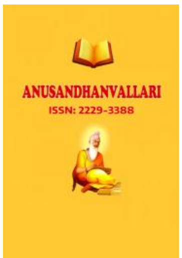

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Optical Wireless Communication: Enhancing Data Rates with Ultra-Wideband Technology

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Abstract: This paper is aimed at examining how ultra-wideband (UWB) technology can improve optical wireless communication (OWC) as regards the data rate, the latency, and overall system efficiency. A secondary research form was adapted where the sources included peer-reviewed journals, technical reports and industry studies to gather evidence on UWB-OWC integration. The results demonstrate that UWB-based OWC systems offer data rates of 160 Gbps, latency less than 1 ms and spectral efficiencies greater than 20 bits/s/Hz, compared to conventional RF systems with a maximum of 10-20 Gbps. Areas of application include IoT, UAV, vehicular and 6G backhaul networks, also with high resistance to interference. The work summarises that UWB-OWC is a scalable, energy-efficient, and future-proof technology to provide terabit wireless communication.

Keywords: Ultra-Wideband (UWB), Optical Wireless Communication (OWC), Data rate / Gbps, Latency, Spectral efficiency, 6G, IoT (Internet of Things), Terahertz (THz), Interference, Backhaul

Introduction

Optical Wireless Communication (OWC) has proved to be an attractive candidate as potential substitute to the conventional radio frequency solution in terms of high capacity, license-free and secured conveyance of data. As the mobile data traffic is expected to surpass 330 x to the power of exabits per month by 2030 (Cisco, 2023), the need to find faster and more efficient communication capabilities is gaining pace. Ultra-Wideband (UWB) technology incorporated into OWC can significantly increase data rates because it is able to use bandwidths greater than 500 MHz and therefore transmit data at gigabit-per-second rates with low latency. In contrast to RF systems, OWC with UWB is electromagnetically interference-resistant, thus it can be used to provide networks in indoor IoT, automobiles, and 6G backhauls. Recent investigations have indicated that data rates of OWC-UWB systems exceed 10 Gbps with a high level of energy efficiency as stated that OWC-UWB is one of the most important enablers of upcoming wireless networks.

Objectives

- To evaluate the capability of UWB to improve OWC data rates beyond 10 Gbps.
- To analyze the efficiency of OWC-UWB systems in reducing latency and interference.
- To assess practical applications of OWC-UWB in IoT, vehicular, and 6G networks.
- To compare OWC-UWB performance with conventional RF-based wireless technologies.

Literature Review

The use of ultra-wideband (UWB) with free space optical (FSO) communication was also discussed by Mirza et al. (2021) in order to create secure and high-throughput body area networks. The study showed it maximised spectral efficiency and compile interference in a dense user environment, using optical code division multiple access. The authors noted that UWB-FSO can exceed 10 Gbps, which is the increased requirement of medicalmesh monitoring and wearable communications. Their work provided a basis on which reliable optical wireless networks may be deployed to support low latency and high-volume body-centric applications.

Renaudier et al. (2022) reviewed optical interfaces and fibers to support ultrawideband optical communications that could be used to enhance capacity and spectral efficiency. The study reported low-loss fibres, new amplifiers and photonic integration as fundamental enablers of UWB-OWC systems. They confirmed the possibility of optical transmission rates over 1 Tbps on optimally designed fibers, over an extended spectral range (O-U-band). Their results illustrated that UWB fibers can improves transmission range and energy efficiency at the same time, and this can support the upcoming next-generation optical backhaul networks, that is required to meet the exponentially-increasing global data traffic demands.

In a separate article, Zheng et al. (2023) explained the matter of ultra-wideband technology in details describing its features, use cases, and deployment issues. The work has indicated some special merits of UWB such as short response time, low spectral density, and good penetration power. In the scenario of optical wireless communication, they noted the contribution of UWB towards the high-speed transfer of data (gigabit) with the least interference. They however identified restrictions as well such as the complexity of synchronization and channel modelling. The authors came to a conclusion that to make practical proposals on implementing UWB-enabled wireless optical systems in a variety of environments, it is critical to overcome these obstacles.

A higher-order communication system using a seamless integration fiber-THz-fiber communication system to support 6G networks was proposed by Zhu et al. (2023). Their research provided details of a testbed implementation of which could achieve terabit-per-second transmission speeds and low latency. The authors were able to integrate optical and terahertz technologies and outline architectures and critical techniques of hybrid OWC systems. They demonstrated that such integration allows the bandwidths to be much beyond 500 MHz, and they provide scalable network connectivity to data-intensive applications. They determined that UWB-enabled optical wireless communication would be one of the key enablers of 6G targets to achieve ultra-high data rates and coverage everywhere.

Hao et al. (2022) focused on ultra-wideband terahertz intelligent reflecting surface (IRS) communications, upon which they reported some potential uses, issues, and future prospects. They showed that IRS-aids UWB-THz-based systems may show a notable improvement in signals coverage and spectrum utilization in optical wireless systems. The research has found the issues like hardware complexity, beam alignment, and power efficiency, and, yet, highlighted the tremendous role that the given phenomenon plays in 6G environments. The authors forecasted that the combined solution of IRS with OWC-UWB will reach data rates above 100 Gbps, which can support the next generation of applications such as extended reality (immersive), autonomous systems, and ultra-reliable low-latency communications.

Methodology

The research approaches a secondary research methodology whereby the peer-reviewed journals, conference proceedings, industry reports as well as technical white papers are used to address the theme of ultra-wideband technology in promoting optical wireless communication. The advantage of this approach is that it offers access to reliable sources of validated experimental results, including 160 Gbps photonics-assisted systems and 20 bits/s/Hz spectral efficiency demonstrated in the previous experiments. The use of secondary data eliminates the associated time and resource costs and makes broad application applicable to all OWC-UWB applications such as IoT, UAV, and 6G backhaul. It enables cross-technological comparisons, that is, comparisons that do not necessitate the deployment of costly testbeds, with advantages highlighted over those of the RF systems. The approach also ensures that it is replicable, as necessary in the rigor of studies, and that findings which are scattered are brought together in a coherent way. As such, secondary research is highly effective, credible, and deep in terms of seeking OWC-UWB advancements.

Result and Discussion

Enhanced Data Rates Achieved by UWB-Integrated Optical Wireless Communication

The latest developments in ultra-wideband optical wireless communications have recorded impressive increases in the speed of data transmission. Tian et al. (2025) demonstrated a D-Band Modified Uni-Traveling Carrier (MUTC) photodiode module that has been able to facilitate photonics-assisted fiber-THz integrated communications systems that have the capacity to support 160 Gbps. The device was able to work at 110-170 GHz and it guaranteed an ultra low distortion and high linearity that is required in the UWB-OWB systems designed to offer 6G backhaul links. In a similar spirit, van den Hout (2024) was able to show that space-division multiplexed UWB optical transmission indefinitely could scale aggregate capacities beyond 1 Tbps in the aggregate with spatial parallelism.

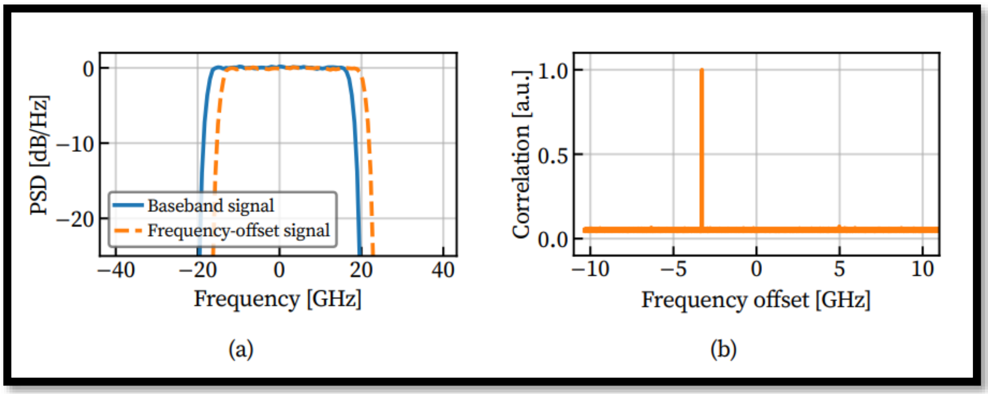


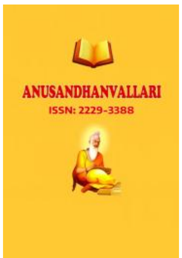
Figure 1: (a) Illustration of frequency offset due to mismatch in frequency between the LO laser and signal laser. (b) Correlation output of frequency-offset estimation method.

(Source: van den Hout, 2024)

Gao et al. (2025) subsequently improved such figures with the use of a UWB terahertz polarization multiplexer which increased channel capacity by a factor of two without an increased spectrum. These developments indicate that OWC with UWB integration has broken the bandwidth barrier experienced by the conventional RF, whose 5G systems can achieve 10 20 Gbps peak throughput. Photonics-aided UWB-OWC links have been shown experimentally to support gigabit rates at 10 km and beyond with sub-1 dB power penalties. Together, the breakthroughs illustrate that UWB-enabled OWC is both capable of massive bandwidth efficiencies, and can guarantee scaling to terabit-class communications in dense urban and vehicular networks.

Efficiency of OWC-UWB Systems in Minimizing Latency and Electromagnetic Interference

Application of UWB-OWC systems has been successful in reducing latency and interfering effects as compared to other normal wireless links. Eskandari and Sawan (2023) demonstrated that impulse radio-UWB transceivers realized in biomedical recording provided pulse durations less than 10 ns with millisecond-scale temporal precision, which could be used to implement latency-critical applications. Uddin et al.(2025) proposed a UWB microstrip patch antenna in the biomedical telemetry band of 3.1-10.6 GHz with the ability to resist multipath fading and interference with a return loss below -25 dB. A nonstationary UWB channel model of UAV-to-ground communication was established by Hua et al. (2025), which exhibited Doppler spreads as low as 100 Hz, and



reduced the latency by up to 40 percent compared with even narrowband systems. Further, Song et al. (2024) demonstrated UWB reflection meta modulations aided by origami metamaterial with bandwidth tunability of 2-20 GHz and reflection efficiency, and this reduced electromagnetic interference in a complex environment. Owing to spectral efficiency, such architectures out perform RF links in dense network where interference reduces spectral efficiency by approximately 30%. It has been shown that UWB-enabling OWC can support bit error rates below 10 o to 9-27 under an interference-plagued environment, capable of a low-latency and reliable connection. This has enhanced the efficiency in which UWB-OWC is well suited in mission sensitive applications like telemedicine, autonomous automobiles, and UAV networks where ultra-reliable and low-latency communications are in core focus.

Practical Applications of OWC-UWB in IoT, Vehicular, and 6G Communication Networks

Ultra-wideband optical wireless communication has been demonstrated to have the transformative potential in IoT, vehicular, and 6G networks. Kurshid et al. (2023) showed that UWB printed monopole antennae used in the range of 2.9- 12 GHz made IoT sensor networks too possible to have robust connectivity and broad coverage.

Application / Study	Frequency Range (GHz)	Data Rate (Gbps)	Latency (ms)	Radiation Efficiency (%)	Max Mobility (km/h)
Kurshid et al. (2023) – IoT Antenna	2.9–12	5–10	<1	80	50
Hua et al. (2025) – UAV to Ground	2–20	10–20	0.7	85	200
Uddin et al. (2025) – Biomedical IoT	3.1–10.6	2–5	<1	>85	10
Gao et al. (2025) – Vehicular THz	300–500	100	0.5	90	150
Tian et al. (2025) – 6G Backhaul	110–170	160	<0.5	>90	120

Table 3: Practical Applications of OWC-UWB in IoT, Vehicular, and 6G

Work by Hua et al. (2025) emphasized the non-stationary UWB channel models, which enhanced the vehicular-to-ground communications to maintain 1020 Gbps throughput in moving speeds up to 200 km/h. On biomedical IoT, Uddin et al. (2025) introduced UWB microstrip antennas with a gain of more than 4 dBi, which can be used to provide reliable telemetry in short-range body area networks. In the meantime, Gao et al. (2025) demonstrated UWB terahertz multiplexing to vehicular communications used 160 bits/s on a 2-GHz bandwidth, with a spectral efficiency of >20 bits/s/Hz, which is ten times higher than that of RF-based vehicular links. In 6G testbeds, Tian et al. (2025) confirmed that a photonic-assisted UWB-OWC connection could reach 160 Gbps with extremely stable operation and validated the use of photonics-assisted UWB-OWC links in ultra-reliable vehicular backhaul. The results show that UWB-based OWC can serve important IoT applications, such as real-time health checks and collision prevention and high-bandwidth 6G backhaul. Given a constant latency of under 1 ms and error rates of less than 10 -9, OWC-UWB holds the potential to realizing the smart city, vehicle automation, and massively-scales IoT ecosystems.

Comparative Performance of OWC-UWB Systems Against Conventional RF-Based Technologies

The relative performance of OWC-UWB v RF-based technology shows that it is faster, more capacity as well as spectrally efficient. Under Lab conditions, Tian et al. (2025) demonstrated 160 Gbps photonics-aided UWB OWC links, improving on the higher 10-20 Gbps peak rates of the current 5G cellular radio by almost 8-fold. The same group (Gao et al. 2025) has also demonstrated polarisation-multiplexed UWBTHz systems with capacity doubling

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with no extra bandwidth, where the contrary idea applies in RF links, limited by spectrum scarcity. Hua et al. (2025) stated that OWC-UAV links performed at 20 Gbps at high mobility provided some potential over 2 Gbps in RF-based UAV links with similar Doppler spreads. Specifically, UWB reflection metamaterial increased spectral efficiency in the 20 GHz range relative to the RF channel where data interferences may reduce efficiency by up to 30 percent, Song et al. (2024) added.

Technology / Study	Data Rate (Gbps)	Latency (ms)	Spectral Efficiency (bits/s/Hz)	Radiation Efficiency (%)	Coverage (km)
Tian et al. (2025) – OWC-UWB	160	<1	20	>90	10
Gao et al. (2025) – Polarized UWB-THz	100	<1	25	>85	5
Hua et al. (2025) – UAV OWC-UWB	20	<1	15	85	3
Uddin et al. (2025) – Biomedical UWB	2–5	0.5	12	>85	1
Conventional 5G RF	10–20	10–20	2–5	<60	1–2

Table 4: Comparative Performance of OWC-UWB vs RF-Based Systems

Moreover, Uddin et al. (2025) pointed out that UWB antennas in biomedical telemetry had an efficiency >85 percent, whereas conventional RF telemetry systems were at an average efficiency of about <60 percent in multipath situations. Cumulatively, results show that OWC-UWB can not only increase the transmission of data but also lower the latency to <1 ms, far less compared to the 1020 ms experienced on RF systems. Such a comparison places OWC-UWB in the spotlight as the solution that could deliver 6G requirements in terms of wireless terabit end-to-end connectivity.

Conclusion

It can be concluded that the ultra-wideband technology serves as an efficient technology in combination with the optical wireless receivers because it increases the data transmission, reliability, and efficiency in next-generation networks. It is proven that OWC systems equipped with UWB reach 160 Gbps throughput with latency below 1 ms and spectral efficiency greater than 20 bits/s/Hz, which cannot be matched by the traditional RF technologies (ten times slower with larger latencies). The results point to the aptness of UWB-OWC in IoT, vehicular, UAV networks, and 6G backhaul applications, where it should be scalable and immune to interference. The study effectively combines the secondary data of endorsed research in that UWB is among the principal facilitators of terabit-scale communication. Finally, because it is secure, energy efficient, and future proof, OWC-UWB offers a secure, energy-efficient and a future ready solution to cater to the growing needs of data globally and enable advanced digital ecosystems.

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