[Invited] UWB Bandpass Filter With Notched Band and Sharp Rejection Using Folded Defected Ground Structure

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Abstract In this paper, an ultra-wideband (UWB) bandpass filter based on folded defected ground structure and slotted step impedance resonator (SSIR) is presented. The proposed filter performance shows a notched response in the passband frequency, due to the use of a folded defected ground structure. The center frequencie and bandwidth of notched bands can be controlled with adjusting dimensions of the folded defected ground structure. The wider upper stopbands occurred from slotted resonator characteristics have also been obtained. The simulated and experimental results show a notched band at 5.38 GHz. High stopband performances are better than 20 dB for a frequency range that is up to 18 GHz. Sharpened rejection skirts are also obtained.

Keyword UWB Bandpass Filter, Folded Defected Ground Structure, Slotted Step Impedance Resonator, Notched Band

1.Introduction

The ultra-wideband (UWB) frequency range is normally between 3.1 to 10.6 GHz for a variety of applications of commercial wireless communication system, which has been authorized by the U.S. Federal Communications Commission (FCC) since 2002 [1]. The UWB system has become a one of the most promising technologies for short-range low-power indoor wireless communications. An UWB bandpass filter is an essential component of UWB systems, and has continuously been developing its performance in recent years. There are various techniques for developing performance for UWB bandpass filters. Stepped impedance resonators (SIR) with multi-mode resonators (MMRs) were utilized with UWB bandpass filters. Its property consists of a low impedance line at the center, high impedance parallel lines at the end, and can also be used for improving the UWB filter in size reduction and stopband performance [2]. The interdigital coupled lines were formed to define their transmission zeros towards the fourth-order resonant frequency of the MMRs [3]-[4]. It has been mentioned that most of these UWB bandpass filters that have superior performance and are suitable for implementation. Moreover, for covering wide frequency, the UWB systems can be interfered by the existing undesired radio signals, such as wireless local-area network, WiMAX and RFID. In order to avoid interferences from the undesired signals, UWB bandpass filters with notched band are definitely required.

The UWB bandpass filters with notched bands using various methods have been proposed. The methods showed the performance of signal rejections., For examples, techniques of adding stubs to the arms of interdigital coupled line [5], using embedded structures in the feed line [6], and adding a parasitic coupled line which is resulted in a narrow notch band as proposed in [7]. The UWB bandpass filter with compact size has been designed by using embedded step-impedance resonator [8]. Many researches proposed notched band with defected ground structures [9], using parallel U-shaped defected microstrip [10] and stub loaded resonator [11].

This paper proposes an UWB bandpass filter with notched band and improved stopband performance. It consists of two slotted step impedance resonators driven by interdigital coupled lines at both ends of the resonator to improve the stopband performances. Also, it has folded defected ground structure at the bottom layer which can be used to generate a notched band. In section 2, the UWB bandpass filter will be presented in the design and optimization. The experimental verification and measured results of the proposed UWB bandpass filter will be described in details of section 3. Finally, our conclusions will be given in section 4.

2. UWB BANDPASS FILTER DESIGN

Fig.1 shows the layout of designed UWB bandpass filter with folded defected ground structure for notched band. The proposed filter will be described in the following sub-sections.

The method used to improve the performance of UWB bandpass filters by intergrating the MMR resonator with interdigital coupled line in order to enhance coupling degree has been studied in the literature [2]. An interdigital coupled line has been widely used and known as a capacitive coupling with two 50 Ω feed lines in the UWB bandpass filters. However, it must be redesigned for achievable design-specified coupling factor between two adjacent line resonators. The strip and slot widths must be reduced in order to achieve a tight coupling degree.

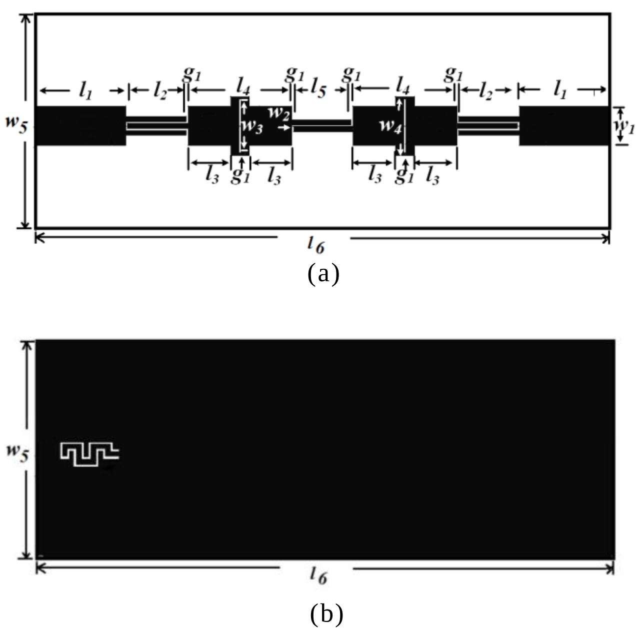


Fig. 1 The layout of proposed filter for notched band (a) top layer (b) bottom layer.

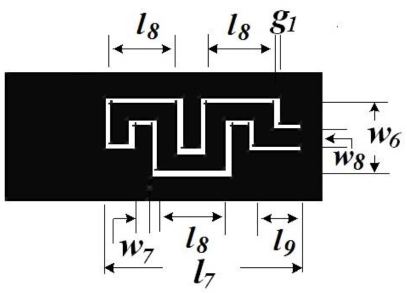


Fig. 2 The folded defected ground structure.

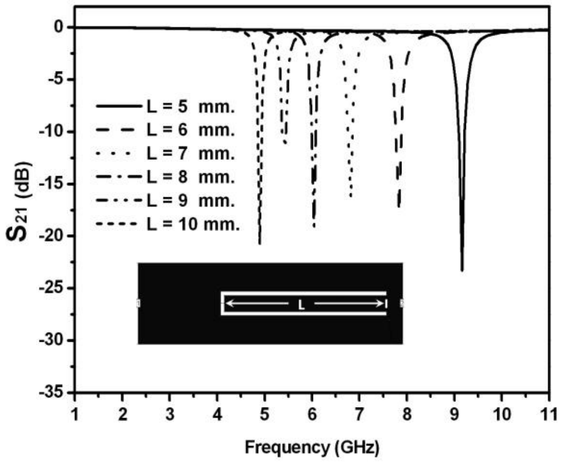
In this work, we design and optimize the interdigital coupled line structure which is designed and fabricated using the RT/Duroid 3003 substrate with a dielectric constant of 3.0 and a thickness of 1.524 mm and a loss tangent of 0.0013, resulting in l_2 = 6.45 mm, w_2 = 0.5 mm, and g_1 = 0.2 mm, as shown in Fig.1. It has been found that this new coupled line has better superior passband characteristics than conventional one.

MMR is formed by attaching slotted resonators at the middle of slotted step impedance resonator. It can be used for extending the stopband range around the upper frequency to be larger than 10 dB from 12 GHz to 18 GHz. Conventional UWB bandpass filter [3], with the use of λg/2 microstrip resonator, has inherently spurious resonant frequencies at $2f_o$ and $3f_o$, where f_o is the fundamental frequency, which may be nearly closed to the desired passband. Microstrip SSIRs have been proposed as shown in [4] for higher stopband performances.

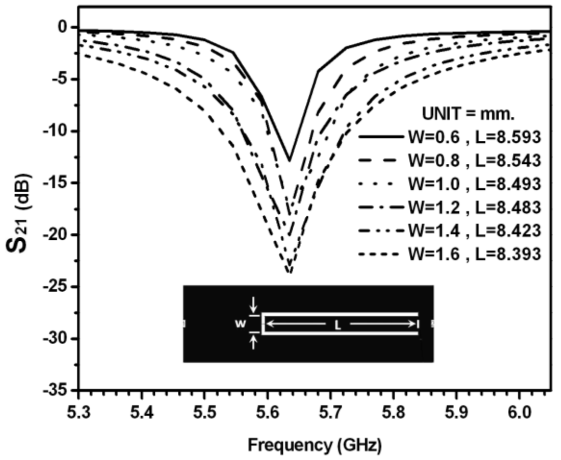
The RT/Duroid 3003 substrate has been used to design the proposed filter. The IE3D program has been used to simulate the performances of the proposed filter. The optimized dimensions of the slotted resonators and the interdigital coupled lines have been obtained in the previous work [4] including l_2 = 6.45 mm, l_3 = 11.0 mm, l_4 = 3.47 mm, l_5 = 6.5 mm, w_1 = 4.0 mm, w_2 = 1.2 mm, w_3 = 4.5 mm and w_4 = 5.5 mm. Also, the optimized dimensions of the folded defected ground structure at the bottom layer for 5.38 GHz with notched band have been obtained are: l_1 = 10 mm, l_6 = 68 mm, l_7 = 5.94 mm, l_8= 2.12 mm, l_9 = 1.47 mm, w_5 = 0.8 mm, w_6 = 2.1 mm, w_7 = 0.52 mm, w_8 = 0.8 mm and g_1 = 0.2 mm. All the dimension parameters are shown in Fig.1 and Fig.2.

The folded defected ground structure at the bottom layer presented here is equivalent as a notch band. The RT/Duroid 3003 substrate has been selected to demonstrate in this study. Fig.3 (a) the frequency responses of S_{21} for the structure inset in Fig. 3 (a) when varying the length L of the defected ground from 5 to 10 mm. It can be found that a center frequency of notched can be moved from 9 GHz down to 5 GHz. When increasing the width W of the defected ground while keeping the center frequency to be the same, the bandwidth of notched band is increased as shown in Fig.3 (b). It can be clearly seen that a 3 dB bandwidth of the notched band is increased from 220 to 810 MHz. Therefore, by tuning the length and width of the defected ground, center frequencies and bandwidth of notched band can be easily adjusted using the proposed technique. Defected ground is therefore suitable for utilizing in the UWB bandpass filter when a notched band is required. To create the notched band at 5.38 GHz, the dimensions of the proposed defected ground include l_7 = 5.94 mm, w_6 = 0.8 mm, and g_1 = 0.2 mm.

To verify the notched mechanism, the current distributions of defected ground structure at notch frequency of 5.38 GHz are shown in Fig.4. We can notice that in Fig.4 (a) the current distribution passes through the conventional bottom layer but it cannot pass through the proposed structure as shown in Fig.4 (b).



(a)

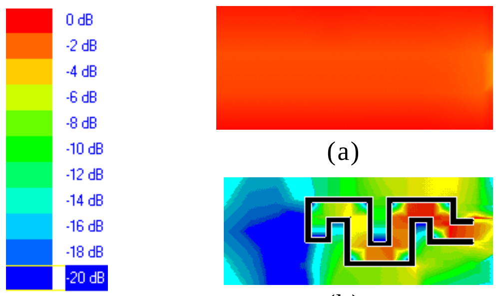


(b)

Fig. 3 S_{21} magnitude responses of the defected ground structure with a slot of 0.2 mm when (a) varying L (b) varying W.

3. SIMULATED AND EXPERIMENTAL RESULTS

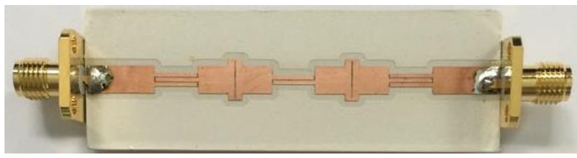
Fig.5 shows photographs of the fabricated UWB filter for notched band. Fig.6 shows a comparison of measured and simulated responses of the UWB filter with a notched band. It can be found that the measured results show agreement with the simulation expectations, confirming that the proposed UWB filter with a notch is capable of narrowing notched band, having good insertion losses within the passband and also widening the upper stopband. The measured return and insertion losses are found to be lower than -10 dB and higher than -2 dB, respectively over desired UWB passband. The notched frequency of about 5.38 GHz has a bandwidth of about 270 MHz. The proposed filter shows narrow notched band and improved upper stopband performance with high insertion loss. The upper stopband with the insertion loss lower than -20 dB occupies an enlarged range of 13 to 18 GHz. The group delay of filter slightly varies between 0.4 to 0.5 ns in the passband. Moreover, the proposed filter exhibits notched band and a wide upper stopband with values of S_{21} lower than -35 dB at 13 GHz and -30 dB at about 17.5 GHz. These superior stopband performances are caused by the stopband characteristics of the proposed slotted resonator structure, and narrow notched band is caused by folded defected ground structure.



(a)

(b)

Fig. 4 Current distributions of notch band at 5.38 GHz (a) convention structure (b) defected ground structure.



(a)

(b)

Fig. 5 Photographs of the fabricated UWB filter for notched band (a) top layer (b) bottom layer.

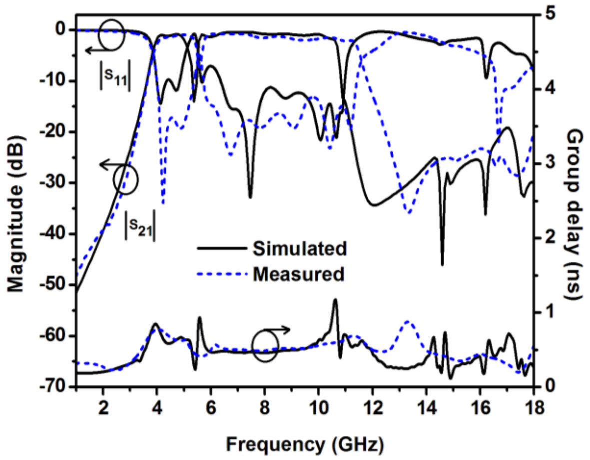


Fig. 6 Comparison of measured and simulated responses of the UWB filter with notched band.

4. Conclusions

The folded defected ground structure with notched band and slotted step impedance resonator with improved upper stopband performances for UWB bandpass filter have been presented and implemented. By properly forming SSIR together with two interdigital coupled lines at both ends and folded defected ground structure at bottom layer, the filter is constructed and its performances are extensively investigated in simulation and measurement. The proposed UWB filter has been demonstrated its capabilities in narrowing notched band with the folded defected ground structure and suppressing spurious responses with slotted resonator. Also, the fabricated UWB filter proved that it can generate notched band, widen the upper stopbands and sharpened rejection skirts.

Acknowledgment

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