

Electro-Optical Measurements Using Anritsu VNAs

Introduction

As the data rates of optical communication systems continue to increase, optical transmit and receive modules require characterization to wider bandwidths. Optical modulators (E/O devices), photo detectors and receivers (O/E devices), as well as optical components can be characterized accurately using vector network analyzers (VNAs). This paper describes the techniques and hardware required to characterize these components with economies of scale and flexibility not present in current lightwave component analyzer (LCA) designs.

Background and Use of VNAs

VNAs are traditionally used to conduct native measurements in the electrical realm of the frequency domain, and have been used for decades to characterize electrical devices and networks. VNAs measure transmission parameters in both magnitude and phase in the microwave and millimeter-wave (mmWave) frequency bands in the form of S-parameters. High-speed optical digital signals transmitted on networks have similar frequency content and bandwidth as high-speed electrical digital signals measured by microwave VNAs in the electrical realm. Therefore, VNAs can be an effective tool to characterize these optical components, as long as the signal can be converted between the electrical and optical mediums. Figure 1 shows the typical optical spectrum of a laser modulated at a 20 Gb/s data rate.

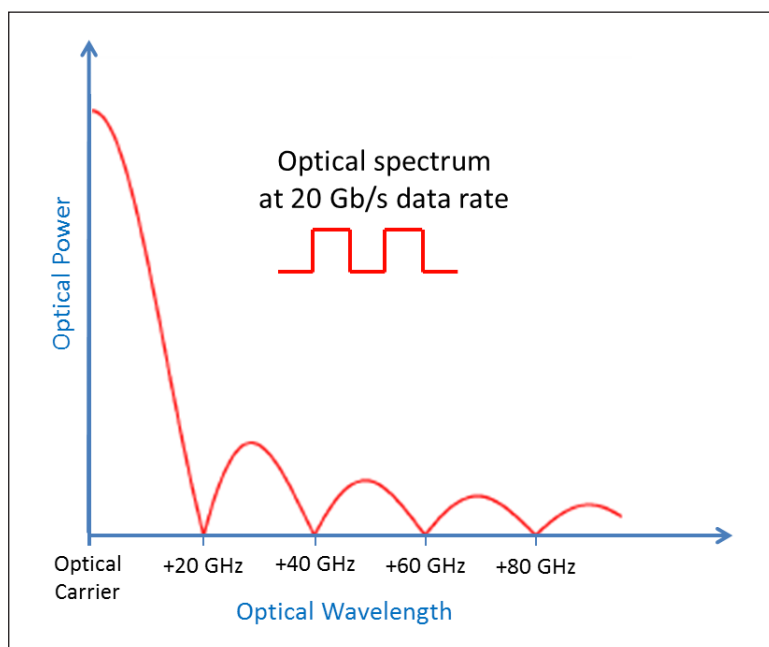


Figure 1. The optical spectrum of a laser modulated at a 20 Gb/s data rate.

Since VNAs make electrical measurements, it is necessary to convert these electrical signals to optical signals on the transmit side and convert them from the optical to electrical signals on the receiver side. To accomplish this, a laser with an RF modulator (E/O) is required on one side and a calibrated photodiode (O/E) on the other. It is necessary to implement a method to calibrate the system to establish reference planes for these measurements, since measurements of both magnitude and phase of the signals are required. This calibration will leverage the VNA's 12-term vector error correction algorithms to account for the physical imperfections of the RF components and increase the accuracy of the electrical measurements.

Finally, having the ability to de-embed components is very useful in moving the measurement planes from the electrical to the optical realm. Anritsu VNAs have these native capabilities on the instrument, so there is no need for additional software.

System Calibration

A standard 2-port electrical calibration is conducted on the VNA to establish the electrical calibration reference planes, as shown in Figure 2. A laser and optical modulator are used to convert the electrical stimulus from the VNA output to optical. This results in an optical stimulus at a wavelength determined by the laser that is modulated with an electrical sinusoidal CW signal. This signal is swept in frequency over a desired measurement bandwidth.

A photodiode is used to convert the optical signal back to an RF signal that can be measured by the VNA. The receiver at the VNA's RF input is tuned to the RF frequency with which the optical signal is modulated.

Because of its architecture, the Anritsu VNA can be tuned to a very narrow instantaneous bandwidth for a very high signal-to-noise (S/N) measurement. The VNA converts these individual measurements into a forward transmission characteristic. It samples the RF output signal and compares it with the measured RF input signal to determine an S_{21} for each measurement. S_{21} is the ratio of RF in/RF out, and has both magnitude and a phase terms.

In Figure 2, the device under test (DUT) can either be an optical modulator or a photodiode.

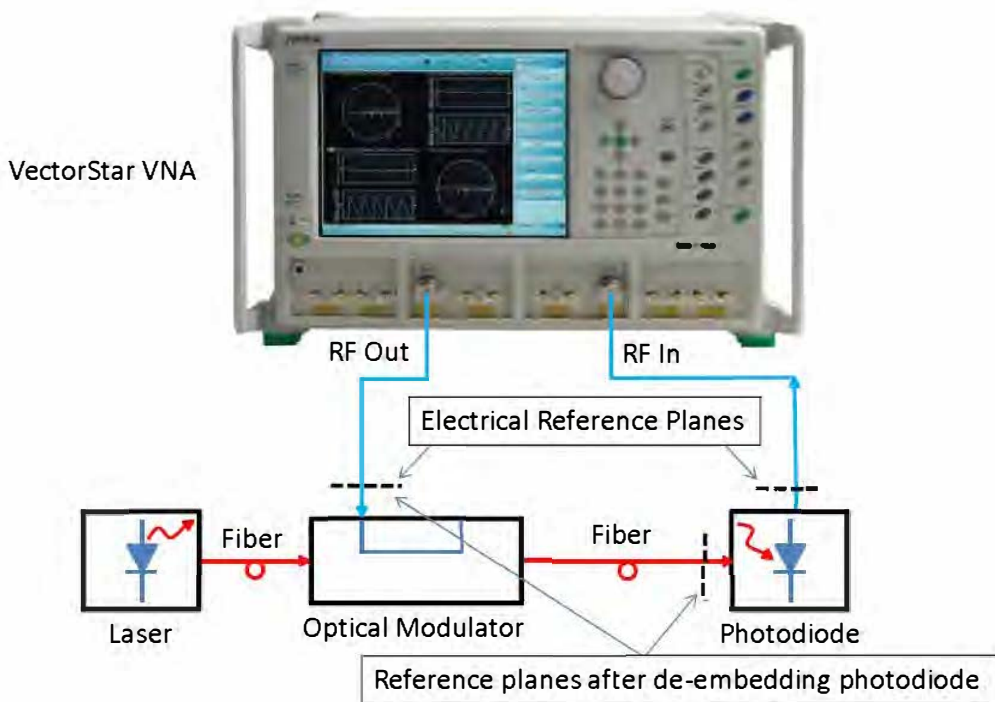


Figure 2. Basic E/O and O/E setup showing the calibrated RF reference planes and reference planes after de-embedding.

This relative transfer function does not take into account the variations in laser output power or optical loss in the fiber, as these don't generally influence the electrical transmission response.

E/O Measurements

A photodiode with a characterized O/E transfer function in magnitude and phase can be de-embedded from the combined measurement. It effectively moves the calibration planes to those shown in Figure 2. This will account for the photodiode response and allow measurements of optical transmitters and modulators with the photodiode effectively removed from the set-up. The resulting E/O measurement is an accurate characterization of these devices. Anritsu provides a characterization file with each O/E calibration module that allows the photodiode to be removed from the measurement. This file is obtained using a primary standard characterized by the National Institute of Standards (NIST), basically a reference photodiode.

When the photodiode is de-embedded from the measurement, its optical response and variation over the measurement bandwidth can be accounted for. Accurate measurement of an optical modulator's electrical-to-optical characteristics, such as bandwidth, amplitude flatness, phase linearity, and group delay, can be made. In addition, electrical return loss of the optical modulator's RF input can be measured.

O/E Measurements

If an O/E device, such as an unknown photodiode, needs to be measured, the same set-up shown in Figure 3 can be used. Because the characterized photodiode has been de-embedded, it can be used to characterize the magnitude and phase performance of the optical modulator to be subsequently used in the O/E measurement. This transfer function file can then be used to de-embed the performance of the now characterized optical modulator. At that point, the unknown photodiode can replace the characterized photodiode to measure its performance.

The uncertainty of this measurement will be slightly higher than the E/O measurement because of the second level of de-embedding involved in the measurement.

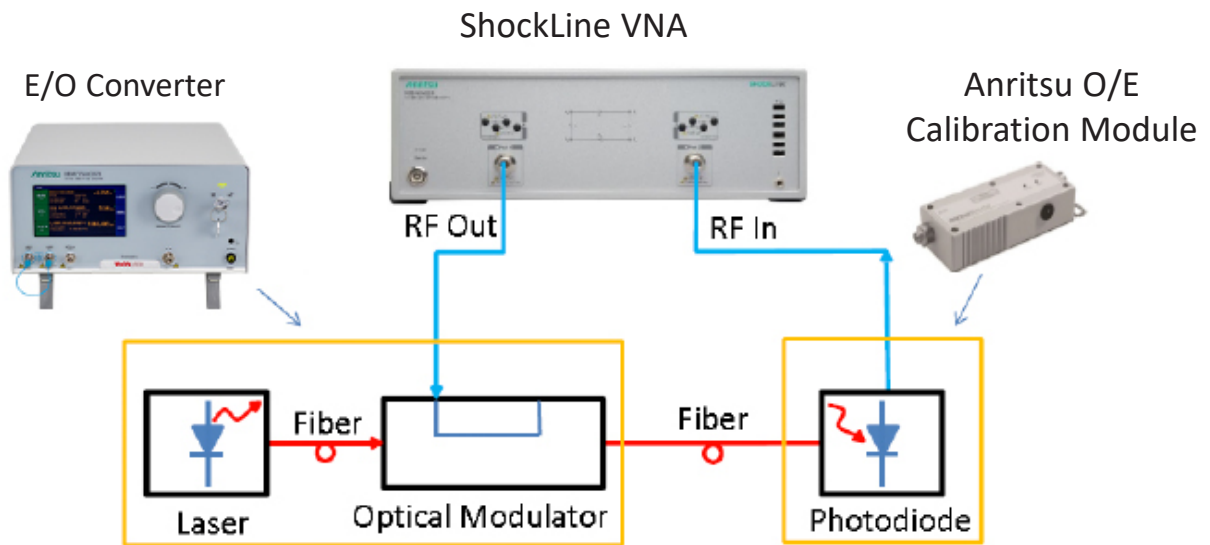


Figure 3. E/O and O/E solutions available from Anritsu.

Anritsu MN4765B O/E Calibration Modules

Anritsu manufactures several instrument-grade O/E calibration modules (Table 1) that can be used to perform O/E and E/O measurements with the VectorStar® and ShockLine™ VNAs. The MN4765B modules are available in different optical wavelengths with various RF bandwidths to support industry requirements.

These modules enable error-corrected Transfer Function, Group Delay, and Return Loss measurements of E/O and O/E components and subsystems when used with Anritsu VNAs.

Magnitude and phase characterization is obtained using a primary standard characterized by NIST and held in the Anritsu Calibration Lab. The magnitude and phase data is provided (in .s2p format) on a USB drive with the module for the purpose of de-embedding the O/E module from the combined measurement. These modules have internal thermal stabilization and precision voltage regulation to minimize drift in photodiode frequency response.

| Anritsu O/E Calibration Modules | | |
|---------------------------------|-----------------------|-----------------|
| Anritsu Model # | Optical Wavelength | Frequency Range |
| MN4765B-040 | 850 nm | 70 kHz-40 GHz |
| MN4765B-042 | 850/1060 nm | 70 kHz-40 GHz |
| MN4765B-043 | 850/1060/1310/1550 nm | 70 kHz-40 GHz |
| MN4765B-070 | 1550 nm | 70 kHz-70 GHz |
| MN4765B-110 | 1550 nm | 70 kHz-110 GHz |
| MN4765B-071 | 1310 nm | 70 kHz-70 GHz |
| MN4765B-072 | 1550/1310 nm | 70 kHz-70 GHz |

Table 1. A listing of the O/E modules available from Anritsu.

E/O Converter-VNA Optical Transmitters

Anritsu also offers a line of laser/optical modulator products to complete the E/O configuration. These units allow easy-to-use, high-performance characterization of photo receivers and photodiodes when combined with the MN4765B O/E module and the de-embedding tools available with Anritsu VNAs.

The laser/optical modulator products (Table 2) feature low RIN DFB laser sources and high bandwidth electro-optical modulators with excellent flatness and low ripple. There is an automatic bias control to lock the operating point of the modulator independent of operating conditions.

| Modulator Products | | |
|--------------------|--------------------|-----------------|
| Anritsu Model # | Optical Wavelength | Frequency Range |
| MN4775A-0040 | 850 nm | 70 kHz-40 GHz |
| MN4775A-0070 | 1550 nm | 70 kHz-40 GHz |
| MN4775A-71 | 1310 nm | 70 kHz-70 GHz |

Table 2. A listing of the E/O optical modulators available from Anritsu.

Conclusion

This paper presents an accurate, flexible and cost-effective technique to conduct electro-optical testing on fiber optic components, such as laser modulators and photodiodes, using VNAs. The simplicity of Anritsu's MN4765B O/E calibration modules allows highly accurate, vector-error-corrected and stable measurements with the full line of Anritsu VNAs.

Additional Reference Documents

- 1) Anritsu Application Note *Electro-to-Optical and Optical-to-Electrical (E/O and O/E) converter measurements* (P/N 11410-00798)
- 2) Anritsu Technical Data Sheet *O/E Calibration Module MN4765B* (P/N 11410-00843)

• United States**Anritsu Company**

1155 East Collins Boulevard, Suite 100,
Richardson, TX, 75081 U.S.A.
Toll Free: 1-800-267-4878
Phone: +1-972-644-1777
Fax: +1-972-671-1877

• 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 Eletrônica 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.**

Av. Ejército Nacional No. 579 Piso 9, Col. Granada
11520 México, D.F., México
Phone: +52-55-1101-2370
Fax: +52-55-5254-3147

• United Kingdom**Anritsu EMEA Ltd.**

200 Capability Green, Luton, Bedfordshire LU1 3LU, U.K.
Phone: +44-1582-433280
Fax: +44-1582-731303

• France**Anritsu S.A.**

12 avenue du Québec, Batiment Iris 1-Silic 612,
91140 Villebon-sur-Yvette, 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: +39-06-502-2425

• Sweden**Anritsu AB**

Kistagången 20B, 164 40 KISTA, Sweden
Phone: +46-8-534-707-00
Fax: +46-8-534-707-30

• Finland**Anritsu AB**

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

• Denmark**Anritsu A/S**

Kay Fiskers Plads 9, 2300 Copenhagen S, 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**

P O Box 500413 - Dubai Internet City
Al Thuraya Building, Tower 1, Suite 701, 7th floor
Dubai, United Arab Emirates
Phone: +971-4-3670352
Fax: +971-4-3688460

• India**Anritsu India Pvt Ltd.**

2nd & 3rd Floor, #837/1, Binnamangla 1st Stage,
Indiranagar, 100ft Road, Bangalore - 560038, India
Phone: +91-80-4058-1300
Fax: +91-80-4058-1301

• Singapore**Anritsu Pte. Ltd.**

11 Chang Charn Road, #04-01, Shiro House
Singapore 159640
Phone: +65-6282-2400
Fax: +65-6282-2533

• P. R. China (Shanghai)**Anritsu (China) Co., Ltd.**

27th Floor, Tower A,
New Caohejing International Business Center
No. 391 Gui Ping Road Shanghai, Xu Hui Di District,
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: +81-46-225-8359

• 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