UDC 621.391.63

LI-FI – WIRELESS DATA TRANSMISSION USING LIGHT

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Annotation. This article explores Li-Fi (Light Fidelity) as an innovative wireless communication technology using light waves for data transmission. It explains Li-Fi's principles based on LED modulation, compares it with traditional Wi-Fi, and highlights advantages such as high speed, security, and low electromagnetic interference. Limitations and potential applications in healthcare, aviation, education and smart infrastructure are also discussed.

Keywords. Li-Fi, wireless communication, LED modulation, high-speed data transmission.

***Introduction*.** The rapid development of digital technologies has significantly increased the demand for faster and more reliable wireless communication systems. At present, Wi-Fi remains the primary means of wireless Internet access. However, the growing number of connected devices leads to network congestion and reduced transmission speeds. Furthermore, radio frequency (RF) communication may cause interference in sensitive environments such as hospitals and aircraft cabins.

In this context, Li-Fi (Light Fidelity) has emerged as a promising alternative. The term was first introduced by Professor Harald Haas in 2011, when he demonstrated the possibility of transmitting data using visible light. Li-Fi belongs to the field of Visible Light Communication (VLC) and represents a new stage in the evolution of wireless networking technologies.

***Main part*.** Li-Fi is part of Visible Light Communication (VLC) technology and can be considered an important stage in the development of modern wireless networks. The operating principle of Li-Fi is based on the rapid modulation of light intensity. LEDs can switch on and off millions of times per second, and these changes are invisible to the human eye. By encoding binary data into light pulses, information can be transmitted from a light source to a receiving device equipped with a photodetector. The photodetector converts variations in light intensity into electrical signals, which are then processed into digital data.

The communication process in a Li-Fi system typically includes three main components: a light source (LED lamp), a driver circuit that modulates the signal, and a photodetector receiver. The driver circuit controls the LED's intensity according to the data being transmitted. When the LED is switched on, it represents a binary "1"; when it is switched off, it represents a binary "0". In more advanced systems, complex modulation techniques such as Orthogonal Frequency Division Multiplexing (OFDM) are used to increase data transmission rates and improve reliability [1].

Unlike Wi-Fi, which functions within the radio frequency (RF) spectrum, Li-Fi operates in the visible light spectrum, ranging from approximately 400 to 800 terahertz. The visible spectrum is nearly 10,000 times broader than the entire RF range. This creates a clear advantage in terms of available bandwidth and helps minimize the risk of network congestion. As the number of connected devices worldwide continues to increase, the RF spectrum becomes more saturated. Li-Fi provides a possible solution by extending wireless communication into a new and largely untapped part of the spectrum.

Another notable advantage of Li-Fi is its high data transmission rate. Under laboratory conditions, data transmission speeds of several gigabits per second have been achieved. Such capabilities make Li-Fi appropriate for high-definition video streaming, virtual reality systems, and the transfer of large volumes of data. Even in real-world applications, Li-Fi technology can deliver speeds comparable to, and sometimes exceeding, those of conventional Wi-Fi networks.

Recent experimental studies have demonstrated that Li-Fi systems can achieve data transmission rates exceeding 10 Gbps under controlled laboratory conditions. Such performance is enabled by advanced modulation techniques and parallel transmission using multiple LED arrays. These findings suggest that Li-Fi has the potential to compete with, and in certain scenarios surpass, existing high-speed wireless communication technologies.

Security is also considered one of the main strengths of Li-Fi technology. Because visible light cannot pass through solid barriers such as walls, the signal remains limited to a specific room or enclosed space. This natural restriction improves data protection and lowers the risk of external interception. For organizations that work with confidential information, including financial institutions and government bodies, Li-Fi can serve as an additional level of cybersecurity protection.

Li-Fi is especially valuable in environments where the use of radio frequency communication is limited or considered unsafe. For example, in hospitals, RF signals may interfere with sensitive medical devices and monitoring systems. In the military sector, Li-Fi can be particularly beneficial due to its enhanced security and minimal risk of signal interception. Since Li-Fi relies on visible light rather than radio waves, it does not create electromagnetic interference, which makes it suitable for use in such sensitive conditions. In addition, industrial facilities and power plants can benefit from Li-Fi technology, as it enables stable communication without negatively affecting electronic equipment [2].

Another important advantage of Li-Fi is its energy efficiency. LED lighting systems are already widely used due to their low power consumption and long lifespan. By integrating Li-Fi into existing LED infrastructure, lighting systems can also simultaneously function as wireless data transmitters. This dual functionality reduces the need for additional equipment and helps lower installation costs. Moreover, such integration contributes to sustainable development initiatives. In smart buildings and smart cities, streetlights equipped with Li-Fi modules could provide internet access while still performing their primary lighting function.

Despite its significant potential, Li-Fi technology also faces several challenges. One of the main limitations is the requirement for a direct or reflected line of sight between the transmitter and the receiver. Any physical object placed between them can block the signal and disrupt communication. In addition, Li-Fi performance may be influenced by strong ambient light sources, especially direct sunlight, which can decrease signal quality. Researchers continue working on improving system stability and ensuring reliable operation under different environmental conditions.

Mobility is another issue to consider. Unlike Wi-Fi networks, which allow users to move freely between rooms and coverage areas, Li-Fi systems may need multiple light sources to maintain continuous connectivity. This may increase infrastructure complexity as well as overall costs. Furthermore, Li-Fi cannot operate when the light source is completely switched off, although communication remains possible when the light is dimmed to a low intensity.

Li-Fi has numerous potential applications in various sectors. In healthcare institutions, it can provide secure communication without interfering with medical equipment. In aviation, the technology may be used for in-flight entertainment and onboard internet systems. Educational institutions could benefit from smart classrooms where LED lighting offers high-speed connectivity. Beyond these examples, Li-Fi may also play an important role in the development of smart cities, underwater communication, and modern industrial automation.

Conclusion. Li-Fi represents an innovative approach to wireless data transmission by using visible light instead of radio waves. This technology has significant advantages such as high speed, security, reduced interference, and energy efficiency. At the same time, problems such as limited range and line-of-sight requirements must be solved for widespread implementation.

Li-Fi has significant potential to complement existing wireless technologies rather than replace them entirely. As research and technological development continue, Li-Fi may become an essential component of next-generation communication networks, contributing to faster, more secure and more sustainable digital connectivity.

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