Analysis of RF transceiver for 5G applications

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Abstract

This paper introduces a new place for Band pass filter (BPF) in RF transceiver (TR_x) system operating in Time Division Duplex (TDD) mode. The analysis is performed in the viewpoint of accommodating a huge number of transceivers for 5G massive MIMO systems for base station as well as user equipment. Location of the BPF in the transceiver is optimized by evaluating the overall system selectivity and out-of-band noise suppression. Placing the BPF near to the antenna, before the T/R switch has a significant impact on the overall transceiver performance. This paper also highlights the improvement in the selectivity of the filter by cascading a two BPFs of very low cost and moderate specifications. Simulation results indicate that a better roll-off of about 30-40 dB is achieved with two cascaded BPFs.

1. Introduction

According to 3GPP (release 15) standards, 5G NR (New Radio) can operate in two frequency bands: FR1 and FR2 [1]. In this paper, a transceiver (TR_x) operating in TDD mode at 3.5 GHz (FR1 band) is chosen for analysis. A band pass filter is one of the crucial components in wireless transceiver (TR_x) systems. The overall system specification and Radio standards requirement are mostly covered by Filter's specification. In TR_x system, filters play a major role in improving the selectivity of the receiver, rejecting spurious harmonic noise generated within the system and also making the system more immune to unwanted radio signals.

In existing TR_x systems [2], the T_x and R_x chain contain separate BPFs. In order to achieve good performance, the overall system components should be selected in such a way that they are band-limited to the operating frequency range. This leads to an increase in cost and size of the system. This limitation can be addressed by placing a single BPF near the antenna and before the T/R switch. In this configuration, a better selectivity can be achieved irrespective of critical selection of other components in the system. The individual BPFs in T_x and R_x chain is eliminated and thereby the reduction in cost and size is achieved. In this paper, the system performance for a single and two cascaded BPF configuration is investigated through simulations. The return loss and the transmission gain of the entire system are compared for different locations of the filter in the system.

2. Basic RF transceiver system

A typical configuration of a TDD based TR_x system is shown in Figure 1. The T_x chain consists of a cascade of driver amplifier that conditions the input signal, a BPF operating at the desired frequency band, and a power amplifier (PA) to boost the signal to a required level for the antenna to transmit. Similarly, the R_x chain consists of a low-noise amplifier (LNA) to increase the signal power to an appropriate level for detection, a BPF, a digital attenuator for adjusting the gain of the system, and an amplifier (AMP) for signal conditioning. The antenna is connected to the T_x and the R_x chain through a single pole double throw (SPDT) RF switch. In addition, a directional coupler (DC) can be placed after the antenna for monitoring and calibration purposes.

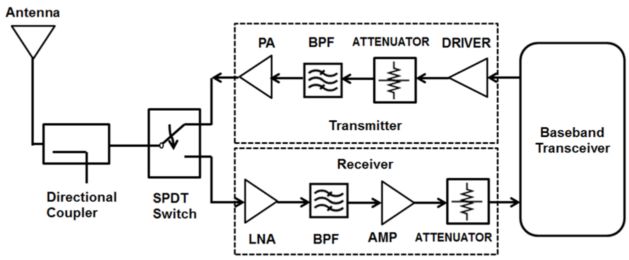


Figure 1. Basic RF Transceiver configuration.

2. A single BPF configuration

Table 1 lists the commercial off the shelf components (COTS) chosen for the analysis. The system level simulation was carried out in Advanced Design System (ADS 2016.01) software using the s-parameter data available for the chosen components.

Table 1. COTS components used in the RF chain.

Components	Vendor	Part number
Directional coupler	Anaren	DC2337J5020AHF
SPDT switch	Analog Devices	HMC8038W
PA	Analog Devices	HMC409LP4E
BPF	Johanson Technology	3600BP14M0600
Driver, AMP	Mini-Circuits	GALI-55+
LNA	Mini-Circuits	TAMP-362GLN+
Attenuator	Analog Devices	HMC1119

The response of the chosen filter (3600BP14M0600, Johanson Tech.) is shown in Figure 2.

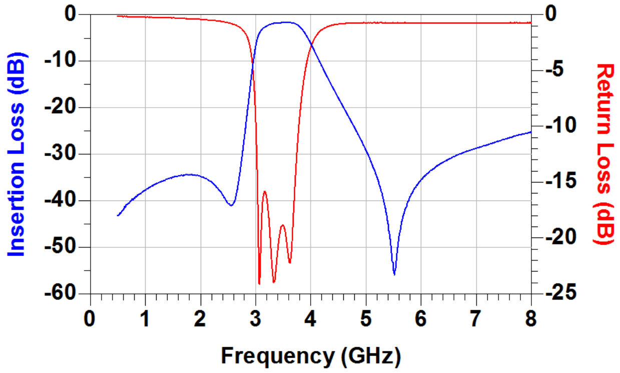


Figure 2. The filter response.

To start with the components were cascaded according to Figure 1. Then different locations where the BPF can be placed were chosen for analysis and are illustrated in Figure 3. The three locations of the BPF are listed viz.

L1-Location1: Between the DC and SPDT switch.
L2-Location 2: At the PA output in T_x chain and at the LNA input in R_x chain.
L3- Location 3: At the PA in T_x chain and at the LNA input in R_x chain.

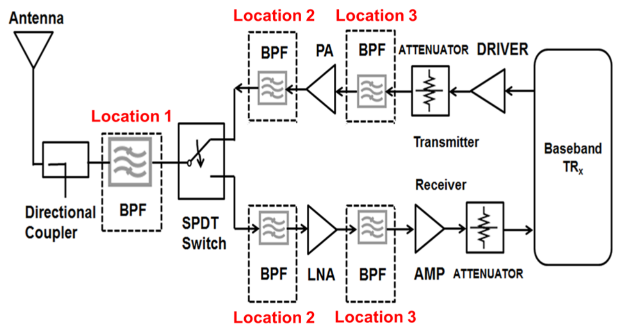


Figure 3. Block diagram representing the different locations of the filter in the RF chain.

Figure 4. illustrates the ADS schematic diagram used for analysis, where the filter was placed in Location 1. The return loss at the antenna port and the transmission gain response for all the three locations were simulated and compared.

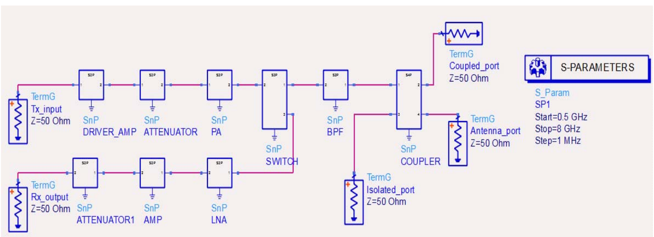
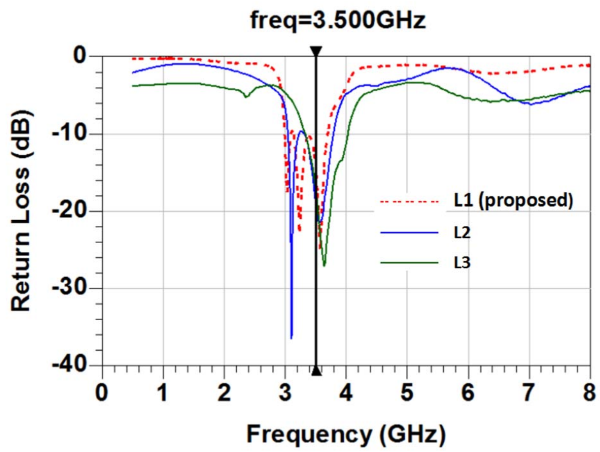
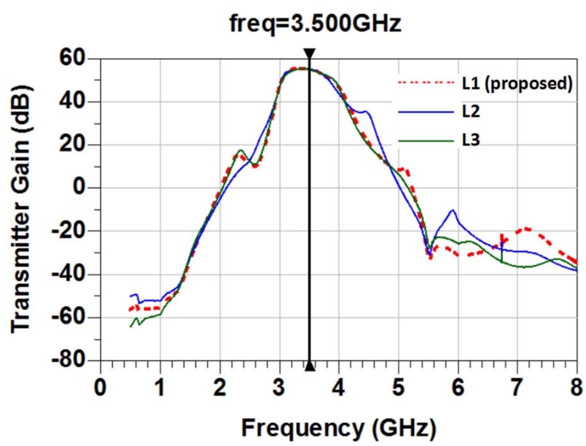


Figure 4. S-parameter simulation setup for BPF in L1 using ADS software.

BPF at L1 shows a better band-limiting characteristics than at other locations, as shown in Figure 5(a) and 6(a). When the BPF was placed at L2 and L3, the return loss at the antenna port is influenced by the combined return loss of other wide band components, such as DC and SPDT switch along with BPF. The transmission gain plots are similar for all the three cases, as shown in Figure 5(b) and 6(b). Hence, the proposed location of the BPF eliminates the need of two individual BPFs in the T_x and the R_x chain.

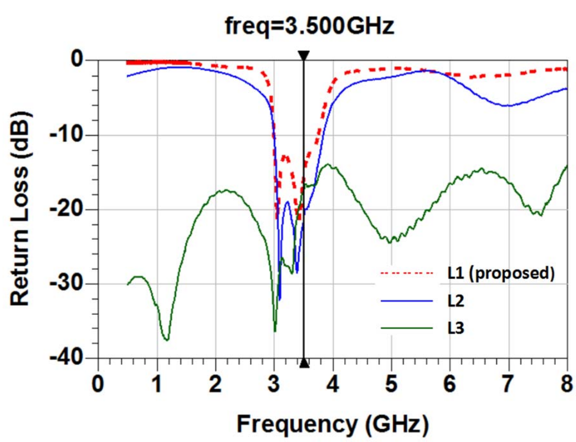


(a)

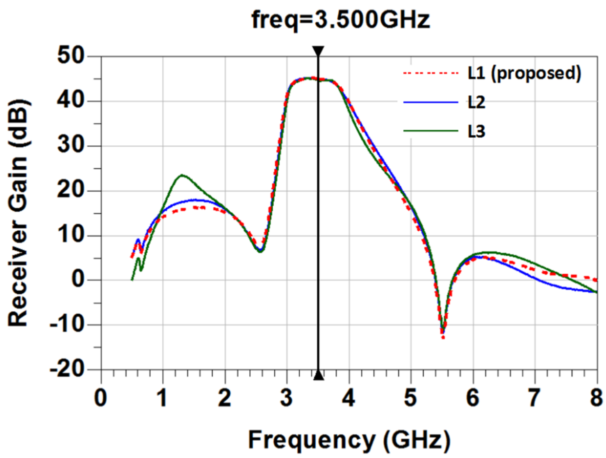


(b)

Figure 5. A single BPF configuration - (a) Return loss (dB) at antenna port, (b) Transmitter gain (dB) for T_x chain.



(a)



(b)

Figure 6. A single BPF configuration - (a) Return loss (dB) at antenna port, (b) Receiver gain (dB) for R_x chain.

3. Cascaded BPF configuration

In order to increase the selectivity of the system, two BPFs were cascaded and placed at different locations (L1, L2 and L3) for analysis. Figure 6 shows the block diagram of this configuration. The simulation procedure is similar to a single BPF configuration as described in the previous section.

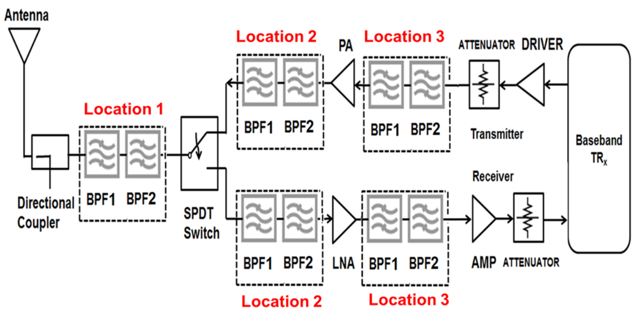
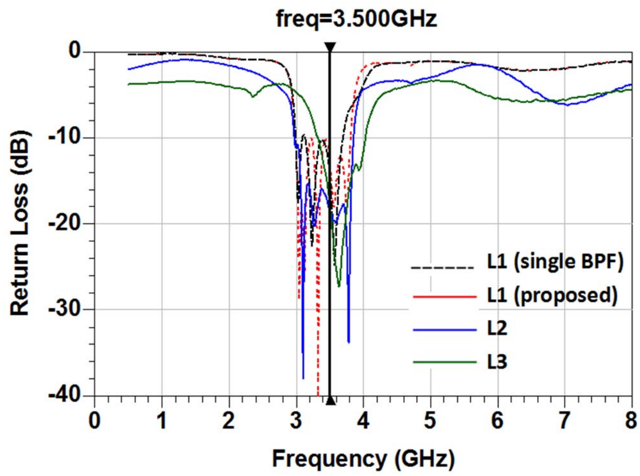
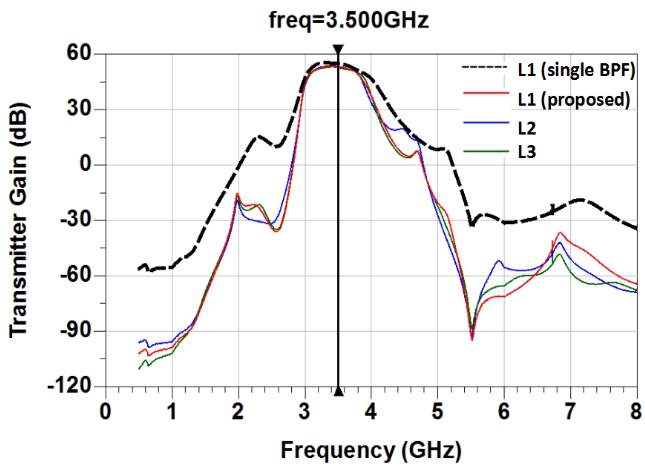


Figure 6. Block diagram representing the two cascaded BPF configuration.

The results were compared with a single BPF placed at L1 location. Figure 7(b) and 8(b) shows that the selectivity of the system is improved by 30-40 dB with cascaded BPFs. The return loss at the antenna port for the cascaded BPF configuration has a flat response in both the passband (3-4 GHz) and the stopband frequencies, as shown in Figure 7 (a) and 8(a).

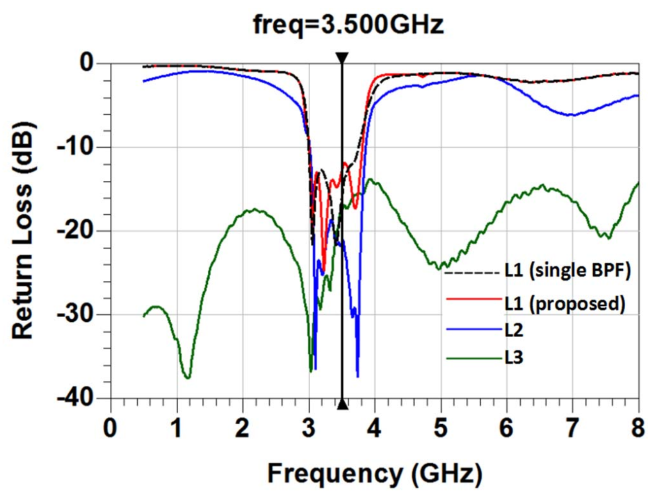


(a)

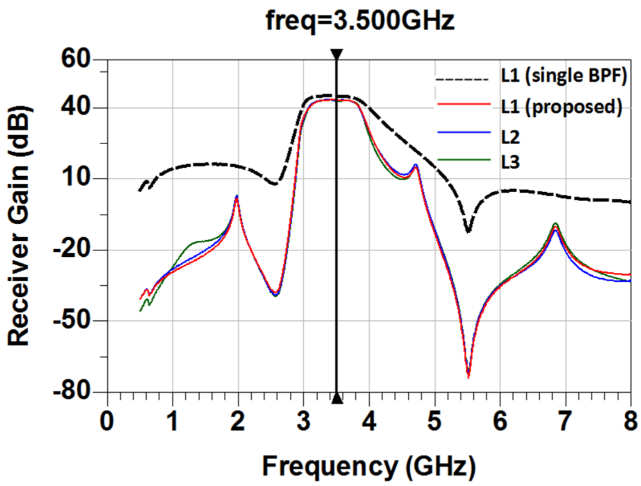


(b)

Figure 7. Cascaded BPFs configuration - (a) Return loss (dB) at antenna port, (b) Transmitter gain for T_x chain.



(a)



(b)

Figure 8. Two BPFs configuration - (a) Return loss (dB) at antenna port, (b) Receiver gain of R_x gain.

4. Conclusion

The effect of the placement of BPF in the 5G-RF transceiver system was presented here. Based on the results, placing the BPF at location 1 yields a very good performance in terms of band limiting characteristics of the overall system. Cascading two such filters in the same location provides an increased selectivity of 30-40 dB compared to a single BPF configuration.

5. Acknowledgements

The work is supported by the grant from Department of Telecommunications, Govt. of India under Indigenous 5G-End to End Test bed project.

6. References

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