Infineon BGT24LTR11N16 24Ghz Radar MMIC Impedance Matching

-The Technical Details behind the Official Evaluation Board-

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Part I: Matching Structures of Official Evaluation Board

The Matching Structures of BGT24LTR11N16 were mentioned in the application note AN472[1]. However AN472 just provided the Matching Structures based on the RO4350B substrate (Figure 1) without necessory technical details about the design process. Thus, it could be confused to port the Matching Structures to the substrates other then RO4350B. As a result, the technical details behind the Matching Structures will be discussed in this paper.

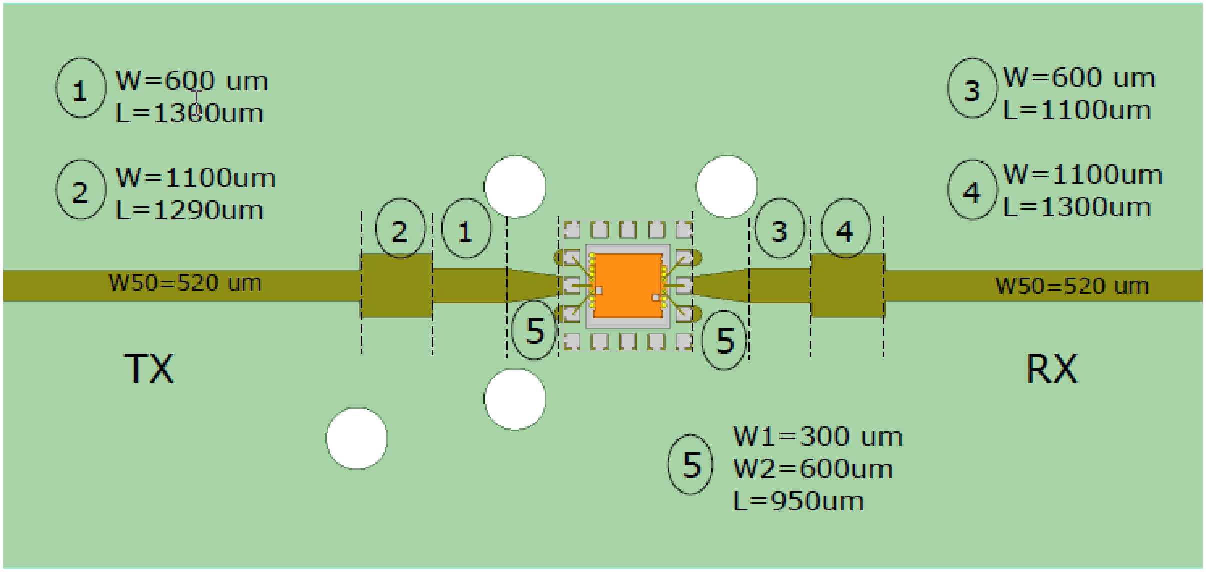


Figure 1: Matching structures to be used on a RO4350B substrate with a thickness of 0.254 mm

Only the RX side of the Matching Structures will be discussed in this article due to the similarity between the TX and RX.

Part II: "Reverse Engineering" of the RX Matching Structures

1. The RX Impedance of MMIC

The RX matching structures were modeled. Simulation results are shown in the Figure 2, Figure 3, and Figure 4. The RX Impedance of MMIC is Z_{RX} =104.667+38.391j Ohm @ 24Ghz.

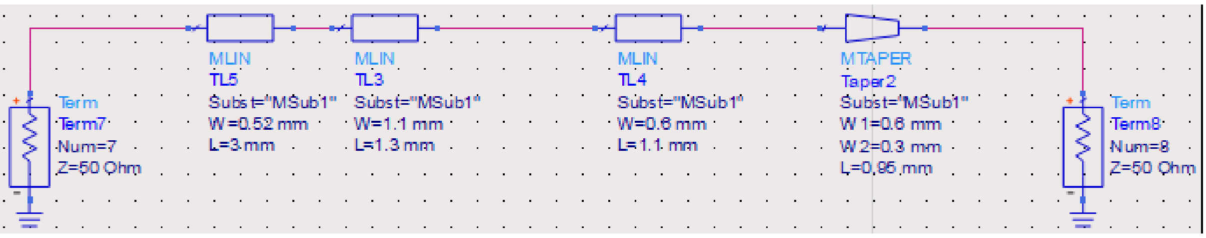


Figure 2: Schematic of the RX Matching Structures with unknown RX Impedance of MMIC

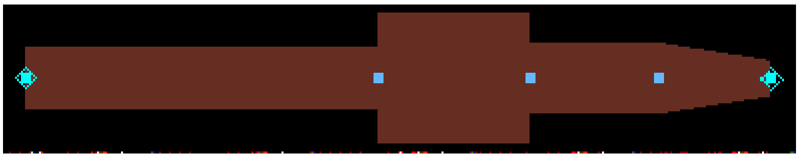


Figure 3: Layout of the RX Matching Structures

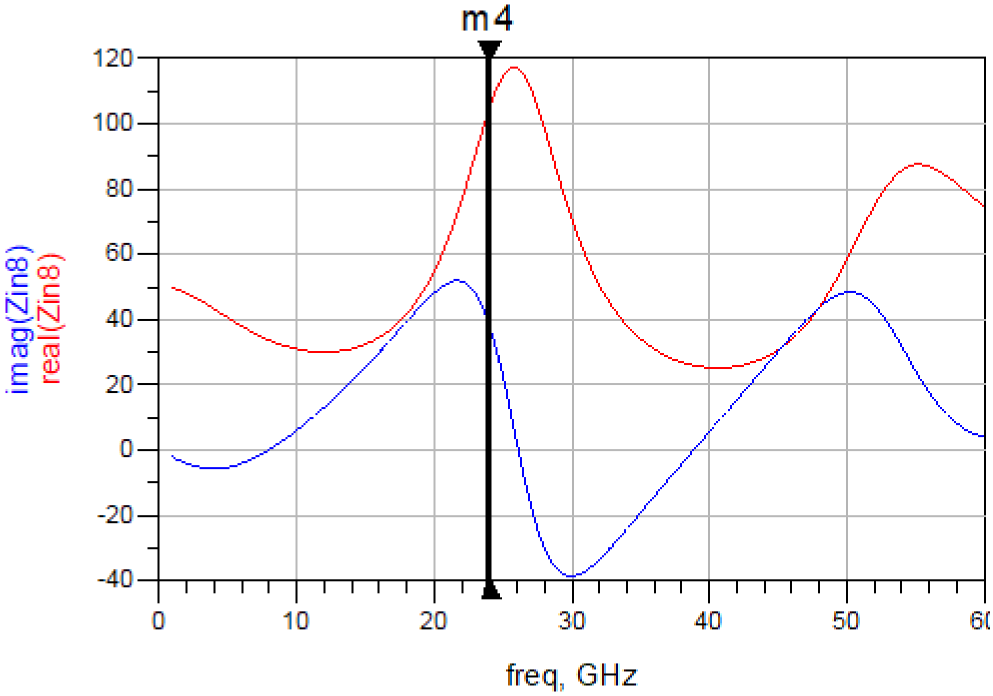


Figure 4: The RX Impedance of MMIC

2. The Performance of the RX Matching Structure

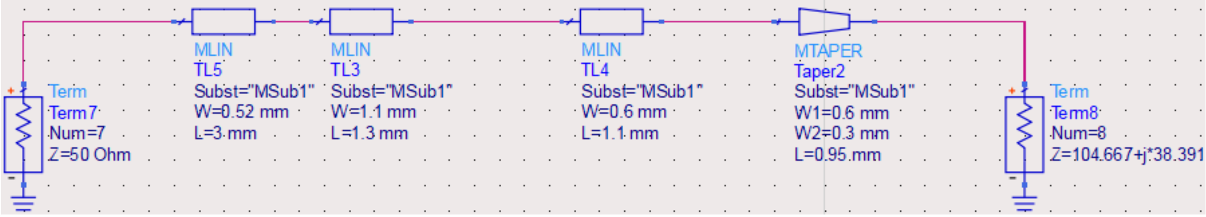


Figure 5: Schematic of the RX Matching Structures with Z_{RX} =104.667+38.391j Ohm

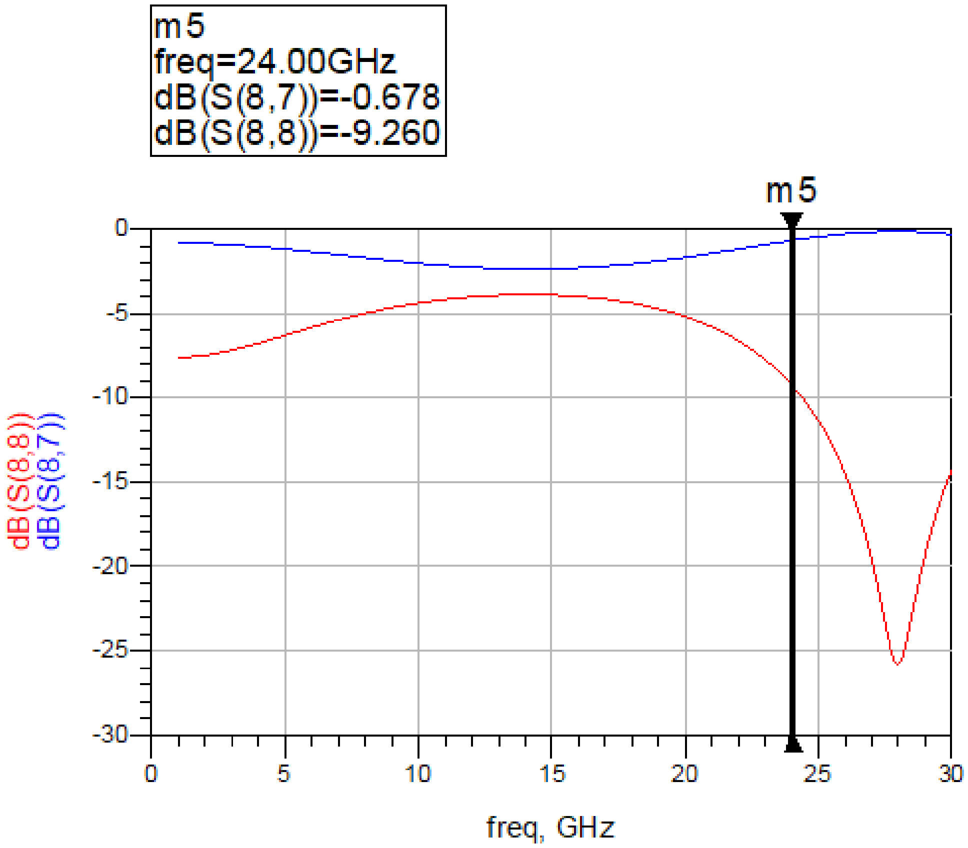


Figure 6: Performance of the RX Matching Structures

According to the figure 6, the RX Matching Structures are not tuned very well but the performance should be still acceptable.

3. <u>The components of the RX Matching Structure</u>

According to the Transmission Line Theory, the RX Matching Structures has three components, Tapered Transformer, Stepped Impedance Filter and 50 ohm Transmission Line.

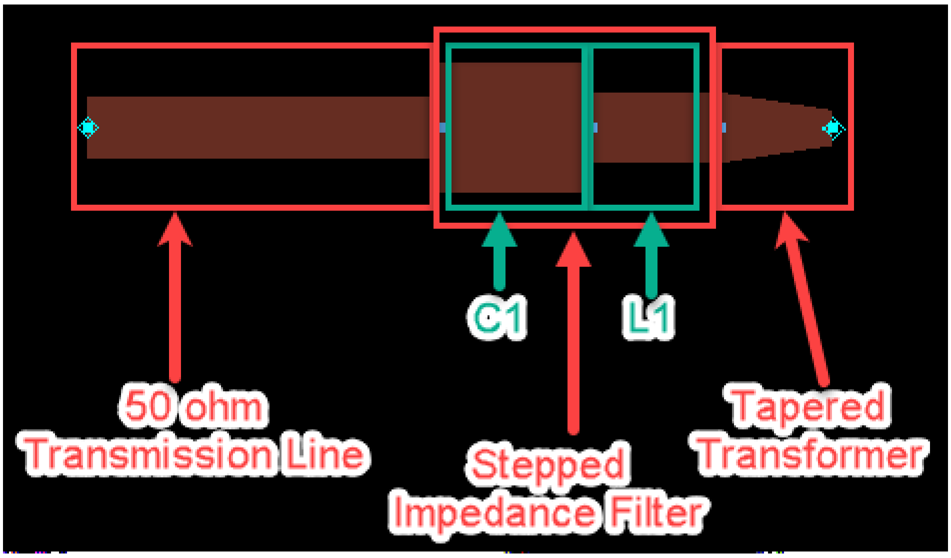
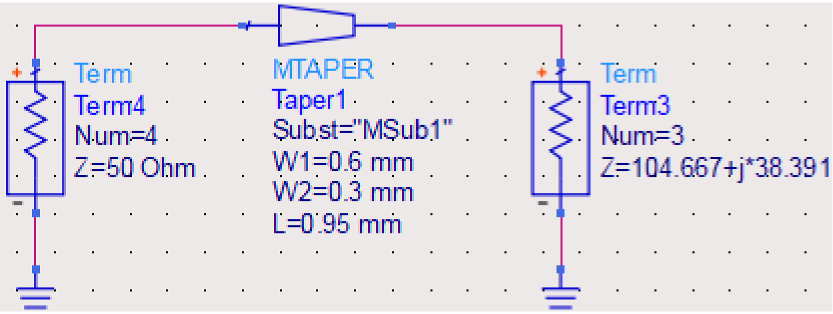


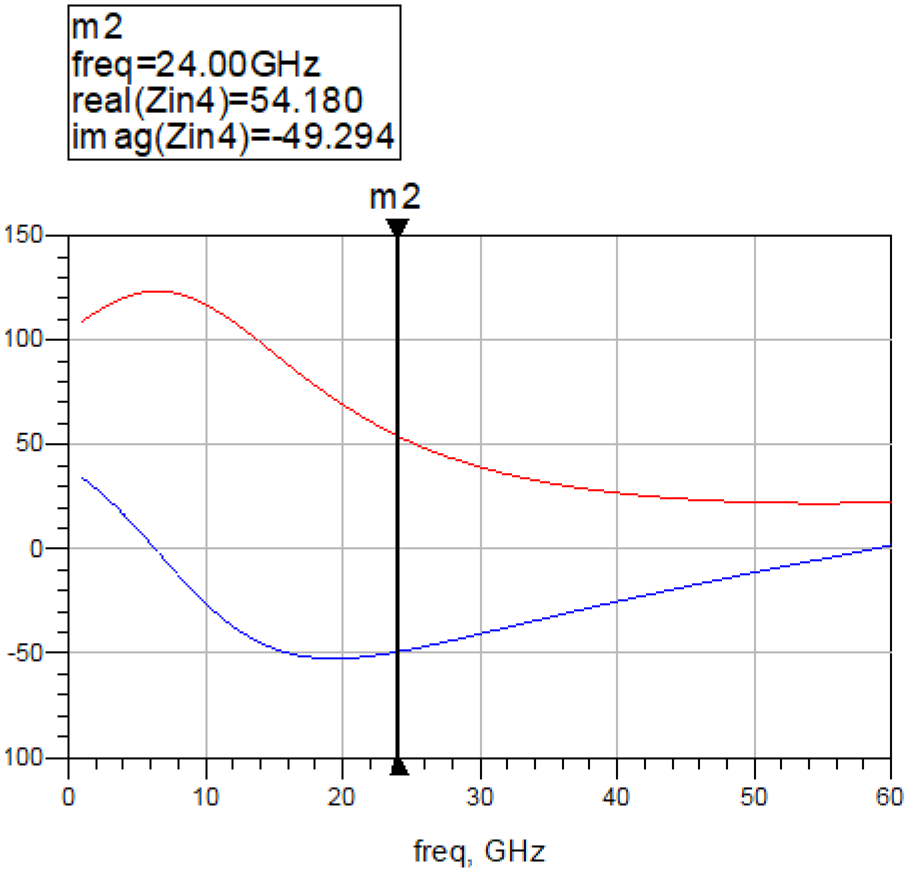
Figure 7: The components of the RX Matching Structure

Components of the RX Matching Structures will be discussed in the following sections.

a. Tapered Transformer

By tapering a transmission line, a very broadband impedance match (low VSWR) can be realized over a wide bandwidth, the longer the taper, the wider the frequency band [2].





The tapered transformer transformed the impedance from Z_{RX} =104.667+38.391j Ohm to 54.18-49.294j Ohm.

b. Stepped Impedance Filter

In this application, this filter is mainly used to match the Tapered Transformer’s output impedance 54.18-49.294j Ohm to 50 Ohm.

Microstrip L1:

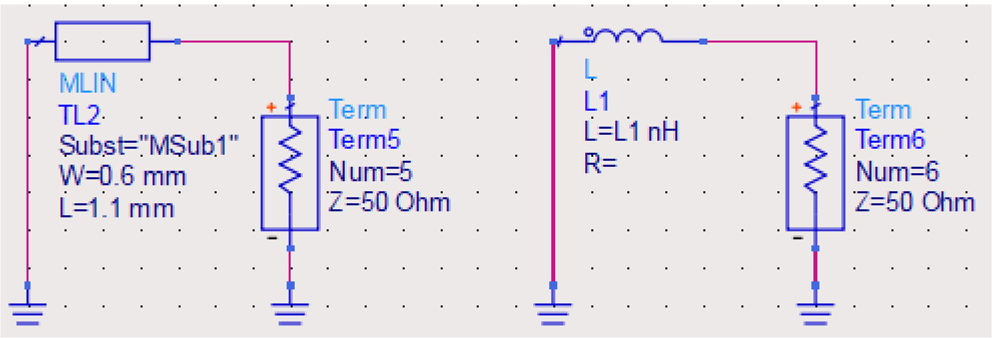


Figure 8: Microstrip L1 (Left hand side) and its equivalent Lumped Inductor (Right hand side)

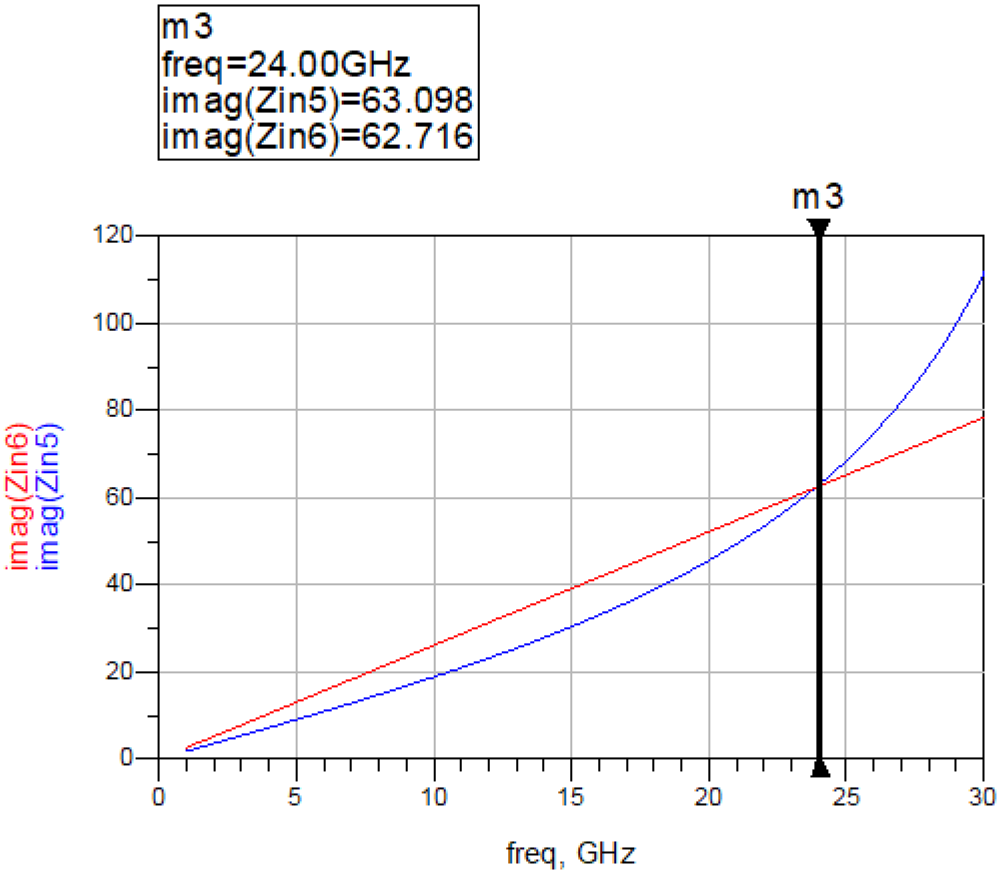


Figure 9: Reactance of Microstrip L1 (Zin5) and its equivalent Lumped Inductor (Zin6)

The equivalent Lumped Inductor (Zin6) could be calculated by:

$$L1 = \frac{X_L}{\omega} = \frac{X_L}{2\pi f} = \frac{Zin5}{2 * \pi * (24 * 10^9)} = 4.184316083 * 10^{-10} H \approx 0.418nH$$

Microstrip C1:

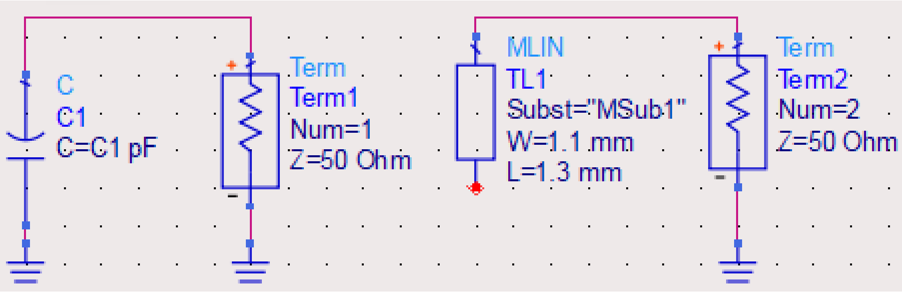


Figure 10: Microstrip C1 (Right hand side) and its equivalent Lumped Capacitor(Left hand side)

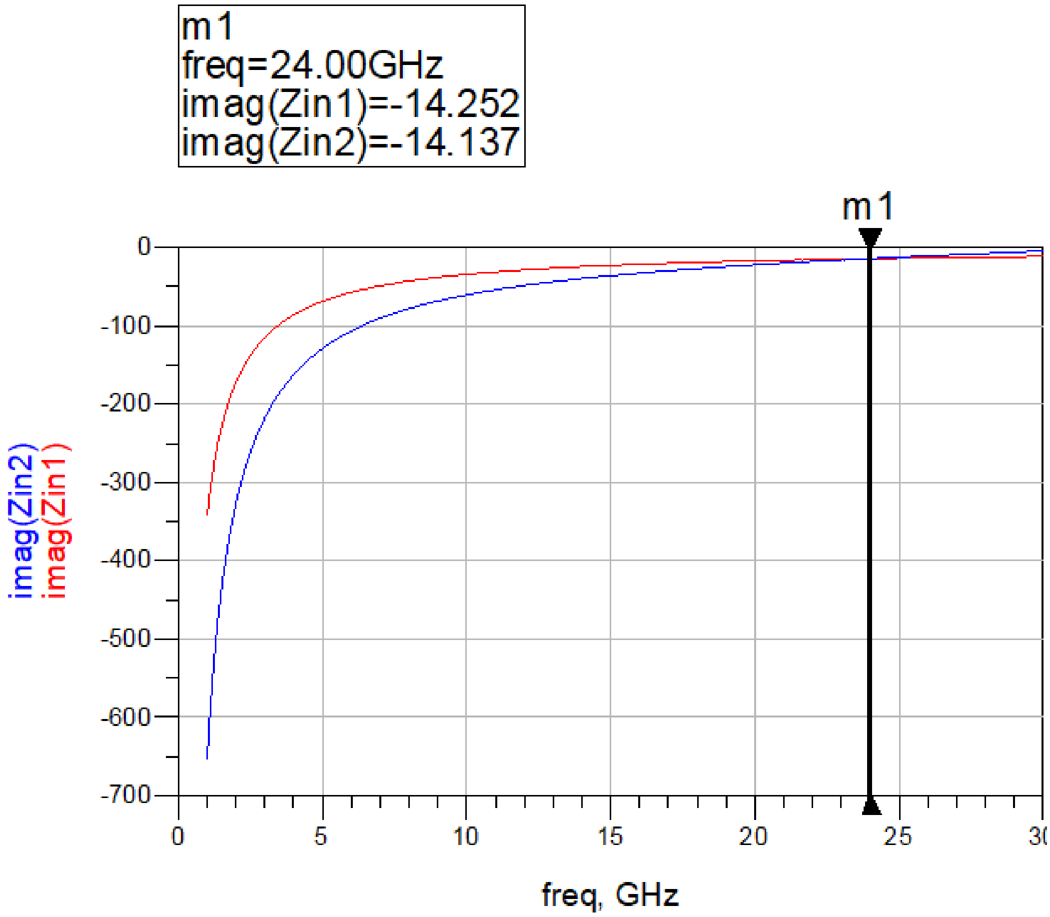


Figure 11: Reactance of Microstrip C1 (Zin2) and its equivalent Lumped Capacitor (Zin1)

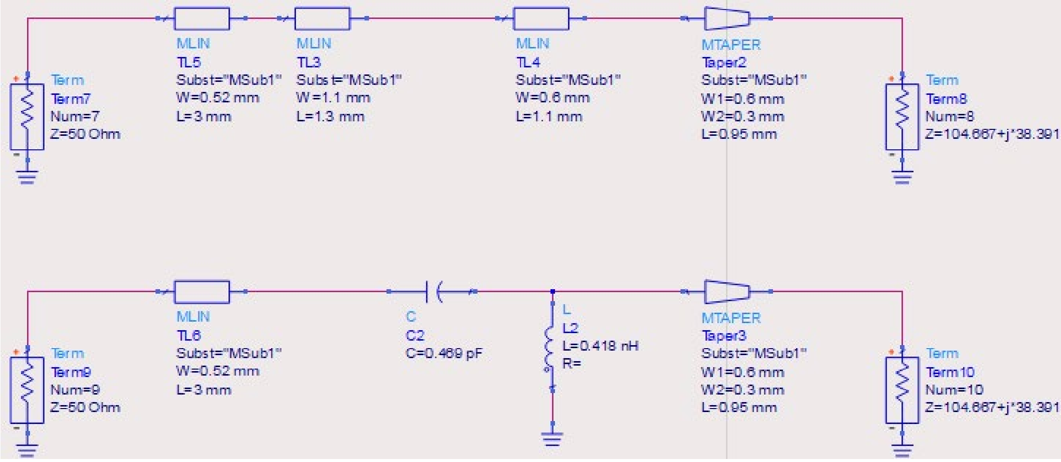
The equivalent Lumped Capacitor (Zin1) could be calculated by:

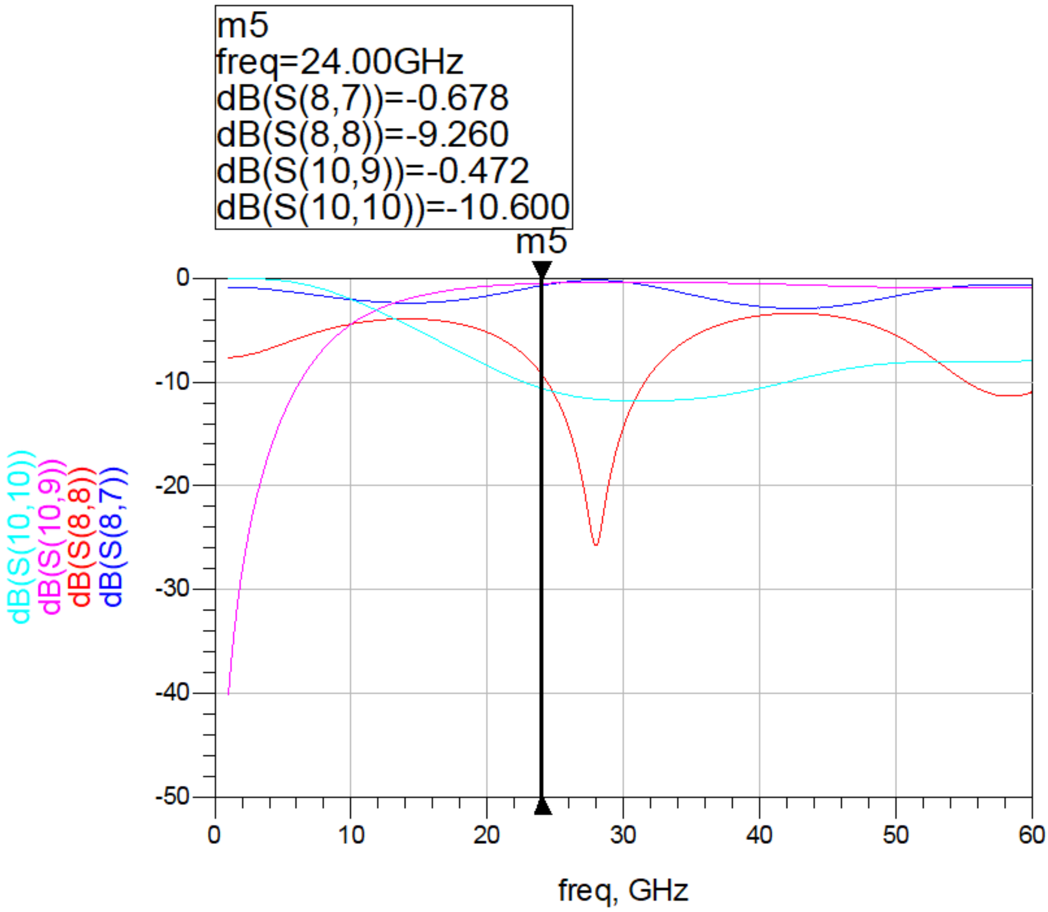
$$C1 = \frac{1}{\omega X_C} = \frac{1}{2\pi f X_C} = \frac{1}{2 * \pi * (24 * 10^9) * Zin2} = 4.690850929 * 10^{-13}F \approx 0.469pF$$

Output Impedance of the Stepped Impedance Filter=Zin4+Zin5+Zin2= (54.18-49.294j) + (63.098j) + (-14.252j) = 54.18-0.715j

This impedance could match to the 50 ohm Transmission Line with an acceptable performance.

The comparation of performances between the Microstrip Version and the Lumped Version:





At 24Ghz, the performances of Microstrip Version and the Lumped Version are similar, the Lumped Version has slightly better performance.

Part III: Conclusion

The Matching Structures of BGT24LTR11N16 24Ghz Radar MMIC has been analyzed using Transmission Line Theory step by step in this paper. During the design process, the theory behind the Matching Structures has been illustrated.

Part IV: References

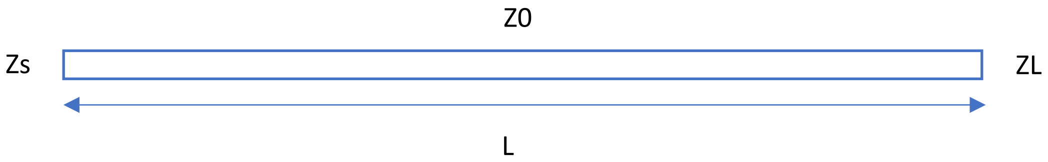
[1] AN472 24 GHz Transceiver: BGT24LTR11. Retrieved Apr 22, 2020, from https://www.infineon.com/dgdl/Infineon-AN472_BGT24LTR11N16_users_guide-ApplicationNotes-v01_04-EN.pdf?fileId=5546d4626cb27db2016d2a87f2447786

[2] Tapered Transformers. Retrieved Apr 22, 2020, from https://www.microwaves101.com/encyclopedias/tapered-transformers

Appendix A

- Transmission Line Matching Technology-

Infineon’s Official Evaluation Board used Stepped Impedance Filter for impedance matching. Stepped Impedance Filter can be used to match the impedance within the relatively small PCB footprint. However, the design process is not straightforward enough. Transmission Line Matching Technology can be used to solve the impedance matching problem straightforwardly within the relatively larger PCB footprint.



For a transmission line with characteristic impedance Z0, load ZL and length L.

$$Zs = Z0\frac{ZL + jZ0 * \tan{(\beta l)}}{Z0 + jZL * \tan{(\beta l)}} \tag{1}$$

Plug Zs=Rs+jXs and ZL=RL+jXL into the equation (1) and we also know that the transmission line length $\theta = \beta l$:

$$Z0 = \sqrt{\frac{Rs * |ZL|^2 - RL * |Zs|^2}{RL - Rs}} \tag{2}$$

$$\theta = \arctan{\left(\frac{Z0 * (Rs - RL)}{Rs * XL + RL * Xs}\right)} \tag{3}$$

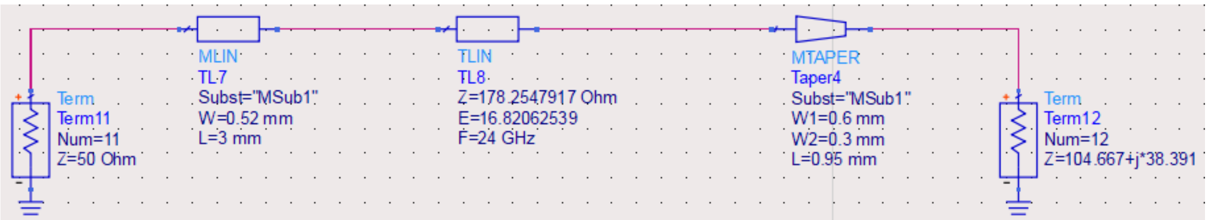
For BGT24LTR11N16, the tapered transformer transformed the impedance from Z_{RX} =104.667+38.391j Ohm to 54.18-49.294j Ohm. We are going to match the impedance form 54.18-49.294j Ohm to 50 Ohm.

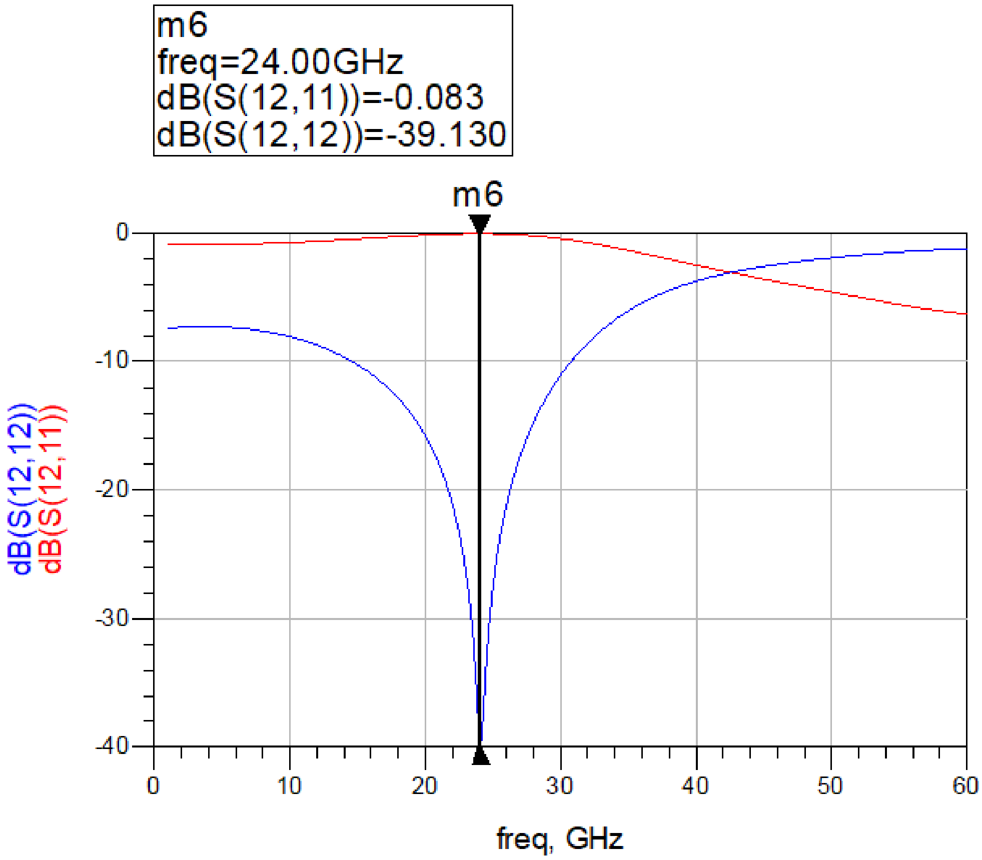
We know that Rs=54.18 Ohm, Xs=-49.294 Ohm, RL=50 Ohm, XL=0 Ohm. So that Zs=54.18-49.294j Ohm and ZL=50 Ohm

Thus, according to equations (2) and (3):

Z0=178.2547917 Ohm

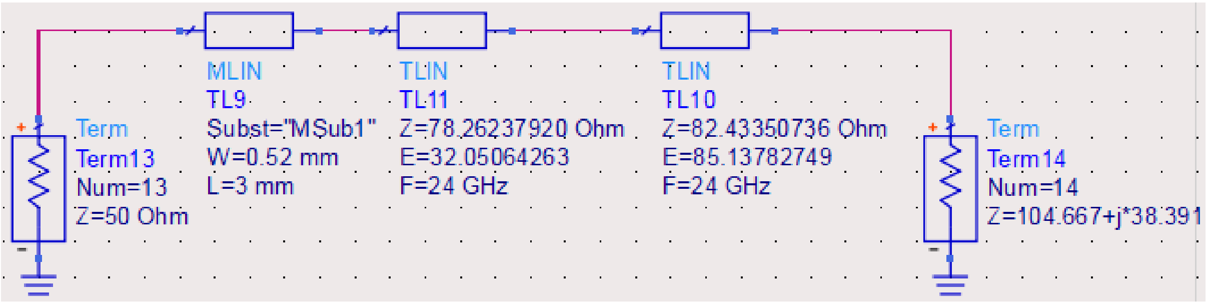
$$\theta = 16.82062539\ degrees$$

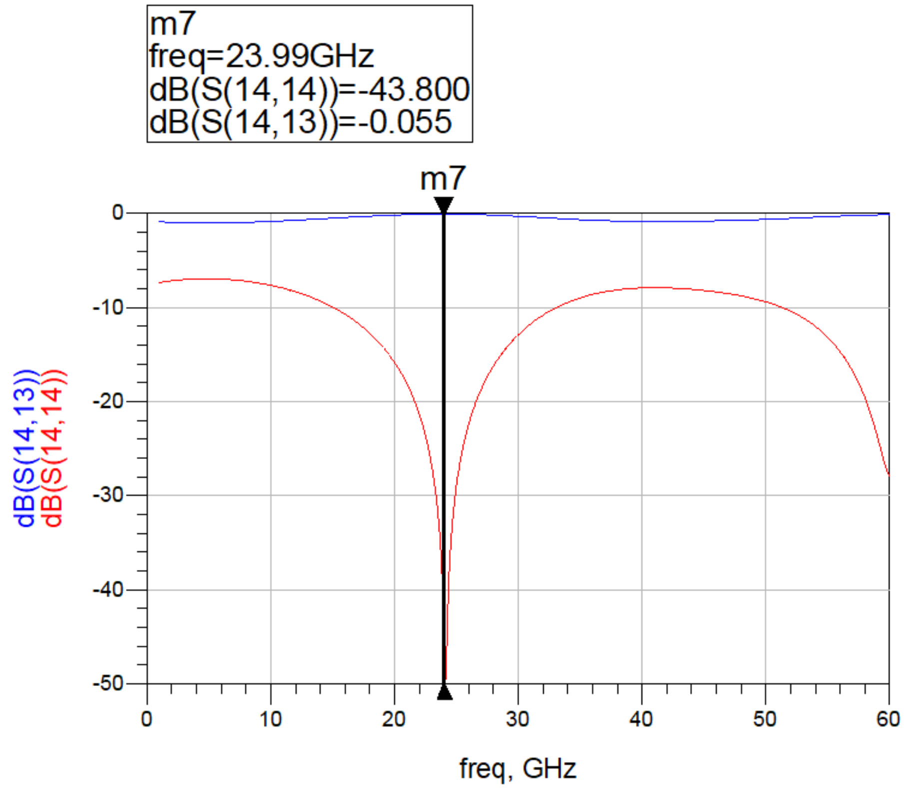




This design has excellently performance in theory, but it is impossible to manufacture 178 Ohm transmission line for almost all widely used substrates. Due to the limitations in manufacturing, the cascading solution should be used for this Matching Structure.

We know that the RX Impedance of MMIC is Z_{RX} =104.667+38.391j Ohm @ 24Ghz. The first stage (TL10), transforms the impedance from 104.667+38.391j Ohm to 60-25j Ohms. The final stage (TL11), transforms the impedance from 60-25j Ohms to 50 Ohms.





This cascading design has excellently performance. The design employed 78.26 Ohm and 82.43 Ohm transmission lines which could be manufactured using almost all widely used substrates.