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Wideband Tri-band Filter Design using Stepped-impedance Stub Resonators

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Abstract

This letter presents a wideband tri-passband filter in which tri-section stepped-impedance shunt-stubs are used as tri-mode resonators, connected by transmission lines. Developed from the topology of quarter-wavelength stub filters, these filters have much wider passbands compared to many other designs published. The stepped-impedance stubs also contribute transmission zeros between the passbands, thus increasing the isolation. A prototype filter with passbands located at 0.6-1, 1.5-1.8 and 2.2-2.4 GHz is designed by an optimization method. Good agreement between simulation and measurements in respect of low insertion loss and high isolation is demonstrated.

Keywords: *Tri-band filters, stepped impedance stubs, J inverters*

1. Introduction

Filters refer to the electrical components to reduce or eliminate the influence of harmonic on power system. It's a kind of device to eliminate the interference noise. The input or output after filtration is DC pure. Outside circuit, frequency of specific frequencies or the frequency of the frequency effectively filter is the filter, its function is to get a specific frequency or eliminating a specific frequency.

The main parameters of filters are the Center Frequency, the Cutoff Frequency, the Bandwidth, the Insertion Loss, the Ripple, the Passband Riplpe, the Return Loss and the Delay. Passbands filters allows a certain frequency signal. Signals, interferences and noises below or above the passbands are forbidden.

An ideal filter should have a completely flat passbands, no gain or attenuation in the passbands, and the band of all frequencies are completely decays away, in addition, through the transition zone and done in the frequency range minimum. In fact, there is no ideal band-pass filters. Filters can not be all frequency range completely attenuate expectations, especially in the pass band and a decay but not isolated range. This is usually referred to as

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the filter roll-off phenomenon, and the use of each of the ten frequency attenuation range of dB to represent. Usually, the filter design to ensure the roll-off range is narrow and better performance of this filters, closer and design.

Recently with the challenging demand of personal communications, multi-band systems that can support two or more systems with good isolation between bands are becoming important. Tri-band filters are one kind of key components in these systems. Various configurations have been proposed to realize tri-band filters. Thus [1] arranged three sets of resonators for realizing three passbands. For higher circuit efficiency, multi-mode resonators are adopted in tri-band filter design [2-4]. In [2], dual-mode and single mode resonators are combined to construct a tri-band filter. In [3] three-section stepped impedance resonator (SIR) technique are introduced for tri-band response with compact dimensions. A kind of stub-loaded tri-mode resonator is proposed to construct tri-band filters with transmission zeroes between the passbands [4]. In most of the above, Input/output and internal couplings are parallel couplings which result in narrow passbands. In this letter, passbands are efficiently broadened by adopting a stub bandpass filter topology [5] with all inhomogeneous stubs replaced by tri-section stepped-impedance stubs.

Tri-section stepped-impedance stub and tri-band filter: A classical wideband filter topology is quarter-wavelength stub filter, in which λ/4 shunt stubs are used as resonators while λ/4 connecting lines are used to implement J inverters for coupling [5]. To realize wideband tri-band filters, we use tri-section stepped-impedance stubs as tri-mode resonators.

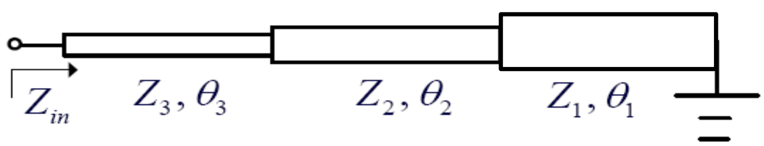

Figure 1. Tri-section stepped-impedance stub resonator

Figure 1 gives the circuit of a tri-section stepped impedance stub having the following input impedance:

$$Z_{in} = j\frac{Z_1Z_2Z_3\tan\theta_1 + Z_2^2Z_3\tan\theta_2 + Z_2Z_3^2\tan\theta_3 - Z_1Z_3^2\tan\theta_1\tan\theta_2\tan\theta_3}{Z_2Z_3 - Z_1Z_3\tan\theta_1\tan\theta_2 - Z_1Z_2\tan\theta_1\tan\theta_3 - Z_2^3\tan\theta_2\tan\theta_3} \quad (1)$$

Here θ_1, θ_2 and θ_3 are frequency dependent electrical lengths. Resonances occur when Z_{in} is infinite while transmission zeros appear at the frequencies where Z_{in} is zero.

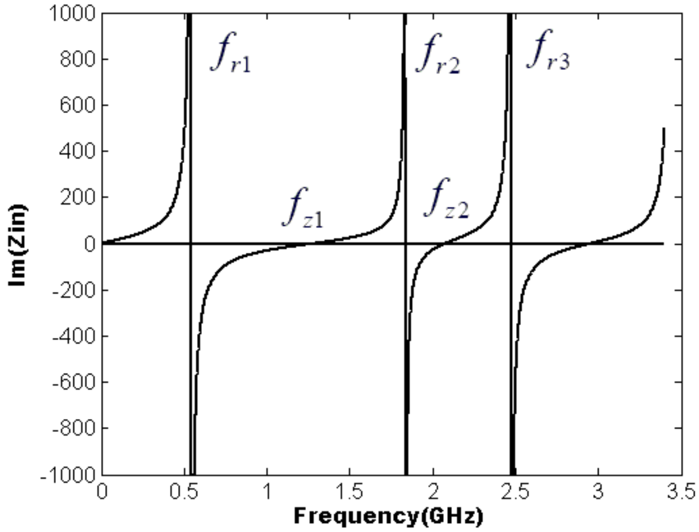

Figure 2. Plot of the input reactance of a tri-section stepped-impedance stub resonator

Figure 2 is the plot of Zin(f), in which we can see two transmission zeros are distributed between three resonating frequencies:

$$f_{r1} < f_{z1} < f_{r2} < f_{z2} < \quad (2)$$

Each stepped-impedance stub should be designed so that three resonating frequencies are located within three passbands respectively thus contributing one transmission pole for each passband. Additionally, correct admittance slopes at the resonating frequencies are required for realizing specified passbands.

An admittance or J inverter is an ideal inverter with an electric length of 90 degrees at all frequencies. Homogeneous transmission lines with fixed lengths can not act as ideal J inverters at all three passbands, so some passbands will have frequency shift and bandwidth variation compared to those desired. These can be compensated by adjusting the circuit parameters of all the tri-section stubs. To achieve good passbands, an optimizing method is utilized for extracting the circuit parameters.

2. Tri-section Stepped-impedance Stub and Tri-band Filter

A tri-band filter with passbands of 0.6-1.0, 1.5-1.8 and 2.2-2.4GHz (fractional bandwidths of 50%、18%、9%) is designed and fabricated. Figure 3 shows the configuration of the tri-band filter, whose parameters are extracted using the optimizing tools integrated in Ansoft Serenade 8.7.

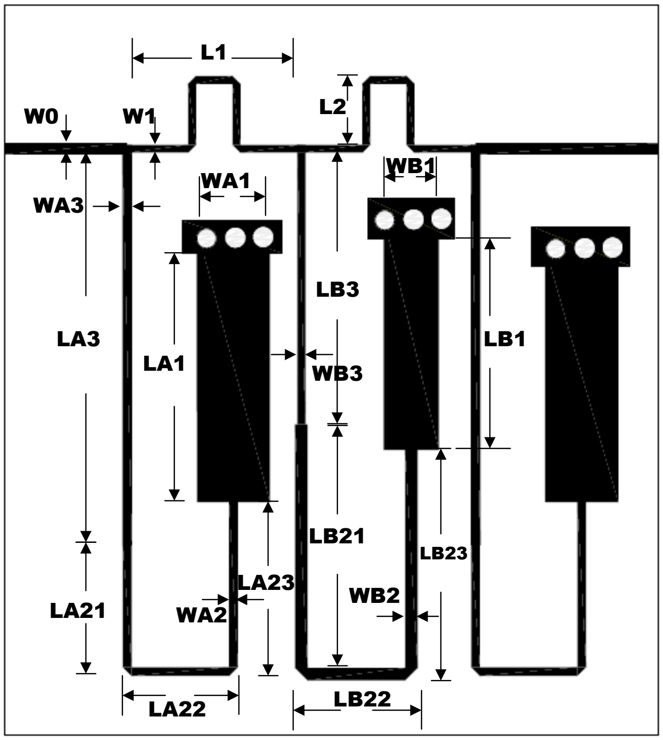

Figure 3. Topology and dimensions of the proposed tri-band filter

This is a three-order tri-band filter in which three tri-section stepped-impedance stubs are connected by two transmission lines with symmetrical dimensions. To realize compact size, folded and meandered transmission lines are used. This filter is fabricated on a substrate with a thickness of 0.406mm and a dielectric constant ε_r of 3.38. All the dimensions designed are given as follows(unit: mm): $W0 = 0.92$, $W1 = 0.64$, $WA1 = 6$, $WA2 = 0.71$, $WA3 = 0.78$, $WB1 = 4.55$, $WB2 = 1.02$, $WB3 = 0.65$, $L1 = 13.95$, $L2 = 5.64$, $LA1 = 20.44$, $LA21 = 10.71$, $LA22 = 9.42$, $LA23 = 14.26$, $LB1 = 17.33$, $LB21 = 20$, $LB22 = 10.04$, $LB23 = 18.92$, $LB3 = 22.3$. Each stepped-impedance stub is grounded at the end with three via holes whose diameters are 0.8mm. The total size of the filter is 53.6 x 60 mm2.

The circuit simulation results and the measured responses are compared in Figure 4, and good agreement is observed. The lowest insertion losses of the three passbands are 0.3dB、0.6dB and 0.9dB respectively, and each passband has return loss over 15dB. Transmission zeros are allocated between the passbands, and thus high isolations of 28dB and 40dB are achieved. There is frequency shift between the simulated and measured plots due to fabrication tolerances.

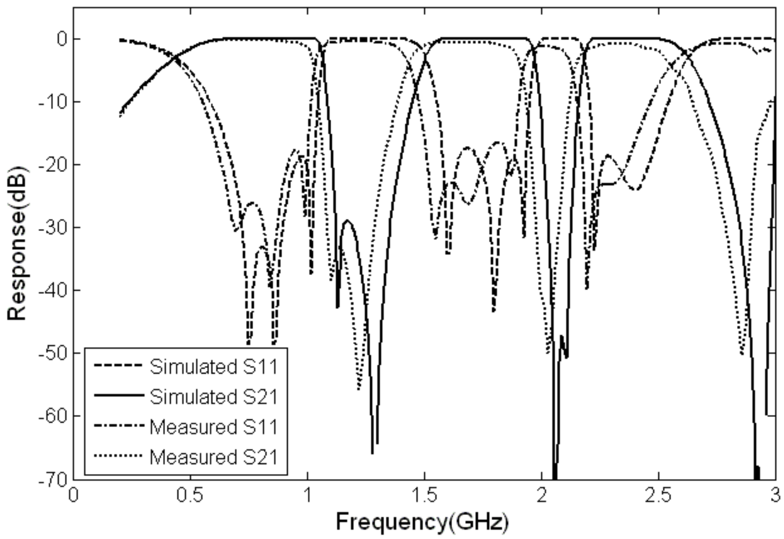

Figure 4. Compared simulation and measurement results of the tri-band filter

3. Results and Discussion

We presents a wideband tri-passband filter in which tri-section stepped-impedance shunt-stubs are used as tri-mode resonators, connected by transmission lines. Developed from the topology of quarter-wavelength stub filters, these filters have much wider passbands compared to many other designs published. The stepped-impedance stubs also contribute transmission zeros between the passbands, thus increasing the isolation. A prototype filter with passbands located at 0.6-1, 1.5-1.8 and 2.2-2.4 GHz is designed by an optimization method.

The wideband tri-band filter realization is proposed by adopting stub filter topology and tri-section stepped-impedance stub resonators. A prototype filter was designed using an optimization technique, fabricated and measured. Experiment results demonstrate good performance features, including wide passbands (50%, 18% and 9%), low insertion loss, high inter-band isolation and compact dimensions.

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