

DOI 10.62821/lp10403

# Impact of AIS Manipulation on Shipping Safety and Strategic Countermeasures

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## ABSTRACT

This study examines the increasing manipulation of the Automatic Identification System (AIS) and its impact on maritime safety. By analyzing instances of AIS disruptions, the study identifies vulnerabilities and risks associated with AIS disruptions. The study also examines the legal framework regarding regulatory response to AIS-related problems. Technological advances and best practices to improve the reliability and security of AIS are proposed. The importance of international cooperation in combating AIS manipulation and ensuring maritime safety is emphasized.

## CITATION

Melnyk, O., Kuznichenko, S., & Onishchenko, O. (2024). Impact of AIS Manipulation on Shipping Safety and Strategic Countermeasures. *Lex Portus*, 10(4), 31–39. <https://doi.org/10.62821/lp10403>

## KEYWORDS

navigational safety, electronic warfare, regulatory compliance, AIS signal interference



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## Introduction

Automatic Identification System (AIS) is a key technology in modern maritime safety and consequently ship navigation processes. It was introduced as a mandatory requirement under the International Convention for the Safety of Life at Sea (SOLAS) to improve ship tracking and communications, thereby enhancing the overall safety of maritime operations. AIS provides other ships and coastal authorities with real-time information about a certain vessel, its position, speed and course, which helps avoid collisions and effectively manage maritime traffic.

However, AIS technology is not without its problems. Increasingly, AIS manipulation is becoming a serious problem, especially in the context of sanctions and security concerns. Vessels may deliberately disable or tamper with their AIS transponders to avoid detection, engage in illegal activities or circumvent sanctions. Such practices not only undermine maritime safety, but also pose significant risks to global security, prompting regulators to tighten controls and impose stricter sanctions for such actions.

Research on the application and impact of AIS data on maritime safety is extensive and varied. Several studies have investigated various aspects of this technology to improve navigation and safety of maritime operations (Karimi et al., 2024). For example, there are numerous studies examining the spatial trajectories of ships to improve maritime surveillance using AIS data (Zhu, 2011; Du et al., 2024; Sage, 2023; Wang et al., 2024). Qu et al. (2023) develop this idea by integrating AIS with visual data to improve traffic monitoring on inland

waterways. Similarly, Wolsing et al. (2022) present an in-depth analysis of anomaly detection in AIS tracks, which is crucial for identifying potential risks in navigation.

The use of AIS data to identify autonomous navigation scenarios is emphasized by Snijders & Elrofai (2020), who focus on safety assessment. Meanwhile, Lei (2020) explores the use of AIS data to analyze conflicts at sea, offering ideas for avoiding collisions and other navigational problems. Baig et al. (2024) offers a comprehensive review of the challenges and opportunities in the inland ferry sector, including how AIS data can be used to improve safety measures. On the other hand, Latt (2024) proposes an integrated approach to maritime safety management where AIS data plays a crucial role in reducing the risks associated with vessel accidents.

In addition, Androjna & Perkovic (2024) explore the vulnerabilities of global navigation satellite systems (GNSS) in maritime navigation, especially in the context of cyber challenges, and how AIS data can be part of the solution. Šakan et al. (2018) discuss the application of near real-time satellite AIS (S-AIS) and its implementation opportunities for global maritime stakeholders, emphasizing the importance of real-time data to ensure the safety and efficiency of maritime operations. Mdakane et al. (2023) describe a multi-source approach to maritime domain awareness in South Africa, utilizing remotely sensed and AIS data to improve situational awareness. Regarding environmental impacts, Cheng et al. (2024) analyze carbon dioxide emissions from maritime transportation using AIS data, demonstrating the versatility of AIS beyond safety. The studies by Melnyk et al. (2022, 2023) contribute to the understanding of navigational safety assessment and ship sea state prediction by showing the importance of modeling techniques incorporating AIS data. In addition, Zaman et al. (2023) addresses the issue of ship trajectory determination based on interpolation from sparse AIS data, which is crucial for accurate maritime navigation and surveillance. Wolsing et al. (2022) also provide a critical review of recent approaches to anomaly detection in marine AIS tracks, further emphasizing the need for continuous monitoring and analysis of AIS data.

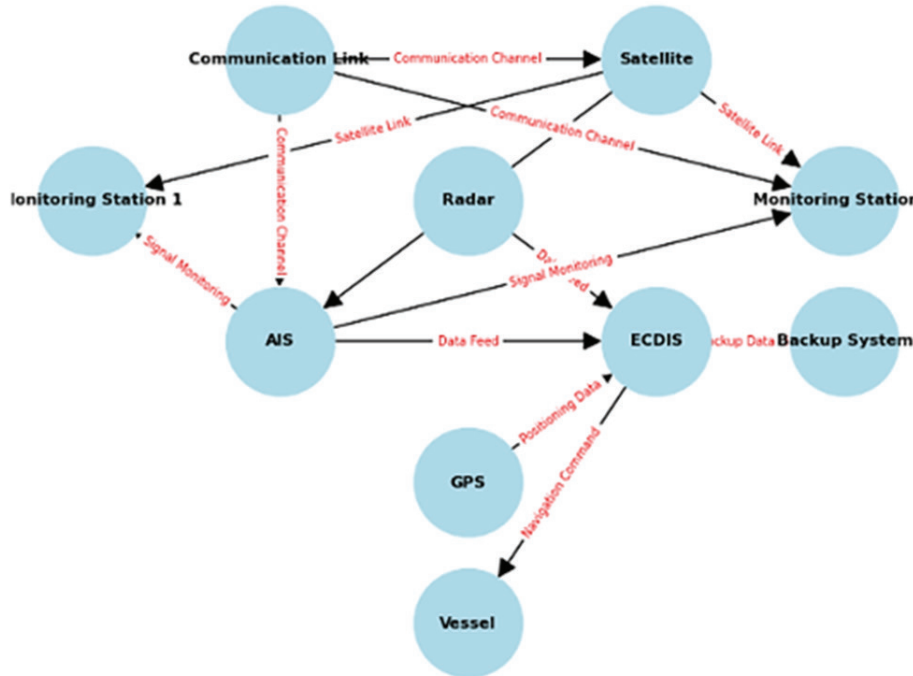
The impact of AIS data on global maritime transportation networks is discussed in "AIS Data for Building a Transport Maritime Network" (Rindone, 2024), which focuses on maritime networking using AIS data. Cheng et al. (2024) also look at the use of AIS data to monitor carbon emissions in the U.S. marine freight sector. Finally, Qu et al. (2023) examine the integration of AIS with other technologies to improve maritime traffic surveillance, showing the continuous development of AIS data applications in maritime safety and environmental management.

The problem of this study focuses on the growing problems and risks associated with the manipulation and misuse of AIS data in marine navigation. Despite the critical role of AIS in improving maritime safety and efficiency, it is vulnerable to exploitation, such as disabling to circumvent sanctions, deception in ship-to-ship data transfer, or masking illegal activities. These actions jeopardize maritime safety, environmental protection and regulatory compliance. The study therefore aims to address these issues by examining the technical, regulatory and operational implications of AIS misuse, proposing solutions to mitigate the risks and ensuring the integrity and reliability of AIS as a navigational tool.

### **1. Challenges and failures in AIS implementation**

AIS occupies a crucial place in nautical navigation network. It serves as the primary source of real-time vessel data that is transmitted to other vessels, monitoring stations and integrated into ECDIS to provide comprehensive situational awareness. AIS data is essential for collision avoidance, route planning and regulatory compliance, making it a fundamental component of modern maritime navigation systems. Its integration with other systems such as radar, GPS

and back-up systems provides a reliable and resilient navigation system. An integrated marine navigation system illustrating the interaction of the various components to ensure safe and efficient ship operation is shown in Figure 1.



**Figure 1.** Integrated marine navigation system (Authors)

Electronic warfare is increasingly becoming a tool for disrupting AIS signals, which affects the safety of navigation. For example, AIS spoofing, where false ship coordinates are transmitted, can lead to navigational errors and potential collisions. Such disruptions are often geopolitically motivated, as observed in regions such as the Black Sea and South China Sea. These cases emphasize the vulnerability of AIS to external interference and the need for robust countermeasures. In particular, significant AIS spoofing was observed in the Black Sea in 2023, resulting in the display of false positions on tracking systems. Such disruptions pose navigational challenges and potential safety risks. In 2022, AIS jamming was observed in the Persian Gulf, resulting in temporary disabling of AIS signals and creating navigational hazards for vessels in that region. In addition, in 2021, the South China Sea experienced interference with AIS signals due to ongoing territorial disputes, further complicating maritime operations (Table 1).

**Table 1.** Summary of ais disruptions due to electronic warfare

| Region          | Year | Type of Disruption      | Impact  |
|-----------------|------|-------------------------|---|
| Black Sea       | 2023 | AIS Spoofing            | False positions on tracking systems                 |
| Persian Gulf    | 2022 | AIS Jamming             | Temporary loss of AIS signal, navigational risks    |
| South China Sea | 2021 | AIS Signal Interference | Disruption of AIS signals amid territorial disputes |

Disabling AIS is often used to circumvent sanctions, especially in the context of transportation of prohibited goods. Recent EU actions against ships manipulating AIS, especially during transit between ships, indicate growing awareness and efforts to combat

such practices. In addition, the use of AIS manipulation to conceal the origin and destination of cargo is a major concern, complicating efforts to enforce international sanctions and regulations. Disabling AIS has become a tactic to circumvent sanctions, particularly in the context of Russian oil transportation.

In 2023, cases of deliberate AIS shutdowns were reported in European waters to avoid EU sanctions on Russian oil. Such shutdowns are part of broader strategies to conceal the origin of sanctioned goods, including crude oil and petroleum products, during ship-to-ship (STS) transits. Similar tactics have been observed in the Mediterranean region, where AIS signals have been manipulated to conceal the true nature of STS operations. In 2022 in the Gulf of Mexico, AIS deactivation was used to circumvent sanctions inspections, particularly with respect to natural gas shipments (Table 2).

**Table 2.** Cases of AIS shutdowns due to sanctions

| Region               | Year | Type of AIS Manipulation | Reason                                    | Sanctioned Goods   |
|----------------------|------|--------------------------|---|--------------------|
| European Waters      | 2023 | AIS Shutdown             | Evasion of EU sanctions on Russian oil    | Crude Oil          |
| Mediterranean Region | 2023 | AIS Signal Manipulation  | Concealment of origin during STS transfer | Petroleum Products |
| Gulf of Mexico       | 2022 | AIS Deactivation         | Avoidance of sanctions compliance checks  | Natural Gas        |

## 2. AIS Manipulation and Its Implications

The BIMCO AIS Switch Off Clause 2021 was introduced to address the problem of AIS manipulation in maritime operations, particularly under charter arrangements. The clause obliges shipowners to maintain continuous AIS operation in accordance with the requirements of the International Convention for the Safety of Life at Sea (SOLAS), except in special situations where switching off is permitted. The clause is important because it establishes legal liability by providing charterers with a mechanism to terminate contracts in the event of AIS manipulation, thereby ensuring accountability and reducing the risk of sanctions violations.

The clause also provides a balance of rights between shipowners and charterers. If AIS is disabled in violation of the clause, charterers can demand an explanation and possibly terminate the contract, reflecting a proactive approach to ensuring maritime operations comply with international regulations.

The Office of Foreign Assets Control (OFAC) has also issued recommendations that emphasize the importance of monitoring AIS activity to prevent violations of international sanctions, particularly those involving ship-to-ship (STS) transfers of sanctioned goods. These recommendations recommend that AIS monitoring be incorporated into due diligence processes to help identify and address potential sanctions evasion.

The implementation of these recommendations has had a significant impact on global shipping practices. By implementing more stringent compliance measures, OFAC seeks to mitigate the risks associated with AIS manipulation, which is often used to conceal the origin and destination of shipments involved in sanctions activity. These enforcement actions have resulted in increased scrutiny and compliance costs for the maritime industry, ensuring that vessels comply with international regulations and contributing to the overall security of global maritime commerce.

Incidents involving failures of Electronic Chart Display and Information System (ECDIS) and Automatic Identification Systems (AIS) are a major concern for maritime safety. These failures often lead to accidents or near accidents, with contributing factors ranging from technical faults to human error. For example, incorrect chart data in ECDIS combined with loss of AIS signal can lead to critical navigational errors. In some documented cases, the crew's failure to respond properly to system alarms or misconfigured parameters exacerbated the situation, emphasizing the importance of both reliable technology and proper training.

One notable example is the grounding of the bulk carrier *Muros* in 2016, when a combination of improper ECDIS management and insufficient situational awareness led to the vessel running aground on the sand at Highsborough in the UK. The investigation revealed that the ECDIS settings had not been properly configured and the crew had ignored numerous alarms, causing the incident. Cases such as this emphasize the need for thorough training and system checks to prevent similar incidents in the future.

The effective implementation of AIS technology presents certain challenges, including electronic interference, integration issues with other bridge systems, and the difficulty of keeping the technology up to date. Electronic interference, for example, can disrupt AIS signals, resulting in inaccurate data transmission and reduced navigational safety. This problem is particularly prevalent in congested maritime areas where multiple signals can overlap and interfere with each other.

In addition, poor integration of AIS with other bridge systems, such as radar and ECDIS, can lead to inefficient operation and increase the risk of errors. This integration is critical to provide a complete picture of the crew's situational awareness, and any failure in this regard can lead to dangerous errors.

Another major challenge is the rapid pace of technological advancement, which requires AIS systems to be constantly updated. Keeping AIS technology up-to-date is necessary not only for accurate data transmission, but also to comply with international regulations. However, the logistical and financial burden of these updates can be significant, especially for smaller operators, resulting in implementation delays and potential gaps in system reliability.

Thus, while AIS is a critical tool for maritime safety, its implementation is hindered by various technological and operational challenges. To address these challenges, a combination of improved technology, increased training, and more rigorous system maintenance is needed to enable AIS to fulfill its role in ensuring safe and efficient maritime navigation.

### **3. Technological improvements, best practices and future directions**

The manipulation of AIS signals poses serious risks to the security of maritime operations. These risks include the deliberate concealment of a vessel's true location, which can lead to unintentional violations of territorial waters, collisions, increased vulnerability to piracy and other maritime crimes. For example, in politically sensitive areas such as the South China Sea, AIS spoofing can make it difficult to identify vessels, making it difficult to monitor maritime boundaries and enforce international maritime laws. This raises concerns not only for individual vessels, but also for national and international security, as the integrity of maritime traffic data is jeopardized.

AIS manipulation also has serious implications for global trade, especially in regions that serve as critical maritime transshipment points or shipping lanes. For example, in areas such as the Strait of Hormuz or the Suez Canal, AIS disruptions can cause significant delays in the movement of goods, causing repercussions for the entire global supply

chain. The uncertainty caused by AIS tampering can lead to increased transportation costs, higher insurance premiums and the need to reroute vessels to bypass high-risk areas, negatively impacting the efficiency and reliability of international trade routes. In addition, the possibility of AIS manipulation being used as a tool of economic warfare or sanctions circumvention further complicates the geopolitical environment, emphasizing the need for robust countermeasures and international cooperation to ensure maritime security and trade.

Technological advances in AIS systems are necessary to improve maritime safety and prevent manipulation. One of the key recommendations is the implementation of stronger encryption protocols and authentication mechanisms that will protect AIS data from unauthorized access and tampering. In addition, integrating AIS with other navigation tools, such as radar and satellite tracking, can create a more comprehensive and resilient system. This layered approach makes it more difficult for attackers to attempt to manipulate data undetected. In addition, developing systems capable of real-time monitoring and automatic alerts of suspicious AIS behavior will allow for immediate response to potential threats, thereby improving overall maritime security. Redundancy systems should also be put in place to ensure that vessels retain their navigational capabilities even during AIS failures, thereby reducing the impact of any disruptions. These technological improvements are vital to protecting maritime operations and ensuring compliance with international regulations (Table 3).

**Table 3.** Recommended Technological Advancements for AIS Security

| <b>Technological Improvement</b> | <b>Description</b>  | <b>Expected Outcome</b>                               |
|----------------------------------|---|---|
| Enhanced Encryption              | Strengthening data protection through advanced encryption | Increased security against unauthorized access        |
| System Integration               | Merging AIS with radar and satellite systems              | Enhanced detection and prevention of AIS manipulation |
| Real-time Monitoring             | Automated systems for detecting anomalies                 | Faster response to AIS-related threats                |
| Redundancy Systems               | Backup systems for AIS failures                           | Continuous navigation capabilities during disruptions |

To ensure compliance with international norms and improve the safety of AIS operations, shipowners and operators should adopt several best practices. First, regular training and certification programs for crew members on the use of AIS and related technologies are essential. These programs should be updated frequently to reflect the latest best practices and changes in legislation. Second, regular system audits are necessary to ensure that the AIS and related navigation systems are functioning properly and to eliminate the possibility of unauthorized tampering or malfunction. Thirdly, international recommendations, especially those set out in the SOLAS convention, need to be followed. This includes following recommended procedures to legally disable AIS under certain circumstances. Finally, it is vital to develop a clear protocol for reporting incidents. This protocol should include reporting AIS-related incidents or anomalies to the appropriate authorities, allowing for the timely detection and remediation of potential threats (Table 4).

**Table 4.** Best Practices for Shipowners and Operators in AIS Compliance

| Best Practice               | Description  | Benefits                                |
|-----------------------------|--|---|
| Regular Training            | Continuous crew education on AIS systems           | Improved operational safety             |
| Routine System Audits       | Regular checks and maintenance of AIS systems      | Early detection of vulnerabilities      |
| Compliance with Regulations | Following SOLAS and other international guidelines | Legal and operational compliance        |
| Incident Reporting          | Protocols for reporting AIS anomalies              | Early intervention in potential threats |

Strengthening international regulations is critical to preventing AIS manipulation and ensuring maritime safety. One key proposal is the standardization of AIS protocols across all vessels, which would create uniformity in data transmission and enhance reliability. Additionally, mandatory reporting of AIS shutdowns should be enforced, with clear guidelines for legitimate reasons to disable the system, increasing transparency and accountability. Enhanced penalties for non-compliance, such as fines or license suspensions, would serve as a deterrent to AIS manipulation. Furthermore, the establishment of a collaborative international monitoring body would enable the rapid identification and response to suspicious behaviors, ensuring the integrity of maritime operations globally. These measures aim to fortify the regulatory framework surrounding AIS, making it a more reliable tool for maritime safety and security (Table 5).

**Table 5.** Proposed Regulatory Enhancements to Prevent AIS Manipulation

| Regulatory Proposal                    | Objective                          | Expected Outcome                          |
|--|------------------------------------|---|
| Standardization of AIS Protocols       | Uniformity in AIS data handling    | Consistent and reliable data transmission |
| Mandatory Reporting of Shutdowns       | Transparency in AIS operations     | Enhanced accountability and monitoring    |
| Enhanced Penalties for Non-compliance  | Deterrence of AIS manipulation     | Reduction in intentional AIS shutdowns    |
| Collaborative International Monitoring | Global oversight of AIS activities | Improved detection of AIS-related threats |

Enhancing cooperation between maritime stakeholders is essential to effectively combat AIS manipulation and bolster maritime security. Key recommendations include the establishment of information-sharing networks that facilitate real-time communication between shipowners, regulatory bodies, and maritime security agencies. This would allow for the swift identification and response to AIS anomalies. Joint training initiatives should also be promoted, involving all relevant stakeholders to ensure they are equipped with the latest knowledge and skills in AIS technology and security practices. Public-private partnerships can further advance the development and deployment of advanced AIS technologies, enhancing overall maritime security. Additionally, strengthening international agreements on the enforcement of sanctions related to AIS manipulation will ensure a unified global approach to addressing this critical issue (Table 6).

**Table 6.** Strategies for Enhancing Cooperation among Maritime Stakeholders

| Cooperation Strategy               | Description                                  | Benefits                              |
|------------------------------------|--|---------------------------------------|
| Information Sharing Networks       | Real-time collaboration among stakeholders   | Faster response to AIS threats        |
| Joint Training Initiatives         | Cross-sector training programs               | Standardized knowledge and skills     |
| Public-Private Partnerships        | Collaboration in AIS technology development  | Enhanced security through innovation  |
| International Sanctions Agreements | Unified enforcement of AIS-related sanctions | Consistent global regulatory approach |

### Conclusions

This article examines the significant challenges and risks associated with AIS manipulation, including the impact of electronic warfare, geopolitical tensions, and regulatory gaps. The analysis identified vulnerabilities in current AIS technologies and their implications for maritime security and global trade. The case studies showed the real-world implications of these challenges, demonstrating the urgent need for robust technological and regulatory responses. To effectively address the problems associated with AIS manipulation, continued research and increased international cooperation are needed. Future efforts should focus on developing advanced technological solutions, standardizing global regulations, and establishing a cooperative framework among maritime stakeholders to ensure the integrity and safety of marine navigation systems..

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**Мельник О., Кузнiченко С., Онищенко О. Вплив манiпуляцiй даними AIS на безпеку судноплавства та стратегiчнi контрзаходи. – Стаття.**

У цьому дослідженні розглядається зростання маніпуляцій даними системи автоматичної ідентифікації (AIS) та їх вплив на безпеку мореплавства. Аналізуючи випадки збоїв у роботі AIS, автори дослідження визначають основні вразливі місця та ризики для системи. У статті також вивчено правову базу регуляторного впливу на проблеми, пов'язані з AIS. Пропонується низка технологічних рішень та кращих практик для підвищення надійності та безпеки AIS. Наголошується на важливості міжнародного співробітництва у боротьбі з маніпуляцією даними AIS та забезпеченні безпеки на морі.

**Ключові слова:** навігаційна безпека, радіоелектронна боротьба, дотримання нормативних приписів, перешкоди сигналу AIS.