DESIGN AND SIMULATION OF 5G BAND PASS FILTER WITH STUB LOADED IMPEDANCE RESONATOR

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Abstract: Filters play a very important role in maintaining the signal quality, reducing interference and maximum use of allocated spectrum for 5G applications. To address specific frequency bands a proper design of filter is implemented. In the proposed work, a band pass filter is designed for isolating signals in heavy frequency environments and it allows frequencies within specific 5G applications. The proposed band pass filters uses stub loaded impedance resonator to achieve desired response. The rectangular slots in the resonator are used to improve tuning and for optimizing performance of communication systems. The slots in filters are helpful in rejecting unwanted frequency bands and can achieve improved selectivity. The design of band pass filter is designed on polyamide substrate with thickness 0.15mm and surface area is 9.5x11mm^2 using HFSS software. The simulated return loss and insertion loss are achieved as -23dB and -1.15dB at centre frequency 31.00GHZ.
Keywords:- Bandpass filter,HFSS,5G,polyamide.

I.INTRODUCTION

In wireless communication systems, filters play a crucial part in providing security, reliability and compatibility with advanced communication technologies. Filters are essential in maintaining multiple devices are connecting to each other ensuring that they can communicate with each other effectively.5G communications aims in providing high speed, high latency and reliable communication which requires control over the spectrum and management of signals. Thus filters play a crucial part in providing all these requirements.

The Federal Communications Commission (FCC) allocated several frequency bands in US which includes low-band (sub-1 GHz), mid-band (1-6GHz) and high-band (mm wave above 24GHz) frequencies for 5G applications. Among all the millimeter wave frequencies provides high data rates for short distance and high speed data in urban areas. The design of resonator filter for mm wave frequencies requires high precision and stability because a small deviation also can affect the performance at high frequencies. Therefore, filters are designed with miniaturized size maintaining filtering capabilities which has an adverse effect in 5G applications.

Even though many filters like bandpass filters, duplexers, Microstrip band pass filters, dielectric filters etc are available for high frequency signals. Among all microstrip band pass filters offers advantages for 5G with antennas in providing flexibility, compact size, cost effectiveness, enhancing signal quality. It can also provide excellent matching between antenna and transmission line in improving power transmission. To characterize any filter performance two important parameters that are to be considered are insertion loss and return loss. For 5G applications it uses printed transmission lines on a substrate which is called as microstrip bandpass filters.

II. PROPOSED FILTER DESIGN

Microstrip BPF design has become critical because it has to handle high data rates, low latency, reliable signal transmission and reception. At high frequencies BPFs are widely used in communication systems because of its ability to select desired range of frequencies and it is essential when multiple signals are transmitted or received simultaneously. The physical properties and parasitic effects are to be taken care in the design. Inductors and capacitors forms the resonant circuit which effects pass band and stop band characteristics. Microstrip line is used a transmission line due to the ease of integration with PCB technology.

The proposed BPF has stub loaded impedance resonator to achieve desired response as shown in fig.1.

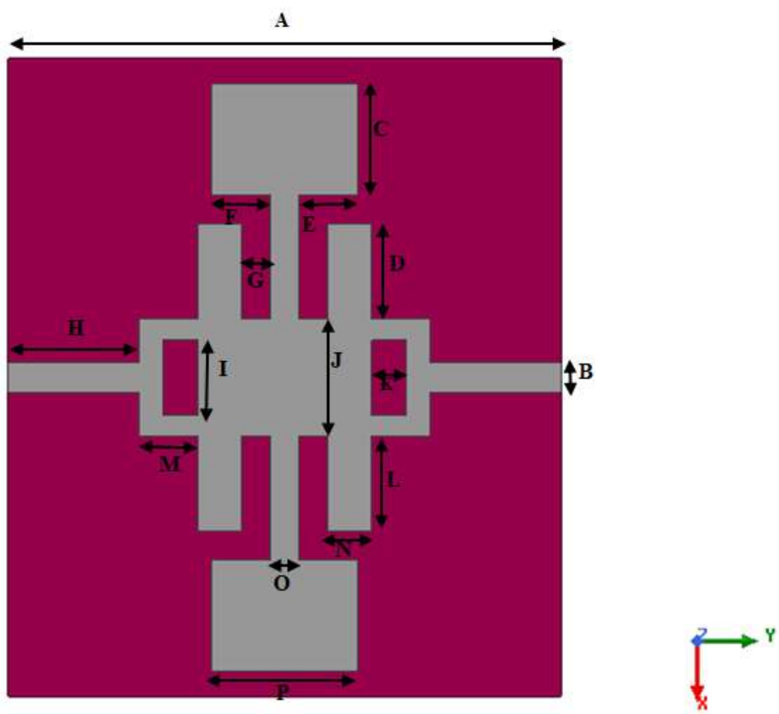

Fig.1: Proposed BPF

The selection of substrate plays a key role in filter design. The filter is designed and simulated on polyamide substrate with dielectric constant ε_r =2.2 and thickness h=0.15mm.The design and optimization of filter performance is done using HFSS software. In order to make filter

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compatible with RF components without any changes ground plane is placed on the same substrate. The dimensions of designed filter are shown in table1:

S.No	Parameter	Value(mm)	Sl.no	Parameter	Value(mm)
1	A	9.5	9	I	1.3
2	B	0.5	10	J	2
3	C	1.9	11	K	0.6
4	D	1.65	12	L	1.65
5	E	1	13	M	1
6	F	1	14	N	0.75
7	G	0.5	15	O	0.5
8	H	2.25	16	P	2.5

Table.1: Dimensions of proposed BPF

III. DESIGN CONSIDERATIONS OF BAND PASS FILTER

In the design of stub loaded impedance resonators chebyshev filters are used because of its sharp cutoff characteristics. Also stubs are loaded at proper position with proper length to enhance stop band attenuation and to obtain better rejection of unwanted signals. The design is modeled where the inductors and capacitors are connected alternately as series and shunt configurations forming a ladder which leads to overall frequency response of a filter. The frequency response is determined by the LC values and their arrangement. Higher order network provide better stop band attenuation.

The slot widths between two low impedance sections will affect the S-parameters. The electrical length of low impedance sections Z_1 and high impedance sections Z_2 are designed to achieve total electrical length which is resonated at desired resonant frequency. Depending on the dielectric constant of a substrate electrical lengths are converted to physical lengths using the effective wavelength in the transmission line.

$$\lambda_g = \frac{\lambda_0}{\sqrt{\varepsilon_{eff}}} \quad \text{———} \quad (1)$$

where λ_0 is wavelength in free space

ε_{eff} is effective dielectric constant

The impedance ratio influences the resonant frequency and bandwidth of BPF. The electrical lengths are related to frequency as

$$\theta_1 = \beta_1 l_1 \text{ and } \theta_2 = \beta_2 l_2 \quad \text{———} \quad (2)$$

The condition for determining the resonant frequency is

$$\tan\theta_1 = R\cot\theta_2 \text{ (odd-mode) at } f=f_1 \quad \text{———} \quad (3)$$

$\cot\theta_1 = -R\cot\theta_2$ (even mode) at $f=f_2$ where $R=\frac{Z_2}{Z_1}$ (4)

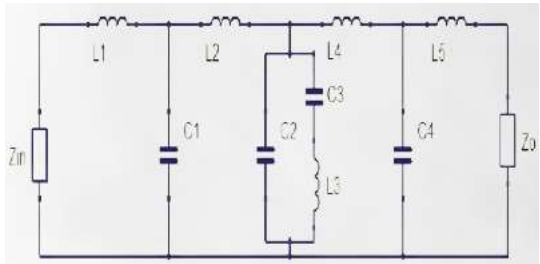

Fig 2. Proposed filter equivalent circuit

In the proposed micro strip Band pass filter, polyamide material is used as a substrate which has dielectric constant $\varepsilon_r = 4.3$,thickness =0.15mm and loss tangent =0.004 to operate at mm wave bands. The width of the substrate is calculated by using

$$z_0 = \frac{60}{\sqrt{\varepsilon_{eff}}}\log\left(\frac{8h}{w}+\frac{w}{4h}\right) \quad (5)$$

And the effective dielectric constant is calculated by using

$$\varepsilon_{eff} = \frac{\varepsilon_r+1}{2}+\frac{\varepsilon_r-1}{2}\left(1+10\frac{h}{w}\right)^{\frac{-1}{2}} \quad (6)$$

Thus by changing the width and length in the design can achieve optimized performance.

IV. SIMULATION RESULTS

The suggested Band pass filter using stub loaded impedance resonates at mm wave frequencies i.e at 31GHz for 5G applications. The performance parameters of filter include return loss and insertion loss. The return loss (S_{11}) and Insertion loss (S_{21}) are achieved as -23.8db and -1.15dB around center frequency. The VSWR is 1.13 and surface current distribution is also shown in fig.6.The filter is designed on a polyamide substrate with thickness 0.15mm and loss tangent 0.004.Open circuited stubs are placed along main transmission line between two low impedance sections to achieve desired resonance.

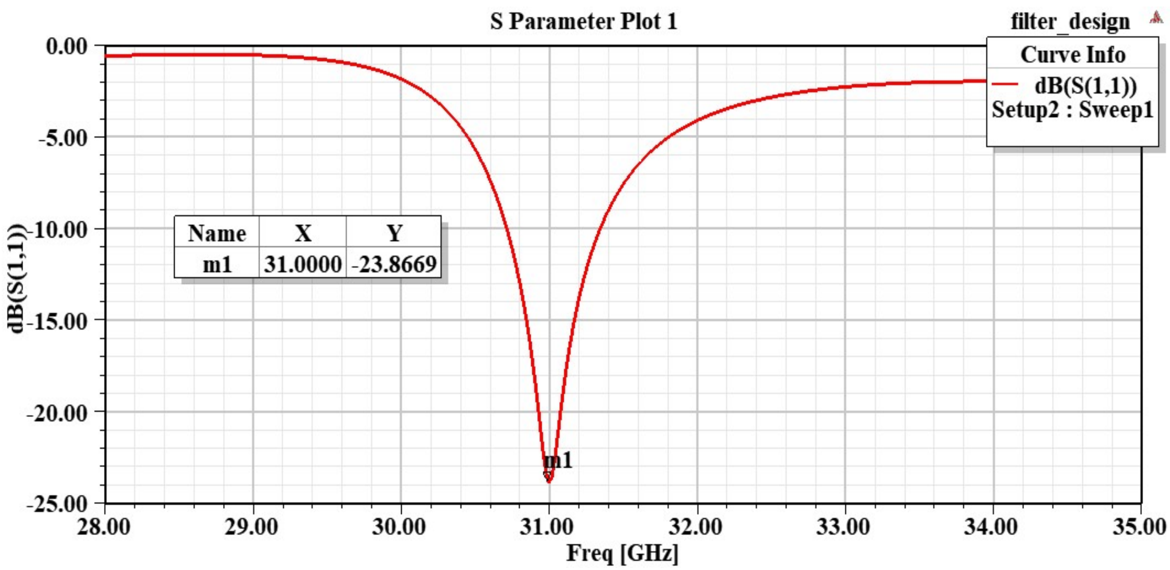

Fig 3: Return loss of BPF

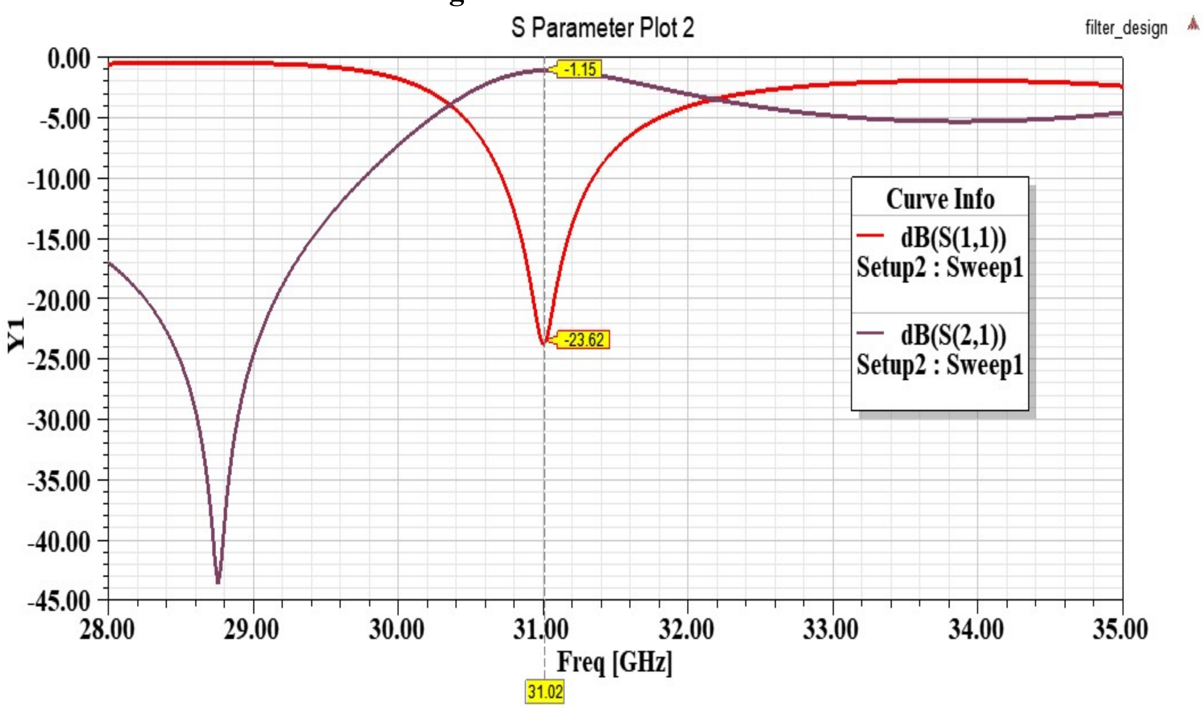

Fig 4: Insertion loss of BPF

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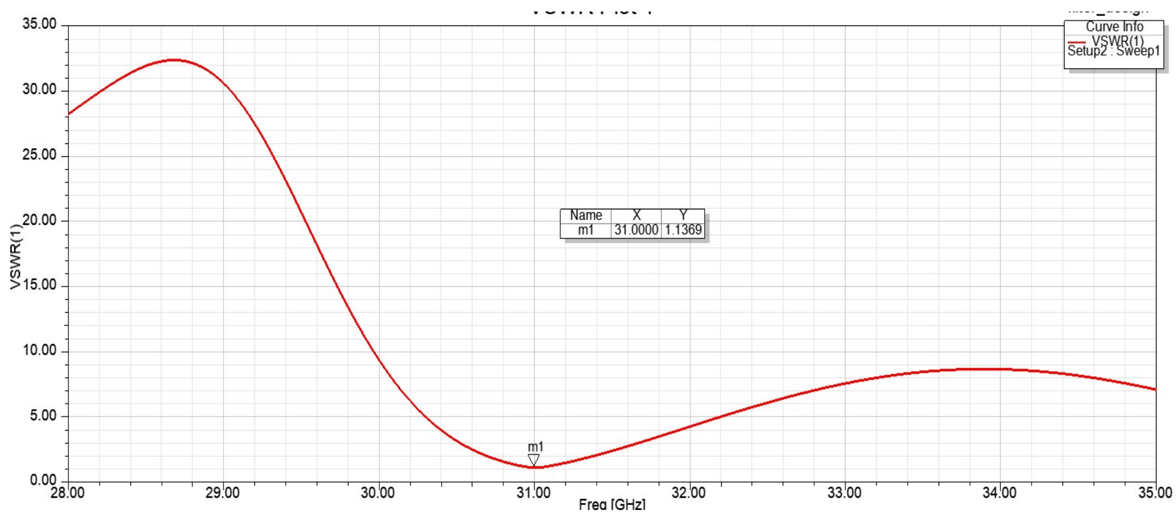

Fig 5: VSWR Plot

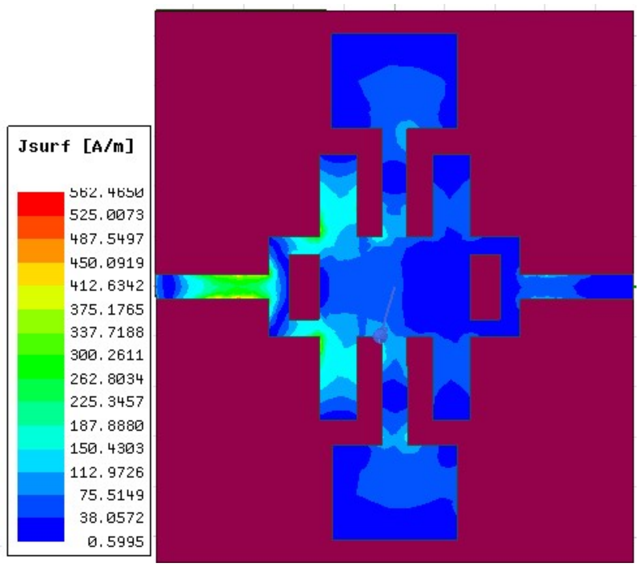

Fig 6: Surface Current Distribution in a filter

V.CONCLUSIONS

The design of Band pass filter with stub loaded impedance resonator for 5G applications is proposed. The proposed Band pass filter realized the pass band of 31.0GHz. Stub loaded impedance resonators are used to enhance the stop band attenuation and allows the desired signal frequencies. Furthermore, the filter can be integrated with antennas, microwave devices and Rf circuits.

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