



HyperLynx® 3D EM

FilterSyn Windows User's Manual

Software Version 15.2

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FilterSyn for Windows

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Introduction to FilterSyn for Windows

FilterSyn is a filter simulation and synthesis module integrated with IE3DLibrary.

FilterSyn has the following useful features.

- Uses accurate analytical models.
- Handles low-pass, bandpass, and bandstop filters.
- Covers coaxial, microstrip, stripline/LTCC, and stripline-like structures.
- Performs fast simulation and synthesis.
- Has a built-in Genetic-Algorithm (GA) optimizer.
- Has a friendly graphical user interface (GUI).
- Creates filter objects and exports them to IE3D.
- Can be invoked from a filter layout as well.
- Has been verified experimentally and extensively.

FilterSyn currently includes the following 25 filter implementations.

- Coax
 1. Coaxial stepped-impedance low-pass filters.
 2. Coaxial gap-coupled bandpass filters.
- Microstrip
 1. Microstrip stepped-impedance low-pass filters.
 2. Microstrip open-circuited stub low-pass filters.
 3. Parallel-coupled microstrip bandpass filters.
 4. Microstrip gap-coupled bandpass filters.
 5. Microstrip hairpin bandpass filters.
 6. Tapped microstrip hairpin bandpass filters.
 7. Microstrip interdigital bandpass filters.
 8. Microstrip interdigital bandpass filters.
 9. Broadband microstrip interdigital bandpass filters.
 10. Tapped microstrip open-circuited stub bandstop filters
- Stripline/LTCC
 1. Stripline stepped-impedance low-pass filters.
 2. Parallel-coupled stripline bandpass filters.
 3. LTCC combined broadside/parallel-coupled stripline bandpass filters.
- Stripline-like
 1. Rectangular-bar combline bandpass filters
 2. Rod combline bandpass filters
 3. Tapped rectangular-bar combline bandpass filters
 4. Tapped rod combline bandpass filters
 5. Interdigital rectangular-bar bandpass filters.
 6. Interdigital rod bandpass filters.
 7. Tapped interdigital rectangular-bar bandpass filters.
 8. Tapped interdigital rod bandpass filters.
 9. Broadband interdigital rectangular-bar bandpass filters.
 10. Broadband interdigital rod bandpass filters.

Installing FilterSyn

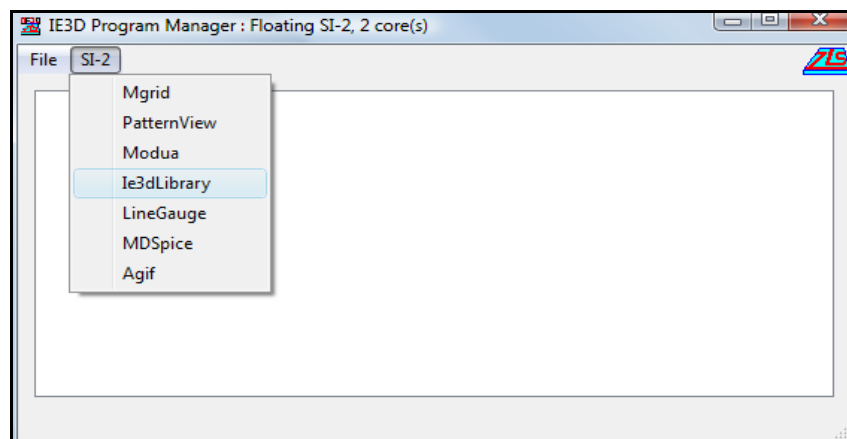
FilterSyn application is part of the Ie3dLibrary application which comes with Mentor Graphics IE3D product group and is included in the standard installation. Follow installation guide of IE3D product to install Ie3dLibrary

Using FilterSyn

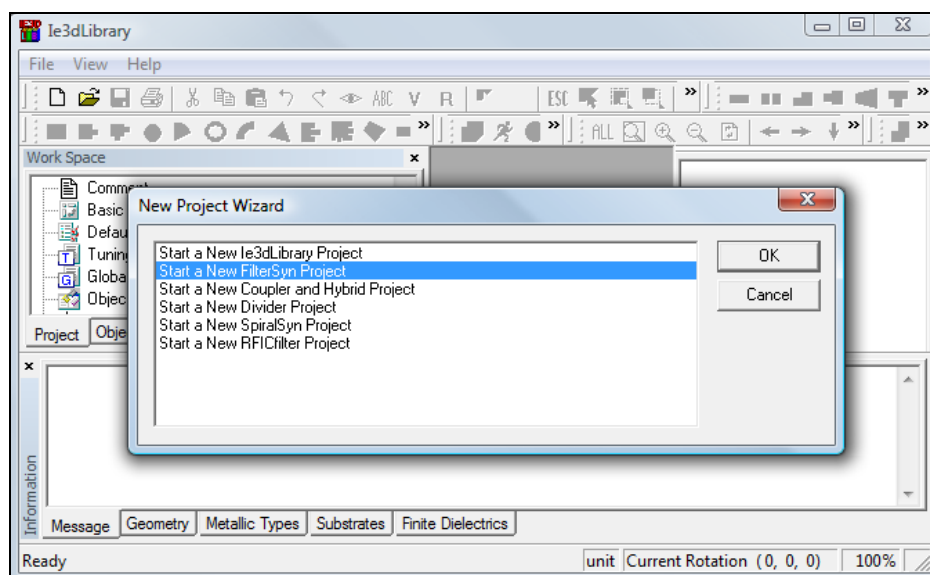
Starting FilterSyn

To start FilterSyn, follow these steps:

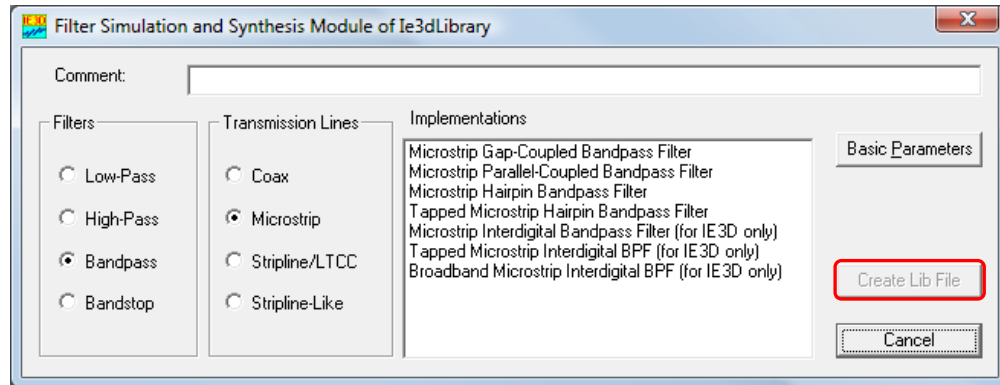
1. Start IE3D Program Manager and Select Ie3dLibrary application as shown below.



2. Once Ie3dLibrary application opens, Go to File → New. “New project Wizard” will come up as shown below. Select “Start a New FilterSyn Project” option from the list and click OK.



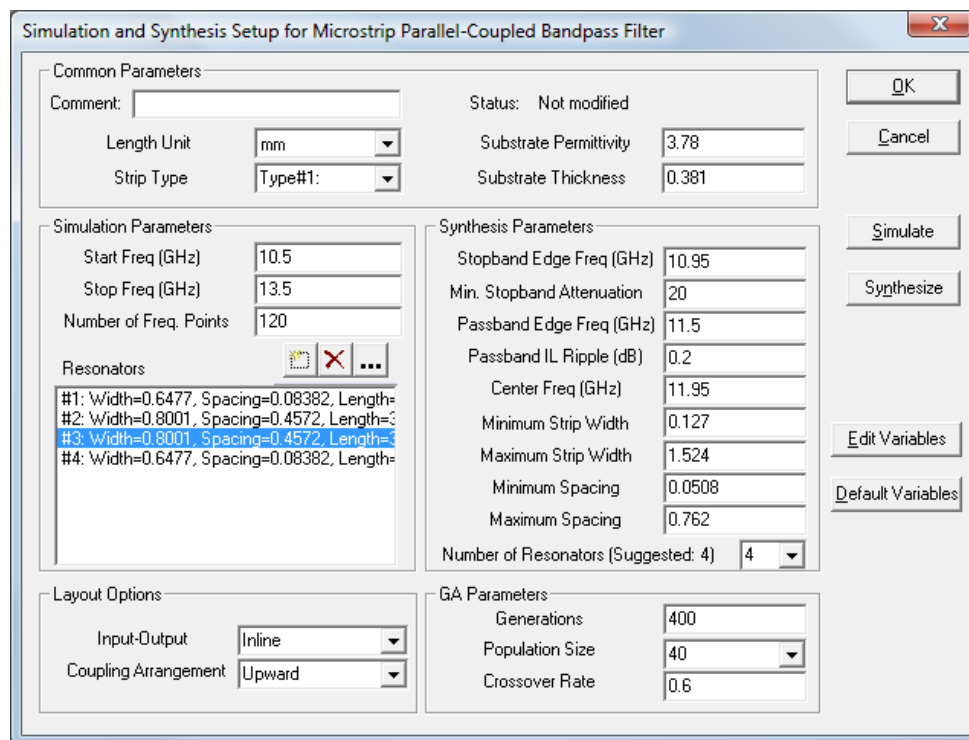
3. 'Filter Simulation and Synthesis Module of Ie3dLibrary' window will come up as shown below with filter, transmission line, and Implementation options to choose.



4. Select filter type, Transmission Line type, and implementation scheme to start simulating or synthesizing a filter. Please note that before starting a filter setup, Create Lib File is disabled.

Simulating a filter

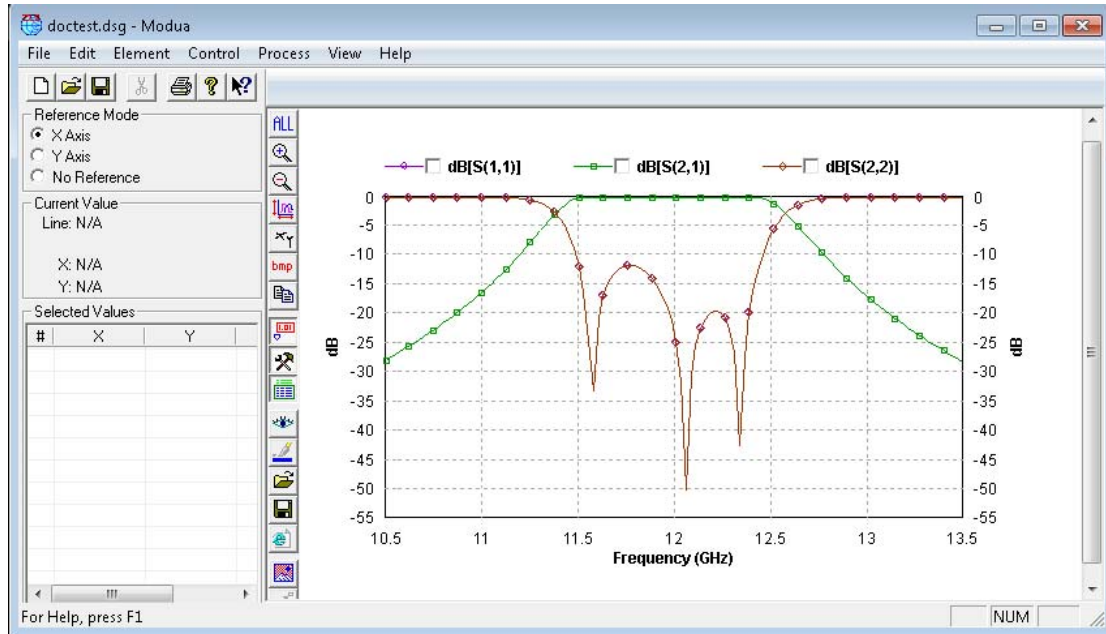
Once a filter type, Transmission Line type, and its implementation are chosen, the filter's setup window will pop up. For example, if *Bandpass* type, *Microstrip* transmission line and *Microstrip Parallel-Coupled Bandpass Filter* implementation are selected, the following window should appear.



To simulate a parallel-coupled microstrip bandpass filter, we only need to edit parameters in Common Parameters and Simulation Parameters area. Other parameters are for synthesis and are to be discussed in next section.

Items in Common Parameters and Simulation Parameters are basically self-explanatory. Only Resonators and their related buttons and data require a little bit of explanation. You can change number of resonators by clicking Add or Delete icons. To change dimensions of resonators, double-click them individually and make corresponding changes.

Once editing/making changes is done, clicking *Simulate* button will start and finish simulation instantly. The simulated magnitudes in dB of the scattering parameters of selected filter will be displayed on a Modua window as shown below. You can also display phase information by going to Control menu under Modua window and select Define Display Graph. Optional view setting is under View menu.

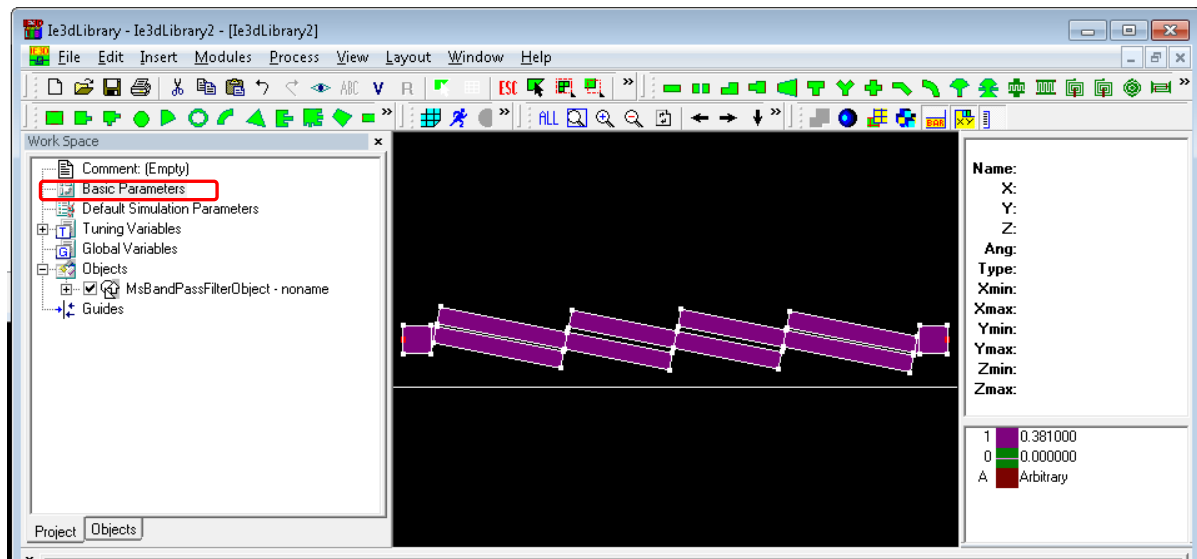


Synthesizing a filter

Synthesis Based on Analytical Formulas

As with the parallel-coupled microstrip bandpass filter example discussed above, synthesizing a filter requires editing Synthesis Parameters and GA (Genetic Algorithm) Parameters in addition to Common Parameters. All these parameters are essentially self-explanatory. Most of the time, we do not need to change Population size and Crossover rate for GA, but we do need to change Generations for GA-powered optimization according to the number of resonators. Generally, the larger the number, the more generations GA needs. Although FilterSyn suggests the number of resonators according to given specs, one can use the suggested number and other numbers as well. Normally, the suggested number will be the best bet. Once all the parameters except Simulation Parameters are set, we can start optimization-based synthesis by clicking synthesis button. The objective fitness is 1.0 and fitness value is dynamically displayed to indicate the approaching to the objective. Optimization terminates when either the objective or the specified

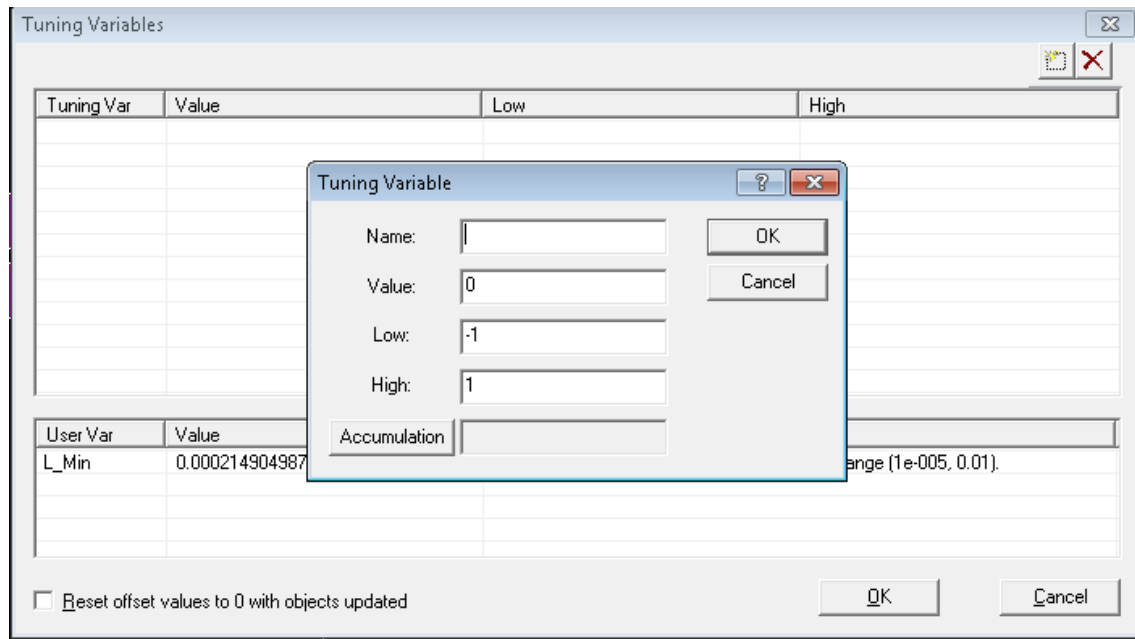
number of generations is reached. After the optimization, the default resonator dimensions will be updated to reflect optimized dimensions corresponding to the synthesis parameters. Then, one can simulate the filter with the optimized dimensions. Clicking OK on the filter setup window will enable *Create Lib File* button on the initial *filter simulation and synthesis* 'Module of *Ie3dLibrary*' window. Clicking *Create Lib File* button will give Basic parameters window. Click OK on this window to accept default values. You can change these values anytime later. Now clicking on IE3Dlibrary layout window will generate the layout of the optimized filter as shown below.



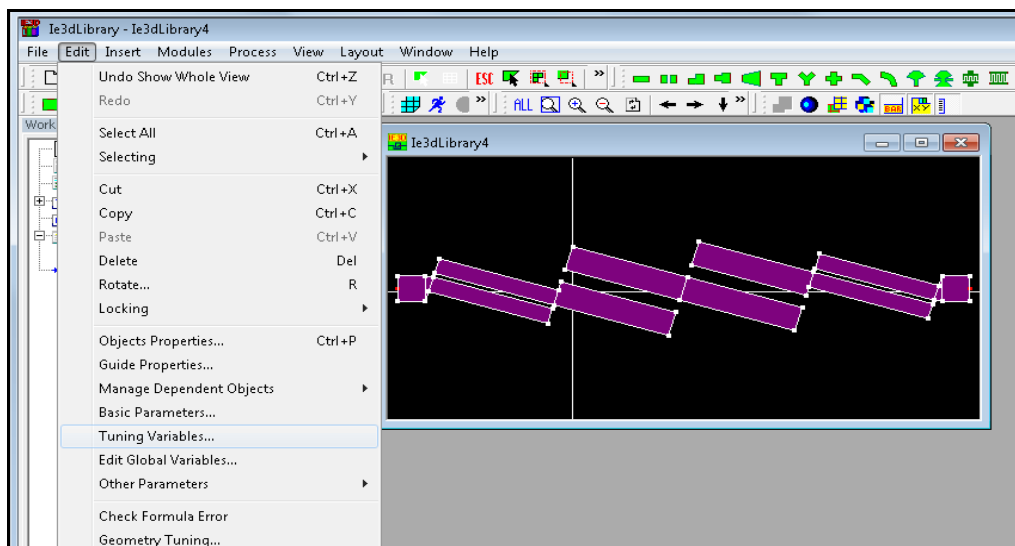
Synthesis Based on EM Simulations

Analytical formulas based synthesis can be further optimized with IE3D full-wave EM simulation. There are two ways to define the range of change of filter dimensions.

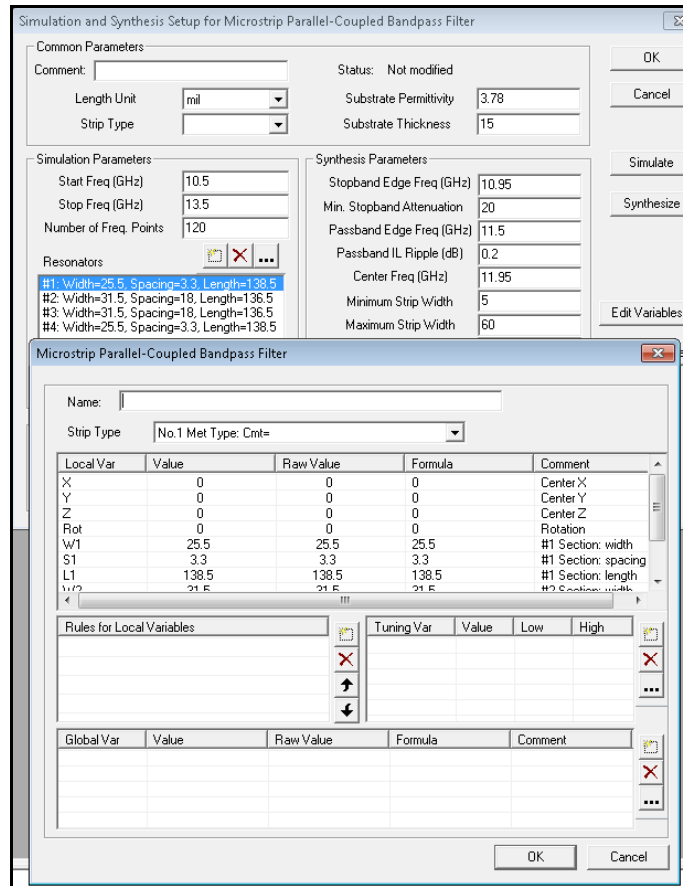
One way is to click Edit Variables button from the filter simulation and synthesis setup to invoke Tuning Variables window and then click the “create” icon at the upper right corner to pop up another window. The following screen capture results from the two clicks.



Another way to do the same is to Click Edit on IE3DLibrary window and select Tuning Variables from a menu.

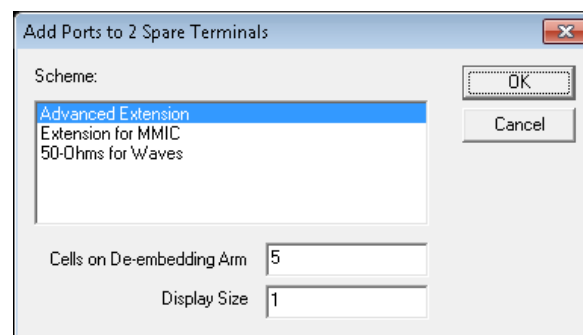


After defining the variable, we can tune filter dimensions. For example, we want to tune the length of the first/last coupled microstrip section by double-clicking the first/last row in the list box. The following screen capture represents this step.



Similarly, we can define more variables and associate each dimension with a different variable so that those dimensions can change independently. Of course, if we associate more than one dimension like lengths of different sections with the same variable, then they will change in the same manner.

Now we need to create ports for this structure. Click on 'Define all ports' option under 'Insert' menu of the Ie3dLibrary window and select Advanced Extension scheme. Click OK. Now two ports will be created.



Once we finish associating the varying dimensions with their corresponding variables, and ports are defined; we can set up optimization goal by clicking Process on the IE3DLibrary window and select Optimize from the menu. We can display mesh and simulate the filter structure the same way we do from IE3D's layout editor, MGrid.

To export the layout for processing by MGrid, we need to go to File menu and select Save As .geo file.

Examples and Experimental Verifications

FilterSyn has been used to simulate and synthesize many design examples. Presented below are just a few of them. In cases where measured data are available, it is seen that FilterSyn simulations agree excellently with corresponding measurements.

Microstrip Stepped-Impedance Low-Pass Filter

Simulation and Synthesis Setup for Microstrip Stepped-Impedance Low-Pass Filter

Common Parameters

Comment:

Status: Modified: Wed May 09 10:07:30 2001 Dimensional Unit:

High-Impedance Line Width: Substrate Thickness:

Low-Impedance Line Width: Substrate Permittivity:

Simulation Parameters

Start Freq (GHz): Stop Freq (GHz): Number of Freq. Points:

Resonators

No.1 Resonator: Low Z, L=61.7
No.2 Resonator: High Z, L=228.6
No.3 Resonator: Low Z, L=132.3
No.4 Resonator: High Z, L=239
No.5 Resonator: Low Z, L=119
No.6 Resonator: High Z, L=115.7

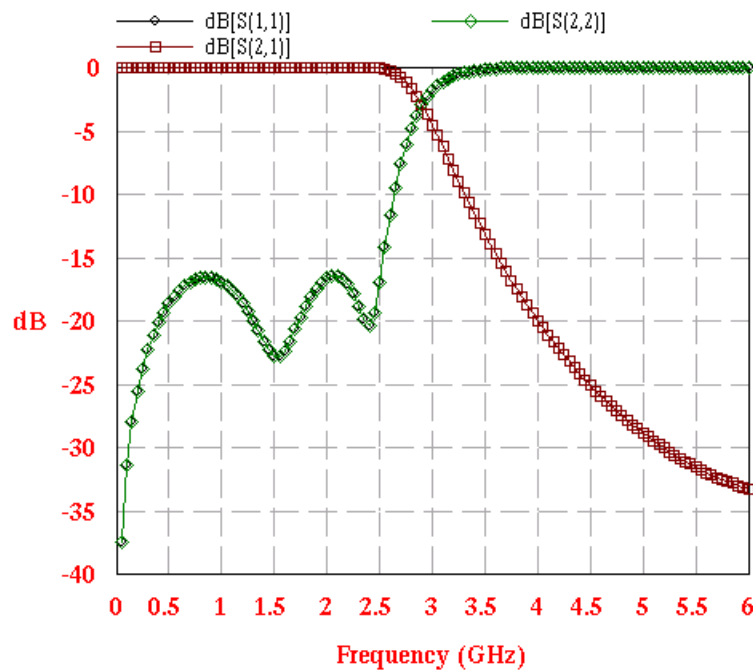
Synthesis Parameters

Passband Edge Freq (GHz): Passband IL Ripple (dB):

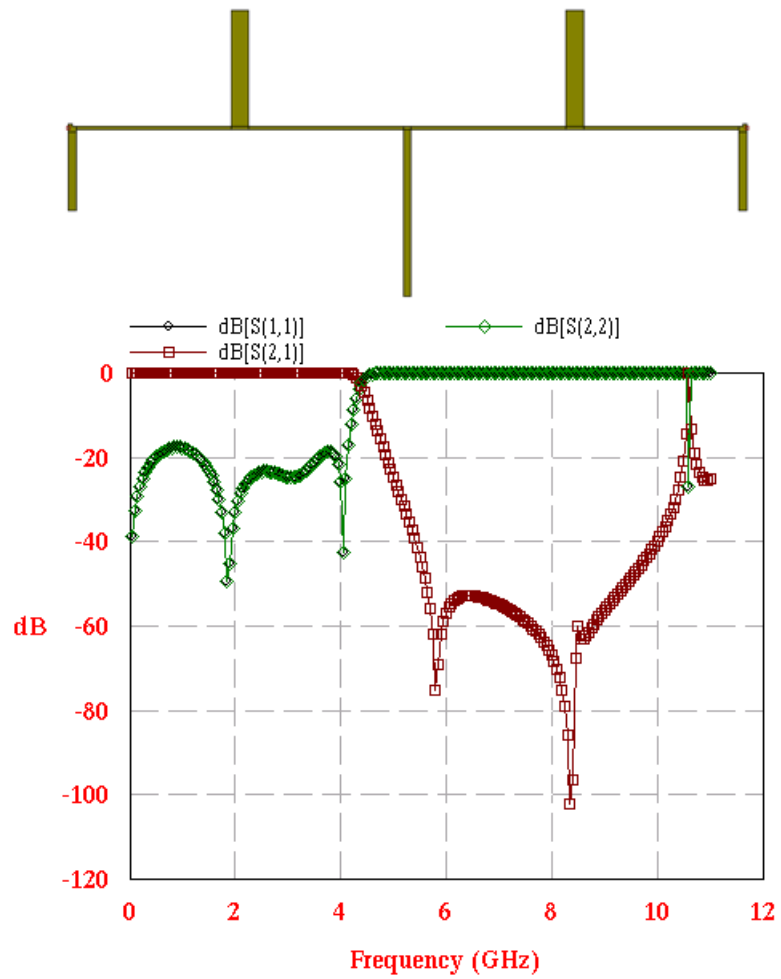
Stopband Edge Freq (GHz): Min. Stopband Attenuation (dB):

GA Parameters

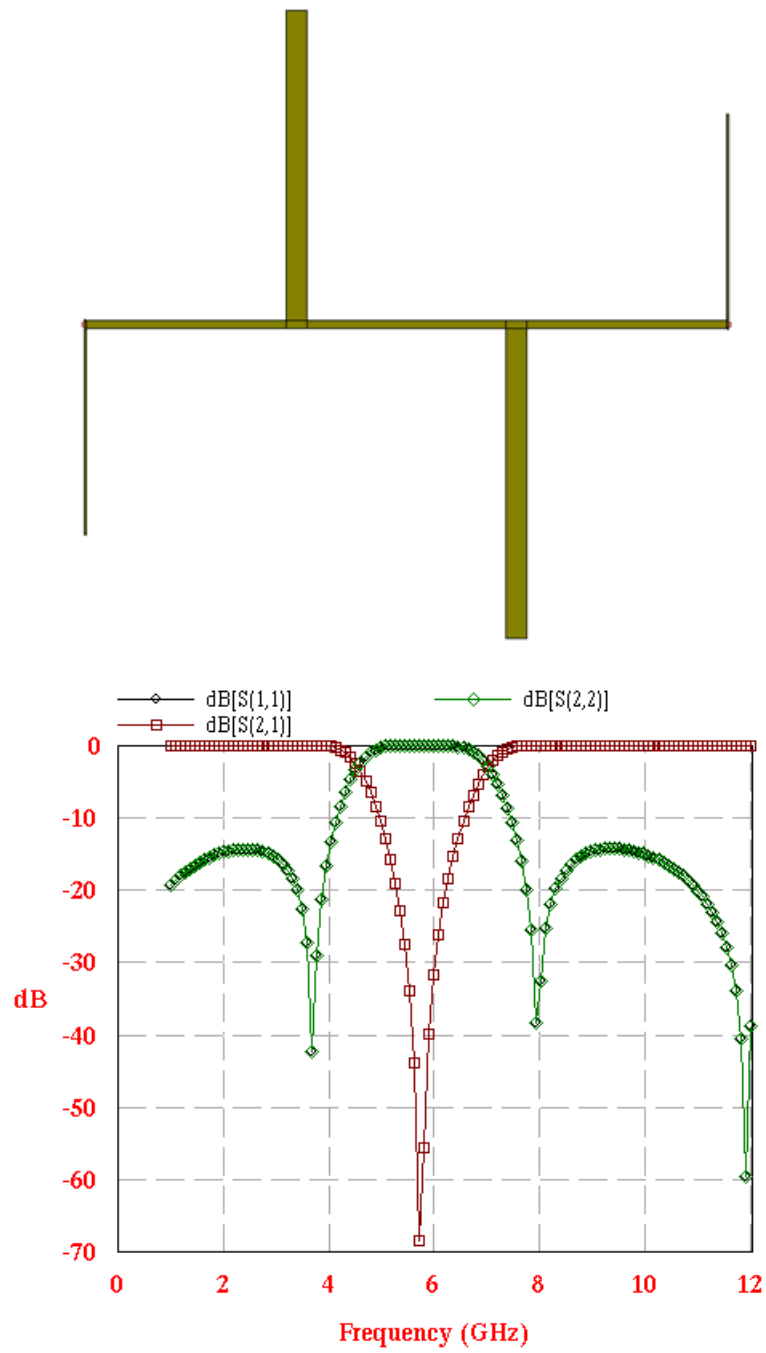
Generations: Population Size: Crossover Rate:



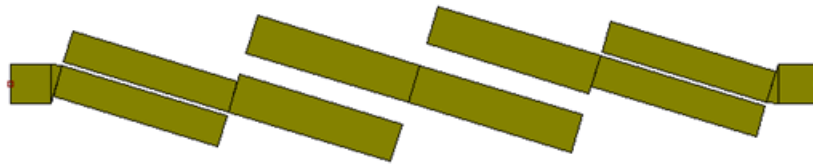
Microstrip Open-Circuited Stub Low-Pass Filter



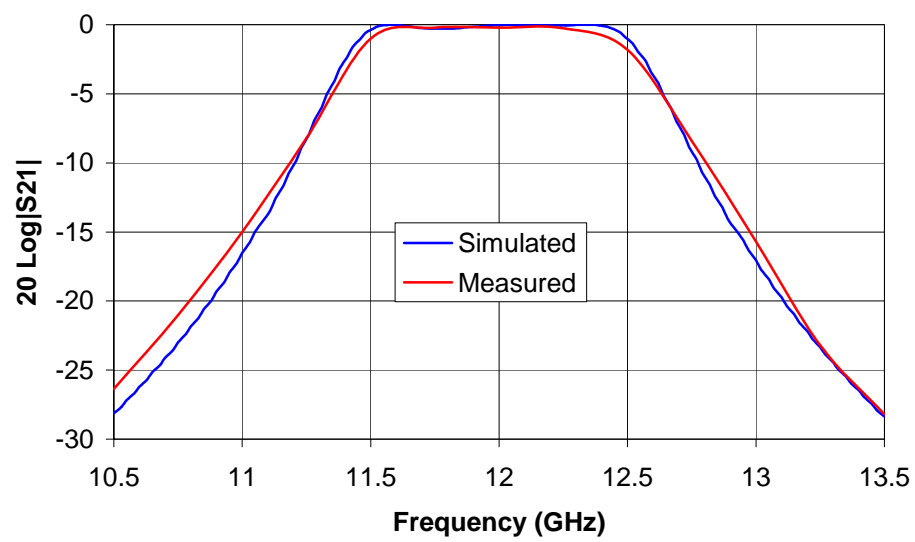
Microstrip Open-Circuited Stub Bandstop Filter



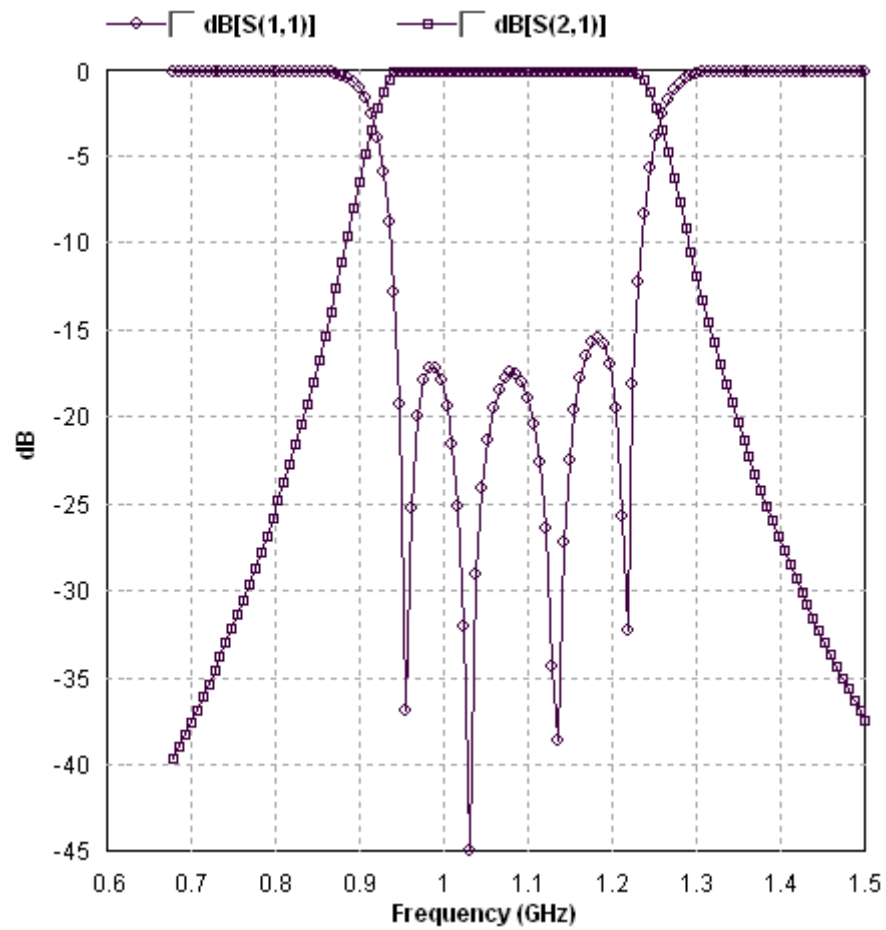
Parallel-Coupled Microstrip Bandpass Filter



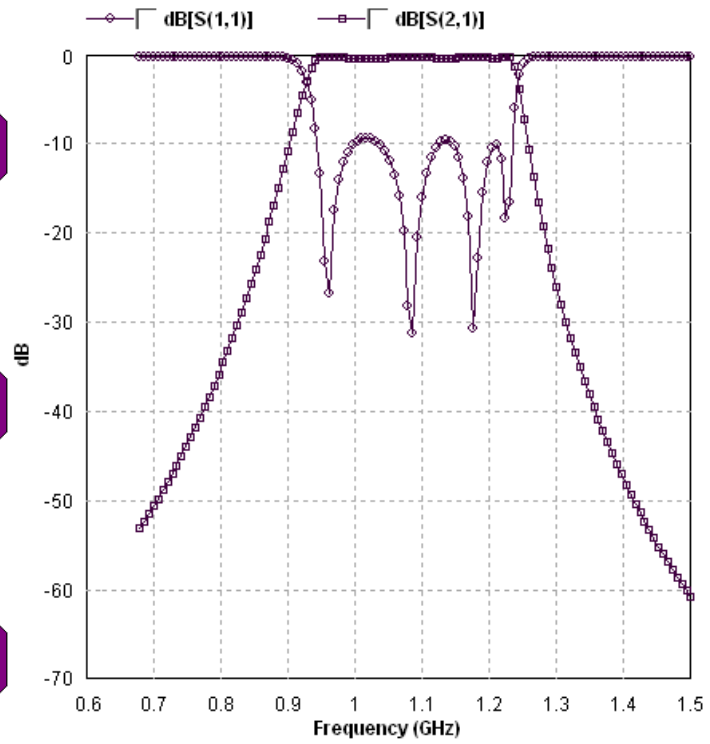
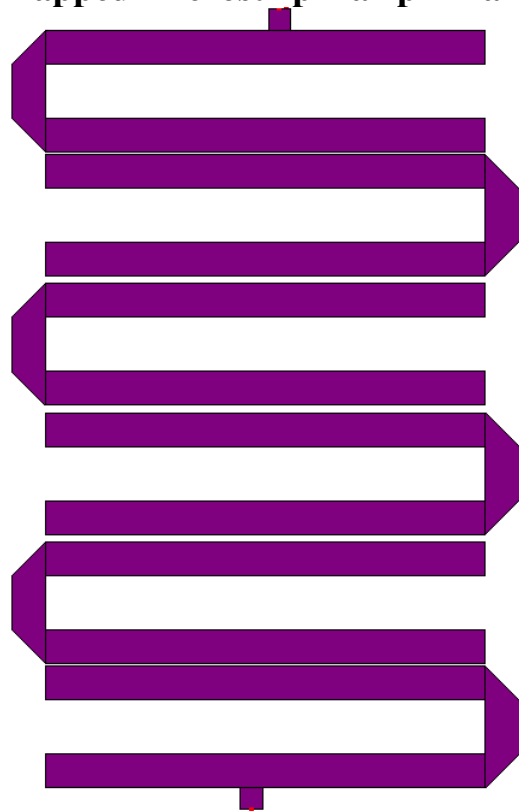
Parallel-Coupled Microstrip Bandpass Filter



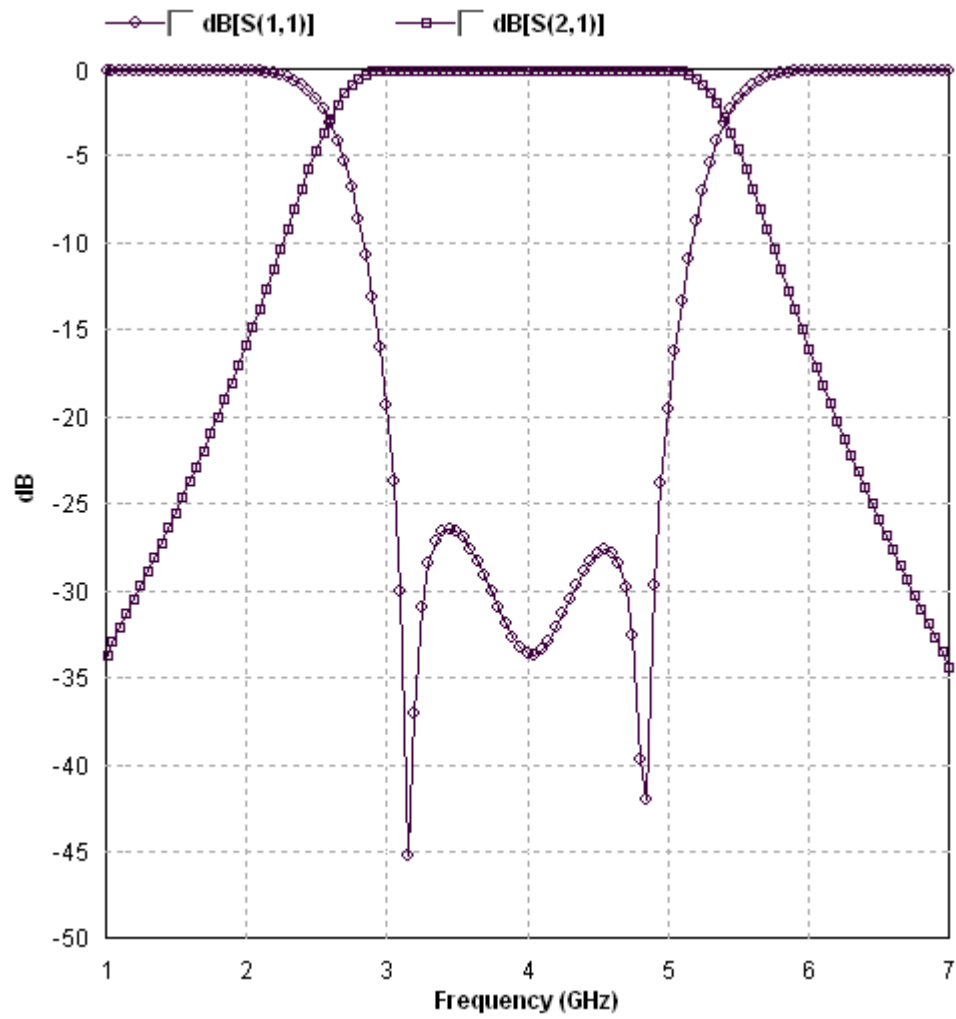
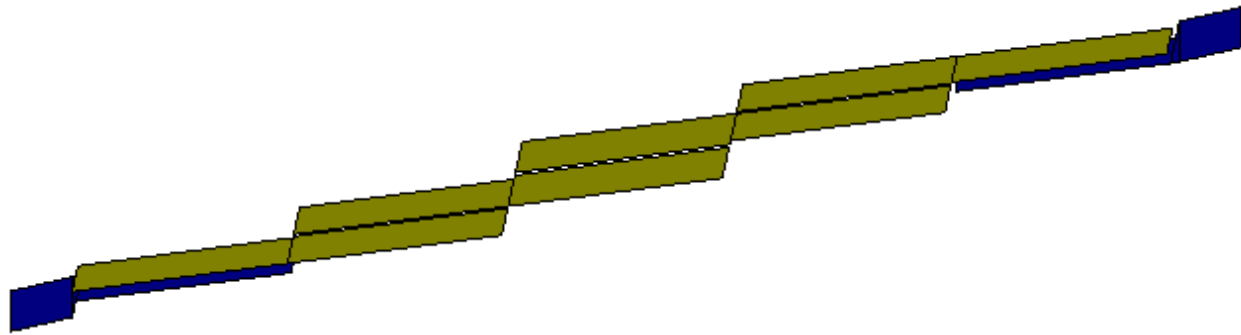
Microstrip Hairpin Bandpass Filters



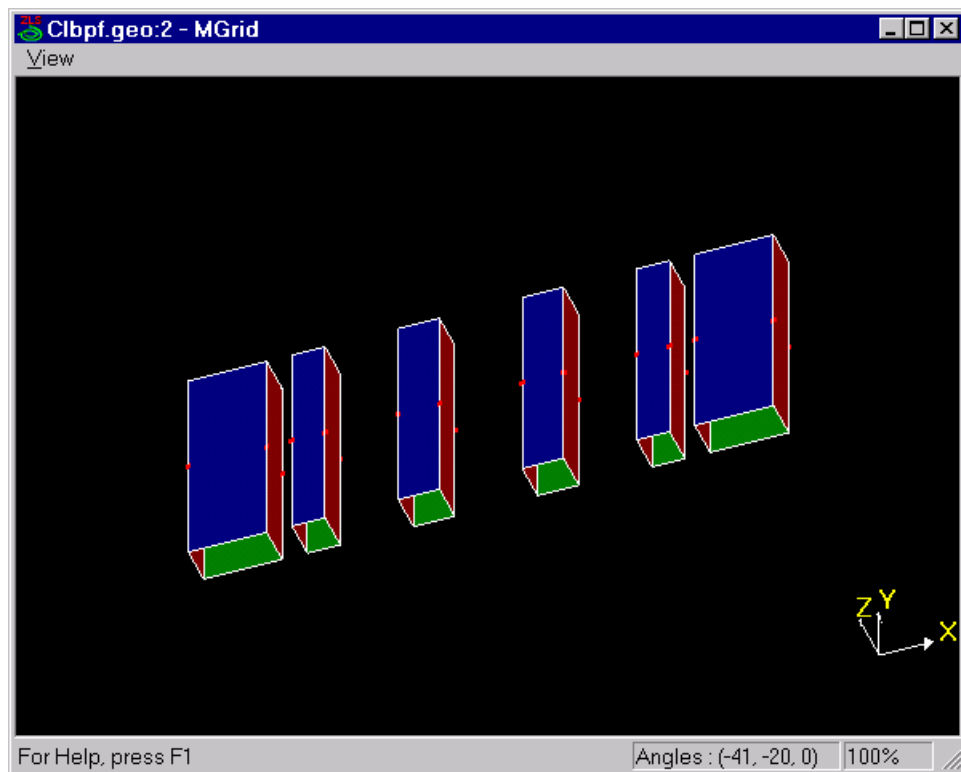
Tapped Microstrip Hairpin Bandpass Filters



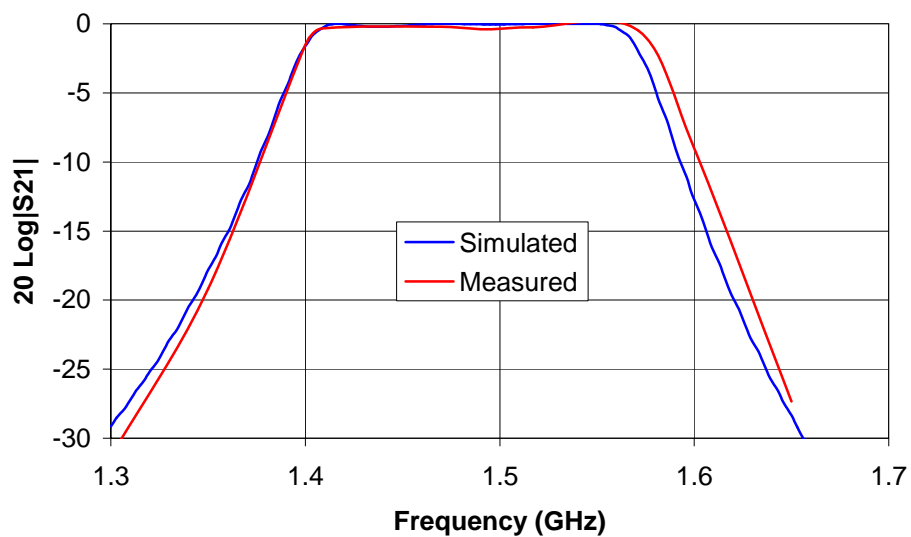
LTCC Combined Broadside/Parallel-Coupled Stripline Bandpass Filters



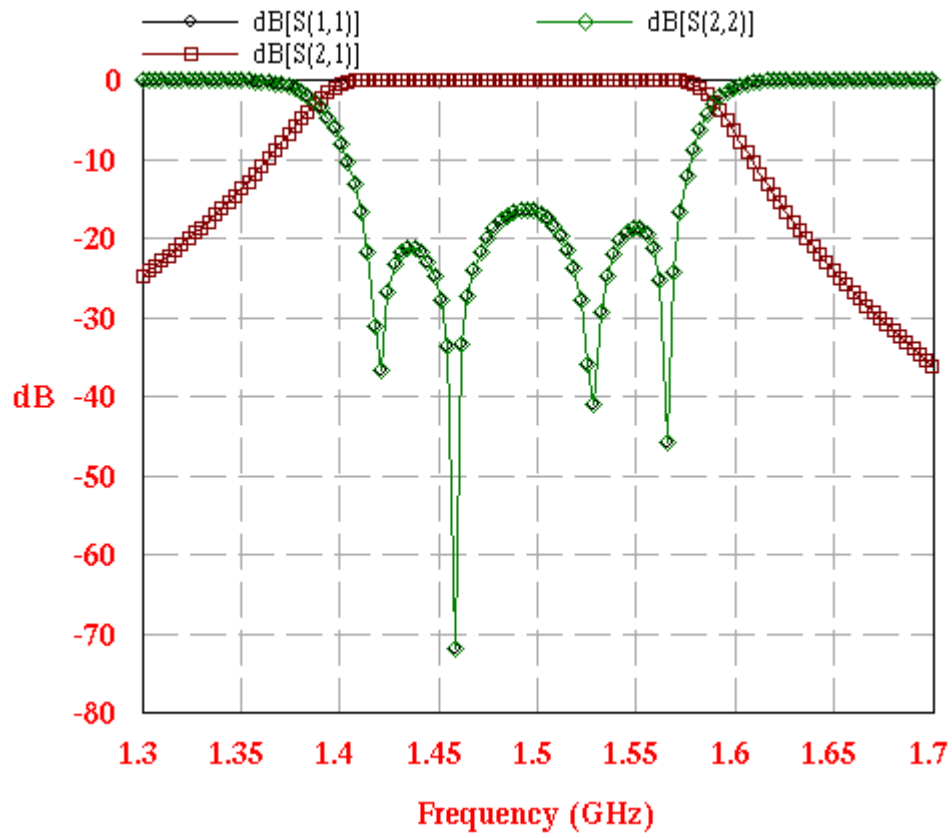
Rectangular-Bar Combline Bandpass Filter



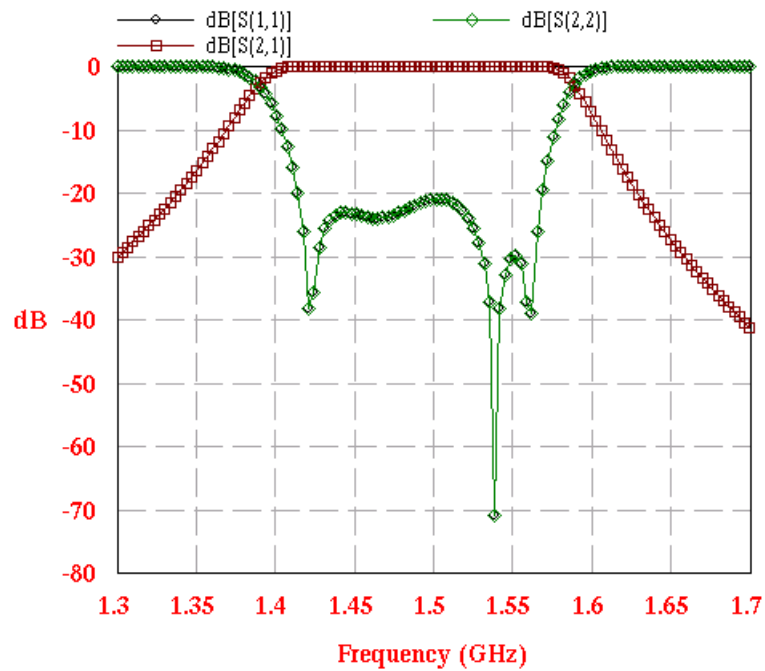
Rectangular-Bar Combline Bandpass Filter



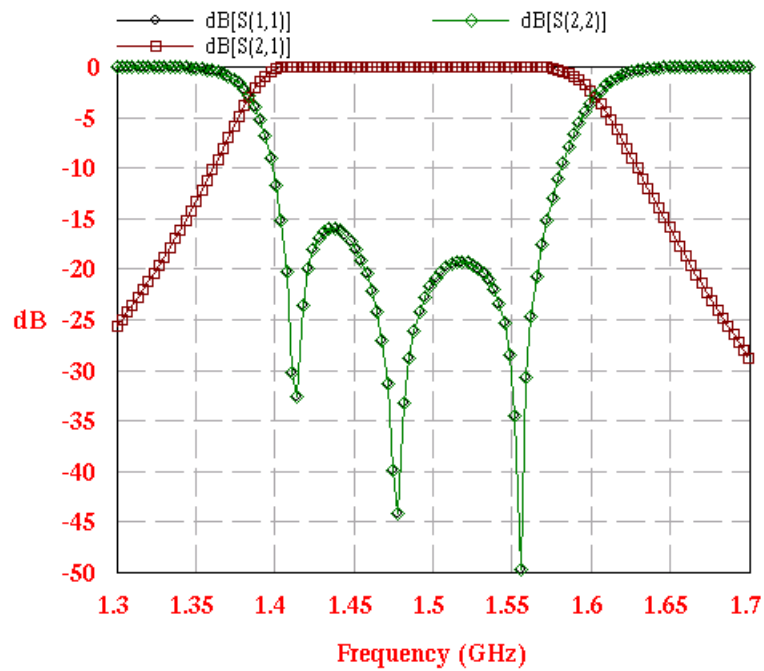
Rod Comblne Bandpass Filter



Tapped Rectangular-Bar Comblne Bandpass Filter

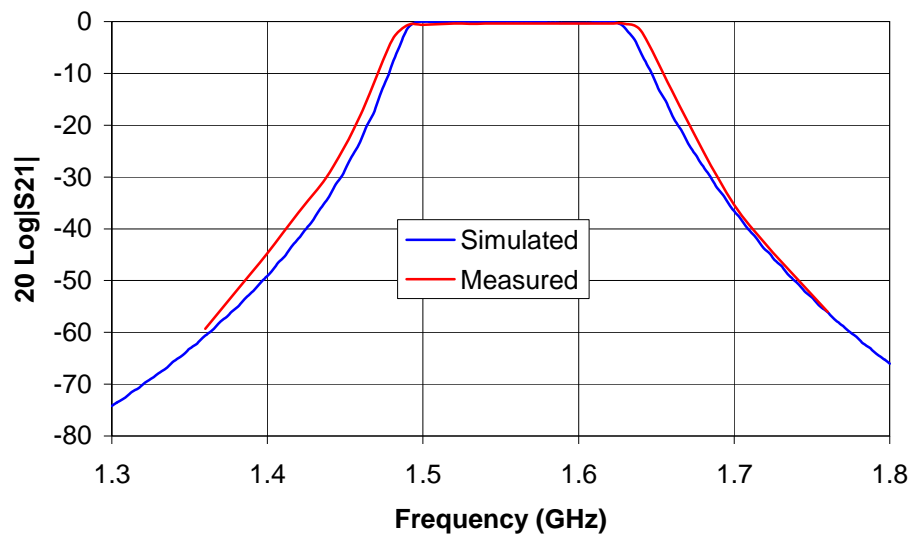


Tapped Rod Combline Bandpass Filter

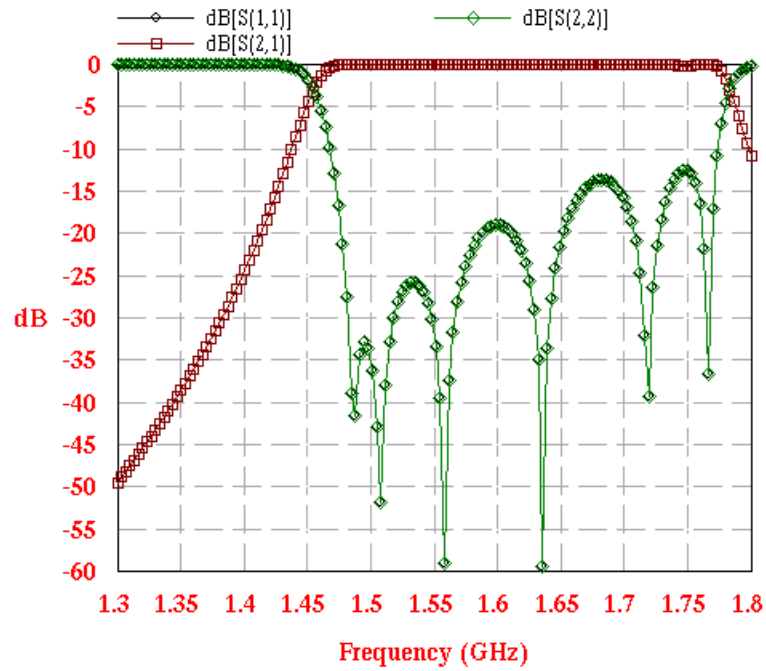


Interdigital Rectangular-Bar Bandpass Filter with Narrow to Moderate Bandwidth

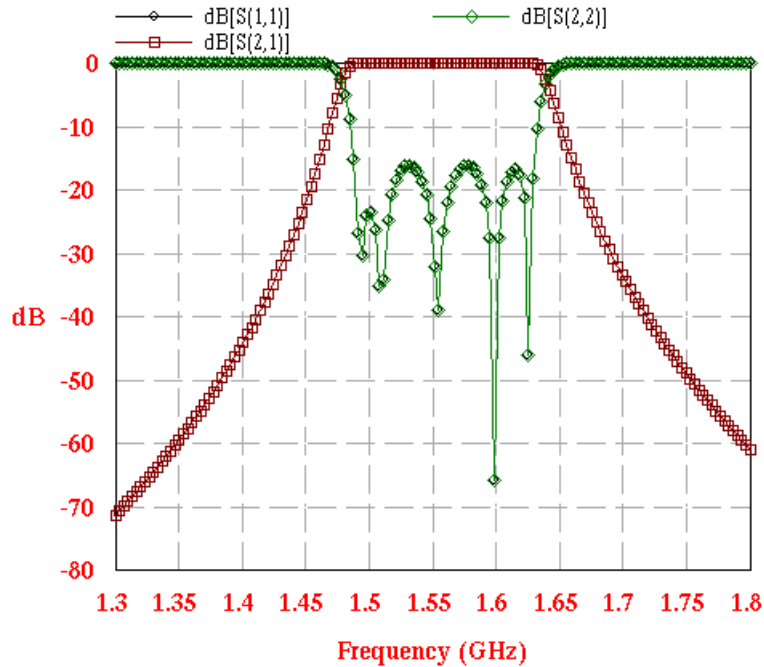
Interdigital Rectangular-Bar Bandpass Filter



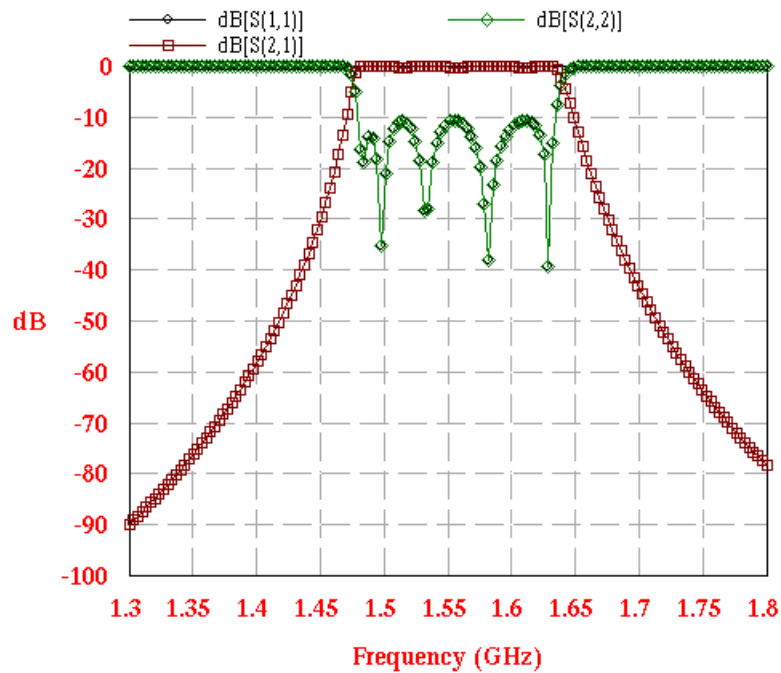
Interdigital Rod Bandpass Filter with Narrow to Moderate Bandwidth



Tapped Interdigital Rectangular-Bar Bandpass Filter with Narrow to Moderate Bandwidth

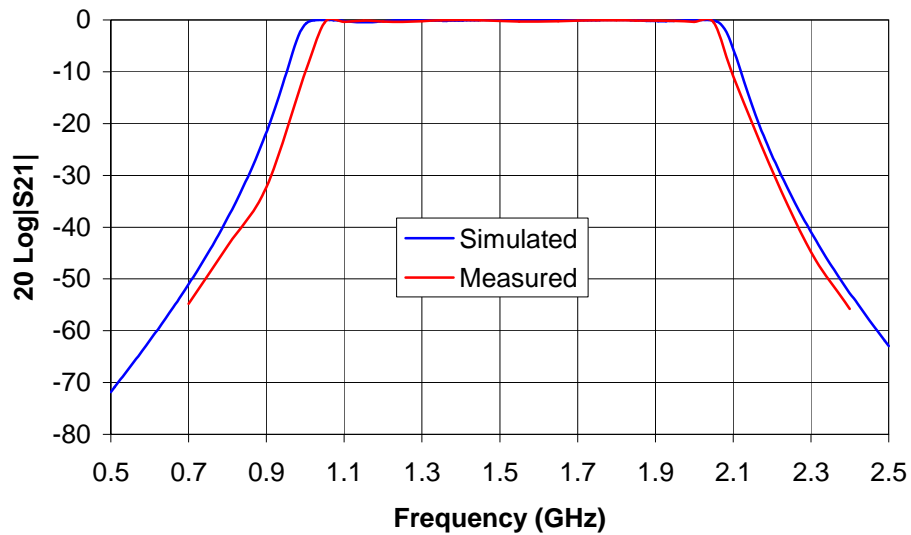


Tapped Interdigital Rod Bandpass Filter with Narrow to Moderate Bandwidth

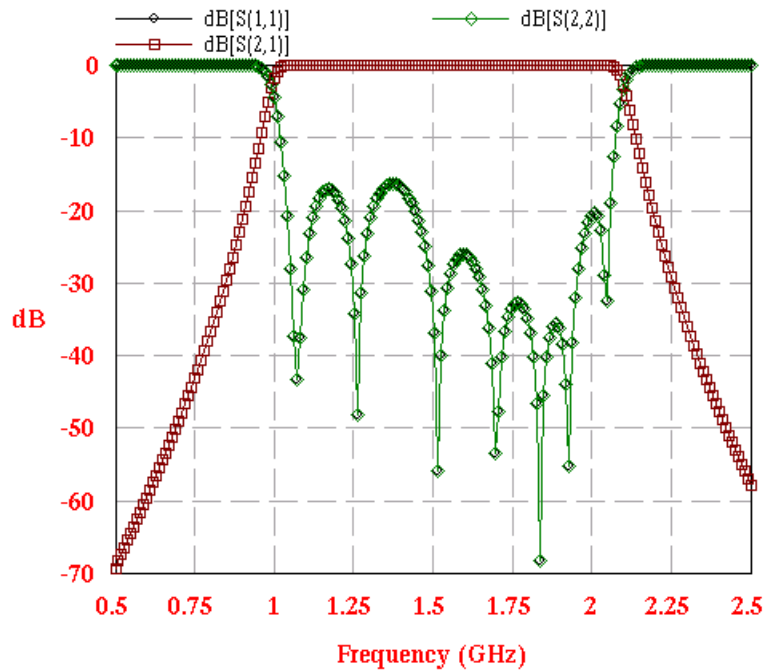


Broadband Interdigital Rectangular-Bar Bandpass Filter

Broadband Interdigital Rectangular-Bar BPF



Broadband Interdigital Rod Bandpass Filter



Hints:

Some hints about synthesizing a filter are helpful. In principle, the more resonators a filter needs, the more generations GA needs to yield a successful design. However, one run with a specified number of generations does not necessarily produce a good design because the GA used in FilterSyn starts with a different initial guess each run. Therefore, several runs are often needed. Occasionally, one run does yield a satisfactory design. Also, slight adjustments to the specs may help create a good design if the original specs are proven to be difficult. Of course, the range of resonator dimensions needs to be checked against practical standards. To gain more confidence in a design by FilterSyn, we can always simulate the design using our highly accurate field solver, IE3D, to verify the performance of the design.

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other software, and shall make those records available to Mentor Graphics upon request. Customer shall not make Products available in any form to any person other than Customer's employees and on-site contractors, excluding Mentor Graphics competitors, whose job performance requires access and who are under obligations of confidentiality. Customer shall take appropriate action to protect the confidentiality of Products and ensure that any person permitted access does not disclose or use it except as permitted by this Agreement. Customer shall give Mentor Graphics written notice of any unauthorized disclosure or use of the Products as soon as Customer learns or becomes aware of such unauthorized disclosure or use. Except as otherwise permitted for purposes of interoperability as specified by applicable and mandatory local law, Customer shall not reverse-assemble, reverse-compile, reverse-engineer or in any way derive any source code from Software. Log files, data files, rule files and script files generated by or for the Software (collectively "Files"), including without limitation files containing Standard Verification Rule Format ("SVRF") and Tcl Verification Format ("TVF") which are Mentor Graphics' proprietary syntaxes for expressing process rules, constitute or include confidential information of Mentor Graphics. Customer may share Files with third parties, excluding Mentor Graphics competitors, provided that the confidentiality of such Files is protected by written agreement at least as well as Customer protects other information of a similar nature or importance, but in any case with at least reasonable care. Customer may use Files containing SVRF or TVF only with Mentor Graphics products. Under no circumstances shall Customer use Software or Files or allow their use for the purpose of developing, enhancing or marketing any product that is in any way competitive with Software, or disclose to any third party the results of, or information pertaining to, any benchmark.

- 5.2. If any Software or portions thereof are provided in source code form, Customer will use the source code only to correct software errors and enhance or modify the Software for the authorized use. Customer shall not disclose or permit disclosure of source code, in whole or in part, including any of its methods or concepts, to anyone except Customer's employees or contractors, excluding Mentor Graphics competitors, with a need to know. Customer shall not copy or compile source code in any manner except to support this authorized use.
- 5.3. Customer may not assign this Agreement or the rights and duties under it, or relocate, sublicense or otherwise transfer the Products, whether by operation of law or otherwise ("Attempted Transfer"), without Mentor Graphics' prior written consent and payment of Mentor Graphics' then-current applicable relocation and/or transfer fees. Any Attempted Transfer without Mentor Graphics' prior written consent shall be a material breach of this Agreement and may, at Mentor Graphics' option, result in the immediate termination of the Agreement and/or the licenses granted under this Agreement. The terms of this Agreement, including without limitation the licensing and assignment provisions, shall be binding upon Customer's permitted successors in interest and assigns.
- 5.4. The provisions of this Section **RESTRICTIONS ON USE** shall survive the termination of this Agreement.
6. **SUPPORT SERVICES.** To the extent Customer purchases support services, Mentor Graphics will provide Customer updates and technical support for the Products, at the Customer site(s) for which support is purchased, in accordance with Mentor Graphics' then current End-User Support Terms located at <http://supportnet.mentor.com/about/legal/>.
7. **AUTOMATIC CHECK FOR UPDATES; PRIVACY.** Technological measures in Software may communicate with servers of Mentor Graphics or its contractors for the purpose of checking for and notifying the user of updates and to ensure that the Software in use is licensed in compliance with this Agreement. Mentor Graphics will not collect any personally identifiable data in this process and will not disclose any data collected to any third party without the prior written consent of Customer, except to Mentor Graphics' outside attorneys or as may be required by a court of competent jurisdiction.
8. **LIMITED WARRANTY.**
 - 8.1. Mentor Graphics warrants that during the warranty period its standard, generally supported Products, when properly installed, will substantially conform to the functional specifications set forth in the applicable user manual. Mentor Graphics does not warrant that Products will meet Customer's requirements or that operation of Products will be uninterrupted or error free. The warranty period is 90 days starting on the 15th day after delivery or upon installation, whichever first occurs. Customer must notify Mentor Graphics in writing of any nonconformity within the warranty period. For the avoidance of doubt, this warranty applies only to the initial shipment of Software under an Order and does not renew or reset, for example, with the delivery of (a) Software updates or (b) authorization codes or alternate Software under a transaction involving Software re-mix. This warranty shall not be valid if Products have been subject to misuse, unauthorized modification or improper installation. MENTOR GRAPHICS' ENTIRE LIABILITY AND CUSTOMER'S EXCLUSIVE REMEDY SHALL BE, AT MENTOR GRAPHICS' OPTION, EITHER (A) REFUND OF THE PRICE PAID UPON

RETURN OF THE PRODUCTS TO MENTOR GRAPHICS OR (B) MODIFICATION OR REPLACEMENT OF THE PRODUCTS THAT DO NOT MEET THIS LIMITED WARRANTY, PROVIDED CUSTOMER HAS OTHERWISE COMPLIED WITH THIS AGREEMENT. MENTOR GRAPHICS MAKES NO WARRANTIES WITH RESPECT TO: (A) SERVICES; (B) PRODUCTS PROVIDED AT NO CHARGE; OR (C) BETA CODE; ALL OF WHICH ARE PROVIDED "AS IS."

- 8.2. THE WARRANTIES SET FORTH IN THIS SECTION **LIMITED WARRANTY** ARE EXCLUSIVE. NEITHER MENTOR GRAPHICS NOR ITS LICENSORS MAKE ANY OTHER WARRANTIES EXPRESS, IMPLIED OR STATUTORY, WITH RESPECT TO PRODUCTS PROVIDED UNDER THIS AGREEMENT. MENTOR GRAPHICS AND ITS LICENSORS SPECIFICALLY DISCLAIM ALL IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE AND NON-INFRINGEMENT OF INTELLECTUAL PROPERTY.
9. **LIMITATION OF LIABILITY.** EXCEPT WHERE THIS EXCLUSION OR RESTRICTION OF LIABILITY WOULD BE VOID OR INEFFECTIVE UNDER APPLICABLE LAW, IN NO EVENT SHALL MENTOR GRAPHICS OR ITS LICENSORS BE LIABLE FOR INDIRECT, SPECIAL, INCIDENTAL, OR CONSEQUENTIAL DAMAGES (INCLUDING LOST PROFITS OR SAVINGS) WHETHER BASED ON CONTRACT, TORT OR ANY OTHER LEGAL THEORY, EVEN IF MENTOR GRAPHICS OR ITS LICENSORS HAVE BEEN ADVISED OF THE POSSIBILITY OF SUCH DAMAGES. IN NO EVENT SHALL MENTOR GRAPHICS' OR ITS LICENSORS' LIABILITY UNDER THIS AGREEMENT EXCEED THE AMOUNT RECEIVED FROM CUSTOMER FOR THE HARDWARE, SOFTWARE LICENSE OR SERVICE GIVING RISE TO THE CLAIM. IN THE CASE WHERE NO AMOUNT WAS PAID, MENTOR GRAPHICS AND ITS LICENSORS SHALL HAVE NO LIABILITY FOR ANY DAMAGES WHATSOEVER. THE PROVISIONS OF THIS SECTION **LIMITATION OF LIABILITY** SHALL SURVIVE THE TERMINATION OF THIS AGREEMENT.
10. **HAZARDOUS APPLICATIONS.** CUSTOMER ACKNOWLEDGES IT IS SOLELY RESPONSIBLE FOR TESTING ITS PRODUCTS USED IN APPLICATIONS WHERE THE FAILURE OR INACCURACY OF ITS PRODUCTS MIGHT RESULT IN DEATH OR PERSONAL INJURY ("HAZARDOUS APPLICATIONS"). NEITHER MENTOR GRAPHICS NOR ITS LICENSORS SHALL BE LIABLE FOR ANY DAMAGES RESULTING FROM OR IN CONNECTION WITH THE USE OF MENTOR GRAPHICS PRODUCTS IN OR FOR HAZARDOUS APPLICATIONS. THE PROVISIONS OF THIS SECTION **HAZARDOUS APPLICATIONS** SHALL SURVIVE THE TERMINATION OF THIS AGREEMENT.
11. **INDEMNIFICATION.** CUSTOMER AGREES TO INDEMNIFY AND HOLD HARMLESS MENTOR GRAPHICS AND ITS LICENSORS FROM ANY CLAIMS, LOSS, COST, DAMAGE, EXPENSE OR LIABILITY, INCLUDING ATTORNEYS' FEES, ARISING OUT OF OR IN CONNECTION WITH THE USE OF PRODUCTS AS DESCRIBED IN SECTION **HAZARDOUS APPLICATIONS**. THE PROVISIONS OF THIS SECTION **INDEMNIFICATION** SHALL SURVIVE THE TERMINATION OF THIS AGREEMENT.
12. **INFRINGEMENT.**
 - 12.1. Mentor Graphics will defend or settle, at its option and expense, any action brought against Customer in the United States, Canada, Japan, or member state of the European Union which alleges that any standard, generally supported Product acquired by Customer hereunder infringes a patent or copyright or misappropriates a trade secret in such jurisdiction. Mentor Graphics will pay costs and damages finally awarded against Customer that are attributable to the action. Customer understands and agrees that as conditions to Mentor Graphics' obligations under this section Customer must: (a) notify Mentor Graphics promptly in writing of the action; (b) provide Mentor Graphics all reasonable information and assistance to settle or defend the action; and (c) grant Mentor Graphics sole authority and control of the defense or settlement of the action.
 - 12.2. If a claim is made under Subsection Mentor Graphics will defend or settle, at its option and expense, any action brought against Customer in the United States, Ca Mentor Graphics may, at its option and expense, (a) replace or modify the Product so that it becomes noninfringing; (b) procure for Customer the right to continue using the Product; or (c) require the return of the Product and refund to Customer any purchase price or license fee paid, less a reasonable allowance for use.
 - 12.3. Mentor Graphics has no liability to Customer if the action is based upon: (a) the combination of Software or hardware with any product not furnished by Mentor Graphics; (b) the modification of the Product other than by Mentor Graphics; (c) the use of other than a current unaltered release of Software; (d) the use of the Product as part of an infringing process; (e) a product that Customer makes, uses, or sells; (f) any Beta Code or Product

provided at no charge; (g) any software provided by Mentor Graphics' licensors who do not provide such indemnification to Mentor Graphics' customers; or (h) infringement by Customer that is deemed willful. In the case of (h), Customer shall reimburse Mentor Graphics for its reasonable attorney fees and other costs related to the action.

- 12.4. THIS SECTION **INFRINGEMENT** IS SUBJECT TO SECTION **LIMITATION OF LIABILITY** ABOVE AND STATES THE ENTIRE LIABILITY OF MENTOR GRAPHICS AND ITS LICENSORS FOR DEFENSE, SETTLEMENT AND DAMAGES, AND CUSTOMER'S SOLE AND EXCLUSIVE REMEDY, WITH RESPECT TO ANY ALLEGED PATENT OR COPYRIGHT INFRINGEMENT OR TRADE SECRET MISAPPROPRIATION BY ANY PRODUCT PROVIDED UNDER THIS AGREEMENT.
13. **TERMINATION AND EFFECT OF TERMINATION.** If a Software license was provided for limited term use, such license will automatically terminate at the end of the authorized term.
 - 13.1. Mentor Graphics may terminate this Agreement and/or any license granted under this Agreement immediately upon written notice if Customer: (a) exceeds the scope of the license or otherwise fails to comply with the licensing or confidentiality provisions of this Agreement, or (b) becomes insolvent, files a bankruptcy petition, institutes proceedings for liquidation or winding up or enters into an agreement to assign its assets for the benefit of creditors. For any other material breach of any provision of this Agreement, Mentor Graphics may terminate this Agreement and/or any license granted under this Agreement upon 30 days written notice if Customer fails to cure the breach within the 30 day notice period. Termination of this Agreement or any license granted hereunder will not affect Customer's obligation to pay for Products shipped or licenses granted prior to the termination, which amounts shall be payable immediately upon the date of termination.
 - 13.2. Upon termination of this Agreement, the rights and obligations of the parties shall cease except as expressly set forth in this Agreement. Upon termination, Customer shall ensure that all use of the affected Products ceases, and shall return hardware and either return to Mentor Graphics or destroy Software in Customer's possession, including all copies and documentation, and certify in writing to Mentor Graphics within ten business days of the termination date that Customer no longer possesses any of the affected Products or copies of Software in any form.
14. **EXPORT.** The Products provided hereunder are subject to regulation by local laws and United States government agencies, which prohibit export or diversion of certain products and information about the products to certain countries and certain persons. Customer agrees that it will not export Products in any manner without first obtaining all necessary approval from appropriate local and United States government agencies.
15. **U.S. GOVERNMENT LICENSE RIGHTS.** Software was developed entirely at private expense. All Software is commercial computer software within the meaning of the applicable acquisition regulations. Accordingly, pursuant to US FAR 48 CFR 12.212 and DFAR 48 CFR 227.7202, use, duplication and disclosure of the Software by or for the U.S. Government or a U.S. Government subcontractor is subject solely to the terms and conditions set forth in this Agreement, except for provisions which are contrary to applicable mandatory federal laws.
16. **THIRD PARTY BENEFICIARY.** Mentor Graphics Corporation, Mentor Graphics (Ireland) Limited, Microsoft Corporation and other licensors may be third party beneficiaries of this Agreement with the right to enforce the obligations set forth herein.
17. **REVIEW OF LICENSE USAGE.** Customer will monitor the access to and use of Software. With prior written notice and during Customer's normal business hours, Mentor Graphics may engage an internationally recognized accounting firm to review Customer's software monitoring system and records deemed relevant by the internationally recognized accounting firm to confirm Customer's compliance with the terms of this Agreement or U.S. or other local export laws. Such review may include FLEXIm or FLEXnet (or successor product) report log files that Customer shall capture and provide at Mentor Graphics' request. Customer shall make records available in electronic format and shall fully cooperate with data gathering to support the license review. Mentor Graphics shall bear the expense of any such review unless a material non-compliance is revealed. Mentor Graphics shall treat as confidential information all information gained as a result of any request or review and shall only use or disclose such information as required by law or to enforce its rights under this Agreement. The provisions of this Section **REVIEW OF LICENSE USAGE** shall survive the termination of this Agreement.
18. **CONTROLLING LAW, JURISDICTION AND DISPUTE RESOLUTION.** The owners of certain Mentor Graphics intellectual property licensed under this Agreement are located in Ireland and the United States. To promote consistency around the world, disputes shall be resolved as follows: excluding conflict of laws rules, this Agreement

shall be governed by and construed under the laws of the State of Oregon, USA, if Customer is located in North or South America, and the laws of Ireland if Customer is located outside of North or South America. All disputes arising out of or in relation to this Agreement shall be submitted to the exclusive jurisdiction of the courts of Portland, Oregon when the laws of Oregon apply, or Dublin, Ireland when the laws of Ireland apply. Notwithstanding the foregoing, all disputes in Asia arising out of or in relation to this Agreement shall be resolved by arbitration in Singapore before a single arbitrator to be appointed by the chairman of the Singapore International Arbitration Centre ("SIAC") to be conducted in the English language, in accordance with the Arbitration Rules of the SIAC in effect at the time of the dispute, which rules are deemed to be incorporated by reference in this section. This section shall not restrict Mentor Graphics' right to bring an action against Customer in the jurisdiction where Customer's place of business is located. The United Nations Convention on Contracts for the International Sale of Goods does not apply to this Agreement.

19. **SEVERABILITY.** If any provision of this Agreement is held by a court of competent jurisdiction to be void, invalid, unenforceable or illegal, such provision shall be severed from this Agreement and the remaining provisions will remain in full force and effect.
20. **MISCELLANEOUS.** This Agreement contains the parties' entire understanding relating to its subject matter and supersedes all prior or contemporaneous agreements, including but not limited to any purchase order terms and conditions. Some Software may contain code distributed under a third party license agreement that may provide additional rights to Customer. Please see the applicable Software documentation for details. This Agreement may only be modified in writing by authorized representatives of the parties. Waiver of terms or excuse of breach must be in writing and shall not constitute subsequent consent, waiver or excuse.

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