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CDR AYUSH KUMAR

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EMERGING COMMUNICATION TECHNOLOGY LIGHT FIDELITY (LI-FI) – A GAME CHANGER FOR MODERN MARITIME OPERATIONS

Cdr Ayush Kumar, is an alumnus of the National Defence Academy and is presently a Qualified Flying Instructor in helicopters.

"If you know the enemy and know yourself, you need not fear the result of a hundred battles. If you know yourself but not the enemy, for every victory gained you will also suffer a defeat. If you know neither the enemy nor yourself, you will succumb in every battle".[1]

- Sun Tzu

Introduction

Effective communication is the backbone of maritime operations where large volumes of data need to flow smoothly. With adversaries sharpening their cyber warfare and intelligence skills there is an urgent need for communication systems that are fast, secure and dependable. In regard to this, Light Fidelity (Li-Fi) has emerged as a groundbreaking technology capable of transforming communication networks within naval operations.

The conflict area today is very fluid and any adversary's first order of business is to neutralise its adversary's Electromagnetic (EM) spectrum and satellite communication to gain superiority in the maritime domain.[2] Nevertheless, due to high

demand in the EM spectrum the frequencies are congested making them unsuitable for high-speed data transfer. In an ever-evolving technological environment the country with the fastest and most secure communication network will always be a step ahead of the rest. To gain this superiority in the future we need to develop and exploit a specific band in the EM spectrum i.e. visible light which give us an edge over the rest. This makes developing and operating Li-Fi in the visible light spectrum that much more critical in the maritime domain.

Perspective on Li-Fi Technology

The term Li-Fi was coined by Professor Harald Haas in 2011 where he brings out the use of wireless communication technology that transmits data using light waves, typically from Light Emitting Diodes (LEDs).[3] This technology operates by adjusting the intensity of light emitted from LEDs to transmit data, which is then captured and decoded by photosensitive receivers. Light waves are exploited for data transmission providing several benefits compared to RF-based communication such as faster data rates, reduced latency and resistance to EM interference. What is important to note is that Li-Fi can operate in both visible light as well as in the invisible spectra (i.e. infrared and ultraviolet) broadening its potential applications in different environmental conditions.[4]

Warships have upgraded from their traditional internal lighting systems to LED based lights making Li-Fi an efficient option that doesn't require expensive and specialised equipment. Li-Fi creates an opportunity for many interesting applications that can be used in an operational environment, maintaining the highest level of security with a high data transfer rate.

Employing Li-Fi in Naval Operations

Naval operations often take place in a very dynamic environment over multiple domains that demand seamless, high-speed and secure communication under various constraints. These operations have a wide gambit ranging from fleet manoeuvres to underwater reconnaissance. Therefore, communication systems must be robust enough to resist an adversary's cyber and physical attack while maintaining high

operational efficiency. Some of the significant aspects in which Li-Fi holds great promise for future naval operations is tabulated below [5]: -

Table 1: Key Attributes of Li-Fi in Naval Operations

Ser	Aspect	Description
(a)	High-Speed Data Transmission	With speeds up to 224 Gbps Li-Fi ensures ships can quickly share vital information without delays.[6]
(b)	Real-time Situational Awareness	Li-Fi has the ability to handle massive amounts of data and will be able to interconnect all platforms, enabling quick and well-informed decisions.
(c)	Enhanced Security	Since Li-Fi relies on LOS transmission it becomes harder to intercept thus adding an extra layer of security.
(d)	Line of Sight (LOS)	Li-Fi signals do not pass through walls or bulkheads minimizing the risk of interception.
(e)	Resilience to Jamming	Unlike radio frequencies Li-Fi is immune to RF jamming providing dependable and reliable communication channels.
(f)	Reduced Electromagnetic Signature	Li-Fi emits nominal EM signals making it ideal for covert operations in a combat situation where stealth is critical.
(g)	Underwater Communication	The use of blue-green light to communicate underwater enhances the performance of underwater missions.[7]
(h)	Submarine-Surface communications	Submarines can maintain a continuous communication link with surface vessels eliminating the need to surface which lowers the risk of detection.[8]
(i)	Autonomous Underwater Vehicles (AUVs)	Li-Fi allows fast and dependable data transfer between AUVs and command centers improving mission coordination and operational efficiency.
(j)	Data Transmission	Secure sharing of data across different sections

Ser	Aspect	Description
	Between Compartments	of the ship can be undertaken without causing additional RF interference.
(k)	Resilient Communication in Battle Conditions	In intense battle conditions, Li-Fi serves as a reliable backup when traditional RF systems are disrupted or overwhelmed.
(l)	Energy Efficiency	It can integrate with existing ship lighting systems offering an energy efficient communication solution.

Li-Fi Deployment in Naval Operations

Li-Fi's unique characteristics make it suitable for a wide range of applications for maritime operations. Mentioned below are a few ways it can enhance maritime operations[9]:-

(a) **Ship-to-Ship Communications-** Li-Fi can be used to ensure secure, high-speed data transmission between ships operating within a fleet. This is key for: -

(i) **Fleet Manoeuvres-** Ships can maintain unhindered communication with each other by using visible/ infrared light beams eliminating the risk of detection. This will ensure secure transmission between ships and the risk of being compromised by any RF interference or interception is low.

(ii) **Stealth Operations-** The reliance of LOS transmission between two Li-Fi systems onboard different platforms make it harder for adversaries to intercept signals, thereby providing a secure alternative during hostile periods.

(b) **Submarine Communications-** There is a wide scope in developing communication networks between submarines and surface ships which is a waterloo for all nations. In submarine warfare maintaining secure and

undetectable communication is crucial. Li-Fi can be used in the following ways:-

(i) **Submarine-to-Submarine Communication-** Submarines could use blue-green light waves to communicate while submerged.[10] This could ensure safe and secure communications while maintaining her stealth component.

(ii) **Ships-to-Submarine Communication-** Li-Fi helps submarines to stay connected with surface platforms without surfacing, keeping them safe from detection. This enhances safety, security and secrecy during naval operations.

(c) **Drone and Unmanned Vehicle Operations-** As Unmanned Aerial Vehicles (UAVs) and Autonomous Underwater Vehicles (AUVs) transform the future battlefields, having secure communication between these systems and their human operators is vital.[11] Li-Fi could offer: -

(i) **Drone-to-Ship Communication-** Drones could use light-based communication to relay ISR data to ships without relying on RF channels that could be intercepted or jammed.

(ii) **AUV-to-Ship/ Submarine Communication-** AUVs conducting underwater missions could use this technology to send data to nearby Ship/ Submarines creating an efficient network of underwater sensors.

(d) **Command and Control Centers-** Command data centers, whether on land or at sea are packed with complex communication systems. They control and coordinate composite naval operations and are prime targets for any kind of cyberattacks.[12] Li-Fi can enhance security by providing: -

(i) **Air Gapped Systems-** As Li-Fi requires a direct line of sight, it is easier to create air gapped networks (networks that are physically isolated from unsecured systems) reducing the risk of breaches in cyber security.

(ii) **Secure Data Transfer-** There is a large flow of sensitive data (platform deployments or intelligence reports) that can be transmitted in a secure environment making it challenging for any state/ non state actor to intercept these communications.

(e) **Logistics and Maintenance-** Managing multiple naval assets presents significant logistical challenges. Li-Fi can streamline communication between ships, bases and ports in the following manner[13]: -

(i) **Fleet Management-** Ships can use Li-Fi to communicate their maintenance status, supply needs or mission readiness without relying on vulnerable RF systems.

(ii) **Secure Data Transfer in Dockyards-** Ships/ Submarines in ports for maintenance/ defect rectification can ensure protected communication links. This prevents leakage of sensitive information about ship/ submarine capabilities or modifications.

Areas of Concerns

Li-Fi holds great potential for operations in the Indian Navy, but there are a few challenges which need to be tackled before widespread adoption is possible. A few key issues to be addressed are listed below: -

(a) **Reliance on Line of Sight-** There is a basic requirement of clear line of sight between the transmitter and receiver.[14] In a dynamic maritime domain maintaining a consistent line of sight can be challenging. Obstructions, weather conditions or changing aspect ratio of a ship could disrupt the light signal.

(b) **Modulation-** The key to Li-Fi communication is modulation i.e. binary data is transmitted by rapidly turning the LED on and off. Modulation must balance data transmission with illumination ensuring LEDs can still communicate even at low light levels. Dimming which is adjusting LED brightness presents the challenge of maintaining data transmission while ensuring user safety and effectiveness during the dimming process.[15]

(c) **Environmental Conditions-** Adverse weather conditions such as heavy rain, fog or dust can interfere with these signals. This is particularly problematic for ship to ship or drone to ship communication where environmental factors could limit effectiveness.

(d) **Range Limitations-** Li-Fi while fast and secure has a more limited range compared to RF systems

Futuristic vs Necessity

Li-Fi has shown a lot of promise in its formative years of development and is slowly gaining momentum. Velmenni an Indian startup specialising in Li-Fi has secured a grant from the Ministry of Defence (MoD) under the iDEX (Innovations for Defence Excellence) initiative to develop secure data transmission between submarines and control centers which traditionally relied on physical cables to transfer data between submarines and shore-based facilities, which can be cumbersome and vulnerable to interception.[16]

There have been great efforts in undertaking R&D in the underwater domain to develop this technology which will most likely develop in the years to come. The technology faces challenges in the underwater environments primarily due to the absorption and scattering of light by water molecules which limits its range.[17] Current efforts are focused on extending the reach and improving the efficiency for underwater applications. However, like any technology to grow and provide the desired outcome there is always some resistance which needs to be put away. In an ever-evolving maritime domain the disabling of communication systems will be the first course of action that needs to be assumed by any adversary. In that scenario ensuring information flow would be the difference between achieving superiority of the battle space. Making use of Li-Fi can be done by basic integration into the fleet communication systems where data flow can continue to happen thereby not requiring the utilisation of satellite or traditional RF systems for operations.

As China and US have made great strides in developing their space and cyber element. India is taking steps in the right direction, but it will take some time till we match up or surpass their capabilities. As ships go silent in a hostile environment, rival

nations will lose the ability to intercept communications due to a reduced signature. Hence, there will be an entire fleet operating with no emissions but will still be able to maintain constant communication with the advent of this technology.

Conclusion

Li-Fi has the potential to revolutionise naval communications with its unmatched speed, security and versatility. As naval operations evolve to rely more on real-time data and network-centric strategies, secure communication will be the key to staying ahead. The ability to operate in an environment particularly where traditional RF systems face limitations makes it an ideal candidate for naval uses.

From ship-to-ship communications to underwater data exchange and intra-ship networks to secure drone operations, Li-Fi can address most of these challenges. As Li-Fi systems embrace immunity to EM interference and the resistance to jamming this makes it a reliable and secure communication tool that will ensure smooth operations in both peacetime and combat situations.

Although Li-Fi comes with its set of challenges, like any other emerging technology the security and operational benefits it promises make it a valuable investment for the future. Integrating Li-Fi into naval operations will require systematic research, testing and strategic planning by any nation to exploit the full extent of this technology. As navies worldwide explore the nuances of this technology, Li-Fi is set to play a pivotal role in the future of naval warfare contributing to a safer, more efficient and more secure maritime environment.

DISCLAIMER

Endnotes

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