

SynMatrix360 User Guideline——Gravity Version

Welcome to SynMatrix360!



SynMatrix360 software package is a robust tool for microwave filter synthesis, design, and optimization. This Gravity version includes three main sections, coupling matrix synthesis, computer aided tuning and powerful tools for sensitivity analysis and coupling matrix optimization. The software is intended for industrial or academic use in design and analysis of microwave filters on both component and system levels. Only fundamental knowledge about filters is required to operate the software.

The section of coupling matrix synthesis facilitates synthesis of coupling matrix for single filters, with arbitrary number of real, imaginary and complex transmission zeros. Based on the information of transmission zeros and layout preference, users can define the filter topologies and synthesis the coupling matrixes with flexibility; meanwhile, it also provides user the corresponded stored energy plot and a convenient way to obtain the maximum handled power capability. Additionally; the software also gives an overview of insertion loss, isolation, group delay versus filter order, return loss and prescribed transmission zeros.

The section of computer aided tuning is an advanced tool to optimize the RF response from either EM software or VNA measurement. A “real-time” coupling matrix is extracted from loaded data and compared with ideal coupling matrix to produce a summary of errors. The error of each coupling matrix parameter provides a fast and direct guidance to optimize the filter response.

The section of tool box contains the coupling matrix optimization and sensitivity analysis (also called Monte-Carlo analysis). The optimization application provides user a multi-functional and powerful engine to help user achieve their design goals. The sensitivity

analysis which is also named as Monte-Carlo sensitivity analysis allows user to investigate how sensitive of the targeted matrix due to manufacturing or assembly tolerances.

The Other features for this new Gravity version include:

- Advanced parameter plotting options (S-parameter, group delay, phase plot and stored energy).;
- Stored energy and power handling calculator;
- Advanced graph and marker functions (analysis window, zoom in, zoom out and marker lines);
- Specification lines with auto colored pass/fail indicators;
- Two types of coupling matrix format including generic coupling matrix and coupling matrix with bandwidth information
- Coupling matrix values are editable and can be fine-tuned by frequency/bandwidth shift to reflect the change of filter response without changing filter specifications.
- Quality factor of each resonator can be custom-defined either uniformly or non-uniformly.
- Dispersion effect can be applied to improve the simulation response confront to reality.
- Coupling matrix and its corresponded S2P file can be exported to text file output.

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
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Coupling Matrix Synthesis:

Input Section:

1. Parameter Input

Parameter Input		
Filter Order:	10	
Center Freq:	1	GHz
Bandwidth:	0.05	GHz
Return Loss:	25	dB
Q:	Infinity	1 ▾ ↺

- The order of the filter must be between 1 and 20(The free edition only supports filter order up to 5).
-  button can switch the format between “Center Frequency/Bandwidth” and “Start/Stop Frequencies”
- Q is defaulted to be infinity however can be custom-defined for each resonator. The function supplies an accessible way to monitor the insertion loss and return loss change for the filters with multiple types of resonators, for instance the hybrid metal-ceramic filter.

➤ An example of customized Q:

Reasonator #1	2000
Reasonator #2	2000
Reasonator #3	3000
Reasonator #4	4000
Reasonator #5	2000

- "Calculate all" button must be clicked to update any change in this section.

2. Transmission Zeros

Transmission Zeroes +

Real		Imaginary	
real		imag	
real		imag	

Transmission Zeroes +

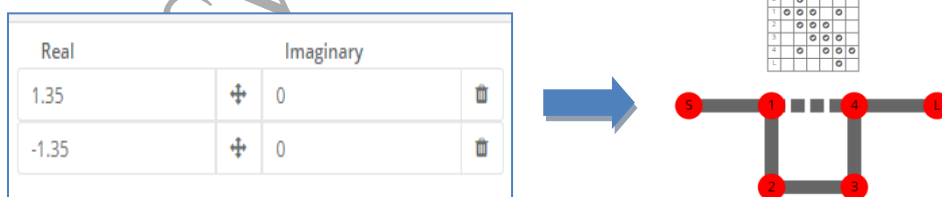
Frequency			
GHz		GHz	
GHz		GHz	

- For an N'th order filter, maximal N finite transmissions zeroes can be specified. SynMatrix360 defaults the real frequency format as the normal input. In the normalized format, the real and complex zeros are always in pairs no matter with symmetric and asymmetric filter response. Therefore the number of real zeros and the number of complex zeros must be even numbers. For imaginary zeros, the number of zeros is even for symmetric response and odd for asymmetric response. A filter without finite transmission zeroes has all its zeroes placed at infinite frequencies. Two examples about the complex zeros are shown as below:

Ex. 1: With complex transmission zeros

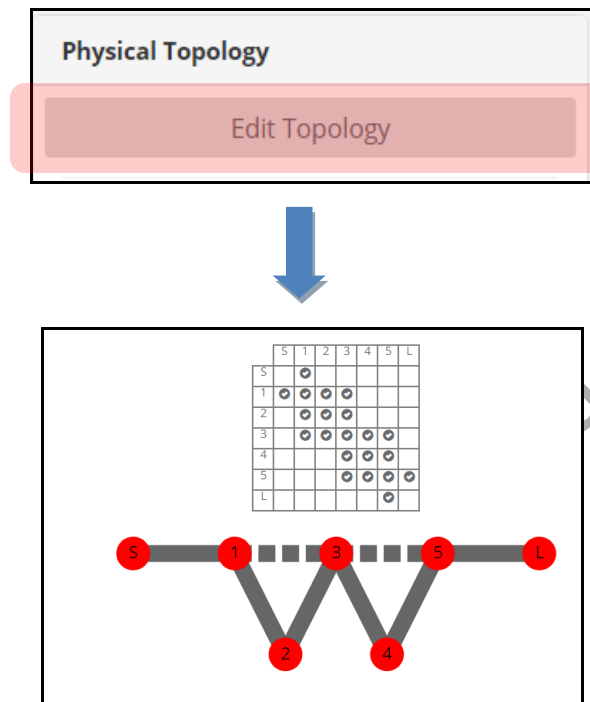


Ex. 2: With a pair of real transmission zeros



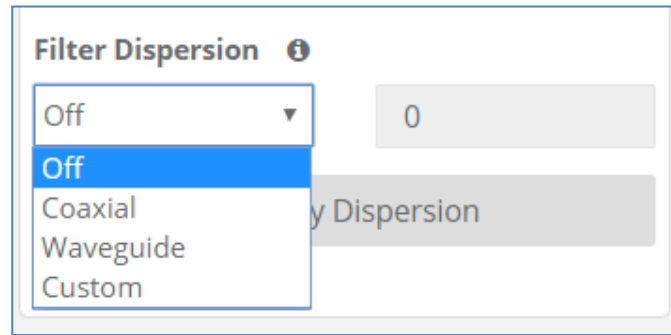
- Users can input either the “normalized (to center frequency) frequency” or “real frequency” of the zeros by clicking the button. For instance, a filter with 2GHz center frequency and 0.1 GHz bandwidth, imaginary zeros “1.5” and “3” are equivalent to the imaginary transmission zeros at frequencies “2.08 GHz” and “2.16 GHz”.
- "Calculate all" button must be clicked to update the change in this section.

3. Physical Topology



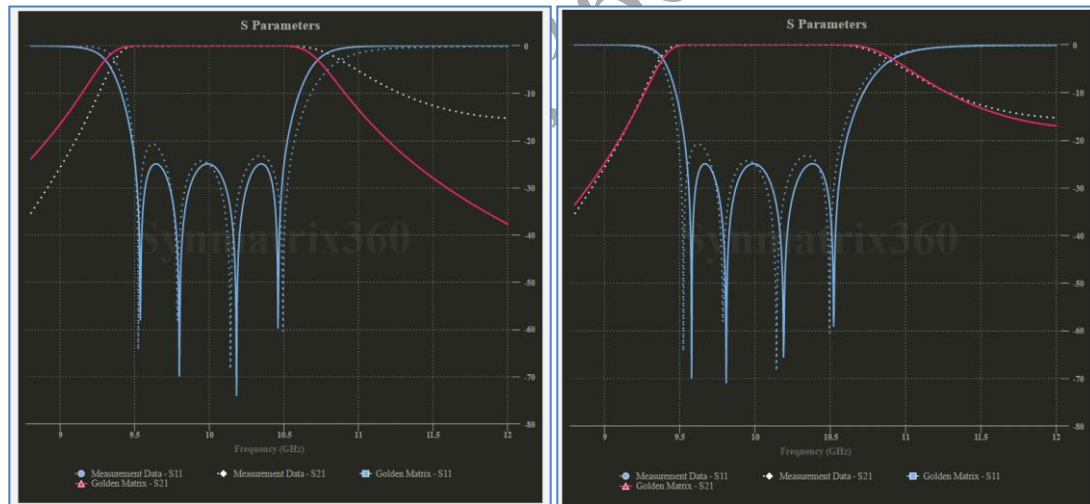
- The topology matrix either can be pre-defined by user after setting the values of transmission zeros, or defaulted as 'Folded' structure without any definitions. The wrong topology definition or unrealistic topology may result in a "Full Matrix" with parameters at random locations or popup an error message
- User can define arbitrary topologies by simply checking boxes in the matrix, and the corresponding topologies are generated automatically. In the matrix, a 'checked' box indicates a signal path, *i.e.* coupling between two resonators and an 'un-checked' field indicates zero coupling. 'S' and 'L' denote input and output ports respectively.
- The defaulted topology is "inline" type filter without transmission zeros and "Folded" structure with transmission zeros under user defined filter order; "Save" button must be clicked to update the change in this section.

4. Filter Dispersion



- If necessary, user can apply dispersion effect on the S-parameter with specific resonator structures (e.g. waveguide or coaxial). This is recommended for filters with wide bandwidth (e.g. fractional Bandwidth $\geq 10\%$). For example, a 4-pole waveguide filter with 1 GHz bandwidth and 10 GHz center frequency, the response with dispersion effect is much closer to the EM simulation / measurement, compared to the one not applying the dispersion.

No Dispersion vs. EM Simulation With Dispersion vs. EM Simulation



- The dispersion value in the right box controls the dispersive amount. It specifies the factor by which the dispersion can be multiplied. The defaulted value for waveguide and coaxial structure is derived and estimated from our heritage simulation and test results thus suitable for most cases. However users can also custom-define the dispersion value in case the defaulted values are inappropriate.
- Please note that the frequency may be varied after applying the dispersion function. The amounts of variation depend on how much of the defined dispersion factor. The positive value will move the frequency to the high side, while the negative value will shift to the low side. SynMatrix360 suggests user to fine tune the filter performance, either shifting the frequency or

bandwidth until the overall performance can satisfy the design specification again.

- Not only the dispersion function can simulate the dispersive effect as well as some abnormal performance which may caused by spurious, but also can assist computer aided tuning capture. By properly setting the dispersive value, the simulated or measured filter performance which are interfered by spurious can be extracted accurately and fast.
- "Apply Dispersion" button must be clicked to update the change in this section. To remove the dispersion effect, choose "Off" and click "Apply Dispersion".

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5. Power Handling Analysis



- Filter peak power handle capability can be obtained by this convenient application. All required information is listed and explained as below:

1. Maximum E Field: The maximum electrical field obtained either from single cavity (Eigen mode) or fully EM structure obtained from any commercial EM software.
2. Corresponding Stored Energy: The corresponded stored energy obtained in EM simulation
3. Max Stored Energy: The maximum stored energy from circuit mode. User can copy this value from "Maximum Stored Energy" directly



Max (nJ)
9.2993

4. Air Breakdown Value: Default as 2.3e6 V/m

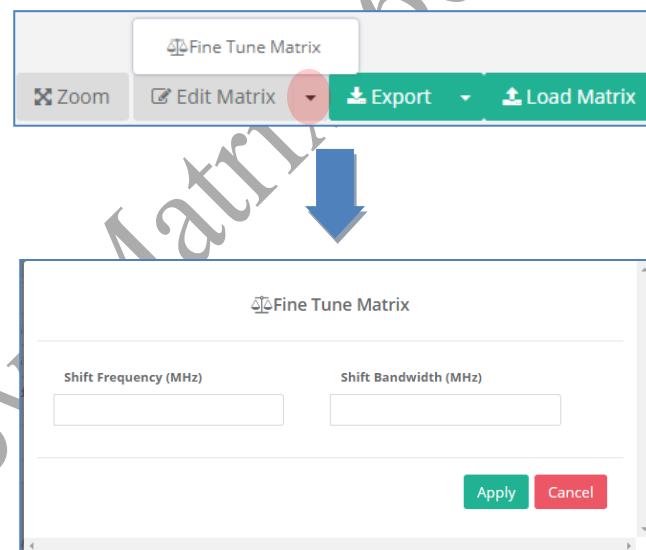
- Once user input all required parameters and click "OK", the corresponded handled power will be obtained.
- Please note that this stored energy is assumed 1watts input power.

6. Analysis Band

Analysis Band		
Start Freq:	1.75	GHz
Stop Freq:	2.25	GHz

- The start and stop frequencies define the frequency band, which are used for plotting the filter characteristics.
- Moreover, user can easily update the result by clicking this "Refresh" icon  once user modify the f0, BW, unloaded Q.
- "Refresh" icon  must be clicked to update the change in this section.

7. Fine Tune Function



The diagram illustrates the workflow for the Fine Tune Function. It starts with the main toolbar where the 'Edit Matrix' button is highlighted with a red circle. A blue arrow points down to the 'Fine Tune Matrix' dialog box. The dialog box contains two input fields: 'Shift Frequency (MHz)' and 'Shift Bandwidth (MHz)', both currently empty. At the bottom right of the dialog are 'Apply' and 'Cancel' buttons.

- The coupling matrix can be fine-tuned by shifting frequency and/or bandwidth without modifying the targeted center frequency and bandwidth in "Parameter Input" tab. This function can be found by clicking the red highlighted black arrow aside of "Edit Matrix". Click "Apply" to execute the shift function.
- The coupling matrix also can be edited manually and saved while clicking "Done editing". Click "Calculate all" to reverse the change.

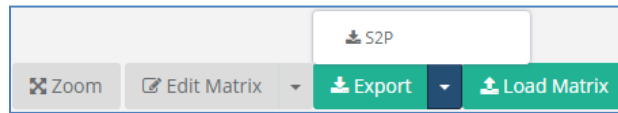
Output Section:

8. Coupling Matrix

	S	1	2	3	4	5	6	7	8	L
S	0	1.0873	0	0	0	0	0	0	0	0
1	1.0873	0	0.9103	0	0	0	0	0	0	0
2	0	0.9103	0	0.6211	0	0	0	0	0	0
3	0	0	0.6211	0	0.5718	0	0	0	0	0
4	0	0	0	0.5718	0	0.5614	0	0	0	0
5	0	0	0	0	0.5614	0	0.5718	0	0	0
6	0	0	0	0	0	0.5718	0	0.6211	0	0
7	0	0	0	0	0	0	0.6211	0	0.9103	0
8	0	0	0	0	0	0	0	0.9103	0	1.0873
L	0	0	0	0	0	0	0	0	1.0873	0

- When the “Calculate All” button is clicked, the coupling matrix is updated with new coupling coefficients corresponding to the pre-defined topology. Different colors indicated different coupling types, e.g. self-coupling, sequential coupling and cross-coupling.
- The coupling coefficients may be displayed in two different formats either as: Normalized M_{ij} , or coupling bandwidth($M_{ij} * BW$).
- If the required filter performance cannot be realized with the pre-defined topology matrix(Out of synthesis theory scope), the software will generate an “optimized” matrix with the coupling coefficients at arbitrary locations.

9. Export S2P File & Load Matrix

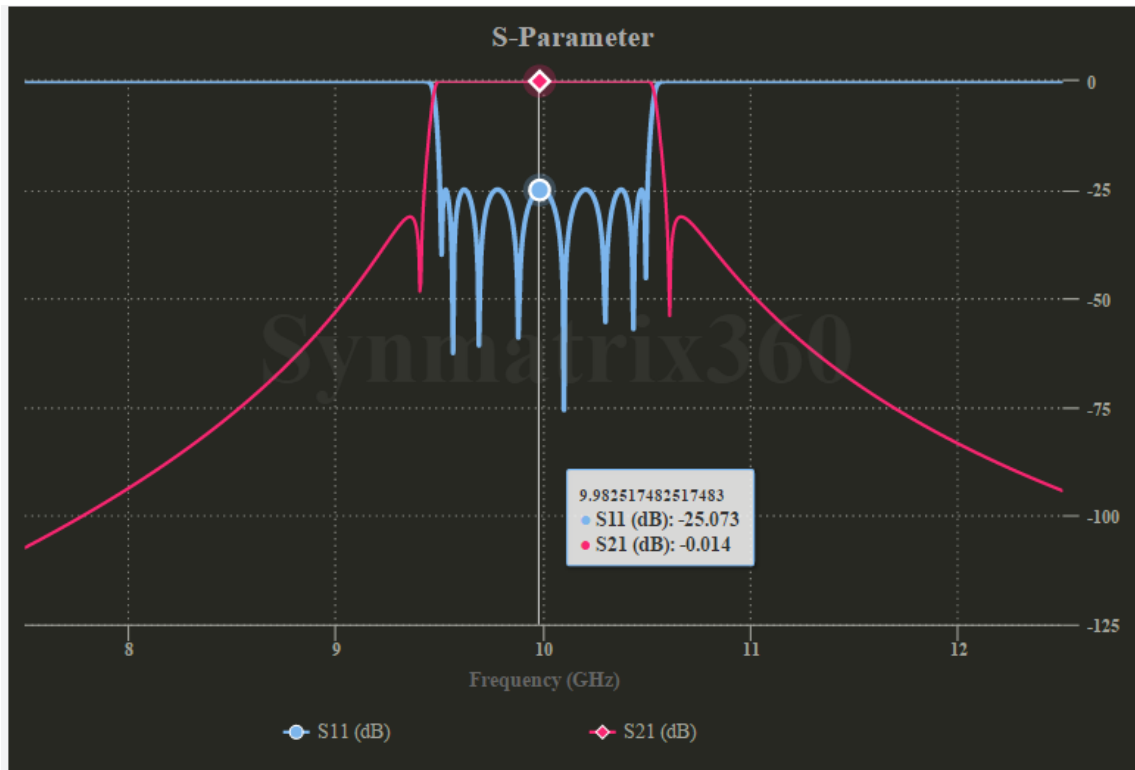


- When the synthesis work has been completed, the generated coupling matrix as well as its corresponded S2P data file can be exported by clicking the "S2P" above of the "Export" button.
- Click "Load Matrix" button and import customized Matrix file with text format. Please note that there are 2 spaces apart between every two values in each row in the matrix file. The wrong format will result in failures. An example of a matrix for a 6-pole filter is as below.

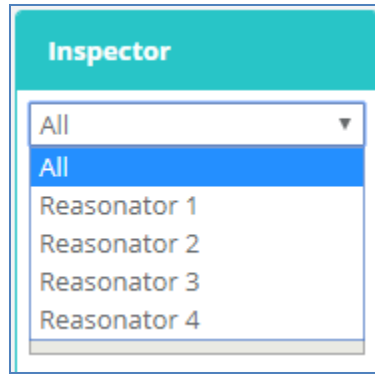
0.0000	1.1032	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1.1032	0.0315	0.8142	0.4702	0.0000	0.0000	0.0000	0.0000
0.0000	0.8142	-0.5936	0.5235	0.0000	0.0000	0.0000	0.0000
0.0000	0.4702	0.5235	0.1262	0.6126	0.0000	0.0000	0.0000
0.0000	0.0000	0.0000	0.6126	0.0959	0.6232	0.2074	0.0000
0.0000	0.0000	0.0000	0.0000	0.6232	-0.2450	0.9170	0.0000
0.0000	0.0000	0.0000	0.0000	0.2074	0.9170	0.0315	1.1032
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.1032	0.0000

- Click "Calculate all" to revert the imported Matrix back to the synthesized Matrix.

10. Plots



- The filter response is plotted based on the synthesized coupling-matrix after clicking the "Calculated All" button.
- Marker line automatically appears (vertical lines) and shows the value of S11 and S21 while moving the mouse inside the plot zone.
- The plot can be zoomed to full screen by simply right-clicking the plot at anywhere.
- Stored energy plot: the corresponded stored energy based on user synthesized matrix will be shown under the "Power Analysis" page. User can investigate each single resonator by choosing different resonator. The stored energy is computed based on 1Watt input power.



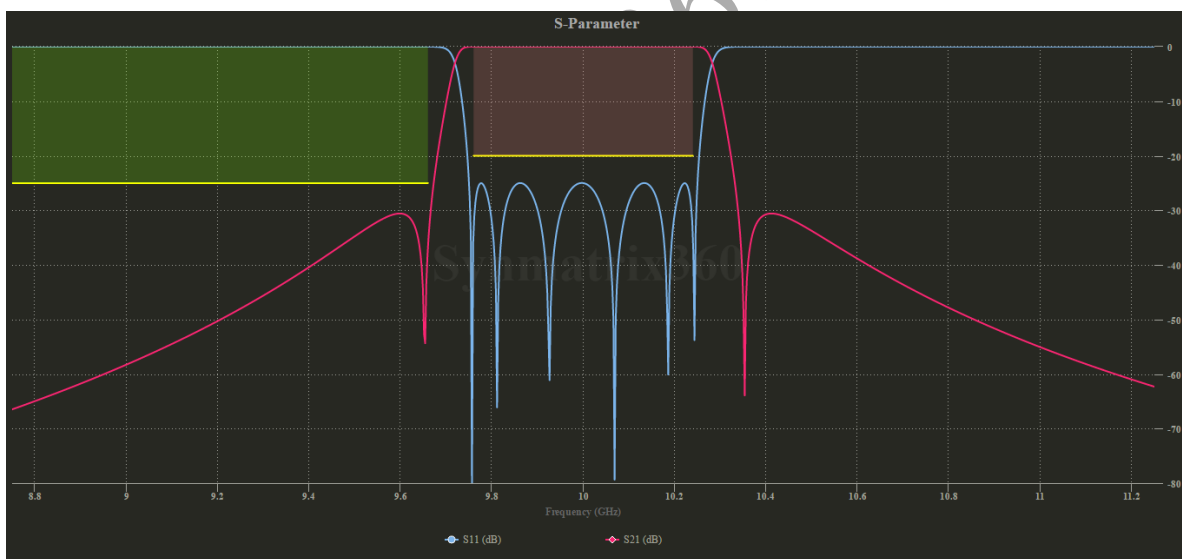
- Inspector: it shows the stored energy information
 - ✓ Max(nJ): the maximum stored energy based on the circuit model calculated from the current synthesized matrix;
 - ✓ Res. No.: To show the index of resonator which has the maximum stored energy
 - ✓ Freq(GHz): The peak frequency at the maximum stored energy

 The image shows a dialog box titled "Inspector". It contains several input fields:

- A dropdown menu with "All" selected.
- A text field labeled "Max (nJ)" with the value "9.2993".
- A text field labeled "Freq (GHz)" with the value "1.0328".
- A text field labeled "Res.No" with the value "Res 2".
- A text field labeled "Air Breakdown Value (V/m)" with the value "2300000".
- An "OK" button at the bottom.

11. Specifications

S Parameter		Group Delay		Specification	
RL (<)		-24	dB	<input checked="" type="checkbox"/>	
9.76	GHz	10.24	GHz	<input type="checkbox"/>	
This spec passes for this data.					
Iso (<)		-25	dB	<input checked="" type="checkbox"/>	
8.75	GHz	9.5	GHz	<input type="checkbox"/>	

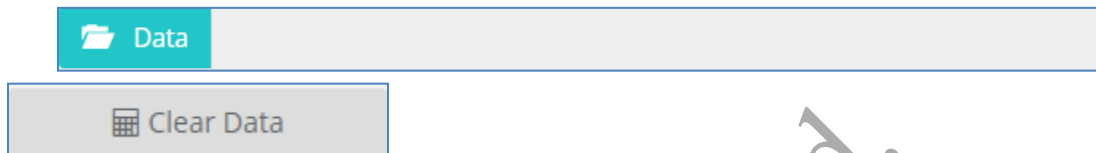


- Specifications of Return Loss (RL), Insertion Loss (IL), Isolation (Iso) and Group Delay (GD) can be input in the "Specification" tab. A blue "Check" or a red "Cross" indicates the current performance meeting or not meeting the input specification after the specification input. Meanwhile the S-plot is automatically updated with the specification lines.

Computer Aided Tuning:

Input Section:

1. Data Import and Clear Data



- Click “Data” button and import “.S2p” file from EM simulation or VNA measurement. Response of the imported data will automatically show in the S-plots
- Click “Clear Data” button to remove the data imported and the corresponding S-parameters.

2. Golden Matrix

The screenshot shows the 'Golden Matrix' tab with a table of S-parameters. The table has columns labeled S, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, and L. The rows are labeled S, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, and L. The values are color-coded: green for 0, orange for non-zero values, and blue for negative values.

	S	1	2	3	4	5	6	7	8	9	10	L
S	0	1.0757	0	0	0	0	0	0	0	0	0	0
1	1.0757	0	0.8901	0	0	0	0	0	0	0	0	0
2	0	0.8901	0	0.4744	0.3759	0	0	0	0	0	0	0
3	0	0	0.4744	0.6775	0.4139	0	0	0	0	0	0	0
4	0	0	0.3759	0.4139	0.0344	0.5377	0	0	0	0	0	0
5	0	0	0	0	0.5377	0.0089	0.5333	0	0	0	0	0
6	0	0	0	0	0	0.5333	-0.0089	0.4215	-0.3339	0	0	0
7	0	0	0	0	0	0	0.4215	0.6432	0.4412	0	0	0
8	0	0	0	0	0	0	-0.3339	0.4412	0	0.6053	0	0
9	0	0	0	0	0	0	0	0	0.6053	0	0.8901	0
10	0	0	0	0	0	0	0	0	0	0.8901	0	1.0757
L	0	0	0	0	0	0	0	0	0	0	1.0757	0

At the bottom of the table, there are three buttons: 'Zoom', 'Edit Matrix', and 'Reload'.

- The Golden Matrix/Ideal Matrix is the coupling matrix whose response is to set as target S-parameter for the filter design and tuning. It is usually automatically transferred from the matrix on the Matrix Synthesis page.
- The Golden Matrix can be edited manually and saved while clicking “Done editing”. Click “Reload” to reverse the change.

3. Capture Range

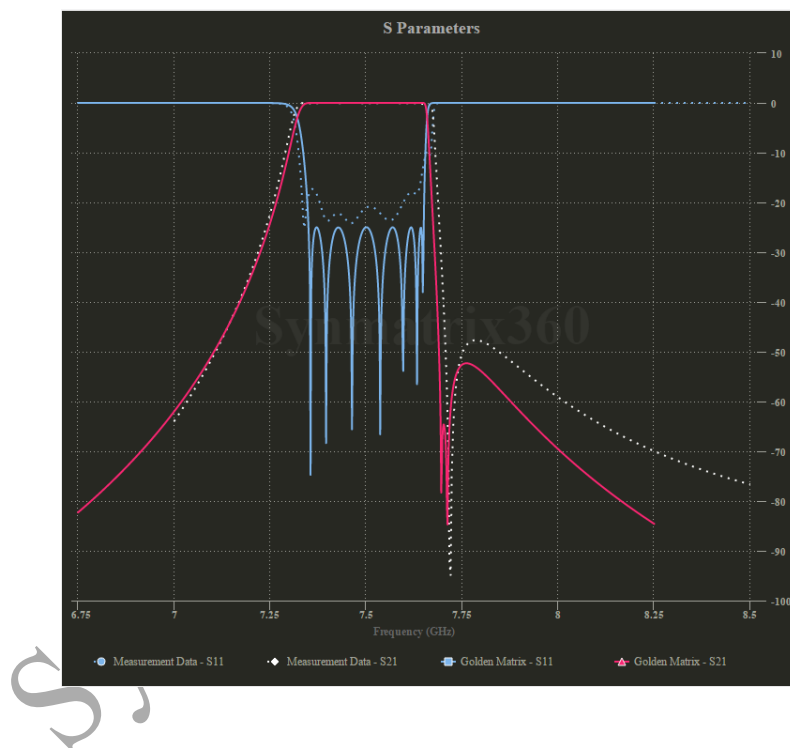
A screenshot of a software interface showing a 'Capture Range' input field. The field is a horizontal rectangle with a light gray background and a thin blue border. It contains the text 'Capture from' followed by a small input box containing the number '0', then the text 'to' followed by another small input box containing the number '0'. The entire field is highlighted with a blue selection box.

- At most cases, the capture frequency range of the S-parameters are auto-determined thus NO need manual input. For some particular cases, user may need define the capture range manually for better capturing effect.

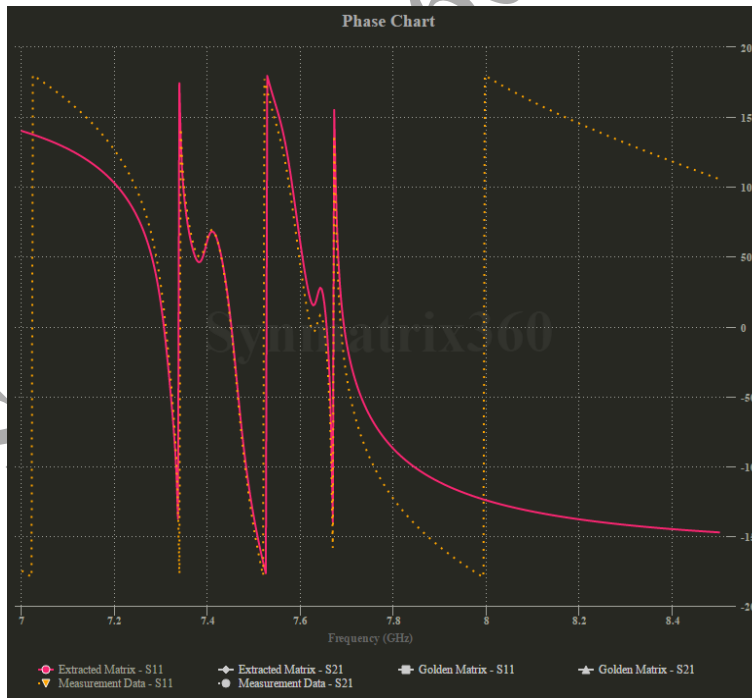
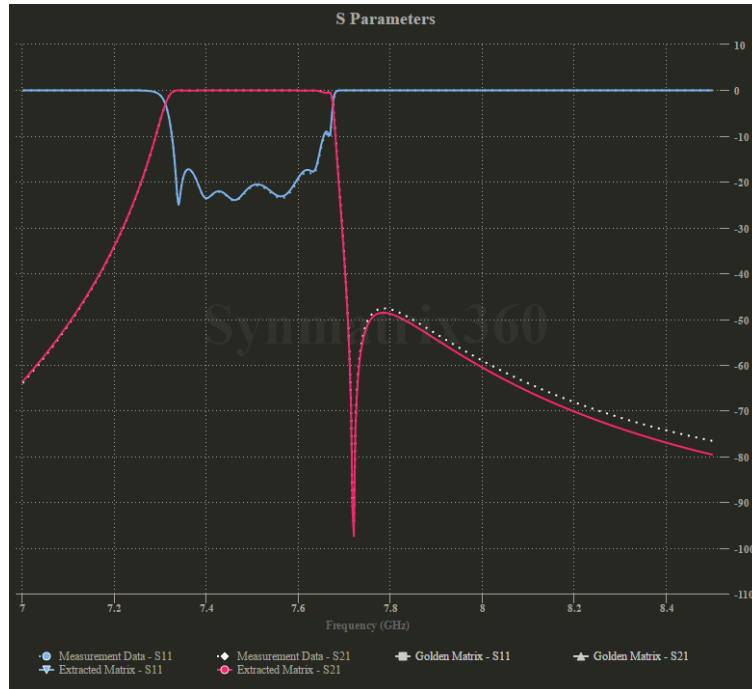
Output Section:

4. Extracted Matrix

- Click “Extract Matrix” button after importing the data file, an extracted matrix corresponding with the data file will be generated. At the meantime, an S-parameter response of “Extracted Matrix S11 and S21” will be shown in the plot and an error summary will be generated to provide guidance of optimization.

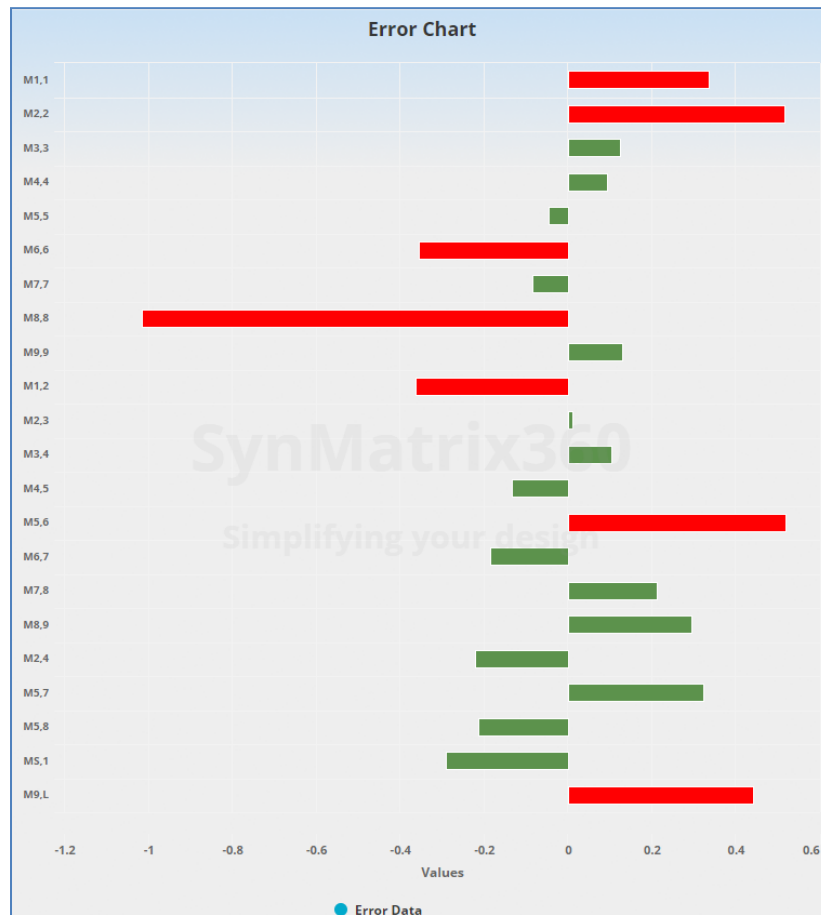


- A good matchup between the “Measurement Data” and “Extracted Matrix” is the key point for a successful optimization. For the example below, the responses of S-parameters and phases are both perfectly aligned.



- To continue the optimization process, users can load the latest data after every simulation and click “Extract Matrix” or hotkey "D" button to update the error summary.

5. Error Summary



- A bar chart of coupling errors will automatically show up after generating the extracted matrix.
- Each bar height corresponds to the coupling difference (error) between the extracted matrix and golden matrix. The longer bar, the larger error of the corresponding coupling matrix parameter. Generally, the relationship between the coupling matrix parameters and the errors are shown in the table as below.

Coupling Matrix Parameters	Error Sign	Corrective Action
Self Coupling (M11, M22,...Mii)	Positive	Decrease the resonator frequency / Increase the resonator size
	Negative	Increase the resonator frequency / Decrease the resonator size
Sequential Coupling (M01, M12,...Mij)	Positive	Decrease the external or internal coupling
	Negative	Increase the external or internal coupling
Positive Cross Coupling	Positive	Decrease the cross coupling
	Negative	Increase the cross coupling
Negative Cross Coupling	Positive	Increase the cross coupling
	Negative	Decrease the cross coupling

- The length of the bar is obtained by these following equations. If the amount of deviation, which is defined as Extracted Matrix subtract Golden Matrix, are smaller than 0.005, the bar will turn green; otherwise it keeps red color.

Error bar length for self coupling= $-BW/2 * (\text{Extracted Matrix} - \text{Golden Matrix})$

Error bar length for sequential coupling(include I/O, cross coupling)= $BW * (\text{Extracted Matrix} - \text{Golden Matrix})$

- Users are suggested to prioritize the modification on the parameters with LARGE error.

Tools Box:

1. Monte-Carlo:

Input Section:

1. Parameters Input:

- Standard filter input parameter including frequency range, unloaded Q; please refer to the section 1 in “Coupling Matrix Synthesis” to obtain more details.
- When user switch to this page, all filter information will be copied from the "Synthesis" page, including generated Coupling matrix, Center Freq, Bandwidth, Unloaded Q and Start/Stop freq

2. Monte-Carlo Configuration:

Monte-Carlo Configuration

☐ Main Coupling ☐ Sequential Coupling ☐ Single Element ☒ All Couplings

Change (%) Sampling No. M (i, j)

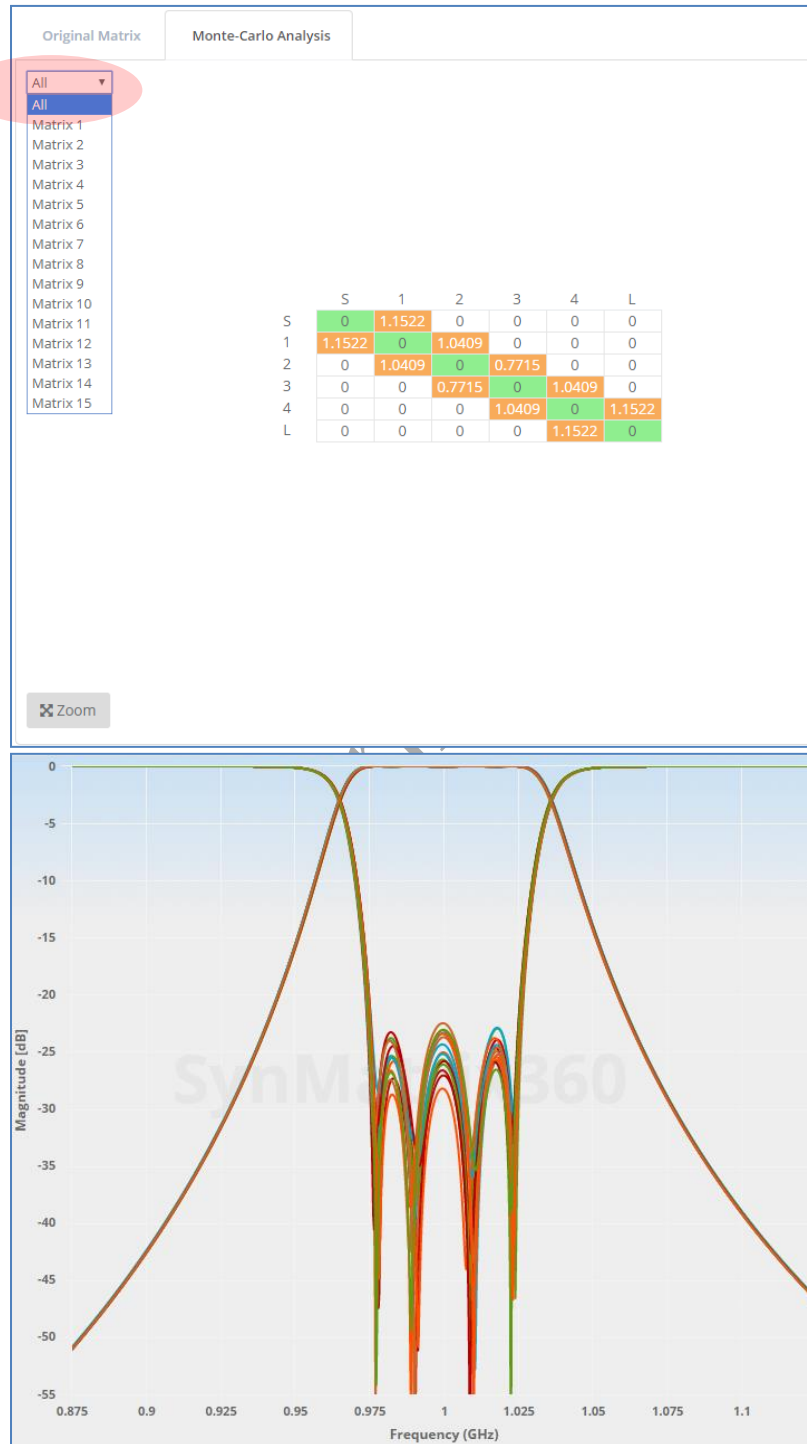
		i-index	j-index
1	15		

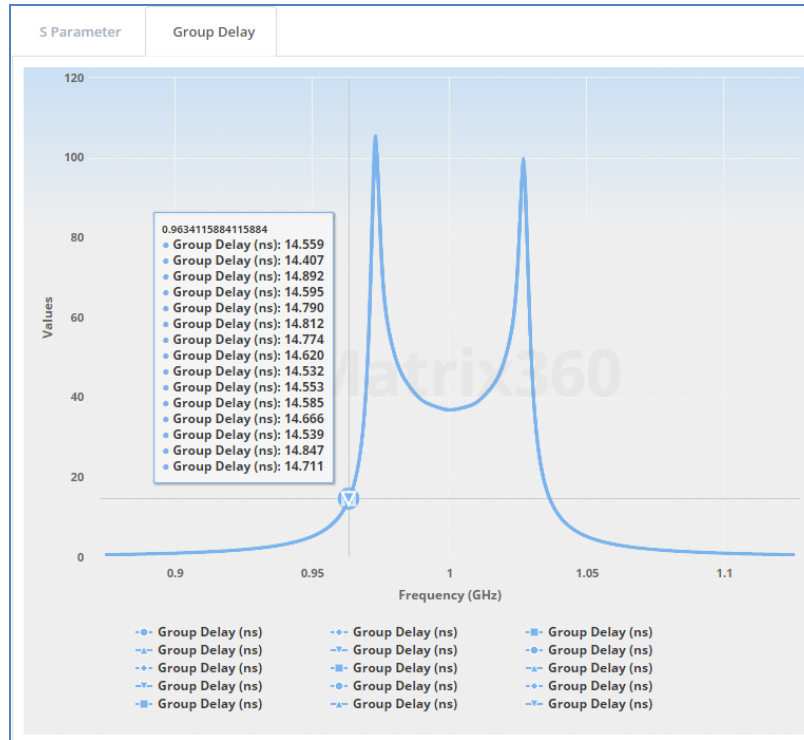
Run

- Monte-Carlo function offers four flexible options to provide user the maximum capability to analyze the matrix's sensitivity or so-called stability.
 - ✓ **Main Coupling**: Analyze the self-coupling values where locate at the main diagonal in the matrix
 - ✓ **Sequential Coupling**: Analyze the sequential coupling values where locate at the sub-diagonal in the matrix
 - ✓ **Single Element**: Analyze how sensitive of the individual element in the matrix. The “i” and “j” represent the column and row index number respectively in the coupling matrix
 - ✓ **All Elements**: Analyze the stability of whole matrix. Each element in the matrix will be involved and analyzed.
 - ✓ **Change(%)**: Parameters change percentage for each option during the Monte-Carlo analysis
 - ✓ **Sampling No.**: Monte-Carlo analysis applies random sampling by using the normal distribution method. The Sampling No. refers to how many points are applied to random sampling. The SynMatrix360 defaults 20 sampling points as the maximum input.

Output Section:

1. Monte-Carlo Analysis Information & Corresponded S-Plot





- SynMatrix360 defaults to plot all S parameters generating from the Monte-Carlo analysis; additionally, by clicking the black arrow at the top left of the "**Monte-Carlo Analysis**" page, user can select the matrix they are interested in to take further the analysis. Since the GD is insensitivity with the coupling matrix varying, SynMatrix360 offers user auto marker function as well as the legend to allow user to select their interested curve.

2. Coupling Matrix Optimization

- Coupling matrix optimization is a flexible and powerful tool to assist users to meet their design goals; especially for non-uniform unloaded Q case and non-synthesizable case. By applying SynMatrix360 developed core optimization algorithms, various specified targets can be met easily and rapidly.
- In order to trade-off the optimization time and performance, Synmatrix360 sets 10 seconds as the basic unit for each optimization running. Users are able to obtain the excellent performance by setting the fine step size while costing longer time correspondingly. Synmatrix360 suggests users to set the moderate step size to obtain the “filter shape” performance firstly and then refining the step size step by step until the goal can be achieved.

Input Section:

1. Parameters Input:

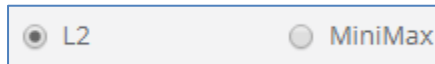
- When user switch to this page, all filter information will be copied from the "Synthesis" page, including generated Coupling Matrix, Center Freq, Bandwidth, Unloaded Q and Start/Stop freq
- Standard filter input parameters which include frequency range, unloaded Q, please refer to the section 1 in “Coupling Matrix Synthesis” to obtain more details.
- **Step Size**: The value is allowed to change at every iteration. The minimum step size cannot be smaller than:

$$\text{Minimum Size} = (\text{displaying stop freq} - \text{displaying start freq}) / 1001$$

The excellent optimized performances benefit from refining the step size, whereas costing the longer time than usual.

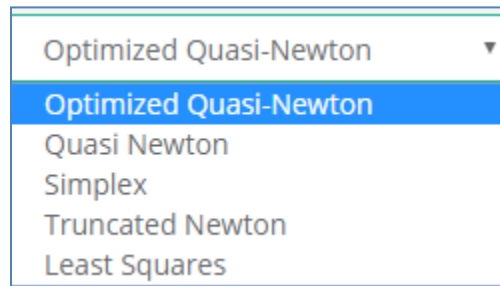
Start Freq.	0.875	GHz
Stop Freq.	1.125	GHz
Step Size	0.001	GHz

2. Cost function:



- **L2**: L2 is known as Least Square, It minimizes the sum of the square of the differences between the target value and the estimated values. It is suitable for global optimization.
- **Minimax**: Minimax will seek to minimize the maximum difference between the target value and the estimated value. It is suitable for local optimization;

3. Optimization Method:



- This tool box offers 5 optimization methods: Newton, Quasi-Newton, Optimized Quasi-Newton, Simplex and least Square. Each option has its own unique advantages and disadvantages in terms of cost function, sampling control, time and matrix complexity. The default method is Optimized Quasi-Newton;

4. Iteration No.:

- The maximum iteration number allow for each time evaluation.

5. Error Threshold:

- The differences between the each time iteration to stop the optimization.

6. Topology & Bound:

Topology

Bounds

	S	1	2	3	4	L
S		<input checked="" type="checkbox"/>				
1	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>			
2		<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>		
3			<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	
4				<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
L					<input checked="" type="checkbox"/>	

Coupling Value Boundaries

	Nominal Value	Lower	Upper
M 1,S	1.1501	0	2
M 1,1	0.0794	-1	1
M 2,1	1.0334	0	2
M 2,2	0.0972	-1	1
M 3,1	0	-1	1
M 3,2	0.6116	0	2
M 3,3	-0.6488	-1	1
M 4,S	0	-1	1
M 4,3	0.8829	0	2
M 4,4	0.0835	-1	1
M L,S	-0.0079	-1	1
M L,4	1.1493	0	2

- User needs to define which parameters in the coupling matrix need to be optimized by defining the check box. Correspondingly, all selected parameters will be sent to “Bound” as bounded parameter during the optimization. User can set the boundary for each selected parameter. For self-coupling and transmission zero related coupling, the bounds default from -1 to 1, for any sequential-coupling defined in the matrix will be from -0 to 2. If user doesn't define the topology, “Chebyshev” type matrix will be defaulted as the initial input.

7. Optimization Target:

Optimization Targets
▶ Start Optimization

+ Add

RL (<)

-25

dB

1

✕

0.975

GHz

1.025

GHz

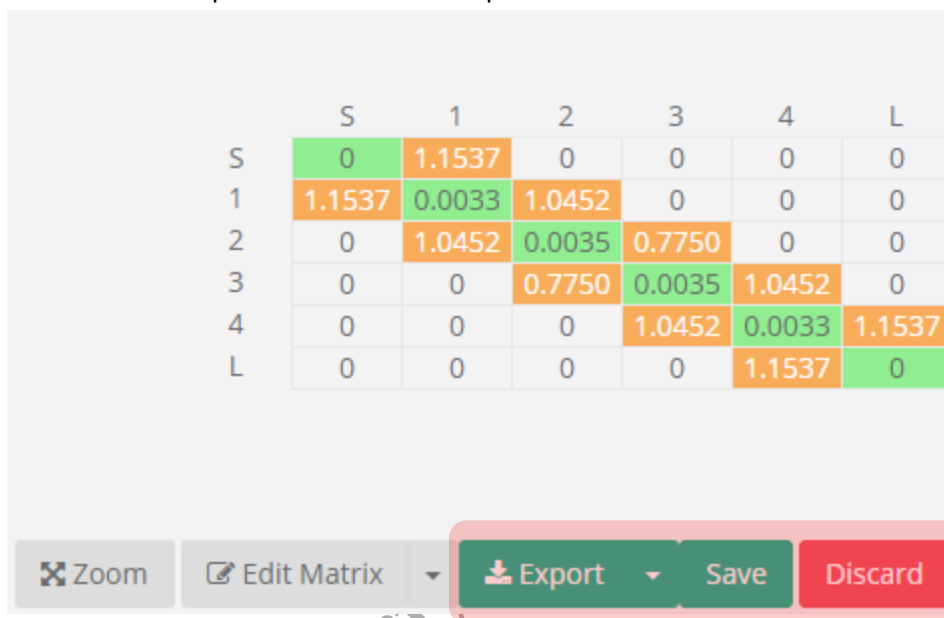
🗑

- The optimization tool box offers user 6 optimization targets, including 2 RLs (in-band S11) and 4 isolations(out of band-S21).

Output Section:

1. Iterated Running:

- For each time running, the option for “Export—To File”, “Export—To Synthesis”, “Save”, “Discard” will be shown up under the returned optimized matrix.



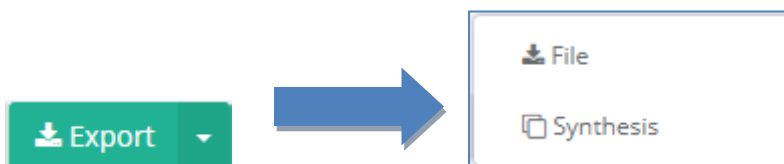
The screenshot displays a 6x6 matrix with rows and columns labeled S, 1, 2, 3, 4, and L. The matrix values are as follows:

	S	1	2	3	4	L
S	0	1.1537	0	0	0	0
1	1.1537	0.0033	1.0452	0	0	0
2	0	1.0452	0.0035	0.7750	0	0
3	0	0	0.7750	0.0035	1.0452	0
4	0	0	0	1.0452	0.0033	1.1537
L	0	0	0	0	1.1537	0

Below the matrix, there are four buttons: "Zoom", "Edit Matrix", "Export", and "Save". The "Export" button is highlighted with a red box, and a "Discard" button is also visible.

- User may have their own decision to select "Save" to collect the current result as the initial one to proceed the next round optimization, or choose "Discard" to revert to the previous optimized result.
- In some tough cases, due to the matrix non-linearity property and the computation accuracy, by applying the “Fine-tune” function incorporated with the optimization, the targets can be achieved easily and rapidly.

2. Export Function



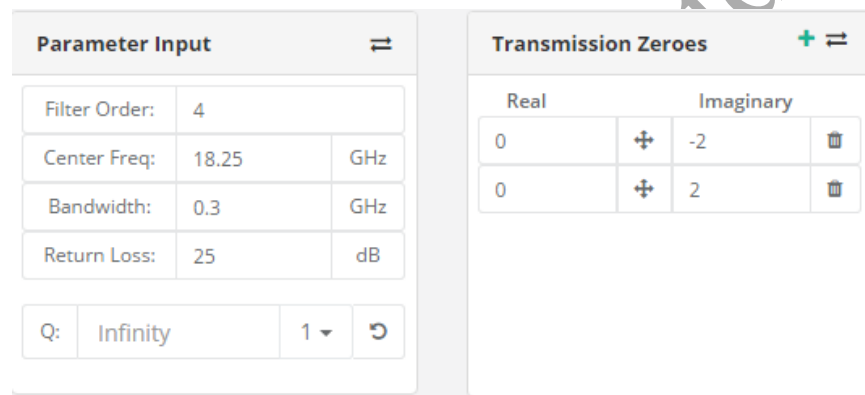
- Once user obtaining the optimal result, this result can be exported either to their local drive, or transfer to the "Synthesis" page for future application. For example, they can set this optimal result as the golden matrix to start the computer aided tuning procedures.

Appendix

Example 1: 4-2-0 Comblane Filter Design

Step I: Launch the software. Fill the filter specifications and synthesis the coupling matrix

Parameter Input:



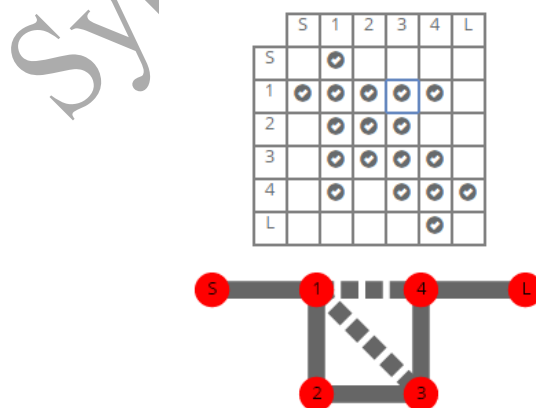
The screenshot shows the SynMatrix360 software interface. The 'Parameter Input' panel on the left contains the following fields:

Parameter	Value	Unit
Filter Order:	4	
Center Freq:	18.25	GHz
Bandwidth:	0.3	GHz
Return Loss:	25	dB
Q:	Infinity	1

The 'Transmission Zeroes' panel on the right contains a table with two columns: 'Real' and 'Imaginary'.

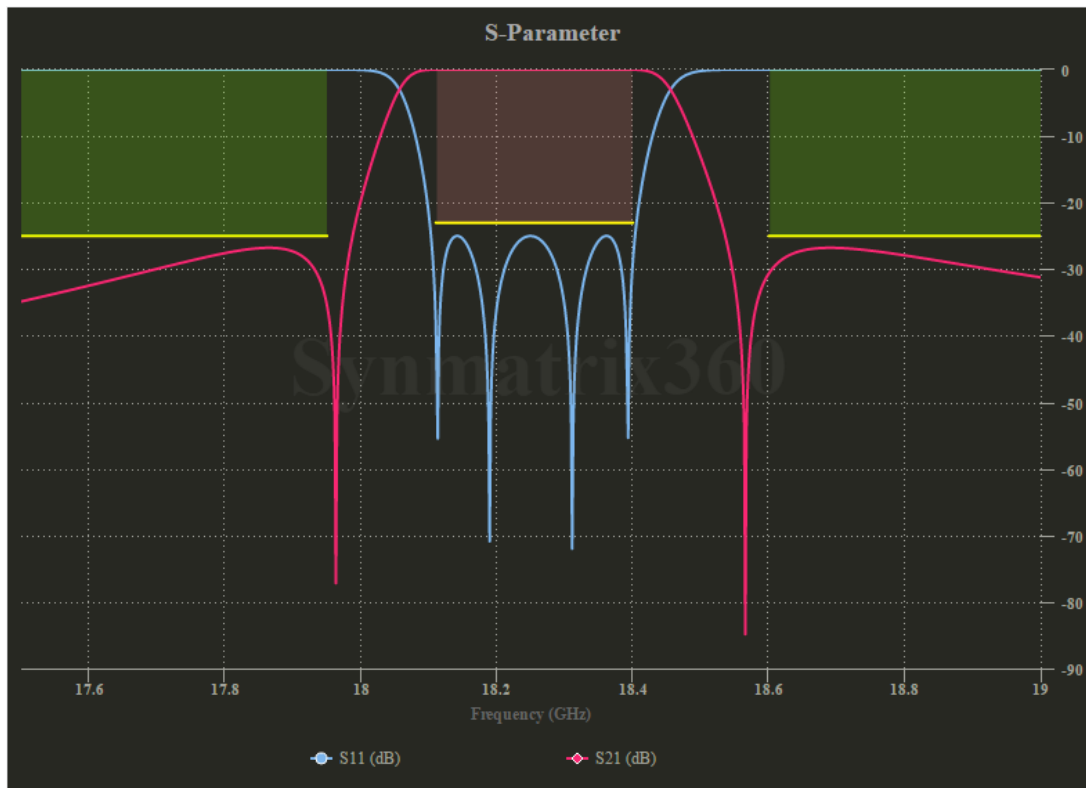
Real	Imaginary
0	-2
0	2

Define Filter topology:



(For cascaded quadruplet (CQ) configuration, a diagonal coupling (M13 or M24) is always suggested to select while defining the filter topology)

S-Parameter:



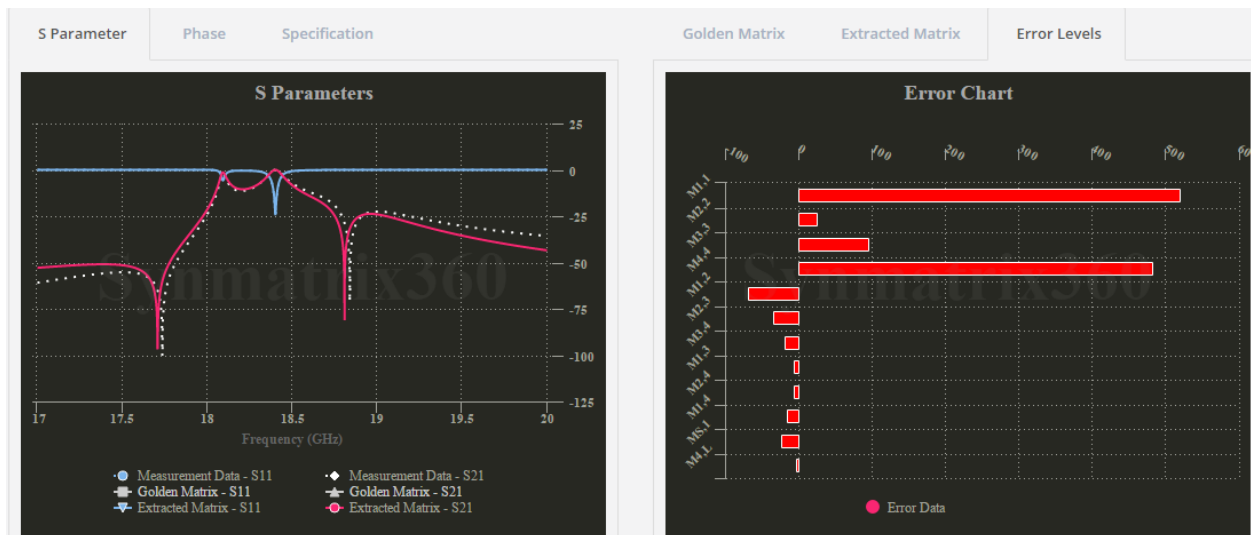
Coupling Matrix:

	S	1	2	3	4	L
S	0	1.1340	0	0	0	0
1	1.1340	0	0.9745	0	-0.2478	0
2	0	0.9745	0	0.8536	0	0
3	0	0	0.8536	0	0.9745	0
4	0	-0.2478	0	0.9745	0	1.1340
L	0	0	0	0	1.1340	0

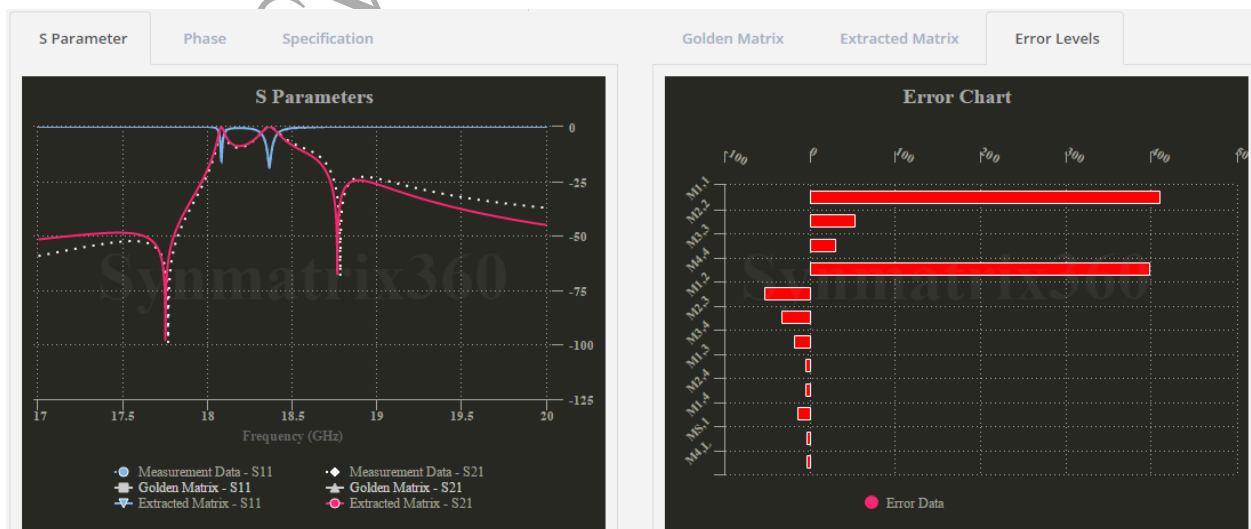
Step II: Build the 3D filter model in any commercial EM software and export the S2P file for initial response.

Step III: Switch to “computer aided tuning” tab, and start optimization process.

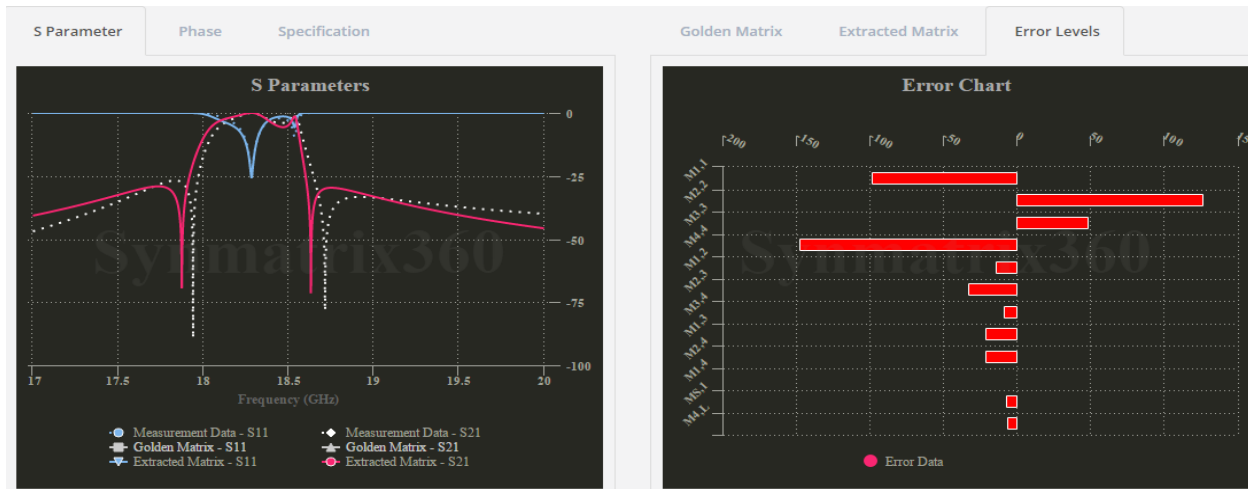
Iteration 1: Maximum Error 500+-----Initial response



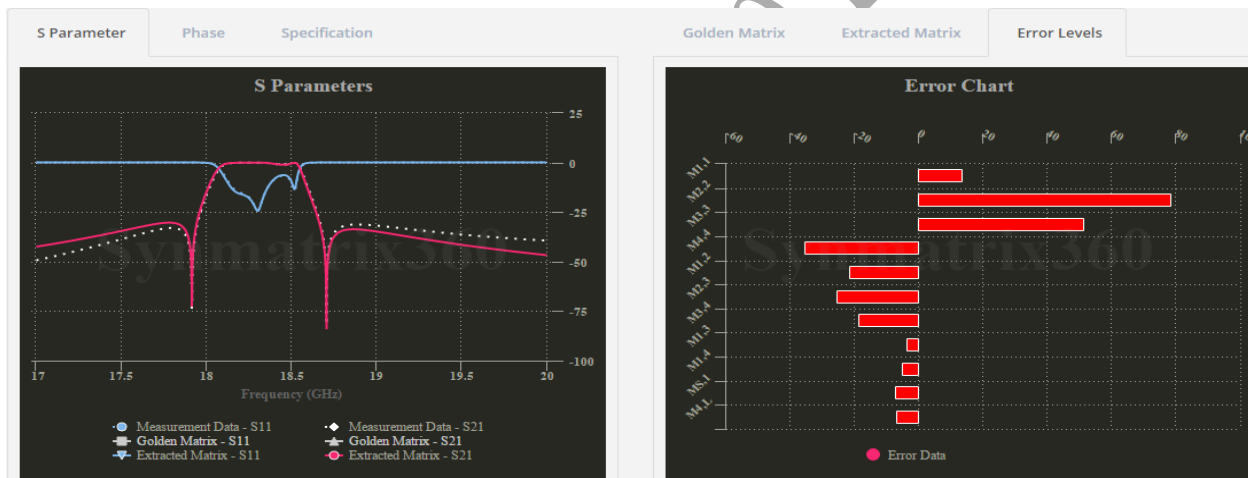
Iteration 2: Maximum Error 400+



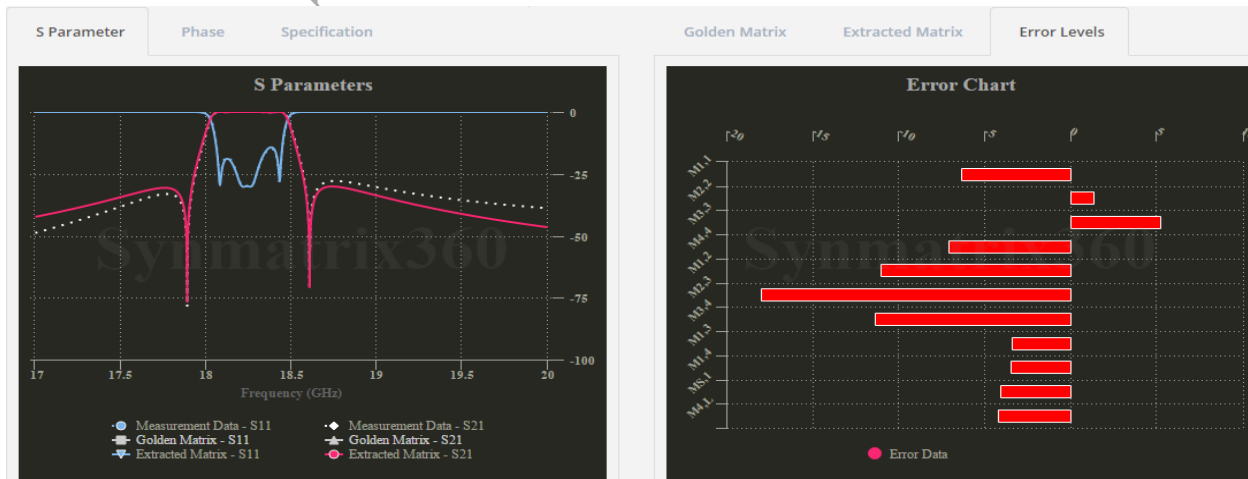
Iteration 3: Maximum Error 150+



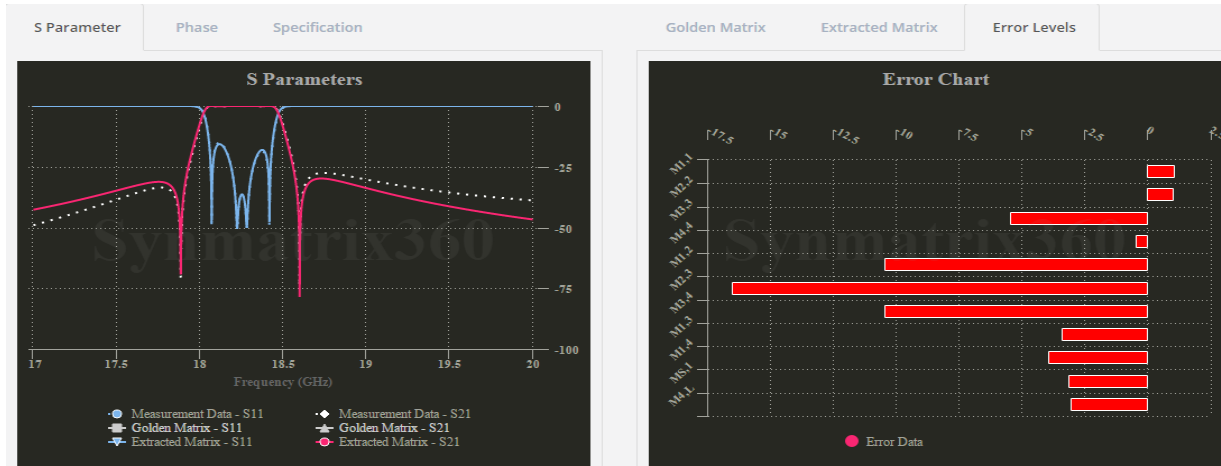
Iteration 4: Maximum Error 50+



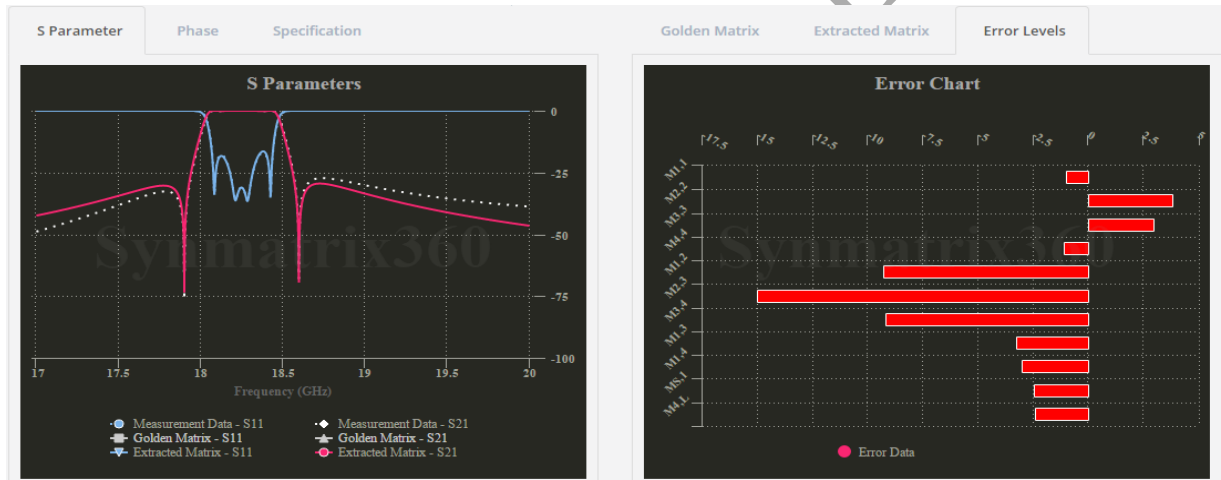
Iteration 5: Maximum Error 15+



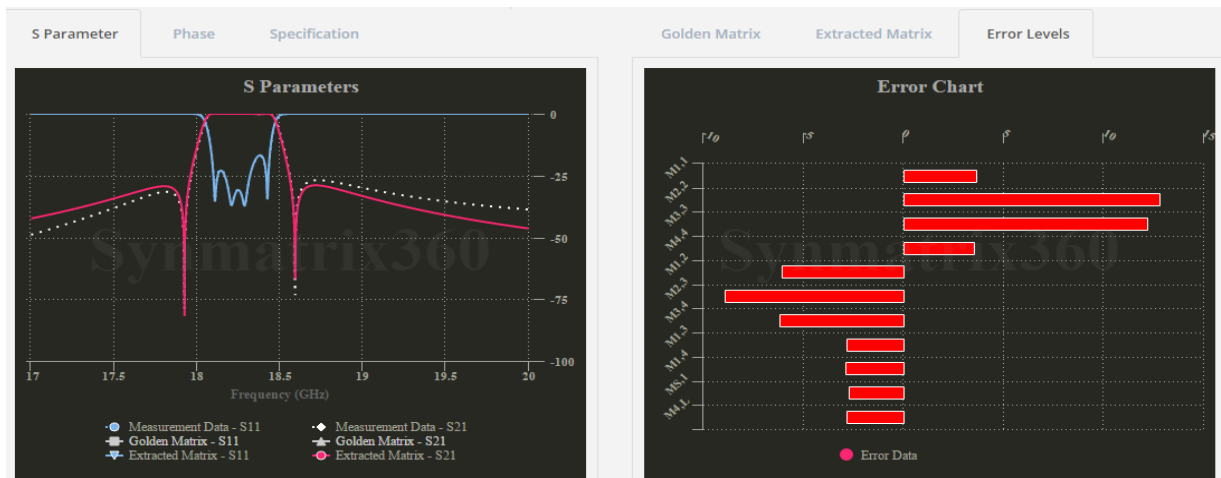
Iteration 6: Maximum Error 16+



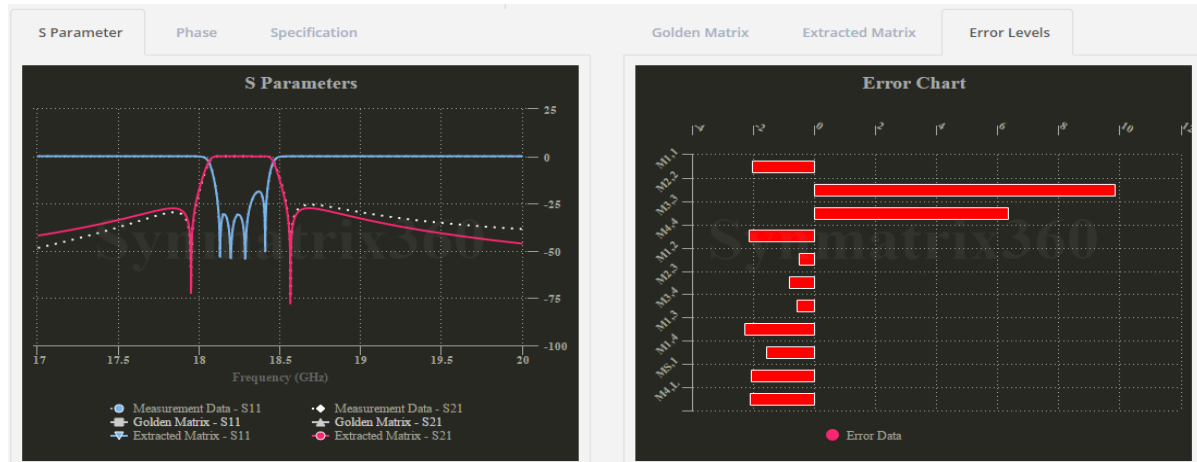
Iteration 7: Maximum Error 15+



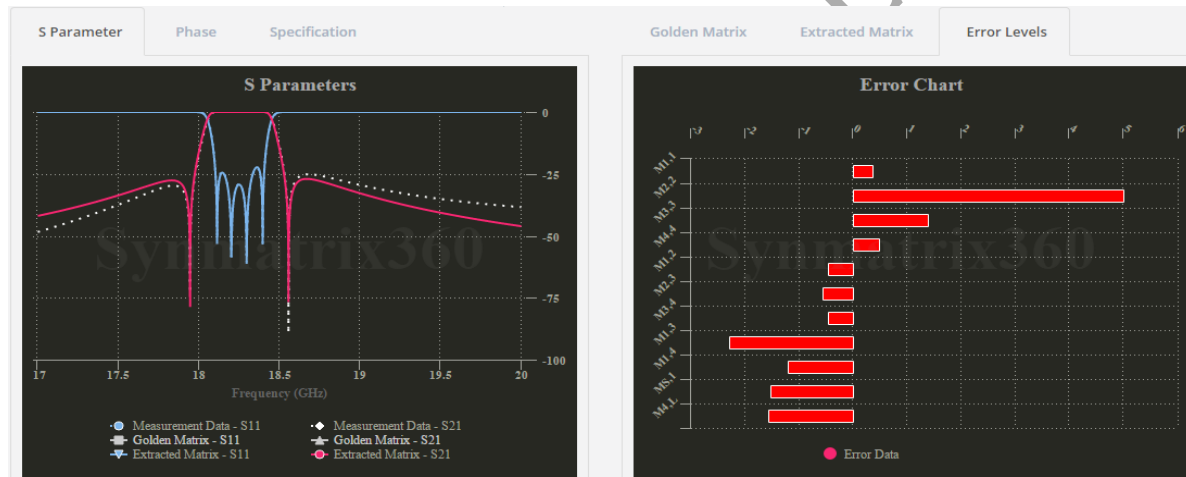
Iteration 8: Maximum Error 10+



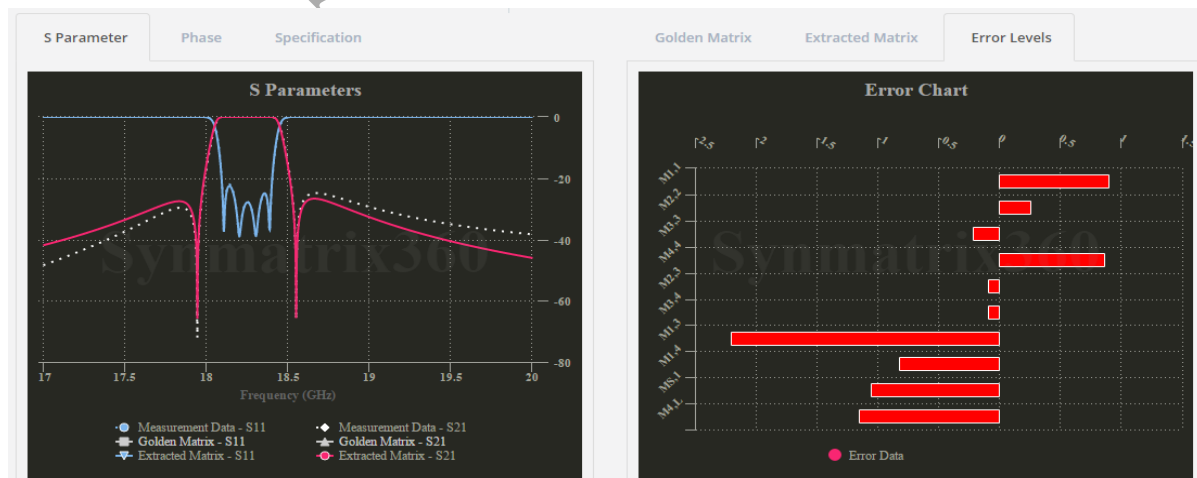
Iteration 9: Maximum Error 9+



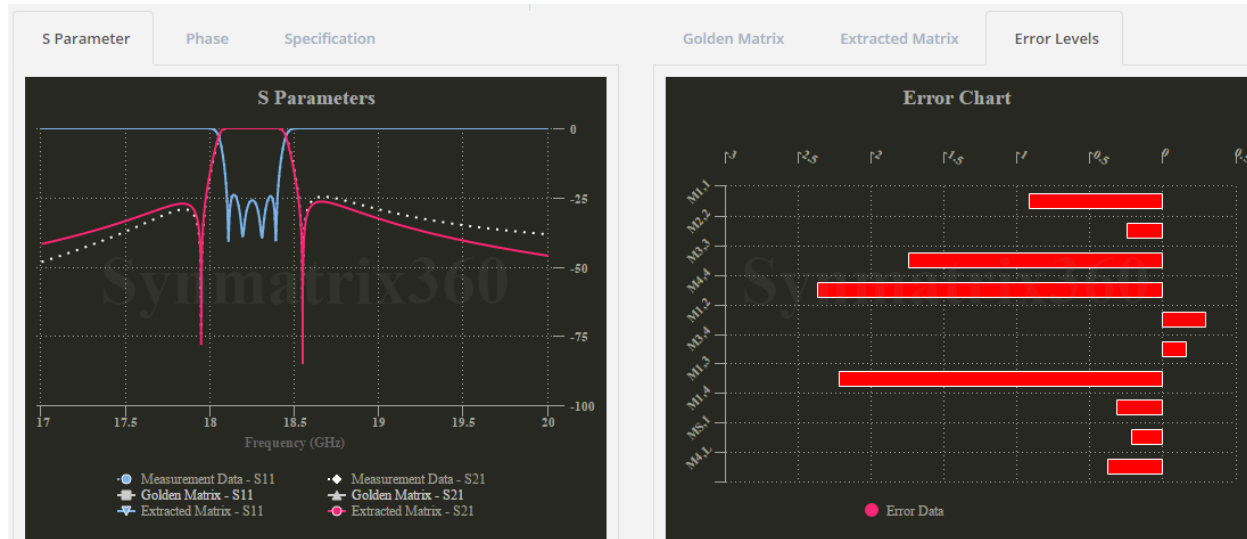
Iteration 10: Maximum Error 5+



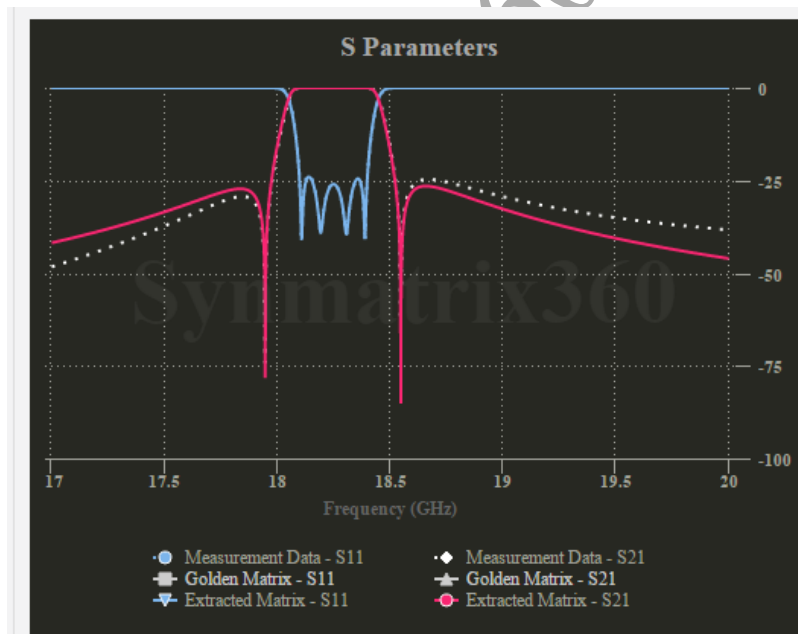
Iteration 11: Maximum Error 2+



Iteration 12: Maximum Error 2+



Final Simulation Response:



The optimization stops here after 12 iterations of the tunings above. The in-balanced notches are due to the stray coupling between resonator 1 and 3, or resonator 2 and 4.

Total simulation and optimization time is less than 2.5 hours.

**System requirement: Memory: 2GB; Processor: Intel Core i5;

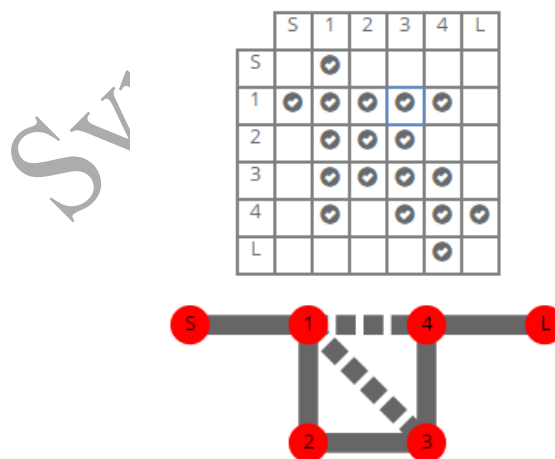
Example 2: 4-0-2 Combine Filter Design

Step I: Launch the software. On “Matrix Synthesis” tab, fill in the filter specifications and synthesis the coupling matrix.

Parameter Input:

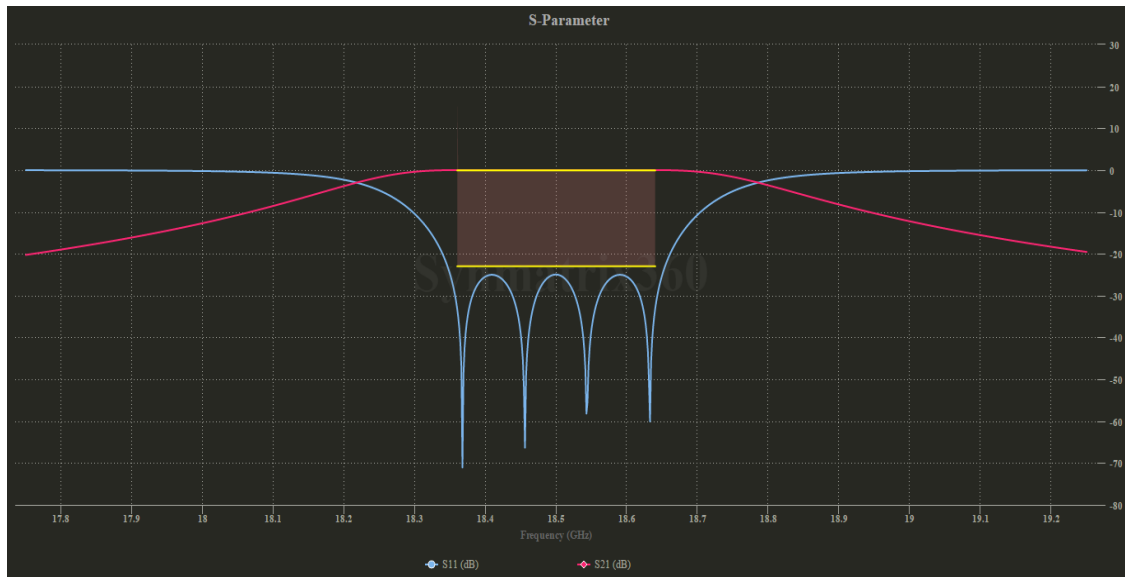
Parameter Input			Transmission Zeroes	
Filter Order:	4		Real	Imaginary
Center Freq:	18.5	GHz	-0.7	0
Bandwidth:	0.3	GHz	0.7	0
Return Loss:	25	dB		
Q:	5000	1		

Define Filter Topology:



(For CQ configuration, a diagonal coupling (M13 or M24) is always suggested to select while defining the filter topology)

S-Parameter:



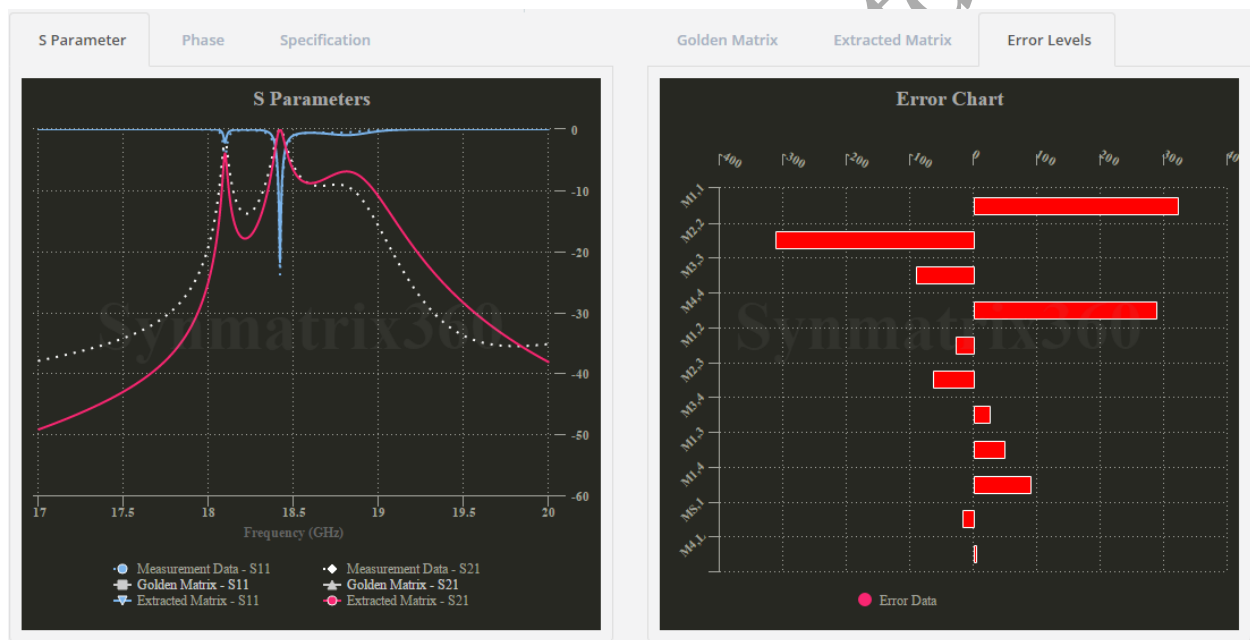
Coupling Matrix:

	S	1	2	3	4	L
S	0	1.2368	0	0	0	0
1	1.2368	0	1.0834	0	0.7866	0
2	0	1.0834	0	0.4880	0	0
3	0	0	0.4880	0	1.0834	0
4	0	0.7866	0	1.0834	0	1.2368
L	0	0	0	0	1.2368	0

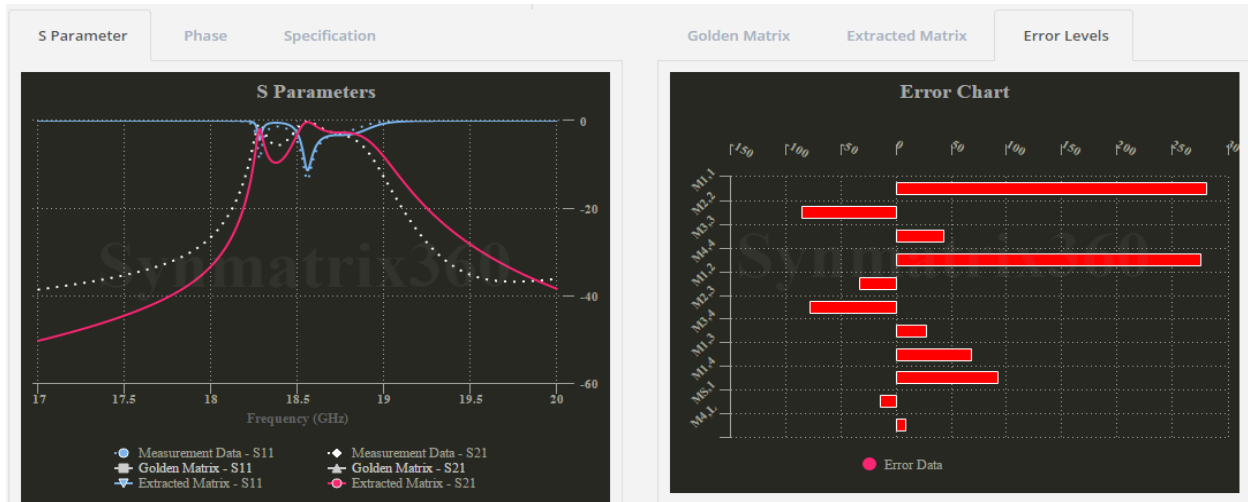
Step II: Build the 3D filter model in any commercial EM software and export the S2P file for initial response.

Step III: Switch to “computer aided tuning” tab, and start optimization process.

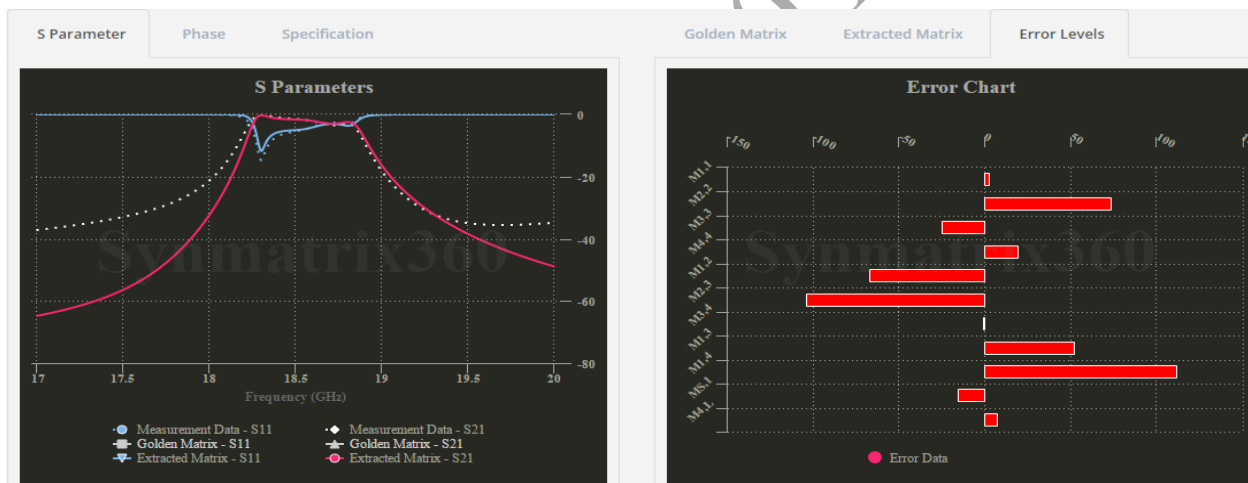
Iteration 1: Maximum Error 300+-----Initial Response



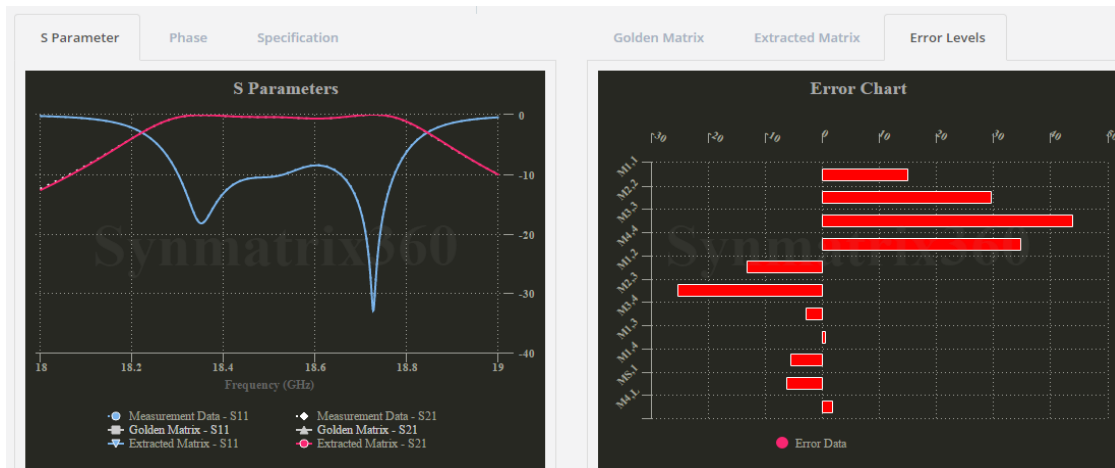
Iteration 2: Maximum Error 250+



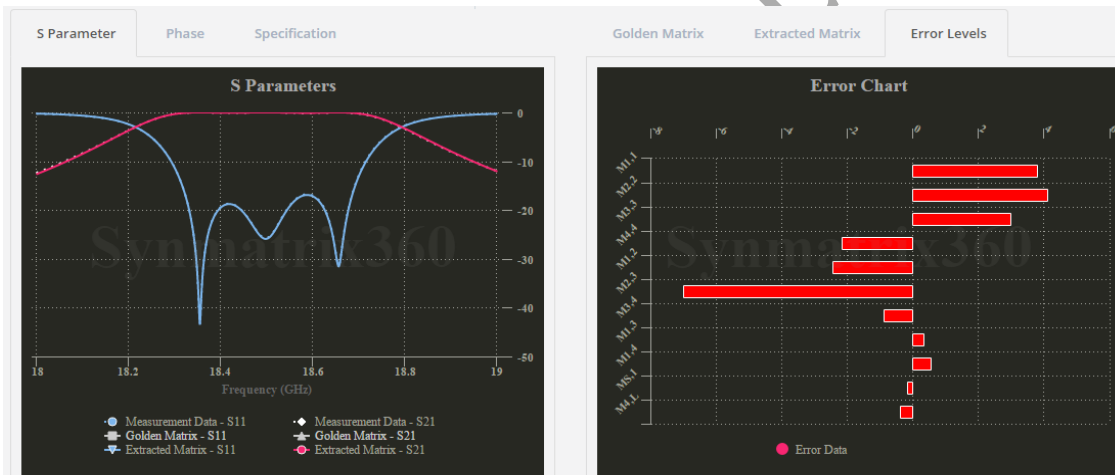
Iteration 3: Maximum Error 100+



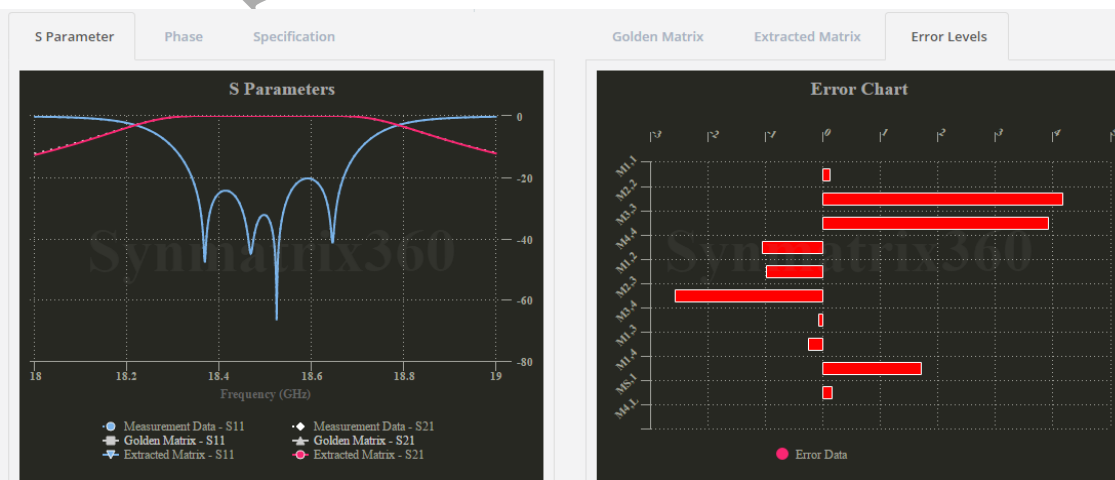
(after 5 more iterations, Maximum Error 40+)



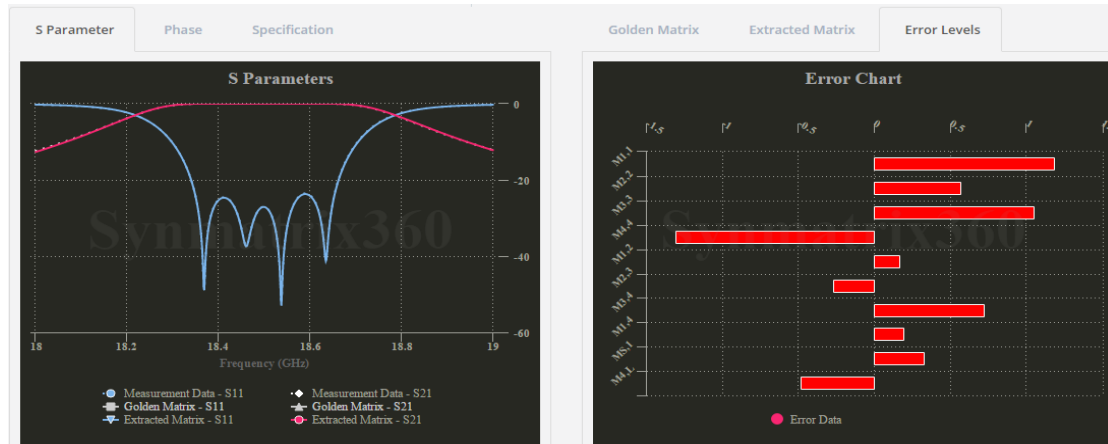
(after 5 more iterations, Maximum Error 6+)



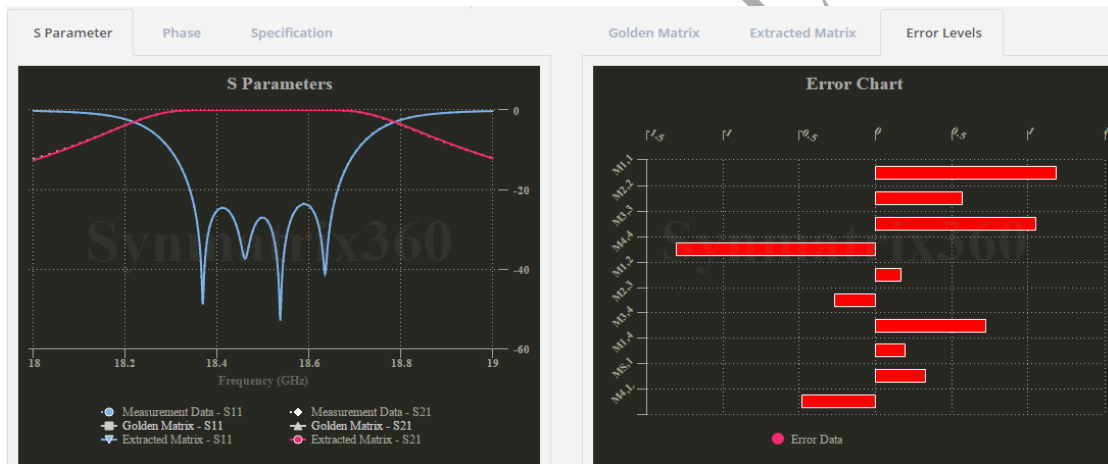
Iteration 14: Maximum Error 4+



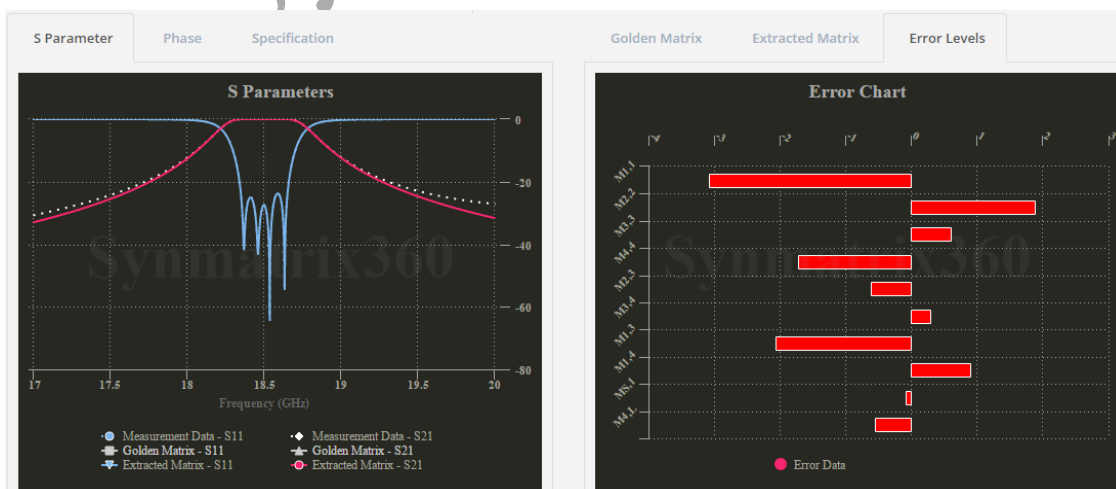
Iteration 15: Maximum Error 1+



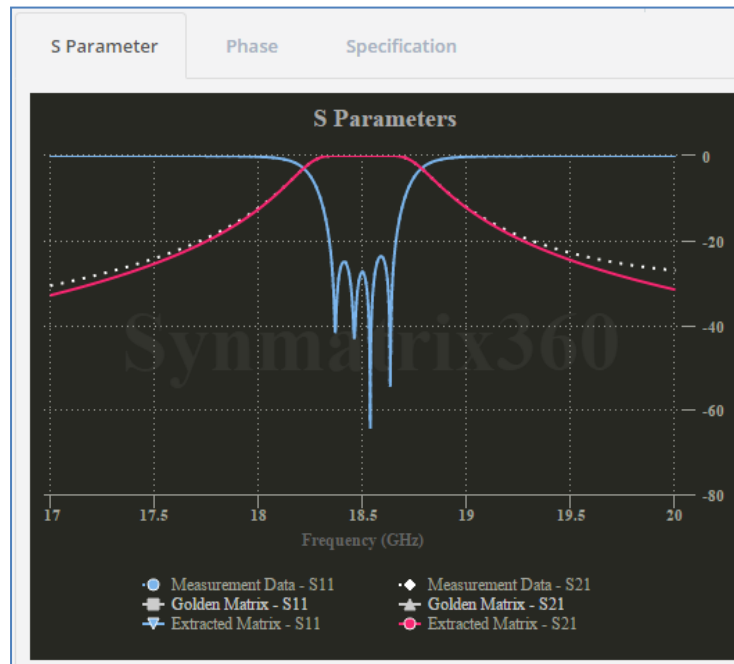
Iteration 16: Maximum Error 1+



Iteration 17: Maximum Error 1+



Final Simulation Response:



The optimization stops here after 17 iterations of the tunings above.

Total simulation and optimization time is less than 3 hours.

**System requirement: Memory: 2GB; Processor: Intel Core i5;

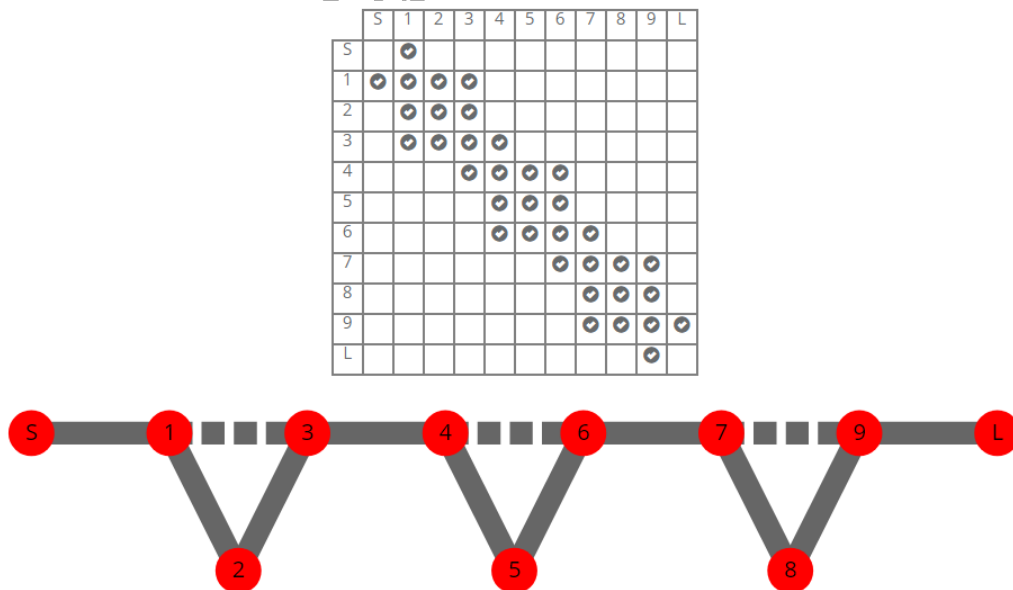
Example 3: 9-3-0 Comblaine Filter Design

Step I: Coupling Matrix Synthesis.

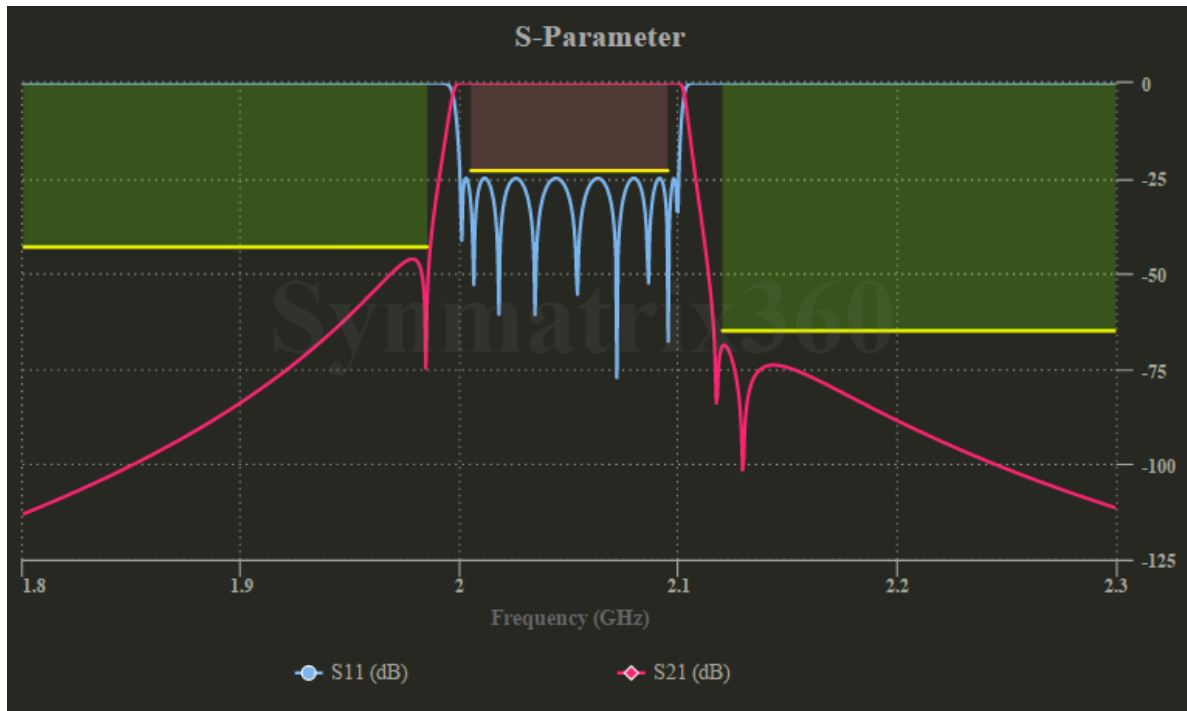
Parameter input:

Parameter Input				Transmission Zeroes			
Filter Order:	9			Frequency			
Center Freq:	2.05	GHz		GHz	+	1.985	🗑️
Bandwidth:	0.1	GHz		GHz	+	2.118	🗑️
Return Loss:	25	dB		GHz	+	2.13	🗑️
Q:	Infinity	1	↺				

Define filter topology:



S-parameters:



Coupling Matrix:

Input GD		5.5e-9		s		Output GD		5.5e-9		s	
	S	1	2	3	4	5	6	7	8	9	L
S	0	1.0786	0	0	0	0	0	0	0	0	0
1	1.0786	0.0036	0.7300	-0.5177	0	0	0	0	0	0	0
2	0	0.7300	0.6874	0.4495	0	0	0	0	0	0	0
3	0	-0.5177	0.4495	-0.0878	0.5632	0	0	0	0	0	0
4	0	0	0	0.5632	-0.0190	0.4741	0.2727	0	0	0	0
5	0	0	0	0	0.4741	-0.5275	0.4663	0	0	0	0
6	0	0	0	0	0.2727	0.4663	0.0311	0.5582	0	0	0
7	0	0	0	0	0	0	0.5582	0.0847	0.5163	0.3971	0
8	0	0	0	0	0	0	0	0.5163	-0.5272	0.8020	0
9	0	0	0	0	0	0	0	0.3971	0.8020	0.0036	1.0786
L	0	0	0	0	0	0	0	0	0	1.0786	0

Step III: Switch to “computer aided tuning” tab, and start optimization process.

Figure 10 displays two plots related to the S Parameters and Error Chart.

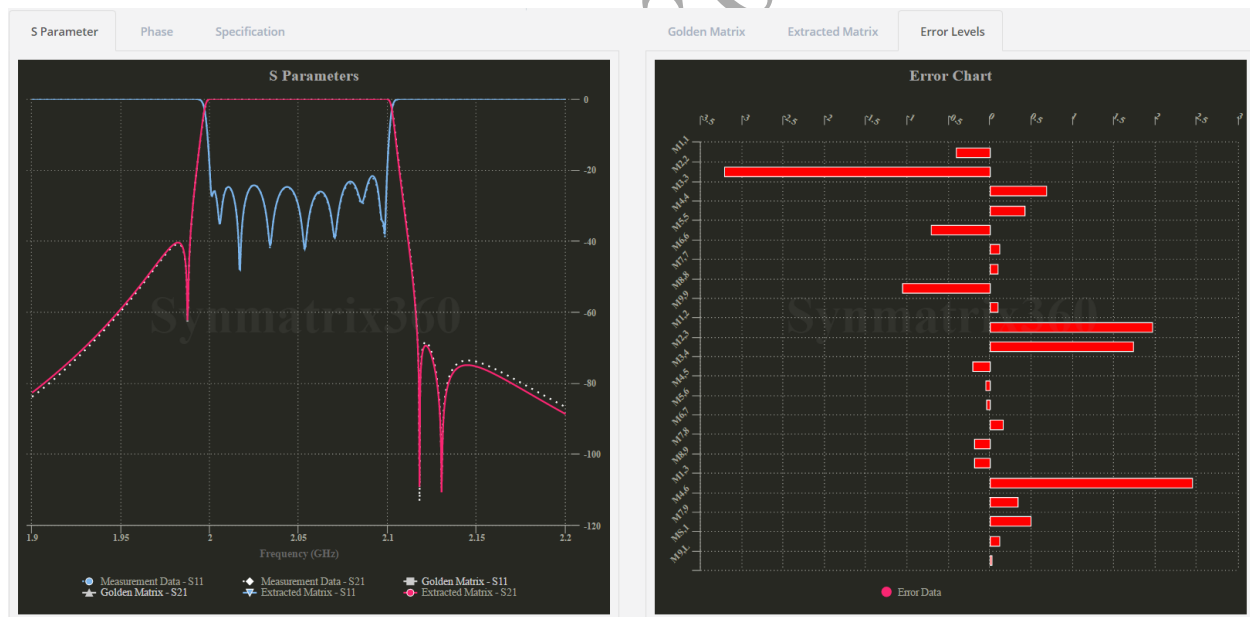
The left plot, titled "S Parameters", shows the magnitude of S Parameters (S11 and S21) versus Frequency (GHz) from 1.8 to 2.4 GHz. The plot compares Measurement Data (S11, S21) with Golden Matrix (S11, S21) and Extracted Matrix (S11, S21). The S11 parameters are shown in blue, and the S21 parameters are shown in red. The plot shows a resonance peak around 2.0 GHz, with the S21 parameter reaching a minimum value of approximately -175 dB.

The right plot, titled "Error Chart", shows the error levels for the S Parameters. The chart displays the error levels for S11 and S21 parameters across various modes (M1 to M100). The error levels are shown as horizontal bars, with the length of the bar indicating the error level. The error levels for S11 are generally higher than for S21, with the maximum error level for S11 reaching approximately 100 dB.

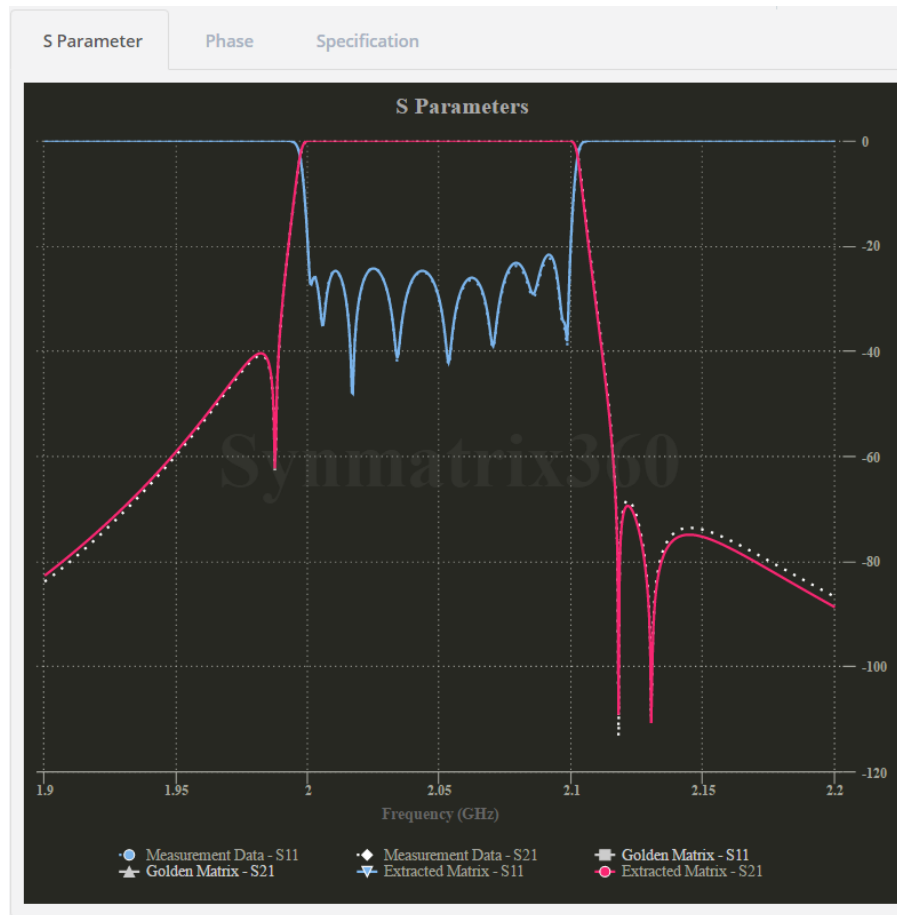
(After 8 more iterations, Maximum Error 8+)



(After 7 more iterations, Maximum Error 3+)



Final Simulation Response:



The optimization stops here after 16 iterations of the tunings above.

Total simulation and optimization time is less than 6 hours.

**System requirement: Memory: 2GB; Processor: Intel Core i5;

Example 4: 11-3-0 Waveguide Filter Design

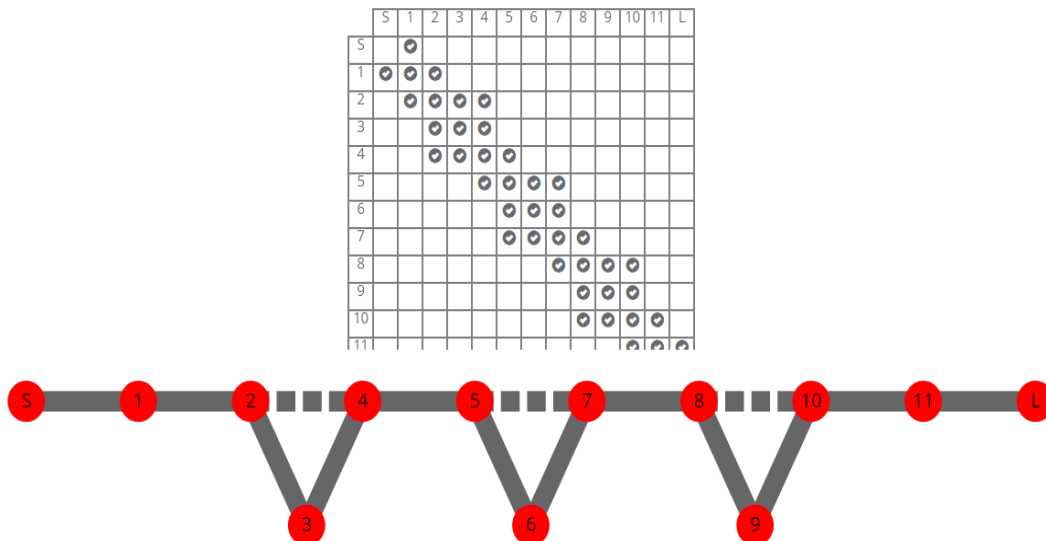
Step I: Coupling Matrix Synthesis

Parameter input:

Parameter Input			
Filter Order:	11		
Center Freq:	7.462	GHz	
Bandwidth:	0.566	GHz	
Return Loss:	30	dB	
Q:	Infinity	1	

Transmission Zeroes			
Real		Imaginary	
real	+	1.13	
real	+	-1.24	
real	+	1.21	

Define filter topology:



S-parameters:



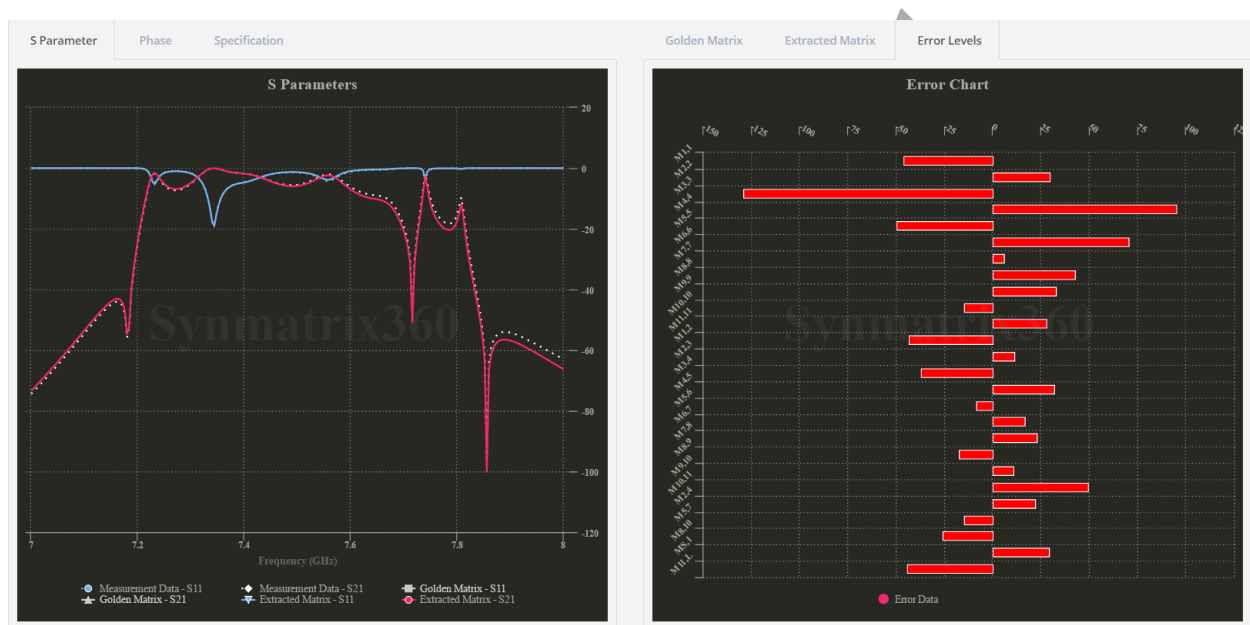
Coupling Matrix:

	S	1	2	3	4	5	6	7	8	9	10	11	L
S	0	1.1593	0	0	0	0	0	0	0	0	0	0	0
1	1.1593	0.0055	0.9736	0	0	0	0	0	0	0	0	0	0
2	0	0.9736	0.0057	0.4416	0.4499	0	0	0	0	0	0	0	0
3	0	0	0.4416	-0.7787	0.3579	0	0	0	0	0	0	0	0
4	0	0	0.4499	0.3579	0.0598	0.5412	0	0	0	0	0	0	0
5	0	0	0	0	0.5412	0.0325	0.4335	-0.3067	0	0	0	0	0
6	0	0	0	0	0	0.4335	0.6279	0.4331	0	0	0	0	0
7	0	0	0	0	0	-0.3067	0.4331	0.0308	0.5405	0	0	0	0
8	0	0	0	0	0	0	0	0.5405	0.0568	0.4169	0.3885	0	0
9	0	0	0	0	0	0	0	0	0.4169	-0.6773	0.4965	0	0
10	0	0	0	0	0	0	0	0	0.3885	0.4965	0.0057	0.9736	0
11	0	0	0	0	0	0	0	0	0	0	0.9736	0.0055	1.1593
L	0	0	0	0	0	0	0	0	0	0	0	1.1593	0

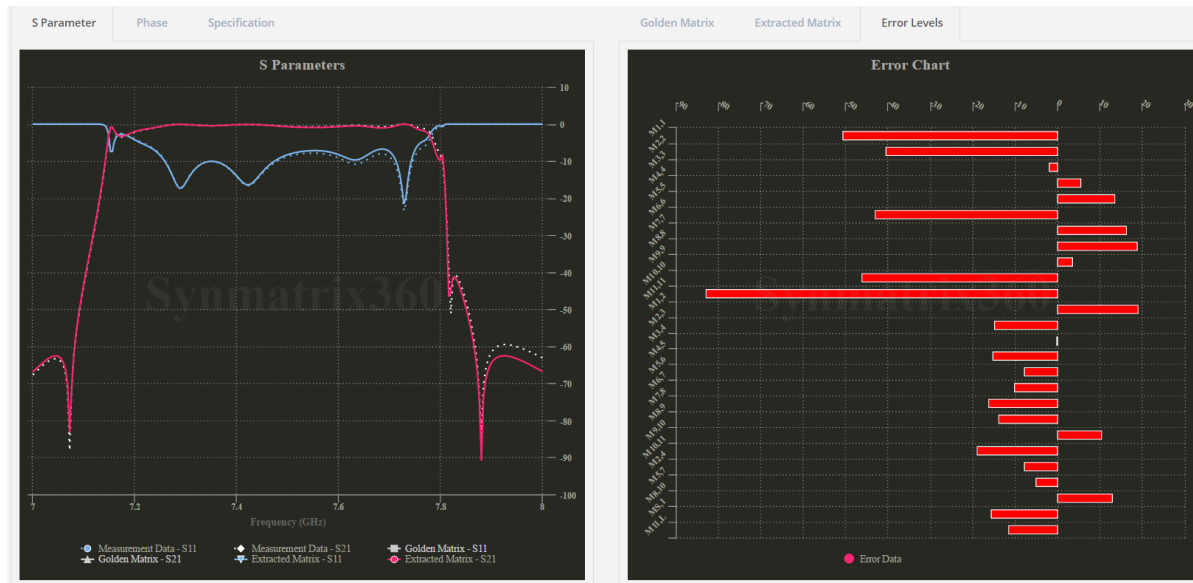
Step II: Build the 3D filter model in any commercial EM software and export the S2P file for initial response.

Step III: Switch to “computer aided tuning” tab, and start optimization process.

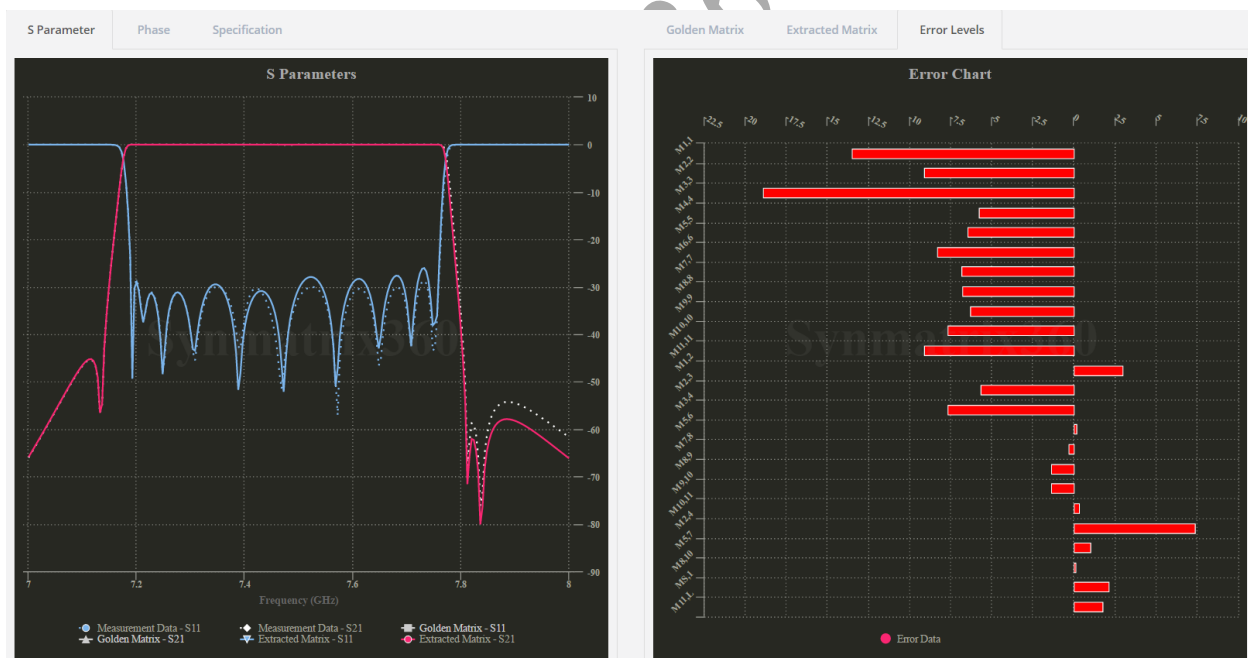
Iteration 1: Maximum Error 125+----Initial Response



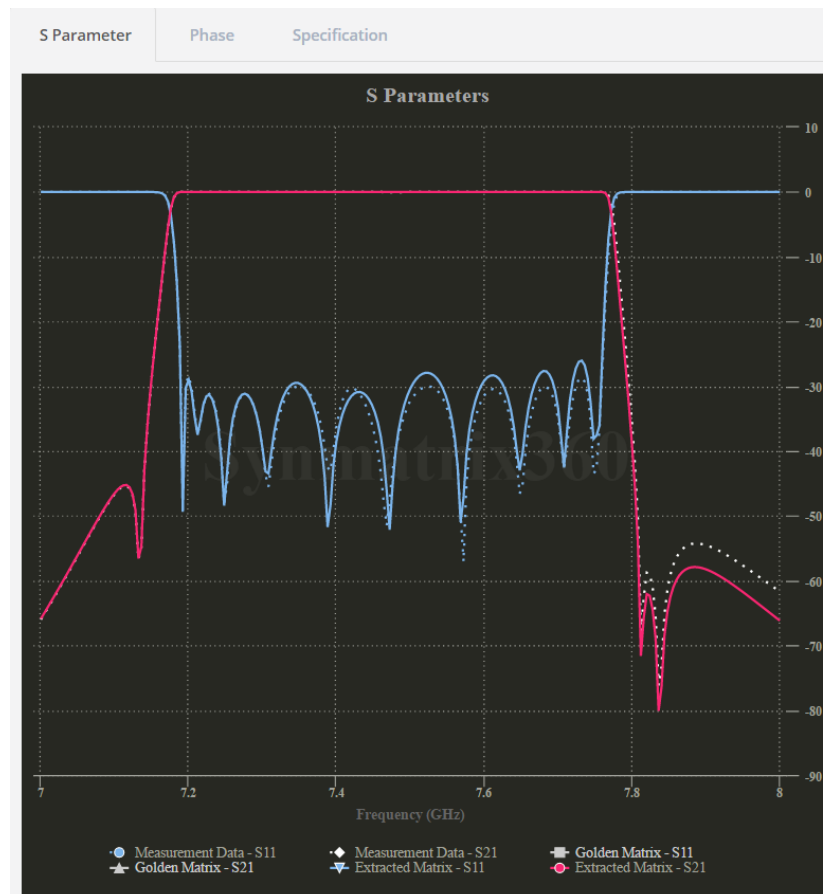
(After 4 more iterations, Maximum Error 80+)



(After 4 more iterations, Maximum Error <20)



Final Simulation Response:



The optimization stops here after 9 iterations of the tunings above. Though the error is still over 20, the current response already meets the requirement.

Total simulation and optimization time is less than 6 hours.

**System requirement: Memory: 2GB; Processor: Intel Core i5;