A Microstrip Diplexer Using Folded Single Stepped-Impedance Resonator for 3G Microcell Stations

S. Theerawisitpong and P. Pinpathomrat

***Abstract*—This paper proposes a microstrip diplexer using folded single stepped-impedance resonator for 3G microcell stations. The filters are designed based second-order with side coupled excitation. The measured uplink band is at 1900-1965 MHz having a passband attenuation of 1.94 dB and return loss of 19.5 dB, while downlink band is at 2085-2135 MHz having a passband attenuation of 2.20 dB and return loss of 22.3 dB, where isolation between uplink and downlink band is 18.4 dB. In addition, second harmonic is suppressed at greater than 40 dB upto 4700 MHz. The advantages of our diplexer include low profile, compactness, high isolation, and high selectivity.**

***Index Terms*—Microstrip, diplexer, stepped-impedance resonator, SIR.**

I. Introduction

Due to rapid growth of mobile internet services in Thailand, consequently, microcell stations are needed to extend capacity, especially in crowded areas, e.g. university zone, shopping malls, tourist attraction. However, interferences among 3G cellular networks and private WiFi networks were surprisingly discovered as surveyed in [1]. At that time, it was solved by frequency optimization, but it seemed unstable in a long term because the frequency optimized might interfere to neighbor sites. Thus, we herein propose an alternative solution using a microstrip diplexer with low profile and ease of fabrication (see Fig. 1).

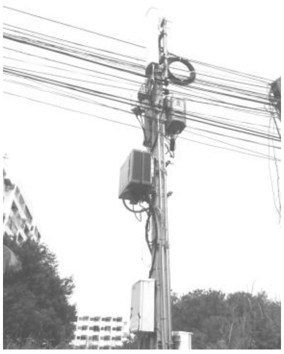

Fig. 1. Remote Radio Unit (RRU) operated as a microcell station in cellular network to extend capacity in crowded areas.

In our research, we designed the second-order filters using folded single stepped-impedance resonator with side coupled excitation, having compactness, high isolation, and high selectivity [2]-[6].

Manuscript received March 2, 2015; revised February 13, 2016. This work was supported in part by the National Research Council of Thailand under Grant 81242.

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II. Schematic of Resonator

The schematic of our resonator is shown in Fig. 2, where dimensions can be determined by impedance ratio R and length ratio N. Note that ratio R is defined by Z_1/Z_2 where Z_1 is the impedance of a strip line having a width W_1 and Z_2 is the impedance of a strip line having a width W_2, while ratio N is defined by L_2/L_1 where L_1 is the length of a low-impedance line and L_2 is the length of a high-impedance line.

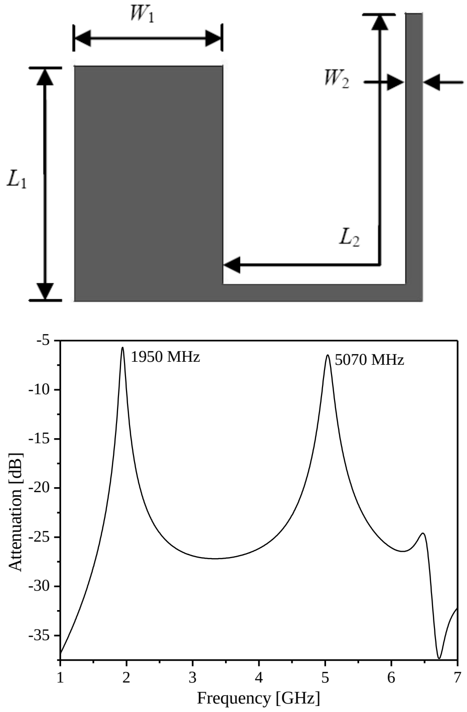


Fig. 2. Schematic of a folded single stepped-impedance resonator, and its response of resonant and second harmonic frequencies.

Regarding to off-band design as recommended in [2], ratios R and N were designed at 0.27 and 2, respectively, in order to achieve second harmonic suppression at more than two times of resonant frequency as shown in Fig. 2. The resonant frequency f_0 is at 1950 MHz and second harmonic is about $2.6f_0$ at 5070 MHz which is sufficient to this work. Hence resonator dimensions are as follows: L_1 = 14 mm, L_2 = 28.03 mm, for uplink band at 1920-1980 MHz, and L_1 = 15.5 mm, L_2 = 30.88 mm, for downlink band at 2110-2170 MHz, where W_1 = 9.77 mm at 30 ohm and W_2 = 1.12 mm at 110 ohm. Material used is a microwave laminate #RT/Duriod 5880 having ε_r = 2.2, tan δ = 0.0009, h = 1.57 mm, and t = 0.0085 mm.

III. Uplink and Downlink Filters Design

A. Excitation Ports

Our diplexer was designed based the second-order filters with side coupled excitation as shown in Fig. 3. In the figure, port 1 is the input/output port of uplink and downlink streams using a 50-ohm line at a width of 4.84 mm having a length of 37.2 mm, while port 2 is an output of uplink stream and port 3 is an input of downlink stream. Regarding to impedance matching to keep a low return loss, ports 2 and 3 were designed as a shaper line including a 50-ohm line at a width of 4.84 mm having a length of 18.5 mm, and a 35-ohm line at a width of 7.84 mm having a length of 14.4 mm.

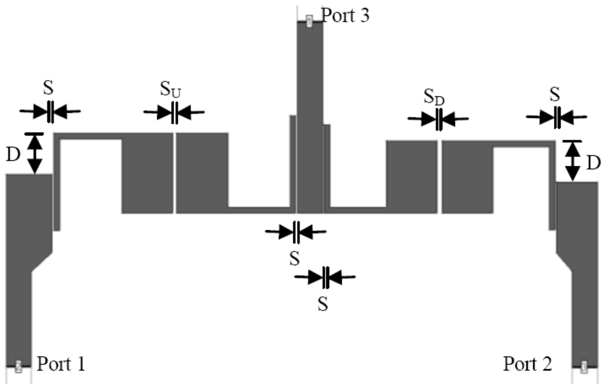


Fig. 3. Schematic of proposed diplexer including uplink and downlink filters based the second-order filter with side coupled excitation.

B. Passband Design

Referring to filter design in [2], [7], the pass-bandwidth of uplink filter at 1920-1980 MHz was determined by a space S_U of 0.8 mm and a port position D of 8 mm. On the other hand, pass-bandwidth of downlink filter at 2110-2170 MHz was determined by a space S_D of 0.94 mm and a port position D of 8 mm. In addition, the space between port and resonator S was designed at a small distance of 0.3 mm to keep strong mixed coupling excitation. The result of our design was verified by a 3D full-wave electromagnetic simulator, as shown in Fig. 4.

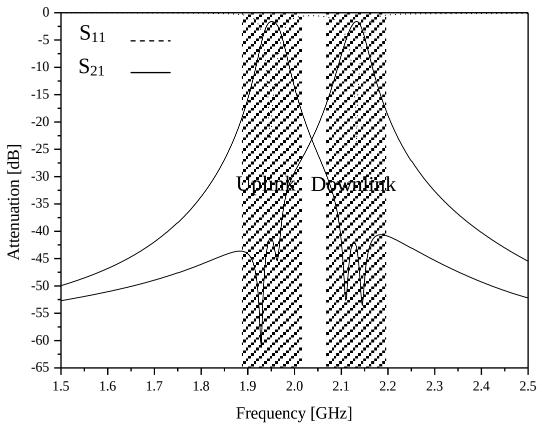


Fig. 4. The passband responses of uplink and downlink filters calculated by a 3D full-wave electromagnetic simulator.

In Fig. 4, filter performance was represented by insertion loss S_{21} denoted by the bold line and return loss S_{11} denoted by the dotted line. At uplink band, frequency range is at 1920-1980 MHz having a passband attenuation of 1.598 dB and a return loss of 18.59 dB. At downlink band, frequency range is at 2110-2170 MHz having a passband attenuation of 1.61 dB and a return loss of 23.88 dB. Meanwhile the isolation between uplink and downlink band is 23.25 dB.

C. Off-Band Design

In the design, second harmonic was designed at 2.6 times of resonant frequency using stepped-impedance technology at ratios R at 0.27 and N at 2. Thus second harmonic frequencies of uplink and downlink filters were designed at 5070 MHz and 5460 MHz, respectively, as shown in Fig. 5. In the figure, uplink filter performance is denoted by the bold line and downlink filter performance is denoted by the dotted line. In particular, suppression band was obtained with a noise margin at greater than 45 dB.

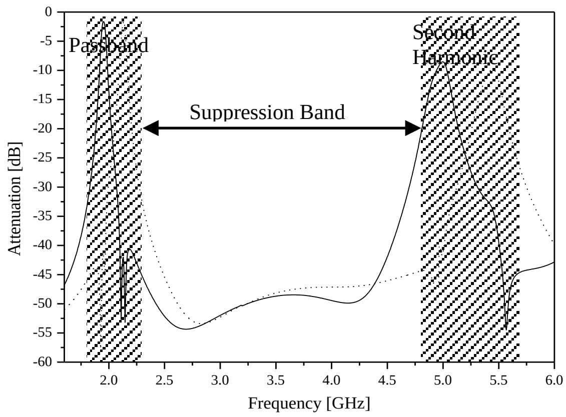
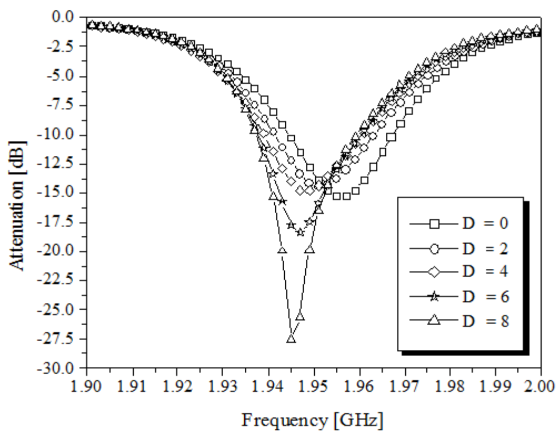


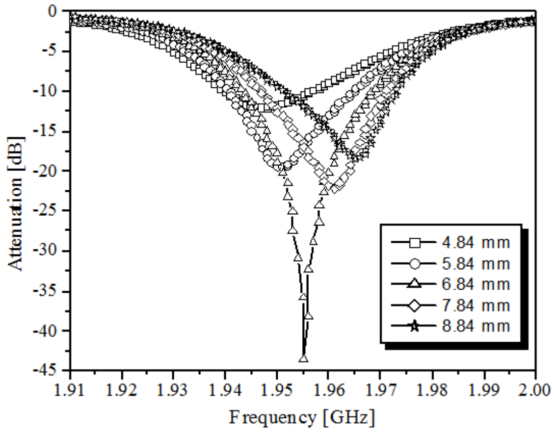
Fig. 5. The calculated result of uplink and downlink filters performance showing passband and second harmonic frequencies.

D. Matching Condition

The dimensions of ports 2 and 3 were optimized to achieve a low return loss regarding to matching condition, while port 1 was designed as a 50-ohm line to avoid complicated structure for uplink and downlink streams through the same path. The optimization approaches of ports 2 and 3 are demonstrated in Fig. 6(a) and Fig. 6(b). Considering optimization results in the figure, port position D at 8 mm offers a return loss at 27.5 dB and shaper size at 6.84 mm offers a return loss at 43.5 dB but the pass-bandwidth may be varied. Therefore, optimized port position and shaper size were recommended at 8 mm and 7.84 mm, respectively, in order to keep a pass-bandwidth at 60 MHz as designed.



(a)



(b)

Fig. 6. The optimization results of (a) port position D and (b) shaper size, to meet a matching condition.

IV. Diplexer Prototype

The prototype fabricated with lithography technology is shown in Fig. 7. However, actual dimensions are different from calculation due to fabrication constraints, as shown in Table I, thus the calculated result is slightly different from the measured results as described in the next section.

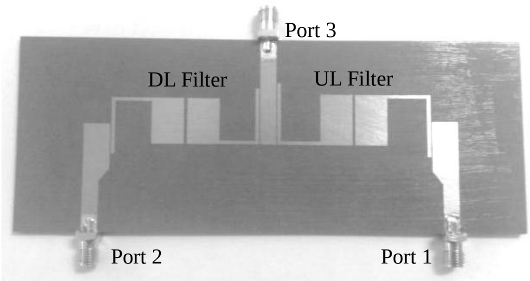


Fig. 7. The diplexer prototype based second-order filters using folded single stepped-impedance resonator with side-coupled excitation.

TABLE I: Comparison of Design vs. Actual Dimensions

	Dimensions [mm]	Design	Actual
UL Filter	L_1	15.5	15.0
	L_2	30.88	30.5
	W_1	9.77	8.278
	W_2	1.12	0.875
	$S_{port\ 1\text{-}resonator}$	0.3	0.507
	$S_{port\ 3\text{-}resonator}$	0.3	0.564
	S_U	0.8	1.021
	D	8.0	6.985
DL Filter	L_1	14.0	13.5
	L_2	28.03	27.75
	W_1	9.77	8.25
	W_2	1.12	0.885
	$S_{port\ 2\text{-}resonator}$	0.3	0.55
	$S_{port\ 3\text{-}resonator}$	0.3	0.502
	S_D	0.94	1.171
	D	8.0	6.892

V. Measurement Results

The proposed filters performances measured by a vector network anaylyzer are shown in Fig. 8 and Fig. 9. In Fig. 8, uplink and downlink filters performance was verified as the following results. At uplink band, passband frequency is at 1900-1965 MHz with passband attenuation at 1.94 dB and return loss at 19.5 dB. At downlink band, passband frequency is at 2085-2135 MHz with passband attenuation at 2.2 dB and return loss at 22.3 dB. The isolation between uplink and downlink band is 18.4 dB. However, a small loss at 1800 MHz was occurred, due to mobile signals interference during our measurement.

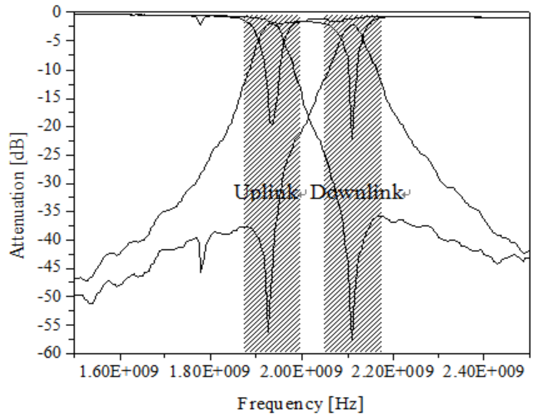


Fig. 8. The measured results of diplexer prototype at uplink and downlink bands represented by insertion and return losses.

In the meantime, second harmonic suppression was also verified as shown in Fig. 9. In the figure, second harmonics of uplink and downlink filters were suppressed at 5032 MHz and 5460 MHz, respectively, where suppression band was achieved with a high noise margin at greater than 40 dB up to 4700 MHz. By the way, the comparison of calculated and measured results is summarized as shown in Table II, with respect to engineer's suggestions aimed to employ for the 3G microcell stations as follows: passband attenuation at less than 2.5 dB, return loss at less than 20 dB, isolation at less than 15 dB, and second harmonic at more than 2 times of passband.

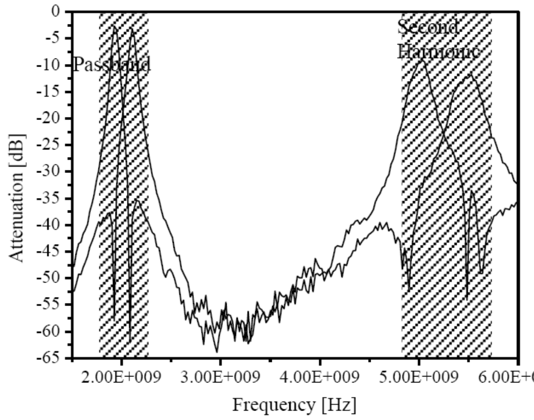


Fig. 9. The measured result of diplexer prototype on a wide band view to verify second harmonic suppression performance.

The specifications exhibited in the table below showed that our diplexer performance was acceptable with respect to the requirement.

TABLE II: Comparison of Calculated vs. Measured Results

	Requirement	Calculation	Measurement
Uplink band [MHz]	1920 - 1980		1900 - 1965
Downlink band [MHz]	2110 – 2170		2085 - 2135
Passband atten.	≤ 2.5		

[dB] - Uplink band - Downlink band		1.598 1.610	1.94 2.20
Return loss [dB] - Uplink band - Downlink band	≥ 20	18.59 23.88	19.5 22.3
Isolation [dB]	≥ 15	22	18.4
Second harmonic suppression	> $2f_0$	$2.6f_0$	

VI. Conclusions

In this paper, a microstrip diplexer based second-order filters using folded single stepped-impedance resonator with side-coupled excitation has been proposed with the advantages including low profile, compactness, high isolation, and high selectivity. The low profile and compactness were obtained by second-order filters using our resonator. Besides, the high isolation between uplink and downlink bands may be affected by side coupled excitation offering a transmission zero for each passband. Finally, the second harmonic suppression at $2.6f_0$ with a noise margin at greater than 40 dB upto 4700 MHz was achieved by stepped- impedance technology as described in the off-band design. Moreover, high return loss regarding to matching condition was optimized using shaper ports.

The proposed diplexer performance was acceptable as well. However, uplink and downlink passbands should be tuned as similar to ITU's recommendations, which will be studied in the future.

Acknowledgment

The authors would like to gratefully thank the National Research Council of Thailand for supporting the research grant, Rajamangala University of Technology Thanyaburi for funding under the Enterprises-University Cooperation Project, and Mr.Direk Homchuen for cellular network survey and suggestions.

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