An Integrated Filtering Antenna with Bandpass Filters For 5G Applications

Kushagra Pratap
School of Electronics Engineering
Vellore Institute of Technology
Vellore-632014, Tamil Nadu, India
kushagra.pratap2022@vitstudent.ac.in

Shiven Shiv Senkumar
School of Electronics Engineering
Vellore Institute of Technology
Vellore-632014, Tamil Nadu, India
shivensen.kumar2022@vitstudent.ac.in

Anubhab Hazra
School of Electronics Engineering
Vellore Institute of Technology
Vellore-632014, Tamil Nadu, India
anubhab.hazra2022@vitstudent.ac.in

Souryadeep Banerjee
School of Electronics Engineering
Vellore Institute of Technology
Vellore-632014, Tamil Nadu, India
souryadeep.banerjee2022@vitstudent.ac.in

Dilip Kumar Choudhary
School of Electronics Engineering
Vellore Institute of Technology
Vellore-632014, Tamil Nadu, India
dilipkumar.choudhary@vit.ac.in

***Abstract*—This paper's 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 null of -11.95 dB and -6.73 dB at 2.84 GHz and 6.16 GHz respectively. As evident through simulated reflection coefficients and radiation patterns, the proposed filtering antenna is an eligible candidate for applications in sub-6 GHz 5G frequency band or other systems implementing wideband applications.**

***Index Terms*—Bandpass filter, filtering antenna, wideband antenna.**

I. Introduction

There is a growing trend for the integration of wireless systems into a single mobile device. In contrast, the mobile device itself is increasingly becoming more compact in size, making it difficult to design multiple RF-front ends, including antennas. Integration and miniaturization of the antenna together with the microwave filter is instrumental, both being necessary parts of the RF front end. Therefore, filtering antennas that can 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 antenna and bandpass filter separately, the design realizes 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 [10], extensive research on the integration technique of antennas 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 incorporating two bandpass filters to the feeding line. RF signals are fed through three independent ports. 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, comparitive 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 will be discussed in Section II. Section III will deal with the simulation results of the antenna. Section IV will draw conclusions.

II. DESIGN OF THE 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-shaped monopole antenna is chosen because it can operate over a wideband. The layout of the Wide band monopole antenna is indicated in Fig. 1. It is printed on a 0.035mm thick FR4 substrate (dielectric constant ε_r = 4.4). The substrate has a dimension of 40 × 41.9 mm square. The top layer consists of a hexagonal-shaped patch as the radiating element which is excited through a 50Ω microstrip feeding line. The length of the microstrip line is 20.5 mm, and the width is 2 mm. As can be seen in Fig. 1, a half rectangular ground plane is printed on the bottom layer of the substrate. Fig(2) gives the s parameters of the antenna.

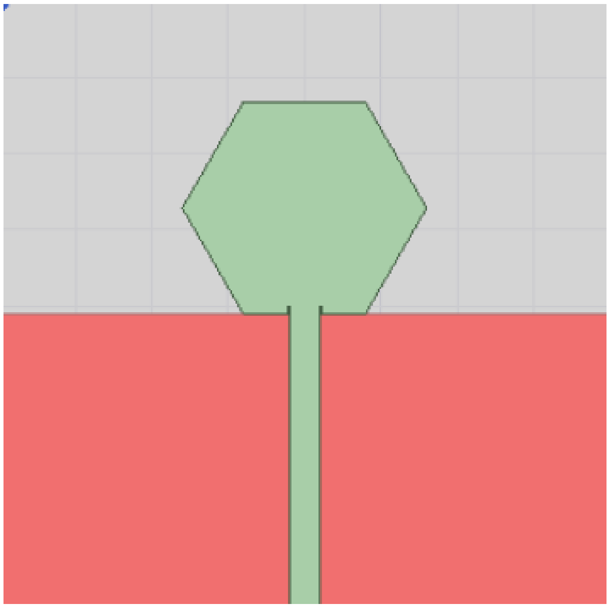


Fig. 1: Proposed Wideband Antenna

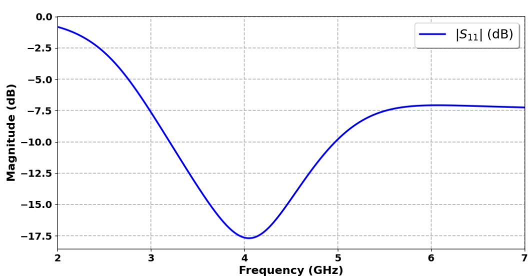
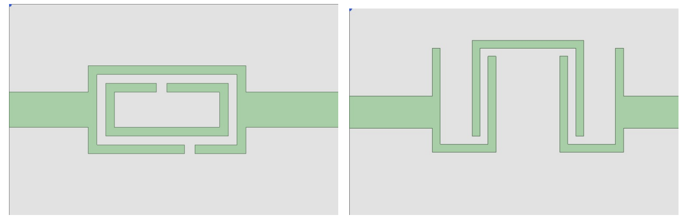


Fig. 2: S parameters of the hexagonal monopole antenna

B. Bandpass Filters Design

Before implementing the filter-antenna integration, it is necessary to design the bandpass filters for the required band.

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)



(a) Nested resonator filter (b) Hairpin resonater filter

Fig. 3: Proposed Band-pass filter designs

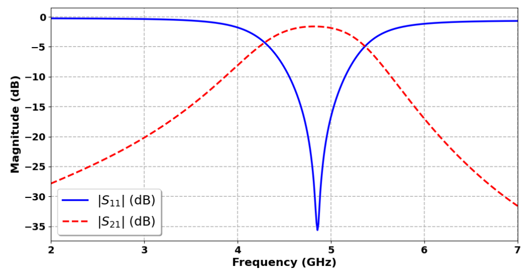


Fig. 4: S parameters of the hairpin filter

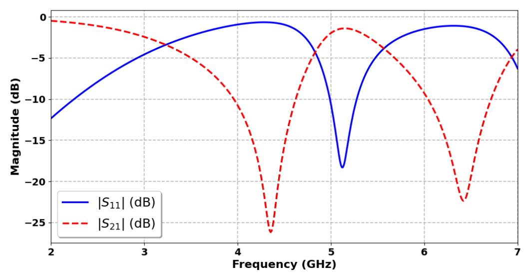


Fig. 5: S parameters of the nested resonator filter

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. 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 Fig3(b) and the s parameters of the hairpin filter and the nested resonator filter are represented in Fig. (4) and Fig. (5), respectively.

C. Filtering Antenna Design

Based on the aforementioned design and analysis , the culminating step is the integration the monopole and bandpass filters to achieve the filtering antenna. Fig. 6 depicts the structure of the proposed filtering antenna, which is composed of three RF ports, a monopole, two bandpass filters and 50 Ω microstrip lines. Analysis concerning G5's and G6's influences on the response of the filtering antenna was also done , after analysis of electric field magnitude across the structure. table contains the dimensions of the filtering antenna-

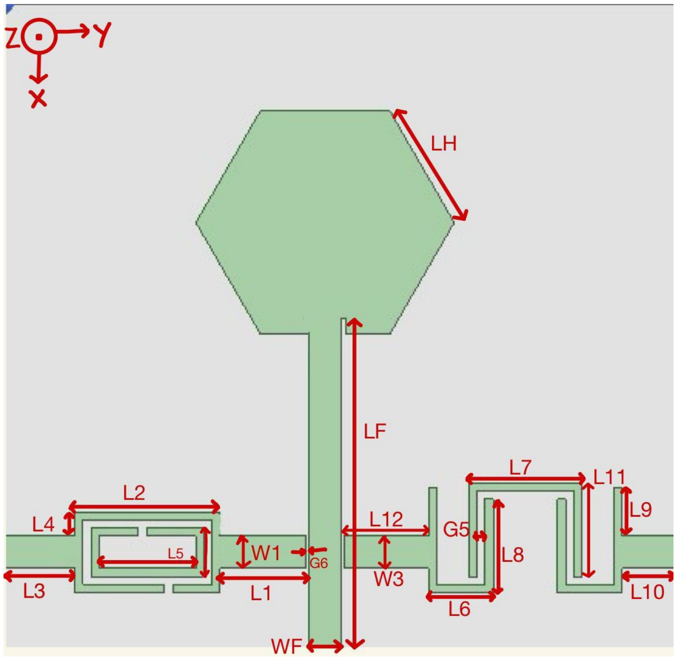


Fig. 6: Schematic of the proposed filtering antenna

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

TABLE I: Dimensions (mm) of the proposed filtering antenna

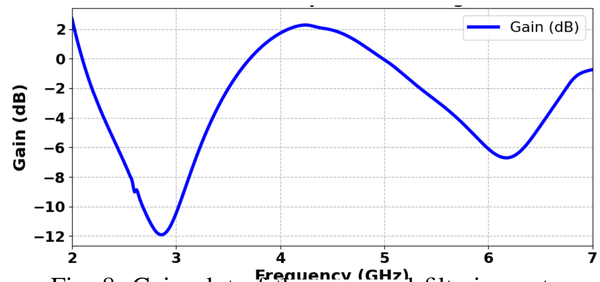


Fig. 8: Gain plot of the proposed filtering antenna

The radiation pattern plots of the filtering antenna for Y-Z and Z-X planes are given in fig(9) and fig(10) , respectively.

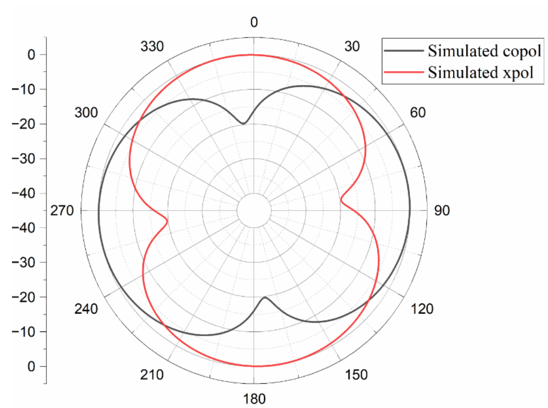


Fig. 9: Y-Z plane radiation pattern of the filtering antenna

III. Results and Discussions

The simulation S parameter plots of the Wideband filtering antenna, are given in Fig. (7).

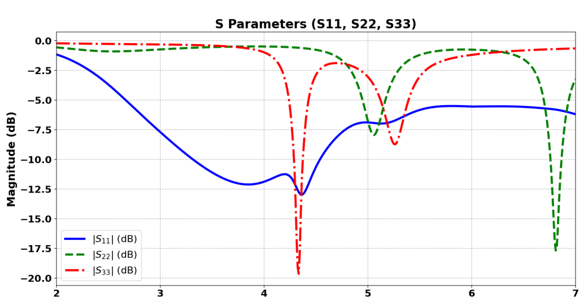


Fig. 7: S parameters of the filtering antenna

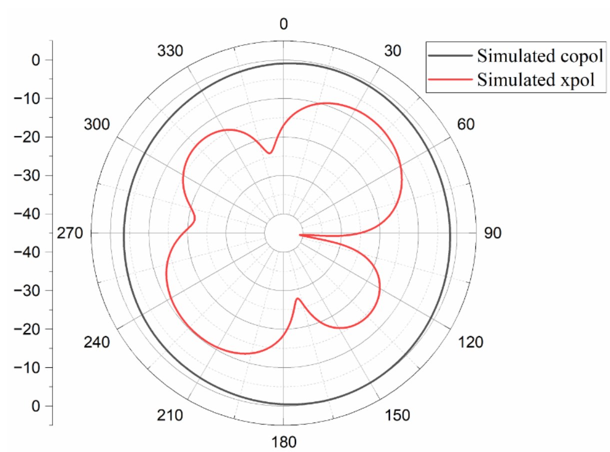


Fig. 10: X-Z plane radiation pattern of the filtering antenna

The proposed filter antenna resonates at 4.36 GHz frequency having 10 dB fractional bandwidth of 31 % . The gain of the presented filter antenna is shown in Figure (8). This structure 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.

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, 10 dB fractional bandwidth, number of radiation nulls and their dimensions.

Table II : Performance comparison of the proposed filtering antenna with earlier published work

	Resonant Freq (GHz)	**Gain (dB)**	**10dB Fractional Bandwidth (%)**	**Number of Radiation Nulls**	**Size (mm $\times$ mm)**
Ref. [4]	4.13	2.2	1.2	-	70.0 $\times$ 50.0
Ref. [3]	3.4	2.5	23.5	2	35.0 $\times$ 23.0
Ref. [5]	2.45	-1.8	4.5	2	45.0 $\times$ 64
This work	4.36	2.3	31	2	40 $\times$ 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.

References

[1] Y. Yusuf, H. Cheng, and X. Gong, "A seamless integration of 3-D vertical 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. XX, no. XX, pp. XX–XX, [Year].

[3] D. K. Choudhary and R. K. Chaudhary, "Compact filtering antenna using asymmetric CPW-fed based CRLH structure," *AEU - Int. J. Electron Commun., Elsevier*, 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] 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.

[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.-M Fakharian, P Rezaei A-A Orouji and M Soltanpur, "A wideband and reconfigurable filtering slot antenna," *IEEE Antennas Wirel Propag Lett*, vol., vol., pp., Dec., [Year].