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Design and Analysis of Stepped Impedance Microstrip Fractal Low Pass Filter

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Abstract

Most communication system contains an RF front end which performs signal processing with RF filters. Micro strip filters are a low cost means of doing this. This paper describes the design of low cost and low insertion loss microstrip stepped impedance Fractal low pass filter (LPF) by using microstrip layout which works at 0.4 GHz for permittivity 4.7 value with a substrate thickness 1.6 mm with pass band ripple 0.1dB. Microstrip technology is used for simplicity and ease of fabrication. The design and simulation are performed using 3D full wave electromagnetic simulator IE3D.

Key Words: Fractal Filter, Stepped Impedance filter, Low Pass Filter, IE3D.

Introduction

Stepped impedance low pass microstrip filters offer better stop band characteristics and are simpler to design. Such filters are formed, from the series connection of high and low impendence Microstrip transmission lines [1]-[2]. In the present work a conventional microstrip Chebyshev low pass filter has been designed and analyzed using IE3D software [7]. To improve the performance of the filter, fractals have been done in the already designed filter. Results of the fractal have been compared with the conventional design.

The general concepts of fractals can be applied to develop various filter elements. Applying fractals [5] to filter elements allows for smaller filters that are provides sharp cut off and better input matching. The fact that most fractals have infinite complexity and detail can be used to reduce filter size and develop low profile filters. Fractal elements or arrays are designed with the concept of self-similarity for most fractals, they can achieve sharper cut off point.

Filter Design Method:

1. Filter Specifications:

Figure 1 shows a low pass stepped impedance Microstrip filter, designed using the conventional technique [3-4]. Specification for conventional microstrip Chebyshev low pass filter of order n = 3 are given bellow

Cut-off frequency, $f_c = 0.4$ GHz

Dielectric constant, $\epsilon_r = 4.7$

Substrate height, h =1.6 mm

Characteristic impedance, $Z_o = 50\ \Omega$

Highest Line impedandce $Z_H = Z_{oL} = 100\ \Omega$

Lowest Line impedance $Z_L = Z_{oC} = 20\ \Omega$

Loss tangent $\delta = 0.02$

Pass band ripple = 0.1dB

Normalized frequency $\Omega c = 1$

2. We have taken the elements value for low pass filter for n = 3 ($g_1 = 1.0316$, $g_2 = 1.1474$, $g_3 = 1.0316$) [6]

3. Electrical length of inductor

$\beta l = L\ Z_o / Z_H$

Electrical length of capacitor

$\beta l = C\ Z_L / Z_o$

L and C are normalized elements values of low pass filter.

4. To calculate the width of capacitor & inductor, we use the following formula

For W/h < 2

$W/h = 8 \exp(A) / (\exp(2A) - 2)$

Where $A = (Z_c / 60) \{(\varepsilon_r+1)/2\} \wedge 0.5 +$

$[(\varepsilon_r + 1) / (\varepsilon_r - 1)] \{0.23 + 0.11/ \varepsilon_r\}$

Where $Z_c = \eta / 2 \pi \sqrt{\varepsilon_{re}} [\ln (8h/w +$

$0.25\ w/h)]$

Where $\eta = 120\ \pi$ ohms is the wave impedance in free space.

For W/h > 2

$W/h = (2/\pi)[B - 1 - \ln(2B - 1) + ((\varepsilon_r - 1)/2$

$\varepsilon_r)) (\ln (B - 1) + 0.39 - 0.61/ \varepsilon_r)]$

Where $B = 377\ \pi / 2\ Z_o \sqrt{\varepsilon_r}$

5. The effective dielectric constant can be found by the following formula

$\varepsilon_{re} = (\varepsilon_r+1)/2 + [(\varepsilon_r-1)/2]\,[(1+12\,h / W)^{-0.5}]$

6. Effective wavelength is also found as

$\lambda_{ge} = \lambda / \sqrt{\varepsilon_{re}}$

7. Fractalization of original filter shape.

Filter Dimension & Simulation Result:

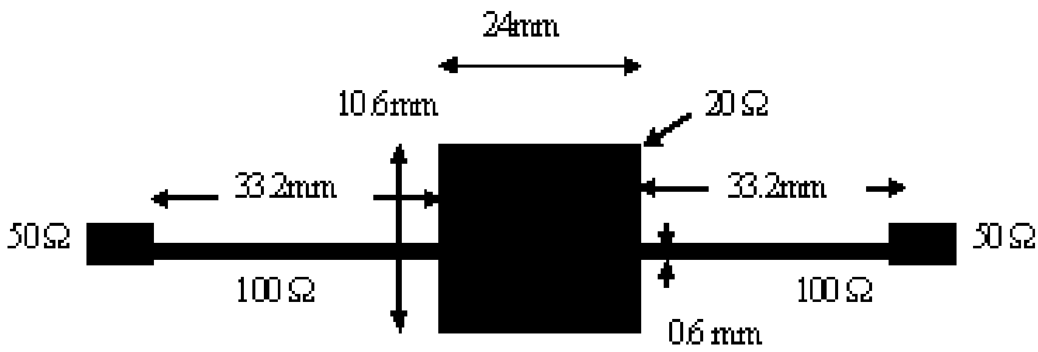

Fig 1: Layout of Microstrip Filter

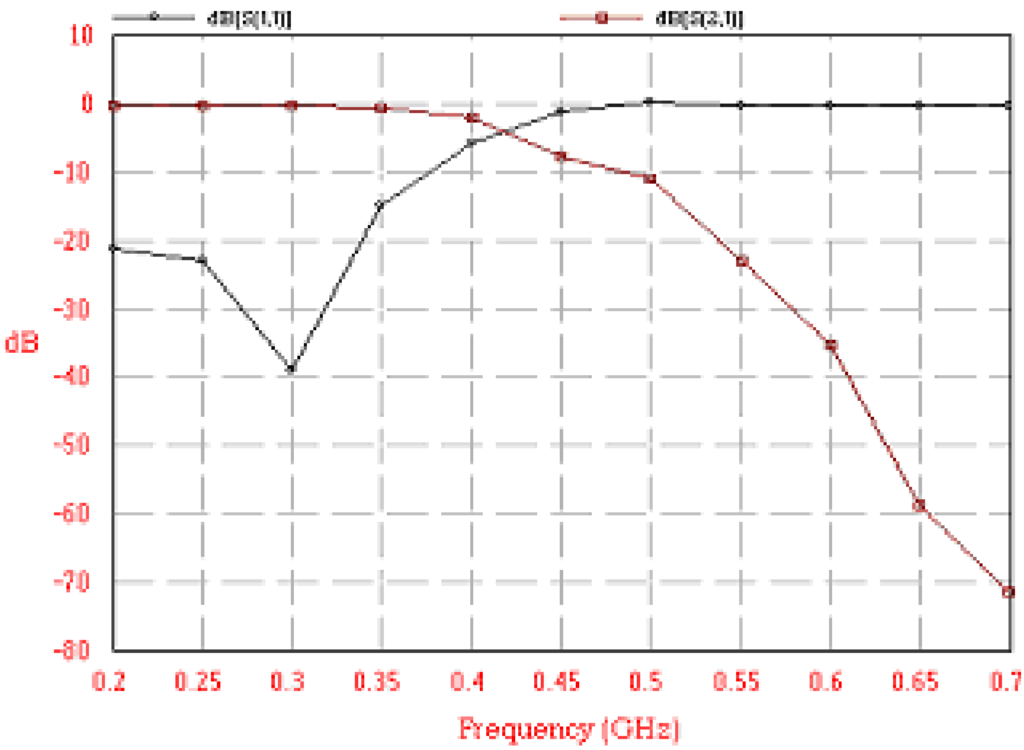

Fig 2: Simulated Result of low pass filter

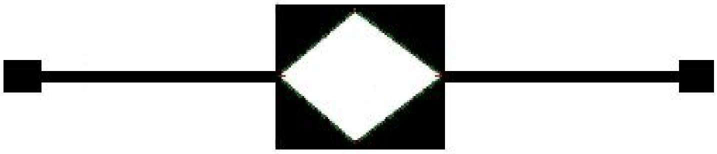

Fig. 3: Fractal Filter

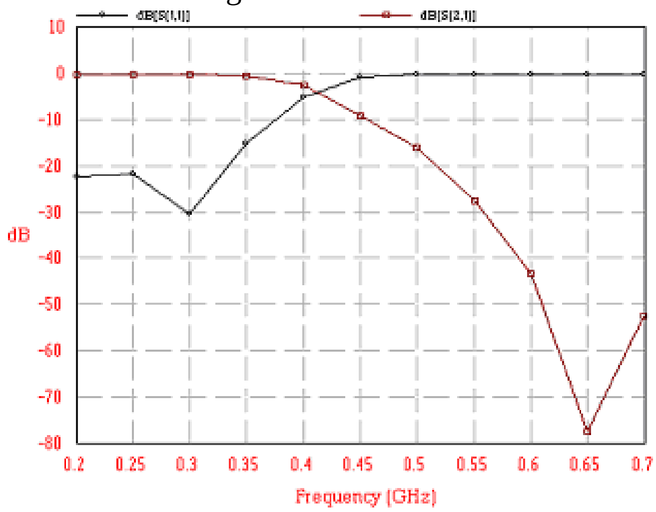

Fig 4: Simulated Result of Fractal low pass filter

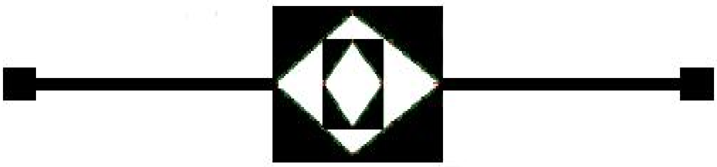

Fig. 5: Fractal Filter

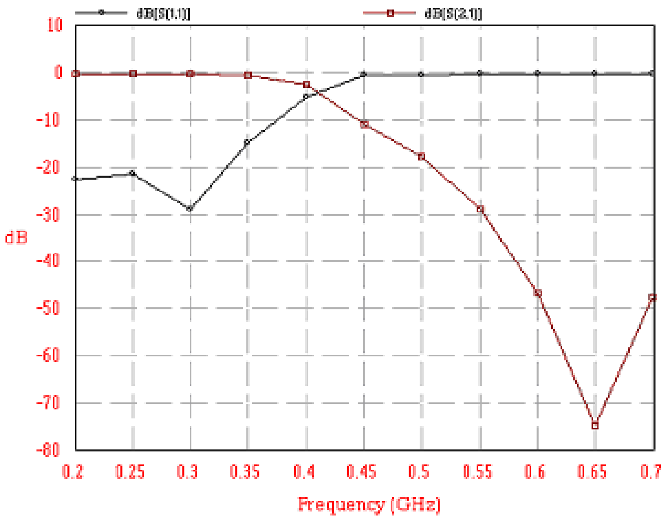

Fig 6: Simulated Result of Fractal low pass filter

Conclusion

The response of Microstrip filter of fig.1 is not having sharp cut off and the attenuation peak is – 59.5dB, at 0.65GHz. To improve the frequency response, different types of fractals have been done in the designed filter. The fractal filter and their responses are shown in figure 3-6. All the filters are having the same dimension as the basic filter. Considerable improvements in the frequency response of the filters have been obtained by fractal.

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