Small Ultra-Wideband (UWB) Bandpass Filter With Notched Band

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***Abstract*—A compact ultra-wideband (UWB) bandpass filter (BPF) with notched band has been proposed and implemented in this letter. H-shaped slot is studied and adopted to tighten the coupling of inter-digital capacitor in order to improve the BPF's performance. Three pairs of tapered defected ground structures (DGS) are formed to assign their transmission zeros towards the out of band signal, thereby suppressing the spurious passband. Combining these two structures we obtain a small sized UWB BPF. Meander line slot is developed to reject the undesired wireless local-area network (WLAN) radio signals. An experimental UWB filter with notched band was fabricated with 35% less length as compared to an embedded open-circuited stub. The measured BPF insertion loss is less than 1.0 dB throughout the pass band of 2.8 to 10.8 GHz, the variation of group delay less than 0.20 ns in this band except for the notched band, and a wide stopband bandwidth with 20 dB attenuation up to at least 20.0 GHz.**

***Index Terms*—Bandpass filter (BPF), H-shaped slot, meander line slot, ultra-wideband (UWB).**

I. Introduction

IN 2002, the Federal Communication Commission (FCC) authorized the frequency band from 3.1 to 10.6 GHz for commercial communication applications [1]. Since then, there have been considerable research efforts put into ultra-wideband (UWB) radio technology worldwide. For the indoor and hand held UWB users, the UWB frequency band of 3.1 to 10.6 GHz may be interfered by the wireless local area network radio signals. Most of the WLAN systems are designed to operate in the 2.4 GHz (IEEE 802.11b and g) and 5.0 GHz frequency bands, e.g., 5.15 to 5.35 GHz (IEEE 802.11a lower bands) and 5.725 to 5.825 GHz (IEEE 802.11a upper bands) are used in the USA. A compact communication system working in this UWB frequency band requires a small bandpass filter (BPF) with a notched band in the UWB passband in order to avoid being interfered by the WLAN radio signals.

Several researchers have proposed some new structures to realize UWB BPFs [2]–[9]. In [2] and [3], the authors utilized the multiple-mode resonator to design UWB BPFs; the designed filter can cover the whole UWB band of 3.1 GHz-10.6 GHz. However, the filters have a narrow upper stopband. In [4], [5], coplanar waveguide (CPW) structures and microstrip/CPW hybrid structures were proposed to design UWB BPF. This kind of filter has sharp skirt selectivity with very simple elements, but the frequency performance at high frequency is marginal. UWB BPFs in [6] and [7] have a wide upper stopband bandwidth by cascading a low pass filter and a high pass filter. However the transition band at the lower frequency is not sharp enough because of the low order of high pass characteristics. UWB BPF with a notched band was realized by an embedded open-circuited stub [8], which is an effective way to reject any undesired radio signal. However this structure has relatively larger footprint.

Based on our previous works [9], a new compact structure was proposed and implemented in this letter, which has high selectivity filtering characteristics and relatively small size. Bandstop filtering effect was achieved by adding a meander line slot to reject the undesired WLAN radio signals. This UWB BPF consists of a high-low impedance microstrip line, a short-circuited stub and interdigital capacitors (IDC). Interdigital capacitors with H-shaped slots were studied to achieve a strong coupling. Different dimensions of defected ground structures were adopted for suppressing the undesired frequency band. The proposed UWB filter has a full frequency pass band from 2.8 GHz to 10.9 GHz in simulation, with a bandwidth of 118%, which can satisfy the frequency requirement of the FCC.

II. UWB Band Pass Filter

As depicted in Fig. 1(a) and (b), the configuration of the BPF mainly depends on cascading the interdigital capacitors combined with H-shaped slots, a low impedance microstrip, and a short-circuited stub [10]. The microstrip width of the terminal part is about 2.8 mm with the relative dielectric constant of 2.65 and the thickness of the substrate is 1 mm, so that it can be matched to 50 Ω. The length of the IDC's finger is 6.2 mm, and the width of the finger is 0.82 mm. With the help of H-shaped slots etched on the back of the circuit board, the distance between the neighbor fingers is 0.17 mm, which is very easily fabricated with the standard PCB technology. The length of the low impedance microstrip is about a quarter of wavelength of the central frequency 6.85 GHz, and the width is about 4.0 mm. The short-circuited stub is connected with the low impedance microstrip to produce a transmission zero at the low frequency. As can be seen from Fig. 1(c), the designed BPF without defected ground structure (DGS) has a wide pass band bandwidth, while the stopband is a little narrow at high frequency. In order to improve the BPF frequency performance at high frequency, DGS realized by etching a defected pattern in the ground plane is studied. Based on traditional DGS unit structure [11]–[13],

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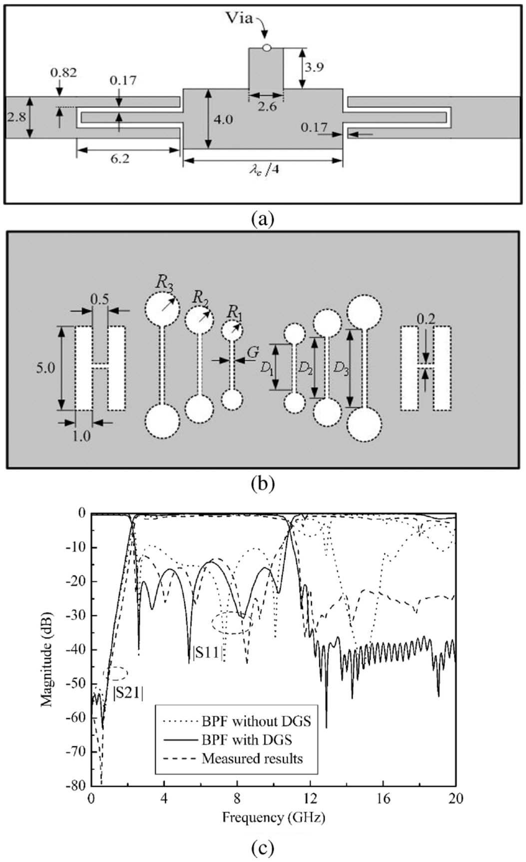


Fig. 1. (a) Schematic top view of UWB BPF. (b) Schematic bottom view of UWB BPF, $D_1 = 3.0$, $R_1 = 0.58$, $D_2 = 4.0$, $R_2 = 0.63$, $D_3 = 5.0$, $R_3 = 0.68$ and $G = 0.2$ mm. (c) Cmparison between the BPF with and without DGS.

the authors studied the tapered dogbone DGS unit to produce the transmission zeroes in the high frequency band. The dimensions of the nonuniform elements vary proportionally to the arithmetic progression sequence, as shown in Fig. 1(b).

Fig. 1(c) shows both the simulated and measured results of the BPF with DGS. The fabricated UWB BPF has a measured pass band from 2.8 GHz to 10.8 GHz at 3 dB of transmission loss. The measured 20 dB isolation bandwidth extends to at least 20 GHz outside the pass band.

III. UWB BPF With Notched Band

Embedded open-circuited stub was proposed to produce a narrow notched band in the wide pass band [8]. In order to minimize the circuit area, a meander line slot was proposed as shown in Fig. 2(a). The meander line slot can produce a narrow notched band, while at the same time the whole circuit area will be more compact. This structure has 35% less length as compared to that proposed in [8]. Fig. 2(b) shows that the resonant frequencies are 4.6 GHz, 5.6 GHz and 7.0 GHz when the values of L_1 are 7.4 mm, 6.0 mm and 4.6 mm, respectively. Also by changing the width and the length of the meander line slot, we can change the width of the notched band. In Fig. 2(c), the 3-dB notched band widths are 0.7 GHz, 0.84 GHz and 0.9 GHz with different values of the W_3 and L_1.

The proposed UWB BPF with a notched band consists of a meander line slot and a BPF. The meander line slot can produce

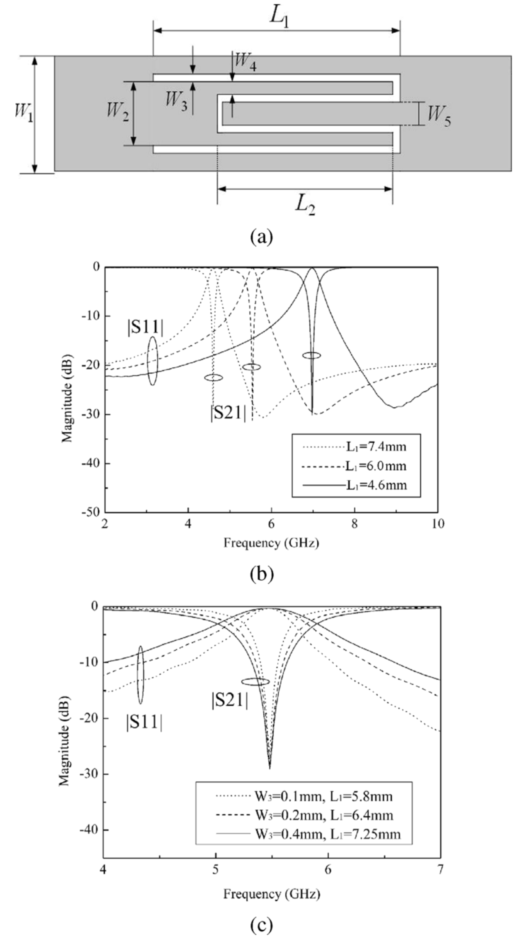


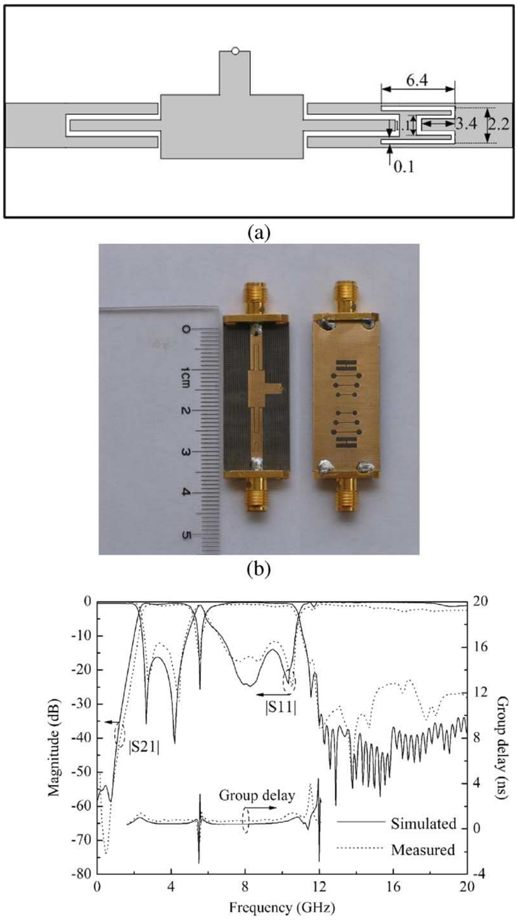
Fig. 2. (a) Meander line slot. (b) Simulated S-parameters, $W_1 = 2.8$, $W_2 = 2.0$, $W_3 = 0.1$, $W_4 = 0.45$, $W_5 = 0.9$ and $L_2 = 3.0$, all in mm. (c) Simulated S-parameters of meander line slot, $W_1 = 2.8$; $W_2 = 2.0$, 1.9 and 1.7; $W_4 = 0.45, 0.35$ and 0.15; $W_5 = 0.9, 0.8$ and 0.6; and $L_2 = 4.4$; all in mm.

a narrow notched band to reject undesired radio signal while the UWB BPF can produce a wide pass band with sharp falling edge both at the lower and upper cut off frequency. The designed UWB filter with a notched band was fabricated on a PTFE substrate, with a thickness of 1.0 mm, dielectric constant of 2.65, as shown in Fig. 3(b). The fabricated filter has a compact size of 36 mm by 16 mm, and it was measured with Agilent 8722ES network analyzer (NA).

The fabricated UWB BPF has a measured pass band from 2.8 GHz to 10.8 GHz, while the width of the notched band is about 0.7 GHz at the center frequency of 5.47 GHz, as shown in Fig. 3(c). The measured group delay is very flat in the whole band except in the notched band. The deviation between simulated results and the measured ones may be caused by the parasitic effects of the SMA connectors and the loss tangent of the substrate.

IV. Conclusion

A compact UWB BPF with a notched band is proposed and implemented. The BPF consists of three pairs of tapered defected ground structures, two tight coupling inter-digital capacitors and a short-circuited stub. The fabricated UWB BPF has a



(c)

Fig. 3. (a) Schematic top view of UWB filter with notched band. (b) Fabricated filters (top and bottom). (c) Simulated and measured results.

wide pass band of 2.8 to 10.8 GHz, and a wide stopband bandwidth with 20 dB attenuation up to >20.0 GHz. A meander line slot is developed to reject the undesired WLAN radio signals, which leads to 35% less length as compared to a conventional embedded open-circuited stub. UWB BPF with a notched band is implemented by combining the BFP and the meander line slot.

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