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Microstrip BPF using SIRs with Wide and Deep Harmonics Suppression Band

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1. Introduction

Microstrip bandpass filters are recently fashionable with various well known features, including low cost, compactness, light weight, easy fabrication, and affordability in active circuit extension. In practice, it needs to be designed with basic characteristics of low passband attenuation, high selectivity, and harmonics suppression. In particular, harmonics suppression characteristic is significantly required for wireless communication systems. Although several harmonics suppression techniques [1]-[3] were presented in recent years, wide and deep harmonics suppression band should be more enhanced with minimized step filters.

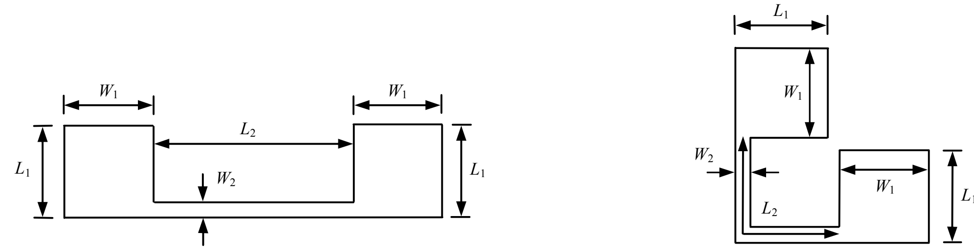
In our research, 2-step and 3-step bandpass filters were designed and fabricated. The centre frequency was 1950 GHz for WCDMA-FDD up-link band with bandwidth of 60 MHz based on IMT-2000 standard. In measurement, the harmonics suppression band was greater than 30 dB from 2.3 to 9.4 GHz for a 2-step filter, and greater than 40 dB from 2.3 to 9.1 GHz for a 3-step filter. The designed folded and straight stepped impedance resonators (SIRs) used for this were designed its physical characteristic based on off-band design while passband design charts were also newly plotted based on various 3-dB bandwidths (maximally flat) [4]. Those passband design charts were used to design any step filter and any bandwidth for any Tchebycheff or maximally flat. In addition, the high selectivity of two transmission zeros on passband was obtained by two open-ended stubs [4]. The harmonics suppression technique was proposed and described in here with even-mode interruption technique for the 2-step and 3-step filters, accordingly, 3-step filter size reduction by using a conventional quarter-wavelength SIR [5].

In the content, designed resonators and filters are described in Sec. 2. The prototype filters and measurement results are shown in Sec. 3 and conclusion is given in Sec. 4.

2. Designed Resonators and Filters

Fig. 1 shows a straight SIR and folded SIR which has been modified from conventional SIR [6]. The length L_1 and width W_1 is defined on low-impedance part and length L_2 and width W_2 is defined on high-impedance part of resonator. The length ratio N and impedance ratio R were defined to design the physical SIR characteristic based on the second harmonic push-away, as called "off-band design" [4]. Subsequently, the ratios N and R were designed as 2 and 0.3, respectively. At those ratios, the second harmonic was approximately at $3f_o$ where f_o means fundamental frequency.

In the design of 2-step and 3-step filters as shown in Fig. 2 and 3, the resonator gap G and port position D were designed by passband design charts [4], hence G = 0.48 mm, D = 0.45 mm for the 2-step Tchebycheff bandpass filter, and G = 0.78 mm, D = 0.38 mm for the 3-step Tchebycheff bandpass filter. Where fed port dimension is as follows: L_{MF} = 8 mm, W_{MF} = 3.32 mm, L_{TF} = 2 mm, and W_{TF} = 1 mm.



(a) Straight SIR (b) Folded SIR

Figure 1: The Physical SIR Characteristic

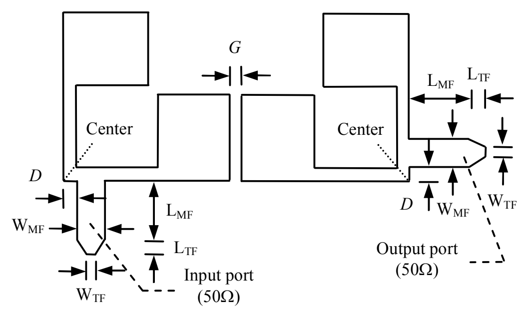


Figure 2: The 2-Step Bandpass Filter

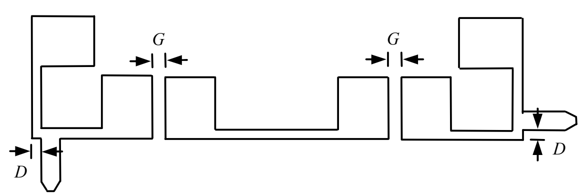


Figure 3: The 3-Step Bandpass Filter

Commercial IE3D simulation software was utilized to verify the frequency response of the 2-step and 3-step Tchebycheff bandpass filters. The result of transmission performance (S_{21}) is shown in Fig. 4.

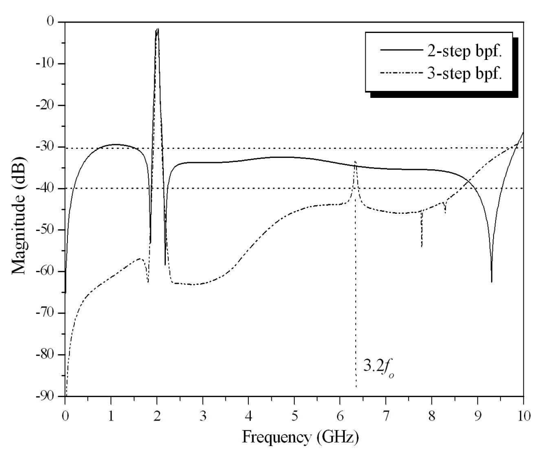


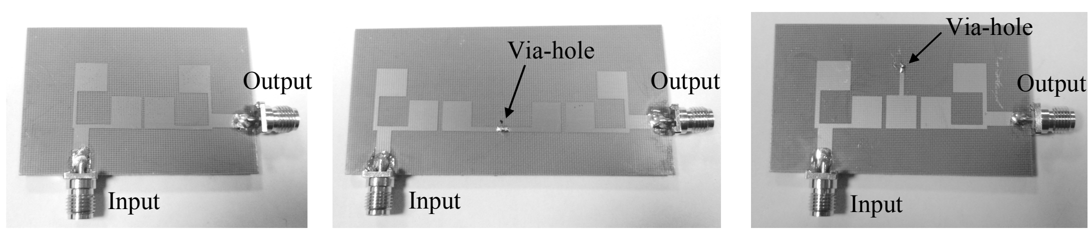
Figure 4: The Transmission Performance of the 2-Step and 3-Step Bandpass Filter

The transmission performance (S_{21}) on the passband of the 2-step and 3-step bandpass filters was consistent with the design.

The even-mode harmonics suppression technique was proposed and applied in this paper. The harmonics suppression band of the 2-step bandpass filter exceeded 30 dB because second resonant mode was destroyed by 50ohm port fed near the centre of resonator length. While the harmonics suppression of 3-step bandpass filter was greater than 40 dB, except a small peak at 3.2*f*o. This small peak was regenerated by the second straight resonator. However, this small peak was suppressed by second resonant mode interruption of a 0.2 mm-dia via-hole which was made at the centre of the second resonator length. Finally, the second straight half-wavelength ($\lambda_g/2$) SIR of the 3-step filter was replaced by a quarter-wavelength ($\lambda_g/4$) SIR to reduce the filter size.

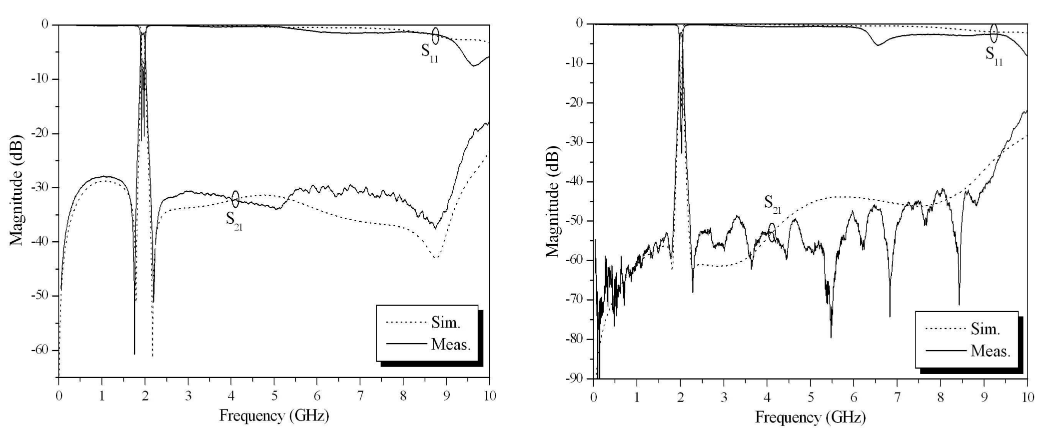
3. Measurement and Results

The prototype filters were fabricated as shown in Fig. 5(a) 2-step filter, (b) 3-step filter using half-wavelength SIRs, and (c) 3-step filter using half- and quarter-wavelength SIRs. The comparison of simulation and measurement results are shown in Fig. 6(a), (b), and (c). For the measurement result of the 2-step Tchebycheff bandpass filter: passband attenuation was 1.577 dB, centre frequency was 1942 MHz with 62 MHz-bandwidth, and harmonics suppression was greater than 30 dB from 2.3 to 9.4 GHz. For the measurement result of the 3-step Tchebycheff bandpass filter using half-wavelength SIRs: passband attenuation was 2.327 dB, centre frequency was 1954 MHz with 66 MHz-bandwidth, and harmonics suppression was greater than 40 dB from 2.3 to 9.1 GHz. For the measurement result of the 3-step Tchebycheff bandpass filter using half- and quarter-wavelength SIRs: passband attenuation was 2.423 dB, centre frequency was 1950 MHz with 65 MHz-bandwidth, and harmonics suppression was greater than 40 dB from 2.3 to 9.4 GHz.

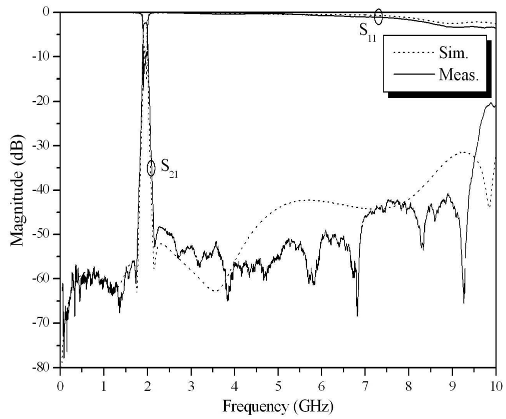


(a) (b) (c)

Figure 5: The Designed Prototype Filters of (a) 2-Step Filter, (b) 3-Step Filter using $\lambda_g/2$ SIRs, and (c) 3-Step Filter using $\lambda_g/2$ and $\lambda_g/4$ SIRs



(a) (b)



(c)

Figure 6: The comparison of Simulation and Measurement Results of (a) 2-Step Filter, (b) 3-Step Filter using $\lambda_g/2$ SIRs, and (c) 3-Step Filter using $\lambda_g/2$ and $\lambda_g/4$ SIRs

4. Conclusion

The 2-step and 3-step Tchebycheff bandpass filters were designed and fabricated. The physical SIR characteristic was designed with length ratio *N* and impedance ratio *R* based on second harmonic push-away. Wide and deep harmonics suppression band were achieved by using even-mode interruption technique with 50ohm port for 2-step filter and via-hole for 3-step filter. Finally, a quarter-wavelength SIR was used in the 3-step filter to avoid second resonant mode operation and 3-step filter size was also reduced.

Acknowledgement

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References

[1] H. Wang, L. Zhu, "Aperture-backed microstrip line stepped impedance resonators and transformers for performance-enhanced bandpass filter", IEICE Trans. Electron., vol. E89-C, No. 3, pp. 403-409, 2006.
[2] A. Namsang, T. Majang, J. Jantree, S. Chaimool, P. Akkaraekthalin, "Stepped impedance hairpin resonators with asymmetric capacitively load coupled lines for improved stopband characteristic", IEICE Trans. Electron., vol. E90-C, No. 12, pp. 2185-2191, 2007.
[3] C.-H. Wu, C.-H. Wang, C.-H. Chen, "Stopband extended balance bandpass filter using coupled stepped impedance resonators", IEEE Microw. Wirel. Commu. Lett., vol. 17, No. 7, pp. 507-509, 2007.
[4] S. Theerawisitpong, T. Suzuki, H. Yamada, N. Morita, Y. Utsumi, "A microstrip bandpass filter with ultra wide stopband using folded stepped impedance resonators", IEICE Technical Report MW 2008-80, vol. 108, No. 195, pp. 7-11, 2008.
[5] S. Theerawisitpong, M. Ogue, F. Okawa, T. Suzuki, T. Kamei, N. Morita, Y. Utsumi, "SIR type bandpass filter with wide suppression band width", IEICE Technical Report MW 2008-189, vol. 108, No. 452, pp. 1-5, 2009.
[6] M. Makimoto, S. Yamashita, "Bandpass filter using parallel coupled stripline stepped impedance resonators", IEEE Trans. Microw. Theory Tech., vol. 28, No. 12, pp. 1413-1417, 1980.