Twisted pair cabling is a type of wiring in which two conductors of a single circuit are twisted together for the purposes of canceling out electromagnetic interference (EMI) from external sources; for instance, electromagnetic radiation from unshielded twisted pair (UTP) cables, and crosstalk between neighboring pairs. It was invented by Alexander Graham Bell.

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Explanation

In balanced pair operation, the two wires carry equal and opposite signals and the destination detects the difference between the two. This is known as differential mode transmission. Noise sources introduce signals into the wires by coupling of electric or magnetic fields and tend to couple to both wires equally. The noise thus produces a common-mode signal which is canceled at the receiver when the difference signal is taken.

This method starts to fail when the noise source is close to the signal wires; the closer wire will couple with the noise more strongly and the common-mode rejection of the receiver will fail to eliminate it. This problem is especially apparent in telecommunication cables where pairs in the same cable lie next
to each other for many miles. One pair can induce crosstalk in another and it is additive along the length of the cable. Twisting the pairs counters this effect as on each half twist the wire nearest to the noise-source is exchanged.

Providing the interfering source remains uniform, or nearly so, over the distance of a single twist, the induced noise will remain common-mode. Differential signaling also reduces electromagnetic radiation from the cable, along with the associated attenuation allowing for greater distance between exchanges.

The twist rate (also called *pitch* of the twist, usually defined in twists per meter) makes up part of the specification for a given type of cable. Where nearby pairs have equal twist rates, the same conductors of the different pairs may repeatedly lie next to each other, partially undoing the benefits of differential mode. For this reason it is commonly specified that, at least for cables containing small numbers of pairs, the twist rates must differ.[1]

In contrast to ScTP (screened twisted pair), STP (shielded twisted pair), FTP (foiled twisted pair) and other shielded cabling variations, UTP (unshielded twisted pair) cable is not surrounded by any shielding. It is the primary wire type for telephone usage and is very common for computer networking, especially as patch cables or temporary network connections due to the high flexibility of the cables.

**History**

The earliest telephones used telegraph lines, or open-wire single-wire earth return circuits. In the 1880s electric trams were installed in many cities, which induced noise into these circuits. Lawsuits being unavailing, the telephone companies converted to balanced circuits, which had the incidental benefit of reducing attenuation, hence increasing range.

As electrical power distribution became more commonplace, this measure proved inadequate. Two wires, strung on either side of cross bars on utility poles, shared the route with electrical power lines. Within a few years, the growing use of electricity again brought an increase of interference, so engineers devised a method called wire transposition, to cancel out the interference.

In wire transposition, the wires exchange position once every several poles. In this way, the two wires would receive similar EMI from power lines. This represented an early implementation of twisting, with a twist rate of about four twists per kilometre, or six per mile. Such open-wire balanced lines with periodic transpositions still survive today in some rural areas.

Twisted pair cables were invented by Alexander Graham Bell in 1881. By 1900, the entire American telephone line network was either twisted pair or open wire with transposition to guard against interference. Today, most of the millions of kilometres of twisted pairs in the world are outdoor landlines, owned by telephone companies, used for voice service, and only handled or even seen by telephone workers.
Unshielded twisted pair (UTP)

UTP cables are found in many Ethernet networks and telephone systems. For indoor telephone applications, UTP is often grouped into sets of 25 pairs according to a standard 25-pair color code originally developed by AT&T Corporation. A typical subset of these colors (white/blue, blue/white, white/orange, orange/white) shows up in most UTP cables. The cables are typically made with copper wires measured at 22 or 24 American Wire Gauge (AWG),[3] with the colored insulation typically made from an insulator such as polyethylene or FEP and the total package covered in a polyethylene jacket.

For urban outdoor telephone cables containing hundreds or thousands of pairs, the cable is divided into smaller but identical bundles. Each bundle consists of twisted pairs that have different twist rates. The bundles are in turn twisted together to make up the cable. Pairs having the same twist rate within the cable can still experience some degree of crosstalk. Wire pairs are selected carefully to minimize crosstalk within a large cable.

UTP cable is also the most common cable used in computer networking. Modern Ethernet, the most common data networking standard, can use UTP cables. Twisted pair cabling is often used in data networks for short and medium length connections because of its relatively lower costs compared to optical fiber and coaxial cable.

UTP is also finding increasing use in video applications, primarily in security cameras. Many cameras include a UTP output with screw terminals; UTP cable bandwidth has improved to match the baseband of television signals. As UTP is a balanced transmission line, a balun is needed to connect to unbalanced equipment, for example any using BNC connectors and designed for coaxial cable.

Cable shielding

Twisted pair cables are often shielded in an attempt to prevent electromagnetic interference. Shielding provides an electric conductive barrier to attenuate electromagnetic waves external to the shield and provides conduction path by which induced currents can be circulated and returned to the source, via ground reference connection.

This shielding can be applied to individual pairs or quads, or to the collection of pairs. Individual pairs are foiled, while overall cable may use braided screen, foil, or braiding with foil.
ISO/IEC 11801:2002 (Annex E) attempts to internationally standardise the various designations for shielded cables by using combinations of three letters - U for unshielded, S for braided shielding, and F for foiled shielding - to explicitly indicate the type of screen for overall cable protection and for individual pairs or quads.

When shielding is applied to the collection of pairs, this is usually referred to as screening, however different vendors and authors use different terminology, employing “screening” and “shielding” interchangeably; for example, STP (shielded twisted pair) or ScTP (screened twisted pair) has been used to denote U/FTP, S/UTP, F/UTP, SF/UTP and S/FTP construction.[4]

Because the shielding is made of metal, it may also serve as a ground. Usually a shielded or a screened twisted pair cable has a special grounding wire added called a drain wire which is electrically connected to the shield or screen. The drain wire simplifies connection to ground at the connectors.

An early example of shielded twisted-pair is IBM STP-A, which was a two-pair 150 ohm S/FTP cable defined in 1985 by the IBM Cabling System specifications, and used with token ring or FDDI networks.[4][5]

Common shielded cable types used by Cat. 6a, Cat. 7 and Cat. 8 cables include:

**Shielded twisted pair (U/FTP)**
Also pair in metal foil. Individual shielding with foil for each twisted pair or quad. This type of shielding protects cable from external EMI from entering or exiting the cable and also protects neighboring pairs from crosstalk.

**Screened twisted pair (F/UTP, S/UTP and SF/UTP)**
Also foiled twisted pair for F/UTP. Overall foil, braided shield or braiding with foil across all of the pairs within the 100 Ohm twisted pair cable. This type of shielding protects EMI from entering or exiting the cable.

**Screened shielded twisted pair (F/FTP and S/FTP)**
Also fully shielded twisted pair, shielded screened twisted pair, screened foiled twisted pair, shielded foiled twisted pair. Individual shielding using foil between the twisted pair sets, and also an outer metal and/or foil shielding within the 100 Ohm twisted pair cable.[6] This type of
shielding protects EMI from entering or exiting the cable and also protects neighboring pairs from crosstalk.

### Examples of common industry abbreviations

<table>
<thead>
<tr>
<th>Industry acronyms</th>
<th>ISO/IEC 11801 name</th>
<th>Cable screening</th>
<th>Pair shielding</th>
</tr>
</thead>
<tbody>
<tr>
<td>UTP</td>
<td>U/UTP</td>
<td>none</td>
<td>none</td>
</tr>
<tr>
<td>STP, ScTP, PiMF</td>
<td>U/FTP</td>
<td>none</td>
<td>foil</td>
</tr>
<tr>
<td>FTP, STP, ScTP</td>
<td>F/UTP</td>
<td>foil</td>
<td>none</td>
</tr>
<tr>
<td>STP, ScTP</td>
<td>S/UTP</td>
<td>braiding</td>
<td>none</td>
</tr>
<tr>
<td>S-FTP, SFTP, STP</td>
<td>SF/UTP</td>
<td>braiding, foil</td>
<td>none</td>
</tr>
<tr>
<td>FFTP</td>
<td>F/FTP</td>
<td>foil</td>
<td>foil</td>
</tr>
<tr>
<td>SSTP, SFTP, STP PiMF</td>
<td>S/FTP</td>
<td>braiding</td>
<td>foil</td>
</tr>
</tbody>
</table>

The code before the slash designates the shielding for the cable itself, while the code after the slash determines the shielding for the individual pairs:

- **U** = unshielded
- **F** = foil shielding
- **S** = braided shielding (outer layer only)
- **TP** = twisted pair
- **TQ** = twisted pair, individual shielding in quads
## Most common twisted-pair cables

<table>
<thead>
<tr>
<th>Name</th>
<th>Typical construction</th>
<th>Bandwidth</th>
<th>Applications</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level 1</td>
<td></td>
<td>0.4 MHz</td>
<td>Telephone and modem lines</td>
<td>Not described in EIA/TIA recommendations. Unsuitable for modern systems. [7]</td>
</tr>
<tr>
<td>Level 2</td>
<td></td>
<td>4 MHz</td>
<td>Older terminal systems, e.g. IBM 3270</td>
<td>Not described in EIA/TIA recommendations. Unsuitable for modern systems. [7]</td>
</tr>
<tr>
<td>Cat.5e</td>
<td>UTP [8]</td>
<td>100 MHz [8]</td>
<td>100BASE-TX &amp; 1000BASE-T Ethernet [8]</td>
<td>Enhanced Cat5. Same construction as Cat5, but with better testing standards.</td>
</tr>
<tr>
<td>Cat.6</td>
<td>UTP [8]</td>
<td>250 MHz [8]</td>
<td>10GBASE-T Ethernet</td>
<td>Most commonly installed cable in Finland according to the 2002 standard. SFS-EN 50173-1</td>
</tr>
<tr>
<td>Cat.7</td>
<td>F/FTP, S/FTP</td>
<td>600 MHz</td>
<td>Telephone, CCTV, 1000BASE-TX in the same cable. 10GBASE-T Ethernet.</td>
<td>Fully shielded cable. ISO/IEC 11801 2nd Ed.</td>
</tr>
<tr>
<td>Cat.7a</td>
<td>F/FTP, S/FTP</td>
<td>1000 MHz</td>
<td>Telephone, CATV, 1000BASE-TX in the same cable. 10GBASE-T Ethernet.</td>
<td>Uses all four pairs. ISO/IEC 11801 2nd Ed. Am. 2.</td>
</tr>
<tr>
<td>Cat.8.1</td>
<td>U/FTP, F/UTP</td>
<td>1600-2000 MHz</td>
<td>Telephone, CATV, 1000BASE-TX in the same cable. 40GBASE-T Ethernet.</td>
<td>In development.</td>
</tr>
<tr>
<td>Cat.8.2</td>
<td>F/FTP, S/FTP</td>
<td>1600-2000 MHz</td>
<td>Telephone, CATV, 1000BASE-TX in the same cable. 40GBASE-T Ethernet.</td>
<td>In development.</td>
</tr>
</tbody>
</table>
Solid core cable vs stranded cable

A solid core cable uses one solid wire per conductor and in a four pair cable there would be a total of eight solid wires.\[8\] Stranded conductor uses multiple wires wrapped around each other in each conductor and in a four pair with seven strands per conductor cable, there would be a total of 56 wires (2 per pair x 4 pairs x 7 strands).\[8\]

Solid core cable is supposed to be used for permanently installed runs. It is less flexible than stranded cable and is more prone to failure if repeatedly flexed. Stranded cable is used for fly leads at patch panel and for connections from wall-ports to end devices, as it resists cracking of the conductors.

Connectors need to be designed differently for solid core than for stranded. Use of a connector with the wrong cable type is likely to lead to unreliable cabling. Plugs designed for solid and stranded core are readily available, and some vendors even offer plugs designed for use with both types. The punch-down blocks on patch-panel and wall port jacks are designed for use with solid core cable.

Advantages

- It is a thin, flexible cable that is easy to string between walls.
- More lines can be run through the same wiring ducts.
- Electrical noise going into or coming from the cable can be prevented.\[9\]
- Cross-talk is minimized.\[9\]

Disadvantages

- Twisted pair's susceptibility to electromagnetic interference greatly depends on the pair twisting schemes (usually patented by the manufacturers) staying intact during the installation. As a result, twisted pair cables usually have stringent requirements for maximum pulling tension as well as minimum bend radius. This relative fragility of twisted pair cables makes the installation practices an important part of ensuring the cable's performance.

- In video applications that send information across multiple parallel signal wires, twisted pair cabling can introduce signaling delays known as skew which cause subtle color defects and ghosting due to the image components not aligning correctly when recombined in the display device. The skew occurs because twisted pairs within the same cable often use a different number of twists per meter in order to prevent crosstalk between pairs with identical numbers of twists. The skew can be compensated by varying the length of pairs in the termination box, in order to introduce delay lines that take up the slack between shorter and longer pairs, though the precise lengths required are difficult to calculate and vary depending on the overall cable length.
**Minor twisted pair variants**

**Loaded twisted pair**
A twisted pair that has intentionally added inductance, formerly common practice on telecommunication lines. The added inductors are known as load coils and reduce attenuation for voiceband frequencies but increase it on higher frequencies. Load coils cause distortion in voiceband on very long lines.[10] In this context a line without load coils is referred to as an unloaded line.

**Bonded twisted pair**
A twisted pair variant in which the pairs are individually bonded to increase robustness of the cable. Pioneered by Belden, it means the electrical specifications of the cable are maintained despite rough handling.

**Twisted ribbon cable**
A variant of standard ribbon cable in which adjacent pairs of conductors are bonded and twisted together. The twisted pairs are then lightly bonded to each other in a ribbon format. Periodically along the ribbon there are short sections with no twisting to enable connectors and PCB headers to be terminated using the usual ribbon cable IDC techniques.

**References**

1. ^ "Crosstalk dependence on number of turns/inch for twisted pair versions of the end-cap umbilical cable" (http://www.hep.ph.ic.ac.uk/~dmray/pdffiles/TP_umbilical_studies.pdf).

4. ^a b Anitech Systems MP 4000 Manual (http://www.anitech-systems.com/MP4000/manual/briefs/ICM-4020E_Hub_Switch_Route_Cable_BR120501.pdf)


8. ^a b "Comparison between CAT5, CAT5e, CAT6, CAT7 Cables" (http://discountcablesusa.com/ethernet-cables100.html).

9. ^a b "Twisted Pair Testing" (http://www.cirris.com/testing/twisted_pair/twist.html).