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Optical Communication ONT

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Report
On
Fiber Optic Cables

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Fiber Optic Cables

1. Introduction

What is Fiber Optic Cable?

Cabling is the process of packaging optical fibers in a cable structure for handling and protection. In some applications bare fibers work just fine, such as fiber optic sensors and laboratory use. However for most communication applications fibers must be packaged in a cable for practical use. The major benefits of fiber optic cabling are:

- **Easy Handling**
  Some communication systems require tens or even hundreds of fibers (such as a metro backbone system). Put fibers in a cable make it very easy to install and maintain.
- **Protection from damaging forces**
  Fiber optic cables have to be pulled into place through ducts (outdoor) or conduits (indoor). Pulling eyes are attached to the strength members or cable outer jackets. This is critical for isolating the fibers from the applied pulling forces. Glass fibers cannot endure more than 0.1% to 0.2% elongation during installation.
- **Protection from harsh environment factors**
  Cable structures protect fibers from moisture (outdoor cables), extreme temperature (aerial cables) and influx of hydrogen into the fiber (which causes light absorption peak at 1380nm which in turn impair fibers' transmission properties).

Fiber Optic Cable Based on Fiber Types

Based upon fiber types in a cable, fiber optic cables can be categorized as three types.

Single Mode Fiber Optic Cable
All fibers in the cable are single mode fibers.

Multimode Fiber Optic Cable - Multi Mode Fiber Optic Cable
All fibers in the cable are multimode cables.

Hybrid/Composite Cable
Both single mode and multimode fibers are packaged in one cable, such as 4 multimode fibers and 4 single mode fibers in a single cable.

Elements in a Fiber Optic Cables

The construction design and choices of materials are vital in determining characteristics of a cable. The design factors for some types of fiber optic cables are listed below.

Indoor cables

Fire safety is the number one factor in selecting indoor cables, particularly those that run through plenum spaces. Indoor cables must pass the flame-retardant and smoke-inhibitor ratings specified by NEC.

Outdoor cables

Moisture resistance and temperature tolerance are the major factors when choosing materials for outdoor environment cables. They also need to be ultraviolet (UV) resistant.

Cable Jacket Materials

Polyethylene (PE)

PE (black color) is the standard jacket material for outdoor fiber optic cables. PE has excellent moisture – and weather-resistance properties. It has very stable dielectric properties over a wide temperature range. It is also abrasion-resistant.

Polyvinyl Chloride (PVC)

PVC is the most common material for indoor cables; however it can also be used for outdoor cables. It is flexible and fire-retardant. PVC is more expensive than PE.

Polyvinyl difluoride (PVDF)

PVDF is used for plenum cables because it has better fire-retardant properties than PE and produces little smoke.

Low Smoke Zero Halogen (LSZH) plastics

LSZH plastics are used for a special kind of cable called LSZH cables. They produce little smoke and no toxic halogen compounds. But they are the most expensive jacket material.

Aramid Yarn

Aramid yarn is a yellow color, fiber looking material. It is strong and is used to bundle and protect the loose tubes or fibers in the cable. It is the strength member to provide tensile strength along the length of the cable during and after installation. When a cable is pulled into a duct, the tension is applied to the aramid yarn instead of the fibers.

Central Strength Member
Many fiber optic cables has a central strength member, made of steel, fiberglass or aramid yarn. Central strength members are needed to provide the rigidity to keep the cable from buckling. Central strength members are common in outdoor cables and some high fiber counts indoor cables.

Gel Compound
Gel compound fills buffer tubes and cable interiors, making the cable impervious to water. It needs to be completely cleaned off when the cable end is stripped for termination.

Ripcord
Ripcord is a thin but very strong thread embedded just below the cable jacket. Its role is to split the cable easily without harming cable interiors.

Two Basic Fiber Structures

Fiber optic cable are available in a wide variety of physical constructions. Fiber cables can be anything from simple simplex or duplex (zipcord) cables used for jumpers to 144-fiber cable for intercity transmission.

However most of the fibers used in these cables come down to two basic configurations – 900µm tight buffered fibers or 250 µm coated fibers (also called bare fibers). Actually tight buffered fibers cover a coated fiber(the coating is soft plastic) with a thick layer of harder plastic, making it easier to handle and providing physical protection.

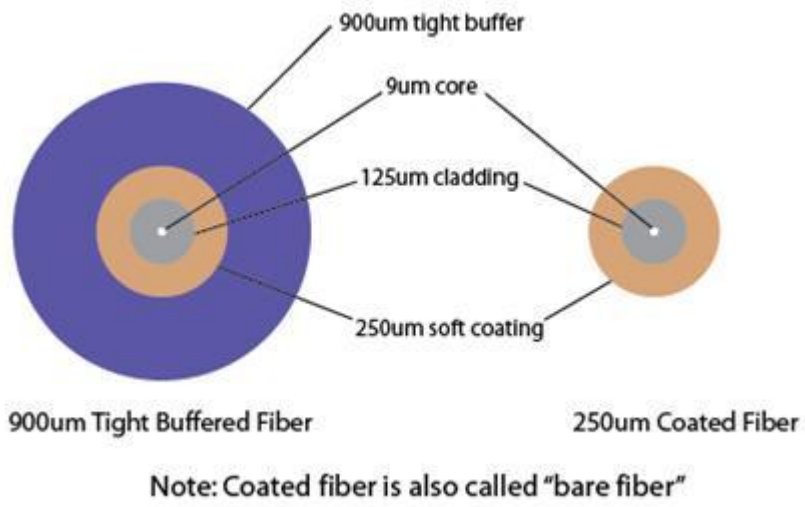


Figure1.1: Difference between Tight Buffered Fiber and Coated Fiber

The structure of a 250µm coated fiber (bare fiber)

- Core (9µm for standard single mode fibers, 50µm or 62.5µm for multimode fibers)
- Cladding (125µm)
- Coating (soft plastic, 250µm is the most popular, sometimes 400µm is also used)

The structure of a 900µm tight buffered fiber

- Core (9µm for standard single mode fibers, 50µm or 62.5µm for multimode fibers)
- Cladding (125µm)
- Coating (soft plastic, 250µm)
- Tight buffer (hard plastic, 900µm)

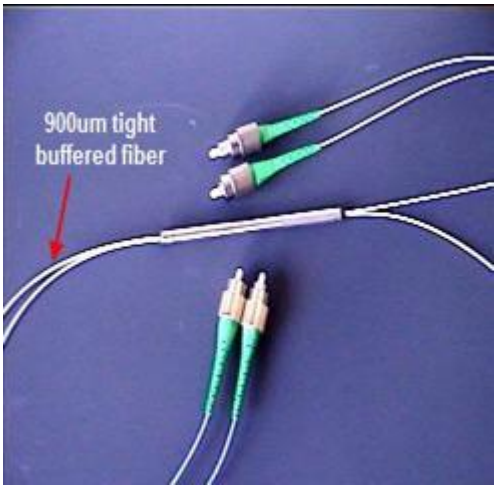


Figure 1.2: 250µm and 900µm tight buffered fiber

<u>Fiber Optic Cable Construction - Two Basic Types</u>

Based on 900µm tight buffered fiber and 250µm coated fiber there are two basic types of fiber optic cable constructions – Tight Buffered Cable and Loose Tube Cable.

<u>Tight Buffered Cable</u>

Multiple color coded 900um tight buffered fibers can be packed tightly together in a compact cable structure, an approach widely used indoors, these cables are called tight buffered cables. Tight buffered cables are used to connect outside plant cables to terminal equipment, and also for linking various devices in a premises network.

Multi-fiber, tight buffered cables often are used for intra-building, risers, general building and plenum applications. Tight buffered cables are mostly built for indoor

applications, although some tight buffered cables have been built for outdoor applications too.

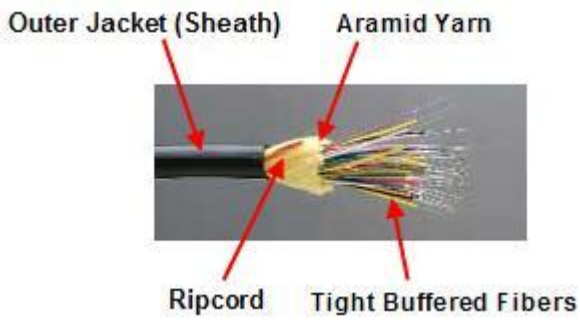


Figure 1.3: Tight Buffered Fiber Optic Cable Sample

Structure of a Tight Buffered Cable

Elements in a tight buffered fiber optic cable

1. Multiple 900µm tight buffered fibers (stranded around the central strength member)
2. Central strength member (in the center of the cable)
3. Aramid Yarn (wrapped around the fibers, for physical protection and cable pulling)
4. Ripcord (for easy removal of outer jacket)
5. Outer jacket (also called sheath, PVC is most common for indoor cables because of its flexible, fire-retardant and easy extrusion characteristics.)

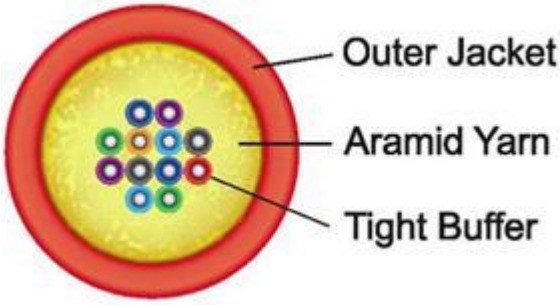


Figure 1.4:Cross Section of a Tight Buffered Fiber Optic Cable

<u>Loose Tube Cable</u>

On the other hand multiple (up to 12) 250µm coated fibers (bare fibers) can be put inside a color coded, flexible plastic tube, which usually is filled with a gel compound that prevents moisture from seeping through the hollow tube. Buffer tubes are stranded around a dielectric or steel central member. Aramid yarn are used as primary strength member. Then an outer polyethylene jacket is extruded over the core. These cables are called loose tube cables.

Loose tube structure isolates the fibers from the cable structure. This is a big advantage in handling thermal and other stresses encountered outdoors, which is why most loose tube fiber optic cables are built for outdoor applications.
Loose-tube cables typically are used for outside-plant installation in aerial, duct and direct-buried applications.

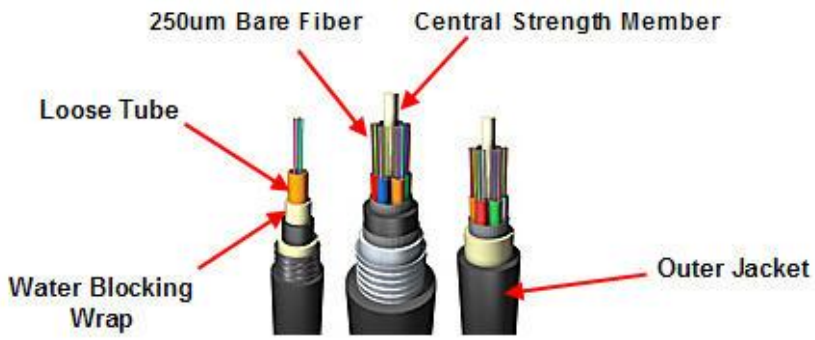


Figure 1.5: Fiber Optic Loose Tube Cable Samples

Structure of a Loose Tube Cable

Elements in a loose tube fiber optic cable:

1. Multiple 250 μm coated bare fibers (in loose tube)
2. One or more loose tubes holding 250 μm bare fibers. Loose tubes strand around the central strength member.
3. Moisture blocking gel in each loose tube for water blocking and protection of 250 μm fibers
4. Central strength member (in the center of the cable and is stranded around by loose tubes)
5. Aramid Yarn as strength member
6. Ripcord (for easy removal of outer jacket)
7. Outer jacket (Polyethylene is most common for outdoor cables because of its moisture resistant, abrasion resistant and stable over wide temperature range characteristics.)

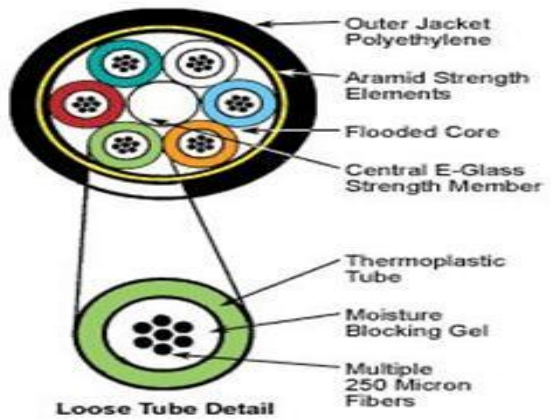


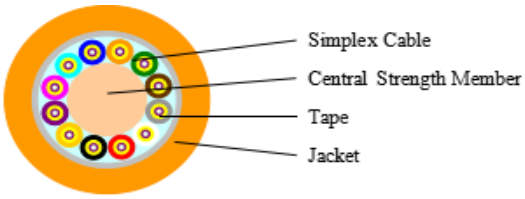
Figure 1.6: Cross Section of a Loose Tube Fiber Optic Cable

2. Categories of Cabling

Fiber-optic cables may be categorized by the type of installation environment, on the number of individual fibers and according to the application. There can be three main categories of cable

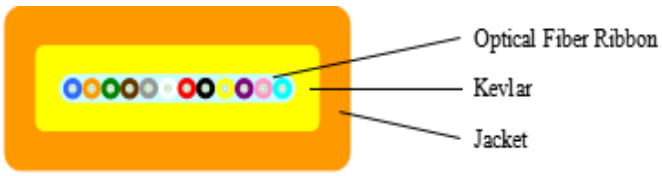
1. Indoor Cables
2. Outdoor Cables
3. Indoor/Outdoor

They can consist of one (simplex), two (duplex) or more (multifiber) individual fibers. Simplex cables provide one-way transmission, while duplex cables allow transmission in both direction. Multifiber cables may carry many fiber pairs surrounding a central strength member, as shown in the Figure: 2-1; or they may take the form of ribbon cables, which are individual cables in a row surrounded by a single jacket Figure: 2-2



Multi-fiber Breakout Indoor Cable I

Figure: 2-1



Flat Optical-fiber-ribbon Indoor Cable I

Figure: 2-2

1 – James N. Downing: *Fiber Optic Communications*, 2005, ISNB: 1-4018-6635-2

Indoor Cables

Elaborating the indoor optical cables they have a diverse variety of applications inside a building. They are replacing outdoor cables because the indoor cables have more flexibility, cheaper and convenience to use inside a building. Indoor cables have some characteristics that allow it to be more favorable. Such as:

- No need grounding and lightning protection - Since they are free of metal
- Easy to strip - They are 900µm TBII tight buffered fibers
- All information of the cable can be printed on the outer sheath.

In addition, letter-coding designation according to German standardization institutes of DIN & VDE (as shown in Table 1.1, page 9)

It is also designed to withstand temperature ups/downs, and to stand against mechanical stresses that the cable might face inside the building. These characters are present while it still has its similar optical transmission as the outdoor cables. This would lead to lower increase in attenuation with the splice joints. Indoor cables are placed in an optical fiber distribution closure inside the buildings. The distribution of the cables could be more flexible to manage and process. Figure: 2-3 shows a verity of indoor cables.

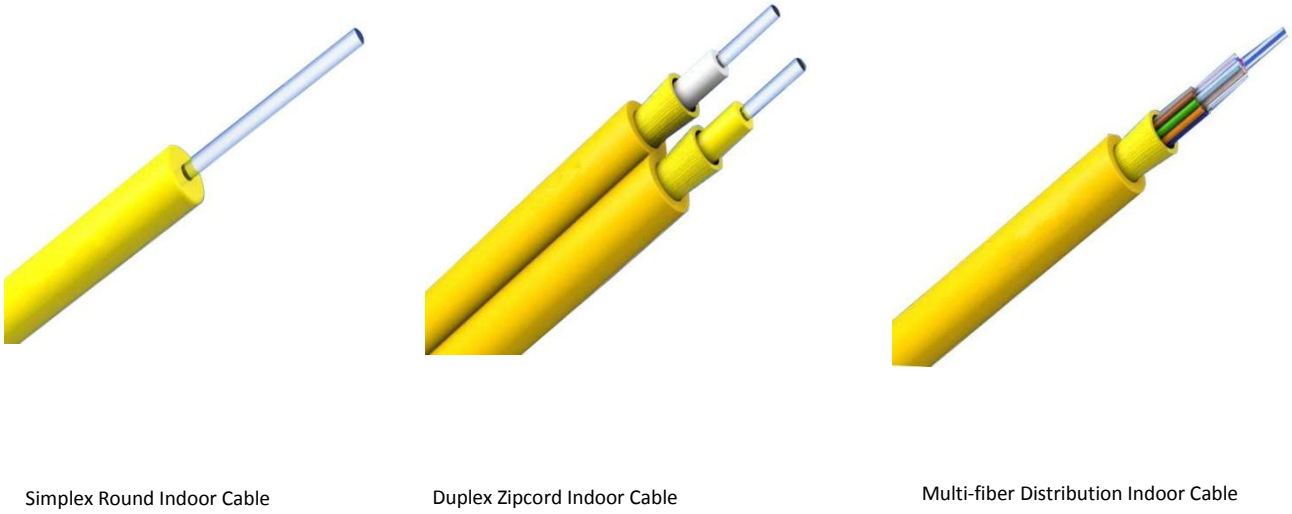


Figure: 2-3: Variety of indoor cables

Codes

Fiber-optics cables, coding according to DIN VDE 0888

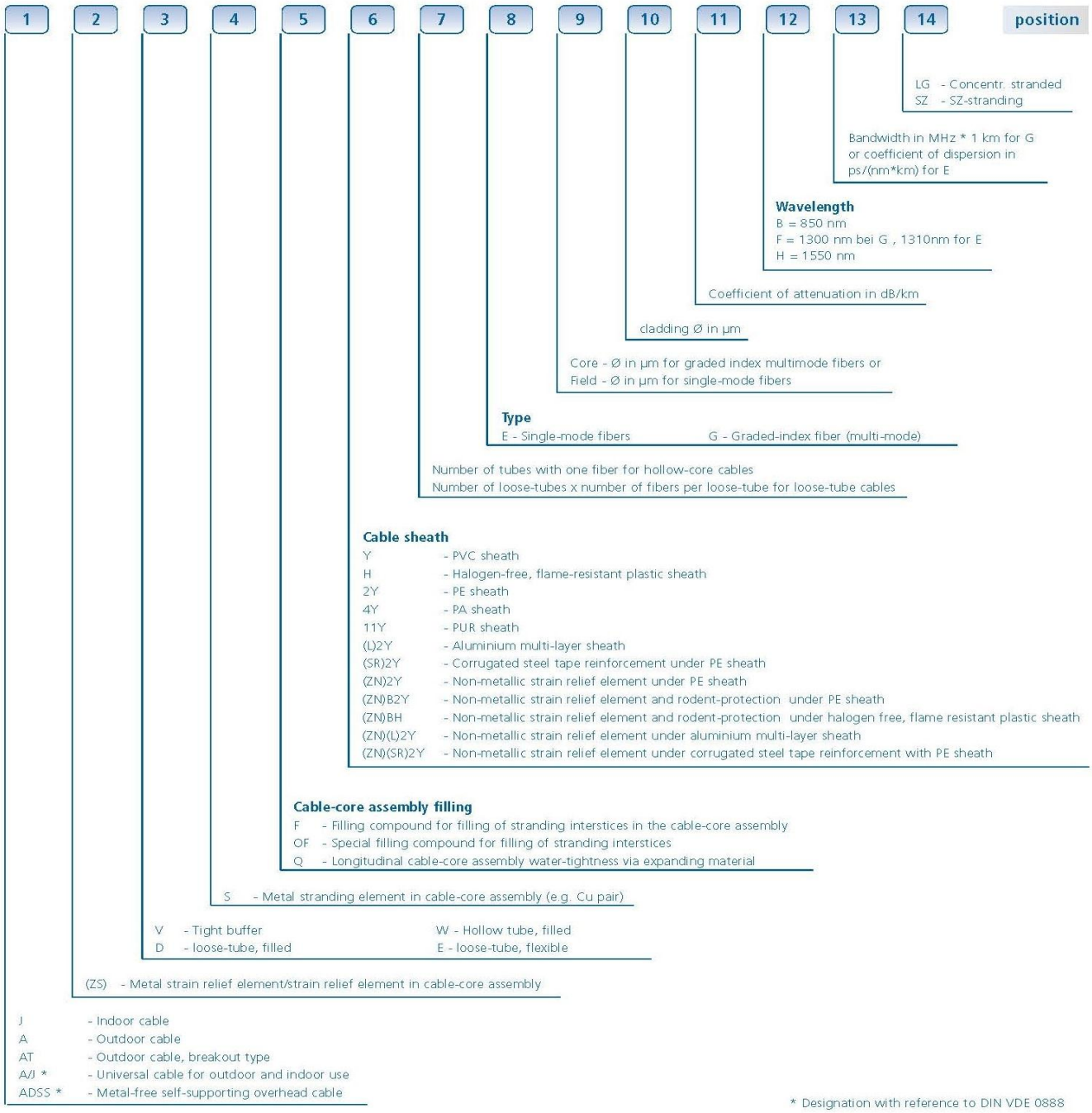


Table 1.1 [2]

2 – Twentsche Kabel Deutschland

Color Coding

It would seems that the color coding, the color of the jackets and buffers means the characteristics (Fire retardant, Mechanical, Single or Multi mode, Dielectric properties of the sheath…) of the cable. But not all manufacturers adhere to the same standards. The color coding, the difference of the color is used to identify the cables, to visual recognize each of them to connect in right order. Table: 1.1 shows the difference of used colors for cables 1-12 fiber strands. In case of more fibers they are indicated with same colors, but with lines or dotted lines.

Figure: 2-4: Color Coding

General requirements

The most important requirements of isolation of the indoor fiber-optic cables:

- Cables must not be supportive and flame retardant and have low smoke and halogen;
- Cables must have a small bending radius;
- Cables must be effectively armored;

Types of indoor cables

There are three types of indoor fiber optic cables:

1.1 Interconnect cables
1.2 Break-out cables (Fan-out)
1.3 Multi-indoor cables (MIC)

Interconnect Cables

Interconnect cables are used to connect the devices, the blocks in the device, process controls, wired office systems to transmit data, image, video, and voice in intra-building distribution. They can one or two fiber designed (Simplex Round, Duplex Zipcord, Duplex Round).

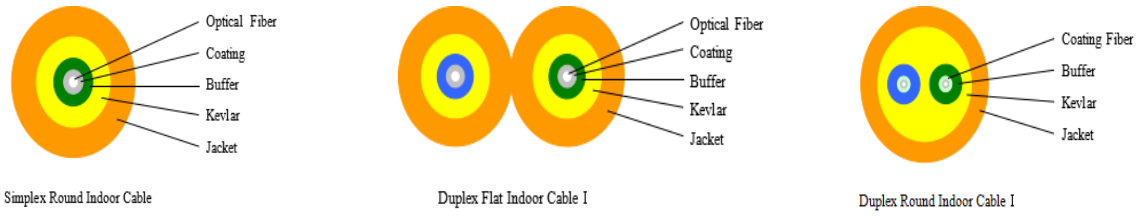


Figure: 2-5

These cables suffer almost minimal mechanical loading. For compounds of the blocks in the device is often sufficient optical fibers in buffer coating. If there is frequently switching of interconnect cables for connections, it may contain coils of protective aramid yarns and an additional outer shell, which provides increased mechanical strength.

Duplex Zipcord

Zipcord Fiber Optic Cables structure contains two simplex cables jointed together; it can be easily split apart by hands. It is used for general indoor applications. Zipcord fiber optic cable can be manufactured as single mode or multimode and with various kinds of connectors like LC, SC, ST. Usually on the zipcord cable, each side is two connectors, and the two connectors may be joined together by a clip. The buffers are color coded for easy identification and installation. This fiber cable is perfect for data centers and indoor point to point connections.

Figure 2-6: LC, SC and ST Connectors

Advantages

- Standard fiber count : 2C
- Light weight and flexible
- Ideal for tight radius installation
- Easy termination, rugged cable-connector interface
- The simplex cords can be easily separated from each other

Application

- For use in the cable assemblies including
- For patch panels within communication closet
- For communication closet jumper assemblies
- Suitable for dropped ceiling installation

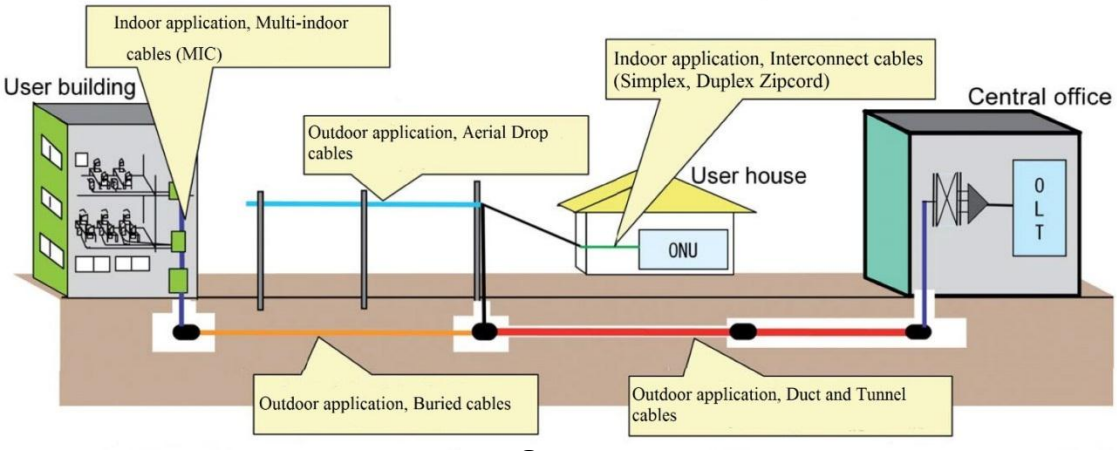


Figure 2.7: **OLT-Optical Line Termination; ONU-Optical Network Unit**

Construction

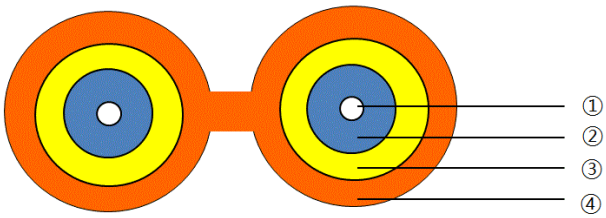


Figure – 2.8

① Optical fiber type : SMF(Sing Mode optical Fiber), MMF (Multi Mode optical Fiber)
② Tight Buffer Coating : PVC or LSZH (Low Smoke Zero Halogen)
③ Dielectric Strength Member : Aramid yarn
④ Jacket : PVC or LSZH (Low Smoke Zero Halogen)

3. Multifiber Breakout Cable

Multifiber Breakout Cable is a favorite where rugged cables are desirable or direct termination without junction boxes, patch panels or other hardware is needed. They are made of several simplex cables bundled together inside a common jacket. This is a strong, rugged design, but is larger and more expensive than the distribution cables. It is suitable for conduit runs, riser and plenum applications. It's perfect for industrial applications where ruggedness is needed. Because each fiber is individually reinforced, this design allows for quick termination to connectors and does not require patch panels or boxes. Breakout cable can be more economic where fiber count isn't too large and distances too long, because is requires so much less labour to terminate. A breakout cable is used when you need to connect two areas of your infrastructure together; whether this is connecting floors in the same building, connecting two buildings on your campus or for linking deployable equipment to a control room.

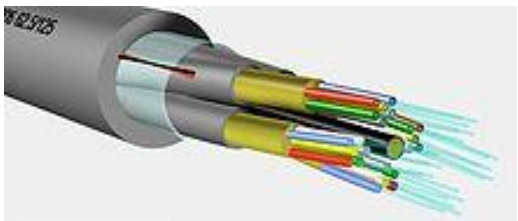


Figure 3.1: Multi Fiber Break out Cable

Cable Design

The design of breakout-style cable adds strength for ruggedized drops, however the cable is larger and more expensive than distribution-style cable.

Since each fiber is individually reinforced, the cable can be easily divided into individual fiber lines. Each simplex cable within the outer jacket may be broken out and then continue as a patch cable, for example in a fiber to the desk application in an office building. This enables connector termination without requiring special junctions, and can reduce or eliminate the need for fiber optic patch panels or an optical distribution frame. Breakout cable requires terminations to be done with simple connectors, which may be preferred for some situations. A more common solution today is the use of a fan-out kit that adds a jacket to the very fine strands of other cable types. . Breakout Cable is by far the least expensive and easiest cable type to terminate and requires the least experience on the part of the installer.

Break Out Cable Varieties

- Indoor/Outdoor breakout cable
  - Plenum rated breakout cable
  - Riser rated breakout cable

Indoor/Outdoor breakout cable

A majority of indoor cable is used in building wiring applications. Installed in walls, between floors, in plenum air handling ducts and under data center floors, this indoor fiber cable used in building wiring applications is built to withstand the tensile stresses present during installation by the contractor or assembler.

Outdoor breakout cables have riser and plenum rated versions. These cables are flexible, easy to handle and simple to install. Since they do not use gel, the connectors can be terminated directly onto the 900µm fiber without difficult-to-use kits. This provides an easy and overall less expensive installation.

Cable cross sections:

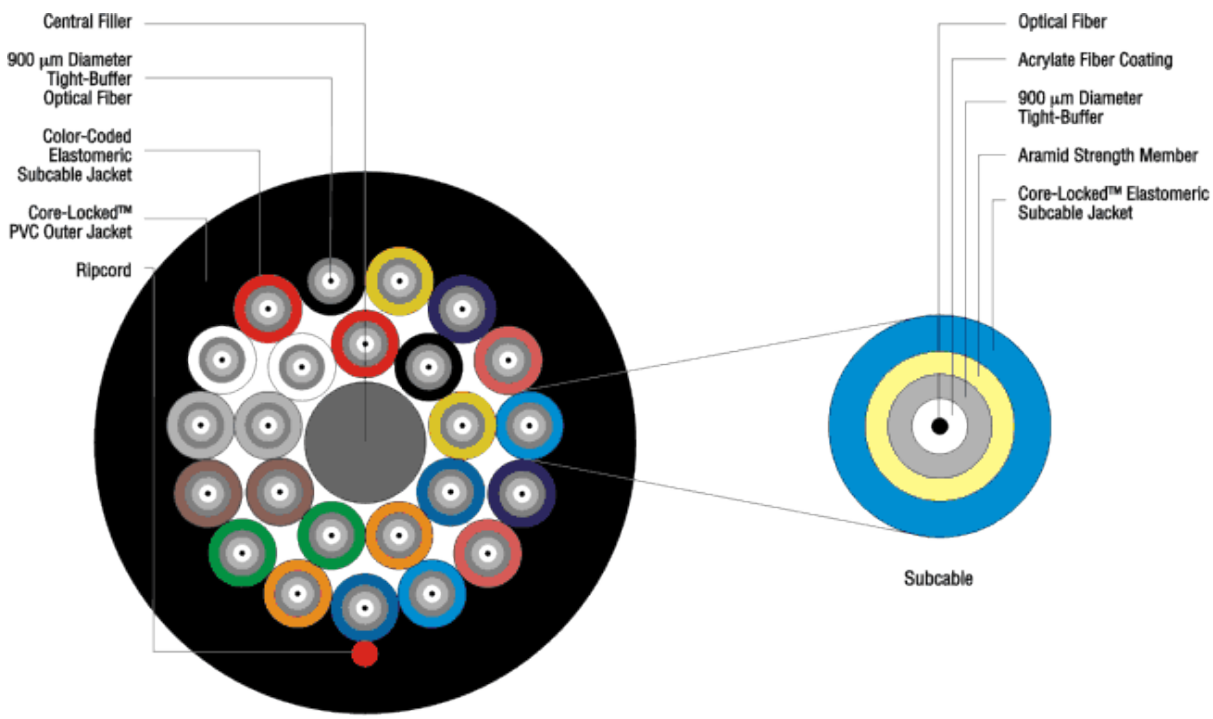


Figure 3.2: Cable Cross-section

Temperature specifications:

- Storage -40°C to +70°C
- Operating -40°C to +70°C
- Installation -20°C to +70°C

Application

1. Ideal for installations requiring an extremely rugged and reliable cable design where maximum mechanical and environmental protection are necessary

2. Easiest cable to install where direct termination of connectors to sub-units and direct run to panels and equipment is desired

Plenum rated Breakout Cable

Plenum is an air-handling, air flowing and air distribution system space which is found above drop ceiling tiles or heating and ventilation ducts. The outer jacket of plenum rated cables are made of materials that retard the spread of flame, produce little smoke and protect electronic equipment from damage in fires. Plenum cables can be run through plenum spaces without special conduits. Plenum rated cables are more expensive, because of the jacket material.

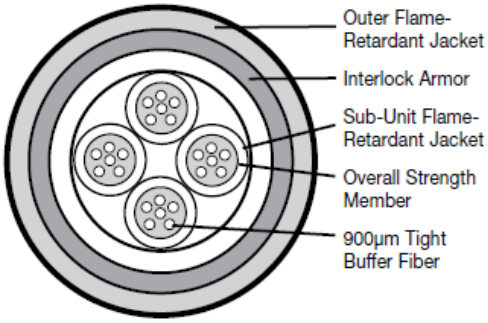


Figure 3.3: Plenum Rated Breakout Cable Cross-section

Temperature:

- Storage -40°C (-40°F) to +70°C (+158°F)
- Operating -20°C (-4°F) to +70°C (+158°F)

Advantages:

- Interlock armor provides outstanding mechanical protection
- Interlock armor is flexible and easy to use
- Tight buffer provides individual fiber protection
- Outer jacket is moisture-resistant, fungus-resistant and UV resistant suitable for outdoor use
- With an overall OFNP (Plenum) rating, this cable is suitable for installations in most spaces requiring UL flame ratings: Plenum, Riser, General Purpose and outside plant

Riser rated Breakout Cables:

Riser is a pathway such as floor opening, shaft or duct that runs vertically through floors. Riser rated cables can be run through building vertical shafts (risers) or from one floor to another floor.

Optical fiber, nonconductive, riser (OFNR) is a type of optical fiber cable. As designated by the National Fire Protection Association (NFPA), this name is used for interior fiber-optic cables which contain no electrically conductive components, and which are certified for use in riser applications; they are engineered to prevent the spread of fire from floor to floor in a building. They are distinct from optical fiber, nonconductive, plenum cable (OFNP), and general-purpose optical cable.

OFNR cables can not be installed in plenum areas since they do not have the required fire and smoking rating as Plenum rated cables. OFNP plenum cables can be used as substitutes for OFNR cables.

CROSS SECTION:

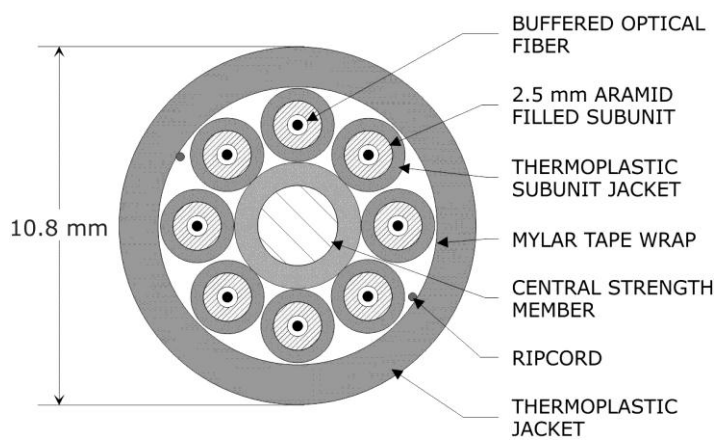


Figure 3.4: Riser Rated Breakout Cable Cross-section

Temperature

- Operating temperature, range -20 .. 75°C
- Ambient installation temperature, range -20 .. 75°C
- Storage temperature, range -40 .. 85°C

Advantages

- One cable design meeting all structured cabling network communications applications
- High tensile strength provides for greater pulling distances
- Ease of installation
- Broad design selection allows for mix and match of fiber components to specific networking applications
- Low cable plant maintenance
- Armor option adds crush resistance and protection from rodent attacks

Maintenance

The use of tight-buffered **indoor/outdoor breakout cables** greatly simplifies system maintenance and reduces restoration time. For routine terminations often required in moves, additions, and changes, only the skills and tooling for installing optical connectors are needed. Tight-buffered cables allow some portion of the fibers to be left dark for future termination with whatever type of connectors may be required. The installation of connectors on the ends of the optical fibers is the minimum skill required of the organization responsible for maintenance of a fiber optic cable plant. Emergency restoration is also made much easier when tight-buffered cables are involved. All of the messy cable stripping, fiber end preparation, and cleaning required for splicing loose-tube gel-filled cables are time consuming and more likely to be successful in a controlled, clean environment. Emergency restoration is most likely to be required in less than ideal, adverse environmental conditions of temperature, rain, snow, mud, etc. In tight-buffered cables there is no gel - the mess and cleaning are completely eliminated. If splicing should be required on a tight-buffered indoor/outdoor cable, the tight-buffered fibers are inherently better protected, and the repair time is greatly reduced.

4. Hybrid Cables

What is Hybrid Cable?

A hybrid fiber cable or hybrid fiber-coaxial cable (HFC cable) is a communication medium that combines fiber optic and coaxial cable-based transmission modes into a unified path. Hybrid cables incorporate mixed optical fiber with copper cable. This multifunctional cable is used for power and data transmission. It delivers voice, Internet, cable TV and other digital interactive solutions and services to individual consumers and organizations.

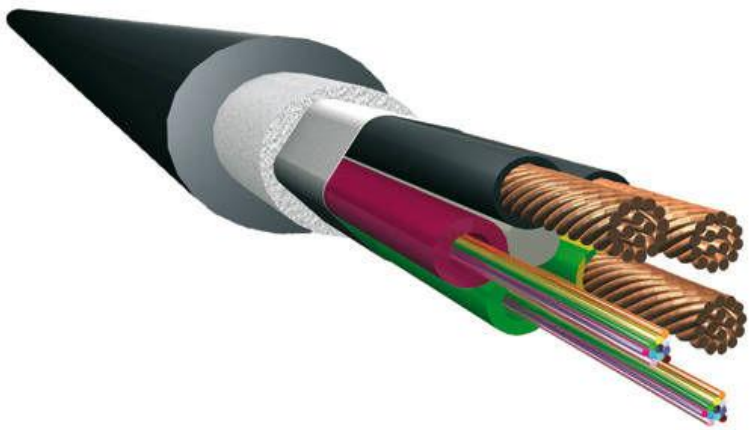


Figure 4.1: Hybrid Cable

When to use hybrid cables?

Hybrid cables are ideal for networks involving real-time image transport or sharing large files. Such applications include computer-aided design and manufacturing, laboratory simulators and hospital imaging systems--or, any other application that may require even higher bandwidths in the future.

Principle of Hybrid Cables:

Copper cables are inexpensive and installation is easier. If we send data over copper cable, every 30Kms we need repeaters to avoid power drop. Whereas optical fibers have lower transmission losses compared to copper wires. This means that data can be sent over long distances, thereby reducing the number of intermediate repeaters needed for these spans.

In a typical HFC cable scenario, a service provider stretches a fiber optic backbone that is located in close proximity to a customer/end-user and terminates it at a node device.

From the node device, the fiber's transmitted light signals are converted into radio frequency signals, which are transmitted via coaxial cable, which expands until it reaches the end user or device.

Structure of the hybrid cable

Hybrid fiber cable/coax cable consists of a single cable sheath that contains fibers and copper cables in different combination. The hybrid cable can have both the distribution as well as the breakout structure. For instance, cables for HDTV cameras usually base on the distribution structure that provides high flexibility with small diameter and low weight. The cable used for underground mining applications will use the breakout structure for better protection against mechanical tensions and working forces.

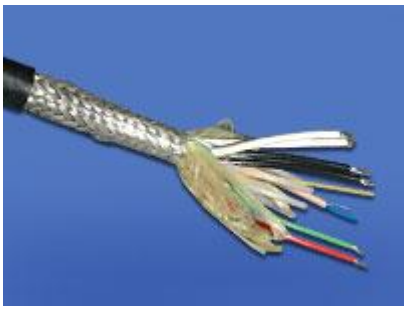


Figure 4.2: HDTV camera hybrid cable.

Figure 4.3: Industrial hybrid cable, breakout structure (Visible optical fibers (yellow and blue), screen braid and electrical wires (red, green and black) and fillers (white))

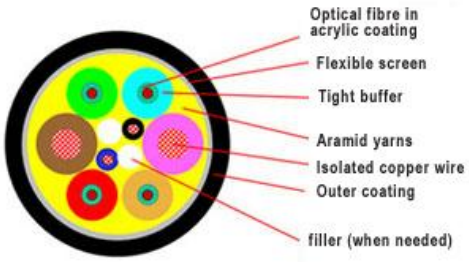


Figure 4.4: Cross-section of the hybrid cable

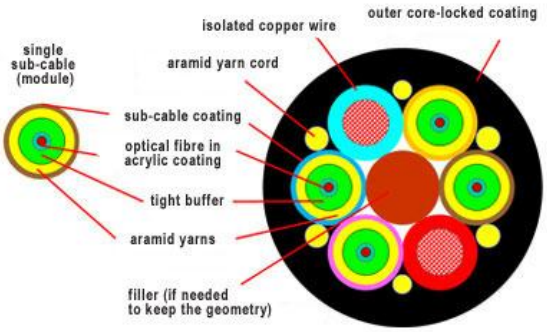


Figure 4.5: Cross-section of the breakout type hybrid cable

The combination of the diameters and gauges of the copper wires or types of the optical fibers is virtually unlimited and depends entirely on the customer needs and requirements. The copper wires can be employed to carry electrical signals or supply the power, so there could be a whole variety of copper cables like wires, twisted pairs, coax, triax, etc. This cable functions for CCTV in tunnels, buildings and airports.

Applications:

HFC cable has a bright future for WAN communications as more is installed in cable TV infrastructure. Using HFC, cable operators can provide telephone service, multiple channels of interactive TV and high-speed data services for PC's. A full HFC system can deliver:

1. Plain old telephone services
2. Over 200 digital TV channels
3. Over 400 digital point channels (customer-requested services)

High-speed, two-way digital data link for PCs.

For example, a cable Internet Service Provider (ISP) may use fiber optic from the central office to each branch exchange of a town. The Internet is delivered on coaxial cables from there to the customer's home or office. This combination of fiber and coaxial cable allows higher speeds to be reached through a fiber backbone close to the customer, while remaining economical and compatible via coaxial cable-based delivery to end users/consumers.

In a hybrid fiber-coaxial cable system, the television channels are sent from the cable system's distribution facility, the hub, to local communities through optical fiber trunk lines. At the local community, a box called an optical node translates the signal from a light beam to electrical signal, and sends it over coaxial cable lines for distribution to subscriber residences. The fiber optic trunk lines provide adequate bandwidth to allow future expansion and new bandwidth-intensive services.

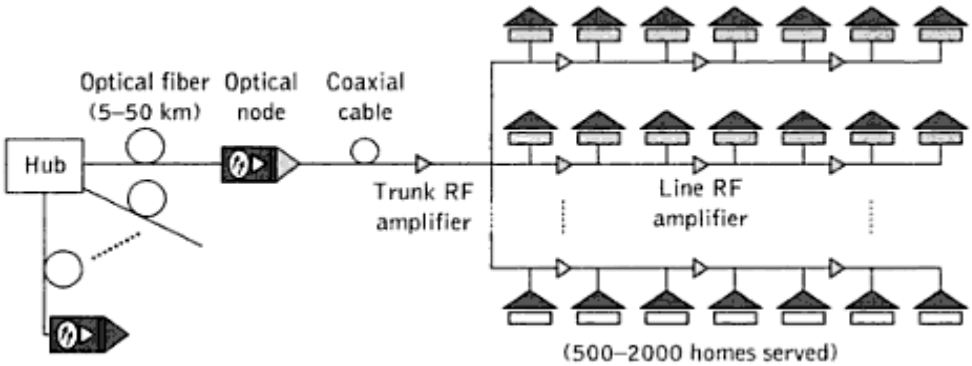


Figure 4.6: A generic hybrid fiber coaxial (HFC) cable network

Advantages and Disadvantages

Advantages

- Cost – Less maintenance costs due to fewer amplifiers required and less electricity is consumed.

- Reliability – Reliable, immune to noise and almost non-existent attenuation (distortion).
- Bandwidth – High bandwidth capabilities, increased from traditional CaTV network (up to 330MHz or 450MHz) to 750MHz with HFC.
- Flexibility – Has ability to adapt to new services such as voice, data or video without changing existing operational parameters (TE Consulting)
- Size – Lighter weight and thinner than copper cables with the same bandwidth, much less space is required in underground cabling ducts and easier for installation engineers to handle.
- Security – Much more difficult to tap information, a great advantage for banks and security installations. Immune to Electromagnetic interference from radio signals, car ignition systems, lightning etc. Can be routed safely through explosive or flammable atmospheres.
- Technology Support – Can support Cable telephones, increased number of CaTV channels (to over 200), a direct infrastructure to new Digital TV standards which assume that networks will use HFC backbones and ATM services.
- Availability – No need to dial-up or tie up a phone line as it uses a separate connection, Cable Internet has constant connectivity.

Disadvantages

- Cost – More expensive than Coaxial Cable, especially costly to rural subscribers due to long cables required.
- Reliability – Due to the huge number of users that a fiber will support, a train derailment, earthquake or other traumatic even can have catastrophic proportions.
- Skill Required – Optical fibers cannot be joined (spliced) together as easily as copper cable and requires additional training of personnel and expensive precision splicing and measurement equipment.
- Symmetry – Asymmetrical, not based on new interactive multimedia. The upstream paths in the HFC network are slower than downstream.
- Signal Quality – Is reduced as more subscribers use the network. Speed of transmissions also decreases. HFC network speeds are limited by the number of users using the network at the same time. Even though a single 7MHz channel can have theoretical speeds of 30Mbps, much of this speed is shared between all the users on the neighborhood node using a cable modem at the same time. Each node is capable of supporting services to 500 - 2000 homes.

Future Prospects:

The appeal of these high-performance cables, which typically combine both metallic conductors and optical fibers within the same jacket, is their long-term cost savings and their ability to meet the projected network performance requirements of the future.

5. Submarine Cables

What is a submarine cable?

A submarine communications cable is a cable laid on the sea bed between land-based stations to carry telecommunication signals across stretches of ocean. The first submarine communications cable was laid in the 1850s and carried telegraphy traffic. Subsequent generations of cables carried telephone traffic, then data communications traffic. Modern cables use optical fiber technology to carry digital data, which includes telephone, Internet and private data traffic. As of 2010, submarine cables link all the world's continents except Antarctica.

Why not Antarctica?

Antarctica is the only continent yet to be reached by a submarine telecommunications cable. All phone, video, and e-mail traffic must be relayed to the rest of the world via satellite, which is still quite unreliable. Bases on the continent itself are able to communicate with one another via radio, but this is only a local network. To be a viable alternative, a fiber-optic cable would have to be able to withstand temperatures of −80˚ C as well as massive strain from ice flowing up to 10 meters per year. Thus, plugging into the larger Internet backbone with the high bandwidth afforded by fiber-optic cable is still an as yet infeasible economic and technical challenge in the Antarctic.

Why not use Satellite Communication always?

Satellites have a two-fold problem: latency and bit loss. Sending and receiving signals to and from space takes time. Meanwhile, researchers have developed optical fibers that can transmit information at 99.7% the speed of light.

History of Submarine cabling:

The first trans-Atlantic cables were laid in the 1860s, and trans-Pacific cables followed in the early 1900s. These cables were incredibly low-bandwidth because repeaters didn’t exist then, so the only way of getting a signal across was by upping the voltage and creating a very noisy link. By the early 1900s, the British Empire had already connected up most of the continents (see image below).

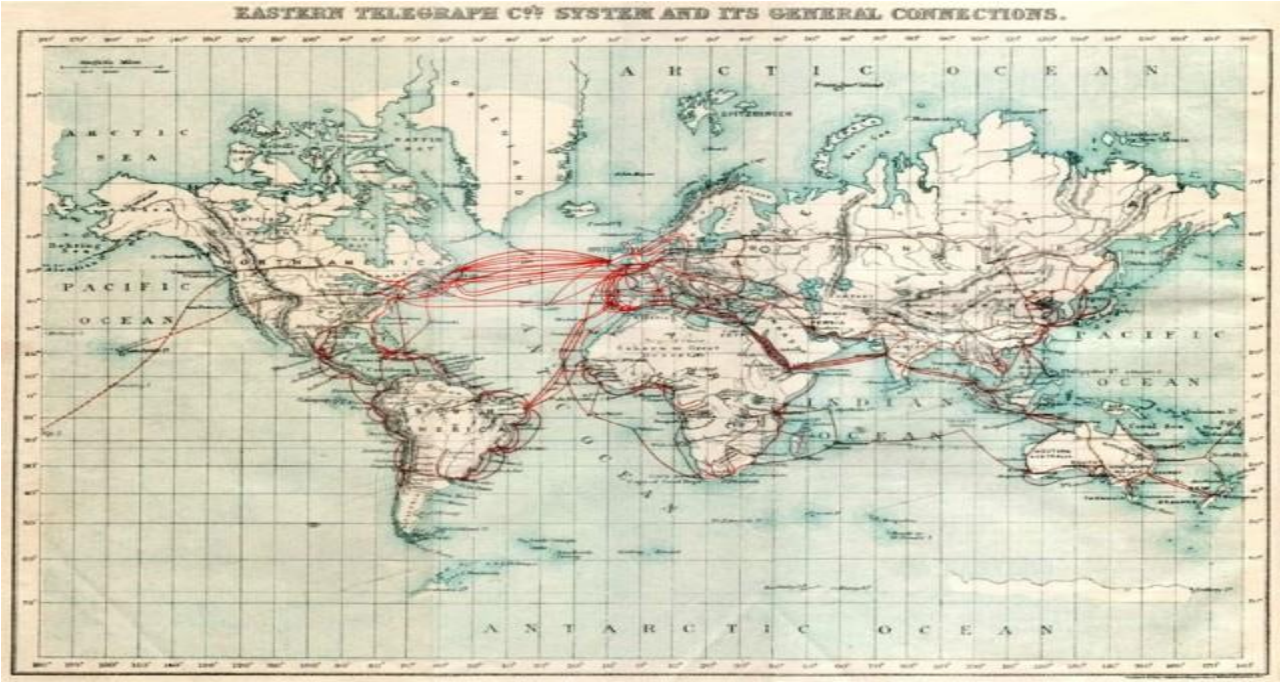


Figure 5.1: Continents connected by British Empire by early 1900s.

Construction:

Modern cables are typically about 25 millimeters (0.98 in) in diameter and weigh around 1.4 kilograms per meter (0.4 lb/ft) for the deep-sea sections which comprise the majority of the run, although larger and heavier cables are used for shallow-water sections near shore. The diameter of a shallow water cable is about the same as a soda can, while deep water cables are much thinner—about the size of a Marker. As seen in Figure below, it has a range of protections; double armored, single armored, lightweight protected, and lightweight. These protections will keep the optical fibers safe at a depth of 8000 m in various seabed conditions.

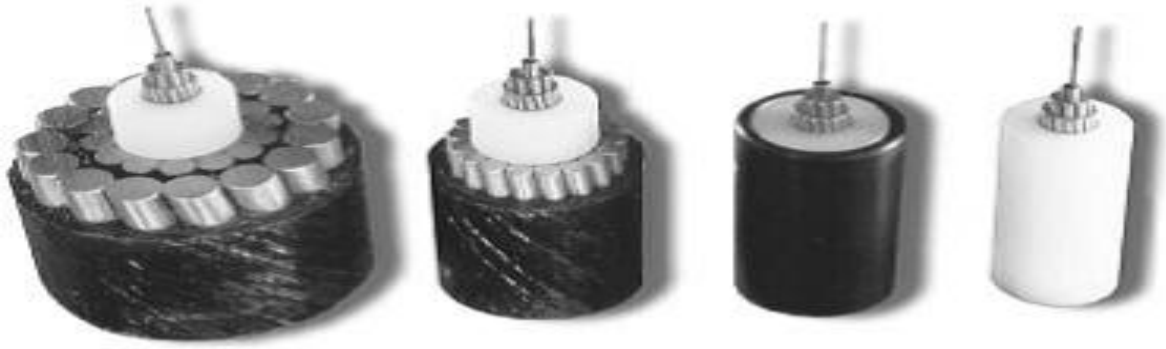


Figure 5.2.: Submarine cables with various protections

The submarine fiber optic cable contains the same components as a land cable, except it has more protection.
A cross section of the shore-end of a modern submarine communications cable.
1 – Polyethylene
2 – Mylar tape
3 – Stranded steel wires
4 – Aluminum water barrier
5 – Polycarbonate
6 – Copper or aluminum tube
7 – Petroleum jelly
8 – Optical fibers

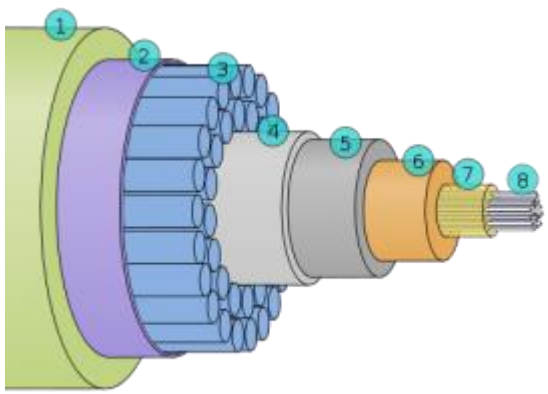


Figure 5.3.: Submarine cables cross-section

<u>Laying a submarine cable:</u>

As far as laying a submarine cable, specialized cable-laying ships must be used called cable-layers. When a cable is broken (usually by a trawler, volcano, tectonic activities, shark bites) another special ship must be used for repair. This generally means that laying a cable is logistically challenging and very expensive. The cables must generally be run across flat surfaces of the ocean floor, and care is taken to avoid coral reefs, sunken ships, fish beds, and other ecological habitats and general obstructions.

Figure 5.4.: Laying of Submarine cable

Bandwidth problems:

Early long-distance submarine telegraph cables exhibited formidable electrical problems. Unlike modern cables, the technology of the 19th century did not allow for in-line repeater amplifiers in the cable. Large voltages were used to attempt to overcome the electrical resistance of their tremendous length but the cables' distributed capacitance and inductance combined to distort the telegraph pulses in the line, reducing the cable's bandwidth due to noise.

Modern optical fiber repeaters use a solid-state optical amplifier, usually an Erbium-doped fiber amplifier. Each repeater contains separate equipment for each fiber. These comprise signal reforming, error measurement and controls. A solid-state laser dispatches the signal into the next length of fiber. The solid-state laser excites a short length of doped fiber that itself acts as a laser amplifier. As the light passes through the fiber, it is amplified. This system also permits wavelength-division multiplexing, which dramatically increases the capacity of the fiber.

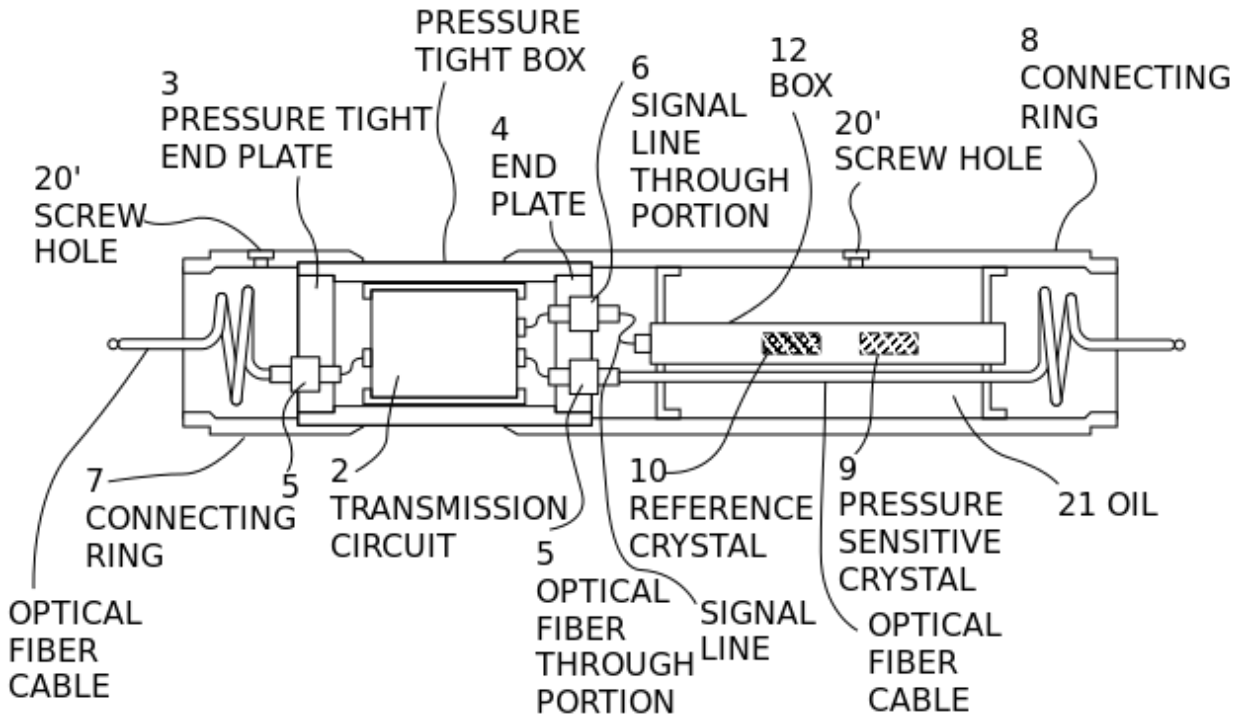


Figure 5.5.: Diagram of an optical submarine cable repeater.

Repeaters are powered by a constant direct current passed down the conductor near the center of the cable, so all repeaters in a cable are in series. Power feed equipment is installed at the terminal stations. Typically both ends share the current generation with one end providing a positive voltage and the other a negative voltage. A virtual earth point exists roughly halfway along the cable under normal operation. The amplifiers or repeaters derive their power from the potential difference across them.

Originally, submarine cables were simple point-to-point connections. With the development of submarine branching units (SBUs), more than one destination could be served by a single *cable system*. Modern cable systems now usually have their fibers arranged in a self-healing ring to increase their redundancy, with the submarine sections following different paths on the ocean floor. One driver for this development was that the capacity of cable systems had become so large that it was not possible to completely back-up a cable system with satellite capacity, so it became necessary to provide sufficient terrestrial back-up capability.

Importance of submarine cables:

The reliability of submarine cables is high, especially when (as noted above) multiple paths are available in the event of a cable break. Also, the total carrying capacity of submarine cables is in the terabits per second, while satellites typically offer only 1000 megabits per second and display higher latency.

Future Prospects:

As of 2014, there are 285 communications cables at the bottom of the ocean, and 22 of them are not yet in use. These are called "dark cables." Submarine cables have a life expectancy of 25 years, during which time they are considered economically viable from a capacity standpoint. Over the last decade, however, global data consumption has exploded. In 2013, Internet traffic was 5 gigabytes per capita; this number is expected to reach 14 gigabytes per capita by 2018. Such an increase would obviously pose a capacity problem and require more frequent cable upgrades. However, new techniques in phase modulation and improvements in submarine line terminal equipment (SLTE) have boosted capacity in some places by as much as 8000%. The wires we have are more than ready for the traffic to come.

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