Experiences in Flight Inspecting GBAS

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Aerodata AG
Flight Inspection of GBAS

Overview

– Basics
– Requirements
– Equipment
– Flight Inspection
– Summary
Ground Based Augmentation System

VDB: VHF Data Broadcast
- Error correction data
- Integrity data
- Approach data for one or more Runways/Approaches

VDB Tx-Frequency Range:
108.000-117.975 MHz
in 25 kHz increments
Ground Based Augmentation System

- One GBAS Ground station may support several runways and approaches
- "ILS Lookalike" Deviations are provided to the pilot:

GLS Distance
GLS Lateral Deviation
GLS Vertical Deviation
**VHF Data Broadcast (VDB) Messages**

- **Type 1:** Differential Error Correction Data
- **Type 2:** Differential Reference Point Data
  - (Integrity Data)
- **Type 3:** Reserved for GBRS Ground Based Ranging Source (Airport Pseudolites)
- **Type 4:** FAS Final Approach Segment Construction Data for one or more Runways/Approaches
- **Type 5:** Ranging Source Availability (optional)
- **Type 6:** Reserved for Carrier Corrections
- **Type 7:** Reserved for Military
- **Type 8:** Reserved for Test
Final Approach Segment Diagram

LTP ≡ Landing Threshold Point
FTP ≡ Fictitious Threshold Point
GPIP ≡ Glide-Path Intercept Point
FPAP ≡ Flight Path Alignment Point
TCH ≡ Threshold Crossing Height
GLS (GNSS Landing System) Vertical Deviation

\[ \alpha_v \text{ Angular Vertical Deviation} \]

\[ \text{Threshold Crossing Point} \]

\[ \text{GPA Glide Path Angle} \]

\[ \text{Threshold Crossing Height} \]

\[ \text{Centerline} \]

\[ \text{FPAP} \]

\[ \text{LTP/FTP Vertical Direction} \]

\[ \text{(Normal to WGS-84 Ellipsoid at LTP/FTP)} \]

\[ \text{GERP} = \text{GLS-Elevation Reference Point} \]

\[ \text{A Line through GERP normal to the Centerline can be compared with ILS Glide Path Intercept Line} \]

\[ \text{Vertical Deviation [DDM]} = \frac{0.175}{0.25 \cdot \text{GPA}} \cdot \alpha_v \]
GLS (GNSS Landing System) Lateral Deviation

GARP ≡ GLS-Azimuth Reference Point

Lateral Deviation Reference Plane

GARP-Offset 305m

Centerline

Vertical Direction (Normal to WGS-84 Ellipsoid at LTP/FTP)

GARP can be compared with the ILS-LLZ Antenna

Lateral Deviation [DDM] = \( \frac{0.155}{\arctan\left(\frac{\text{CourseWidth}}{D_g}\right)} \)
Comparison GLS – ILS

GLS Azimuth Reference Point
GLS Elevation Reference Point
Deviation calculated in DDM

Localizer Antenna Position
Glide path intercept Line
Deviation measured in DDM

GLS is similar to ILS
What influences the Performance / Precision of GBAS?

- **Signal of GBAS – Ground Station**
  - Coverage
  - Interference
  - Incorrect FAS-Data

- **Availability of Satellites at the Ground Station**
  - Satellite Masking
  - Multipath
  - Interference

- **Availability of Satellites at the Aircraft**
  - Satellite Masking
  - Multipath
  - Interference

- **Satellite Constellation**
  - DOP
When is Flight Inspection required?

- Prior to commissioning on each runway served and for each approach
- Whenever interference is reported or suspected and ground testing cannot confirm elimination of the source of interference
- As a result of a procedure modification or the introduction of a new procedure
- Whenever changes occur to the GBAS configuration such as the location of the GBAS ground subsystem antenna phase-centre, the location of the data link transmit antenna, or the system database
- Whenever site changes such as new obstructions or major construction occur that have the potential to impact GNSS signal reception and data broadcast transmission
- After certain maintenance activities
What should be inspected on ground

- Data Contents
  - FAS
    Horizontal Tolerance: 0,4m horizontal, uncertainty 0,05m
    Vertical Tolerance: 0,2m vertical, uncertainty 0,05m
  - Integrity Data
  - Differential Correction Data
- Runway surface coverage
  (> -99 dBW/m² < -35 dBW/m² @ 3,7m / 12ft above runway)
- Availability of Satellites at Ground Station
- Multipath at Ground Station
- Interference at Ground Station
- Coverage of VDB Ground Station
- Frequency Spectrum of VDB Frequency ±100 kHz either side in case of suspected interference
- Frequency Spectrum of GPS Frequency (1559-1595 MHz) when GPS Parameters indicate possible RF interference
- Satellite Availability at aircraft (PRN#)
- Satellite Constellation (VDOP, HDOP, EPE)
The minimum operational VDB coverage area has to be:

-35 dBW/m² > Field Strength > -99 dBW/m²
Procedures

20 NM Arc around LTP/FTP @ 0.3 – 0.45 Theta (~2000ft HAT) ±10°
15 NM Arc around LTP/FTP @ 0.3 – 0.45 Theta (~1500ft HAT) ±35°

Level Run from 20 NM to 13 NM or less at ~ 10000ft HAT
Level Run from 21 NM to 2.5 NM or less at ~ 2000ft HAT

Field Strength > -99 dBw/m²

Main Purpose:
Coverage of VDB – Ground Station, Satellite availability, DOP
Problem:
The Primary Aircraft Avionic (in Flight Inspection Aircraft) does NOT support GBAS (GNLU) installation!
How to provide Guidance to the pilots?

Solution:
The AFIS provides GBAS(GLS) Deviations via the AFIS Flight Guidance Interface on EFIS

AFIS Provides:
• GLS Lateral Deviation
• GLS Vertical Deviation
• GLS Distance
⇒ Use of Autopilot for GLS!
GBAS Software

• Measurement Programs for Coverage Arcs, Level Runs and Approaches

• Evaluation of GLS Deviations

• GLS Flight Guidance in cockpit provided through AFIS to provide GBAS Guidance to pilots (GBAS receiver can not be integrated to current avionic of flight inspection aircraft)

• Graphical and numerical analysis of VDB Signal in Space Power Density

• GPS L1 and L2 Spectrum Analyzer Measurement Program

• VDB Spectrum Analyzer Measurement Program
## Software – Procedure Definition

### Procedure Definition

<table>
<thead>
<tr>
<th>Facility</th>
<th>Name: Dremen</th>
<th>Facility...</th>
<th>Procedure Inspection</th>
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<tbody>
<tr>
<td>Airport</td>
<td>Runway: 309</td>
<td>Profile: -- The profile is not defined --</td>
<td></td>
</tr>
<tr>
<td>DOPS</td>
<td>Radius: 5.0 NM</td>
<td>Location: NO DOPS</td>
<td></td>
</tr>
<tr>
<td>TWADGPS</td>
<td>Location: NO TWADGPS</td>
<td>Reflect: NO REFPL</td>
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</table>

### LLZ

<table>
<thead>
<tr>
<th>Program: NO PROGRAM</th>
<th>Back Course</th>
<th>TX1</th>
<th>TX2</th>
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### V/GSI

<table>
<thead>
<tr>
<th>Program: NO PROGRAM</th>
<th>TX1</th>
<th>TX2</th>
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### V/OB/GBAS

<table>
<thead>
<tr>
<th>Program: NO PROGRAM</th>
<th>TX1</th>
<th>TX2</th>
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### Approach

<table>
<thead>
<tr>
<th>APP</th>
<th>Engineering (Approach, from 21 to 0 [LO])</th>
<th>TX1</th>
<th>TX2</th>
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</table>

### LLA

<table>
<thead>
<tr>
<th>LLA</th>
<th>Lower Level Run</th>
<th>TX1</th>
<th>TX2</th>
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</thead>
</table>

### V/C1

<table>
<thead>
<tr>
<th>On</th>
<th>TX1</th>
<th>TX2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
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</tbody>
</table>

### DME Scan

<table>
<thead>
<tr>
<th>On</th>
<th>TX1</th>
<th>TX2</th>
</tr>
</thead>
<tbody>
<tr>
<td>No</td>
<td></td>
<td></td>
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</tbody>
</table>

### V/C2

<table>
<thead>
<tr>
<th>On</th>
<th>TX1</th>
<th>TX2</th>
<th>VHF/ADF: NONE</th>
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<tbody>
<tr>
<td></td>
<td></td>
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<td></td>
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</table>

### MKR

<table>
<thead>
<tr>
<th>On</th>
<th>TX1</th>
<th>TX2</th>
<th>V/C1: NONE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
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</tbody>
</table>

### NDBs

<table>
<thead>
<tr>
<th>NDBs</th>
<th>TX1</th>
<th>TX2</th>
<th>V/C2: NONE</th>
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<tbody>
<tr>
<td></td>
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### Flight Inspec.

<table>
<thead>
<tr>
<th>DME Scan</th>
<th>On</th>
<th>TX1</th>
<th>TX2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Read from FMS</td>
<td>No</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Related Pages

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- Basics
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- Flight Inspec.
- Summary
Software – Graphic Selection

- Calibration
- Common Items
- ILS (current)
  - GBAS Distance (Distance uA)
  - GBAS Lateral (Distance DDM)
  - GBAS Lateral (Distance uA)
  - GBAS Overview (Distance uA)
  - GBAS Parameters (VDB Distance)
  - GBAS Position Error (Distance)
  - GBAS Rectilinear (Distance ft)
  - GBAS Track Error (Distance)
  - GBAS Vertical (Distance DDM)
  - GBAS Vertical (Distance uA)
- Run (current)
- Spectrum Analyzer

Filter: [ ] ignore Case

Arrange  Cascade  Full
Update    Ok       Close
Software – FAS Data


Overview Basics Requirements Equipment

Summary Flight Inspec.
Software – FAS Data

Overview
Basics
Requirements
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Flight Inspec.
Summary
Hardware
GBAS Coverage Arc

Ideal Clearance
(Full Deflection everywhere outside Course Sector)

Ideal Linearity in Course Sector

No Deviation Error

Constant and sufficient VDB Signal In Space Power Density
GBAS Approach (lateral)

No Roughness on “Course Beam”

No Deviation Error

Increasing and sufficient VDB Signal In Space

Power Density

GLS LTP Distance $X$ [NM]
GBAS Approach (vertical)

- No Roughness on “Course Beam”
- Almost no Deviation Error
- Slight increase of Deviation Error (caused by GBAS vertical accuracy)
- Increasing and sufficient VDB Signal In Space Power Density

Overview  Basics  Requirements  Equipment  Flight Inspect.  Summary
GBAS Level Run

GBAS Vertical (Distance uA) (VDBW VDB: TX1-LR)

1. GLS Reference GP Deviation [µA]
2. GLS GP Deviation [µA]
3. GLS GP Deviation Error [µA]
4. VDB SIS Power Density [dBW/m²]

Ideal Behavior of "Glidepath Beam"
No Deviation Error

Overview | Basics | Requirements | Equipment | Flight Inspec. | Summary
GBAS GPS Signal Analysis

Overview Basics Requirements Equipment Flight Inspect. Summary
In order to measure field strength accurate (+/- 3dB):
- VDB AGC Characteristics of receiver (GNLU) needs to be proper calibrated (polynomial correction curve)
- Aerodata therefore has developed GNLU calibration procedure.
- Cable Losses need to be compensated
- Antenna Characteristics of VDB Antenna needs to be compensated:
  - Azimuth compensation
  - Frequency Compensation

**Ground tests have demonstrated AFIS measures VDB Signal Strength with an absolute accuracy better than +/- 3dB!!!
In order to measure position Errors and Deviation Errors:

- GNLU shows different Time behavior for:
  - Position Output
  - GLS LLZ Deviation Output
  - GLS GP Deviation Output

These Time Delays need to be compensated for accurate measurements
- Typical Flight Inspection Aircraft are not primary GNLU equipped;
- Retrofit solution for a GNLU installation in e.g. Beech King Air cockpit is not available

**How to fly the GLS Approach, especially if it is no overlay to ILS?**

Solution: AFIS Flight Guidance Interface to aircraft EFIS allows the pilots to fly GLS Approaches using the AFIS GNLU.

Only this feature allows to:
- Evaluate the fly ability of GLS approaches with „regular“ Flight Inspection Aircraft
- Fly GLS approaches with autopilot
GBAS Requirements

Aircraft:
• Capability to fly GBAS Approach (e.g. provided by AFIS flight guidance)
• Capability to use autopilot for flying GBAS approach
• VDB and GPS antenna for GBAS (GNLU)

Flight Inspection System:
• GBAS receiver (GNLU) with AGC output (non – standard version)
• Provide Cockpit Flight Guidance to fly GBAS procedures (Arcs, Level runs, Approaches)
• High accurate Reference Position with proven integrity (e.g. PDGPS)
• Compensation of Antenna Lever arms on flight inspection aircraft
• Compensation of Antenna Pattern characteristic for accurate field strength measurements
• Proper Time Synchronization of data (synchronization by timestamp!)
• Spectrum Analyzer interface
GBAS Benefits

For Airlines:
• Nearly ideal Guidance Signal provided to pilots
• Fuel savings, noise abatement and reduced emissions (flexible flight paths)
• Higher precision guidance
• Minimal pilot training (similar to ILS)

For Airports:
• Improved airport capacity (simultaneous operations to parallel runways, simultaneous)
• No Protection Areas (as required for ILS)
• Improved airport access, even where ILS cannot be installed for terrain or economic reasons.

For Air Navigation Service Providers:
• Reduced cost and lower ongoing maintenance (one GBAS covers all runways at an airport)
• Flexibility to add or change final approach procedures without changing system configuration
• Continued operations during routine flight inspection or airport works.
GBAS Disadvantages

Fully dependant on GPS:
• GPS Interference or jamming could disable entire system
  (Complete airport / all runways simultaneously!)
  Example: A simple 1 Watt handheld GPS Jammer can blast GPS Signals in a 100 kilometer radius

Intentional Jamming:
• GPS Jammer like this can simply be bought via Internet

Unintentional Interference:
• A defective microwave oven on board of a sailboat jammed GPS on an entire airport in the US.
• A wireless network router from University jammed GPS at an airport in Spain

• Costly Precision Approach Lighting system is required for every runway
Thank you for your attention!