

CASCADED SQUARE LOOP BANDPASS FILTER WITH TRANSMISSION ZEROS FOR LONG TERM EVOLUTION (LTE)

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Abstract – In this paper, we present a bandpass filter that passed frequency of 1.7 GHz – 1.8 GHz. It is applied for an uplink frequency in 4G 1800MHz. This filter is created by using substrate PCB TMM-10i and has a compact size of 42 mm x 42 mm. The compact size is also important besides selectivity. The selectivity is achieved by implementing cascade square loop resonator method which generated transmission zeros. Actually, transmission zeros are obtained from the coupled resonator. The bandpass filter is designed by adding an external resonator on each square of the resonator loop and a patch to the inside of the square loop resonator. The parameter performances are simulated by HFSS. The parameter performances for return loss value is 14.24 dB at frequency 1.75 GHz and insertion loss value is 0.65 dB at frequency 1.75 GHz. By using VNA Anritsu MS 2026A, prototype bandpass filter is measured. The measurement results for return loss value is 6.8 dB and insertion loss value is 2.2 dB.

Keywords: Bandpass filter; Microstrip filter; Cascaded square loop; LTE; BPF

INTRODUCTION

Long Term Evolution (LTE) is a new service that has high ability in a mobile communication system and designed to increase the capacity and speed of mobile phone networks. A filter is one of the important circuits in a wireless telecommunication system because it is used to pass or reject the frequency for a further process (Rahayu et al., 2017). There is a microstrip technology to produce the filter by implementing transmission lines. The transmission lines of microstrip are used to miniaturize high frequency (RF) and microwave (MIC/Microwave Integrated Circuit and MMIC/Monolithic Microwave Integrated Circuit) circuits. The advantage of integrating passive and active components are easy integration, low profile, cheap for mass production, but not all the Printed Circuit Board could be implemented as MIC/MMIC (Alaydrus, 2009).

Selectivity is the important parameter when the bandpass filter is designed. Selectivity of the bandpass filter can be obtained by using coupled method between two resonators as investigated by (Astuti et al., 2013; Xue and Jin, 2017; Ieu et al., 2017). It produces transmission zeros response to sharpen the transition between bandpass and bandstop region. In the research of (Zang et al., 2012) the realization of a filter is done by transmission zeros approach on one resonator.

METHODE

The filter is designed by using cascaded square loop resonator on the coupling between feeding microstrip channel with a resonator. This method gives compact size and selective

response then can be generated by using Defected Ground Structure (DGS) resonator method as shown at (Wei et al., 2017; Jin et al., 2016). Taneja et al. (2016) showed the design of bandpass filter by using the interdigital method, and the result showed that the filter is applied on the LTE frequency.

A bandpass filter is designed by using transmission zeros approach with cascade square loop resonator method that is applied at 1.75 GHz frequency. The frequency is applied for the uplink frequency in the cellular network of 4G 1800MHz. We used Roger TMM-10i substrate with a thickness of 1.27 mm, a permittivity of 9.8 and loss tangent of 0.002. The TMM10i

RESULTS AND DISCUSSION

The frequency range of bandpass filter is 1710 MHz to 1785 MHz. The selectivity related to the passband ripple, L_{Ar} . Table 1 shows the specification of bandpass filter design.

Table 1. Specification of bandpass filter

No	Parameter	Specification
1	Center Frequency	1.75 GHz
2	Bandwidth	100 MHz
3	Insertion Loss	1 dB
4	Return Loss	≥ 10 dB
5	Frequency range of BPF	1710 MHz $< f <$ 1785 MHz
6	Port Impedance	50 Ohm
7	L_{Ar}	3.01 dB

The bandpass filter is designed to fulfill the specifications filter as shown in Table 1. The transformation of the specification into the filter

design is achieved by studying parametric. TMM10i substrate is chosen because of the consideration the permittivity value that relates to the wavelength of the resonator of a filter (Astuti et al., 2013).

The length and width of resonator input/output are shown on (Astuti et al., 2013) and

(Hong, 2011). The width input/output transmission line or w , is 1.2 mm as shown in Fig. 1. The figure shows a bandpass filter design with a cross-sectional patch (Zang et al., 2012) with an additional patch inside the second square resonator or we called patch B.

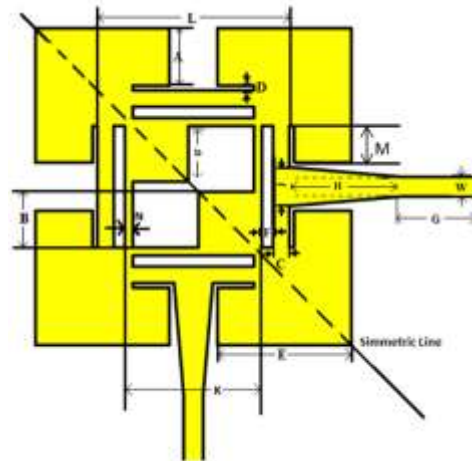
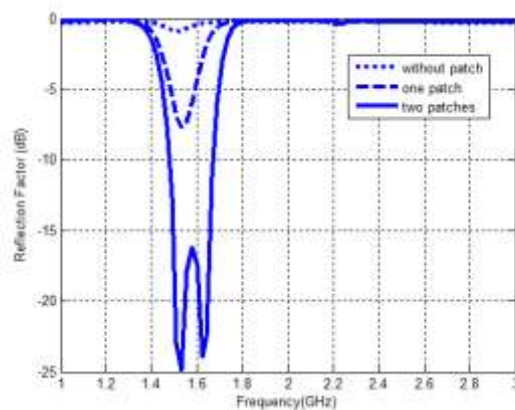
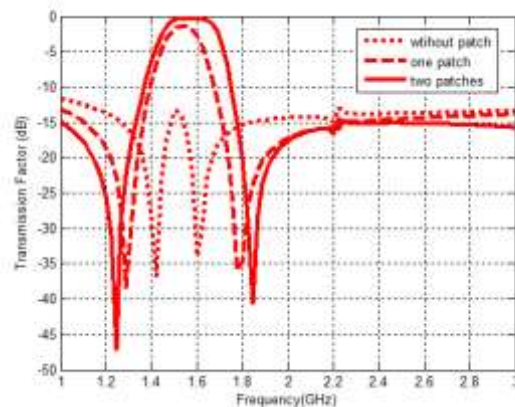


Figure 1. Bandpass filter design



(a)



(b)

Fig 2. (a) Simulation result of S11 additional patch; (b) Simulation result of S21 additional patch.

The parametric study of patch B parameter is shown in Fig. 2 by using HFSS simulator, to get the best response of the filter (Table 1). As shown in Fig. 2, the addition of a patch to the square resonator gives better selectivity results with near-zero insertion loss and wider bandwidth. The Filter without patch B has insertion loss value 13.32 dB, return loss 1.5 dB and 40 MHz bandwidth. The filter with one patch B has an insertion loss value 1.4 dB, 7.5 dB return loss and 160 MHz bandwidth. It means that it is better than to be omitted without patch B. The filter with two patches B gives the best response because the insertion loss value is 0.5 dB, return loss value is 25 dB and bandwidth 180 MHz.

Filter with two patches gives good insertion loss and return loss values, but the frequency response and the bandwidth width still did not meet the initial specifications of filter manufacture. Therefore, the addition of N variable or second square loop resonator as shown in Fig. 1 is investigated by varying the dimensions.

Fig. 3 is the simulation results with a parametric study of N parameter. The optimization of N parameter is 0.5 mm, because it gives a suitable frequency at 1.75 GHz for LTE application. It also has bandwidth value 100 MHz, insertion loss value 0.65 dB and returns loss value 14.24 dB.

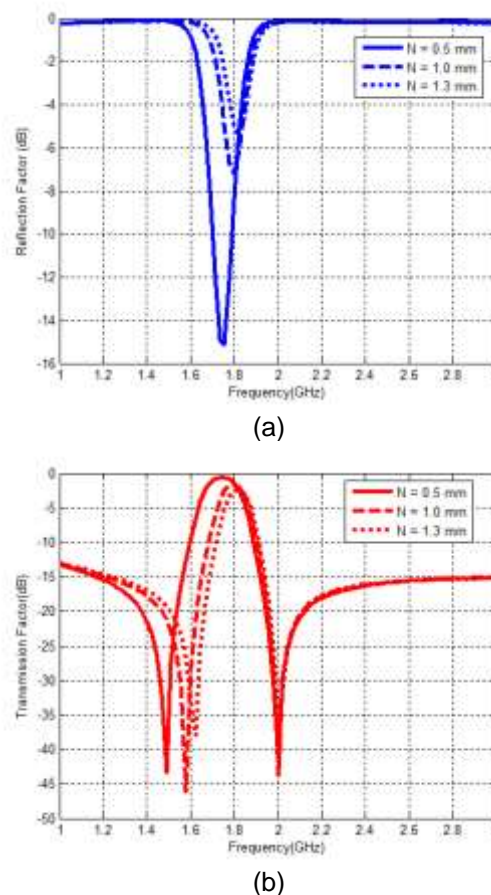
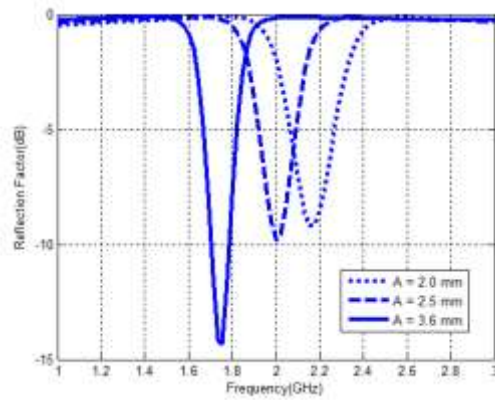


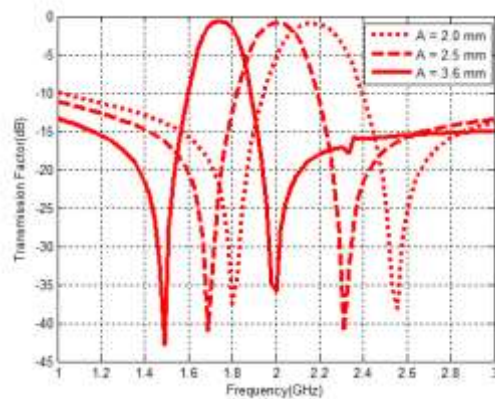
Fig 3. (a) Simulation result of S_{11} respond S_{11} with variable N; (b) Simulation result of S_{11} respond S_{21} with variable N

As shown in Fig. 3, it can be concluded that the change of N variables from $N = 1.3$ mm (dot line) to $N = 0.5$ mm (solid line) causes the bandpass filter shift to smaller frequency. The bandwidth becomes wider, and the insertion loss values will be better. The insertion loss and return loss values are shifting from 2.5 dB to 0.6 dB and from 5.5 dB to 0.6 dB

The optimization of A parameter as the external resonator is shown in Fig. 1. It is investigated to get the best S_{11} and S_{21} response as well as the appropriate of the frequency and bandwidth. The external resonator also has been investigated by Zang et al. (2012). By adding a resonator to the four outside corners of the resonator, the simulation result is shown in Fig. 4 with the parameters in Table 2.



(a)



(b)

Fig 4. (a) Comparison graph of S11 result; (b) Comparison graph of S21 result.

The optimization of bandpass filter parameters (B, N, and A variables) are shown in Table 2.

bandwidth (170 MHz). It could be concluded that A parameter as the frequency control.

Table 2. Parameter size of BPF. (Fig. 1)

Parameter	Size (mm)
L	12
w	1,2
A	3,6
B	3,5
b	3,5
C	1
D	0,3
E	8,4
F	0,7
G	8
H	7
J	2,4
K	8,6
N	0,5
M	2,3

Fig. 4 show, if the A parameter is increased (from 2 mm to 3.6 mm), the frequency response will shift from higher frequency to the lower frequency. It also achieves better return loss (14.24 dB), insertion loss (0.65 dB), and narrow



Fig 5. Prototype Filter

The cascaded square loop bandpass filter with transmission zeros for LTE is fabricated as shown in Fig. 5. By using Anritsu MS 2026A for 1 - 6 GHz frequency, the prototype of a filter is measured. The comparison between the simulation and measurement result are shown in Fig. 6 and Table 3.

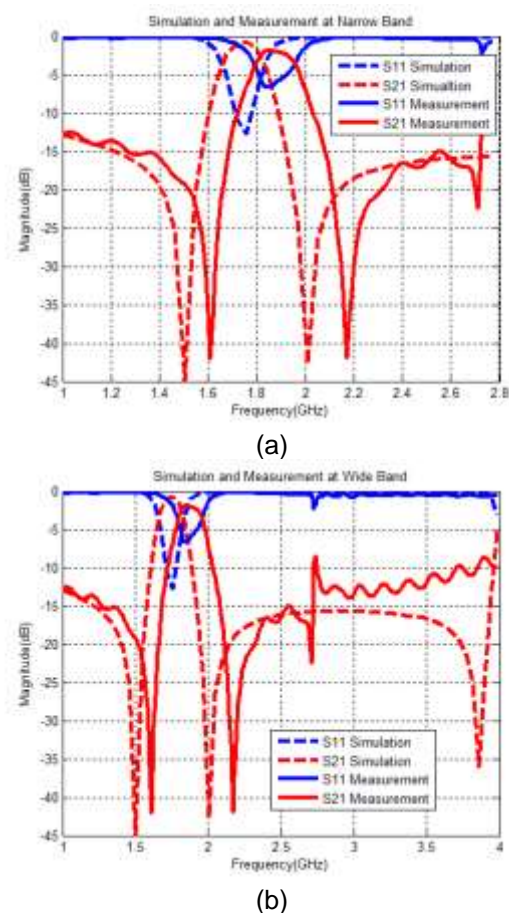


Fig 6. (a) The comparison of simulation and measurement result for narrow band; (b) The comparison of simulation and measurement results for wide band;

The simulation results as shown in Fig. 6 give the returns loss value 14.24 dB, and the insertion loss value 0.65 dB for the frequency center at 1.75 GHz. After the design of filter is fabricated, the measurement results give the return loss value 6.8 dB and insertion loss 2.2 dB with working frequency at 1.85 GHz and the bandwidth 150 MHz, there is a working frequency shift of 100 MHz as well as widening the bandwidth by 50 MHz.

Table 3. Comparison of Simulation and Measurement result

Parameter	Simulation	Measurement
Center Frequency	1.75 GHz	1.85 GHz
Bandwidth	100 MHz	150 MHz
Insertion Loss	0.68 dB	2.2 dB
Return Loss	14.24 dB	6.8 dB

There is a working frequency shift of 100 MHz as well as widening the bandwidth by 50 MHz. The results obtained are still not close to the tolerance limit of the filter which the insertion loss approaching the 0 dB and the return loss approaching minus infinity. Differences in

response results are influenced by several factors, including unsuitable manufacturing factors and the connector solder process that can damage the etching filter results.

CONCLUSION

The additional patch inside the square resonator BPF improves the value of insertion loss and return loss on the filter. It gives a good insertion loss and returns loss response results, but the bandwidth is too wide and the frequency does not meet the initial specification criteria. Therefore, the N layer or second square loop resonator is added to the inside then set the width of A parameter or the outer resonator of the BPF. The cascaded square loop bandpass filter with transmission zeros has been designed, fabricated and measured. The measurement result gives discrepancy rather than the simulation result. The measurement results give the increases value for insertion loss and the decreases value for the return loss. It could be caused by the soldering connectors or process calibration at the measurement.

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