Applied Scientific Paper Proposal: Optimizing Radar Operation While Sailing in Rough Weather

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Abstract.
Maritime shipping faces high risks due to rough weather that impairs visibility and increases the potential for collisions, especially in congested waters such as the Strait of Malacca. This study aims to identify optimal radar operation and supporting efforts for navigational officers when the MT. Ginga Lion is sailing in the moderate sea. Using a descriptive qualitative approach with a case study design, the navigational officer population was purposively sampled (captain, chief officer, second officer AB). Instruments included observation, in-depth interviews, and documentation; data analysis followed the Miles and Huberman model with NVivo 14. The results showed that adjustments to Gain, Rain, Sea Clutter, and a combination of S-Band (long range) and X-Band (precision detection) radars were effective in overcoming rain clutter, supported by routine checks and navigational briefings. The conclusion confirms that the integration of technical, human resources, and procedures significantly improves navigational safety.

Keywords: *Rough Weather, Navigation Safety, Radar Optimization, S-Band Radar and X-Band Radar.*

I. INTRODUCTION

Shipping is the backbone of global maritime transport, with global cargo volume reaching 11 billion metric tons by 2023, with navigation playing a central role in maintaining safety (UNCTAD, 2024). Recent trends indicate an increase in accidents due to extreme weather conditions, with the International Maritime Organization (IMO) reporting 852 ship collision incidents in 2022–2024, a 12% increase compared to the previous period, particularly in tropical waters such as Southeast Asia (IMO, 2025). In Indonesia, as the largest archipelagic country, shipping supports 90% of export-import trade, but navigation challenges are becoming increasingly complex due to climate change, which exacerbates severe weather (Ministry of Transportation, 2024).

Nationally, the sinking of the KM. Sahabat on January 21, 2014, due to high waves killed dozens of people, while a similar incident in the Singapore Strait involving the MT. Parigi P1030 in 2023 nearly resulted in a collision due to radar misinterpretation (Rahman et al., 2017; Sidauruk et al., 2023). Data from the Meteorology, Climatology, and Geophysics Agency (BMKG) from 2021–2024 shows an 18% increase in tropical storms in Indonesian waters, which worsen visibility and disrupt electronic navigation equipment (BMKG, 2025). This phenomenon emphasizes the urgency of optimizing navigation, especially in vulnerable areas such as the Strait of Malacca and eastern Indonesia, where ship traffic reaches 120,000 transits per year.

Previous studies have explored the role of radar as a primary navigation tool, with Arleiny et al. (2018) emphasizing the function of S-Band and X-Band radars in detecting objects at frequencies of 2900–3100 MHz and 9300–9500 MHz according to PM 004 of 2023. Pratama's (2024) study found that radar reduces the risk of collision by up to 40% under normal conditions, while Ngujiharto (2016) defined navigation as precise direction control to the destination. However, this state of the art focuses more on standard operations than adaptation to rough weather (Dzikron & Yulianto, 2019).

A comparison of studies reveals inconsistencies: Lutfiana and Tirono (2013) reported a 60% drop in radar accuracy in adverse weather due to rain clutter, while Sidauruk et al. (2023) found blackouts and narrow channels as the main triggers for collisions, in contrast to Arleiny et al.'s (2018) optimistic findings on radar integration with digital maps. The methodological limitations of previous studies lie in their purely qualitative approach without empirical simulations of extreme weather, as well as their lack of focus on navigation officer training in the Indonesian context (Rahman et al., 2017).

A clear research gap arises from the lack of specific operational guidance for radar optimization during adverse weather, despite the 1997 SOLAS regulation requiring dual radars on ships ≥3,000 GT (Pratama, 2024). The problem statement is formulated as: How can navigational officers optimize radar operations to prevent collisions in adverse weather, along with supporting measures? This gap is crucial because previous studies have not provided contextualized protocols for nautical cadets at Indonesian maritime polytechnics.

This study aims to (1) identify optimal radar operation during rough weather and (2) formulate supporting measures for navigation officers. The urgency is pressing considering the projected 25% increase in storms until 2027 in Indonesian waters (BMKG, 2025), while its novelty lies in the development of operational guidelines based on real cases such as MT. Parigi, going beyond previous descriptive studies. The theoretical contribution enriches maritime navigation literature with an adaptive model of rough weather, while the practical contribution supports the graduation of cadets of the Surabaya Maritime Polytechnic and improves the safety skills of ship crews in the era of climate change.

II. METHODS

This research adopts a descriptive qualitative approach with a case study design, which aims to describe in depth the phenomenon of optimal radar operation on tankers in adverse weather conditions. This approach aligns with Sugiyono's (2023) definition, which states that qualitative research is postpositivist, where the researcher is the primary instrument for collecting data through triangulation to emphasize meaning over generalization. This is also supported by Emzir (2022) who emphasizes the description of natural phenomena in a nautical context. Case studies were chosen because they allow contextual exploration of a single unit of analysis, such as ship operations, as recommended in recent maritime research (Flick, 2020; Maulida, 2022).

The study population included navigation officers and deck crew on the MT. Ginga Lion, a liquid chemical tanker operating internationally in Southeast Asian waters. A purposive sampling technique was used to select four key informants: the captain, chief officer, second officer A, and second officer B, based on inclusion criteria such as a minimum of five years of experience in rough weather navigation and direct responsibility for S-Band and X-Band radars; non-navigation crew were excluded to maintain relevance. This selection followed Sudaryono's (2021) principle for informants who are intensively involved in the study phenomenon, as well as purposive sampling in shipping studies that ensure rich and credible data (Nuralim et al., 2023).

The primary instrument was the researcher herself, supported by semi-structured observation guidelines, in-depth interview protocols, and documentation sheets to record radar operation, severe weather clutter indicators, and gain/sea clutter adjustments. Validity was strengthened through source triangulation (observations, interviews, navigation log documents) and member checks with informants, while reliability was achieved via an audit trail of audio-visual recordings; indicators included object detection accuracy, vector response, and radar frequency adaptation in accordance with PM 004/2023 (Sugiyono, 2023; Miles & Huberman, 2024).

The research procedure began with the preparation stage by obtaining the captain's permit and ethical clearance from the Surabaya Maritime Polytechnic, followed by implementation during the Sea Practice (Prala) from October 2024, to February 2026, on the MT. Ginga Lion. This included direct observation on the bridge during transit through the Straits of Malacca and Singapore, semi-structured interviews lasting 45–60 minutes per informant, and document collection such as radar logbooks and navigational CCTV recordings. Data were collected iteratively for saturation, with daily transcriptions to ensure accuracy, as per maritime case study protocol (Creswell & Poth, 2022).

Data analysis followed the interactive model of Miles and Huberman (2024), including data reduction through thematic coding (e.g., the theme "adjustment of severe weather radar"), data presentation in narrative matrices and operational flowcharts, and drawing conclusions via pattern matching with navigation theory (Arleiny et al., 2018; Pratama, 2024). NVivo 14 software was used to cluster thematic nodes and visualize the network, enabling in-depth triangulation that supports radar optimization objectives (Sugiyono, 2023).

Ethical considerations included obtaining written informed consent from all informants prior to the interviews, ensuring confidentiality of identity and data through coded anonymity (e.g., Informant 1 for the captain), and limited access to primary data for researchers and supervisors only. The research adhered to the Indonesian Code of Research Ethics (KEPI) and the principle of non-maleficence, with operational permission from the MT. Ginga Lion shipowner to avoid compromising navigational safety (Emzir, 2022; Nuralim et al., 2023).

III. RESULTS AND DISCUSSION

Data Presentation

1. Observation Results

Based on the results of observations made by the author with reference to data related to the use of radar navigation equipment on board tankers, the author conducted research on optimizing radar operations to improve navigation safety on the MT. Ginga Lion. During the research, the ship was completing the loading and discharging of liquid chemical cargo and preparing to sail to the next port. This ship often operates in congested waters such as the Malacca Strait, Rotterdam Netherlands, and Ulsan South Korea, as well as frequently changing weather conditions, so the use of radar has a very important role to detect potential navigation hazards and maintain shipping safety, especially when the ship enters the port or passes through narrow channel.

In such conditions, radar becomes a key tool in ensuring navigational safety, as it detects objects around the ship, such as other vessels, buoys, or hazards on the sea surface. Based on the author's experience during sailing, when a ship is on the high seas, some navigational instruments frequently used are ECDIS and RADAR, as well as visual observation using binoculars. However, radar is more frequently used intensively when the ship enters harbor waters, narrow channels, or when visibility is reduced due to rough weather. The results of observations of events observed during sea practice are as follows.

A. Incident 1

On October 17, 2025, at approximately 10:15 LMT, when MT. Ginga Lion was approaching the shipping lane towards the anchorage area in Vizag, India, the weather conditions were bad. It was raining heavily with wind speeds reaching 25-30 knots and waves reaching a height of about 3 meters, while visibility was limited to only about 1.2 NM. In this situation, the Captain immediately ordered the officer on watch to use the X-Band Radar to optimize the Lookout, because this type of radar has a better ability to detect small objects at close range. However, overcast clouds and high waves interfered with the screen display, indicating rain clutter interference which caused targets around the ship to appear blended or blurred, making it difficult to distinguish.

To overcome this interference, the officer on duty adjusted the A/C Rain setting by turning the control clockwise until the rain reflection reduced, and adjusted the Gain to make the target display clearer. The observation results showed an unknown target on the starboard bow of the ship at a distance of 2.5 NM, but information from the object did not appear on the AIS because the ship probably did not turn on the transponder. After conducting visual observations using binoculars, it was discovered that the target was a small fishing boat.

Upon learning of the situation, the officer on watch immediately altered course 10° to port with the captain's approval to avoid a collision. After maneuvering, the ship dropped anchor at 11:43 LMT. This incident was recorded in the Bell Book and Deck Log Book. This demonstrates that optimal radar operation and rapid coordination between the officer on watch and the captain are crucial to maintaining safe navigation.

B. Incident 2

The second incident occurred on the date November 3, 2025, around 03.45 LMT, when MT. Ginga Lion sailing in the waters Strait of Malacca after departure from Dumai heading to Paranagua, Brazil. The weather at that time was thick cloudy with heavy rain and northwest winds around 28 knot, while visibility is only about 1.8 NM The Strait of Malacca is known as one of the busiest shipping lanes in the world, making radar monitoring crucial to avoid collisions with other vessels.

In that situation, *Second officer* A as OOW (Officer On Watch) Conduct observations very carefully. All navigational instruments are used to facilitate observation, including S-Band and X-Band Radar. S-Band Radar is used for long range.12 NM, while the X-Band radar is used for close-range monitoring 6 NM. From the results of observations, there are severalmoving target on the right bowat the distance between 2 to 4 NM. And there are several fishing boats that after being acquired show CPA (Closest Point of Approach) as big as 0.6 NM, which means too close and potentially dangerous.

Second Officer A immediately ordered a change of course 8° to portto the AB (Able Body Seaman) who is on the bridge to assist with observation or Look-out, after the maneuver is carried out, the CPA increases to 1.7 mill, and the situation returned to safety. This incident shows the importance ofuse of dual radar (S-Band and X-Band) as well as the quick analytical skills of the officer on duty in determining the right action in heavily trafficked waters.

C. Genesis 3

On September 17, 2025, around 22.30 LMT, when the ship MT. Ginga Lion currently at anchor inMozambique Anchorage.The weather at the time was light rain and a fairly strong current from the south. The ECDIS was set to Anchor Watch and Radar mode. X-Band operated with a range 0.5 NM to get a more detailed view of the movement of ships in the vicinity. From the monitoring results, it was detected there is another tanker who is maneuvering at a distanceless than 1 NM from the ship's own position. The officer on watch immediately carried out *range* and lie down to wards the target to ensure there are no dangerous changes in direction and to conduct visual observations with binoculars periodically until the target moves away and the situation becomes safer.

This incident shows that in conditions where the ship is anchored, continuous radar operation and disciplined observation by the watch officer is essential To prevent accidents between ships, the use of short-range radar combined with AIS and visual observation has proven effective in maintaining safe navigation.

Based on these three incidents, it can be concluded that the ability to operate radar optimally, accompanied by a good understanding of water conditions, weather, and effective coordination between the watch officer and the captain, greatly influences the improvement of navigation safety on the MT. Ginga Lion. The proper use of radar not only helps in detecting potential hazards around the ship, but also supports fast and accurate decision making in dealing with complex and dynamic navigation situations. Based on the regulations of the STCW Convention (Safety of Training, Certification and Watchkeeping) in 2010 Chapter II, Section A11 / 1 regarding the functionality to provide knowledge in order to control and operate radar alarms on ships. The skills that a navigator must have are as follows:

1) Understanding Radar and ARPA integrity performance
2) Operate by interpreting targets
3) Analyzing information on ARPA

2. Interview Results

In this study, the authors formulated several issues related to efforts to optimize radar operations to improve the safety and security of navigation on board ships. This research was conducted using the radar installed on the MT. Ginga Lion. Furthermore, the authors also sought further information regarding the obstacles encountered in radar use during navigation. Interviews were conducted with three informants:

No	Name	Position	Interview Results
	Amin MD Ruhul	*Captain*	According to the captain, radar is a crucial navigational instrument for safe navigation, especially in conditions of limited visibility. Its use is divided into two specific functions: S-Band is optimized for long-range surveillance and penetrating extreme weather, while X-Band is focused on accurate detection of close-range objects and SART signals. Standard procedures before facing severe weather include a thorough

		inspection of technical components (antenna, power, and monitor) and conducting a navigational briefing to align perceptions among officers regarding operational responsibilities.
Khalil KM Ibrahim	*Second Officer A*	Radar plays a crucial role for watch officers in maintaining safe navigation, especially when visibility is impaired by fog or rain. Technical challenges such as rain clutter—which obscures the screen due to the reflection of water droplets—must be mitigated through proper calibration of the Rain, Gain, and Sea Clutter features. In addition to operational aspects, physical maintenance such as cleaning the antenna from corrosion and dust, and checking cable installations, is essential. Neglecting routine maintenance can reduce the accuracy of radar data, potentially triggering the risk of accidents at sea.
Amin Nurul Haider	*Second Officer B*	As a crucial instrument for nighttime navigation and in adverse weather, radar requires systematic operational procedures. The initial step begins with verifying technical readiness, such as antenna power and mechanical stability, followed by optimizing the Sea, Gain, and Rain features to clear signal reflections. In extreme weather, the officer on watch must be meticulous in minimizing rain clutter to ensure the original target remains detectable. The effectiveness of this tool ultimately rests on the operator's competence in interpreting data and solid coordination with the captain, especially in high-risk sailing areas.

It was concluded that optimal radar operation depends not only on the technical condition of the equipment, but also on the skill, accuracy, and good coordination between officers on board. Radar serves as a crucial navigational aid in maintaining safe navigation, especially when the ship operates in waters with heavy traffic, rough weather, or limited visibility. Therefore, every officer on watch must have a thorough understanding of the function and operation of radar, including the ability to adjust its settings according to the sailing situation at hand.

Furthermore, routine radar maintenance, such as antenna inspections, component cleanliness, and power stability, is crucial to ensure optimal equipment performance. Regular radar training and simulations are also essential to ensure officers have the ability to analyze and make quick and accurate decisions in emergency situations. There fore, the combination of equipment reliability, operator competence, and effective coordination between officers are key factors in enhancing navigational safety and security on the MT. Ginga Lion.

3. Documentation

Documentation conducted during the author's sea practice at MT. Ginga Lion, which aims to support observation and interview findings related to optimizing radar use during rough weather.

Fig. 1. S-Band Radar

Source: Author's Documentation

S-Band radar is a type of radar that operates at a frequency of 2–4 GHz and has a longer wavelength than X-Band. This radar functions for long-range detection and navigation surveillance because it has the ability to penetrate heavy rain and weather disturbances well. S-Band is widely used on ships for wide-area monitoring and long-range navigation, especially when facing rough weather such as heavy rain or thick fog, where other radars experience reduced accuracy. This radar is very effective for use when sailing on the high seas because it is able to provide a stable display with minimal interference even in extreme weather conditions.

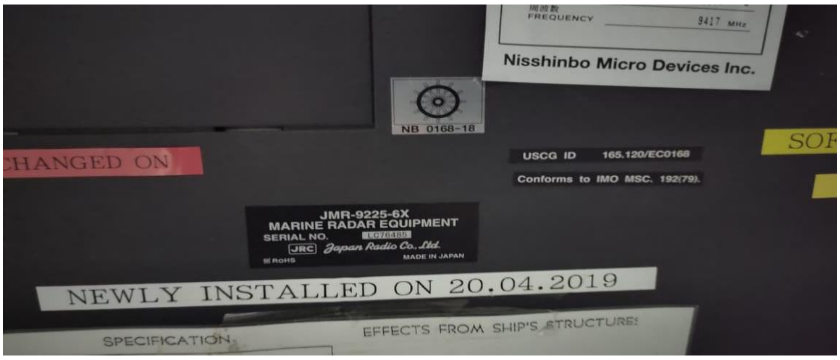

Fig. 2. X-Band

Source: Author's Documentation

X-Band radar operates at a frequency of 8–12 GHz with a shorter wavelength, thus providing higher target resolution. This radar is used to detect small objects around the ship, such as fishing boats, SART or other floating objects at close range. Due to its high sensitivity, X-Band radar is very effective when used when maneuvering in harbors, narrow channels, or when detailed observation of targets around the ship is required. However, this radar is more susceptible to interference from rain reflections (rain clutter) than S-Band radar.

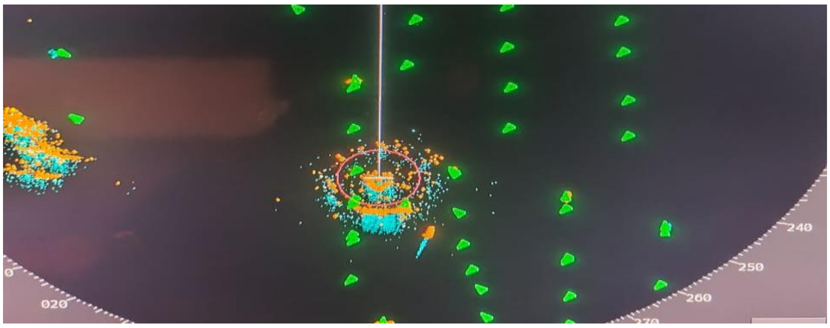

Fig. 3. Radar Rain Clutter

Source: Author's Documentation

The photo above shows a ship's radar screen during rain clutter, a disturbance on the radar screen caused by the reflection of radar waves from heavy raindrops around the ship. This reflection creates a thick yellow or green spot on the radar screen around the ship, which can obscure or disguise actual targets such as other vessels or navigation buoys.

Data analysis

Based on the results of observations and interviews conducted on board the ship MT. Ginga Lion, it is clear that radar operation plays a crucial role in maintaining navigational safety and security, particularly when a ship is sailing in adverse weather conditions and with limited visibility. Radar serves as the primary aid for detecting the presence of other ships, buoys, and objects or obstacles around the ship that cannot be observed visually. Field observations indicate that optimizing radar operation in adverse weather is highly dependent on the ability of the officer on watch to adjust radar settings, such as Gain**,** Rain**,** And Sea Clutter, so that the reflection of rain and waves does not interfere with the target display. Use a combination X-Band radar And S -Band Simultaneously, the X-Band radar was used to detect small objects at close range, while the S-Band radar was better able to penetrate heavy rain at longer distances. Furthermore, rapid coordination between the officer of the watch and the captain in interpreting radar displays and executing precise navigational maneuvers was a key factor in preventing potential collisions at sea.

Results of the interview with *Captain*, *Second Officer A* , And *Second Officer B* This reinforces these findings. The three emphasized that radar optimization is determined not only by the sophistication of the equipment, but also by the skill, precision, and discipline of the officers on watch in carrying out navigational watch procedures. The captain emphasized the importance of radar checks and navigational briefings before the ship enters a risky area. *Second Officer* A highlighted the need for routine maintenance on the antenna, cables, and monitor displays to ensure the radar is always ready for use. Meanwhile, Second *Officer B* emphasized the importance of radar readiness before operation, and that good and accurate communication between the officer on duty and the captain is equally important.

From the results of the overall analysis, it can be concluded that Optimization of radar operations on the MT. Ginga Lion ship is influenced by three main aspects, that istechnical aspects, which includes the condition and performance of radar equipment;human resources aspects, namely the operator's skills, accuracy and experience in reading and interpreting radar data; andprocedural and coordination aspects, namely discipline in carrying out navigational watch procedures and cooperation between the officer of the watch and the captain. These three aspects are interrelated and are determining factors in optimal radar operation. With the implementation of proper radar settings, routine maintenance, and effective coordination on the bridge, radar operation on a ship can be achieved. MT. Ginga Lioncan run optimally and contribute significantly to improving shipping safety and security, especially when facing rough weather conditions and heavy shipping traffic.

IV. DISCUSSION

The research problem is how to optimize radar operation when a ship is sailing in rough weather and what efforts can be made by the navigation crew to optimize this operation. This discussion is based on data analysis obtained on the MT. Ginga Lion and is supported by theory and best practices in the use of ship radar.

How to optimize radar operation when sailing in rough weather?

Based on the data analysis described above, optimal radar operation during adverse weather conditions depends heavily on the watch officer's ability to adjust the radar system settings to suit the sailing conditions. In heavy rain or thick fog, radar often experiences interference from rain reflections, which can cause targets to appear blurry and difficult to recognize. To address this, adjustments are made to the Rain, Gain, and Sea Clutter features to minimize reflections from rain and waves, thus improving target visibility.

In addition, changing the radar range from long-range to short-range is necessary so that the area around the ship can be observed in greater detail. Observations show that using a combination of X-Band Radar and S-Band Alternately or simultaneously, it is very effective in improving detection accuracy. X-Band radar is used to detect small objects at close range, while S-Band radar has the ability to penetrate heavy rain at longer ranges. Quick and precise decisions regarding maneuvering based on radar observations are key to preventing potential collisions at sea.

Thus, optimizing radar operation in adverse weather conditions can be achieved by adjusting radar settings according to weather conditions and visibility, using a combination of X-Band and S-Band radars to maximize target detection, additional visual surveillance using binoculars to verify radar results, and rapid coordination between the officer of the watch and the captain in making navigation decisions. These steps show that successful radar operation in adverse weather depends not only on the reliability of the equipment, but also on the operator's skill in adjusting radar parameters and analyzing sailing conditions accurately.

What are some measures that can help optimize radar operations by navigational officers when sailing in rough weather?

Interviews conducted by researchers during observations revealed that radar optimization depends not only on technology and equipment specifications, but also on personnel readiness and routine maintenance. Before a ship enters a risky area or encounters severe weather, a thorough inspection of the radar system is performed, including checking the antenna, electrical power stability, and monitor display clarity. Furthermore, a navigation briefing is necessary to ensure each officer understands their responsibilities and procedures during the voyage.

Routine radar maintenance is also crucial for maintaining the equipment's performance. The antenna should be kept clean from dirt, salt, and rust, while cables and electrical connections should be inspected to prevent power outages. Proper maintenance will ensure accurate radar displays that are responsive to changing conditions around the vessel. Furthermore, regular radar training and simulations under various weather conditions are essential to improve operators' ability to read radar displays and make informed decisions in emergency situations.

From the results of the interview, it can be concluded that efforts to optimize radar operations by navigation officers include checking and maintaining navigation equipment before sailing, conducting periodic navigation briefings, improving operator capabilities through familiarization training, and strengthening communication between the watch officer and the captain in making navigation decisions.

V. CONCLUSION

This study concluded that optimizing radar operation during rough weather on the MT. Ginga Lion relies heavily on adjusting Gain, Rain, and Sea Clutter settings to reduce rain reflection interference, and the simultaneous use of S-Band radar for long-range and X-Band radar for close-range precision detection, as seen in three observation events in the Strait of Malacca, Vizag, and Mozambique Anchorage. Key supporting measures include routine antenna and power checks, pre-voyage navigation briefings, and data interpretation training for officers of the watch, corroborated by interviews with the captain and second officer, effectively preventing dangerous CPA in heavily trafficked waters.

However, the limitations of this study lie in its single focus on a single chemical tanker with limited primary data from sea practice, without quantitative simulations or comparisons across ship types, so generalization to other fleets is still limited. Suggestions for future research are to adopt a mixed methods approach on multiple vessels to measure training effectiveness, while the practical implication is the development of STCW-compliant training modules for cadets of the Surabaya Maritime Polytechnic to reduce human error amidst extreme weather that is predicted to become more frequent.

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