A Compact Flexible Antennas for ISM and 5G Sub-6-GHz band Application

Wahaj Abbas Awan[1], Niamat Hussain[2], Adnan Ghaffar[3], Abir Zaidi[4],Xue Jun Li[3]
[1]Department of Electrical and Computer Engineering, COMSATS University Islamabad, Sahiwal, Pakistan
wahajabbasawan@gmail.com
[2]Department of Computer and Communication Engineering, Chungbuk National University, Republic of Korea
hussain@osp.chungbuk.ac.kr
[3]Department of Electrical and Electronic Engineering, Auckland University of Technology, Auckland 1010, New Zealand
{aghaffar[3]; xuejun.li[5]}@aut.ac.nz
[4]Department of Electrical Engineering Laboratory EEA & TI, Hassan II University, Faculty of Science and Techniques (FSTM)
Mohammedia Casablanca, Morocco

***Abstract*—The design and realization of a flexible broadband coplanar waveguide (CPW) fed patch antenna, characterized by a compact size are presented in this manuscript. The proposed antenna is dedicated for Industrial Scientific and Medical (ISM) as well as 5G sub-6-GHz band, particularly at the frequency of 3.5 GHz. The design of antenna is evolved from a traditional rectangular patch antenna, where stubs are used to improve antenna's bandwidth. The antenna shows good results compared to related works in the same domain. The good results of proposed work with state of the art work in terms of bandwidth, impedance matching, and radiation patterns demonstrates the potential of the proposed antenna for ISM and 5G applications**

Index Terms—*Flexible antenna, CPW, broadband antenna, compact size antenna.*

I. Introduction

The demand for flexible devices is exponentially increasing due to numerous advantages including reduced weight, durability, and low power consumption. Moreover, modern day technologies including Internet of Thing (IoT) and 5th generation of communication also known as 5G requires high data rate transmission [1–2].

Co-planar waveguide (CPW) fed antennas are well known due to their compactness and stable gain while maintaining broad bandwidth as compared to other types of antenna, therefore, widely used in modern communication systems.

Researchers have proposed many kinds of antennas for 2.45 GHz Industrial Scientific and Medical (ISM) band and 3.5 GHz 5G sub-6-GHz band [3–11]. Although the works presented in [3–7] provides excellent radiation characteristics have resonance at just single band of ISM. In [8], a stub loaded fractal antenna was proposed for 2.45 GHz band; the antenna is characterized by compact size as well as a wide bandwidth of approximately 444 MHz. In [9–11], dual band rigid antennas were proposed for ISM band application. A CPW-fed double inverted triangular geometry was used in [9] to achieve a miniaturized antenna along with broad bandwidth of 330 MHz. However, the antenna presented in [10–11] not only have drawback of rigid structure but they had deficiency of very narrow bandwidth. Moreover, all of these antennas only work at a single ISM band.

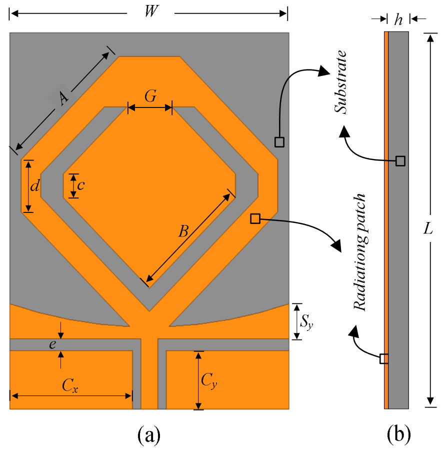


Fig. 1. Geometery of proposed antenna for ISM and 5G sub-6-GHz band: (a) Front view and (b) side view

On the other hand, frequency switchable flexible antennas operating in sub-6-GHz band spectrum were presented for multiband operation [12–13]. In [12], a CPW-fed T-shaped antenna is proposed. The presented antenna in this paper is operating at dual-bands of 2.36 GHz and 3.64 GHz, with respective impedance bandwidth of 180 MHz and 270 MHz, while in [13], a split-ring CPW-fed antenna is proposed to operate at dual bands of 2.6 GHz and 3.48 GHz with respective bandwidth of 100 MHz and 330 MHz. Although dual band antennas having the advantages of flexibility have been realized in these designs, however, they suffer from a narrow band especially in the lower resonance, besides having other drawbacks such as its larger size, disqualifying them to be used in modern compact devices.

We can infer from aforementioned discussion that a broadband flexible antenna with stable gain and compact size is still a need of the time. Therefore, stub loaded CPW fed flexible and compact antenna is proposed for future 5G and ISM band applications. The antenna geometry includes an octagonal patch, extracted from conventional rectangular antenna by truncating all ends, while stubs were utilized to enhance the bandwidth of the antenna. Furthermore, slots in radiator are employed to lower the resonance in order to reach

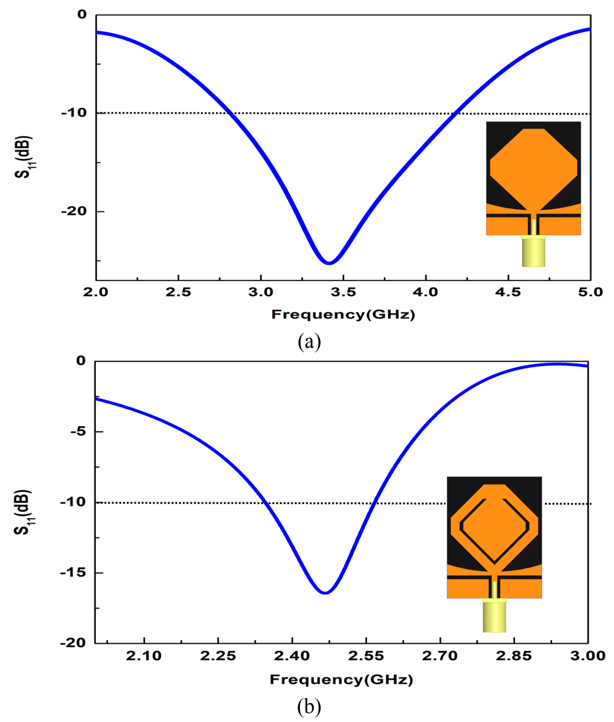


Fig. 2. Return loss of proposed antenna: (a) 5G sub-6-GHz band antenna. (b) ISM band antenna

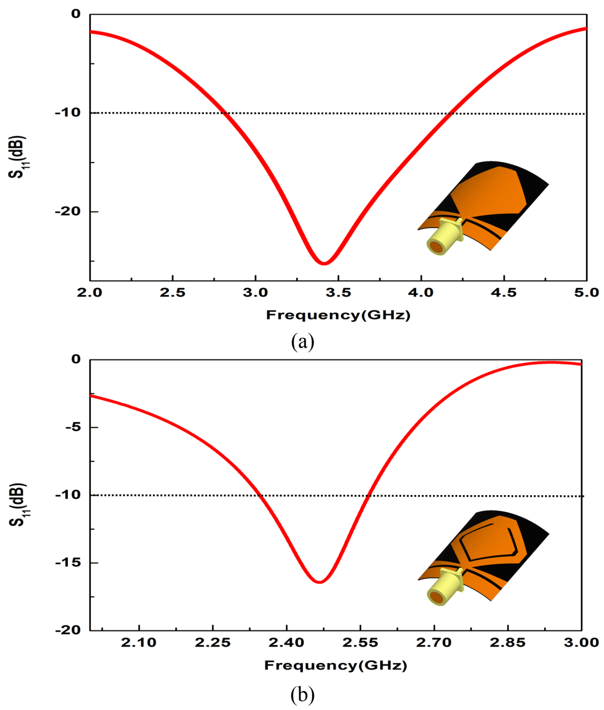


Fig. 3. Bending analysis of proposed antenna: (a) 5G sub-6-GHz band antenna.(b) ISM band antenna.

for a compact antenna resonating at 2.45 GHz. The rest of the manuscript adheres to the following pattern: Section-II contains the configuration of proposed antennas, Section-III presents the results while whole discussion was wind up in Section-IV.

II. Antenna Configuration

The geometry of the proposed flexible antenna is depicted in Fig. 1. The radiating element is engraved over a flexible substrate Rogers 5880 (ε_r = 2.2 and $tan\delta$ = 0.0009) with a standard thickness of 0.254 mm. The antenna consists of an overall compact size of 32 × 25 × 0.254 mm^3 with length *L*, width *W*, and height *h*. The antenna geometry is extracted from a conventional monopole antenna, the inadequacy of narrow band of the rectangular radiator was removed by truncating the patch. A detailed discussion of the effect of truncated patch on the bandwidth of the antenna is presented in [14–15]. To improve the impedance mismatching of the antenna, a stub was inserted between main radiator and feed line [16]. Besides, slot was introduced in antenna's radiating element because of their well-known ability to lower the resonant frequency. To do this, a modified U-shaped slot was inserted into the antenna structure, which caused a disruption of the antenna surface current distribution, and thus provided a longer patch for the antenna current flow. Therefore, the introduction of the slots resulted in a shift of the resonances to the low frequencies.

The parameters of the slot were optimized to get the desired resonating frequency. To minimize the fabrication error, a SMA connector having impedance of 50-Ω is designed in electromagnetic solver Higher Frequency Structural Software (HFSS), to excite antenna. The optimized parameters of the proposed antenna were enlisted here: *W = 25mm; L = 32mm;* C_x *= 11mm;* C_y *= 5mm; A = 12.45mm; B = 10.89mm; G = 4mm; c = 2mm; d = 4.4mm; e = 1mm; Sy = 2.98mm.*

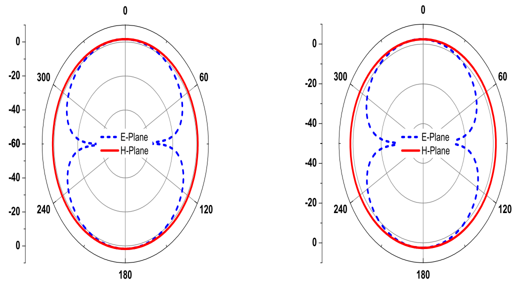
III. Antenna Chracterstics

The various performance parameters of the proposed antenna such as reflection coefficient, conformability analysis, gain, radiation efficiency, and radiation patterns were investigated in this section.

Fig. 2 (a-b) presents the scattering parameters of both proposed antennas. It can be seen from Fig. 2(a) that the proposed antenna without slot covers complete 5G sub-6-GHz band, covering the wide impedance bandwidth of 2.85 – 4.15 GHz with respect to $|S_{11}|$ < -10 dB. On the other hand, after the introduction of the slot, the antenna starts resonating at 2.45 GHz, as shown in Fig. 2(b), while covering complete ISM band by showing a broad impedance band width of 2.35–2.56 GHz.

Figure 3 depicts a comparison of antenna's return loss for bending conditions. Both antennas show nearly similar results compared to non- bended antennas, as shown in Fig. 3(a) and 3(b) for 5G and ISM band antenna, respectively. This observation verifies the potential use of the antenna in flexible devices. The antenna shows a stable gain and high radiation efficiency at the desired frequency bands. The simulated gain values are observed 1.74 dB and 2.51 dB, while efficiency value 94% and 92.7% at 2.45 GHz and 3.5 GHz for ISM band and 5G band, respectively.

Radiation patterns of the proposed antenna are presented in Fig. 4(a-b). In both cases the antenna exhibits nearly omnidirectional pattern in *E*-plane, while an *8* shaped pattern in *H*-plane like a conventional monopole.



(a) (b)

Fig 4. Radiation patterns of proposed antenna for ISM and 5G sub-6-GHz band: (a) 2.45 GHz (b) 3.5 GHz

Table. 1 Comparison of proposed work with recent antennas reported in literature.

Ref.	*Size (mm^2)*	*Bandwidth (MHz)*	*Flexibility*	*Frequency Switching*
[9]	450	330/1560	No	No
[10]	216	40/2040	No	No
[11]	576	20/22	No	Yes
[12]	990	100/330	Yes	No
[13]	800	180/640	Yes	Yes
Proposed	800	210/1300	Yes	Yes

Table. 1 presents the comparison of proposed antennas with state-of-the-art-work. In general, the antenna outperforms the antennas owing to its compact size, wider bandwidth, and capabilities of frequency switching and flexibility.

IV. CONCLUSION

In this paper, a stub loaded flexible patch antenna with compact size and broad bandwidth is proposed for on demand bands of ISM and 5G-sub-6-GHz. A fabricated prototype of the proposed antenna is realized for measurement in order to validate the simulated results. The results reported shows a good agreement between simulated and measured results. Besides of good impedance and radiation characteristics, the antenna also showed great stability against bending of the geometry. Moreover, we demonstrated that the proposed antenna outperforms the existing related antenna in terms of compactness, impedance matching and bandwidth, besides the flexible functionality, which qualifies the proposed antenna to be an excellent candidate for future ISM and 5G band applications.

REFERENCES

[1] N. Hussain, M.J. Jeong, J. Park, and N. Kim, "A broadband circularly polarized Fabry-Perot resonant antenna using a single-layered PRS for 5G MIMO applications," *IEEE Access.*, vol. 7, pp. 42897-907, 2019.

[2] A. Zaidi, A. Baghdad, W. A. Awan, A. Ballouk, and A. Badri, "CPW fed wide to dual band frequency reconfigurable antenna for 5G applications," *International Conference on Wireless Technologies, Embedded and Intelligent Systems (WITS)*, pp. 1-3. IEEE, 2019.

[3] Z. Xia et al., "A wideband circularly polarized implantable patch antenna for ISM band biomedical applications," *IEEE Trans Antennas Propag* [in press]

[4] C. Liu, Y. X. Guo, and S. Xiao, "Capacitively loaded circularly polarized implantable patch antenna for ISM-band biomedical applications," *IEEE Trans. Antennas Propag.*, vol. 62, no. 5, pp. 2407–2417, May 2014.

[5] A. Tronquo, H. Rogier, C. Hertleer and L. Van Langenhove, "Robust planar textile antenna for wireless body LANs operating in 2.45 GHz ISM band," *Electronics Letters*, vol. 42, no. 3, pp. 142-143, 2 Feb. 2006.

[6] J. I. Lee and J. Yeo, "Compact bent slot antenna for 2.45 GHz band," in *Electronics Letters*, vol. 48, no. 8, pp. 420-422, 12 April 2012.

[7] Z. Yang, S. Xiao, L. Zhu, B. Wang and H. Tu, "A circularly polarized implantable antenna for 2.4-GHz ISM band biomedical applications," *IEEE Antennas Wirel Propag Lett*, vol. 16, pp. 2554-2557, 2017.

[8] W.A. Awan, N. Hussain, and T.T. Le "Ultra-thin flexible fractal antenna for 2.45 GHz application with wideband harmonic rejection," *AEU-Int J Electron Comm.*, vol. 110, pp. 152851, 2019.

[9] W.A. Awan, A. Ghaffar, N. Hussain, and X.J. Li, "CPW-fed dual-band antenna for 2.45/5.8GHz applications," *Asia-Pacific Conference on Antennas and Propagation (APCAP)*, Incheon, Korea, pp. 1-2. IEEE, 2019.

[10] A. Ghaffar, X.J. Li and B.C. Seet, "Compact Dual-Band Broadband Microstrip Antenna at 2.4 GHz and 5.2 GHz for WLAN Applications," *IEEE Asia-Pacific Conference on Antennas and Propagation (APCAP)*, Auckland, pp. 198-199. IEEE, 2018.

[11] S.A. Naqvi, and M. S. Khan, "Design of a miniaturized frequency reconfigurable antenna for rectenna in WiMAX and ISM frequency bands" *Microw Opt Technol Lett.*, vol. 60, no. 2, pp. 325-330, 2018.

[12] G. Dattatreya and K.K. Naik, "A low volume flexible CPW-fed elliptical-ring with split-triangular patch dual-band antenna," *Int J RF Microw Comput Aided Eng*. vol. 29, no. 8, pp. 21766, 2019.

[13] S.M. Saeed, C.A. Balanis, and C.R. Birtcher, "Inkjet-printed flexible reconfigurable antenna for conformal WLAN/WiMAX wireless devices," *IEEE Antennas Wirel Propag Lett.* vol. 15, pp. 1979-1982, 2016.

[14] N. Hussain, M. Jeong, J. Park, S. Rhee, P. Kim, and N. Kim, "A compact size 2.9□23.5 GHz microstrip patch antenna with WLAN band□rejection," *Micro Opt Technol Lett.*, vol. 61, no. 5, pp. 1307-1313, 2019.

[15] S. Mathew, R. Anitha, U. Deepak, C. K. Aanandan, P. Mohanan and K. Vasudevan, "A Compact Tri-Band Dual-Polarized Corner-Truncated Sectoral Patch Antenna," *IEEE Trans Antennas Propag.*, vol. 63, no. 12, pp. 5842-5845, Dec. 2015.

[16] W.A. Awan, A. Zaidi, N. Hussain, A. Iqbal, and A. Baghdad," Stub loaded, low profile UWB antenna with independently controllable notch□bands," *Microw Opt Technol Lett.*, 61, no. 11, pp. 2447-2454, 2019.