Plactic Optical Fiber

Market&Technology Assessment Study

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HWAYING

Introduction

1. POF Historical Development
2. Why POF
3. Technical Characteristics of POF Fibers Systems
4. POF Data Communications Applications
5. POF and Related Standards
6. POF Market
   - -POF Components –Present Status
   - -POF Suppliers
   - -POF Components Price Trends
   - -POF Market Drivers
   - -Market Forecast
7. Opportunities in POF Business
8. Strategies for Success in the POF Market

Part 1: POF Historical Development



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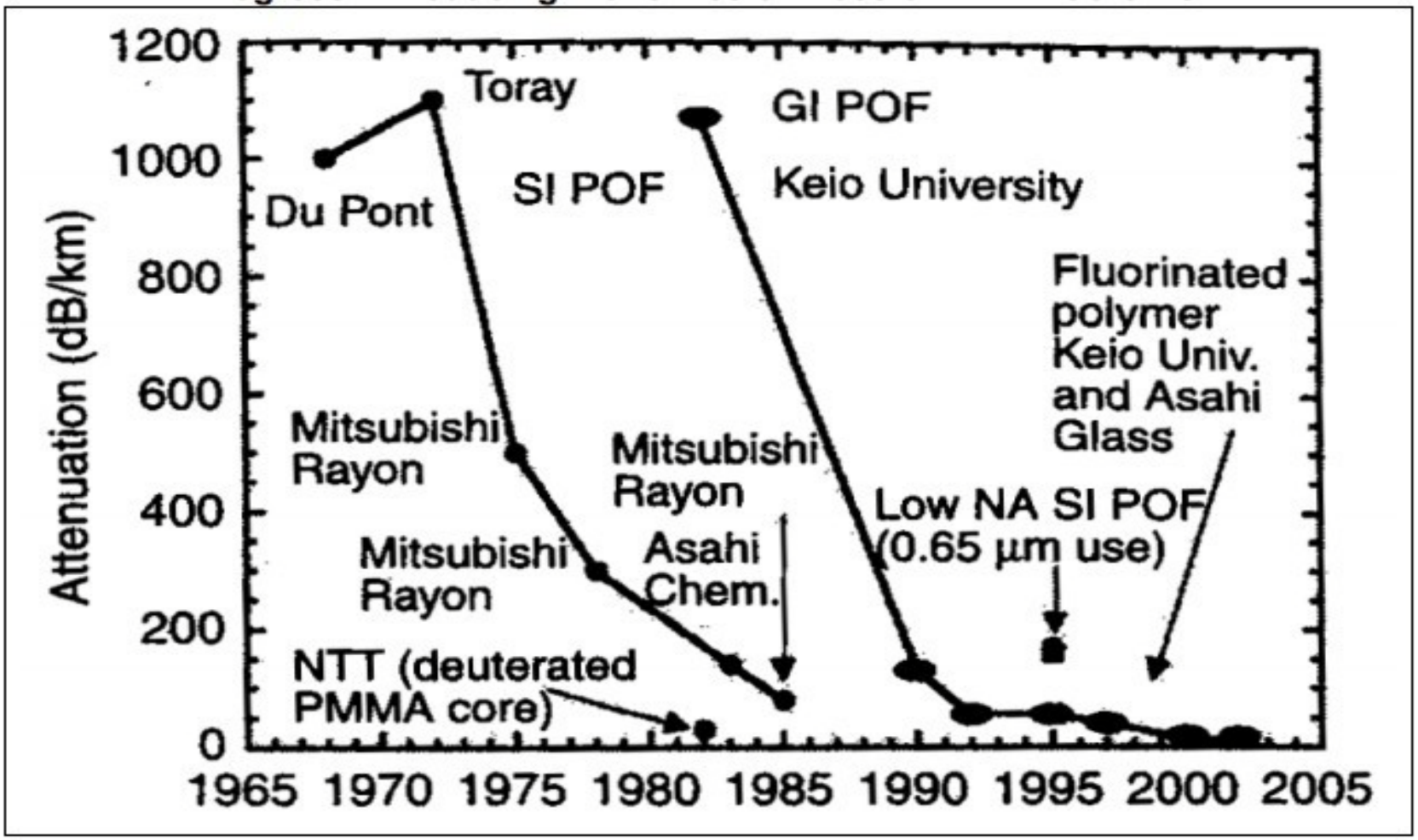
POF Development



POF Development in US and Europe

- **US**:1994, DARPA,$6 million, POF Consortium, POF Production and Application;

  1997, OMNET, $30millions, POF(GI-PF POF)
- **France**:"French Plastic Optical Fiber Club", rearch on POF as part of ACTS program
- **Germany**:POF research, development, and manufacturing are flourishing mainly driven by the auto industry led by Daimler-Benz and BMW

Part2: Why POF



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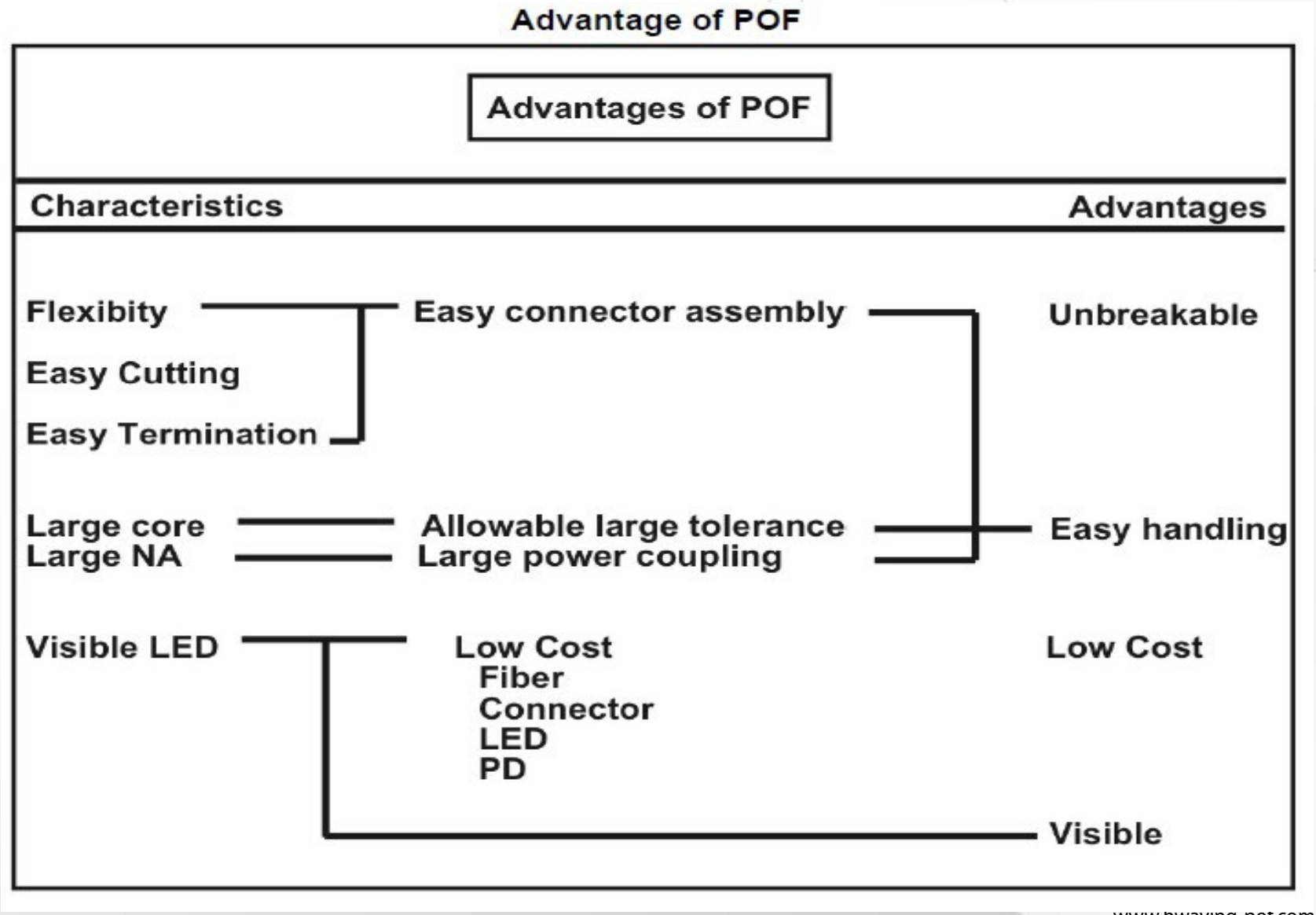
Why POF

- Ease of Connectorization
- Durability
- Large Diameter
- Lower Costs
- Transmitters (Transceivers)
- Receivers
- Connector Size
- Installation
- Test Equipment
- Maintenance
- Ease of Handling
- Safety
- Bandwidth
- Standard situation is improved
- Many Market are open to POF

Advantage of POF



Comparision Between Copper,GOF,and POF

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Exhibit 3.1
Advantages of POF vs. GOF vs. Copper

	Plastic	Glass	Copper
Component Costs	Potentially low-cost fiber and components	More expensive fiber and components	Low cost
Loss	High-medium loss (short distance)	Medium-low loss (long distance)	High loss
Connectorization	Easy to connectorize, requires little training or special tools	Takes longer, requires special tools and training	Easy
Handling	Easy to handle	Requires training and care	Easy
Flexibility	Flexible	Brittle	Flexible
Wavelength operating range	Operating in visible	Operating in infrared	NA
Numerical aperture	High (0.4 N.A.)	Low (0.1-0.2 N.A.)	NA
Bandwidth	High (11Gbps over 100 meters)	Large (40Gbps)	Limited to 100 meters at 100Mbps
Test equipment	Low-cost	Expensive	High
Systems costs	Low overall	High	Medium

Part3: Technical Characteristics of POF Fibers Systems



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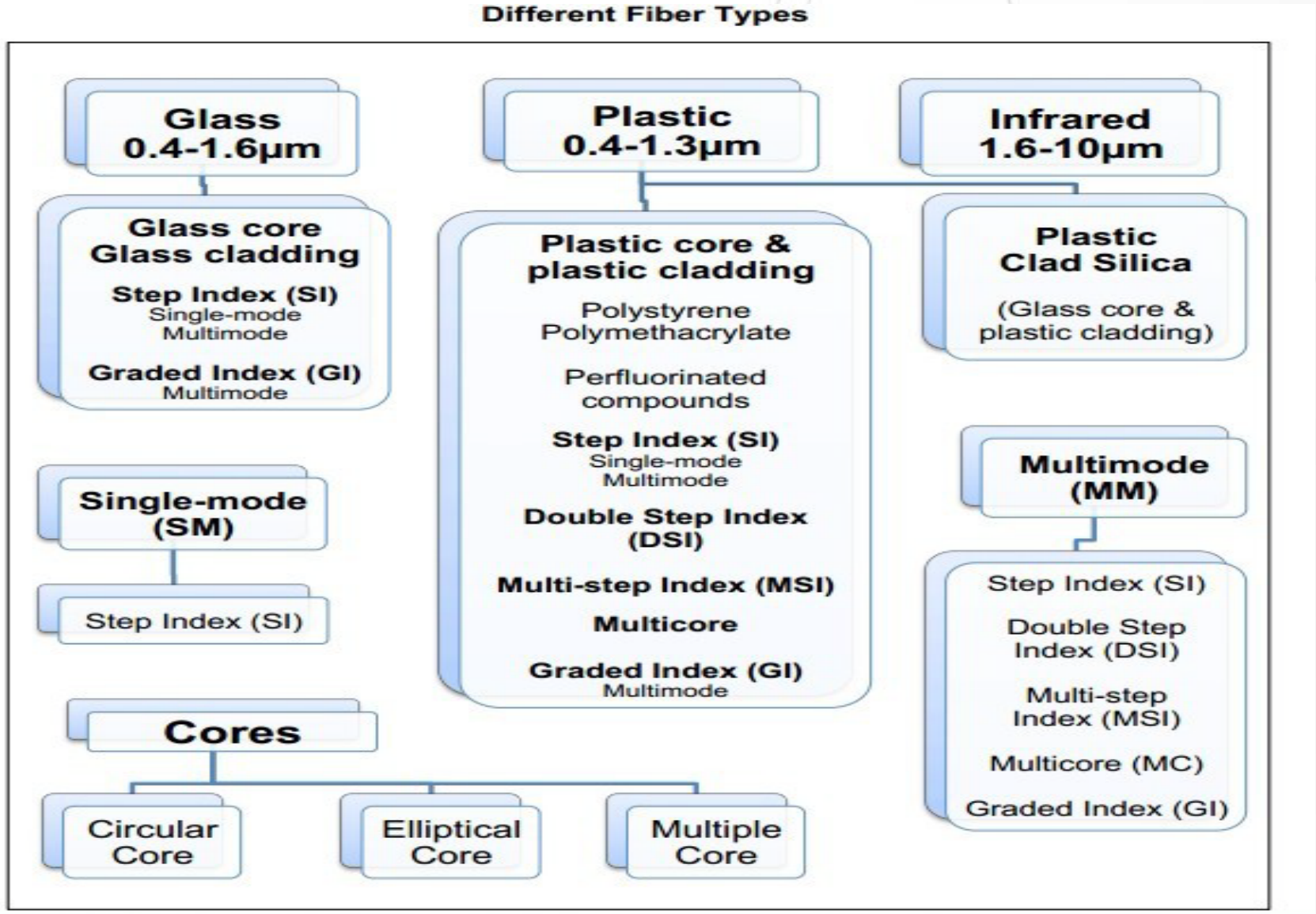
Technical Characteristics of POF Fibers Systems

Types of optical fibers

- Step index(SI)multimode fiber
- Multimode graded index fiber(GI)
- Single-mode step index fibers(SMF)

Types of optical fibers



Plactic Optical Fibers

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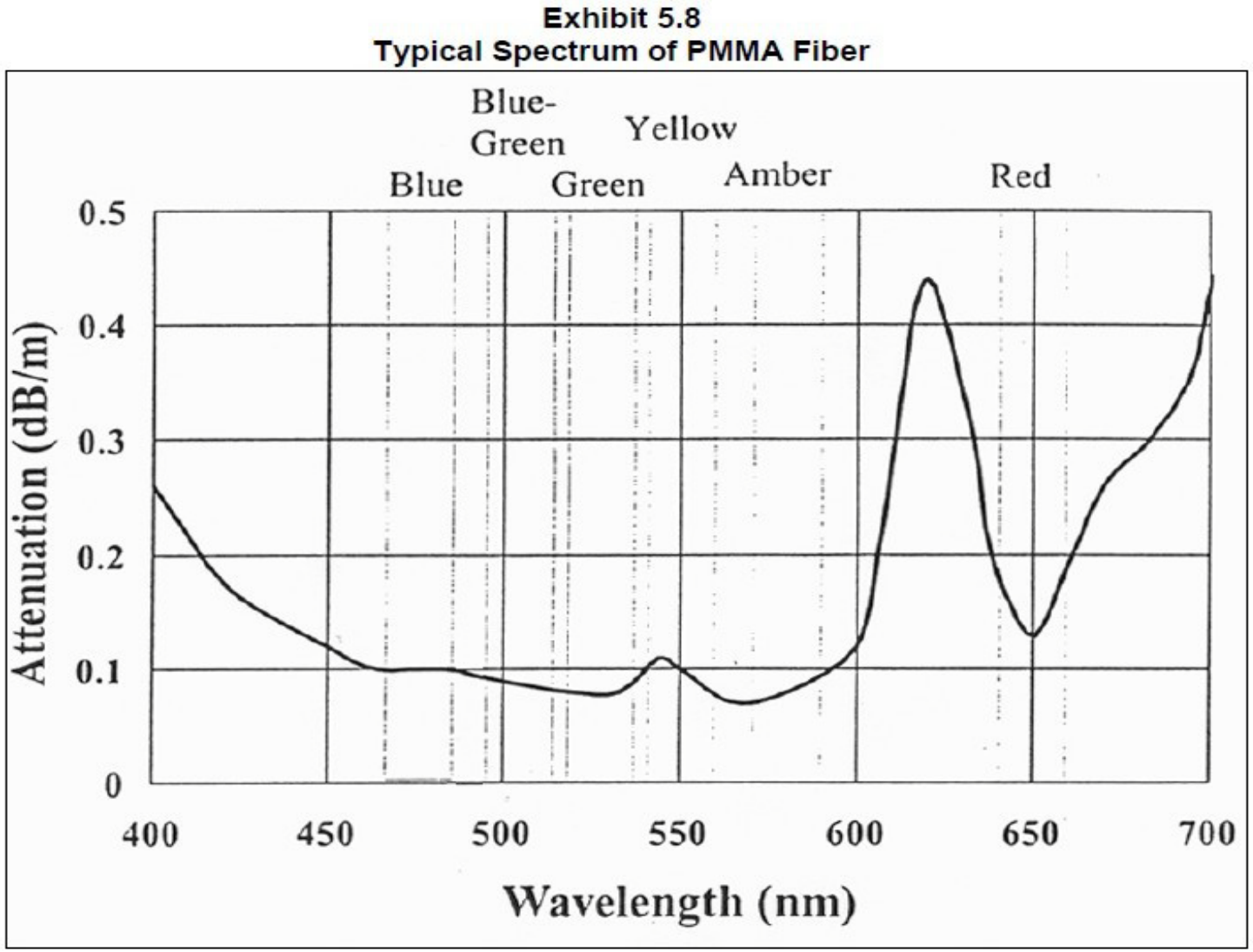
Exhibit 5.6
Basic Materials Used for Plastic Optical Fiber

Core material	Wavelength (nm)	IR-absorption (dB/km)	Rayleigh scattering (dB/km)	UV-absorption (dB/km)	Total loss (dB/km)
Polystyrene	580	4	78	11	93
	624	22	58	4	84
	672	24	43	2	69
PMMA	516	11.3	26	-	37.3
	568	17.2	17.7	-	34.9
	650	95.9	10.3	-	106.2
P(MMA-D8)	568	0.2	15.5	-	15.7
	650	0.6	9.0	-	9.6
	680	1.6	7.5	-	9.1
Poly(2,2,3,4,5,6-hexafluorobutyl-methacrylate	516	6.2	13.8	-	20.0
	568	9.5	9.5	-	19.0
	650	52.7	5.5	-	58.2
Poly(2,2,3,4,4,4-hexafluoro 1,1,2-threedeuterobutyl perdeuteromethacrylate	568	5.5	10.0	-	15.5
	650	0.3	5.5	-	5.8
	680	0.9	4.6	-	5.5

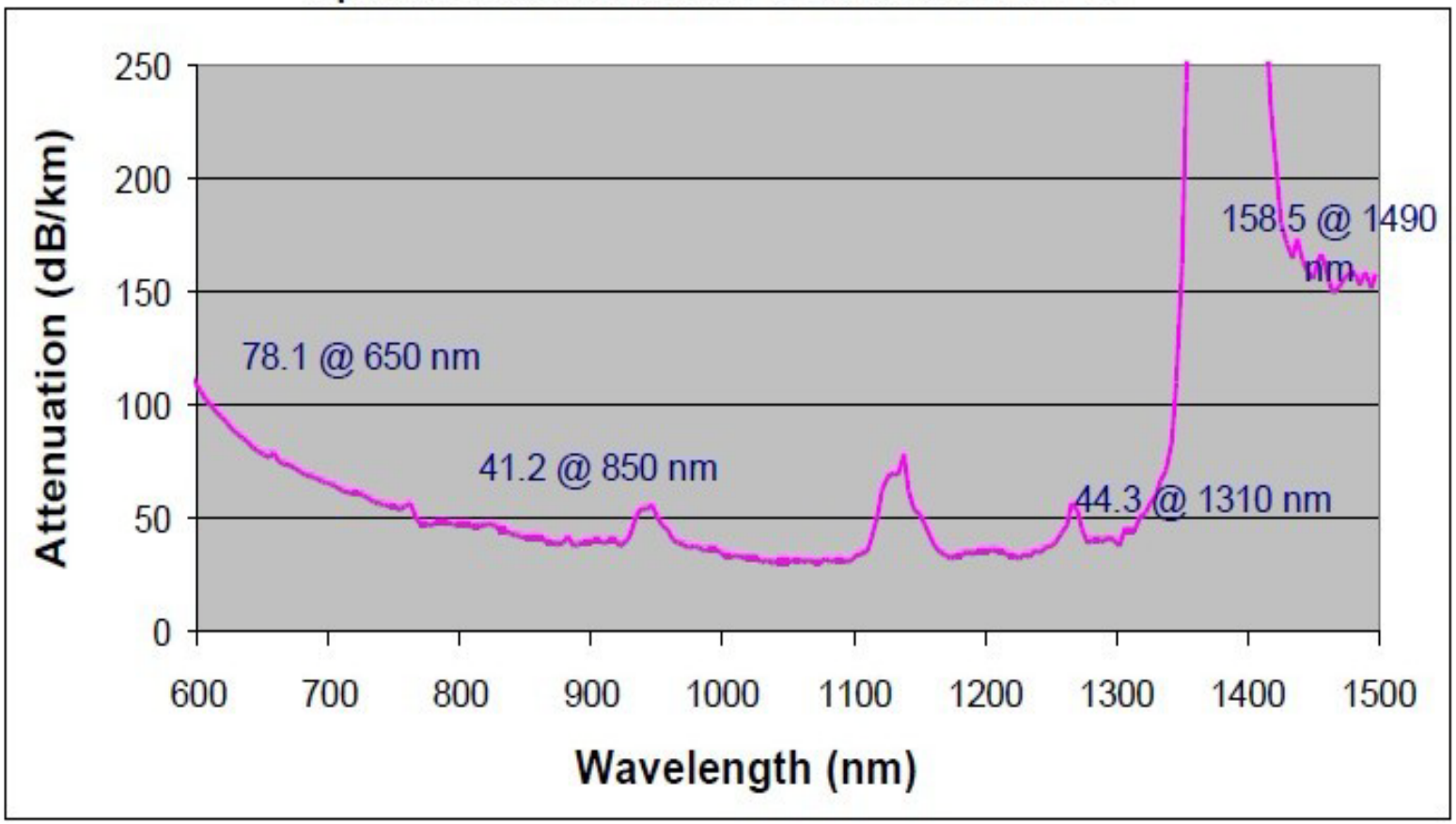
Attenuation

- **GOF**:850nm-1600nm, infrared region
- **PMMA POF**: 500nm-750nm, visible
- **Perfluorinated fibers**: 650nm-1300nm, 50dB/km
- The main applications have been at the 650nm window(largest attenuation)using red LEDs and Laser diodes.

Typical Spectrum of PMMA Fiber



Spectral Attenuation for Perfluorinated GI-POF



Bandwidth

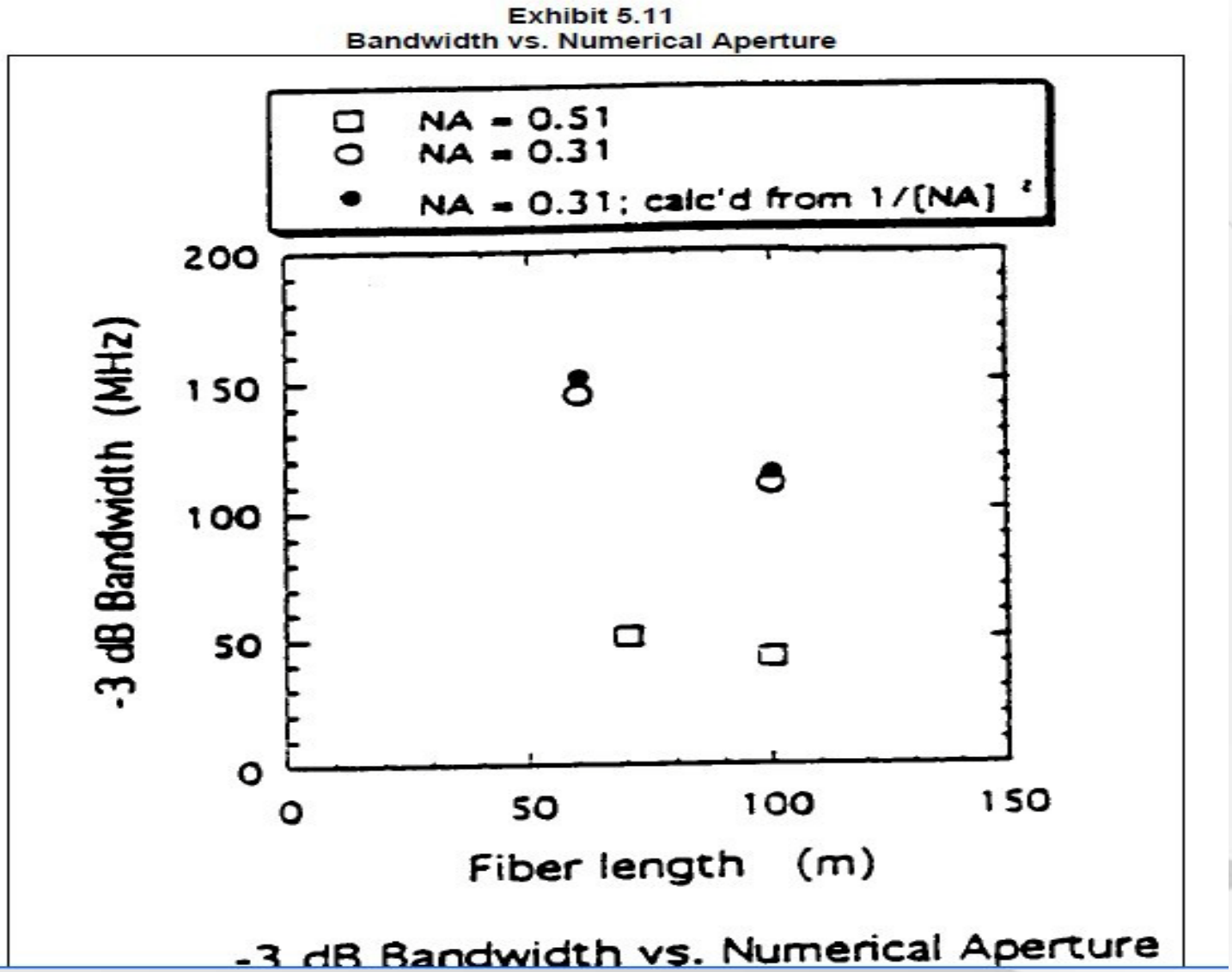


Exhibit 5.11
Bandwidth vs. Numerical Aperture
NA = 0.51
NA = 0.31
NA = 0.31; calc'd from 1/[NA]²
-3 dB Bandwidth (MHz)
200
150
100
50
0
0
50
100
150
Fiber length (m)
-3 dB Bandwidth vs. Numerical Aperture

Bandwidth

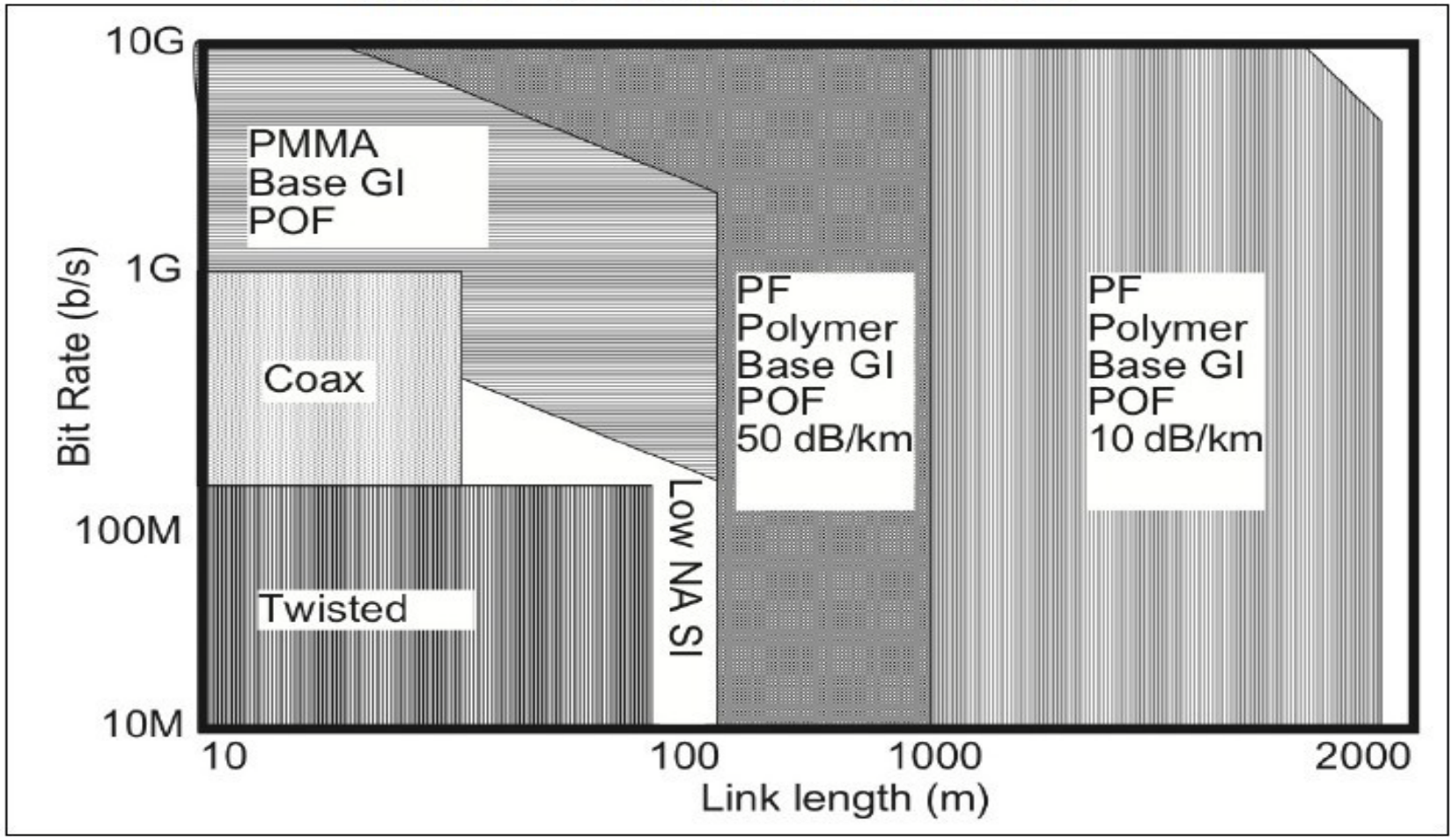
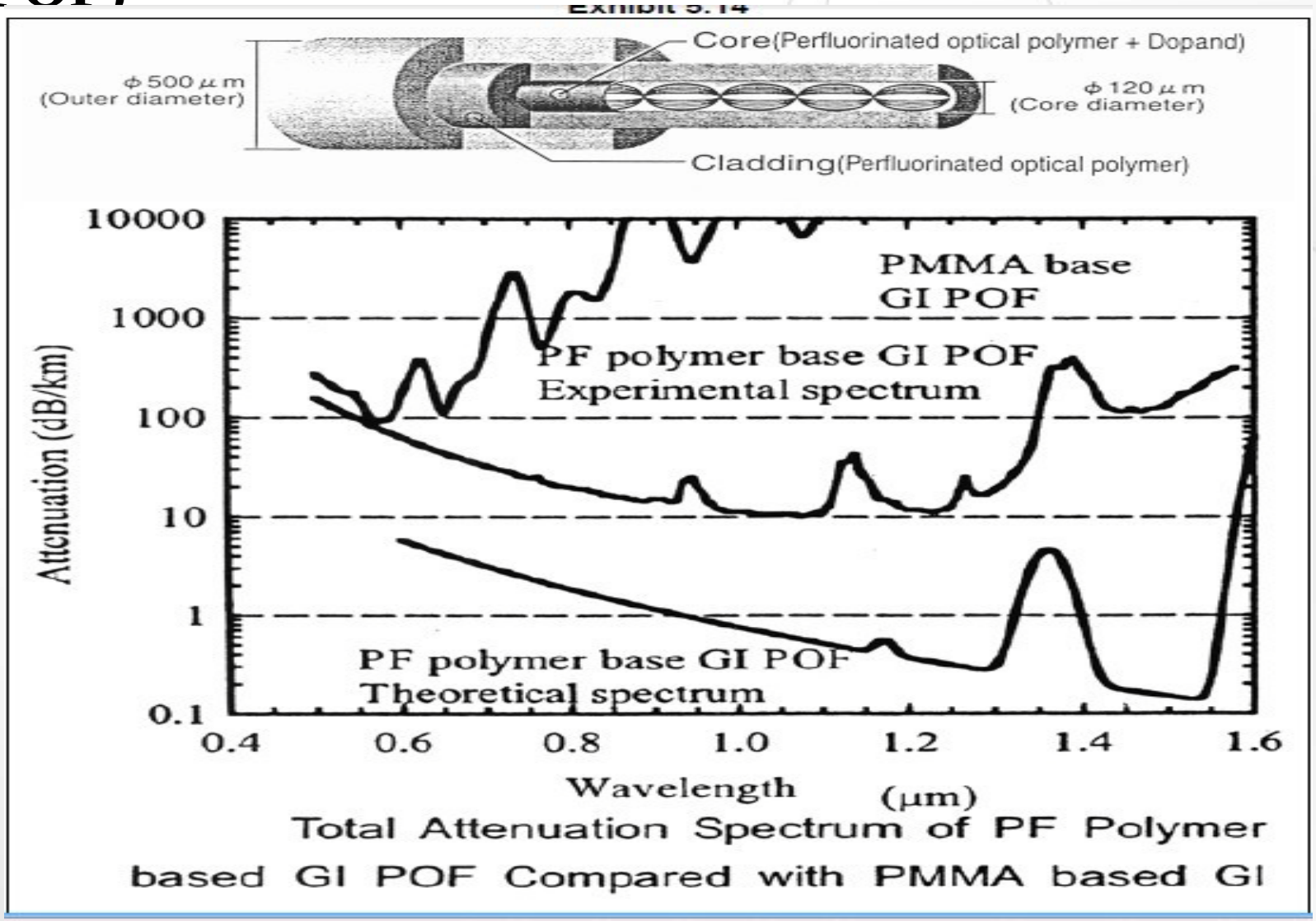


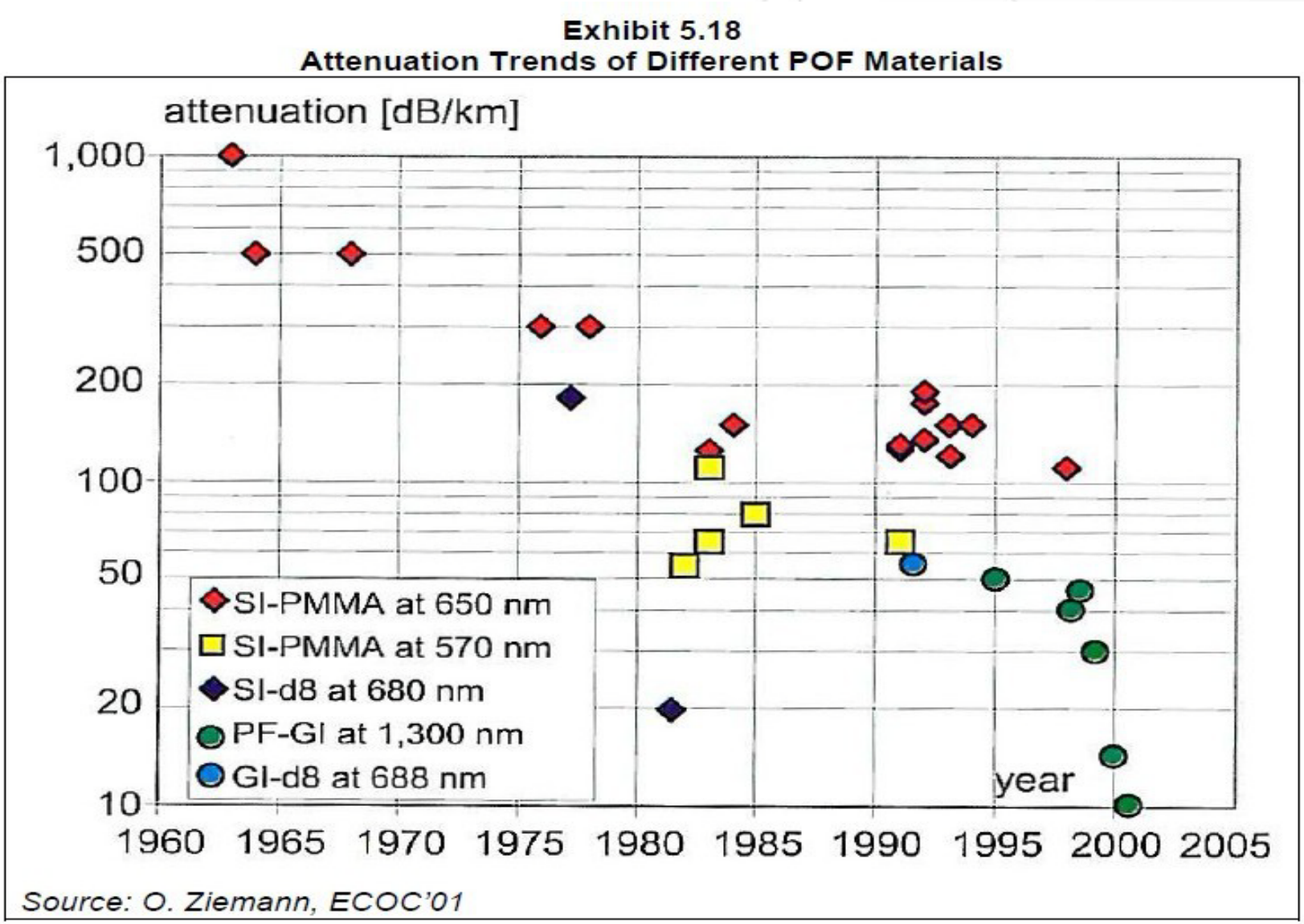
Exhibit 5.13
Data Rate vs. Distance for Various Media
10G
1G
100M
10M
Bit Rate (b/s)
PMMA
Base GI
POF
Coax
Twisted
Low NA SI
PF
Polymer
Base GI
POF
50 dB/km
PF
Polymer
Base GI
POF
10 dB/km
10
100
1000
2000
Link length (m)

Perfluorinated POF (PF GI-POF)&Grade Index PMMA POF(GI-POF)

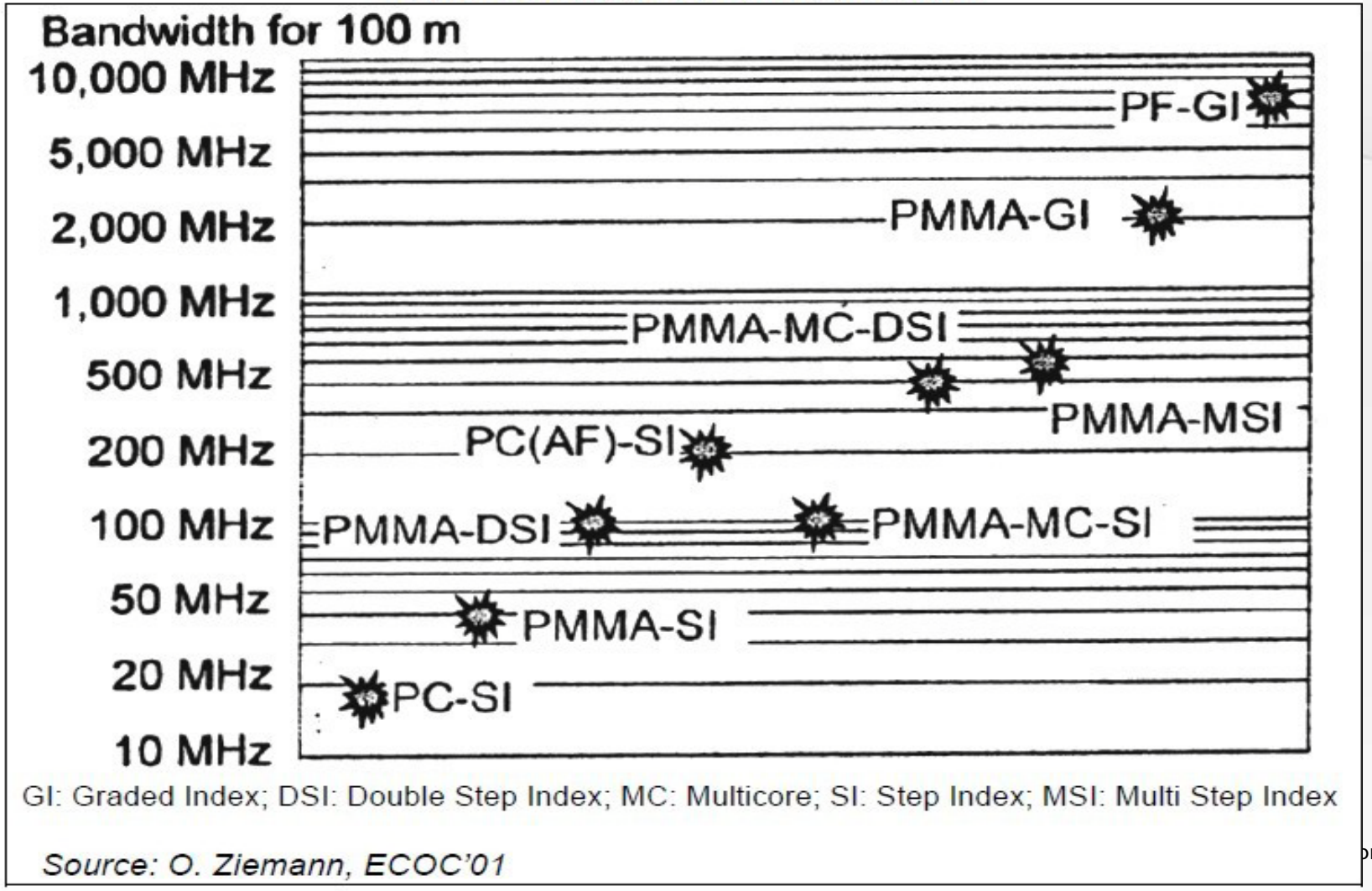


Total Attenuation Spectrum of PF Polymer based GI POF Compared with PMMA based GI

Attenuation of Different POF Materials



Index Profiles of POF and Bandwidth



Manufacturing Methods of POF

- **Extrusion**: SI PMMA POF
- **Preform Drawing**: GI PMMA POF,
- **Continuous Extrusion** : PF GI-POF

Light Sources

- LEDs
- Resonant Cavity LEDs(RC-LEDs)
- Laser Diodes
- Vertical Cavity Surface Emitting Lasers(VCSELs)

Optical Connectors

Cutting Tools

- Polishing technique
- Hotplate technique

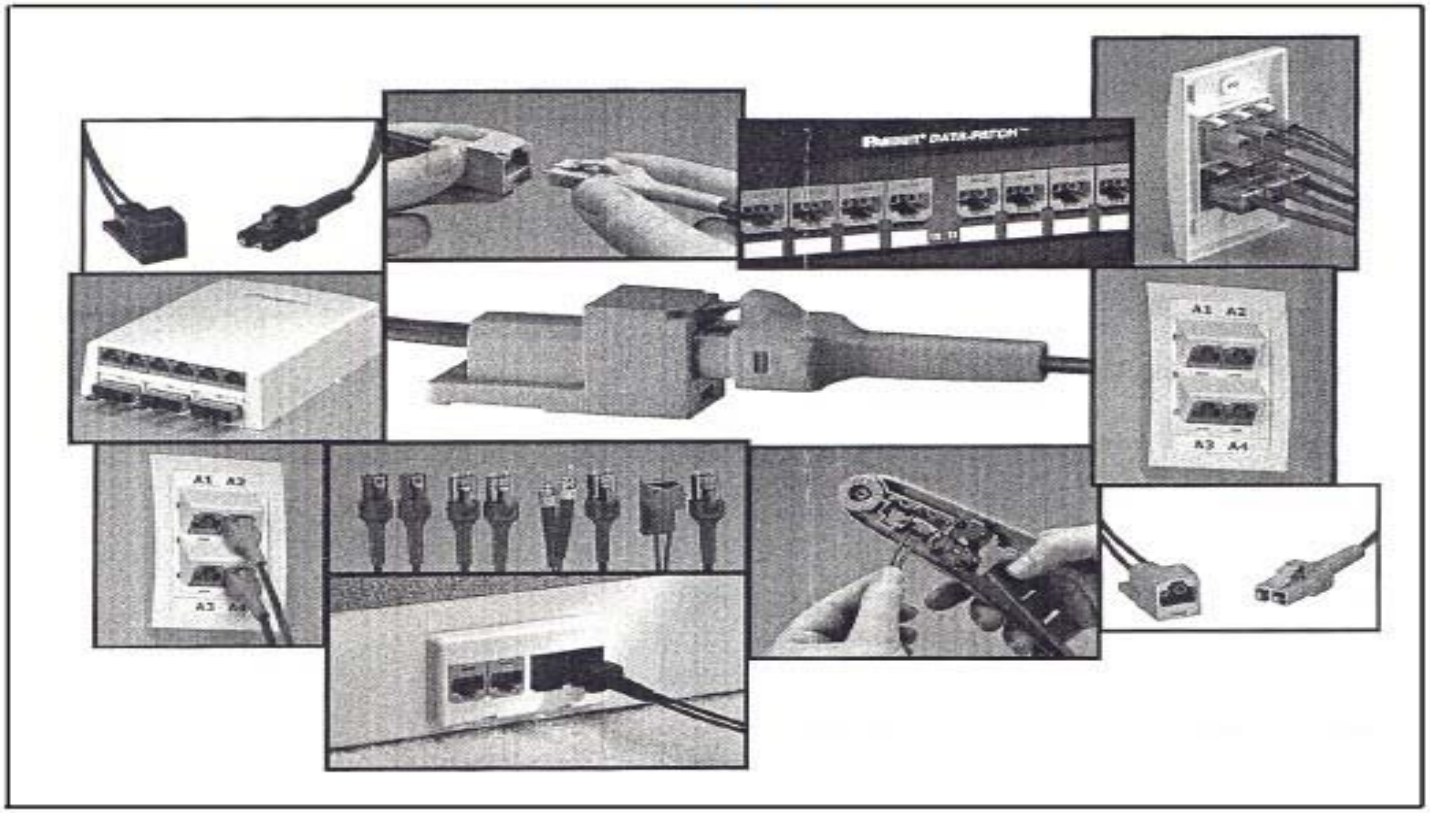
POF Connect types

- PN Connector
- Small multimedia Interface(SMI)
- IDB-1394 POF interface and Latch Connector
- Packard Hughes Interconnect
- Optical Mimi Jack
- Panduit Poly-Jack

OptoLock

Uses for Poly-Jack

Exhibit 7.8
Uses for Poly-Jack



The POLY-JACK Plastic Optical Fiber Connector from Panduit can be used anywhere an "RJ45" style connector can be used.

OptoLock Termination Steps

Exhibit 7.10
OptoLock Termination Steps

Slice the POF cable.

Split the POF strands.

Insert POF into OptoLock.

Press OptoLock to hold POF into place.

Other POF Technical Components

Switches

Integrated Optics

- Planar Waveguides and Other Passive Devices

Lenses

- Polymeric Lenses
- High-efficiency Optical Concentrators for POF

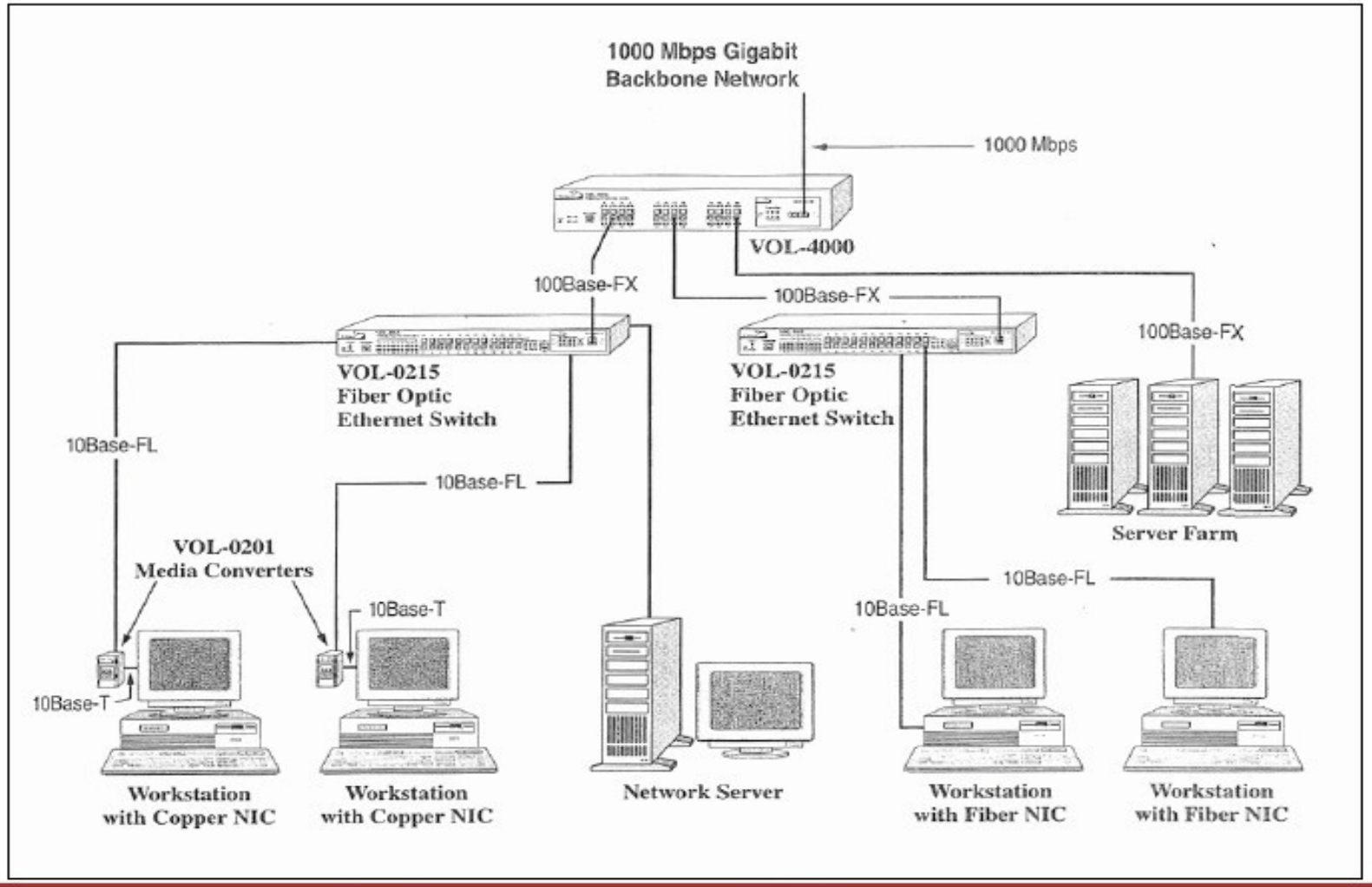
Fiber Bragg Gratings

Optical Amplifiers

Test Equipments

- OTDRs (Optical time domain reflectometers)

POF Systems-- Ethernet Example



POF Hardware

- POF 2005 in Hong Kong, Varing, demonstrated a Fast Ethernet systems using GI-POF and a media converter that converted single-mode fiber signals to POF
- Some companies have developed hardware product for POF: Leviton, NEC, and Panduit, but not active in the market.

Part4 : POF Data Communications Applications



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POF Data Communications Applications

Exhibit 17.1
POF Applications by Distance

Very short distance (0.01 to 1 meter)	PCB (printed circuit board) interconnects Extended optocoupler Digital audio interface Optical interconnects Optical switches Interboard and intraboard Fibers imbedded in PCBs
Short distance (1 to 10 meters)	Digital consumer electronics CRT connection to CD-ROM PC-peripherals DBS terminals VCR for connection to TV Equipment interconnects CRT to video link Automobiles Parallel optical interconnects Backbones of switches
Medium distance (10 to 200 meters)	RS 232, RS 432 Point-of-sale (POS) links NCM machine links Electronic tollbooths Wiring closet to desktop Surveillance Work areas Femtocells

POF Data Communications Applications

Long distance (200 to 500 meters)	PCS antenna to switch Industrial controls Building controls Low-data-rate interconnects
Local area networks (approx. 100 meters)	Apartment buildings Small to midsized businesses Office LANs Industrial LANs Avionic LANs CAN Automobile LANs Home automation networks SANs
Premises wiring (approx. 100 meters)	Wiring closets to wall plates Wall plates to terminals

POF Data Communications Applications

Exhibit 17.2
Actual and Potential Applications of POF

Automotive	NTSC Interfaces
AOC (Active Optical Cables)	Office Automation
ATM Machines	Office Equipment
Avionic Data Links	Optical Backplanes
CAN (Controller Area Networks) Links	Optical Circuitboards
CAT Scanners	Optical Computers
Cellular Networks	Optical Interconnects
CENTRONICS Links	Optical Switches
Consumer Data Links	PCB Data Links
Copier machines	PCIe Networks
CRT-CD/ROM	Point of Sale Terminals to CPE
CRT-Video Link	Power Switches
Digital Audio Interfaces (DAI)	Robotics
Digital Video Interface (DVI)	Routers
DVD Players	RS-232 Links - DTE-DTE - DCTE-DTE - DTE-DCE - DTE-Plotter
EMC Reflected Systems	
Factory Automation	
Gaming Machines	
High-Definition Multimedia Interface (HDMI)	Satellite Wiring - Satellite Launch Facilities - Space Station - Satellites
High Voltage Accelerators	
High Voltage Isolation	
Home Automation (Home wiring)	

POF Data Communications Applications

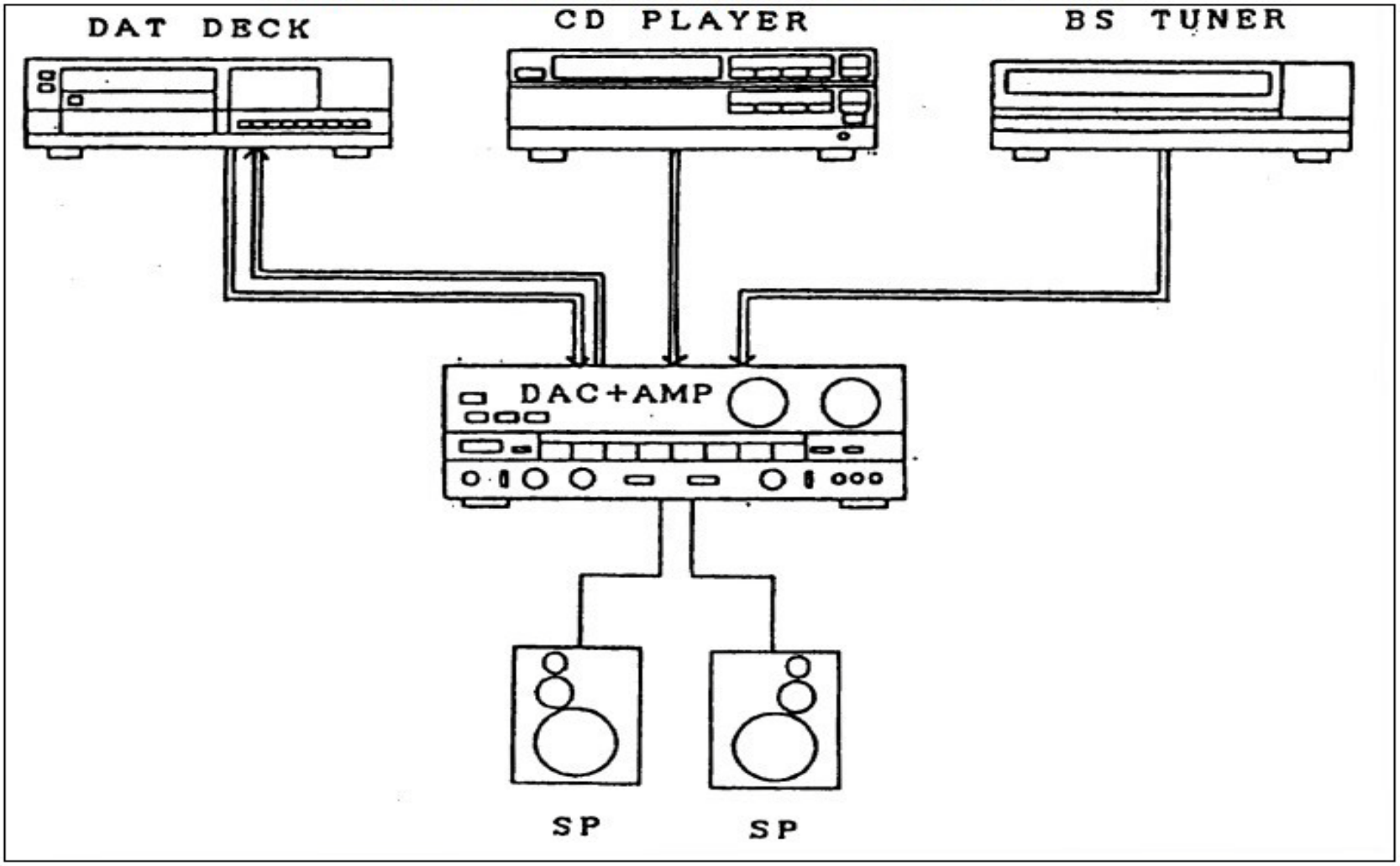
Hot Tubs	Security - Industrial - Home
Hydraulic Lifts	
Industrial Control Equipment	
Instrumentation (RS-488)	Static Protection
ION Implementation Devices	Sensors
Light Switches	Switches
Local Area Networks - Optical Ethernet - SANs - ATM	Tempest - Secure Data Communications
	Thermostats
	Toll Booths
Machine Tool Controls (SERCOS)	Trains
Medical Instrumentation	Trucks
Meter Reading	USB 3.0
MRI Machines	VCR-CRT
NMR Machines	Wireless LANs RF Links

Example of POF Data Communications Applications

- Optocoupler Applications
- Printed Circuit Board Interconnects
- Digital Audio Interface
- Avionic Data Link
- Automotive Applications
- Tollbooth Application
- Factory Automation
- Medical Applicaiton
- High Voltage Isolation
- Home Networks
- Secuirity

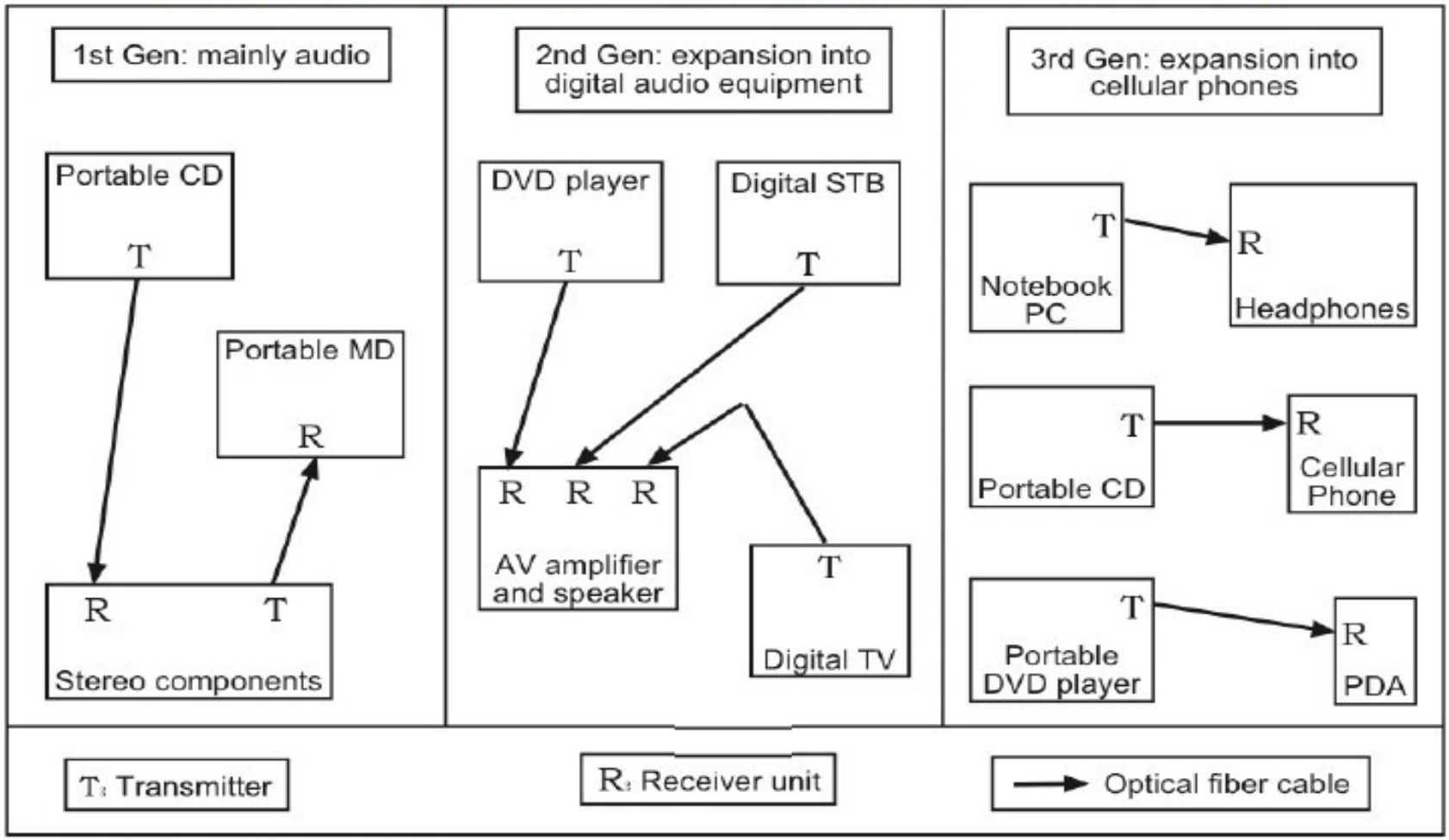
Digital Audio Interface

Exhibit 17.5
DAI (Digital Audio Interface) Optical Fiber Datalinks



Digital Audio Interface

Exhibit 17.6
Expansion of Optical Fiber Links for Digital Audio Applications



Source: Sharp Electronics

Avionic Data Link

Aircraft applications include a number of bus systems:

1) Flight-critical systems (currently hard-wired systems) guaranteeing that the aircraft can fly;

2) Flight management (e.g, engine fuel control etc.);

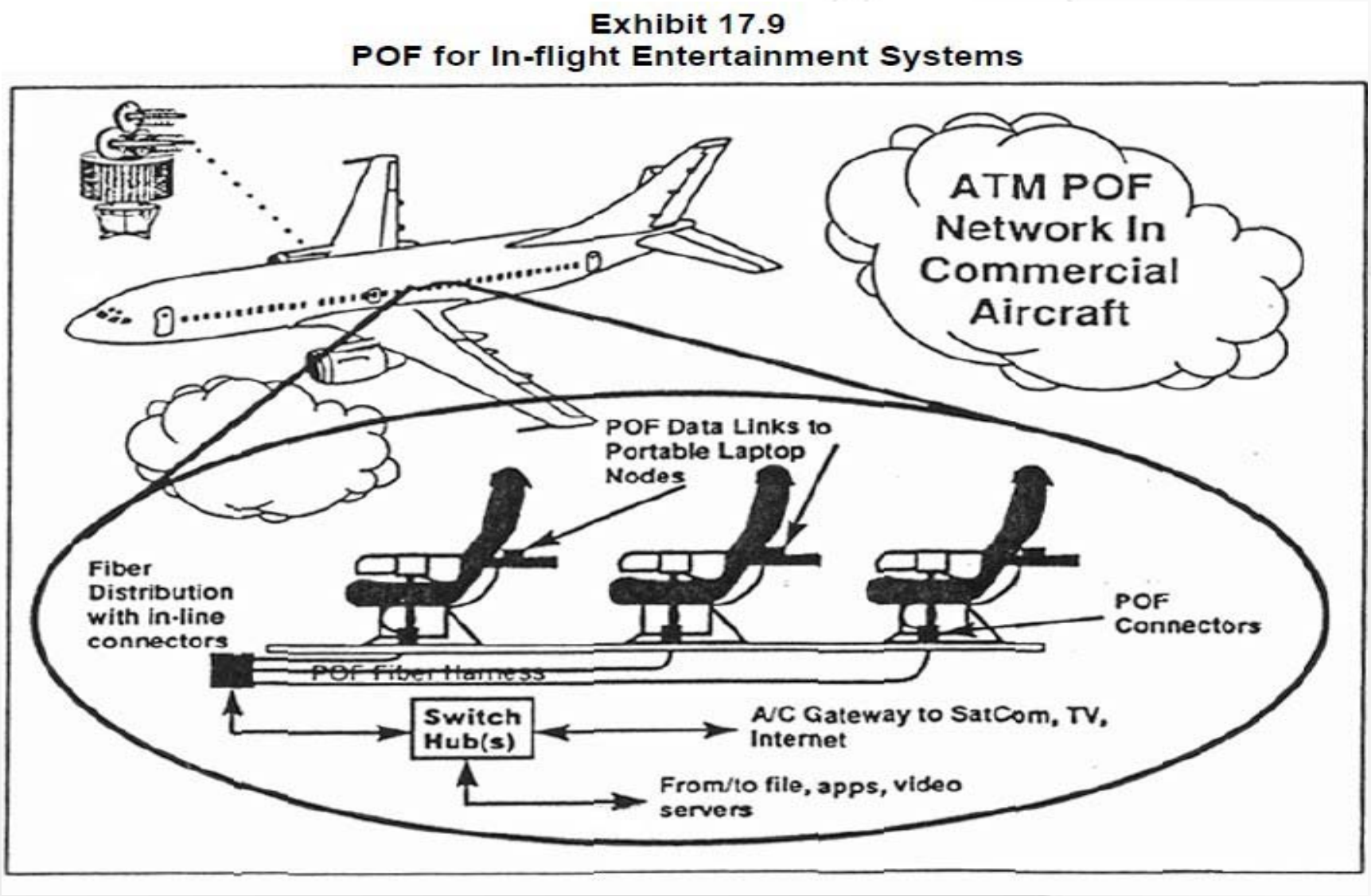
3) Non-critical flight systems;

4) Navigation;

5) Entertainment systems;

6) Armaments.

Avionic Data Link



Automotive Applications of POF

Automobile Standards:

- MOST: (Media Oriented Systems Transport) is the name of a joint venture between auto OEMs, systems suppliers, software developers, and equipment manufacturers in their quest for a common goal: develop a standard for an onboard multimedia network protocol and network model.

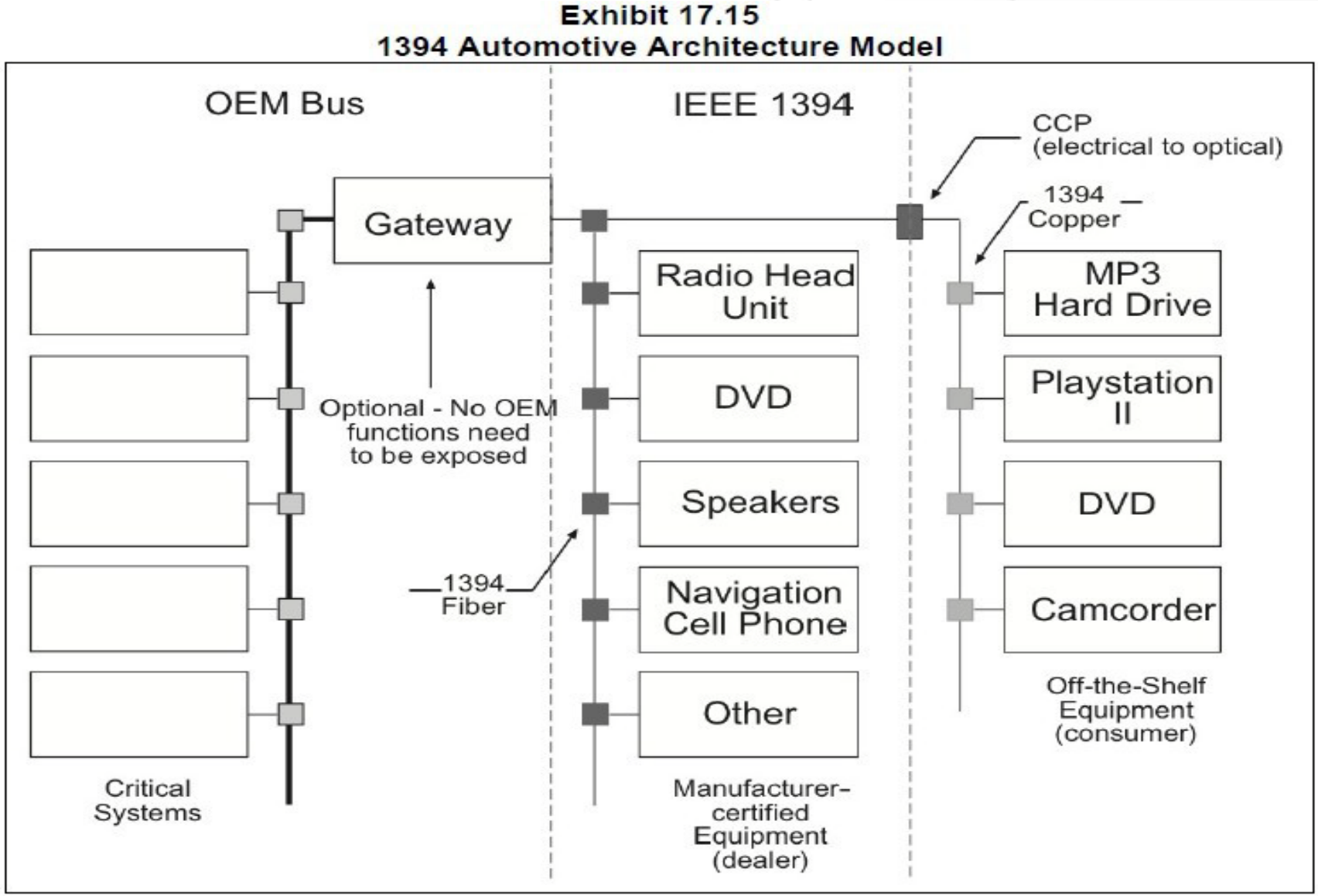
MOST


Exhibit 17.13
MOST Partners and Associate Partners
Alpine, ALPS Electric,
Analog Devices, ASK Industries,
Avago Technologies, AWTCE, Bang & Olufsen, Bosch, Bose, Clarion,
Continental Automotive Systems,
D&M PSS,
Delphi,
Dension Audio,
DENSO,
Elektrobit Automotive,
FiberDyne Systems,
Firecomms,
Fujitsu TEN,
Furukawa,
GADV,
GÖPEL electronic,
Hamamatsu,
Hirschmann,
Hosiden,
HYUNDAI MOBIS,
ICT Software
Engineering,
Intrepid Control Systems,
Iriso, Johnson Controls,
K2L, KETI, Lear, LeCroy, LG Electronics, Magneti Marelli,
Melexis, Mitsubishi Electric, Mitsubishi Rayon,
Molex, Movimento,
Visteon, X2E, Xilinx, Yazaki.
Ubiquitous, Vector,
TYCO Electronics,
TTTech Automotive,
TOYODA GOSEI,
Telemotive,
Tata Consultancy
Services,
STMicroelectronics,
Softing,
RUETZ SYSTEM
SOLUTIONS,
Renesas Electronics,
RELNETyX,
paragon, Pioneer,
Panasonic Automotive
Systems,
Ontorix,
Nippon Seiki,
NAV-TV,
Ford
ASTON MARTIN
VOLVO
GM
Audi
BMW Group
DAIMLER
HARMAN
smsc
HONDA
HYUNDAI
JAGUAR
KIA
KIA MOTORS
LAND ROVER
NISSAN
TOYOTA
PSA PEUGEOT CITROEN
Partners
Associated Partners: Carmakers
Associated Partners: Suppliers

The Essential Features of MOST Technology

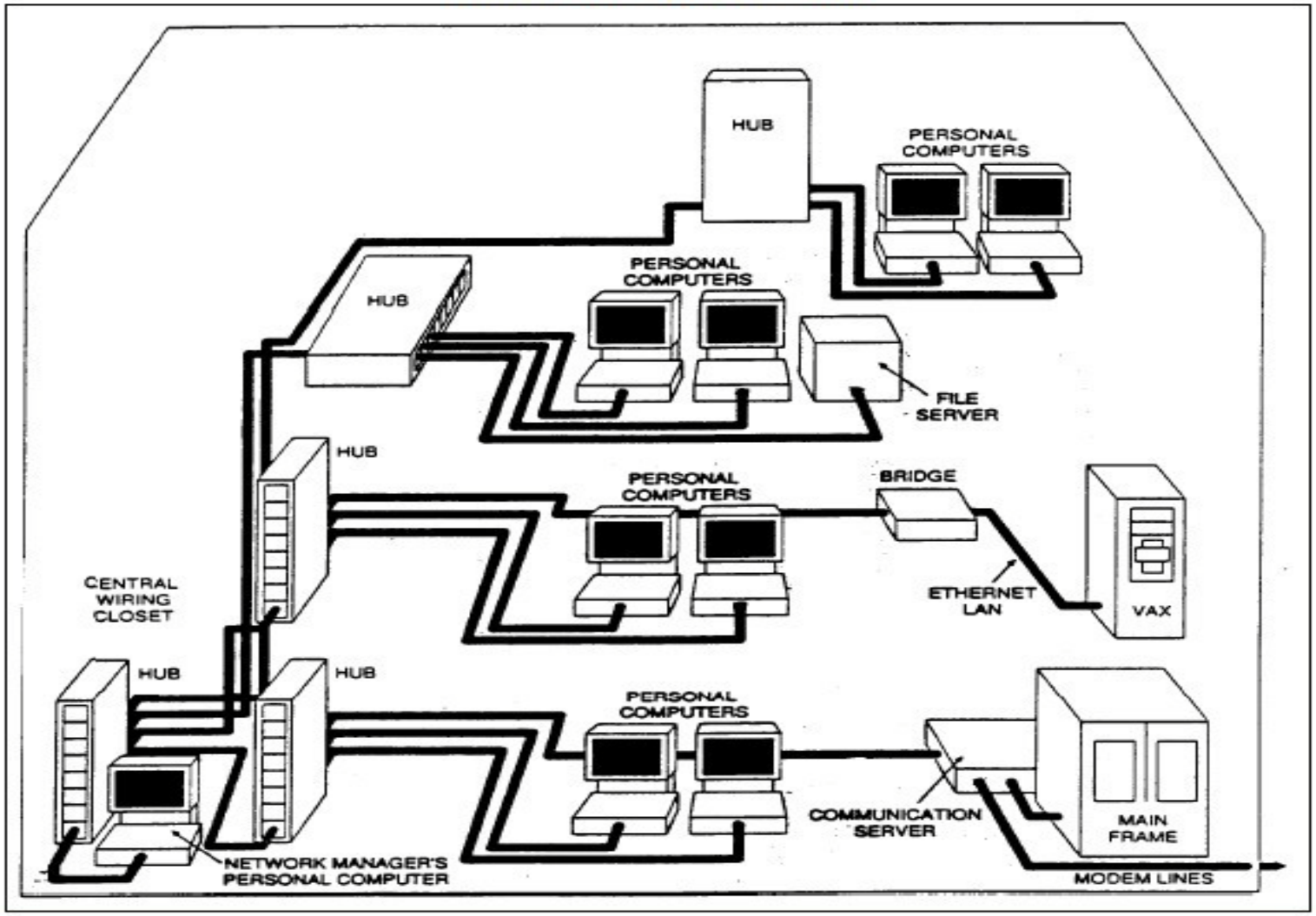
- Simple to use
- Broad-based application spectrum
- Flexibility
- Low installation costs

1394 Automotive Working Group and IDB

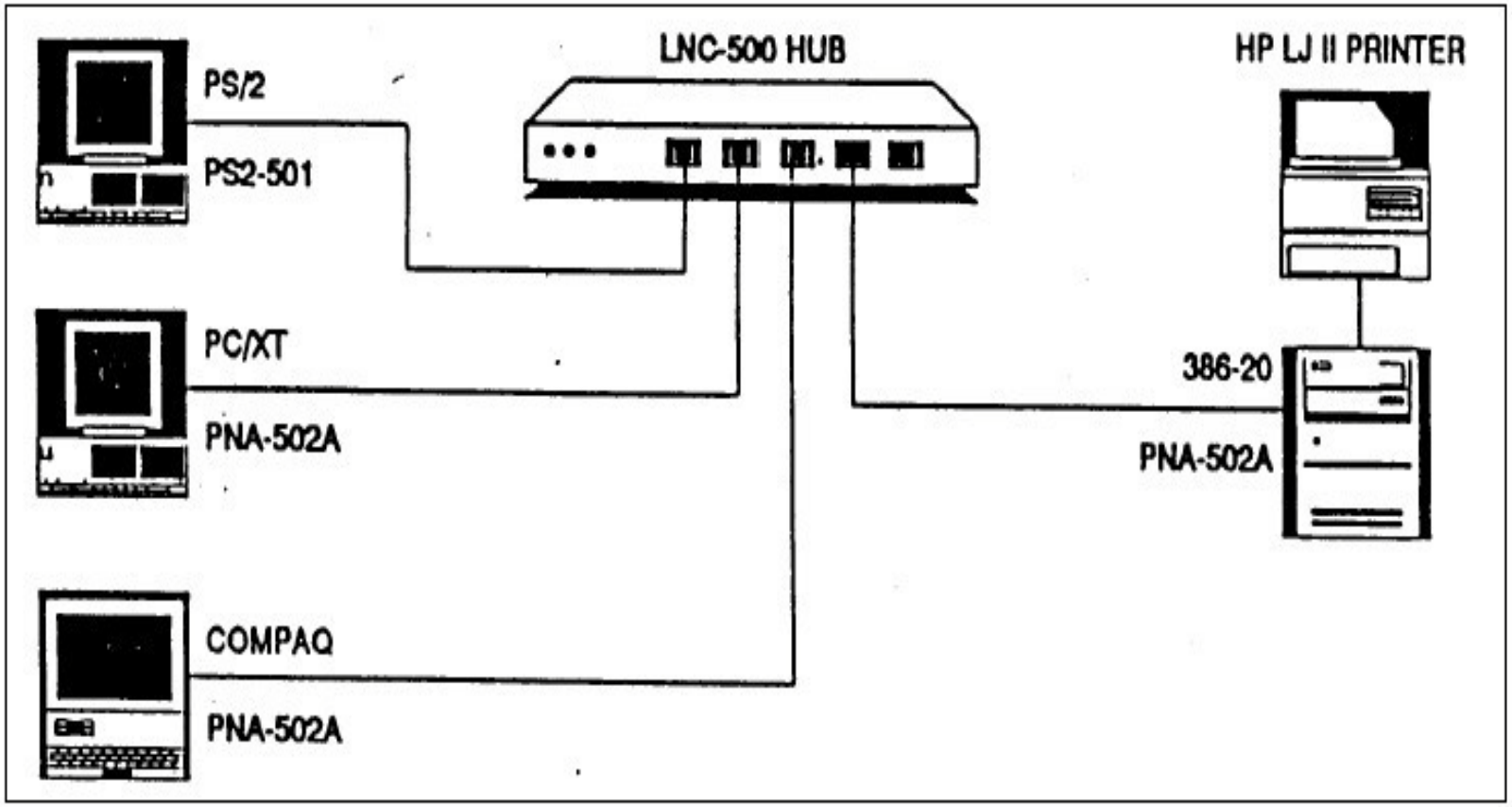


Local Area Networks

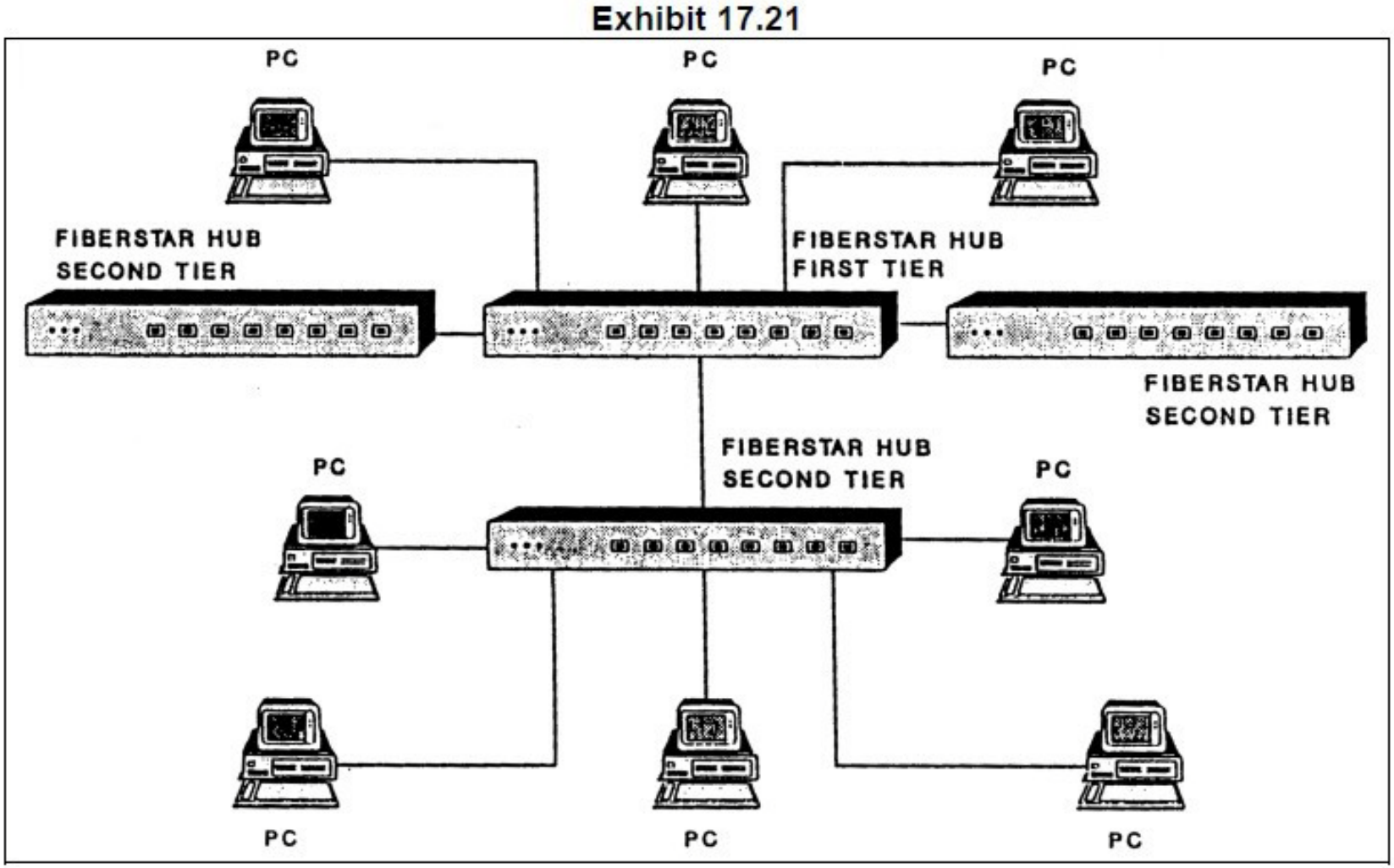
Exhibit 17.19
FIBERSTAR Network



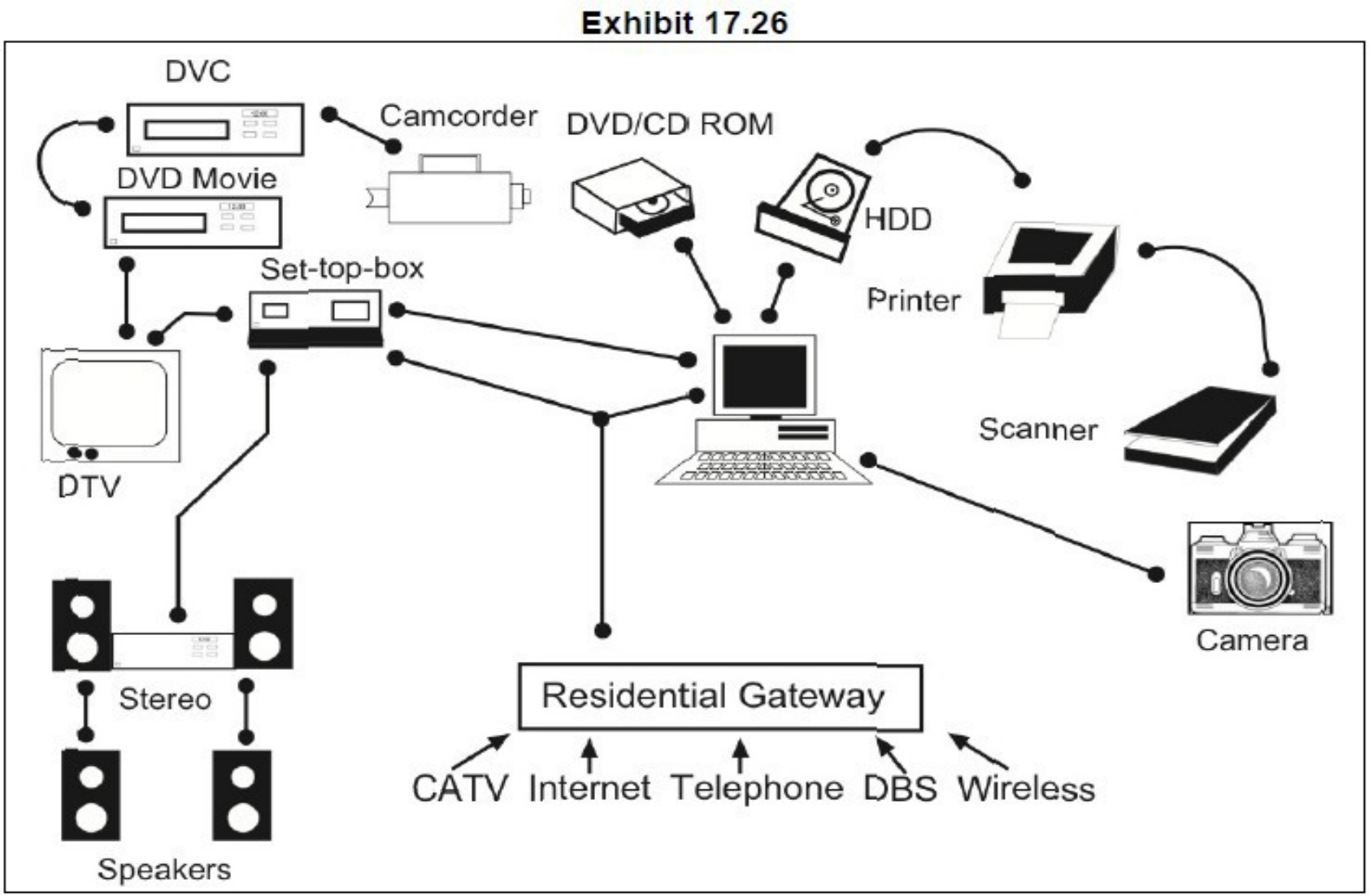
Local Area Networks



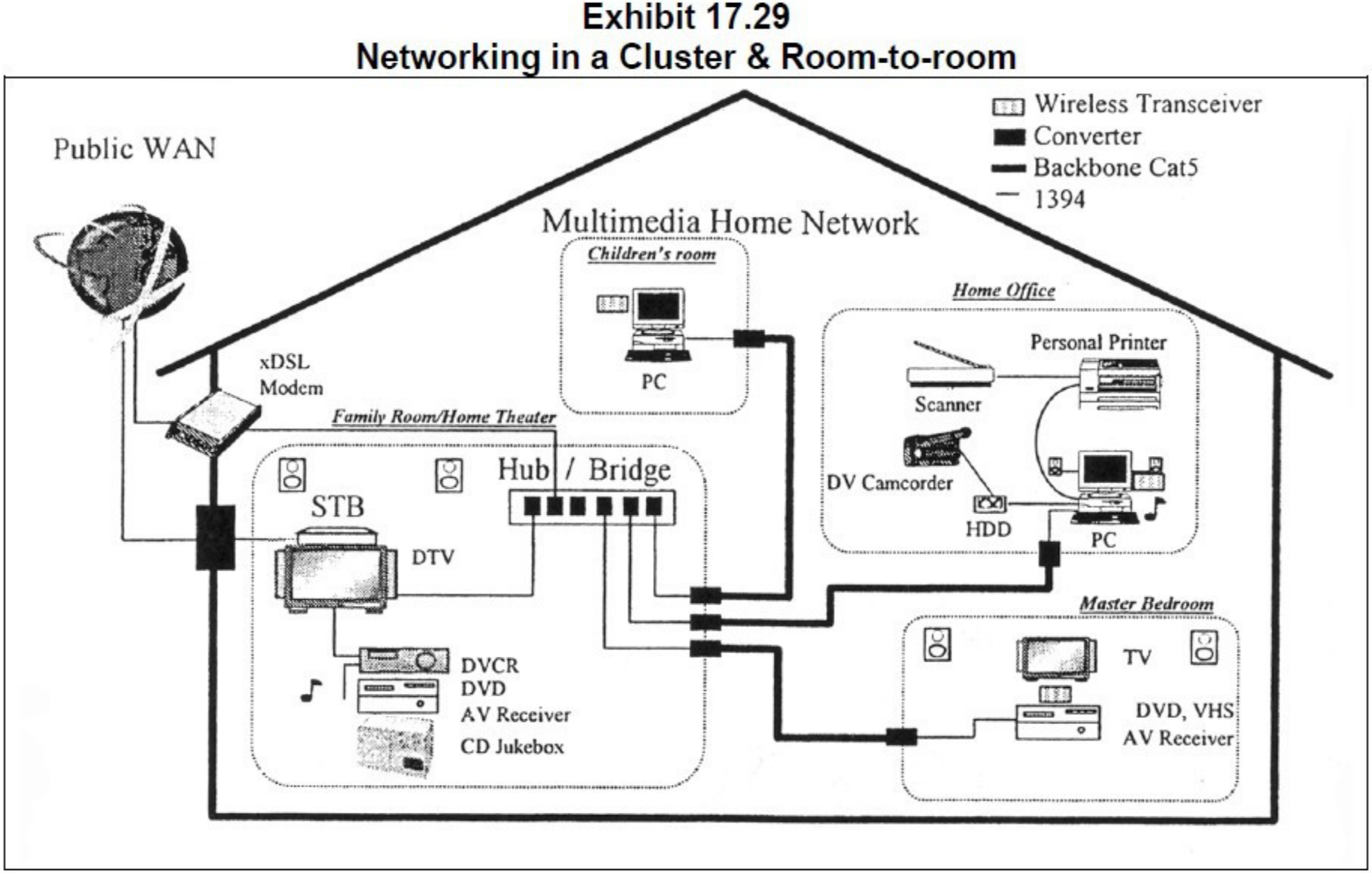
Local Area Networks



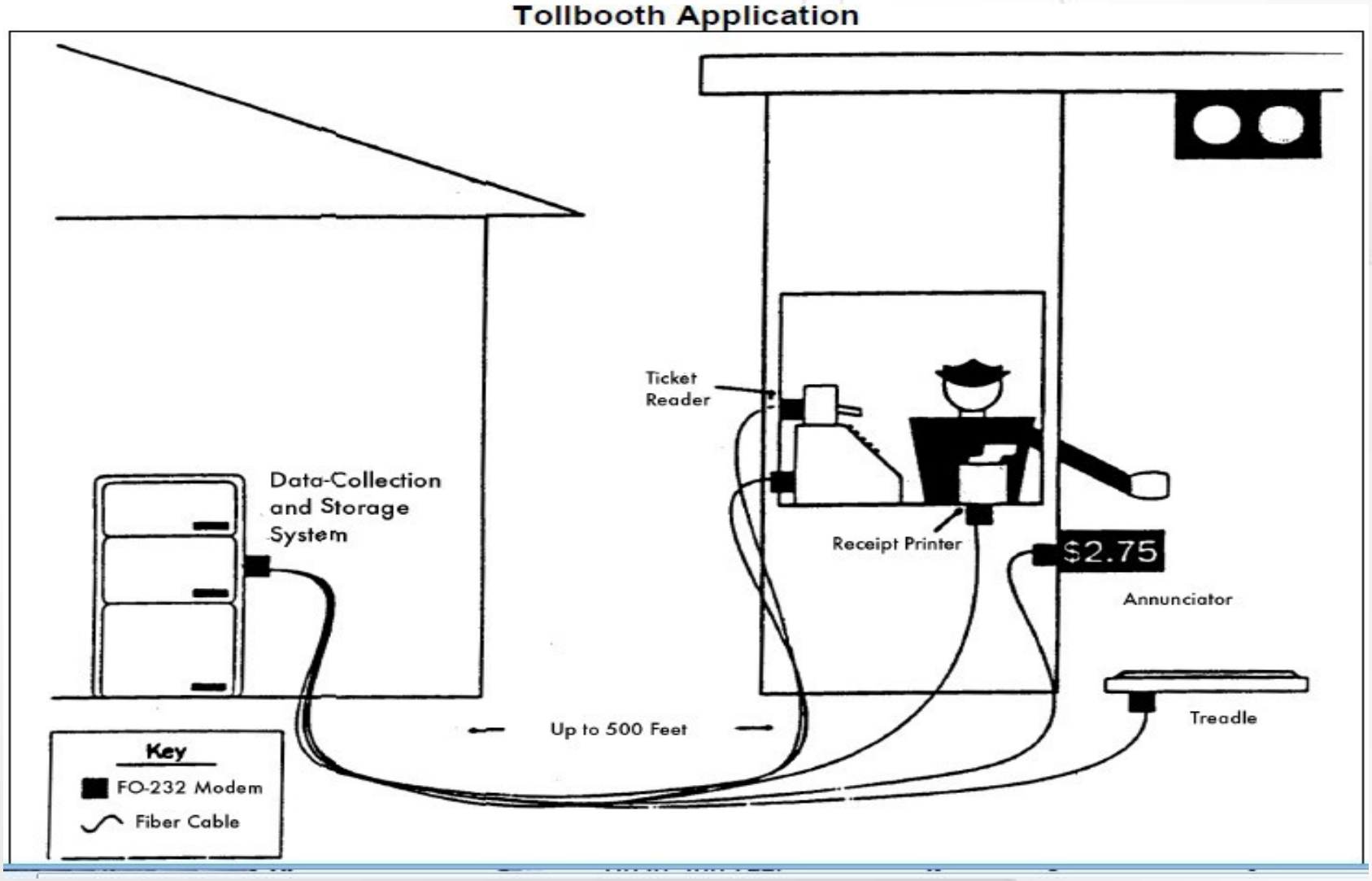
IEEE 1394 FireWire



IEEE 1394 FireWire



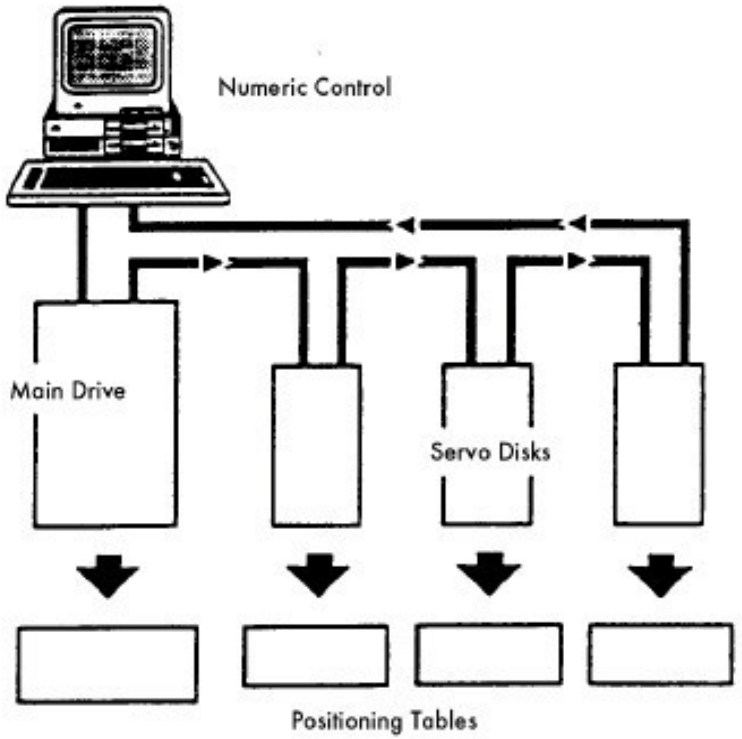
Tollbooth Applications



Factory Automation

Exhibit 17.35
Factory Automation

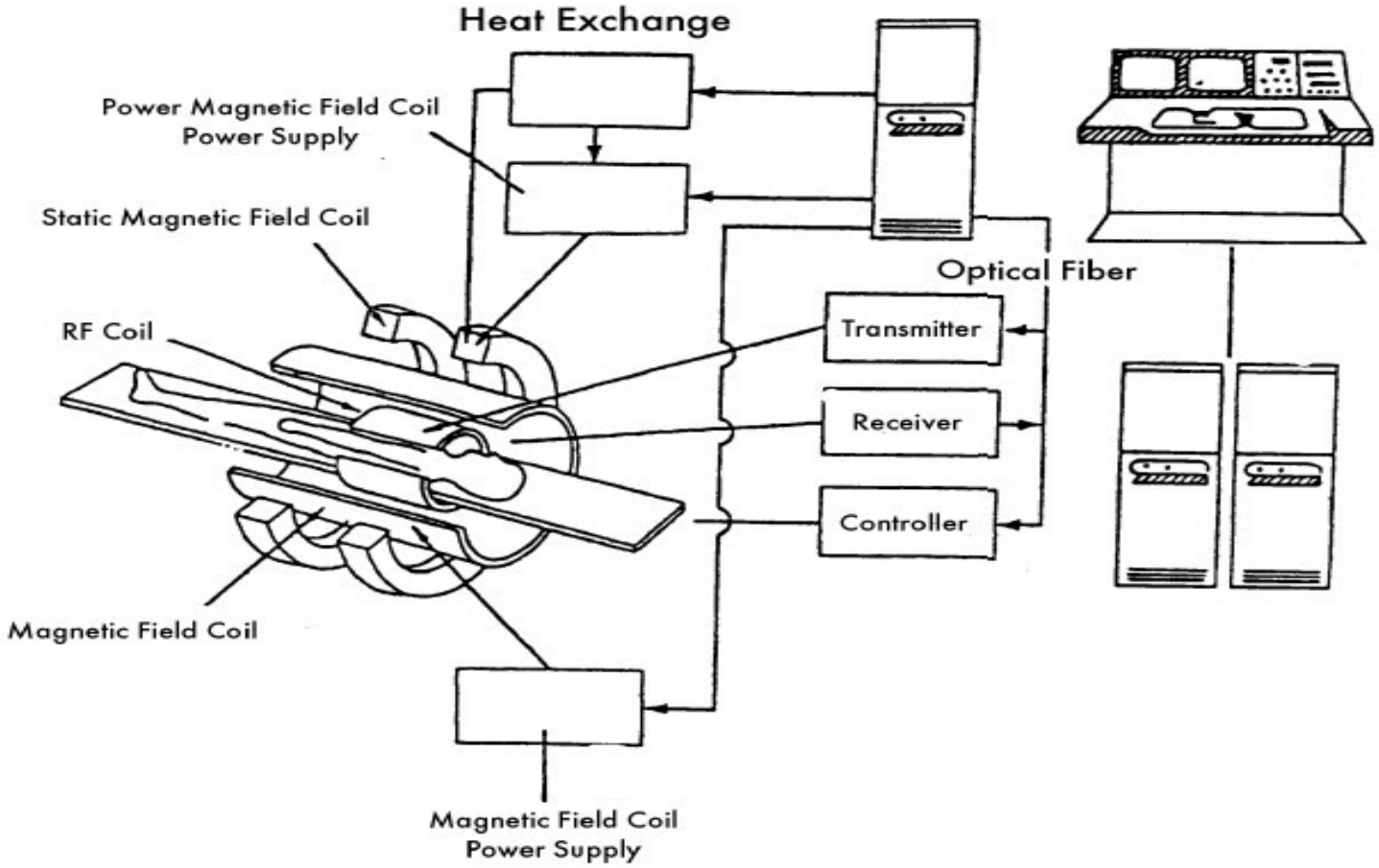
ZVEI SERCOS SPECIFICATION - SUBMITTED TO IEC



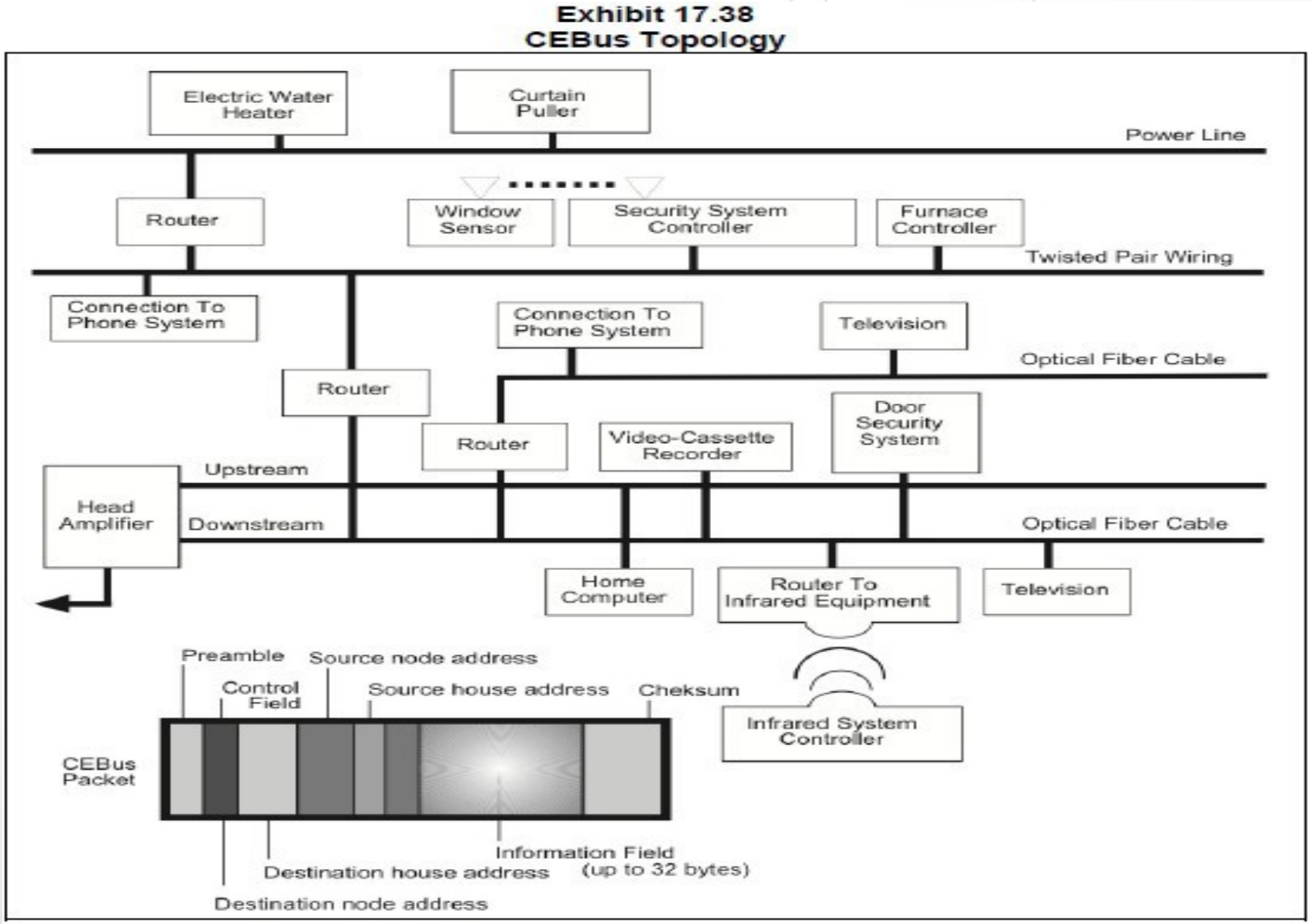
Transmission System:
- 980 Micron POF
- SMA Connectors
- 40 Meter Segment Length
- 2 Mbps data rate

Medical Applications

Exhibit 17.36
NMR Diagnostic Devices

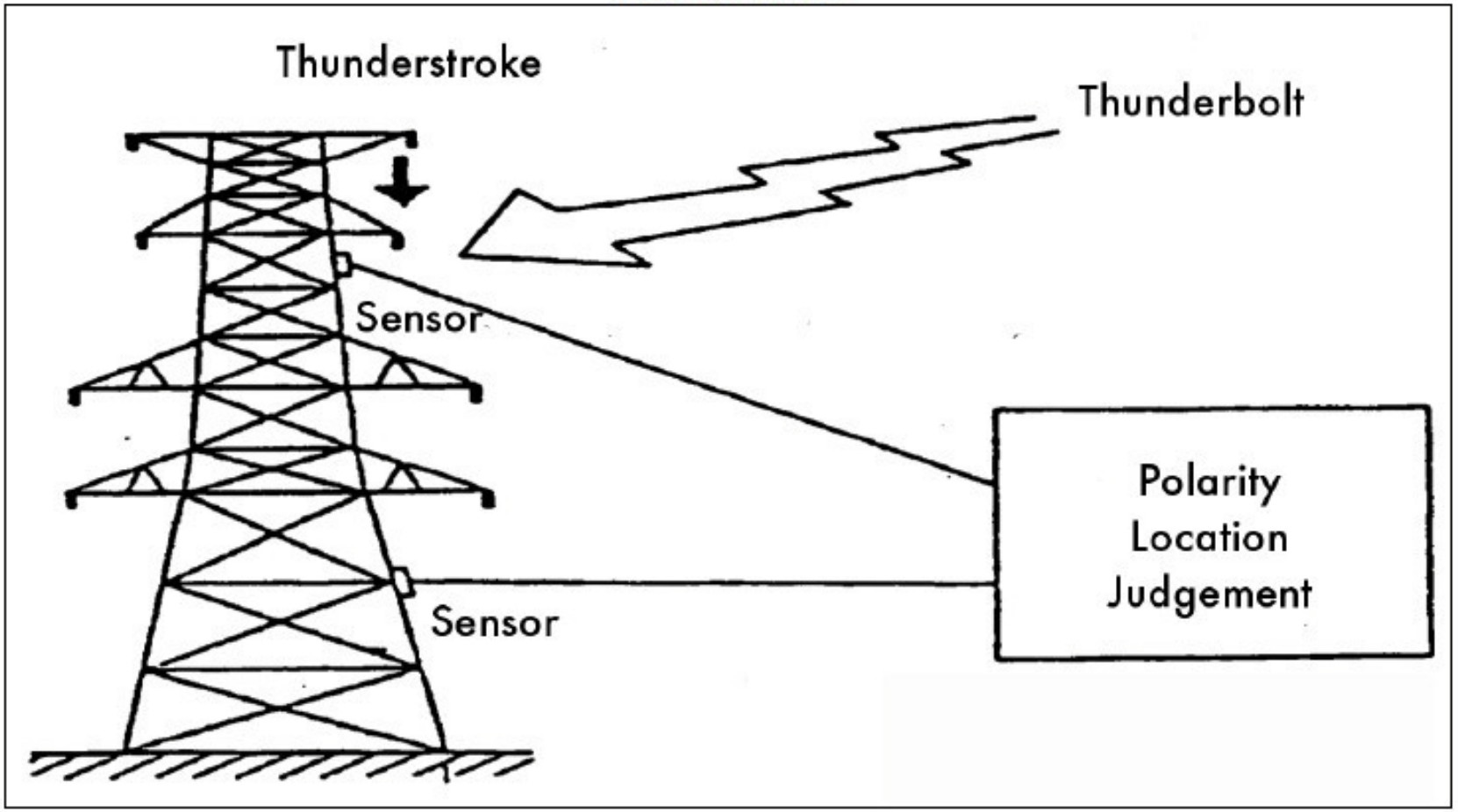


Home Networks--CEBus Home automation topology system



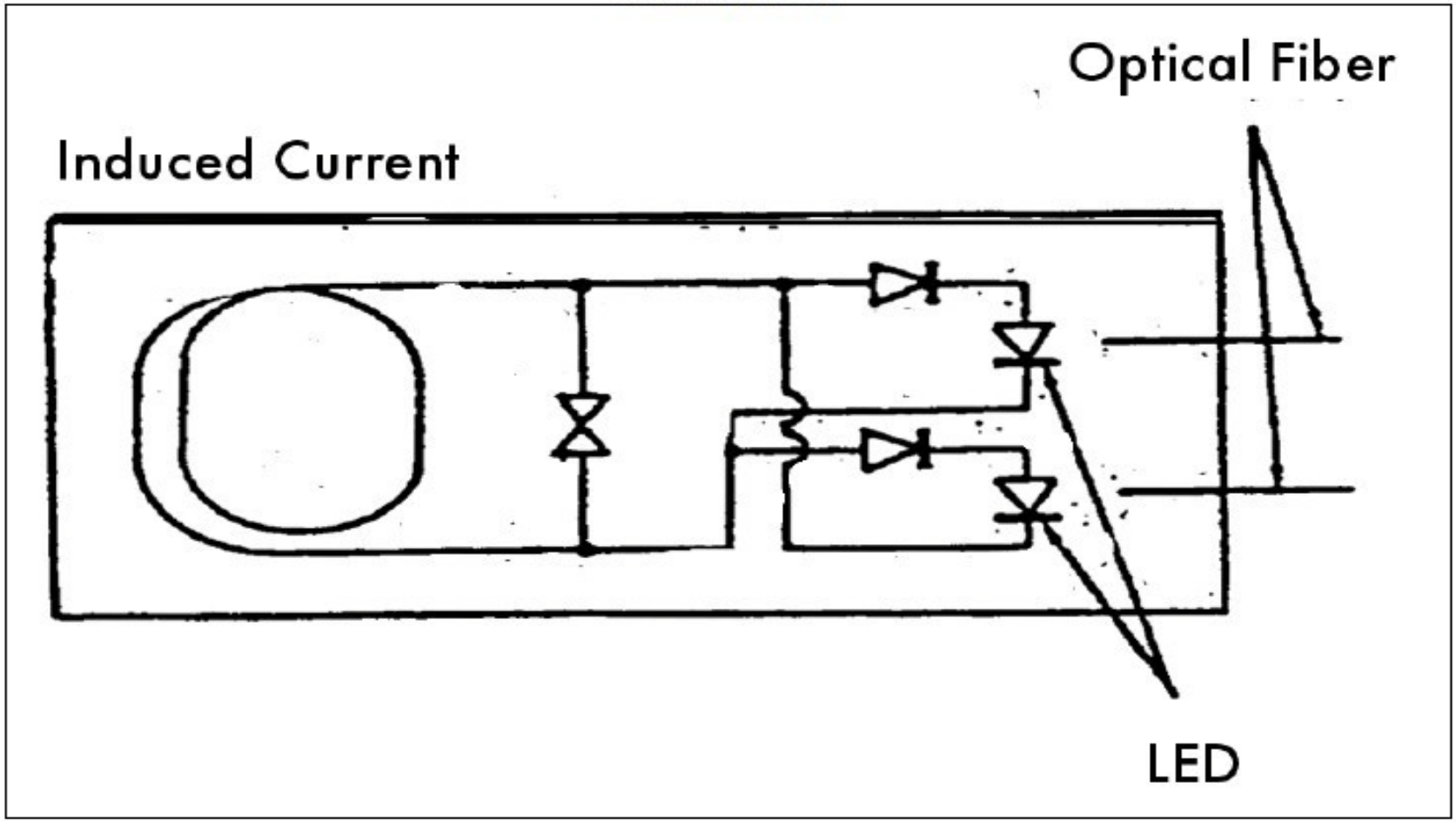
POF Sensors

Exhibit 17.40

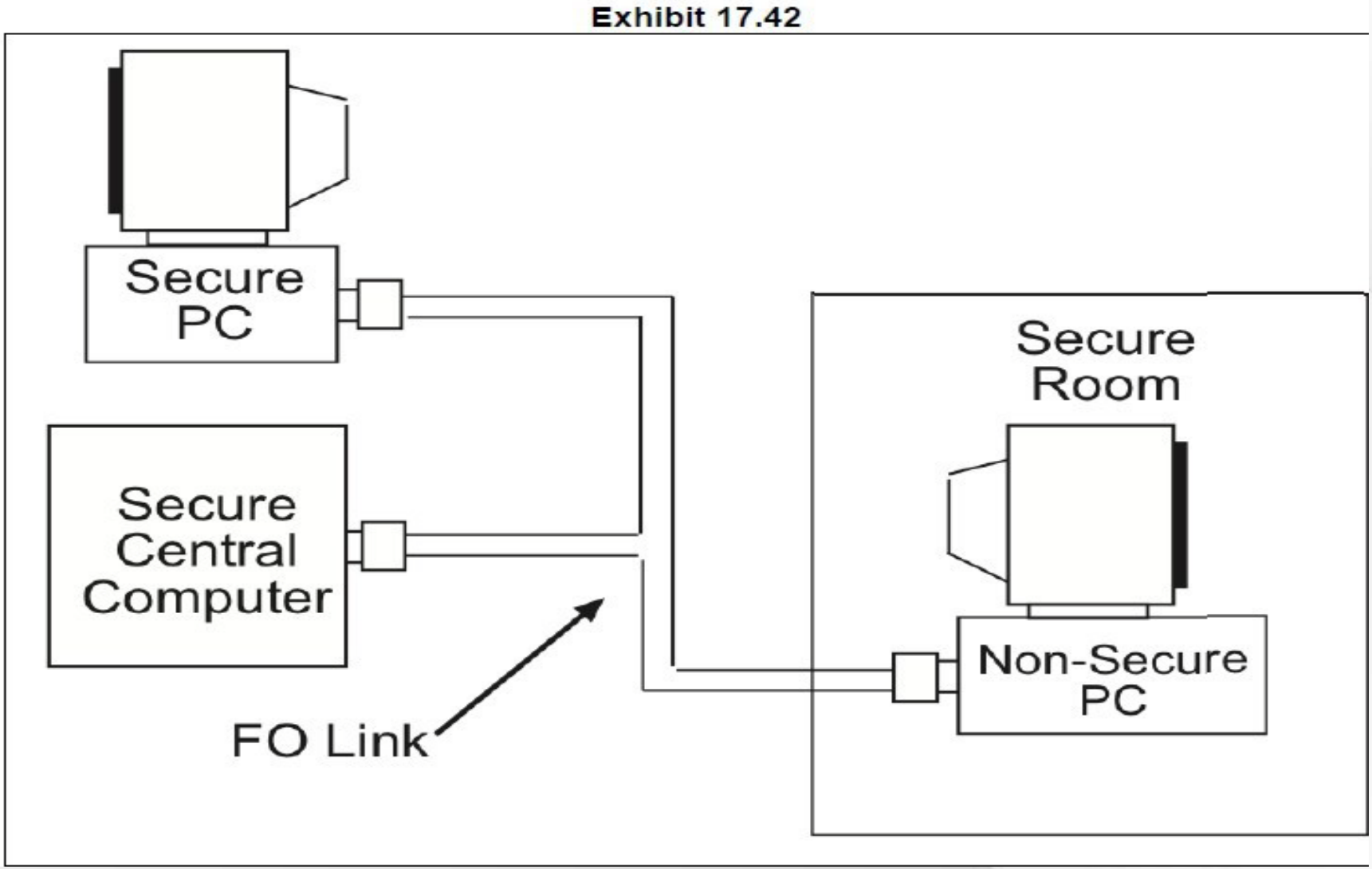


POF Sensors

Exhibit 17.41

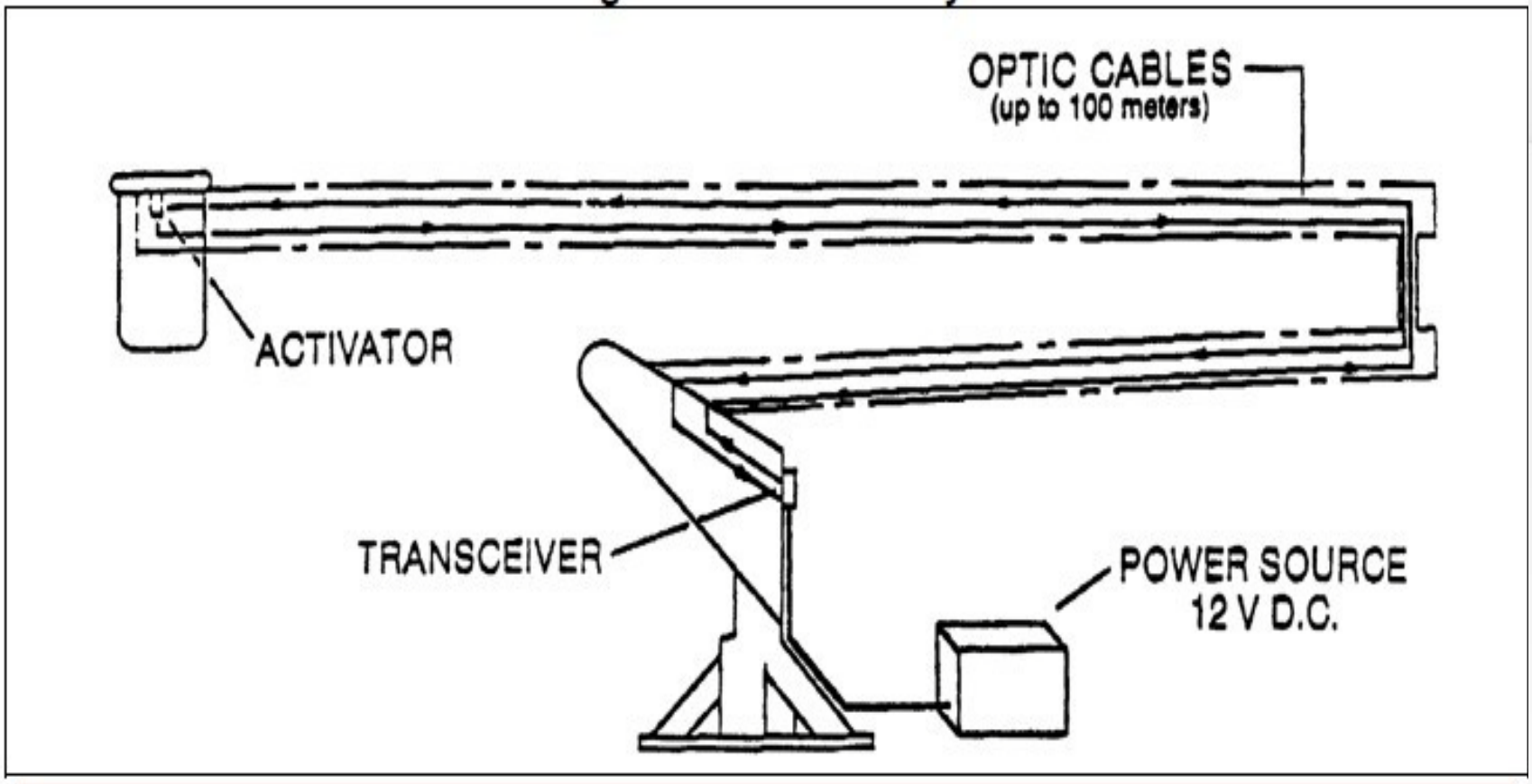


Security (Tempest)



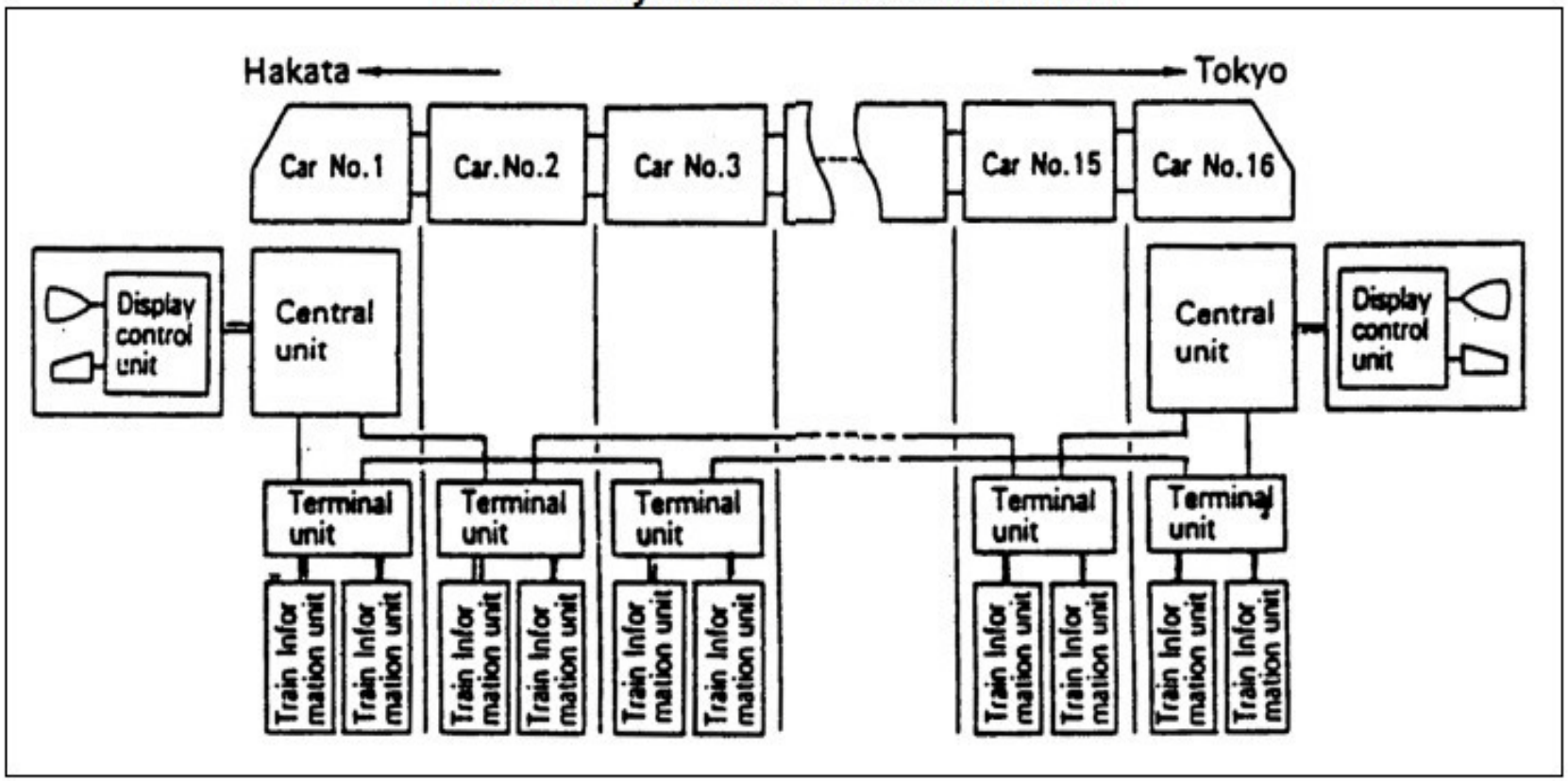
Hydraulic Lifts

Exhibit 17.43
Bohlinger Inc. Fibri-Lite System

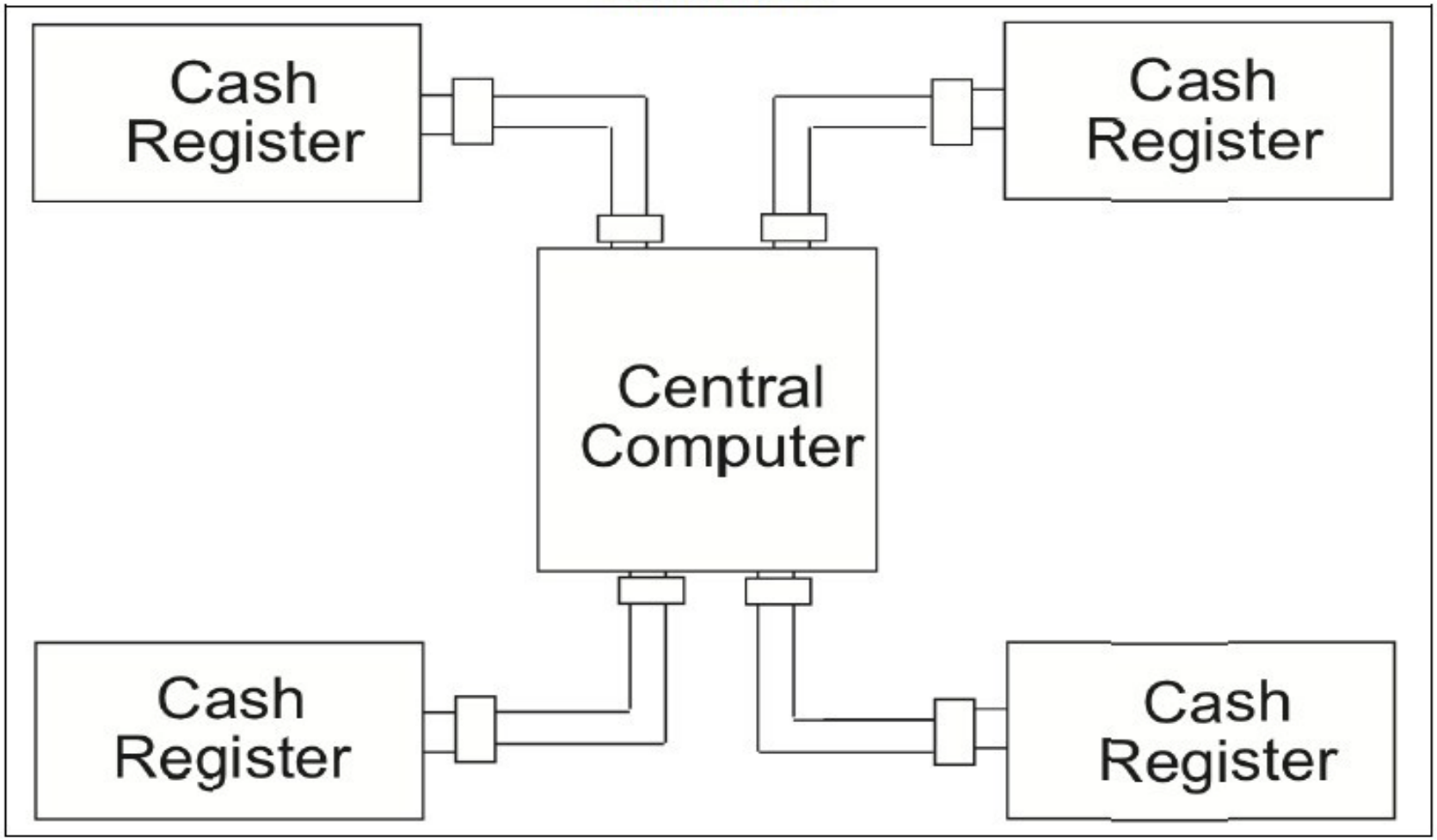


Trains

Exhibit 17.44
Monitor System for 100 Series Train



Point-of-sale Terminals



Robotics

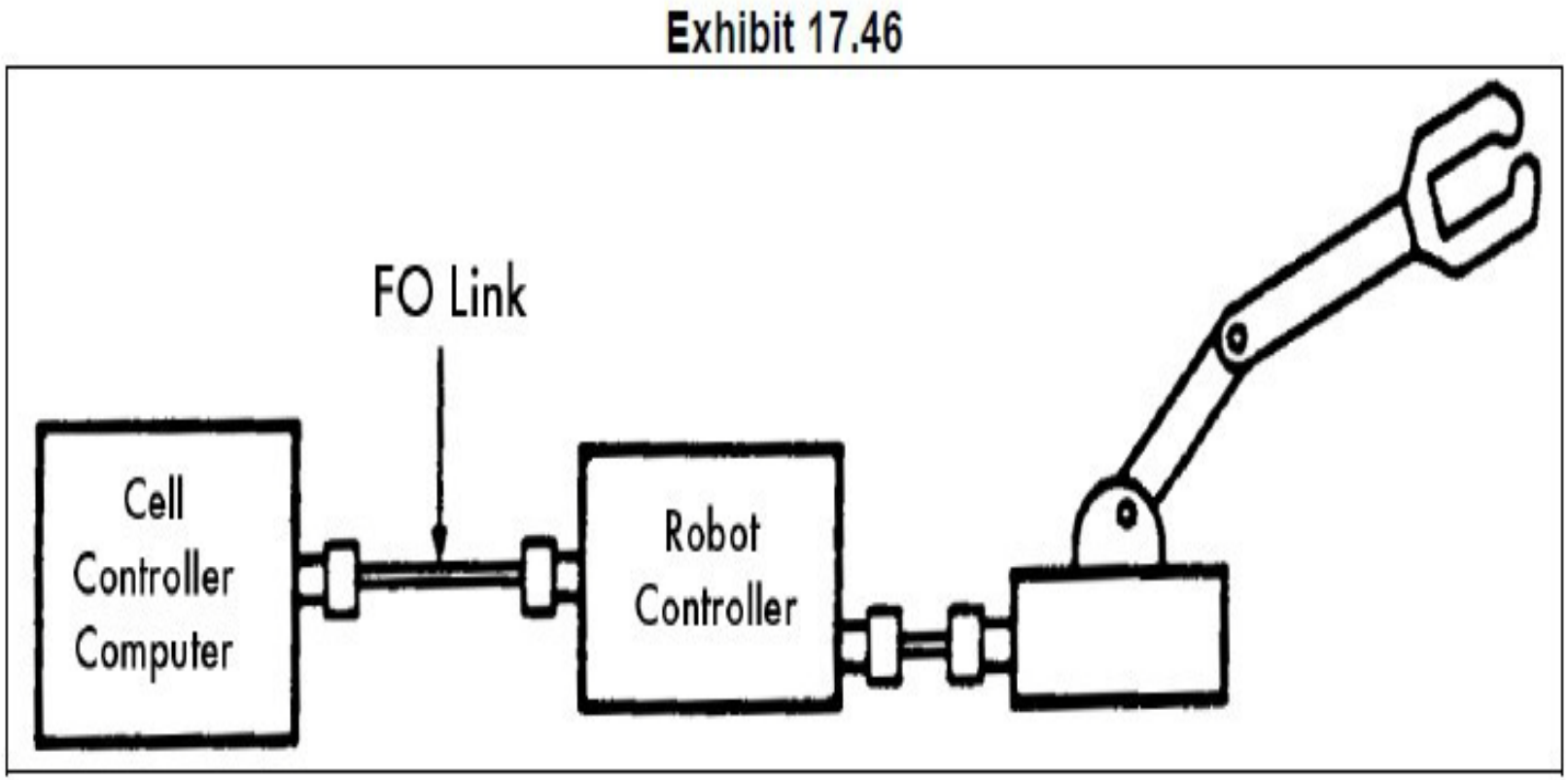
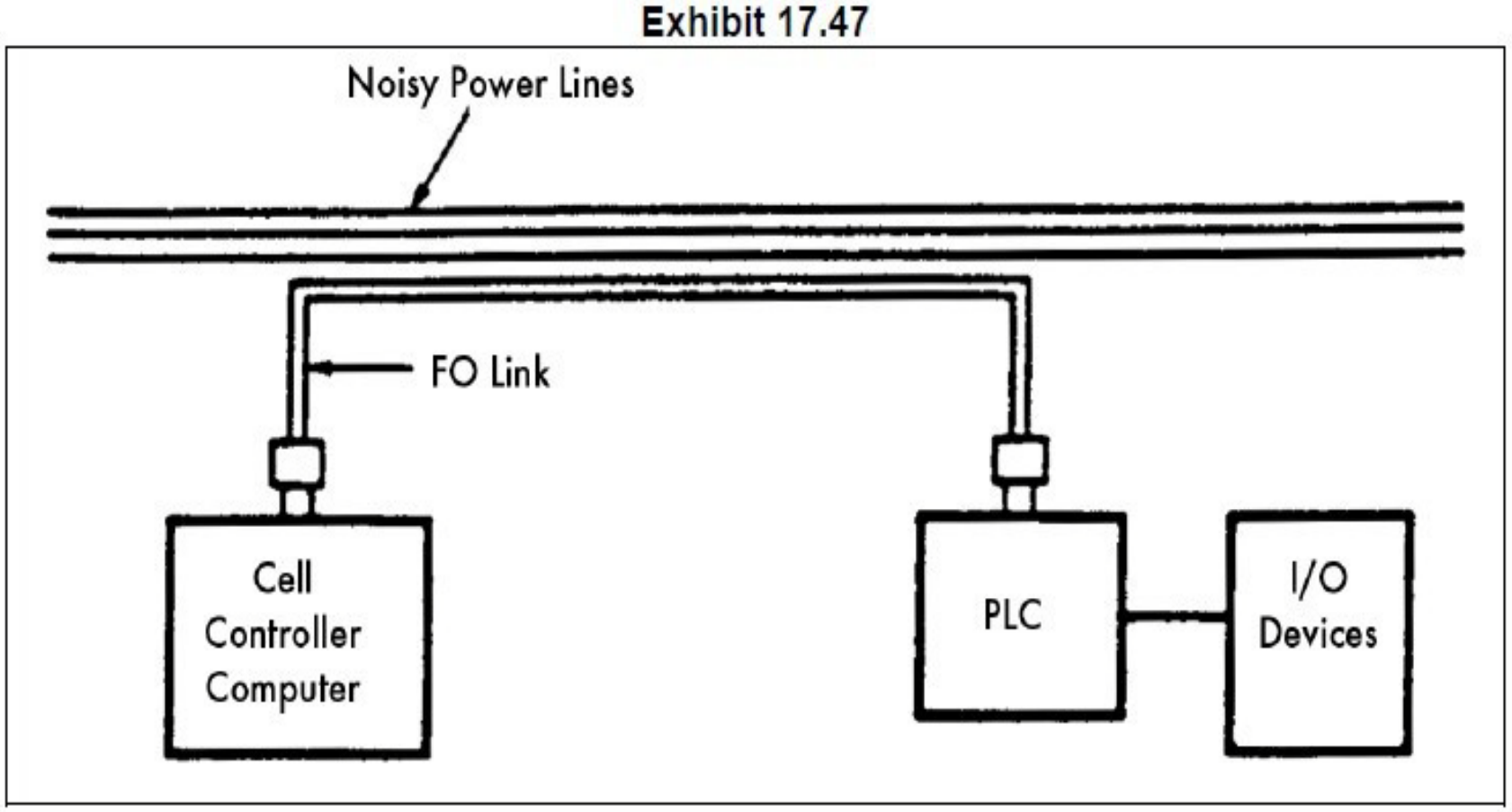


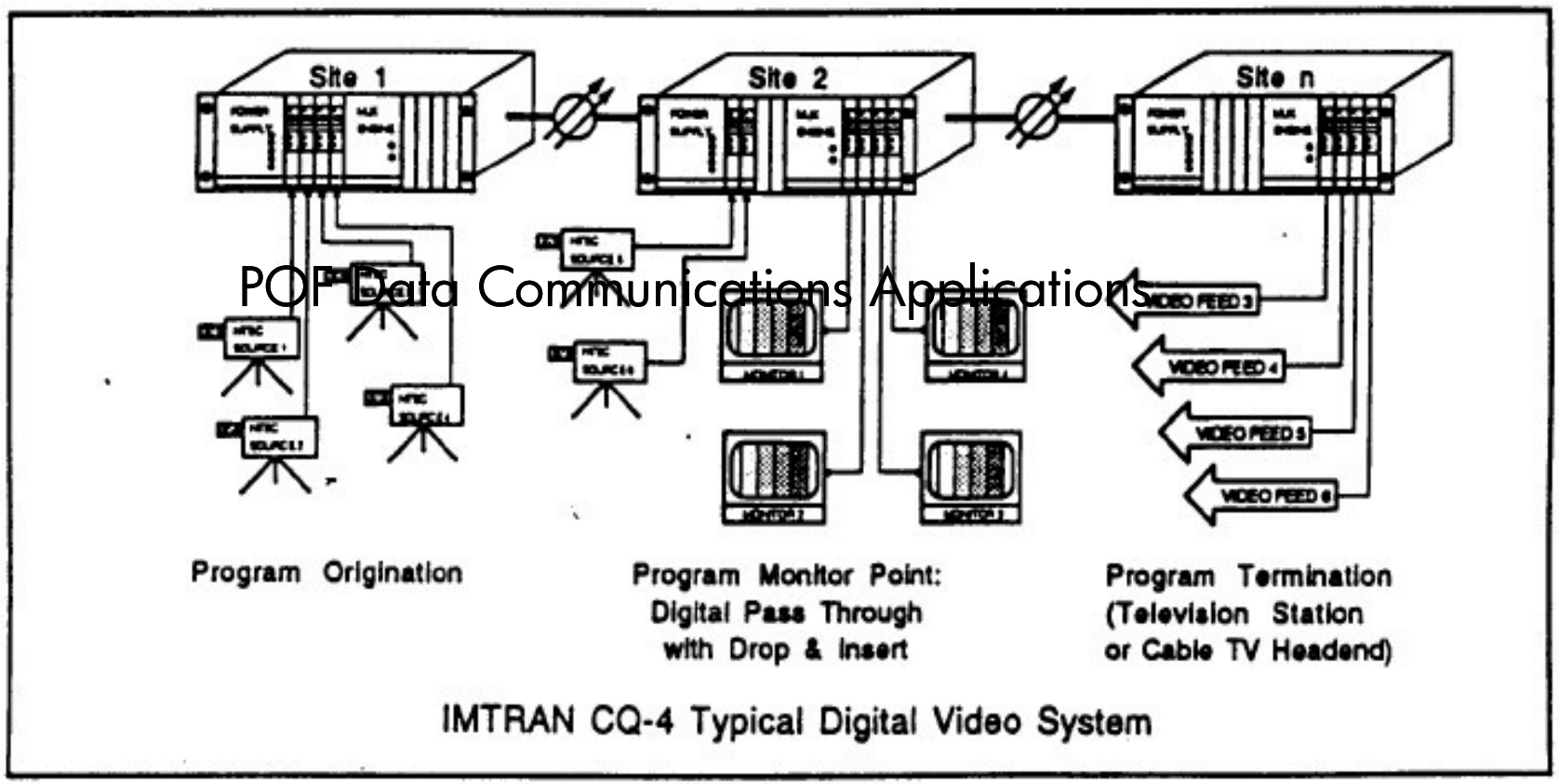
Exhibit 17.46
FO Link
Cell
Controller
Computer
Robot
Controller

Programmable Controllers (PLC)



Video Surveillance

Exhibit 17.48



IMTRAN CQ-4 Typical Digital Video System

Part 5: POF and Related Standards



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6. POF and Related Standards

- **Process control**

-SERCOS,

-Profibus,

-Interbus

- **Automotive**

-MOST,

-IDB-1394

-ByteFlight

- CEA Aftermarket

- **Computer**

-ATM

-1394b

- **Home Networking**

-CEBUS

-ATM Home Network

-1394b

- **Consumer electronics**

-ATM Home Network

-1394b

Part 6: POF Components– Present Status



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POF Components– Present Status

- Mitsubishi Rayon
- Asahi Kasei
- Toray Industries Inc
- Shenzhen Dashing Optoelectronic Technology
- Aashi Glass
- Nanoptics (US)
- Redfern Polymer(Kiriama)
- Nexans (South of France)
- Fuji Film
- Luxantix
- Optimedia(Korean)
- Jiang Daisheng Co. Ltd
- Seikishi Chemical Company

POF Suppliers

- **POF Cable**
  - Mitsubishi Rayon
  - Asashi Kasei
  - Asahi Glass
  - Toray Industries Inc
  - Nexans
  - Luceat Spa
  - Shenzhen Dasheng
  - German Companies for the MOST Program
- **Semiconductors**
  - KDPOF
  - Ethernet transceiver
- **Light Sources**
  - LED: SLEDs, ELEDs
  - Resonant cavity LEDs (RC-LEDs)
  - Laser Diodes
  - VCSEL
- **Photodiodes**
  - Avago technologies
  - Firecomms,
  - NEC, Toshiba etc
- **Connectors**
  - Agilent,FCI
  - Tyco. Yazaki
- **Coupler**
  - Delphi Interconnect

POF Suppliers

- **Test Equipment:** Only few supplers, Noyes Fo Systems, Tempest, Lucio
- **Splicing**: Phasoptx
- **Media Converter**: Dimoto, ELLT, Fiberfin, Homefiber etc
- **Data Links**: Toshba TOSLINK for digital audio Interface applications
- **POF Network**: Provide Ethernet Network: Dimoto Ltd(Australia), Luceat(Italy), NYCE(Canada) etc

Market Drivers

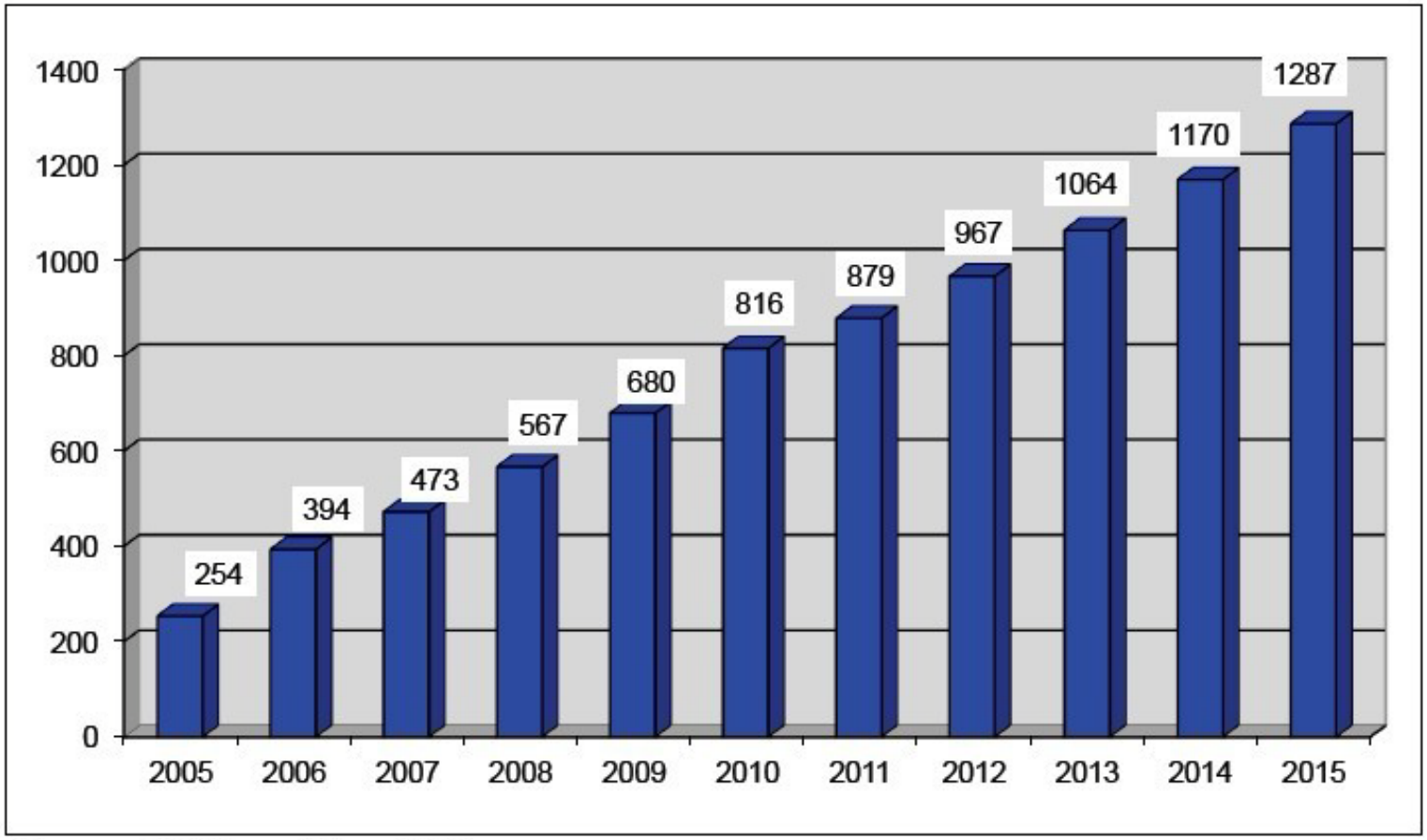
- Technology
- Standards
- Market need
- Government funding
- Education of users
- Market push
- Lack of a major player
- Resistant to change and imbedded infrastructure

POF Markets and Forecast

- Automotive Market: MOST
- Consumer Electronic Market and 1394
- POF Industrial Controls Market
- Home Market and IPTV
- Interconnect Market
- Medical Market
- Total POF Market Potential

Automotive POF Market

Exhibit 25.2
Estimated Automotive POF Market ($ millions)



Source: IGI Consulting, 2011

Consumer POF Market

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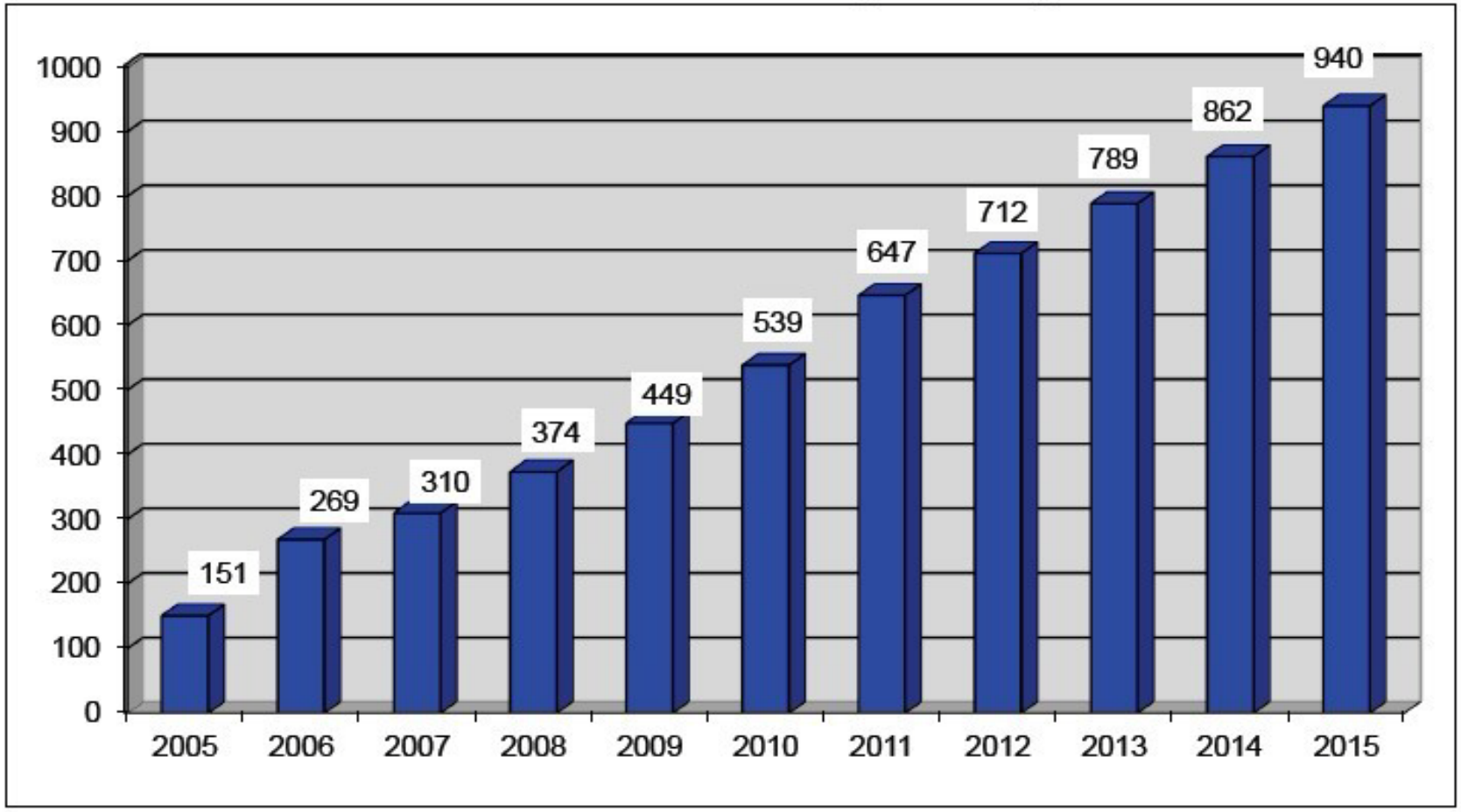
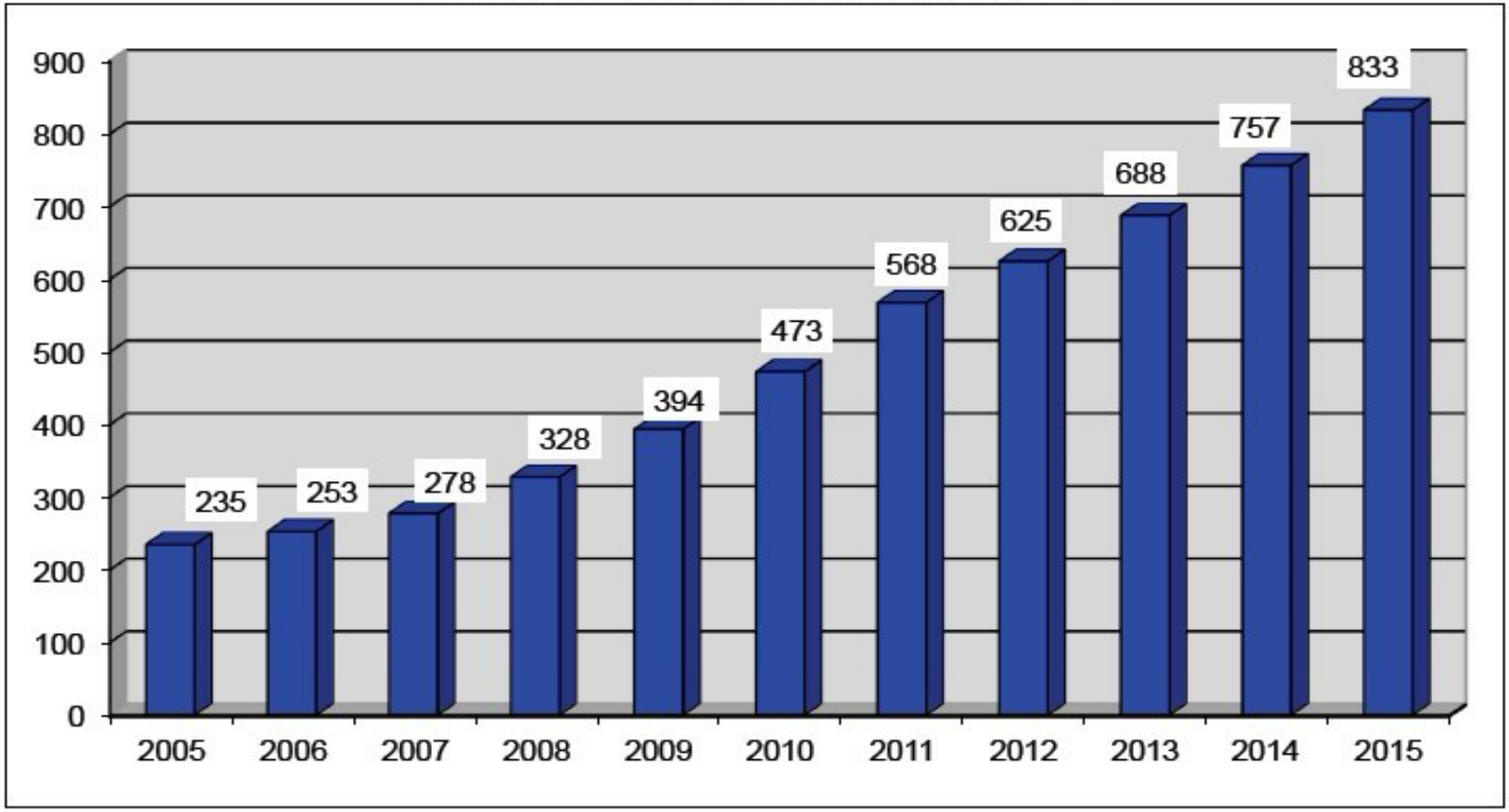
Exhibit 25.3
POF Consumer Market ($ millions)



Source: IGI Consulting, 2011

Industrial Controls Market

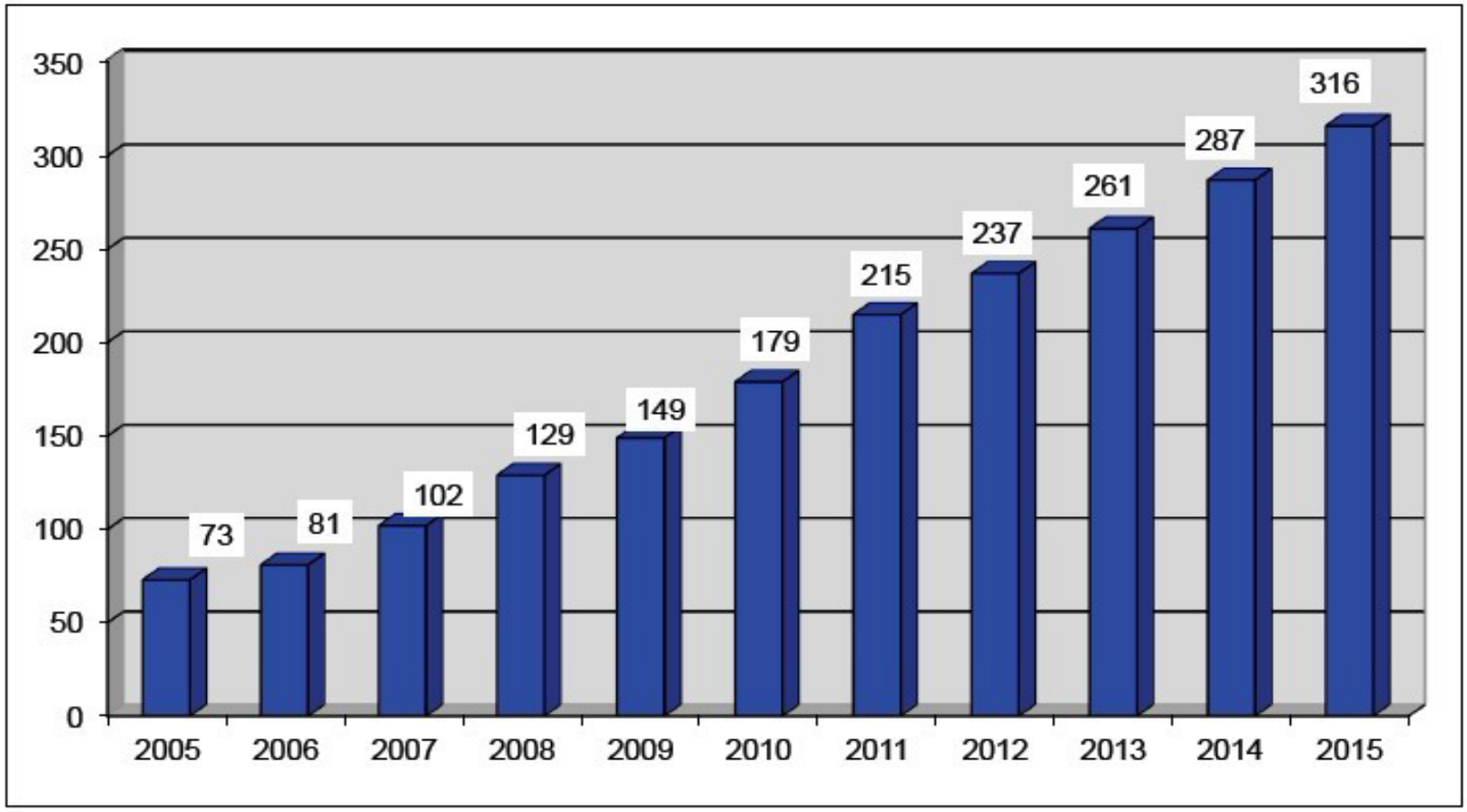
Exhibit 25.4
Industrial Controls Market ($ millions)



Source: IGI Consulting, 2011

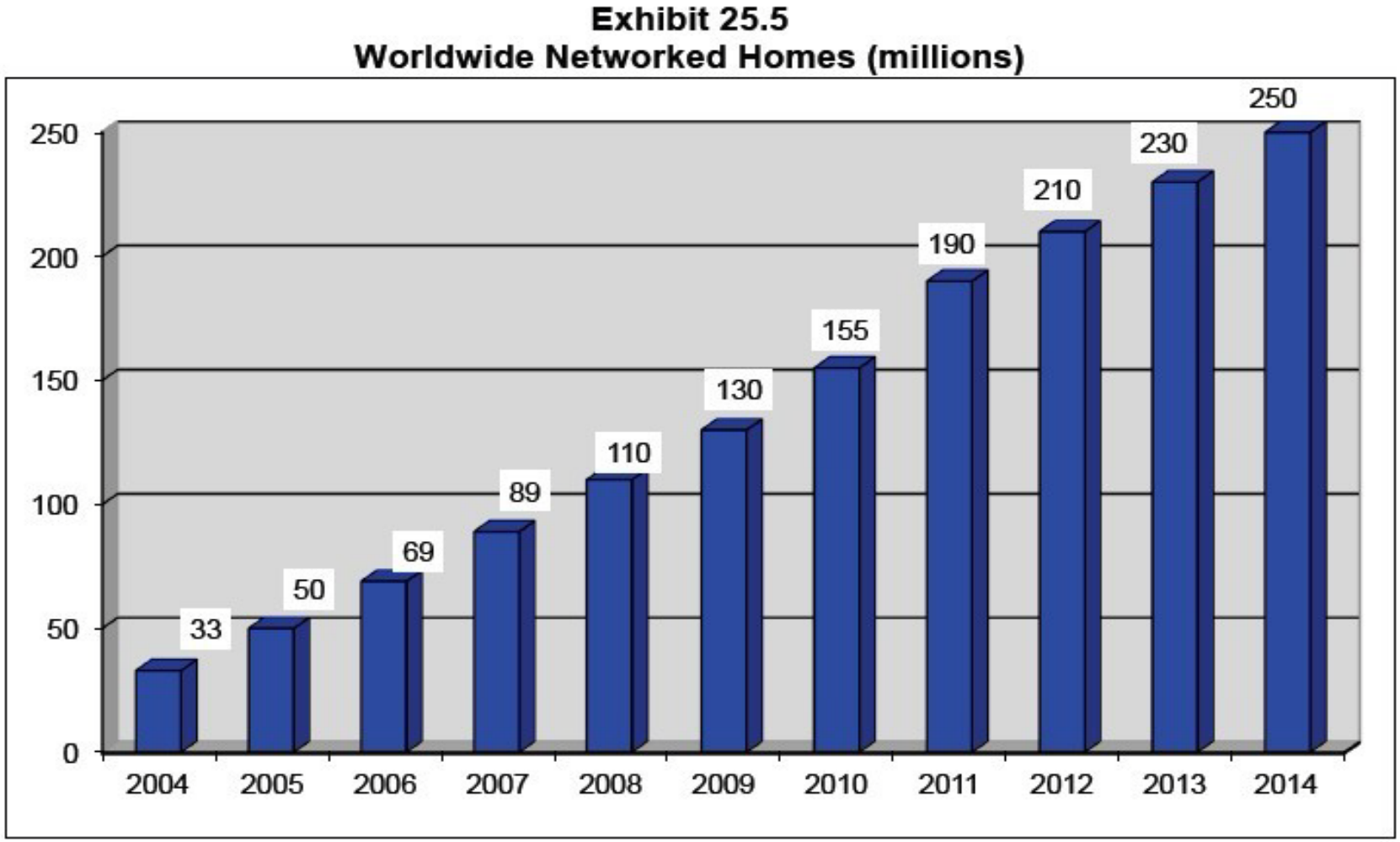
Interconnect Market

Exhibit 25.9
POF Interconnect Market ($ Millions)



Source: IGI Consulting, 2011

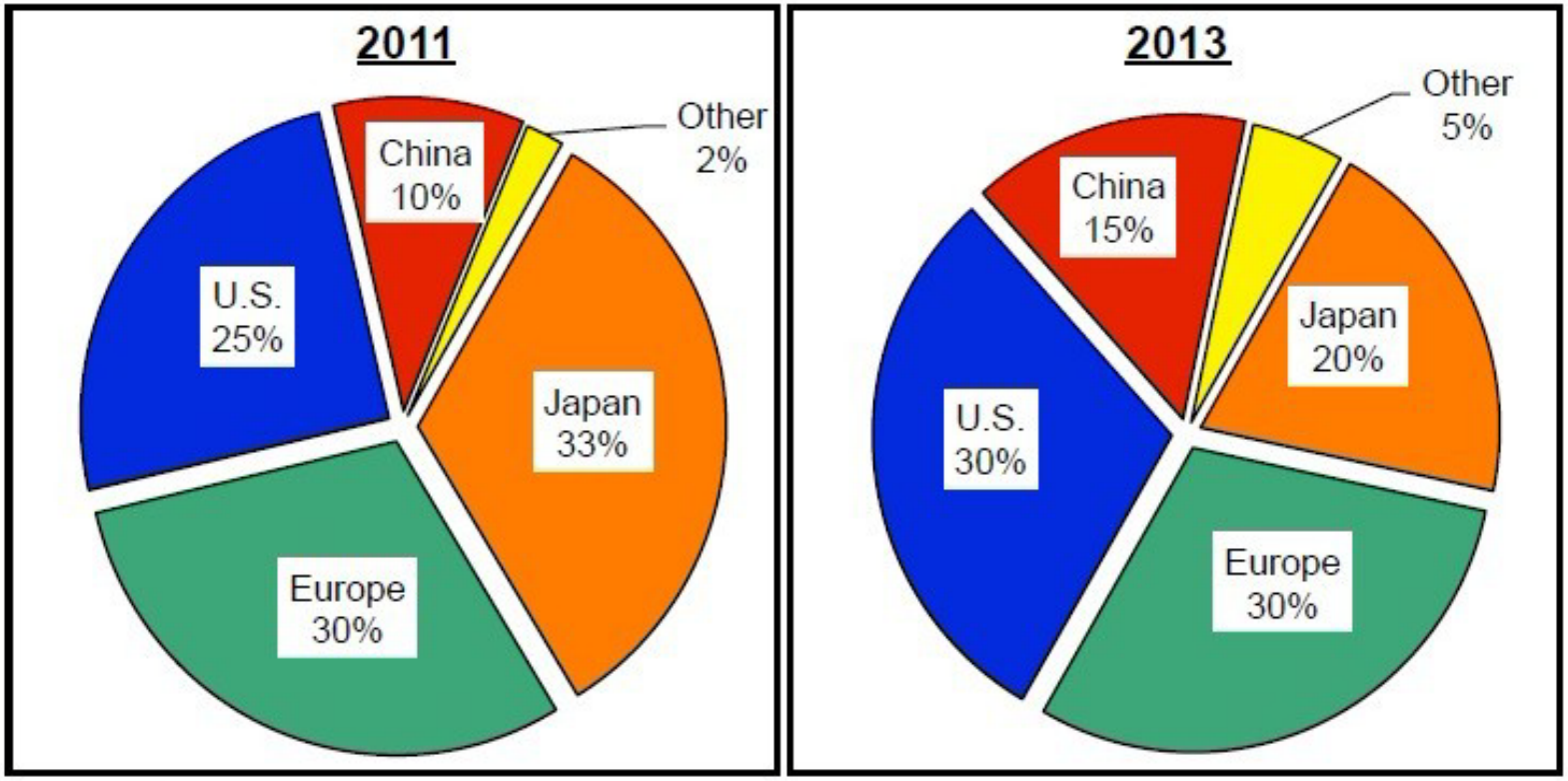
Total POF Market



Source: OVUM, IGI Consulting, 2011

Total POF Market Potential

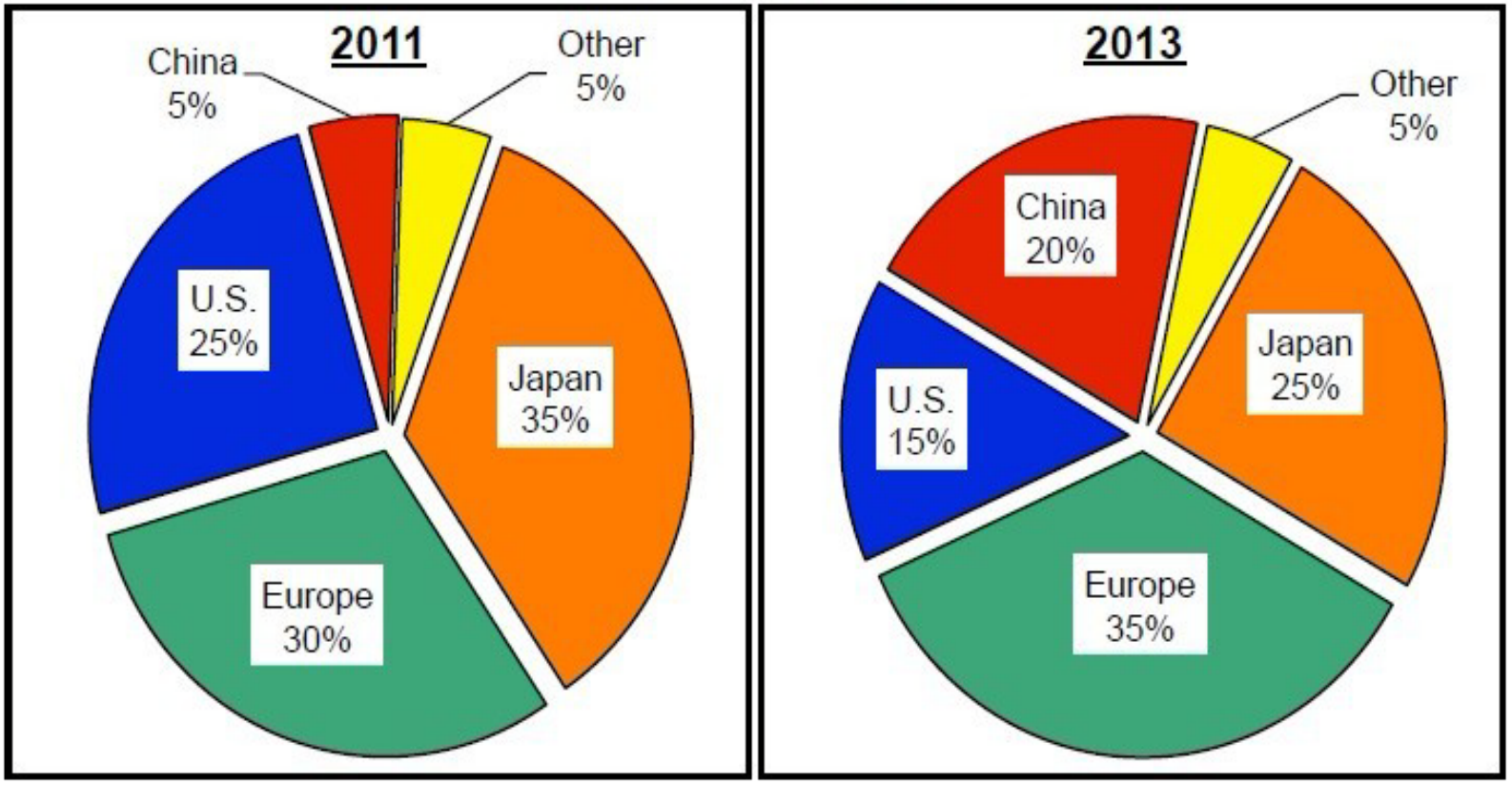
Exhibit 25.12
POF Market by Region



Source: IGI Consulting

Total POF Market Potential

Exhibit 25.13
POF Market by Supplier



Source: IGI Consulting

Part 7: Opportunities in POF Business



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Opportunities in POF Business

- Low-Speed Links
- System Solutions
- Distribution Networks
- POF Applications centers

Opportunities in POF Business

Low-Speed Links

A major market for POF exists for simple low-speed point-to-point links where there is a problem with electromagnetic inteference, need for electrical isolation, etc. Existing POF technology and products are readily avaibable. However, because of the lack of awareness, availability of information, and aggressive marketing, these low-speed markets are being served by copper cables rather than POF, The POF industry has focused on the higher-speed applications, which are tougher to crack and require advanced technology. The industry should use these lower-speed applications to build a base and migrate to the higher speeds.

Opportunities in POF Business

System Solutions

There also is an opportunity for companies that provide total systems solutions such as Fast Ethernet and Gigabit Ethernet

Opportunities in POF Business

Distribution Networks

There are possibly only a few places where potential users and deginers of POF can go to find all the POF components required for a complete system or just a simple link.

Opportunities in POF Business

POF Applications centers

A major issue is how can POF be used for existng and new links. For example, the POF Applications Center has shown that POF can be used for HDMI links and parallel optics links up to 100G.More development centers are needed similar to this around the world.

Part 8: Strategies for success for POF Market



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Strategies for success for POF Market

- Patience
- Financing
- Vision

The Japanese firms have been in the field for close to 20 years, DuPont did not see the potential and dropped out.

Strategies for success for POF Market

- **Firms that pick specific industries**

  company pick the specific industries, invest the necessary resources, and work to develop standards for POF will reap the benefits of their investments, Without POF written into standards as an option, the market will not develop.

Strategies for success for POF Market

- **Educating the customer**

  Marketing will be the key factor, which includes educating the customer.and the major reason for the lack of market acceptance is that the necessary resources have not been put into marketing. Even though companies develop superior products, customers will not beat a path to the suppliers'door without marketing.

QUESTIONS?