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Optical network testing in a 5G environment

BY STEPHEN .HARDY

You can't have 5G without fiber – or at least that's what the fiber community will tell you. And while wireless options and HFC will have roles to play in 5G fronthaul, midhaul, and/or backhaul networks, the fiber folks are likely going to be right more often than not in their assertions. And that means more fiber testing, particularly as the number of fibers involved likely will be greater that in 4G support applications. Whereas operators have grown accustomed to a pair of fibers to each radio unit, some experts suggest that 5G radio units might require as many as 12. And that could mean new cable compositions and connectors, such as MPOs.

5G networks are starting to roll out — and fiber is expected to play a major part. That means fiber test procedures should be reviewed.

Add in the fact that 5G will require significantly more radio units than 4G to cover the same service area, and field technicians will be very busy with fiber as 5G rolls out. So regardless of whether an operator plans to support their own 5G mobile services or supply backhaul/midhaul/fronthaul assistance to others, the time to consider the fiber test requirements for this application is now.

Start with the basics

There are several fiber network topology options coming to market to support 5G requirements. Most are based on either some form of wavelength-division multiplexing (WDM) or passive optical network (PON) technology. Yet some basic aspects of fiber testing will remain constant regardless of the network topology.

The first is fiber inspection. Light should efficiently enter the fiber on one end and exit at the other, naturally. This evaluation process begins with endface inspection; as any fiber veteran will tell you, dirty connections are the root of most problems. Endface inspection tools are widely available from a variety of sources. Several of these vendors have developed MPO-friendly tools that can make inspection

easier and more efficient when the technician is confronted with one of the multi-fiber connectors expected to be used more frequently in 5G applications. Many of these tools provide automated pass/fail inspection, which can be save a lot of time and headaches.

Once you've determined that connector-related debris won't get in the way of your signal, it's time to do Tier 1 and Tier 2 fiber certification. Tier 1 involves the use of a light source on one end of the fiber and a power meter on the other to ensure that the amount of light that makes it across the connection is sufficient for the requirement.

Tier 2 sees the use of an optical time domain reflectometer (OTDR), which further characterizes the fiber and can uncover any issues that might have been detected during the Tier 1 test. OTDRs identify, measure the effects of, and locate just about anything that can degrade an optical signal. These "events" can be as innocuous as a mated connector or splice or something potentially more harmful such as a bend or break. As the unit's name implies, the OTDR is able to detect light reflecting off of any of these events, which means it can be effective with access to just one end of the fiber.

Measurements a typical OTDR can make include:

- Attenuation, which is the optical power or signal loss or the rate of loss between two points along the link.
- Event loss, which is the difference in the optical power before and after an event.
- Reflectance, which is the ratio of the reflected power to the incident power of an event.
- Optical return loss (ORL), which is the ratio of the reflected power to the incident power for a fiber link.

While the ability to perform these tests from just one end of the link is certainly efficient, test vendors suggest that field technicians perform an OTDR examination on both ends of the link. Events can have differing effects on optical transmission depending upon the direction from which the transmission originated, they point out. In particular, fiber backscatter coefficient mismatches can cause a splice to appear as gain in one direction and a loss in another. Averaging the gain and loss recorded via bidirectional measurements can provide a more accurate portrayal of a splice's loss characteristics.

WDM complexities

While these measurements are commonly performed regardless of the architecture choice, WDM and PON each bring their own set of requirements. As WDM is likely to be used more widely for 5G support networks, we'll start there.

WDM, of course, sees multiple wavelengths transmitted across a fiber, generally (but not always) in the same direction. Again, Tier 1 and Tier 2 type tests are required, and they're quite similar in philosophy to the tests just described. But they're necessary because individual wavelengths in a multiwavelength transmission are more susceptible to link events and interference from fiber elements and each other than a single-wavelength signal. And, particularly in DWDM applications, optical power might not be distributed evenly among all the wavelengths, meaning one wavelength might stream safely through a particular link and another might encounter problems.

Therefore, technicians must repeat the Tier 1 testing that combines a light source on one end and a power meter on the other. But, in this instance, the light source must be able to transmit across multiple wavelengths and the

power meter (often called a "channel checker") must detect incoming wavelengths across the same spectrum. The testing requires a degree of coordination between the technicians on each end of the link to make sure the instruments on the two ends are in synch. Tests sets are available that can not only perform wavelength presence and power level measurements, but also detect drift, offset, and channel spacing.

WDM link Tier 2 testing once again calls for an OTDR, but one that can perform the evaluations mentioned above across multiple wavelengths. OTDRs can be used both before multiplexing/demultiplexing is applied to a link as well as afterwards for certification and, when necessary, troubleshooting.

Pondering PON

PON hasn't been a popular method for backhauling 4G network traffic, principally because GPON and EPON didn't match well with the latency requirements of CPRI. However, with the advent of eCPRI and time-sensitive Ethernet in 5G schemes on the one hand and 10-Gbps PON approaches on the other, PON may prove a tempting choice for some operators, particularly if the infrastructure also can be used to support residential and business services delivery.

From a testing perspective, the wild card in PON deployments is the splitter, which adds another loss element to the network and can make end-to-end testing tricky. Test vendors recommend that one-sided OTDR tests be conducted from the optical network terminal/optical network unit end, which will be from the radio unit back toward the next hub. However, bidirectional OTDR testing is also recommended, as PONs transmit signals on multiple wavelengths and in each direction. OTDRs specially designed for the complexities of PON infrastructure are available from multiple vendors.

And you're ready to go

Once you've certified that the fiber network should be able to handle 5G traffic, the network operator isn't done with testing, of course. The transmission health of that traffic and overall network operation needs to be ascertained and monitored (as described in "Fiber Optical Testing Needs for the 5G Network Evolution"). But if the steps described here are taken, the foundation for a successful 5G fronthaul/midhaul/backhaul network will have been laid.

Stephen Hardy *is editorial director of Broadband Technology Report.*

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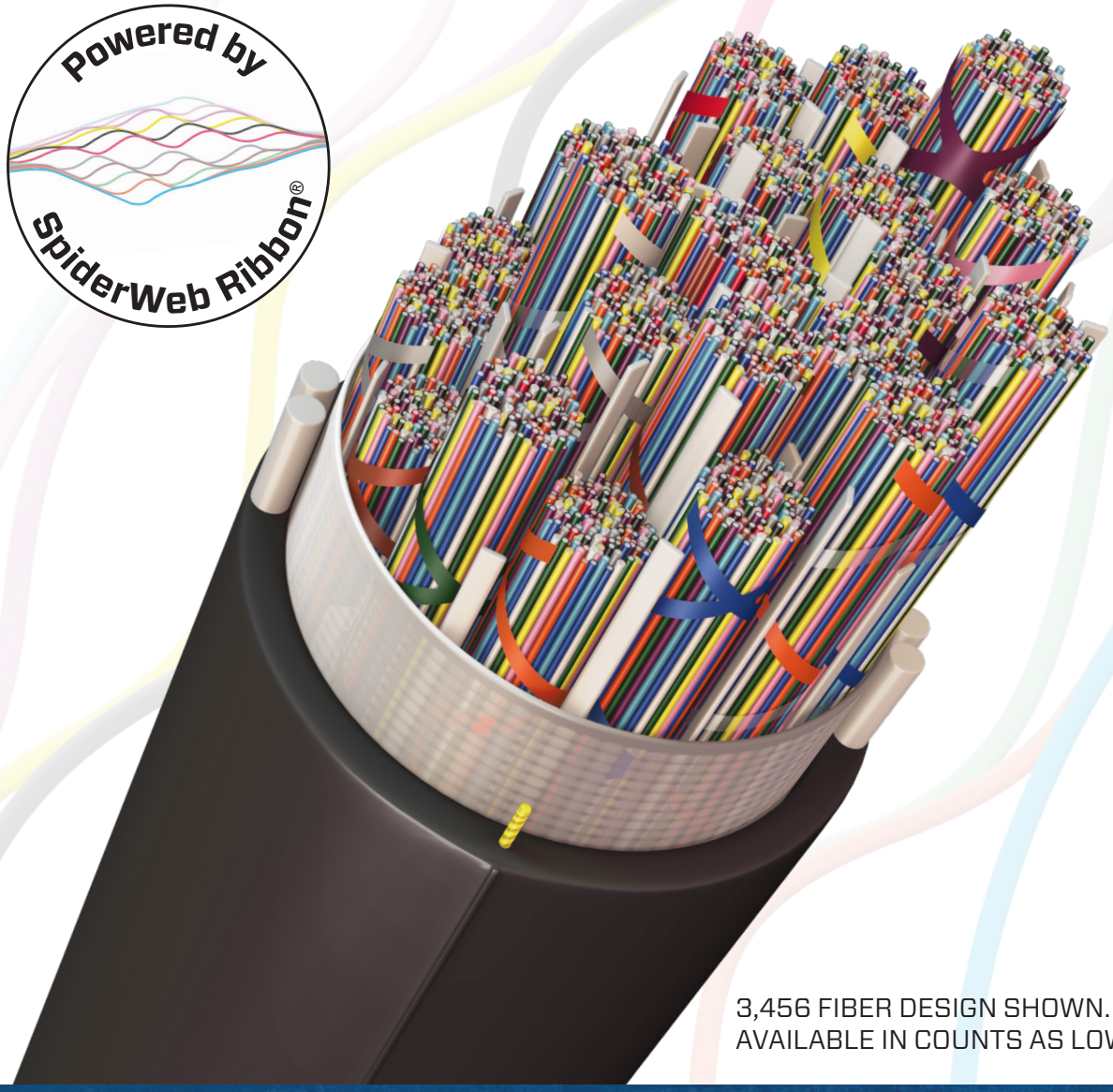

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Fiber Optical Testing Needs for the 5G Network Evolution

BY DANIEL GONZALEZ

As the network concepts and technologies develop for 5G, so will the corresponding test methods and processes evolve to keep pace. Future 5G test methods will need to provide a high confidence to operators that the technology and services are implemented according to specification and that the quality of service (QoS) matches the requirements of the application or service being delivered.

5G will be both an evolution and a revolution: an evolution as mobile evolves to support a wide range of new use cases, and a revolution as the architecture concept completely transforms to enable these attributes:

- provide fast, highly efficient network infrastructure
- support more device connections
- low latency, low power consumption
- data rates that exceed 10 Gbps.

5G includes the evolution of existing 4G networks that use technologies such as centralized radio access networks (C-RANs) and heterogenous networks (HetNet) to increase the capacity of existing networks at an affordable cost. But revolution for core architecture is on the way to fully use SDN/NFV and network "slicing," a new millimeter-wave-band air interface for higher capacity, and a new architecture/signaling for extremely low latency.

5G networks are expected to have speeds and bandwidth that match – or at least rival – wireline systems. To achieve that goal, new network design elements have been developed and there will be even greater integration of fiber optics into the fronthaul as well as the central unit (CU). Optical test systems that meet these expanded verification requirements have now been developed to address these new demands and help optimize installation and operation of 5G networks so they meet specified key performance indicators (KPIs).

Fiber's expanding role

Fiber has played a growing role in wireless networks, as expanding use cases have required greater network speed. That will become even more prominent with 5G, which will operate unlike any other wireless network due to its expanded latency requirements, bandwidth, and transmission speeds. This evolution has meant new standards, designs, and testing requirements.

When it comes to 5G transport, 3GPP is developing standards based on identifying different types of traffic and dividing the traffic by application. 4G treated all traffic the same with respect to transport. Applications are prioritized upon bandwidth need in 5G. Streaming video

for entertainment, surfing the Web, and similar are given a lower priority. For mission-critical applications, including industrial Internet, smart grids, remote surgery, and intelligent transportation systems, ultra-reliable low-latency communication (URLLC) is being used.

URLLC is part of GPP Release 15 and specifies 1-ms speed, which can only be attained with end-to-end low latency. It is ideal for mission-critical applications because of its security and 99% reliability. Because of these requirements, a different approach to system design and operations must be taken compared to 4G.

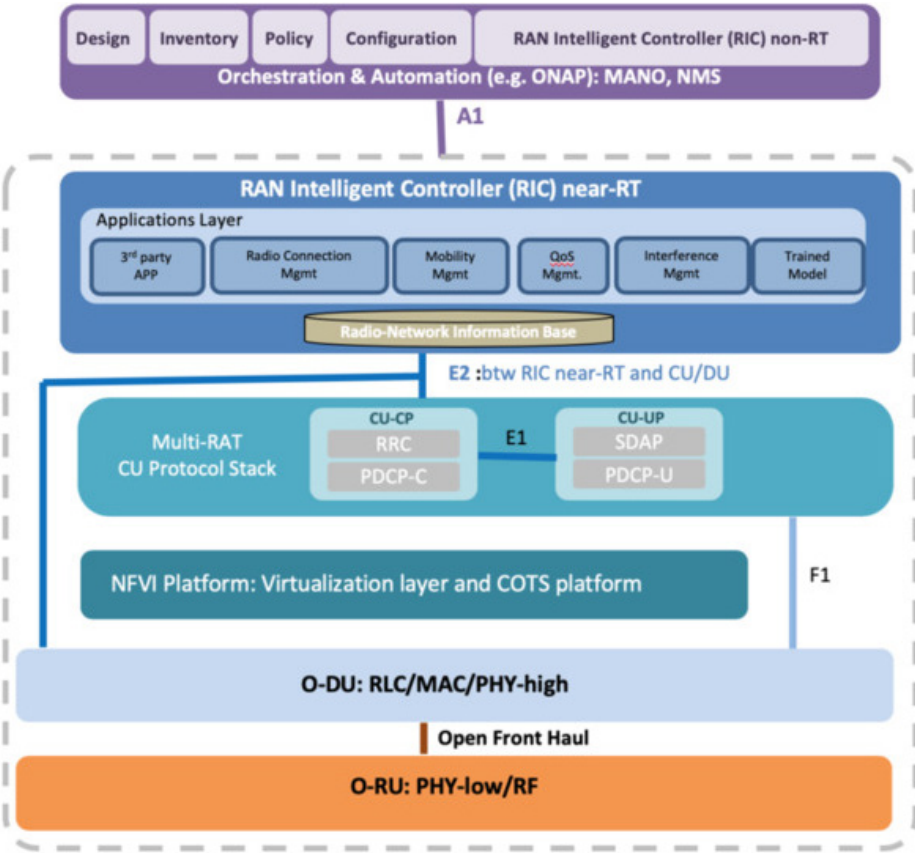

Figure 1. The Open Radio Access Network Alliance (O-RAN) architecture.O-RAN Alliance

The physical layer is daunting because URLLC must satisfy both low latency and ultra-high reliability. This combination creates a considerably different type of QoS goal compared to traditional mobile broadband applications. Therefore, enhanced mobile broadband (eMBB) services are integrated into URLLC to establish one 5G air interface framework.

Open standards for agnostic design

Mobile operators are driving an initiative to establish standards via the Open Radio Access Network Alliance (O-RAN) to evolve the fronthaul to satisfy the demands of 5G. O-RAN is an open standard designed to replace CPRI, which is a 4G specification developed by equipment manufacturers. Figure 1 shows the O-RAN architecture.

The O-RAN standard includes Open Fronthaul Specifications composed of control, user, synchronization, and management plane protocols. User planes will treat traffic based on the O-RAN protocol, so all the network equipment is compatible. Most operators and OEMs are committed to adopting the fronthaul specifications agreed to by the Alliance and are introducing O-RAN-compliant products in commercial 5G networks.

IEEE also developed two transport network standards for 5G networks. 1914.1 is for architecture and divides the fronthaul into two Next Generation Fronthaul Interface (NGFI),

or xhaul, elements to prioritize traffic. The standard splits traffic into the CU (Centralized Unit) and Distributive unit (DU). The 5G base station is divided into two logical segments. The DU performs the heavy processing of the data. Once that is complete, the data is sent to the RU for transmission with data given priority based upon use case and its mission-critical nature.

The other is IEEE 1914.3, which establishes the Radio over Ethernet (RoE) standard that specifies a transport protocol and encapsulation format for transporting time-sensitive wireless data between two endpoints over Ethernet-based transport networks. RoE was developed so networks can take the necessary evolution from CPRI to Ethernet. It is preferred over eCPRI, even though the latter provides a faster path for 5G deployment and utilization. eCPRI has the same concerns as CPRI in that it is a specification developed by equipment manufacturers, not an open industry standard. IEEE 1914.3 will be compliant with the O-RAN standard.

Optical testing in 5G networks

All these new standards and design considerations make verifying the performance of 5G networks a greater challenge. Testing takes on greater importance due to these variables, as well as the performance specifications associated with next-generation networks. Below are some important capabilities in field instruments as it relates to optical testing:

Bandwidth – Everyone knows 5G increases network bandwidth tremendously. With 4G, it was 10 Gbps, but it will be 25 Gbps per radio or sector with 5G. The transmission jump will increase aggregate data transmitted and received to a tower by 10X compared to 4G. For this reason, field transport testers need to measure high data rates to support this added bandwidth capability.

Data splicing – The functional split by application of 5G adds another verification step field technicians must make on networks. Field instruments need splicing testing capability to accurately measure the difference between low and high latencies.

Packet-based testing – Given the 5G standards and protocols that will split and prioritize data transmissions based upon their mission-critical nature, packet-based testing is a priority. Most field technicians are not experienced in this area, so simple profiles must be integrated into the test instrument. Such instruments also should enable duplicate testing in the field and repeatable measurements to be conducted that comply with 3GPP-based latency and timing thresholds.

Network synchronization – 4G networks are synched via cost-effective GPS, because LTE has favorable line of site. The 5G approach is to rely on Ethernet and the Precision Time Protocol (PTP) grandmaster clock, as defined by IEEE 1588, to distribute timing through the fiber to the nodes. Time-sensitive Ethernet networks will be used where GPS is not available or as a backup when GPS fails or jams.

There are two challenges associated with this approach. As a signal transmits through each network element the timing slips slightly. If there are too many elements, a timing error will occur. Phase error is another issue. Operators and network engineers need to determine the maximum number of elements to ensure coverage but not adversely affect timing.

To address this issue, two profiles were developed. The PTP G.8275.2 enhanced profile meets the synchronization requirements of technologies such as LTE-TDD, LTE-A CoMP, and LTE-MBSFN. The G.8275.1 profile is also used in networks where phase or time-of-day synchronization is required and where each network device participates in the PTP.

Because a boundary clock is used at every node in the chain between PTP grandmaster clock and PTP slave elements, there is a reduction in time error accumulation through the network.

Test instruments must measure the element threshold based upon these standards or performance issues, including dropped calls and outages, will eventually occur. Many of these problems will not directly point to poor synchronization, which makes troubleshooting long, expensive, and frustrating. Therefore, field technicians need a PPT-aware test set that can connect to the grandmaster clock to determine the nodes that are causing slips and fails. To conduct the most accurate timing error analysis, the test system should be able to measure timing error within +/-20 ms.

eCPRI/IEEE1914.3 (RoE) – For time and cost efficiencies, both eCPRI and RoE measurements should be made with a single instrument. Some instruments have a dual-port 25G eCPRI/RoE function to optimize testing by offering efficient signal generation and analysis plus precision one-way latency measurement of transport networks. This ability provides support for implementing URLLC.

Conclusion

Fiber networks and the testing of fiber optics will play significant roles in the evolution of 5G. 5G networks require multiple new design elements and standards to achieve the latency, speed, and bandwidth expected by the next-generation network, as well as meet the needs of many mission-critical use cases. Because of this, transport testing has become more robust and complicated. Field test tools must address the standards and measurement requirements in a simple and efficient manner for optimal deployment, installation, and operation of 5G networks to achieve KPIs.

Daniel Gonzalez *is a business development manager for Anritsu Co. He possesses more than 17 years' experience in digital and optical transport testing, development, training, and execution spanning technologies including TDM, SONET, OTN, ATM, Carrier Ethernet and physical layer signal integrity. In his current role, he is responsible for providing technical support to sales, marketing and customers in North and South America.*

Fiber update: Progress continues despite COVID-19

BY MONTA MONACO HERNON

The thought is that in 2020 essential fiber deployments will continue, but the coronavirus situation will cause some planned installations to be adjusted because of unanticipated capacity demands, said Rosemary Cochran, principal of Vertical Systems Group. Meanwhile, test equipment companies are doing their part to ensure these deployments go smoothly.

By the end of 2019, there were more than 1 million fiber-lit buildings in the United States according to Vertical Systems Group. Network providers concentrated on footprint expansion with new fiber deployments providing dedicated access to network services, connecting 5G small cells, enabling low latency for edge computing, and supporting the massive bandwidth surge for webscale companies.

The VSG LEADERBOARD results indicate that in the United States AT&T led the number of on-net fiber-lit buildings, followed by Verizon, Spectrum Enterprise, Comcast, Cox, Crown Castle Fiber, Frontier, Zayo, Altice USA, Atlantic Broadband, Windstream and Consolidated Communications. The 13 retail and wholesale fiber providers each had 10,000 or more on-net U.S. fiber-lit commercial buildings as of year-end 2019.

Additionally, 12 companies qualified for the 2019 Challenge Tier as follows (in alphabetical order): Cincinnati Bell, Cleareon, Cogent, Conterra, DQE Communications, Everstream, FirstLight, IFN, Logix Fiber Networks, Segra, Unite Private Networks, and Uniti Fiber. Those fiber providers each had between 2,000 and 9,999 U.S. fiber-lit commercial buildings.

Fiber-to-the-home (FTTH) announcements continue with Mississippi-based Monroe County Electric Power Association (EPA) selecting Conexon to provide broadband management services including network design and engineering, construction management, and customer support for the association's FTTH network.

Monroe County EPA plans to begin construction on the network by 4Q 2020, with the first customers expected to be connected by early 2021. The four-year buildout is planned to span 1,500 miles of fiber, serve 100% of the power association's 10,800 members and is anticipated to cost in the range of $29 million.

From a home installation standpoint, ClearField has introduced Home Deployment Kits designed to streamline FTTH installation. The kits, which include everything needed to connect a home to

fiber, are intended to reduce install time by 30 minutes per install and also to enable consumer self-installs.

Clearfield's new Home Deployment Kits are designed to complete the fiber connection from outside the home to the point where the customer premises equipment (CPE) is located inside the home, regardless of home size, shape, and building material, by packaging all the necessary materials in one kit.

Home Deployment Kits are expected to be available for shipment in May.

Other vendors continue to be active as well. AFL was awarded two new patents over the past quarter for technology and developments in optical connectivity and apparatus (OCA) products.

The first patent is for "Communications Module Housing." The commercialized product–the CGM Plus–is a rack-mount panel that accepts different size and form factor xWDM modules (CGM and LGX). The invention includes a fiber management guide region that pivots downward to allow access to the module storage slots, allowing for flexibility in the field to combine various modules for xWDM applications.

The second patent is for "Methods, systems and apparatus for manufacturing a cable assembly with breakout and molded cable assembly." The patent recognizes a process for creating a cable assembly furcation kit for protection of fibers under extreme environmental conditions. It also provides for scaling across a range of fibers. The new system has enabled AFL to improve manufacturing efficiencies via an automated machine that creates a uniform profile of the furcation tubes to ease the insertion of fiber into the right slots and provide the proper dimension to securely fit into the module. AFL has standardized on this format, calling it the SST furcation system.

A testing time for fiber

Meanwhile, test system vendors have continued to bring new tools to market to help operators improve the efficiency and success of their deployments. For example, AFL earlier this year unveiled the ROGUE OLTS Certifier. Applicable to a wide variety of fiber installation scenarios, the two-unit optical loss test set (OLTS) features a test port on each of the paired units to measure insertion loss, return loss and length bi-directionally to industry standards on multimode or single-mode networks.

The ROGUE units are available with dual bi-directional test ports that enable technicians to certify two single-mode fibers simultaneously without swapping test cords. The OLTScan be paired with an optional multi-fiber switch to certify MPO-terminated fiber cables bi-directionally to IEEE 40G and 100G test limits.

EXFO recently introduced the Optical Wave Expert, which integrates DWDM channel power validation and OTDR fault-locating capabilities on a single port to help field technicians automatically measure, diagnose and troubleshoot optical fiber links.

The integration of channel checker and OTDR capabilities on a single port is intended to reduce unnecessary manipulation of the optical fiber and improve field efficiency to reduce time-to-repair and accelerate service turn-up. Real-time channel power readings are available through a GUI environment, as well as bar graph and table views on a touchscreen display.

VIAVI Solutions launched OneAdvisor, a modular 5G instrument test platform. The first OneAdvisor solution, ONA-800, combines technology coverage, test features, and test process automation to facilitate aggressive 5G wireless network deployment at scale.

The ONA-800 is designed to allow cell site technicians to test fiber, RF, and CPRI/Ethernet from a single instrument, replacing multiple independent tools (OTDR, CAA, fiber scope). The workflow UI in the instrument is designed to guide technicians through a pre-configured common test process, and it is supported by reporting and workflow software to automate job certification reports.

The ONA-800 combines the relevant features of VIAVI's CellAdvisor 5G base station analyzer, T-BERD/MTS-5800 handheld Metro Ethernet test solution, and T-BERD/MTS 4000 OTDR into a portable form factor designed to allow a distributed workforce to address multiple network technologies from site to site.

The ONA-800 can be configured to test fiber, coaxial cable, RF spectrum, Common Public Radio Interface (CPRI), Ethernet and antenna alignment, based on carrier test plans.

Last fall, VeEX announced the NET-BOX, a multi-port HTTP/TCP test set for the gigabit Internet market to help assure customers that they're receiving the fiber-supported bandwidth they've been promised. Driven by a tablet or smartphone app, the battery-operated test set (Patent No. US008902607) offers four simultaneous 1 GigE ports, along with one 2.5 GigE SFP port. The NET-BOX is designed to deliver up to 4 Gbps of Layer 4+ throughput line rate.

The NET-BOX is an FPGA-based QoS testing platform designed to test the limits of the service being provisioned, verify QoS and assure QoE for Internet services beyond 1 Gbps.

Monta Monaco Hernon *is a Contributing Writer for Broadband Technology Report.*

Founded in 1984, AFL is an international manufacturer providing end-to-end solutions to the energy, service provider, enterprise and industrial markets as well as several emerging markets. The company's products are in use in over 130 countries and include fiber optic cable and hardware, transmission and substation accessories, outside plant equipment, connectivity, test and inspection equipment, fusion splicers and training. AFL also offers a wide variety of services supporting data center, enterprise, wireless and outside plant applications.

- **VIDEO:** FlexScan® FS300 Quad OTDRs with SmartAuto® & LinkMap® Overview
- **PRODUCT:** OTDRs and Fiber Characterization
- **BLOG:** The Best Medicine for Network Outage Headaches
- **PRODUCT:** Fiber Identification
- **PRODUCT:** Optical Loss Testing