[Matrix Format]

Rules for Version 1.0 Files:
The [Matrix Format] keyword is not permitted in version 1.0 files.

Rules for Version 2.0 Files:
The [Matrix Format] keyword entry specifies whether the network data given elsewhere in the file is specified for each and every port, or for a subset of the ports. This subset would be a reduced matrix, where only half (lower or upper) of the port-to-port data is specified, assuming symmetrical behavior in the matrix data. This assumption is most appropriate for interconnects. Note that all ports are still represented, but the format for the data takes advantage of symmetry to reduce the overall file size.

The [Matrix Format] section must begin with the keyword [Matrix Format], in brackets as shown. This keyword is followed by one of three possible strings: "Full", "Lower" or "Upper".

[Matrix Format] may only appear after the [Reference] keyword and before any network data.

[Matrix Format] is optional. If [Matrix Format] is not present, the network data included in the file is assumed to be of type "Full" and the network data for each port as specified under [Number of Ports] must be specified for each frequency point.

[Matrix Format] has no effect on noise data.

Example 2:

```
! 4-port S-parameter data
! Default impedance is overridden by the [Reference] line
! Data cannot be represented using 1.0 syntax.
[Version] 2.0
# GHz S MA R 50
[Number of Ports] 4
[Reference] 50 75 0.01 0.01
[Matrix Format] Full
5.00000 0.60 161.24 0.40 -42.20 0.42 -66.58 0.53 -79.34 !row 1
        0.40 -42.20 0.60 161.20 0.53 -79.34 0.42 -66.58 !row 2
        0.42 -66.58 0.53 -79.34 0.60 161.24 0.40 -42.20 !row 3
        0.53 -79.34 0.42 -66.58 0.40 -42.20 0.60 161.24 !row 4
```

Example 3:

```
! 4-port S-parameter data
! Default impedance is overridden by the [Reference] line
! Data cannot be represented using 1.0 syntax.
[Version] 2.0
# GHz S MA R 50
[Number of Ports] 4
[Reference] 50 75 0.01 0.01
[Matrix Format] Lower
5.00000 0.60 161.24                                     !row 1
        0.40 -42.20 0.60 161.20                         !row 2
        0.42 -66.58 0.53 -79.34 0.60 161.24             !row 3
        0.53 -79.34 0.42 -66.58 0.40 -42.20 0.60 161.24 !row 4
```

Network Parameter Data

Following the option line and/or [Reference] keyword are the network parameters (S-parameter, Z-parameter, etc.) of the type specified by the option line. Groups of n-port parameters are preceded by the frequency value for which the data was obtained, and the n-port parameters themselves are formatted as pairs of values (magnitude-angle, dB-angle or real-imaginary).

Network data is grouped into one or more 'lines' which end with a terminating newline character (e.g., CR or CR/LF). In version 1.0 files, for each frequency, n-port parameters for 1-port and 2-port networks are contained on one data line, while data for 3-port and larger networks are arranged on multiple data lines in a matrix row-wise order.

In summary, there are five general rules for formatting network data into lines:

1. In version 1.0 files, no more than four pairs of n-port parameters are allowed per data line. No restriction exists on the number of data pairs on a line in version 2.0 files.
2. Individual entries in data lines are separated by whitespace.
3. A data line is terminated by a newline character (CR or CR/LF combination).
4. All data lines must be arranged in increasing order of frequency.
5. Frequency values may only appear at the beginning of lines, after the newline character.

Detailed descriptions for arranging the data for various n-port networks follow.

Note that H- and G- parameters are defined for 2-port networks only. These hybrid parameters cannot be used to describe networks containing any other number of ports.

Rules for Version 2.0:
In version 2.0 files, the data associated with any one frequency may be split across any number of lines or may be placed on a single line of arbitrary length. Data in a version 2.0 file is parsed using the [Number of Ports] entry and the [Matrix Format] entry. For a Full matrix, a new frequency point is expected every $2n^2+1$ values, where n is the number of ports, regardless of intervening newline characters. For a Lower or Upper matrix, a new frequency point is expected every $n*(n+1)+1$ values. Data is organized in a row-wise fashion, where all columns in a row of data must be represented before data for the next row can be shown.

1-port and 2-port Networks

Network parameter data for 1-port and 2-port networks at a single frequency can be contained on a single data line. As shown below, the data line consists of a frequency value followed by either one or four pairs of data values.

1-port data (line)
<frequency value> <N11>

2-port data (line)
<frequency value> <N11> <N21> <N12> <N22>

where

frequency value	frequency at which the network parameter data was taken or derived.
N11, *N21*, *N12*, *N22*	network parameter data points, where N11, N21, etc. represent pairs of data values

Network parameter data points will be in magnitude-angle, dB-angle or real-imaginary format (i.e., pairs of values) as specified by the option line. For 1-port networks, only '11' data is allowed for Full, Upper or Lower format.

For Full 2-port networks, all four port data pairs are required. If [Matrix Format] is specified as Lower or Upper, 2-port network data includes only '11', '21' and '22' data, in that order (as '21' and '12' are assumed identical, Lower and Upper 2-port network data matrices are identical).

Note the order in which 2-port n-port parameters are entered: '21' data precedes '12' data in Full matrices.

All entries in a data line are separated by one or more whitespace characters; a data line itself is terminated by a newline character (CR or CR/LF). Multiple data lines are allowed but, as mentioned above, they must be arranged in increasing order of frequency.

Shown below are some examples of Touchstone® files for 1-port and 2-port networks. Lines beginning with a bang (!) symbol are comments.

Example 3 (version 1.0):

```
!1-port S-parameter file, single frequency point
# MHz S MA R 50
!freq magS11 angS11
2.000 0.894  -12.136
```

In the above example, the value of S11 at a frequency of 2 MHz is given in magnitude-angle format. The reference impedance is 50 ohms. [Matrix Format] is not specified.

Example 4 (version 1.0):

```
!1-port Z-parameter file, multiple frequency points
# MHz Z MA R 75
!freq  magZ11 angZ11
100    0.99   -4
200    0.80   -22
300    0.707  -45
400    0.40   -62
500    0.01   -89
```

Note that, in the above example, Z11 is normalized to 75 ohms, as given by the reference impedance (R 75) in the option line. [Matrix Format] is not specified.

Example 5 (version 2.0):

```
!1-port Z-parameter file, multiple frequency points
[Version] 2.0
# MHz Z MA
[Number of Ports] 1
!freq  magZ11 angZ11
100    74.25   -4
200    60      -22
300    53.025  -45
400    30      -62
500    0.75    -89
```

This example duplicates the data in Example 4, using version 2.0 syntax. Note that normalization has been removed. [Matrix Format] is not specified.

Example 6 (version 1.0):

```
!2-port H-parameter file, single frequency point
# kHz H MA R 1
! freq magH11 angH11 magH21 angH21 magH12 angH12 magH22 angH22
2 .95 -26 3.57 157 .04 76 .66 -14
```

In the above example, the H-parameters are given in magnitude-angle format, normalized to 1 ohm.

Example 6a (version 2.0):

```
!2-port H-parameter file, single frequency point
# kHz H MA R 1
[Matrix Format] Full
! freq magH11 angH11 magH21 angH21 magH12 angH12 magH22 angH22
2 .95 -26 3.57 157 .04 76 .66 -14
```

In the above example, the H-parameters are given in magnitude-angle format, normalized to 1 ohm.

Example 7 (version 1.0):

```
!2-port S-parameter file, three frequency points
# GHz S RI R 50.0
!freq  RelS11 ImS11    ReS21   ImS21   ReS12   ImS12  ReS22   ImS22
1.0000 0.3926 -0.1211 -0.0003 -0.0021 -0.0003 -0.0021 0.3926 -0.1211
2.0000 0.3517 -0.3054 -0.0096 -0.0298 -0.0096 -0.0298 0.3517 -0.3054
10.000 0.3419  0.3336 -0.0134  0.0379 -0.0134  0.0379 0.3419  0.3336
```

In the above example, the S-parameter data is given in real-imaginary format, with a 50 ohm reference impedance.

3-port and 4-port Networks

Rules for Version 1.0 Files:
The network parameter data for a 3-port or 4-port network is arranged in a matrix row-wise order, with each line of data representing one row of the matrix. In other words (as shown below), the data for a 3-port network is entered as three lines of data, with each line containing three data pairs (i.e. a 3x3 matrix of network parameter values). Likewise, the data for a 4-port network is entered as four lines with four data pairs per line (a 4x4 matrix). As required by the general rules, each network parameter data group is preceded by the frequency value at which the data was taken.

3-port Full network description
<frequency value> <N11> <N12> <N13>
<N21> <N22> <N23>
<N31> <N32> <N33>

4-port Full network description
<frequency value> <N11> <N12> <N13> <N14>
<N21> <N22> <N23> <N24>
<N31> <N32> <N33> <N34>
<N41> <N42> <N43> <N44>

where

frequency value	frequency at which the network parameter data was taken or derived.
N11, *N12*, etc.	network parameter data, where N*ij* represent a pair of data values.

As usual, network parameter data is entered in magnitude-angle, dB-angle or real-imaginary format (i.e. pairs of values) as specified by the option line. All entries in a data line are separated by one or more whitespace characters; a data line itself is terminated by a newline character (CR or CR/LF)..

Shown below is an example of an S-parameter description of a 4-port network.

Example 8:

```
! 4-port S-parameter data, taken at three frequency points
# GHz S MA R 50
5.00000 0.60 161.24 0.40 -42.20 0.42 -66.58 0.53 -79.34 !row 1
        0.40 -42.20 0.60 161.20 0.53 -79.34 0.42 -66.58 !row 2
        0.42 -66.58 0.53 -79.34 0.60 161.24 0.40 -42.20 !row 3
        0.53 -79.34 0.42 -66.58 0.40 -42.20 0.60 161.24 !row 4

6.00000 0.57 150.37 0.40 -44.34 0.41 -81.24 0.57 -95.77 !row 1
        0.40 -44.34 0.57 150.37 0.57 -95.77 0.41 -81.24 !row 2
        0.41 -81.24 0.57 -95.77 0.57 150.37 0.40 -44.34 !row 3
        0.57 -95.77 0.41 -81.24 0.40 -44.34 0.57 150.37 !row 4

7.00000 0.50 136.69 0.45 -46.41 0.37 -99.09 0.62 -114.19 !row 1
0.45  -46.41 0.50  136.69 0.62 -114.19 0.37 -99.09 !row 2
0.37  -99.09 0.62 -114.19 0.50  136.69 0.45 -46.41 !row 3
0.62 -114.19 0.37  -99.09 0.45  -46.41 0.50 136.69 !row 4
```

Note that the data pairs do not have to be aligned in columns; the only requirement is that there be 3 (3-port networks) or 4 (4-port networks) pairs of n-port parameters per data line.

Rules for Version 2.0 Files:
As noted earlier and as required by the general rules, each group of network parameter data is preceded by the frequency value at which the data was taken. The rest of the data for that frequency may follow on the same line or be split across multiple lines with intervening line-termination characters. Each frequency point must begin after a line-termination character on the first column of the line.

For files using a [Matrix Format] of Lower or Upper, data is still represented in a row-wise format. "Row" here refers to the arrangement of ports into rows and columns, not in terms of actual lines of data in the Touchstone file text (e.g., Sij refers to the S-parameters from port j to port i; the port is therefore considered to be located on row i in column j). In a Full Matrix, data for all elements in a matrix row must be shown before data for the next row can be shown.

Matrices using the Upper format will include explicit data for row 1 ports (i.e., S11, S12…S1n) before any data for row 2 is shown (i.e., S22, S23…S2n). In the Upper format, each successive row will contain one fewer element than the previous row. The element removed is the column number (current row – 1). For example, the first element of the second row of data is S22. S21 is not shown, as it is assumed to be identical to S12 from symmetry. The final element in an Upper matrix will be Snn, where n is the total number of ports, representing the only data for that row.

In the Lower format, each successive row will contain one more element than the previous row. The first row consists of only one element, S11. The final row will contain elements for each column from 1 to n, where n is the total number of ports.

Therefore, for a three-port matrix, data would be ordered as shown below.

[Matrix Format] Lower <*frequency value*> <*N11*> <*N21*> <*N22*> <*N31*> <*N32*> <*N33*>

[Matrix Format] Upper <*frequency value*> <*N11*> <*N12*> <*N13*> <*N22*> <*N23*> <*N33*>

where

frequency value	frequency at which the network parameter data was taken or derived.
N11, *N12*, etc.	network parameter data, where N*ij* represent a pair of data values.

5-port and Above Networks

The n-port parameters for 5-port and above networks are also arranged in a matrix row-wise order.

Rules for Version 1.0 Files:
Version 1.0 files are limited to a maximum of 4 network parameter data pairs per line, additional entries beyond the first four pairs in the matrix row must be continued on the following line(s). Each row of the matrix must start on a new line.

Rules for Version 2.0 Files:
Version 2.0 files may continue data on the same line, or across multiple lines. As usual, each group of network data pairs is preceded by the frequency value at which this data was taken.

For files using a [Matrix Format] of Lower or Upper, data is still represented in a row-wise format, as shown for 3- and 4-port networks above.

These rules are illustrated by showing the format for a 6-port network:

6-port Full network format (single frequency point)

```
<frequency value>  <N11> <N12> <N13> <N14>          !row 1
<N15> <N16>
<N21> <N22> <N23> <N24>                             !row 2
<N25> <N26>
<N31> <N32> <N33> <N34>                             !row 3
<N35> <N36>
<N41> <N42> <N43> <N44>                             !row 4
<N45> <N46>
<N51> <N52> <N53> <N54>                             !row 5
<N55> <N56>
<N61> <N62> <N63> <N64>                             !row 6
<N65> <N66>
```

6-port Lower network format (single frequency point)

```
<frequency value>  <N11>                            !row 1
<N21> <N22>                                         !row 2
<N31> <N32> <N33>                                   !row 3
<N41> <N42> <N43> <N44>                             !row 4
<N51> <N52> <N53> <N54><N55>                        !row 5
<N61> <N62> <N63> <N64>                             !row 6
<N65> <N66>
```

6-port Upper network format (single frequency point)

```
<frequency value>  <N11> <N12> <N13> <N14>          !row 1
<N15> <N16>
<N22> <N23> <N24>                                   !row 2
<N25> <N26>
<N33> <N34>                                         !row 3
<N35> <N36>
<N44><N45> <N46>                                    !row 4
```

<N55> <N56> !row 5
<N66> !row 6

where
frequency value frequency at which the network parameter data was taken or derived.

N11, *N12*, etc. network parameter data, where N*ij* represent a pair of data values.

As shown, each row of matrix data extends over two lines of the file, and each new row of the matrix starts on a new line. As usual, n-port parameters values are entered in pairs according to the format specified in the option line and each entry is separated by whitespace.

Following is a more detailed example illustrating the Full data matrix for a 10-port network. The Y-parameter data is in magnitude-angle format, and is for a single frequency.

Example 9:

```
# frequency_unit Y MA R impedance
freq magY11 angY11 magY12 angY12 magY13 angY13 magY14 angY14 ! 1st row
magY15 angY15 magY16 angY16 magY17 angY17 magY18 angY18
magY19 angY19 magY1,10 angY1,10
magY21 angY21 magY22 angY22 magY23 angY23 magY24 angY24      ! 2nd row
magY25 angY25 magY26 angY26 magY27 angY27 magY28 angY28
magY29 angY29 magY2,10 angY2,10
magY31 angY31 magY32 angY32 magY33 angY33 magY34 angY34      ! 3rd row
magY35 angY35 magY36 angY36 magY37 angY37 magY38 angY38
magY39 angY39 magY3,10 angY3,10
magY41 angY41 magY42 angY42 magY43 angY43 magY44 angY44     ! 4th row
magY45 angY45 magY46 angY46 magY47 angY47 magY48 angY48
magY49 angY49 magY4,10 angY4,10
magY51 angY51 magY52 angY52 magY53 angY53 magY54 angY54     ! 5th row
magY55 angY55 magY56 angY56 magY57 angY57 magY58 angY58
magY59 angY59 magY5,10 angY5,10
magY61 angY61 magY62 angY62 magY63 angY63 magY64 angY64     ! 6th row
magY65 angY65 magY66 angY66 magY67 angY67 magY68 angY68
magY69 angY69 magY6,10 angY6,10
magY71 angY71 magY72 angY72 magY73 angY73 magY74 angY74     ! 7th row
magY75 angY75 magY76 angY76 magY77 angY77 magY78 angY78
magY79 angY79 magY7,10 angY7,10
magY81 angY81 magY82 angY82 magY83 angY83 magY84 angY84     ! 8th row
magY85 angY85 magY86 angY86 magY87 angY87 magY88 angY88
magY89 angY89 magY8,10 angY8,10
magY91 angY91 magY92 angY92 magY93 angY93 magY94 angY94     ! 9th row
magY95 angY95 magY96 angY96 magY97 angY97 magY98 angY98
magY99 angY99 magY9,10 angY9,10
!10th row
magY10,1 angY10,1 magY10,2 angY10,2 magY10,3 angY10,3 magY10,4 angY10,4
magY10,5 angY10,5 magY10,6 angY10,6 magY10,7 angY10,7 magY10,8 angY10,8
magY10,9 angY10,9 magY10,10 angY10,10
```