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Signal quality evaluation of multi-mode optical fiber communication under vibrational environment

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Optical fiber communication is a crucial technology that underpins modern information and communication systems. With the rapid surge in data traffic, particularly in data centers, the demand for optical fiber communication systems continues to grow. Beyond data centers, these systems are increasingly being deployed in diverse applications, including aerospace, automotive, and industrial sectors [1]. In such environments, optical fiber communication systems must operate reliably under extreme conditions, such as high temperatures and strong mechanical vibrations. In the automotive sector, for instance, optical fiber networks are expected to function in highly dynamic and thermally challenging conditions, with operating temperatures ranging from -40 to 105 degrees Celsius. To address these demands, the IEEE 802.3cz standard has been established for multi-gigabit optical automotive Ethernet, specifying the use of multimode optical fiber [2]. However, in high-vibration environments, signal quality degradation can occur due to fluctuations in optical path length and misalignment of optical axes at connectors induced by mechanical vibrations.

We experimentally assess the signal quality of a multimode optical fiber communication system subjected to vibrational disturbances. To replicate the misalignment effects induced by vibration at the optical connector, we employ an optical aligner to deliberately introduce misalignment and analyze the resulting modal noise of the emitted optical signal using a near-field pattern monitoring system. Our experimental findings reveal a substantial increase in noise levels when misalignment is applied, with certain conditions failing to meet the IEEE standard requirements [3]. To further investigate the system's behavior under real-world vibrational conditions, we employ a mechanical vibrator to apply controlled vibrations to both the connector and fiber cables (Fig. 1). The vibration frequency extends up to approximately 200 Hz, with acceleration reaching 8 N/m, as measured by an accelerometer.

We present our latest findings on signal quality under these vibration conditions and discuss the broader implications of such harsh environmental factors on multimode optical fiber communication systems. Our study provides valuable insights into the robustness of optical fiber links in dynamic environments and highlights key considerations for designing resilient optical communication systems in the automotive and industrial sectors.

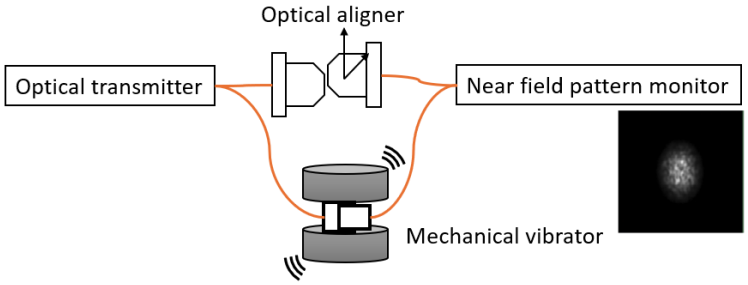

Figure 1. Experimental setup for near-field pattern measurement under misalignment and vibration conditions.

References

[1] Ethernet Alliance, "Ethernet Roadmap 2024," 2024: https://ethernetalliance.org/technology/ethernet-roadmap/

[2] IEEE802.3cz-2023, "IEEE 802.3cz Multi-Gigabit Optical Automotive Ethernet," April 2023: https://www.ieee802.org/3/cz/

[3] A. Kanno, "Clock-Data-Recovery-Based Delta-Sigma Modulation over Multi-Mode Fiber under Axis-Misalignment Condition," MWP2024, Pisa, Italy, Ps16, September 2024.