Data Communications

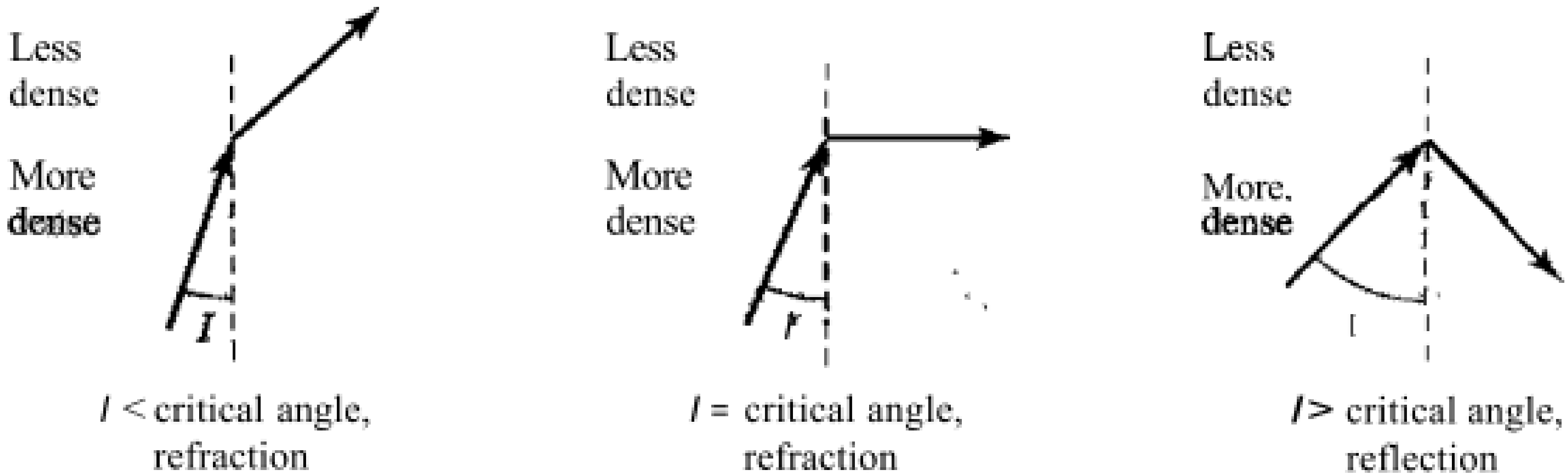
Unguided Media

Multiplexing

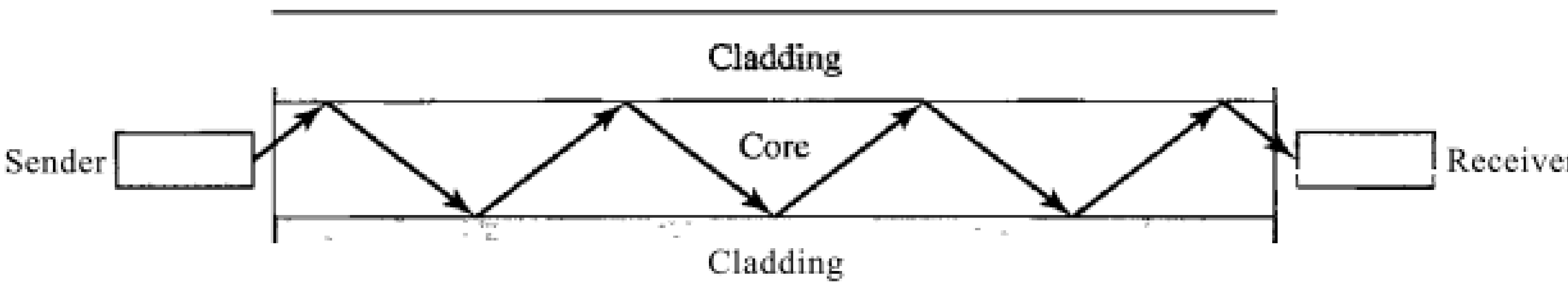
Fiber-Optic Cable

- A fiber-optic cable is made of glass or plastic and transmits signals in the form of light.
- If a ray of light traveling through one substance suddenly enters another substance (of a different density), the ray changes direction.

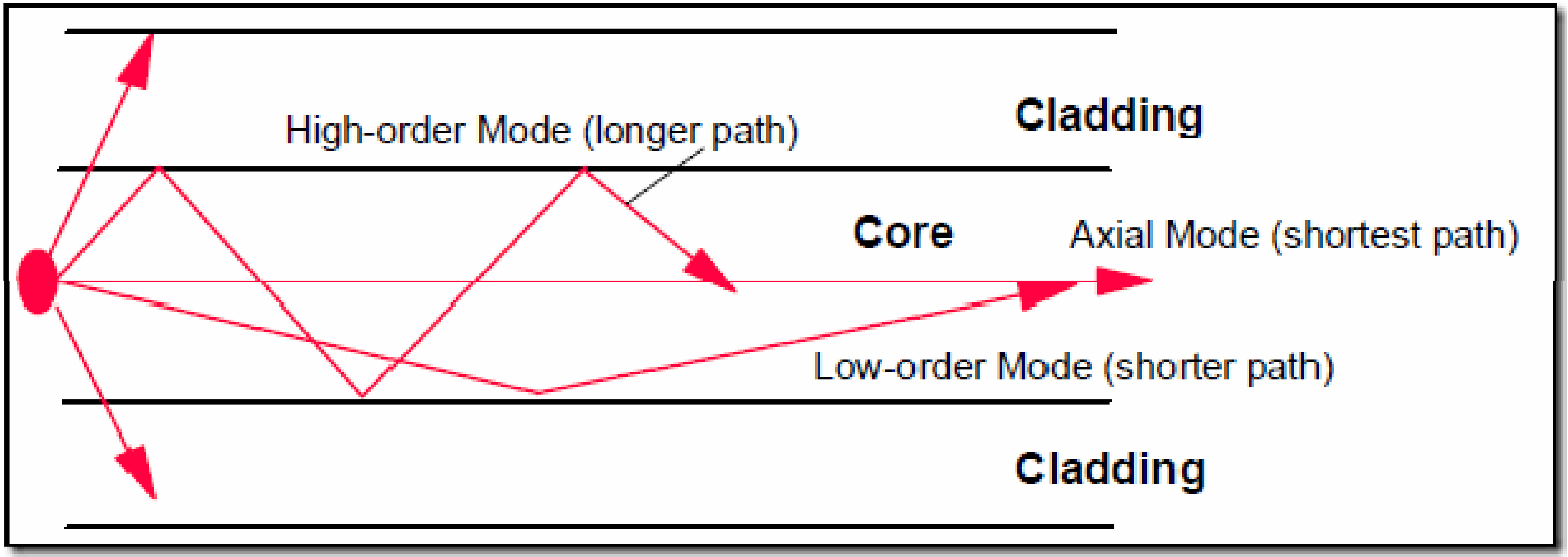
Fiber-Optic Cable



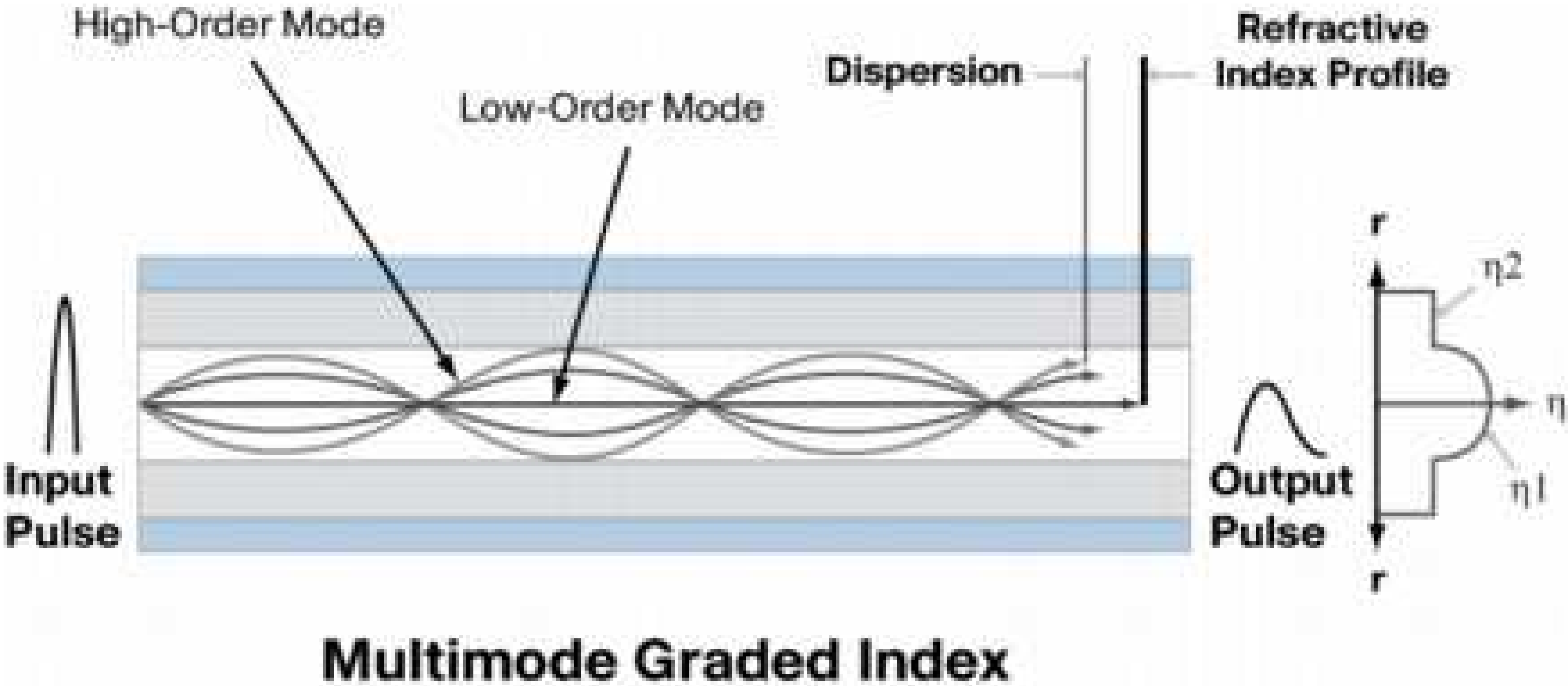
Fiber-Optic Cable



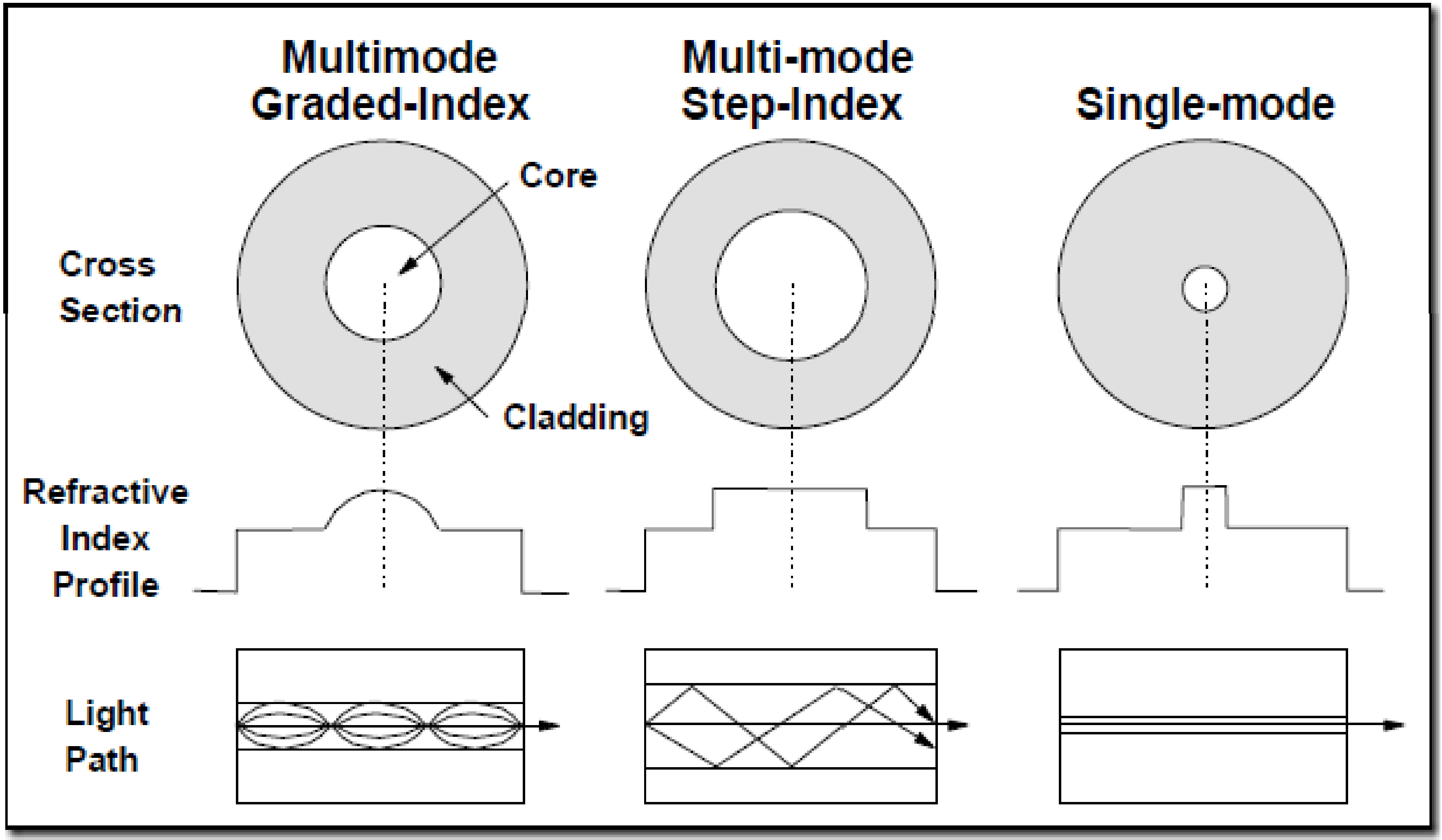
Multimodal Step-Index Fiber Optics



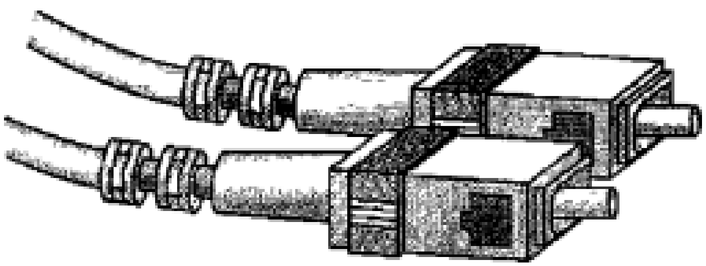
Multimodal Graded Index Fiber Optics



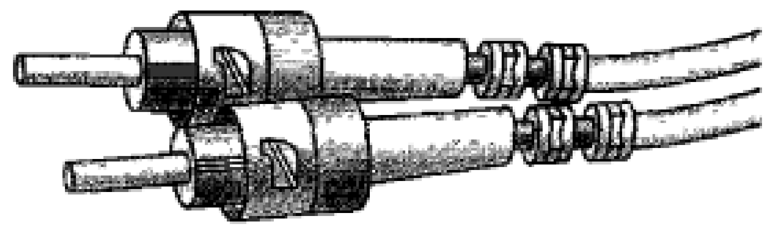
Multi- and Single-Modes



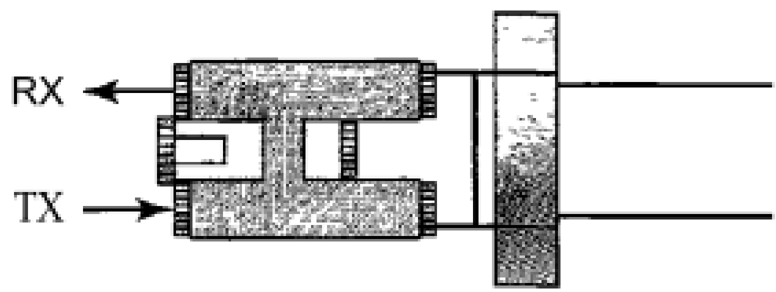
Fiber Optics Connectors



SC connector



ST connector

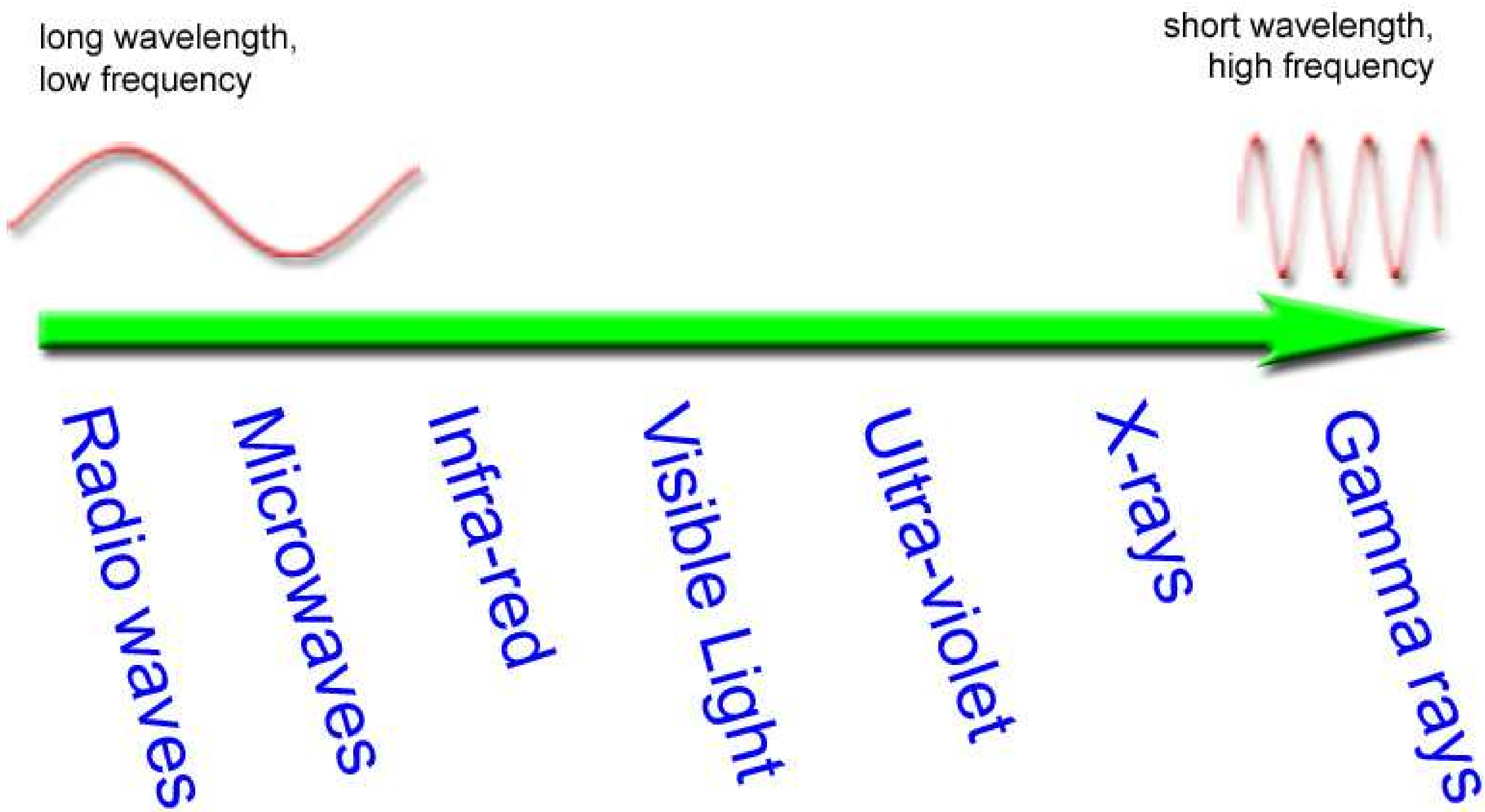


MT-RJ connector

Unguided Media

- Unguided media transport electromagnetic waves without using a physical conductor.
- This type of communication is often referred to as wireless communication.
- Signals are normally broadcast through free space and thus are available to anyone who has a device capable of receiving them.

Electromagnetic Spectrum



Propagation Types

- Ground propagation: radio waves travel through the lowest portion of the atmosphere
- Sky propagation: higher-frequency radio waves radiate upward into the ionosphere (the layer of atmosphere where particles exist as ions) where they are reflected back to the Earth.
- Line-of-sight propagation: very high-frequency signals are transmitted in straight lines directly from antenna to antenna

Propagation Types

Ground propagation
(below 2 MHz)

Sky propagation
(2-30 MHz)

Line-af-sight propagation
(above 30 MHz)

Frequency Bands

Band	*Range*	*Propagation*	*Application*
VLF (very low frequency)	3-30 kHz	Ground	Long-range radio navigation
LF (low frequency)	30-300 kHz	Ground	Radio beacons and navigational locators
MF (middle frequency)	300 kHz-3 MHz	Sky	AM radio
HF (high frequency)	3-30 MHz	Sky	Citizens band (CB), ship/aircraft communication
VHF (very high frequency)	30-300 MHz	Sky and line-of-sight	VHF TV, FM radio
UHF (ultrahigh frequency)	300 MHz-3 GHz	Line-of-sight	UHF TV, cellular phones, paging, satellite
SHF (superhigh frequency)	3-30 GHz	Line-of-sight	Satellite communication
EHF (extremely high frequency)	30-300 GHz	Line-of-sight	Radar, satellite

Multiplexing

- Whenever the bandwidth of a medium linking two devices is greater than the bandwidth needs of the devices, the link can be shared.
- Multiplexing is the set of techniques that allows the simultaneous transmission of multiple signals across a single data link.

Demultiplexing

- Demultiplexing is the process of reconverting a signal containing multiple analog or digital signal streams back into the original separate and unrelated signals.
- Demultiplexing is the inverse of multiplexing.

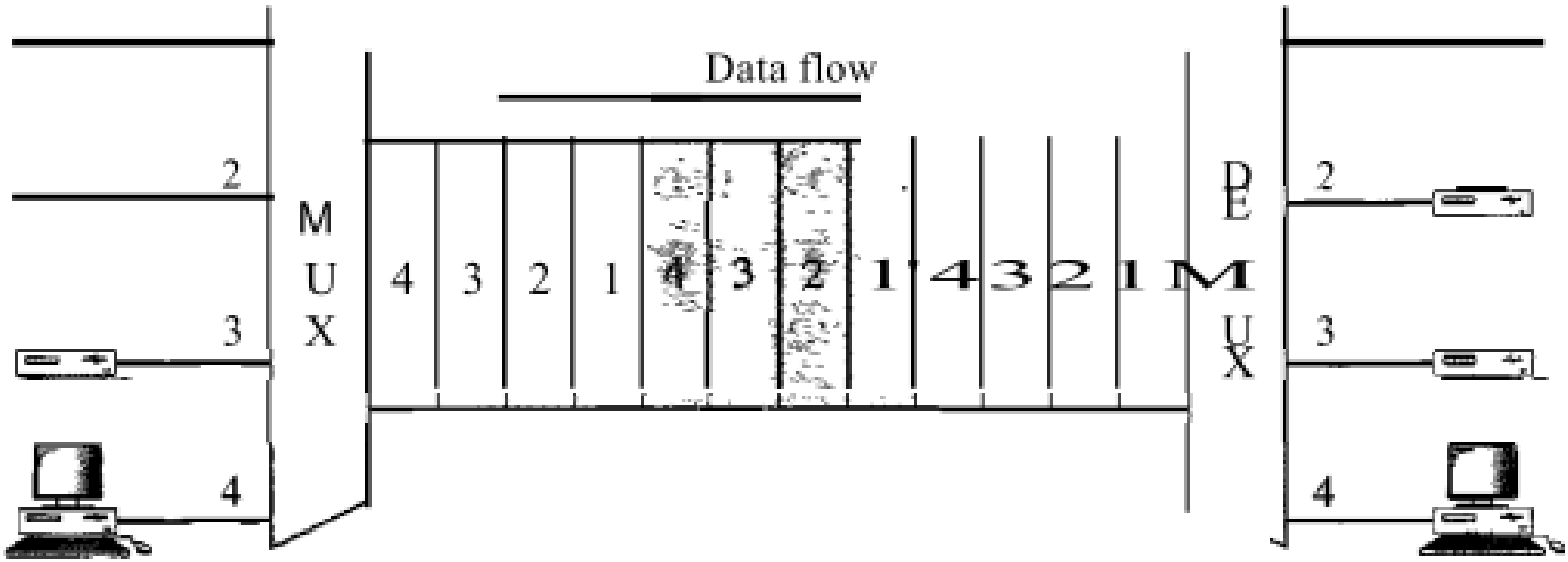
Types of Multiplexing

- In a multiplexed system, n lines share the bandwidth of one link.
- Sharing can be achieved by
  - Dividing Time
  - Dividing Frequency
  - Dividing Wavelength
  - Dividing Code

Time Division Multiplexing (TDM)

- Time-division multiplexing (TDM) is a digital process that allows several connections to share the high bandwidth of a link Instead of sharing a portion of the bandwidth as in FDM, time is shared.
- Each connection occupies a portion of time in the link

Time Division Multiplexing (TDM)



Time Division Multiplexing (TDM)

Example

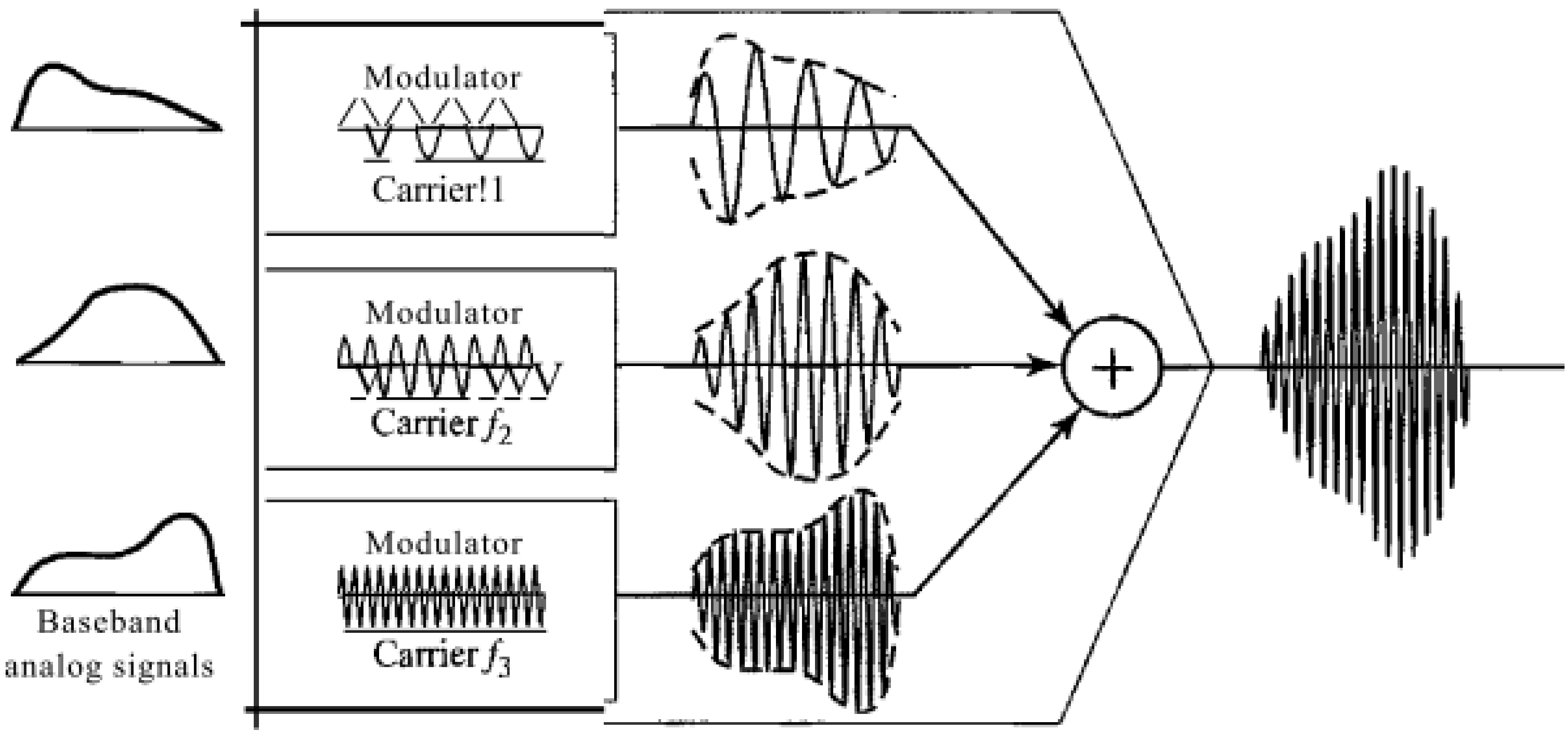
- T1 Carrier:

  T1 runs at a data rate of 1.544 Mbit/s. Original T1 format carried 24 pulse-code modulated, time-division multiplexed speech signals each encoded in 64 kbit/s streams, leaving 8 kbit/s of framing information.

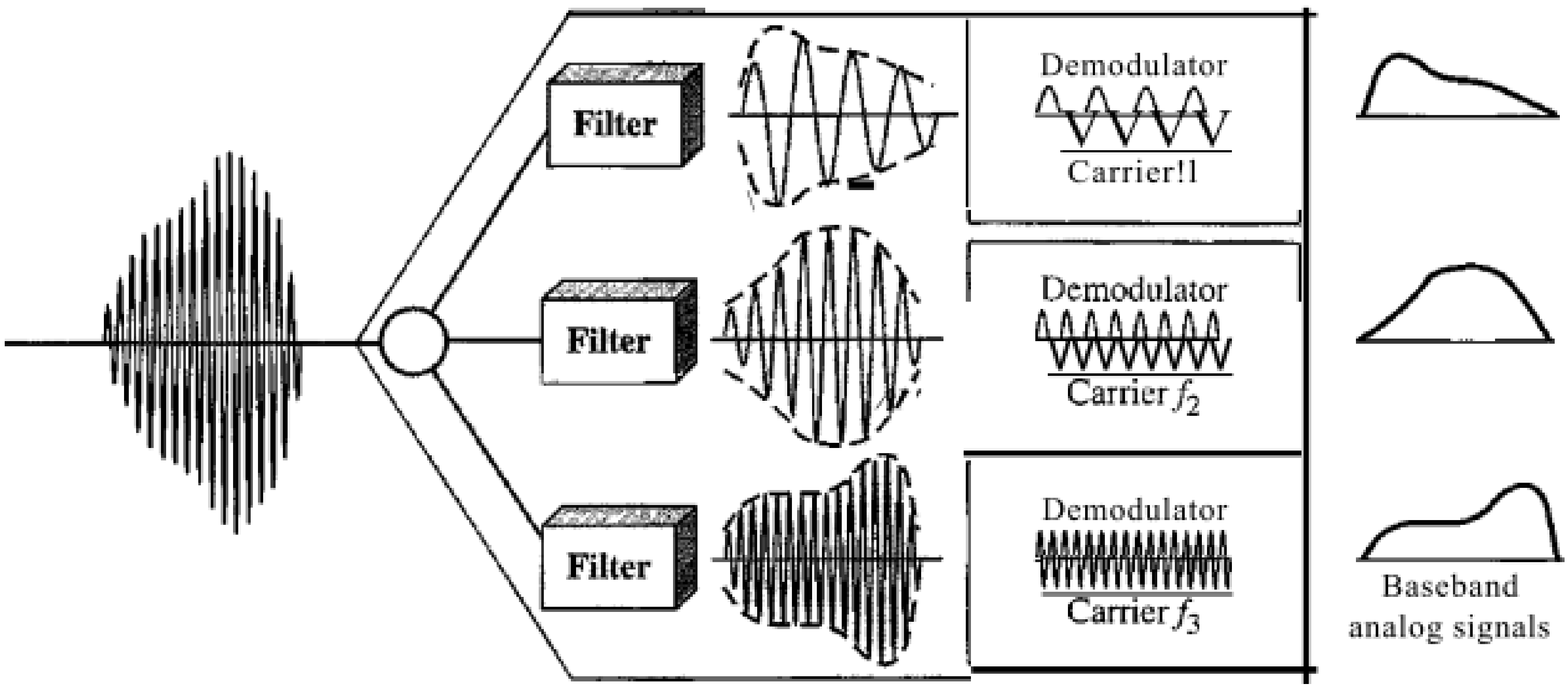
Frequency Division Multiplexing (FDM)

- In FDM, signals generated by each sending device modulate different carrier frequencies.
- These modulated signals are then combined into a single composite signal that can be transported by the link.
- Channels can be separated by strips of unused bandwidth-guard bands-to prevent signals from overlapping.

Frequency Division Multiplexing (FDM)



Demultiplexing FDM



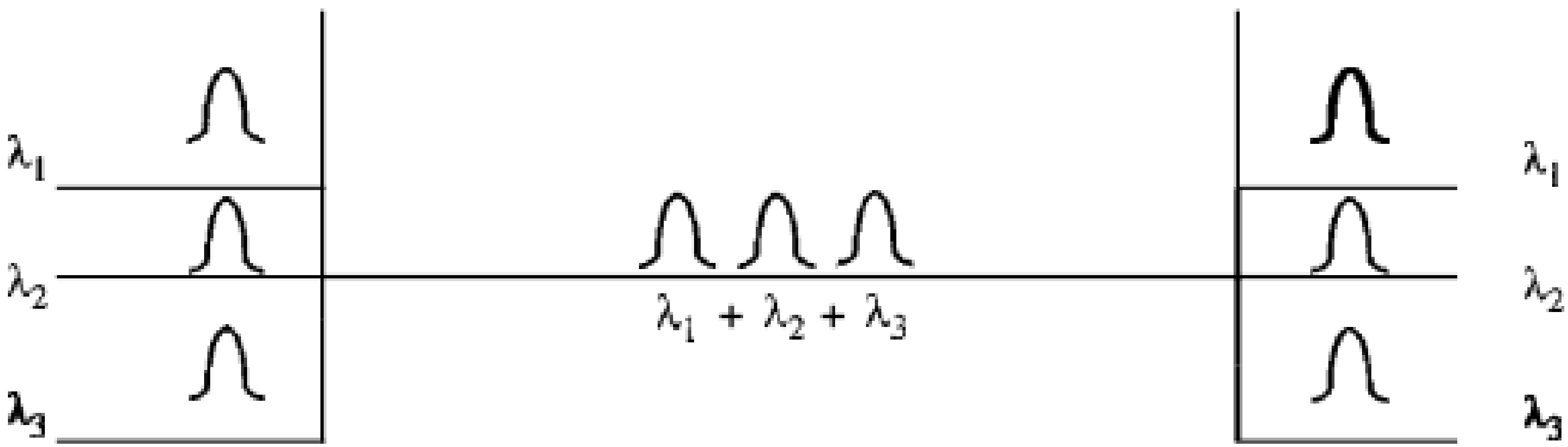
Example

- Five channels, each with a 100-kHz bandwidth, are to be multiplexed together. What is the minimum bandwidth of the link if there is a need for a guard band of 10kHz between the channels to prevent interference?

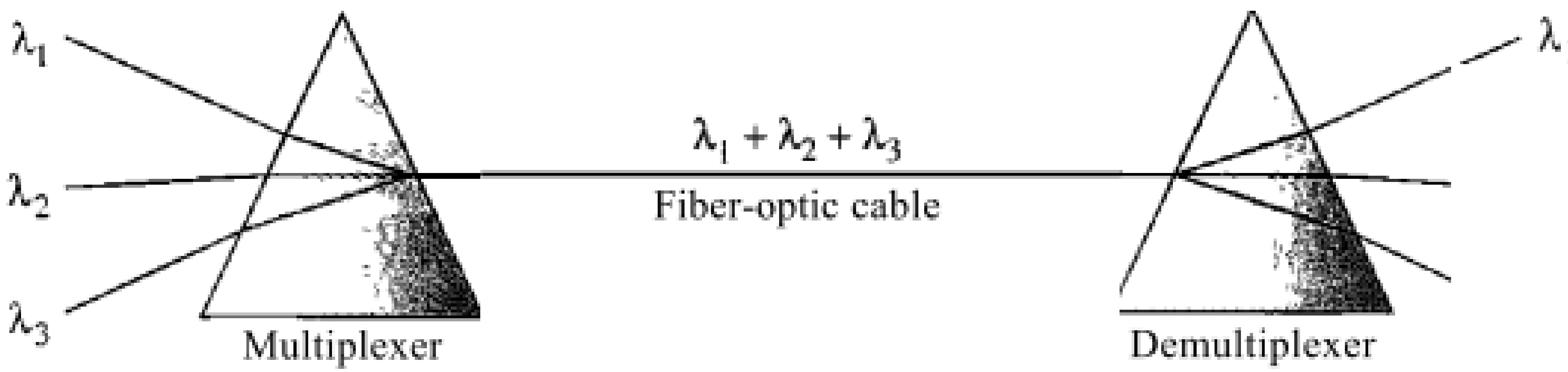
Wavelength Division Multiplexing (WDM)

- WDM is conceptually the same as FDM, except that the multiplexing involve optical signals transmitted through fiber-optic channels.
- WDM combines different signals of different frequencies.

Wavelength Division Multiplexing (WDM)



Wavelength Division Multiplexing (WDM)



Code Division Multiplexing (CDM)

- All hosts send on the same frequency probably at the same time and can use the whole bandwidth of the transmission channel
- Each sender has a unique chip code, the sender XORs the signal with this code the receiver can "tune" into this signal if it knows the pseudo random number, tuning is done via a correlation function

Code Division Multiplexing (CDM)

Sender A

- sends A_d = 1, key A_k = 010011 (assign: “0”= -1, “1”= +1)
- sending signal $A_s = A_d * A_k$ = (-1, +1, -1, -1, +1, +1)

Sender B

- sends B_d = 0, key B_k = 110101 (assign: “0”= -1, “1”= +1)
- sending signal Bs = $B_d * B_k$ = (-1, -1, +1, -1, +1, -1)
- Both signals superimpose in space
- $A_s + B_s$ = (-2, 0, 0, -2, +2, 0)

Receiver wants to receive signal from sender A

- apply key A_k bitwise (inner product)
- A_e = (-2, 0, 0, -2, +2, 0) • A_k = 2 + 0 + 0 + 2 + 2 + 0 = 6
- result greater than 0, therefore, original bit was “1”

Receiving B

- B_e = (-2, 0, 0, -2, +2, 0) • B_k = -2 + 0 + 0 - 2 - 2 + 0 = -6, i.e. “0”