Sonnet Suite Application Note

Equations in the Sonnet Response viewer

Sonnet Suite Release

9.0

Author

Dr.-Ing. Michael Reppel

Dr. Mühlhaus Consulting & Software GmbH

Ruhrstr. 92a, D-58456 Witten, Germany

Last Modified

December 3, 2003

Key Words

Pre-defined equation

User-defined equation

Argument definition

Argument index.

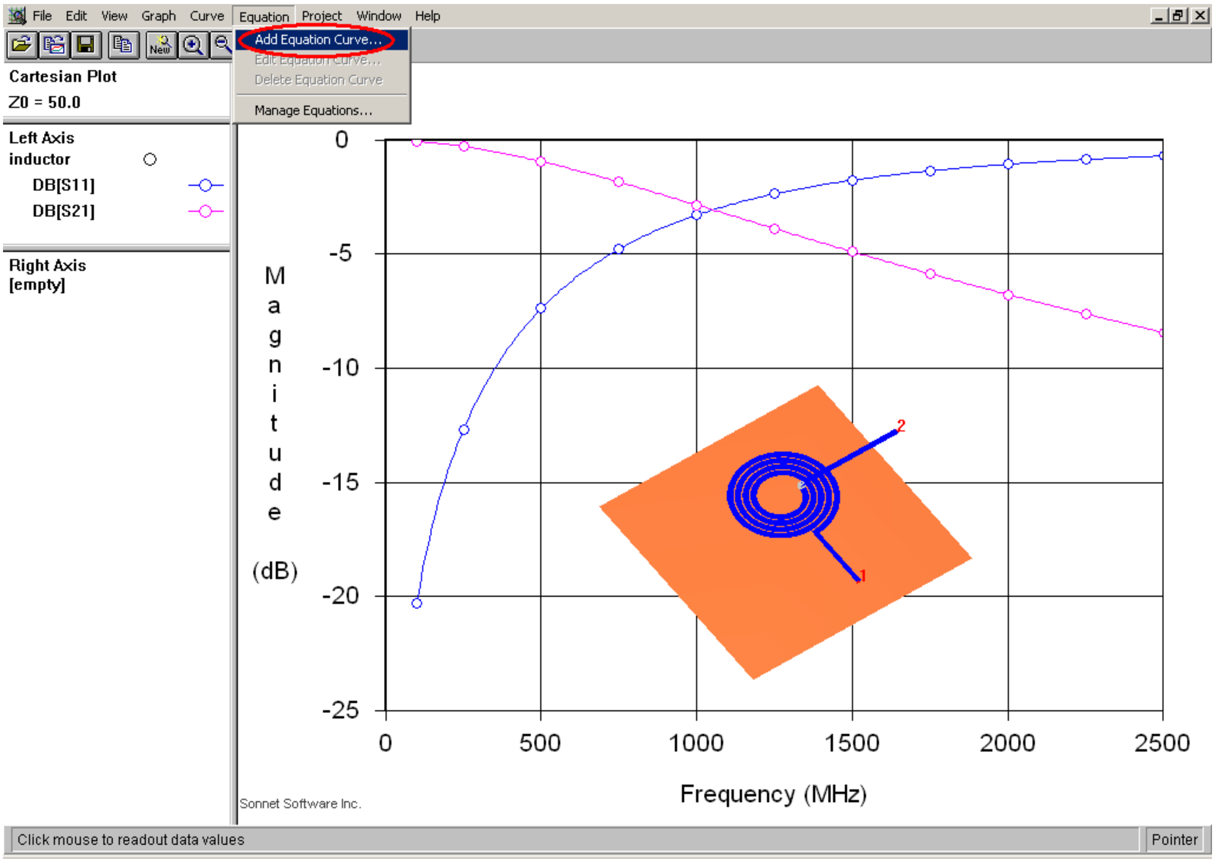
Equation syntax

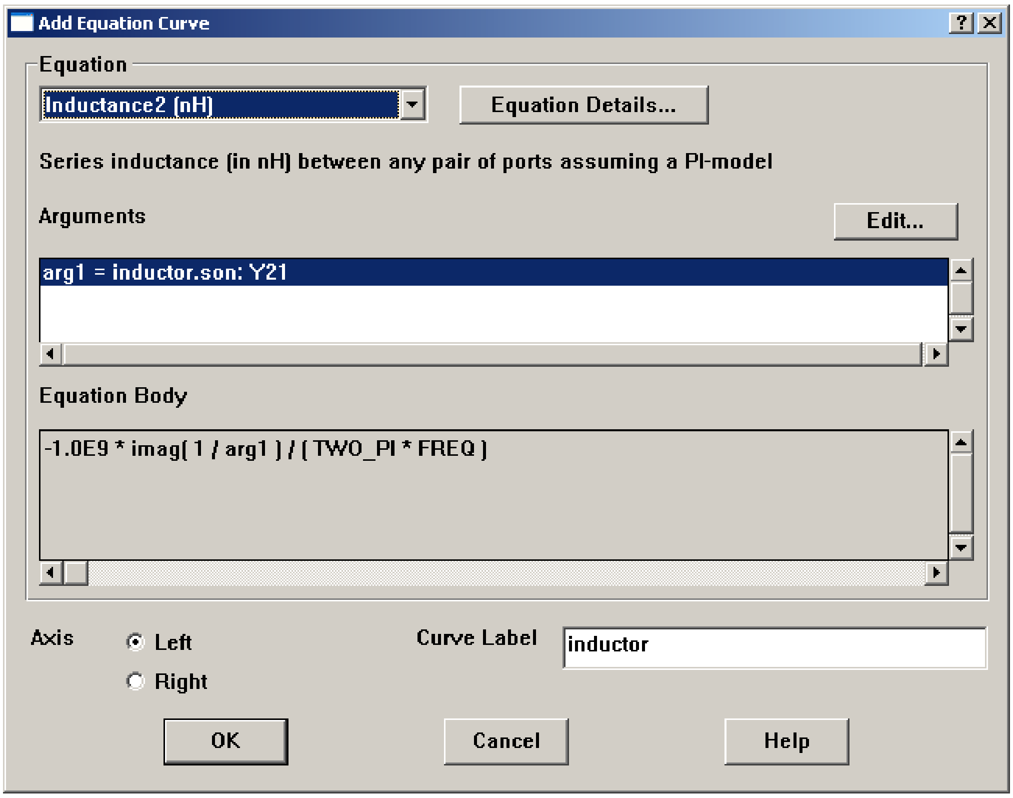
Constants

Introduction: With Sonnet 9.0 you have can define a curve in the response viewer as a function of an equation. Equations are available through the new equation menu in the response viewer. Sonnet supplies a basic set of equations including inductance, capacitance, Q factor, phase difference, dB difference, and group delay as well as allowing the users to define their own equations. This application note gives an overview on how the equations in the response viewer are used.

Note: In addition to the equations, four new data types for standard curves have been added in the response viewer: VSWR, Zin, GMax and Loss.

Pre-defined equations: The screen shot below shows the S-parameter result of the two-port analysis of a spiral inductor. The inductance and the quality factor of the inductor can be plotted in the Sonnet response viewer by adding the appropriate equations. An equation is added by selecting *Equation ⇒ Add Equation Curve…* in the response viewer. This will open the *Add Equation Curve* dialog box as shown on the next page.





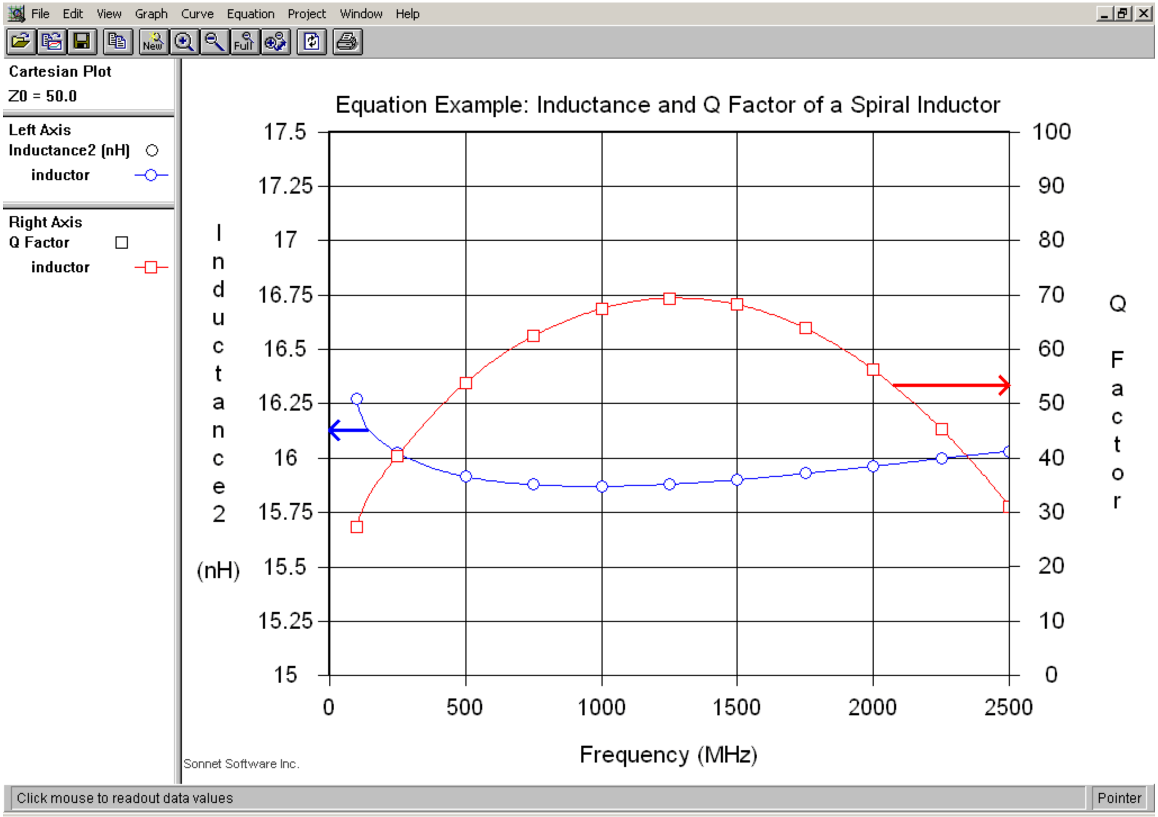
You can choose the appropriate equation from a number of pre-defined equations in a drop down menu at the upper left hand side of the *Add Equation Curve* dialog box. In this example, we want to display the inductance value of an inductor, and we choose *Inductance2 (nH)* as equation. This equation calculates the series inductance in nano Henry between any pair of ports assuming a PI-model. A short explanation of the selected equation is displayed when you click on the *Equation Details…* button on the right hand side of the drop down menu.

In the *Arguments* field below the drop down menu all arguments used in the equation are defined. Here, S-, Y- or Z-parameter results of the analysis can be assigned to an argument name. The *Inductance2* equation assigns Y21 to the argument *arg1*, and there is no need to change this setting.

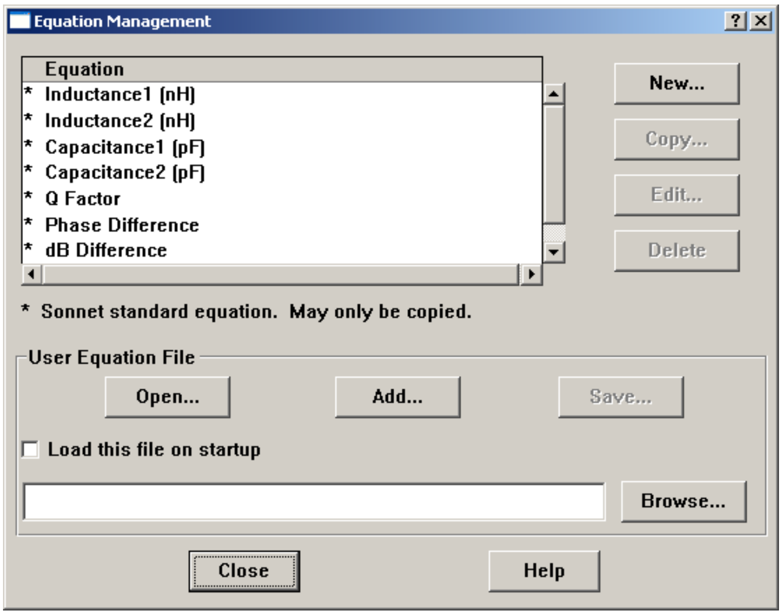
The definition of the selected equation *Inductance2* is displayed in the *Equation Body* field below the arguments. This standard definition for the inductance value between two ports has been taken from the literature. The equation syntax is addressed later in this document.

Finally you can choose whether the left or the right axis will be used for the inductance values, and you can modify the curve label. When you choose the left axis and click the OK button, a message appears that the old curves with the S-parameters will be replaced by the new inductor value curve.

The screen shot below shows a graph with the added inductance curve As there is already a pre-defined equation for the quality factor, a curve for the Q factor has been plotted as well. The left axis displays the frequency dependant inductance value, the right axis the Q factor.



User-defined equations: You can define your own equation by selecting *Equation ⇒ Manage Equations…* in the response viewer. This will open the *Equation Management* dialog box as shown below.



In the *Equation* window of this dialog box all presently defined equations are displayed. The Sonnet standard equations are marked with an asterisk symbol (*). In this dialog box you can enter, copy, view or edit, and delete equations. The second section of the dialog box allows you to control files containing equations that you have already defined. The set of equations from Sonnet is always available and may be copied and used as templates for your own equations. You can modify your own equation file by applying one of three actions:

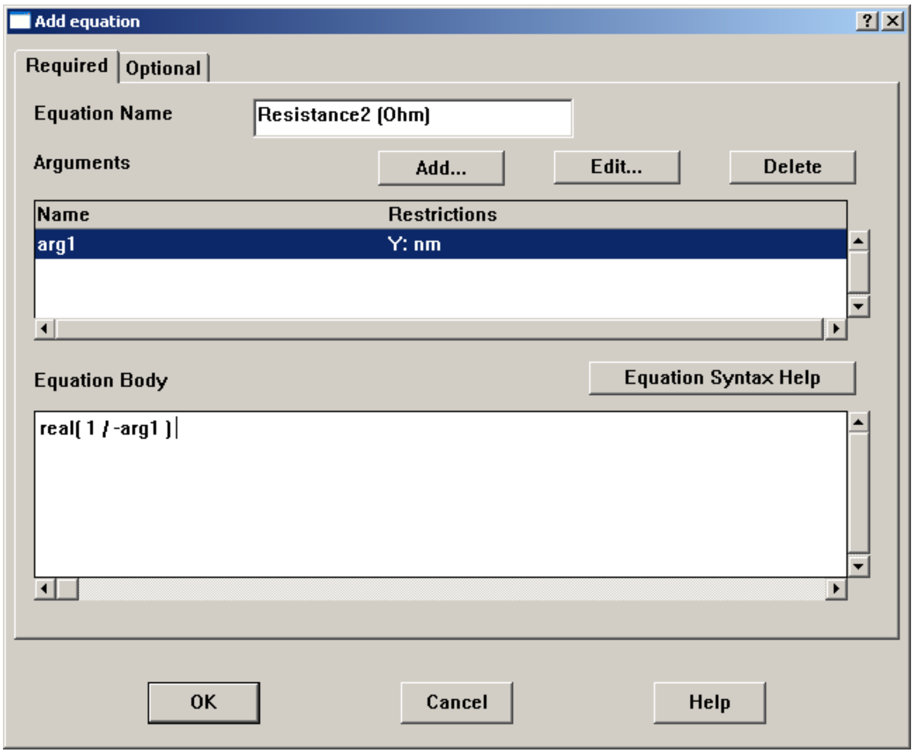
Open: Click on this button to load an equation file. A browse window is opened which allows you to select an equation file on your computer. Once the file is opened, the equations contained in the file are displayed in the equation list in this dialog box replacing any equations, aside from the Sonnet equations, on display from the previous equation file. If you wish to retain the present set of equations and add equations from another equation file, use the *Add* button.

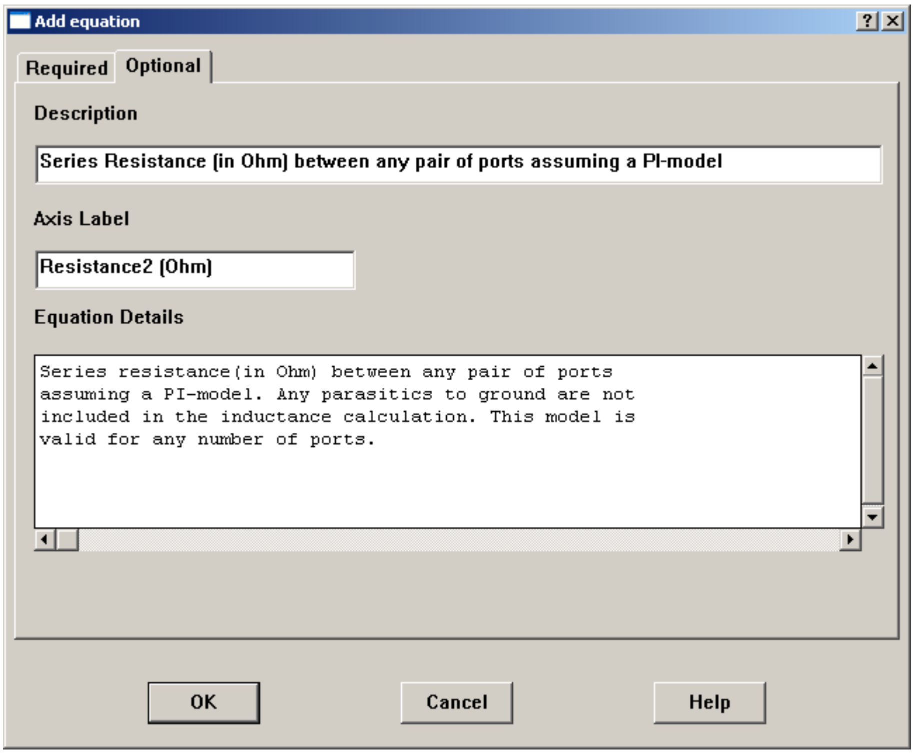
Add: Click on this button to open an equation file and add its contents to the present session of the response viewer while retaining any equations previously loaded from another equation file. A browse window appears which you use to select the equation file you wish to add. If there are duplicate names in the equations being loaded and those already available, the extension of "_2" is added to the equation name from the file you are adding.

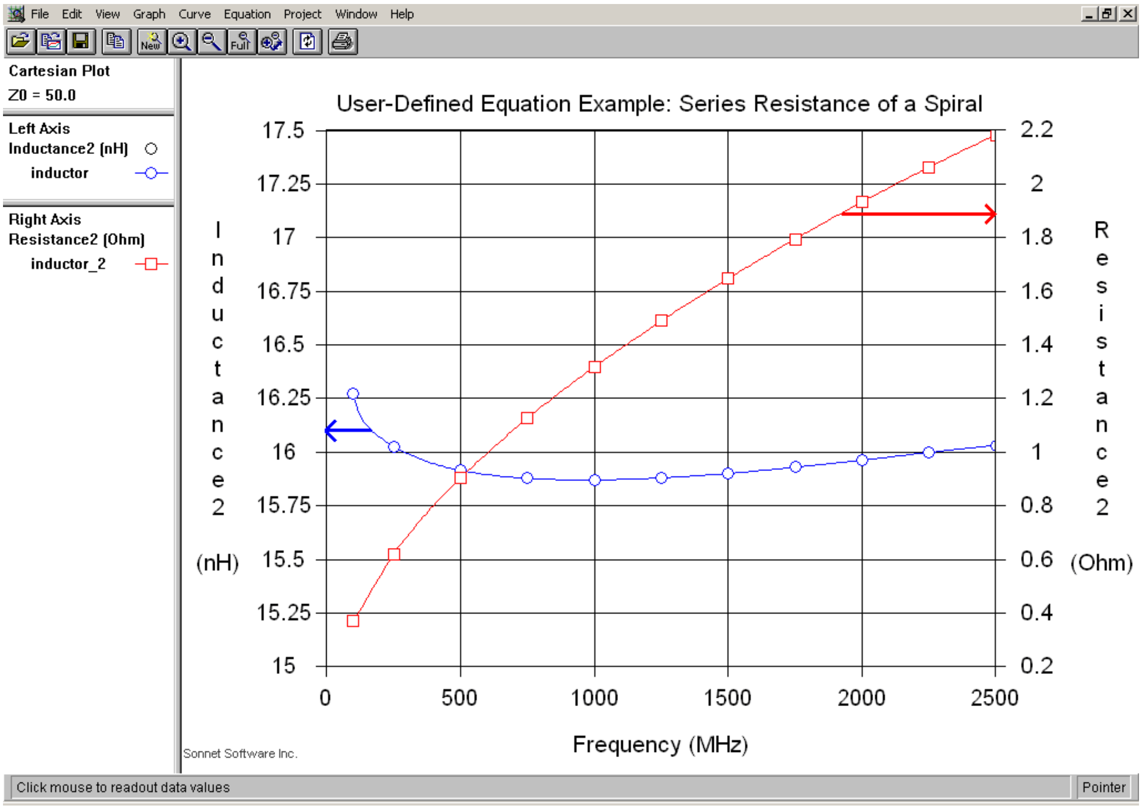
Save: Clicking on this button saves all the user generated equations in the present session to the presently selected equation file. This should be done after adding new equations, editing existing equations, copying equations or adding an equation file if you wish to retain the changes made in this session for future sessions of the response viewer.

As example, we define an equation for the resistive part of a series inductance. This resistance can be calculated with the approximation $R = Re\{1/-Y_{21}\}$, with Y_{21} being a Y-parameter of a loaded response file. A simple way to obtain the equation is to copy the Inductor2 equation and to edit the copy. In the equation management dialog box we select the Inductor2 equation and click the *Copy* button. This will open the *Add Equation* dialog box. In this dialog box we change the name from *Inductor2 (nH)_2* to *Resistance2 (Ohm)*, and in the equation body we delete the old equation and enter *real(1 / -arg1)* instead. The arguments field can be left unchanged (see section argument definition further below). Next we change from the *Required* section of the dialog box to the *Optional* section. In this section we modify adequately the *Description*, *Axis Label*, and *Equation Details* texts to match the new Resistance2 equation. After clicking the OK button, the Resistance2 (Ohm) equation is available in the equation list.

The two screen shots on the next page show how the new equation has been defined in the *Add Equation* dialog box, and the next screenshot shows an example curve for the new *Resistance2 (Ohm)* equation.


Add equation
Required
Optional
Equation Name
Resistance2 (Ohm)
Arguments
Add...
Edit...
Delete
Name
Restrictions
arg1
Y: nm
Equation Body
Equation Syntax Help
real(1 / -arg1)
OK
Cancel
Help


Add equation
Required
Optional
Description
Series Resistance (in Ohm) between any pair of ports assuming a PI-model
Axis Label
Resistance2 (Ohm)
Equation Details
Series resistance(in Ohm) between any pair of ports
assuming a PI-model. Any parasitics to ground are not
included in the inductance calculation. This model is
valid for any number of ports.
OK
Cancel
Help



Argument definition: Clicking on the *Add* or *Edit* button in the *Add/Edit Equation* dialog box opens the *Add/Edit Argument Definition* dialog box which allows you to add a new or edit an existing argument to your equation. Any S-, Y- or Z-parameter can be assigned to an argument. Please note that all arguments may be complex values, but if you define an equation for which the result is complex, and you plot that equation, the response viewer plots only the real part of that equation.

Argument Names: Argument names must consist of only upper or lowercase alpha-numeric characters, and the first character must be a letter.

Argument Description: You can enter a description of the argument in this field. This allows you to explain the meaning of the argument in detail and enter any important assumptions or constraints which should be kept in mind when using this argument.

Parameter and Port Specifications/Restrictions: Select the type of parameters which are allowed for this argument. The selection you make here controls which parameters are available to select for the argument in the *Argument Entry* dialog box. The choices available are shown in the table below:

S, Y, Z	The user may choose S-, Y- and Z- parameters for the argument
S	The user may choose only S-parameters for the argument
Y	The user may choose only Y-parameters for the argument
Z	The user may choose only Z-parameters for the argument
S, Y	The user may choose S- and Y- parameters for the argument
S, Z	The user may choose S- and Z- parameters for the argument
Y, Z	The user may choose Y and Z- parameters for the argument

Ports: Select or enter which ports are allowed for this argument. The entry you make here controls which responses are available to select for the argument in the *Argument Entry* dialog box. You may specify any desired ports by directly editing the entry as long as you use the correct syntax or select a choice in the drop list. The choices available are shown in the table below:

Any	The user may select any combination of ports. For a 4 port circuit the choices would include 11, 12, 13, 14, 21, 22, 23, 24, 31, 32, 33, 34, 41, 42, 43, and 44.
nm	The user may select any parameter whose two port numbers are different. For a 4 port circuit the choices would include 12, 13, 14, 21, 23, 24, 31, 32, 34, 41, 42, and 43. **11, 22, 33, and 44 would not be allowed**.
nn	The user may select any parameters whose two port numbers are the same. For a 4 port circuit the choices would include 11, 22, 33, and 44.
11	The user may select any parameter whose two port numbers are 1.
12	The user may select any parameter whose two port numbers are 1 and 2.
21	The user may select any parameter whose two port numbers are 2 and 1.
22	The user may select any parameter whose two port numbers are 2.

Argument index: All user defined arguments and the FREQ constant can be indexed by appending [f] to the argument. The indexing starts at f = 0 and ends at f = (Nf - 1) where Nf is the total number of frequencies. If Nf is equal to five, the index f would start at 0 and end at 4. When "Arg" is a user defined argument, Arg[f-1] represents the previous value of "Arg." Arg[f+1] represents the next value of Arg. FREQ[f] represents the frequency in hertz at the present frequency index "f". For example, you have analyzed a circuit at 5, 10, 15, 20 and 25 GHz. The values for FREQ[f], FREQ[f-1] and FREQ (f+1) are shown in the table below.

Frequency	FREQ(f)	FREQ[f-1]	FREQ[f+1]
5 GHz f = 0	5 GHz	No data point.	10 GHz
10 GHz f = 1	10 GHz	5 GHz	15 GHz
15 GHz f = 2	15 GHz	10 GHz	20 GHz
20 GHz f = 3	20 GHz	15 GHz	25 GHz
25 GHz f = 4	25 GHz	20 GHz	No data point.

Equation Syntax: Functions and operators should always use lower case characters. Use parentheses in your equation to delineate the order in which the operations should be performed. For example ((x * y)^2) would multiply the complex number x by the complex number y and square the resulting complex number.

In the list functions and operators below, x and y represent the argument used in the equation. For example, if you wished to multiple two arguments "arg1" and "arg2," the expression would be "arg1 * arg2."

Entry	Definition
x + y	Complex addition of x and y
x - y	Complex subtraction of y from x
x * y	Complex multiplication of x and y
x/y	Complex division of x by y
x^y	Power x^y = x raised to the power of y
sin(x)	Sine of complex value x
cos(x)	Cosine of complex value x
real(x)	Real part of complex value x
imag(x)	Imaginary part of complex value x
mag(x)	Magnitude of complex value x
deg(x)	Phase of complex value x in degrees
rad(x)	Phase of complex value x in radians
db10(x)	dB of a Power value (i.e. S21^2) = 10Log10(x)
db20(x)	dB of a voltage value (i.e. S21) = 20Log10(x)
log10(|x|)	The base 10 logarithm of the magnitude of x
ln(|x|)	The natural logarithm of the magnitude of x
exp(x)	Natural antilogarithm of x
conj(x)	Conjugate of a complex number ((x+iy) -> (x-iy))
cmplx(x,y)	Complex: form a complex number from two values CMPLX(x,y) = (x+iy)
sqrt(x)	Square root of x

Exponential Notation Syntax: When using exponential notation, you must use a minus sign “-” to indicate a negative exponent. A positive exponent may be indicated by a "+" sign. The positive sign may be used but is not necessary; the positive is implied. Please see the example below.

2.988×10^{8} = 2.988e8

6.626×10^{-34} = 6.626e-34

Constants: Below is a list of the constants and their values available for use in Sonnet Equations. All constants use uppercase characters. FREQ is a special case of a constant which may be indexed.

Below is a list of the constants and their values available for use in Sonnet Equations. All constants use uppercase characters. FREQ is a special case of a constant which may be indexed. For details on indexing, see Arguments.

Entry	Definition
FREQ	The frequency at which the present data point is being calculated.
PI	π = 3.14159265358979323846264338327950288841971
TWO_PI	2π = 6.28318530717958647692528676655900576839 42
EPSILON_0	ε_0 - The permittivity of free space
MU_0	μ_0 - The permeability of free space
ETA_0	η_0 - The impedance of free space
RAD_TO_DEG	Factor to convert radians to degrees 57.295779513082320876798154814105 17.
DEG_TO_RAD	Factor to convert degrees to radians. 1.0/57.295779513082320876798154814105 17
VELC	c_0 - Speed of light in free space