

2x2 Multicore Fiber Polarity

Alexander Sheldon | Shane R Rainey | Zachary Carpenter | Rebecca Lovely

Executive Summary

Multicore fiber (MCF) technology is rapidly advancing towards deployment in both short-reach and long-haul applications; however, polarity definition and implementation are not yet standardized, and inconsistent conventions persist across the industry.

This white paper presents a consolidated polarity framework derived from extensive internal analysis and cross-functional technical discussions. The conclusions demonstrate that core polarity requirements differ fundamentally by system architecture. In co-propagating systems, polarity mismatches are inherently resolvable through system software and digital signal processing, provided marker core quadrant alignment is maintained. In contrast, counter-propagating architectures – particularly those optimized for long-haul performance – require controlled polarity at defined system boundaries to preserve transmit and receive directionality.

The resulting framework emphasizes hemispherical alignment and controlled breakouts rather than end-to-end polarity tracking.

Background and Problem Statement

As telecom markets pursue higher fiber density and improved spectral efficiency, multicore fiber has emerged as a viable path forward for both intra- and inter-data center connectivity. Industry experience indicates that polarity management requirements and tolerances become increasingly important from short-reach to long-haul applications.

With multicore, polarity focus is not on controlling per-core polarity through an end-to-end link but enabling core identification where correct system operation depends on it.

Definitions

- **Multicore fiber (MCF)** – fiber that has multiple data transmission cores in a single fiber optic strand (4 cores per strand demonstrated in this paper)
- **Marker** – a marking on, or in, the fiber (typically an additional core) visual identification (not data transmission) of the data transmission cores
- **Co-propagation** – All 4 transmission cores in one optical strand are either Tx or Rx, wherein light flows in unidirectionally through all four cores of the fiber
- **Counter propagation** – 2 cores are Tx and 2 cores are Rx, data transmits in opposing directions in neighboring cores inside one fiber strand

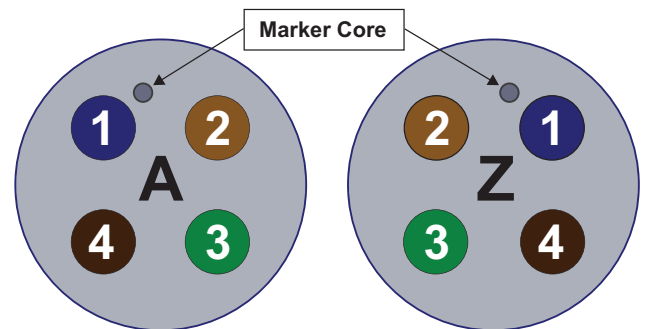


Figure 1: An asymmetric type marker core and transmission core positions for A and Z ends of a given fiber strand.

- **Marker quadrant alignment** – the area of the MCF end face where the marker core must be located for consistent referencing (shown in Figure 3)

Multicore Fiber System Architectures

Co-propagating architectures can leverage a digital signal processor with crossbar functionality which enables digital switching of data channels within a port via lane mapping. As a rule of thumb, counter-propagating systems with MCF have cores 1 and 3 as transmitting cores, and cores 2 and 4 as receiving cores (see Figure 2).

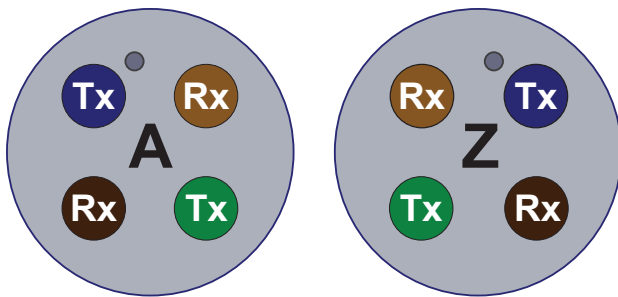
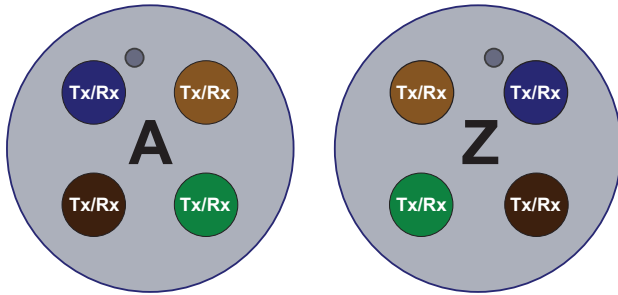


Figure 2: Top: Co-propagation system transmitting or receiving orientation for MCF. Bottom: counter-propagation system transmitting and receiving orientation for MCF.

Not all parts of a system need active core polarity management; but incorrect marker core orientation at any point upstream in a system can lead to downstream complexity. Without knowing that system polarity is maintained, identifying which fiber core has which data requires extra, time-intensive verification.

To ensure standardized system polarity, marker cores must be in the same quadrants as defined in this paper.

Fiber Position vs. Core Position

Fiber position within TIA-568 defined Type A, B, C, U1, and U2 polarities remain consistent for MCF.

Core position polarity is defined by this paper. A given “Core ID” may appear in different physical quadrants at opposite ends of a MCF (See Figure 1) without breaking polarity if marker core alignment is preserved.

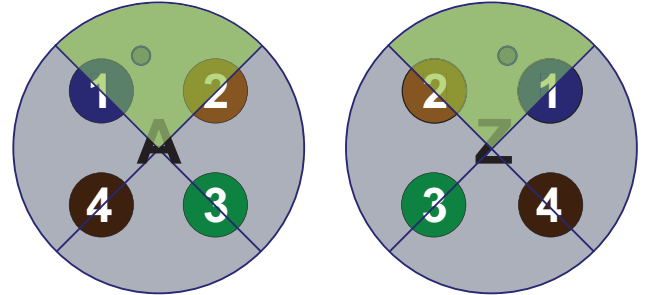


Figure 3: Example of consistent marker quadrant alignment.

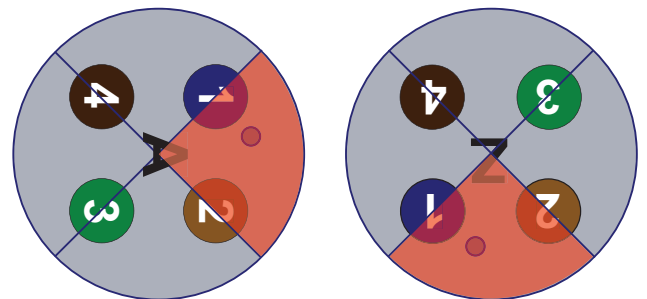


Figure 4: Example of some incorrect orientations showing the marker core without consistent marker quadrant alignment.

Marker Core Alignment Requirement

Asymmetric Marker Core

The asymmetric marker core can be visually recognized on the end face of a fiber by splicing equipment. Asymmetric marker cores allow inspection equipment to identify the fiber cores regardless of which end of the fiber is being inspected. This enables the splicers to not only align the data carrying cores with each other during a splice, but to also ensure the cores of one MCF are matched up to the correct cores of the second MCF to maintain a controllable, predictable core polarity.

The standard defined here is to maintain marker core quadrant alignment. This applies to both symmetric and asymmetric MCF constructions.

During fusion splicing, the asymmetric marker cores do not have to align or match together. This is expected and is designed into the system, and is explored further in the paper. On the next page are the two configurations that can occur in a correctly spliced MCF splice.

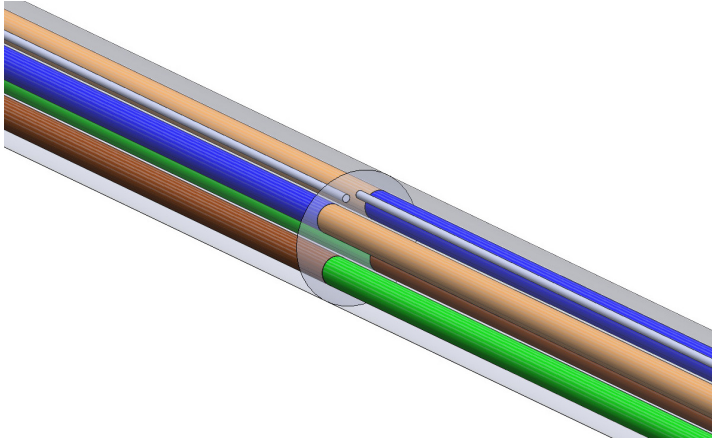


Figure 5: A correct A-A or Z-Z splice as the marker cores maintain quadrant orientation with the fiber. The marker cores do not perfectly align, but the data carrying cores do.

In Figure 5, the marker cores do not align within the A-A or Z-Z end splice configuration. This isometric view is not how splicers view the fiber's lateral and end face. With an asymmetric marker core, A-end vs. Z-end fibers can easily be identified as the A-end has the marker core to the left of the center line when the marker core quadrant alignment is maintained.

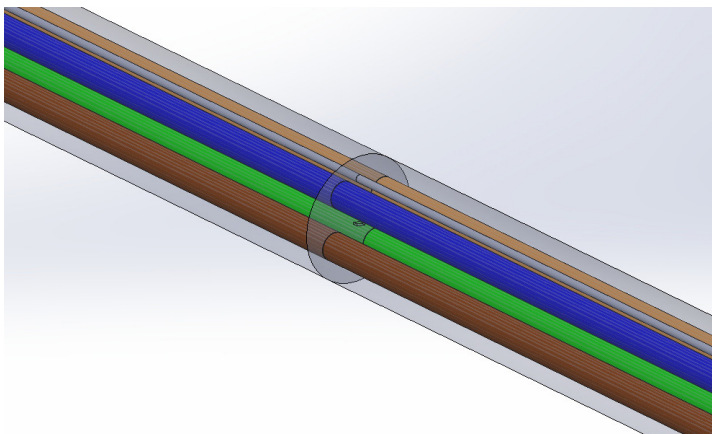


Figure 6: A-Z splice. This is also a correct splice (as shown in Figure 4) as the marker cores are both oriented in the upper quadrant of the fiber. Here, the marker cores do align perfectly.

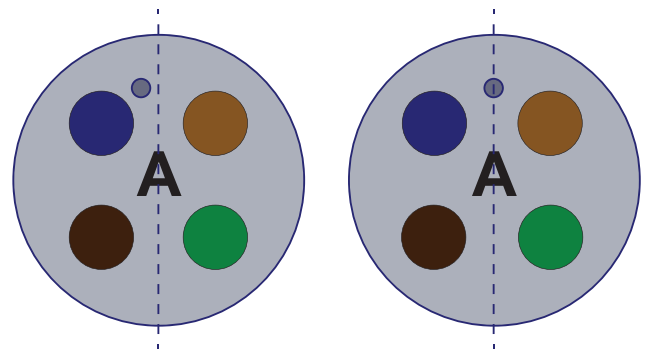


Figure 7: The A-end of a MCF with an asymmetric marker core on the left, and an A-end of a MCF with a symmetric marker core on the right. Note that the A- and Z-end of the symmetric marker core MCF are indistinguishable.

Symmetric Marker Core

Symmetric marker cores within a MCF are functionally similar to asymmetric marker cores. As with asymmetric marker cores, splicers must orient the marker cores to the same quadrant and then align the fiber data cores within. Symmetric A-A end splices and A-Z end splices are indistinguishable from one another.

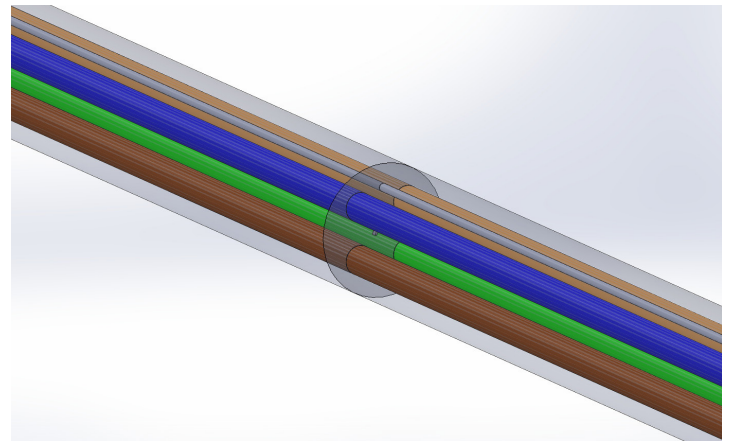


Figure 8: A-Z end splice. Marker core is aligned exactly and fiber data cores are both aligned and matched to production identification of core number.

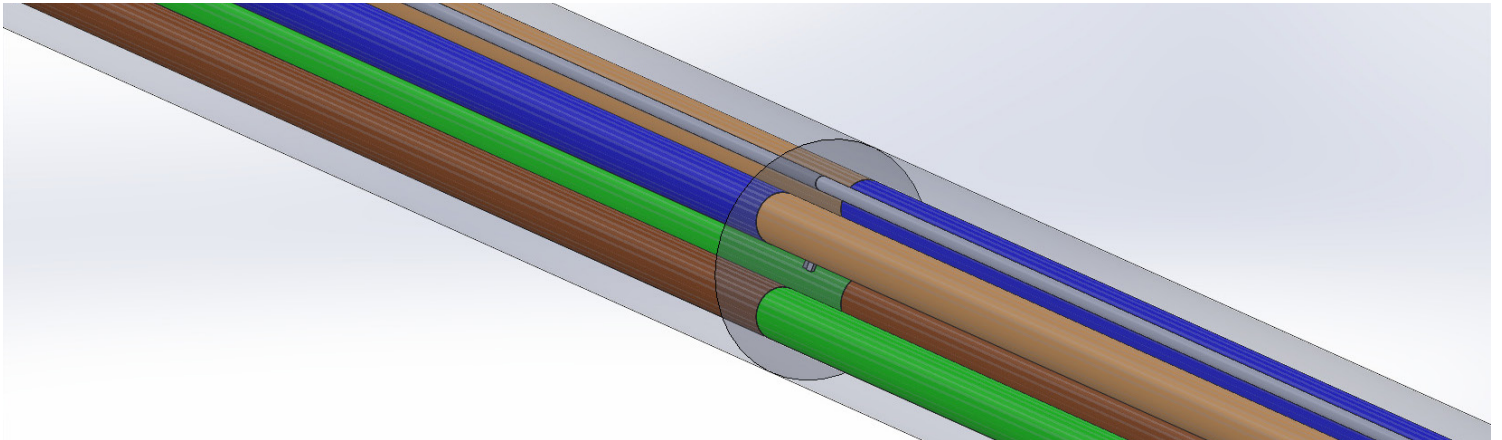


Figure 9: A-A end splice. Marker core is still aligned exactly and fiber data cores are aligned, but they do not match up with the labeling provided by production.

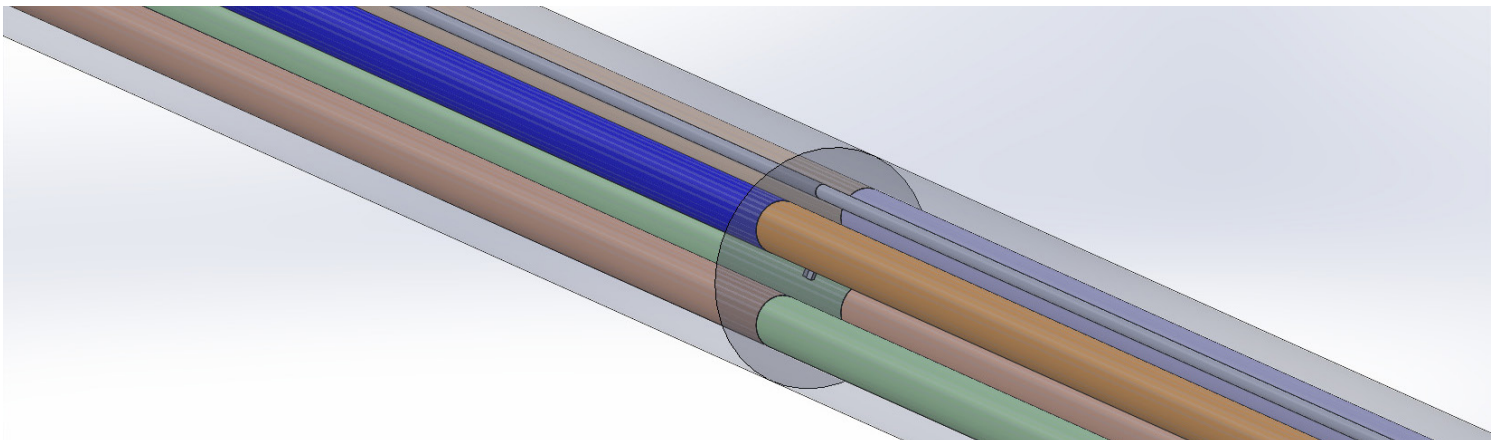


Figure 10: Light path illuminated in the above A-A end splice. Even though the light goes from fiber 1 core 1 to fiber 2 core 2, it remains in the expected position relative to the marker core.

Splice Study

A future splice study is planned to compare symmetric vs. asymmetric splices to reinforce the above statements about the preference for fiber tracking and troubleshooting. The results of this study may further refine or reinforce these assertions.

Multifiber Connectors

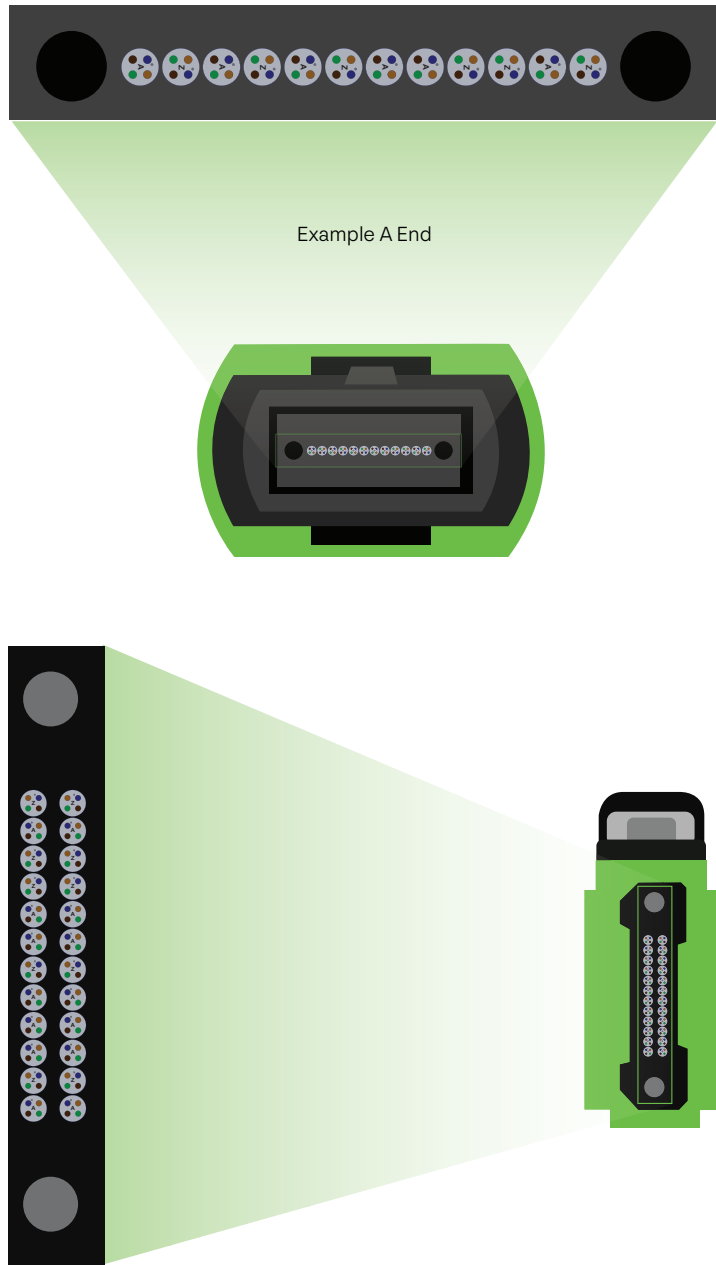


Figure 11: Top: Inconsistent A and Z ends grouped in an 8-fiber MTP connector with the MTP connector key to the left. Bottom: Inconsistent A and Z ends grouped in a 24 fiber MMC connector with the MMC latch at the top.

Figure 11 illustrates MTP[®] and MMC[®] ferrules with installed MCF fibers. The placement of A and Z fibers are arbitrary and will vary between every connector. Note though, that mirroring what is shown in Figure 3, the marker cores are all in the same quadrant orientation. This is important for polarity management across MCF systems.

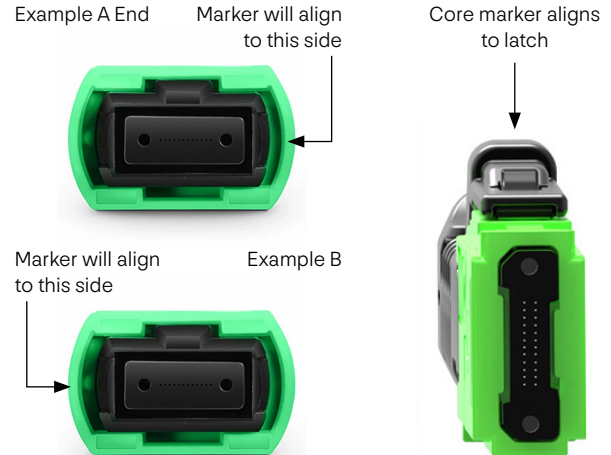


Figure 12: Marker core orientation for MMC and MTP connectors.

The Marker core of an MCF fiber must always point towards the Latch/Key on an MMC connector. For MTP assemblies there must be a distinction made for A end and B end of an assembly, on the A end of an assembly the marker must always point to the right of the MTP connector when viewed from the front with the MTP key facing up. On the B end of the assembly the marker must always point to the left of the MTP connector when viewed from the front with the MTP key facing up. This ensures that when these connectors are mated, they mate with marker cores in the same quadrant. The difference between the MMC and MTP orientation is due to how these two connectors mate. MMC connectors mate latch to latch which allows the markers to align to the latch which insures quadrant alignment. MTP connectors mate key up to key down which requires the marker to be facing offset sites which allows for quadrant alignment when the MTPs are mated. MCF MMC connectors are expected to be APC for lowest loss.

Facilitating communication across an MCF system depends on channel alignment between MCF transceivers. Polarity must be managed in MCF components to achieve this channel alignment. Figure 13 on page 6 shows a 2-channel representation of a 2-port MCF transceiver.

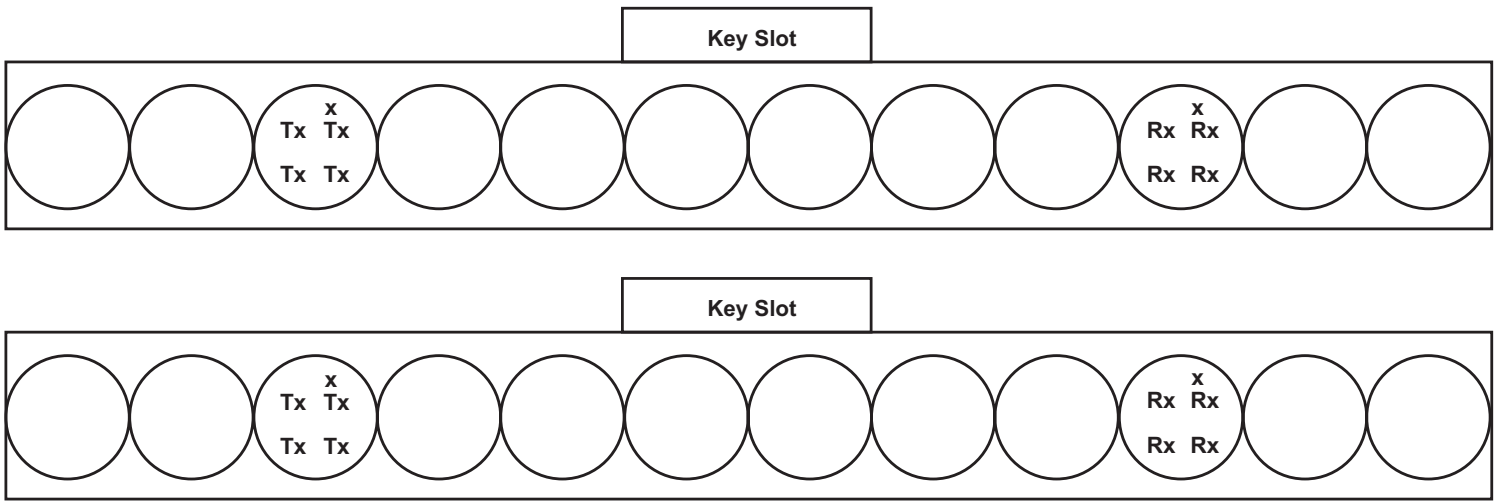
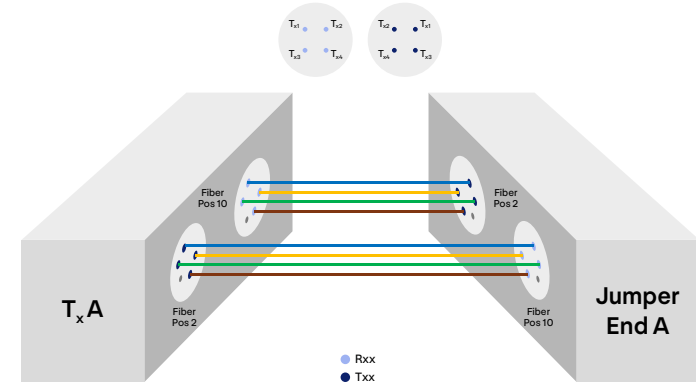


Figure 13: 2-port MCF transceiver with 4 active fibers.

The MCF transceivers contain 2 Tx fibers and 2 Rx fibers, each one with 4 cores. The result is 16 total channels with 8 Tx fibers needing to map to 8 Rx fibers. Look at these transceivers obliquely at two ends of a system to help visualize how they will be placed in a real system.

The MCF cable assembly in Figure 15 is formed by placing Figure 14 between the two transceivers shown in Figure 13.



Looking at the fiber positioning in the ferrule of the jumper connecting the transceivers, we can see that A-end Position 2 goes to B-end Position 10. It is necessary to have a ‘flip’ in the jumper to translate Tx on one side to Rx on the other. The connection between the two transceivers must be an overall ‘B’ polarity. This is the same as single core MTP® transceivers, where trunks and overall systems must be B polarity. Thankfully MCF fiber positioning matches what we see in SCF systems.

Figure 14: 2 MCF transceivers facing one another in a system.

The polarity rules established in SCF will translate to those established in MCF. The fiber position from end to end will be opposite (i.e., Position 2 to Position 10 in the example above). Or in the SCF system, Position 1 to Position 12 will achieve Tx-Rx on MTP native connections.

The cabling between these two transceivers will act as a straight pipe as shown below:

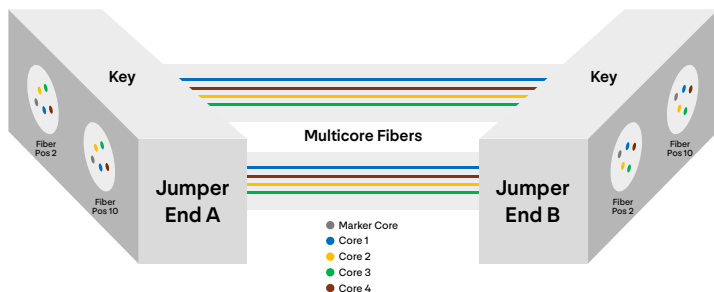
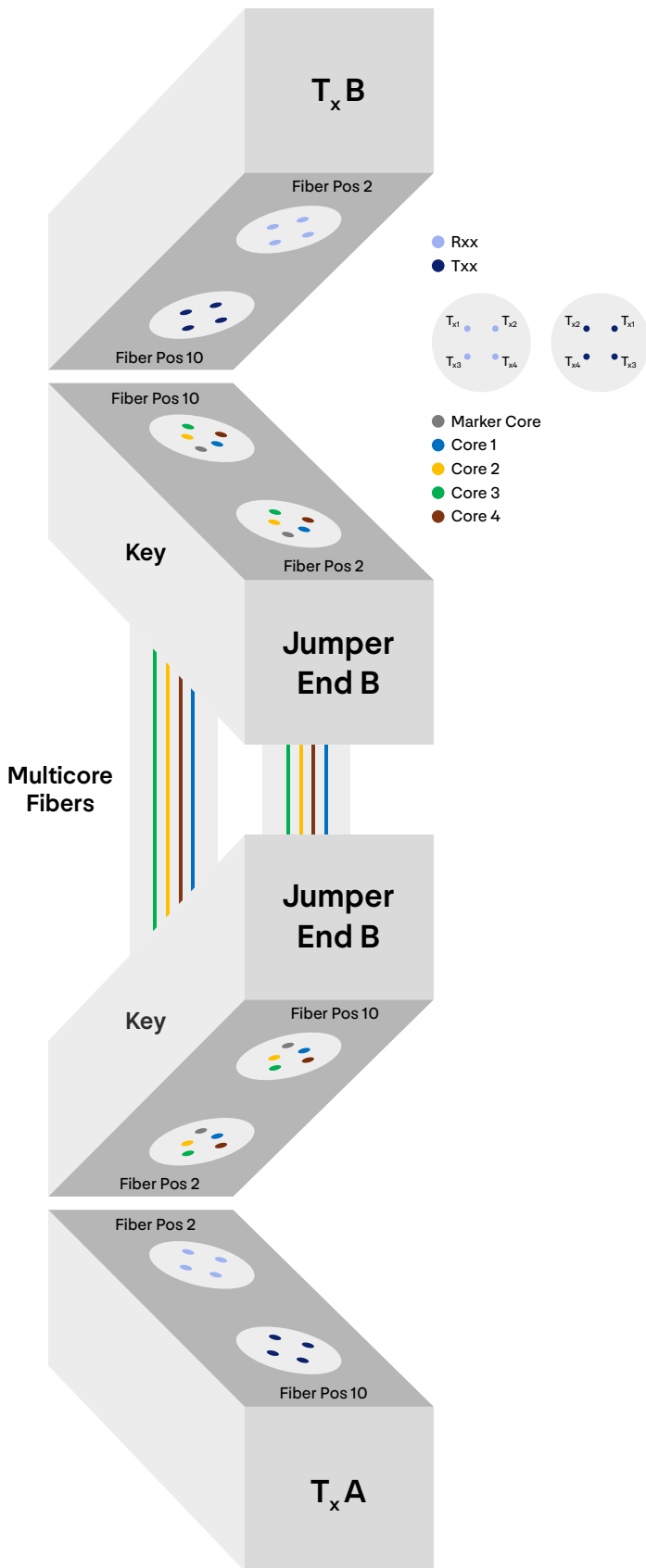


Figure 15: Example of an MCF cable assembly.



A Polarity	B Polarity
F1C1 – F1C1	F1C1 – F8C1
F1C2 – F1C2	F1C2 – F8C2
F1C3 – F1C3	F1C3 – F8C3
F1C4 – F1C4	F1C4 – F8C4
F2C1 – F1C1	F2C1 – F7C1
F2C2 – F2C2	F2C2 – F7C2
F2C3 – F2C3	F2C3 – F7C3
F2C4 – F2C4	F2C4 – F7C4
F3C1 – F3C1	F3C1 – F6C1
F3C2 – F3C2	F3C2 – F6C2
F3C3 – F3C3	F3C3 – F6C3
F3C4 – F3C4	F3C4 – F6C4
F4C1 – F4C1	F4C1 – F5C1
F4C2 – F4C2	F4C2 – F5C2
F4C3 – F4C3	F4C3 – F5C3
F4C4 – F4C4	F4C4 – F5C4
F5C1 – F5C1	F5C1 – F4C1
F5C2 – F5C2	F5C2 – F4C2
F5C3 – F5C3	F5C3 – F4C3
F5C4 – F5C4	F5C4 – F4C4
F6C1 – F6C1	F6C1 – F3C1
F6C2 – F6C2	F6C2 – F3C2
F6C3 – F6C3	F6C3 – F3C3
F6C4 – F6C4	F6C4 – F3C4
F7C1 – F7C1	F7C1 – F2C1
F7C2 – F7C2	F7C2 – F2C2
F7C3 – F7C3	F7C3 – F2C3
F7C4 – F7C4	F7C4 – F2C4
F8C1 – F8C1	F8C1 – F1C1
F8C2 – F8C2	F8C2 – F1C2
F8C3 – F8C3	F8C3 – F1C3
F8C4 – F8C4	F8C4 – F1C4

Table 1: A polarity and B polarity listed for reference. Standard Polarity Schemes apply across SCF and MCF.

Figure 16: MCF transceiver to MCF transceiver through MCF assembly.

Polarity Control Through Breakouts and FIFOs

While the A-end and Z-end facing in ferrules is not considered when making MCF assemblies, it must be managed when breaking out MCF to SCF via FIFOs (first in, first out) or breakouts. This management is because in an end-to-end MCF system, the signal traveling through a core will always stay in one quadrant (See Figure 11). Even if it moves to a different core, it will remain in the quadrant. When this signal gets to a breakout to SCF there needs to be traceability in the breakout/FIFO component to which the signal is directed — for example, quadrant 1 in the MCF will be going to an expected SCF port on the breakout. This guarantees that the SCF positions that are mapped to the MCF fiber in the assembly/FIFO are consistent.

Note: Depending on the FIFO polarity, system polarity tracking/fiber mapping can quickly become challenging.

Splicing, Repair, and Manufacturing Implications

Splicing operations, including field repairs, should not attempt exact marker core alignment, but splicing does require consistent marker core quadrant orientation alignment. Core polarity can be normalized at the ends of a system using known polarity terminations. This reduces the need for extensive VFL tracing or post-repair polarity correction.

Testing and Troubleshooting Considerations

Existing OTDR, VFL, and fiber mapping tools remain valid. Software abstraction enables compatibility without new testing paradigms.

Conclusion

MCF core polarity can be simplified by focusing on marker core quadrant orientation alignment and controlled breakouts. This approach enables scalable deployment, interoperability, and standards alignment with minimal operational burden without limiting marker core options.