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PERFORMANCE ANALYSIS OF IMC MODULE IN OTE DT100 VHF RADIO BASED ON REQUIRED COMMUNICATION PERFORMANCE STANDARDS

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Abstract: Communication between Air Traffic Controllers (ATC) and pilots is essential for flight safety and operational efficiency. Very High Frequency (VHF) communication systems support air-to-ground communication, with the Interface and Management Card (IMC) module managing automatic change-over between main and standby transmitters. This study analyzes the performance of the IMC module in the OTE DT100 VHF radio system based on Required Communication Performance (RCP) 60 standards, focusing on continuity and availability. A mixed-method approach was employed, combining field observations during On-the-Job Training at Minangkabau International Airport, interviews with communication technicians, and analysis of fault logs and downtime records. Continuity was evaluated based on unexpected communication interruptions, while availability was calculated from system uptime relative to total operational time. The results indicate that IMC malfunction reduced system availability below the minimum RCP 60 requirement and increased continuity interruptions during transmitter change-over, potentially compromising operational communication performance.

Keywords: VHF Radio, IMC Module, Change-Over, Required Communication Performance

Introduction

Aviation in Indonesia plays a crucial role in connecting the nation's vast archipelago and supporting economic growth and tourism (Undang-Undang Republik Indonesia Nomor 1 Tahun 2009 Tentang Penerbangan, 2009). Despite various challenges, the aviation sector continues to expand and remains essential in linking Indonesian regions to both domestic and international destinations. Two fundamental supporting components in aviation operations are airports and air navigation systems (Dharmawan, 2012). Air navigation ensures that aircraft are directed safely and efficiently from one location to another in accordance with standardized procedures (International Civil Aviation Organization, 2025). One of its key elements is aeronautical communication, which is categorized under the Communication, Navigation, Surveillance, and Data Processing (CNS/ATM) framework. Within this domain, the Very High Frequency (VHF) radio system plays a vital role in establishing direct voice communication between pilots and Air Traffic Controllers (ATC) (Asri & Lidyawati, 2018).

VHF radios are used to transmit clear and real-time instructions, clearances, and essential flight information (Sari et al., 2023). Operating within the 118–137 MHz frequency range and transmitting at 25–50 W, VHF systems can provide coverage of up to 87 nautical miles (NM), depending on aircraft altitude and line-of-sight conditions (Sari et al., 2023). One of the primary devices used for ATC communication in Indonesia is the OTE DT100 VHF radio, which is

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operated by Perum LPPNPI (AirNav Indonesia) (Permatasari, 2024). This device supports both analog and digital communication modes and employs a redundant configuration to maintain communication continuity (SELEX Communication, 2008).

A critical component of this redundancy is the Interface and Management Card (IMC) module, which automatically manages the change-over between the main and standby transmitters. The IMC ensures that when a fault occurs in the primary transmitter, communication is seamlessly transferred to the standby unit (OTE, 2004). However, during a Daily Check on May 28, 2024, at Minangkabau International Airport, a VSWR Level Comm Error was detected on the 118.3 MHz Transmitter 1. This condition indicated a malfunction in the IMC module, which disabled the automatic change-over function and caused the system to remain in a neutral position (not connected). To ensure these communication systems are dependable and secure, the International Civil Aviation Organization (ICAO) defines a set of requirements known as Required Communication Performance (RCP) (International Civil Aviation Organization, 2006). RCP establishes performance benchmarks in terms of reliability, timeliness, continuity, and availability for air-ground communication. For Aerodrome Control (ADC) and terminal operations, where relatively rapid communication is necessary but not as instantaneously critical as automated data links, the RCP 60 standard is commonly applied as the normative benchmark. RCP 60 mandates a transaction time of ≤ 60 seconds, a continuity probability of ≥ 0.99, and an availability of ≥ 0.9995.

Based on the May 28, 2024 incident at Minangkabau International Airport, this paper presents a case study evaluating the operational impact of IMC module failure on VHF communication redundancy. This study aims to analyze the extent to which a single-point failure in the IMC module degrades system continuity and availability, and whether the resulting service level complies with ICAO's RCP 60 operational expectations.

Method

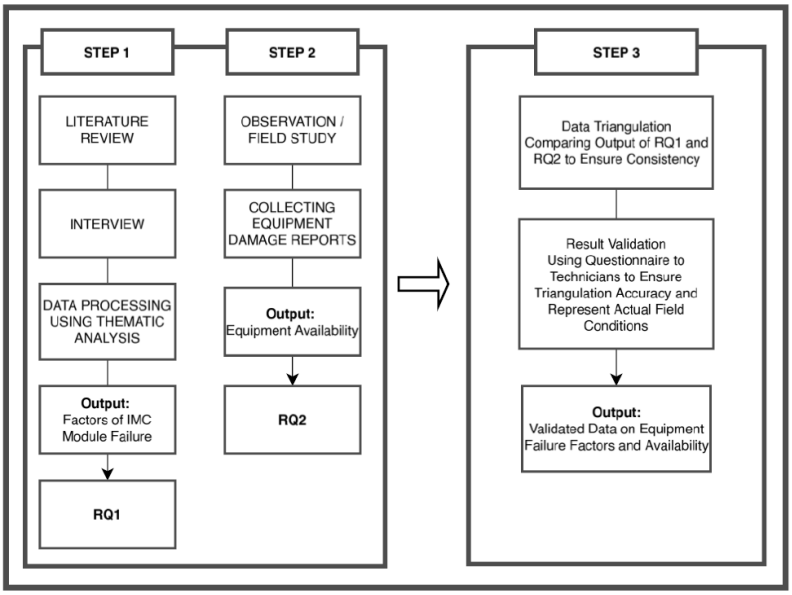

Figure 1. Research Design Flowchart

This study employed a mixed-method approach combining qualitative and quantitative techniques to evaluate the performance of the Interface and Management Card (IMC) module in a Very High Frequency (VHF) air-ground communication system. The mixed-method design was selected to allow triangulation between field-based evidence and numerical performance indicators, thereby improving the validity and reliability of the analysis. The qualitative

component aimed to identify technical and operational factors contributing to IMC malfunction, while the quantitative component focused on assessing communication continuity and availability in accordance with Required Communication Performance (RCP) standards.

The research was conducted at the communication facility of Minangkabau International Airport under the management of Perum LPPNPI (AirNav Indonesia) Padang Branch during the author's On-the-Job Training (OJT) period from March to August 2024. The object of analysis was the Interface and Management Card (IMC) module installed in the OTE DT100 VHF radio system operating at the Aerodrome Control (ADC) frequency of 118.3 MHz, The IMC module functions as a control interface that manages automatic change-over between the main and standby transmitters to ensure uninterrupted communication service.

Data collection was carried out through several complementary techniques, including a literature review of ICAO documentation and manufacturer technical manuals, direct field observations during IMC failure events and troubleshooting activities, and structured interviews with licensed VHF communication technicians experienced in operating and maintaining the OTE DT100 system. In addition, validation questionnaires were distributed to confirm the consistency of qualitative findings with actual field conditions.

Qualitative data obtained from interviews and observations were analyzed using thematic analysis to identify recurring patterns and dominant themes related to IMC failure mechanisms and their operational impacts. Quantitative analysis focused on evaluating RCP performance parameters, specifically continuity and availability. Availability is the probability that an operational communication transaction can be initiated when needed (Gómez Depoorter & Lücke, 2015), availability was measured using system uptime and downtime records obtained from equipment fault logs and maintenance reports. The availability metric was calculated using general equation for calculating the availability in a month,

$$A = \frac{\text{Uptime}}{\text{Uptime} + \text{Downtime}} \times 100\% \quad (1)$$

Equation (1) represents the ratio of operational uptime to the total observation time. For this case study, the observation window was defined as a standard 30-day operational month (720 hours) to provide a standardized baseline for availability calculations. Continuity was operationalized not as an abstract concept, but as the system's empirical ability to execute an automatic change-over to the standby transmitter without requiring manual ATC or technician intervention. An unscheduled communication interruption caused by IMC malfunction, which forced manual radio operation, was recorded as a continuity failure.

Discussion

System Downtime and Availability, Observational data and equipment fault logs were analyzed for a standard 30-day operational period (720 hours). During the recorded event on May 28, 2024, the VSWR Level Comm Error on Transmitter 1 resulted in a total system downtime of 8 hours, during which the automatic change-over mechanism failed to activate. Applying Equation 1, the system's operational uptime was 712 hours. Therefore, the actual system availability during this observation window was calculated as 98.88% (712 / 720).

Continuity Assessment, During the observed failure, the IMC module remained in a neutral state, effectively nullifying the hardware redundancy architecture. Because the system could not automatically recover from the Transmitter 1 fault, the probability of maintaining an uninterrupted communication session dropped to 0 for the duration of the incident. Air Traffic Controllers were forced to manually transition to portable VHF devices, constituting a definitive interruption of the primary communication service.

Qualitative Observations on Failure Mechanisms, Preliminary qualitative insights obtained from structured interviews with two licensed VHF technicians (stationed in Padang and Palembang) highlighted several recurring technical vulnerabilities. Both technicians independently reported that IMC degradation in the OTE DT100 is frequently associated with hardware aging (as the system was installed in 2005, exceeding 20 years of continuous service), inadequate thermal dissipation (overheating during peak operational loads), and electrical instability (overvoltage). Furthermore, maintenance recovery times were reportedly exacerbated by constraints in spare part availability across regional branches.

Table 1. AirNav Padang Facility Data Installation

Location	Category	Brand	Type	Installation
PADANG	Communication VHF A/G	OTE	DT100	2005

The OTE DT100 VHF radio system is designed as a redundant air–ground communication system supporting Aerodrome Control (ADC) operations. It operates within the 118.000–137.000 MHz frequency band and employs dual transmitter and receiver configurations to maintain communication reliability (Lin & Chen, 2011). A critical element in this redundancy architecture is the Interface and Management Card (IMC), which supervises transmitter status and executes automatic change-over between the main and stand by transmitters to prevent communication interruption.

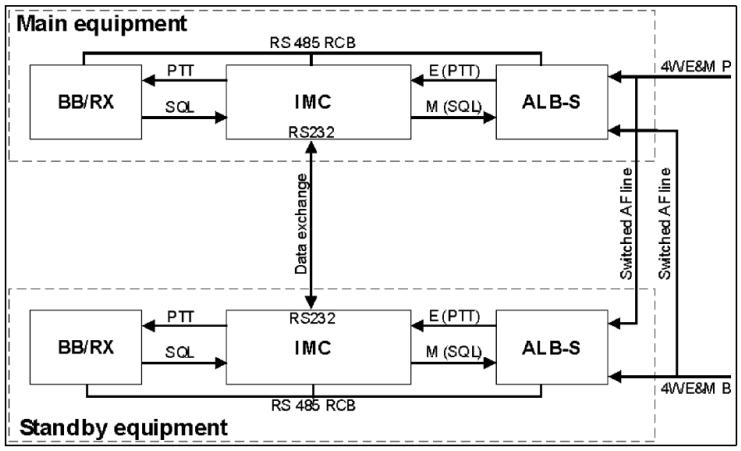

Figure 2. Interconnection Main and Standby Block Diagram of OTE DT100

Under normal operational conditions as shown in Figure 2, the IMC continuously monitors key system parameters such as Voltage Standing Wave Ratio (VSWR), transmitter output power, and internal communication status. When abnormal conditions are detected in the active transmitter, the IMC is expected to initiate immediate switching to the standby unit without requiring manual intervention. This automatic recovery mechanism is essential to support communication services that are expected to meet Required Communication Performance (RCP) criteria, particularly in terms of continuity and availability.

During a Daily Check conducted on 28 May 2024 at Minangkabau International Airport, a VSWR Level Comm Error was detected on Transmitter 1 (TX1) operating at the ADC frequency of 118.3 MHz. Field observations and maintenance logs indicated that the IMC failed to complete the automatic change-over process, causing the system to remain in a neutral (disconnected) state. As a result, the intended redundancy mechanism was rendered ineffective, and the system

operated without standby support. This condition represents a failure of the communication service rather than a single hardware malfunction, as the inability to recover automatically directly affects operational communication performance.

From the perspective of ICAO's RCP framework (International Civil Aviation Organization, 2017), communication performance is evaluated at the service level rather than as an equipment certification parameter. ICAO Doc 9869 defines continuity as the probability that a communication transaction is completed without unscheduled interruption, while availability represents the proportion of time that the communication service is operational and usable when required. The RCP framework assumes that communication systems supporting safety-critical operations achieve these performance levels through effective redundancy and timely fault recovery.

For ADC operations, RCP 60 is commonly referenced, reflecting operational environments where short communication delays or interruptions may still be tolerable, provided that continuity and availability remain within defined limits. ICAO technical documentation implicitly assumes that VHF voice systems supporting such operations maintain high availability through automatic recovery mechanisms. The observed IMC malfunction contradicts this assumption by preventing automatic transmitter switching, thereby increasing the likelihood of unscheduled communication interruption.

Table 2. RCP (Required Communication Performance) Standards Parameters

RCP Type	Transaction time (sec)	Continuity	Availability	Integrity
RCP 10	10	0.995	0.99998	10^{-5}
RCP 60	60	0.99	0.9995	10^{-5}
RCP 120	120	0.99	0.9995	10^{-5}
RCP 240	240	0.99	0.9995	10^{-5}
RCP 400	400	0.99	0.999	10^{-5}

The thematic analysis was conducted based on structured interviews with two licensed VHF communication technicians and supported by field observations, equipment fault logs, and quantitative performance records. Although the number of interview participants was limited, both technicians independently reported similar failure characteristics, indicating strong thematic convergence and internal consistency.

The first identified theme concerns technical degradation of the Interface and Management Card (IMC) module. Both technicians reported that IMC malfunction is frequently associated with component aging, insufficient thermal dissipation, and instability in the microcontroller and interface circuits. These conditions were also observed during on-site troubleshooting activities, particularly under prolonged transmitter operation and peak traffic conditions. Fault log records further indicate that VSWR-related alarms and loss of automatic change-over functionality occurred concurrently with these technical conditions, supporting the causal linkage between IMC degradation and communication service interruption. Such findings are consistent with established VHF system reliability principles, which recognize control and interface modules as critical failure points due to continuous operation and exposure to thermal and electrical stress.

The second theme relates to system support limitations, which indirectly influence IMC reliability. Both interviewees identified restricted availability of spare IMC components and limited access to advanced diagnostic training as contributing factors to prolonged system downtime following failures. Maintenance records confirm that delayed component replacement

extended periods of reduced availability, increasing reliance on reactive rather than preventive maintenance practices. This condition contrasts with ICAO's performance-based communication philosophy, which emphasizes proactive reliability management and redundancy effectiveness to sustain required communication performance.

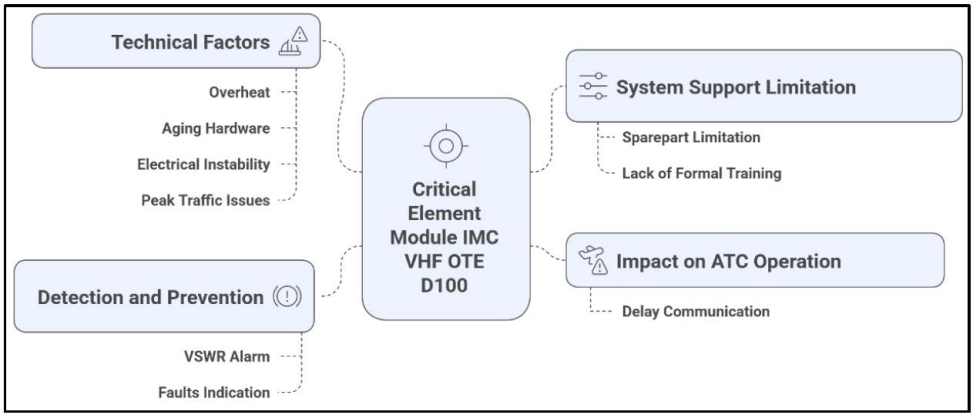

Figure 3. Thematic relationship between Interface and Management Card (IMC) failure factors and their impact on VHF aeronautical communication performance

Triangulation between interview findings, field observations, and quantitative performance measurements confirms that IMC malfunction represents a dominant contributor to communication service degradation. Quantitative analysis shows that IMC failure resulted in a measurable reduction in system availability to 0.9888, falling below the operational assumptions associated with RCP 60. Furthermore, the loss of automatic change-over capability directly compromises the continuity parameter, as manual intervention is required to restore transmitter functionality. This operational condition contradicts the redundancy assumptions embedded in ICAO Annex 10 Volume II and the Required Communication Performance framework, which assume immediate service continuity following equipment failure.

Overall, these findings suggest that while the OTE DT100 VHF radio system is fundamentally capable of supporting aerodrome control communication, degradation of the IMC module can temporarily undermine the redundancy mechanisms expected for RCP 60 compliance. While this single event does not imply a systemic collapse of safety-critical operations, it highlights a specific vulnerability where the communication service experiences degraded reliability, forcing ATC to rely on manual mitigations.

It is important to acknowledge the limitations of the qualitative evidentiary base in this case study. The insights regarding failure mechanisms such as the 2005era hardware aging and thermal dissipation were drawn from structured interviews with two technicians. While their field observations perfectly contextualize the quantitative downtime data and align with expected hardware lifecycle degradation, these thematic findings should be considered preliminary. They serve to explain the localized failure mechanism at Minangkabau International Airport rather than establish a definitive, nationwide diagnostic profile.

Conclusion

This case study evaluated the performance impact of an Interface and Management Card (IMC) module failure within a VHF aeronautical communication system against Required Communication Performance (RCP) 60 expectations. The analysis indicates that a failure in the automatic change-over mechanism can temporarily reduce system availability and continuity below the normative RCP 60 thresholds. While ATC can maintain operations via manual mitigation using portable radios, the absence of automated redundancy introduces unscheduled

interruptions that increase controller workload and potential communication delays.This study is subject to several limitations that should be acknowledged. The analysis was confined to a single airport facility and focused on one VHF system configuration, which limits the generalizability of the findings. In addition, qualitative insights were derived from a limited number of technicians, and performance evaluation relied on historical fault and downtime records rather than controlled experimental testing or long-term system monitoring.Future research should expand the scope of investigation by incorporating multiple airport facilities, different VHF system manufacturers, and extended observation periods to enable comparative and longitudinal analysis. Further studies may also integrate quantitative reliability modeling, redundancy performance simulation, or real-time monitoring of RCP parameters to more accurately characterize communication performance under varying operational and environmental conditions. Nevertheless, the findings of this study provide practical insight for air navigation service providers in identifying critical vulnerabilities within VHF communication systems. Strengthening preventive maintenance strategies, improving environmental control for key modules, and modernizing aging components are essential steps to ensure sustained compliance with ICAO RCP requirements and to enhance the reliability of air–ground communication services.

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