RF CAD LABORATORY BASED PROJECT ON BAW QUADPLEXER DESIGN

Submitted By

ASISH NAYAK **EE22M103**

M.Tech in RF and Microwave

Department of Electrical Engineering

INDIAN INSTITUTE OF TECHNOLOGY, TIRUPATI

भारतीय प्रौद्योगिकी संस्थान तिरुपति

TIRUPATI

CONTENTS

PROBLEM STATEMENT

Designing of a BAW QUADPLEXER Module using AWR Software.

ACKNOWLEDGEMENT

It is difficult to acknowledge the precious debt of knowledge and learning. But we can only repay it through our gratitude. I, Asish Nayak, a M.tech student in RF and Microwave Engineering , would like to convey my heartfelt gratitude to my professor ***Dr. M.V Kartikeyan*** *, for blessing us with his immense knowledge of Microwave Engineering and being a constant source of inspiration for me.*

I would also like to thank Mr. ***Mr. Sai Haranadh(PhD Scholar, IIT Tirupati)*** *for his valuable instruction and support through this project by clarifying my doubts and guiding me with his novel ideas.*

Regards,

Asish Nayak

M.Tech RF and Microwave Engineering (2022 batch)

Roll: EE22M103

INTRODUCTION

The Concept of Impedance BAW Quadplexer Module immersed from the idea of transmitting and receiving of frequencies of two different bands at same time from an antenna. Multiple carrier technology has gained significance in the mobile communication sector with the development of LTE-Advanced and orthogonal frequency division multiple access (OFDMA) approaches. Design professionals are overcoming the difficulty of dealing with multi-carrier signal-frequency systems by using RF circuits' diplexers and duplexers to split various carriers. A diplexer, for instance, can be used to split two carrier signals. Compact-designed duplexers and multiplexers significantly improve the functionality of aggregated carriers for transmit (TX) and receive (RX).

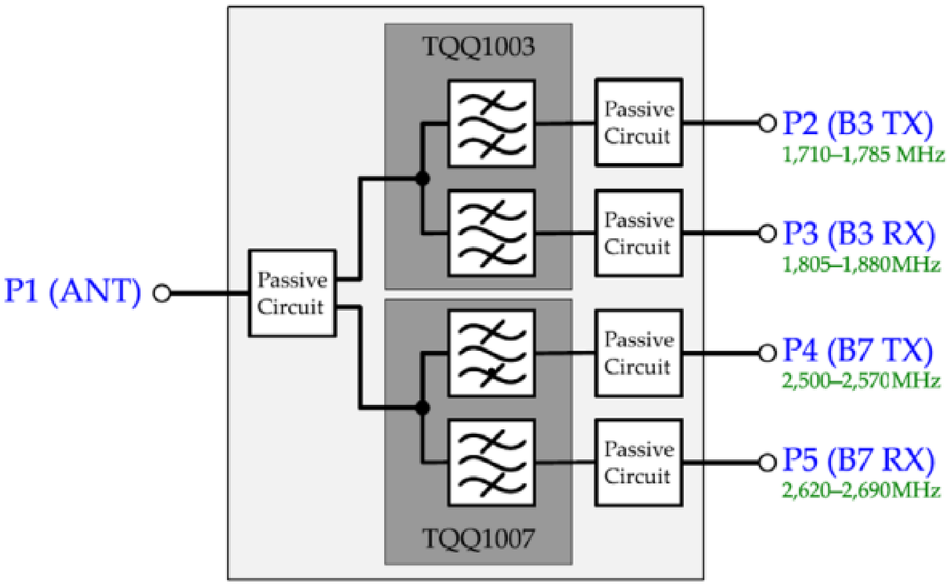
In this project, I have designed a Carrier aggregation (CA) Bulk Acoustic Wave (BAW) Quadplexer module. The module has a strong in-band and cross-band isolation and is designed for the LTE-3 and LTE-7 bands. The circuit was designed using Qorvo TQQ1003 and TQQ1007 BAW duplexers for the duplexer.

*The software that has been used in this project is Cadence AWR design Environment platform, specifically Cadence AWR Microwave Office Circuit Design software**.** The whole circuit is designed on a patch of* ***Rogers Duroid 6010*** *substrate of dielectric constant 10.8 and height 0.635mm. The concept of Microstrip line is used for designing of Transmission line. The design is described in steps: filter, T junction, Diplexer and Quadplexer.*

THEORY

BAW Filter Technology

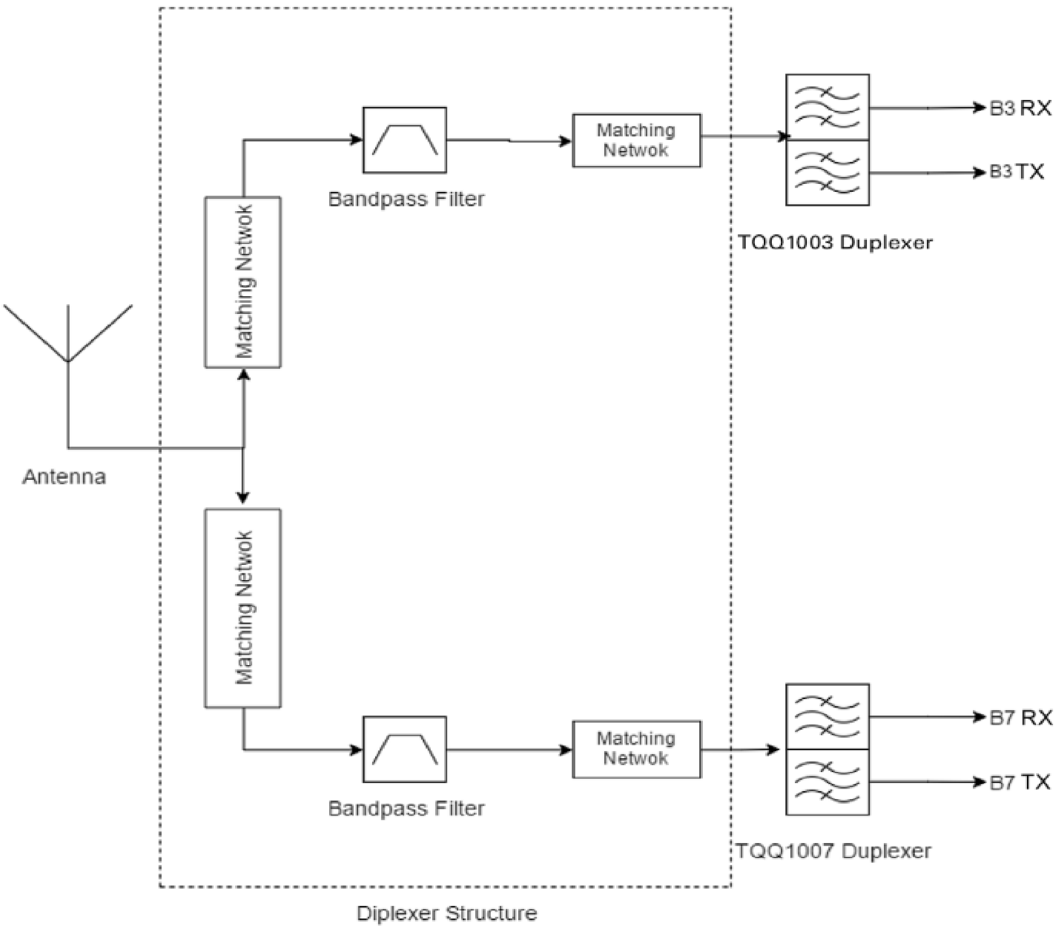
Designers may produce narrowband filters with unusually steep filter skirts and great rejection thanks to BAW technology. Because of this, BAW is the technology of choice for many difficult interference issues. BAW is a complimentary technology to surface acoustic wave (SAW), which is most successful at lower frequencies but scaled down in size. BAW gives similar benefits at frequencies above 1.5GHz up to 6GHz and is used for many of the new LTE bands over 1.9GHz.



The design described in this report used BAW filters to create a quadplexer that could operate in the B3 and B7 LTE bands, encompassing frequencies of 1710 MHz to 1880 MHz and 2500 MHz to 2690 MHz, respectively. The TX and RX signals at the bands were separated using two BAW duplexers. High in-band and cross-band isolation, good reflection loss (below 10dB), and precise insertion loss above -6dB were the quadplexer's specifications. The basic circuit layout and ports for the quadplexer are shown in above figure.

General Structure of Quadplexer

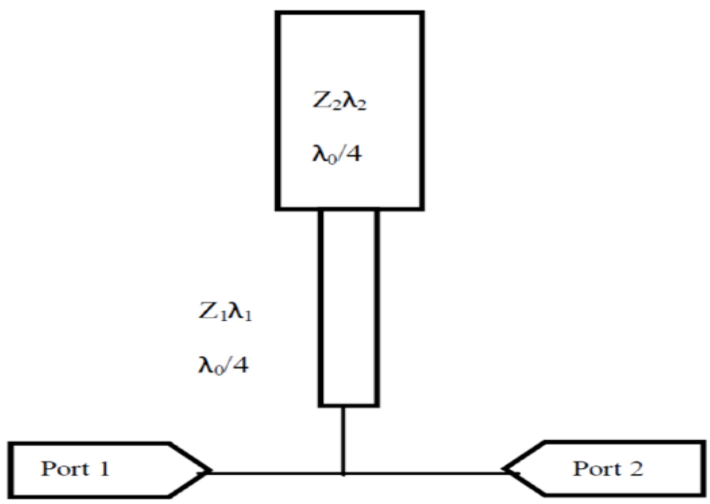
The quadplexer proposed in this report consists of two Duplexers combined via a diplexer that consists of two filters. The S-parameters of LTE 3 and LTE 7 band Duplexers were imported using AWR Microwave Office through a touchstone file from Qorvo. While creating the common node for two duplexers, we had two methods of design. One was to create a power divider based on a coupler that splits and combines input power to and from the duplexers but this method introduces some additional insertion loss for all frequencies which is not desirable at all because it will cause an increase in overall insertion loss. Second option was to design a frequency divider that switches lower frequencies to one path and higher frequencies to another path and hence avoids the power loss that occurred while using passive coupler architecture. Starting from common node to duplexers, the diplexers consisted of several structures such as filters, matching networks and T Junctions.



DESIGN AND IMPLEMENTATION USING AWR

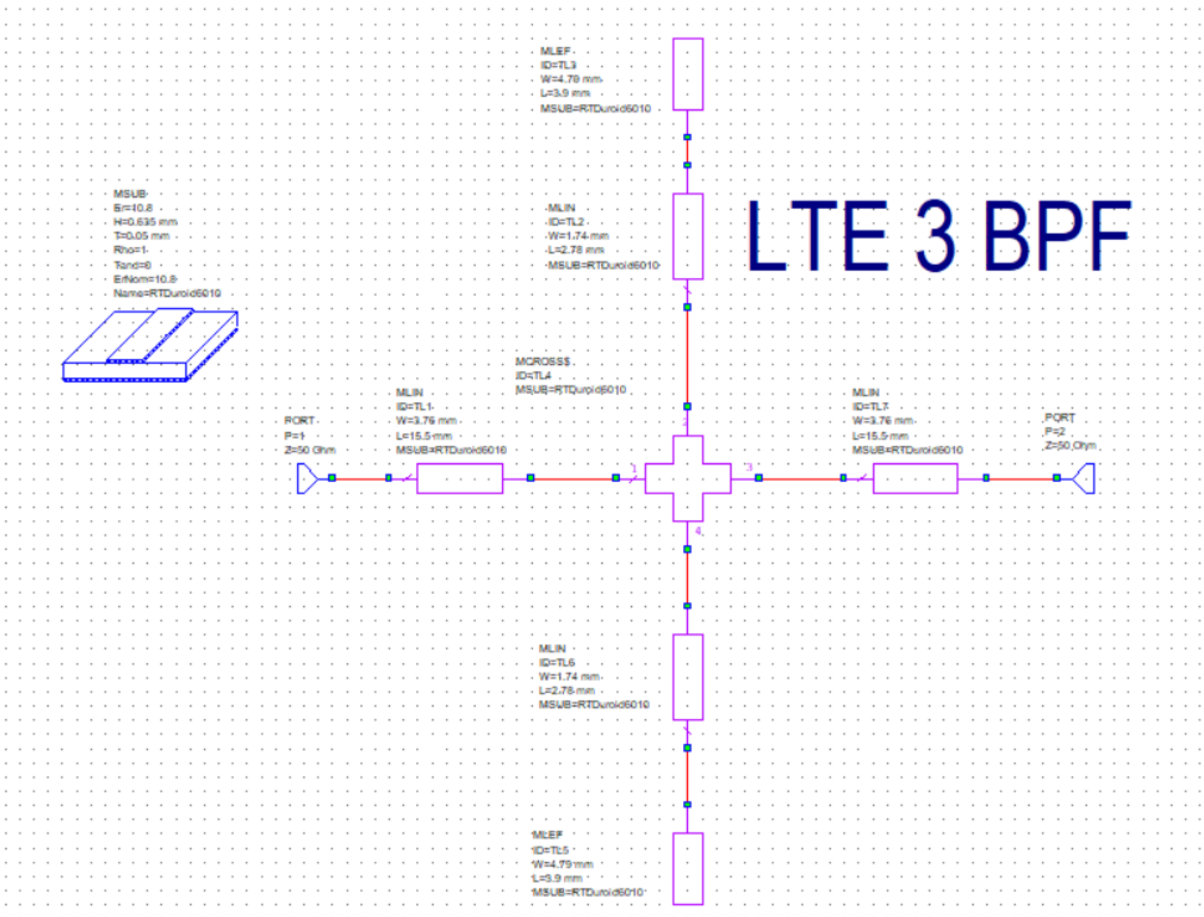
Filters

The BPFs were designed at center frequencies of 1.8GHz and 2.6GHz for LTE 3 and LTE 7 bands. A first Order Chebyshev filter was preferred in order to decrease the size and also give steep cutoff at edge of transition bands. For designing BPF, we have used one microstrip Transmission and two stepped-impedance open stub resonators so as to generate two transmission zeros near passband frequency and the respective bandwidth can be controlled by relocating the transmission zeroes. Following figure shows the configuration of stepped-impedance model where each step is of $\lambda/4$ *electrical length at the respective center frequency and Z1 and Z2 are impedances at each segment.*

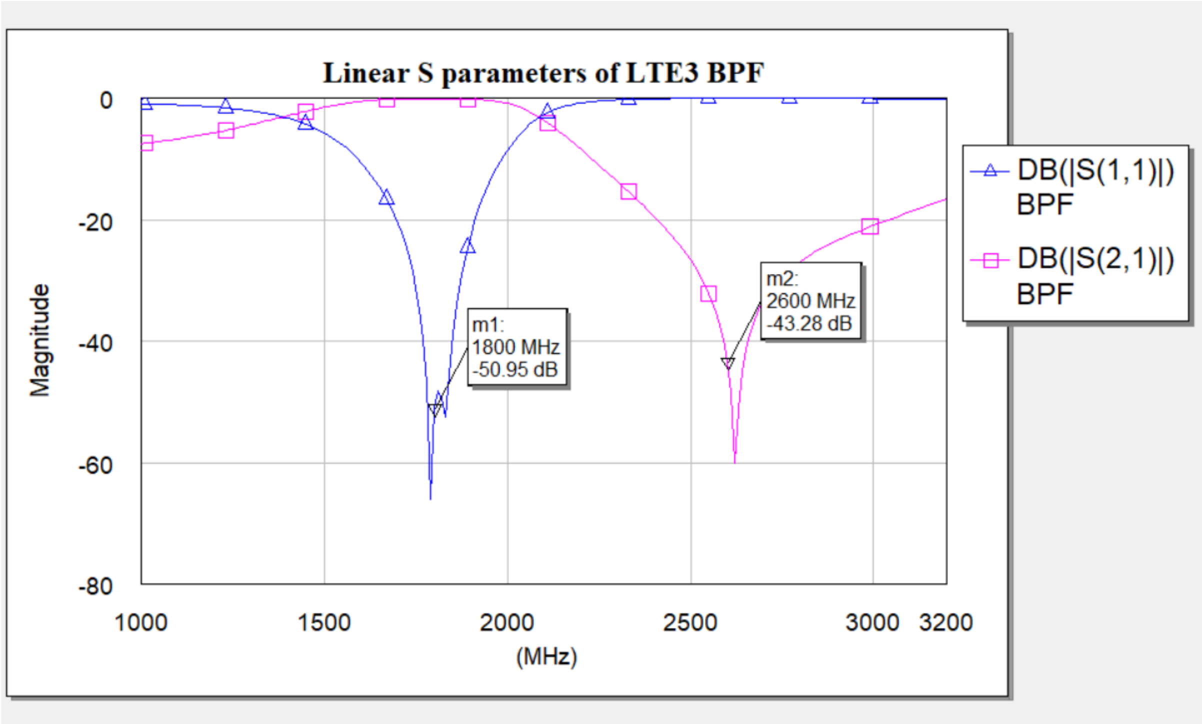


According to the electrical length of the quarter-wave length for a Rogers Duroid 6010 substrate with a dielectric constant of 10.8 and thickness of 0.635mm, the line width and length of the microstrip transmission lines were determined. The TX-LINE transmission-line calculator from AWR Microwave Office software was used to perform the computations. To improve the stopband rejection ratio, two identical stepped-impedance open stubs were employed.

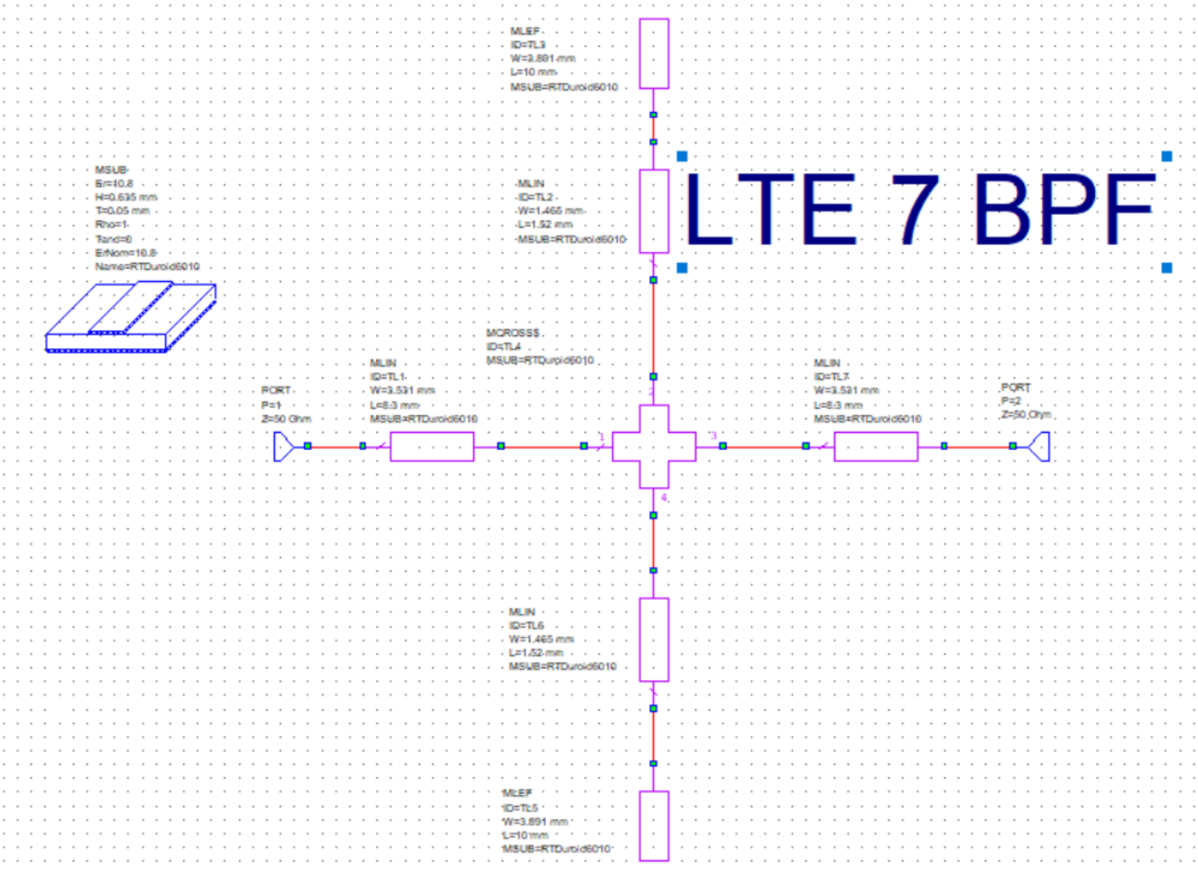
Following figure shows BPF of LTE 3 band with centre frequency of 1.8GHz



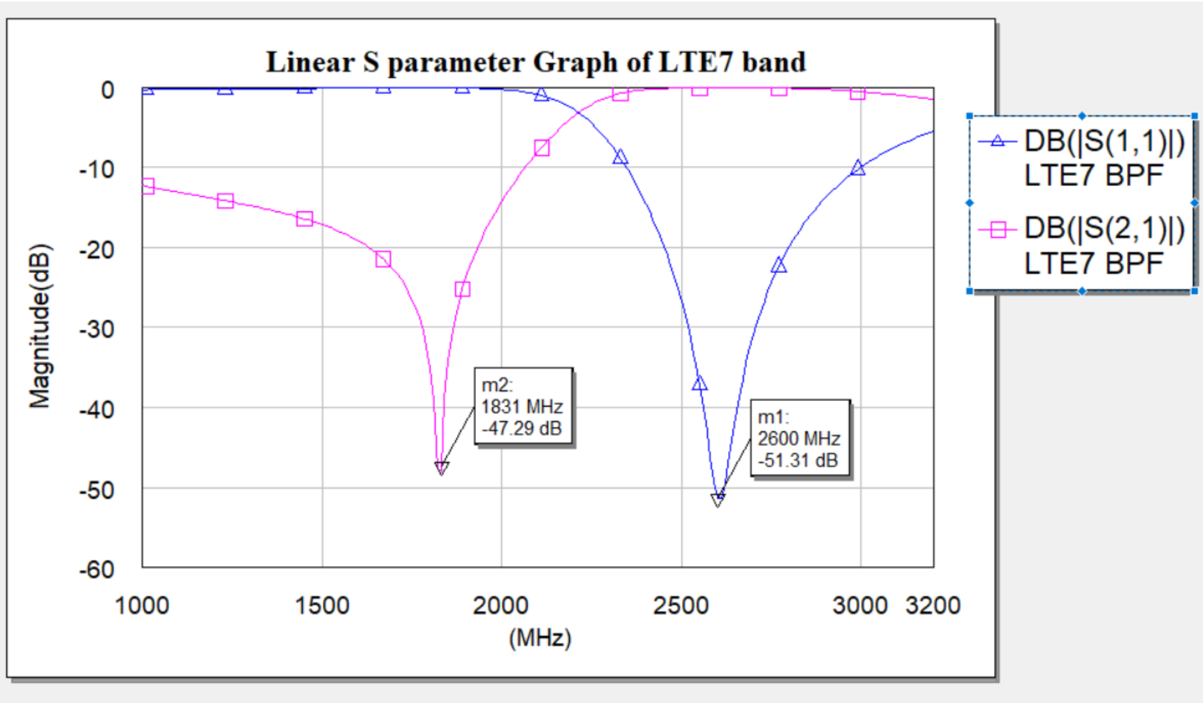
Following is the simulation result of above LTE 3 BPF. There were two ways of performing simulation. One is linear simulation where overall system parameters are calculated by separately cascading S-parameters of each element. Another way is to perform EM simulation which provides better accuracy and insights about circuit behaviour after manufacturing.



Observing the above graph, we can see that the BPF of LTE3 band has good return loss of below 20dB and transmission zero at 2.6GHz that will provide satisfied isolation for diplexer. Following figure consists of circuit elements of LTE 7 band BPF. The two filters have similar layout with different dimensions.



And following presents us with simulation result

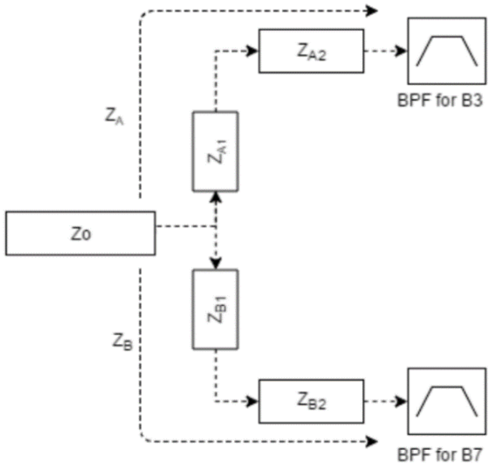


As seen from above, the BPF of LTE 7 band has a good return loss of below 20 dB and transmission zero at 1.8GHz.

T-Junction

The matching network and combining filters made sure that both filters had a suitable amount of isolation from one another and were matched to the same node. Transmission lines of different lengths and widths were used to connect the two circuits using a T-junction with a practical tuning impedance. Two transmission line sections were attached to each end of the T-shaped connector. The connections were done so that a high, preferably infinite, impedance for Filter A was provided at the load of Filter B for that particular frequency, and vice versa.

The T-junction's circuit model is depicted in following figure.

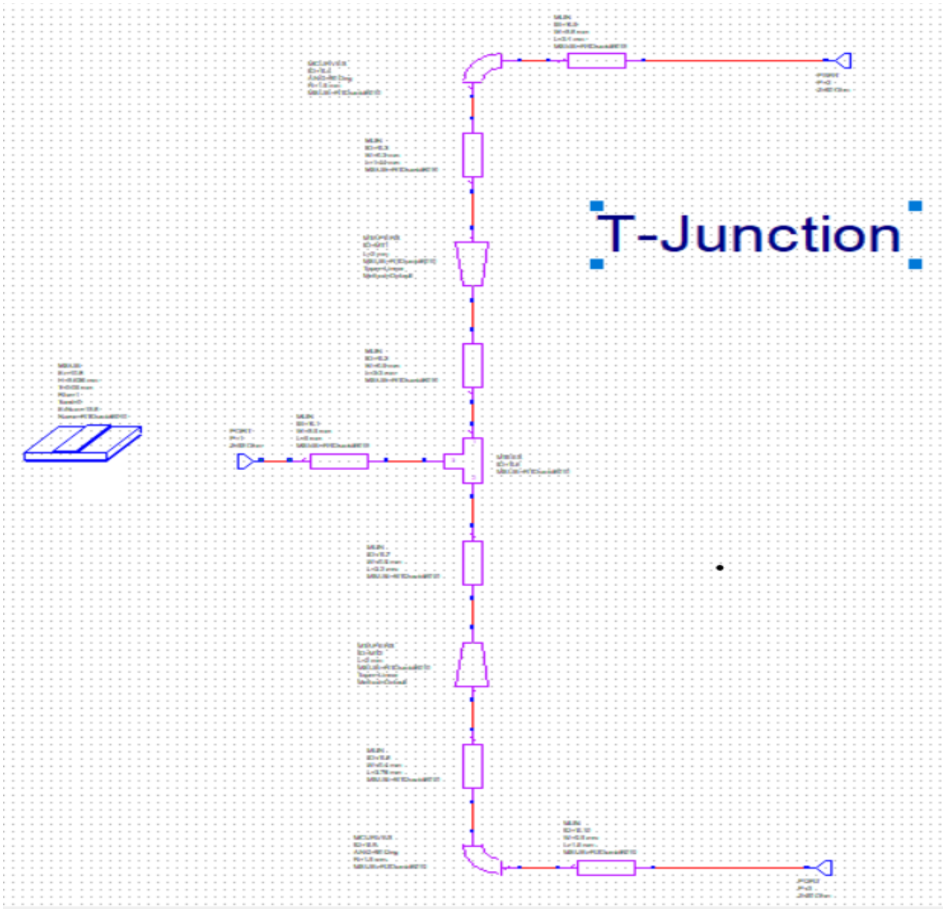


According to above discussion, following criteria must be satisfied:

$$Z_A = \begin{cases} \infty \text{ (open) at 2.6GHz} \\ 50\ \Omega \text{ at 1.8GHz} \end{cases}$$

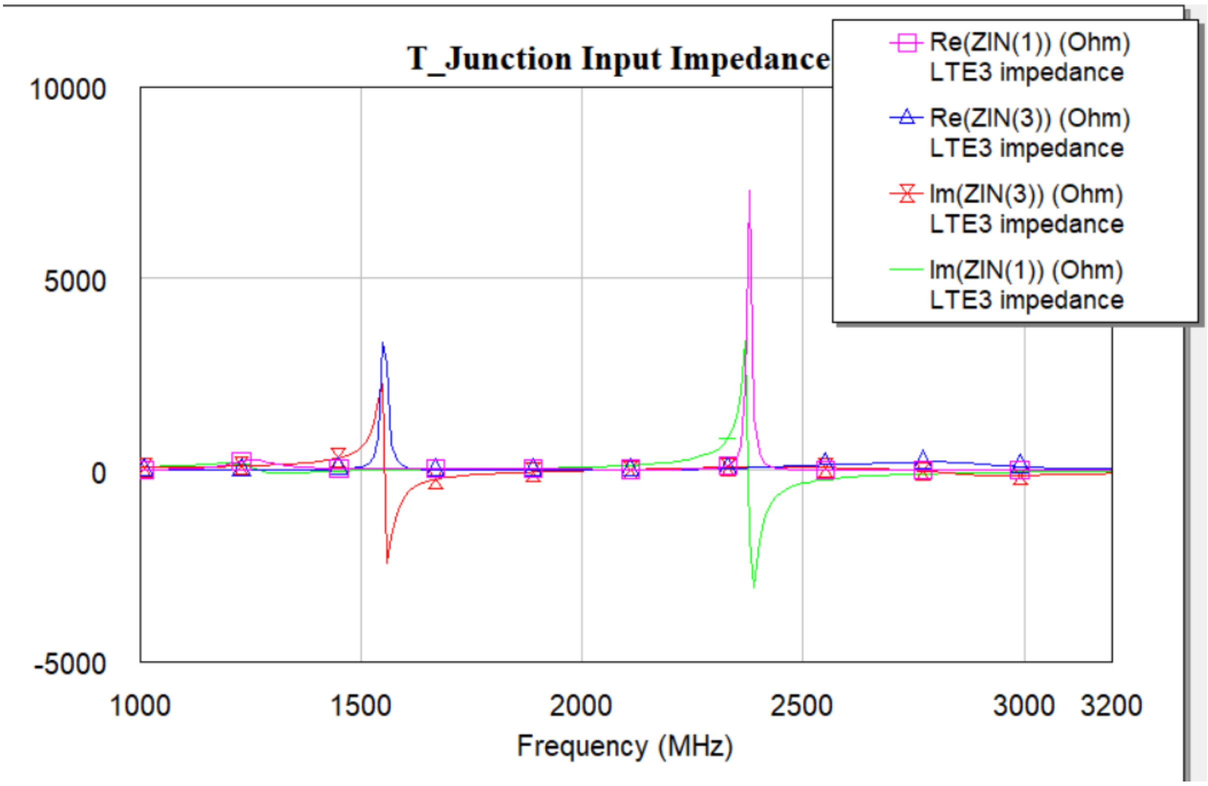
$$Z_B = \begin{cases} \infty \text{ (open) at 1.8GHz} \\ 50\ \Omega \text{ at 2.6GHz} \end{cases}$$

Z_{A1} and Z_{B1} are the 50Ω transmission lines which convert impedance at the input to open circuit for counter frequencies whereas Z_{A2} and Z_{B2} are high impedance transmission lines that are combined with 50Ω transmission lines so as to increase effective input impedance.



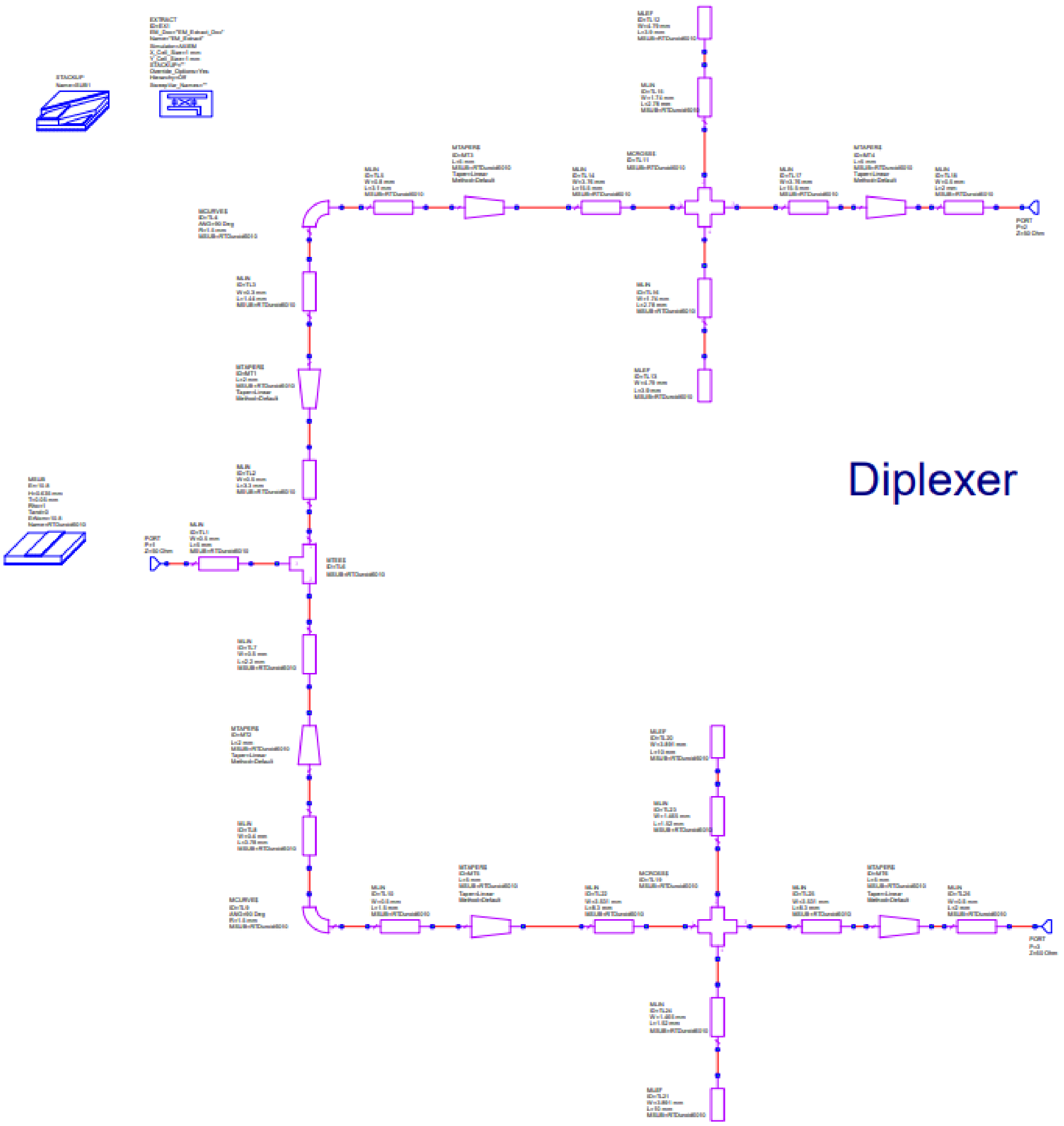
Following figure shows real and imaginary impedances of T-junction:

\



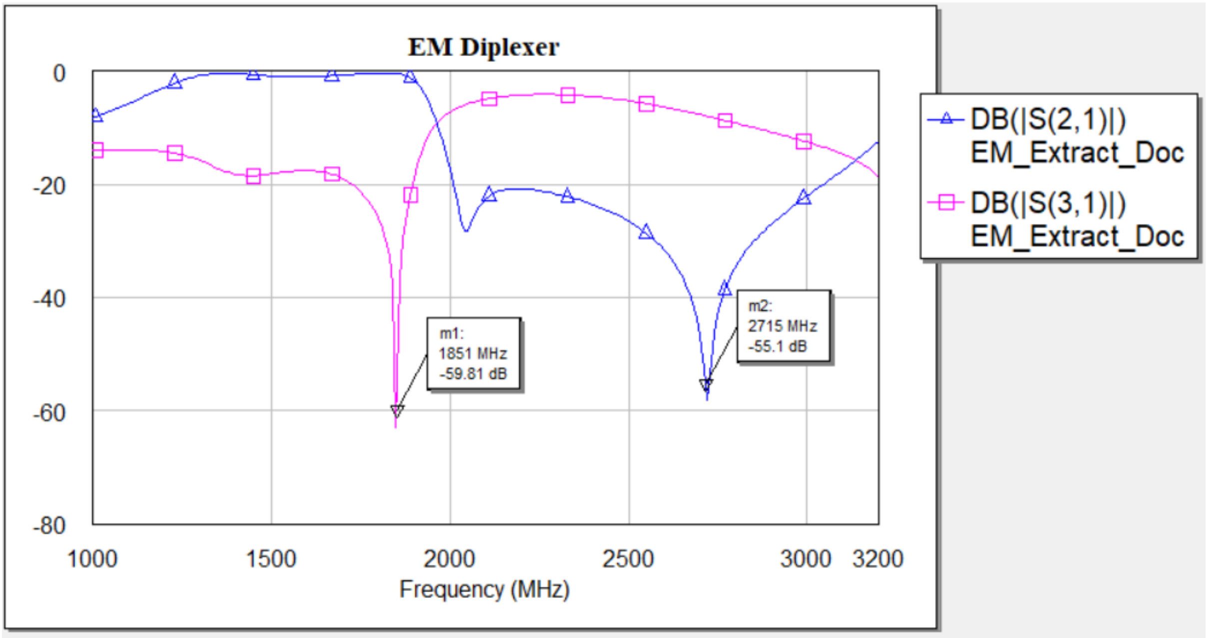
Diplexer

Following the design of BPFs and T-Junction, the next step was to connect them together which forms the structure of diplexer. Following figure gives us the AWR structure of diplexer.



The approximate width of this T-junction is 0.4mm and that of BPF is 4mm and tapered transmission lines are added in between to avoid width mismatches between TLs and for this some lengths needed fine tuning so as to avoid any change in circuit behaviour.

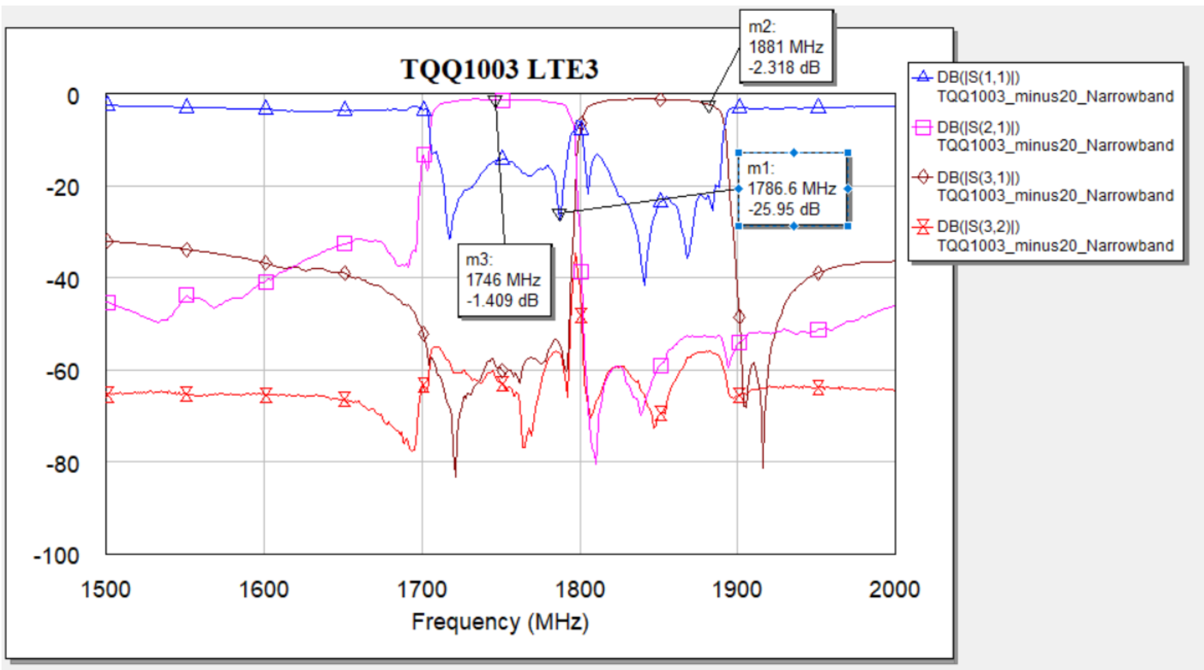
Following figure shows insertion loss while delivering power from port 1 to port 2 and 3 in diplexer structure.



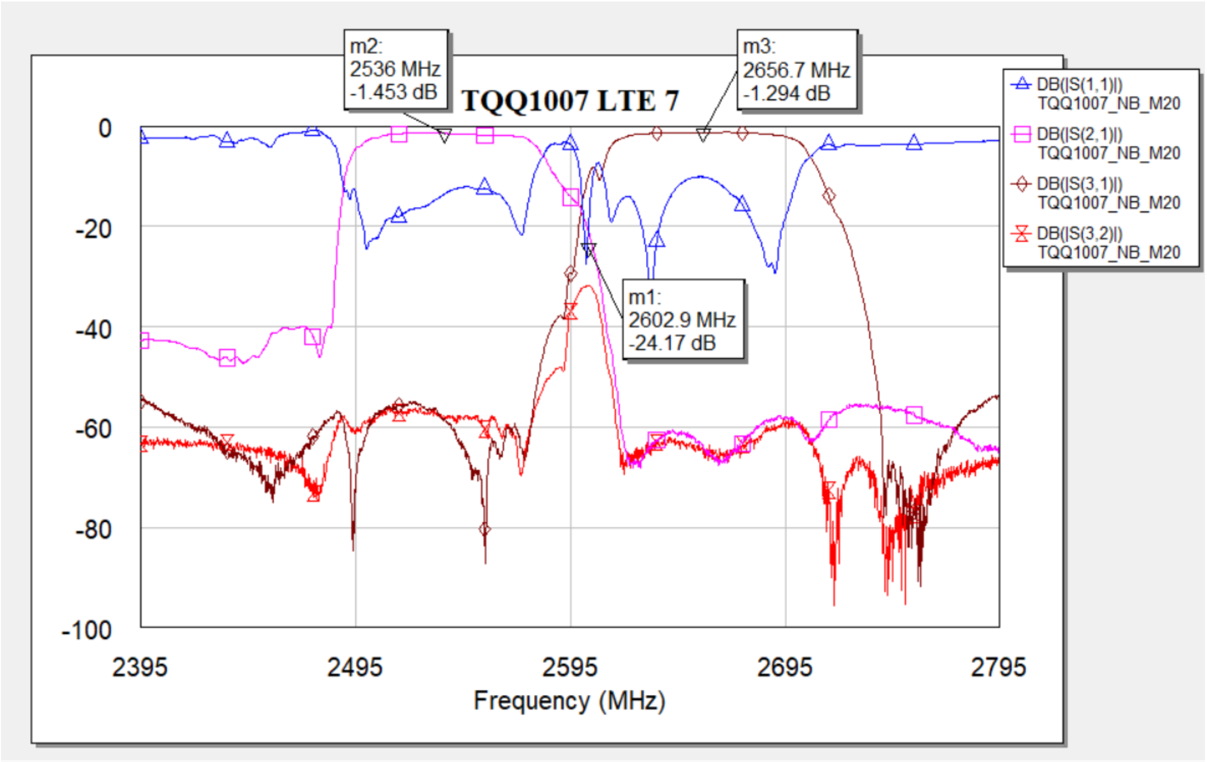
Quadplexer:

Before connecting the Duplexers with diplexer, we will first analyze its S-parameters.

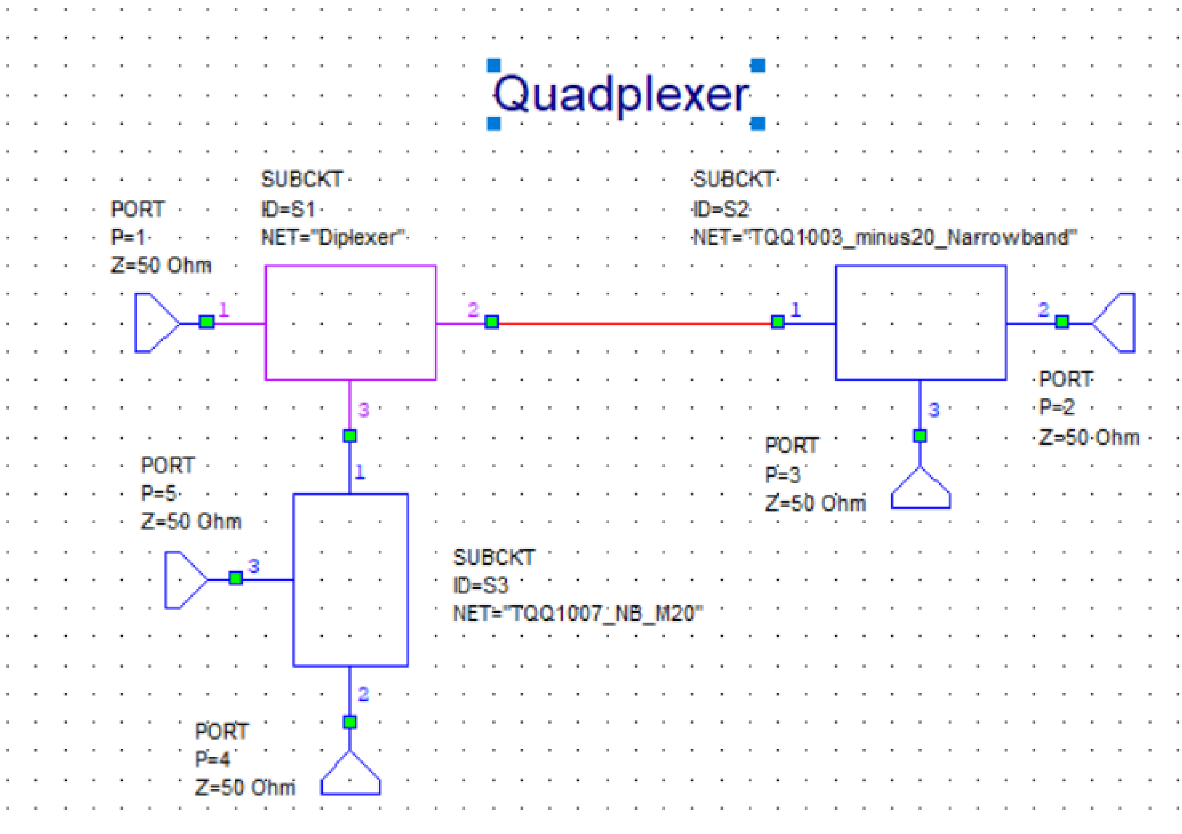
For LTE 3 band (TQQ1003):



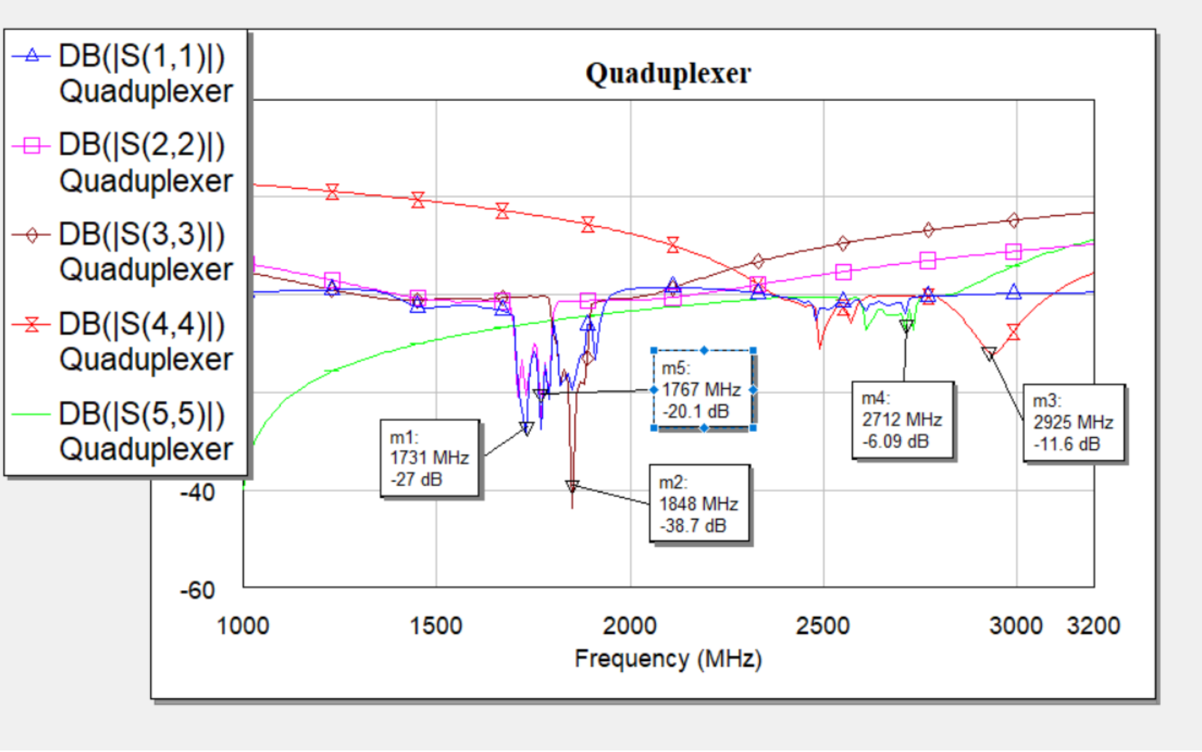
For LTE 7 band (TQQ1007):



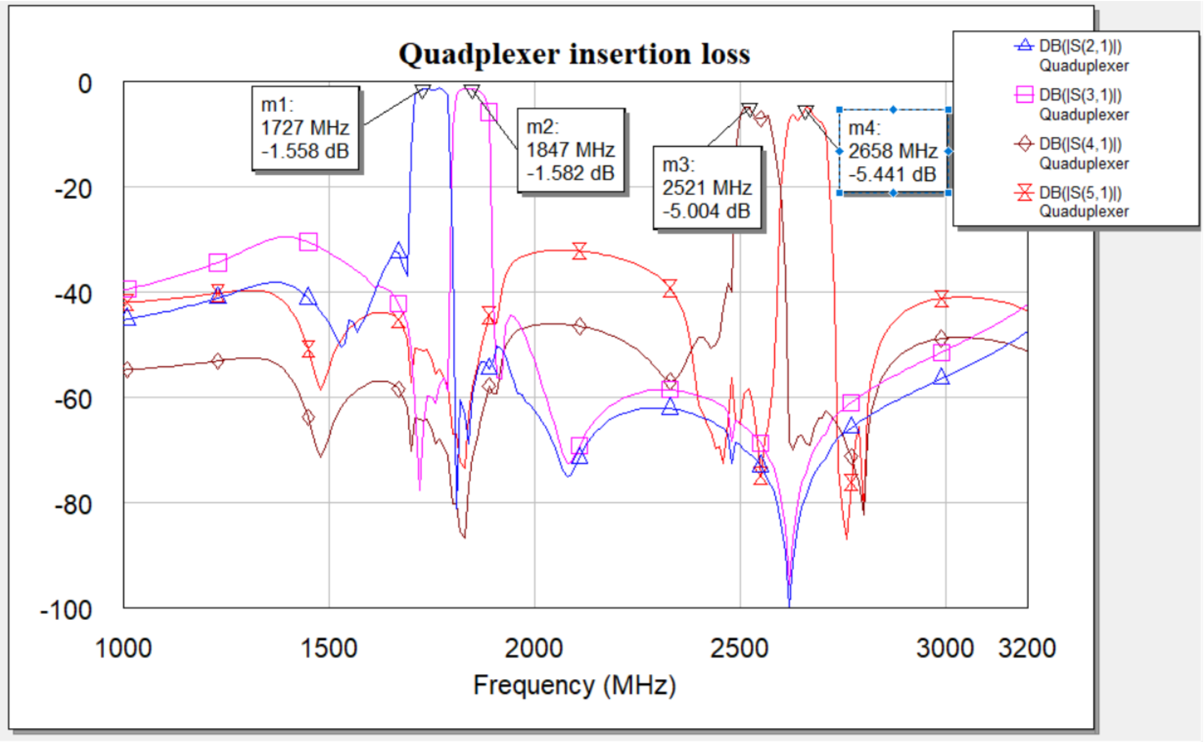
After combining it with Diplexer, we get the final quadplexer design:



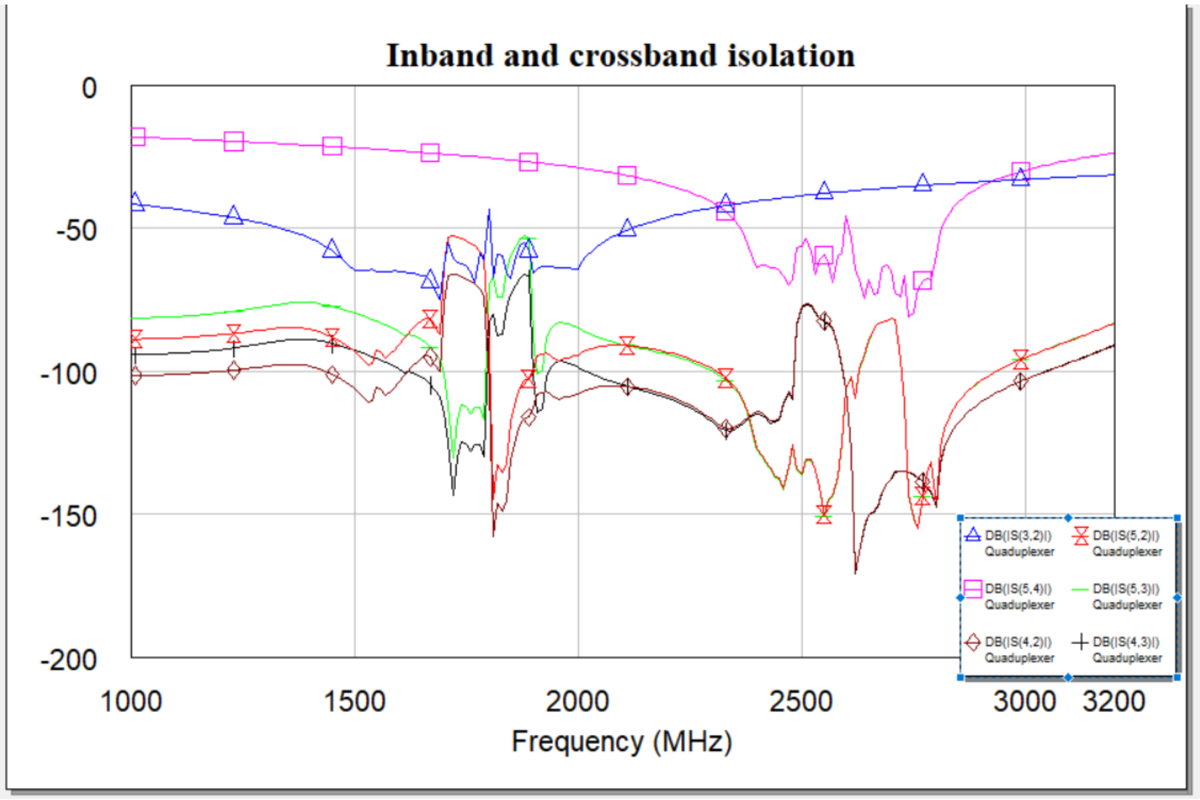
The return loss for each and every port is shown below:



The insertion loss from input to every port is shown here:



In-band and Cross- band Isolation:



CONCLUSION AND REFERENCES

Hence, the quadplexer for LTE3 and LTE7 band is designed whose cross-band isolation is at a satisfactory level and in-band isolation is also good at least around -50dB which is greater than expected. The lowest performance is achieved at around 2.54GHz because of discontinuity present there.