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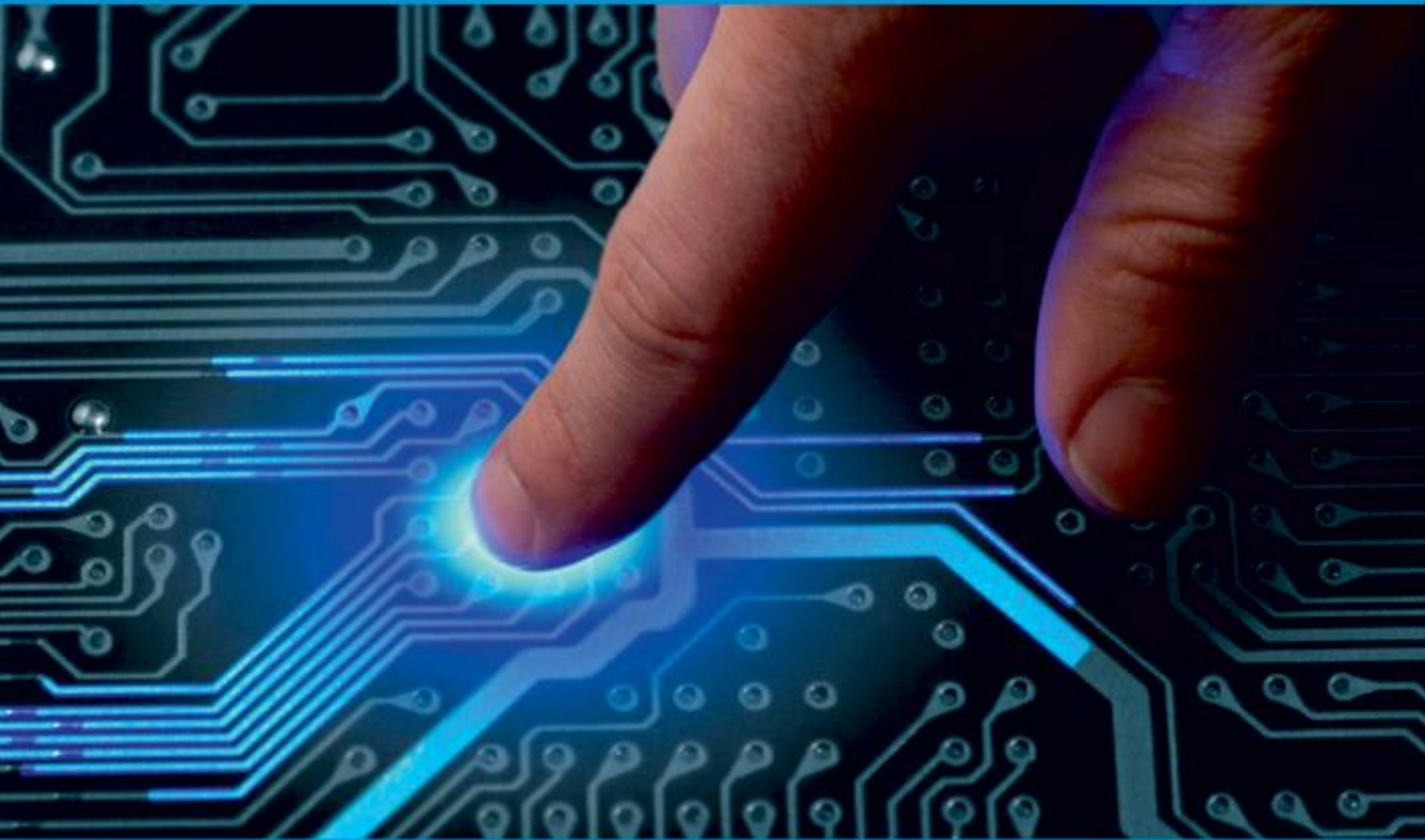

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Design and Implementation of Microwave Filters

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ABSTRACT: Microwave filters play a crucial role in various communication and signal processing systems by selectively allowing certain frequency ranges to pass while attenuating others. The design and implementation of microwave filters require a comprehensive methodology to ensure optimal performance and reliability. This paper presents an abstract that outlines the key aspects and considerations involved in the design and implementation of microwave filters. The abstract also highlights the importance of collaboration and communication among multidisciplinary teams involved in the design and implementation process.

KEYWORDS: HFSS, Microstrip, Microwave filters,Fabrication techniques, Filter design software

1. INTRODUCTION

In the rapidly evolving field of microwave engineering, the design and implementation of advanced filters play a pivotal role in shaping the performance of various wireless communication systems. This project delves into the realm of microwave digital filters, with a specific focus on the design and implementation of a stepped impedance low pass filter operating at a frequency of 2.4 GHz. By leveraging the inherent characteristics of stepped impedance structures, this innovative filter aims to selectively pass low-frequency signals while effectively attenuating high-frequency signals, thereby ensuring optimal signal integrity and efficient frequency spectrum utilisation and also a low-pass filter has numerous helpful properties like simple fabrication, compact size, and very low insertion loss. The High-Frequency Structure Simulator (HFSS) software, renowned for its robust capabilities in microwave design and analysis, serves as the primary platform for modeling, simulation, and performance evaluation.

A filter is a two-port system used to control the frequency response at one point in an RF or microwave system by giving transmission at frequencies inside the pass band of the filter and constriction in the stop band of the filter and the significance of this project lies in its direct relevance to commercial applications across diverse sectors, including but not limited to medical, radar, and military domains. By effectively suppressing unwanted high-frequency components and allowing passage of essential low-frequency signals, this filter design holds the potential to revolutionise critical areas such as medical diagnostics, radar systems for accurate target detection, and military communication networks.

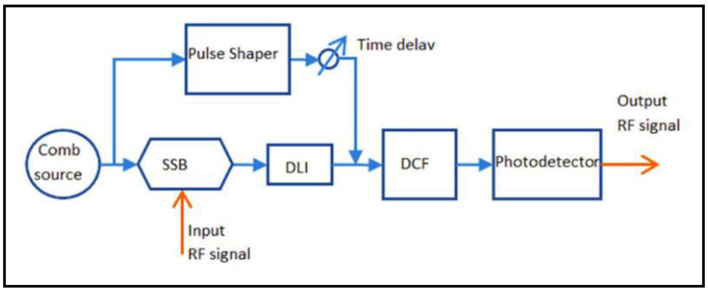

Fig 1:- Block Diagram of Microwave Filter Structure

2 .FILTER SPECIFICATIONS

The initial step in the design methodology is to perform a thorough analysis of the specifications and design requirements of the stepped impedance low pass filter. This analysis ensures a clear understanding of the project objectives and allows for the development of a targeted design approach. Here are the key aspects to consider during the specification analysis phantom. Differently, the reflected signals are collected and converted from the frequency domain to the time horizon. After processing, the signals produced are employed in confocal microwave image reconstruction algorithm to visualize the presence of a tumour inside the human head.

Thus, specification contains some aspects to understand the need of design ,

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a.Design Requirements: Identify the specific design requirements of the filter, such as the cutoff frequency, insertion loss, return loss, and impedance matching. Determine the desired frequency range over which the filter should effectively attenuate high-frequency signals.
Consider any application-specific requirements, constraints, or trade-offs that need to be addressed in the design.

b. Frequency Range: Define the frequency range of interest for the low pass filter. In your case, it is centered around 2.4 GHz. Consider the potential interference sources or desired signal bandwidth within this frequency range, taking into account the specific application context.

Response Type	Butterworth (or) Maximally flat
Cut off frequency(f_c)	2.4 GHz
Source and load impedance (Z_o)	50 ohm
Substrate height	1.2 mm
Dielectric Constant	4.4
Normalized frequency(Ω_c)	1 GHz
Loss tangent tan δ	0.01
Highest line impedance	93 ohm

Table 1 : Filter design specifications

3. FILTER TOPOLOGY SELECTION

The selection of an appropriate filter topology is a crucial step in the design methodology. The choice of topology determines the overall performance, complexity, and feasibility of the filter design. In this project, the stepped impedance low pass filter topology has been selected to achieve the desired frequency response characteristics. The following points elaborate on this selection:

A. Stepped Impedance Topology: The stepped impedance topology is a popular choice for designing low pass filters as it provides a gradual transition of impedance along the signal path. It offers improved performance in terms of stopband rejection, insertion loss, and return loss compared to other filter topologies. The stepped impedance topology achieves these characteristics by introducing impedance steps at specific locations within the filter structure.

B. Low-Pass Design : Basic design of microwave filters of type's low-pass, band-pass and band-stop, operating at arbitrary frequency bands and between arbitrary resistive loads, are made from a prototype low-pass design through:
1) Some frequency transformer,
2) Element normalization and Simulation of these elements by means of sections of microwave transmission line,

3) Design of a prototype low-pass filter with the desired pass band characteristics,
4) Transformation of this prototype network to the required type (low-pass, high-pass, band-pass) filter with the specified center and band-edge frequencies.
5) Realization of the network in microwave form by using sections of microwave transmission lines

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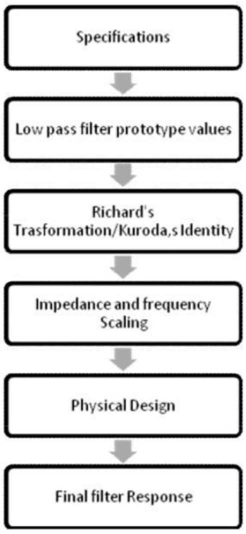

Fig 2 :- Implementation of Stepped Impedance pass filter

4. DESIGN PROCEDURE OF FILTER

1. Determine the number of sections from the specification characteristics for micro strip parameters.

- Filter Specifications:
- Relative Dielectric Constant εr =4.4
- Cutoff frequency=2.4GHz
- Height of substrade, h=1.6mm
- The filter impedance Z0 =50Ω
- The highest line impedance ZH=ZOL=120Ω
- The lowest line impedance ZL=ZOC=20Ω

2. To calculate the width of capacitor and inductor we use the following formula.

For $\frac{W}{h} < 2$

$$\frac{W}{h} = \frac{\theta exp(A)}{(exp(2A)-2)} \quad (1)$$

Where, $A = \frac{Z_c}{60}\sqrt{\frac{\varepsilon_r+1}{2}}\frac{\varepsilon_r-1}{\varepsilon_r+1}(0.23 + \frac{0.11}{\varepsilon_r}$ (2)

Where, $Z_c = \frac{\eta}{2\pi}\sqrt{\varepsilon_{re}}[\text{In}(\frac{gh}{w} + 0.25\frac{w}{h})]$ (3)

Where, η = 120π ohms is the wave impedance in free space.

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For, $\frac{W}{h} > 2$

$\frac{w}{h} = \frac{\eta}{\pi}[B - 1 - \ln(2B - 1) + \frac{\varepsilon_r - 1}{2\varepsilon_r}\{\ln(B - 1) + 0.39 - \frac{0.61}{\varepsilon_r}\}]$ (4)

The effective dielectric constant can be found by the following Formula,

$\varepsilon_{re} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_{r-1}}{2}[1 + 12\frac{h}{w}]^{-0.5}$ (5)

Effective wavelength is also found as,

$\lambda_{ge} = \frac{\lambda}{\sqrt{\varepsilon_{re}}}$ (6)

3. The effective dielectric constant obtained by using following equation,

when $(\frac{W}{H}) < 1$

$$\varepsilon_e = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}[(1 + 12(\frac{H}{W}))^{-\frac{1}{2}} + 0.04(1 - \left(\frac{W}{H}\right))^2$$

When$(\frac{W}{H}) \geq 1$

$$\varepsilon_e = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}(1 + 12(\frac{H}{W}))^{-\frac{1}{2}}$$

$$\varepsilon_e = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\frac{1}{[1 + 12(\frac{H}{W})]}$$

4. The electrical lengths of inductors and capacitors sections of the transmission line are obtained from following formula

$$\beta L = \frac{Z_0 L}{Z_{high}} forinductor$$

$$\beta L = \frac{C Z_{low}}{Z_0} forcapacitor$$

Where β is the phase constant, transmission line physical lengths is represent as l . High is the inductive impedance and Slow is the capacitive impedance of the transmission lines

when $(\frac{W}{H}) < 1$

$$\varepsilon_e = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}[(1 + 12(\frac{H}{W}))^{-\frac{1}{2}} + 0.04(1 - \left(\frac{W}{H}\right))^2$$

When$(\frac{W}{H}) \geq 1$

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$$\varepsilon_e = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}(1+12(\frac{H}{W}))^{-\frac{1}{2}}$$

$$\varepsilon_e = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\frac{1}{[1+12(\frac{H}{W})]}$$

With the above equations we have calculated the design calculations step involves performing the necessary calculations to determine the required impedance steps, dimensions, and component values for the stepped impedance low pass filter. The normalised element are then changed to L-C components for the craved cut off frequency and normally 50Ω source impedance is use for micro-strip filter. In this paper cutoff frequency of 2.4Ghz , the FR4 substrate having 4.4 dielectric constant with 1.6mm thickness has been utilised

5. SIMULATION AND ANALYSIS

Simulation analysis plays a crucial role in the design and optimisation of the stepped impedance low pass filter. By leveraging electromagnetic simulation software, such as HFSS (High-Frequency Structure Simulator), you can accurately model and analyse the behaviour of the filter.

a. Simulation Frequency Range: Specify the frequency range for the simulation to encompass the desired operating frequency range of the stepped impedance low pass filter. Consider the requirements of the application and the frequency-dependent behaviour of the filter in selecting the appropriate frequency range. Ensure that the frequency range is wide enough to capture the passband, stop band, and any critical transition regions of the filter response.

Thus , the stimulation result in the design and optimisation of the stepped impedance low pass filter.

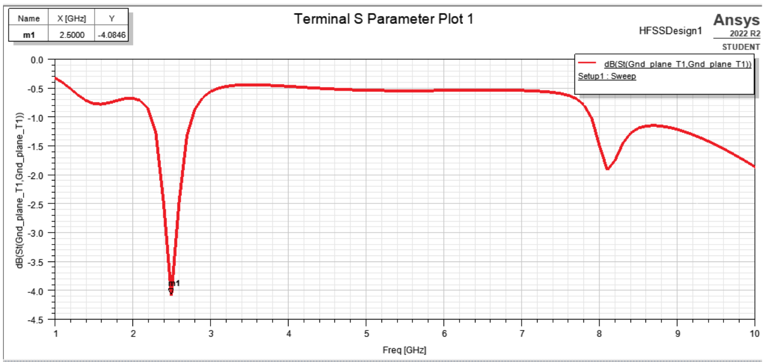

Fig 3:- S(1,1) Parameter Of Low Pass Filter

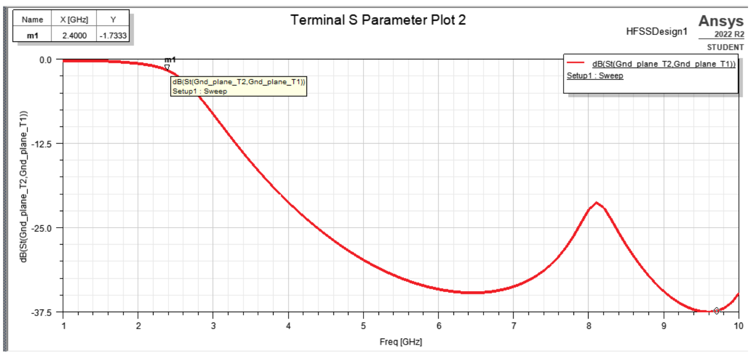

Fig 4:- S(2,1) Parameter Of Low Pass Filter

6. FABRICATION AND IMPLEMENTATION

The fabrication and implementation phase is a crucial step in bringing the designed stepped impedance low pass filter from the simulation stage to a physical prototype. This phase involves translating the design into a tangible form using appropriate fabrication techniques and ensuring its proper implementation.

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a. Microfabrication Processes: Micro fabrication techniques, including thin-film deposition and etching, are suitable for fabricating high-frequency and miniaturised filters.These processes involve depositing thin films of conductive and dielectric materials on a substrate and selectively removing them to create the desired filter structure. Choose the appropriate deposition technique, such as sputtering or evaporation, to achieve precise and uniform film thicknesses. Utilise advanced lithography techniques, such as photolithography or electron beam lithography, for accurate patterning of the deposited films.

b. Compatibility with Fabrication Techniques: Ensure that the selected material is compatible with the chosen fabrication techniques. Consider the material's compatibility with processes such as photolithography, etching, deposition, or lamination. Verify that the material can withstand the temperatures, pressures, and chemical exposures involved in the fabrication steps.

c. Fabrication and Testing of Revised Prototype:

Fabricate a revised prototype incorporating the design modifications identified in the previous step.
Follow the established fabrication process, taking into account the lessons learned from the initial prototype.
Conduct thorough testing and evaluation of the revised prototype, measuring its performance parameters and comparing them against the design specifications.

Thus the fabrication process measure its performance by Developing a flow diagram that outlines the fabrication process steps for manufacturing the microwave filter.This diagram includes steps such as substrate preparation, material deposition, photolithography, etching, metallisation, and any other relevant processes.

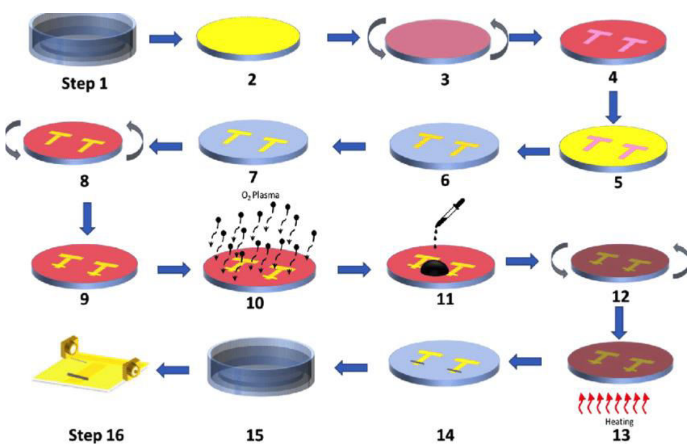

Fig 5:- Fabrication procedure to followed to fabricate the filter

7. CONCLUSION

In conclusion, the design and implementation of a stepped impedance low pass filter for commercial use have been successfully accomplished. A low pass filter with tenable frequency ratio is a versatile and cost-effective solution for removing unwanted high-frequency noise from a signal. Its flexibility and simplicity make it a popular choice in a wide range of applications, from audio to radio communications.

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