BPF (Hairpin & Microstrip) & Short Transmission Line (0mm) Analysis

1. Calibration:

Figure 1a: Connecting the Ecal module via USB cords to Network Analyzer

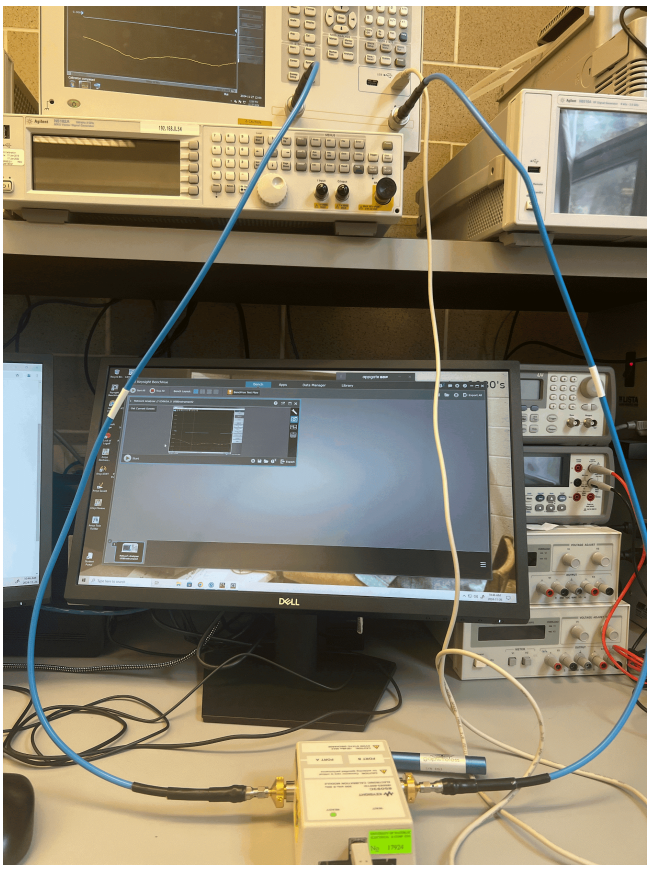

Figure 1b: Module to Network Analyzer setup

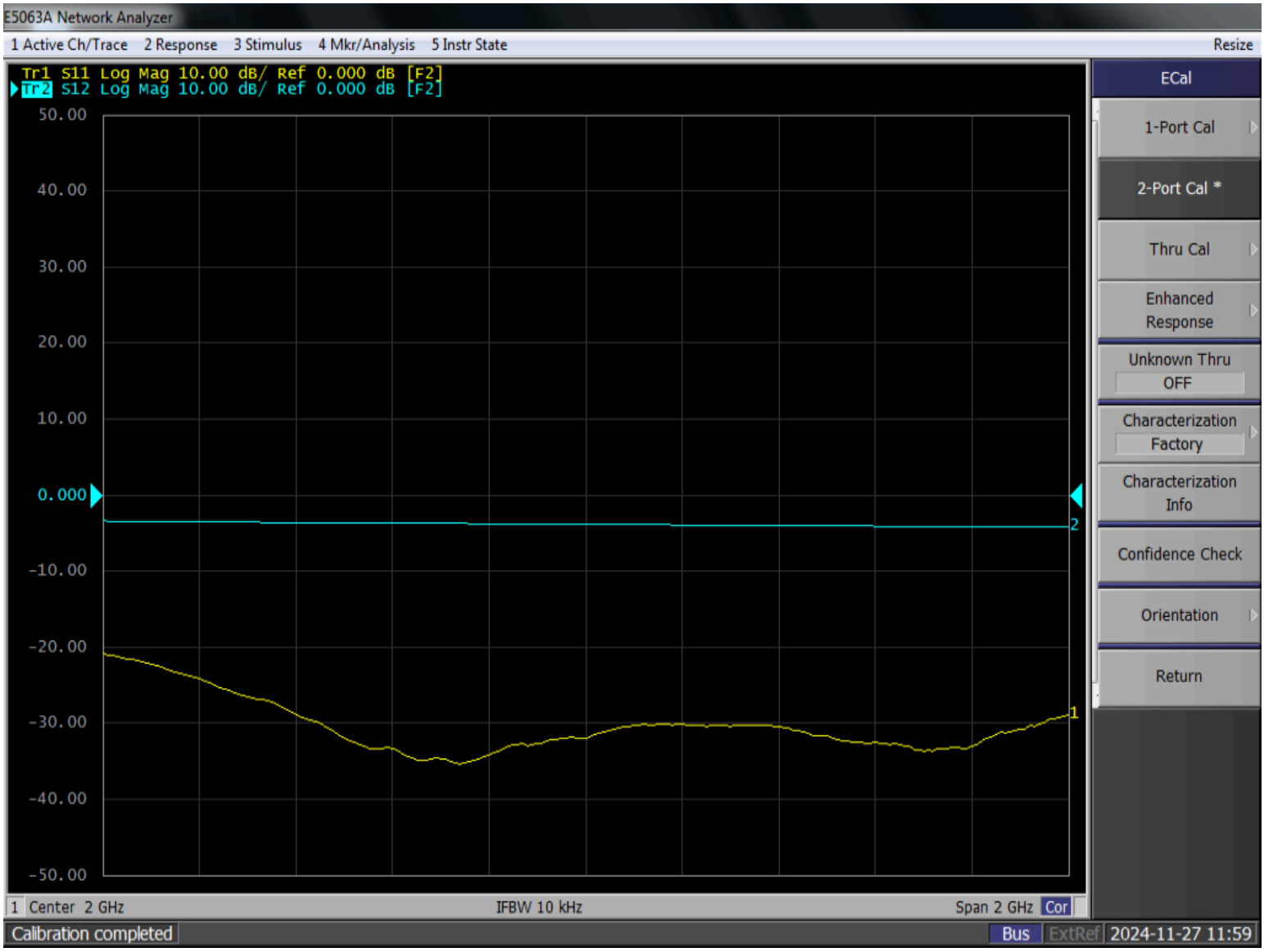

Figure 1c: S12 (turquoise) is seen at approximately 0dB, this represents efficient transmission. This makes sense as the Ecal module is calibrated such that the cord lengths act as matched circuits. S11 (yellow) is seen below -30dB which represents small reflection

2. Short Transmission Line:

Figure 2a: Short Transmission Line (~0mm) connection to calibrated cords

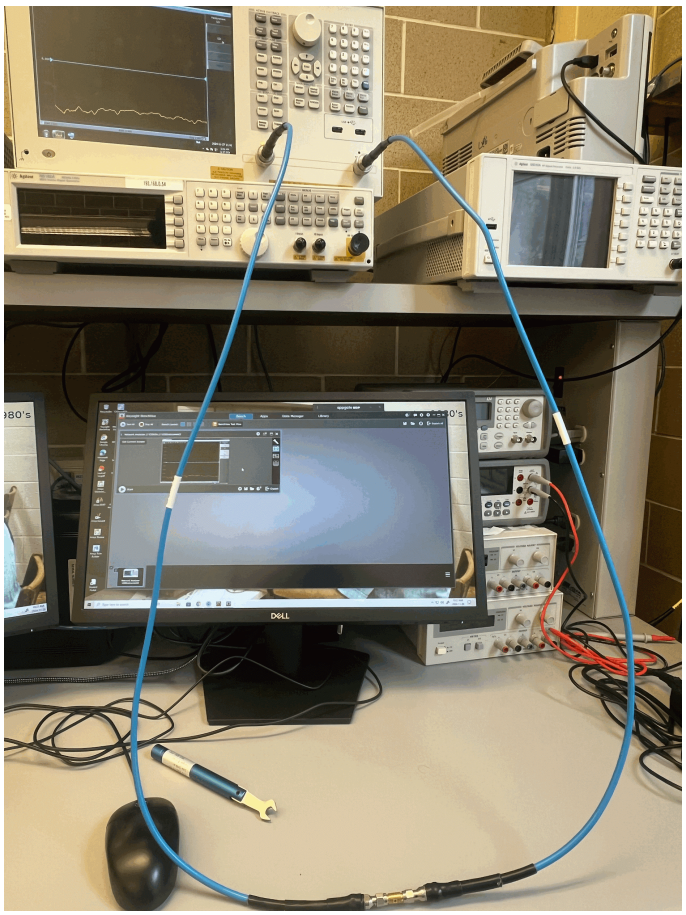

Figure 2b: Short TL connection to Network Analyzer

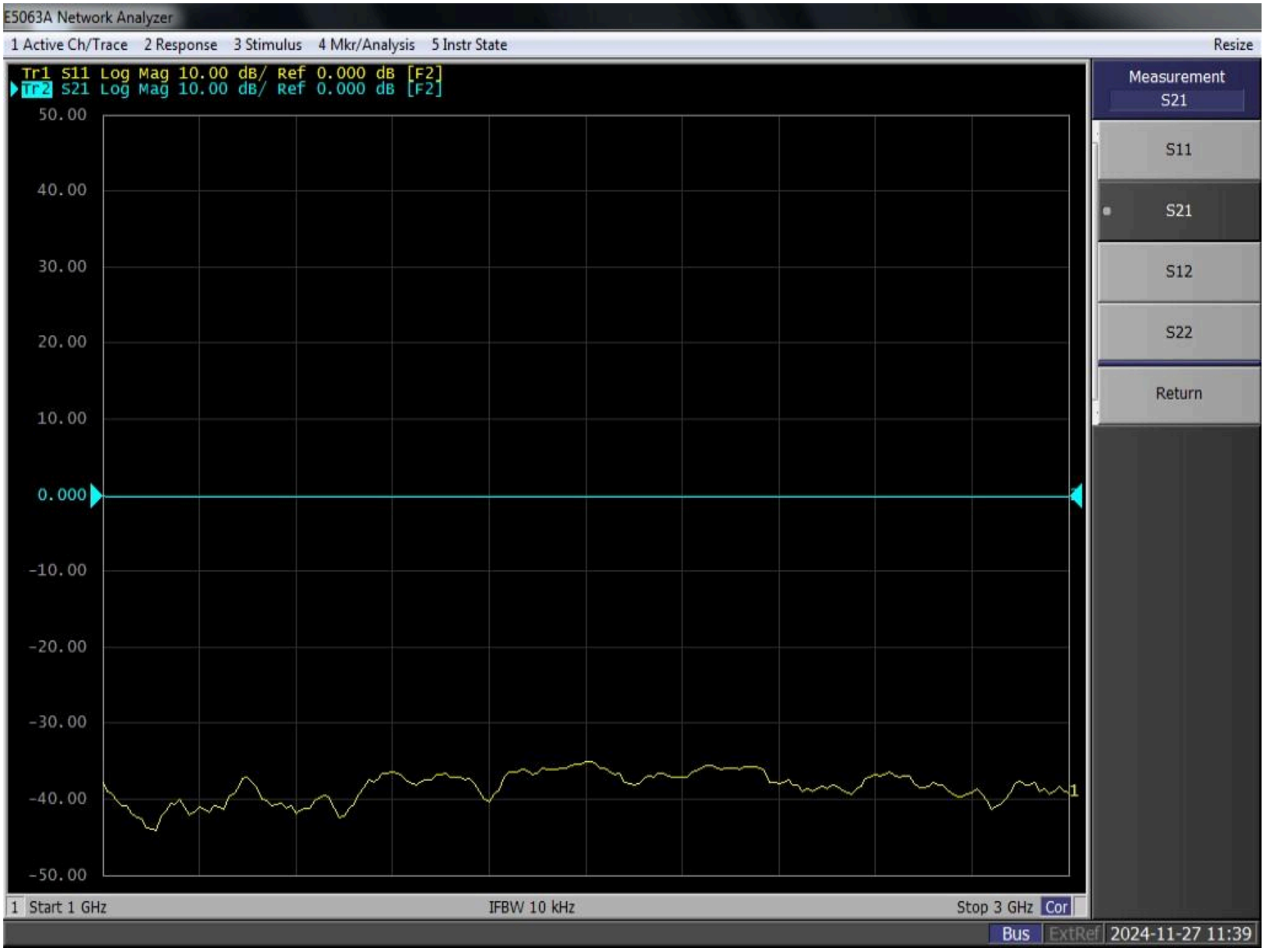

Figure 2c: S21 (turquoise) is at 0dB, this makes sense as the circuit is seen as a matched circuit (since calibration has matched the cords and the short TL adds no extra length). Similar reasoning can be used to see why S11 is below -30dB (due to pure reflection)

3. Hairpin BPF:

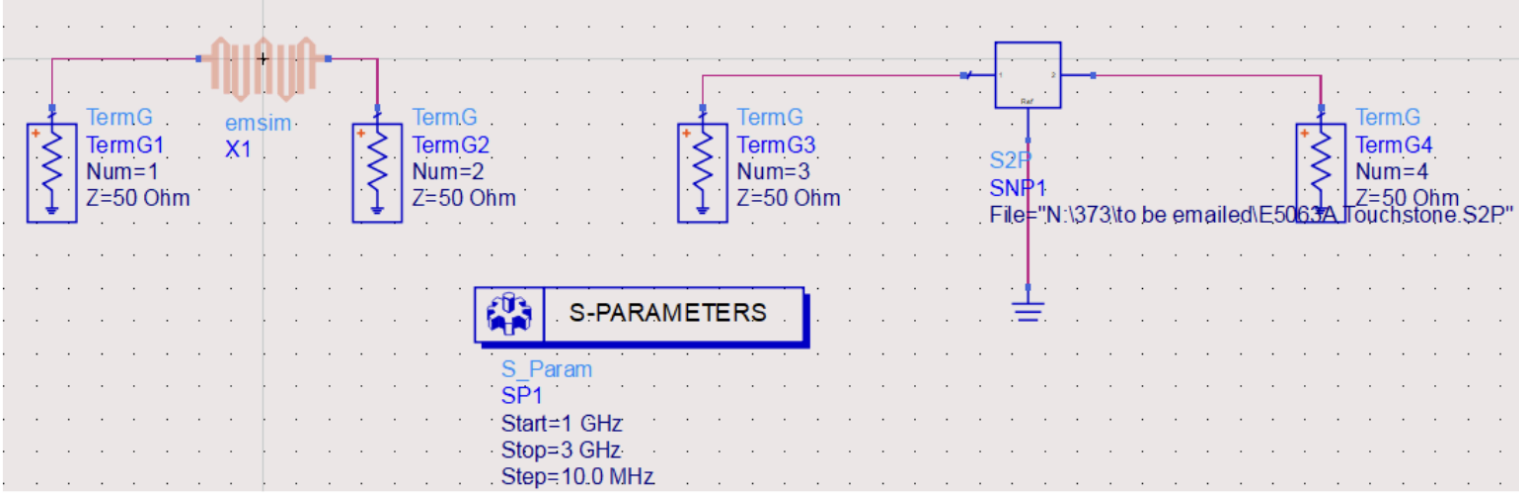

Figure 3a: Schematic of hairpin BPF. On the left, we have an EMmodel, on the right we have a S2P file (2 port S parameter characterization data from Network Analyzer). Schematics were made to compare measured vs simulated results from 1GHz-3GHz .

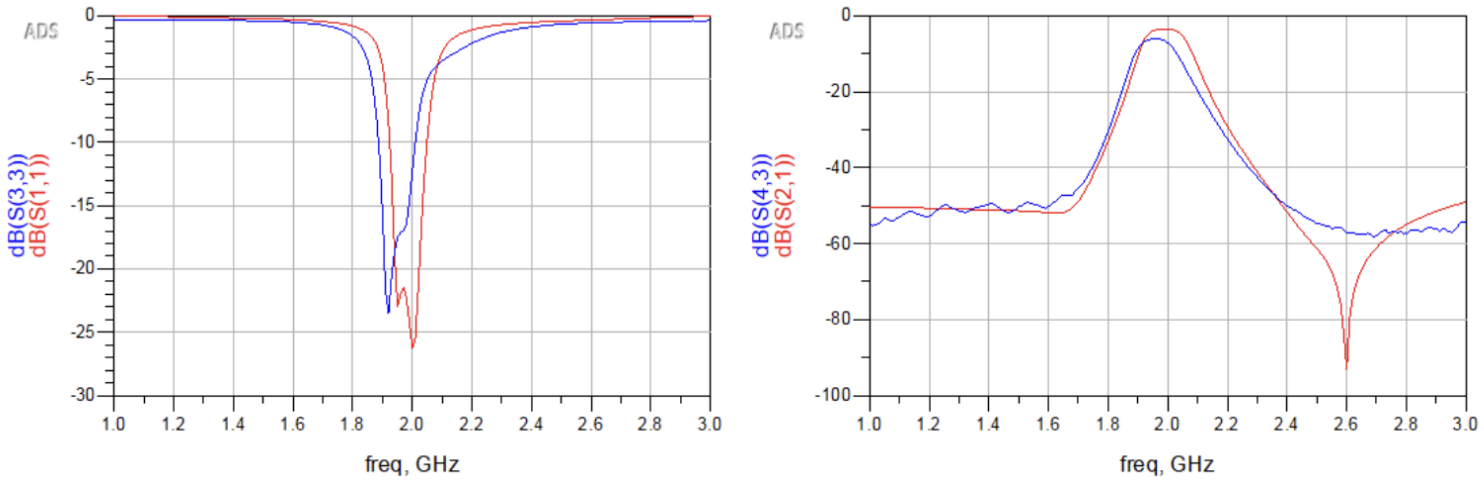

Figure 3b: On the left, we compare S11 parameters, in red we have EM simulated results while in blue we have experimented results. On the right, red represents EM simulated results while blue represents experimented results for S21 parameters. Difference in curves could be due to: Fabrication tolerances (Variations in etching, substrate properties, or connector placement), Material properties (Differences between the assumed dielectric constant/loss tangent in the simulation and the real substrate), Measurement setup (Connector losses, calibration errors, or cable mismatches), Simulation limitations (Approximations in the simulation, such as ignoring parasitics of SMA connectors or radiation losses)

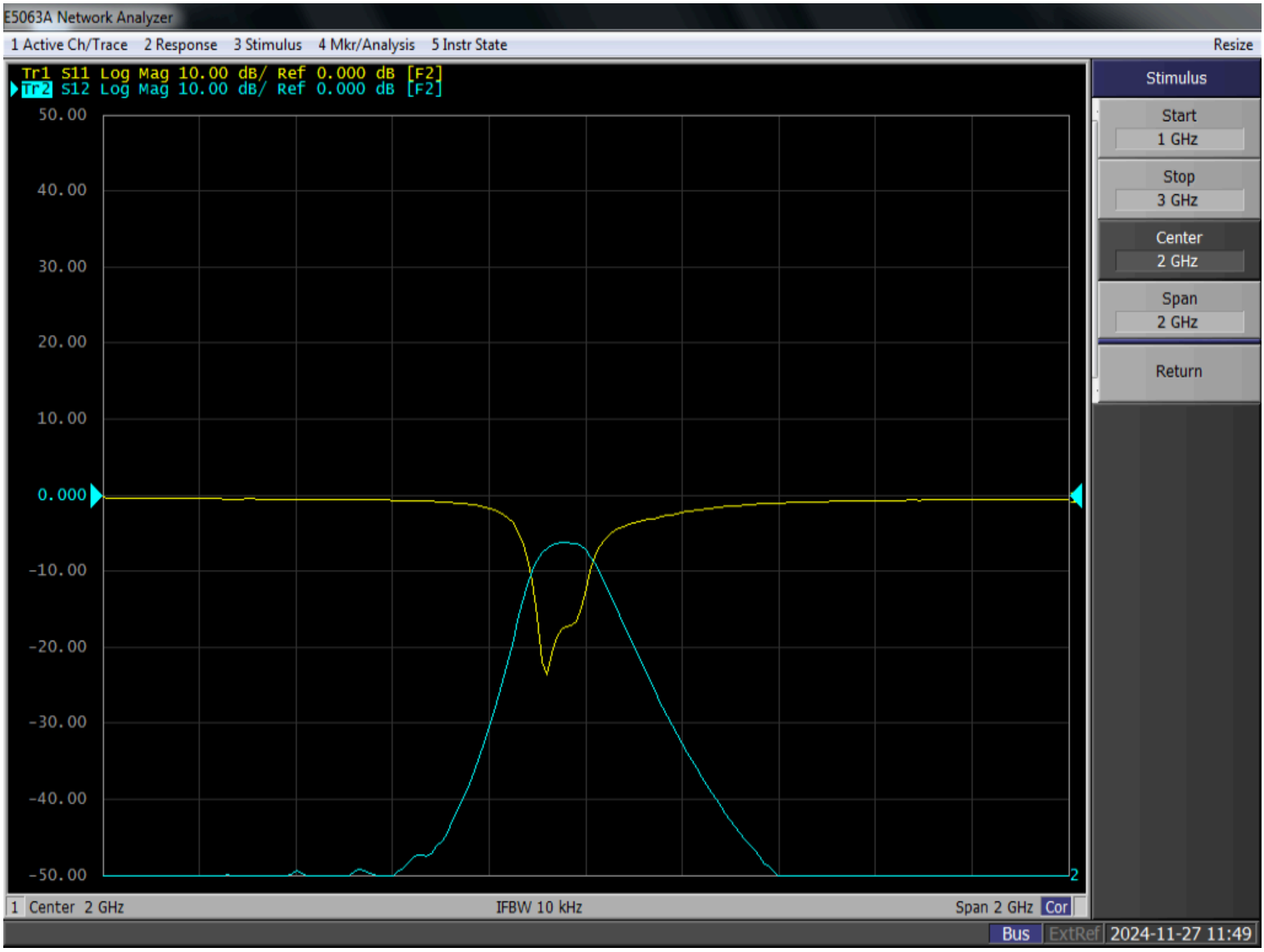

Figure 3c: S12 (turquoise) represents transmitted power, and S11 (yellow) represents reflected power. The results make sense as a band pass filter allows for signal transmission between certain frequencies (in this case, the frequency is 2GHz). Outside a certain fractional bandwidth, we notice that S21 (turquoise) is roughly -50dB which represents small signal transmission (more reflection which is shown from S11), which correctly matches the design of the circuit.

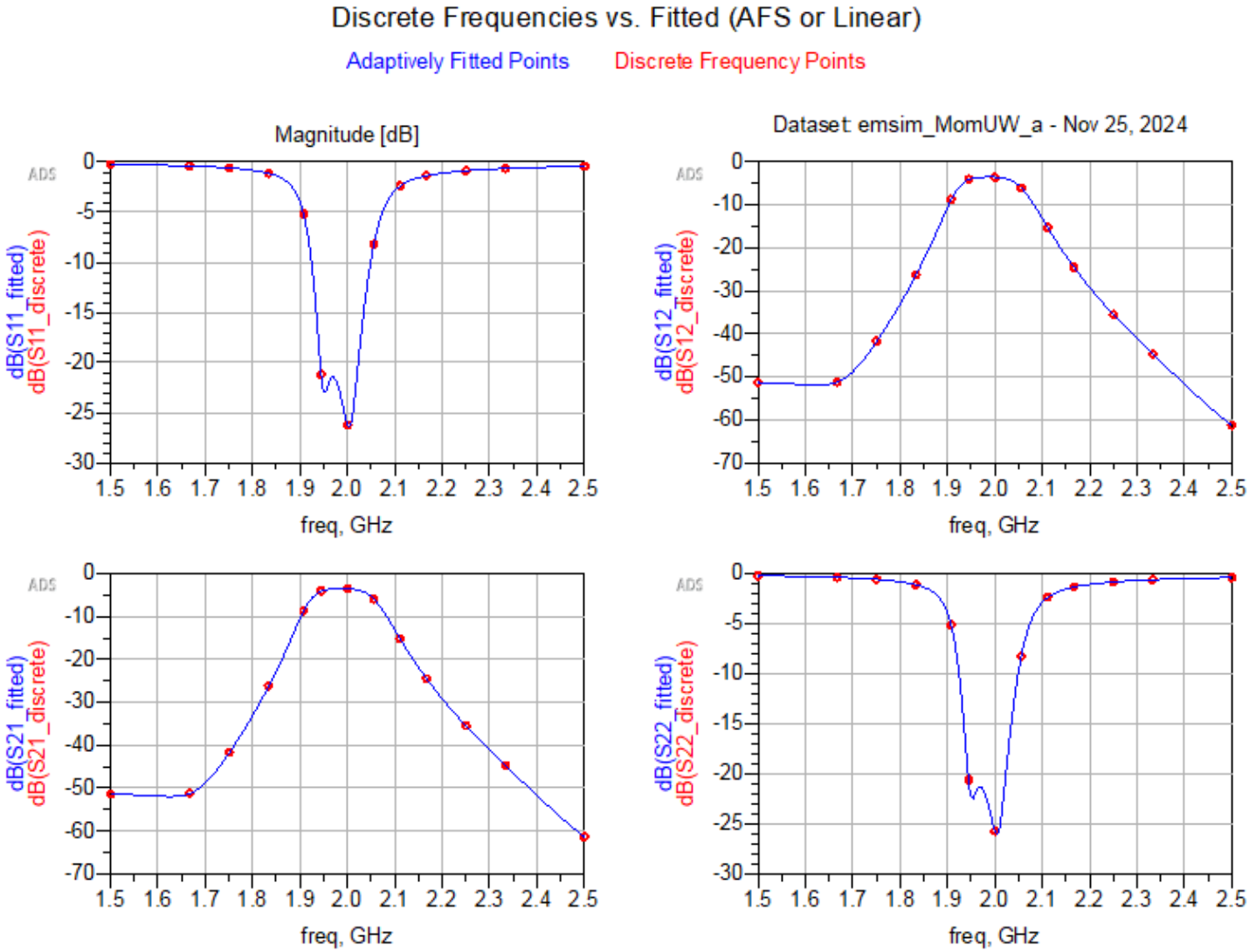

Figure 3d: EM simulated results. Top left graph represents S11, top right represents S12, bottom left represents S21, & bottom right represents S22.

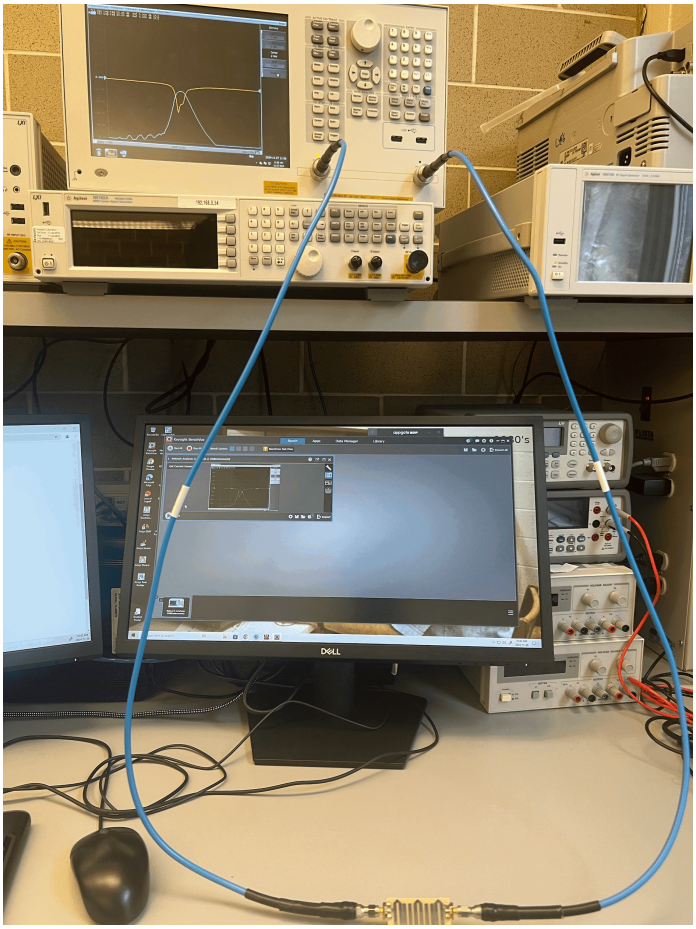

Figure 3e: Hairpin BPF connection to Network Analyzer

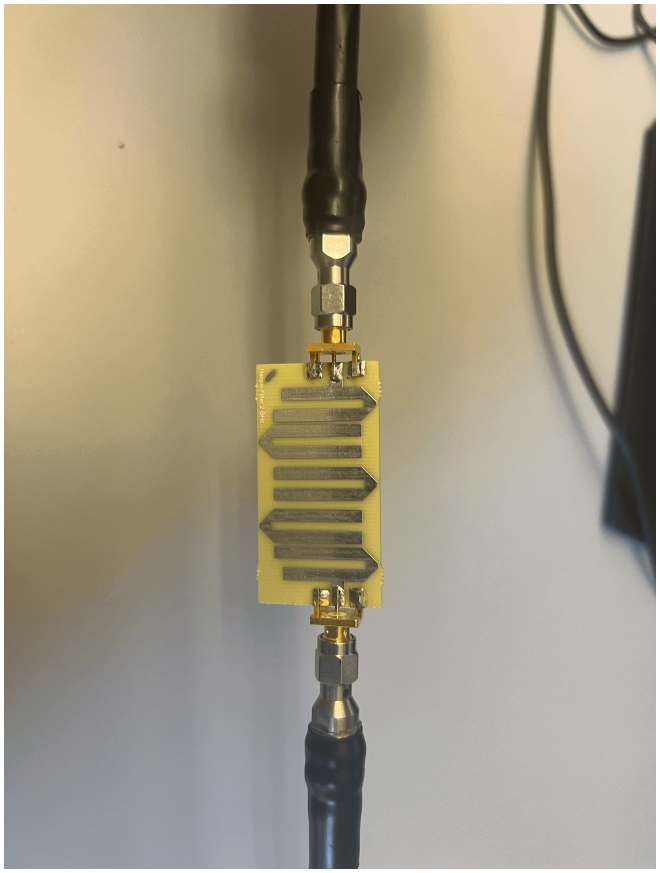

Figure 3f: Fabricated Hairpin BPF

4. Microstrip BPF:

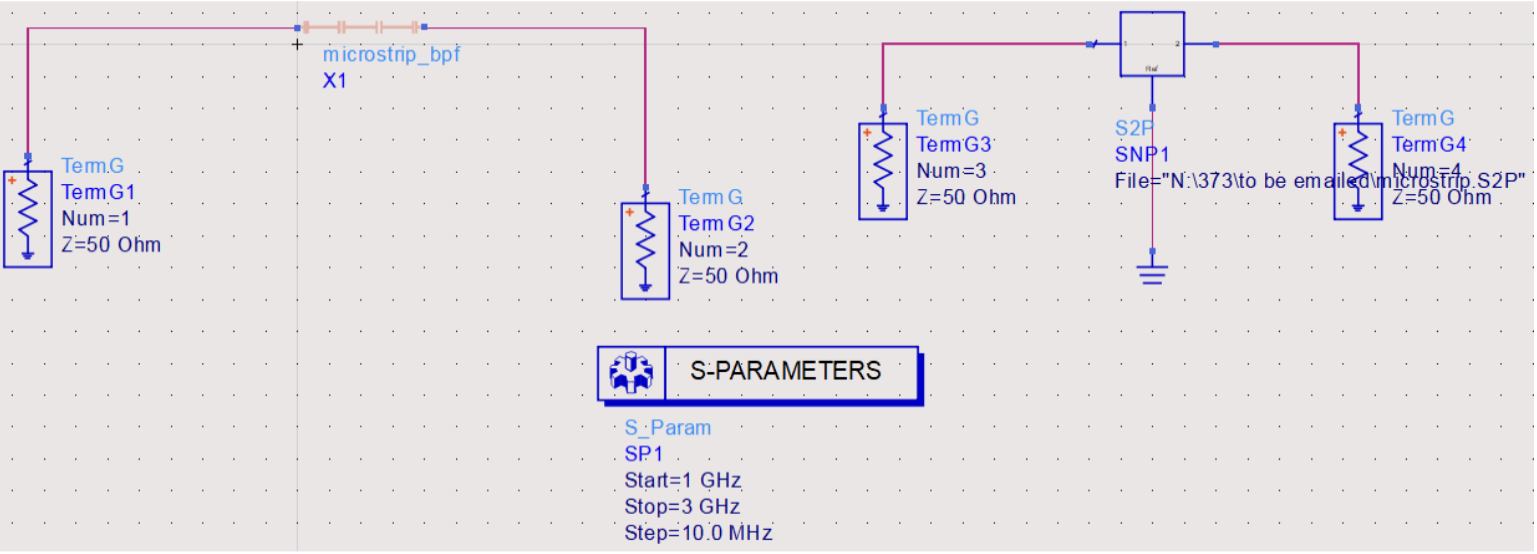

Figure 4a: Schematic of Microstrip BPF. On the left, we have an EMmodel, on the right we have a S2P file (2 port S parameter characterization data from Network Analyzer). Schematics were made to compare measured vs simulated results from 1GHz-3GHz

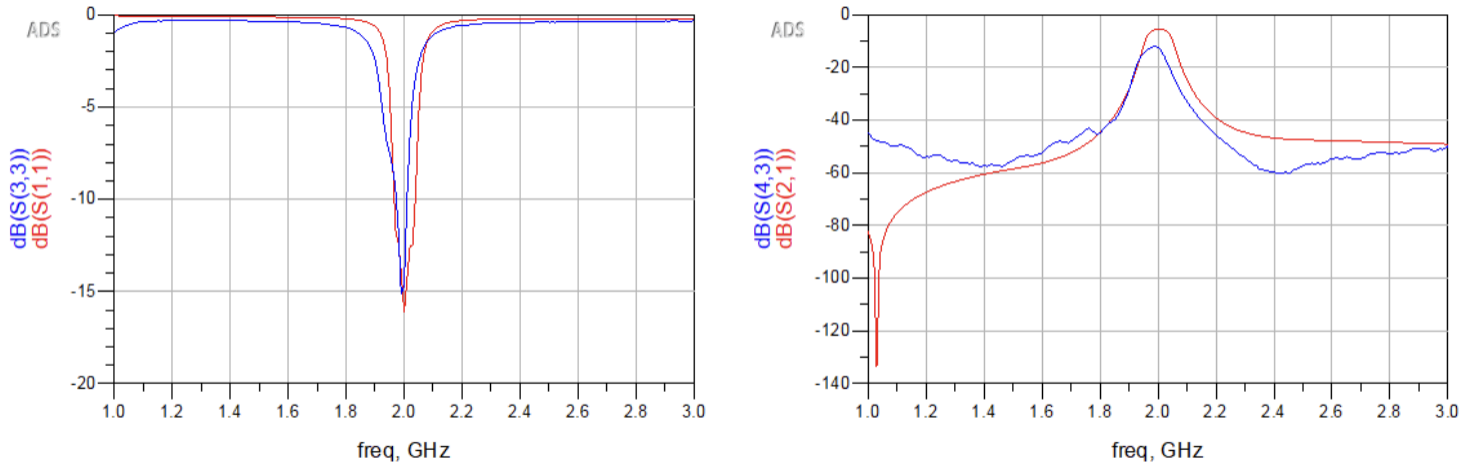

Figure 4b: On the left, we compare S11 parameters, in red we have EM simulated results while in blue we have experimented results. On the right, red represents EM simulated results while blue represents experimented results for S21 parameters. Difference in curves could be due to: Fabrication tolerances (Variations in etching, substrate properties, or connector placement), Material properties (Differences between the assumed dielectric constant/loss tangent in the simulation and the real substrate), Measurement setup (Connector losses, calibration errors, or cable mismatches), Simulation limitations (Approximations in the simulation, such as ignoring parasitics of SMA connectors or radiation losses). NOTE: Similar factors to hairpin BPF.

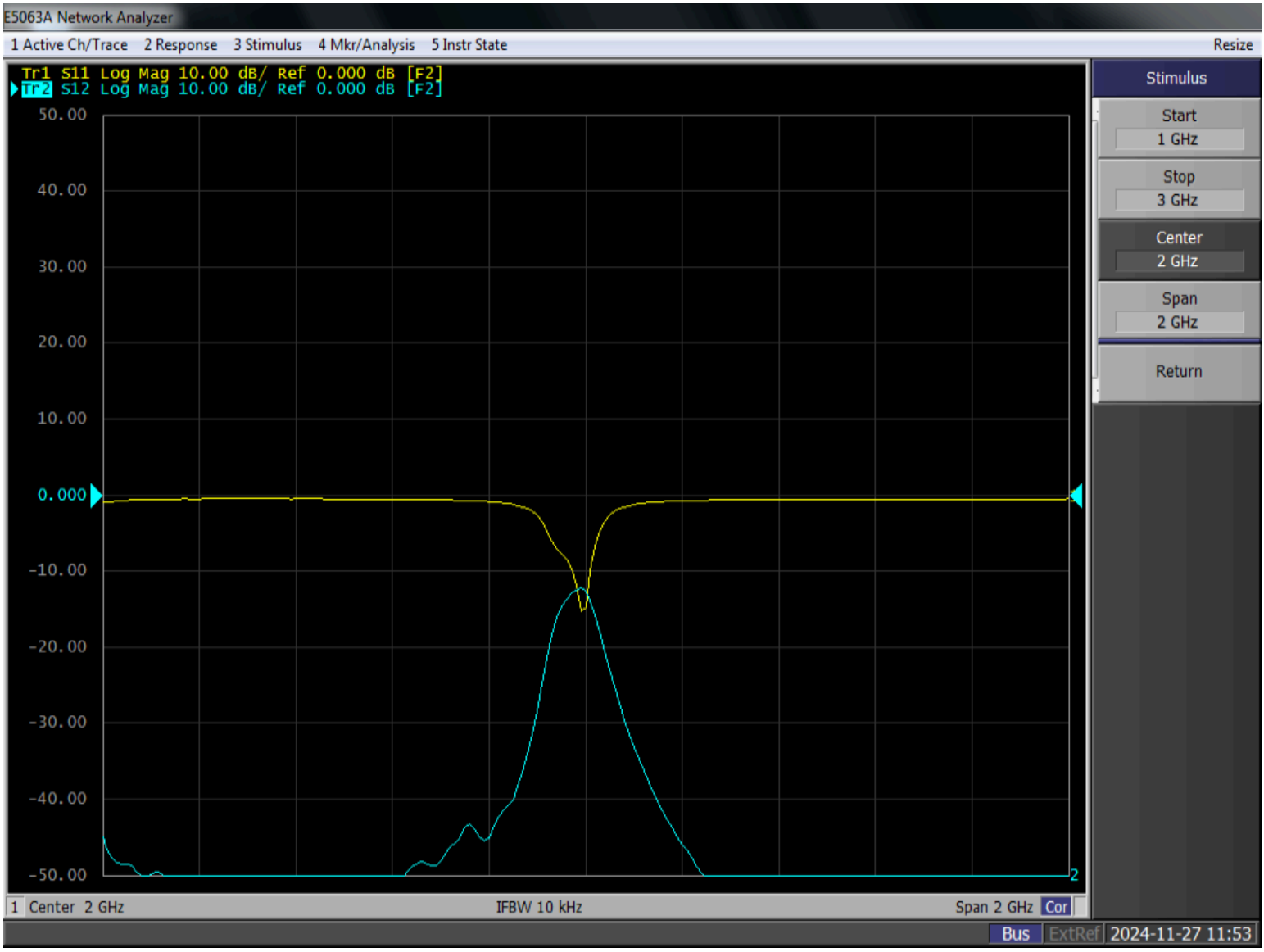

Figure 4c: When testing the fabricated microstrip BPF on the network analyzer, we see the following results for S11, & S12. S12 (turquoise) represents transmitted power, and S11 (yellow) represents reflected power. The results make sense as a band pass filter allows for signal transmission between certain frequencies (in this case, the frequency is 2GHz). Outside a certain fractional bandwidth, we notice that S21 (turquoise) is roughly -50dB which represents small signal transmission (more reflection which is shown from S11), which correctly matches the design of the circuit.

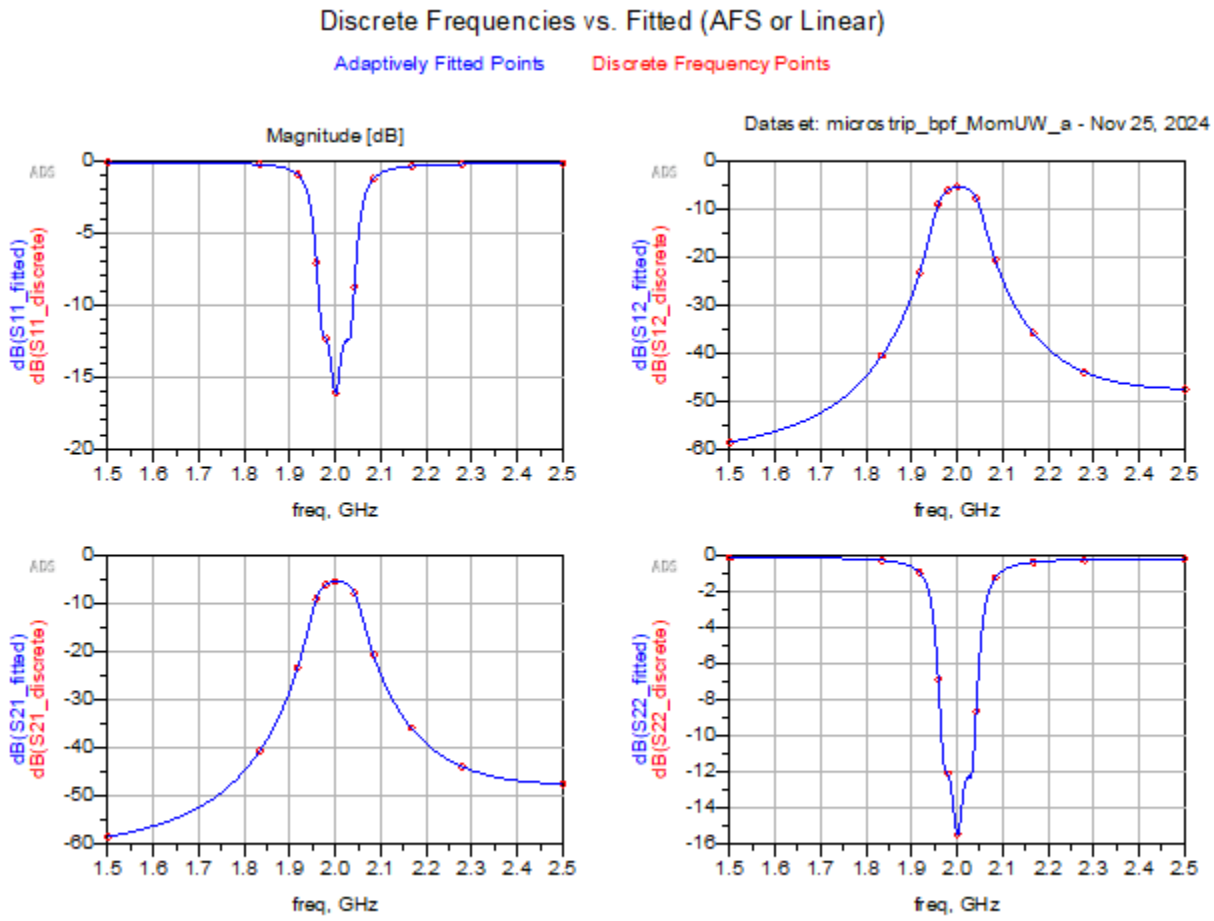

Figure 4d: EM simulated results. Top left graph represents S11, top right represents S12, bottom left represents S21, & bottom right represents S22.

Figure 4e: Fabricated microstrip BPF

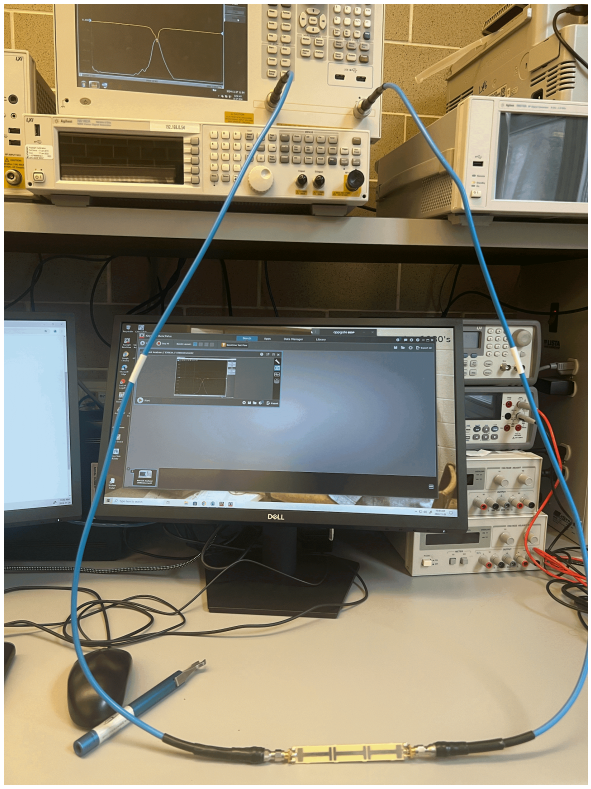

Figure 4f: Microstrip BPF connection to Network Analyzer