
Application Note: Factors Involved in Recommended Minimum Bend Radii for Electro-Optical Cables

Introduction

Electro-optical cables, often utilized in high-performance environments where both electrical and optical signals must be transmitted, are vital in industries such as telecommunications, aerospace, defense, and medical equipment. A key consideration in the installation and long-term performance of these cables is their minimum bend radius. Exceeding the recommended bend radius can lead to mechanical damage, signal degradation, or even complete cable failure. Understanding the factors that influence the recommended minimum bend radius helps ensure proper installation, longevity, and optimal performance of the electro-optical cable system.

Some manufacturers may overstate the MBR of a cable, but this comes at a risk of reducing life and potentially having a break in the field. A manufacturer employing proper cable design techniques will be balancing all of the parameters of a cable such as diameter, weight, strength, bend performance and optical loss.

Factors Influencing Minimum Bend Radius

1. Cable Construction and Material

The composition of an electro-optical cable, including its internal structure and materials used, plays a pivotal role in determining the minimum bend radius. Key components include:

Optical Fiber Elements: Optical fibers are typically made of glass and are sensitive to mechanical stress. Bending the fibers beyond their limits can cause micro-cracks or excessive attenuation (signal loss), degrading optical performance.

Electrical Conductors: Copper or other metallic conductors in the cable may be more resilient to bending than optical fibers, but they too can suffer damage, particularly in cases of repetitive flexing.

Jacketing Materials: The outer jacket or sheathing material can be composed of many materials, like PVC or polyurethane, and contribute to the cable's flexibility. A stiffer outer sheath will increase the minimum bend radius, while softer materials may allow tighter bends.

2. Optical Bend Loss

When one refers to the Minimum Bend Radius (MBR) of a cable it is generally considered a mechanical limitation to prevent damage of the inner components, but when fiber optics are used in optical and electro-optical cables, one must also consider the bend losses (attenuation) of the fiber.

Fibers will have a rating for macrobending losses. Each fiber manufacturer will provide data on the number of turns a fiber can make around a certain sized mandrel and the additional attenuation that is induced through this bending. More turns equal higher losses, smaller bend radii will also lead to higher losses.

In larger composite, hybrid cables, the cable elements are constructed in a manner that will limit the attenuation of the optics within the cable and recommended mechanical MBR of the overall cable will typically be large enough not to cause additional attenuation of the optical signal.

3. Cable Diameter

The overall diameter of the cable, including its insulation, sheathing, and shielding, is a critical factor. A general rule of thumb is that the minimum bend radius is a multiple of the cable's outer diameter. This multiple may range from 10x to 20x the cable diameter, depending on the specific type and construction of the cable. A larger diameter cable requires a larger bend radius due to the increased mechanical stress during bending.

Typical Industry Recommendations are as follows;

Type of Usage	Definition	MBR Recommendation
Static (installation)	Flexed into position: no further movement (e.g. clipped into a position)	5 x overall cable diameter
Flexing	General motion (unsupported cable movement)	10 x overall cable diameter
Dynamic use	High frequency use (constant flex & load)	20 x overall cable diameter

4. Operating Environment

The environment in which the cable will be deployed also affects the recommended minimum bend radius. High-stress environments, such as those with extreme temperatures, mechanical vibration, or movement, can increase the need for a larger bend radius:

Temperature: Cold temperatures can make the cable materials more brittle, increasing the risk of damage when bending. In contrast, higher temperatures can soften materials, making the cable more flexible but potentially compromising long-term durability.

Vibration and Movement: Cables installed in dynamic applications, such as robotics or aerospace, may be subjected to repetitive bending. For these applications, the bend radius should be more conservative to avoid fatigue and ensure longevity.

5. Static vs. Dynamic Installation

The recommended bend radius will differ based on whether the cable is installed in a static or dynamic application:

Static Bend Radius: When a cable is permanently installed and subjected to minimal movement, the recommended minimum bend radius may be smaller. However, exceeding this bend radius even slightly could still result in performance degradation over time.

Dynamic Bend Radius: Cables used in applications where they are repeatedly flexed or moved must have a larger minimum bend radius. This ensures that the cable can withstand continuous bending without degradation of the optical or electrical signals, or mechanical damage to the fibers and conductors.

6. Manufacturer Specifications and Testing

Cable manufacturers typically provide specific recommendations regarding minimum bend radii. These specifications are often based on extensive testing under various conditions, including mechanical stress, temperature variations, and long-term performance evaluations. Manufacturer guidelines should always be followed to ensure optimal performance and prevent premature failure.

Testing protocols such as TIA/EIA-568 or IEC 60794 can provide insight into the durability and bending tolerance of electro-optical cables, which can then be used to guide proper installation practices.

7. Installation Techniques

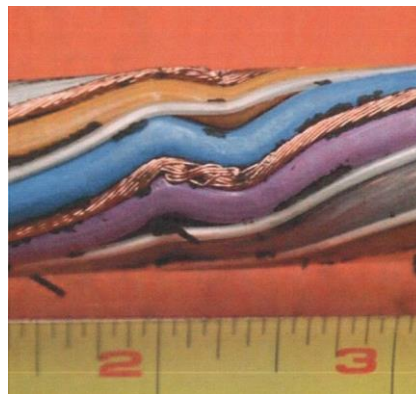
Pulling Tension: Excessive pulling force during installation can lead to excessive stress at bends, increasing the risk of exceeding the minimum bend radius. Careful attention must be given to tension limits during cable pulling.

Bend Protection Devices: Tools such as bend radius guides or protective grommets can be used during installation to prevent the cable from exceeding its recommended bend radius. These devices are particularly useful in high-bend environments such as tight spaces or curved conduits.

Conclusion

Most of the recommendations above are given to improve the performance and life of the cable, ensuring peak performance and longevity of a cable. The MBR recommendations are guidelines and not hard fact rules. In certain circumstances a cable can be net such that it greatly exceeds the MBR recommendations, but does not damage the cable. As with most things, repeated exposure increases risk. This is true for MBR as well. Repeatedly exceeding recommendations will likely reduce the expected lifespan of the cable.

In extreme cases where the MBR is exceeded the “lay-up” of the internal elements can be affected in such a way that a fiber may break, conductor may stretch and/or z-kinking can occur where the elements create a kink that will very likely break an element inside the cable.



Z-Kinking

The recommended minimum bend radius for electro-optical cables is influenced by various factors including cable construction, fiber type, cable diameter, environmental conditions, and installation methods. Adhering to manufacturer guidelines and understanding the conditions in which the cable will be deployed is essential to maintaining cable integrity, performance, and lifespan. Careful consideration of the above factors will help ensure that electro-optical cables operate efficiently and reliably in their intended applications.