

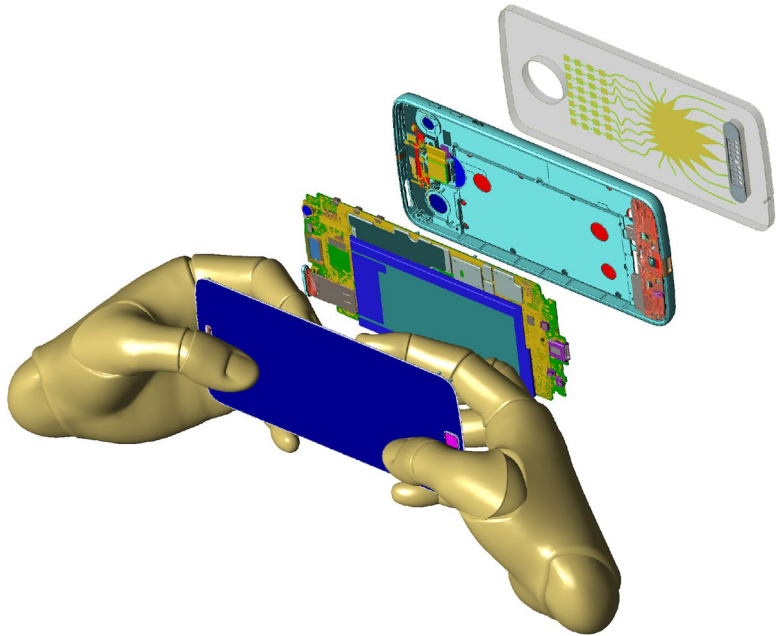


Electromagnetic Simulation Software

Impedance Tuner Matching

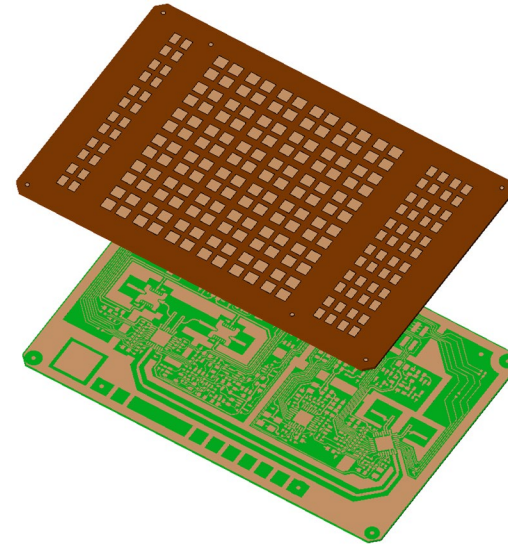
Overview of XFDTD's schematic editor

XFDTD Full-Wave Simulation



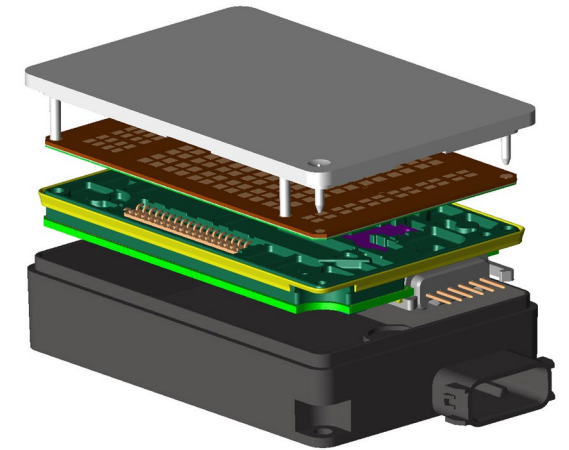
Cellular Phone

- LTE antennas w/ carrier aggregation
- Diversity, WiFi, BlueTooth, GPS antennas
- 5G FR2 in mmWave bands
- Compliance testing for human exposure (SAR)



Automotive Radar

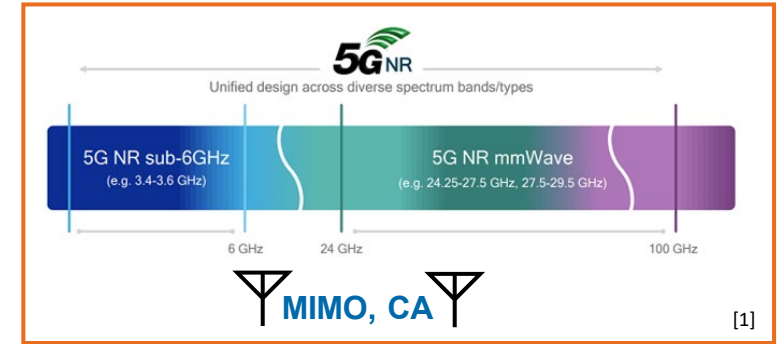
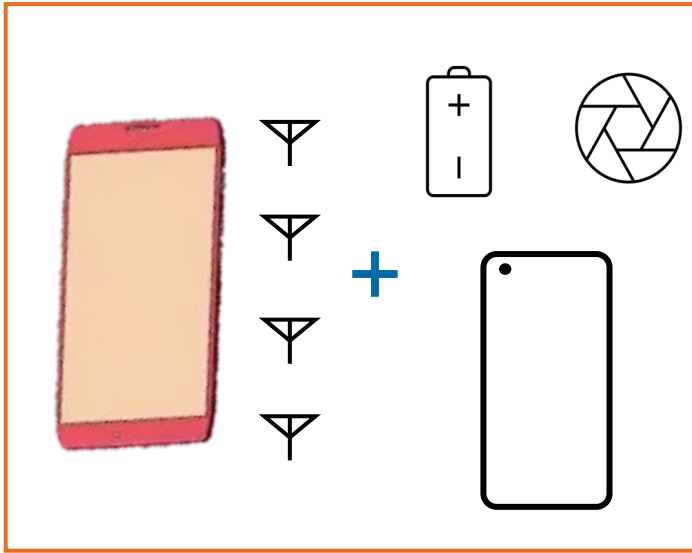
- 24-81 GHz bands
- Antenna, feeding network, LO design and coupling
- Radome, mounting bracket, fascia attenuation analysis



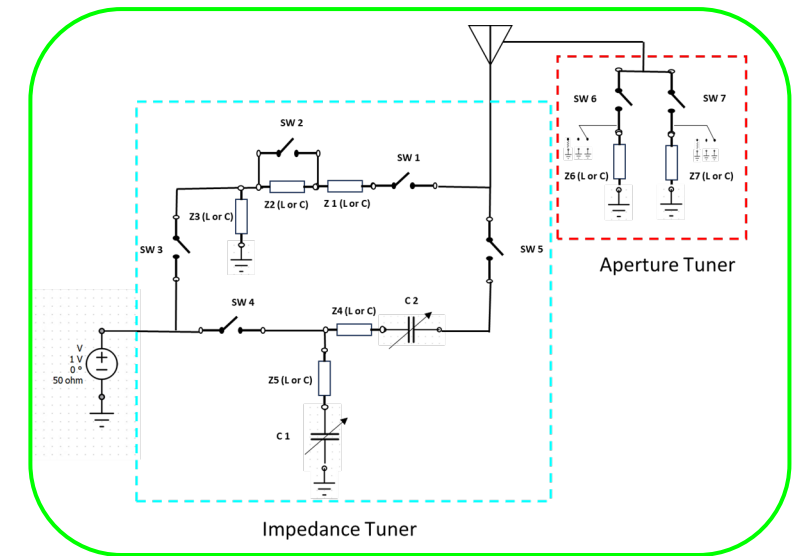
Optimizations in the Schematic Editor

Bands & Standards

Industrial Design



Impedance and Aperture Tuner



Additional Bands + Modern Industrial Designs + Device States = Necessitates the need for tuners

*Motorola Mobility provided the 3-D CAD model of the phone, which was then modified for demonstration purposes to include an external floating antenna

[1] <https://www.rfpage.com/what-are-5g-frequency-bands/>



What's New in XFtd?

- Incorporated particle swarm optimizer directly into our schematic editor allowing us to optimize fixed component types and values as well as the tune codes associated with specific goals and operating modes.
- The optimizer can optimize on a variety of antenna/RF metrics such as return loss, isolation between ports, and system efficiency.



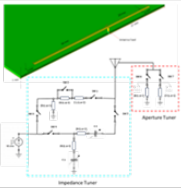
Example Project Summary

- Simple DILA Antenna Structure
- Employ impedance and aperture tuners implemented as subcircuits in the overall matching circuit for the antenna
- Using new optimizations we'll get a matching circuit allowing for different cellular bands of operation
- The operating modes in our example will be different cellular frequency bands

Workflow for Matching Network of DILA Antenna


Step 0

Determine Antenna and Circuit Topology




Step 1

Use the Circuit Topology To Guide the Layout



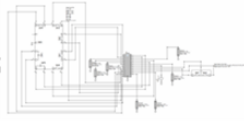
Step 2

XFDTD Simulation of the Antenna and PCB Layout




Step 3

Employ SE to Construct Schematic which includes XF Data, Impedance and Aperture Tuners, and Fixed Components




Step 4

Use SEO to Optimize The Types and Values of Fixed Components and the Tune Codes of the Tuners

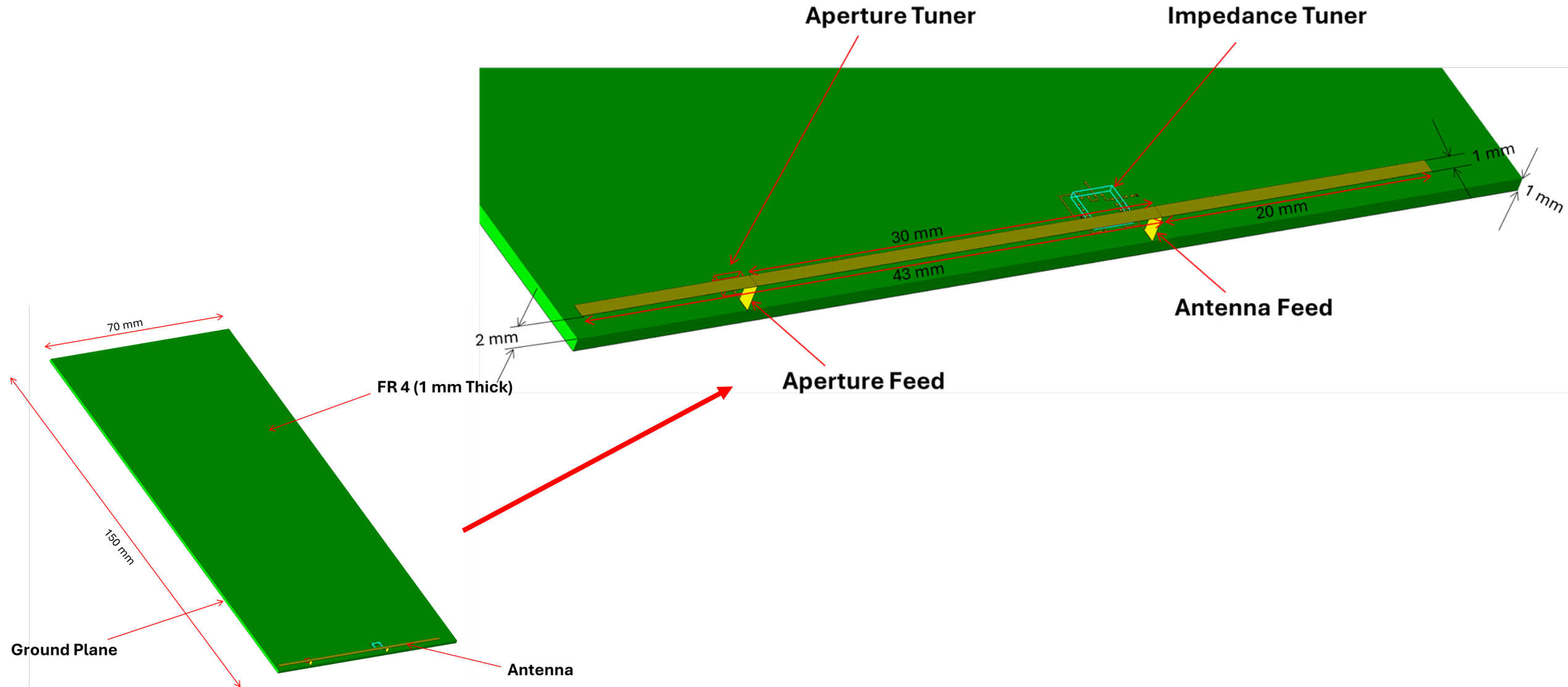


Step 5

Review The Optimized Results !



Device and Antenna with Tuners



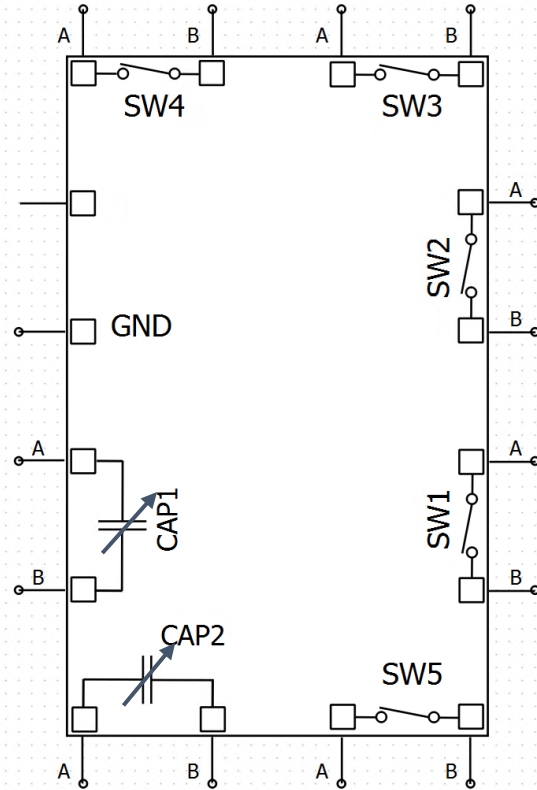
Impedance Tuner Subcircuit

Tunable Capacitor Configuration

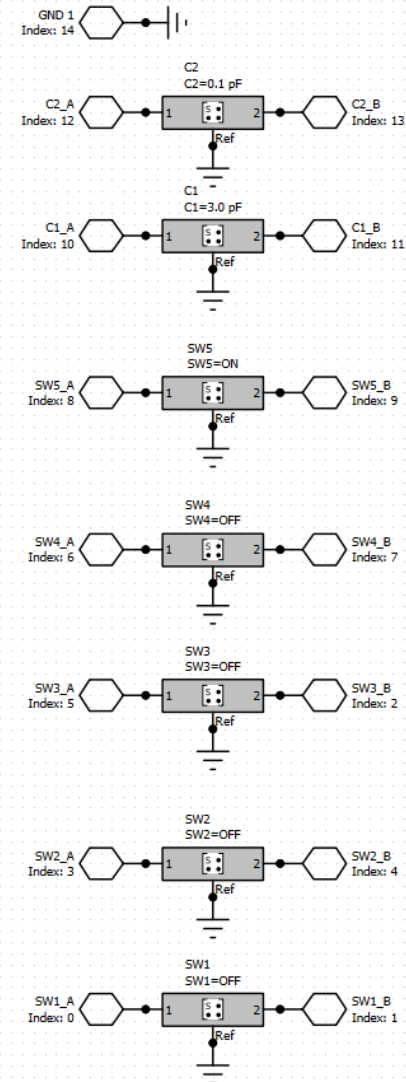
Switch Configuration

Tune Code

Generic Tuner Beta
 C1 = 3.0 pF
 C2 = 0.1 pF
 Register 1 = 0x10
 Register 2 = 0x11
 Register 3 = 0x00
 SW1 = OFF
 SW2 = OFF
 SW3 = OFF
 SW4 = OFF
 SW5 = ON
 Tune Code = 10 11 00

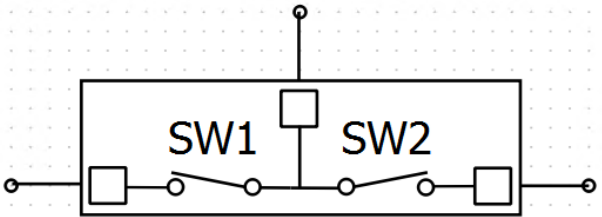


Impedance Tuner Subcircuit



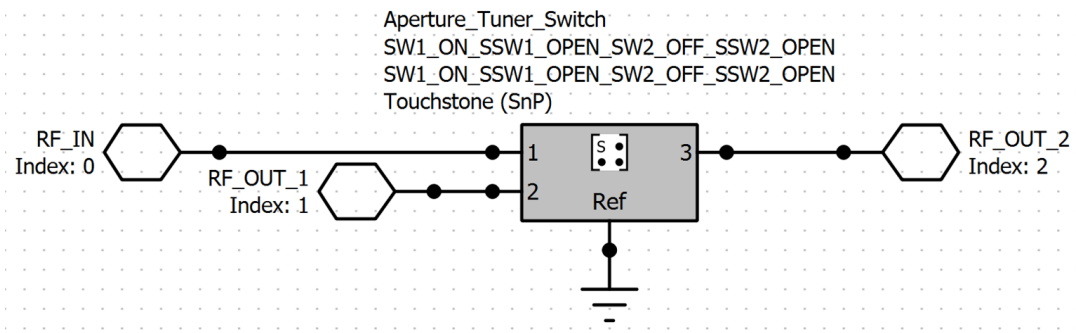
Lower Level of the Subcircuit
 Containing the Underlying S-
 Parameter Data
 (Measured or Simulated)

Aperture Tuner Subcircuit



Generic Aperture Tuner Switch
Aperture_Tuner_Switch = SW1_ON_SSW1_OPEN_SW2_OFF_SSW2_OPEN
Register Aperture Tuner Switch = 0x0D

Aperture Tuner Subcircuit

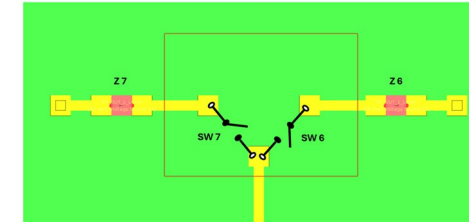
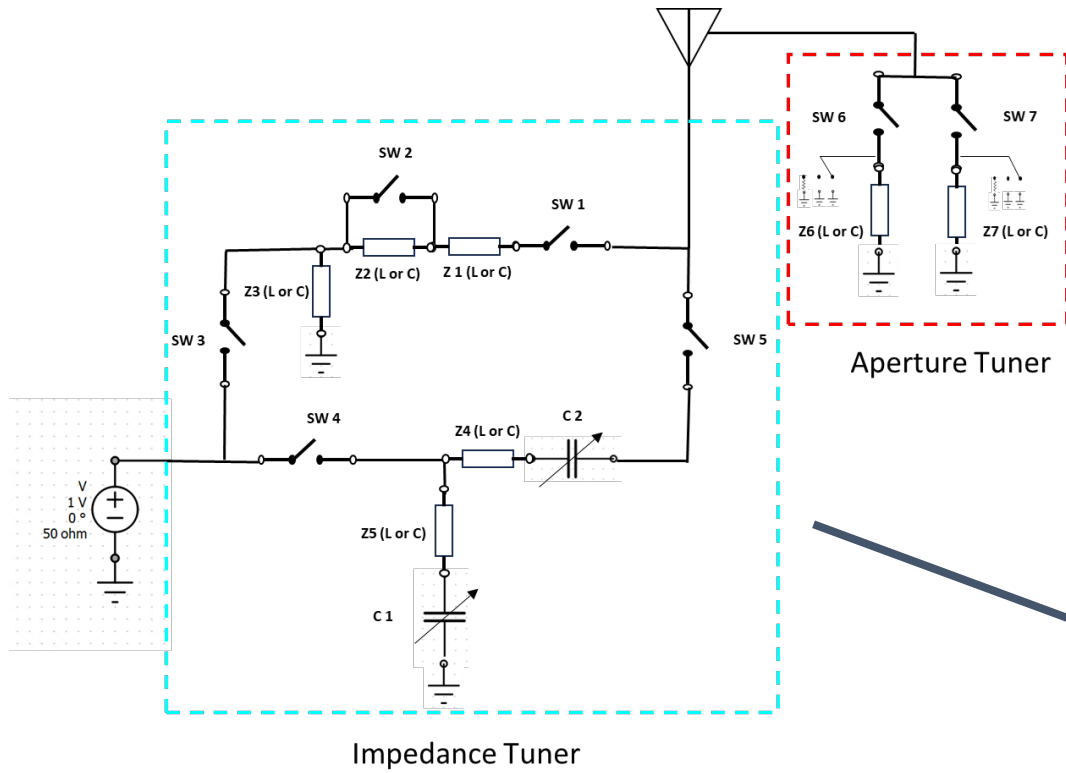


Lower Level of the Subcircuit
Containing the Underlying
3 Port S-Parameter Data

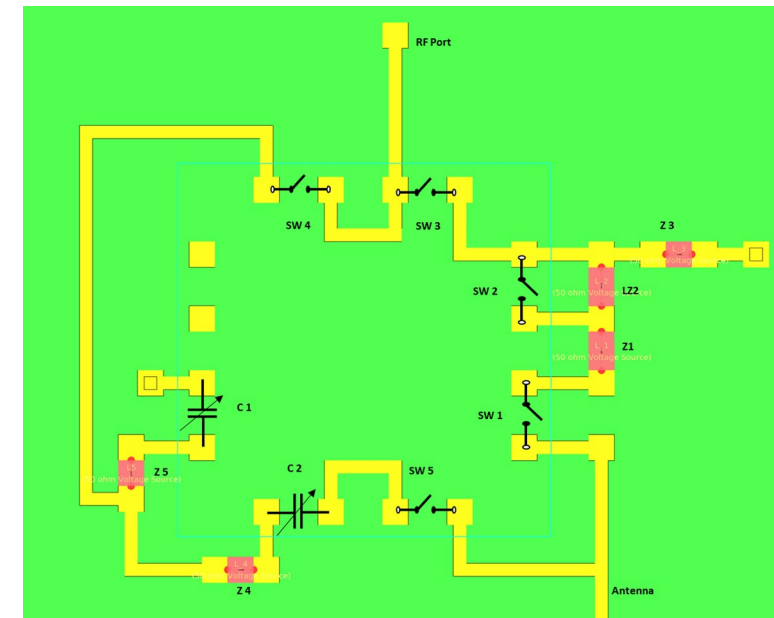


Step 1 Layout

Step 1 Layout in XFDTD



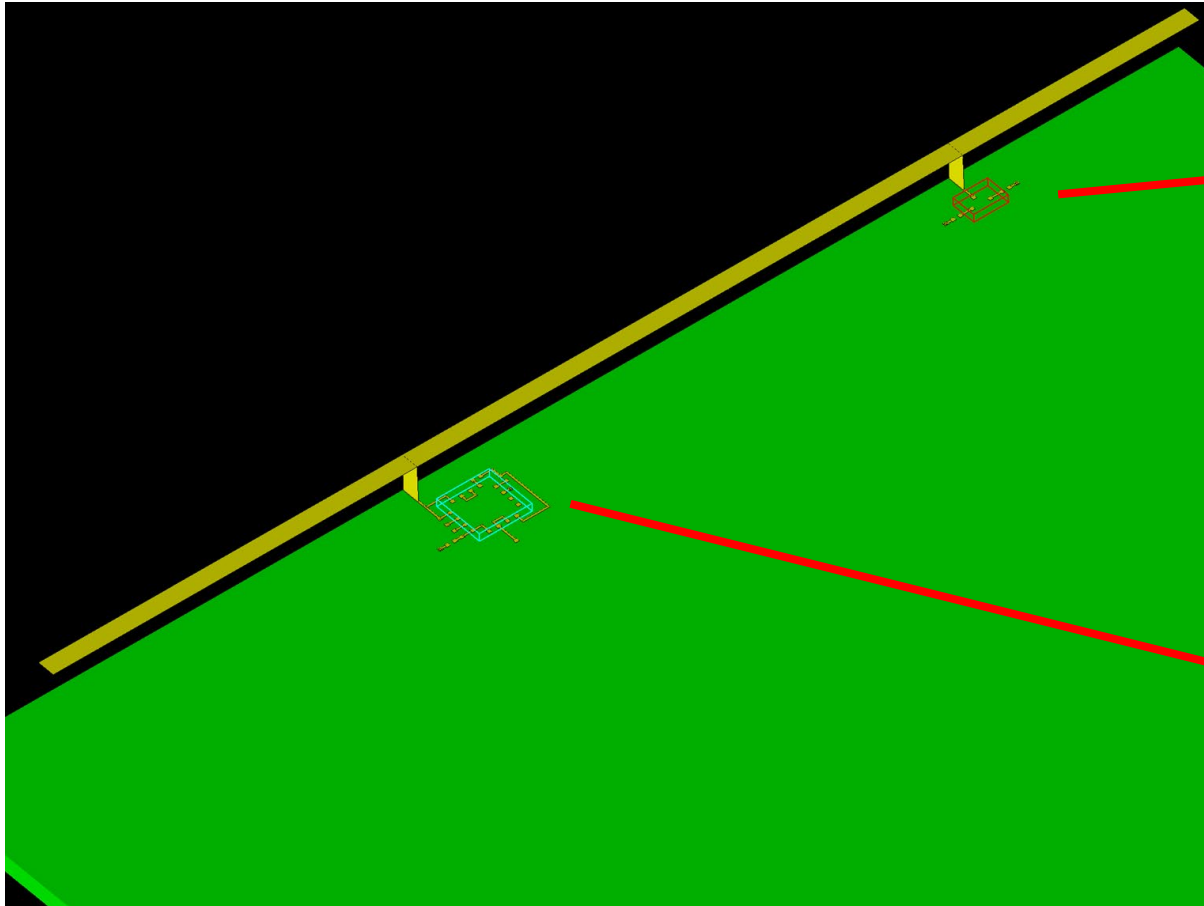
Aperture Tuner Layout



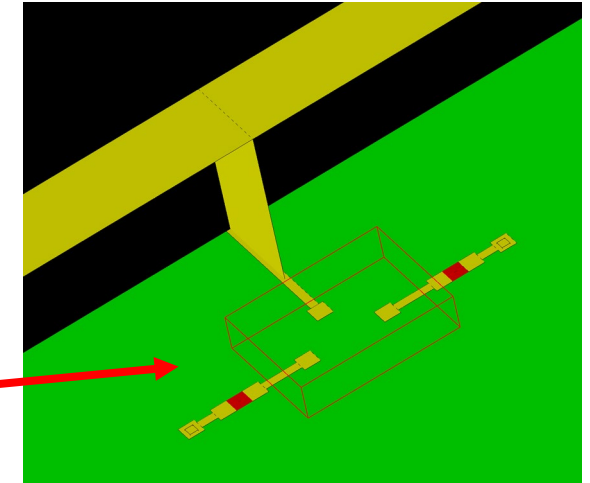
Impedance Tuner Layout

Step 1 Matching Network Layout Details and Antenna

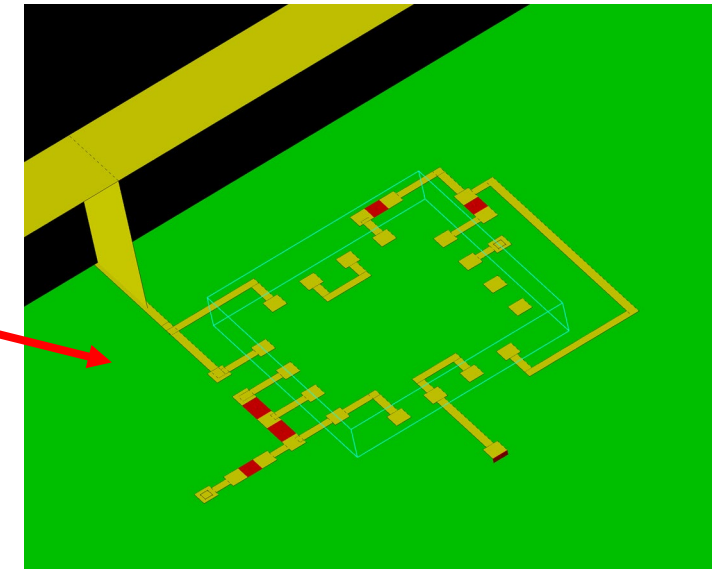
Pads and transmission lines connect all matching network components



Aperture Tuner Layout



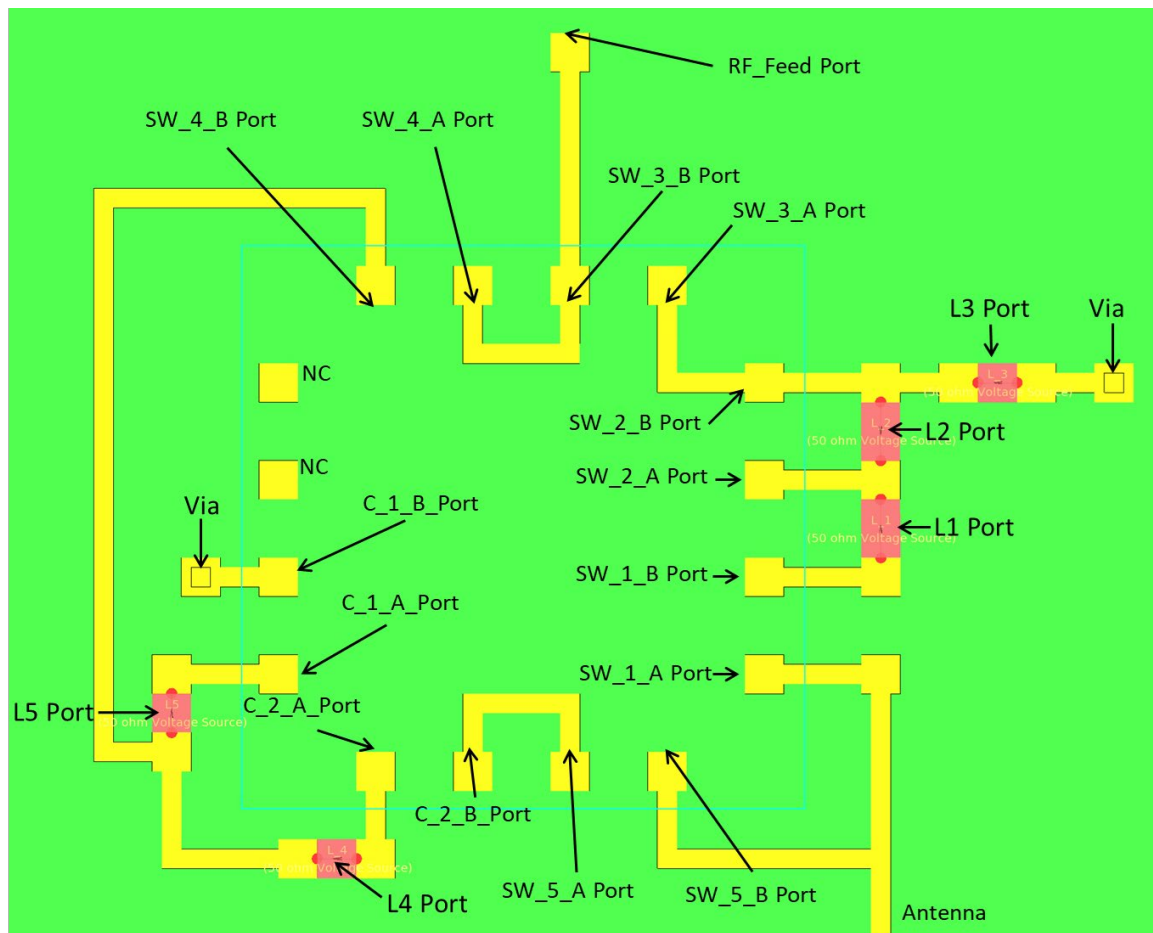
Impedance Tuner Layout



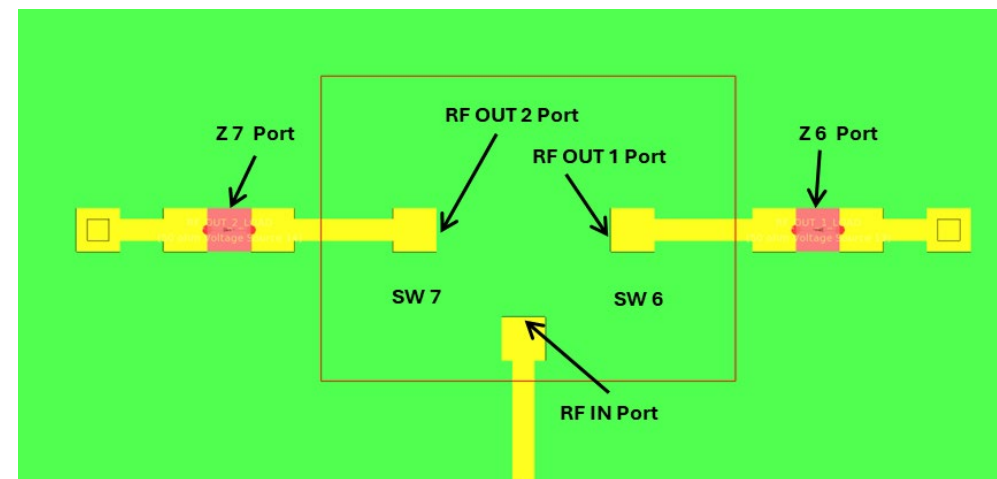


Step 2 XFdtd Simulation

Step 2 Port Details of the Impedance Tuner Layout



Port Details of the Impedance Tuner Layout



Port Details of the Aperture Tuner Layout

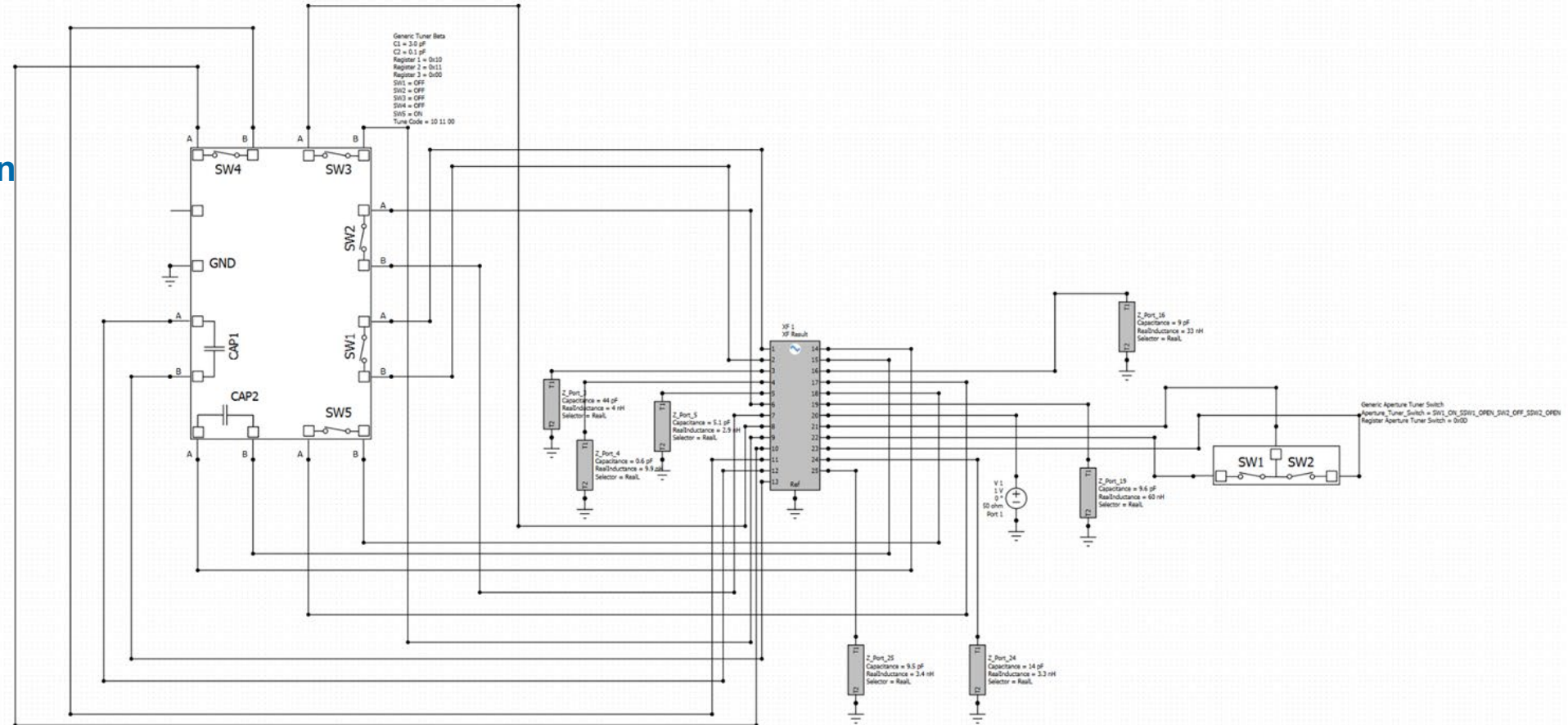


Step 3 Schematic Editor

Step 3 Schematic Editor

Schematic Includes:

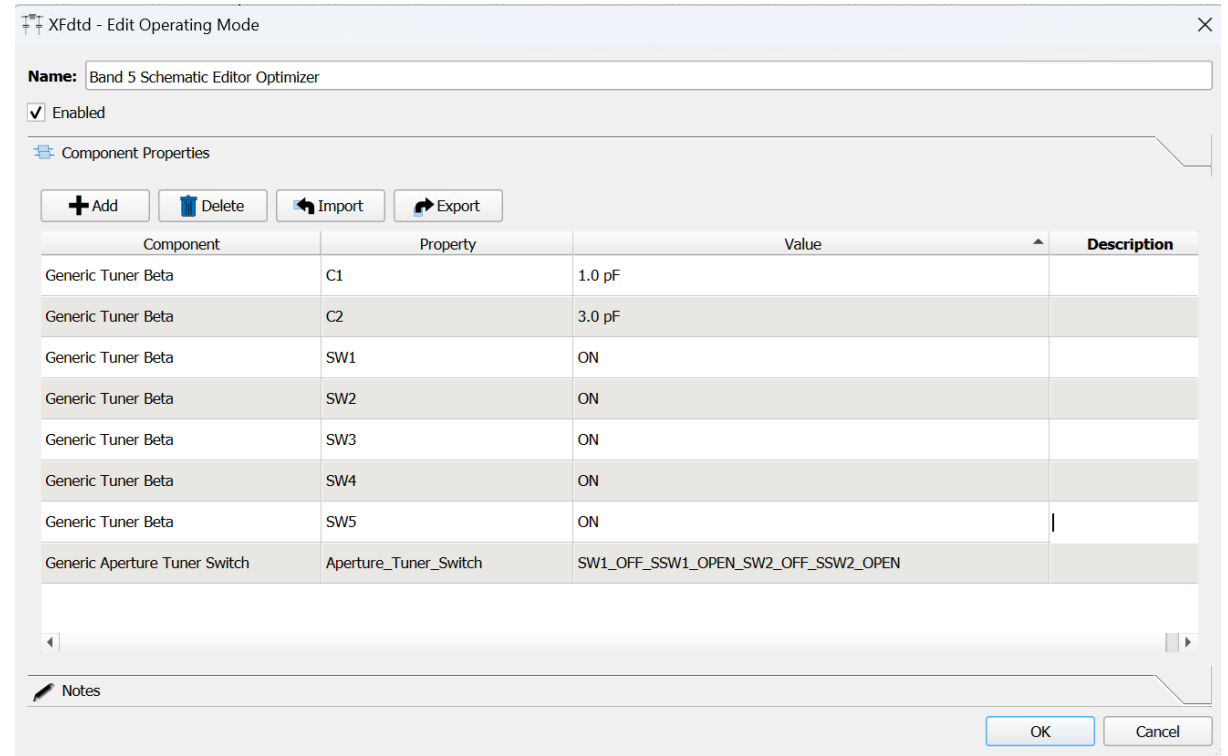
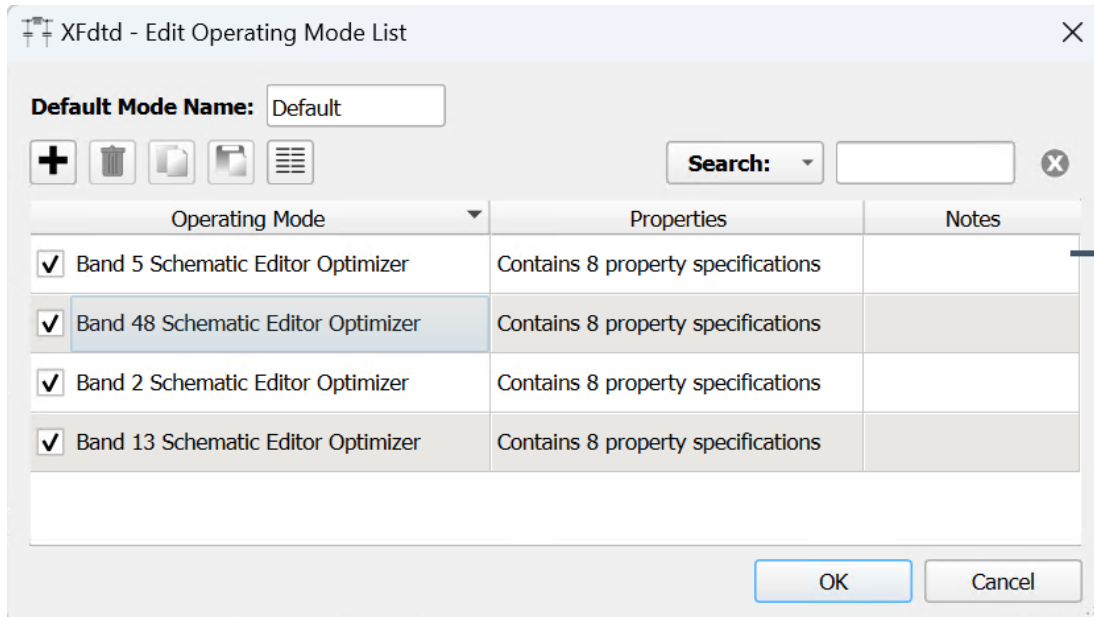
- 25-port FDTD Simulation
- Impedance Tuner
- Aperture Tuner
- 7 Fixed L or C Components





Step 4 Schematic Editor Optimizer

Step 4 Define Operating Modes



Step 4 Configure Goals on Operating Modes

XFtdt - Design Goals

Data Detail Show Only Enabled Search:

| Name | Result | Evaluation | Target Bounds | Samples | Method | Weight | Goal Report Pass/Fail |
|---------------------------|---------------------------|-----------------------|------------------|---------------------------------------|-----------------|--------|-----------------------|
| Band 5 UL System ... | Band 5 Schematic Edit... | $\epsilon_s > -6$ dBp | [-7 dBp, -5 dBp] | 5 samples in [0.824 GHz, 0.84... | Center Weighted | 1 | 0 / 5 (0.00 %) |
| Band 5 DL System ... | Band 5 Schematic Edit... | $\epsilon_s > -6$ dBp | [-7 dBp, -5 dBp] | 5 samples in [0.869 GHz, 0.89... | Center Weighted | 1 | 0 / 5 (0.00 %) |
| Band 48 System Efficiency | Band 48 Schematic Edit... | $\epsilon_s > -3$ dBp | [-4 dBp, -2 dBp] | 10 samples in [3.55 GHz, 3.7 ... | Center Weighted | 1 | 6 / 4 (60.00 %) |
| Band 2 UL System ... | Band 2 Schematic Edit... | $\epsilon_s > -3$ dBp | [-4 dBp, -2 dBp] | 5 samples in [1.85 GHz, 1.91 GHz] ... | Center Weighted | 1 | 0 / 5 (0.00 %) |
| Band 2 DL System ... | Band 2 Schematic Edit... | $\epsilon_s > -3$ dBp | [-4 dBp, -2 dBp] | 5 samples in [1.93 GHz, 1.99 GHz] ... | Center Weighted | 1 | 0 / 5 (0.00 %) |
| Band 13 UL System ... | Band 13 Schematic Edit... | $\epsilon_s > -6$ dBp | [-7 dBp, -5 dBp] | 5 samples in [0.777 GHz, 0.78... | Center Weighted | 1 | 3 / 2 (60.00 %) |
| Band 13 DL System ... | Band 13 Schematic Edit... | $\epsilon_s > -6$ dBp | [-7 dBp, -5 dBp] | 5 samples in [0.746 GHz, 0.75... | Center Weighted | 1 | 2 / 3 (40.00 %) |

Select the goal(s) to edit

OK Cancel



XFtdt - Design Goals

Data Detail Show Only Enabled Search:

| Name | Result | Evaluation | Target Bounds | Samples | Method | Weight | Goal Report Pass/Fail |
|----------------------|--------------------------|-----------------------|------------------|----------------------------------|-----------------|--------|-----------------------|
| Band 5 UL System ... | Band 5 Schematic Edit... | $\epsilon_s > -6$ dBp | [-7 dBp, -5 dBp] | 5 samples in [0.824 GHz, 0.84... | Center Weighted | 1 | 0 / 5 (0.00 %) |

Name: Band 5 UL System Efficiency Enable Goal

Quantity Analysis: AC Analysis

Operating Mode: Band 5 Schematic Editor Optimizer

Sensor: XF 1

Result: System Efficiency

Part: Not Complex

OK Cancel



Name: Band 5 UL System Efficiency Enable Goal

Quantity

General

Weight: 1

Method: Center Weighted

Comparison: > (Greater Than)

Target

Target Type: Value

Unit: decibels (power)

Target: -6 dBp

Min Bound: -7 dBp

Max Bound: -5 dBp

Sampling

Source: Frequency Band

Application: Legacy

Category: Response Matrix

Band Name: [S B5,CDMA BCD]

Link Type: Uplink

Min: 0.824 GHz

Max: 0.849 GHz

Samples: 5

OK Cancel

Step 4 Configure Particle Swarm Optimizer

Name: Generic Tuner Beta Generic Aperture Tuner

Workspace Solver Settings Results

Frequency Sweep Settings

Start Frequency: 0.5 GHz

Stop Frequency: 5 GHz

Number of Points: 7001

Sweep Type: Linear Logarithmic

Optimization Analysis Settings

Specify number of particles manually

Specify number of particles per variable

Number of Particles: 100

Particles Per Variable: 10

Max Iterations: 50000

Advanced

Neighborhood Size: 5

Number of Predators: 10

CVT

Human Behavior

Details of the Particle Swarm Optimizer

PSO Execution

XFtdt - Schematic Optimization

Automatically apply values

Start Stop

Optimization Progress:

Best Fitness: 0.871756 (0.00 %)

Goals Evaluated: 7/7

Goals Passed:

| Name | Success | Passed |
|---------------------------|---------|--------|
| Band 13 DL System ... | 40.00% | 2 3 |
| Band 13 UL System ... | 60.00% | 3 2 |
| Band 2 DL System ... | 0.00% | 0 5 |
| Band 2 UL System ... | 0.00% | 0 5 |
| Band 48 System Efficiency | 60.00% | 6 4 |
| Band 5 DL System ... | 0.00% | 0 5 |
| Band 5 UL System ... | 0.00% | 0 5 |

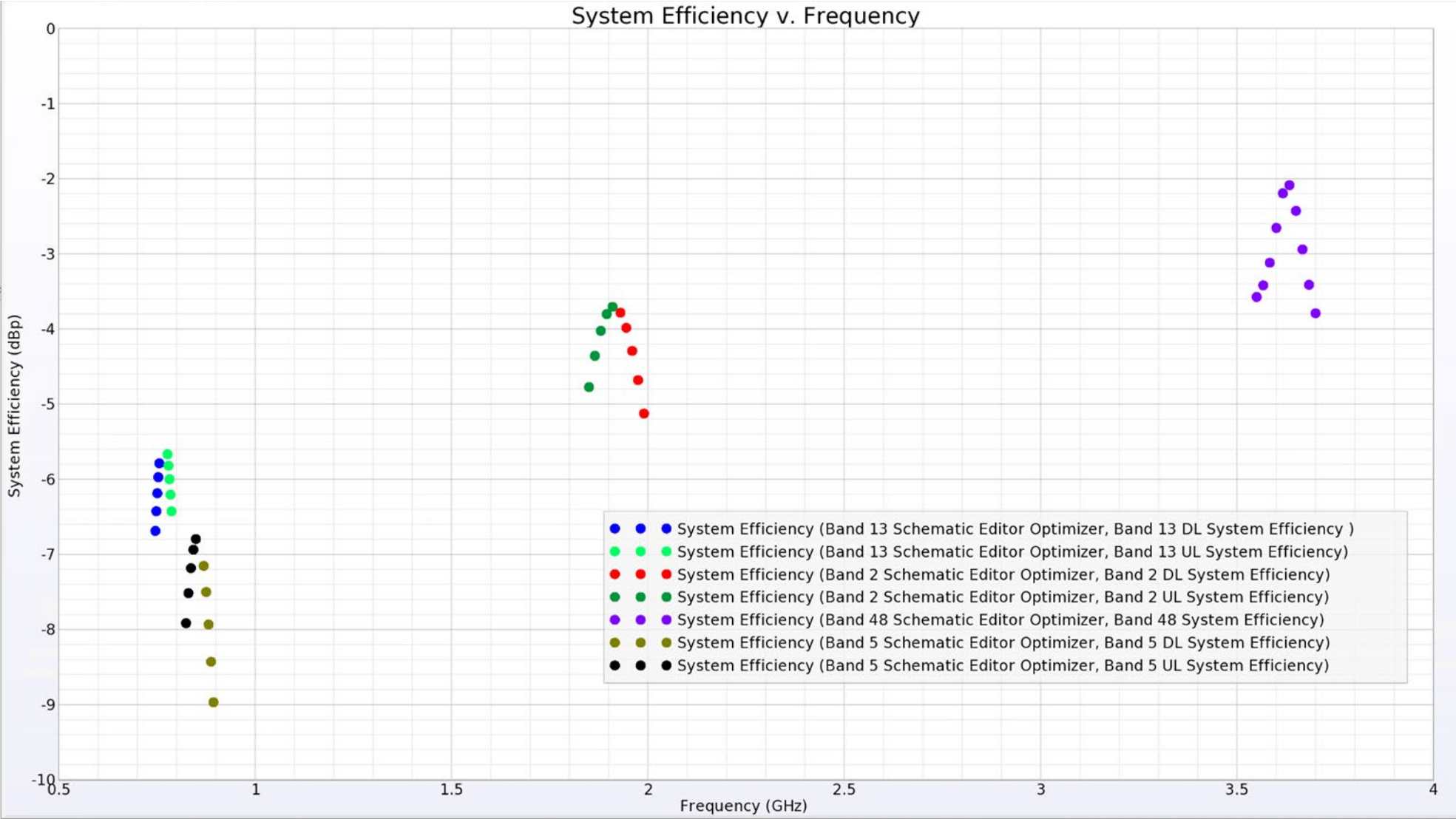
Optimizer output

```
Checking input schematic validity...
Extracting properties for analysis...
Preloading schematic data...
Performing initial solve...
Initializing particle swarm...
Swarm initialized with 980 particles and 10000 generations...
Optimizing...
Finished generation 1 / 10000 fitness: 0.871756
Finished generation 2 / 10000 fitness: 0.871756
Finished generation 3 / 10000 fitness: 0.871756
Finished generation 4 / 10000 fitness: 0.871756
```



Step 5 Review Results

Step 5 Optimized System Efficiency Results



Step 5 Tune Codes and Fixed Component Values

XFtd - Schematic Operating Modes Detailed Info

Show All Properties Fill Default Values

| Operating Mode | Tuner Beta | Capacitor | Inductor | SW1 | SW2 | Generic Aperture Tuner Switch | SW1 | SW2 | Register 1 | Register 2 | Register 3 | Generic Tuner Beta Tune Code (dependent) | Generic Aperture Tuner Switch Register | Aperture Tuner Switch (dependent) |
|------------------------------------|------------|-----------|----------|-----|-----|---------------------------------------|-----|-----|------------|------------|------------|--|--|-----------------------------------|
| Band 5 Schematic Editor Optimizer | ON | 3.0 pF | 1.4 pF | ON | ON | SW1_OFF_SSW1_OPEN_SW2_OFF_SSW2_OPEN | ON | ON | 0x1f | 0x0d | 0x11 | 1f 0d 11 | | 0x05 |
| Band 48 Schematic Editor Optimizer | ON | 3.0 pF | 3.0 pF | ON | ON | SW1_OFF_SSW1_OPEN_SW2_OFF_SSW2_OPEN | ON | OFF | 0x1e | 0x11 | 0x11 | 1e 11 11 | | 0x05 |
| Band 13 Schematic Editor Optimizer | ON | 3.0 pF | 3.0 pF | ON | OFF | SW1_OFF_SSW1_SHORT_SW2_OFF_SSW2_SHORT | ON | ON | 0x1d | 0x11 | 0x11 | 1d 11 11 | | 0x0A |
| Default (Default) | ON | 0.1 pF | 3.0 pF | OFF | OFF | SW1_ON_SSW1_OPEN_SW2_OFF_SSW2_OPEN | OFF | OFF | 0x10 | 0x11 | 0x00 | 10 11 00 | | 0x0D |
| Band 2 Schematic Editor Optimizer | ON | 3.0 pF | 3.0 pF | OFF | ON | SW1_ON_SSW1_OPEN_SW2_ON_SSW2_OPEN | ON | ON | 0x17 | 0x11 | 0x11 | 17 11 11 | | 0x0F |

Done



Push Schematic to XF Simulation

- As long as the simulation is set up properly, we only have to run one XF simulation.
- We can push the schematic back onto our previously run XF simulation to determine quantities such as envelope correlation coefficients, far field patterns, near field results such as SAR.
- By use of the superposition principle these data can be determined from the previously run XF simulation.
- Allows users to quickly post process the full-wave results in the presence of the circuit.

Contact



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Email:

sales@remcom.com

support@remcom.com

Website:

www.remcom.com/contact

support.remcom.com





Backup Slides

LC Definitions

Allowable component values

| Component | Property | Current | Enabled | Continuity | Analyze | Values |
|-------------------------------|-----------------------|------------------------------------|---------|------------|---------|---|
| GND 6 | EnabledState | Enabled | false | Discrete | Auto | All values (Enabled, Disabled (Open)) |
| Z_Port_3 | EnabledState | Enabled | false | Discrete | Auto | All values (Enabled, Disabled (Short), Disabled (Open)) |
| Z_Port_3 | Capacitance | 44 pF | true | Discrete | Custom | 140 values ([0.1 pF : 10 pF : 0.1 pF], [11 pF : 50 pF : 1 pF]) |
| Z_Port_3 | RealInductance | 4 nH | true | Discrete | Custom | 150 values ([0.1 nH : 10 nH : 0.1 nH], [11 nH : 60 nH : 1 nH]) |
| Z_Port_3 | Selector | Reall | true | Discrete | Auto | All values (C, Reall) |
| GND 2 | EnabledState | Enabled | false | Discrete | Auto | All values (Enabled, Disabled (Open)) |
| GND 5 | EnabledState | Enabled | false | Discrete | Auto | All values (Enabled, Disabled (Open)) |
| GND 7 | EnabledState | Enabled | false | Discrete | Auto | All values (Enabled, Disabled (Open)) |
| GND 3 | EnabledState | Enabled | false | Discrete | Auto | All values (Enabled, Disabled (Open)) |
| GND 1 | EnabledState | Enabled | false | Discrete | Auto | All values (Enabled, Disabled (Open)) |
| Z_Port_4 | EnabledState | Enabled | false | Discrete | Auto | All values (Enabled, Disabled (Short), Disabled (Open)) |
| Z_Port_4 | Capacitance | 0.6 pF | true | Discrete | Custom | 140 values ([0.1 pF : 10 pF : 0.1 pF], [11 pF : 50 pF : 1 pF]) |
| Z_Port_4 | RealInductance | 9.9 nH | true | Discrete | Custom | 150 values ([0.1 nH : 10 nH : 0.1 nH], [11 nH : 60 nH : 1 nH]) |
| Z_Port_4 | Selector | Reall | true | Discrete | Auto | All values (C, Reall) |
| Z_Port_5 | EnabledState | Enabled | false | Discrete | Auto | All values (Enabled, Disabled (Short), Disabled (Open)) |
| Z_Port_5 | Capacitance | 5.1 pF | true | Discrete | Custom | 140 values ([0.1 pF : 10 pF : 0.1 pF], [11 pF : 50 pF : 1 pF]) |
| Z_Port_5 | RealInductance | 2.9 nH | true | Discrete | Custom | 150 values ([0.1 nH : 10 nH : 0.1 nH], [11 nH : 60 nH : 1 nH]) |
| Z_Port_5 | Selector | Reall | true | Discrete | Auto | All values (C, Reall) |
| Z_Port_16 | EnabledState | Enabled | false | Discrete | Auto | All values (Enabled, Disabled (Short), Disabled (Open)) |
| Z_Port_16 | Capacitance | 9 pF | true | Discrete | Custom | 140 values ([0.1 pF : 10 pF : 0.1 pF], [11 pF : 50 pF : 1 pF]) |
| Z_Port_16 | RealInductance | 33 nH | true | Discrete | Custom | 150 values ([0.1 nH : 10 nH : 0.1 nH], [11 nH : 60 nH : 1 nH]) |
| Z_Port_16 | Selector | Reall | true | Discrete | Auto | All values (C, Reall) |
| XF 1 | ActiveDataName | XF Result | false | Discrete | Auto | All values (XF Result) |
| XF 1 | EnabledState | Enabled | false | Discrete | Auto | All values (Enabled, Disabled (Open)) |
| GND | EnabledState | Enabled | false | Discrete | Auto | All values (Enabled, Disabled (Open)) |
| Z_Port_25 | EnabledState | Enabled | false | Discrete | Auto | All values (Enabled, Disabled (Short), Disabled (Open)) |
| Z_Port_25 | Capacitance | 9.5 pF | true | Discrete | Custom | 140 values ([0.1 pF : 10 pF : 0.1 pF], [11 pF : 50 pF : 1 pF]) |
| Z_Port_25 | RealInductance | 3.4 nH | true | Discrete | Custom | 150 values ([0.1 nH : 10 nH : 0.1 nH], [11 nH : 60 nH : 1 nH]) |
| Z_Port_25 | Selector | Reall | true | Discrete | Auto | All values (C, Reall) |
| Z_Port_24 | EnabledState | Enabled | false | Discrete | Auto | All values (Enabled, Disabled (Short), Disabled (Open)) |
| Z_Port_24 | Capacitance | 14 pF | true | Discrete | Custom | 140 values ([0.1 pF : 10 pF : 0.1 pF], [11 pF : 50 pF : 1 pF]) |
| Z_Port_24 | RealInductance | 3.3 nH | true | Discrete | Custom | 150 values ([0.1 nH : 10 nH : 0.1 nH], [11 nH : 60 nH : 1 nH]) |
| Z_Port_24 | Selector | Reall | true | Discrete | Auto | All values (C, Reall) |
| GND 8 | EnabledState | Enabled | false | Discrete | Auto | All values (Enabled, Disabled (Open)) |
| GND 9 | EnabledState | Enabled | false | Discrete | Auto | All values (Enabled, Disabled (Open)) |
| V 1 | Amplitude | 1 V | false | Continuous | Auto | Values in range [0.5 V, 1.5 V] |
| V 1 | EnabledState | Enabled | false | Discrete | Auto | All values (Enabled, Disabled (Short), Disabled (Open)) |
| V 1 | Phase | 0 ° | false | Continuous | Auto | Values in range [0 °, 360 °] |
| V 1 | SourceActive | true | false | Discrete | Auto | {true, false} |
| V 1 | SourceResistance | 50 ohm | false | Continuous | Auto | Values in range [25 ohm, 75 ohm] |
| Z_Port_19 | EnabledState | Enabled | false | Discrete | Auto | All values (Enabled, Disabled (Short), Disabled (Open)) |
| Z_Port_19 | Capacitance | 9.6 pF | true | Discrete | Custom | 140 values ([0.1 pF : 10 pF : 0.1 pF], [11 pF : 50 pF : 1 pF]) |
| Z_Port_19 | RealInductance | 60 nH | true | Discrete | Custom | 150 values ([0.1 nH : 10 nH : 0.1 nH], [11 nH : 60 nH : 1 nH]) |
| Z_Port_19 | Selector | Reall | true | Discrete | Auto | All values (C, Reall) |
| Generic Tuner Beta | EnabledState | Enabled | false | Discrete | Auto | All values (Enabled, Disabled (Open)) |
| Generic Tuner Beta | C1 | 3.0 pF | true | Discrete | Auto | All values (0.1 pF, 0.2 pF, 0.3 pF, 0.4 pF, 0.5 pF, 0.6 pF, 0.7 pF, 0.8 pF, 0.9 pF, 1.0 pF, 1.1 pF, 1.2 pF, 1.3 pF, 1.4 pF, 1.5 pF, 2.0 pF, 2.5 pF, 3.0 pF) |
| Generic Tuner Beta | C2 | 0.1 pF | true | Discrete | Auto | All values (0.1 pF, 0.2 pF, 0.3 pF, 0.4 pF, 0.5 pF, 0.6 pF, 0.7 pF, 0.8 pF, 0.9 pF, 1.0 pF, 1.1 pF, 1.2 pF, 1.3 pF, 1.4 pF, 1.5 pF, 2.0 pF, 2.5 pF, 3.0 pF) |
| Generic Tuner Beta | SW1 | OFF | true | Discrete | Auto | All values (OFF, ON) |
| Generic Tuner Beta | SW2 | OFF | true | Discrete | Auto | All values (OFF, ON) |
| Generic Tuner Beta | SW3 | OFF | true | Discrete | Auto | All values (OFF, ON) |
| Generic Tuner Beta | SW4 | OFF | true | Discrete | Auto | All values (OFF, ON) |
| Generic Tuner Beta | SWS | ON | true | Discrete | Auto | All values (OFF, ON) |
| GND 4 | EnabledState | Enabled | false | Discrete | Auto | All values (Enabled, Disabled (Open)) |
| Generic Aperture Tuner Switch | EnabledState | Enabled | false | Discrete | Auto | All values (Enabled, Disabled (Open)) |
| Generic Aperture Tuner Switch | Aperture_Tuner_Switch | SW1_ON_SSW1_OPEN_SW2_OFF_SSW2_OPEN | false | Discrete | Auto | All values (SW1_OFF_SSW1_LOAD_SW2_OFF_SSW2_LOAD, ..., SW1_ON_SSW1_OPEN_SW2_ON_SSW2_OPEN) |

Select the definition(s) to edit

Design Goals

List of design goals

XFtdt - Design Goals

+ [trash] [copy] [paste]

Data Detail [eye] Show Only Enabled Search: [input] [x]

| Name | Result | Evaluation | Target Bounds | Samples | Method | Weight | Goal Report Pass/Fail |
|---------------------------|---------------------------|-----------------------|------------------|---------------------------------------|-----------------|--------|-----------------------|
| Band 5 UL System ... | Band 5 Schematic Edit... | $\epsilon_s > -6$ dBp | [-7 dBp, -5 dBp] | 5 samples in [0.824 GHz, 0.84... | Center Weighted | 1 | 0 / 5 (0.00 %) |
| Band 5 DL System ... | Band 5 Schematic Edit... | $\epsilon_s > -6$ dBp | [-7 dBp, -5 dBp] | 5 samples in [0.869 GHz, 0.89... | Center Weighted | 1 | 0 / 5 (0.00 %) |
| Band 48 System Efficiency | Band 48 Schematic Edit... | $\epsilon_s > -3$ dBp | [-4 dBp, -2 dBp] | 10 samples in [3.55 GHz, 3.7 ... | Center Weighted | 1 | 6 / 4 (60.00 %) |
| Band 2 UL System ... | Band 2 Schematic Edit... | $\epsilon_s > -3$ dBp | [-4 dBp, -2 dBp] | 5 samples in [1.85 GHz, 1.91 GHz] ... | Center Weighted | 1 | 0 / 5 (0.00 %) |
| Band 2 DL System ... | Band 2 Schematic Edit... | $\epsilon_s > -3$ dBp | [-4 dBp, -2 dBp] | 5 samples in [1.93 GHz, 1.99 GHz] ... | Center Weighted | 1 | 0 / 5 (0.00 %) |
| Band 13 UL System ... | Band 13 Schematic Edit... | $\epsilon_s > -6$ dBp | [-7 dBp, -5 dBp] | 5 samples in [0.777 GHz, 0.78... | Center Weighted | 1 | 3 / 2 (60.00 %) |
| Band 13 DL System ... | Band 13 Schematic Edit... | $\epsilon_s > -6$ dBp | [-7 dBp, -5 dBp] | 5 samples in [0.746 GHz, 0.75... | Center Weighted | 1 | 2 / 3 (40.00 %) |

Select the goal(s) to edit

OK Cancel

Optimized Fixed Components

