

# TRAPS AND PITFALLS RELOADED

## Stefan Jagieniak

Aerodata AG  
Hermann-Blenk-Str. 34-36  
38108 Braunschweig, Germany

Phone: +49 531 2359-135  
Fax: +49 531 2359-222

Internet: <https://www.aerodata.de>  
E-Mail: [jagieniak@aerodata.de](mailto:jagieniak@aerodata.de)

## BIOGRAPHY

Dipl.-Ing. Stefan Jagieniak received his Diploma in Electrical Engineering from the Technische Universität Braunschweig, Germany in 1991. Since then, he has been working for the Aerodata AG in Braunschweig in various positions, starting with hardware development and systems integration. For several years, he was in charge of the position reference system involving GNSS, PDGNSS and hybrid Systems. Since 2001, he is responsible for the AD-AFIS software as a senior software architect, including management, customer training and support in various countries.

## ABSTRACT

During flight inspection missions, surprising or unexpected results may appear. A typical situation for this might happen during the commissioning of a brand new, accurate FI System. Its results are compared to those of a well known, but ageing system, which had been approved and even certified decades ago. The typical consequence is to blame any differences on the new system, because the legacy one had been accepted and therefore is assumed to be correct.

Current FI systems should be more sensitive on detecting errors compared to systems installed in airliner aircraft, which intend to provide guidance even in case the signal is not perfect. This may lead to the situation that FI reveals a problem that some cockpit installations do "smooth away". Even legacy FI systems are just not able to detect all existing problems.

Surprises may also arise from not being aware of the impact of some subtle potential errors as they just happen in daily life.

This paper depicts some real cases from more than 30 years of experience. Physical effects are explained. Cases for traps and pitfalls in flight inspection are given based on the following examples:

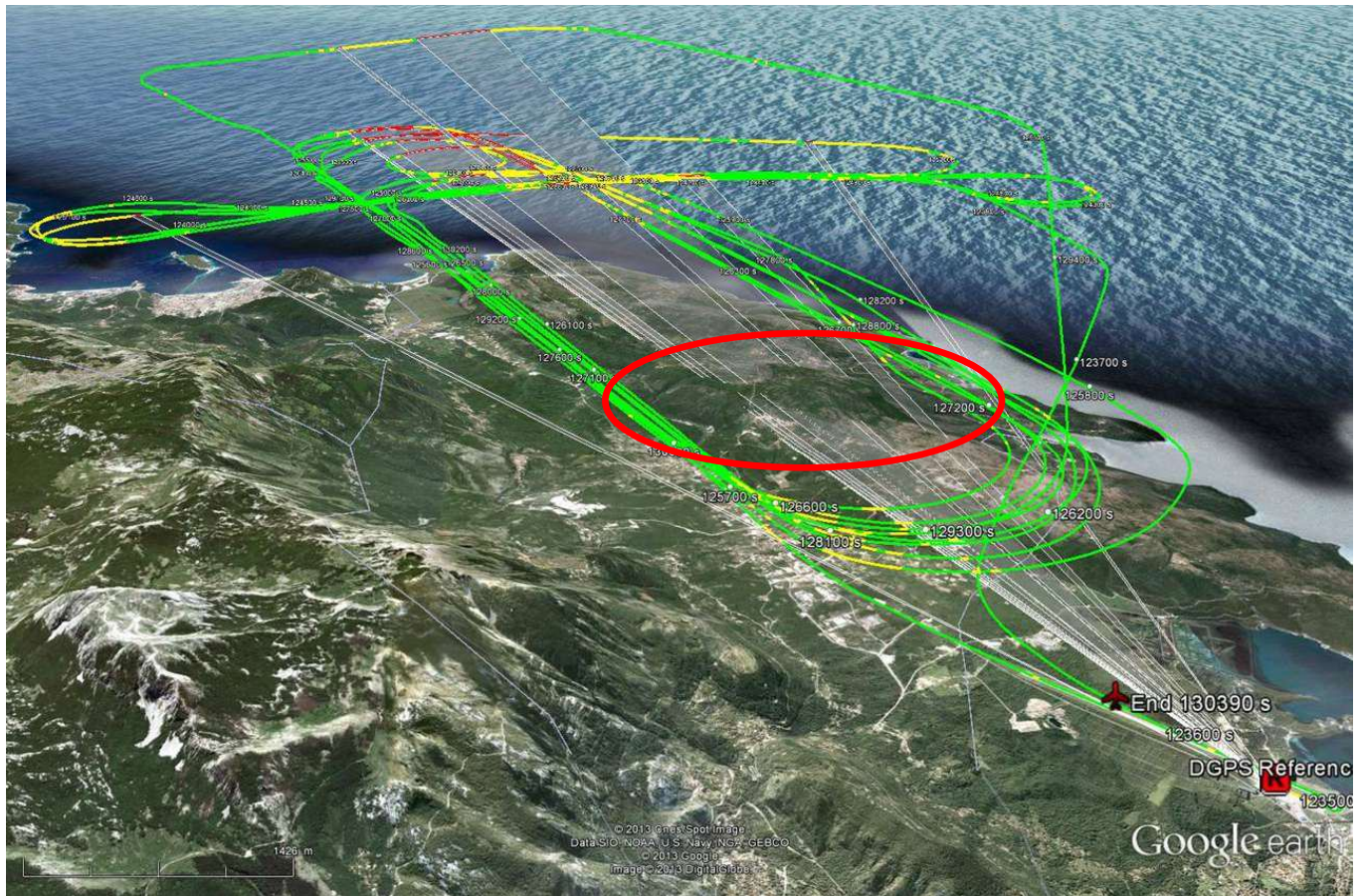
- Survey and database issues
- Is the glidepath tolerance check wrong?
- VOR multipath effects
- FI antenna effects

Please see also [1] and [2] for other cases.

## INTRODUCTION

Over the years, from time to time unexpected results occur when doing flight inspection. These may be caused by unusual environmental conditions, problems “between the ears”, real faults of a navaid, or failures if the Flight Inspection equipment. A few of them are pointed out here to help avoiding surprises if an operator is ever confronted with similar effects and to help distinguishing between the possible causes. For more traps and pitfalls, see [1] and [2].

## SURVEY AND DATABASE ISSUES: LINE-OF-SIGHT



**Figure 1: DGPS Status during an ILS Inspection**

Figure 1 shows the PDGPS status during an ILS commissioning. The color code indicates the GPS quality. The operator was not satisfied with the availability and provided the data for analysis.

Red areas show telemetry interruptions. At 20 NM distance, a height of 2000 ft gives an elevation angle of only  $0.9^\circ$ . Any obstacle like a building, a hill, a mountain will prevent a line-of-sight connection. This is necessary for full integrity and accuracy information. It is important to keep in mind that even such low obstacles at  $0.9^\circ$  have to be avoided when selecting the ground location of the DGPS telemetry uplink antenna. Satellite-based DGPS like SBAS or TerraStar overcomes this issue, but may have drawbacks concerning license cost and proven integrity.

The red ellipse highlights the mountain peaks interrupting the line-of-sight.

## SURVEY AND DATABASE ISSUES: DATA COCKTAIL

Another, almost unbelievable survey issue occurred during an ILS commissioning which was accompanied during on-the-job training. The customers facility data were documented in a rather impressive professional survey report carrying several signatures of responsible people. It had a very precise photo and textual description of all the survey points and summarized the coordinates in a table. The data from this table was then re-typed to the AFIS facility database.

The recommendation to crosscheck the data with e.g. google earth was not possible due to lack of internet connection at the airfield. The survey data remained unquestioned. There was also no threshold lineup check with the aircraft.

During the flight, the ILS results were totally strange. It looked like pulling the plug of the ILS would be the only option. The mission was cancelled for the day and the recorded data was reviewed and crosschecked later.

Google Earth showed the GP on threshold and the threshold at the localizer position. This pretty much explained the strange computation results. But how could that ever happen? Let's have a look at the table sorting user interface of a well known office application:

Let's sort this alphabetically by selecting the first column and clicking "Sort" in Microsoft Excel...

Just click away that annoying warning message ...

Figure 2: Table column selection and sorting

Who reads these messages when being under time pressure? In this case obviously nobody. It warns about the selection of only the first column. That results in only the first column being sorted and the other columns remain unsorted. Probably this message might have been not present in an older software version. This resulted in sorting of the idents column only and garbling the assignment to the Lat, Lon, Alt coordinates, as depicted in Figure 3.

And you end up with what you deserve ...

Put this in your AFIS database and start flying ...

Figure 3: Ignoring warning messages may give you this

## IS THE GP TOLERANCE CHECK WRONG? HARD LANDINGS

A FI Regulator at a customer event complained about the GP structure tolerance line being wrong. It took some time to come from this early conclusion back to the real observation. This gave a slightly different picture.

The glidepath inspection was passed within tolerances, but later airliner pilots reported uncomfortable „hard landings“.

The recorded GP data showed that the aircraft was crossing the threshold rather high, but with the glidepath signal being consistent with the reference position.

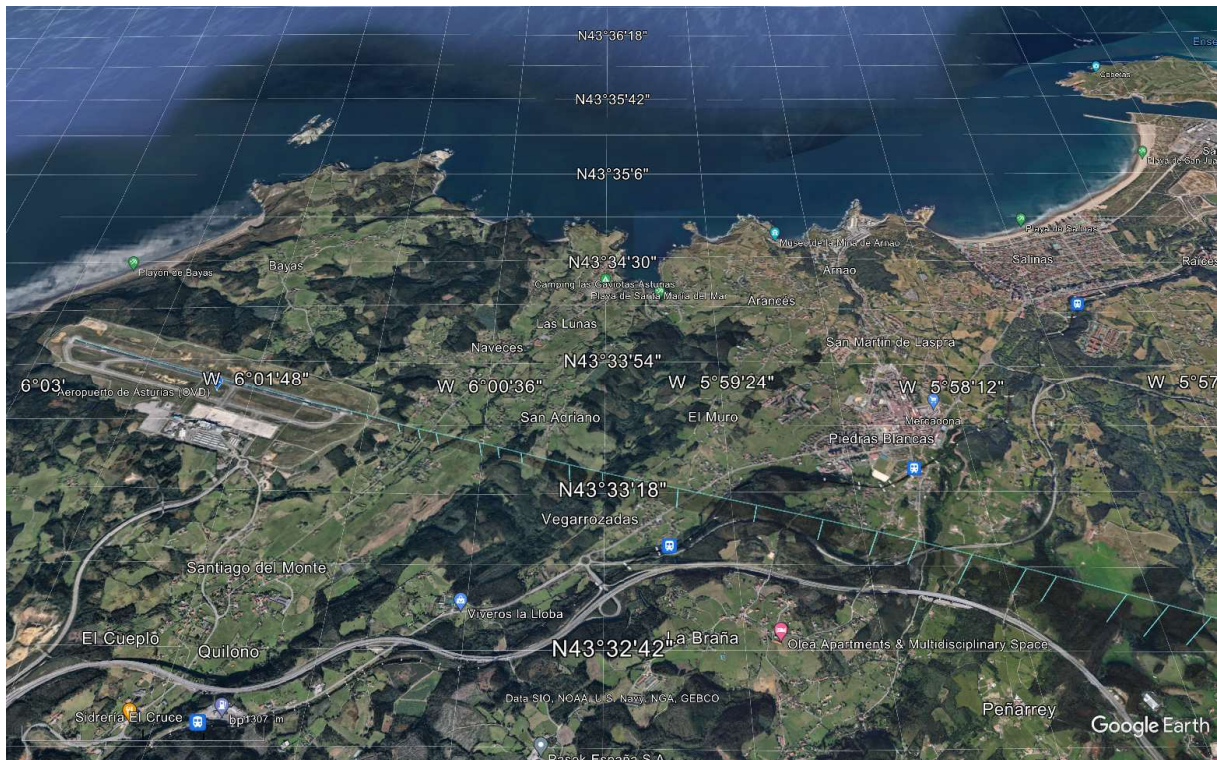


Figure 4: Recorded approach track

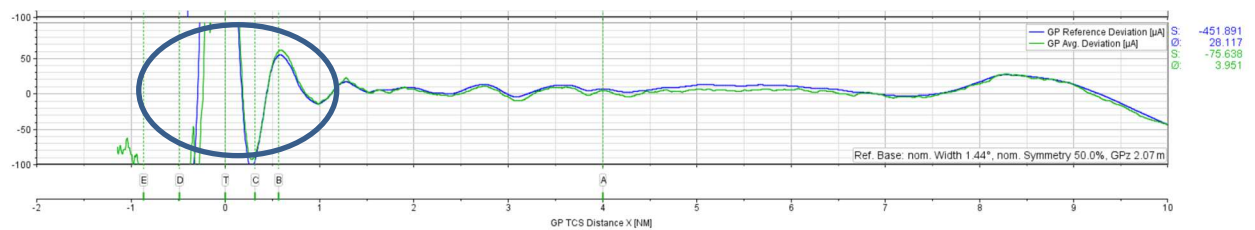
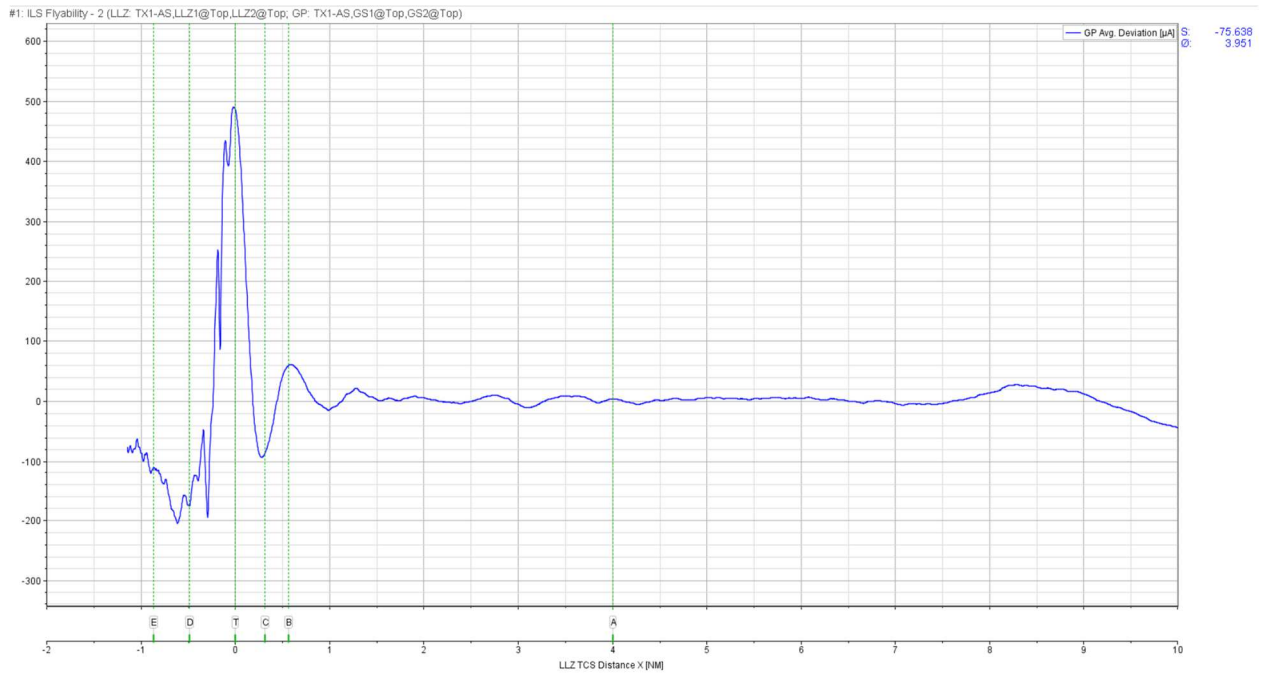


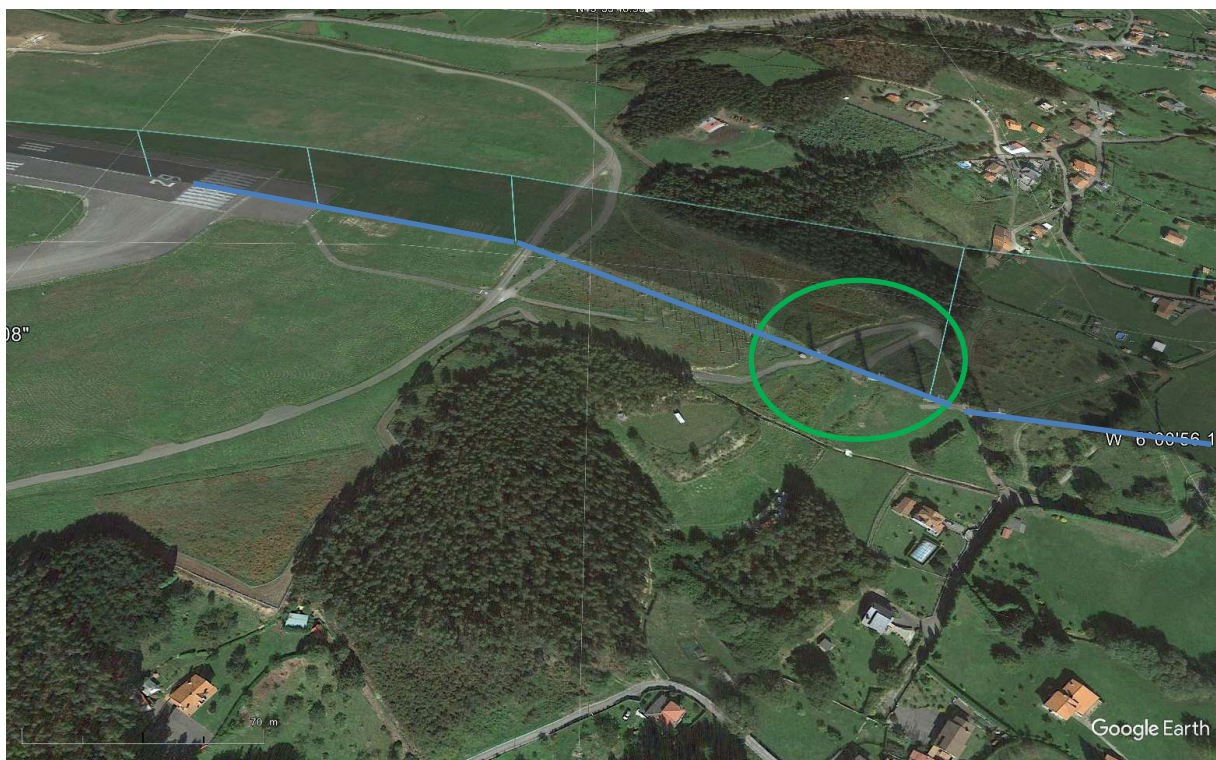
Figure 5: GP measured and reference deviations

However, the aircraft performed a climb to +500µA at threshold followed by a step descend. Why?

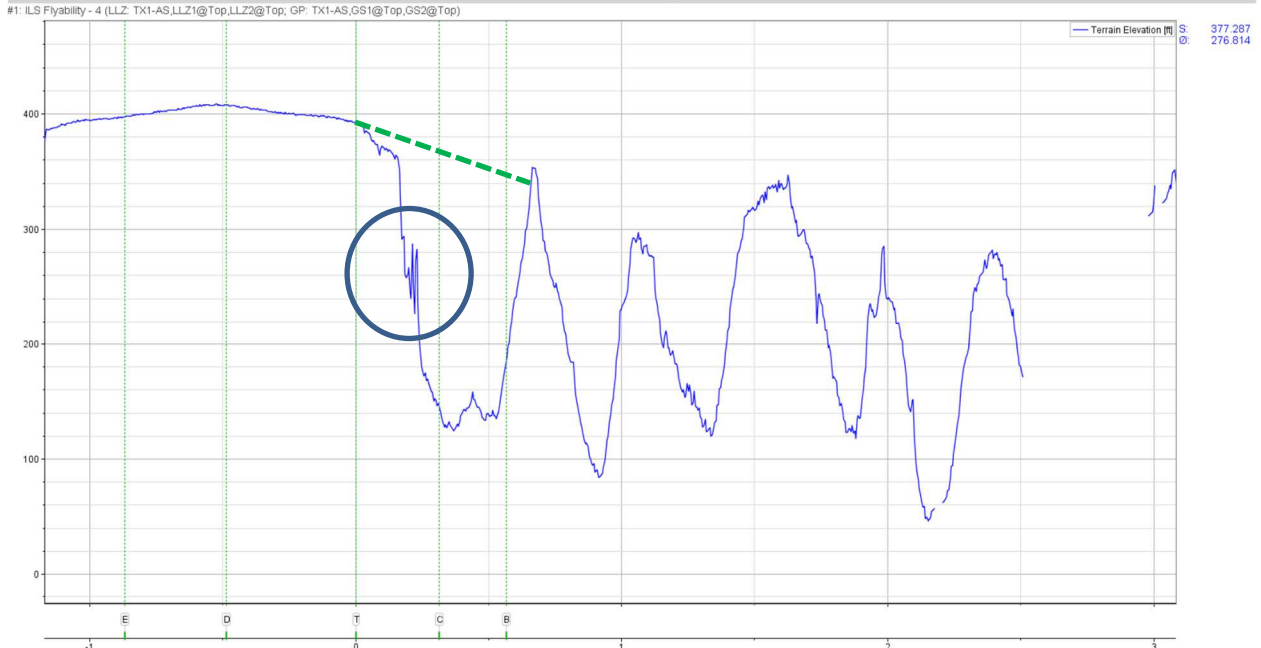


**Figure 6: Scaled up: Peak in GP Deviation = Peak in vertical Flight Path**

The terrain profile, as obtained by Reference Altitude minus Radio Altitude, shows a series of waves perpendicular to the approach and a steep terrain gradient immediately before the threshold. Google earth shows a road of serpentine style consistent to the changing terrain gradient. There were radar reflectors installed, but the radio altitude was only mildly impacted. So, the irregular terrain shape (see [3]) was not fully mitigated by the installed reflectors. The problem cannot be new, as the reflectors are already present also on much older Google Earth pictures.



**Figure 7: Terrain gradient change (blue) and installed radar reflectors (green)**

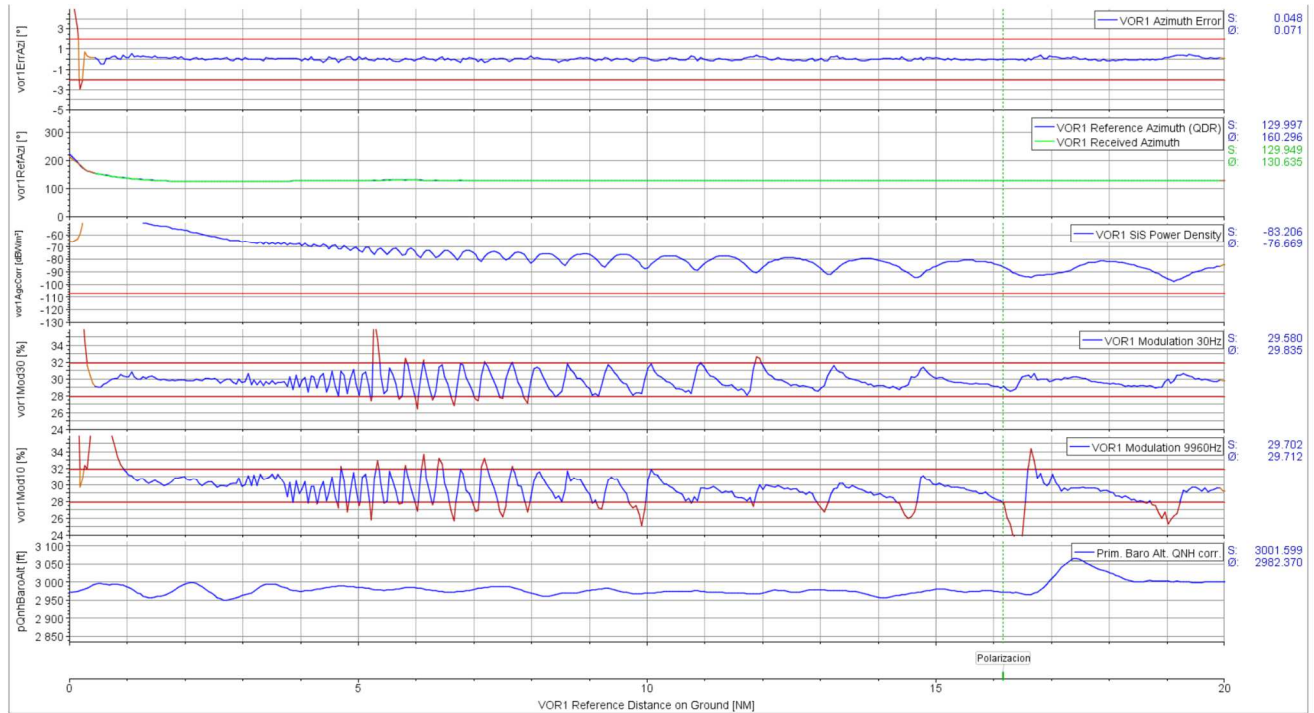


**Figure 8: Terrain and Radio Reflectors**

The Radio Altimeter, which plays a significant role in the last approach section before touchdown, does not get the green dashed signal, but the blue one which indicates the ground comes closer rather quickly. Very likely, this causes the aircraft to fly up and immediately later, plunge down. The sequence of five (!) equidistant perpendicular valleys may even match the frequency of the autopilot control loop leading to a resonance effect.

### VOR MULTIPATH EFFECTS

There was a customer's request to explain different signal-in-space (SiS) results at a VOR radial when using top and tail VOR antenna. The first reason was rather straightforward. The VOR SiS graph shows typical "bouncing" effects when flying over water, which was the case, as Google Earth revealed.



**Figure 9: VOR radial showing typical multipath pattern**

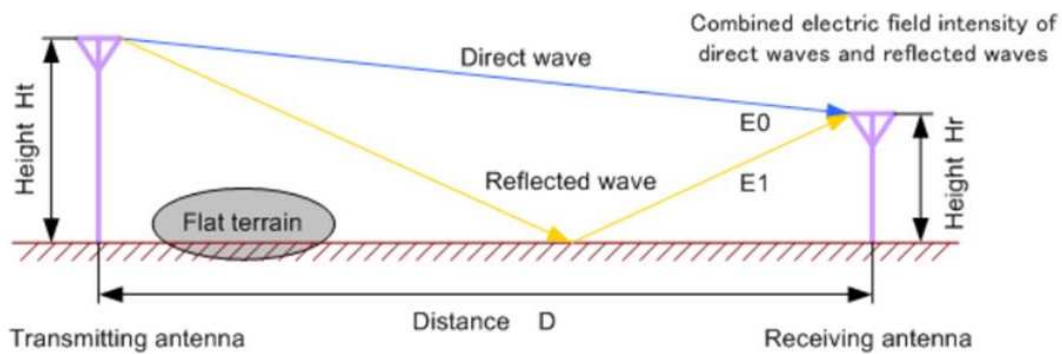


Figure 10: Principle of multipath pattern

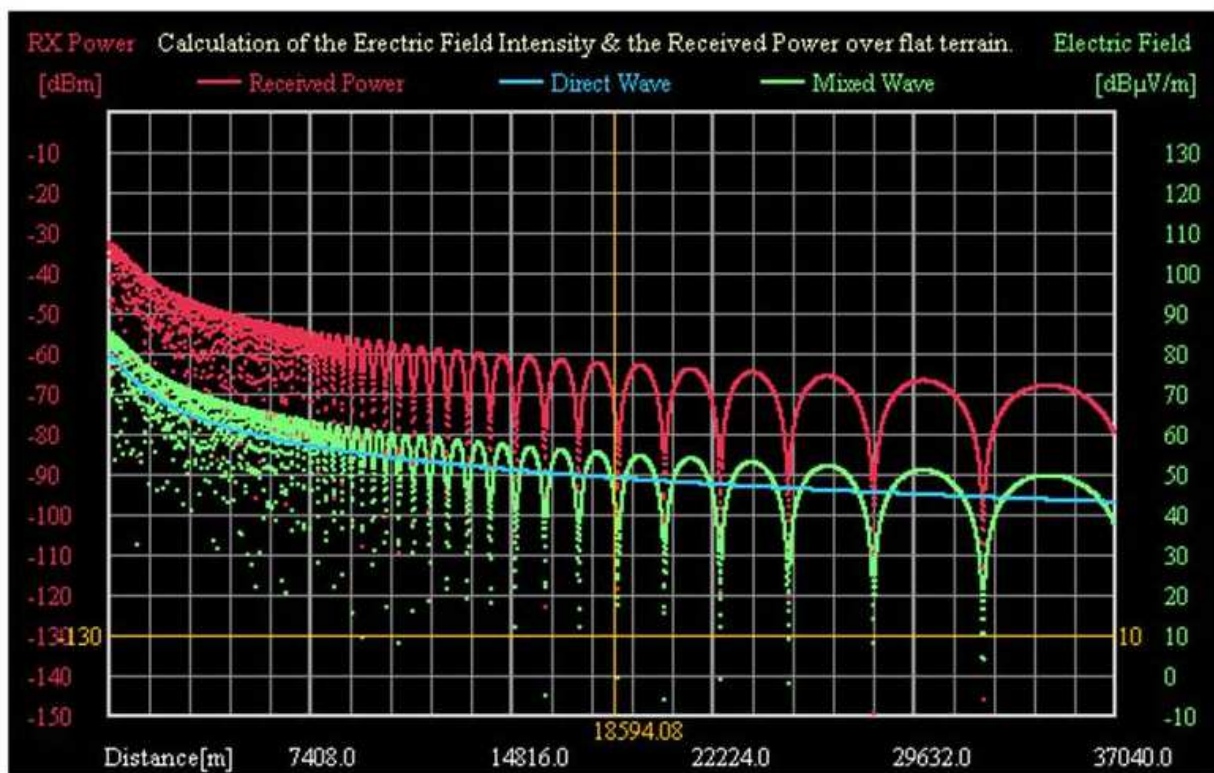


Figure 11: Numerical SiS Simulation using the given VOR geometry

Simulation and real data nicely matched proving that the effect was related to the facility geometry.

The VOR was located at some dozen meters elevation at the oceans shore.

The signal shows typical multipath, exactly as in simulation.

The inbound radial uses the top antenna. The outbound radial uses the tail antenna.

Dependent on the location at the aircraft, top and tail antenna show different amounts of multipath, because the reception situation is beyond specification and the field changes rapidly with location.

The recommendation was to either relocate the VOR or install antenna modifications to reduce the multipath.

## FI ANTENNA EFFECTS

On the same flight, which already showed the “bouncing” SiS indicating multipath as in the training books, a second, independent effect appeared: On some profiles, the 9960 Hz modulation was significantly weak, the 30 Hz modulation and the azimuth error had strange peaks going out of tolerance (Figure 12, Figure 13). This happened at the top antenna only. The crosscheck using the tail antenna was good and the effect was independent of the receiver.

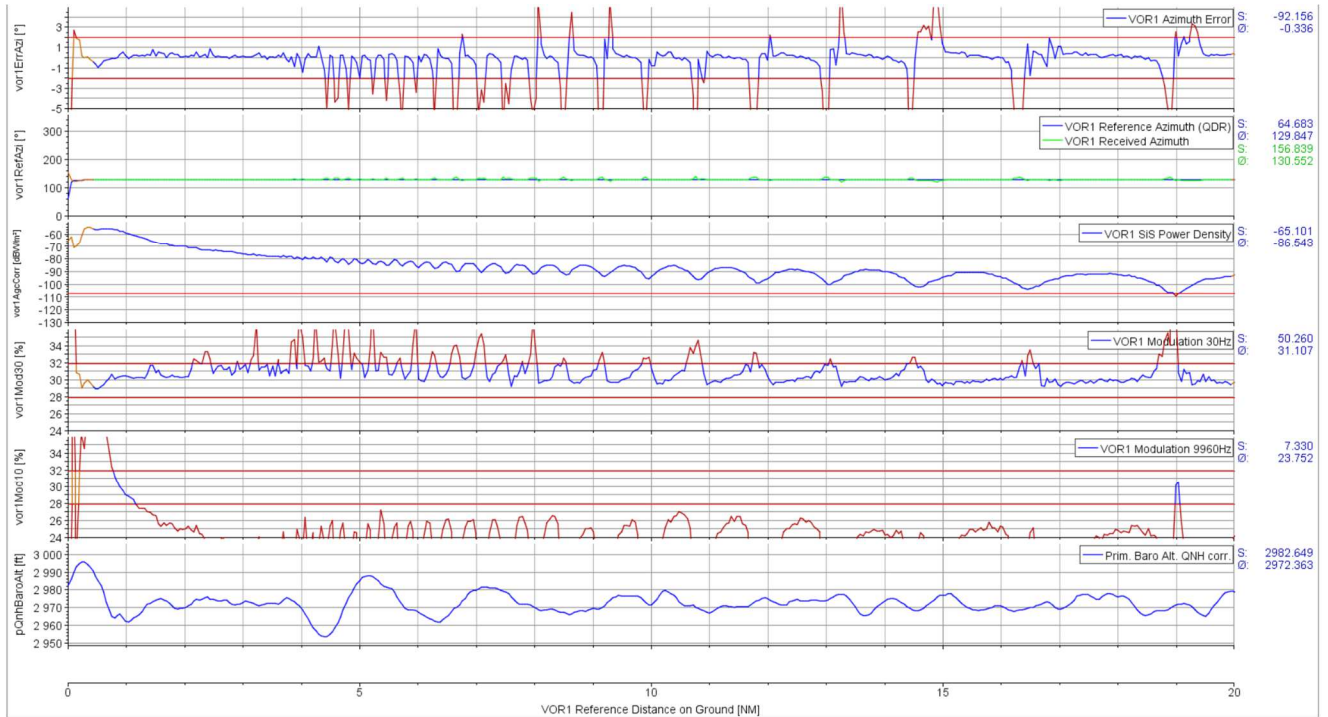


Figure 12: VOR radial with glitches and low 9960 modulation

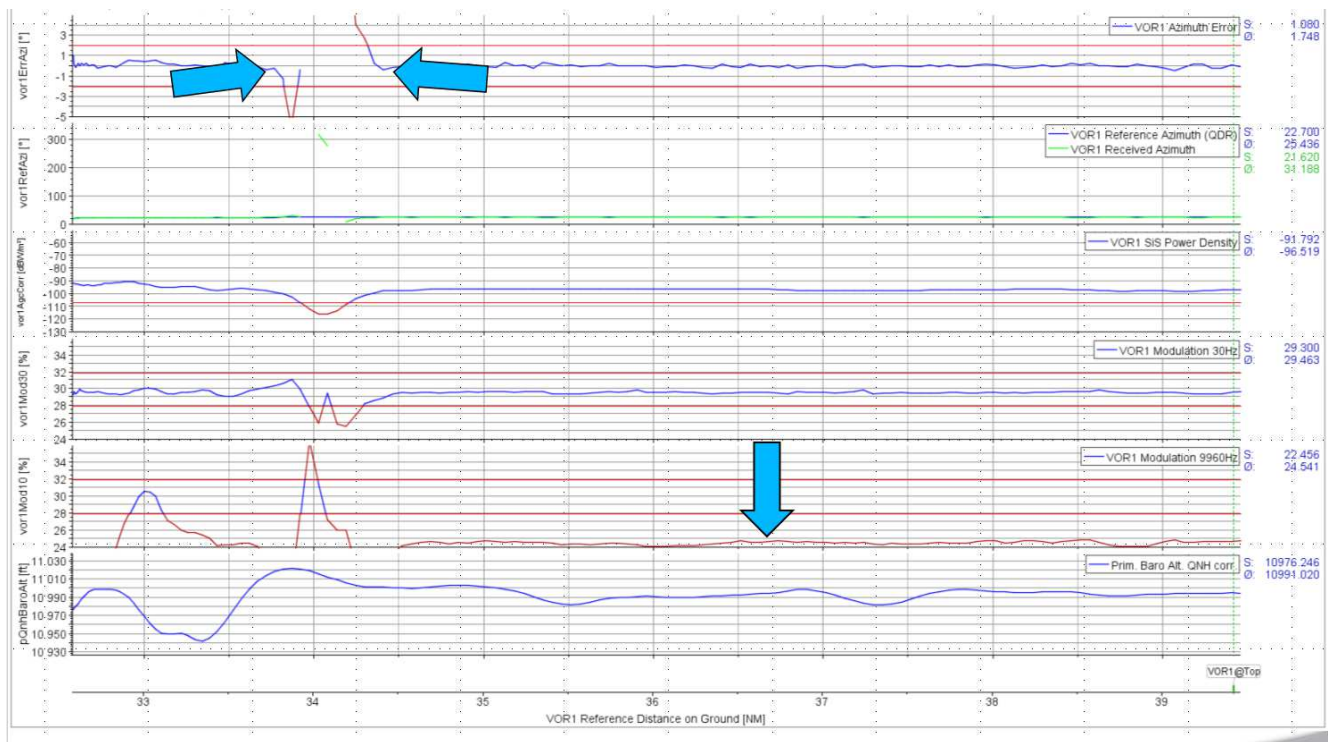
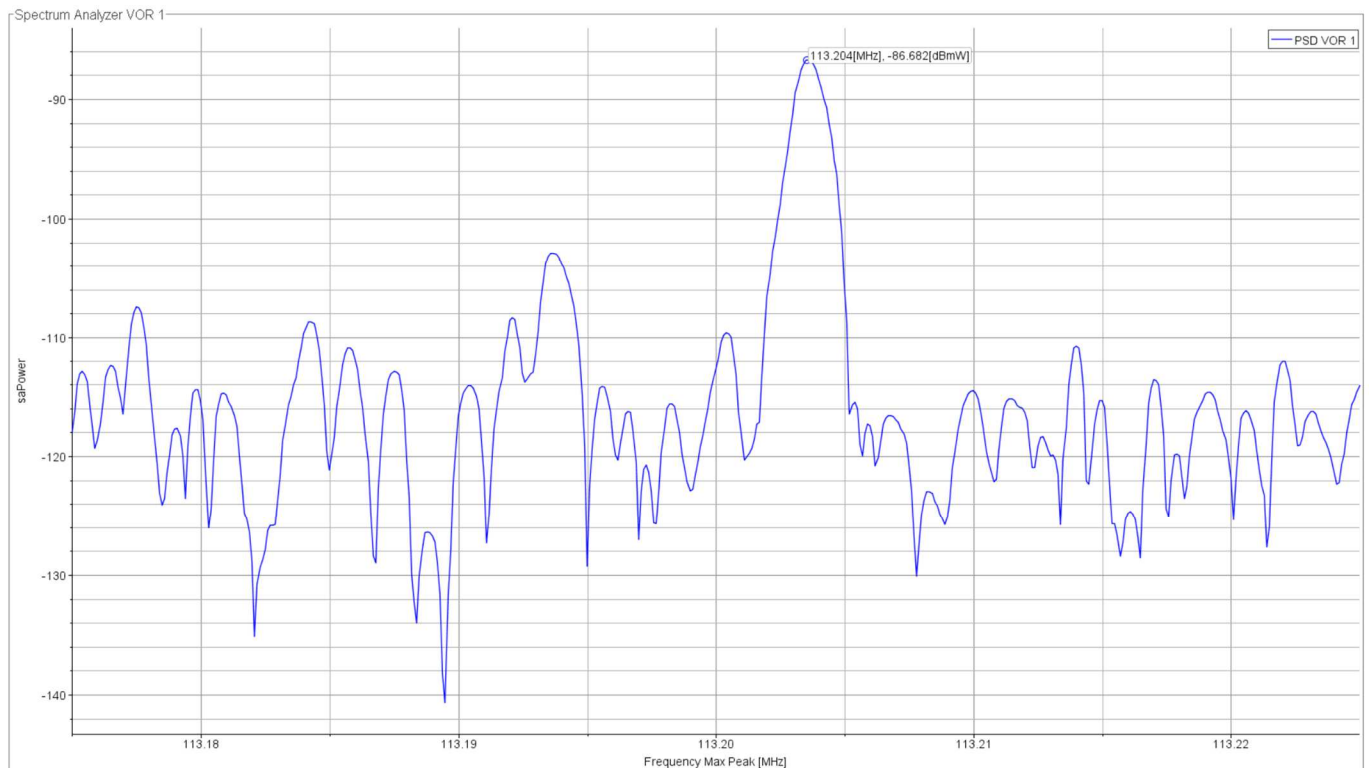


Figure 13: Zoom of a single glitch

This gives a strong indication that the antenna is the root cause. But how can it impact the 9960 Hz modulation despite the SiS being fine? The spectrum analyzer allows a deeper look into the antenna characteristic by visualizing the VOR video.



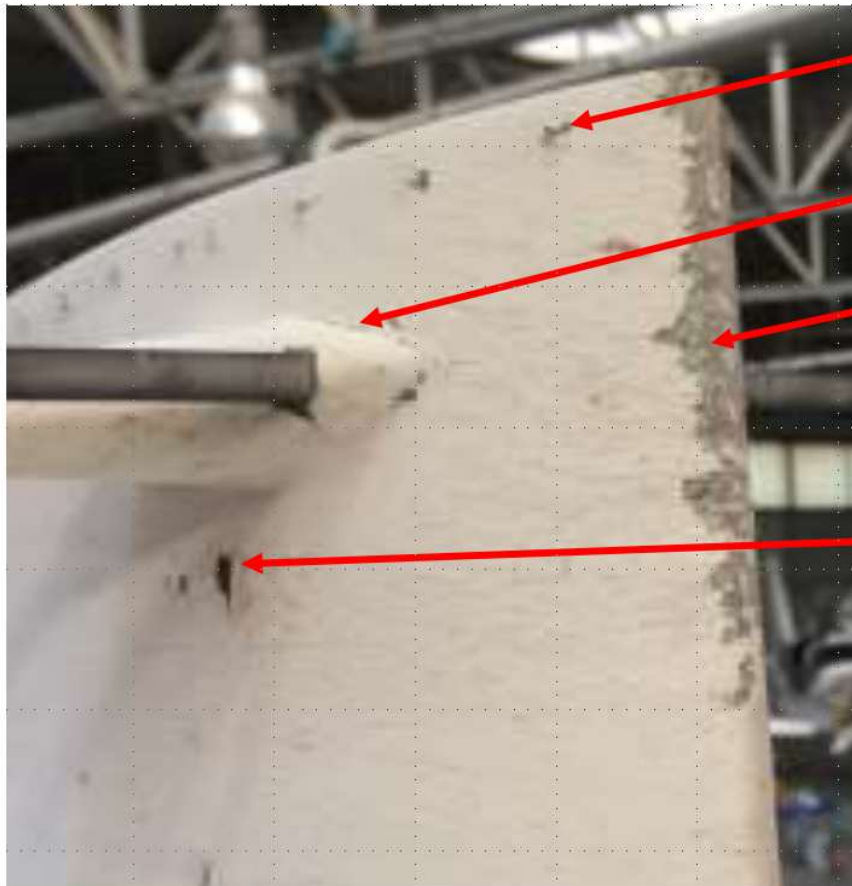
**Figure 14: Spectrum analyzer plot of top antenna**

Figure 14 shows a strongly distorted VOR video, obtained from the top antenna. The modulation peaks are almost gone. No wonder, that the receiver cannot identify 9960Hz modulation and a very small value is indicated.

As the tail antenna provides a reasonable result with both receivers, the effect is neither correlated with the ground facility nor the flight inspection receivers.

Only a few options remain, as the top antenna itself, cabling or antenna switching equipment.

A support specialist was sent out to examine the system.



Rivets

Cracks

Wear and tear  
down to raw  
glass fibre, no  
paint anymore

Paint gone

Figure 15: Visual Inspection of the Top Antenna

Figure 15 indicates a poor mechanical status of the top antenna and already indicates a due exchange.

Further investigations were done to check the remaining electrical performance.



Figure 16: VSWR plot of top antenna

The antenna was checked with a “reflected energy versus frequency” test, also known as “VSWR” test.

This antenna had a center frequency outside the NAV band, at about 128 MHz.  
The reflection, shown in "dB" unit, is far outside the standards over the full NAV band.

This explains weak AGC and modulation, but there is even more ...

It was expected, that this antenna may also have an "intermittent contact" problem inside.

This was tested by mechanical vibration on the radiating elements.

While the manually forced vibration the reflection plot was monitored, and as short-time spikes showed up, a mechanical intermittent contact was identified.

Crack sound was also on the audio. Funny enough, the GP signal was still fine.



Figure 17: Magic Finger performing mechanical Test



## Figure 18: Glitch proving intermittent electrical disconnection

The antenna was in rather poor shape. How did this happen despite of periodic maintenance?

- The FI console was under regular maintenance
- The aircraft was under regular maintenance
- The FI antennas were not checked at all for 10 years.
- Maintenance responsibility for FI antennas was not clearly defined.

The antenna was exchanged. It was recommended to revise the maintenance plan to include the FI antennas.

### SUMMARY

Again, it was proven true that things go wrong, no matter how well the preparation is. Sometime the little details, like sorting a table of coordinates with a standard office application, can change a training flight into a nightmare. Mountains in the line-of-sight can be overlooked if the elevation of the line-of-sight is just low enough. Beyond electrical measurements, also the terrain and weather (snow!) may have a significant impact to the overall performance.

Never touch a running system. This actually has proven wrong. Legacy systems may still hide unexpected problems behind decades of undoubted operation.

### REFERENCES

- [1] Jagieniak, *Traps and Pitfalls in Flight Inspection*, IFIS 2016, Belgrade, Serbia, 2016.
- [2] Jagieniak, *More Traps and Pitfalls*, IFIS 2018, Monterey, USA, 2018.
- [3]. ICAO Annex 14, Aerodromes.