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Lowpass Filter with Sharp Rolloff Factor Using Open Circuit Stubs and Modified π-Defected Ground Structure

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Abstract

A lowpass filter with a very sharp rolloff factor of $(70.18\mathrm{dB/GHz})$, using modified π defected ground structure (π-DGS) and open circuit stubs is described. The lowpass filter was designed at a cutoff frequency of 2.67 GHz, which is suitable for GSM900, GSM1800 and UMTS applications of mobile communications. The proposed lowpass filter provides a size of 30x28x0.78 mm^3, and have a good transition band with a good performance in the passband and it has a wide rejection band up to 11.0 GHz plus harmonic suppression in the stopband. Measurement results show good agreement with the simulated ones.

Key-words: microstrip, lowpass filter, rolloff, defected ground structure, open circuit stub, GSM

1. Introduction

Microstrip filter is an essential component in microwave communication systems. With the current expansion of the wireless communication industry, the requirement of high performance filters is increasing. In recent researches, the compact size and harmonic suppression for the lowpass filter structures are two significant factors in the design. There are different features of the microstrip lowpass filters to improve; first, very sharp cutoff frequency response and low ripple corresponding to return loss in the passband; second, wide stopband characteristic and good stopband rejection; third, small and compact size. Most of these features can be achieved by using the defected ground structures (DGS). The defected ground structures gained interest for their simple planar structures and ease of fabrication [1]. They are very useful in the design of lowpass and bandpass filters, since a few DGSs can provide a cutoff frequency and an attenuation pole without the need of a periodic array as needed to build a filter with electromagnetic band gap (EBG) structures. The DGS's have many advantages [2], first; the fabrication cost can be reduced with a simulation improvement of the filter performance. Second; they can be easily modeled using simple RLC circuits, especially for microstrip line structures. Because of the excellent stopband and slow wave characteristics, the DGS have been applied widely to microstrip filters, amplifiers and antennas, etc. DGSs are realized by etching defects in the backside metallic ground plane beneath the microstrip line [3]. A basic and widely used DGS cell is composed of two wide defected areas and a narrow connecting slot. Such a structure blocks the signal around its resonant frequency and may be used to introduce a wide stopband for lowpass and bandpass filters. Such filters have sharp transitions between the passband and the stopband, low insertion loss in the passband, wide and high attenuation in the stopband. Etching in the backside metallic ground plane for the microstrip line perturbs the current distribution, which increases the effective inductance and capacitance of the microstrip line. DGSs have been widely used in RF circuits, offering advantages such as compact physical dimensions, spurious response suppression, and bandgap characteristics in some frequency bands [3-4]. Nonuniform configurations of DGSs have also been investigated to obtain a wide or an ultra-wide stopband [5-6]. Various shapes of DGS have been investigated in filters applications [1–10].

In this paper, a lowpass filter with very sharp rolloff factor is implemented using stepped impedance microstrip line with modified π dumbbell defected ground structure in addition to open circuit stubs on the conductor sides. The designed lowpass filter gives wide stopband covering the frequency range from 2.67 GHz up to 11.0 GHz with attenuation less than (−17 dB). The measured return loss in the passband is less than (−21.5 dB). The realized lowpass filter measurements gave good agreement with the simulated ones.

2. Design and Simulation

The lowpass filter is designed using a modified π defected ground structures (DGS) on RT/Duriod

5880 (ε_r=2.2, h=0.7874 mm) substrate material. The filter dimensions are shown in Fig.1. The lowpass filter is simulated using IE3D readymade software, and the simulation results are shown in Fig.2. The structure yields the performance of lowpass filter with cutoff frequency of 2.66 GHz with return loss (S_{11}) less than (-7.6dB) in the passband, whereas; the stopband extends up to 10.0 GHz with an insertion loss (S_{21}) less than (-11.3dB). The return loss (S_{11}) suffers around (-2dB) at upper frequency band (9-10GHz). Modifying the defected ground structure in the ground plane as shown in Fig.3(a), the simulated results of the filter enhanced, Fig.3 (b). The cutoff frequency shifted to 3.1 GHz, while the return loss (S_{11}) in the passband is less than (-9.35dB) and the insertion loss (S_{21}) in the stopband is less than (-11.45dB). When it is compared with previous regular π-defected ground structure, Fig.2, it appears that the cutoff frequency shifted upward the spectrum while (S_{11}) in the passband has a better value. To enhance the passband and stopband of the lowpass filter to a better value, a three open circuit stubs were added to the LPF as shown in Fig.3, where the dimensions of the circuit with open circuit stubs is shown in Fig.4 (a). Its performance is shown in Fig.4 (b), where, the cutoff frequency is 2.6 GHz. The return loss (S_{11}) in the passband has a value less than (-17.5dB) and the insertion loss in the stopband (S_{21}) is less than (-13.8dB). The lowpass filter has (72.6 dB/GHz) rolloff factor, with good performance up to 11GHz, after which, the performance deteriorated. To enhance the LPF performance and extend the stopband, two extra open circuit stubs were added, Fig.5(a). The simulated filter performance is shown in Fig.5(b), where the cutoff frequency is 2.63 GHz, and the return loss (S_{11}) in the passband is less than (-16.6dB) and the insertion loss (S_{21}) in the stopband is less than (-16.5dB). The lowpass filter has a $(-63.29\text{dB}/\text{GHz})$ rolloff factor; also the stopband of the lowpass filter extended to 13GHz.

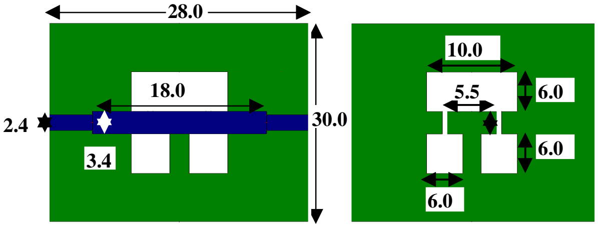
3. Equivalent circuit

In general, the dumbbell slots with its connecting slot under the microstrip line can be represented by parallel LC circuit. The value of the inductance and capacitance are calculated using the following formula [11]:

$$C = \frac{5f_c}{\pi(f_o^2 - f_c^2)} \qquad (1)$$

$$L = \frac{250}{C\,(\pi f_o)^2} \qquad (2)$$

Where C, L and F are measured by picofarad (pF), nanohenry (nH) and GHz, respectively. The frequencies f_o and f_c represent the attenuation and cutoff frequency, Fig.5. The frequencies f_o and f_c for the lowpass filter with five open circuit stub are 2.626 GHz and 3.0 GHz, respectively. The equivalent circuit of the proposed lowpass filter is shown in Fig.6. The performance of this equivalent circuit is shown in Fig.7.



Upper side **Lower side**

Fig.1 The dimensions for the upper and the lower sides of the designed lowpass filter

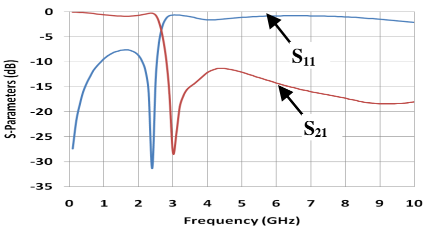


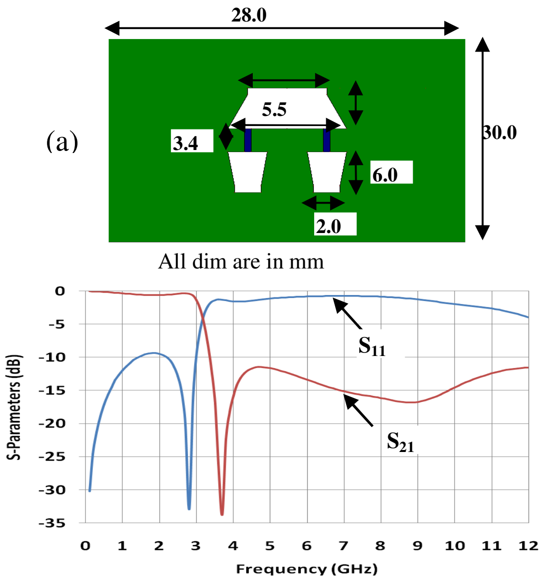
Fig.2 The return and insertion loss of the designed lowpass filter

4. Fabrication and Measurements

The lowpass filter with five open circuit stubs was realized on RT/Duroid 5880 (ε_r=2.2, h=0.7874 mm) substrate material. The filter was fabricated in the microstrip laboratory at the Electronics Research Institute using thin film technology and photolithographic technique. The photos of the realized circuit are shown in Fig.8. The measured return and insertion losses are compared with the simulated ones, as shown in Fig.9. The realized lowpass filter with five open circuit stubs have a cutoff frequency of (2.80 GHz) and it has a return loss (S_{11}) in the passband which is less than (-21.5 dB) where, the insertion loss (S_{21}) in the stopband is less than (-17.0dB). The simulated lowpass filter has a cutoff frequency of 2.67GHz, with a shift in the cutoff frequency around 130 MHz, which may be attributed to fabrication tolerance and mismatch. The realized lowpass filter has a $(70.18\text{dB}/\text{GHz})$ rolloff factor; also the stopband of the lowpass filter is extended to 11 GHz.

Conclusion

In this article, a novel lowpass filter ($30x28x0.78mm^3$) on RT/Duroid 5880 (ε_r=2.2, h=0.7874 mm) substrate, using modified π-DGS and five open circuit stubs is designed. It has a very sharp rolloff factor of (70.18dB/GHz) and a cutoff frequency of 2.8 GHz, which is suitable for GSM900, GSM1800 and UMTS applications of mobile communications. The proposed filter was realized and measured, it has return loss (S_{11}) in the passband less than (-21.5 dB), and insertion loss (S_{21}) in the stopband less than (-17.0 dB). Good transition band and good performance in the passband is obtained while, it has a wide rejection band up to 11.0 GHz plus harmonic suppression in the stopband. Measurement results showed good agreement with the simulated ones.

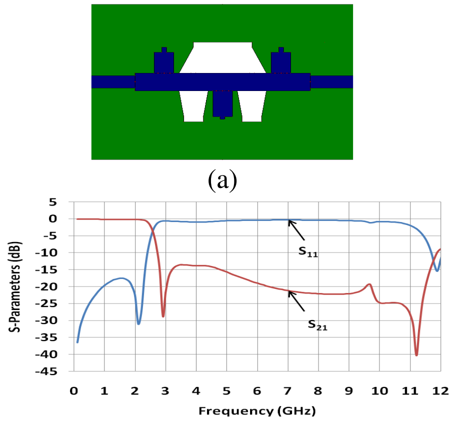


(a)

All dim are in mm

(b)

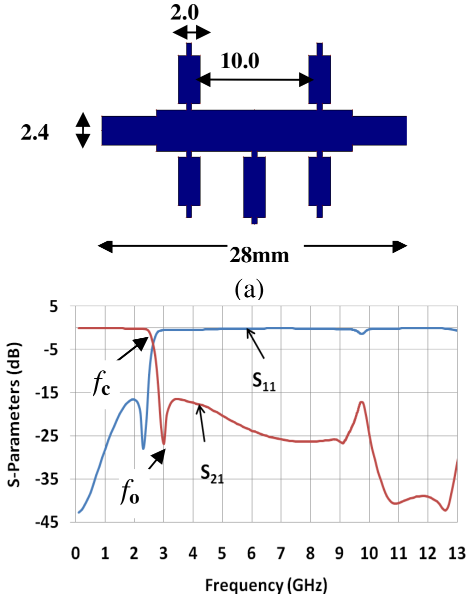
Fig.3 The dimension and performance of the lowpass filter with modified DGS



(a)

(b)

Fig.4 The configuration and performance of the lowpass filter with three open circuit stubs



(a)

(b)

Fig.5 The dimensions and performance of the lowpass filter with five open circuit stubs

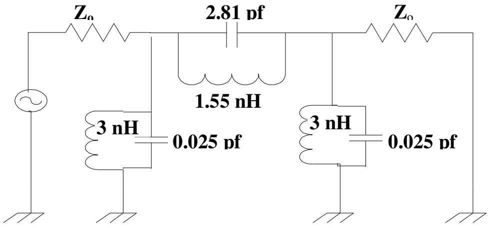


Fig.6 The lowpass filter equivalent circuit with its lumped elements

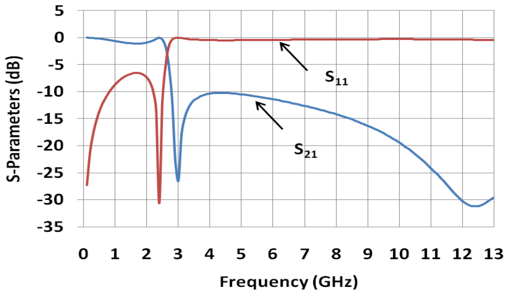
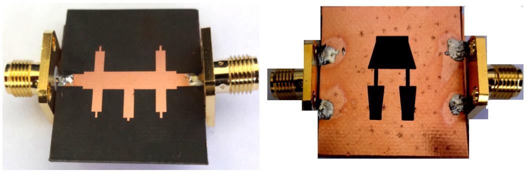


Fig.7 The equivalent circuit performance



Upper side **Lower side**

Fig.8 The photos of the realized lowpass filter with five open circuit stubs

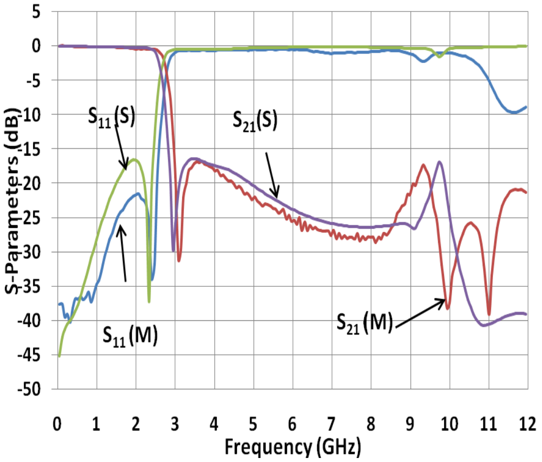


Fig.9 The measured and simulated results of the lowpass filter with five open circuit stubs

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