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REGULAR ARTICLE

Compact Broadband Microstrip Patch Antenna for 5G Communication Applications

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Recently, the Microstrip Patch Antenna (MPA) has gained prominence in different wireless communication systems as well as in 5G communication. Despite various advantages, a primary disadvantage of MPA that limits its applications is its low bandwidth. This research implements a broadband antenna with satisfactory gain by utilizing a shortened ground plane and incorporating several slots in the radiating plane. In order to achieve numerous frequency bands, slots are added to the patch. The dimensions of the slots are selected to allow for the staggering effect of the closely spaced frequency bands, which results in broadband properties. To ensure appropriate impedance matching, the ground plane is altered. The suggested antenna provides a wide impedance bandwidth of 4 GHz (3-7 GHz) with a fractional bandwidth of 80 %, resonating at 3.6 and 5.5 GHz. Within this frequency range, the proposed antenna exhibits a peak gain between 2.2 and 3.2 dBi, alongside a maximum radiation efficiency of 90 %. Additionally, adequate co-polarization and cross-polarization separation are attained in all directions for the proposed antenna. The exhibited broadband antenna features a symmetrical radiation pattern. The designed antenna is compact and lightweight, exhibits consistent gain, and is compatible with wireless system equipment. The antenna is designed on a 1.542 mm-thick Rogers RO473G3 dielectric substrate, featuring a loss tangent of 0.0022 and a relative permittivity of 3. The proposed antenna is suitable for n77, n78, and n79 5G communication applications since it is part of UWB wireless technology, characterized by its broadband capabilities, high radiation efficiency, and satisfactory radiation pattern. The proposed antenna is developed, optimized, and simulated with Computer Simulation Technology's (CST) Microwave Studio Suite software.

Keywords: Broadband, Microstrip patch antenna, Rogers RO473G3, Slot.

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1. INTRODUCTION

We are surrounded by a wide variety of digital devices in the current world. These could include computing, portable, and consumer electronics equipment. These gadgets are frequently connected with one another via wireless communication. Due to the overlapping of digital devices, high data rate common technology is needed. Due to bandwidth limitations in narrowband systems, the ratio of the intended signal power to the undesired signal intensity primarily determines the channel capacity. However, channel capacity improves slightly with a large shift in the signal-to-noise ratio (SNR) because of the logarithm relationship. Additionally, increasing signal power is impractical for the majority of digital devices. Under these conditions, broadband, wideband, super wideband or ultra-wideband (UWB) technology seems like a promising solution that can handle large channel capacity. These factors make the aforementioned technologies useful for wireless communication, positioning systems, networking, radar, imaging, and other applications. Therefore, it is reasonable to anticipate that these technologies will be used more and more in computing devices, medical equipment, smartphones, internet of Things (IoT) peripherals, and other contemporary gadgets. Printed planar antennas (PPAs) are extensively utilized in contemporary communication systems due to their numerous advantages, including compact dimensions, lightweight construction, and compatibility with a broad spectrum of resonant frequencies. However, its modest gain and narrow impedance bandwidth limit its utility to a few diverse wireless applications. Short pulses cannot be transmitted throughout the wider frequency range by narrowband antennas. Because broadband technology uses a wide range of frequencies, it has become more popular in recent years [1]. Researchers are exploring many diverse techniques to improve bandwidth and gain to a large extent. These include applying various feeding techniques – dual, multiple, and other – using parasitic patches, applying various dielectric substrates, applying metamaterials, increasing the width of the substrate

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material utilizing air gap procedures, using modified ground structures, slots loading in both patch and ground planes, changing current path course and many more. Additionally, open slot and stub impedance matching techniques are employed to enhance bandwidth while ensuring appropriate impedance matching. Another way to generate a broad bandwidth is to load slot stubs which will eventually upset the resonant modes of the antenna. Utilizing a log periodic array of patches, variously shaped patches (such as E, Diamond, etc.), and traditional patches with various shaped slots are some other well-liked techniques for increasing bandwidth. By adding new modes in between desired modes or by linking desired modes together, these slots aid in achieving huge bandwidth [2]. The use of hybrid structures both in patch and ground planes is another method for achieving large impedance bandwidth [3-5].Occasionally, a multiband antenna that has each band separated by a suitable wavelength to minimize interference between them can handle a wide bandwidth. However, this kind of antenna's impedance fluctuates too much, making it difficult for the transmitter and receiver to provide energy without losses [6-7]. Therefore, for better impedance matching and enhanced energy transmission, matching devices using lumped elements, tapered lines, stubs, transformers, and other devices can be used [8]. Broadband functioning is achieved by efficiently modifying the feeding structure discussed in [9-11]. In [12-15] authors have used conventional equations for designing reference antennas and new resonant frequencies are produced by loading conventional and curved slots on the patch by disrupting the surface current flow. Close frequency bands are achieved with the right slot length. Ground plane slot loading and feedline modification improved impedance matching by combining nearby frequency bands to provide wideband characteristics as a result of the staggering effect. For upcoming mobile applications, T. Goel and A. Patnaik in [16-17] propose compact planar broadband antennas based on windmill-like form. The suggested antennas' asymmetrical construction causes them to radiate in a boresight direction, whilst their antipodal structure offers wideband behavior. In [18-19] design of a small, wideband, rectangular-printed, partly slotted ground antenna is designed. The design method that makes use of the slotted partial ground plane is far more adaptable in terms of enhancing the antenna performance.

This article discusses a rectangular shaped printed radiator with a slot-loaded patch and a reduced finite ground plane fed by a microstrip line. The presented antenna has consistent gain and efficiency with a broad bandwidth of 4 GHz (3-7 GHz). Due to broadband characteristics, high efficiency, acceptable gain, and stable spatial distribution of radiation, the presented antenna can be utilized for a number of UWB applications as well as 5G wireless communications on n77, n78, and n79 networks.

2. REFERENCE AND PROPOSED ANTENNA

The original reference antenna design was primarily for Wi-Fi 6E devices operating in the standard 6 GHz frequency band. A 1.542 mm thick Rogers RO473G3 substrate with a relative dielectric constant (ε_r)of 3 is used for the antenna that is being described. Therefore, using the standard equation [20] (1), where c represents the velocity of light, the width of the patch (W_P) at a resonant frequency (f_r)of 6 GHz can be determined using the Equation (1)

$$W_P = \frac{c*\sqrt{2}}{2*f_r*\sqrt{1+\varepsilon_r}} \quad (1)$$

Equation (2) is used to get the patch's effective dielectric constant.

$$\varepsilon_{reff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2} * [1 + 12 * \frac{h}{W_P}]^{-\frac{1}{2}} \quad (2)$$

Equation (3) determines the patch's extended incremental length, ΔL.

$$\Delta L = 0.412 * h * \frac{(\varepsilon_{reff}+0.3)*(\frac{W_P}{h}+0.264)}{(\varepsilon_{reff} - 0.258)*(\frac{W_P}{h}+0.8)} \quad (3)$$

Equation (4) determines the patch's actual length.

$$L = \frac{c}{2*f_r*\sqrt{\varepsilon_{reff}}} - 2\Delta L \quad (4)$$

And the effective length is given by (5)

$$L_{eff} = L + 2\Delta L \quad (5)$$

The dimensions of the radiator corresponding to a resonant frequency (f_r)of 6 GHz are 17.678 mm (W_P) and 13.728 mm (L_P), respectively. The initial reference antenna's radiating patch and ground plane layout, as well as its measurements (mm), are depicted in Fig. 1. First, a 28 mm × 35.6 mm × 1.542 mm substrate is used as a reference. A radiating patch in the shape of a rectangle is created on top of the substrate.

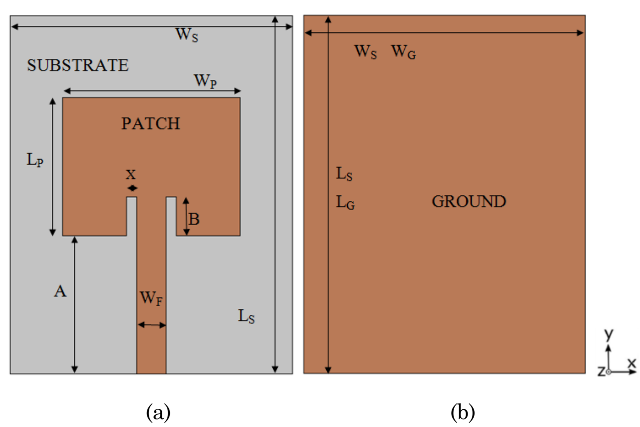


Fig. 1 – Reference antenna: (a) Radiating plane (b) View of ground plane

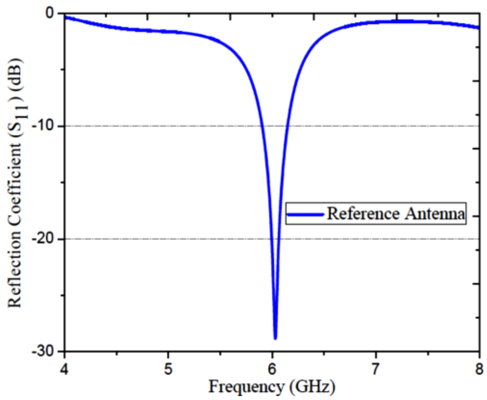
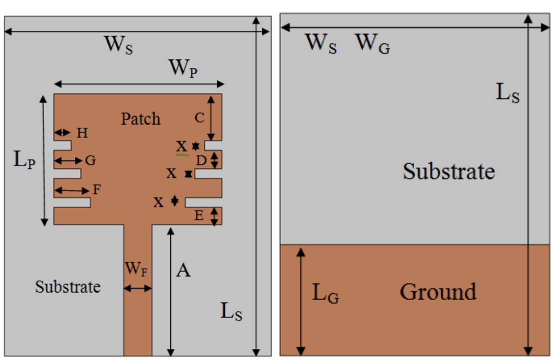


Fig. 2 – Reflection Coefficient (S_{11}) of Reference antenna

Fig. 2 illustrates the S_{11} (dB) of the reference antenna which resonates at 6.06 GHz. Fig. 3 shows the proposed antenna configuration and Table 1 tabulates dimensions of all design parameters. In order to produce numerous frequency bands, slots are added to the patch. The size of the slots is adjusted to allow for the achievement of broadband characteristics because of the staggering effect of the closely spaced frequency bands. For appropriate impedance matching, a finite ground plane has been employed. The patch's slot dimensions are first constructed with the present line length in mind, then optimization is carried out by a thorough parametric analysis. To operate the antenna for wideband applications, variables like length, the width of slots, number of slots, and slot location on the intended geometry are optimized through a rigorous parametric study.



(a) (b)

Fig. 3 – Proposed antenna. (a) Propounded patch (b) Partial Ground plane (PGP)

Table 1 – Design parameters with optimal measurements in mm

Parameter	Dimension	Parameter	Dimension
L_S	35.6	C	4.864
L_G	35.6	D	2
W_S, W_G	28	E	1.864
W_F	3	F	4
L_P	13.728	G	3
W_P	17.678	H	2
A	13.728	X	1

3. ANTENNA RESULTS AND DISCUSSIONS

The CST MWS program has been implied to run all of the simulations on the reference and presented antennas. Figure 4 displays the suggested antenna's computed reflection coefficient, S_{11}. An expansive impedance bandwidth of 4 GHz (ranging from 3 to 7 GHz) and an 80 % fractional bandwidth are features of the antenna that is being showcased.

Fractional bandwidth has been calculated from the obtained result.

$$\%\ \text{Bandwidth} = \left(\frac{(F_H - F_L)}{F_C} \times 100\right)\%$$

Where the symbols (F_H, F_L, and F_C) signify their usual meanings

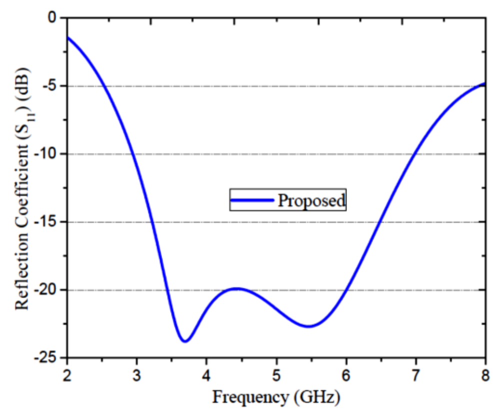


Fig. 4 – S_{11} parameter in dB for the prescribed antenna

Fig. 5 illustrates the peak gain (dBi) and efficiency of the recommended radiator. Efficiency is greater than 90 % and peak gain ranges from 2.2 to 3.2 dBi across the whole frequency range of 3 to 7 GHz.

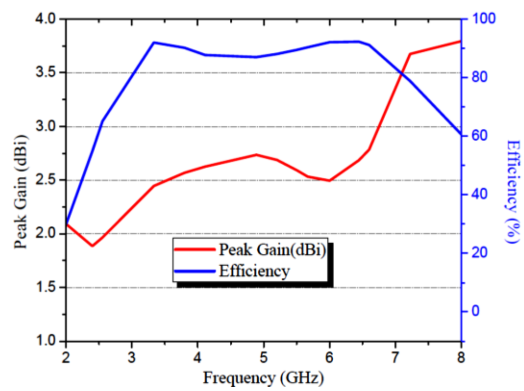
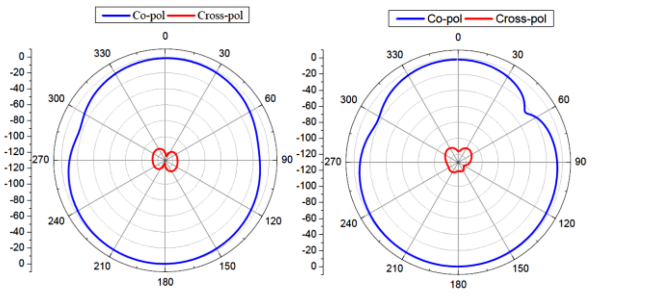


Fig. 5 – Efficiency (%) and peak gain of the proposed antenna

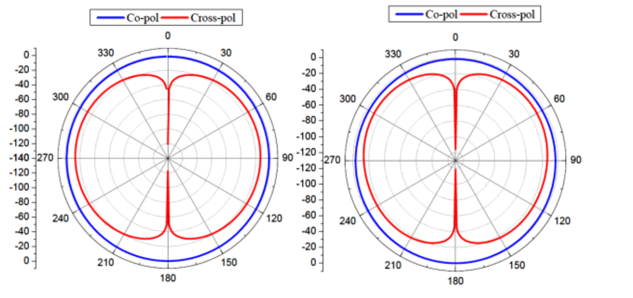
The antenna's normalized simulated radiation pattern is displayed in Figures 6 and 7 for the E and H planes at 3.6 and 5.5 GHz resonant frequencies, respectively. Co-pol is greater than cross-pol in all the directions with sufficient separation.

At the resonance frequencies of 3.6 and 5.5 GHz, Fig. 8 displays the 3D polar gain graphs.



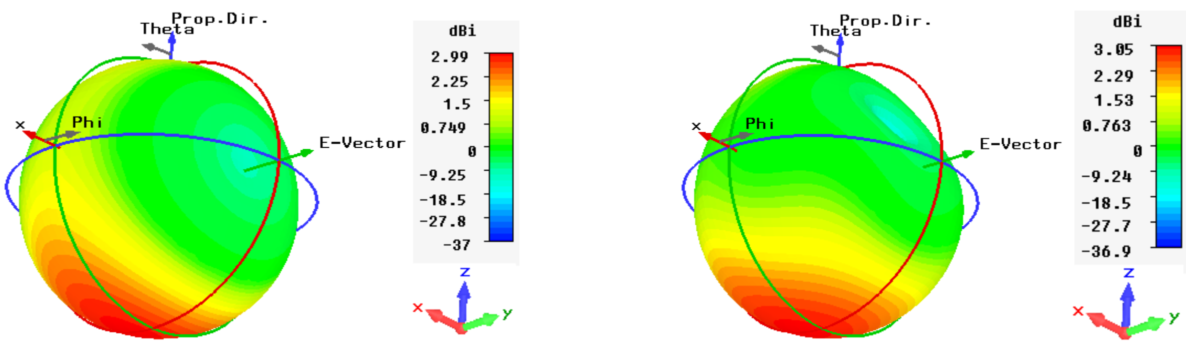
(a) (b)

Fig. 6 – Radiation patterns (*E*-plane) at (a) 3.6 and (b) 5.5 GHz



(a) (b)

Fig. 7 – Radiation patterns (*H*-plane) at (a) 3.6 and (b) 5.5 GHz



(a) (b)

Fig. 8 – 3D polar gain plots at (a) 3.6 GHz (b) 5.5 GHz

4. CONCLUSION

For wireless communication applications, a low-profile, broadband rectangular MPA with a reduced finite length ground plane and slot-loaded radiating patch is presented in this paper. The suggested antenna exhibits broadband characteristics (3-7 GHz) with 80 % percentage bandwidth. Throughout the entire operating band, it exhibits consistent gain, high efficiency, and stable spatial distribution of radiationwith enough co-pol and cross-pol component separation. The proposed antenna is an appropriate choice for NR n77, n78, and n79 5G communication applications, part of UWB wireless application due to its low profile structure, high radiation efficiency, and acceptable radiation pattern.

REFERENCES

1. O.P. Kumar, P. Kumar, T. Ali, P. Kumar, S. Vincent, *Micromachines* **14**, 5 (2023).
2. S.A.R. Parizi, *Bandwidth Enhancement Techniques. Microstrip Antennas: Trends in Research* (2017)
3. W. Yibo, W. Shuyue, Z. Jinju, *AEU – Int. J. Electron. Commun.* **127**, 153475 (2020).
4. T. Tewary, S. Maity, A. Mukherjee, A. Roy, S. Bhunia, *J. Nano- Electron. Phys.* **15** No 3, 03015 (2023).
5. V. Dhasarathan, T. Nguyen, M. Sharma, et al., *Wireless Netw.* **26**, 4287 (2020).
6. S. Bhunia, K. Guha, T. Tewary, *J. Nano- Electron. Phys.* **16** No 4, 04017 (2024).
7. S. Mukherjee, A. Roy, S. Maity ,T. Tewary, P. P. Sarkar, S. Bhunia, *Int. J. Microwave Wireless Technol.* **15** No 3, 526 (2023).
8. S. Mukherjee, A. Roy, S. Maity, T. Tewary, K. Dutta, S. Bhunia, *Int. J. Commun. Syst.* **36**, e5565 (2023).
9. S. Sharma, C. C. Tripathi, R. Rishi, *Indian J. Sci. Technol.* **10** No 28 (2017).
10. J. Liu, S. Zhong, K. P. Esselle, *IEEE Trans. Antennas Propag.* **59** No 2, 667 (2011).
11. T. Tewary, S. Maity, S. Mukherjee, A. Roy, P. P. Sarkar, S. Bhunia, *AEU – Int. J. Electron. Commun.* **139**, 153905 (2021).
12. T. Tewary, S. Maity, S. Mukherjee, A. Roy, P. P. Sarkar, S. Bhunia, *AEU – Int. J. Electron. Commun.* **158**, 154465 (2023).
13. S. Maity, T. Tewary, S. Mukherjee, A. Roy, P.P. Sarkar, S. Bhunia, *Int. J. Commun. Syst.* **35** No 14, e5268 (2022).
14. T. Tewary, S. Maity, A. Roy, and S. Bhunia, *J. Microwave. Optoelectron. Electromagn. Appl.* **22** No 2, 329 (2023).
15. T. Tewary, S. Maity, A. Roy, K. Mandal, S. Kundu, S. Bhunia, *Int. J. Commun. Syst.* **37** No 8, e5754 (2024).
16. R.V. Gatti, R. Rossi, M. Dionigi, *Electronics* **10** No 3, 264 (2021).
17. T. Goel, A. Patnaik, *IEEE Trans. Antennas Propag.* **66** No 5, 2299 (2018).
18. P. Kumar, G. Singh, *Smart Systems and IoT: Innovations in Computing. Smart Innovation, Systems and Technologies*, 141 (2020).
19. A. Kapoor, R. Mishra, P. Kumar, *Int. J. Smart Sens. Intel. Syst.* **13** No 1, 1 (2020)
20. C.A. Balanis, *Antenna Theory, Analysis and Design, 4th Edition* (Wiley: 2016).

Компактна широкосмугова мікросмужкова патч-антена для 5G-зв'язку

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Останнім часом мікросмужкова патч-антена (MPA) набула популярності в різних системах бездротового зв'язку, а також у зв'язку 5G. Незважаючи на різні переваги, основним недоліком MPA, який обмежує її застосування, є низька пропускна здатність. У даному дослідженні реалізовано широкосмугову антену із задовільним коефіцієнтом посилення, використовуючи скорочену заземлювальну площину та додавши кілька слотів у випромінювальну площину. Для досягнення численних частотних смуг до патча додаються слоти. Розміри слотів вибрані таким чином, щоб враховувати ефект коливання близько розташованих частотних смуг, що призводить до широкосмугових властивостей. Для забезпечення належного узгодження імпедансу заземлювальну площину змінено. Запропонована антена забезпечує широку смугу пропускання імпедансу 4 ГГц (3-7 ГГц) з частковою смугою пропускання 80 %, резонуючи на частотах 3,6 та 5,5 ГГц. У цьому діапазоні частот запропонована антена демонструє піковий коефіцієнт посилення від 2,2 до 3,2 дБі, а також максимальну ефективність випромінювання 90 %. Крім того, для запропонованої антени досягається адекватне розділення кополяризації та крос-поляризації у всіх напрямках. Представлена широкосмугова антена має симетричну діаграму спрямованості. Розроблена антена є компактною та легкою, демонструє стабільний коефіцієнт посилення та сумісна з обладнанням бездротових систем. Антена сконструйована на діелектричній підкладці Rogers RO473G3 товщиною 1,542 мм, що має тангенс кута втрат 0,0022 та відносну діелектричну проникність 3. Запропонована антена підходить для застосувань зв'язку 5G n77, n78 та n79, оскільки вона є частиною бездротової технології UWB, що характеризується своїми широкосмуговими можливостями, високою ефективністю випромінювання та задовільною діаграмою спрямованості. Антена розроблена, оптимізована та змодельована за допомогою програмного забезпечення Microwave Studio Suite від Computer Simulation Technology (CST).

Ключові слова: Широкосмуговий зв'язок, Мікросмужкова патч-антена, Rogers RO473G3, Слот.