REMCOM®

Electromagnetic Simulation Software

Time Domain EM/Circuit Co-Simulation

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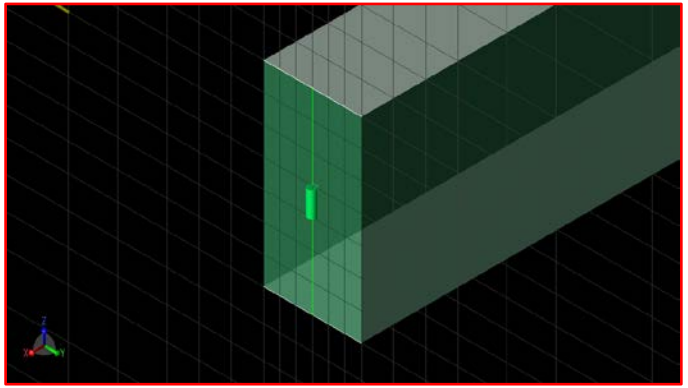
Overview

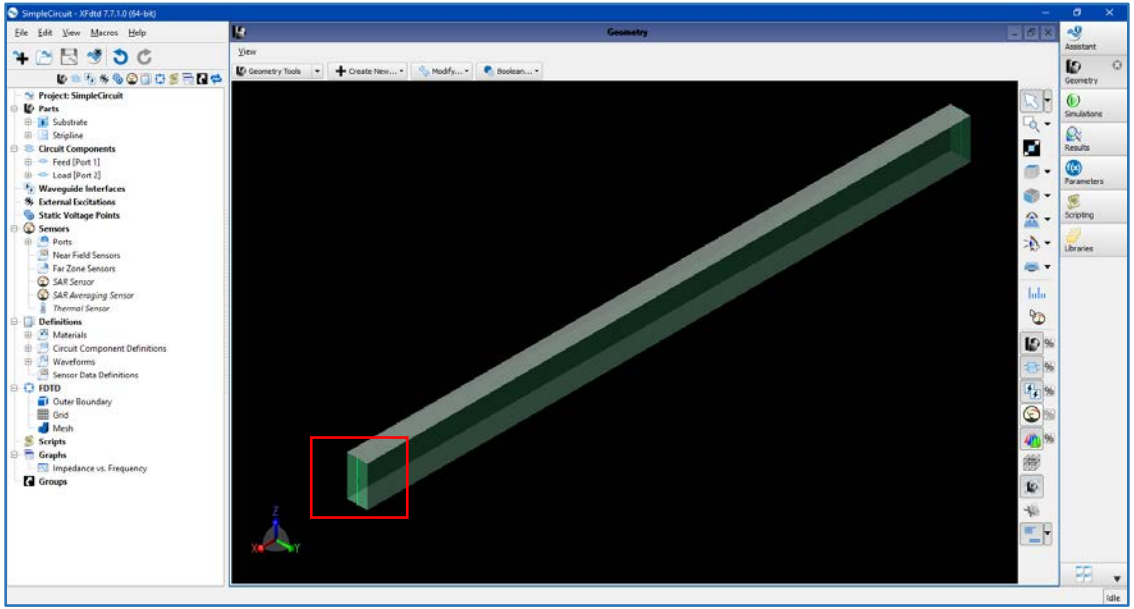
1. Lumped Circuit Elements in XFdtd® Electromagnetic Simulation Software
2. XFdtd/Circuit Co-Simulation
3. Simple Antenna Matching
4. WiFi/WiMAX Multiband Matching
5. Conclusions

Lumped Circuit Elements in XFdtd

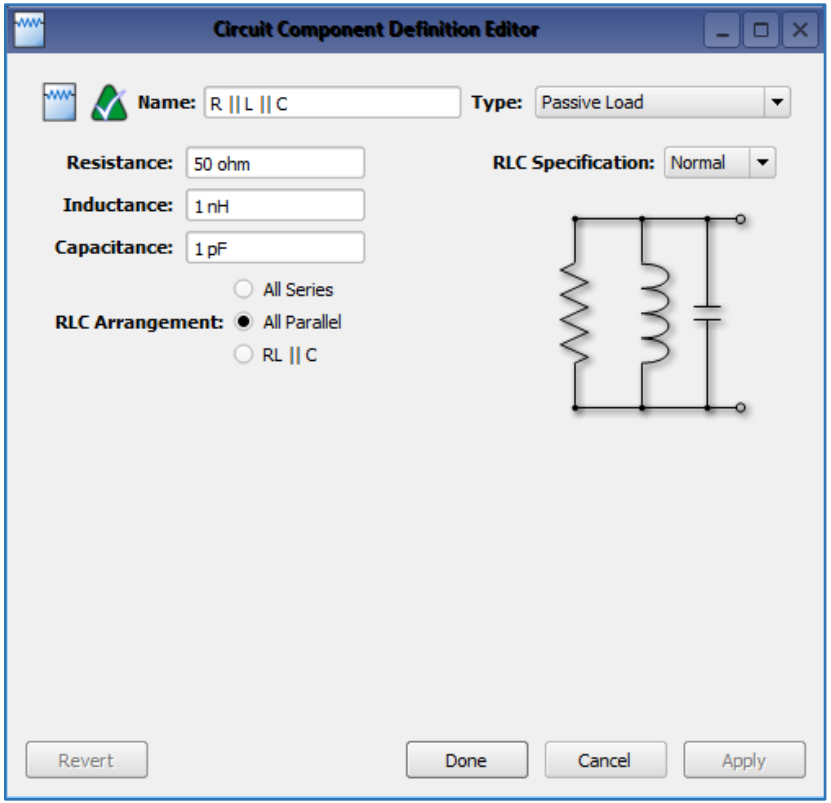
Time domain EM software packages have supported simple RLC configurations for many years.



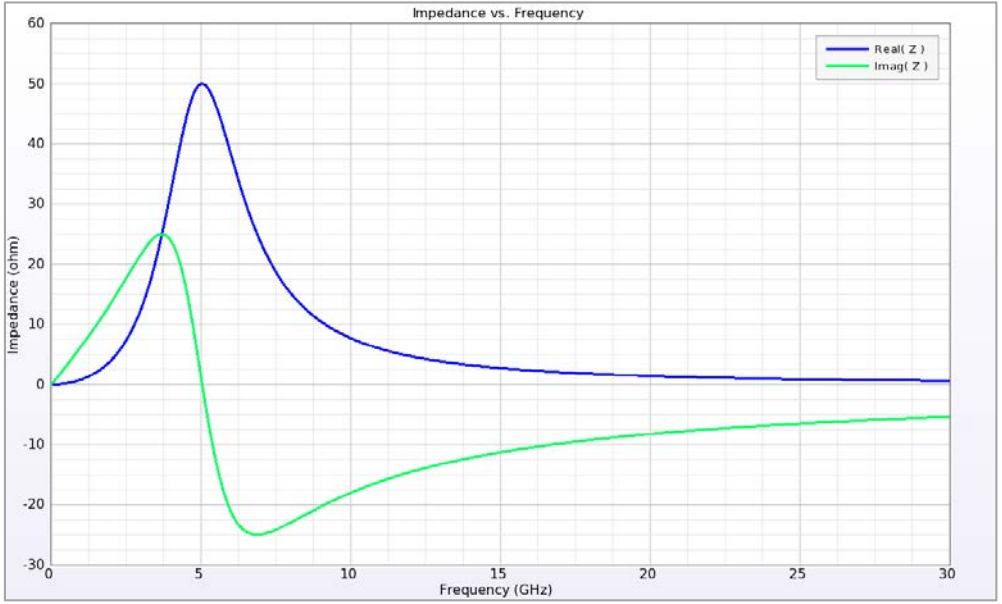
Lumped element occupies one FDTD cell edge.



Lumped Circuit Elements in XFdtd



Simple passive load in XFdtd.



XFdtd/Circuit Co-Simulation

Norton Equivalent Circuit of FDTD/Circuit Interface

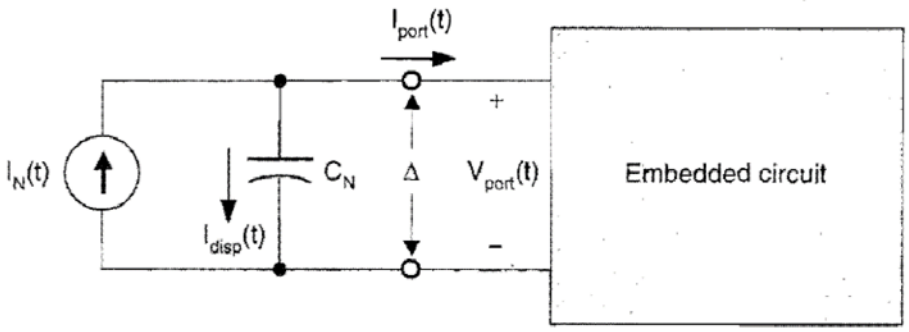
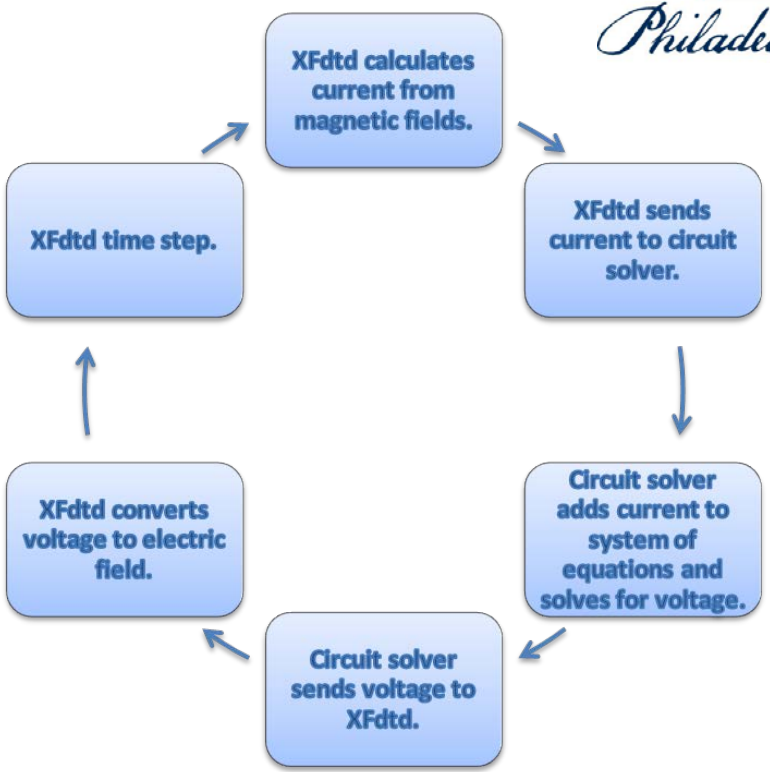
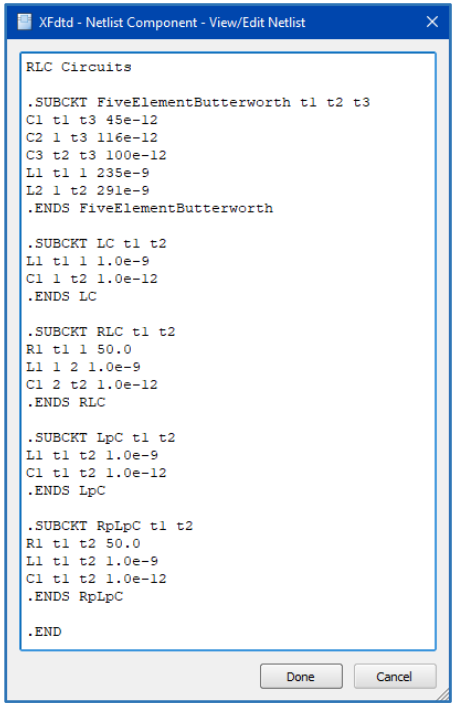


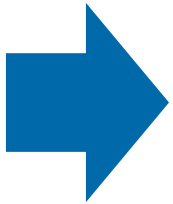
Fig. 15.16 from Taflove, A., and S. C. Hagness, *Computational Electrodynamics: The Finite-Difference Time-Domain Method*, 3rd ed., Norwood, MA: Artech House, 2005.

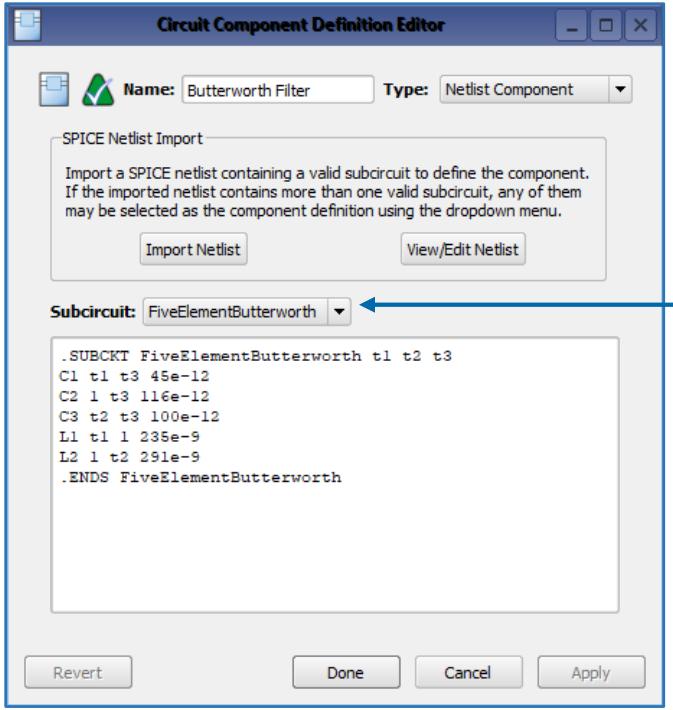


XFdtd/Circuit Co-Simulation

Import Spice3 format netlist files.



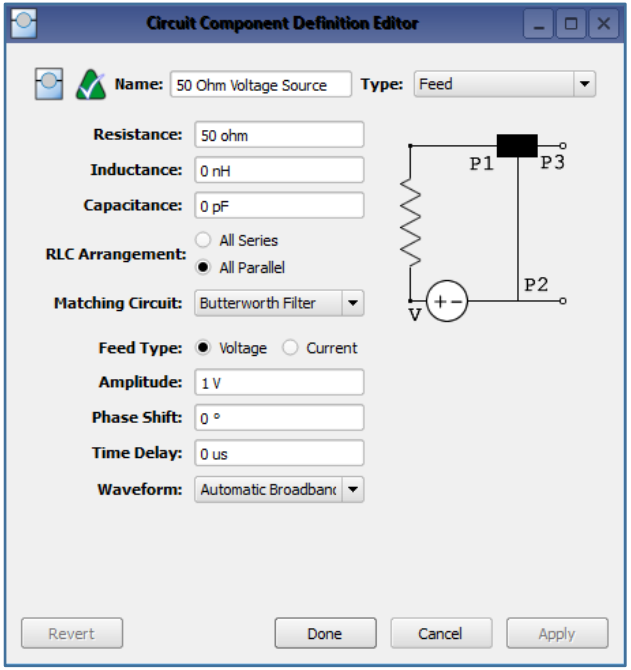


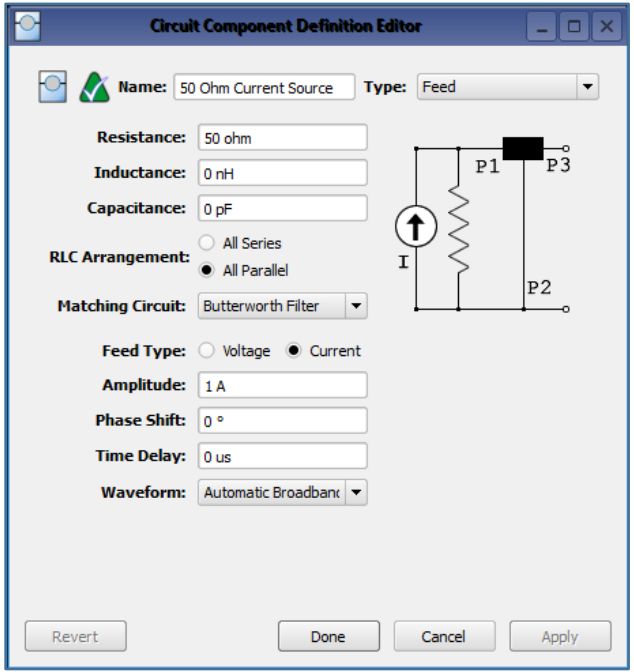


Select from valid subcircuit definitions.

FDTD/Circuit Co-Simulation

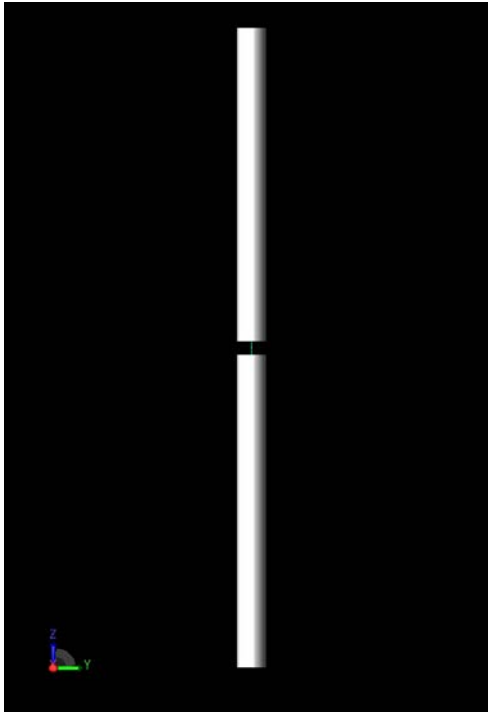
Netlist components can be used as 2-terminal passive loads or 2, 3, or 4 terminal matching circuits.

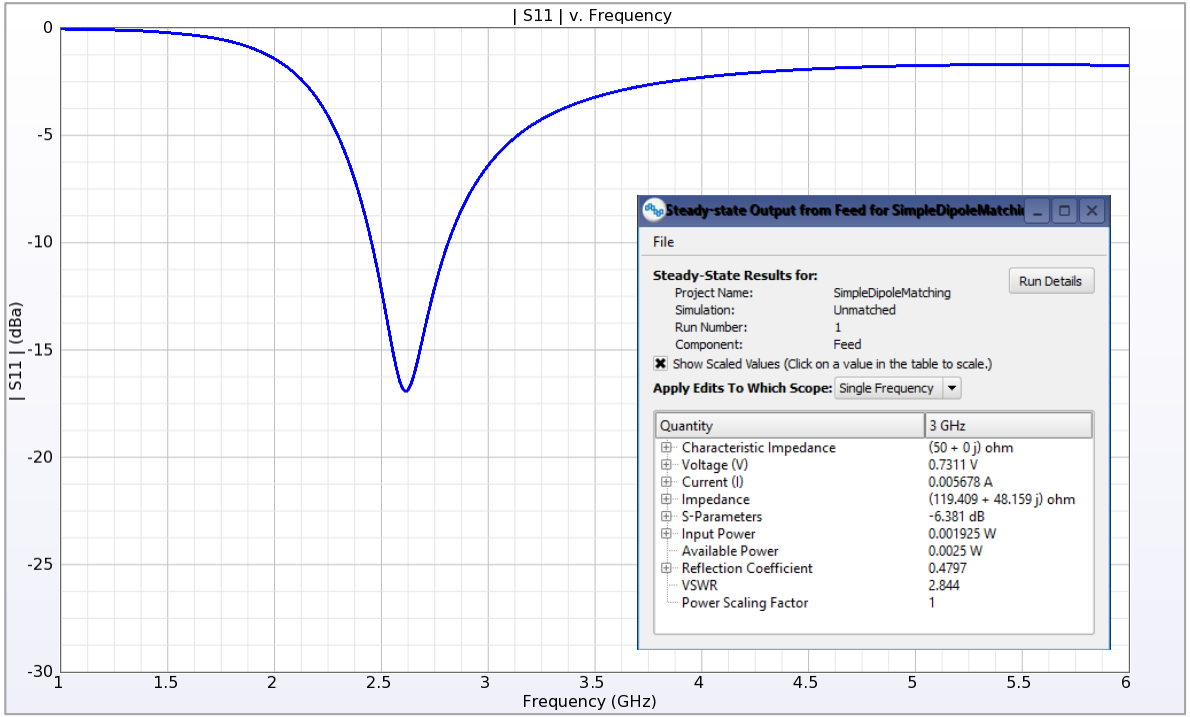




Simple Antenna Matching

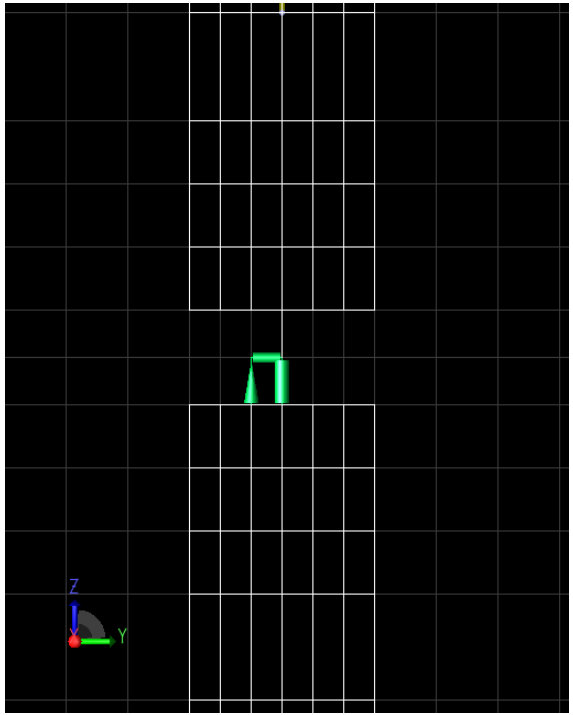
Unmatched 3 GHz Half-Wave Dipole

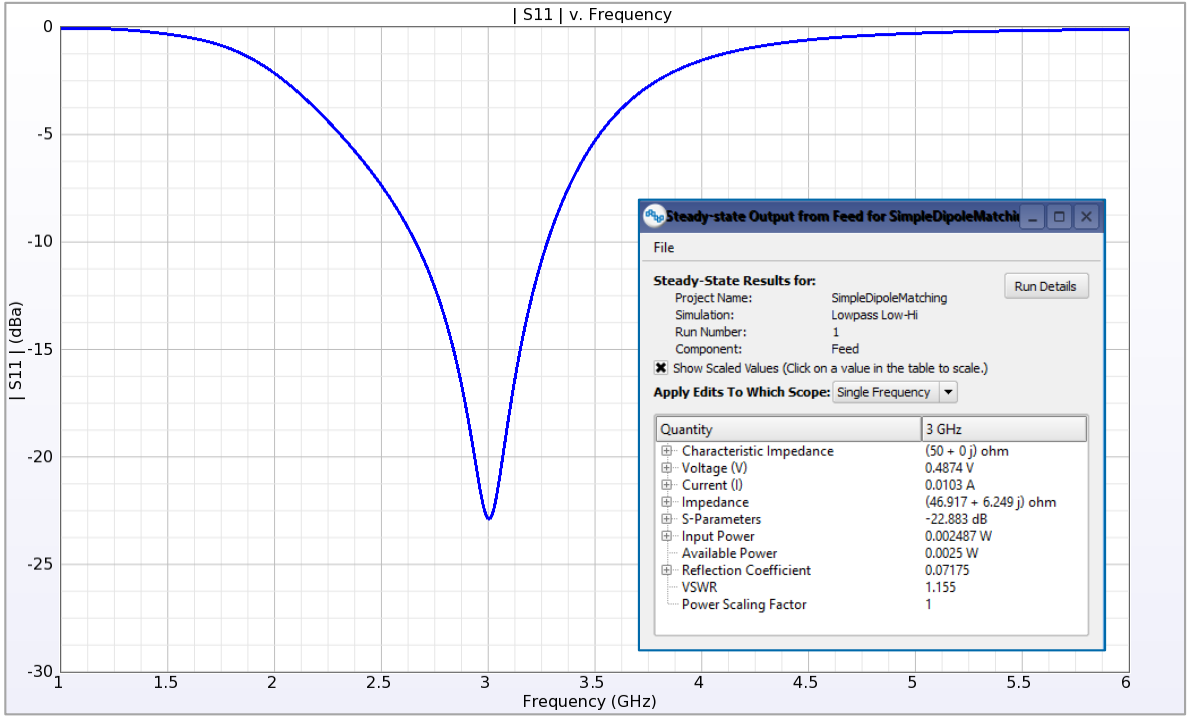




Simple Antenna Matching

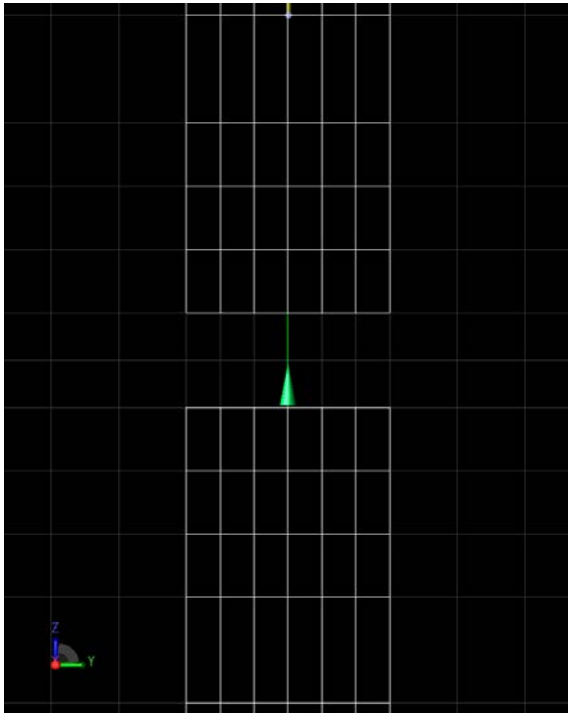
Matched 3 GHz Half-Wave Dipole

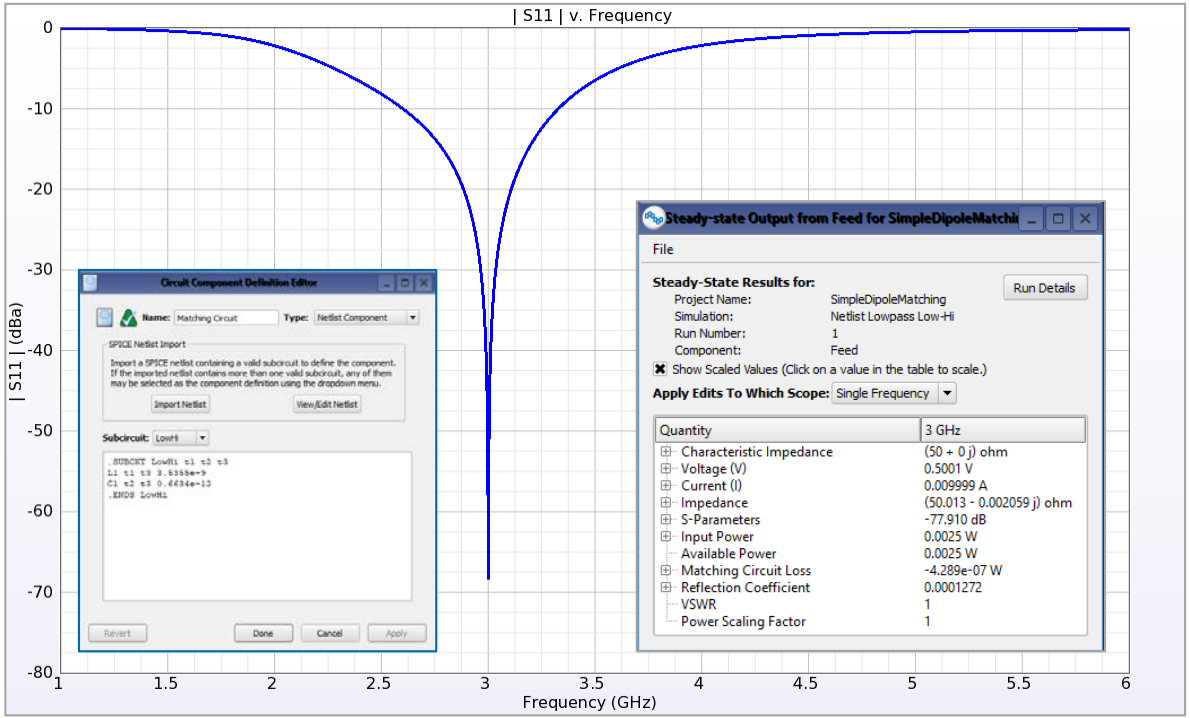




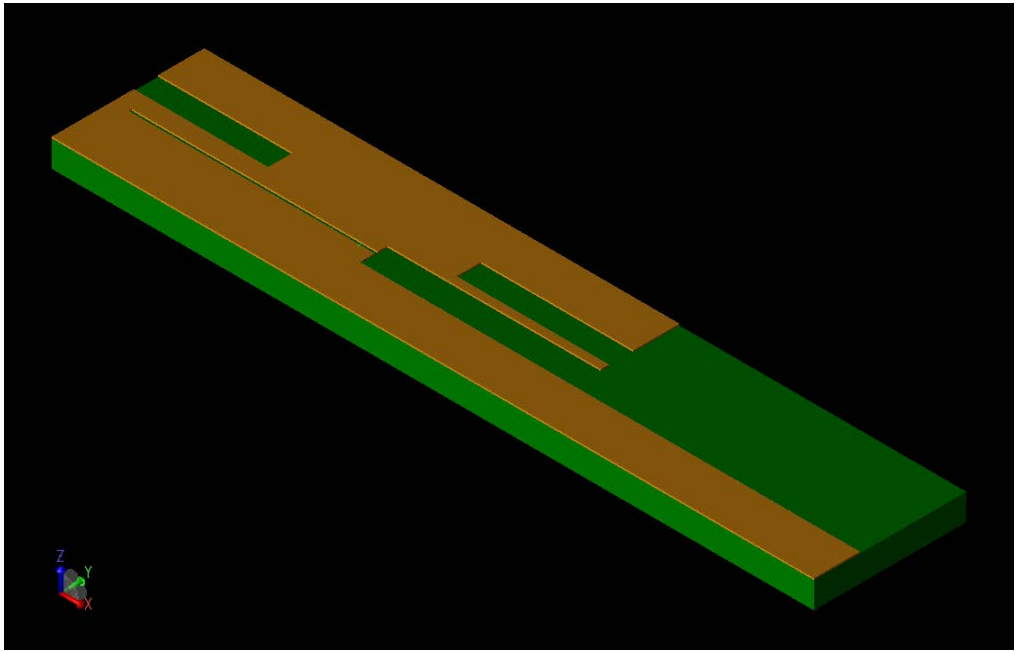
Simple Antenna Matching

Netlist Matched 3 GHz Half-Wave Dipole





WiFi/WiMAX Multiband Matching

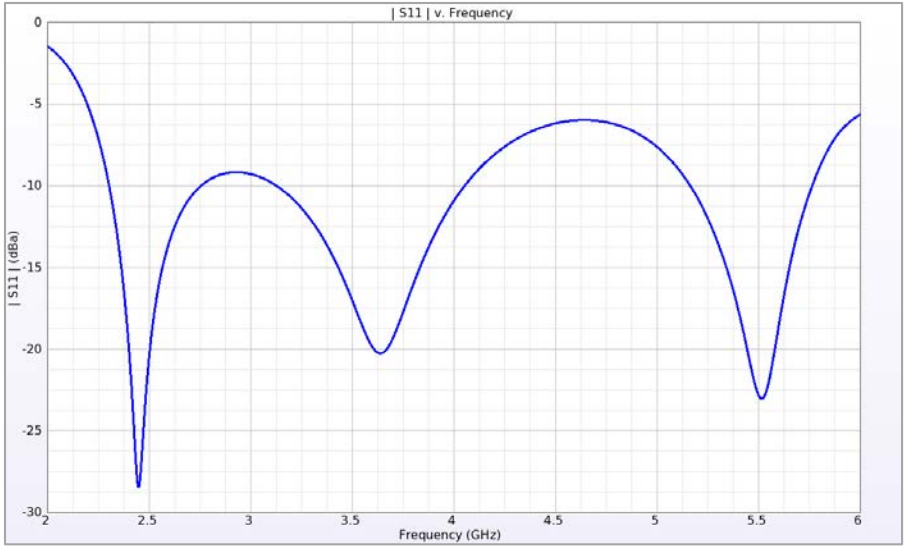


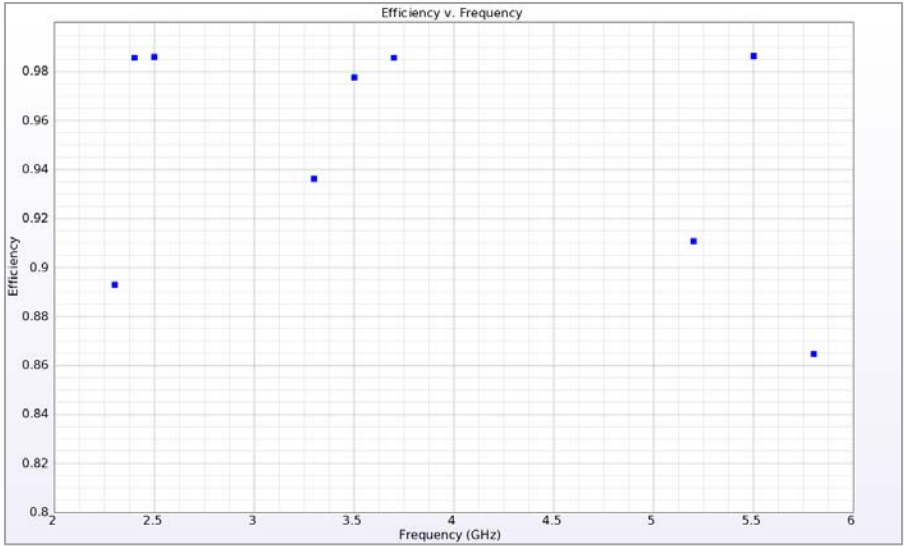
System	Operating band designation		Frequency range (GHz)
Wi-Fi, IEEE 802.11	2.4 GHz		2.4–2.5
	5 GHz	5.2 GHz	5.15–5.35
		5.5 GHz	5.47–5.725
		5.8 GHz	5.725–5.875
Mobile WiMAX, IEEE 802.16e 2005	2.3 GHz		2.3–2.4
	2.5 GHz		2.5–2.69
	3.3 GHz		3.3–3.4
	3.5 GHz		3.4–3 6
	3.7 GHz		3.4–3.8
Fixed WiMAX, IEEE 802.16- 2004	3.7 GHz		3.4–3.8
	5.8 GHz		5.725–5.850

Pazin, L. and Y. Leviatan, "Inverted Laptop Antenna With Enhanced Bandwidth for Wi-Fi/WiMAX Applications," *IEEE Trans. Antennas Propag.*, vol. 59, no. 3, pp. 1065-1068, Mar. 2011.

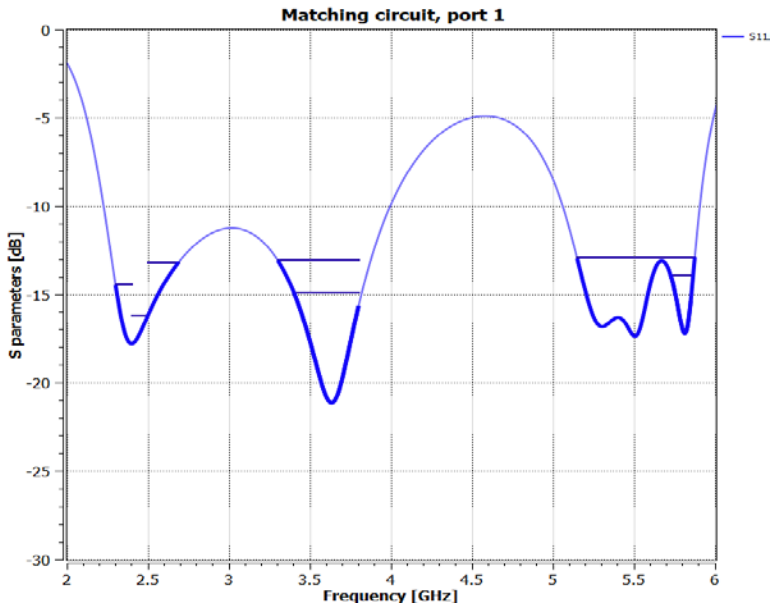
WiFi/WiMAX Multiband Matching

Unmatched Multiband S-Parameters and System Efficiency

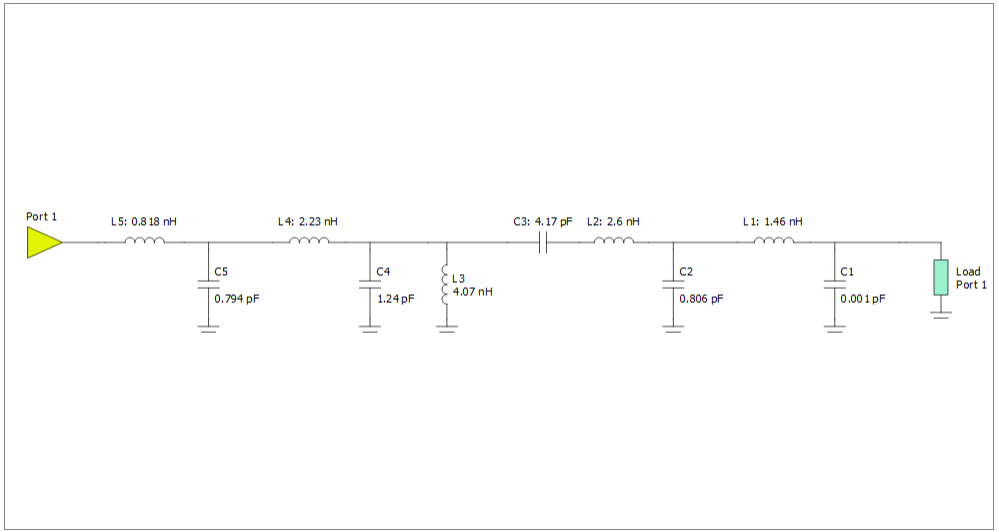




WiFi/WiMAX Multiband Matching

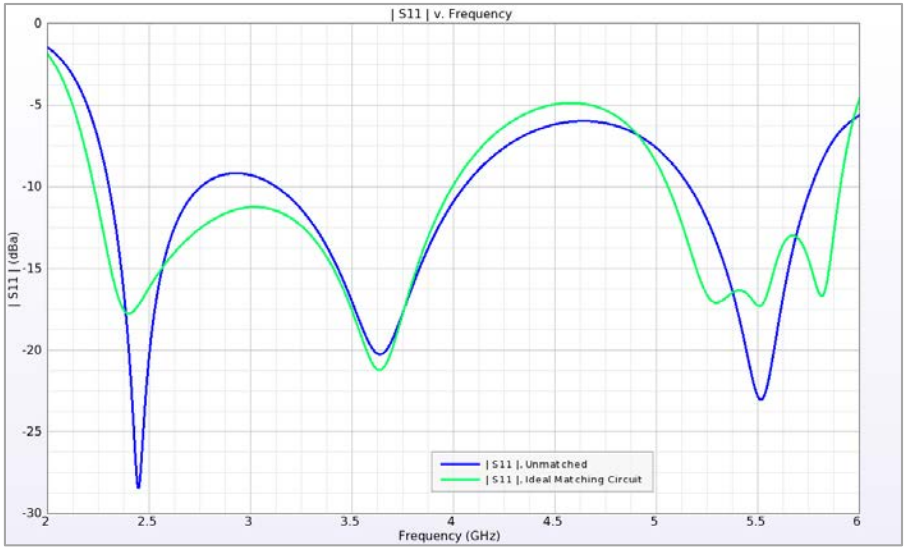


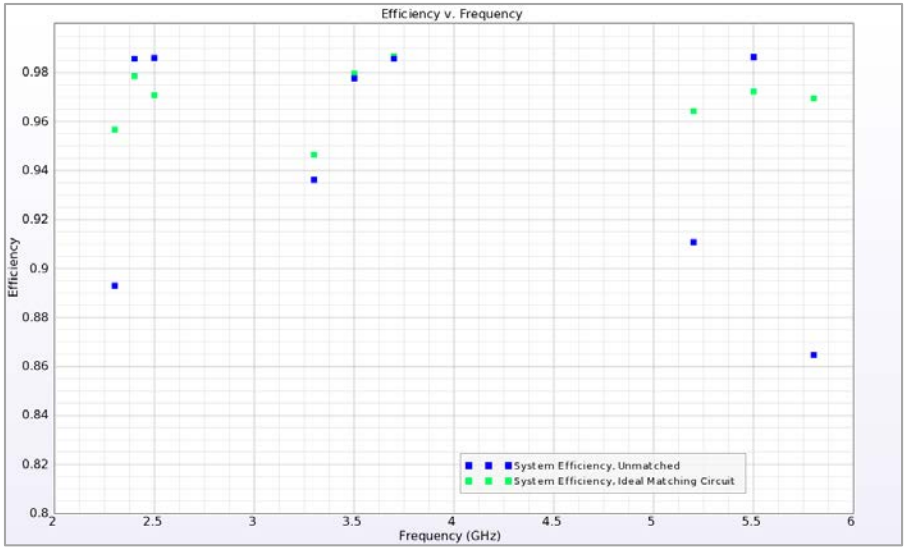
Optenni Lab Ideal Matching Circuit



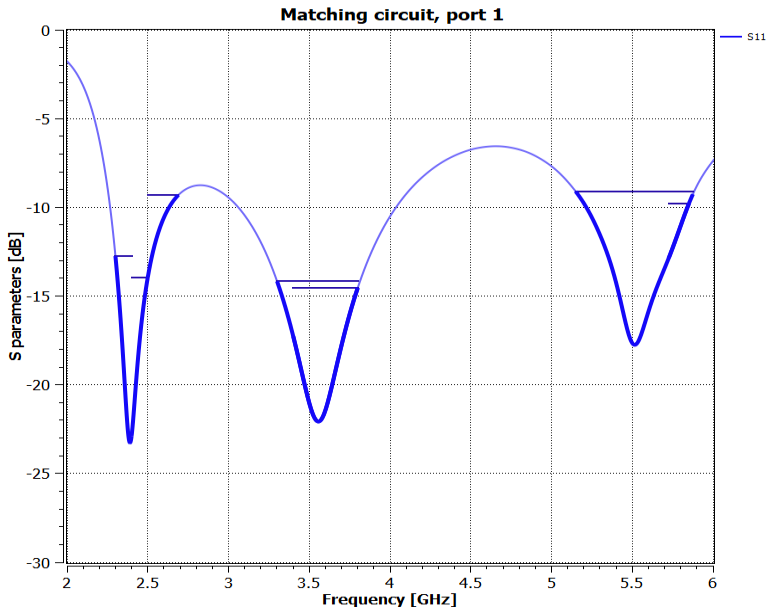
WiFi/WiMAX Multiband Matching

Ideal Matched Multiband S-Parameters and System Efficiency

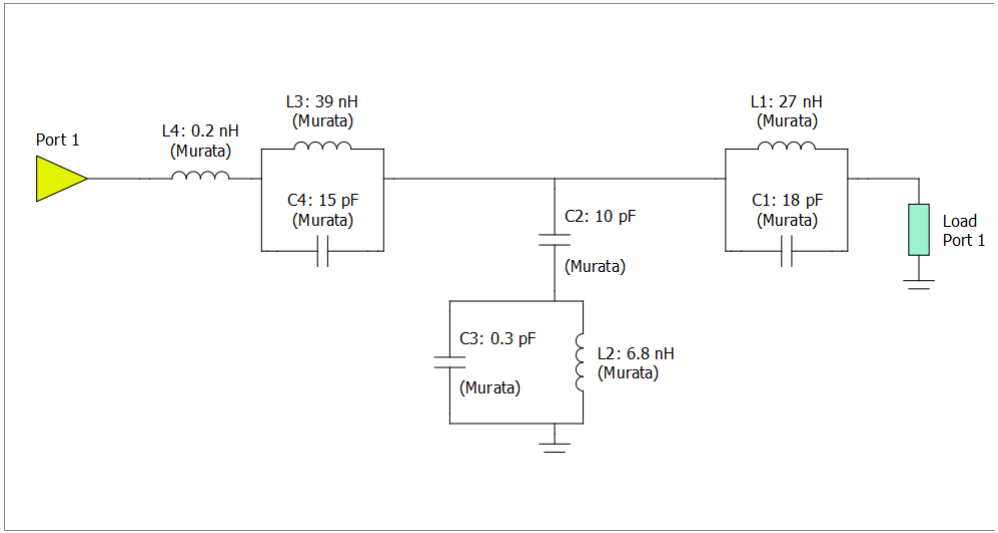




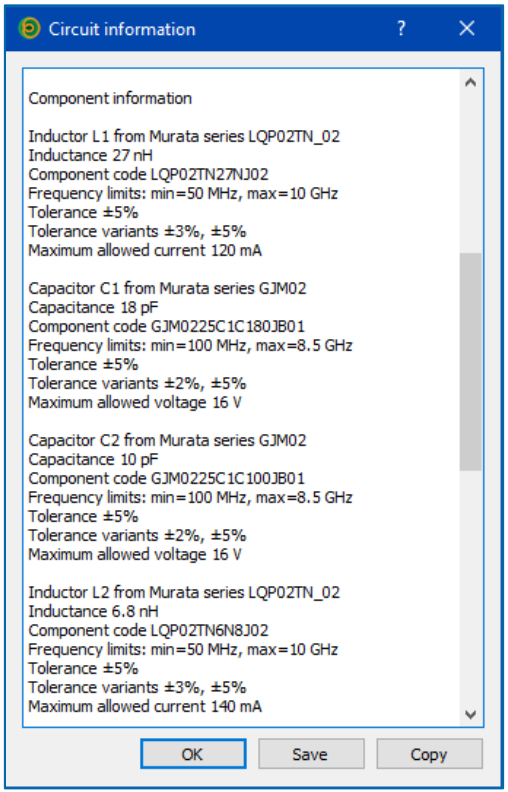
WiFi/WiMAX Multiband Matching



Optenni Lab Real Matching Circuit



WiFi/WiMAX Multiband Matching



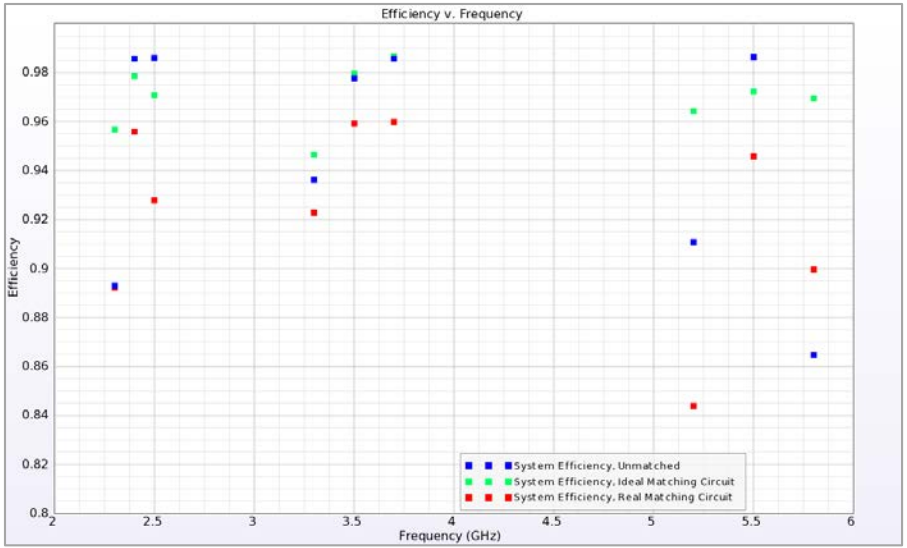
Use accurate broadband component models in XFdtd.

```
*-------------------------------------------------------------------------------
* SPICE Model generated by Murata Manufacturing Co., Ltd.
* Copyright(C) Murata Manufacturing Co., Ltd.
* Description :0402M(01005)/C0G(-55to125[deg])/1.80e-05uF/16[V]
* Murata P/N :GJM0225C1C180JB01
* Property : C = 1.80e-05[uF]
*-------------------------------------------------------------------------------
* Applicable Conditions:
*   Frequency Range = 100[MHz]-9[GHz]
*   Temperature = 25 degC
*   DC Bias Voltage = 0V
*   Small Signal Operation
*-------------------------------------------------------------------------------
.SUBCKT GJM0225C1C180JB01 Port1 Port2
C01 Port1 N01 1.80e-11
R01 Port1 N01 1.00e+10
L02 N01 N02 1.58e-10
R03 N02 N03 9.00e-02
L04 N03 N04 8.12e-12
R04 N03 N04 2.41e-01
L05 N04 N05 6.98e-13
R05 N04 N05 1.15e-02
C06 N05 Port2 1.88e-10
L06 N05 Port2 2.41e-12
R06 N05 Port2 1.54e+00
.ENDS GJM0225C1C180JB01
*-------------------------------------------------------------------------------
```

```
*-------------------------------------------------------------------------------
* SPICE Model generated by Murata Manufacturing Co., Ltd.
* Copyright(C) Murata Manufacturing Co., Ltd.
* MURATA P/N : LQP02TN27NJ02
* Property : L = 27[nH]
*-------------------------------------------------------------------------------
* Applicable Conditions:
*   Frequency Range = 1MHz - 20GHz
*   Temperature = 25 degC
*   DC Bias Current = 0 A
*   Small Signal Operation
*-------------------------------------------------------------------------------
.SUBCKT LQP02TN27NJ02 port1 port2
C1 port1 port2 1.32e-13
L2 port1 1 3.98e-8
R2 1 port2 3.43
R3 port1 port2 7.00e+3
L4 port1 2 2.20e-7
R4 2 port2 600
L5 port1 3 4.80e-7
R5 3 port2 550
L6 port1 4 2.30e-7
R6 4 port2 40.0
L7 port1 5 3.00e-7
R7 5 port2 70.0
L8 port1 6 1.20e-8
C8 6 7 1.55e-14
R8 7 port2 90.0
.ENDS LQP02TN27NJ02
*-------------------------------------------------------------------------------
```

WiFi/WiMAX Multiband Matching

Real Matched Multiband S-Parameters and System Efficiency



Conclusions

- XFdtd/circuit co-simulation allows engineers to:
  - Embed arbitrarily complex electronic circuits as passive loads and/or matching networks in their full wave electromagnetic simulations.
  - Improve the accuracy of EM simulations containing lumped circuit elements by using broadband circuit component models provided by manufacturers. This is especially critical for dissipated power and efficiency computations.
  - Couple and study the effects of electromagnetic phenomenon including EMI, EMP, and ESD on complex integrated circuits.

Contact Us

- XFdtd co-simulation questions, collaborations, feature requests, beta testing, etc.: Gregory.Moss@remcom.com
- General:

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  Tel: 1-814-861-1299

  Email: sales@remcom.com

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- Website Contact: www.remcom.com/contact