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Design of Novel UWB Band-pass Filter with Single Notched Band Based on the Micro-strip Line and CPW Hybrid Structure

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Abstract: In this study, a novel Ultra-wideband (UWB) bandpass filter with single notched band based Microstrip line and Coplanar Waveguide (CPW) Hybrid Structure is presented which can effectively restrain the electromagnetic interference between systems, to ensure immunity of the system. The proposed filter is based on microstrip-fed CPW resonant structure, among which, two identical structure microstrip feeder and open-ended coplanar waveguide are located in the upper and lower layers of the dielectric substrate. The Complementary Split-Ring Resonators is embedded on the lower structure in the middle of a length of approximately 1/2 wavelength CPW which gets the adjustable notch band, thereby gaining the dual band. Experiment results demonstrated that the bandwidth of filter designed is from 3.1 to 10.6 GHz (-3 dB bandwidth), fractional bandwidth of 92% at the central frequency 6.8 GHz and the notch band can be changed optionally from 3.6 to 9 GHz.

Key words: Microstrip line, CPW hybrid structure, CSRR, notch band, dual-band, BPF

INTRODUCTION

Since 2002, the US Federal Communications Commission (FCC) lifted a ban to 3.1~10.6 GHz band and allowed that UWB were applied to UWB devices (FCC, 2002). UWB technology has been paid close attention by Academic and industrial sessions which attracted the research boom of UWB technology. On the other hand, modern communication development requires that communication system must satisfy multiple protocol used in parallel, so that demand of multiple bandpass filter is increasing. Therefore, research and design of UWB dual band pass filter with the adjustable notch band has become a hot issue in the field of microwave filter.

Initially, though cascading high-pass and low-pass filters, UWB filters are achieved (Hong and Shaman, 2005; Hsu *et al*., 2005). But the kind of filter has large size, not compact and poor passband characteristic. These are not appropriate for the further study of double band-pass design. Then the microstrip/CPW hybrid structure is used in UWB filter (Williams and Schwarz, 1983; Kuo *et al*., 2001). Its structure is very compact. It consists of the two segment identical structure in the upper of the dielectric substrate and open-ended CPW in the lower. Because of these, the filter has very strong coupling characteristic. So, its pass band is good and stable. So, based on the structure this study presents a UWB filter with the adjustable notch band. The filter inherits compact structure and stable passband of the original one. And by embedding CSRR the surface current flow is changed to obtain adjustable notch band. So, this filter is very good to meet the needs of practical application.

CSRR UNIT ANALYSIS

When Martin and his research team explored the characteristics of a notched ring resonator structure, the corresponding nested gap annular structure was defined, namely the CSRR (Complementary Split-Ring Resonators) which is used in related research of microwave devices (Sgawa *et al*., 1989). The ring structure is intended to place two straight-flanked or circular ring nested and notch in symmetric position of each ring, as shown in Fig. 1. Initially the ring structure is arranged below the transmission line, contributing to the couple between the transmission lines and gaining bandpass effect by this coupled formation which also can generate frequency suppression effect (Djaiz and Denidni, 2006). The ring structure would be the equivalent to the parallel resonant circuit as shown in Fig. 1.

The following is the characteristic analysis of CSRR using simulation software-CST. In the process of modeling, the square ring is placed below the transmission line and the resonant characteristic is analyzed by measuring the curve-S_{21}, whose detailed parameters in Fig. 2. The values of the structural

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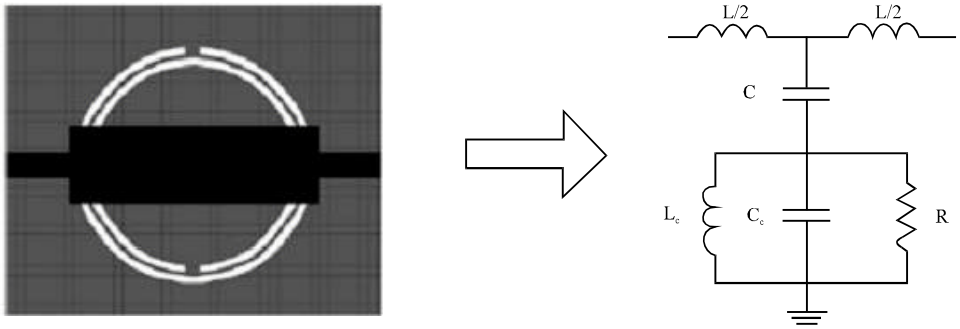

Fig. 1: Geometry and equivalent circuit of CSRR structure (Sgawa *et al*., 1989)

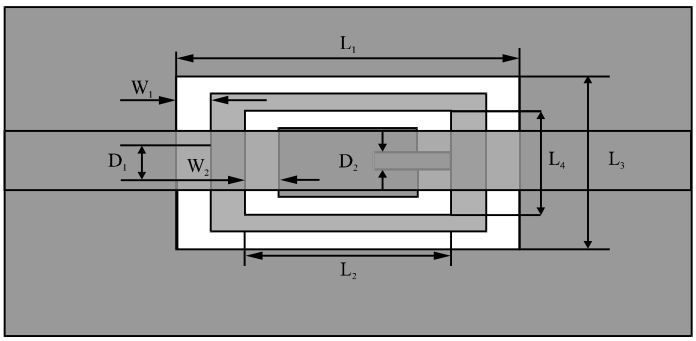

Fig. 2: Geometry of the proposed CSRR unit

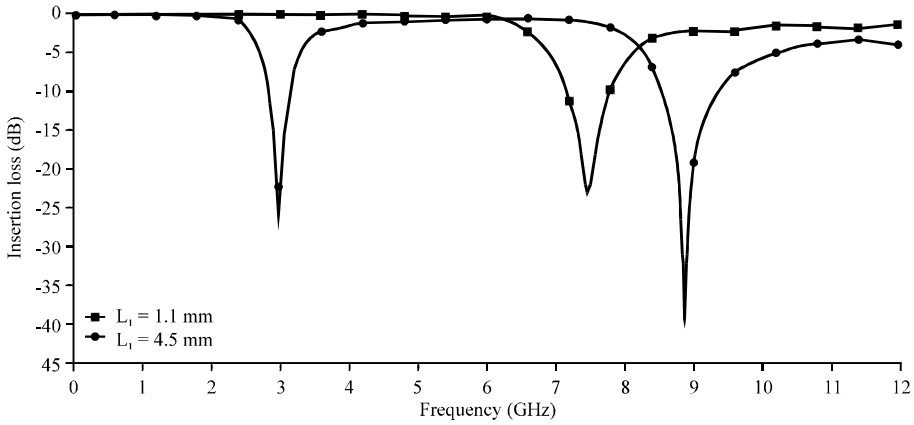

Fig. 3: Simulated insertion loss curves of CSRR unit for different dimensions of L_1

parameters are set as follows: L_2 = 0.8 mm, L_3 = 1.1 mm, L_4 = 0.6 mm, W_1 = 0.2 mm, W_2 = 0.2 mm, D1 = D_2 = 0.4 mm.

The transfer characteristic curves when L_1 = 1.1 mm and L_1 = 4.5 mm are shown in Fig. 3. It can be seen that a transmission zero is produced in 7.6 GHz when L_1 = 1.1 mm and two transmission zeros are produced in 3.0 and 8.8 GHz when L_1 = 4.5 mm, in other words the resonance is generated in the corresponding frequency, so that, the results can be applied to the study of double pass band and the three pass band. In order to further analysis, this study simulates the current trend of this structure in two kinds of frequencies using CST, to explore its resonant characteristics.

The electric field distribution of the CSRR in the pass band (6 GHz) and stop band (7.9 GHz) when L_1 = 1.1 mm is shown in Fig. 4a-d. It is seen in the vertical view of electric

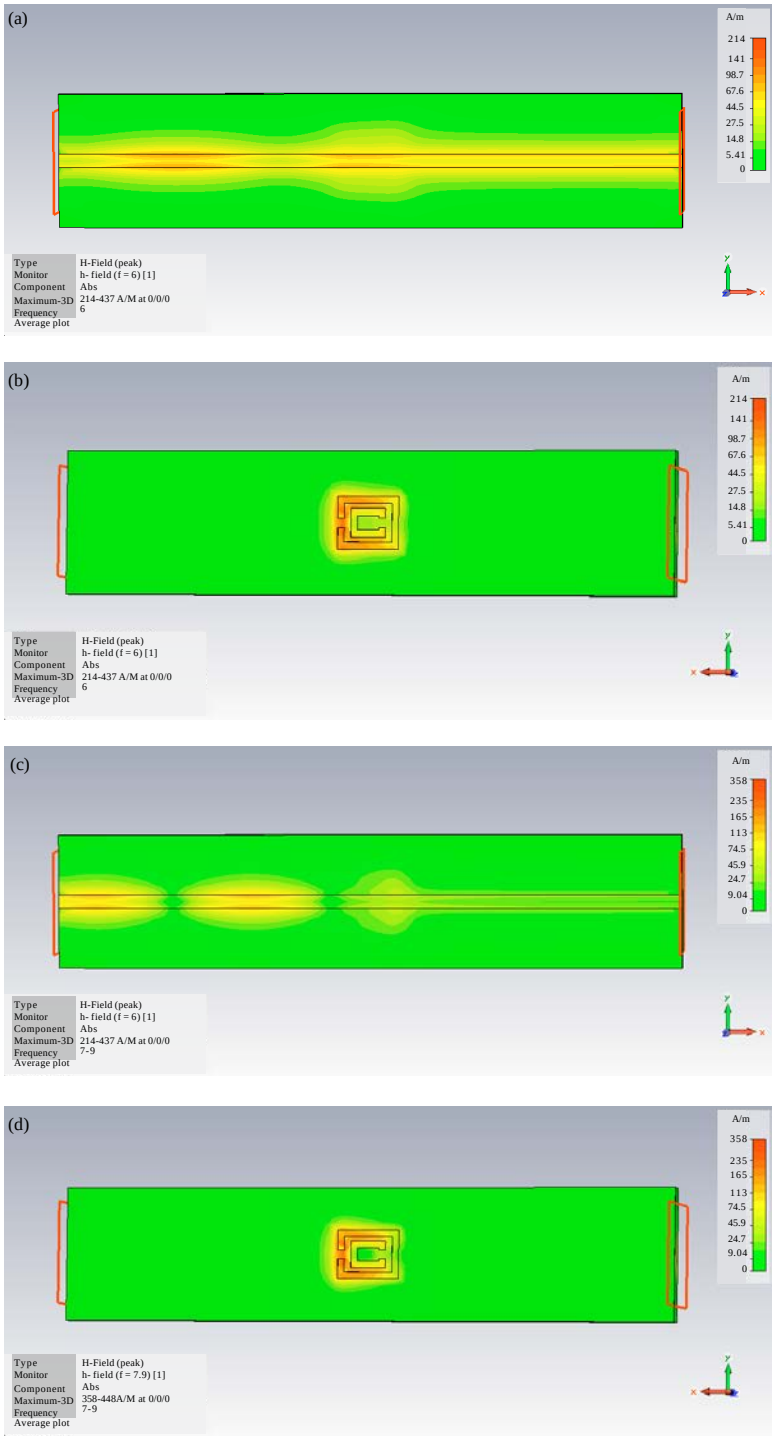

Fig. 4(a-d): Simulated electric field distribution on the CSRR unit at 6 GHz (passband) and 7.9 GHz (stop band) for L_1 = 1.1 mm, (a) The top view of simulated electric field distribution at 6 GHz, (b) The bottom view of simulated electric field distribution at 6 GHz, (c) The top view of simulated electric field distribution at 7.9 GHz and (d) The bottom view of simulated electric field distribution at 7.9 GHz

field distribution in 6 GHz that the current flows along the microstrip line from one end to the other, the same conclusion as Fig. 3 which explains that 6 GHz is in the pass band. In the upward view of electric field distribution in 6 GHz the electric field is mainly concentrated in the slot of outer ring and the outer ring line near the slot. In the vertical view of 7.9 GHz the current flows along the microstrip line from one end to the intermediate and gradually decreases, almost no current flowing to the other end, the same conclusion as Fig. 3 which explains that 7.9 GHz is in the stop band. In the upward view of 7.9 GHz the electric field is mainly concentrated in the same position as in 6.0 GHz. Through the combinatory analysis of Fig. 3 and 4, it is explained that the ring is influenced in the pass band (6 GHz) and stop band (7.9 GHz) by the slot of outer ring and the outer ring line near the slot, therefore the future research about the adjustment range of band-pass filter can mainly analyze L_1 and D_1.

FILTER DESIGN

Figure 5 shows the geometry and parameters of the proposed UWB filter with single notch band. Because of the CSRR embedded in the bottom structure, the original filter gets the notch stop-band characteristics. And the resonant frequency can be changed by adjusting the CSRR size, thereby changing the notch stop-band. This is the core of this design. The values of the structural parameters are set as follows: L_1 = 5.30 mm, L_2 = 3.70 mm, L_3 = 18.04 mm, L_4 = 9.84 mm, L_5 = 5.28 mm, d_1 = 0.60 mm, d_2 = 0.92 mm, d_3 = 2.88 mm, d_4 = 2.48 mm, d_5 = 0.92 mm. The patch is supported by a substrate with dielectric constant ε_r (10.8) and thickness h_0 (0.6 mm), whose material is copper. The dimension is 6×28 mm.

RESULTS AND DISCUSSION

Using the electromagnetic simulation software CST, this proposed filter is simulated when L_6 is changed from 2 to 7 mm and d_6 is changed from 01 to 1.5 mm, so that, specific changes of the notch band are observed, as shown in Fig. 6 and 7.

Through the observation of S parameter curve in Fig. 8, we can see, when L_6 = 2.2 mm and d_6 = 0.4 mm, the resonant frequency is 7.8 GHz, the stop-band attenuation in 3.1-10.6 GHz is far more than 25 dB, the -3 dB passband range is from 3.1 to 7.0 GHz and from 8.5 to 10.6 GHz, the fluctuation range in the two passband is less than 0.3 dB, its high frequency decays rapidly from 11 GHz to the end frequency of simulation and the attenuation in the stop-band is far more than 25 dB. From these parameters the excellent performance of the proposed filter can be seen.

Then the simulation graph of another important characteristics is the group delay characteristic curve, as shown in Fig. 9, the following conclusions after observing is: the group delay of two pass band, from 3.1 to 7.0 GHz and from 8.5 to 10.6 GHz, is in 0.2 to 0.6 ns range, the group delay increases rapidly when the resonant frequency is 7.8 GHz which is the same as the reaction of

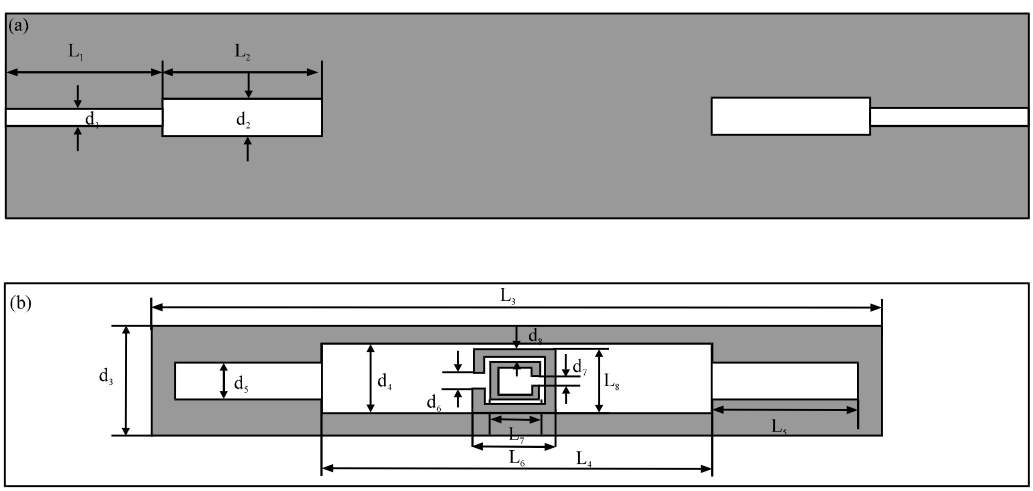

Fig. 5(a-b): Geometry of the proposed filer (a) Top view and (b) bottom view

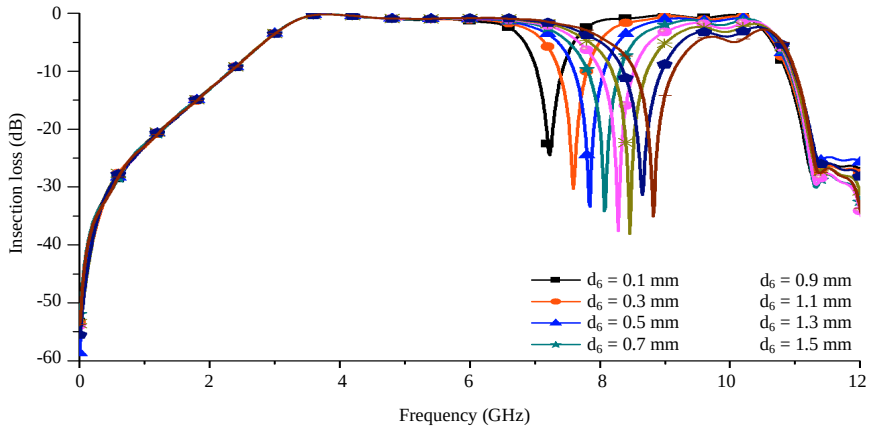

Fig. 6: Simulated insertion loss curves of the propose filter for different dimensions of d_6

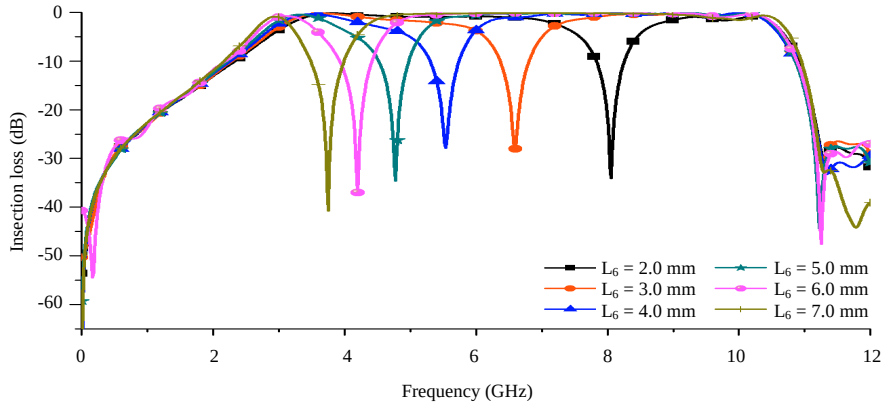

Fig. 7: Simulated insertion loss curves of the propose filter for different dimensions of L_6

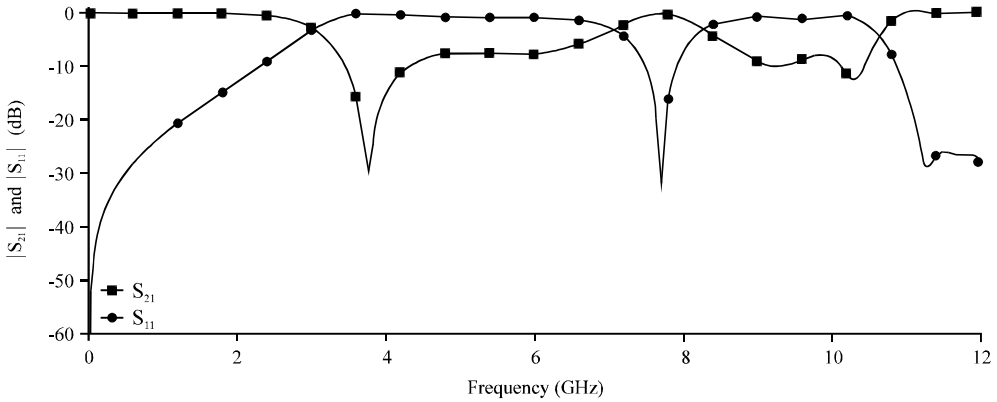

Fig. 8: Simulated S parameter curves of the proposed UWB BPF

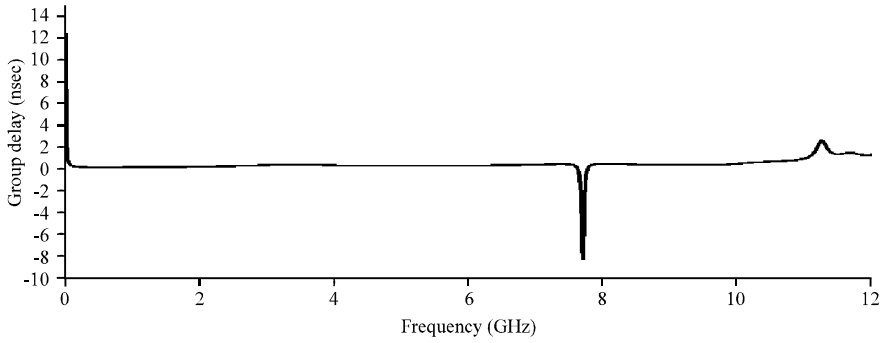

Fig. 9: Simulated Group delay of the proposed UWB BPF

the transmission curve. These indicate that this filter is to comply with the technical requirements and is a qualified UWB filter.

CONCLUSIONS

In this study, a UWB filter with single notch band is presented. Based on microstrip/CPW structure, single notch stop-band for ultra wide band filter is explored and through the simulation and analysis of the CSRR, using the resonance characteristics, the double passband UWB filer with the characteristic of effectively suppressing frequency interference in the frequency range of UWB is designed. The filter has good UWB characteristics, especially suitable for the existing system when communication protocol is used in parallel with UWB. At the same time the CSRR of a specific dimension has double resonance which will be helpful to the research of double notch band.

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