

Electromagnetic Simulation Software

Time Domain EM/Circuit Co-Simulation

Gregory Moss XFdtd[®] Research Manager



10-15 June 2018 Philadelphia, PA

VISIT US AT BOOTH 1917

315 S. Allen St., Suite 416 | State College, PA 16801 USA | +1.814.861.1299 phone | +1.814.861.1308 fax | sales@remcom.com | www.remcom.com | © Remcom Inc. All rights

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.

uit - XEduct 7 7 1 0 054 h

Macros Hele

3 3 0

Lumped element occupies one FDTD cell edge.

REMC







D)

14

View

Lumped Circuit Elements in XFdtd



Real(Z) Imag(Z)

Circuit Component l	Definition Editor	
Resistance: 50 ohm	Type: Passive Load ▼ RLC Specification: Normal ▼	Simple passive loa
Inductance: 1 nH Capacitance: 1 pF All Series RLC Arrangement: All Parallel RL C		60 Impedance vs. Frequency 50 40
		30 (Into 20 0 0
Revert	Done Cancel Apply	

REMC

© Remcom Inc. All rights reserved.

30

25

sive load in XFdtd.

15

Frequency (GHz)

20

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.



dtd - Netlist Component - View/Edit Netlist X	Circuit Component Definition Editor 🔤
Circuits	Turan Netter Comment
BCKT FiveElementButterworth t1 t2 t3	Butterworth Filter
tl t3 45e-12	
1 t3 116e-12	SPICE Netlist Import
t2 t3 100e-12	
tl 1 235e-9	Import a SPICE netlist containing a valid subcircuit to define the component.
1 t2 291e-9	If the imported netlist contains more than one valid subcircuit, any of them
DS FiveElementButterworth	may be selected as the component definition using the dropdown menu.
BCKT LC t1 t2	Import Netlist View/Edit Netlist
tl 1 1.0e-9	
1 t2 1.0e-12	
DS LC	Subcircuit: FiveElementButterworth
BCKT RLC tI t2	
	.SUBCKT FiveElementButterworth t1 t2 t3
1 2 1.00-9	C1 t1 t3 45e-12
2 t2 1.0e-12	C2 1 t3 116e-12
5 KEC	C3 t2 t3 100e-12
BCWT InC +1 +2	L1 t1 1 235e-9
+1 +2 1 0e-9	L2 1 t2 291e-9
t1 t2 1.0e-12	ENDS FiveElementButterworth
S LDC	
BCKT RpLpC t1 t2	
t1 t2 50.0	
t1 t2 1.0e-9	
t1 t2 1.0e-12	
S RpLpC	
	· · · · · · · · · · · · · · · · · · ·
	Revert Done Cancel Apply

Circuit Component Definition Editor

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.

Circuit	t Component Definition Editor
💽 🔬 Name: 50	Ohm Voltage Source Type: Feed
Resistance:	50 ohm
Inductance:	0 nH P1 P3
Capacitance:	0 pF
RLC Arrangement:	All Series All Parallel D2
Matching Circuit:	Butterworth Filter
Feed Type:	Voltage Current
Amplitude:	1 V
Phase Shift:	0 °
Time Delay:	0 us
Waveform:	Automatic Broadbanc 🔻
Revert	Done Cancel Anniv
1007010	

Circui	t Component Definition Editor	_ _ ×
🔄 🔬 Name: 50	Ohm Current Source Type: Feed	•
Resistance:	50 ohm	
Inductance:	0 nH P1	P3
Capacitance:	0 pF	
RLC Arrangement:	All Series I All Parallel	50
Matching Circuit:	Butterworth Filter	P2
Feed Type:	○ Voltage ● Current	
Amplitude:	1 A	
Phase Shift:	0 °	
Time Delay:	0 us	
Waveform:	Automatic Broadband	
Revert	Done Cancel	Apply



Simple Antenna Matching

Unmatched 3 GHz Half-Wave Dipole







REMC

SOUNES MEDICINE/MOB

Simple Antenna Matching

-5

-10

S11 | (dBa) -1-

-20

-25

-30

Matched 3 GHz Half-Wave Dipole



Frequency (GHz)

REMC

Simple Antenna Matching

Netlist Matched 3 GHz Half-Wave Dipole











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

REMC



Unmatched Multiband S-Parameters and System Efficiency





REMC

Ideal Matched Multiband S-Parameters and System Efficiency





South IMS2018

Philadelphia





Optenni Lab Real Matching Circuit







Circuit information ?	×	Use accurate broadband component	Philadelph
 Circuit information Component information Inductor L1 from Murata series LQP02TN_02 Inductance 27 nH Component code LQP02TN27NJ02 Frequency limits: min=50 MHz, max=10 GHz Tolerance 45% Tolerance variants ±3%, ±5% Maximum allowed current 120 mA Capacitance 18 pF Component code GJM0225C1C180JB01 Frequency limits: min=100 MHz, max=8.5 GHz Tolerance variants ±2%, ±5% Maximum allowed voltage 16 V Capacitor C2 from Murata series GJM02 Capacitance 10 pF Component code GJM0225C1C100JB01 Frequency limits: min=100 MHz, max=8.5 GHz Tolerance 45% Tolerance 10 pF Component code GJM0225C1C100JB01 Frequency limits: min=100 MHz, max=8.5 GHz Tolerance 45% Tolerance 45% Tolerance 45% Tolerance 10 pF Component code GJM0225C1C100JB01 Frequency limits: min=100 MHz, max=8.5 GHz Tolerance 45% Tolerance 45% Tolerance 55% Tolerance 56 Tolerance 45% Tolerance 50 Tolerance 50 Tolerance 50 Tolerance 45% T		<pre>Use accurate broadband component models in XFdtd. * SFICE Model generated by Murata Manufacturing Co., Ltd. * Copyright(C) Murata Manufacturing Co., Ltd. * Applicable Conditions: * Trequency Range = 100(HHz]-9[GHz] * Trequency Range = 100(HHz]-9[GHz] * Trequency Range = 100(HHz]-9[GHz] * Trequency Range = 1010(HHz]-9[GHz] * Treperty :: L 20[2011/27H00 * Shall Signal Operation * Treperty :: L 20[2011/27H00 * Trepercy Range = 1HHz - 20GHz * Treperty :: L 20[2011/27H00 * Tre</pre>	Philadelpha
Frequency limits: min=50 MHz, max=10 GHz Tolerance ±5% Tolerance variants ±3%, ±5% Maximum allowed current 140 mA	✓	RS 3 port2 550 I6 port1 4 2.30=-7 R6 4 port2 40.0 I7 port1 5 3.00=-7 R7 5 port2 70.0 I8 port1 6 1.20=-8 C8 6 7 1.55=-14 R8 7 port2 90.0 ENDS LQP02TN27NJ02	

REMC

Philadelphia

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 *Philadu* requests, beta testing, etc.: <u>Gregory.Moss@remcom.com</u>
- General:

- Toll Free: 1-888-7REMCOM (U.S. and Canada)
- Tel: 1-814-861-1299
- Email: sales@remcom.com
- www.remcom.com
- Website Contact: <u>www.remcom.com/contact</u>



