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OPTIMAL RADAR OPERATIONAL ANALYSIS WHILE NAVIGATING THE KM ORIENTAL GALAXY

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ABSTRACT

Radar plays a vital role in maritime navigation by assisting ship crews in detecting targets, identifying potential hazards, and maintaining navigational safety. However, technical limitations and improper operation can reduce radar effectiveness and increase the risk of navigational incidents. This study aims to examine problems encountered in radar operations aboard KM Oriental Galaxy and identify measures to optimize its performance. The study employed a qualitative research approach, with data collected through direct observation and interviews with relevant personnel. The data were analyzed descriptively to identify operational deficiencies, technical obstacles, and potential improvements. The findings indicate that radar operations aboard KM Oriental Galaxy did not fully comply with established operating procedures. The identified problems included ineffective target detection, reduced magnetron performance, blind sectors in radar coverage, and spurious echoes that did not correspond to actual objects. These limitations may affect the accuracy of target identification and the crew's awareness of surrounding navigational conditions. Recommended improvements include enhancing crew competence through training and guidance on proper radar operation, conducting routine equipment inspections and maintenance, and improving awareness of radar limitations. The novelty of this study lies in examining the relationship between procedural compliance, equipment condition, and radar-related detection problems within a specific vessel context. The study concludes that strengthening operational competence and maintaining radar equipment are essential to improving radar reliability and supporting safer maritime navigation.

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1. INTRODUCTION

Maritime transportation plays an important role in supporting domestic and international trade, particularly in an archipelagic country such as Indonesia. Safe ship navigation depends on the competence of the crew, the reliability of navigational equipment, appropriate operating procedures, and compliance with maritime safety regulations. One of the essential navigational instruments used to support these activities is marine radar. Radar enables navigators to detect surrounding objects, determine their relative range and bearing, and monitor potential navigational hazards, particularly under restricted visibility. However, the effectiveness of radar depends not only on the availability of the equipment but also on the operator's ability to configure the system, interpret the displayed information, and make appropriate navigational decisions.

Marine radar operates by transmitting electromagnetic waves and receiving the signals reflected by objects within its detection area. Its performance is influenced by target characteristics, radar operating parameters, environmental conditions, and the technical condition of the equipment. Ding et al. (2021) discussed the assessment of shipboard radar reliability, while Wang et al. (2021) investigated multidimensional automatic detection of marine targets from scanning radar images. Chen et al. (2021) examined radar detection methods that combine multiple features to control false alarms. These studies demonstrate that radar effectiveness involves both equipment reliability and the ability to distinguish genuine targets from unwanted echoes. Consequently, optimal radar operation requires appropriate equipment settings, continuous monitoring, and correct interpretation of the radar display.

Target detection is one of the main challenges in marine radar operation. Radar echoes may contain information from actual targets as well as unwanted reflections from the sea surface, precipitation, and other sources of interference. Rosenberg (2022) discussed continuing challenges in modelling radar sea clutter, particularly under varying sea conditions and observation geometries. Wen et al. (2022) investigated the suppression of sea clutter and target detection through joint filtering in the spatial and temporal domains. Li et al. (2022) examined principal component analysis for detecting small targets in sea clutter, while Wang et al. (2022) studied target detection in clutter regions using shipborne high-frequency surface-wave radar. Although these studies employ different technical approaches, they collectively indicate that clutter can reduce target visibility and increase the possibility of missed detections or false alarms.

Further developments in radar signal processing have explored methods to improve target detection under complex maritime conditions. Battula and Eppili (2022) examined moving-target detection using visual features and a Deep Maxout Network under sea-clutter conditions. Wang and Li (2023a) proposed a convolutional neural network approach incorporating dual-perspective attention for maritime radar target detection in sea clutter. Wang and Li (2023b) developed the SALA-LSTM method to improve maritime radar target detection through the modelling of sequential radar-echo characteristics. These studies emphasize the importance of identifying meaningful target information within complex radar returns. For operational ship navigation, however, the practical effectiveness of radar also depends on appropriate range selection, gain adjustment, clutter control, and the operator's ability to recognize the limitations of the equipment.

Radar operation also involves interpreting target range, bearing, and movement. Functions such as the Electronic Bearing Line (EBL), Variable Range Marker (VRM), and Automatic Radar Plotting Aid (ARPA) support the assessment of relative target positions and movements. In addition, the Closest Point of Approach (CPA) and Time to Closest Point of Approach (TCPA) can assist navigators in evaluating potential collision risks. These functions are useful only when their outputs are interpreted correctly and considered alongside the vessel's navigational situation. Zhang et al. (2024) investigated a marine radar monitoring system using Internet of Things technology and target detection based on

plan-position indicator images. Their work illustrates the continuing development of radar monitoring and target-identification methods to improve maritime situational awareness.

The integration of radar with other navigational information can further support target monitoring. Sun et al. (2023) investigated the use of Automatic Identification System (AIS) information to assist marine radar target tracking when detection is obstructed. Wang et al. (2023) examined marine-area supervision through the fusion of AIS and X-band radar data. Fan et al. (2025) studied ship-target tracking using multisensor data fusion. More recently, Ren et al. (2026) investigated a two-stage method for detecting vessel targets in sea clutter using time-frequency features from shipborne high-frequency surface-wave radar, while Shi et al. (2026) proposed a framework for integrating AIS and radar data in restricted inland waterways. These studies show that combining complementary sources of navigational information can improve target monitoring. Nevertheless, AIS and other sensor information should be treated as complementary aids rather than replacements for radar observation, visual lookout, and professional navigational judgment.

In addition to environmental and operational factors, the technical condition of radar equipment is important for maintaining reliable detection. Equipment degradation, component failure, and inadequate maintenance may affect the continuity and effectiveness of radar operation. In systems that use a magnetron transmitter, deterioration in magnetron performance may affect transmitted power and contribute to reduced target-detection effectiveness. Basuki et al. (2021) examined preventive maintenance of a Kelvin Hughes MKVII X-band navigation radar, providing a basis for considering maintenance planning in shipboard radar management. Melnyk et al. (2025) investigated the reliability of marine radionavigation systems under degradation factors, including gradual deterioration and sudden failures. Their findings support the importance of monitoring equipment condition, identifying potential faults, and implementing appropriate maintenance measures. In this context, radar inspection, functional testing, maintenance documentation, and compliance with manufacturer recommendations are essential considerations when investigating possible equipment-related problems.

Human factors also contribute to the effectiveness of radar operation. Navigators must understand radar principles, select appropriate operating settings, interpret target movements, recognize false echoes, and communicate relevant information to other bridge-team members. Incorrect adjustment or misinterpretation of radar information may result in missed targets or inaccurate assessments of collision risk. Cinar et al. (2025) examined ship-operator reliability in relation to potential cyberattacks on integrated navigation systems, highlighting the importance of human reliability in technology-supported ship operations. Therefore, radar-related competence should be considered together with equipment reliability, bridge-team communication, and the ability to cross-check information from different navigational sources.

Radar-assisted navigation must also be consistent with applicable maritime safety requirements. The International Regulations for Preventing Collisions at Sea (COLREGs) establish requirements for maintaining a proper lookout, proceeding at a safe speed, and assessing collision risk. Rule 7 specifically

addresses the determination of collision risk and cautions against drawing conclusions from insufficient radar information. The International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW) provides an international framework for seafarer training and competence. Accordingly, radar should be operated as part of an integrated navigational process. Navigators must continue to maintain situational awareness, evaluate available information critically, and apply the relevant collision-prevention rules.

In the context of KM ORIENTAL GALAXY, the effectiveness of radar operation requires investigation to identify the factors that may hinder target detection and navigational monitoring. Potential issues include ineffective target detection, reduced magnetron performance, inappropriate radar settings, environmental interference, and limitations in the operator's use of available radar functions. These issues should be examined through direct observation, interviews with relevant crew members, and supporting documentation, including equipment inspection and maintenance records where available. Such evidence can help distinguish problems associated with equipment condition from those related to operating procedures, environmental conditions, and the interpretation of radar information.

Although previous studies have examined radar reliability, target detection in sea clutter, radar and AIS integration, multisensor tracking, and preventive maintenance, the interaction between operating practices, equipment condition, and navigational decision-making still requires examination within the operational context of an individual vessel. Research on radar signal processing primarily addresses technical approaches to target detection, whereas maintenance studies emphasize equipment reliability. The present study focuses on the practical operation of radar on KM ORIENTAL GALAXY and the relationship between operational procedures, technical obstacles, and navigational safety. Therefore, this study aims to analyze radar operation during navigation on KM ORIENTAL GALAXY, identify the factors affecting its effectiveness, and formulate recommendations for improving operating procedures, crew competence, and equipment maintenance. The findings are expected to contribute to more effective radar utilization and support safe navigation.

2. METHODS

This study employed a qualitative descriptive approach to examine the use of radar and identify factors affecting the optimization of radar functions during navigation aboard KM *Oriental Galaxy*. The qualitative approach was selected because the research aimed to obtain an in-depth understanding of the crew's operational practices, knowledge, and experiences in using radar under actual shipboard conditions. The study focused on radar operation, the crew's understanding of radar optimization, and operational or technical factors that could affect its effectiveness in supporting navigational safety.

Radar function optimization was defined as the appropriate use of radar equipment to support target detection, situational awareness, and the identification of potential navigational hazards. The type

of radar installed aboard the vessel was examined as a relevant technical characteristic rather than treated as an independent variable in a quantitative causal model.

The research was conducted aboard KM *Oriental Galaxy* over a period of 12 months, coinciding with the author's Marine Practice (Praktik Laut/PRALA). The vessel served as the research setting because it provided an opportunity to observe radar use during actual navigational operations. The research focused on how deck officers and other relevant crew members operated radar, interpreted displayed information, and used the equipment to support navigational decision-making. The exact starting and ending dates should be specified in the final manuscript.

The research population consisted of the entire crew of KM *Oriental Galaxy*. The research sample comprised five informants: one Second Officer, one Third Officer, two helmsmen assigned to watchkeeping duties, and one deck cadet. These participants were selected using purposive sampling because their duties or involvement in navigational activities provided relevant information about radar use aboard the vessel.

The Second Officer and Third Officer provided information concerning radar operation and its role in navigational watchkeeping. The two helmsmen and the deck cadet provided supporting information regarding their observations and involvement in bridge operations, within the limits of their respective responsibilities. The sample size was determined by the specific roles and availability of the identified participants during the research period. The adequacy of the information obtained should be described based on the actual findings and the extent to which the research questions were addressed.

The research instruments consisted of an observation guide, an informal interview guide, and a documentation checklist. The observation guide was used to record radar operating practices and the use of radar information during navigation. Informal interviews were conducted to explore the crew's understanding of radar operation, difficulties encountered, and factors that could affect its effectiveness. The documentation checklist was used to examine available technical documents, equipment manuals, and relevant operational records.

The analysis focused on the following indicators:

1. Radar operation: How radar equipment was operated and monitored during navigational watchkeeping.
2. Radar configuration and use: The use of available settings and functions, where observable and relevant to the equipment installed aboard the vessel.
3. Target detection and interpretation: The crew's ability to interpret radar displays and recognize relevant targets or potential navigational hazards.
4. Crew knowledge and competence: The crew's understanding of radar functions, limitations, and appropriate operational practices.
5. Technical and operational constraints: Equipment-related limitations, operational difficulties, and other factors identified through observation, interviews, or documentation.

These indicators were used as qualitative analytical guides rather than standardized quantitative variables. The research instruments were aligned with the research objectives. The credibility of the findings was strengthened by comparing observations, interview responses, and documentary evidence. Formal validity or reliability tests should be reported only if they were actually conducted.

Data were collected through direct observation, informal interviews, and documentation studies. First, direct observation was conducted aboard KM *Oriental Galaxy* during the 12-month Marine Practice period. The researcher observed radar use during navigational activities, focusing on operational practices, the interpretation of radar information, and the role of radar in supporting situational awareness and hazard identification. Observations were recorded systematically without interfering with navigational duties or vessel safety. Second, informal interviews were conducted with the selected informants to obtain information about their experiences and understanding of radar operation. The interviews explored operational practices, difficulties in interpreting radar information, perceived equipment limitations, and factors affecting the effective use of radar during navigation. Third, documentation studies were conducted by reviewing available radar manuals, technical documentation, and relevant operational records, where accessible and authorized. These documents provided supporting information for interpreting the observations and interview responses.

Primary data consisted of information obtained through direct observation and interviews, while secondary data consisted of relevant technical documents, manuals, and operational records. Information from these sources was organized and compared to identify recurring patterns and discrepancies related to radar use.

The data were analyzed using qualitative descriptive analysis based on the framework proposed by Miles, Huberman, and Saldaña (2014), which comprises data condensation, data display, and conclusion drawing and verification. First, data condensation involved selecting, organizing, and coding information from observation records, interview notes, and relevant documents. The information was grouped according to themes such as radar operating practices, interpretation of radar displays, crew competence, technical limitations, and navigational safety. Second, data display involved presenting the findings in descriptive narratives or thematic summaries to explain how radar was used and what factors affected its effectiveness during navigation. Third, conclusion drawing and verification involved interpreting recurring patterns and comparing findings across observations, interviews, and documentary sources. The results were then examined in relation to relevant radar operating guidance and navigational safety principles to identify potential gaps between recommended practices and actual operational practices.

The analysis aimed to describe the implementation of radar operation, identify factors that affected its effective use, and formulate recommendations for improving radar utilization in support of navigational safety. No statistical inference was performed because the study employed a qualitative descriptive design.

The research was conducted with due consideration for participant confidentiality and navigational safety. The necessary authorization to conduct observations aboard the vessel and access relevant operational documents was obtained from the appropriate vessel or company authority, where required. The research purpose was explained to interview participants, and informed consent was obtained before interviews. Participants' identities and any confidential operational information were protected in the research report unless explicit authorization for disclosure had been provided.

Photographs, technical records, and internal vessel documents were included only where the necessary permission had been obtained. Institutional ethics committee approval was obtained where required by the applicable institutional policy. If applicable, the name of the ethics committee and approval number should be reported in the final manuscript.

3. RESULTS AND DISCUSSION

The During practice on board the KM Oriental Galaxy, various abnormal conditions were found on the radar due to the crew's lack of knowledge in operation and maintenance. Problems that arise include false echoes, blind sectors, shadow sectors, and decreased radar performance due to lack of periodic maintenance. The data also shows a low understanding of the officers' understanding of the responsibilities of navigation equipment. To overcome this problem, technical guidance was provided to the crew regarding radar setup, screen interpretation, emergency handling, and basic maintenance to improve competence and ensure navigation safety.

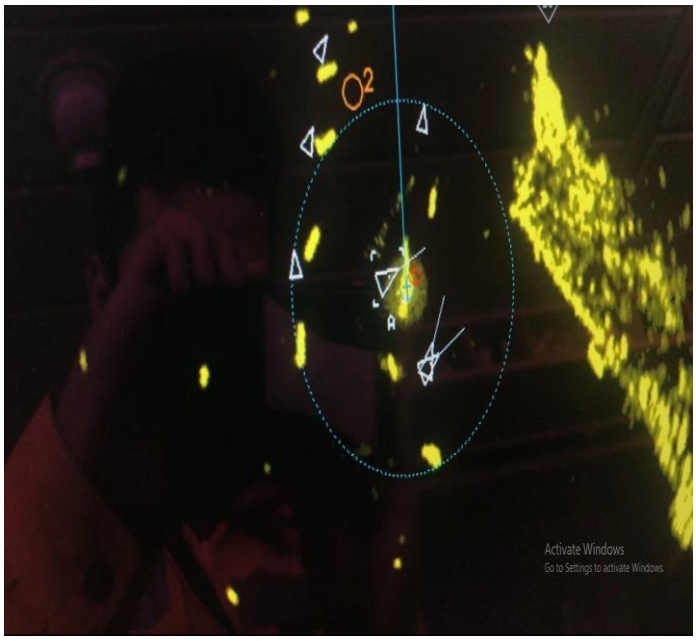
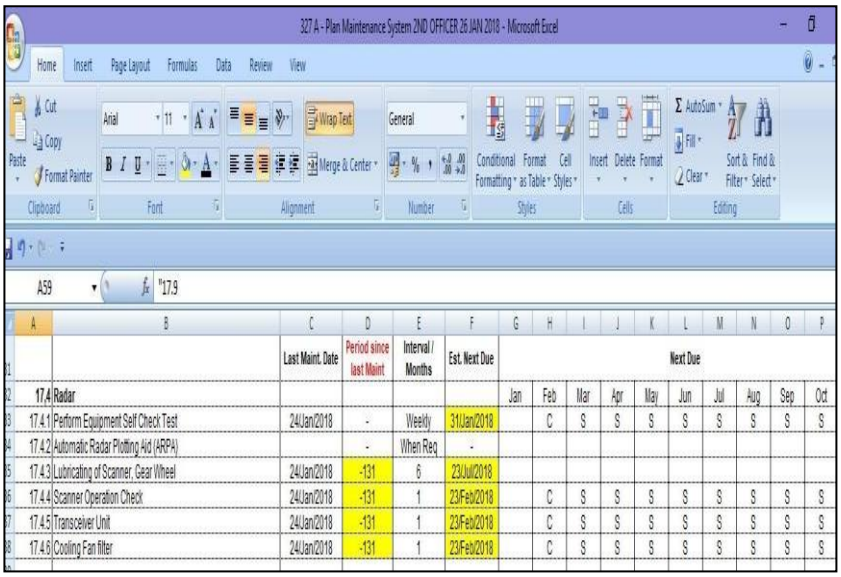


Figure 1. Echo distortion on radar screens

The radar has various display modes such as Head-up, Course-up, North-up, and True Motion, each of which helps navigation in different conditions. Additional features such as Electronic Bearing Line (EBL), Gain Adjustment, Sea/Rain Clutter Reduction, Off-Centre Display, Target Trails, Parallel Index Lines, and the use of AIS data enrich the radar's function in detecting and monitoring targets.

These features, if optimized, are essential to improve navigation safety, analyze collision risk, and support decision-making in the field.

The integration of modern radars such as Furuno with ECDIS allows for the visualization of the shipping path directly on the radar screen. Navigation officers can monitor the ship's position against the planned route, as well as get early warnings when the ship goes off course, supporting safe navigation in busy waters such as Makassar. On tankers, the use of radar when docking or unloading and unloading must be avoided to prevent interference with sensitive electronic devices. Radar operation must follow strict procedures, including recording usage in the radar logbook and periodic maintenance to ensure optimal performance. In operating the Furuno radar, operators need to pay attention to safety aspects such as maintaining distance from the antenna, performing routine maintenance, adjusting radar settings according to conditions, understanding radar displays, and recording important changes and responding to alarms quickly. In addition, the use of radar must be documented in the radar logbook to facilitate surveillance by guard officers.



		Last Maint. Date	Period since last Maint	Interval / Months	Est. Next Due	Next Due									
17.4	Radar					Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
17.4.1	Perform Equipment Self Check Test	24/Jan/2018	-	Weekly	31/Jan/2018		C	S	S	S	S	S	S	S	S
17.4.2	Automatic Radar Plotting Aid (ARPA)		-	When Req	-										
17.4.3	Lubricating of Scanner Gear Wheel	24/Jan/2018	-131	6	23/Jul/2018										
17.4.4	Scanner Operation Check	24/Jan/2018	-131	1	23/Feb/2018		C	S	S	S	S	S	S	S	S
17.4.5	Transceiver Unit	24/Jan/2018	-131	1	23/Feb/2018		C	S	S	S	S	S	S	S	S
17.4.6	Cooling Fan filter	24/Jan/2018	-131	1	23/Feb/2018		C	S	S	S	S	S	S	S	S

Figure 2. Radar maintenance report

Radar maintenance is mandatory to follow the manufacturer's guidelines to maintain the reliability of navigation tools, in accordance with the principles of the ISM-Code. Ship technicians typically perform cable inspections, power supply units, software updates, and replacement of parts such as magnetrons or PCBs. After repairs, the radar is tested and the crew is provided with brief training. In addition, ships routinely undergo inspections or vetting by the owner's and charterer's companies to ensure all operational and safety aspects, including radar conditions, are in line with maritime industry standards, especially for tankers.

4. CONCLUSION AND RECOMMENDATIONS

This study concludes that radar is an essential navigational aid for maintaining situational awareness, particularly during nighttime navigation, restricted visibility, and adverse weather

conditions. Based on the observations conducted during sea practice on board KM Oriental Galaxy, the radar system was found to operate in accordance with the operational standards observed during the study. Nevertheless, reliable radar performance depends on the crew's understanding of its functions and limitations, compliance with proper operating procedures, and implementation of routine maintenance in accordance with the Planned Maintenance System (PMS). These factors are important to support safe navigation and effective decision-making on board.

To maintain radar reliability, shipping companies should ensure the availability of necessary spare parts, respond promptly to equipment repair requests, and recruit qualified personnel for shipboard positions. Ship officers should also strengthen their knowledge of radar operation, fulfill their navigational responsibilities diligently, and conduct routine equipment checks in accordance with established procedures. This study is limited to observations on a single vessel, KM Oriental Galaxy, during the sea practice period; therefore, its findings may not represent radar performance across other vessels and operating conditions. Future research should examine radar maintenance practices and operational performance across multiple vessels to identify how equipment condition, crew competence, and maintenance management influence navigational safety and reliability.

DECLARATIONS

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