More Traps and Pitfalls

Stefan Jagieniak, *Aerodata AG, Germany*

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.

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 25 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
- VOR ground cabling issue
- VOR multipath effects
- FI Antenna effects

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].

“If anything can go wrong, it will.”

SURVEY AND DATABASE ISSUES: LINE-OF-SIGHT

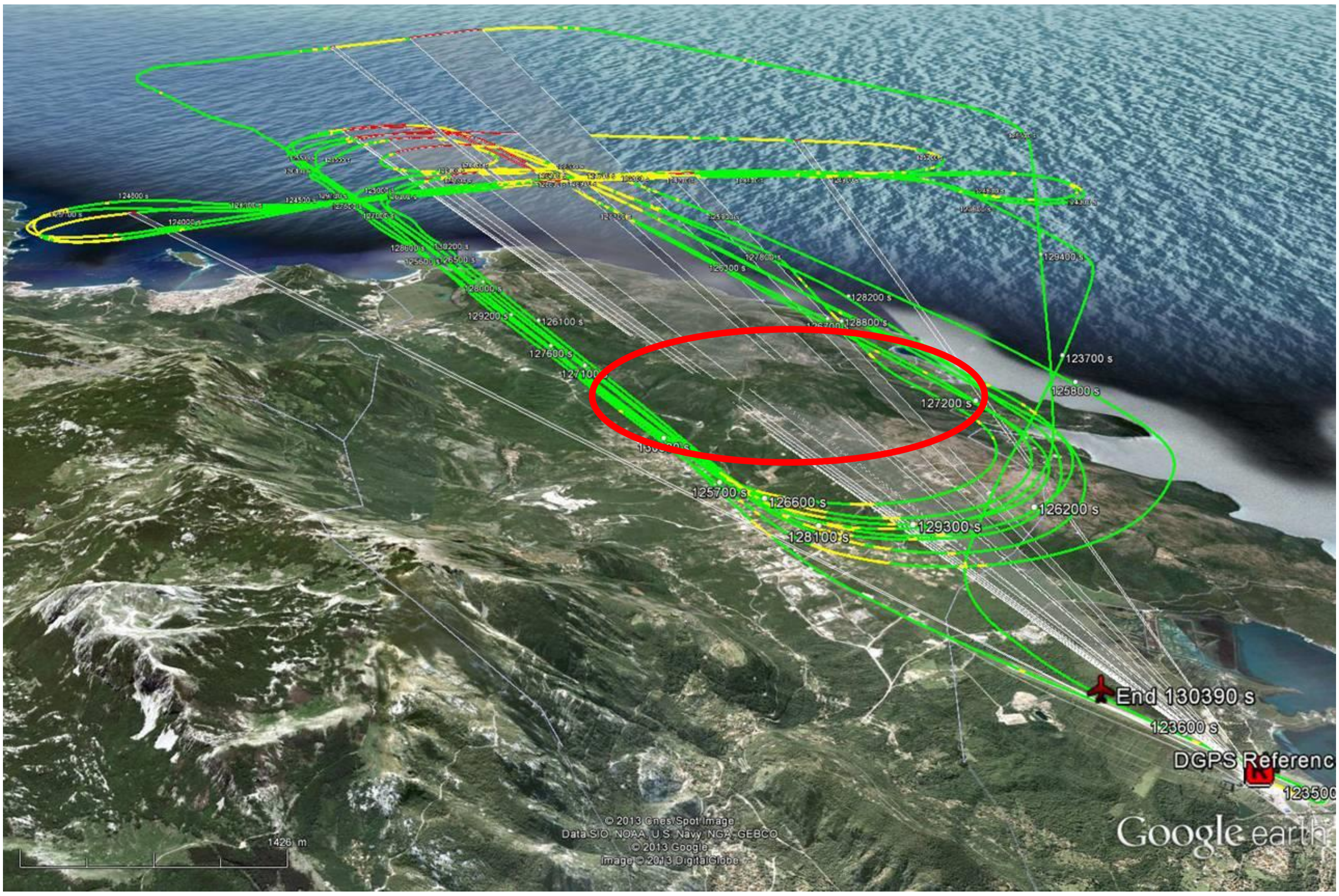

Figure 1: DGPS Status during an ILS Inspection

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°. 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° 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:

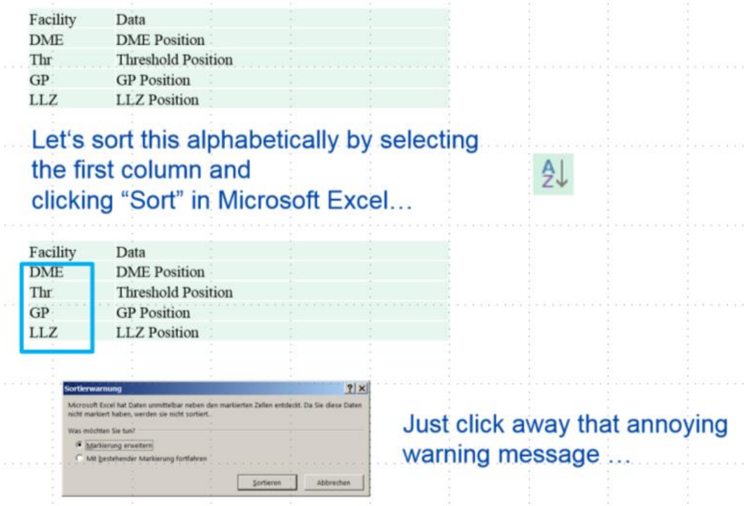

Figure 2: Table column selection and sorting

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.

Figure 3: Ignoring warning messages may give you this

VOR GROUND CABLING ISSUE

Already a couple of years ago, a comparison of two flight inspection receiver candidates was performed. During a VOR commissioning, 10 NM VOR Orbits were performed and the results of the two receiver types compared. Unexpectedly, there were significant differences.

NAV Rx1: AD-RNZ850

NAV Rx2: Bendix RNA-34AF

Figure 4, Figure 5 and Figure 6 show the significant graphs from the same orbit flight from both receivers.

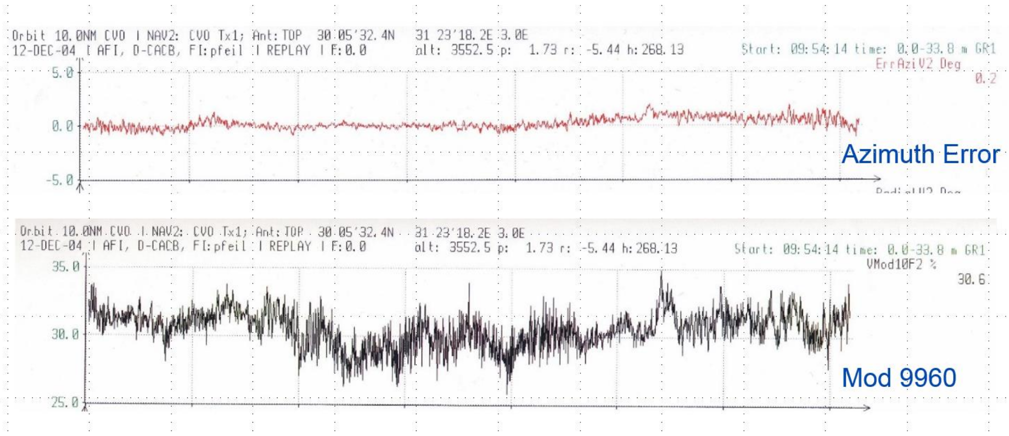

Figure 4: VOR azimuth error and modulation from RNA-34AF

Figure 4 looks pretty normal, perhaps a little bit noisy.

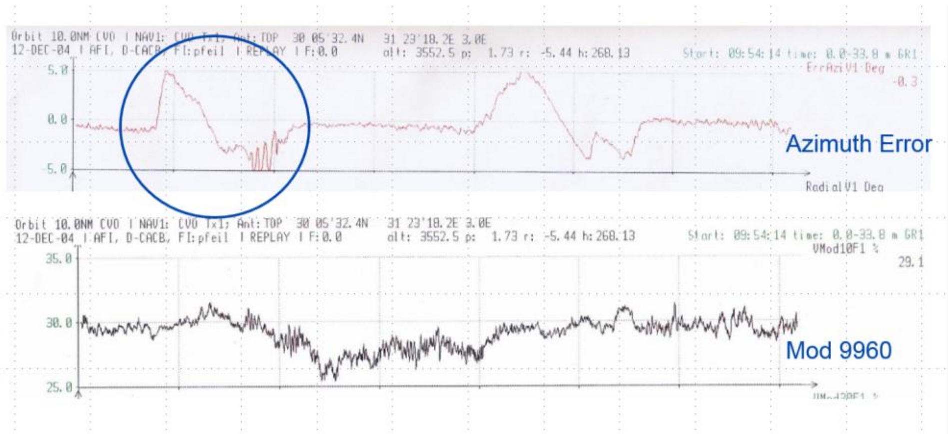

Figure 5: VOR azimuth error and modulation from AD-RNZ850

Figure 5 is from the same run, same input, with a different FI receiver. Now there is a significant azimuth error at two positions.

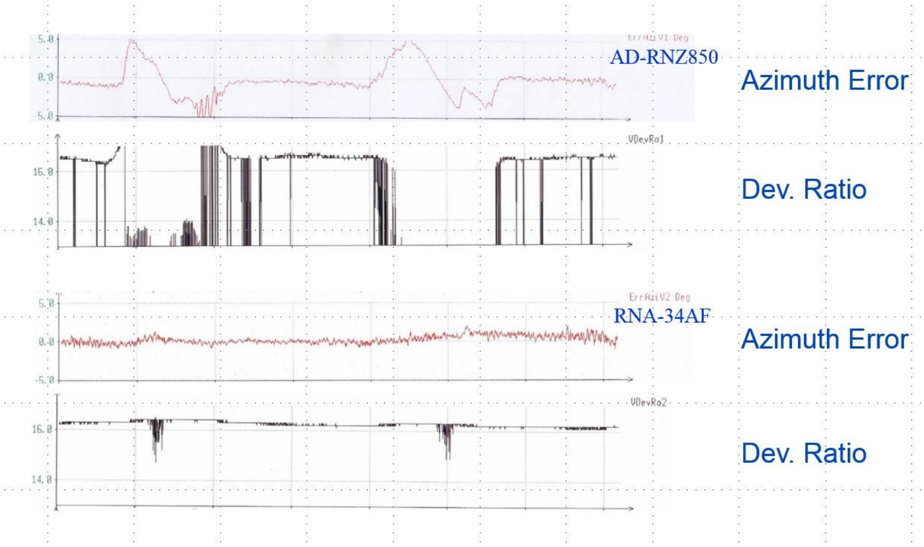

Figure 6: VOR azimuth error and deviation ratio in comparison

Also the deviation ratio has significant outages in the second graph which were not seen before.

The well established and known receiver showed rather normal data with only minor glitches. The flight inspector intended to sign off the VOR as fully serviceable. The alarming systematic azimuth error of about 6° and the strong deviation ratio break in of about 13 instead of 16 were assigned to the – at that time – new receiver type which was not trusted.

Interestingly enough, the primary cockpit equipment also showed a significant heading error. A lengthy discussion started. Problems of the new ground installation were not considered, because the legacy FI equipment did not show the problem. The equipment was known for decades, fully trusted, and certified. Newcomer-receiver results were doubted.

After a while and a lot of tests, the discussion became quiet.

Finally the problem was revealed as a cable swap of antenna segments on ground.

We learn:

Wrong question: What is wrong now?

Right question: How could this ever work?

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.

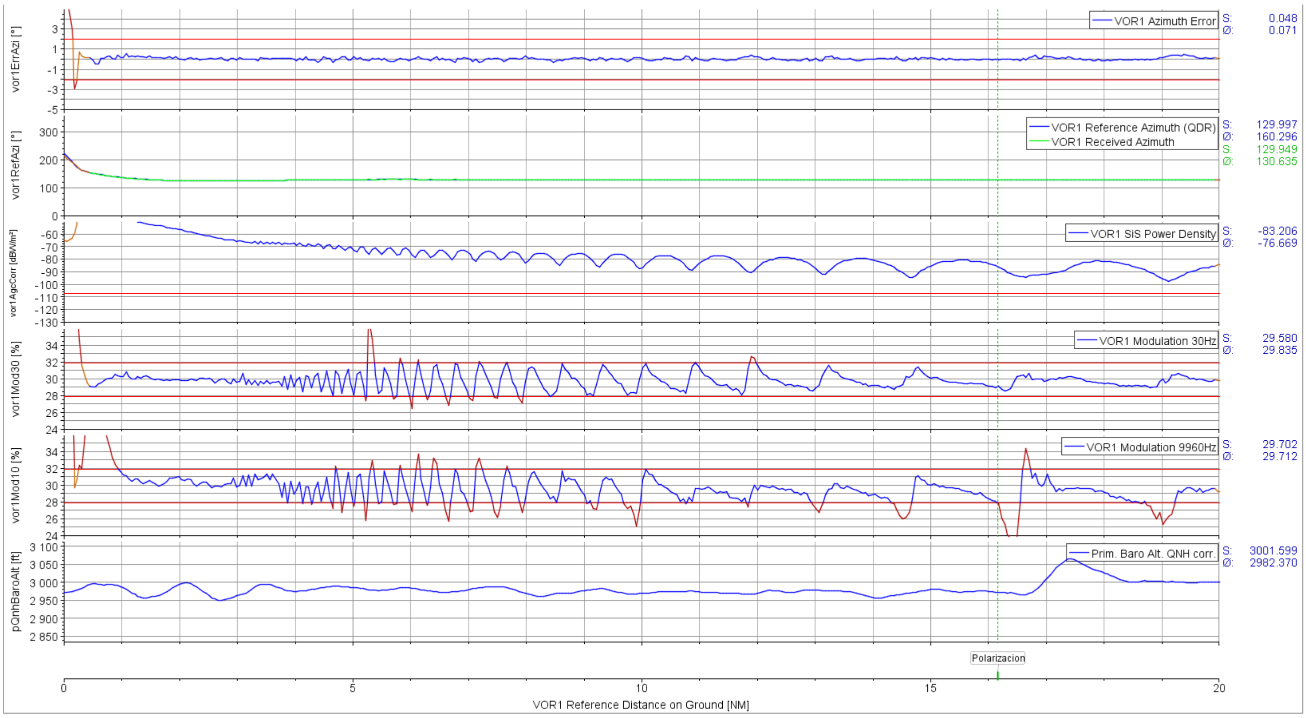

Figure 7: VOR radial showing typical multipath pattern

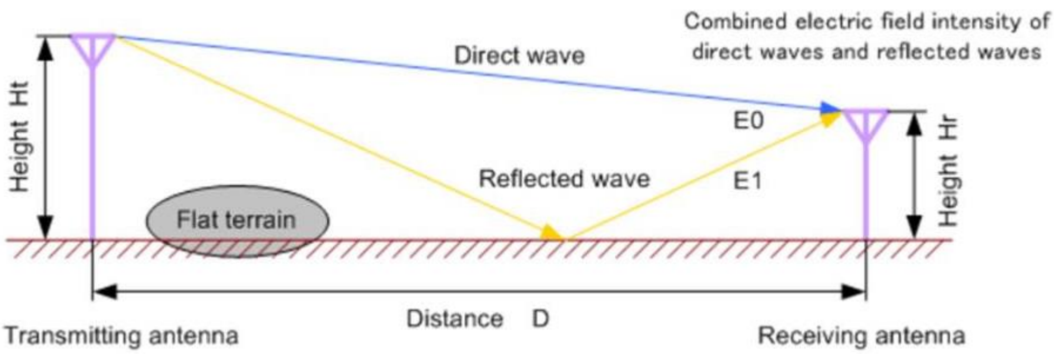

Figure 8: Principle of multipath pattern

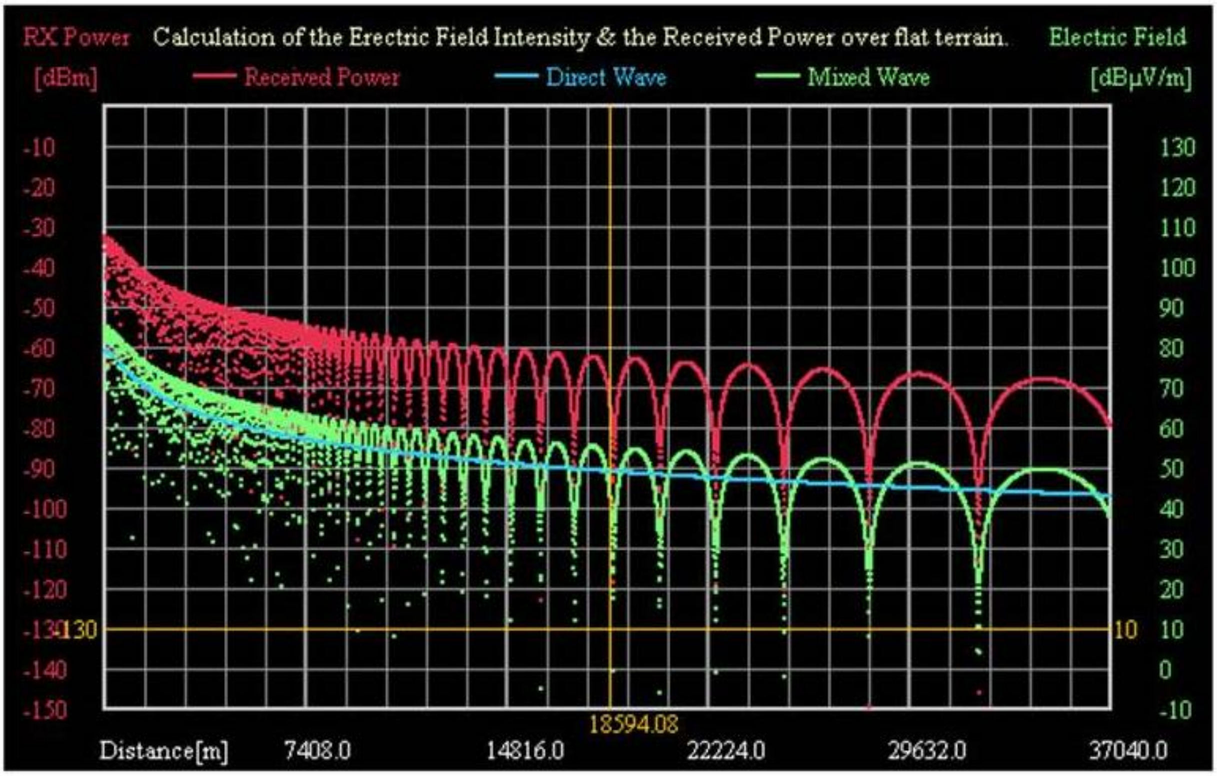

Figure 9: Numerical SiS Simulation using of the actual VOR geometry

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

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 10, Figure 11). 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).

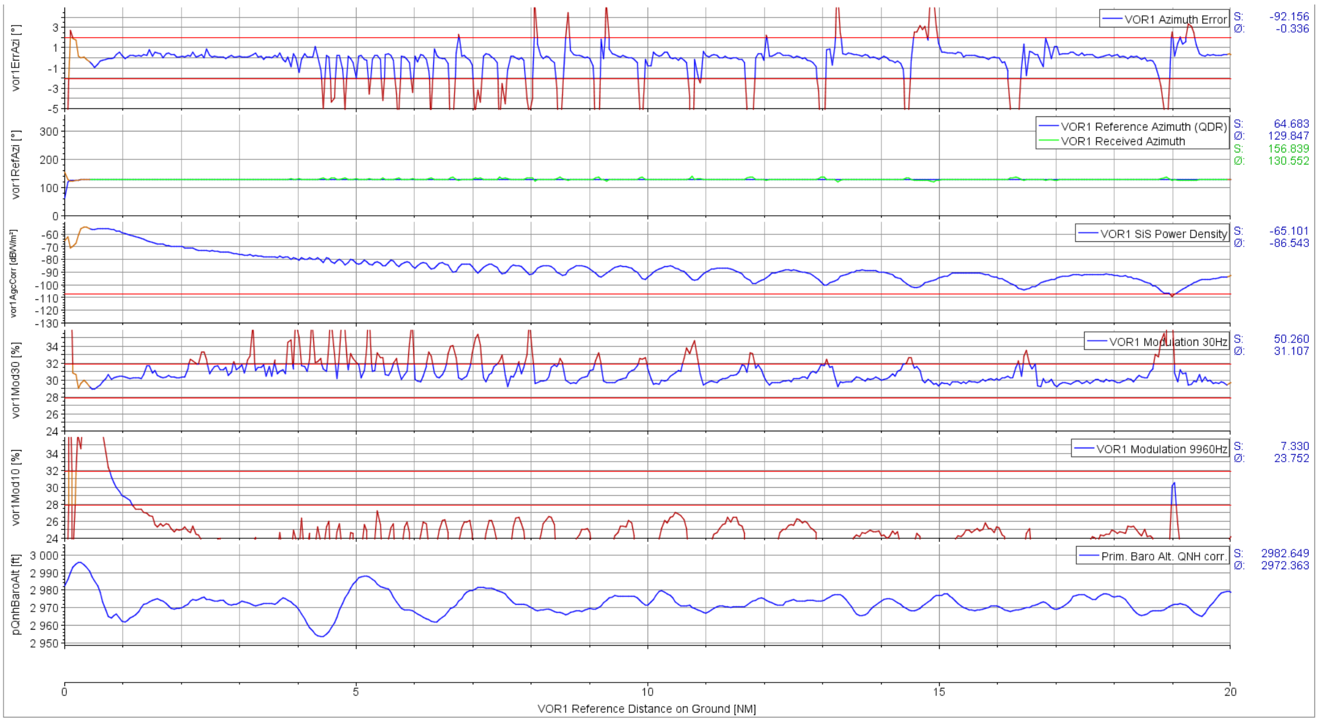

Figure 10: VOR radial with glitches and low 9960 modulation

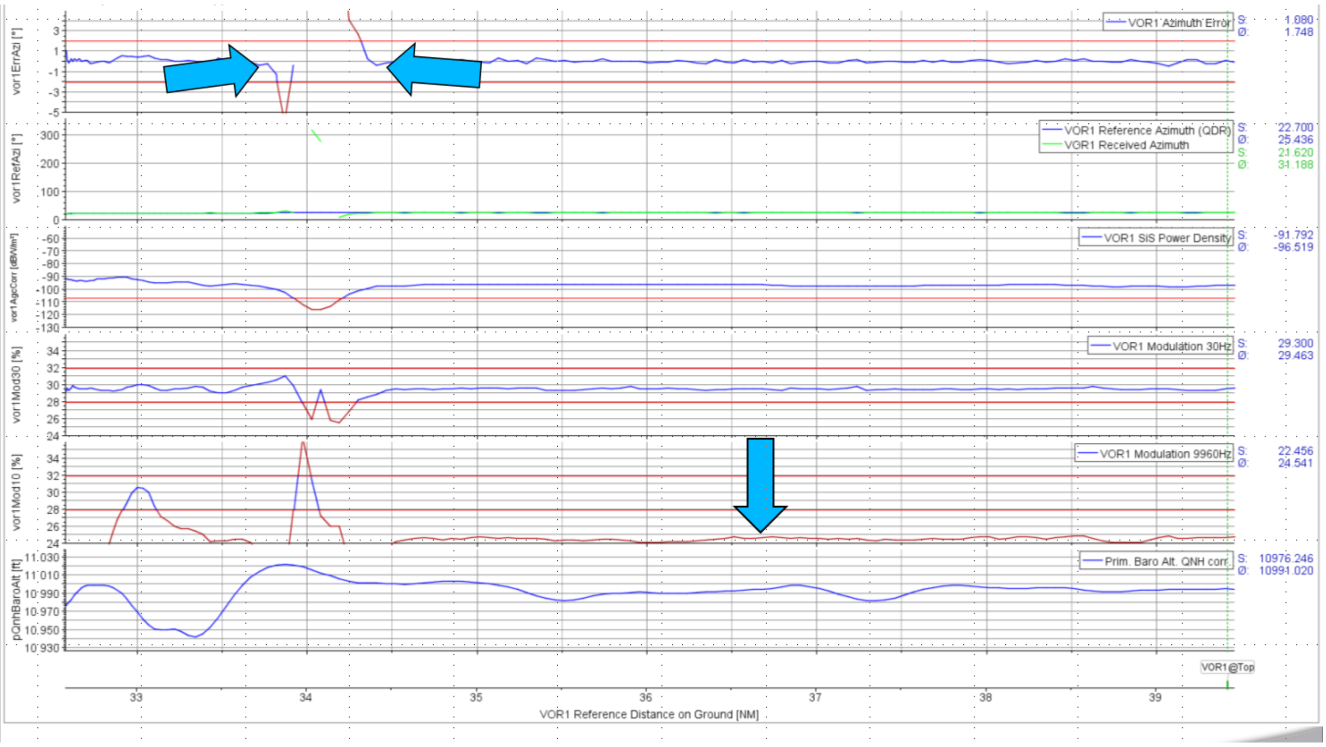

Figure 11: Zoom of a single glitch

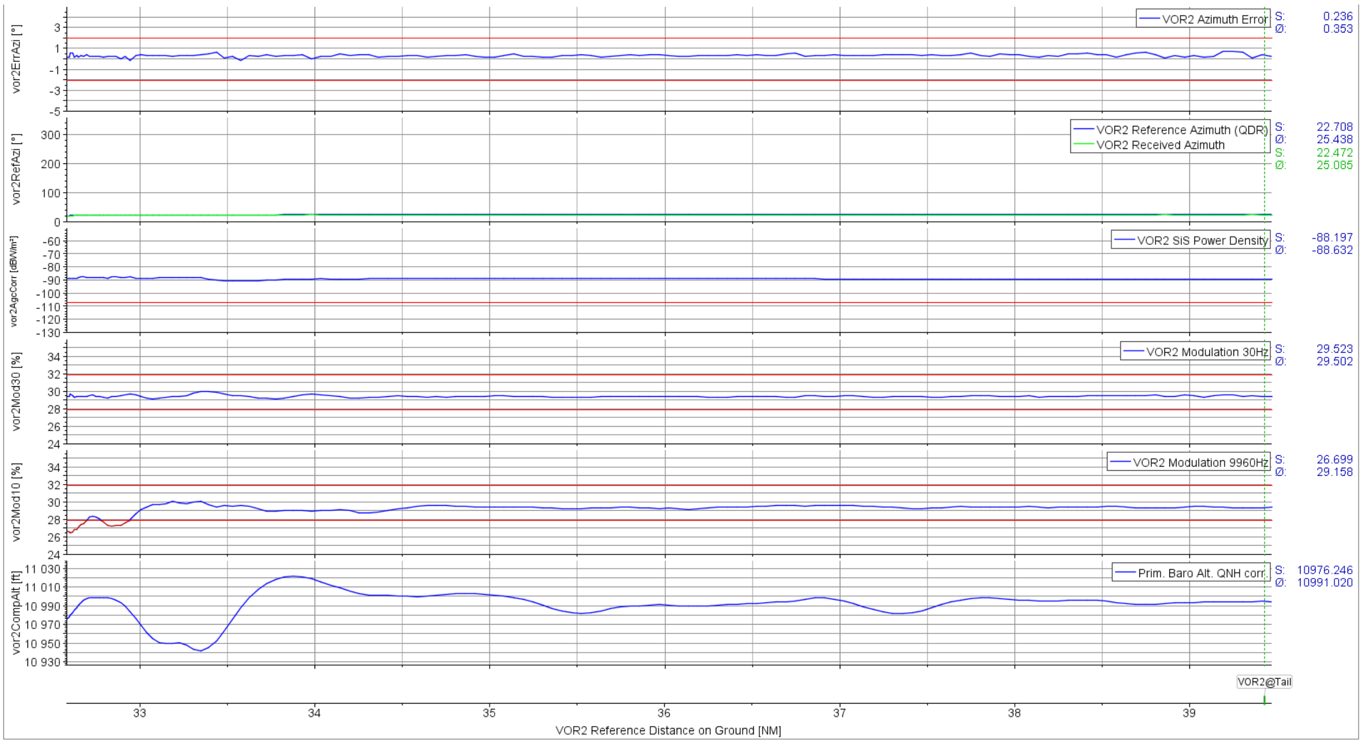

Figure 12: Everything is fine with the tail antenna

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.

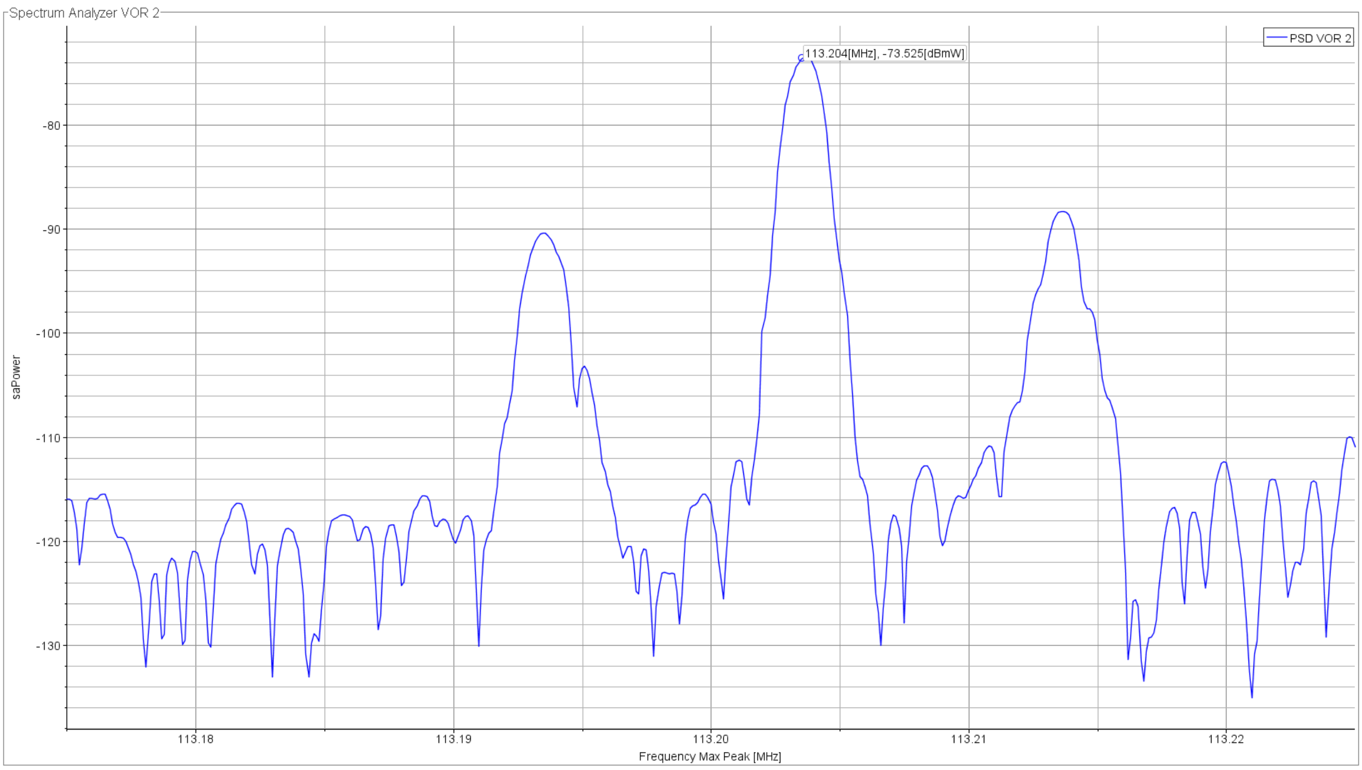

Figure 13: Spectrum analyzer plot of tail antenna

The normal VOR video in Figure 13 shows a peak at the carrier frequency and two smaller peaks at carrier +/- 9960 Hz modulation.

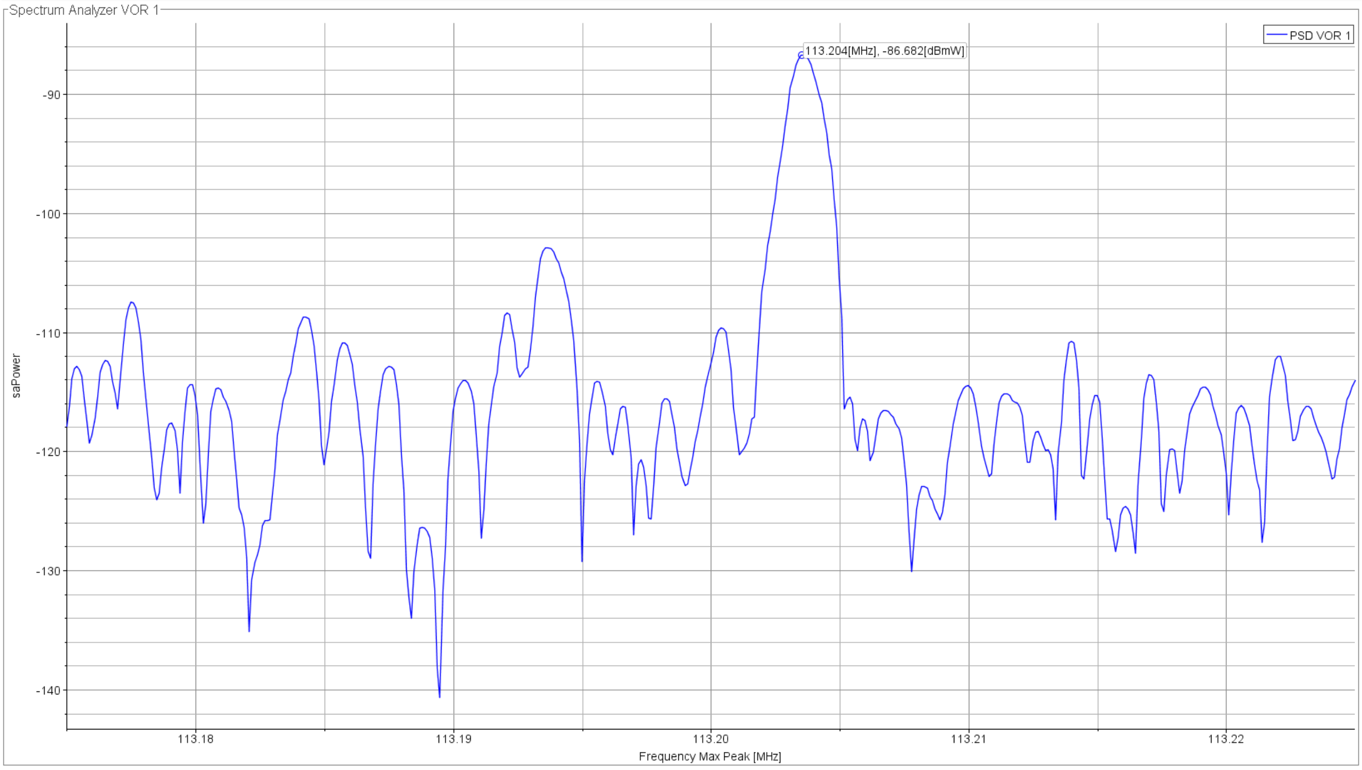

Figure 14: Spectrum analyzer plot of top antenna

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.

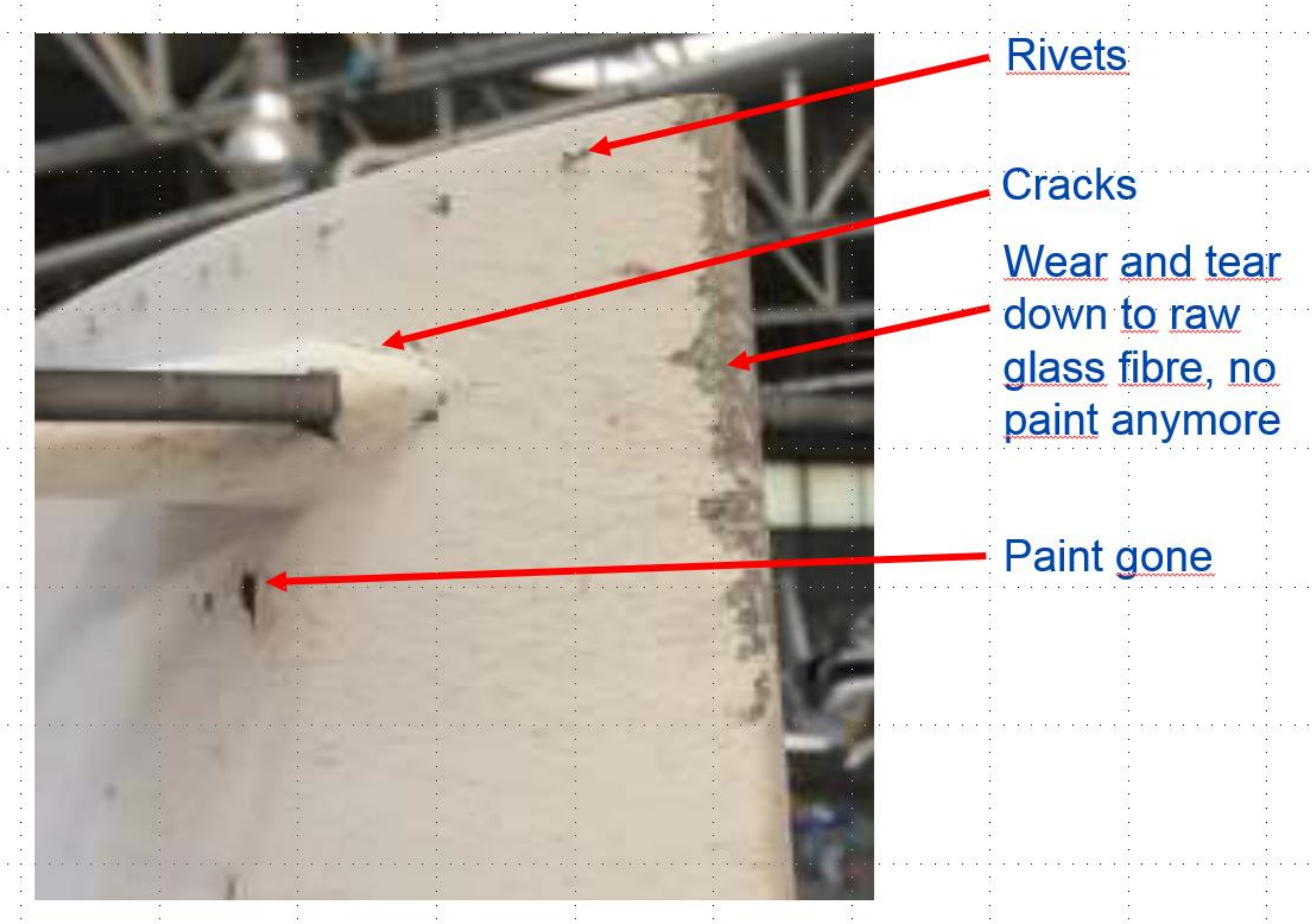

Figure 15: Visual Inspection of the Top Antenna

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.

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

REFERENCES

[1] Jagieniak, *Traps and Pitfalls in Flight Inspection*, IFIS 2016, Belgrade, Serbia, 2016.

[2] „Murphys Law,“ [Online]. Available: http://jcdverha.home.xs4all.nl/scijokes/9_6.html.