

RF Toolbox 2

Design, model, and analyze networks of RF components

RF Toolbox extends MATLAB with functions and a graphical user interface (GUI) for designing, modeling, analyzing, and visualizing networks of radio frequency (RF) components. You can use RF Toolbox for working on wireless communications, radar, and signal integrity projects.

You can execute RF Toolbox functions from the MATLAB command line or the RF Tool GUI, or call the toolbox functions from your own MATLAB scripts and functions. The toolbox includes rectangular, polar, and Smith® charts for visualizing data.

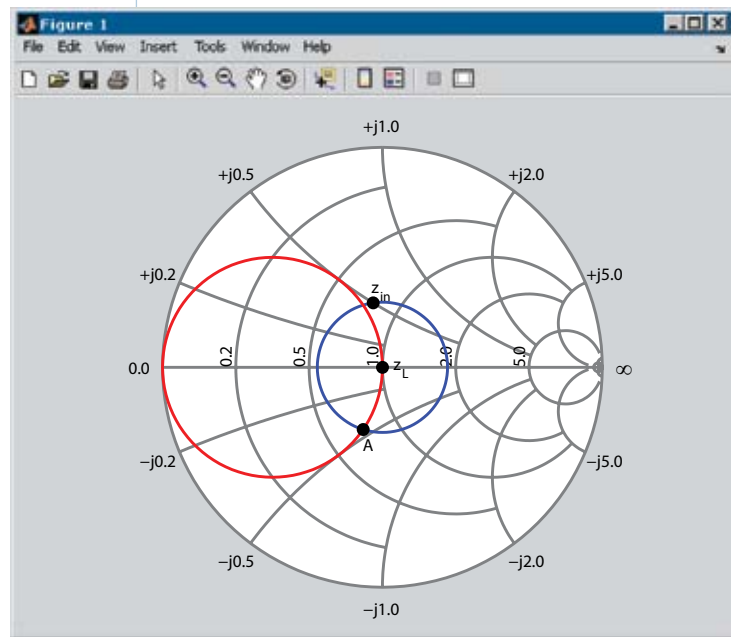
Defining RF Components

A key challenge in RF engineering is accounting for impedance difference and reflection effects that occur when components are configured into a network. RF Toolbox represents an RF component by its network parameters, which are sufficient to determine its small signal response. From the individual network parameters of a set of components, RF Toolbox can determine the network parameters and small signal response of any configuration containing these components.

Design and analysis of input and output matching networks that maximize the power an amplifier delivers to a 50-ohm load.

KEY FEATURES

- Provides read and write access to industry-standard file formats for network parameters
- Defines RF filters, transmission lines, amplifiers, and mixers by their experimental or theoretical network parameters and physical properties
- Calculates network parameters for RF components in series, parallel, cascade, hybrid, and inverse hybrid configurations
- Builds models using the rational function fitting method
- Exports rational function models to Simulink or as Verilog-A modules
- Calculates noise figures and third-order intercept points for cascaded components
- Converts among S, Y, Z, ABCD, h, g, and T network parameters
- Includes rectangular and polar plots and Smith® charts for visualizing data



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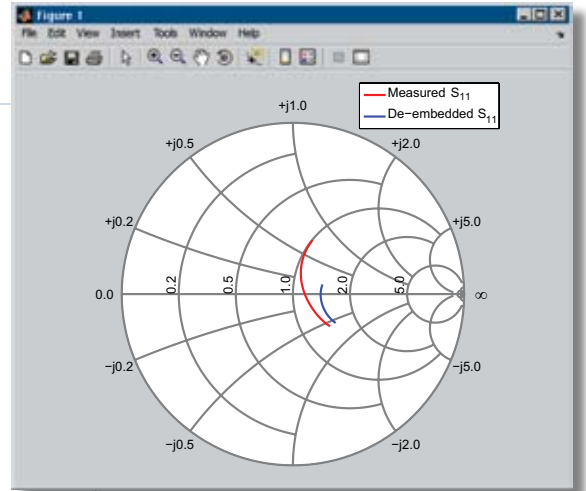
measured_data = read(rfdata.data, 'samplebjt.s2p');
input_pad = rfckt.cascade('Ckts', {rfckt.seriesrlc('L', 1e-9),...
    rfckt.shuntrlc('C', 100e-15)}); % L = 1nH, C = 100fF
output_pad = rfckt.cascade('Ckts', {rfckt.shuntrlc('C', 100e-15),...
    rfckt.seriesrlc('L', 1e-9)}); % L = 1nH, C = 100fF

freq = measured_data.Freq; % Analysis frequency
analyze(input_pad, freq);
analyze(output_pad, freq);

z0 = measured_data.Z0;
sparams1 = extract(input_pad.RFdata, 'S_Parameters', z0);
sparams3 = extract(output_pad.RFdata, 'S_Parameters', z0);
de_embedded_sparams = deembedsparams(measured_data.S_Parameters,...
    sparams1, sparams3); % De-embed
de_embedded_data = rfdata.data('Z0', z0, 'S_Parameters', ...
    de_embedded_sparams, 'Freq', freq);

smith(de_embedded_data, 's11', 's22');
legend show

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A script (left) illustrating the steps to read S-parameter data from a fixtured device-under-test (DUT), de-embed the DUT from the fixture impedances, and calculate de-embedded S-parameters. The Smith chart (above) displays the results.

RF Toolbox enables you to use network parameters to specify RF filters, transmission lines, amplifiers, and mixers, either directly or by their physical properties. Network parameters can be generated from within MATLAB or read in from external data. You can read and write industry-standard data file formats, such as Touchstone .snp. You can also specify components by their physical properties, such as RLC topology and values and transmission line properties. RF Toolbox calculates the corresponding network parameters.

Using RF Toolbox, you can define components in the following ways:

- Passive networks and general circuit elements, using data from Touchstone .snp, .ynp, .znp, and .hnp files
- Amplifiers and mixers, using data from Touchstone file formats (.s2p, .y2p, .z2p, and .h2p) and MathWorks file format (.amp)
- Transmission lines, using the lines' geometries and electrical properties
- LC ladder filters, using the filters' topology and values

Designing Networks

RF Toolbox helps you build complex RF networks from simpler components in a visual environment. Using the RF Toolbox, you connect components in series, parallel, cascade, hybrid, and inverse hybrid configurations by calling the appropriate toolbox function with the components as arguments. The return value is a new object that represents the configuration's behavior. This object can be passed in turn as an argument to other toolbox functions.

In addition to calculating the small signal frequency response, RF Toolbox calculates input and output reflection coefficients, stability factors, noise figures, and third-order intercept points for cascaded components. It also enables you to de-embed S-parameters from cascaded networks.

Modeling with Rational Functions

You can use RF Toolbox to model single-ended and differential high-speed transmission lines using rational functions. This type of model is useful in signal integrity engineering, where the goal is the reliable connection of high-speed semiconductor devices using, for example, backplanes and printed circuit boards.

Rational function fitting provides the following advantages over traditional techniques, such as inverse fast Fourier transform:

- Simpler models for a given accuracy
- Model order reduction, letting you trade off complexity and accuracy
- Zero phase on extrapolation to DC, avoiding the need to write elaborate constraint algorithms
- Physical correspondence between the model and transmission line characteristics, providing greater insight

In the typical signal integrity workflow, you use RF Toolbox after you characterize the backplane with 4-port network parameters and before you begin the design of the high-speed semiconductor I/O circuitry. Specifically, you:

- Measure the network parameters with a vector network analyzer
- Import the Touchstone data file
- Convert the single-ended 4-port S-parameters to 2-port differential S-parameters
- Compute the transfer function
- Fit the transfer function to a closed-form rational function model, reducing the order as needed
- Export the model to Simulink or in Verilog-A format for use as a test environment in the SPICE-like analog circuit simulator, which you use to design the I/O circuitry

Converting Network Parameters

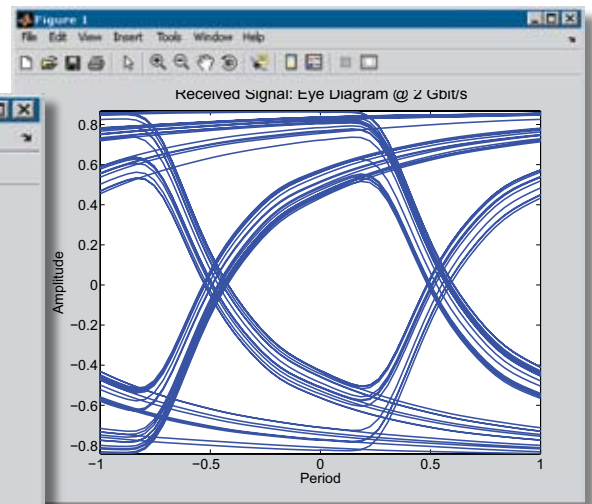
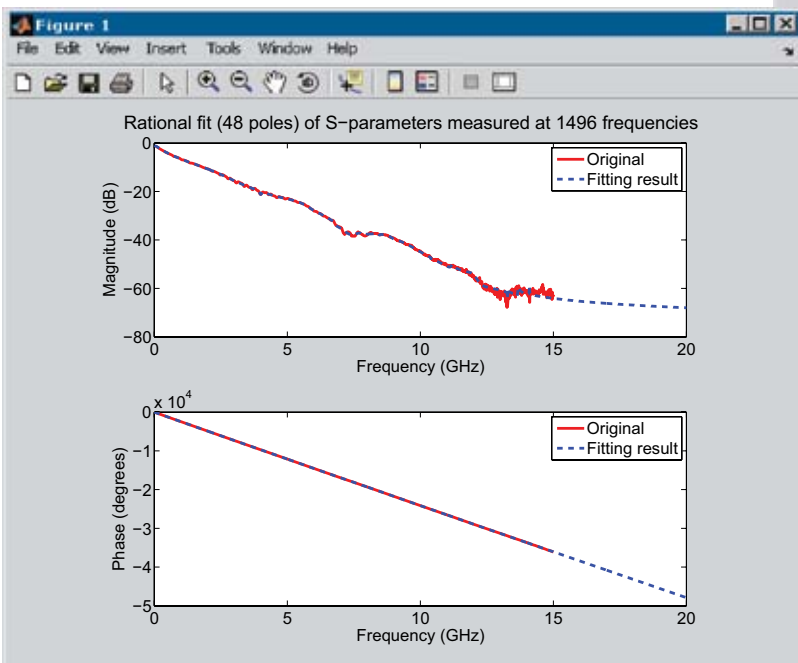
The RF Toolbox lets you choose the appropriate format for your task by converting among S, Y, Z, ABCD, h, g, and T network parameter formats. Y-parameters are convenient for calculating network parameters of RLC circuits, while S-parameters are better for visualizing the frequency responses. In addition, you can convert S-parameters to S-parameters with different reference impedance.

Visualizing Component and Network Behavior

The RF Toolbox provides specialized charts and plots for visualizing component and network behavior, including:

- Smith® charts
- Rectangular plots
- Polar plots

You can also create these charts and plots from the RF Tool GUI.



Frequency response (left) of a rational function model created from measured S-parameters. The model was used to create the eye diagram (above) for analyzing intersymbol interference.

Sample Functions

- Read and write RF data in .amp, .snp, .ynp, .znp, and .hnp formats from a file
- Connect components in series, parallel, cascade, hybrid, or inverse hybrid configuration
- Create and analyze RF circuits and networks
- Convert 4-port, single-ended S-parameters to 2-port, differential mode S parameters
- Convert 2-port S-parameters to a transfer function
- Model RF components by fitting the network parameters to a rational function
- Write a Verilog-A module based on a rational function model
- Plot reflection coefficient on a Smith® chart
- Convert S-, Y-, Z-, ABCD-, h-, or g-parameters to Y-, Z-, or ABCD-, h-, g- or S-parameters
- Calculate the stability factor of a 2-port network

Required Products

MATLAB

Related Products

Communications Blockset. Design and simulate the physical layer of communication systems and components

Communications Toolbox. Design and analyze algorithms for the physical layer of communication systems

RF Blockset. Design and simulate the behavior of RF systems and components in a wireless system

Signal Processing Toolbox. Perform signal processing, analysis, and algorithm development

Signal Processing Blockset. Design and simulate signal processing systems and devices

Platform and System Requirements

For platform information and system requirements, visit www.mathworks.com/products/rftoolbox

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