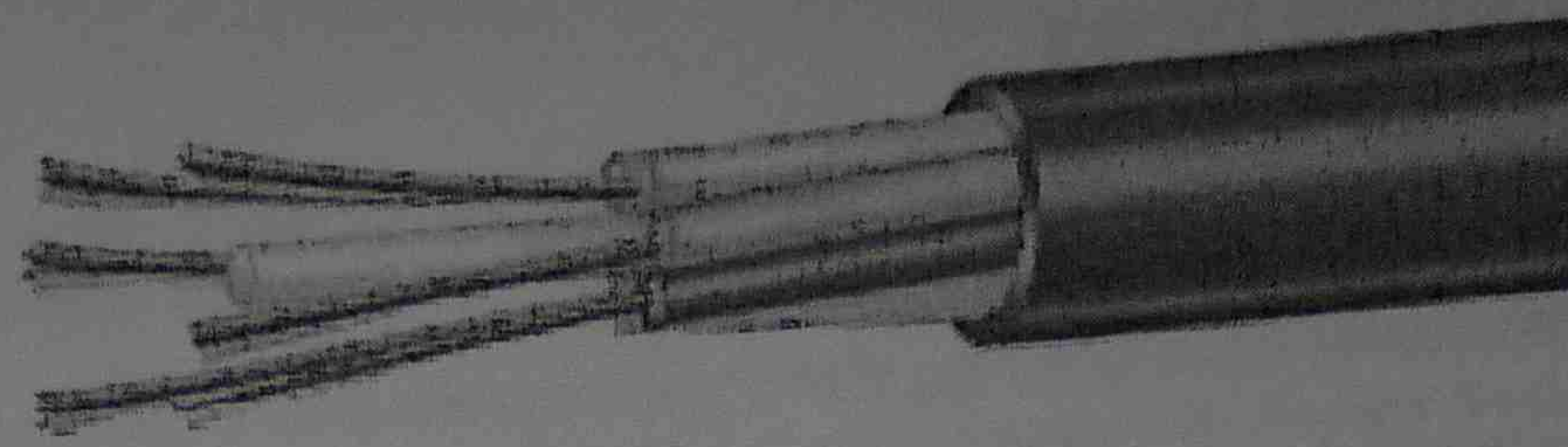


Figure 6: Optical fibres.

Optical fibres are made from very thin (less than the diameter of a human hair) strands of glass and are used to transmit vast amounts of information carried on a light beam. Optical fibres are used for submarine communication between continents; across Australian deserts; under and above suburban streets; and between and within buildings to transmit voice and data.

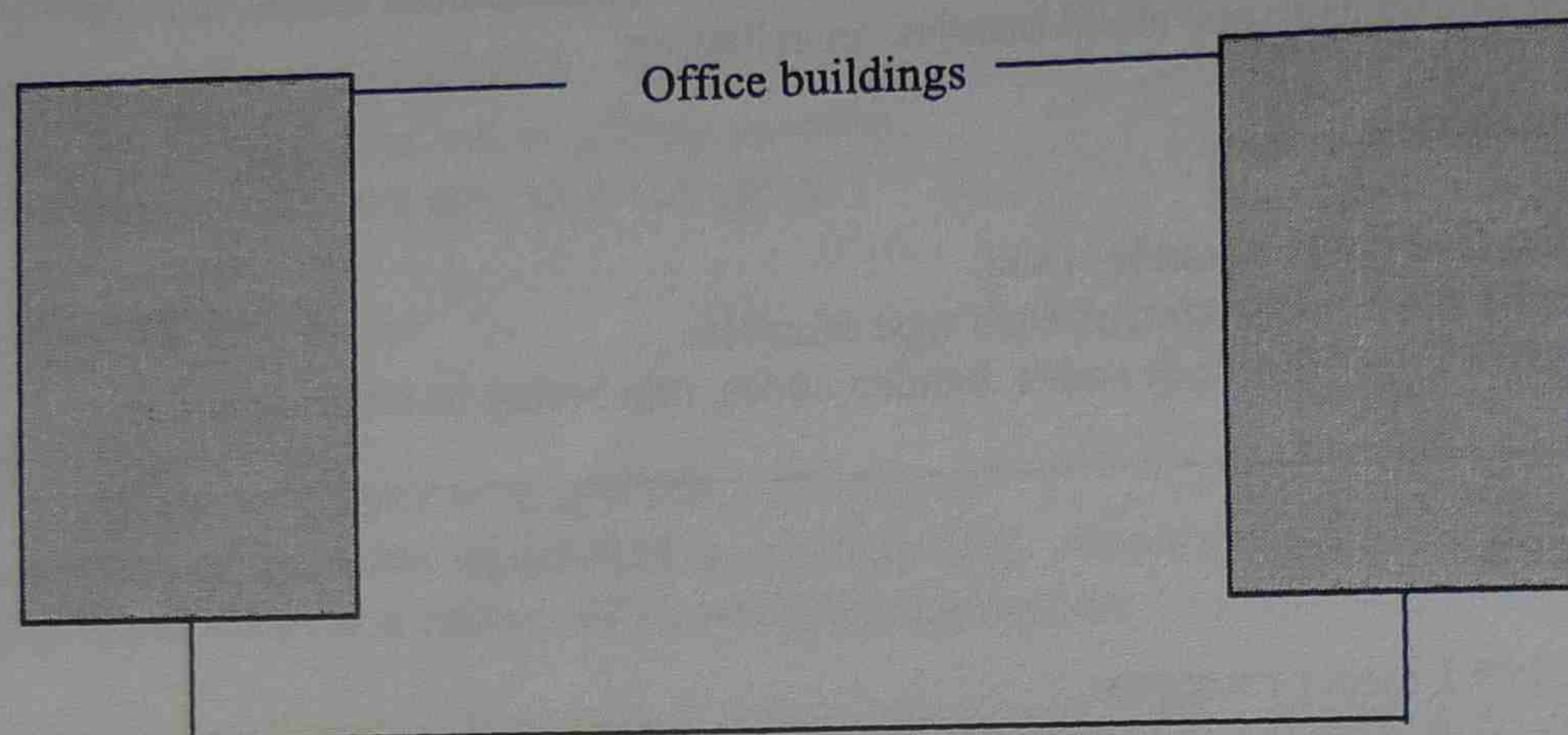


Figure 7: Example of fibre optic cable link.

These four basic cable types are available for use in the following:

a. indoor
b. underground
c. aerial.

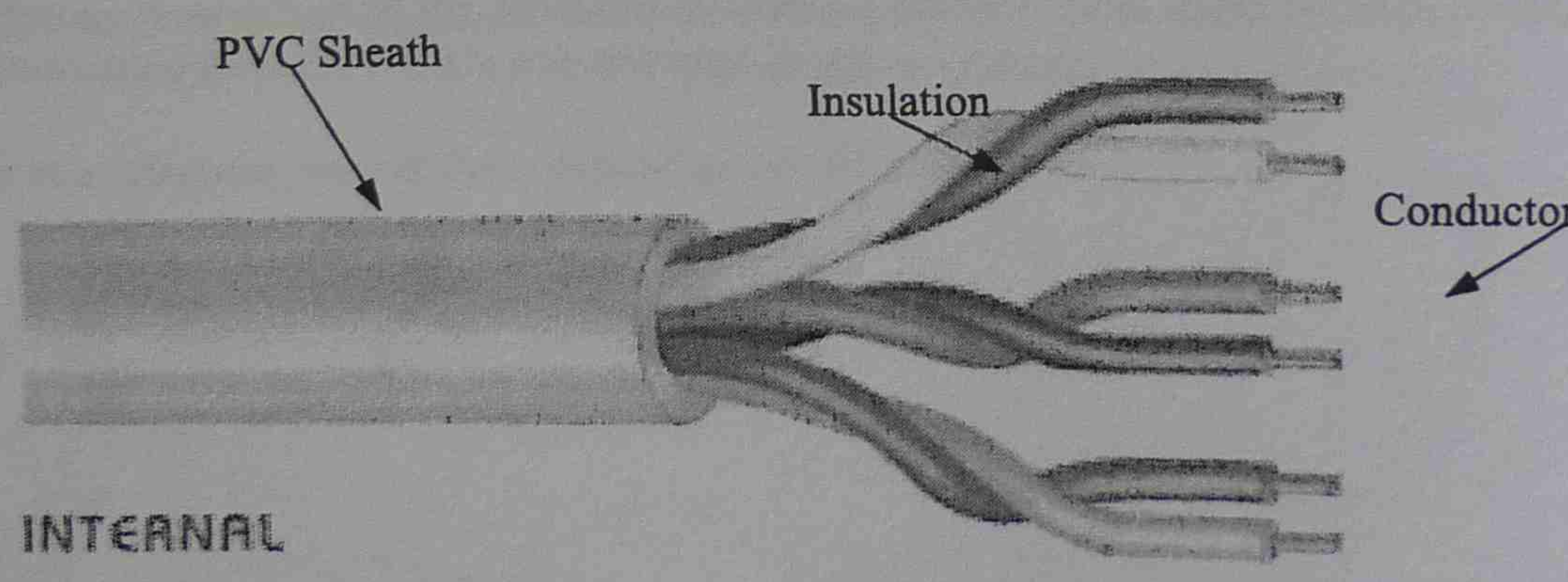


Figure 8: three pair UTP – indoor.

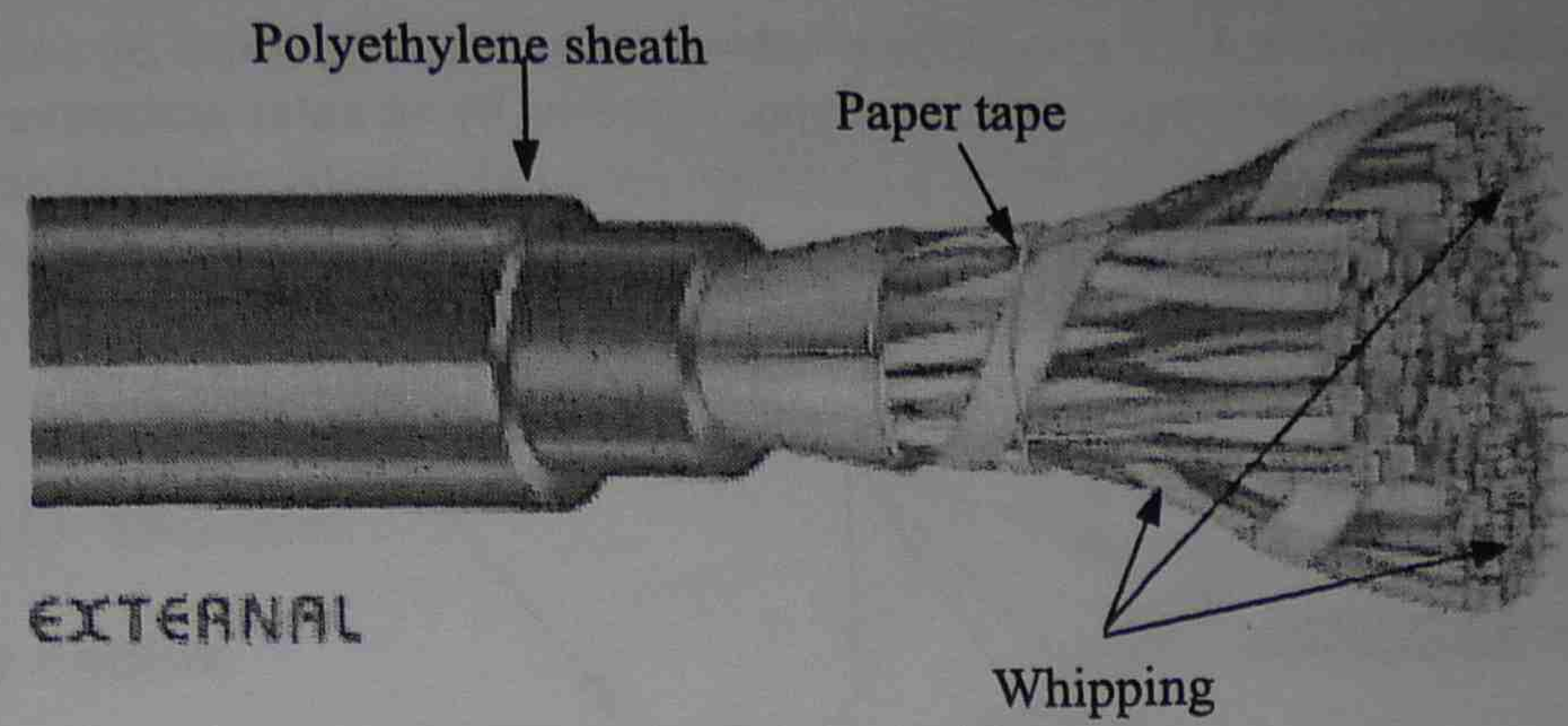


Figure 9: Multi-pair UTP – underground.

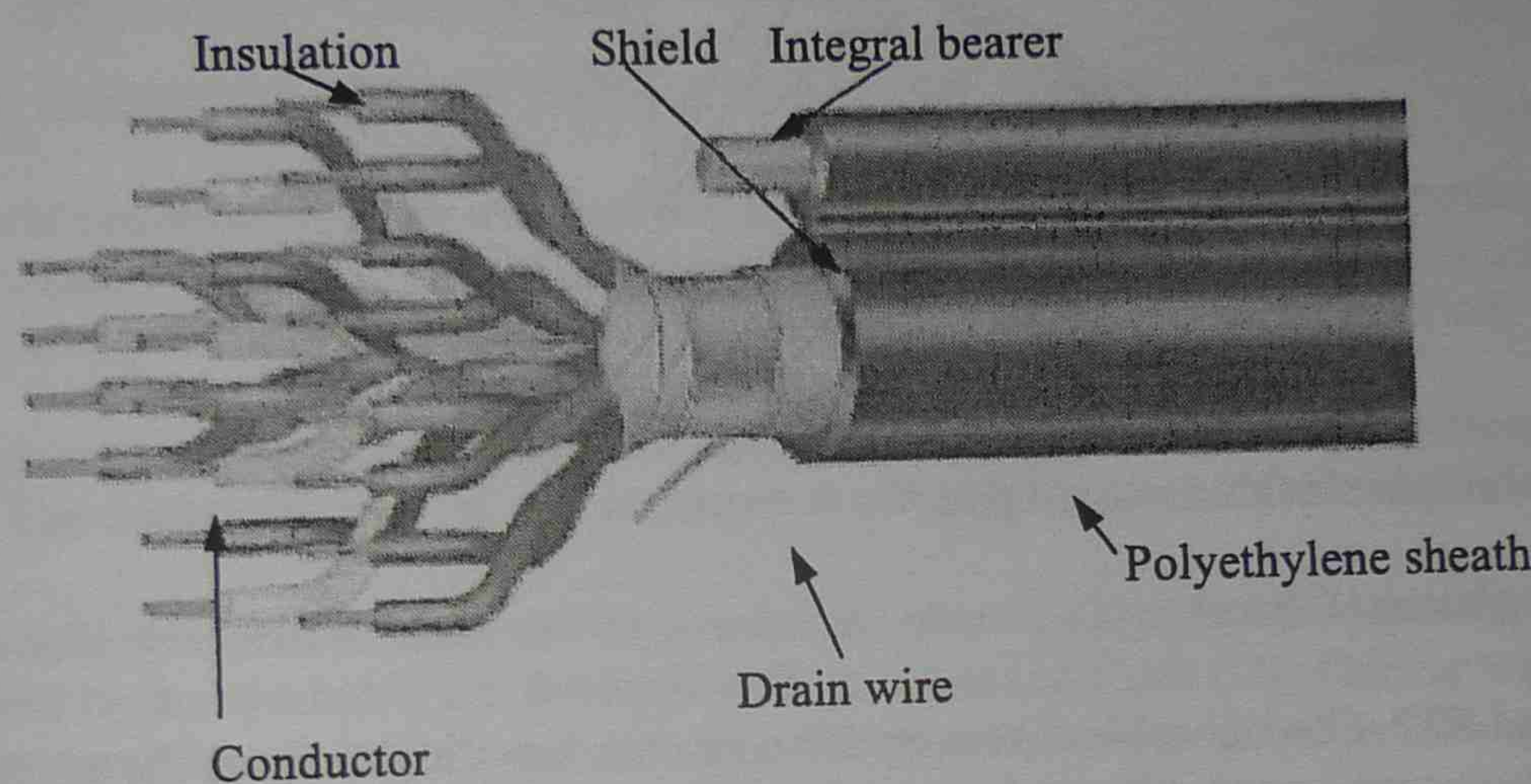


Figure 10: Multi-pair STP. (10 pair) – aerial.

Cable construction

The first three cable types (UTP, STP and Coax) have some things in common. Each has copper wire (or aluminium in some coaxial cables) in the middle surrounded by insulation.

Unshielded twisted pair

As the name suggests UTP does not have any shielding. Its construction is twisted pairs of copper wire (conductors), each wire surrounded by insulation and the combined pairs enclosed in an outer sheath. (See figure 1).

Shielded twisted pair

STP is similar in construction to UTP except the combined pairs are surrounded by a metallic shield (either copper braid or copper or aluminium tape) covered by an outer protective sheath of PVC or polyethylene. (See figure 2). Some STP cables have individually shielded pairs. This prevents leakage of signals from one pair of wires to another in the same cable. These are called Multiple shielded twisted pair cables (or Multi STP). (See figure 11).

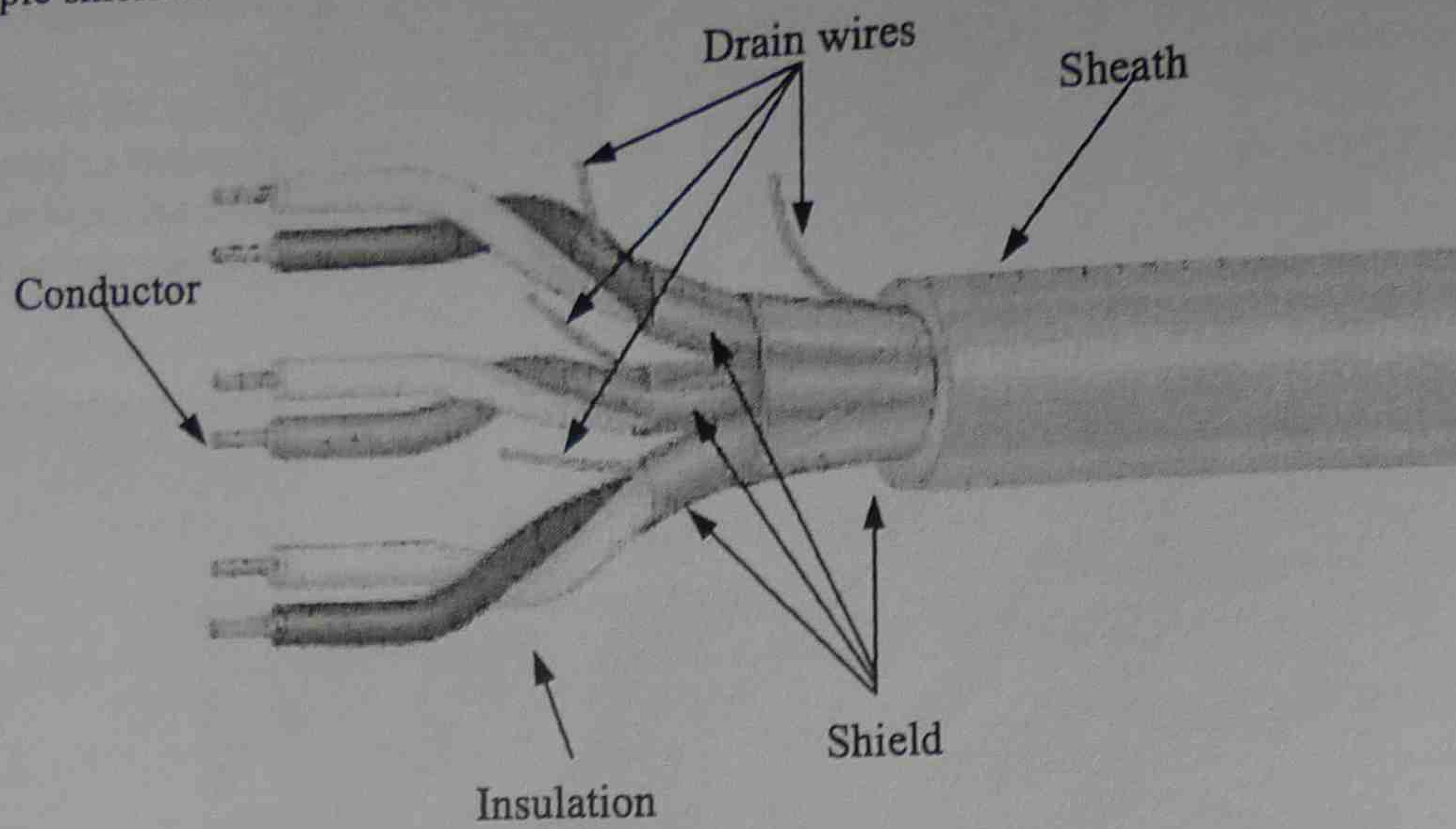


Figure 11: Multiple shielded twisted pair.

Coaxial Cables (Coax)

Like UTP and STP, Coaxial cables use copper (some coax has aluminium) as the conductor. Coaxial cable is constructed differently from that of UTP and STP in that instead of using multiple pairs of twisted wires to carry the signal, it uses a single central conductor surrounded by insulation. This insulation is then surrounded by a metallic shield (either copper braid or copper or aluminium tape) covered by another outer protective sheath of PVC or polyethylene. (See figure 3). Coax uses the metallic shield as the second conductor to complete the circuit whereas UTP and STP are in pairs. i.e. two conductors. Coaxial cable is available in a variety of configurations. Some data transmission cables have several coaxial conductors combined in the same sheath. (See figures 12 and 13).

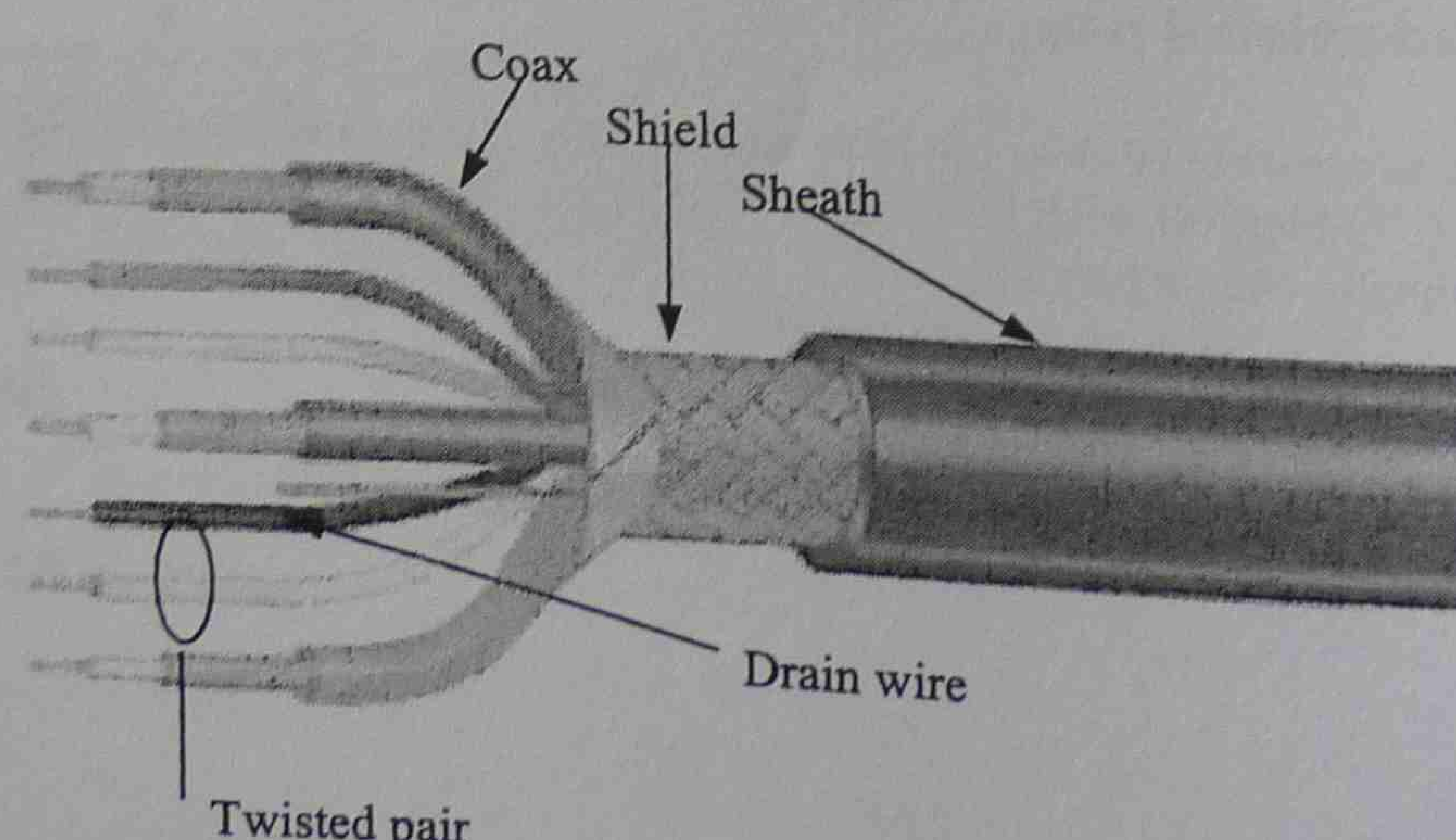


Figure 12: multiple coaxial with 2 twisted pair.

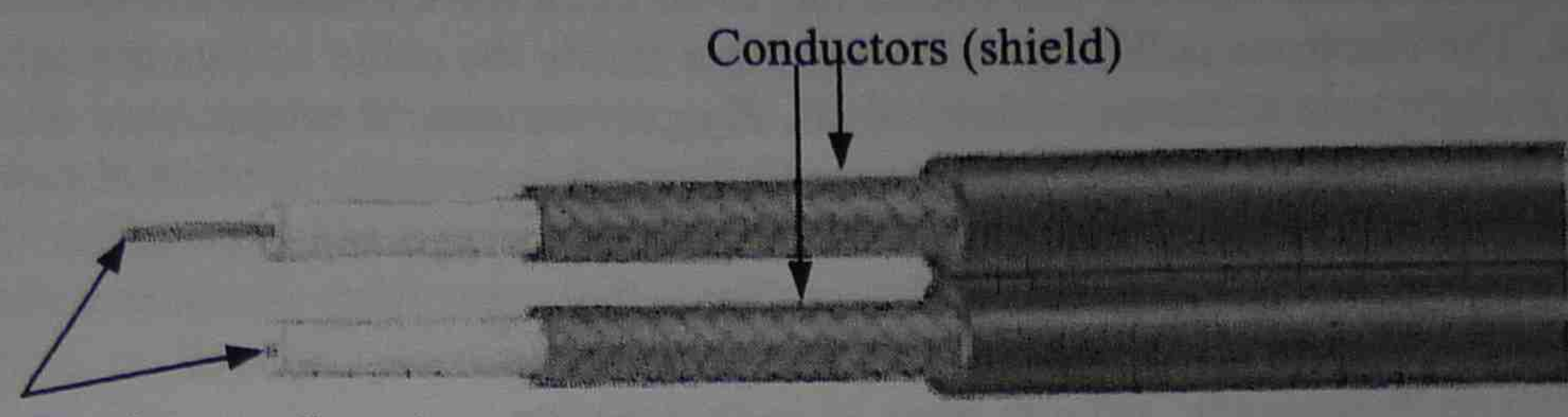


Figure 13: Twin-axial.

Older cables

Twisted pair cables used in Telecommunications many years ago used copper conductors surrounded by paper or cotton insulation and enclosed in a lead sheath. The lead sheath performed the same function as a shield on STP cable coax.

Central copper conductor (UTP and STP cables)

The central conductor is made of copper - a good conductor of electricity. Sometimes this wire may be coated with solder. When this happens it is said that the wire is tinned. Since solder is made up of a mixture of lead and tin, the solder coating helps to prevent corrosion.

The conductors in twisted pair cables are supplied in a range of different diameters e.g. 0.4mm - 0.9mm. The thicker the wire the less resistance it offers to the signals that travel along it.

Resistance is measured in ohms and the symbol for ohms is Ω (omega). A quantity of resistance is signified by the symbol R. i.e. Resistance (R) measured in ohms (Ω). Thicker wire is often used to transmit signals over long distances. Cable resistance is specified in ohms per loop kilometre (Ω/km) i.e. for a pair of wires connected together at one end and measured at the other end with an ohmmeter. (See figure 14).

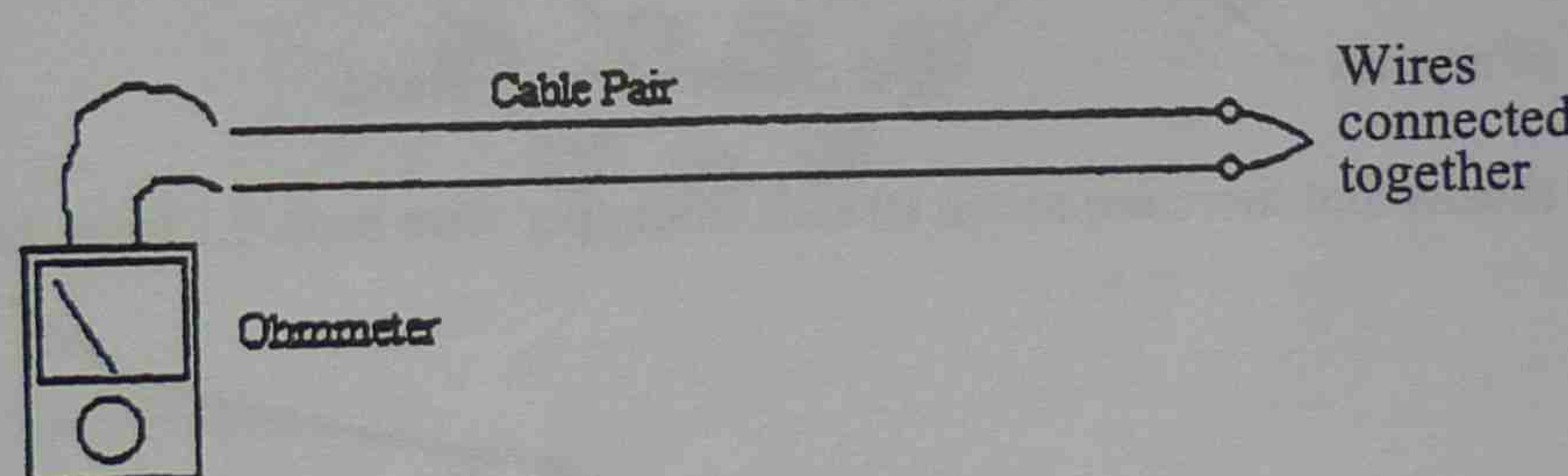


Figure 14: Measuring resistance of a cable pair.

This resistance means that the transmitter has to do extra work to make the electrons flow down the cable. The electrons colliding with each other inside the cable causes the cable to heat up - only very slightly in communication cables. By comparison, if proper care is not taken with power cables, the heat generated may cause the insulation to melt. Table 1 shows a comparison between different diameter conductors made of both copper and aluminium. Note: a larger diameter aluminium cable is required to achieve the same loop resistance per kilometre as copper. This is because aluminium does not conduct electricity as well as copper. For more information on 'Resistance', refer to page 36 in this section.

Cable type	Loop resistance (ohm/km)
0.40mm Cu	267
0.52mm Al	267
0.51mm Cu	164
0.64mm Cu	107
0.81mm Al	107
0.90mm Cu	53.4
Cu = Copper	Al = Aluminium

Table 1: Cable resistances.

The central copper wire may be just a single (solid) wire or consist of multiple strands of thinner copper wire. The problem with a single thick (solid) wire is that repeated flexing may cause it to break. Thinner stranded cables are more flexible. A multiple stranded flexible cable is designated as follows:

7 / 0.13mm

no. of strands — diameter of each strand

This code means that there are seven strands of copper wire each 0.13mm diameter.

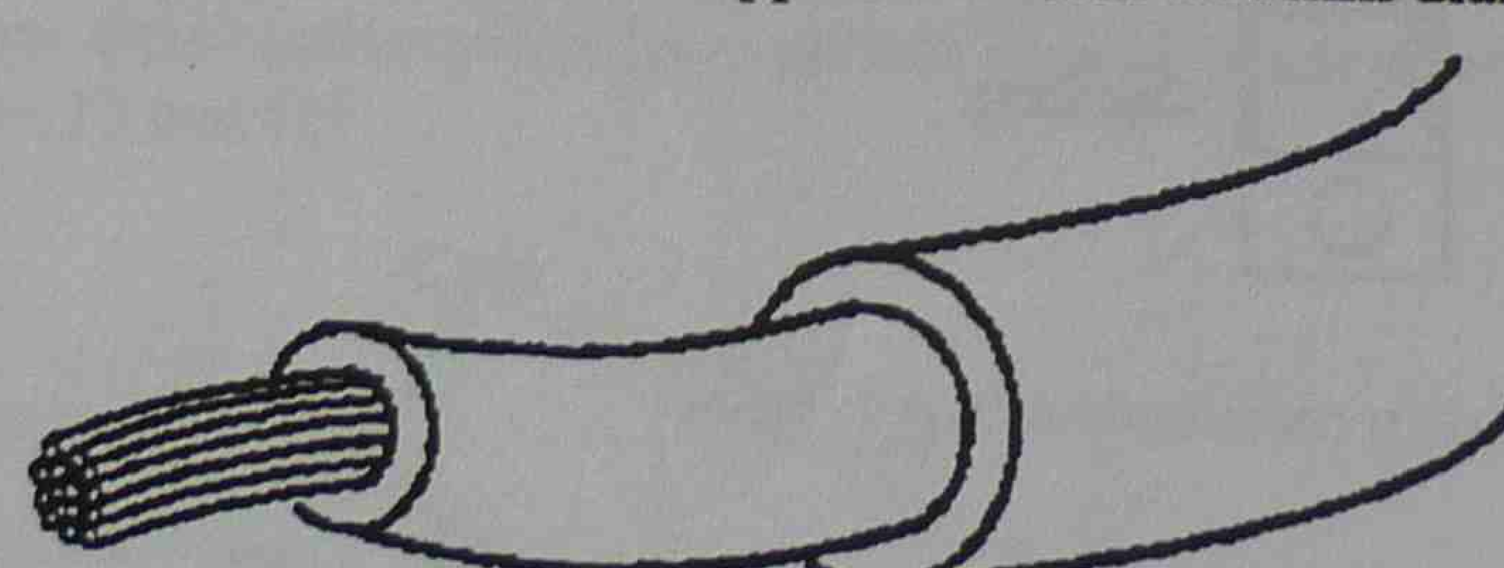


Figure 15: Multi-stranded cable.

Single (solid) conductor wire is used in fixed installations where the only movement is during installation. Flexible multi-strand cables or cords are used where there is regular movement e.g. the cord to a telephone handset. Think of the things used in every day life that has a cord that plugs in or is moved around e.g. cords on toasters, kettles, computer mouse and welding cables. All of these have multi-stranded conductors in their cords or cables.

Cable pairs and twists

For communication signals, wire is used in pairs. Signals are transmitted along the cable using both wires in each pair. This is especially useful for reducing the amount of noise that can accidentally interfere with the signal. Twisting the wire pairs together along the length of the cable also reduces the effect of unwanted signals interfering with the wanted signal.

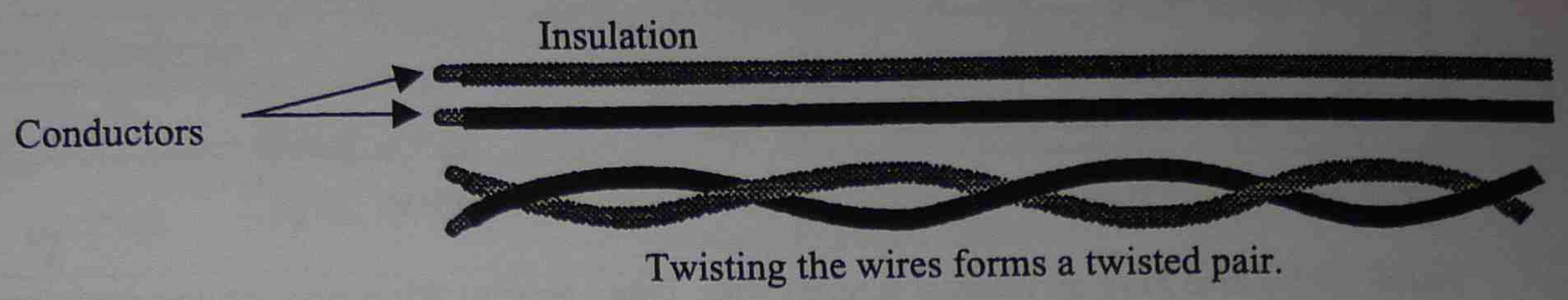


Figure 16: Twisted pair.

Identification of pairs

Sometimes many pairs of wires are laid in the same cable. In a multi-pair cable (e.g., a 100 pair cable) it would be difficult to work out which pair is which without some means of identification. For this reason, each pair is identified by using special colour codes. (See section 6). When cables are manufactured, the pairs are laid within the sheath from the outside of the cable to the core. In a 20 pair cable, pair number 1 would be found on the outside layer, just under the sheath, and pair number 20 would be found in the centre or core of the cable. (See figure 17).

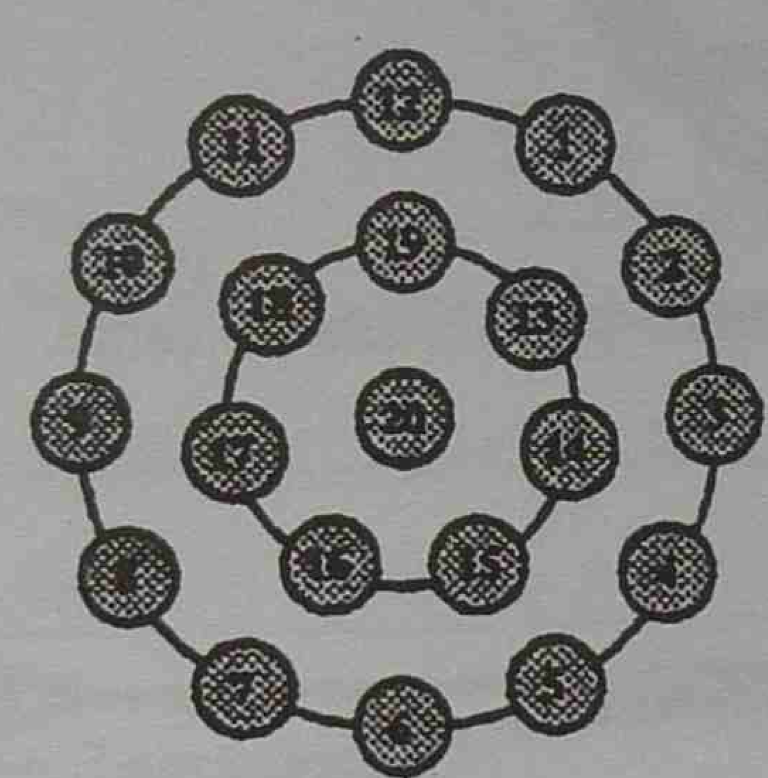


Figure 17: Cable identification.

Internal support for cables

Cables are sometimes installed in conduits, which are PVC or metal pipes, to protect them from damage. Conduits can also be installed underground to provide protection to the cables and for ease of installation and maintenance. Cables are often pulled through conduits by attaching ropes to them. To prevent the wires in the cable being stretched or broken, strong synthetic or metallic strands (supports) are built into the cable. Figure 18 shows the strengthening member in a fibre optic cable. Australian Communications Authority Standards (ACA Technical Standard 008) specify the maximum tension that may be applied to a fibre optic cable as it is drawn through a conduit.

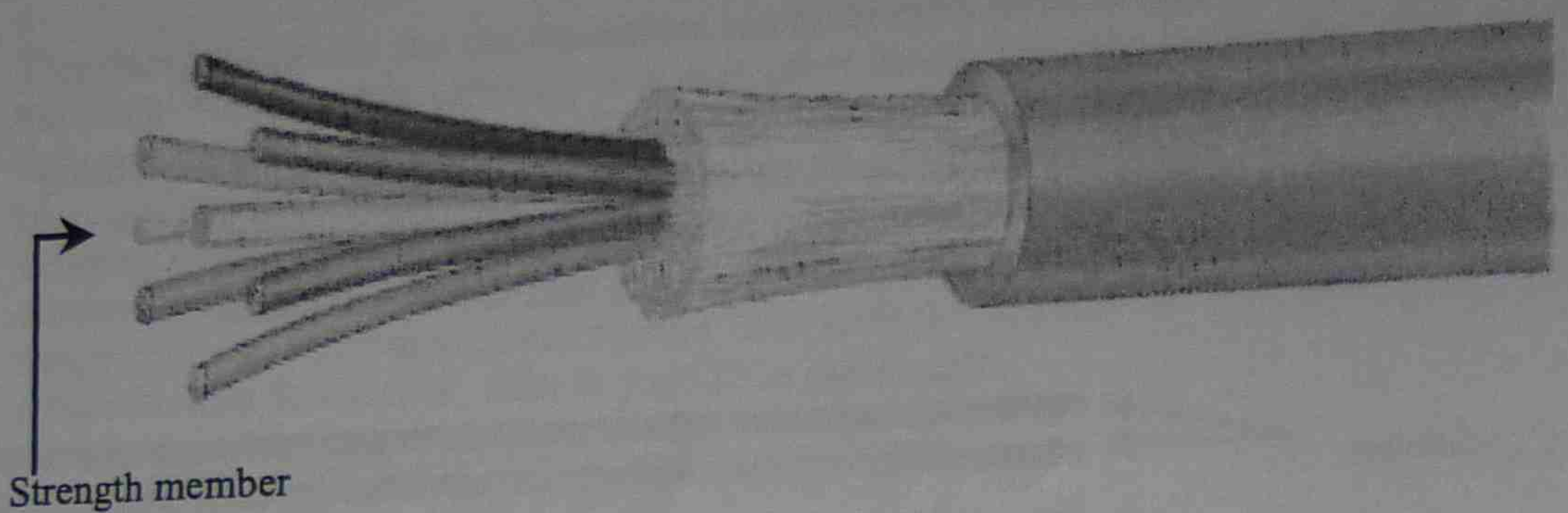


Figure 18: Internal support or strength member (Optic fibre cables).

Aerial cables also have an integral support wire. These support wires prevent any strain being placed on the conductors that may deform or break them and lead to possible loss of performance. In the telecommunications industry, aerial cables are often referred to as Integral Bearer or IB cables.

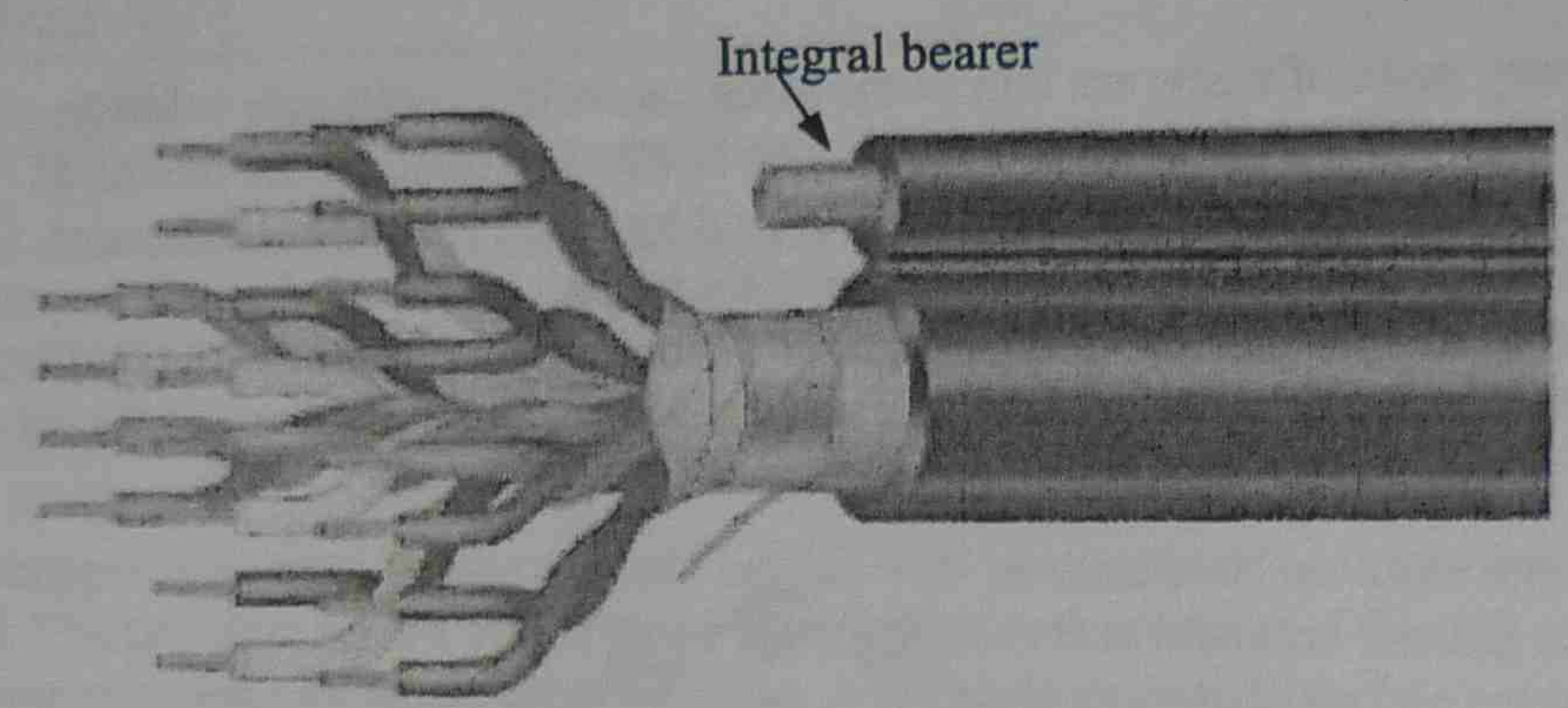


Figure 20: Integral bearer (aerial) multi-pair telephone cable.

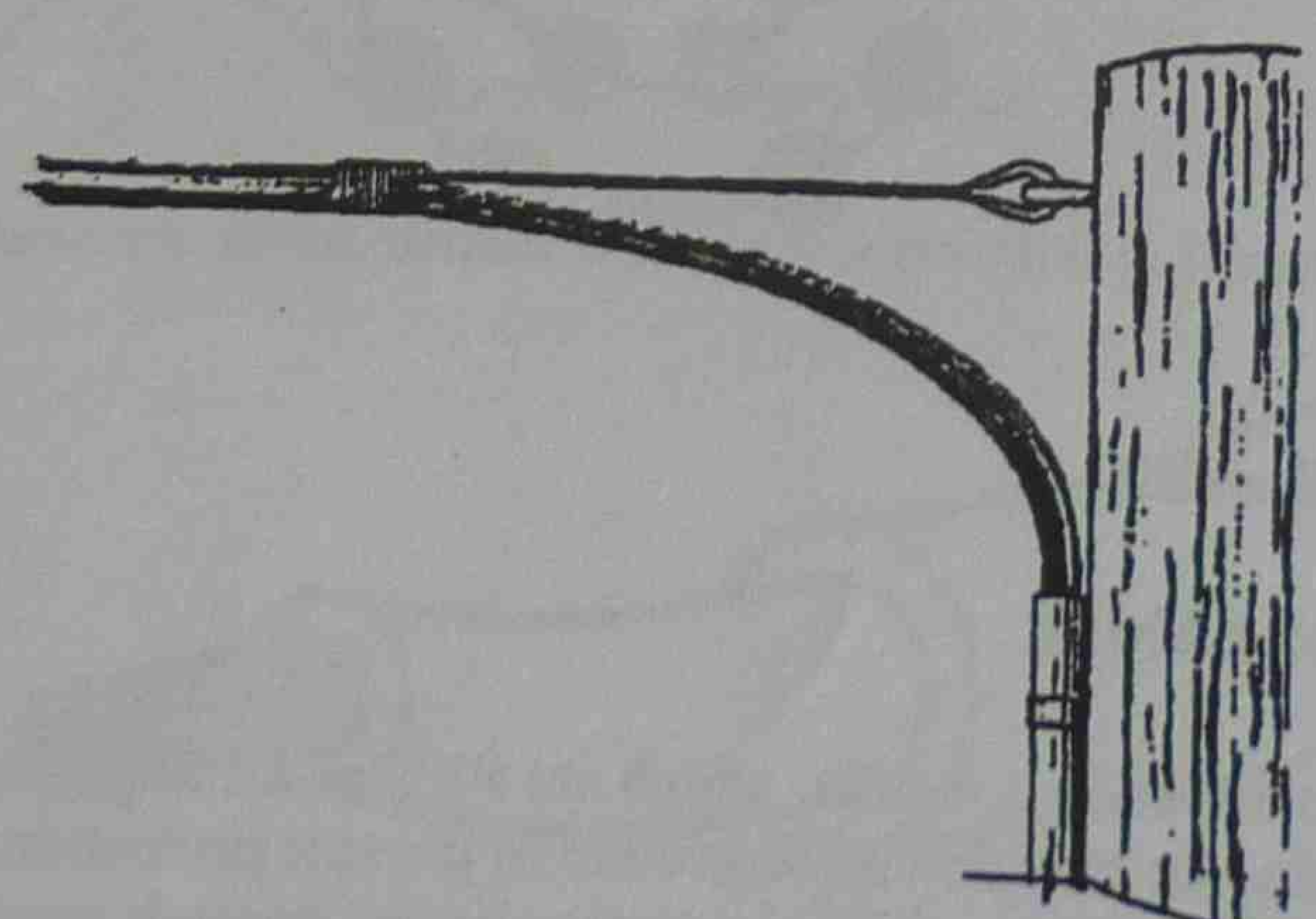


Figure 21: Typical integral bearer (aerial) cable installation.

Self help questions

1. Complete the table below:

Cable type	Use
Unshielded twisted pair	Telephone / low speed data
Shielded twisted pair	Low-level signal
coaxial cable	High speed data links, radio antenna links.
optic fibre	Very high-speed data backbone, international communication links.

2. Why is copper used as the conductor wire?

Good conductor

3. Copper wires that have been coated with solder are said to be?

Tinned

4. What does tinning help prevent?

corrosion, breaks in wire

5. A wire is specified as 25 / 0.13.

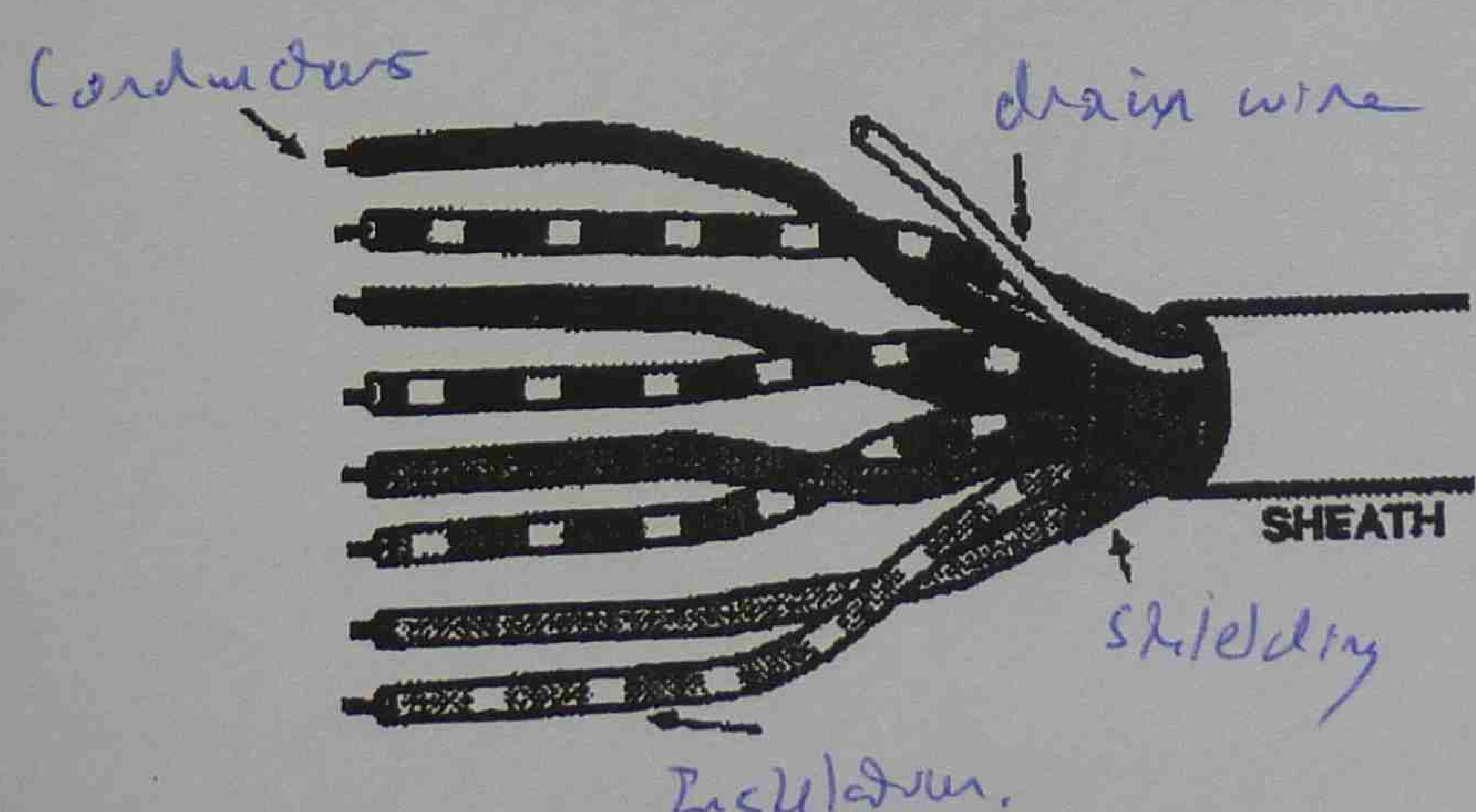
How many strands does it have? 25

What is the diameter of each strand? 0.13

6. UTP stands for Unshielded twisted pair

7. STP stands for Shielded twisted pair

8. Supply the missing labels to the diagram below:



9. Why would a 23 / 0.10 cable be preferred to a 1 / 0.90 cable in a handset cord?

much more flexible

10a. The unit of electrical resistance is the ohm. The unit is identified by the symbol Ω.

10b. A quantity of electrical resistance is identified by the symbol R.

11. The size(diameters) of conductors in twisted pair cables range from 0.4mm to 0.9.

12. How are pairs identified in multi-pair cables?

By the use of colour code and the layout inside the cable

13. What is the purpose of twisting the wires inside a cable?

so it minimises the external signals.

Answers are at the back of this book.

Cable damage

Imagine a backhoe operator accidentally cracking a water pipe with his bucket while digging a trench. The pipe may not leak immediately, but it would be unwise to leave the pipe in service as it could leak at any time and leave consumers without an essential service.

In the same way telecommunication cables may be damaged and so fail to provide the standard of service requested. The damage may not be immediately evident. With Cat. 5 cable rated at 100Mbps the cable may work perfectly well at 2Mbps and 16Mbps but problems may arise when the rated 100Mbps traffic is applied.

Common types of damage include the following.

Damage	Problem	Solution
Sheath cut. abraded or chewed.	Allows water to enter and weakens performance.	Select correct cable for the environment exercising proper care.
Cable burnt.	Destroys insulation, melts wires together.	Exercise care when soldering and using gas torch.
Cable crushed.	Upsets to spacing of conductors may increase coupling of signals from one pair to another (crosstalk). In coaxial cables, it will upset the geometry of inner core to shield, causing a short circuit or seriously degrading the performance.	Exercise due care, protect cable, and use armoured cable.
Cable stretch.	Wires may be broken, destroys geometry.	Use cable with integral bearer wire. Ensure no obstructions when pulling cable.
Cable kinking.	Alters twist geometry.	Install and handle cable carefully. Monitor cabling bending radius, normally a maximum of 10 times the external diameter of the cable.
Sheath twisted.	Destroys twist geometry.	The cable must not exhibit any visible damage.
Impact.	Cable being hit.	No visible damage.

The performance of various cables must not be impaired after suffering damage such as those listed above.

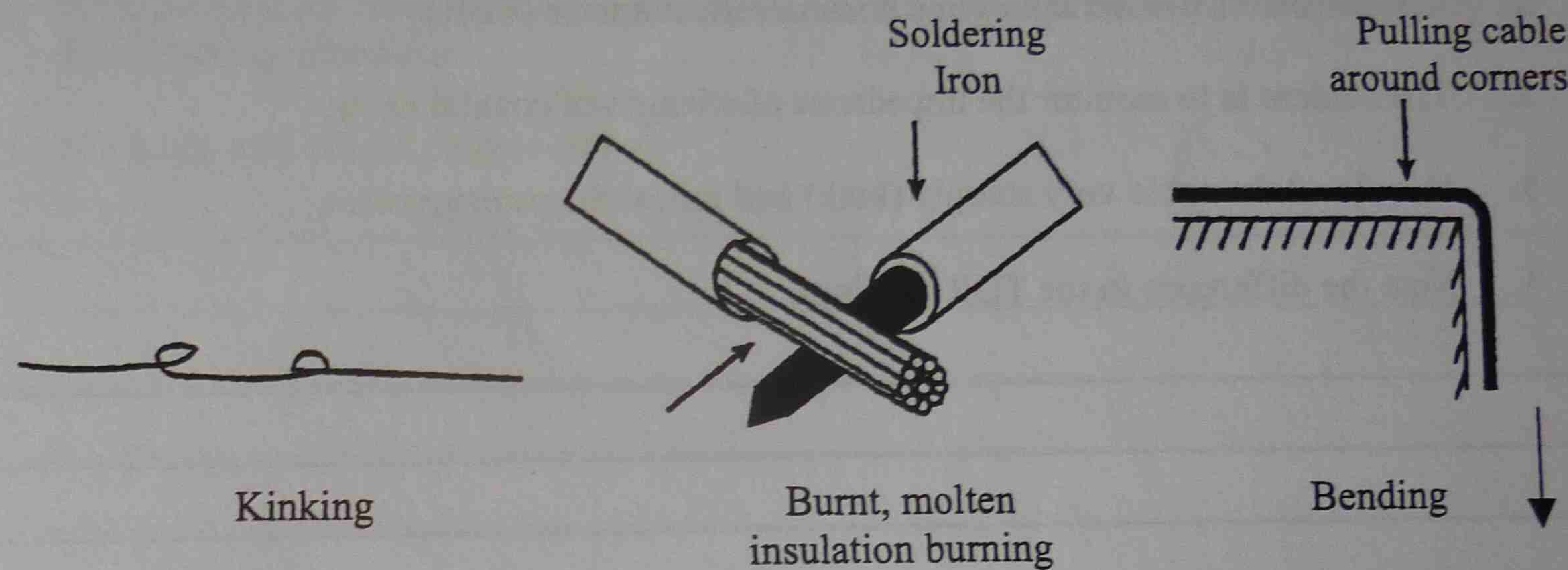


Figure 53: Diagram showing bending, kinking, burnt examples.

Stripping the sheath

The first step in preparing a cable for termination is to strip off the protective sheath if present. Cables from different manufacturers and different types may have sheaths of differing thickness. Sheath removal is best done using a tool designed for the particular cable. Cable manufacturers often supply special tools for use on their cables. A little practice may be required to get used to stripping sheath from a particular cable with the recommended tool. With a large range of cables available from a number of manufacturers, the purchase of these special tools can be very costly. Therefore, industry generally uses cutters to cut and sheath the cable.

Note: For optical fibre, coaxial or underground and aerial cables, special tools must be used to remove sheaths. Optical fibre cables also require specific tools to remove cladding and to cleave (cut) the fibre. Cutters must not be used on Optical fibre cables.

If the cable is armoured then delicate sawing may be necessary to cut through the armour. Again, a special tool may be available for this task.

The length of sheath to be removed is determined by the type of cable and the type of termination required. Most proprietary termination blocks and fittings come with instructions as to how much sheath and insulation should be removed. This data from the manufacturer must be checked before commencing work.

In the case of category five cables, it is important that the pairs do not separate or untwist. Standards specify that no more than 13 mm of each pair is untwisted. Because unsheathed pairs are more susceptible to untwisting, kinks and any other trauma, it is preferable to strip back only the amount of sheath that is required for termination. In cases where short strip back lengths are not practical, the cable sheath may be removed significantly more than 13mm (to 130mm) without any additional transmission degradation, provided that reasonable precautions are observed during installation and maintenance is given to ensure that untwisting and other deformation of the pairs is minimised.

Once the sheath has been butted or cut, by placing a circular cut around it, it should be easily withdrawn from the cable to expose any underlying shielding and the cable or pairs.

Most indoor telephone and category five cable manufacturers insert a rip or pull cord just under the sheath during the manufacture of the cable. This makes sheath removal easier and minimises the likelihood of damage to the conductors or insulation by accidental cutting when butting the cable. To use the pull cord, simply nick the cable sheath from the end for approximately 50mm. Gently open the sheath to find the pull cord. Pull cords are usually strong white coloured strings. Once located, hold the pull cord firmly with your fingers or long nosed pliers and pull it down the cable to rip a slit along the sheath to the point where you need the sheath removed. Next fold the sheath back along the cable to the proposed butt and, with angle cutters, cut or butt the cable being careful not to cut any conductors.

If there is shielding, this can then be peeled back to the length specified by the manufacturer's instructions. Care must be taken with any drain wires. These will need to be terminated too.

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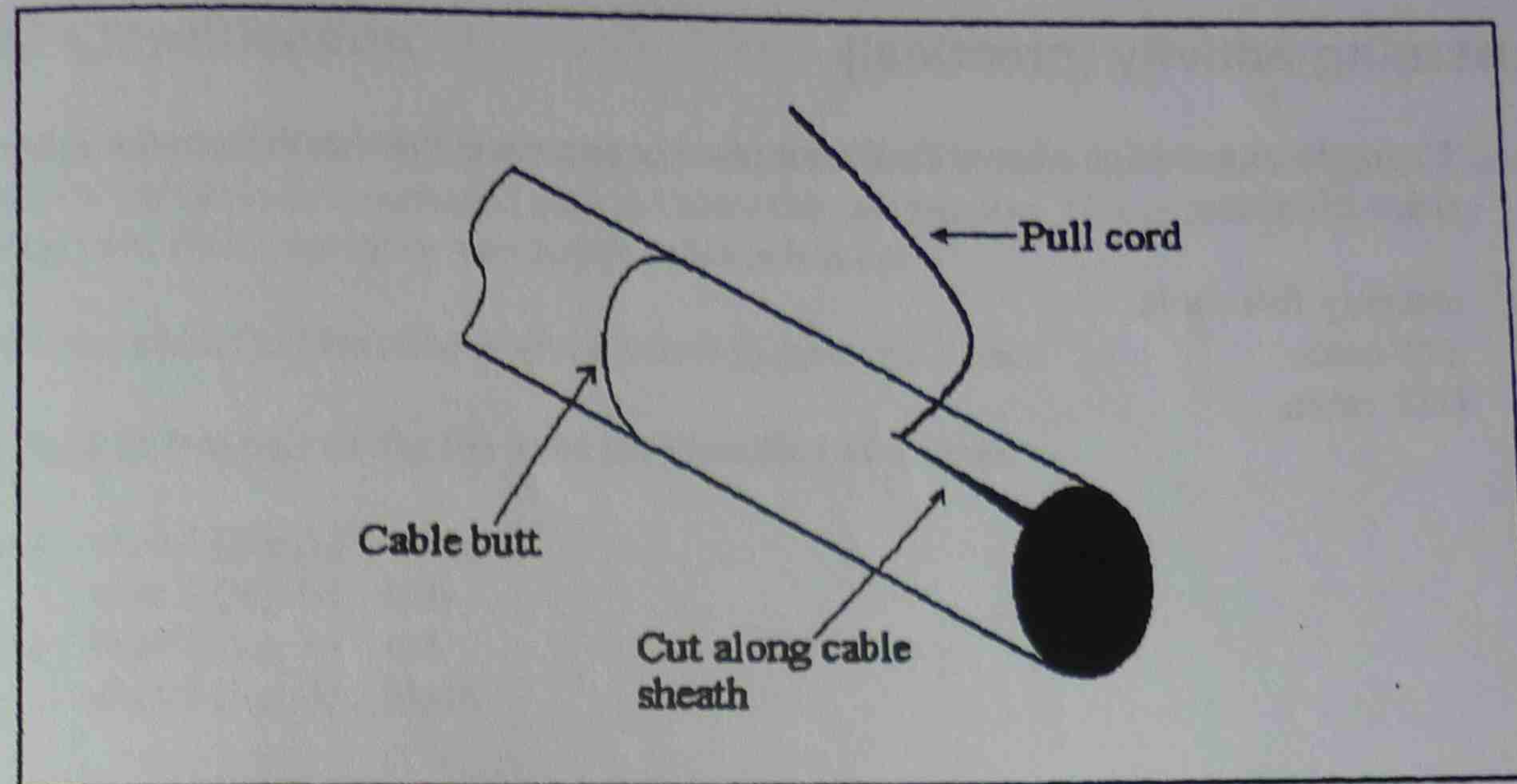


Figure 60: Cable sheath stripping.

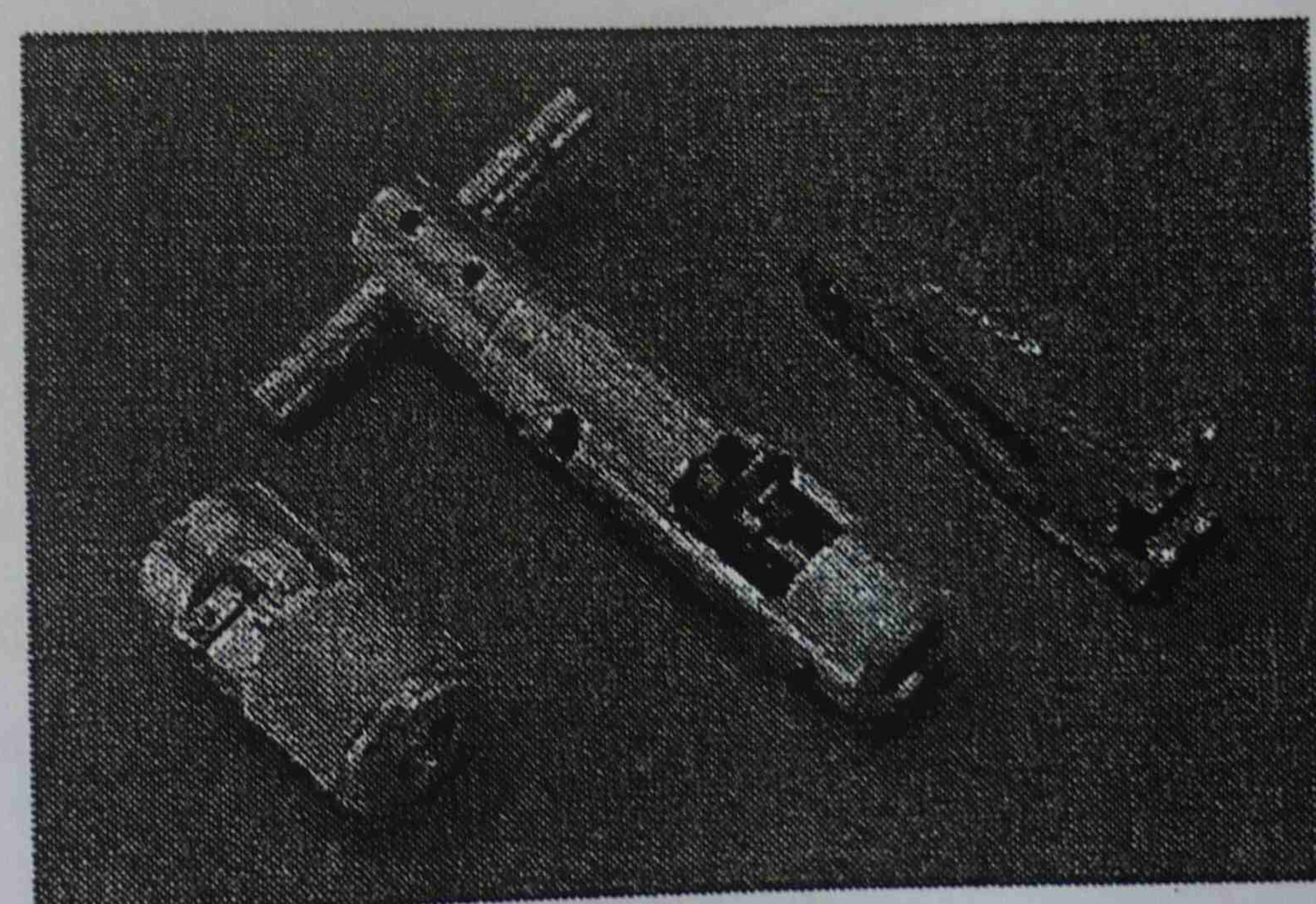


Figure 61: Various stripping tools.

Now you are ready to identify the various conductor pairs.

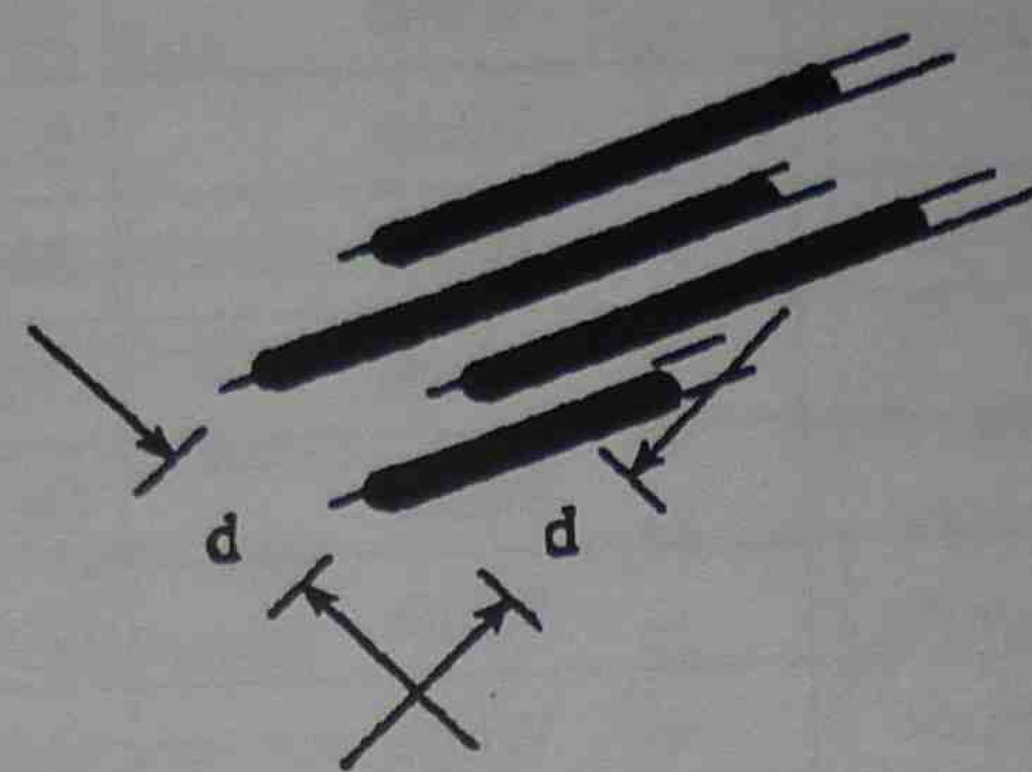
Pair identification

In order to identify the pairs in a multipair cable, standard colours have been assigned. The way in which the cable is constructed also indicates the pair number. This is best illustrated by having your facilitator show you how a cable is laid up.

However, a brief explanation is given below to give you a start.

For quad or two pair cables the pairs are identified as follows:

Pair 1	wire 1 (leg A)	white
	wire 2 (leg B)	blue
Pair 2	wire 1 (leg A)	red
	wire 2 (leg B)	black



Quad cable

All pairs are equidistant to ensure good transmission quality.

Figure 62: Quad cable layout.

Pairs in a multipair indoor cable, number from the outside of the cable to the core in a circular fashion.

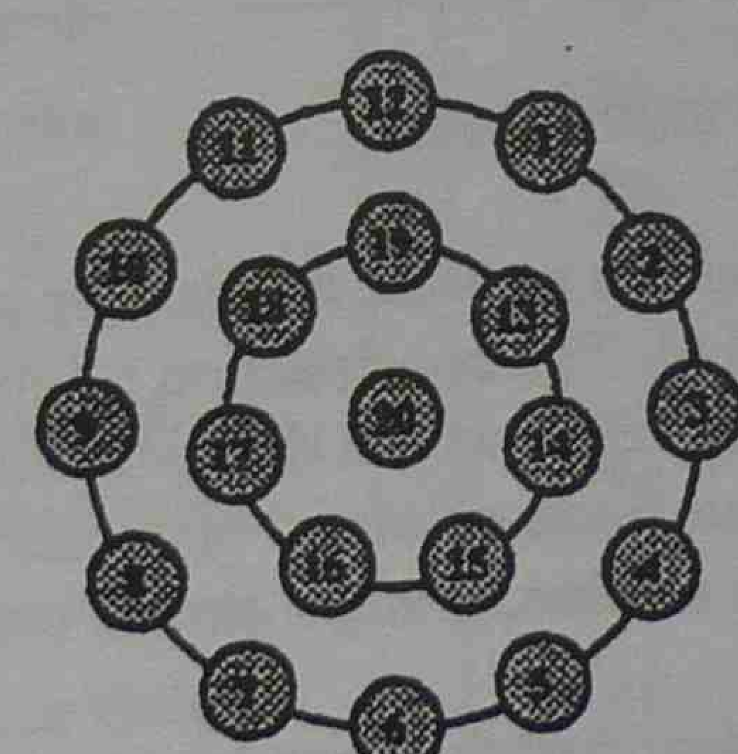


Figure 63: Arrangement of pairs (20 pair indoor cable).

The following table is the colour code for the identification of pairs in a 20 pair indoor cable.

Pair number	A – Leg (positive)	B – Leg (negative)
1	White	Blue
2	White	Orange
3	White	Green
4	White	Brown
5	White	Grey
6	White	Blue/white
7	White	Blue/orange
8	White	Blue/green
9	White	Blue/brown
10	White	Blue/grey
11	White	Orange/white
12	White	Orange/green
13	White	Orange/brown
14	White	Orange/grey
15	White	Green/white
16	White	Green/brown
17	White	Green/grey
18	White	Brown/white
19	White	Brown/grey
20	White	Grey/white

Table 14: Colour code for 20 pair indoor cable.

Where there are more wire pairs laid in a cable, it is laid or constructed in such a way as to allow groups of pairs to be identified. The construction might be compared to that of the layers in an onion. There are various layers each with a different coloured ring or wrap e.g. white, yellow, black, violet and red. Within each coloured layer the pairs are made up of the layer colour plus the repeating sequence of blue, orange, green, brown and grey. (See table 15).

Once these groupings have been identified they can be separated and fanned out for stripping off the insulation and termination.

When separating cable pairs for fanning it is often highly critical that the pairs do not become untwisted. The cable twist must be maintained right up to the termination. This is very important for category five and higher data rate cables.

Different manufacturers use variations of this colour identification code in their smaller proprietary cables. It is best to consult each manufacturer's data book for each cable.

The following are typical colour codes for 100 pair indoor telephone cables.

Pair No.	A Leg	B Leg
1	White	Blue
2	White	Orange
3	White	Green
4	White	Brown
5	White	Grey
6	White	Blue/white
7	White	Blue/orange
8	White	Blue/green
9	White	Blue/brown
10	White	Blue slate
11	White	Orange/white
12	White	Orange green
13	White	Orange/brown
14	White	Orange/grey
15	White	Green/white
16	White	Green/brown
17	White	Green/grey
18	White	Brown/white
19	White	Brown/grey
20	White	Grey/white
21	Yellow	Blue
22	Yellow	Orange
23	Yellow	Green
24	Yellow	Brown
25	Yellow	Grey
26	Yellow	Blue/white
27	Yellow	Blue/orange
28	Yellow	Blue/green
29	Yellow	Blue/brown
30	Yellow	Blue slate
31	Yellow	Orange/white
32	Yellow	Orange green
33	Yellow	Orange/brown
34	Yellow	Orange/grey
35	Yellow	Green/white
36	Yellow	Green/brown
37	Yellow	Green/grey
38	Yellow	Brown/white

Pair No.	A Leg	B Leg
51	Black	Orange/white
52	Black	Orange green
53	Black	Orange/brown
54	Black	Orange/grey
55	Black	Green/white
56	Black	Green/brown
57	Black	Green/grey
58	Black	Brown/white
59	Black	Brown/grey
60	Black	Grey/white
61	Violet	Blue
62	Violet	Orange
63	Violet	Green
64	Violet	Brown
65	Violet	Grey
66	Violet	Blue/white
67	Violet	Blue/orange
68	Violet	Blue/green
69	Violet	Blue/brown
70	Violet	Blue slate
71	Violet	Orange/white
72	Violet	Orange green
73	Violet	Orange/brown
74	Violet	Orange/grey
75	Violet	Green/white
76	Violet	Green/brown
77	Violet	Green/grey
78	Violet	Brown/white
79	Violet	Brown/grey
80	Violet	Grey/white
81	Red	Blue
82	Red	Orange
83	Red	Green
84	Red	Brown
85	Red	Grey
86	Red	Blue/white
87	Red	Blue/orange
88	Red	Blue/green

39	Yellow	Brown/grey
40	Yellow	Grey/white
41	Black	Blue
42	Black	Orange
43	Black	Green
44	Black	Brown
45	Black	Grey
46	Black	Blue/white
47	Black	Blue/orange
48	Black	Blue/green
49	Black	Blue/brown
50	Black	Blue slate

89	Red	Blue/brown
90	Red	Blue slate
91	Red	Orange/white
92	Red	Orange green
93	Red	Orange/brown
94	Red	Orange/grey
95	Red	Green/white
96	Red	Green/brown
97	Red	Green/grey
98	Red	Brown/white
99	Red	Brown/grey
100	Red	Grey/white

Table 15: Colour code for 100 pair indoor cable.

Pair no.	A leg	B leg	Whipping
1	White	Blue	Blue
2	White	Orange	Blue
3	White	Green	Blue
4	White	Brown	Blue
5	White	Grey	Blue
6	Red	Blue	Blue
7	Red	Orange	Blue
8	Red	Green	Blue
9	Red	Brown	Blue
10	Red	Grey	Blue
11	White	Blue	Orange
12	White	Orange	Orange
13	White	Green	Orange
14	White	Brown	Orange
15	White	Grey	Orange
16	Red	Blue	Orange
17	Red	Orange	Orange
18	Red	Green	Orange
19	Red	Brown	Orange
20	Red	Grey	Orange
21	White	Blue	Green
22	White	Orange	Green
23	White	Green	Green
24	White	Brown	Green
25	White	Grey	Green
26	Red	Blue	Green
27	Red	Orange	Green
28	Red	Green	Green
29	Red	Brown	Green
30	Red	Grey	Green
31	White	Blue	Brown
32	White	Orange	Brown
33	White	Green	Brown
34	White	Brown	Brown
35	White	Grey	Brown
36	Red	Blue	Brown
37	Red	Orange	Brown
38	Red	Green	Brown

Pair no.	A leg	B leg	Whipping
51	White	Blue	Blue/white
52	White	Orange	Blue/white
53	White	Green	Blue/white
54	White	Brown	Blue/white
55	White	Grey	Blue/white
56	Red	Blue	Blue/white
57	Red	Orange	Blue/white
58	Red	Green	Blue/white
59	Red	Brown	Blue/white
60	Red	Grey	Blue/white
61	White	Blue	Orange/white
62	White	Orange	Orange/white
63	White	Green	Orange/white
64	White	Brown	Orange/white
65	White	Grey	Orange/white
66	Red	Blue	Orange/white
67	Red	Orange	Orange/white
68	Red	Green	Orange/white
69	Red	Brown	Orange/white
70	Red	Grey	Orange/white
71	White	Blue	Green/white
72	White	Orange	Green/white
73	White	Green	Green/white
74	White	Brown	Green/white
75	White	Grey	Green/white
76	Red	Blue	Green/white
77	Red	Orange	Green/white
78	Red	Green	Green/white
79	Red	Brown	Green/white
80	Red	Grey	Green/white
81	White	Blue	Brown/white
82	White	Orange	Brown/white
83	White	Green	Brown/white
84	White	Brown	Brown/white
85	White	Grey	Brown/white
86	Red	Blue	Brown/white
87	Red	Orange	Brown/white
88	Red	Green	Brown/white

39	Red	Brown	Brown
40	Red	Grey	Brown
41	White	Blue	Grey
42	White	Orange	Grey
43	White	Green	Grey
44	White	Brown	Grey
45	White	Grey	Grey
46	Red	Blue	Grey
47	Red	Orange	Grey
48	Red	Green	Grey
49	Red	Brown	Grey
50	Red	Grey	Grey
89	Red	Brown	Brown/white
90	Red	Grey	Brown/white
91	White	Blue	Grey/white
92	White	Orange	Grey/white
93	White	Green	Grey/white
94	White	Brown	Grey/white
95	White	Grey	Grey/white
96	Red	Blue	Grey/white
97	Red	Orange	Grey/white
98	Red	Green	Grey/white
99	Red	Brown	Grey/white
100	Red	Grey	Grey/white

Table 16: Colour code for 100 pair outdoor cable.

Preparing filled cables for termination

Filled cable requirements

Filled cables are used in areas where water penetration into cables is a possibility. This restricts the use of filled cables to external underground and aerial cables. Filled telecommunications cables must comply with ACA technical standard TS 008 (or its replacement).

Learning activity: Summarise the requirements for filled cables

1. Using TS 008 (or its replacement) found in your communications cabling manual summarise the requirements for filled cables in the space below.

Preparing filled cables

Filled cables are prepared in the same way as any other cable but with one exception. The filling material around the cables must be carefully removed prior to terminating. Once the sheath is removed from the cable and pairs separated, filling material should be removed using a solvent such as isopropyl alcohol. At all times rubber gloves should be worn and eye protection is advisable. The work area should also be well ventilated.

The filling material in these cables has been known to cause allergic reactions in many people so all due care should be taken during the preparation phase. Any rags used to wipe down the cable should be sealed in plastic bags and disposed of appropriately. Gloves should also be disposed of at the end of the task. Any filling compound should be immediately removed from the work site to prevent future contamination. Hands should be washed after the work is complete and all tools used should be cleaned.

Overview

In the previous sections you have learnt about earthing and how it applies to telecommunications cabling. In this section you will learn about surge suppression devices and their earthing requirements.

Causes of surges

Within a telecommunications network there are a number of faults that may arise to cause damage to personnel or equipment. Surge suppression is designed to reduce the risks of excessive surges of voltage that damage telecommunications networks or equipment.

One of the main causes of voltage surges in a telecommunications network is lightning. However, other electrical surges may result from equipment malfunctions, the power distribution network and static electricity.

As you learnt in the second section of this module, Earth potential rise can result from power system faults and can be dangerous to a telecommunications network. When lightning from a thunderstorm hits the ground, a similar effect to EPR can be the result.

Lightning is the flow of an electrical charge over a very short period of time that results from atmospheric disturbances. When a lightning strike hits the earth, the ground surrounding the lightning strike assumes a very high potential, and any telecommunications conductors in this region may suffer from its effects. The effect is even more dramatic if lightning directly strikes parts of the telecommunications network, such as overhead wires.

The effects may range from minor noise or disruption of the service due to induction, to severe damage of cable and equipment and injury to users, due to insulation failure and high-induced EMFs. In any event, it is worth noting the warnings in all phone directories to avoid using telecommunications equipment during thunderstorms.

Surge suppression techniques

As you have already learnt, cable shielding can protect cables from unwanted interference. In the case of lightning strikes however, cable shielding is not always effective as the very high voltages encountered can breakdown shields and insulation. There are two main methods used to protect telecommunications plant and personnel from overvoltage surge hazards:

1. interception of the lightning strike
2. diversion of the lightning surge to earth.

Interception

This involves the use of a lightning down-conductor to attract the lightning to itself rather than to the telecommunications network. This method is used commonly in the telecommunications network but not at individual installations.

Diversion

This method of protection is used at individual installations to protect them from any excessive voltage surges. In using this method, devices are connected between the incoming telecommunications lines and earth. When a voltage surge is detected by one of the devices, a short circuit to earth is created and the voltage surge flows to earth. The most common device used for this purpose in a telecommunications installation is a gas filled surge diverter. These devices are also known as surge suppressors. The operating principle of these devices will be discussed before you study the methods of installation and component requirements.

Ceramic gas filled surge diverters

These devices are the most commonly used protectors for telecommunications circuits in Australia. As figure 18 shows, they consist of a glass or ceramic shell that is filled with an inert gas (i.e. a non-reactive gas) below atmospheric pressure. A small amount of radioactive material is enclosed in the device to help with ionisation and stability.

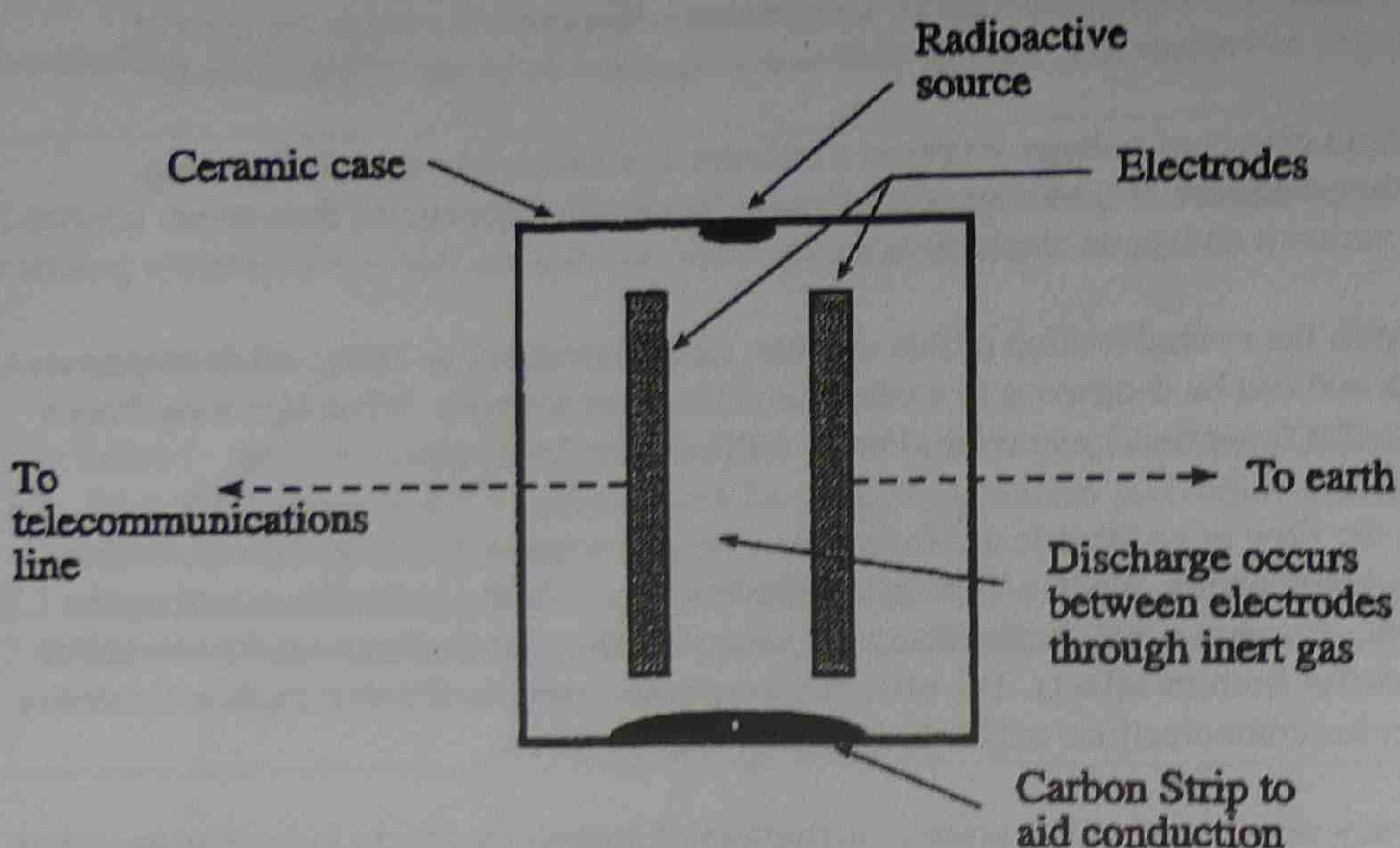


Figure 18: Simplified gas filled surge suppressor.

Under normal conditions, one electrode is connected to earth while the other is connected to a telecommunications line conductor. The gas between the electrodes conducts only very small amounts of current (typically in the range of nano-amps) at this stage. As the voltage across the electrodes starts to increase, the gas begins to arc and small amounts of current flow. This is known as the arc discharge mode and a few hundred milli amps of current may flow. As the voltage increases further, the device enters the glow discharge mode and large amounts of current may flow. This successfully diverts the over-voltage surge to earth and the installation is therefore protected.

As you can imagine, the effectiveness of these devices will rely on their speed and the voltage at which they switch or divert surges. These devices can typically respond to surges in a fraction of a microsecond. The voltages at which they operate will now be discussed in the following paragraphs.

ACA requirements for surge suppressors

ACA Technical Standard 001 stipulates safety requirements for customer equipment. This technical standard has been cross-referenced to AS/NZS 4117 for the specifications applicable to surge suppressors in a telecommunications installation.

Because of the hazards associated with lightning, surge suppression must be installed where the risk of injury from a strike is high, as assessed in accordance with AS 4262.1. The carrier will usually install surge suppression devices in high-risk areas, but if the network boundary is not on or in the building where the user equipment is or will be located, then it is the responsibility of the cabler to assess the situation and install surge suppression devices accordingly. This requirement is detailed in clause 5.1.17 of TS 009 (or its replacement). The class and voltage specifications of the appropriate surge suppressors can be found, for ease of reference, in the notes to clause 5.1.17 of TS 009 (or its replacement).

Some CE have their own built-in surge suppression and these devices must comply with AS/NZS 3260. These may be of solid-state construction, whereas devices for use in a customer cabling installation must be gas filled or include a gas filled device.

The following exercise will help you understand the value of the surge suppressors. Re-read the notes in clause 5.1.17 of TS 009 (or its replacement). This describes surge suppression devices installed between telecommunications line conductors and earth.

1. Make a note of all the voltages mentioned and any terms you don't understand in clause 5.1.17 of TS 009.

a) A class 1 device min 400VAC max 1200VAC
b) A class 3 device min 190 AC max 800 AC
* class 3 has 230VAC suppressors
on CD/BD.

In these notes in clause 5.1.17 of TS 009 (or its replacement) mention is made of the term firing voltage. This is the voltage at which the device will become low resistance and conduct any surges to earth. This firing voltage is commonly regarded as the value that the suppressor is known by as an alternative to the class value.

To consider any devices installed at a CD or BD, you must look at clause 5.1.17 (a). This clause states that devices installed in the CD/BD can be either a Class 1 or Class 3 device.

A Class 1 device will have a minimum limiting voltage of 400V AC and a maximum limiting voltage of 1200V AC. To achieve this criterion a nominal firing voltage of 500V will be required.

A Class 3 device will have a minimum limiting voltage of 190V AC and a maximum limiting voltage of 800V AC. To achieve this criterion a nominal firing voltage of 230V will be required.

Cable

Two insulated copper conductors form the basis of the telephone service to the customer's premises. Twisting insulated wires together forms a 'twisted pair'. This twisted pair is the pathway for signals between the customer's telephone and the carrier's exchange. Cable compliant to TS 008 must be used for customer cabling. These cables must carry a compliance mark when sold.

Figure 1 depicts the construction of a simple twisted pair cable.

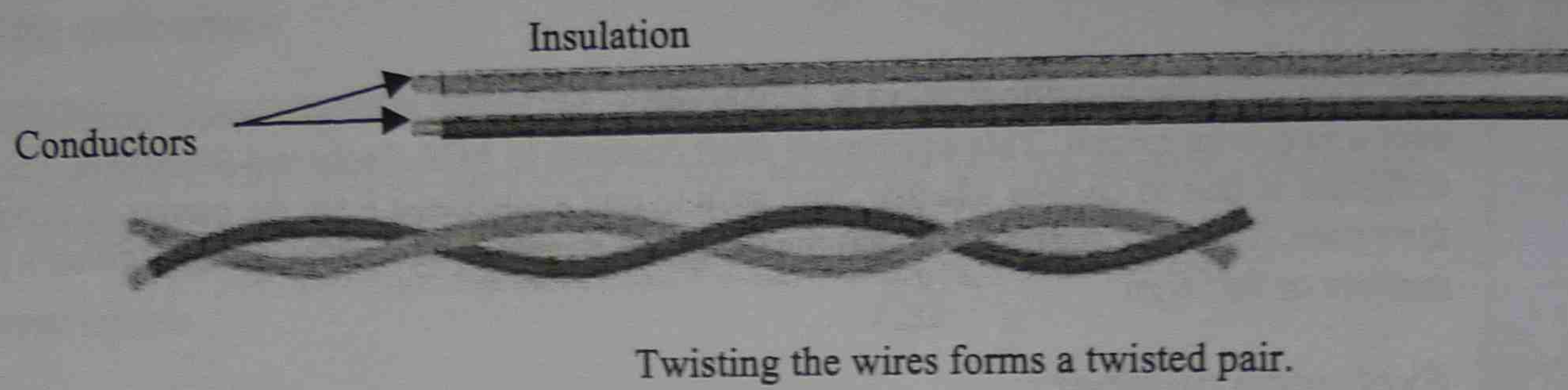


Figure 1: Construction of a simple twisted pair cable.

Telecommunications services use various styles of twisted pair cables. The twisted pair cable shown in Figure1 is a jumper wire. Apart from jumper wire, cables suitable for use in telecommunications, fall into two main categories:

- indoor
- outdoor.

Both indoor and outdoor cables incorporate a sheath over the basic twisted pair construction. A cable may consist of one pair or hundreds of pairs. A colour code distinguishes the individual pairs. In cables having larger pair counts, a binding tape identifies individual bundles of pairs.

Note: Cables containing more than three pairs for use on telephone cabling are beyond the scope of a person with an RCL.

Indoor cable

This type of cable (up to three pair construction) usually has a cream coloured PVC sheath over PVC insulated wires. The construction of this cable may be either unshielded twisted pair (UTP) construction or overall foil shielded twisted pair (FTP) construction. This type of cable is suitable for installation either indoors or outdoors. It is not, however, suitable for use in underground situations, or locations that expose it to direct sunlight or weather. Indoor cable has typically 0.5 mm diameter copper conductors.

Figure 2 depicts the basic construction of a two pair indoor cable.

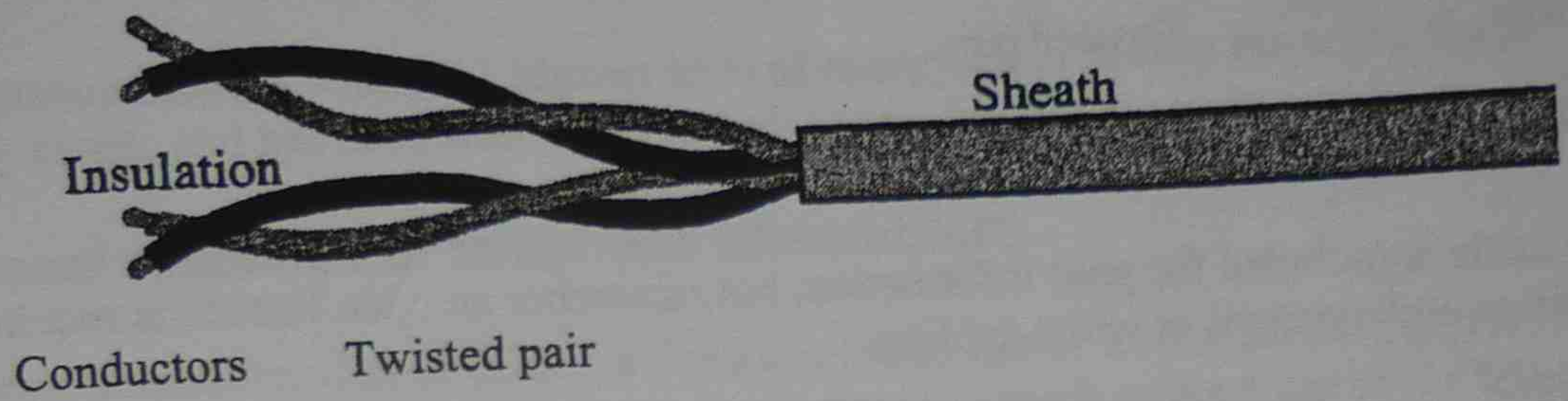


Figure 2: Two pair indoor cable - basic construction.

Outdoor cable

Outdoor cable forms two more groups. These are aerial and underground cables. Underground cable usually has polyethylene conductor insulation (solid or foam) and a polyethylene sheath. The core of an underground cable may incorporate a water-blocking compound. Sometimes underground cables employ an additional outer jacket of nylon to protect the cable from termites. Underground cable has typically 0.4 mm diameter copper conductors (0.64 mm and 0.9 mm are also available). This depends on location, line length and intended use.

Figure 3 depicts the typical construction of a two pair underground cable.

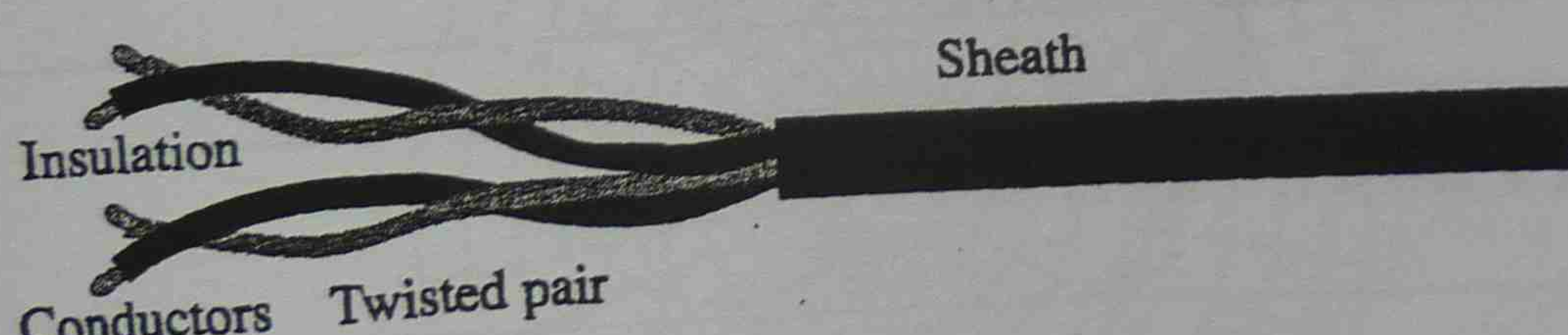


Figure 3: Typical two pair underground cable.

Aerial cable also employs a polyethylene sheath and conductor insulation. Aerial cables often incorporate a strong support wire known as an integral bearer wire. This bearer wire may be steel or hard drawn copper. The core of an aerial cable may also incorporate a water-blocking compound. Aerial cable has typically 0.4 mm diameter copper conductors (0.64 mm and 0.9 mm are also available).

Figure 4 depicts the typical construction of a two pair, aerial cable.

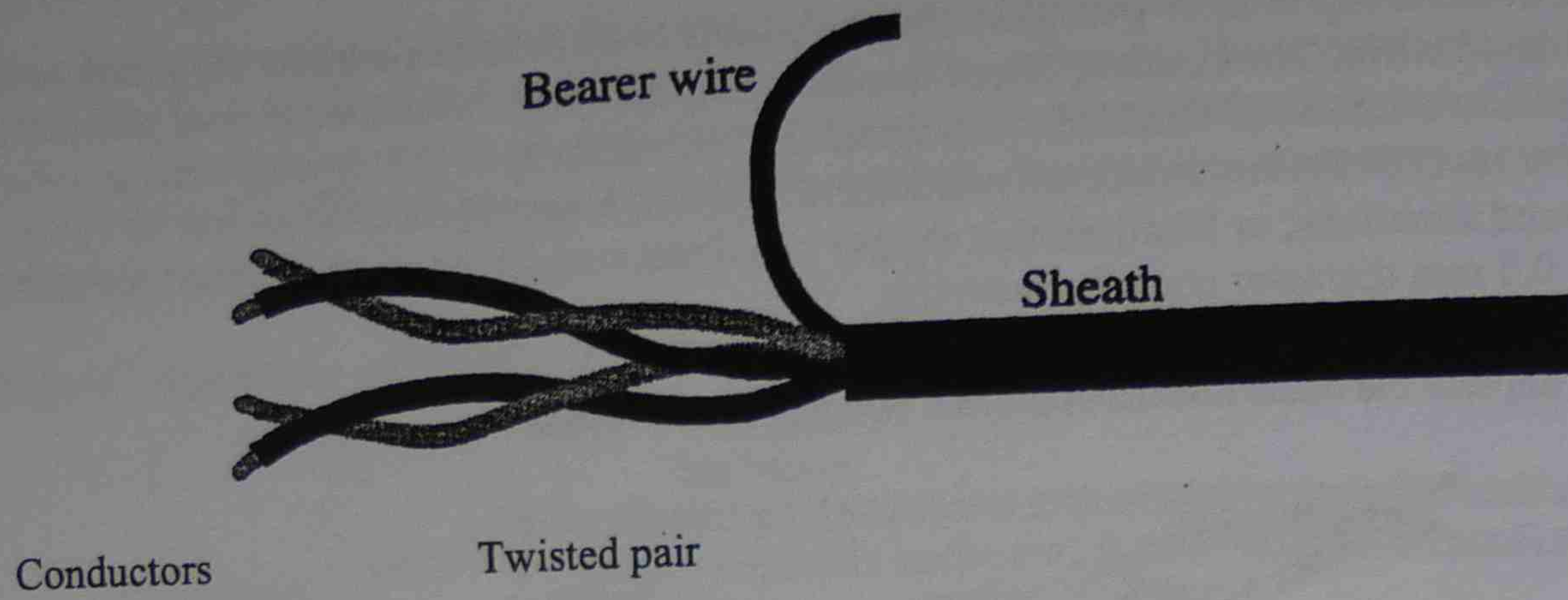


Figure 4: Typical two pair aerial cable construction.

Outdoor cable is included for your information, but remember an open licence is required to install this as underground or aerial cabling.

Self help questions

1. Which cable incorporates PVC sheath over PVC insulated wires?

3 pair construction.

2. What is the typical conductor diameter for outdoor cable?

0.4mm (0.64mm and 0.90mm are also used)

3. Which outdoor cable may incorporate an integral bearer wire?

Areiw

4. What is the typical conductor diameter for indoor cable?

0.5mm

Answers are at the back of this book.

Function of the telephone transmitter

The telephone transmitter or microphone is actually a transducer, which converts acoustic energy to electrical energy. A transmitter can be described as an input transducer. Not all of the sound energy entering a transmitter is converted to electrical current, as no transducer is 100 percent efficient.

A telephone transmitter must be efficient, that is, have good sensitivity to produce a relatively high output for a given sound source of loudness. A telephone transmitter should also have a flat frequency response from 300Hz to 3400Hz, be physically robust and produce minimum distortion.

This frequency range is where the highest level of energy exists within the wider voice frequency range, and has been selected as the telephony frequency range.

Directional response of telephone transmitters

A telephone transmitter should exhibit a directional response or have a pick-up pattern in only one direction. That is, the transmitter is most sensitive to sounds at the front of the transmitter, and least sensitive to sounds at the rear of the transmitter. A microphone or transmitter with this type of response is often called a cardioid pattern (heart shaped) transmitter. An omni-directional transmitter or microphone has the characteristics of being sensitive in every direction.

The diagram below illustrates the response of a cardioid or uni-directional microphone, compared to the circular response of an omni-directional transmitter or microphone.

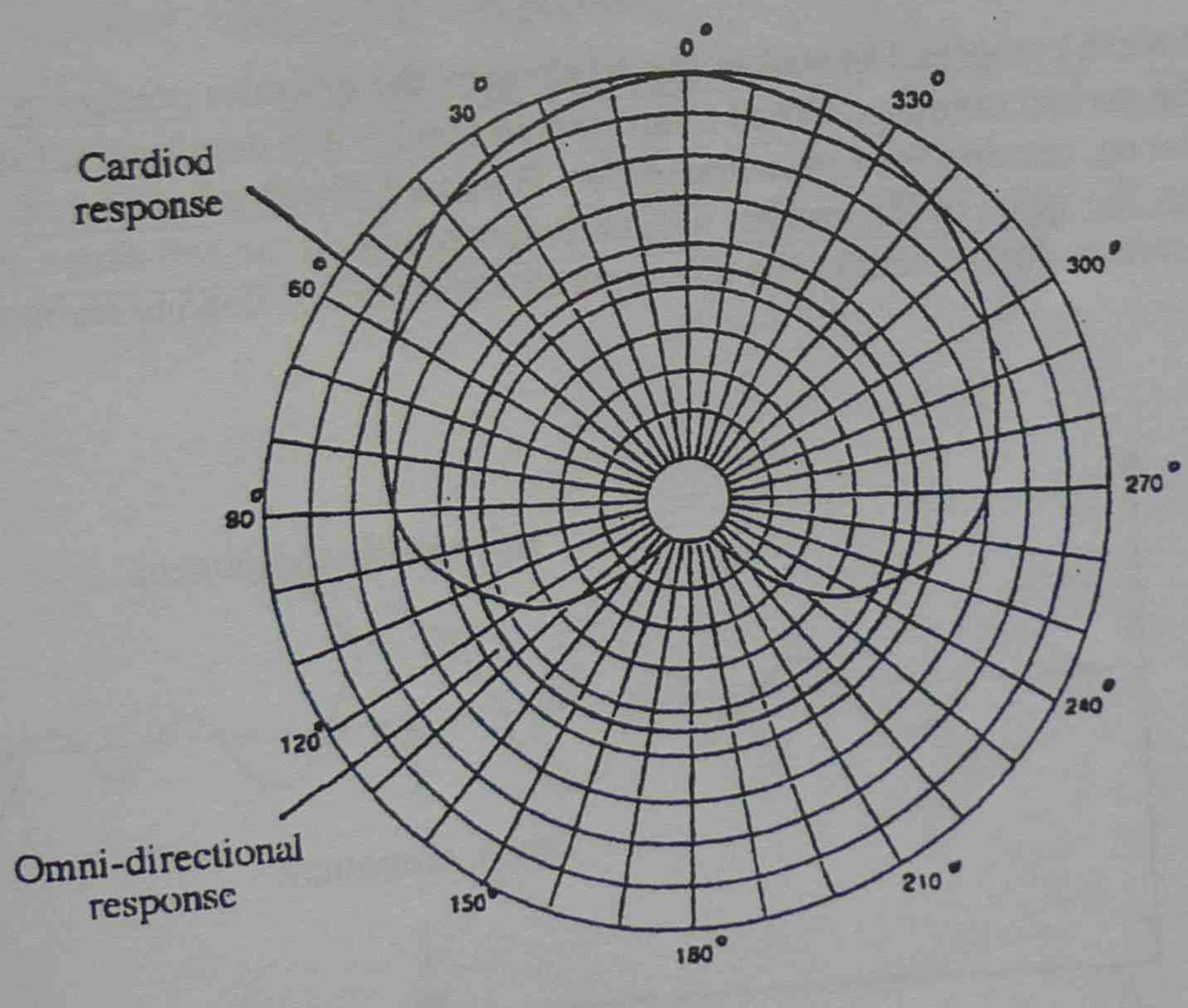


Figure 5: Microphones response patterns.

Data communications systems

Definition

The term *data communications* refers to the transfer of binary information (1's and 0's) between two or more pieces of computer equipment.

Typical system

The source and destination of data in a data communication system is referred to as the *Data Terminal Equipment* (DTE) which includes equipment such as terminals and computer systems. The transmitting and receiving devices are referred to as the *Data Communications Equipment* (DCE) which includes equipment such as modems. In addition, a Transmission Channel is needed to carry the information between the two DTE's (normally via DCE's). See Figure 1.

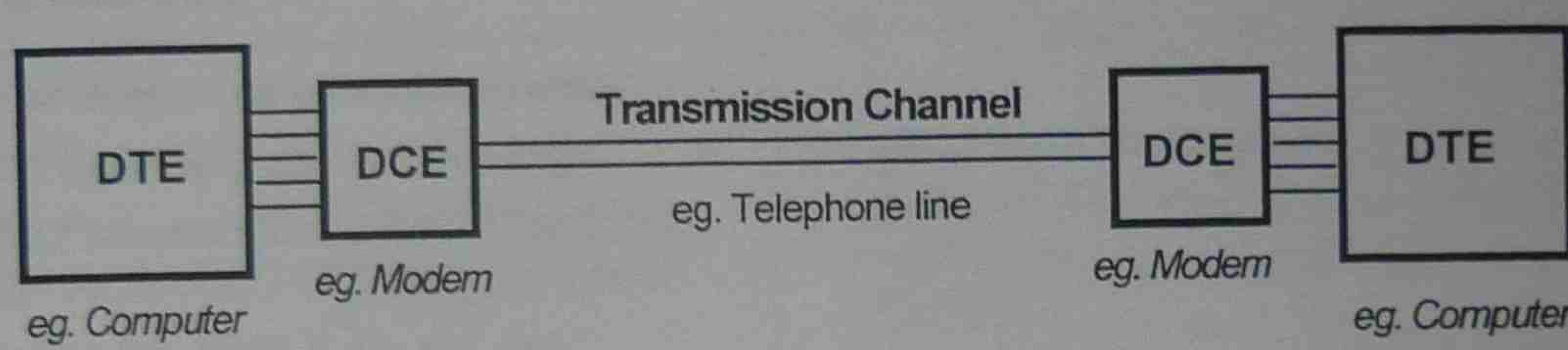


Figure 1: A basic communications system

Communication modes

There are three basic ways of setting up a communication system:

1. In a *Simplex* system, communication can only occur in one direction only, for example, as in broadcast television.
2. In a *Half-Duplex* system, communication can occur in either direction, but not at the same time. For example, CB radio.
3. In a *Full-Duplex* system, data communication can occur in either direction simultaneously, for example, normal telephone.

Serial versus parallel data transfer.

There are two basic ways to send binary information: in parallel or in serial. In *serial* data communications, data is sent one bit at a time over a single wire (plus a ground wire). In *parallel* data communications, data is sent several bits at a time over several wires (including a ground wire).
Parallel data transfer is faster that serial data (when all other factors are equal) because several bits are being sent at the one time, whereas serial data is generally more economical as only one signal wire is required.

Data transmission codes

A data transmission code is a method of assigning standard binary codes to alphanumeric and control characters to be used in a data transmission system.

ASCII (American Standard Code for Information Interchange) is a 7-bit binary code, which means it can be used to represent $2^7 = 128$ different characters, including letters, numbers, symbols, and control characters (of which 96 are printable characters).

Extended IBM (8-bit) ASCII is used often in PC systems which allows a further 128 characters to be represented (as $2^8 = 256$). This includes the standard ASCII character set as the first 128 characters with additional foreign letter, mathematical, and graphics symbols represented.

Asynchronous serial data transmission

Definition

Asynchronous serial data transmission, as the name implies, is a system in which the source and destination DTE/DCE's are not electronically synchronised to each other. Instead, these systems include special *start bits* and *stop bits* with each character so that the receiver can lock into the correct timing.

Parity

Some systems use a special *parity* bit for use in error detection attached to the data word as the most significant bit (MSB). For example, a 7-bit ASCII system that utilises a parity bit will require eight bits to represent each character (not including start and stop bits) where the parity bit is the MSB of the data word. The parity bit is generated buy the transmission system prior to transmitting the data.

The parity type can be either *odd* or *even*, and it works like this:

> The parity bit is made a 1 or a zero so that the total number of 1's in the data word, including the parity bit (but not the start and stop bits) is odd or even, depending on the type of parity used.

For example, the ASCII code for the letter "S" is 101 0011. A simple count will show that this comprises four 1's which is an even number. If the parity type used is even, then the parity bit will be a 0. If the parity type used is odd, then the parity bit must be made a 1 so that the total number of 1's will not become five which is an odd number. This is summarised below with the parity bit shown in bold.

ASCII for the letter "S" using even parity: 0101 0011
ASCII for the letter "S" using odd parity: 1101 0011

Once the receiving system receives the data, it recalculates the parity bit and compares this with the one sent. If they do not match, the receiver assumes an error occurred during transmission, and takes appropriate action (which may including asking for that character to be resent). This system works on the basis that usually only one bit of a character becomes corrupted.

Protocol

In any communication system, the term *protocol* refers to the rules of the communication. Specifically in an asynchronous serial data system, this refers to the speed of the transmission, the number of data bits, the parity type, and the number of stop bits. In addition, one start bit (logic low) is sent, but this is not normally mentioned as part of the protocol:

The **number of data bits** per character is normally 5, 7, or 8 depending on the type of transmission code used. For normal ASCII, this would be seven.

The **parity** type can either be odd, even or none (the latter meaning that no parity bit is included in the word).

The **data rate** (often incorrectly referred to as the baud rate) is the speed of the transfer in bits per second (bps) and includes speeds such as 300, 1200, 2400, 9600, 19 200, 38 400, 57 600, 115 200.

The number of **stop bits** included in each character is normally either 1, 1½, or 2 (where 1½ refers to a duration of 1½ bits). The stop bit(s) are always logic high.

Remember that there is also one logic-low *start bit* at the beginning of each character, but this is assumed in the protocol.

A protocol may be abbreviated as 9600·E71 where 9600 is the data rate, E is even parity, 7 is the number of data bits, and 1 is the number of stop bits. Modern systems tend to use eight data bits, no parity, and 1 stop bit (eg. 38400·N81).

Data format

Each data character in an asynchronous serial system will include an additional start bit, stop bit(s) and parity bit. Normally, the start bit is first, followed by the data word (from LSB through to MSB), the parity bit, then the stop bit(s).

For example, the data format for the protocol 9600·7E1 is shown in Figure 2.

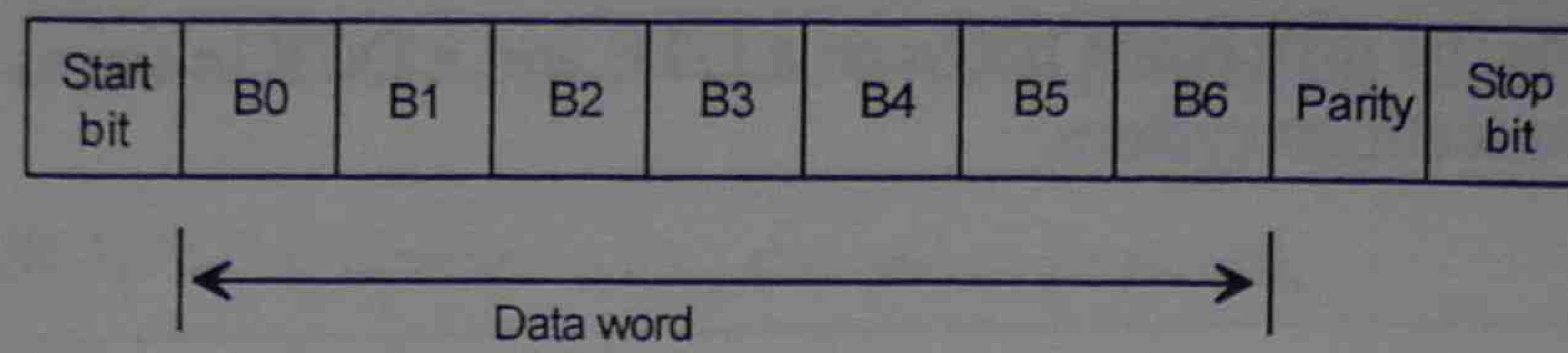


Figure 2: A typical asynchronous serial data word.

The only logic levels we can predict in the above word will be the start bit (low) and the stop bit (high). The rest will depend on the data being sent. As an example, the data format for the ASCII character "S" is shown in Figure 3 below, along with the corresponding data stream.

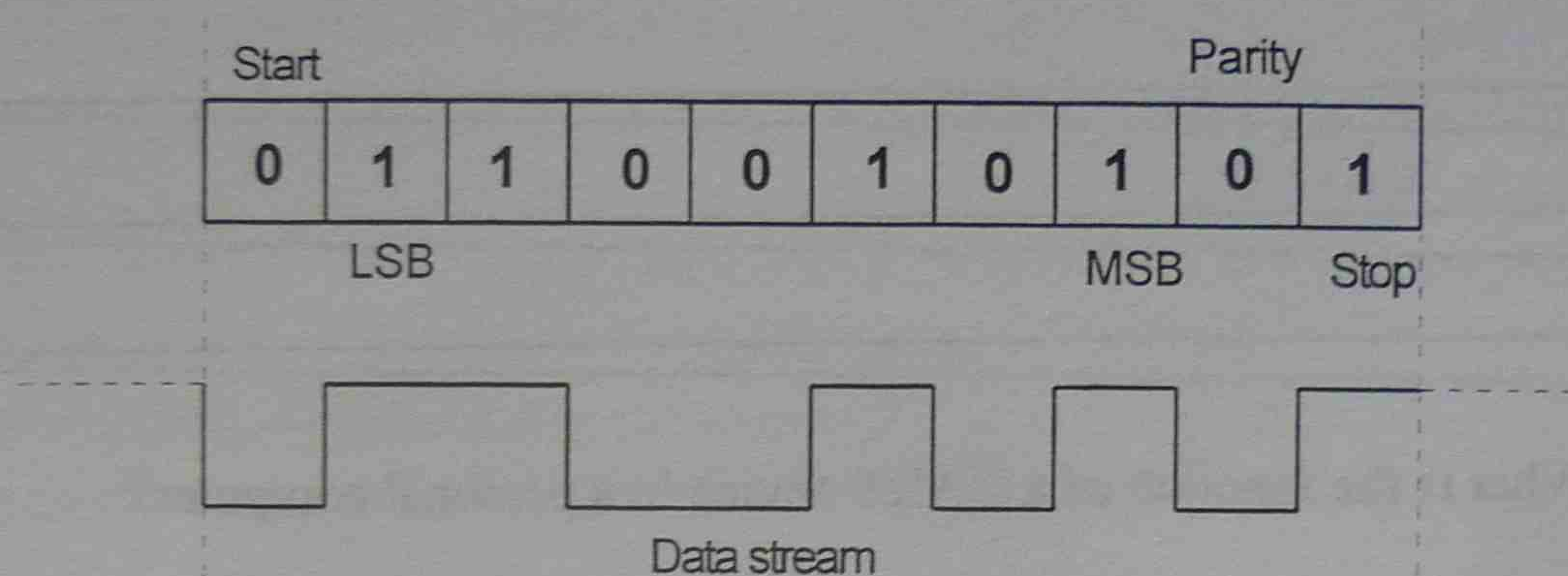


Figure 3: Data format and data stream for ASCII "S" using 9600·7E1.

The UART chip

A UART (Universal Asynchronous Receiver Transmitter) chip is the device that drives the serial port in a PC system. It's job is to convert parallel data from the system's microprocessor, to serial form, and sets the protocol by inserting the start and stop bits and setting the data rate. When receiving data, the UART strips the start, stop and parity bits from the word, and converts it so a parallel form that can be read by the microprocessor.

Asynchronous serial data timing

Recall from the previous section that asynchronous serial data is transmitted using special start and stop bits with each character for timing purposes.

The receiving device uses the falling edge of the start bit to synchronise bit timing. It then waits 1½ bits duration, then samples (or "reads") each bit in the middle of its duration, to allow for errors such as timing drift. The start and stop bits also *frame* each complete character so that the receiver knows when each character starts and stops.

When no data is being sent, the line idles high, so that when the next incoming start bit arrives, the line changes logic levels (to a low).

Timing calculations

So far, we have not used the bit rate information supplied in the protocol. However, this information is useful for predicting estimated transfer times. For example, using the protocol 14400-E71 sending a 50K file:

Time to send one bit

The time to send one bit is the reciprocal (inverse) of the bit rate:

$$\text{time/bit} = \frac{1}{\textit{bit}\text{ rate}} = \frac{1}{14400} = 69.4\ \mu\text{s}.$$

Bits per character

The number of bits per character can be determined by adding up all the bits specified in the protocol:

$$\begin{aligned}\text{bits/char} &= \text{1 start bit} + \text{No. of data bits} + \text{Parity (if any)} + \text{no. of stop bits.}\\ &= 1 + 7 + 1 + 1\\ &= 10\end{aligned}$$

Time to send one character

The time to send one character can be worked out by multiplying the number of bits per character by the time per bit:

$$\begin{aligned}\text{time/char} &= \text{bits/char x time/bit.}\\ &= 10 \text{ x } 69.4\ \mu\text{s}\\ &= 694\ \mu\text{s}\end{aligned}$$

Character rate

An important quantity in data communications is the character rate, which is how many characters are sent per second. This is the inverse of the time per character:

$$\text{chars/sec} = \frac{1}{\textit{time/char}} = \frac{1}{694\ \text{s}} = 1440\ \text{char/sec}$$

Time to send a file

The time to send a text file of a certain number of characters can be worked out by multiplying the number of characters in the file times the time/char:

$$\begin{aligned}\text{Time to send file} &= \text{no. of characters in the file} \times \text{time/char} \\ &= 50\text{K} \times 694\ \mu\text{s} \\ &= 50 \times 1024 \times 694\ \mu\text{s} \\ &= 35.5\ \text{sec}\end{aligned}$$

Note: In this example, K was taken to mean $2^{10} = 1024$.

Exercise

A data communications system uses the protocol 33600·N81. Calculate the:

1. time to send one bit.
2. number of bits per character
3. time to send one character
4. character rate
5. time to send a file of 100K characters.

Solution

1. $\text{time/bit} = \frac{1}{\textit{bit}\ \text{rate}} = \frac{1}{33600} = 29.8\ \mu\text{s}.$

2. bits/char = 1 (stop) + 8 (data) + 0 (parity) + 1 (stop) = 10.

3. time/char = bits/char x time/bit = 10 x 29.8 μs = 298 μs.

4. $\text{chars/sec} = \frac{1}{\textit{time/char}} = \frac{1}{298\ \text{s}} = 3356.$

5. time to send file = file size x time/char = 100 x 1024 x 298 μs = 30.5 s.

Note: In the above example, K was taken to mean $2^{10} = 1024$.

RS-232C

Introduction

RS-232C is a world communications standard, and is the serial standard associated with most computer hardware such as PC serial ports, modems and printers. The proper name for RS-232C is "Interface Between Data Terminal Equipment and Data Communications Equipment Employing Serial Binary Data Interchange", the latest revision being "C". The standard describes the mechanical and electrical characteristics of the interface, as well as the function of each signal.

Contrary to wide belief, RS-232C does not define the DB-25 (see Figure 1) or the DB-9 connector as the standard to be used, though these have become the adopted one because of their wide use in PC's.

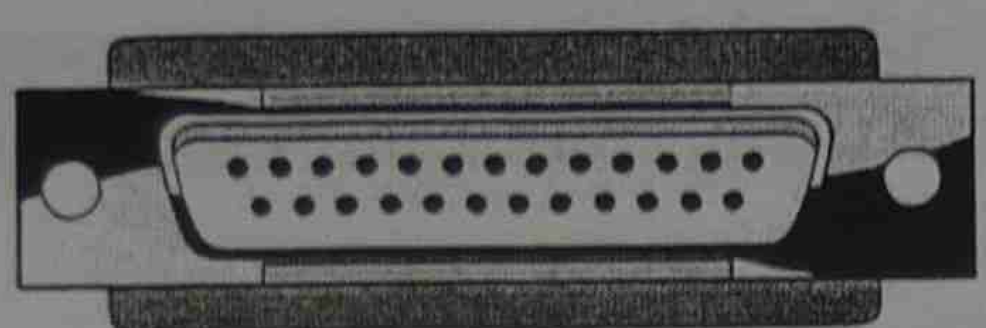


Figure 1: DB-25 connector. Male used for DTE and female for DCE.

Voltage levels

The RS-232 standard uses rather unconventional logic levels when compared to standard TTL (Transistor-Transistor Logic). For the data transmission lines:

Logic 1	-5V to -15V	(nominally -12V)
Logic 0	+5V to +15V	(nominally +12V)

For the control lines however, the voltage polarities are reversed. Using RS-232 voltage levels allow better noise immunity that standard digital (TTL) voltage levels and therefore are less susceptible to noise interferences and hence bit errors.

The Motorola MC1488 and MC1489 chips are used to convert TTL to RS-232 signal levels and vice-versa respectively, so that standard computer circuits can be interfaced to RS-232 systems.

Maximum distance

The maximum distance is defined as being 50 feet (15m) at the highest data rate (stated at 20,000 bps) however, longer distances are possible at slower speeds.

Pin descriptions

The RS-232 standard describes the following pin assignments, and states that the DTE will use a male connector while the DCE will use a female connector. Although the RS-232C standard does not specify the use of DB-25 (or DB-9) connectors, these have become a pseudo-standard and their pin assignments are outlined below:

Pins 1 and 7 are the Protective Ground and Signal Ground pins respectively.

Pins 2 and 3 are the Transmitted Data (TxD) and Received Data (RxD) lines respectively. Note these are named from the DTE's perspective, which means the Transmitted Data line, for example, is an output on a DTE but an input on a DCE.

Pins 4 and 5 are the Request to Send (RTS) and Clear to Send (CTS) lines respectively. These are the main handshaking likes between the DTE and DCE used to control the flow of data. The DTE (computer) tells the modem it is ready to send via the RTS line. When the DCE (modem) is ready, it will respond by asserting the CTS line. The DCE however, cannot decide to drop the CTS line until the DTE has dropped RTS.

Other important lines include:

Pins 6 and 20 are the Data Set Ready (DSR) and Data Terminal Ready (DTR) lines respectively. DSR indicates that the modem is on and not in the test mode. DTR is used by the terminal to tell the modem to answer an incoming call (go off hook).

Pin 22 is the Ring Indicator (RI). The modem (DCE) uses this line to tell the computer (DTE) that the phone line is ringing.

You might like to refer to the reference texts for information about some of the other RS-232C pin descriptions.

Flow control

Flow control refers to the handshaking that controls the flow of data between the DTE and DCE. There are two types of flow control, hardware and software.

Hardware flow control refers to the use of RTS and CTS as outlined in the previous section. This is the most important type for fast modems. If the flow control is incorrectly set, data may be lost or corrupted.

The alternative to hardware flow control is software (XON/XOFF) flow control. In this system, two special ASCII control characters DC1 and DC3 (Device Control 1 and 3) are used to control the flow of data, and are often called XON and XOFF. These characters correspond to Control-Q (resume) and Control-S (pause) on a keyboard.

With this type of flow control, the DCE (normally printer in this case) tells the computer to pause (using XOFF) when it's buffer is approximately 80% full, and resume (XON) when it's buffer is approximately 20% full. The DCE sends these to the DTE over Pin 3 - Received Data. The advantage of this system over RTS/CTS flow control is that the DCE can ask the DTE to pause, whereas with RTS/CTS, the DCE can not unassert CTS whenever it wants.

The type of flow control used can be selected from most communications software and in the *Modem Settings* in the Control Panel in Windows 95.

RS-232 connections

A minimum RS-232 connection is shown in Figure 2 below.

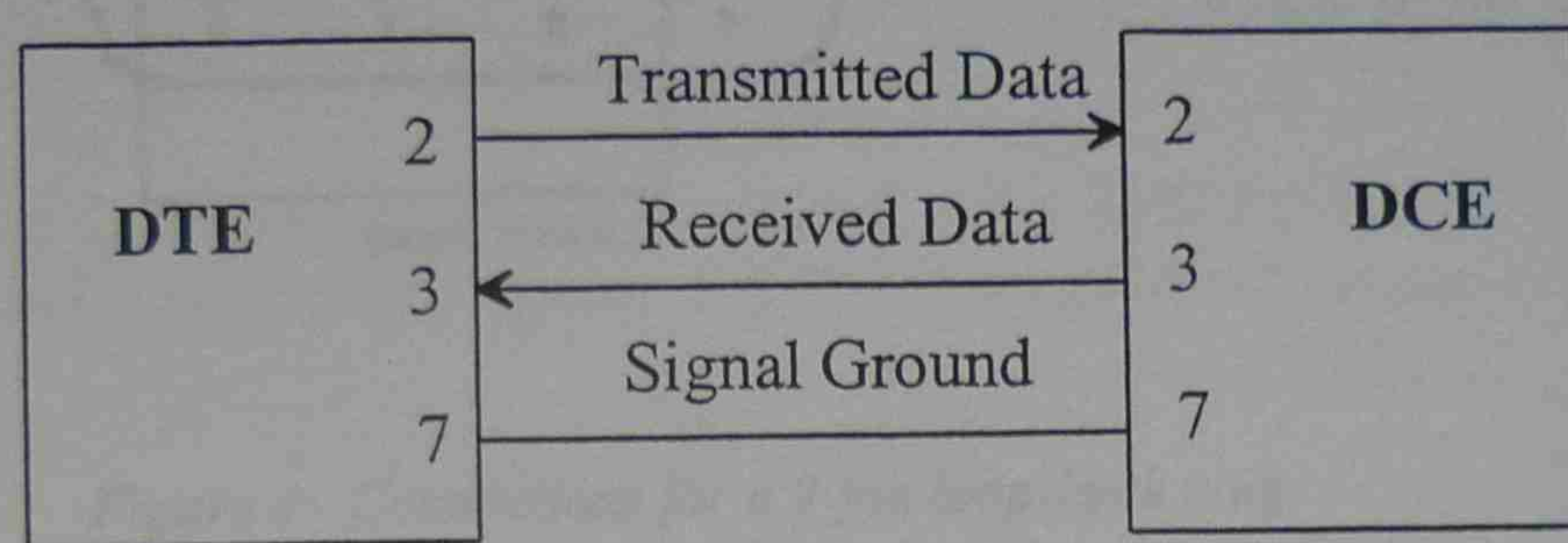


Figure 2: DTE to DCE RS-232 connection.

In reality, some of the additional lines would be used such as RTS and CTS for flow control. If the DCE was a modem, then the DTR, DSR and RI lines might also be used.

Null-modem connection

A null-modem connection allows two DTE's to be directly connected together for the purpose of transferring data and playing games! In this case, Pins 2 and 3 are swapped over as shown in Figure 3.

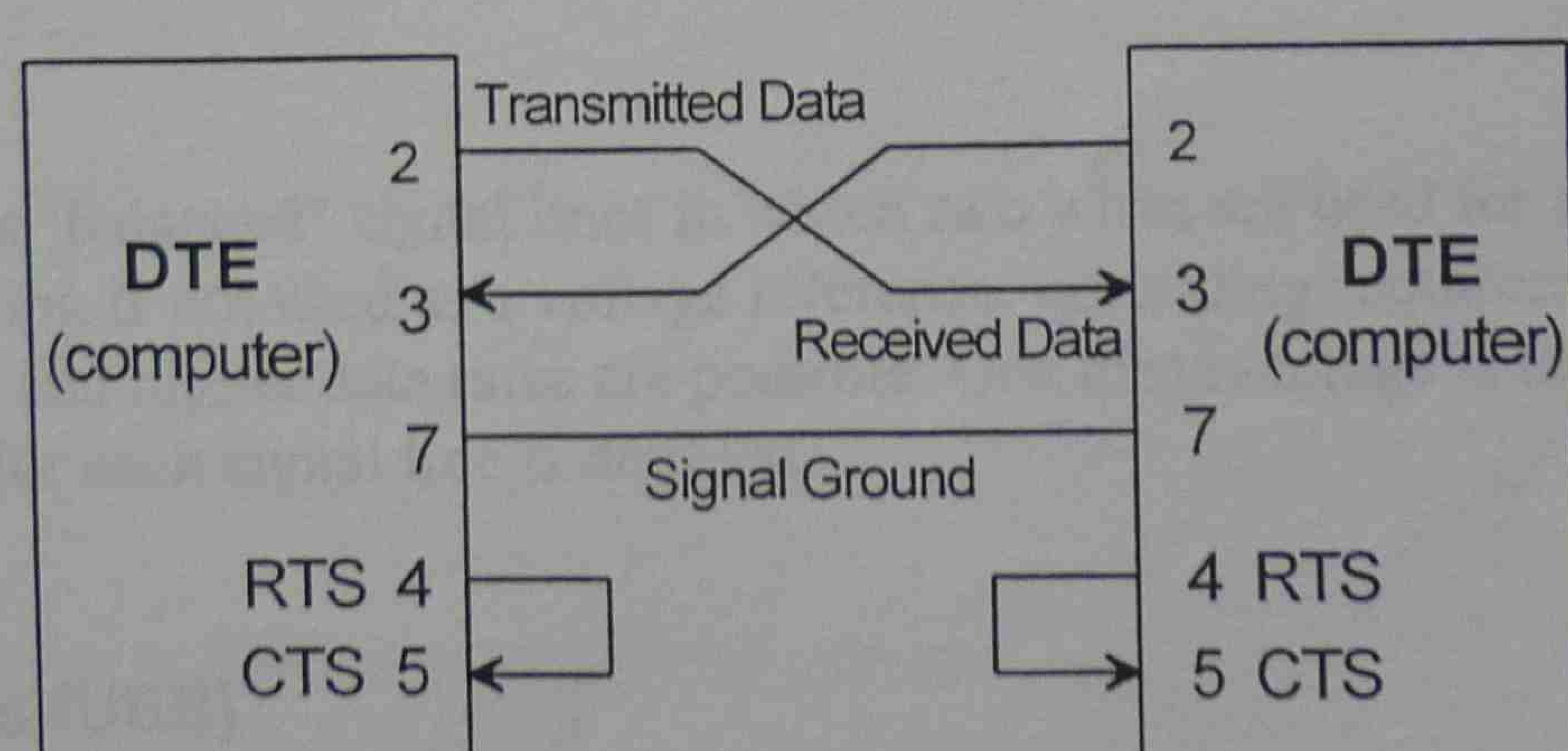


Figure 3: DTE to DTE (null-modem) connection.

Serial loop-back plugs

A serial loop-back (or wrap) plug is a special adapter used with diagnostic software to test the correct operation of the serial ports in a PC system. It works by looping Pins 2 and 3 so that the data transmitted out is received back in. The diagnostic software checks that the data sent is equal to the data received. If so, it assumes the port is working correctly. The connections for a 9-pin loop-back plug are shown in Figure 4 below.

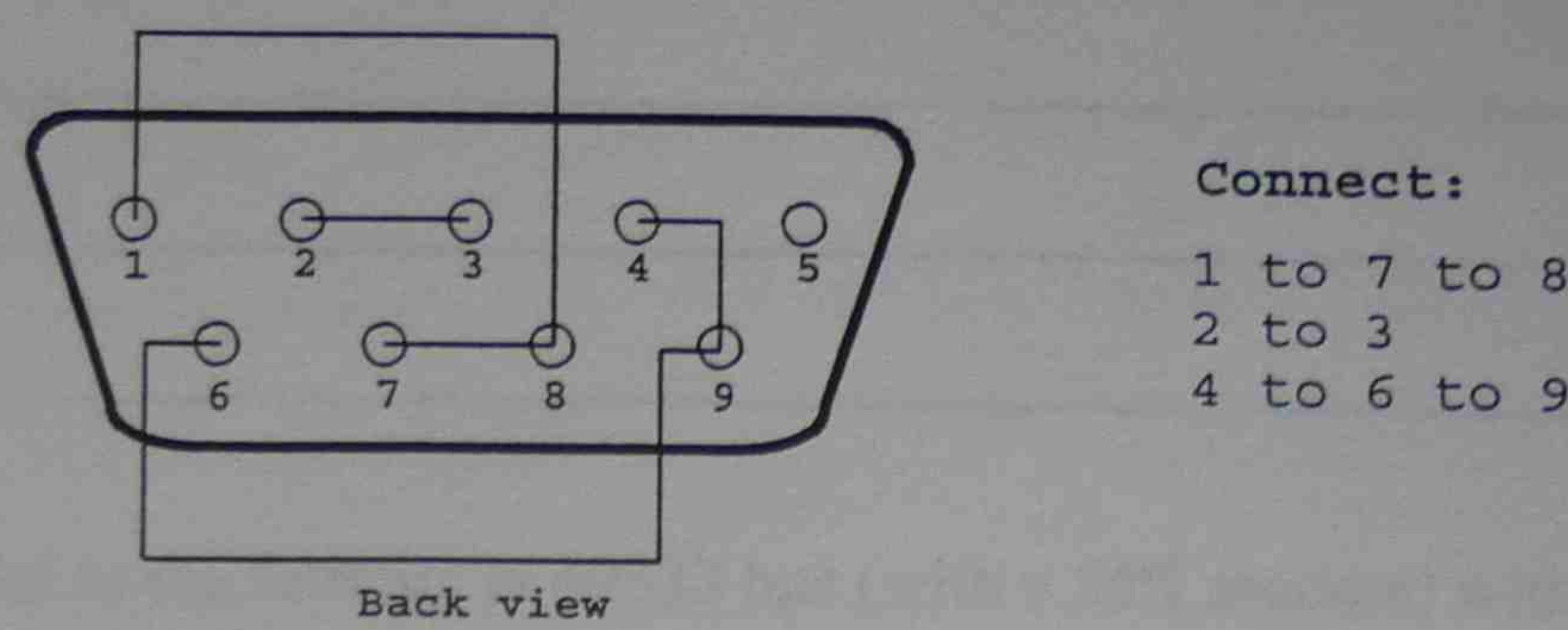


Figure 4: Connections for a 9-pin loop-back plug.

Limitations of RS-232

One of the main limitations with RS-232 is that if there is a difference in the ground potential between the two ends of the cable, a logic level may be misinterpreted and error occur. In addition, the line length is limited to 15m (at the higher data rates) because of the effects of line capacitance which can affect the "squareness" of the data signal. These problems are overcome in other standards such as RS-422, RS-423, and RS-449 which are less commonly found in the PC world but play a much larger role in the wider scope of data communications.

RS-422A

This standard uses "balanced" signal lines in which two wires are used for each data signal. As grounding is not used as a voltage reference, grounding requirements are much less critical and higher data rates are possible. One disadvantage is that the number of wires for each signal line is doubled.

Universal Serial Bus (USB)

The USB was designed as a way to connect a variety of different peripherals to a system using a 12M bps (or 1.5M bps) interface over a simple four-wire connection. The bus supports up to 127 devices and has a slower 1.5Mbit/sec subchannel for low-performance peripherals such as mouses and keyboards.

Introduction to modems

The telephone network

The telephone network is an ideal medium for computers and Fax machines to connect to other systems around the world because the network is already in place. The telephone system plays an integral role in connecting PCs to the Internet, delivering Fax messages, and connecting Local Area Networks together (LANs) to produce Wide Area Networks (WANs).

The main disadvantage with standard telephone lines is that the circuitry associated with these lines was originally designed to carry voice signals and therefore has a limited bandwidth. The bandwidth of the standard telephone system is 300 Hz to 3.4 kHz and is shown in Figure 1. The bandwidth of a system is the range of frequencies it allows to pass through without significant losses.

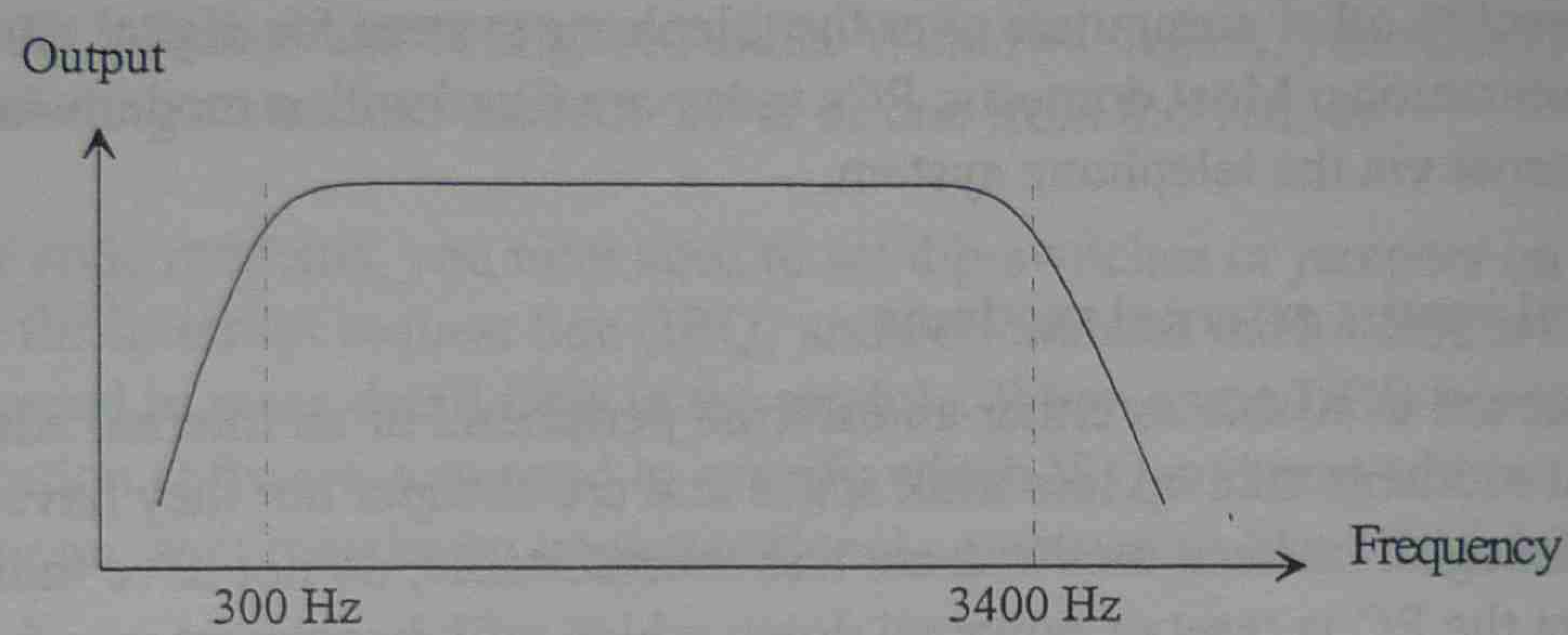


Figure 1: Bandwidth of a standard telephone system.

Nature of digital signals

Digital signals like the ones transmitted from the serial port of a computer appear as a stream of pulses changing between logic one and zero. An example of a digital signal is shown in Figure 2.

Figure 2: Example of a digital signal.

Digital signals like the one shown in Figure 2 are "square" in nature and they contain an infinite number of frequency components. This means that any system which is to pass such signals ideally requires an infinite bandwidth, or at least a very wide bandwidth.

The bandwidth of the telephone system shown in Figure 1 is clearly too narrow to pass digital signals unaffected. Therefore, the standard telephone system in suited to digital data transmission.

Need for a modem

The function of a modem is to convert digital signals from the computer into corresponding electrical "audio tones". These tones are analog signals and are within the telephone line's bandwidth. Similarly, a modem must also be able to convert incoming electrical "audio tones" from the remote modem back into digital signals for the computer to understand.

In the case of a modem, the process of converting to analog is called modulation and the process of converting back to digital is called demodulation. The modem therefore gets its name for the contraction of the two words MOdulator and DEModulator or MODEM.

Modem as a computer peripheral

Modems are normally considered a computer peripheral device that allows a computer to connect to other computers over the telephone system for digital data communications. Most domestic PCs today are fitted with a modem for connection to the Internet via the telephone system.

Internal versus external modems

Modems are available as either an external peripheral or an internal adapter card. Internal modems take up less desk space and are cheaper but they have some disadvantages. Internal modems are less transportable; do not have indicator lamps; and are reset the PC is reset or powered down which will disconnect you from any remote system. External modems will retain their connection under these conditions.

What to look for in a modem

The most important thing to look for in a modem is its speed. Advancements in modem technology has seen maximum speeds increase from 14400, 19200, 28800, 33600, to 56000 bits per second (bps). The manufacturer of the modem's chipset is also an important consideration. A reliable and respected manufacturer like Rockwell virtually ensures a reliable and robust modem.

Most modems also support Fax communications. Some modems provide voice communication facility which may also include digital voice mail.

Modem standards

The international telecommunications standards body CCITT (now called ITU-T) established a set of modem standards which refer to the maximum speed of the modem. Some literature refers to these standards when describing a modem's speed:

V.21 & Bel 103 (300 bps), **V.22** & Bel 212 A (1200 bps), **V.22 bis** (2400 bps), **V.23** & Bel 202 (1200/75), **V.32** (9600), **V.32 bis** (14,400 bps), **V.34** (28,800 bps), **V.34 bis** (33,600 bps), **V.90** (56,000 / 33,600 bps).

Installing modems

External modems

There are normally **three** connections to an external modem; an RS232 cable to the computer, a telephone cable to the telephone outlet, and a connection from a mains operated power pack.

When using DOS-based communications software, the modem is directly accessed through the serial port the modem is connected to. There is normally no need for special driver programs. Under Windows, the modem is often automatically detected and the user is given the choice of loading a standard modem driver or one from the vendor that is shipped with the modem.

Internal modems

Internal modems are like any other adapter card and normally plug into either an ISA or PCI slot on the motherboard. If the modem is Plug n Play compatible, it should be automatically detected and configured under Windows. Again, you should be given the choice of loading a standard modem driver or one from the vendor.

With older style modems, you may need to set dip-switches or jumpers on the modem card to set the interrupt request line (IRQ) and port address the modem will operate on. This is covered in more detail later in the module. When using DOS-based communication software, you need to specify which IRQ and port address the modem is operating on, as it may be an unconventional combination like COM 3, IRQ 5.

Modem lights

External modems are normally fitted with LED lamps that indicate the status of the moment - handy for simple troubleshooting. These are shown in Figure 3 below.

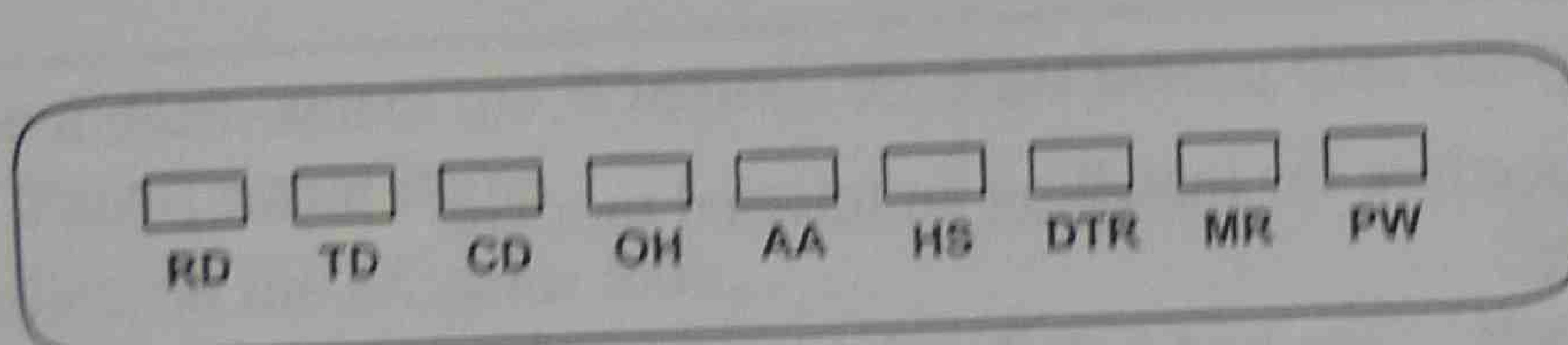


Figure 3: Typical lamps on a modem.

RD	Receive Data. Flickers when data is being received.
TD	Transmit Data. Flickers when data is being transmitted.
CD	Carrier Detect. On when communication is established with remote modem.
OH	Off Hook. On when modem "opens" the telephone line.
AA	Auto Answer. On when modem is set to answer incoming calls.
HS	High Speed. On when modem is operating at its highest speed.
DTR	Data Terminal Ready. On when communications software is loaded.
MR	Modem Ready. On when the modem is ready to communicate.
PW	Power.

Introduction

Recall from the previous section that digital signals are not suitable for transmission over a standard telephone line because the system has a relatively narrow bandwidth. When data needs to be sent down the telephone line, for example when connecting to your Internet Service Provider (ISP), a modem is used to convert the digital serial data from your computer to an analog signal in the form of electronic audio tones. Similarly, the modem converts in-coming analog signals from the telephone line back into digital data.

Block diagram of a modem

The block diagram of a basic modem (DCE) is shown in Figure 1. An RS232 interface is used to communicate with the computer's serial port. Serial data from the computer is fed to a modulator which coverts the data to an analog signal suitable for transmission over the telephone line. The telephone interface couples these signals to the telephone line. Similarly, analog information received from a remote modem through the telephone line is fed to a demodulator circuit which converts the signal back into digital form and sent top the local PC. Modern modems use a CPU is used to accept commands form the host computer (DTE) and control operation of the system.

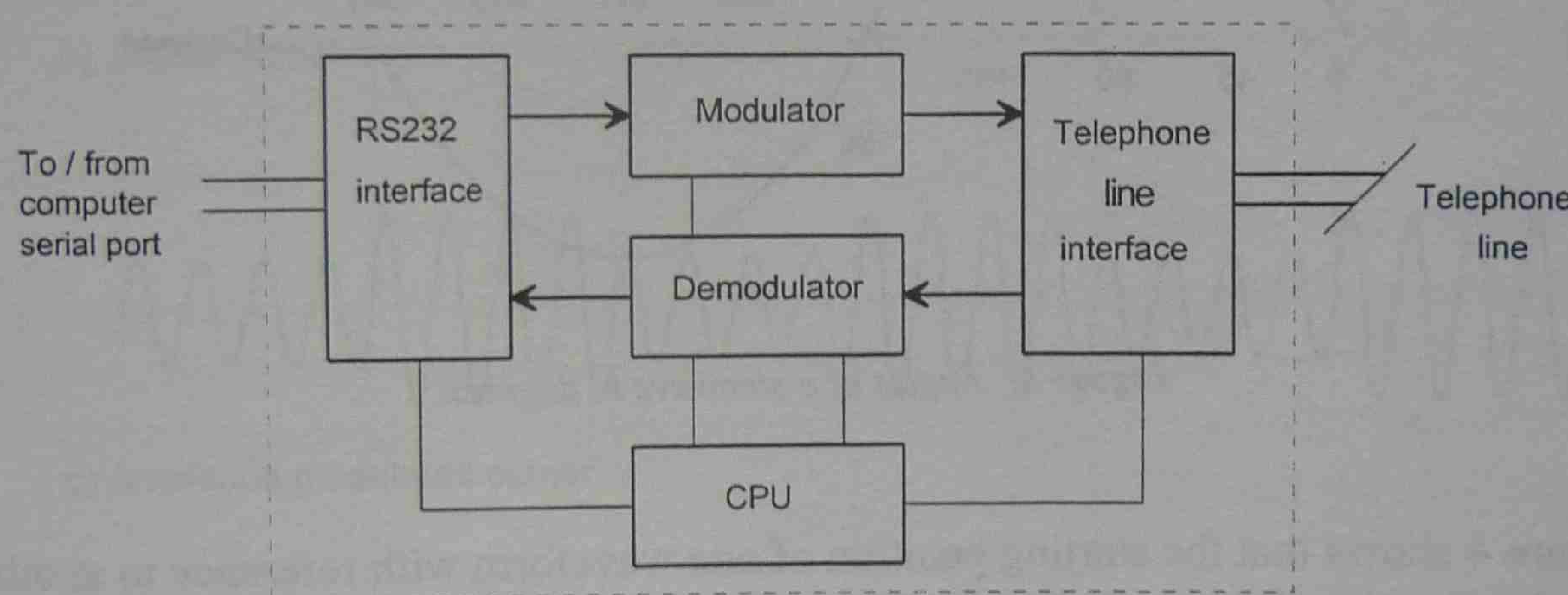


Figure 1: Block diagram of a basic modem.

Revision of analog signals

Figure 2 shows a sinewave with its amplitude and period marked. The amplitude is the "height" of the waveform and may represent the electrical voltage or current of the waveform. The period is the time taken for once complete cycle to occur. The frequency of the waveform (the number of cycles per second) is found by taking the inverse of the period, and is stated in hertz (Hz).

$$\text{Frequency} = \frac{1}{Period}$$

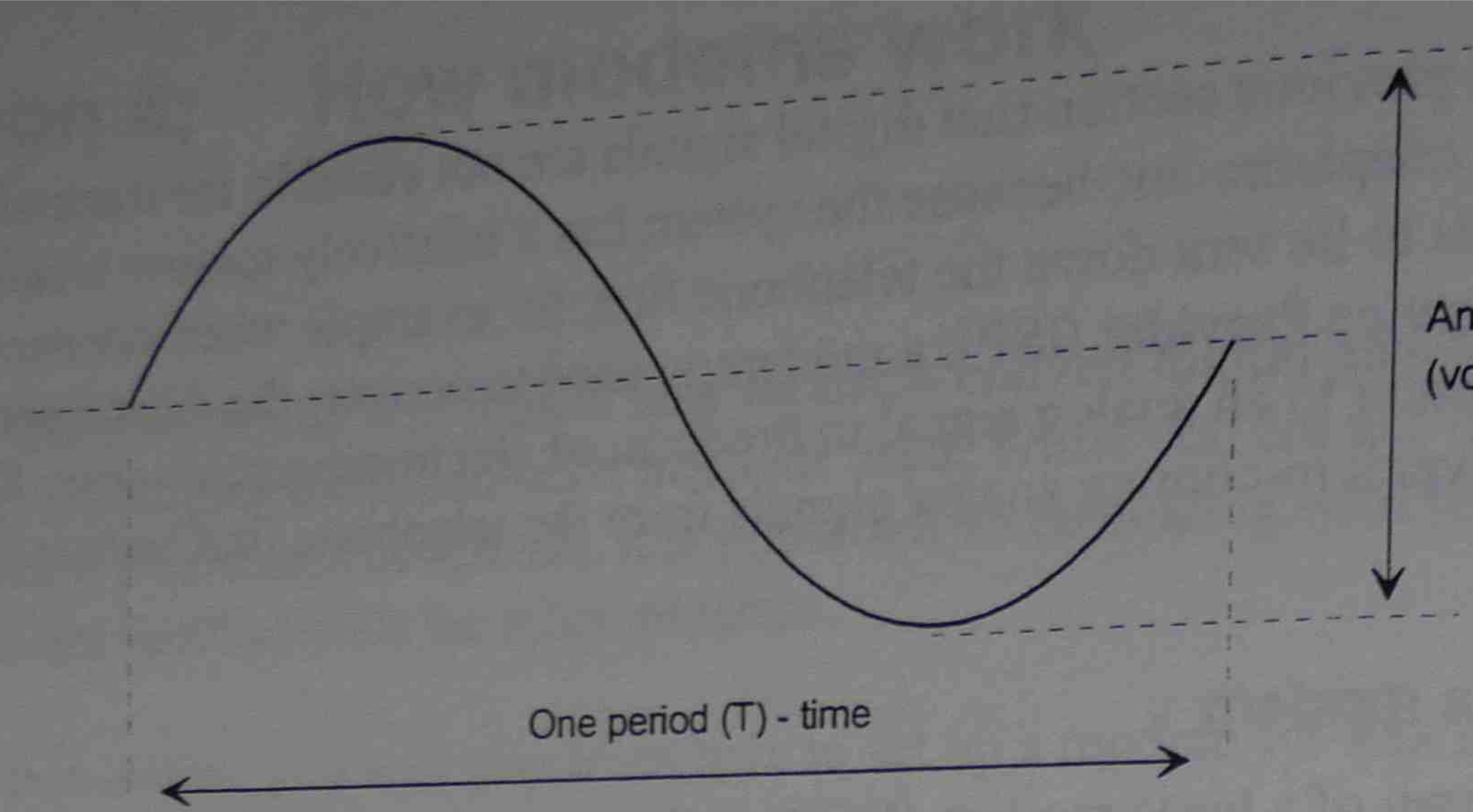


Figure 2: Amplitude and period of a sinewave.

Figure 3 shows how one complete cycle of a sinewave can be thought of as a complete circle having 360°. Half a cycle is therefore 180°, a quarter of a cycle is 90° and so on.

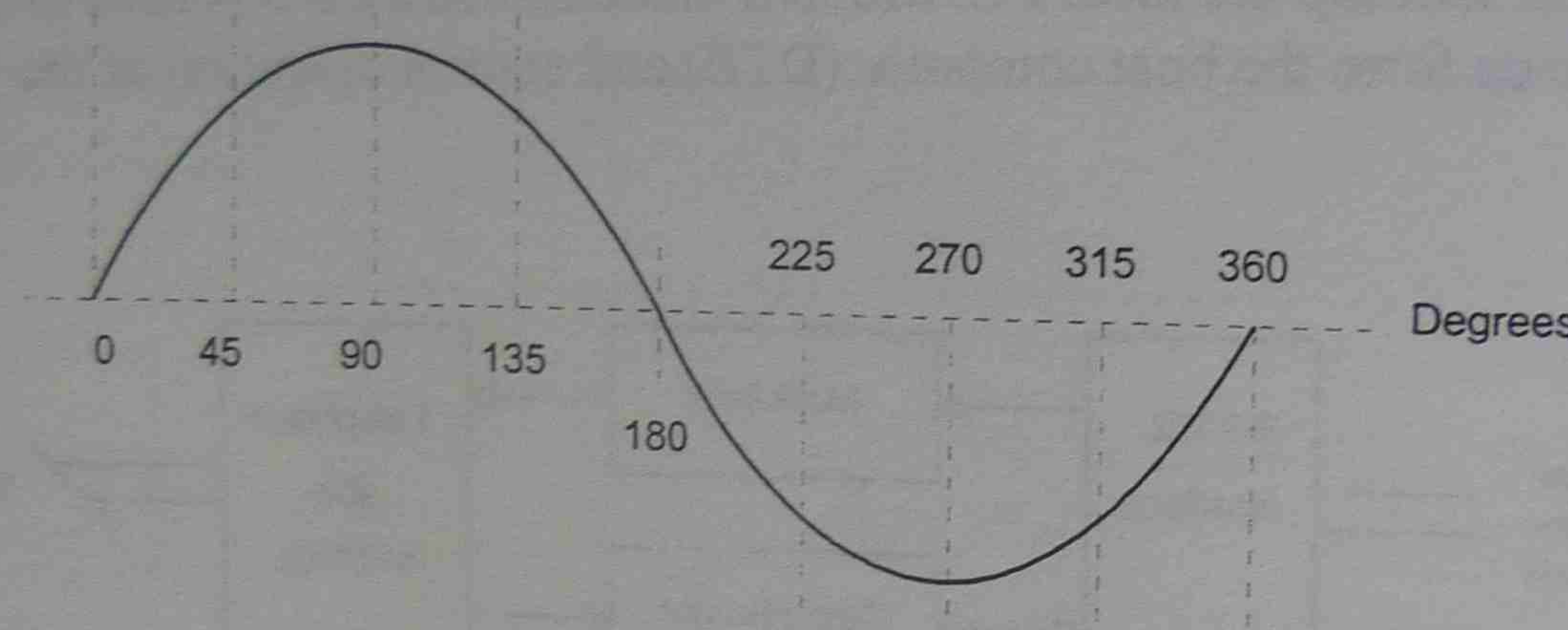


Figure 3: Angles of a sinewave in degrees.

Figure 4 shows that the starting position of one waveform with reference to another can also be stated in degrees. In Figure 4, waveform A leads waveform B (because it is happening first in time) by 45°. It can also be said that B lags A by 45°.

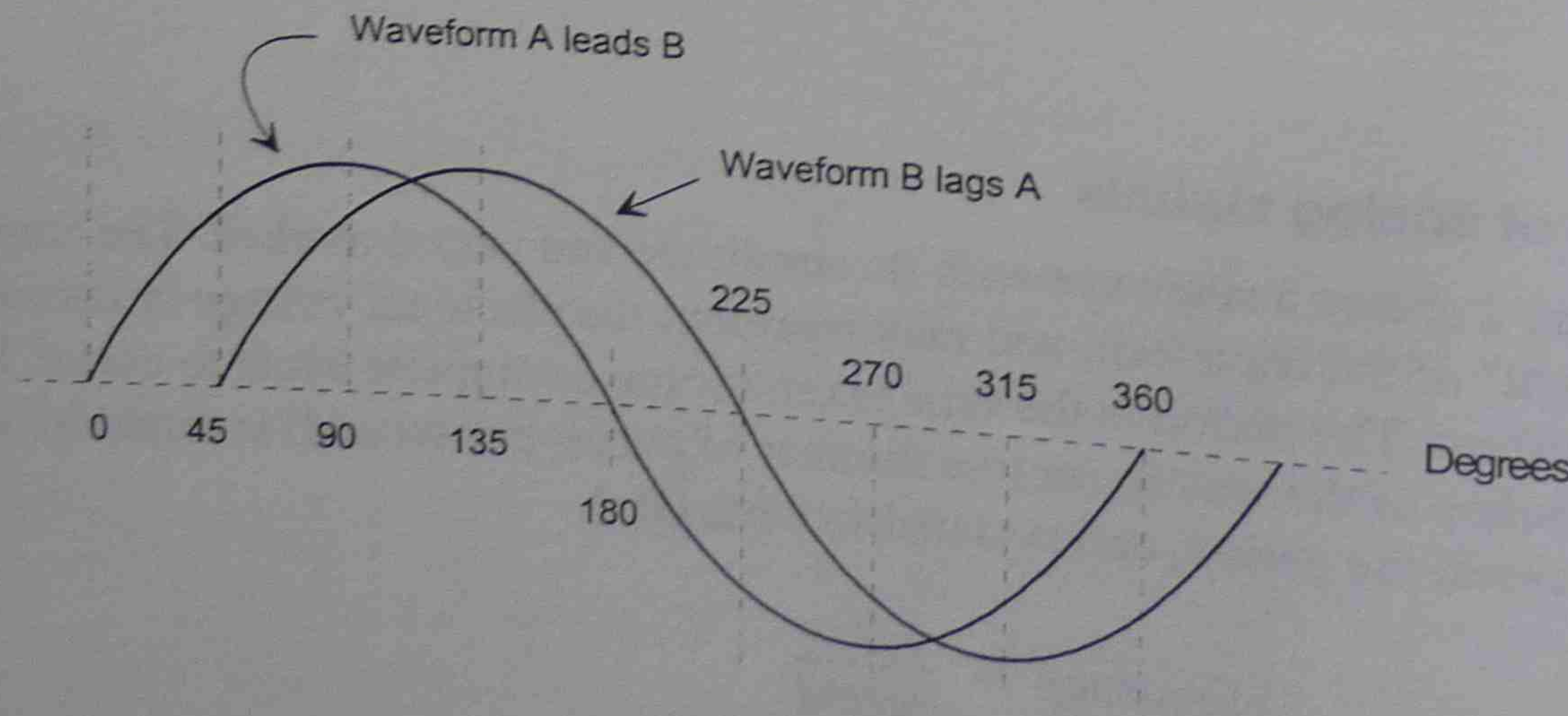


Figure 4: Out of phase sinewaves.

Modulation

In a modem, the term *modulation* means to vary one or more properties of an analog (sinewave) *carrier* signal in a way that represents the digital information to be sent. There are three general ways of modulating an analog carrier signal:

- Amplitude modulation (AM)
- Frequency modulation (FM)
- Phase modulation (PM)

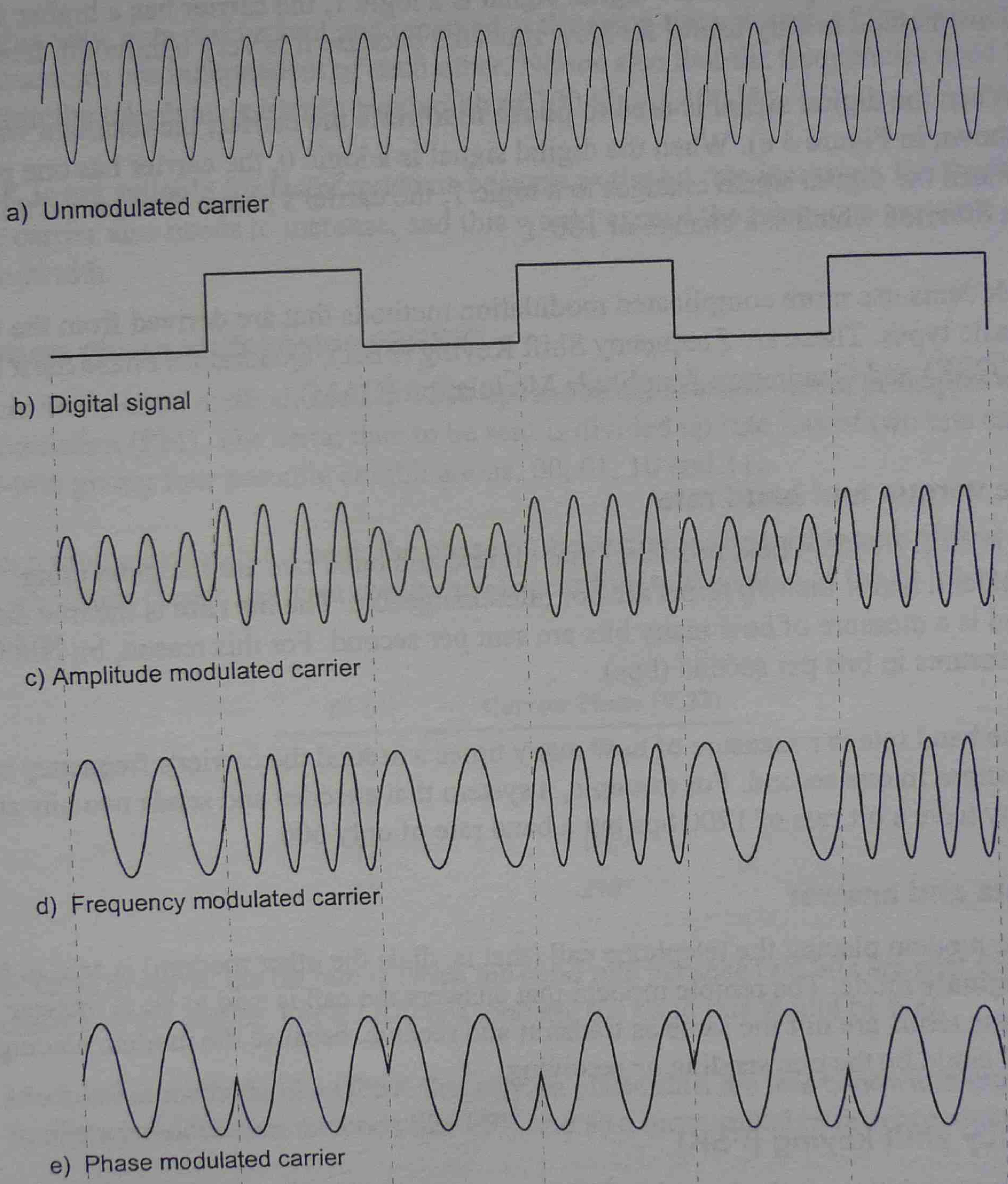


Figure 5: Three basic modulation methods.

Figures 5 a) and b) show an unmodulated sinewave carrier signal and the digital modulating signal respectively.

When the digital signal is used to **amplitude modulate** the carrier, the resultant waveform is shown in Figure 5 c). When the digital signal is a logic 0, the carrier has minimum amplitude. When the digital signal is a logic 1, the carrier has maximum amplitude. This method is not suitable for digital transmission because of its susceptibility to noise. Just think about how *scratchy* AM radio sounds.

When the digital signal is used to **frequency modulate** the carrier, the resultant waveform is shown in Figure 5 d). When the digital signal is a logic 0, the carrier has lower frequency. When the digital signal is a logic 1, the carrier has a higher frequency. This method is only useful for slow modems because it is very bandwidth hungry.

When the digital signal is used to **phase modulate** the carrier, the resultant waveform is shown in Figure 5 e). When the digital signal is a logic 0, the carrier has one phase. When the digital signal changes to a logic 1, the carrier's phase changes (in this case it is inverted which is a change of 180°).

Modems use more complicated modulation methods that are derived from the three basic types. These are Frequency Shift Keying (FSK), Quadrature Phase Shift Keying (QPSK) and Quadrature Amplitude Modulation (QAM).

Bit rate versus and baud rate

It is a very widely held misbelief that bit rate and baud rate are the same thing. They are not, and hence the two terms are not interchangeable. The **bit rate** is the true data rate and is a measure of how many bits are sent per second. For this reason, bit rate is measures in bits per second (bps).

The baud rate is a measure of how many times a second the carrier's frequency or phase changes in one second. For example, a system that encodes and sends two bits at a time may have a bit rate of 1200 bps but a baud rate of only 600.

Originate and answer

The modem placing the telephone call (that is, dials the other modem) is said to be in **originate** mode. The remote modem that answers the call is said to be in **answer** mode. These terms are **not** the same as transmit and receive, because the modem placing the call could be the one sending *or* receiving.

Frequency shift keying (FSK)

This modulation method, used in **300** bps and 1200/75 bps modems, is basically the same as FM (frequency modulation) described earlier. The digital signal is used to vary the frequency of the carrier signal.

In this system, the bit rate is equal to the baud rate because the carrier changes once in frequency for every change in bit.

Full duplex operation is achieved by using four different frequencies as shown below.

		Originate End (Hz)	Answer End (Hz)
Transmit	Logic 0	1070	2025
	Logic 1	1270	2225
Receive	Logic 0	2025	1070
	Logic 1	2225	1270

In this way, data can be sent and received at the same time as each of the four frequencies are independent of each other. Notice also that the frequencies used lie within the telephone system's bandwidth of 300 Hz - 3,400 Hz.

FSK is not suitable for faster modems because as the bit rate increases, the frequency of the carrier also needs to increase, and this would exceed the telephone system's bandwidth.

Quadrature phase shift keying (QPSK)

This modulation method, used in **1200** bps modems, is based on the principles of phase modulation (PM). The serial data to be sent is divided up into lots of two bits called **di-bits** giving four possible combinations: 00, 01, 10 and 11.

Each time a new di-bit is sent, the phase of the carrier is changed to one of four possibilities (hence the term *quadrature*) according to the value of the di-bit as shown below.

Di-bit	Carrier Phase (V.22)
00	0°
01	90°
11	180°
10	270°

In these systems, the bit rate is twice the baud rate because two bits are sent for each change of the carrier. For a 1200 bps modem, the baud rate would be 600.

Modulation methods like QPSK that rely on phase shift are less bandwidth hungry than frequency modulation methods like FSK and so a more suited to faster modems.