Analysis and Design of Dual Band-Notched Interdigital Hairpin UWB Bandpass Filter

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Abstract—**In this paper, a new dual band-notched UWB (Ultra Wideband) bandpass filter which is proposed to control harmonic components of 2.14 GHz is designed and tested. Interdigital hairpin structure is applied in the dual band-notched UWB bandpass filter design. By adding only one pair of folded fingers on both side extremities of single band notched UWB bandpass filter, the fabricated filter can suppress the second and third harmonics of fundamental frequency. The dual notched bands can be easily controlled by changing the parameters of each finger. Without changing the first notched frequency band, the second reject frequency band can be shifted by changing its corresponding parameter of finger independently. In this paper, one dual band-notched UWB bandpass filter are designed to control the second and third harmonics of 2.14 GHz. The measured result of the final fabricated circuit shows that insertion loss at 4.28 GHz and 6.42 GHz are 13.99 dB and 4.16 dB, respectively. Because of the folded finger structure, the filter is compact in size. The dimension of our proposed filter is 5.5 mm x 21.3 mm.**

Keywords- dual band-notched; UWB bandpass filter; Interdigital hairpin; Harmonic suppression

I. INTRODUCTION

With the development of third generation (3G) mobile telecommunications network systems, various researches is presented recently for switch mode power amplifier with high power added efficiency (PAE). For example, class F and inverse class F power amplifier which bi-harmonic or poly-harmonic modes are applied. The most popular method to suppress harmonic is using λ/4 transmission line [1], [2]. Band notched UWB bandpass filter as an ideal candidate to reject undesired harmonic bands can be applied in switch mode power amplifier.

Recently, many researches [3]-[9] for bandpass and bandstop filters have been explored and reported. Different applications of stepped impedance resonators (SIRs) have been presented in [3], [4], defected-ground structures (DGS) are widely used in tri-band bandpass filters [5]. SIRs [6] and DGS [7] are also employed for bandstop filters. UWB bandpass filter with interdigital coupled line has been introduced in [8]. UWB bandpass filter with notched band has been proposed in [9] for antenna application.

In section II, the structure and characteristic of interdigital hairpin structure is presented. Section III presents the procedure of designing dual band-notched UWB bandpass filter. The fabrication and measured results are reported and discussed in section IV.

II. INTERDIGITAL HAIRPIN STRUCTURE

The band-notched UWB bandpass filter is designed based on the linear identical interdigital hairpin structure, as shown in Fig. 1. To analyze the effect of the number of fingers on the number of notched bands in UWB, we design three kinds of interdigital hairpin filters as shown in Fig. 1 (a), Fig. 1 (b) and Fig. 1 (c) with 3, 5, and 7 linear identical fingers, respectively. There are three basal parameters, L, w1 and w3. L is the length of each linear finger, w1 is the width of each coupling finger, and w3 is the gap between each two fingers.

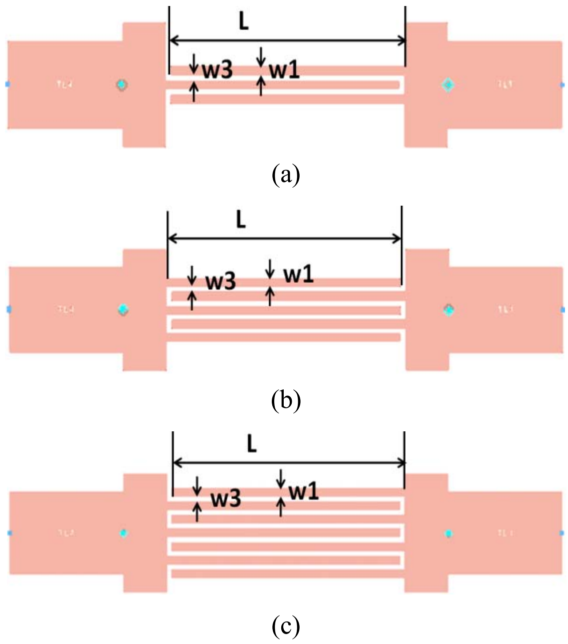

Figure 1. Interdigital hairpin structures with different number of fingers.

By fixing L=8.40 mm, w1=0.30 mm, and w3=6.00 mil, we do momentum simulation for each circuit in Fig. 1 and the simulation result is shown in Fig. 2. With three linear fingers, there is not notched band from 2.14 GHz to 10.70 GHz as the solid line shows us. By adding two fingers on both side extremities of Fig. 1 (a), we obtain one band notched as the dot line shows in Fig. 2 [9]. As the dash line in Fig. 2 shows, two notched bands are obtained by adding another two linear fingers on both side extremities of Fig. 1 (b), the circuit is as Fig. 1 (c) shows us with 7 linear fingers. If we want to get more notched bands, we can add more pairs of linear fingers on both side extremities. We have already got three and four notched bands in UWB by adding the number of linear fingers to 9 and 11, respectively.

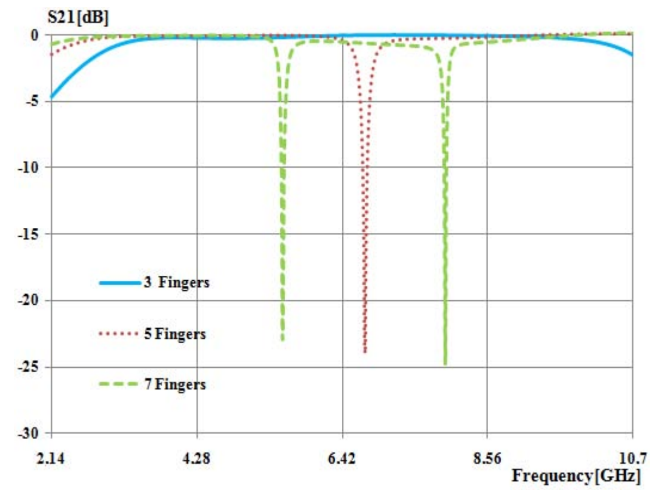

Figure 2. The number of linear fingers affects the number of notched bands.

To shift the notched band, we can change the value of the basal parameters w1, w3 and L. Take the simple band-notched UWB bandpass filter as an example, by changing the value of L from 7.60 mm to 8.80 mm with step 0.40 mm and fixing the another two parameters w1=0.30 mm and w3=0.15 mm, the momentum simulation result is shown in Fig. 3. By increasing the value of L to 8.80 mm, the notched band is shifted from 7.37 GHz to the third harmonic of 2.14 GHz.

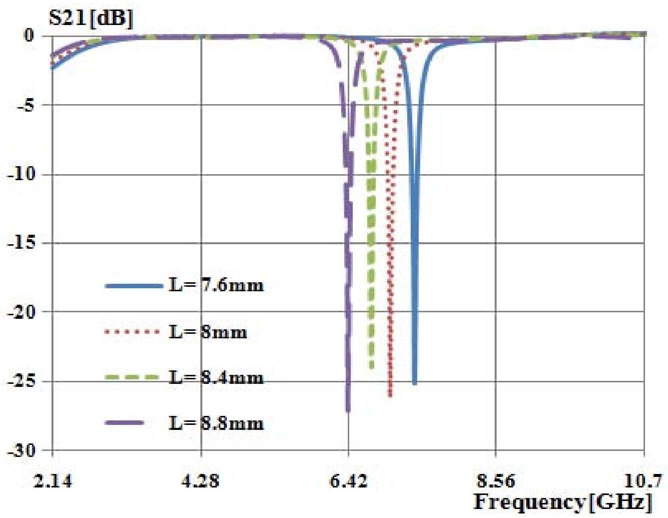

Figure 3. Simulation result of single band-notched UWB bandpass filter by tuning L.

III. Design of Dual Band-Notched UWB Bandpass Filter

As analyzed in section II, to get dual band-notched performance in UWB, we need to increase the number of linear identical fingers to 7 as shown in Fig. 1 (c). However, the two notched bands shown in Fig. 2 are not the desired notched band (the second and third harmonic of the fundamental frequency 2.14 GHz). To achieve our design purpose of rejecting signal generated at the desired frequency bands, we need to modify the lengths of the outermost two pairs of fingers (L1 and L2) separately.

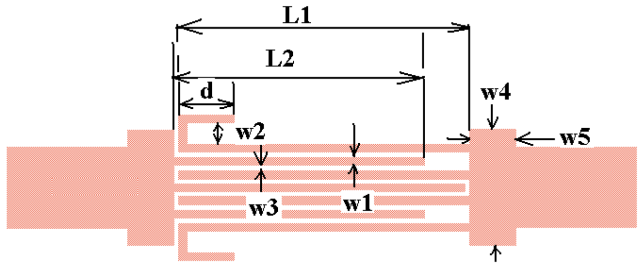

Figure 4. Layout of dual-band notched (2nd and 3rd harmonics of 2.14 GHz) UWB bandpass filter.

Fig. 4 shows us the topology of our proposed dual band-notched UWB bandpass filter which rejects the signal generated at the second and third harmonics of 2.14 GHz. In this filter, there are 8 parameters (w1, w2, w3, w4, w5, L1, L2, and d). The definitions of w1 and w3 are the same as gave in section II. w2 is the distance between the parallel parts of the outermost pair of folded fingers, L1 is the length of the internal side of the outermost folded finger, d is the length of the external side of the outermost folded finger, and L2 is the length of the second outermost pair of linear fingers. By setting all parameters as Table I, the simulation result is shown in Fig. 5. At 4.28 GHz the insertion loss is 25.32 dB, at 6.42 GHz the insertion loss is 24.80 dB and at fundamental frequency 2.14 GHz, the insertion loss is 0.56 dB.

TABLE I. Parameters of Fig. 4

Parameter	Value (mm)
w1	0.30
w2	0.95
w3	0.15
w4	4.00
w5	1.58
L1	9.80
L2	8.50
d	1.90

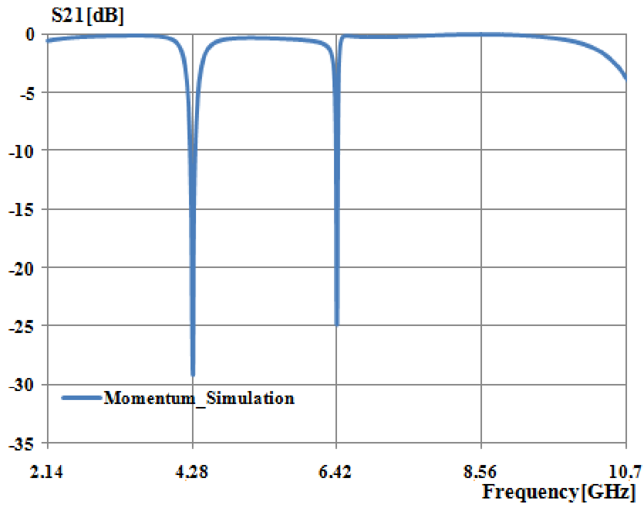

Figure 5. Simulation result of proposed dual band-notched (2nd and 3rd harmonics of 2.14 GHz) UWB bandpass filter.

By changing the value of L1 from 9.40 mm to 10.20 mm with step 0.40 mm, the two notched bands are shifted as Fig. 6 shows. Obviously, when L1=9.80 mm, the second and third harmonics (4.28 GHz and 6.42GHz) of 2.14 GHz are rejected effectively.

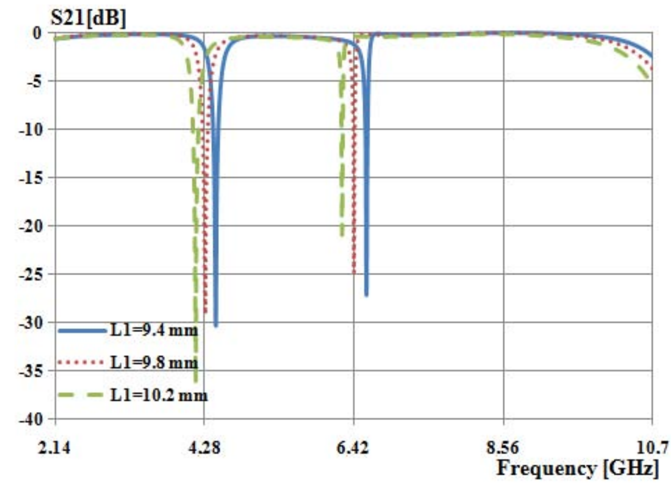

Figure 6. Simulation result of proposed dual band-notched (2nd and 3rd harmonics of 2.14 GHz) UWB bandpass filter by changing L1.

As we analyzed before, by changing the value of L1, the two notched bands will shift simultaneously. We cannot reject the second and third harmonics of the desired fundamental frequency by only changing the value of L1, because there's always one certain band distance between the two notched bands. We must fix one of the notched bands and shift another notched band independently. Among the eight variable parameters (w1, w2, w3, w4, w5, L1, L2, and d), by changing the value of L2, we can shift the higher notched band while not effecting the lower notched band (the second harmonic of 2.14 GHz). As Fig. 7 shows us, change the value of L2, the first notched band 4.28GHz is fixed while the second notched band is shifted around 6.42 GHz. With this method, we can control the two notched bands easily to reject our desired frequency bands in UWB.

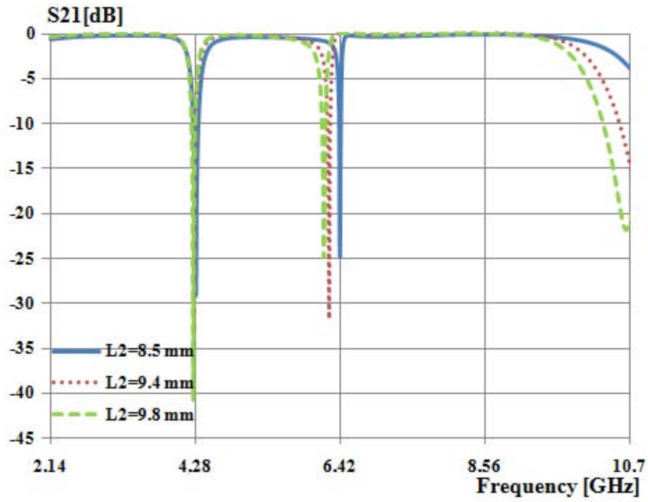

Figure 7. Simulation result of proposed dual-band notched UWB bandpass filter by changing the value of L2 while fixing other parameters.

IV. FABRICATION AND MEASUREMENT

Our proposed dual band-notched (2nd and 3rd harmonics of 2.14 GHz) UWB bandpass filter is fabricated on substrate TLX-8-0620-C2/C2 from Taconic with dielectric constant of 2.55 and thickness of 62 mils. To investigate the influence of the parameters (L1 and L2 in Fig. 4), we fabricated a series of dual band-notched UWB bandpass filters with different values of L1 and L2. The fabricated proposed filter is shown in Fig. 8. Fig. 9 shows the comparison of simulated and measured result. At 4.28 GHz and 6.42 GHz, the insertion loss of the measured result is 13.99 dB and 4.16 dB, respectively. The size of the proposed filter is 5.5 mm x 21.3 mm.

Figure 8. Fabricated dual band-notched (2nd and 3rd harmonics of 2.14 GHz) UWB bandpass filter.

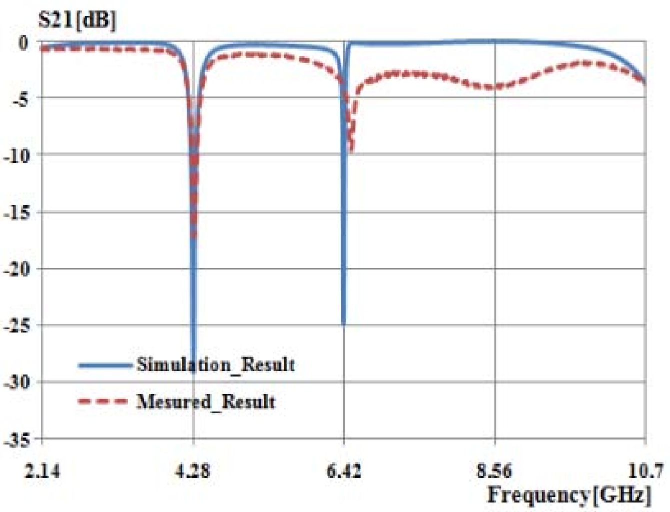

Figure 9. Comparison of simulated and measured result of porposed dual band-notched (2^{nd} and 3^{rd} harmonics of 2.14 GHz) UWB bandpass filter.

V. CONCLUSION

In this work, we proposed a novel dual band-notched UWB bandpass filter. By analyzing the effect of the number of linear identical fingers on the number of notched bands, we designed a UWB bandpass filter with two notched bands. We proposed one novel structure to control the second and third harmonics of fundamental frequency 2.14 GHz for switch mode power amplifier application. By adding two pairs of fingers on each side of the interdigital hairpin fingers (three fingers), two notched bands are achieved. By changing the value of L1, we decide the lower notched frequency band first and fix the value of L1. We change the value of L2 to shift the higher notched frequency band without influencing the lower notched frequency band. By this kind of method, the two notched bands can be shifted independently. With this characteristic, we can easily design our proposed dual band-notched filter for harmonic suppressing application. The fabricated novel dual band-notched UWB bandpass filter is designed for passing the signal generated at its fundamental frequency 2.14 GHz, and blocking its second and third harmonics. Compare to the conventional harmonic control circuit, the size of this filter is small. The measured S_{21} at 4.28 GHz and 6.42 GHz are 13.99 dB and 4.16 dB, respectively. The insert loss at 2.14 GHz is 0.69 dB. The size of the proposed filter is 5.5 mm x 21.3 mm.

REFERENCES

[1] David Yu-Ting Wu and Slim Boumaiza, "Comprehensive first-pass design methodology for high efficiency mode power amplifier," IEEE Microwave Magazine, vol. 11, no. 1, pp. 116-121, February 2010.

[2] Mohamed Helaoui and Fadhel M. Ghannouchi, "Optimizing losses in distributed multiharmonic matching networks applied to the design of an RF GaN power amplifier with higher than 80% power-added efficiency," IEEE Transactions on Microwave Theory and Techniques, vol. 57, no. 2, pp. 314-322, February 2009.

[3] Bo-Jiun Chen, Tze-Min Shen, and Ruey-Beei Wu, "Design of tri-band filters with improved band allocation," IEEE Transactions on Microwave Thoery and Technique, vol. 57, no. 7, pp. 1790-1797, July 2009.

[4] Ching-Her Lee, Chung-I. G. Hsu, and He-Kai Jhuang "Design of a new tri-band microstrip BPF using combined quarter-wavelength SIRs," IEEE Microwave and Wireless Components Letters, vol. 16, no. 11, pp. 594-596, November 2006.

[5] L.-Y. Ren, "Tri-band bandpass filters based on dual-plane microstrip/DGS slot structure," IEEE Microwave and Wireless Components Letters, vol. 20, no.8, pp. 429-431, August 2010.

[6] Chih-Kang Lung, Kuo-Sheng Chin, and Jeffrey S. Fu "Tri-section stepped-impedance resonators for design of dual-band bandstop filter," 39th European Microwave Conference, Rome, Italy, pp. 771-774, September 2009.

[7] Adel Z. El Dein, Adel B. Abdel-Rahman, Raafat E. Fat-Helbary, and A. M. Montaser, "Tunable-compact bandstop defected ground structure (DGS) with lumped element," 7th International Multi-Conference on Systems, Signals and Devices, Amman, Jordan, June 2010.

[8] Sheng Sun and Lei Zhu, "Capacitive-ended interdigital coupled lines for UWB bandpass filters with improved out-of-band performances," IEEE Microwave and Wireless Components Letters, vol. 16, no. 8, pp. 440-442, August 2006.

[9] Azzeddine Djaiz, Mohamed A. Habib, Mourad Nedil, and Tayeb A. Denidni, "Design of UWB filter-antenna with notched band at 5.8GHz," IEEE International Symposium on Antennas and Propagation, Charleston, USA., June 2009.