Application Note

Utilizing Line-Reflect-Line (LRL) Calibration Method to Measure a Surface-Mount Bandpass Filter on a Fixture

Introduction

Microwave devices are typically packaged as a surface-mounted device (SMD) that are either soldered or socket-mounted to a PCB fixture. However, as the frequency of the device increases, the effect on the fixture can no longer be ignored. For this application note, a Line-Reflect-Line (LRL) calibration method is introduced to demonstrate how to achieve an accurate measurement of the SMD when it is soldered onto a PCB fixture. The advantage of LRL calibration is that the calibration kit has the same material or dielectric constant and similar trace characterization as the fixture, which enables customers to readily fabricate the LRL calibration kit from the same lot as the fixture. In addition, the length of the shortest line in the LRL kit can be arbitrary and unknown as long as it is the same length as the fixture, therefore the reference plane can be moved to where the DUT is placed in the fixture.

LRL Calibration Method

LRL uses two or more transmission lines and a reflect standard, either an open-like or a short-like. In the LRL calibration technique, the optimum electrical length of the line is 90º or an odd-multiple of a quarter-wavelength. Avoid the electrical lengths near 00 or even-multiples of 90º, which would result in ill-conditioned, closed-form equations. For example, the algorithm will not work at DC or a frequency where the difference in length is N x (λ/2) (where N is an integer number and λ is the wavelength).

The equipment used for this application note were:

- Anritsu's ShockLine™ MS46122B-040 or MS46524B-040 vector network analyzers
- A signal microwave LRL calibration kit (Figure 1)
- A fixture for the surface mounted device 3225 (3.2 mm x 2.5 mm) (Figure 2)
- The device-under-test soldered on the fixture is a Mini-Circuit B FCV-52 70+ bandpass filter (Figure 2)

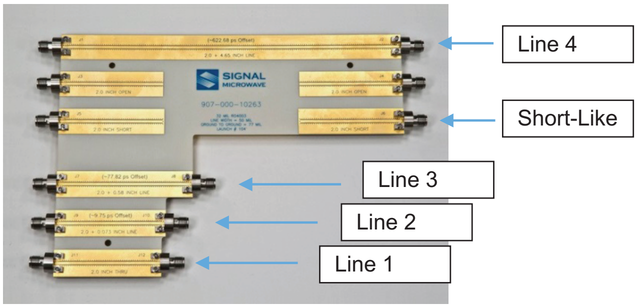

Figure 1. LRL Calibration Kit

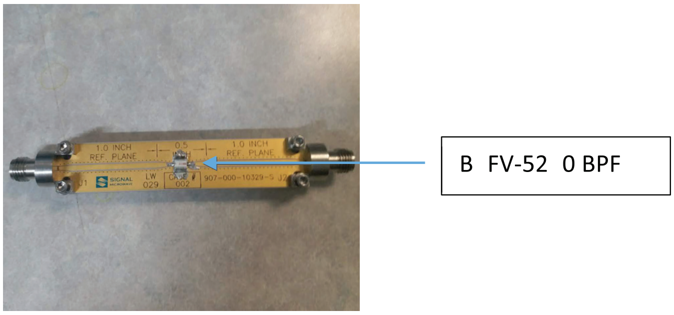

Figure 2: Fixture with B FCV-52 70+ Bandpass Filter

LRL Calibration Procedure

1. **First define the frequency range to calculate the number of bands required.**
   Because of the phase restrictions, each line is fundamentally band-limited to something around an 8:1 ratio (some users may restrict it further for measurements requiring very low uncertainties when the line losses are low). For most cases, a phase difference between 2^0 and 16^0 is recommended which yields an 8:1 ratio. For this example, the calibration needs to be valid from around 245 MHz to 40 GHz, so we need to decide how many bands or lines are required. To calculate number of bands, one needs to find out the ratio of highest to lowest frequency. In this example, it is 163. Using the 8:1 ratio, 8^3=512 is the next number that covers 163, this means that we need 3 bands (4 lines) in order to cover the frequency range.

2. **Next, measure the delay on each line.**
   Perform a 1-port full calibration on the ShockLine VNA and measure τ, the delay in ps, for each line (shown in Figure 1). In this case: Line 1 is 355ps; Line 2 is 365ps; Line 3 is 438ps; Line 4 is 999ps; short-line is 316ps. Note: τ=electrical length × speed of light. Once the delay is measured, to calculate the effective or electrical length simply divide the delay by the speed of light.

3. **$20<360\times f\times \Delta L\div vph<160$** *equation [1]*
   ƒ is the frequency of interest in Hz, Δ*L* is the offset in length in meters, and *vph* is the velocity of the line and equals 2.9978 10^8 m/s for air dielectric. By entering each length in ps, one can calculate the rest parameters as in the table below based on equation [1]. From this table, this LRL calibration can cover from 86 MHz to 44.4 GHz.

Enter Length in ps				
Dielectric Constant	1.000000	Effective Length mm	Lower Limit	Upper Limit
Line 1 (ps)	355.000000	**106.426323**		
Line 2 (ps)	999.000000	**299.492666**	**0.086266**	**0.690131**
Line 3 (ps)	438.000000	**131.309097**	**0.669344**	**5.354752**
Line 4 (ps)	365.000000	**109.424247**	**5.555556**	**44.444444**
Short-Like (ps)	316.000000	**94.734417**		

4. Enter the values in the ShockLine LRL table as shown in Figure 3. Specifically, select **Middle of Line 1**. This will move the reference plane to where the DUT is placed.

5. To convert time to distance, use effective length = speed of light x delay for the short-like length.

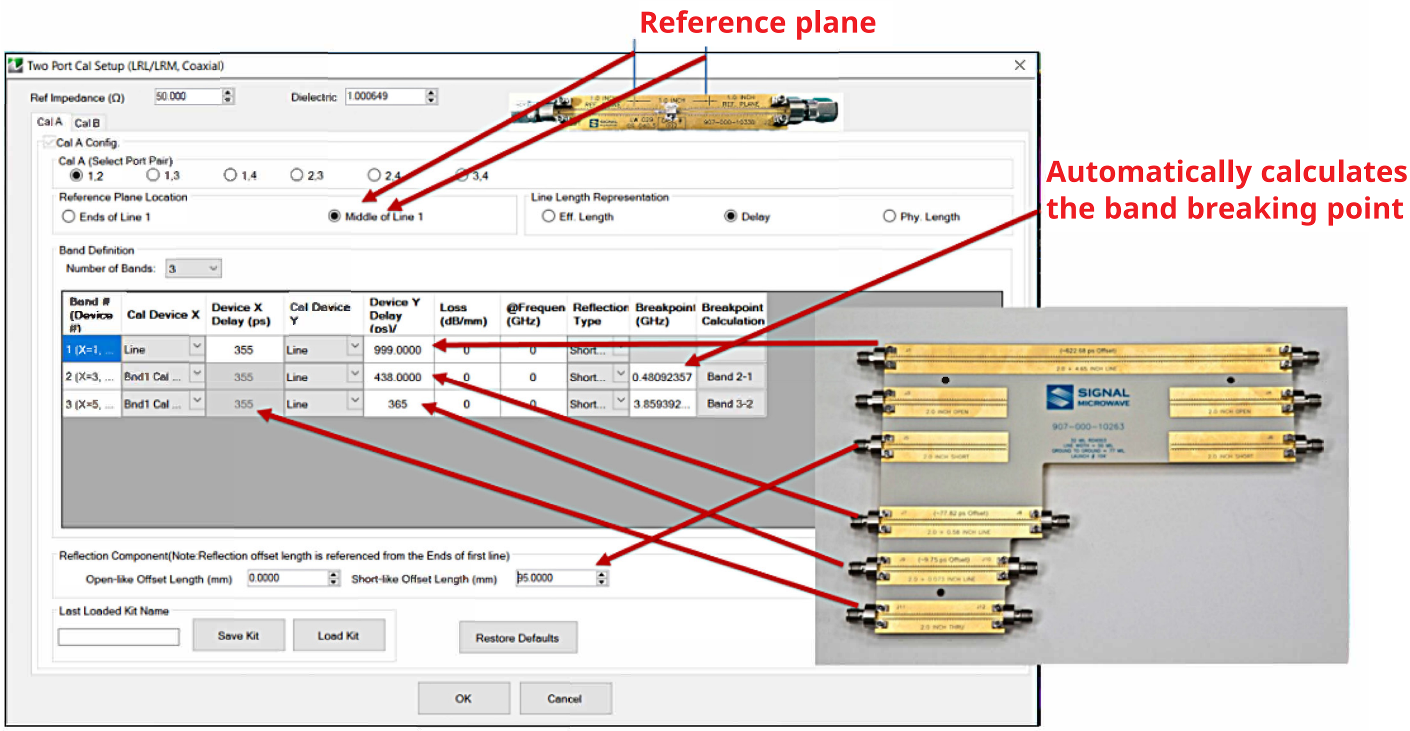

Figure 3. LRL Menu Setup

SOLT and LRL comparison is also measured. LRL appears more accurate than the SOLT measurement because the LRL can de-embed the fixture closer to where the SMD is soldered, ulike the SOLT calibration where the reference plane is at the end of the RF cable and does not de-embed the fixture. The blue curve is where the reference plane is, where the connector center pin touches the fixture. This is done by selecting **Ends of Line 1** in the LRL setup menu.

Summary

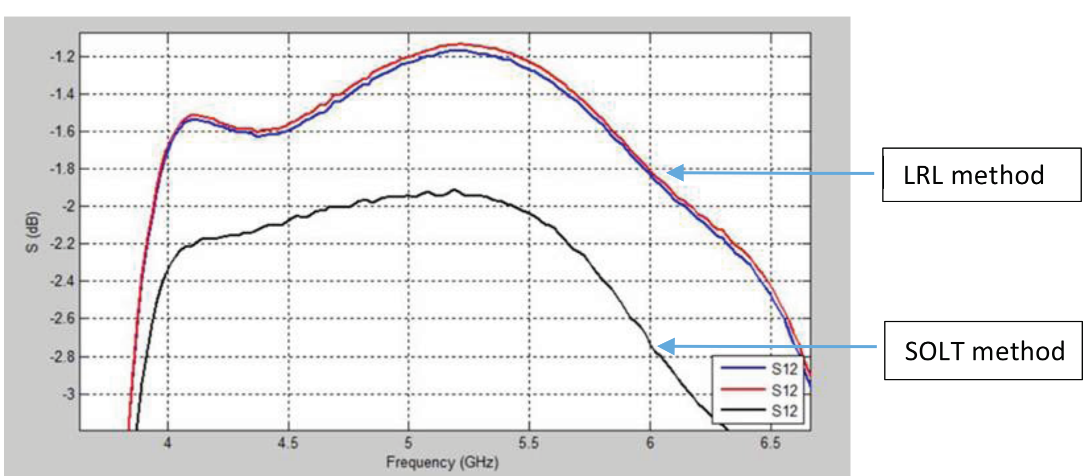

Figure 4. S12 Measurement Comparison Between SOLT and LRL Methods. The Reference Plane for the Blue Line is End of Line 1; the Red Line Reference Plane is Middle of Line 1.

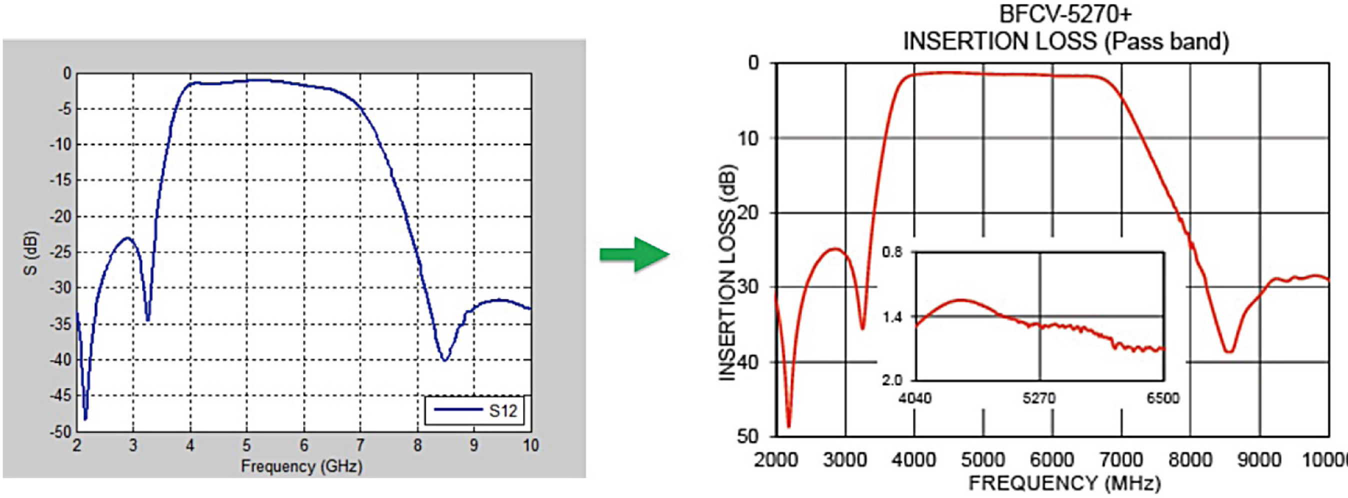

Figure 5. Comparison Between LRL Method and S2P File From BFCV-7270

LRL calibration can de-embed the fixture closer to the thru SMD measurement. In addition, the LRL calibration kit is easier to fabricate and can match the fixture material more closely than other types of calibration kits. This calibration becomes particularly useful in a mass production environment where the fixture is part of an automated test equipment (ATE) setup.

References:

[1] ShockLine MS46522B and MS46524B Calibration and Measurement Guide, available online at anritsu.com

envision : ensure

Specifications are subject to change without notice.

• United States
Anritsu Company
450 Century Parkway, Suite 190, Allen,
TX 75013 U.S.A.
Phone: +1-800-Anritsu (1-800-267-4878)

• Canada
Anritsu Electronics Ltd.
700 Silver Seven Road, Suite 120,
Kanata, Ontario K2V 1C3, Canada
Phone: +1-613-591-2003
Fax: +1-613-591-1006

• Brazil
Anritsu Electrônica Ltda.
Praça Amadeu Amaral, 27 - 1 Andar
01327-010 - Bela Vista - Sao Paulo - SP - Brazil
Phone: +55-11-3283-2511
Fax: +55-11-3288-6940

• Mexico
Anritsu Company, S.A. de C.V.
Blvd Miguel de Cervantes Saavedra #169 Piso 1, Col. Granada
Mexico, Ciudad de Mexico, 11520, MEXICO
Phone: +52-55-4169-7104

• United Kingdom
Anritsu EMEA Ltd.
200 Capability Green, Luton, Bedfordshire LU1 3LU, U.K.
Phone: +44-1582-433200
Fax: +44-1582-731303

• France
Anritsu S.A.
12 avenue du Québec, Batiment Iris 1-Silic 612,
91140 VILLEBON-SUR-YETTE, France
Phone: +33-1-60-92-15-50
Fax: +33-1-64-46-10-65

• Germany
Anritsu GmbH
Nemetschek Haus, Konrad-Zuse-Platz 1
81829 München, Germany
Phone: +49-89-442308-0
Fax: +49-89-442308-55

• Italy
Anritsu S.r.l.
Via Elio Vittorini 129, 00144 Roma Italy
Phone: +39-06-509-9711
Fax: +39-6-502-2425

• Sweden
Anritsu AB
Isafjordsgatan 32C, 164 40 KISTA, Sweden
Phone: +46-8-534-707-00

• Finland
Anritsu AB
Teknobulevardi 3-5, FI-01530 VANTAA, Finland
Phone: +358-20-741-8100
Fax: +358-20-741-8111

• Denmark
Anritsu A/S
Torveporten 2, 2500 Valby, Denmark
Phone: +45-7211-2200
Fax: +45-7211-2210

• Russia
Anritsu EMEA Ltd.
Representation Office in Russia
Tverskaya str. 16/2, bld. 1, 7th floor.
Moscow, 125009, Russia
Phone: +7-495-363-1694
Fax: +7-495-935-8962

• Spain
Anritsu EMEA Ltd.
Representation Office in Spain
Edificio Cuzco IV, Po. de la Castellana, 141, Pta. 5
28046, Madrid, Spain
Phone: +34-915-726-761
Fax: +34-915-726-621

• United Arab Emirates
Anritsu EMEA Ltd.
Dubai Liaison Office
902, Aurora Tower,
P O Box: 500311- Dubai Internet City
Dubai, United Arab Emirates
Phone: +971-4-3758479
Fax: +971-4-4249036

• India
Anritsu India Pvt Ltd.
6th Floor, Indiqube ETA, No.38/4, Adjacent to EMC2,
Doddanekundi, Outer Ring Road, Bengaluru – 560048, India
Phone: +91-80-6728-1300
Fax: +91-80-6728-1301

• Singapore
Anritsu Pte. Ltd.
11 Chang Charn Road, #04-01, Shriro House
Singapore 159640
Phone: +65-6282-2400
Fax: +65-6282-2533

• P. R. China (Shanghai)
Anritsu (China) Co., Ltd.
Room 2701-2705, Tower A,
New Caohejing International Business Center
No. 391 Gui Ping Road Shanghai, 200233, P.R. China
Phone: +86-21-6237-0898
Fax: +86-21-6237-0899

• P. R. China (Hong Kong)
Anritsu Company Ltd.
Unit 1006-7, 10/F., Greenfield Tower, Concordia Plaza,
No. 1 Science Museum Road, Tsim Sha Tsui East,
Kowloon, Hong Kong, P. R. China
Phone: +852-2301-4980
Fax: +852-2301-3545

• Japan
Anritsu Corporation
8-5, Tamura-cho, Atsugi-shi, Kanagawa, 243-0016 Japan
Phone: +81-46-296-6509
Fax: +81-46-225-8352

• Korea
Anritsu Corporation, Ltd.
5FL, 235 Pangyoyeok-ro, Bundang-gu, Seongnam-si,
Gyeonggi-do, 13494 Korea
Phone: +82-31-696-7750
Fax: +82-31-696-7751

• Australia
Anritsu Pty Ltd.
Unit 20, 21-35 Ricketts Road,
Mount Waverley, Victoria 3149, Australia
Phone: +61-3-9558-8177
Fax: +61-3-9558-8255

• Taiwan
Anritsu Company Inc.
7F, No. 316, Sec. 1, NeiHu Rd., Taipei 114, Taiwan
Phone: +886-2-8751-1816
Fax: +886-2-8751-1817

nqa ISO 9001 Registered

11410-01122, Rev. A Printed in United States 2020-04