



APPENDIX **A**

Recommended Tools and Test Equipment

Table A-1 lists the basic tools and test equipment necessary to perform general maintenance and troubleshooting tasks on the Cisco uBR10012 router.

Table A-1 *Recommended Tools and Test Equipment*

Equipment	Description
Number 2 Phillips and flat-head screwdrivers	Small and medium-sized.
Voltage tester	Refer to the “ Testing with Digital Multimeters and Cable Testers ” section on page A-1.
Optical fiber test equipment	Refer to the “ Testing with Digital Multimeters and Cable Testers ” section on page A-1.
Cable testing equipment	Refer to the “ Testing with Digital Multimeters and Cable Testers ” section on page A-1.
HFC network physical layer equipment.	Refer to the “ HFC Network Physical Layer Testing and Troubleshooting ” section on page A-4.
ESD-preventive wrist or ankle strap with connection cord	—

The following sections describe advanced testing equipment to aid in complex problem isolation.

Testing with Digital Multimeters and Cable Testers

Use a digital multimeter to measure parameters such as AC and DC voltage, current, resistance, capacitance, cable continuity. Use cable testers, also, to verify physical connectivity.

Use cable testers (scanners) to check physical connectivity. Cable testers are available for shielded twisted pair (STP), unshielded twisted pair (UTP), 10BaseT, and coaxial and twinax cables. A given cable tester might be able to perform any of the following functions:

- Test and report on cable conditions, including near-end crosstalk (NEXT), attenuation, and noise.
- Perform time domain reflectometer (TDR), traffic monitoring, and wire map functions.
- Display Media Access Control (MAC) layer information about LAN traffic, provide statistics such as network utilization and packet error rates, and perform limited protocol testing (for example, TCP/IP tests such as ping).

Test fiber-optic cable both before installation (on-the-reel testing) and after installation. Continuity testing of the fiber requires either a visible light source or a reflectometer. Light sources capable of providing light at the three predominant wavelengths, 850 nanometers (nm), 1310 nm, and 1550 nm, are used with power meters that can measure the same wavelengths and test attenuation and return loss in the fiber.

Testing with TDRs and OTDRs

This section describes time domain reflectometers (TDRs) and optical time domain reflectometers (OTDRs), which are typically used to detect cable defects.

TDR, also known as a metallic time domain reflectometer is used to characterize and troubleshoot metallic transmission lines such as twisted pair and coaxial cables. The TDR transmits pulses into one end of the line being tested and impedance mismatches in that line will reflect some or all of each transmitted pulse back to the instrument. Units with graphical displays can also plot a signature of the line being tested, allowing the operator to measure line length, identify splices, passives, actives, and locate damage to the line. TDRs are mainly useful for troubleshooting buried and hidden cables.

OTDR is used to characterize and troubleshoot optical fiber. The OTDR transmits pulses into one end of a fiber being tested and optical events in that fiber will cause backscatter of some or all of the transmitted pulses. OTDR measures the time from when each pulse is transmitted to when the backscatter is returned. As such, the OTDR can be used to measure fiber and event loss, identify specific events, and measure the distance to those events. There are two broad categories of optical events: reflective and non-reflective. Reflective events include the end of the fiber, connectors, mechanical splices, and breaks in the fiber (air/glass gap). Non-reflective events include fusion splices, breaks in the fiber (no air/glass gap), macrobends, and microbends.

Testing with TDRs

Use time domain reflectometers to test for the following cable defects:

- Open and short circuits
- Crimps, kinks, and sharp bends
- Impedance mismatches
- Other defects

A TDR works by “bouncing” a signal off the end of the cable. Open circuits, short circuits and other problems reflect the signal back at different amplitudes, depending on the problem.

A TDR measures:

- the amount of time it takes for the signal to reflect
- The physical distance to a fault in the cable
- The length of a cable

Some TDRs can also calculate the propagation rate based on a configured cable length.

Testing with OTDRs

Use optical time domain reflectometers to:

- Locate fiber breaks
- Measure attenuation
- Measure the length of a fiber
- Measure splice or connector losses

An OTDR can be used to identify the “signature” of a particular installation, noting attenuation and splice losses. This baseline measurement can then be compared with future signatures if you suspect a problem in the system.

Testing with Breakout Boxes, Fox Boxes, and BERTs/BLERTs

Use breakout boxes, fox boxes, and bit/block error rate testers (BERTs/BLERTs) to measure the digital signals present at:

- PCs
- Printers
- Modems
- CSU/DSUs

These devices can monitor data line conditions, analyze and trap data, and diagnose problems common to data communication systems. Traffic from data terminal equipment (DTE) through data communications equipment (DCE) can be examined to:

- Isolate problems
- Identify bit patterns
- Ensure that the correct cabling is installed

These devices cannot test media signals such as Ethernet, Token Ring, or FDDI.

Testing with Network Monitors

Use network monitors to:

- Track packets crossing a network
- Provide an accurate picture of network activity at any moment
- Provide a historical record of network activity over a period of time

Network monitors do not decode the contents of frames. Monitors are useful for baselining, in which the activity on a network is sampled over a period of time to establish a normal performance profile, or baseline.

Monitors collect information such as packet sizes, the number of packets, error packets, overall usage of a connection, the number of hosts and their MAC addresses, and details about communications between hosts and other devices. This data can be used to:

- Create profiles of LAN traffic
- Locate traffic overloads
- Plan for network expansion
- Detect intruders

- Establish baseline performance
- Distribute traffic more efficiently

Testing with Network Analyzers

Use network analyzers (also called protocol analyzers) to decode protocol layers in a recorded frame and present the layers as readable abbreviations or summaries, detailing which layer is involved (physical, data link, and so forth) and the function each byte or byte content serves.

Most network analyzers can perform many of the following functions:

- Filter traffic that meets certain criteria so that, for example, all traffic to and from a particular device can be captured.
- Time-stamp captured data.
- Present protocol layers in an easily readable form.
- Generate frames and transmit them onto the network.
- Incorporate an “expert” system in which the analyzer uses a set of rules, combined with information about the network configuration and operation, to diagnose and solve, or offer potential solutions to, network problems.

DOCSIS 3.0 RF Protocol Analyzer

DOCSIS 3.0 RF Protocol Analyzer is the industry standard for functional DOCSIS network analysis. This device is optimized for real-time signal processing with FPGA technology and can analyze up to four single or bonded upstream and downstream channels.

HFC Network Physical Layer Testing and Troubleshooting

This section provides an overview of test equipment commonly used to maintain and troubleshoot the Hybrid fibre-coaxial (HFC) network physical layer. It is not intended to be an exhaustive list, nor to provide how-to instructions, which are available from the respective test equipment manufacturers. General test and measurement guidelines are also available in publications such as the latest edition of *Recommended Practices for Measurements on Cable Television Systems*, available from the [Society of Cable Telecommunications Engineers](#).

A properly designed, constructed, and maintained HFC network is capable of supporting reliable high-speed data, voice and video services, as long as the entire network-headend, distribution plant, and subscriber drops-meets or exceeds certain minimum technical performance criteria. Those criteria include compliance with relevant government technical regulations applicable to cable, such as Part 76 of the [Electronic Code of Federal Regulations](#); and the assumed downstream and upstream RF channel transmission characteristics summarized in the [DOCSIS® Radio Frequency Interface Specification](#).

Most of the test equipment described here are intended to be used to test and troubleshoot the HFC network itself, regardless of the types of signals carried on the network. Certain instruments, such as digital signal analyzers, are designed specifically to measure digitally modulated signals such as the quadrature amplitude modulation (QAM) signals at the downstream output of the CMTS or edge-QAM modulator.

Broadband Sweep

Typically comprising a sweep transmitter and a sweep receiver, this class of test equipment is used to characterize the cable network's frequency response specifically its amplitude-versus-frequency response. Sweep equipment may use a transmitted continuous low-level sweep signal (30 dB to 40 dB below analog TV channel visual carrier levels), sweep insertion points (carriers briefly inserted at specific frequencies, typically between channels), or sweepless sweep, in which the sweep receiver measures the amplitude of each operating carrier on the network and to produce a coarse indication of frequency response. Sweep equipment is available for downstream and upstream applications, and works well for initial and periodic alignment of the network, identifying improperly adjusted actives, missing or damaged plant components, and other problems that degrade the network's frequency response from an ideal situation.

Cable Modem Upstream Adaptive Pre-equalization Coefficients

CableLabs® and its proactive Network Maintenance Working Group in 2010 published a best practices document and reference implementation that describe the use of cable modem upstream pre-equalization coefficients to troubleshoot certain outside plant impairments. Though not technically a test equipment, the cable modems connected to an HFC network can be powerful tools for troubleshooting plant problems. The best practices document and reference implementation can be downloaded from the following URLs.

- *DOCSIS Proactive Network Maintenance Using Pre-equalization*
<http://cablelabs.com/specifications/CM-GL-PNMP-V01-100415.pdf>
- Reference Implementations and the associated demo package
<http://www.cablelabs.com/cablemodem/ri/>

Digital Multimeter

Most Digital multimeters (DMM) support measurement of AC and DC voltage and current, resistance, and continuity. The use of a true root mean square (RMS) DMM is recommended, since the latter provides more accurate measurement of the quasi-square wave AC voltage (nominally 60 or 90 volts) used to operate an HFC network's outside plant active devices. Lower cost non-true RMS DMMs generally read about 10% high when measuring the latter.

Examples of typical uses for DMMs include measurement of the:

- AC plant voltage
- commercial utility AC mains voltage
- regulated DC voltages inside amplifiers and nodes
- opto-electronic DC voltage test points that correspond to optical power levels

and identifying specific cables that go to specific outlets at the subscriber premises, and basic continuity testing of wiring and cabling.

Digital Signal Analyzer

Digital signal analyzer is also known as a QAM analyzer. It is impossible to fully evaluate a QAM signal merely by measuring its digital channel power or looking at it on a spectrum analyzer. It is necessary to look further inside the signal to see what is going on. This is where the digital signal analyzer plays an important role.

In addition to incorporating signal level meter-type functionality for the measurement of analog TV channel signal level and digital channel power, most digital signal analyzers support several functions that can be used to characterize the health and performance of downstream QAM signals such as:

- Constellation display
- Modulation error ratio (MER)
- Pre- and post-FEC (forward error correction)
- BER (bit error ratio)

Depending on the make/model, some digital signal analyzers also have the ability to characterize linear distortions such as amplitude ripple and tilt (poor in-channel frequency response), micro-reflections (using the analyzer's adaptive equalizer graph), and group delay. Most digital signal analyzers can be used to troubleshoot transient impairments such as sweep transmitter interference and downstream laser clipping. Tracking down some types of in-channel ingress is even possible with most digital signal analyzers. A digital signal analyzer's constellation display can be used to identify a variety of impairments based on how the constellation is distorted by those impairments.

Some digital signal analyzers are also designed to troubleshoot upstream problems.

Optical Power Meter

This is used to measure the optical power at the output of downstream laser transmitters and node upstream transmitters, the input of upstream receivers and node downstream receivers, optical amplifier inputs and outputs, and fiber loss. Optical power meter measurements are out-of-service measurements, which means service will be disrupted during this type of testing. Optical power meters are often used at the time fiber links are installed and commissioned, and sometimes when troubleshooting catastrophic link failures such as cut fibers.

Oscilloscope

It is an instrument that provides a graphical display of baseband or RF signals in the time domain (amplitude-versus-time.) The display on older oscilloscopes is a cathode ray tube, while modern versions are often LCD-based display. Battery operated portable oscilloscopes have been available for many years, and are useful for troubleshooting and measuring the amount of AC ripple in DC power supply outputs, including those in outside plant amplifiers. When properly terminated in the characteristic impedance of the circuit being measured, an oscilloscope can be used to accurately measure baseband analog video or audio signals. High bandwidth, high-speed oscilloscopes can be used to display and measure complex baseband data signals, as well as individual QAM signals in the RF domain.

Signal Leakage Detector

In theory, HFC networks are supposed to be closed RF transmission systems. This allows what is called frequency reuse, where frequencies inside the cables can be used to carry signals that are different from signals that exist on the same frequencies in the over-the-air environment. If the shielding integrity of the HFC network is compromised for any reason (such as cracked cable shield, loose or damaged connectors, rodent or environmental damage, direct connection of the subscriber drop to poorly shielded TVs and VCRs, etc.) signals inside the cable can leak out and cause interference to over-the-air services and vice versa. Signal leakage detectors are used by cable operators to measure and troubleshoot problems that cause signals inside the cable network to leak out. If signal leakage exists, it is likely that ingress (over-the-air signals leaking into the HFC network) also exists, so leakage detectors can be used for both leakage and ingress troubleshooting. Leakage detectors are also used to ensure compliance with government regulations that mandate the maximum allowable field strength caused by cable signal leakage.

Signal Level Meter

The most basic signal level meter (SLM) is used to measure the amplitude, specifically the peak envelope power of analog TV channel visual and aural carriers. Newer SLMs generally include the ability to also measure digital channel power (average power) of QAM signals. Additional features available in some models include measurement of parameters such as analog TV channel carrier-to-noise ratio and hum modulation, and can perform various types of channel amplitude scans across the operating spectrum. In some instances, SLMs have the ability to conduct limited QAM signal analysis.

Spectrum Analyzer

An instrument that provides a graphical display of RF signals (and sometimes baseband signals if suitably designed for this purpose) in the frequency domain (amplitude-versus-frequency.) The display on older spectrum analyzers is a cathode ray tube, while modern versions are often LCD-based display. Battery operated spectrum analyzers are available for portability. Some spectrum analyzers incorporate digital signal analysis functionality. Conventional spectrum analyzers are useful for measurement of signal levels of analog TV channels and often also digitally modulated signals, carrier-to-noise and carrier-to-distortion ratios, analog TV channel visual carrier depth of modulation and aural carrier frequency deviation, hum modulation, and a variety of other metrics and impairments. Many spectrum analyzers are able to operate in zero span mode, which facilitates an amplitude-versus-time display. The latter may be useful for viewing and measuring bursty upstream time division multiple access (TDMA) signals. Certain types of impairments such as linear distortions-micro-reflections, amplitude ripple/tilt, and group delay cannot be seen on a spectrum analyzer, unless the instrument is a combination spectrum analyzer and digital signal analyzer. A spectrum analyzer can be used to maintain and troubleshoot most of the HFC network elements such as the headend, most opto-electronics (RF inputs and outputs), hardline coax distribution plant, and subscriber drops.

