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New Approach For 6-Pole Stepped Impedance Microstrip Low Pass Filter Using DGS

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Abstract:
Demand for newer microwave and millimeter wave system with respect to size, cost and performance. This paper presents a compact microstrip stepped impedance lowpass filter Filters play an important role in microwave applications. Micro strip filters play various role in wireless communication or mobile communication systems. There is an increasing to meet the emerging telecommunication challenge with ultra-wide stop band. A compact double equilateral U-shaped defected ground structure (DGS) unit is proposed. In contrast to a single finite attenuation pole characteristic offered by the conventional dumbbell DGS the proposed DGS unit provide dual finite attenuation poles that can be independently controlled by the DGS lengths. A 1.5-GHz microstrip low pass filter using five cascaded double U-shaped DGS unit is designed and compared with conventional DGS low pass filter.

***Key words**: low pass filter, Dielectric constant, Microstrip filter, Defected ground structure (DGS)*

1.INTRODUCTION
With the rapid development of microwave communication systems, microwave low pass filters (LPFs) with low cost, small size, low insertion loss, high selectivity, and wide stop band have attracted wide attention for years. Various technologies have been developed in practice, but the microstrip LPFs are more dominant due to the reduction of circuit sizes. Stepped-impedance structure is a relatively popular way to implement microstrip LPFs by cascading very high and very low characteristic impedance transmission line alternatively. Applications uctiof defected ground structure (DGS) in radio frequency/microwave (RF/MW) circuits find numerous advantages like circuitry size redon and superior response suppression. The conventional DGS element uses a dumbbell-shaped pattern etched in the ground plane This DGS element exhibits a bandgap charactertics at some frequency, which is mainly attributed by a finite attenuation poles. The relationship between attenuation pole frequency and the physical dimensions of the DGS unit was also explored. Recently it usage in the low pass filter for wide stop band implementation has been focused and demonstrated. In fact , these DGS elements with uniform dimensions are cascaded in a one dimensions (1-D) periodic pattern in order to realize wider stop band even the pass band ripple is concerned To counteract this ripple problem, nonuniform configuration have been proposed to achieve much WIDER stopband and smaller passband ripples simultaneously. It is found that the more DGS element are used, the wider stopband is achieved.
In this paper low pass filter is optimized for high performance and efficient. Microstrip technology is used for simplicity and easy of fabrication. The design and simulation are performed using 3D full wave Electromagnetic simulator IE3D.

2.DGS Unit
There have been two research aspects for adequately utilizing the unique performance of DGS: DGS unit and periodic DGS. A variety of slot geometries etched in the microstrip line ground plane have been reported in the literature. In Fig. 2, it is shown that a variety of attached area shapes including spiral head, arrowhead-slot and “H” shape slots and so on. There also have been more complex DGSs so as to improve the circuit performance shown in Fig. 2, such as: a square open-loop with a slot in middle section, open-loop dumbbell and interdigital DGS. The new DGS unit could control the two transmission zeros near the passband edges and easily control the frequency of the slot by changing the length of the metal fingers.

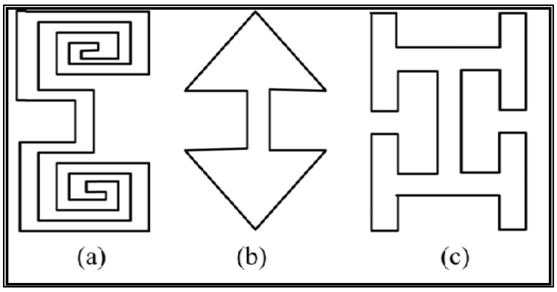

Figure 1(a), 1(b), 1(c)

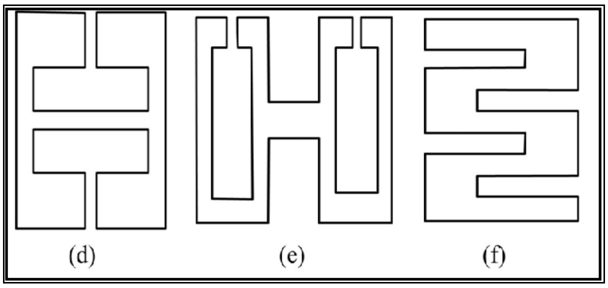

Figure 1(d), 1(e),. 1(f)

Figure 1**.** Various DGSs: (a) spiral head, (b) arrowhead-slot, (c) "H" shape slots, (d) a square open-loop with a slot in middle section , (e) open-loop dumbbell and (f) interdigital DGS.
The use of a bent microstrip line does not significantly change the frequency behavior that remains as for the straight DGS microstrip line. The bending technique leads to a 2D configuration, in which the microstrip line presents multiple bends, following a similar structure as that of a meander line. This configuration has a broad stopband and allows a large number of periods in a reasonable circuit area. New proposed DGS unit has some advantages than dumbbell DGS:

- A higher slow wave factor and more compact circuit. The circuit area of filter using "H" shape slots is much smaller about 26.3% than using dumbbell DGS.
- A narrow width stopband and deeper rejection.
- A slightly larger external Q. To compare the transfer characteristics of the U-slot DGS with that of the conventional DGS, the spiral-shaped DGS and U-slot DGS are designed to provide the same resonance frequency. Q factor of the spiral DGS is 7.478 (3 dB bandwidth of 0.39 GHz), while the U-slot DGS provides a high-Q factor of 36.05 (3 dB bandwidth is 0.081 GHz) .

In a word, more and more new DGSs are proposed which bring a great convenience to the design of microwave circuit to realize various passive and active device compact structures and to suppress the harmonics.

3.U-SHAPED DGS UNIT

Despite the different periodic DGS proposed in the past, the main laggard of these approaches is the excess circuitry size introduction due to the cascade DGS configuration . In order to realize simultaneously wide stopband and size minimization for the microstrip low pass filter with DGS a double equilateral U- shaped DGS unit that can offer dual attenuation poles is proposed. The paper control of these two attenuation poles can significantly suppress the spurious response in the stopband with much smaller defected ground area. A microstrip low pass filter prototype with a cut off frequency of 1.5GHz and wide stop band up to 10GHz has been designed and experimentally characterized to demonstrated the proposed DGS usefulness.

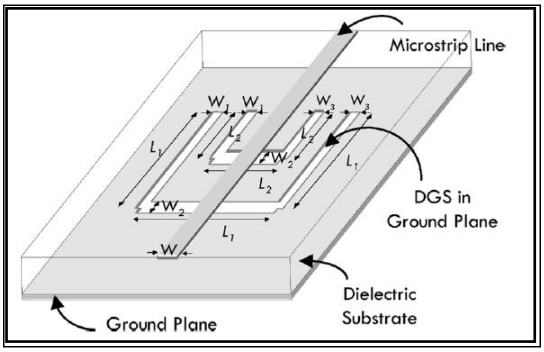

Figure 2: Three Dimensional View Of Proposed DGS Unit

The proposed double equilateral U shaped DGS unit shown in fig.1, it has a 6-pole ordinary microstrip low pass filter on the top and five equilateral U shaped pattern that are symmetrically etched in the ground plane. Each U shaped pattern consist of three etched lines with the same length but the different width (W_1, W_2, and W_3) by setting these five U shaped pattern with different length (L_1,L_2 where $L_1>L_2$). The smaller one can easily be embedded inside the larger ones with the open end alignment.

4.Filter Desinge Method

The design of low pass filters involves two main steps. The first one is to select an appropriate low pass prototype. The choice of the type of response, including pass band ripple and the no of reactive element will depend on the required specification. The element values of low pass prototype filter, which are usually normalized to make a source impedance g_0=1 and a cut off frequency Ω_c =1.0,are than transform to L-C element for the desired cut off frequency and the desired source impedance ,which is normally 50 ohms for microstrip filters. The next main step in the design of microstrip low pass filter is to find and appropriate microstrip realization that approximately lumped element filter .The element value low pass prototype with maximally flat response at pass band ripple factor L_{AR}=0.1dB. Characteristic impedance source/load Z0=50ohms , are taken from normalized value g_i i.e. g_1, g_2, g_3, g_4………..g_n. The filter is assumed to be fabricated on a substrate a dielectric constant ϵ_r and of thickness h mm for angular (normalized) cut off frequency Ω_c, using the element transformation.

4.1.Filter Specifications
Relative Dilectric constant, E_r =4.4
Height of substrate, h=1.6 mm
The substrate used-
The loss tangent $\tan^{\delta}$=0.02
Input impedence Z_o =50Ω
Ω_c = 1Ω
Cutoff frequnecy f_c=2.4GHz

4.2.Designe Equation
Determine the valus of the prototype elements to realize the specifications. Aiso we have taken the
$L_i=(Z_o/g_o)(\Omega_c/2\pi f_c)g_i$
$C_i=(g_o/Z_o)(\Omega_c/2\pi f_c)g_i$
$I_L=\lambda_{g1}/2\pi\sin^{-1}(\omega_c L_i/Z_{oL})$
$I_c=\lambda_{gc}/2\pi\sin^{-1}(\omega_c C_i Zoc)$
To calculate the width of capacitor and inductor we use the following formula
W/h=8 exp(A)/exp(2A)-2
$Z_c=\eta/2\pi\sqrt{\epsilon re}\left[\ln\left(\frac{8h}{w}+\frac{0.25w}{h}\right)\right]$
The effective dielctric constant can be found by the following formula
$\epsilon_{re}=(\epsilon_r+1)/2+(\epsilon_r-1)/2[(1+12h/w)-0.5]$

5.Dimention Of The Filter

Sr.no	$Z_i=Z_h$ or Z_l (Ω)	W_i (mm)	L_i (mm)
1	93	0.83855	10.348
2	23	9.2593	9.72
3	93	0.83855	23.94
4	23	9.2593	7.731
5	93	0.83855	23.942
6	23	9.2593	9.32
7	50	3.679	3

Table 1: Dimensions Of The Stepped Impudence Low Pass Filter (For N=6)

6.SIMULATED RESULTS
The proposed filter is composed of sixth-order stepped impedance LPF of varied width and U-shaped DGS unit. The feed line is designed 50 ohm all geometric dimensions are shown in table-1 and fig. 3, 4 shows simulated results of the proposed microstrip low pass filter. For the simulation purpose we have used method of moment based full-wave EM solver IE3D.

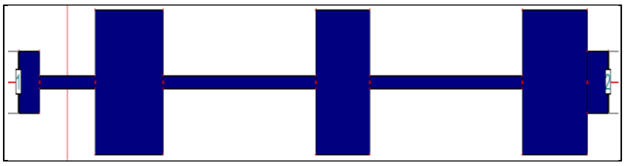

Figure 3(a): Layout Of The Simulated 6-Pole Stepped Impedance Microstrip LPF (Top Layer)

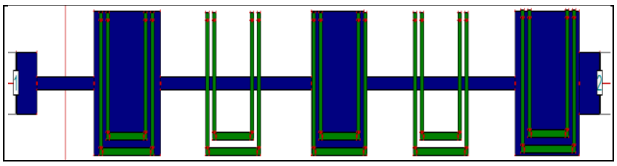

Figure 3(b): Layout Of The U-Shaped Cascaded DGS. (Bottom Layer)

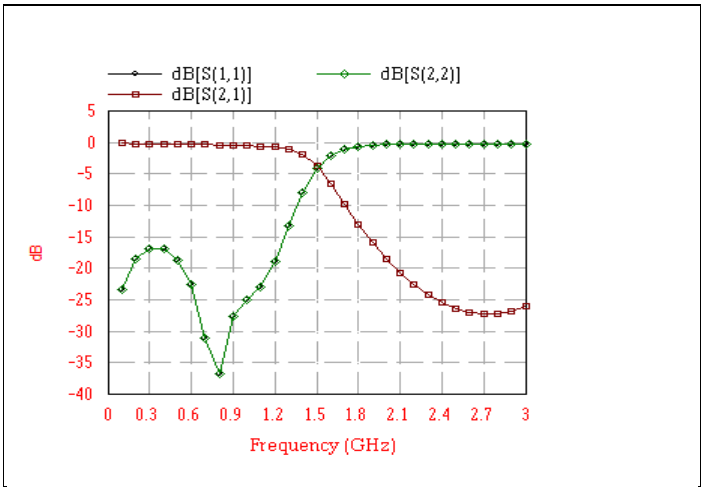

Figure 4: Simulated Result Of Stepped Impedance LPF Using U-Shaped DGS This Graph Is Plotted Between S(1,1) And S(1,2)

7.Current Distribution

we use this program to analyze current distribution , the photograph of the filter along with their respective current distribution function are shown in figure 5.

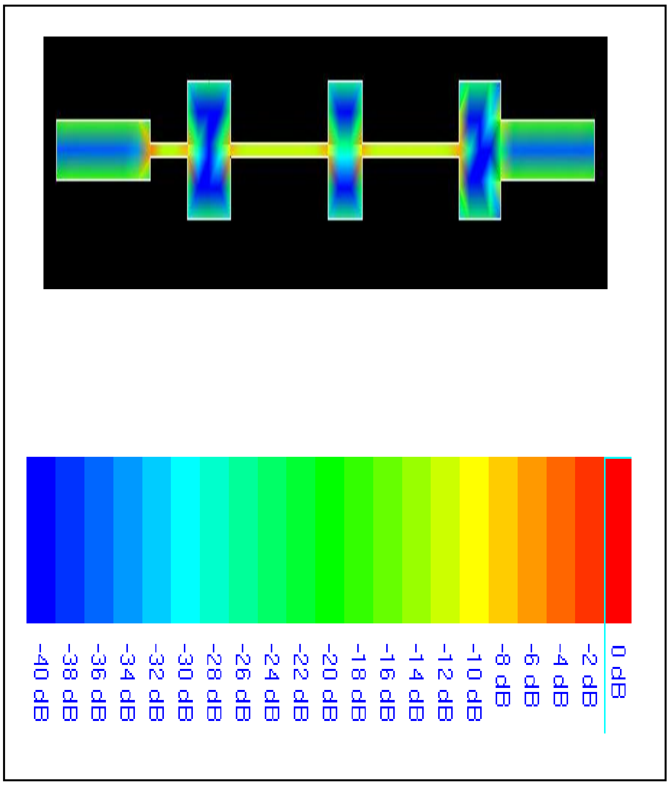

Figure 5: Surface Current Distribution

The objective of the following study is to prove the dependence of the equivalent circuit elements (capacitance and inductance) on the surface current distribution. As shown in figure 5 , the structure is divided into two regions. In region I, the electric field is highly concentrated in the gap, hence any change in dimensions of the gap affects the effective capacitance of the structure. In region II, the electric field nearly vanishes. The current is distributed throughout the whole structure. Therefore, any change in the length of the meander arm strongly affects the magnetic field distribution and hence the surface current, which in turn leads to a change in the effective inductance of the structure. So it will be easy to guarantee, that region I corresponds to a capacitance and region II corresponds to an inductance, thus the full structure corresponds to parallel LC-resonator.

8.Conclusion

The paper present an efficient approach to improve conventional stepped impedance lowpass filter transition band performance with a miniaturized area. from the simulated results the lowpass filter based on the proposed DGS unit offers significant improvement of the stopped band attenuation and size reduction when compared with the conventional low pass filter. Thus this method is very flexible for configuration and specially use full low pass filter design to develop sharp transition band.

9.Acknowlegement

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