WILKINSON POWER DIVIDER FINAL PROJECT

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WILKINSON POWER DIVIDER

- Three-port networks must have one of:
  - lossy
  - non-reciprocal
  - not matched

- *An N-Way Hybrid Power Divider,* E.J. Wilkinson '60
  - No dissipated power w/ matched external loads
  - Isolation between output ports
  - Internal loads require crossover for n > 2

- Microstrip line schematic for 2-way Wilkinson
  - Initial simulations for design with center frequency ~2.45 GHz
  - Selection of substrate and layout

APPROACH

- Iterative approach: Using RO4003C substrate (dk = 3.55), Keysight Genesys circuit, layout, then Ansys HFSS model of 2-way 2.45 GHz WPD
  - For circuit: do linear analysis simulation then tune
  - For layout simulation: do method and moments simulation then tune
  - For HFSS Ansys: do 3D analysis simulation then tune

- Create Gerber file from layout file to mill in LPKF

- Mill on LPKF

- Solder surface mount resistor and SMA ports

- Test and record S-parameters on VNA

STARTING RANGES

- Roger's Microwave Impedance Matching Calculator for starting parameters
  - Provided starting range for quarter wavelength width and length and characteristic impedance width

CIRCUIT SCHEMATIC

- Keysight Genesys 1:2 WPD circuit design
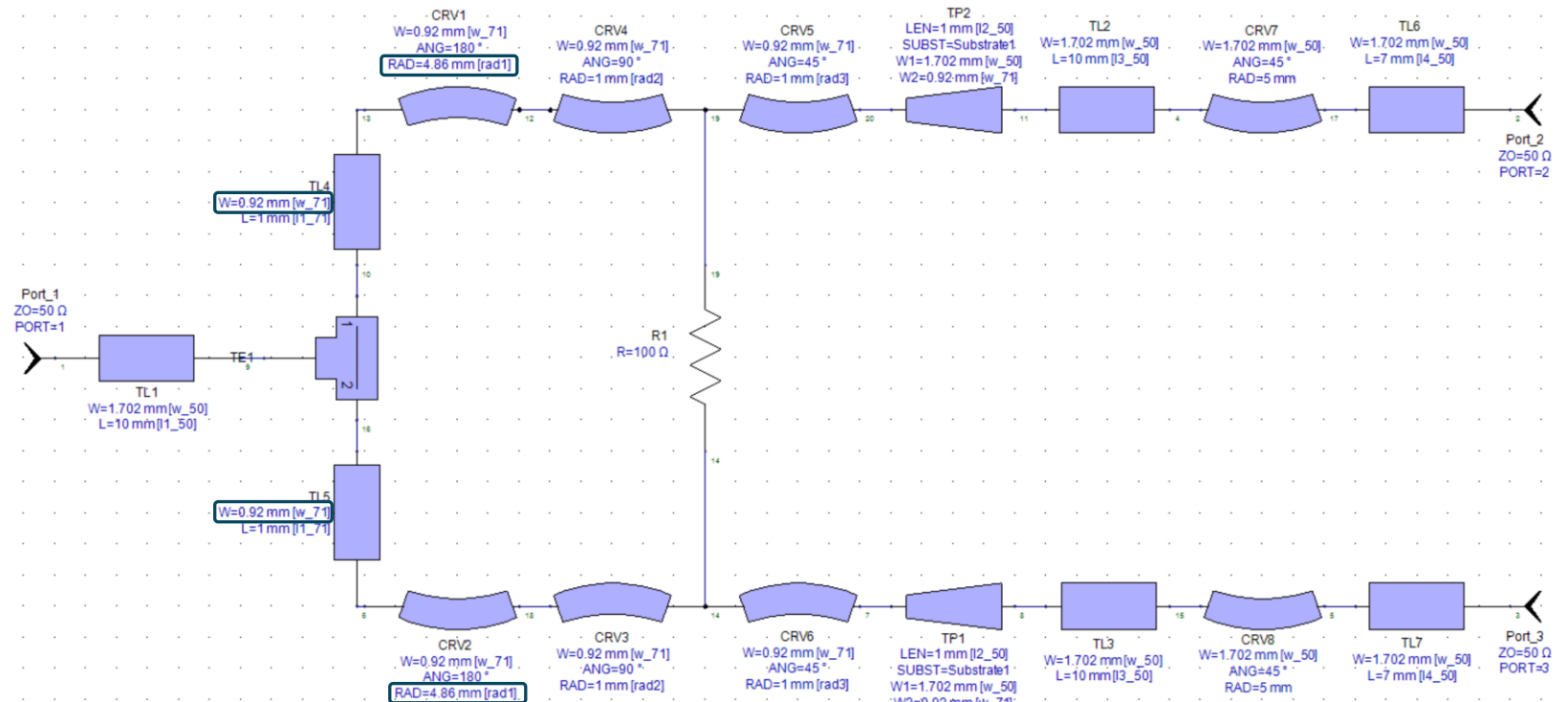
CIRCUIT SIMULATION

- Keysight Genesys 1:2 WPD circuit simulation results

Circuit Simulation S-Parameters Results
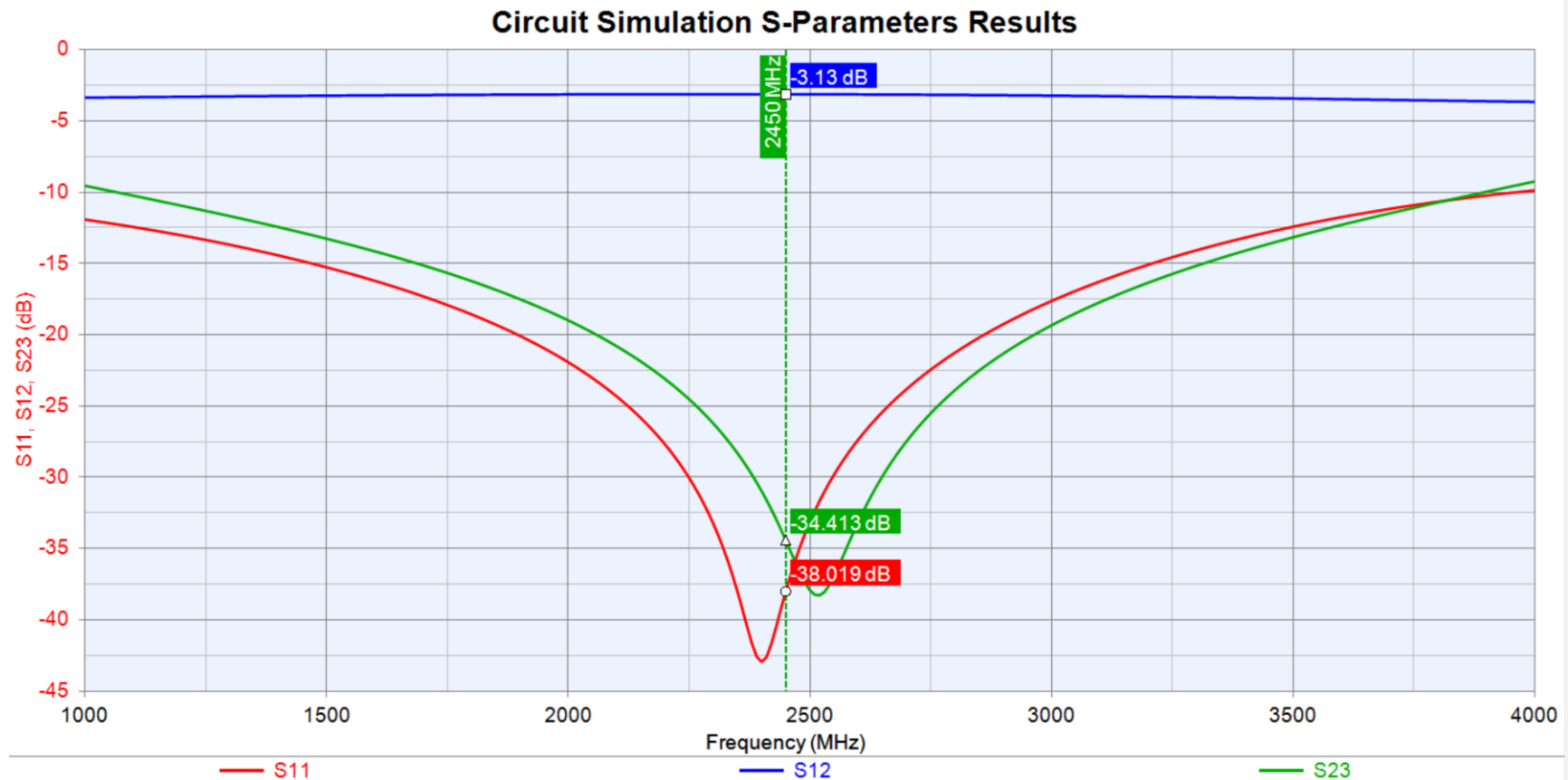
CIRCUIT LAYOUT

- Keysight Genesys 1:2 WPD layout design
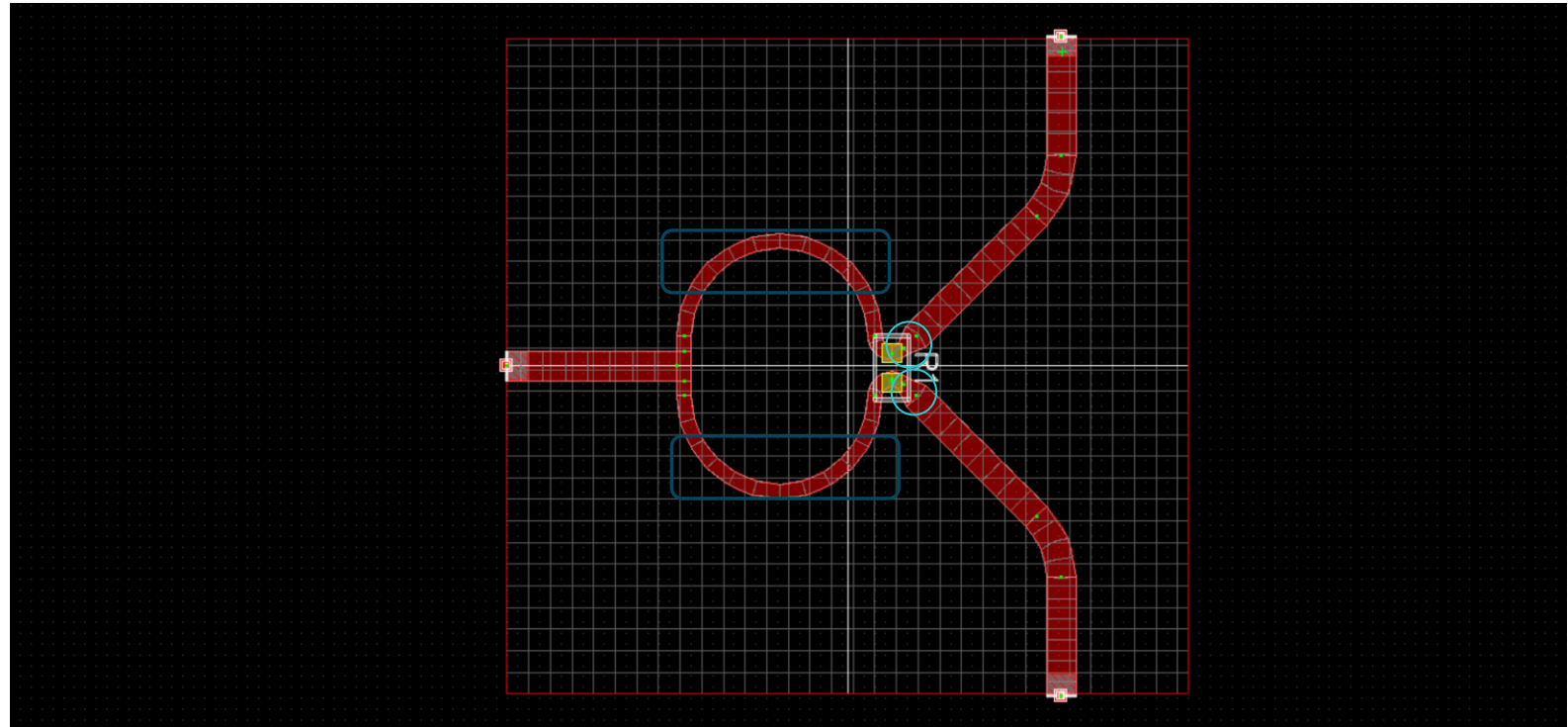
MOMENTUM GXF (METHOD OF MOMENTS)

- Keysight Genesys 1:2 WPD layout simulation results

Layout Simulation S-Parameters Results
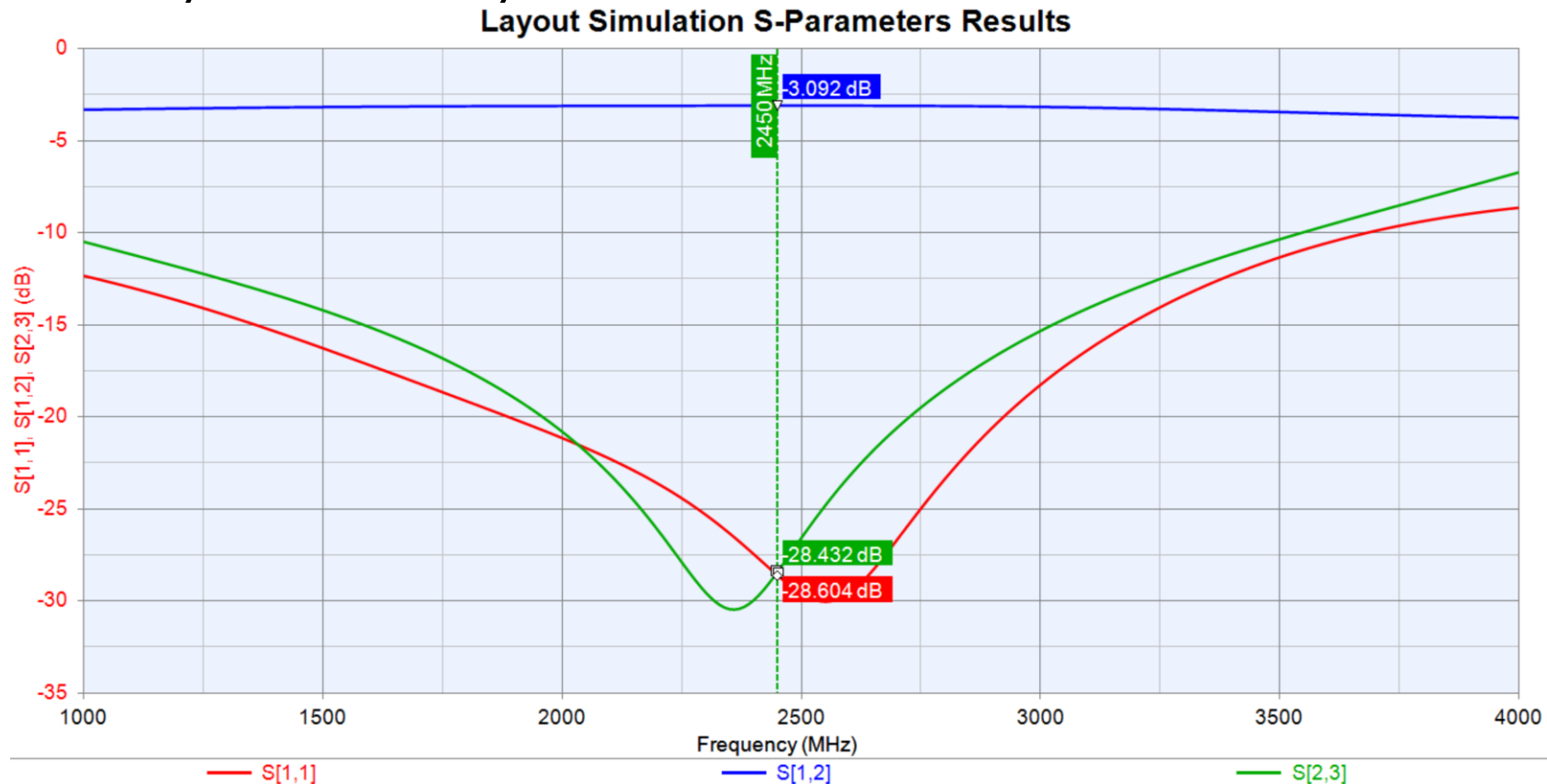
3D SIMULATION DESIGN OF LAYOUT

- Ansys HFSS 1:2 WPD 3D design
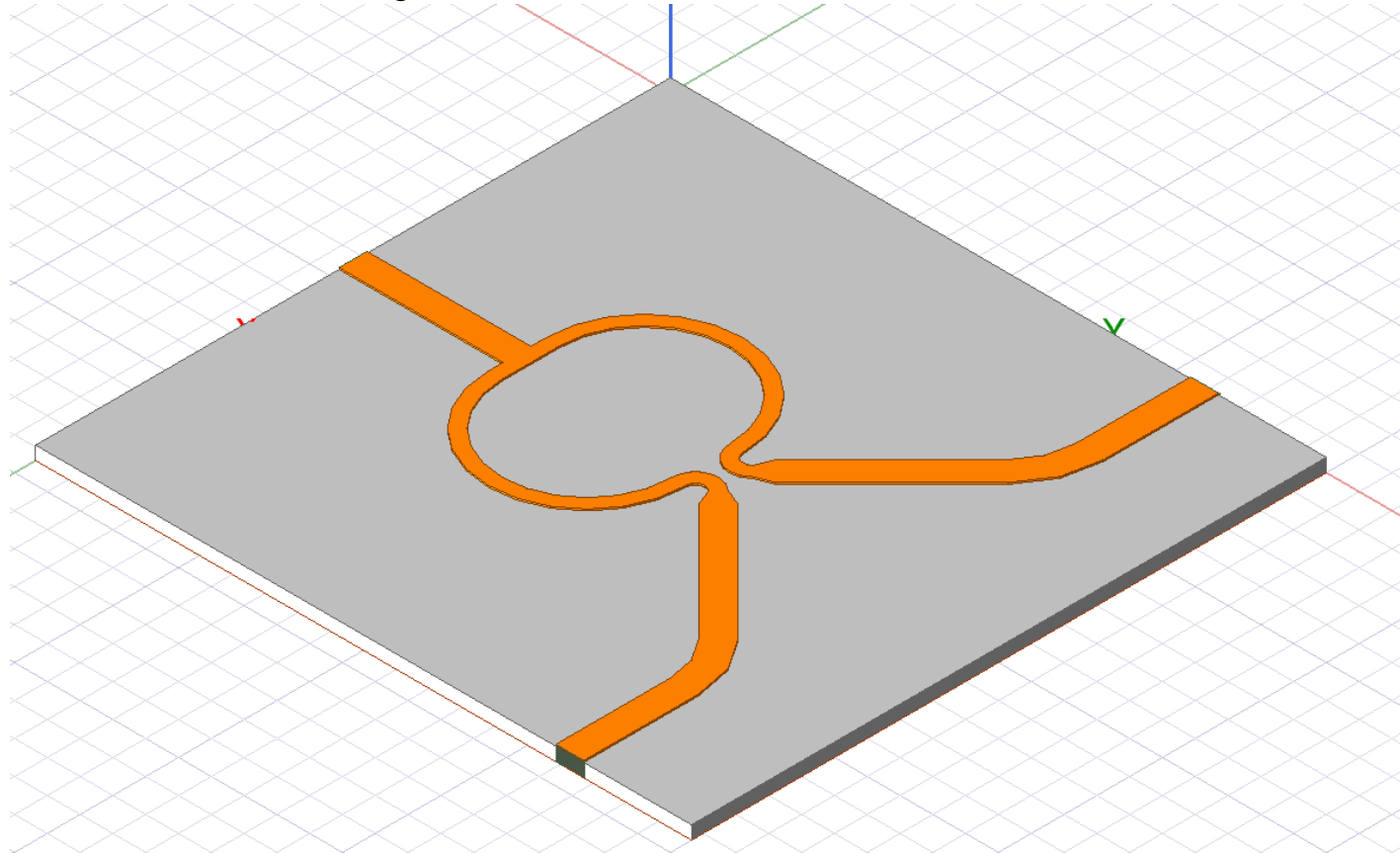
ANSYS HIGH FREQUENCY SIMULATION SOFTWARE

- Ansys HFSS (similar to CST)1:2 WPD 3D analysis simulation results
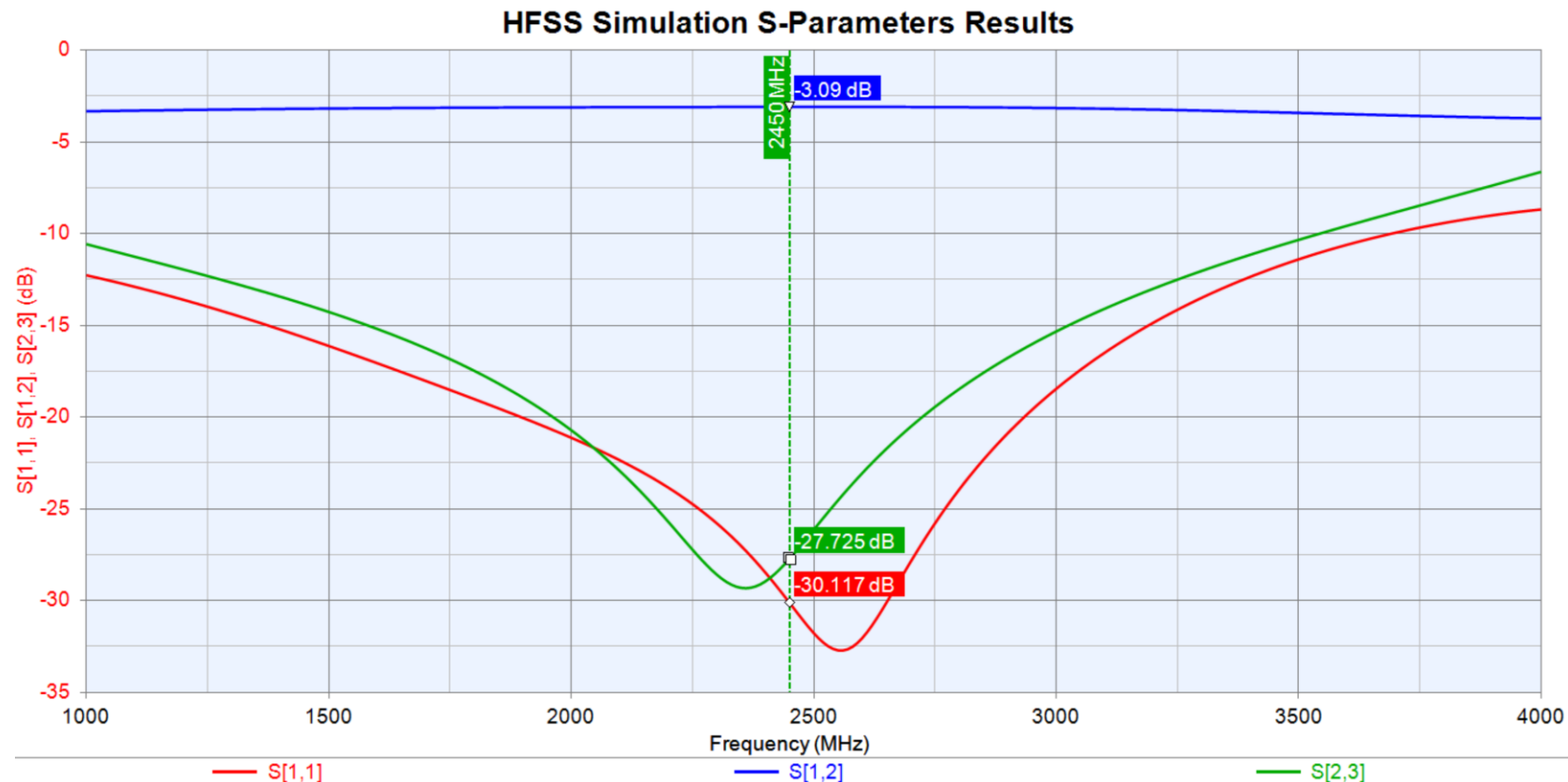
MILLING PROCESS WITH LPKF

- Activate Air Compressor connected to LPKF

- Add RO4003C substrate onto mat

- Follow user friendly LPKF CircuitPro PM software to set up system

- Transfer Gerber file from final design consisting of board outline then mill
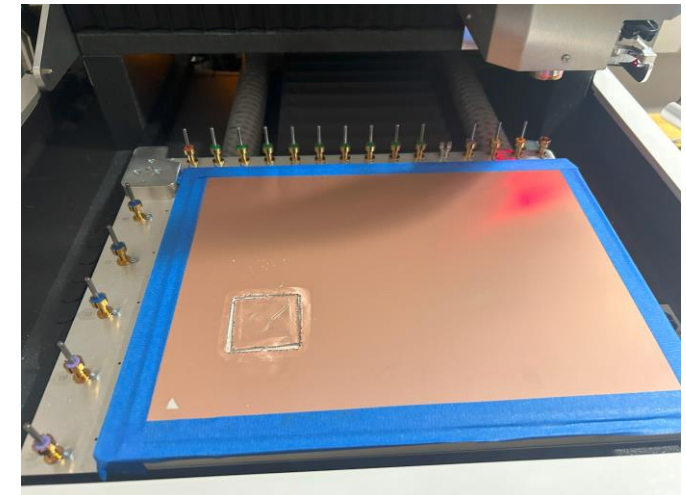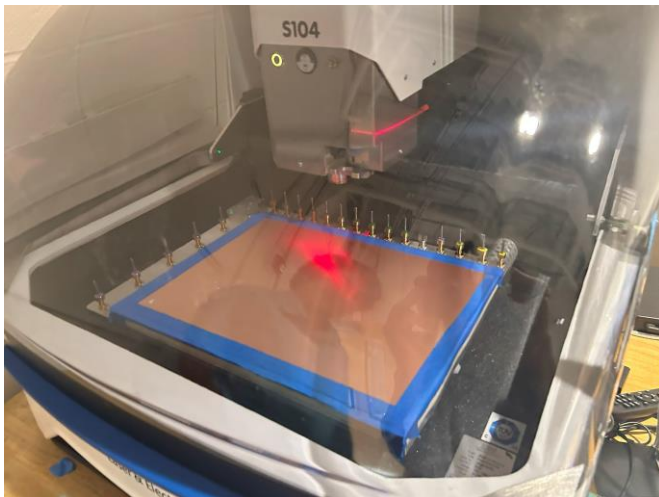
CONSTRUCTING WPD

- Peel excess conducting strip

- Solder 0603 resistor and SMA female launch end connector

- Collect VNA (LibreVNA), SMA Cables, and 50-ohm termination for measuring
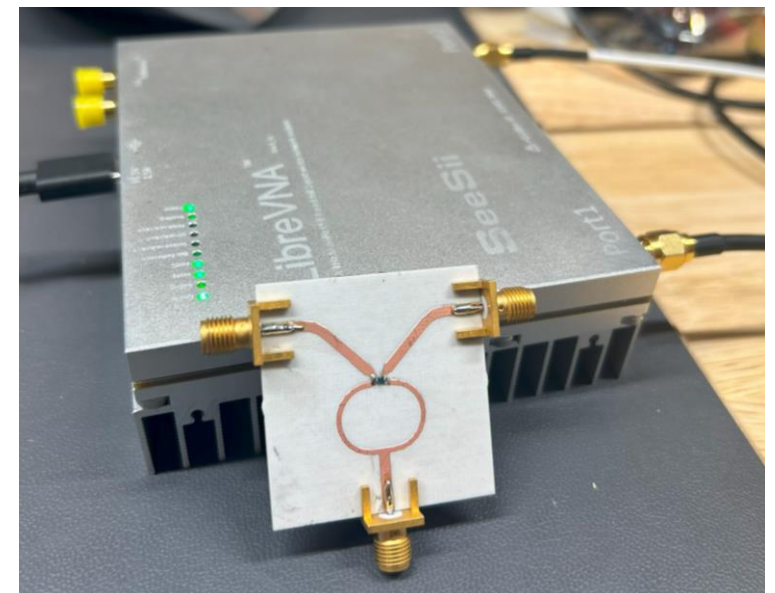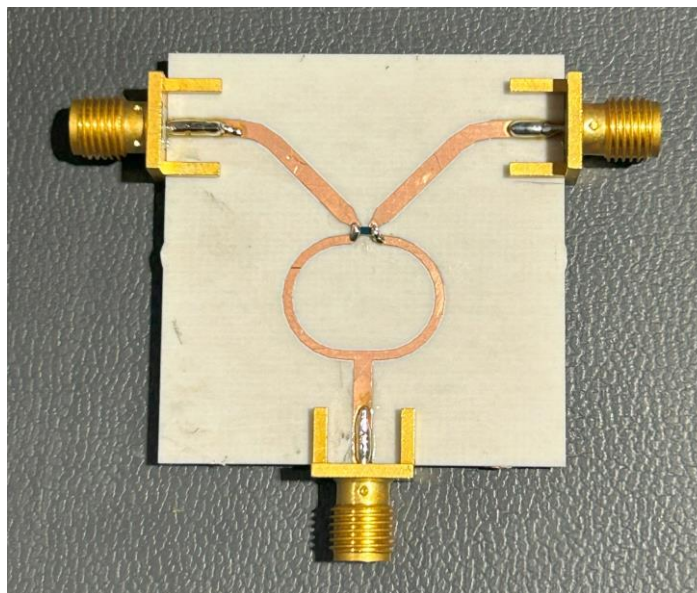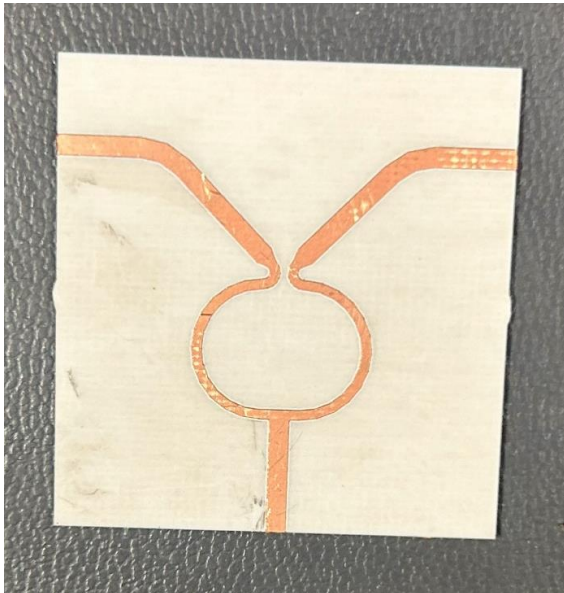
RESULT (REFLECTION)

- S11 resonance roughly at 2.338 GHz but -27.4 dB at 2.45 GHz
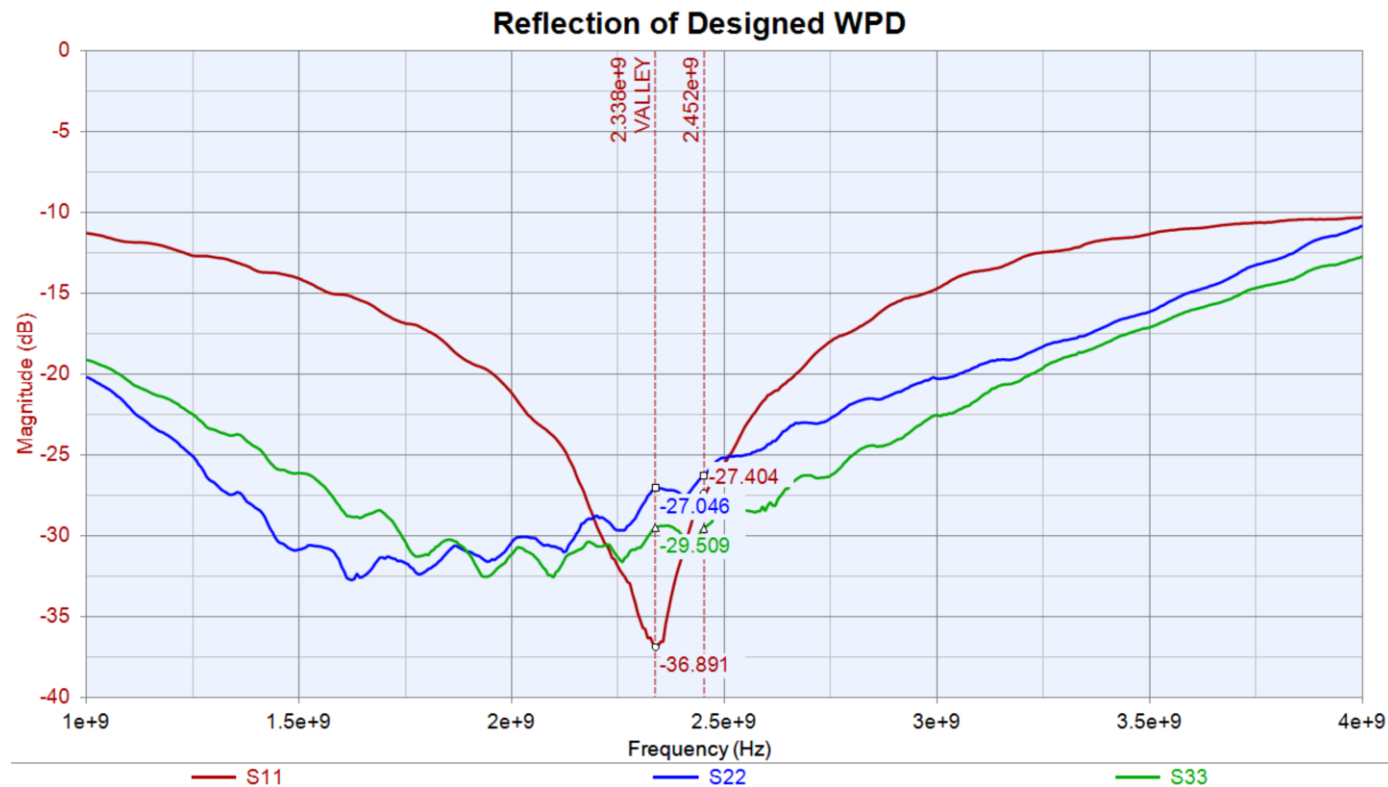
RESULT (ISOLATION)

- S23 and S32 roughly at 2.338 GHz resonance and -35.1 dB at 2.45 GHz
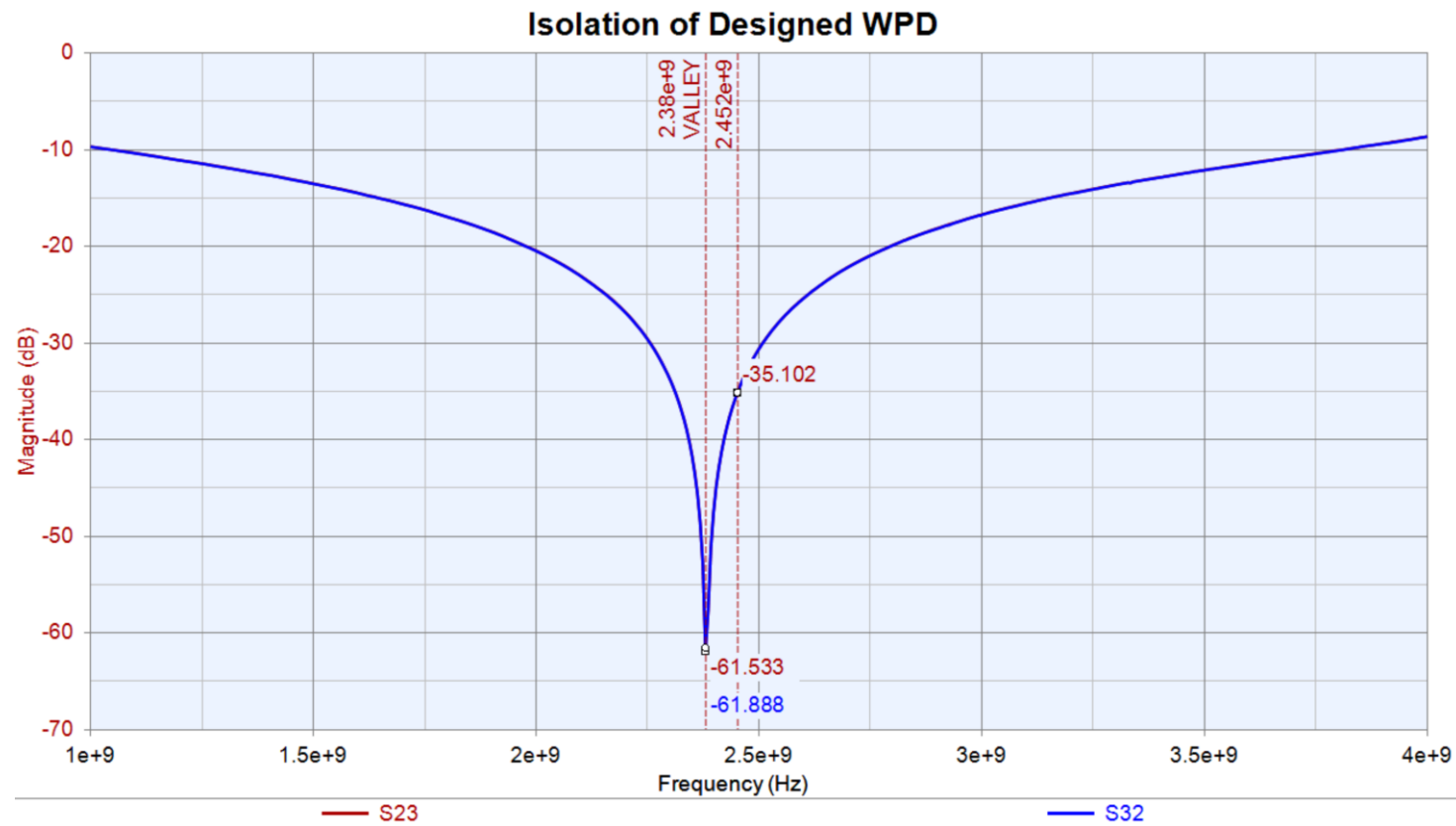
RESULT (TRANSMISSION)

- Roughly half power (i.e. -3dB)

Transmission of Designed WPD
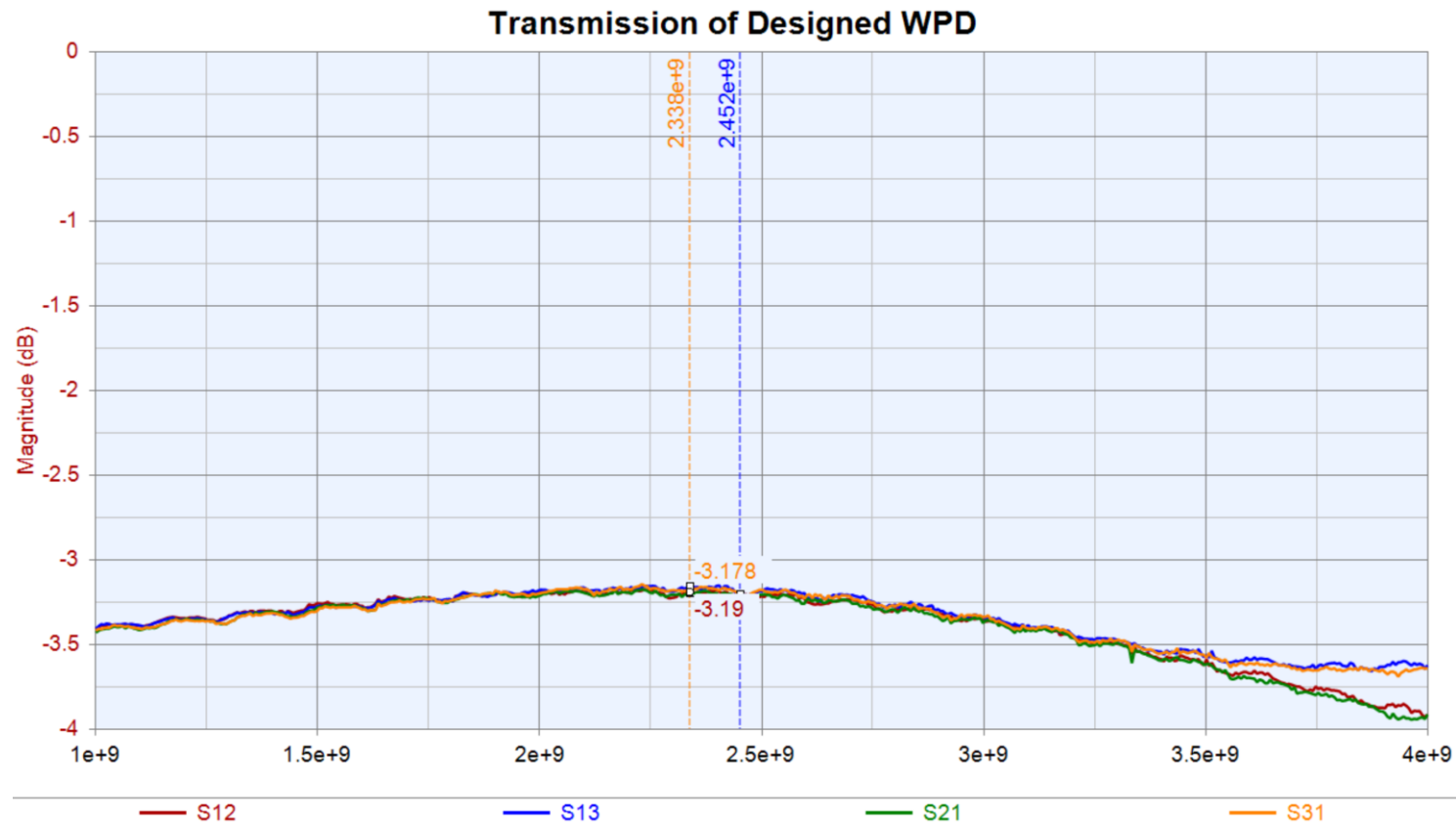
HFSS VS VNA RESULT
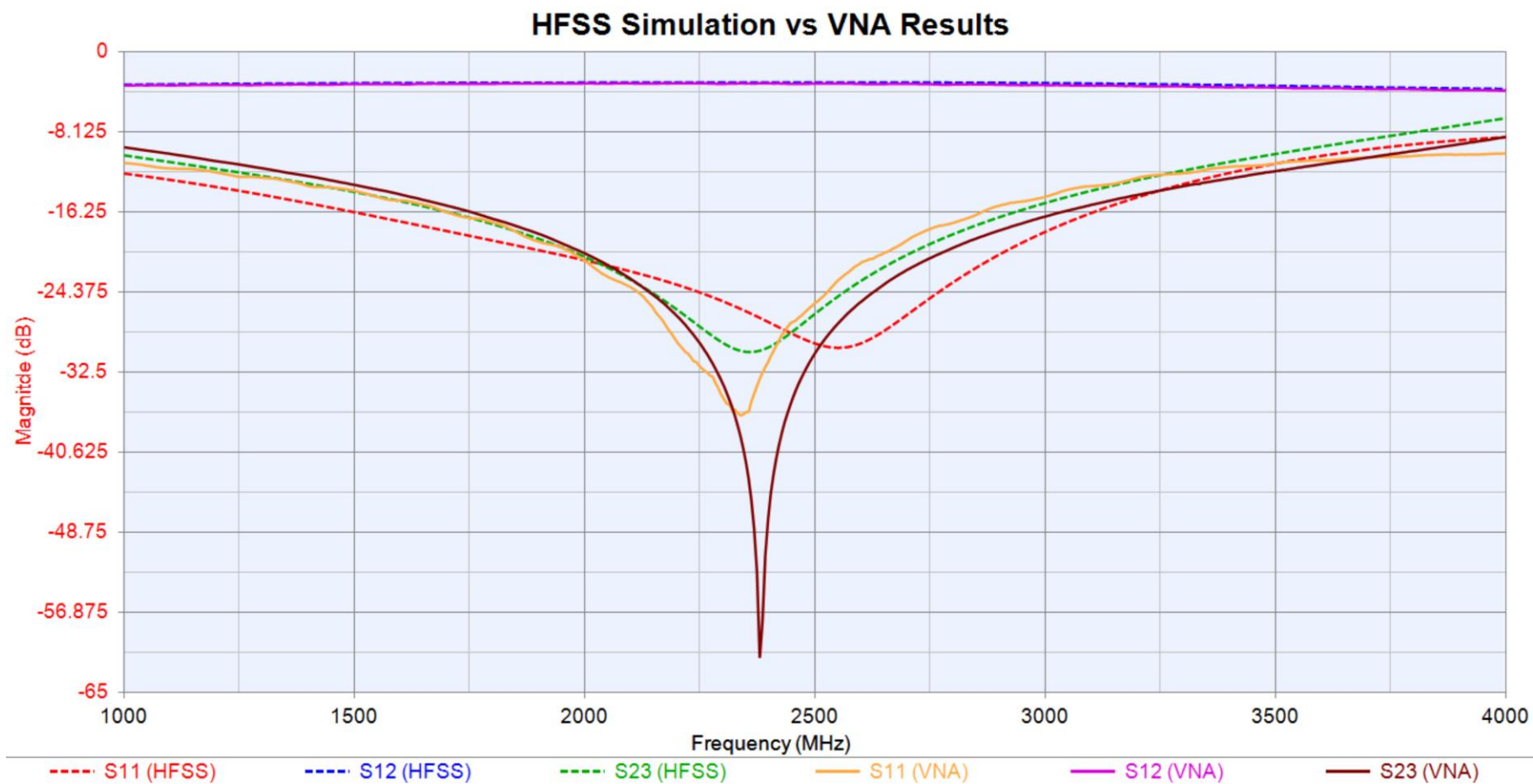
POSSIBLE IMPROVEMENTS

- Coupling issues from taper in design

- Drum off quarter wavelength to match 2.45 more closely

FURTHER DEVELOPMENTS

- Power Capabilities

  o *N-Way Power Divider/Combiner Suitable for High-Power Applications,* U.H. Gysel '75

- Increased Bandwidth

  o *Design of an Ultra-wideband Wilkinson Power Divider,* B.Mishra '07

- High Frequency Applications

  o *Modified Wilkinson Power Dividers for Millimeter Wave Integrated Circuits,* S. Horst...
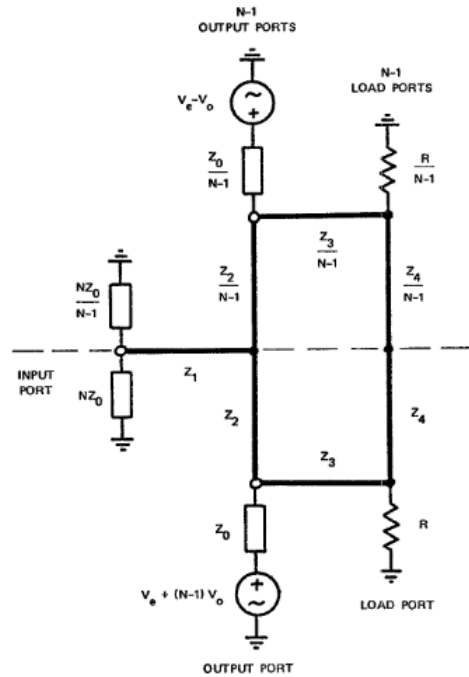
FIGURE 2. EQUIVALENT FOUR-PORT FOR THE N-WAY COMBINER
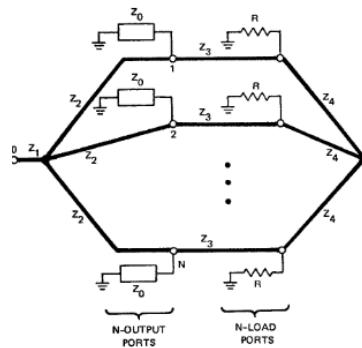
1 HIGH-POWER N-WAY DIVIDER/COMBINER
(all transmission lines are a quarter-wavelength long at midband)

INCREASED POWER

- Wilkinsons Design:
  - Low insertion loss, high isolation, matched conditions
  - Power handling limited by internal loads

- Shunt connected loads
  - Loads are external, can use high-power elements

- Power-handling limited by:
  - Breakdown voltage of TL
  - Heat-dissipation capacity

- Realizable in miscrostrip

INCREASED BANDWIDTH

- Wilkinson's Design:

  o 20 percent band

- Binomial multi-section matching transformer

- Ultra-wideband

  o 3.1 - 10.6 GHz

- Isolation between outputs greatly improved vs. WPD

- Generally, the number of sections is given by:

  o ratio of low end of frequency range to center

(a) $W_1 = 2.204$ mm, $W_2 = 1.254$ mm, $L_1 = 5$ mm, $L_2 = 7.0675$ mm, $W = 13$ mm, $L = 20$ mm, $R = 100$ Ω

(b) $W_1 = 2.204$ mm, $W_2 = 0.9$ mm, $W_3 = 1.682$ mm, $L_0 = 5$ mm, $L_1 = L_2 = 7.0675$ mm, $W = 13$ mm, $L = 24$ mm, $R_1 = 100$ Ω, $R_2 = 184$ Ω

(c) $W_1 = 2.204$ mm, $W_2 = 0.75$ mm, $W_3 = 1.254$ mm, $W_4 = 1.932$ mm, $L_0 = 5$ mm, $L_1 = L_2 = L_3 = 7.0675$ mm, $W = 13$ mm, $L = 32$ mm, $R_1 = 100$ Ω, $R_2 = 184$ Ω, $R_3 = 145$ Ω

Fig. 3 Geometry of the microstrip WPD using (a) single (b) two and (c) three sections

INCREASED CENTER FREQUENCY
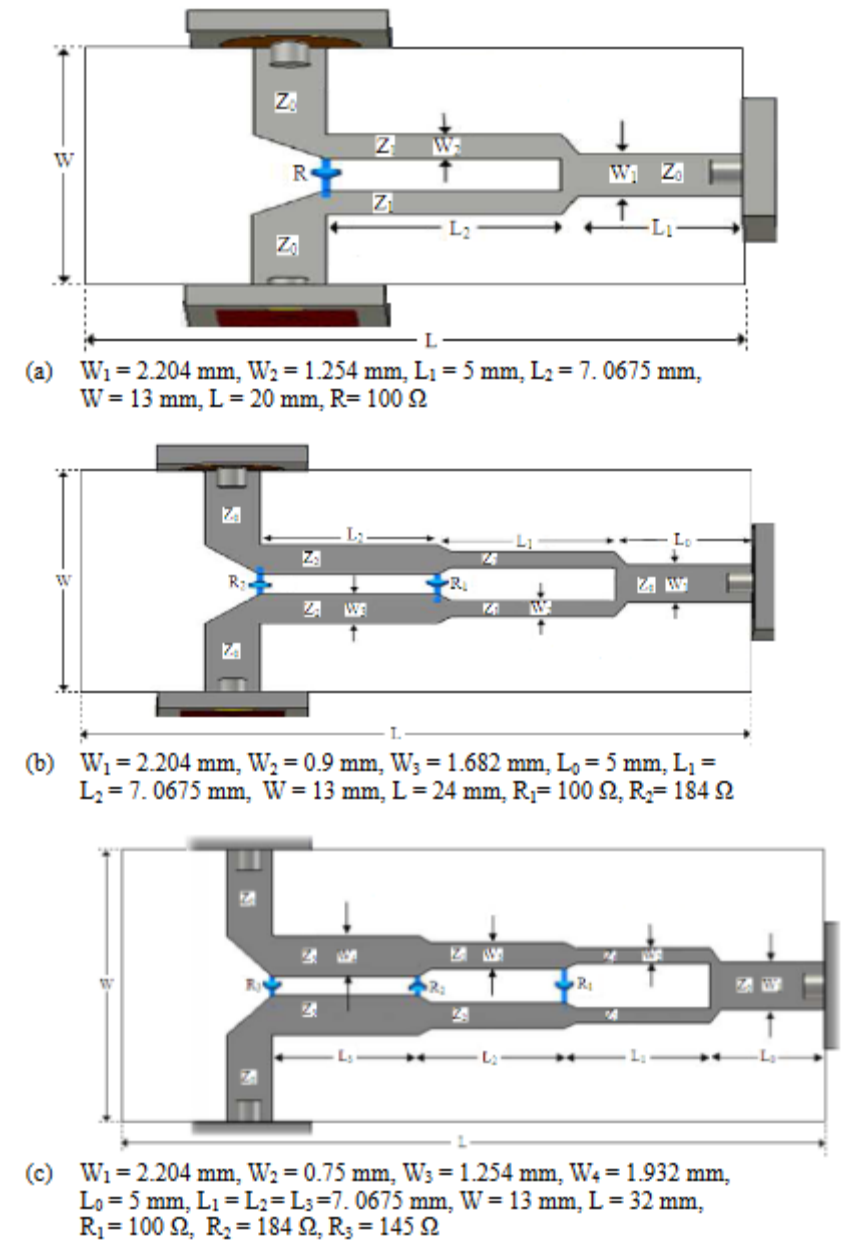

Fig. 2. Proposed modification of the Wilkinson design.
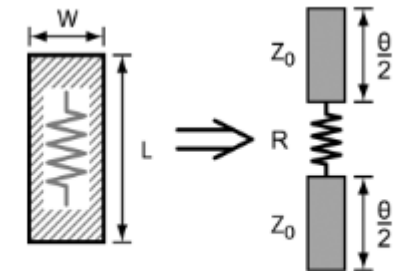
Fig. 5. Equivalent high-frequency model of an integrated resistor used in the proposed design.

- Wilkinsons Design:
  - Low insertion loss, high isolation, matched conditions
  - Center frequency ~500 MHz

- Originally designed for shielded coax systems
  - Parasitic effects of geometric inconsistencies negligible

- RF and mmWave designs require precision layouts

- Additional TL elements Increases spacing reduce coupling

- Standard Wilkinson divider good below 10 GHz

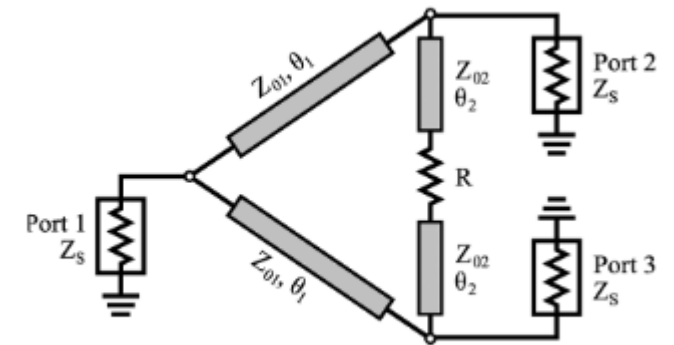- Underdetermined system of equations gives range of solutions

$$z_{01} = z_{02}$$

$$r = z_{02}^2$$

$$\theta_2 = \tan^{-1}\left(\sqrt{1 - \frac{r}{2}}\right)$$

$$\theta_1 = \frac{\pi}{2} + \theta_2.$$

RESOURCES

- [1] D. M. Pozar, *Microwave engineering*. Hoboken, Nj: Wiley, 2012.

- [2] E. J. Wilkinson, "An N-Way Hybrid Power Divider," in IRE Transactions on Microwave Theory and Techniques, vol. 8, no. 1, pp. 116-118, January 1960, doi: 10.1109/TMTT.1960.1124668.

- [3]"Microwaves101 | Circulators," Microwaves101.com, 2024. https://www.microwaves101.com/encyclopedias/circulators (accessed Jun. 04, 2024).

- [4] R. F. Harrington and Ieee Antennas And Propagation Society, Field computation by moment methods. Piscataway, Nj: Ieee Press, 1993.

- [5] *"Wilkinson Power Splitters," Microwaves101.com, 2019.* *https://www.microwaves101.com/encyclopedias/wilkinson-power-splitters*

- [6] B. Mishra, A. Rahman, S. Shaw, M. Mohd, S. Mondal and P. P. Sarkar, "Design of an ultra-wideband Wilkinson power divider," *2014 First International Conference on Automation, Control, Energy and Systems (ACES)*, Adisaptagram, India, 2014

- [7] S. Horst, R. Bairavasubramanian, M. M. Tentzeris and J. Papapolymerou, "Modified Wilkinson Power Dividers for Millimeter-Wave Integrated Circuits," in *IEEE Transactions on Microwave Theory and Techniques*, vol. 55, no. 11, pp. 2439-2446, Nov. 2007