Bandwidth Testing Of Multimode Fiber Becomes Important Again

In the beginning of fiber optics as a means of communications, around 1980, the highest technology available used multimode fiber (50/125 micron to be exact) and 850 nm lasers. Links went as far as 15 km at speeds up to 145 Mb/s, where the bandwidth of the fiber created a barrier to further expansion.

Fast forward twenty years and how things have changed. Long distance telecommunications has been using singlemode fiber with virtually infinite bandwidth since 1984 and networks routinely go hundreds of km at 2.5 Gb/s. But computer networks have advanced too, with Gigabit Ethernet (GbE) becoming available. It's "déjà vu all over again" as GbE still uses multimode fiber and 850 nm lasers, although the lasers are now inexpensive VCSELs which cost about 1% as much as the lasers used 20 years ago.

The fiber for GbE is a bit different too. Beginning about 1985, the multimode fiber of choice for LANs became 62.5/125, which had a bigger core that was more compatible with LED sources than the earlier 50/125 fiber. Some early LANs used 100/140 fiber too, but it needed a different connector size, making it much less popular and leading to its early obsolescence.

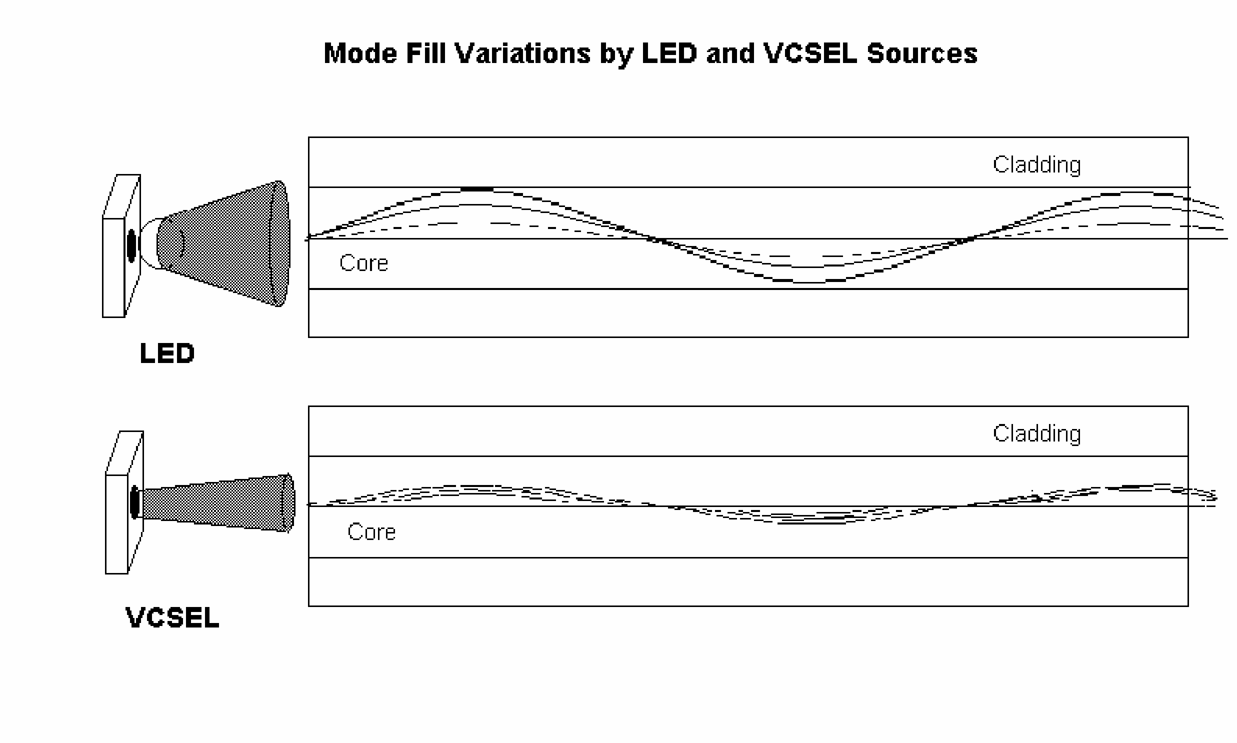
With the advent of GbE, the length of fiber links was limited by the bandwidth of the fiber, not the attenuation as on most slower links. Fiber manufacturers reintroduced 50/125 fiber, since it had higher bandwidth than 62.5/125 fiber and allowed longer links on GbE. Acceptance of 50/125 fiber was slow since most users already had 62.5/125 fiber installed that they wanted to use for GbE, if it was at all possible.

Now we are looking at Ethernet at 10 gigabits per second and users still want to use their installed fibers. Is this possible? Let's examine the problem more carefully.

Fiber Does NOT Have Infinite Bandwidth

The desire to run GBE over legacy multimode fiber cable plants in premises applications creates a problem. Multimode fiber works well with LEDs, but somewhat unpredictably with coherent laser sources. Coherent sources emit light in phase, and interaction of various modes in multimode fiber can create modal noise, causing bit error rate problems.

Furthermore, LEDs have a wide angle of light output which must be focused into the fiber, while lasers have a much narrower beam that is more easily coupled to the fiber. The LED will fill the higher order modes in the fiber (higher modes = wider angles), lasers will concentrate the light in the center of the fiber, especially the long wavelength lasers with singlemode pigtails.

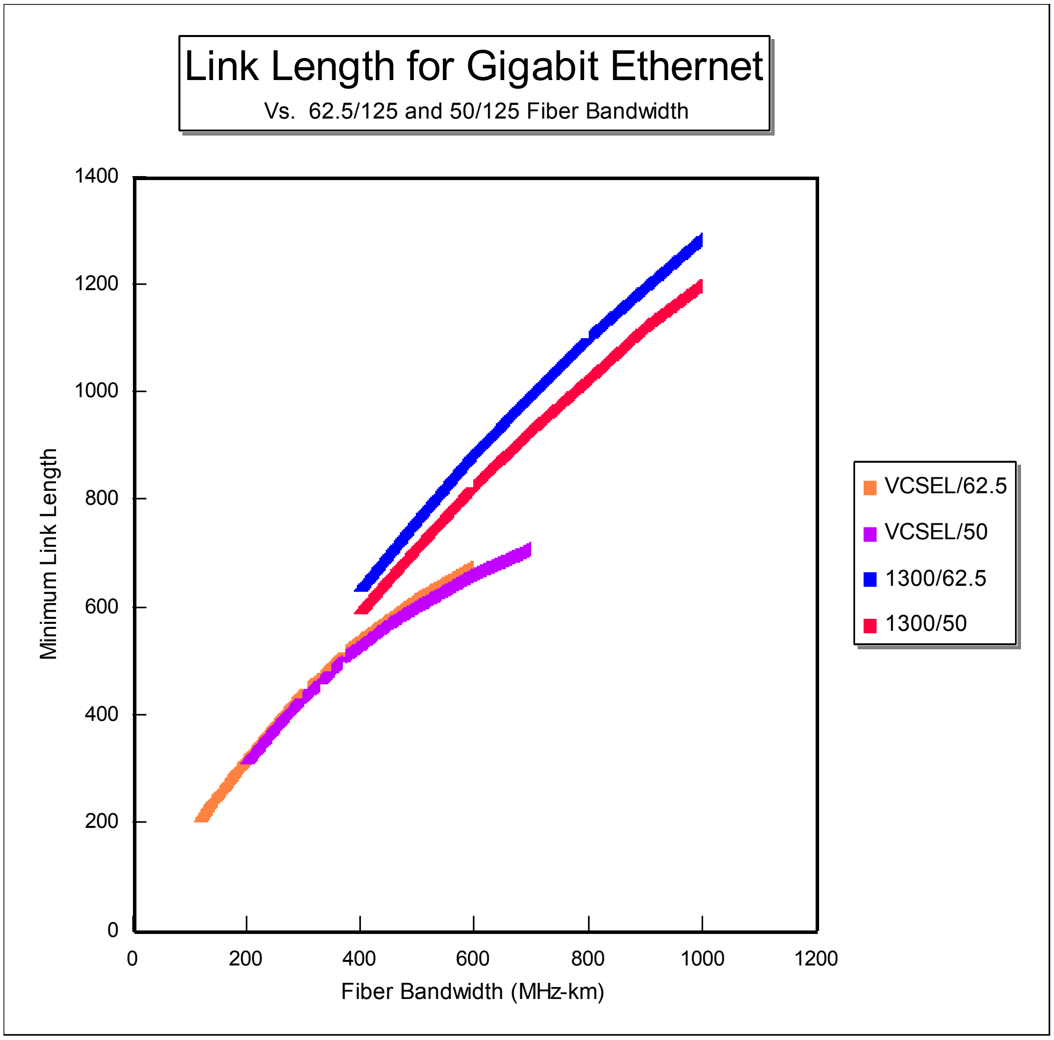


While this could theoretically allow higher fiber bandwidth to the laser, the laser can have severe problems with some fibers if the core is not perfectly manufactured. To minimize the problems, transceiver manufacturers are looking at changing the source output to create offset or even “doughnut” launches to minimize modal problems.

Most “legacy” multimode fibers have their bandwidth optimized for 1300 nm, not 850 nm, adding to the problems of short wavelength lasers. Fiber manufacturers offer fiber with high bandwidth capability at 850 nm as well as 1300 nm but it is 50/125 fiber that is incompatible with currently installed 62.5/125 fiber.

Most of the 62.5/125 fiber installed in backbones is “FDDI spec” with bandwidths of 160 MHz-km at 850 nm and 500 MHz-km at 1300 nm. The big question is how far you can go on this fiber before encountering problems – or is it usable at all.

For multimode fiber, it’s a function of the fiber bandwidth and transceiver design as shown in the graph below. This is theoretical data calculated for worst case conditions by engineers working on the GbE spec and published in the addenda.



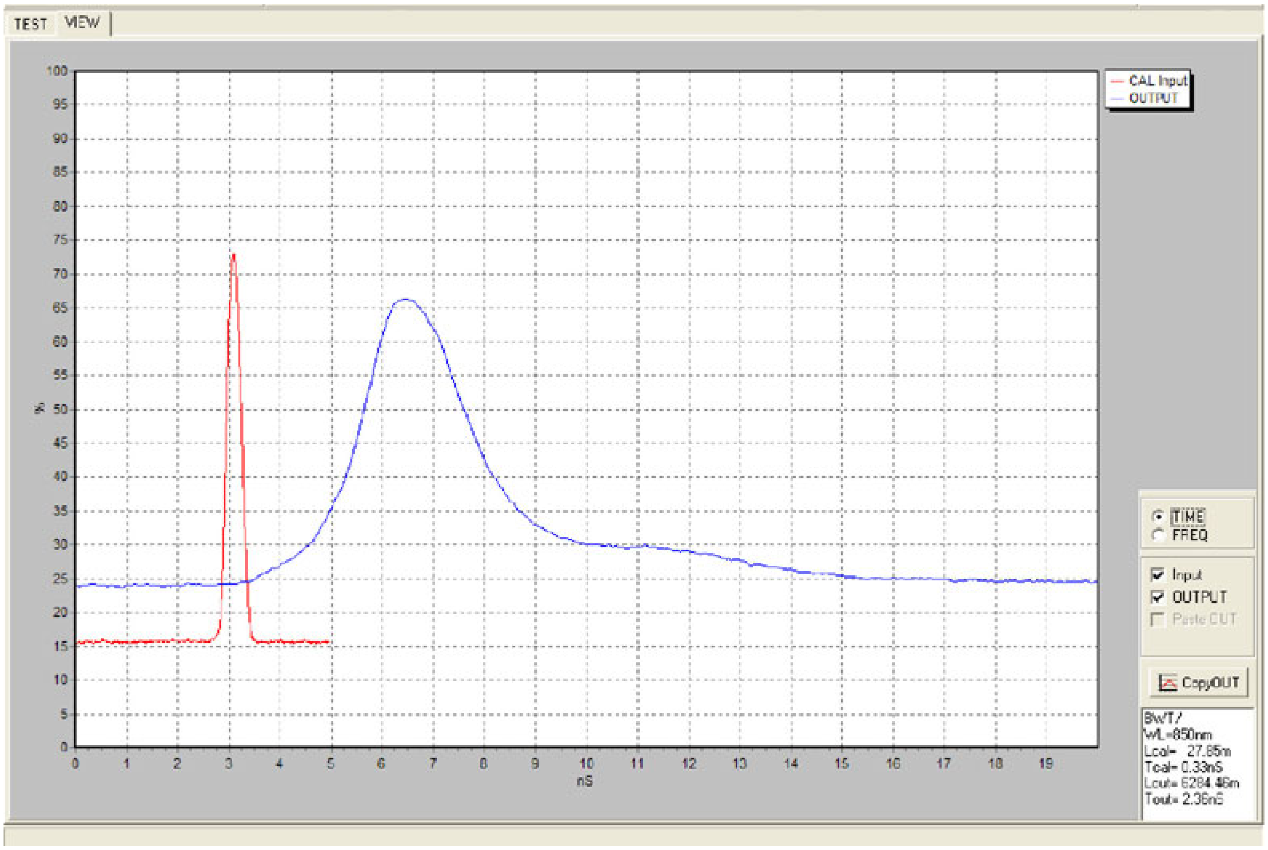
If you are planning on running on fiber already installed, you probably do not have the actual fiber performance data, so you must assume the worst case lengths and/or look for modal conditioning methods to enhance the application. The adventuresome user will just try it, as successful links running more than twice the worst case lengths have been reported. It appears to be a very conservative standard.

Testing Bandwidth

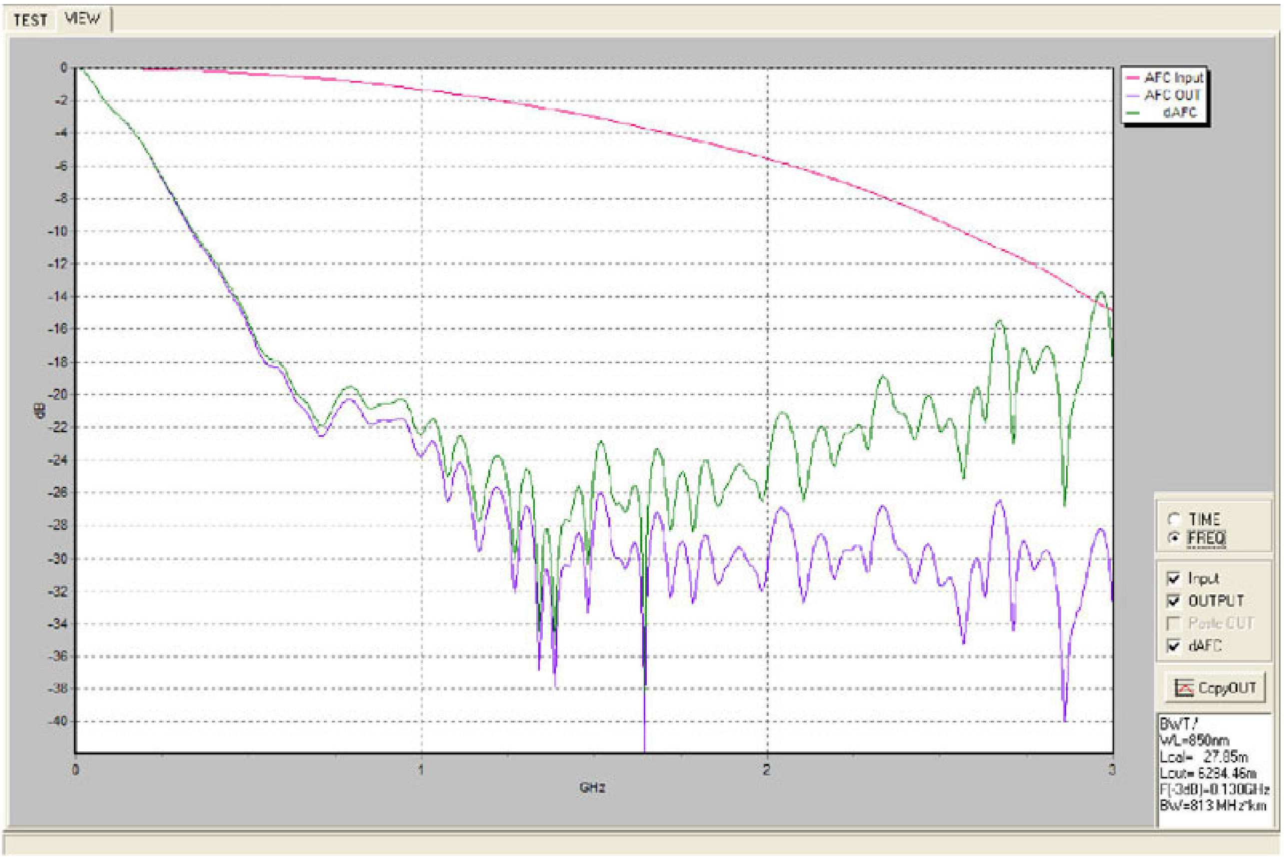
You cannot easily test the fiber you already have installed for bandwidth. It's a more complex test that requires very high speed equipment to reach the limits of the fiber performance envelope. Fiber manufacturers routinely test bandwidth using a method called DMD or differential modal delay, but they use laboratory testers which are enormous and cost hundreds of thousands of dollars.

A simpler test can be done by simply transmitting a very short (sub-nanosecond) pulse down the fiber and capturing the pulse at the other end to analyze the effect of the fiber. A simple electrical analogy makes the process more understandable: the fiber acts like an electronic "filter," removing high frequency components and spreading the pulse out.

Using analysis of the pulse spreading allows calculating the effective bandwidth of the fiber.
We have built such a tester, using modern digital signal processing techniques to simplify the Fourier transforms necessary to analyze the test results and a inexpensive personal computer to do the necessary calculations and display results.



Here are pulses from a sample test of 3.5 km of fiber viewed in the “time domain” like an oscilloscope. The red pulse is the test pulse from the 850 nm laser transmitter. Note it is only about 0.3 ns wide (FWHM – full width half max). After traveling down the fiber, you can see the pulse broadening, just like an electrical pulse is broadened by a filter.



Here is the same data after analysis. We are looking at the frequency domain now, where we see the attenuation of the fiber in dB on the Y-axis and the frequency on the X-axis. The red line is the input and the green line the output. The blue line shows the difference between the two which is the affect of the bandwidth of the fiber itself. From the data panel on the lower right, we see the calculated bandwidth of the fiber is 536 MHz-km.

Performing these tests is simple. Attach a short calibration cable to the tester between the transmitter and receiver. Make a short measurement and store the data (the red pulse shown above.) Remove the reference cable from the receiver and attach it to the cable to be tested. Connect the other end of the cable to test to the receiver. Make a second measurement and within a few seconds the PC calculates the test data and provides a display of the data like that shown above.

What About Standards? There are two methods offered by standards for testing the bandwidth of multimode fiber. We mentioned the DMD method, covered by FOTP-220. The method used here goes back to FOTP-30 and is also covered in the new FOTP-204.

The method used here has one other advantage for testing. You can actually analyze the performance of currently installed fibers by looking at the display, just like with an OTDR. A good fiber will have a clean, smooth pulse, while bad fibers, such as those with problems with core index dips, will have very ragged, sometimes double pulses. Bad fiber fibers are easy to spot and can be marked for use with slower networks. Good fibers will be obvious to the trainer user, just like properly installed fibers have easily-red traces on an OTDR.

Conclusion

The bandwidth tester described here offers the possibility of actually determining whether currently installed fibers are viable for higher speed networks, thus saving the cost of installing new fibers in many applications.