NetSeminar Q&A for Dispersion Measurement Challenges for the Next Generation 40Gb/s Optical Network (Mar. 5, 2002)

The following questions pertain to the Agilent 40G Industry Buzz.

Q: Who approved SPI-5?
A: The Optical Internetworking Forum (OIF) is a standardization body that worked on SPI-5. If you take a look at the list of the manufacturers who actually voted on this, it's a very wide set of service providers, network equipment manufacturers, and component manufacturers.

Q: Why would anyone use serial 40G in short haul lengths when they could use several lower rate streams with aggregate 40 Gb/s throughput using either fiber ribbons or multiple wavelengths over one fiber?
A: The answer is what is the lowest cost per bit. In the Nov. 2001 40G eSeminar we showed that for every successive increase in speed, from 622 MHz to 2.5G to 10G and then to 40G, each one brought a lower cost per bit. They might have been somewhat more expensive, but you had a four-time increase in throughput at a lower cost per bit. There is a lot of belief that this will happen in 40G systems and that the short reach interfaces won't have all the overhead of chromatic dispersion, PMD dispersion, optical amplifiers and so forth. This may be the first place where this would occur. But even if the cost per bit were about the same, many service providers say that they would prefer to go to a single fiber at a higher rate because reducing the number of fibers reduces the number of the potential points of breakage, of maintenance and so forth.

The parallel ribbon fiber is a very interesting alternative. If it really delivers significantly lower cost per bit, that may be something people will consider. It's 850 nm and not all central offices are set up for that. So I think it's going to be a decision based on the particular desires and infrastructure strategy of the service providers. It will be very interesting when the first 40Gb/s serial links short reach, probably 2 kilometers come out, and see how this plays out.

Q: When do you see rates going from 10G to 40G?
A: There is development work being done in the 40G arena right now with a few network NEMs working on 40G products. According to RHK, one of the industry analysts that look at these trends, they predict that the 40G will take off in the year 2004 to year 2005 time frame.

Q: You were talking about a 850 nm range, is it available now or is that coming later?
A: Agilent presently has no solution that covers the 850nm range.

The following questions pertain toward Dispersion Measurements.

Q: What is the CD-PMD measurement method used by the 86038A?
A: The 86038A Optical Dispersion Analyzer uses the industry standard modulation phase shift method.

Q: Are you able to mention prices for the 86038A or the 81910A?
A: No. Please contact your local Agilent representative for local pricing information.

Q: You mentioned that at 40G you can go 4 km and at 10G you can go 59 km, is that on NDSF or NZDSF fiber?
A: I believe it's the dispersion shifted fiber that you can attain these type of link lengths.

Q: Do you have a solution for field measurements of PMD and PDL?
A: The 86038A and 81910A systems are targeted for R&D and manufacturing customers. For field measurement purposes currently Agilent does not have a solution. But stay tuned, we may be have something in the future.

Q: Can one easily and accurately measure dispersion slope or slope of slope with either the 86038A or the 81910A?
A: Yes. The dispersion slope and slope of slope can be measured by both the 86038A and the 81910A. The 86038A is targeted for narrow band devices, optical fiber, amplifiers and systems. The 81910A is targeted for narrow band components, so you cannot measure optical fiber.

Q: Do you think that the solution to PMD is to use polarization maintaining fiber?
A: Using polarization maintaining fiber is not going to mitigate this problem. PMD results because as the light pulse travels through a device that has PMD, the pulse gets broken up into two polarization modes that have slightly different speeds of propagation.

Q: Are there any tunable CD compensators currently available?
A: Yes, there are a few currently available. This is an area that's being developed for 10G and 40G networks. I know one compensator that uses the VIPA technique for tunable CD compensation.

Q: Are there any tunable PMD compensators available?
A: That's an area currently under development. I know of two companies currently working on tunable PMD compensators, but I don't believe they are available yet. They would be required for 10 and 40G networks.

Q: What measurement methods are commonly used for CD and PMD?
A: The measurement methods currently used for CD are the differential phase shift method, the modulation phase shift method, which is the industry standard, and a new method -- the swept homodyne interferometry method. For PMD measurements there is a fixed analyzer, the Jones matrix Eigenanalysis method (JME), the low coherence interferometry method, and the modulation phase shift method to do CD and PMD. The JME method is one of the more accurate measurement methods currently available for PMD measurements, and the modulation phase shift method also gives you very good accuracy for PMD measurements.

Q: What's the best modulation frequency to measure the CD, for example in the range of 1550 to 1560 nm?
A: For the modulation frequency in the modulation phase shift method you need to consider some things. If you are interested in seeing the detail of group delay curve or the detail of the group delay ripple, you need to bring your modulation frequency down. But keep in mind as you bring the modulation frequency down you start increasing the phase noise. So there is a trade-off between seeing high resolution and also increasing phase noise. To overcome this problem on the 86038A optical dispersion analyzer we offer some correction factors, so that with very low modulation frequency values you are able to achieve very high resolution and very high accuracy.

The best modulation frequency depends on what you want to do in terms of your measurement. As you bring modulation down you start to see finer details. However, if you want to do reasonable measurement with good resolution and good accuracy, you need to choose the modulation frequency that is good for your measurement. I can't give you a specific modulation frequency for your measurement. Typically, customers use modulation frequencies anywhere from 500 MHz to 2 GHz for measurements.

Q: What components of a network require CD and PMD testing at 40G?
A: Pretty much all the components in a DWDM network require CD and PMD testing at 40 Gb/s. Components such as multiplexers, demultiplexers, EDFAs, isolators, and optical dispersion compensating optical fiber lengths and the long optical fibers that are present. All these different components require CD and PMD to be measured.

Q: What accuracy is required for 40G CD and PMD measurements?
A: When the bit rate starts increasing from 2.5 Gb/s to 10 Gb/s and beyond, the amount of CD and PMD that can be tolerated in a link goes way down. CD goes from 16,000 ps/nm down to 63 ps/nm if there is no compensation. PMD goes from 40 ps to 2.5 ps. So each component in that 40G optical network needs to have a very low level of CD and PMD because all of them add up to form the total amount. For instance, for 40G components the amount of CD that components typically have is going to be in the femtosecond range. Very low levels of CD and PMD are required on these components for 40G.

Q: Are CD and PMD compensation done on the current networks?

A: Yes, there is some level of CD and PMD compensation done. However, most of the compensation done in the current networks are static compensated. As the bit rate increases to 10 Gb/s and beyond you would require dynamic compensation in order to do proper dispersion slope compensation.

Q: How big an impact is the environment on PMD and PDL measurements?
A: The environmental effects for PMD are quite big. For instance, if there is an optical fiber in the ground and there is some force acting on the optical fiber, that will change the birefringence and cause PMD to change. For an aerial optical fiber link, as it sways in the wind, that could affect the amount of PMD that is present because of different forces acting on the optical fiber.

Q: Have there been studies regarding the magnitude of fast PMD variations due to vibrations on the total PMD of a link?
A: There have been some studies that have been published in the IEEE Magazine. One of them I was by M. Karlsson, but there are also some other papers published that talk about change of PMD due to environmental conditions and different forces acting on a fiber link.

Q: In slide 15, "CD in Single Mode Fiber", is that a WDM system or are we concerned with the frequency components of a single wavelength?
A: These are the frequency components of a single, modulated light signal at a single wavelength. Because of modulation, the signal gets broadened out. And yes, this is off a single wavelength.

Q: In slide 26, "Measurement of DGD over Wavelength and Time", how much of the apparent DGDs are really changes in polarization state because of differences in preferential planes of polarization with wavelength rather than DGD?

A: The color coded data shown in the slide does in fact represent the differential group delay as functions of wavelength and time. The measurement method was Jones Matrix Eigenanalysis (JME), and industry standard. Of course, the polarization transformation caused by the fiber changes with wavelength, but this change is evidence of the PMD and in fact it is this polarization change that contains the information we are after. The JME method effectively measures the rate of rotation of the output state of polarization in 'polarization space' (the Poincare sphere) with respect to wavelength. The JME method involves stimulating the test path with three polarization states at each test wavelength. The pattern of states must repeat at each wavelength, but the absolute states of polarization are not important to the measurement.

Q: Is PMD drift a function of minutes, hours or days?
A: In slide 26, I showed the work that M. Karlsson did on a 127 kilometer dispersion shifted optical fiber that was buried in the ground. In a stable environment like that, you would see PMD drift happen in days. However, if you have an aerial optical fiber link that sways in the wind, that could be something that happens in the seconds or minutes format, because it changes the birefringence and causes PMD to drift.

Q: At what distance and data rates does PMD really come into play?
A: Slide 31 shows the amount of chromatic dispersion and polarization mode dispersion that can be tolerated in a link. The amount of PMD that can be tolerated at 2.5 Gb/s bit rate is about 40 ps, and at 40 Gb/s bit rate it goes down to 2.5 ps. At 10 Gb/s it's 10 ps that can be tolerated in a link. So, the corresponding link lengths could be in the hundreds of kilometers range of PMD.

Q: In slide 37, "Strategies for 1st Order Optical PMDC", you mention two methods for compensating PMD. The second method was to align the signal polarization and a PSP. Can you please explain what this means, possibly describing a physical implementation?
A: Yes. In any long optical fiber there exists two orthogonal states of polarization known as the principal states of polarization (PSP). For each input principal state of polarization there corresponds an output principal state of polarization. In this method you need to align the signal polarization with one of the principal states of polarization in order to bring about some PMD compensation.

Q: Slide 44, "Zooming in on GD Ripple", shows a plot of group delay versus wavelength for different modulation frequencies. Why are the actual measured values of group delay different with different modulation frequencies? You mentioned that the fine structure is resolved with lower modulation frequencies but the absolute values of group delay are different.

A: In slide 44 we show some measurements that were done at different modulation frequencies from 2 GHz down to 125 MHz. The Y-axis on that plot shows the relative group delay and not the absolute group delay. That's why you are seeing these plots at different levels. If you were to take the absolute group delay and plot it, all of the traces should fall on top of each other.

Q: Could you please explain how polarization scramblers work and how they are used?

A: Polarization scramblers use different techniques for doing the polarization scrambling. One of the techniques I use is optical fiber loops. These optical fiber loops are on paddles that can be moved back and forth in order to change the different states of polarization. Another method that is used is quarter wavelength plates. These wavelength plates are rotated in order to generate different states of polarization. The polarization scramblers typically can be used to measure PDL.

Q: In slide 46, "Common PMD Measurement Methods", how does the low coherence interferometry PMD measurement method work?

A: In the low coherence interferometry method to measure PMD, two signals are taken and combined together with each other and the resulting birefringence that happen are measured in order to determine the amount of PMD present in the signal.

Q: What are your feelings on PMDC?

A: PMD compensation is required especially for DWDM networks that work at 10 Gb/s and beyond. PMD compensation, however, is not going to be an easy thing to implement, since it requires some active feedback mechanism to do a proper compensation for PMD. There are some companies that have some products available for PMD compensation.

Q: Does Agilent sell PMDCs? What's the general cost of a PMDC?

A: No, Agilent does not sell PMD compensators. As for cost, there is quite a big range. I would recommend going to the web site of one of the PMD manufacturers to get that information. Dynamic compensators are currently being developed so there is not a lot available yet.

Q: Beside BFG and compensation fiber, is there any other dispersion compensation method?

A: Besides Bragg fiber grating (BFG) and compensation fiber, the other methods that are used for chromatic dispersion compensation, based on dynamic compensators, one technology that is called the virtual image phase array (VIPA) technology, which has been developed by two vendors. This specific method is pretty good for dynamic compensation for CD. So that's another compensating method that is currently available. There are a few others that are available.

Q: Is it possible to perform broadband dispersion compensation for a 10 Gb/s ULH system or is single channel compensation always necessary?

A: For a 10 Gb/s ultra long haul system it is possible to do broadband dispersion compensation, so long as you can match the dispersion slope, because dispersion slope compensation often becomes very important otherwise that problem adds up. So at 10 Gb/s bit rates for long haul and ultra long haul systems, I believe you would be able to do some sort of broadband dispersion compensation. Keep in mind when you are doing dispersion compensation you need to pay close attention to the dispersion slope.

Q: What detailed application notes are available on the Agilent Website?

A: The Agilent web site has application notes on narrowband CD and PMD measurements

Q: Can I get a copy of the presentation?

A: Yes, go to slide 61 of the eSeminar archive. From there you can get a copy of the presentation plus find many valuable links for more information on the subject. There is also a 40G discussion forum link (http://www.agilent.com/find/forums) if you would like to pose/review other questions.