

# Mobile fronthaul

## Testing reference guide

A best practices approach for validating  
fronthaul networks

Smarter  
network  
in sight™

**EXFO**

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# 1 Introduction

The mobile industry is undergoing a major transformation that is being driven by the exponential growth of traffic (mobile broadband and video), new services (e.g., the Internet of Things and private mobile radio) and new requirements (lower latency and ubiquitous coverage). The traditional radio access architecture is migrating to a distributed architecture (centralized radio access network [C-RAN]), with the replacement of copper radio frequency (RF) cables by optical fibers (fiber-to-the-antenna, or FTTA). This transformation requires a split of the radio elements (remote radio head [RRH] or remote radio unit [RRU]) and the broadband unit functions (baseband unit [BBU] or digital unit [DU]), and deployment of two competing digital RF communication protocols: Common Public Radio Interface (CPRI) and Open Base Station Architecture Initiative (OBSAI). These elements are typically referred to as *fronthaul technology*.

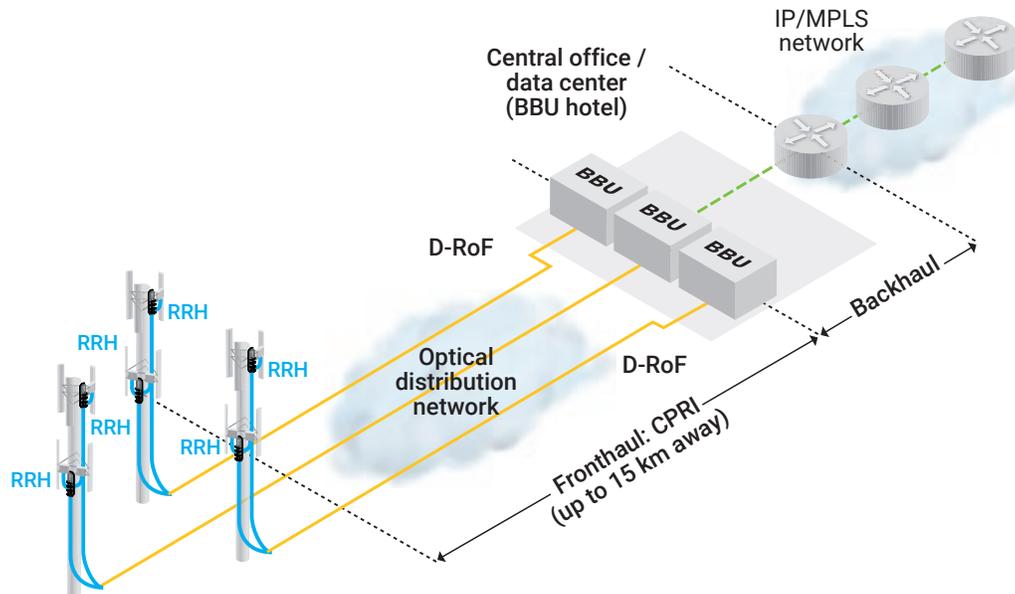


Figure 1. A typical fronthaul network

This document will start with a review of the best practices applicable when the RRH and BBU are collocated, which represents the foundation for the next step: C-RAN. In a C-RAN environment, the BBUs are pooled at a central site, usually in a central office or data center—also commonly referred to as the *BBU hotel*. Next, the document will review best testing practices applicable during C-RAN deployment.

Prior to discussing the fronthaul, it is important to take a closer look at the RAN architecture without any fronthaul implications, as follows:

- The mobile core is connected to the base station through an IP network that is referred to as the *backhaul*
- The base station (BTS or Node B/eNodeB) itself is made up of the following four components:
  - The BBU, which is the intelligence of the RAN (eNodeB or eNB)
  - Radio management
  - RF amplifiers
  - Antennas
- Antennas are connected to the cell-site cabinet through copper cables, which have the following disadvantages:
  - Are very expensive
  - Are subject to passive interference modulation (PIM)

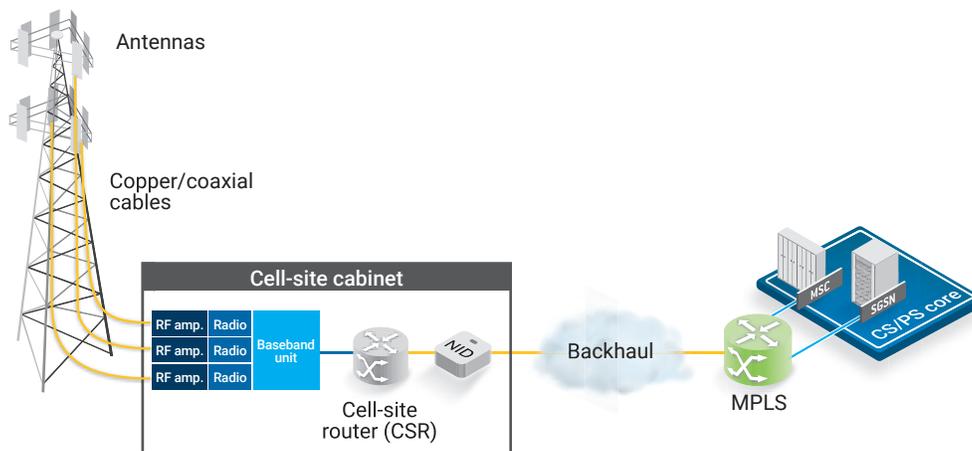


Figure 2. Typical architecture for 2G/3G cellular deployments

To reduce costs and replace copper cables, the radio/RF component is displaced to the top of the cell tower or rooftop. This new element, the remote radio head (RRH), is connected to the BBU through optical fibers. This connection between the RRH and BBU is referred to as the *fronthaul*, and uses the CPRI transport protocol. The fronthaul supports all radio access technologies (RATs), including 2G, 3G, 4G LTE and LTE A; it will soon support 5G as well.

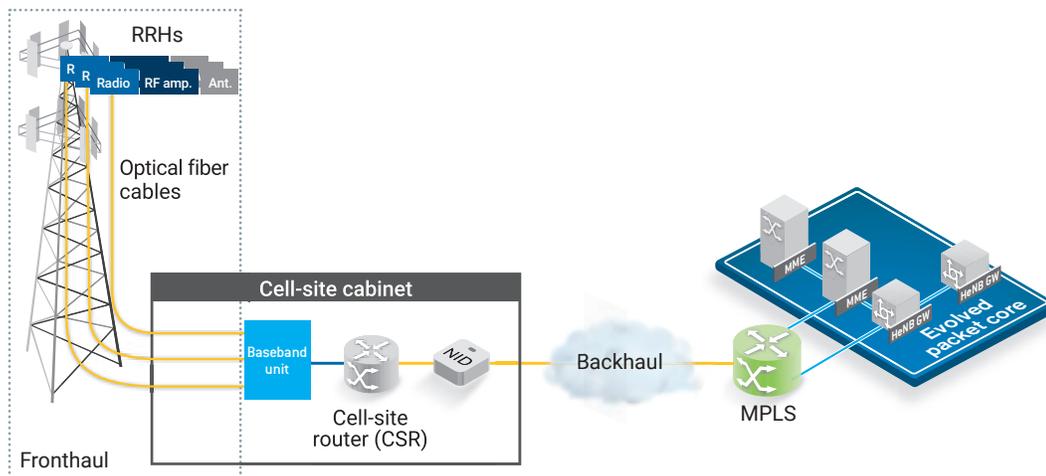


Figure 3. Typical architecture for 4G/LTE cellular deployments

With fronthaul architecture, the mobile communications industry is going through a major transformation in radio access. As such, the deployment, maintenance and assurance of fronthaul requires a new test methodology combining optical fiber and transmission testing, as well as service assurance.

Fiberization of antenna sites is the first and most significant step for:

- The deployment of new RATs (e.g., LTE-A coordinated multipoint [CoMP])
- Increased RAN efficiency (C-RAN)
- Preparation of the 5G era (with RAN virtualization and mobile edge computing, or [MEC])

FTTA is the foundation of RAN modernization. Testing FTTA at the rollout phase will ensure the readiness of the antenna sites to support:

- The next evolution to C-RAN
- The increase of bit rates (larger carrier bands)

FTTA is the first critical step towards the adoption of new RAN architectures such as C-RAN (and vRAN, its virtualized flavor), and the addition of service-specific processing at the RAN level for services such as Video on Demand (VoD) and local content delivery network (CDN) functions (MEC).

Given the importance of FTTA as the foundation for next-generation wireless architectures, a high level of vigilance is required during its deployment phase. If the execution of the FTTA rollout is performed without quality measures in place, the cell site will require retesting, and may need a rebuild to ensure efficient centralization of BBUs.

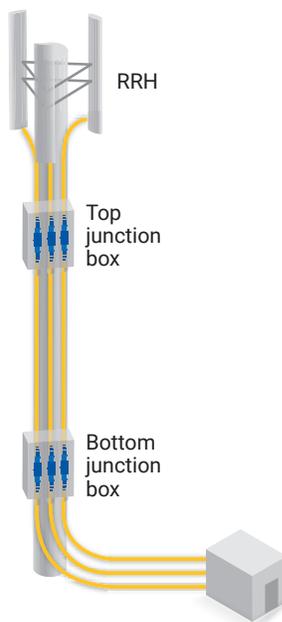
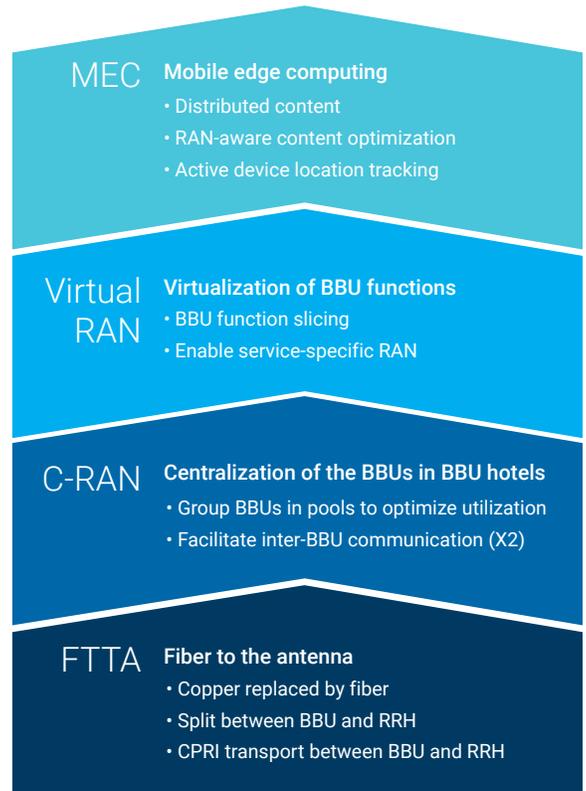


Figure 4. FTTA deployment with collocated BBU and RRH at the cell-tower location

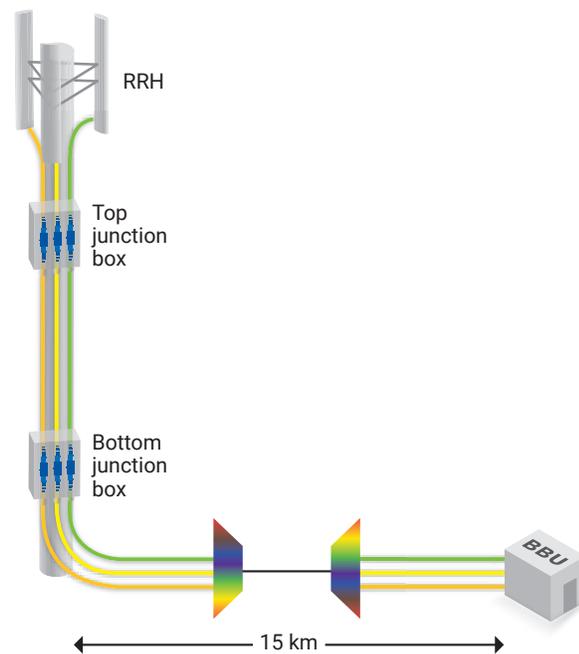


Figure 5. C-RAN architecture: FTTA deployment using a CPRI transport system

## Best practices—testing during the construction phase

Installation of the optical physical layer during the construction stage is one of the most important steps towards an easy-to-maintain system. However, many customers have been observed using a no-test approach early on in the deployment phase. During a mobile fronthaul installation, there can be as many as four connection points, and this is where many issues will first be seen, as confirmed by professionals with fiber experience. Another key element is the type of fiber used. For example, some installations have bend-resistant fibers (ITU-T G.657), whereas others use standard fibers (ITU-T G.652), which is sensitive to macrobending. Fiber mismatch is also a very common issue, in which the connector is not well seated into the small form-factor pluggable (SFP), the wrong SFP is used, or the SFP data rate is incorrect. In addition, because optical fibers with different wavelengths are used for wavelength-division multiplexing (WDM) systems (mainly in C-RAN deployment), it is very important to ensure that the right wavelength from the customer is connected into the right port on the WDM muxes and demuxes. Old dark fiber is rented and prone to impairments, such as chromatic dispersion (CD) or polarization mode dispersion (PMD). As a result, if the work is not done properly, the turn-up team that is called on-site may have to send for another climbing crew in order to change the SFP, which is expensive, ranging from \$1,000 to \$1,500 per day, depending on the region.

This document describes all the steps needed to improve the key performance indicator, which is *do it right the first time!*

## 1.1 Fiber characterization

The purpose of any fiber-optic network is to perform high-speed, error-free data transmission. Adequate testing during each phase of the network deployment guarantees that products meet specifications, in addition to minimizing costly and time-consuming troubleshooting efforts such as locating dirty/damaged connectors, questionable splices and other faulty components before they disrupt service.

One of the most important factors in ensuring proper transmission is controlling the power loss in the network against the link loss budget specifications from the network design requirements. This is done by establishing a total end-to-end loss budget with sufficient margin while keeping back reflection to a minimum. The following section will take a closer look at parameters that are capable of greatly affecting network performance.

One of the first tasks that needs to be performed during the design phase of a fiber-optic network is an evaluation of the acceptable budget loss in order to create a product that will meet application requirements.

What causes loss in the fiber? Loss includes both intrinsic attenuation and extrinsic discontinuities in a fiber-optic cable, such as connectors and splices. Link loss is wavelength dependent, measured in decibels per kilometer or dB/km, and used in calculations for determining the overall loss budget.

The following key parameters are usually considered in order to adequately characterize budget loss:

- Transmitter: launch power, temperature and aging
- Fiber connections: connectors and splices
- Cable: fiber loss and temperature effects
- Receiver: detector sensitivity
- Others: safety margin and repairs

When one of these variables fails to meet specifications, the performance of the network could be greatly affected—or worse, the degradation could lead to network failure.

The illustration on the right (Figure 6) shows an example of the typical total loss budget calculation.

Important specifications for consideration:

- Connector loss, typically around 0.2 dB per connector pair.
- Fiber loss, which is equal to attenuation multiplied by distance. The maximum distance is limited by the loss budget at the worse-case attenuation wavelength (1310 nm with approximately 0.33 dB/km attenuation). The maximum length in an RRH application will be hundreds of meters for a large deployment.

The budget loss calculation should be one of the first verifications performed prior to any deployment. If, for example, a system is designed with the elements present in the figure below, the launch power of the transmitter at 1550 nm is 0 dBm, and the detector sensitivity is at -10 dBm, the accepted budget loss of 10 dB will compromise system performance. However, tighter design tolerances can be set in order to prevent long-term evolution of the network. For example, the typical budget loss in a collocated BBU-RRH will be between 1.5 dB and 3 dB, depending on the number of connectors or splices present. Still, in a passive C-RAN installation, the budget will be affected by the different elements, leaving less margin. In the example below, the budget loss could vary from 8.8 dB up to 14.7 dB if at the maximum of each tolerance.

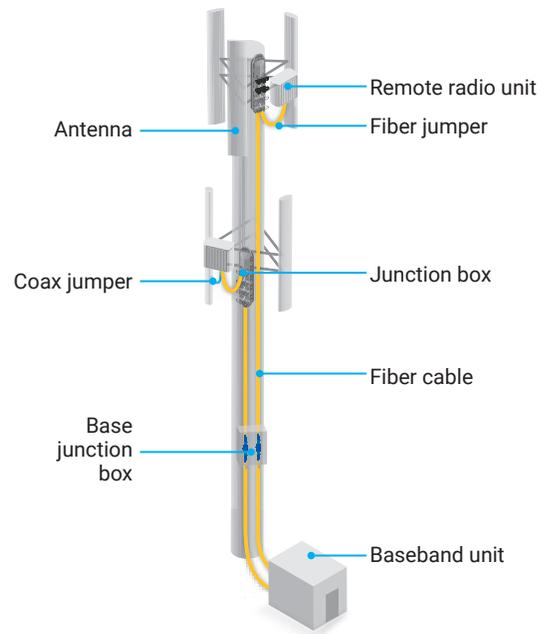


Figure 6. Typical RRH installation

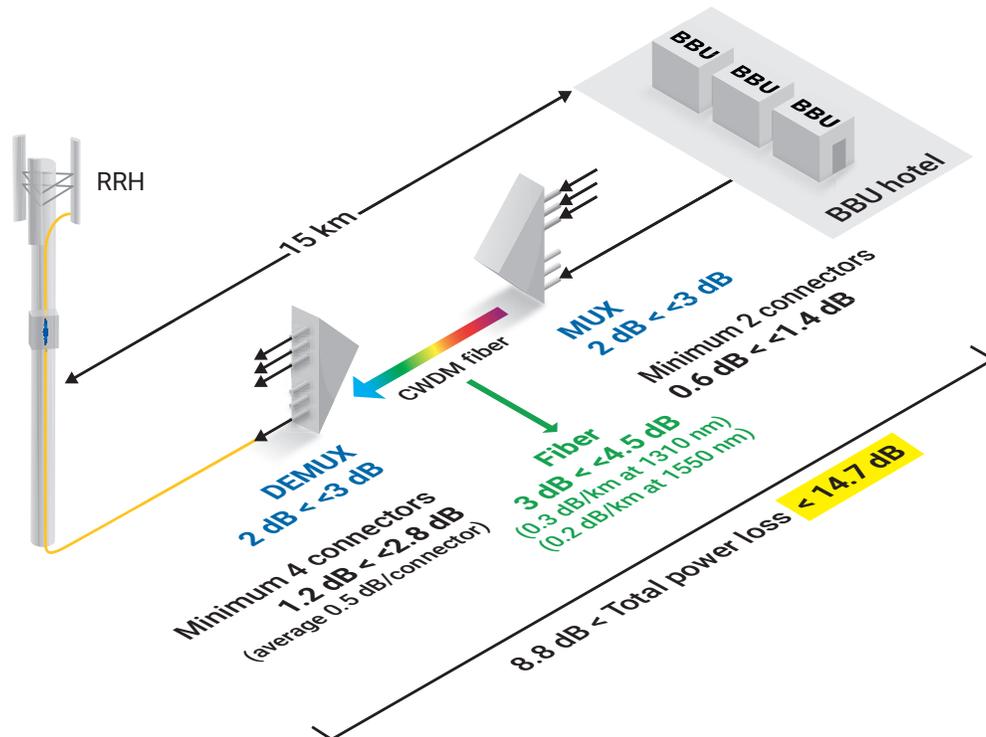
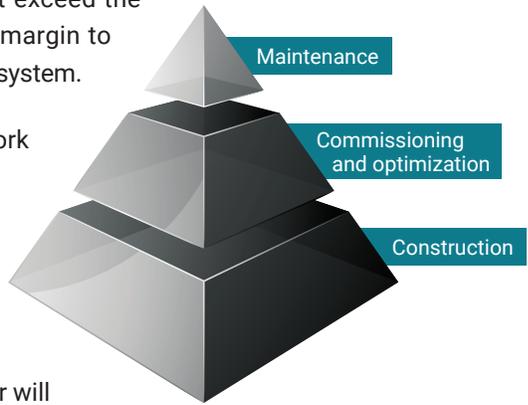


Figure 7. Budget-loss variation in a passive C-RAN installation

Therefore, the total loss measured during network deployment should not exceed the total loss budget allowed by the system design, and should have enough margin to compensate for any loss fluctuation that could occur during the lifecycle of the system.

Once the design of the system has been completed, the lifecycle of a network generally consists of three main phases, as shown in the diagram to the right. This section focuses primarily on fiber characterization during the construction phase.



The bottom of the pyramid represents the construction deployment stage, which involves most of the work required to prepare the dwelling-connected fiber up to the fiber expansion units. In some cases, the installation contractor will be responsible for this stage.

Installation of the optical physical layer during the construction stage is one of the most important steps for an easy-to-maintain system and a high return on investment. Sufficient testing during construction will locate problematic splices, dirty or damaged connectors, and other faulty components before they can cause service disruption—all of which minimizes costly and time-consuming troubleshooting efforts during the commissioning phase. It is therefore essential to implement best practices for optical testing during this phase in order to ensure a successful yet easy-to-maintain RRH in the future.

Proper connector care and fiber-optic cable handling are important pieces of the puzzle, and ensure a less problem-prone network. Another important aspect is end-to-end fiber documentation. These documents are critical to ensuring a shorter response time to resolve customer complaints or service interruptions caused by network-related issues.

Testing during the construction phase is a key step to:

- Qualify each fiber section of the system and document it for future reference
- Ensure that transmission system requirements (standards) are met
- Avoid delays and costly repairs once the system has been turned up

	Construction
<b>Test type</b>	Out-of-service test
<b>Why test?</b>	<ul style="list-style-type: none"> <li>– To qualify each optical element (e.g., fiber and connector) of the system</li> <li>– To ensure the installation meets transmission system requirements</li> <li>– To avoid delays and costly repairs during system turn-up</li> <li>– To future-proof the network</li> </ul>
<b>Test parameters</b>	<ul style="list-style-type: none"> <li>– Connector and ferrule cleanliness</li> <li>– Optical loss or insertion loss (IL) of each element</li> <li>– Total end-to-end loss as compared to the optical loss budget</li> <li>– Fiber mapping</li> <li>– Optical return loss (ORL) measurement, especially for RF/analog video</li> <li>– In C-RAN: CD and PMD for long fiber (&gt;10 km)</li> </ul>
<b>Test gear</b>	<ul style="list-style-type: none"> <li>– OTDR or intelligent Optical Link Mapper (iOLM)</li> <li>– Fiber inspection probe</li> <li>– CD and PMD</li> </ul>
<b>Testing considerations</b>	<ul style="list-style-type: none"> <li>– Connector inspection</li> <li>– Testing at different wavelengths (1310 nm and 1550 nm) for IL and ORL</li> <li>– LinkView or OTDR trace documentation using 1310/1550 (reporting)</li> <li>– Data storage</li> <li>– Testing the total link or segments</li> <li>– Applicable work/labor</li> </ul>

## 1.1.1 Connector inspection

All connectors on the link must be inspected using the inspection tools indicated in the section below. Inspection results are held to International Electrotechnical Commission (IEC) standards for acceptance criteria selected in the user interface. Most fiber connectors present in the RRH application will be LC/ultra-polished connector (UPC), and will require use of the **IEC SM SF UPC ORL  $\geq$  45 dB (61300-3-35, 1.0)** configuration.



To inspect the APC connector on the iOLM port, the **IEC SM SF APC (61300-3-35, 1.0)** configuration is required.



				
<b>Part number</b>	<b>FIPT-400-LC-SQ</b>	<b>FIPT-400-LC-APC</b>	<b>FIPT-400-FC-SC</b>	<b>FIPT-400-SC-APC</b>
<b>Description</b>	LC/UPC tip for bulkhead adapter	LC/APC tip for bulkhead adapter	FC-SC/UPC tip for bulkhead adapter	SC/APC tip for bulkhead adapter
				
<b>Part number</b>	<b>FIPT-400-U12M</b>	<b>FIPT-400-U12MA</b>	<b>FIPT-400-U25M</b>	<b>FIPT-400-U25MA</b>
<b>Description</b>	Universal patchcord tip for 1.25 mm LC ferrules	Universal patchcord tip for 1.25 mm LC APC ferrules	Universal patchcord tip for 2.5 mm SC ferrules	Universal patchcord tip for 2.5 mm SC APC ferrules
				
<b>Part number</b>	<b>FIPT-400-LC-A6</b>	<b>FIPT-400-MF-MPO</b>	<b>FIPT-400-MF-MPO-APC</b>	<b>FIPT-400-MF-MPO-X</b>
<b>Description</b>	LC angled tip for bulkhead adapter (60 degrees)	MPO/UPC Universal Patchcord and Bulkhead 12 fibers row connector. Compatible with single and dual row connectors, up to 24 fibers	MPO/APC Universal Patchcord and Bulkhead 12 fibers row connector. Compatible with single and dual row connectors, up to 24 fibers	MPO/UPC Universal Patchcord and Bulkhead 16 fibers row connector. Compatible with single and dual row connectors, up to 32 fibers

## 1.1.2 Inspecting and cleaning a connector

As detailed in the previous section, connectors are key elements that interconnect the different components of a network; failure to inspect and clean them as needed can lead to network failure.

### Where and what to inspect and clean

- Active equipment (BBU and RRH)
- CPRI panel
- Junction box
- Test jumper
- Cable connectors
- MUX/DEMUX (add/drop), if not spliced

### When to inspect and clean the connectors

The very first step to fiber testing is inspection of connectors at all testing phases (construction, optimization and maintenance). Connectors should be cleaned only if inspection reveals they are dirty.

### What to look for during connector inspection

During inspection of a connector ferrule, two types of problems may be encountered: a damaged endface or a dirty endface.

Physical damage to connector endfaces is generally permanent and in most cases will require connector replacement, except in cases where the damage is not detrimental to the endface. When determining whether or not the damage is detrimental, a good rule of thumb is to discard or replace any connectors with scratches near or across the fiber core (Figure 8.a), because these scratches can generate high loss and affect connector performance. For physical damage, including chipped cladding (Figure 8.b), worn connectors, and/or excessive epoxy residue on the cladding, the connector must be replaced.

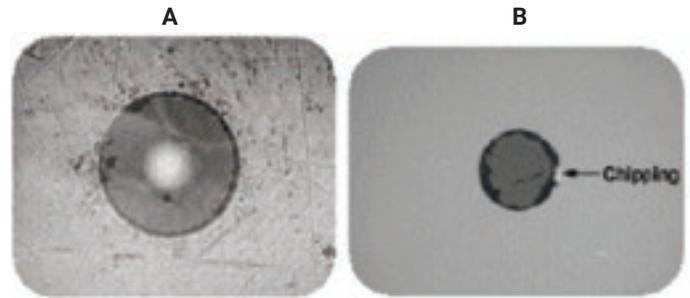


Figure 8. a) Scratch in the core region; b) Chipping on the cladding

In an ideal environment (i.e., free of contaminants), connector endfaces would remain clean and never require in-depth maintenance. However, this is rarely the case due to the high amount of fiber-optic connector contaminants present in most situations. For example, a 1  $\mu\text{m}$  dust particle on a singlemode (SM) core is capable of blocking up to 1% (0.05 dB loss) of light and, accordingly, a 9  $\mu\text{m}$  dust particle would block a significantly higher percentage of light. Another factor that should be taken into consideration is the effect of high-power components on the connector endface. Some modern telecommunications components can produce signals with power levels up to 30 dBm (1 W); this can have catastrophic results when paired with a dirty or damaged connector endface (e.g., fiber fuse).

Dust, isopropyl alcohol, oil from hands, mineral oils, index-matching gel, epoxy resin, oil-based black ink and gypsum are among the contaminants that can affect a connector endface. Some of these contaminants are single soil particles, whereas others are complex soil combinations.

Note that each contaminant shows up differently and, regardless of the appearance of these contaminants, the most critical areas for inspection are the core and cladding because contamination in these regions can greatly impact signal quality. Figure 9 illustrates the endfaces of different connectors that have been inspected with a video inspection probe.

A best practice to avoid connector endface damage or contamination is to always keep a protective cap on unused connectors. As such, it is also important to store unused protective caps in a sealed container to prevent contamination.

When inserting the protective cap on a ferrule, do not push it all the way in, because small dirt particles can accumulate at the bottom of the cap and contaminate the connector endface upon contact. Note that outgassing from the manufacturing process of the dust cap can leave a residue of the mold release agent or materials in the cap; the role of these protective devices is merely preventive—their presence does not guarantee cleanliness. In addition, test jumpers and connectors received in sealed bags from the supplier may not have been clean at the time of packaging, in which case they will be dirty upon removal. Fortunately, soiled connectors can be cleaned effectively using the appropriate cleaning tools and procedures.

**Note:** To ensure cleanliness, inspection should be performed on all brand-new, factory-delivered jumpers and cables.

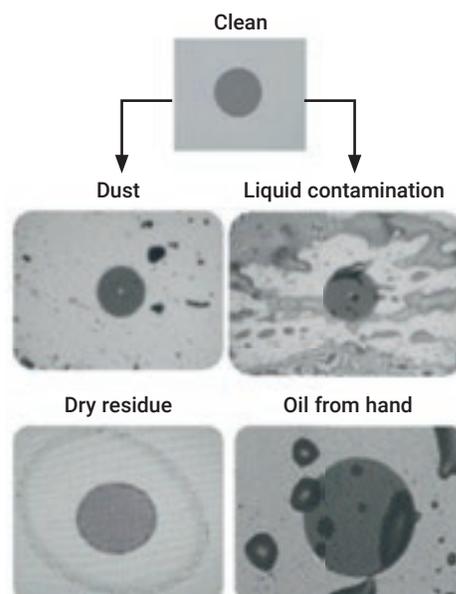


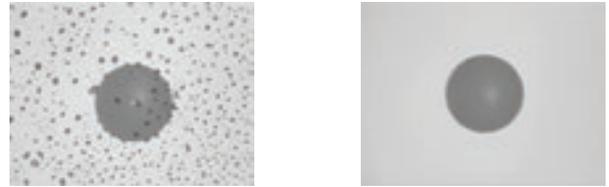
Figure 9. Clean connector endface vs. different contaminant types

## Most common connector issues

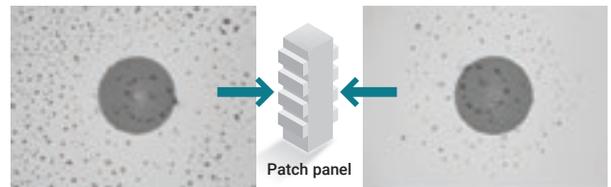
### Dust/dirt residue

If connectors are not cleaned properly, residues will be transferred and can lead to permanent damage during mating.

Before mating

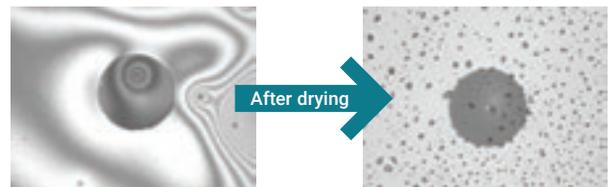


After mating



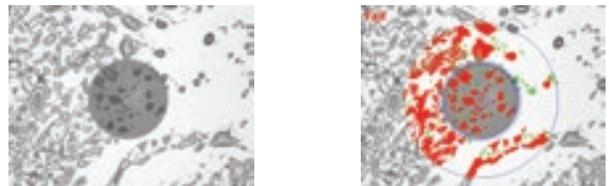
### Wet residue

- Most often caused by an incorrect cleaning technique
- Fibers must be carefully dried after a wet cleaning



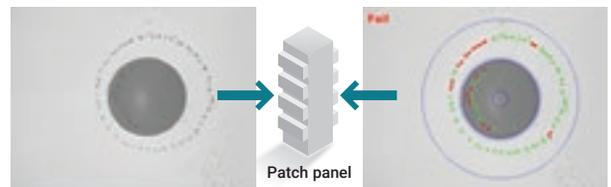
### Oily residue

- Most often caused by touching with fingers; technicians must avoid touching the fiber ends
- An oily residue may act as a matching gel
- May or may not affect IL and return loss (RL) in the short term
- May trap dust and increase IL and RL over time



### Circular residue

- Most often caused by an incorrect cleaning technique
- Occurs when fiber is mated while still wet
- Typically happens in the contact area
- Contamination will migrate from male to female fiber ends



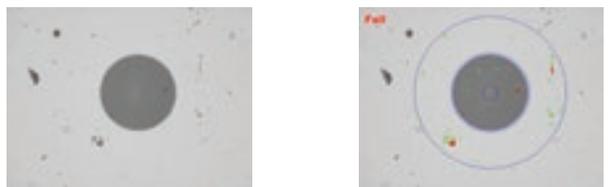
### Adhesive region defects

- May occur during the manufacturing process or from mishandling
- Epoxy residue and chips may occur in this region
- Normal if size does not exceed standards



### Dirty/damaged connector

- Most often results from poor handling or cleaning
- Defects appear small, but may still fail inspection criteria



### Scratches

- May appear as light or dark defects
- May be difficult to see with the naked eye
- Critical when in the core area of SM fibers



## Step-by-step inspection instructions

1. Connect the probe to the connector being inspected, and then select the corresponding IEC standard.
2. Set the probe magnification to high.\*
3. Locate, center and adjust the focus.\*
4. Start the analysis using the Capture button.
5. View the pass or fail result.
6. Clean or replace the connector, depending on the result.
7. Save the analysis report.

\* During inspections performed using the FIP-430B/FIP-435B Wireless Fiber Inspection Probe, steps 2 and 3 are automated.



Figure 10. Step-by-step inspection instructions

## Tools needed for cleaning

Appropriate cleaning methods and accessories must be used on any connector that fails acceptance criteria for endface inspection. Failure to use proper cleaning accessories and techniques may result in connector damage and/or network failures.

### Dry cleaning

The first recommended step is to use a mechanical cleaner. If, after two dry cleaning attempts, there is still soil on the connector, proceed to hybrid cleaning.



Single-fiber mechanical cleaner  
(male/female)



Multifiber mechanical cleaner  
[MTP/MPO] (male/female)



Patchcord mechanical cleaner  
(female only)

### Dry cleaning method

Insert the jumper, and then push the outer shell to begin cleaning. A clicking sound will indicate that cleaning is complete. Some mechanical cleaners are compatible with male and female jumpers, in addition to multifiber push-on (MPO) and other connectors.



### Hybrid cleaning

Hybrid cleaning is a combination of the wet and dry cleaning methods, and involves use of a solvent. The first step involves cleaning the connector endface with a solvent and then drying off any remaining residue using either a wipe or swab. If, following the hybrid cleaning procedure, the connector still fails to meet the acceptance criteria, it should be replaced.



**Cleaning pen**  
Used to dispense optical grade solvent to clean optical connectors



**Cleaning swabs**  
Used to clean the inside of female connectors and adaptors



**Lint-free wipes**  
Used in dry cleaning procedures and also used to dry out any solvent

### Cleaning connectors using the hybrid method

1. Wet a corner of the wipe with solvent.
2. Using a smooth, linear motion, trace the endface of the jumper over the wet area two times.
3. Using a smooth, linear motion, trace the endface of the jumper over the dry area three times.

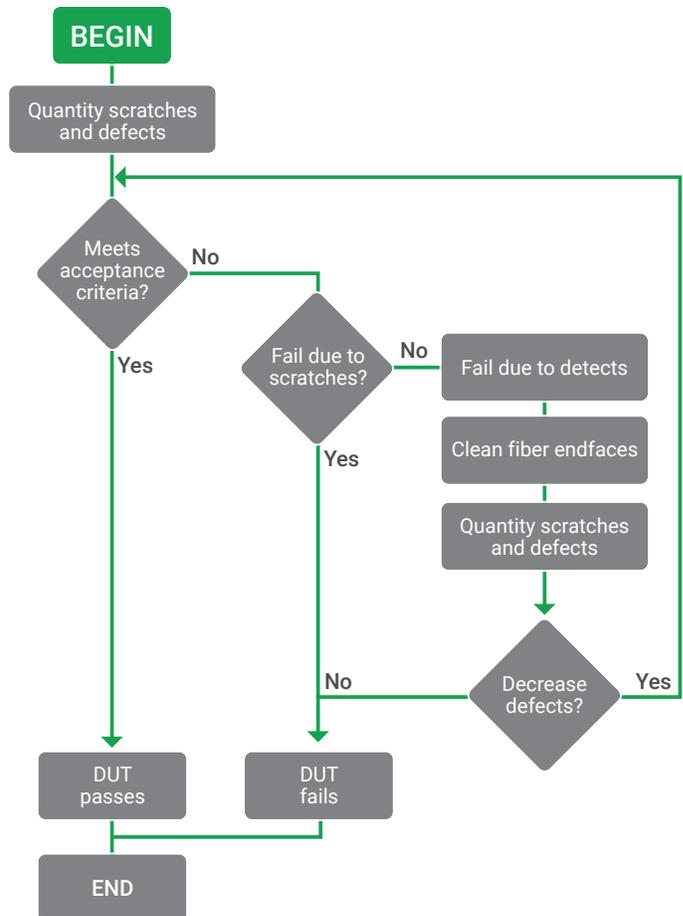


Figure 11. Flowchart demonstrating the inspection procedure recommended by the IEC-61300-3-35 standard (<http://webstore.iec.ch/webstore/webstore.nsf/artnum/034902>)

### 1.1.3 Fiber loss measurement

For these characteristics, an OTDR-based measurement method is recommended, and is described in IEC 61280-4-2. Although alternative methods of performing end-to-end loss measurement do exist (e.g., handheld power meters and light sources), only an OTDR-based method will provide full characterization and mapping of each element (connector, splice and fiber section) present on the link. OTDRs can also be used to find faults that could be present on the link.

Detailed analysis of these OTDR traces allows for accurate measurement of total link attenuation and total link ORL; it also provides a full breakdown of component losses along the link, including fiber section attenuation, splice losses, connector insertion and return loss. In addition, excessive mismatches between fibers in different cable sections along the route can be identified along with any problems, such as bends on the fiber. Normally, for commissioning or acceptance of a dark fiber section, OTDR (or more recently, iOLM) testing is carried out at a minimum of two wavelengths. These wavelengths should be representative of the wavelengths at which the fiber is to operate.

For WDM systems used mainly in C-RAN deployments, which use optical filters (different wavelengths), it is very important to ensure that the right wavelength (specified by the customer) is connected to the right port on the WDM muxes and demuxes. To effectively test the circuit and ensure that both the transmitter (Tx) and receiver (Rx) are patched correctly, it is necessary to use an iOLM with WDM wavelengths. The iOLM can be used to measure the fiber loss at the specific WDM wavelength through the network cable to the drop site (cell site), provided that the MUX and DEMUX are optically designed. Furthermore, the fiber can then be looped with an additional launch fiber onto the return fiber connected to the BBU. This means that both the Tx and Rx links can be tested in one measurement.

#### OTDR-based solutions

The iOLM performs several consecutive OTDR-like measurements at different wavelengths, in addition to measurements at different power and pulse widths to ensure that there is no compromise on range or resolution, thus providing greater accuracy. All of these traces are compared, analyzed and integrated for a complete, extremely accurate and repeatable link mapping. The iOLM application is the best method capable of providing full assurance and consistency of the test results.

It is recommended that a launch and receive fiber be used to fully characterize the front and end connector. This method produces a true and accurate end-to-end characterization.

### 1.1.4 iOLM set-up

#### Launch, loop and receive fiber calibration

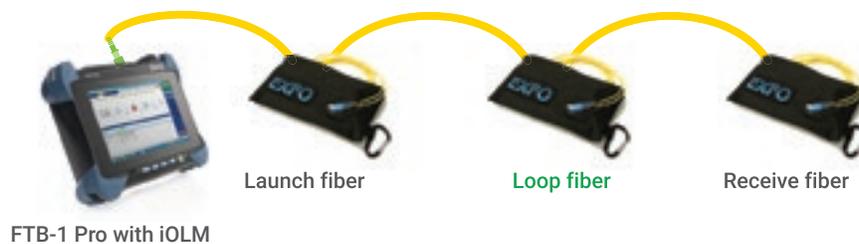


Figure 12. Automatic measurement of launch and receive fibers

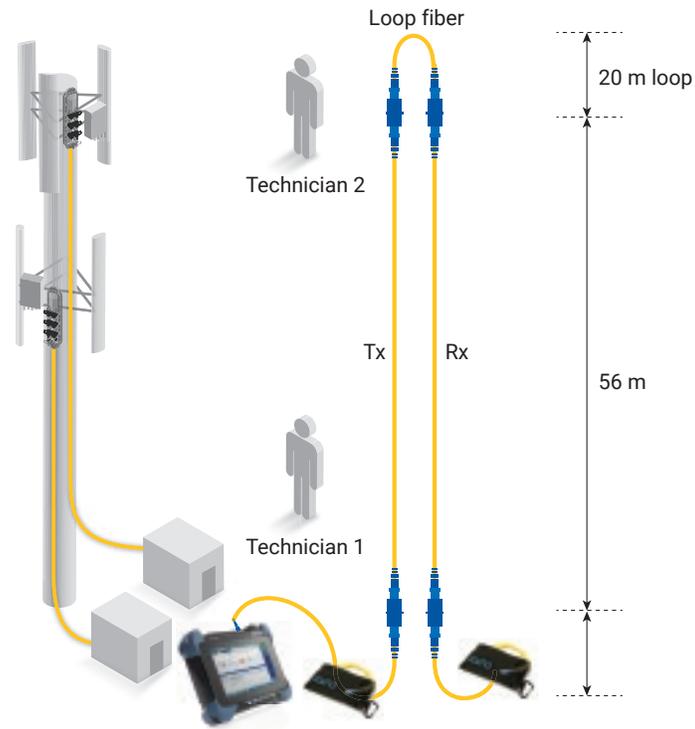


Figure 13. FTTH testing with the FTB-1 Pro platform and iOLM application

### Specialized testing techniques

As shown in the figure below, specialized software (such as iLOOP for the iOLM) will separate the two fibers in the original measurement to generate a clear pass/fail status for each fiber. This enables the user to test the upload and download fibers at the same time, as shown below.

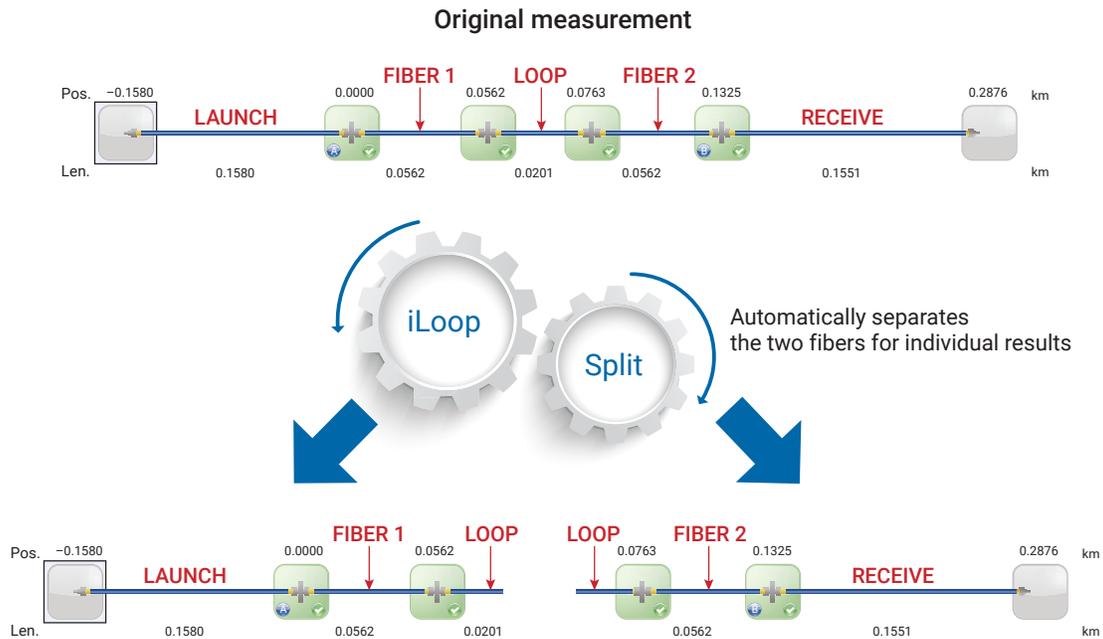


Figure 14. iLoop application splits the iOLM results into two individual links—one for each fiber

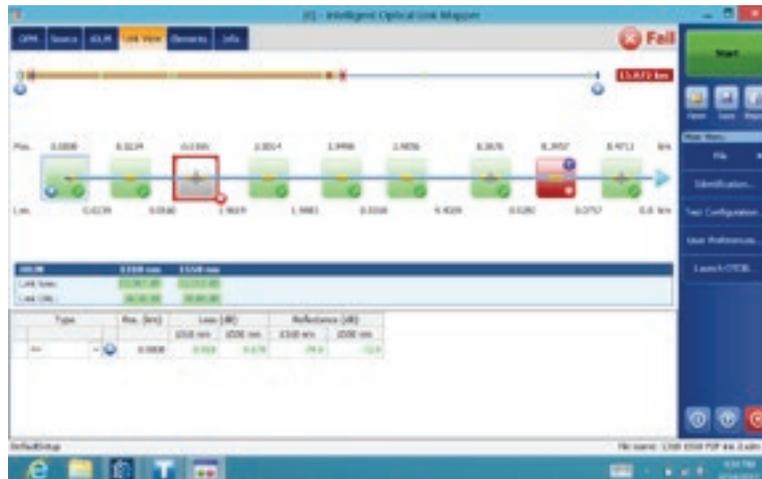


Figure 15. iOLM graphical display

Type of fault	Diagnostic	Solving the issue
<b>Bad connector</b> 	The connector or bulkhead is damaged, dirty or not well connected	Inspect and clean as needed.
<b>Macrobend</b> 	Excessive fiber bend	Inspect the fiber in this area for excessive bending. Use of a visual fault locator (VFL) could help identify the exact location of the macrobend.
<b>Bad splice</b> 	Excessive loss of a non-reflective fault	Inspect the splice at this location, and resplice if needed. Use of a VFL could help identify the exact location of a bad splice.

Table 1. iOLM diagnostic examples

The link composition is described below.

The detailed iOLM analysis of the total span or fiber link allows for accurate measurement in a single, simple linear view.

Measurements also generate pass/fail analysis according to the provider's criteria:

- Total span distance
- Section and distance attenuation
- Total link loss (attenuation)
- ORL: the ratio of the forward optical power to the reflected optical power
- Splice loss: loss of optical power at a (fusion) splice point
- Connector loss: the loss of light at a mated pair of connectors
- Connector reflection: the percent of power reflected back from a mated pair of connectors
- Excessive mismatches between fibers in different cable sections

Element diagnostics are associated with specific link element issues. Each failed link element will have associated diagnostics to assist with troubleshooting. Some elements (such as macrobends) will have associated diagnostics, even in the case of a pass status.

Connector loss, macrobends and splice loss that fall out of the design specifications will give clear failure analysis with diagnostics and pointers to help resolve the problem.

Once the test has been completed, the result sections can be referenced for information about any potential fault present on the fiber.

## 1.2 Fronthaul link validation

The fronthaul represents the portion of the network from the BBU to the RRHs at the cell-site location. As previously discussed, there are two types of fronthaul architectures:

- Distributed radio access network (D-RAN) architecture, which is the collocation of the BBU and RRH
- Centralized radio access network (C-RAN) architecture, which is the centralization of the BBUs in a common location such as a central office (CO) or data center, with the RRH located in a remote site many miles/kilometers away

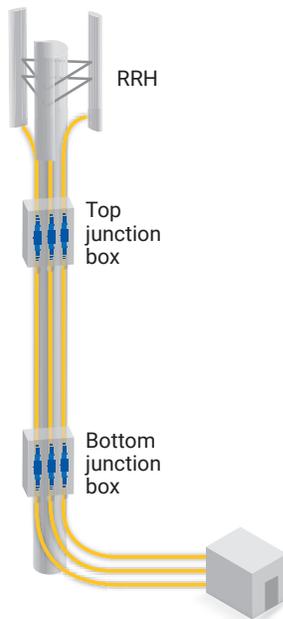


Figure 16. D-RAN fronthaul architecture

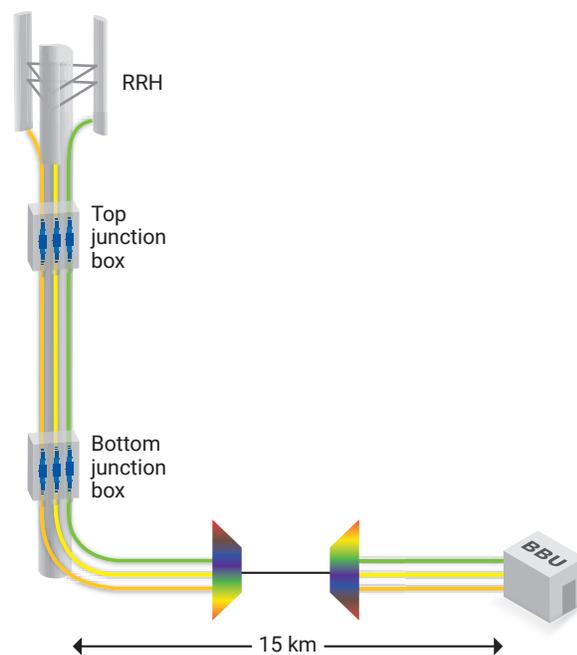


Figure 17. C-RAN fronthaul architecture

In both architectures, the RRH validation test is necessary. However, for C-RAN architecture, additional tests are recommended. C-RAN includes a CPRI transport system. At the optical level, the system can be a coarse wavelength-division multiplexing (CWDM) or dense wavelength-division multiplexing (DWDM), while at the protocol layer, it is based on an optical transport network (OTN) CPRI transport system. As such, two important validation tests are recommended. One test validates the signal integrity of the transport system by measuring the bit error rate (BER). The other test involves measuring latency through the system and fiber span. Minimizing latency in the transport system and long-distance fiber span is critical in order to ensure proper cellular network operation. The following section describes the recommended test steps for complete fronthaul link validation in detail.

## 1.2.1 Technical requirements

Supported on the FTB-1 Pro test platform, the NetBlazer modules shown in figures 18, 19, 20 and 21 all have the framed CPRI test capability. The supported CPRI rates range from 1.2 Gbit/s to 9.8 Gbit/s.

Connection to the CPRI optical interface requires use of an SFP optical module. EXFO has qualified a multirate SFP+ (SFP-8600) that is capable of covering all currently supported NetBlazer CPRI rates (e.g., 1.2G, 2.4G, 3.1G, 4.9G, 6.1G and 9.8G).

The figures to the right show the SFP port interface used on various NetBlazer V2 Series modules. These ports are used to communicate with a BBU or RRH using the CPRI protocol test application.

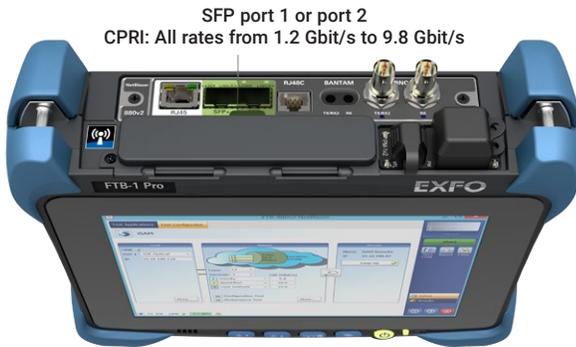


Figure 18. CPRI interfaces on the FTB-870 V2/FTB-880 V2 modules

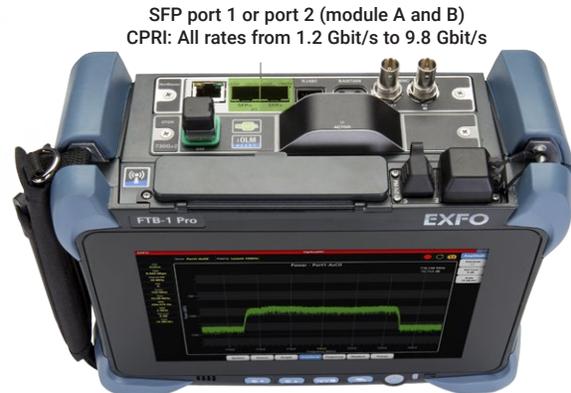


Figure 19. CPRI interfaces on the FTB-720G V2/FTB-730G V2 modules



Figure 20. CPRI interfaces on the FTB-870Q/FTB-880Q quad modules



Figure 21. CPRI interfaces on the FTB-890NGE 100G module

## 1.2.2 RRH validation test

The RRH validation test can be performed for D-RAN and C-RAN architectures. From the BBU location, this test validates that the RRH is powered up correctly, the SFP optical module and fibers are connected properly, and the RRH is fully operational at the interface rate being tested without any CPRI errors or alarms.

### 1.2.2.1 How to start the CPRI test application

The following steps must be completed on the EXFO NetBlazer tester.

1. Select the Wireless tab at the bottom of the screen. Depending on the number of activated test applications, this step may not be required.
2. Select the CPRI/OBSAI BERT option.
3. Select the Test Configurator tab.



Figure 22. Starting the CPRI Test Application

### 1.2.2.2 CPRI interface rate configuration

There are currently six CPRI interface rates, which range from 1.2G to 9.8G, supported on the NetBlazer. The user must know the CPRI interface rate at which the RRH validation test will be performed. Perform the steps described below to configure the desired CPRI interface rate and emulation mode. Before proceeding with the test, please ensure that the NetBlazer unit is properly connected to the uplink and downlink fibers of the RRH.

1. Select the Modify Structure button.
2. Select the Framed L2 option for framed CPRI layer 2 (default setting).
3. Select the CPRI interface rate at which the test is to be performed (1.2 Gbit/s to 9.8 Gbit/s).
4. Select the Base Station option under Emulation Mode.
5. Select OK to finish.

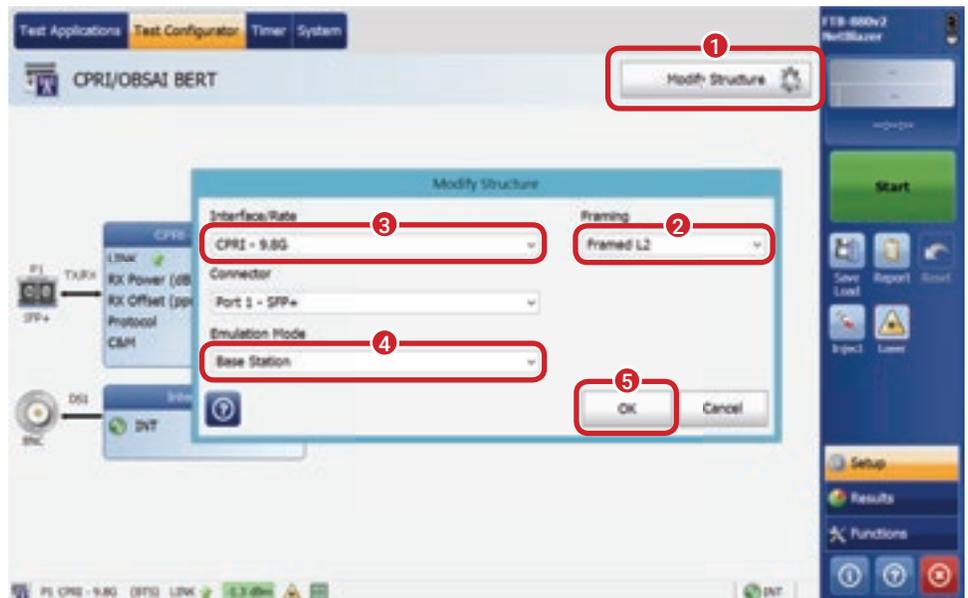


Figure 23. Configuring the CPRI Interface Rate

### 1.2.2.3 CPRI link-up

Once the correct CPRI interface rate has been configured, the CPRI Link-Up status should be displayed with a green arrow.

1. Verify that the CPRI link is operational. This is depicted by a green up arrow indicating that communication with the RRH is operational. If the CPRI link is down, it will be displayed with a red down arrow. In some cases, a CPRI link down is due to the fact that the CPRI configured rate does not match the configured rate of the RRH under test. EXFO recommends trying different CPRI rates to see if a link up can be achieved.

Also, the following sections describe other possible troubleshooting measures that can be taken when the CPRI link is down.

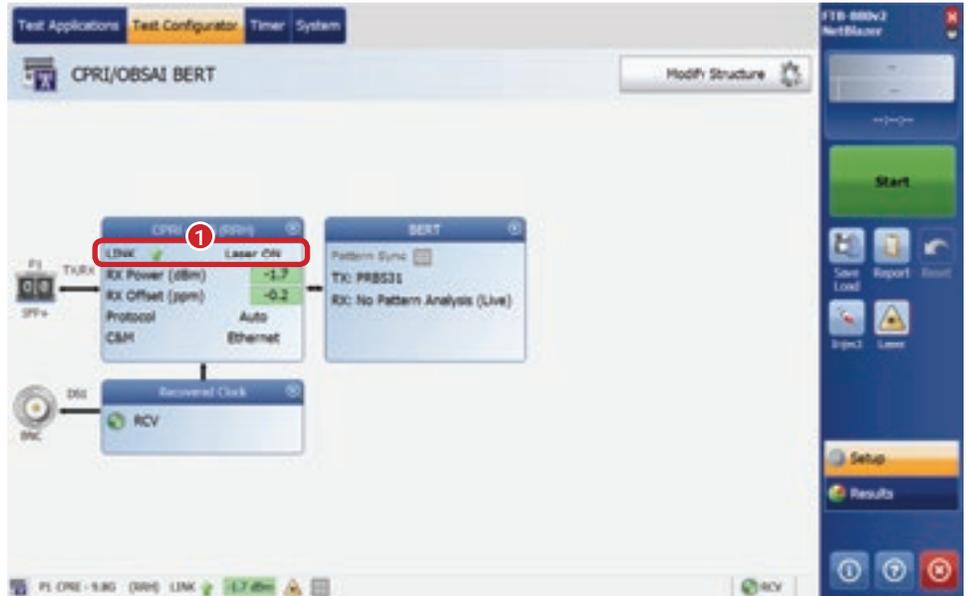


Figure 24. CPRI link-up status

### 1.2.2.4 How to verify the CPRI state

The CPRI protocol standard defines states that are used by the RRH and BBU to establish and set up communication. The following steps ensure that the CPRI state is operational.

1. Select the CPRI configuration box.

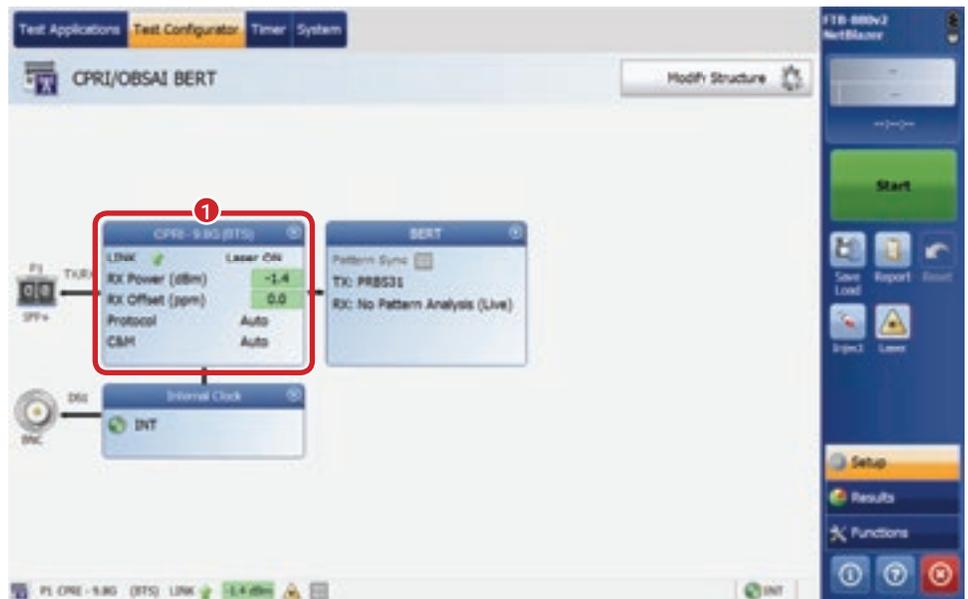


Figure 25. Navigating to the CPRI configuration

1. Verify the CPRI state.

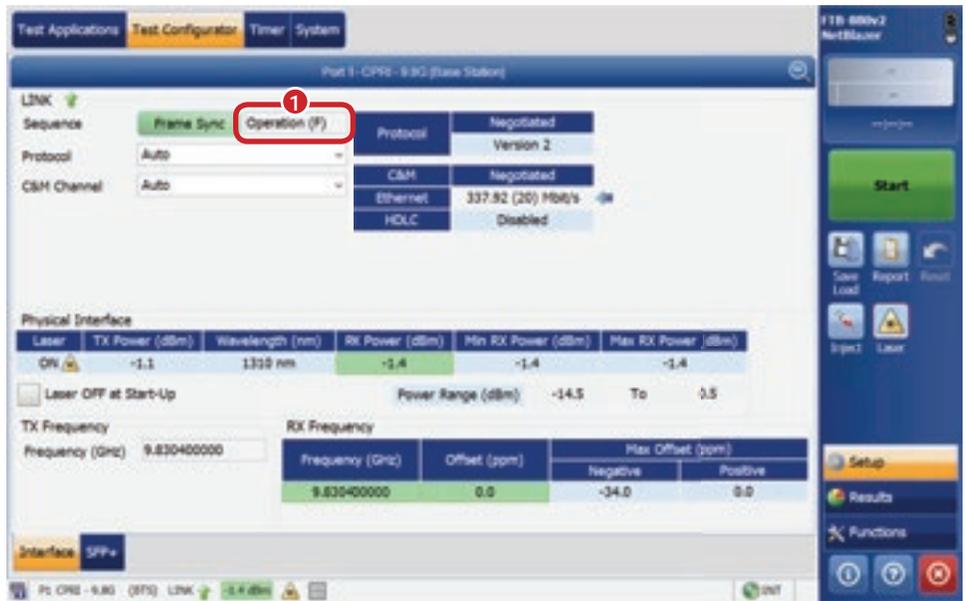


Figure 26. Reading CPRI States

States A to E are intermediate states during which a negotiation between the BBU and RRH occurs to establish a proper CPRI communication link. The State F (active link) or State G (passive link) must be reached in order to start the test. If State F or G is not achieved, the CPRI link is not operational.

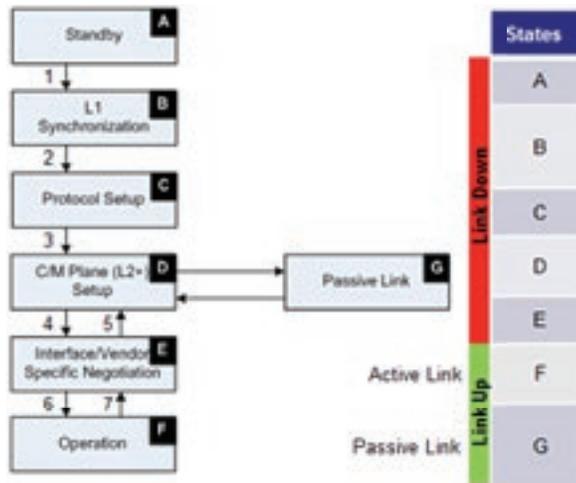


Figure 27. State of CPRI link

### 1.2.2.5 CPRI protocol version

The term *protocol version* as defined in the CPRI protocol standard is used to indicate whether or not line scrambling is enabled. Protocol version 1 signifies unscrambled; protocol version 2 signifies scrambled. Scrambling is only possible on the higher CPRI interface rates starting at 4.9 Gbit/s. (In digital communication, the scrambling function is used for proper direct-current [DC] balancing on the transmission line. This ensures that the same number of 1s and 0s are present in the data stream over time, thereby minimizing signal drifts and bit errors.)

1. Keep the Protocol field set to Auto to enable the NetBlazer to self-adjust to the protocol capabilities of the RRH. **The Auto setting is the recommended setting.** However, during a troubleshooting or lab-testing phase, the protocol can be set manually.
2. Verify the negotiated protocol with the RRH. The negotiated protocol indicates the capabilities negotiated with the RRH.

Note: If the protocol capabilities of the RRH do not match the NetBlazer's capabilities (when set to a specific protocol), the Negotiated box will appear in red.

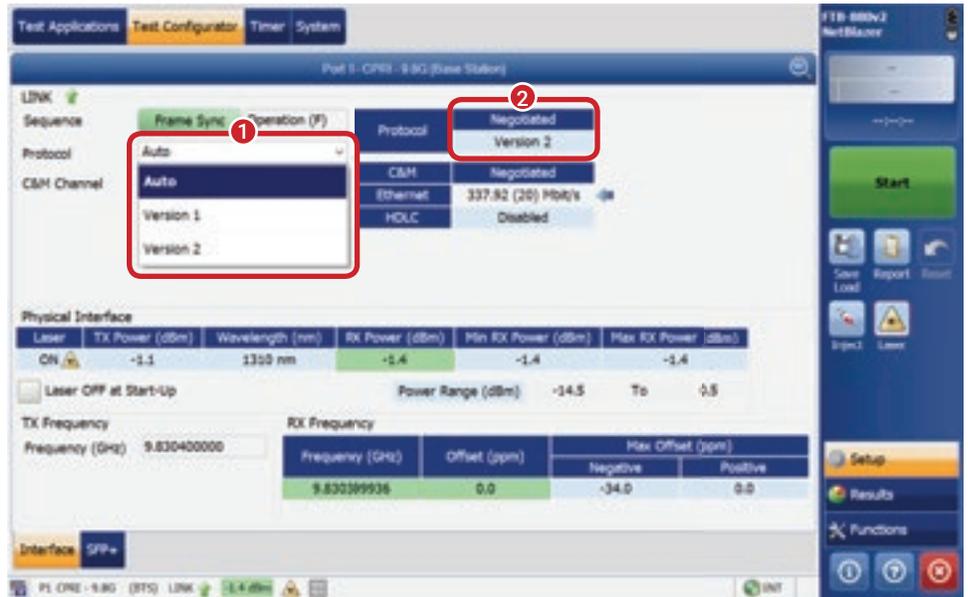


Figure 28. Changing the protocol version

### 1.2.2.6 CPRI control and management (HDLC and Ethernet)

CPRI provides two control and management (C&M) communication channel types: slow bit rate with high-level data link control (HDLC) (legacy) and fast bit rate with Ethernet.

1. Keep the C&M Channel field set to Auto to enable the NetBlazer to self-adjust to the capabilities of the RRH. **The Auto setting is the recommended setting.** However, during a troubleshooting or lab testing phase, the C&M channel type and rate can be set manually.
2. Verify the negotiated C&M type and bit rate with the RRH. Note: The blue arrow in the box is pointing to the C&M type that was negotiated with the RRH. If the C&M type and/or bit-rate capabilities of the RRH do not match the NetBlazer's capabilities (when set to a specific C&M type and/or bit rate), the Negotiated box will appear in red.

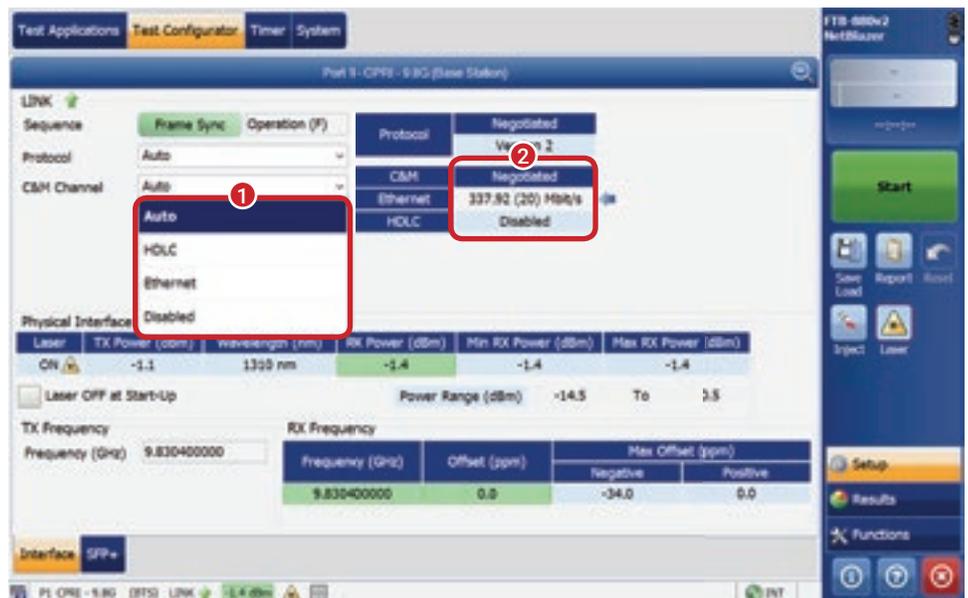


Figure 29. Changing C&M type and bit rates

### 1.2.2.7 SFP/SFP+ information

This step is not related to CPRI testing; however, it contains valuable information about the optical SFP module inserted into the NetBlazer.

1. If information regarding the SFP inserted in the NetBlazer is required, click the SFP/SFP+ tab.

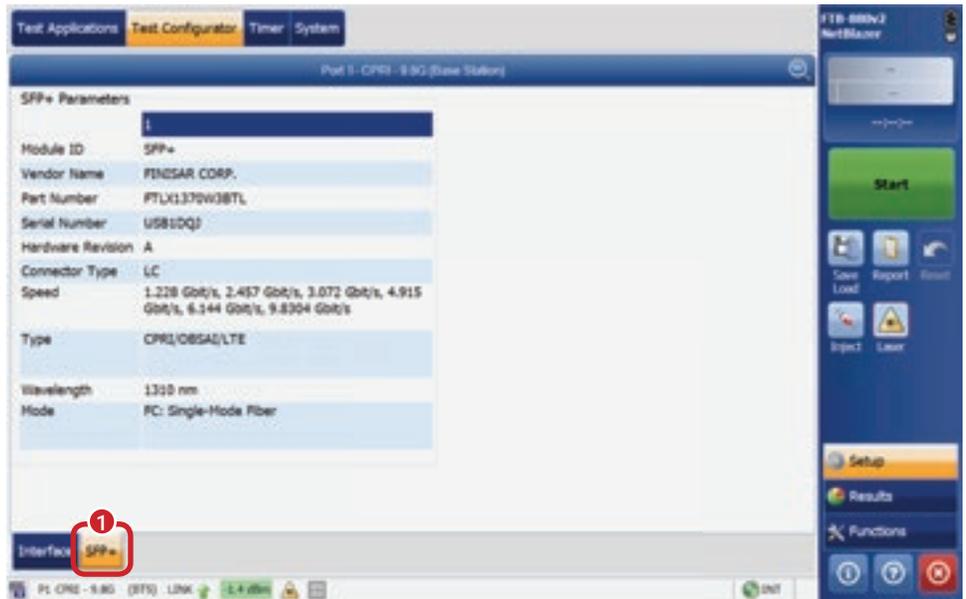


Figure 30. SFP/SFP+ information

### 1.2.2.8 Confirming that CPRI data has been received

Once the CPRI link is operational (start-up sequence in State F or State G), the test can be launched. The test will report the statistics in terms of transmitted and received CPRI hyperframes and codewords. In addition, the negotiated protocol version and C&M type/bit rate will be displayed.

1. Make sure that the NetBlazer is either in State F or State G.
2. Press the Start button to start the test. The results page will automatically display. Note that because the CPRI test application is always generating and monitoring CPRI frames, starting the test will only start the statistical counters, and CPRI error and alarm monitoring.

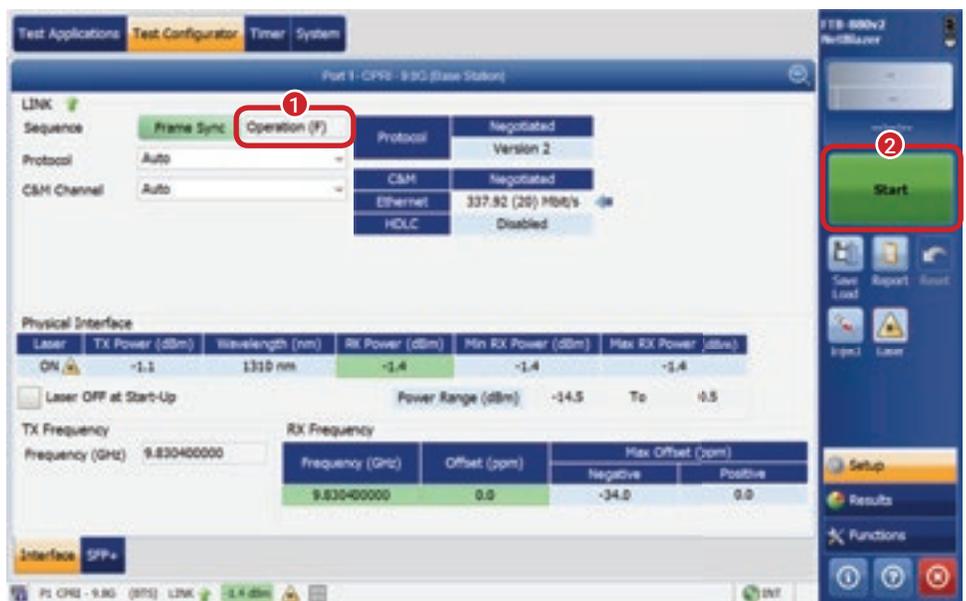


Figure 31. CPRI statistics results display

1. Verify that the quantity of transmitted and received hyperframes and codewords are increasing.
2. The test is complete once the NetBlazer reports a Pass and No Alarm result.

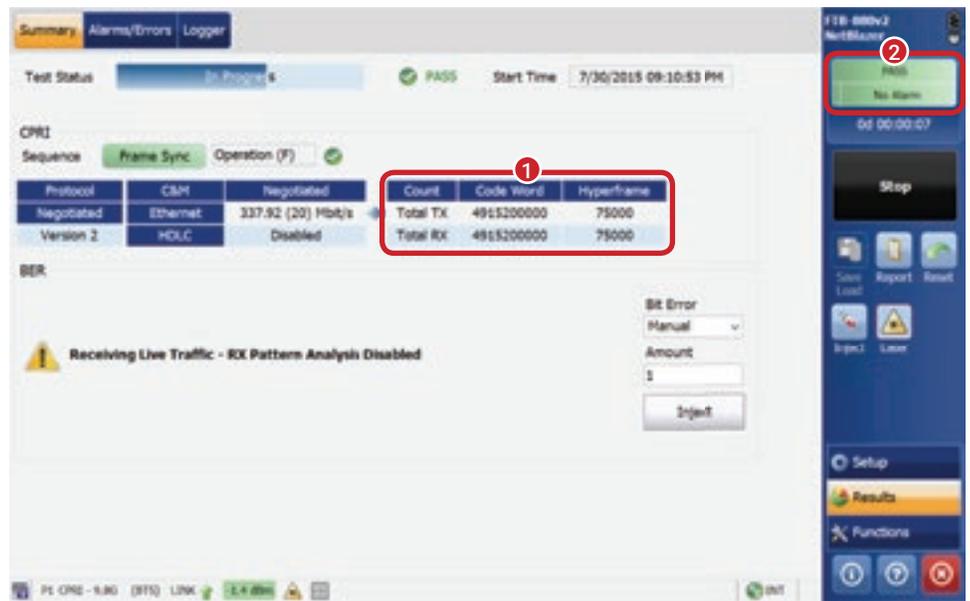


Figure 32. Reading CPRI frame statistics

### 1.2.2.9 Verification when alarms or errors are present

If alarms or errors occur during the test, the alarm or error type can be verified by navigating to the Alarms/Errors tab.

1. Select the Alarm/Errors tab to view the reporting page.
2. A yellow status will appear to the left of an item that was previously in an error or alarm state. In this example, the interface was previously in a loss of signal (LOS) state that lasted for 11 seconds.
3. A red status will appear for an item that is currently in an error or alarm state. In this example, the CPRI link is reporting a remote alarm indication (RAI) that has been ongoing for nine seconds.
4. Time near each item is cumulative. Box no. 4 in the CPRI alarms section shows that the CPRI link was down for 20 seconds (9 seconds for LOS and 11 seconds for RAI).
5. Click the Reset button to clear the alarms/errors statistics counters.

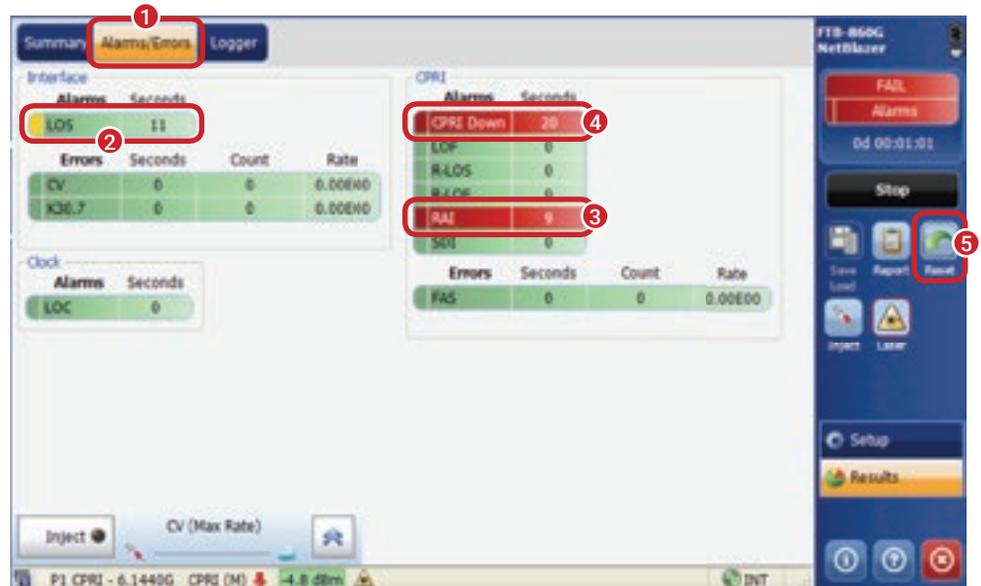


Figure 33. Alarms/errors reporting page

### 1.2.2.10 Extra—how to inject alarms and errors

The NetBlazer provides capabilities for injecting alarms and errors into the CPRI protocol. These alarms and errors are sent to the RRH, mainly for troubleshooting and lab purposes.

1. From the Alarms/Errors tab in the Results section, select the arrow.
2. Select the layer to be tested (interface or CPRI).

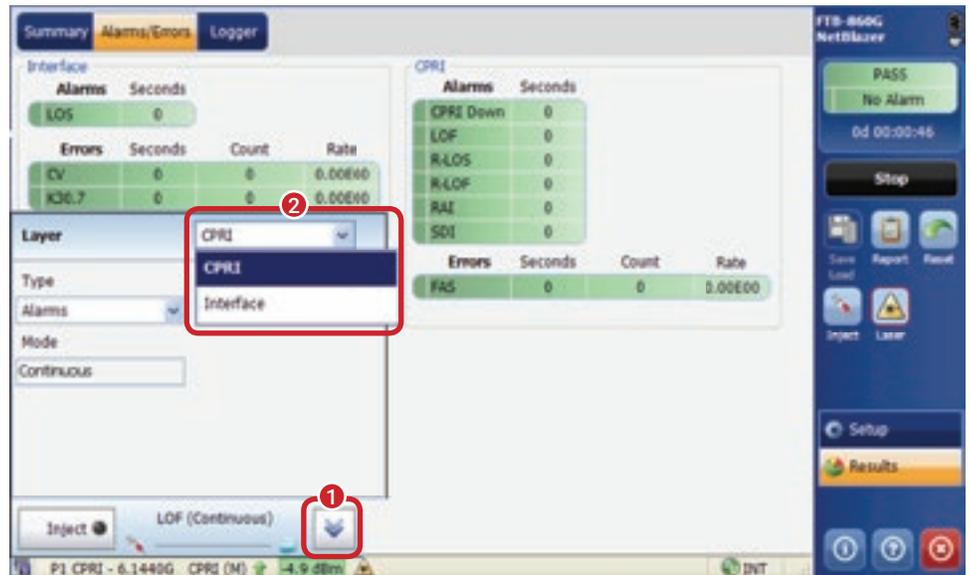


Figure 34. Selecting the interface or CPRI for alarm/error injections

1. Select the type (Alarms or Errors) to be tested. Note: For interface only, the LOS alarms selection is available.
2. Select Inject. Note: The RRH will receive a continuous LOS alarm, and should then return an R-LOS alarm.

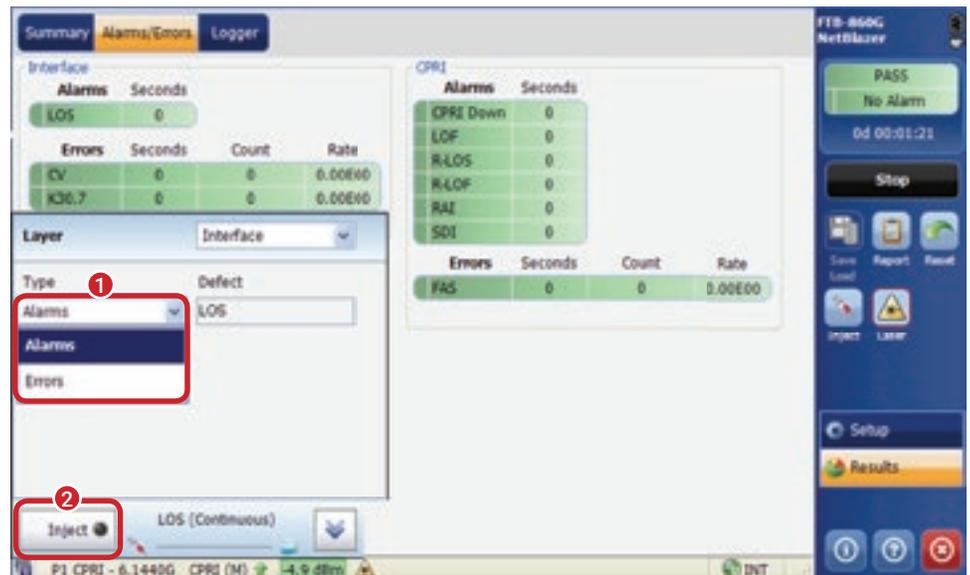


Figure 35. Selecting the alarm or error to inject

1. For the interface, Code Violation and K30.7 can be independently injected to simulate defects.

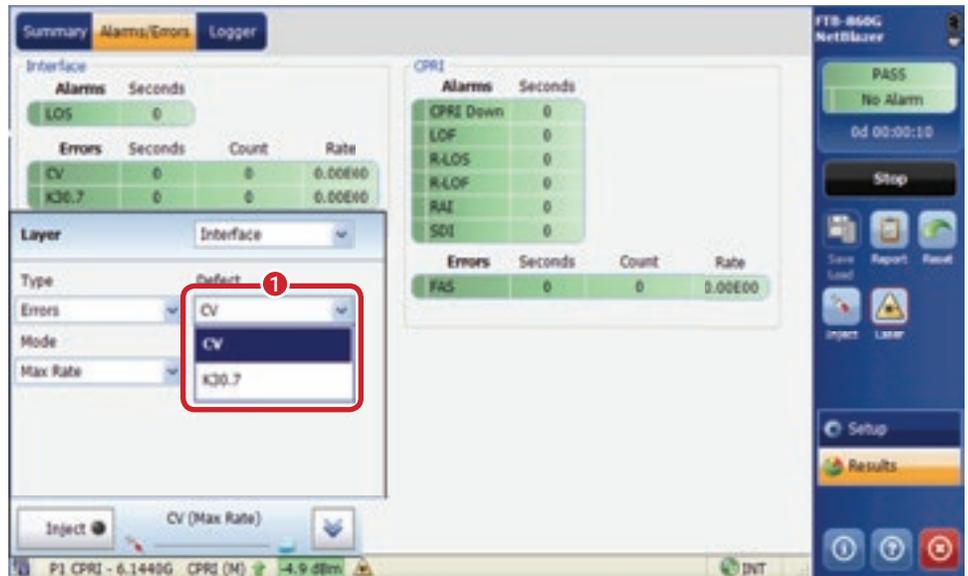


Figure 36. Available error defects

1. CPRI Alarms can be injected by the NetBlazer to the RRH.

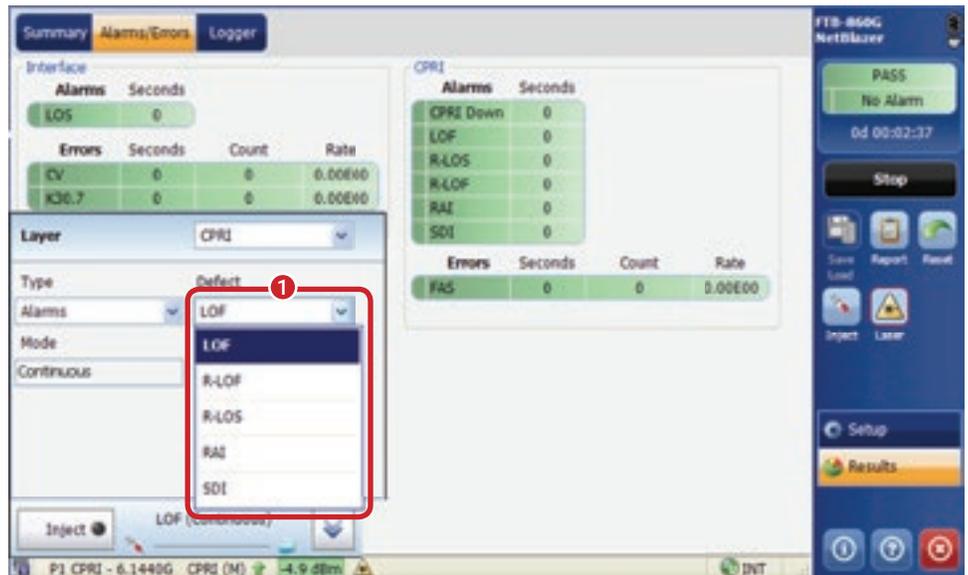


Figure 37. CPRI injectable alarm type

## 1.2.3 C-RAN architecture validation tests

### 1.2.3.1 CPRI bit error rate validation test

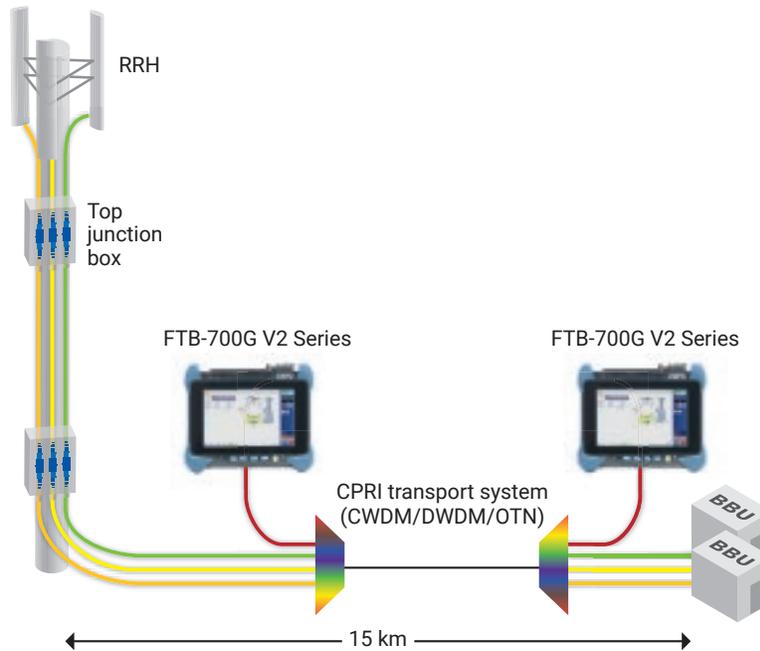


Figure 38. CPRI BER validation through the CPRI transport system

As with any digital transport system, it is critical to ensure the lowest possible bit error rate (BER), because doing so guarantees optimal performance and improved user experience. The BER test (BERT) is best performed using two EXFO NetBlazer testers. Each testing direction can be tested independently, and if any errors are observed, the faulty direction can easily be isolated and investigated further. The pass criterion for a CPRI BERT is a BER that is better than  $1.0E-12$ . However, the transport system should ideally carry the signal error-free.

### 1.2.3.2 CPRI BERT configuration

The CPRI interface rate at which BER testing is to be performed must be provided by the CPRI transport system vendor. EXFO's recommendation is to perform the BERT at the fastest CPRI interface rate supported by the CPRI transport system to ensure that the CPRI link operates correctly up to the fastest supported rate.

The CPRI interface rate configuration must be completed on each EXFO NetBlazer tester as follows:

1. Select Modify Structure.
2. Select Framed L2.
3. Select the CPRI interface rate at which the test is to be performed.
4. Select Base Station for the tester located at the BBU/base-station location.
5. Select Remote Radio Head for the tester located near the RRH location.
6. Click OK.

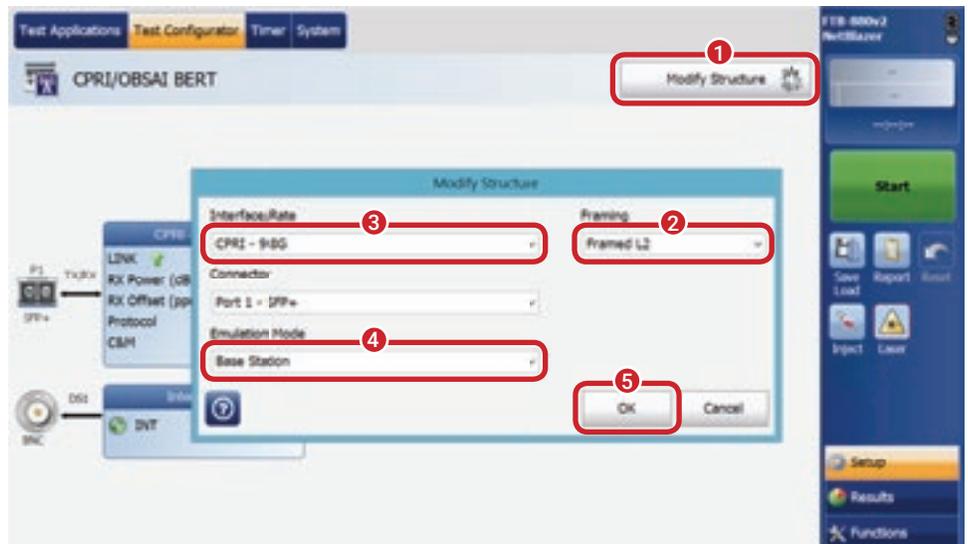


Figure 39. Configuring the CPRI interface rate

The CPRI BERT configuration must be performed on each EXFO NetBlazer tester.

1. Select the BERT box to enter the BERT configuration window.

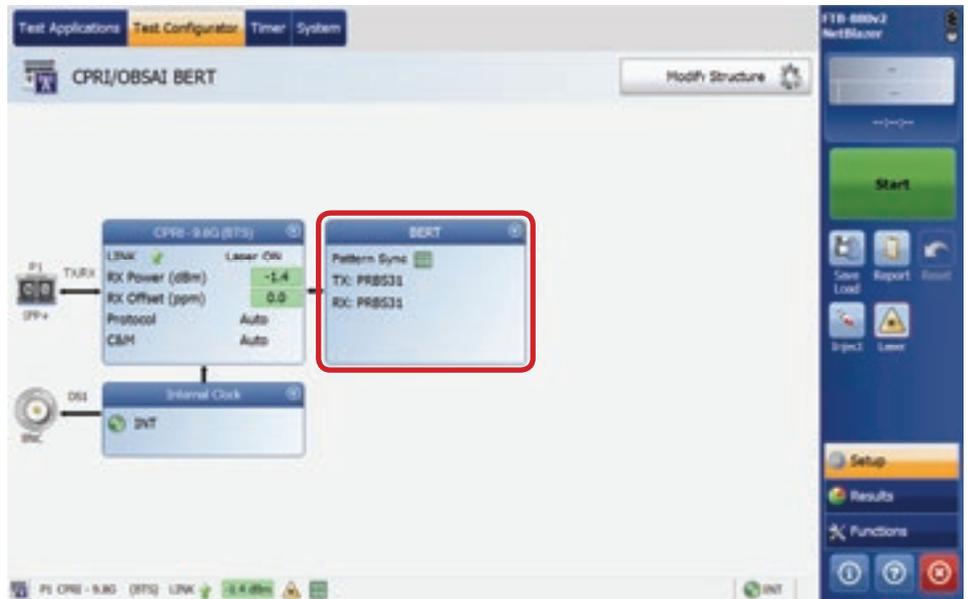


Figure 40. CPRI BERT window

The CPRI BERT configuration must be performed on each EXFO NetBlazer tester.

1. Uncheck the No Pattern Analysis (Live) box to enable BERT.
2. Select the pseudo-random bit sequence (PRBS) for the Tx and for Rx paths. The recommended pattern is the default PRBS31 setting, which is the most stringent pattern. The Tx pattern of one tester must match the Rx pattern of the other tester, and vice versa.
3. In the Pass/Fail Verdict field, select Bit Error Rate from the drop-down list (for a rate), or select Bit Error Count (for a count).
4. In the BER Threshold field, set the threshold to 1.0E 12 or a specific bit error count threshold.

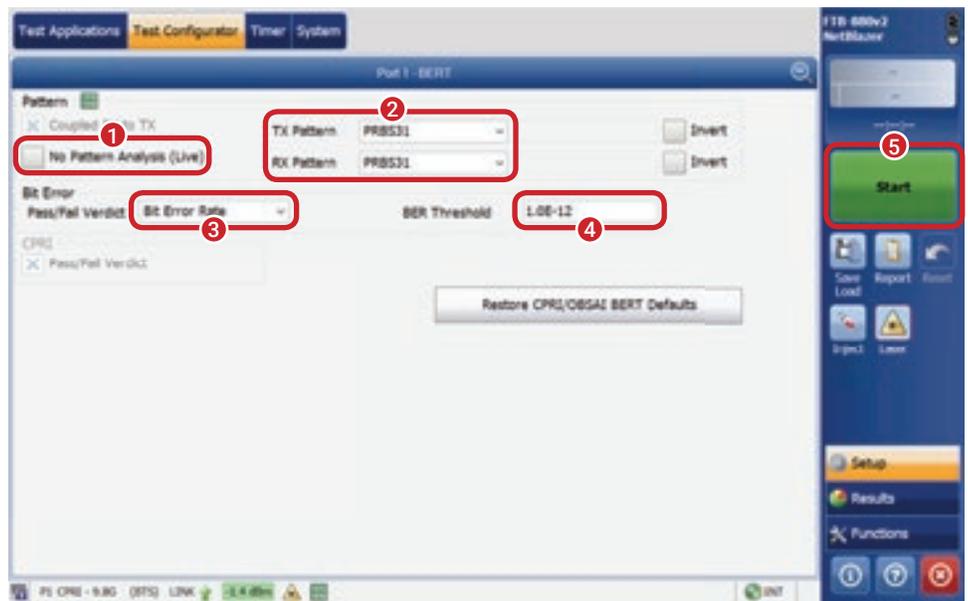


Figure 41. CPRI BERT configuration

Note: The CPRI specification requires that the BER be better than 1.0E-12. Ideally, no bit errors should be present in the system. Setting the bit error count to 0 for the Pass/Fail Verdict implies that no bit errors are accepted during this test.

5. Select Start on each EXFO tester. Note that the Results page will display automatically.

If the CPRI BERT is to be performed for a specific time duration, the following steps must be completed. The CPRI BERT duration configuration must be completed on each EXFO NetBlazer tester.

1. Click the Timer tab.
2. Check the Duration option and enter a user-defined time period, or select a time period from the predefined times in the drop-down list.

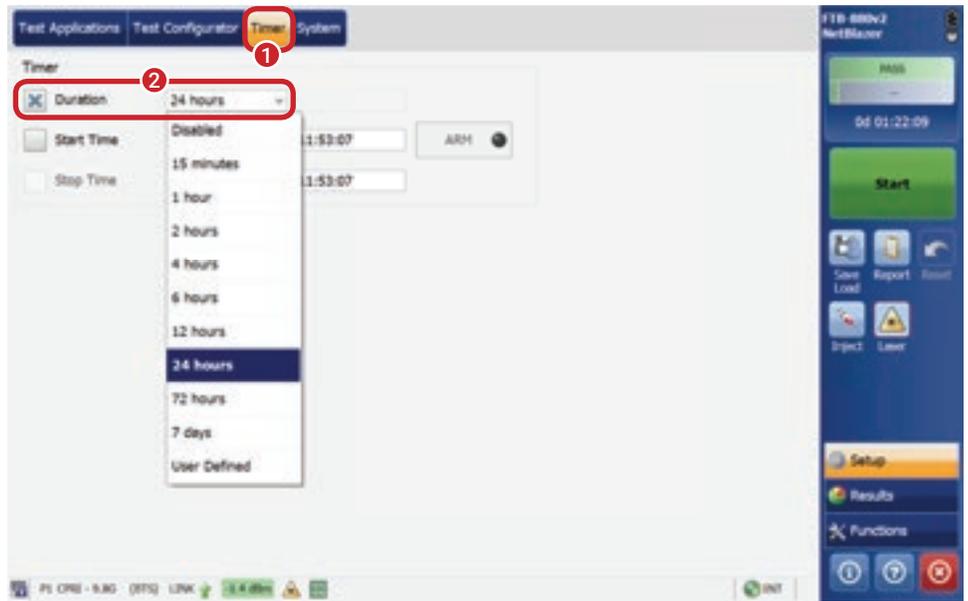


Figure 42. CPRI BERT test duration configuration

### 1.2.3.3 CPRI bit error rate measurement

BERTs are executed to ensure that a network under load can deliver the specified throughput with a bit error rate below a predetermined threshold for the testing period. For proper execution of a BERT, the test duration must be in the 12- to 24-hour range. This duration may vary from one operator to another. The duration must be long enough to ensure that the optical and network components reach stability and remain in that mode for a substantial amount of time. This ensures long-term link stability and performance. A BERT can also be performed for a few minutes in order to gain a quick sense of short-term link stability.

When the CPRI BERT is running on each EXFO tester, test results will be available on each unit. The test results appearing on the tester at the BBU location provide BER measurement for the RRH-to-BBU link direction. The test results appearing on the tester at the RRH location provide BER measurement for the BBU-to-RRH link direction.

1. Verify the Bit Error Rate and Count fields.
2. Verify that the Status is Pass.

A Pass with the No Alarm status indicates that no bit errors were observed. A Pass with the Alarms status indicates that the bit error rate or count is below the specified threshold.

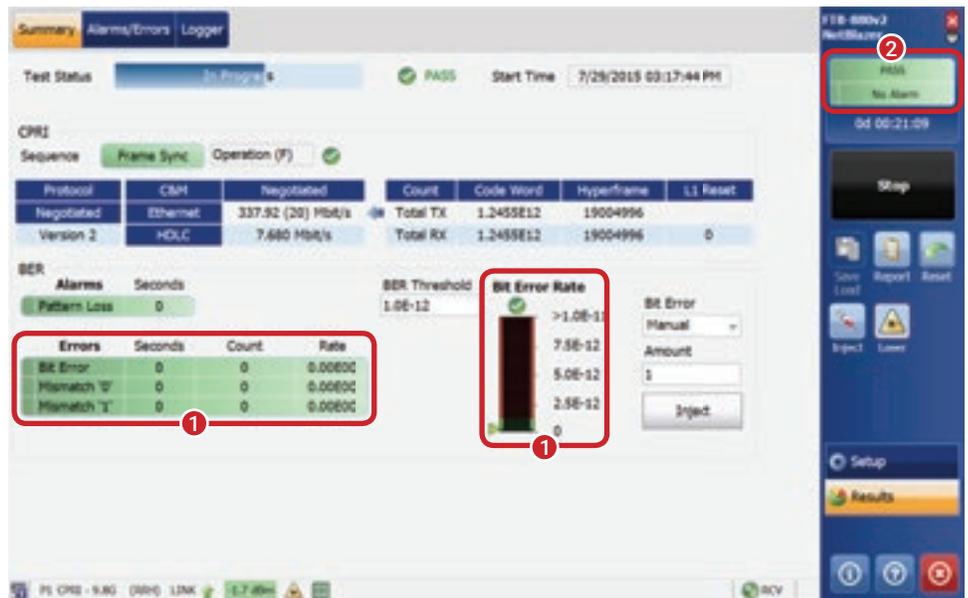


Figure 43. CPRI BERT results

1. Once the test has been completed, a PASS status displayed in green is a confirmation that the CPRI BERT was completed successfully.
2. Select Yes or No to generate a test report. Note: The generated test report can be used for validation of successful CPRI BERT completion.
3. If other CPRI interface rates need to be validated, select Setup and return to the CPRI Interface Rate Configuration section.

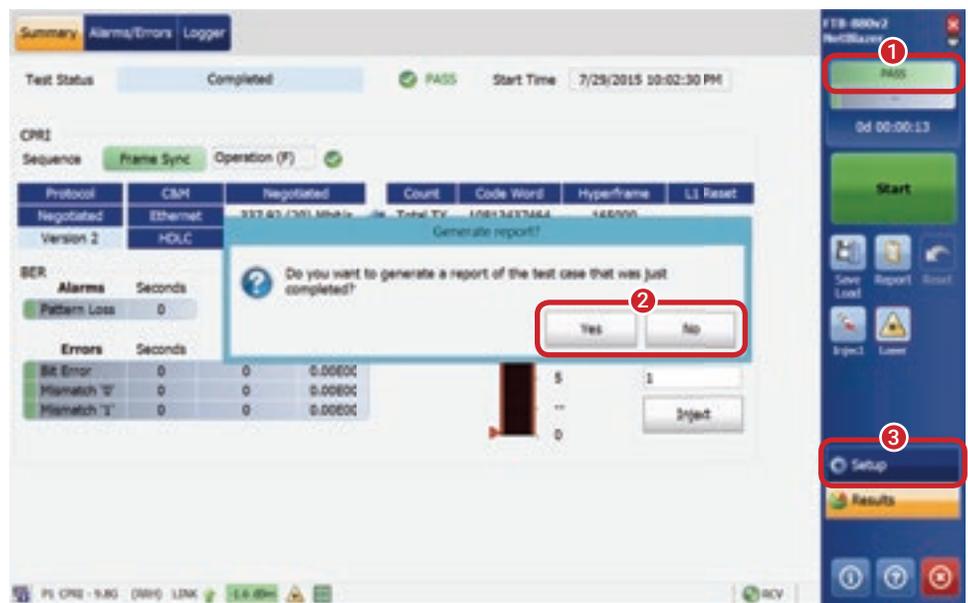


Figure 44. CPRI BERT report generation

### 1.2.3.4 Optional step—CPRI BERT configuration validation

Some service providers may want further validation that the CPRI BERT is operating correctly. Bit error injection will ensure that the CPRI BERT is configured properly. If this type of validation is required, the following steps can be performed prior to launching a long-term BERT.

With the CPRI BERT running on one of the EXFO testers, perform the following steps from the Results window:

1. Set the Bit Error injection type to Manual.
2. Set the Amount of bit errors for injection to 50.
3. Select Inject to inject 50 bit errors, and then verify whether the errors have been detected on the remote EXFO tester.

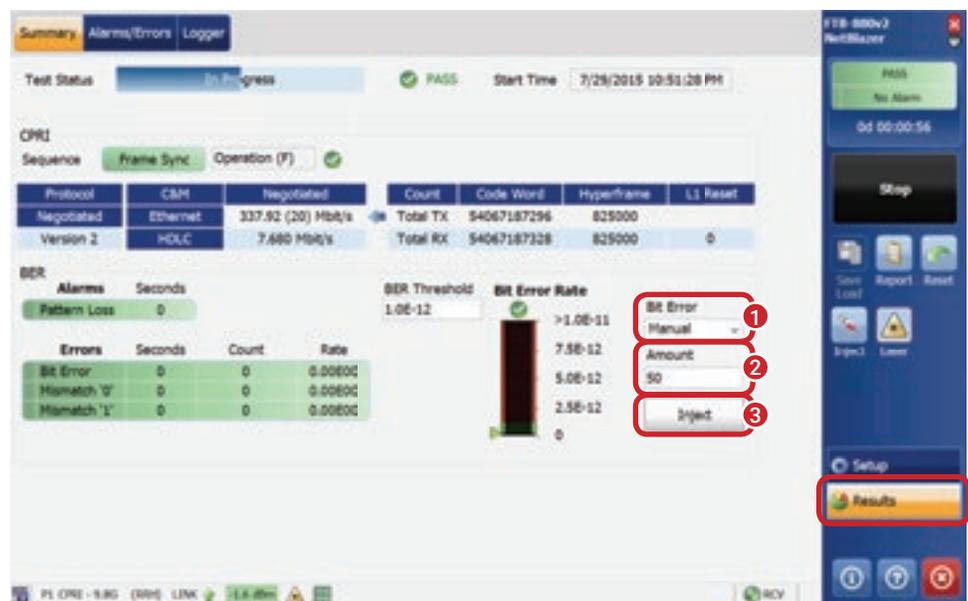


Figure 45. CPRI BERT error injection

1. Verify on the EXFO NetBlazer remote tester that the test status changed to FAIL.
2. Verify that the bit error count is 50.
3. Select Reset to clear the alarms.

If desired, repeat the previous steps on the EXFO tester that just measured the bit errors in order to validate the opposite testing direction (remote tester to local tester).

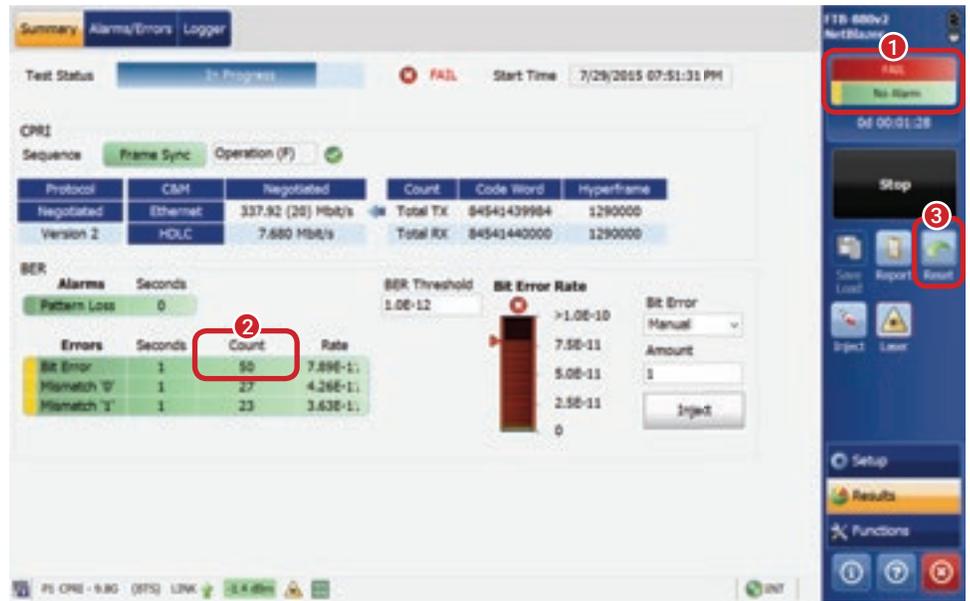


Figure 46. CPRI BERT error injection detection remote tester

### 1.2.3.5 CPRI latency measurement

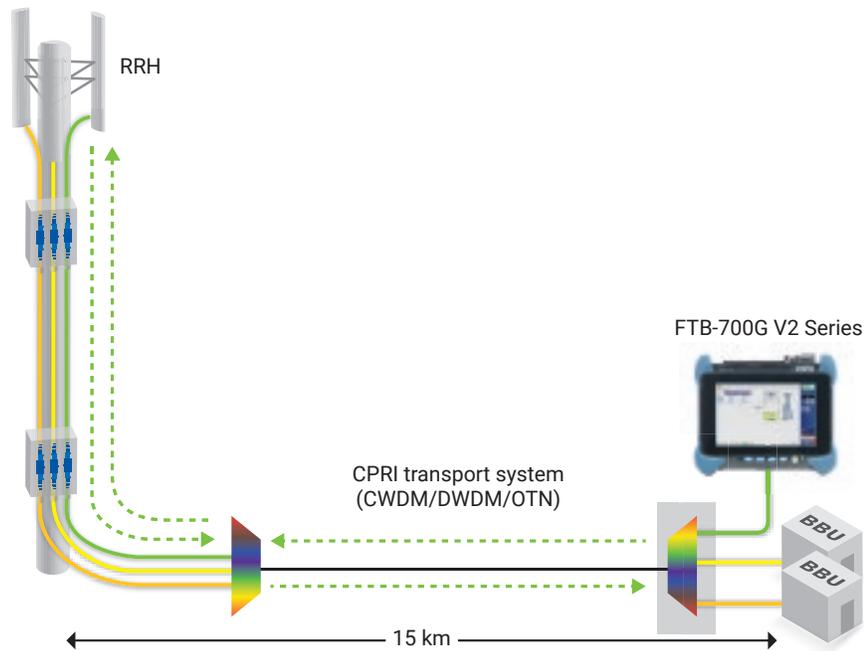


Figure 47. CPRI round-trip delay measurement

The round-trip delay (RTD) measurement from the BBU site location to and from the RRH can be performed with the EXFO NetBlazer tester. The following steps outline the procedure for performing RTD measurements through a CPRI transport system.

On the EXFO tester at the BBU site location, in the CPRI test application Test Configurator window, perform the following steps:

1. Select Modify Structure.
2. Select Framed L2.
3. Select the CPRI interface rate at which the test is to be performed.
4. Select Base Station under the CPRI Emulation Mode.
5. Select OK.
6. Select the Start button.

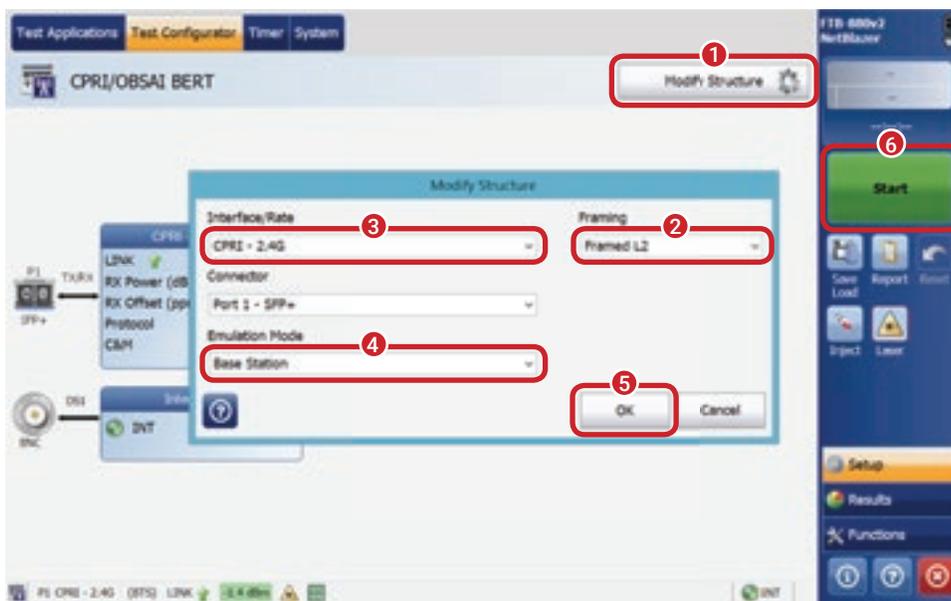


Figure 48. Configuring the CPRI interface rate

If the CPRI transport system and the RRH are operating correctly, the previous configuration steps (1 to 5) should allow a CPRI link-up to be achieved, as shown in the adjacent image.

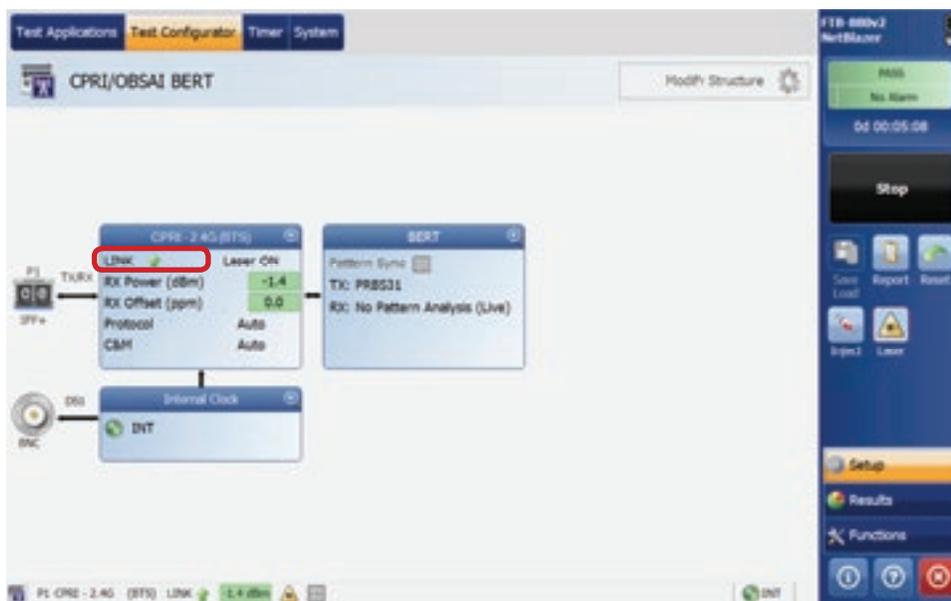


Figure 49. RTD Measurement: CPRI link-up with RRH

Once the CPRI Link-Up is obtained with the RRH, RTD can be measured. Follow the steps as detailed in the adjacent image.

1. Select the Functions button.
2. Select the measurement unit ( $\mu$ s or ns).
3. If the internal processing time of the RRH is known, enter the Toffset (ns) value.

The RRH manufacturer may provide the Toffset value. This will make it possible to obtain a separate cable delay measurement that includes the fiber delay and transport system delay without the RRH processing delay.

4. The total RTD measurement is displayed in the Round Trip Delay results table. The Delay T14 value is the total RTD.
5. Select the Stop button.
6. Select Yes or No to generate a test report that includes the RTD measurement.

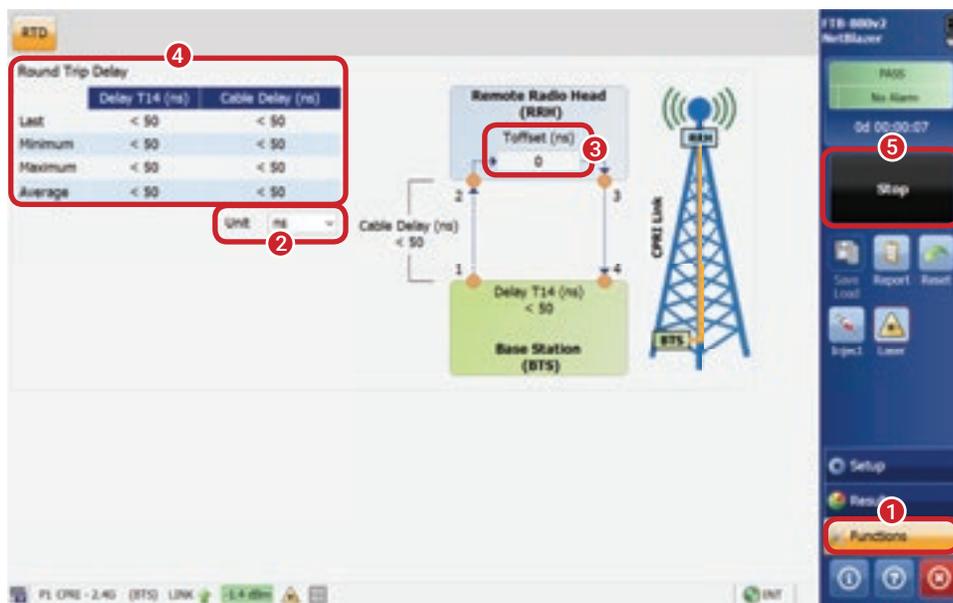


Figure 50. CPRI RTD measurement configuration

Note: In a fronthaul link, the total RTD should be no more than 3 msec, including the processing time at the BBU. Using the BBU technology available in 2015, the internal BBU processing time is typically around 2.75 msec. Excluding the BBU, this leaves around 250  $\mu$ s (3 msec minus 2.75 msec) of RTD budget for the CPRI transport system, the fiber link and the RRH processing time. Accordingly, EXFO recommends that RTD (Delay T14) measurements be below 250  $\mu$ s, and also recommends that further information be obtained from the network equipment (BBU/RRH) manufacturer regarding the maximum tolerable RTD on the fronthaul link in order to ensure reliable communication between the BBU and the RRH.

## 1.3 Site commissioning using BBU emulation

EXFO's BBU emulation test application allows mobile cell technicians and contractors to ensure that cell sites are installed correctly the first time prior to the site being handed over to the mobile network operator (MNO) for integration. The system is designed for simple one-click operation, with clear pass/fail results that make it possible to isolate problems quickly and generate a complete test report, creating a birth certificate for the cell site.

The BBU emulation test can be performed for D-RAN and C-RAN architectures. The test is performed by connecting the fibers from the RRH to the FTB-1 Pro, directly at the BBU location. The test provides full emulation of the CPRI C&M and IQ data, where valuable information, like local SFP, remote SFP, antenna RET status and tilt, received signal strength indication (RSSI), and voltage standing wave ratio (VSWR) measurements, are identified and reported. The BBU emulation test generates LTE transmission, which is used to perform PIM testing and isolate problems associated with RF interference.

The following steps must be completed on EXFO's FTB-1 Pro test platform with the BBU emulation application.

### 1.3.1 Connection from the RRH to the FTB-1 Pro

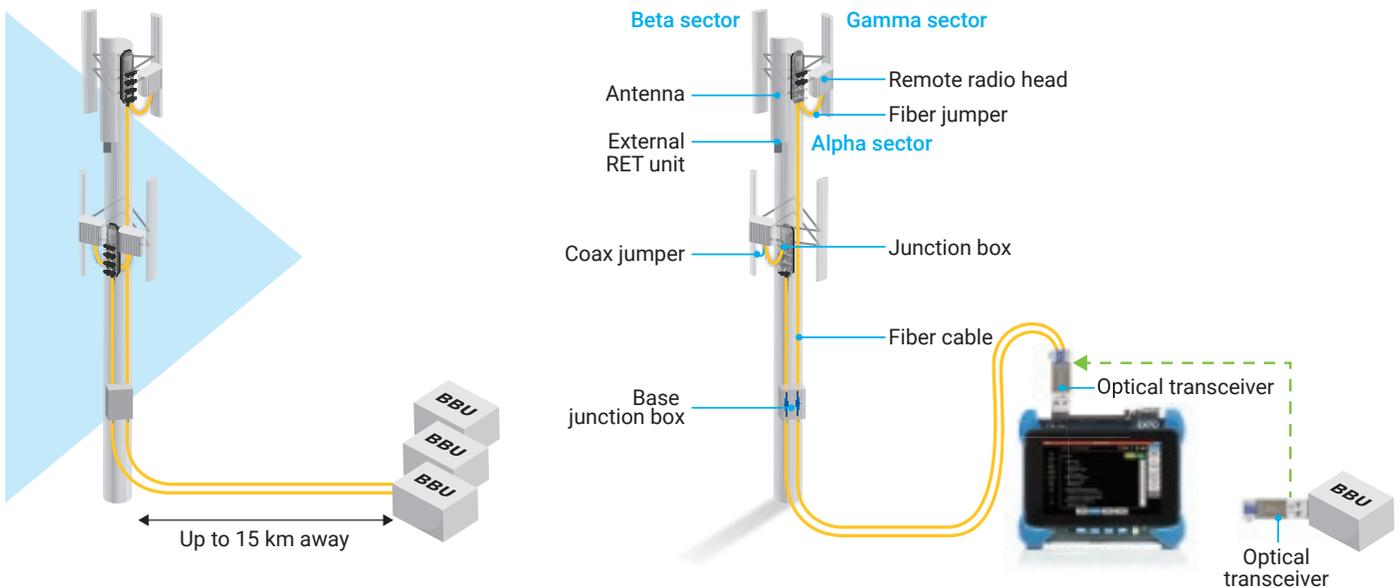


Figure 51. RRH to FTB-1 Pro connection

Test Config	Description
ALU-LTE Basic	Basic emulation test (RRH inventory and SFP information)
ALU-LTE Link Validation	Link validation with RRH
ALU-LTE Turnup NoRET	Full turn-up of the cell site without RET support (inventory, SFP, VSWR and RSSI)
ALU-LTE Turnup	Full turn-up of the cell site (inventory, SFP, ALD, AISG bus scan, RET, VSWR and RSSI)
SelfTest	BBU emulation application self-test (loopback needed)
SFP Test	Fiber and SFP validation (loopback needed)

Table 2. BBU emulation tests

### 1.3.2 Starting the BBU emulation application

1. From the FTB-1 Pro platform toolbox, select BBU emulation.

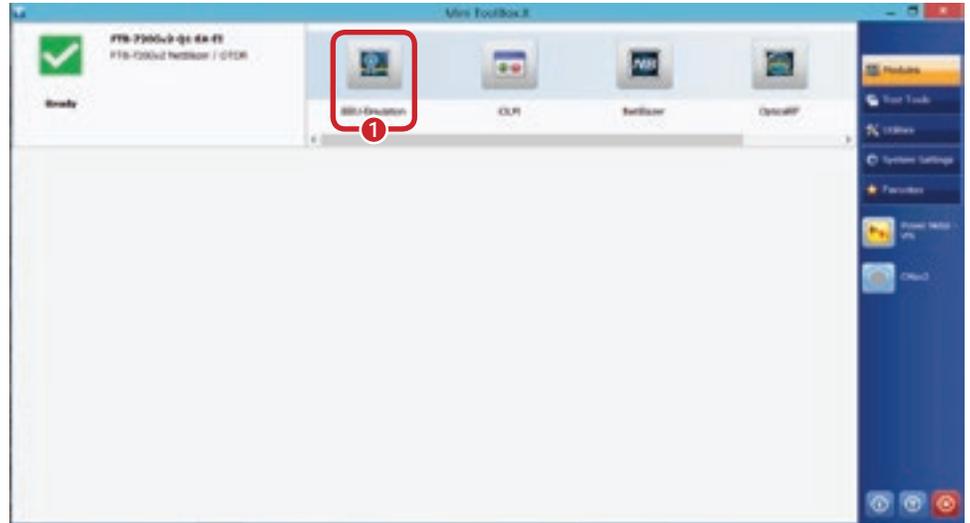


Figure 52. FTB-1 Pro platform toolbox

### 1.3.3 Setting up the BBU emulation application to initiate the test

1. Select the **Port1** or **Port2** option.
2. Select the CPRI rate from the list (Rate 2 to Rate 7).
3. Verify that the CPRI link is operational. This is depicted by the link status changing to **Active**. If the link status stays at **LossOfSignal**, the CPRI rate or the connection to the RRH needs to be re-verified. (Do not proceed without an active link.)
4. Select the Emulate menu.



Figure 53. BBU emulation main interface

1. Select the desired Test Config option (Refer to table 2 in section 1.3.1).
2. Run the test.
3. The test will stop after sending 10,000 radio frame counts; by enabling monitor mode, the test will run continuously.

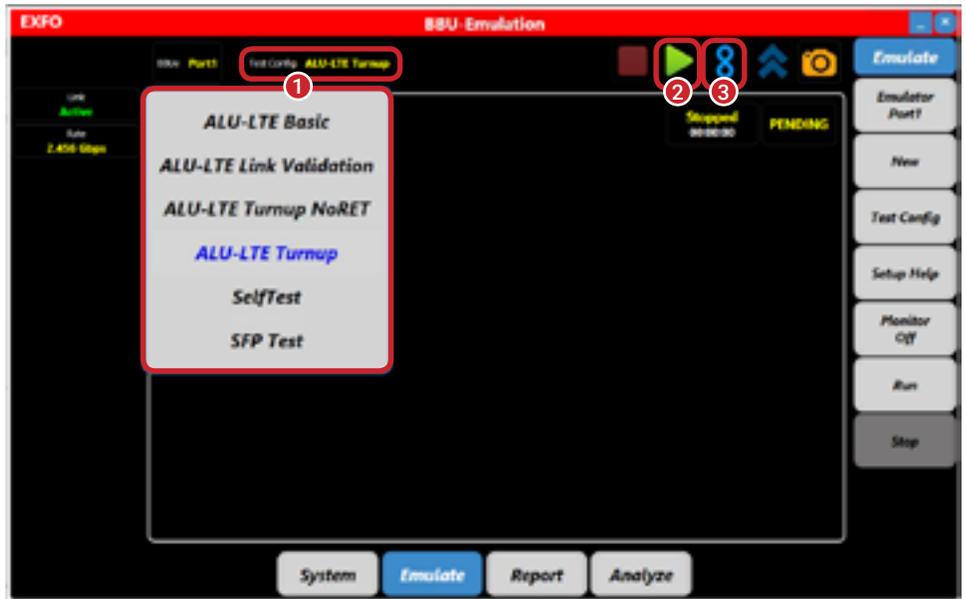


Figure 54. BBU emulation emulate tab

### 1.3.4 Creating reports in BBU emulation

1. Verify that the test has generated a **PASS** or **FAIL** notification.
2. Select the **Add/Report** button.
3. Enter the desired test name and select **OK**.
4. Repeat steps 1, 2 and 3 for all sectors and until all technologies of the cell tower have been covered.
5. Select the Report tab and blue positioning bars will appear. Tap on one of the blue positioning bars and the Report window will be inserted at that location.

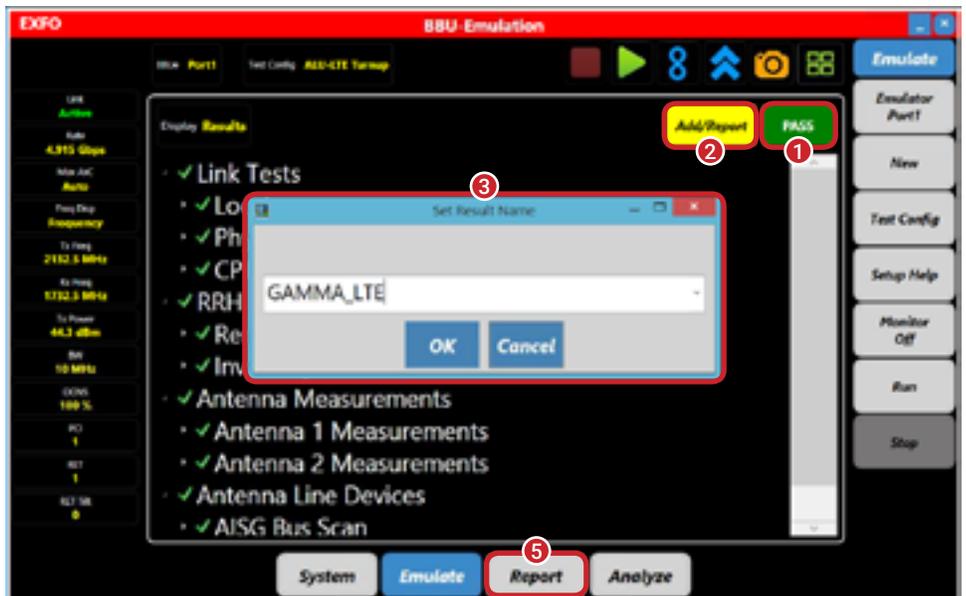


Figure 55. BBU emulation add to report

1. The Report name, site and notes field can be updated by selecting the **Edit** button.
2. Right-clicking on one of the tests gives many options, like **Rename** and **Delete**.
3. Once the report is ready, select the **Export PDF** button to generate a PDF version of the report.

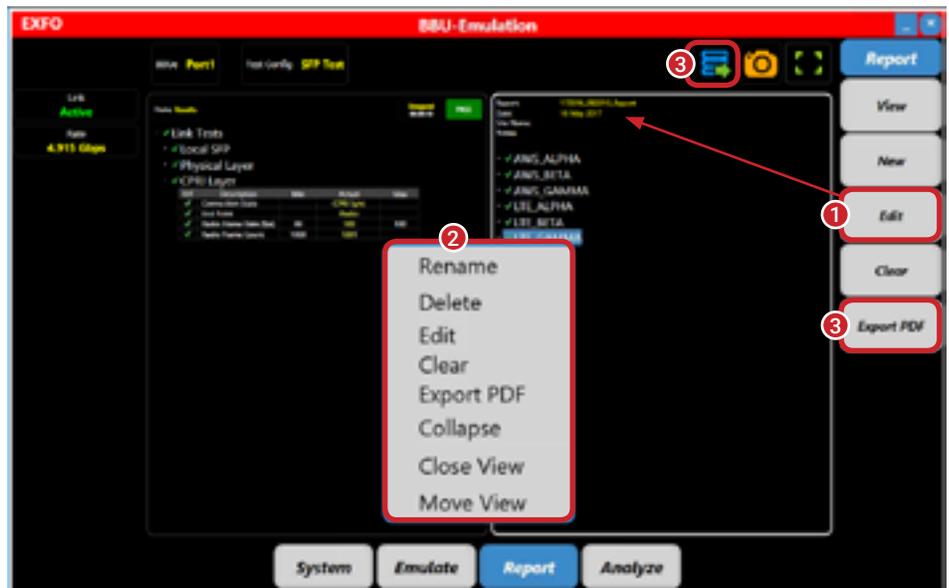


Figure 56. BBU emulation Emulate and Report tabs

## 1.3.5 Additional/optional BBU emulation features

### 1.3.5.1 BBU emulation results and log



Figure 57. BBU emulation results, results/log and log view

### 1.3.5.2 Antenna carrier and Rx-Tx frequency

1. EXFO's BBU-Emulation application provides the ability to automatically or manually configure the number of AxCs.
2. The RRR's upper and lower Tx/Rx operating frequency limits are automatically determined by EXFO's BBU emulation test application. The user can modify and set the desired Tx and Rx operating frequency within the RRR's operating frequency range.



Figure 58. BBU emulation Tx frequency

### 1.3.5.3 Bandwidth, VSWR and Tx power

When **VSWR** readings are required, make sure the Tx power is at least 80% of the maximum power of the RRH. VSWR readings are available in Antenna Measurements under the Results section.

1. Select the current signal bandwidth (BW): **5 MHz, 10 MHz or 20 MHz**.
2. The RRH's upper and lower Tx power limits are automatically determined by EXFO's BBU emulation test application. The user can modify and set the desired Tx power used for the test.

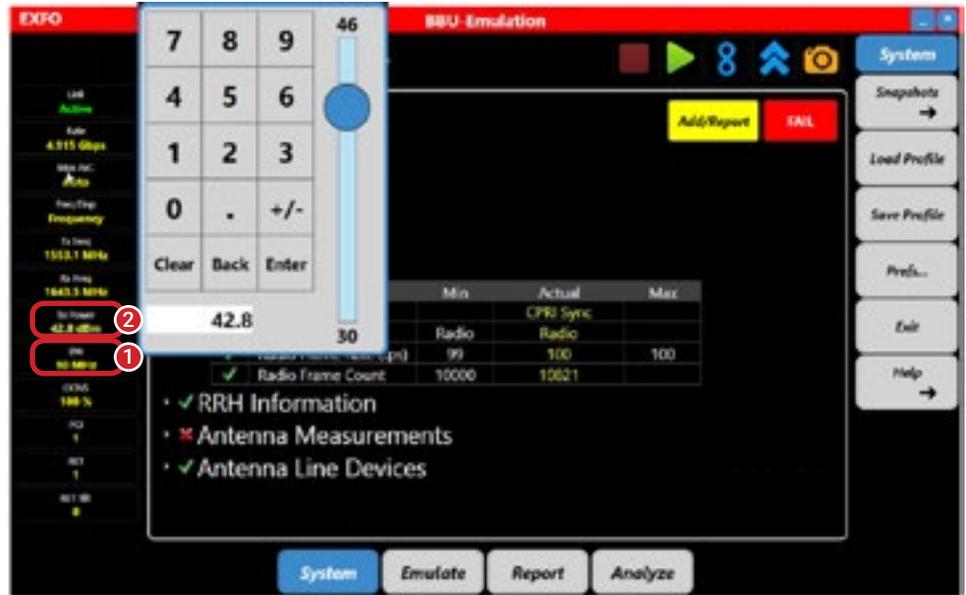


Figure 59. BBU emulation Tx power

### 1.3.5.4 OCNS, PCI, RET and RET Tilt

1. Orthogonal channel noise simulator (OCNS) simulates user load on the downlink: **Off, Idle, 50%** and **100%**. The number of users on a radio system loads up the available resource blocks and affects how the mobile system performs. In order to simulate real-world loading, OCNS is applied to the last phase of the emulate tests.
2. Set the physical cell identification (PCI) that will be transmitted by the RRH.
3. Select the RET that is attached to the RRH that is under test.
4. RET Tilt sets the tilt (in 0.1 degree increments) of the selected antenna RET.



Figure 60. BBU emulation RET

## 1.4 RF spectrum analysis over CPRI

EXFO's OpticalRF™ enables field technicians to troubleshoot cell sites by accessing the RF signal at the BBU location. The system is designed to provide the most powerful real-time, high-resolution RF spectrum analysis over CPRI to quickly identify external RF interference.

CPRI RF spectrum validation can be performed for D-RAN and C-RAN architectures. The FTB-1 Pro is connected from the BBU location to the digital uplink, where the CPRI protocol carries the RF signal in a digital format (IQ data). Once the link becomes active, the RF spectrum over CPRI analysis will identify the RF signal quality.

The following steps must be completed on EXFO's FTB-1 Pro test platform with the OpticalRF™ application.

### 1.4.1 Connecting to the digital uplink

The uplink is the signal that the tower receives from cellphones, and needs to be verified because of its low power and high susceptibility to RF interference.

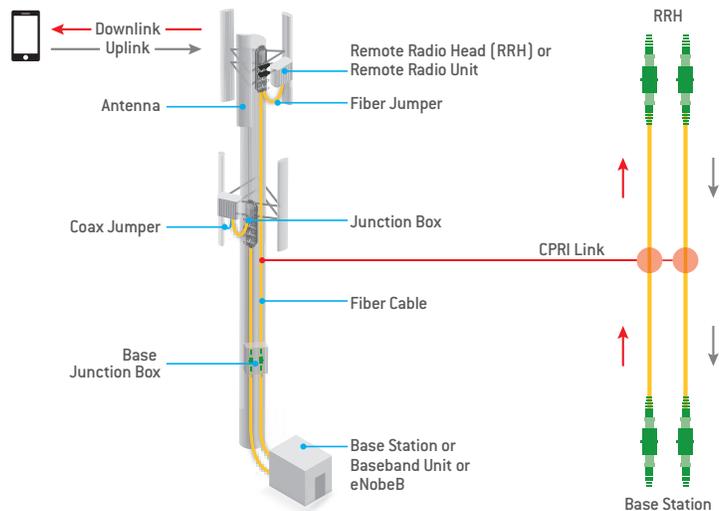


Figure 61. CPRI cell tower

1. Connect the fiber from the RRH to the A port of the splitter (TAP).
2. Connect the TAP's B port to the BBU.
3. From the FTB-1 Pro, connect the uplink (A) of the AB port to the SFP+ Rx port 1 or port 2. The SFP on the FTB-1 Pro must be the same wavelength as the SFP on the BBU and RRH. Also, the SFP must support the link speed.

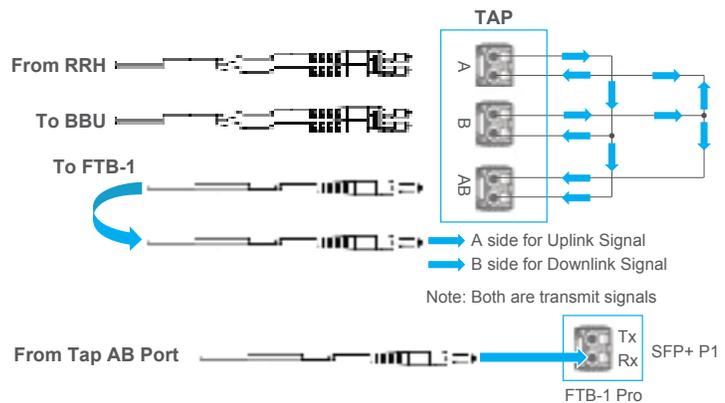


Figure 62. FTB-700G V2 Series and splitter (TAP) connections

## 1.4.2 Starting the OpticalRF™ application

1. Select the OpticalRF™ application from the FTB-1 Pro toolbox.



Figure 63. FTB-1 Pro platform toolbox

## 1.4.3 Setting up the OpticalRF™ application to view the RF spectrum over CPRI

1. Select the **Port1** or **Port2** option under **Source**.
2. Select **Auto** from the drop-down menu to automatically discover the correct CPRI rate option.



Figure 64. OpticalRF™ main interface

3. Verify that the CPRI link is operational by seeing whether the Link status changed to **Active**. If the link status remains **LossOfSignal**, the CPRI rate or the connections to the uplink need to be reverified. Do not proceed without an active link.
4. Select the **Mapping** option. The RRH manufacturer and Channel Bandwidth (Channel BW) are required.
5. Select the proper Antenna Carrier (**AxC**).
6. Set the **Center** frequency.



Figure 65. OpticalRF™ Graph tab

### 7.a. Auto scaling (recommended)

1. Select the **Amplitude** Menu.
2. Select the **Full Scale** button to switch it on. The RF spectrum will auto-adjust the trace to get a full view.

### 7.b. Manual scaling

3. The reference level moves traces along the power axis (Y-axis.) Change the reference level to center the trace.
4. The scale changes the number of dB per division in Y-axis.



Figure 66. OpticalRF™ Amplitude tab

## 1.4.4 Validating the CPRI RF spectrum

After completing the steps above, the RF signal will be displayed on the FTB-1 Pro using a real-time, high-resolution spectrum over CPRI, making it easy to quickly identify issues such as external RF interference and passive interference modulation (PIM). A quick look at the spectrum gives a general idea of whether the RF signal is good or if there is major interference affecting it.

OpticalRF™ enables multiple antenna carriers (AxC) to be displayed at the same time. This facilitates the ability to identify internal from external interference by visualizing diversity imbalances.

1. The port/file that is already selected is highlighted in blue.
2. Select the **Overlay** button
3. Select the second trace to be overlaid.



Figure 67. OpticalRF™ System tab

## 1.4.5 Additional/optional RF spectrum configurations

Sometimes there will be a small spike in the RF spectrum, making it difficult to determine whether it is RF interference or normal mobile traffic. This situation requires more troubleshooting; OpticalRF™ has all the functions required to verify this uncertainty.

### Crosshair

1. Select the **Graph** menu.
2. Select the **Crosshair** button to switch it on.
3. Move the crosshair across the graph.
4. Get the power (dB) and frequency (MHz) readings.



Figure 70. OpticalRF™ Crosshair

### Zoom

1. Select the **Graph** menu.
2. Select the **Enable Zoom** button to switch it on.
3. Click and drag from bottom to top on the desired zoom location.

### UnZoom

4. Select the **UnZoom** button.



Figure 68. OpticalRF™ Zoom and UnZoom

### Recording

1. Select the red button in the top right-hand corner. Type a filename and press **OK**.

### Replaying

2. Change the source to **File1** or **File2**. Select the green loop in the top right-hand corner to play back a file and then select a filename to open.

### Snapshots

3. Select the orange camera in the top right-hand corner to save a snapshot of the current RF spectrum.



Figure 69. OpticalRF™ Record, Replay and Snapshot

### Minimum/Maximum/Average hold

1. Select the **Traces** menu.
2. Select the **Trace** button and a list of options will open.
3. Select the type of trace.
4. Select the **Enabled** button to switch it on.

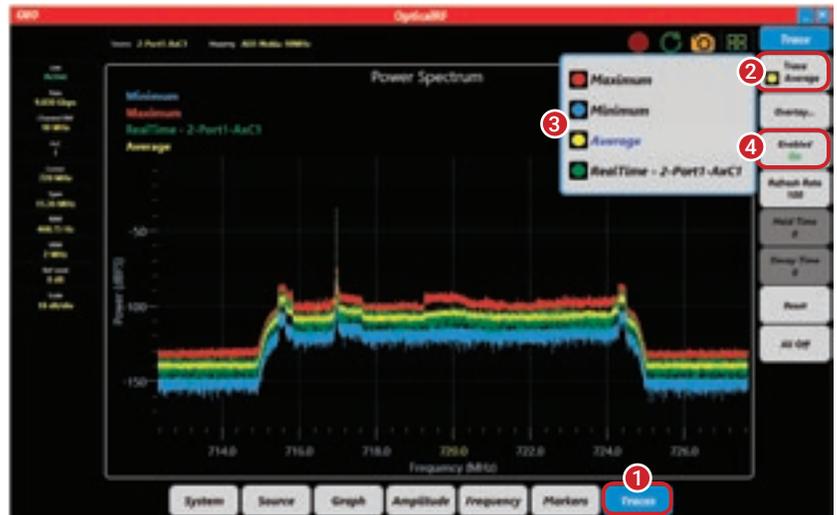


Figure 71. OpticalRF™ Traces tab

### Displaying multiple graphs

1. Select the **Graph** menu.
2. Select the **New** button.
3. Select the type of graph from the box and click OK.
4. Tap on any of the blue positioning bars and the new graph will be inserted.

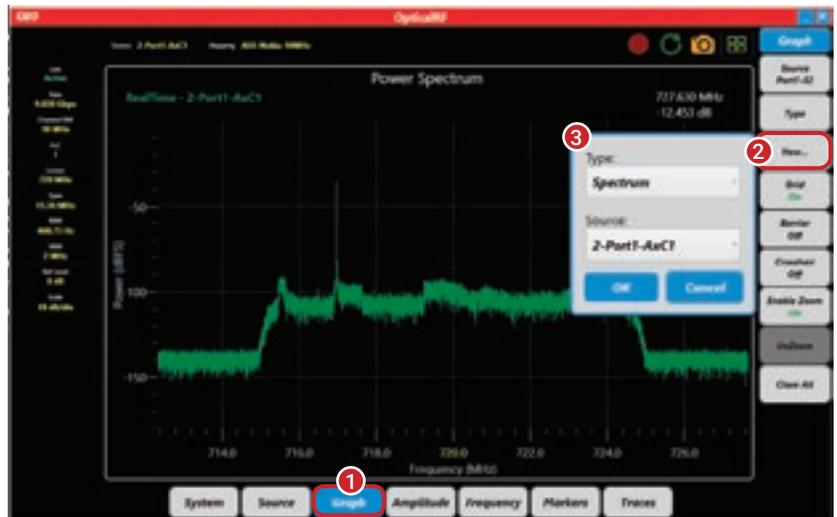


Figure 72. OpticalRF™ New graph



Figure 73. OpticalRF™ Select View

## 2 Test documentation

Although network test documentation helps with the planning and expansion of network capacity (bandwidth and routing), this need is generally considered only when a problem occurs. When the network is down, productivity is normally lost and customers may not be supported, all of which could lead to high revenue loss. When a problem occurs and network documentation is readily available, the team in charge of resolving the issue will be able to quickly obtain an understanding of the network and minimize the time required to fix the problem—resulting in lower costs for you and/or your customer. Good documentation is not only helpful when a problem occurs, but also aids the internal and external transfer of knowledge.

Another important consideration is that many networks are built by contractors or subcontractors who, in most cases, must submit test reports for job completion and payment. Therefore, it is mandatory to save the test results of work performed in the field.

All native files from the FIP, iOLM and CPRI tests can be submitted via EXFO Connect. A report must be sent containing all the files, in PDF format, generated by the test units. From the unit, generate a report after each FIP, iOLM and CPRI test.

For examples of test reports, refer to the figures below.



Figure 74. FIP test report



Figure 75. iOLM test report

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### Results Summary

Test Status	
Test Status	Completed
Pass/Fail Verdict	PASS
Start Time	3/26/2015 02:26:31 PM
Duration	00:00:00:25
Power Recovery	0

CPRI Link Operation				
Sequence	Received Protocol	Negotiated Ethernet Subchannel	Negotiated HDLC Rate	Verdict
Frame Sync	Passive (0)	Version 1	Disabled	PASS

CPRI Counts		
Count	Code Word	Hyperframe
Total TX	54025009	345000
Total RX	54025009	345000

RX Power Level		
	Min	Max
Power Range (dBm)	-23.0	-2.0
Rx Power Level (dBm)	-4.0	-4.0

RX Frequency		
	Max Negative Offset	Max Positive Offset
Frequency Offset (ppm)	0.0	0.0

CPRI\_OBISAI\_BERT\_2015-03-26\_14:26:58 3/26/2015 2:27:22 PM

Figure 76. CPRI test report

Sometimes, measurements taken in the field will not require extra post-processing, but in other cases extra processing will be required to perform proper analysis, establish accurate diagnoses, and ultimately document the network properly (test report or birth certificate), as per customer requirements or the network owner's standard. As indicated in the table below, the three logical steps of data post-processing generally consist of editing, analyzing and documenting the test results.

1. Edit	2. Analyze	3. Document
Adjust the cable and fiber parameters (e.g., job information)	Perform OTDR or iOLM bidirectional analysis	Report customization
Add/remove OTDR/iOLM events	Detect duplicated measurements	Various report types
Adjust detection thresholds	Easily identify the results that fail network requirements	Combined reports such as: – Fiber characterization – iOLM with connector inspection results
Perform manual measurements on OTDR files		
Set pass/fail thresholds		

Table 3. Data post-processing actions

## 3 PMD/CD dispersion

Polarization mode dispersion (PMD) and chromatic dispersion (CD) are two effects that can lead to bit errors, which cannot be overlooked during the commissioning or troubleshooting phase of any network path.

PMD is caused primarily by fiber defects, imperfections and external stresses. These external stresses may be natural (e.g., earthquakes and storms), or artificial (e.g., digging and vehicle-induced vibration). As such, PMD can vary quite rapidly and is not wavelength dependent. When testing for PMD, a safety margin is often required. PMD cannot be compensated for in the optical domain. Some advanced technologies, such as those used in 100 Gbit/s coherent transmission, partly help to mask the impact of PMD.

CD is caused by normal light dispersion in a medium such as glass, where some wavelengths travel faster than others. CD is a given value for a given fiber; as such, it can be easily compensated for once identified.

### 3.1 Best practices

There are several methods for testing PMD and CD; however, single-ended solutions are the most cost-effective in a dark fiber implementation in short-haul and metro networks:

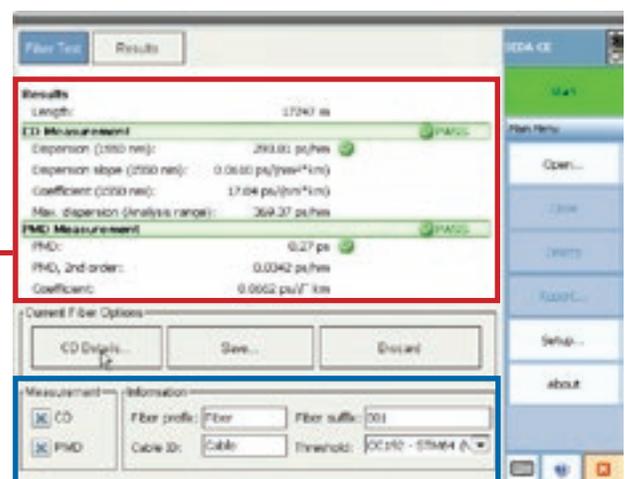
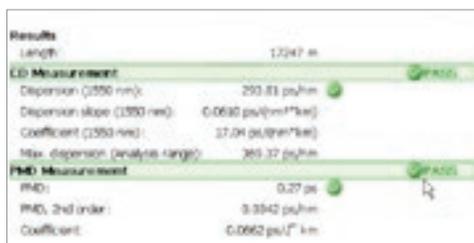
- Single-ended: Based on OTDR-like technology, these solutions offer the benefit of much faster and simpler characterization procedures because a single technician can carry out two measurements (PMD and CD) without waiting for a second technician to move from one site to another. These methods are ideal; they are the recommended test approaches for CWDM-based and metro networks, because they are typically less than 150 km and do not contain amplifiers.

The single-ended approach can have the two testing capabilities (CD and PMD) within the same unit, tested at the same time, and without the need to reconfigure or to disconnect test equipment. In the process, these units also measure fiber length, which can serve the following purposes:

- Validate the fiber length found by the iOLM
- Automatic calculation of CD and PMD co-efficient, which is the amount of dispersion per kilometer, and often an indication of fiber quality and type

### 3.2 Doing the test

Performing the test is extremely simple using the FTB-5700 Single-Ended Dispersion Analyzer, which integrates both CD and PMD testing capabilities within the same unit.



Data rate	CD tolerance	PMD tolerance <sup>1</sup>
2.5 Gbit/s	18 468 ps/nm	37.5 ps
10 Gbit/s	1193 ps/nm	9.3 ps

<sup>1</sup> Assuming an outage probability of 0.001%.

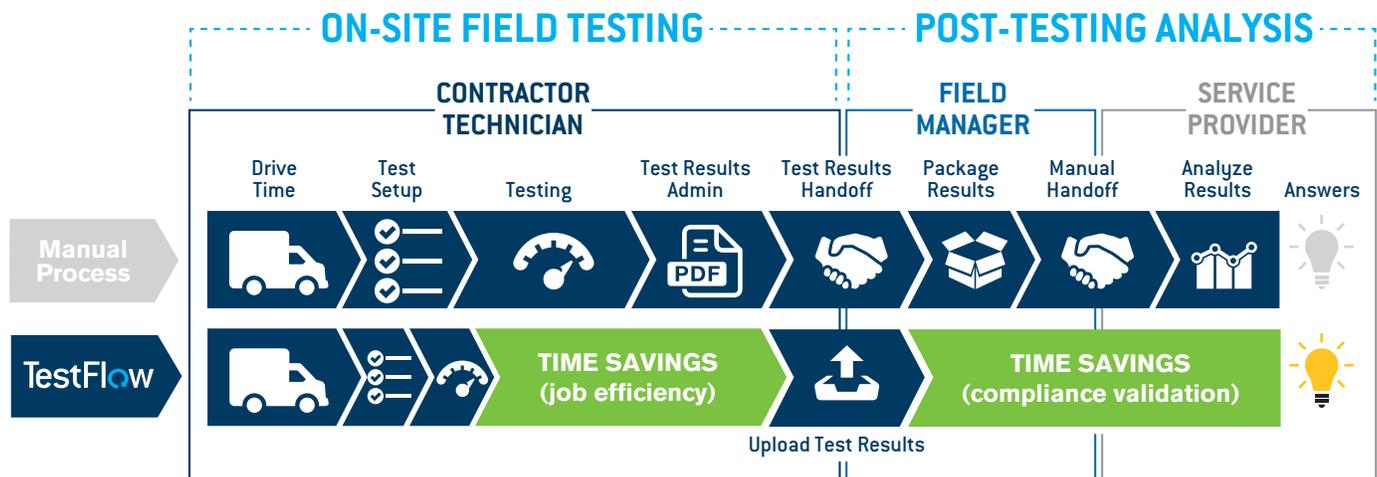
## 4 Field test process automation and analytics

Many field issues require testing verification during construction in order to prevent costly deployment delays and future service outages. However, this involves highly manual and error-prone management tasks, and is further complicated by the many levels of contractors/subcontractors involved. Building a solid process is one thing, but ensuring that a varied and ever-changing set of contractor companies and technicians are following it correctly is another. In addition, the task of analyzing and interpreting reams of test results that are full of ID and file naming data entry errors is something else entirely. EXFO's TestFlow field test process automation and analytics application is fully capable of addressing the process compliance and analytics requirements essential to successful fronthaul deployments. Through this combined approach, contractors and their technicians are able to benefit from higher efficiency and better job quality with minimal training required; service providers are able to gain control of their fiber deployments, maximize return on investment through on-schedule project delivery, and proactively prevent future service issues.

TestFlow integrates the fully automated fiber inspection probe, the single-touch automated iOLM OTDR and the CPRI link validation test functionality to enable complete validation of new or upgraded fiber-based mobile architectures.

### 4.1 Key benefits of the TestFlow solution

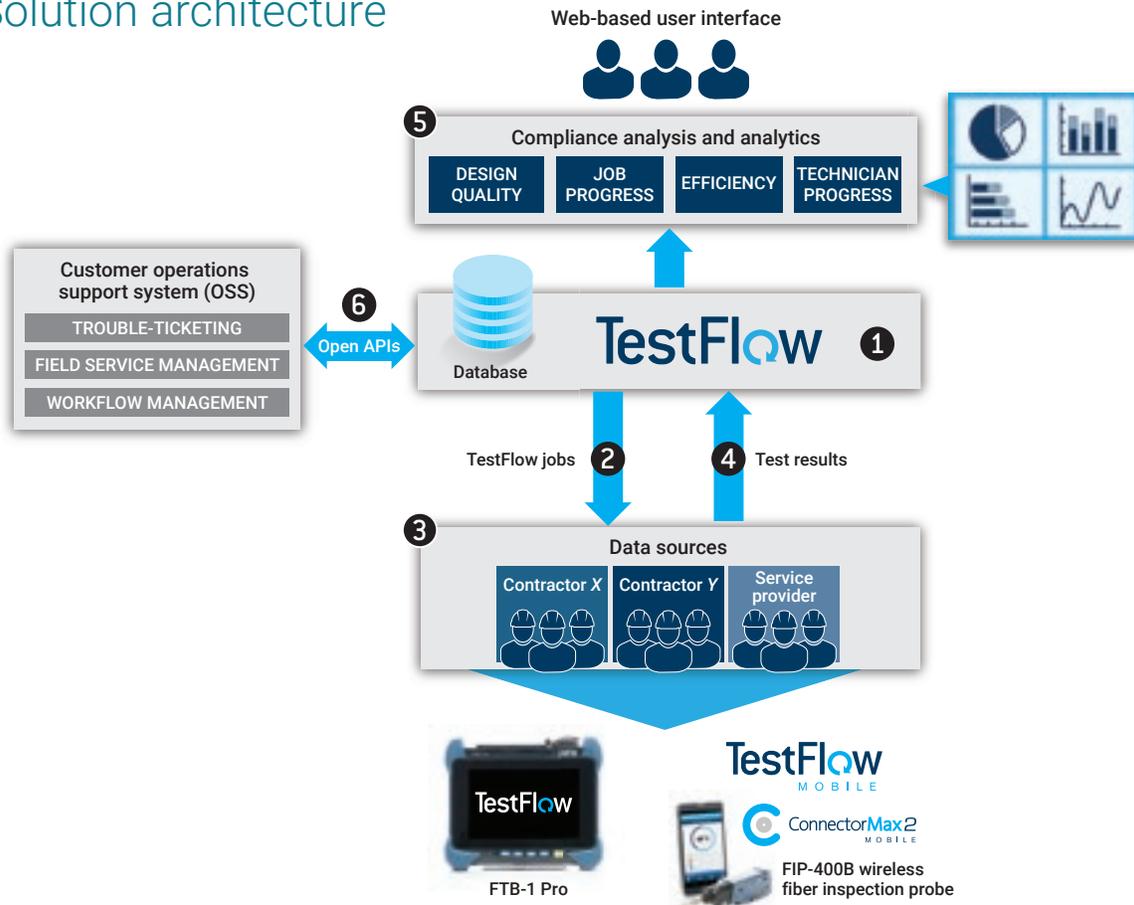
- Digitizes and automates field construction and testing to ensure that work performed by the technicians is labeled and tracked 100% of the time without the need for post-processing, bookkeeping or unnecessary processing of manually collected results
- Standardizes all tasks and tests to provide workforce conformity to quality construction and testing processes
- Centralizes and analyzes all field test results into a unified set of dashboards for fast, easy verification and tracking focused on job performance, status, efficiency and quality



From the frontline and manager or supervisor perspectives, field test process automation and analytics assure compliance with network standards and maximize technician efficiency. However, for network engineers and designers, and operations and marketing executives at MSOs, cable companies, MNOs and telcos, it is the foundation for the following progressive, escalating benefits:

- Reduced network construction time and costs
- Faster, high-quality, on-schedule network deployments
- Accelerated time-to-revenue for new services
- Decreased troubleshooting and sustained service revenue
- Reduced subscriber churn and enhanced corporate brand

## 4.2 Solution architecture



### 1 Make Sure that Your Entire Workforce Is on the Same Page

The process starts with the conversion of a static methods and procedure (M&P) document into a digitized and automated task sequence. Once defined, the TestFlow template is pushed directly to the assigned technicians from the TestFlow server to their units. TestFlow templates can be shared with different technician groups, contractors and subcontractors, depending on the job types that need to be performed. The information can also be shared via the EXFO Link app to provide step-by-step instructions to the contractor.

If a template is updated, it can be pushed out again the next time the relevant test sets connect back to the server; technicians don't need to manage template versions. This ensures a standardized and repeatable approach for everyone in the workforce.

### 2 Address the Challenge of Controlling and Guiding Work in the Field

As the user progresses through the test sequence, each fiber inspection, intelligent Optical Link Mapper (iOLM) fiber characterization and CPRI link validation test will be properly documented and organized. Whenever internet connectivity is available, it will be possible to upload and centralize test results to the TestFlow database directly from the test set; this prevents any test results with file naming errors, or time wasted in transferring the information via USB device and e-mail. To provide accurate geolocation tagging of test results, technicians must run the EXFO Link app on their smartphones, then use its GPS and location acquisition capability. This will transmit the information to the TestFlow application running on the EXFO FTB-1 Pro test platform. If needed, the technician can also upload third-party test results using the EXFO Link app (e.g., from RF spectrum analyzers for FTTA and distributed antenna system [DAS] deployments), along with key metadata such as job ID and pass/fail indication, directly from a smartphone to the TestFlow server.

Moreover, EXFO Link can capture any result in the form of pictures, files or PDFs; it also interacts with the user to verify results based on defined thresholds.

### 3 Capture All the Results in a Central Repository

Once the user has verified the results and confirmed job completion using the summary report, the test results and all pictures, files and PDFs will be uploaded to the central server repository for further analysis and closeout.

### 4 Analyze Results and Close Out Without the Hassle

Test results are stored in a centralized database and can be analyzed using the TestFlow software to identify performance, efficiency, status and quality issues. Each stakeholder can access relevant pieces of information based on individual user privileges. The information is made readily available in the form of preconfigured analytics dashboards with contextual filtering, drilldown to detailed reports, and even individual per-test results for detailed troubleshooting.

These analytics dashboards provide a comprehensive review of all work performed in the field via a single screen and without the need for any manual intervention.

### 5 Integrate TestFlow server with back-office systems using open APIs

Cross-functional collaboration is made possible through the use of open application programming interfaces (APIs) supporting integration into service provider OSS for field service and workflow management as well as trouble-ticketing. These APIs remove the barriers to workflow optimization across multiple processes and drive operational efficiencies throughout the organization.



Figure 77. Example of test results tracked within the TestFlow application on the FTB-1 Pro test platform.

### 4.3 Project tracking and compliance analysis

TestFlow analytics offer a highly flexible way of reporting on data collected in the field and relevant derived metrics. The example in the image below illustrates specific regional, market and location views of project status and shows how each project is performing. In addition, it provides all the tests—iOLM in this example—performed in accordance with established practices and thresholds, thus guaranteeing first-time-right deployments.



Figure 78. Example dashboard showing project status and progress

## 5 Network quality monitoring systems (NQMS)

### 5.1 Key tools for dark fiber providers involved in FTTA

Challenge: Dark fiber providers typically have no access to BBU/RRH equipment; they are responsible for the fiber (including the infrastructure), but not for the equipment. However, they want to be aware of issues and respond to their customers with reliable data about the past and present condition of the fiber. The particular challenge is to understand whether the fibers are affected up to a demarcation point close to or at the RRH equipment optical ports, typically the endface of the fiber links.

Solution: The solution involves installing a fixed, permanent OTDR, optical switching and any passive test access device on all new installations for remote testing and fiber surveillance. Dark fiber providers can therefore propose link monitoring as an option to fiber leasing in order to enforce and improve their service level agreements (SLAs), thus increasing the value of their service offering. It is common practice to take OTDR snapshots of the fiber from day one and understanding when and how the fiber condition changes up to a demarcation location. The demarking device can be as simple as the end of the fiber shown clearly on an OTDR trace, or consist of more sophisticated reflective filters that are capable of acting as a demarcation device and of blocking or attenuating the OTDR signal to ensure that it doesn't affect RRH transmit/receive functions.

### 5.2 Equipment—remote test unit (RTU)

Application: remote OTDR testing and monitoring of cloud/centralized/distributed RANs

- OTDR-based; single-ended means no need for an end-of-line active device.  
In some cases, a passive OTDR rejection filter is needed to isolate the receive fiber (Rx)
- Active, in-service fiber testing, proactive monitoring or reactive troubleshooting
- OTDR models adapted to FTTA and centralized RAN for 100 m to 40 km+ ranges
- Equipment is to be placed in central or temperature-controlled macrocell sites
- Scalable in ports; single OTDR shared among a large number of test ports is the best value
- Down three seconds per port (round-robin 16 ports in less than one minute for up to 15 dB attenuation)



Figure 79. Scalable from eight to 96 ports in 2U size rack



Figure 80. Configuration with 24 ports based on 12-f MPO and test access module kit (TAMK) that houses 24 WDMs, all occupying a 3U space

Refer to the figure below to see how it all works together.



Figure 81. Fiber pair cases operated by a dark fiber provider

### 5.3 Motivations for monitoring fiber in the fronthaul

With value-added services running on fixed and mobile networks, as well as 5G looming on the horizon, dark fiber providers are under increasing pressure to ensure that access networks are stable and reliable. In addition, it will be important to have the right tools in place to provide essential data needed to validate the quality of the fiber at all times.

Top line:

- Offer higher-value dark fiber services
- Mobile operators to improve the quality of service (QoS) of 4G LTE
- Fiber providers to gather and present historical data to their prospective carriers
- Improve customer service (being aware of issues before answering the call)
- Improve customer loyalty

Bottom line:

- Reduce the cost of maintenance and troubleshooting in any access-type network
- Achieve faster times in understanding, isolating and locating fiber-related issues
- Centralize operations at the network operations center
- Spend less time and money on managing tenants
- Avoid penalties
- Faster mean time to repair
- Maintain quality over time (e.g., change management and repair verification)

## 6 Appendix A—list of acronyms

API	application programming interface	MPLS	multiprotocol label switching
BBU	baseband unit	MPO	multifiber push-on
BER	bit error rate	OBSAI	Open Base Station Architecture Initiative
BERT	bit error rate test/testing	OCNS	orthogonal channel noise simulation
BTS*	base transceiver station	OTN	optical transport network
C&M	control and management	ORL	optical return loss
CD	chromatic dispersion	PCI	physical cell identification
CDN	content delivery network	PIM	passive interference modulation
CO	central office	PMD	polarization mode dispersion
CoMP	coordinated multipoint	PRBS	pseudo-random bit sequence
CPRI	Common Public Radio Interface	RAI	remote alarm indication
C-RAN	centralized radio access network	RAT	radio access technology
CSR	cell-site router	RF	radio frequency
CWDM	coarse wavelength-division multiplexing	RL	return loss
DAS	distributed antenna system	RRH	remote radio head
DC	direct current	RSSI	received signal strength indication
D-RAN	distributed radio access network	RTD	round-trip delay
DU	digital unit	RTU	remote test unit
DWDM	dense wavelength-division multiplexing	Rx	remote receive fiber
FTTA	fiber-to-the-antenna	SFP	small form-factor pluggable
HDLC	high-level data link control	SLA	service-level agreement
IEC	International Electrotechnical Commission	SM	singlemode
IL	insertion loss	Tx	transmitter
iOLM	intelligent Optical Link Mapper	QoS	quality of service
LOS	loss of signal	UPC	ultra-polished connector
M&P	methods and procedure	VoD	video on demand
MEC	mobile edge computing	VSWR	voltage standing wave ratio
MNO	mobile network operator	WDM	wavelength-division multiplexing

\*Or NodeB/eNodeB





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