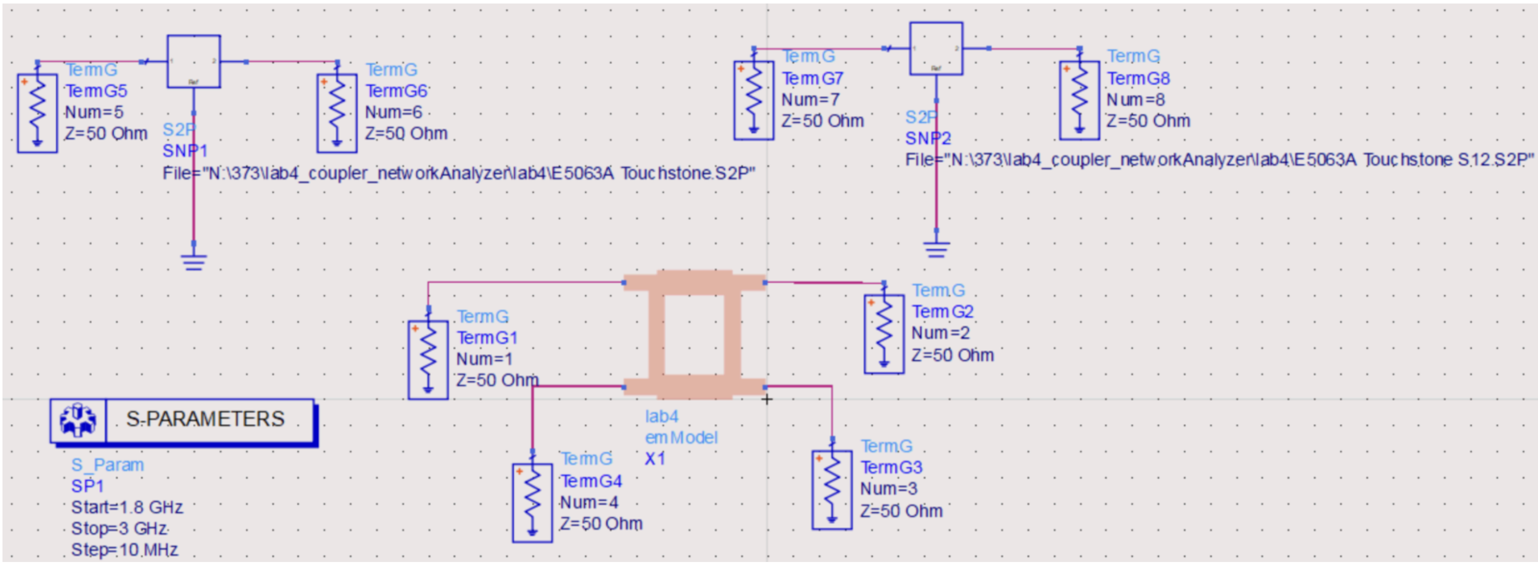
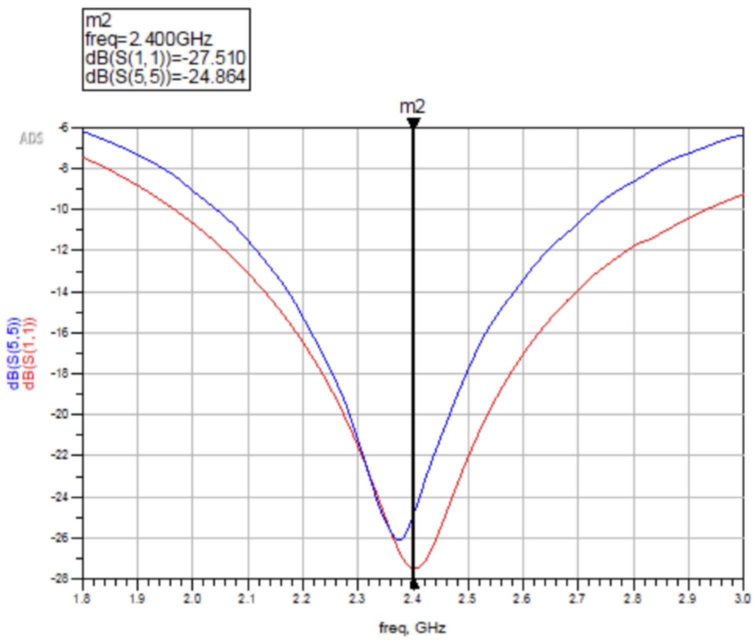
# SIMULATED VS MEASURED COUPLER ANALYSIS

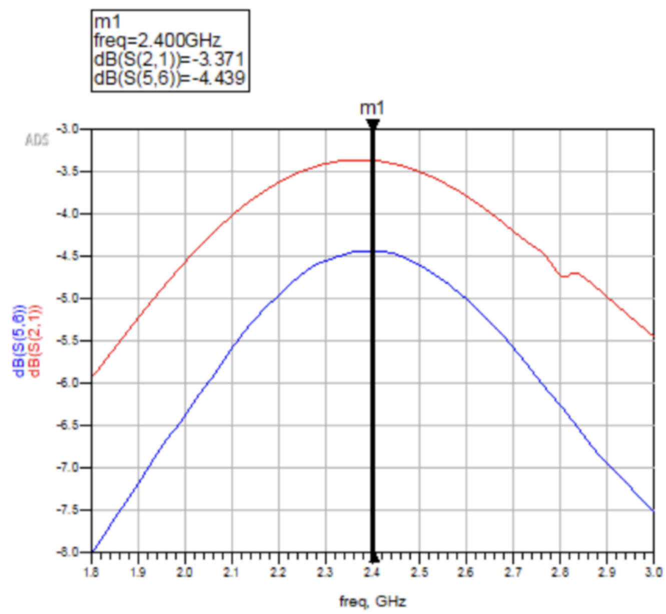
Here are the following results:

Schematic:

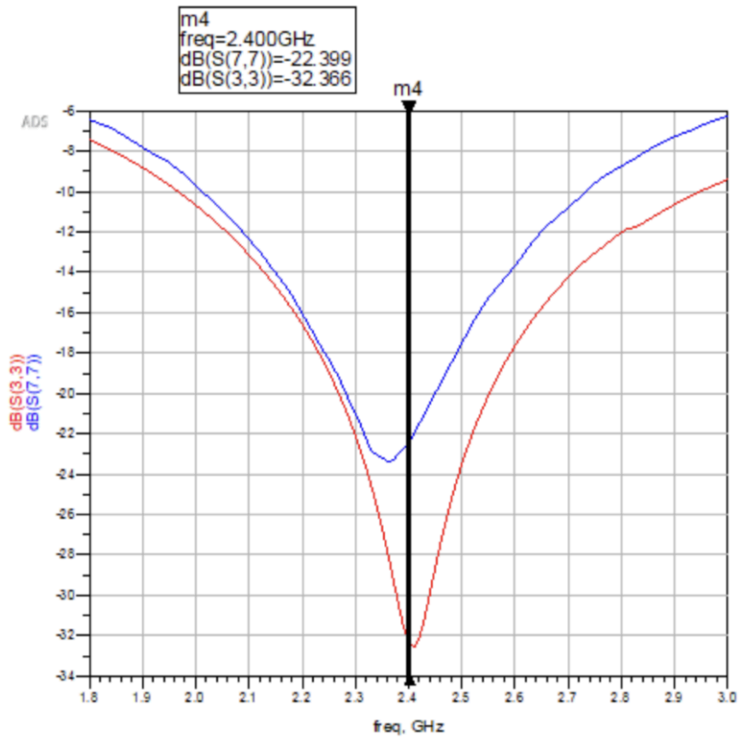


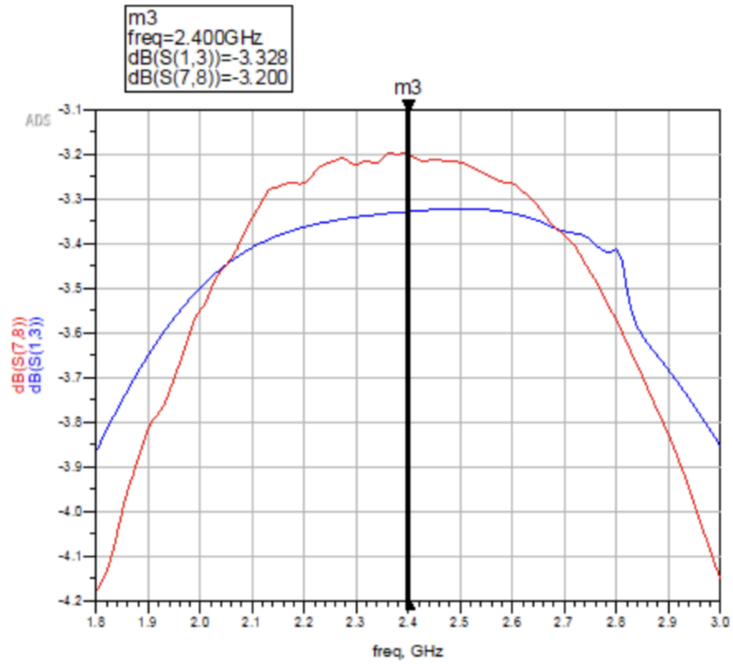

Below is a comparison between the EMSimulation and measured results through the Network Analyzer for S11 S21 when there is a connection between the input and through port (since the coupled port & isolated port were terminated):




Below is a comparison between the emSimulation and measured results through the Network Analyzer for S33 S31 when there is a connection between the input and coupler port (since the through port & isolated port were terminated):




Discrepancies between simulated and measured results:

- When comparing S11 (S11 for the simulation) and S55 (S11 for the through port measurement), we notice simulated results provide better matching than measured results by roughly 3dB (difference taken at 2.4GHz)
- When comparing S21 (S21 for the simulation) and S65 (S21 for the through port measurement, since ports 3 and 4 were terminated), we notice simulated results provide better transmission of power than measured results by roughly 1dB (difference taken at 2.4GHz)
- When comparing S33 (S33 for the simulation) and S77 (S11 for the coupled port measurement), we notice simulated results provide better matching than measured results by roughly 10dB (difference taken at 2.4GHz)
- When comparing S13 (S13 for the simulation) and S78 (S11 for the coupled port measurement), we notice simulated results provide better transmission than measured results by roughly 0.12dB (difference taken at 2.4GHz)

Shift in center frequencies between measured and simulated results:

- When measuring matching for both the through port and the coupling port, we realize that the center frequency of the measured results is slightly shifted to the left (roughly 2.35GHz). The reason for this occurrence could be accounted for in measurement setup. There are losses in the connectors and calibration errors that could provide mismatch in the center frequency

Measured values for return loss and insertion loss compared to simulation:

- First, return loss is the measure of how much power is reflected from a port relative to the power delivered to it. Ideally when measuring return loss, we would want –inf dB to show that efficient matching is created, and no power is reflected (all power is transmitted). Therefore, when we compared measured RL to simulated RL, we see that the simulated results have a much sharper crest (lower dB compared to measured) at 2.4GHz, resulting in better RL, and more matching.
- Second, insertion loss represents the amount of power transmitted through the network relative to the input power. It indicates the loss introduced by the device in the forward or reverse direction. Ideally when

measuring insertion loss, we would want a low dB to show that efficient transmission is yielded through the device. Therefore, when we compared measured IL to simulated IL, we see that the simulated results have higher values (higher dB compared to measured) at 2.4GHz, resulting in more IL in the measured results.

- Some reasons for this could be differences between dielectric constant or tangent losses. For instance, we input the relative dielectric constant to some precision, which would ideally be off from the actual dielectric constant within the real substrate. Other than materialistic properties, there could be limited approximations with the simulation itself prohibiting it to account for ideal parameters (such as ignoring parasitics of SMA connectors or radiation losses), this reason would also affect the RL and IL results.

Comparing BW of simulated vs measured results:

- When comparing the graphs, we notice that bandwidth is generally larger for the simulated results when compared to the measured results, resulting in more frequencies for effective operation. This could be the case due to fabrication tolerances: which could be variations in etching, substrate properties or connector placement.

Therefore, when we compare the coupling and isolation of the quadrature coupler to the simulated values, we notice that our simulations make sense as they would not include factors that are not considered in the real substrate. Simulations look accurate and are close to measured results.