Bibliography

Senior, J. M. (1992). *Optical Fiber Communications*. Prentice Hall, ISBN 0136354262. This book provides a detailed theoretical treatment of the subject. It is a standard reference work with over 900 pages of solid information. Worth keeping within reach but it is not light holiday reading.

Telecommunications Distribution Methods Manual, BICSI.

Telecommunications Cabling Installation Manual, BICSI.

BICSI Information Transport Systems (ITS) Dictionary, 3rd edn, BICSI.

Elliott, B. and Gilmore, M. (2002). *Fiber Optic Cabling*. Newnes, ISBN 0 7506 50133.

Elliott, B. (2000). *Cable Engineering for Local Area Networks*. Marcel Dekker, ISBN 08247 05254.

Elliott, B. (2002). *Designing a structured cabling system to ISO 11801*. Woodhead, ISBN 1 85573 612 8.

Glossary

Absorption loss
Loss of light in a fiber due to impurities.
Acceptance angle
The largest angle of incident light that lies within the cone of acceptance.
Adapter
A device to join and align two connectors.
Amplification
An increase in power level measured at two points. Usually measured in decibels.
Analog
A data format which allows smooth changes of amplitude using all intermediate values.
Angle of incidence
The angle between the incident ray and the normal.
Armoring
Cable protection, usually corrugated steel or steel wires, for outdoor mechanical protection.
Attenuation
A decrease in power level between two points. Usually expressed in decibels. Opposite to amplification.
Avalanche diode
A device to convert light into an electrical current.
Axial ray
The ray that passes straight through the center of a fiber without being refracted.
Backbone cable
The cables that provide a pathway between floors, buildings and equipment rooms.
Backscatter
The small proportion of light scattered by Rayleigh scattering which is returned towards the source.

Bandwidth
The range of modulation frequencies that can be transmitted on a system while maintaining an output power of at least half of the maximum response.
Bend loss
Losses due to bends in the fiber. The loss increases as the bend radius decreases. See *macrobend* and *microbend*.
Bend radius
Minimum bend radius. The smallest acceptable bend for a fiber or cable before bend loss is apparent.
BER
Bit error rate. The proportion of incoming bits of data that are received incorrectly.
Bi-phase
See *Manchester code*.
Bit
Abbreviated version of binary digit.
Braid
Interwoven metallic strands to shield insulated conductors to prevent electrical noise and other electromagnetic interference.
Buffer
See *primary coating*.
Cable
One or more optic fibers contained in a jacket, usually also containing strength members, etc.
Campus
A group of buildings such as a university or business park.
Chromatic dispersion
Dispersion caused by different wavelengths contained in the transmitted light traveling at different speeds.
Cladding
The clear material surrounding the core of an optic fiber. It has a lower refractive index than the core.
Coherent bundle
A group of optic fibers in which each fiber maintains its position relative to the other fibers so that images can be transmitted along the bundle.
Cone of acceptance
The cone formed by the angles of the light able to enter the fiber core measured from the center line of the core.
Connector
A means of joining optic fibers in a way that allows easy disconnection. In conjunction with an adapter, it performs the same function as a plug and socket in copper based systems.
Core
The central part of the fiber through which most of the light is transmitted. It has a higher refractive index than the cladding.
Coupler
A device to combine several incoming signals onto a single fiber or to split a single signal onto several fibers in a predetermined power ratio.
Critical angle
The lowest angle of the light ray measured with respect to the normal that can be reflected by a change in refractive index.

dB
Abbreviation for decibel. A logarithmic unit used to compare two power levels.
dBm
A power level compared with 1 milliwatt.
dBr
A power level compared with another stated power level.
Decibel
A logarithmic unit used to compare two power levels.
Digital
A data format in which the amplitude can only change by discrete steps.
Dispersion
The widening of light pulses on an optic fiber due to different propagation velocities of the pulse components.
Dolly
A polishing guide used to support a connector during the polishing process.
Dynamic range
The range of usable power levels expressed in decibels.
Eccentricity
Core eccentricity. The amount by which the core is not placed centrally within the cladding.
Ethernet
The most common Local Area Network protocol. Defined by the IEEE 802.3 committee.
FDDI (Fiber Distributed Data Interface)
A token-passing ring network using optic fibers.
Ferrule
A rigid tube used to confine and support the stripped end of a fiber as found in connectors.
Fiber
An abbreviation for *optic fiber* or *fiber optic*.
Fiber optic
Fiber optic system. A communication system using optic fibers. Often abbreviated to *fiber*.
Fresnel reflection
A reflection that occurs from a surface whenever there is a sudden change in the refractive index as at the end of a fiber. The '*s*' is not pronounced.
Fusion splice
A low loss, permanent means of connecting two fibers involving heating the fibers until they fuse together.
Giga
A thousand million, e.g. gigabit Ethernet sends 1000 000 000 bits per second.
Graded index fiber
A fiber in which the refractive index of the core is at a maximum value at the center and decreases towards the cladding.
Ground
A connection between electrical equipment or cable to the earth.
Hybrid cable
A cable that contains different types or cores, e.g. copper and fiber within a single sheath.
Index matching gel
Index matching fluid. A material with a refractive index close to optic fibers and used to reduce the amplitude of Fresnel reflections in couplers, mechanical splices, etc.

Infrared
The electromagnetic spectrum used for optic fiber transmission that extends between 660 nm and 1550 nm.
Insertion loss
The loss of power due to the insertion of a device, e.g. a connector.
Jacket
The outer layer of a cable, also called the *sheath*.
Jumper
An optic fiber with connectors at both ends.
LAN, Local Area Network
A communication network connecting computers and other instruments within a limited area, such as a building or groups of buildings like a campus. See also *MAN*, *WAN*.
Laser
A coherent light source of low spectral width.
LED
Light emitting diode. A semiconductor device used as a low power light source. The spectral width is greater than a laser.
Loose tube construction
A cable in which the optic fibers are contained loosely in a tube.
Macrobend
A bend in a fiber with a radius of curvature less than the recommended value. It causes a localized power loss which can be eliminated by straightening the fiber.
MAN, Metropolitan Area Network
Similar to a LAN but covers a larger area. It may connect several LANs together and extend across the size of a city. See also *LAN*, *WAN*.
Manchester code
A digital encoding system where the voltage changes in the middle of each binary digit sent.
Mechanical splice
A permanent method of connecting fibers usually involving adhesive and mechanical support and alignment of the fibers.
Mechanical splicing
Permanently joining two optic fibers together by mechanical means rather than fusion splicing.
Meridional ray
A ray which always passes through the core axis as it is propagated.
Micro
A prefix indicating a millionth.
Microbend
A tight bend or kink in the core over distances of a millimeter or less giving rise to a loss.
Micron
A unit of distance, one millionth of a meter, the preferred unit is the micrometer.
Milli
A prefix indicating one thousandth.
Modes
Separate optical waves capable of being transmitted along a fiber. The number of modes with a given light wavelength is determined by the NA and the core diameter.

Modulation
A process whereby a feature of a wave, such as amplitude or frequency, is changed in order to convey information.
Monomode fiber
Alternative name for single mode fiber.
Multimode fiber
An optic fiber able to propagate more than one mode at the same time.
Multiplexing
The transmission of several different signals along a single fiber.
Nanometer
One thousandth of a micrometer.
Network interface card (NIC)
A computer card that must be installed to connect a computer to a network.
Network
A group of devices such as computers that can communicate with each other.
NIC
See *network interface card.*
nm
Abbreviation for nanometer.
Node
A point where a computer, printer, etc. is connected to a network.
Normal
A line drawn at right angles to the position of a change in refractive index, e.g. between the core and the cladding.
Numerical aperture (NA)
The sine of the critical angle between the core and the cladding.
Optic fiber
The length of clear material that can be used to transmit light. Often abbreviated to *fiber.*
Optical Time Domain Reflectometer (OTDR)
An instrument that measures losses along a fiber by analyzing reflected light occurring on the optic fiber.
Patchcord
A short cable, usually terminated by a connector at each end used to reconfigure a route as required.
Photodiode
A semiconductor device that converts light into an electrical current.
Pico
A prefix indicating a millionth of a millionth.
Pigtail
A short length of fiber with a connector at one end and bare fiber at the other.
Power budget
The maximum possible loss that can occur on a fiber optic system before the communication link fails.
Primary coating
Buffer, buffer coating, primary buffer. A plastic coating applied to the cladding during manufacture to provide protection.
Ray
A line drawn to represent the direction taken by the light energy at a point.

Rayleigh scatter
The scattering of light due to small inhomogeneous regions within the core.
Refraction
The bending of a light path due to a change in refractive index.
Refractive index
The ratio of the speed of light in a material compared to its speed in free space.
Regenerator
Placed at intervals along a digital transmission route, it reconstructs the digital pulses.
Repeater
A transmitter and a receiver used at intervals along a transmission route to increase the power in an attenuated signal.
Server
A device that is used to provide and manage shared devices on a network.
Sheath
A plastic coating which covers one or more optic fibers. The first layer is called the primary sheath and the outer one, the secondary sheath. Beware – the terminology is not consistent between manufacturers.
Signal to noise ratio
The ratio of the signal level to the background noise. Usually measured in decibels.
Single mode fiber
An optic fiber which propagates a single mode.
Skew ray
A ray that never passes through the axis of the core during propagation.
Small Form Factor (SFF)
A duplex optical connector with a footprint size similar to a copper RJ45 8-pin connector.
Spectral width
The range of wavelengths emitted by a light source.
Splice
A permanent means of connecting two fibers. Alternatives are fusion splice and mechanical splice.
Star coupler
A device that allows a single fiber to be connected to several others.
Step index fiber
A fiber in which the refractive index changes abruptly between the core and the cladding.
Tee coupler
A 1×2 coupler used to tap off a proportion of the power from a system. It usually has a high splitting ratio and is used as part of a network.
Threshold current
The lowest current that can be used to operate a laser.
Tight-buffered cable
An optic fiber cable in which each fiber is tightly buffered by a 900-micron plastic coating.
Token
An electronic code passed from device to device to allow each device access to a ring network.
Topology
The layout of a network.
Total internal reflection (TIR)
Reflection occurring when the light approaches a change in refractive index at an angle greater than the critical angle.

Twisted pair cable
A cable containing one or more pairs of copper conductors that are twisted to reduce the likelihood of electromagnetic interference.

UTP, Unscreened Twisted Pair
Twisted pair copper cables that contain no screening elements.

VCSEL, Vertical Cavity Surface Emitting Laser
A low cost laser used in high-speed data communications equipment.

WAN, Wide Area Network
Similar to a LAN but covers a very large area using telephone systems, satellites and microwave links rather than cable. See also *LAN*, *MAN*.

Wavelength Division Multiplexing (WDM)
The simultaneous transmission of several signals of different wavelengths along a single fiber.

Windows
Commonly used bands of wavelengths. The 1st window is 850 nm, the 2nd is 1300 nm and the 3rd is 1550 nm.

Quiz time answers

Quiz time 1

1 c
2 a
3 d
4 d
5 b

Quiz time 2

1 b
2 d
3 b
4 a
5 d

Solution to quiz time 2 question 5

Using Snell's law:

$$n_1 \sin \theta_1 = n_2 \sin \theta_2$$

Insert the known values:

$$1.49 \sin 50° = 1.475 \sin \theta_2$$

assuming θ_2 is the angle shown as ?.

Transpose for sin θ_2 by dividing both sides of the equation by 1.475. This gives us:

$$\frac{1.49 \sin 50^\circ}{1.475} = \sin \theta_2$$

Simplify the left-hand side:

$$0.7738 = \sin \theta_2$$

The angle is therefore given by:

$$\theta_2 = \arcsin 0.7738$$

So:

$$\theta_2 = 50.7$$

Quiz time 3

1 a

2 b

3 d

4 d

5 c

Solution to quiz time 3 question 2

$$f = \frac{V}{\lambda} = \frac{3 \times 10^8}{660 \times 10^{-9}} = 4.54 \times 10^{14} \text{ Hz}$$

Quiz time 4

1 d

2 b

3 c

4 c

5 a

Solution to quiz time 4 question 2

Using Snell's law

$$n_{air} \sin 15^\circ = n_{core} \sin(\text{angle of refraction})$$

So:

$$1 \times 0.2588 = 1.47 \sin(\text{angle of refraction})$$

So:

$$\frac{0.2588}{1.47} = \sin(\text{angle of refraction})$$

Thus:

$$\text{angle of refraction} = \sin^{-1} 0.1760 = 10.137^\circ = 10.14^\circ$$

Solution to quiz time 4 question 5

$$\text{NA} = \sqrt{n^2_{\text{core}} - n^2_{\text{cladding}}}$$

So:

$$\text{NA} = \sqrt{1.47^2 - 1.44^2} = \sqrt{0.0873} = 0.2955$$

So:

$$\text{angle of acceptance} = \sin^{-1} 0.2955 = 17.1875^\circ = 17.19^\circ$$

Quiz time 5

1 d

2 b

3 c

4 b

5 c

Solution to Quiz time 5 question 1

$$\begin{aligned}\text{Power level in dBm} &= 10 \log \frac{50 \times 10^{-6}}{1 \times 10} = 10 \log 0.05 \\ &= 10 \times -1.3 = -13 \text{ dBm}\end{aligned}$$

Solution to Quiz time 5 question 2

As the input power is −5 dBm and the output power is −26 dBm, the difference in power levels is 21 dBm. The 2 km length of fiber has a total loss of:

$$2 \times 3 = 6\,\text{dB}$$

The known losses are the two attenuators and the fiber, so:

$$\text{total losses} = 2 + 4 + 6 = 12\,\text{dB}$$

As the total loss of the system is 21 dB, and we have only accounted for 12 dB, link A must represent the remaining 9 dB. At 3 dB loss per kilometer, this means that link A must be 3 km in length.

Solution to Quiz time 5 question 3

There are two methods:

The first is to convert the 0.25 mW into dBm then work in decibels and finally convert the answer back to watts.

The second is to convert the −15 dB into a ratio and work in power levels throughout.

The second method is slightly better as it only involves one conversion:

$$-15 = 10\log\frac{\text{power}_{\text{out}}}{\text{power}_{\text{in}}} = 10\log\frac{\text{power}_{\text{out}}}{0.25\times10^{-3}}$$

Divide by 10:

$$-1.5\text{ dB} = \log\frac{\text{power}_{\text{out}}}{0.25\times10^{-3}}$$

Take the antilog:

$$0.0316 = \frac{\text{power}_{\text{out}}}{0.25\times10^{-3}}$$

So:

$$\text{power}_{\text{out}} = 0.0316\times0.25\times10^{-3} = 7.9\,\mu\text{W}$$

Solution to Quiz time 5 question 4

Loss is measured in dB, so that has eliminated two out of the four options. When the figures are fed into the standard formula, the result is a negative value. This is because the output is less than the input:

$$\text{power gain} = 10\log\frac{\text{power}_{\text{out}}}{\text{power}_{\text{in}}} = 10\log\frac{0.8\times10^{-3}}{2\times10^{-3}}$$

So:

$$\text{power gain} = 10\log(0.4) = 10\times-0.398 = -3.98\,\text{dB}$$

So there is a loss of 3.98 dB.

Quiz time 6

1 a

2 b

3 d

4 a

5 b

Solution to Quiz time 6 question 2

Starting with the standard formula:

$$\text{reflected power} = \left(\frac{n_1 - n_2}{n_1 + n_2}\right)^2$$

where n_1 and n_2 are the refractive indices of the two materials. So:

$$\text{reflected power} = \left(\frac{1.45 - 1.0}{1.45 + 1.0}\right)^2 = \left(\frac{0.45}{2.45}\right)^2$$

Dividing out:

$$\text{reflected power} = (0.1837)^2 = 0.03375 = 3.375\%$$

Taking the light input as 100%, the light output is:

$$100 - 3.375 = 96.625\%$$

This loss can be expressed in dB by treating it as a normal input/output situation:

$$\begin{aligned}\text{decibels} &= 10\log\frac{\text{power}_{\text{out}}}{\text{power}_{\text{in}}}\\ &= 10\log\frac{96.625}{100}\\ &= 10\log 0.96625\\ &= 10 \times -0.0149\\ &= -0.149\ \text{dB}\end{aligned}$$

So:

$$\text{loss} = 0.149\,\text{dB}$$

The minus disappears because it is referred to as loss.

Quiz time 7

1 c

2 d

3 b

4 a

5 a

Solution to Quiz time 7 question 2

Find the numerical aperture:

$$\mathrm{NA} = \sqrt{1.48^2 - 1.46^2}$$

So:

$$\mathrm{NA} = 0.2424$$

Insert the figures into the formula:

$$\text{number of modes} = \frac{\left(\text{diameter of core} \times \mathrm{NA} \times \dfrac{\mu}{\lambda}\right)^2}{2}$$

where NA = fiber numerical aperture and λ = wavelength of the light source.

So:

$$\text{number of modes} = \frac{\left(62.5 \times 10^{-6} \times 0.2424 \times \dfrac{\mu}{865 \times 10^{-9}}\right)^2}{2}$$
$$= 1513.78$$

The number of modes cannot be a fraction so the calculated value is always rounded down to a whole number. Hence the answer is 1513.

Quiz time 8

1 d

2 a

3 c

4 d

5 a

Quiz time 9

1 b
2 b
3 d
4 c
5 a

Quiz time 10

1 c
2 a
3 d
4 c
5 d

Quiz time 11

1 a
2 b
3 c
4 b
5 c

Quiz time 12

1 c
2 a
3 a
4 b
5 a

Quiz time 13

1 d
2 a
3 b
4 c
5 d

Solution to Quiz time 13 question 2

Start by converting the excess loss of 0.4 dB into a power ratio to find the total output power available:

$$-0.4 = 10\log\left(\frac{\text{power}_{\text{out}}}{\text{power}_{\text{in}}}\right)$$

Divide both sides by 10:

$$-0.04 = \log\left(\frac{\text{power}_{\text{out}}}{\text{power}_{\text{in}}}\right)$$

Take the antilog of each side:

$$0.912 = \frac{\text{power}_{\text{out}}}{\text{power}_{\text{in}}}$$

Insert the known value for the input power:

$$0.912 = \frac{\text{power}_{\text{out}}}{0.2\ \text{mW}}$$

Transpose to find the output power:

$$\text{power}_{\text{out}} = 0.912 \times 0.2\,\text{mW} = 182\,\mu\text{W}$$

This is the power level within the coupler after the excess loss has been taken into account. It is now split in the ratio of 9:1 so the tap power is 0.1 of the available power:

$$\text{tap power} = 0.1 \times 182 = 18.2\,\mu\text{W}$$

Quiz time 14

1 b

2 b

3 b

4 d

5 d

Quiz time 15

1 a

2 d

3 b

4 c

5 a

Quiz time 16

1 c

2 a

3 c

4 c

5 a

Solution to Quiz time 16 question 3

$$\sqrt{0.5^2 + 1.5^2 0.025^2} = 1.58 \text{ ns}$$

Remember that the fiber rise time was in ps, and as we are working in ns, it had to be converted to 0.025 ns.

Solution to Quiz time 16 question 4

Step 1

The known losses.

We have two pairs of connectors at 0.2 dB each = 0.4 dB and a fusion splice of 0.1 dB.

The present losses amount to 0.1 + 0.4 = 0.5 dB.

Step 2

In addition, we must include the aging losses, repair losses and the 'spare' power held back for emergencies.

For repairs, the assumed value is 0.1 dB and for aging losses 1 dB in total.

Spare, 3 dB as usual.

So:

$$\text{total losses} = \text{losses from Step 1} + \text{repair power} + \text{aging loss} + \text{spare power}$$

In this case:

$$\text{total losses} = 0.5 + 0.1 + 1.0 + 3.0 = 4.6\,\text{dB}$$

Step 3

Find the power available for the required cable run.

Transmitter output power is quoted as 30 μW which needs to be converted into decibels:

$$\text{decibels} = 10\log\frac{30\times10^{-6}}{1\times10^{-3}}15.22\ \text{dBm}$$

The total power available for the system is the difference between the transmitter output power and the minimum input power of the receiver.

In this case it is 14.78 dB.

Of this 14.78 dB, we have already accounted for 4.6 dB.

The spare power for the fiber is 14.78 − 4.6 = 10.18 dB.

Step 4

The fiber in use has a loss of 3.2 dBkm − 1, so the length that could be accommodated is:

$$\frac{10.18}{3.2} = 3.18\ \text{km}$$

giving an approximate value of 3.2 km.

Solution to Quiz time 16 question 5

$$\frac{0.44}{44\times10^{-12}} = 10\ \text{GHz}$$

Quiz time 17

1 d

2 a

3 c

4 b

5 b

Quiz time 18

1 b

2 a

3 d

4 c

5 b

Quiz time 19

1 a

2 b

3 c

4 b

5 a

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