An Integrated Filtering Antenna with Bandpass Filters For 5G Applications

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***Abstract*—This paper objective is to propose a novel filtering monopole antenna design aimed towards wide-band applications. The antenna features three distinct ports. By integrating two nested resonator and hairpin filter designs directly with the antenna, a compact form factor is achieved. The antenna is resonating at 4.03 GHz frequency, the rectangular nested resonator structure is resonating at 4.35 GHz frequency and the hairpin resonator structure is resonating at 4.85 GHz frequency. Overall, the filtering antenna is resonating at 4.36 GHz frequency with a working frequency band of 3.32-4.54 GHz, providing a constant gain of 2.3 dB in the working band. Proposed structure gives 31.0% 10 dB fractional bandwidth along with two radiation nulls of -11.95 dB and -6.73 dB at 2.84 GHz and 6.16 GHz respectively. It can be used for applications in sub-6 GHz 5G frequency band or other systems implementing wideband applications.**

Keywords—Filtering antenna, passband filter, wideband, antenna.

I. INTRODUCTION

A increasing trend is present. for the integration of wireless systems into the single mobile device. In contrast, the mobile the gadget itself is increasingly shrinking in size, making it designing several RF-front ends is challenging, including antennas. Integration and miniaturization regarding comprises both the microwave filter and the antenna is instrumental, both as essential components of the RF front end. Consequently, filtering antennas that may simultaneously achieve radiation functionality and filtering capacity have been proposed in recent times [1-5]. Some reconfigurable and multi-band structures have also been proposed [6-8]. By circumventing the need of designing the bandpass filter and antenna independently, the design appreciates a more compact structure, which eventually results in a better performance of the whole RF front-end. A paramount concern for devices in wireless communication is the miniaturization and integration technique. In [9-12], extensive research on the antenna integration method and the filtering antenna is proposed, where a slot antenna is used to replace the last resonator of the filter. Based on these aforementioned studies, a design of a filtering antenna from a wideband state is proposed in this paper, achieved by adding a pair of bandpass filters to the feed line. Three separate ports are used to receive RF transmissions [13-14]. The novelty of this structure lies in the following aspects. The integrated bandpass filters give satisfactory frequency selectivity and satisfactory harmonic suppression for the concerned antenna design. An improved radiation efficiency, comparative to traditional designs is offered. A stable gain is achieved throughout the concerned bandwidth. Because of its simple structure, it can be easily integrated into systems and other designs.

The design as well as integration of all the components is covered in Part II. The antenna's simulation results will be covered in Section III. Section IV will draw conclusions.

II. GEOMETRY AND ANALYSIS OF FILTERING ANTENNA

This section includes design of wideband antenna, two passband filters and integrate both antenna and filters to design of filtering antenna.

A. Wideband Antenna Design

A Hexagonal- figure based bent monopole antenna is selected due to its wideband operation. The design of the Wide band monopole antenna is indicated in Fig. 1. It is printed on a 0.035mm thick FR4 substrate (dielectric constant εr = 4.4). The substrate has a dimension of 40 × 41.9 mm square. The radiating element in the top layer is a hexagon-shaped patch that is activated by a 50Ω microstrip feeding line. The microstrip line has dimensions of 2 mm in width and 20.5 mm in length. The bottom layer of the substrate is printed with a half-rectangular ground plane, as shown in Fig. 1 and the Fig.2 provides the antenna's s specifications..

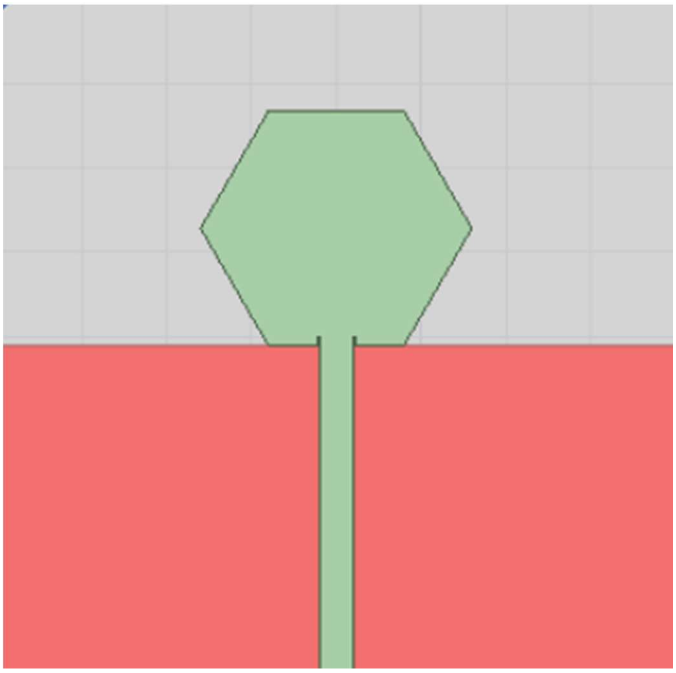


Fig. 1. Presented Wideband Antenna

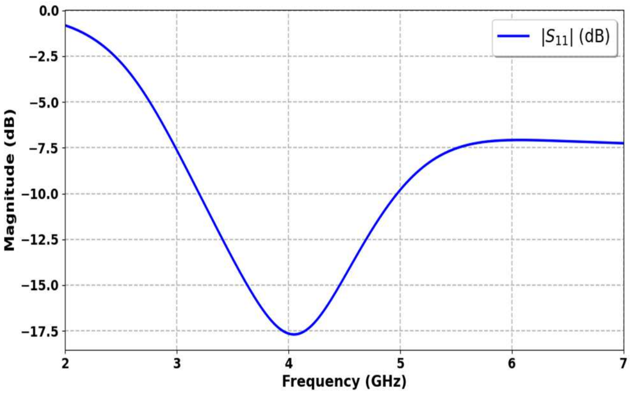
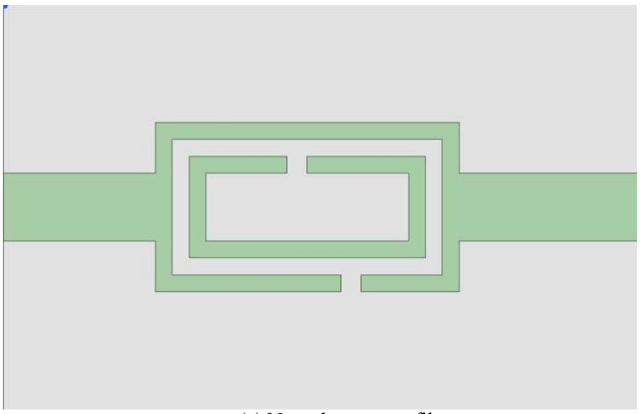


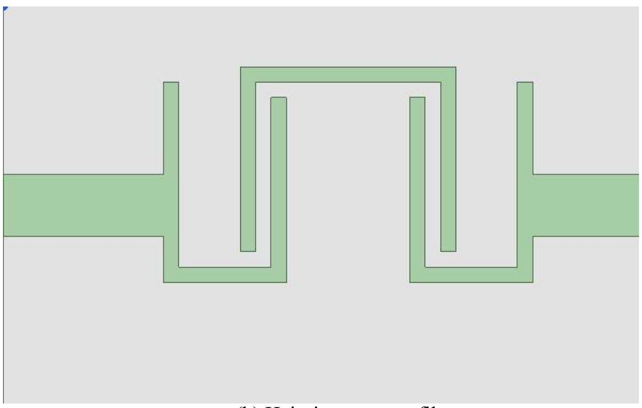
Fig. 2. S parameters of hexagonal presented antenna

B. Passband Filter Design

Designing the bandpass filters for the required band precedes the implementation of the filter-antenna integration. On the left side of the feed line, a nested resonator structure, is implemented using concentric rectangular loops. This geometry introduces strong coupling effects between the inner and outer resonators, creating a frequency-selective response at the desired band. The design parameters, including resonator dimensions and coupling gaps, are optimized to achieve satisfactory rejection in out-of-band frequencies while maintaining low insertion loss in the passband. The design parameters, including resonator dimensions and coupling gaps, are optimized to achieve satisfactory rejection in out-of-band frequencies. Structure of the nested resonator filter is given in Fig.3(a). The filter on the right of the feed line is a meandering hairpin resonator filter, a hybrid structure that incorporates aspects of hairpin resonators and meander lines.



(a) Nested resonator filter



(b) Hairpin resonator filter

Fig. 3. Proposed Band-pass filter designs

This is useful for applications where available space is scarce. The basic construction of the filter is made up of two U-shaped folding resonators that produce the required frequency response, maintaining low insertion loss in the passband. The structure is illustrated in Fig. 3 (b) and the s parameters of the hairpin filter and the nested resonator filter are represented in Fig. 4 and Fig. 5, respectively.

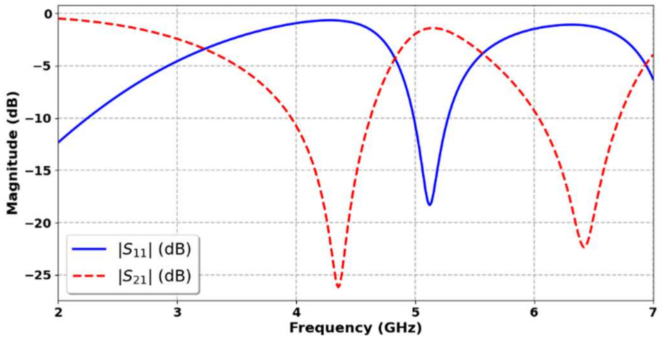


Fig. 4. Result of nested resonator filter

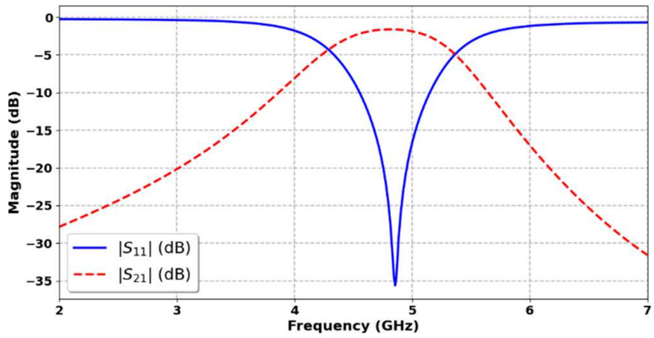


Fig. 5. Result of hairpin filter

C. Filtering Antenna Design

On foundation of the aforementioned strategy and investigation, the culminating step is the integration of the pair of filters and antenna designed, to realize the presented antenna. The proposed filtering antenna schematic illustrated in Fig. 6.

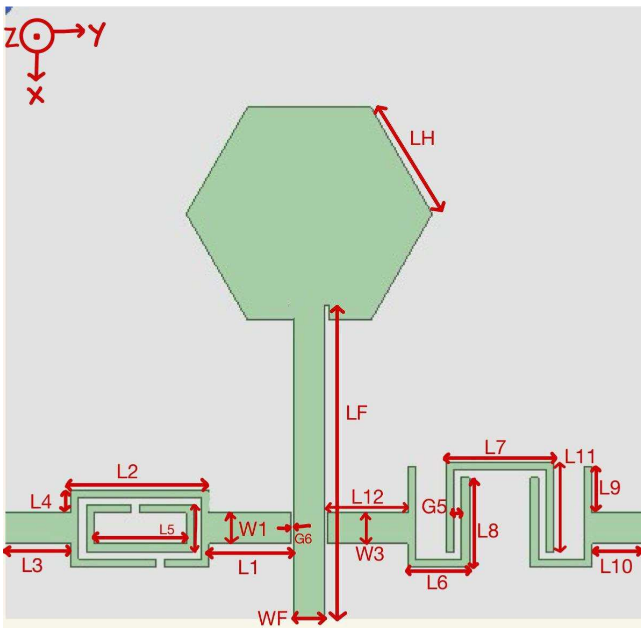


Fig. 6. Schematic of presented filtering antenna structure.

It comprises three RF ports, a monopole antenna, two filters with bandpass functionality and 50 Ω microstrip lines. The optimized dimensions in mm are shown in table I. Its analysis concerning 5th and 6th generation influences on the response of the filtering antenna and electric field magnitude across the structure.

TABLE I. SPECIFICATIONS (MM) OF PRESENTED FILTERING ANTENNA

L1	L2	L3	L4	L5	L6	L7	L8
5.3	9	4.5	1.5	6	4	7	5.8
L9	L10	L11	L12	LH	LF	W1	W3
3	3.5	5.8	5.2	8	20.5	2	2

III. RESULTS AND DISCUSSION

The simulated scattering parameters plot of presented wideband antenna with filtering response is depicted in Fig.7, are given in Fig. (7). The S11, S22 and S33 plot response represents the input reflection coefficients of filtering antenna, nested resonator filter and hairpin resonator filter respectively. The proposed filter antenna resonates at 4.36 GHz frequency having 10 dB fractional bandwidth of 31.0 %. The gain of the presented filter antenna is shown in Fig.8. This shows nearly constant gain in the working band of around 2.3 dB and two radiation nulls of -11.95 dB and -6.73 dB at 2.84 and 6.16 GHz, respectively.

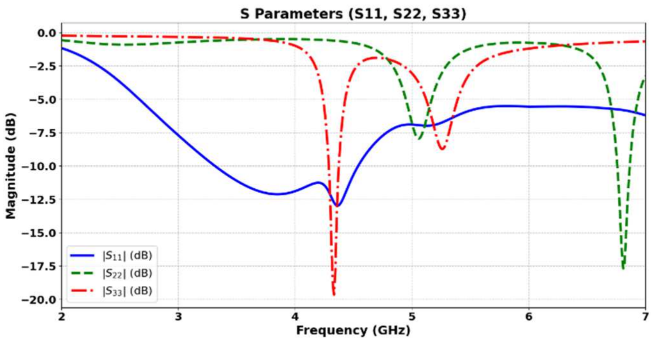


Fig. 7. S-parameters of presented work.

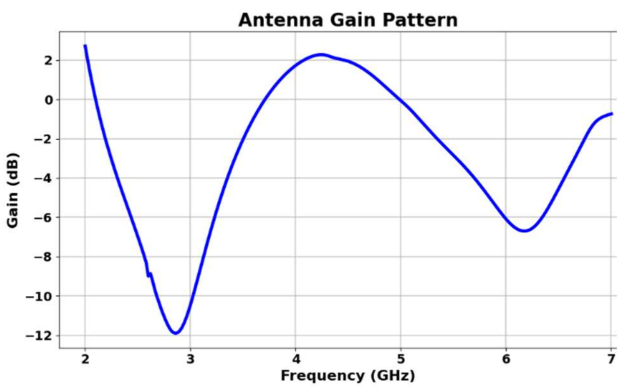
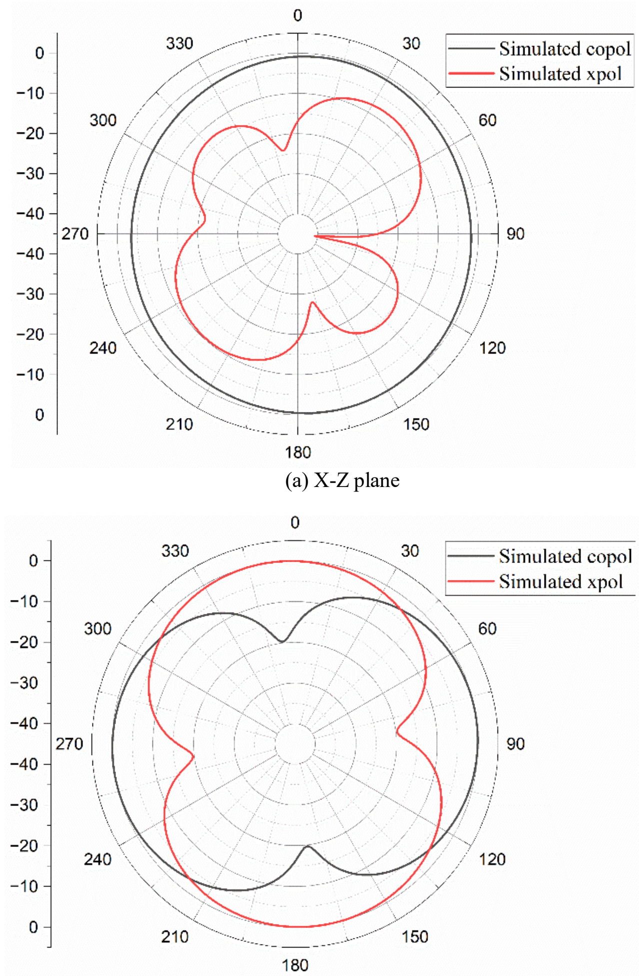


Fig. 8. Gain plot of presented filtering antenna.

The plot of pattern of radiation for presented wideband filtering antenna at operating frequency of 4.36 GHz fox XZ and YZ plane are illustrated in Fig. 9. Table II presents a comparison of the presented structure with other similar structures presented in recent times. The comparison is based upon the parameters of resonant frequency, gain, percentage of bandwidth, radiation count nulls and their dimensions. Proposed work provides compactness along with wider bandwidth compared to similar type of works.



(a) X-Z plane

(b) Y-Z plane

Fig. 9. Pattern of radiation for presented structure at resonance frequency.

TABLE II. EVALUATION OF THE SUGGESTED FILTERING ANTENNA'S PERFORMANCE COMPARED TO PREVIOUS PUBLICATIONS

Ref.	*Resonance Frequency (GHz)*	*Gain (dB)*	*Fractional bandwidth (%)*	*Rradiat ion null*	*Size (mm×mm)*
[3]	3.4	2.5	23.5	2	35.0×230
[4]	4.13	2.2	1.2	--	70.0×50.0
[5]	2.45	-1.8	4.5	2	45.0×64.0
[11]	3.9	1.24	6.4	1	50.0×50.0
[12]	1.8	1.9	61.2	1	78.8×47.0
This work	4.36	2.3	31.0	2	40.0×41.9

IV. CONCLUSION

A filtering antenna is realized, suitable for wideband applications. By virtue of its simple design, it can be easily integrated into other designs. It possesses satisfactory performance in the intended working band. This filtering antenna can be useful for applications in the sub-6 GHz frequency band of 5G. It provides fractional bandwidth of 31.0 % along with working band average gain of 2.3 dB and two radiation nulls of -11.95 dB and -6.73 dB at 2.84 and 6.16 GHz, respectively.

REFERENCES

[1] Y. Yusuf, H. Cheng, and X. Gong, "A seamless integration of 3-Dvertical filters with highly efficient slot antennas," IEEE Trans. Antennas Propag., vol. 59, no. 11, pp. 4016-4022, Nov. 2011.

[2] J. Deng, S. Hou, L. Zhao, and L. Guo, "A reconfigurable filtering antenna with integrated bandpass filters for UWB/WLAN applications," IEEE Antennas Wirel. Propag. Lett., vol. 66, no. 1, pp. 401-404, 2017.

[3] D. K. Choudhary and R. K. Chaudhary, "Compact filtering antenna using asymmetric CPW-fed based CRLH structure," AEU-International Journal of Electronics and Communications, vol. 126, Article No. 153462, 2020.

[4] Dhwaj K., L.-J. Jiang, and T. Itoh, "Dual-band filtering antenna with novel transmission zero characteristics," IEEE Antennas Wirel Propag Lett, vol. 17, pp. 2469-2473, Dec. 2018.

[5] C.-Y. Hsieh, C.-H. Wu, and T.-G Ma, "A compact dual-band filtering patch antenna using step impedance resonators," IEEE Antennas Wirel Propag Lett, vol. 14, pp. 1056-1059, Jun. 2015.

[6] P. Pal, D. K. Choudhary, and S. K.Mahto, "High gain dielectric resonator filtering antenna for 6G applications," AEU-International Journal of Electronics and Communications, vol. 197, Article No. 155835, 2025

[7] P.-Y Qin, F Wei, and Y.-J Guo, "A wideband-to-narrowband tunable antenna using a reconfigurable filter," IEEE Trans Antennas Propag, vol. 63, no. 5, pp. 2282-2285, May 2015.

[8] L Ge and K.-M Luk, "A band-reconfigurable antenna based on directed dipole," IEEE Trans Antennas Propag, vol. 62, no. 1, pp. 64-71, Jan. 2014.

[9] G.-H Sun, S.-W Wong, L Zhu and Q-X Chu, "A compact printed filtering antenna with good suppression of upper harmonic band," IEEE Antennas Wirel Propag Lett, vol. 15, pp. 1349-1352, Apr., 2016.

[10] M.A Abdalla, D.K Choudhary, and R.K Chaudhary, "A compact reconfigurable bandpass/lowpass filter with independent transmission zeros based on generalized NRI metamaterial International Journal of RF and Microwave Computer-Aided Engineering, vol. 15, Vol. 30(3), Article No. e22074, 2019.

[11] Z. Wu, A. Zhang, J. Chen, X. Lu, and J. Li, "Co-design of low profile single-fed circularly polarized filtering antenna with high out-of-band rejection," AEU - Int. J. Electron. Commun., vol. 102, pp. 99-104, 2019.

[12] B. Sahu, S. Singh, M. K. Meshram, and S. P. Singh, "Integrated design of filtering antenna with high selectivity and improved performance for L-band applications," AEU - Int. J. Electron. Commun., vol. 97, pp. 185-194, 2018.

[13] M. M. Fakharian, P. Rezaei, A. A. Orouji, and M. Soltanpur, "A wideband and reconfigurable filtering slot antenna," IEEE Antennas Wireless Propag. Lett., vol. 15, pp. 1610-1613, 2016.

[14] Z.-X Wu, A.-P Zhang, J.-L Chen, X.-F Lu, and J.-H Li, "Co-design of low-profile single-fed circularly polarized filtering antenna with high out-of-band rejection," AEU - Int J Electron Commun, vol. 102, pp. 99-104, Mar. 2019.