International Journal of
INTELLIGENT SYSTEMS AND APPLICATIONS IN ENGINEERING

IJISAE

ISSN:2147-6799 www.ijisae.org Original Research Paper

Design of Microstrip Band Pass Filter with the Effect of Slot Width For 5g Applications

Sneha Talari [1]*, Dr.P.Chandra Sekhar [2]

Submitted:11/03/2024 **Revised**: 26/04/2024 **Accepted**: 03/05/2024

Abstract: In wireless communication, design of filters play an important role in narrowing and broadening the bandwidth and ensures the reliability, efficiency and performance of any system by depending on the requirement of any application. In this article, a microstrip band pass filter is designed based on stepped impedance resonators using microstrip feed lines at input and input ports. The proposed design of the filter covers the frequency range 28GHz to 35GHz which helps in fulfilling the requirements of 5G applications. The rectangular slots which are placed on two sides of microstrip lines are used to improve the stop band characteristics of a filter. By changing the slot width of the rectangular slots on two sides in the range from 0.25mm,0.45mm and 0.65mm the designed filter can resonate at triple band frequencies 33.02GHz, 32.72GHz and 31.00GHz with return loss -20.05dB,-20.51dB and -23.57dB and insertion loss -1.15dB,-1.01dB and -1.15dB provides good performance. The design of band pass filter is designed on polyamide substrate with thickness 0.15mm and surface area is 104.5mm^2 .The optimization and simulation is done in HFSS software.

Keywords: *Band pass filter, rectangular slots, microstrip, HFSS, 5G.*

1. Introduction

In recent days, there are much advancement in technologies like 5G and sub 6G applications with the demand of increase in high performance and high data rates. Currently, the deployment of 5G will occur in one of the three frequency bands i.e. low band, mid band and high frequency band. The high band whose frequency is above 25 GHz is accessible for high speed, high latency and high security which are accessible for large communication networks.

The microwave band pass filter is a very important component in any communication systems in order to enhance the system performance because of having light weight, low cost and planar structure. In the design of filter to meet the requirements of 5G, the factors like size and weight has to be miniaturized for the development of compact and portable devices. To achieve this, the miniaturization techniques used are microstrip and substrates integrate waveguide techniques. The microstrip parameters are obtained using chebyshev and butter worth prototypes. The filter is capable of accepting the pass band signal characteristics and helps in attenuating the stop band characteristics. However the traditional methods like hybrid microstrip or defected ground structure cells are used to in the design of BPF but they result in less transmission zeros which in turn reduces the ability of selectivity.

In the design and implementation of microstrip band pass filter, several types are in-corporated like composite right/left resonator, cross coupled resonator, stepped impedance resonators and stub impedance resonators. The band pass filters is composed of two resonators which helps in achieving zero transmission characteristics. Thus this characteristic helps to design an excellent high frequency microstrip line with high selectivity by generating a zero transmission outside the pass band.

2. Literature Survey

The following section describes some recent research on design of filters.

Kiouach et.al[13] suggested design of a novel bandpass filter specifically tailored for 5G mm-Wave communications. The filter utilizes a rectangle loop resonator loaded with a stepped impedance line stub at its center and incorporates Rogers RT/duroid 5880 substrate with a relative dielectric constant of 2.2, a loss tangent of 0.0009, and a thickness of 0.64 mm.The resulting filter exhibits a center frequency at 22.65 GHz, with a bandwidth of 10.5 GHz The reflection coefficient is approximately -39.12 dB, while the insertion loss of about -0.59 dB.

Boddu et.al [14] suggested a design of a 2.6 GHz microstrip filtering antenna for 4G and 5G global mobile services. The filtering antenna is designed using a hairpin bandpass filter integrated with an elliptical microstrip aerial.Achieved 10 dB return loss bandwidth of the filtering antenna is approx. 5.7%, with the maximum gain for the elliptical filtering antenna of approx. 2.2 dB.

[1]*Research Scholar, Department of Electronics and Communication Engineering, University College of Engineering, Osmania University, India*
Email id:talarisneha02@gmail.com
[2]*Professor,Department of Electronics and Communication Engineering, University College of Engineering, Osmania University, India*
Email id:sekharpaidimarry@gmail.com

Wang et.al [15] suggested the design a low-profile dual-polarized filtering microstrip patch antenna (MPA) with improved gain and bandwidth is realized without requirement of filtering circuit. Here,the characteristic mode analysis (CMA) method is adopted to analyze the antenna performances. Achieved a impedance bandwidth reaches to about 7.4% with a low-profile of about 0.038 free-space wavelength. Besides, a stable enhanced gain of around 10 dBi is achieved over the operating band.

Upesh Patel et.al[16] suggested a Design of a fractal antenna in the shape of a crossed flower with a split ring resonator geometry. This suggested antenna serves the Sub-6 GHz 5G and satellite repeater applications for wireless devices operating in the frequency range of 4.01–4.82 and 7.6–7.94 GHz. Acheived an electrical impedance bandwidth of −10 dB at lower frequency band (4.01–4.82 GHz) and upper frequency band (7.6–7.94 GHz) of −10 dB.

3. Design Structure of Band Pass Filter

In RF and microwave circuits, the type of filter used is microstrip bad pass filter which allows only specific frequencies. For compact designs a microstrip technology is used where a conducting strip is placed on a substrate and on the other side of a substrate ground plane is placed. The impedance depends on the thickness of substrate, width of strip and dielectric constant of substrate. The important parameters to be considered in the design are insertion loss, return loss and center frequency. The design involve the use of resonators which can be implemented using open or short circuited stubs for proper impedance matching so that maximum power and less reflections can be achieved at input and ouput ports of filter.

Many of the existing researches proposed stepped impedance resonators in the design of band pass filters because of its advantages. So the resonator based band pass filter is introduced to reject spurious response with the use of stepped impedance resonator. SIR's are used to suppress higher order frequencies.

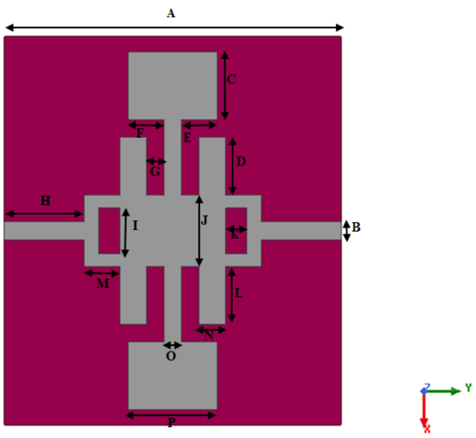


Fig 1. Proposed BPF

The schematic of proposed design is shown below in fig.1. In the proposed design, a microstrip band pass filter is designed using stepped impedance resonator to improve the stop band characteristics and open loop stub resonators for impedance matching. The polyamide substrate is used in the design with thickness h=0.15mm, dielectric constant ε_r=4.3, loss tangent tan δ =0.004, relative permeability =1 and simulation is done in the High Frequency structure simulator (HFSS) software. A ground plane is placed on the back of substrate in order to make the components used in the design compatible with the filter.

The dimensions of the filter by HFSS software are as follows: A=9.5mm, B=0.5mm, C=1.9mm, D=1.65mm, E=1mm, F=1mm, G=0.5mm, H=2.25mm, I=1.3mm, J=2mm, K=0.6mm, L=1.65mm, M=1mm, N=0.75mm, O=0.5mm and P=2.5mm.

4. Analysis of Equivalent circuit model

The equivalent circuit model is shown in fig 2.It consists of two units one is stepped impedance units and the other is band response unit. Mathematical model is done using equi ripple approach which is cheybyshev filter design of order 6.In the design of filter, two rectangular slots are placed in two low impedance sections which is separated from one high impedance sections. By changing the width of the slots the filter can be resonated at different frequencies used for 5G applications.

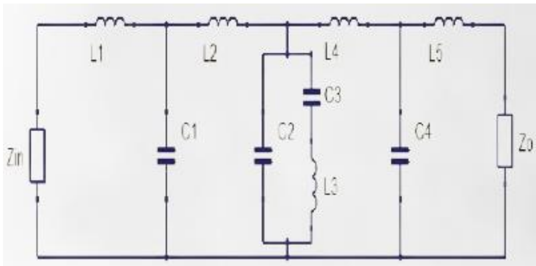


Fig 2. Eq.circuit model

The conditions to find the resonant frequency of SIR is given as

$$\tan\theta_1 = R\cot\theta_2 \text{(odd mode) at } f=f_1 \quad (1)$$

$$\cot\theta_1 = -R\cot\theta_2 \text{(even mode) at } f=f_2 \quad (2)$$

where R=impedance ratio and is given as

$$R = \frac{Z_2}{Z_1}. \quad (3)$$

The length of type of SIR is given by θ_A which is given as

$$\theta_A = 2(\theta_1+\theta_2) = \pi/2 \quad (4)$$

When R>1, resonator attains a maximum value and when R<1,resonator achieves minimum value. For getting a maximum and minimum length the condition is

$$\theta_1 = \theta_2 \equiv \theta_0 = \tan^{-1}\sqrt{R} \quad (5)$$

By changing the impedance ratio R, the frequency response can be controlled. For the design of chebyshev filter the normalized values can be obtained as

$$g_k = \frac{a_{k-1}a_k}{b_{k-1}b_k} \quad (6)$$

where $a_k = 2\sin\left\{\frac{(k-1)\pi}{2n}\right\}$ k= 1,2,--n (7)

$$b_k = 0.35 + \sin^2\left\{\frac{k\pi}{2n}\right\} \quad \text{k=1,2,--n} \quad (8)$$

Equivalent L_k and C_k can be calculated using equations (6),(7),(8)

$$L_k = \frac{Z_0 k}{\omega_c} \quad \text{and} \quad C_k = \frac{k}{Z_0 \omega_c} \quad (9)$$

The width and corresponding ε_{eff} of the substrate is obtained from

$$Z_0 = \frac{60}{\sqrt{\varepsilon_{eff}}}\log\left(\frac{8h}{w} + \frac{w}{4h}\right) \quad (10)$$

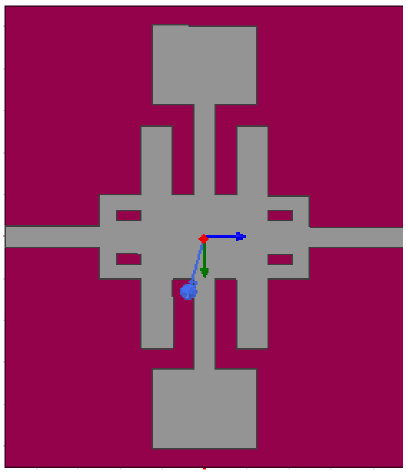
$$\varepsilon_{eff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left(1 + 10\frac{h}{w}\right)^{-\frac{1}{2}} \quad (11)$$

By using the above equations the design of band pass filter is proposed.

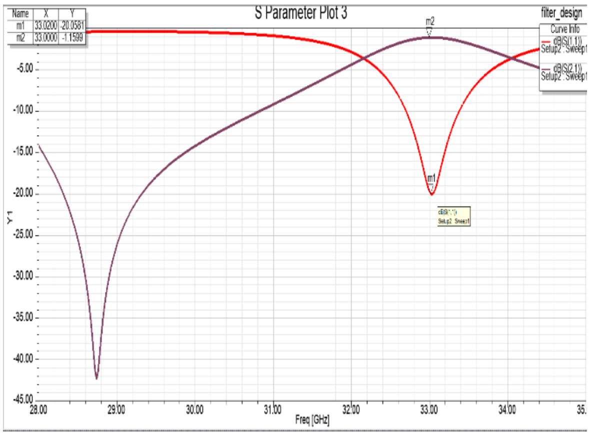
5. Simulation Results

The microstrip band pass filter is resonated at different frequencies by changing the slot widths. The slot widths are changed in the range 0.25mm, 0.45mm and 0.65mm to achieve better insertion loss and return loss and also used to fulfil the requirements of 5G applications at the desired cut off frequency 28GHz.

1.when slot width=0.25mm



(a)

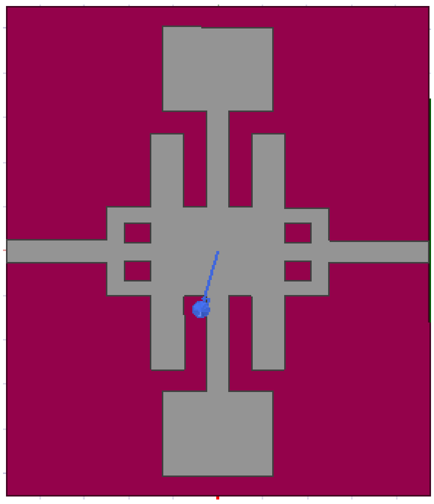


(b)

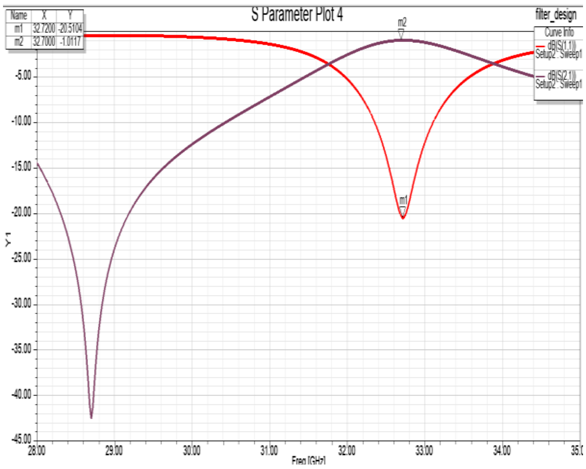
Fig 3.(a).Slot width I=0.25mm (b).return loss and insertion loss performance

In the analysis, when I=0.25mm, the filter resonates at 33.02GHz with return loss of -20.05 dB and insertion loss of -1.15dB.

2. when slot width=0.45mm



(a)

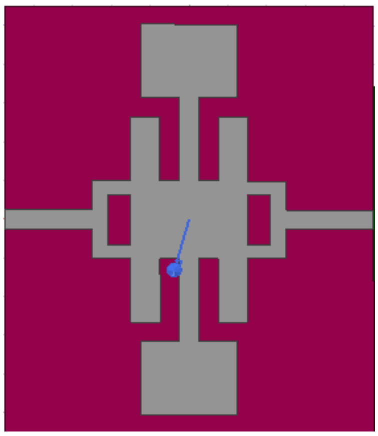


(b)

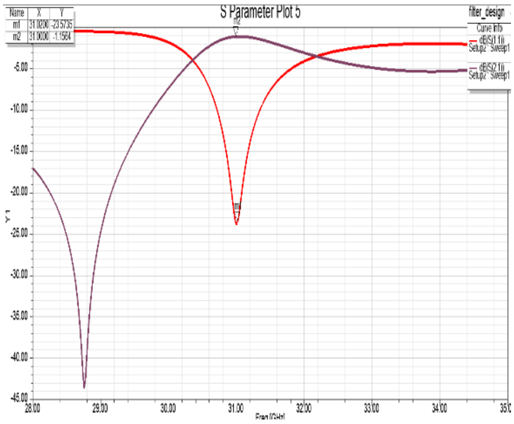
Fig 4 (a) Slot width I=0.45mm (b) return loss and insertion loss performance

In the analysis, when I=0.45mm, the filter resonates at 32.72GHz with return loss of -20.57 dB and insertion loss of -1.01dB.

3. when slot width=0.65mm



(a)

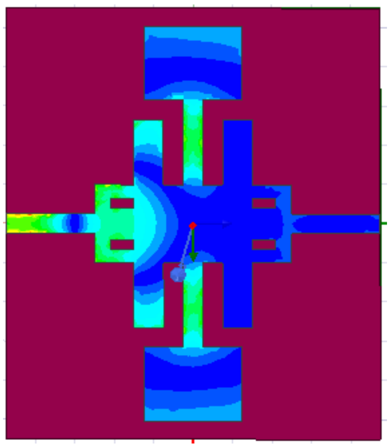


(b)

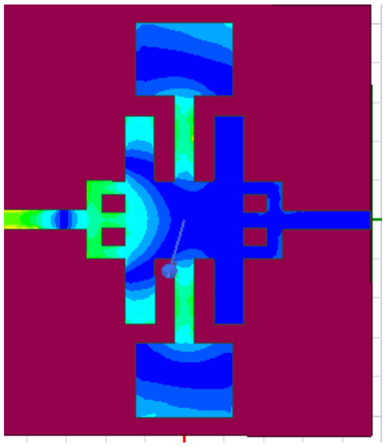
Fig 5 (a) Slot width I=0.65mm (b) return loss and insertion loss performance

In the analysis, when I=0.65mm, the filter resonates at 31.02GHz with return loss of -23.57 dB and insertion loss of -1.15dB.

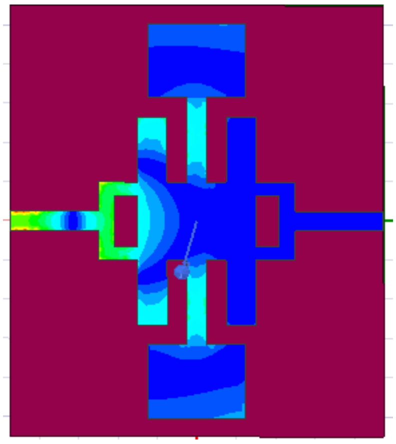
4. Surface current distributions



(a) Slot width=0.25mm



(b).Slot width=0.45mm



(c).Slot width=0.65mm

Fig 6 (a),(b),(c) Surface current distributions

The summary of effect of slow widths in the design of band pass filter is given in table.1.

Table1. Summary of effect of slot widths in filter design

Slot width(mm)	Resonating Frequency(GHz)	Return loss(dB)	Insertion loss(dB)
0.25mm	33.02GHz	-20.05 dB	-1.15dB
0.45mm	32.72GHz	-20.57 dB	-1.01dB
0.65mm	31.02GHz	-23.57 dB	-1.15dB

6. Conclusions

The design of microstrip Band pass filter with stepped impedance resonator and open loop stub loaded impedance resonator for 5G applications is proposed. The proposed Band pass filter is resonating at three different frequencies at 33.02GHz, 32.72GHz and 31.00GHz with return loss -20.05dB,-20.51dB and -23.57dB and insertion loss -

1.15dB,-1.01dB and -1.15dB by changing the slot widths 0.25mm,0.45mm and 0.65mm.It is designed on a polyamide substrate with dielectric constant ε_r=4.4 and thickness h=0.15mm. Furthermore, the filter can be integrated with antennas, microwave devices and RF circuits.

Conflicts of interest

The authors declare no conflicts of interest.

References

[1] Wireless Planning and Coordination Wing, Government of India Ministry of Communications Department of Telecommunications National Frequency Allocation Plan – 2018.

[2] E. H. Fooks, R. A. Zakarevicius, "Microwave Engineering Using Microstrip Circuits," Prentice Hall, 1990.

[3] J. S. Hong, M. J. Lancaster, "Microstrip Filters for RF/Microwave Applications," wiley vol. 64, New York, 2001

[4] S. C. Hwu and B. Razavi, "An RF Receiver for Intra-Band Carrier Aggregation," IEEE Journal of Solid-State Circuits, vol. 50, no. 4, April 2015.

[5] M. Zhao and Y. Zhang, "Compact wearable 5-GHz flexible filter," Electronics Letters., vol. 53, no. 10, pp. 661–663, May 2017.

[6] A. Zaidan, B. B. Zaidan et al., "A survey on communication components for IoT-based technologies in smart homes," Telecommunication Systems, vol. 69, no. 1, pp. 1-25, Sept. 2018.

[7] L. Gao, X. Y. Zhang et al., "Novel multi-stub loaded resonators and their applications to various bandpass filters," IEEE Trans. on Microw. Theory and Tech., vol. 62, no. 5, pp. 1162-1172, May 2015

[8] S. C. Hwu and B. Razavi, "An RF Receiver for Intra-Band Carrier Aggregation," IEEE Journal of Solid-State Circuits, vol. 50, no. 4, April 2015.

[9] M. Zhao and Y. Zhang, "Compact wearable 5-GHz flexible filter," Electronics Letters., vol. 53, no. 10, pp. 661–663, May 2017.

[10] A. Zaidan, B. B. Zaidan et al., "A survey on communication components for IoT-based technologies in smart homes," Telecommunication Systems, vol. 69, no. 1, pp. 1-25, Sept. 2018.

[11] L. Gao, X. Y. Zhang et al., "Novel multi-stub loaded resonators and their applications to various bandpass filters," IEEE Trans. on Microw. Theory and Tech., vol. 62, no. 5, pp. 1162-1172, May 2014.

[12] Zanella, N. Bui et al., " Internet of Things for Smart Cities," IEEE Internet of Things Journal., vol. 1, no. 1, pp. 22-32, Feb. 2014.

[13] Kiouach, Fatima, Bilal Aghoutane, and Mohammed El Ghzaoui, "Novel Microstrip Bandpass Filter for 5G mm-Wave wireless communications" e-Prime-Advances in Electrical Engineering, Electronics and Energy 6 (2023): 100357

[14] Boddu, Ramesh, Arindam Deb, and Jibendu Sekhar Roy," Design of a Microstrip Filtering Antenna for 4G and 5G Wireless Networks." Journal of Telecommunications and Information Technology - 2023.

[15] Wang, Zong-Zhuo, Neng-Wu Liu, and Liang Fang," Low-profile Dual-polarized Filtering Antenna with Improved Gain and Impedance Bandwidth using Characteristic Mode Analysis" The Applied Computational Electromagnetics Society Journal (ACES) (2023): 767-773.

[16] Upesh Patel, Trushit Upadhyaya , Vishal Sorathiya , Killol Pandya , Abdullah Alwabli , Kavan Dave , Nag laa F. Soliman , Walid El-Shafai "Split ring resonator geometry inspired crossed flower shaped fractal antenna for satellite and 5G communication applications" Results in Engineering 22 (2024): 102110.