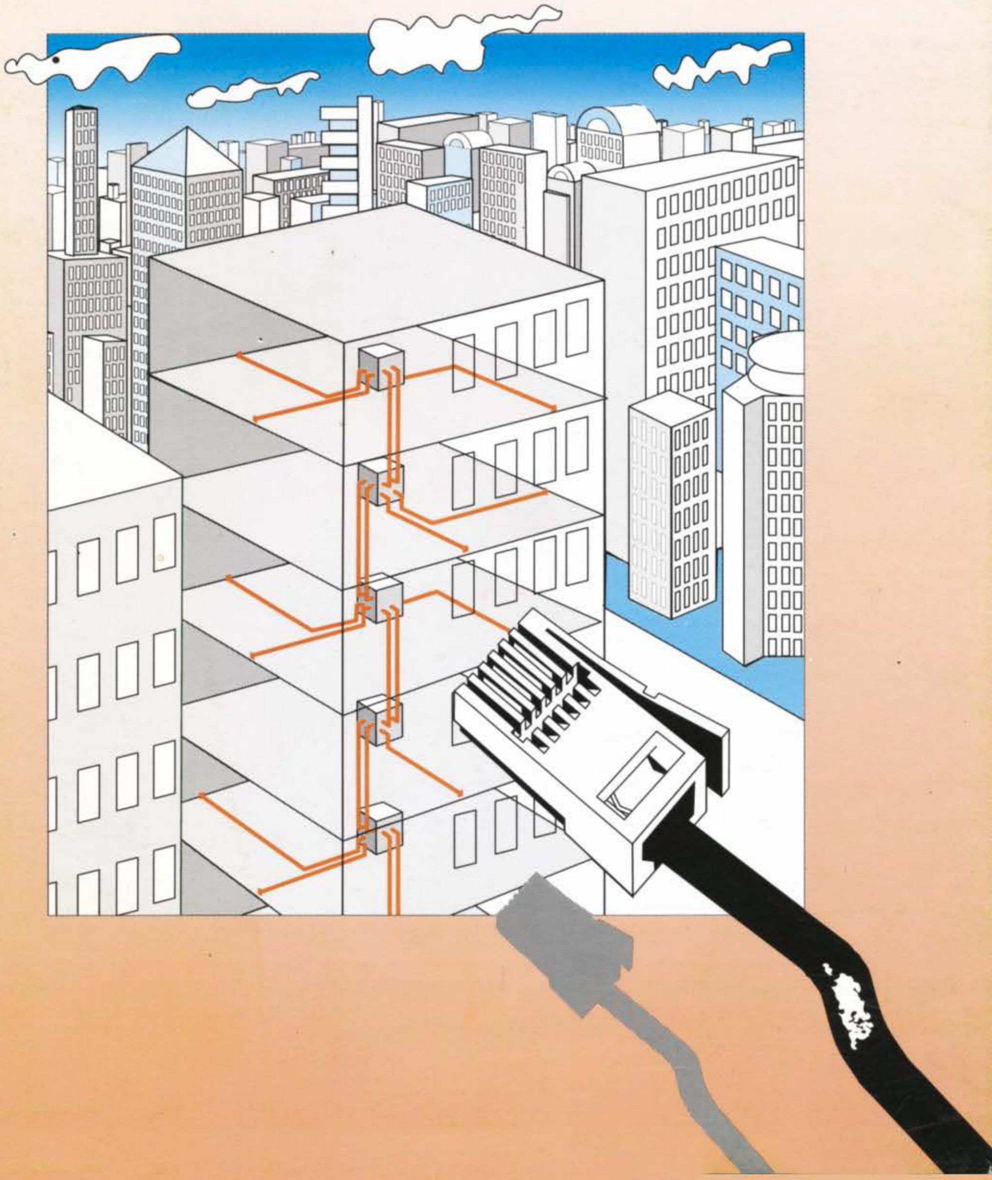
THE WIRING CODE

PART3

Shared Cabling



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GLOSSARY OF ABBREVIATIONS

BS	British Standard (from the BSI - British Standards Institution)
CCITT	International Telegraph and Telephone Consultative Committee
CRA	call routing apparatus
dBm	dB with respect to 1 mW in 600 ohm
dBm0	as above but referred to a point of zero relative level
dc	direct current
EIA	Electronic Industries Association (USA)
EMC	electromagnetic compatibility
EN	Norme Européenne (European Standard)
ENEXT	effective near end crosstalk
ETSI	European Telecommunications Standards Institute
FDDI	fibre distributed data interface
FDP	floor distribution point
GA	general approval
IEC	International Electrotechnical Commission
ISDN	integrated services digital network
ISO	International Organization for Standardization
LAN	local area network
mf	multifrequency
NEXT	near end crosstalk
NTP	network termination point
OSI	open systems interconnection
PBX	private branch exchange
PTN	public telecommunications network
PTO	public telecommunications operator
SELV	safety extra low voltage
S/T	S and T reference points (CCITT Recommendation I.411)
STP	screened twisted pair
TIA	Telecommunications Industries Association (USA)
TJF	test jack frame
UTP	unscreened twisted pair
vf	voice frequency
XT	crosstalk

Terms marked * in the text are defined in Annex A.

CONTENTS

SCOPE

1 This handbook is Part 3 of OFTEL's *Wiring Code* and covers wiring that is shared on the customer's side of the network termination point (NTP) within one sheath between circuits of different types*. A typical installation will have several exchange lines in one or more service categories and may have a variety of internal circuit types. For example wiring may be required to carry analogue voice-band speech and a digital signal such as 64 kbit/s speech or an ISO 8802-3 (Ethernet) 10baseT data signal. There are often economic advantages in being able to share wiring and this handbook contains the Principles and guidelines that show how this may best be done. It also gives advice on what may be best avoided.

2 Part 3 of the *Wiring Code* is divided into three main sections:

- Section A is a general section intended for all readers,
- Section B covers the application of the sharing guidelines. This material is intended for the installers, maintainers and designers of customer premises wiring installations and
- Section C is aimed primarily at persons responsible for the overall design of customer premises wiring installations.

Compared with Part 1 and Part 2 of the *Wiring Code*, Part 3 contains relatively complex technical material likely to be of interest to specialists. You may need to seek professional advice in the interpretation of Part 3. Further specialised information is available from OFTEL's Library in the form of a document entitled *Technical basis for the crosstalk data contained in Part 3 of the OFTEL Wiring Code.*

*any item marked with an asterisk is defined in Annex A

3 Part 1 of OFTEL's *Wiring Code* deals with simple installations and covers most domestic wiring situations, while Part 2 covers business and other complex installations. Part 3 complements the previous parts and adds to the Principles (A to X) that are stated there and which remain unchanged. Part 1 is concerned with analogue circuit wiring while Part 2 deals with analogue and digital circuit wiring. Both of these types of wiring are approved apparatus as explained in Part 2, paragraph 24, and their approval numbers are abbreviated to GA5 for analogue circuit wiring in isolation and GA9 for digital circuit wiring in isolation. Neither of these approvals covers wiring shared between analogue and digital circuits although different types of digital signal may share digital circuit wiring, but as is recognised in paragraph 96 of Part 2 problems may arise if this is done.

Warning

4 The information in this handbook is based on probabilities and adherence to the guidelines contained herein is not a guarantee of satisfactory operation. An adverse combination of tolerances can result in a performance inferior to that indicated.

A GENERAL PRINCIPLES AND GUIDELINES

5 Principles and guidelines in this handbook are based on two legal obligations

- what you are licensed to do and
- what your apparatus is approved to do.

In addition, the handbook contains guidance on how wiring may be shared with minimum impairment to the performance of your network and the public network.

6 In this context shared wiring is

- wiring that is described as included in Part 2 paragraph 9 but which contains circuits of different types* within one sheath and when one or more of these circuits is connected to a public telecommunication operator's (PTO's) network,

shared wiring excludes

- integrated wiring as defined in Part 2, paragraph 119
- all the types of wiring excluded in Part 2, paragraph 9
- cable runs in which none of the circuits in a sheath is connected to a PTO network - this is called **private shared wiring.**

By this definition flexible leads and approved series connected apparatus are excluded from the definition of shared wiring but this does not mean that any impairments that they introduce can be ignored. Although private shared wiring is excluded, the principles and guidelines which apply to wiring connected to PTO networks may well be usefully applied to private wiring in a number of situations.

7 All relevant apparatus must be approved under the Telecommunications Act 1984 and this includes shared wiring (see Principle I in Part 2). The General Approval process for wiring does not involve an independent approval body but is a self certification process on the part of the manufacturer or supplier of the parts concerned. As from December 1992 shared wiring and the components associated with it have been approved under OFTEL General Approval NS/G/1235/N/100018 (GA18). Alternatively wiring may be approved for sharing as part of the apparatus to which it is attached; for example some 'black box' approved PBXs (see paragraph 34 herein and Part 2 paragraphs 32 and 36) permit shared wiring to be used for analogue and digital extensions. Approved apparatus may only be connected to a PTO network by approved wiring (Principle C of Part 1 of the *Wiring Code*), but

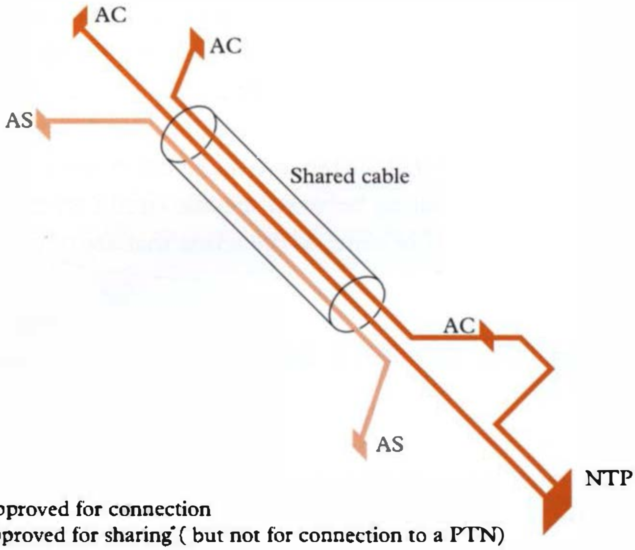
Y Apparatus that makes use of shared wiring but which is not connected to a PTO network need not be approved for connection to a PTO network but shall be approved under OFTEL General Approval NS/G/1235/N/100019 (GA19).

Apparatus approved under GA19 has to comply with the safety requirements in Table 1 (or must be connected via a barrier device in accordance with Principle AC) but there are no other requirements for such apparatus. Thus, as illustrated in Figure 1, a circuit joining two items of apparatus approved to GA19 can share a cable sheath with a circuit connecting apparatus to a PTO network.

8 The general principles and guidelines contained in Part 2 paragraphs 17 to 26 and 35 to 48 apply to shared wiring; note particularly that shared wiring that is connected in any way to call routing apparatus (CRA) will probably be subject to the designated maintenance requirements in the licence under which the system is run but in other respects the same Principles apply to all wiring configurations. However when (as shown in Figure 1) apparatus approved to GA19 is connected to shared wiring that is a Designated Maintainer's responsibility that responsibility may be confined to the wiring up to the point at which the apparatus approved to GA19 is attached and therefore:

Z Apparatus not maintained by a Designated Maintainer can be connected to shared wiring that is a Designated Maintainer's responsibility.

Nevertheless it is highly desirable that Designated Maintainers be kept



AC: approved for connection
AS: approved for sharing* (but not for connection to a PTN)

Figure 1 Sharing of a cable connected to apparatus not approved for connection to a PTN

informed of additions and changes to shared wiring connections when apparatus for which they are not responsible is involved. There is of course nothing to prevent a Designated Maintainer maintaining apparatus approved to GA19 and before connecting such apparatus you should establish with your Designated Maintainer whether it is included in or excluded from your maintenance contract.

9 Paragraph 27 of Part 2 of the *Wiring Code* explains (Principles J and K) when analogue and digital circuit wiring apply. There is a further principle for shared wiring:

AA Analogue circuits may share wiring with digital circuits provided that the performance of the approved shared wiring is adequate, in terms of Principle AD, for the relevant analogue/digital circuit combinations of circuit.

10 The satisfactory sharing of wiring between circuits of the same type or different types is highly dependent on achieving a high enough value of crosstalk* attenuation in the cable that couples them. Section C states the assumptions that are made and outlines the design procedures for establishing whether the crosstalk performance of the wiring is good enough for sharing between specific circuit types. Annex A contains definitions of some of the terms that are of direct relevance to Section B.

B APPLICATION OF THE SHARING GUIDELINES

Safety

11 Apparatus attached to different circuits in shared wiring will have been approved to different safety standards; for example information technology equipment to BS 7002 (EN 60950) and telecommunications apparatus to BS 6301. Of the relevant safety standards BS 6301 permits the highest voltages to be present and shared wiring components must be able to withstand safely, voltages at the BS 6301 'excessive voltage' limit.

AB The insulation resistance of shared wiring components must be tested at the voltage specified in OFTEL General Approval NS/G/1235/N/100019 (GA19) and must meet the limit specified there.

(**Note:** it is current practice to test insulation resistance at a voltage of several hundred volts (eg 500 V dc)).

Table 1 lists the relevant safety standards that are acceptable for apparatus connected to a public telecommunication system and which apply to all apparatus in this context.

AC Equipment that does not meet any of the safety standards listed in Table 1 may not be connected to shared wiring unless it be

Table 1 Safety standards

Standards body				
BSI	*IEC*	*ETSI*	*Interface condition*	*Equipment type*
415	65	-	Accessible terminals as defined and specified	Household-mains powered
5850 (withdrawn)	380	-	Accessible ports of limited current	Office machinery
6204 (withdrawn)	435	-	or SELV circuits	Data processing equipment
7002	950	EN 60950	-	IT and electronic business equipment
6301	-	EN 41003	Protected circuits as defined and specified	Telecommunications equipment

connected through a barrier or type-approved device having ports type-approved for connecting apparatus using voltages in excess of those implicit in meeting the requirements of Table 1.

Using the sharing guidelines

12 Whether a given combination of circuit types (eg analogue voice and ISDN) is suitable for sharing wiring depends on:

- The cable crosstalk* performance category (XT1 to XT5, see paragraph 15) for the relevant disturber* and disturbed circuits*.
- Whether that category is suitable for sharing at the reference length (which is 300 m unless indicated otherwise) and what the effective near end crosstalk (ENEXT) attenuation is at that length.
- If the cable category is suitable and the actual length is greater than the reference length, whether it is still suitable for sharing at the greater length.

- If the cable category is unsuitable for sharing at the reference length, whether it is suitable for sharing at the actual length when that length is less than the reference length.

- If there is more than one circuit causing crosstalk disturbance, whether sharing is still valid in the presence of multiple disturbers.

- Whether there are wiring components in addition to cable, eg connectors, that have an adverse effect on crosstalk performance.

Annex B contains a number of worked examples showing how the guidelines are applied in practice. Paragraphs 15 to 25 describe briefly what is covered under each of the steps listed above. The basis for establishing the material in these 11 paragraphs is contained within Section C.

13 Figure 2 is a flow chart which if read in conjunction with the following paragraphs helps to explain the procedures and decisions involved in establishing the suitability of cable for sharing.

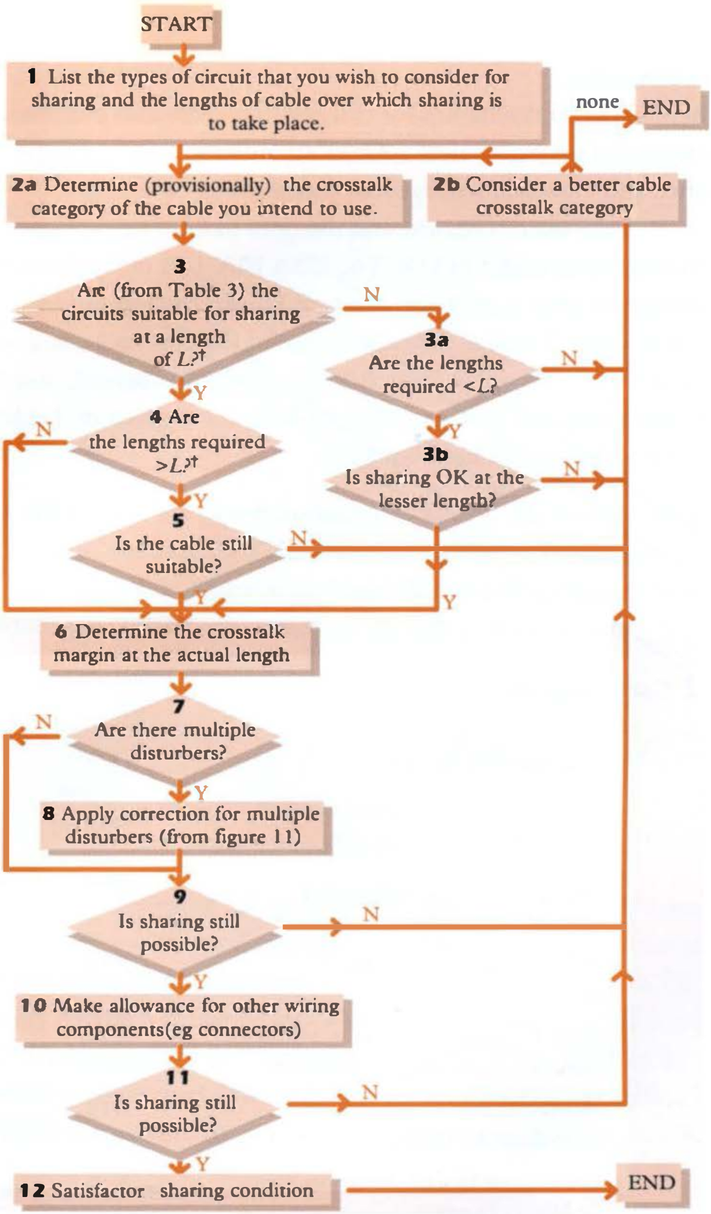
14 The following principle applies:

AD Wiring of any type is considered to be adequate for sharing between analogue and digital circuits provided that:

- The wiring is approved to OFTEL General Approval NS/G/1235/N/100018 (GA18), and

- For a disturbed analogue circuit, the chosen category of cable and after any necessary corrections for length and multiple disturbers, the ENEXT attenuation margin is equal to or greater than 0 dB.

The ENEXT attenuation margin is a measure (see paragraph 37) of how near crosstalk is to becoming unacceptable in a specific set of circumstances.



†L= 300 m unless Table 3 indicates the contrary

Figure 2 Cable sharing design - flow chart

Cable categories

15 There are several schemes for categorising cable into performance categories based on parameters such as attenuation, characteristic impedance and crosstalk attenuation. For sharing, crosstalk attenuation is the major concern and the only basis of categorisation for approving cable under GA18. The USA EIA/TIA organisations have established what is probably the best known categorisation scheme and Table 2 relates their categories to the crosstalk categories specified in GA18. When an international standard is agreed, and if the crosstalk categories in it are different from those given in Table 2, they will be added to this handbook.

16 Figure 3 shows the NEXT attenuation masks for each of the XT1 to XT5 categories. The masks express NEXT attenuation as a function of frequency and are all based on a length of 300 m. To qualify for approval under a specific category, the NEXT attenuation

Table 2 Cable categories

EIA/TIA category and functional description		*OFTEL crosstalk category*
1	Analogue voice and data up to a rate of about 20 kbit/s	XT1
2	ISDN and data up to a rate of about 4 Mbit/s	XT2
3	8802-3 (10baseT), 8802-5 at 4 Mbit/s Data rates up to about 16 Mbit/s	XT3
4	16 Mbit/s token ring. Data rates up to about 20 Mbit/s	XT4
5	Twisted pair FDDI*. Data rates above 20 Mbits/s (4 pairs)	XT5

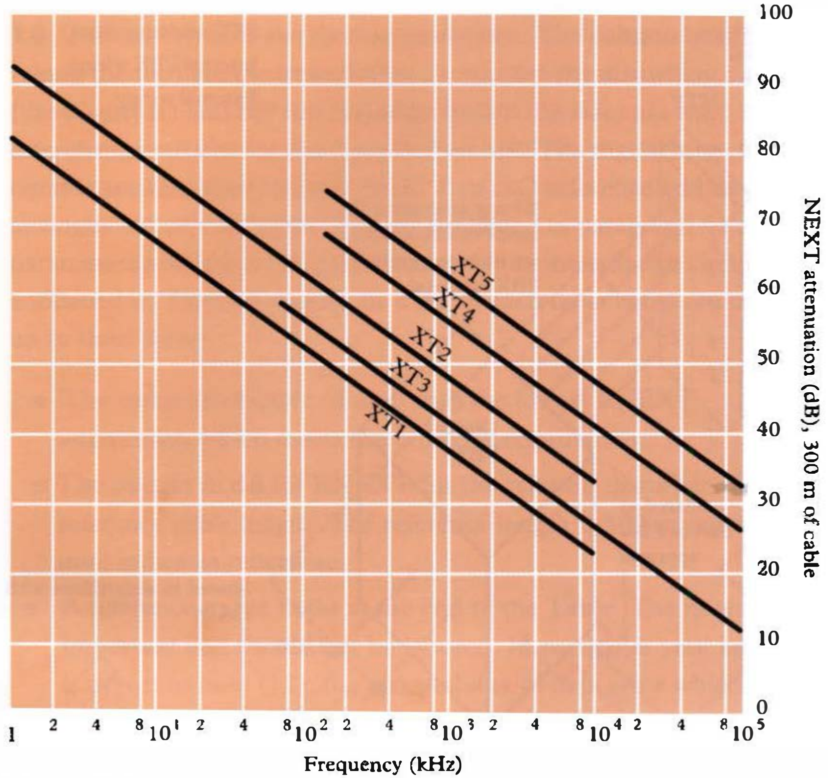


Figure 3 Near end crosstalk limits for cable categories XT1 to XT5

at all frequencies must fall on or to the right of the mask. Under the EIA/TIA scheme the performance of categories 1 and 2 cables is not quantified and this leads to the anomalous situation of the XT2 category having a better crosstalk performance than the XT3 category. EIA/TIA categories 3 to 5 are identical with XT3 to XT5 as far as crosstalk is concerned. The crosstalk performance of categories XT1 and XT2 correspond to cables commercially available in the UK.

Sharing table

17 The sharing table (Table 3, pages 28 and 29) applies specifically to pairs of circuits in twisted pair cable that are not screened from

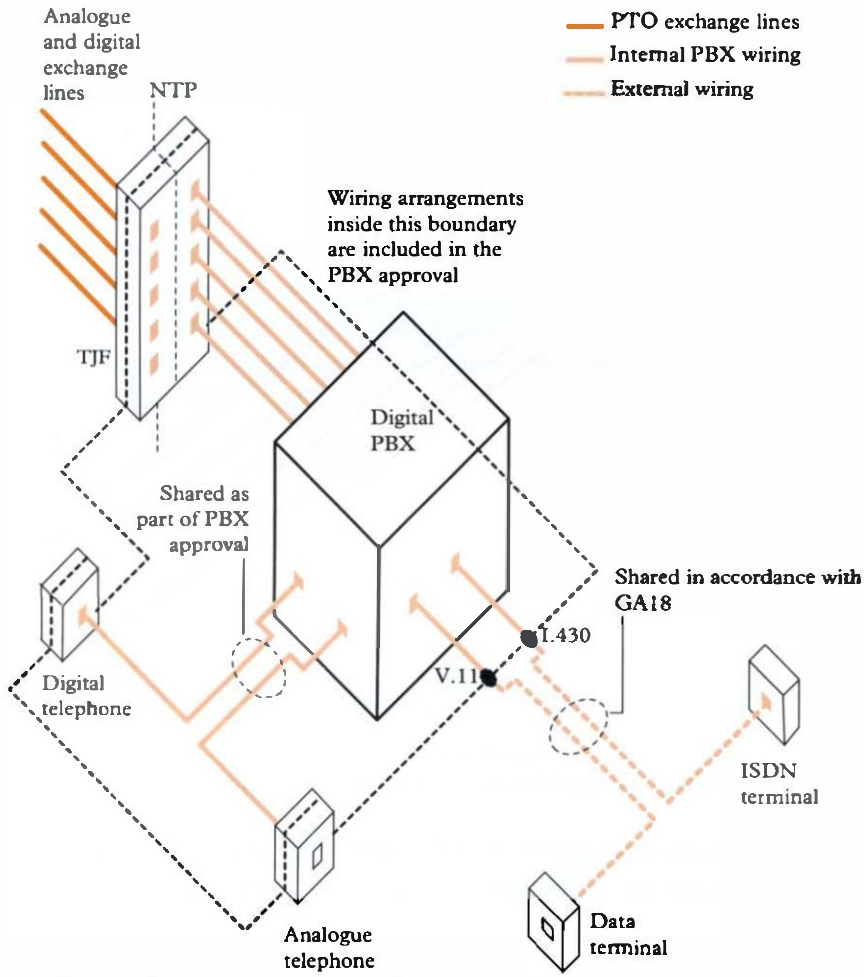


Figure 4 Example of shared wiring within and without the PBX approval boundary

each other (unscreened twisted pair or UTP). The table does not apply to sharing where the cable is approved as part of an apparatus approval, eg for a black box PBX. In such cases sharing is confined to what is specifically allowed in the relevant approval. Figure 4 gives examples of wiring within and outside the PBX approval boundary.

18 Table 3 contains the sharing guidelines. The column headings (along the top) are the interchange circuits for the disturbing circuit (the disturber) and the row headings (down the side) are the interchange circuits for the disturbed circuit. The digital interchange circuits are identified by their CCITT or ISO reference and the analogue circuits by 'types' that are explained in paragraph 61. Key parameters relating to the performance of the interchange circuits are contained in Tables 5 and 6. In Table 3 each table entry can contain up to three items:

- The category of cable (if any) with the lowest ENEXT attenuation which meets the crosstalk requirement.
- The margin in dB for ENEXT for the relevant disturber at the reference cable length. The reference length is 300 m unless a note indicates otherwise.
- A reference to the notes at the end of the Table. The notes are important and should not be ignored. In particular your attention is drawn to note (12); the acceptability of data error which are likely to arise from impulsive noise in analogue circuits depends on factors falling outside the scope of this *Wiring Code* and expert advice may be required.

For example an entry that reads XT3, 7 dB, (7) means that the XT3 category of cable has a margin of 7 dB for a length of 300 m and note (7) provides further information.

19 In situations where circuits of different types, say types A and B, share a cable the crosstalk attenuation requirement when A is regarded as the disturber will be different from the crosstalk requirement when B is regarded as the disturber and there are two entries in the Table, one under the A column and the other under the B column. The cable category (XT) entry in the table is determined by the lower of these two crosstalk attenuation values, or some other criterion apart from crosstalk, irrespective of which column the entry is in. However the ENEXT margin itself applies to the disturber that heads the column. For example, the V.11 (disturber) column shows a margin of 13 dB against the disturbed 8802-3 circuit (row) and the 8802-3 column shows a margin of 5 dB against the V.11 row. The latter is the more critical margin.

20 A crosstalk margin is also given when circuits of the same type share a cable (self-sharing). This margin is generally sufficient to allow any number of circuits of this one type and any length of cable up to a limit length set by other considerations such as attenuation. For a given circuit type, the self-sharing cable crosstalk category is the minimum considered to be satisfactory for any sharing situation.

21 An 'NA' in the Table means that for reasons of incompatibility of function (eg the length limit on one circuit is so short as to be incompatible with the normal length requirement of the other) the combination is not worth considering for sharing. A 'No' in the table indicates that there are no known practical situations in which the relevant combination is suitable for sharing. An 'NA' however does not indicate prohibition when all the circuits involved are digital. For combinations of digital circuit for which an 'NA' or a 'No' applies or for digital interchange circuits which are not listed at all in Table 3, you are free to reach your own conclusions as to suitability for sharing and act accordingly.

Table 4 Increase in ENEXT margin between XT categories

	Cable category				
	XT1	*XT3*	*XT2*	*XT4*	*XT5*
Increase in margin in dB	-	3	7	8	6

22 In some cases the chosen cable type will have a greater crosstalk attenuation than the category of cable given in Table 3. Table 4 gives the increase in margin in going from one category to the next better one. For example, suppose category XT1 is specified in Table 3 and the margin is 2 dB. The chosen cable category is XT4. Then from Table 4, the margin given in Table 3 is increased by 3+7+8 = 18 dB, giving a revised margin of 2+18 = 20 dB.

23 The ISDN digital section interface (CCITT Recommendations G.960, G.961) can use a variety of line codes, here U1 = MMS43, U2 = 2B1Q, U3 = AMI, U4 = AMI/TCM, U5 = Biphase and U6 = SU32. Table 3 is incomplete in respect of the crosstalk between digital sections and other types of digital circuit. This is a topic needing further consideration and it is intended to update this *Wiring Code* when further information is available.

Length correction

24 Depending on the type of circuit that constitutes the disturbing circuit, different length correction values will apply. Length correction graphs for some of the interchange circuits listed in Table 3 are as follows:

Digital disturbed circuits

Figure 5 - V.10 as disturber

Figure 6 - V.11 as disturber

Figure 7 - G.703 as disturber

Figure 8 - I.430, 8802-3 and 8802-5 as disturbers

Analogue disturbed circuits

Figure 9 - V.11, I.430 and G.703/64 kbit/s as disturbers

Figure 10 - G.703/2 Mbit/s, 8802-3 and 8802-5 as disturbers

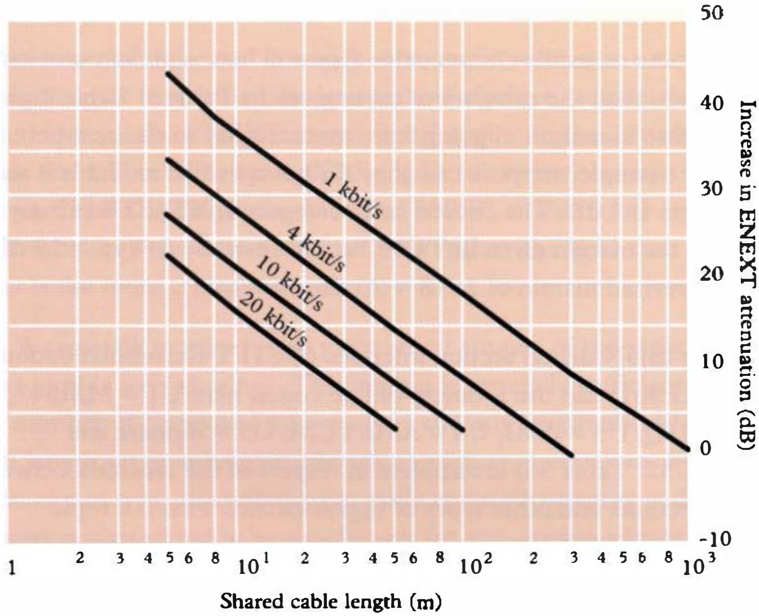


Figure 5 Length corrections for V.10 as disturber - digital disturbed circuit

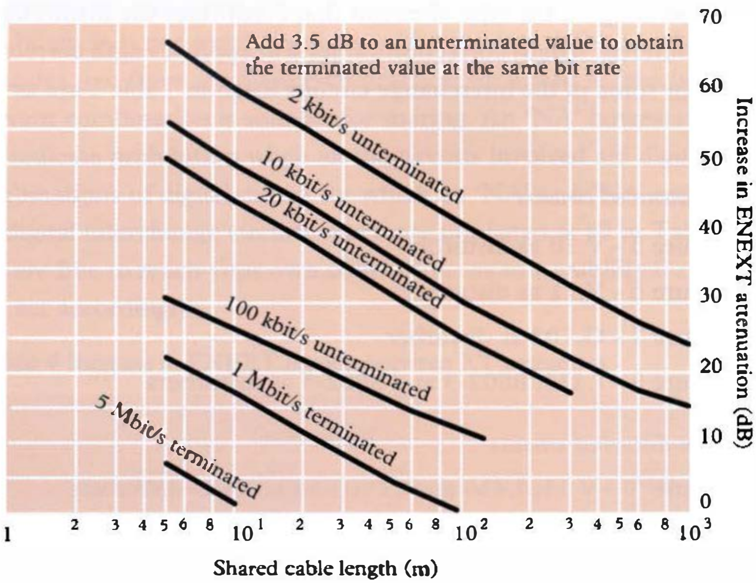


Figure 6 Length corrections for V.11 as disturber - digital disturbed circuit

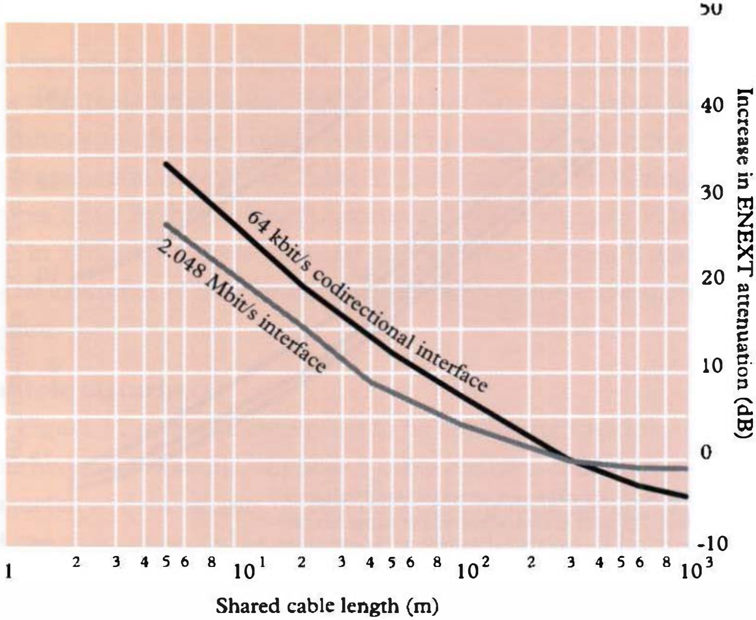


***Figure* 7** Length corrections for G.703 as disturber - digital disturbed circuit

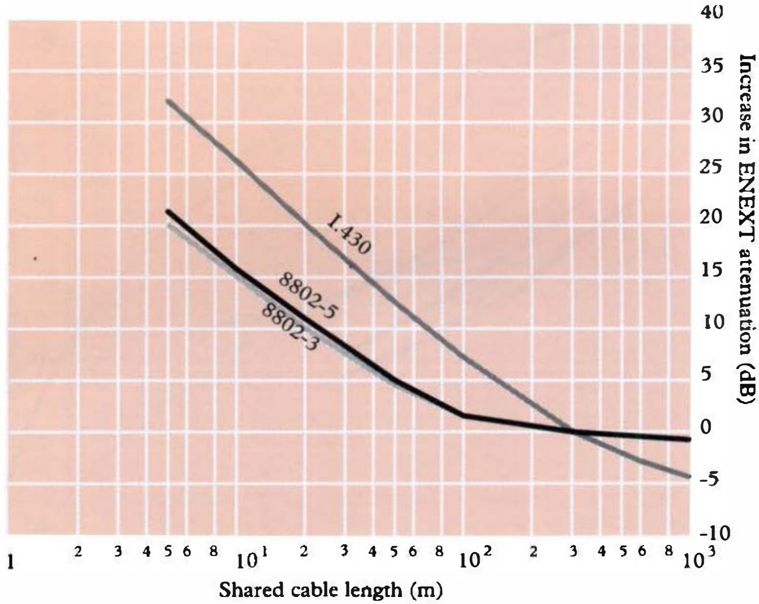


Figure 8 Length corrections for I.430, 8802-3 and 8802-5 - digital disturbed circuit

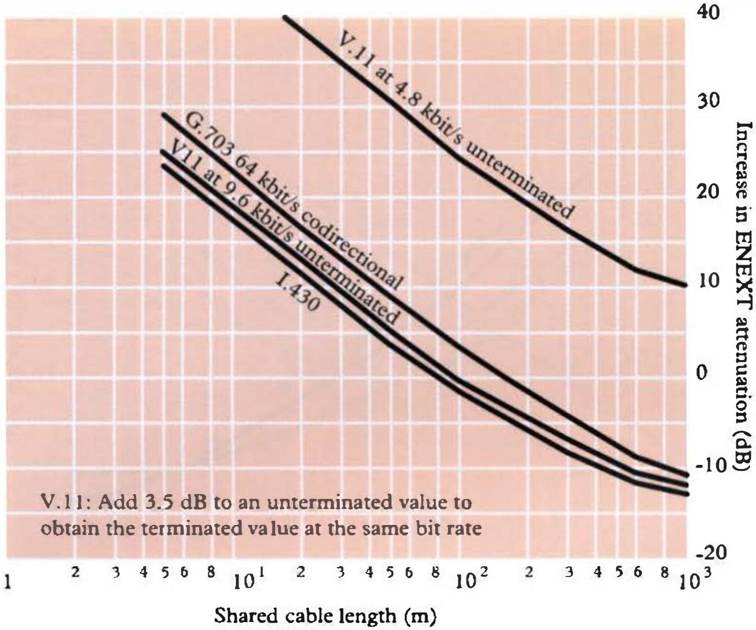


Figure 9 Length corrections for analogue disturbed circuits

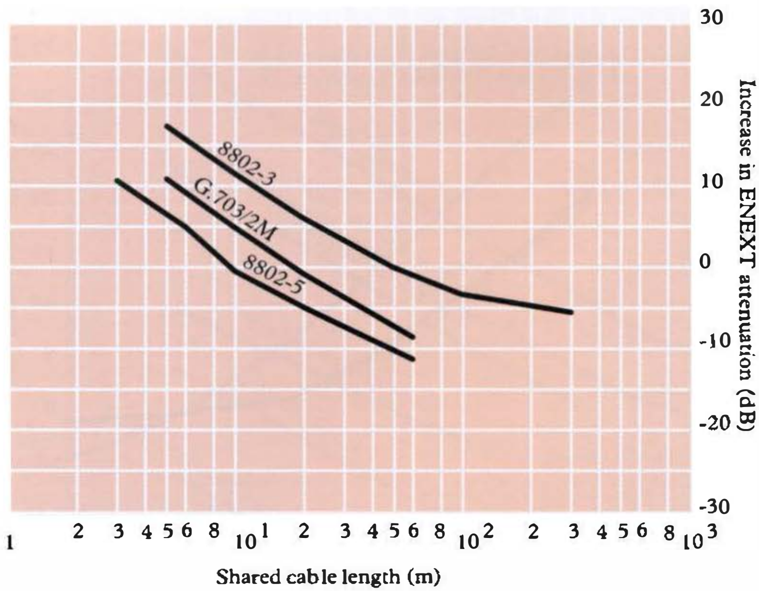


Figure 10 Length corrections for analogue disturbed circuits

The corrections for V.10 and V.11 are complicated because the data rates with these interchange circuits are not fixed and hence data rate constitutes another variable in addition to length. Corrections for V.28 are contained in note (6) of Table 3. (See Part 2 of the Wiring Code, Figures 7 and 8, for the length constraints which apply to V.10 and V.11 in addition to those imposed under Part 3.) Annex B contains several examples of how length correction procedures are applied in practice.

Multiple disturbers

25 Figure 11 gives the correction to be applied for multiple disturbers. For example, suppose a cable contains four pairs connected to data circuits (ie two data circuits each having two pairs) and one pair connected to an analogue speech circuit. The go and

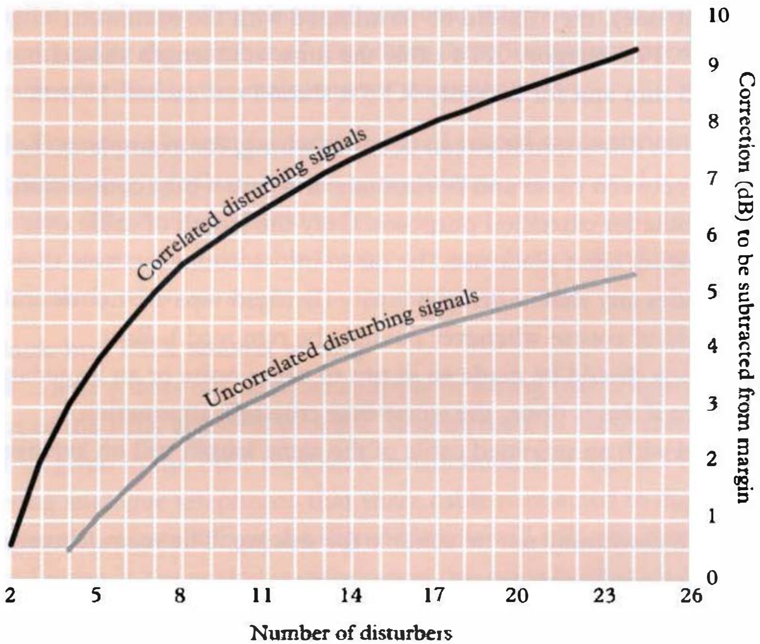


Figure 11 Corrections for multiple disturbers

return pairs in each circuit are treated as being equally a source of crosstalk, thus there are four disturbers. The correction for four disturbers in the (more common) uncorrelated case is taken from the lower curve of Figure 11 and is 0.5 dB but if the data signals are correlated, then the upper curve of Figure 11 applies and from this curve it may be seen that for four disturbers 3.1 dB should be subtracted from the margin given in Table 3. Further examples of the multiple disturber correction procedures are given in Annex B.

Installation practices

26 Preserving twisted pair integrity is very important. Split pairs will give rise to excessive crosstalk.

27 Twisted pair wiring terminations should be made with the minimum of untwisting and in the abnormal situation when coaxial cables are terminated on a multipin connector (rather than a concentric one), they should be terminated with the minimum length of pigtail*. For category XT4 cable the untwisted length should not exceed 25 mm and for category XT5 it should not exceed 13 mm.

28 Various discontinuities can occur in wiring, for example at the junction between risers and horizontals or where a butt connection, or join, is made for extension purposes. Only the length of cable over which sharing takes place need be taken into account but note that this includes any shared bridged taps*. (Bridged taps are not desirable and should of course whenever possible be removed.) Butt connections should be made so as not to cause noise or an impedance mismatch; if this is done, the worst case crosstalk attenuation compared with an unjoined cable of the same length will on average increase.

29 Patch cords may not be suitable for sharing. The manufacturers advice may need to be sought on this topic.

30 In some installations shared UTP cables may contain unused pairs. It is common practice to leave such pairs open circuit and this is usually satisfactory with balanced circuits. For unbalanced circuits* leaving pairs open circuit is inadvisable and it is a better practice either to connect both wires to the common return at each end or terminate them correctly at each end.

31 A PTO may require evidence at the time of bringing into service of an installation containing shared wiring that such wiring complies with the requirements of Part 3 of the *Wiring Code*.

Shared cable management

32 The *Wiring Code* Part 2 (as amended in January 1992), paragraphs 127 to 129, contains general guidance on record keeping. With shared cabling the likelihood of damage is greater if wrong connections are made than is the case with separated analogue and digital wiring and hence even more emphasis needs to be placed on labelling and recording circuit allocations. Where sharing depends on length and/or the number of disturbers these limitations need to be clearly specified in the maintenance documentation.

33 For record keeping computer-based record management systems are increasingly replacing more conventional paper-based recording systems. The built-in checking features contained in most computer-based systems are a valuable feature for consistency checking, particularly when wiring re-arrangements are made.

Black-box PBX shared wiring

34 Table 3 does not necessarily apply to wiring that is approved as part of the PBX approval process. Sharing rules in such circumstances are as given in the PBX supplier's instructions. For digital PBXs having analogue telephones that share cable connected to digital terminals, crosstalk from the digital circuits will still give rise to out-of-band noise in the analogue circuits but this noise is likely to be attenuated in the PBX and the requirements for sharing in these circumstances may be less stringent than those given in Table 3.

SECTION C DESIGN PROCEDURES

35 Section C contains what is largely supporting material giving in fairly general terms the engineering basis for the material in Section B. It does not contain in detail the design equations that are used to calculate the data contained in Table 3 and Figures 5 to 11. Further information on this topic is however available on request to OFTEL, see paragraph 2.

Scope

36 For any point-to-point connecting medium the electric and magnetic fields extend beyond the transmission bearer or bearers and result in near-fields, which can couple to adjacent bearers, and radiated far-fields which can give rise to problems of electromagnetic compatibility (EMC). Near-field coupling or crosstalk with metallic conductors as bearers is the major topic here. Optical transmission and EMC are treated briefly.

Definitions and assumptions

37 Coupling from one circuit, the disturbing circuit, into a neighbouring circuit, the disturbed circuit, results in crosstalk which can be regarded as noise in the disturbed circuit. Crosstalk is expressed in terms of the attenuation between the disturbing and disturbed circuit at a specific frequency or set of frequencies. Two forms of crosstalk are relevant in this context:

Near end crosstalk (NEXT)

The transmitting end is the near end and contains the disturbing circuit. The receiving or disturbed circuit is also at the near end. NEXT is expressed as an attenuation value in dB at one or more spot frequencies. Typically NEXT attenuation decreases with increasing frequency at about 15 dB/decade.

Effective near end crosstalk (ENEXT)

In practice data signals contain multiple frequency components (eg they have square or trapezoidal waveforms) and NEXT at a particular frequency is not a very good measure of actual crosstalk behaviour. ENEXT applies to a specified disturbing waveform at a specified data rate and takes account of the variation of NEXT with frequency. Thus, cable performance in isolation is expressed in terms of NEXT but when the performance of cable shared between circuits is being quantified ENEXT attenuation is the appropriate measure.

38 The crosstalk attenuation between two circuits depends on whether at the transmitting and receiving ends:

(a) both circuits are balanced,

(b) one circuit is balanced and the other is unbalanced* or

(c) both are unbalanced.

As a rough rule of thumb crosstalk attenuation becomes typically 25 dB lower (worse) and for the worst case 20 dB lower in going from (a) to (b). A further reduction in attenuation (worsening of crosstalk) of about 40 dB might be assumed in going from (b) to (c). These guidelines do not apply if the net crosstalk attenuation is less than about 10 dB. Unbalanced circuits should not in any case be used at data rates in excess of about 100 kbit/s so in general very low crosstalk attenuation values should not be encountered. In Table 3 most of the circuits under consideration are balanced but there are instances where balanced and unbalanced circuits share and in these cases 20 dB is subtracted from the balanced NEXT value in Figure 3. No NEXT values are given for unbalanced circuits sharing with unbalanced circuits (eg V.10 with V.10) because of uncertainty regarding the correction factor to be used but in any case the length limit guidelines given in Part 2 of the *Wiring Code* are based on crosstalk considerations.

39 Irrespective of whether the disturbing circuit is balanced or not,

Table 3 The sharing table

Disturber:	Analogue voice			ISDN (17)	ISDN digital section (1)			
Disturbed:	1	2	3	S/T	U1	U2	U3	U4
Analogue voice 1, 2 and 3	XT1 (10)	XT1 (10)	XT1 (10)	XT2 0dB (11)	XT3 4dB (13)	XT3 12dB (14)	XT3 4dB (15)	XT3 3dB (15)
ISDN S/T	XT2 (12)	XT2	XT2 (12)	XT1 36dB	NA	NA	NA	NA
ISDN digital section								
U1	XT3 (12)	XT3	XT3 (12)	NA	XT3 7dB	NA	NA	NA
U2	XT3 (12)	XT3	XT3 (12)	NA	NA	XT3 7dB	NA	NA
U3	XT3 (12)	XT3	XT3 (12)	NA	NA	NA	XT3 7dB	NA
U4	XT3 (12)	XT3	XT3 (12)	NA	NA	NA	NA	XT3 7dB
U5	XT3 (12)	XT3	XT3 (12)	NA	NA	NA	NA	NA
U6	XT3 (12)	XT3	XT3 (12)	NA	NA	NA	NA	NA
V.10	No	No	XT1 (12)	XT1 19dB	No	No	No	No
V.11	XT2 (12)	XT2	XT1 (12)	XT1 39dB				
V.28	No	No	XT1 (12)	XT1 62dB (18)	NA	NA	NA	NA
G.703								
64 kbit/s	XT2 (12)	XT2 (12)	XT2	XT1 36dB				
2 Mbit/s	XT5 (12)	XT5 (12)	XT5	XT1 47dB				
LAN								
8802-3 10BaseT	XT5 (12)	XT5	XT5 (12)	XT3 41dB	No	No	No	No
8802-5 4 Mbit/s	XT5 (12)	XT5	XT5 (12)	XT3 50dB	No	No	No	No

n			V.10	V.11 (1)	V.28 (1)	G.703		LAN	
	U5	U6				64 kbit/s	2 Mbit/s	8802-3	8802-5
	XT3 8dB (15)	XT3 12dB (16)	No	XT2 0dB (8)	No	XT2 0dB (19,22)	XT5 0dB (20)	XT5 0dB (21)	XT5 0dB
	NA	NA	XT1 15dB	XT1 8dB (3)	XT1 18dB (6)	XT1 35dB	XT1 11dB	XT3 2dB (7)	XT3 -1dB (4)
	NA	NA	No		NA			No	No
	NA	NA	No		NA			No	No
	NA	NA	No		NA			No	No
	NA	NA	No		NA			No	No
	XT3 7dB	NA	No		NA			No	No
	NA	XT3 7dB	No		NA			No	No
	No	No	XT1 (2)	XT1 -10dB (3,4)	XT1 (2,6)	XT1 18dB	XT1 -7dB (4)	No	No
			XT1 18dB (5)	XT1 11dB (3)	XT1 21dB (6)	XT1 38dB	XT1 13dB	XT3 5dB	XT3 1dB (7)
	NA	NA	XT1 (2)	XT1 24dB (18)	XT1 (2,6)	NA	NA	NA	NA
			XT1 16dB (5)	XT1 8dB (3)	NA	XT1 36dB	XT1 11dB	XT3 2dB (7)	XT3 -1dB (4)
			XT1 26dB (5)	XT1 18dB (3)	NA	XT1 46dB	XT1 21dB	XT3 13dB	XT3 9dB
	No	No	No	XT3 13dB (3)	NA	XT3 41dB	XT3 16dB	XT3 4dB	XT3 1dB (7)
	No	No	No	XT3 22dB (3)	NA	XT3 49dB	XT3 25dB	XT3 13dB	XT3 9dB

Notes for table 3

(1) Subject to length restrictions (see Part 2 of the *Wiring Code*)

(2) Unbalanced to unbalanced. No accurate figure for the ENEXT attenuation margin is available.

(3) Reference condition is 100 m at a data rate of 1 Mbit/s and with a terminated cable.

(4) Negative margin, a better grade of cable should be used or the cable length should be reduced (or when relevant the data rate might be reduced).

(5) Reference condition is 300 m at a data rate of 4 kbit/s.

(6) Length limit is 15 m, data rate is 20 kbit/s.

Margins for other data rates - disturbed circuit is digital:

Data rate in kbit/s	*Increase in margin in dB*
10	5
4	10
2	16

(7) Narrow margin, a better grade of cable may be advisable.

(8) Data rate 9.6 kbit/s, length 160 m, unterminated and critical frequency 52.8 kHz

(9) Length 100 m, critical frequency 160 kHz

(10) Crosstalk is not an issue

(11) Length 85 m, critical frequency 144 kHz

(12) Impulsive noise can cause data errors, see paragraph 67.

(13) At 500 kHz

(14) At 50 kHz

(15) At 160 kHz

(16) At 80 kHz

(17) Applies to a length of cable set by the maximum attenuation limit, see Figure 7/G.961

(18) At limit length of 15 m

(19) Length 10 m, critical frequency 1.024 MHz

(20) Length 50 m, critical frequency 10 MHz

(21) Length 6 m, critical frequency 4 MHz

(22) An adapter may be required to match the characteristic impedance of a PTO cable to that of the twisted pair.

the disturbed circuit will have induced in it two crosstalk components:

- a balanced component which is known as transverse crosstalk and
- an unbalanced component which is known as longitudinal or common-mode crosstalk.

For a balanced disturbed circuit the longitudinal component of crosstalk is only of interest if the apparatus terminating the wiring is imperfectly balanced. For example, referring to Figure 12, if the transverse component of cable crosstalk attenuation is 60 dB (worst case), then the longitudinal component is about 40 dB. If the signal balance about earth is 30 dB then the imbalance produces a transverse component of crosstalk from the longitudinal one corresponding to

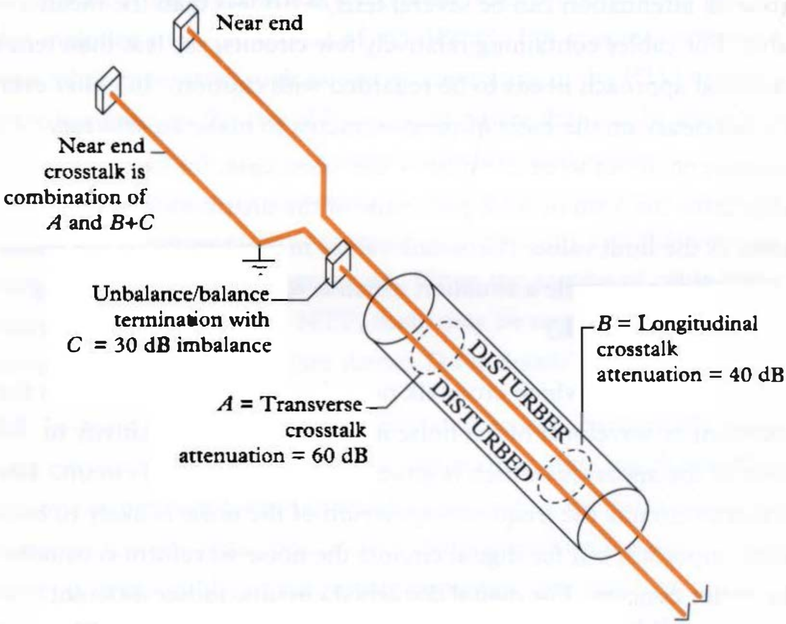


Figure 12

Effect of longitudinal crosstalk with an imperfectly balanced termination about 70 dB. In practice the transverse component produced by terminal imbalance is usually negligible compared with the direct transverse component from the cable; for example BS 6305 and BS 6328: Part 1 requires terminal apparatus signal balance about earth to be better than 46 dB up to a frequency of 3.4 kHz giving an ample noise margin in the speech band. At frequencies above the speech band balance is likely to be worse than 46 dB but the transmission losses of the balancing device may increase such that the net effect is not significantly worse than for transverse crosstalk on its own.

40 In a sheath containing a substantial number of circuits there is considerable variation between the crosstalk attenuation between any two circuits taken at random and crosstalk attenuation is expressed in terms of a mean value and a standard deviation. The worst case crosstalk attenuation can be several tens of dB less than the mean value. For cables containing relatively few circuits, say less than ten, a statistical approach needs to be regarded with caution. In either event it is necessary on the basis of measurements to make an arbitrary assumption about what constitutes the worst case, for example with a large cable the 95th or 98th percentile of the distribution might be taken as the limit value. (Crosstalk values in this handbook are based on the 96th percentile a situation which is reflected in the warning given in paragraph 4.)

41 The extent to which crosstalk noise is acceptable depends on the spectrum or waveform of the noise in relation to the sensitivity to noise of the apparatus which is attached to the disturbed circuit. For analogue circuits the frequency spectrum of the noise is likely to be more important but for digital circuits the noise waveform is usually the major concern. For digital disturbed circuits, rather different considerations apply when:

- the disturbing digital circuit carries a continuous bit stream and the waveform or spectrum of the noise introduced into the disturbed circuit is a continuous signal and

- the major source of noise is random impulses, as is often the case when the disturbing circuit is an analogue voice-band circuit, and the interference consists of discontinuous pulses having an occurrence rate typically measured in tens of impulses per minute.

42 Noise immunity requirements (with which apparatus including wiring may have to comply) may extend beyond the pass band of the terminal apparatus when that apparatus is connected to a network in which out-of-band noise has undesirable effects. A prime example of this is the transverse noise specification in BS 6305 Figure 3 and BS 6328: Part 1, Figure 5 which is repeated here as Figure 13 (Figure 13 also includes an in-band limit of -65 dBm0). For reasons connected with other apparatus, such as carrier apparatus, in the PTO network there is a limit on the out-of-band noise power that can be allowed at the NTP. BS 6305 applies strictly to the terminal apparatus in isolation and makes no allowance for additional noise introduced by the wiring, however statistical considerations apply and this topic is considered further in paragraph 44. When the section of cable being shared is remote from the NTP, there may be scope for increasing the margins given in Table 3 (see Annex D for details).

43 In-band noise needs to be considered as well, particularly when a data circuit is the disturbed circuit, although in this case the problem is less one of network harm (although signalling to and from the network is a consideration) than one of determining whether the source of data errors is in the public or the private network. The effect on the disturbed circuit can be expressed as a bit error rate and the seriousness of a given error rate depends on the error detection and

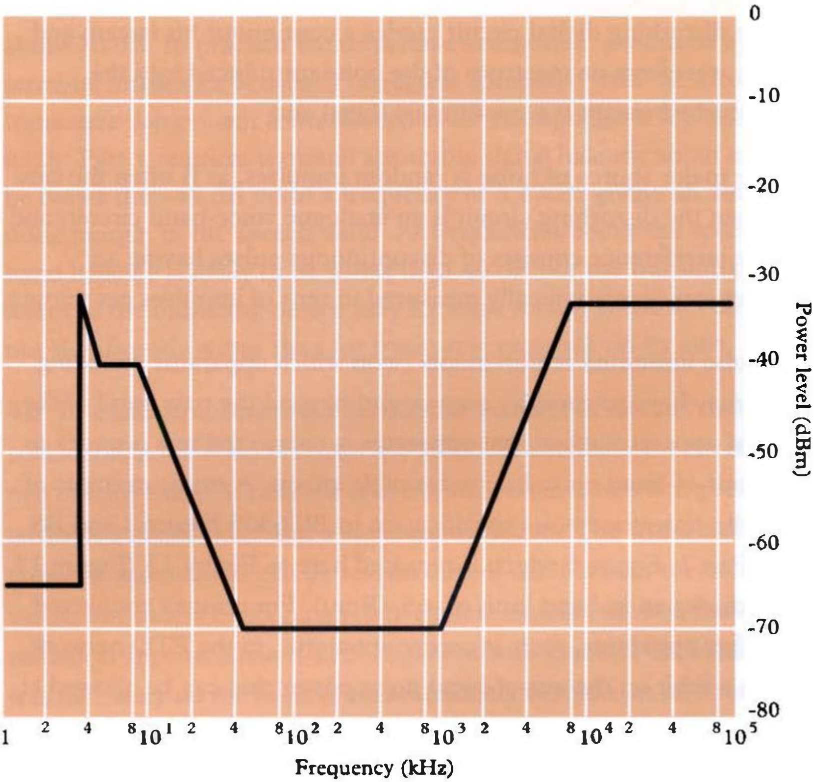


Figure 13 Noise mask for voiceband circuits (BS 6305/BS 6328)

correction procedures associated with higher level protocols (OSI layers 2 and above).

44 In paragraph 42 it was pointed out that if the apparatus attached to the cable is at the specified noise limit then there is no freedom for the wiring to introduce further noise. However the apparatus too is likely to have noise characteristics with a statistical distribution in which the mean is much less than the worst case and the network over which the noise is transmitted together with the apparatus that is subject to interference will show statistical behaviour too. Because the probability of all worst case combinations occurring simultaneously is very low, the wiring can be allowed to introduce noise comparable with the threshold set for the terminal apparatus in isolation.

45 If the crosstalk performance of a particular type of cable is inadequate there are a number of potential remedies and these include:

(a) a cable of the same type with better performance (see Table 4)

(b) a cable of a different type, eg a screened cable in place of an unscreened one

(c) physical separation of circuits of different types within the cable cross-section

(d) a filter in the disturbed circuit to remove the crosstalk noise selectively (the use of ferrite beads may be worth considering)

(e) a connecting network between the disturbed circuit and disturbing circuit that cancels the crosstalk.(This entails an individual adjustment for every pair of circuits.)

(d) and (e) are not considered further here because they involve complex design considerations beyond the scope of this handbook and in any event any additional apparatus involved in crosstalk reduction must be approved apparatus.

Types of cable

46 There are many types of cable that can be used for building wiring but unscreened twisted pairs (UTP) is by far the most widely used and the only type to be considered in detail in Section B. All relevant types are however briefly discussed in the following paragraphs.

AE Any type of cable that is approved under GA NS/G/1235/N/100018 may be shared subject to the conditions of Principle AD

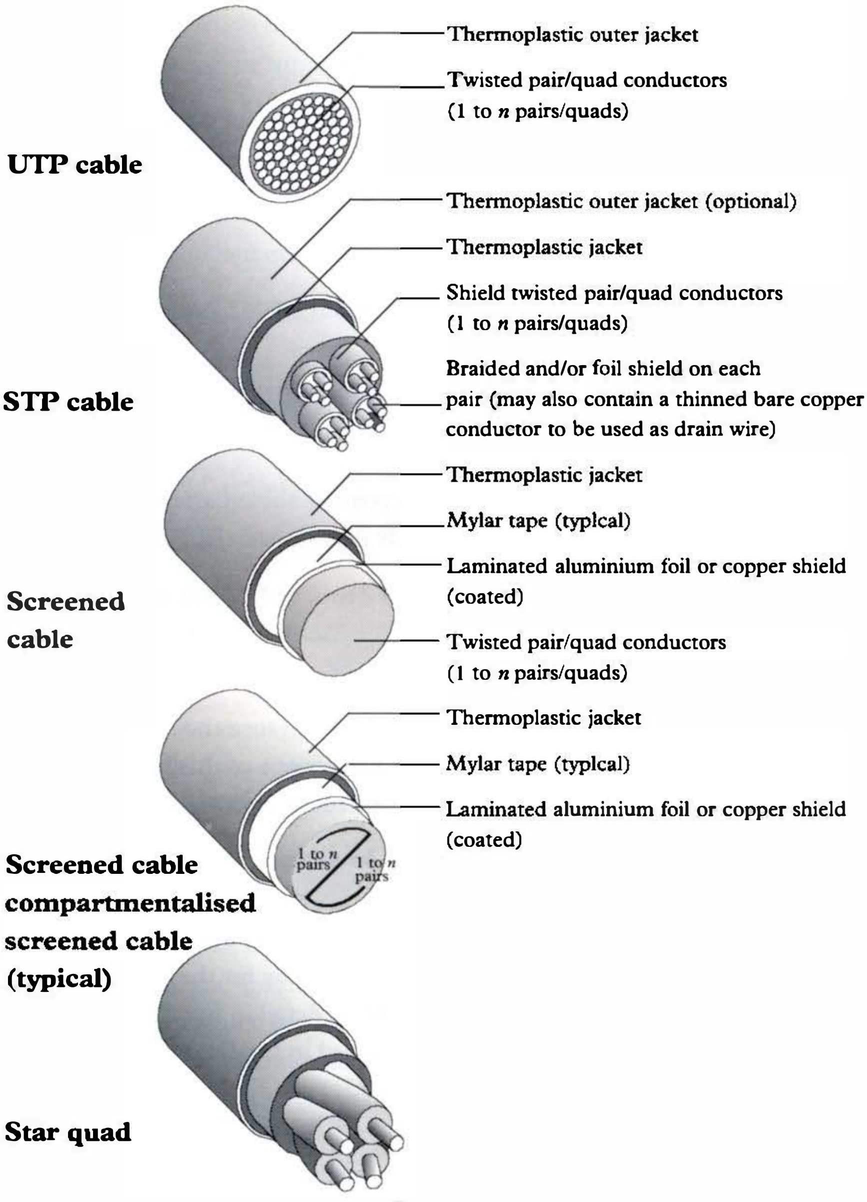


Figure 14 Cable types

AF For cables other than UTP cables, crosstalk attenuation values, length corrections and multiple disturber rules may be different from the UTP values but if they are approved as being in a specific category they must have a crosstalk performance that in all respects is no worse than that of the UTP cable in the same category.

47 UTP cables are available in many sizes, ranging from a single pair up to many tens of pairs. Some grades of cable are better suited to high frequency operation than others (see Table 2).

48 Twisted pairs are available with various screening* arrangements (see Figure 14), namely:

(a) individual pairs or a quad - screened twisted pair (STP)
(b) the complete cable - screened cable
(c) transverse screen - compartmentalised screen cable
(d) (a) or (c) with an additional outer screen

Screening twisted pairs individually may be ineffective when inductive coupling is a significant cause of crosstalk. In the case of voice frequency circuits terminated in 600 ohms capacitive coupling predominates and screening is therefore effective in reducing crosstalk within the speech band. At frequencies in the 10 kHz to 100 kHz region screening is usually not worthwhile but at frequencies above a few MHz it becomes increasingly important. An outer screen reduces electromagnetic radiation but has little effect on crosstalk performance. Screening binder groups* and ensuring that all circuits in a given binder group are of the same type results in a combination of screening and physical separation that is normally effective in reducing crosstalk between different types of circuit.

49 Coaxial cable is available in various grades and is specified as a transmission medium in some LAN systems for example. It should give crosstalk performance superior to twisted pairs at frequencies above about 5 MHz. At low frequencies coaxial cables in a common sheath or laid in close proximity have significant inductive coupling and can show crosstalk performance inferior to that of twisted pairs. If screens are earthed at both ends of a connection and there is a difference of earth potential between these ends, a current will flow in the screen which may be a cause of interference. On the other hand at the highest data rates crosstalk and radiation (EMC) may be reduced if the screen is earthed at both ends. It may be advisable to seek expert advice on this topic.

50 Multiple optical fibres are available in a common sheath and provided individual fibres have an opaque outer coating, there should be no measurable crosstalk between them. Without an opaque outer coating there might be significant crosstalk particularly with multimode fibres.

51 Ribbon copper cable is unlikely to be suitable for shared use except perhaps for lengths of up to one or two metres. In general it is more susceptible to EMC problems than the other types of cable mentioned here.

52 Composite cables can contain various combinations of the cable types given in paragraphs 47 to 51. While the guidance given above applies to the individual cable types within the composite, it is not possible to generalise about the coupling between different types and you are advised to consult the cable manufacturer on this topic.

53 Outdoor versions of some of the above types of cable are available as drop wires, aerial, self-supporting, etc. However the crosstalk performance of the basic cable type is unlikely to be affected by cladding and strengthening.

Wiring component parameters

54 The basis of the five crosstalk categories given in Table 2 is NEXT attenuation but implicit in the NEXT attenuation values are other parameters of the cable which in the case of categories XT3 to

XT5 are given in the relevant EIA/TIA specifications. In general the key parameters relating to the performance of high frequency cables are:

(a) The attenuation for a specified length at one frequency at least in the frequency range for which the cable is intended to operate. (**Note:** At frequencies above about 5 kHz cable attenuation is to a fair approximation, proportional to the square root of the frequency.)

(b) The characteristic impedance over the range of frequencies for which the cable is intended to be used.

(c) Near end crosstalk (NEXT) attenuation for a specified length and at least one frequency in the frequency range for which the cable is intended to operate.

Crosstalk performance depends significantly on (a) and (b).

55 The parameters listed in paragraph 54 are also required for cross-connection wiring, ie multiple jumpers and multiple patch cords (which are probably best avoided), although the lengths over which the measurements are made are likely to be much less than the several hundred metres of the UTP or STP cable. NEXT calculations should include the effect of distribution frames, patch panels or matrices as well as the effects, if any, of jumpers or patch cords. Particularly at high data rates, the use of factory terminated patch cords to administer moves and changes can eliminate the performance variations that can occur with uncontrolled field practices.

56 No parameters are required for coaxial connectors that are compatible with the characteristic impedance of the cables to which they are attached. Edge connectors can have inter-electrode capacitances that are significant in crosstalk terms, particularly at data rates of 10 Mbit/s and higher, and it may be necessary to make an allowance for their effect in the overall assessment of crosstalk performance. The behaviour associated with edge connectors is complex and is considered further in Annex C.

57 Untwisted and unscreened connections are a source of radiated energy which energy may be significant as far as meeting emerging EMC requirements is concerned.

Cable categories for crosstalk

58 Figure 3 applies to a single disturber and assumes that both the disturbed and disturbing circuits are correctly terminated* at both ends. Any cable that is classified as being in a category must have a crosstalk attenuation as a function of frequency that is equal to or greater than that specified by the mask. Thus for example a category XT2 cable (which is a better cable than category XT1 from the point of view of crosstalk performance) must have a crosstalk attenuation at 100 kHz of 63 dB or more. An upper limit on crosstalk attenuation for a category is not a necessity but has an implicit value set by the lower limit on the category above.

Note: Cable with a NEXT performance inferior to that of category XT1 is not suitable for sharing between analogue and digital circuits under any circumstance but may be considered for sharing between digital circuits of different types if crosstalk margins are satisfactory.

Interchange circuits

59 It is not possible to determine crosstalk performance unless the signal levels and frequency performance of the signals on the disturbing circuit are specified and the noise margins on the disturbed circuit are known. The circuits considered here are those for which a reasonably stable international or national interface specification exists. The number of circuits covered will be increased in later editions of Part 3 of the *Wiring Code* as new specifications are ratified.

60 Table 5 contains relevant data for analogue circuits and Table 6 for digital circuits. For circuits connected in pair combinations to the listed interfaces, the parameter values given in these tables form the basis for calculating acceptable crosstalk attenuation values as presented in Table 3. The notes associated with the tables indicate a number of assumptions that have had to be made. The contents of Tables 5 and 6 are relevant to detailed crosstalk calculations which are contained in a separate OFTEL document (see paragraph 2), but the basic methodology is described in subsequent paragraphs.

Table 5 Analogue circuit interface conditions

Interface	*Maximum signal*		*Threshold*		*Signalling*	*Notes*
	Inband	*Outband*	*Inband*	*Outband*		
Voice Band 1						
Public	BS 6305		-65 dBm0	BS 6305	50 V dc	1
	4.3.5		4.3.5	Figure 3		
Private	BS 6328 Part 1		-	BS 6328	50 V dc	1,3
	5.4.1	5.4.5	-	Figure 5		
		5.4.6				
Voice Band 2						
Public	BS 6305		-65 dBm0	BS 6305	mf or vf	2
	4.3.5	4.1.4		Figure 3		
Private	BS 6328 Part 1		-	BS 6328	mf or vf	2,3
	5.4.1	5.4.5	-	Figure 5		
		5.4.6				
Voice Band 3			-65 dBm0		any	4

Notes:

(1) Circuits carrying 50 V calling, clearing, dialling or telephone ringing signals. For example PSTN circuits or inter PBX circuits

(2) Circuits with no 50 V and no telephone ringing signals. For example, circuits connected to modems.

(3) The BS 6328 clauses quoted should be amended to correspond to the equivalent clauses in BS 6305.

(4) Circuits with no direct analogue path to a PTO's network, eg an analogue extension telephone circuit connected to a digital PBX (see Figure 2 in Part 2 of the *Wiring Code)*.

Table 6 Digital circuit interface conditions

Interface	*Bal/unbal*	*Transmit* max V	*Threshold* min V	*Data rate* kBaud	*Fractional rise time*	*Line code*	*Note*
CCITT							
V.10	U	6	0.3	4	0.05	BB	1
V.11	B	6	0.3	1000	0.05	BB	1
V.28	U	15	3	20	0.0002	BB	
G.703 at 64 kbit/s	B	1.2	0.23	64	0.054	AMI	3
G.703 at 2048 kbit/s	B	3.6	0.75	2048	0.2	HDB3	4
I.430 point to point	B	0.825	0.22	96	0.05	Pseudo ternary	
G.961U1)	B	2.2	0.007	120	-	MMS43	5
(U2)	B	2.63	0.0027	80	-	2B1Q	5
(U3)	B	2.2	0.007	160	-	AMI	5
(U4)	B	6.6	0.021	320	-	AMI TCM	5
(U5)	B	1.68	0.005	160	-	Biphase	5
(U6)	B	1.18	0.004	108	-	SU32	5
ISO							
8802-3 10baseT	B	2.8	0.29	20000	0.28	Manchester (Wal 1)	6
8802-5	B	3.7	0.8	8000	0.0002 (7,8)	Manchester (Wal 1)	7

61 Three types of analogue circuit are listed in Table 5 which, purely for the purposes of this handbook, are called Voice Band 1 to 3. Voice Band 1 circuits use dc signalling whereas Voice Band 2 circuits do not. It follows from note (4) to Table 5 that there is no out-of-band crosstalk requirement with Voice Band 3 circuits and they may be used in any sharing combination which is found to be operationally acceptable (see paragraph 34 for when such circuits use wiring that is

Notes for Table 6

B or bal = balanced: BB = balanced binary: U or unbal = unbalanced: V = volts: fractional rise time = zero to peak rise time as a fraction of the inverse of the Baud rate.

(1) Based on length limit and data rate of Figure 6 of Part 2

(2) Based on length limit and data rate of Figure 7 of Part 2

(3) Codirectional interface

(4) Applies only to twisted pair bearer

(5) Scrambled line code, crosstalk performance for most disturber/disturbed combinations needs further consideration.

(6) 100 ohm termination

(7) 100 ohm termination

(8) Filtered in accordance with ISO 8802-5 specification

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approved as part of black-box PBX approval). As a disturbing circuit, Voice Band 3 may behave as Voice Band 1 or Voice Band 2 depending on the type of signalling used. Analogue three-wire circuits (see Part 1 of the Wiring Code, paragraphs 24 and 25) are not considered for sharing in any circumstance.

62 In calculating crosstalk margins the following assumptions are made, that:

- The voltage on the disturbing circuit is at the upper limit of its tolerance range,
- The wanted signal in the disturbed circuit is at the lower limit of its tolerance range with the threshold level of the receiver set to accommodate that level,
- Unless the signal transmitted is specified as being scrambled, the disturbing circuit carries a worst case data pattern. (Normally the worst case pattern is taken to be a continuous string of alternating positive and negative levels at the highest possible Baud rate which, because it is unlikely to occur in practice, may be an over stringent assumption.),

- Pulse shapes are trapezoidal and if the rise time is not specified as having a minimum value it is taken as being half the maximum value when that is specified, and

- Pulse shapes accord with the line code specified and characterised in the relevant recommendation or specification.

For circuits not operating at their maximum length and having an adjustable receiver threshold margin, the net crosstalk margin will improve pro rata with receiver threshold margin.

Sharing tables

63 The cable categories and margins in Table 3 depend on whether:

- the disturbed circuit is analogue or digital and

- the disturbing circuit is analogue Voice Band 1, Voice Band 2 or Voice Band 3 (see Table 5)

64 When both the disturbing and disturbed circuit are digital, ENEXT is calculated at spot frequencies in the spectrum of the disturbing circuit for the worst case disturbing waveform. The attenuation margin is given at the frequency for which the difference in noise power in the disturbed circuit and the noise power given for the noise mask of Figure 13 is a minimum.

65 When both the disturbing and disturbed circuits are digital, ENEXT is calculated taking into account the spectral components of the worst case disturbing waveform, the NEXT attenuation and phase characteristics (transmission line model) of the cable, the length of the cable and the noise threshold level in the disturbed circuit. The margin quoted is based on the assumption that the peak disturbing voltage occurs at the decision point or 'eye' of the disturbed circuit.

66 When both circuits are balanced analogue voice band ones, there is not considered to be a crosstalk problem and a margin is not given.

67 Analogue circuits Voice Band 1 with 50 volt battery signalling are a major source of impulsive noise while analogue circuits of Voice Band 2 are not significant in this respect. (Although in some installations power supply interference could also be a source of data errors.) For analogue voice band circuits decadic dialling impulses, off-hook, on-hook and ring trip all contribute to impulsive noise and the situation is compounded by relay bounce and contact arcing. Because some of the components of this interference are balanced about earth and others are not, crosstalk depends on both the longitudinal and transverse components of crosstalk attenuation. Insufficient information is available for the net effect to be adequately quantified.

68 The number of errors that occur on a disturbed data circuit owing to impulsive noise is a function of the crosstalk attenuation, the call attempts on disturbing analogue lines and the data rate of the disturbed line. For data rates of the 50 to 200 kbit/s order there is some experimental evidence to show that significant errors (ie 10 or more errors per call attempt) can occur with cables of category XT1 that are at or close to the worse case attenuation limit. For this reason, cable in a higher category than XT1 is generally recommended. How serious such errors are depends on what error detection and correction procedures are associated with the disturbed data circuits.

Dependency of crosstalk on cable length

69 The basis for the length correction graphs given in Figures 5 to 10 is essentially the same as that described in paragraphs 64 and 65 except that the calculations are performed for various lengths and for Figures 5 and 6 at several data rates. Note that all circuits are assumed to be point-to-point. Multipoint circuits are not covered in this edition of the *Wiring Code*.

Allowances for multiple disturbers

70 A crosstalk limit that is set on the basis of a worst case single disturber may not be valid in the presence of more than one disturber, which while not being as bad as the worst case disturber, can introduce additional noise.

71 Table 3 applies to the simple case where there is a single disturber but in a cable containing n pairs there can be up to n -1 disturbers. Because Table 3 is based on a worst case disturber, the effect of most of the other disturbers is relatively smaller but nevertheless the cumulative effect of multiple disturbers is significant. Three cases may need to be considered:

(1) Where the disturbing signals are uncorrelated and continuous.

(2) Where the disturbing signals are correlated and continuous.

(3) Where the disturbing signals are uncorrelated and discontinuous, ie impulsive noise.

72 Uncorrelated signals are assumed to add on a root mean square basis and for a 95% confidence limit the worse case crosstalk attenuation is given by the following approximate empirical relationship:

For $n < 4$ no correction required

For $n > 3$

$$C_n = C_1 - 6.25(\log(n) - 0.52)$$

where C_1 is the worse case crosstalk attenuation for a single disturber under specified conditions and n is the number of disturbers. This equation is shown as the lower curve in Figure 11.

Note: n is the total number of active pairs irrespective of whether they are go or return pairs. For four wire duplex circuits the number of circuits is $n/2$. However a four wire circuit working in half-duplex would have only one active pair.

73 Correlated signals are assumed to add with random sign (ie there is an equal probability that they will add or subtract) in which case the crosstalk attenuation for a 95% confidence limit is given by the following approximate empirical relationship:

For $n > 1$
$$C_n = C_1 - 8(\log(n) - 0.22)$$

where C_1 and n are as defined in paragraph 72. This equation is shown as the upper curve in Figure 11.

74 The subject of impulsive noise is addressed in paragraphs 67 and 68 from which it is evident that at present it is not possible to quantify the effect of multiple disturbers in general terms. In situations where the worse case crosstalk attenuation is marginal in terms of error rate, multiple disturbers should have only a very small effect in comparison with the worse case single one alone. Keeping noisy analogue circuits well separated from digital ones in a cable may be sufficient to reduce the error rate to a very low value, ie a few errors per day. (It may of course be difficult to use all the pairs in the cable under these circumstances.)

ANNEX A DEFINITIONS

Binder group A group of twisted pairs in a multipair cable that is separated from other similar groups by a thread or tape being wound round it.

Bridged tap A length of unterminated and unused wiring connected to an active circuit at an intermediate point.

Circuits of different types Circuits using different parts of the frequency spectrum. For example, Group 3 fax and voiceband speech are circuits of the same type because they both use the spectrum between 300 Hz and 3.4 kHz whereas V.10 interchange circuits, ISDN circuits and digital speech circuits use different parts of the spectrum and so are of different types.

Correctly terminated (correct termination) The termination specified for normal operation, eg 600 ohms for an analogue voice circuit or, say 120 ohms for a circuit connect to the ISDN S/T reference point.

Crosstalk Expressed as the attenuation in decibels (dB) between the circuit causing the interference (the disturbing circuit or the disturber) and the circuit being interfered with (the disturbed circuit).

Disturbed circuit A circuit that is affected by crosstalk from other circuits.

Disturber A circuit that is a potential source of crosstalk in other circuits.

Equivalent near end crosstalk (ENEXT) See paragraph 37

FDDI Fibre distributed data interface

Near end crosstalk (NEXT) See paragraph 37

Pigtail The outer braid of a cable unfurled and twisted to form a connecting lead.

Screen A metallic braid or foil that encloses a set of insulated conductors and which is normally connected to earth. In this context screen and shield are synonymous.

Shield See screen

Unbalanced circuits Circuits in which the equipment connected to the wiring is unbalanced with respect to earth, eg a V.10 interchange circuit.

ANNEX B WORKED EXAMPLES

Example 1

	First circuit type: V.11	Second circuit type: Analogue type 1
Circuits	1	2
Pairs	2	2
Data rate	4.8 kbit/s	
Length	100 m	100 m

V.11 as disturber From Table 3 the cable category is XT2 and the margin is 0 dB. Note (8) tells us that this is based on a data rate of 9.6 kbit/s and a length of 160 m. Figure 9 applies because the disturbed circuit is analogue and shows us that for a length of 100 m and a data rate of 4.8 kbit/s the margin is increased by 25 dB. From Figure 11, assuming uncorrelated signals, no additional margin is required for two disturbing pairs. Thus the net margin is 0 + 25 = 25 dB.
Analogue type 1 as disturber The crosstalk cable category is determined by V.11 as disturber but note (12) warns that errors may occur in the V.11 circuit.

Example 2

	First circuit type: V.11	Second circuit type: Analogue type 2
Circuits	4	3
Pairs	8	3
Data rate	9.6 kbit/s	
Length	200 m	200 m

V.11 as disturber From Table 3, the cable category is XT2 and from note (8) the actual condition is longer than the reference condition and from Figure 9 the margin is -5 dB. However there are 8 disturbers which for V.11 can normally be regarded as uncorrelated. The lower curve of Figure 11 tells us that for 8 disturbers the margin is reduced by 2.4 dB, giving a net margin of -5 - 2.4 = -7.4 dB. Because a negative margin is not acceptable this requirement cannot be met as it stands. Using the XT4 category of cable would (see Table 4) increase the margin to -7.4 + 8 = 0.6 dB which would solve the problem.

Analogue type 2 as disturber There is no crosstalk problem this way round.

Example 3

	First circuit type:	Second circuit type:
	8802-3	ISDN S/T
Circuits	2	2
Pairs	4	4
Data rate	10 Mbit/s	96 kbit/s
Length	200 m	200 m

8802-3 as disturber From Table 3 the cable category is XT3 and the margin at 300 m is 2 dB. From Figure 8, the margin at 200 m increases by about 0.5 dB, giving a net margin of 2 + 0.5 = 2.5 dB. The disturbing signals in this case might be regarded as correlated and there are 4 of them. The upper curve of Figure 11 shows that 3 dB must be subtracted from the margin, giving a net margin of -0.5 dB which is unacceptable. If there are edge connectors common to both types of circuit (see Annex C) a further allowance would be required and XT4 or XT5 cable would be advisable. From the crosstalk point of view XT2 would be satisfactory but it does not meet the functional description in Table 2.

ISDN S/T as disturber From Table 3, there is a margin of 41 dB. From Figure 8 this increases by about 2.5 dB for a 200 m length giving a net figure of 43.5 dB. Signals on circuits attached to the ISDN S/T reference point are unlikely to be correlated and the lower curve of Figure 11 shows that for 4 disturbers a correction of 0.5 dB is required. Thus the net margin remains 43 dB which is ample and means that 8803-2 as disturber is the critical condition.

ANNEX C CONNECTOR PERFORMANCE

Connectors, particularly edge connectors, can affect crosstalk performance in digital circuits. Connectors can be regarded as lumped capacitors connected in parallel with a cable having distributed parameters. The combined behaviour is complex because it depends

Table C1 Examples of reduction in crosstalk margin with a single near-end connector - digital disturbed circuit

Disturbing circuit (Note 1)	*Reduction in crosstalk margin in dB (Note 2)*	
	XT1	*XT3*
V.10	(Note 3)	
V.11	<0.1	<0.1
V.28	(Note 4)	
G.703 at 64 kbit/s	0.4	0.6
G.703 at 2 Mbit/s	1.1	1.6
I.430	0.6	0.9
8802-3	1.5	2.1
8802-5	0.2	0.4

Notes:

(1) Operating conditions as for Table 3

(2) The sign of the connector crosstalk is chosen to give the maximum reduction in margin.

(3) Unbalanced circuit connector crosstalk is not significant.

(4) Unbalanced circuit, connector crosstalk is unlikely to be significant but is dependent on rise time of waveform (which is not specified).

on the relative phases of the various frequency components present in the disturbing circuit's waveform. The aggregate coupling can make the crosstalk better or worse depending on these phase relationships but there is a 50% probability that it will be worse. The relative effect of connectors is greatest when the crosstalk attenuation of the cable is large and a connector at the near end of the cable will most probably produce the largest change in NEXT. The net effect also depends on the length of the cable.

Examples of the worst case effect on ENEXT attenuation of coupling two circuits at their near end by a capacitor of 4 pF (eg adjacent pins on an ISO 8877 connector) assuming a line of 100 ohms impedance are shown in Table C1. (The condition corresponds to a crosstalk attenuation for the connector in isolation of 58 dB at 1 MHz.)

Connectors at the far end, or at flexibility points along the cable, can also further degrade performance but compared with a near end connector the effects are generally smaller and it is not very probable that the waveform associated with any one connector will add in phase with those of the others so as to provide significant reinforcement.

ANNEX D INCREASED CROSSTALK MARGIN BETWEEN DIGITAL AND ANALOGUE CIRCUITS WHEN SHARING IS REMOTE FROM THE NTP

Figure D1 illustrates one situation (and there may well be others for which similar considerations apply) in which, for a structured wiring scheme, sharing takes place over a horizontal, while circuits in the riser between the floor distribution point (FDP) and NTP are voiceband analogue only. For the length, *L*, of the horizontal the NEXT margin at the FDP is *X* dB at *Y* MHz (*Y* MHz being the critical frequency for the digital circuit as specified in the notes to Table 3). The attenuation of the cable between the FDP and the NTP is *Z* dB at *Y* MHz. In these circumstances the NEXT margin may be increased by *Z* dB to give a margin of *X* + *Z* dB.

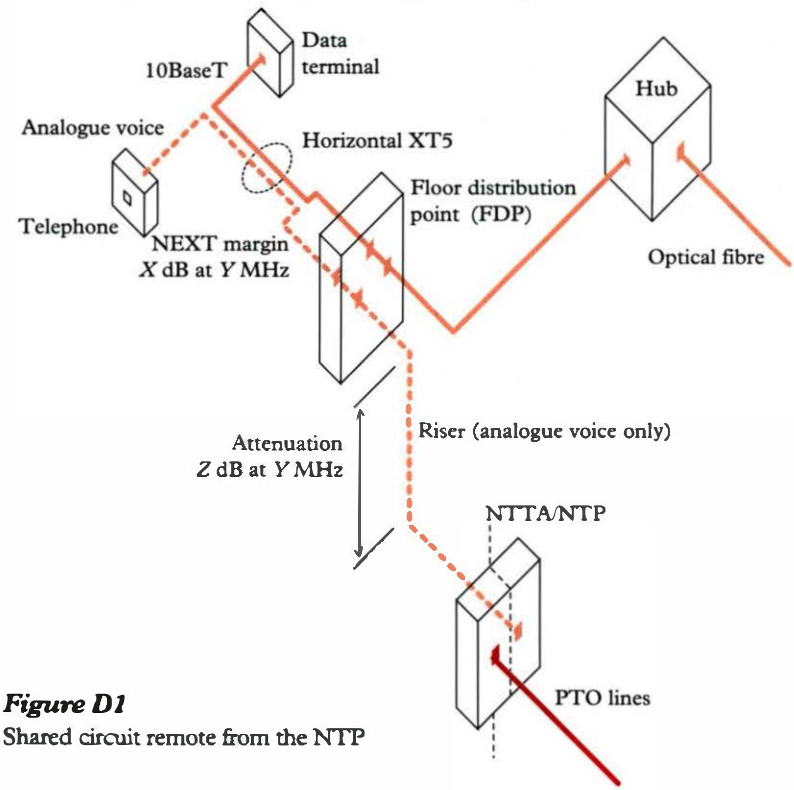

Figure D1
Shared circuit remote from the NTP

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