Vol. 7, No. 1, February 2025, pp. 53~64, p-ISSN 2685-2381, e-ISSN 2715-2626
http://dx.doi.org/10.28989/avitec.v7i1.2847

# Anomalous Investigation of ILS Glide Path Signals on Runway 24 at the Jakarta Air Traffic Service Center

**Muh Wildan[1]*, Priyo Wibowo[2], Mochamad Sugeng Wicaksono[3], Muhammad Arif Sulaiman[1], Eldo Tri Rahmadani[1], Muhamad Adimukti Prasojo[1]**
[1]Air Navigation Engineering, Indonesia Civil Aviation Polytechnic, Indonesia
[2]Research Center for Testing Technology and Standard, National Research and Innovation Agency, Indonesia
[3]Navigation and Surveillance Division, Jakarta Air Traffic Service Center - Airnav Indonesia, Indonesia

**Article Info**

**Article history:**
Submitted January 30, 2025
Accepted February 14, 2025
Published February 17, 2025

**ABSTRACT**

Precision landing guidance is critical for aircraft safety, yet recurring signal anomalies in the ILS Glide Path on runway 24 at the Jakarta Air Traffic Service Center raise concerns about approach and landing reliability. Despite compliance with standard regulations, persistent signal anomalies affecting glide slope accuracy raise concerns about safe aircraft approach. This study investigates the sources of distortion, quantifies their impact on ILS Glide Path performance, and proposes mitigation strategies. Spectrum analysis, environmental assessments, and signal evaluation through oscilloscopes and navigation analyzers were employs to identify and quantify sources of distortion. Results indicate that while composite audio signals comply with standards, navigation analyzer readings reveal persistent deviations in Difference in Depth of Modulation (DDM) due to harmonic distortions at 30 Hz and its multiples up to 450 Hz. These distortions could interfere with DDM values received by calibration aircraft, making conventional technical adjustments, such as power level settings and antenna reconfigurations, insufficient for complete resolution. Instead, alternative mitigation approaches including reducing environmental reflections, optimizing siting criteria, and refining regulatory compliance measures are recommended. These findings provide valuable insights for enhancing ILS Glide Path reliability, refining signal mitigation strategies, and ensuring regulatory compliance for safer aviation navigation systems.



**Keywords:**
ILS Glide Path;
glide slope accuracy;
signal anomalies;
harmonic distortion;
siting criteria.

***Corresponding Author:***
Muh Wildan,
Teknik Navigasi Udara, Politeknik Penerbangan Indonesia Curug, Tangerang, Indonesia,
Jl. Raya PLP Curug, Serdang Wetan, Kec. Legok, Tangerang, Banten 15820.
Email: *muh.wildan@ppicurug.ac.id

## 1. INTRODUCTION

The Instrument Landing System (ILS) is a crucial navigation aid used for precision approach and landing at airports. It provides both lateral and vertical guidance to pilots, ensuring safe landings, particularly in low-visibility conditions. The Instrument Landing System (ILS) is a non-visual navigation instrument that utilizes radio waves to assist pilots in conducting accurate approach and landing procedures at an airport [1] [2]. The accuracy of this guidance is highly dependent on the quality of the transmitted signal generated by the ILS. The runway centerline alignment guidance is provided by the ILS Localizer (ILS LOC), while the landing angle guidance, with an approximate slope of ±3 degrees to ensure the aircraft reaches the correct touchdown point, is provided by the ILS Glide Path (ILS GP). The ILS LOC operates in the VHF frequency range between 108 MHz and 111.975 MHz, whereas the ILS GP operates in the UHF frequency range between 328.6 MHz and 335.4 MHz [3] [2] [4]. The ILS functions by modulating 90 Hz and 150 Hz audio signals onto the RF signal, resulting in a Difference in Depth of Modulation (DDM) value, which represents the modulation comparison received by the aircraft. A DDM value of 0 indicates that the aircraft is precisely aligned with the runway centerline or the designated glide slope for landing [5] [6].

Recent flight inspection data from Runway 24 at the Jakarta Air Traffic Service Center (JATSC) – Soekarno-Hatta Airport, revealed signal instability in the ILS GP transmission. Specifically, an anomalous reverse crossing effect was detected at point A to B that is between 4 Nautical Miles (NM) and the runway threshold. Such deviations indicate non-compliance with standard tolerances, prompting the need for an in-depth investigation into the underlying causes of these anomalies. Refer to [4], standard value DDM course structure

ILS GP in point A to point B must be linear decrease to 15 µA (Cat I). The transmitted signal data read more than 15 uA at points A and B, so it does not meet the permissible tolerance standards, as illustrated in Figure 1.

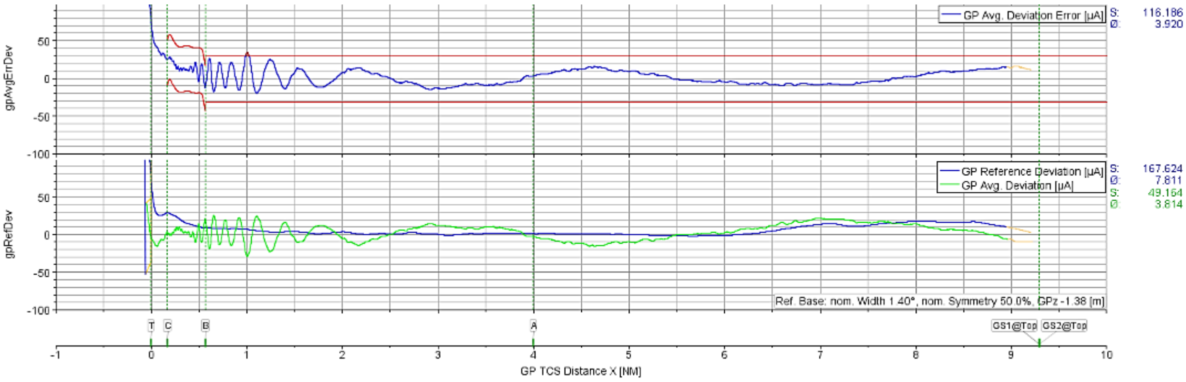



Figure 1. ILS GP Average Deviation (µA) Graph on Calibration Aircraft on runway 24 at JATSC [7]

Meanwhile, the installation layout of the ILS GP equipment on Runway 24 is shown in Figure 2 below.


Figure 2. ILS GP Equipment Installation on Runway 24

Previous studies have analyzed ILS disturbances caused by various factors, including electromagnetic interference (EMI), multipath reflections from terrain and buildings, and system calibration errors. However, there remains a lack of comprehensive research addressing combined technical and environmental influences on ILS GP performance at Soekarno-Hatta Airport.

While studies such as [8] analyzed solutions for assessing the impact of electromagnetic fields at airports. The influence of the Northeast Two Hills on the Glide Path transmission for Runway 36 at Sam Ratulangi Airport, Manado, was studied by [9]. The modeling of ILS glide slope antenna transmission in relation to the surrounding terrain using half-plane geometry was examined by [10]. The analysis of multipath interference caused by obstacles affecting ILS transmissions was investigated by [11]. Furthermore, the impact of buildings on ILS Glide Path antenna transmissions was analyzed by [12], while [13] conducted computer-based modeling to evaluate ILS GP transmissions in relation to terrain conditions. The objective of this study is to analyze the causes of anomalies in the ILS Glide Path signal transmission for Runway 24, specifically the instability of the signal (reverse crossing) in the DDM parameter of the landing angle (glide slope) within the landing area, from a distance of 4 NM up to the runway threshold. This analysis aims to ensure the smooth operation of air navigation services using the ILS facility on Runway 24 at the Jakarta Air Traffic Service Center (JATSC) – Soekarno-Hatta Airport, in accordance with Instrument Flight Rules (IFR).

This research aims to bridge that gap by conducting a thorough technical analysis and environmental assessment to pinpoint the primary factors affecting ILS GP signal propagation at Runway 24. This study is designed to evaluate the technical integrity of the ILS GP transmission by measuring signal modulation, harmonic distortions, and power levels. Compare ILS GP performance across different airport locations (Adi Sucipto and Juanda Airports) is also conducted to determine whether anomalies are site-specific or systemic.

## 2. RESEARCH METHODS

This study adopts a mixed-methods approach, combining technical signal measurements and environmental assessments to analyze anomalies in the Instrument Landing System Glide Path signal on Runway 24 at the Jakarta Air Traffic Service Center (JATSC) – Soekarno-Hatta Airport. The methodology follows a structured workflow to ensure comprehensive data collection, analysis, and validation.

### 2.1 Research Framework

This study employs a systematic, stepwise methodology to identify and evaluate potential factors contributing to Instrument Landing System Glide Path signal instability. The research framework, as illustrated in Figure 3, comprises the following key stages.

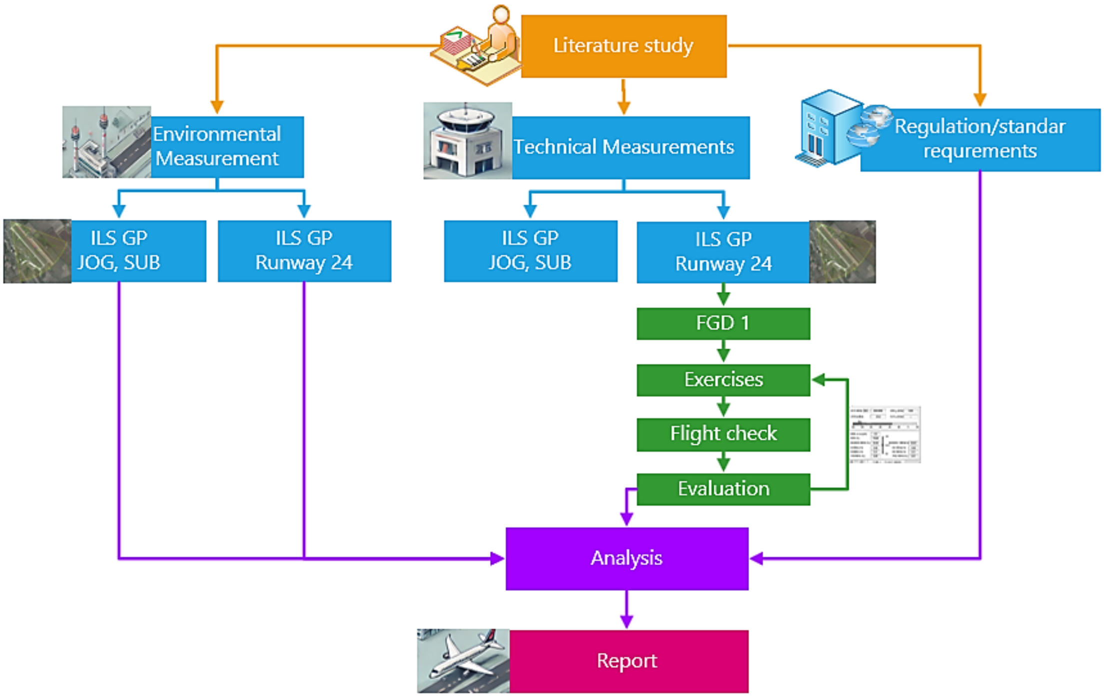



Figure 3. Flowchart of Research Methodology

a. Literature Review and Regulatory Compliance Check
   i. A comprehensive review of relevant literature and International Civil Aviation Organization (ICAO) standards (Annex 10, Volume I) was conducted to establish a foundation for understanding ILS signal interference and performance criteria.
   ii. Standard tolerances for key parameters, including Difference in Depth of Modulation (DDM), Sum Depth of Modulation (SDM), and RF transmission characteristics, were identified to serve as benchmarks for evaluating signal stability.
b. Initial Equipment Condition Assessment
   i. A detailed inspection of the ILS GP transmitter was performed to assess critical operational parameters, including power output, modulation depth, and antenna phasing.
   ii. The transmitter's performance was verified against the manufacturer's specifications to ensure compliance and rule out equipment malfunctions as a primary cause of signal instability.
c. Technical Signal Measurements
   i. Oscilloscope Analysis: Used to assess composite audio signals (90 Hz and 150 Hz) to verify proper modulation and phase alignment.
   ii. Navigation Analyzer Testing: Measures the Difference in Depth of Modulation (DDM) and Sum Depth of Modulation (SDM) to evaluate signal stability and compliance with ICAO standards.
   iii. Spectrum Analyzer Testing: Identifies potential harmonic distortions and unintended RF emissions that may interfere with ILS GP performance.
   iv. Vector Network Analyzer (VNA) Testing: Evaluates antenna impedance matching and return loss to ensure optimal signal transmission and minimize reflections.
d. Comparative Benchmarking with Other Airports
   i. To determine whether the observed anomalies at Soekarno-Hatta Airport were equipment-specific or influenced by external factors, similar ILS GP frequency spectrum measurements were conducted at Adi Sucipto (JOG) and Juanda (SUB) Airports.
   ii. This comparative analysis provided insights into the potential role of localized environmental or operational conditions in signal instability.
e. Environmental Assessment
   i. On-site Observations: Terrain conditions, obstacles, and reflective surfaces within the critical and sensitive areas surrounding the ILS GP antenna were measured and documented.

ii. Geospatial Analysis Using Google Earth: Permanent structures, such as fences, rivers, and buildings, were identified and analyzed to assess their potential contribution to multipath interference.

f. Data Correlation and Analysis

i. Signal parameters were compared before and after equipment adjustments to quantify the impact of technical interventions on signal stability.

ii. The correlation between environmental factors (e.g., terrain, obstacles) and observed reverse crossing signal instability was evaluated to identify potential causal relationships.

### 2.2 Justification for Measurements

Each measurement technique was selected based on its ability to address specific research questions. Oscilloscope Analysis: Ensures that the modulated signal contains the correct composite frequency components (90 Hz and 150 Hz), which are essential for accurate DDM and SDM formation. Navigation Analyzer: Provides precise readings of DDM drift, SDM balance, and RF power levels—critical parameters for evaluating ILS GP stability. Spectrum Analyzer: Detects unwanted harmonic frequencies and spurious emissions that may interfere with aircraft reception of the ILS signal. VNA Testing: Identifies any impedance mismatches or antenna inefficiencies that could lead to RF signal degradation. Comparative Airport Benchmarking: Helps distinguish whether the anomaly is due to equipment malfunctions or local environmental factors. Environmental Observations and Google Earth Analysis provides insights into terrain-induced multipath interference and ensures compliance with ICAO antenna siting criteria.

The height of the ILS GP antenna is analyzed for compliance based on the Equations (1) - (4) [14]. Incorrect antenna height can exacerbate multipath interference, where signals reflect off terrain, buildings, or other obstacles. This can distort the ILS signal, causing fluctuations or false indications in the glide slope guidance.

Lower Antenna Height ($h_{A1}$),

$$h_{A1} = \frac{\lambda}{4} sin 3° \quad (1)$$

Middle Antenna Height ($h_{A2}$),

$$h_{A2} = 2(h_{A1}) \quad (2)$$

Upper Antenna Height ($h_{A3}$),

$$h_{A3} = 3(h_{A1}) \quad (3)$$

Wavelength,

$$\lambda = \frac{c}{f} \quad (4)$$

The measurement of the frequency spectrum transmission quality is conducted to identify sources of interference, both intentional and unintentional, such as Electromagnetic Interference (EMI) [15], Co-channel Interference, Adjacent Channel Interference [16], Multipath Interference, and Intermodulation [17]. The impact of RF interference can result in disturbances in the RF transmission signal, such as Signal Degradation, Noise, Data Loss [18], Fading, and Signal Fluctuations.

Spurious emissions in Radio Frequency transmissions are also analyzed outside the main band to ensure that the transmitted signal does not interfere with other frequencies, including harmonics, intermodulation [19], sidebands, and noise emissions [20]. When a system operates at a fundamental frequency $f_0$, harmonics occur at frequencies $2f_0, 3f_0, 4f_0, \ldots$ and so on. These harmonic frequencies are undesirable components that distort the original signal or waveform. Harmonics can occur in both radio frequency and audio frequency transmissions. Another important parameter is Total Harmonic Distortion (THD). THD is expressed as a percentage and indicates the extent of distortion relative to the original signal. THD can be expressed as Equation (5) [21],

$$THD = \sqrt{\frac{V_1+V_2+V_3+\cdots+V_n}{V_1}} \times 100\% \quad (5)$$

with: $V_1$ being the amplitude of the fundamental frequency,
$V_2 + V_3 + \cdots + V_n$ representing the amplitude of the frequencies.

Interference from FM radio broadcasts and electrically powered railway lines can significantly impact aviation navigation systems, particularly the Instrument Landing System (ILS) [17], [22]. Third-order intermodulation distortion from FM stations can cause interference that adversely affects flight navigation [22]. This disturbance can lead to disrupted audio communication, distorted signal reception, and errors in directional deviation [17]. Multipath effects, caused by signal reflections and scattering, also impact the operational performance of ILS [23]. To mitigate these issues, various solutions have been proposed, including the application of filters at broadcasting stations [22] and the design of improved receivers based on spatial spectrum estimation concepts [23]. Additionally, electromagnetic compatibility analysis and compliance are crucial when constructing public facilities near airports to ensure the safe operation of navigation lighting systems [24].

Technical measurements using a spectrum analyzer were conducted on the ILS GP signal transmission at Runway 24, Soekarno-Hatta, and the results were compared with those from ILS GP at Adi Sucipto Airport, Yogyakarta, and Juanda Airport, Surabaya. The environmental assessments were carried out in the critical and sensitive areas around the ILS GP antenna on Runway 24. The siting criteria for antenna installation are significantly influential as they are a key factor in the success of signal transmission, which in turn impacts the provision of flight navigation services.

The position of the ILS GP antenna installation in Figure 4(a), is shown the ideal airport runway location, while Figure 4(b) illustrates the standard criteria for ILS GP antenna siting within the boundaries of critical and sensitive areas. The measurements were conducted using direct observation of objects around the antenna, along with an analytical method utilizing the Google Earth application. The collected data were evaluated and compared to provide an in-depth analysis of the root causes of the ILS GP signal disturbance on Runway 24, JATSC, and were also compared to the terrain conditions of the ILS GP at Adi Sucipto Airport, Yogyakarta, and Juanda Airport, Surabaya.

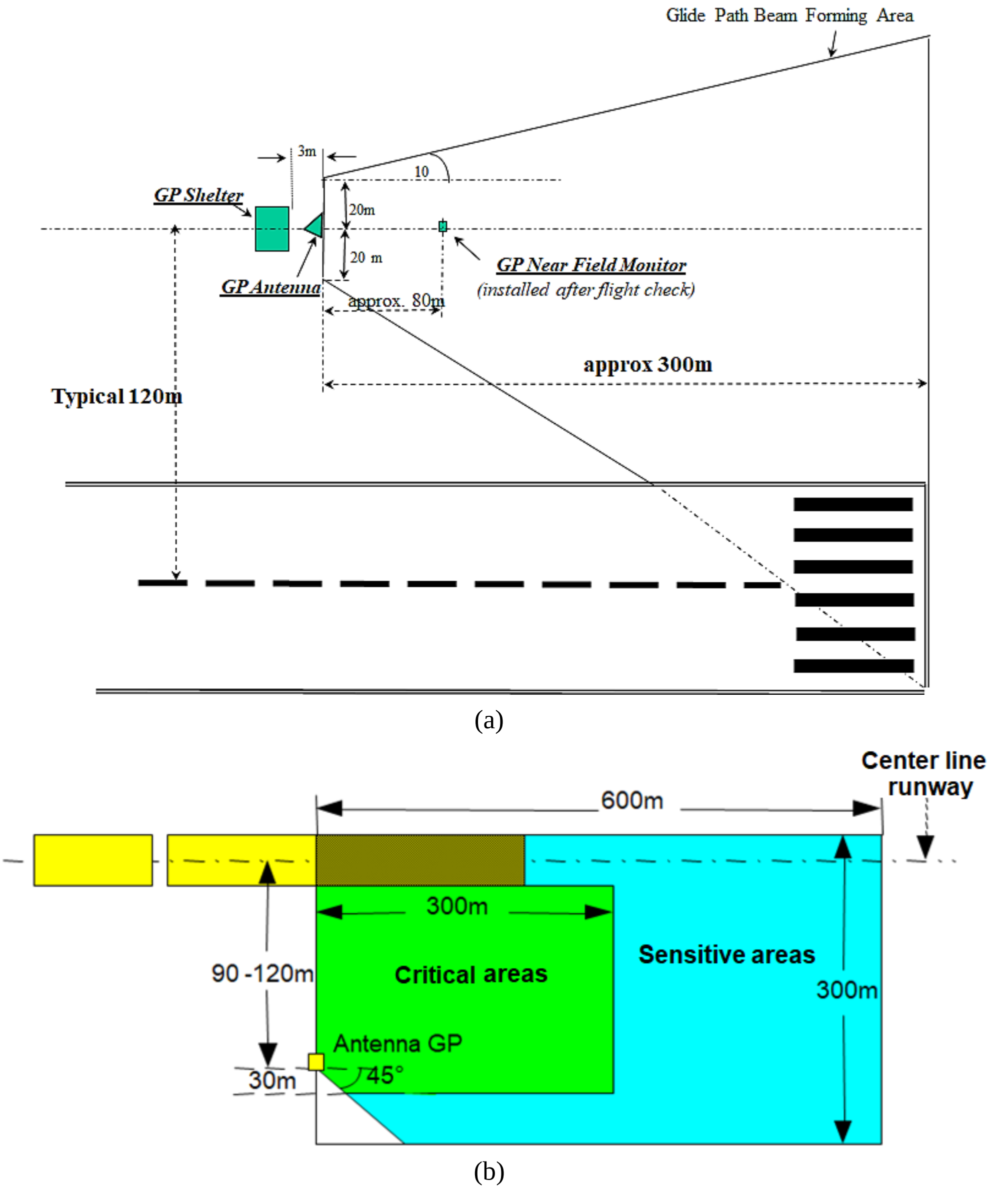



Figure 4. (a) Typical ILS GP Antenna Installation and (b) ILS GP Antenna Siting Criteria

Primary data collection on the technical equipment was performed through direct measurements using instrument measuring devices, including an Oscilloscope, Navigation Analyzer, Spectrum Analyzer, and Vector Network Analyzer. Meanwhile, environmental measurements were conducted by observing and measuring the distance and height of obstacles in the critical and sensitive areas, in accordance with the applicable equipment siting standard criteria.

## 3. RESULT AND DISCUSSION

Checking transmitter data is conducted first before performing technical measurements of equipment with measuring instruments that have been prepared. This involved inspecting the transmitter power output of the ILS, specifically at the CSB Course, SBO Course, and CSB Clearance on TX1 and TX2. Figure 5 shows the power output conditions working normally, with TX1 at 4.62 W and TX2 at 4.68 W for the CSB Course, TX1 at 0.46 W and TX2 at 0.44 W for the SBO Course, and TX1 at 2.82 W and TX2 at 3.10 W for the CSB CLR.

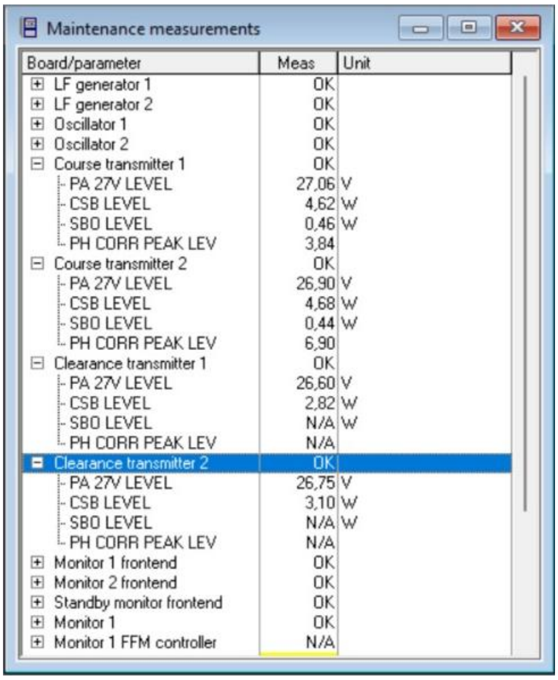
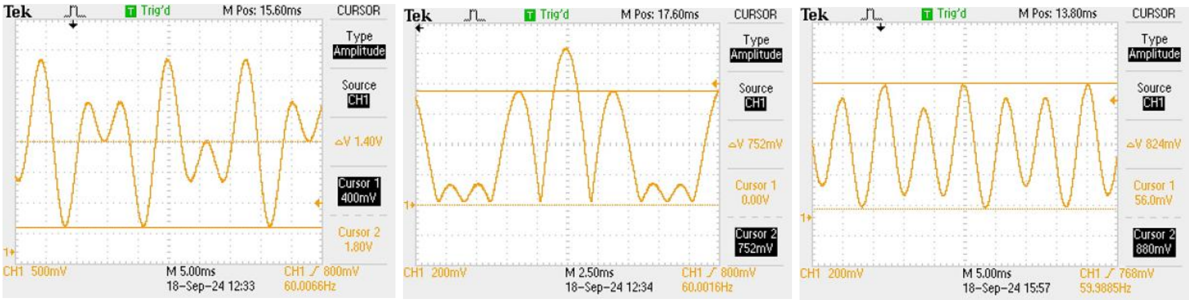



Figure 5. Transmitter Equipment Data

The next measurement was the waveform of the composite signal with frequencies of 90 Hz and 150 Hz during the signal mixing of CSB and SBO, using an Oscilloscope. Figure 6 shows the waveform measurements of the three RF Outputs: CSB COU, SBO COU, and CSB CLR, all of which are still in normal condition.

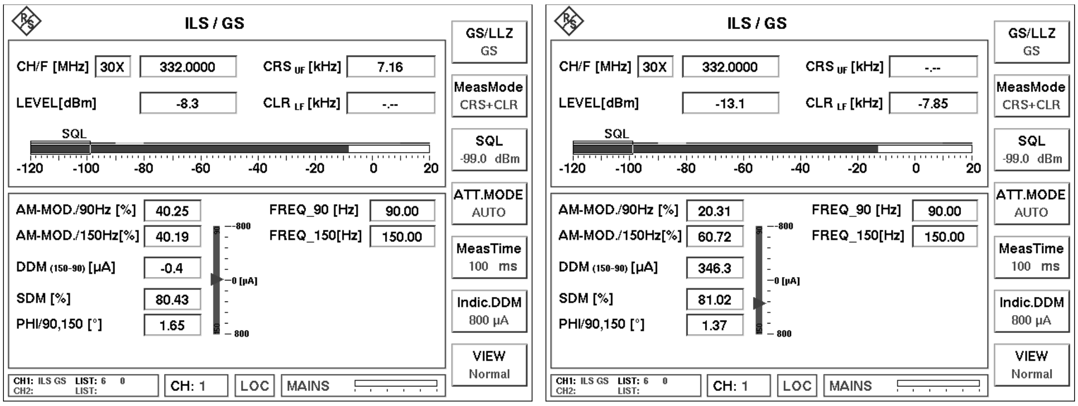



(a) (b) (c)

Figure 6. Composite Audio Signal Waveform Data ILS GP: (a) CSB COU, (b) SBO COU, (c) CSB CLR

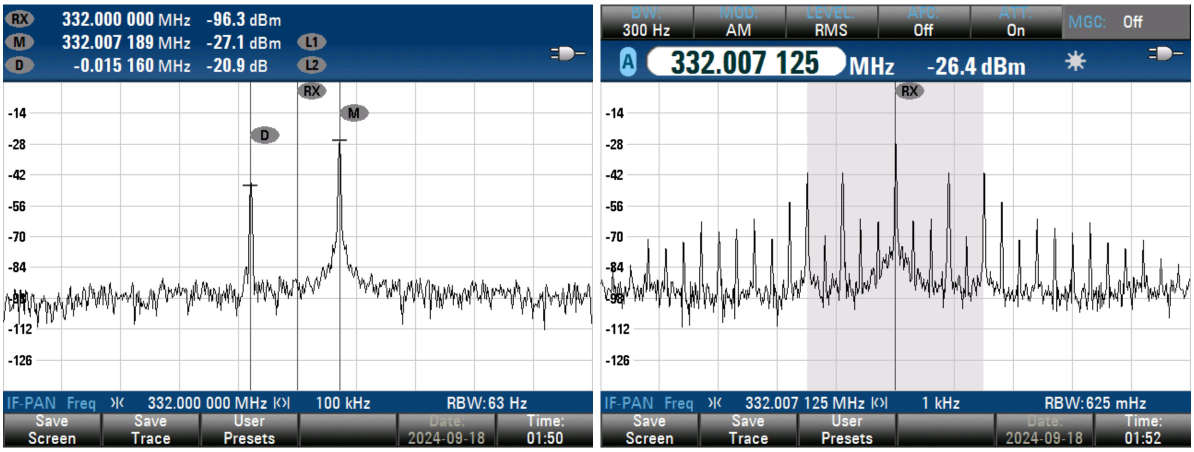
The next signal parameter measurement was the DDM and SDM parameters on the RF Course and RF Clearance using the Navigation Analyzer. Figure 7 shows that the measured values are also within normal conditions, with the DDM and SDM values on the RF Course being -0.4 µA and 80.43%, respectively, while the DDM and SDM values on the RF Clearance are 346.3 µA and 81.02%. The Difference Frequency between the RF Course and RF Clearance is 15.01 kHz.

The frequency spectrum measurement on the ILS GP transmission was also analyzed. Figure 8 shows the spectrum measurement, where the difference frequency between RF Course and RF Clearance was measured as normal at 15.16 kHz. However, during the audio measurement with a 1 kHz span, the frequency measured at RF Course was 332.007125 MHz with an RF level of -26.4 dBm. Distortion was found in the audio frequencies at 30 Hz, 60 Hz, 120 Hz, 180 Hz, 240 Hz, 270 Hz, 300 Hz, and 450 Hz. This could cause interference and potentially affect the quality of the DDM signal parameters being transmitted and received by the aircraft.



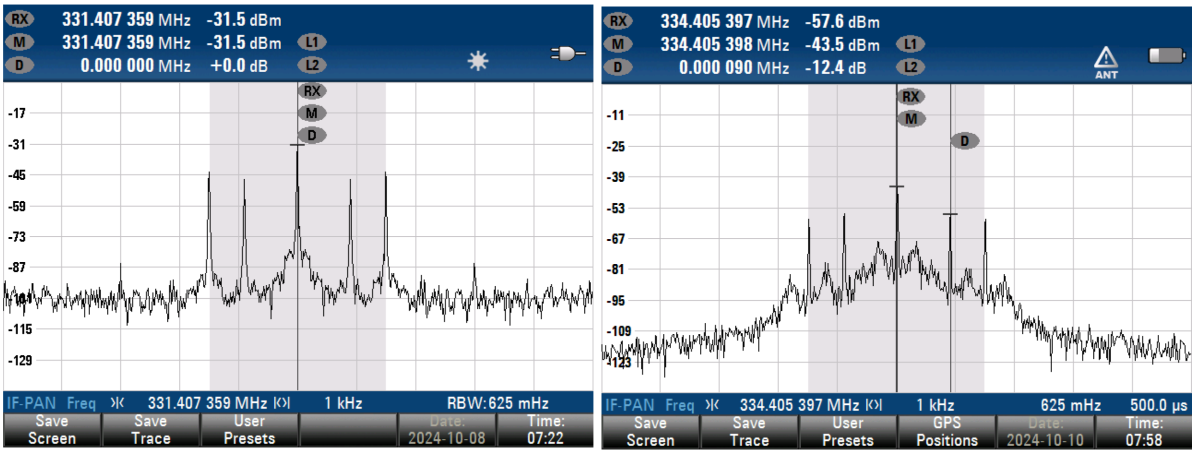
(a) (b)

Figure 7. DDM and SDM Measurement Data ILS GP: (a) RF Course, (b) RF Clearance



(a) (b)

Figure 8. Frequency Spectrum Measurement Data: (a) RF Course and RF Clearance, (b) Audio on RF Course



(a) (b)

Figure 9. ILS GP Frequency Spectrum Measurement Results: (a) Yogyakarta, (b) Surabaya

To validate the findings, a comparison was made with ILS GP transmissions at Adi Sucipto Airport, Yogyakarta, and Juanda Airport, Surabaya. The comparison of technical aspects, including test parameters and frequency test results, at ILS GP locations with the same brand, namely ILS Adi Sucipto, Yogyakarta, and ILS Juanda, Surabaya, is shown in Figure 9. During the frequency test measurements at ILS GP Yogyakarta and Surabaya, no harmonic audio frequencies were detected. The measurement results at ILS GP Yogyakarta showed a frequency of 331.4 MHz with a received RX level of -31.5 dBm, while at ILS GP Surabaya, the operating frequency was 334.4 MHz with a measured RX level of -43.5 dBm. Spectrum analysis at these locations showed no significant harmonic distortions, reinforcing the hypothesis that the distortions at Runway 24 are abnormal and require further mitigation.

Several contributing factors to the observed distortions were identified including technical factors and environmental factors. Antenna mismatch issues was observed by measured Return loss ($S_{11}$) and VSWR of the ILS GP Antenna using a Vector Network Analyzer. This stage is conducted to ensure the antenna's matching condition at the ILS GP operational frequency of 332.0 MHz was in good condition. The measurement results in Table 1 show that all antennas still meet the equipment specifications, with values less than -20 dB or a VSWR smaller than 1.2.

Table 1. Return Loss and VSWR Measurement of ILS GP Antenna

| Antenna | Return loss ($S_{11}$) | VSWR |
|---|---|---|
| A1 | -34.78 dB | 1.03 |
| A2 | -33.10 dB | 1.04 |
| A3 | -28.32 dB | 1.07 |

Phasing issues was also observed using a Vector Network Analyzer. The measurement results of the phasing cable, antenna coaxial, and Antenna Distribution Unit on the ILS GP are shown in Table 2. There are values outside the tolerance range, such as the A1-RF SBO value, which should be 180 degrees but was measured at 137.82 degrees. Meanwhile, the A1-RF CSB value should be 0 degrees, but it was measured at -3.9 degrees.

Table 2. Phasing Cable and ADU Measurement of ILS GP Antenna

| Antenna | RF CSB | | | | RF SBO | | | |
|---|---|---|---|---|---|---|---|---|
| | Amplitude (dB) | | Phase (degree) | | Amplitude (dB) | | Phase (degree) | |
| A1 | -43.50 | (<30) | -3.90 | (0) | -5.14 | (-6) | 137.82 | (180) |
| A2 | -6.12 | (-6) | 177.40 | (180) | 0.00 | (Ref) | 0.00 | (Ref) |
| A3 | 0.00 | (Ref) | 0.00 | (Ref) | -6.00 | (-6) | -178.00 | (180) |

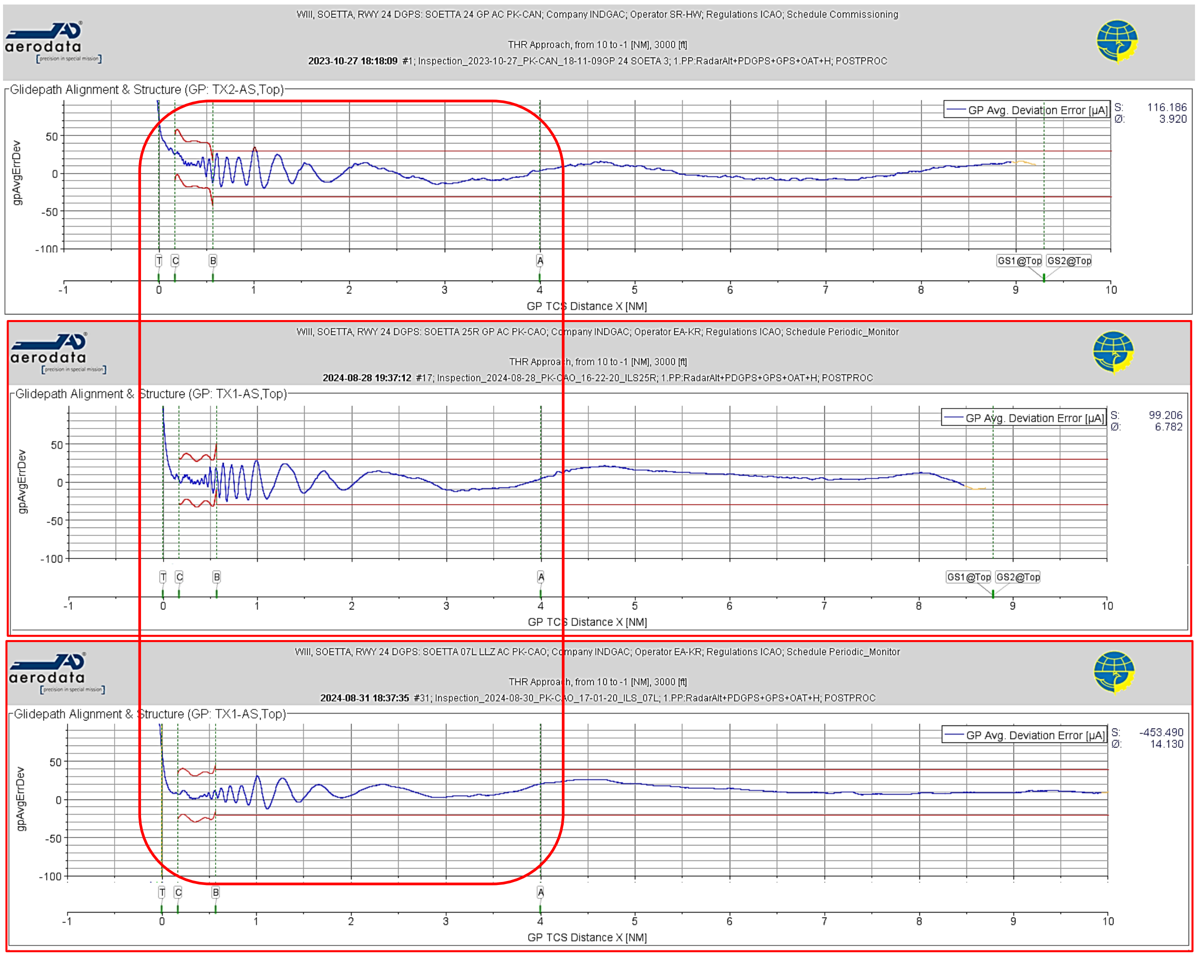



Figure 10. Comparison of ILS GP parameter readings on runway 24 at JATSC, average deviation error (µA): initial (top), testing after LF Module repair (middle), testing after adjustment of 40% modulation (bottom) [7]

Efforts to adjust the equipment were carried out by lowering and raising the antenna, reducing the CSB power, turning off the RF Clearance transmission, changing the phasing after RF SBO, and replacing the Low Frequency (LF) module, as well as lowering the SDM value from 80% to 40% to observe the effects of changes in the reverse crossing signal during the flight inspection test. Figure 10 shows a comparison of the calibration aircraft test results when replacing the LF module and lowering the SDM level to 40%. However, the graph reading still shows a reverse crossing signal, with no significant changes observed between 2 NM and zone B.

The comparison with other airports confirms the anomaly, suggesting both technical and environmental factors as potential causes. The flight inspection results for ILS GP Yogyakarta and Surabaya are in normal condition with no signal anomalies, as shown in Figure 11.

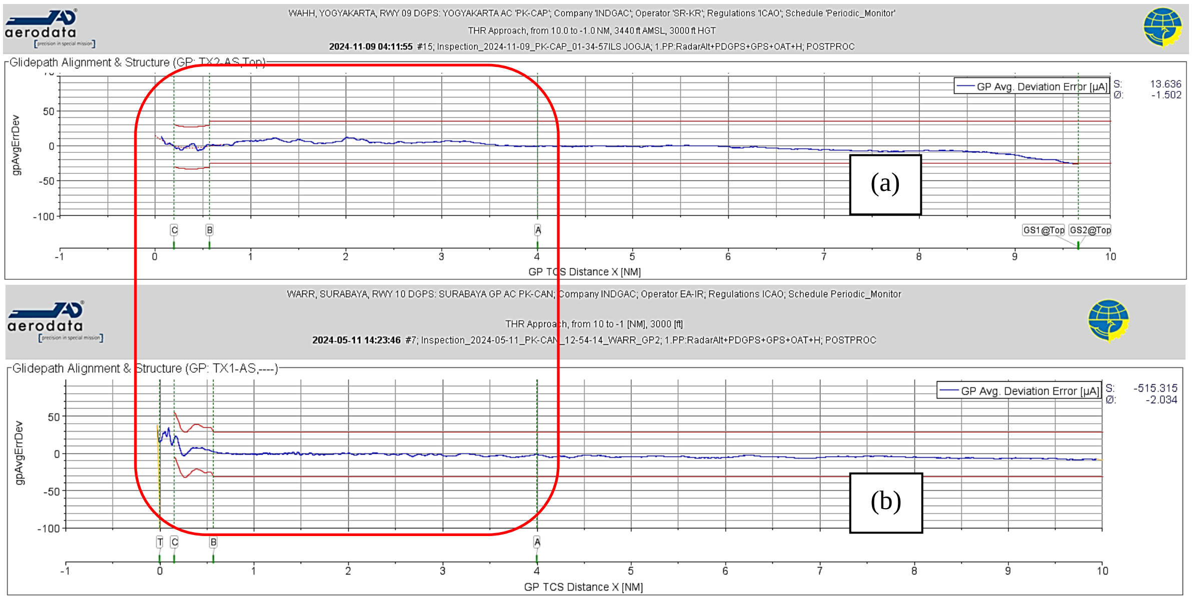



Figure 11. Comparison of ILS GP Parameter Readings, DDM (µA) at Yogyakarta (upper) [25] and Surabaya (lower) [26]

Direct observations and measurements conducted in the critical and sensitive areas, as well as measurements using Google Earth, also indicate environmental discrepancies with the standard siting criteria for ILS GP. In the critical area, there is a river located 19.5 meters from the ILS GP antenna, and in the sensitive area, there is a metal fence located 36.7 meters away with a height of 2.8 meters extending toward the landing angle. Additionally, there is a perimeter road and residential buildings still within this area, which does not comply with the standard siting criteria for ILS GP.

Figure 12. Observation of obstacles such as a metal boundary fence, perimeter road, residential buildings, and a river.

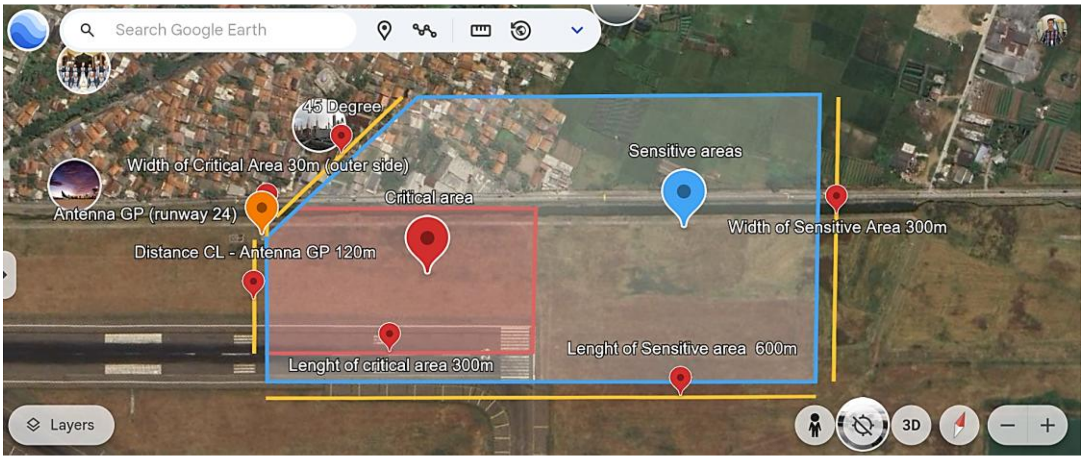
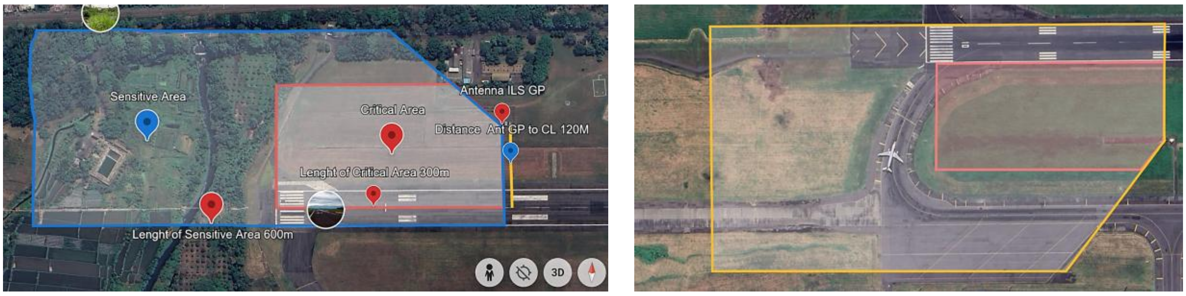



Figure 13. Observation of obstacles in the critical and sensitive areas using Google Earth.

In both Figure 12 and Figure 13, it can be analyzed that there are obstacles in the critical and sensitive areas, as well as uneven terrain in front of the ILS GP antenna, which can significantly affect the graph readings of the flight inspection results. Therefore, it is crucial to create an ideal condition in these areas so that the ILS GP calibration test results for DDM/GP Average Deviation parameters can be satisfactory, and the ILS navigation service can be used for aircraft landing on runway 24.

Meanwhile, a comparison of the environmental aspects is also observed in the siting criteria for ILS GP at Yogyakarta and ILS GP at Surabaya as in Figure 14.




(a) (b)

Figure 14. Observation of Sitting Criteria for ILS GP: (a) Yogyakarta and (b) Surabaya

In the Google Earth observation (Figure 14), it shows that at the airports Yogyakarta (a) and Surabaya (b), there are no significant obstacles, and no buildings, houses, or rivers are visible in the critical or sensitive areas. This reinforces that the flight inspection results at both airports are normal. One of the reasons for this is due to the environmental factors, which are still in accordance with the required standards and criteria.

## 4. CONCLUSION

This study identifies key technical and environmental factors influencing ILS GP signal propagation on Runway 24 at the Jakarta Air Traffic Service Center (JATSC) – Soekarno-Hatta Airport, highlighting the limited effectiveness of parameter adjustments in resolving alignment discrepancies. Technical evaluations demonstrate that while composite audio signals and parameter adjustments such as tuning harmonic frequencies and modifying antenna height result in measurable changes in signal characteristics, their effectiveness in correcting alignment discrepancies is limited. In contrast, environmental influences, particularly multipath interference from surrounding obstacles and non-compliant antenna siting, are suspected to play a significant role in persistent signal distortions. These findings underscore that ensuring safe aircraft approaches requires more than conventional technical adjustments. Targeted environmental modifications in the critical areas surrounding the ILS GP antenna are essential to meet regulatory standards and enhance signal integrity. The study contributes to aviation regulatory safety and system optimization by demonstrating that addressing environmental challenges is also crucial for reliable ILS GP alignment. Future research should explore advanced mitigation techniques and promote collaboration with aviation regulators and stakeholders to refine best practices for ILS GP installations in complex airport environments.

## REFERENCE

[1] A. Kwasiborska, M. Grabowski, A. N. Sedláčková, and A. Novák, "The Influence of Visibility on the Opportunity to Perform Flight Operations with Various Categories of the Instrument Landing System,"

*Sensors*, vol. 23, no. 18. 2023. https://doi.org/10.3390/s23187953
[2] ICAO, “Annex 10, Aeronautical Telecommunications ,Volume I Radio Navigation Aids,” International Civil Aviation Organization, vol. I, 2019.
[3] G. Wibisono, M. Wildan, J. Wahyudi, E. Widoro, and T. Firmansyah, “Co-design Structure of Dual-Band LNA and Dual-Band BPF for Radio Navigation Aid Application,” *Wirel. Pers. Commun.*, vol. 116, Feb. 2021. https://doi.org/10.1007/s11277-020-07754-9
[4] ICAO, “ICAO DOC 8071 Manual on testing of radio navigation aids,” Vol. I, 2018.
[5] Leif W. Nyback, “NORMARC 7000 ILS–ILS principles and equipment theory,” Park Air Syst., Peterborough, UK, Tech. Rep, vol. 21478, 2015.
[6] A. Novák, K. Havel, and M. Janovec, “Measuring and Testing the Instrument Landing System at the Airport Zilina,” in *Transp. Res. Procedia*, vol. 28, pp. 117–126, 2017. https://doi.org/10.1016/j.trpro.2017.12.176
[7] Directorate General of Civil Aviation, “Flight Inspection Report - Instrument Landing System - Soekarno Hatta Int’l - Jakarta, Rwy 24,” 2023.
[8] J. Honda, “Influences of scattered field caused by buildings to ILS localizer in Airport,” *2015 International Symposium on Antennas and Propagation* (*ISAP*), pp. 1–4, 2015, [Online]. Available: https://ieeexplore.ieee.org/document/7447465
[9] M. Santoso, “Pengaruh Keberadaan Bukit Timur Laut Dua Terhadap Pancaran Glide Path Runway 36 Di Bandar Udara Sam Ratulangi Manado,” in *Pros. Semin. Nas. Inov. Teknol. Penerbangan*, 2019. https://doi.org/10.46491/snitp.v3i1.337
[10] J. Godfrey, H. Hartley, G. Moussally, and R. Moore, “Terrain modeling using the half-plane geometry with applications to ILS glide slope antennas,” *IEEE Trans. Antennas Propag*., vol. 24, no. 3, pp. 370–378, 1976. https://doi.org/10.1109/TAP.1976.1141339
[11] K. Cho and Y. Kwak, “Multipath Interference Error Analysis on Obstacles Effect,” in *2015 8th International Conference on Signal Processing, Image Processing and Pattern Recognition* (*SIP*), pp. 25–29, 2015. https://doi.org/10.1109/SIP.2015.18
[12] J. Xu, J. Ye, F. Liang, Y. Li, and H. Lin, “Simulation Analysis and Research on the Influence of Buildings on a Glide Path Antenna,” in *2021 International Conference on Computer Technology and Media Convergence Design* (*CTMCD*), pp. 63–66, 2021. https://doi.org/10.1109/CTMCD53128.2021.00022
[13] M. M. Poulose, “An improved computer model for ILS glideslope evaluation,” *IET Conf. Publ*., vol. 2014, no. CP649, 2014. https://doi.org/10.1049/cp.2014.1105
[14] Iungaitis E. M., Voytovich N. N. I., Ershov A. A. V., Zhdanov B. B. V., Zotov A. A. V., “ILS Glide Slope Antenna Array for Airfields with a High Level of Snow Cover,” in *2019 13th European Conference on Antennas and Propagation* (*EuCAP*), pp. 1–4, Mar. 2019. [Online]. Available: https://ieeexplore.ieee.org/document/8740267
[15] Q. Huang, “DesignCon 2019 A Fast and Simple RFI Mitigation Method without Compromising Signal Integrity,” 2019, [Online]. Available: https://www.amazon.science/publications/a-fast-simple-rfi-mitigation-method-without-compromising-signal-integrity
[16] M. Tschauner, M. Adrat, V. Le Nir, K. Pärlin, and T. Riihonen, “Crosstalk and Self-Interference Cancellation in Full-Duplex Communication Systems,” in *2023 Int. Conf. Mil. Commun. Inf. Syst*., pp. 1–8, 2023. https://doi.org/10.1109/ICMCIS59922.2023.10253529
[17] T. Iliev, I. S. Stoyanov, G. Y. Mihaylov, and E. P. Ivanova, “Study the influence of intermodulation products on navigation signals,” *IOP Conf. Ser. Mater. Sci. Eng*., vol. 1032, 2021. https://doi.org/10.1088/1757-899X/1032/1/012013
[18] G. D. Verma and A. Mathur, “RIS Assisted RF Communication Systems with H-ARQ Protocols and Imperfect CSI,” in *2023 IEEE 97th Veh. Technol. Conf*., pp. 1–5, 2023. https://doi.org/10.1109/VTC2023-Spring57618.2023.10199193.
[19] S. S. Abramov, I. I. Pavlov, E. S. Abramova, and D. Y. Starysh, “Ways to ensure quality of work radio transmitters to base stations,” in *2016 13th Int. Sci. Conf. Actual Probl. Electron. Instrum. Eng*., vol. 2, pp. 40–44, 2016. https://doi.org/10.1109/APEIE.2016.7806475
[20] Z. M. Gizatullin and E. Konstantinov, “Technique for Research Spurious Electromagnetic Emission from Electronic Means,” in *2020 Int. Russ. Autom. Conf*., pp. 380–384, 2020. https://doi.org/10.1109/RusAutoCon49822.2020.9208059
[21] A. Arranz-Gimon, Á. L. Zorita-Lamadrid, D. Morinigo-Sotelo, and Ó. Duque-Pérez, “A Review of Total Harmonic Distortion Factors for the Measurement of Harmonic and Interharmonic Pollution in Modern Power Systems,” *Energies*, vol. 14, No. 20, 2021. https://doi.org/10.3390/en14206467
[22] A. Acakpovi, I. Tefutor, K. Quist-Aphetsi, N. I. Nwulu, R. A. Sowah, and R. Abubakar, “Impact Analysis of Induced FM Radio Interferences on Aeronautical Radio Navigation Systems: Case Study of Kotoka International Airport, Accra-Ghana,” in *2019 Int. Conf. Comput. Comput. Model. Appl*., pp. 19–197, 2019. https://doi.org/10.1109/ICCMA.2019.00011

[23] X. Zhao, Y. Wang, H. Jiang, and C. Dai, "Multipath effect suppression for instrument landing system based on MUSIC," in *Proceedings Volume 5985, International Conference on Space Information Technology*. https://doi.org/10.1117/12.658625

[24] H. Lin, X. Sun, F. Liang, and Y. Li, "Simulation and Analysis of Active Disturbance of Electrified Railway to Instrument Landing System," in *2019 IEEE 3rd Adv. Inf. Manag. Commun. Electron. Autom. Control Conf.*, pp. 1034–1038, 2019. https://doi.org/10.1109/IMCEC46724.2019.8983885

[25] Directorate General of Civil Aviation, "Flight Inspection Report - Instrument Landing System - Adi Sutjipto Airport – Yogyakarta," 2024.

[26] Directorate General of Civil Aviation, "Flight Inspection Report - Instrument Landing System - Juanda Airport – Surabaya," 2024.