International Journal of Recent Development in Engineering and Technology
Website: www.ijrdet.com (ISSN 2347-6435(Online) Volume 5, Issue 8, August 2016)

Design and Analysis of Microstrip High Pass Filter Using Metamaterial

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***Abstract*--In this paper, design of six stubs i.e. six degree filter is being proposed and analyzed by using simulated S-parameters response with IE3D software. Also Highly selective filter based on complementary split ring resonator is pointed out. The structure shows a composite right or left handed (CRLH) behavior and, by properly tuning the geometry of the elements, a high pass response with a sharp transition band is achieved. Since the resonant elements are small, filter dimensions are compact .It comprises two CSRR sections with additional microstrip patches. The inter-digital capacitors are introduced to prevent transmission at lower frequencies. Left handed micro-strip lines are implemented by etching CSRRs in the ground plane and series capacitive gaps in the signal strip.**

***Index Terms*- composite right/left handed (CRLH), CSRR, and IE3D.**

I. Introduction

Micro-strip filters are the two port network used to control the frequency response at a certain point in a microwave system by providing transmission at frequencies within the pass band of the filter and attenuation in the stop band of the filter. RF/microwave filters may be designed as lumped element or distributed element circuits. Micro-strip filters are of four types namely; low pass filter, high pass filter, band reject filter and band pass filter.

The term"metamaterial" refers to any material that is artificially constructed with the purpose of achieving desired properties. In electro-magnetics, a meta-material can be created from a structure with elements of size less than the wavelength of the incoming electromagnetic wave. One important type of meta-material is the left-handed meta-material.

J. B. Pendry proposed a structure, which is named as split ring to produced negative effective permeability in microwave (GHz) range.

The synthesized capacitance, together with the natural inductance of split ring cylindrical structure, makes split rings resonant and has an effective relative permeability as follows:

$$\mu_{eff} = 1 - \frac{\pi r^2/a^2}{1 - \frac{2\sigma i}{\omega r \mu_0} - \frac{3dc_0^2}{\pi^2\omega^2 r^3}} \qquad 1.1$$

Where *r* is the radius of split ring, *a* is the spacing distance between rings, and *d* is distance between inner and outer rings. It is apparent that the split ring resonator (SRR) will achieve resonance and large effective permeability at resonance frequency $\omega_0 = \sqrt{\frac{3dc_0^2}{\pi r^3}}$. Also the effective permeability will show negative values when second term of above equation is greater than unity, which corresponds to the frequency range between resonance frequency and magnetic plasma frequency

$$\omega = \omega_0\sqrt{1 - \frac{\pi a^2}{r^2}} \qquad 1.2$$

Split Ring Resonators (SRR) and Complementary Split Ring Resonators (CSRRs) are widely used to design meta-material structures. These structures when excited by suitable electromagnetic fields have resonance behaviour and show unusual properties such as negative permeability and permittivity near the resonance frequency region. Also, because of their resonance behaviour SRRs and CSRRs can be used to design slow wave transmission lines, phase shifters, various kinds of micro-strip filters, etc. SRRs are small resonant particles with a high quality factor at microwave frequencies. The SRR can be viewed as an externally driven LC circuit with a resonant frequency tunable by device dimensions (*r*, *c*, and *d*). The resonant frequency is

$$\omega_0 = \frac{1}{\sqrt{LC}} \qquad 1.3$$

or

$$f_0 = \frac{1}{2\pi}\sqrt{\frac{2}{\pi r_0 L C_{pull}}} \qquad 1.4$$

Where C_{pull} is the per unit length capacitance between the concentric rings, *L* is the total inductance of the SRR, and r_0 is the average radius of the SRR. To excite optimally the SRR, the incident H-field needs to be polarized in the axial direction of the ring. This can be done in micro-strip technology placing the rings in the same plane as the conductor strip. But this solution makes difficult the integration of the rings in the same area than other parts of the circuit. This problem is solved by using the complementary SRR (CSRR).

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II. Stub Microstrip High Pass Filter Using Via Hole Grounding

Fig 1.1 shows the proposed six stubs (short-circuited) optimum distributed high pass filter. The design parameters under consideration are as follows:

Cut-off frequency, f_c = 1.5 GHz

Dielectric Constant, ε_r = 4.4

Height of substrate, h = 1.6 mm

Pass band ripple = 0.1dB

Characteristic impedance of terminating micro-strip line, Z_0 = 50Ω

Effective permittivity of the micro-strip, ε_{eff}= 3.0622

Guided wavelength, λ_{gc} = 65.77636 mm

Number of stub elements, n = 6

Electrical length, θ_c = 33 degree (0.588 radians)

III. Proposed Geometry Of Six Stubs Filter

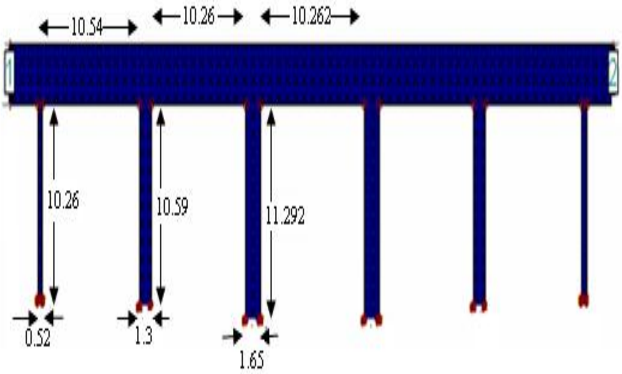

Fig 1.1: Proposed Geometry of Six Stubs Filter (f_c = 1.5 GHz)

IV. Comparative Analysis Of Simulated And Measured Results

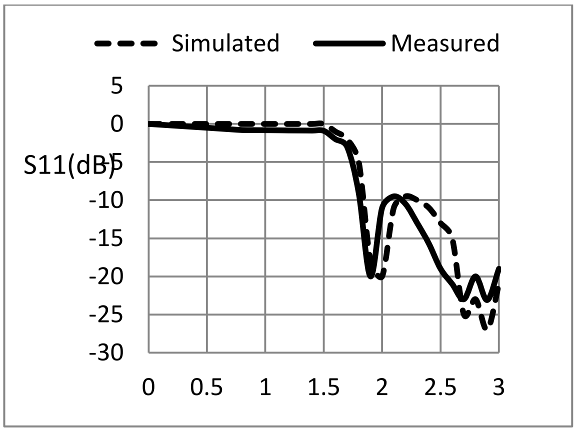

Fig. 1.2 Return Loss versus Frequency

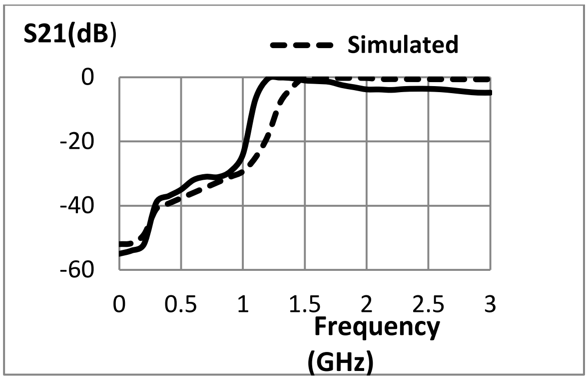

Fig 1.3 Transmission Coefficient versus Frequency

V. Design Of High Pass Filter Using CSSRs

The substrate characteristics are:
Dielectric Constant ε_r = 4.4
Thickness H =1.6mm
Tangent Tan Δ=0.02
Filter Dimensions Are:
Radius of the CSRRS , r_{ext}= 16.91 mm
Width of the Inner Ring = 1.99 mm
Width of the Outer Ring = 1.49mm
Rings Seperation D = 1.45 mm
Number of Fingers = 14
Width of each Finger = 1.08 mm
Seperation between each Finger = 1.08 mm
Line width W = 1.35 mm
Total filter length = 108 mm

VI. Simulated Geometries

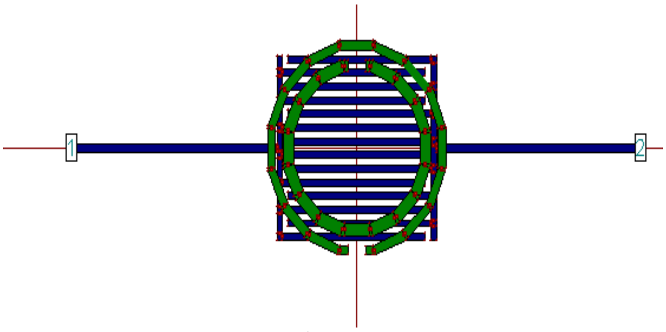

Fig. 1.4 Simulated Geometry of Single Stage CSRR Based High Pass Filter

VII. Comparative Analysis Of Simulated And Measured Results

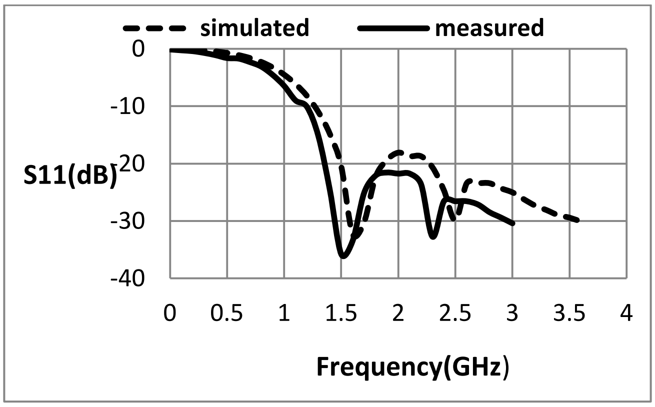

Fig.1.5 Return Loss versus Frequency

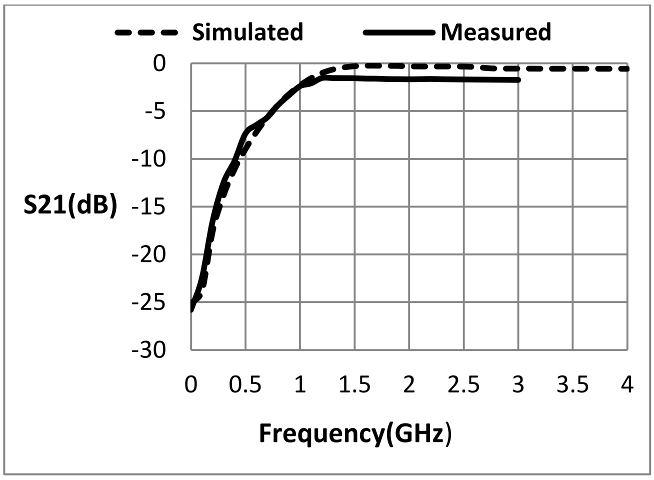

Fig. 1.6 Transmission Coefficient versus Frequency

VIII. High Pass Filter Based On CSRRs Having Two Stages

Fig.1.7 shows the layout of the proposed high pass filter having two stages of inter-digital high pass section. It comprises two CSRR sections with additional micro-strip patches .The inter-digital capacitors are introduced to prevent transmission at lower frequencies. The length of the transmission line embedded between the two sections can be adjusted to optimize the response of the total structure, which is similar to the elliptic function circuit [11]. The dimensions are:

l = 8mm, w_1 = 1.4mm, s_1 = 2mm

s_2 = 2mm, g_1=0.4mm, g_2 = 2.4 mm, l_1=21.6 mm

Total length = 104 mm.

The measured 3 dB cut off frequency is 2.6 GHz and the suppression is more than 19 dB below 2.2 GHz.

It can be seen that the proposed high pass filter exhibits steep rejection slope owing to the resonance of the CSRRs. Split Ring Resonators (SRR) and Complementary Split Ring Resonators (CSRR) are widely used to design meta-material structures. These structures when excited by suitable electromagnetic fields have resonance behaviour and show unusual properties such as negative permeability and permittivity near the resonance frequency region [5].

IX. Proposed Geometry

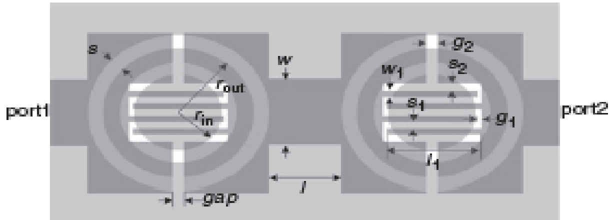

Fig. 1.7 Proposed Geometry of High Pass Filter

X. Simulated Geometry

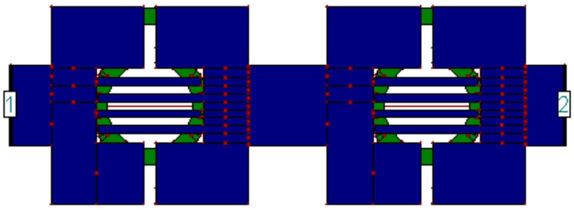

Fig.1.8 Simulated Geometry of CSRR

XI. Comparative Analysis Of Simulated And Measured Results

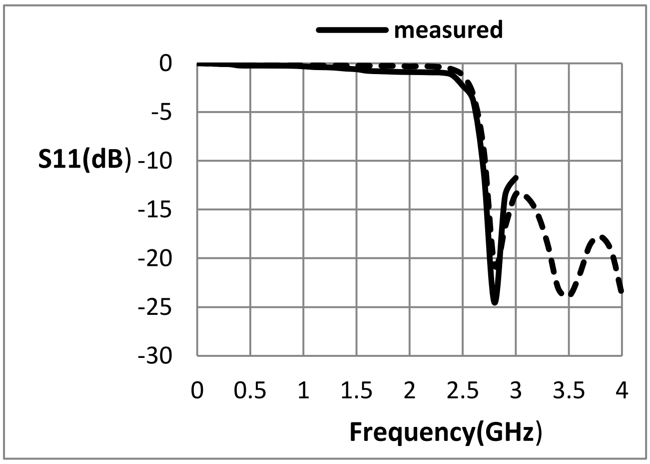

Fig.1.9 Return Loss versus Frequency

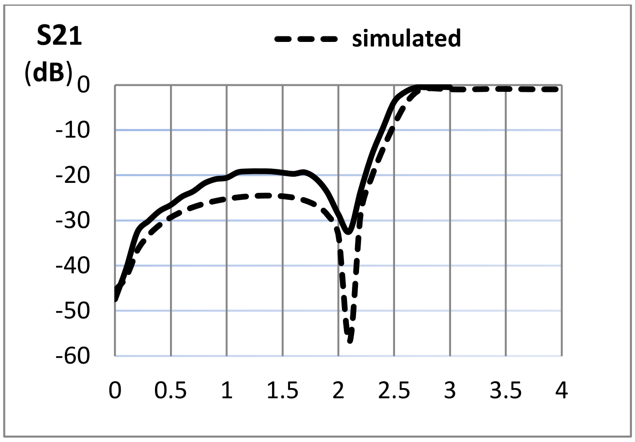

Fig.1.10 Transmission Coefficient versus Frequency

XII. Conclusion

In this paper, three compact micro-strip high pass filters using via hole grounding, unit cell complementary split ring resonator, two cell complementary split ring resonator are implemented and examined.

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