

# Ultra-Reliable Wireless Transmission Over Dense Fog Conditions Enabled by Hybrid FSO-mmWave

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Free-space optics (FSO) is the new frontier for broadband wireless communications. The most prominent benefits of FSO include the provision of fiber-like bandwidth, unlicensed spectrum, and immunity to electromagnetic interference. These key features make FSO a promising technology for 6G terrestrial, and satellite communications. However, the benefits of FSO systems come at the cost of increased sensitivity to weather conditions such as fog and turbulence, particularly for terrestrial links. In locations where fog occurrence is statistically relevant, the propagation loss can severely reduce the uptime of FSO systems. This poses a limitation on the maximum link length if a high availability standard is required. On the other hand, radio-frequency based links have always been known for their weather resilience, but lack the high data capacity of FSO due to their narrower available spectrum and regulatory constraints.

Thus, to address the high-bandwidth and reliability requirements for wireless links, we have proposed and implemented a hybrid FSO and millimeter-wave (mmWave) wireless link, bringing together both

technologies' strengths. This hybrid system was subjected to the impact of fog, which was generated inside an atmospheric chamber developed in partnership with PIC-Advanced. By exploiting adaptive modulation on the FSO link, we maximized the system throughput while maintaining maximum reliability with extreme fog conditions.

With this work, we demonstrated transmission capacity ranging from 25 to 425 Gbps with 100% reliability and tolerating more than 50 dB of power attenuation which would be equivalent to a 50 km link with a visibility of 13km.

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## References

[1] B. T. Brandao et al., "Ultra-Reliable 25G-400G+ Wireless Transmission Over Dense Fog Conditions Enabled by Hybrid FSO-mmWave," ECOC 2024; 50th European Conference on Optical Communication, Frankfurt, Germany, 2024, pp. 1251-1254.

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**FIGURE 1**  
Experimental setup of the hybrid FSO-mmWave transmission though dense fog exploiting adaptive modulation to maximize capacity and reliability.

