50.3.1 ITS Equipment Communications Requirements

50.3.1.1 ITS Equipment Communications Channels

In telecommunications in general, a channel is a separate path through which signals can flow. The existing communication system assigns a *channel* and *drop* to each individual field device. Each channel is capable of carrying 16 drops (device). As a general rule, 12 drops are initially assigned per channel, allowing for increased system reliability and future expansion. While multiple data devices can be placed on a single channel, **variable message signs (freeway or arterial) must be placed on a channel separate from other data devices such as ramp meters, detector stations, etc.** For additional information on data channel and drop assignments, consult the Statewide Traffic Operations Center.

For fiber optic communications, fiber allocation is critical when designing a system. For each individual fiber, the fiber optic system operates as follows for both of these types of devices:

- **Data Devices** - 2-way data communication, with 2 fibers per data channel allocated across the system. Each channel carries up to 12 drops, with each drop consisting of 1 data device (ramp meter, detector station, etc.)
- **Video Devices** - 1-way video communication with 2-way data control communication. Each camera (or video sharing) site requires only 1 fiber for video and data communication.

50.3.1.2 Detection and Ramp Meter Controls

Typically, both the detector stations and ramp meters use the same processing/controller hardware and controlling software. These are the most numerous field devices in the current system being located at on-ramps and at nominal 1/2-mile intervals along the freeway — approximately 3 or 4 per mile in the “high-density” segments. These types of equipment currently require 1200-baud data circuits in a multi-dropped configuration, with up to 12 controllers on one channel. Communication between hubs and field processors are regularly polled therefore require full time availability.

In addition to the vehicle detectors for measuring volume, occupancy, and speed, additional detectors have been and will continue to be installed along the freeway for vehicle classification (i.e., number of axles) and pavement condition (e.g., dry, wet, ice, etc.). Each type of detector communicates over separate low-speed channels to the hub or control center on a regular polled basis. Accordingly, these channels will require full-time availability.

50.3.1.3 Dynamic Message Signs

Dynamic Message Signs (DMS) use field controllers furnished by sign vendors and implement the communications protocol that is compatible with the central system DMS protocol and format. DMS communications typically use the same type of data channels as detectors and ramp meters, but on channels separate from the vehicle detectors and ramp meters. There is a requirement for 100 percent availability for “instantaneous” message display when required and verification purposes, though there is actually less than 25 percent actual use.

50.3.1.4 CCTV Cameras / Video

The primary purpose of video surveillance is incident verification, requiring only short duration visual information. However, during the verification process, the video must have resolution and sharpness near broadcast quality video. The video network, MONITOR, has cameras throughout the state that are available 100 percent of the time for incident verification and other surveillance functions, though the time that most of the cameras will be used for that purpose will be relatively small. The exception to this general rule might be construction areas where the detectors are disabled, and it becomes necessary for the system operators to constantly monitor the freeway (via CCTV) for congestion management and incident detection.

The MONITOR system has been whether the video signals will be full-motion analog or digital using CODEC hardware. This has involved a trade-off between video quality, communication costs (both capital and recurring), and the capabilities of future compression technologies. For the initial implementation stages, the video communications has been analog; communications media and methods have been followed which allows such a mode of transmission. Initially, video communications was provided through leased analog video services. However, as digital services became available and capable of producing significant revenue for the provider, the pricing structure for the leased analog video created a situation that a State-owned fiber optic communications system became cost effective. CODEC hardware and compression techniques continue to become more standardized, equipment costs are decreasing, and quality of the digitized video will equal and likely surpass current “broadcast” quality in the future. As such, ITS video transmissions will ultimately be digital. Since the State-owned fiber optic network is capable of both analog and digital configurations, the future transition from current analog video to digital will be straightforward — replacing analog communications hardware with the improved digital equipment (e.g., CODECs, multiplexers) with minimal configuration of the fiber optic cabling and conduit network itself.

50.3.2 State Owned ITS Communications Design Standards & Guidelines

State-owned communication design standards and guidelines can be broken down into the categories of conduit design, wired communication design, and wireless communication design.

50.3.2.1 Conduit Design Standards

State-owned communication conduit design standards can be broken down into the following categories:

- General installation considerations
- Trenched communication conduit guidelines
- Directional bore guidelines, and
- Structure mount conduit guidelines

Guidelines for each category are presented in the following sections.

50.3.2.1.1 General Design Considerations

When designing communication conduit systems, the following general issues should be considered:

- As a general rule, multicell conduits should be **installed on a single side of the freeway.** The conduit path is to provide a continuous system. The various components of ITS deployments will likely be located on both sides of the freeway, and therefore lateral conduits (described below) will be necessary to access equipment locations. The designer should avoid conduit design which switches back and forth on either side of the freeway whenever possible. This is not always possible due to obstacles or constructability concerns, however minimizing the amount of cross-over will make it easier for future maintenance, locating, and system record-keeping.
- **More than one conduit per run is desirable**, particularly if the Department wishes to lease conduit space to other public agencies or private concerns. Under such an arrangement, one conduit would be used by the system, the other conduit would be leased. The majority of installation expense (especially with trenched conduit) is in digging and back filling the trench, not just in the material cost.
- For multi-cell conduit design, all inner ducts should **include a pre-lubricated woven pull tape**.

50.3.2.1.2 Trenched Conduit Design Guidelines

When designing trenched communication conduit, the following general issues should be considered. Illustrations of both trenched multicell conduit and plowed and trenched HDPE conduit are provided in Figure 50.3-1 and Figure 50.3-2.

- Communication conduit consists of two different types: multi-cell conduit or high-density polyethylene (HDPE) conduit. **Multi-cell conduit** consists of 3 or 4 *innerducts* (1¼ inch diameter each) within a 4 ½ -inch conduit, whereas HDPE conduit comes in varying sizes. Multi-cell conduit is installed via “in-trench” installation, where a trench is opened, the conduit is assembled, placed in the trench, and back-filled. With **HDPE conduit**, reels are placed on a plowing machine, where the trench, placement, and back-fill are performed in one operation rather than three. For this reason, in addition to material costs, the cost to install four 1¼-inch HDPE conduits is approximately half the cost to install 1 multi-cell conduit.
- **HDPE conduit must be UL listed**.
- **HDPE conduit must be installed in one continuous run** between access points.
- Freeway conduits should be generally **a minimum of 36 inches below finished grade**.
- Installation of **conduits in grass freeway medians should be avoided**. This limits the potential for communication system disruption under future additions of acceleration, deceleration, or auxiliary lanes.
- The **most desirable location of communication conduit is near the right-of-way edge** (typically a right-of-way fence), as far from the traveled way as possible.
- Conduit designed in sloped terrain with a 4:1 or steeper slope should be designed to run longitudinally to (i.e., up/down) the slope, not along the slope.
- **Underground warning tape** should be laid above all underground conduits, 12 inches below grade.

- A **copper wire (10 or 12-awg typ.) should be installed** in one of the conduits between access points. This locate wire is to be electrically connected between conduit runs to allow for continuous locate signal transmission throughout the conduit network.
- Communication conduit may be installed in the same trench as other conduit systems, such as freeway lighting. However, the freeway conduit should never enter the street light foundations, hand holes, or pullboxes. Similarly, the street light conduit should never interfere with the communication conduit. In essence, the conduit network for street lighting and the conduit network for the freeway system should be totally separate and independent of one another, even though they are collocated in the same trench.

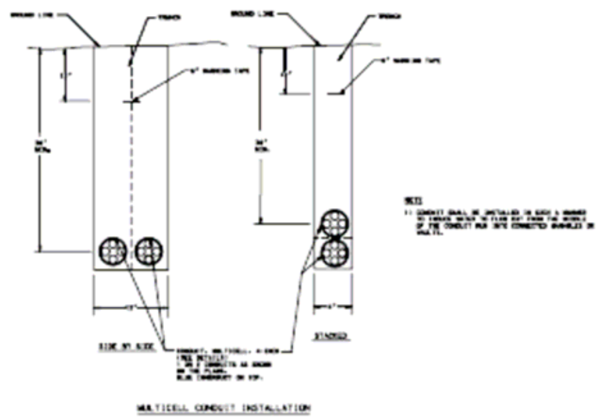

Figure 50.3-1 Typical Multi-cell Conduit Installation

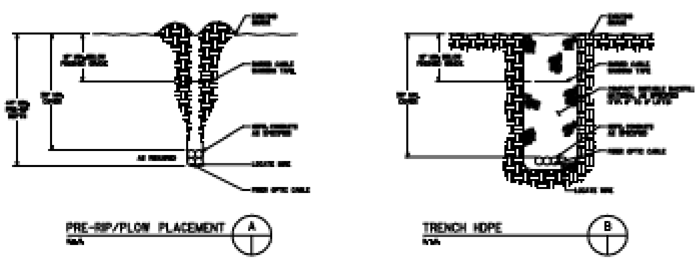

Figure 50.3-2 Typical HDPE Conduit Installation

50.3.2.1.3 Directional Bore Conduit Design Guidelines

When designing communication conduit under paved surfaces, the following general issues should be considered:

- **Lateral conduits** should be **installed at all interchanges, as well as all existing and potential future equipment locations.** For estimating future locations, a nominal 0.5-mile interval, depending on the spacing of interchanges, is typically adequate.
- Directional bore locations **require adequate room for conduit assembly and layout for "pull-back" operation.** This distance must allow for assembly of the entire length of conduit for the directional bore installation. During directional boring operations, multi-cell conduit is assembled, and a cable/wire rope is installed in one of the cells and is attached to a pullback assembly plate at the far end of the conduit run. This is done to prevent conduit separation during the pullback operation.
- Directional bore **installations under railroad tracks** require a minimum depth of 5- feet or as required by the railroad company. In addition, railroads typically require use of metallic conduit underneath railroad tracks.

50.3.2.1.4 Structure-Mount Conduit Design Guidelines

Guidelines for designing and installing the conduit network are summarized below:

- If a bridge (or other elevated section) is to be included as part of the reconstruction project, **four to eight 1-¼ inch conduits matching the inner duct should be incorporated within the barrier wall and parapets**. (See Figure 50.3-3) If this is not feasible, or if a multiple conduit network is being installed, 4½-inch fiberglass multi-cell conduits should be attached to the structure of the overpass (i.e., surface mounted) in accordance with WisDOT Standards.

- **Expansion fittings** should be installed wherever surface mounted 4 ½ inch conduit crosses an expansion joint in the freeway structure to provide a sliding joint, in addition to matching the expansion requirements of the conduit.
- All **structure-mounted multi cell conduit should be constructed of fiberglass**. All other conduit should be PVC constructed.
- **For each bridge or structure** requiring exterior-mounted conduit, **a separate construction detail must be provided**. (An example is provided in Figure 50.3-4) The designer should avoid providing “typical” construction details for a wide variety of bridge types, since mounting methods and installation requirements will vary greatly.
- Junction boxes should be installed opposite manholes on concrete parapet walls in which fiber optic conduit is being installed. A 4-inch sleeve should be provided connecting the fiber optic cabinet to the pull box.
- Two junction boxes should be installed, one on either end of the bridge, allowing access to the conduits on either side of the bridge.
- Each junction box should be equipped with a cable rung assembly allowing 20-30 ft. of fiber optic cable to be looped around inside the box.
- Junction boxes should conform to NEMA 4 or 4X, with a nominal dimension of 36 inches wide by 30 inches high by 12 inches deep.

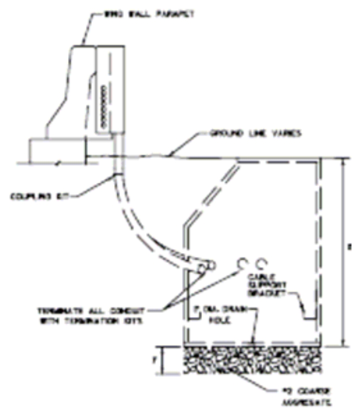

Figure 50.3-3: Conduit Transition From Trenched to Interior Parapet Conduit Systems

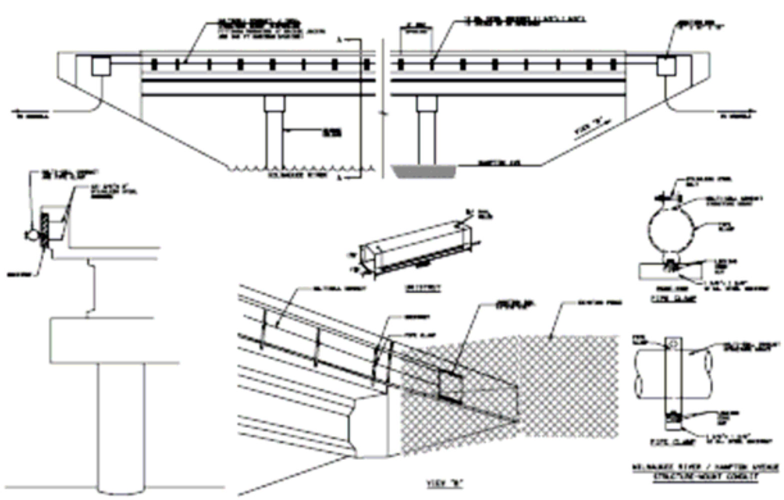

Figure 50.3-4: Bridge-specific Structure Mount Conduit Detail Example

50.3.2.1.5 Communication Manhole Design Standards

Guidelines for designing and installing the communication manholes are summarized below. A typical manhole installation detail is provided in Figure 50.3-5.

- Fiber optic manholes should be spaced at recommended intervals of 2500 feet, with the maximum allowable interval being 3500 feet allowing access to the multi-cell conduit at regular intervals.
- Fiber optic manholes should be installed at all locations wherever the conduit bends (as measured cumulatively from the last manhole) exceeds 360 degrees (180 degrees preferred).
- Manhole installation is not required whenever there is a change in the conduit installation method (e.g., from "in-trench" to "on-structure").
- Fiber optic manholes should not be installed along on-ramps, rather there should be a minimum of one manhole at each interchange where the distribution communication cabling transitions from multi-cell conduit to normal PVC conduit.
- The minimum dimensions of the manholes should be 36 inches (diameter) x 60 inches (depth). Manholes deeper than 60 inches may be considered "confined spaces" thereby adding complexly to persons entering the manholes.
- Manholes should be equipped with heavy-duty covers as they will be subject to occasional passage of heavy vehicles and cable rungs to allow excess cable to be coiled and raised off the ground.
- Final installed elevation for manhole, including cover, should be noted on plan when placed in the areas where roadwork (ramp widening, etc.) will be performed simultaneous with manhole installations.
- Two "knock-outs" should be provided on each sidewall of the manhole where the conduit does not enter.
- Manholes should be located to avoid drainage swells. Manholes located on slopes should be designed to not expose the side of the manhole that might be a hazard to traffic.
- Wherever applicable, the multicell conduit will be beneath the lighting conduit. Therefore, the manholes will have to be offset from the long axis of the conduit run. It is recommended that this offset be 24 inches.

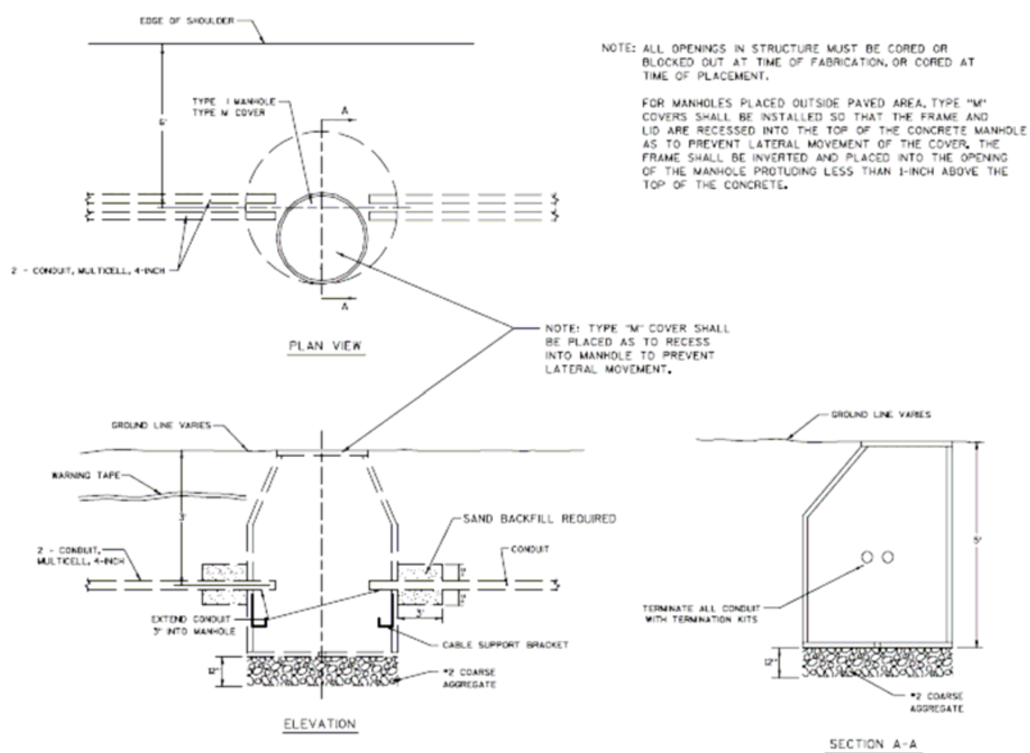

Figure 50.3-5: Typical Communication Manhole Installation

50.3.2.2 Wired Communication Design Standards

In most cases, there are two options available for wired communication, fiber optic cable or twisted pair cable.

50.3.2.2.1 Fiber Optics

Fiber optic cable has numerous advantages when considered for a dedicated communications network. These advantages include large capacity, immunity to electromagnetic and RF interference, a small flexible lightweight cable, and the capability to transmit data, voice, and video. The electronic equipment required (e.g., fiber muxes, video transceivers, etc.) is commonly available in a robust market with a good future.

The use of fiber optics typically requires a dedicated, WisDOT-owned communications network. This requires right-of-way and conduit throughout the network. Right-of-way is usually the limiting factor for private companies, but not for the State. The cost of installing conduit, however, can be significant. The backbone fiber optic network that runs throughout Wisconsin is often referred to as ITSNet.

Design criteria for fiber optic cable installation are as follows:

- Use cable with the correctly rated outer jacket material. Outdoor rated for underground installation in conduit, riser rated for vertical installations, and plenum rated for indoor installation.
- Design cable segments such that maximum pulling tension for individual cables is not exceeded. Different types and sizes of cabling have different maximum pulling tension.
- Design cable segments and access points (e.g., pull boxes, vaults, cabinets, etc.) such that minimum bending radius is not exceeded. Designers need to be aware that there are different bending radii depending upon loaded (during pulling, under tension) and unloaded (long term, at rest) conditions.
- Design cable segments and access points with nominal and maximum cable reel sizes in mind. Typical nominal reel sizes are 3,000 to 10,000 feet, with maximums upwards of 25,000 feet. Both the nominal and maximum reel sizes are dependent upon the type and diameter of the specific cable.
- Cables should not be pulled through any intermediate access point without the correct equipment and procedure. All tension must be eliminated at each access point. Alternately, the cable must be completely pulled from one access point to the next and safely stored in a figure-8 pattern.
- Excess fiber optic cable (100-ft typical) should be provided in each manhole in the system. This cable is coiled and fastened to cable support brackets. (See Figure 50.3-6)

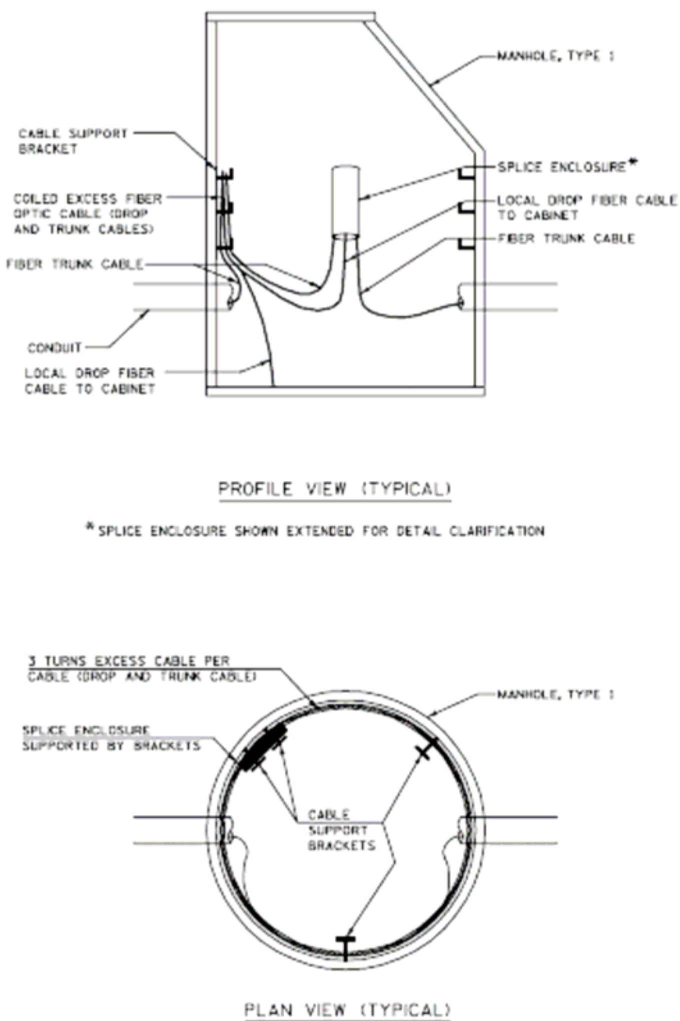

Figure 50.3-6: Communication Cable Installation in Manholes

To assist in record keeping and other system configuration and maintenance activities, a standardized naming convention for fiber optic cables is necessary. Figure 50.3-7 provides guidance on proper designation of fiber optic cables. This method is based from industry standard nomenclature.

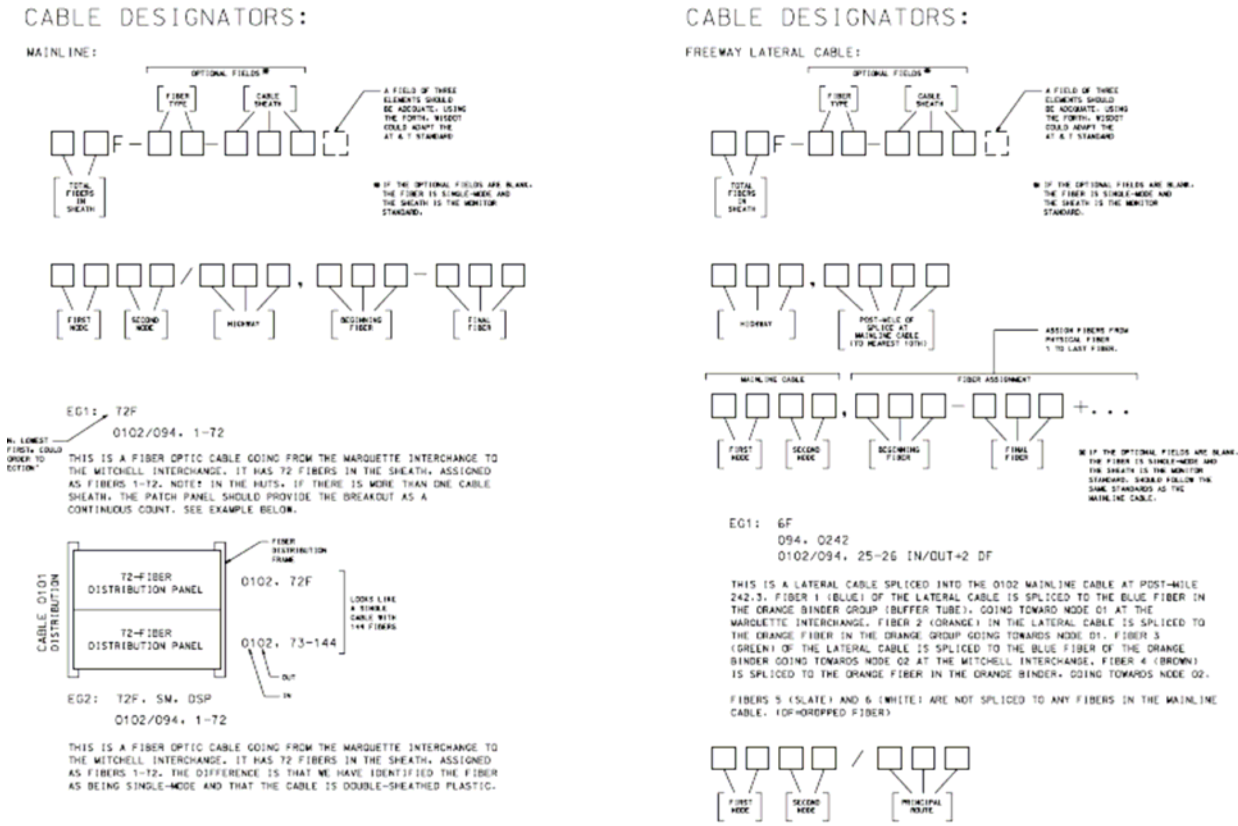

Figure 50.3-7: Fiber Optic Cable Designation and Naming Convention

50.3.2.2.2 Twisted Pair Cable

WisDOT-owned twisted pair cable has been widely used for the low-speed transmission of data in traffic signal systems, and between hubs and field elements within freeway management systems, with the network configured with between 8 and 12 field drops on each two-pair (4-wire) channel. The exact number of drops depends on the amount of data to be transferred between the hub and the field locations, and the rate of transfer. Twisted pair cable can support transmission distances of 8-10 miles before repeaters become necessary.

Twisted pair cable is a reliable and proven technology with established standards for cable and modems. A properly designed and installed twisted-pair communications system features reasonable low maintenance requirements in terms of average time between failures, the average time to repair, and the necessary levels of skill and equipment. Like fiber optics, it does require right-of-way and conduit, the latter often resulting in significant costs.

Design criteria for twisted-pair cable installation are as follows:

- Use cable with the correctly rated outer jacket material. Outdoor rated for underground installation in conduit, riser rated for vertical installations, and plenum rated for indoor installation.
- Design cable size and number of pairs taking into account the smallest diameter conduit or inner-duct the cable must pass through. A 25-pair cable has a nominal outer diameter of 1 inch.
- For interchanges consisting of multiple data devices, consider the use of smaller numbers of twisted pairs (e.g., 6-pair cable) to consolidate these devices to one of the local cabinets. For example, if three cabinets exist within a localized area, interconnect these cabinets with a 6-pair cable while bringing the mainline twisted pair cable into only one cabinet.
- In each manhole, provide for a service loop (one loop around the perimeter) of excess twisted pair cable

50.3.2.3 Wireless Communication Design Standards

One of the chief advantages of a radio-based communications subsystem is that no physical connection is required between the transmitter and receiver. This can translate into a significant cost savings over the capitalintensive cost of installing a cable conduit network, or the unpredictable ongoing costs for a leased facility. A proven radio alternative is the use of a spread-spectrum radio.

With spread-spectrum radio, the entire band (i.e., 902-928 MHz) is available for use by all users. Instead of subdividing the band, the FCC charged that each device operating in this range not exceed 1 Watt output power and be able to tolerate any interference generated in the band. This is accomplished by "spreading" the signal over the entire 26 MHz (in the 902-928 MHz band), and requiring that the receiver "know" where to look for the pieces of the signal.

Due to the spreading of the signal over a wide frequency range, electromagnetic noise (interference typically generated at a very narrow bandwidth) has less effect on signal integrity. Any noise interfering with a spread spectrum signal will tend to obscure only a very small fraction of the entire band and, since the signal is divided and spread over the entire spectrum, the transmitted signal can still be reliably reconstructed at the receiver.

Several low-speed spread-spectrum products are currently on the market, providing the following capabilities:

- Channel data rates of 9600 bps - 56 kbps
- Multiple channel capability
- Nominal range of 5 miles in open or over unobstructed ground (i.e., line-of-sight), with antenna
- RS-232 serial interface
- No FCC license required (although the manufacturer must have operation authorization)

Spread-spectrum radios transmitting at fractional and full T-1 rates (i.e., 512 kbps to 1.44 Mbps) over the frequency range of 5725 to 5850 MHz are also available. Both of these devices have a nominal range (with directional antenna) of 10 miles.

Design criteria for spread spectrum radio and antenna installation are as follows:

- Antennas can be mounted on standard poles, such as WisDOT Type 5 poles (30-ft), light poles, or camera poles.
- For large-diameter antenna (coaxial) cables, conduit installation between the local controller cabinet, pull boxes, and pole bases require the use of a 45-degree bend, a straight section, and another 45-degree bend to ease the installation sweep. (Typical installations into signal poles make use a single 90-degree bend.)
- Clear line-of-sight between antenna locations is not mandatory, but is preferred. Transmission quality is affected through significant changes in terrain elevations, trees, or tall buildings. If clear line-of-sight is indeterminable, engineering judgment should be used to determine the amount of terrain change or blockage between the two antenna locations.

50.3.3 Leased Communication System Considerations

Leased telephone circuits possess the flexibility and speed for application to ITS Deployment communications network as both low-speed and trunk connections. A wide variety of circuits are available from the telecommunications provider, including Type 3002 voice-grade data channels providing full-duplex multi-point analog service at 1200 - 9600 bps. These circuits can be used to provide analog communications between the control center and the VMS, ramp meters, and detector stations, and for camera control.

The telecommunications provider also offers digital services, which provide two-way digital data channels transmitting at rates between 2.4 (2400 bps) and 64 kbps. These circuits can be used for low-speed multi-point data channels operating at rates between 2400 and 9600 bps. These circuits thus can also be used for data trunking in which several low-speed channels are collected at a “hub”, multiplexed together in a higher speed Digital Services trunk, and transmitted to the control center. They may also be used for digital video transmission with a proprietary 56 kbps CODEC.

- ISDN channels each transmitting at 144 kbps (i.e., dual 64-kbps switched with 16 kbps data packet. These circuits can be used for data trunking, as well as for digitized video transmissions. for the video applications, 3 ISDN circuits would be used for each camera/CODEC to provide the appropriate video quality.
- DS1 (T-1) channels can also be used for digitized video. As compared to multiple ISDN circuits, the video quality would be significantly better, but at a greater monthly cost.
- DSL channels can also be used for both digital data and digitized video. Comparable to ISDN circuits, the video quality would be similar, but at a lower monthly cost.
- Fiber optic cables are also available from the telecommunications provider. It is noted that telephone companies throughout the United States make extensive use of fiber optic cables; but these networks are typically utilized solely for digital communications. The telecommunications provider is an exception

in that they will offer fiber optic cables for analog video. This approach provides “broadcast quality” video images.

Leased telephone is a very reliable communications solution in that there is a grid redundancy element due to the general coverage of the carrier’s network. One potential advantage over a dedicated network is that maintenance responsibilities are shifted from WisDOT to The telecommunications provider. Moreover, the service can generally be abandoned at any time, thereby providing flexibility to change the communications media should the need or opportunity arise. At the same time, the potential drawbacks associated with a leased approach must also be considered, including:

- Freeway Access - WisDOT is typically required to provide the telephone company with a conduit between the field cabinet and the nearest telephone facility. Along some segments, this distance may be significant and could result in an extensive conduit network being installed. This is not a major concern for the Milwaukee MONITOR in that the telecommunications provider only requires a conduit between the field cabinet and the freeway right-of-way.
- Cost - The costs for a leased network are not limited to the installation of the conduit. There are recurring expenses associated with the monthly cost of the circuits. Additionally, there is no guarantee that recurring charges will not significantly increase in the future unless WisDOT, and the telephone company enter into a contract. Several systems have converted from leased telephone to a jurisdiction-owned communications because of previous rate increases and the uncertainty of future hikes.
- Video Transmission - As a result of the improvements in CODEC technology during the last few years, the transmission of video over leased telephone is not as significant of an issue as it once was. Nevertheless, use of leased digital facilities for video requires a circuit capable of a data rate of 384 kbps (minimum for relatively good quality), a CODEC unit with CSU/DSU at both ends of the circuit, and an environmental enclosure (with heat and air conditioning) to house the field CODEC.

50.3.4 Communication Hut Design Requirements and Standards

Communication hub requirements for the state of Wisconsin have been established under previous ITS implementation projects. While these requirements are necessary to establish a basis for uniformity across the system, communication shelter manufacturers will have varying manufacturing processes materials which may or may not be acceptable.

Huts are not to be confused with communications hub. Hubs are points where fiber and/or other communications are connected through switches and routers, but do not have a physical location other than a cabinet or pull box.

Placement

- Communication hubs should be placed near logical crossing points of a communication network. Typically, system interchanges are ideal locations for communication hubs.
- The communication hub should be placed in a relatively flat area (4:1 slope or less)
- Hubs should be located in an area that is ultra-safe from vehicular travel.
- Communication shelters should be placed in a secure area, typically inside freeway right-of way fences with access via a locked gate.

Size

- Minimum interior dimensions of 8 feet (W) x 12 feet (L) x 9 feet (H)
- Frame type construction with both interior and exterior walls perpendicular to the floor

Structural Parameters

- Minimum roof live load 40 pounds per square feet
- Minimum side-wall live load 100 mile per hour wind load
- Minimum uniform floor load 150 pounds per square ft (over entire area)
- Minimum concentrated floor load 300 pounds per square ft (over one sq. ft)

The floor deck should be supported on a structural steel base / frame designed to permit the entire structure, complete with floor load, to be relocated. The base / frame shall incorporate full perimeter structural members, which protect and close off the complete building perimeter. The perimeter members shall accommodate lifting, anchoring, and support of the building. Skid-type base / frames shall not be acceptable. A concrete slab suspended between the perimeter members will provide necessary floor support. The entire underside of the base / frame shall be closed with a seam-welded steel plate to provide permanent barrier against moisture, insects, rodents, and vermin.

The base / frame shall be suitable for installation on a foundation system that provides multipoint support and anchoring along the long side of the base/frame structural members. Four concrete pier type foundations extending a minimum of 12 inches below normal frost line shall meet the requirements of the communication hub manufacturer. Piers shall be sized to accommodate an assumed soil bearing capacity of 3000 pounds per square feet.

An 8 feet (W) x 12 feet (L) x 12 inch (D) crushed aggregate base coarse pad shall be placed within the footprint of the fiber optic communications hub. Crushed aggregate base course shall adhere to the requirements of Section 304 in the Standard Specifications.

Anchoring shall permit repositioning, adjustment, and leveling of the building on the foundation during installation. Pre-cast anchor bolts shall not be allowed. Lifting and anchoring points shall be integral. No open holes shall be left in the perimeter of the base / frame after anchoring.

Insulation and Weather Proofing

- Insulation value – Floor, R11
- Insulation value – Sidewall, R11
- Insulation value - Ceiling / Roof, R19
- Maximum air filtration, 300 cubic feet per hour
- All areas insulated shall include a vapor barrier
- The communication hub shall be protected against the entrance of blowing rain or snow
- All door and conduit/cable openings shall be suitably protected and sealed

Heating-Ventilation-Air Conditioning

- Electric, forced air heating
- Operations controlled by environmental control panel
- Two speed ventilation system
- Exhaust fan with gravity damper
- Thermostatic control of the exhaust fan and exhaust damper shall be provided at the environmental control panel
- One (1) window type air conditioner (30,000 BTU per hour)
- Air conditioner unit shall permit the fan to cycle on and off with the compressor
- Air conditioner operation will be controlled by the environmental control panel

Environmental Control Panel (ECP)

- Provides remote thermostatic control of heating, ventilation, air conditioning, and emergency ventilation stages functions
- All environmental components shall be switched or otherwise controlled by devices properly rated and UL-listed
- Each environmental function shall be electrically interlocked to prevent simultaneous operation of multiple functions
- ECP shall have a five degree temperature differential between the ventilation and air conditioning stages to ensure the air conditioning does not conflict with outside ventilation, and vice-versa
- ECP shall contain visible indications of 1) Power ON, 2) Heat ON, 3) Vent ON, 4) Air Conditioner ON, 5) Emergency Vent ON; as controlled by the panel.
- Functional controls and internal terminal blocks shall be labeled with engraved plastic nameplates (dymo-type labels are not acceptable)

Safety, Security, and Remote Alarms

- Fire extinguisher
- Smoke detector
- Entrance intrusion
- High temperature
- Emergency Ventilation

Electrical

- Comply with National Electric Code
- All wiring will be surface mounted with straps in EMT conduit or other approved raceway
- All conduit will run horizontal or vertical
- 120/240 volt, single phase, 200 amps, with 30 branch circuits
- 100 amp auxiliary receptacle with manual transfer switch

Miscellaneous

- Four (4) 19 inch, non-enclosed racks, 7 feet in height, anchored to floor, wired complete with power with a minimum six (6) 120 VAC outlets along the rack
- One (1) 12 inch wide by 10 feet long cable tray
- One (1) 4 feet x 8 feet x ¾ inch plywood backboard