CENTRAL
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AUTHORITY

CFX Inspection Reference & Training Manual

Chapter 6

Fiber Optic Network (FON)

6.0 OVERVIEW OF THE FIBER OPTIC NETWORK (FON)

This section provides a general overview of CFX's IT, ITS and Tolling systems outside plant communications infrastructure commonly referred to as FON. CFX's FON consists of various conduit systems, fiber optic cables, and storage vaults which connect to network switches within CFX's Headquarters and Hiawassee Backup Data Center as well as all mainline toll plazas. CFX's FON is comprised of both the backbone and feeder cables which are installed in a ring configuration throughout all of CFX's system. Both the backbone and feeder cables are housed within conduit. Extra slack cable is stored within the fiber optic manholes (FOMHs) typically installed within the outside paved shoulder, but in some instances, it may be installed near the right of way fence. During construction projects, the FON may be temporarily installed within the median or other suitable locations with CFX's permission.

The communications path for Tolls and IT network infrastructure is referred to as the Backbone, while the communications path for ITS network infrastructure is referred to as the Feeder. The main differences between the Backbone and Feeder cables are the types of traffic being transmitted. Both the Backbone and Feeder utilize trans-lateral connections which provide an additional layer of redundancy and are typically installed at the mainline toll plazas and CFX's Headquarters building. The Feeder is also comprised of fiber optic drop cables which are 12sm and connect to each ITS device location.

There are many advantages to the FON:

- Capable of transmitting data for longer distances
- Faster data transmission rates (bandwidth)
- The signal is not susceptible to electromagnetic interference

For these reasons, FOC is the communications medium CFX uses to transmit the various types of tolling and traffic data they collect. FOC is therefore installed along every roadway that is under CFX's jurisdiction, forming CFX's FON. Knowledge of the following terminology is critical to understand how the FON works:

FIBER PAIRS – Fiber pairs are used throughout the system for switch to switch communications at both the Layer 2 (Managed Field Ethernet Switch) and Layer 3 (Core switch/router) levels. There are fiber pairs that are used solely for the purpose of connecting core switches as well as other pairs that are used between local HUBs (cabinets) to connect field devices to the network.These fiber pairs are used to transmit and receive data over the FON. The same two fibers are not exclusively used throughout the system, as this would put unnecessary bandwidth on these two fibers. Instead of using the same two fibers at each Managed Field Ethernet Switch (MFES), fiber pairs are leap frogged in a daisy chained connection between Toll Plazas. This provides a reduction in bandwidth on a single pair of fibers, as the traffic is now spread out over more fiber optic pairs and also reduces device outages. When an individual site looses connection to the network, it will not adversely affect its neighboring devices as every other MFES uses a separate pair of fibers.

SWITCHES – The FON uses both Layer 2 MFES and Layer 3 switches. For reference, Layer 1 defines the relationship between a device and the communications medium and includes copper or fiber optic cable, and the items use to establish and terminate a connection to the Layer 2 and Layer 3 equipment. Layer 2 and Layer 3 both include switches, with Layer 2 working at the data link layer and uses MAC addressing to communicate whereas Layer 3 utilizes segmented routing over an IP network. With regard to the CFX Network, the Layer 2 MFES are located within the field device cabinets and communicate between field devices and back to the Toll Plaza. The Layer 3 switches are located within the Toll Plazas and take data from the Layer 2 switches and transmits it between Toll Plazas and back to CFX's Headquarters Building and Hiawassee Backup Data Center utilizing the fiber backbone.

MEDIA CONVERTER – A media converter can be used to change one communications medium to another. In most instances on CFX, this will be a Fiber to Ethernet media converter, which converts the analog signal from Ethernet to a digital signal to be communicated across the fiber.

GBIC – A gigabit interface converter (GBIC) is used in switches and other transceivers to change the digital signal to an optical signal and vice-versa to allow transmission of data over the FON. In the early 2000's the GBIC was largely replaced by the small form-factor pluggable transceiver (SFP), which performs the same functions but is in a smaller form. The optics within the SFP have a transmitting (Tx) side and a receiving (Rx) side. The transceiver on the Tx side has a laser which communicates to the receiving side of the optic on the other side of the fiber connection.

6..0.1 The Basics of a FON: The FON Communications infrastructure provides the communications path for ITS and Tolling components. A 72 fiber cable backbone for Tolls communications and a 72 fiber cable for ITS communications, which connects communication sites and devices, are the two main fiber cables of the FON. Figure 6.1 is a Network Diagram for CFX, which shows how the Layer 3 Switches (top 2 items in the diagram), Routers (2 items to the left and right) and Layer 2 switches are connected via fiber optic cables.

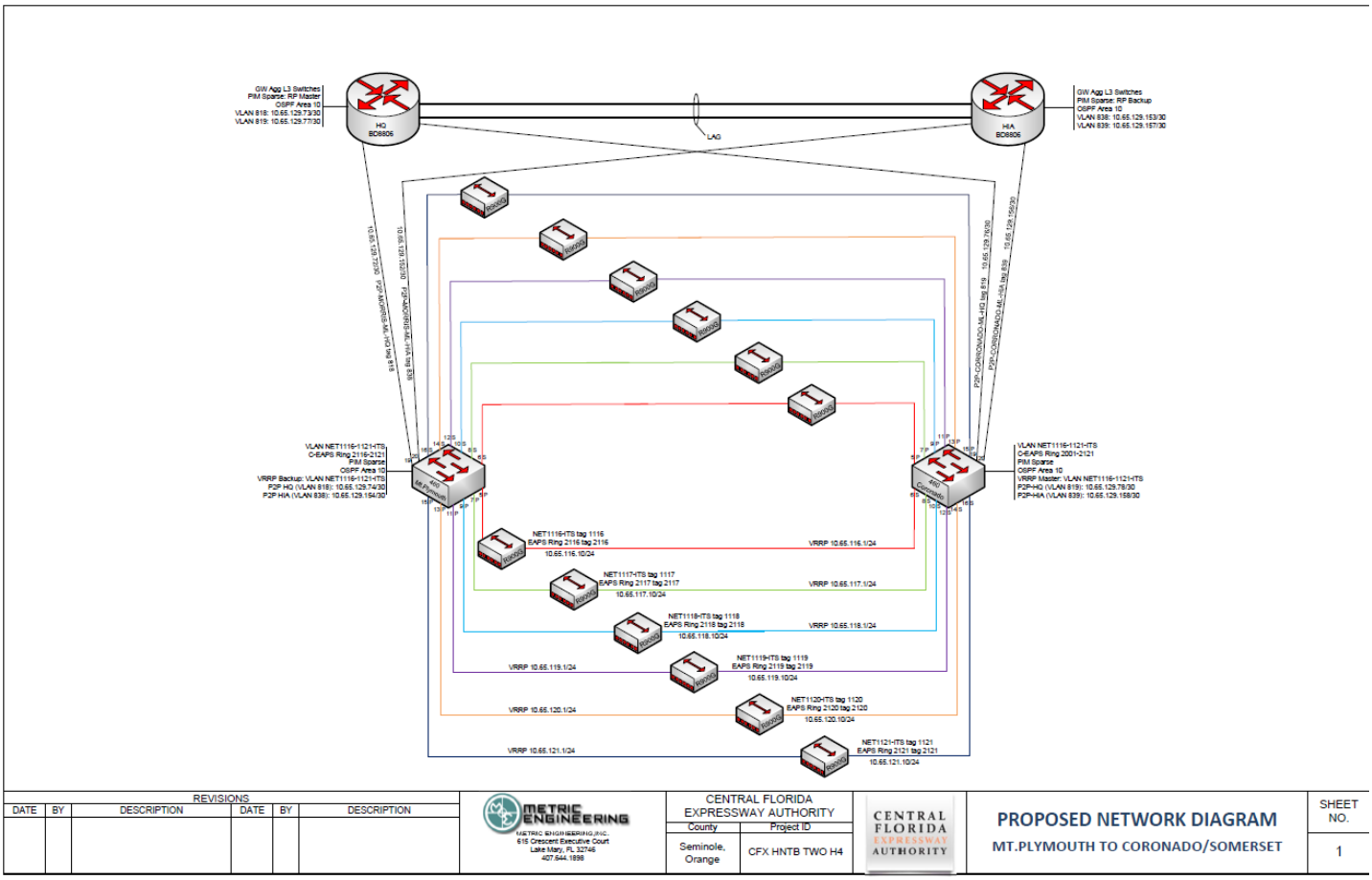


Figure 6.1: Typical WAN

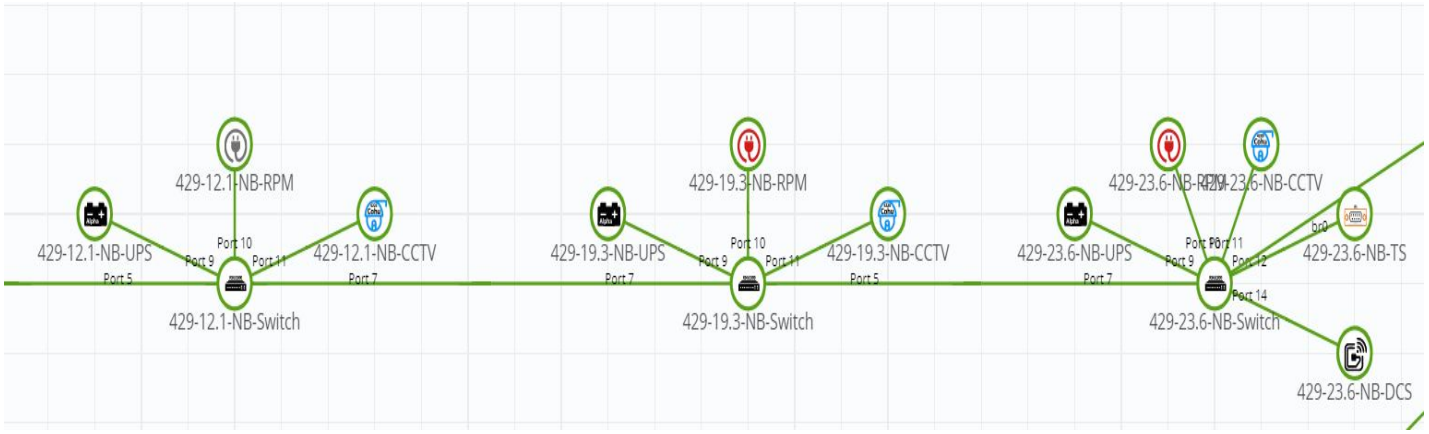


Figure 6.2: A portion of the WAN as represented in What's Up Gold (Network Monitoring Platform)

6.1 FIBER OPTIC NETWORK COMMUNICATIONS

The correct functioning of an optical data link depends on modulated light reaching the receiver with enough power to be demodulated correctly. Below are definitions you will hear when reviewing and observing fiber optic testing.

- **Dispersion** is the spreading of the signal over time. An efficient optical data link must have enough light to exceed the minimum power that the receiver requires to operate within its specifications. In addition, the total dispersion must be less than the limits specified for the fiber link.
- **Modulation** means to vary the amplitude, frequency, or phase of a carrier wave or a light wave for the transmission of information. A Modulator is a device that performs modulation. A demodulator (sometimes called a detector or demod) is a device that performs demodulation, the inverse of modulation.
- **Transmitters** convert an electrical input signal to an optical signal. Its drive circuit varies the current flow through the light source, which in turn varies the irradiance of the source. The process of varying the irradiance as a function of time is called modulation.
- **Optical Link** - A fiber optic data link (optical link) has three primary functions. It must convert an electrical input signal to an optical signal, send the optical signal over fiber, and then convert the optical signal back to an electrical signal.

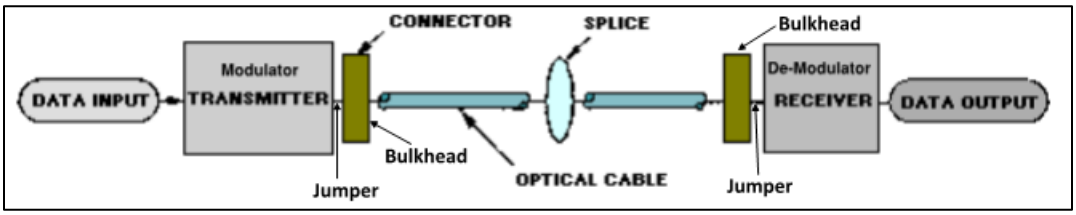


Figure 6.3: Full Optical Path

6.1.1 CFX FON Uptime: Any work on the FON is to be scheduled with CFX a minimum of 2 weeks in advance. Additionally, when a Backbone cable is being interrupted, both CFX and FDOT need to be provided 2 weeks advanced notice, as FDOT shares paths along CFX's routes. A housing and cable inventory at work locations must be scheduled no earlier than 45 calendar days in advance of work on the FON per CFX specifications 631-6.2.

A network integrity test, which is to be conducted by CFX staff, is required to be performed and passed before allowing cuts or prior to any maintenance taking place on the Backbone or Feeder. This step is essential due to CFX's WAN not running in an automatic redundant failover configuration. The physical connections are in place, however redundant ports are blocked manually and need to be activated in the event of port failure, or fiber route disruption. The fiber optic backbone systems shall be maintained at all times with no loss in connectivity. At no time will both sides of the fiber optic rings be permitted to be down simultaneously. If there is a suspected fiber cable cut within the construction limits of a roadway project, the CEI will investigate the damage and check with the FON maintenance contractor for any network alarms. The CEI will inspect the Primary Service Restoration repair work and verify all alarms detected by the FON maintenance contractor have been cleared, to verify that repairs have been successfully completed.

6.2 BACKBONE

The FON Backbone conduit system includes nine-1-inch HDPE SDR 11 conduits. A primary Backbone consists of a 72 SM FOC in the orange conduit for backbone trunk cable and 72 SM FOC in the blue conduit for feeder trunk cable. The black with red stripe conduit is reserved for the Line Management System (LMS) tone wire and is to be placed on top of the eight 1-inch fiber optic HDPE conduits. If only eight-1-inch conduits are present, the LMS tone wire is in the yellow conduit.

A typical primary Backbone cross-section consists of the following:

- CFX Specification Section 631-2.4.1- (9) - 1" HDPE SDR-11 or thicker (Smoothwall) roll pipe (The color code format shall be orange, blue, brown, green, white, black, yellow with orange stripe, red w/gray stripe and black w/red stripe)
- CFX Specification Section 638-2.6.7 Fiber Optic Warning Tape
- CFX Specification Section 638-2.6.6 Tone Wire for Location of Underground Ducts and Conduits
- CFX Specification Section 638-2.6.8 Tubular Route Markers
- CFX Specification Section 636 Fiber Optic Manholes (FOMH)

- CFX Specification Section 633 Fiber Optic Cable

6.2.1 Backbone Communications: The CFX Tolling and IT systems communicate on a 72 fiber cable that typically follows the Expressway's corridors on both sides throughout the CFX right of way limits. Also known as a WAN, the backbone includes industrial network switches, computers, plaza security systems and Voice Over Internet Protocol (VOIP) phone systems installed at tolling plazas along CFX's corridors. This system is critical for toll collection and communication and shall be protected and monitored at all times during construction and system upgrades.

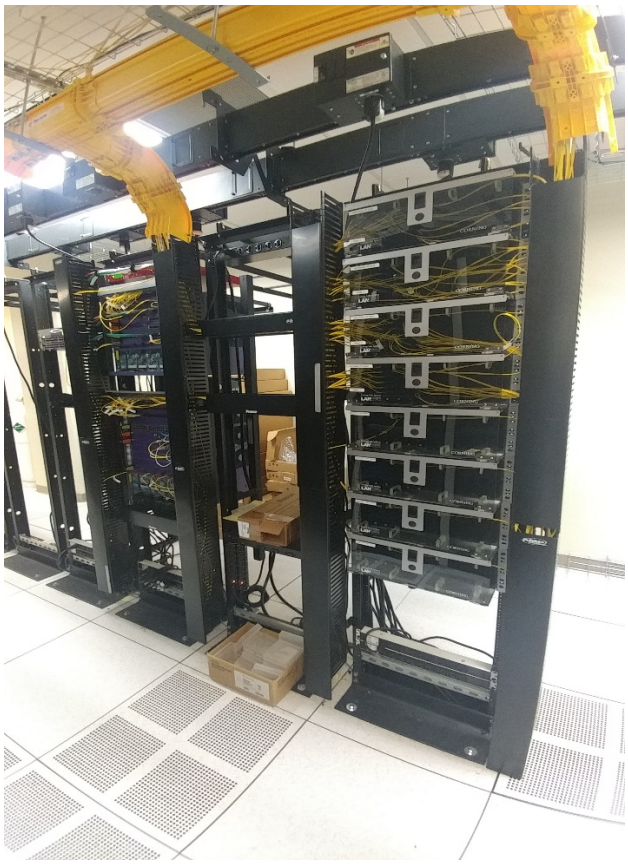


Figure 6.4: CFX Headquarters FON

6.2.2 Cable Management: Cable management is a priority and is to be maintained on all CFX facilities. Cable management includes keeping dust caps on all unused bulkheads and approved labeling and bundling with approved cable ties or Velcro straps on all cables, patch panels, and equipment. A good example of cable management within a Fiber Optic Manhole is shown in Figure 6.5 on the following page.

Additionally, CFX requires Panduit to be used in all cabinet locations to provide for a neat and easy means of cable management. Panduit will be discussed in more detail in Chapter 7 Cabinets.

6.2.3 ITS Feeder/ Communications: The CFX ITS system communicates via a 72 single-mode fiber cable (Feeder) that typically parallels the Backbone through the CFX corridors on both sides of the roadway throughout the CFX right-of-way limits. CFX shares the white buffer tube on the 72 fiber Backbone with FDOT throughout the system. FDOT operates District Five's ITS system at the Regional Traffic Management Center (RTMC) in Seminole County and partners with CFX to operate the CFX ITS system from the RTMC, as well.

As discussed earlier, the ITS Layer 3 switches are collocated in Toll Plazas, feeding Layer 2 switches at local device sites via midspan splice enclosures at the local device level. The CFX ITS local hub network equipment includes, but is not limited to Ethernet switches, port servers, and routers, installed at the various ITS and Toll/IT sites throughout CFX's system. These sites support ITS devices serving as local Layer 2 HUBs, or Tolling Plazas at Layer 3.

Drop or feeder cables, are used to span the final network segment to local devices and will typically be 12F single-mode. All drops will be terminated and landed on bulkheads on both ends unless fusion spliced to the feeder trunk in a Fiber Optic Manhole (FOMH).

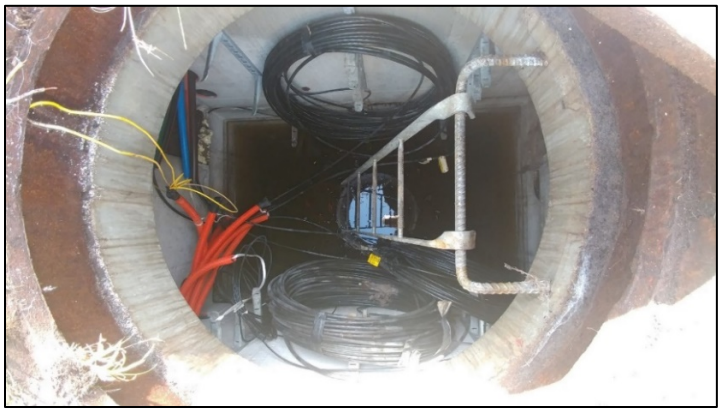


Figure 6.5: CFX FOMH

6.3 TRANS-LATERALS

Trans-laterals are typically placed at mainline plaza locations for access to the FON backbone. This access is through a FOMH. These Trans-laterals allows for access to backbone and feeder fiber cables on both sides of the roadway for redundancy. The Figure on the following page illustrates how these boxes will be tied-into the conduit system.

A typical primary Tran-lateral cross-section consists of the following:

- CFX Specification Section 631-2.4.1 - (9) - 1" HDPE SDR-11 or thicker (Smoothwall) roll pipe (The color code format shall be orange, blue, brown, green, white, black, yellow with orange stripe, red w/gray stripe and black w/red stripe)
- CFX Specification Section 638-2.6.6 Tone Wire for Location of Underground Ducts and Conduits
- CFX Specification Section 638-2.6.7 Fiber Optic Warning Tape
- CFX Specification Section 638-2.6.8 Tubular Route Markers
- CFX Specification Section 636 Fiber Optic Manholes (FOMH)
- CFX Specification Section 635-2.2 Large Fiber Optic Pull Box
- CFX Specification Section 635-2.3 Small Fiber Optic Pull Box

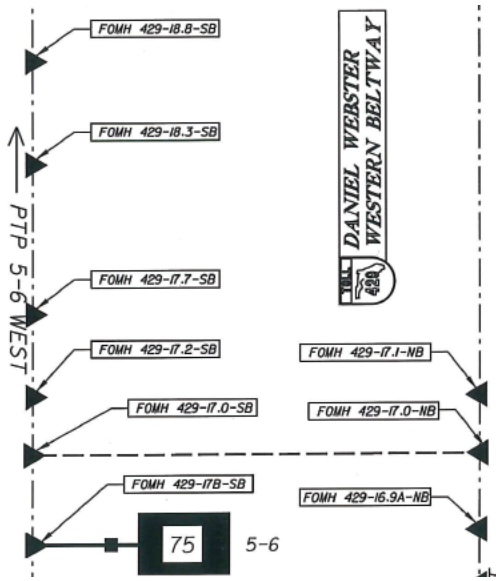


Figure 6.6: Diagramatic Example showing a Trans-lateral fiber optic cable between two backbone cables

6.4 LATERAL CONDUIT SYSTEM

The CFX Lateral Conduit System ties tolling plazas facilities into the backbone conduit system, at the FOMH nearest the plaza and consists of four 1-inch HDPE SDR 11 conduits with tone wire and fiber optic warning tape.

A typical Lateral Conduit System cross-section consists of the following:

- To Ramp Toll Plazas: CFX-SECTION 631-2.4.1.2 - (4) - 1" HDPE SDR-11 or thicker (Smoothwall) roll pipe (The color code format shall be orange, blue, brown and green)
- To Mainline Toll Plazas: CFX-SECTION 631-2.4.1.2 (9) - 1" HDPE SDR-11 or thicker (Smoothwall) roll pipe (The color code format shall be orange, blue, brown, green, white, black, yellow with orange stripe, red w/gray stripe and black w/red stripe)
- CFX-SECTION 638-2.6.6 Tone Wire for Location of Underground Ducts and Conduits
- CFX-SECTION 638-2.6.8 Tubular Route Markers
- CFX-SECTION 636 Fiber Optic Manholes (FOMH)
- CFX-SECTION 635-2.2 Large Fiber Optic Pull Box
- CFX-SECTION 635-2.3 Small Fiber Optic Pull Box
- CFX-SECTION 638-2.6.7 Fiber Optic Warning Tape

6.5 DEVICE DROP CONDUIT SYSTEM

Drop conduit systems consist of three, 1-inch HDPE SDR 11 conduits. Drop conduit systems run from FOMHs to roadside devices or ITS hubs with a 12SM FOC in the blue conduit, tone wire in the black with red stripe conduit, and the orange conduit is empty for possible future use.

A typical Drop Conduit System cross-section consists of the following:

- CFX Specification Section 631-2.4.1- (3) - 1" HDPE SDR-11 or thicker (Smoothwall) roll pipe (The color code format shall be orange and blue and black with a red stripe)
- CFX Specification Section 638-2.6.6 Tone Wire for Location of Underground Ducts and Conduits
- CFX Specification Section 638-2.6.8 Tubular Route Markers
- CFX Specification Section 636 Fiber Optic Manholes (FOMH)
- CFX Specification Section 635-2.2 Large Fiber Optic Pull Box
- CFX Specification Section 635-2.3 Small Fiber Optic Pull Box

- CFX Specification Section 638-2.6.7 Fiber Optic Warning Tape
- CFX Specification Section 633 Fiber Optic Cable (12 SM Fiber)

6.6 LINE MANAGEMENT SYSTEM (LMS)

CFX uses the FLS-2 transmitter system installed at mainline plazas to transmit a frequency signal onto the CFX tone wire facilities. The tone wire is within one of the conduits that is installed along with the fiber optic cable, as detailed previously. The LMS can be remotely activated when locates are needed in that area. The LMS is used for locating the FON system; this assists in avoiding buried cables and pipes during excavation, reducing the risk of injury to personnel and damage to the fiber optic cable.

Figure 6.7: LMS Transmitter

The FLS-2 transmitter sends a predefined signal that is less than 10 kHz along the trace wire, generating an electromagnetic field for the length of the cable. The FLS-2 transmitter also has the ability, via the terminal interface options, to measure Impedances (Volts, mA, watts, and Ohms) per leg as seen in figure 6.8 below.

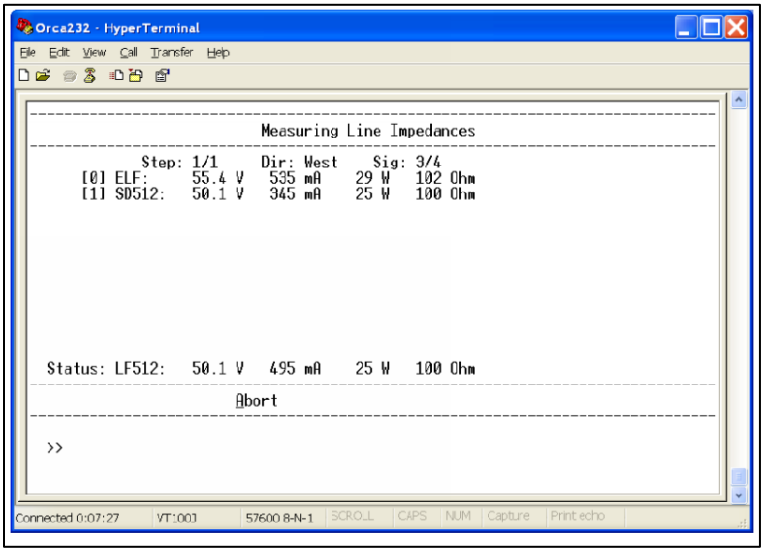
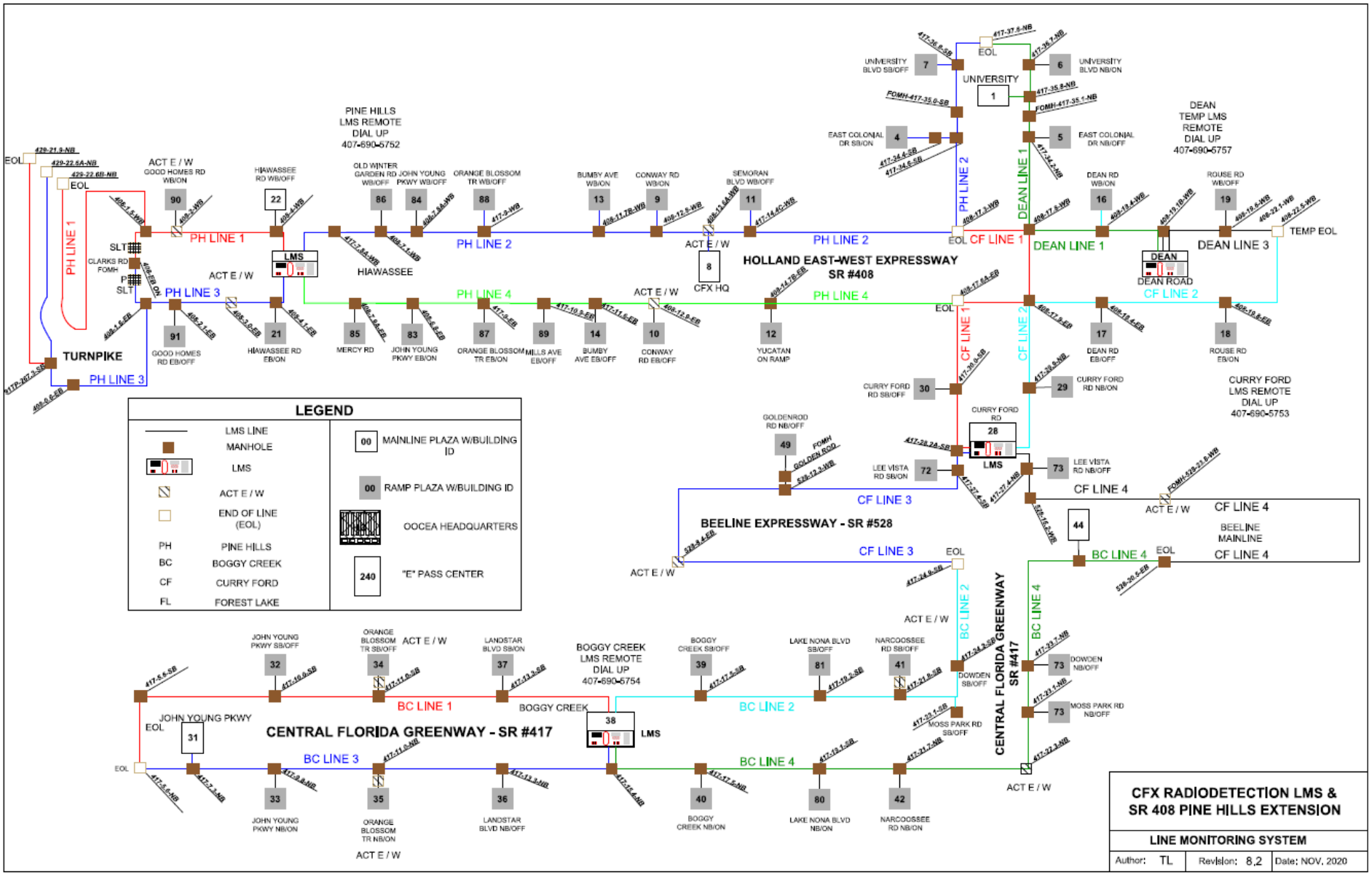
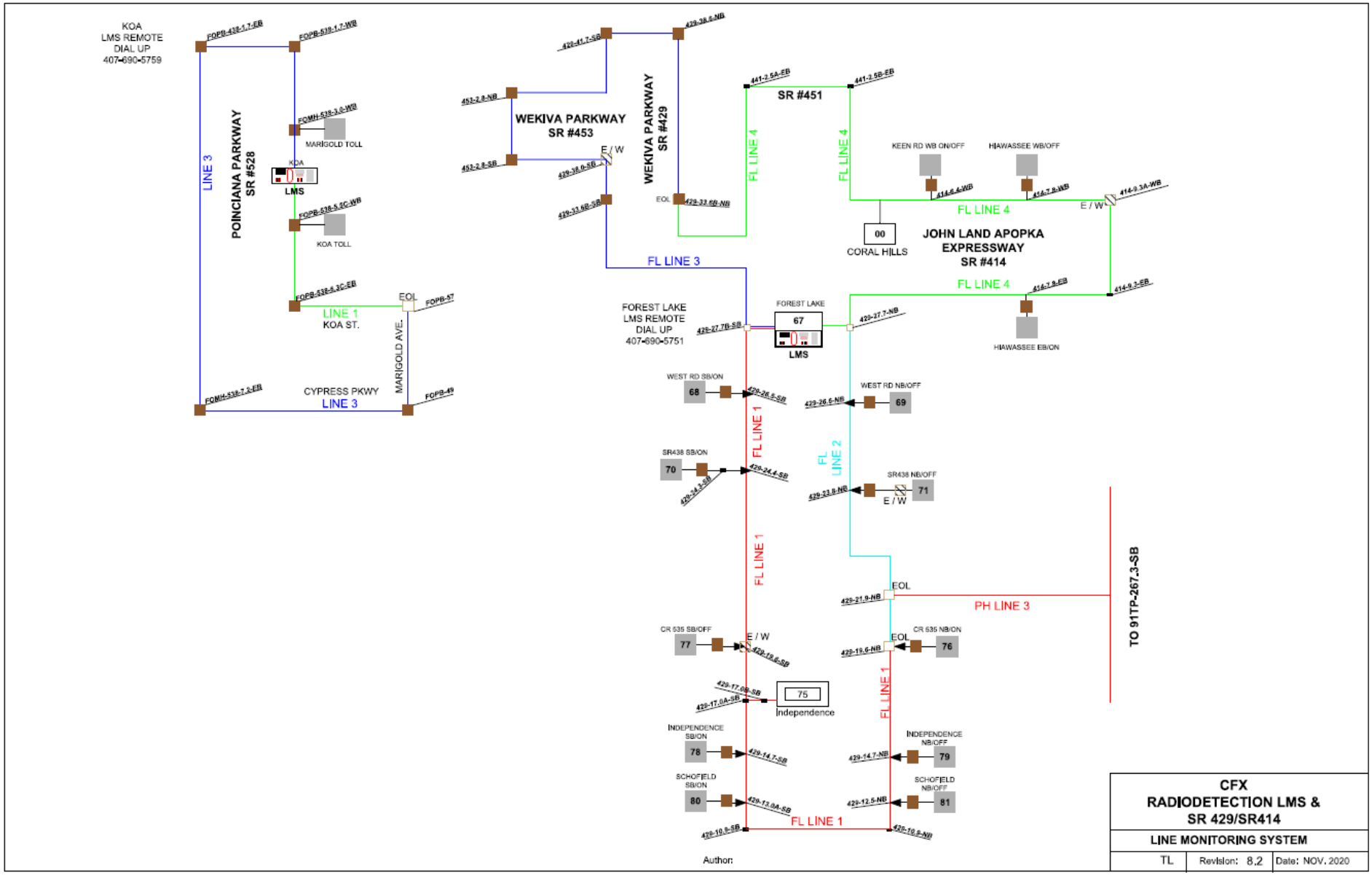


Figure 6.8: Measuring Line Impedances

The following pages detail the current configuration of the LMS. Please contact the CFX General Engineering Consultant for phone numbers and instructions on using the LMS for your specific project.


PINE HILLS LMS REMOTE DIAL UP 407-690-5752
DEAN TEMP LMS REMOTE DIAL UP 407-690-5757
CURRY FORD LMS REMOTE DIAL UP 407-690-5753
BOGGY CREEK LMS REMOTE DIAL UP 407-690-5754
HOLLAND EAST-WEST EXPRESSWAY SR #408
BEELINE EXPRESSWAY - SR #528
CENTRAL FLORIDA GREENWAY - SR #417
CENTRAL FLORIDA GREENWAY SR #417
TURNPIKE
PH LINE 1
PH LINE 2
PH LINE 3
PH LINE 4
CF LINE 1
CF LINE 2
CF LINE 3
CF LINE 4
BC LINE 1
BC LINE 2
BC LINE 3
BC LINE 4
DEAN LINE 1
DEAN LINE 3
LMS
SLT
ACT E / W
EOL
CFX HQ
DEAN ROAD
TEMP EOL
LEGEND
LMS LINE
MANHOLE
LMS
ACT E / W
END OF LINE (EOL)
PH PINE HILLS
BC BOGGY CREEK
CF CURRY FORD
FL FOREST LAKE
MAINLINE PLAZA W/BUILDING ID
RAMP PLAZA W/BUILDING ID
OOCEA HEADQUARTERS
"E" PASS CENTER
CFX RADIODETECTION LMS & SR 408 PINE HILLS EXTENSION
LINE MONITORING SYSTEM
Author: TL
Revision: 8.2
Date: NOV. 2020


KOA
LMS REMOTE
DIAL UP
407-690-5759
POINCIANA PARKWAY
SR #528
LINE 3
MARIGOLD TOLL
KOA
LMS
KOA TOLL
LINE 1
KOA ST.
EOL
MARIGOLD AVE.
CYPRESS PKWY
LINE 3
WEKIVA PARKWAY
SR #453
E / W
WEKIVA PARKWAY
SR #429
EOL
SR #451
FL LINE 4
KEEN RD WB ON/OFF
HIAWASSEE WB/OFF
E / W
00
CORAL HILLS
JOHN LAND APOPKA
EXPRESSWAY
SR #414
FL LINE 3
FOREST LAKE
LMS REMOTE
DIAL UP
407-690-5751
FOREST LAKE
67
LMS
HIAWASSEE EB/ON
WEST RD SB/ON
68
WEST RD NB/OFF
69
FL LINE 1
FL LINE 2
SR438 SB/ON
70
SR438 NB/OFF
71
E / W
EOL
PH LINE 3
TO 91TP-267.3-SB
CR 535 SB/OFF
77
E / W
EOL
CR 535 NB/ON
76
75
Independence
INDEPENDENCE
SB/ON
78
INDEPENDENCE
NB/OFF
79
SCHOFIELD
SB/ON
80
SCHOFIELD
NB/OFF
81
FL LINE 1
Author:
CFX
RADIODETECTION LMS &
SR 429/SR414
LINE MONITORING SYSTEM
TL
Revision: 8.2
Date: NOV. 2020

6.6.1 Remote Transmitter: CFX can also use the Radiodetection™ model RD8100 TX-10 transmitter in the event the LMS Outside Plant line management system has faults or damage due to construction. Locates can be performed by attaching the electronic transmitter to one end of the tone wire and then locating the signal along the wire route using a receiver.

There are three methods of connecting to the line you need to locate:

6.6.1-1 Direct Connection: This method directly connects to the tone wire, at an access point, and the circuit is completed by connecting to a stake or other ground point. The tone is then detectable along the line for an undetermined distance, which is dependent on the line size and soil conditions.

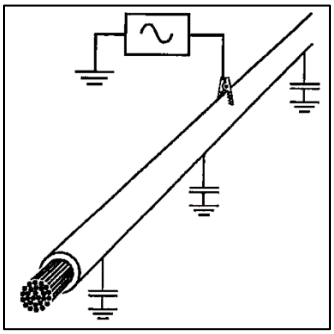


Figure 6.9: Remote Direct Connection

6.6.1-2 Induction Connection: When using an Induction connection, the coil of the transmitter is set-up on top of the line and induces a magnetic field through the coil, which returns through the earth. This is the least recommended method.

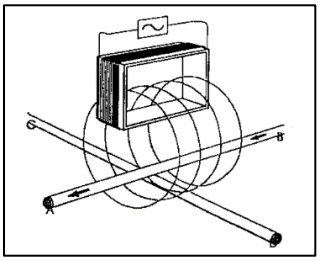


Figure 6.10: Remote Induction Connection

6.6.1-3 Clamping connection: Clamping uses induction and does not require a direct connection to the tone wire. This is a preferred method, as it avoids cutting the wire to access the conductor. A clamping connection will carry a strong signal, provided it has a good ground on each side of the cable.

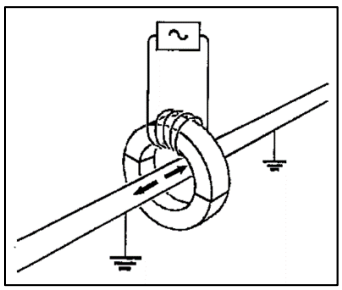


Figure 6.11: Remote Clamping Connection

6.6.2 Receiver: CFX uses the Radio Detection™ RD8100 receiver on its outside plant to locate the electromagnetic field emitted around the underground tone wire from either the FLS-2 transmitter or portable RD8100 TX-10. By using one of the predefined transmitter signals, the receiver can estimate the relative position and path of the cable.

Items to note when using the receiver to locate power lines:

- The better the A/C balance the more difficult detection becomes.
- High-voltage cable loadings are generally better balanced.
- The passive search built into the receiver may easily detect street lighting or ITS device services. Still, it can miss 11kV power lines nearby, or live but unloaded lines that radiate no power tone.
- It is recommended to use the radio modes if possible when uncertain of electrical lines in the area.

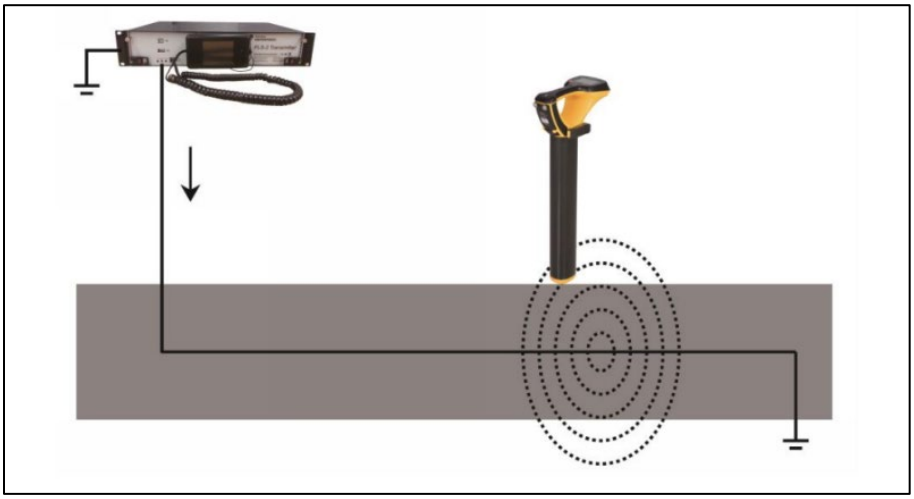


Figure 6.12: RD8100 Receiver Locating

6.7 TONE WIRE

All Tone wire shall be #12 AWG, stranded or single conductor copper core, 45 mil high-density polyethylene insulated underground tone wire, manufactured by Burton Wire & Cable or CFX approved equivalent. The tone wire high-density polyethylene sheath must be orange in color per CFX specifications 638-2.6.6. To ensure that the tone wire system continues to support the existing Outside Plant Line Management System, tone wire installed in construction areas shall be spliced to the existing tone wire system installed in adjacent project sections at each end of the backbone for a continuous circuit. Each lateral tone wire shall end at a junction box outside the ramp toll plaza and be grounded in the designated manhole per plans. Cutting the tone wire is not permitted for FON system locates. All splices shall be made within a FOMH and shall be environmentally protected per the manufacturer's recommendations with a CFX approved tone wire splice kit. .

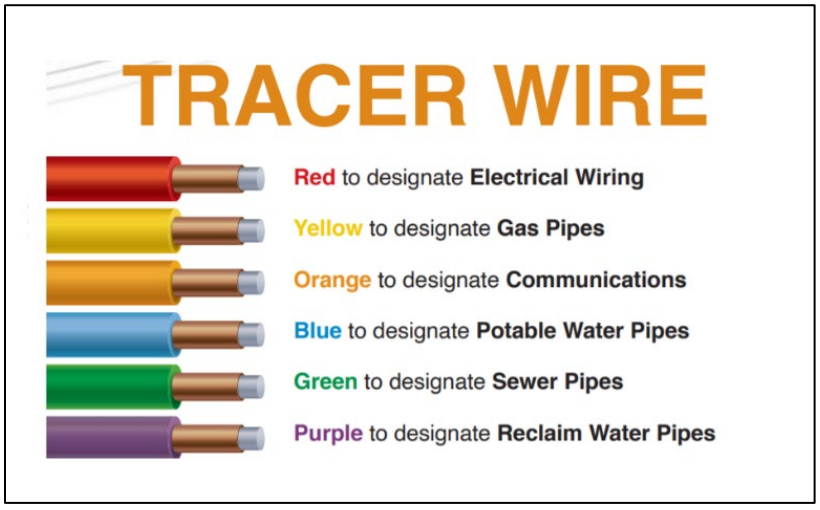


Figure 6.13: Tone Wire Color Chart

6.8 PRE-ACTIVITY CONSIDERATIONS

Below are items that need to be considered during Maintenance or Construction on CFX's FON system:

1) **Review CFX Specifications**: Section 631 details the requirements for the protection and locating of CFX's FON.

2) **Pre-construction Proofing Conduit** - Review the initial proofing of the unoccupied (spare) high-density polyethylene (HDPE) communication conduits. The proof test method to be applied throughout the project shall consist of blowing a proofing dart through the conduit system in both directions. The ability to successfully blow the proofing dart in the conduit shall satisfy the requirement for testing an airtight seal. The Contractor shall provide a minimum of 48 hours advance notification before the proof testing activity. The Contractor shall submit a written report to CFX documenting the results of the conduit proofing.

3) **LMS** – Ensure that Contractors test the Line Management System (LMS), test for tone wire continuity, and locate the FON within the project limits within fifteen (15) days of the notice to proceed (NTP). The Contractor shall submit a written report to CFX documenting the results of the readings for LMS continuity testing within five (5) days of the completion of testing. Any damage to the FON system found during the initial proofing shall be reported and is the responsibility of CFX.

4) **SunShine One Call -** Coordinate with the Contractors on any works within CFX right of way or near the CFX FON Backbone Feeders or Power system. Any underground work requires that **Sunshine One Call** be notified and properly marked or cleared by all utility owners within the ticketed area before earthwork begins.

5) **Scheduling -** Any work on the FON is to be scheduled with CFX a minimum of 2 weeks in advance. Additionally, when a Feeder ITS cable is being interrupted, both CFX and FDOT need to be provided 2 weeks advanced notice, as FDOT shares paths along CFX's routes. A housing and cable inventory at work locations must be scheduled no earlier than 45 calendar days in advance of work on the FON per CFX specifications 631-6.2.

6) **Network Testing -** A network integrity test is required to be performed and must pass before allowing cuts or maintenance activities on the Backbone or Feeder.

7) **Material -** Review materials submitted for FON and LMS works.

- Conduits are to be 1-inch HDPE SDR 11 verify count and color match path type being installed.
- Verify the Black with red stripe 1-inch HDPE SDR 11 conduit is above all other conduits in trenched or plowed conduit paths.
- Fiber optic warning tape shall be 3" wide, six mils thick, orange fiber-optic warning tape manufactured by Carlon Telecom Systems, Part Number MAT3051 or CFX approved equivalent.
- The tone wire system shall consist of a #12 AWG insulated stranded or single conductor copper core, 45 mil high-density polyethylene insulated orange underground tone wire, manufactured by Burton Wire & Cable or CFX approved equivalent.
- The tubular route markers shall consist of a 3-½ inch (outside diameter) white HDPE post, 6-foot in length with a minimum wall thickness of 0.125 inches. And they have the appropriate designation for the cable type being marked. Within fifteen (15) days of the notice to proceed, the Contractor shall verify the condition of all route markers in the project limits and report any deficiencies—review CFX Standards 631-3.3.

8) **Weekly Testing -** Weekly LMS testing shall be conducted during the length of the project, until final acceptance. The Contractor shall verify the integrity of the LMS system within the project limits weekly and submit a written report within one business day of the completion of each LMS system test to CFX documenting the voltage and current (milliamps) readings from the LMS system

test. If the readings are not within 10% of the original readings, the Contractor shall be responsible for all costs associated with locating and repairing damage to the tone wire system within the project construction limits. The Contractor shall designate a qualified technician and submit the make and model of the equipment to be used for testing to CFX for approval.

9) **Proofing -** The Contractor shall coordinate with the CEI to witness the proof test of the entire HDPE conduit system and FON system. Final acceptance testing will start after the completion of all work (guard rail, fencing, paving, etc.) that could damage the conduit. Start final proofing of the unoccupied (spare) high-density polyethylene (HDPE) communication conduits, and checking the Line Management System (LMS) readings for tone wire continuity within the project limits within five (5) days of the semi-final inspection. Review the Contractor submitted written report to CFX documenting the results of the conduit proofing and the readings for LMS continuity testing within five (5) days of the completion of testing. Any damage to the FON system found after the initial proofing will be the responsibility of the Contractor to repair. Any damage to the system found as part of final proofing, and tone wire continuity testing shall be repaired within five (5) days of the final inspection.

10) **LMS Final acceptance testing** - Within (10) days of the final project acceptance, The LMS System components impacted or installed by the project shall be retested for voltage and current (milliamps) readings by the Contractor with a CFX representative present. The Contractor shall submit a written report to CFX documenting the voltage and current (milliamps) readings from the LMS system test within five (5) days of the completion of LMS testing. Review CFX specifications 631-3.2 for full requirements.

11) **Route Markers -** Within five (5) days of the semi-final inspection, the Contractor shall reinstall the U-channel posts and route markers in their original or plan requirement locations. Review CFX Standards 631-3.3.

12) **Lateral - Drop Testing -** In addition to checking the LMS readings, manual checks of lateral and device drop tone wire runs may be necessary. Testing will be conducted and verified in the presence of a CFX representative at CFX's discretion. The Contractor shall notify CFX a minimum of 48 hours in advance of any testing to schedule a CFX representative to be present.