J. Webster (ed.), *Wiley Encyclopedia of Electrical and Electronics Engineering*

BUILDING WIRING

Usually the many kinds of information used on premises are allocated to three application groups in increasing order of their bandwidth requirements:

(1) *Commands and Controls and Communications in Buildings* (*CCCB*) Controls, commands, alarms, voice, and picture, using up to about 100 kHz for intercom, telephone, Home electronic systems (*HES*s) class 1, home and building electronic systems (*HBES*s) class 1, home control systems (*HCS*s), and many conventional systems such as burglar and fire alarms and heating, ventilation, and air conditioning (*HVAC*).
(2) Information and Telecommunications Technology (*ICT*) Voice, text, data, graphics, music, and still as well as moving images, using up to about 600 MHz for computer networks, the Integrated Services Digital Network (ISDN), and multimedia.
(3) *Home Entertainment* (*HE*) Music and video, using up to about 2.5 GHz for radio, TV, and multimedia.

Although mains signaling and infrared and radio transmission are also used to carry such information, cabling dedicated to information transfer is the medium predominantly used within buildings and on premises. While in the past specific cables were dedicated to specific applications, today there is a clear trend to generic cabling, a common cabling infrastructure that provides few kinds of transmission channels and can serve large groups of applications: ideally, one cable for CCCB, one for ICT, and a third for HE unless the ICT includes HE. The listing of multimedia under ICT as well as HE hints at a possibility of serving home entertainment applications with digital technologies and within the application group of ICT, with less bandwidth than needed for traditional HE technologies.

The first result of this trend is standards for generic cabling for ICT on the international, the regional, and the national level; see Table 1. Presently, the principles that were implemented in generic cabling for ICT are being applied to develop standards for CCCB and HE cabling. This article follows the trends towards generic cabling for all kinds of information and towards reducing the barriers between cabling for information transfer and for mains distribution.

The importance of the cabling infrastructure is similar to that of other fundamental building utilities such as heating, lighting, and plumbing. As with other utilities, interruptions of the service can have serious impact. Poor quality of service due to lack of design foresight, use of inappropriate components, incorrect installation, poor administration, or inadequate support can threaten an organization's effectiveness.

Historically, the cabling on premises comprised both application-specific and multipurpose networks. Very often even the same kind of information (e. g., data) required different cables when conveyed by different applications. *Application* is the expression used for transmission techniques used in this article. The *token ring*, originally specified for 150 Ω balanced cables, and *carrier sense multiple access / collision detection* (*CSMA / CD*), which started to gain its market on 50 Ω coaxial cable, are examples of two data applications that originally required different cables and now use the same: 100 Ω (or 120 Ω) balanced cables.

Table 1: Standards for Generic ICT Wiring

Geographical area	Title	Contents in relation to ISO/IEC 11801
World wide	ISO/IEC 11801: 2000-01, Edition 1.2. Generic Cabling for Customer Premises	Master
Australia	AS/NZS 3080-A	Slight modifications
Belgium	NBN EN 50173	Nearly identical
Canada	CSA T529-A	Modified
Europe	EN 50173: Information Technology. Generic Cabling Systems	Nearly identical
Germany	EN DIN 50173	Nearly identical
Ireland	EN 50173	Nearly identical
Israel	IS 1907 Part 1	Slight modifications
Japan	JIS X 5150	Identical
Norway	NS-EN 50173	Nearly identical
Switzerland	SNEN 50173	Nearly identical
Spain	UNE-EN 50173. Tecnologias de la Informacion. Sistemas Decableado Genericos	Nearly identical
United Kingdom	BS EN 50173. Information technology. Generic Cabling Systems	Nearly identical
United States	TIA/EIA-568-A and B. Commercial Building Telecommunications Cabling Standard	Modified

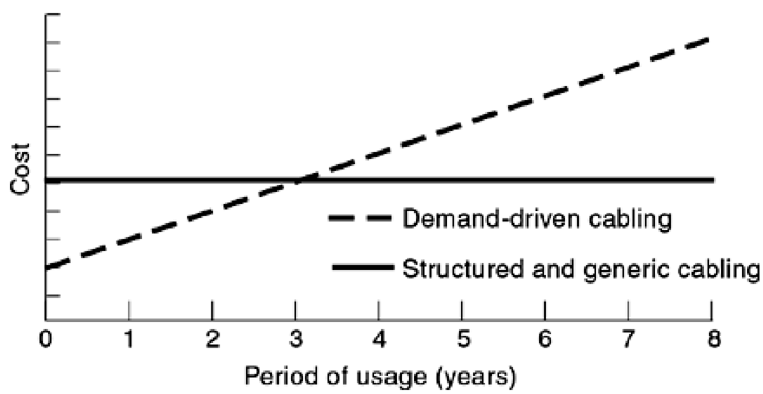

Fig. 1. Economics of generic cabling.

Dedicated networks and cabling characteristics that are tailored to a specific transmission protocol or application decrease the flexibility of a building's telecommunications infrastructure and increase cost. The most cost-effective approach is to precable premises in such a way that any application will be compatible with the installed transmission channel.

Figure 1 shows a comparison of cost versus time for the two cabling strategies: precabling with a structured and generic cabling system, and demand-driven cabling with application-specific material. The figure shows that generic cabling is more economical than demand-driven cabling. From as early as three to five years after initial investment, precabling with generic cabling is more cost-effective than demand-driven cabling when two conditions are met. First, the cabling must be installed in such a way that transmission channels can be made accessible and available. Second, the material used must ensure that the channels have the appropriate transmission characteristics. Thus the topology of precabling must allow access to all the points where cabling might be needed, and the cabling links installed must allow the establishment of channels that meet the needs of the most demanding application.

Advances in cabling technology, liberalization of regulations, and the intensive use of ISO/IEC 11801 (1), the international cabling standard, as well as its regional and national derivatives has led to the predominant use of generic cabling for ICT applications.

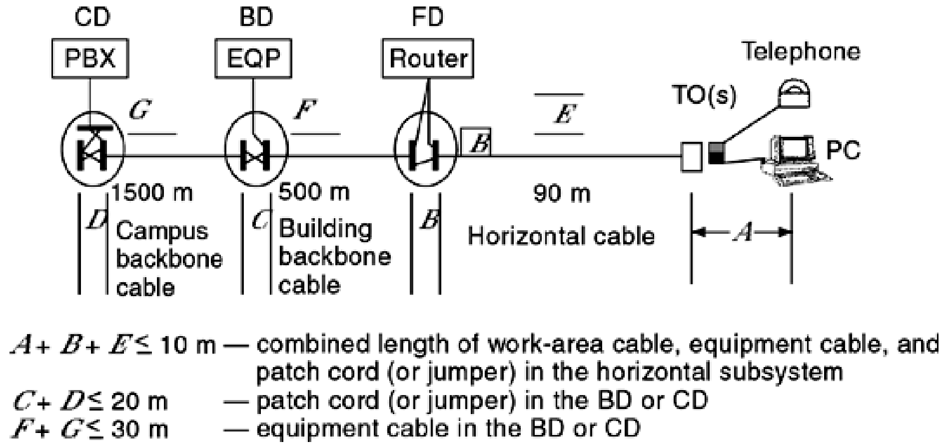

Fig. 2. Examples of transmission channels implemented on structured cabling (source: ISO/IEC 11801 modified (1). All lengths are mechanical lengths. EQP = application-specific equipment; TO = telecommunications outlet (under certain conditions two terminals may share one outlet).

As the principles guiding ISO/IEC 11801 also apply to CCCB and HE cabling, all kinds of information will eventually use a common cabling infrastructure. International and European standards for CCCB cabling as well as for a combination of CCCB, ICT, and HE cabling for small offices and home offices (*SOHO*) are already being developed.

This article gives a preview of this future multipurpose cabling and outlines principles of a generic cabling system for all kinds of information.

The Objective of Cabling

Applications communicate with each other via transmission channels. Transmission channels run all the way from sender to receiver. Figure 2 shows three examples of such channels for ICT. The blue channels go from a PC in a work area to a router in the floor distributor and back to the PC. They are composed of:

- Transmission paths (pairs) in the work area
- Cable from the terminal to the telecommunications outlet (all in blue), and in the horizontal cable and the horizontal distributor (all in black), including the patch cords (all in blue)
- The equipment cable extending from the floor distributor (*FD*) to the router (all in blue).

Building cabling provides the basis for such channels. It consists of permanently installed cables and connecting hardware, shown in black in Fig. 2: means to connect the applications directly (hard-wired or via flexible cords) to the fixed cabling and to combine two sections of fixed cabling at distributors to form a longer link.

The other examples in Fig. 2 show channels going beyond the horizontal distributor. The channels (one or more) between a telephone set and a private branch exchange (*PBX*) are shown in red. They go from the telephone to the PBX and back again. The channels between a router and a file server are in green.

The application only sees the electrical characteristics of the channel. Generic cabling has to be designed in such a way as to ensure that the minimum channel performance required to support the most demanding application during the lifetime of the cabling will be met.

Even when it does not meet the minimum performance of present cabling standards already installed, cabling may be used for an application when the specific channel needed meets the minimum requirements of the planned application.

Cabling Characteristics

To meet user demands, a cabling system must satisfy the following basic requirements, which are treated in successive subsections of the following section:

- Provide links to the points of present and future demand
- Follow a clear structure and thus provide flexibility for changes, moves, and addition of applications
- Provide the ability to configure channels with appropriate transmission characteristics for present and future applications
- Provide standardized interfaces for connection of applications
- Support administration with clear structure identification and documentation
- Meet the safety (electrical, fire, etc.) standards and regulations applicable at the place of the installation
- Share the responsibility for electromagnetic compatibility (*EMC*) with the attached applications in a fair manner so that the system comprising cabling plus attached applications meets the EMC requirements at the place of the installation

Specification of a Generic Cabling

Points of presents.

Application groupings. Presently at least five kinds of cabling, as listed in Table 2, may be found in commercial and sometimes also in residential buildings. In addition, special cabling is used, for example, between a PC and a printer, and between a hi-fi amplifier and loudspeakers, as indicated in the "Other" column of Table 2. These different types of cabling have evolved independently over many decades.

These different cabling types have many common characteristics and may be integrated into a generic infrastructure with some resources shared by all applications and other resources shared by groups of applications. Spaces, pathways, and distributors are examples of shared resources.

With changing technology, new regulations, and modernized electrical codes it is feasible to have a single cabling infrastructure for all applications, since the electrical characteristics of the transmission links and the topology required by these different applications can be united to few cable types, interfaces, and topologies. But the integration will not go as far as one cable to do everything. Different cable types are still required to accommodate diverse requirements related to the needs of (electrical) safety, of EMC, and of transmission characteristics.

Different applications have different requirements concerning the electrical characteristics of the transmission channel and its topology. Variations can also be found in the number of outlets to be served and topologies accommodated by an application, e.g., point-to-point or bus. In some commercial buildings separate networks for security and/or telephone may also be implemented for contractual reasons.

Taking into account:

- The transmission characteristics of the links required by different groups of applications

Table 2: Applications and associated cabling for homes and small businesses

Application Field		Present Cabling Topology / Cable Type[a]									
1		2	3	4	5	6	7	8	9	10	11
No.	Name	Mains	Phone	TV	Intercom	Security	Home Control	Other	Application Group	HES Class	Minimum Channel Class[b]
2	Mains supply	O/p							Mains supply	N/A	
3	Lighting control	O/p					O/h, p, t		CCCB	I	A
4	Building control	O/p					O/h, p, t		CCCB	I	A
5	Appliance control	O/p					O/h, p, t		CCCB	I	A
6	Burglar alarm					B/t			CCCB	I	A
7	Fire alarm					B/t			CCCB	I	A
8	Intercom				B/t		O/h, t	X	CCCB/ICT	I	A
9	Telephone		E/t						CCCB/ICT	II	A
10	ISDN		E/t						ICT	II	D
11	Computing		B, S/t		B, S/t	B, S/t	B, S/t, D	O/d	ICT	II	D
12	Hi-fi							S/l,	HE	II	D
13	CCTV			B,S/c	B, S			B/c	HE	III	Coax, F
14	Radio and TV			B, S/c				B/c	HE	III	Coax, F

Source: ISO/IEC CD 15018, revised (2).

[a] B: bus; c: coaxial cable; d: data cable; E: extended star; h: hcs cable; l: loudspeaker cable; O: open topology (for mains distribution based on local regulations this may exclude loops); p: power distribution cable; S: star; t: simple telephone cable.

[b] A: channel specified up to 100 kHz, minimum requirements; see ISO/IEC CD 15018. D: Channel specified up to 100 MHz, minimum requirements; see ISO/IEC 11801:2000-01, edition 1.2. E: Channel specified up to 250 MHz, minimum requirements; see ISO/IEC 11801: 2nd ed. in preparation. F: Channel specified up to 600 MHz, minimum requirements; see ISO/IEC 11801: 2nd ed. in preparation. Coax: Coaxial channel specified for TV (up to 2.3 GHz), minimum requirements; see TV standards and ISO/IEC CD 15018.

- The difference of cost and place of demand for low- and high-performance cables
- The need to provide coaxial cables for HE at least for another decade a generic infrastructure for all kinds of applications presently consists of three channel classes, as outlined in column 11 of Table 2, besides the mains distribution network. They serve the application groups listed in column 9, which are allocated to HES classes indicated in column 10.

Note that this table aims at homes and small business and therefore does not contain optical fiber.

Application versus points of availability. The principle of generic cabling requires that it provide transmission channels meeting the requirements of all applications that are likely to be used on specific premises and that such channels may be accessed at all points where any of these applications may be connected. As different groups of applications have different link requirements and not all applications need to be connected to all places, there is no need to provide all kinds of links to all possible connection points. For example, there is no need for providing a coaxial link to a connection point for a lamp in the ceiling. Therefore, the final planning is influenced by those applications that can be excluded from ever being used on specific premises or ever being connected at a specific location.

Table 3, an excerpt from such a table in the ISO/IEC draft for cabling of SOHO, presents an overview of cabling endpoints required by different applications and the kind of channels needed. This table is the basis

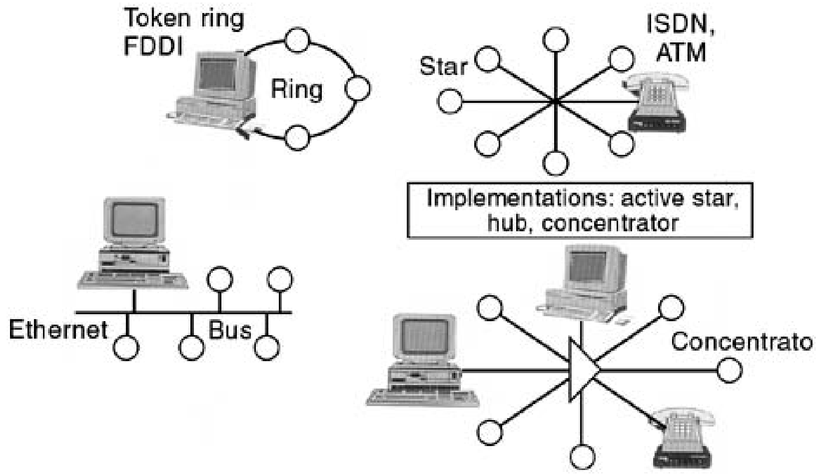

Fig. 3. Star: the universal topology.

for planning a specific installation. Note that telephone connections may be needed at entertainment devices in addition to coax in order to support access to advanced set-top converter/decoder devices.

The utmost flexibility is provided by precabling all the endpoints with all the links indicated for that location in Table 3, as it will be provided in ISO/IEC 15018 (2). When certain applications can be excluded at least for the next fifteen years at a specific building, the endpoints and links needed for these applications may be excluded from planning.

Topologies.

Principles. Topologies are the logical and physical representations of the layout of the terminals, conductors, cables, or pathways that make up an installed network. The physical characteristics (cable route, terminal sites, etc.) are completely independent of the logical topologies (sequences of addresses). Any topology can be described in terms of common geometric shapes.

In communications via cabled media one can observe physical and logical levels of topology: the topology of pathways and spaces, the cable topology, the link topology, the physical topology of the channels, and finally the logical topology of the application. The first three levels are important for the installation of cabling. The fourth level is supported by appropriate connecting hardware that serves to terminate and to interconnect cables. And the fifth level is handled by software. It is important to note that cables installed in a star topology provide the highest flexibility for the support of channel topologies, as the link segments can be connected at a central point to stay a star or to form rings and buses. Figure 3 shows channels in ring, star, and bus topologies, all of which can be implemented with the help of cables installed in a star topology. Ethernet logically is bus-structured, while the cabling links have the shape of a star.

Pathways and spaces. Cabling (cables and connecting hardware) and application equipment (such as PBXs, routers, bridges, and also centralized file servers and printers) need space to be installed in. Cables need pathways so that they can be run between these spaces and from distributors to outlets. At the outlets, sufficient space is required to house the connecting hardware and to give room for the length of the cable that is needed during the installation of the outlet, which is to be stored with an appropriate bending radius. Pull boxes are required when ducts and conduits span a long distance or go around multiple corners.

Whenever a building is designed or refurbished, one should consider these needs and plan for the headroom needed during the entire useful life of a building. Although some national standards are available and an international standard for pathways and spaces on customer premises is being developed, both the architect

Table 3: Cabling Connection Points for SOHO

Place	Function	Application	Application Field (Number as Specified in Table 2) 1	2	3	4	5	6	7	8	9	10	11	12	13	14	Link Class[a] (Minimum)	Example
Power sockets for sophisticated device	Convey information to/from device	Appliance control Appliance control	1	2	3	4	5										A	Heating/climate control, telephone, TV, intelligent appliance
Power sockets for simple device	Control power supply to attached device	Remote power control, dimming of lamps	1	2	3		5										A	Household appliances, lamps
Other power outlets for simple devices	Control power supply to attached device	Home appliance control	1	2	3		5										A	Venetian blind, fan, outdoor light
Possible connection point for lighting	Control power supply to attached device	Lighting control	1	2		4											A	
Possible control point for home appliances	See status of, give order to appliance	Appliance control						5									A	Switch position near door
Possible control point for lighting	Switch, dim lighting	Lighting control		2													A	Switch position near door
Possible control point for climate		Climate control			3			5									A	Position to measure/ control temperature
Radiator	Control water supply	Heating control, zone heating	1		3												A	
Window	Control window/ venetian blind (open/closed)	Burglar alarm, control control	1	2	3			6									A	Close water supply for radiator; if window is open, close window when rain starts
Window	Monitor glass for breakage				3												A	

Table 3: Continued

Place	Function	Application	Application Field (Number as Specified in Table 2) 1	2	3	4	5	6	7	8	9	10	11	12	13	14	Link	Example
Door	Open/closed	Burglar alarm, climate control			3			6		8	9	10			13		A	
Door	Glass whole/broken	Burglar alarm			3			6									A	
Main entrance	Activate/deactivate burglar alarm; house all out/inhabited	Burglar alarm			3		5	6	7	8							A	
Mains distributor	Control mains switch home from inhabited to empty, trigger alarm in case of power failure with severe consequences.	Optimize power tariff	1	2	3	4	5										A	
Gate	Open/closed	Burglar alarm entrance control	1	2				6	7	8							A	
Locations to input alarm personally	Attack button	Burglar alarm						6	7								A	
Door opening area	Oversee entrance and open door	Burglar alarm, operate entrance						6		8							A	
Outlet for fire detector	OK/smoke/ high temperature	Fire alarm							7								A A	
Pool		Spa control	1	2	3		5										A	
Pool		Communication 2nd pleasure								8	9	10			13	14	F, coax	
Outside location with representative temperature	Measure outside temperature				3		5		7								A	
Outside location not artificially lit	Measure intensity of outside light			2	3		5										A	
Outside location with representative humidity	Measure outside humidity	Watering control			3		5										A	

Table 3: Continued

Place	Function	Application	Application Field (Number as Specified in Table 2) 1	2	3	4	5	6	7	8	9	10	11	12	13	14	Link	Example
Gutter	Measure humidity in gutter	Control gutter heating	1		3												A	
Power sockets for ICT device	Convey information to from device	Appliance and HE control and ICT	1						7		9	10	11	12			D	PC , PBX, telephone, TV
			1						7		9	10	11	12			D	
Work areas	PC outlet, telephone outlet, printer outlet	Work	1								9	10	11	12			D	
Communication area	Telephone	Communications	1					6	7	8	9	10	11	12			D	
Equipment rooms	Printer outlet, server outlets, centralized setup box, PBX		1					6	7	8	9	10	11	12			D	
Telephone entrance								6	7	8	9	10		12		14	D	
Additional entrances, e. g., cellular antenna													11			14	D	
Digital loudspeaker outlet			1							8	9	10	11			14	D	
Satellite entrances			1										11			14	Coax	
Antenna entrance			1										11			14	Coax	
Overlooking door, gate	Camera outlet	Burglar alarm, entrance control		2	3			6							13		F, coax	
Power sockets for HE device	Convey information to/from device	Appliance and HE HE control and ICT	1			4		6					11		13	14	F, coax	TV
Entertainment area	TV	Video entertainment	1								9	10	11			14	F, coax	
CTV entrance			1		3							11			14	F, coax		
Video recorder outlet			1					6					11			14	F, coax	
Video outlets														12	13	14	F, coax	
Locations overseeing entrance	Detect movement	Burglar alarm, lightning control,		2				6							13		A	
Locations overseeing a room, area	Detect movement	Burglar alarm, lighting control, appliance control		2				6							13		A	
Outlet for heat/smoke detector	Detect fire	Fire alarm							7								A	

Source: ISO/IEC CD 1518 (2).

[a]A: Channel specified up to 100 kHz, minimum requirements; see ISO/IEC CD 15018. D: Channel specified up to 100 MHz, minimum requirements; see ISO/IEC 11801:2000-01, edition 1.2. E: Channel specified up to 250 MHz, minimum requirements; see ISO/IEC 11801:2nd ed. in preparation. F: Channel specified up to 600 MHz, minimum requirements; see ISO/IEC 11801:2nd ed. in preparation. Coax: Coaxial channel specified for TV (up to 2.3 GHz), minimum requirements; see TV standards and ISO/IEC CD 15018.

and engineer have the opportunity to fit pathways and spaces into the architecture. In order for buildings to properly support generic telecommunications cabling in accordance with cabling standards such as ISO/IEC 11801 (1) and ISO/IEC CD 15018 (2), a few principles need to be observed:

- Conductive loops—including conductive material included in other facilities like water and heating—should be avoided or at worst minimized to reduce the electromagnetic energy picked up, for example, from lightning.
- Pathways and spaces should support a hierarchical star, that is, a tree topology, as used for ICT cabling; see ISO/IEC 11801 (1).
- The distance—in terms of cable length—between an outlet for ICT or for HE and the horizontal distributor must not exceed 90 m in commercial buildings. Whether the maximum distance should be shortened in private environment was being debated during the preparation of this article. One figure proposed was 40 m—to make 90 m for a link from one outlet to another via the center of the star. Since this proposal has not been discussed by a wide audience, the reader is advised to look for results of the standards process in due time. For sources see the section "standardization" below.
- For the material used for this level of topology, international standards are available that cover ducts, cable trays, installation channels, and installation boxes. See the subsection "Pathways and Spaces" below.

Cable topology. Cables bridge a distance and are connected to other cables or to interfaces at their ends. Cables should be installed in a structured fashion. Figure 4 provides an example of a cabling topology for information cabling as proposed for SOHO in ISO/IEC CD 15018 (2). It shows structured cabling with three kinds of information cables installed in pathways and spaces. (The cables for power are not shown, although they may share pathways and spaces with information cabling,) The spaces to house equipment and to administer cables are located at central points for all logical levels of the premises: for a single-family dwelling these are premises, building, floor, room. Pathways connect these spaces to each other. The cables for ICT and HE go from space to space, connecting outlets in a daisy chain to the room connection point (*RCP*), while the cables for CCCB and power use a mixture of bus, tree, and branch.

Link topology. The link topology is the basis for administration and establishment of channels. A cable can house multiple links, and a link can contain pairs from multiple cables. In practice one often has a cable that contains enough pairs to serve many outlets from the floor distributor to a transition point or a consolidation point, and individual cables from transition and consolidation points to outlet. In this case links consist of two segments, one from the distributor to the transition or consolidation point, and the second from that point to the outlet. These links have the shape of a star with the central point at the floor distributor, while the cables have a tree-and-branch topology. In addition, they may be installed in a pathway shaped like a bus.

Channel topology. At interfaces the application may be connected to a link: the channel is nothing more than the link plus attachment cords.

Link segments may also be interconnected to form more complex structures like buses.

Logical topology. Logical topology is determined by the logical addresses associated with each application connected to the cabling.

Transmission channels.

Channel performance. The application does not see the topology of cabling links or the distance a channel spans; it does not even see the cable characteristics themselves. The application only sees the electrical characteristics of the complete channel. In addition, the application may use the cabling as an antenna to be influenced by the environment and to radiate.

Applications differ not only in their requirement for a specific channel characteristic [e.g., one application tolerates a higher attenuation-to-crosstalk ratio (*ACR*) than another one], but also in their sensitivity to different characteristics. For example, applications that use a single pair for transmission in each direction are not sensitive to delay skew, whereas those that use parallel transmission are.

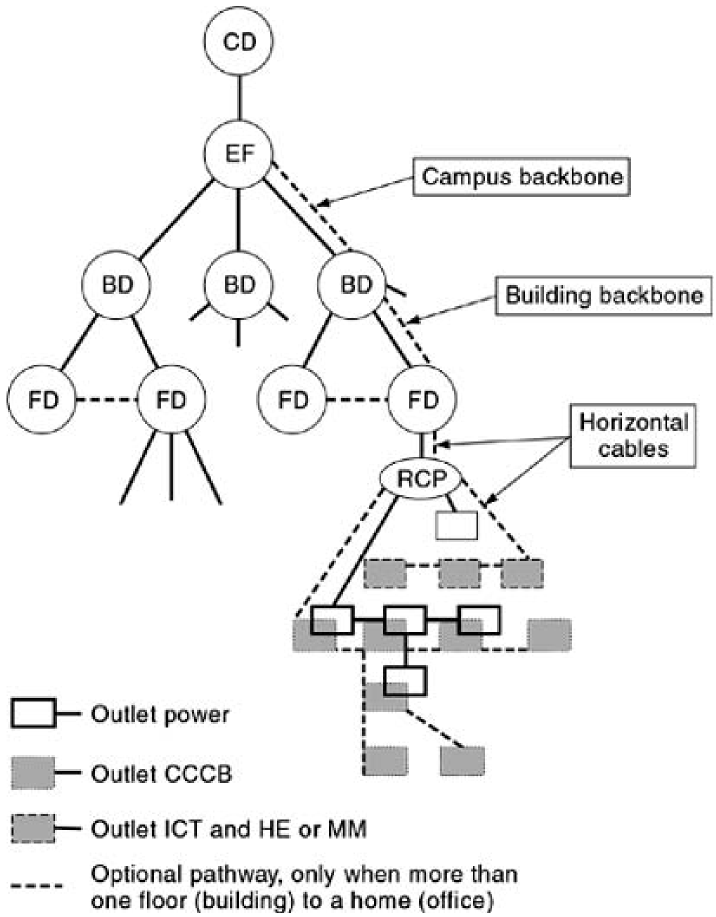

Fig. 4. Topology of pathways, spaces, and cables for SOHO (source: ISO/IEC CD 15018 (2)). RCP: room connection point.

To make sure that a channel will meet the requirements of an application group, performance classes for channels are specified. By taking into account the requirements of the most demanding application for each channel characteristic, compatibility of generic cabling with any application is assured.

ISO/IEC 11801:2000 (1) lists four copper channel classes for ICT, characterized by the upper frequency of the spectrum the channel is specified for, and by one optical class. The copper classes are:

Class A, specified up to 100 kHz
Class B, up to 1 MHz
Class C, up to 16 MHz
Class D, up to 100 MHz

The edition of ISO/IEC 11801 expected for 2001 will also include specifications for class E, up to 250 MHz, and class F, up to 600 MHz, and will provide more than one class for optical fiber.

The minimum performance of channels for CCCB and HE applications will be specified in ISO/IEC CD 15018 (2) which is in draft status as this article is being written.

Table 4: Characteristics of Mains Channels[a]

Dc resistance, maximum	1.45	Ω at	70°C
Current carrying capacity, minimum	17.5	A at	70°C
Insulation resistance, minimum	0.6	GΩ at	70°C

[a] The values are typical for a 1.5 mm mains distribution channel from the last distribution panel to the end user with a length of 100 m.

Characteristics of mains channels. Mains channels have to carry current and protect the environment from voltage. The few characteristics listed in Table 6 are sufficient to characterize it.

Characteristics of balanced channels. The transmission capabilities of balanced cables have considerably improved during recent years. With the sophistication of transmission technologies and their sensitivity to transmission characteristics, the number of parameters to be defined for the channel has grown. Table 7 shows an example of a transmission channel specified up to 600 MHz; the characteristics listed in this table apply to many balanced channels.

Sometimes also the following two characteristics are provided; they are also component characteristics, and their effect as far as the channel is concerned is already incorporated in the coupling attenuation, which includes screening attenuation:

Longitudinal to differential conversion loss, specified as a minimum in decibels
Transfer impedance of the shield, specified as a maximum in milliohms per meter

Characteristics of optical channels. The description of an optical channel specifies a few parameters for each window. Table 8 only gives an example for one window.

Note that the calculation of the optical modal bandwidth of a channel based on component specifications only provides accurate results as long as the method used to measure the modal bandwidth is compatible with the way the application sees the fiber.

Sometimes also the numerical aperture is provided; it also is a component characteristic.

Characteristics of coaxial channels. Coaxial channels used today are characterized by the parameters listed in Table 9.

Interfaces to cabling.

General. Applications may be directly hardwired to cabling links, as a lamp in the ceiling is hardwired to power, or connected to the cabling by a connector, as a PC is connected to a local area network (*LAN*).

For hardwired connections any product may be used as long as the transmission characteristics of the channel are provided reliably over the time of usage.

With connectors at the interfaces of cabling, maintaining the transmission characteristics is also mandatory but not sufficient. Reliability and performance of the connections after a number of operation cycles is also needed at some points in the cabling, as well as compatibility of plugs and sockets coming from different sources. Therefore, standardization of such interfaces is of great importance. Many cabling interfaces are standardized on a national level only, although international standards may be available for a connector as a component used at such interfaces.

Interfaces to mains. A number of attempts have been made to standardize the mains interfaces on an international level, up to now without success. Thus many different interfaces exist, which are listed in IEC Technical Report 60083 (3) and standardized nationally, sometimes on a regional level. Some examples are listed in Table 10.

Table 5: Characteristics of Balanced Channels[a]

Characteristic impedance, nomial	100	Ω
Return loss, minimum	8.0	dB at 600 MHz
Attenuation,[b] maximum	54.6	dB at 600 MHz
Near-end crosstalk (NEXT) loss, minimum	51.2	dB at 600 MHz
Power sum NEXT, minimum	48.2	dB at 600 MHz
Far-end crosstalk loss (ELFEXT), minimum	19.7	dB at 600 MHz
Power-sum ELFEXT, minimum	16.7	dB at 600 MHz
Attenuation-to-crosstalk ratio (ACR), minimum	1.1	dB at 600 MHz
Power-sum ACR, minimum	−1.9	dB at 600 MHz
Dc resistance,[b] maximum	40	Ω
Propagation delay, maximum	0.545	μs at 600 MHz
Delay skew, maximum	0.015	μs at 600 MHz
Coupling attenuation, minimum	70	dB at 600 MHz
Unbalance attenuation, minimum	37.2	dB at 600 MHz

[a]The values are quoted from a working document of ISO/IEC JTC 1/SC 25/WG 3, April 2000, and are characteristic for a class F channel. They represent the best channels—following the two-connector model—discussed at the time this article was written. An international standard specifies the channel for the full frequency range; this table only quotes a few values.
[b]At the maximum temperature the channel is planned to operate at.

Table 6: Characteristics of Optical Channels[a]

Attenuation, maximum	2.5	dB
Wavelength window	790 to 910	nm
Optical modal bandwidth, minimum	100	MHz
Return loss, minimum	20	dB

[a] The values are quoted from ISO/IEC 11801:2000-01, edition 1.2. They are specified for a multimode horizontal channel used in the 850 nm window.

Interfaces for CCCB. International standardization of interfaces to CCCB networks is still pending in ISO/IEC CD 15018 (2). For the time being a number of different connectors are being used, while many applications are hardwired to the cabling.

Some examples are listed in Table 11.

Table 7: Characteristics of coaxial channels[a]

Characteristic impedance, nominal	75	Ω	
Return loss, minimum	20	dB at	100 MHz
Attenuation, maximum	8.0	dB at	100 MHz
Dc resistance, maximum	12	Ω	
Propagation delay, maximum	500	ns at	100 MHz
Screening attenuation of outer conductor, minimum	75[b]	dB at	30 MHz to 1 GHz

[a]The values are quoted from a comment to ISO/IEC CD15018.

[b]For the cable itself a screening attenuation of 85 dB, corresponding to a transfer impedance of 20 mΩ/m at 300 MHz, is quite common. A shield around the coaxial cable further improves the screening attenuation and is used in special cases. The quality of such a shield is a cable characteristic specified as the transfer impedance of the shield, with 100 mΩ/m at 30 MHz as a acceptable value.

Table 8: Mains Interfaces

Mains Characteristics	Interface type[a]	Connector Specifications	Geographical Area
50 Hz, 220 V	European, Australian	IEC TR 60083	China, parts of south America
50 Hz, 220 V to 230 V	European	IEC TR 60083	Europe except Denmark and Switzerland; most of Asia, parts of Africa
50 Hz, 220 V to 230 V	Euroconnector for class-II equipment	EN 50075	Most European countries
50 Hz, 220 V to 240 V	European, British	IEC TR 60083	Africa
50 Hz 110 V to 127 V	American		
50 Hz, 230 V	British	IEC TR 60083	United Kingdom
50 Hz, 240 V	Australian	IEC TR 60083	Australia
60 Hz, 120 V	American	IEC TR 60083	United States, Canada, Mexico, Prts of Brazil

[a] There are a number of implementations of the American, Australian, British, and European types.

Interfaces for ICT. For ICT, ISO/IEC 11801 (1) specifies the interfaces to connect applications to cabling links on a worldwide basis as listed in Table 12.

Based on ISO/IEC 11801, the SC connector has been accepted worldwide for optical fiber, and the IEC 60603-7 connector (4) (often also called “Western” or “RJ45”) has been accepted for 100 Ω (and 120 Ω) cabling. Its frequency range originally went up to 3 MHz; today ranges up to 600 MHz are being specified.

To be prepared in case an interface that is backward compatible with IEC 60603-7 does not in fact meet the minimum requirements for class F channels, a mating interface was chosen as a fallback solution at the end of June 1999. A specification for connectors with this mating interface is being developed in the IEC in parallel with the development of the standard with the IEC 60603-7 interface. The backup solution will offer the possibility to plug either one plug with four pairs, or two plugs with two pairs each, or even four plugs with one pair each, into one socket.

Interfaces for Home Entertainment. Interfaces of HE applications to cabling are largely the same. Those in widest use are listed in Table 13.

Table 9: CCCB Interfaces

Network Characteristics	Interface	Connector Specification
Batibus	2-pin station connector	CLC/R 205-009
EIB	2-pin wire connector	CLC/R 205-009
ESA	6-pin bus socket	CLC/R 205-009

Table 10: ICT Interfaces

Network characteristics	Interface at TO	Connector Standard
Copper 100 Ω, 120 Ω, classes A to D	IEC 60603-7	IEC 60603-7 plus Amendments
Copper 150 Ω, class D	IEC 60807-8	IEC 60807-8
Copper up to class E	IEC 60603-7	New work approved
Copper up to class F	IEC 60603-7-7[a]	Under consideration; see IEC 61076-3-104, Part 1
	IEC 61076-3-104[b]	Under consideration; see IEC 61076-3-104, Part 2
Optical channels	SC	IEC 60847-19
Optical channels in premises already using the ST connector	ST	IEC 60847-10

[a] Backward compatible with IEC 60603-7.
[b] New interface that allows up to four plugs in one socket.

Table 11: HE Interfaces

Network Characteristics	Interface	Connector Standard	Country
Radio	Coaxial unmatched connector	IEC 60169-2	European countries
TV from broadcast	Coaxial unmatched connector	IEC 60169-2	European countries
	F connector	IEC 60169-24	United States
Radio and TV from satellite	F connector	IEC 60169-24	Worldwide

Characteristics of channel components.

General. Channels comprise various elements, including permanently installed cables, flexible cables, splices, and connecting hardware. These cabling elements are used to configure a wide variety of cabling implementations. Connectors are used at places such as distributors where the user can influence the choice of both parts (e.g., plug and socket) and at places where there is little control over the source of the parts interconnected, such as the TO.

In the design of building cabling all these aspects need to be considered, including the effects of interaction between components, of cable termination at a connector, of long-term reliability and characteristics of components, of environmental influences, and of user behavior.

Table 12: Characteristics of Connections

Electrical Characteristics[a]			
Attenuation, maximum	0.4	dB at	100 MHz
NEXT loss, minimum	40	dB at	100 MHz
Return loss, minimum	12	dB at	100 MHz
Input-to-output resistance, maximum	300	mΩ at	d c
Transfer impedance, maximum	200	mΩ at	10 MHz
Current capacity, minimum	0.75	A at	60 °C[b]
FEXT loss, minimum	35	dB[c] at	100 MHz
LCL (balance), minimum	26	dB[c] at	100 MHz
Optical Characteristics[d]			
Attenuation, maximum	0.5	dB	
Return loss, minimum	20	dB	
Mechanical Characteristics[a]			
Mating interface	Tolerances specified on drawing in millimeters		
Number of conductors, maximum	8		
Conductors to be terminated	0.5 to 0.65	mm	
Maximum outer diameter, cables to be terminated,	20	mm	
Mechanical operations, minimum number	750		
Means to connect shield	Characterized by electrical performance		

[a] The values are quoted from ISO/IEC 11801:2000-01, Edition 1.2 as minimum requirement for a IEC 60603-7 connector category 5. In principle the IEC specification could be more demanding.
[b] Maximum temperature the channels are foreseen to operate at.
[c] Under consideration for international standardization.
[d] The values are quoted from ISO/IEC 11801:2000-01, Edition 1.2, as minimum requirements for a SC connector specified in IEC 60874-14 when it is used for generic cabling. In principle the IEC specifications could be more demanding than the minimum requirements specified in cabling standards.

Channels and components are not always characterized by the same terms. While the transfer impedance of the shield will be specified for a cable in milliohms per meter, such a value is not meaningful for a connector. Thus the channel may be characterized in terms of a parameter, such as coupling attenuation, that combines shielding effectiveness and balance of the component.

Cables. It is important that the desired transmission characteristics be provided throughout many years of service. Thus, besides the electrical performance on the drum at 20°C, many other cable characteristics are needed to judge whether a cable will provide the electrical transmission performance described under all the conditions foreseen for its use.

Such characteristics are:

- Mechanical and electrical stability against stresses during installation and use. The latter may require protection against rodents, traffic flow, and multiple bending.

Table 13: Standards in the Area of Materials for Pathways and Spaces

Number	Title
IEC 60423 (1993-10)	Conduits for electrical purposes—outside diameters of conduits for electrical installations and threads for conduits and fittings
IEC 60439-2 (1987-11)	Low-voltage switchgear and controlgear assemblies. Part 2: Particular requirements for busbar trunking systems (busways)
IEC 60439-3 (1990-12)	Low-voltage switchgear and controlgear assemblies. Part 3: Particular requirements for low-voltage switchgear and controlgear assemblies intended to be installed in places where unskilled persons have access for their use—distribution boards
IEC 60439-5 (1996-03)	Low-voltage switchgear and controlgear assemblies. Part 5: Particular requirements for assemblies intended to be installed outdoors in public places—cable distribution cabinets (CDCs) for power distribution in networks
IEC 60529 (1989-11)	Degrees of protection provided by enclosures (IP Code)
IEC 60614-1	Conduits for electrical installations—specification. Part 1: General requirements
IEC 60614-2-1	Specification for conduits for electrical installations. Part 2: Particular specifications for conduits. Section One: Metal conduits
IEC 60614-2-2 (1980-01)	Specification for conduits for electrical installations. Part 2: Particular specification for rigid plain conduits of insulating materials
IEC 60614-2-3 (1990-05)	Specification for conduits for electrical installations. Part 2: Particular specifications for conduits. Section Three: Pliable conduits of insulating material
IEC 60614-2-4 (1985-01)	Specification for conduits for electrical installations. Part 2: Particular specifications for conduits. Section Four: Pliable self-recovering conduits of insulating materials
IEC 60614-2-5 (1992-11)	Specifications for conduits for electrical installations. Part 2: Particular specifications for conduits. Section 5: Flexible conduits
IEC 60614-2-6 (1992-11)	Specifications for conduits for electrical installations. Part 2: Particular specifications for conduits. Section 6: Pliable conduits of metal or composite materials
IEC 60614-2-7 (1995-10)	Conduits for electrical installations—specification. Part 2: Particular specifications for conduits. Section 7: Rigid non-threadable conduits of aluminium alloy
IEC 61084-1	Cable trunking and ducting systems for electrical installations. Part 1: General requirements
IEC 61084-2-1	Cable trunking and ducting systems for electrical installations. Part 2: Particular requirements. Section 1: Cable trunking and ducting systems intended for mounting on walls or ceilings
IEC 61084-2-4	Cable trunking and ducting systems for electrical installations. Part 2: Particular requirements. Section 4: Service poles
IEC 61386-1	Conduit systems for electrical installations. Part 1: General requirements

- Long-time behavior when exposed to higher, lower, or changing temperature, to humidity, and to any chemicals and gases in the environment and when the cable is installed.
- Stability of electrical characteristics with respect to the earth potential. Some constructions of cables are more sensible to the influence of earth potential near the cable. Such potentials (due, e.g., to the reinforcing steel within concrete) may repeatedly change the impedance of a cable.

The cabling standard ISO/IEC 11801 (1) primarily specifies the minimum channel performance, in particular for the material needed to implement channels spanning the recommended maximum horizontal distance. It is important to note that the channel performance is specified independent of temperature, while the cable values are specified at 20°C. In the standard, the designer of a cabling system is instructed to consider the temperature to which the installed cable will be subjected with the following words:

> The channel performance specification of the relevant class at all temperatures at which the cabling is intended to operate.

The sensitivity to temperature depends on the transmission parameters and the cable construction. For example, the attenuation of unshielded cables with a certain jacket may degrade at a rate of 1%/°C, while another cable with a shield between the pairs and the same kind of jacket may only degrade at a rate of 0.2%/°C Thus the sensitivity to temperature differs in this example by a factor of five.

Today many cables are on the market that meet the minimum requirements of category 5, 6, or 7 when tested for product certification. (It should be noted that as far as category 6 and category 7 are concerned, no international or even national standard had been published at the time this article was being written. Since suppliers already offered cables "meeting" category 6 and category 7, the reader is advised to ask for the origin of the specification quoted by the supplier.)

Cables that meet the comparatively well-defined category 5 still have different prices, which often reflect different costs, a different headroom between minimum requirements to meet category 5, the actual performance of the cable, and (last but not least) its long-term behavior in an installation.

Cables need to support installation and administration. Thus characteristics like

- Size and shape of diameter (space occupied in ducts)
- Ease of handling during installation, termination, and trouble shooting
- Identification of conductors, of pairs, and of fibers (as with color coding)
- Identification of electrical and optical options used within an installation (100 Ω or 120 Ω balanced cable, 50 μm or 62.5 μm optical fiber cable)

need to be considered.

Cables become part of the building. Thus the influence of the material on safety has to be taken into account during product selection:

- Flame retardation
- Transport of fire
- Fire load
- Behavior during fire (emission of smoke, gas, acid, toxic substances)
- Dielectric strength of the insulation to any metallic parts that could carry potential

Cabling carries most of the information exchanged in an organization. Thus its susceptibility to electronic surveillance (tapping) is of high importance. You can only tap an optical fiber by touching it, and there are ways to detect whether a fiber is subject to tapping: the reduction of energy at the receiving end caused by tapping may be detected, as well as the reduction of pressure in a pressurized cable. Copper cables radiate and pick up signals. Thus such cables need not be physically touched to detect or to corrupt the data flow.

Cables used for information transfer.

General. Three kinds of cables are used for building cabling at present: optical fiber cables with silica fibers, balanced cables, and coaxial cables. A fourth kind, optical fiber cable with plastic fibers, is discussed here without a clear indication whether the benefits (ease of handling and of combination with power cables) will be stronger than the drawbacks (low bandwidth, high attenuation, and likelihood of performance degradation with aging). With the progress in balanced cables, coaxial cables are no longer recommended for the ICT part of generic cabling; their use in new installations is mostly limited to cable TV distribution.

Optical fiber cables. An optical fiber cable contains a number of optical fibers made of silica (SiO_2) covered by a cladding to protect them against stresses during installation and use, and especially against water. With optical fiber cables in general one fiber is used per direction for ICT applications; thus normally multiples of two fibers are needed at each interface to the cabling.

In principle there are two fiber constructions: the single-mode fiber and the multimode fiber. There is no significant difference in cost between these types at present, yet there are still significant differences in the cost of the systems connected with them. Single-mode fiber has better transmission performance by far, but needs lasers in the transmitters that are still expensive, whereas multimode fiber can do with LEDs. Therefore, multimode fiber at the moment is the predominant construction used within buildings.

Single-mode fibers have a core diameter of 9 μm. Multimode fibers offered today have a core diameter of 50 μm or of 62.5 μm. The 50 μm size has better performance but a smaller opening to receive light; thus in the overall system in general it outperforms the 62.5 μm size at the longer distances (usually above 500 m). All three fibers have a cladding diameter of 125 μm. Since the single-mode fiber has a much smaller core, the mechanical accuracy in connecting two single-mode fibers has to be much higher than with multimode. This increases the cost of connections for single-mode as compared to multimode fibers.

Many industry experts are confident that the future lies in the optical fiber, that the balanced cable only fills the gap until this future becomes present. Some believe that when we have reached that point the single-mode fiber will be used even in horizontal cabling, whereas today it is found primarily in the premises backbone. Few dare to predict when this point will in fact be reached, as the improvement in balanced cabling (cables and connecting hardware) has pushed it further away every year.

Between premises, in networks of telecommunication carriers, and also in the long-distance parts of distribution networks for cable TV, single-mode fiber is the medium installed today.

For short distances, as found in cars, trucks, and buses, plastic fiber is used. As these fibers are much thicker, they are easy to handle. The performance of plastic fibers continues to improve, so that they may some day become an alternative to silica fibers for building cabling on small premises such as homes.

Balanced cables. A balanced cable contains one or more symmetrical cable elements. For application in data transmission such elements are twisted pairs or star quads (see Fig. 5). The two conductors of one transmission line are symmetrical with respect to earth and twisted together. They carry the information with help of a differential mode signal: two signals on the two conductors of the pair, which look the same, but have opposite polarity. These signals are added at the receiving end to obtain the wanted signal. (See Fig. 6.) Interfering signals may create common-mode coupling: signals on both conductors with the same polarity. This common-mode signal ideally is canceled in the matching transformer.

As far as disturbances from outside and radiation to the outside are concerned, there are also common modes and differential modes. The disturber may be coupled through the inductive loop created by one conductor

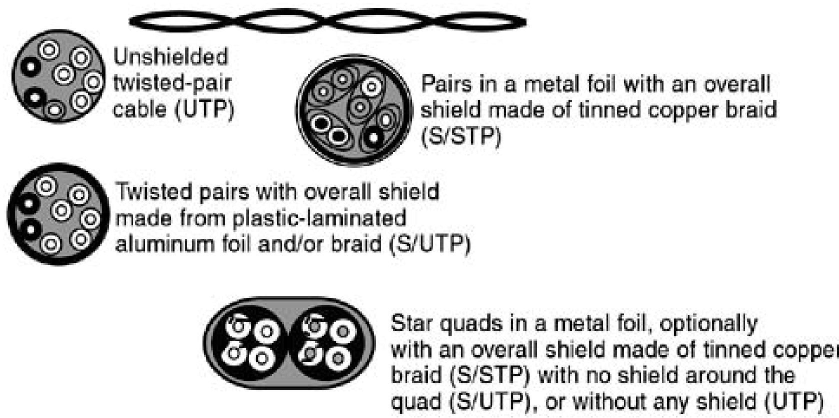

Fig. 5. Balanced cable constructions.

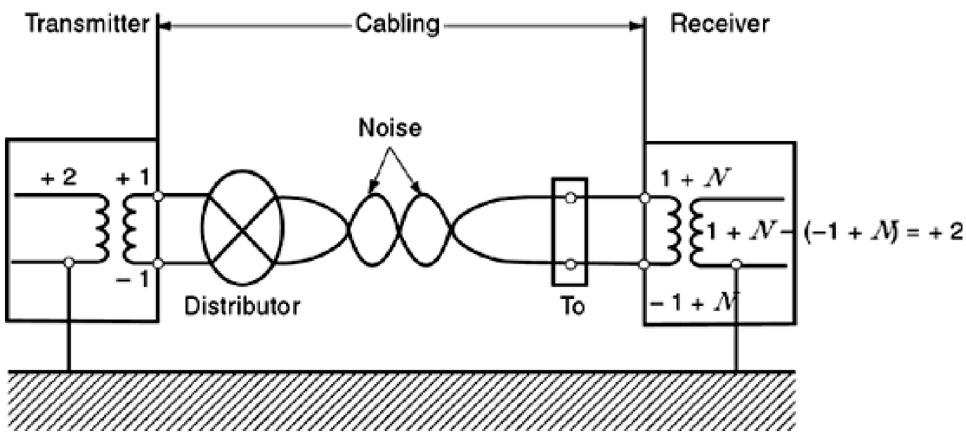

Fig. 6. Theory of balanced transmission. (Source: Oehler.)

and the earth. In this case a common mode disturbance is created. A signal induced by a disturber so far away that the energy coupled into the loop with conductor 1 is equal to that coupled to the loop with conductor 2 is canceled at the end of the line. (Theoretically this would also be so if the pair were not twisted and the disturber were at exactly the same distance from both conductors.) The twist is effective against a disturber at any location relative to the pair, as it provides the above-mentioned similarity of distances. Thus a common-mode disturbance picked up by one turn of conductor 1 is balanced by the disturbance picked up by the following turn of conductor 2, which takes the place of conductor 1 relative to the disturber because of the twist. It is worth noting that although the two common-mode signals of identical amplitude are canceled out in that they do not produce a disturbing signal, their voltages reaching the transformer at the end of the line may be too high and destroy the transformer.

A disturber may also induce a differential-mode signal through the loop consisting of the transmitter and receiver conductors. In this case the twist breaks the big loop into many very small ones. (See Fig. 7.) The voltages induced in the conductors change their sign from loop to loop; thus the resulting differential-mode signal reaching the receiver ideally is zero.

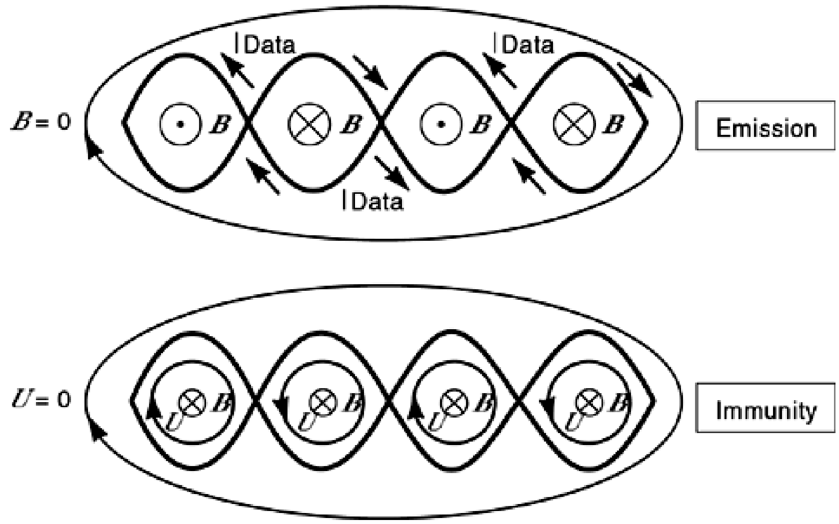

Fig. 7. The effect of the twist in balanced transmission. (Source: Mohr, Siemens AG.)

In the same manner the radiation caused by common- and differential-mode signals is wiped out, as long as the system (pair, transmitter, and receiver) is ideal and symmetrical.

With balanced cables in general one pair is used per direction; thus normally two pairs are used for one application. As the conductors are made of copper, the pairs used for the information transfer may also be used for the powering of terminals—the common case with the telephone. Power supply in most cases is provided without additional conductors, very often with help of the phantom circuit established by a sending and a receiving pair. Sometimes an additional pair is used for power. Recently applications have been developed that use more than one pair per direction. They are to distribute the data on up to four pairs per direction at the same time, using the pairs bidirectionally. The purpose of this sophisticated transmission technology and coding is to squeeze the last bit out of cables already installed (and designed for up to 100 MHz only).

With most applications the quality of the transmission is determined by the signal-to-noise ratio, which depends on the ACR of the channel. Figure 8 shows the improvement in attenuation, NEXT, and ACR from one cable category to the next.

There are many different ways to implement balanced cables. Many abbreviations are used to identify them. Abbreviations such as UTP, STP, FTP, S/UTP, and S/FTP hide more than they tell. A cable is characterized by its electrical and mechanical characteristics and not by three or four letters, especially since these letters have a second meaning: in the United States one often uses UTP to characterize cables with an impedance of 100 Ω, while STP means 150 Ω.

Balanced cables used for ICT and HE applications have an impedance of 100 Ω, 120 Ω, or 150 Ω. New installations in most countries have 100 Ω, but 120 Ω cables are also newly installed. The installed base of 150 Ω is significant, but this impedance is not recommended for new installations.

Coaxial cables. Coaxial cables consist of an inner conductor and an outer conductor that completely encloses it. Dielectric material is used to keep the distance between inner and outer conductor constant. Inner and outer conductor together provide the transmission link. As the outer conductor is part of the transmission channel, it may only be grounded at one point; otherwise the protective ground might carry currents caused by the information transfer. Such currents would cause earth potential differences and ground loops. In principle

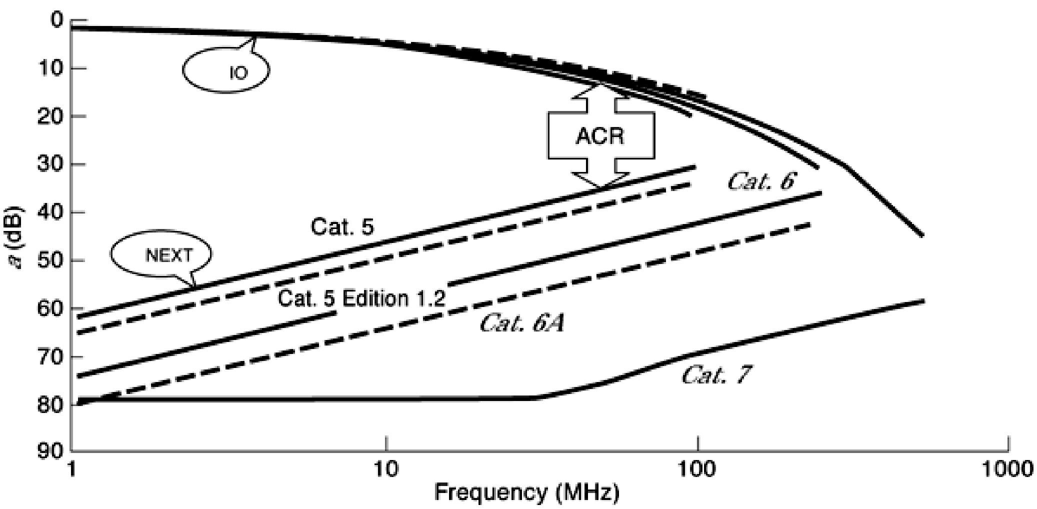

Fig. 8. Attenuation and NEXT of 100 m cable. (Source: Oehler.) Values for categories in italics are under consideration.

the electromagnetic energy used for transmission is enclosed between the inner and the outer conductor. Thus the outer conductor also has a shielding effect, and coaxial cables emit little energy. The construction of the outer conductor provides the means to reduce the radiated energy.

Nevertheless, there are cases where a special shield around the coaxial cable is needed. This construction is often referred to as a triaxial cable. The extra shield may be grounded at more than one point.

Since the transmission path in a coaxial cable is not symmetrical, transmitters and receivers connected to them are different from those connected to balanced cables and use a common-mode signal.

Cables used for power. The objective of cables used for mains distribution is to carry power safely to the users. In most cases the power cables pass load switches on their way to the powered equipment, used to control the operation of that equipment. With modern technology, the load switch that opens and closes the circuit for an electric load (e.g., a lamp) is often placed directly at the equipment using the power, while the control used to operate the load switch functions as a remote control communicating with it via data transmission. The latter may use information cabling, power cabling, infrared transmission, or radio transmission.

Integration of power and information. The boundary between cables and conductors used for power and for information was never a sharp dividing line. Since the very beginning of telephony the telephone line has conveyed the information and at the same time carried the power needed to operate the telephone set all the way from the battery at the central switch to the subscriber. On the other hand, the suppliers of electricity have used their power lines to convey commands and control signals as well as their internal telephone and data transmission for many years. Today the boundary between cabling for power and for information is becoming even more permeable, for technical and legal reasons.

Fiber optic cables neither radiate to the outside nor pick up electromagnetic energy from it, nor can they carry dangerous voltages, unless metal is used as a strength member or for protection against external stresses, such as rodents. Thus they may be installed directly adjacent to power cables without risk to electrical safety or EMC. Therefore optical fibers can be integrated in the ground cables of high-voltage power lines. Because of their immunity to electromagnetic interference (EMI), it is much easier to install fiber optic cables together with cables used for distribution of power and adjacent to railway tracks. To use copper cables at these places, heavy shields are needed.

Modern technology provides the means to convey digital information with bit rates up to 1 Mbit/s over a few hundred meters via power lines.

With the deregulation of the telephone business, all the entities that have pathways or access lines to the end user, such as telephone companies and suppliers of power, cable TV, gas, water, and distributed heating, are eager to harvest an additional crop from their access. Thus technicians are challenged to create an added value on these lines. Conveying data directly via power lines is one possibility.

With the increased use of cables within buildings and of integration of power distribution and information transfer, the importance of equipotential bonding and of TN-S power systems increases. The latter require separation of protective earth (PE) and neutral (N). All metallic parts within a building (reinforcing steel, pipes, etc.) and the conductors used for the common bonding network have to be bonded to a single ground potential, usually called earth potential. The conductors of the common bonding network must be capable of carrying earth current to make sure that all points of the common bonding network have the same (ground) potential. For details see EN 50310 (5).

Connecting devices.

General. Connections are used to terminate cables in a safe and orderly way, to support their use and their administration. They connect link segments in order to establish longer links, and connect application equipment to permanent cabling via equipment and work-area cables, at the same time completing the channels.

Some of these connections will last a very long time, whereas some need to be established and opened very frequently.

In principle there are three kinds of connections: permanent, semipermanent, and matable connections.

(1) Soldered joints, certain insulation displacements, and splices are called permanent connections.
(2) Finger splices and jumpers in a cross-connect made up by insulation displacement are called semipermanent, as the jumper is thrown away when the connection is opened but a new connection can easily be made with a new jumper. The effort needed to open and to reestablish such a connection, as well as the number of repetitions possible, varies considerably from one product to another. With some technologies (e.g., certain punchdown blocks), there is no big difference from connectorized connections with respect to number of operations and ease of handling.
(3) Matable connections are administered using plugs and sockets that are designed for fast and repeatable establishment and opening of connections without the need for a tool.

Whenever connecting products are chosen, one should consider whether all parts of the connection are under the control of the provider of the cabling and should request information on their electrical and mechanical performance. During planning and selection it is important to consider whether a single source must be used for all parts of the connection, or if different sources may be used for mating components such as plugs and sockets for copper connectors, or fiber adapters for optical connectors. The reasons are as follows: On the one hand, international standards for connectors do not specify the connector in the detail needed to guarantee the specified performance when plug and socket come from different sources. On the other hand, the user cannot make sure that the plug coming along with the terminal will have optimal performance with the socket in the wall. Thus it is advisable to make sure that plug and sockets harmonize, wherever the same user controls both parts of a connection, as in case of cross-connects, transition points, and consolidation points

Characteristics of connections. Connections are characterized by their transmission performance and the number of connecting operations they are intended for. Table 14 lists the characteristics and gives values for specific examples.

Table 14: Standardization Committees Associated with Cabling

International Committee	International Title	European Mirror	German Mirror	US Mirror
Committees for Cabling				
ISO/IEC JTC 1/SC 25/WG 3	Customer Premises Cabling	CLC TC 215	DKE GK 715.3	TIA/EIA TR 42.1 to 42.3
IEC SC 100D	Cabled Distribution Systems	CLC TC 209	DKE K 735	
Committees for Cables				
IEC TC 20	Electrical Cables	CLC TC 20	DKE K 411	
IEC SC 46A	Coaxial Cables	CLC 46XA	DKE UK 412.3	
IEC SC 46C	Wires and Symmetrical Cables	CLC 46XC	DKE UK 412.1	
IEC SC 86A	Optical Fibres and Cables	CLC TC 46X	DKE K 412	
Committees for Connecting Hardware				
IEC SC 46D	RF Connectors	CECC SC 46D	DKE UK 412.4	TIA/EIA TR 42.7
IEC SC 48B	Connectors	CECC SC 48B	DKE UK651.4	
IEC SC 86B	Fibre Optic Connecting Devices and Passive Components	CLC SC 86XB	DKE UK 412.7	TIA/EIA TR 42.8
Committees for Applications				
IEC TC 79	Alarm Systems	CLC TC 79	DKE K 713	
IEC TC 57	Power System Control and Associated Communications	—	DKE K 952	
IEC TC 100 100	Audio, Video and Multimedia Systems and Equipment	CLC TC 100X	DKE K 42	
ISO/IEC JTC 1/SC 6	Telecommunications and Information Exchange Between Systems	—	NI 6	
ISO/IEC JTC 1/SC 25/WG 3	Home Electronic Systems	CLC TC 205	DKE UK 715.3/716	
ISO/IEC JTC 1/SC 25/WG 4	Interconnection of Computer Systems and Attached Equipment	CLC TC 205	DKE UK 715.4	
Committees for Safety and Security				
IEC TC 64	Electrical Installations and Protection against Electrical Shock	CLC TC 64	DKE K 221	
ISO/IEC JTC 1/SC 27	IT Security Techniques	—	NI 27	
Committees for EMC				
IEC TC 77	Electromagnetic Compatibility	CLC TC 210	DKE K 767	
CISPR	International Special Committee for Radio Interference	CLC TC 210	DKE K 767	

Note that presently available standards do not necessarily ensure that plugs and sockets from different sources will provide adequate performance when connected. Also, data sheets for connectors published by suppliers typically do not cover interoperability with other manufacturers.

As with cables, the long-term behavior and sensitivity to mechanical and chemical stresses as well as changing temperatures need to be considered when choosing a certain product.

Connectors. The connectors used at points where applications are connected are listed above in the subsection “Interfaces to Cabling.” The minimum performance of premises cabling connectors is specified in ISO/IEC 11801 (1) for ICT channels and will be specified in ISO/IEC 15018 (2) for other channels. ISO/IEC 11801 also specifies performance categories (1 to 5 at present; 6 and 7 planned) for connecting hardware. They correspond to the channel classes A to F.

As far as cabling standards are concerned, any connector may be used at other place in the cabling than the TO as long as it meets the electrical or optical performance as well as the handling and reliability requirements for the specific channel.

Since the mating interfaces for applications at the TO need to be the same for a long time and need to be ready to accept plugs from many sources, they can not readily follow every technological trend. Thus the mating interfaces at the TO is kept rather stable by standardization committees while the mating interfaces at other places in the cabling are left to the discretion of the user. It is also worth noting that connections made up of plugs and sockets optimized to each other, such as one can use in a distributor, may provide higher performance than plugs and sockets from arbitrary sources. Using the freedom given by the standards to use any connector at many places of the cabling, its designer may gain space, performance, and money.

Distribution devices. In many places in the cabling, two cables have to be connected in a semipermanent and orderly way. The instruments to do so are distribution devices: cross-connects and interconnects. The floor distributor in Fig. 2 is implemented in such a way that it provides a cross-connect for connections between horizontal cable and backbone. For the connection of the router it provides interconnect capabilities. In addition, such distribution devices may provide facilities to ease tests, to overcome short-term failures with temporary patch connections, and to restore the permanent connection when the short-term patch is removed.

In an interconnect one cable is permanently terminated and the second one is semipermanently terminated or connected to it.

Traditionally, cabling for telephones used punchdown blocks for all sides of cross-connects and interconnects, while in data networks the semipermanent connections were established with connectors. Since the number of operations of good punchdown blocks meets the requirement of about 200 changes, it is a question of equipment price and training of personnel whether one uses connectorized or punchdown technology for the semipermanent connections.

In many cases, the capability to handle shields cannot be added to a distributor at a later time. Therefore ISO/IEC 11801 says: "in case the use of shielded cables is envisaged the distributors shall be able to handle shields." The European standard puts it slightly differently: "in order not to exclude the possibility to use shielded cables the distributors should be able to handle shields."

Similar considerations apply to consolidation points.

Pathways and spaces. Pathways and spaces are closely related to building customs, which differ considerably from country to country. Therefore, international standardization has just started, while national standards exist. On the other hand, material used for pathways and spaces is provided on a worldwide market and is also specified in international standards. Examples of such standards are listed in Table 15.

Administration.

Objectives. Administration is an essential aspect of cabling. The flexibility of a cabling system can be fully exploited only if the cabling is properly administered. Administration involves accurate identification and recordkeeping for all the components of the cabling system, for all connections within the cabling and to applications, and for the pathways and spaces in which they are installed. All changes to the cabling should be recorded as they are carried out. Computer-based administration of records is strongly recommended.

More detailed advice on cabling administration is provided in ISO/IEC 14763-1 (6), which specifies identifiers, records, and documentation in more detail.

Identifiers. Every element of cabling, and the pathways and spaces, should be readily identifiable. A unique identifier (such as name, color, number, and/or string of characters) should be assigned to every cable, distributor, and termination point in the cabling.

Each TO should be labeled to reference the following information regarding the choice and implementation of installed cabling:

(1) CCCB Connection Point Segment number, cable type
(2) TO with IEC 60603-7 (4) Cable impedance, category of cabling components, and pair count at the TO
(3) TO with Optical Fiber Optical fiber design
(4) HE Connection Point Branch number, cable type.

Suitable identifiers should also be applied to the pathways and spaces in which the cabling is installed.

The elements to which the identifiers are assigned must be clearly marked. Cables should be marked at both ends and whenever they pass a space.

Records. Records of the administration of the generic cabling should be maintained. A reference to the results of acceptance tests, if made, should also be kept.

It is also advisable to associate with the records of the system configuration a list of applications that are being supported. This will facilitate troubleshooting in case of problems.

Documentation. Good control of all of the records kept (such as as-built drawings showing cable routes, TO locations and identification, distributor construction and layout, test and acceptance results, and connectivity mapping) is vital to the administration process. As changes are made to the configuration of the cabling, it is also important to ensure that suitable procedures are implemented and followed for timely updates to documentation. It is advisable to document a change *before* it is made.

Safety.

Introduction. The safety requirements are specified in a number of standards and regulations. Local authorities do not limit themselves to quoting the applicable international standards Therefore, the designer of cabling needs to investigate which rules are applicable to the place of installation and has to meet them.

Electrical safety.

Proximity to mains. With a few exceptions mentioned below, cabling conveying information today does not carry dangerous voltages; however, it needs to be well separated from mains and other hazardous voltages (protective separation). (National) electrical codes—which very often quote standards—specify how to meet this requirement.

As an example, for Europe the installation of mains and other cabling using the same pathway has to comply with HD 384.5.52 S1:1995/A1:1998 (7). This standard allows even wires carrying mains to share the same duct with cables carrying information, on two conditions: First, the cables used for information must only carry protective extralow voltage (PELV) or safety extralow voltage (SELV) (see IEC 60364-4-41 (8)). Second, these cables must have a sheath.

Cabling used for analog telephone service may be subject to ringing voltages of up to 180 V (as used in large countries), which, together with inductive bells, may lead to spikes on the order of kilovolts.

Lightning protection. Cabling installed within a buildings may be connected to cables coming from outside. Should these cables contain metallic parts, appropriate lightning protection must be installed at the building entrance. Details of such precautions may be found in the electrical codes applicable at the place of installation as well as in IEC 61663 (9,10).

Cabling should not be installed so as to create inductive loops that will pick up energy from lightning.

Grounding and bonding. Grounding and bonding increase electrical safety. They are required by electrical codes such as the National Electrical Code of the United States (ANSI/NFPA 70 (11)), and they are specified in standards on international, regional, and national levels such as IEC 60364 (8,12,13,14) and EN 50310 (5).

Fire. Building cabling may contain flammable material. It may also provide paths that support the spread of fire in two ways: The fire uses the burning material within cables to spread. It also uses the pathways and spaces through which the cabling is routed to enable airflow, and to reach other parts of the building. A secondary effect of burning cables, the danger of which must not be underestimated, is the production of dangerous gases and vision-obstructing smoke.

Actions against the associated dangers are:

- Reduction of fire load, that is, keeping the number and size of cables installed as small as possible. Generic cabling is a great help to this effect, as it replaces a number of different cables needing individual spares by multipurpose cabling having a common pool of spare pairs and fibers.
- Fire barriers in pathways.

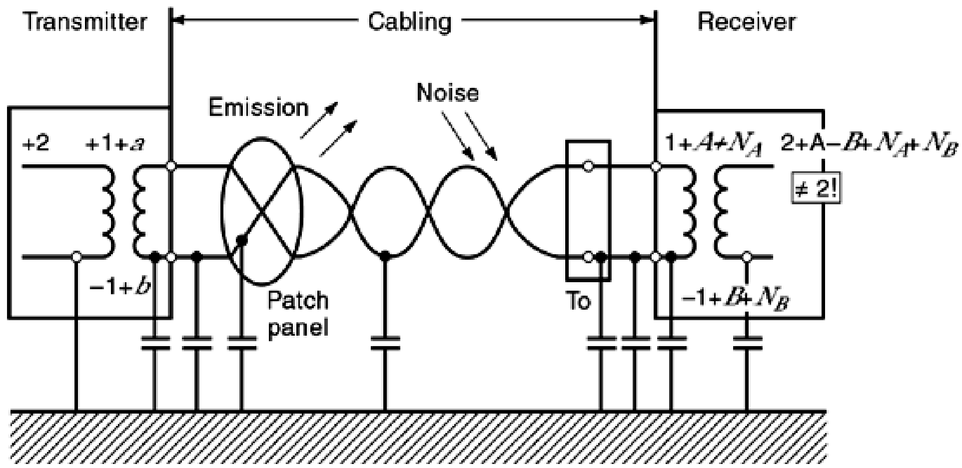

Fig. 9. "Balanced" transmission in reality: difference of capacitances against earth. (Source: Oehler.)

- Use for the cable sheaths of insulation materials that are flame-retardant or self-extinguishing and do not emit dangerous gases or smoke. The pros and cons of various materials are under debate and need to be considered with respect to their effect in a specific environment. Examples are fire-resistant, self-extinguishing, halogen-free, low-smoke, and fire-retardant materials.

Electromagnetic compatibility.

A Responsibility Shared by Cabling and Application. Cabling itself is passive, but connected to an application it may be an antenna that radiates and disturbs other applications. It may also pick up noise or undesired signals that will disturb the application connected to it whenever a certain threshold is surpassed.

A perfectly balanced cable neither radiates nor picks up any signal when connected to perfectly balanced transceivers. But as soon as one of these systems is out of balance, radiation increases and immunity to external interference decreases as shown in Fig. 9.

A perfectly balanced application will radiate when connected to unbalanced cabling, and perfectly balanced cabling will radiate when used with an unbalanced signal. Since the world is not perfect, there is always radiation and reception of noise. Both increase with the imbalance of cabling and the imbalance of the attached application equipment. The frequency, shape, and amplitude of the signal also determine radiation. A signal with large amplitude and a steep signal slope radiates more and induces more energy in a cable than a smooth wave. Thus cabling and application share the responsibility for electromagnetic compatibility. Figure 10 symbolizes that the different levels of immunity and emission required by the regulator may be met with help of different cabling systems for an application with a specified signal and a specific imbalance for transmitter and load. On the other hand there is the possibility to meet such requirements with specified cabling by varying the application parameters.

In practice there are two cases of EMC:

(1) Radiation from a cable to the environment and reception of disturbances from the environment into the cable
(2) Coupling from one circuit in a cable to another circuit of that same cable used by another application.

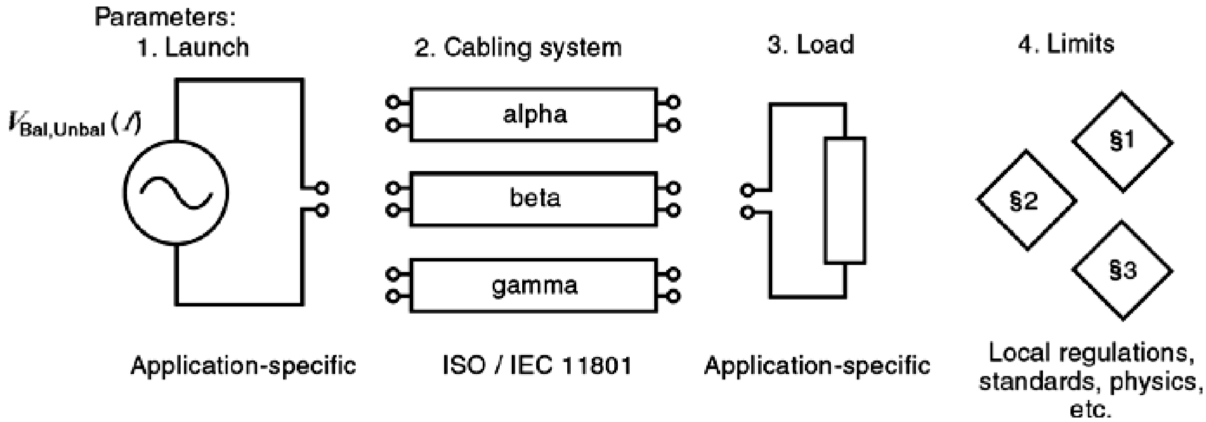

Fig. 10. EMC: cabling and application share responsibility. (Source: Oehler.)

Note that:

- Crosstalk becomes a limiting factor when two circuits in a cable, such as the sending and the receiving circuit, are used by the same application.
- When two circuits in a cable are used by different applications, one is concerned with electromagnetic compatibility and cable sharing.

The degree of coupling from one circuit to another one is characterized by the near-end crosstalk attenuation (NEXT) and the far-end crosstalk attenuation (*FEXT*) of a cabling. The ability to reduce radiation and reception of disturbances from outside are determined by shielding effectiveness and balance. To be able to better compare shielded and unshielded cables, there are proposals to use coupling attenuation, which combines the effect of these two characteristics.

Shielding of individual pairs may be used to improve NEXT and FEXT as well as the coupling attenuation.

Cabling standards specify the minimum requirements for NEXT and FEXT. Appropriate material can be chosen by consulting the data sheets on cables and connecting hardware alone. The international cabling standard preserves the design freedom to achieve the required values for these characteristics with help of shields or with other methods.

Presently cabling experts expect to meet attractive NEXT and FEXT requirements up to 250 MHz without shielding one pair from the other. Above this frequency they see a need for shields within a cable to achieve the NEXT and FEXT required between circuits used by a single application as well as for cable sharing.

Below the frequency of 250 MHz, shields may be needed to meet EMC requirements for one of the following reasons or to reduce the exposure to tapping and sabotage:

- The application connected to the cabling has high signal value, sharp signal shape, or highly unbalanced transmitters and receivers of
- The system (the combination of cabling and application) is subject to EMC regulations that require low emission or high immunity levels.
- The environment has higher than normal levels of electromagnetic noise.

In a number of countries shields are more or less mandatory when frequencies above 30 MHz are used.

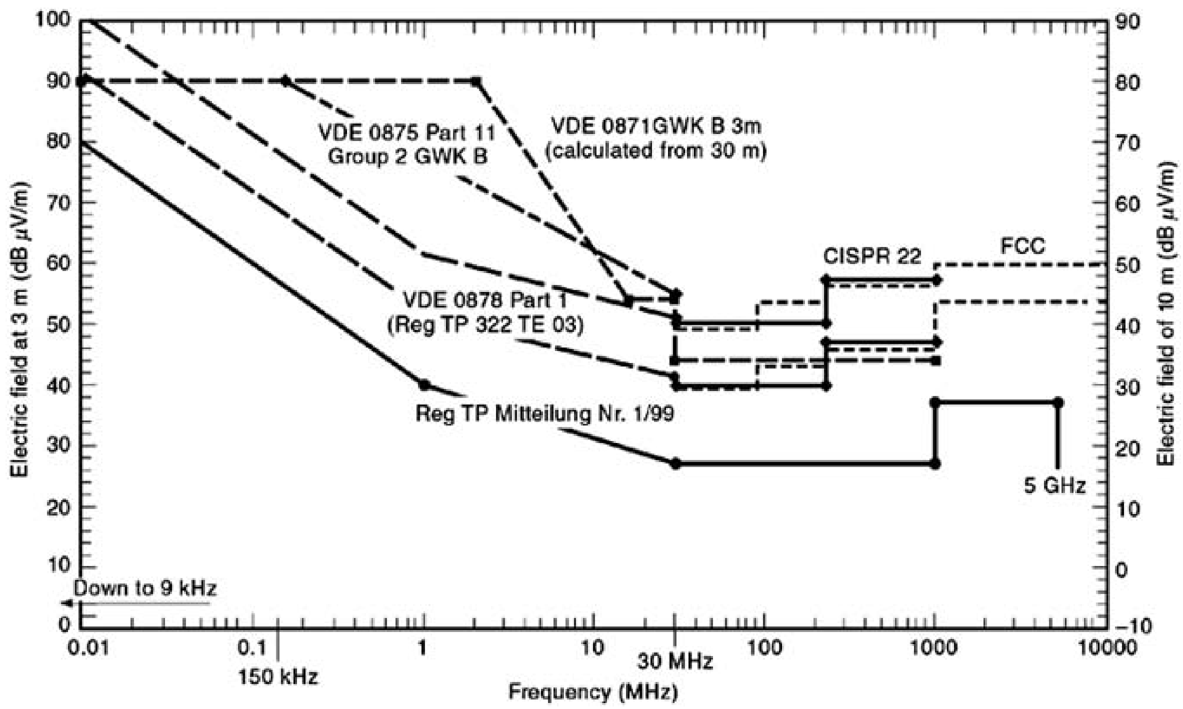

Fig. 11. Limits for field emission.

Figure 11 shows the limits for radiation specified in the US national regulation FCC 15, the international standard CISPR 22 (15), and the German regulation that quotes VDE. The FCC limits are applicable in the United States; CISPR 22 or its national and regional equivalents are quoted in the regulations of many countries (e.g., the European EMC directive quotes EN 55022 (16), the European equivalent to CISPR 22, and requires Class B for residential areas).

Figure 12 shows the radiation of an arbitrary standard conformant 10BASE-T product connected to unshielded cabling. It demonstrates that there is no guarantee of meeting this requirement with an arbitrary 10BASE-T product using unshielded cabling. Transmitters and receivers must also meet the application standard.

It is worth stressing that optical fibers neither radiate nor pick up disturbances; that they are subject to tapping and sabotage only in case the enemy can get near enough to the cable as to touch and manipulate it.

Shielding. The debate on shielding sometimes takes on aspects of a religious war. Its advantages and disadvantages have been the subject of heated debate between industry experts for many years. Because shielding has been used for decades, most of its properties are well known. As shown in Fig. 13, the shield provides an inductive loop for the disturber, thus preventing its energy from seeking a path via the conductors reserved to transfer information. Another benefit of shielding is the improvement of the temperature dependence of the cables attenuation; see the sub-subsection “Cables” above.

Shields in general are helpful to:

- Reduce emission to and reception from the environment, and coupling between cables and cable elements.
- Stabilize the electrical characteristics of a cable (element) by providing a well-defined ground plane. (Note: To a limited extent the stabilizing effect of a shield around the cable can be achieved by grounding unused pairs should such be available in a cable without shields. The penalty is an increase of imbalances to earth.)

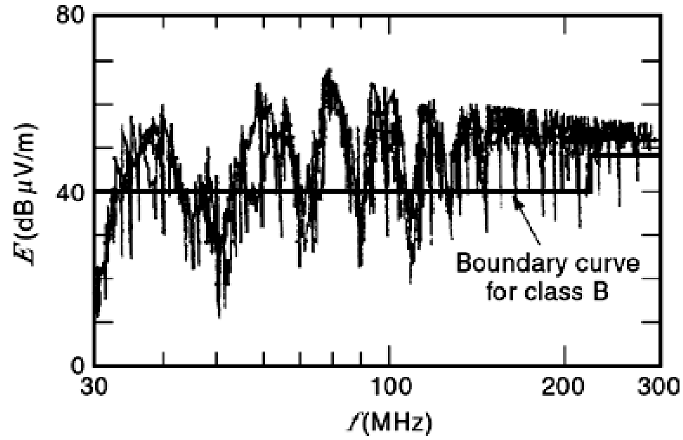

Fig. 12. Radiation of 10BASE-T via unshielded 100 Ω cable. (Source: Oehler, EFOC/LAN '92.)

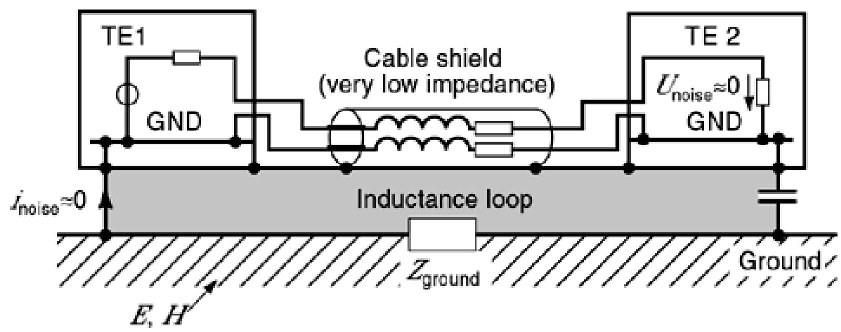

Fig. 13. Mechanism of shielding. (Source: Oehler.)

- Reduce the common-mode disturbance and thus contribute to the protection of attached equipment against dangerous voltages. (Note: A shield with a screening effectiveness of 35 dB will reduce a common-mode disturbance from 1 kV—a voltage that may be induced by a locomotive—to 10 V.
- Reduce emissions and improve immunity to interference from external sources.

As explained under "Balanced Cables" above, there are common- and differential-mode signals. Shields affect the pickup and emission of both. The shield is part of an inductive loop for the common mode, which absorbs much of the energy of the potential disturber. Thus the common mode affecting the conductors behind the shield is reduced to an extent determined by the screening attenuation. At high frequency the differential-mode signals create eddy currents on the shield, which reduce the emitted energy as well as the energy reaching the pair from outside. At low frequencies ferrous materials are needed to make a shield effective.

Shields around individual pairs or quads therefore:

- Improve the NEXT and FEXT
- Improve the delay skew, as the need for different twists is reduced

To be effective, shields generally require:

- Connecting hardware that supports shield connections and high-frequency shield effectiveness.
- Proper termination and a closed Faraday cage. To avoid radiation and reception, the Faraday cage has to be closed around the system. Thus the application-specific equipment as well as the cables connecting it have to be shielded, and their shields have to be interconnected without leaving holes bigger than one-eighth of the wavelength at the highest frequency the shield is to block. Shielded cabling is rightly said to require well-trained installers, but the same applies to any cabling, shielded or unshielded, if it is intended to work properly at 100 MHz and above.

Shields need to be bonded to ground for safety reasons, as they may convey dangerous voltages. The same applies to any other grounded metallic part, such as strength members or unused pairs.

In principle a Faraday cage will work without any grounding. But, as soon as one of the terminals connected to the cabling is grounded, the shield has to be bonded to earth for safety reasons. In this case shields should also be grounded for optimum electromagnetic performance. The more often the shield is grounded, the better the eddy currents induced at high frequencies are grounded. Such multiple grounding requires proper protective grounds at all the places where the shield is grounded. Providing such protective grounds is laborious and thus often avoided in practice. In such cases the shield is directly grounded at distributors, while at other places the shield is only grounded for high frequencies with the help of capacitors.

There are several schools of thought with respect to grounding of shields: whether at two ends or at one end or the other. Such advice may be helpful in cases where there is no common ground network providing a common and stable ground. The best advice is to implement such a network and to ground the shields at as many points as possible.

Verification of Cabling Performance

As with many other technologies, the performance of cabling will meet the requirements when three conditions are met:

- The channel is properly designed.
- The components meet the specification for the design of the channel is based on.
- They are properly installed.

In most cases the design is reduced to the application of specific rules and guidelines. Also, simple tests should be sufficient to check whether the channel meets the designed performance.

For ICT channels, ISO/IEC 11801:2000 (1) specifies 90 m as the maximum distance for a permanent link in the horizontal cabling with one or two connectors in the floor distributor as well as at the TO; see Fig. 14. In case cables and connectors meeting the minimum performance of category 5 are used, and the maximum distances specified in the horizontal model are met, the channel will meet the requirements of class D. The next edition of ISO/IEC 11801 will keep the 90 m maximum but is expected to include a fourth connector for a visible consolidation point as worst case for the calculation of minimum component requirements.

With copper cabling it is sufficient to test conductors and shields for short and for open circuits, as well as for color codes. With optical cabling attenuation, return loss and color codes need to be checked.

Additional tests are only needed in case one suspects that the material was damaged during installation or the cables have been poorly terminated at connecting hardware. Hand-held testers are offered and commonly used for such tests. They allow a fast check of most transmission characteristics and usually provide a go–no-go output based on the minimum criteria specified in cabling standards.

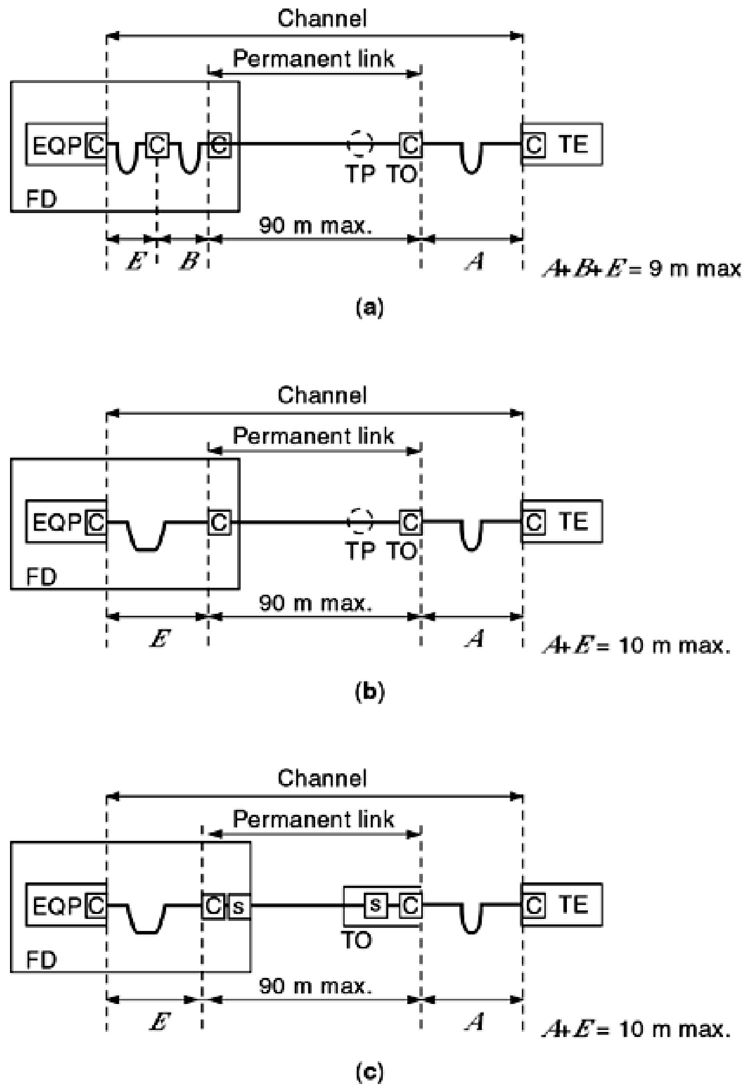

Fig. 14. Example of horizontal channel implementation (source: ISO/IEC 11801:2000-01 Edition 1.2): (a) balanced copper horizontal cabling (with cross-connect); (b) balanced copper horizontal cabling (with interconnect); (c) Optical fiber cabling (with interconnect). C: connection (e.g., plug and jack or mated optical connection); s: optical fiber splice; EQP: application-specific equipment. All lengths are mechnical lengths.

It should be noted that a pass indication on a permanent link test is necessary, but not sufficient, to confirm that the channel will meet the users' needs or that the material was properly installed. Materials that are damaged or improperly handled can pass acceptance testing, but may degrade or become unstable over time.

In case the test is run at lower temperatures than the temperature the channel will be used at, the channel may fail with the application although it passed the test.

In case the permanent link is shorter than the allowed maximum or the material on the drum is better than the required minimum, the material may have been damaged during installation or poorly terminated

Table 15: Standards and Projects for Cabling on the International Level

ISO/IEC 11801:2000-01, Edition 1.2. Information technology—generic cabling for customer premises
ISO/IEC TR 12075:1994. Information technology—customer premises cabling—planning and installation guide to support ISO/IEC 8802-5 token ring stations
ISO/IEC 14709-1:1997. Information technology—configuration of customer premises cabling (CPC) for applications—part 1: Integrated Services Digital Network (ISDN) basic access
ISO/IEC 14709-2:1998. Information technology—configuration of CPC for applications—Part 2: ISDN primary access
ISO/IEC 14763-1. Information technology—implementation and operation of customer premises cabling—part 1: Administration
ISO/IEC TR 14763-2 Information technology—implementation and operation of customer premises cabling—part 2: Planning and installation of copper cabling
ISO/IEC TR 14763-3. Information technology—implementation and operation of customer premises cabling—part 3: Acceptance testing for optical cabling
ISO/IEC CD 15018. Cabling for SOHO
WD. Cabling for CCCB (cabling for HES and building automation)
WD. Pathways and spaces for customer premises cabling

CD: committee draft; NW: new work (authorized); WD: working draft.

and still the hand-held tester will signal "go," unless the value for a pass is set taking into account the real temperatures and distances and materials.

Standardization

Standardization committees for cabling and related subjects. Premises cabling, applications connected to the cabling, components used within the cabling and for its housing, and the general aspects of safety, EMC, and environmental conditions are subject to standardization on national, regional, and international levels. Table 16 gives examples of committees involved on international level and in Europe, Germany, and the United States. Quite often the same or nearly same technical content is published on different levels, as is shown in *Fehler! Verweisquelle konnte nicht gefunden werden*, taking ICT cabling as an example.

Cabling standards and projects. Standardization of cabling and its components develops fast. Table 17, Table 18, and Table 19 provide an overview of standards and projects as of April 2000. More current information may be found using the home pages of standardization organizations or of the specific committees. Table 20 lists such home pages.

Interpretation of ISO/IEC 11801.

Objectives of an International Standard. A standard is a technical specification developed by all concerned parties in an open and democratic process aiming at consensus.

Table 16: Standards and Projects for Cables on the International Level

IEC 61156-1 Ed. 1.0 (1994-07). Multicore and symmetrical pair/quad cables for digital communications—part 1: Generic specification
IEC 61156-2 Ed. 1.0 (1995-07). Multicore and symmetrical pair/quad cables for digital communications—part 2: Horizontal floor wiring - Sectional specification
IEC 61156-2-1 Ed. 1.0 (1995-06). Multicore and symmetrical pair/quad cables for digital communications—part 2: Horizontal floor wiring - Section 1: Blank detail specification
IEC 61156-3 Ed. 1.0 (1995-07). Multicore and symmetrical pair/quad cables for digital communications — Part 3: Work area wiring - Sectional specification
IEC 61156-3-1 Ed. 1.0 (1995-06). Multicore and symmetrical pair/quad cables for digital communications—part 3: Work area wiring—section 1: Blank detail specification
IEC 61156-4 Ed. 1.0 (1995-07). Multicore and symmetrical pair/quad cables for digital communications—part 4: Riser cables—sectional specification
IEC 61156-4-1 Ed. 1.0 (1995-06). Multicore and symmetrical pair/quad cables for digital communications—part 4: Riser cables—section 1: Blank detail specification
CCDV IEC 61156-1: Amendment No. 1 to IEC 61156-1—test procedures for determining characteristic impedance (Z_c), structural return loss (SRL), and return loss (RL)
ANW IEC 61156-2 Amd. 2. Amendment to IEC 61156-2—horizontal wiring. Specification for velocity of propagation
ANW IEC 61156-2 Amd. 2. Amendment to IEC 61156-2: sectional specification for multicore and symmetrical pair/quad cables for digital communications—horizontal wiring—specification for unbalance attenuation [at the near end (LCL) and at the far end (LCTL)]
ANW IEC 61156-2-1 Amd. 2. Amendment to IEC 61156-2-1—horizontal wiring. Specification for velocity of propagation
ADIS IEC 61156-2-1 Amd. 2. Amendment to IEC 61156-2-1: Blank detail specification for multicore and symmetrical pair/quad cables for digital communications—horizontal wiring—specification for inbalance attenuation [at the near end (LCL) and at the far end (LCTL)]
ADIS IEC 61156-3 Amd. 2. Amendment to IEC 61156-3—work area wiring. Specification for velocity of propagation
ADIS IEC 61156-3-1. Amendment to IEC 61156-3-1—work area wiring. Specification for velocity of propagation
ANW IEC 61156-3-1 Amd.1. Amendment to IEC 61156-3-1: Blank detail specification for multicore and symmetrical pair/quad cables for digital communications—work area wiring specification for inbalance attenuation [at the near end (LCL) and in the far end (LCTL)]
ADIS IEC 61156-4 Amd. 2. Amendment to IEC 61156-4—riser cables. Specification for velocity of propagation
ADIS IEC 61156-4. Amendment to IEC 61156-4: sectional specification for multicore and symmetrical pair/quad cables for digital communications—riser cables—specification for inbalance attenuation at the near end (LCL) and at the far end (LCTL)
ADIS IEC 61156-4-1. Amendment to IEC 61156-4-1—riser cables. Specification for velocity of propagation
ANW IEC 61156-4-1. Amendment to IEC 61156-4-1: Blank detail specification for multicore and symmetrical pair/quad cables for digital communications—riser cables—specification for imbalance attenuation at the near end (LCL) and at the far end (LCTL)
ANW IEC 61156-6. Balanced cables to be used up to 200 MHz and 600 MHz
APUB IEC TS 61873. State of the art for symmetrical pair/quad cables with transmission characteristics beyond category 5
ANW IEC 62012. Sectional specification for multicore and symmetrical pair/quad cables for digital communication for use in harsh environment and in case of fire (security)

ADIS: approved draft international standard; ANW: accepted new work; APUB: approved for publication; CD: committee draft; CCDV: committee draft for vote; LR: liaison report; NWIP: new work item proposal; PNW: proposed new work; WD: working draft; St: study.

From this definition one can deduce that standards will contain compromises, as they have to meet the requirements of many parties. The larger the geographical area served by a standard, the wider is the span of circumstances, interests, and backgrounds it has to cover. An international standard has to meet needs on a global basis. The specifications an international standard provides have to respond to hot and cold, damp and dry climates, and to countries with low and high densities of trained professionals and with all levels of living standards. Since it is neither the job of international standards nor desirable to make the world look the same wherever you go, standards committees have to respect that the world is different and at the same time support establishment of systems crossing borders, and of international trade and commerce.

Thus an international standard will specify the requirements for a system as tightly as necessary to guarantee a minimum of compatibility and performance. At the same time, its requirements must remain as

Table 17: Standards and Projects for Connectors on the International Level

Connectors for Mains

IEC/TR3 60083 (1997-08). Plugs and socket outlets for domestic and similar general use standardized in member countries of IEC

Connectors for CCCB

European level: CENELEC TR 9. Home and Building Electronic Systems (HBES)—Technical Report 9: Media and media dependent layers—network based on twisted pair class 1.

Copper Connectors for ICT

IEC 60603-7:1996. Connectors for frequencies below 3 MHz for use with printed boards—part 7: Detail specification for connectors, 8-way, including fixed and free connectors with common mating features, with assessed quality

ADIS 60603-7-1. Inclusion of shield mating in IEC 60603-7

ADIS 60603-7-2. Amendment to IEC 60603-7: Detail specification for 8-way connectors, with assessed quality, including fixed and free connectors with common mounting features; test methods and related requirements for use at frequencies up to 100 MHz

ANW IEC 60603-7-4. Characterization of IEC 60603-7 up to 200 MHz

1CD IEC 60603-7-7. Definition of an 8-way connector (possibly based on IEC 60603-7) up to 600 MHz

IEC 60807-8:1992. Rectangular connectors for frequencies below 3 MHz—part 8: Detail specification for connectors, four-signal contacts and earthing contacts for cable screen

PNW 48B-766. Measurement of transfer impedance of multipole connector, in the frequency domain, for frequencies up to 1 GHz

Fiber Optic Connectors for ICT

IEC 60847-10:1992. Connectors for optical fibers and cables—part 10: Sectional specification—fiber optic connector type BFOC/2,5

IEC 60847-10-1:1997. Connectors for optical fibers and cables—part 10-1: Detail specification for fiber optic connector type BFOC/2,5 terminated to multimode fiber type A1

IEC 60847-10-2:1997. Connectors for optical fibers and cables—part 10-2: Detail specification for fiber optic connector type BFOC/2,5 terminated to single-mode fiber type B1

IEC 60847-10-3:1997. Connectors for optical fibers and cables—part 10-3: Detail specification for fiber optic adaptor type BFOC/2,5 for single and multimode fiber

IEC 60847-14:1993. Connectors for optical fibers and cables—part 14: Sectional specification for fiber optic connector—type SC

IEC 60847-14-1:1997. Connectors for optical fibers and cables—part 14-1: Detail specification for fiber optic connector type SC/PC standard terminated to multimode fiber type A1a, A1b

IEC 60847-14-2:1997. Connectors for optical fibers and cables—part 14-2: Detail specification for fiber optic connector type SC/PC tuned terminated to single-mode fiber type B1

IEC 60847-14-3:1997. Connectors for optical fibers and cables—part 14-3: Detail specification for fiber optic adaptor (simplex) type SC for single-mode fiber

IEC 60847-14-4:1997. Connectors for optical fibers and cables—part 14-4: Detail specification for fiber optic adaptor (simplex) type SC for multi-mode fiber

IEC 60847-14-5:1997. Connectors for optical fibers and cables—part 14-5: Detail specification for fiber optic connector type SC-PC untuned terminated to single-mode fiber type B1

IEC 60847-14-6:1997. Connectors for optical fibers and cables—part 14-6: Detail specification for fiber optic connector—type SC-APC 9° untuned terminated to single-mode fiber Type B1

IEC 60847-14-7:1997. Connectors for optical fibers and cables—part 14-7: Detail specification for fiber optic connector type SC-APC 9° tuned terminated to single-mode fiber Type B1

IEC 60847-19-1:1995. Connectors for optical fibers and cables—part 19: Sectional specification for fiber optic connector—type SC-D(uplex)

Copper Connectors for HE

IEC 60169-2 (1965-01). Radio-frequency connectors—part 2: Coaxial unmatched connector

IEC 60169-24 (1991-11). Radio-frequency connectors—part 24: Radio-frequency coaxial connectors with screw coupling, typically for use in 75 Ω cable distribution systems (type F)

ADIS: approved draft international standard; ANW: accepted new work; CD: committee draft; CCDV: committee draft for vote; LR: liaison report; NWIP: new work item proposal; PNW: proposed new work; WD: working draft; St: study.

Table 18: Standardization Organizations and Committees for Cabling on the World Wide Web[a]

Organization/Committee	Title	Address
IEC	International Electrotechnical Commission	http://www.iec.ch/
ISO	International Standards Organisation	http://www.iso.ch/
ITU	International Telecommunications Union	http://www.itu.int/
ISO/IEC JTC 1/SC 25	Interconnection of information technology equipment	http://www.iec.ch/sc25/home-e.htm
ISO/IEC JTC 1/SC 25/WG 3	Customer premises cabling	http://www.iec.ch/sc25/txt/wg3/presentation/home_wg3.htm
IEC SC 100D	Cabled distribution systems	http://www.iec.ch/cgi-bin/procgi.pl/www/ iecwww.p?wwwlang=E&wwwprog=dirdet.p&committee=SC&number=100D
CENELEC	European Committee for Electrotechnical Standardization	http://www.cenelec.be
CLC/TC 215	Electrotechnical aspects of telecommunication equipment	

[a]Committees for cables, connecting hardware, and applications may be found via their parent organizations IEC, ISO, and ITU.

open as possible to give all the freedom needed to adjust its implementation to the requirements of the many different countries who are asked to use the international standard as a pattern for their national standards.

There are many ways to achieve this flexibility and still meet the aim of international standards. Specification of interfaces to neighboring systems and of the overall performance of a system while allowing freedom of internal implementation of the system itself is a common method. Listing options is another way. ISO/IEC 11801 (1) uses both methods: it is based on the black box approach, it lists a number of options, and in some places it limits itself to functional requirements.

Design freedom.

Allowed Thinking. ISO/IEC 11801 (1) specifies minimum requirements, and it provides models for horizontal cabling. The user is free to choose his way to meet the minimum requirements. Implementations that are not forbidden are allowed, as long as they meet the requirements.

The author has had many discussions with respect to freedom given or taken by the standard. Here are answers to frequently asked questions, which allow the reader to develop his own answer to other questions:

- As long as the performance and administration of generic cabling is ensured, there is no objection to the installation of additional material.
- With the exception of the TO, any mating interface meeting performance requirements specified in the standard may be used.
- A link whose length is 1.6 km will deliver sufficient bandwidth when a fiber with 160 MHz·km is installed. Thus the fact that the standard specifies a minimum cable bandwidth of 200 MHz·km to support a full 2 km distance does not preclude alternative cable specifications when used with shorter links.

The black box approach. As far as the performance of channels and permanent links is concerned, ISO/IEC 11801 primarily specifies the minimum overall performance and gives its user freedom of design. As long as the application gets at least the performance specified and as long as the specified mating interfaces are provided at the TO, the cabling designer is free to choose any material. To make life easier and to provide guidance to the manufacturers of components, models for horizontal channels are contained in the standard. (See Fig. 14.) These channels span the maximum lengths provided for in this standard for horizontal cabling. Parts of the channel performance are allocated to the parts of the channel in such a way that material just meeting the minimum performance for a specific category will provide the minimum performance of the appropriate channel over the maximum distance, as long as the material is installed properly and the channel is not operated at higher temperatures than calculated. For example, category 5 will provide the minimum performance of class D as long as the channel is operated from transmitter to receiver at or below the temperature corresponding to the cable's compliance to the standardized minimum performance. It should be noted that most cable characteristics are specified at 20°C and that some of them vary with temperature.

As often in life, more freedom is associated with more responsibility. When the designer chooses to use the freedom, greater design expertise is required. In principle it is even possible to go beyond the 90 m of the maximum distance for the permanent link. Using the excellent cables on the market, a designer may choose to serve three floors from one distributor, but would still be well advised to allocate space for a distributor within 90 m of the TO. Whenever the standardization bodies develop a new channel class, they will make sure that it is possible to produce components meeting the new performance class with permanent links of 90 m and with connecting hardware at the horizontal distributor, transition/consolidation point, and TO. Whether the market will also provide the material for longer links of that new channel class remains unknown.

Many transmission characteristics of a channel change with the temperature of the cables used. The minimum channel performance required by the application is constant regardless of the ambient temperature to which the cabling is exposed. In general, the cable characteristics are specified at 20°C. In case the cabling is routed through areas with higher temperatures, its designer has to calculate the effects of that temperature and make sure that the minimum performance of the transmission channel is met.

Paths for Applications and Cabling. One of the objectives of ISO/IEC 11801 (1) and its regional and national equivalents is to provide a stable and reliable interface between cabling and applications. It separates the markets for cabling and for applications. This separation intensifies international competition and promotes innovation in the two technical areas. Applications developed in one part of the world will run on the infrastructure developed elsewhere. As long as a consistent migration strategy is observed, this achievement is preserved with further development.

A successful standardization strategy for cabling, its components, and applications could look as follows. Cabling standards specify a minimum performance for channels on the basis of the best components found on the market. New installations observe this specification, and over time a significant share of the installed cabling offers this minimum performance to applications. This is the moment when new applications are developed that require this upgraded channel performance, though their users were satisfied with less performant channels as long as those were in the majority. As the number of applications grows that require this upgraded channel performance, the developers of cabling components upgrade their material, and even better channels may be specified for a next generation of cabling and for another generation of applications. How often this process is repeated is open. Not long ago many experts believed that optical fiber would take over horizontal cabling above 100 MHz; today copper channels are being standardized up to 250 MHz and 600 MHz. Many predict this to be the end for balanced cables, while others promote the use of balanced cables for TV distribution, which may require more than 1 GHz.

Options in ISO/IEC 11801.

100 Ω and 120 Ω Cables. ISO/IEC 11801 (1) provides for nominal impedances of both 100 Ω and 120 Ω. Applications will work with both, as an application is less sensitive to the small mismatch between channel and application than to irregularities of the impedance within the channel. As long as the return loss is beyond a certain minimum, the mismatch between a 100 Ω application and a 120 Ω cable will not pose a problem.

Two-pair and four-pair Cables. Most applications standardized today use one pair or one fiber per direction. Some can do with one pair for both directions. Sometimes another pair is used for power, although power can also be provided via the phantom formed by two pairs. Standards are now being developed for an application using all four pairs that are supported by IEC 60603-7 (4). However, at the end of the eighties, when only applications using one or two pairs for transmission where known, the IEC 60603-7 connector with eight pins was chosen for the TO. At that time one expected ISDN to need four pairs, two for information; the phantom and another two pairs were intended for different kinds of power. After the IEC 60603-7 connector had been chosen for ISDN, it was also used by other applications. To avoid mistakes, many of these applications have chosen pair assignments different from that of ISDN. Figure 15 lists many standardized applications with their pin assignment. Today these different assignments cause more trouble than good. First, there are more applications than possibilities to differentiate with help of pin assignment. Second, misconnection has

	Digital telecommunications interfaces				Analog telecommunications interfaces			Computer-network interfaces						LAN interfaces			Multiplex interface		ATM interfaces
Pin	S_0 ISO 8877		U_{PN} U_{PO} U_{200} U U_{2B1Q}	U_{PN} U_{PO} U_{200}	Analogue a/b		PBX a/b/c/d	AFP 4-Pint	IMD/AFP 2-Pint	BAM 4-Pin	IBM Coax, Twinax, AS400			10BASE-T	Token ring 4, 16 Mbit/s	FDDI & TP-PMD: CDDI, TPDDI	S_2		ATM with TP-PMD
	Stan-dard	Option	Standard	Option	PBX	1TR2					Balun alternative 1	Balun alternative 2	DPC				Stan-dard	Option	
1								Trans-mitter a	XA 1	T A	X			TD +		X			X (planed)
2								Trans-mitter b	XA 2	T B	X			TD –		X			X (planed)
3	T +	T +		Loc.P.–	W	b	c	Receiver a		R A			X	RD +	TX–A		R	R	
4	R +	R +	a	a	a	E	a					X			RX–A		T	T	
5	R –	R –	b	b	b	W	b					X			RX–B		T	T	
6	T –	T –		Loc.P.+	E	a	d	Receiver b		R B			X	RD –	TX–B		R	R	
7		Loc.P.–														X		Loc.P.–	X (planed)
8		Loc.P.+														X		Loc.P.+	X (planed)
	Shielded cabling not needed											Shielded cabling needed							

Fig. 15. Pin assignment for IEC 60603-7. (Source: Siemens.) Balun: Depending on the balun, differenet pin assignments may be used. Loc. P: local power. PBX: example of one specific PBX.

to be coped with by the application equipment; thus different pin assignments are not in fact needed. Third, differences in pin assignment may require administration.

A generic cabling system has to provide its channels to any of these applications; thus it has to offer to each of them the pairs it needs. To do so in case the application only needs two pairs, as most of them do, there are three options:

- *Always terminate four pairs at an IEC 60603-7 interface* (see left side of Fig. 16): *the right two pairs are always there.*

Benefits

(1) Easy to handle, standard cord
(2) Cables with lower NEXT may be used

Drawbacks

(1) Waste of copper and space in ducts and
(2) distributors
(3) Higher burning load
(4) Higher investment in cables

- *Run four pairs to an outlet, and either serve two IEC 60603-7 interfaces with inserts or connect all four pairs to one outlet* (see right side of Fig. 16): *the right two (one, three, or four) pairs are provided by inserts.*

Benefits

(1) Standard cord
(2) Easy to handle for the user
(3) Low conduit fill and burning load

Drawbacks

(1) Network configuration has to administer inserts
(2) Higher investment in connecting hardware

- *Always terminate two pairs at an IEC 60603-7 interface* (see middle of Fig. 16): *different cords provide the right pairing.*

Benefits

(1) Efficient use of hardware
(2) Low conduit fill and burning load

Drawbacks

(1) User has to administer different connecting cords
(2) Four-pair application needs a Y cable, which may create a large delay skew

While Y cables are quite common in certain parts of the world, the most commonly used strategies are shown in Fig. 17: cable sharing with help of inserts at the TO, and TOs fully equipped with four pairs but very seldom using all of them.

The international cabling standard gives the user the freedom to choose whether to invest in cables, connecting hardware, or administration of cords. There are products available that run four pairs to a possible double outlet. With help of inserts one can provide the application with any pin assignment; see Fig. 16.

In case a country converts the international standard to a national one, it even may eliminate one or the other option to better reflect the customs of the country or availability of national resources. As an example, North America, with the United States and Canada being two of the world's three biggest suppliers of copper, prefers to install four pairs per outlet, while Europe uses labor to administer inserts and cords rather than buy and install unused copper.

Shielded and Unshielded Cables. In ISO/IEC 11801 (1) shielding is an option. Again, some countries have specified shielding as mandatory in their national standard for channels used above 30 MHz.

As explained in the subsection "Electromagnetic Compatibility" above, there is a interrelation between the signal shape and amplitude, the balance of applications, and the coupling attenuation of cabling. A user who invests in higher coupling attenuation may gain the freedom to choose applications that have sharper signals or cheaper line adapters, since less effort has been put into their balance.

The user may also choose the option of shielding for security reasons and to protect data from external interference. Shielded cabling may also be required to meet the national EMC regulations.

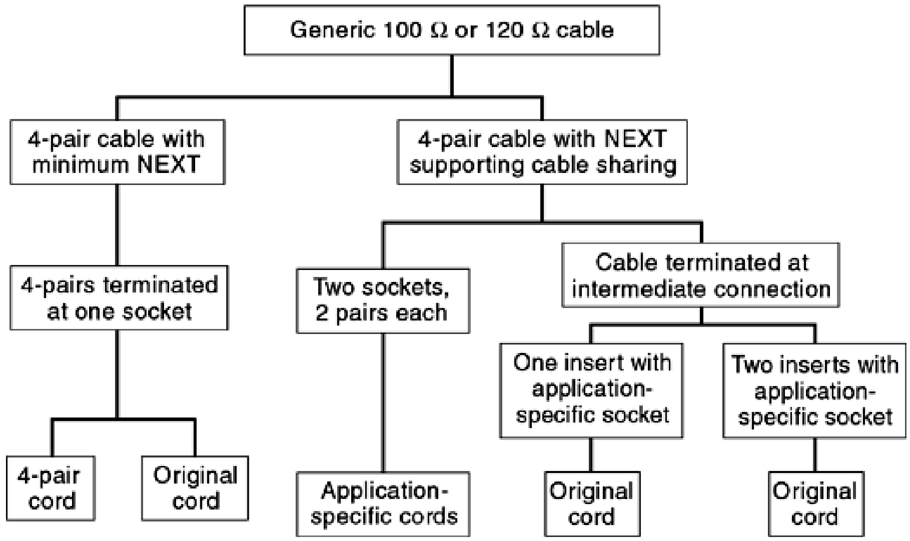

Fig. 16. Cabling strategies.

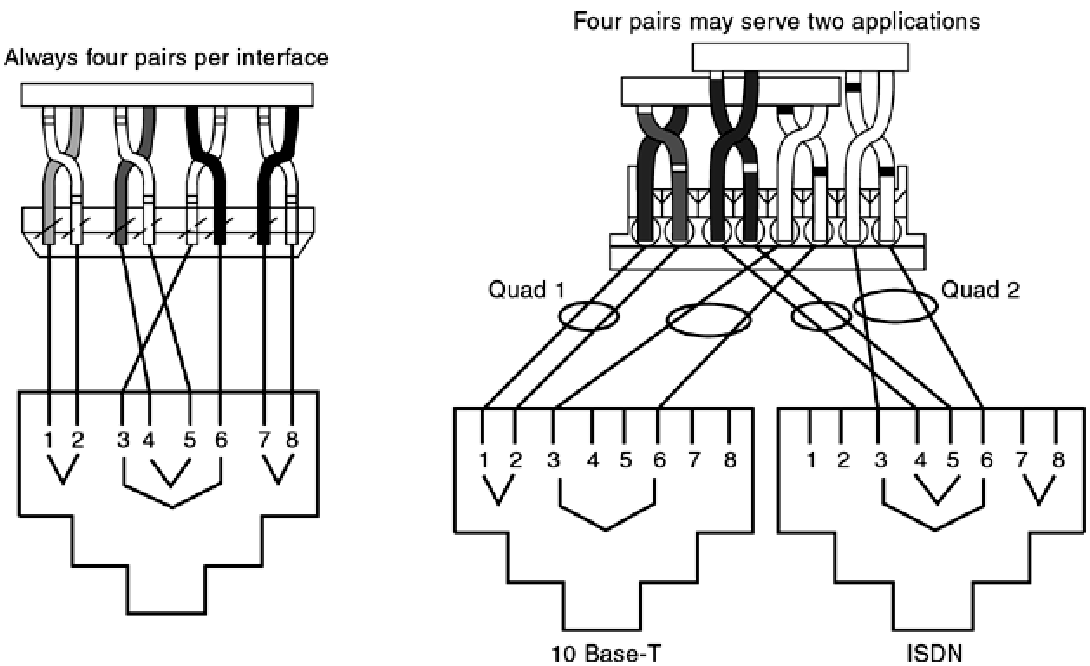

Fig. 17. Most common cabling strategies.

Cross-connected versus Interconnected Calbes. As shown in Fig. 2, there are many locations in the cabling topology where cables may be interconnected. At distributors there is the question whether this should be done with a cross-connect or an interconnect.

In a cross-connect the cables from different cabling subsystems and equipment are each terminated on dedicated termination fields in the form of patch panels or connecting blocks. These termination fields are connected to one another using patch cords or jumpers. In an interconnect there is only one termination field. Connections to equipment or between subsystems are provided at the termination fields with the use of attachment cords.

In the campus and the building distributor cross-connects are commonly used. At the transition point one uses interconnects. For the floor distributor there are alternatives. As far as the connections between horizontal cabling and backbone are concerned, the cross-connect is the common solution. Connections to application-specific equipment are accomplished using a cross-connect or interconnect as shown in Fig. 2. With an interconnect the equipment cable is directly connected to the block or patch panel where the horizontal terminal is terminated. With a cross-connect the equipment cables are terminated at a block of their own, and patch cords or jumpers provide the connection to the horizontal cable. Both solutions have their followers; thus the international standard presently allows the two options.

It should be noted that the choice between these two options requires some performance calculation. With higher frequency the influence of crosstalk of connecting hardware on channel performance increases. To allow for all acceptable cabling implementations, channel requirements include an allowance for cross-connections at the FD.

The effect of multiple connectors has to be calculated on the basis of the voltage sum in the case where the distance between connectors is on the order of a few wavelengths. For longer distances the power sum applies. In case of a cross-connect, two connections are very near to each other; thus voltage sum applies:

$$\mathrm{NEXTChannel} = -20\log\left(10^{-\frac{\mathrm{NEXTcable}}{20}} + 10^{-\frac{\mathrm{NEXTNonnectingHW}}{20}}\right) \qquad (1)$$

In case both blocks have the same NEXT, the channel performance is degraded by 6 dB, as compared to 3 dB for the power sum. In order to meet the channel performance in a cross-connect, connecting hardware therefore has to have less crosstalk than in an interconnect environment, the channel performance of which may be calculated with

$$\mathrm{NEXTChannel} = -10\log\left(10^{-\frac{\mathrm{NEXTcable}}{10}} + 2\times 10^{-\frac{\mathrm{NEXTNonnectingHW}}{10}}\right) \qquad (2)$$

Abbreviations

ac	Alternating current
ACP	Application connection point
ACR	Attenuation-to-crosstalk ratio
ADO	Auxiliary disconnect outlet
BD	Building distributor
CATV	Community antenna TV
CCCB	Commands, controls, and communications in buildings
CTV	Cable television
CD	Campus distributor
CI	Cabling interface
CSMA/CD	Carrier sense multiple access/collision detection
DD	Distribution device
DP	Demarcation point
EF	Entrance facility
EMC	Electromagnetic compatibility

EMI	Electromagnetic interference
EQP	Application-specific equipment
FCC	Federal Communications Commission (United States)
FD	Floor distributor
FEXT	Far-end crosstalk attenuation
ffs	for further study
HBES	Home and building electronic systems (a generic term for home and commercial building automation systems)
HCS	Home control system (a term for a generic home automation system)
HE	Home entertainment
HES	Home electronic system, an ISO/IEC standard (under development in 1998)
hi-fi	High fidelity
HVAC	Heating, ventilating, and air conditioning
ICT	Information and communications technology
ISDN	Integrated Services Digital Network
IT	Information technology
MM	Multimedia
N/A	Not applicable
NEXT	Near-end crosstalk attenuation
PBX	Private branch exchange
PE	Protective earth
PELV	Protective extralow voltage
RCP	Room connection point
SELV	Safety extralow voltage
SOHO	Small offices and home offices
TE	Terminal equipment
TO	Telecommunications outlet
TP	Transition point
TR	Technical report
TV	Television

Definitions

Application.. (ISO/IEC 11801 modified (1)) A system with an associated transmission method that is supported by the generic cabling.

Application class.. A group of applications with common channel requirements.

Balanced cable.. (ISO/IEC 11801 (1)) A cable comprising one or more metallic symmetrical cable elements (twisted pairs or quads).

Building.. (ISO/IEC CD15018 (2)) An individual fixed structure. This may contain commercial, residential, or light industrial premises.

Cable.. (ISO/IEC 11801 (1)) An assembly of one or more cable units of the same type and category in an overall sheath. It may include an overall shield.

Cable element.. (ISO/IEC 11801 (1)) The smallest construction unit in a cable. A cable element may have a shield.

Cable unit.. (ISO/IEC 11801 (1)) A single assembly of one or more cable elements, usually of the same type or category. The cable unit may have a shield.

Cabling.. (ISO/IEC CD15018 (2)) The assembly of all cables, connections, patch panels, and other passive components that constitute the telecommunications infrastructure.

Campus.. (ISO/IEC 11801 (1)) A premises containing one or more buildings.

Consolidation point.. (Draft) An easily adapted location in the horizontal cabling where a cable may end, that is not subject to moves and changes, and whence another cable leads to the TO.

Cross-connect.. A facility enabling the termination of cable elements and their connection, primarily by means of patch cords or jumpers.

Distribution device.. (ISO/IEC CD15018 (2)) A facility located within a dwelling unit for interconnection or cross-connection.

Equipotential bonding.. Fittings for reducing the voltage difference between accessible devices or between buildings.

HE (home entertainment) applications.. (ISO/IEC CD15018 (2)) The group of applications providing home entertainment (radio, TV) in analog or digital format via antennas or coaxial cables, with a bandwidth typically up to 2 GHz or 2.5 GHz.

HES class I.. (ISO/IEC CD15018 (2)) The group of applications with the lowest bandwidth requirement, such as appliance control and building control.

HES class II.. (ISO/IEC CD15018 (2)) The group of applications with a medium bandwidth requirement, such as telephony and LANs.

HES class III.. (ISO/IEC CD15018 (2)) The group of applications with the highest bandwidth requirement, such as radio, TV, and multimedia.

Home.. (ISO/IEC CD15018 (2)) A fixed residential premises for use by a single family or household as a dwelling place. This may be an individual building or a part of a larger building, such as an apartment.

Home distributor.. (ISO/IEC CD15018 (2)) A distributor in which the floor backbone cables terminate and where connections are made to external cabling systems (e.g., carriers), or to the building backbone in multitenant buildings.

Home electronic system.. (ISO/IEC CD15018 (2)) A network and communications protocol for home control systems that conform to the ISO/IEC HES standard (under development in 1998). Applications span appliance control, entertainment, security, lighting, and environmental management (such as HVAC). An HES network may apply in homes and mixed-use buildings that combine residential and commercial spaces. Other terms related to HES are defined in CD 10192-1: Information technology—Home Electronic System—Part 1: Terminology.

ICT (information and communications technology) Applications.. (ISO/IEC CD15018 (2)) The group of applications making up information and telecommunications, such as telephone, ISDN, and LANs, spanning a frequency range up to 100 MHz or higher.

Interconnect.. (ISO/IEC 11801 (1)) A location at which equipment cables are terminated and connected to the cabling subsystems without using a patch cord or jumper.

Jumper.. (ISO/IEC 11801 (1)) A cable unit or cable element without connectors, used to make a connection on a cross-connect.

Link.. (ISO/IEC 11801 (1)) The transmission path between any two interfaces of generic cabling. It excludes equipment and work-area cables.

MM (multimedia) applications.. (ISO/IEC CD15018 (2)) The sum of applications found in information and telecommunications technology as well as home entertainment. Many multimedia applications use digital techniques to enhance the quality and durability of the source material and to compress it for efficient transmission and storage.

Network termination.. (ISO/IEC CD15018 (2)) The functional group on the network side of a user–network interface.

Outlet.. (ISO/IEC CD15018 (2)) The point at which applications are connected to the cabling, with either a fixed or a connectorized cable.

Patch cord.. (ISO/IEC 11801 (1)) A flexible cable unit or element with connector(s), used to establish connections on a patch panel.

Pathway.. The route a single cable or multiple cables take. It can be a duct, a canal, a dedicated space, or just the route an unprotected cable takes.

Link.. (ISO/IEC 11801 (1)) The transmission path between any two interfaces of generic cabling.

Power feeding.. (ISO/IEC CD15018 (2)) The function that provides the capability to transfer power across the interface of the home or small office.

Room.. (ISO/IEC CD15018 (2)) Part of a building enclosed by walls or partitions, floor, and ceiling.

Room distributor.. (ISO/IEC CD15018 (2)) The central point from which the cabling of a room (or small group of rooms) disseminates.

Shielded twisted-pair cable.. (ISO/IEC 11801 (1)) An electrically conducting cable comprising one or more elements each of which is individually shielded. There may be an overall shield, in which case the cable is referred to as a shielded twisted-pair cable with an overall shield.

Separation.. (ISO/IEC CD15018 (2)) Routing of cables along different paths that maintain a specified minimum distance between cables.

Transition point.. (ISO/IEC 11801 (1)) A location in the horizontal cabling where a change of cable form takes place; for example, flat cable connects to round cable, or cables with differing numbers of elements are jointed.

Twisted pair.. (ISO/IEC 11801 (1)) A cable element consisting of two insulated conductors twisted together in a determined fashion to form a balanced transmission line.

Unshielded twisted-pair cable.. (EN50173 (17)) An electrically conducting cable comprising one or more pairs none of which is shielded. There may be an overall shield, in which case the cable is referred to as unshielded twisted-pair cable with an overall shield.

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