandwidth and high gain are especially needed to support 5G communication systems. This paper provides a solution by proposed a wide bandwidth and high gain microstrip antenna operating at a resonant frequency of 3.5 GHz for a 5G communication system. The proposed antenna was developed in four stages starting from a single element, a two-element series array, a 4-element series array and a 4×2-element planar series array. A series planar array technique is proposed to increase the gain and bandwidth of the microstrip antenna simultaneously. In this paper, simulations and measurements from the proposed antenna are displayed and compared comprehensively to show the performance improvement from each stage of the development of the proposed model. Based on the measurement results, the designed antenna has an impedance bandwidth (IBW) of 0.6 GHz and fractional bandwidth (FBW) of 17.14 % with a frequency range of 3.11–3.71 GHz and maximum gain of 12.2 dB at a resonant frequency of 3.5 GHz. The bandwidth and gain of the antennas increased by 205 % and 99.03 % compared to single element antennas, respectively. Therefore, the proposed antenna can be recommended to be used as a receiving antenna for 5G communication systems

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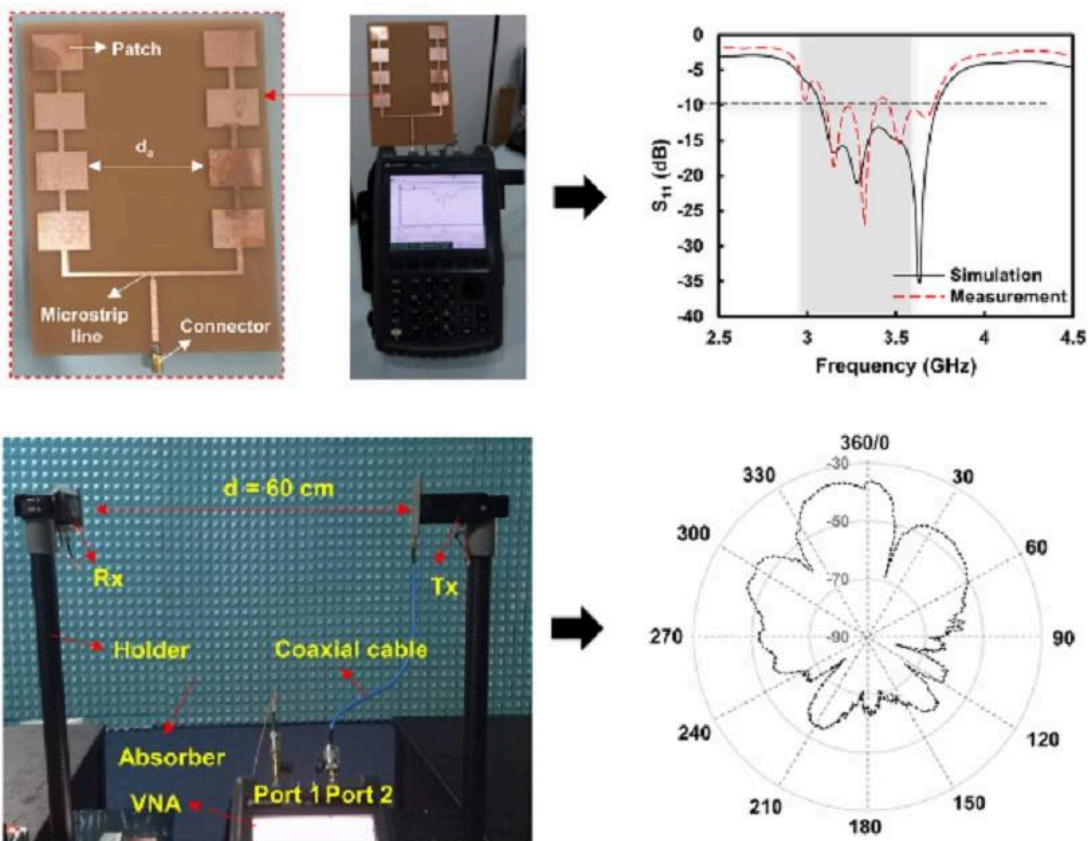
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References

- Hobbs, S. (2018). Valuing 5G Spectrum: Valuing the 3.5 GHz and C-Band Frequency Range. Coleago Consulting.
- Hikmaturokhan, A., Ramli, K., Suryanegara, M. (2018). Spectrum Considerations for 5G in Indonesia. 2018 International Conference on ICT for Rural Development (IC-ICTRuDev). doi: <https://doi.org/10.1109/icitr.2018.8706874>
- Höyhtyä, M., Apilo, O., Lasanen, M. (2018). Review of Latest Advances in 3GPP Standardization: D2D Communication in 5G Systems and Its Energy Consumption Models. *Future Internet*, 10 (1), 3. doi: <https://doi.org/10.3390/fi10010003>
- Zhang, G., Basit, A., Khan, M. I., Daraz, A., Saqib, N., Zubir, F. (2023). Multi Frequency Controllable In-BandSuppressions in a Broad Bandwidth Microstrip Filter Design for 5G Wi-Fi and Satellite Communication Systems Utilizing a Quad-Mode Stub-Loaded Resonator. *Micromachines*, 14 (4), 866. doi: <https://doi.org/10.3390/mi14040866>
- Tawfeeq, N. N. (2017). Size Reduction and Gain Enhancement of a Microstrip Antenna using Partially Defected Ground Structure and Circular/Cross Slots. *International Journal of Electrical and Computer Engineering (IJECE)*, 7 (2), 894. doi: <https://doi.org/10.11591/ijece.v7i2.pp894-898>
- Surjati, I., Alam, S., Karnadi, J. (2019). Design of spiral labyrinth microstrip antenna for DVB-T application. *TELKOMNIKA (Telecommunication Computing Electronics and Control)*, 17 (1), 76. doi: <https://doi.org/10.12928/telkomnika.v17i1.11628>
- Sandi, E., Rusmono, R., Diamah, A., Vinda, K. (2020). Ultra-wideband Microstrip Array Antenna for 5G Millimeter-wave Applications. *Journal of Communications*, 15 (2), 198–204. doi: <https://doi.org/10.12720/jcm.15.2.198-204>
- Liu, J., Liu, H., Dou, X., Tang, Y., Zhang, C., Wang, L. et al. (2021). A Low Profile, Dual-Band, Dual-Polarized Patch Antenna With Antenna-Filter Functions and Its Application in MIMO Systems. *IEEE Access*, 9, 101164–101171. doi: <https://doi.org/10.1109/access.2021.3096969>
- Ullah, S., Yeo, W.-H., Kim, H., Yoo, H. (2020). Development of 60-GHz millimeter wave, electromagnetic bandgap ground planes for multiple-input multiple-output antenna applications. *Scientific Reports*, 10 (1). doi: <https://doi.org/10.1038/s41598-020-65622-9>
- Naga Jyothi Sree, G., Nelaturi, S. (2021). Design and experimental verification of fractal based MIMO antenna for lower sub 6-GHz 5G applications. *AEU - International Journal of Electronics and Communications*, 137, 153797. doi: <https://doi.org/10.1016/j.aeue.2021.153797>
- Tarpara, N. M., Rathwa, R. R., Kotak, N. A. (2018). Design of Slotted Microstrip patch Antenna for 5G Application. *International Research Journal of Engineering and Technology (IRJET)*, 05 (04). Available at: https://www.academia.edu/37016852/Design_of_Slotted_Microstrip_patch_Antenna_for_5G_Application
- Ali, H., Singh, P., Kumar, S., Goel, T. (2017). A Minkowski fractal ultrawide band antenna for 5G applications. 2017 IEEE International Conference on Antenna Innovations & Modern Technologies for Ground, Aircraft and Satellite Applications (IAIM). doi: <https://doi.org/10.1109/iaim.2017.8402541>
- Hu, W., Liu, X., Gao, S., Wen, L.-H., Qian, L., Feng, T. et al. (2019). Dual-Band Ten-Element MIMO Array Based on Dual-Mode IFAs for 5G Terminal Applications. *IEEE Access*, 7, 178476–178485. doi: <https://doi.org/10.1109/access.2019.2958745>
- An, W., Li, Y., Fu, H., Ma, J., Chen, W., Feng, B. (2018). Low-Profile and Wideband Microstrip Antenna With Stable Gain for 5G Wireless Applications. *IEEE Antennas and Wireless Propagation Letters*, 17 (4), 621–624. doi: <https://doi.org/10.1109/lawp.2018.2806369>
- Cai, Q., Li, Y., Zhang, X., Shen, W. (2019). Wideband MIMO Antenna Array Covering 3.3–7.1 GHz for 5G Metal-Rimmed Smartphone Applications. *IEEE Access*, 7, 142070–142084. doi: <https://doi.org/10.1109/access.2019.2944681>
- Alam, S., Surjati, I., Sari, L., Hilyawan, M. R., Zakaria, Z., Shairi, N. A. et al. (2022). Triple Band Notched Microstrip Antenna Using Planar Series 2x2 Element Array for 5G Communication System. *Journal of Nano- and Electronic Physics*, 14 (1), 01019-1-01019-5. doi: [https://doi.org/10.21272/jnep.14\(1\).01019](https://doi.org/10.21272/jnep.14(1).01019)



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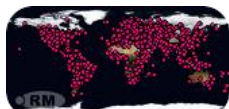
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**RESEARCH OF HIGH-FREQUENCY
REMAGNETIZATION MODEL IN LAMINATED
MAGNETIC CORES OF ELECTROMECHANICAL AND
ELECTROMAGNETIC ENERGY CONVERTERS (p. 6–15)**

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The object of research in the work is charged magnetic conductors of electric machines and transformers.

Laminated magnetic wire together with windings are important active parts of electric machines that participate in electromechanical energy conversion.

The reliability of the entire machine is mainly determined by the actual condition of the inter-sheet insulation. Violation of the insulation causes parasitic eddy current circuits, which increases the specific losses, and also significantly affects the additional heating of the magnet wire and winding.

The normative method for determining the quality of the charged core is the assessment of specific losses at a frequency of 50 Hz and an induction of 1 T, which should not exceed 2.5–4 W/kg. To determine local damage to the core, methods of local heating and fixation of overheating sites are used, which should not exceed 45 °C compared to the main part of the magnetic core.

In the work, a two-dimensional field mathematical model of a charged magnetic circuit is developed. This makes it possible to carry out electromagnetic calculations in a near-real magnetic conductor, taking into account the variability of magnetic permeability, hysteresis, and the interaction of currents in adjacent plates of the magnetic conductor with each other, the so-called "proximity effect".

On the basis of the developed models, graphs of current distribution and distribution of magnetic induction in one, two and three sheets were obtained. The resulting graphs show how the effect of current displacement increases with increasing frequency, where at a frequency of 100 kHz the magnetic induction density in the middle of the sheet goes to zero. The results of the research confirm the correctness of the model development in comparison with the classical calculation models also given, which allows them to be used for further research of high-frequency processes in charged magnetic circuits of electric machines.

Keywords: charged magnetic wire, high-frequency remagnetization processes, eddy currents, surface effect.

References

- Colonel, Wm., McLyman, T. (2017). *Magnetic Core Selection for Transformers and Inductors. A User's Guide to Practice and Specifications*. CRC Press, 672. doi: <https://doi.org/10.1201/9781315214856>
- Rudenberg, R. (1950). *Transient performance of electric power systems*. McGraw-Hill.
- Yang, G., Zhang, S., Zhang, C. (2020). Analysis of Core Loss of Permanent Magnet Synchronous Machine for Vehicle Applications under Different Operating Conditions. *Applied Sciences*, 10 (20), 7232. doi: <https://doi.org/10.3390/app10207232>
- Boubaker, N., Matt, D., Enrici, P., Nierlich, F., Durand, G. (2019). Measurements of Iron Loss in PMSM Stator Cores Based on CoFe and SiFe Lamination Sheets and Stemmed From Different Manufacturing Processes. *IEEE Transactions on Magnetics*, 55 (1), 1–9. doi: <https://doi.org/10.1109/tmag.2018.2877995>
- Zhang, S., Ducharme, B., Takeda, S., Sebald, G., Uchimoto, T. (2021). Low-frequency behavior of laminated electric steel sheet: Investigation of ferromagnetic hysteresis loops and incremental permeability. *Journal of Magnetism and Magnetic Materials*, 538, 168278. doi: <https://doi.org/10.1016/j.jmmm.2021.168278>
- Shah, S. B., Osemwinyen, O., Rasilo, P., Belahcen, A., Arkkio, A. (2018). Thermographic Measurement and Simulation of Power Losses Due to Interlaminar Contacts in Electrical Sheets. *IEEE Transactions on Instrumentation and Measurement*, 67 (11), 2628–2634. doi: <https://doi.org/10.1109/tim.2018.2829321>
- Aydin, U., Martin, F., Rasilo, P., Belahcen, A., Haavisto, A., Singh, D. et al. (2019). Rotational Single Sheet Tester for Multi-axial Magneto-Mechanical Effects in Steel Sheets. *IEEE Transactions on Magnetics*, 55 (3), 1–10. doi: <https://doi.org/10.1109/tmag.2018.2889238>
- Urabinahatti, C., Ahmad, S. S., Narayanan, G. (2018). Magnetic Characterization of Ferromagnetic Alloys for High Speed Electric Machines. 2018 IEEE International Conference on Power Electronics, Drives and Energy Systems (PEDES). doi: <https://doi.org/10.1109/pedes.2018.8707819>
- Nguedjang Kouakeuo, S. H., Ducharme, B., Solignac, A., Morel, L., Raulet, M. A. et al. (2021). Non-invasive local magnetic hysteresis characterization of a ferromagnetic laminated core. *Journal of Magnetism and Magnetic Materials*, 527, 167783. doi: <https://doi.org/10.1016/j.jmmm.2021.167783>

10. Zhao, H., Eldeeb, H. H., Zhang, Y., Zhang, D., Zhan, Y., Xu, G., Mohammed, O. A. (2021). An Improved Core Loss Model of Ferromagnetic Materials Considering High-Frequency and Nonsinusoidal Supply. *IEEE Transactions on Industry Applications*, 57 (4), 4336–4346. doi: <https://doi.org/10.1109/tia.2021.3072930>
11. Sirotic, I., Kovacic, M., Stipetic, S. (2021). Methodology and Measurement Setup for Determining PWM Contribution to Iron Loss in Laminated Ferromagnetic Materials. *IEEE Transactions on Industry Applications*, 57 (5), 4796–4804. doi: <https://doi.org/10.1109/tia.2021.3094501>
12. Kulan, M. C., Baker, N. J., Liogas, K. A., Davis, O., Taylor, J., Korsunsky, A. M. (2022). Empirical Implementation of the Steinmetz Equation to Compute Eddy Current Loss in Soft Magnetic Composite Components. *IEEE Access*, 10, 14610–14623. doi: <https://doi.org/10.1109/access.2022.3148593>
13. Chumack, V., Kovalenko, M., Tymoshchuk, O., Stulishenko, A., Ihnatiuk, Y. (2023). Design of a multilink system for calculating high-frequency processes in electric machines with mesh windings. *Eastern-European Journal of Enterprise Technologies*, 3 (8 (123)), 54–63. doi: <https://doi.org/10.15587/1729-4061.2023.282375>
14. Ostroverkhov, M., Chumack, V., Kovalenko, M., Kovalenko, I. (2022). Development of the control system for taking off the maximum power of an autonomous wind plant with a synchronous magnetoelectric generator. *Eastern-European Journal of Enterprise Technologies*, 4 (2 (118)), 67–78. doi: <https://doi.org/10.15587/1729-4061.2022.263432>
15. Ostroverkhov, M., Chumack, V., Tymoshchuk, O., Kovalenko, M., Ihnatiuk, Y. (2022). Designing a voltage control system of the magnetoelectric generator with magnetic flux shunting for electric power systems. *Eastern-European Journal of Enterprise Technologies*, 5 (5 (119)), 16–25. doi: <https://doi.org/10.15587/1729-4061.2022.265861>

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WIDE BAND AND HIGH GAIN MICROSTRIP ANTENNA USING PLANAR SERIES ARRAY 4x2 ELEMENT FOR 5G COMMUNICATION SYSTEM (p. 16–24)

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The 5G communication system requires an antenna as a receiving device that has high performance including wide bandwidth and high gain. Microstrip antennas have advantages such as low cost, suitable for high frequencies and easy to integrate with other devices. One of the disadvantages of microstrip antennas is their narrow bandwidth and low gain. Therefore, microstrip antennas with wide bandwidth and high gain are especially needed to support 5G communication systems. This paper provides a solution by proposed a wide bandwidth and high gain microstrip antenna operating at a resonant frequency of 3.5 GHz for a 5G communication system. The proposed antenna was developed in four stages starting from a single element, a two-element series array, a 4-element series array and a 4x2-element planar series array. A series planar array technique is proposed to increase the gain and bandwidth of the microstrip antenna simultaneously. In this paper, simulations and measurements from the proposed antenna are displayed and compared comprehensively to show the performance improvement from each stage of the development of the proposed model. Based on the measurement results, the designed antenna has an impedance bandwidth (IBW) of 0.6 GHz and fractional bandwidth (FBW) of 17.14 % with a frequency range of 3.11–3.71 GHz and maximum gain of 12.2 dB at a resonant frequency of 3.5 GHz. The bandwidth and gain of the antennas increased by 205 % and 99.03 % compared to single element antennas, respectively. Therefore, the proposed antenna can be recommended to be used as a receiving antenna for 5G communication systems.

Keywords: antenna, microstrip, planar, series, array, bandwidth, gain, 5G, communication system, high frequencies.

References

1. Hobbs, S. (2018). Valuing 5G Spectrum: Valuing the 3.5 GHz and C-Band Frequency Range. Coleago Consulting.
2. Hikmaturokhman, A., Ramli, K., Suryanegara, M. (2018). Spectrum Considerations for 5G in Indonesia. 2018 International Conference on ICT for Rural Development (IC-ICTRuDev). doi: <https://doi.org/10.1109/icictr.2018.8706874>
3. Höyhtyä, M., Apilo, O., Lasanen, M. (2018). Review of Latest Advances in 3GPP Standardization: D2D Communication in 5G Systems and Its Energy Consumption Models. *Future Internet*, 10 (1), 3. doi: <https://doi.org/10.3390/fi10010003>
4. Zhang, G., Basit, A., Khan, M. I., Daraz, A., Saqib, N., Zubir, F. (2023). Multi Frequency Controllable In-BandSuppressions in a Broad Bandwidth Microstrip Filter Design for 5G Wi-Fi and Satellite Communication Systems Utilizing a Quad-Mode Stub-Loaded Resonator. *Micro-machines*, 14 (4), 866. doi: <https://doi.org/10.3390/mi14040866>
5. Tawfeeq, N. N. (2017). Size Reduction and Gain Enhancement of a Microstrip Antenna using Partially Defected Ground Structure and Circular/Cross Slots. *International Journal of Electrical and Computer Engineering (IJECE)*, 7 (2), 894. doi: <https://doi.org/10.11591/ijece.v7i2.pp894-898>
6. Surjati, I., Alam, S., Karnadi, J. (2019). Design of spiral labyrinth microstrip antenna for DVB-T application. *TELKOMNIKA (Tele-*

- communication Computing Electronics and Control), 17 (1), 76. doi: <https://doi.org/10.12928/telkomnika.v17i1.11628>
7. Sandi, E., Rusmono, R., Diamah, A., Vinda, K. (2020). Ultra-wide-band Microstrip Array Antenna for 5G Millimeter-wave Applications. *Journal of Communications*, 15 (2), 198–204. doi: <https://doi.org/10.12720/jcm.15.2.198-204>
 8. Liu, J., Liu, H., Dou, X., Tang, Y., Zhang, C., Wang, L. et al. (2021). A Low Profile, Dual-Band, Dual-Polarized Patch Antenna With Antenna-Filter Functions and Its Application in MIMO Systems. *IEEE Access*, 9, 101164–101171. doi: <https://doi.org/10.1109/access.2021.3096969>
 9. Ullah, S., Yeo, W.-H., Kim, H., Yoo, H. (2020). Development of 60-GHz millimeter wave, electromagnetic bandgap ground planes for multiple-input multiple-output antenna applications. *Scientific Reports*, 10 (1). doi: <https://doi.org/10.1038/s41598-020-65622-9>
 10. Naga Jyothi Sree, G., Nelaturi, S. (2021). Design and experimental verification of fractal based MIMO antenna for lower sub 6-GHz 5G applications. *AEU - International Journal of Electronics and Communications*, 137, 153797. doi: <https://doi.org/10.1016/j.aeue.2021.153797>
 11. Tarpara, N. M., Rathwa, R. R., Kotak, N. A. (2018). Design of Slotted Microstrip patch Antenna for 5G Application. *International Research Journal of Engineering and Technology (IRJET)*, 05 (04). Available at: https://www.academia.edu/37016852/Design_of_Slotted_Microstrip_patch_Antenna_for_5G_Application
 12. Ali, H., Singh, P., Kumar, S., Goel, T. (2017). A Minkowski fractal ultrawide band antenna for 5G applications. 2017 IEEE International Conference on Antenna Innovations & Modern Technologies for Ground, Aircraft and Satellite Applications (IAIM). doi: <https://doi.org/10.1109/iaim.2017.8402541>
 13. Hu, W., Liu, X., Gao, S., Wen, L.-H., Qian, L., Feng, T. et al. (2019). Dual-Band Ten-Element MIMO Array Based on Dual-Mode IFAs for 5G Terminal Applications. *IEEE Access*, 7, 178476–178485. doi: <https://doi.org/10.1109/access.2019.2958745>
 14. An, W., Li, Y., Fu, H., Ma, J., Chen, W., Feng, B. (2018). Low-Profile and Wideband Microstrip Antenna With Stable Gain for 5G Wireless Applications. *IEEE Antennas and Wireless Propagation Letters*, 17 (4), 621–624. doi: <https://doi.org/10.1109/lawp.2018.2806369>
 15. Cai, Q., Li, Y., Zhang, X., Shen, W. (2019). Wideband MIMO Antenna Array Covering 3.3–7.1 GHz for 5G Metal-Rimmed Smartphone Applications. *IEEE Access*, 7, 142070–142084. doi: <https://doi.org/10.1109/access.2019.2944681>
 16. Alam, S., Surjati, I., Sari, L., Hilyawan, M. R., Zakaria, Z., Shairi, N. A. et al. (2022). Triple Band Notched Microstrip Antenna Using Planar Series 2x2 Element Array for 5G Communication System. *Journal of Nano- and Electronic Physics*, 14 (1), 01019-1-01019–5. doi: [https://doi.org/10.21272/jnep.14\(1\).01019](https://doi.org/10.21272/jnep.14(1).01019)

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IMPROVING THE HEAT TRANSFER CHARACTERISTICS OF MINIATURE TWO-PHASE THERMOSYPHONS WITH NANOFLUIDS BASED ON UKRAINIAN NATURAL ALUMOSILICATES (p. 25–33)

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In order to improve the heat transfer characteristics of miniature thermosyphons, a study of the processes of heat transfer by them using water and nanofluids as heat carriers was carried out. A water mixture based on nanoparticles of Ukrainian natural aluminosilicate – attapulgitite with the addition of 0.1 % carbon nanotubes was used as nanofluids. The data of the study of the maximum heat flow and the minimum thermal resistance of copper thermosyphons with an internal diameter of 5 mm and a length of 700 mm are presented. Orientation of thermosyphons in space: vertical. The length of the heating zone varied from 50 mm to 200 mm, with the same amount of heat-carrier. The fill factor varied from 0.44 to 1.93.

A comparison was performed of the heat transfer capabilities of thermosyphons with water and with a nanofluid with a mass concentration of 0.5 %. It has been shown that nanofluid thermosyphons transmit 53 % more heat flow compared to water, and thermal resistances are reduced by 25 %.

The influence of the concentration of nanoparticles on the heat transfer characteristics of thermosyphons is shown. Nanofluids with concentrations (0.1 %, 0.5 %, 0.7 %) showed the same level of thermal resistances, with an increase in maximum heat flows compared to distilled water. Thus, when compared with the lowest concentration (0.1 %), the use of 0.5 % nanofluid gives an advantage of up to 40 %, and 0.7 % – an advantage of up to 51 %. This is explained by the appearance of a specific porous structure of anisometric nanoparticles on the heating surface, which contributes to the appearance of additional centers of vaporization during boiling and improves the heat transfer characteristics of thermosyphons.

Thus, the use of such thermosyphons with nanofluids when cooling elements of electronic equipment could improve their functional characteristics.

Keywords: miniature thermosyphon, nanofluids, concentration, filling factor, heat flow, thermal resistance.

References

1. Singh, A., Dubey, S., Dubey, H. (2019) Nanotechnology: the future engineering. *International Journal of Advance and Innovative Research*, 6 (2), 229–233. Available at: <https://www.researchgate.net/publication/333448927>
2. Zhang, Y., Zhou, Y. (2022). The recent progress of nanofluids and the state-of-art thermal devices. *Highlights in Science, Engineering and Technology*, 13, 82–89. doi: <https://doi.org/10.54097/hset.v13i.1335>
3. Yang, L., Xu, J., Du, K., Zhang, X. (2017). Recent developments on viscosity and thermal conductivity of nanofluids. *Powder Technology*, 317, 348–369. doi: <https://doi.org/10.1016/j.powtec.2017.04.061>
4. Vanaki, Sh. M., Ganesan, P., Mohammed, H. A. (2016). Numerical study of convective heat transfer of nanofluids: A review. *Renew-*

- able and Sustainable Energy Reviews, 54, 1212–1239. doi: <https://doi.org/10.1016/j.rser.2015.10.042>
5. Akilu, S., Sharma, K. V., Baheta, A. T., Mamat, R. (2016). A review of thermophysical properties of water based composite nanofluids. Renewable and Sustainable Energy Reviews, 66, 654–678. doi: <https://doi.org/10.1016/j.rser.2016.08.036>
 6. Xu, Y., Xue, Y., Qi, H., Cai, W. (2021). An updated review on working fluids, operation mechanisms, and applications of pulsating heat pipes. Renewable and Sustainable Energy Reviews, 144, 110995. doi: <https://doi.org/10.1016/j.rser.2021.110995>
 7. Kim, T. I., Chang, W. J., Chang, S. H. (2011). Flow boiling CHF enhancement using Al_2O_3 nanofluid and an Al_2O_3 nanoparticle deposited tube. International Journal of Heat and Mass Transfer, 54 (9-10), 2021–2025. doi: <https://doi.org/10.1016/j.ijheatmasstransfer.2010.12.029>
 8. Sözen, A., Menlik, T., Gürü, M., Boran, K., Kılıç, F., Aktaş, M., Çakır, M. T. (2016). A comparative investigation on the effect of fly-ash and alumina nanofluids on the thermal performance of two-phase closed thermo-syphon heat pipes. Applied Thermal Engineering, 96, 330–337. doi: <https://doi.org/10.1016/j.applthermaleng.2015.11.038>
 9. Bondarenko, B. I., Moraru, V. N., Sydorenko, S. V., Komysh, D. V., Khovavko, A. I. (2016). Nanostructured Architectures on the Heater Surface at Nanofluids Boiling and Their Role in the Intensification of Heat Transfer. Nanoscience and Nanoengineering, 4 (1), 12–21. doi: <https://doi.org/10.13189/nn.2016.040102>
 10. Moraru, V. N. (2017). The Mechanism of Raising And Quantification of Specific Heat Flux at Boiling of Nanofluids in Free Convection Conditions. Energotehnologii i resursoberezhennie, 3, 25–34. Available at: http://nbuv.gov.ua/UJRN/ETRS_2017_3_5
 11. Liu, Z. H., Yang, X. F., Guo, G. L. (2007). Effect of nanoparticles in nanofluid on thermal performance in a miniature thermosyphon. Journal of Applied Physics, 102 (1). doi: <https://doi.org/10.1063/1.2748348>
 12. Paramatthanuwat, T., Boothaisong, S., Rittidech, S., Booddachan, K. (2009). Heat transfer characteristics of a two-phase closed thermosyphon using de ionized water mixed with silver nano. Heat and Mass Transfer, 46 (3), 281–285. doi: <https://doi.org/10.1007/s00231-009-0565-y>
 13. Humnic, G., Humnic, A., Morjan, I., Dumitrache, F. (2011). Experimental study of the thermal performance of thermosyphon heat pipe using iron oxide nanoparticles. International Journal of Heat and Mass Transfer, 54 (1–3), 656–661. doi: <https://doi.org/10.1016/j.ijheatmasstransfer.2010.09.005>
 14. Humnic, G., Humnic, A. (2011). Heat transfer characteristics of a two-phase closed thermosyphons using nanofluids. Experimental Thermal and Fluid Science, 35 (3), 550–557. doi: <https://doi.org/10.1016/j.expthermflusci.2010.12.009>
 15. Xue, H. S., Fan, J. R., Hu, Y. C., Hong, R. H., Cen, K. F. (2006). The interface effect of carbon nanotube suspension on the thermal performance of a two-phase closed thermosyphon. Journal of Applied Physics, 100 (10). doi: <https://doi.org/10.1063/1.2357705>
 16. Khandekar, S., Joshi, Y. M., Mehta, B. (2008). Thermal performance of closed two-phase thermosyphon using nanofluids. International Journal of Thermal Sciences, 47 (6), 659–667. doi: <https://doi.org/10.1016/j.ijthermalsci.2007.06.005>
 17. Moraru, V. N., Komysh, D. V., Khovavko, A. I., Snigur, A. V., Gudkov, N. N., Sidorenko, N. A., Marinin, A. I. (2015). Nanofluids on the Basis of Ukrainian Natural Aluminosilicates are Promising Heat-Carriers for Power Engineering. Energotehnologii i resursoberezhennie, 1, 22–32. Available at: <http://dspace.nbuv.gov.ua/handle/123456789/127461>
 18. Khazaei, I., Hosseini, R., Noie, S. H. (2010). Experimental investigation of effective parameters and correlation of geyser boiling in a two-phase closed thermosyphon. Applied Thermal Engineering, 30 (5), 406–412. doi: <https://doi.org/10.1016/j.applthermaleng.2009.09.012>
 19. Kravets, V. Yu. (2018). Protsesy teploobminu u miniatiurnykh vyparno-kondensatsiinykh systemakh okholodzhennia. Kharkiv: FOP Brovin O. V., 288.
 20. Kravets, V., Konshin, V., Hurov, D., Vorobiov, M., Shevel, I. (2022). Determining the influence of geometric factors and the type of heat carrier on the thermal resistance of miniature two-phase thermosyphons. Eastern-European Journal of Enterprise Technologies, 4 (8 (118)), 51–59. doi: <https://doi.org/10.15587/1729-4061.2022.263180>
 21. Tolubinskii, V. I. (1980). Teploobmen pri kipenii. Kyiv: Naukova dumka, 316.
 22. Pekur, D. V., Nikolaenko, Yu. E., Sorokin, V. M. (2020). Optimization of the cooling system design for a compact high-power LED luminaire. Semiconductor Physics, Quantum Electronics and Optoelectronics, 23 (1), 91–101. doi: <https://doi.org/10.15407/spqeo23.01.091>
 23. Kamyar, A., Ong, K. S., Saidur, R. (2013). Effects of nanofluids on heat transfer characteristics of a two-phase closed thermosyphon. International Journal of Heat and Mass Transfer, 65, 610–618. doi: <https://doi.org/10.1016/j.ijheatmasstransfer.2013.06.046>

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DEVISING TECHNOLOGICAL SOLUTIONS FOR GAS SENSORS BASED ON ZINC OXIDE FOR USE AT CRITICAL INFRASTRUCTURE FACILITIES (p. 34–40)

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This paper reports a study of a gas sensor based on nano-structured zinc oxide in order to establish the conditions for its production and operating characteristics under the influence of the target gas ethanol. The studied samples were produced by magnetron sputtering on direct current. The method of forming the device structure was chosen among others due to the fact that it has a high rate of deposition at low values of the working gas pressure, there is no overheating of the substrate, a low degree of contamination of the obtained films, the possibility of obtaining samples of uniform thickness on a large area of the substrate. A VUP-5M vacuum unit with an original material-saving magnetron was used to obtain the films. Studies of the effect of temperature on the resistance of a gas sensor based on ZnO have been carried out. It was established that the change in the resistance of the tested sample depends on the temperature of the substrate. The resistance of the gas sensor in atmospheric air decreases with increasing substrate temperature from room temperature (25 °C) to 200 °C. A further increase in temperature from 200 °C leads to an increase in the resistance of the structure until it stabilizes in the temperature range of 300–400 °C. It was established that the operating temperature range of the gas sensor based on ZnO is within 300–400 °C. The characteristics of the gas sensor based on ZnO were studied and the working temperature of the sensor was determined for the rapid identification of ethanol in atmospheric air at a target gas concentration of 500 ppm. It was established that for rapid operation of the instrument structure, the temperature of the substrate should be 400 °C, a decrease or increase in temperature leads to a decrease in the sensitivity of the sensor to the target gas. It was established that the gas sensor demonstrates stability and a consistent sensitivity response upon repeated exposure to the target gas.

Keywords: ZnO, gas sensor, magnetron sputtering, operating temperature, sensitivity, reaction stability.

References

- Vambol, S., Vambol, V., Sobyna, V., Koloskov, V., Poberezhna, L. (2019). Investigation of the energy efficiency of waste utilization technology, with considering the use of low-temperature separation of the resulting gas mixtures. *Energetika*, 64 (4). doi: <https://doi.org/10.6001/energetika.v64i4.3893>
- Chernukha, A., Teslenko, A., Kovalov, P., Bezuglov, O. (2020). Mathematical Modeling of Fire-Proof Efficiency of Coatings Based on Silicate Composition. *Materials Science Forum*, 1006, 70–75. doi: <https://doi.org/10.4028/www.scientific.net/msf.1006.70>
- Kovalov, A., Otrosh, Y., Rybka, E., Kovalevska, T., Togobytska, V., Rolin, I. (2020). Treatment of Determination Method for Strength Characteristics of Reinforcing Steel by Using Thread Cutting Method after Temperature Influence. *Materials Science Forum*, 1006, 179–184. doi: <https://doi.org/10.4028/www.scientific.net/msf.1006.179>
- Sadkovyi, V., Andronov, V., Semkiv, O., Kovalov, A., Rybka, E., Otrosh, Yu. et al.; Sadkovyi, V., Rybka, E., Otrosh, Yu. (Eds.) (2021). Fire resistance of reinforced concrete and steel structures. Kharkiv: PC TECHNOLOGY CENTER, 180. doi: <https://doi.org/10.15587/978-617-7319-43-5>
- Pospelov, B., Kovrehin, V., Rybka, E., Krainiukov, O., Petukhova, O., Butenko, T. et al. (2020). Development of a method for detecting dangerous states of polluted atmospheric air based on the current recurrence of the combined risk. *Eastern-European Journal of Enterprise Technologies*, 5 (9 (107)), 49–56. doi: <https://doi.org/10.15587/1729-4061.2020.213892>
- Pospelov, B., Rybka, E., Krainiukov, O., Yashchenko, O., Bezuhla, Y., Bielai, S. et al. (2021). Short-term forecast of fire in the premises based on modification of the Brown's zero-order model. *Eastern-European Journal of Enterprise Technologies*, 4 (10 (112)), 52–58. doi: <https://doi.org/10.15587/1729-4061.2021.238555>
- Neshpor, O., Deyneko, N., Ponomarenko, R., Maiboroda, A., Kropyva, M., Blyashenko, O. et al. (2022). Optimization of the technology for designing sensitive gas sensors based on zinc oxide using a sol-gel method. *Eastern-European Journal of Enterprise Technologies*, 4 (5 (118)), 30–36. doi: <https://doi.org/10.15587/1729-4061.2022.263686>
- Zhang, Y., Li, D., Qin, L., Zhao, P., Liu, F., Chuai, X. et al. (2018). Preparation and gas sensing properties of hierarchical leaf-like SnO₂ materials. *Sensors and Actuators B: Chemical*, 255, 2944–2951. doi: <https://doi.org/10.1016/j.snb.2017.09.115>
- Kołodziejczak-Radzimska, A., Jesionowski, T. (2014). Zinc Oxide—From Synthesis to Application: A Review. *Materials*, 7 (4), 2833–2881. doi: <https://doi.org/10.3390/ma7042833>
- Lorenz, M., Ramachandra Rao, M. S., Venkatesan, T., Fortunato, E., Barquinha, P., Branquinho, R. et al. (2016). The 2016 oxide electronic materials and oxide interfaces roadmap. *Journal of Physics D: Applied Physics*, 49 (43), 433001. doi: <https://doi.org/10.1088/0022-3727/49/43/433001>
- Zhang, H., Babichev, A. V., Jacopin, G., Lavenus, P., Julien, F. H., Yu. Egorov, A. et al. (2013). Characterization and modeling of a ZnO nanowire ultraviolet photodetector with graphene transparent contact. *Journal of Applied Physics*, 114 (23). doi: <https://doi.org/10.1063/1.4854455>
- Xu, Q., Cheng, L., Meng, L., Wang, Z., Bai, S., Tian, X. et al. (2019). Flexible Self-Powered ZnO Film UV Sensor with a High Response. *ACS Applied Materials & Interfaces*, 11 (29), 26127–26133. doi: <https://doi.org/10.1021/acsami.9b09264>
- Mohan, A. C., Renjanadevi, B. (2016). Preparation of Zinc Oxide Nanoparticles and its Characterization Using Scanning Elec-

- tron Microscopy (SEM) and X-Ray Diffraction(XRD). *Procedia Technology*, 24, 761–766. doi: <https://doi.org/10.1016/j.protcy.2016.05.078>
14. Bian, H., Ma, S., Sun, A., Xu, X., Yang, G., Yan, S. et al. (2016). Improvement of acetone gas sensing performance of ZnO nanoparticles. *Journal of Alloys and Compounds*, 658, 629–635. doi: <https://doi.org/10.1016/j.jallcom.2015.09.217>
 15. Yan, H., Song, P., Zhang, S., Yang, Z., Wang, Q. (2016). Facile synthesis, characterization and gas sensing performance of ZnO nanoparticles-coated MoS₂ nanosheets. *Journal of Alloys and Compounds*, 662, 118–125. doi: <https://doi.org/10.1016/j.jallcom.2015.12.066>
 16. Umar, A., Khan, M. A., Kumar, R., Algarni, H. (2018). Ag-Doped ZnO Nanoparticles for Enhanced Ethanol Gas Sensing Application. *Journal of Nanoscience and Nanotechnology*, 18 (5), 3557–3562. doi: <https://doi.org/10.1166/jnn.2018.14651>
 17. Zhang, D., Yang, Z., Li, P., Zhou, X. (2019). Ozone gas sensing properties of metal-organic frameworks-derived In₂O₃ hollow microtubes decorated with ZnO nanoparticles. *Sensors and Actuators B: Chemical*, 301, 127081. doi: <https://doi.org/10.1016/j.snb.2019.127081>
 18. Miasoiedova, A., Minska, N., Shevchenko, R., Azarenko, O., Lukashenko, V., Kyrychenko, O. et al. (2023). Improving the manufacturing technology of sensing gas sensors based on zinc oxide by using the method of magnetron sputtering on direct current. *Eastern-European Journal of Enterprise Technologies*, 2 (5 (122)), 31–37. doi: <https://doi.org/10.15587/1729-4061.2023.277428>
 19. Khrypunov, G., Vambol, S., Deyneko, N., Sychikova, Y. (2016). Increasing the efficiency of film solar cells based on cadmium telluride. *Eastern-European Journal of Enterprise Technologies*, 6 (5 (84)), 12–18. doi: <https://doi.org/10.15587/1729-4061.2016.85617>

DOI: 10.15587/1729-4061.2023.286002**РОЗРОБКА ВИСОКОЧАСТОТНОЇ МОДЕЛІ ПЕРЕМАГНІЧУВАННЯ ШИХТОВАНИХ МАГНІТОПРОВОДІВ ЕЛЕКТРОМЕХАНІЧНИХ І ЕЛЕКТРОМАГНІТНИХ ПЕРЕТВОРЮВАЧІВ ЕНЕРГІЇ (с. 6–15)****В. В. Чумак, О. Л. Тимошук, М. А. Коваленко, В. А. Баженов, Є. С. Ігнатюк, А. С. Стулішенко**

Об'єктом дослідження в роботі є шихтовані магнітопроводи електричних машин і трансформаторів.

Шихтований магнітопровід разом з обмотками є важливими активними частинами електричних машин, що приймають участь в електромеханічному перетворенні енергії.

Надійність роботи всієї машини головним чином визначається фактичним станом міжлистової ізоляції. Порушення ізоляції викликає паразитні контури вихрових струмів, що збільшує питомі втрати, а також суттєво впливає на додаткове нагрівання магнітопроводу та обмотки.

Нормативним методом визначення якості шихтованого осердя є оцінка питомих втрат на частоті 50 Гц та індукції 1 Тл, які не повинні перевищувати 2,5–4 Вт/кг. Для визначення місцевих пошкоджень осердя використовують методи локального нагріву та фіксації місць перегріву, які не повинні перевищувати 45 °С в порівнянні з основною частиною магнітопроводу.

У роботі розроблено двомірну польову математичну модель шихтованого магнітопроводу. Це дає можливість здійснювати електромагнітні розрахунки в наближеному до реального магнітопроводі з врахуванням змінності магнітної проникності, гістерезису та взаємодії струмів у суміжних пластинах магнітопроводу між собою, так званий «ефект близькості».

На основі розроблених моделей отримано графіки розподілу струму та розподіл магнітної індукції в одному, двох та трьох листах. На отриманих графіках показано, як зі збільшенням частоти посилюється ефект витіснення струму, де на частоті 100 кГц густина магнітної індукції в середині листа прямує до нуля. Результати досліджень підтверджують правильність розробки моделі в порівнянні з також приведеними класичними моделями розрахунку, що дозволяє використовувати їх для подальших досліджень високочастотних процесів в шихтованих магнітопроводах електричних машин.

Ключові слова: шихтований магнітопровід, високочастотні процеси перемагнічування, вихрові струми, поверхневий ефект.

DOI: 10.15587/1729-4061.2023.285395**ШИРОКОСМУГОВА ТА МІКРОСМУГОВА АНТЕНА З ВИСОКИМ ПОСИЛЕННЯМ З ВИКОРИСТАННЯМ ПЛАНАРНОГО СЕРІЙНОГО МАСИВУ 4Ч2 ДЛЯ СИСТЕМИ ЗВ'ЯЗКУ 5G (с. 16–24)****Syah Alam, Indra Surjati, Lydia Sari, Yuli Kurnia Ningsih, Suryadi, Galang Trihantoro, Teguh Firmansyah, Zahriladha Zakaria**

Для системи зв'язку 5G потрібна антена як приймальний пристрій із високою продуктивністю, включаючи широку смугу пропускання та високе посилення. Мікросмугові антени мають такі переваги, як низька вартість, придатність для високих частот і легкість інтеграції з іншими пристроями. Одним з недоліків мікросмугових антен є їх вузька смуга пропускання і малий коефіцієнт підсилення. Тому мікросмугові антени з широкою смугою пропускання та високим коефіцієнтом підсилення особливо необхідні для підтримки систем зв'язку 5G. У цій статті запропоновано мікросмугову антену з широкою смугою пропускання та високим коефіцієнтом посилення, яка працює на резонансній частоті 3,5 ГГц для системи зв'язку 5G. Запропонована антена була розроблена в чотири етапи, починаючи з одного елемента, двоелементної послідовної решітки, 4-елементної послідовної решітки та 4 2-елементної плоскої послідовної решітки. Для одночасного збільшення коефіцієнта підсилення та смуги пропускання мікросмугової антени запропоновано послідовну планарну решітку. У цьому документі моделювання та вимірювання запропонованої антени відображаються та всебічно порівнюються, щоб показати покращення продуктивності на кожному етапі розробки запропонованої моделі. Виходячи з результатів вимірювань, спроектована антена має смугу пропускання імпедансу 0,6 ГГц і фракційну смугу пропускання 17,14 % з частотним діапазоном 3,11–3,71 ГГц і максимальним посиленням 12,2 дБ на резонансній частоті 3,5 ГГц. Смуга пропускання та посилення антен зросли на 205 % і 99,03 % порівняно з одноелементними антенами відповідно. Тому запропоновану антену можна рекомендувати використовувати як приймальну антену для систем зв'язку 5G.

Ключові слова: антена, мікросмугова, планарна, серія, решітка, смуга пропускання, посилення, 5G, система зв'язку, високі частоти.

DOI: 10.15587/1729-4061.2023.286320**ПОКРАЩЕННЯ ТЕПЛОПЕРЕДАВАЛЬНИХ ХАРАКТЕРИСТИК МІНІАТЮРНИХ ДВОФАЗНИХ ТЕРМОСИФОНІВ З НАНОРІДИНАМИ НА БАЗІ УКРАЇНСЬКИХ ПРИРОДНИХ АЛЮМОСИЛКАТІВ (с. 25–33)****В. Ю. Кравець, Д. І. Гурав, В. Н. Морару**

З метою підвищення теплопередавальних характеристик мініатюрних термосифонів проведено дослідження процесів передачі теплоти ними при використанні води і нанорідин як теплоносіїв. В якості нанорідин застосовувалися водна суміш на базі

наночастинок українського природного алюмосилікату – атапульгіту з додаванням 0,1 % вуглецевих нанотрубок. Приводяться дані дослідження максимального теплового потоку і мінімального термічного опору мідних термосифонів, з внутрішнім діаметром 5 мм, довжиною 700 мм. Орієнтація термосифонів у просторі: вертикальна. Довжина зони нагріву змінювалася від 50 мм до 200 мм, при однаковій кількості теплоносія. Коефіцієнт заповнення змінювався від 0,44 до 1,93.

Проводилося порівняння теплопередавальних здібностей термосифонів з водою та з нанорідиною із масовою концентрацією 0,5 %. Показано, що термосифони з нанорідиною передають на 53 % більший тепловий потік у порівнянні з водою, а термічні опори знижуються на 25 %.

Показано вплив концентрації наночастинок на теплопередавальні характеристики термосифонів. Нанорідини з концентраціями (0,1 %; 0,5 %; 0,7 %) показали однаковий рівень термічних опорів, при підвищенні максимальних теплових потоків у порівнянні із дистильованою водою. Так, при порівнянні з найменшою концентрацією (0,1 %), використання 0,5 % нанорідини дає перевагу до 40 %, а 0,7 % – перевагу до 51 %. Це пояснюється виникненням специфічної пористої структури з анізотричних наночастинок на поверхні нагріву, яка сприяє появі додаткових центрів пароутворення при кипінні і підвищенні теплопередавальних характеристик термосифонів.

Таким чином, застосування таких термосифонів з нанорідинами при охолодженні елементів електронної техніки може підвищити їх функціональні характеристики.

Ключові слова: мініатюрний термосифон, нанорідини, концентрація, коефіцієнт заповнення, тепловий потік, термічний опір.

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РОЗРОБКА ТЕХНОЛОГІЧНИХ РІШЕНЬ ГАЗОВИХ СЕНСОРІВ НА ОСНОВІ ОКСИДУ ЦИНКУ ДЛЯ ВИКОРИСТАННЯ НА ОБ'ЄКТАХ КРИТИЧНОЇ ІНФРАСТРУКТУРИ (р. 34–40)

Н. В. Мінська, В. М. Гвоздь, О. С. Шевченко, Є. Д. Слепужніков, Р. К. Мурасов, В. В. Христин, В. В. Стрілець, С. С. Кривоніс, В. Б. Ротар, В. О. Липовий

Проведені дослідження газового сенсору на основі наноструктурованого оксиду цинку для встановлення умов його отримання та робочих характеристик під впливом цільового газу етанолу. Досліджувані зразки були виготовлені методом магнетронного розпилення на постійному струмі. Метод формування приладової структури був обраним серед інших завдяки тому, що має високу швидкість осадження при невисоких значеннях тиску робочого газу, відсутній перегрів підкладки, низький ступінь забруднення отриманих плівок, можливість отримання рівномірних за товщиною зразків на великій площі підкладки. Для одержання плівок використовували вакуумну установку ВУП-5М з оригінальним матеріалозберігаючим магнітроном. Проведені дослідження впливу температури на опір газового сенсору на основі ZnO. Встановлено, що зміна опору досліджуваного зразка залежить від температури підкладки. Опір газового сенсору в атмосферному повітрі знижується зі зростанням температури підкладки від кімнатної (25 °C) до 200 °C. Подальше збільшення температури від 200 °C призводить до зростання опору структури до моменту його стабілізації в діапазоні температур 300–400 °C. Встановлено, що робочий температурний діапазон газового сенсору на основі ZnO знаходиться в межах 300–400 °C. Досліджено характеристики газового сенсору на основі ZnO та визначена робоча температура сенсору для швидкої ідентифікації етанолу в атмосферному повітрі при концентрації цільового газу на рівні 500 ppm. Встановлено, що для експресної роботи приладової структури температура підкладки повина складати 400 °C, зниження або підвищення температури призводить до зниження чутливості сенсору до цільового газу. Встановлено, що газовий сенсор демонструє стабільність і послідовну реакцію чутливості при повторному впливі цільового газу.

Ключові слова: ZnO, газовий сенсор, магнітронне розпилення, робоча температура, чутливість, стабільність реакції.

The 5G communication system requires an antenna as a receiving device that has high performance including wide bandwidth and high gain. Microstrip antennas have advantages such as low cost, suitable for high frequencies and easy to integrate with other devices. One of the disadvantages of microstrip antennas is their narrow bandwidth and low gain. Therefore, microstrip antennas with wide bandwidth and high gain are especially needed to support 5G communication systems. This paper provides a solution by proposed a wide bandwidth and high gain microstrip antenna operating at a resonant frequency of 3.5 GHz for a 5G communication system. The proposed antenna was developed in four stages starting from a single element, a two-element series array, a 4-element series array and a 4×2-element planar series array. A series planar array technique is proposed to increase the gain and bandwidth of the microstrip antenna simultaneously. In this paper, simulations and measurements from the proposed antenna are displayed and compared comprehensively to show the performance improvement from each stage of the development of the proposed model. Based on the measurement results, the designed antenna has an impedance bandwidth (IBW) of 0.6 GHz and fractional bandwidth (FBW) of 17.14 % with a frequency range of 3.11–3.71 GHz and maximum gain of 12.2 dB at a resonant frequency of 3.5 GHz. The bandwidth and gain of the antennas increased by 205 % and 99.03 % compared to single element antennas, respectively. Therefore, the proposed antenna can be recommended to be used as a receiving antenna for 5G communication systems

Keywords: antenna, microstrip, planar, series, array, bandwidth, gain, 5G, communication system, high frequencies

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WIDE BAND AND HIGH GAIN MICROSTRIP ANTENNA USING PLANAR SERIES ARRAY 4×2 ELEMENT FOR 5G COMMUNICATION SYSTEM

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1. Introduction

The 5G communication system offers high data rates and low latency, so it requires wide bandwidth [1]. Based on [2], the resonant frequency of the 5G communication system is divided into three classifications: high band, middle band and low band. One of the recommended frequencies for 5G communication systems is 3.5 GHz which is included in the middle band category [3]. Furthermore, to support the communication system between transmitter and receiver, antennas with high performance are needed. The key parameters to show the performance of the antenna are reflection

coefficient, bandwidth, gain and radiation pattern [4]. One of the antennas that has been developed for wireless communication systems is the microstrip antenna because it has the advantages of compact dimensions, low cost and has the ability to operate at high frequencies [5, 6]. However, microstrip antennas have limitations including narrow bandwidth, low gain, and low directivity [7]. Furthermore, to support the communication system between transmitter and receiver, antennas with high performance are needed. The key parameters to show the performance of the antenna are reflection coefficient, bandwidth, gain and radiation pattern [8]. Therefore, antennas with wide bandwidth and high

gain are needed to support wireless communication systems such as Wi-Fi, 4G and 5G.

2. Literature review and problem statement

One of the antennas that has been developed for wireless communication systems is the microstrip antenna because it has the advantages of compact dimensions, low cost and has the ability to operate at high frequencies [9, 10]. However, microstrip antennas have limitations including narrow bandwidth, low gain and directivity [11]. Several previous studies have described and proposed microstrip antennas for 5G communication systems using several techniques including fractal, array and parasitic [12–14]. Previous studies presented by [15] have described microstrip antennas with wide bandwidth by adding parasitic elements that are placed above to the radiating elements. However, the gain of the antenna is still low, so it needs to be increased. Another study by [16] proposed a microstrip antenna configured in an array with four elements operating at a resonant frequency of 3.5 GHz with a bandwidth of 0.7 GHz and a gain of 9.24 dB. However, the increase in bandwidth is not in line with the gain so that when the bandwidth increases, the gain will decrease.

Therefore, a method and stages of development are needed to produce an antenna that has wide bandwidth and high gain simultaneously. Therefore, new methods and model development are needed to produce antennas that have wide bandwidth and high gain simultaneously. Generally, the addition of elements from antennas with a parallel configuration will increase the gain, but on the other hand the bandwidth becomes narrower. This is due to the mutual inductance between the elements of the antenna. For this reason, series arrays can be used as a solution to reduce mutual inductance between elements so that the gain and bandwidth can increase simultaneously.

3. The aim and objectives of the study

The aim of the study is to produce a compact microstrip antenna for 5G communication system.

To achieve this aim, the following objectives are accomplished:

- to simulation of characteristics of the antenna;
- to enhance bandwidth of microstrip antenna ≥ 200 MHz;
- to enhance gain of microstrip antenna ≥ 10 dB.

4. Materials and methods

4.1. Development model of proposed antenna

In this paper, the proposed antenna is developed based on four stages starting from a single element, a series array with 2 elements, a series array with 4 elements and the final stage is a series planar array with 4×2 elements. The model and development stages of the proposed antenna are shown in Fig. 1.

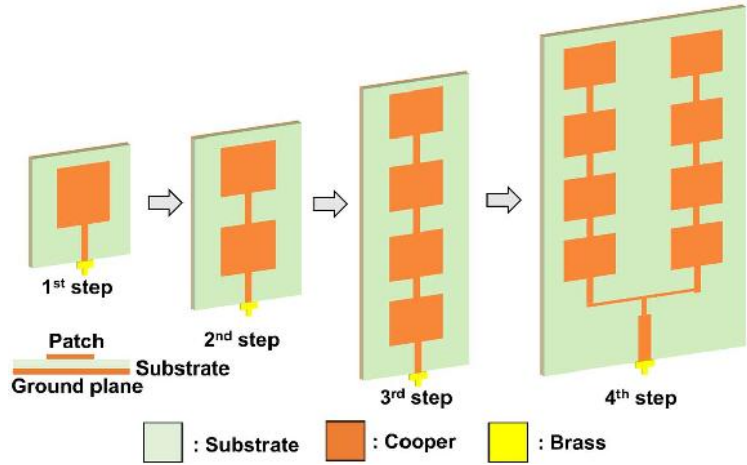


Fig. 1. Development model of proposed antenna

Fig. 1 shows a single element microstrip antenna with a rectangular shape where the patch antenna is on the top layer of the substrate which functions as a radiating element while the bottom layer functions as a ground plane as 1st step. The substrate used was FR-4 with a dielectric constant of 4.3, a loss tan of 0.0265 and a thickness of 1.6 mm. The proposed antenna is connected directly with the RP-SMA connector with an impedance of 50 Ω . In the 2nd and 3rd step, single element antennas are configured in series arrays with two and four elements. It should be noted, the dimensions of the patch antennas are identical whereas the microstrip lines are used to control the impedance and reflection coefficient of the proposed antenna. Furthermore, the 4th step model shows that the antenna is developed with a series planar array with 4×2 elements. It should be noted, the distance between radiating elements in a series planar array structure will greatly affect the bandwidth and gain of the antenna.

4.2. Design of single element microstrip antenna

Basically, the dimensions of a microstrip antenna are greatly influenced by the type of substrate and the resonant frequency used. In this paper, microstrip antennas are developed based on a rectangular shape where the length of the patch is represented as L while the width is represented as W . Furthermore, the dimensions of W and L can be determined based on following equation as follows:

$$W = \frac{c}{2f_o \sqrt{\frac{\epsilon_r}{2}}}, \quad (1)$$

$$L = L_{eff} - \Delta_L, \quad (2)$$

$$L_{eff} = \frac{c}{2f_o \sqrt{\epsilon_{eff}}}, \quad (3)$$

$$\epsilon_{eff} = \frac{\epsilon_r + 1}{2} + \frac{\epsilon_r - 1}{2} \left[1 + 12 \frac{h}{W} \right]^{-1}, \quad (4)$$

$$\Delta_L = 0.412 \frac{(\epsilon_{reff} + 0.3) \left(\frac{W}{h} + 0.264 \right)}{(\epsilon_{reff} - 0.258) \left(\frac{W}{h} + 0.8 \right)}, \quad (5)$$

where W and L represent the length and width of the patch, f_0 represents the resonance frequency, ϵ_r represents the permittivity of the substrate, ϵ_{eff} represents the effective permittivity of the substrate at a certain resonance frequency, h represents the thickness of the substrate while Δ_L represents the edge effect of the fringing field of the patch.

Furthermore, microstrip lines are proposed to control the impedance and reflection coefficient of the antenna. The dimensions of the microstrip line are greatly influenced by the input impedance and the resonant frequency used. In this paper, the input impedance used is 50 ohms. The dimensions of the microstrip line can be determined using the following equation:

$$W_z = \frac{2h}{\pi} \left\{ \frac{B-1-\ln(2B-1)+\epsilon_r-1}{2\epsilon_r} \left[\ln(B-1)+0.39-\frac{0.61}{\epsilon_r} \right] \right\} \quad (6)$$

$$B = \frac{60\pi^2}{Z_0\sqrt{\epsilon_{eff}}} \quad (7)$$

where W_z is the width of the microstrip line, Z_0 is the impedance of the antenna and B is the impedance constant. The impedance of the antenna is 50 Ω in line with the impedance of the connector used. Furthermore, the length of the microstrip line (L_z) is $\frac{1}{4}$ lambda (λ_g) which is determined by the following equation:

$$L_z = \frac{1}{4}\lambda_g \quad (8)$$

$$\lambda_g = \frac{\lambda}{\epsilon_{eff}} \quad (9)$$

The structure and design of the single element microstrip antenna with a rectangular shape is shown in Fig. 2.

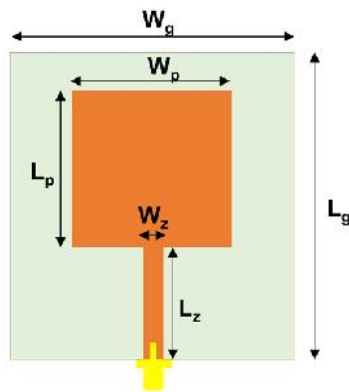


Fig. 2. Design of single element microstrip antenna

Fig. 2 describes the structure of a single element microstrip antenna where the antenna is connected to the connector using a transmission line with an impedance of 50 Ohms. The dimensions of the antenna are obtained using equations (1) to equations (5) while the dimensions of the transmission line are obtained using equations (6) and equations (7). Moreover, the overall dimensions of the single element microstrip antenna are shown in Table 1.

Table 1

Dimension of single element microstrip antenna

Parameter	Dimension (mm)
W_g	40
L_g	40
W_z	3
L_z	12.7
W_p	25
L_p	20

The antenna is designed and simulated using electromagnetic (EM) simulation with the Finite element method (FEM) based on HFSS 15.0. Parameters observed were reflection coefficient, VSWR and gain of the designed antenna. The simulation results of a single element microstrip antenna are shown in Fig. 3.

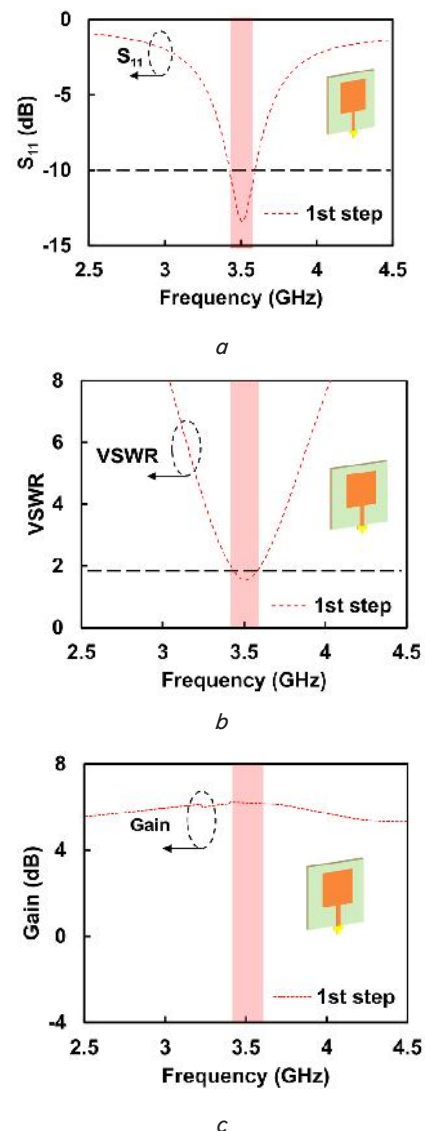


Fig. 3. Simulation result of single element microstrip antenna: a – S_{11} ; b – VSWR; c – Gain

Fig. 3, a shows that the single element microstrip antenna has been operating at a resonant frequency of 3.5 GHz

with a reflection coefficient (S_{11}) -13.39 dB. Moreover, the proposed antenna has VSWR of 1.54 and a gain of 6.2 dB as shown in Fig. 3, *b, c*. Furthermore, the impedance bandwidth (IBW) of the single element microstrip antenna is 0.2 GHz with a frequency range of 3.42–3.62 GHz. These findings indicate that the bandwidth obtained is narrow, so it needs further optimization.

4.3. Design of series array microstrip antenna with two and four elements

At this stage, the antenna is developed using a series array configuration with two elements. The dimensions of the patch and transmission line antennas are identical for a single element. The target of adding a patch in a series array configuration is to increase the gain of the antenna. Fig. 4 shows the design of a microstrip antenna with a series array configuration with two elements.

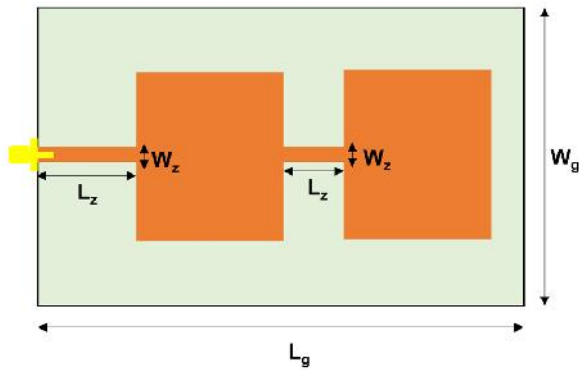


Fig. 4. Design of series array microstrip antenna with two elements

Fig. 4 shows that the two patch antennas are connected using a transmission line with $L_z=12.7$ mm in series and arranged in a vertical configuration. The dimensions of W_g and L_g are 40 mm and 75 mm, respectively. Furthermore, the simulation results of a microstrip antenna configured in series array with two elements are shown in Fig. 5.

Fig. 5, *c* shows that the implementation of a series array with two elements produces a high gain antenna characteristic with a gain of 8.37 dB at a resonant frequency of 3.5 GHz. However, the impedance bandwidth of the antenna is still narrow where the antenna operates at two different resonance frequencies of 3.15 GHz and 3.61 GHz with $S_{11} \leq -10$ dB and $VSWR \leq 2$ as shown in Fig. 5, *a, b*. Therefore, it is necessary to do further optimization so that the bandwidth of the antenna increases. It should be noted, the impedance bandwidth is observed from $S_{11} \leq -10$ dB and $VSWR \leq 2$. Furthermore, the proposed antenna is optimized using a series array with four elements as shown in Fig. 6 with W_g of 42 mm and L_g of 142 mm, while the simulation results are shown in Fig. 7.

Fig. 7, *a, b* shows that the impedance bandwidth of the antenna increases after being configured using a series array with 4 elements. The proposed antenna has an impedance bandwidth of 0.44 GHz with a frequency range of 3.11–3.55 GHz. In addition, the gain of the antenna also increases to 9.09 dB at a resonant

frequency of 3.5 GHz as shown in Fig. 7, *c*. These findings indicate that the addition of the number of elements greatly affects the bandwidth and gain of the antenna. Furthermore, the bandwidth and gain of the antenna will be optimized using a series planar array configuration with 4x2 elements.

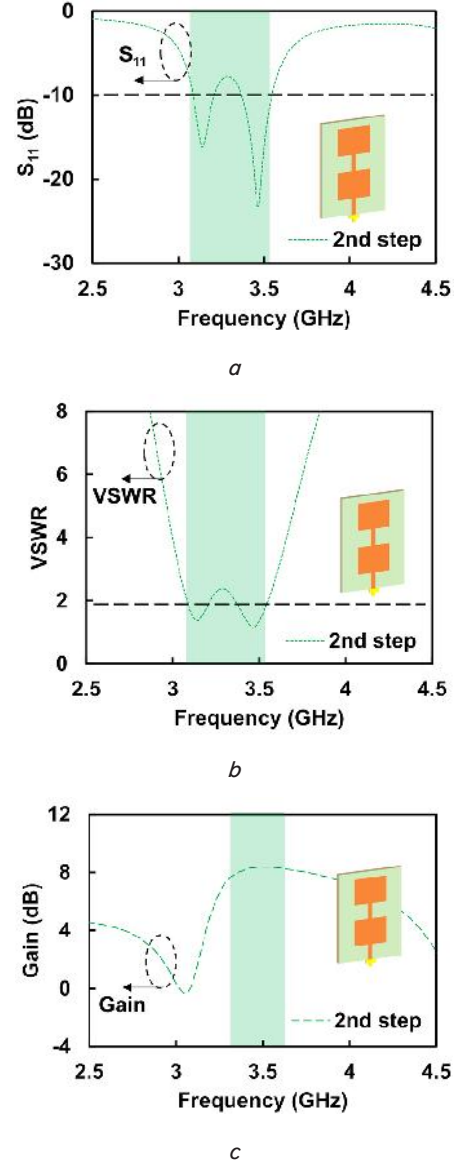


Fig. 5. Simulation result series array microstrip antenna with two elements: *a* – S_{11} ; *b* – VSWR; *c* – Gain

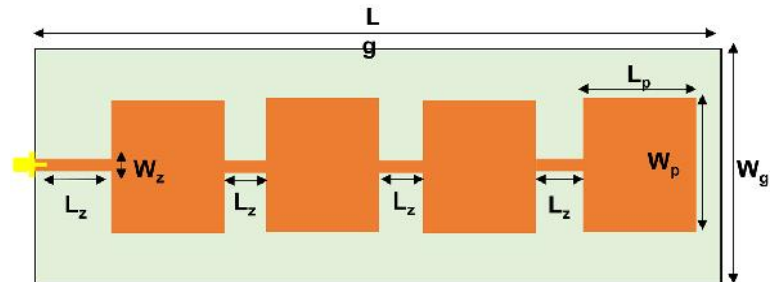


Fig. 6. Design of series array microstrip antenna with four elements

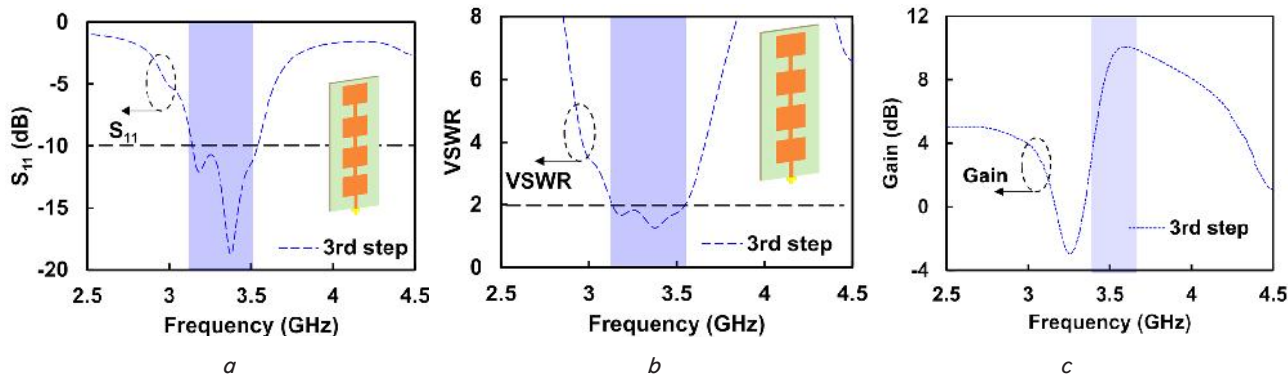


Fig. 7. Simulation result series array microstrip antenna with four elements: a – S₁₁; b – VSWR; c – Gain

4. 4. Design of planar series array microstrip antenna with 4x2 elements

At this stage, the antenna with the series array is configured as a vertical planar separated by a distance represented by d_a . The distance between elements (d_a) is determined by the following equation:

$$d_a = \frac{1}{4}\lambda, \tag{9}$$

$$\lambda = \frac{c}{f}, \tag{10}$$

where d_a represents the gap between the elements of the array, λ represents the electrical length of the antenna and c is the speed of light (3×10^8 m/s). The design and model of the series planar array antenna with 4x2 elements is shown in Fig. 8.

Fig. 8 shows that the series array configuration antenna with four elements each connected planar using a transmission line with a step impedance of 50 Ohm (Z_0), 70.7 Ohm (Z_s) and 100 ohm (Z_L) which functions as impedance matching to control the reflection coefficient and VSWR of antenna. The width of the transmission line determines its impedance while the impedance of the transmission line can be determined based on the following equation:

$$Z_s = \sqrt{Z_0 \cdot Z_L}. \tag{11}$$

Furthermore, the overall dimensions of the series planar array antenna with 4x2 elements are shown in Table 2.

The overall simulation results of a series planar array antenna with 4x2 elements are shown in Fig. 9.

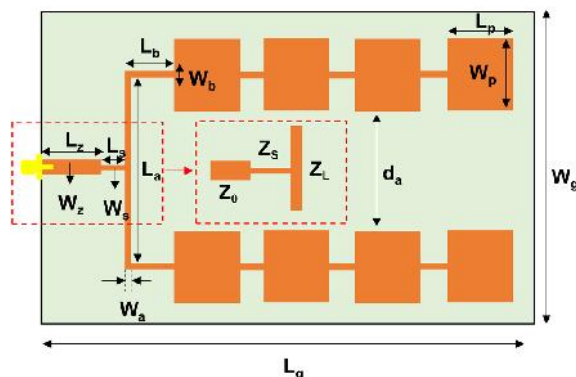


Fig. 8. Design of series planar array microstrip antenna with 4x2 element

Table 2

Dimension of series planar array antenna with 4x2 elements

Parameter	Dimension (mm)
W_g	130
L_g	187
W_z	3
L_z	40
W_p	25
L_p	20
W_s	1
L_s	3
W_a	2
L_a	94
W_b	3
L_b	12.7

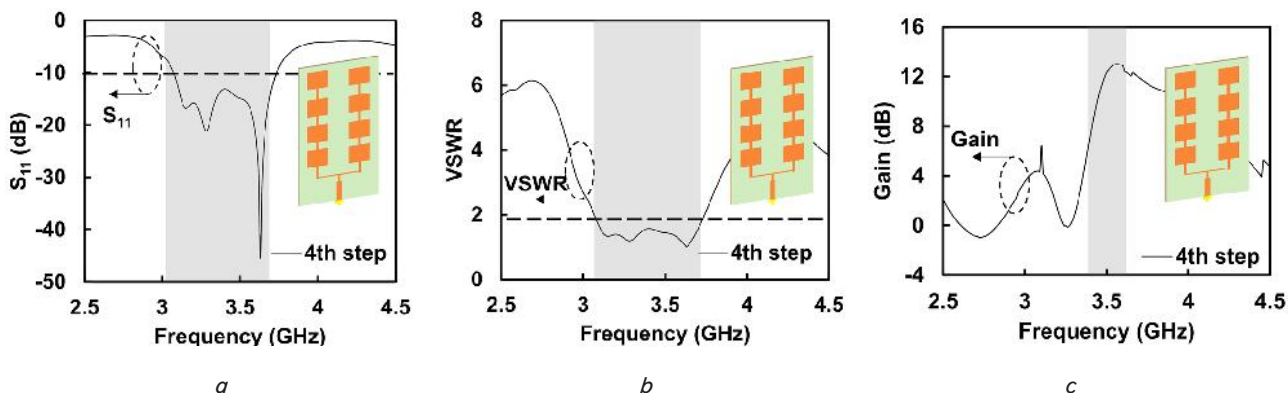


Fig. 9. Simulation result of series planar array microstrip antenna with 4x2 elements: a – S₁₁; b – VSWR; c – Gain

Fig. 9 shows the bandwidth and gain of the antenna significantly increased after being configured with a series planar array with 4×2 elements. The impedance bandwidth of the antenna is 0.61 GHz with a frequency range of 3.1–3.71 GHz as shown in Fig. 9, *a, b* while the gain increases to 12.34 dB at a resonant frequency of 3.5 GHz as shown in Fig. 9, *c*. These findings indicate that the performance of the antenna increases significantly after being developed with a series planar array configuration with 4×2 elements.

5. Results of development compact microstrip antenna for 5G communication system

5.1. Simulation of characteristics of the antenna

The model development of the proposed antenna has been described and simulated in the previous section. Furthermore, the performance of the antenna development is observed by comparing the impedance bandwidth and gain. A comparison of the simulation results for each stage is shown in Fig. 10.

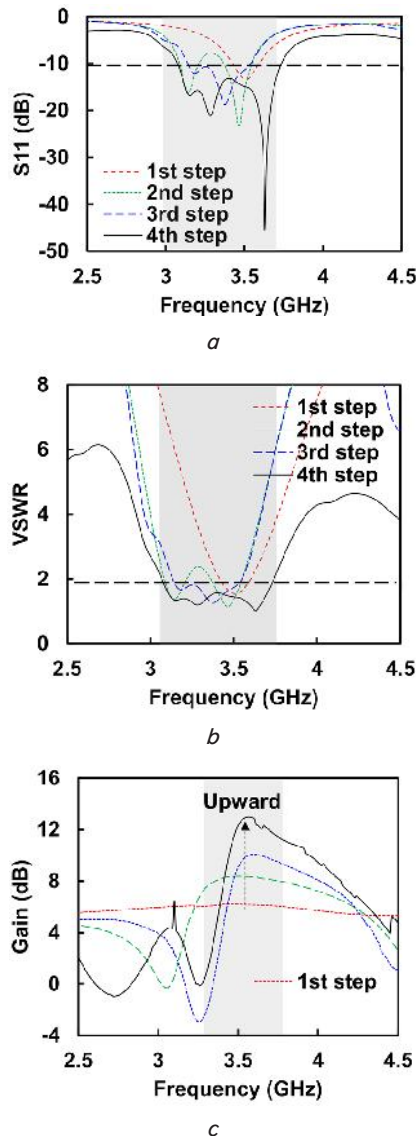


Fig. 10. Comparison of simulation result from development model of proposed microstrip antenna: *a* – S_{11} ; *b* – VSWR; *c* – Gain

Fig. 10, *a, b* show that the bandwidth impedance of the antenna increases significantly after being configured with a series planar array. At the 1st step, the bandwidth of the antenna is 0.2 GHz which increases to 0.44 GHz and 0.62 GHz at the 3rd and 4th steps, respectively. Furthermore, the gain of the antenna at the resonant frequency of 3.5 GHz also increases gradually where the 1st step gain is 6.2 dB, the 2nd step is 8.37 dB while the 3rd step and 4th step are 9.09 dB and 12.34 dB, respectively. In other words, the bandwidth and gain of the proposed antenna increase by 205 % and 99.03 % compared to the single-element microstrip antenna. These findings indicate that the gain and bandwidth of the proposed antenna increase simultaneously.

Based on Fig. 10, *a, b*, the bandwidth performance of the antenna at the 1st step, 2nd step, 3rd step and 4th step are shown in Table 3.

Table 3

Bandwidth of proposed antenna based on development model

Step	Range of frequency (GHz)	Bandwidth (GHz)
1 st step	3.42–3.62	0.20
2 nd step	3.38–3.54	0.16
3 rd step	3.11–3.55	0.44
4 th step	3.10–3.70	0.60

Based on Table 3, the bandwidth of the antenna increases at the 3rd and 4th step. However, at the 2nd step, the bandwidth of the antenna is narrower and has dual band characteristics as shown in Fig. 5, *a, b*. Furthermore, the performance comparison of the proposed antenna is determined based on the following equation:

$$BW = \frac{(Optimized\ BW - Initial\ BW)}{Initial\ BW} \times 100\ \% \quad (12)$$

5.2. Bandwidth performance of proposed antenna

Furthermore, the antenna was fabricated using FR-4 substrate with a dielectric constant (ϵ_r) of 4.3, a loss tan ($\tan \delta$) of 0.0265 and a thickness (*h*) of 1.6 mm. The proposed antenna is connected to the RP-SMA connector with an impedance of 50 Ω as shown in Fig. 11, *b*. The measurement setup of the antenna is shown in Fig. 11, *a* where the proposed antenna is connected to port 1 of the Vector Network Analyzer (VNA). The frequency range used in the measurement process is 2.5–4.5 GHz with a sweep frequency of 0.01 GHz and an ambient temperature of 25 °C. Moreover, the simulation and measurement results are comprehensively compared to observe the performance of the fabricated antenna. Comparison results of the simulation and measurement processes of the proposed antenna are shown in Fig. 12.

Fig. 12 shows that the fabricated antenna has performance and characteristics that are in line with the simulation process. The impedance bandwidth (IBW) of the antenna with $S_{11} \leq -10$ dB and $VSWR \leq 2$ from the measurement process is 0.6 GHz with a frequency range of 3.11–3.71 GHz. The proposed antenna has wide bandwidth characteristics and meets the criteria and specifications for a 5G communication system where the required bandwidth is 200 MHz.

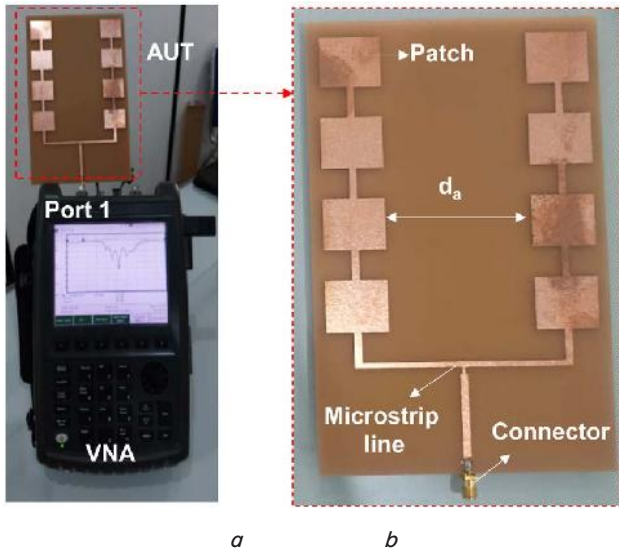


Fig. 11. Measurement process of proposed antenna: a – measurement setup for near-field parameter; b – fabrication of proposed antenna

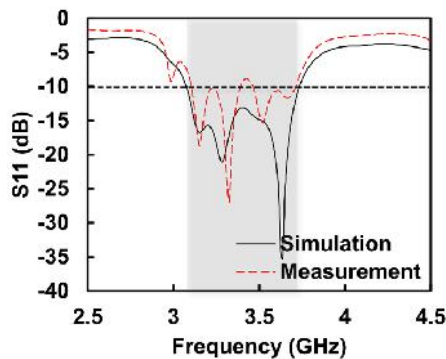


Fig. 12. Comparison between simulation and measurement of reflection coefficient of proposed antenna

The bandwidth of the single element antenna represents the initial bandwidth while the optimization bandwidth is obtained from the 2nd, 3rd and 4th steps. Based on equation (12), the bandwidth of the single element antenna increases 102 % and 205 % at the 3rd and 4th steps respectively. Furthermore, the performance is also observed in terms of increasing the gain of the antenna. Based on Fig. 10, c, the gain performance of the antenna at the 1st step, 2nd step, 3rd step and 4th step is shown in Table 3.

Table 4

Gain of proposed antenna based on development model

Step	Resonant frequency (GHz)	Gain (dB)
1 st step	3.5	6.20
2 nd step	3.5	8.20
3 rd step	3.5	9.09
4 th step	3.5	12.34

Based on Table 4, the gain of the proposed antenna increases gradually from the 1st, 2nd, 3rd and 4th steps in line with the increase in the number of elements of the antenna. Furthermore, the performance comparison of the proposed antenna is determined based on the following equation:

$$BW = \frac{(Optimized\ Gain - Initial\ Gain)}{Initial\ BW} \times 100\ \% . \quad (13)$$

5. 3. The gain of microstrip antenna

Furthermore, the gain and radiation pattern of the proposed antenna are observed by measuring in the anechoic chamber as shown in Fig. 13 where the designed antenna is positioned as a receiver (Rx) and a comparison antenna is used as a transmitter (Tx) separated by a distance $d=60$ cm and connected to port 1 and port 2 of the VNA using a coaxial cable.

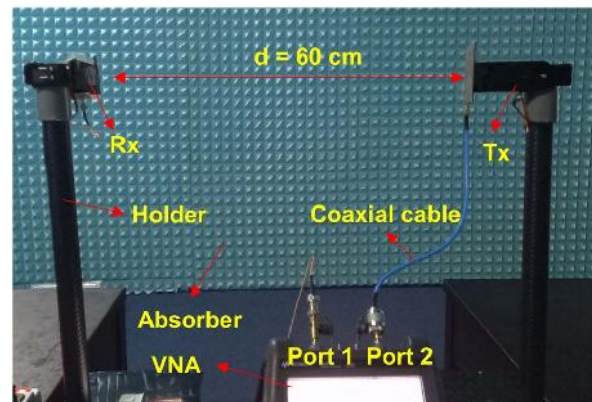


Fig. 13. Measurement setup for far-field parameter in anechoic chamber

Fig. 14, a, b shows the radiation pattern from the measurement results in line with the simulation results with a resonant frequency of 3.5 GHz with gain of 12.5 dB. These findings confirm that the proposed antenna has a high gain ≥ 10 dB with a directional radiation pattern at a resonant frequency of 3.5 GHz.

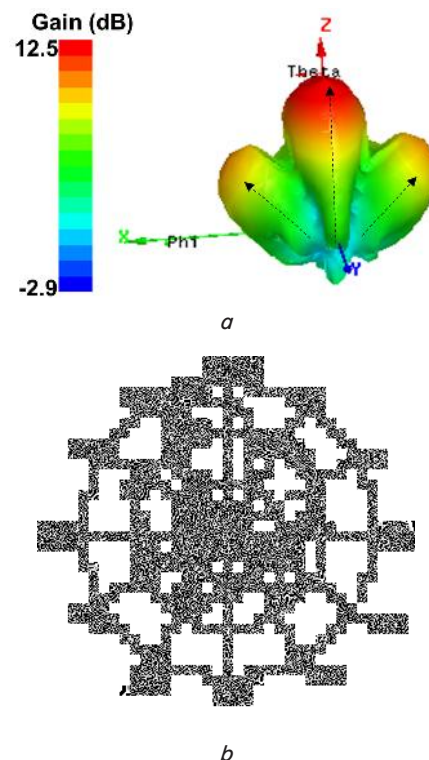


Fig. 14. Far field of proposed antenna: a – simulation result; b – measurement result

6. Discussion of experimental result of proposed antenna

The gain of the single element antenna represents the initial gain while the optimization gain is obtained from the 2nd, 3rd and 4th steps. Based on equation (13), the bandwidth of the single element antenna increases 32.25 %, 45.48 % and 99.03 % at the 2nd, 3rd and 4th steps respectively. In addition, the results presented in Fig. 12, 13 show that the antenna has a bandwidth and gain performance that is in line between the simulation and measurement. This indicates that the antenna has met a predetermined target.

Overall, this paper has comprehensively described and investigated the development of microstrip antennas with wide bandwidth and high gain. The antenna was developed in four steps including single element antenna, series array with two elements, series array with four elements and planar series array with 4x2 elements. The bandwidth and gain of the antenna were successfully increased based on the proposed steps. From the measurement results, the series planar array antenna with 4x2 elements has succeeded in increasing the performance in terms of bandwidth and gain up to 205 % and 99.03 % compared to single element antennas. Moreover, the proposed antenna has a wide bandwidth of 0.6 GHz and a directional radiation pattern with a high gain of 12.34 dB at a resonant frequency of 3.5 GHz. Furthermore, the planar series array method succeeded in increasing the gain and bandwidth simultaneously. The bandwidth of the antenna has met the target ≥ 200 MHz with a gain ≥ 10 dB.

However, there are several limitations, including the dimensions of the antenna which are still quite large and only operate at one resonant frequency. Therefore, the future work of this research is to reduce the dimensions of the antenna and optimize the antenna to work at several resonant frequencies so that it can be used for other communication systems such as 4G, Zigbee and Wi-Fi.

7. Conclusions

1. The bandwidth and gain of the proposed antenna is improved simultaneously through four stages including single elements, series arrays with 2x1 elements, series arrays with 4x1 elements and the final stage uses planar series arrays with 4x2 elements.

2. Bandwidth impedance of the proposed antenna is 0.6 GHz and successfully increased up to 205 % compared to single element antenna.

3. Gain of the proposed antenna is 12.5 dB and successfully increased up to 99.03 % compared to single element antenna.

Conflict of Interest

The authors declare that they have no conflict of interest in relation to this research, whether financial, personal, authorship or otherwise, that could affect the research and its results presented in this paper.

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Data availability

Manuscript has no associated data.

References

- Hobbs, S. (2018). Valuing 5G Spectrum: Valuing the 3.5 GHz and C-Band Frequency Range. Coleago Consulting.
- Hikmaturokhman, A., Ramli, K., Suryanegara, M. (2018). Spectrum Considerations for 5G in Indonesia. 2018 International Conference on ICT for Rural Development (IC-ICTRuDev). doi: <https://doi.org/10.1109/icictr.2018.8706874>
- Höyhtyä, M., Apilo, O., Lasanen, M. (2018). Review of Latest Advances in 3GPP Standardization: D2D Communication in 5G Systems and Its Energy Consumption Models. *Future Internet*, 10 (1), 3. doi: <https://doi.org/10.3390/fi10010003>
- Zhang, G., Basit, A., Khan, M. I., Daraz, A., Saqib, N., Zubir, F. (2023). Multi Frequency Controllable In-BandSuppressions in a Broad Bandwidth Microstrip Filter Design for 5G Wi-Fi and Satellite Communication Systems Utilizing a Quad-Mode Stub-Loaded Resonator. *Micromachines*, 14 (4), 866. doi: <https://doi.org/10.3390/mi14040866>
- Tawfeeq, N. N. (2017). Size Reduction and Gain Enhancement of a Microstrip Antenna using Partially Defected Ground Structure and Circular/Cross Slots. *International Journal of Electrical and Computer Engineering (IJECE)*, 7 (2), 894. doi: <https://doi.org/10.11591/ijece.v7i2.pp894-898>
- Surjati, I., Alam, S., Karnadi, J. (2019). Design of spiral labyrinth microstrip antenna for DVB-T application. *TELKOMNIKA (Telecommunication Computing Electronics and Control)*, 17 (1), 76. doi: <https://doi.org/10.12928/telkomnika.v17i1.11628>
- Sandi, E., Rusmono, R., Diamah, A., Vinda, K. (2020). Ultra-wideband Microstrip Array Antenna for 5G Millimeter-wave Applications. *Journal of Communications*, 15 (2), 198–204. doi: <https://doi.org/10.12720/jcm.15.2.198-204>
- Liu, J., Liu, H., Dou, X., Tang, Y., Zhang, C., Wang, L. et al. (2021). A Low Profile, Dual-Band, Dual-Polarized Patch Antenna With Antenna-Filter Functions and Its Application in MIMO Systems. *IEEE Access*, 9, 101164–101171. doi: <https://doi.org/10.1109/access.2021.3096969>
- Ullah, S., Yeo, W.-H., Kim, H., Yoo, H. (2020). Development of 60-GHz millimeter wave, electromagnetic bandgap ground planes for multiple-input multiple-output antenna applications. *Scientific Reports*, 10 (1). doi: <https://doi.org/10.1038/s41598-020-65622-9>
- Naga Jyothi Sree, G., Nelaturi, S. (2021). Design and experimental verification of fractal based MIMO antenna for lower sub 6-GHz 5G applications. *AEU - International Journal of Electronics and Communications*, 137, 153797. doi: <https://doi.org/10.1016/j.aeue.2021.153797>

References

1. Hobbs, S. (2018). Valuing 5G Spectrum: Valuing the 3.5 GHz and C-Band Frequency Range. Coleago Consulting.
2. Hikmaturokhman, A., Ramli, K., Suryanegara, M. (2018). Spectrum Considerations for 5G in Indonesia. 2018 International Conference on ICT for Rural Development (IC-ICTRuDev). doi: <https://doi.org/10.1109/icitr.2018.8706874>
3. Höyhtyä, M., Apilo, O., Lasanen, M. (2018). Review of Latest Advances in 3GPP Standardization: D2D Communication in 5G Systems and Its Energy Consumption Models. *Future Internet*, 10 (1), 3. doi: <https://doi.org/10.3390/fi10010003>
4. Zhang, G., Basit, A., Khan, M. I., Daraz, A., Saqib, N., Zubir, F. (2023). Multi Frequency Controllable In-Band Suppressions in a Broad Bandwidth Microstrip Filter Design for 5G Wi-Fi and Satellite Communication Systems Utilizing a Quad-Mode Stub-Loaded Resonator. *Micromachines*, 14 (4), 866. doi: <https://doi.org/10.3390/mi14040866>
5. Tawfeeq, N. N. (2017). Size Reduction and Gain Enhancement of a Microstrip Antenna using Partially Defected Ground Structure and Circular/Cross Slots. *International Journal of Electrical and Computer Engineering (IJECE)*, 7 (2), 894. doi: <https://doi.org/10.11591/ijece.v7i2.pp894-898>
6. Surjati, I., Alam, S., Karnadi, J. (2019). Design of spiral labyrinth microstrip antenna for DVB-T application. *TELKOMNIKA (Telecommunication Computing Electronics and Control)*, 17 (1), 76. doi: <https://doi.org/10.12928/telkomnika.v17i1.11628>
7. Sandi, E., Rusmono, R., Diamah, A., Vinda, K. (2020). Ultra-wideband Microstrip Array Antenna for 5G Millimeter-wave Applications. *Journal of Communications*, 15 (2), 198–204. doi: <https://doi.org/10.12720/jcm.15.2.198-204>
8. Liu, J., Liu, H., Dou, X., Tang, Y., Zhang, C., Wang, L. et al. (2021). A Low Profile, Dual-Band, Dual-Polarized Patch Antenna With Antenna-Filter Functions and Its Application in MIMO Systems. *IEEE Access*, 9, 101164–101171. doi: <https://doi.org/10.1109/access.2021.3096969>
9. Ullah, S., Yeo, W.-H., Kim, H., Yoo, H. (2020). Development of 60-GHz millimeter wave, electromagnetic bandgap ground planes for multiple-input multiple-output antenna applications. *Scientific Reports*, 10 (1). doi: <https://doi.org/10.1038/s41598-020-65622-9>
10. Naga Jyothi Sree, G., Nelaturi, S. (2021). Design and experimental verification of fractal based MIMO antenna for lower sub 6-GHz 5G applications. *AEU - International Journal of Electronics and Communications*, 137, 153797. doi: <https://doi.org/10.1016/j.aeue.2021.153797>
11. Tarpara, N. M., Rathwa, R. R., Kotak, N. A. (2018). Design of Slotted Microstrip patch Antenna for 5G Application. *International Research Journal of Engineering and Technology (IRJET)*, 05 (04). URL: https://www.academia.edu/37016852/Design_of_Slotted_Microstrip_patch_Antenna_for_5G_Application
12. Ali, H., Singh, P., Kumar, S., Goel, T. (2017). A Minkowski fractal ultrawide band antenna for 5G applications. 2017 IEEE International Conference on Antenna Innovations & Modern Technologies for Ground, Aircraft and Satellite Applications (IAIM). doi: <https://doi.org/10.1109/iaim.2017.8402541>
13. Hu, W., Liu, X., Gao, S., Wen, L.-H., Qian, L., Feng, T. et al. (2019). Dual-Band Ten-Element MIMO Array Based on Dual-Mode IFAs for 5G Terminal Applications. *IEEE Access*, 7, 178476–178485. doi: <https://doi.org/10.1109/access.2019.2958745>
14. An, W., Li, Y., Fu, H., Ma, J., Chen, W., Feng, B. (2018). Low-Profile and Wideband Microstrip Antenna With Stable Gain for 5G Wireless Applications. *IEEE Antennas and Wireless Propagation Letters*, 17 (4), 621–624. doi: <https://doi.org/10.1109/lawp.2018.2806369>
15. Cai, Q., Li, Y., Zhang, X., Shen, W. (2019). Wideband MIMO Antenna Array Covering 3.3–7.1 GHz for 5G Metal-Rimmed Smartphone Applications. *IEEE Access*, 7, 142070–142084. doi: <https://doi.org/10.1109/access.2019.2944681>
16. Alam, S., Surjati, I., Sari, L., Hilyawan, M. R., Zakaria, Z., Shairi, N. A. et al. (2022). Triple Band Notched Microstrip Antenna Using Planar Series 2x2 Element Arrayfor 5G Communication System. *Journal of Nano- and Electronic Physics*, 14 (1), 01019-1-01019–5. doi: [https://doi.org/10.21272/jnep.14\(1\).01019](https://doi.org/10.21272/jnep.14(1).01019)

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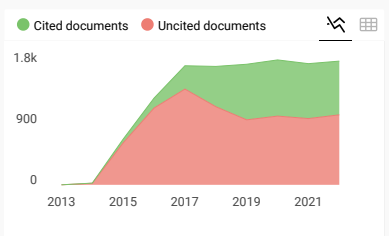
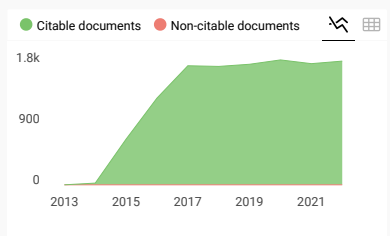
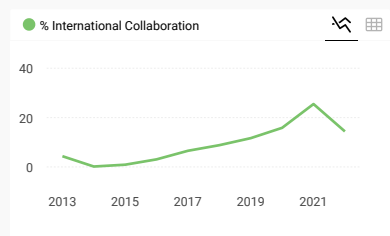
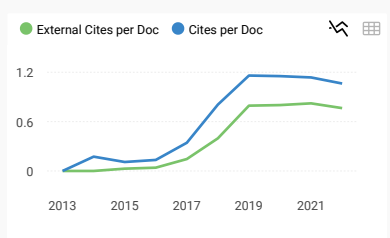
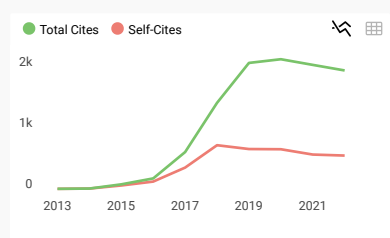
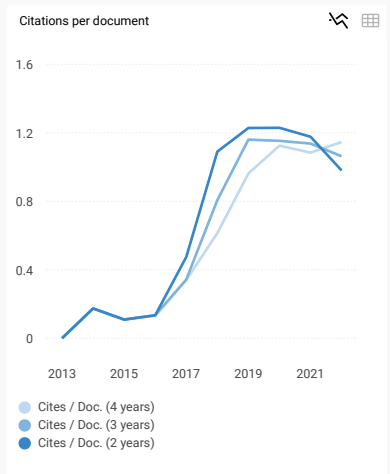
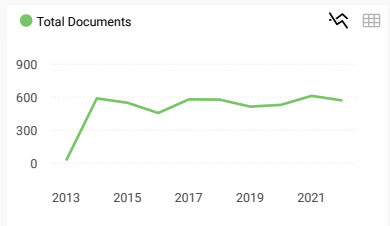
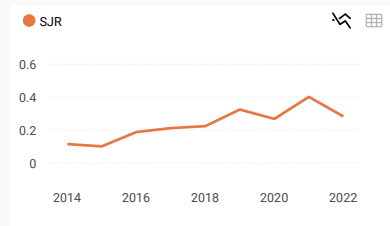
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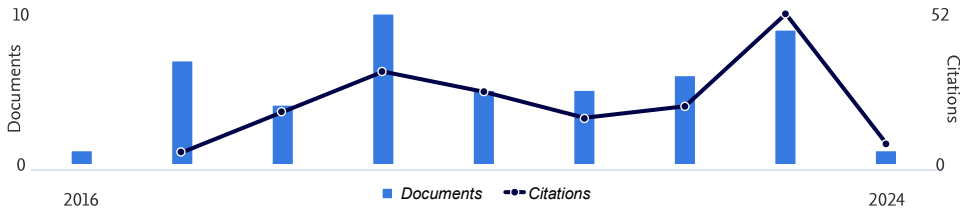
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