

DAFTAR PUSTAKA

- [1] D. M. Pozar, *Microwave Engineering*, 4th ed. Hoboken, NJ, USA: John Wiley & Sons, 2012.
- [2] ITU-R, "IMT-2030: Framework and overall objectives of the future development of IMT for 2030 and beyond," Recommendation ITU-R M.2160-0, Nov. 2023. [Online]. Available: <https://www.itu.int/rec/R-REC-M.2160-0-202311-I/en>
- [3] Telkomsel, "Spesial di Ulang Tahun ke-31, Telkomsel Tegaskan Makna 'Melayani Sepenuh Hati' untuk Hadirkan Pengalaman Terbaik Bagi Pelanggan di Indonesia," 2026. [Online]. Available: <https://www.telkomsel.com/about-us/news/spesial-di-ulang-tahun-ke-31-telkomsel-tegaskan-makna-melayani-sepenuh-hati-untuk>. [Accessed: Aug. 21, 2026]
- [4] F. H. Ahmed, R. Saad, and S. K. Khamas, "A Novel Compact Broadband Quasi-Twisted Branch Line Coupler Based on a Double-Layered Microstrip Line," *Micromachines (Basel)*, vol. 15, no. 1, p. 142, Jan. 2024, doi: 10.3390/mi15010142.
- [5] P. Kim-Thi, T. Nguyen-Van, D. Nguyen-Tien, and T. Bui-Thanh, "A compact design of four-port high-gain MIMO antenna using hybrid coupler and dual-polarized radiators," *PLoS One*, vol. 20, no. 12 December, pp. 1–12, 2025, doi: 10.1371/journal.pone.0337293.
- [6] M. Steer, *Microwave and RF Design: Networks*, 3rd ed. Raleigh, NC, USA: NC State University, 2019.
- [7] R. Smolarz, K. Wincza, and S. Gruszczynski, "Chebyshev-Response Branch-Line Couplers with Enhanced Bandwidth and Arbitrary Coupling Level," *Electronics (Basel)*, vol. 9, no. 11, p. 1828, Nov. 2020, doi: 10.3390/electronics9111828.
- [8] R. Smolarz, K. Wincza, and S. Gruszczynski, "Impedance transforming rat-race couplers with modified Lange section," *Journal of Electromagnetic Waves and Applications*, vol. 32, no. 8, pp. 972–983, 2018, doi: 10.1080/09205071.2017.1411836.
- [9] S. Srisawat et al., "Design and fabrication of a compact microstrip hybrid ring coupler with harmonic reduction for L band radar system," *Sci. Rep.*, vol. 15, 2025, doi: 10.1038/s41598-025-01304-8.
- [10] K. V. Phani Kumar, R. K. Barik, and S. S. Karthikeyan, "A novel two section branch line coupler employing different transmission line techniques," *AEU—International Journal of Electronics and Communications*, vol. 70, no. 5, pp. 738–742, May 2016, doi: 10.1016/j.aeue.2016.02.011.
- [11] X. Wu and L.-P. Shen, "Compact Ultra-Wideband Microstrip 3dB Branch-Line Coupler Using Coupled-Lines," in 2022 IEEE Int. Symp. Antennas

- Propag. USNC-URSI Radio Sci. Meeting (AP-S/URSI), Denver, CO, USA, 2022, pp. 1462–1463, doi: 10.1109/AP-S/USNC-URSI47032.2022.9886053.
- [12] TSGR, “ETSI TS 138 521-1 - V18.6.0 - 5G; NR; User Equipment (UE) conformance specification; Radio transmission and reception; Part 1: Range 1 standalone (3GPP TS 38.521-1 version 18.6.0 Release 18), 2025. [Online]. Available: https://www.etsi.org/deliver/etsi_ts/138200_138299/138211/18.06.00_60/ts_138211v180600p.pdf
- [13] TELCOMA Global, "5G Frequency Bands." [Online]. Available: <https://www.telcomaglobal.com/p/5g-frequency-bands>. [Accessed: Aug. 10, 2026].
- [14] FrequencyCheck, "Indonesia Wireless Frequency Bands and Carriers." [Online]. Available: <https://www.frequencycheck.com/countries/indonesia>. [Accessed: Aug. 10, 2026].
- [15] R. Tiwari *et al.*, “Advancing 5G connectivity: A comprehensive review of MIMO antennas for 5G applications,” *International Journal of Antennas and Propagation*, vol. 2023, Art. ID 5906721, 2023, doi: 10.1155/2023/5906721.
- [16] D. N. K. A. Zaidel *et al.*, “Improvement of the bandwidth and scattering parameter performances of 5G branch-line coupler design for the use in Intelligent Transportation System (ITS),” *Journal of Telecommunication, Electronic and Computer Engineering*, vol. 10, no. 1–12, pp. 89–92, 2018.
- [17] K. Thiyagarajan, T. Kesavamurthy, K. A. Banupriya, and R. Sindhuja, “Miniaturised broadband branch line coupler for WiMAX and LTE applications,” *International Journal of Wireless and Mobile Computing*, vol. 8, no. 1, p. 66, 2015, doi: 10.1504/IJWMC.2015.066748.
- [18] L. Punitha, S. P. Sugumar, and P. H. Rao, “Analysis of RF transceiver for 5G applications,” in *Proc. URSI Asia-Pacific Radio Science Conference (AP-RASC)*, New Delhi, India, 2019.
- [19] A. Es-saleh, M. Bendaoued, S. Lakrit, S. Das, and A. Faize, "Design aspects of MIMO antennas and its applications: A comprehensive review," *Results Eng.*, vol. 25, p. 103797, 2025.
- [20] M. Moubadir, A. Mchbal, N. A. Touhami, and M. Aghoutane, “A switched beamforming network for 5G modern wireless communications applications,” *Procedia Manufacturing*, vol. 32, pp. 753–761, 2019, doi: 10.1016/j.promfg.2019.02.282
- [21] M. Jeon *et al.*, “Investigation on Beam Alignment of a Microstrip-Line Butler Matrix and an SIW Butler Matrix for 5G Beamforming Antennas through RF-to-RF Wireless Sensing and 64-QAM Tests,” *Sensors*, vol. 21, no. 20, p. 6830, Oct. 2021, doi: 10.3390/s21206830.

- [22] F. Huang, W. Chen, and M. Rao, "Switched-beam antenna array based on butler matrix for 5G wireless communication," in *2016 IEEE International Workshop on Electromagnetics: Applications and Student Innovation Competition (iWEM)*, IEEE, May 2016, pp. 1–3. doi: 10.1109/iWEM.2016.7505030.
- [23] A. A. Abdulbari, S. K. Abdul Rahim, P. J. Soh, M. H. Dahri, A. A. Eteng, and M. Y. Zeain, "A review of hybrid couplers: State-of-the-art, applications, design issues and challenges," *International Journal of Numerical Modelling: Electronic Networks, Devices and Fields*, vol. 34, no. 5, Art. no. e2919, 2021, doi: 10.1002/jnm.2919.
- [24] Dong Il Kim and Y. Naito, "Broad-Band Design of Improved Hybrid-Ring 3-dB Directional Couplers," *IEEE Trans. Microw. Theory Tech.*, vol. 30, no. 11, pp. 2040–2046, Nov. 1982, doi: 10.1109/TMTT.1982.1131373.
- [25] N. H. A. Rahim, R. Rasid, S. Z. Ibrahim, N. Khalid, M. S. Razalli, and T. G. Siang, "Development of branchline coupler using parallel coupled transmission lines," in *2016 3rd International Conference on Electronic Design (ICED)*, IEEE, Aug. 2016, pp. 76–79. doi: 10.1109/ICED.2016.7804610.
- [26] M. Park, W. Lee, and T. Son, "Composite GPS Patch Antenna for the AR Bandwidth Enhancement," *International Journal of Antennas and Propagation*, vol. 2016, Art. no. 3250920, pp. 1–6, 2016, doi: 10.1155/2016/3250920.
- [27] H. Madiawati, A. B. Simanjuntak, and F. P. Senja, "Optimasi antena mikrostrip 4 elemen untuk aplikasi VSAT dengan pencatutan proximity coupled pada frekuensi Ku-Band," *JTERA (Jurnal Teknologi Rekayasa)*, vol. 9, no. 1, pp. 13–20, Jul. 2024, doi: 10.31544/jtera.v9.i1.2024.13-20.
- [28] Z. Ma, E. Yamashita, and K. Atsuki, "Microstrip Lines," in *Encyclopedia of RF and Microwave Engineering*, Wiley, 2005. doi: 10.1002/0471654507.eme228.
- [29] F. Rizqa, D. Arseno, and T. Yunita, "Analisis dan desain antena mikrostrip untuk komunikasi satelit pada frekuensi Ka-Band," *AVITEC*, vol. 2, no. 1, 2020, doi: 10.28989/avitec.v2i1.590.
- [30] S. Roshani et al., "Design of a miniaturized 90-degree quadrature hybrid coupler with harmonic suppression ability using π -shaped lumped elements," *Sci. Rep.*, vol. 14, 2024, doi: 10.1038/s41598-024-78328-z.
- [31] A. El Berbri, A. Saadi, and S. Bri, "Optimized Design of Two Section Branch Line Coupler for Future 5G Applications," *International Journal of Microwave and Optical Technology*, vol. 15, no. 1, pp. 44–49, Jan. 2020.
- [32] CST Studio Suite, "CST Studio Suite 3D Electromagnetic Simulation Software", [Online]. Available: <https://www.technia.com/en/advanced-simulation/software/cst-studio-suite/>

- [33] A. Abdipour and E. Zare, "A design of branch-line coupler with harmonic suppression and size reduction using closed-loop and open-loop resonators," *Radioengineering*, vol. 26, no. 4, pp. 999–1005, Dec. 2017, doi: 10.13164/re.2017.0999.
- [34] Keysight Technologies, *Signal Integrity Analysis Series Part 1: Single-Port TDR, TDT, and S-parameter Measurements*, Application Note 5989-5763EN. Santa Rosa, CA, USA: Keysight Technologies. [Online]. Available: <https://www.keysight.com/us/en/assets/7018-01461/application-notes/5989-5763.pdf>
- [35] Keysight Technologies, *S-parameter Design*, Application Note 154, 5952-1087. Santa Rosa, CA, USA: Keysight Technologies. [Online]. Available: <https://www.keysight.com/us/en/assets/7018-06743/application-notes/5952-1087.pdf>
- [36] Kementerian Komunikasi dan Digital Republik Indonesia, "Hasil Seleksi Pengguna Pita Frekuensi Radio 700 MHz dan 2,6 GHz untuk Keperluan Penyelenggaraan Jaringan Bergerak Seluler Tahun 2026," Jul. 10, 2026. [Online]. Available: <https://www.komdigi.go.id/berita/siaran-pers/detail/hasil-seleksi-pengguna-pita-frekuensi-radio-700-mhz-dan-26-ghz-untuk-keperluan-penyelenggaraan-jaringan-bergerak-seluler-tahun-2026>. [Accessed: Aug. 21, 2026].

