

Offline Split 2x-Thru Touchstone File to Two 1x-Thru Using Equation Editor in ShockLine™ Vector Network Analyzer

Introduction

In the signal integrity world, one of the most useful features is network extraction. Many channels used in signal integrity applications have fixtures or connectors required for measurement that will affect the measured S-parameters. Typical fixtures include Baluns, connectors, and/or PCB traces. Having a way to remove these features and structures from the measurement is often very useful. Network extraction is the process of determining the S-parameters for the features that we want to de-embed from (or embed into) the measurement and results in a touchstone file that can be saved and later applied during embedding or de-embedding. ShockLine™ vector network analyzers provide full features on different scenarios to extract fixtures based on incomplete known standards. All of this can be done while online, but, what do we do in an offline situation?

For complete network extraction and embedding or de-embedding features please refer to: VectorStar™ MS464xB Series Calibration and Measurement Guide, 10410-00318 and De-embedding and Network Extraction Application Note, 11410-01032.

One of the easiest network extractions is Type-D Multi-Standards feature. This is a standard feature in ShockLine vector network analyzer to split 2x-thru to 1x-thru while online. Currently in ShockLine vector network analyzer, there is no feature to import a 2x-thru touchstone file and perform network extract to split it to two (2) 1x-thru files while offline.

In network extraction features, there is Type-D for Multi-Standards network extraction feature which is a standard feature in ShockLine, but it only permits a live (online) 2x-thru trace connecting between two ports of vector network analyzer and performs network extraction, the result of 1x-thru can be saved as a touchstone file and later it can be used for de-embedding or embedding the fixtures.

This application note provides a step-by-step process to perform network extraction of a 2x-thru touchstone file using equation editor to split 2x-thru to 1x-thru offline.

Background

The network extraction feature is a tool used to extract fixtures with incomplete calibration standards. After extracting the fixtures, the user can import it to a third party simulation software such as MATLABs, ADS, and other similar simulation software's to either proceed with de-embedding or embedding the fixtures to analyze the effects of the characteristics of the DUTs.

One of the easiest, and the most used, network extractions is to split 2x-thru to 1x-thru, with no calibration standards required. This is available as a standard feature, Type-D Multi-Standards, in ShockLine vector network analyzers but it needs to operate in live/online mode.

This application note shows how to extract 2x-thru to 1x-thru using equation editor feature in offline mode since 2x-thru is the most popular network extraction method for splitting to two (2) 1x-thru.

The step-by-step process below shows how to perform a network extraction using the equation editor and the result as it is compared to the Type-D Multi-Standards network extraction.

- 1) Save a PCB trace as a 2x-thru .s2p file
- 2) Follow the procedure to complete a network extraction of a PCB trace using the Type-D Multi-Standards feature, the result of the network extraction file -1xthru.txt will be saved
- 3) The saved 2x-thru.s2p file is recalled and will use the equation editor to perform similar algorithm as Multi-Standards
- 4) The result is compared with the Type-D Multi-Standard method

Solution

- 1) Providing an offline method to do the network extraction for 2x-thru by using Equation Editor
- 2) Extracting 2x-thru offline to 1x-thru
- 3) No 2x-thru fixture is needed – only a touchstone file
- 4) Importing 1x-thru to the third party simulation software to simulate the effect of de-embedding or embedding of the fixtures

Theory

The algorithm is based on the principle of square root of a complex number.

A complex number 'z' can be written in polar coordinates as:

$$z = re^{i\varphi}, r \geq 0, -\pi < \varphi \leq +\pi.$$

The principal square root of complex number 'z' as:

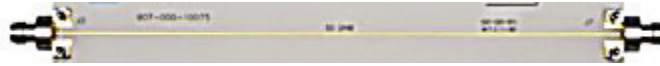
$$\sqrt{z} = \sqrt{r}e^{i\varphi/2}, -\pi/2 < \varphi/2 \leq +\pi/2.$$

From the principal square root of complex number 'z', the phase is truncated and limited to ± 90 degree, the truncation of the phase is due to the naïve of the square root of a complex number, although mathematically it is correct, in vector network analyzer world, it needs to be ± 180 degree. Hence, a rewrap of the phase is required to get the correct set of root choices.

Measurement Example

Any ShockLine vector network analyzer model can perform this 2x-thru network extraction using equation editor. This example shows how to generate 2x-thru using Giga Probe demo board and network extraction Type-D Multi-Standards feature to extract 1x-thru touchstone file from 2x-thru measurement. The following equipment and accessories are needed to perform this example:

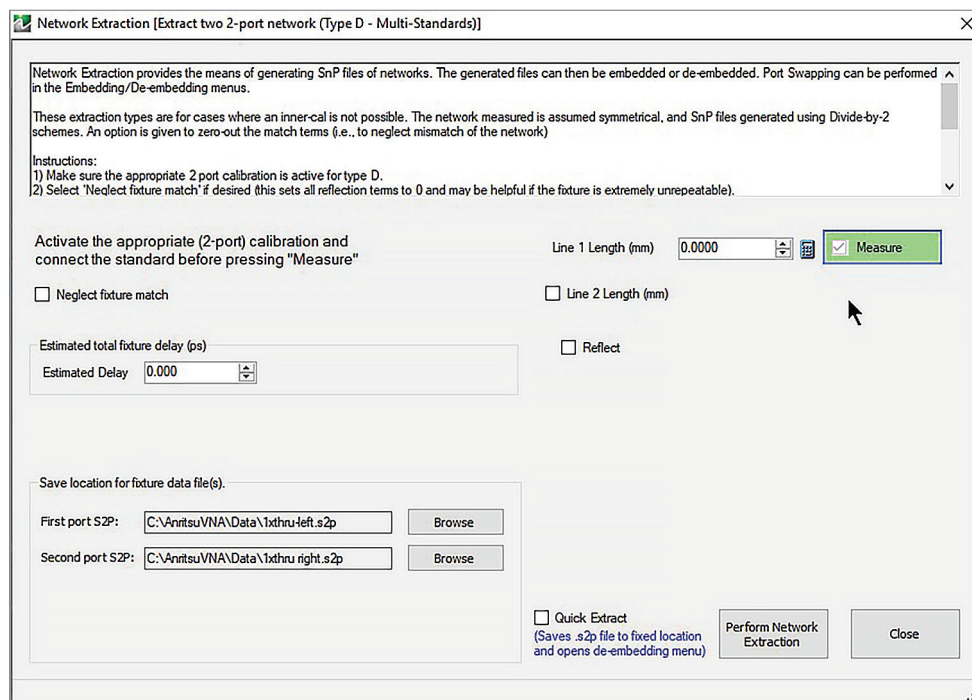
- 1) 2-Port Compact ShockLine Vector Network Analyzer MS46122B-043
- 2) A demo board for measure the trace as 2x-thru



- 3) TOSLKF50A calibration kit
- 4) Two (2) RF cables

Procedure to generate 1x-thru using Type-D Multi-Standard feature:

- 1) Setup the harmonic frequency plan: Start frequency: 20 MHz, Stop frequency: 20 GHz, number of points 1000
- 2) Perform full 2-port calibration
- 3) Save as full 2p.chx file
- 4) Connect VNA port 1 and port 2 to the Giga Probe trace enclosed by the red rectangular
- 5) Save the measurement as 2x-thru touchstone file
- 6) Go to De-Embedding Tools under the Calibration menu and select 2-Port Network Extraction and choose Type-D Multi-Standards, fill out the first and second port .s2p names and leave Line 1 Length (mm) as "0.0000". The algorithm will automatically detect the trace length, then click on the Measure button. After the measurement has been completed, click on Perform Network Extraction. See below for a screen shot of what the Type-D Multi-Standard screen should look like populated.

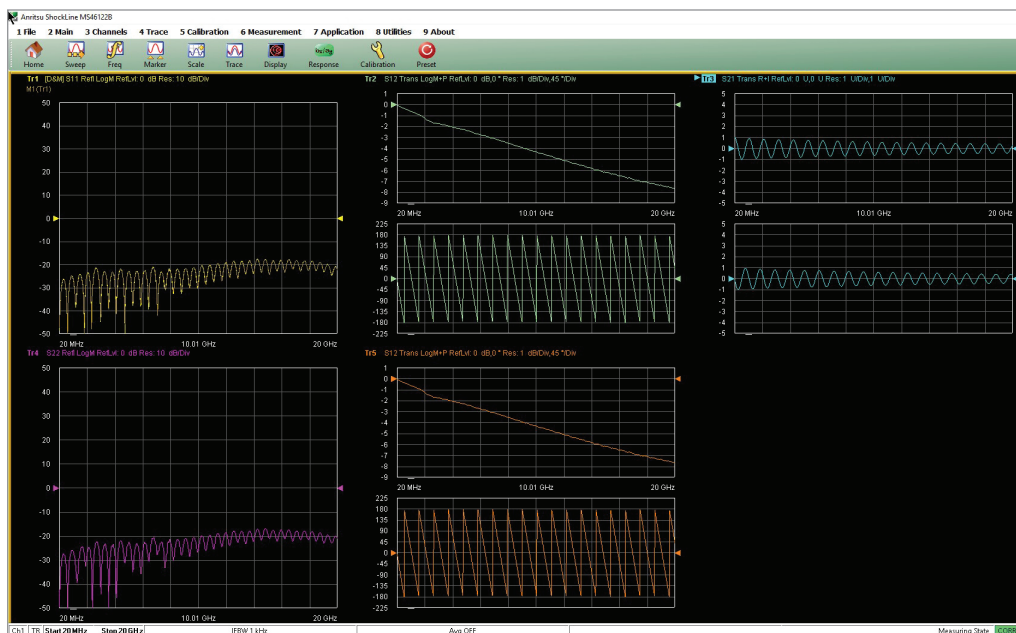


After clicking Perform Network Extraction, both First Port S2P and Second Port S2P will be saved

The following procedure is to perform Type-D Multi-Standards using equation editor:

- 1) Launching ShockLine Vector Network Analyzer MS46122B-043 application software
- 2) Recall full 2p.chx setup file
- 3) Put sweep on "HOLD"
- 4) Recall 2x-thru.s2p file
- 5) Arrange the trace layouts as:
 - a. Tr1 S11 LogMag format
 - b. Tr2 (LogMag and Phase) or doesn't matter but put the equation editor on here
 - c. Tr3 (Real and Imaginary) or doesn't matter but put the equation editor on here
 - d. Tr4 S22 LogMag format
 - e. Tr5 S21 (LogMag and Phase) and use this as the input trace for the equation editor

The layout is shown below.



- 6) Go to Inter-trace Math-> Equation Editor
- 7) Enter this equation for both Tr2 and Tr3 using Tr5 as input in the equation as depicted here:

$$\sqrt{z} = \sqrt{r}e^{i\varphi/2}$$

Equation Editor for Ch1.Tr3

$\text{SQRT}(\text{ABS}(\text{cTr5})) * \text{EXP}(j * \text{ANGLE}(\text{REWRAP}(\text{SQRT}(\text{cTr5}))))$

Extend Entry

Clear Equation Show History Clear History < > Delete On-Screen Keyboard

Arithmetic

7 8 9
4 5 6
1 2 3
. 0 .
+ - *
() /
j PI E
FREQ NUM_POINTS

Channel Selection

Ch1 Ch2 Ch3 Ch4 Ch5 Ch6 Ch7 Ch8
Ch9 Ch10 Ch11 Ch12 Ch13 Ch14 Ch15 Ch16

Only those channels are available which have same # of points as Active channel Active (Ch1)

Trace Selection

☒ Trace ☐ S-Parameter ☐ SnP File

Tr1 Tr2 Tr3 Tr4
Tr5 Tr6 Tr7 Tr8
Tr9 Tr10 Tr11 Tr12
Tr13 Tr14 Tr15 Tr16

Format

☐ Formatted (cal applied but uses current graph type format)
☒ Corrected (complex number with cal applied)
☐ Raw (complex number)

☐ Use All Traces as Time Domain data

Data Source

☒ Data
☐ Memory

Function Selection

ABS
ACOS
ANGLE
ASIN
ATAN
ATAN2
CONJ
COS
CPX
EXP
IM
KFACTOR
LN
LOG10
MAG

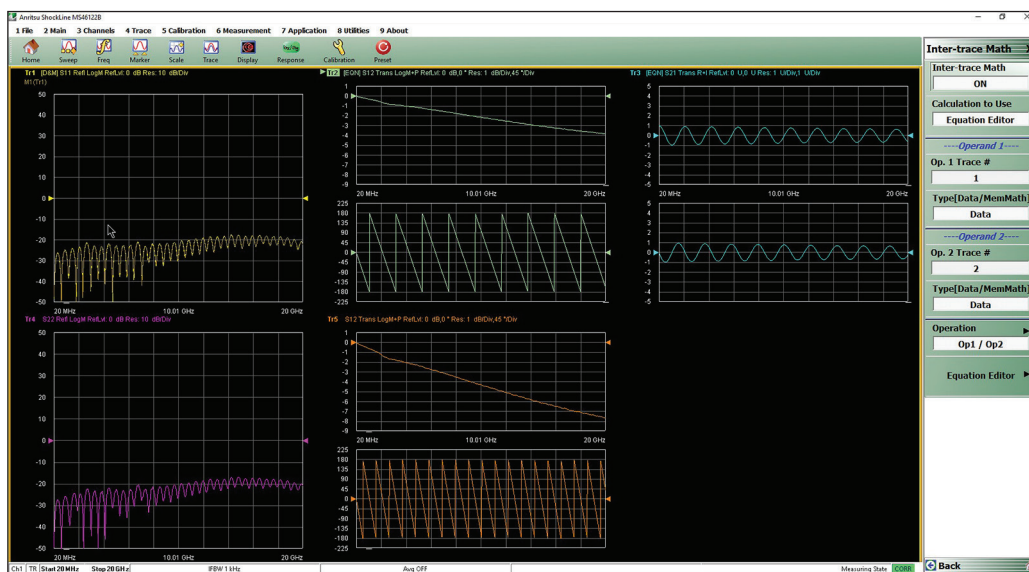
Function Info:

ABS(input)
Returns complex magnitude for complex input and absolute value for real input. Output is real.

SnP 1 File Select file Browse
SnP 2 File Select file Browse
SnP 3 File Select file Browse
SnP 4 File Select file Browse
SnP 5 File Select file Browse
SnP 6 File Select file Browse
SnP 7 File Select file Browse
SnP 8 File Select file Browse

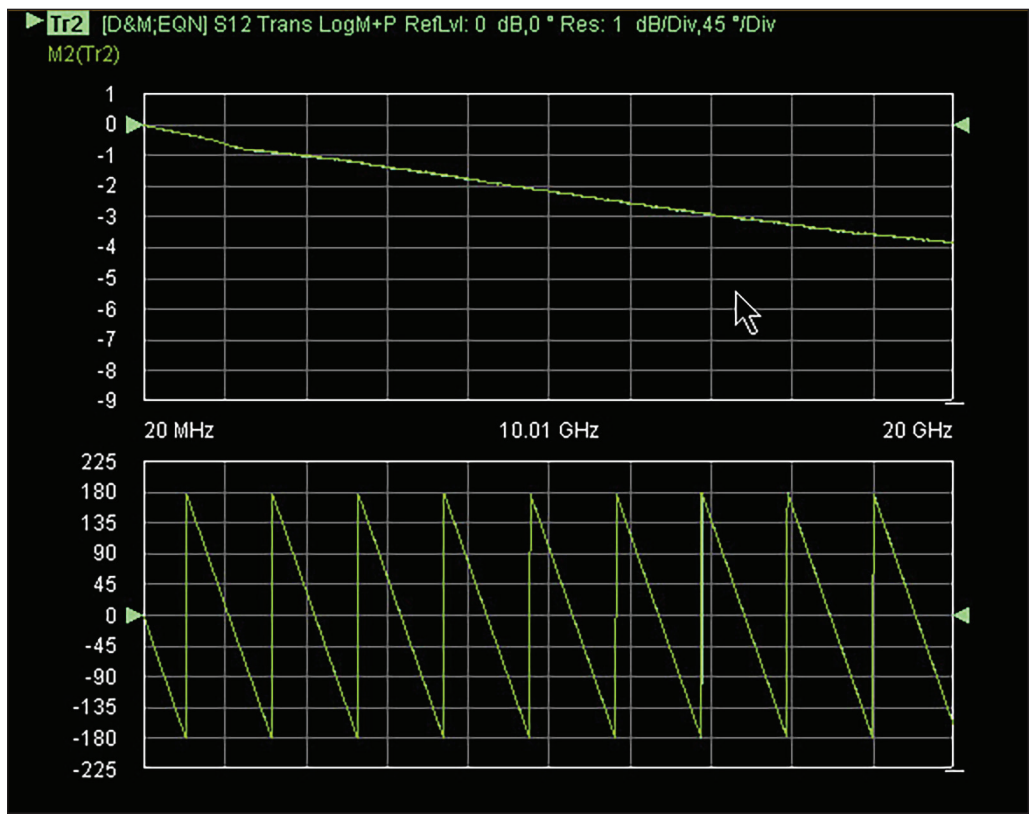
Apply Cancel Save Recall

8) Turn Inter-trace Math "ON" for both Tr2 & Tr3 as depicted below:



The result of Tr2 LogMag&Phase graphtype and Tr3 Real&Imaginary graphtype are 1x-thru as compared with Tr5 LogMag&Phase graphtype which is 2x-thru.

9) Here is the comparison of using Type-D Multi-Standards and equation editor:



These two traces can be seen as over laid over each other

Conclusion

Completed functionality to perform 2x-thru can be done with the ShockLine vector network analyzer along with the equation editor. Online this can be done through standard Type-D Multi-Standard features and offline, this can be done resulting in a 2x-thru touchstone file.

Caution is needed when performing certain network extractions using the equation editor. For this simple 2x-thru algorithm, if the step size is big relatively to $1 / (\text{length of fixture})$, this can get into aliasing trouble.

In addition, some modifications are needed to convert 1x-thru.txt to 1x-thru.s2p. This is due to after equation editor operation the touchstone file cannot be saved. But, with this equation added and Type-D Multi-Standards feature as a standard feature, a ShockLine vector network analyzer can perform either online or offline network extraction of 2x-thru without extra cost.

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