PROJECT REPORT
on
MICROWAVE FILTERS

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CERTIFICATE

*Certified that the seminar report entitled “ **MICROWAVE FILTERS** ” is a bonafide work of ALEENA MARIA GEORGE, AMRITA UNNI ,BASITHA A L, BHAGYALAKSHMI PA, JOEL ROY…. towards the partial fulfillment for the award of the degree of B.Tech in Electronics and Communication of Cochin University of Science and Technology, Kochi-682022.*

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ABSTRACT

Microwave filters are key elements in microwave and RF engineering, serving as critical components in communication systems, radar systems, and various wireless applications. These filters are designed to manipulate the spectral characteristics of signals by allowing desired frequencies to pass through while attenuating unwanted frequencies. The demand for efficient and compact filters has led to the development of diverse filter topologies, including cavity filters, microstrip filters, and lumped element filters. Advanced materials and fabrication techniques are employed to achieve optimal performance in terms of insertion loss, bandwidth, selectivity, and size. Microwave filters find applications in satellite communication, cellular networks, radar systems, and scientific research. Different filter architectures, such as cavity filters, microstrip filters, and lumped element filters, are employed based on the specific requirements of the application.microstrip filters utilize printed circuit board technology, enabling compact and lightweight designs that are well-suited for modern wireless communication devices. Lumped element filters, which consist of discrete components like inductors and capacitors, offer flexibility in design but may be limited in terms of size and frequency range.

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LIST OF FIGURES

CHAPTER 1

INTRODUCTION

Microstrip filters are a class of electronic filters that are widely used in radio frequency (RF) and microwave applications. These filters are particularly popular due to their compact size, low cost, ease of fabrication, and compatibility with integrated circuit technologies. Microstrip filters find extensive use in communication systems, radar systems, satellite communication, and various other wireless applications. Microstrip filters are a type of planar transmission line filter that is constructed on a substrate using microstrip technology. The microstrip technology involves the use of a thin conductor strip (usually made of copper) on the surface of a dielectric substrate, with a ground plane on the opposite side. The design and configuration of the microstrip filter elements determine their filtering characteristics.

Key Features of Microstrip Filters:

1. 1. Compact Size: Microstrip filters are known for their compact size, making them suitable for applications where space is a critical factor.
2. 2. Ease of Fabrication: The fabrication process of microstrip filters is relatively straightforward and compatible with standard printed circuit board (PCB) manufacturing techniques. This contributes to their cost-effectiveness.
3. 3. Frequency Range: Microstrip filters cover a broad range of frequencies, from radio frequency (RF) to microwave frequencies. They can be designed for various wireless communication standards.
4. 4. Configurations:Microstrip filters come in various configurations, including low-pass, high-pass, band-pass, and band-stop filters, providing flexibility in meeting different filtering requirements.
5. 5. Integration: Microstrip filters can be easily integrated into microwave integrated circuits (MICs) and monolithic microwave integrated circuits (MMICs), enabling the development of multifunctional RF and microwave systems.

Types of Microstrip Filters:

1. Low-Pass Filters: Allow signals with frequencies below a certain cutoff frequency to pass through.
2. High-Pass Filters:Allow signals with frequencies above a certain cutoff frequency to pass through.
3. Band-Pass Filters: Permit signals within a specific frequency range to pass while attenuating others.
4. Band-Stop Filters (Notch Filters):Block signals within a specific frequency range while allowing others to pass.

Applications:

Microstrip filters are utilized in various applications, including:

- Communication Systems:Microstrip filters play a crucial role in wireless communication systems, including cellular networks, Wi-Fi, and satellite communication. -
- Radar Systems:Radar systems use microstrip filters for signal processing and frequency selection. -
- Medical Imaging:Microstrip filters are employed in medical devices, such as MRI machines and communication systems in healthcare applications.
- Aerospace and Defense:Microstrip filters are commonly used in avionics and defense applications for their reliability and performance.

CHAPTER 2

IMPLEMENTATION AND DEVELOPMENT

IMPLEMENTATION

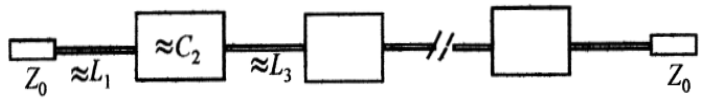
Since this semester , our project work mainly concentrated on understanding the basics of microwave planar filters . Some references were taken from Microstrip Filters for RF/Microwave Applications. Jia-Sheng Hong, M. J. Lancaster. We simulated four filters in HFSS and obtained the S11 and S21 parameters of the same

2.1.LOW-PASS FILTERS

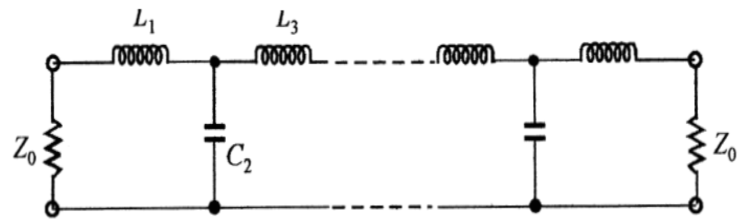
In general, the design of microstrip lowpass filters involves two main steps. The first one is to select an appropriate lowpass prototype and the choice of the type of response, including passband ripple and the number of reactive elements, will depend on the required specifications.The element values of the lowpass prototype filter, which are usually normalized to make a source impedance g0 = 1 and a cutoff frequency c = 1.0, are then transformed to the L-C elements for the desired cutoff frequency and the desired source impedance, which is normally 50 ohms for microstrip filters. The lowpass filters we simulated in HFSS are as follows:

2.1.1 Stepped-Impedance, L-C Ladder Type Lowpass Filters

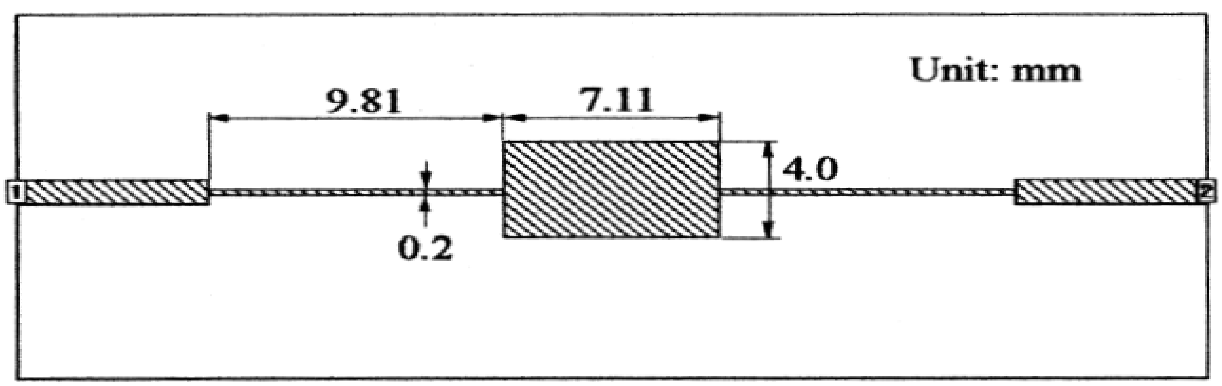
Figure 2.1(a) shows a general structure of the stepped-impedance lowpass microstrip filters, which use a cascaded structure of alternating high- and low impedance transmission lines. These are much shorter than the associated guided wavelength, so as to act as semi lumped elements. The high-impedance lines act as series inductors and the low-impedance lines act as shunt capacitors. Therefore, this filter structure is directly realizing the L-C ladder type of lowpass filters of Figure 2.1(b).



(*a*)



General structure of the stepped-impedance lowpass microstrip filters. L-C ladder type of low pas filters to be approximated.



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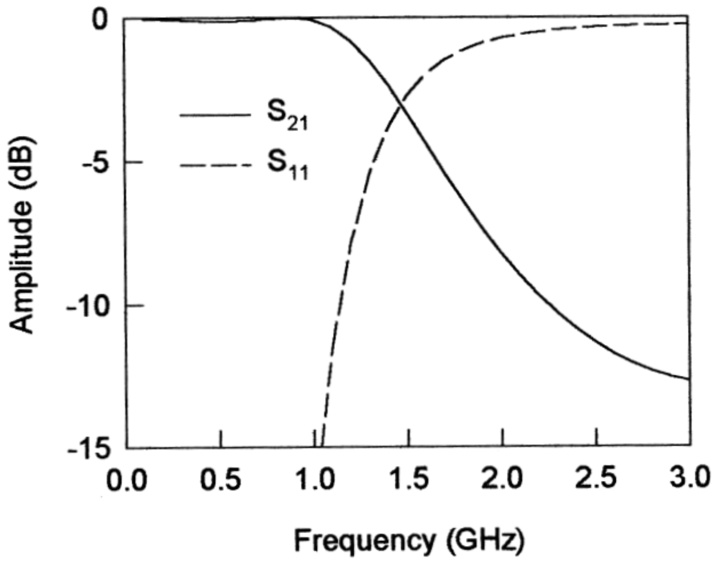
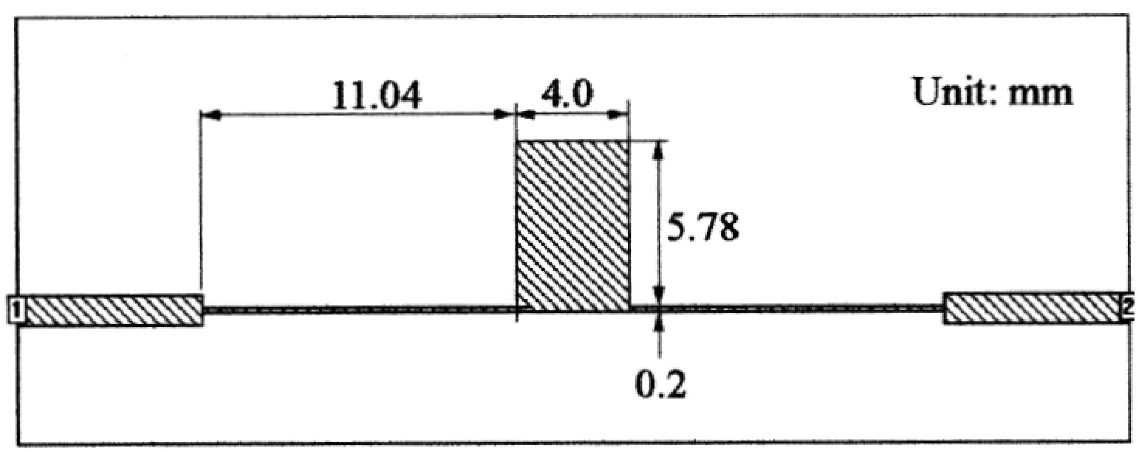


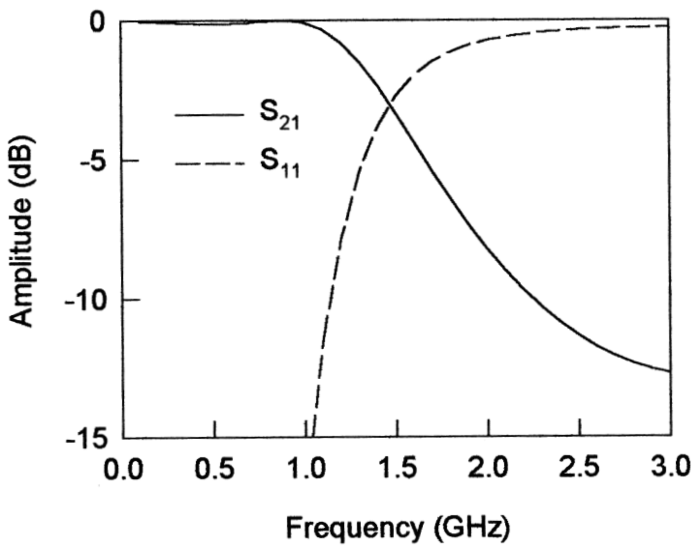
2.1 a) Layout of a three-pole, stepped-impedance microstrip lowpass filter on a substrate with a relative dielectric constant of 10.8 and a thickness of 1.27 mm. (b) Full-wave EM simulated performance of the filter

2.1.1.1L-C Ladder Type of Lowpass Filters Using Open-Circuited Stubs

The previous stepped-impedance lowpass filter realizes the shunt capacitors of the lowpass prototype as low impedance lines in the transmission path. An alternative realization of a shunt capacitor is to use an open-circuited stub .



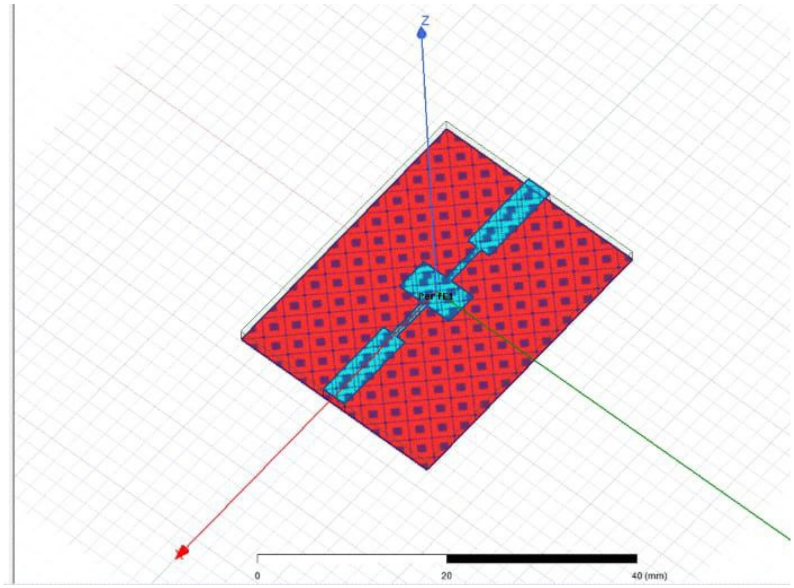
The S21 and S11 response of the filter will be as follows:

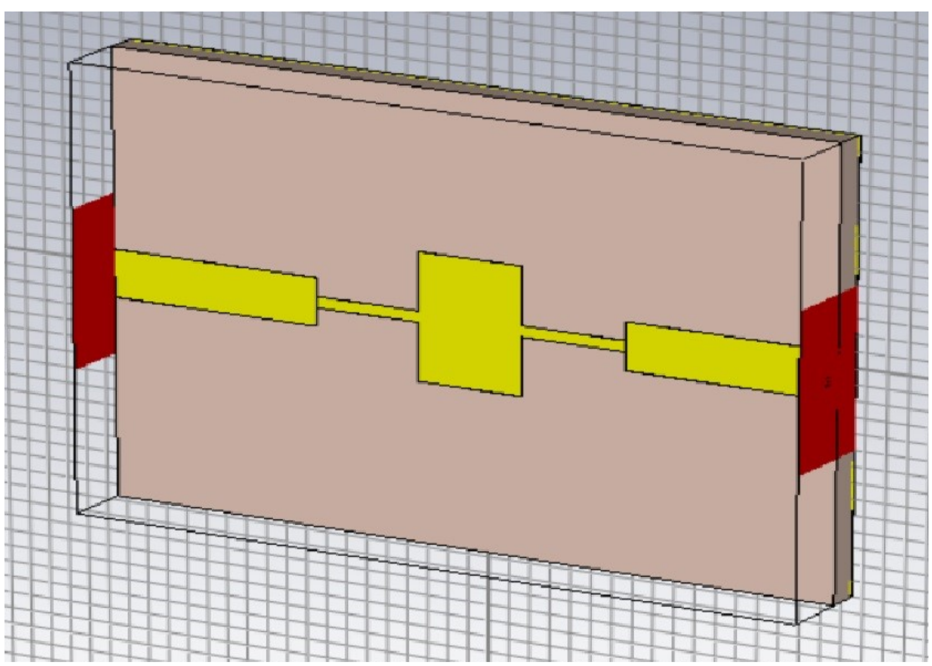


The filter was implemented in HFSS. A substrate with a relative dielectric constant of 10.8 and a thickness of 1.27 mm. and obtained the corresponding responses.

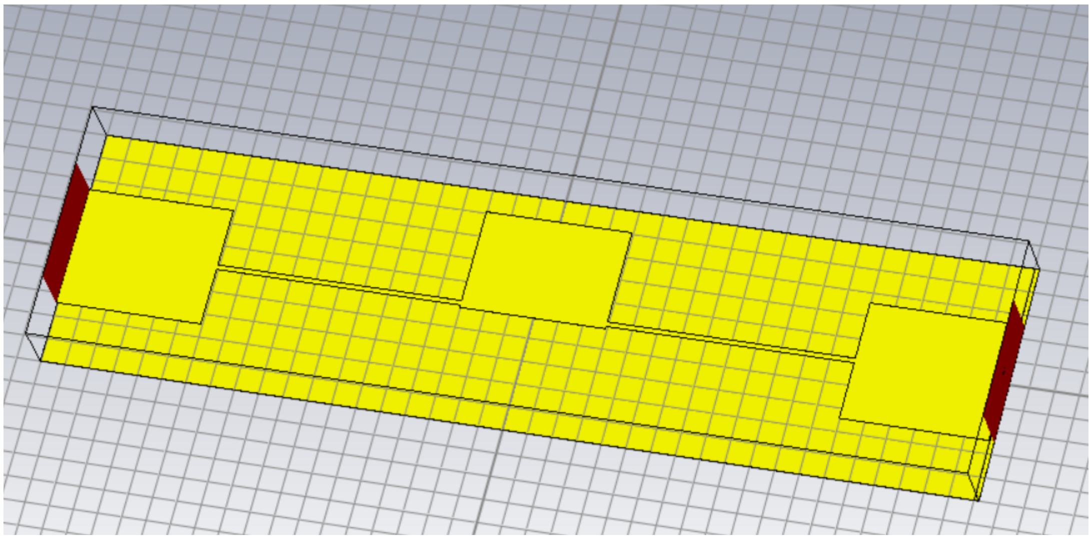
FILTER IMPLEMENTED IN HFSS AND CST

i.Stepped-Impedance, L-C Ladder Type Low-pass Filters





ii.**L-C Ladder Type of Lowpass Filters Using Open-Circuited Stubs**



2.2BANDPASS FILTER

Designing a microwave bandpass filter involves specifying the center frequency and bandwidth, selecting an appropriate filter type (e.g., lumped or distributed element), calculating component values based on chosen topology, simulating the design using specialized software to ensure performance meets specifications, building a physical prototype, and testing the filter using equipment like vector network analyzers. Considerations include soldering quality, layout, temperature stability, and the need for tuning during the prototyping phase. The choice between lumped and distributed elements depends on factors such as compactness, frequency range, and power handling capabilities. Consulting experienced RF engineers or using specialized tools is recommended for those unfamiliar with microwave filter design.

2.2.1 3 Pole Microstrip End-Coupled Half-Wavelength Resonator

The Pole Microstrip End-Coupled Half-Wavelength Resonator (PMHWR) is a specific configuration commonly employed in the design of microwave bandpass filters. This type of filter utilizes microstrip transmission lines to create resonators that determine the frequency response of the filter. The PMHWR design involves coupling a microstrip line with an open-ended stub to create a half-wavelength resonator. The resonator's characteristics, such as the length of the microstrip line and the coupling at the open end, influence the filter's performance. The end-coupling method allows for precise control over the filter's bandwidth and center frequency. Engineers often use simulation tools to optimize the dimensions and achieve desired specifications. Fabrication involves precise construction of microstrip lines on a substrate, and testing is crucial to validate the real-world performance of the bandpass filter, considering factors like insertion loss, return loss, and out-of-band rejection.

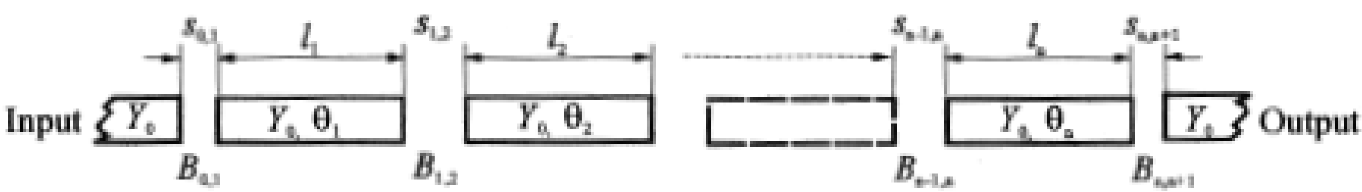
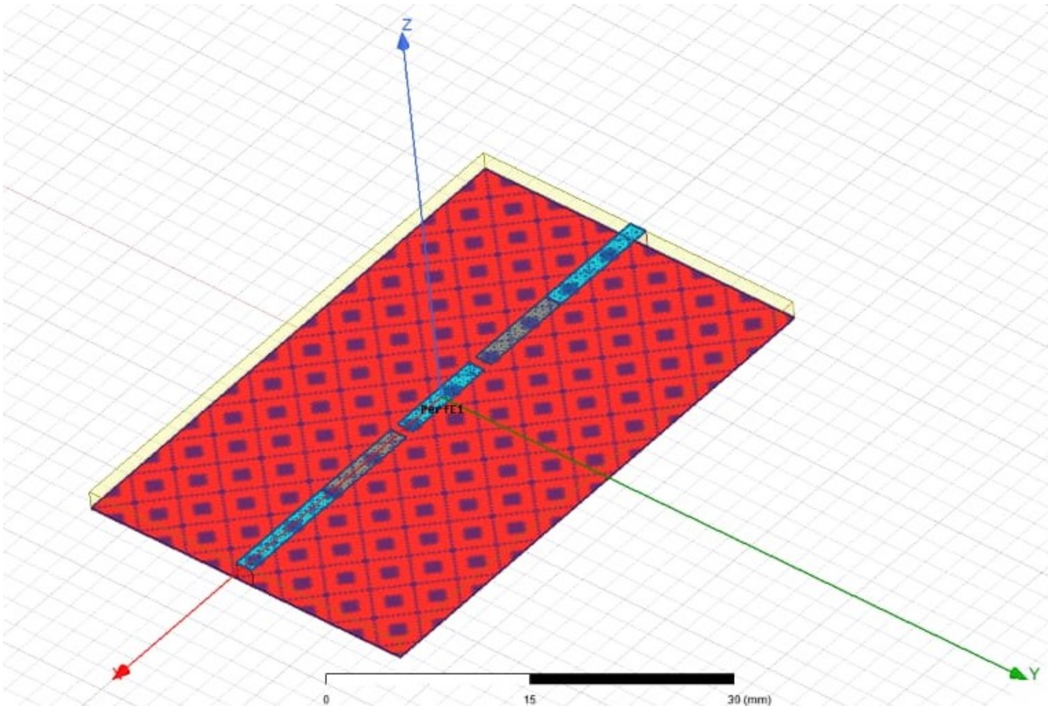


fig2.1 General configuration of end-coupled microstrip bandpass filter.

FILTER IMPLEMENTED IN HFSS



2.2.2 5-Pole Microstrip Bandpass Filter

A 5-pole microstrip bandpass filter is a type of microwave filter that incorporates five resonators to achieve a specific frequency response. These filters are designed using microstrip transmission lines, which are printed on a substrate such as a printed circuit board. Each resonator contributes to shaping the filter's frequency characteristics, and the combination of these resonators creates the desired bandpass filter response. The microstrip technology allows for compact and lightweight designs suitable for various microwave applications.

Engineers use simulation tools to determine the dimensions and characteristics of each resonator, optimizing the filter's performance in terms of center frequency, bandwidth, and selectivity. The fabrication process involves precision in the layout and construction of the microstrip lines on the substrate. Testing, typically done with network analyzers, verifies the actual performance of the 5-pole microstrip bandpass filter in terms of insertion loss, return loss, and the ability to reject out-of-band signals.

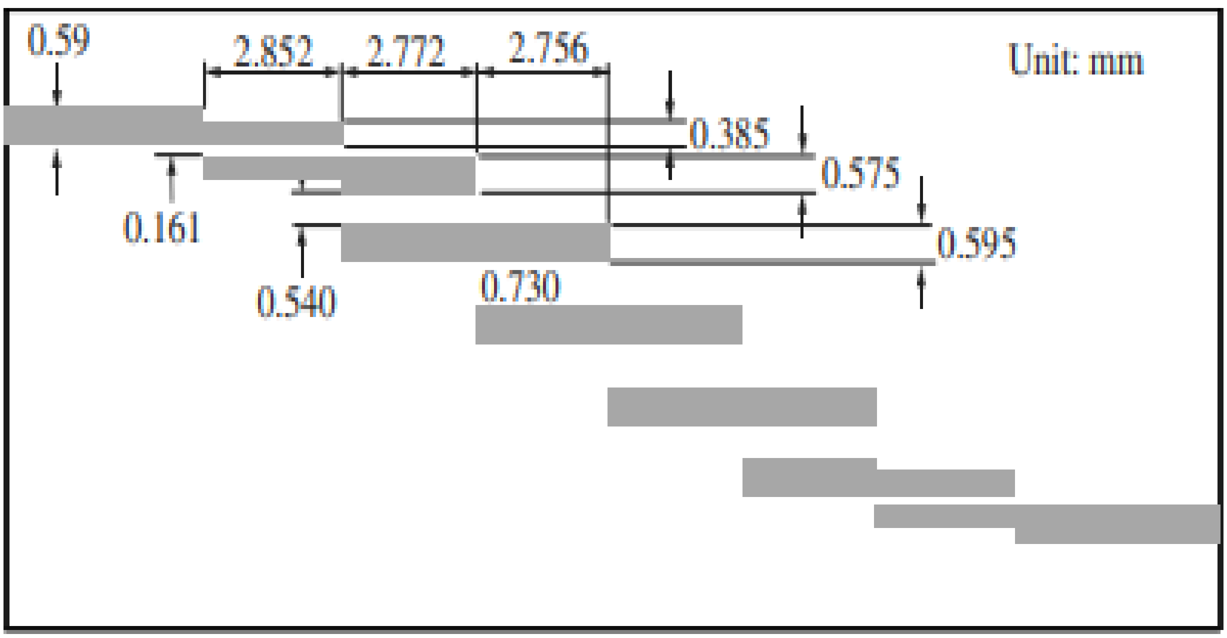
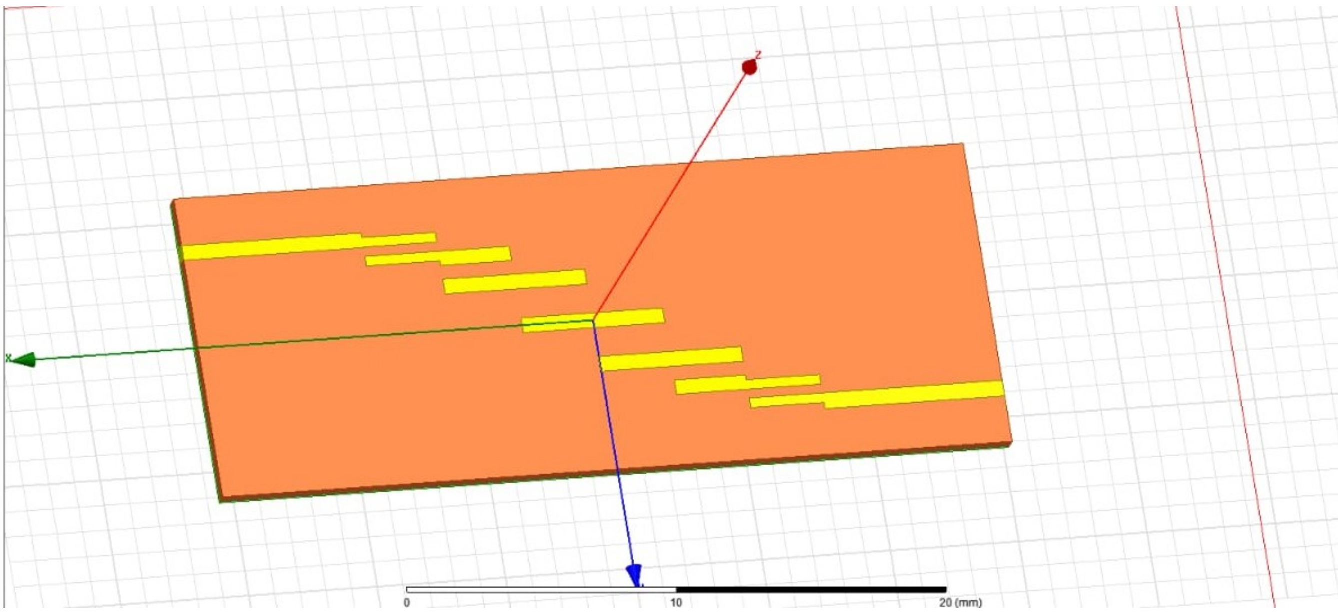


fig2.2 Layout of a five-pole microstrip bandpass filter designed on a substrate

FILTER IMPLEMENTED IN HFSS



CHAPTER 3

RESULTS

1. LOW-PASS FILTERS

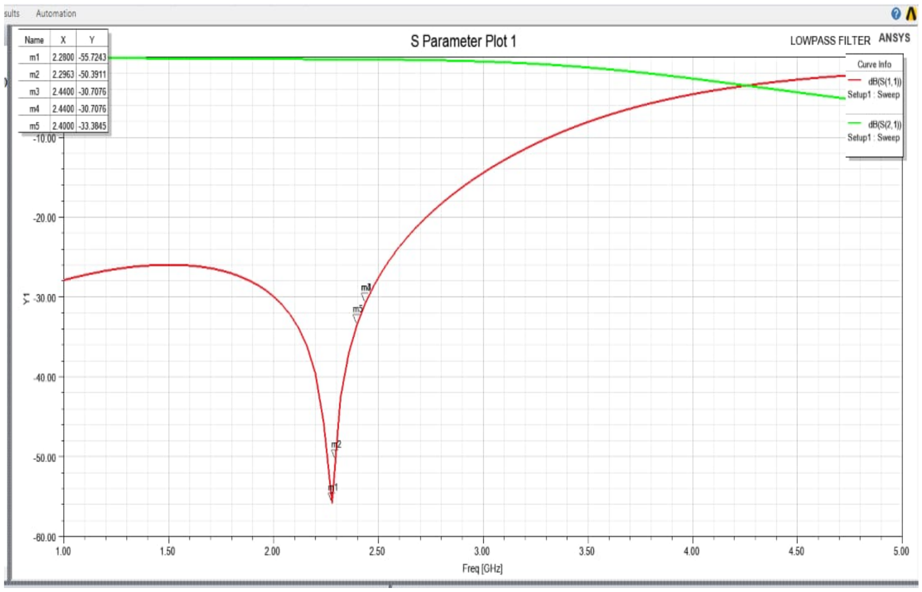


Fig 8.1 3 pole stepped impedence Low pass Filter ,plotted S11 and S21.

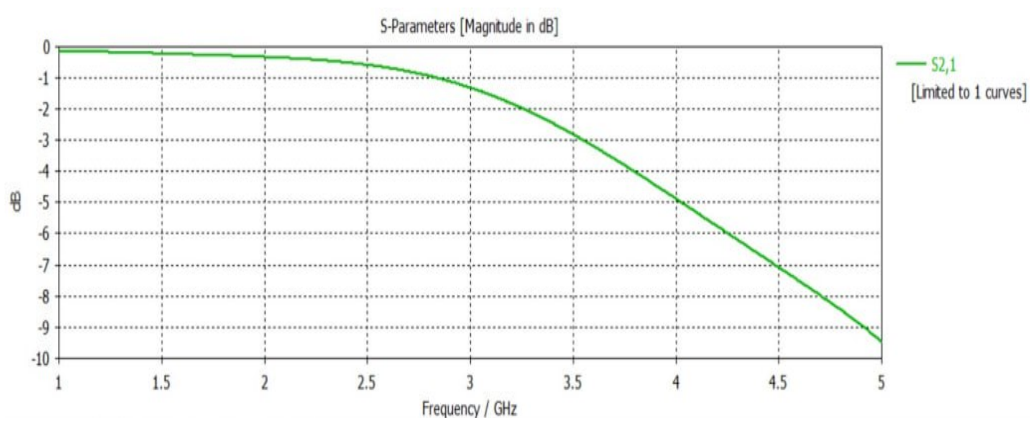


Fig8.2 3 pole open circuited stub Low pass Filter, S21 plotted

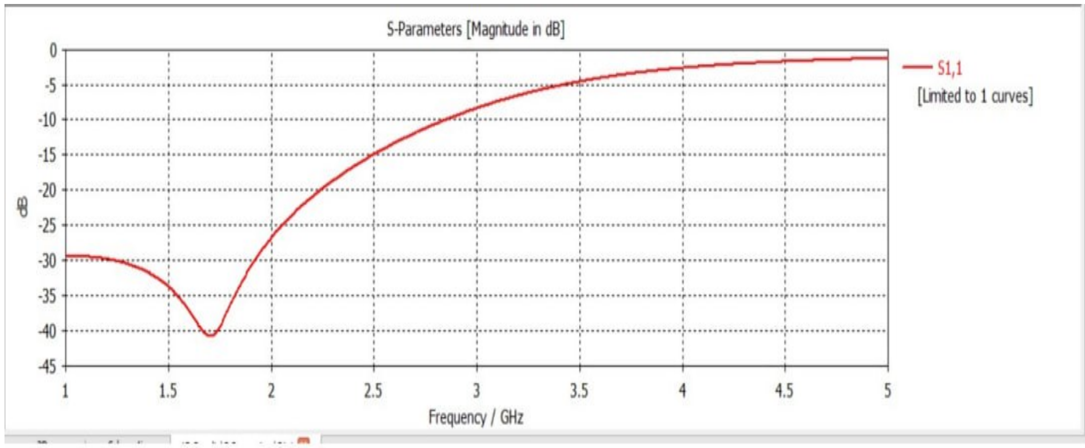


Fig 8.3 3 pole open circuited stub Low pass Filter, S11 plotted

2.BAND-PASS FILTERS

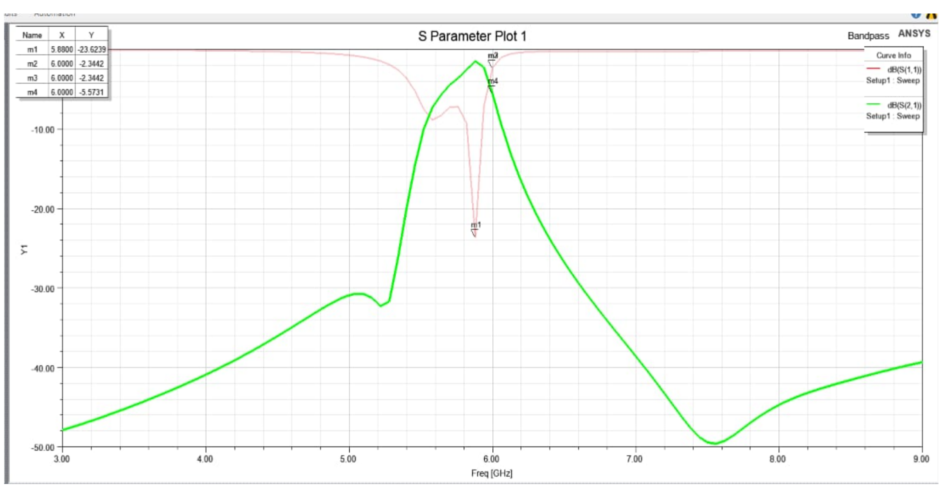


Fig 8.4 3 pole microstrip end coupled half wavelength resonator filter,S11 and S21 plotted

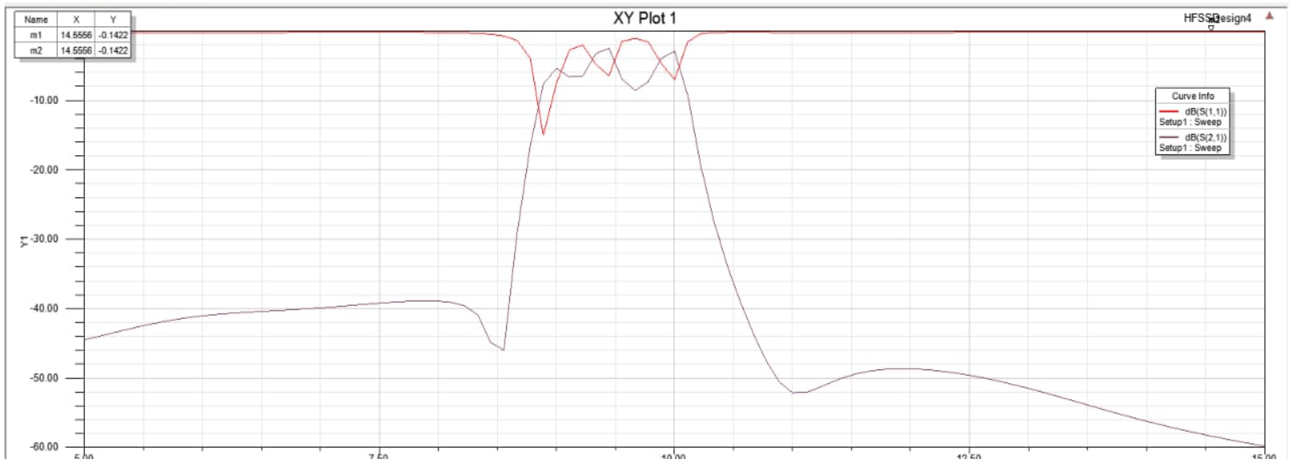


Fig8.5 5 pole microstrip band pass filter,S11 and S21 plotted

S-parameters, such as S21 and S11, are crucial in characterizing the behavior of RF (radiofrequency)components like filters or antennas. Here's the importance of each parameter:

1. S21 (Transmission Coefficient):

- - Importance:Represents the signal transmission from port 1 to port 2 in a network.
- - Use Case: For filters, S21 indicates how well the filter allows signals to pass through at different frequencies. It's vital for understanding the transmission characteristics of a component or system.

2. S11 (Reflection Coefficient at Port 1):

- - Importance:Reflects the portion of the signal that is reflected back from the input (port 1) of the network.
- - Use Case:Helps assess how well the device or component matches the impedance of the connected system. Low S11 values indicate good power transfer.

3. S22 (Reflection Coefficient at Port 2):

- \- Importance: Reflects the portion of the signal that is reflected back from the output (port 2) of the network.
- \- Use Case:Similar to S11, but for the output. Low S22 values indicate effective power transfer.

4. S12 (Transmission Coefficient from Port 2 to Port 1):

- \- Importance: Represents the signal transmission from port 2 to port 1 in a network.
- \- Use Case:Useful in systems with bidirectional signal flow. It helps understand how signals propagate in the reverse direction.

CHAPTER 4

CONCLUSION AND FUTURE PROSPECTS

Designing a low-pass filter using HFSS involves defining requirements, selecting filter type, modeling geometries, assigning materials, setting up excitation and ports, meshing, performing simulations, optimization, analyzing results, and ultimately exporting for fabrication. The success of the design is confirmed through real-world testing and potential iterations for refinement. HFSS provides a comprehensive platform for accurate and efficient low-pass filter design, aiding in meeting specific frequency range, insertion loss, and other performance criteria. The low-pass filter in the antenna system allows the desired low-frequency signals, typically the fundamental frequency or the operating frequency, to pass through with minimal attenuation. Meanwhile, it attenuates or blocks higher harmonic frequencies and spurious signals that could interfere with other communication systems or cause distortion in the transmitted or received signals.

The design and implementation of a low-pass filter in a system contribute to maintaining signal integrity, reducing electromagnetic interference, and ensuring compliance with regulatory standards. It's a crucial element, especially in applications where strict control over the frequency spectrum is necessary.Designing a microstrip low-pass filter involves using microstrip transmission line structures to create the desired frequency response. The design and parameters of the filter, including the specific values of inductors and capacitors, are crucial in determining its frequency response and performance characteristics within the desired frequency range.

Microstrip filters are commonly used in various wireless communication systems and RF applications. The ultimate goal is to achieve a filter that effectively attenuates high frequencies while allowing low frequencies to pass through. Real-world testing and potential iterations contribute to refining the design for optimal performance. The use of HFSS provides a robust platform for accurate simulation and successful realization of low-pass filters meeting specific design.

REFERENCES

1.Microstrip Filters for RF/Microwave Applications-Jia Sheng Hong,M.J.Lancaster

2.Design of Low Pass Filter using Microstrip Line,publisher:IEEE - A Comparative Study

APPENDICES

1.https://youtu.be/bbePoHzv1B8?si=fdH-peMmAfe44AMK

2.https://youtu.be/vFQeJHayPoU?si=dzeiq6kH5v9bkIei

3.https://youtu.be/3H45Igzv84c?si=7COxdFZHClSZh0Bj