Novel Design of Compact H-Shape Microstrip Filter for Multi-Band Applications

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Abstract—*Microstrip Filters are well known for compact size, lighter in weight, and cost effective with these advantages Microstrip Filters play an important role in various RF/microwave applications. Emerging trends in wireless communications persist with even more tough requirements like higher performance, these requirements are fulfilled up to some extend by using recent development in novel materials and fabrication technologies such as monolithic microwave integrated circuits (MMIC) high-temperature superconductors (HTS) and micromachining technology. The manuscript presented here is a novel H-Shape microstrip filter for multi-band applications. We represents five microstrip filter each having H –Shape but the substrate material is changed in each design. On the basis of proposed design we investigate the effect of different material on Insertion loss, reflection coefficient, VSWR and Q factor. In this paper we chose two range of material one with lower dielectric constant and other range with higher dielectric constant like FR4, Gallium Arsenide, Rogers RO3010, RT Duroid 5880 and Rogers TMM 10i.*

Keywords—Multiband Bandpass Filters (BPFs), FR4, Gallium Arsenide, Rogers RO3010, RT Duroid 5880 and Rogers TMM 10i

I. INTRODUCTION

In the present scenario of wireless communication systems, the demand for multiband microwave filters has increased rapidly and high-performance microwave dual or multiband bandpass filters (BPFs) are highly desirable [1,2] to operate in different radiating frequency bands. To accumulate these requirements, we represents H-shape microstrip filter (MF).The main objective of this paper is based on material of substrate, we consider dielectric constant in the range of $2.2\leq\varepsilon_r\leq12$ [3,4]. The performance of Microstrip Filter changes by changing material of substrate and its thickness. However, by growing thickness, surface waves come into picture and degrade performance of microstrip filter [1,2]. Hence, in order to design an suitable filter the impact of dielectric material must be analyzed.

The working range of frequency is 1 GHz to 8 GHz which wrap-ups most of the everyday communication. The rest of the paper is organized in following sections, Section II explains different materials and their properties which is used as substrate of proposed microstrip filter. Section III represents proposed H-Shape designs of MF for five different materials. Section IV illustrates the simulation results and performance parameters for the proposed design. Lastly, in Section V conclusion is made and future work is proposed.

II. SUBSTRATE MATERIAL

There are numerous material used as substrate for MF in this work we investigate on five different material, keeping in mind that we will take both range of material with dielectric constant of $2.2\leq\varepsilon_r\leq12$. The effective dielectric constant i.e $1\leq\varepsilon_{eff}\leq\varepsilon_r$ depends on the frequency of operation [1,2,3] by the following relationship.

$$f_c \cong \frac{1}{2L\sqrt{\varepsilon_0\mu_0\varepsilon_r}} \tag{1}$$

Where f_c is the center frequency or critical frequency and other symbols are representing their standard meaning. The proposed design is based on the substrate materials and their properties are accessible in Table 1 and their brief description is given in this section.

A. FR-4 or (FR4) Gloss Epoxy

FR-4 or (FR4) materials are glass reinforced epoxy laminate which is a composite material [7]. FR-4 glass epoxy is a high-pressure laminate with good strength to weight ratio. With about 0.10% water absorption [7] with dielectric breakdown parallel to laminate is greater than even 60 KV with very good electrical insulating properties.

B. RT Duroid 5880

RT Duroid is Glass Microfiber [9] that has the lowest electrical loss for Reinforced PTFE material with low moisture absorption and excellent chemical resistance [10]. Most common application of RT Duroid substrate is in commercial airline broadband antenna, microstrip and stripline circuits and missile guided system. It is easy for cutting, machining and is also environment friendly.

C. Gallium arsenide

Gallium arsenide is used primarily to make light- emitting diodes [6], lasers, laser windows, and photodetectors and in the photoelectronic transmission of data through optical fibers. Gallium arsenide was chosen for investigation because of its extensive use in the microelectronics industry.

D. Rogers RO3010

RO3010 high frequency circuit materials [8] are ceramic-filled PTFE composites intended for use in commercial microwave and RF applications. This family of products was designed to offer exceptional electrical and mechanical stability at competitive prices. RO3000 series laminates are ceramic-filled PTFE based circuit materials with mechanical properties that are consistent regardless of the dielectric constant selected. This allows the designer to develop multi-layer board designs that use different dielectric constant materials for individual layers, without encountering warpage or reliability problems.

E. Rogers TMM 10i

TMM thermoset microwave materials [10] are ceramic, hydrocarbon, thermoset polymer composites designed for high plated-thru-hole reliability strip line and microstrip applications. TMM laminates are available in a wide range of dielectric constants and claddings. The electrical and mechanical properties of TMM laminates combine many of the benefits of both ceramic and traditional PTFE microwave circuit laminates, without requiring the specialized production techniques common to these materials.

Parameters	FR-4	RT Duroid	Gallium arsenide	RogersRO3010	RogersTMM 10i
Dielectric constant	4.4	2.2	12.9	10.2	9.8
Loss tangent	0.013	0.0004	0.0016	0.0022	0.002
Tensile strength	<310MPa	450MPa	<138 MPa	1934 MPa	1.8 MPa
Surface resistivity	$1{\times}10^{8}$MΩ	3.0×10^{7}MΩ	$1{\times}10^{7}$MΩ	1×10^{5}MΩ	$4{\times}10^{7}$MΩ

Table 1: Properties of different substrates

III. Design

In this section we have taken five different materials as substrate for microstrip filter design the proposed design is a H-Shape microstrip filter with substrate height of 1.6 mm. Different substrates with a dielectric constant of 2.2, 4.4, 9.8, 10.2 and 12.9 are used for investigation. First we take a basic H slot antenna and then four more designs are investigated by introduction different dielectric materials in the radiating patch of filter. Our main aim is to change material and find its effect of Microstrip Filter.

A. Basic H-Shape Model

The basic model of Microstrip filter, consist of a H-Shape metallic strip which is grown on a dielectric substrate of 1.6 mm thickness and area of ground plane and substrate is 32 mm by 26 mm. and the dimension of patch is 23 mm of length and 17 mm width. We cut a slot of H shape from [17.18,19] the metallic patch which is shown in the Figure 1.

The physical dimension of the proposed microstrip filters are optimized through ansys-HFSS simulation software. The analysis is based on a frequency range of 2 to 8 GHz. In the proposed design we use two lumped port as input and output port, both of them are identical and symmetrical to each other and their dimensions are 6mm X 5 mm. in first design we use FR-4 Gloss Epoxy as our substrate.

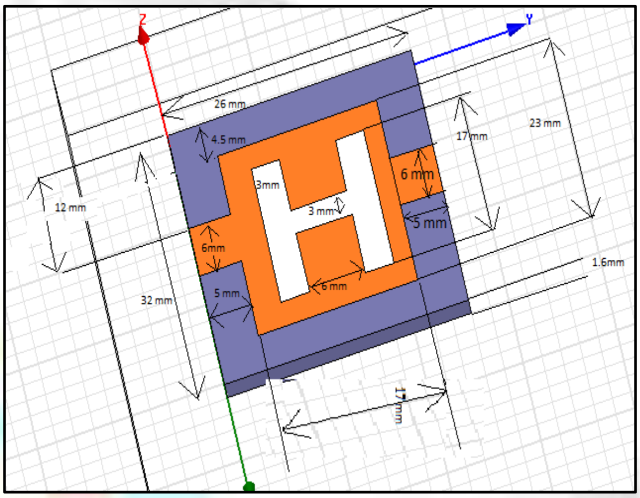

Fig.1: Top view of basic H slot Microstrip filter model.

In other four design the dimension of proposed filter is same but with different materials, in second design we use RT Duroid as substrate, in third design we use Gallium arsenide in fourth we use Rogers RO3010 and in fifth we use Rogers TMM 10i [8,9,10] as substrate material with different physical and electrical properties shown in table 1.

IV. Results

The main performance parameter [13,14] we consider in microstrip filter design is presented here viz. Return Loss, VSWR, Bandwidth, Insertion Loss, Q Factor and Number of operating bands for the proposed five design. For first design we achieve two operating band of operation with center frequency 3 GHz and 5.85 GHz. On the other hand for second design we get only one operating range, for third design we get three operating range at 2.3 GHz, 3.9 GHz and 5.9 GHz as center frequency. Again for forth design we get only one operating range and in fifth design we three bands of operation respectively, the overall results obtained by all five designs are shown in table 2, 3, 4, 5 and table 6.

Insertion Loss (dB) Maximum	Bandwidth at -10dB at 3GHz (MHz)	Bandwidth at -10dB at 5.85 GHz (MHz)	VSWR (dB) minimum	Return loss (dB) minimum	Q-factor
-1.269	1254.5	573.3	1.10	-26.5	2.26 (at 3 GHz)
					5.142 (at 5.85 GHz)

Table 2: Result analysis of First Design with FR-4 substrate.

In the figure 2, 3 and 4 represents return loss S11, VSWR at port, Insertion loss S21, and -10 dB Bandwidth for first design.

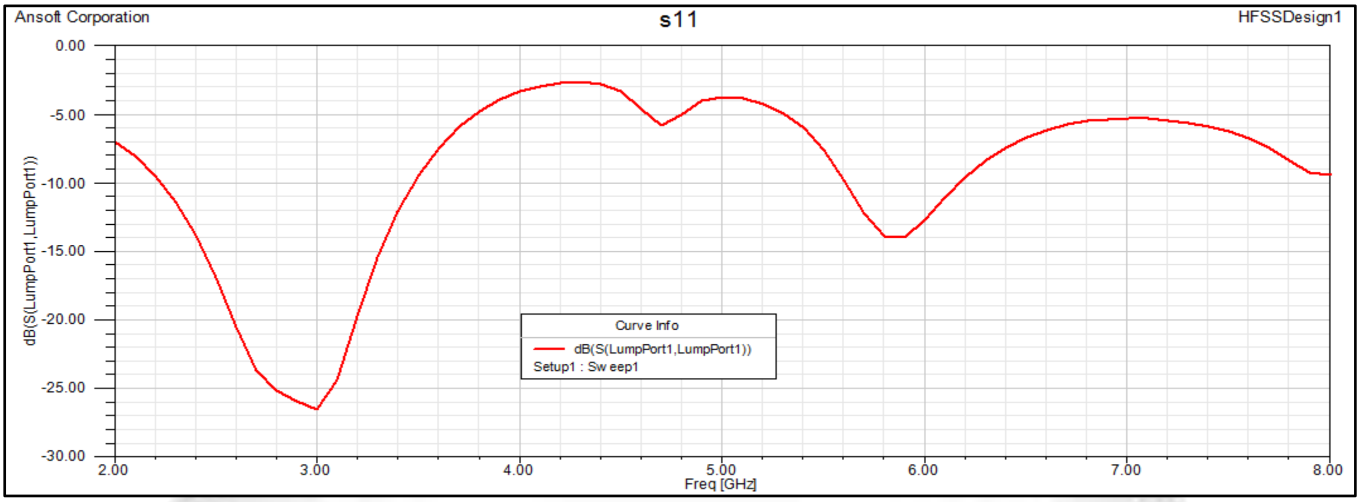

Fig. 2:Return loss of simulation result for Design 1 With FR-4 substrate.

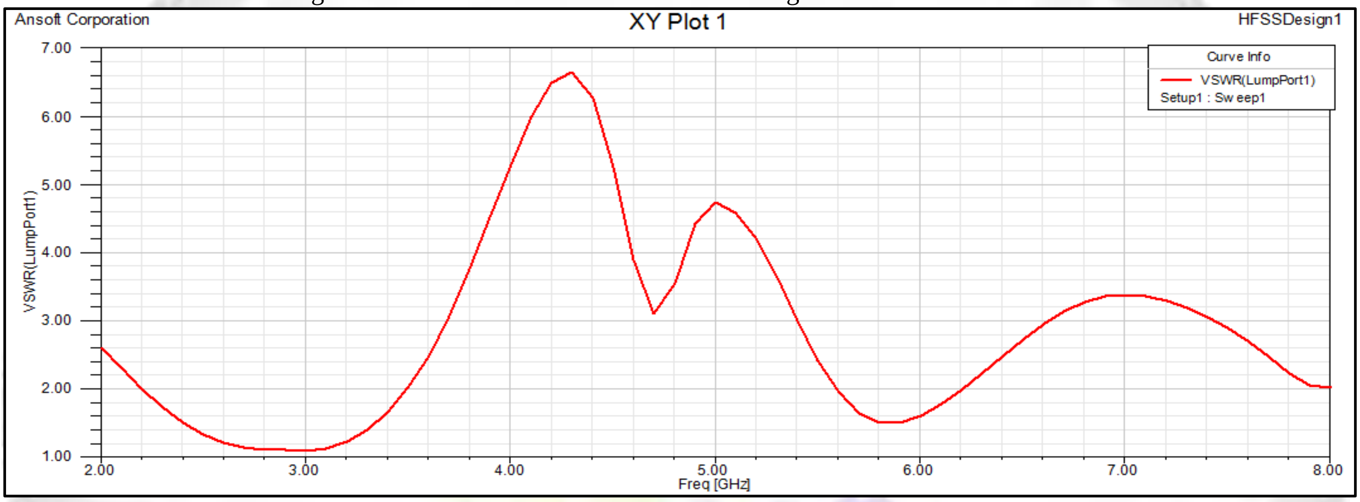

Fig. 3:VSWR of simulation result for Design 1 With FR-4 substrate.

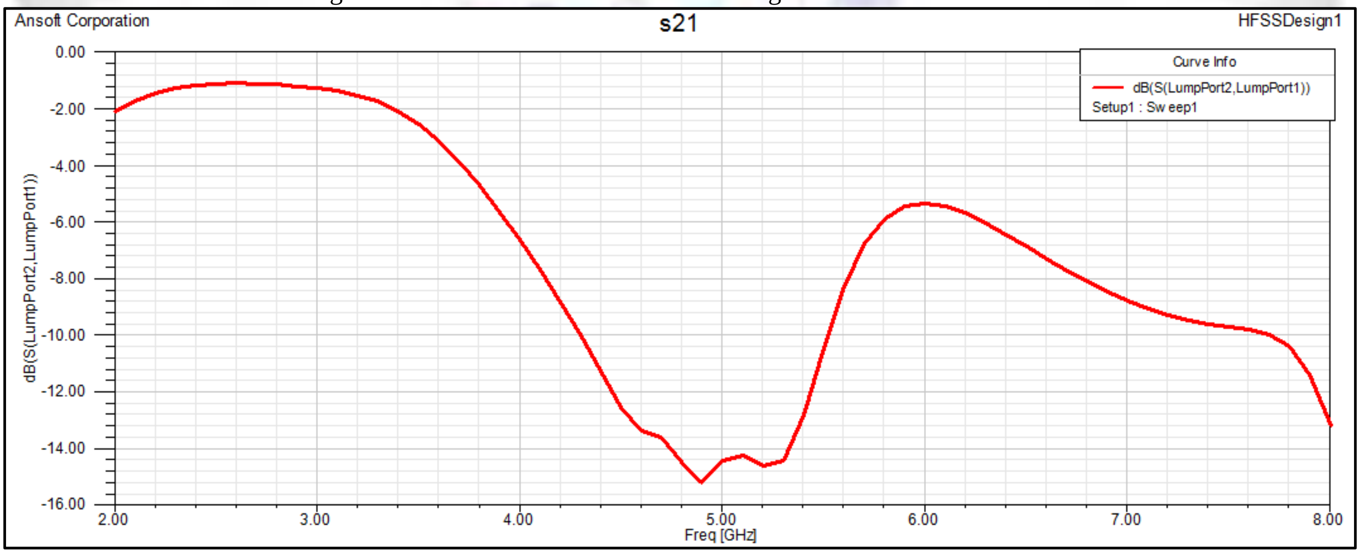

Fig. 3:Insertion Loss of simulation result for Design 1 with FR-4 substrate.

Insertion Loss (dB)Maximum	Bandwidth at -10dB at 3.45 GHz (MHz)	VSWR (dB)minimum	Return loss (dB)minimum	Q-factor
-2.72	293.7	1.234	-20.0	10.202(at 3.45 GHz)

Table 3: Result analysis of First Design with Gallium Arsenide substrate.

In the figure 4, 5 and 6 represents return loss S11, VSWR at port, Insertion loss S21, and -10 dB Bandwidth for second design.

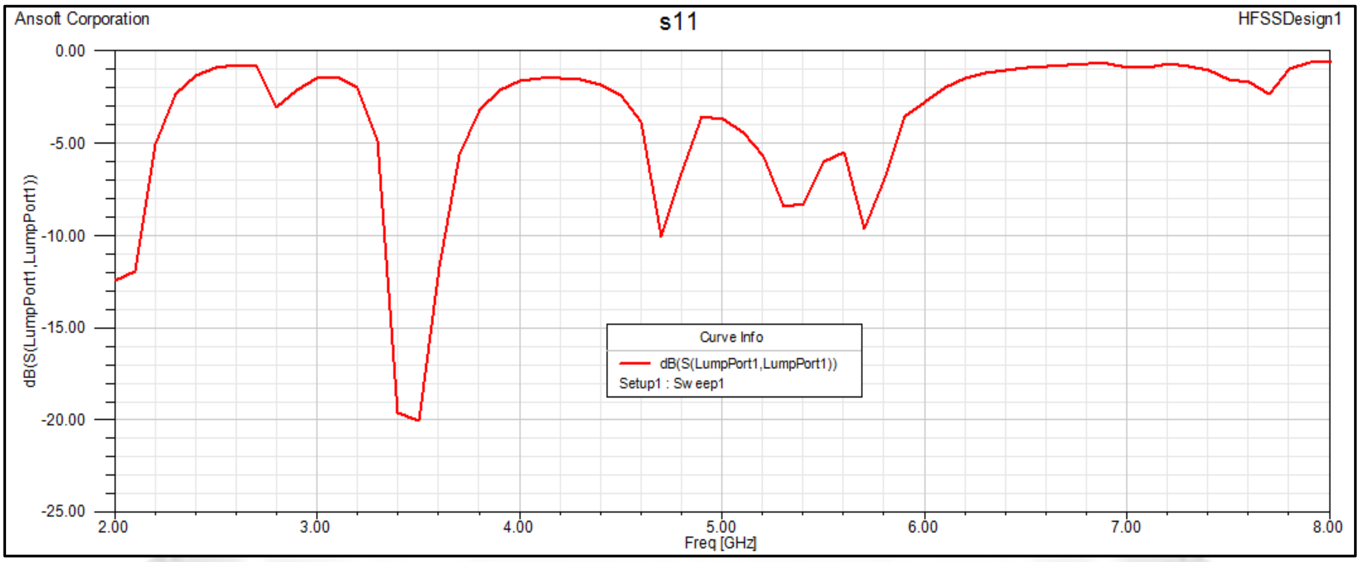

Fig. 4: Return loss of simulation result for Design 2 withGallium Arsenide substrate.

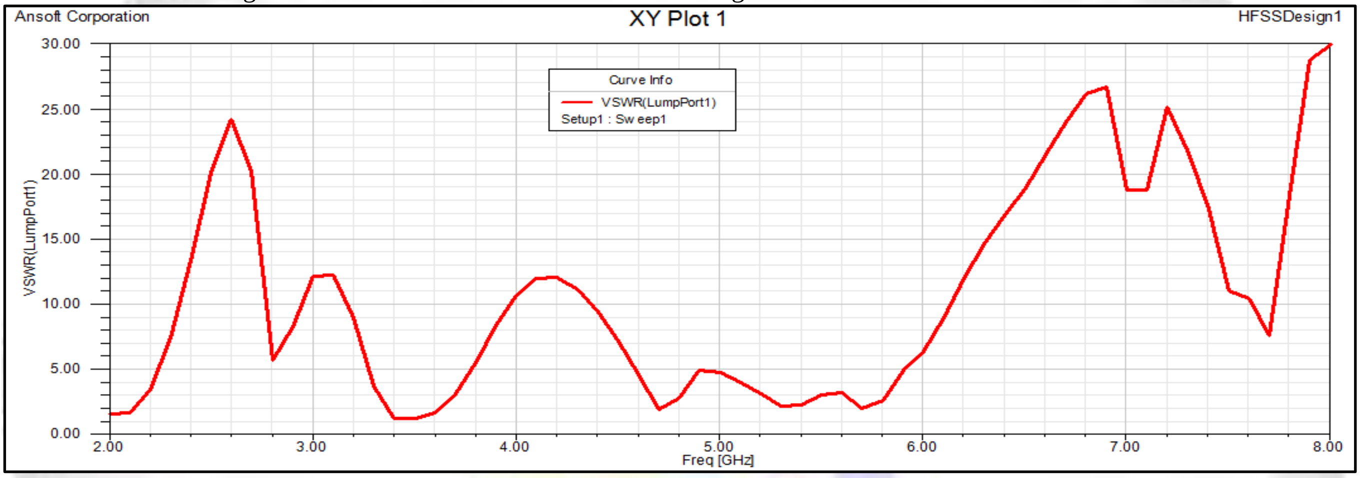

Fig. 5: VSWR of simulation result for Design 2 withGallium Arsenide substrate.

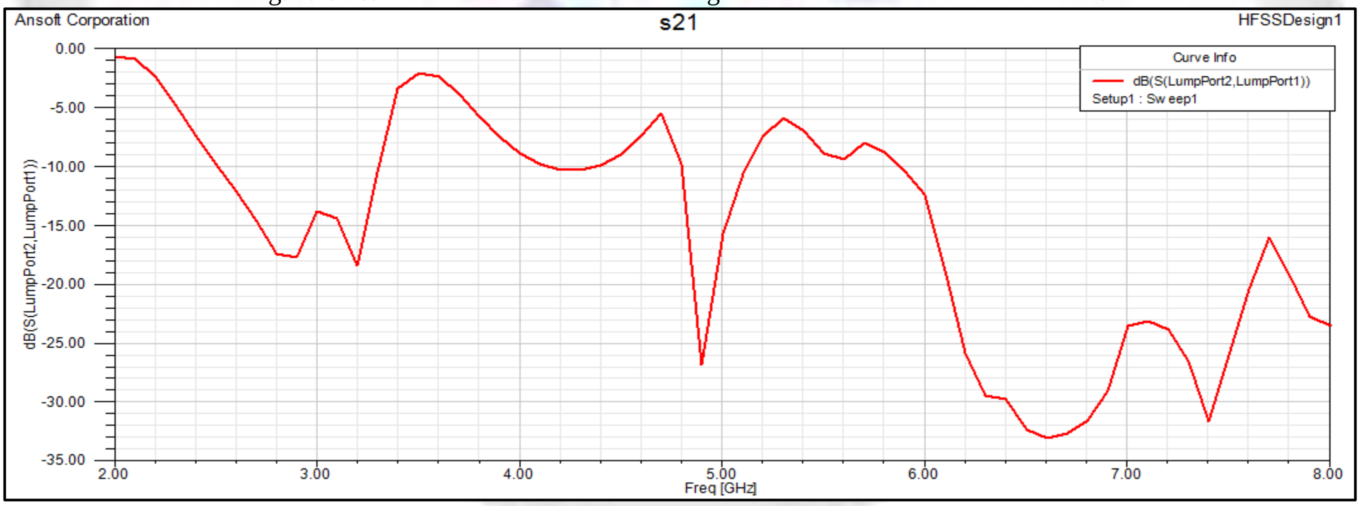

Fig. 6: Insertion Loss of simulation result for Design 2 withGallium Arsenide substrate.

Insertion Loss(dB) Maximum	Bandwidth at -10dB at 2.3GHz (MHz)	Bandwidth at -10dB at 3.9 GHz (MHz)	Bandwidth at -10dB at 5.9 GHz (MHz)	VSWR (dB) minimum	Return loss(dB) minimum	Q-factor
-0.844	248.4	321.3	86.0	1.194	-21.06	5.86(at 2.3 GHz) 7.733(at 3.9 GHz) 8.485 (at 5.9 GHz)

Table 4: Result analysis of First Design with Rogers RO3010 substrate.

In the figure 7, 8 and 9 represents return loss S11, VSWR at port, Insertion loss S21, and -10 dB Bandwidth for third design.

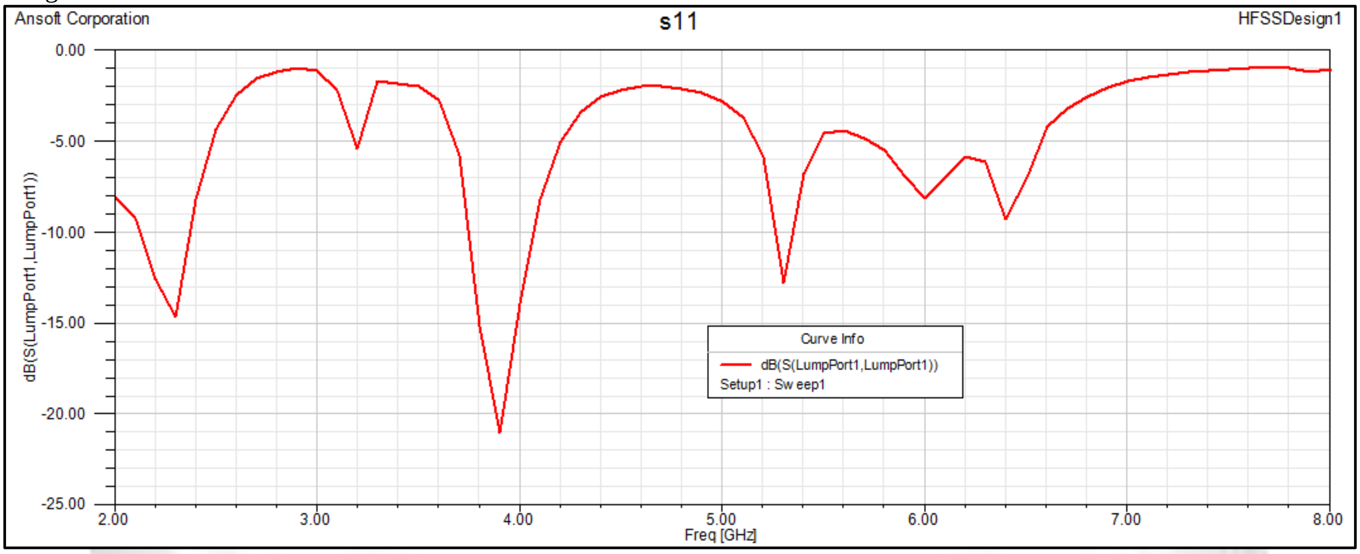

Fig. 7: Return loss of simulation result for Design 3 withRogers RO3010 substrate.

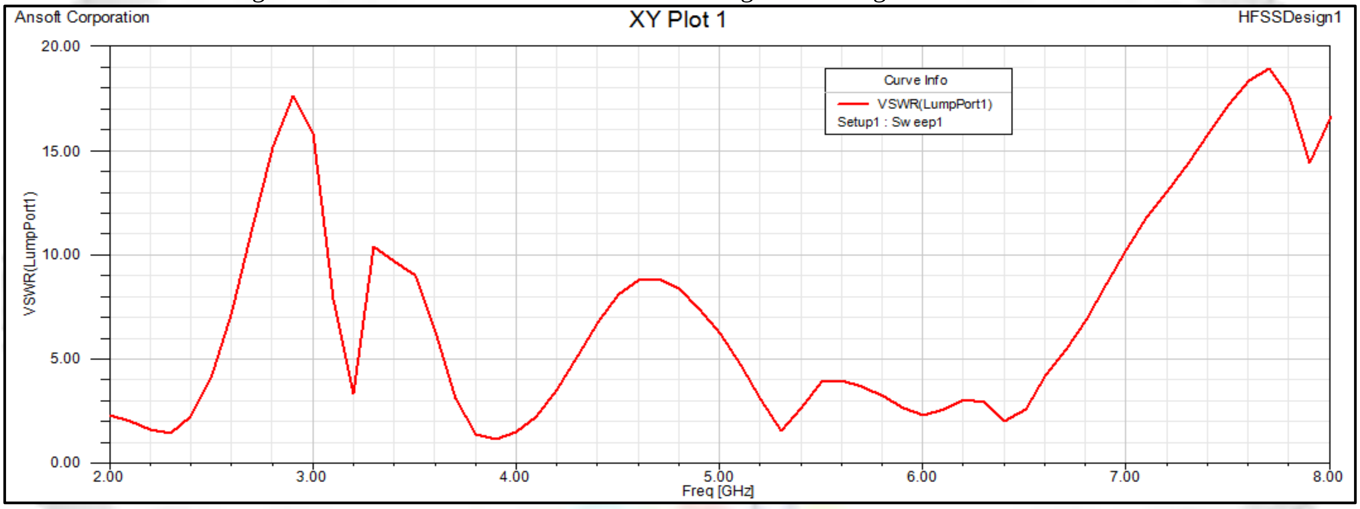

Fig. 8: VSWR of simulation result for Design 3 withRogers RO3010 substrate.

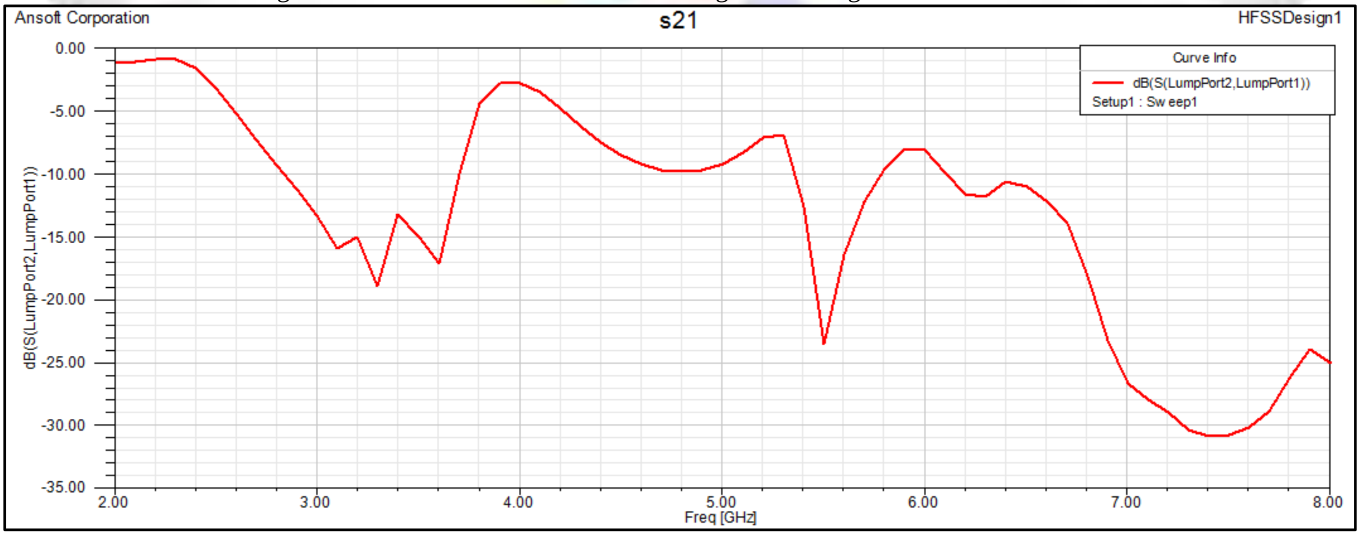

Fig. 9: Insertion Loss of simulation result for Design 3 withRogers RO3010 substrate.

Insertion Loss (dB)Maximum	Bandwidth at -10dB at 3.9 GHz (MHz)	VSWR (dB)minimum	Return loss (dB)minimum	Q-factor
-1.733	1300	1.56	-13.26	2.185(at 3.9 GHz)

Table 5: Result analysis of First Design with RT Duroid 5880 substrate.

In the figure 10, 11 and 12 represents return loss S11, VSWR at port , Insertion loss S21, and -10 dB Bandwidth for forth design.

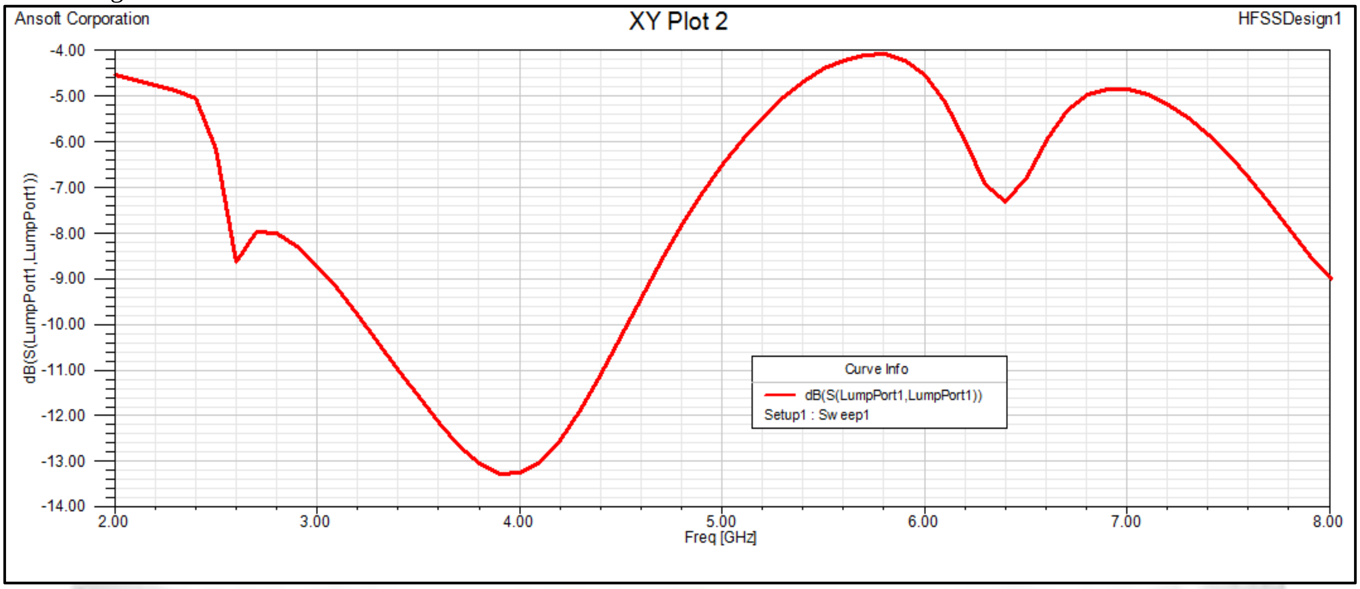

Fig. 10: Return loss of simulation result for Design 4 withRT Duroid 5880 substrate.

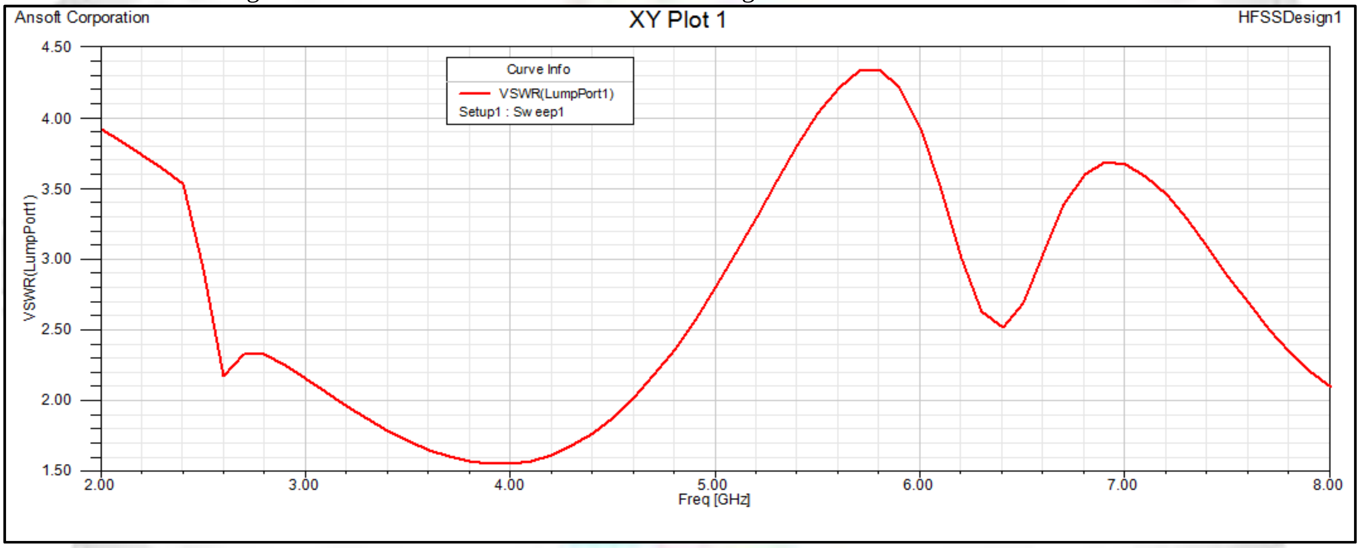

Fig. 11:VSWR of simulation result for Design 4 withRT Duroid 5880 substrate.

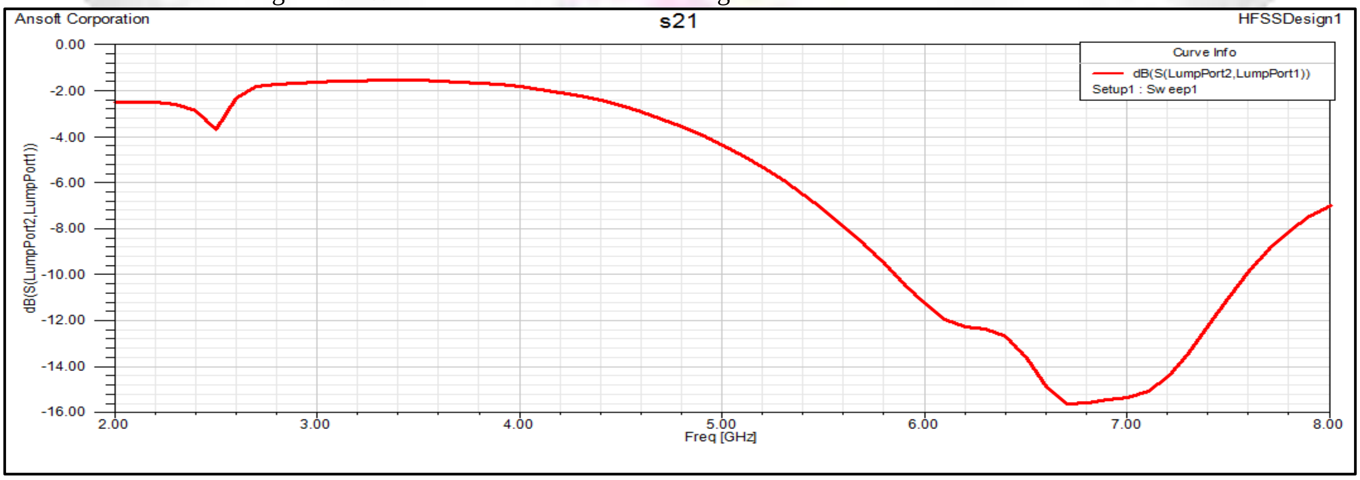

Fig. 12: Insertion Loss of simulation result for Design 4 withRT Duroid 5880 substrate.

Insertion Loss(dB) Maximum	Bandwidth at -10dB at 2.3GHz (MHz)	Bandwidth at -10dB at 4.0 GHz (MHz)	Bandwidth at -10dB at 5.4 GHz (MHz)	VSWR (dB) minimum	Return loss(dB) minimum	Q-factor
-0.80	260.0	320.0	88.0	1.25	-19.03	5.25

						(at 2.3 GHz)
						8.877 (at 4.0 GHz)
						10.289(at 5.4 GHz)

Table 6: Result analysis of First Design with Rogers TMM 10i substrate.

In the figure 13, 14 and 15 represents return loss S11, VSWR at port, Insertion loss S21, and -10 dB Bandwidth for fifth design.

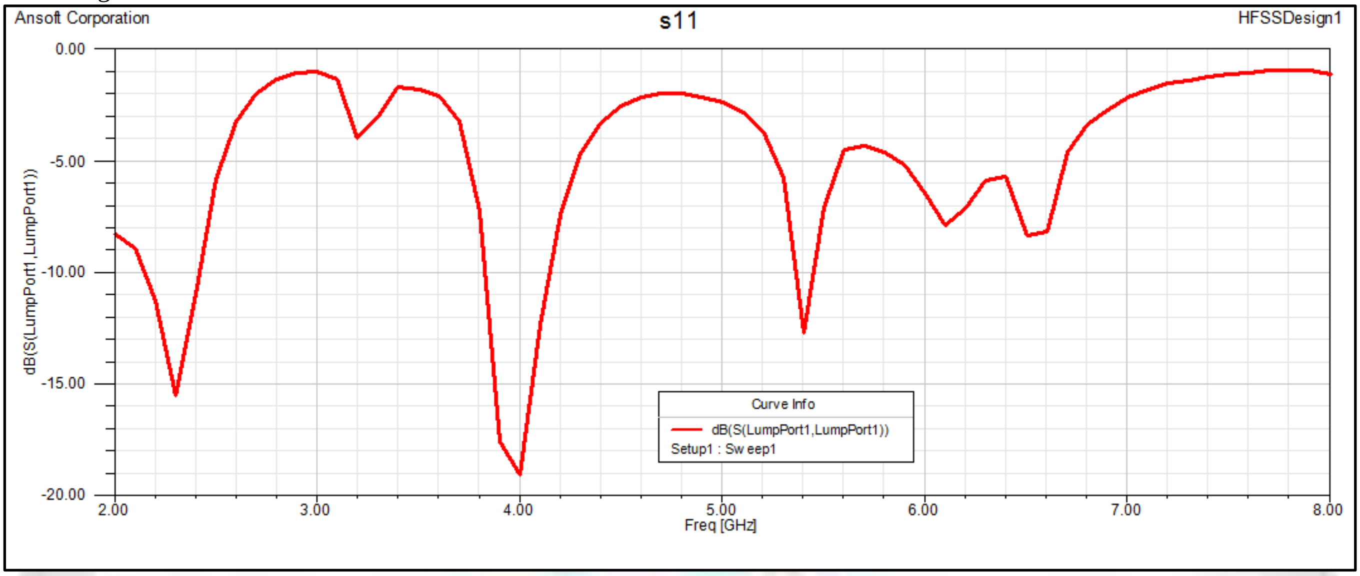

Fig. 13: Return loss of simulation result for Design 3 with Rogers TMM 10isubstrate.

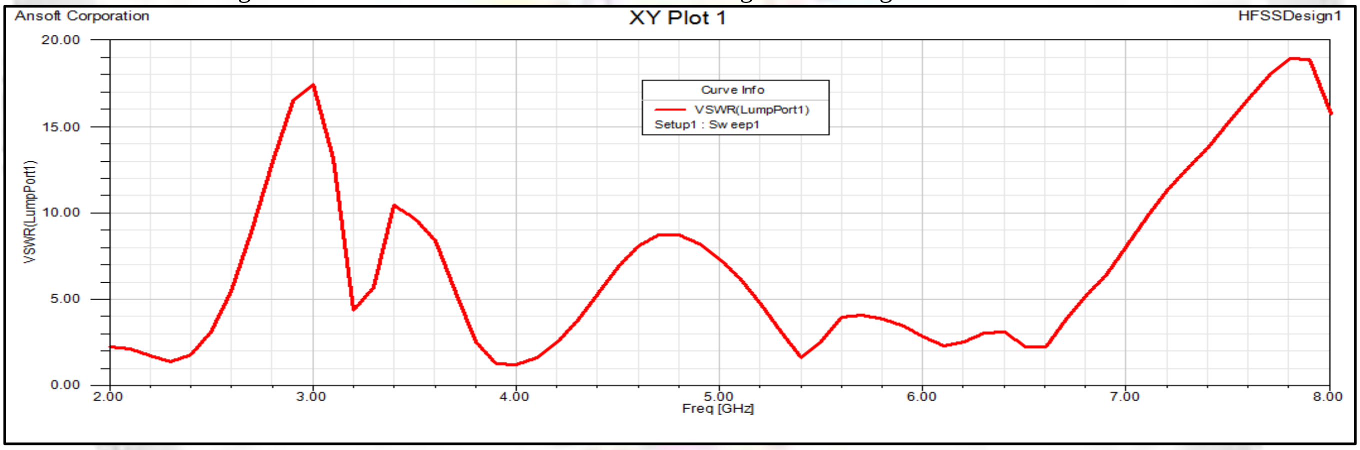

Fig. 14: VSWR of simulation result for Design 3 with Rogers TMM 10i substrate.

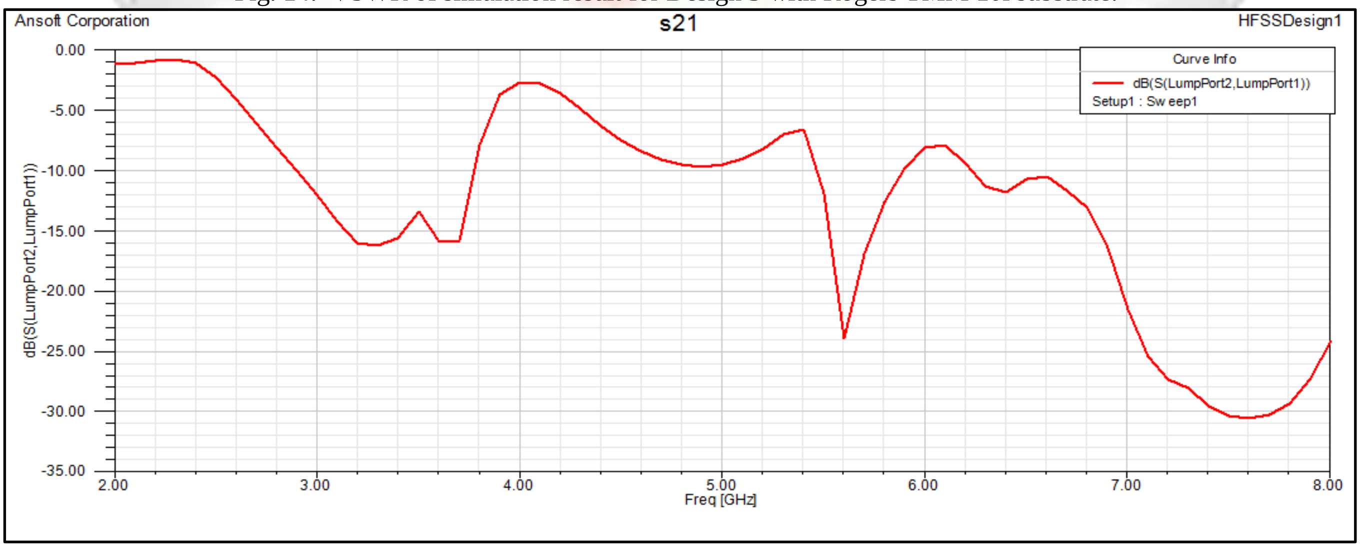

Fig. 15: Insertion Loss of simulation result for Design 3 with Rogers TMM 10i substrate.

V. CONCLUSION AND FUTURE WORK

In this paper we can conclude the performance of different design of Microstrip Filter based on substrate materials, we have taken five design each of them have different substrate material, the choice of material is taken in such a way that both lower and higher value of dielectric constant i.e$2\leq\varepsilon_r\leq12$ are investigated. In Fourth design we finds that RT Duroid 5880 with ε_r = 2.2, performs worst in terms of operating range, insertion loss, return loss, VSWR and Q factor but having very good bandwidth of 1300 MHz. On the other hand second design, Gallium Arsenide with ε_r = 12.9, has very good Q factor of 10.202 but having only one operating band, its return loss is also good, so we decide to take three more design based on three different materials and find that fifth design, Rogers TMM 10i and third design Rogers RO3010 with ε_r = 9.8 and ε_r = 10.2 respectively out performs and having multi-band of operation (3 bands) with better return loss and higher Q Factor. Thus we can conclude that substrate material with dielectric constant $5\leq\varepsilon_r\leq10$ is used for multiband operation and better return loss and higher Q Factor. Onthe other hand first design with dielectric material FR-4 has two operating range and its results are better than RT Duroid 5880. On the basis of results Rogers TMM 10i and Rogers RO3010 based design i.e fifth and third design respectively are the best designs for multiband microstrip filter. Future research can be carried out on more materials, we can also analyse the performance of conducting polymers and nonmaterial's.

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