Modeling and Analysis of a Novel UWB Filter

Shao Junyu[1, a *], Ding yong[2,b] and Xiang Chao[1,c]

[1]Shanghai Eletro-Mechanical Engineering Institute, Shanghai 201109, China

[2]School of Electronic Engineering And Optoelectronic Technology, NUST, Nanjing 210094,China

[a]shao_jy@foxmail.com, [b]nj1039510583@gmail.com, [c]xiangchao050726@foxmail.com

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Abstract. A novel UWB filter is proposed based on Split Ground Structure(SGS) in this paper. LC equivalent circuit of SGS is drew by analyzing its electric field, magnetic field and current distribution, giving its methods and formulas of SGS parameter extraction. Finally we give LC equivalent circuit of the entire UWB filter structure we proposed and point out the impact of relevant parameters variation on UWB filter performance. Results show that the modeling method is right and effective.

Introduction

Since February 2002, the U.S. Federal Communications Commission (FCC) lifted 3. 1-10. 6GHz band, causing a wave of ultra-wideband (Ultra wideband, UWB) wireless systems research boom in academia and industry [1].In recent years, some new technologies have been proposed to design UWB filter [2-7].For example, UWB filter is formed by high and low pass filter cascading, which can achieve relatively good sideband suppression, but this will undoubtedly increase the volume of the UWB filter, is not helpful to miniaturization [2-3].Zhu L et al. introduced multimode resonance (MMR) to obtain a better pass-band effect, but its upper sideband suppression is not enough [4]. Single layer E-shape microstrip structure was used to design UWB bandpass filter [5]. Other UWB filters like folded stepped-impedance resonator (SIR) [6] and employing defected ground structure [7].

In this paper, a novel UWB bandpass filters is Modeled and Analyzed. In Section II, the UWB BPF is designed with wide stopband. In the same time, the filter structure including Top layer and bottom layer are both shown in this section. Then LC equivalent circuit of SGS and methods and formulas of SGS parameter extraction are demonstrated. Further more, LC equivalent circuit of the entire UWB filter structure and the impact of relevant parameters variation on UWB filter performance are also displayed in Section II. Finally, conclusions are followed in Section III.

UWB Bandpass Filter Based on SGS

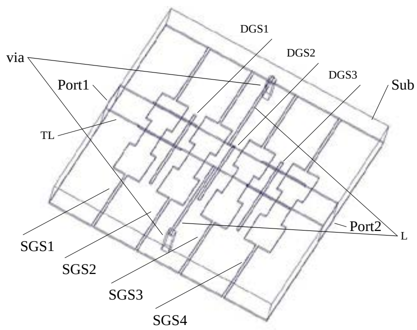


Fig. 1. Layouts for proposed UWB BPF

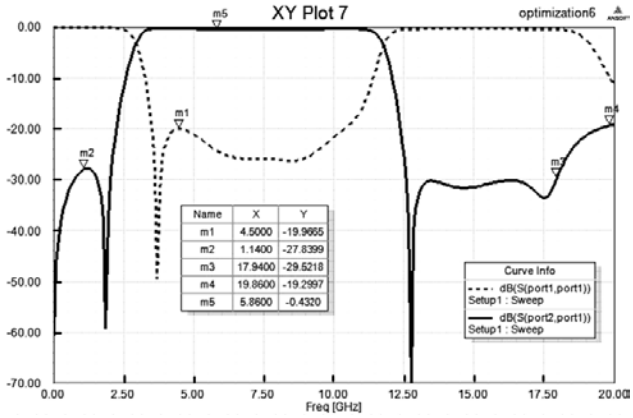
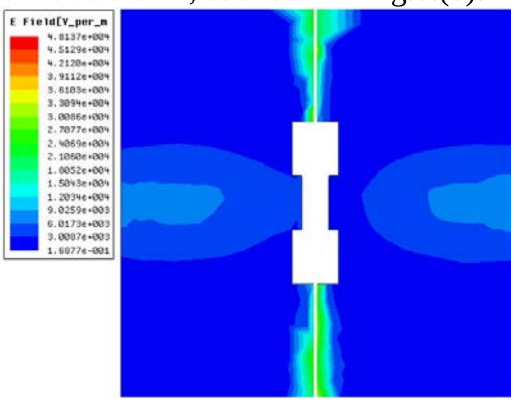


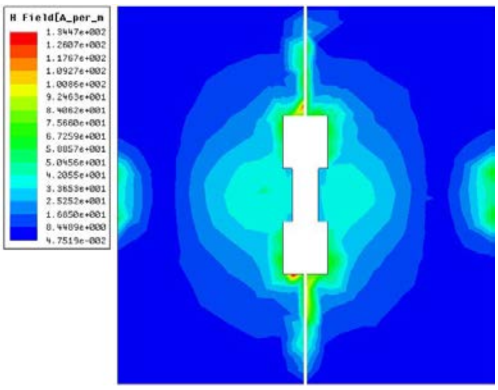
Fig. 2. Frequency response of proposed UWB BPF

Physic structure of UWB filter[8]. Fig. 1 shows the 3-D structure for the proposed UWB bandpass filter. The proposed UWB BPF has two metal layers. The input and output ports have 50Ω impedance; In top layer, it comprises of 50Ω transmission line and two elongated transmission lines connected to bottom layer by two vias forming a transmission zero in lower stopband; In bottom layer, the UWB BPF has four SGS Units and three rectangle DGSs, which can provide wide passband and upper stopband performance. Fig.2 presents the frequency response of proposed UWB BPF.

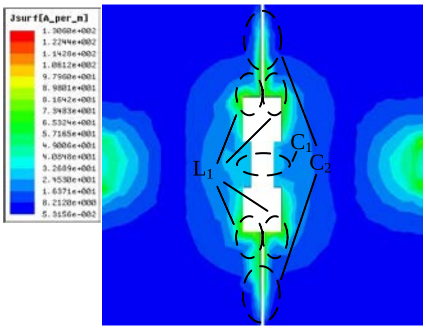
LC equivalent circuit of SGS and parameter extraction. SGS we proposed increases a slit on the basis of DGS. Fig. 3 (a), (b), (c) show its electric field, magnetic field and current distribution respectively. LC equivalent circuit diagram of SGS unit is shown in Fig.4. After studying Fig.3, we may seriously draw the conclusion that extra crack forms the capacitance C2, The remaining structure (DGS) forms capacitors C1 and inductors L1, as shown in Fig.3.(b).



(a)



(b)



(c)

Fig. 3. (a) Electric field distribution (b) Magnetic field distribution and (c) Current distribution

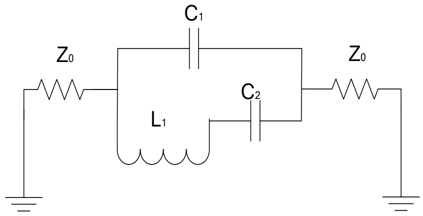


Fig. 4. LC equivalent circuit

When extracting parameters of SGS equivalent circuit, it is essential to use three-dimensional electromagnetic simulation software to simulate the structure in order to get its frequency response curve. According to its frequency response S21, the parallel resonant frequency f_0, 3dB lower sideband cutoff frequency f_{c1} and upper sideband cutoff frequency f_{c2} of SGS can be obtained, before converting these frequency parameters into the corresponding angular frequency ω_0, ω_{c1} and ω_{c2}. According to Fig.5, parallel resonance angular frequency:

$$\omega_0 = \frac{1}{\sqrt{\mathrm{LC}}} = \sqrt{\frac{C_1 + C_2}{C_1 C_2 L_1}} \tag{1}$$

where ω_0 corresponds to attenuation pole of S21. When frequency is high relatively, The entire loop electrical resistance at angular frequency ω:

$$X = 1\Big/\left(\frac{1}{\omega L_1 - 1/(\omega C_2)} + \omega C_1\right) \tag{2}$$

Series reactance of one order Butterworth prototype low-pass filter:

$$X' = \omega L = \omega' Z_0 g_1 \tag{3}$$

Where ω' is normalized angular frequency, Z_0 is standard impedance of the input / output, g_1 is prototype parameters of one order butterworth lowpass filter, in the light of look-up table g_1=2, reactance is equal at the upper sideband cutoff frequency, then $X|_{\omega=\omega_{c2}} = X'|_{\omega'=1}$, so:

$$1\Big/\left(\frac{1}{\omega_{c2} L_1 - 1/(\omega_{c2} C_2)} + \omega_{c2} C_1\right) = \omega' Z_0 g_1 \tag{4}$$

Similarly, when the frequency is low, the electrical admittance of the entire loop at the angular frequency ω:

$$B = \frac{1}{\omega L_1 - 1/(\omega C_2)} + \omega C_1 \tag{5}$$

Series susceptance of one order Butterworth high-pass filter:

$$B' = \omega C = \frac{\omega'}{Z_0 g_1} \tag{6}$$

Series susceptance is equal at Lower sideband cutoff frequency, then $B|_{\omega=\omega_{c1}} = B'|_{\omega'=1}$, so:

$$\frac{1}{\omega_{c1}L_1 - 1/(\omega_{c1}C_2)} + \omega_{c1}C_1 = \frac{\omega'}{Z_0 g_1} \tag{7}$$

According to (1)、(4) and (7), the value of C_1、C_2 and L_1 can be solved。

For example, when extracting parameter of SGS (l=1.4mm, g=0.8mm, a=1.2mm, b=1.4mm, s=0.1mm) using the way mentioned above, we can find L1=0.759nH, C1=0.214pF, C2=0.6pF, by using ADS simulate the derived parameter, frequency response S21 and S11 are shown in Fig.5.

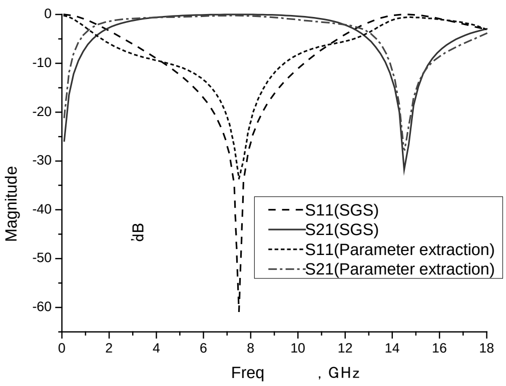


Fig. 5. The frequency response of SGS and its LC equivalent circuit

As can be seen from the chart above, after the parameters extraction using the above-described method, the S-parameters of the LC equivalent circuit and SGS are nearly the same. Therefore, LC equivalent circuit diagram and parameter extraction model we have established are correct.

Although the frequency response (S21 and S11)of the LC model and the actual SGS are not always consistent, this is due to the fact that we did not create the equivalent capacitance and inductance and carry out parameters extraction for the distributed capacitance and inductance of other structure except for SGS.

LC equivalent circuit of the entire UWB filter structure and the impact of relevant parameters variation. When building LC equivalent circuit of the entire UWB BPF structure, it must be noted that this structure is not microstrip line filter owing to SGS structure, although it looks like microstrip line filter. So we can’t analyze this filter using microstrip strictly. In fact, Double-Sided Parallel Strip Line (DSPSL) theory can be used in comprehending the structure. On the other hand, considering that the crack of SGS added in DGS is minor and its effect is nearly negligible, especially when the frequency is high. So we could still analyze the UWB filter structure approximatively by adopting some theory related to microstrip line.

Generally, we apply series inductance and shunt capacitance to build microstrip transmission line model. As is shown in Fig.4, SGS unit can be built equivalent circuit by two capacitances and one inductance. The equivalent circuit of rectangle DGS unit could be built by connecting a capacitance and inductance parallelly[9]. In top layer, two elongated transmission lines connected to bottom layer by two vias forming a transmission zero in lower stopband, so a LC series circuit is used to build its model. Fig. 6 presents the lumped-element bandpass prototype for UWB BPF proposed.

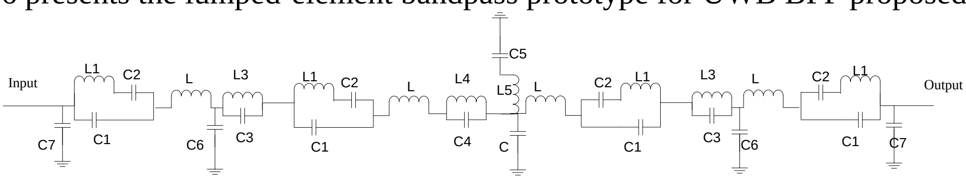


Fig. 6. Lumped-element bandpass prototype for proposed UWB BPF.

By choosing parameters properly, we could draw the compare of Lumped-element bandpass prototype and proposed UWB BPF, which is demonstrated in Fig.7, curve S(4,3), S(3,3)is frequency response of UWB filter proposed, while curve S(2,1),S(1,1)is frequency response of bandpass prototype. L=0.08nH, C=0.46pF, L1=0.18, C1=0.7pF, L2=0.19nH, C2=1pF, L3=0.38nH, C3=0.37 pF, L4=0.09nH, C4=0.52pF, L5=1.77nH, C5=4.36pF, C6=0.28pF, C7=0.015pF.

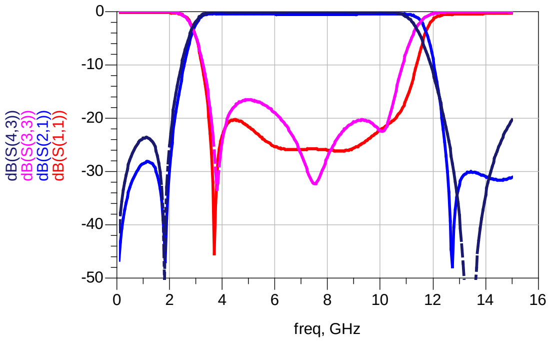
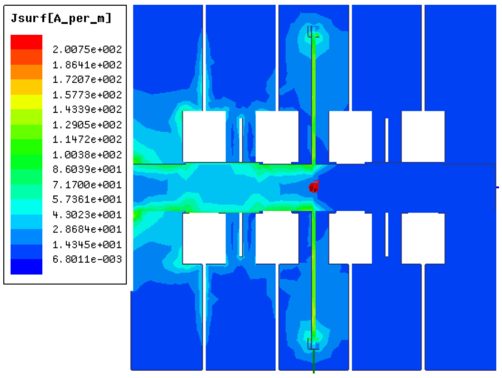
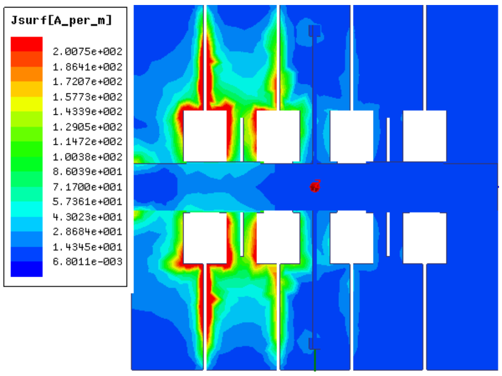


Fig. 7. Frequency response of bandpass prototype

After building lumped-element bandpass prototype for proposed UWB BPF, Since the SGS and rectangle DGS can provide good harmonic suppression by producing transmission zero in upper stopband. By choosing its parameters properly, we could decide these transmission zeros distribution, then the unwanted harmonic response can be avoided in the upper stopband. On the other hand, two elongated transmission lines in top layer will influence the position of transmission zero in lower stopband, the length variation of two elongated transmission lines will change the transmission zero. Fig.8 demonstrate the current distribution of two transmission zeros (at1.85GHz and 12.75GHz), showing the reasons of formation of the two transmission zeros, which are consistent with our analysis before.



(a)



(b)

Fig. 8. (a) Current distribution of 1.85GHz (b)Current distribution of 12.75GHz

Conclusion

In this paper, we analyze electric field, magnetic field and Current distribution of SGS, giving methods and formulas of SGS parameter extraction. Then we give LC equivalent circuit of the entire UWB filter structure and illustrate the impact of structure variation on UWB filter performance. Results show that the modeling method is right and effective.

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