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MULTIPLE INPUTS, NUMEROUS OUTPUTS—INTELLIGENT SOLUTIONS FOR TESTING MXN COMPONENTS

APPLICATION NOTE

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Introduction

Passive and active components are continuing to evolve, even during this period of consolidation and negative growth. As the market turns around, passive component manufacturers are designing, qualifying and manufacturing components with multiple input and output ports, as well as offering component arrays. These multiport devices, in many cases simply testing multiple components, have two or more inputs and many outputs, and offer a considerable challenge for the test and measurement engineer. Below is a description of some of the techniques available for testing these MxN passive devices, which will assist you in designing a test system that provides optimum results in the least amount of time, while making a minimum number of compromises. Although it is relatively easy to test 1xN devices, Nx1 or MxN components are much more difficult to test.

Multipath Testing of Passive Devices

There are a number of different applications for which it is important to measure the multipath optical transmission properties of passive components. Depending on the device, insertion loss, return loss, polarization-dependent loss, polarization-dependent wavelength, bandwidth, flatness, crosstalk, directivity and other important parameters must be evaluated. Some of the more common applications are summarized in the following paragraphs.

Qualification and Reliability Testing

Qualification testing is one of the most demanding applications, as it requires testing many different parameters on multiple components over extended periods of time. This often means full compliance to optical criteria, as well as environmental and reliability life tests. For example, Telcordia qualification requires a minimum of 11 samples tested for the long-term reliability and durability of passive components that are under the environmental stresses of temperature, humidity and mechanical shock. In order to accurately measure small changes in the performance of the samples, the optical transmission properties must be accurately measured with high precision and repeatability.

Testing Optical Crossconnects (OXC) and Other Switches

By definition, an OXC has multiple input and output ports and, therefore, poses some of the same challenges as qualification testing, testing multiple optical parameters over many different optical paths. Even a simple 8x8 crossconnect would have 64 different optical paths. Generally, the basic IL, ORL and PDL measurements are required. Whether wavelength-dependent measurements are required or not, depends on the technology behind the device. Most of the optomechanical-technology devices (2D and 3D MEMS, fiber-to-fiber) are mostly broadband in nature, while many of the other technologies (AWG, thermo-optic, grating, holographic) have wavelength-dependent properties that require characterization. It is important to note, however, that even broadband components may require spectral characterization, especially when used in high-data-rate DWDM networks.

Testing Multiplexers, OADMs and Other Hybrid Products

Multiplexers and OADMs also have multiple ports. Often, a multiplexer can be tested as a demultiplexer, in which case there is only a single input and the standard multichannel DWDM test system is perfect for the job. However, when you need to test in the demultiplexing direction, you need to use a switch on the input side to launch into the different ports. The switch adds complexity, test time and measurement uncertainty, but offers a total integrated solution that will even allow you to test directivity, a very difficult measurement to automate.

Testing Arrayed Components

Arrayed components are typically small packages, incorporating two or more 1x1 or MxN optical components. One of the more frequent configurations is the variable optical attenuator (VOA) array, which contains 8, 16, 32 or more VOAs on a single planar lightguide circuit (PLC). Other examples include low-density switches, shutters and tap couplers. Since the devices are independent, testing the different segments of the array in parallel saves a significant amount of time. For this reason, it may be interesting to use a coupler instead of a switch at the input of the component array.

A Flexible Approach

The challenge for component manufacturers is to find the solution that provides all the test parameters within a single package, while giving accurate and fast measurements. The solution must be flexible enough to evolve with testing needs. Since most of the measurements required for the above applications require full or limited spectral characterization, the solution discussed here is based on a swept, tunable laser DWDM test system that has been optimized for testing multiple optical paths.

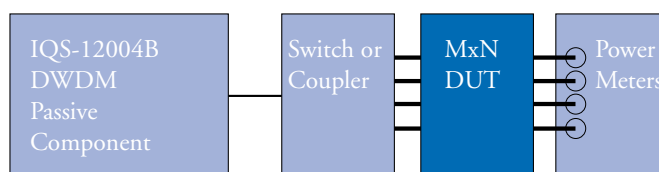


Figure 1. Typical setup for testing multiple optical paths

The basic system hardware includes a tunable laser source, a polarization controller, a wavelength reference module (IQS-12004B, in the above diagram) along with multichannel power meters and a switch or coupler. There are a number of important questions that need to be asked regarding this configuration.

Why not use a switch on both sides of the DUT?

There are two reasons. Switches introduce insertion loss repeatability errors and, in most cases, will degrade PDL measurement accuracy. Connecting the output ports directly to power meter photodetectors will significantly improve measurement specifications. The second reason is related to parallel measurements (for example, while testing a crossconnect). While launching light into one port, it is often necessary to measure the transmission properties on several outputs. If we use a switch on the output, then we have to perform multiple measurements. Connected directly to the power meters as shown, all ports can be measured at the same time. The end result is a faster and more accurate measurement.

What is the impact of the front-end switch on the measurements?

There is no question that the front-end switch will have a negative effect on the accuracy and repeatability of some of the measurements, and in the case of optical return loss, the front-end switch will reduce the measurement sensitivity. The table shown below summarizes a comparison between measurement specifications of a standard DWDM component test system and one designed for multipath applications.

Specification	IQS-12004B	IQS-12004B-MPT
Wavelength Accuracy	± 0.005 nm	± 0.005 nm
Wavelength Repeatability	± 0.001 nm	± 0.001 nm
Insertion Loss Accuracy	± 0.05 dB	± 0.06 dB
Insertion Loss Repeatability	± 0.01 dB	± 0.04 dB
PDL Accuracy	± 0.02 dB	± 0.05 dB
PDL Repeatability	± 0.01 dB	± 0.025 dB
ORL Range	0 dB to 65 dB	0 dB to 55 dB
ORL Accuracy	± 0.5 dB	± 1 dB
ORL Repeatability	0.1 dB	± 0.3 dB

Although the loss measurement specifications are very slightly degraded with the MultiPath Testing (MPT) option, the wavelength measurements are not. This degradation is mostly due to the repeatability error of the switch.

What is the trade-off between PDL accuracy and ORL performance?

The specifications in the above table for the MPT option would apply to setups using a low-PDL switch. Low-PDL switches avoid angled collimators or lenses that are often used to improve the ORL of the switch. If we had selected a high-ORL switch (low backreflection) to improve the ORL measurement capability of the test system, the switch would most likely have a higher PDL and, thus, likely degrade the PDL measurement performance. There are ways to minimize the PDL effect of the switch/coupler; this is addressed later in the article.

How do I improve the long-term performance of the switch?

Instrument manufacturers often specify switch repeatability for a certain number of cycles, often within a limited period of time, and at a constant temperature. This performance is generally very good, but for long-term qualification testing, it is important to maintain the best repeatability possible. When we are attempting to measure drift values that amount to tens of mdB, all efforts should be employed to optimize this important parameter. There are a number of tips that can help in this type of testing situation:

1. Minimize the number of switch cycles. If a measurement is required every four hours, or once an environmental chamber attains a preset temperature, there is no reason to go through any unnecessary switch cycles. Over a long period of time, this could add up to a large number of needless cycles.
2. Use reference channels. There should always be several reference channels that are connected directly from a switch port to a power meter. These ports are used to monitor the drift of the switch and can be used to correct the DUT measurement data. There is a lot of experimental evidence demonstrating that this improves the long-term performance of a multipath testing system.
3. Maintain constant temperature. In a room where there may be multiple environmental chambers cycling continuously, that ambient temperature will vary considerably. Most test equipment is somewhat sensitive to temperature variations and this includes fiber-optic switches. Installing the complete MPT system in a temperature-stabilized cabinet will have a very positive impact on the long-term performance of the system.

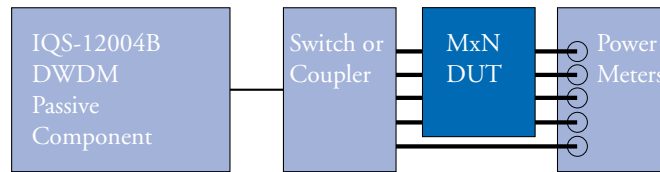


Figure 2. Using one or more reference channels in the setup will help long-term performance.

Should we use a coupler or a switch at the front end?

The answer to this depends on the application. A coupler is extremely useful for testing multiple components or component arrays. A good example would be to use it for testing a PLC with eight VOAs on the chip. As shown in the diagram, a 1x8 coupler could be used with eight power meters so that all VOAs would be tested in parallel. Using a switch in this application would unnecessarily increase testing time. Since attenuators are often tested at numerous attenuation levels, the time saved is tremendous.

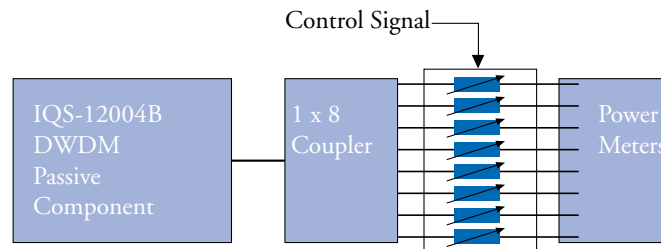


Figure 3. Setup using a coupler for testing IL and PDL of an eight-array PLC attenuator

Using high-sensitivity auto-ranging power meters helps in this application since there is significant loss through the coupler and, at the same time, the VOAs will be cycled across a wide attenuation range. This setup would allow for IL and PDL testing, while the setup shown below would allow for IL, PDL and ORL testing.

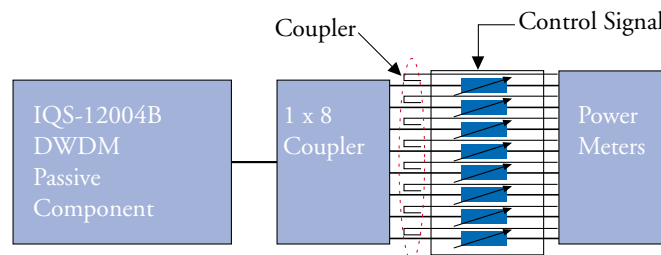


Figure 4. Setup using a coupler for testing IL, PDL and ORL of an eight-array PLC attenuator

What is the best way to calibrate and reference the system?

The best way to illustrate this is to assume the worst-case scenario, which would be testing an MxN optical crossconnect. To properly evaluate the OXC, we need to launch a signal into each input and measure the IL on the selected output and the isolation on all other outputs. For a complete characterization, there are MxN different optical paths. In the case of an 8x8 switch, there are 64 optical paths, for higher-density switches, many more. Since we know that our front-end switch is not perfectly uniform (same loss for all channels) and we also realize that our power meters are not identical in response, the measurement system must be calibrated to accurately measure all of these paths. So unless we think of an alternate solution, we will have 64 reference measurements to take.

A well-designed test system can address this problem and reduce the number of required reference measurements to $M+N$, instead of $M \times N$. This process is called intelligent referencing. So for our 8x8 OXC, we would need 16 reference measurements instead of 64. Here is how it is done:

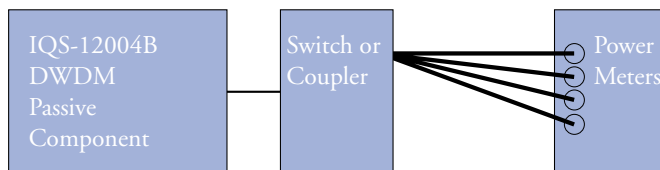


Figure 6. Step 1 in intelligent referencing

In this first step, we connect switch channel 1 to each of the power meters required by the test. This allows the system to compensate for any differences in the response of the power meters. These differences could either arise from the actual detector response, the adapters used, or from any coupling losses in the output fiber array.

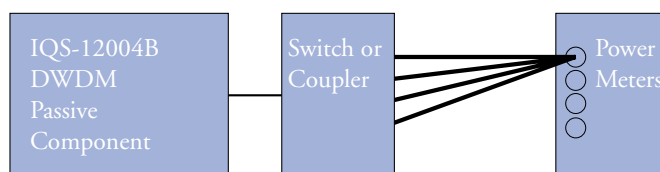


Figure 7. Step 2 in intelligent referencing

In the second step, we connect each of the switch ports to the first power meter. This allows the system to fully characterize all switch ports. In addition, if this is done with a swept tunable laser system, we also compensate for any non-uniformity in the wavelength response of each switch port. Once the system knows the response of each switch channel, along with the response of each power meter, the system software is able to create an internal reference matrix that, in effect, will compensate for each of the 64 possible optical paths, unquestionably a significant timesaver.

How do we minimize the effect of the switch/coupler PDL?

Most test engineers know from either experience, or theory, that you cannot directly reference out PDL and, in fact, any PDL that is part of the setup will only add to the overall measurement uncertainty. This is always true when using the polarization scrambling method for PDL measurements; however, when using the Mueller Matrix (MM) calculation method, a few helpful hints can be used to avoid these effects. If, during the second step of the intelligent referencing procedure, we perform our reference at all four states of polarization (SOP) used by the MM method, the PDL characteristics of each switch channel can be included as part of the reference. If, during the measurement of the DUT, the same four SOPs are used, the PDL properties of the DUT can then be measured without degrading the measurement accuracy. However, if, during the measurement, the four SOPs are different, the measurement error will increase.

How can we ensure that the DUT measurements will be made at the same SOPs as when the reference was performed? The only way is to use fixed fiber conduits (rigid or semi-rigid) as interconnecting fibers between all instruments up to, and including, the input to the front-end switch/coupler.

Requires Flexible Software

Since the multitude of applications for multipath testing are very different, flexible software and/or development tools are required. What is more important, however, is that these tools address the problems associated with accurate multipath spectral characterization. Any product addressing these applications should:

- Include the necessary instruments that provide high-accuracy measurements
- Provide target specifications
- Provide documented DLL functions that are simple to integrate
- Provide calibration and intelligent referencing procedures built into the DLL functions
- Provide a complete sample application in a common development environment, including source code that can be used for further development
- Provide the flexibility to control external devices
- Provide a temperature-stabilized environment

The software should be able to manage different component and test configurations, as well as provide flexible data analysis and graphical viewing capacity.

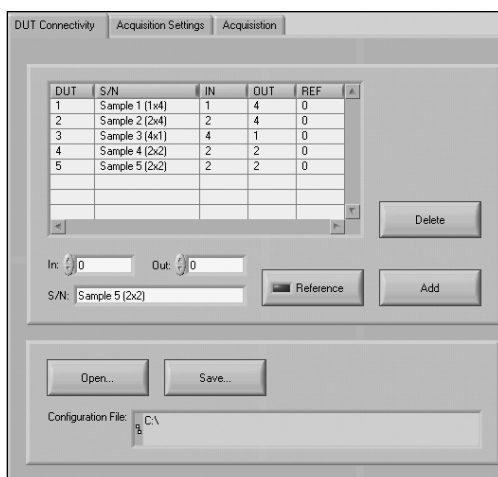


Figure 8. Typical configuration for multiple-device testing

This figure shows how an interface can be designed to test any number of components with different numbers of inputs and outputs. The only requirements are to have a switch or coupler with several ports, and a sufficient number of power meters. In the example shown above, DUT 1 is a 1x4, DUT 2 a 2x4 device and DUT 3 is a 4x1 component.

Finally...Some Results!

Once you have gone through the process of designing your multipath testing system and application software, it is always rewarding when everything comes together and you realize that you have perhaps even surpassed your expectations. One thing is certain, multipath testing generates megabytes of test data, especially when testing multiple parameters on several devices over a set period of time. Your software needs to be able to display this data. It must also be able to save the data in a convenient format that can be exported to other applications. Some of the considerations are as follows:

- Ability to see all data for a particular device
- Ability to see multiple measurements of the same optical path
- Ability to select a specific measurement for a specific optical path
- Ability to view average, minimum, maximum and standard deviation of any measurement
- Ability to view parameter drift over time/cycle

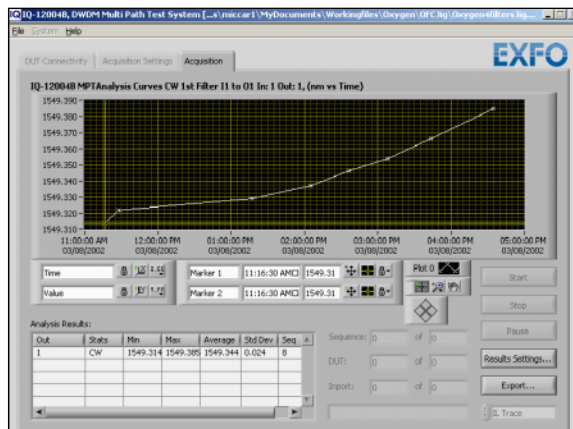


Figure 9. Multiple-trace graphical display

In the example shown above, a filter element has been measured at different temperatures. In the graph, we can clearly see the different transmission responses and, in the table, we can see the calculated results for the various temperatures. The results shown below are for the same data, however, the drift in central wavelength is displayed along with the minimum, the maximum and the average value.

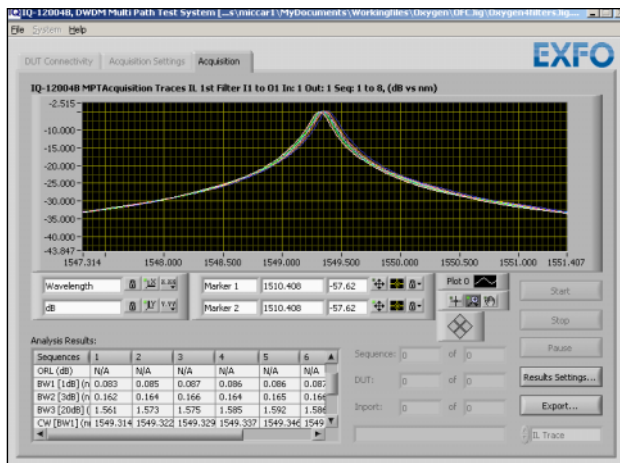


Figure 10. Graphical display of parameter drift

Conclusion

Testing devices with multiple inputs and multiple outputs can be efficiently and accurately performed. However, it is often a tricky application in which a certain number of compromises may be necessary. Hopefully, the above has explained some of the options and possible solutions. If you are not happy with the results of your current test system or are planning to develop a similar application, keep in mind that Test and Measurement companies have a lot of experience in this field and most likely have a solution to your particular problem.

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