Islamic Azad University , Shiraz Branch
نشریه تحلیل مدارها، داده ها و سامانه ها
Journal of Circuits, Data and Systems Analysis
sanad.iau.ir/journal/jcdsa

Design and Experimental Verification of a Dual-Band 4G LTE/5G Antenna for 2.6 GHz and 3.5 GHz Frequency Bands

Amir Rezagholi[1*], Hossein Zargar[2], Iran Sarafraz[3]

[1] Electrical Engineering Department, Zand Institute of Higher Education, Shiraz, Iran
amir.rezagholi@shirazu.ac.ir
[2] Radio Communications Group, ICT Research Institute (ITRC), Tehran, Iran
h.zargar@itrc.ac.ir
[3] PhD Student, Department of Electrical Engineering, Shiraz Branch, Islamic Azad University, Shiraz, Iran
ideh.sarafraz@gmail.com

Abstract:

Building upon 4G LTE, 5G NR establishes the foundation for enhanced mobile broadband, including more capacity for wireless users, improved links among users (less lag time and network loss), and enhanced data rates. n38 (2600 MHz), n48 (3500 MHz), and n78 (3500 MHz) 5G NR bands are among the most commonly tested and deployed 5G frequency bands due to their relatively common availability. Dual-band or multi-band antennas are the key requirements of 5G coexistence with 4G. Since slots make patch antennas smaller and more low-cost, slot-patch antennas are extremely attractive to be used in 4G/5G dual-band or multi-band applications. In this paper, we have demonstrated a dual-band 4G LTE/5G NR slot-patch antenna for 2.6 GHz (for both 4G LTE and 5G NR) and 3.5 GHz (for 5G NR) frequency bands, and successfully verified its performance experimentally. A very good agreement can be seen between simulations and experimental results.

Keywords: 4G LTE, 5G NR, Multi-band antenna, Patch antenna, Slot.

JCDSA, Vol. 2, No. 1, Spring 2024	**Online ISSN: 2981-1295**	**Journal Homepage: https://sanad.iau.ir/en/Journal/jcdsa**
Received: 2023-12-25	Accepted: 2024-05-12	Published: 2024-06-13

CITATION

Rezagholi, A., et. al., " Design and Experimental Verification of a Dual-Band 4G LTE/5G Antenna for 2.6 GHz and 3.5 GHz Frequency Bands ", Journal of Circuits, Data and Systems Analysis (JCDSA), Vol. 2, No. 1, pp. 52-58, 2024.
DOI: 00.00000/0000

[*] Corresponding author

1- Introduction

By Q3 2023, more than 11.7 billion mobile connections, including cellular IoT, and nearly 5.6 billion unique mobile subscribers are reported [1-2], and it is expected to reach 6.3 billion unique mobile subscribers in 2030 [1-3]. There will be also more than 600 million new subscribers by 2025 [1-2]. Global mobile data usage will also grow almost fourfold by 2025 [1-2]. Other reports show the same growth [4-7]. Mobile computing with wireless communications has already changed how people socialize and how companies do business. Early examples of this exciting future include virtual and augmented reality, autonomous driving, smart cities, wearable computers, connected devices, and on-demand video [8]. The available spectrum has a major impact on how a network's maximum capacity and coverage are defined [9]. Some services depend on ultra-low latency capabilities, while others need superfast download speeds. Some need highly localized connectivity, while others need nationwide connectivity. Each of these examples needs different spectrum and network resources [6-7]. The aggregation of the different spectrum bands from sub-1 GHz to mm-waves provides the best combination of coverage, capacity and user data rates. An important feature of the 3GPP[1] Release 15 standard resides in the ability for LTE[2] and NSA[3] 5G NR[4] to coexist and share the same low frequency bands without having to fully free those bands from LTE use [10-11]. The IMT[5]-2020 Vision (Recommendation ITU[6]-R M.2083) includes three usage scenarios for NSA 5G NR, as shown in Fig. 1 [11-12].

The mid-band frequencies meet the needs of wide area coverage and data rates of up to a few Gbps [13-14]. Higher frequency bands in 5G will provide capacity with smaller cells, and lower bands will provide coverage with larger cells [14]. ITU-R has identified the 2500-2690 MHz as a global band for IMT and this was formally included in the Radio Regulations in accordance with Resolution 223 (Rev.WRC-15) [11-15]. 3400-3600 MHz (formally known as 3.5 GHz band) is harmonized in the Radio Regulations, and the use of 3300-4200 MHz for mobile broadband is the subject of harmonization activity from 2003 [14-17]. As multi-band operation is the key requirement of 5G, a single antenna is highly desirable if it can operate at different 5G bands, especially if they are common to 4G [18], and may provide an alternative to large-bandwidth planar antennas, in applications with operation at two separate bands. Various dual-band or even tri-band antenna deigns can be found in the literature for different frequency bands, which most of them are for GSM[7], DCS[8], UMTS[9], Bluetooth, WLAN[10], WiMAX[11], or satellite communications [19-22]. For dual-band/tri-band 5G designs, most of the work has been done for high-band (mm-Wave) frequencies, in which 28/38 GHz and 38/60 GHz combinations seem to be the most favored [23-29]. However, some designs can be found on dual-band 4G/5G applications, which is the case of our interest. Ojaroudi proposed double-element square-ring slot radiators located on the corners and fed by a microstrip-line for a multi-band antenna array for 2.5–2.7 GHz, 3.45–3.8 GHz, and 5.00–5.45 GHz [30]. Ojaroudi proposed eight identical PIFA elements placed at different edge corners of the handset mainboard operating at 2.5–2.7 GHz, 3.4–3.75 GHz, and 5.6–6 GHz [31]. Yang proposed a compact wideband printed antenna which can provide three wide operating bandwidths over 685–1012 MHz, 1596–2837 MHz, and 3288–3613 MHz for 4G/5G/WLAN communication systems [32]. In this paper, a dual-band 4G LTE/5G NR patch antenna based on L-shaped slots is proposed for n38 (2600 MHz), n48 (3500 MHz), and n78 (3500 MHz) 5G NR bands. These bands are among the most commonly deployed 5G frequency bands due to their common availability.

The paper is structured as follows. Different methods of achieving multi-band performance as well as L-shaped slots are described in the 2nd section. Our design method based on L-shaped slots is presented in the 3rd section, and finally, the simulations and measurements results are summarized and compared in the 4th section. The conclusions are stated at the end.

2- Dual-band Patch Antennas based on L-Shaped Slots

Conventional techniques to achieve dual-band operation are orthogonal modes, multiple patches, and reactive loadings [33]. By using multiple patches, the dual-band operation is achieved through multiple radiating elements [33]. This method does not seem to be a suitable method for our case, since the achieved frequency ratio is practically above 1.5 in most cases, while in our case, the frequency ratio is 3.5/2.6 = 1.346.

Another popular technique for obtaining frequency ratios below (as well as above) 1.5 is introducing reactive loadings such as connecting stubs or introducing additional resonant lengths [33]. Exploiting capacitive and inductive effects through U-shaped or L-shaped slots also results in two resonant frequencies [24-25]. With these L-shaped slots close to the edges, as shown in Fig. 2, widening the L3 gap between slots increases the first resonant frequency, while widening the L1 gap between slots increases the second resonant frequency [24-25].

[1] 3rd Generation Partnership Project
[2] Long-Term Evolution
[3] Non-Standalone
[4] New Radio
[5] International Mobile Telecommunications
[6] International Telecommunication Union (ITU)
[7] Global System for Mobile Communications
[8] Digital Communication System
[9] Universal Mobile Telecommunications Service
[10] Wireless Local-Area Network
[11] Worldwide Interoperability for Microwave Access

Fig. 1. Multi-layer frequency band for NSA 5G NR usage scenarios. 2-6 GHz is mentioned as mid-band in [13].

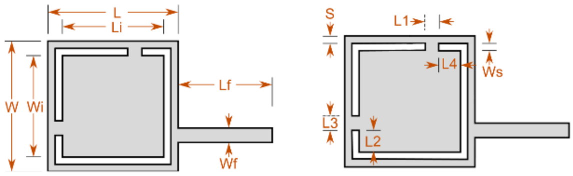

Fig. 2. L-shaped slots close to the edges of the patch to achieve dual-band behavior

Fig. 3. The PTFE Teflon substrate specifications

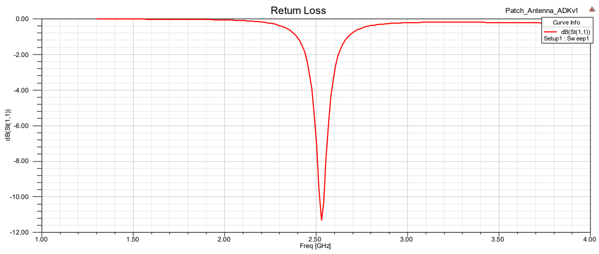

Fig. 4. S11 parameter of the proposed single-band rectangular patch antenna for 2.6 GHz

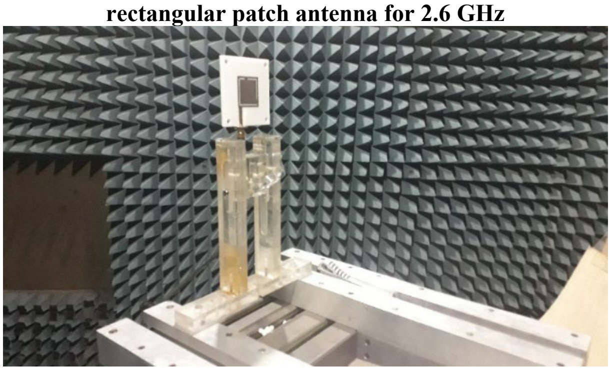

Fig. 5. Radiation pattern measurement of the proposed 4G/5G dual-band antenna

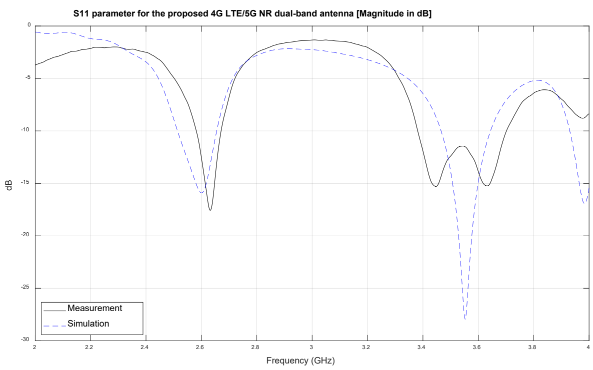

Fig. 6. Comparison of measured S11 with simulation results

TABLE 1. Design parameters (in mm) of the proposed dual-band antenna

Parameter	W_f	L_f	L	L_i	W	W_i	l_{slot1}
Value (mm)	5	16.17	33.43	26.96	33.43	26.96	55
Parameter	l_{slot2}	L_1	L_2	L_3	L_4	W_s	S
Value (mm)	35.88	8	8	0.918	0.026	1.078	2.157

TABLE 2. The electrical length of the proposed antenna compared with some similar works

Paper	Antenna dimensions	Patch dimensions
Ojaroudi et al., 2019	$1.36\lambda_g \times 1.36\lambda_g$	$\mathbf{0.32\lambda_g \times 0.32\lambda_g}$
Manteghi and Rahmat-Samii, 2007	$1.71\lambda_g \times 0.85\lambda_g$	$\mathbf{0.27\lambda_g \times 0.17\lambda_g}$
Ojaroudi et al., 2020	$2.7\lambda_g \times 1.36\lambda_g$	$\mathbf{0.61\lambda_g \times 0.52\lambda_g}$
Our proposed antenna	$0.91\lambda_g \times 0.91\lambda_g$	$\mathbf{0.42\lambda_g \times 0.42\lambda_g}$

TABLE 3. The fractional bandwidth of the proposed antenna compared with others

Paper	First resonance	Second resonance
Ojaroudi et al., 2019	7.69%	**9.59%**
Manteghi and Rahmat-Samii, 2007	4.08%	**3.81%**
Ojaroudi et al., 2020	7.69%	**9.79%**
Our proposed antenna	3.42%	**9.16%**

3- Dual-band Antenna Design Procedures

To build an antenna supporting both 2.6 GHz and 3.5 GHz frequency band for 4G LTE and 5G NR, a rectangular patch antenna with two slots is considered. Since the lower resonant frequency determines the dimensions of the antenna, Ansoft HFSS Antenna Design Kit recommends a 45.61×38.11 mm^2 rectangular patch on top of a PTFE[1] substrate, shown in Fig. 3, with $\varepsilon_r = 2.1$, tand = 2×10^{-4}, and H = 5.14 mm for 2.6 GHz which is fed by a 4.852 mm-thick strip line at the edge.

These dimensions and specifications are in complete agreement with patch design formulas [34]. The S_{11} parameter of such single-band patch antenna is shown in Fig. 4. As seen, the desired resonant frequency of 2.6 GHz has shifted to the left and has a very low 10 dB depth. Since the two L-shaped slots introduce LC resonances [24-25], the resonant frequency of the patch increases and hence, the dual-band patch can be designed in smaller dimensions. The initial length of each slot is half of its corresponding resonance wavelength [24-25]. Hence, the two lengths are initially:

$$l_{slot1} = \lambda_1 / 2 = 57.7\ mm$$
$$l_{slot2} = \lambda_2 / 2 = 42.8\ mm \quad (1)$$

in which λ_1 and λ_2 are resonance wavelengths. As mentioned in Section 2, the width of the gap between slots can control the first and second resonance frequencies. The final dimensions of the proposed dual-band antenna, as shown in Fig. 2, are listed in Table 1.

[1] Polytetrafluoroethylene

4- Results and Discutions

The comparison of S_{11} and radiation pattern measurements, shown in Fig. 5, with simulations results are shown in Figs. 6-8. As Fig. 6 shows, the proposed dual-band antenna has a typical 6 dB bandwidth of 182.545 MHz for 2.6 GHz band and 503.861 MHz for 3.5 GHz band. However, for the strict 10 dB criteria, the bandwidths are 89.5509 MHz and 320.496 MHz, respectively. With a little approximation for 6 dB bandwidth, the 3.5 GHz frequency band can be extended up to more than 4.1 GHz and this increases the bandwidth to more than 700-800 MHz. As Fig. 6 shows, the proposed dual-band antenna has a typical 6 dB bandwidth of 182.545 MHz for 2.6 GHz band and 503.861 MHz for 3.5 GHz band. However, for the strict 10 dB criteria, the bandwidths are 89.5509 MHz and 320.496 MHz, respectively. With a little approximation for 6 dB bandwidth, the 3.5 GHz frequency band can be extended up to more than 4.1 GHz and this increases the bandwidth to more than 700-800 MHz. The electrical equivalent size and the fractional (10 dB) bandwidth of the proposed dual-band antenna is compared with some similar works in Tables 2 and 3, respectively, in which λ_g is the guided-wavelength and takes the different used substrates into account.

As seen in Table 2, our design has a very good specification among other designs, especially for antenna's total dimensions. Also, it can be seen in Table 3 that the second fractional bandwidth is among the best values obtained from other designs. The radiation pattern of the proposed antenna is shown in Figs. 7-8 for the two principal planes. As seen, the proposed antenna has a broad beam and the HPBW (Half-Power Beam Width, also known as 3 dB beam width) is ~80° at both resonances. The comparison of radiation patterns (ignoring the back-lobe radiations) for the proposed dual-band L-shaped slot antenna with (ideal) single-band 2.6 GHz patch antenna is shown in Fig. 9. The similarity of both radiation patterns is very interesting. Fig. 9 shows that, in fact, the two L-shaped slots have not very strong effect on the radiation pattern, but have actually made the single-band patch antenna to work dual-band. The proposed dual-band antenna has 86% and near 90% radiation efficiency, and 83% and 86% total efficiency for 2.6 GHz and 3.5 GHz bands, respectively, as shown in Figs. 10-11. The current densities on the patch are shown in Figs. 12-13. As seen in Fig. 12, the 2.6 GHz current density covers the entire patch, which confirms the initial design procedure of the patch dimensions for 2.6 GHz frequency, and higher values of the current density can be seen around both slots. However, as seen in Fig. 13, the current density reduces dramatically on the patch for 3.5 GHz band, and its higher values focuses mainly around the shorter slot, whose dimensions are exactly calculated for 3.5 GHz resonance. These two figures clearly demonstrate the reason for dual-band behavior of the proposed antenna.

5- Conclusion

In this paper, we demonstrated the dual-band behavior of a rectangular patch antenna with two L-shaped slots placed on top of a PTFE substrate with $\varepsilon_r = 2.1$ for operation in 2.6 GHz and 3.5 GHz, as the two harmonized frequency bands in worldwide. The proposed dual-band antenna has a typical 6 dB bandwidth of 182.545 MHz for 2.6 GHz band and 503.861 MHz for 3.5 GHz band. However, for the strict 10 dB criteria, the bandwidths are 89.5509 MHz and 320.496 MHz, respectively, which fulfill the minimum technical requirements of ITU to meet the IMT-2020 criteria. The proposed antenna has a broad beam and its HPBW is ~80° at both resonances. Comparisons of results show very good agreements between measurements and simulations.

Acknowledgment

The authors would wish to thank Mr. R. Bahri (Head of Radio Communications Group) from ICT Research Institute, Mr. A.A. Faraj-Zadeh from Nasooz Sanat Apadana (http://nsapadana.ir), Mr. M.H. Alighanbari, Mr. Tayyebi from Raad Sanat, Mr. A. Abbasi from Zarrin-Hak (http://www.zarrinhak.com), and Eng. Rezayati and Eng. Akhlagh Pasand from ICT Research Institute for their great help and support of this work, and wish them all the best.

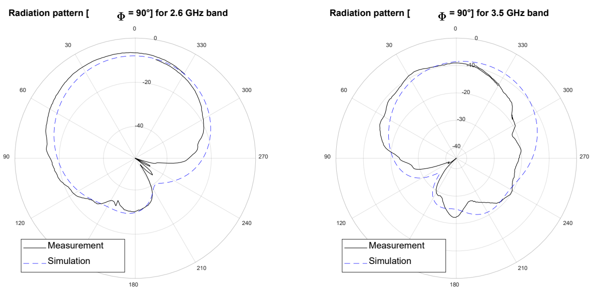

Fig. 7. Comparison of φ = 90° radiation pattern measurements with simulations

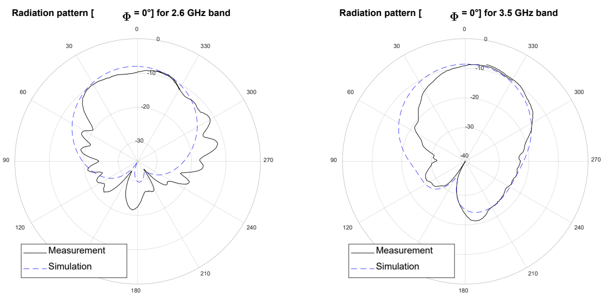

Fig. 8. Comparison of φ = 0° radiation pattern measurements with simulations

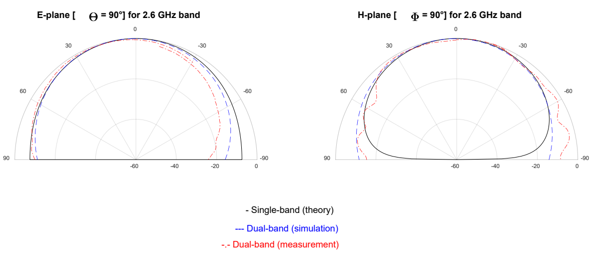

Fig. 9. Comparison of radiation patterns (ignoring the back-lobe radiations) for the proposed dual-band L-shaped slot antenna with (ideal) single-band patch antenna

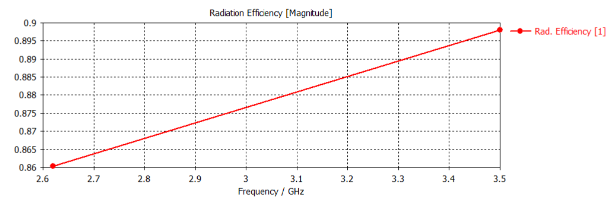

Fig. 10. Radiation efficiencies for the proposed dual-band antenna

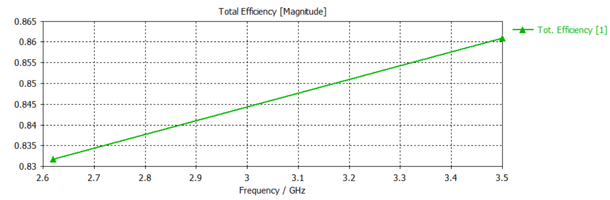

Fig. 11. Total efficiencies for the proposed dual-band antenna

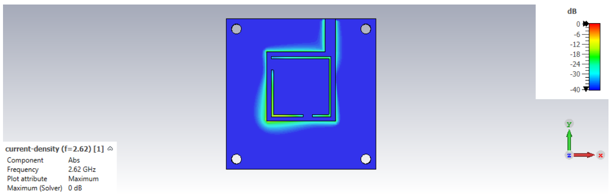

Fig. 12. Current density (calculated for maximum field amplitude) for 2.6 GHz band

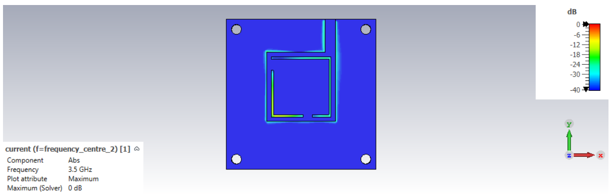

Fig. 13. Current density (calculated for maximum field amplitude) for 3.5 GHz band

References

[1] GSMA. (2023). The Mobile Economy 2023. London, UK. https://www.gsma.com/mobileeconomy/wpcontent/uploads/2023/03/270223-The-Mobile-Economy-2023.pdf

[2] GSMA. (2023). GSM Association: https://www.gsmaintelligence.com/data/

[3] 5G Americas. (2021). 3GPP Releases 16 & 17 and beyond. Bellevue, Washington. USA. https://www.5gamericas.org/wp-content/uploads/2021/01/InDesign-3GPP-Rel-16-17-2021.pdf

[4] Cisco. (2020). Cisco Annual Internet Report (2018–2023) White Paper. San Jose, California, USA. https://www.cisco.com/c/en/us/solutions/collateral/executive-perspectives/annual-internet-report/white-paper-c11-741490.pdf

[5] Ericsson. (2018). The 5G consumer business case: Revision A. Stockholm, Sweden.

[6] 5G Americas. (2017). LTE to 5G: Cellular and Broadband Innovation. Bellevue, Washington. USA. http://www.5gamericas .org/wpcontent/uploads/2019/07/2017_5G_Americas_Rysavy_LTE_5G_Innovation__Final_for_Upload_v2.pdf

[7] 5G Americas. (2018). LTE to 5G: The Global Impact of Wireless Innovation. Bellevue, Washington. USA. http://www.5gamericas.org/wpcontent/uploads/2019/07/2018_5G_Americas_Rysavy_LTE_to_5G_The_Global_Impact_of_Wireless_Innovation_final.pdf

[8] GSMA. (2022). 5G Spectrum Positions Offer a Roadmap for Regulators. London, England, UK. https://www.gsma.com/spectrum/wp-content/uploads/2022/07/5G-Spectrum-Positions.pdf

[9] Nokia. (2017). 5G deployment below 6 GHz: Ubiquitous coverage for critical communication and massive IoT. Espoo, Finland.

[10] GSMA. (2019). The 5G Guide: A Reference for Operators. London, England, UK. https://www.gsma.com/wp-content/uploads/2019/04/The-5G-Guide_ GSMA_2019_04_29_compressed.pdf

[11] Huawei. (2020). 5G Spectrum: Public Policy Position. Shenzhen, Guangdong, China. https://www-file.huawei.com/-/media/corporate/pdf/publicpolicy/public_policy_position_5g_spectrum_2020_v2.pdf?la=en

[12] ITU. (2015). Recommendation ITU-R M.2083-0: IMT Vision – Framework and overall objectives of the future development of IMT for 2020 and beyond. United Nations Economic and Social Council. Geneva, Switzerland. https://www.itu.int/dms_pubrec/itu-r/rec/m/R-REC-M.2083-0-201509-I!!PDF-E.pdf

[13] Huawei. (2019). New 5G, New Antenna. Shenzhen, Guangdong, China. https://carrier.huawei.com/~/media/CNBGV2/download/products/antenna/New-5G-New-Antenna-5G-Antenna-White-Paper-v2.pdf

[14] GSMA. (2021). 3.5 GHz in the 5G Era: Preparing for New Services in 3.3-4.2 GHz. London, England, UK. https://www.gsma.com/spectrum/wp-content/uploads/2021/02/3.5-GHz-for-5G.pdf

[15] ITU. (2015). Final Acts WRC-15. United Nations Economic and Social Council. Geneva, Switzerland. https://www.itu.int/dms_pub/itu-r/opb/act/R-ACT-WRC.12-2015-PDF-E.pdf

[16] GSMA. (2021). WRC-23 IMT Agenda Items Overview. London, England, UK. https://www.gsma.com/spectrum/wp-content/uploads/2021/03/WRC-23-IMT-Agenda-Item Overview -Map.pdf

[17] ITU. (2019). Resolution 811 (WRC-19): Agenda for the 2023 world radiocommunication conference. United Nations Economic and Social Council. Geneva, Switzerland. https://www.itu.int/dms_pub/itur/oth/0c/0a/R0C0A00000D0041PDFE.pdf

[18] GSMA. (2020). Roadmaps for awarding 5G spectrum in the MENA region. London, England, UK . https://www.gsma.com/spectrum/wp-content/uploads/2020/10/Roadmaps-for-awarding-5G-spectrum-in-the-MENA-region.pdf

[19] M. Farias *et al.*, "2.4–5.8 GHz dual-band patch antenna with FSS reflector for radiation parameters enhancement," *AEÜ. International journal of electronics and communications*, vol. 108, pp. 235–241, Aug. 2019, doi: https://doi.org/10.1016/j.aeue.2019.06.021.

[20] W. . Kwak, S. . Park, and J. . Kim, "A Folded Planar Inverted-F Antenna for GSM/DCS/Bluetooth Triple-Band Application," *IEEE Antennas and Wireless Propagation Letters*, vol. 5, no. 1, pp. 18–21, Dec. 2006, doi: https://doi.org/10.1109/lawp.2005.863617.

[21] M. Manteghi and Y. Rahmat-Samii, "A novel miniaturized triband PIFA for MIMO applications," *Microwave and Optical Technology Letters*, vol. 49, no. 3, pp. 724–731, Jan. 2007, doi: https://doi.org/10.1002/mop.22239.

[22] N. Ojaroudi, N. Ghadimi, Y. Ojaroudi, and S. Ojaroudi, "An omnidirectional PIFA for downlink and uplink satellite applications in C-band," *Microwave and optical technology letters*, vol. 56, no. 11, pp. 2684–2686, Aug. 2014, doi: https://doi.org/10.1002/mop.28672.

[23] A. Abdelaziz and E. K. I. Hamad, "Design of a Compact High Gain Microstrip Patch Antenna for Tri-Band 5 G Wireless Communication," *Frequenz*, vol. 73, no. 1–2, pp. 45–52, Jan. 2019, doi: https://doi.org/10.1515/freq-2018-0058.

[24] Hanieh Aliakbari, Abdolali Abdipour, Rashid Mirzavand, A. Costanzo, and P. Mousavi, "A single feed dual-band circularly polarized millimeter-wave antenna for 5G communication," Apr. 2016, doi: https://doi.org/10.1109/eucap.2016.7481318.

[25] El Shorbagy, M., Shubair, R. M., AlHajri, M. I., & Mallat, N. K. (2016, November). On the design of millimetre-wave antennas for 5G. In *2016 16th Mediterranean Microwave Symposium (MMS)* (pp. 1-4). IEEE. DOI: 10.1109/ MMS.2016.7803878

[26] O. M. Haraz, M. A. Ali, Ayman Elboushi, and Abdel-Razik Sebak, "Four-element dual-band printed slot antenna array for the future 5G mobile communication networks," Jul. 2015, doi: https://doi.org/10.1109/aps.2015.7304386.

[27] H. M. Marzouk, M. I. Ahmed, and A.-E. H. Shaalan, "NOVEL DUAL-BAND 28/38 GHZ MIMO ANTENNAS FOR 5G MOBILE APPLICATIONS," *Progress In Electromagnetics Research C*, vol. 93, pp. 103–117, 2019, doi: https://doi.org/10.2528/pierc19032303.

[28] Marzouk, H. M., Ahmed, M. I., & Shaalan, A. H. A. (2019). Novel dual-band 28/38 GHz MIMO antennas for 5G mobile applications. *Progress In Electromagnetics Research C*, *93*, 103-117.. DOI: 10.1109/APUSNCURSINRSM.2019.8888799

[29] M. H. Sharaf, A. I. Zaki, R. K. Hamad, and M. M. M. Omar, "A Novel Dual-Band (38/60 GHz) Patch Antenna for 5G Mobile Handsets," *Sensors*, vol. 20, no. 9, p. 2541, Apr. 2020, doi: https://doi.org/10.3390/s20092541.

[30] N. Ojaroudi Parchin, H. Jahanbakhsh Basherlou, Y. I. A. Al-Yasir, A. Ullah, R. A. Abd-Alhameed, and J. M. Noras, "Multi-Band MIMO Antenna Design with User-Impact Investigation for 4G and 5G Mobile Terminals," *Sensors*, vol. 19, no. 3, p. 456, Jan. 2019, doi: https://doi.org/10.3390/s19030456.

[31] N. Ojaroudi Parchin, H. Jahanbakhsh Basherlou, and R. A. Abd-Alhameed, "Design of Multi-Mode Antenna Array for Use in Next-Generation Mobile Handsets," *Sensors*, vol. 20, no. 9, p. 2447, Apr. 2020, doi: https://doi.org/10.3390/s20092447.

[32] M. Yang, Y. Sun, and F. Li, "A Compact Wideband Printed Antenna for 4G/5G/WLAN Wireless Applications," *International Journal of Antennas and Propagation*, vol. 2019, p. e3209840, Sep. 2019, doi: https://doi.org/10.1155/2019/3209840.

[33] J. C. Saturday, K. M. Udofia, and A. J. Jimoh, "Design of Dual Band Microstrip Antenna Using Reactive Loading Technique," *DOAJ (DOAJ: Directory of Open Access Journals)*, Oct. 2016.

[34] Balanis, C. A. (2016). *Antenna theory: analysis and design*. John wiley & sons.

PARSAN - 2469

Amir Rezagholi was born in Shiraz, Fars, Iran, in 1988, and received his B.S. degree in Electrical Engineering, M.Sc. degree in Fields Communication Engineering, and PhD degree in Fields Communication Engineering in 2011, 2013, and 2020, respectively, all from Shiraz University, Shiraz, Iran. He has published several technical papers and proceeding articles, and his research interests include mobile technologies, fractal antennas, optimization algorithms, plasma applications in microwave and antenna design, and artificial intelligence (AI).

Hossein Zargar was born in Khoor, Isfahan, Iran, in 1985. He received the B.E. degree from Iran University of Science and Technology, Tehran, Iran, in 2007, and the M.E. degree from Tehran University, Tehran, Iran, in 2010, Ph.D. degree from Sharif University, Tehran, Iran in 2015 all in electrical engineering. Since 2019, he has been a member of the faculty with the IRAN Telecommunication Research Center (ITRC). His main interests include power amplifier behavioral modeling and microwave circuits design, mixed-signal circuit design and new radio technology development.

Iran Sarafraz was born in Shoosh, Khuzestan, Iran, in 1983, and received her B.S. degree from Islamic Azad University, Dezfoul Branch, Dezfoul, Iran, in Electrical Engineering and her M.Sc. degree from Islamic Azad University, Shiraz Branch, Shiraz, Iran, in System Communication Engineering, in 2006 and 2016, respectively. She is now a PhD candidate in System Communication Engineering in Islamic Azad University, Shiraz Branch, Shiraz, Iran, and her research interests include mobile technologies, image processing, sound processing, and artificial intelligence (AI).

Islamic Azad University , Shiraz Branch
نشریه تحلیل مدارها، داده ها و سامانه ها
Journal of Circuits, Data and Systems Analysis
sanad.iau.ir/journal/jcdsa

طراحی و تست آنتن دو بانده 4G/5G برای باندهای فرکانسی ۲/۶ GHz و ۳/۵ GHz

امیر رضاقلی*[۱]، حسین زرگر[۲]، ایران سرافراز[۳]

۱- استادیار، بخش مهندسی برق، دانشکده فنی و مهندسی، موسسه آموزش عالی زند شیراز، شیراز، ایران (amir.rezagholi@shirazu.ac.ir)
۲- استادیار، گروه ارتباطات رادیویی، پژوهشگاه ارتباطات و فناوری اطلاعات، تهران، ایران (h.zargar@itrc.ac.ir)
۳- دانشجوی دکتری، گروه مهندسی برق، واحد شیراز، دانشگاه آزاد اسلامی، شیراز، ایران (ideh.sarafraz@gmail.com)

چکیده: نسل پنجم شبکه تلفن‌های همراه (5G NR) با تکیه بر نسل چهارم (4G LTE) خود، پایه و اساس پهنای باند بهبودیافته شامل ظرفیت بیشتر برای کاربران بی‌سیم، لینک‌های بهبود یافته بین کاربران (زمان تأخیر و تلفات کمتر) و افزایش نرخ داده را برقرار می‌نماید. باندهای n38 (۲۶۰۰ مگاهرتز)، n48 (۳۵۰۰ مگاهرتز) و n78 (۳۵۰۰ مگاهرتز) به دلیل در دسترس بودن نسبتاً متداول، از رایج‌ترین باندهای فرکانسی 5G تست شده و مستقر می‌باشند. آنتن‌های دو یا چند بانده از الزامات اصلی همزیستی 5G با 4G هستند. از آنجایی که شکاف‌ها، آنتن‌های پچ را کوچک‌تر و کم‌هزینه‌تر می‌کنند، آنتن‌های پچ شکاف‌دار برای استفاده در کاربردهای دو یا چند بانده 4G/5G بسیار جذاب می‌باشند. در این مقاله، یک آنتن پچ شکاف‌دار دو بانده برای باندهای فرکانسی ۲/۶ گیگاهرتز (برای هر دو4G LTE و 5G NR) و ۳/۵ گیگاهرتز (برای 5G NR) ارائه و پیشنهاد شده و عملکرد آن به صورت تجربی با موفقیت بررسی و تأیید شده است. توافق بسیار خوبی بین شبیه‌سازی ها و نتایج تجربی مشاهده می‌شود.

واژه های کلیدی: 4G LTE، 5G NR، آنتن چندبانده، آنتن پچ، شکاف.

* نویسنده مسئول