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DESIGN AND IMPLEMENTATION OF A MONITORING SYSTEM FOR DVOR EQUIPMENT STATUS USING LABVIEW

Kevin Raflyfasya[1*], Muhammad Arif Sulaiman[2], Havan Hakim[3]
[1]Kantor Otoritas Bandara Wilayah 10, Merauke, Indonesia
[2]Telecommunication and Navigation Engineering Study Programme,
Politeknik Penerbangan Indonesia Curug, Indonesia
[3]Airport Engineering Technology Study Programme, Politeknik Penerbangan Palembang, Indonesia
*Correspondence e-mail: kevin6@gmail.com

Abstract

The Doppler VHF Omnidirectional Range (DVOR) is a critical air navigation system that provides aircraft with azimuth information based on the Doppler effect. Monitoring of DVOR transmitter status at many facilities still relies on manual inspection or direct on-site intervention. This study designed and implemented a real-time DVOR status monitoring system in LabVIEW, integrated with RS-232 serial communication, and tested it on a THALES 432 DVOR at the CNS Laboratory of Politeknik Penerbangan Indonesia Curug. The system acquires serial data, parses the 5th byte of each data frame to classify the equipment status as Normal, Warning, or Alarm, and displays the results via color-coded LED indicators and a Waveform Chart, while logging timestamped records to an Excel file. Five functional tests across all three status conditions produced results fully consistent with the DVOR RCMS reference display, confirming the system's accuracy and reliability for real-time DVOR status monitoring.

Keywords: *air navigation, DVOR, LabVIEW, real-time monitoring, RS-232*

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Introduction

Doppler VHF Omnidirectional Range (DVOR) is a ground-based radio navigation aid operating in the VHF band (108–117.95 MHz) that provides aircraft with omnidirectional azimuth information relative to the ground station. Using the Doppler effect, the system compares the phase difference between a 30 Hz reference signal and a 30 Hz variable signal to determine the aircraft's bearing over the range 0° to 360°. The signal is periodically transmitted with a Morse code identifier, enabling pilots to verify the correct station before using it as a navigation reference. Effective range can approach 200 nautical miles at cruising altitude, though terrain and low-altitude operations significantly reduce it (Nugraha & Caesar, 2016).

The operational continuity of DVOR is governed by international and national standards that impose strict requirements on equipment availability and maintenance (Abrar et al., 2024; Siddik et al., 2026). ICAO Annex 10 prescribes performance standards for VOR/DVOR systems including signal accuracy, monitoring thresholds, and fault response times, requiring that ground-based monitoring systems detect out-of-tolerance conditions and initiate automatic changeover or shutdown within defined limits. In the Indonesian context, Peraturan Menteri Perhubungan and the technical directives issued by Airnav Indonesia stipulate that navigation aid equipment must be continuously monitored and that technicians must respond to alarms within prescribed response times (Simamora & Zainuddin, 2021). The DVOR THALES model 432, deployed at PPI Curug's CNS Laboratory and at operational sites across Indonesia, is equipped with an Automatic Data Recording and Control System (ADRACS) port that outputs equipment status data via RS-232 serial communication a hardware feature specifically intended to support external monitoring integration but which, in many laboratory and field installations, remains unutilized due to the absence of a compatible monitoring interface.

The reliability of DVOR operation is fundamental to aviation safety. Anomalies in transmitter status must be detected and rectified promptly to prevent navigational inaccuracies. Eibert et al. (2023) and Kinanti et al. (2025) stated that in current practice, monitoring of DVOR transmitter status often requires manual on-site inspection or reliance on the facility's proprietary Remote Control and Monitoring System (RCMS), which limits the ability to log historical data or provide automated alerts. Al-Ma'ruf & Tawakal (2022) demonstrated that an integrated monitoring design using RTL-SDR can improve technician efficiency; however, that approach relies on over-the-air signal capture and is subject to RF attenuation and interference. Ambarsari & Oktaviyan (2021) found that manual DVOR monitoring requires periodic physical inspections and lacks real-time capability, thereby underscoring the need for an automated solution.

Laboratory Virtual Instrument Engineering Workbench (LabVIEW) is a graphical programming environment developed by National Instruments and widely used in instrumentation and data acquisition (Istoni et al., 2025; Kalaivani et al., 2025). Its data-flow architecture and native integration with NI-VISA for serial communication make it well-suited for developing real-time monitoring interfaces for serial-connected equipment (Limbong et al., 2024). RS-232 serial communication provides a direct, low-latency data channel via the DVOR ADRACS port, offering improved stability over wireless or over-the-air approaches. Xu et al. (2025) and Yulianti et al. (2023) confirmed that RS-232-based serial communication is a reliable method for monitoring electronic equipment via a computer interface.

Among available software platforms for data acquisition and monitoring, LabVIEW was selected for this study based on three characteristics relevant to the DVOR monitoring problem. First, its native NI-VISA library provides direct, low-level RS-232 serial communication without requiring third-party drivers, ensuring compatibility with the DVOR THALES 432 ADRACS port output. Second, its data-flow programming paradigm, in which execution is driven by data availability rather than sequential instruction, naturally models the continuous polling architecture required for real-time serial monitoring. Third, its built-in Write to Measurement File node enables timestamped data logging in industry-standard formats (e.g., Excel .xlsx) without additional programming, directly addressing the logging gap identified in current RCMS-only monitoring practice. Kurniawan & Mulia (2022) noted that the signal quality and path-loss characteristics of DVOR affect the reliability of over-the-air monitoring approaches, further supporting the use of direct wired serial communication as a more robust alternative for equipment-level status monitoring. The combination of these factors positions LabVIEW integrated with RS-232 as a technically appropriate and practically deployable solution for the identified monitoring gap at the DVOR THALES 432 installation (Sembiring et al., 2025).

This study addresses the gap in automated, real-time DVOR status monitoring by designing and implementing a LabVIEW-based system that acquires serial data directly from the DVOR THALES 432 transmitter, parses the data stream to determine equipment status, visualizes the results in real time, and logs timestamped data to Excel for post hoc analysis. The system was developed and tested at the CNS Laboratory of Politeknik Penerbangan Indonesia Curug from January to July 2025.

Methods

This study applied a Research and Development (R&D) approach using the ADDIE model, with the steps Analysis, Design, Development, Implementation, and Evaluation, to design and implement a real-time DVOR equipment status monitoring system. The ADDIE model was selected for its iterative and systematic nature, enabling a structured progression from needs identification through design, prototype development, deployment, and functional evaluation, consistent with its application in hardware-integrated software development studies (Abuhassna et al., 2024; Spatioti et al., 2022). Research was conducted at the DVOR laboratory in the CNS Building of Politeknik Penerbangan Indonesia Curug from January to July 2025, using a DVOR THALES model 432 as the target equipment.

In the Analysis stage, direct observation of the DVOR THALES 432 at the CNS Laboratory was conducted to identify system requirements and constraints. Observation confirmed that the DVOR transmits status data continuously through its ADRACS (Automatic Data Recording and Control System) port via RS-232 serial communication. The RCMS (Remote Control and Monitoring System) display in the laboratory serves as the reference monitor for Normal, Warning, and Alarm conditions but does not provide automated data logging or remote access. This establishes the primary functional requirements for the monitoring system: (1) real-time serial data acquisition from the DVOR ADRACS port, (2) automated status classification, (3) visual status display, and (4) timestamped data logging for post-hoc analysis.

In the Design stage, the system architecture was specified across three layers: hardware connectivity, software structure, and data flow. For hardware connectivity, the DVOR ADRACS RS-232 output (DB-9 connector) is connected to a laptop via two Aten DB9-to-USB converters in series, with Pin 3 (TXD) from the DVOR connected to Pin 2 (RXD) at the laptop and Pin 5 (GND) as the common reference. For software structure, the LabVIEW VI was designed as a While Loop containing five sequential functional modules: (1) serial port initialization via VISA Configure Serial Port, (2) data acquisition via VISA Read (206 bytes per iteration), (3) byte-array parsing and header verification, (4) status classification via Case Structure, and (5) data logging via Write to Measurement File. The VISA serial port parameters were set to match the DVOR THALES 432 transmission specification: 19,200 bps baud rate, 8 data bits, no parity, 1 stop bit, and no flow control. Prior to finalizing the design, Serial Monitor Eltima was used to capture and inspect raw byte streams from the DVOR under Normal, Alarm, and Warning conditions to identify the data frame structure and determine the position of the status-encoding byte.

In the Development stage, the LabVIEW block diagram was built incrementally in five modules and tested individually before integration. In the initialization module, VISA Configure Serial Port was wired to set the

COM port, baud rate, data bits, parity, stop bits, and flow control, with the resource name connected to a Front Panel control for flexibility (Sivaranjani et al., 2021). In the data acquisition module, VISA Read was configured to read 206 bytes per iteration from the serial buffer, with the byte count determined from the frame length identified during the Analysis stage. In the parsing module, String to Byte Array converted the VISA Read output to a U8 array; Search 1D Array located the header byte (0xC9); a Verify Header sub-routine confirmed the header trail sequence (header+1=0x06, header+2=0xC0, header+3=0x06); and the 5th byte (header+4) was extracted as the status-discriminating field.

A shift register was added to retain unprocessed bytes across While Loop iterations, preventing data loss from partial frame arrivals. In the status classification module, a Case Structure evaluated the 5th-byte counter pattern against the three identified ranges and assigned a status index (1=Normal, 2=Warning, 3=Alarm) with priority ordering Normal > Warning > Alarm; the result drove LED indicators (green/yellow/red) and a Waveform Chart on the Front Panel. In the logging module, Write to Measurement File was configured to save one file per session with time-stamped records in Excel (.xlsx) format, with Segment Headers set to "One header only" and Action set to "Save to one file" to produce a continuous log.

In the Implementation stage, the integrated VI was deployed at the CNS Laboratory DVOR workstation. The RS-232 hardware connection was established, and the COM port assignment was verified via Device Manager before running the program. In the Evaluation stage, five functional test scenarios were designed to cover all three status conditions: two tests for the Normal condition (Tests 1 and 5), two tests for the Alarm condition (Tests 2 and 4), and one test for the Warning condition (Test 3). Each test was evaluated by comparing the status displayed on the DVOR RCMS panel (ground truth) with the LED indicator state and Waveform Chart value displayed on the LabVIEW Front Panel. A result was recorded as "Match" if the LabVIEW status indicator corresponded exactly to the RCMS display, and as "Consistent" if the correspondence was maintained throughout the observation period.

Results And Discussions

System Design

The DVOR monitoring system connects the DVOR THALES 432 ADRACS RS-232 output port to a laptop via DB9-to-USB converters. Three pins of the DB-9 connector are used: Pin 3 (TXD transmit from DVOR), Pin 2 (RXD receive on the laptop), and Pin 5 (GND). Pin configuration is detailed below:

Table 1. RS-232 Pin Configuration

Pin	Signal	Direction	Function
2	RXD (Receive Data)	Input to DVOR / PC	Receives data from external device
3	TXD (Trans. Data)	Output from DVOR	Transmits data to laptop/LabVIEW
5	GND (Ground)	Reference	Common voltage reference for stable communication

Figure 1 illustrates the RS-232 wiring schematic connecting the DVOR ADRACS port to the monitoring computer.

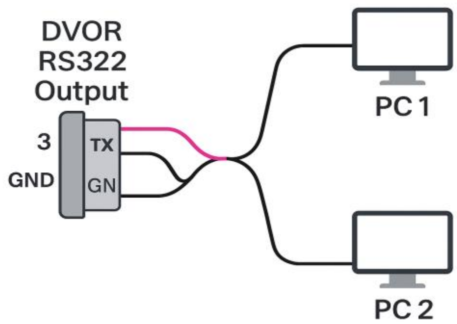

Figure 1. RS-232 Wiring Schematic for DVOR-to-LabVIEW Connection

The LabVIEW VI was structured as a While Loop containing four functional modules: (1) VISA Configure Serial Port initializes the RS-232 connection; (2) VISA Read acquires 206 bytes per iteration from the serial buffer; (3) a parsing module converts the string to a U8 byte array, searches for the packet header (0xC9), verifies the header trail, and extracts the 5th byte as the status-encoding field; and (4) a Case Structure evaluates the 5th byte value and assigns a status index with priority ordering Normal > Warning > Alarm. Status is displayed via color-coded LED indicators and a Waveform Chart. All data with timestamps are written to an Excel file via Write to Measurement File. Details of the VISA serial port configuration parameters used shown in Table 2.

Table 2. VISA Serial Port Configuration Parameters

Parameter	Setting	Rationale
COM Port	Device-dependent	Set to port assigned by OS to USB-RS232 adapter; verify via Device Manager
Baud Rate	19200 bps	Matches DVOR THALES 432 specification; prevents character loss
Data Bits	8	Standard 8-bit frame encoding for RS-232 serial communication
Parity	None	No parity bit; connection quality assumed stable with direct cabling
Stop Bits	1	Single stop bit; standard for RS-232 at 19200 bps
Flow Control	None	DVOR is TX-only; flow control is unnecessary

Data Frame Analysis

Prior to building the LabVIEW VI, Serial Monitor Eltima was used to capture raw byte streams from the DVOR under Normal, Alarm, and Warning conditions. Comparative analysis of the captured frames revealed that the 5th byte at position header+4 is the status-discriminating field. Table 3 summarizes the identified byte patterns for each condition.

Table 3. DVOR Data Frame: 5th Byte Status Patterns

Status	5th Byte Pattern	Index	Characteristic
NORMAL	0x37, 0x38, 0x39 (increment +1)	1	Simple counter +1 per frame; consistent and predictable
WARNING	Variable (e.g. 0x31–0x34); ByteB ≈0x92 (constant)	2	ByteB is likely a status/type field; ByteA acts as counter within warning condition
ALARM	0x4C, 0x4D, 0x4E (increment +1)	3	Distinct counter range from NORMAL; separate frame type for fault condition

Figure 2 shows the frame comparison output from Serial Monitor Eltima, illustrating the visible difference at the 5th byte position between Normal and Alarm frame sequences.

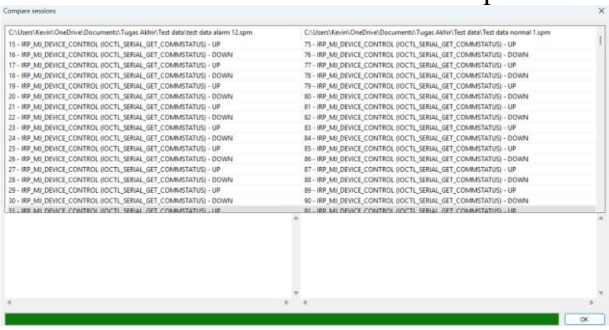

Figure 2. Serial Monitor Eltima: Comparative Frame Analysis (Normal vs. Alarm Warning)

The NORMAL condition exhibits a +1-counter pattern (0x37→0x38→0x39) indicating standard frame sequencing. The ALARM condition uses a distinct counter range (0x4C→0x4D→0x4E), representing a separate frame type for fault reporting. In the WARNING condition, the 5th byte varies while ByteB remains approximately constant at 0x92, suggesting ByteB encodes the condition type. These distinct patterns form the basis for automated status classification in the LabVIEW Case Structure.

System Testing

Five functional test scenarios were conducted on 26 August 2025 at the CNS Laboratory. Each test evaluated correspondence between the DVOR RCMS display (ground truth) and the LabVIEW Front Panel, summarized in Table 4.

Table 4. Functional Test Results: RCMS Display vs. LabVIEW Display

Test	Date	RCMS Display	LabVIEW Disp.	Result	Remark
1st	26/08 /2025	Normal — green, stable	Normal — green LED,	Match	Consistent

Test	Date	RCMS Display	LabVIEW Disp.	Result	Remark
			chart at 1		
2nd	26/08 /2025	Alarm — red, exceeded	Alarm — red LED, chart at 3	Match	Consistent
3rd	26/08 /2025	Warning — yellow, near limit	Warning — yellow LED, chart at 2	Match	Consistent
4th	26/08 /2025	Alarm — red, error detected	Alarm — red LED, chart at 3	Match	Consistent
5th	26/08 /2025	Normal — green, all safe	Normal — green LED, chart at 1	Match	Consistent

All five tests produced fully consistent results between the RCMS display and LabVIEW interface, confirming accurate real-time status detection across all three conditions. Figure 3 illustrates representative test outputs for Alarm and Normal conditions, respectively.

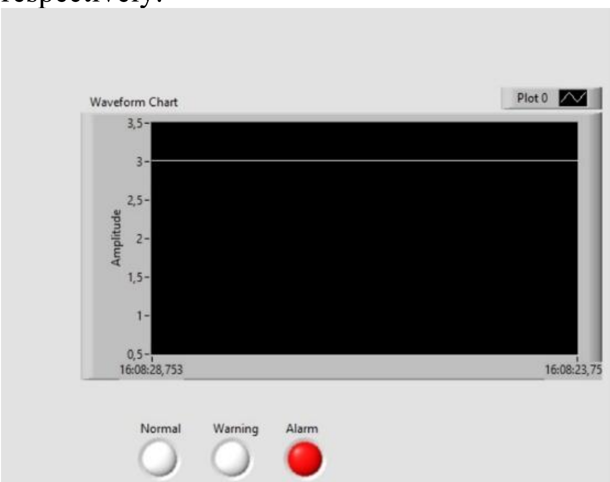

Figure 3. Test Result: Alarm Condition-Red LED Active, Waveform Chart at Value 3

The system demonstrated 100% correspondence between RCMS reference and LabVIEW interface across all five test scenarios. The key technical contribution is the data-frame parsing approach: by identifying status directly from the 5th-byte counter pattern, the system avoids reliance on high-level protocol decoding, thereby reducing processing overhead and ensuring a low-latency response suitable for continuous monitoring. Compared to the RTL-SDR-based approach of Al-Ma'ruf & Tawakal (2022), which captures the DVOR signal over the air and is subject to signal attenuation and environmental interference, the RS-232 direct serial connection provides a more stable and deterministic data source, eliminating the need for antenna positioning and RF front-end hardware. This aligns with Dewi (2024), who confirmed RS-232 as a reliable medium for monitoring electronic equipment via a computer interface.

The LabVIEW data-flow architecture, as described by Samkria et al. (2021), proved well-suited to this application. The While Loop enables continuous serial port polling; the shift register retains unprocessed bytes across iterations to handle partial frame arrivals, and write to measurement file provides automatic timestamped logging, a significant operational advantage over RCMS-only monitoring, offering a persistent record for maintenance analysis and trend identification.

Several limitations should be noted. The system was tested exclusively on the DVOR THALES 432; the byte-frame structure and status-encoding byte position may differ across other DVOR models or manufacturers, requiring re-analysis before deployment on different equipment. The current implementation does not include automatic notification upon Alarm detection, which is critical for operational deployment (Abrar et al., 2024). Additionally, the RS-232 channel is unencrypted, posing data security risks in networked environments (Sanjaya & ElAarag, 2022). Future development should address notification integration, expanded equipment compatibility, and communication security.

Conclusion

This study successfully designed and implemented a real-time DVOR equipment status monitoring system using LabVIEW integrated with RS-232 serial communication, tested on the DVOR THALES 432 at the CNS

Laboratory of Politeknik Penerbangan Indonesia Curug. The system acquires serial data at 19,200 bps, parses the 5th byte of each data frame to classify status as Normal (index 1), Warning (index 2), or Alarm (index 3), and displays results via colour-coded LED indicators and a Waveform Chart while logging timestamped records to Excel. All five functional tests produced results fully consistent with the DVOR RCMS reference, confirming accuracy and reliability across all three status conditions. The RS-232 wired connection provides improved stability over over-the-air methods, and automated logging delivers a persistent maintenance record not available from RCMS alone. Future work should focus on automatic alarm notification, compatibility with other DVOR equipment types, and data security implementation for operational deployment.

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