Chapter 13 OPTICAL FIBER

Japan has been applying intensive efforts in developmental research on optical fiber cable techniques. These techniques have matured sufficiently for optical fibers to be introduced into use as actual signal transmission lines. Large scale commercial tests cover such wide fields as fiber quality control during manufacturing, cabling, installing, splicing, measurement and maintenance. This chapter describes the background for the developmental research and explains the designing method for the optical fiber cable.

13.1 Introduction

Optical fiber has non-induction characteristic, as well as low-loss and broad-bandwidth transmission characteristics, compared with conventional metallic transmission lines. Therefore, optical fiber is foreseen as an excellent transmission line medium, which is versatile and economical in use for various digital transmission systems and video transmission systems indispensable to the new communication services.

The optical fiber cable introduction has various advantages in construction and maintenance because of its small diameter an light weight and the possibility of a drastic reduction of repeaters in transmission systems.

13.2 Histrical review

The invention of laser enabled generation of light with stable frequency and phase and high radiance. Around 10^{14} Hz are used which is $10^4 \sim 10^5$ times higher than that of an existing microwave. As a result, the laser is well suited for use as carrier in wide band, high capacity transmission systems.

The glass fiber attenuation loss was, at first thousands of dB which made its use as a transmission system medium impossible. However, Mr. Kao and others at STL in England predicted in 1966 that by eliminating impurities from the glass material, the loss of glass fiber could be decreased sufficiently to allow practical optical fiber transmission. Actually, in 1970, optical fiber with a loss of 20 dB/Km was manufactured by Corning Glass Works in U.S.A.

This epoch-making optical fiber had a great impact on optical telecommunication research. Evidentely, efforts were focused on decreasing optical fiber loss. As a result, at present fiber with an average loss of $1 \sim 3$ dB/Km are easily manufactured in the factory. In the laboratory 0.1 dB/Km loss fiber is achieved.

For Optical sources, application of semiconductor lasers had been investigated earnestly since 1966. It was made clear that semiconductor lasers could be directly modulated to carry very high frequencies. In 1970, for the first time in the world semiconductor lasers worked continuously at room temperature. Since then, great efforts have been made to get a long-lifetime semiconductor laser (or laser diode: LD). Around a million hours lifetime can now be obtained.

Along with lasers, light-emitting-diode (LED), which has been widely used since 1962, has been improved so that it has higher radiance.

Optodetectors, such as photo-diode and avalanche-photo-diode which were in practical use in 1960s, were applied as a receiver in optical transmission system. These optodetectors have a frequency handling range from D.C. to 1GHz or more, and have a sufficiently good performance and characteristics to assure their efficient use as a receiver component in fiber transmission system.

13.3 Characteristic features of optical fiber

(1) Optical fiber cable has very low loss compared with the conventional metal cable. Thus, repeater spacing of optical transmission can be lengthened by several tens times compared to that composed of the metal cables.

(2) Optical fiber is small in size and has wide-band frequency response. In addition, optical waves with various wavelengths are propagated in a fiber simultaniously. As a result, extremely large transmission capacity is realized.

(3) Optical fiber is free from the electric and magnetic disturbances due to noninductive materials which optical fiber is made of. So electric power cable and thunder, or inductive noise from various sources can never disterb the transmission and highly reliable transmission line can be realized.

(4) Temperature dependence of transmission characteristics is rather small in optical fiber. Thus equalization and compensation of the characteristic change is not necessary and/or is simplified.

(5) Cross talk between fibers is not a problem.

(6) Light weight cable is fabricated using the optical fiber, because the specific weight of glass is a quarter of that of copper.

(7) The raw material, SiO, of the optical fiber is one of the most

Table 13.1 Advantages of fiber optics system

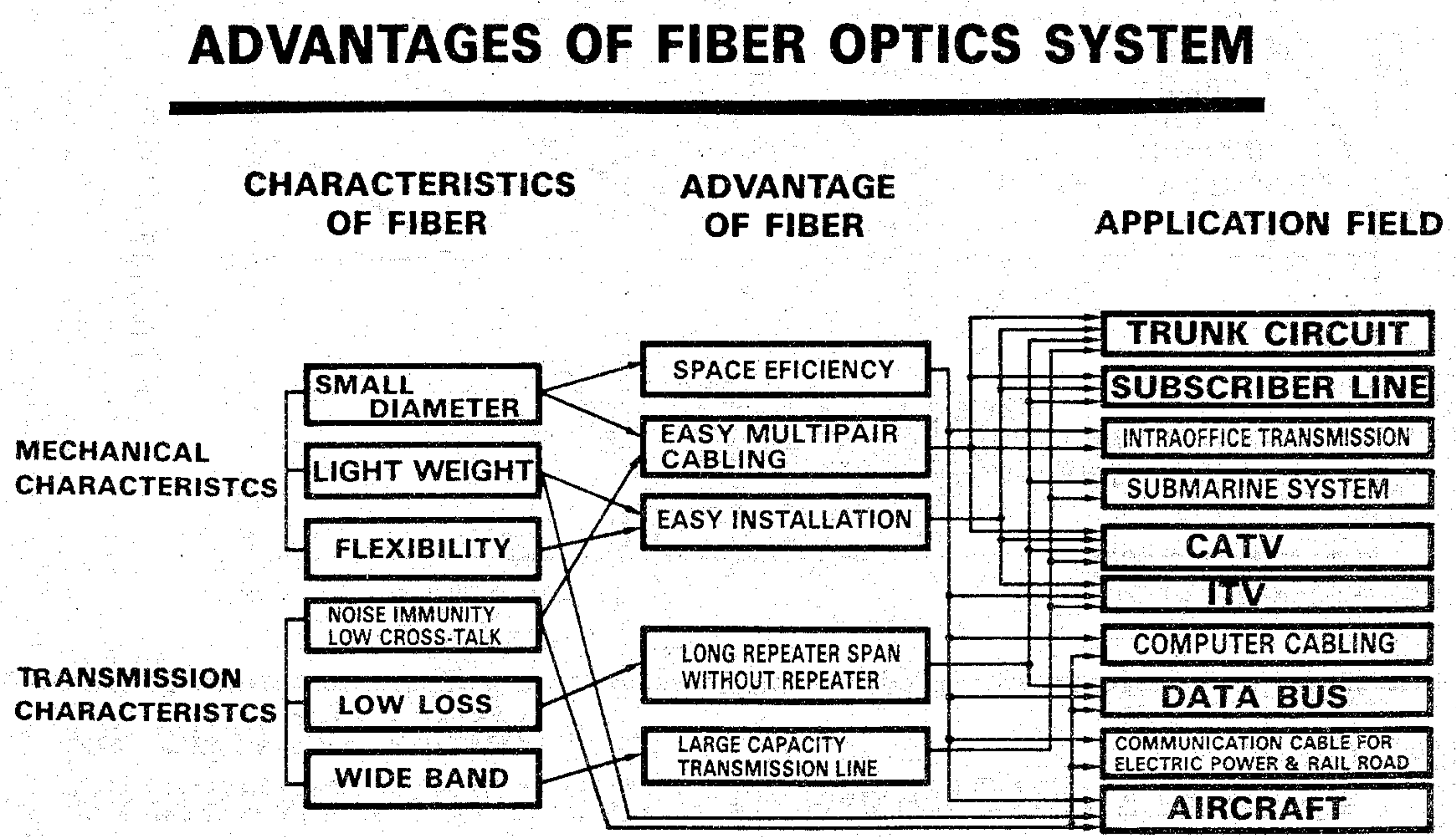
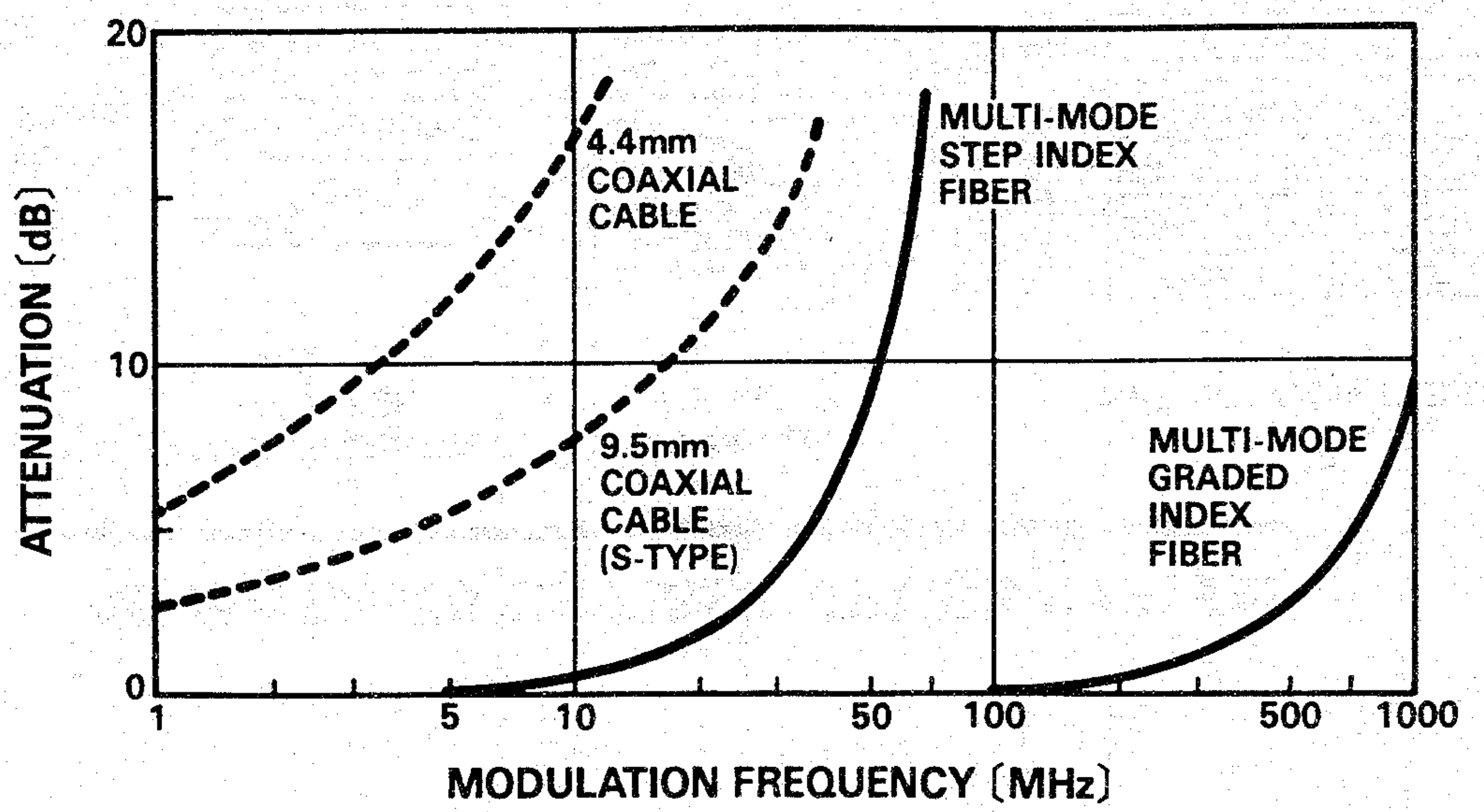


Fig. 13.1 Baseband transmission characteristics of optical fiber

BASEBAND TRANSMISSION CHARACTERISTICS OF OPTICAL FIBER



plentiful resource on earth.

13.4 Basic structure and classification

Optical fiber consists of core, high refractive index region in center, and clad, low refractive index region surrounding the core. In general, fiber outer diameter and core diameter are in the range of 100 to 300 μm and 50 to 100 μm, respectively.

Optical wave in fiber is propagated in the core, subjected by the principle of total reflection. In such a waveguide structure, the optical wave has specific discrete propagation angles, which are determined by the phase relations of the optical wave along and perpendicular to the fiber axis.

In general, the optical wave satisfying the relations is called "mode". Number of modes to be propagated in a fiber is determined by optical wavelength, refractive index difference between core and clad, refractive index profile in the core, and core dimension.

A fiber supporting only one mode is called a single-mode fiber, and that supporting plural number of modes is called a multimode fiber.

The multimode fiber is classified into step-index and graded-index types due to the difference in the refractive index profile in the core. The graded-index fiber with almost parabolic profile exhibits wide band frequency characteristics, because the propagation speed differences between modes are small for such a fiber. In single-mode fiber, only one mode can be propagated and the problem peculiar to the multimode fiber does not essentially occur. However, small core dimension of the single mode fiber causes the loss at the launch points into fiber from the light source and at the connection points between two fiber.

13.5 Light propagation in an optical fiber

Structure of fiber is shown in Fig. 13.2. The fiber is composed of two kinds of glasses; the core, in the center of fiber and the clad, in the outer region. It is essential that the refractive index n_1 of the core is larger than n_2 of the clad.

Light wave propagating in the core suffers reflection at core-clad boundary, when almost all of the light enters into a fiber. In Fig. 13.3 the incident angle of light A is assumed to be smaller than critical angle, therefore light A is confined, and propagated in the core by repeating complete

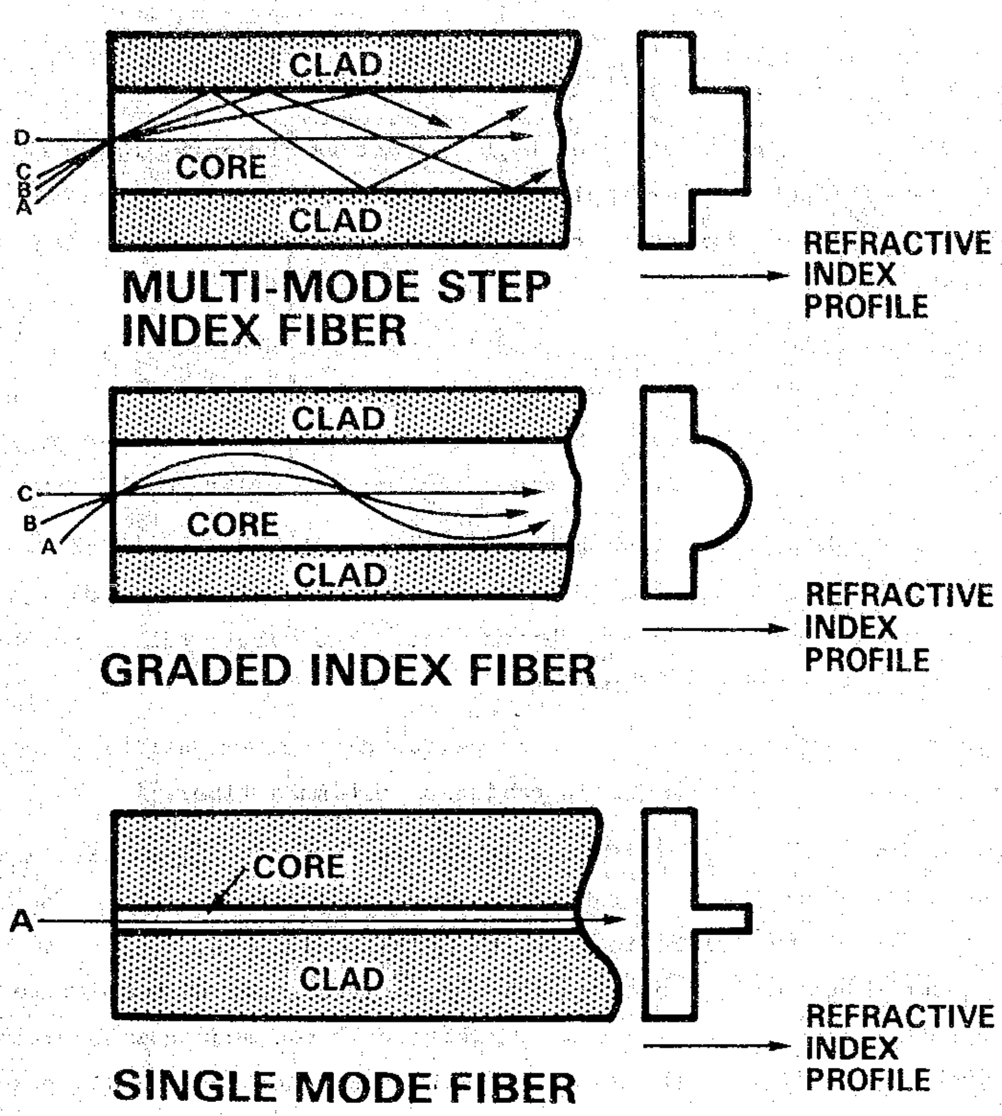


Fig. 13.2 Structure of optical fiber

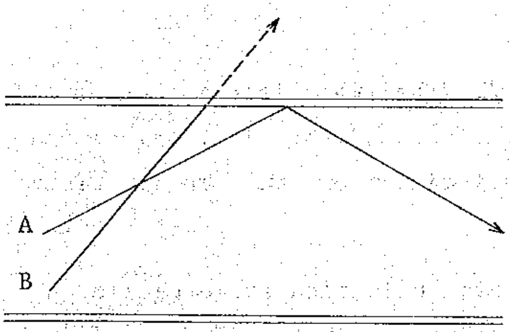


Fig. 13.3 Light reflection

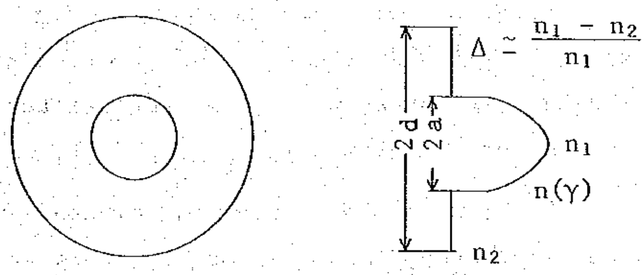


Fig. 13.4 Refractive index profile

reflection at the boundary surface. Light B, whose incident angle is larger than the critical angle, radiates out of the core and vanishes.

In Fig. 13.5 three kinds of propagation form are illustrated. In a step-index multimode fiber (1), many propagation modes exist. As the group velocity of the light going straight along an axis is faster than that of the light reflecting many times, modal dispersion occurs. This dispersion degrades transmission characteristics and widens pulse width. Graded index multimode fiber (2) is an improvement on step-index multimode fiber. Its refractive index is so made that it would to $\sqrt{1-X^2}$ distribution.

Such refractive index distribution reduces modal dispersion to a very small amount. This mechanism is as follows. A light which takes a propagation route far away from the axis (higher number mode), has to travel a longer distance.

When refractive index is smaller and group velocity gets further in a far away region, every mode has nearly the same group velocity and modal dispersions are diminished.

Mathematical analysis indicates that parabolic refractive index distribution is optimum to reduce modal dispersion.

Single mode fiber (3) permits only one mode to propagate. Therefore, in principle, no modal dispersion occurs and there is no signal degradation in a single mode fiber. This means that single mode fiber has potentiality to be an ultra wide bandwidth medium.

The diameter of single-mode fiber is very small, example 2 μm, compared with multimode fiber core diameter 40 ∿ 100 μm.

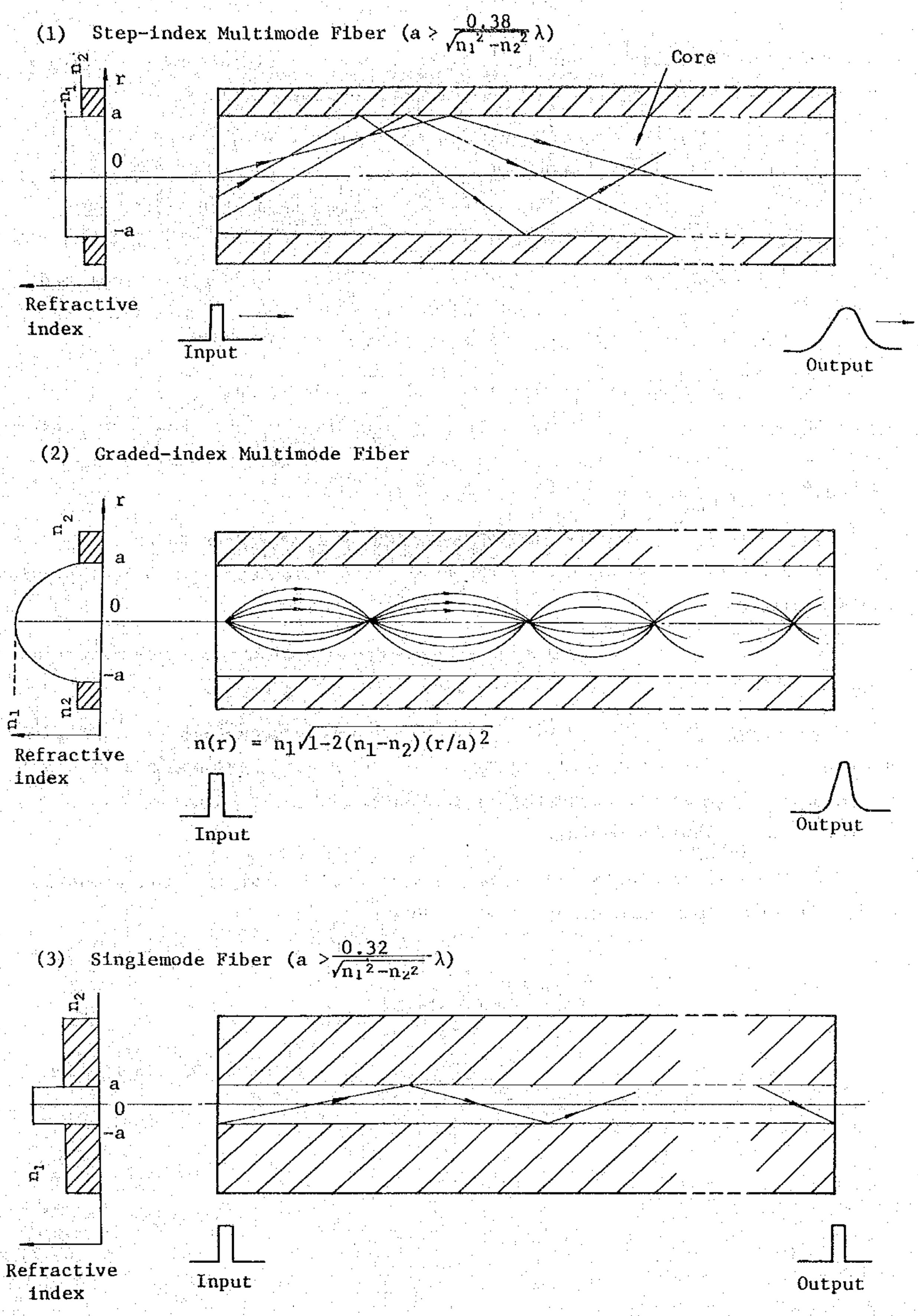


Fig. 13.5 Propagation mode in fibers

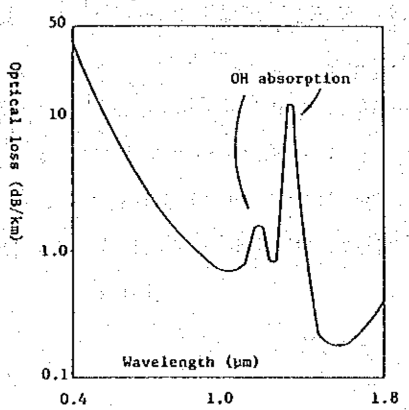
13.6 Transmission characteristics of optical fiber

The fundamental transmission characteristics of optical fiber are (1) the optical loss, (2) the baseband frequency response. The optical loss is classified into (1) intrinsic loss of the optical fiber, (2) loss due to fiber bending, (3) connection loss between fibers, (4) coupling losses between optical fiber and optical devices.

Optical loss in a fiber is caused by absorption of core-impurities, inherent scattering loss due to core material ununiformity (rayleigh scattering) and radiation loss due to imperfection of fiber structure. See Fig. 13.6.

Major absorption loss results from impurities, such as Fe, Cu and OH iron, included in glass material. However, thanks to high level techniques developed in semiconductor industry to purify material to the order of ppm or ppb (one part per billion), glass is also purified, like a semiconductor. Rayleigh scattering occurs due to microscopic fluctuation of the refractive index in the core, and the loss is inversely proportional to λ^4 (wave length).

Glass has inherent nonuniformity smaller than light wavelength and it scatters light. As the scattering loss (Rayleigh) is proportinal to λ^{-4}, it decreases as becomes larger. From this stand point, 1.0 ∿ 1.5 μm wavelength range is more desirable than that of 0.85 μm. Therefore, optical source and photodetectors which operate at 1.0 ∿ 1.5 μm range have been developed in many countries and will be adopted for optical communication systems.



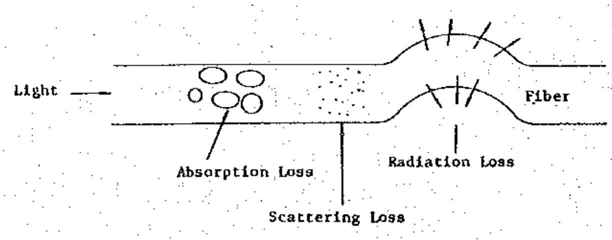


Fig. 13.6 An example of optical loss

13.7 Optical Loss reduction

The research on optical fiber cable in ECL began in 1971. It was one year after the fabrication of the 20 dB/Km fiber Cable at Corning Glass works. At first, the main research objective was multicomponent glass fiber, but it had gradually changed to research on silica glass fiber. Optical loss reduction, which is one of the most important problems, has drastically been promoted by the removal of impurities, progress in preform fabrication technique and so on. In 1976, multimode fiber, whose optical loss was 0.5 dB/Km (at 1.2 μm wavelength), the lowest in the world at that time, was realized. In 1979, single-mode fiber, whose optical loss was 0.2 dB/Km (at 1.55 μm wavelength), was fabricated. Fiber manufacturing technique applicable to actual transmission lines has been mostly established by the marked improvement in fiber parameter control and fiber strength, together to with optical loss reduction.

13.8 Optical fiber manufacturing

Several optical fiber fabrication methods are known. In the case of a silica fiber, Chemical Vapor Deposition (CVD) and Vapor Axial Phase Deposition (VAD) techniques are usually employed.

The CVD process, shown in Fig. 13.7, is as follow. At first, a cylindrical quartz tube is set between rotating edges. From one side edge carrier gas (Ar, N_2, O_2) containing main material ($SiCl_4$) and refraction control material (called "dopant"; for example GeCl, POCl and so on) flow through this tube. At the same time the tube is heated to 1,400 ∿ 1,700°C by a burner. Then, the dopants deposit around the inside the tube. After enough deposition, the carrier gass is stopped and the inner gas pressure reduces. The tube is heated up to 2,000°C to soften and collapse because of the atmospheric pressure. In this way a solid glass cylinder, a preform, a fiber is spun out by heating and pulling.

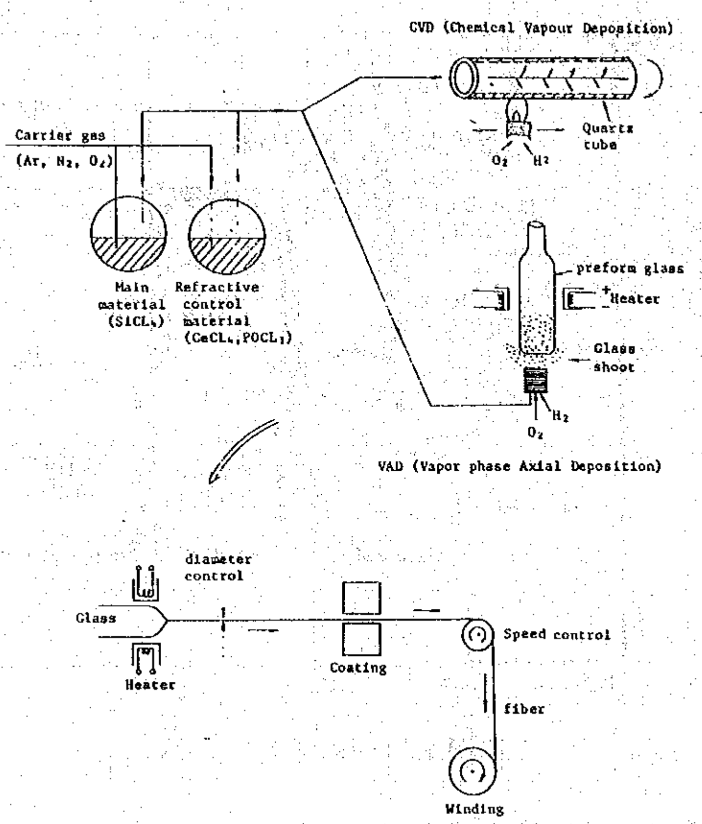


Fig. 13.7 Optical fiber fabrication

The VAD method has a little different process from the CVD process. Carrier gas, containing main material and dopant, are dissolved into "glass soot" by hydrogen and oxygen burner blaze. Soot deposit at the bottom of the standing rod increases, growing one layer after another. This process is very attractive because it enables making preforms continuously. (In the case of CVD, the preform length is limited to 1.0 ∿ 2 meters.) This soot preform is made transparent, through high temperature electric furnace. Fibers are easily obrained by pulling these preforms.

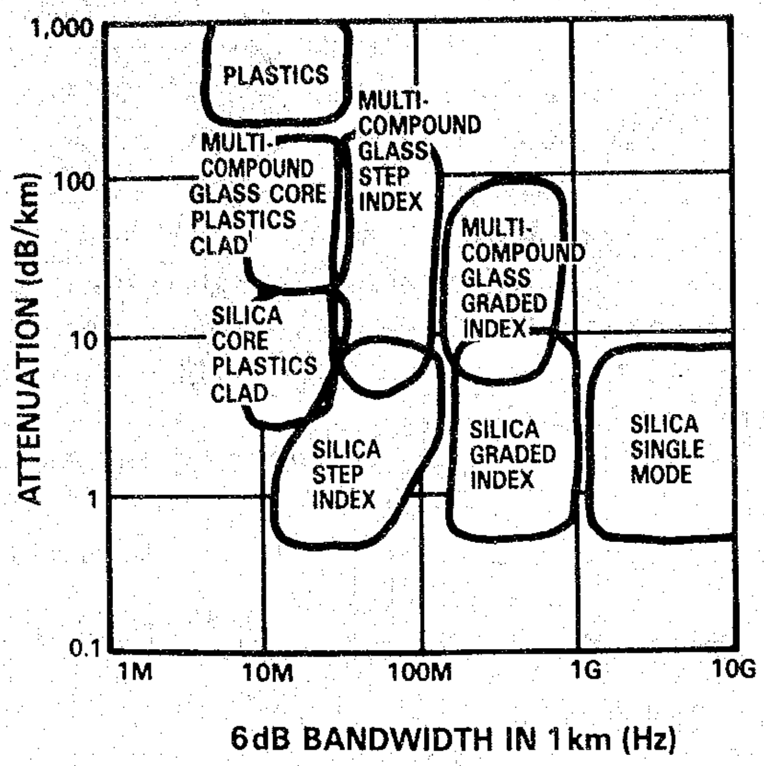


Fig. 13.8 Material performances in fields of optical fiber

13.9 Related techniques

Splicing, installation and measurement techniques in respect to optical fiber cable are necessary when constucting optical fiber transmission line and have been developed with the research on optical fiber cable.

13.9.1 Splicing techniques

Optical fiber needs precise splicing techniques, different from that for copper line.

Following splicing methods were mainly investigated:

(a) Two optical fibers are inserted into a V-groove or a sleeve so that their optical axes are matched end to end and are held in place by an adhesive.

(b) The ends of two optical fibers are heated and fused together.

The latter method (a fusion method) is foreseen to be best of the two in regard to long-term reliability. From this viewpoint a fusion splice machine has been developed and investigation has been made on the arc-fusion conditions, in laying stress on the fusion method. Consequently, the "pre-fusion" method was suggested making the splice loss and the failure rate lower. After it was confirmed that the pre-fusion method could be used practically in the first field trial, efforts were made to automate, miniaturize and lighten the splicing machine. A practical machine was completed, by which less than 0.1 dB average splice loss could be easily obtained.

Together with the development of the pre-fusion splicing machine, fiber cutting tool and splice protection have been investigated. For fiber cutting, a stapler shaped fiber cutter, utilizing controlled fracturing technique, was developed which made accurate fiber stub lengths suitable for splicing. A V-groove protector with a holding lid has been developed which was confirmed to be usable for making up a reliable splice.

13.9.2 Cable installation

Long cable installation, making the best use of the light weight and small diameter optical fiber cable features, greatly contributes to total splice loss reduction by decrease in number of splice points, construction work simplification and reliability improvement.

13.10 Coated optical fiber design

The diameter of an optical fiber coated with a primary coat for mechanical properties improvement, is nearly 0.2 mm. A secondary coat is necessary on the primary coated fiber for mechanical protection, reduction in external force influence and for handling ease. Plastic resin, which has good ability to withstand various environmental conditions and has no influences on optical fiber transmission characteristics, is chosen as a secondary coat material. A buffer plastic layer with a small Young's modulus, between primary coat and secondary coat, can reduce microbanding loss caused by secondary coat material shrinkage in the low temperature region below-20°C and radial stress during optical fiber cable installation.

13.11 Optical fiber cable design

13.11.1 Unit design

Various kinds of optical fiber cables have been proposed as follows; (1) A layer cable in which the coated fibers are stranded around a central strength member in one or two laters. (2) A unit cable composed of units in which individual coated fibers arranged in a layer around a central material. (3) A ribbon cable which is formed by optical fibers arranged in a flat packet.

It is found that a layer cable has very stable transmission characteristics and is superior to the others in regard to optical fibers contained in a small space and cable productivity, for less than 10 fibers. A flat ribbon cable has several advantages for mass-splice and is attractive for over 100 fibers.

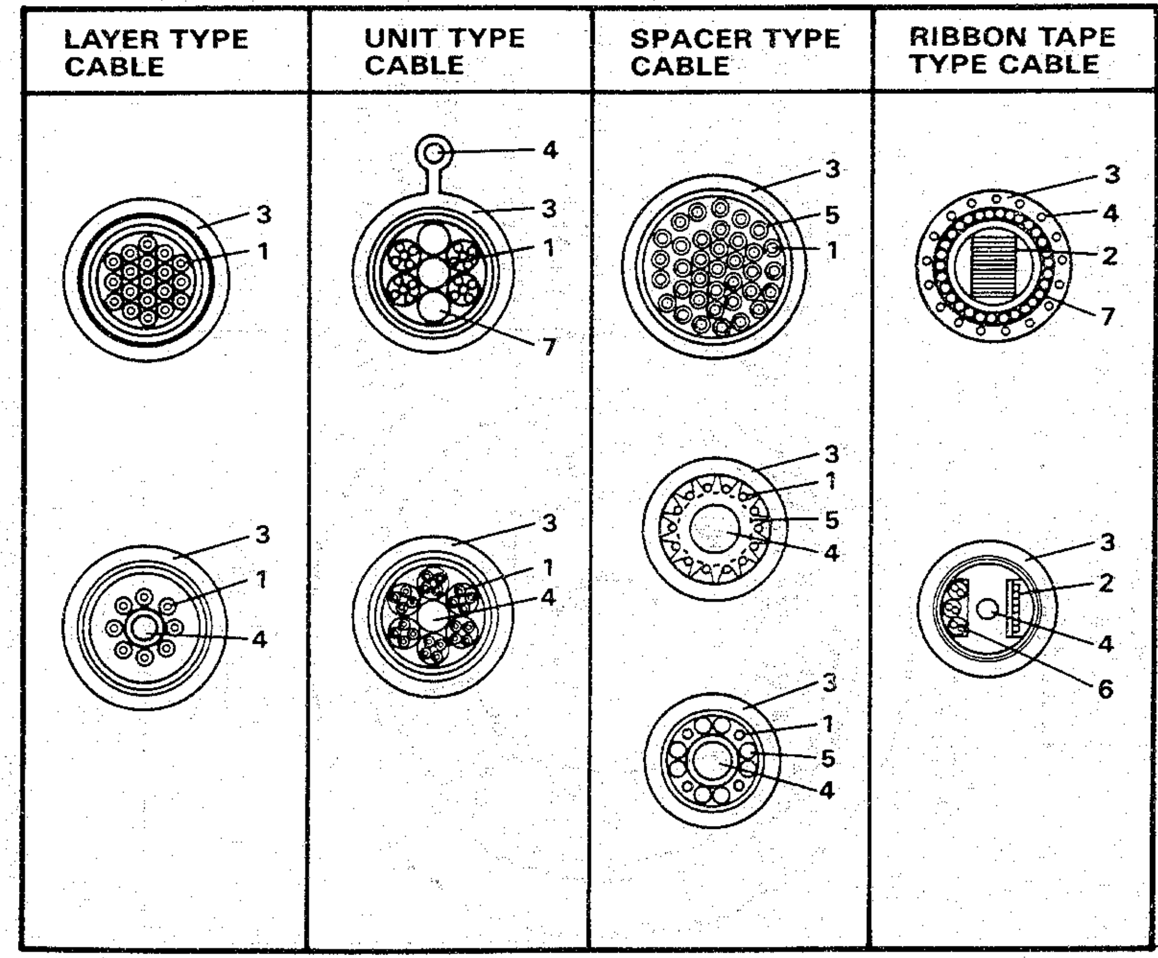
13.11.2 <u>Pulling tension and strength member</u>

Pulling tension on cable installation depends on the cable weight, installation length and installation environment. In optical fiber cable, it is desirable that splice points be as few as possible, because splice losses in optical fibers cannot be neglected.

It was decided to use 1 km as a standard installation length for optical fiber cable, taking into account installation technology and cable production conditions.

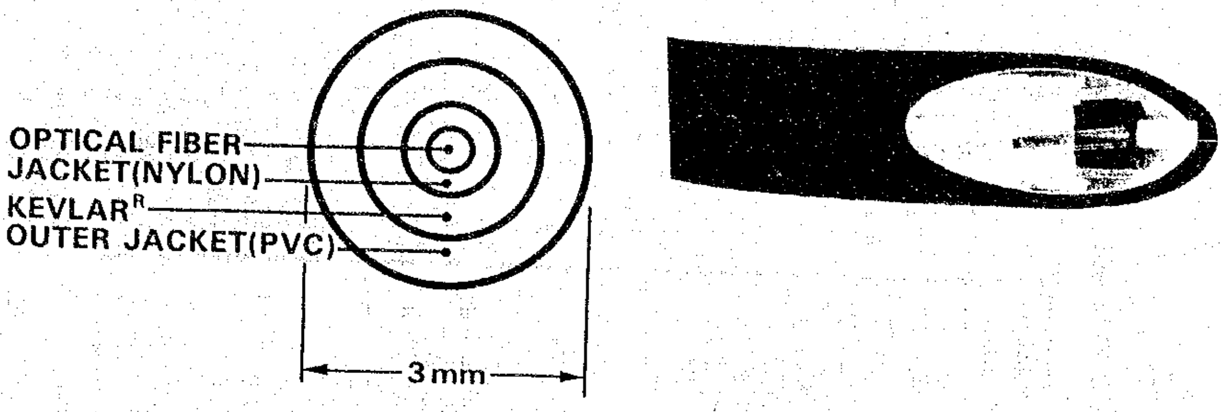
Pulling tension during cable installation in a duct is usually more than that in a tunnel or that in an overhead section, due to the friction bearing on the entire length of cable in the duct.

STRUCTURE OF OPTICAL FIBER CABLE

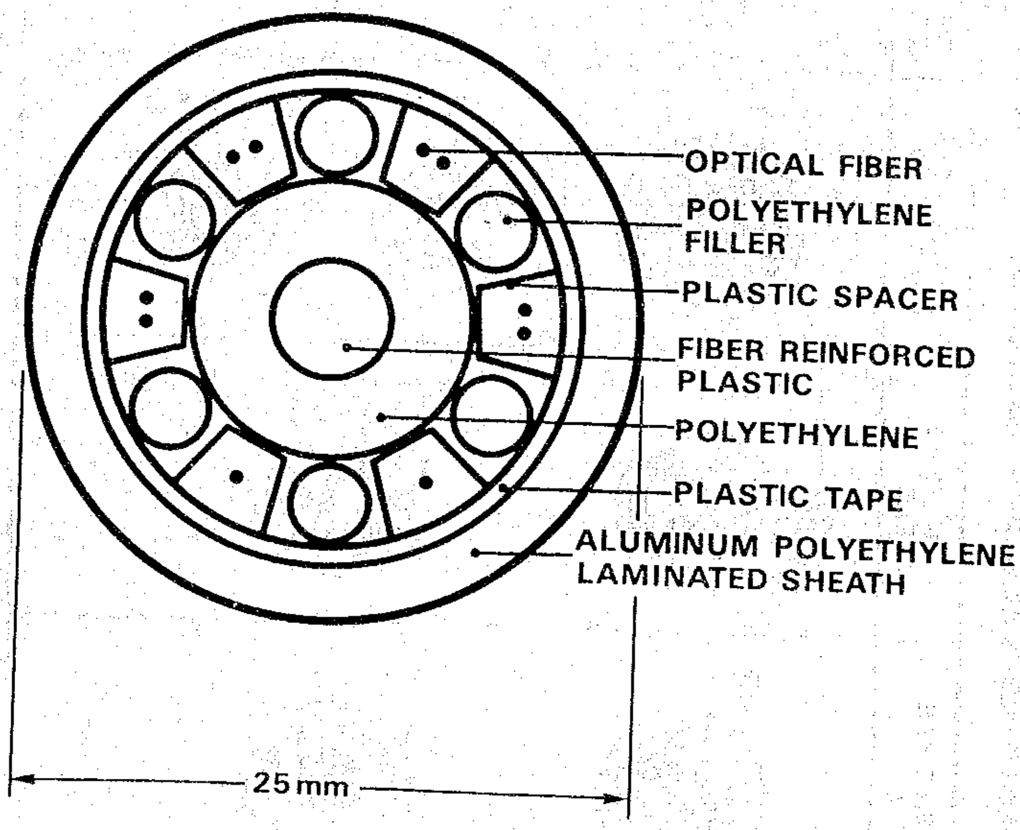


1 : OPTICAL FIBER, 2 : FIBER SHEET, 3 : SHEATH, 4 : TENSION MEMBER,
5 : SPACER, 6 : INTERSTITIAL PAIRS

SINGLE FIBER CORD



10 CORE FIBER CABLE



It is desirable that allowable pulling tension applied to the optical fiber cable be more than that corresponding to the 1 km cable weight, in order to safely install a 1 km cable.

However, it is difficult for this pulling tension to be distributed only among optical fiber units and cable sheath, considering the present fiber strength and longterm cable reliability. Therefore, a strength member is necessary. There are three strength member arrangement methods, as follow;

(1) In the center of the cable core. (2) Separate locations inside the cable core. (3) Outside the cable core.

Estimates of these methods, from the viewpoints of transmission characteristics, mechanical properties, splice workability and so on. A strength member had better be arranged in the center of the cable core.

13.12 Measurement technique

Optical fiber is entirely different from conventional metallic copper conductors and coaxial line, not only in respect to structure and materials, but also to the form of signal transmission. Therefore, quite new measurement technique and instruments are necessary for performance test during manufacturing or inspection of the product, and transmission characteristics measurement during construction and maintenance.

Measurement technique and instruments concerning the latter are described in this section. The main measurement items necessary to be estimated for optical fiber cable construction and maintenance, are considered to be optical loss (including splice), base band characteristics and fault location.

Chapter 14 OPTICAL FIBBER TRANSMISSION SYSTEM

In previous Chapter 13, Basic Optical fiber technology is described. This Chapter, Maximum merit of optical fiber developed through the optical Fiber Transmission System is discribed.

14.1 Configuration of transmission by fiber optics

Fiber optics can transmit only the signals, shaped of light, as on/off pulse of light (Digital Input) or gradual Change of Intencity of light (Analog Direct Input).

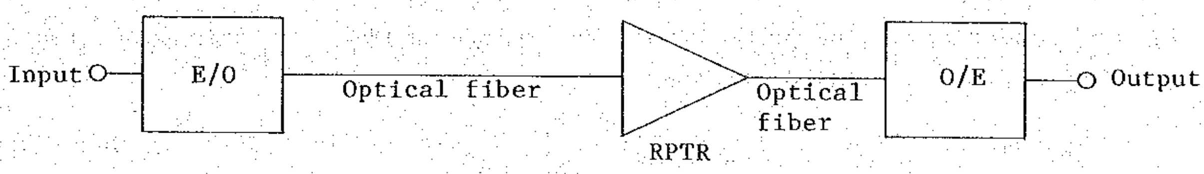


Fig. 14.1 Basic configuration of transmission by fiber optics

See Fig. 14.1, Signal Inputs connected with Any Electric Signal resources, is converted into optical signal by E/O converter, then the optical signal is transmitted through optical fiber, if long distance Repeater (consisting of O/E, AMP, E/O) is required to recover the attenuated signal, reaches to O/E Converter, which transform the optical Signal into Electric Signal, and is delivered to Output devices.

14.2 Light source and detector

14.2.1 Light emitting diode (LED)

The electroluminescent radiation from an LED is incoherent and arises from the p-n junction of a semiconductor diode. A basic measure of the use-fullness of such an incoherent source for optical communication application is its radiance (or brightness), as measured in watts of optical power radiated into a unit solid angle per unit area of the emmiting surface. Another important consideration is its emission response time, which limits the band-width with which the source can be modulated directly by variation in the injection current.

An asset of the LED is the ease with which it can be directly modulated by analog signal, as compared with lasers.

This is because the relationship between the out putpower and the input current is linear over a usefully wide range.

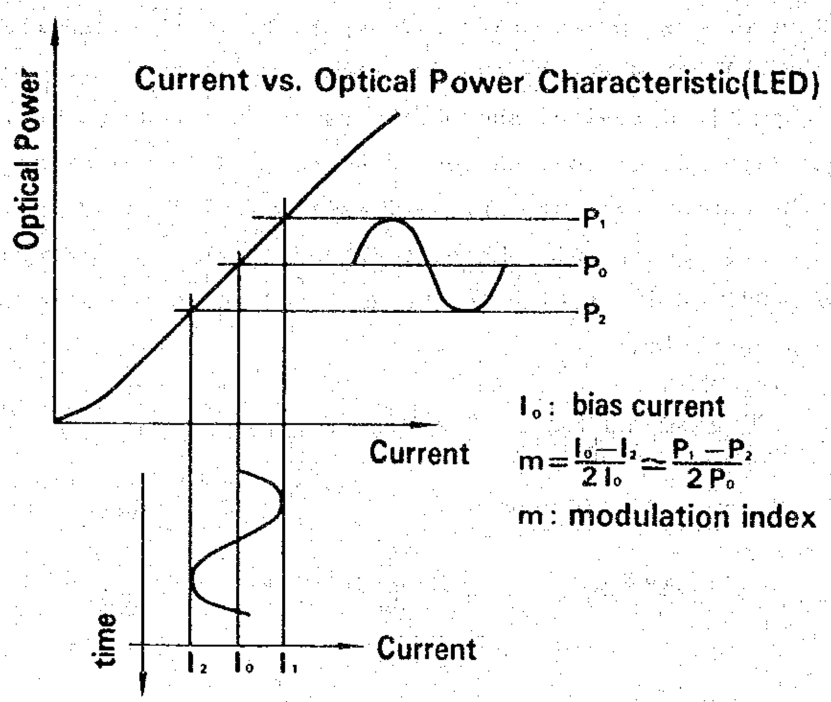


Fig. 14.2

14.2.2 Injection lasers

Among lasers of all types, the semiconductor injection laser is exceptionally well suited for optical-fiber transmission. Some desirable attributes are that it is physically small, inherently rugged, highly efficient, and can be pumped and modulated simply and directly by means of the injected current. The reliability of lasers is the most important problem and the key point of the optical fiber communication system development. Injection laser life time achieved more than 5×10^4 hours and is getting longer.

Above mentioned injection lasers are used at about 0.8 μm wavelength, which is called the first fiber window. However, it is necessary that another laser work at the second fiber window, 1.2 ∿ 1.3 μm wavelength, and the third fiber window, 1.4 ∿ 1.6 μm. For this wavelength region, for example. In GaAsP LD and APD have been developed.

14.2.3 Detectors

Photodiode Detection Process

The photons absorbed in a detector generates, through band-to-band transmissions, electron-hole pairs which are separated in the high-field depletion region and are collected across the junction. While the carriers are moving through the high-field region, photocurrents are induced in the load current. For low-level light detection, photodiodes are usually operated with reverse bias, where the output current varies linearly with incident light intensity. A relatively large reverse bias helps to reduce carrier drift time and diode capacitance. Carrier drift time in the depleted region need to be kept short for high speed operation.

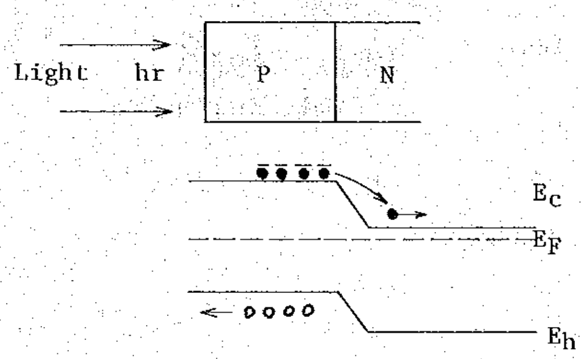


Fig. 14.3 PN Junction

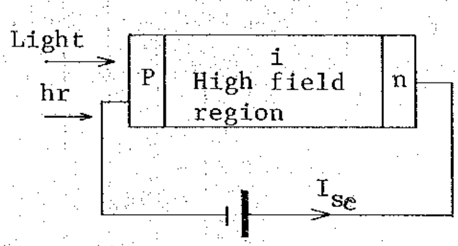


Fig. 14.4 PIN Diode

14.2.4 Avalanche photodiodes (APD)

Avalanche photodiodes combine the detection of optical signals with internal amplification of the photocurrent. The internal gain is realized through avalanche multiplication of carriers in the high-field region of a highly reverse biased junction, where photocarriers gain sufficient energy to create new electron-hole pairs through impact ionization. High gain is achieved by taking special precautions to assume uniformity of carrier multiplication and to avoid microplasmas and excessive leakage currents. Gain-handwidth products between 20 and 100 GHz have been reported for various silicon and germanium avalache photodiodes. And latest development in this field, Ga (Gallum), In (Indium), As (arsenic), P (phosphorus)' semiconductors are used.

Avalanche diodes require power supplies of moderately high voltage (a few hundred volts) and stabilization of gain against temperature variation.

Comparison of light source and detector

Light source

	Optical output	Linearity	Band-width	Applications
Laser DIODE	Large	Good	Large	Long haul transmission analogue pulse modulation
LED	Small	Excellent	Small	Short haul transmission direct modulation

Light detector

	Receiving sensitivity	Linearity	Application
PIN-PD	Good	Sufficiently good	Short haul transmission
APD	Excellent	Sufficiently good	Long haul transmission

OPTICAL BI-DIRECTIONAL TRANSMISSION SYSTEMS

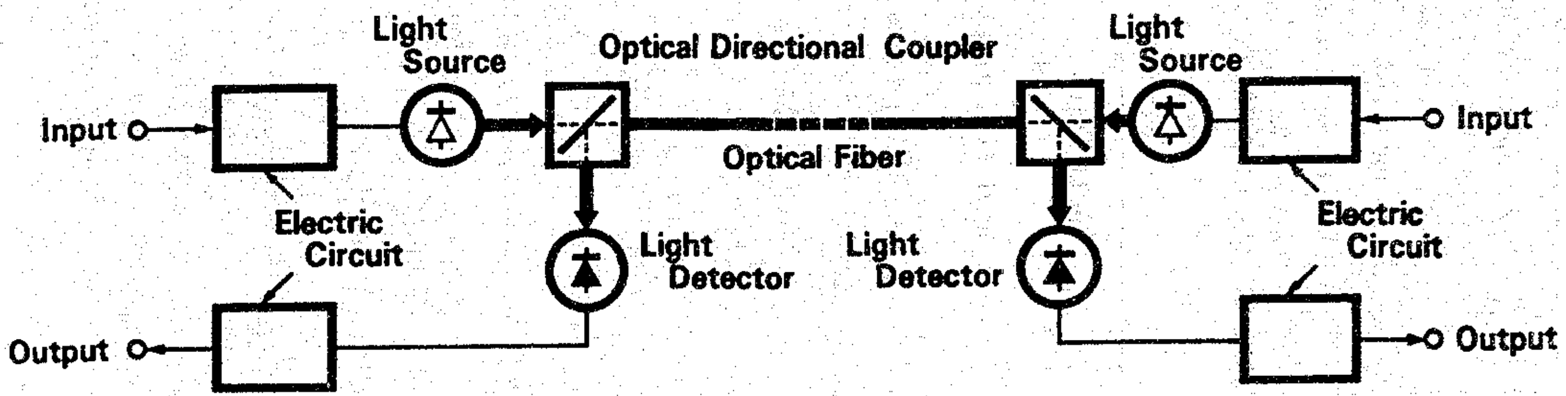


FIG 14.5 Directional Coupler Method

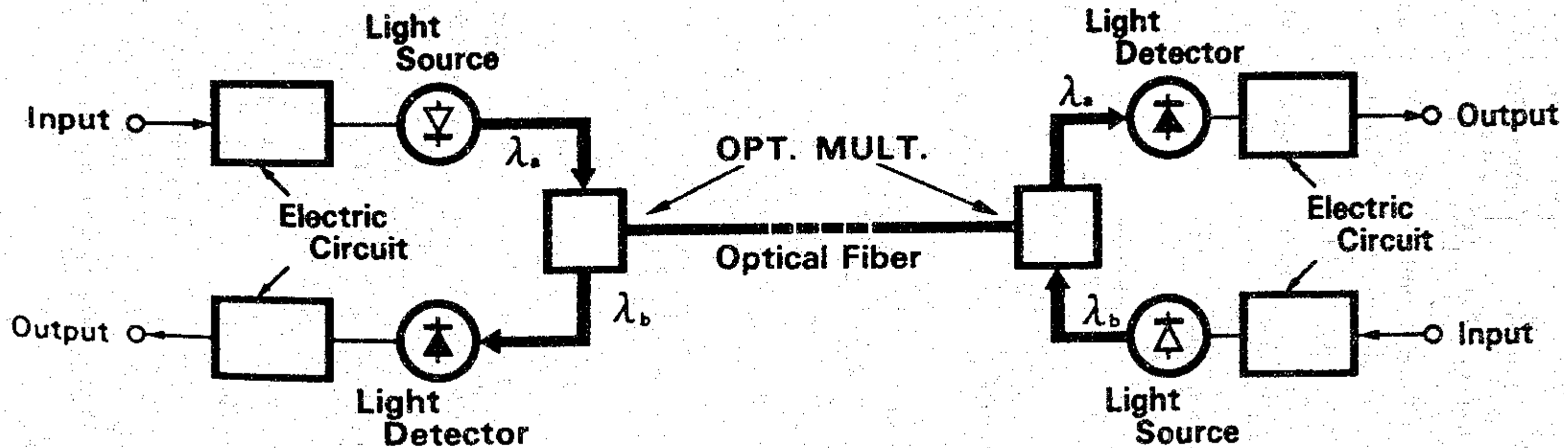


Fig. 14.6 Wavelength division multiplex system

14.3 BI-Directional transmission systems

An Optical Cable has usually more than one pair fibers, and the pair fibers are used for each direction communication, as A for sending, B for receiving. But See Fig. 14.5 and Fig. 14.6 one optical fiber can be used for both direction through Optical Directional Coupler (physically separated), or through Optical Multiplexer (different wavelength detector).

14.4 Optical analogue transmission

The Input signal are modulated by Modulator, through E/O convertor, the Electric signals are converted to Optical Signals and travels through optical fiber, if necessary RPTR (Optical Signal Repeater) amplifies or regenerates the signals, then through O/E converter, optical signals converted into the Electric Signals and Demodulated by DEM and handed over to Output devices.

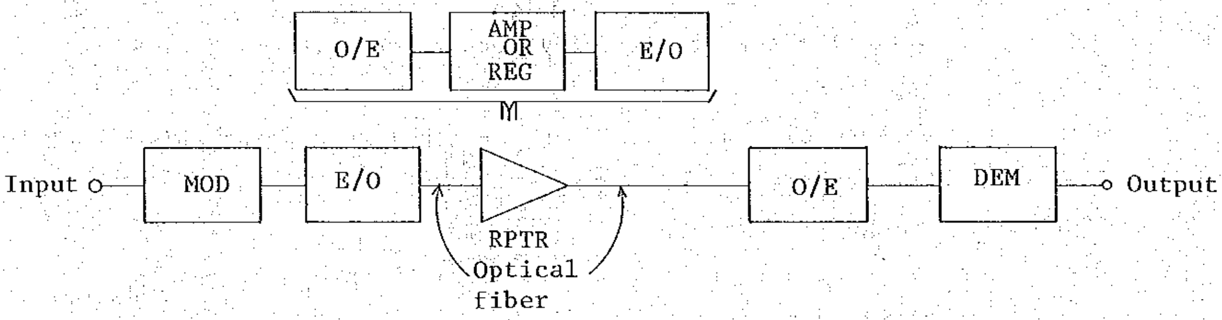


Fig. 14.7 Configuration of analogue transmission by fiber optics

14.5 Modulation method for analogue transmission

Following modulation can be applied for Analogue Transmission by Fiber Optics.

IM	:	Intensity Modulation	TV/multiplex transmission
PPM	:	Pulse Phase Modulation	Suitable for multiplex transmission
DPPM	:	Differential Pulse Phase Modulation	
PWM	:	Pulse Width Modulation	
Pulse FM:		Pulsed	
PFM	:	Pulse Frequency Modulation	Suitable for TV
PNM	:	Pulse Number Modulation	
PIM	:	Pulse Interval Modulation	

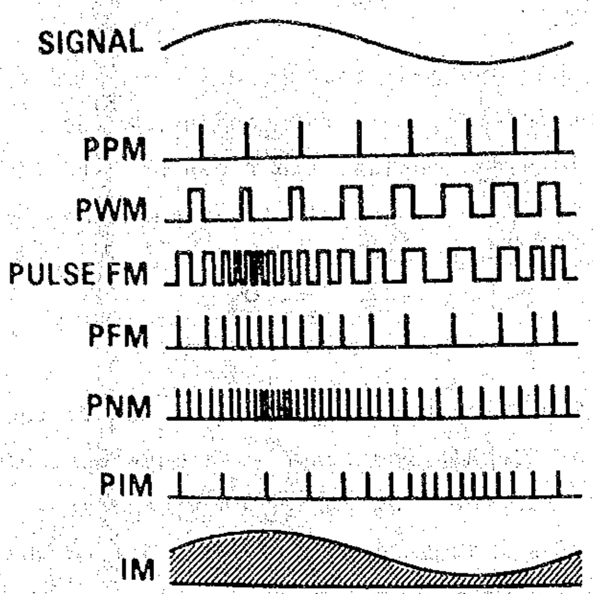


Fig. 14.8 Modulation method for analogue

AT, Electric Signal stage, original Signal Amplitude information are converted into pulse position, pulse width, frequency, Pulse Interval, and pulse Number etc. then modulated into optical pulses and Transmitted.

PPM: Pulse Interval is directly proportional to original signal amplitude.

PWM: Pulse width is directly proportional to original signal amplitude.

PULSE FM : Sliced FM Modulation.

PFM: Pulse repeating Frequency is directly proportional to original signal amplitude.

PIM: Square of pulse Internal is directly proportional to "

PNM: Numbers of pulse per unit is directly proportional to "

14.6 Digital transmission system by fiber optics

In Digital method, Analogue signals are converted into binary signal and Band width compressed by PCM (Pulse Code Modulation), DPCM (Differential PCM), or Intraframe Coding then Multiplexed, converted from electrical Signal into optical signal then transmitted through optical fiber and converted into Electric Signal again, Demultiplexed, Decoded in case of Analogue signal, handed over each Terminal Equipment. See Fig.14.9.

For Multiplexing following two method are command in the world. Fig. 14.10 shows Japan, U.S.A's PCM Hierachy, Fig. 14.11 shows Europe's PCM Hierachy.

CONFIGURATION OF DIGITAL TRANSMISSION SYSTEM BY FIBER OPTICS

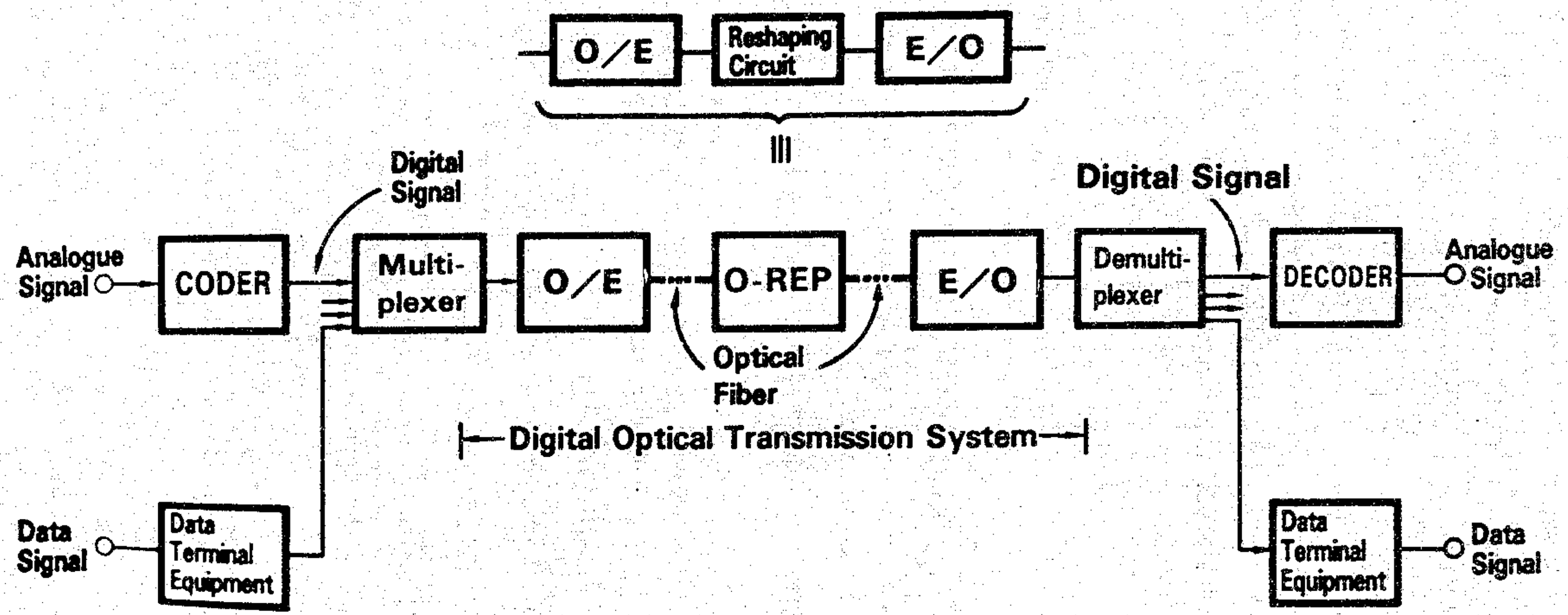


Fig. 14.9

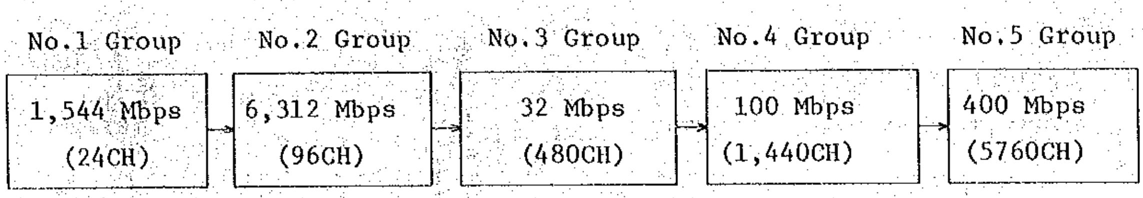


Fig. 14.10 PCM Hierachy (Japan, U.S)

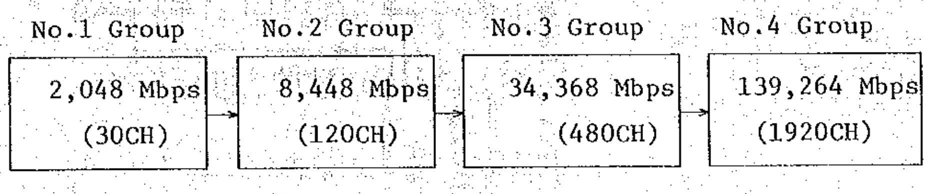


Fig. 14.11 PCM (CEPT) Hierachy

14.7 Wave-length division multiplex (WDM) system

WDM system can transmit different wavelength lights through a optical fiber simultaneously.

WDM system has following merits and demerits.

"Merit"

1) It is easy to select the modulation mode in each carrier , corresponding to the Original Signal Characteristics.

2) Each Carrier is not required to have always wide band characteristics

3) Each Carrier's power can be occupied respective Original Signal.

"Demerit"

1) Light Sourcers and Light Detectors are required in each wave length.

2) Light Coupler, Light separators are required.

DIGITAL TRANSMISSION SYSTEM AND OPTICAL FIBER TRANSMISSION (CEPT Hierarchy)

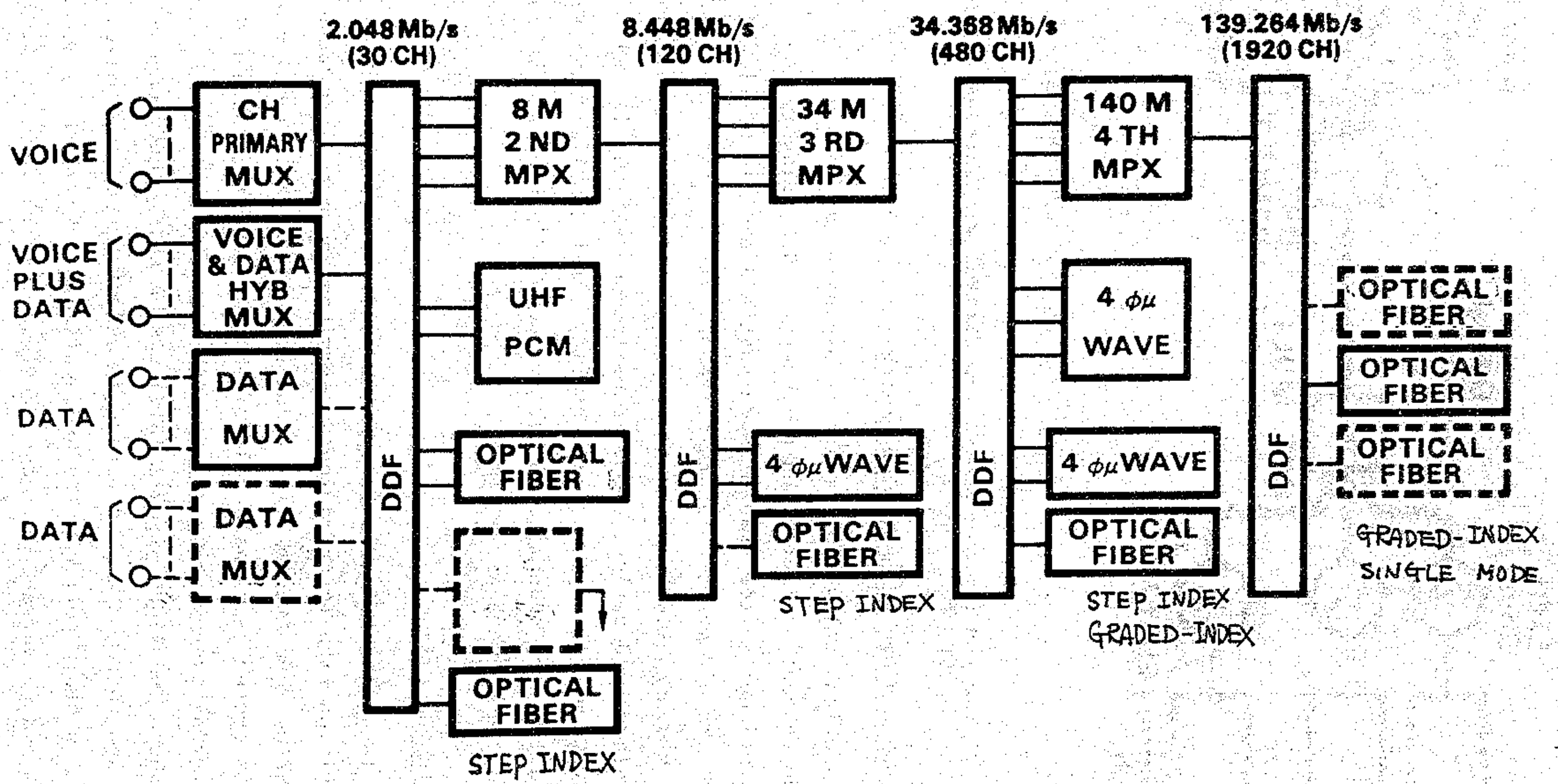


Fig. 14.12

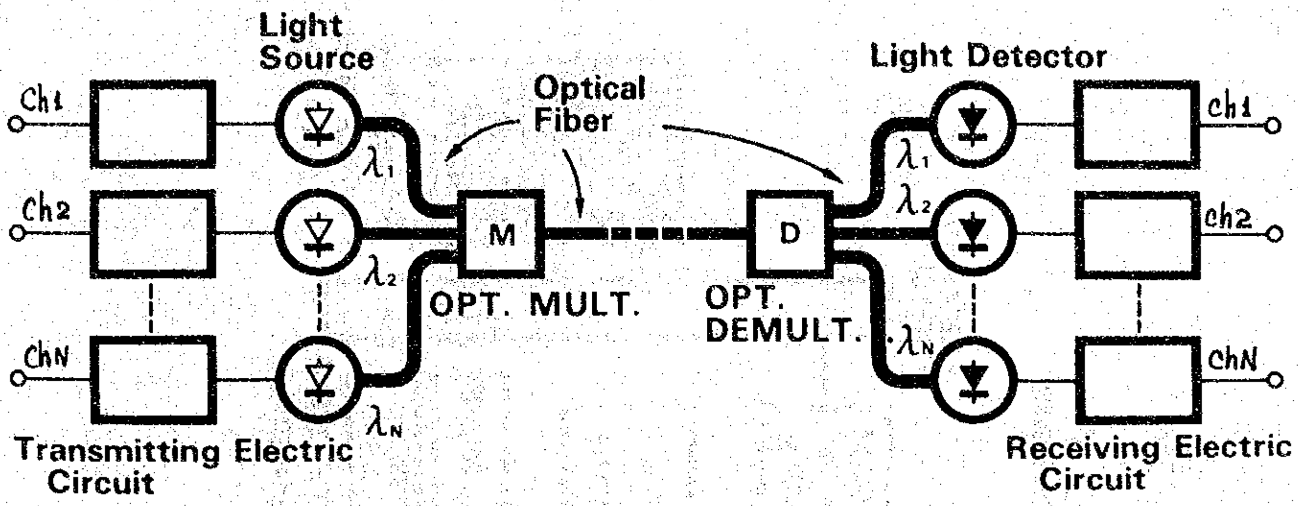


Fig. 14.13 WDM system

At the end of this chapter, a digital video transmission system is shown.

14.8 New video transmission system (Example)

Various television signal transmission systems have been introduced in Japan to meet an increasing demand for video transmission service. However, conventional system transmission cost and picture quality do not satisfy the user's requirements. For this reason, NTT has been developing video transmission systems, video codecs (coder and decoder) utilizing bandwidth compression techniques and optical video transmission systems, in order to offer the video services at low cost and high quality. This article describes the recent trend in video transmission systems using fiber optic transmission systems and video coding methods.

1. Introduction

The Closed Circuit Television (CCTV) and video conference service, as television signals transmission services, have been furnished in Japan. Hitherto, when transmissing video signals, such as Industrial Television (ITV), ITV-4M system using balanced-pair cable, Vestigial Sideband-Amplitude Modulation (VSB) system using coaxial cable and Simultaneous Transmission System for Telephone and Video Signals (STV) system using lower-band microwave are used. Although there is a good latent demand of actual implementation because conventional system cost, quality and application domain have not been sufficiently developed to warrant introducing video transmission services. It is assumed possible to satisfy there conditions for realization of new services, such as the Video Response System (VRS) in the future.

Recently, however, innovative technologies, such as fiber optic transmission system and video coding methods, which have overcome the limitations of usual systems, reached the practical stage. Optical fiber transmission systems with wide bandwidth, high-capacity and low-loss performance are a boon to video transmission services. For this reason, optical fiber transmission systems are economically introduced in most domains from subscriber lines to toll trunk lines. On the other hand, video coding methods have remarkable progress with rapid improvement in digital devices, such as digital IC, LSI and others, video coding methods are necessary to reduce the cost of a long distance video transmission.

This article describes the recent trend in video transmission systems, using optical fiber transmission systems and video coding methods.

2. Video coding method

Digital video transmission systems with bandwidth compression techniques have an advantage over analog systems in transmitting video signals economically.

For the video signal with a 4 MHz bandwidth, assuming the video signal occupies 1,500 telephone channels in an analog system is translated into digital hierarchical levels (1.5, 6.3, 32, 100 Mbit/s) in a digital system. NTT has been researching video codes. Already, some codecs have been put into commercial use.

2.1 Coding methods

In this section, the general aspect of video codes (coder and decoder) are discussed.

The basic configuration of the video codec is shown in Fig. 2. The video codec is composed of analog-to-digital (A/D) or digital-to-analog (D/A) converter as analog interface, digital-to-digital (D/D) converter for bandwidth comparison (compression and expansion), and digital interface circuit for matching trnsmission line.

In the encoder, an imput analog signal is translated into 7 - 9 bit/picture element (pel) PCM signal by A/D converter at about 10 MHz sampling rates. The digitalized video signal bit rate (bandwidth) is compressed by D/D converter utilizing a coding method to reduce video signal reduce video signal redundancy.

Digital interface circuit has buffer memories to enable transmistting at constant bit rates, when information arrives unequally from the D/D converter. Moreover, error correction is employed in this circuit, because the more the redundancy in the information is reduced, themore easily the picture quality is degraded by digital error caused in transmission line. In addition, digital signal scrambling is employed to inhibit sequential zero signal appearance in transmitting coded signal.

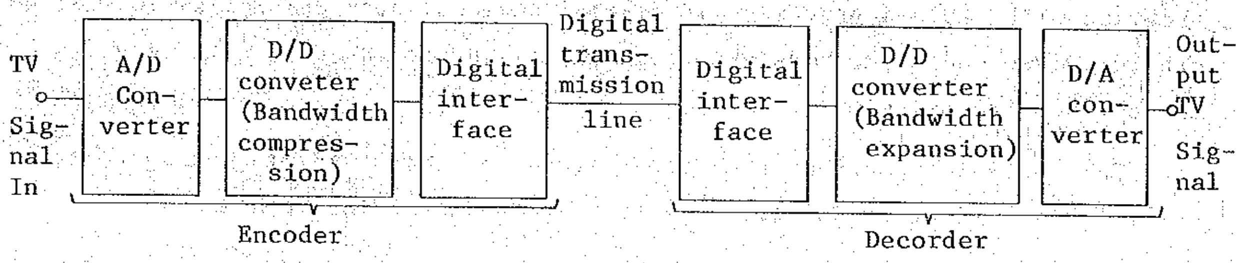


Fig. 14.14 Configuration of coding system

Video coding methods, used at the D/D converter for reducing bandwidth are as follow.

(1) PCM Coding

PCM (Pulse Code Modulation) coding consists of sampling the waveform (usually at Nyquist rate) and quantizing each sample using N levels. N is usually taken to be a power to two (i.e. N=2B). 8 is chosen for the B value in most cases. Since the PCM coding is the simplest one, it is the most economical method and has the least picture quality degradation. However, it has a disadvantage of high transmission bit rate and high transmission cost.

(2) Predictive coding

In predictive coding systems, the prediction of the sample to be encoded is made from previously coded information. The error resulting from subtraction of the prediction from the actual value of the sample is quantized into a set of discrete amplitude levels. These levels are representated as binary words of either fixed or variable word length. The predictive coders have three basic components: a) predictor, b) quantizer and c) code assigner. Depending upon the number of quantizer levels, distinction is made between delta modulation (DM) (N=2) and differential PCM (DPCM), which has an N greater than 2.

Predictive coding is usually classified depending on the location of previous samples used for prediction. Intraframe coding uses the samples in the same frame. One-dimensional prediction of intraframe coding uses previous samples in the same line of the video-sognal, and two-dimensional prediction uses samples in the previous frames. Interframe coding has a disadvantage in reappearance of higher motion video signals, because there is less correlation between the present sample and the previous frame samples.

(3) Other coding methods

(A) Interpolative coding

A subset of picture elements is transmitted and remaining pels are interpolated. For example, in 2:1 sub-sampling picture elements are transmitted every other sample and staggered from one line to the next line. The picture elements omitted are interpolated by averaging the value of the nighboring picture elements.

(B) Motion compensated coding

Motion vector, which tracks the object movement from one frame to the next frame, is transmitted. It is expected that the transmission bit rate can be reduced 1/2-1/3, in comparison with interframe coding.

Other coding methods, such as transform coding, block coding bit-plane coding and so on, were studied for still picture transmission.

Moreover, there are two ways to enclode a color television signal. One is component coding, by which divided color video signal components, luminance signal and two chrominance signals, respectively, are encoded. The other is composite color video signals are encoded collectively.

In practical systems, some coding techniques are chosen from above-mentioned classification and combined in order to fit for the purpose.

Some video codecs, using intraframe or interframe coding methods, have been pit into commercial use as a result of progress in device technologies, especially analog/digital converters and ISI memories. In the future, economization of equipment cost will be expected through further improvement in device technology, that is LSI and VLSI devices for coding television signals.

2.2 Video codec corresponding to service

There are many kinds of video transmission services. The coding methods application depends on the future standardization on the basis of required quality and transmission cost.

(1) Broadcasting television

For transmitting broadcasting television signals, PCM linear coding at the 100 Mbit/s rate and intraframe coding at the third-stage digital hierarchy rate (32 Mbit/s in Japan, 34 Mbit/s in Europe and 44 Mbit/s in North America) have been investigated in several countries. In intraframe coding, most codecs employ two-dimensional prediction and composite coding because of its high quality and simple configuration. Further study is required to firm up the international standard for coding a broadcasting television signal.

(2) Closed circuit television (CCTV)

It is necessary to reproduce motion pictures closely for CCTV, such as ITV service. Moreover, picture quality must meet ITV standards and transmission cost must be reduced sufficintly for long-distance ITV services. Intraframe coding, using one-dimensional prediction and composite coding method at 32 Mbit/s, is preferable for ITV service because picture quality degradation in motion pictures is inconspicuous and system configuration is simple and low cost.

(3) Video conference

In this case, it is possible to greatly reduce video signal redundancy, because motion is slower in video conference than in ITV. In addition, it is possible to lower the rate per hour, even if equipment cost is expensive, because one long-haul trunk is used in common by plural number of subscribers in video conference service. Under this condition, interframe coding at 6.3 M bit/s, for example, TRIDEC, etc., is applied.

Furthermore, 1.5 Mbit/s codec, utilizing interpolative coding or motion compensated coding, has been studied to further economize the transmission cost.

3. Fiber optic video transmission technology

3.1 Video transmission systems using optical fiber cables

Optical fiber cables have superior performance, such as wide bandwidth, low loss, good cross-talk ratio and no induction, in comparision with both balanced pair cables and coaxial cables. So, optical fiber cables might be an ideal transmission media for wide bandwidth signals, such as television signals. There are both analog and digital video transmission systems using optical fiber cables. Analog transmission systems include Direct Intensity Modulation system (D-IM), and Pulse Frequency Modulation-Intensity Modulation system (PFM-IM). Digital transmission systems include Pulse Coding Modulation Intensity Modulation system (PCM-IM) and differential PCM system, which is combined intraframe prediction codec and digital optical fiber transmission system, such as F-32M and F-100M system. The above mentioned optical fiber transmission systems also include short and long wavelength, according to applied optical wavelength.

3.2 Practical use of optical video transmission systems

PCM-IM system has already been put into commercial service. The DIM system, using LED and Wave Length Division Multiplex (WDM) was put into practical use at Kobe Port island Exhibition in 1980. The DIM system using LD field trial was completed in 1979, respectively. Furthermore, NTT has been carrying out multiple research effort on optical fiber transmission system. As a result, the F-32M and F-100M system, which are digital fiber optic transmission systems with 32 Mbit/s and 100 Mbit/s bit rates for intra-city and short-haul intercity trunks, respectively, have been developed and put into commercial use in 1981. The F-400M system, which is a 400 Mbit/s digital transmission system for long-haul intercity trunks, will be introduced into NTT's networks in 1983. By applying picture bandwidth compression coder to these digital fiber optic transmission systems, it is possible to realize economical video transmission systems.

Chapte 15 LOCAL AREA NETWORK

"Personal Computer is "the small GIANT". The innovation by Micro Computers and VLSI technologies is rapidly spreading to the world from Japan "20th Centuries Miracle" and U.S.A. The Auther recommends here to Developing Country's Authority that, it is better not to buy General purpose Computer, or rather large size Computers in each organizations for General purposes. Because now the personnel Computers is so much powerful. The hard-ware, soft-ware of the personal computer developments have been carried out to meet the computer needs for rather medium or small enter-prizes. See the Fig. 15.1, Reader can easily understand from this figure that the personal - computer's production growth is so rapid, and proving such as low costs, highly reliable, spare parts availability, easy handling, etc. through the Automation, mass production technlogy of the countries.

"Word processor" is a microcomputer built-in typewriter with Large Quantity of Memories, with additional functions of automatic error correction, easy to make multi address text duplicated letters, keeping quite large volume of files, easy reproduction of a new letter with the help of old letter file etc.

"Personal computers, nearly costs $1,000 - 4,000, are being used several hundreds in some business company in Japan.

"Digitalized Facsimile" has been introduced, instead of Telex and telephone communications, and can sent one page of letter or picture, or both mixed, within 2 to 10 seconds.

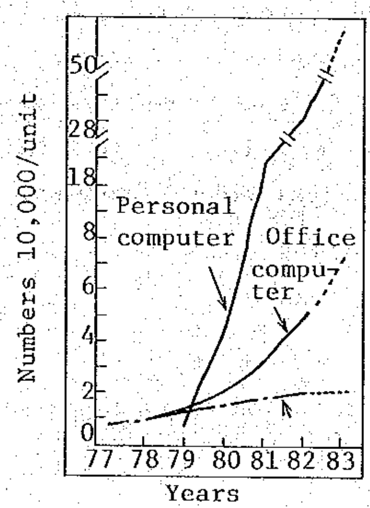


Fig. 15.1 Productions of computers yearwise in Japan

In view of the current advances in office automation (OA) networks will be a vital necessity in the future. The author, in order to develop an appropriate policy or guidance in this field has felt, therefore the necessity to carry out research on office automation networks. The studies will be based on local area networks (LAN) and lectronic private branch exchange (FPBX).

At the present time, word processors, office computers, facsimile and other office machine (computer aided graphic drawing machine, copy machine, electronic mail etc.) are being introduced at random into the world of industry, government office to increase efficiency. This alone, however, is not sufficient to improve the flow of information. It will be necessary to systemize the flow by linking up office machines in a network, using LAN and EPBX.

In this chapter the functions required of OA networks, system structure, connection with public telecommunications networks, and OA networks are explained.

15.1 Classify of Local Network

Local Network can classify into three groups as follows.

1.1 Form of Network

a) Bus (Ethernet, Net/one, Z-NET, OMNNET, ARC Network, WANGNET)

b) Ring (Loop 6530, Loop 6830, Shigumanet, H-8644 loopnet F2881, F2883)

c) Start style

d) Tree style (BRANCH 4800)

1.2 Transmission media

a) Coax cable (Ethernet, Net/One, Z-NET, ARC NET)

b) Optical fiber (Loop 6530, Loop 6830, Shiguma-net, H-8644-Loopnet, F2881, F2883)

c) Twised pair (OMNINET)

d) Parallel pair

e) CATV-coax cable (WANGNET)

1.3 Access mode

a) CSMA (CSMA/CD): (BRANCH 4800, Ethernet, Net/One, Z-NET, WANGNET, OMNET)

b) Token passing: (H-8644 loopnet, ARC NET)

c) Time division multiplex: (Shiguma-net, F2881, F2883)

d) Hybrid exchange: (Loop 6530, Loop 6830)

Form of network:

A controller of network is called "Node", which controls numbers of workstations, computers, magnetic-disk, printers etc. which consist the network. If these equipments are connected in one communications cable, the form of connection is called "Bus structure". Ethernet, American XEROX, INTEL and DEC cooperatively developed, belongs "Bus Structures" group. See Fig. 15.2.

A Example of Ethernet

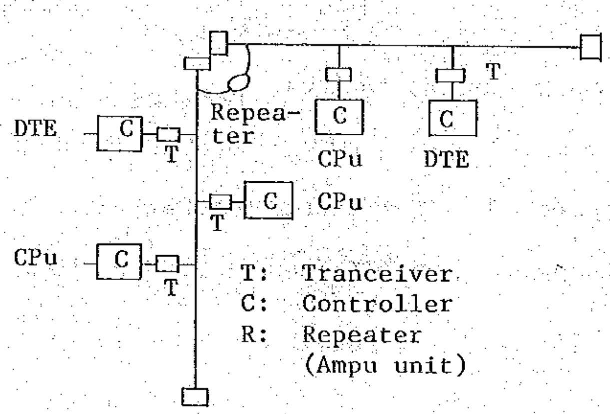


Fig. 15.2 Bus structure

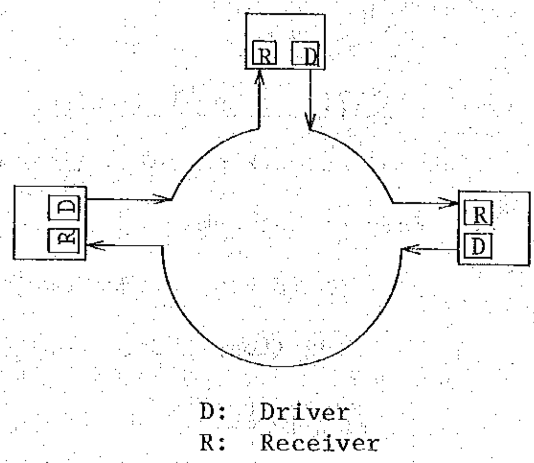


Fig. 15.3 Ring structure

On the other hand a work cable forms a round or a circular, is called a Ring or Loop structure such as C&C Net Loop 6530, NEC).

The Bus structure has a merit as it is very free and easy connection designed, adding or removing various kinds of equipments from Bus structure network is easy. The Ring structure has a merit as each node has a driver/receiver, it can extend quite long range of network cover area.

Transmission media:

Transmission media is classified by a kind of communications cable, and optical fiber and coaxial cable are more used now.

Access mode:

Access mode is one of the communication protocol, which shows the procedure of Data communication as CSMA (Carrier Sense Multi Access), CSMA/CD (Carrier Sense Multi Access/Collision Detect) and Token Passing mode.

CSMA/CD mode, if there is no data flow on the network, a node can transmit Data in any time. But in this case there is a possibility that another nodes also starts to transmit Data at the same time, and causes a Data collision, the Data becomes null. After a certain periode from the collision the node retransmits the data. If there are several failures of retransmission, the Data transmitter will be informed the transmission error.

Token Passing mode is a protocol to avoid the Data collisions, assigning only one node which can transmit Data. The Token is a right to send data, turned to each node in order, so there is equally less chance of waiting to transmit.

What mode select depends on the user's volumes of Data and frequency of data origination.

High speed transmission using optical fiber

Connection of Loop & Branch Network

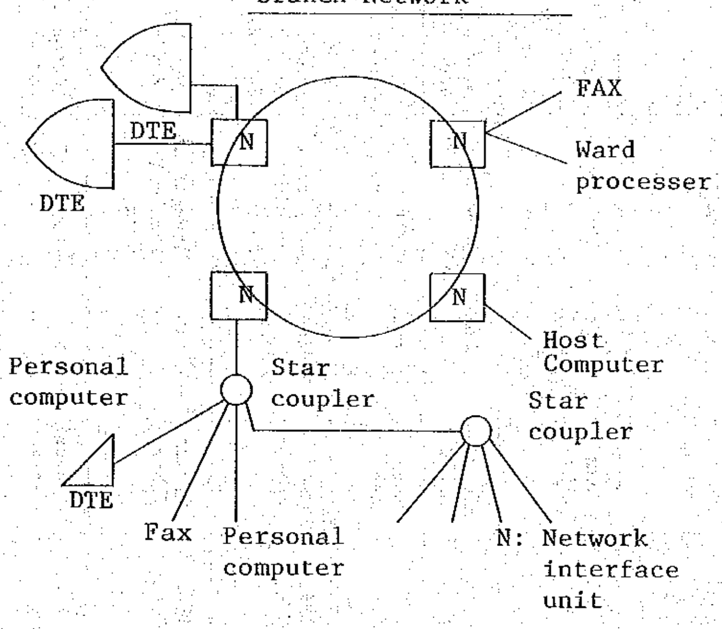


Fig. 15.4

NEC (C&C NET Loop 6530, Loop 6830, BRANCH 4800), HITACHI (Shigma Network, H-8644 Loopnetwork), Fujitsu (FACOM 2881, 2883) are commenly offering high speed, 32 Mbps through optical fiber cable.

Main Local Network Specification

Name of network	Name of farm	Announce year	Transmission media	Network form	Access mode	Band width	Transmission speed	Length of network	Numbers of node	Connection interface
C&C NET Loop 6830	NEC Japan	1982 May	Optical fiber	Ring	Hybrid. (Packet Ex)	(Optical comm.)	32 Mbps	12 km Maximum interval of next node	Total 128 node	CCITT V24, V35, X20, X21, X25, Telephone, picture
C&C NET BRANCH4800	NEC Japan	1982 May	Optical fiber	Tree	CSMA/CD	(Optical comm.)	10 Mbps	1 km (within star coupler)	Basic unit, 6 node 4 terminal/node	CCITT V24 (RS-232C) 8 bit parallel
H-8644 Loop network	HITACHI Japan	1982 May	Optical fiber	Ring	Talken passing	(Optical comm.)	32 Mbps	100 km Total max loop length, node interval 2 km	Total 125 node,	CCITT X25, HDLC, HSC, Asynchrous terminals
Ethernet	XEROX DEC, Intel USA	1981 Feb.	Coax cable	Bus	CSMA/CD	Base band	10 Mbps	Coax cable 500 m 2.5 km for max communication length	100 node/cable Total	Terminal are connected through controller
Net/One	Ungermann-Basse USA	1981 Dec.	Coax cable	Bus	CSMA/CD	Base band	10 Mbps	Coax cable 500 m 2.5 km for max. communication length	100 node/cable Total	RS-232C, IEEE-488 (GPIB), Direct bus, RS-422, 423, 449
Z-NET	Eailog USA	1981 Feb.	Coax cable	Bus	CSMA/CD	Base band	0.8 Mbs	2 km max.	255 max. node	RS232C, IEEE-488, 8 bit parallel
ARC Local network	Data point USA	1979	Coax cable	Bus	Talken passing	Base band	2.5 Mbps	Basic unit 7.2 km between nodes	255 node	Data point business processer, built in "RIM"
WANGNET	WANG labo. USA	1982 Jan.	CATV cable	Bus	Wang band or CSMA/CD	Broad band 340 MHs	WANG Band or 12 Mbps	3.2 km Max.	65535, Wang band address	Wang band connected through cable interface RS-232C, RS-499, 366
FACOM 2881	Fujitsu Japan	1982 Oct.	Optical fiber	Ring	Time division multiplex	(Optical comm.)	4 Mbps	96 km Loop length 3 km between nodes	32 node 32 terminal/node	CCITT, V24, V35, voice inter, serial loop interf. telephone interface
FACOM 2883	Fujitsu Japan	1982 Oct.	Optical fiber	Ring	T.D.M.	(Optical comm.)	33 Mbps	576 km loop length 9 km node interval	64 node 64 terminal/node	CCITT, V24, V35, voice, serial loop, telephone interface

Reference

Mr. Makoto ITO, Mr. Hiroaki IKEDA, Mr. Hiroshi YAMAMOTO, Interface 11, 1980 CQ publisher, Japan

Mr. Kazunori MATSUO KONNICHIWA No. 47 1983 KDD RDL, Japan MPT Press Release, 27, Sep. 1982, Japan

Nikkei Economic Journal 13, Nov., 1982, Japan

JTEC Telecommunication Forum Mar., 1982, Pakistan

Mr. Hideo FUKUTOMI Telecommunication Outside Plant Engineering, Ohm-sha, Japan

Mr. Tsuneo NAKAHARA, Present optical communications and its future, SUMITOMO Electric Lett, May 1981, Japan

Mr. James MARTINE, DATA COMMUNICATIONS, Prentice, 1978 USA

Mr. M. HORIGUCHI and OSANAI, Spectral Losses of Low-OH-content optical fibers, Electron, Lett, 1980 Japan

Mr. T. MIYA, TERUNUMA, T. HOSAKA, MIYASHITA, An ultura Low loss single mode fiber at 1.55 um, Electron. Lett, Vol. 15, 1979 Japan

Mr. IZAWA, KOBAYASHI, SUDO and HANAWA, Continuous fabrication of high silica fiber preform, Technical digest, 1977 Japan

Mr. HANAWA, SUDO, KAWACHI and NAKAHARA, Fabrication of completely OH-Free VAD fiber, Electron, Lett., Vol. 16, No. 18, 1980 Japan

Mr. HORIGUCHI, YANIFUJI and TOKUDA, Baseband frequency receponse of a Graded-index excited by a stp-index fiber, Apple. Opt., Vol. 19, No. 15, 1980 Japan

Mr. SHIMADA and MATSUNO, Short-haul optical fiber transmission system field trial, JTR, Vol. 21 Vol. 22, 1979 Japan

Comments on fiber-parameter tolerances, COM XV No. 355. CCITT SGXV Q.38, 1979

C.C.I.T.T Recommendation V, M, X, O series

Standard Telephone Transmission, Q20, NTT 1965, Japan

Mr. Nezu, International Data Communication Engineering, KDD 1981, Japan

JICA