

ILS ground and flight inspection comparison tool

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ABSTRACT

Reducing flight inspection intervals has become a major goal in many countries. To achieve this goal accurate ground measurements must be performed regularly and a strong correlation with flight measurements must be established. The ILS simulation software packages ATOLL (Localizer) and LAGON (Glide path) can now be connected to an ILS receiver to record and plot ILS parameters. It is also possible to import flight inspection measurements either in text format or as an image. This allows easy comparison between flight and ground measurements. Additionally, simulations can be overlaid to assess the measurements regarding the expected theoretical data. All important settings on the real equipment can be simulated: Transmitter adjustments, antenna positions and feeding, diffraction of the radiated signal from surrounding objects, as well as settings in the Flight Inspection Systems (FIS). It is thus possible to determine which parameter drift or maladjustments led to the errors recorded during flight or ground inspections. This presentation will give an overview on the recording and simulation features in ATOLL and LAGON and show a few use cases.

INTRODUCTION

To reduce flight inspection intervals, a strong correlation between flight measurements and ground measurement must be established.

To achieve this goal accurate ground measurements must be performed regularly.

Investigating issues that may appear during flight inspections can also be quite challenging.

Therefore, having a tool that can carry-out measurements, import flight inspection measurements and compare with simulations can be quite helpful.

The French civil aviation university has developed 2 ILS simulation software packages.

- ATOLL (Advanced Trainer on Localizer) for the localizer
- LAGON (Learning About Glide for Overall Needs) for the glide path

ATOLL and LAGON were primarily designed as education and training tools for ILS teachers. Over time many features have been added

ATOLL and LAGON are now well suited for:

- Initial training
- Continuous education
- Tracking down equipment and antenna errors
- Training for flight inspection crews and ground personal.
- Assessment for impact of new buildings and taxiing aircrafts using the method of physical optics (PO)

FEATURES AVAILABLE IN ATOLL

Runway layout

Before starting a simulation, one must set the runway parameters.

Following parameters can be set and saved.

- Runway length
- Localizer setback

- Sector width, manual or computed.
- Antenna array
- Transmitter type
- Localizer frequency

It is also possible to add a background picture of the runway which will be used in other windows.

Antenna settings

The antenna setting panel has 2 tabs, one for the mechanical setting and the other for the electrical settings.

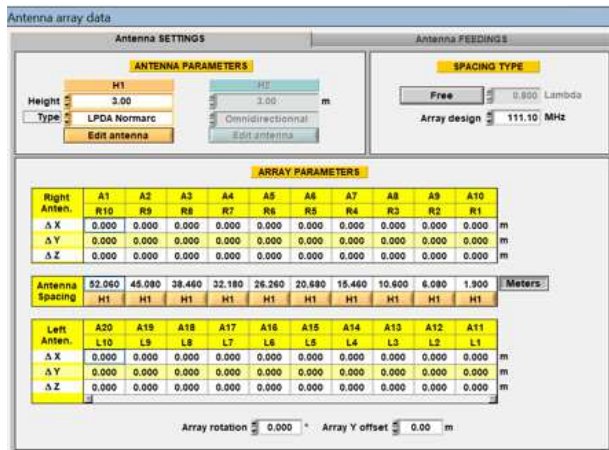


Figure 1. Mechanical settings tab

From the mechanical settings tab, one can select the antenna type and the spacing between the antennas. It is also possible to add some antenna placing errors.

The antenna feedings tab permits to set the amplitude and the phase of the feedings of the antennas. Antenna feeding errors coming for example from bad soldering or some moisture in the connectors can also be added.

Transmitter settings

The basic transmitter adjustment panel gives access to the adjustments available on all kind of transmitters and permits to test some transmitter maladjustments.

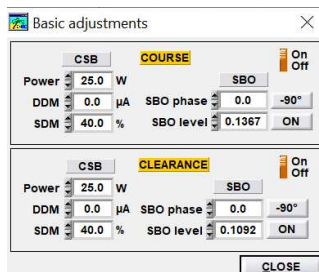


Figure 2: Basic adjustments panel

For some ILS systems the complete block diagram with all the adjustments available on the real equipment can be displayed.

It is therefore possible to simulate more transmitter specific maladjustments and see how they can change the recorded signal in space.

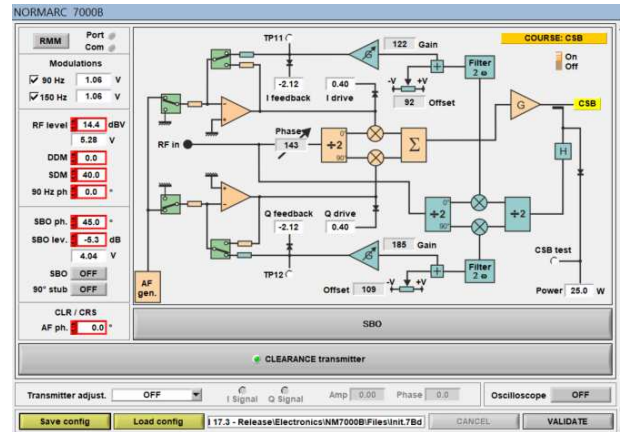


Figure 3: NORMARC transmitter panel

It is also possible to connect the manufacturer adjustment software to ATOLL and make the settings the same way as if connected to the real equipment.

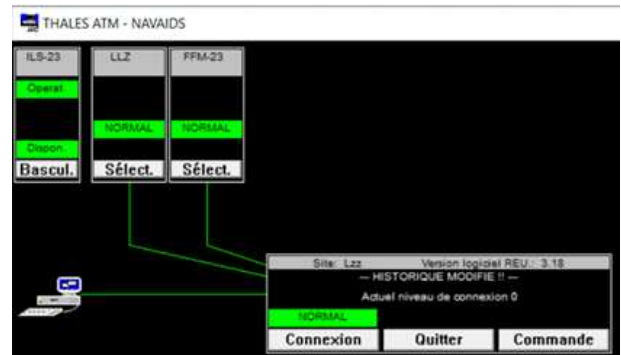
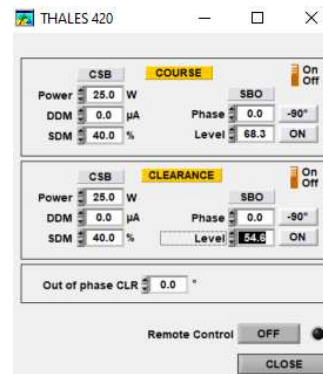


Figure 4: THALES transmitter panel and Remote control software

Scattering objects panel

Obstacles, such as taxiing aircrafts, cranes or buildings present in the vicinity of the runway can produce unwanted multipath signals, thus degrading the performance of the ILS.

The method of Physical Optics (PO) on a polygonal plate is used to simulate the objects that may disturb the ILS signal.

One can add these objects and set their location and size from the Scattering objects panel.



Figure 5: Scattering objects panel

Visualization of ILS parameters

ATOLL can display plots in the same way as what one can see in a Flight Inspection System

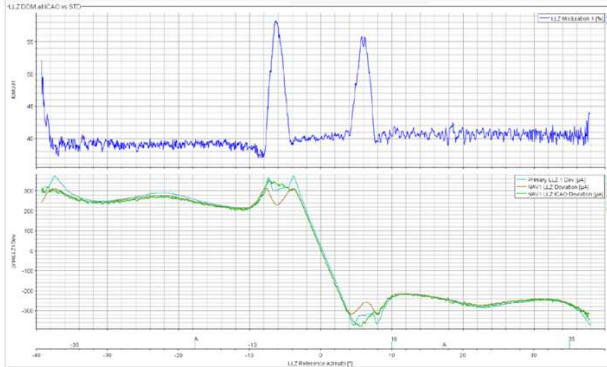


Figure 6. Flight inspection orbit plot

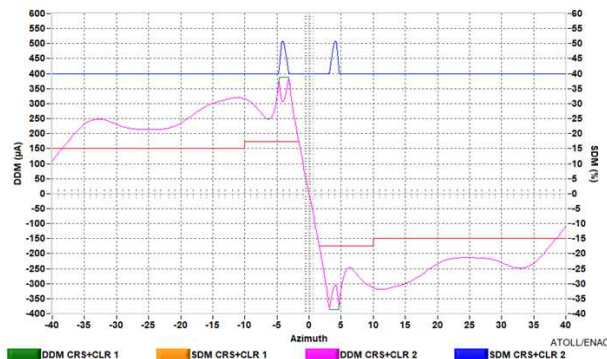


Figure 7. Simulated orbit plot with ATOLL

It is possible to import flight inspection data from a text file generated by the FIS.

This makes it easy to compare flight results with simulations.

Below is an example of a FIS data file imported in ATOLL.

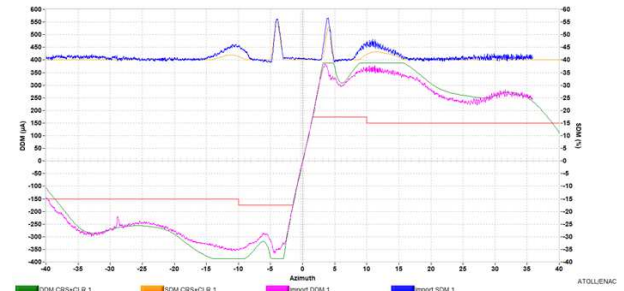


Figure 8: Comparison between measurement and simulation at 20 km from the localizer

A simulation has been overlaid to compare if the measurement follows the expected behavior.

Using the same feature with ground measurements gives an easy way to show the expected differences between flight and ground measurement.

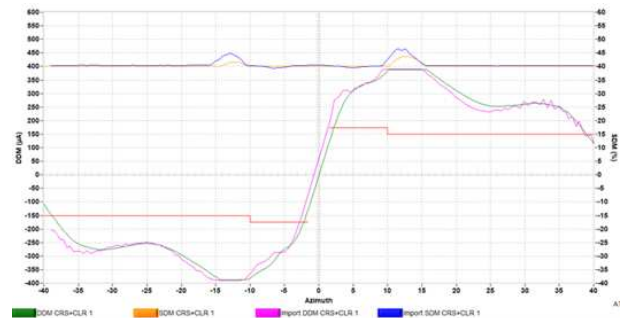


Figure 9: Comparison between measurement and simulation at 210 m from the localizer

Connection to ground measurement devices.

To make things even more easy, ATOLL and LAGON can be connected to ILS receivers from Rohde & Schwartz (EVS300 and EVS1000) and from Indra (NM7710)

One can run a simulation and then start a recording and compare in real time the measurement with the expected outcome.

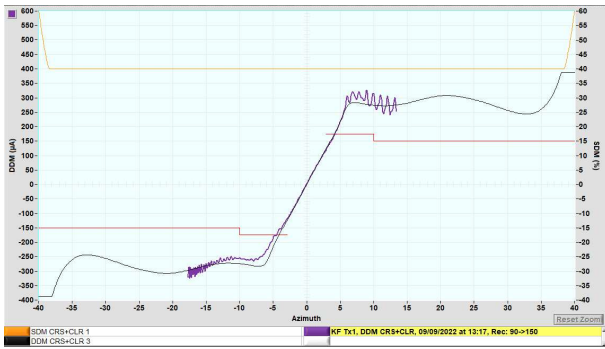


Figure 10: Comparison of ground measurement with simulation

Real life example

Here is a record of some monitor readings from an ILS.

Recordings of Monitor Signal inputs to the Cabinet:

tem	Parameter	TX 1	TX 2
6.1	CL DDM	1,3 µA	1,4 µA
6.2	CL SDM	39,98 %	39,98 %
6.3	CL RF-Level	-20,8 dBm	-20,8 dBm
6.4	DS DDM	149,1 µA	149,1 µA
6.5	DS SDM	39,94 %	39,89 %
6.6	DS RF-Level	-22,3 dBm	-22,2 dBm
6.7	NF DDM	N/A µA	N/A µA
6.8	NF SDM	N/A %	N/A %
6.9	NF RF-Level	N/A dBm	N/A dBm
6.10	CLR DDM	75 µA	75,8 µA
6.11	CLR SDM	39,32 %	39,37 %
6.12	CLR RF-Level	-28,8 dBm	-28,9 dBm

Figure 11: Monitor readings

One can see that there is an issue with the clearance DDM.

But an orbit measurement on the ground shows no correlation with the DDM readings.



Figure 12: Ground measurement in front of localizer

So, what is wrong?

After a lengthy investigation it was found that one antenna was not correctly connected

If the ground measurement would have been made with ATOLL, one could directly recognize that something is wrong with the DDM plot by comparing with the expected DDM behavior.



Figure 13: Expected DDM plot simulated with ATOLL.



Figure 14: Simulated DDM plot with the same error

A tool included in ATOLL can also help to find a faulty antenna by analyzing the monitor readings.

One can just enter the monitor readings and click on the search button. The software tries to find an error which gives the closest DDM match with the monitor readings.

Ant. Errors	Monitors	Search Faulty Ant.	DDM / SDM	Coupling	Attached Elec.	Photo					
Non-read	CL	Width	CLR	NF On	search range	Min Step Max					
DDM	0.00	150.00	212.90	0.00	Amp	20.00 5.00 100.00					
Nom. OFF	0.00	0.00	0.00	0.00	Phase	-90.00 1.00 90.00					
Left antennas Right antennas											
Errors	A21	A20	A19	A18	A17	A16	A15	A14	A13	A12	A11
L10	L9	L8	L7	L6	L5	L4	L3	L2	L1	CA	%
Amp	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Phase	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Σ ΔDDM	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Figure 15: Search for Faulty antenna tool

It is also possible to import flight inspection plots as a picture. This feature will be demonstrated later in the glide path section with LAGON through a real-life example.

FEATURES AVAILABLE IN LAGON

GP Layout Panel

In this panel one can set:

- Terrain parameters (slopes and height)
- Aiming point height
- Antenna positions
- Near field monitor position
- GP type
- Frequency

- Published approach angle.
- Theoretical RDH (Reference Datum Height). This value will be used for computing the setback of the GP mast.

It is also possible to display the theoretical approach path and the real locus of $DDM=0\mu A$ as shown below.

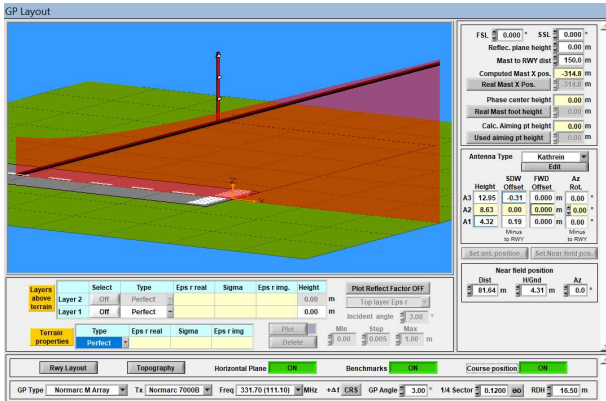


Figure 16: GP Layout panel

Some other features on this panel will be discussed later in the real-life example.

Antenna Distribution Unit and Monitor Combining Unit

The Antenna Distribution Unit panel gives access to all the adjustments available on the real equipment (phase shifters and power dividers).

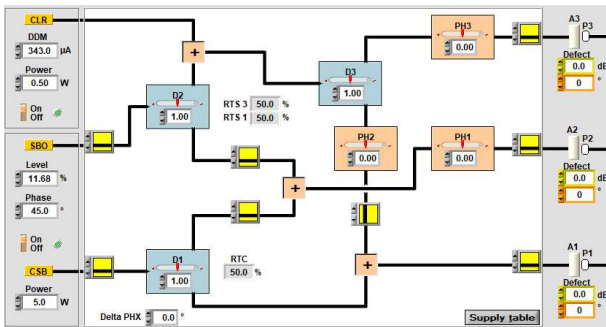


Figure 17: Antenna Distribution Unit

It is possible to simulate antenna errors as well as special settings needed during flight inspection, like disconnecting some signals to given antennas or adding quadrature stubs. The main adjustments from the transmitter are also available from this panel.

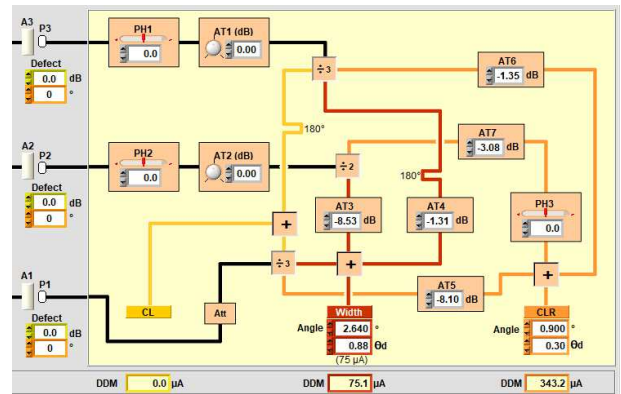


Figure 18: Monitor Combining Unit

The Monitor Combining Unit panel simulates accurately the real MCU and features the same adjustment devices. It is also possible to add some errors to the probes coupling and cabling. At the bottom the monitor readings are displayed. These values are also available in the signal measurement panel.

FIELD POINTS				Nearfield		MONITORS				
Course	Sector	Clearance		1.00	lin	Course	Sector	Clearance	lin	
RF level	0.40	0.33	0.14	mV		RF level	1.00	1.00	1.00	
DDM	2.8	77.7	343.0	μA	1.6	μA	DDM	0.0	75.2	343.3
SDM	80.00	80.00	80.00	%	80.00	%	SDM	80.00	80.00	80.00

Additional parameters: D 49734 m/THR, θ 2.640, θ 0.900, α 0.00°, D 80.05 m, H 4.28 m.

Figure 19: GP signal measurements panel

The Signal Measurement panel is very useful because it displays simultaneously the far field readings as seen by the flight inspection receiver, the monitor readings, and the near field monitor readings. It is therefore easy to see how some maladjustments or errors are seen from the ground in comparison of what is seen from the air.

Scattering objects and terrain panel

This panel features 2 tabs, one for the scattering objects and the other for adding some terrain unevenness.

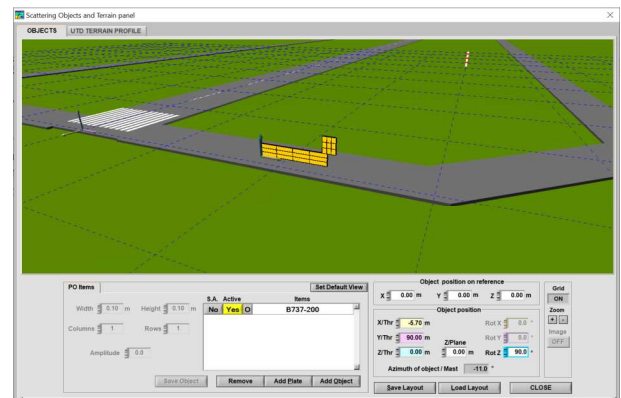


Figure 20: Scattering objects and terrain panel

The method of Physical Optics on rectangular plates is used for simulating the scattered signals from objects around the antenna system.

Terrain features tab

With this panel it is possible to add some terrain unevenness in front of the antennas.

The real terrain is approximated by a set of rectangular plates simulating the terrain profile and the scattered signal is calculated using the method of Unified Theory of Diffraction (UTD).

Adjustments panel

It is not always easy to get a clear picture on all the side effects an adjustment may have.

In this panel one gets an overview on all effects an adjustment will have on the radiated signal.

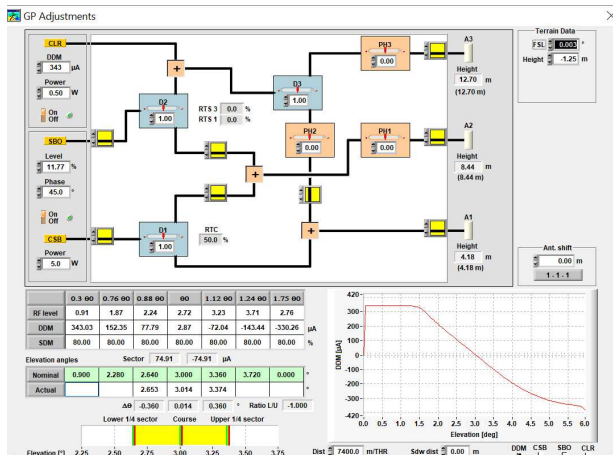


Figure 21: Adjustment panel

All the main adjustment one may have to tune during a flight inspection are gathered on this panel. It is therefore possible to check if adjusting one parameter is not degrading another one and how to mitigate these side effects.

REAL LIFE EXAMPLE

One day, I have been asked to analyze following recording, featuring a bending of the DDM in opposite direction of what is expected. What could be the reason of this behavior and what correction measures could be applied.

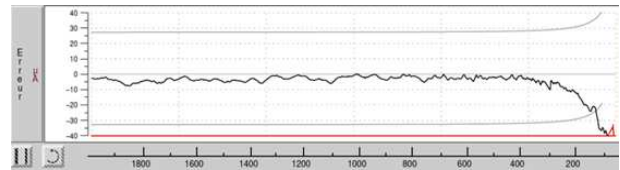


Figure 22: Approach plot

This record comes from the GP on runway 04 L at Nice airport.



Figure 23: Airport layout

One can see that the hyperbolic behavior of the DDM is inverted.

As for ATOLL, it is possible to import a picture of the GP layout and scale it. This picture is then reused in other windows.

To analyze the error, we first start to model the reflection plane.

A terrain survey can be imported and display in 3D.

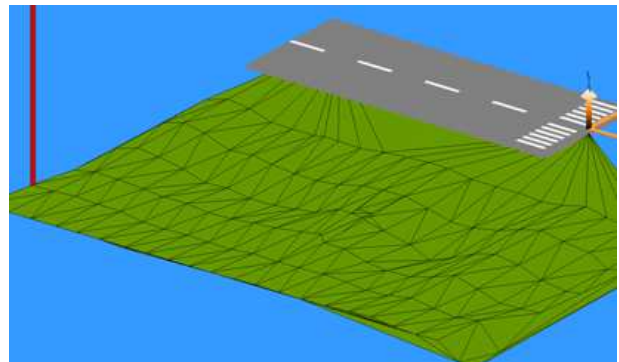


Figure 24: 3D view of the terrain

From the terrain survey, the software calculates the parameters of the mean reflection plane.

These data are used in the GP layout panel to calculate the antenna mast position as well as the antenna heights and offsets.

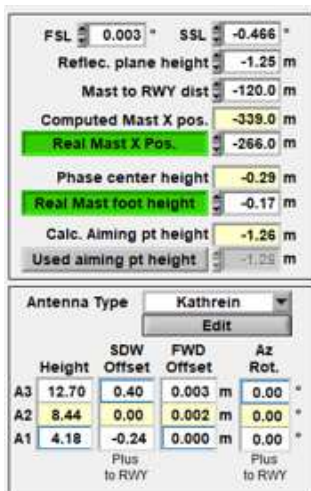


Figure 25: GP layout parameters

Once all parameters are correctly set, we can run a simulation which shows how the expected DDM plot should look like.

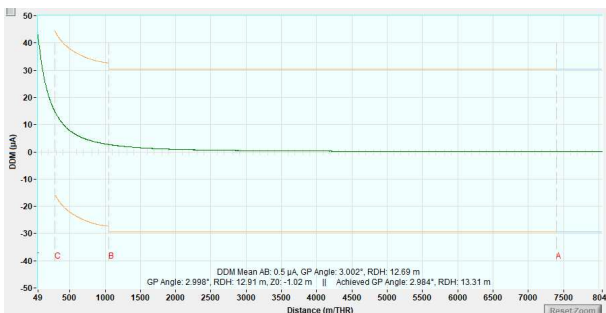


Figure 26: Approach plot

To compare the simulation with the flight inspection record, we are going to import it by using the feature of importing a plot from a picture.

We can copy the plot from the flight inspection report to the clipboard and then paste it in the import window.

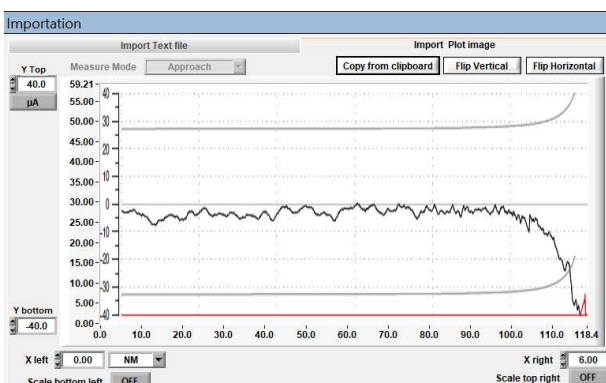


Figure 27: Import of flight inspection plot from clipboard

We must now flip and scale the image.

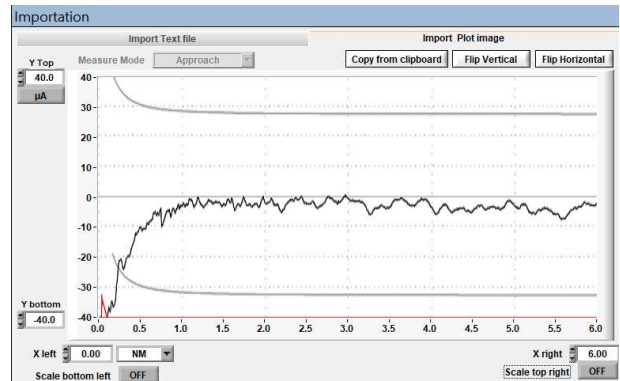


Figure 28: Flipped and scaled image

A click on *Close and Display* will add the picture to the plot chart and allow an easy comparison with simulations.

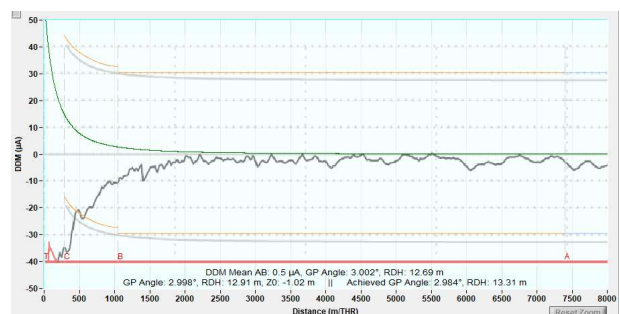
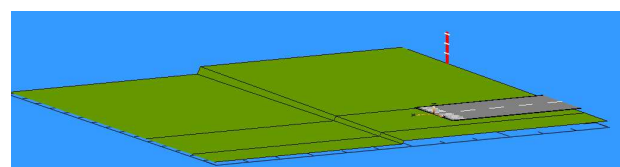


Figure 29: Comparison between simulation and measurement

We have now the simulation and the measurement on the same chart and can start to check different hypothesis on the origin of this behavior.

The first idea was to check the effect of the truncated reflection plane.



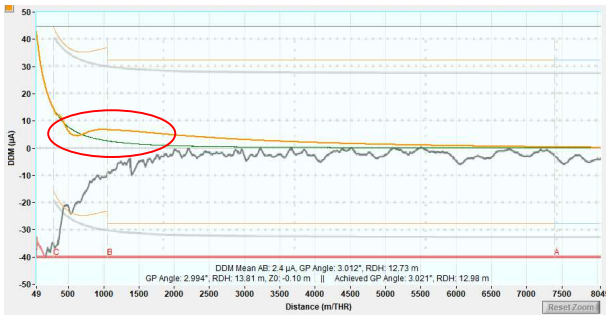


Figure 30: Simulation of truncated reflection plane

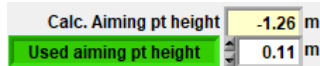
One may note a small decrease of the DDM after point B, but not as much as on the recorded plot.

Second idea was to check the effect of a change of the aiming point height.

LAGON calculates an estimated aiming point height depending on the terrain parameters. The theoretical value is -1.26 m.

But the value set in the flight inspection system was +0.11 m.

We can enter this value as the used aiming point height.



A new simulation with this new value gives the pink plot.



Figure 31: Simulation of incorrectly estimated aiming point (pink plot).

So, in addition to the truncation, we can say the aiming point height was not correctly estimated.

But there is also an issue with the RDH which is only 13.83 m.

The reason for this low RDH is the incorrect position of the GP mast.

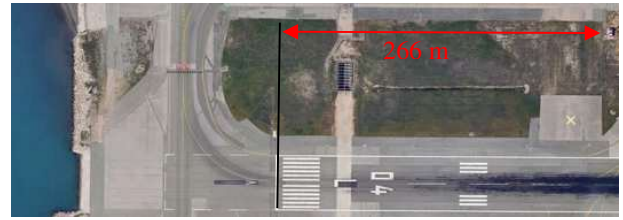


Figure 32: Position of GP mast

The computed theoretical value to get an RDH of 16.5 m is 339 m.

The computed theoretical value to get an RDH of 15.0 m is 310 m.

But because of a taxiway, the GP mast could not be setback further.

The idea was then to keep the Aiming point height at +0.11 m and rotate the upper antenna by 4° to the runway. This should raise a bit the RDH.

A simulation confirms this hypothesis.



Figure 33: Simulation with rotation of the upper antenna by 4° to the runway (blue plot).

The simulated RDH is now 14.83 m.

To further improve the signal quality, it was decided to try to optimize the GP for a short reflection plane.

With a PHX of 200° instead of 180°, the simulation gives the red plot.

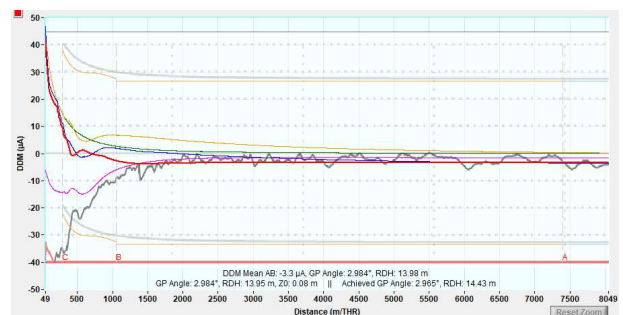


Figure 34: Simulation by applying a PHX of 200° instead of the usual 180° (red plot).

After applying all the findings, the resulting flight inspection plot is now as follows.

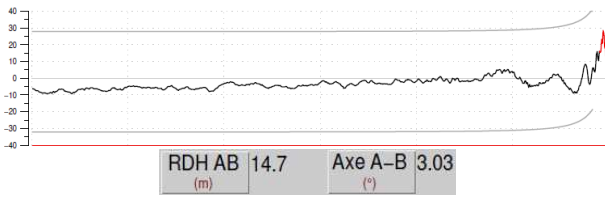


Figure 35: Resulting Flight inspection plot with PHX = 180°

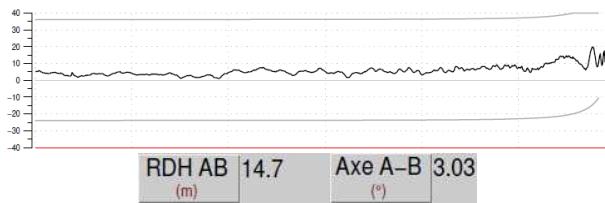


Figure 36: Resulting Flight inspection plot with PHX = 200°

We can see that the resulting recording looks now much better than the one at the beginning. All options could be tested ahead of the flight inspection and the obtained results are very close to the expectations.

CONCLUSIONS

This paper gives an overview of the main features available in the ATOLL and LAGON software packages and how they can be used for flight inspections.

One may note that following points are of special interest for flight inspection:

- Initial and continuous training of flight inspection crews
- Comparing flight inspection measurements with ground measurements
- Analyzing flight inspection results and finding the cause of recorded errors.

The use of the software packages may help to reduce flight inspection cost by:

- Reducing initial setting issues
- Playing scenarios to solve some issues before flying the most relevant ones.
- Analyzing more quickly the plots featuring some issues
- Improving communication between ground and flight staff