Design and Fabrication of Six Pole Microstrip Elliptical Low Pass Filter

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Abstract **- Design and analysis of a stepped impedance elliptical microstrip low pass filter has been described in this paper. To improve the frequency response, fractals have been proposed in the conventional design. Simulated and measured results of the conventional as well as the fractal filter have been analyzed.**

Index terms- Elliptical, Filter, Fractal Microstrip, Stepped Impedance.

I INTRODUCTION

The electromagnetic spectrum is limited, which has to be shared for many applications, and filters are used to select or confine the microwave signals within assigned spectral limits. Emerging applications such as wireless and satellite communications, etc. continue to challenge RF filters with ever more strict requirements like smaller size, lighter weight and higher performance [1-3].

The term fractal means fractional dimensions. This is nothing but broken or irregular fragments introduced to describe a family of complex shapes, that posses an inherent self-similarity or self-affinity in their geometrical structure with dimensions that do not fall neatly into a whole number category. One property of a certain class of fractals is that it can have an infinite length while fitting in a finite volume [4]. A wide variety of applications for fractals continue to be found in many branches of science and engineering. Fractal techniques have shown the possibility to miniaturize filters and to improve input matching. In the present work a conventional microstrip elliptical low pass filter has been designed and analyzed [5].

To improve the performance of the filter, fractal geometry has been applied to the conventional filter. The performance of the fractal filter has been compared with the conventional design.

II. FILTER DESIGN AND ANALYSIS

The most general prototype of elliptical low pass filters as shown in fig.1.The frequency response of an elliptical filter that has equal ripples, in both the pass band and the stop band as shown in fig.2.To obtain sharp cutoff for a given number of reactive elements, it is necessary to design filter structures having infinite attenuation at finite frequencies. Elliptical low pass filter which contains, two series-resonant branches connected in shunt, used to short out transmission at their resonant frequencies as shown in fig.3.

A transfer functions

The transfer function of prototype elliptical low pass filter for even and odd as given below.

$$|S_{21}(j\Omega)|^2 = \frac{1}{1+\varepsilon^2 F_n^2(\Omega)} \tag{1}$$

$$F_n(\Omega) = \begin{cases} M \dfrac{\prod_{i=1}^{n/2}(\Omega_i^2 - \Omega^2)}{\prod_{i=1}^{n/2}\left(\Omega_s^2/\Omega_i^2 - \Omega^2\right)} & \text{; for n even} \\[2ex] N \dfrac{\Omega \prod_{i=1}^{(n-1)/2}(\Omega_i^2 - \Omega^2)}{\prod_{i=1}^{(n-1/2)}\left(\Omega_s^2/\Omega_i^2 - \Omega^2\right)} & \text{; for n odd} \end{cases} \tag{2}$$

Where, Ω_i ($0 < \Omega_i < 1$) and $\Omega_s > 1$, represent critical frequencies, whereas M and N, are constants. $F_n(\Omega)$ will oscillate between ± 1 for $|\Omega| \le 1$, and $|F_n(\Omega = \pm 1)| = 1$.

B. *Equations*

The prototype low pass filter has a pass band ripple L_{Ar} = 0.18dB and minimum stop band attenuation, L_{As} = 38.1 dB at Ω_s = 1.194 for the cutoff frequency Ω_c= 1.0 having element values as:

$$g_0 = g_7 = 1.000$$
$$g_{L4} = g'_4 = 0.7413$$
$$g_{L1} = g_1 = 0.8214$$
$$g_{C4} = g_4 = 0.9077$$
$$g_{L2} = g'_2 = 0.3892$$
$$g_{L5} = g_5 = 1.1170$$

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$$g_{C2} = g_2 = 1.0840$$
$$g_{C6} = g_6 = 1.1360$$
$$g_{L3} = g_3 = 1.1880$$

Where g_{Li} and g_{Ci} denote, the inductive and capacitive elements respectively. The L-C element values, can be determined by

$$L_i = \frac{1}{2\pi f_c} Z_0 g_{Li} \qquad 3)$$

$$C_i = \frac{1}{2\pi f_c}\frac{1}{Z_0} g_{Ci} \qquad (4)$$

The step-impedance implementations of microstrip elliptical low pass filter as shown in fig.4. The series inductors in the low-pass prototype can be replaced with high-impedance line sections Z_H and the open capacitors can be replaced with low-impedance stub line section Z_L, the actual values of Z_H and Z_L are usually set to the highest and lowest characterized that can be practically fabricated. Prototype filter elements are then scaled the impedance and frequency level and the physical length of the elements are obtained using the following relations:

$\beta l = \mathrm{Sin}^{-1}(\omega L/ Z_H) \approx \omega L/ Z_H$ (5)

$\beta l = \mathrm{Sin}^{-1}(\omega C Z_L) \approx \omega C Z_L$ (6)

The conventional elliptical low pass filter, designed using the above equations for the following parameters.

C. *Design parameters*

Cut-off frequency, fc = 0.75GHz

Dielectric constant, $\varepsilon_r = 4.7$

Substrate height, h = 1.6mm

Characteristic impedance and $Z_o = 50\Omega$

The frequency response of conventional design as shown in fig.5. The plus–shaped fractals are obtained by placing the rectangles of size 5x3mm, one at a time, perpendicular to each other, from the center as shown in fig.6. These fractals are etched out in the low impedance regions of this filter. All filter designs are simulated using IE3D and the parameter S_{21} obtained. Now, these filters are fabricated using “Epoxy Glass” printed circuit board and the parameter S_{21} noted at different frequencies, using the Spectrum Analyzer. Measured & Simulated results of microstrip low pass filters are plotted between S_{21} (dB) and frequency (GHz), and compared in fig.5 & 7.

III. ELLIPTIC FUNCTION LOW PASS PROTOTYPE FILTERS

Commonly used network structure for elliptic function low pass prototype filters are shown in fig.1.The shunt branches of series-resonant circuits are used for implementing the finite-frequency transmission zeros, since they short out transmission at resonance.

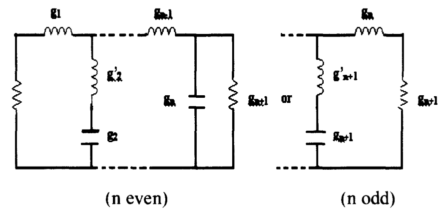

Fig. 1: Low pass prototype filters for Elliptic response

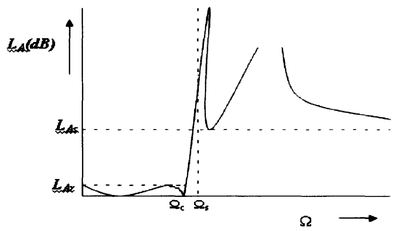

Fig.2: Elliptic low pass frequency response

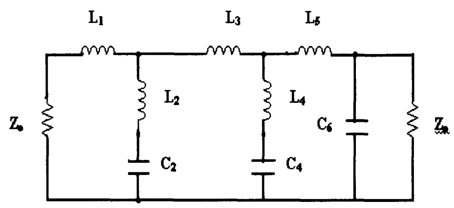

Fig.3. L-C circuit for six pole low pass Elliptical filter

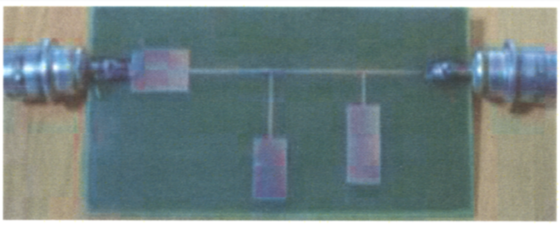

Fig.4. Microstrip elliptical low pass filter

IV. CONCLUSION

Improvements can be seen in the frequency response of the fractal low pass filter as compared to the conventional filter. It is observed that the attenuation level increased by 7 dB, measured and simulated results of both conventional and fractal filter are found to be similar. The improvement in the frequency response is achieved by applying the fractal method without changing any design parameters. Future line of work includes with different materials and different fractal geometries can be analyzed.

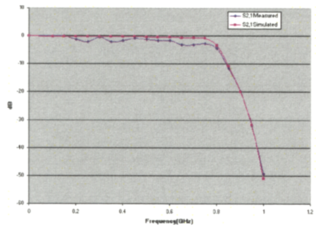

Fig.5. Response of microstrip elliptical low pass filter

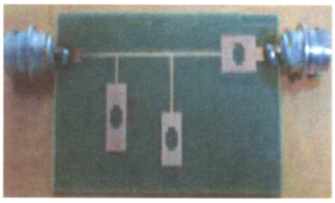

Fig.6. Fractal microstrip elliptical low pass filter

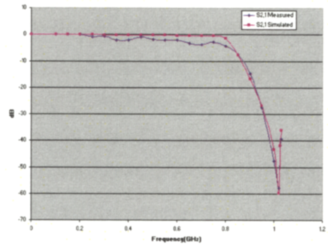

Fig.7. Response of fractal microstrip elliptical low pass filter

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