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# METAS VNA Data Explorer - User Manual V2.8.1

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# 1 Installation

## 1.1 System Requirements

The following list describes the minimum software and hardware requirements of the METAS VNA Data Explorer.

- Microsoft Windows 7
- Microsoft .NET Framework 4.6.2
- Microsoft Windows Installer 4.5
- At least 512 megabytes (MB) of RAM (1024 MB is recommended)
- At least 100 megabytes (MB) of available space on the hard disk
- Video adapter and monitor with SVGA (800 x 600) or higher resolution (1280 x 1024 is recommended)

## 1.2 Steps

The following steps describe the installation of METAS VNA Data Explorer.

1. Double-click on the METAS VNA Data Explorer setup program
2. Accept license agreement
3. Select installation folder
4. Confirm installation
5. Installation complete

After installation, one can start METAS VNA Data Explorer by double-clicking on its desktop shortcut.



## 2 Overview

The METAS VNA Data Explorer is designed to visualize S-parameter files. The graphical user interface is split up into two parts. The file explorer is on the left and the visualization with different tabs is on the right.

### 2.1 Filetypes

Table 1 shows the supported file types. S-Parameter Data files can only contain S-parameter

Table 1: File types

Description	Extension
S-Parameter Data Binary	(.sdatb)
S-Parameter Data Xml	(.sdatx)
S-Parameter Data Covariance Text	(.sdatcv)
S-Parameter Data Touchstone	(.s*p)
S-Parameter Data Touchstone V2.0	(.ts)
VNA Data Binary	(.vdatb)
VNA Data Xml	(.vdatx)
VNA Data Covariance Text	(.vdatcv)
VNA Data CITI	(.cti;.citi)
S-Parameter Data Collection Binary	(.scolb)
S-Parameter Data Collection Covariance Text	(.scolcv)
VNA Data Collection Binary	(.vcolb)
VNA Data Collection Covariance Text	(.vcolcv)
ZIP with embedded data files	(.zip)
PDF with embedded data files	(.pdf)

data. In contrast VNA Data files can contain receiver values and ratios of receiver values.

### 2.2 File Explorer

The following user controls are available:

**Root Path** sets the root directory.

**Help** contains the following items: User Manual, Data Formats, Website, License and About.

**Collapse All** collapses all tree nodes.

**Auto Refresh** refreshes the file explorer on the left (default: on).

**Auto Update Panel** updates the visualization tabs on the right (default: on).

**Sort Selected Items** sorts the selected items (default: on).

**Filter** sets file filter (default: \*.\*).



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**Freq List Browse** can be used to select a frequency list file (\*.fl). All selected files in the tree view will be interpolated (default: None).

**Freq List On** turns frequency list interpolation on or off (default: Off).

**Tree View** can be used to select one or multiple files. Additional files can be selected while holding the Ctrl or Shift key.

### 2.2.1 Content Menu

The content menu of the File Explorer provides some tools for post processing of data sets. All post processing tools propagate the uncertainties of the inputs to the results. The following tools are available:

**Show in Windows Explorer** shows a file or directory in the Windows Explorer.

**Set as Root Path** sets the current directory as root path.

**New Folder** creates a new folder in the current directory.

**New Shortcut** creates a new shortcut in the current directory.

**Save Data As ...** saves the current file in another file. Supported file formats are S-Parameter Data (\*.sdatb or \*.sdatx), S-Parameter Data Covariance Text (\*.sdatcv), Touchstone (\*.s1p, \*.s2p, \*.s\*p), Touchstone V2.0 (\*.ts), VNA Data (\*.vdatb or \*.vdatx), VNA Data Covariance Text (\*.vdatcv) or CITI (\*.cti or \*.citi).

**Save Collection As ...** saves the current files in a collection file. Supported file formats are S-Parameter Data Collection (\*.scolb), S-Parameter Data Collection Covariance Text (\*.scolcv), VNA Data Collection (\*.vcolb) or VNA Data Collection Covariance Text (\*.vcolcv).

**Frequency and Port Definitions** shows the port assignment, the port reference impedance and the frequency conversion per port.

**Change Port Assignment** changes the port assignment and a subset can be taken<sup>1</sup>. The new ports can be optionally sorted in the following order: port number, port mode (s, d, c).

**Change Port Zr** changes the reference impedance by cascading a transmission line junction to each port or simply reassigns the reference impedance to a specified complex value in Ohm.

**Mixed-Mode S-Parameters** converts single-ended S-parameters to mixed-mode S-parameters or vice versa.

**Time Gating** does a transformation from frequency domain to time domain, gates the data in time domain and transforms it back to frequency domain. See section 3.2.

**Math** provides the following math tools:

**Add (1st + 2nd)** adds  $N$ -port 1 and  $N$ -port 2.



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**Subtract (1st - 2nd)** subtracts  $N$ -port 2 from  $N$ -port 1.

**Subtract (2nd - 1st)** subtracts  $N$ -port 1 from  $N$ -port 2.

**Multiply (1st x 2nd)** multiplies  $N$ -port 1 with  $N$ -port 2.

**Divide (1st / 2nd)** divides  $N$ -port 1 by  $N$ -port 2.

**Divide (2nd / 1st)** divides  $N$ -port 2 by  $N$ -port 1.

where 1st and 2nd are referring to the order of the two selected files.

**Cascade** provides the following cascade tools:

**Cascade (1st and 2nd)** cascades  $2N$ -port 1 with  $N$ -port 2 or cascades 2-port 1 with 2-port 2.

**Cascade (2nd and 1st)** cascades  $2N$ -port 2 with  $N$ -port 1 or cascades 2-port 2 with 2-port 1.

**Cascade (inv(1st) and 2nd)** cascades inverted  $2N$ -port 1 with  $N$ -port 2 or cascades inverted 2-port 1 with 2-port 2.

**Cascade (inv(2nd) and 1st)** cascades inverted  $2N$ -port 2 with  $N$ -port 1 or cascades inverted 2-port 2 with 2-port 1.

**Cascade (1st and inv(2nd))** cascades  $N$ -port 1 with inverted  $2N$ -port 2 or cascades 2-port 1 with inverted 2-port 2.

**Cascade (2nd and inv(1st))** cascades  $N$ -port 2 with inverted  $2N$ -port 1 or cascades 2-port 2 with inverted 2-port 1.

where 1st and 2nd are referring to the order of the two selected files.

**Make Reciprocal** makes an  $N$ -port reciprocal ( $S_{jk} = S_{kj}$ ).

**Merge (lower and upper)** merges two data sets at a given frequency point.

**Mean Data Set** computes the mean of a data set.

**Circle Fit Data Set** computes the circle fit of a data set consisting of at least 3 measurements. The circle fit supports  $N$ -port data set where one port is terminated by a sliding load.

**Properties** shows the file or directory properties.

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<sup>1</sup>only single-ended S-parameter data



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### 3 Visualization

#### 3.1 Modes

METAS VNA Data Explorer supports different view modes:

**Graph** shows a graphical visualization of multiple files, see section 3.1.1.

**Table** shows a tabular visualization of a single file, see section 3.1.2.

**Point** shows an uncertainty budget for one frequency point and one parameter of a single file, see section 3.1.3.

**Covariance** shows a covariance matrix for a single frequency point or a single parameter of a single file, see section 3.1.4.

**Info** shows file information including MD5 checksum of multiple files, see section 3.1.5.

#### 3.1.1 Graph

The graph tab supports multiple selected files, see figure 1. The following user controls are

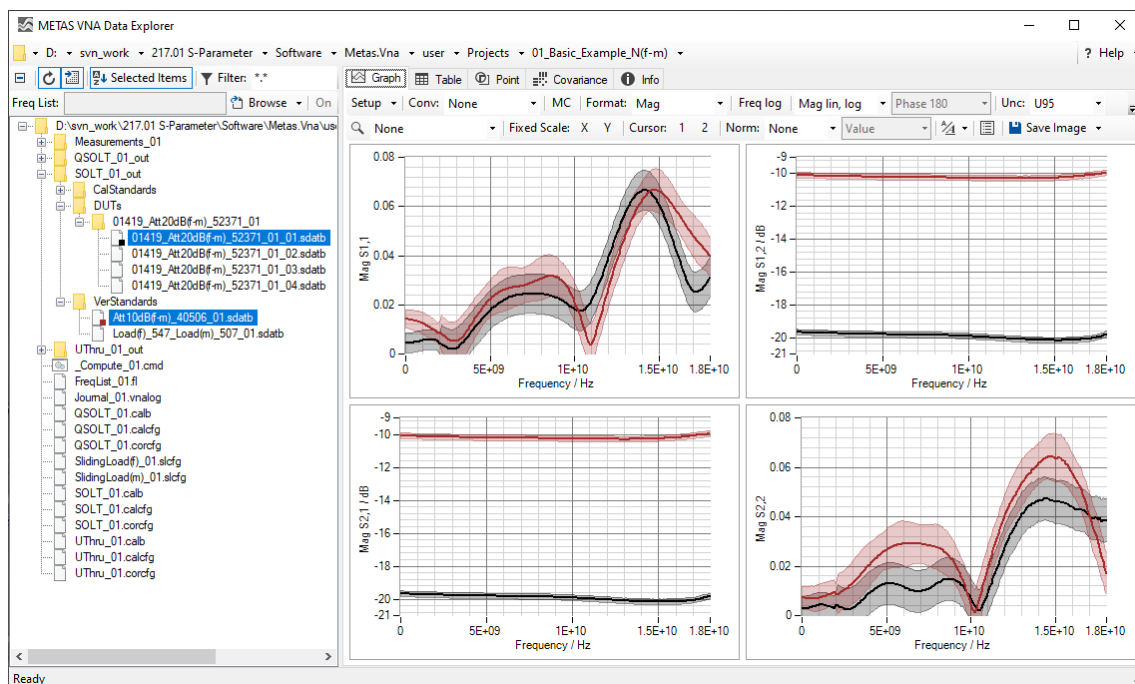


Figure 1: Data Explorer / Graph

available:

**Setup** sets up the plots (default:  $S_{x,x}$  Ports: 1, 2).

**Conv** sets the conversion to None,  $S/S'$ , Passivity Check, Absorbed Power, Z-Parameter, Y-Parameter, Impedance, Admittance, Time Domain, Time Domain Impedance or Time Domain Admittance (default: None). See section 3.3 for more information.



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**MC** sets the uncertainty propagation to Monte Carlo for formatting a complex quantity. Correlation between frequency points and different traces are ignored.

**Format** sets the data format to Real Imag, Mag Phase, ReIm MP (reflection real imag and transmission mag phase), Real, Imag, Mag, Phase or Cartesian (default: Mag Phase).

**Freq log** sets the frequency axis to linear or logarithmic (default: Freq lin).

**Mag format** sets the magnitude format to Mag lin (reflection and transmission linear), Mag log (reflection and transmission logarithmic), Mag lin log (reflection linear and transmission logarithmic),  $\text{Mag}^2$  (reflection and transmission linear<sup>2</sup>), VSWR lin (reflection VSWR and transmission linear) or VSWR log (reflection VSWR and transmission logarithmic) (default: Mag lin).

**Phase format** sets the phase format to Phase 180, Phase 360, Phase Unwrap, Phase Delay or Group Delay (default: Phase 180).

**Time Domain Mode** sets the time domain mode to Low Pass Step, Low Pass Impulse or Band Pass Impulse (default: Band Pass Impulse).

**Window** sets the window function used for transforming from frequency domain to time domain to Rectangular, Triangle, Hann, Hamming, Blackman, Blackman Harris, Blackman Nuttall, Exact Blackman, Flat Top, Minimum Kaiser ( $\beta = 0$ ), Normal Kaiser ( $\beta = 6$ ) or Maximum Kaiser ( $\beta = 13$ ) (default: Normal Kaiser).

**Unc** sets the uncertainty mode to None, Standard or U95 (default: None).

**Interaction Mode** sets interaction mode to None, Zoom or Pan (default: None).

**Fixed Scale** activates or deactivates automatically scaling of the x- and y-axis.

**Cursor** shows or hides one or two cursors.

**Norm** normalizes all traces to one selected trace or to the mean value of all traces (default: None). In the neighboring control one can select if normalization is with respect to value or value and uncertainty. Normalizing to a value means subtracting certain values from the dataset. The resulting uncertainties are the same as from the input data. Normalizing to value and uncertainty means subtracting uncertain numbers from the dataset. The resulting uncertainties are different from the previous case because the uncertainties are as well subtracted.

**Font** specifies the font for the current plots.

**Legends** shows or hides the legend.

**Save Image** saves the current plots to a bitmap file. Supported file formats are BMP, JPG and PNG.

**Copy Image** copies the current plots to the clipboard.











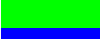







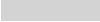



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Table 2 shows the different colors for each trace and its associated uncertainty region.

Table 2: Trace Colors

Trace	Value	Unc	Color
1			black
2			brown
3			red
4			orange
5			yellow
6			green
7			blue
8			violet
9			gray
10			light gray





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### 3.1.2 Table

The first of the selected files will be shown in the table view, see figure 2. The following user

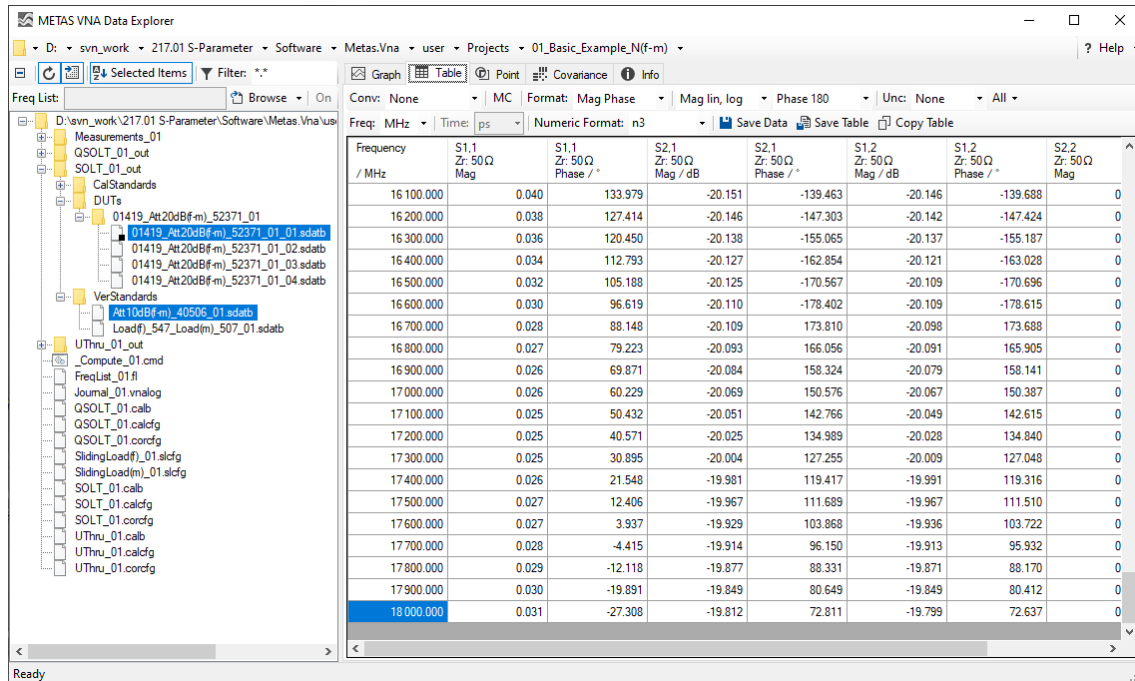


Figure 2: Data Explorer / Table

controls are available:

**Conv** sets the conversion to None, S/S', Passivity Check, Absorbed Power, Z-Parameter, Y-Parameter, Impedance, Admittance, Time Domain, Time Domain Impedance or Time Domain Admittance (default: None). See section 3.3 for more information.

**MC** sets the uncertainty propagation to Monte Carlo for formatting a complex quantity.

**Format** sets the data format to Real Imag, Mag Phase, ReIm MP (reflection real imag and transmission mag phase) or Mag (default: Mag Phase).

**Mag format** sets the magnitude format to Mag lin (reflection and transmission linear), Mag log (reflection and transmission logarithmic), Mag lin log (reflection linear and transmission logarithmic),  $\text{Mag}^2$  (reflection and transmission linear<sup>2</sup>), VSWR lin (reflection VSWR and transmission linear) or VSWR log (reflection VSWR and transmission logarithmic) (default: Mag lin).

**Phase format** sets the phase format to Phase 180, Phase 360, Phase Unwrap, Phase Delay or Group Delay (default: Phase 180).

**Time Domain Mode** sets the time domain mode to Low Pass Step, Low Pass Impulse or Band Pass Impulse (default: Band Pass Impulse).



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**Window** sets the window function used for transforming from frequency domain to time domain to Rectangular, Triangle, Hann, Hamming, Blackman, Blackman Harris, Blackman Nuttall, Exact Blackman, Flat Top, Minimum Kaiser ( $\beta = 0$ ), Normal Kaiser ( $\beta = 6$ ) or Maximum Kaiser ( $\beta = 13$ ) (default: Normal Kaiser).

**Unc** sets the uncertainty mode to None, Standard or U95 (default: None).

**Freq** sets the frequency format to Hz, kHz, MHz, GHz or THz (default: MHz).

**Time** sets the time format to s, ms, us, ns or ps (default: ps).

**Numeric Format** sets the numeric format (default: f3).

**Save Data** saves the current data in a file. Supported file formats are S-Parameter Data (\*.sdatb or \*.sdatx), S-Parameter Data Covariance Text (\*.sdatcv), Touchstone (\*.s1p, \*.s2p, \*.s\*p), Touchstone V2.0 (\*.ts), VNA Data (\*.vdatb or \*.vdatx), VNA Data Covariance Text (\*.vdatcv) or CITI (\*.cti or \*.citi).

**Save Table** saves the current formatted data in a file. Supported file formats are Text (\*.txt) or L<sup>A</sup>T<sub>E</sub>X (\*.tex).

**Copy Table** copies the current formatted data to the clipboard.

One can select one or more rows of the table and copy the data to the clipboard with Ctrl-C or with the context menu of the table. Ctrl-A selects all data.

### 3.1.3 Point

The first of the selected files will be shown in the point view. One can select one frequency point and one parameter and obtains the uncertainty budget of the selected data point, see figure 3. The following user controls are available:

**Freq** selects a frequency point for the uncertainty budget (default: None).

**Time** selects a time point for the uncertainty budget (default: None). Only visible when conversation is set to Time Domain.

**First** selects the first frequency or time point.

**Last** selects the last frequency or time point.

**Parameter** selects a parameter for the uncertainty budget (default: None).

**Conv** sets the conversion to None, S/S', Passivity Check, Absorbed Power, Z-Parameter, Y-Parameter, Impedance, Admittance, Time Domain, Time Domain Impedance or Time Domain Admittance (default: None). See section 3.3 for more information.

**MC** sets the uncertainty propagation to Monte Carlo for formatting a complex quantity.

**Format** sets the format to Real, Imag, Mag, Mag log, Mag<sup>2</sup>, VSWR, Phase, Phase 360, Phase Unwrap, Phase Delay or Group Delay (default: Mag).



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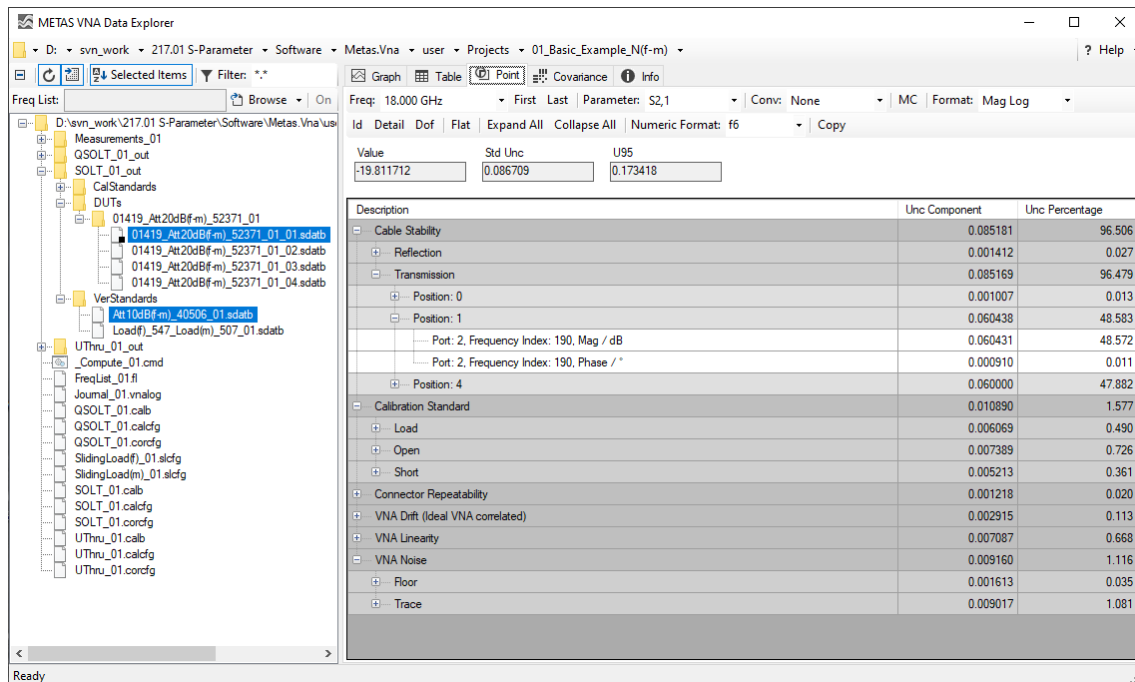


Figure 3: Data Explorer / Point

**Time Domain Mode** sets the time domain mode to Low Pass Step, Low Pass Impulse or Band Pass Impulse (default: Band Pass Impulse).

**Window** sets the window function used for transforming from frequency domain to time domain to Rectangular, Triangle, Hann, Hamming, Blackman, Blackman Harris, Blackman Nuttall, Exact Blackman, Flat Top, Minimum Kaiser ( $\beta = 0$ ), Normal Kaiser ( $\beta = 6$ ) or Maximum Kaiser ( $\beta = 13$ ) (default: Normal Kaiser).

**Id** shows or hides the uncertainty input ids (default: Hide).

**Detail** shows or hides the distribution, value, standard uncertainty and sensitivity columns (default: Hide).

**Dof** shows or hides the degrees of freedom (default: Hide).

**Flat** shows a flat or tree uncertainty budget (default: Tree).

**Expand All** expands all tree nodes.

**Collapse All** collapses all tree nodes.

**Numeric Format** sets the numeric format (default: f6).

**Copy** copies the uncertainty budget to the clipboard.

The following items will be shown for the selected data point:

**Value** indicates the value.



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**Std Unc** shows the standard uncertainty (68% coverage factor,  $k = 1$ ).

**U95** shows the expanded uncertainty (95% coverage factor,  $k = 2$ ).

**Unc Budget** shows a tabular visualization of the uncertainty budget.

### 3.1.4 Covariance

The first of the selected files will be shown in the covariance view. There are two modes in the covariance view. Either one can select a single frequency point and obtains the covariance matrix of multiple parameters at the selected frequency point. Or one can select all frequency points and a single parameter in the desired format and obtains the covariance matrix for the selected parameter and format over the hole frequency range, see figure 4. The following user

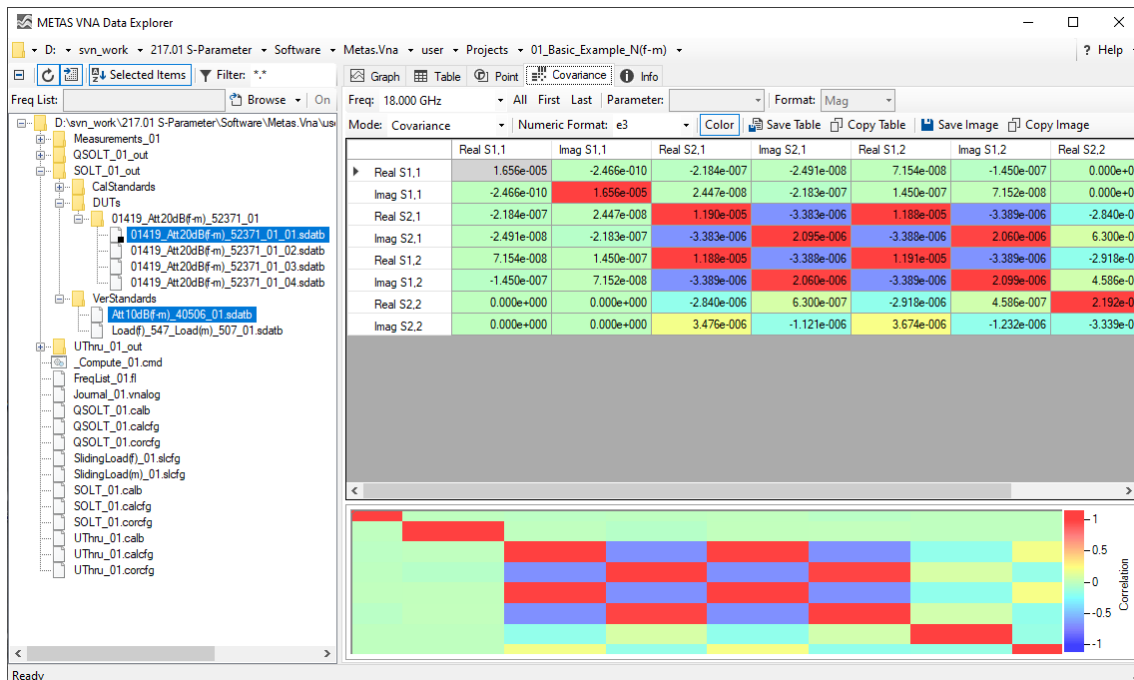


Figure 4: Data Explorer / Covariance

controls are available:

**Freq** selects a frequency point or all frequency points for the covariance view (default: None).

**All** selects all frequency points.

**First** selects the first frequency point.

**Last** selects the last frequency point.

**Parameter** selects a parameter for the covariance view (default: None).

**Format** sets the format to Real, Imag, Mag or Phase (default: Mag).



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**Mode** sets the mode to covariance or correlation (default: Covariance).

**Numeric Format** sets the numeric format (default: e3).

**Color** shows or hides the graphical representation of the correlation matrix (default: show).

**Save Table** saves the current formatted covariance in a file. Supported file formats are Text (\*.txt) or L<sup>A</sup>T<sub>E</sub>X (\*.tex).

**Copy Table** copies the current formatted covariance to the clipboard as text.

**Save Image** saves the current covariance to a bitmap file. Supported file formats are BMP, JPG and PNG.

**Copy Image** copies the current covariance to the clipboard as bitmap.

### 3.1.5 Info

The info tab supports multiple selected files. One can obtain information about multiple files by holding the Ctrl or Shift key and selecting the files. The info tab shows the file name, size, modification date and computes the checksum for each selected file. See Figure 5. The

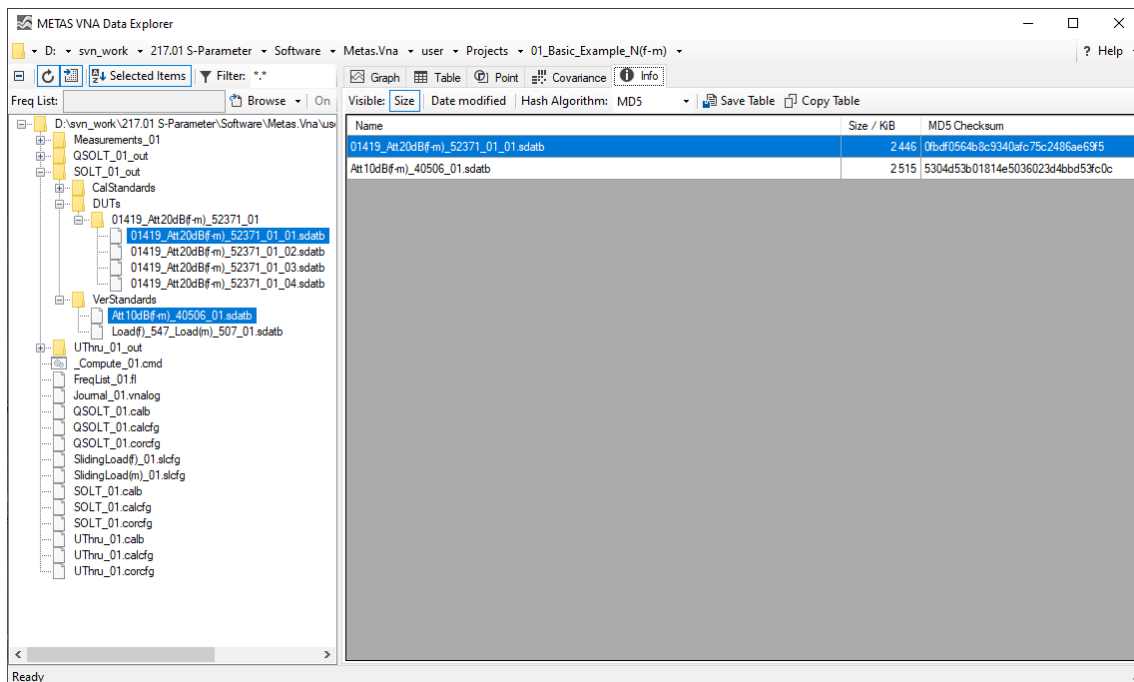


Figure 5: Data Explorer / Info

following user controls are available:

**Size** shows or hides the file sizes (default: Show).

**Data modified** shows or hides the file dates (default: Hide).



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**Hash Algorithm** specifies the used hash algorithm to compute the checksum (default: MD5).

**Save Table** saves the current information in a file. Supported file formats are Text (\*.txt) or  $\text{\LaTeX}$  (\*.tex).

**Copy Table** copies the current information to the clipboard.

### 3.2 Time Gating

The dialog called Time Gating, see figure 6, is designed to gate S-parameter data in time domain and transform it back to frequency domain. The following user controls are available:

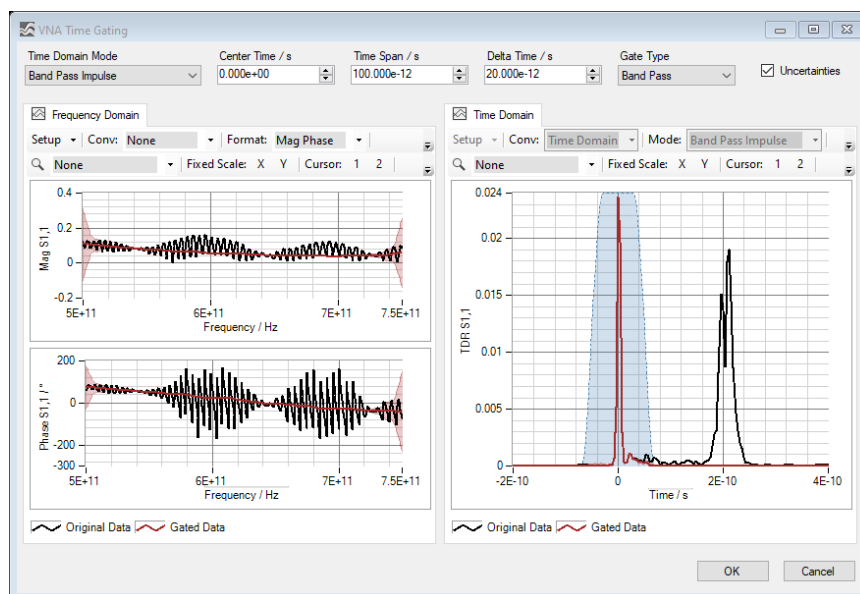


Figure 6: Data Explorer / Time Gating

**Time Domain Mode** sets the time domain mode to Low Pass Step, Low Pass Impulse or Band Pass Impulse (default: Band Pass Impulse).

**Center Time / s** specifies the time of the center of the gate shape (default: 0 ps).

**Time Span / s** specifies the time span from 50 % to 50 % of the gate shape (default: 100 ps).

**Delta Time / s** specifies the delta time from 0 % to 50 % or from 50 % to 100 % of the gate shape (default: 20 ps). The Time Span must be at least two times the Delta Time.

**Gate Type** sets the gate type to Band Pass or Notch (default: Band Pass).

**Uncertainties** enables uncertainty propagation. Note that time gating with more than 1000 frequency points and uncertainty propagation is very memory and time consuming.

**Frequency Domain** shows a graphical visualization of the original data and the gated data in frequency domain.

**Time Domain** shows a graphical visualization of the original data, the gated data and the gate shape in time domain.



### 3.3 Math

The same equations are used in Graph, Table and Point tab for data conversion and formatting. Table 3 shows the equations for data conversions in METAS VNA Data Explorer. Variable  $x$  is the input quantity,  $y$  is the converted output,  $Z_r$  is the reference impedance and  $Y_r$  is the reference admittance. Index  $i$  is the frequency point,  $j$  is the receiver port and  $k$  is the source port. Table 4 shows the equations used for data formatting. Variable  $y$  is the converted input

Table 3: Conversions

Conversion	Equation
None	$y = x$
S/S'	$y_{jk} = x_{jk}/x_{kj}$
Passivity Check	$y_{jk} = (\text{eig}(\mathbf{I} - \mathbf{X}^* \mathbf{X}))_{jk}$
Absorbed Power	$y_{jk} = (\text{AbsorbedPower}(\mathbf{X}))_{jk}$
Z-Parameter	$y_{jk} = ((\mathbf{I} + \mathbf{X})(\mathbf{I} - \mathbf{X})^{-1})_{jk} Z_r$
Y-Parameter	$y_{jk} = ((\mathbf{I} - \mathbf{X})(\mathbf{I} + \mathbf{X})^{-1})_{jk} Y_r$
Impedance	$y = \frac{1+x}{1-x} Z_r$
Admittance	$y = \frac{1-x}{1+x} Y_r$
Time Domain	$y = \text{FDtoTD}(x, \text{mode}, \text{window})$
TD Impedance	$y = \frac{1+t}{1-t} Z_r$ with $t = \text{FDtoTD}(x, \text{mode}, \text{window})$
TD Admittance	$y = \frac{1-t}{1+t} Y_r$ with $t = \text{FDtoTD}(x, \text{mode}, \text{window})$

from Table 3 and  $z$  is the formatted output.



Table 4: Formats

Format	Equation
Real	$z = \Re(y)$
Imag	$z = \Im(y)$
Mag	$z =  y $
Mag log	$z = 20 \log_{10} ( y )$
Mag <sup>2</sup>	$z =  y ^2$
VSWR	$z = \frac{1+ y }{1- y }$
Phase	$z = \frac{180^\circ}{\pi} \arg(y)$
Phase 360	$z = \begin{cases} \frac{180^\circ}{\pi} \arg(y) & , \arg(y) \leq 0 \\ \frac{180^\circ}{\pi} \arg(y) - 360^\circ & , \arg(y) > 0 \end{cases}$
Phase Unwrap	$z = \frac{180^\circ}{\pi} \text{unwrap}(\arg(y))$
Phase Delay	$z_i = -\frac{\varphi_i}{2\pi f_i}$ with $\varphi = \text{unwrap}(\arg(y))$
Group Delay	$z_i = \begin{cases} -\frac{\varphi_2 - \varphi_1}{2\pi(f_2 - f_1)} & , i = 1 \\ -\frac{\varphi_{i+1} - \varphi_{i-1}}{2\pi(f_{i+1} - f_{i-1})} & , 1 < i \wedge i < n \\ -\frac{\varphi_n - \varphi_{n-1}}{2\pi(f_n - f_{n-1})} & , i = n \end{cases}$ with $\varphi = \text{unwrap}(\arg(y))$

### 3.4 Uncertainty

There are three different uncertainty modes:

**None** hides the uncertainty.

**Standard** shows the standard uncertainty. In a scalar case this means 68% coverage and  $k = 1$ . In a two dimensional case this means 39% coverage and  $k = 1$ .

**U95** shows the expanded uncertainty. In a scalar case this means 95% coverage and  $k = 2$ . In a two dimensional case this means 95% coverage and  $k = 2.45$ .

Here a scalar quantity consist of only one component, e.g. magnitude of S-parameter, whereas a two dimensional quantity consists of two components, e.g. complex S-parameter. In graphical representations the dimension is determined by the number of components shown in one subplot.

The uncertainties are computed with linear uncertainty propagation. This leads to well known problems when computing the absolute value and phase of small quantities.