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NOVEL DUAL-COMPOSITE RIGHT/LEFT-HANDED TRANSMISSION LINE AND ITS APPLICATION TO BANDSTOP FILTER

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Abstract—A novel structure of dual-composite right/left-handed transmission line (D-CRLH-TL) is proposed in this paper, and its electromagnetic characteristics are investigated in theory and simulation. The dispersion curve of the proposed structure has been derived by using Bloch-Floquet theory. The structure is composed with an "H"-shaped defected ground structure (DGS) and two stubs with rectangular patches, compared with the structure of D-CRLH-TL proposed in paper [6, 7], this structure is simpler and more easily adjusted. Then, an ultra wide-stopband (UWSB) bandstop filter based on the proposed D-CRLH-TL is designed, fabricated, and measured. The simulated and measured results show that the centre frequency of the filter is 5.1 GHz, the bandwidth of stopband is 90.2%, and the filter has sharp transmissions at the two edges of the stop-band. Besides, the designed filter in this paper has a smaller size than traditional ones, and can be easily fabricated.

1. INTRODUCTION

Since the material with a negative magnetic permeability and a negative electric permittivity was first proposed by Veselago in 1968 [1], this special material has been applied in various fields [2–6]. In 2001, the existence of left-handed materials (LHMs) was experimentally verified by Smith and co-workers by using a split-ring resonator and a thin wire [5]; in 2002, the composite right/left-handed transmission line (CRLH-TL) was first proposed by Caloz and Itoh, this structure

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provides left-handed (LH) and right-handed (RH) characteristics at low and high frequency bands respectively [2]; in 2006, the equivalently model of D-CRLH-TL was proposed by Caloz, according to the equivalently model of CRLH-TL [3]. Compared with CRLH-TL, D-CRLH-TL has two right-handed frequency bands, and there is a stopband between the first right-handed frequency band and the left-handed one. We can use these special characteristics of D-CRLH-TL to design bandstop and dual-band microwave instruments [4, 7].

Bandstop filters are essential building blocks in wireless systems. Such filters play the main role of filtering out the unwanted signals. Compact design, high rejection in the stopbands, excellent performance, and high selectivity are important characteristics of bandstop filters. So far, there are three methods to design bandstop filters. In paper [8], by using quarter-wavelength short-circuited stubs, a bandstop filter is designed; in papers [9–13], some different bandstop filters are designed by using stepped-impedance open-circuited stubs the loop resonator and other methods But the enormous size is the same shortage of these designed filters.

In this paper, a novel structure of D-CRLH-TL is proposed, which is composed by an "H"-shaped DGS and two stubs with rectangular patches. The DGS is equivalently modelled as a parallel LC resonance tank connected in series on host transmission, and the stub with rectangular patch is represented by a series LC resonance tank connected in shunt between the signal and ground line. Figure 1 shows the equivalent circuit model. By using these characteristics of D-CRLH-TL, a bandstop filter is designed, simulated, fabricated and measured. The simulated and measured results show that: the centre frequency of the filter is 5.1 GHz, and the bandwidth of stopband is 90.2%, because of the 3-dB bandwidth is 5.2 GHz, and the 20-dB bandwidth is 4.6 GHz, the shape factor is 0.88, so this filter has high selectivity and high rejection in the stopbands.

2. UNIT STRUCTURE OF D-CRLH-TI AND THEORY ANALYSIS

Figure 2 shows the proposed structure of D-CRLH-TL in this paper.

Figure 2 shows the structure of proposed D-CRLH-TL, and it is based on a dielectric substrate of permittivity $\varepsilon_r = 2.65$ and the thickness $h = 1$ mm. The structure parameters are shown in Table 1.

By using the circuit and full wave simulation, the S-parameters of D-CRLH-TL are shown in Figure 3.

In Figure 3, we can see, when D-CRLH-TL is balanced, there is one transmission zero (4.9 GHz), as shown in (a); when it is not

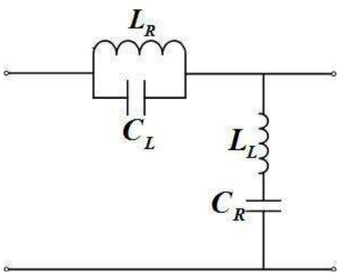


Figure 1. Equivalent circuit of D-CRLH-TL.

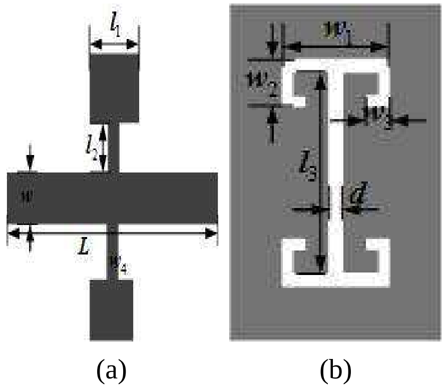


Figure 2. Structure of D-CRLH-TL. (a) Top view. (b) Bottom view.

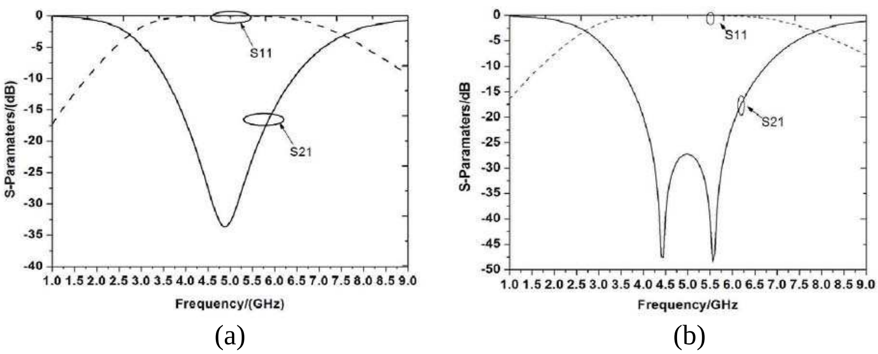


Figure 3. S-parameter of D-CRLH-TL.

Table 1. Parameters I and parameters II (mm).

	L	w	l_1	l_2	l_3	w_1	w_2	w_3	w_4	d
I	6	2	4	4	8	4	1.4	0.8	0.2	0.3
II	6	2	4	4	8	4	1.7	0.8	0.2	0.3

balanced; there are two transmission zeros (4.45 GHz and 5.55 GHz).

In order to analysis the unit cell deeply, the optometric function is used in the circuit and full wave simulation. The results are shown in Figure 4.

In Figure 4, the distance between two transmission-zeros reduces

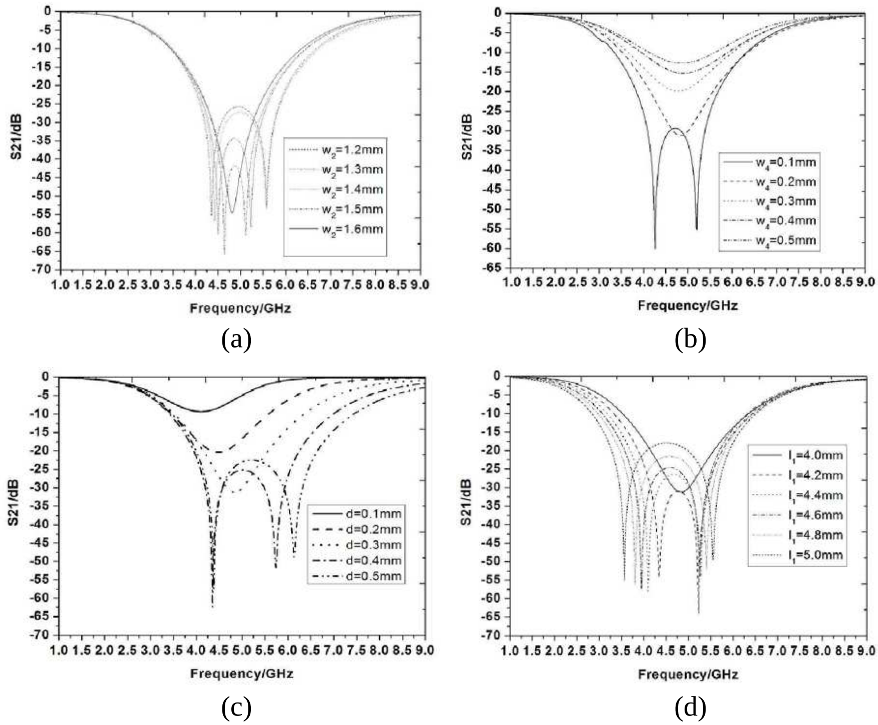


Figure 4. Simulated results of D-CRLH-TL.

with the augment of w_2; and the transmission loss (S_{21}) will reduce with the augment of w_2, too. The high transmission zero is controlled by d, it will reduce with the decrease of d; the low transmission zero is controlled by l_1, it will increase with the decrease of l_1.

When the unit cell structure is balanced, the cut-off frequency of right-handed (ω_{CR}) and left-handed (ω_{CL}) can be derived by Expression (1).

$$\omega_{cL/R} = \omega_0 \sqrt{1 + \frac{\omega_L}{8\omega_R} \pm \sqrt{\frac{\omega_L}{4\omega_R}} \sqrt{1 + \frac{\omega_L}{16\omega_R}}} \tag{1}$$

When the unit cell structure is balanced, there is a stop band between the left-handed frequency and the first right-handed one.

The dispersion curves of the proposed D-CRLH-TL can be estimated by Expression (2), which is shown in Figure 5.

$$|\beta(\omega)d| = \left| \mathrm{re}\left[ar\cos\left(\frac{1 - S_{11} \cdot S_{22} + S_{12} \cdot S_{21}}{2 \cdot S_{21}} \right) \right] \right| \tag{2}$$

In Figure 5, we can see that the left-handed cut-off frequency $\omega_{CL} = 5.54\,\text{GHz}$ and the right-handed cut-off frequency $\omega_{CR} = 3.45\,\text{GHz}$.

3. BANDSTOP FILTER DESIGN AND MEASURED

Figure 6 shows the fabricated bandstop filter. The filter is composed of three unit cells of D-CRLH-TL, and the distance between two unit cells is 4 mm.

By using Ansoft's commercial software high-frequency structure simulator (HFSS10), the properties of the proposed bandstop filter have been simulated. Then the fabricated filter is measured by using the s-parameter-network-analyser. The simulated and measured results are shown in Figure 7.

Figure 7 shows that the measured results are in good agreement with the simulated. The transmission loss (S_{21}) is of $-30\,\text{dB}$, and the return loss S_{11} equals to 0.1 dB. The centre frequency of the

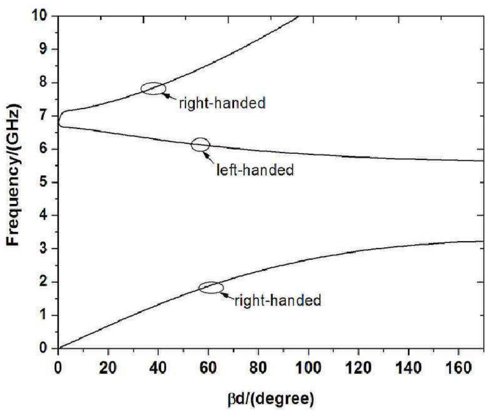
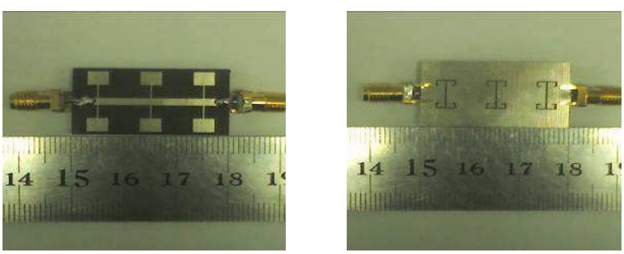


Figure 5. Dispersion curves of D-CRLH-TL.



(a) (b)

Figure 6. Structure of filter. (a) Top view. (b) Bottom view.

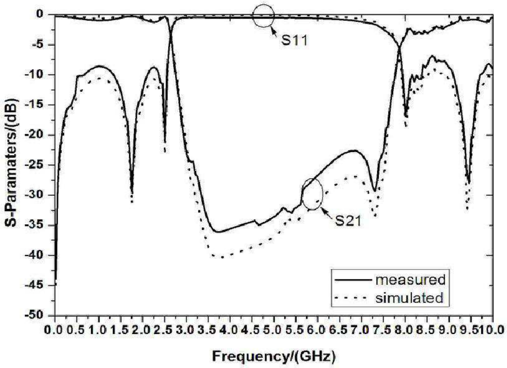


Figure 7. Simulated and measured results.

designed filter is 5.10 GHz; the bandwidth of stopband is 90.2%. The bandwidths of 3-dB and 20-dB are 5.2 GHz and 4.6 GHz, the shape factor is 0.88, so the designed filter has high selectivity and high rejection in the stopband. Besides, compared with traditional bandstop filters, the size of the designed filter in this paper reduces 50% at least, and the miniaturization is realized.

4. CONCLUSION

A UWB bandstop filter using the D-CRLH-TL, which is consists of an "H"-shaped DGS and two stubs with rectangular patches, is proposed in this paper. The designed bandstop filter is simulated, fabricated and characterized. The measured results are in good agreement with the simulated, and the centre frequency of the designed structure is 5.10 GHz. The bandwidth of stopband is 90.2%, and in this band the filter exhibits high selectivity and high rejection. Besides, the size of the designed bandstop filter reduces 50%, compared with traditional bandstop filter.

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