2015 Design Training Expo

Fiber Design for Traffic Signals and ITS Projects

PRESENTER:

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- 16 Years Telecom Experience
- 13 Years with ATKINS
- Sr. Network Engineer
- ITS Network Design
- Toll Network Design

AGENDA:

- Overview of Fiber Optic Cable
- Design Concepts
- Design Plans
- Examples

FIBER OPTIC CABLE OVERVIEW

FIBER OPTIC CABLE

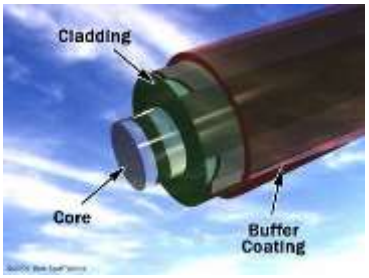
- What is it
- How it works
- Why we use it

FIBER OPTIC CABLE: What Is It?

In a word… GLASS!

EXTREMELY Pure Glass

- Any trace impurities cause attenuation
- 3 Primary Components:
  - Core
  - Cladding
  - Buffer Coating



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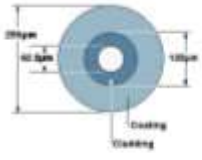
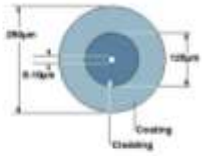
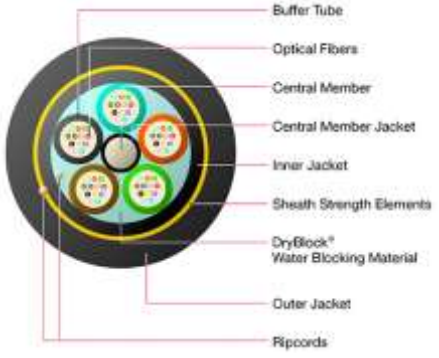
FIBER OPTIC CABLE: What Is It?

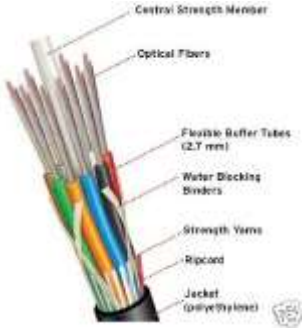
- Primary Categories:
  - ➢ Multimode
    - 50-62.5 micron core
    - Short-haul communications
  - ➢ Singlemode
    - 8-10 micron core
    - Long-haul communications





FIBER OPTIC CABLE: What Is It?





FIBER OPTIC CABLE: How It Works

FIBER OPTIC CABLE: Why We Use It

- Extremely Low Loss
  - ✓Transmit data over 120km without repeaters or regeneration
- Extremely High Bandwidth
  - ✓40 Gbps over a pair of fiber
  - ✓100 Gbps in development
- Data Security
- Resistance to EMI (Electromagnetic Interference)
- Light Weight & Smaller Size (compared to copper)
- Low Cost (Cheaper than equivalent length of copper)

FIBER OPTIC CABLE: Standards

COLOR CODE

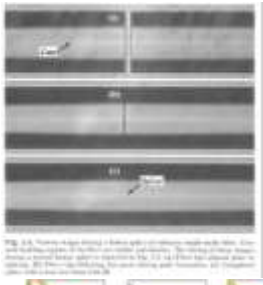
FIBER OPTIC CABLE: Terminology

- Backbone (or Trunk Line)
  - Carries data from multiple network segments
  - Has the highest demand for capacity
- Distribution (or Branch circuit)
  - Used for connecting multiple drop cables to the backbone
- Drops (or stubs)
  - Carries data at the local equipment cabinet level

Illustration of Cable Classifications

FIBER OPTIC CABLE: Terminology

- Fusion Splice – Fuses or welds two fibers together using an electric arc



- **Termination:**
  Common Connector Types:

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FIBER OPTIC CABLE: Color Code

EIA/TIA – 598 STANDARD:
"Optical Fiber Cable Color Coding" schema

Position	Jacket color
1	Blue
2	Orange
3	Green
4	Brown
5	Slate
6	White
7	Red
8	Black
9	Yellow
10	Violet
11	Rose
12	Aqua

FIBER OPTIC CABLE: Color Code

MVDS STA 126+56

SPLICE LOCATION	TRUNK CABLE - 144 FIBER SM				FUSION SPLICE		DROP CABLE - 12 FIBER SM					PORT NUMBER
	BUFFER TUBE		FIBER				BUFFER TUBE		FIBER		FUNCTION	
	NUMBER	COLOR	NUMBER	COLOR	WEST	EAST	NUMBER	COLOR	NUMBER	COLOR		
PULL BOX, TP 7 STA 126+63	1	BLUE	1	BLUE	X		1	BLUE	1	BLUE	FIELD SWITCH - RX	1
			2	ORANGE	X				2	ORANGE	FIELD SWITCH - TX	1
			3	GREEN	X				3	GREEN	TERMINATED SPARE	
			4	BROWN	X				4	BROWN	TERMINATED SPARE	
			5	SLATE					5	SLATE	--	
			6	WHITE					6	WHITE	--	
			1	BLUE		X			7	RED	FIELD SWITCH - TX	2
			2	ORANGE		X			8	BLACK	FIELD SWITCH - RX	2
			3	GREEN		X			9	YELLOW	TERMINATED SPARE	
			4	BROWN		X			10	VIOLET	TERMINATED SPARE	
			5	SLATE					11	ROSE	--	
			6	WHITE					12	AQUA	--	

FIBER DESIGN HIGH-LEVEL CONCEPTS:

Primary Fiber Design Concepts

- Planning for Future Growth & Scalability
- Minimize Exposure
- Design with Redundancy in Mind
- Link Budgets

Cable Capacity – Planning for the Future

- Drop Cable
  - 12-count is fairly standardized
  - 4 lit fibers; 4 spare fibers; 4 unused fibers
- Distribution Cable
  - Typically used to consolidate several long drop cable runs
  - 24-strand is typical
- Backbone Cable
  - 48 strand minimum (arterials)
  - 72, 96, or 144 strand is typical (highways)
  - Consider partner agencies

Network Data Capacity

- Need to determine how much data will be transmitted through the fiber
  - SM FOC can carry virtually unlimited amounts of data
- Determined by business need (and price)
- Data capacity can vary across the network
  - Current state of the art: 40 Gbps
    - (Transmit contents of Library of Congress in ~ 4 minutes)
  - Current widely-adopted standard: 10 Gbps
  - Typical ITS network: 1 Gbps
  - Typical CCTV Camera: 1-2 Mbps

Network Design Guidelines

- Limit number of switches per fiber pair
  - ✓Rule of Thumb: Max of ~15 switches (Not a hard limit)
- Limit number of CCTV Cameras per fiber pair
  - ✓Rule of Thumb: Max of ~8 CCTV (Not a hard limit)
- Bandwidth is rarely the limiting factor

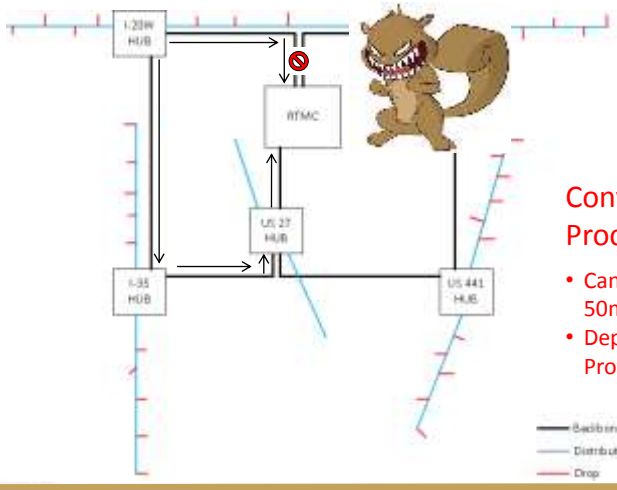
Limit Exposure

Network Redundancy

- Redundancy is crucial in communication networks
- Avoid Single Point of Failure
- Natural Enemies of fiber optic cable:



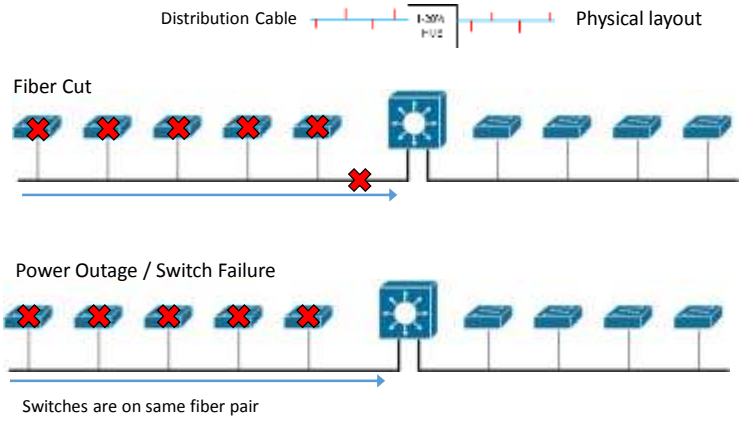

Physical Ring Topology



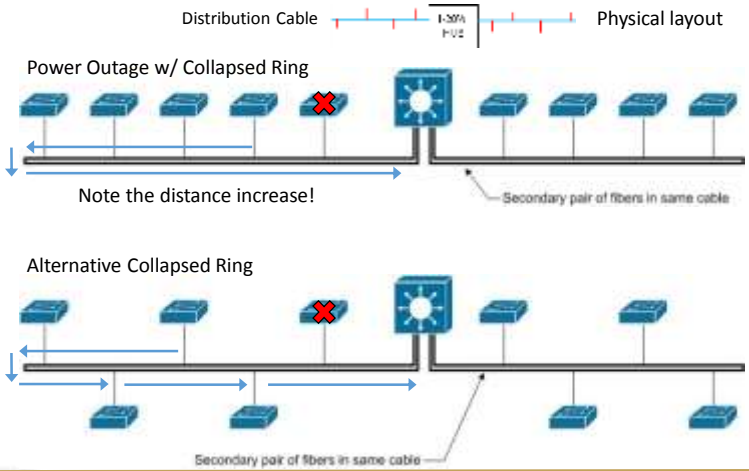
Convergence:
Process to Restore

- Can take anywhere from 50ms to 45sec
- Dependent on Network Protocols Implemented

Non-Redundant Topology



Collapsed Ring Topology



Attenuation / Expected Loss

3 Primary Categories of Loss:

- Distance Traveled
  - 0.4 dB/km @ 1310nm
  - 0.3 dB/km @ 1550nm
- Fusion Splices – (0.1 dB)
- Connectors – (0.5 dB)

633-3.1.8.1 End to End Attenuation Testing: Perform testing on all fibers to ensure that end to end attenuation does not exceed allowable loss (0.4 db/km for 1310 nanometer wavelength, 0.3 db/km for 1550 nanometer wavelength, plus 0.5 db for any connectors and 0.1 db for splices). Repair or replace cable sections exceeding allowable attenuation at no cost to the Department.

Example Link Loss Table

- Distance: 5 km
- Qty of Splices: 2
- Qty of Connectors: 2

SAMPLE LINK-LOSS BUDGET SPREADSHEET

Distance (km)	Allowable loss over length per wavelength (dB)		Number of connection types		Allowable loss per connection type (dB)		Total allowable loss (dB)	
	1310 nm (0.4 dB/km)	1550 nm (0.3 dB/km)	Fusion	Connector	Fusion (0.1 dB/ea)	Connector (0.5 dB/ea)	1310 nm	1550 nm
5	2	1.5	2	2	0.2	1	3.2	2.7
15	6	4.5	2	2	0.2	1	7.2	5.7
70	28	21	3	2	0.3	1	29.3	22.3

Link Budget Analysis

Min TX – Min RX >
Total Allowable Loss

AFFECTS OVERALL COST

- ✓ Standard Range GBIC (10km)
- ✓ Extended Range GBIC (40km)
- ✓ Long Range GBIC (70km)

Product	Transmit Power Range (dBm)	Receive Power Range (dBm)	Maximum Channel Insertion Loss in dB (by fiber type)*	Transmit and Receive Wavelength Range (nm)
[illegible]	-3 to -9.5	0 to -17	2.4 (FDDI-grade) 2.6 (OM1) 3.4 (OM3/OM4) 3.6 (OM2) 5 (OM3)	770 to 860
[illegible]	-3 to -9.5	-3 to -20	**10.5 dB**	1270 to 1355
[illegible]	+3 to -1	+1 to -22	**21.0 dB**	1260 to 1355
[illegible]	+5 to 0	-3 to -23	**23.0 dB**	1500 to 1580

Distance (km)	Allowable loss over length per wavelength (dB)		Number of connection types		Allowable loss per connection type (dB)		Total allowable loss (dB)	
	1310 nm (0.4 dB/km)	1550 nm (0.3 dB/km)	Fusion	Connector	Fusion (0.1 dB/ea)	Connector (0.5 dB/ea)	1310 nm	1550 nm
10	4	3	2	2	0.2	1	5.2	4.2
40	16	12	2	2	0.2	1	17.2	13.2
70	28	21	3	2	0.3	1	29.3	22.3

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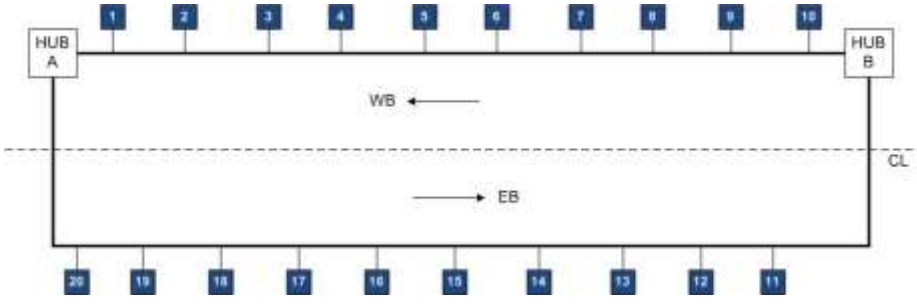
Design Exercise

- 2 Hub Locations
- 20 Devices (assume no CCTV)
- Backbone fiber on both sides of the road



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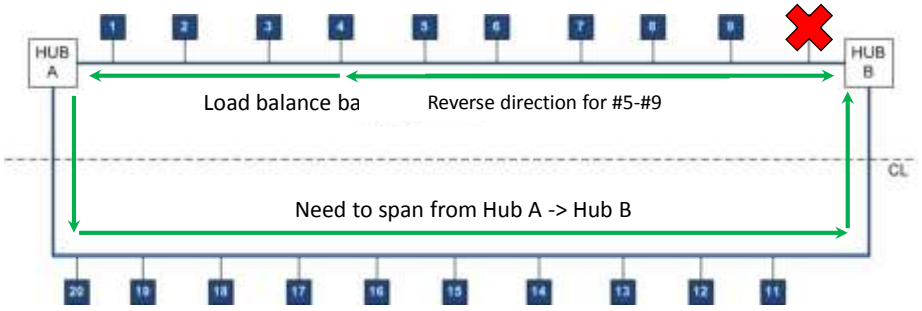
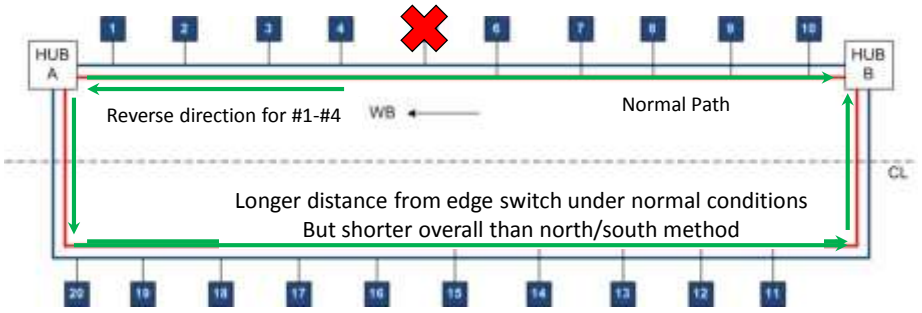
Design Exercise

- Divide into 2 Rings (North & South)
- Minimize distance between devices
- Longer distance between hubs



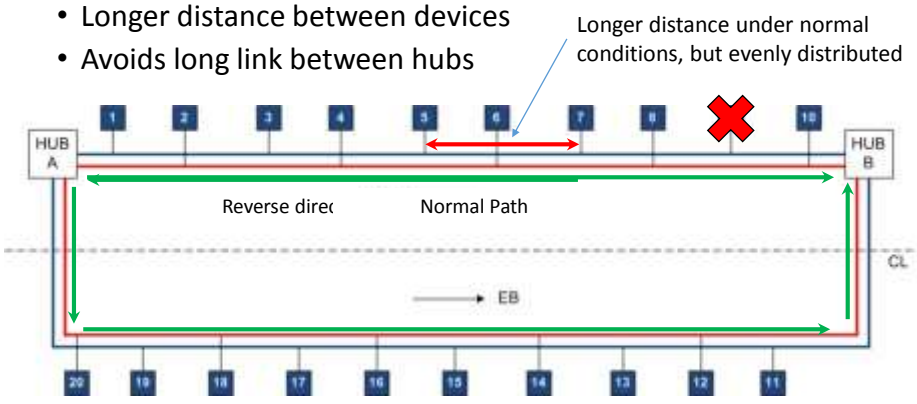
Design Exercise

- Divide into 2 Rings (East & West)
- Minimize distance between (most) devices
- Longer distance between last switch and hub



Design Exercise

- Divide into 2 Rings (Evens & Odds)
- Longer distance between devices
- Avoids long link between hubs

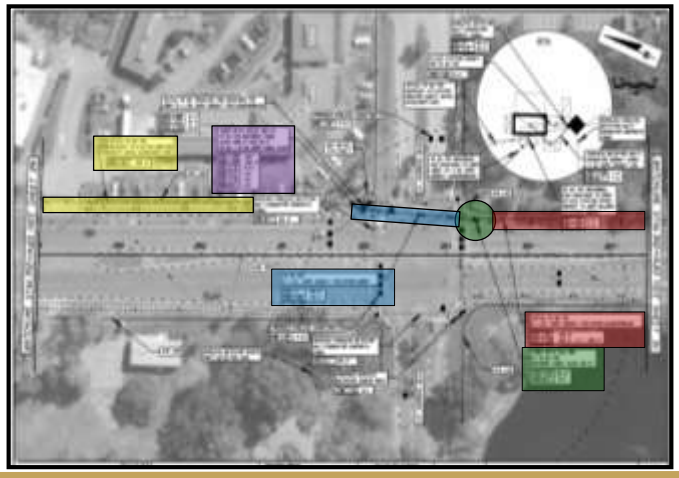


Design Exercise

- ➢ No "One Size Fits All" Solution for Network Design
- ➢ Examine all variables
- ➢ Carefully consider Distances / Span Loss
  - Distance Between Devices
  - Distance Between Major Hubs / TMCs

FIBER DESIGN PLANS

Fiber Design in Plan Sheets



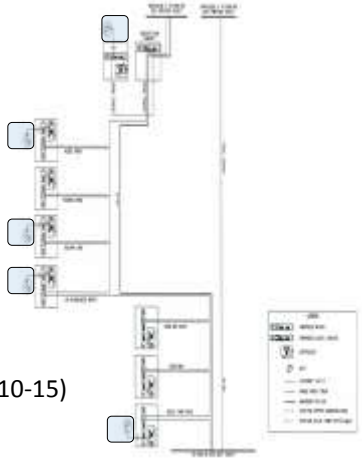
Fiber Design in Plans: Details

5 Primary Details (Best Practice):

1) Network Block Diagram
2) Splicing Details
3) Port Assignments
4) Link Loss Budget
5) Wiring Diagram

Fiber Design Plans: Block Diagram

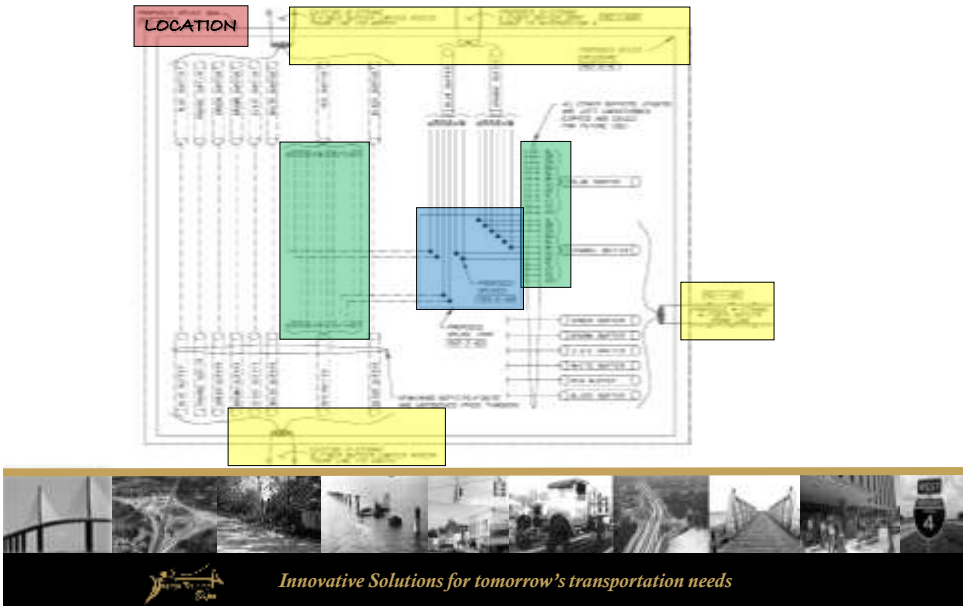
- Backbone
- Distribution
- Drops
- Local Hubs
- ITS / ATMS Devices
- Legend



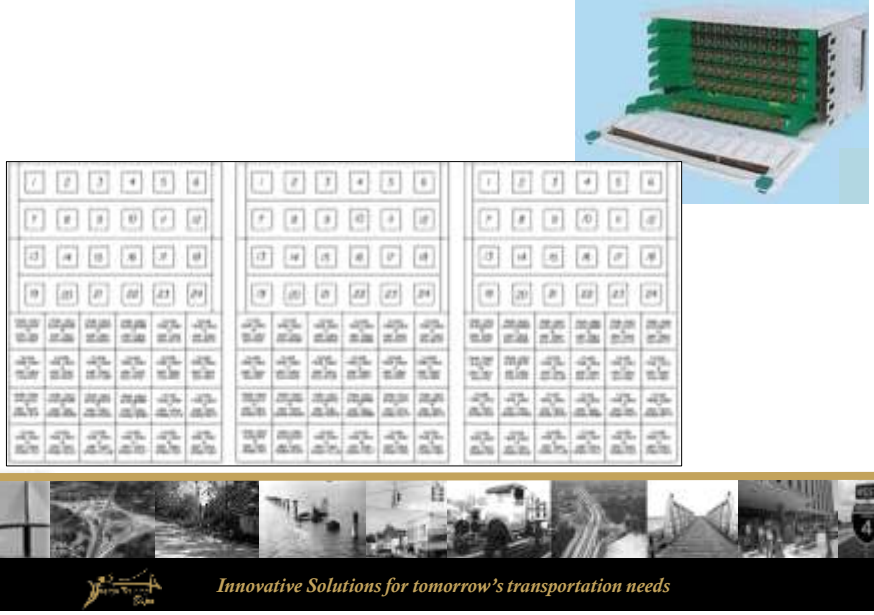
RULE OF THUMB:

- Limit Number of Switches per Ring (10-15)
- Limit Number of CCTV per Ring (6-8)

Fiber Design Plans: Splicing Detail



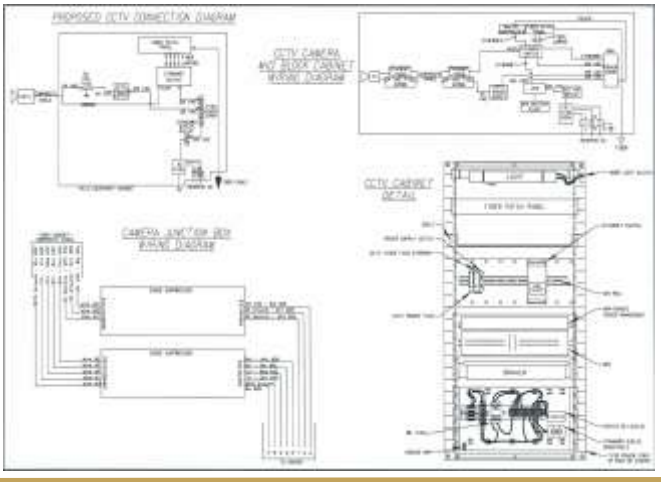
Fiber Design Plans: Port Assignments



Fiber Design Plans: Link Budget

SAMPLE LINK LOSS BUDGET SPREADSHEET									
Typical Route	Distance (km)	Allowable loss over length per wavelength (dB)		Number of connection types		Allowable loss per connection Type (dB)		Total allowable loss (dB)	
		1310nm (0.4dB/km)	1550nm (0.3dB/km)	Fusion (dB)	Connector (dB)	Fusion (0.1dB per)	Connector (0.5dB per)	1310nm	1550nm
1	5	2	1.5	3	2	0.3	1	3.3	2.8
2	1	0.4	0.3	1	1	0.1	0.5	1	0.9
3	2	0.8	0.6	2	2	0.2	1	2	1.8
4	3	1.2	0.9	3	3	0.3	1.5	3	2.7
5	4	1.6	1.2	4	4	0.4	2	4	3.6

Fiber Design Plans: Wiring Diagrams



Examples of Fiber Components

- Fiber Optic Cable
- Connection Types
- Hardware for FOC

Examples: Fiber Optic Cable

Struct. 633- 1.ABC FIBER OPTIC CABLE LF

A= Operation
1 (Furnish & Install)
3 (Install) Furnished by FDOT or local agency, C=0
4 (Relocate) C=0
6 (Remove) C=0, effective July 2014, through 6/2014, see 690 removal items

B= Location
1 (Overhead)
2 (Underground)

C= Number of Fibers in Cable
1 (216 12)
2 (13 to 48)
3 (49 to 96)
4 (97 to 144)

Notes *Remove item may require plan details and/or tech spec

- *As required in the Standard Specs:*

633-1 Description.
Furnish and install underground and aerial communication cable as shown in the Plans and Design Standards.

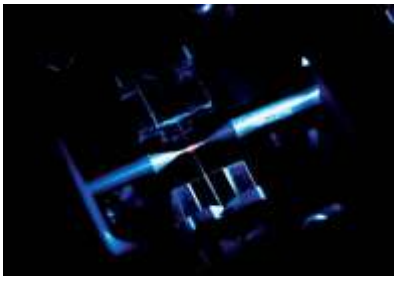
  - *The general notes or design tags should specify the fiber count within each buffer tube of the fiber optic cable (FOC)*
    - *Typical specifications include:*
      - *Total count (12, 24, 48, 72, 96, or 144)*
      - *12-fibers per buffer*

Examples: Fiber Optic Connection

Struct. 633- 2- AB FIBER OPTIC CONNECTION EA

A= Operation
3 (Install)
B= Type
1 (Splice)
2 (Termination)

Fusion Splice:



Termination Connector Types:

ST SC FC LC

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Examples: Fiber Optic Hardware

Struct. 633- 3- AB FIBER OPTIC CONNECTION HARDWARE EA

A= Operation
1 (Furnish & Install)
3 (Install)
4 (Relocate)
5 (Adjust /Modify)

B=Component
1 (Splice Enclosure)
2 (Splice Tray)
3 (Preterminated Connector Assembly)
4 (Buffer Tube Fan Out Kit)
5 (Patch Panel, Preterminated)
6 (Patch Panel, Field Terminated)
7 (Connector Panel)

B = 1; Splice Enclosure:

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Examples: Fiber Optic Hardware

B = 2; Splice Tray:

B = 3; Pre-terminated Connector Assembly (Pigtail):

Examples: Fiber Optic Hardware

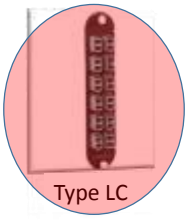
B = 4; Buffer Tube Fan-out Kit:

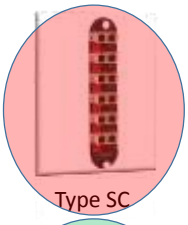
B = 5; Patch Panel (Pre-terminated):

Examples: Fiber Optic Hardware

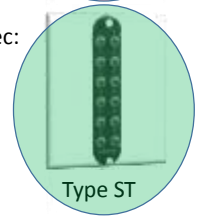
B = 6; Patch Panel (Field terminated):

B = 7; Connector Panel:





FDOT Spec:



Patch Cord:

REFERENCES AND RESOURCES

Links / References

- FDOT Traffic Engineering and Operations
  http://www.dot.state.fl.us/trafficoperations/
- FDOT Specifications and Estimates
  http://www.dot.state.fl.us/programmanagement/default.shtm
- FDOT Design Standards
  http://www.dot.state.fl.us/rddesign/DesignStandards/Standards.shtm
- Approved Product List
  https://fdotwp1.dot.state.fl.us/ApprovedProductList/Specifications
- Traffic Engineering Manual (TEM)
  http://www.dot.state.fl.us/trafficoperations/Operations/Studies/TEM/TEM.shtm

Links / References

- Florida Intersection Design Guide
  http://www.dot.state.fl.us/rddesign/FIDG-Manual/FIDG.shtm
- Plans Preparation Manual
  http://www.dot.state.fl.us/rddesign/PPMManual/PPM.shtm
- Master Pay Item List / WebGate
  https://fdotwp1.dot.state.fl.us/wTWebgateReports/Login.aspx
- FHWA Manual on Uniform Traffic Control Devices (MUTCD)
  http://mutcd.fhwa.dot.gov/

You don't have to know it all ….
…. You just have to know where to find it

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QUESTIONS?