

INDUSTRIAL ELECTRICAL ENGINEERING

The Comprehensive Engineering Guide to Shielded Cables: Design, Standards, and Industrial Applications

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In the contemporary landscape of industrial automation, telecommunications, and power distribution, the integrity of signal transmission is paramount. As electronic systems become more compact and operate at higher frequencies, the risk of electromagnetic interference (EMI) and radio frequency interference (RFI) increases exponentially. This technical analysis explores the critical role of cable shielding, the material science behind effective barriers, and the regulatory frameworks governing their application, specifically focusing on the innovations in **power, control, and signaling cables**.

The Fundamental Necessity of Cable Shielding

Shielding is not merely an optional feature for cables; it is a critical engineering component designed to isolate the electrical conductors from the surrounding electromagnetic environment. EMI can be generated by various sources, including heavy machinery, motors, fluorescent lighting, and radio transmitters. Without adequate shielding, these external fields can induce unwanted currents in signal conductors, leading to data corruption, equipment malfunction, or even complete system failure.

Mechanisms of Interference

To understand the necessity of shielding, one must examine how interference interacts with a conductor. Interference typically occurs through four primary mechanisms:

- **Capacitive Coupling:** Occurs when an electric field exists between two conductors, effectively acting as a capacitor.
- **Inductive (Magnetic) Coupling:** Occurs when a varying magnetic field from one conductor induces a voltage in a nearby conductor, governed by Faraday's Law of Induction.
- **Radiated Interference:** High-frequency signals that travel through space as electromagnetic waves.
- **Conducted Interference:** Noise that travels along the physical path of the conductors themselves.

A shield acts as a **Faraday Cage**, a grounded enclosure that blocks external static and non-static

electric fields by distributing the charge around the exterior of the shield, thereby neutralizing the effect within the interior of the cable.

Technical Taxonomy of Shielding Materials and Construction

The effectiveness of a shield depends heavily on its material composition and physical architecture. Modern manufacturers, such as **LAPP Camuna Cavi**, utilize a variety of shielding techniques tailored to specific industrial stressors. The provided technical data highlights the use of **Al/Pet tape** (Aluminum/Polyester) and **red copper braids** as primary shielding components.

1. Foil Shielding (Al/Pet Tape)

Foil shielding consists of a thin layer of aluminum laminated to a polyester (Mylar) carrier for mechanical strength. This configuration provides 100% coverage of the underlying conductors.

- Advantages: 100% coverage ensures excellent protection against high-frequency RFI. It is thin, lightweight, and cost-effective.
- Disadvantages: Higher electrical resistance than braid. It is fragile and can crack under repeated flexing, which compromises its effectiveness at low frequencies.
- Typical Application: Static installations where space is limited and high-frequency noise is the primary concern.

2. Braid Shielding (Copper Braid)

Braid shields are constructed by weaving together fine strands of bare or tinned copper wire. The density of the weave, or "coverage," typically ranges from 70% to 95%.

- Advantages: Superior structural integrity and flexibility. The lower DC resistance of the copper makes it highly effective at lower frequencies and provides an excellent path to ground.
- Disadvantages: It does not provide 100% coverage (small gaps exist between the woven strands), and it is bulkier and more expensive than foil.
- Typical Application: High-vibration environments, flexible power cables, and applications requiring robust grounding.

3. Combination Shielding (Double Shielding)

For critical applications, engineers specify a combination of both foil and braid. This dual-layer approach provides 100% coverage for high frequencies while maintaining low resistance and mechanical durability for lower frequencies. As noted in the **Cavi Coax 75 Ohm** specifications, double shields are often utilized to ensure signal purity in sensitive data transmission.

Comparative Analysis: Shielded vs. Unshielded Cables

The decision to utilize shielded (STP) versus unshielded (UTP) cables involves a trade-off between performance, cost, and environment. Below is a structured comparison of these two architectures.

Feature	Shielded Cable (STP/FTP)	Unshielded Cable (UTP)
EMI/RFI Protection	Excellent; ideal for noisy industrial environments.	Minimal; relies on differential signaling/twisting.
Grounding Requirement	Mandatory; requires specialized connectors and grounding.	Not required.
Flexibility & Diameter	Larger diameter; stiffer due to shield layers.	Smaller diameter; highly flexible.
Installation Complexity	High; requires precision in termination and grounding.	Low; straightforward termination.
Cost	Higher due to material and manufacturing complexity.	Lower; cost-effective for commercial office use.
Data Integrity	Maintains high speeds over longer distances in noise.	Subject to crosstalk and external noise over distance.

Fire Safety and Regulatory Standards: CPR and CEI 20-27

In the European market, cables are subject to the **Construction Products Regulation (CPR)**, which classifies cables based on their reaction to fire. Technical data for **Camuna Cavi** products often mentions classifications such as **Cca-s3, d1, a3**. Understanding these codes is vital for compliance with safety regulations like **CEI 20-27** and **UNEL 35384**.

Decoding the CPR Classification

The classification string provides a detailed profile of how the cable behaves during a fire:

1. **Class (Cca)**: Indicates the fire spread and heat release. 'Cca' is a high standard often required for public buildings and critical infrastructure.
2. **Smoke Production (s3)**: Rates the opacity of smoke produced. 's3' indicates no requirement for smoke obscuration (often used in areas where low smoke is not the primary concern).
3. **Flaming Droplets (d1)**: Indicates the presence of flaming particles. 'd1' means no flaming droplets/particles lasting more than 10 seconds.
4. **Acidity (a3)**: Measures the corrosivity and toxicity of gases. 'a3' indicates high acidity/corrosivity, whereas 'a1' would indicate low acidity.

Furthermore, **low halogen emission** and **oil resistance** are critical for industrial environments like oil and gas refineries or automotive assembly lines, where chemical exposure and fire safety are simultaneous risks.

Engineering Principles of Coaxial Cables (75 Ohm)

Coaxial cables, such as the **CAVI COAX 75 Ohm**, represent a specialized form of shielding where the shield serves as the return path for the signal. The 75 Ohm impedance is the industry standard for video and telecommunications because it minimizes signal attenuation (loss) over long distances.

The Role of Dielectric and Double Shielding

In a 75 Ohm coax, the distance between the center conductor and the shield, maintained by the dielectric (insulation), determines the impedance. The **double braid shield** mentioned in the technical data (e.g., 1x0.32 75 Ohm) ensures that even in high-interference zones, the signal-to-noise ratio (SNR) remains high. This is achieved by reducing the transfer impedance, a metric that describes the effectiveness of the shield in preventing leakage.

Practical Implementation: Grounding and Termination Best Practices

The most sophisticated shield is rendered useless if not properly terminated. A shield that is not grounded effectively acts as an antenna, potentially worsening the interference it was intended to prevent.

Step-by-Step Procedure for Shield Termination

1. **Preparation:** Use precision stripping tools to remove the outer jacket without nicking the shield or the underlying insulation.
2. **Shield Management:** In the case of braid, unweave the braid or use a "pigtail" method. However, for high-frequency applications, 360-degree termination using a conductive gland is superior to a pigtail, as pigtails introduce inductance.
3. **Grounding:** Ensure the shield is grounded at the appropriate end. In industrial control systems, shields are typically grounded at the source (the PLC or controller) to prevent ground loops, which occur when there is a potential difference between two different ground points.
4. **Testing:** Perform a continuity test to ensure the shield is unbroken from end to end and a high-voltage insulation test (Hi-Pot) to verify that no shorts were created during termination.

Case Studies and Failure Analysis

Case Study 1: Variable Frequency Drive (VFD) Interference

In a packaging plant, sensors were providing erratic data every time a large motor, controlled by a VFD, began to ramp up. The original installation used unshielded power cables. The fast switching of the VFD transistors (PWM) generated significant RFI. The solution involved replacing the power cables with **shielded cables featuring a copper braid (H2/H3 type)**. The low-impedance path to ground provided by the braid successfully shunted the high-frequency noise away from the signal wires, restoring sensor accuracy.

Case Study 2: Signal Loss in Long-Distance Coax

A surveillance system using 75 Ohm coax experienced significant ghosting and signal degradation. Analysis revealed that the cable, although shielded, did not have the 100% coverage required for the environment's high RFI level. Replacing it with a **double-shielded Al/Pet + Braid cable** (similar to those produced by **Camuna Cavi**) eliminated the ghosting by providing the necessary 100% coverage for the high-frequency video signals.

The Future of Cable Shielding: Materials and Sustainability

As we move toward Industry 4.0, the demands on cable technology continue to evolve. There is an increasing focus on **Tinned Copper** versus **Bare Copper**. Tinned copper, while slightly more expensive, offers significantly better resistance to oxidation and corrosion, extending the cable's

lifespan in harsh environments. Furthermore, the push for **halogen-free (LSZH)** materials is driven by both safety regulations and environmental sustainability goals, ensuring that cables do not release toxic gases if subjected to high heat.

Summary and Strategic Selection

Selecting the correct cable requires a holistic understanding of the electrical, mechanical, and environmental constraints of the application. Whether it is the flexibility of a **red copper braid** for robotic arms or the 100% RFI protection of **Al/Pet tape** for data centers, the choice of shielding is the foundation of system reliability. Engineering standards such as **CEI 20-27** and the **CPR** framework provide the necessary benchmarks to ensure that these components perform safely under duress.

Ultimately, the integration of advanced shielding materials with rigorous manufacturing standards allows for the seamless operation of complex electronic systems in an increasingly crowded electromagnetic spectrum. For engineers and system integrators, prioritizing high-quality shielded cables from reputable sources like **LAPP Camuna Cavi** is an investment in long-term operational stability and safety.