Microwave Engineering

ECE3011 – C2+TC2

DESIGN OF A MICROSTRIP PARALLEL COUPLED BANDPASS FILTER

By

Shikhar Chandra – 18BEC0146

Arun Nambiar – 18BEC0928

Abhinav Kumar – 18BEC2017

Submitted to

Rajeshkumar V

Associate Professor Sr.

School of Electronics Engineering

TABLE OF CONTENT

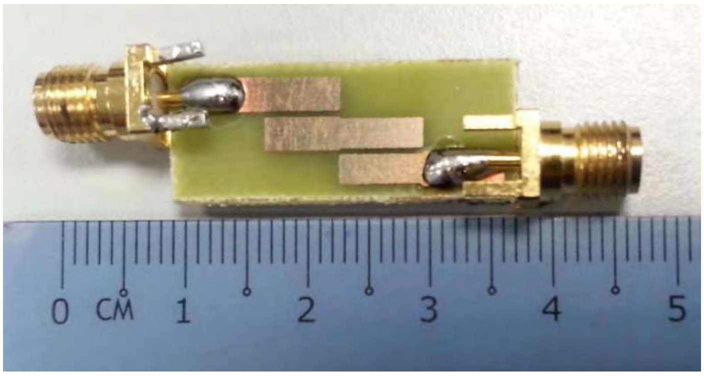
ABSTRACT

A 3rd order microstrip coupled line bandpass filter is proposed in this project which has a center frequency of 3.9 GHz and a bandwidth of 1250 MHz. The proposed filter is modelled on a commercial design and simulator, CST Microwave Studio. The dimensions and impedances of the filter are calculated using Admittance Inverter technique. Frequency Domain Solver (FDS) is used to simulate the S - parameters of the filter and obtain the results. The functionality of the filter is visualized by plotting the surface current distribution at different frequencies around the pass-band. Additionally, an experimental design is conducted where triangular edges are appended on the coupled lines to reduce the filter ripples. The performance of the filter is measured by calculating the minimum return loss (S11) and maximum insertion loss (S21).

INTRODUCTION

The key component in the microwave communication system is filter. There are various types of filters that are used in microwave communication systems classified as lowpass filter, high-pass filter, band-pass filter, and band-stop filter. The Microwave band pass filter is a fundamental device that contributes to the overall performance of a wireless communication system, be it in receiving or transmitting devices, to filter out unwanted frequency. The wireless communication systems have increased the demand of bandpass filters with higher accuracy due to growing applications and standards introduced in the modern communication system, the demand for the précised, narrow bandwidth and low loss had led to the innovative design of a band-pass filter. While designing a bandpass filter, consideration of parameters such as center frequency, bandwidth, low pass frequency, high frequency etc. needs to be made. As communication devices are getting smaller day by day and due to rough use, robustness and compact size of the filter are another important design consideration.

Microstrip filters are built as a carefully defined pattern on a PC board. There is almost no limit to the filter designs which can be built using a PC board pattern cut with hairpin curves, straight lines of varying widths, and other geometric arrangements singly or in combinations. Some microstrip bandpass filters simultaneously handle two or more frequencies, and also include notch filters as well, which would be difficult or impossible using other RF/microwave filter structures. What makes envisioning these filters and verifying them before actually making them is sophisticated EM-field modelling software, which analyses both their basic characteristics as well as the sensitivity of critical dimensions.



A fabricated microstrip filter

LITERATURE SURVEY

S.No	TITLE	Author and Journal	Key concepts
1.	Design of a Coupled-Line Microstrip Bandpass Filter at 3.5 GHz	Rajendra N. Kadam, Dr. A.B. Nandgaonkar IRJET (Vol 2, Issue 6, September 2015)	Chebyshev 4th order coupled line configuration. Centre frequency of 3.564GHz. Bandwidth ranges from 3.4368GHZto 3.6787GHz. Admittance inverters and Odd Even mode impedances of coupled line resonators
2.	Design of Compact 5th Order Parallel Coupled Microstrip Band pass filter	D.Nithya, V.Ashwini, G.Josephin Malkiya Thebarol, C.Jaysheela, R.Aishwarya UJAREEIE(Vol 7, Issue 3, March 2018)	Chebyshev 5th order filter, Half wavelength coupled lines, Realisation of Admittance inverters for the design. Centre frequency of 2.45 GHz Bandwidth ranges from 2.195-2.61GHz
3.	Design And Simulation Of 3.9 GHz Microstrip Parallel Coupled Line Bandpass Filter	A. H. Sani, C. Jianwen, M. T. Khan, S. B.Yussif, S. Nahar, K. E. Ewald, C. C. Ukwuoma IEEE (2019 16th International Computer Conference on Wavelet Active Media Technology and Information Processing)	Center frequency of 3.9GHz in the frequency range of 3.26-4.5 GHz. To reduce filter ripples, a small edge bent at 30 degrees is appended to the coupled lines.

CALCULATIONS

Desired Bandwidth = 1250 MHz

Desired Center Frequency = 3.9 GHz

Fractional Bandwidth: Δ = 1250 MHz / 3.9 GHz = 0.32

Order of Filter: N = 3

Equal-ripple 3 dB LPF prototype element value:

n	g_n
1	1.5963
2	1.0967
3	1.5963
4	1

Admittance Inverter Constants:

$$Z_0 J_1 = \sqrt{\frac{\pi \Delta}{2 g_1}},$$

$$Z_0 J_n = \frac{\pi \Delta}{2\sqrt{g_{n-1} g_n}} \quad \text{for } n = 2,\ 3, \ldots, N,$$

$$Z_0 J_{N+1} = \sqrt{\frac{\pi \Delta}{2 g_N g_{N+1}}}.$$

Odd And Even Impedances:

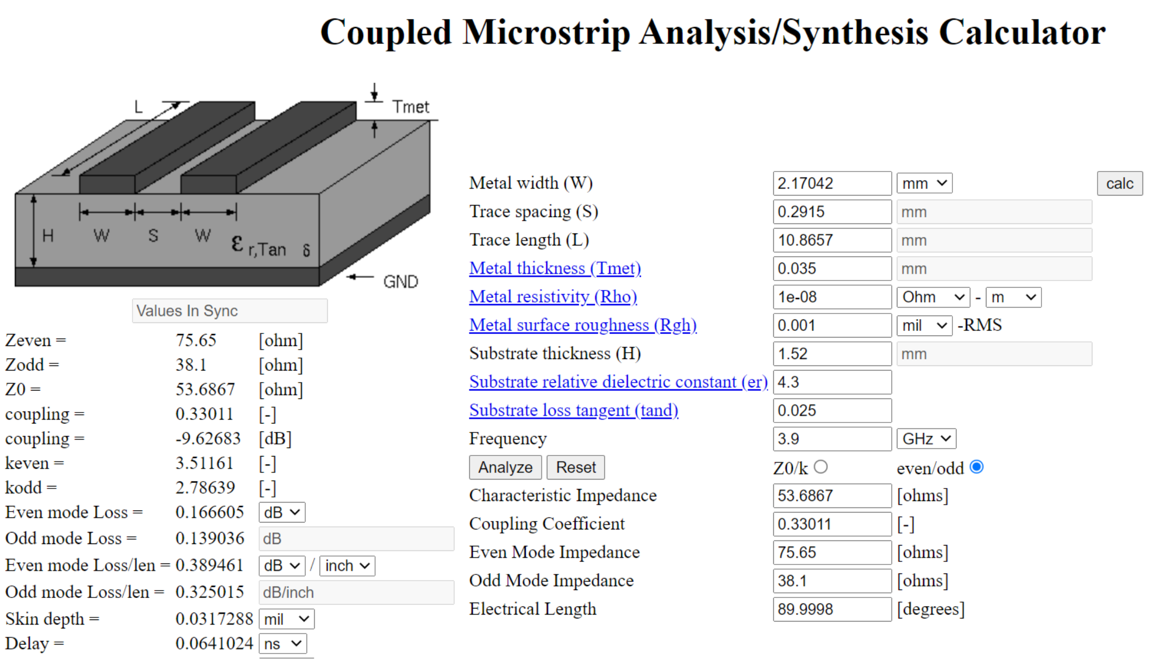
$$Z_{0e} = Z_0[1 + J Z_0 + (J Z_0)^2],$$

$$Z_{0o} = Z_0[1 - J Z_0 + (J Z_0)^2].$$

Calculated Even and Odd Mode Impedances:

Element n	***Even Mode Impedance Z0e (Ω)***	***Odd Mode Impedance Z0o (Ω)***
1	93.19	37.52
2	75.65	38.1
3	75.65	38.1
4	93.19	37.52

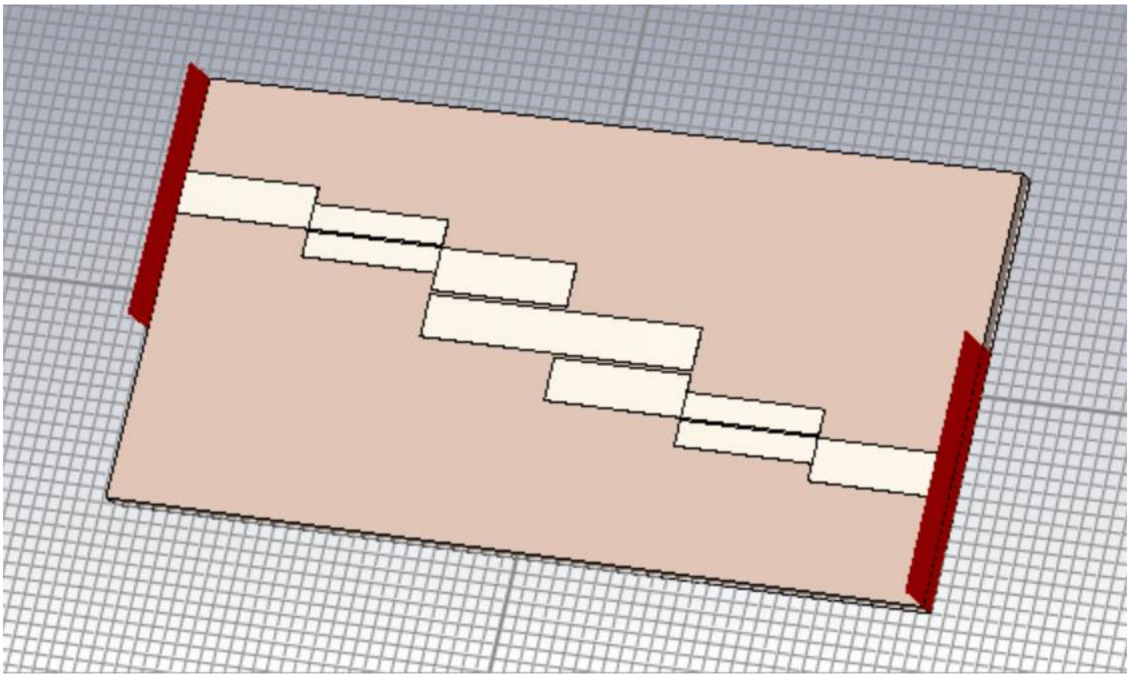
Online Tool to Calculate Length, Width and Gap of Coupled Lines:



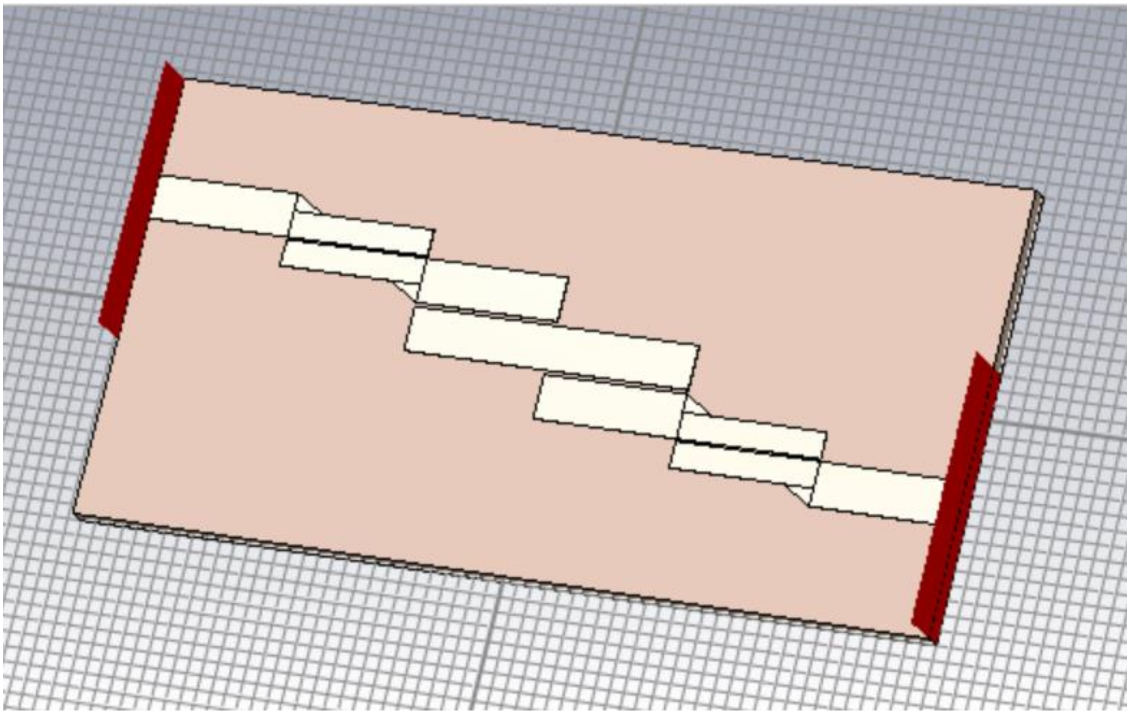
(Source: http://wcalc.sourceforge.net/cgi-bin/coupled_microstrip.cgi)

DESIGN

I. 3rd Order Bandpass Filter with Parallel Coupled Microstrip Lines:



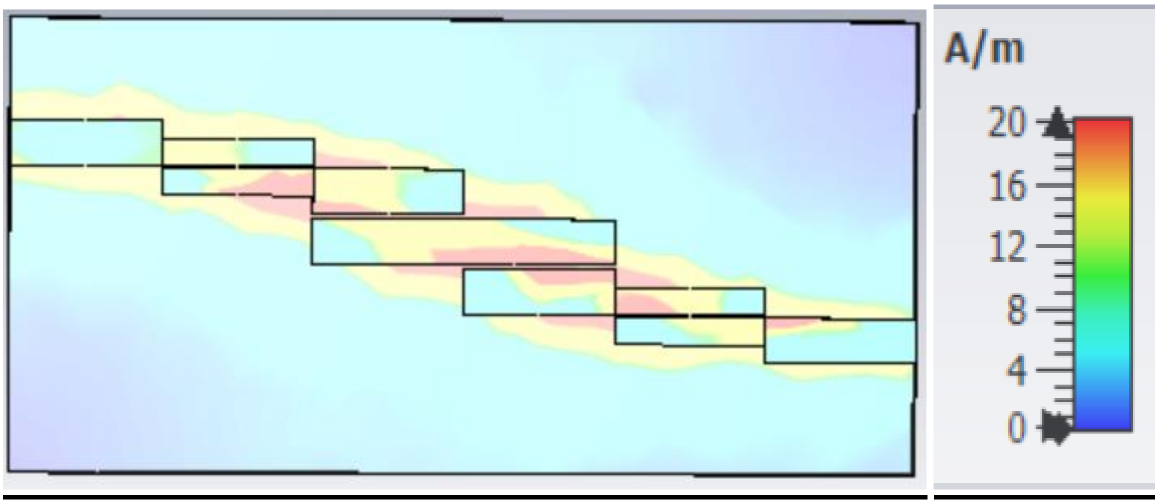
II. Bandpass Filter with appended triangular edges on coupled lines:



RESULTS AND INFERENCES

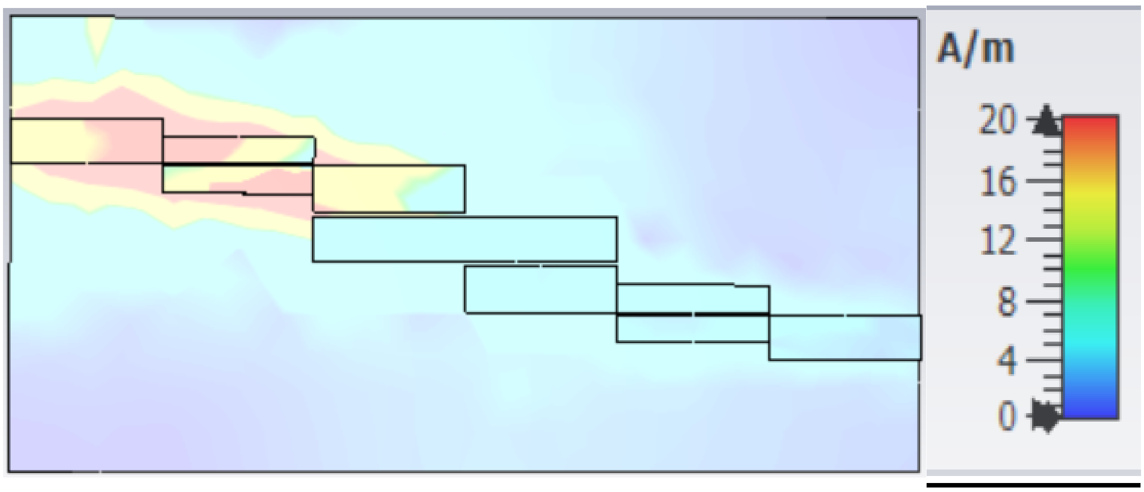
I. Surface Current Distribution of the bandpass filter

a. At f = 3.9 GHz:



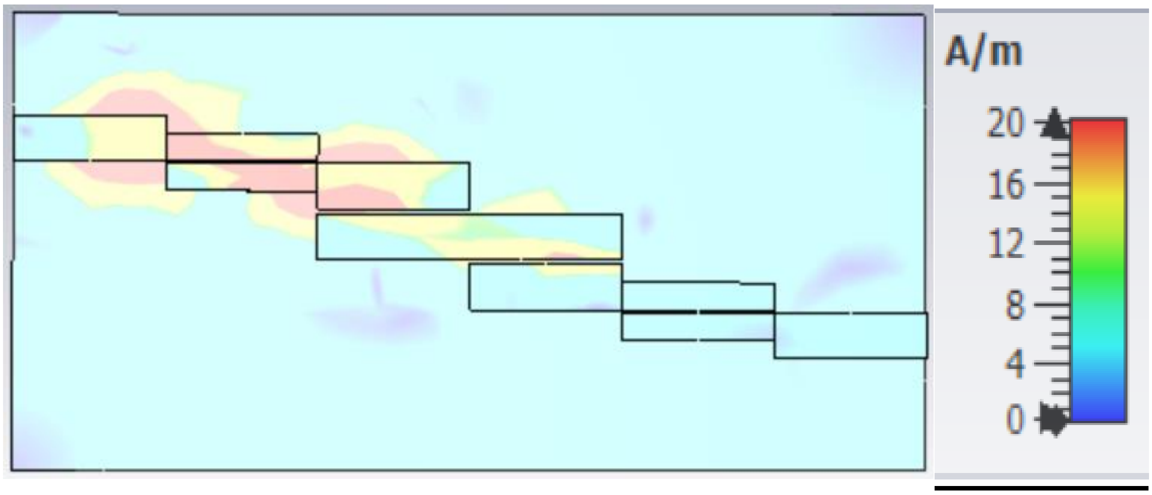
It is observed that at center frequency of 3.9 GHz, the surface current density is maximum throughout the bandpass filter. Hence, the signal is being passed from input port to output port at this frequency.

b. At f = 2.7 GHz:



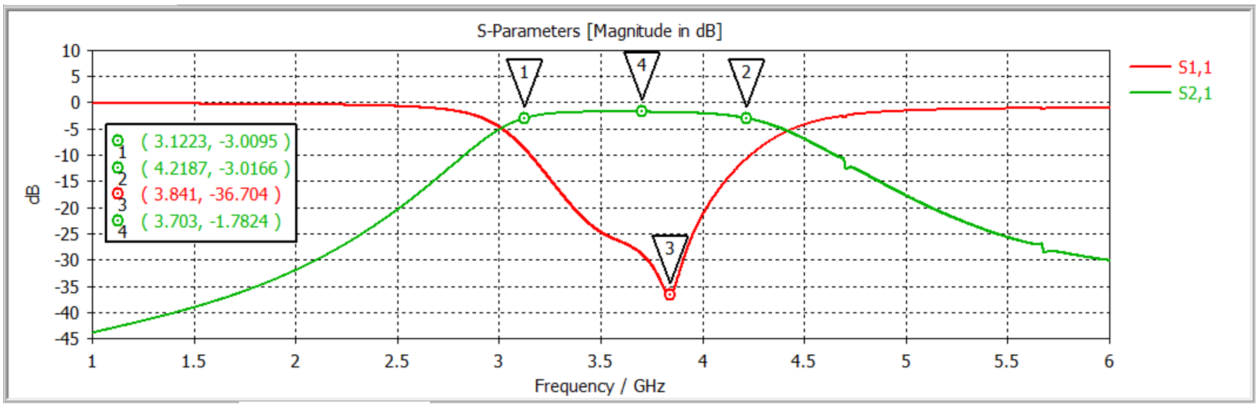
At frequency of 2.7 GHz, the surface current density is only maximum at the input port region of the bandpass filter. Hence, the signal is not being passed from input port to output port at this frequency.

c. At f = 4.5 GHz:



At frequency of 4.5 GHz, the surface current density is only maximum at the output port region of the bandpass filter. Hence, the signal is not being passed from input port to output port at this frequency.

II. Return Loss and Insertion Loss of Bandpass filter without added edges:



III. Return Loss and Insertion Loss of Bandpass filter with added edges:

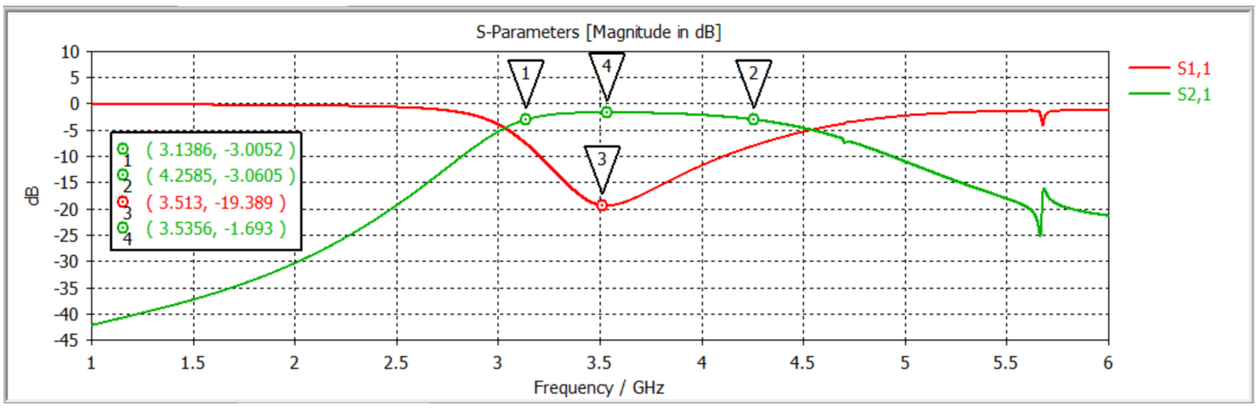


Table I. SIMULATION RESULTS

Filter Design	***Center Frequency (GHz)***	***3 dB Bandwidth (MHz)***	***Minimum Return Loss (dB)***	***Maximum Insertion Loss (dB)***
Without triangular edges	3.841	1096.4	-36.704	-1.7824
With triangular edges	3.513	1119.9	-19.389	-1.693

The initial filter design having no triangular edges has a center frequency close to the desired center frequency. However the bandwidth is less than the desired bandwidth. The filter provides a good minimum return loss of -36.704 dB, while a maximum insertion loss of -1.7824 dB.

The modified design with appended triangular edges has a shifted center frequency of 3.513 GHz and an increased bandwidth. The return loss is poor in this case but the insertion loss has improved.

CONCLUSIONS AND FUTURE WORK

The microstrip bandpass filter was successfully designed and simulated on CST Microwave Studio. The results of the software simulation approximately match with the theoretical design calculations. The filter has a very compact design and can be integrated in devices easily unlike the bulky waveguide and lumped element filters. The modified design with added edges has reduced the filter ripples and slightly increased the bandwidth of the filter. The filter, designed to operate at a center frequency of 3.9 GHz, will find use in many applications of mobile broadband. Based on the simulated results obtained, in future work the filter will be fabricated and further experiments would be conducted by adjusting the parameters to design the filter for factory applications such as in WiFi, WLAN etc.

REFERENCES

1. Design of a Coupled-Line Microstrip Bandpass Filter at 3.5 GHz, Rajendra N. Kadam, Dr. A.B. Nandgaonkar, IRJET (Vol 2, Issue 6, September 2015)

2. Design of Compact 5th Order Parallel Coupled Microstrip Band pass filter, D.Nithya, V.Ashwini, G.Josephin Malkiya Thebarol, C.Jaysheela, R.Aishwarya, UJAREEIE (Vol 7, Issue 3, March 2018)

3. Abubakar, Hassan & Jianwen, Chen & Khan, Muhammad & Yussif, Sophyani & Nahar, Saifun & Kuupole, Ewald & Ukwuoma, Chiagoziem. (2020). DESIGN AND SIMULATION OF 3.9 GHz MICROSTRIP PARALLEL COUPLED LINE BAND PASS FILTER.

4. O. Yeşilyurt, M. Köksal and T. İmeci, "Microstrip band pass filter design," 2015 23nd Signal Processing and Communications Applications Conference (SIU), 2015, pp. 379-382, doi: 10.1109/SIU.2015.7129838.

5. P. Priyanka , Dr. S. Maheswari , , 2018, Design of Microstrip Coupled Line Bandpass Filter Using Synthesis Technique, INTERNATIONAL JOURNAL OF ENGINEERING RESEARCH & TECHNOLOGY (IJERT) PECTEAM – 2018 (Volume 6 – Issue 02), http://dx.doi.org/10.17577/IJERTCON044

6. D.M Pozar, “Microwave Engineering”, 2nd edition, 1998 John-Wiley & Sons.

7. http://wcalc.sourceforge.net/cgi-bin/coupled_microstrip.cgi