ACCL
Make Connections

Guide to Design & Specification of Structured Cabling Systems

Procedure Guide Introduction

Active Communication Company was formed based on the simple knowledge that reliable, effective and flexible cable network infrastructures are of critical importance to all of the companies and customers of ACCL.

Today’s sophisticated communications environment is driven by the need for high-speed connectivity and your choice of structured cabling, the system and the installation is vitally important. ACCL understand our customer’s needs for high performance networks today and that this must include the capacity to accommodate the applications of the future.

This ACCL Procedure Guide aims to serve two distinct purposes not only for our clients, but also project consultants and own installation teams. This Procedure Guide outlines every aspect of the total quality service that ACCL provides all of it’s customers from areas of design and specification of product, installation standards, project management, working practices and testing and certification of your network infrastructure.

The second aim of this ACCL Procedure Guide is to act as a future reference manual for our clients as it covers in detail the precise working methods and Standards employed by ACCL and those that must be followed. The ACCL Procedure Guide is a benchmark tool for the cabling industry.

ACCL

Make Connections

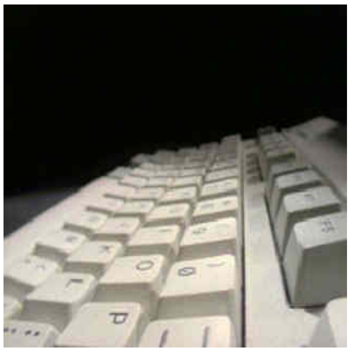
Active Communication Company Limited is committed to the highest quality service in voice and data distribution.

Earth, Water, Air and Fire are thought to be ancient elements drawn together giving life to the world. ACCL liken Power, Voice and Data to these essential elements. The cables and connections that we design, supply and install are the life-blood of the buildings on which we work.

We believe passionately in total quality service and that this is achieved by the personal touch of the reactive, efficient company, working hand in hand with the customer, putting in place the final connections.

Wayne Connors
Managing Director
Active Communications Company Limited

Local Area Networks



Local Area Networks (LAN's) provide the infrastructure for high-speed data transmission around small and large businesses alike. There are two separate sections of a LAN, which are defined as the active and passive components. The active components of the LAN consist of units that contain electronics for routing and the switching of data packets throughout the LAN, i.e. computers, servers, hubs and routers.

In the beginning mainframes offered us the first true types of networks. Mainframe computers allowed users to access data, run applications and send each other mail electronically. The users worked with dumb-terminals, non-intelligent systems that were directly wired back into the mainframe. One of the main problems with these potentially massive mainframe systems was that one company could not easily communicate with another.

The two big players in mainframe systems in the late 1960's were IBM and the Digital Equipment Corporation (now Compaq). Each one of these companies produced a data communication system that could only 'talk' with those terminals that utilised the same language, protocols and applications.

The mainframe war almost began with both IBM and the Digital Equipment Corporation fighting to become the top player and take control of the mainframe market. Thankfully the American government stepped in, as they did not want one manufacturer to become all 'powerful' and control the American marketplace and probably that of the world.

The American government also had its own hidden agenda; after all, the Cold War was very much a threat at that time. The whole of the American defence department relied on these massive mainframes for strategic support and general administration etc.

In itself these mainframes were not a problem, the problem was that different governmental departments throughout America had purchased mainframes from different suppliers, and electronic communication was of paramount importance.

If a war did take place, and the potential threat at that time was a nuclear one at that; departments would not be able to communicate with each in a state of emergency.

The Advanced Research Project Agency (ARPA) was therefore commissioned in 1969 to develop a computer network and language system where computers, no matter where located could communicate and understand each other.

The ARPA (Net) network was born shortly after, a network that linked four universities that were also involved with government research. ARPA commissioned Stanford University to develop in 1973 a system of protocols that would allow the interconnection of different types of networks. TCP/IP (transmission control protocol / Internet protocol) was created and this gave birth to what we know as the Internet and the World Wide Web.

Mainframes soon stated to disappear, personal computers quickly started to replace the dumb-terminals, and true local area networks started to appear.

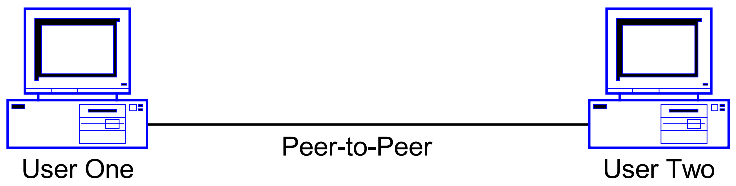
The first signs of ad-hoc structured cabling began in the middle of the 1970's as business computers started to take hold as a valuable tool within companies. The first examples were simply one user connecting his or her business computer to another. No one cared about too much about cabling being strewn across from one desk to another; the birth of structured cabling was about to commence.

The local area community really took up momentum with the birth of severs, which in the early 1980's were really just beefed up personal computers with larger disk drives and increased RAM (random access memory). Disk drives were wholly reliable at that time compared to modern state of the art hard drives as used today.

Modern networks offer us all many multimedia applications that can support and provide sound, video conferencing and games, email and on-line learning packages, VoIP and even more. Modern LAN's can deliver a service that easily exceeds 100 Mbps, up to data rates of 1Gbps (twisted pair copper) at this moment in time, but 10Gbps is expected for copper very shortly.

There are two main characteristics of types of LAN's, either peer-to-peer or client/server based local area networks.

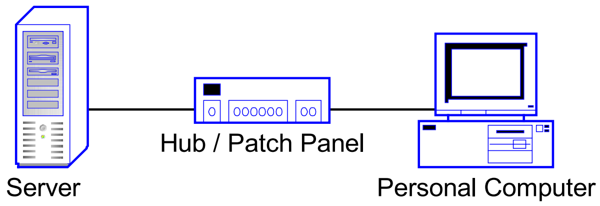
Peer-to-Peer Networks



Peer-to-peer networks have successfully served both small and medium sized business well and will continue to do so for a few more years. The theory behind these networks in brief is that each user can, if permissions have been granted from the network manager act as either or a client, print and disk server to every other node in the LAN.
Hot-desking with available software applications is made easy here, provided that as a user he or she has been allocated password authorisation of the required number of personal computers.

Why chose the peer-to-peer option. Firstly the company will not require a centralised management system (control of user accounts etc) and secondly there only tends to be a small number of users that will need IT support.

Client – Server Networks

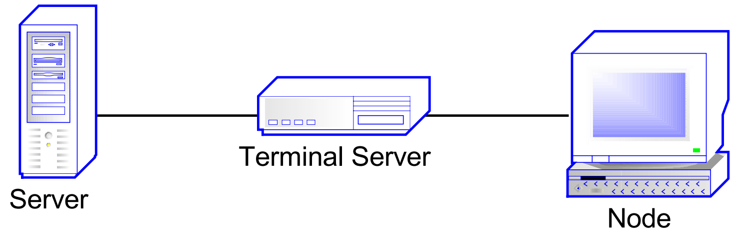


The modern LAN's of today are primarily client – server based, utilising operating software such as either UNIX, NetWare or one of the Windows family, NT or 2000. The main server of this network type is the bastion of all things powerful. Every user will have an individual protected password before he or she can log onto the system.

The central server holds all of the key business information, apart from files and folders that are stored locally on a personal computer. One potential problem with this centralised warehouse of business folders is that someone may try and enter a folder titled 'Human Resources – Salaries'. I would suggest that the management team would not like a user having access to salary information of every employee within the business; and that is why we are all issued login codes and passwords.

The server can, with the correct management by the IT section create user groups or domains. Passwords will identify the user and allocate the associated rights required by the user, i.e. the groups or domains they are able to enter. These user rights can be controlled by the server to such a degree that the network manager can even choose to make files within folders read only if they so wish.

Thin Client – Server



Thin client – servers are also available for use on a local area network. The network manager on this occasion has decided to reject the 'normal' approach of allowing users personal computers and has opted for a system that only utilises 'dumb terminals'. When the user performs a logon, they will be connected as a Thin Client such as Citrix MetaFrame, which in turns connects the user onto a more powerful server.

The main powerful central server issues out all of the required software applications required by the user. By using a Thin Client system the individual user is not able to load or open any items not permitted by the IT section. This ensures that no illegal software can be installed onto a local node and also ensures that the network manager and technicians always have total control over the network.

Because the main central servers hold all of the business software applications and that the software programmes are issued out to the user, he or she can only enter mouse clicks or keyboard strokes into the network.

The previous diagram above depicts not only the main server but also a terminal server. These terminal servers act as a buffering system or cache between the main powerful server and the user. This enables high reliable performance of the local area network, reducing the amount of bandwidth required (typically Citrix MetaFrame systems only require 10Mbps to operate efficiently). Because less processing power is needed users hardware such as personal computers (which can still be connected to the Thin Client – Server LAN) can have a greater and longer live, therefore saving money on personal computer upgrades.

Summary

Therefore a local area network is both a passive and active system made up of personal computers, servers, hubs etc, connected via either optical fibre or copper cable within either a building or campus to transmit and receive data as and when required.

Network Topologies

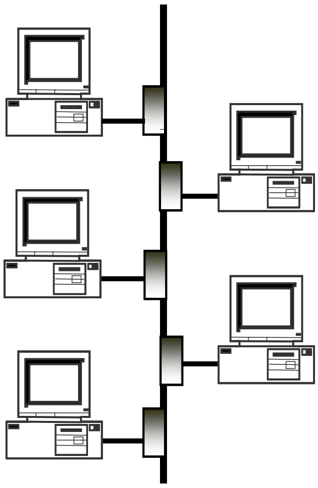
Within the network infrastructure there are typically four different topologies styles. Each network topology has it's own advantages and disadvantages for each type, be it a Bus, Ring, Star or Hybrid and the use of switches within a network.

Bus Topology

The Bus topology is sometimes also referred to as a Linear Bus topology and is the simplest of all the topology types from an installation point of view and is also one of the oldest styles of topologies used. The Bus topology historically consisted of a single backbone cable that has workstations and other peripheral devices attached directly to it.

Bus topologies tend to be utilised within smaller networks with up to ten users on each Thicknet Bus.
Thicknet cable was the preferred choice for these types of networks. Thicknet cable is rated as a 10Base5, i.e. 10mbps, baseband transmission type with a maximum length (known as a segment) of 500 meters.

Thicknet cable utilises a vampire tap system and uses a transceiver with metallic teeth, which cut into the cable sheath to make contact with the copper conductor, which carries the data signal.



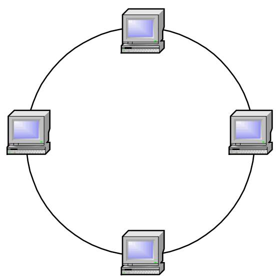
The transceiver is a device that acts both as a receiver and as a transmitter from which typically an RS 232 connection is made to the workstation or peripheral equipment.

Bus topology based networks have high possibility of complete network failure known in this instance as a single point of failure. For example if there were a problem with the backbone cable, then the complete network would be taken out of operation. The Bus topology has (like all topologies) some very distinct disadvantages:

1. From the network managers and network support staff point of view they can be very difficult to troubleshoot any problems with the LAN data speed etc.
2. The workstations need to be ideally 'intelligent' so they could identify which data packets were intended for them. The problem with Bus networks is that data packets are sent across the whole backbone and they are viewed by every workstation in turn and this obviously takes up more time and network usage.
3. Expansion of the network is difficult due to the fact that an additional cable will be required if more than 10 users are required to be linked onto the Bus.

RING Topology

Ring topologies once again like the Bus topology use a single cable to deliver the network services and operate in some way as a peer-to-peer network, i.e. the data packets run from one workstation to the next in turn.



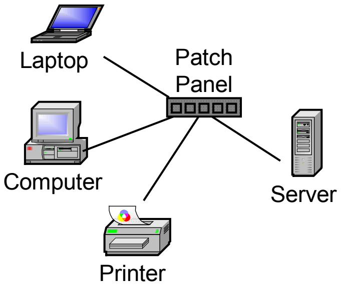
These types of network still exist today, but mainly in the form of small networks used in very small businesses and for HAN's (Home Area Networks).

These Ring style topologies are easy to create and manage because of the fact that they are cheap to install and that there is no need for expensive items such as hubs etc. However there are several disadvantages to this type of network.

1. If one workstation were to fail, then the network would fail; another factor is the number of workstations and the possible increased number of points of failure.
2. Most Ring topologies utilised the BNC style connector and coaxial cable. This type of connector and coaxial is susceptible to breaking down.

STAR Topology

Star topology based networks are now considered the normal style for data networks. The Star network is based on the idea of centralisation with all workstations leading back to the main server located within either a telecommunications or equipment room.

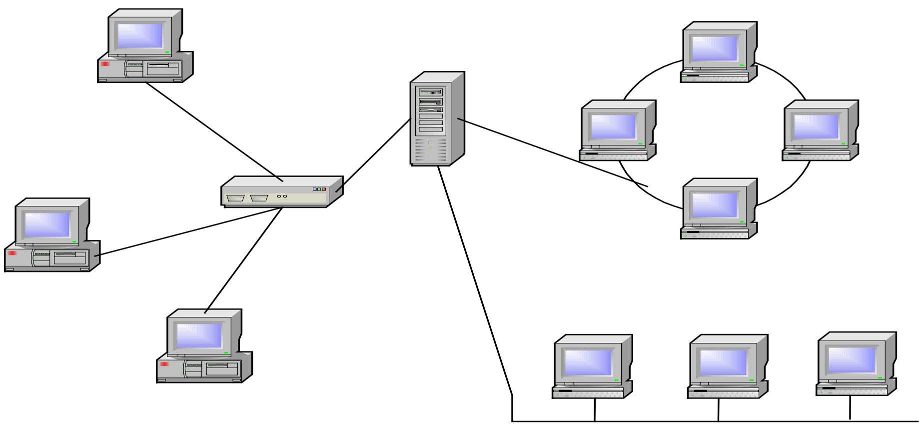


Each piece of active equipment, laptops, personal computers and printers etc and directly connected to a patch panel which in turn is connected to a centralised server. This centralised system offers large benefits over the previous network as the network system integration staff can make all users and other system specific adjustments from just one single location. Unlike the Bus and Ring topologies, if one single workstation were to fail it would not affect the other users.

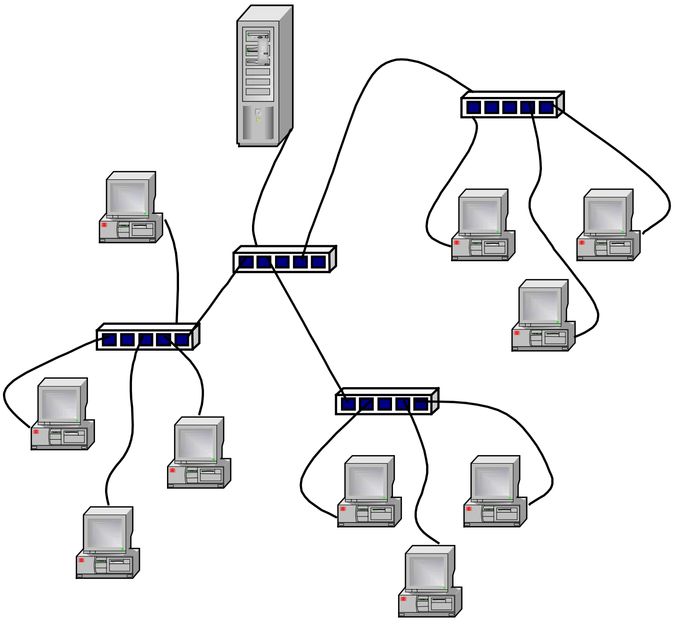
The Star topology however has a major single point of failure and that is the main server; if the main server were to crash then the whole network would crash. Personal computers are more likely to be used on a Star topology because users can still work to some degree while the network is down.

Hybrid Topologies

Hybrid topologies are in the simplest terms a combination of different topology types, which are joined together in one continuous stream.



Topology Expansion & Switches



If we were required to extend the Star topology in size, we could by carefully selecting and adding a combination of hubs and switches, as the above diagram depicts.

Expansion via Hubs

The server could be connected to a daisy chain format of interconnected hubs, however the only problem is that data packets will be broadcasted to every hub and node, whereas expansion with switches.

Expansion via Switches

Switches allows the network a time saving on data packet transfer due to the fact that data packets will now be only sent to the correct hub and not broadcasted over the complete LAN to every workstation or personal computer. The majority of modern networks now utilise a switched network topology.

Transmission Theory

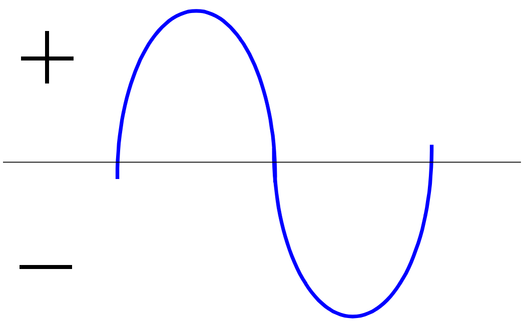
Forgetting items such as active equipment (routers & hubs etc), data transmission whether it is in a digital or analogue format is dependent on the performance characteristics of a specific cable type in respect of copper and optical fibre. Local area network infrastructures are entirely dependent on the transmission media, and the wrong choice of cable type and connectivity will have a dramatic affect on the LAN performance.

The signals that travel on our communication cables can be either analogue or digital, although analogue signals are converted or translated into digital formats for data and voice communication.

Analogue Signals & Frequency

Analogue signals are constantly changing from a positive state to a negative state and can be monitored as a waveform. These analogue waveforms are measured in two ways, frequency and amplitude.

Frequency is measured by the number of cycles that occur within a 1second-time period and are expressed in a unit of measurement known as Hertz. The UK mainland electricity supply operates at a frequency range of 50 Hertz, therefore the signal is changing pattern from positive to negative 50 times per second. Modern copper data communication cables are able to handle frequencies from Cat5e100Mhz (100 million cycles per second) to Cat 6 with a frequency range of 250Mhz.



Voice signals are constantly varying waveforms, due to pitch (frequency) and amplitude (how loud we talk). The basic telephone needs to be able to convert these varying analogue signals into electrical signals and then into a digital format for transmission.

The human voice produces sound waves and these sound waves are continually subjected to changes in pressure as they pass through the air. Every small pressure increase causes compression of the sound wave, and this creates a decrease of pressure (rarefaction). The number of complete cycles per second is referred to as the frequency of the sound wave.

Digital Transmission and Bit Rates

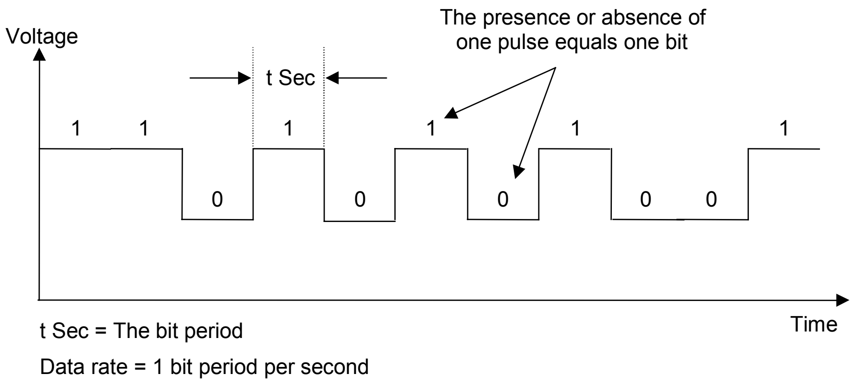
Digital transmission consists of several discrete voltage levels. One level will represent a “1” whilst the other level represents a “0”, digital information is transferred using this two level code. A code word in ones and zeroes could be a magnitude such as someone’s bank balance. On the other hand each code word might represent an alphanumeric character as in text file transfer.

If one of the code levels such as a “one” is interfered with, and is turned into a “zero”, your bank balance may change dramatically or the text letter change from say an “A” to a “P” creating a text error.

Electrical interference particularly induced “spikes” or switching transients is one cause of data errors

Reflections of data energy in the cable medium is due to the twisting or kinking of the cable, thus creating an impedance mismatch between connecting leads and the cable, this can also result in data errors.

Data rates are described in terms of the number of digital information elements transmitted per second or bits per second. A “bit” is the smallest digital signalling element, that is, a “1” or “0”, one level or the other level. The reciprocal of the bit period gives the bit rate.



1. 15 kb/s = Therefore equates to 15,000 bits per second.
2. 100 Mb/s therefore equates to 2 million bits per second.
3. 1000 Mb/s is the highest data rates currently being used over customer premises structured cabling systems.
4. 10 GB/s means 10,000 million bits per second. The telecommunication carrier networks used in long distance data transmission utilise optical fibre for this extremely high bit rate.

Bandwidth

One term that is used everyday within the data and telecommunications industry is the term bandwidth. Bandwidth is an indication of how much possible data we can carry effectively down a communications channel or pipe. Bandwidth is measured in Hertz (frequency).

1 Hz	=	One cycle per second.
1 kHz	=	One Thousand cycles per second.
1 MHz	=	One Million cycles per second.
1 GHz	=	One Billion cycles per second.

Copper data communications cables (optical fibre will be covered later) state their bandwidth in Hertz, as the following table demonstrates.

Type	Class	Category	Bandwidth (Hz)
Copper	A	-	100KHz
Copper	B	-	1MHz
Copper	C	3	16MHz
Copper	D	5e	100MHz
Copper	E	6	250 MHz
Copper	F	7	600MHz

It is important to realise that the bandwidth and data throughputs (Mbps) are not one in the same thing.

Data Throughput

Each type of copper communication channel will have a maximum amount of how much data it can carry, for example a Cat5e cable can deliver a data rate of 1G/b (1000 Million bits of data). The higher the frequency range the more data we can carry.

Data throughput and bandwidth are closely linked to each other, imagine if you can that bandwidth (frequency) assigns the number of lanes that a roadway can contain and that data throughput is how many cars or articulated lorries can travel down it. If we apply this imaginary principle, we can all agree that a motorway will cater for more cars in an hour as opposed to a single carriageway. Data packets are encoded to reduce their amount of size therefore allowing us the ability to push more data over the roadway in the same amount of time.

It therefore equates that single carriage roadways can only deliver a small amount of data and that a motorway can deliver vast amounts of data. Bandwidth allows the communication channels more lanes on a carriageway, and the encoding used to convert the data into smaller pieces of actual data.

Actual Data Transfer

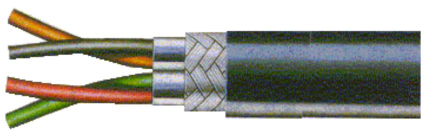
Now we understand some of the basics of or communications network, it must lead onto how we actually send the data traffic across the communications line.

Data transmission over copper-based networks is also based on how we choose to send the data packets and how we choose to encode the data.

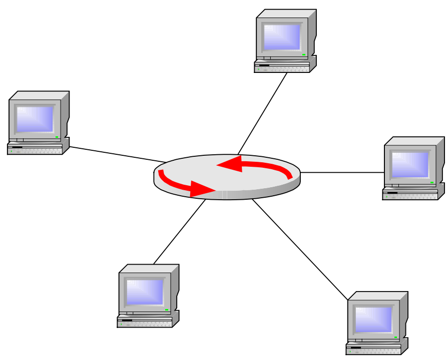
Within the basic levels of the data world, we often use words such as token ring and Ethernet, so it is important that we have some basic understanding of what each of this are before we can progress any further.

Token Ring

Token Ring first appeared as a communication system in 1985 by IBM. The cable type originally used for Token Ring applications, operated at a data rate of 4Mbps over 150Ω shielded twisted pair cable (STP), which utilised only two pairs as opposed to modern copper cables that utilise four pairs. The need for faster data networks during the mid-1980 forced a new version of Token Ring cable, which operated at a frequency of 20Mhz (Category 4) and delivered a data rate of 16Mbps.



Token Ring started to lose favour with many network consultants, as Ethernet become the preferred choice. Token Ring has been through various stages of evolution in an attempt to regain its popularity and performance levels up with the launch of the IEEE 802.5t Standard for 100 Mbps.



Token Ring operates by literally sending a token from one node to another in a network. If any node wishes to transmit they can, provided that they have control of the token at that precise moment of time.

Ethernet Transmission

Ethernet is the most used method of data transfer in the world today, due to the fact it is highly reliable as a communication carrier. Ethernet started its working life with the cable loving known as 'Thicknet' or by its true name 10Base5. Thicknet cable delivered a total data rate of 10Mbps to a total length of 500m.

This cable type is typically yellow in colour with thick black bands at specific internals along its length. Transceivers are fitted at these black bands to enable the transfer of data.

A cable type known as ‘CheaperNet’ or 10Base2 replaced ThickNet cable. ‘CheaperNet’ utilised the BNC style connector, as previously described. Ethernet now operates on both optical fibre and twisted pair copper data cable.

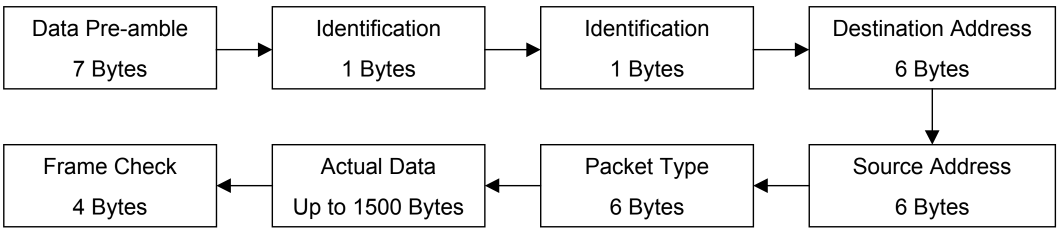
Ethernet is seen as a contentious method of communication system by the manner in which it operates. The nodes on a modern network all want and need to send data constantly; after all on average up to 30% all of network communication traffic is used for synchronisation. With all these nodes wanting to transmit data all at the same time the last thing any network manager or use wants is data packets to collide, therefore Ethernet utilises a communications protocol known as CSMA/CD. The term CSMA/CD refers to Carrier Sense Multiple Access and CD as Collision Detect.

Carrier Sense Multiple Access, in layman’s terms monitors the network and if two nodes attempt to transmit data at the same time it will tell them to back off and wait for a typically unspecified amount of time before trying to send the data again (collision detect).

Ethernet Frames

It would not be efficient or practical within a data network to transmit one piece of data at a time so instead Ethernet data systems (1000BaseT, 100BaseT etc) place of the pieces of data (bytes) into a single packet.

The following diagram clearly depicts the data transfer sequence:



1. The ‘Data Preamble’ is where the sender device transmits a combination of binary digits so that both the sender and receive can synchronise with each other.
2. The ‘Identifier’ signals the actual start of the data packet and the information it actually contains.
3. The active pieces of equipment can now read the required delivery address of the data packet.
4. The ‘Source Address’ informs the receiver who the sender is and an embedded contact address if subsequent data packets need to be re-transmitted.
5. The ‘Packet Type’ informs the receiver if the data packet contains data or whether it is in fact a network service packet.

6. The ‘Actual Data’ is now transmitted to the receiver. The receiver device could be any type of network equipment, such as workstations, dumb terminals or printers.
7. ‘Frame Check’ is the last process within the data transfer. It is where the sender or originator device informs the receiver that al the data has been sent. The receiver will then check the amount of data that has been actually transmitted compared to what the sender stated it would send. If there is any difference between the two, the receiver would note that bit errors that have been made.

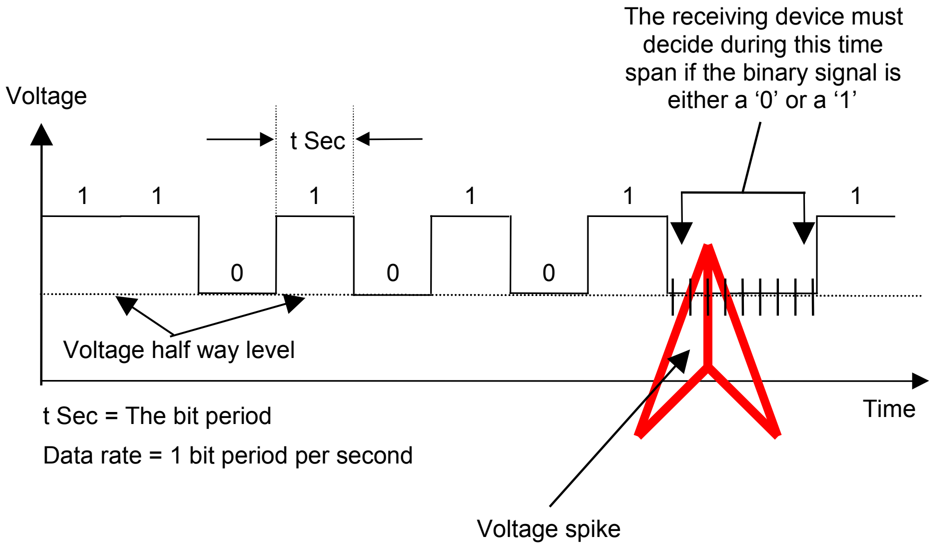
If any data errors have been made, the receiver will request the complete packet to be re-sent from the transmitting device. Every single time that data packets need to be re-transmitted the performance of the data network is being reduced.

If we were to send one complete typed report over the network containing 1500 bytes plus all of the other information, this would total 1530 bytes. Given the fact that there are a total of eight bits per byte this would equate to a total of 8 X 1530 = 12240 bits.

Now compare this with your data speed of 100 Mbps and the problem is a very real threat to your installed network performance.

Bit Errors

Data transmissions are also subjected to errors in data transfer, known as bit errors. Data transfer is conducted through a binary system with the numerical number one and zero.



The receiving device, by the rules of data transmission is required to make a decision on whether the binary digit (bit) is either a ‘one’ or a ’zero’ at the centre of each bit time period. It is able to do so as its internal clock is synchronised to the bit rate (or bit speed) by the synchronisation pattern heading each Ethernet Frame.

Therefore at the centre of each bit time period, the receiving device will make the decision whether the signal is above or below the half way mark. The previous diagram demonstrates that if a voltage spike or a reflected pulse occurred near the centre of a bit time period that it would be possible that the receiving device will make the wrong decision and call a " zero" a " one", this would be a bit error.

Types of Interference

Interference, which causes data bit errors, can come from outside the cable or within the cable. We might say from the " enemy without" or the "enemy within". Generally, the "enemy without" is easier to get rid of than the " enemy within".

Examples of interference emanating from outside the cable (the enemy without):

1. Induced electrical "spikes" or transients from electrical power cables particularly those carrying heavy switching currents
2. Induced/radiated electrical "spikes" or transients from electric motors, fluorescent lights, photocopiers, air-conditioning motors, electric arc welders,
3. Electrical transformers especially under fault (unbalanced) conditions
4. Induced transients from lightning or surge suppression discharge currents
5. This type of interference can generally be controlled by:
6. Sufficient physical separation
7. Shielding of the interference source or shielding of the cable
8. Examples of interference emanating from within the cable (the enemy within):
9. Near End and Far End Crosstalk – which is data signal coupling from the disturbing pair into the disturbed pair
10. Secondary data signals within a cable pair caused by a portion of the original signal reflecting from impedance discontinuities and interfering with the original line data transmission

These are more difficult to eliminate but are controlled by:

1. Cable manufacture (different twist rates for each pair accurately implemented)
2. Careful cable installation to eliminate physical stress to the cable which can cause impedance discontinuities
3. Use of matched cable component; modules/sockets and patch cords designed to match to the cable impedance

Basic Physics

Copper data communications is subjected to a few other areas that we need to be conversant with such as resistance, amperage and even ohms law.

Voltage

Volt is the unit of measurement for an electromotive force or a potential difference that may exist between two different electrical circuits.

Resistance

Resistance is the term used for how hard it is to push something up a corridor when there is a blockage. Current Cat5e and Cat 6 cable ‘corridors’ have a resistance value of 100Ω. When electrical signals are forced up a corridor the resistance creates heat as a by-product. Within the data communications industry you may occasional hear resistance also being referred to as impedance.

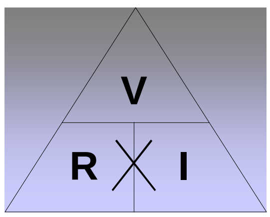
Amps

Electrical strength is measured in a unit known as Amps (electrical current), and the higher the amperage the more chance of serious injury from electrical circuits. Most household appliances, the refrigerator and a kettle for example contain a fuse, which is rated at 13amps. It is important to note that even just a few milli-amps have the potential to kill.

Ohms Law

Voltage, resistance and amperage all need each other to complete an electrical circuit, and with the application of Ohms law we can ascertain any one of those items, provided we know the other two.

V	**=**	**Volts**
R	**=**	**Resistance**
I	**=**	**Amperage**



For example, if we knew that a circuit had a resistance of 4 Ohms and amperage of 3amps. The calculation would be as follows:

Resistance X Amperage = 12v

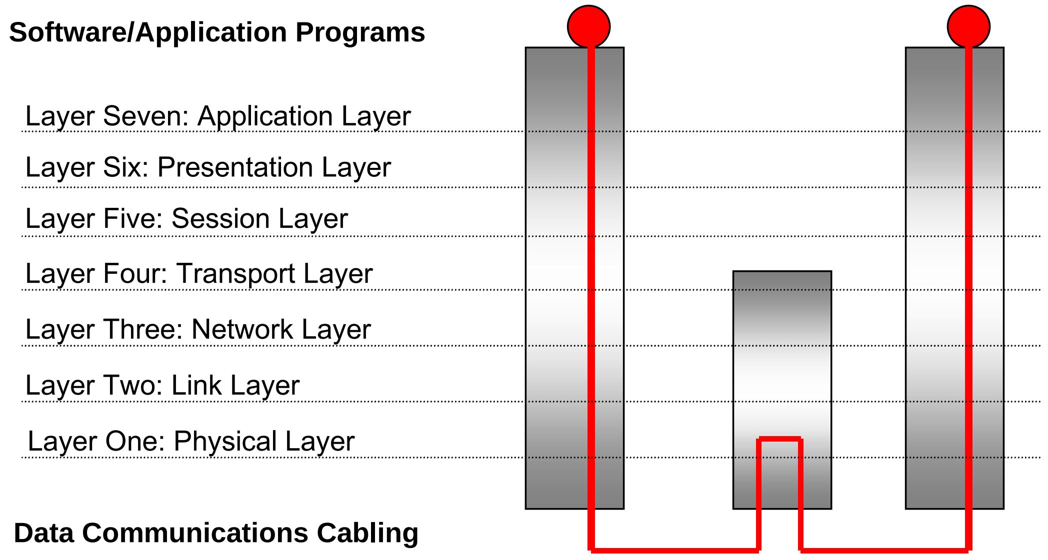
Therefore this example shows a circuit operating on 12 volts. For a second example, we have a circuit with 12 volts and a resistance value of 4 Ohms; the calculation is as follows:

Voltage ÷ Resistance = 3 Amps

The OSI Reference Model

The OSI reference model specifies standards for describing "Open Systems Interconnection" with the term 'open' chosen to emphasise the fact that by using these international standards, a system may be defined by which it is open to all other systems obeying the same standards throughout the world.

The definition of a common technical language has been a major catalyst to the standardisation of communications protocols and the functions of a protocol layer.



The above diagram depicts the seven distinct layers of the OSI reference model showing a connection between two end systems communicating using one intermediate system.

The structure of the OSI architecture indicates the protocols used to exchange data between two users A and B. The figure shows bi-directional (duplex) information flow; information in either direction passes through all seven layers at the end points.

When the communication is via a network of intermediate systems, only the lower three layers of the OSI protocols are used in the intermediate systems.

Services provided by each Protocol Layer

Layer 1:

> Physical Layer**:** Provides electrical, functional, and procedural characteristics to activate, maintain, and deactivate physical links that transparently send the bit stream; only recognises individual bits, not characters or multi-character frames.

Layer 2:

Data link layer: Provides functional and procedural means to transfer data between network entities and (possibly) correct transmission errors; provides for activation, maintenance, and deactivation of data link connections, grouping of bits into characters and message frames, character and frame synchronisation, error control, media access control, and flow control (examples include HDLC and Ethernet.

Layer 3:

Network Layer: Provides independence from data transfer technology and relaying and routing considerations; masks peculiarities of data transfer medium from higher layers and provides switching and routing functions to establish, maintain, and terminate network layer connections and transfer data between users.

Layer 4:

Transport Layer: Provides transparent transfer of data between systems, relieving upper layers from concern with providing reliable and cost effective data transfer; provides end-to-end control and information interchange with quality of service needed by the application program; first true end-to-end layer.

Layer 5:

Session Layers: Provides mechanisms for organising and structuring dialogues between application processes; mechanisms allow for two-way simultaneous or two-way alternate operation, establishment of major and minor synchronisation points, and techniques for structuring data exchanges.

Layer 6:

Presentation layer: Provides independence to application processes from differences in data representation, that is, in syntax; syntax selection and conversion provided by allowing the user to select a "presentation context" with conversion between alternative contexts.

Layer 7:

Application layer: Concerned with the requirements of application. All application processes use the service elements provided by the application layer. The elements include library routines, which perform interprocess communication, provide common procedures for constructing application protocols and for accessing the services provided by servers, which reside on the network.

The communications engineer is concerned mainly with the protocols operating at the bottom four layers (physical, data link, network, and transport) in the OSI reference model. These layers provide the basic communications service. The layers above are primarily the concern of computer scientists who wish to build distributed applications programs using the services provided by the network.

‘Hop-by-Hop’ Network-wide and ‘End-to-End’ Communication

The two lowest layers operate between adjacent systems connected via the physical link and are said to work ‘hop by hop’. The protocol control information is removed after each "hop" across a link (i.e. by each System) and a suitable new header added each time the information is sent on a subsequent hop.

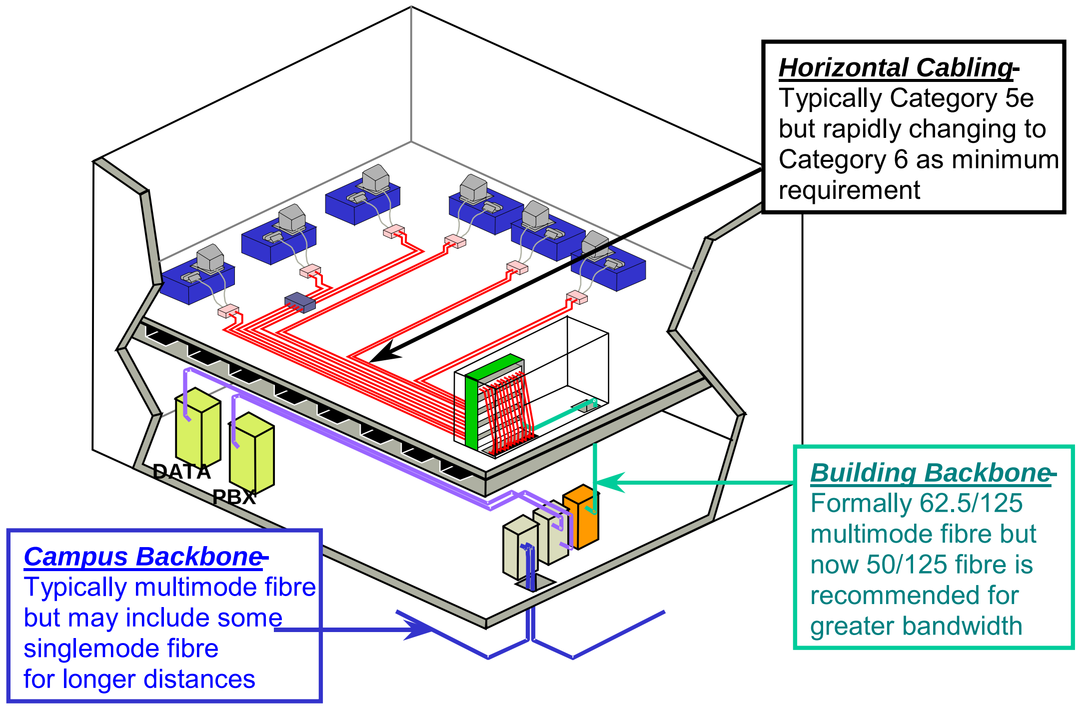
The network layer (layer 3) operates network-wide and is present in all systems and responsible for overall co-ordination of all systems along the communications path.

The layers above layer 3 operate ‘end to end’ and are only used in the End Systems (ES), which are communicating. The Layer 4 - 7 protocol control information is therefore unchanged by the IS in the network and is delivered to the corresponding ES in its original form. Layers 4-7 (if present) in Intermediate Systems (IS) play no part in the end-to-end communication.

The basic structure of LAN cabling

The following diagram depicts the 'make up' of a structured cabling system.

Generic Cabling – Subsystems



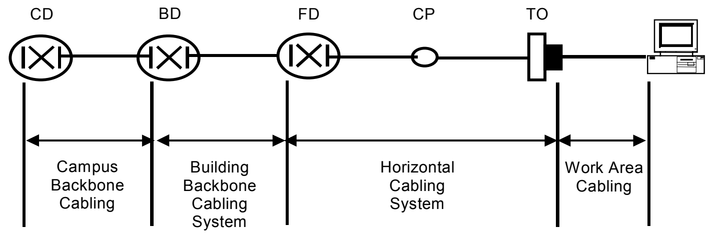
The functional elements of a structured cabling system are grouped to form three cabling subsystems within the cabling 'Standards'.

At the junction of these subsystems, active equipment may be connected or one sub-system interconnected passively (by patch cords), or actively (via equipment), to form the overall communication channels.

The three cabling sub-systems are:

1. Campus Backbone (CD)
2. Building Backbone (BD)
3. Floor Distribution (FD) Cabling (Horizontal or cabling)

The following diagram demonstrates the inter-connection of these elements to form overall communication channel(s).



Connections between subsystems occur at distributors.

The campus backbone cable sub-system consists of the following elements:

1. Campus backbone cables (which may be either twisted pair copper and/or optical fibre).
2. Terminations of those cables.
3. Jumpers and patch cords in the campus distributor (CD).

The building backbone cable sub-system consists of the following elements:

1. Building backbone cables (may be either twisted pair copper or optical fibre).
2. Terminations of those cables.
3. Jumpers and patch cords in the building distributor (BD).

The building backbone must not contain Consolidation Points (CP).

The horizontal cabling sub-system consists of the following elements:

1. The horizontal (floor distribution) cables which include, typically 4 pair Category 5e or Category 6 UTP/FTP cables, not forgetting the possibility of optical fibre cables with fibre to the desk.
2. Termination hardware at Floor Distribution (FD) and Telecommunication Outlets (TO).
3. Optional CP (Consolidation Point).
4. TO’s (which may be configured in a group as a MUTOA)
5. Cross-connect or interconnect hardware at the FD.

The horizontal cabling shall be continuous (no joints) from FD to TO's except for the special case of a CP in the link and it must meet specific requirements.

Maximum Cable Lengths

The longer the cable length, the greater is the signal loss from one end to the other. This loss is called the insertion loss of the cable. If the cable is too long, the signal arriving at the distant end will be too weak to be correctly read by the data receiver and data errors/corruption will occur.

In addition, stranded cables, (used for patch and connecting cords where flexibility is required), have a higher loss (attenuation/loss) over a given length compared with solid conductor cable, as is used in the fixed cabling installation.

The result is that strict limits are placed on the maximum length of fixed horizontal cable and associated patch cords / jumpers.

Therefore as a general rule the following length limitations apply for structured cabling local area networks.

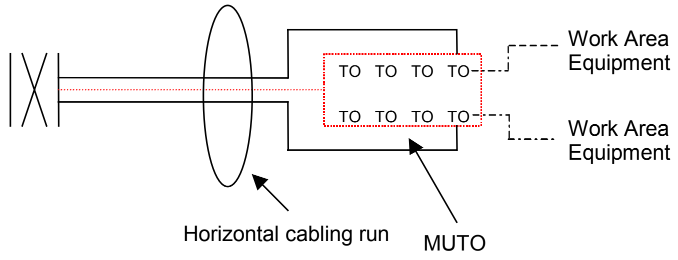
1. 100m maximum for physical length of channel (includes connecting cords/patch cords).
2. 90m maximum for physical length of fixed horizontal cabling (excluding connecting/patch cords).
3. 10m maximum for physical length of patch cords, equipment cords and work area cords included in the channel when the fixed cable is at 90m maximum length.
4. 5m maximum for physical length of jumpers/jumpers.

In a multi-user TO assembly (MUTOA design) the length of the work area cord should not exceed 20m; in a MUTOA design, the maximum length of the fixed horizontal cable is reduced in accordance with the "MUTOA formula".

Multi-user Telecommunications Outlet

In an open office environment, an assembly (group) of Telecommunication Outlets (TO's) may serve a group of work areas. The work area connecting leads from the Telecommunications Outlet to the active equipment may need to be longer than usual in order to utilise this method of cabling design/distribution.

The impact of "longer than usual" connecting leads must be taken into account in determining the maximum length of the Floor Distribution (FD) to the Multi-user Telecommunications Outlet Assembly (MUTO); horizontal cabling distance, in order to ensure that Class of performance transmission parameters are still maintained.



MUTO Design in Horizontal Cabling

The design/installation criteria for the use of a MUTOA includes the following:

1. A MUTOA shall be located in an open office area so that each work area is served by at least one multi-user TO assembly.
2. A MUTOA should be limited to serving a maximum of 12 work areas.
3. A MUTOA should be located in user-accessible, permanent locations such as on building columns and permanent walls.
4. A MUTOA shall not be installed in obstructed areas (such as passageways and stairways, etc).

The performance contribution of work area cords, equipment/equipment cords, shall be taken into account to ensure that the channel performance requirements for balanced cabling are met.

The length of the cord should be limited to ensure cable management in the work area and should not exceed 20m in length.

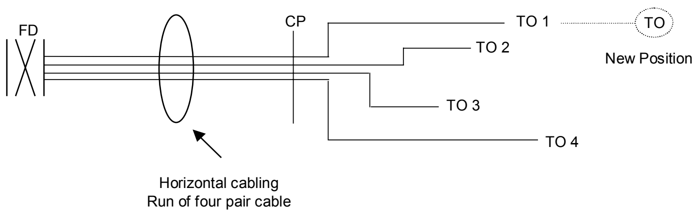
Length of work area cables	Length of FD cross-connect & equipment cords	Maximum length of fixed horizontal cable
3m	7m	90m
5m	7m	87.5m
10m	7m	80m
15m	7m	72.5m
20m	7m	65m

It should be noted that since flexible (stranded conductor) connecting patch cords have a higher insertion loss than solid conductor cable, the maximum horizontal cabling length might be significantly reduced where long work area connecting cords are used.

Consolidation Point

Consolidation Points (CP) are an inter-connection point (in reality a joint) in horizontal cabling, the purpose of which is in providing flexibility when making changes within an office area. The CP can prevent against re-runs of cable or disturbing and potentially damaging current laid copper cable.

The new CP run literally runs from the Telecommunications Outlet (TO) to the CP, as the following diagram demonstrates.



The CP is **not** a jumpering or cross-connection point. The end cable length is called the “CP cable”, that is, from the CP to the TO.

The CP is located centrally to the “office” area to be served.

The rules for CP design and installation are as follows:

1. Only one CP allowed in a horizontal cabling run (between a FD and a TO).
2. A CP shall only contain passive connection hardware.
3. A CP shall not be used for cross-connections.

4. Shall be located so that each work area group is served by at least one CP.
5. Each CP should be limited to serving a maximum of twelve work areas.
6. CP’s should be located in accessible locations.
7. For balanced cabling, the CP shall be located so that it is at least 15m from the FD (and the TO’s).
8. The CP shall be part of the administration system; i.e. part of the cabling records system so it’s location is identified.

When a horizontal cable is tested for its Class of performance the test may be carried out from FD to TO, through the CP.

Alternatively, if the cables have not yet been established, testing can be done, using the appropriate and more stringent test specification, from FD to CP to confirm the quality of that portion of the installation.

Planning Guide

Why do ACCL take so much time to plan a structured cabling infrastructure, why is so much effort placed in making sure that everybody fully understands all of the building and telecommunications drawings and plans etc?

There are typically four distinct phases in the design, planning and installation of a network. The following diagram easily demonstrates how each of the structured cabling 'Standards' work in relation to the a) the Design, b) the implementation, c) the operations & maintenance and d) the documentation of a structured cabling system.

Building Design Phase	Cabling Design Phase	Planning Phase	Implementation Phase	Operation Phase
EN 5031 **5.** **2** Common bonding network (CBN) within a building **6.3** AC Distribution system and bonding of the protective conductor	**EN 50173 – 1** **4.** Topology **5.** Channel performance **7.** Cable requirements **8.** Connecting hardware requirements **9.** Requirements for cords **A.1** Link performance limits	**EN 50174 – 1** **4.**Specification considerations **5.** Quality assurance **and** **EN 50174 – 2** **4.** Safety requirements **5.** General installation practices for metallic & optical fibre cabling **6.** Additional installation practice for optical fibre cabling **and** **EN 50174 – 3** **and** (for equipotential bonding) EN 50310 **5.2** Common bonding network (CBN) within a building **6.3** AC Distribution system & bonding of the protective conductor	**EN 50174 – 1** **6.** Documentation **7.** Cabling administration **and** EN 50174 – 2 **4.** Safety requirements **5.** General installation practices for metallic & optical fibre cabling **6.** Additional installation practice for optical fibre cabling **and** EN 50174 – 3 (for equipotential bonding) **EN 50310** **5.2** Common bonding network (CBN) within a building **6.3** AC Distribution system & bonding of the protective conductor **and** **EN 50346** **4.** General requirements **5.** Test parameters for balanced cabling **6.** Test parameters for optical fibre cabling	**EN 50174 – 1** **5.** Quality assurance **7.** Cabling administratio n **8.** Repair & maintenance

The aim on completion of a design, plan and installation is that your client will receive a network infrastructure that will perform as it was intended. The design and installation may include copper, optical fibre and even wireless links from either within just one building or to a group of many.

Design

Network design takes two forms: The Logical and Physical Layout:

Logical Phase

The logical phase is the common sense phase. What services will your client expect to be able to deliver over a structured cabling system?

What types of cable must be installed correctly to ensure these services, Cat 5e, Cat 6, multimode optical fibre and or singlemode?

Infrastructure Layout Phase

It is likely that the cable installation and cable containment will be the most expensive part of the network. Therefore it makes good business sense to pursue the idea of future expansion requirements because adding a few extra cables at this time will cost very little and will allow for expansion. Good sense also suggests of a minimum of two data outlets per user, ideally one for data and the other for voice circuits.

You may have already identified at this stage (from the logical phase) that your client's application, software and active equipment may only require just two of the pairs from a data cable.

The client may then request that the cable be split across two telecommunications outlets. This practice is not recommended for data communication. However it is acceptable to split the cable from the telecommunications outlet onwards if multiple voice circuits are to be used, e.g. a RJ45 connector connected into the telecommunications outlet, having four separate single pairs of voice cable connected to the telephones.
This offers you client the ability to run more voice circuits over the structured cabling system, provided that the main distribution frame and PABX are wired to support this system. It is important to note that once wired the left-and telecommunications outlet can only be used for voice circuits.

Implementation Phase

The cabling contractor should now carefully select the installation crew, keeping in mind what cable type and other products need to be installed. Training although expensive and easily available from a myriad of sources is essential, no matter whether the installation crews are trained by manufacturers or have formal recognised qualifications, as this increases both the quality of the installation and naturally increases the faith of the end user or client.

Many of the structured cabling 'Standards' also recommends the need for training and ACCL ensures that only competent individuals undertake the installation of copper and optical fibre.

Will the cabling contractor or another contractor be installing all of the cabling containment, be it galvanised cable tray or plastic trunking. Ensure that whatever containment is installed that the correct size is fitted and one that allows for future expansion. Installation guidelines recommend that cable containment only is filled to 50% of its total capacity at the time of new installations and this then allows 25% available for future network cabling expansion. The total fill rate that can be applied to any type of containment is 75% of its total capacity.

There may also be a requirement to offer end-user training at this stage; i.e. explaining the layout scheme of the patch panels and which patch panels are associated with different areas.

Operations and Maintenance Phase

When the structured cabling installation has been completed, it is important that the end user is supplied with a document commonly referred to as the 'O&M (operations & maintenance) manual'. The O&M manual should outline some if not all of the following items:

1. Test results for both the copper and fibre optic cables.
2. Cable route plans & schematics.
3. Cable coding schemes.
4. Electrical certificates, if any dedicated electrical work has been performed.
5. Instruction manuals for air conditioning units, fire protection units or similar that may have been installed.
6. Plans of the sub-duct routes and what each sub duct contains.
7. Documentation of each piece of active equipment that has been installed with the communications / equipment room.

Planning Rules

Wiring considerations

It is essential that all structured cabling systems have some form of segregation from all electrical cable and any other device or piece of equipment that can possibly cause any interference within a building or floor. The BS EN 50174 Standard Part II offers advice on segregation distances form electrical circuits with reference to backbone cable runs as detailed in the table below

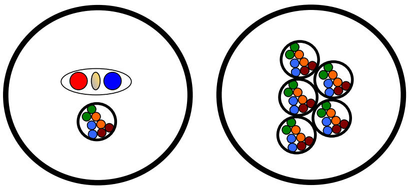
Backbone Installation Type	Without a divider of any kind	Aluminium divider	Steel divider
Un-screened power & un-screened IT cable	***200mm***	***100mm***	***50mm***
Un-screened power cable and screened IT cable[1]	***50mm***	***20mm***	***5mm***
Screened power cable and un-screened IT cable	***30mm***	***10mm***	***2mm***
Screened power cable and screened IT cable[1]	***0mm***	***0mm***	***0mm***

Horizontal cable

Part II of BS EN 50174 states that the minimum distance that shall be applied between data cables and lamps (neon, fluorescent, mercury vapor, or any other high-intensity discharged lamp) must be 130mm.

When data communication cables are installed within an environment where three-phase electrical power (i.e. greater than >415v AC) is present then the following rules apply:

1. Unshielded power lines or electrical equipment which is close to non-metallic non-grounded pathways: 127mm
2. Unshielded power lines or electrical equipment close to grounded metallic pathways: 64mm
3. Transformers and or electric motors: 1016mm
4. That power and data communications are not to be enclosed within the same containment, e.g. conduit runs.



The Standard also makes recommendations for shielded horizontal runs, but currently (at time of manual publication) offers no separation distances for horizontal un-shielded cable runs. The British Standard 6701 however, offers additional information as a Code of Practice with regard to horizontal UTP cable runs and electrical separation. This can be summarized as follows:

50V to 600V there must be a separation distance of no less than 50mm with a divider that meets the requirements of BS 7671. For voltages that exceed 600V the separation distance shall be no less than 150mm with a divider that also meets the requirements of BS 7671.

The information on UTP horizontal cable segregation can be summarized as:

1. For low voltage systems (50V – 600V A/C) telecommunication and data cabling must be contained in separate containment systems.
2. If data and power cables are to share the same cable tray or similar then a distance of not less than 50mm must separate them.
3. If the cable tray or similar, distance needs to reduced than a metal separator must be used.
4. If any of the containment used is metal, then it must conform to the earth bonding requirements of BS 7671, which requires that each piece of the metalwork is earth bonded.

Wiring within buildings

Internal building cables should be of the type known as LSZH (low smoke zero halogen) or LSZHFR (low smoke zero halogen flame retardant). Special attention must to make sure the LSZH/LSZHFR cables are used in a plenum area (air supply ducts, floor or ceiling voids, or other spaces spanning a large area of a building).

Telecommunications or equipment rooms should be designed to for each area of approximately 400 square metres for a high-density area such as an open-plan office or a radius of 50 metres (roughly equivalent to a cabling distance of 90 metres). As a minimum, allow for a 750-mm high, wall-mounted rack cabinet with personnel and cable access space around. Everywhere served by the wiring closet should be within the same equipotential earth zone (same electrical mains supply). An electrical mains power point will be needed.

1. The electrical mains power point should preferably be on a dedicated supply from the electrical mains distribution point (ideally a non-switched fused spur). If this is not possible, the power point may be supplied from the normal ring main as long as this does not supply equipment that causes electrical noise, surges or sags to the supply. One double outlet is required; if the networking equipment is to be located in the same area, further outlets should be installed.

2. Telephone and data may share the same wiring system, unless the telephones are connected directly to the public telephone network (UK regulation).

3. Wherever possible, the building should be wired using a structured wiring scheme. The detailed design of the scheme will depend of the building and its intended use but the general principle is that the wiring closets are interconnected to form a building backbone network with distribution from each wiring closet to the area around.

4. Trunking and cable trays should be installed throughout the building even though the cabling may not be installed until later. Access should be provided to the trunking and cable tray, even if cabling is installed from the outset, to facilitate later changes or extensions to the system.

5. It is much easier, and therefore cheaper, to install cable in trunking with removable covers. Apart from secure military infrastructures, which must be wielded shut.

6. Care must be taken when installing data communication cable within any conduit runs. An ACCL recommendation for the use of conduit containment maintains that there should be no more than two-bends in a run unless either a managed turning box or inspection cover is installed. This will help ensure that the cable is protected at all times. Conduit runs must also contain a draw rope.

7. Use gusset-corners and bends in trunking and cable tray to avoid sharp corners. Fibre-optic cable will be damaged if it is installed with a too-small bending radius; typically 250 mm is suitable for fibre-optic cable and for multi-pair copper cable.

8. A bend radius of 35 mm is the absolute minimum for UTP distribution cable and a smaller radius will affect the transmission properties of the cable. Internal grade fibre-optic cable typically has a tensile strength of only 500 N. The specifications recommend that copper cables be bent to no more than 8 times their diameter during installation and 4 times there diameter when installed. For fibre optic cables, as a rule of thumb use bends of more than 10 times the cable diameter.

9. There will be a concentration of cables in the vicinity of a wiring closet; allow adequate capacity of cable containment leading to/from a wiring closet.

10. If different services are to be supplied via the same trunking, consider the use of multi-compartment trunking. Multi-compartment trunking will be essential if electrical power is to be installed in the trunking.

11. Category 5e/6 Unshielded Twisted Pair (UTP), Foil Twisted Pair (FTP) or Screened Twisted Pair (STP) wiring with Category 5e or Cat 6 terminating hardware is recommended. Although Category 3 cabling and terminating hardware is less expensive than Category 5e or Cat 6 it is suitable only for telephone-only services.

12. The desk or wall sockets to which the telephone equipment is connected should be RJ45 types.

13. The termination pattern for copper based data communication cable must be standardised as either 568A or 568B. Ensure that the same wiring scheme is maintained throughout the permanent link, work area cables and patch cords.

External wiring

1. Wiring on the outside of buildings or hung between buildings may lead to severe damage to equipment as well as being a hazard to personnel. Such wiring should be avoided wherever possible; but where it is necessary, it should be installed in a metal duct that is connected to an efficient earth that is separate from the mains earth.

2. The metal duct should not be accessible to personnel. Alternatively, a completely non-metallic fibre-optic cable with an external grade moisture barrier should be used; note that the some external grade fibre-optic cables have a metallic (aluminium foil) moisture barrier and often a steel strength member.

3. ACCL installation guidelines suggest that only fibre optics should be used when wiring between buildings.

4. Because the cost of installing multiple ducts on a given route is only marginally more that that of installing a single duct, it is sensible to install multiple ducts to cater for future expansion and multiple services.

5. Telecommunications ducting is most commonly grey or green in colour. The colours have been standardised to identify different public utilities (e.g. yellow for gas, blue for water). Waterproof and gas-proof seals must be used when jointing and external ducting together.

6. Ducts should be installed as deep as possible to avoid accidental damage. Ducting should be at least 300 mm when laid under a hard surface or 600mm when laid under a soft surface. Suitably annotated tape should be laid some 150mm above the ducts to warn anyone excavating subsequently. Consider a protective concrete layer above the ducts if they must be installed at a shallow depth. Alternatively, a plastic-covered steel duct may be used.

7. Most ducting has a small amount of flexibility so that it can be 'swerved' around obstacles. However, any bends should be accommodated using a routing chamber (inspection pit) with a removable cover.

8. Gas safety: where an external duct enters a building, it is essential that there is a barrier to prevent marsh gas or natural gas from a leak, which may have seeped into the external duct run, from entering the building and becoming an explosion hazard. The recommended method of forming the barrier is to use a gland caulking, glued to the duct, and sealed internally with Compound 16, a special putty-like compound. Where it is not possible to use a gland caulking, a suitable proprietary foam sealant may be used.

9. Gas safety: it is similarly essential that the outside of the duct be sealed to the fabric of the building to prevent gas leaking into the building around the outside of the duct.

10. Where a gland caulking has been used to provide an internal seal, the outside of the gland should be sealed to the building fabric.

11. Water: the sealing against the ingress of gas, above, will also prevent water leaking into the building. It will be convenient, to prevent a deluge of water when a Gland Caulking is unsealed, or when a foam seal is broken, if the duct run slopes downward as it goes away from the building until it reaches the first routing chamber.

12. Draw-ropes should be installed in external ducts before cabling. The draw-rope must not break the gas seal. Draw-ropes should not be left in ducts that have been cabled because of the danger of the rope becoming entangled with an existing cable. The next time the rope is used a cabled duct should be re-rodded before another cable is installed - this will help to ensure that there is a clear route.

13. Ducts will fill with water and, therefore, cables installed in ducts must be external grade cables with a moisture barrier. Such cables typically have a polyethylene (PE) sheath or contain PE tubes, PE being impervious to water. Such cables are therefore much more inflammable than internal grade cables. External cables are therefore not run through buildings but are joined to internal cables immediately on entering a building. Dual-use, internal/external cable is recommended to avoid the need to change the type of cable at building entries.

14. Electrical safety: the steel strength member, if any, and the metallic water barrier, if any, must be earthed at one end and it is recommended that they be fully insulated at the other end. The earthing is to prevent electrical shocks caused by fault conditions or lightning discharges; the recommendation to earth only one end is to prevent large circulating earth currents which might occur if the two ends of the cable were within different equipotential earth zones (refer to 'Standard' BS EN 50310).

Planning – Routing of cables

The routing of cables throughout the building is dependent on the type of building and the cable management systems installed. Various applications include:

1. Dado/Skirting
2. Ceiling void
3. Floor void (Computer flooring or trunking)
4. Independent trunking/conduit system
5. Surface run
6. Cable tray

When planning cable routes, attention must be given to avoiding perceptible danger spots. As a general rule, cables should be routed only in areas that can be accessed exclusively by the user. Control will be facilitated by a clear layout of lines.

Routes and individual cables should always be laid out in such a way that they are protected against direct damage caused by persons, vehicles and machines.

When selecting a site for devices, it should be ensured that the cables are not run in walking or driving areas. If this cannot be avoided, the cables must be protected by adequate duct systems in the light of the anticipated mechanical loads.

As a general rule, attention must be given, in the case of appliance cords (flexible cables), to sufficient pull relief of the cables in the connector(s). In instances, it may be expedient to do without screwing of the connectors. In case of tensile load, only the plug-in connections, and not the connector/cable or connector/device soldering points will be torn apart.

Underground car parks pose a major problem as regards damage-minimising routing of cables. Due to the automatic operation of control devices and on account of the long periods during which entrance gates are open, access by outsiders to underground car parks can never be ruled out. On account of the normally low height of ceilings, simple means suffice to obtain access to the lines located there. When lines are located in the driving area, there may not be enough space left for the admissible height of vehicles. In that case, damaging or destruction of ducts and cables by vehicles cannot be precluded.

When buildings are used jointly with third parties, it must be ensured that cables are not run in floor ducts in areas occupied by those parties. Floor and windowsill duct systems must, by mechanical means, be tightly shielded against the areas of external users. The preferable solution is to confine such ducts to the user's own area.

Areas with a high fire hazard must be avoided. If this is not possible and the operating state of all cables run on a cable route must be maintained, fire sealing must be provided for that route. If only individual cables must be kept in an operative condition, an appropriate cable must be selected for this purpose.

In production plants, high inductive loads and the resultant interference fields are to be expected. These must also be taken account of in the layout of ducts and cables. For cable protection, an approach similar to that in case of fire sealing is to be taken.

In the case of underground lines, warning tapes must be laid approx. 10mm above the cable. For individual cables (without conduit), it is advisable to provide cable covers.

Cable Routing Options

1. Dado/Skirting trunking: A popular method of cable management is wall mounted trunking, which, when run at waist height is known as Dado trunking. Normally it has separate compartments to segregate the mains cabling from the voice and data cables. Special fittings are available to mount telecommunications and mains outlets although the design of the trunking sometimes requires outlets that are specifically designed to suit.

2. If the Dado/Skirting trunking already contains cables, an inspection should be made to ensure that enough spare capacity is available for the new cable system and that no power cables have been run in the voice compartment. If this is the case an electrician should transfer the mains cable into the mains compartment, which may be preferable to having more trunking installed. In a stand-alone system, sections of mini trunking or similar is used in conjunction with the Dado/Skirting trunking to route the multi-pair cables to the DP's.

3. Ceiling void: A common avenue is to route the cables via the ceiling void so-called plenum cabling. Information regarding fire regulations for the building should be obtained as these sometimes restrict the use of the ceiling void for installing cables.

In any event Low Smoke Zero Halogen (LSZH) cables should be used to avoid dangerous fumes being emitted in the case of fire. Cables can be routed via the ceiling void in trunking, on cable trays of fixed directly to the true ceiling. Whichever method is used the routes should be well defined and the ceiling hangers should not be used for attaching cables. If the true ceiling has a fireproof coating it should not be drilled.

A false ceiling commonly has removable ceiling tiles that just need to be lifted out of the hangers but attention should be paid not to mark the tiles with dirty finger marks. This is easy to do as the ceiling void is usually dusty but the marks are difficult to remove. If the ceiling is made up of keyed tiles it is advisable to have a specialist remove the tiles to avoid damage.

1. Floor void: Cables can be routed through the floor void in trunking, on cable trays or fixed directly to the floor of the void. Whichever method is used the routes should be well defined and the floor supports should not be used for attaching cables. False floors normally have recessed floor boxes installed, which provide mountings for standard outlets. Cable entries to these boxes should be fitted with grommets.

2. The standard practice is to leave 2 to 3 meters of spare cable (where possible) looped, not coiled as this may affect the impedance of the cable beneath the floor box to allow the tile containing the box to be interchanged with adjacent tiles to facilitate movement of office furniture. Note that when running cables in concealed locations, the rules applying to the segregation of telecommunications from mains circuits must be

adhered to at all times, and defined routes for services through voids are advisable.

Planning – Independent Trunking/Conduit System

Where no cable management of floor/ceiling void exists, a complete trunking system may be required. The customer should consider installing a system to facilitate installation of other services, e.g. mains, signalling and alarm systems, fire protection etc.

In a multi-storey building a service riser is required to route cable via floors on route to the TJF/BDF. The riser must be closely inspected to ensure segregation or separation is available from other services, especially mains. Adequate fixings must be made in the riser. Usually a cable tray is installed, but if this is not possible there are other methods such as cleating or banding, provided that the containment in no way damages the data communications cable.

When choosing cable routes around the building it is sometimes necessary to make holes in walls or floors to route the cables through. Such building work requires careful planning and the full agreement of the building owner/agent before starting.

Engineering plans and plans showing the routes of other services within the building should be sought. Points to consider here are:

1. Structural damage
2. Hidden water pipes
3. Drains
4. Hidden mains cables

Major building work e.g. drilling through concrete floors, should be undertaken by the building owner/agent except when agreed otherwise.

The following factors should be considered during the planning stage of the cable network:

1. Type of cable distribution to be adopted and the size to meet the initial requirement plus forecast growth and the date when the system is to be brought into service
2. Wiring and cabling facilities for the connection to the public network and to the terminating equipment
3. Wiring and cabling requirements for extension telephones, data services and miscellaneous facilities, e.g. secretarial arrangements and status line indicators etc.

Fire Considerations

Fire containment is an essential part of any installation crew’s duties, as you will often create new openings through walls and ceilings within a building. These openings must be closed safely according to fire and construction regulations, this is known as fire stopping.

Fire stopping refers to the correct installation of approved fire-stop materials and devices in openings made through fire rated walls, floors and ceilings for structured cabling. Always ensure that you follow the manufacturers' guides for each material or device used for fire stopping.

Different types of fire stopping materials or devices must be used for pipes, cables, conduits, cable trays and trunking. Each type of material or device has been independently tested and rated to exact standards.

Installation technicians must be aware of their own liability with regards to fire stopping. It is a requirement by law and must be adhered too. If a fire was to catch hold, the installation technician who did not install fire stops may be found personally liable.

Fire stopping locations will be decided following these considerations:

- Local & National Building Regulations
- Architect’s instructions
- Construction designs and drawings
- Reference standards
- Insurance underwriters
- Fire officer

ACCL will not under any circumstances change the make or requirements of fire stopping without the express permission of the architect, design technician or the client. Always obtain in writing permission to change fire stopping and have the work ‘signed-off’ when completed.

Planning – Security

It should not be possible to alter or interfere with the wiring without the use of tools except where access is restricted to maintenance staff, other authorised staff or where appropriate the network operator staff.

Wherever possible, access to rooms dedicated as apparatus rooms should have controlled access and restricted to authorised personnel only.

Where accommodation specifically dedicated to housing apparatus does not exist, then all documentation such as line plant wiring records, configuration details and product manuals should be entrusted to a representative on site for safe keeping, in these circumstances it is also prudent to retain copies of such documentation off site.

In cases where equipment is connected to a mains supply, EU regulations require that a means of disconnecting the supply be provided. The possibility of accidental or inadvertent disconnection should be avoided by a suitable means such as labelling or warning notices.

Planning – Wayleaves

In situations where it is necessary to route cables over or under premises not owned by the customer, it is essential to obtain the necessary wayleaves and/or planning permission.

In these circumstances the customer must be made aware of this requirement and it his legal obligation to take the necessary actions accordingly.

It is important to note that Structured Building System standards specify a maximum distance (cable length) between buildings (1,500 m between campus and building distributor, 500 m between building and floor distributors) and the geographic area of the site.

Where a user’s premises consist of two or more buildings within close proximity of each other it may be feasible to install link cabling via a private duct. If this duct crosses a public area, a licence order is normally required from the local authorities.

ACCL take extreme care when excavating the trench, as some long established services may not be on existing plans.

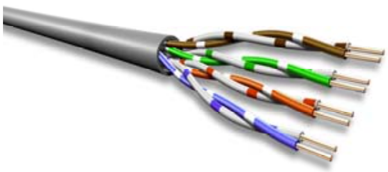
Copper Data Communication Cable

Modern data networks today utilise cable that either optical fibre or copper. With copper based technologies the cable limit length for this twisted pair cable was reduced from that of its coaxial brothers down to 90 metres, with a further 10 meters available for patch cords.

The copper twisted pair cable types consist of the following types:

Within the structured cabling industry there are several main types twisted pair available for us to use. The selection of reach type of copper medium will be based on its performance factor and its ability to protect itself from electromagnetic interference (covered later).

UTP: Unshielded Twisted Pair



UTP cable has existed within the telecommunications for a long time and is mainly used for data solutions although voice circuits can be run over four pair UTP cable as well. It is manufactured with the following specifications: -

1. Pairs of wires twisted together
2. Available from 2 pairs right up to thousands of pairs
3. Has a characteristic impedance of 100Ω
4. Recommended conductor size is 22-24 American Wide Gauge

Category 5e UTP is the current most used grade of cable as it operates at 100Mhz, although Category 6 is becoming more favoured. However, please be aware they if you install a Category 5e or Category 6 cabling system, and your client then connects a Category 3 patch lead for business computer connection they will turn the system into, by default, a Category 3 system.

Cabling networked systems can only work as fast as the slowest device or cable within the chain.

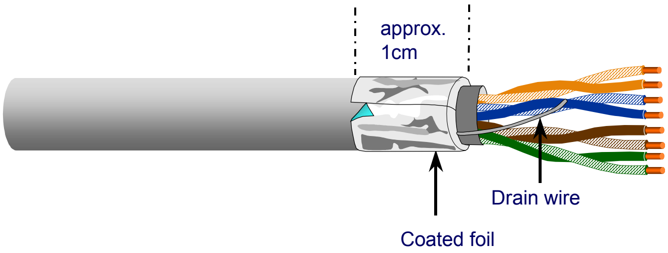
FTP: Foil Twisted Pair

Aluminium foil is wrapped around each individual pair. There is a twin version of this cable type for 2 X 4 pairs.

STP: Shielded Twisted Pair

The bare foil shields are normally silver in colour. Most manufacturer termination procedures recommend that after removing the cable sheath that 2cms of bare aluminium foil exposed

Coated foil shield is generally red, blue or green in colour. Strip back the cable sheath, so that 1cm of foil is exposed. Fold the coated foil back over the sheath so that only bare un-coated foil is exposed.



Shielded twisted pair has individual pairs protected against interference. This cable was originally designed at a time when UTP was believed to be unsuitable for high-speed network connections.

1. Composed of two to four pairs of copper wires.
2. Overall braid to reduce electromagnetic interference.
3. Has a shield that must be grounded.
4. Conductor size of 22 American Wide Gauge.

PIMF: Screened Twisted Pair Cable

Screen twisted pair offers an increased level of immunity to electrical interference and noise. The core of the cable consists of the four pairs each individually surrounded by a foil shield and the introduction of a drain wire. The term PIMF refers to ‘Pairs in metal foil’.

The purpose of the drain wire is to act as a pathway for any unwanted electrical influences to find earth, as the foil shield is not strong enough itself to complete such a task. Screen twisted pair will offer the same level of performance as UTP.

Solid & Stranded Conductors

Copper data and voice communication cable are available in two types of construction, solid and stranded conductors.

Solid Core copper data cable consists of just one single strand of copper, whereas stranded cable is constructed of several strands of a smaller individual wires that are twisted around each other to form a larger overall gauge cable.

Copper data communication cable that makes up the building backbone and horizontal runs must always be solid core to be 'Standards' compliant. Stranded cables are normally used for patch cords, but it is important to note that they are generally 20% less efficient than solid core cables, due to the effects of skin effect.

Under Carpet Cable

Some installations may require the use of under carpet cable where an odd situation may require the installation of a data outlet in an obscure place. Care must be taken in ensure that no excessive loads are placed on top of the cable, so this will affect the performance characteristics of the cable and overall network performance.

Conductor Sizes

Part of a copper media performance is dependant upon the size of the copper itself. Many manufacturers and installation companies tend to refer to the AWG (American Wide Gauge) for sizing. The following table makes the comparison between and AWG and the standard mm^2 sizes.

AWG	mm^2
27	0.102
26	0.129
25	0.162
24	0.205
23	0.258
22	0.326
21	0.723

It is interesting and important to note that as the European size expressed as mm^2 increases, the AWG size reduces.

Voice Cables

Voice cables within the UK market are often referred to as 'CW1308'. This cable type utilises colour coding to ensure that that the correct pairs are being worked with. CW1308 cable is designed for speech circuits (100KHz).

The size of CW1308 cable is readily available in sizes ranging from two pairs to 4800 pairs.

Cable Colour Coding

The following table is based on 25 pair CW1308 cable.

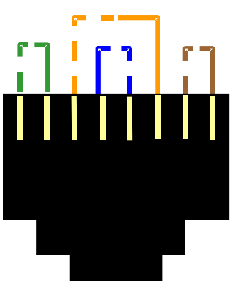
Pair Number	Colour	Pair Number	Colour
1*	WHITE/Blue	**14**	BLACK/Brown
2*	WHITE/Orange	**15**	BLACK/Grey
3*	WHITE/Green	**16**	YELLOW/Blue
4*	WHITE/Brown	**17**	YELLOW/Orange
5	WHITE/Grey	**18**	YELLOW/Green
6	RED/Blue	**19**	YELLOW/Brown
7	RED/Orange	**20**	YELLOW/Grey
8	RED/Green	**21**	VIOLET/Blue
9	RED/Brown	**22**	VIOLET/Orange
10	RED/Grey	**23**	VIOLET/Green
11	BLACK/Blue	**24**	VIOLET/Brown
12	BLACK/Orange	**25**	VIOLET/Grey
13	BLACK/Green		

*These colours are also utilised as the normal cable colour for four pair copper structured cabling environments.

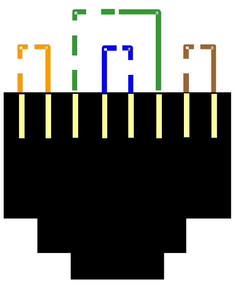
Patch Cords

There are two standard wiring codes for patch cords 568A & 568B. The following line drawing details both the wiring plans.

Pair One: White Blue / Blue
Pair Two: White Orange / Orange
Pair Three: White Green / Green
Pair Four: White Brown / Brown



568A



568B

Categories & Cable Classes

The following graph demonstrates the combination of categories and classes of cable types within the copper environment. The Americans market tends to prefer the use of the term ‘category’, whereas in Europe, the term ‘class’ may also be used. In Europe we use Category for components and a class to refer to a link made up of category components.

Compliant links therefore can only be as good as the lowest value category component for example, a cabling system link with Category 5e and Category 6 components can only be a class D link.

Category	Class	Frequency	Usage
1	A	100Khz	Telephone
2	B	1Mhz	Low speed Data & ISDN
3	C	16Mhz	Token Ring & Ethernet
4	-	20Mhz	Lived for 6 months
5	D	100Mhz	Ethernet
5e	D	100Mhz	Fast Ethernet
6	E	250Mhz	Any Application
7	F	600Mhz	Any Application*

* Category 7 is not generally available from the majority of manufacturers. Category 7 will also require new connectors and must be also be backward compatible with other Categories and Classes of cables.

Optical Fibre in Detail

Before we begin with this full chapter dedicated to optical fibre, I must refer to training once again. Those people who are in some way involved be it directly or indirectly in the installation of optical fibre must attend some formal training, as text book theory is just not simply enough.

In the United Kingdom the preferred basic standard courses for fibre optics are the City & Guilds or FIA range of courses and therefore is the minimum training level required by ACCL for warranted installations of optical fibre.

Intro to Optical Fibre

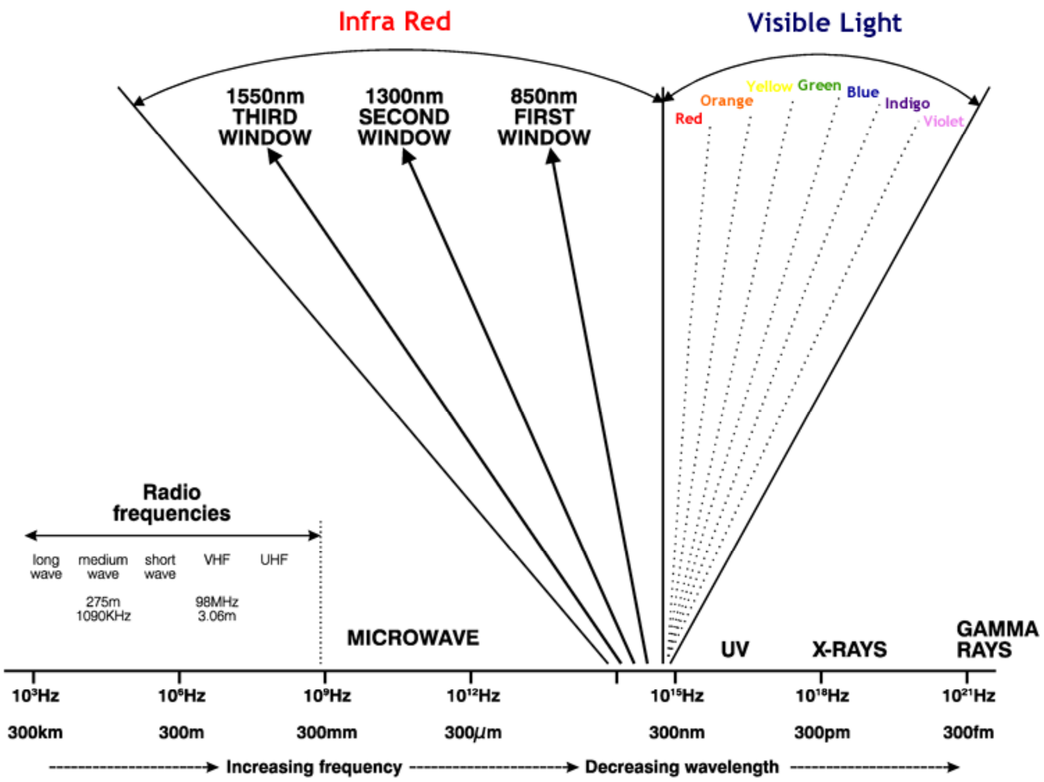
Copper data communication systems may be easily damaged or affected by any form of electrical interference or noise (EMI), electromagnetic pulses (EMP) and or by high frequency radio systems. Whereas fibre optics are typically immune to electrical interference and therefore can be utilised in environments where copper would not be suited.

Copper data communication systems have further restrictions such as the distance the copper can be run. Whereas fibre optics, provided can run immense distances (far in excess of 120Km without the need for repeaters).

Copper data communication systems can be easily 'tapped' and sensitive corporate information could become available without the company even being aware. Optical fibre on the other hand offers no radiated signals and is not easily tapped into. If optical fibre were to be 'tapped' a piece of test equipment (OTDR) would detect and show the user where the 'tap' lay.

Optical fibre is cheaper than copper length against length, but the equipment required to drive optical equipment is very expensive as opposed to the equipment required for copper. Each system has their own distinct merits and disadvantages, and our aim is not to discuss them here and let you make your own mind up.

Light as the transmission system



Light is the transmission method for communication systems and can be referenced or described in either frequency or wavelength terms. Typically within the data communications marketplace at this moment in time, optical fibre operates using three separate light wavelengths, which are referred to, as Windows of Operation.

First Window of Operation

The first window utilises light wavelengths between 800nm to 900nm for data communications. The light range for this window is quite large compared to the other operating windows and is therefore used on a fibre network utilising multimode systems.

Second Window of Operation

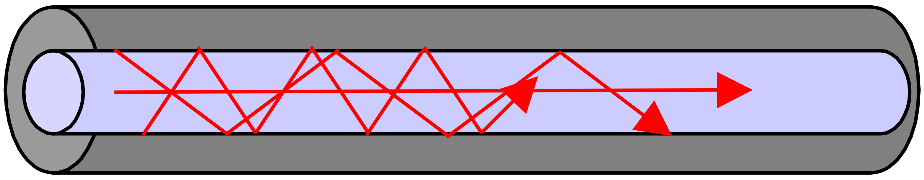
The second window operated within a wavelength guide of 1300nm. The second window offers the end-user better overall performance than the first window.

Third Window of Operation

The last commonly used window operates between 1530nm and 1550nm for use on singlemode optical fibre networks.

Multimode

Multimode optical fibre is able to receive many different ‘modes’ or angles of light provided that they do exceed the limits of the refractive indexes of the fibre. Multimode fibres have the light (data signals) generated by LED (light emitting diodes). Because of the fact that light ranges within LED’s disperse there will be multiple paths of light from the LED’s entering the optical fibre.



The light passing down multimode optical fibre takes longer and shorter path lengths and consequently the signal is dispersed in time (Modal Dispersion), which restricts the bandwidth of the fibre and the distance over which the fibre can operate satisfactorily.

Multimode optical fibre is generally available in two different sizes. The sizes relate the core and cladding sizes respectively:

1. 50μm/125μm
2. 62.5μm/125μm

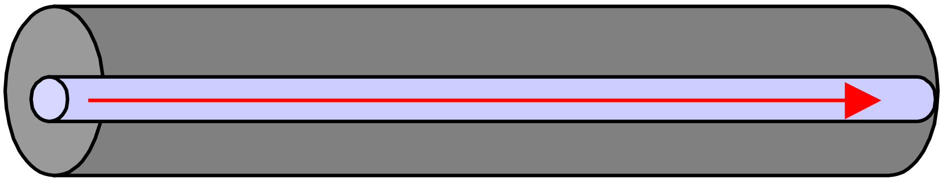
The bandwidth of multimode optical fibre also needs to be referenced as a bandwidth per kilometre e.g. 300MHz/Km. this figure is then placed against a frequency rate (MHz). From these figures we can easily find out the maximum transmission of the optical fibre.

For example, a data signal operating within a frequency range of 600MHz could transmit a signal 1Km on a fibre operating at 600MHz/Km or 3Km if the data signal frequency was 200MHz.

Multimode Bandwidth	Frequency	**Maximum Distance**
300 MHz/Km	300 MHz	1Km
300 MHz/Km	600 MHz	500m
300 MHz/Km	1.2 GHz	250m
600 MHz/Km	300 MHz	2Km
600 MHz/Km	600 MHz	1Km
600 MHz/Km	1.2 GHz	500m
1200 MHz/Km	300 MHz	4Km
1200 MHz/Km	600 MHz	2Km
1200 MHz/Km	1.2 GHz	1Km

Singlemode

With singlemode optical fibre, the core diameter has been reduced to such a level that only one mode of light can travel down the fibre. In singlemode fibre the light pulses travel directly through the central axis of the fibre and cannot spread out and disperse (as they do in multimode optical fibre), therefore singlemode has a much higher bandwidth than multimode optical fibre.



The cladding size of singlemode optical fibre is the same as multimode (125μm), but the core size of may range between 6μm - 9μm.
Optical Fibre Transmission Characteristics

Unlike metallic transmission lines, with optical fibres the significant transmission characteristics of optical fibres can be reduced to two, namely:

1. Optical attenuation or loss per km

2. Pulse dispersion, which for multimode fibres, is expressed as a bandwidth-distance.

The attenuation per km is the more important characteristic governing the distance performance of single mode fibres, whilst pulse dispersion (bandwidth-distance) primarily determines multimode distance performance for a given data rate.

Crosstalk between fibres is virtually non-existent, as is interference from external sources.

Like the importance of longitudinal impedance regularity in metallic lines, the regularity of the longitudinal wave-guide properties of the fibre is also important. Splices, in particular, if poorly made, can be significant causes of light reflection and poor transmission.

Attenuation or Optical Power Loss per km

Attenuation describes how light power reduces (attenuates) along a fibre and is normally measured and expressed in dB/km (decibels per kilometre), for a particular wavelength.

In addition to physical changes to the light pulse, which result from frequency or bandwidth limitations, there are also reductions in level of optical power as the light pulse travels to and through the fibre.

Light power, which does not reach the end of the fibre, has either left the fibre or has been absorbed (converted to heat) in it.

The following factors contribute to light loss:

1. Rayleigh-scattering
2. Fresnel loss at interfaces
3. Inhomogenities
4. Flaws in construction
5. Irregularities in core diameters
6. Abrupt bends

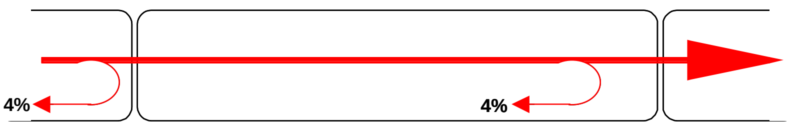
Light, which is incident perpendicular to a surface, cannot fully penetrate that surface.

A small part will be reflected and this is called Fresnel reflection and represents a loss of approximately 4% at each incident face.

Micro bending Loss

Without protection, an optical fibre is subject to losses of optical power caused by micro bending. Micro bends are minute fibre deviations caused by lateral forces, which cause optical power loss from the core.

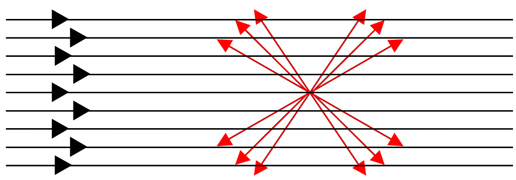
Different types of protection for the fibre are available to minimise micro bending. Step index fibres are relatively more resistant to micro bending losses than graded index fibre.



Fresnel Reflection Losses

When light propagates through a not-completely homogenous glass material with some impurities, the light can be seen in other directions than that of the direction of propagation.

This phenomenon called Rayleigh scattering, results from the presence of impurities.



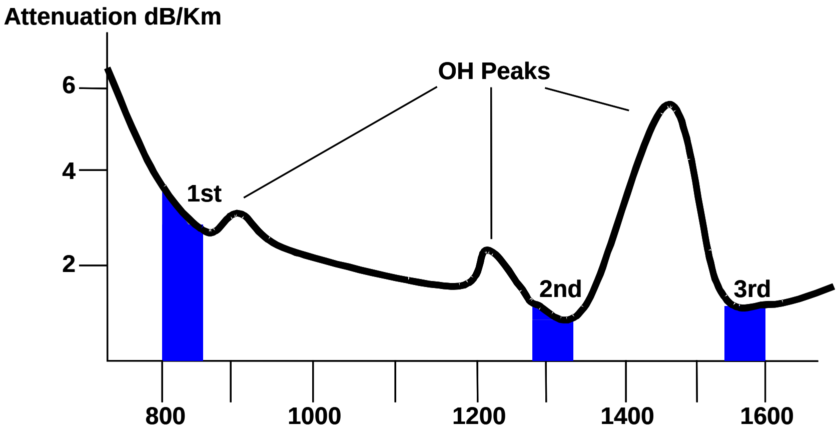
These impurities are illuminated and emit or scatter light in all directions. This is called Tyndalight and is proportional to wavelength - that is, more scattering occurs at longer wavelengths. It is analogous to light seen from fog particles when a car headlight illuminates the fog.

The following factors contribute to absorption in the infrared light region:

1. Hydroxyl ions (OH)
2. Humidity
3. Metal ions
4. Damage from too high hauling tension

Loss-wavelength characteristic

The silica fibre loss characteristic varies with the wavelength of the light source used. For multimode fibres the characteristic is shown in the following diagram.



Low loss windows exist at 1300 nm and 1550 nm wavelengths and a window at 850 nm are also used in some LED systems.

Intrinsic Optical Fibre Loss

Light is an electromagnetic wave of vibrating nature. Short wavelengths are in the ultraviolet spectrum.

Microwaves, radar, television and radio operate in the longest wavelength areas.

In between the ultraviolet and the microwave spectrums, we have optic fibre wavelengths, which are in the infrared spectrum.

Just as the speed of light slows when travelling in transparent materials, each infrared wavelength is transmitted differently within the fibre. Therefore, attenuation, or optical power loss, must be measured in specific wavelengths for each type of fibre.

Wavelengths are measured in manometers (nm) - billionths of meters - that represent the distance between two cycles of the same wave.

Losses of optical power at the different wavelengths occur in the fibre due to absorption, reflection and scattering. These occur over distance depending on the specific fibre, its size, purity and refraction indexes.

The amount of optical power loss due to absorption and scattering of optical radiation at a specified wavelength is expressed as an attenuation rate in decibels of optical power per kilometre (dB/km).

Fibres are optimised for operation at certain wavelengths. For example, less than 1dB/km loss is typical in 50/125μm multimode fibre operating at 1300nm, and less than 3dB/km (50% loss) is typical for the same fibre operating at 850nm.

These two wavelength regions, 850 and 1300nms, are the areas most often specified for fibre optic transmission. These wavelengths are commercially useable with transmitters and receivers. Optical fibres have also been optimised at the 1550nm region for single mode transmission systems.

1. Use of the 1300 nm or 850 nm wavelength

2. Use of multimode fibre of core diameter 62.5 μm and cladding diameter 125 μm and graded index construction

3. Maximum optical power loss in cabled fibres of 1.0 dB/km at 1300nm and 3.5 dB/km at 850nm

Unlike copper transmission lines, in optical fibres significant contributions to overall power loss or attenuation can come from:

1. Fibre splices, connectors and terminations

2. Installation practices which result in sharp bends in the fibre and/or excessive tension

3. Poor coupling efficiency of light source into fibre and fibre into receiver

Installation practices to minimise these effects will be discussed later in this course.

Compliance Testing

Standards require compliance testing of the completed installation form terminated fibre to terminated fibre and in both directions and requires that:

1. The fibre loss shall be no greater than 1.0 dB/Km at 1300 nm and 3.5 dB/Km at 850 nm.

2. The total optical attenuation measured through the cross-connect from any terminated fibre to any other terminated fibre shall be no greater than 1.5 dB plus loss due to length of fibre itself.

3. Fibre optic splices, fusion or mechanical splices shall not exceed a maximum optical attenuation of 0.3 dB.

4. Individual connectors shall average no more than 0.5 dB/connection with an absolute maximum of 0.75 dB/connection.

Pulse Dispersion

Pulse dispersion due to the variation in modal path lengths sets a limit to the maximum rate of data transmission for a given distance to prevent pulse spreading causing corruption of data. This is a multimode fibre limitation. It is largely eliminated in single mode operation.

In multimode fibre, a figure of merit is specified as the fibre's bandwidth-distance parameter. This figure of merit is set by the fibre material and fibre geometry.

1. 500 MHz-Km at 1300 nm for graded index62.5/125μm multimode fibre

2. 200 MHz-Km at 850 nm for graded index 62.5/125μm multimode fibre

The following requirements are being considered for 50/125μm fibre**.**

1. 600 MHz-Km at 1300nm for graded index 50/125μm multimode fibre.

2. 500 MHz-Km at 850 nm for graded index 50/125μm multimode fibre.

Since bandwidth sets the maximum data rate, this parameter determines the highest data rate that can be sent on a link of given distance, using multimode fibre.

Impact of ISO-11801: 2000

The ISO-11801 standard, “Generic Cabling for Customer Premises Cabling”. ISO-11801 tightens loss at 1300 nm for multimode optical fibre to 1 dB/Km maximum and per connector loss to 0.5dB average with 0.75 dB absolute maximum. This imposes even more stringent requirements on the care exercised in connectorisation, as higher performance for a pair of connectors is required.

ISO-11801: 2000 specify maximum link loss on inter-building and within building OF links, both backbone and floor cabling and for links in tandem. These losses refer to install, connectorised cabling without active repeaters and may be summarised as follows.

Cabling Sub-System	**Link/Channel Length (m)**	**Attenuation (dB)**			
		Singlemode		**Multimode**	
		1310nm	1550nm	850nm	300nm
Horizontal	100	2.2	0.2	0.5	0.2
Building Backbone	500	2.7	0.7	0.9	0.6
Campus Backbone	1500	3.6	0.6	0.4	0.6

The link/channel lengths and attenuation values given here are achievable using optical fibre components meeting the minimum requirements.

Care should be taken with short optical links/channels to ensure that the additional optical power carried in the fibre cladding does not overload the receiver.

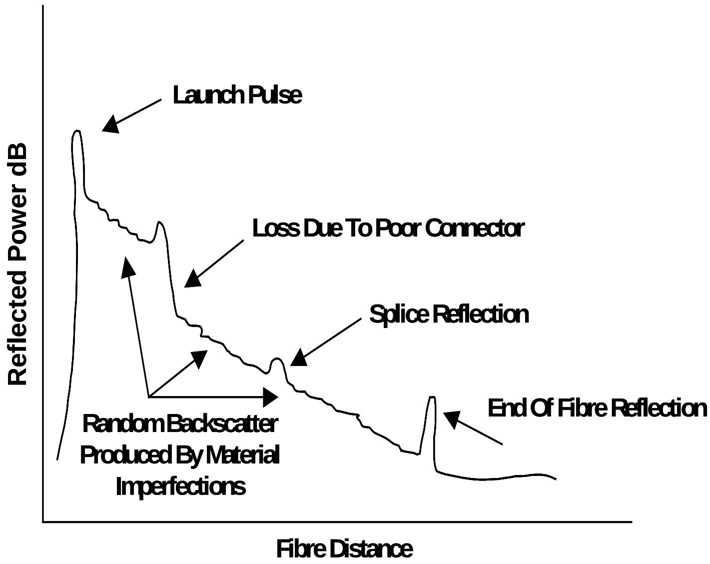
These figures are stated for the worst-case scenario of a connector and a splice at either end of each sub system.

These figures are designed to ensure that a cabling design to ISO 11801 will ensure no greater than 11dB attenuation through any optical fibre link or combination of optical fibre links in a campus/building/floor distributor composite link consisting of 62.5/125µm, or 8/125µm optical fibre. For Centralised Optical fibre cabling, additional restrictions apply.

Optical Time Domain Reflectometer (OTDR)

The principles used in time domain reflectometry for optical fibre testing are similar to those used with metallic transmission lines.

When applied to optical fibres, the OTDR instrument provides a graphical display of the structural regularity of the fibre along its length and therefore its propensity to production of light reflections along its length.



Due the random 'backscatter' of light from random variations in glass density and composition, which results from the manufacturing process, the slope of the backscatter signal shown on the OTDR also indicates fibre loss.

Structural irregularities at splices are also indicated by the return energy from each splice and the graphical display gives the position of the splice and the loss of light power at the splice in dB.

Optical Fibre Installation

Optical Fibre Installation Principles

1. Once a design and plan for an optical fibre cable installation has been determined, the installation involves four stages:
2. Pre-test of fibre on drum for individual fibre continuity (and possibly for loss or an OTDR test for quality).
3. Cable installation (placement, hauling) into ducts, conduits, trays, etc.
4. Fibre termination (and splicing if necessary)
5. This is dealt with in Section 9 of the course.

Optical Fibre Pre-Test

Testing each fibre (end to end) for optical continuity before installation may save considerable time and effort at a later stage.

A simple test can be done with a torch shining into the end of the fibre and observing the light at the other fibre end. Moving the torchlight across the fibre and observe the light variation at the opposite end thus verifying the optical continuity of the fibre path.

Providing the manufacturer (supplier) provides test certification for each cable drum and the manufacturer and the transportation company has a proven record for reliability, there is probably no need for a more detailed test of each fibre with say an OTDR before installation commences. However, where the reliability of the supplier and the integrity of the associated cable transport system are unproven loss measurements and/or OTDR tests on each fibre may be considered necessary.

Cable Installation (Placement and hauling and securing)

In some respects, because of their lightweight and flexibility, optical fibre cables are more easily installed than copper conductor cables.

The critical installation parameters, which may adversely affect optical fibre cables, are:

1. Maximum tensile force

2. Minimum bending radius

To ensure that the maximum tensile force and minimum bending radii are not compromised during installation requires:

1. Careful planning of the cable route and choice of pathways

2. Careful planning of the installation process and monitoring of that process

The minimum bending radii and maximum tensile loading allowable are different for the dynamic installation stage as compared with the static long-term environment.

Optical Fibre Maximum Tensile Loading

For the same diameter, optical fibres have greater tensile strength than steel and a copper conductor must have twice the diameter for equivalent tensile strength.

Tensile weakness in fibre is cause by microscopic cracks on the fibre surface and flaws within the fibre itself.

Surface defects grow in size under tensile loading, which may be of short duration (initial hauling into conduits) or long term (weight of cable on a vertical run).

Temperature changes mechanical and chemical changes and normal ageing also promotes defects.

The defects can grow to eventually cause a fibre to snap. This mechanism is similar to the normal process used to cut glass. A scriber is used to scratch the glass surface and then tension (bending) used to propagate the 'flaw' until the glass breaks along the line of the initial 'scratch'.

Tension can also affect the optical loss in a fibre:

1. Initially, an increasing tensile load will cause an increase in loss, which reverses when the load is removed. This situation may occur under low hauling tensions.
2. At greater tensions, the increase in loss may be irreversible and finally cracking of the fibre occurs.

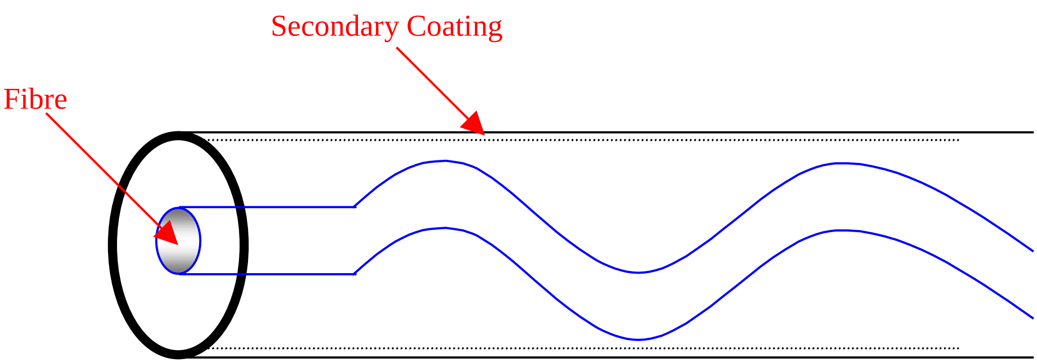
Static and Dynamic Tension

Higher tensions may be accepted during initial installation (hauling) than for long-term static and continuous loadings such as the weight of the cable on a vertical run. Further, the continuous loading such as cable unsupported or vertical runs can lead to fibre creep as the super cooled liquid glass actually flows "slowly" under tension. Optical fibre cable requires regular support on vertical runs to arrest this long-term creep.

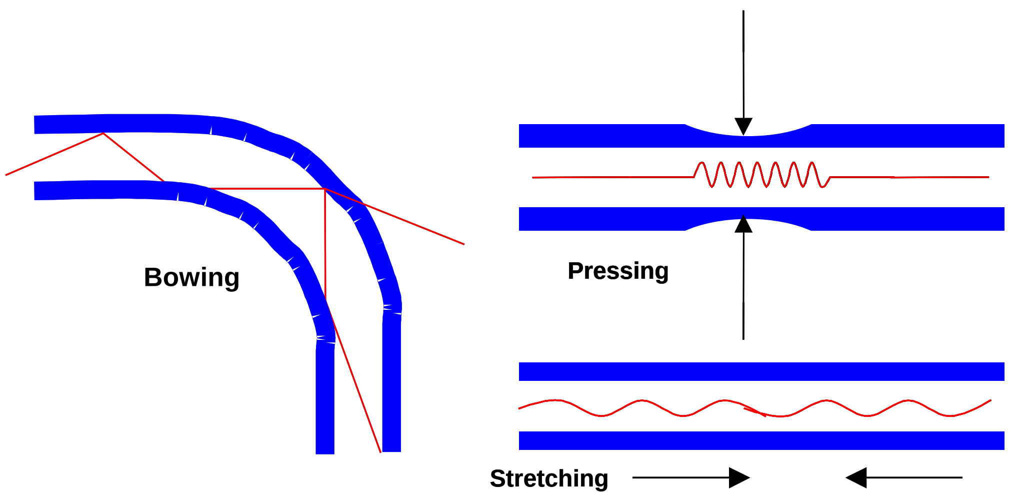
Minimum Bending Radius

Optical losses in fibres arise from:

- **Intrinsic loss** from scattering and absorption within the fibre – the diagrams below show the typical intrinsic losses versus wavelength for silica fibre.



Bowing, bending stretching & pressing Losses



Micro bending Losses

Micro bends are small variations in the core to cladding interface, which causes higher order modes to be incident at the boundary at angles less than the critical angle for total internal reflection. These modes are lost into the cladding with a consequent loss of optical power through the fibre. Micro bends can occur during manufacturing and poor installation technique or due temperature changes when the core and cladding having different rates of thermal expansion.

Macro bending Losses

If the fibre is bent in too small a radius, the higher order modes are incident at the core to cladding boundary at angles less than the critical angle for total internal reflection. This results in the loss of these higher order modes into the cladding with overall optical power loss in the fibre. This effect becomes detectable at bending radii of between 5 to 10 cm.

In addition, bends decrease the tensile strength of a fibre as small surface imperfections become magnified by tensile stress leading to possible fibre fracture, as glass is a very brittle medium. So pulling a fibre cable around bends will cause tensile failure at a lower tensile load than in a straight haul.

A good rule of thumb is to maintain fibre bends:

1. Greater than 10 times the cable diameter for an unstressed cable.

2. Greater than 20 times the cable diameter for a stressed cable.

3. Minimum bend radius of conduit should be greater than 10 times the conduit diameter.

Termination of Optical Fibres

Interconnection of optical fibre to optical fibres and to optical system components involves use of:

1. Connectors (dis-connectable / re-connectable between fibres and between fibres and equipment, using patch leads).

2. Splices (between fibres)

In each case, the key to optical fibre interconnection is precise alignment of the mated fibre cores so that nearly all light is coupled from one fibre across the junction to the other fibre or optical interface.

Desirable features of an optical fibre interconnection device include:

1. Low loss.
2. Easy and speedy installation preferably without need for specialist training or specialist tooling.
3. Repeatability - connecting/disconnecting should not change the losses at the connector.
4. Consistency - the loss should not change with different installers or at different locations and times and should not change during the life of an installation.
5. Economical - the connector or splice should be inexpensive in material and in application tooling and in time to implement.

It is not a simple matter to produce a splice and a connector, which meets all these criteria.

1. Splice loss to be no greater than 0.3 dB
2. Maximum loss from terminated fibre to terminated fibre per pair of connectors, to be no greater than 1.5 dB excluding the inherent fibre loss.
3. 0.5 dB average /0.75 dB maximum per connector

These limits require good quality, low loss connectors and splices.

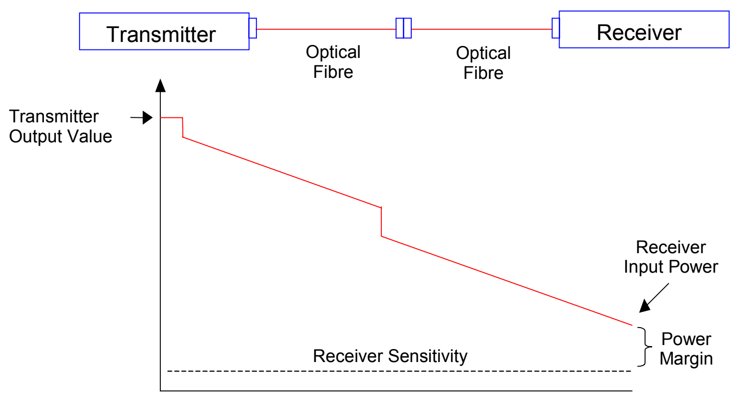
Fibre Connector losses

1. Intrinsic - Poor manufacturing quality, alignment, incorrect dimensions
2. Extrinsic - Dirt on ferrule, poor polishing of connector face
3. Transmission - Modal distribution, launch conditions, distance

Power Budget

A fibre optic link consists of:

1. A transmitter
2. A receiver
3. The passive components which inter-connect them



Optical Power Budget - Link Losses

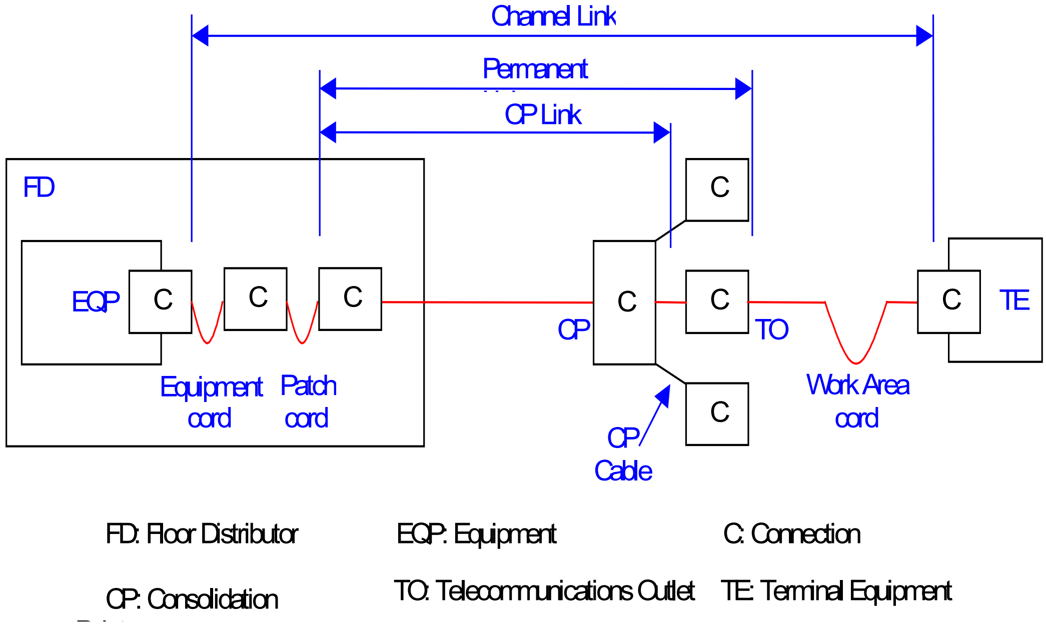
The passive inter-connecting components may include:

1. The optical fibre cable
2. Splice(s) in the fibre
3. Connectors terminating the fibre at either end
4. Optical fibre patch cords
5. Optical switches, splitters, couplers, wavelength division multiplexers (WDM's)

If the optical power level reaching the receiver is below its minimum sensitivity, the digital signals cannot be detected and regenerated without error.

The power budget for an optical link is the maximum allowable loss in the passive components for a given transmitter output level and a given receiver sensitivity. The power budget is the difference between the output power level of the transmitter and the receiver power sensitivity level.

Testing Overview



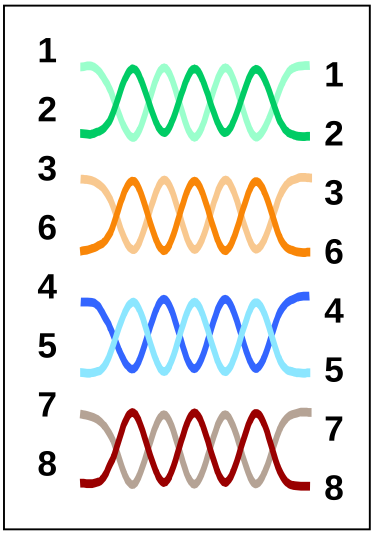
ACCL utilise continuity checkers to verify end-to-end connections and a series of expensive test tools, such as the Fluke DSP range and the Microtest OMNIScanner provide a full wire map, measure length with a TDR, and provide additional useful functions. This kind of tool is great for testing voice cabling, making quick checks on data cabling, and for the growing residential LAN wiring market.

Today's cable standards for this kind of cabling requires several measurements to be made in order to certify the cabling meets stated performance requirements. Some tests are performed worldwide, while others are specific to the U.S. or Europe. Each of these standards has unique pass/fail limits, which vary depending upon the Class and link definition.

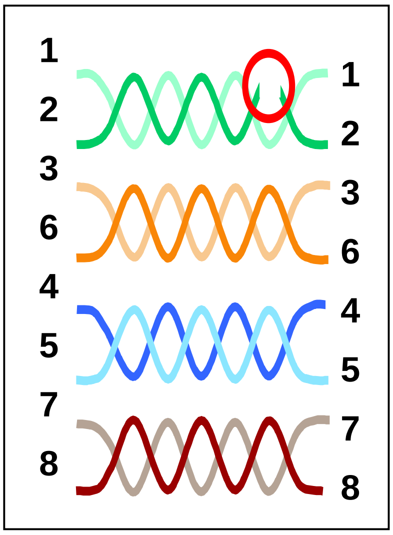
Wire-Map

The first is called wire map. Wire map verifies end-to-end pin-to-pin connectivity, as well as checking for split pairs. Any miss-wires, breaks, opens, shorts, crossovers, or splits should be detected.

The left wiring diagram demonstrates a correctly wired data communications outlet, whereas the diagram on the right indicates that the conductors highlighted within the red circle are what are known as an open-circuit.

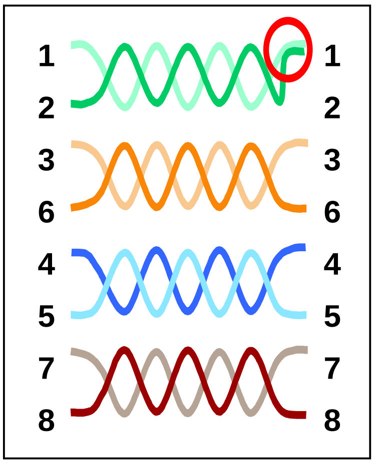


Correctly Wired

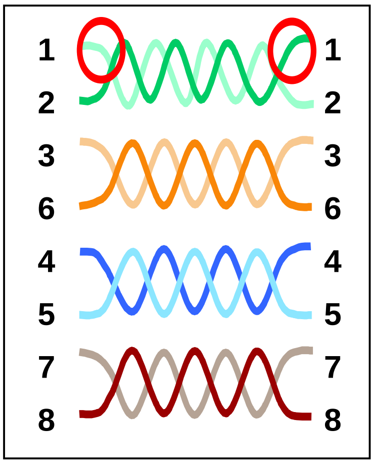


Open-Circuit

The following left-handed diagram depicts a short circuit on pins one and two as we can see that the conductors are in contact with each other. The right-handed diagram demonstrates a reversed pair.

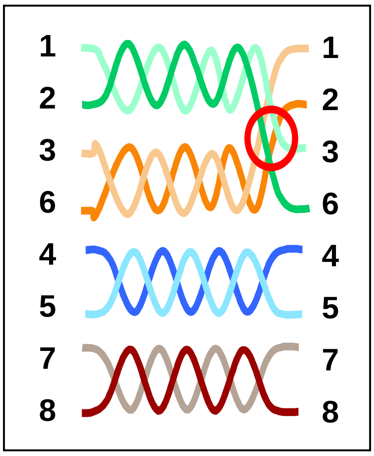


Short Circuit

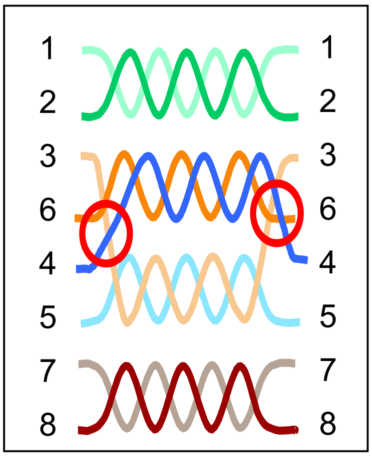


Reversed Pair

The following diagram on the left demonstrates what is known as, transposed pairs. The diagram on the right identifies split pairs.



Transposed Pairs



Split Pairs

Results Interpretation: Wire-Map

In most cases you will expect to see straight through connections. With simple tools, such as LED display testers, a lamp will light up indicating a short or open. Advanced tests, such as reversed or split pairs, are often not available in such equipment. While such tools are usually adequate, it must be noted that a passing result does not necessarily guarantee wiring has been installed correctly. In particular, split pair detection requires the measurement of NEXT, which is beyond the capability of low-end testers. Split pairs will cause a high degree of NEXT (typically over 22 dB), which will severely limit available bandwidth on the installed cabling.

Wire map is a fundamental test, but it is important to note that correct wiring does not verify bandwidth performance. Frequency-dependent tests such as NEXT, Attenuation, and Return Loss are key to ensuring cabling is capable of supporting high-speed applications.

Note that the Wire Map test automatically isolates breaks, but not high resistance connections.

Wire-Map Troubleshooting Recommendations

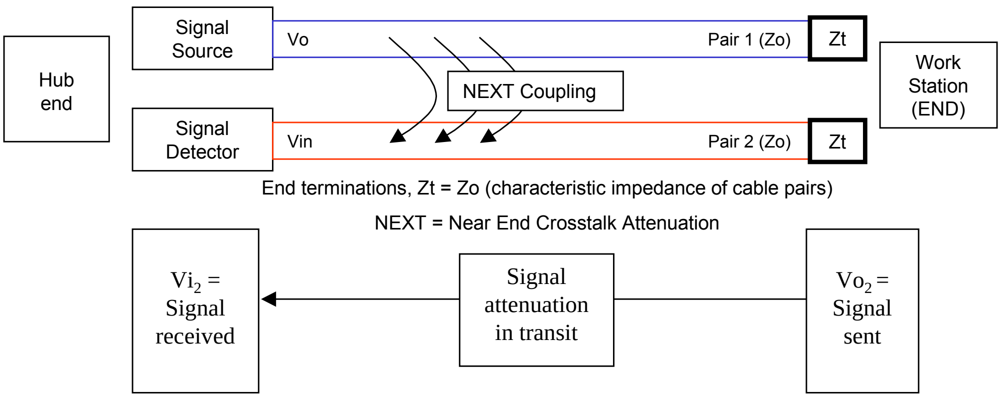
In the case of a wire map failure, a careful examination of the installation (IDC block or Connector) will usually show that one or more wires have been transposed. Inspect and re-terminate as necessary.

If conductors are missing, it could be because they are unnecessary for the intended application. For example, 10BASE-T and token ring each require only four conductors. Some wiring designs purposely use one four pair copper data cable to supply two RJ45 connections each with two pairs. The important issue is to ensure the installed cabling meets the required design criteria.

If an open conductor is found, use the length measurement capability of your Field Tester to determine whether the open is at the near or far end to speed fault isolation and repair.

In the case of Screened twisted pair cabling you will need to also verify screen continuity. This is usually only available on more advanced certification tools.

Near End Crosstalk



Another key measurement used to qualify LAN cabling is Attenuation also called Insertion Loss. Every electromagnetic signal loses strength as it propagates away from its source, and LAN signals are no exception.

Attenuation increases with temperature and frequency. Higher frequency signals are attenuated much more than low frequency signals, which is one of the reasons why a cable may have correct pin-to-pin continuity, pass low speed traffic like 100BASE-T perfectly, yet not be able to handle 1000BASE-T. With, Cat 5e & Cat 6 copper data cable, attenuation is remarkably varying from one manufacturer to manufacturer.

The most important test in qualifying the performance of network cabling is near end crosstalk (NEXT). Crosstalk occurs when signals from one pair of wires radiate and are picked up by an adjacent pair of wires.

Crosstalk increases with frequency, so that just as for attenuation, a Cat 3 cable may be fine for 10BASE-T, but can't handle 100BASE-T.

When current flows in a wire, an electromagnetic field is created which can interfere with signals on adjacent wires. As frequency increases, this effect becomes stronger. Each pair is twisted because this allows opposing fields in the wire pair to cancel each other. The tighter the twist, the more effective the cancellation and the higher the data rate supported by the cable. Maintaining this twist ratio is the single most important factor in any successful Cabling installation.

If wires are not tightly twisted, the result is near end crosstalk (NEXT). If you have ever had a telephone call where you could hear another conversation faintly in the background, you have experienced crosstalk. In fact, the name crosstalk derives from telephony applications where 'talk' came 'across'.

In LANs, NEXT occurs when an adjacent pair of wires picks up a strong signal on one pair of wires. NEXT is the portion of the transmitted signal that is electro-magnetically coupled back into the received signal.

Results Interpretation: Near End Crosstalk

Since NEXT is a measure of difference in signal strength between a disturbing pair and a disturbed pair, a larger number (less crosstalk) is more desirable than a smaller number (more crosstalk). Because NEXT varies significantly with frequency, it is important to measure it across a range of frequencies, typically 1 - 100 MHz. If you look at the NEXT on a 50-meter segment of twisted pair cabling, it has a characteristic "roller coaster going uphill" shape. That is, it varies up and down significantly, while generally increasing in magnitude. This is because the coupling between the twisted pairs becomes less effective at higher frequencies.

The field tester should compare successive readings across the frequency range against a typical pass/fail line, such as the Class D specification. If the NEXT curve crosses the pass/fail line at any point, then the link does not meet the stated requirement. Since NEXT characteristics are unique to each end of the link, six NEXT results should be obtained from each end: i.e. Pair 1 - Pair 2, Pair 1 - 3, Pair 1 - 4, Pair 2 -3, Pair 2 - 4 and Pair 3 - Pair 4.

Near End Crosstalk Troubleshooting Recommendations

In many cases, excessive Crosstalk is due to poorly twisted terminations at connection points. All connections should be twisted to within 13 mm of the point of termination. The first thing to do in the event of a NEXT failure is to use the field tester to determine at which end the NEXT failure occurred. Once this is known, check the connections at that end, and replace or re-terminate as appropriate.

If this does not appear to be the problem, check for the presence of lower Category patch cords (such as voice grade cable in a Class E installation). Making up Patch cords on site using crimped RJ45 plugs and normal horizontal cable causes many problems. This procedure should be avoided; crimped connectors are notoriously poor and cannot be uniformly made on site.

Another possible cause of NEXT failure is split pairs, discussed earlier. This should be identified automatically with the wire map function of your field tester. Female couplers are another high source of crosstalk and should not be used in a data installation. If a cable is not long enough, replace it with a cable of the required length rather than adding another cable.

Sometimes a NEXT failure is caused when an inappropriate test has being selected. For example, you cannot expect a Cat 5e installation to meet Cat 6 performance requirements.

The Microtest OMNIScanner has a TDNXTTM, a function available that clearly identifies the cause of the NEXT failure, whether it is the patch cord, connection, or horizontal cable.

In event you have eliminated all of the above NEXT sources are still experiencing NEXT failures it could be caused by faulty or bad connectors, contact the system designer for further assistance.

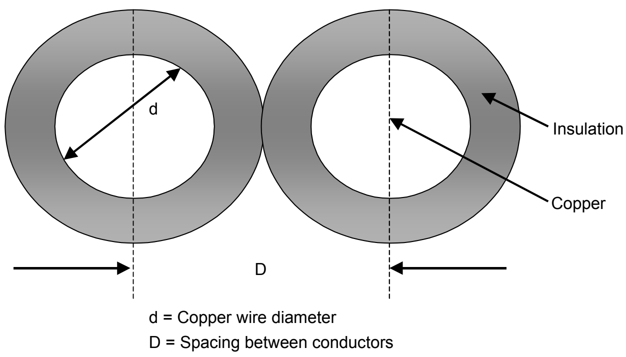
Cable Geometry

The smooth flow of signal energy from source to receiver depends on all components in the communications channel having the same characteristic impedance. This means that patch/equipment connecting cords; the cable itself and the cable termination components must be designed to closely match, impedance-wise. In addition, impedance mismatches along the cable length due to practices will also cause energy reflections and data errors.

This characteristic impedance is physically determined by the cable geometry:

- The wire diameter
- And wire to wire spacing
- And, to a lesser extent, the insulation material between the wires

Since cable geometry is the major factor determining characteristic impedance, it is vital that the wire diameter and within pair spacing is maintained during both manufacture and installation. Poor installation practices such as excessive pulling tension, frequent kinking of the cable sheath; too small a bending radius and cable ties too tight can cause sufficient distortion of the cable geometry to affect characteristic impedance. The result may be to cause data errors through signal reflections on the line.

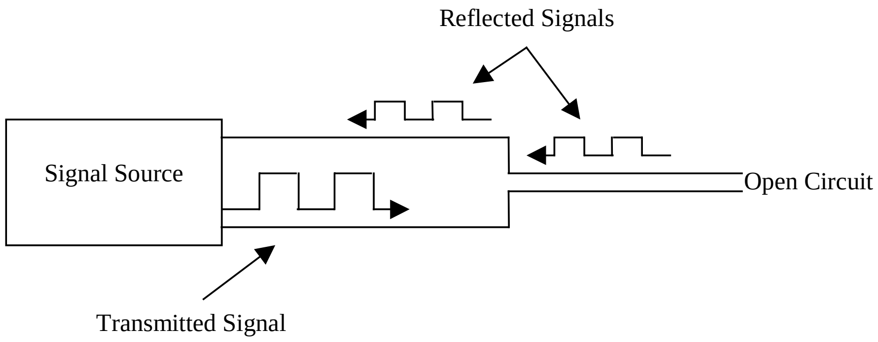


If the conductor diameter and within pair spacing is maintained constant, the signal sees a constant impedance as it travels down the line. Signal energy is transferred smoothly and efficiently from the input to the output of the line.

However, variations in cable geometry cause localised changes in the characteristic impedance. The signal treats these as discontinuities and small signal reflections emanate from these and travel back towards the input. Signal energy is not transferred smoothly. Losses occur.

Signal reflection will also occur if the end of a line is not terminated in the same impedance as the line's characteristic impedance.

The overall effect of multiple signal reflections can be to corrupt the data transmission causing errors in transmission.



Keeping the pairs tightly twisted and well-balanced best minimises crosstalk. These tight twisting causes opposing electromagnetic fields too more effectively cancel each other, thus reducing emissions from the pair. Cat 5 cable is much more tightly and consistently twisted than Cat 3 cable and uses better insulation materials that further reduce crosstalk and attenuation.

Standards require that all terminations be properly twisted to within 13mm (0.5 inches) of the termination, whereas, the ACCL standard is that the copper cable pair twist is maintained as close as possible to the point of termination.

Characteristic Impedance

Impedance is a measure of the opposition to the flow of current. It includes the effects of resistance, capacitance, and inductance. Data cabling is commonly rated at 100 ohms impedance and this value should be constant (+/- 15%) over the length and operating bandwidth of the cable.

Impedance can be specified in different ways. Input Impedance and Characteristic Impedance are the two most common terms. Characteristic Impedance refers to the impedance of an infinitely long cable. Any change in impedance within cable causes internal reflections, which lead to return loss and attenuation. Characteristic Impedance is measured on cable, not links, and is a laboratory measurement. There are no published field test documents that require characteristic impedance measurement.

Input Impedance

Impedance is a measure of the opposition to the flow of current. It includes the effects of resistance, capacitance, and inductance. Data cabling is commonly rated at 100 ohms and this value should be constant (+/- 15%) over the length and operating bandwidth of the cable.

Impedance can be specified in different ways. Input impedance and characteristic impedance are the two most common terms.

Input impedance is the impedance seen looking into a cable. It can be mathematically derived from return loss. Return loss has become the preferred method of specifying link impedance uniformity, and so input impedance is not used in a field measurement.

NVP

Nominal Velocity of Propagation (NVP) refers to the ‘inherent speed of signal travel relative to the speed of light in a vacuum’ (designated as a lower case c). NVP is expressed as a percentage of c, for example, 72%, or 0.72c. All structured wiring cables will have NVP values in the range of 0.6c to 0.9c. Similarly, if you know the physical length and the delay of a cable, you can calculate the NVP.

Nominal Velocity of Propagation (NVP) refers to the speed that signals travel in a cable. It is expressed as a percentage of the speed of light. Incorrectly set NVP is a very common error. If the NVP is set for 75% and the actual cable's NVP is 65%, that's a 10% error straight away. Furthermore, NVP is unique to each pair and also varies with frequency. For Category 3 cables and hybrid Cat 5e cables, NVP can vary by up to 12% between pairs!

Attenuation to Crosstalk Ratio

Attenuation to Crosstalk Ratio (ACR) is a measurement that determines the effective signal-to-noise ratio of a cabling link. ACR is simply the difference between the NEXT and the Attenuation. It is a measure of the strength of the signal that survives attenuation from the far end relative to crosstalk noise.

For example, imagine an instructor standing in front of a room giving a lecture. The goal of the instructor is to be heard by the students. The volume of the instructor’s voice is a key factor in determining this, but it isn’t as important as the difference between the instructor’s voice and the background noise. The instructor could be speaking in a very quiet library, so that even a whisper could be heard. But imagine that same instructor, speaking at the same volume, at a noisy football game. The instructor would have to raise his voice, so that the difference between his voice (the desired signal) and the cheering crowd (the background noise) is enough for him to be heard. That’s ACR!

Results Interpretation: Attenuation to Crosstalk Ratio

ACR is an important figure of merit for twisted pair links. It provides a measure of how much ‘headroom’ is available, or how much stronger the signal is than the background noise. The greater the ACR, the better.

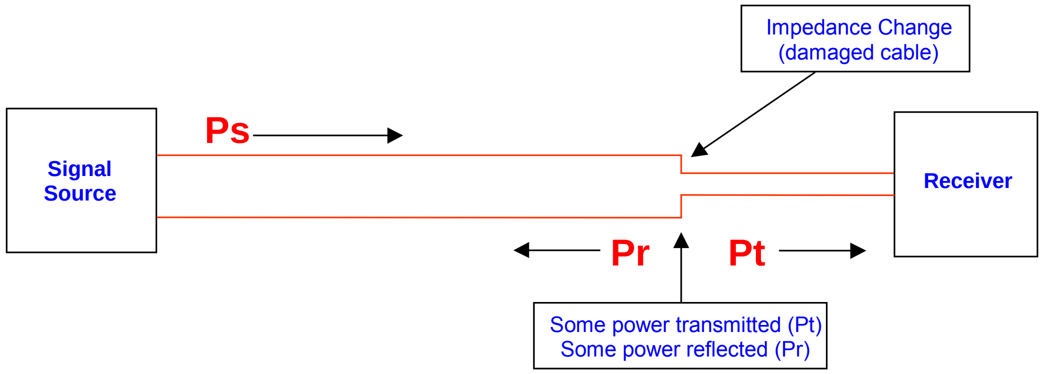
Because NEXT characteristics are unique to each end of the link, ACR results will also be different at each end. The worst case ACR results must be used.

Attenuation to Crosstalk Ratio Troubleshooting Recommendations

ACR is derived from NEXT and Attenuation data. Any steps taken to improve either NEXT or Attenuation performance will improve ACR performance.

In practice, this usually means troubleshooting for NEXT, because the only way to significantly improve Attenuation is to shorten the length of the cable.

Return Loss



Return Loss is the ratio, expressed in decibels, of the fractional amount of signal reflection caused by an impedance mismatch. Return loss is increasingly important when trying to get premium performance from UTP. Manufacturers of very high quality UTP have taken special care to ensure impedance is very uniform throughout the link, and also that all components are very well matched. So while return loss wasn't a big issue when Cat 5 cabling first appeared it is an important issue for Cat 5e and Cat 6 cabling?

Return Loss is a measure of the ratio of signal power transmitted into a system to the power reflected (i.e. 'returned'). In simple terms, it can be thought of as an echo that is reflected back by impedance changes in the link. Any variation in impedance from the source results in some returned signal. Real-life cabling systems do not have perfect impedance structure and matching, and therefore have a measurable return loss.

Twisted pairs are not completely uniform in impedance. Changes in twist, distance between conductors, cabling handling, cable structure, length of link, patch cord variation, varying copper diameter, dielectric composition and thickness variations, and other factors all contribute to slight variations in cable impedance.

In addition, not all-connecting hardware components in a link may have equal impedance. At every connection point there is the potential for a change in impedance.
Each change in the impedance of the link causes part of the signal to be reflected back to the source.

Return Loss is a measure of all the reflected energy caused by variations in impedance of a link relative to the source impedance of 100 ohms.

Each impedance change contributes to signal loss (Attenuation) and directly causes Return Loss.

Results Interpretation: Return Loss

Return Loss is a swept frequency measurement, and the results of a test must be under the limit line for the relevant link type (basic link, permanent link, or channel). There have been some recent developments that have shown return loss results in the field for Cat 5, Cat 5e and Cat 6 to be worse than expected. Follow the troubleshooting recommendations below to resolve such instances.

Return Loss Troubleshooting Recommendations

There are many possible causes for return loss failures. These include variable patch cord impedance, patch cord impedance changes due to handling effects, installation practices, and lack of link margin in Standards models, non-compliant cable, and non-compliant connecting hardware. The Standards Committees are working to specify patch cord return loss requirements, as well as improve the link model. The current model allows worse case compliant components to fail the link limits, which is clearly unacceptable.

Patch cord effects should not be a problem when testing the basic link with the Microtest OMNIScanner™ or Fluke DSP range because their test cords are pre-qualified for return loss and NEXT performance. This may not be true for other field testers.

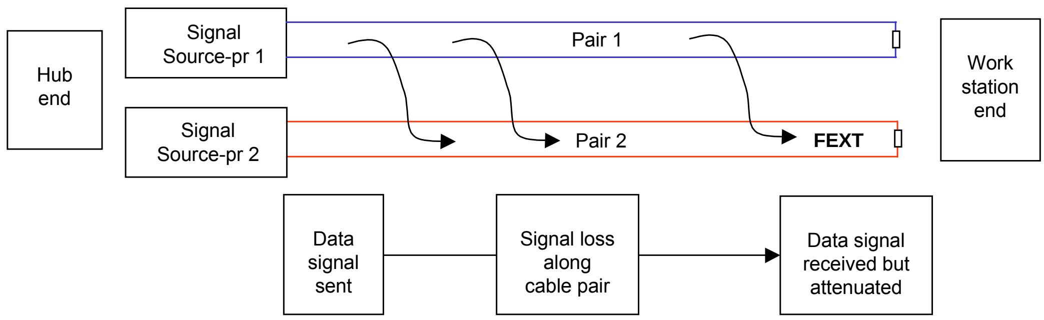
Installation practices are more important on Cat 5e and 6 than they were for Cat 5. Additional unnecessary untwist in terminations can add several dB of return loss in some cases. Be sure to apply a high level of care when installing cabling that requires return loss qualification.

TDR techniques may be able to indicate gross impedance changes, but are generally insufficient for pinpointing the source of a Cat 5e or 6 return loss failures.

Power-Sum

Power-sum NEXT (PSNEXT) is actually a calculation, not a measurement. PSNEXT is derived from an algebraic summation of the individual NEXT effects on each pair by the other three pairs. PSNEXT and FEXT (discussed below) are important measurements for qualifying cabling intended to support 4 pair transmission schemes such as Gigabit Ethernet.

Far End Crosstalk



Far End Crosstalk (FEXT) is similar to NEXT, except the signal is sent from the local end and crosstalk measured at the far end.

FEXT by itself is not a useful measurement. This is because FEXT is highly influenced by the length of the cable, since the signal strength inducing the crosstalk is affected by how much it has been attenuated from its source.

For this reason, Equal Level FEXT or ELFEXT is measured instead. ELFEXT simply subtracts attenuation from the result, so that the result is normalised for attenuation (length) effects. Then, just to make things interesting, we also have power-sum ELFEXT, or PSELFEXT.

Length

Length is defined as the physical or sheath length of the cable. It should correspond to the length derived from the length markings commonly found on the outside jacket of the cable.

Length measurement may seem straightforward but actually can be tricky. In essence, a Permanent link should not exceed 90 meters and a Channel should not exceed 100 meters. The accuracy of a length measurement is affected by several factors, including Nominal Velocity of Propagation (NVP) of the cable; twist length vs. physical sheath length, and impulse dispersion over long lengths.

When you are measuring length with a field test tool, you are usually measuring time delay, and converting it to a length estimate based upon an assumption of signal speed.

In addition, the copper conductors in UTP are twisted, so the actual length of the wire is longer than the length of the cable jacket. On a 300-meter spool, you could easily have 310 meters of copper.

For these reasons, consider length results from hand held testers to be good approximations, not precise values.

Physical length is in contrast to electrical or helical length, which is the length of the copper conductors. Physical length will always be slightly less than electrical length, due to the twisting of the conductors.

In order to measure length, a test set first measures delay, and then uses the cable's nominal velocity of propagation to calculate length.

By convention, length is derived from the shortest electrical length pair in the cable. Because of delay skew, the length of the four pairs often appears slightly different. This is normal and no cause for concern, with the exception of significant (over 10%) variances.

Most high-level testers have a pre-installed set of values for most common cable types or specific cables from manufacturers. This means that on most field testers the user can select a cable from the internal cable library and it will automatically have the NVP associated with it.

Results Interpretation: Length

The main concern when measuring length is that there is not too much cable in any segment. For horizontal structured cabling, this means 90 meters for the Permanent Link and 100 meters for the Channel. LAN transmission systems have been designed to support a maximum signal propagation delay, and if the link is too long, this delay could be exceeded. Occasionally, installers may leave a service loop (excess cable) in the ceiling or wall in anticipation of future needs. This is fine as long as it is considered part of the overall run. Note that tightly coiling this excess cable can lead to undesirable performance degradation due to additional Return Loss and Near End Crosstalk.

Length Troubleshooting Recommendations

The most common reasons for failing length on a test is that the NVP is set incorrectly.

If you are not careful and use the pre-set cable type it may not match the NVP of the cable under test. In this case, you can have an NVP difference of 10% or more, which translates directly into a length error. In the event the length is only slightly too long, check the NVP and cable type.

Assuming the NVP is correct, another cause of excess length is extra cabling looped in the ceiling or walls. Does the link in question meet the anticipated plan?

Sometimes, for example in the case of an airline hanger or warehouse, a remote station may be forced to be over 100 meters from the wiring closet.

If this has been planned for, and the intended application supports the excess length, then the link may fail structured wiring standards but still be approved for the application.

Some field testers allow customised auto-tests to be configured that permit variances from Standard TIA and ISO/CENELEC requirements. Such auto-tests are useful in that they verify the installation meets requirements, allow for planned variances, and still give the customer a "PASS" result.

DC Loop Resistance

DC Loop Resistance is the total resistance through two conductors looped at one end of the link. This is usually a function of the conductor diameter and varies only with distance.

This measurement is sometimes done to ensure there are no faulty connections, which can add significant resistance to the link.

Note that the wire map test automatically isolates breaks, but not high resistance connections.

DC resistance is often confused with impedance, a term describing the dynamic resistance to signal flow, usually at a specified frequency. Both are measured in ohms because they define different types of opposition to electrical current flow. DC resistance increases proportionately with the length of the cable tested while impedance remains "fairly" constant regardless of length.

From a signalling perspective, Attenuation (Insertion Loss) is now a more useful measurement, and DC resistance has become less important.

Results Interpretation: DC Loop Resistance

Variations in loop resistance between pairs can often be a quick indication of a cabling problem. In a shorted loop-back test environment, the expected value is simply twice the sum of the value expected for the given length. This is a simple test for any advanced field tester such as the Fluke DSP range, or the Microtest OMNIScanner.

DC Loop Resistance Troubleshooting Recommendations

In case of unexpected high DC resistance, compare the failed pair against other pairs in the cable. This will determine whether the issue is specific to the one failed pair or due to a problem affecting the entire cable. If a single pair is at fault, inspect termination points for a poorly made or oxidised connection.

If a more sophisticated measurement tool is available with a TDR or TDRLTM capability, use it to locate the distance to the fault.

If all four pairs have unexpected high DC resistance, check your assumptions.

- Did you allow for double the resistance to include the loop-back?

- Is the resistance assumption correct for the gauge of wire used?

- 5mm have a higher resistance value per meter than 5.5mm.

- Do you have an unusual patch cord in the link that could have high resistance?

- Look for anything unusual, especially if adjacent cables appear to be normal.

Propagation Delay

Propagation Delay is a measure of the time required for a signal to propagate from one end of the circuit to the other. Delay is measured in nanoseconds (Ns). Typical delay for Cat 6 UTP is a bit less than 5 Ns per meter (worst case allowed is 5.7 Ns/m).

Delay is the principle reason for a length limitation in LAN cabling. In many networking applications, such as those employing CSMA/CD and especially Gigabit Ethernet, there is a maximum delay that can be supported without losing control of communications.

Nominal Velocity of Propagation (NVP) on the other hand, is different. NVP refers to the inherent speed of signal travel relative to the speed of light in a vacuum (designated as a lower case c). NVP is expressed as a percentage of c, for example, 72%, or 0.72c. All structured wiring cables will have NVP values in the range of 0.6c to 0.9c.

Results Interpretation: Propagation Delay

Delay measurements are relatively straightforward. Most structured wiring standards expect a maximum horizontal delay of 570 Ns. If design specifications allow, higher delay can be acceptable.

Since each pair in the cable has its own unique twist ratio, the delay will vary in each pair. This variance (delay skew, discussed in the next section) should not exceed 50 Ns on any link segment up to 100 meters. Standards require that propagation delay for a cable be considered to be the propagation delay of the fastest pair, that is, the shortest propagation delay.

Propagation Delay Troubleshooting Recommendations

Excessive propagation delay can have only one cause: the cable is too long. If you fail propagation delay, check to ensure that the pass/fail criteria match the design specifications.

In many cases, a cable up to 25% too long (125m for Cat 5) will still support most LAN applications. However, the installation will fail most structured wiring standards, such as those published by CENELEC, ISO/IEC, and the TIA.

In some cases, if the customer insists on the location of the terminal equipment, and an excessive length cannot be avoided, you can verify other cable parameters. If they pass, you can provide information that indicates the cable meets frequency-dependent parameters but is non-compliant with overall standards due to excessive length. This provides professional results to the user while placing on them the responsibility for non-compliant cabling.

Propagation Delay Skew

Propagation Delay Skew (or simply Delay Skew) is the difference between the propagation delay on the fastest and slowest pairs in a UTP cable. Some cable construction employ different types of insulation materials on different pairs. This effect, in addition to unique twist ratios per pair, contributes to Delay Skew.

Delay Skew is important because several high speed networking technologies, notably Gigabit Ethernet uses all four pairs in the cable. If the delay on one or more pairs is significantly different from any other, then signals sent at the same time from one end of the cable may arrive at different times at the receiver. While receivers are designed to accommodate some slight variations in delay, a large Delay Skew will make it impossible to recombine the original signal.

Results Interpretation: Propagation Delay Skew

Well constructed and properly installed structured cabling should have skew less than 50 nanoseconds over a 100-meter link. Lower Delay Skew is better. Anything under 25 Nano sec is excellent. Delay Skew between 45 and 50 nanoseconds is marginally acceptable.

Propagation Delay Skew Troubleshooting Recommendations

If the Delay Skew is high, provided the intended application is a 2-pair application such as 10Base-T or token ring, the application should still perform. If one pair is much higher or lower in delay than the others, very high Delay Skew may result.

Examine the results for each pair; if one pair exhibits uncharacteristically high or low delay, re-examine the installation.

Attenuation /Insertion Loss

All electromagnetic signals lose strength as they propagate away from their source, and LAN signals over cabling are no exception. This loss of signal strength in the cable is Attenuation. The more Attenuation you have, the less signal is present at the receiver. Attenuation increases with both frequency and length.

Attenuation is measured in dB. Since it is a loss, it is usually expressed as a negative value. Thus, -10 dB is a weaker signal than -8 dB. Decibels are logarithmic, such that if any two signals are 6 dB different, one is twice the voltage of the other. Thus, a -10 dB signal has twice the voltage of a -16 dB signal, and four times as much as a -22 dB signal.

Results Interpretation: Attenuation or Insertion Loss

Attenuation is generally fairly linear with length and frequency. Unlike NEXT or Return Loss, Attenuation does not exhibit oscillatory behaviour (with the possible exception of high frequencies, where Insertion Loss Deviation may occur). The attenuation in a cable is largely dependent upon the diameter of conductor used in constructing the pairs. 0.5mm wires will have less Attenuation than the same length 0.4mm (thinner) conductors will. Also, stranded cabling will have 20-50% more attenuation than solid copper conductors which is especially important in the case of Patch cords that are manufactured using stranded conductors.

Attenuation Troubleshooting Recommendations

The most common reason for excess Attenuation is excessive Length. Therefore Attenuation troubleshooting often relates to Length troubleshooting.

Another possible reason for excessive Attenuation is poorly terminated connections. A poor connection can add significant Attenuation. A clue to this is to compare the Attenuation on all four pairs; if only one or two pairs have high Attenuation, this suggests an installation issue. If all pairs have high Attenuation, check for excess length.

Temperature also affects Attenuation in some cables. The dielectric materials, which form the conductor insulation and cable jacket, absorb some of the transmitted signal as it propagates along the wire. This is especially true of cables containing PVC. PVC material contains a chlorine atom that is electrically active and forms dipoles in the insulating materials. These dipoles oscillate in response to the electromagnetic fields surrounding the wires, and the more they vibrate, the more energy is lost from the signal. Temperature increases exacerbate the problem, because they make it easier for the dipoles to vibrate in the insulation. This results in increasing loss with temperature.

This is why standards bodies tend to specify Attenuation requirements adjusted for 20°C. Cables operating in temperature extremes can be subject to additional attenuation.

Insertion Loss Deviation

Impedance uniformity is an increasingly important parameter to understand, measure, and quantify for high-speed full duplex transmission systems. The most common way to specify cable roughness or impedance uniformity has been to measure Return Loss. Since Return Loss is a reflection measurement, the amount of impedance variation measured becomes restricted at high frequencies to the first few meters of cabling.

At the moment engineers and the Standards Organisations are looking at the degree of impedance uniformity over an entire 100 meter segment in such a way as the high frequency components or roughness are not masked or attenuated by distance.

One way to accomplish these objectives is to make a through measurement rather than a reflection measurement. When insertion loss is measured on links exhibiting structural impedance variations, a ripple occurs in the insertion loss results at high frequencies (typically above 75 MHz). This ripple increases in magnitude as a function of frequency and the amount of structure in the cable. Insertion loss deviation is a measure of the worst-case difference in magnitude between the expected insertion loss and the actual measured insertion loss. Insertion loss deviation is measured by first finding the insertion loss, and then computing the maximum amplitude across the specified frequency range between the insertion loss and the least squares curve that fits the insertion loss data.

The term "insertion loss" is used instead of attenuation because attenuation assumes matching impedance between the system under test and the test device. For insertion loss measurements the test device is set at 100 ohms and the system under test may have an input impedance between 85 and 115 ohms.

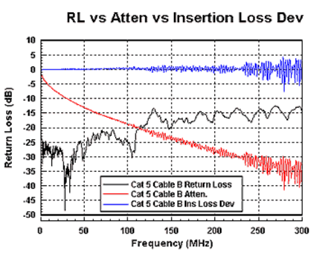
Experiments show that return loss is not necessarily correlated to insertion loss deviation.

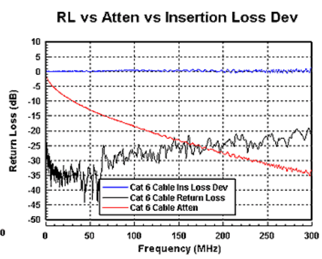
Results Interpretation: Insertion Loss Deviation

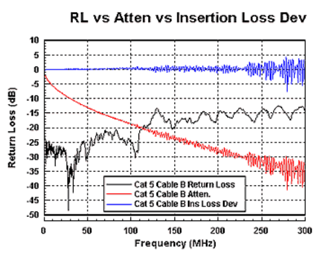
While insertion loss deviation is under study as a Cat 6 link tests, there are as yet no pass/fail limits set. All that can be said is the minimum possible insertion loss is desirable.

As an illustration of insertion loss deviation, two Cat 5e cables and one Cat 6 cable were tested with a network analyser. Attenuation and return loss were measured, then insertion loss deviation computed. All three results were plotted on the same graph to 300 MHz.

Cat 5e cable C shows a correspondence between an insertion loss minimum at 112 MHz and a return loss maxim. The worst-case insertion loss deviation on cable C was slightly less than 2 dB. The worst-case insertion loss deviation on cable B was much worse, at 8 dB, yet cable B showed better return loss performance. This suggests some structure effects are only evident at higher frequencies. Because return loss is a reflection measurement, much of these high frequency effects are not seen if they are more than a few meters from the measurement port (due to attenuation effects).







Power-sum NEXT

Power-sum NEXT (PSNEXT) is actually a calculation, not a measurement. PSNEXT is derived from an algebraic summation of the individual NEXT effects on each pair by the other three pairs. PSNEXT and ELFEXT are important measurements for qualifying cabling intended to support 4 pair transmission schemes such as Gigabit Ethernet. There are four PSNEXT results at each end of the link per link tested.

Results Interpretation: Power-sum NEXT

Since PSNEXT is a measure of difference in signal strength between disturbing pairs and a disturbed pair, a larger number (less crosstalk) is more desirable than a smaller number (more crosstalk). Because PSNEXT varies significantly with frequency, it is important to measure it across a range of frequencies, typically 1 - 100 MHz.

If you look at the PSNEXT on a 50-meter segment of twisted pair cabling it has a characteristic "roller coaster going uphill" shape. That is, it varies up and down significantly, while generally increasing in magnitude. This is because twisted pair coupling becomes less effective for higher frequencies.

Typically PSNEXT results are around 3 dB lower than the worst-case NEXT result at each end of the link.

Power-sum NEXT Troubleshooting Recommendations

Since PSNEXT is a calculation based on NEXT measurements, troubleshooting for PSNEXT failures reduces to troubleshooting for NEXT problems. Once you have isolated and repaired the NEXT problem, PSNEXT will automatically improve.

Attenuation to Crosstalk Ratio (ACR) is the difference between the NEXT and the attenuation for the pair in the link being tested. Due to the effects of attenuation, signals are at their weakest at the receiver end of the link. But this is also where NEXT is the strongest. Signals that survive attenuation must not get lost due to the effects of NEXT.

Using PSNEXT and attenuation, Power-sum ACR (PSACR) can also be calculated.

Power-sum Attenuation to Crosstalk Ratio (PSACR)

Power-sum Attenuation to Crosstalk Ratio (PSACR) is actually a calculation, not a measurement. PSACR is derived from an algebraic summation of the individual ACR effects. There are four PSACR results at each end of the link per link tested.

Results Interpretation: Power-sum Attenuation to Crosstalk Ratio (PSACR)

Since PSACR is a measure signal to noise ratio, a larger number (more signal and less noise) is more desirable than a smaller number (more noise and less signal). Typically PSACR results are around 3 dB lower than the worst-case ACR result at each end of the link.

Power-sum Attenuation to Crosstalk Ratio (PSACR) Troubleshooting Recommendations

Since PSACR is a calculation based on ACR measurements, troubleshooting for PSACR failures reduces to troubleshooting for ACR problems. As mentioned earlier, troubleshooting for ACR reduces in turn to troubleshooting NEXT and attenuation. Once you have isolated and repaired the ACR problem, PSACR will automatically improve.

Far End Crosstalk (FEXT)

Far End Crosstalk is similar to NEXT, except that the signal is sent from the local end and Crosstalk is measured at the far end.

Because of Attenuation, signals that induce FEXT can be much weaker, especially for longer cable lengths. This effect means that for a given quality of cabling, more FEXT will be seen on a short link than a long link.

For reason, FEXT results are not meaningful without an indication of the corresponding Attenuation on the link. Thus, FEXT is measured but rarely reported. FEXT results are used to derive Equal Level Far End Crosstalk (ELFEXT).

Equal Level Far End Crosstalk (ELFEXT)

Equal Level Far End Crosstalk (ELFEXT) is a calculated result, rather than a measurement. It is derived by subtracting the Attenuation of the disturbing pair from the FEXT this pair induces in an adjacent pair. This normalises the results for length. Consider the FEXT and attenuation measured on two links constructed of the same materials with the same workmanship, but different lengths.

Another way to understand ELFEXT is to think of far-end ACR, which amounts to the same thing.

Results Interpretation: Equal Level Far End Crosstalk (ELFEXT)

Compare the results of measurements made from both ends of the link to the appropriate CENELEC/ISO or TIA limits. There are 12 ELFEXT measurements made from each end, for a total of 24. This is because the Attenuation can vary slightly depending upon which pair is energised. So as an example, the field tester will energise pair 1 and listen on pair 2 at the far end, then energise pair 2 and listen on pair 1 at the far end.

ELFEXT that is too high is indicative of either excessive attenuation, higher than expected FEXT, or both.

Equal Level Far End Crosstalk (ELFEXT) Troubleshooting Recommendations

The same factors that contribute to NEXT problems contribute to FEXT problems. So troubleshooting for ELFEXT reduces to troubleshooting for NEXT and attenuation problems, just as you would for ACR problems.

Power-sum Equal Level Crosstalk (PSELFEXT)

Power-sum ELFEXT (PSEFLEXT) is actually a calculation, not a measurement. PSELFEXT is derived from an algebraic summation of the individual ELFEXT effects on each pair by the other three pairs.

There are four PSELFEXT results for each end. PSELFEXT has the dubious distinction of being the longest acronym in the LAN cabling technology field.

Results Interpretation: Power-sum Equal Level Crosstalk (PSELFEXT)

Typically PSELFEXT results are around 3 dB lower than the worst-case ELFEXT result at each end of the link.

Coupling Attenuation

There are some concerns about the amount of possible electromagnetic radiation emitted from active cabling, notably in Europe. One proposed method for measuring this phenomenon is via coupling attenuation. Coupling attenuation is the relationship between the transmitted power through the conductors and the maximum radiated peak power, conducted and generated by common mode currents. It is measured by energising a pair and measuring the signal coupled into an attached absorbing clamp.

Results Interpretation: Coupling Attenuation

There are presently no standards for coupling attenuation, and it is restricted to laboratory measurements. This is because it is very difficult to isolate a single cable in a typical field environment from all surrounding EMC influences. Values of coupling attenuation depend on frequency, balance, screen material, and whether there is a single or double screen. Tests have shown that the values differ between 25-50 dB for UTP cable, 50-75 dB for an FTP cable, and 75-95 dB for a SSTP cable.

Alien Crosstalk

When cables are adjacent to each other, emissions from one cable can affect pairs in other cables. This effect is called Alien Crosstalk. It is a possible concern for UTP cables that are closely bundled together for a distance of more than 15 meters.

Alien crosstalk, unlike NEXT, is an unpredictable, un-cancellable noise source. Measurement of alien crosstalk is difficult because it requires synchronising two sets of test instruments, and it is a lab measurement only. There are no pass/fail limits proposed or set.

Fibre Optics Cable Testing

Fibre is now beginning to appear in traditional 'Twisted-pair territory'. There have been continual improvements in optical fibre performance, fibre cable designs, connectivity technology, and test equipment. Not only are these fibre products more craft friendly than ever, they are also less expensive. New advancements in transceiver products will make fibre even more attractive in the LAN environment.

Fibre optic cable comes in two basic types: multimode or single mode. Multimode fibre has a relatively large core diameter, typically 50µm or 62.5µm (microns). Light from LED sources can be efficiently coupled into multimode fibre. Multimode fibre is most often used in LED-based LAN systems. Single-mode fibre has a very small core diameter (8 -10µm). Single-mode fibre propagates only one optical mode, significantly increasing bandwidth. Single-mode fibre is primarily used in laser-based long haul and interoffice applications. Single-mode fibre is beginning to be used in LAN as backbone cabling and to "future proof" networks.

How is fibre tested?

Historically, the quality of fibre cable was so good and bandwidth more than adequate that some network designers specified that only a simple continuity check was required for fibre cable certification. Today's higher speed networks demand more from the fibre and are making this simple approach obsolete. Industry standards bodies including the TIA/EIA, IEEE, ISO and ANSI have published standards that define maximum supportable distance and maximum channel attenuation for LAN. See Fibre Standards for pass/fail limits by application.

Therefore when installing cable to support a standardised network application (i.e. Ethernet, FDDI, and ATM), it is appropriate to test cable and compare the results to the appropriate standard. In practice, network designers and architects are frequently unaware of the standards or chose to use their own user-defined pass/fail criteria. This can result in a cabling plant that is either not tested as thoroughly as necessary, jeopardising network performance, or tested too severely which can needlessly add to the cost and time of the cable installation and testing.

What is really required?

ACCL comply with the appropriate fibre application standard, all of which require direct attenuation measurement. These standards have been painstakingly developed and approved by a large group of leading companies in the industry. You can be confident of acceptable network performance when you certify that the cabling plant meets the requirements of the standard. If you are installing cable and the transmission standard is unknown or is a new transmission protocol for which a standard has not yet been published, it is recommended that you follow the guidelines as set forth by the networking equipment manufacturer or a general building standard. That means TIA/EIA-568-A in North America or ISO/IEC 11801 in Europe. Other regional and country-specific standards exist.

There are a variety of tools available for testing fibre cable. Which tool(s) to use will depend upon the type of job to be performed, how frequently you test fibre networks, and your test equipment budget?

Optical Fibre tools for the field include:

1. Simple white light sources for fibre identification and continuity checks
2. Laser-based visual fault locators to detect fibre breaks
3. Optical loss test kits and sets to measure loss
4. Certification tools to measure loss/length and compliance to standards
5. Optical time domain Reflectometer (OTDR) for diagnostics and measuring distance to optical events.

Fibre and Copper Measurement Compared

It is interesting to contrast measurements necessary to qualify a fibre optic cable installation with those of a copper cable installation.

To certify a copper installation it is important to consider wire-map, length, attenuation, NEXT and PSNEXT at both ends, ACR at both ends, ELFEXT at both ends, return loss at both ends, delay, and delay skew. In contrast, to certify a fibre installation only attenuation, at one or two wavelengths, is usually measured. Length may also be measured or physically recorded.

Test Methodology

Fibre cable can be tested one fibre at a time using the end-to-end technique. This methodology uses an optical source and power meter for direct measurement of attenuation. The fibres are tested, results recorded and later compared to an industry or user-defined standard to evaluate the success of the installation. For those who test fibre frequently, new fibre test technology is available for quicker, more productive network testing and certification. With tools such as the Microtest's CertiFibre and OMNIFibre, multiple measurements can be made over a Rx/Tx fibre pair with the push of one button and the pass/fail status of the fibre is instantly displayed.

Optical Time Domain Reflectometers (OTDR's) are used for troubleshooting fibre optic cabling. An OTDR can measure optical length and display the distance to an optical event (fibre break, end of fibre, fibre splice or connector). OTDR are not suitable for making end-to-end power loss measurements.

ACCL expects the use of LAN fibre networks to become more commonplace as technology and costs improve. Fibre standards do exist and networks should be tested to the appropriate application standard (Ethernet, FDDI, and ATM) when possible. If unknown, a general commercial building standard such as TIA-568A or ISO 11801 should be followed. Network designers and equipment vendors may have proprietary standards that must be followed. A range of test tools is available to ensure that you can accurately and reliably test fibre networks.

EN/ISO Permanent Link

The permanent link has been defined in TIA 568 B, EN 50173 and ISO 11801, and includes:

1. All the permanently installed horizontal cable

2. The mated connection at the wiring closet end of the link

3. The telecommunications outlet at the far end of the link

4. An optional consolidation point (used for example in the case of modular furniture).

The permanent link is used to verify the performance of permanently installed cabling. It differs from the basic link in that it does not include the field tester cord. Of the course, the field tester cord is necessary, but this link definition requires the field tester to somehow compensate for all the characteristics of the cord so that as much as possible the test cord is invisible to the measurement. This is very difficult to do, and to be done properly requires very sophisticated electronics and software in the field tester. The permanent link definition does include the mated plug at the end of the field tester cord, but not the cord itself.

TIA/EN/ISO Channel

The channel, as described in TIA 568A, EN 50173 and ISO 11801 includes:

1. Up to 90 meters of horizontal cable, a work area equipment cord, an optional transition point,
2. 2 cross-connections in the telecommunications closet,
3. A patch jumper between these two connections,
4. And a telecommunications closet equipment cord.

In simple terms, the channel includes everything necessary to get data from a PC in an office to a hub in wiring closet.

The channel does not include the mated connection at the hub or PC. This means the plug at the end of the user's patch cord at both ends of the link is considered part of the data terminating equipment (DTE) and not part of the link.

The reason for this is connectors must be considered as mated pairs of plugs and jacks, and since the jack is fixed in the DTE it was decided that connection would be part of the DTE.

In practice, the channel is rarely used in link certification, because user patch cords are almost never available when the permanent cabling is installed.

Structured Cabling Standards

ACCL as a matter of good working practices adheres to all of the relevant European and international Standards for the specification and installation of structured cabling systems. The following list identifies the main Standards that ACCL follow:

ISO 11801
Information technology – Generic-cabling for customer premises.

BS EN 50173
Information technology – Generic-cabling systems: General requirements and office areas.

BS EN 50174 Part 1
Information technology – Cabling installation: Specification and quality assurance.

BS EN 50174 Part II

Information technology – Cabling installation: Installation planning and practices inside buildings.

BS EN 50174 Part III

Information technology – Cabling installation – Installation planning and practices outside buildings.

BS EN 50310
The Standard that governs the application of equipotential bonding and earthing in buildings with information technology equipment.

BS EN 50346
Information technology – Cabling installation: Testing of installed cabling.

BS 6701
Installation Standard for apparatus intended for connection to certain telecommunication systems.

For further information of the positive impact of these Standards on the design, installation and commissioning of a structured cabling network infrastructure please your representative at ACCL for further assistance. This Procedure Guide will however as a matter of course refer to specific Standards as and when required.

Method & Standards of Works

The work methodology employed by ACCL complies with the strictest controls of regulation that are put into place by the Health & Safety Executive and also those imposed by the structured cabling industry.

Health & Safety Obligations

The Health & Safety at Work Act (1974) is law and any infringement may result in legal action carried out by the Health & Safety Executive (HSE).

ACCL is required by the HSE to provide all employees the following:

1. Safe place of work.
2. Safe working practices.
3. Safe equipment e.g. tools etc.
4. Personal protective equipment to be supplied free of charge (where necessary).
5. Safe accesses to and from (egress) your place of work.
6. Risk assessments.
7. An emergency procedure, to include the evacuation from gas & fire exposure and what to do if asbestos is found on site etc.
8. General safety policy.

ACCL further requires all employees:

1. To take care and not to injure yourself and others.
2. Not to misuse or break any equipment, tools and health & safety equipment etc.
3. Co-operate with your employer with regards to health & safety.
4. To refrain from using any piece of equipment that you are not trained to use correctly and safely.

Risk Assessment

ACCL is committed to the Health & Safety at Work Act (1974) and ensures that a risk assessment is fully completed prior to the commencement of any work to protect the employees of the client and ACCL from accidents, which could be hazardous to health and perhaps even fatal.

Virtually every job role within any company must be assessed for the protection of its' staff based on the possibility of risks. The first stage of the process is to ascertain what, if any potential hazards would that worker be exposed to while performing a specific task and what potential risks will remain after the assessment.

The actual risk assessment in its initial phase must be concerned with the following basic questions in mind:

1. What activity or work processes may cause any potential risk?
2. How people would or are directly involved with this potential risk?
3. What potential risk may still remain following the risk assessment?

The Management of Health & Safety at Work Regulations (1999) state that 'Risk reflects the likelihood that harm will occur and it's severity'. The following table will help as a strong guide to designing and making risk assessments. Once the information has been gathered, multiply the severity rating against the likelihood rating (severity X likelihood).

Severity (injury)	Assessment Criteria	Rating Value
Trivial	Injuries that can be treated by a qualified first aider.	**1**
Slight	Injuries that require visit to a hospital for treatment	**2**
Serious	Injuries that require immediate/urgent hospital treatment	**3**
Major	Major trauma or death	**4**

Likelihood (injury)	Assessment Criteria	Rating Value
Very unlikely	Zero probability	**1**
Unlikely	Conceivable probability	**2**
Likely	Probable	**3**
Very likely	High probability	**4**

Once the total risk rating has been decided upon, the control measures can be addressed.

Risk Rating	Required Control Measures
1 or 2	Current control measures are adequate
3 or 4	The control measures need to be reviewed and additional measures/actions may need to be taken
6 or 8	Urgent control measures/actions to be taken to reduce any potential risk of possible injury.
9 or more	Stop the activity immediately. Control measures/actions need to be put into place before restarting the activity.

The information gathered from the table above will only produce effective results provided you clearly understand the thought processes on how to reduce possible risk; the following list will aid you in this task.

1. ACCL will wherever possible eliminate the risk altogether, by changing the current working practices by using safer material or equipment?

2. Prevent access or contact with the hazard, i.e. by use of guarding or containment.
3. What personal protective equipment is available to help assist in the activity? Will improved extraction or safety equipment reduce the risk or hazard?
4. ACCL will reduce the amount of personnel who will be at risk during this activity by simply changing current working practice or restricting the time exposed?

ACCL firmly believe that if they were to just increase the amount of PPE equipment to get around a hazard, they would have misunderstood the whole point behind risk assessments.

ACCL as a company firmly supports the ideology that PPE must only be used as a last resort.

Risk assessments do not only concern those members of staff within a company, but also include all visitors to company's premises as well. ACCL will request that a permit to work procedure is agreed and signed prior to the commencement of any work.

Confined Spaces

When routing cables or planning the installation of equipment care must be taken to select a safe route for both the installation staff and cables to reside in.

The structured cabling 'Standards' often, as one should expect, refer and make suggestion for the protection of the cable, but they also make strong recommendations for the protection of the installation team as well e.g. when the cables will run through a confined space.

Confined spaces fall under the control of the Confined Spaces Regulations 1997, and it is amazing that so many us will either knowingly or perhaps unwittingly enter a confined space on a regular basis. Confined spaces are those areas, which by their nature are enclosed and therefore regarded as confined.

Examples of confined spaces include:

1. Chambers
2. Pits
3. Trenches
4. Enclosed building risers
5. Pipes
6. Sewers

The Confined Spaces Regulations set out guidelines of why we must be concerned about the environment in which we are about to enter, and these guidelines can be described as three separate environments such as:

Environments where workers may become unconscious or have a fatal incident due to either:

a) A rise in temperature that will greatly affect the workers body temperature.
b) A build up of gases or vapours.
c) A lack of oxygen leading to asphyxiation.

Environments where workers may become unconscious or have a fatal incident due to either:

a) Drowning due to becoming trapped in water.
b) Asphyxiation from becoming trapped where fine powders are located/stored.

Fine powders include materials such as flour, sugar and even custard powder are to be considered as hazardous in a confined area and will be referred to as 'free flowing solids'.

1. Environments where workers may become unconscious or have a fatal incident due to either:

a) Working in an environment where explosive gases or highly flammable materials are stored/located.

The possible list of hazards when working in a confined space is enormous, but we must all think before we act when confronted with a confined space as to these possible hazards. The hazards may be:

1. Physical damage
2. Infection & disease
3. Flooding
4. Entrapment
5. Heat
6. Explosions
7. Fire

Overhead work

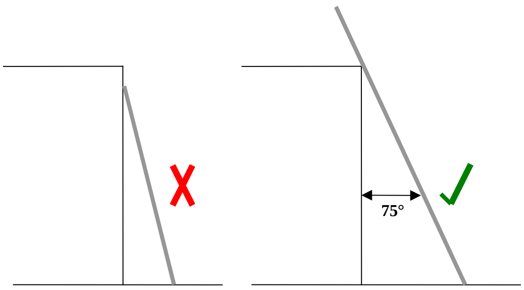
Overhead work includes all working practices that require you to work above ground level, either on platforms or ladders. It is of paramount importance to health & safety that this work only commences once you are sure that no one will be able to walk through or underneath the working area. The area must be secure with visible barriers and with personnel guarding the area to prevent any person entering the area while work is being carried out. Always check for overhead hazards i.e. electricity cables before commencing work.

Ladders

Ladders (including stepladders) pose one of the biggest accidental risk opportunities. ACCL request that all ladders must be checked prior to use to ensure that they are safe to use and fit for purpose and requires the following items to be adhered too.

1. Inspect the ladder to ensure that is are damage free prior to use.
2. That the step rungs themselves are well fixed into the sub-frame of the ladder.
3. That all rivets and welds are clean and strong.
4. That all position-locking levers work correctly and that they fully secure the ladder into a locked position.
5. Wooden ladders must not be painted as this may hide any defects in a ladder.

6. Wooden ladders must not be varnished, as they cause the ladder to become conductive.
7. Aluminium ladders fitted with rubber feet need to be inspected to ensure that the feet are not damaged through wear, thereby causing a possible route to earth and allowing a conductive path.
8. Do not place a ladder in the vicinity of a door unless the door is locked shut or secured open with a guard.
9. Damaged ladders need to be labelled with a 'DO NOT USE' sign or card and must be either repaired fully or preferably destroyed.



The position of a ladder must be safe to ensure the safety of the person intending to use the equipment. The following diagram depicts two possible options, with only one demonstrating a safe working practice.

The angle of the ladder should extend out from the base of the wall by an angle of 75° and should extend beyond the height of the climb by at least four rungs.

The purpose of a ladder is for gaining access to or from an environment, they are not designed for working from. The ladder must also be secured or anchored at the top.

When requested to work at height, the requirement is to use a scaffold tower with foot and guardrails (when over 2 metres) to prevent the workers and tools or equipment following out of the tower to the ground below.

Workers within the tower will also be required to wear safety harnesses.

If the tower is moveable the wheels must have the brakes applied prior to use and the tower must not be manoeuvred from one location to another while workers are still located on the tower.

When working at heights always ensure that adequate barriers are positioned around to prevent people entering the working area.

Roof Tops

ACCL ensures that its employees never climb or walk on a roof without adequate protection and harness protection and only after ensuring that the roof is safe enough to climb on. Some roofs may be covered with corrugated coverings and may require crawl boards. ACCL believes it is essential that a thorough risk assessment is completed and safety procedures are in place before working directly on roofs.

Under-floor/ground working

Installing data communications cable underground or through a floor will require the lifting of manholes, suspended floor tiles and or wooden floors to facilitate a working area large enough for the installer to fit into safely with ease of evacuation or fear of becoming trapped to install data cabling. It is essential that care and thought be considered to whether the installer will be entering a confined space and the necessary controls that need to be in place.

Prior to entering a manhole check for gas or foul air and with a gas tester and follow the guidelines of the Confined Spaces Regulation. Manholes must be surrounded by a barrier at all times while open and be also supported by a physical guard.

It is required that both the person contained within the confined space and the observer have completed some successful training in working in confined spaces and can deal effectively with any emergency should it arise. Manhole covers must always be replaced once the work has been completed.

When working in a floor area, suitable barriers must be erected to prevent any person entering the area. Once all the work has been completed the floor tiles or floor traps must be securely placed back into their final position.

General Housekeeping

Safety

The law requires that all personnel that are either visiting or working on a site have some form of site health & safety awareness training prior to being allowed on site that they are fully made aware of any hazardous environments. This training should cover some of the following items:

1. The client or customers own specific health & safety requirements.
2. Emergency evacuation procedures.
3. Known chemical hazards, including asbestos, gases and other materials.
4. The location and how to contact qualified first aiders in case of an emergency.

Chemical Safety

Installation technicians who are involved with the installation of fibre optics may require specific chemicals such as Isopropyl alcohol for the cleaning and preparation of fibre ends and often some type of adhesive materials for connectorisation.

Chemicals and the like must be stored in lockable cupboards suitable for the purpose or similar (in accordance with CoSHH regulations) while not is use. It is entirely feasible that some personnel could an allergic reaction to some of the stored chemicals. Material Safety Data Sheets for each specific product must be stored and readily accessible if an allergic reaction takes place so that hospital staff and administer the correct medical procedures.

Always read the material safety data sheets (MSDS) before using any chemical or hazardous substance.

Installation Safety

Site tidiness is key for all installation technicians and other contractors. Tools, cables and equipment must also be kept clear of any emergency evacuation routes and placed in an area where they will not cause injury or impede a safe walkway for others.

PPE is required on all working sites and includes safety hard hats (not bump hats), safety shoes, goggles, protective clothing and gloves.

Once the working day has been completed it is expected that:

1. All raised floorboards, covers, etc. are replaced.
2. That all tools are either locked into a secure tool trunk or removed from site, so as to prevent the equipment being stolen and or other contractors using your equipment, some of which they may not be trained on how to use safely.
3. Copper and fibre optic cable is placed together safely and in a location where it itself is free of being damaged accidentally by other contractors.

4. That scaffolding towers are locked and made secure that they cannot be moved or used by any other personnel.
5. Ladders must be made secure and locked to prevent being stolen or used by other personnel. However, if the ladder is to remain tied into its present location a scaffold board should be locked into place over the rungs to prevent any person climbing.
6. Barriers and warning lights fitted as and where required.
7. That all waste is disposed of correctly and in accordance with the client's instructions. Remember that waste and rubbish run the risk of being fuel for accidental fires.

Electrical Safety

Within the EU, only 110v tools are permitted for use on site when a direct power source is required. The transformer must be clearly visible and are yellow in colour. The power leads to and from the transformer must not be damaged with any scoring or abrasions and checked for electrical safety prior to use.

Before drilling into any surface it is imperative that consideration be given to any other services that may or may not be located behind. The wall surface should be checked for hidden electrical, water & gas supplies prior to drilling.

Sign Safety

Safety signs exist in all business environments to warn you of any potential hazards. There are four main types of signage that we all need to be aware of:

Yellow/Orange signage is used when a warning is required to make us all aware when there is a potential hazard.

Blue signage is used when there is a mandatory requirement that must be followed e.g. if the sign states that masks must be worn – Then they must.

Green signs are used to show a safe condition. The signage shown here is used for evacuation escape routes.

Red circles with a line running through depict prohibited actions.

Fire Extinguishers

There are four types of fire extinguishers available for use in the case of fire, although special mention must be that you should only attempt to tackle a fire yourself if it safe to do so and always sound the evacuation alarm.

The four types of fire extinguisher include:

1. Water: Class A fire.
2. Foam: Class B fire.
3. Dry Powder: All classes of fire.
4. CO^2: Classes B, C & electrical.

You will note from the above list that each type of fire has a class associated with, this means that only particular types of fire extinguisher equipment can only be used on certain types of fires, as detailed in the following list.

1. Class A fires include carbon based materials such as paper & wood etc.
2. Class B fires includes liquids such as petrol fires.
3. Class C fires include gases such as propane.
4. Class D fires include metals such as magnesium and aluminium.

In the case of electrical fires you should only use a CO^2 extinguisher and ensure that the electrical supply has been turned off.

It is interesting to note that fifty percent of all fires are started due to arson and twenty percent are caused by electrical installations.

Under European regulations all fire extinguisher shall be red in colour but clearly marked by the following colour coding to identify the several types of extinguisher:

1. Red: Water
2. Cream: Foam
3. Blue: Powder
4. Black: CO^2

Halon Systems

Halon systems are easily identifiable by Green markings, but all halon systems must be removed from use by the end of 2003. Halon works by removing oxygen from the fire, the question to understand the reason why halon is being withdrawn is, would you like to use an extinguisher in a confined area that removes oxygen therefore your own air supply.

Data cabling or equipment must never be installed in a location that can or cause any access or hindrance to a fire hose or fire extinguisher.

Asbestos

Asbestos within a work environment falls under the Control of Asbestos at Work Regulations 2002.

Asbestos exists in many buildings and was used since the Second World War but extensively during the years between 1950 and 1970. There are three types of asbestos:

1. Blue Asbestos (crocidolite).
2. Brown Asbestos (amosite).
3. White Asbestos (chrysotile).

Blue and Brown asbestos are more dangerous than White asbestos, but they are all extremely hazardous however it is impossible to identify asbestos by colour alone and laboratory testing is required to identify a particular type of fibre.

Asbestos fibres enter the body via the air as fibres through the mouth and nose. The body generally rejects large fibres but small fibres can be passed through to the lungs and become trapped. It is these small fibres in the lungs that lead to disease and death. There is currently no cure for asbestos related diseases.

Asbestos related deaths in the UK alone exceed 2000 per year, but this number will reduce as more legislation is passed and working procedures take the hazard of working with asbestos into account.

Asbestos has since both governmental and voluntary bans over last few years as the following time line demonstrates.

1970	1985	1985
Blue asbestos stopped being used.	Sprayed asbestos coatings banned.	Installation of asbestos board stops.
1999	**1992**	**1988**
Importation & supply of asbestos banned, with the exception of a few specialised applications.	Asbestos decorative plaster banned.	The use of asbestos paints/varnishes stops.

Asbestos is utilised within buildings in so many products it is necessary to detail the uses to make you better aware and prepared to protect yourself from Asbestos.

The most likely products or areas where asbestos can be found are:

1. Some ceiling tiles.
2. Fire breaks in ceiling/plenum rated areas usually in a sprayed format or in loose packing (fire stopping devices).
3. Thermoplastic or vinyl tiles.

4. Asbestos cement products, such as corrugated roofing sheets, guttering and pipes etc.
5. Some in electrical equipment insulation.

Employers are required to prevent employees against asbestos exposure, or if not possible to reduce the exposure to the lowest possible level.

1. Employers must find out if asbestos is on the premises and what condition it is in.
2. They must suspect all material as being asbestos until proved otherwise.
3. Provide information on the type of asbestos, condition and location of asbestos to anyone who is likely to work in that area or disturb it.

The HSE recommends that only a licensed asbestos contractor should work for long periods where asbestos can be found.

Data and telecommunication installation engineers may easily come in contact with asbestos and the Health & Safety Executive make the following suggestions.

ACCL ensures that if any employee who in contact with asbestos that:

1. Keep everyone out of the work area that does not need to be there.
2. Take care not to create dust.
3. Keep the material wet, whenever possible (to reduce asbestos dust spreading).
4. Wear a suitable respirator and protective clothing.
5. Clean any dust up with a vacuum cleaner, which complies with BS 5415 (Type ‘H’).

ACCL further ensures that employees will not:

1. Break up large pieces of asbestos.
2. Use high-speed power tools – as these create high levels of dust.
3. Expose other workers who are not protected.
4. Take protective clothing home to wash.

If any ACCL employee suspects at any time that they are working near asbestos, that they stop work immediately and that of others around them as they may be at risk and notify the site manager or similar. ACCL will not start works again until they are satisfied that it is safe to do so.

Asbestos Further: Suggested Reading:

Introduction to Asbestos Essentials: HSE Books ISBN 0-7176-1901-X
Managing Asbestos in Premises: HSE Books ISBN 0-7176-2381-5

Basic Data & Telecommunications Terminology

10Base2
The IEEE/ISO 8802-3 (IEEE 802.3) standard for thin Ethernet coax network – 10 Mbps transmission, baseband signalling, 185m per coax segment. Also known as Thinnet or Cheapernet.

10Base5
The IEEE/ISO 8802-3 (IEEE 802.3) standard for Ethernet backbone (trunk) cable networks – 10Mbps per second, baseband signalling, 500m per coax segment. Also known as Thicknet.

10BaseFL, FB, FP
The IEEE/ISO 8802-3 (IEEE 802.3) standard for optical fibre Ethernet networks connections for inter-repeater links, synchronous links and passive links – 10 Mbps transmission.

10BaseT
The IEEE/ISO 8802-3 (IEEE 802.3) standard for UTP Ethernet networks – 10 Mbps transmission, baseband twisted pair cable. Maximum allowable cable length 100m (channel).

100BaseFX
The IEEE/ISO 8802-3 (IEEE 802.3) standard for optical fibre Ethernet network connections – 100 Mbps transmission.

100BaseSX
The IEEE/ISO 8802-3 (IEEE 802.3) 'Standard' for optical fibre Ethernet network connections over multimode optical fibre using short wavelengths (850nm) – 100 Mbps transmission.

100BaseT
The IEEE/ISO 8802-3 (IEEE 802.3) standard for Ethernet network connections over Category 5 and above unshielded/screened twisted pair cable utilising only two cable pairs.

100BaseT4
The IEEE/ISO 8802-3 (IEEE 802.3) ‘Standard’ for Ethernet network connections over Category 3 and above unshielded/screened twisted pair cable utilising all four cable pairs – 100 Mbps transmission.

100VG-AnyLAN
The IEEE 802.12 standard for token ring, arbitrated network connections – 100 Mbps transmission. Media type may be UTP or optical fibre.

1000BaseELX/ZX
Proposed standards for optical fibre Ethernet network connections over Singlemode optical fibre using wavelengths (1300 & 1550nm) – 1000 Mbps transmission.

1000BaseLX
The IEEE/ISO 8802-3 (IEEE802.3) standard for optical fibre Ethernet connections over single & multimode optical fibre using long wavelengths (1300 & 1550nm) – 1000 Mbps transmission.

1000BaseSLX0
A proposed standard for optical fibre Ethernet network connection over single mode optical fibre using long wavelengths (1550nm) – 1000 Mbps transmission.

1000BaseSX
The IEEE/ISO 8802-3 (IEEE 802.3) 'Standard' for optical fibre Ethernet network connections over multimode optical fibre using short wavelengths (850nm) – 1000 Mbps transmission.

1000BaseT
The IEEE/ISO 8802-3 (IEEE 802.3) standard for Ethernet network connections over Category 5e and above unshielded/screened twisted pair cable utilising bi-directional transmission on four pairs – 1000 Mbps transmission.

1000BaseTX
The proposed standard for Ethernet network connections over Category 6 and above unshielded/screened twisted pair utilising bi-directional transmission on four pairs, two transmit and two receive – 1000 Mbps transmission.

ACR
Attenuation –Crosstalk ratio. The value of attenuation, less the crosstalk value, both expressed in dB, at a particular frequency. A quality factor for cabling that expresses the relation of two important measured values.

ADSL
See Asymmetric Digital Subscriber Line.

Adapter, Optical Fibre
A passive coupling device that connects two male optical fibre connectors, aligning the light path.

Analogue Signal
An electrical signal that varies continuously, without discrete steps as with a digital signal.

ANSI
American National Standards Institute.

Approved Ground
A building ground and or bonded earth connections that meet Health & Safety requirements and latest edition (16th) of Electrical Standards.

Asymmetric Digital Subscriber Line
ADSL. A high-speed, digital telecommunications technology offering fast downloads capabilities of 6Mbps, but much slower uploading speeds of 65Kbps.

ATM
Asynchronous Transfer Mode. A transport protocol based on fast switching of 53 byte cells. With its high-speed operation, fast switching, and guaranteed delay times, ATM can transmit voice, data, and video efficiently along the same transmission path.

Attenuation
The decrease in magnitude of a signal as it travels through any transmitting medium, such as copper cable or optical fibre. Attenuation is measured as a ratio or as a logarithm or a ratio (dB). Optical fibre attenuation is measured in dB/Km.

Audio Frequency
The range of frequencies within the range of human hearing. This range is generally as 20 to 20 000Hz, although few of us can detect sounds below 30Hz or above 16Hz.

Average Power
The average level of power in a signal that varies with time.

AWG
American Wide Gauge. An American wire diameter specification. The smaller the AWG number the larger the wire diameter.

Backbone Cable
Cable that connects distribution units in a single building or a group of buildings.

Back-scattering
An optical fibre term that refers to the scattering of light, in the opposite direction from which it was originally travelling.

Balun
A transforming device that matches an un-balanced circuit to a balanced circuit. An impedance matching device.

Bandwidth
The range of frequencies required for proper transmission of a signal, expressed as a difference in hertz (Hz). A continuous range from zero is said to be a baseband signal, while a range, which starts substantially above zero, is said to be broadband (or narrowband in the case of RF signals).

Baseband
Audio and video signals sent over coaxial cable, typically used in CATV.

Basic Link
The portion of a structured wiring cable connection between the cable termination at the horizontal cross-connect and the work area outlet connector. The length of a basic link is 90m. Note that the basic link now been replaced with the Permanent Link.

Baud
The number of digital data signal-level transitions per second. For some common coding schemes, this would equate to bits per second, but this is not true for more complex coding schemes.

Bel
A unit that represents the logarithm of the ratio of two power levels. See dB.

Bend Loss
Increased attenuation in an optical fibre caused by an excessively small bend radius. Bend loss may be temporary or permanent if the micro-fractures caused by the bend attenuate the light signal through the affected area.

Bend Radius
The radius of curvature of a bend in a cable. Cables may have transmission performance degradation from a bend radius that is below a certain amount.

BER
Bit Error Rate. The fraction or number of bits of digital data not transmitted or received fully.

Binder
A tape of thread used for holding groups of pairs together within a cable. Multi-pair cables often bind in pair’s in-groups of 25 and 100 pairs.

Bit
One binary digit. A bit may assume a binary value of 0 or 1.

BNC
A coaxial cable connector that uses a ‘bayonet’ style turn-and-lock mechanical mating method.

Bonding
The method used to produce good electrical contact between metallic parts. In the wiring context, bonding describes electrical connection of grounding bars and straps within a building to the central approved ground.

Bridge
A network hardware device that connects LAN segments together.

Broadband
A very high-speed data transmission system, capable of supporting large transfers of media such as sounds, video, and other data.

Butt Set
A telephone-testing device resembling an oversized handset that is used for temporary connection and operation of a telephone line.

Byte
Commonly believed to be a group of 8 bits, although in fact a byte may be as much as 10 bits although only 8 will be used for data.

CATV
An acronym for cable television. The term was derived from Community Antenna Television.

Cell
A fixed-length data packet transmitted in certain digital systems such as ATM.

Central Office
An American telecommunications phrase that refers to either a telephone company facility for switching signals among local telephonic circuits or another used as another term for a PABX, although generally a large voice switch that is able to handle in excess of 1000 users.

Channel
The entire structured cabling wiring connection between equipment in the telecommunications room to the work area equipment, including all users cords, patch cords and jumper wires. Total length is referred to as 90m (permanent link) + 10m (patch cords etc).

Characteristic Impedance
A value of impedance (resistance and reactance) of a transmission line measured over a frequency range that would exist if the line were infinite in length. A transmission line of finite length will have perfect power transmission, allowing for absorptive transmission losses, if driven and terminated by exact conjugates matching load impedance. An exact match will cause reflections that increase transmission loss.

Coaxial Cable
A type of cable consisting of a conductor contained inside a tubular conducting shield, separated by a dielectric material and covered with an insulating jacket. The shield may be foil, wire, braid, or solid metal, and is typically at ground potential.

Compression
Reducing the number of bits required too encode a digital signal. This is generally achieved by eliminating long strings of identical bits or bits that do not change in format.

Consolidation Point
A location between a telecommunications room and user work areas at which multiple station cables are brought together for cross-connection or interconnection and consolidation. Typically used in modular offices as a permanent point of termination between the telecommunications room and the movable office modules.

Core
The light transmitting central portion of an optical fibre. The core is surrounded with a cladding that has a higher refractive index and thus helps channel the light along the core, as a wavelength.

CMET
Customer main earthing terminal

Crossed Pair
A wring error in twisted pair cabling where both conductors of one pair are incorrectly exchanged for conductors of another pair at one end of the cable.

Crosstalk
The coupling of unwanted signals from one pair within a cable to another pair.

CSMA/CD
Carrier Sense Multiple Access with Collision Detection. The access method used by Ethernet.

Dark Fibre
Installed optical fibre without a transmitter or receiver. Typically installed to offer expansion capacity.

dB
Decibel abbreviation. A logarithmic unit of measure expressing the ratio between two power levels. The value is 10 times the value in Bels (named after Alexander Graham Bell).

Demarc
Demarcation point. The point of telecommunications termination by a telecommunications carrier within a building or residence. The user (subscriber) has the responsibility for circuit operation beyond the demarcation point.

Dielectric
An insulating material between two conductors.

Digital Signal
An electrical signal that uses two or more discrete physical layers or signal phases to transmit information. For example, the conversion of a voice waveform to a digitally encoded representation of the waveform produces a data stream in which instantaneous amplitude samples of the voice are represented by a binary value. The data stream may then be transmitted as discrete elements and decoded at the far end to reproduce the original signal.

Digital Subscriber Line
A service offered by telecommunication service providers that transmits digital signals to homes at speeds exceeding 100 kilobits (up to 10 megabits per second) over twisted-pair cabling – Reaching higher frequency rates that voice signals.

Dispersion
The phenomenon in an optical fibre whereby light photons arrive at a distant point in different phase than they entered the fibre. Modal dispersion occurs when elements of the optical signal take slightly different paths along the fibre and the different path lengths cause the received signal to lose definition. Chromatic dispersion is caused by differing transmission times of different wavelengths of light, which are refracted differently, according to each wavelength. Dispersion causes light signals distortion that ultimately limits the bandwidth and usable length of the optical fibre link.

Drain Wire
An un-insulated wire in contact with the shield braid of foil along its length. At terminating points of the cable, the drain wire may be used to connect to the shield.

DSL
See digital subscriber line.

DTV
Digital television.

Duplex
Consisting of two parts, bi-directional transmission. Duplex optical fibre cable consists of two fibre strands that are separately jacketed and joined together.

Earth
A term for zero-referenced ground.

EC
European community

EIA
Electronic Industry Association. A membership association of manufacturers and users that establishes standards and publishes test methods (see TIA).

Electromagnetic Field
The combined electric and magnetic fields caused by electron motion in conductors. EM fields may exist at great distances from conductors; however, near-field effects are of more concern in wiring.

Electrostatic
The electrical charge that exists when the charge is at rest.

Electromagnetic Interference
An interfering electromagnetic signal. Networks wiring and equipment can be susceptible to EMI and emit EMI as well.

ELFEXT
Equal-level FEXT (see FEXT)

Equipment Room
ER. An area that contains telecommunications or LAN equipment. An ER may be collocated within a telecommunications (wiring) room.

EMI
See electromagnetic interference.

Erbium-Doped Optical Fibre Amplifier
An optical fibre doped with the rare earth element Erbium, which can amplify light at 1530 to 1565nm when pumped by an external light source.

Ethernet
A LAN topology and access method that uses CSMA/CD transmission method. Ethernet may be used with two types of coax cable, twisted pair, or optical fibre.

Ferrule
A tube contained with in an optical fibre connector that contains the core of an optical fibre.

FDDI
Fibre Distributed Data Interface. A LAN topology and access method that passes tokens over dual counter-rotating optical fibre rings.

FE
Functional Earth

FEP
Fluorinated ethylene propylene. A thermoplastic with excellent dielectric properties, which is often used for conductor insulation in fire-rated cables.

FEXT
Far-end crosstalk. Crosstalk between two twisted pairs, measured at the opposite end of the cable from the signal source.

Fire-Stop
A material that prevents the passage of flame or smoke through an opening in a wall or floor.

Firewall
A device that examines each data packet's source address. If that address is on an approved list, the packets gain entry. If not, they are rejected.

FOIRL
Optical fibre inter-repeater link. An Ethernet optical fibre connection method intended for connection of repeaters. FOIRL is standardised as 10BaseFL and is defined in IEEE/ISO 8802-3 (IEEE 802.3).

Frequency
The number of times a periodic action occurs in a unit of time. The unit measure is the Hertz, abbreviated Hz. One hertz equals 1 cycle per second.

Frequency Response
A range of frequencies within which a device operates within expectations. The limits are usually given as the frequencies for which the normal signal transfer of a device falls 3dB below the nominal level of 20-20 000Hz, while a telecommunications circuit may have a frequency response of 300-3000Hz.

FTP
Foil Twisted Pair.

Full Duplex
A communications method where both transmitted and received signals are simultaneously present (e.g., the common telephone instrument and full-duplex Ethernet.

Gbps
Gigabits per second.

Gigabit
One billion bits of data. Abbreviated Gb.

Gigahertz
GHz. A unit of frequency equal to 1 billion hertz.

GIPOF
Graded index plastic optical fibre.

Ground Loop
A condition whereby an unintended connection to ground is made through an interfering electrical conductance.

Half Duplex
A communications method where both transmitted and received signals are not simultaneously present, but alternate in presence (e.g., commercial two-way push-to-talk radio and standard, half-duplex Ethernet).

Hertz
The unit of frequency, 1 cycle per second.

Horizontal Wiring
Telecommunications (structured) wiring from the user station to the first termination point in the telecommunications room.

Hub
A device that is used to connects computers together on a LAN, typically in a star topology.

HVAC
Heating, Ventilation, and air-conditioning units.

Hz
Abbreviation for hertz.

IDC
Insulation displacement connection

Impedance
The total resistance and reactance offered by a component. The unit of impedance is the ohm and is specified with resistive and reactive values as a complex number. The common symbol for impedance is Z.

Impedance Match
A condition where the impedance of a device is a conjugate (equal resistive component and opposite component) match to the device to which it is connected.

Inner-Duct
A flexible plastic raceway for protection of optical fibre cables. Inner-duct is usually round and corrugated.

Insulator
A device or material that has an extremely high resistance to current flow.

Insulation
A material that is non-conductive to the flow of electrical current. The coasting (usually thermoplastic) of a conductor that insulates it from other conductors.

Interference
Undesirable signals that interfere with the normal operation of electronic equipment of an electronic transmission.

ISDN
Integrated Services Digital Network. A transmission system for digital circuit distribution. The basic rate (BRI) uses one pair for subscriber delivery of 64 Kbps 'bearer' (user data) channels and one 16kbps 'data' (used for signalling & sometimes user data) channel. The primary rate interface (PRI) delivers twenty-three 64 Kbps bearer channels and one 64 Kbps data channel.

ISO
Abbreviation for the International Organisation of Standardisation.

LAN
Local Area Network. A computer network that typically exists within a single building or office or among a group of nearby buildings. Modern LAN's may now interconnect various branches of a retail outlet spanning the United Kingdom and beyond.

Laser
A coherent source of light with a narrow beam. The word comes from 'light amplification by stimulated emission of radiation'. Laser sources are normally used for Singlemode optical fibre transmissions. The laser source for most LAN connections is a semi-conductor laser diode.

LED
Light emitting diode.

LSZH
Low Smoke Zero Halogen. Cable sheath type for preferred use in plenum rated areas.

MAU
Media attachment unit. The transceiver in an Ethernet network; also a common name for the MSAU in a token-ring network.

Mbps
Megabits per second. A bit is one unit of a digital signal.

Mega
Prefix meaning million.

Megahertz
Unit of frequency equal to 1 million hertz (1 million cycles per second).

Micro
Prefix meaning one-millionth.

Microfarad
One millionth of a farad.

Micron
Millionth of a meter.

Mode
A single electromagnetic wave travelling in a wave-guide, such as optical fibre.

Modal Dispersion
See Dispersion.

MSAU
Multi-station Attachment Unit. The device for interconnecting station lobe cables to from a ring in the token-ring network.

Multimode Optical Fibre
A fibre wave-guide that supports the propagation of multiple modes. Multimode fibre may have a typical core diameter of either 50μm or 62.5μm with a refractive index that is graded or stepped. It allows the use of inexpensive LED light sources and connector's alignment and coupling is less critical than with Singlemode fibre. Distances of transmission and transmission bandwidth are less than Singlemode fibres because of dispersion of the light signal.

Nano
One-thousandth of one-millionth.

Nanometre
(nm) One-billionth of a meter.

Nanosecond
One-billionth of a second.

Neoprene
A synthetic rubber that has good resistance to chemicals and flame. The chemical is polychloroprene.

NEXT
Near-end crosstalk. Crosstalk between two twisted pair measured at the same end of the cable as the signal source.

NVP
See nominal velocity of propagation.

Nominal Velocity of propagation
The speed of signal propagation through a cable, expressed as a decimal fraction of the speed of light in a vacuum. Considered being 'nominal' because variations in geometry along a cable may produce absolute variations in the value. The NVP is used in reflectometry to closely estimate the length of a cable by the formula length = ½t X NVP x c, where t is the transit time for the reflected pulse and c is the speed of light in a vacuum. NVP is sometimes given as a percentage, but must be converted to a decimal fraction to be used in the formula.

Ohm
The electrical unit of resistance. The value of resistance through which a potential difference of 1 volt will cause a current flow of 1 ampere.

Open
A break in the circuit or wiring.

Optical Fibre
A thin filament of glass used for the transmission of information-bearing light signals.

OTDR
A version of the TDR intended for use with optical fibre cables.

Packet
A group of bits grouped serially in defined format, containing a command or data message over a network.

Patch Panel
A panel containing jacks or connectors that is used to connect or provide access to telecommunications or data circuits.

Permanent Link
The portion of a structured wiring connection between the cable termination at the horizontal cross-connect and the work area outlet connector, excluding the test cables entirely. The permanent link total length is 90m.

Pico
Prefix meaning one-millionth.

PIMF
Pairs in Metal Foil (a type of STP cable).

Plenum
Any space, whether closed or open that is used for air circulation. For example, air ducts, return ducts, airshafts, and above ceiling air return spaces. Workspaces are not generally considered plenum spaces.

Plenum Cable
Cable that has been certified by the manufacturer as meeting accepted standards for installation in plenum spaces without enclosing in metallic conduit. Plenum cable is generally fire resistant and has low emissions of smoke and toxic fumes in contact with a flame.

Polyvinyl Chloride
PVC. A general-purpose thermoplastic used for wire and cable installation and jackets. PVC is known for its high flexibility. Often used in non-plenum wire and cable installations.

PS
Power Sum. A term that indicates that a measured parameter includes the sum of contributions from all pairs in a cable, excluding the pair under test, with no other pairs excited simultaneously.

PVC
Polyvinyl Chloride.

RF
Abbreviation for radio frequency.

Receiver
A device whose purpose is to capture transmitted signal energy and converts that energy for useful functions.

Reflection
A return of electromagnetic energy that occurs at an impedance mismatch in a transmission line, such as LAN cable. Reflections in an operating system are undesirable and may result from a physical problem, such as crushing, or untwist, or from an electrical connectivity problem, such as a short or open circuit.

Repeater
A device that connects two segments in an Ethernet network, or two portions of a token-ring network ring so as to extend and regenerate the LAN signal.

Reversed Pair
A wiring error in twisted pair cabling where the conductors of a pair are reversed between connector pins at each end of the cable.

Shield
A metallic foil or multi-wire screen mesh that is used to prevent electromagnetic fields from penetrating or exiting a transmission cable. Also referred to a ‘screened’.

Short
A near-zero-resistance connection between two wires of a circuit. A short is usually unintended and considered as a failure.

Signal
The information conveyed through a communication system.

Singlemode Optical Fibre
A fibre wave-guide in which only one mode will propagate. Singlemode fibre has a very small core diameter of 8.3μm. It allows signal transmission for long distances with relatively high bandwidths.

Skin Effect
The tendency of alternating current to travel on the surface of a conductor as frequency increases. As much as 63% of a signal can move away from the copper core of twisted pair when the frequency rate exceeds 1Mhz and above.

SNMP
Simple Network Management Protocol. A remote management protocol this is part of the TCP/IP suite of protocols. Devices that support SNMP can be monitored and controlled remotely over a network.

SONET
Synchronous optical network. SONET is an optical fibre technology that is used to transport telecommunications at 155Mbps and greater. It is the physical level for several ATM implementations.

Step-Index Optical Fibre
An optical fibre in which the core is of a uniform refractive index with a sharp decrease in the index of refraction at the core-cladding interface.

ScTP
Screened Twisted Pair.

STP
Shielded twisted pair.

Switch
A network device that can filter and forward data across segments of a LAN. Often used to connect different types of LAN technologies (such as 10BaseT and 100BaseT LAN segments). Switching is done on the mechanical level, as opposed to bridges that use slower software switching. The term switch may also be used to describe a PABX

TCP/IP
Transmission Control Protocol/Internet Protocol. A protocol used in the interconnection of computers. Although TCP/IP is actually a single protocol, the term is generally used to refer to a suite of closely related protocols for networking. The TCP/IP protocol is used extensively in the Internet.

TDR
Time Domain Reflectometry. A technique for measuring cable lengths by timing the period between a test pulse and the reflections of the pulse from an impedance discontinuity on the cable. The returned waveform reveals many undesirable cable conditions, including shorts, opens, and transmission anomalies due to excesses bends or crushing. The length to any anomaly, including the un-terminated cable end, may be computed from the relative time of the wave return and the nominal velocity of propagation of the pulse through the cable (see nominal velocity of propagation).

TIA
Telecommunications Industry Association.

Topology
The physical or logical interconnection pattern of a LAN.

Twisted Pair
A communications cable using one or more pairs of wires that are twisted together. When a pair is balanced (twisted), the twisting reduces the susceptibility to external interference and the radiation of signal energy (see skin effect).

Underground Cable
Cable that is intended to be placed beneath the surface of the ground (often referred to as UG) in ducts or conduit.

WAN
Wide Area Network. An extension of a local computer network (a LAN) over data communications lines provided by telecommunications common carriers. A typical WAN connects one or more remote office sites to the central corporate site over dedicated analogue or digital circuits.

Waveform
The amplitude of a signal over time.

Wavelength
The physical distance between successive peaks of a wave in a transmission medium. Wavelength may be calculated from the frequency of a signal and the nominal velocity of propagation. In a vacuum, the NVP is simply the speed of light (300 000Km/s).

Z
Symbol for impedance.