New Microstrip Low Pass Filter with Transmission Zero and Wide Stopband

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Abstract New microstrip low pass filters with low insertion loss, ultra-wide stopband and transmission zero are presented by using triangular and trapezoidal patch resonators with fractal defection. With such defection and a certain parallel feed method, undesired responses and harmonics are effectively suppressed and wide band, sharp attenuation obtained. The new filters have simpler and more compact configurations even better filter properties than the traditional line based ones.
Key words triangular resonator lowpass filter, fractal defection, wide stopband, transmission zero

1. Introduction

Fractal means broken or fractured which is derived from Latin word "fractus" dates back to the 19th century as a branch of classical mathematics. Fractal can generate almost any complex configurations in nature by iterating certain simple geometries, and have advantages including miniaturization and wide band or multi-band operation[1], which attribute to its basic properties of self-similarity and space filling. Self-similarity means a portion of the fractal geometry always looks like that of the entire structure, and space filling means a fractal shape can be filled in a limited region as the order increases without increasing the whole area. In microwave filters design, harmonic suppression is very important, and some method such as DGS(defected ground structure)[2] is proved efficiency, however, it make filters complicated and have a leaky wave problem due to the discontinuity in ground plane. Now, fractal principle brings a new way to overcome the above deficiencies. For a patch resonator filter, fractal defection can act as filter perturbation which suppresses the undesired harmonics for implementing a wide band. Conventional implementation of a low pass filter(LPF) involves the use of open stubs or stepped-impedance microstrip lines. However, these structures have gradual cut-off response that only by increasing the number of section, the filter rejection characteristic can be improved, and this improving method increases the passband insertion loss and filter physical size. Recently, some new methods such as DGS[3,4] and complementary split ring resonators(CSRR)[5] et al, are applied to design LPFs, however, the filter performances such as bandwidth of stopband and sharp attenuation responses are enhanced by increasing cells, which lead to larger size and more transmission losses. In our report, new microstrip low pass filters using single patch resonator with fractal-shaped defection are proposed for the first time to implement nicer performances of transmission zero to get sharp attenuation, ultra-wide stopband and low insertion loss, which have advantages of simple and compact circuit topology, miniaturization, et al.

2. Filter Design

Patch resonator is popular for miniature microstrip bandpass filter design, however, seldom used to other filters implementation. Fractal-shaped defection has very important applications to patch resonator filter, which acts as perturbation and introduce degenerate modes or higher order modes operation, and suppress the undesired harmonics to implement a multi-band or wide band. For a regular triangular fractal defection, it consists of a loop resonator filter with bandpass operation[6], however, if the triangular fractal defection is reversed to intersect the patch hemline, the perturbation will be strong enough to suppress the reject-band of a bandpass filter. If the upper reject-band of a bandpass filter with dominant mode $TM_{1,0,-1}$ operation is suppressed and a passband instead, a lowpass filter can be obtained.

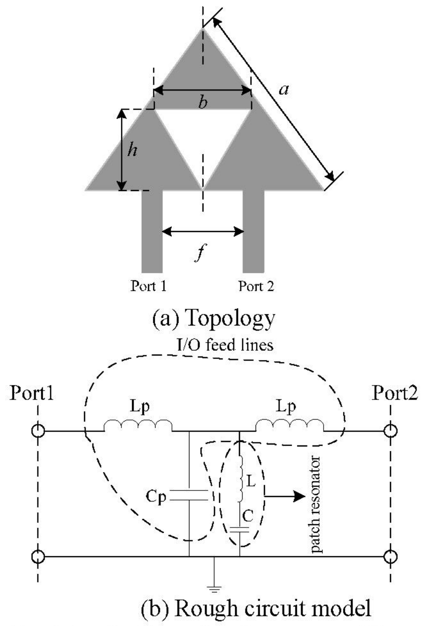


Fig. 1 Equilateral triangular low pass filter (a=15mm, b=8mm, h=6mm)

The proposed low-pass filter topology and circuit model are shown in Fig.1, where, an inverted isosceles triangular defection with hemline length of *b* and height of *h* is etched in the equilateral triangular patch with triangle side length of *a*, and divided it into three similar parts. I/O feed-lines that set at the triangular hemline are microstrip lines with characteristic impedance of 50 Ω, and act as coupled lines that the shunt capacitor between them can be tuned to obtain sharp attenuation, and the corresponding equivalent circuit consists of C_p and L_p. The filter is fabricated on a polystyrene substrate with a relative dielectric coefficient of 2.56 and a thickness of 0.775mm, and the patch geometric parameters are optimized as *a*=15mm, *b*=8mm, *h*=6mm. Fig.2 is the simulated frequency responses, it can be seen the filter is provided with a cut-off frequency of 5.9GHz, ultra-wide stopband of more than 8GHz, and max. insertion loss of no more than 0.3dB, as well as transmission zero to get sharp attenuation. The distance between two parallel feed-lines affects the location of transmission zero and degree of sharp attenuation, and more less it, more shaper attenuation. Frequency responses comparison of two different topologies is illustrated in Fig.3, it shows that for a smaller dimension of equilateral triangle side length *a*=10mm, the filter cut-off frequency increases to about 10GHz, and also has transmission zero as well as ultra-wide stopband. It shows the proposed filter has a wide utility.

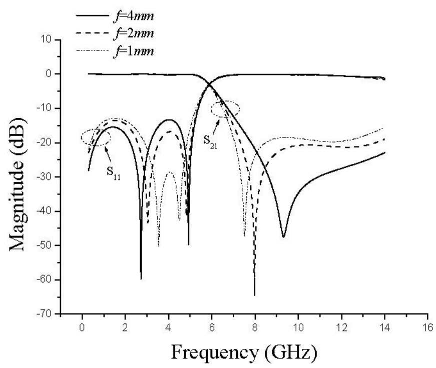


Fig.2 Simulated frequency responses

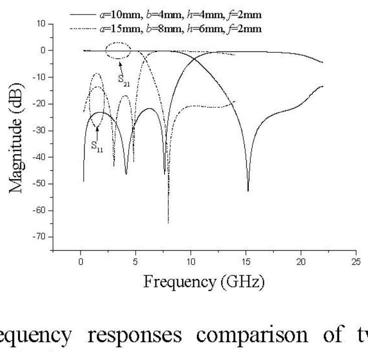


Fig. 3 Frequency responses comparison of two different topologies

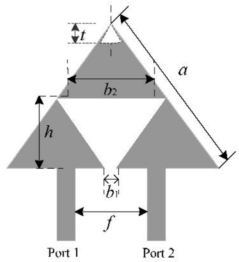
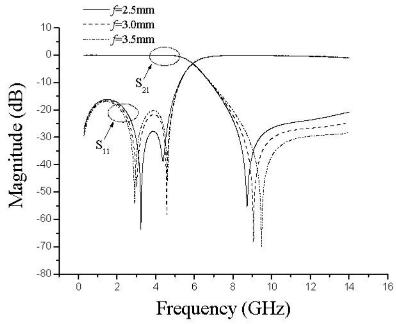
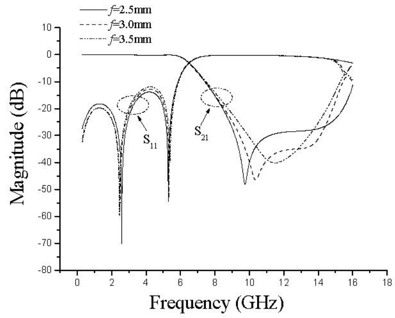


Fig. 4 Equilateral triangular LPF with a top triangle cut and a trapezoidal defection (a=15mm, b1=2mm, b2=8mm h=6mm)



ε_r=2.56, t=1mm

Fig. 5 Frequency responses of the LPF with a trapezoidal defection



ε_r=2.56, t=3mm

Fig. 6 Frequency responses of the LPF with a trapezoidal defection

A second LPF using equilateral triangular patch resonator with a top triangle cut and a trapezoidal defection is also proposed, as shown in Fig.4, and which brings a smaller size, and can be seen as a trapezoidal fractal-shaped structure. Filter geometric parameters are designed as *a*=15mm, b_1=2mm, b_2=8mm and *h*=6mm, and simulated frequency responses are shown in Fig.5 and Fig.6. It can be seen that for a triangular patch resonator with top triangle cut of t=1mm, the filter provides with a cut-off frequency of 5.94GHz, and transmission zero with attenuation of no less than 55dB, and wide reject-band of more than 8GHz. For t=3mm, the filter cut-off frequency increases to 6.5GHz, and still has a wide reject-band.

3. Conclusion

New low-pass filter is proposed to implement transmission zero and ultra-wide stopband of more than 8GHz by using triangular patch resonator with fractal-shaped defection, a new kind of filter design technique to get multi-band or wide band as well as miniaturization. The filter has a compact size, simple structure, and can be easily calculated and tuned, which are all popular for RF circuit applications.

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