AV Cable Types

PINANSON S.L.

Engineering department
PINANSON S.L.
Elizabeth Sánchez Manzanero

www.pinanson.com
engineering@pinanson.com

INDEX

1. INTRODUCTION

Cables are a system component, not an accessory. The cable installation is the most laborious part in the installation. In a professional AV equipped system, the signal should not go through a cable susceptible to interference or noise.

The function of the cable is transmitting a signal from point ***A*** to point ***B*** without degradation.

Audio, Video, Control applications, and Networks of less than 50V are considered low voltage wiring.

This document will explain the parts included in a cable and then describe the main cable types used in the AV sector, both copper wire and optical fiber cable.

2. CABLE COMPONENTS

2.1. CONDUCTOR

A conductor is an electrical current conductive element and therefore the element that transmits the signal.

Signal cables wires are made of materials that transmit with "ease" the electric current. All conductors have a resistance through which power is dissipated through heat. This loss is not very significant in cables that work with a small signal such as the audio-video signals, but it is something to be considered when a cable has to transmit high current and power as power cables. Resistance is related to the conductor size. The smaller conductor, the higher resistance.

Silver has the least resistance within the conductive materials, but it is expensive and difficult to work with. The following low-resistance conductive material is **Copper**, which is considerably cheaper and more accessible. Hence copper is the most common material for the wire manufacture. Aluminium is also used as a conductor when price is what matters, except for uses as shielding tape material in high quality cables.

In many conductors, **copper** is **tinned.** Tin gives the conductor a **special resistance to**: pollutants, chemicals and salt (important in marine applications). Tinned copper has limitations in high-frequency due to the *skin-effect* (at high-frequencies current goes through the outer layers of the conductor) in these cases conductor must be either bare copper or a conductors made with a single layer of copper covering a steel conductor, for instance.

Sometimes copper is also laminated with silver. Silver is a more conductive material than copper but its greatest advantage is that silver oxide has the same resistance than silver itself, while the copper oxide is only a semiconductor. Silver cables are often used for the navy.

There are two types of conductors according to its structure:

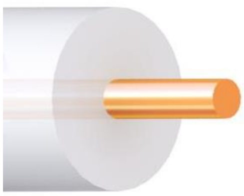
- **Rigid conductor:**

A **solid conductor** uses a single thread and is cheaper than a stranded conductor. Although relatively more rigid, this cable can be bent easily during installation within its minimum bend radius. These cables are typically used in fixed installations.

Rigid and stranded cables applications
Solid conductors within a cable are typically used for high-current applications (larger conductors) and telephony, data and control circuits in low-current applications. Solid conductors in a cable provide the least amount of resistance and provide for a good mechanical connection to punch-blocks and special wire-pinching connection schemes. Stranded conductors within a cable are typically used for low-voltage installations, where flexibility is a prime concern. Typical uses for this type of cable are microphone, line level, serial control data, and loudspeaker circuits. Stranded cables are typically terminated with a connector at the intended device end.

- **Stranded conductor:**

Conductors that combine several strands of material, called filaments will be called here **stranded conductors.** These cables are more flexible and therefore easy to handle, allowing an easy installation. But they are more expensive. Used when cable flexibility is important (e.g. for connecting cameras that do not stop moving). The more wires in a stranded cable, higher cost and more *flexible life* (*how long will last a wire until it breaks*). Stranded cables offer a slightly lower resistance than rigid conductors at comparable sections.



a.1

a.2

Fig. A: (a.1) Bare copper conductor, solid (a.2) Tinned copper conductor, stranded.

2.2. INSULATION

While a cable can have bare conductor, it is more common that these conductors are insulated, which means that the conductor is covered with a non-current conductive or insulating. Currently, different types of plastics or rubbers are used as insulating material, data that must be provided by the cable manufacturer. To define in quantitative way the isolation of a material we use the *Dielectric Constant* referenced to the maximum isolation, vacuum with **value 1**. All dielectric materials have values greater than 1 (e.g. polyethylene = 2.3).

> Thermoplastic materials (plastics) used as insulators: VINYL, Polyethylene (PE), *TEFLON ®*, Polypropylene (PP).
>
> *Thermoset materials* (rubber compounds) used as insulators: *SILICONE, NEOPRENE RUBBER, EPDM (ethylene-propylene-diene monomer).*
>
> Thermoset materials are hard but more expensive than plastic, so that Thermoplastic materials are much more used for wiring manufacture.

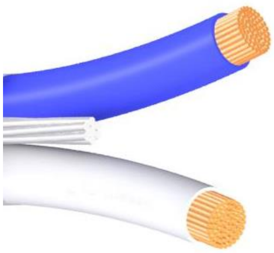


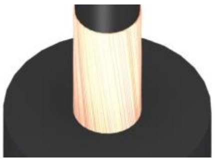
Fig. B: Insulation of twisted pair cable.

2.3. SHIELDING

Cable shielding and pair twisting ensures the integrity of the audio and video signal against possible EMI and RFI (Electromagnetic Interference and Radio Frequency Interference) around the cable. Cables can be shielded or unshielded, except coaxial cables where, by definition, require a single shielded conductor.

Shielding types:

Spiral Shield



Spiral shield is "wrapped" around the cable. These shields can be single or double. Are more flexible than braided shields and easier to finish. Due to its spiral structure (coils) can show inductance effects and therefore they are not suitable for working at high frequencies. Normally used for analog audio signals frequencies. With flexion, these types of shield tend to open losing effectiveness especially at high frequencies.

Braid Shield

The braid shield provides superior structural integrity while maintaining good flexibility and durability. These shields are ideal for minimizing low frequency interferences and in radio frequency have a lower DC resistance than the tape shield.
The coverage that can be obtained with a single braided shield can be 95% and with a double braided shield it can reach 98%. With a braided screen is not physically possible to reach 100% coverage.

Foil Shield

Foil shields can be made of metal or copper but the most common is the aluminium-polyester tape. Foil shields can provide 100% coverage. Because these types of shields are thin to be used as a contact point, a wire along the shield and close to it is used and it is called *Drain wire*. This will be the contact point. Due to the fact that the wavelength on high frequencies can travel through the holes of the braid shields, this type of shield is the most effective at high frequency.

Combination Shields

Different types of shields can be combined in one cable summing the properties of each one.
For example: *Foil + Spiral*, *Foil + Braid*, *Foil + Braid + Foil* or *Braid + Foil + Braid*

2.4. OUTER SHEATH

The choice of the cable sheath is an important factor since it determines its durability. Flexibility is a parameter to be also considered in a cable, especially if you intend to use it in critical mobility or environmental situations. A good choice of cable sheath can prevent deterioration due to the effect of heat, cold or mechanical mistreat.

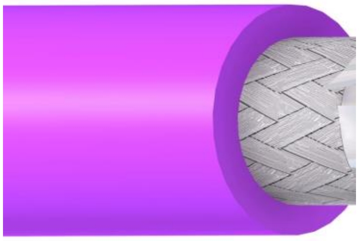


Fig. C: Coaxial cable sheath.

The materials used are the same that shown in the section of *Insulation*.

There is a cable classification according to the response to the fire of their sheaths.
These cables have the requirements for flammability, smoke and life safety in case of fire, flame retardation and no harmful or deadly fumes emission when it burns. Any cable sheath made of PVC or rubber fails and cannot be used in a return air duct.
The application and environment determine the selection of the cable.
The most popular are:

- ***LSOH o LSZH*** → *Low Smoke Zero Halogen*
- ***FRLS*** → *Flame Retardant Low Smoke*
- ***Plenum Rating, Non-plenum Rating…***

3. CABLE TYPES

3.1. TWISTED PAIR CABLE:

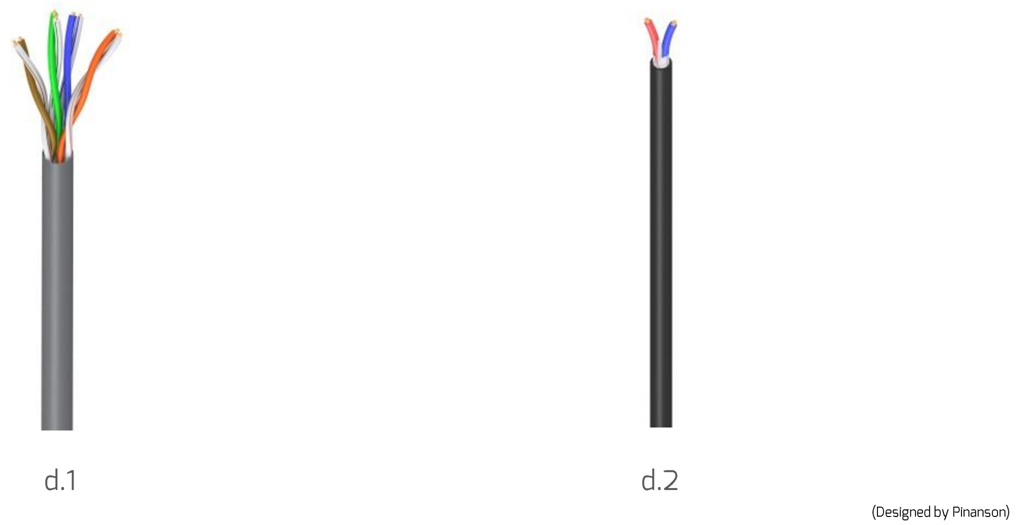


Fig. D: Examples of twisted pair cables: (d.1) Unshielded Category cable, (d.2) Audio cable with tape sheath + drain wire.

A twisted pair cable comprises two joined insulated conductors forming a twist. These cables can drive *balanced lines*. A ***balanced line*** [(1)] is a configuration of two electrically identical conductors. The electrical signal is referenced to ground that is point zero in the circuit. Balanced lines reject noise from low-frequency 50/60 Hz (Power line) up to megahertz or higher signals.

Virtually all professional audio installations use shielded twisted pair audio signal due to its properties against noise. **Microphone and Line level audio signals** between -60 and -20 dBu and +4 dBu [(2)] respectively, are transmitted over twisted pair.

In the consumer equipment line level is transmitted at level of -10 dBV and the cable has a connection "live" and a shield, which we call ***unbalanced cable***. These cables are effective only for short distances and they only have the noise protection offered by the shield.

(1) To learn more about BALANCED LINES go to glossary on our website: ***BALANCED SIGNAL*** http://www.pinanson.com/en/glosario/?explanatory_dictionary_alphabet_letter=B

(2) See the article "The decibel" on our website: http://www.pinanson.com/white-papers/

At the beginning twisted pair wiring was designed to drive low frequency signals as telephone audio signal. But later it began to design twisted pair cables to transmit high frequency signals as the data signals (**Category cables**). So that **USB, DVI, HDMI, IEEE 1394** cables, among others, also transmit its signal through twisted pair cables.

3.2. COAXIAL CABLE:

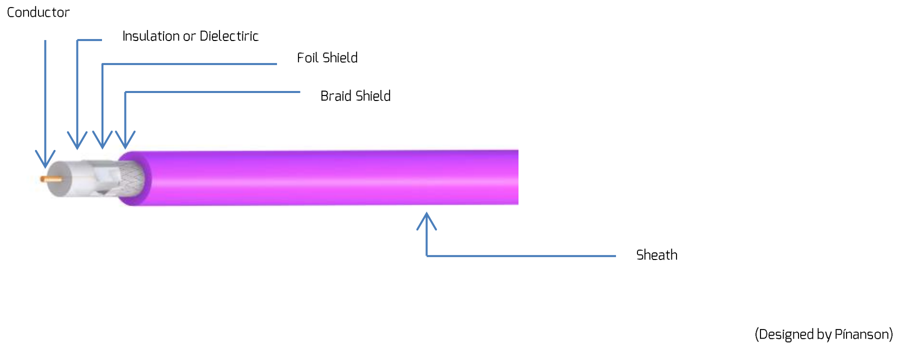


Fig. E: Coaxial Cable

A **coaxial cable** design is a structure in which the conductor is centered within another with both connectors transmitting current (from the source to the load and return). Every part of the cable is on the same axis (they are coaxial). They are used for high frequency signals. Coaxial cables have a much better response over 100 KHz than the twisted pairs. However, the coaxial cables are ***unbalanced lines*** (3) so they lose the noise rejection feature that twisted pairs have working as balanced lines. The insulation between the conductor and shield of the coaxial cable affects the impedance and the durability of the cable. The best insulators after *vacuum* are the *air* and *nitrogen*. The insulators used for this type of cable are chemical insulating foam or nitrogen gas injected foam. The ideal material is the *high density foam* which has solid plastics density and high percentage of nitrogen gas. The importance of high density (with high propagation speed 82-84 %) of the insulating foam is that the conductor is protected when the cable is bent maintaining impedance variations at minimum.

(3) To learn more about BALANCED LINES go to glossary on our website: ***BALANCED SIGNAL*** http://www.pinanson.com/en/glosario/?explanatory_dictionary_alphabet_letter=B

For **very high frequencies** such as radio frequency signals or television channels only the outer parts of the conductor work due to the *Skin effect* (discussed in the section *Conductor*). Therefore wires are used with steel made conductor coated with an outer layer of copper, because only the copper layer will transmit the signal current.

Coaxial cables are used for video systems: *CCTV* (*closed circuit television*), *CATV* (*cable TV*), transmission of professional analog and digital video or digital audio (*AES 3id*). All of them have a characteristic impedance of 75 Ω.

If we talk about professional digital video we talk about *SDI* (*Serial Digital Interface*) and its versions: *SD-SDI* (*Standard Definition*), *HD-SDI* (*High Definition*), *3G-SDI* (*3 Gbps HD higher HD-SDI*). These signals are transmitted through a single 75 Ω coaxial cable terminated with a 75 Ω BNC connector.

There are different digital video cables depending on the insulator and conductor diameter. The different models are identified according to its dimensions (in mm o inches), 1st number is the conductor diameter and 2nd number is the insulator diameter: *0.6/2.8, 0.8/3.7, 1.0/4.6, 1.4/6.6, o 1.6/7.2*. The **maximum length for a cable** is specified by a *return loss of* **20 dB at half of clock frequency**.

3.3. TRIAXIAL CABLE:

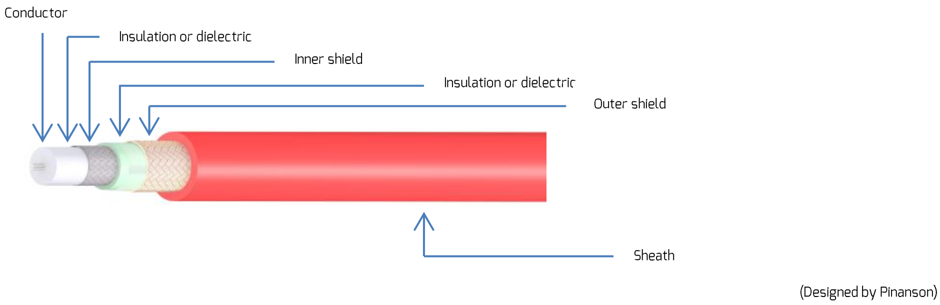


Fig. F: Triaxial Cable

Triaxial or Triax cable is used for connect a video camera and its corresponding equipment. Triaxial cable contains **a central conductor** and **two insulated shields**; it is ready to perform various functions in the same cable. The inner conductor and the outer shield carry the video signal and the intercom, monitoring and camera power. The central shield carries the ground of video signal or common ground.

Triaxial cable is generally used in two types: *TRIAX 8* and *TRIAX 11*, which correspond to the approximate diameter of the cable itself, of 8.5 mm and 11 mm respectively.

3.4. INSTRUMENT CABLE

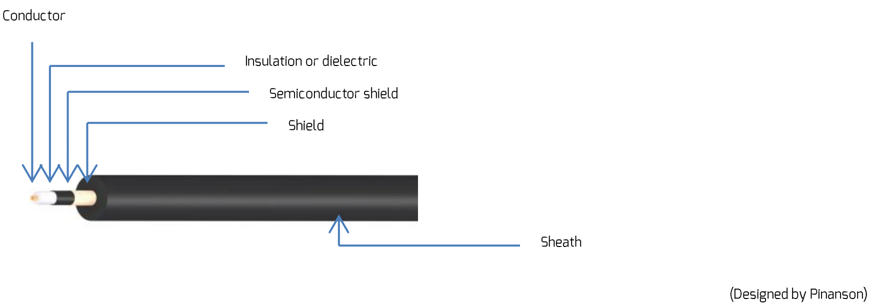


Fig. G: Instrument cable

The instrument cable is a special cable for high impedance instrument signals such as a guitar or bass. Its structure is like a coaxial cable but with a semiconductor shield covering the insulation.

This is a special structure because these cables are often affected by the *triboelectric noise* in guitar or high impedance microphone cables, because of his constant movement

Therefore, instrument cables which have not that structure this mechanical noise will be heard.

The so-called ***triboelectric noise*** affects this type of audio cable. It is a mechanically induced noise. This type of noise is generated by the movement of the cable that makes the inner threads rub against each other inside, thus electric shocks are created by these relative position conductors changes. A highly amplified audio signal becomes that noise audible. The insulation around the conductor helps maintaining a constant space and the semiconductor shield helps dissipating the load accumulation.

3.5. SPEAKER CABLE:

(Designed by Pinanson)

Fig. H: Speaker cable.

The speaker cable is used to connect the amplifier to the speaker. Such cables are not usually shielded, as the signal transmitted is higher voltage (higher than +25 dBu [4]) and therefore they are signals less likely to be affected by background noise.

It is very important to consider the cable section that will depend on:

- The **impedance of the speaker** to be connected, the lower impedance, the bigger section of the cable.
- The **number of speakers**, the more boxes, the bigger section of the cable.
- The **length of the cable**, the longer cable the bigger section of the cable.

With professional devices we can find multicore configurations with different number of speaker cables. This depends on the number of speakers you need to feed. Therefore, if we want to feed through a speaker multicore a 4-way system (*Treble, Mid Treble, Mid Bass and Bass*), we will need a multicore with 8 speaker cables with the section needed according to commented factors.

(4) See the article "The decibel" on our website: http://www.pinanson.com/white-papers/

3.5. MULTICORES.

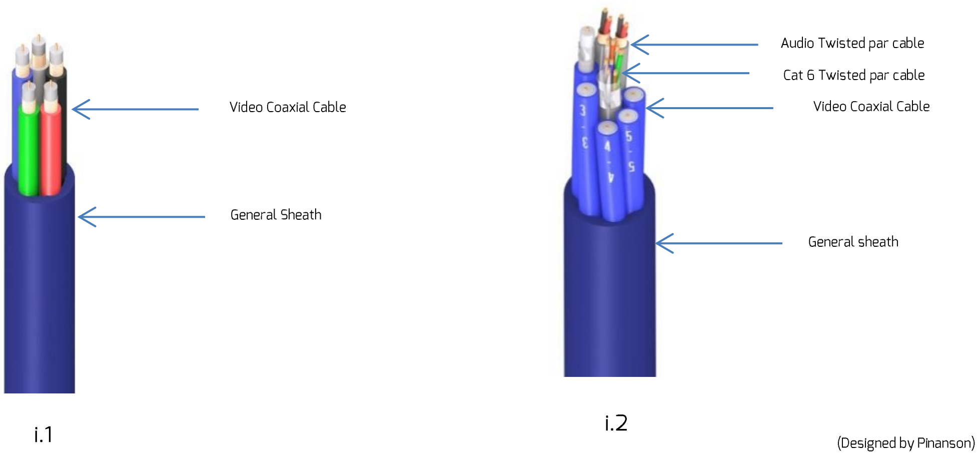


Fig. I: (i.1) Multicore with 5 coaxial video cables. (i.2) Hybrid or mixed multicore with 5 VIDEOS + 1 CAT 6 + 2 AUDIO.

In many installations or events several different signals need to be transmitted simultaneously. To meet this need in a comfortable and durable way, multicores are used. These consist of several cables (as the number of signals to be transmitted) inside a sheath and common screen. Each of the cables must be individually screened and individually sheathed. Multicores can be wired with the same type of signals (i.1) or with different signals that we call *Hybrid or Mixed multicores* (i.2). Audio, Video, Data, Power signals and signals by optical Fiber can be transmitted at the same multicore. The type of multicore should be chosen depending on what you need it for, for instance, flexibility needed (if it is for fixed installation or not). The correct construction of this type of multicores plays an important role in preventing, for example, the curling of the sheath over time.

> An example of hybrid multicore is the ***SMPTE 311*** (to be used with ***SMPTE 304*** connectors) containing: copper wiring and single mode fiber.

4. OPTICAL FIBER

4.1. OPTICAL FIBER PARTS

In this document we will only make a short presentation of transmission by optical fiber cables because the topic is very extensive and well worth a specific document.

Optical fiber signal transmission is based on the transmission of light through transparent fiber made of glass, fused silica, or plastic, for obtain information.

The main advantage of using fiber for signal transmission is this system can transmit very high bandwidth signals with low loss over long distances without signal amplification. Another feature that makes it a good transmission system is that signal conduction is not made through a conductive metallic material and therefore achieves immunity to EMI or RFI (electromagnetic interference or radio frequency interference) and *crosstalk* noises will be eliminated.

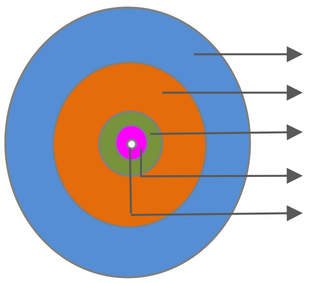


Fig. J: Optical Fiber cable scheme

(1) **Outer sheath**: Protection against possible external agents. Made of different plastic materials.

(2) **Dielectric amour** : extra protection against attacks such as: crushing, rodent attack, fire … It may be fiberglass rods (endow stiffness), fiberglass yarns (more flexible deterrent against rodents), fiberglass braid (dielectric and deterrent effect), permanent protection and fire barrier in some

(3) **Inner sheath /Buffer**: mechanical and insulation protection (plastic cover) of the core in case of destruction of the outer cover.

(4) **Coating / Cladding:** dielectric material covering the core of the fiber. Prevents light "out" from the core, acting as a waveguide. Index of Refraction n2.

(5) **Core:** silicon crystal where light travels. With Index of refraction n1.

NOTE: To have Total Reflection n1>n2

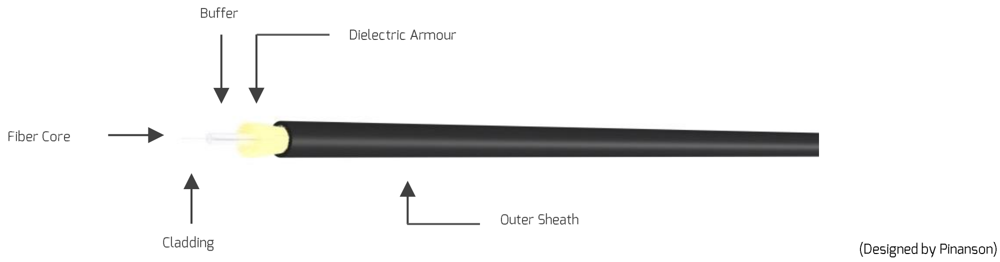


Fig. K: Example of optical fiber cable

4.2. TYPES OF FIBER

Optical fiber is typically classified by their refractive index profile and the core size:

- ***Single mode Fiber*:** It has a diameter ranging from about 8 µm to 10 µm, depending on the manufacturer. To use this type of fiber, a very precise source must be used which can produce a single mode of light radiation into the fiber. The index of refraction of a single mode fiber is very low because such a small core prevents the ray dispersion. This optical fiber is capable of propagating wavelengths of 1310 nm and 1550 nm, slightly attenuates the signal (for example: 0.4 dB / Km). It is used for long distances and high bandwidth.

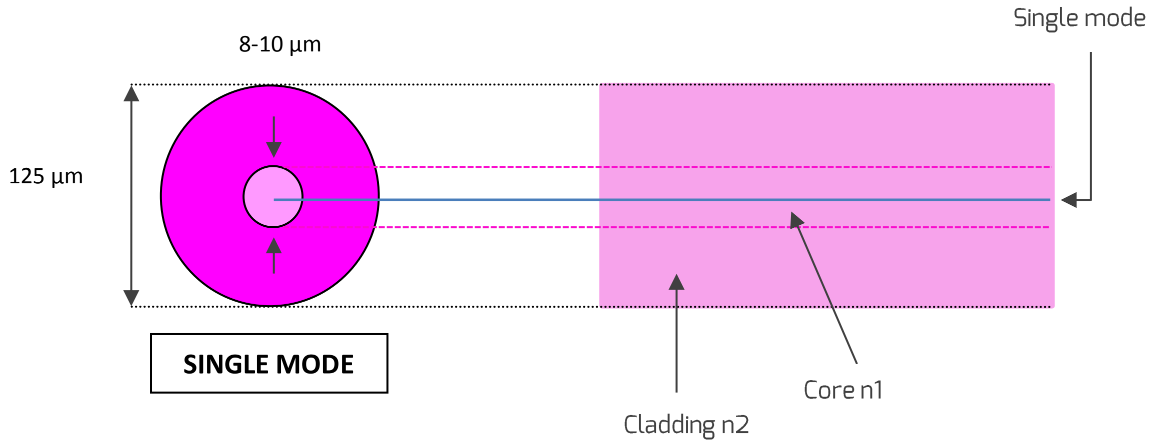


Fig. L: Single mode fiber transmission scheme

- ***Multimode Step Index Fiber***: if the core layers exhibit the same optical properties the fiber is classified as *Step Index Fiber*. This fiber requires repeaters located at short intervals. The goal is that all rays or modes arrive together to produce a replica as close as possible to the input signal. In communications modes uses to go on different channels which are controlled for their arrival is at the same instant.

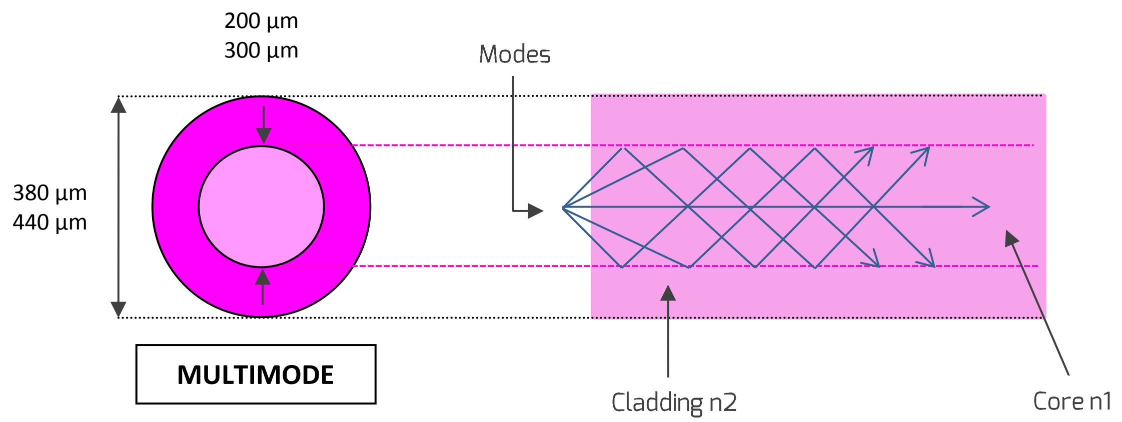


Fig. M: Multimode Fiber transmission approximate scheme.

- ***Multimode Graded Index Fiber***: if the core layers have different types of materials (which provide various transmission characteristics, different index of refraction), the fiber is called *Graded Index Fiber*. In this type of fiber the core axis contains a higher density material so that the waves travel slowly to "synchronize" with waves travelling through longer path. Density grades are progressively smaller from the axis outward to achieve again that the waves arriving at a time and thus achieve a higher intensity of the received wave.

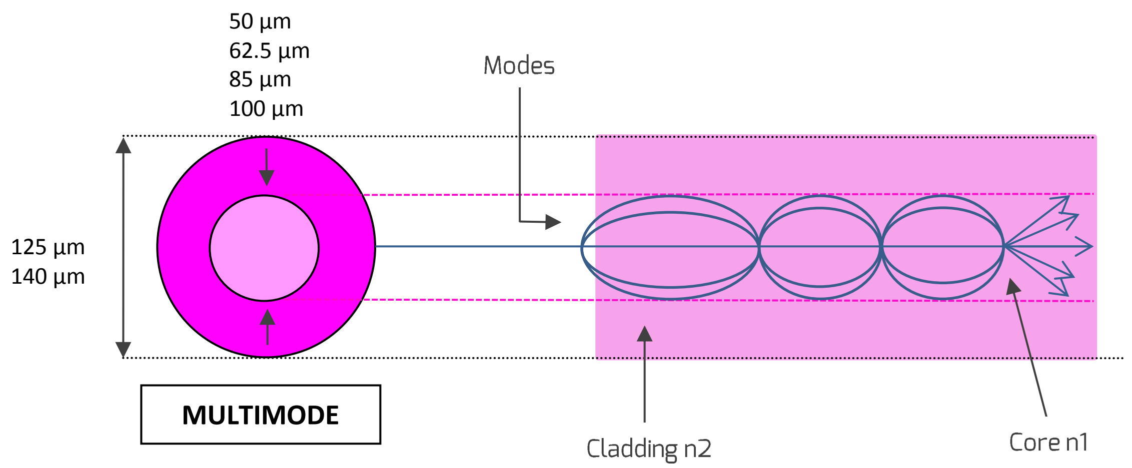


Fig. N: Multimode Fiber transmission approximate scheme.

Multimode fibers have a higher attenuation than the Single mode (up to 6 dB / Km) being *Step Index Fibers* those with higher attenuation within the glass fibers.

ñ.1 ñ.2 (Designed by Pinanson)

Fig. Ñ: (ñ.1) Fiber with adjusted structure (ñ.2) Loose fiber structure.

In wires with *adjusted structure* each fiber has dielectric armour and an outer protection plastic each. In wires with *loose structure* the dielectric armour and outer protection plastic protects all fibers at once.

5. CABLE or TRANSMISSION LINE?

A cable consists of two or more conductors that are held closed its entire length. A pair of such conductors, due to the same current goes and comes to the load in opposite directions, the magnetic fields have the same intensity but different polarities. In theory, external fields would be zero and inductance would be net zero if conductors could occupy the same space. The cancellation of the send and return inductance due to magnetic coupling varies with the cable construction, with typical values of 70% for twisted pair and 100% for coaxial construction.

At very high frequencies, a cable exhibits very different characteristics from those that it has, say, at 60 Hz. This is because of the finite speed called *propagation speed*, to which the electrical current travels through the conductors.

A cable is called electronically short when its physical length is less than 10% of the wavelength at the highest frequency of interest.

There are different voltage values along transmission line. Its electrical equivalent is a circuit that is compound of high number of coils and resistors in serial and capacitors in parallel. A short cable can be represented by a resistor $R_{conductor}$ and R_{shield}, coil $L_{conductor}$ and L_{shield} and l capacitor $C_{conductor\text{-}shield}$.

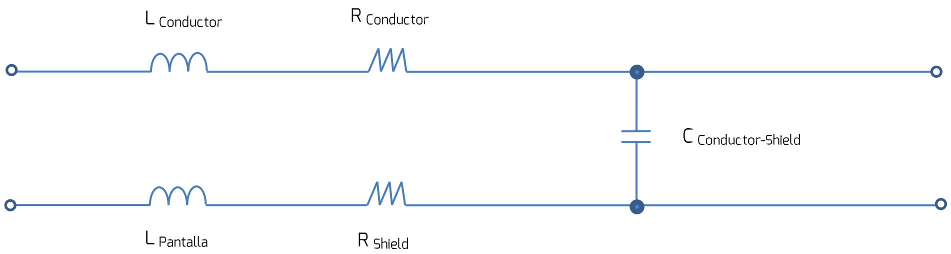


Fig. 0: Model of electrically short coaxial cable

When a cable is longer than 10% of the wavelength, signals can be considered as electromagnetic waves and the cable called TRANSMISSION LINE

This includes typical cables of:

- More than 7 m at 10 MHz video signal.
- 20 cm for radio FM signal of 100 MHz.
- 2 cm for CATV signal of 1000 MHz.

This cable's *characteristic impedance* is the result of its inductance and its capacitance per unit length, which is determined by its physical construction.

If the end of the line is terminated with a resistor having the same value as the characteristic impedance of the line, the wave energy will be **completely absorbed**. For the wave, this impedance is a continuation of the cable, simply. In a transmission line this impedance matching is essential and when achieved, it is said that the line is matched. Generally, the impedances from the source and receiver are properly matched with the characteristic impedance of the line. In a line in which there is no impedance matching, interaction between outgoing wave and reflected wave causes a phenomenon called: ***Standing Waves***. A measurement called Standing Waves-Ratio (SWR) indicates the mismatch system, **a SWR of 1.00 that means a perfect match**.

Therefore if our cable has the characteristics of a transmission line, then its impedance and its adaptation begin to be important. If we have not this in mind the **reflection loss** can be high and the transmission signal will not be of quality.

[1] AV Design Reference Manual. First Edition. InfoComm International.
[2] Handbook for Sound Engineers. Glen Ballow. Forth edition. Focal Press.

www.pinanson.com
pinanson@pinanson.com

See our full range cable and optical fiber cable:

http://www.pinanson.com/catalogue/en/97-cable-and-optical-fibre

See our Glossary on:

http://www.pinanson.com/en/glosario/

Pinanson S.L.
Avda. Constitución, 40
Mondéjar (Guadalajara) SPAIN
C.P.: 19.110
Phone: +34 949 387 180
www.pinanson.com
engineering@pinanson.com