Assessment of ILS protection areas impact on large aircraft operations

V1.3 09/11/2006

1 Executive Summary

The A380 is expected to begin commercial operation by end of 2007. The A380 is bigger than the B747 aircaft, especially the tail fin is bigger and rise higher up than that one of the B747. Therefore larger ILS protection areas may be expected.

Alternatively, ILS localizer arrays performances can be optimized with resulting benefits in terms of protection area dimensions.

Up to now, so called Critical and Sensitive Areas have been defined for different aircraft sizes and different ILS- respectively antenna systems. These ILS protection areas shall grant a secure ILS operation.

The evaluation process for the ILS protection areas for new large aircraft began in 2005 and an international collaboration has started in order to involve the Air Navigation System Service Providers (NATS, DFS, LVNL, DSNA), airport operators (BAA and FRAPORT AG) and manufacturers (AIRBUS). Support from Universities (ENAC, OHIO University) or research companies (NAVCOM Consult, Flight Calibration Services (FCS)) was also obtained.

In order to validate adequate Critical and Sensitive areas dimensions to be proposed to international communitiy, it was decided to intensively use validated theoretical simulation tools; ground and flight measurements campaigns were therefore organized in order to validate a set of simulation tool to be used in a second step to define the areas dimensions.

This report describes the measurement campaigns, the simulation tools predictions and the validation process to conduct to define critical and sensitive area dimensions

Special thanks to Airbus, Fraport, BAA, ENAC, NAVCOM Consult, Ohio University, FCS for their contribution to the test program and report preparation.

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List of Acronyms

AC	Aircraft
CDI	CrossPointer Deflection Indicator
CL	Runway-Centreline
CSA	Critical and Sensitive Areas
CSB	Carrier and Side Band
DDM	Difference in Depth of Modulation
ft	Foot (one ft is equivalent to 0.304m)
GP	Glide Path equipment
ICAO	International Civil Aviation Organisation
ILS	Instrument Landing System
LLZ	Localizer equipment
LHS	Left Hand Side
LSA	Localiser Sensitive Area
LVP	Low Visibility Procedures
m	Metre (S.I. unit of measurement)
OoT	Out of Tolerance
RF	Radio Frequency
RHS	Right Hand Side
RVR	Runway Visual Range
RWY	Runway
SARPS	Standards And Recommended Practices
SiS	Signal in Space
SBO	Side Band Only
TWY	Taxiway
µA	Micro Ampere (150 µA cause the CDI to indicate full scale deviation)

2 Introduction

Low visibility procedures are today the major runway capacity limiting factor. During poor visibility conditions (i.e. RVR below 600 m), ILS approaches are conducted mainly in automatic down to the aircraft full deceleration on the runway. During the very last segment of approach (below 200'), the ILS signal could be significantly disturbed by the reflection of other taxiing or holding aircraft. That is why protection areas have been defined to ensure that during such approaches no potential reflector (i.e. aircraft) are within those areas: they are known as ILS sensitive and critical areas. The requirement to ensure that those areas are free of any aircraft or vehicle has a direct impact on the separation distance between two approaching aircraft and therefore a direct impact on the runway capacity in those conditions. It is commonly observed that the impact on runway capacity can reach a fifty percent capacity reduction.

With the exploitation of larger aircraft (e. g. A380) than those operating today, concerns have been expressed regarding the potential impact on runway capacity in LVP leading to a further reduction. The initial simulation and investigations conducted did not lead to a common agreed evaluation of these impacts leading to the need to further analyse these issues.

A joint activity has been set up at the initiative of several European ANSP to consolidate the analysis by taking advantage of the availability of A380 to conduct both simulations and field measurements.

All these activities have been coordinated in such a way that a common report summarising the method of work used, the ground and flight measurement achieved and the correlation with several models together with final conclusions has been produced.

This is the content of this report that is intended to be used as the technical justification of the Low Visibility Procedures as appropriate with such large aircraft. The report will be used in various European States as the technical demonstration to be provided to the various National Supervisory Authorities for operational approval.

3 Current regulatory framework and practices in some European States

3.1 ICAO SARPS and Guidance Material

The Standards and Recommended Practices Annex 10 Volume 1 (Radio Navigation Aids) describe the technical requirements an ILS has to meet. In order to meet the required quality of the course structure, Attachment C gives guidelines to protect the ILS signal from multipath. To provide adequate protection of the ILS signals critical and sensitive areas are to be defined.

The ILS critical area is an area of defined dimensions about the localizer and glide path antennas where vehicles, including aircraft, are excluded during all ILS operations. The critical area is protected because the presence of vehicles and/or aircraft inside its boundaries will cause unacceptable disturbance to the ILS signal-in-space.

The ILS sensitive area is an area extending beyond the critical area where the parking and/or movement of vehicles, including aircraft, is controlled to prevent the possibility of unacceptable interference to the ILS signal during ILS operations. The sensitive area is protected against interference caused by large moving objects outside the critical area but still normally within the airfield boundary.

Several factors have to be taken into account when defining the dimensions of the sensitive area. They include at least:

- Category of operation (i.e. CAT I, II or III);
- type of ILS antenna;
- orientation and size of aircraft;
- ILS multipath due to the environment (e.g. buildings, humped runway).

The dimensions of the sensitive areas required to protect Category I, II and III operations will vary. Category I operations require the smallest area, Category III the largest.

Operationally, the required critical and sensitive areas need to be respected in order to guarantee a safe operation during low visibility conditions. EUR Doc 013 “European Guidance Material on Limited Visibility Conditions” provides guidelines with respect to (amongst others) this issue.

Apart from dynamic distortion, an ILS might suffer from static distortions caused by for example buildings. In order to protect the ILS from this static multipath, building restricted areas around the facility will have to be defined. ICAO EUR Region has developed guidance material on managing these building restricted areas. Guidelines with respect to the analysis of the possible impact of buildings and other man-made structures are laid down in ICAO EUR Doc 015 “European Guidance Material on Managing Building Restricted Areas”. This document also provides typical dimensions of ILS building restricted areas.

When defining the sensitive area the acceptable dynamic distortion (caused by e.g. aircraft) and the static distortion (caused by e.g. buildings) will have to be balanced. The total ILS course structure distortion is determined, as an approximation, by the root sum square summation of static and dynamic distortions. Therefore, static objects causing large course bends leave less margin for dynamic distortion. As a result, an increase of the ILS sensitive area might be required.

ICAO Annex 10 gives some typical examples of critical and sensitive areas defined in the past. With the emergence of New Large Aircraft, such as the Airbus A380, additional guidance material is required as these types of aircraft are not sufficiently covered in Annex 10.

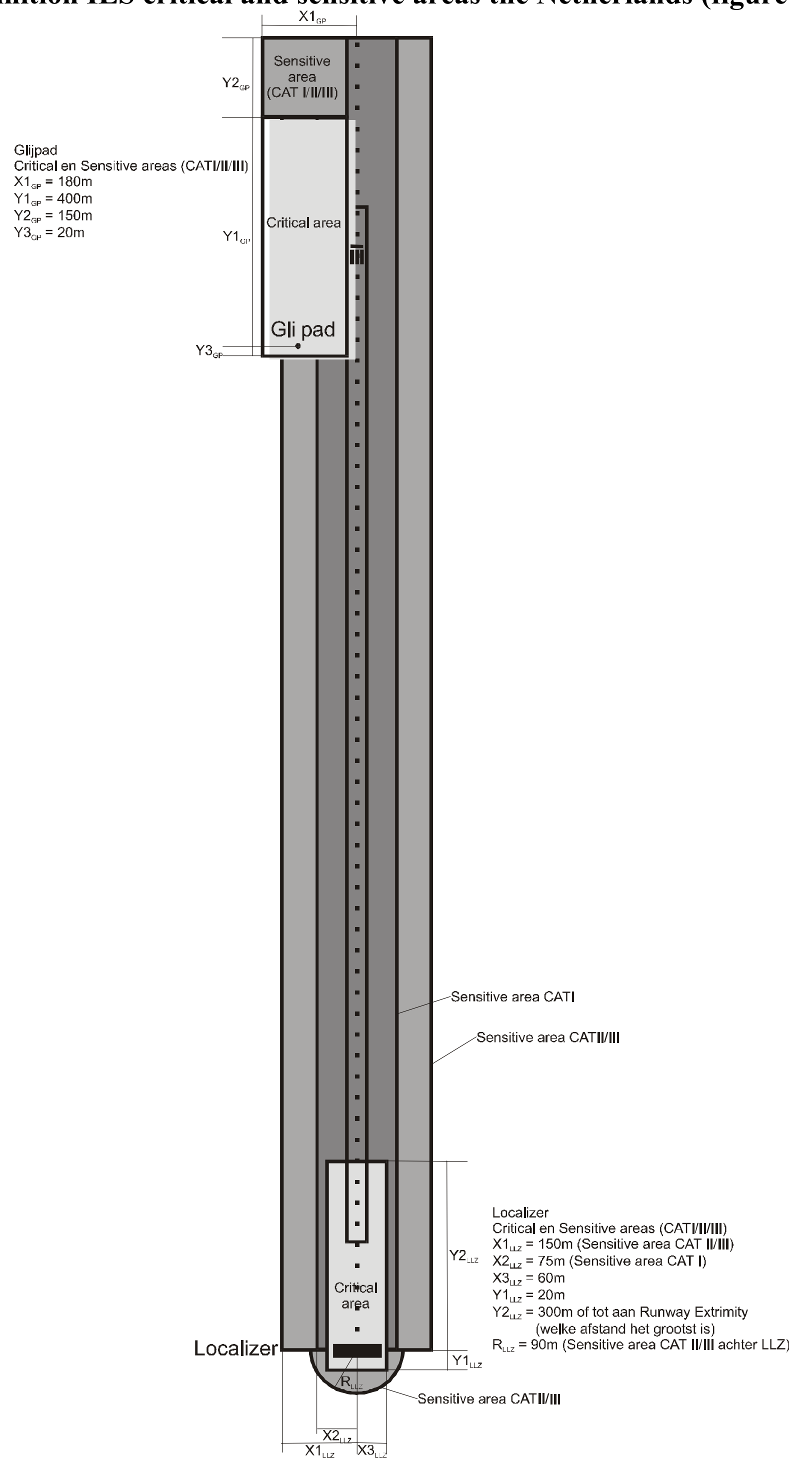
3.2 The Netherlands

Currently, the Netherlands has defined two types of sensitive areas: an area for CAT I operations and an area for CAT II/III operations. These sensitive areas are based on B747 aircraft and wide-aperture antenna systems. Figure 1 depicts this definition.

The policy is to protect the ILS at Schiphol Airport against CAT III requirements. Real estate developments within the boundaries (and in the vicinity of the airport) are equally weighed against the accommodation of landing/taxiing aircraft. This means that bends due to static objects are allowed up to 50% (root sum square) of the maximum allowable ILS bends. The remaining 50% is reserved for dynamic distortions.

In order to protect the ILS signal quality an analysis procedure is put in place which is in line with ICAO EUR DOC 015 “European Guidance Material on Managing Building Restricted Areas”. The potential impact of buildings and building activities on and in the vicinity of the airport is analysed. For this purpose, protection surfaces have been defined and translated into Dutch legislation.

Figure 1: Definition ILS critical and sensitive areas the Netherlands (figure not to scale)



3.3 Germany

DFS has defined to the ATC personal Critical and Sensitive Areas of each of the ILS systems in operation together with the operational performance category. This definition respects the ILS type of system (1-frequency or 2-frequency systems, wide aperture or medium aperture antenna) as well as category of operation and aircraft size operating at the particular airport. This distinctiveness is in order to provide each airport with optimum regulations towards airport capacity management.
While the size of the Critical Area is independent of antenna system, aircraft size and category of operation, the sensitive areas size is based on the assumption that static bends do not exceed 3 µA and varies for different aircraft size, antenna system and category of operation.

The following figures show the current Critical and Sensitive Areas for the wide aperture antenna up to aircraft size B747. (The areas for smaller aircraft or CAT I operation are not shown here.) Distance "B" is for adaptation of the length of the runway, resp. threshold distance.

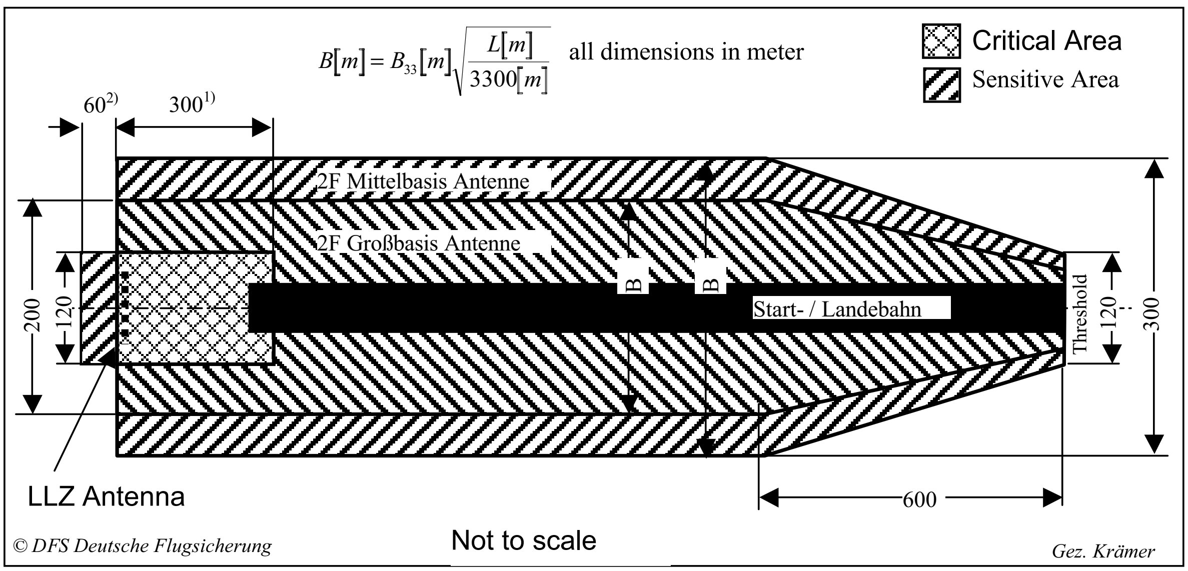


Figure 2 :DFS Critical and Sensitive Area for CAT II/III with LLZ 2F wide/ medium aperture antenna, valid for up to B747 airplane size

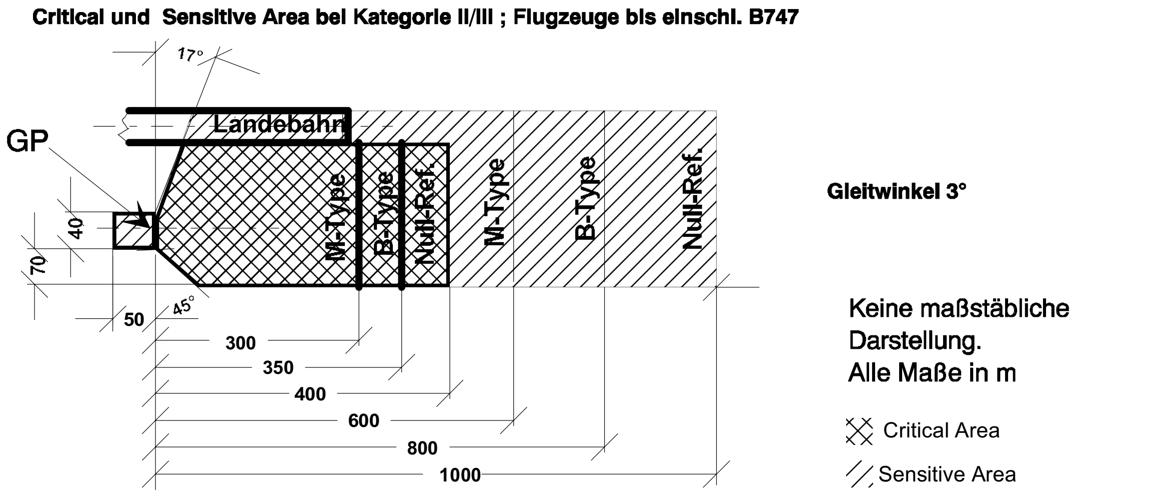


Figure 3 : DFS GP Critical and Sensitive Area for CAT II/III, valid for up to B747 airplane size

German ATC does control the Sensitive Area in such a way, that the aircraft must finally have left the Sensitive Area before an approaching aircraft has reached the distance of 2 NM to threshold. The Critical Area must be clear of any mobile object when ever the system is in operational use.

3.4 United Kingdom

The United Kingdom has based its critical and sensitive area requirements on ICAO Annex 10 requirements and a report produced in 1971 named "The Reiffer Report". This report was commissioned due to the introduction of the Boeing 747.

Following the guidelines laid down in ICAO Annex 10 and the conclusions of the "Reiffer Report" UK Localiser Sensitive Areas are currently set so 137m either side of runway centre line for the entire runway length.

Localiser critical areas are currently 60m either side of runway centreline and extends 300m from the Localiser antenna or to the runway end, whichever is the greatest and 10m behind the Localiser antenna.

For the Glide Path a critical area extending from the antenna to threshold or 300m, whichever is the greatest and from runway edge to a point 30m beyond the antenna for Category I operations and 53m for Category II and III operations.

Glide Path sensitive areas for Category II and III are complex and are typically as shown below, whereas for Category I Glide Path systems UK CAA have just introduced a requirement to specify a sensitive area, but the actual dimensions, for Category I, have not yet been established.

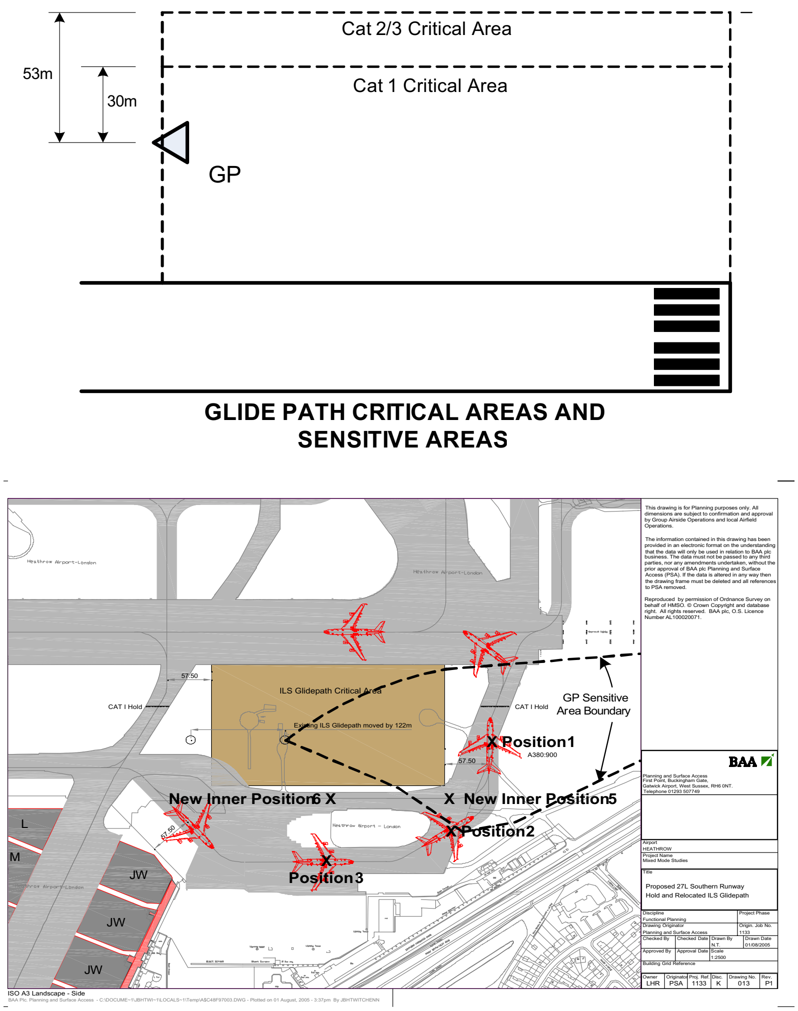


Figure 4 : UK GP Critical and Sensitive areas

3.5 France

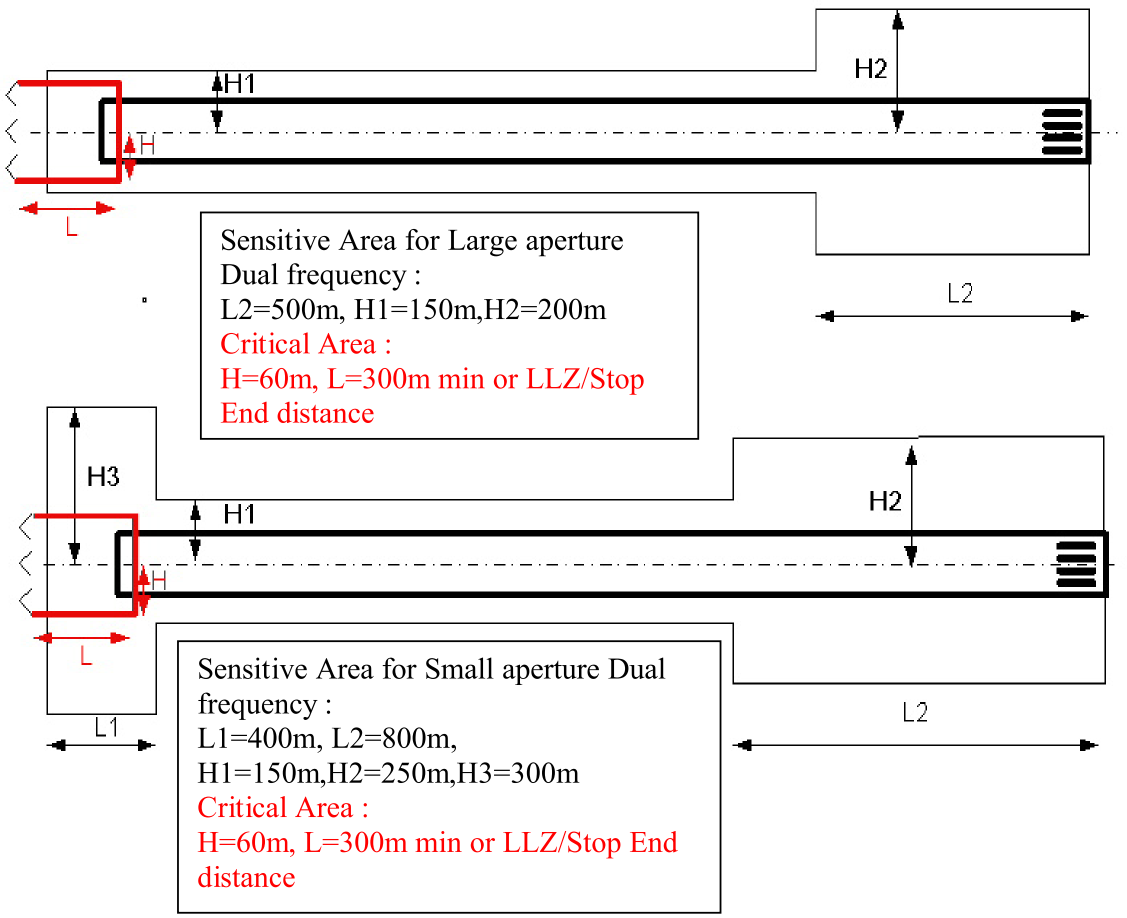


Figure 5 : French LLZ critical and sensitive areas

The dimension of the CAT II/III ILS Localizer sensitive and critical areas which are applied in France are presented in the previous Figure . They differ for small or large aperture systems and are therefore site specific.

During Low Visibility Procedures, the Sensitive Area must be cleared of any moving obstacle (taxiing, holding aircraft) as soon as the approaching aircraft is closer to 2 NM from Threshold. In some specific cases (i.e. CDG), the 2 NM from Threshold distance is reduced to 1 NM with a notice to the flight crew that a late landing clearance will be delivered and potential Localizer disturbance may be seen down to 1 NM from threshold.

4 Objective

The activity conducted by the various parties covered a double objective:

1. To validate the size of the sensitive and critical areas to be applied in order to cope with the introduction of the A380 at various European airports.
2. To validate simulation models (raw data and filtered data) that could be used in the future to assess local situations to define the appropriate sensitive and critical areas.

To achieve this double objective ground and flight measurements have been made on several airports to evaluate the effects of the most dimensioning case by positioning the A380 at very specific positions and orientations and to correlate those measurements with the results of the various simulation tools.

The measurement activity has been mainly done by DFS and DSNA at Frankfurt and Toulouse airports in collaboration with FRAPORT. Some supporting measurements have been made at London Heathrow involving the NATS and BAA.

4.1 Validation of the size of ILS critical and sensitive areas with A380 introduction

This objective was to evaluate the adequacy of the size of the current sensitive and critical area. Those sizes are not totally harmonized in Europe and are all initially based upon very old demonstrations based upon B747 simulations and field measurements conducted within the ICAO framework.
The activity associated with this objective was mainly to identify the various situations in terms of reflection affecting ILS operations.

4.2 Qualification of ILS signal modelling for further local assessment

This objective was to ensure that the modelling tool could be used in the future to assess specific local situations in order to take strategic decisions with a very high level of confidence.
The purpose of this activity was to compare the measurement in the field with the modelling results and to verify that the correlation of the results was correct.

5 Methodology

5.1 Use of various signal modelling to identify the test cases

The first step of this methodology consists in the selection of test points to be tested during real ground and flight measurements with an A380 aircraft. In order to reduce the effort, it is important to select a minimum number of points including the worst case geometry conditions as well as the most representative operational positions to help in the validation of the models.

To determine a coherent set of test points, signal propagation modelling tools were used.

To simulate the readings of an ILS receiver receiving an ILS signal in an adverse environment is quite tricky and requires several steps:

1. Simulate the radiation patterns delivered by the ILS.
   This changes from airport to airport because of the different types of installed ILS antenna systems, as well as the local settings and installation tolerances.
2. Define the appropriate model for the A380 depending on the used modelling tool.
3. Simulate the propagation taking into account the environment.
   Several methods are today available. All of them give a solution for Maxwell equations with more or less accuracy depending on the validity of the approximations used to solve them. Another point is that more the methods are close to exact solution of Maxwell equations more they need computation power, memory and time. Because these methods are based on approximations under certain restrictions or conditions, it is important to validate them through measurements. The most used methods are listed below :
   - Physical Optics
   - Improved Physical Optics
   - Geometrical Optics
   - Geometrical Theory of Diffraction
   - Parabolic equations
   - Method of Moments
   - Multi level fast multipole method
   - Etc…
4. Simulate the radiation pattern of the receiver's antenna.
   Given that the scattering signals are not all coming from the same direction, the attenuations applied by the receiving antenna can have a large contribution to the delivered output signal.
5. Simulate the receiver signal processing.
   As the signal processing in receivers of different types and coming from different manufacturers is quite different, the output readings for a given input signal may differ. So the results coming from different ground inspection receiver as well as from different flight inspection receivers can show quite big differences. The Nyquist criteria has also to be taken into account when digital signal processing is used.
6. Simulate the measurement path and receiver speed.
   Depending on the speed of the receiver the output signal will be more or less filtered and affected by the in-beam capture effects (due to Doppler shift), so it is important to take this parameter into account for the simulations.

Several modelling tools are available on the market. Some of them are mainly radiation propagation simulators useful for step 3, but requiring a lot of pre and post processing. The tools used in this study are dedicated to ILS simulations.
The simulation tools used in the study are :

- AXIS from NANCO, Oslo.
  DOS program based on Physical Optics.
- ATOLL from ENAC, Toulouse.
  Windows program based on Physical Optics.
- NPPM from OHIO University
  Windows program based on Physical Optics
- IHSS 3D modelling by NAVCOM Consult
  Can use several methods mentioned at step 3

5.2 Ground and Flight measurements for test case situations

When the selected airfields (Toulouse Blagnac, Frankfurt and London Heathrow) layout allows, significant operational positions were included in the test plan.

Main concern was the localizer CSA protection. However, the Frankfurt test campaigns included three tests positions for Glide Path as well.

For the Localizer sensitive area definition purpose, these points were :

- For Frankfurt airport :
  - P2, PX, P3, P4, P5 (ref. Figures 6 and 7)
- For Toulouse airport :
  - P9, P11,P11bis, P6ter (ref. Figure 8)
- For London airport :
  - A1, A2, B1, B2, Airbus 122 and G (ref. Figure 9)

For the Localizer critical area definition purpose, these points were :

- For Frankfurt airport :
  - P1, P8 (ref. Figures 6 and 7)
- For Toulouse airport :
  - P6, P6bis (ref. Figure 8)

For the Glide Path Critical and Sensitive Areas, these points in Frankfurt were P6, 7 and 9 (Ref. Figure 6).

5.3 Receiver characteristics

When affected by a multipath, the localizer signal is disturbed. The disturbance is constant in space i.e. at a fixed position if the geometry (transmitter, receiver and obstacle) does not change. A moving receiver passing through this disturbed signal will output a guidance error. Due to the receiver characteristics (sampling rate, automatic gain control feature, tone filters, output filters characteristics, etc…), the receiver output will vary depending on the speed of the vehicle or aircraft carrying the receiver and its antenna characteristics.

For example, the receiving antenna characteristics will play a major role when significant reflections reach the antenna from the rear or perpendicular.

In case of a pure theoretical sine-like error with a fixed longitudinal period of 100m, a 10m/s receiver will see a zero-µA error every 5s (i.e. a time period of 10s i.e. a frequency of 0.1 Hz). For the same spatial error, an 20m/s receiver will see a zero-µA error every 2.5s (i.e. a time period of 5 s i.e. a frequency of 0.2 Hz). If the output low-pass filter corner frequency of the receiver is 0.15 Hz, the output error will be different for the 10 and 20 m/s speed.

This example shows clearly that the speed of the receiver during the ground tests may have impact on the measurements results and this impact needs to be clearly identified.

In order to take into account the receiver output low-pass filter characteristics when assessing the bend structure of a localizer, the Annex 10 Guidance Materials recommend to apply to the raw measurements a low pass filter with a time constant equal to 92.6/V where V is the vehicle speed in km/h. This methodology was used in order to determine the error during ground measurements.

However, as the ultimate goal of this evaluation is to protect the user from multipath errors, it was felt necessary to know the behaviour of a MOPS compliant receiver facing A380 created disturbance during a realistic operational approach, landings and roll-out phase of flight. For that, characteristics of some receivers (R&S EVS 200 and 300, ARTUS324, R&C RV4 , Bendix RNA34-AF, THALES MMR) were determined through laboratory test and realistic aircraft speeds were calculated in order to compute these receivers output facing measured disturbed signal. Further analysis is on-going to include more commercial off-the-shelf receivers.

In order to get a good correlation between modelling tool results and ground measurements, it was necessary to implement realistic receiver characteristics in the model. For that, a theoretical analysis of the multipath error was conducted and one model was modified to implement specific receiver characteristics which were felt critical to simulate in particular the speed effect.

Annex O is presenting some analysis results illustrating the receiver characteristics impacts.

5.4 Validation of the modelling techniques

To validate the modelling tools, a comparison of outputs of modelling tools and real measurements was made. The same filter (ICAO one) was used to filter the raw data provided by the receiver or the modelling tool to allow the comparison. Annex K, L, M, N are presenting the results of the comparison of modelling tools for Frankfurt and/or Toulouse case. Annex J is presenting the results of another modelling tool for Heathrow case.

For the comparison between modelling tools predictions and measurements results, an algebraic difference was used rather than a geometric one as presented in Annexes K and L.

6 Field test

6.1 Frankfurt campaigns

Measurements have been conducted using both A380 and B747.

In order to validate the current critical and sensitive areas for B747 and the modelling tool, additional measurements for this type of aircraft were conducted (see Chapter 6.1.2).

6.1.1 A380 test positions and objectives

Upon the predictions of theoretical analysis and simulations, DFS and NAVCOM Consult defined the positions for the aircraft as indicated in the following Tables and Figures.

The results of the defined test positions should permit the definition of the protection areas.
Measurements were conducted

a) by flight check (during A380 trial, not during succeeding B747 trial)
b) by ground vehicle, equipped with field receiver as described below.

The ground measurements employed both methods:

ba) receiver in motion along the runway centreline while the aircraft hold in steady position
bb) receiver steady while aircraft in motion.

The measurement results in the rear of the Localiser antenna and in the vicinity of the Glide Path antenna up to now have not been sufficient enough to define precise safeguarding areas for the rear of the Localiser and/or Glide Path without further investigations. Annexes A and B provides detailed information on the ILS characteristics and measurement and recording equipments.

The following Table and Picture illustrates the test positions within the runway layout of Frankfort airport for the A380 as well as for the B747. Test positions for the Glide Path system are in blue colour.

Test Pos.	AC position in relation to LLZ antenna	Objective	Operational ILS	Comments	Measurement Method
P-1	AC departing the RWY, starting 362 m in front of the antenna	Check Critical Area extent	LLZ-25L	Final RWY Departure of a landing	AC in motion. GND RX steady, Flightcheck (Course structure)
P-2	AC in the rear of the antenna at 190m, orthogonal to RWY-CL	Check Sensitive Area in the rear of the antenna	LLZ-25L	Sensitivity for taxiing	AC steady. GND RX RWY drive, Flightcheck (Course structure)
P-X	Tail 1850m from LLZ and 200m parallel from RWY-CL	Check Sensitive Area	LLZ-25L	Sensitivity for taxiing	AC steady. GND RX RWY drive, Flightcheck (Course structure)
P-3	Tail 3100m from LLZ and 200m parallel from RWY-CL	Check Sensitive Area	LLZ-25L	Sensitivity for taxiing	AC steady. GND RX RWY drive, Flightcheck (Course structure)
P-4	Tail 3600m from LLZ and 200m parallel from RWY-CL	Check Sensitive Area. At this distance the width of the LSA is expected to be at it's largest.	LLZ-25L	Sensitivity for taxiing, where the LSA is at it's maximum width	AC steady. GND RX RWY drive, Flightcheck (Course structure)
P-5	Tail 3620m from LLZ and 210m from RWY-CL, rotated by 30°, respectively 23°	Check Sensitive Area with the airplane neither orthogonal nor parallel to the RWY-CL.	LLZ-25L	Sensitivity for taxiing, where the LSA is at it's maximum width	AC steady. GND RX RWY drive, Flightcheck (Course structure)

		At this distance the width of the LSA is expected to be at it's largest.			
P-6	AC 180 m in the rear of the GP antenna	Check Sensitive Area of the GP.	GP-25L	Sensitivity for taxiing in the rear of the GP antenna	AC steady. Flightcheck only (GP Course structure and angle)
P-7	AC 150 m aside and 150 m in front of the GP antenna	Check Sensitive Area of the GP.	GP-25L	Sensitivity for taxiing aside the GP antenna	AC steady. Flightcheck only (GP Course structure and angle)
P-8	AC crossing the RWY at a distance of 900 m in front of the antenna	Check Critical Area extent	LLZ-07R	Sensitivity for RWY crossings	AC in motion. GND RX steady, Flightcheck (Course structure)
P-9	AC 240 m in front of the GP antenna	Check Critical and Sensitive Area of the GP.	GP-25R	Sensitivity of the GP antenna front area	AC steady. Flightcheck only (GP Course structure and angle)

Table 1 Summary of A380 tests scenarios - ILS Frankfurt

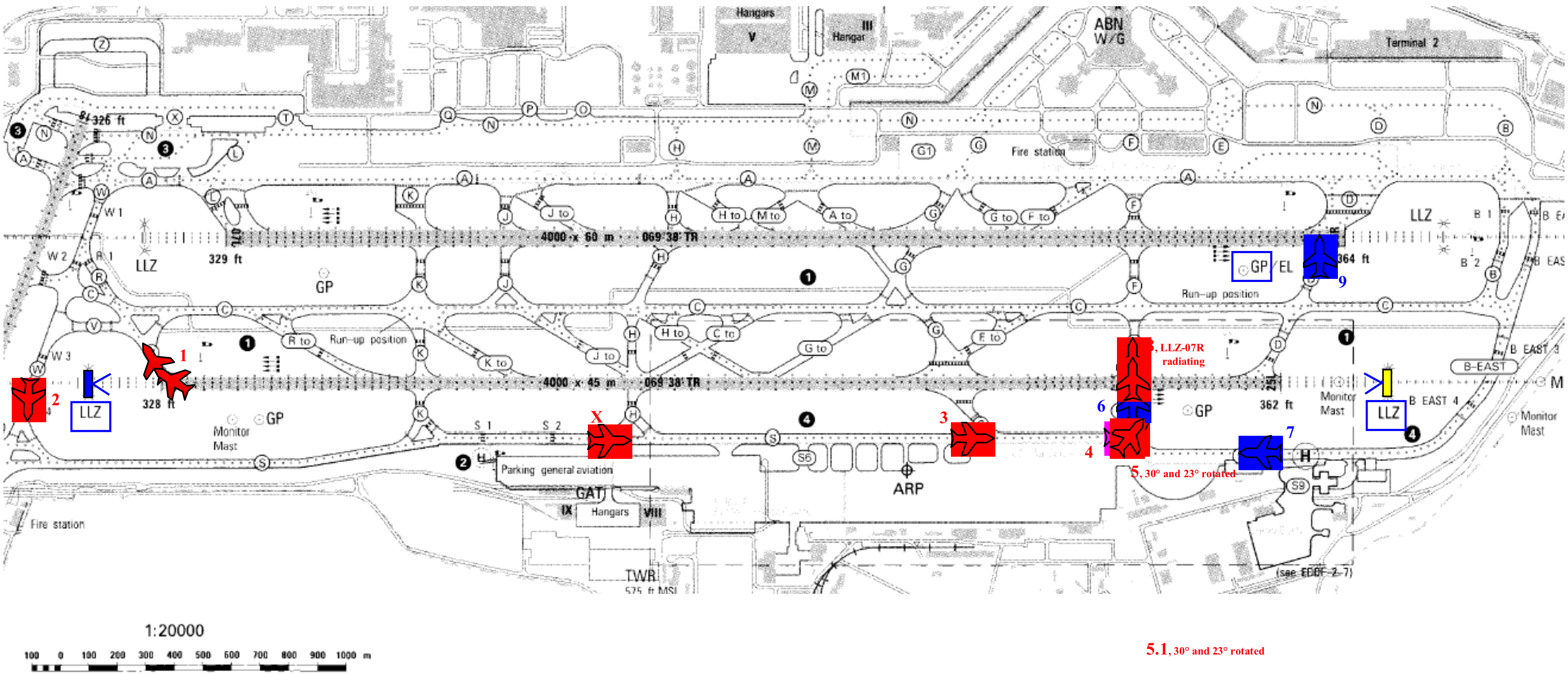


Figure 6 Test position for A380 at Frankfurt airport

Note: blue coloured positions indicate GP related measurements

6.1.2 B747 test positions and objectives

For the test campaign with the B747-400 only these positions have been tested which caused an Out-Of-Tolerance distortion by the A380. Therefore the positions PX, P3, P4, P6 and P7 of the A380 campaign were not necessary to be checked with the B747.
Two more positions however have been added to the B747 test campaign, see table and picture below.
For the B747 test campaign only ground measurements have been performed, since the effects towards the approach path, i.e. towards flight check measurements can be derived from the lesson of the A380 test campaign.

A/C Position / Movement	Measurement (ground meas. only)	Aspect / Objective
P1: analog to A380, dynamic, departure RWY	LLZ-25L static measurement on ground	Check Critical Area
P2: similar to A380, but dynamic on TWY-W	LLZ-25L static measurement on ground	Check Sensitive Area behind LLZ
P5: analog to A380, static position	LLZ-25L RWY-Drive measurement, 2 different speeds, each beginning at TWY intersection H	Check Sensitive Area and compare to A380
P8: analog to A380, dynamic, RWY crossing	LLZ-07R static measurement ground	Check Critical and Sensitive Area and compare to A380
Additional Tests		
P1.1: dynamic, departure RWY, analog to P1 but at different distance to LLZ (380m)	LLZ-07R static measurement ground	Check Critical Area
P5.1: static position, analog to P5 but at different distance to LLZ	LLZ-25L RWY-Drive measurement, 2 different speeds, each beginning at TWY intersection H	Check the “ears” to the Sensitive Area

Table 2 B747 Frankfort Test / Test positions and objectives

The following picture illustrates the test positions within the runway layout of Frankfort airport. The former A380 positions not relevant for the B747 test are in light colour while the active positions are in red colour, respectively orange colour.

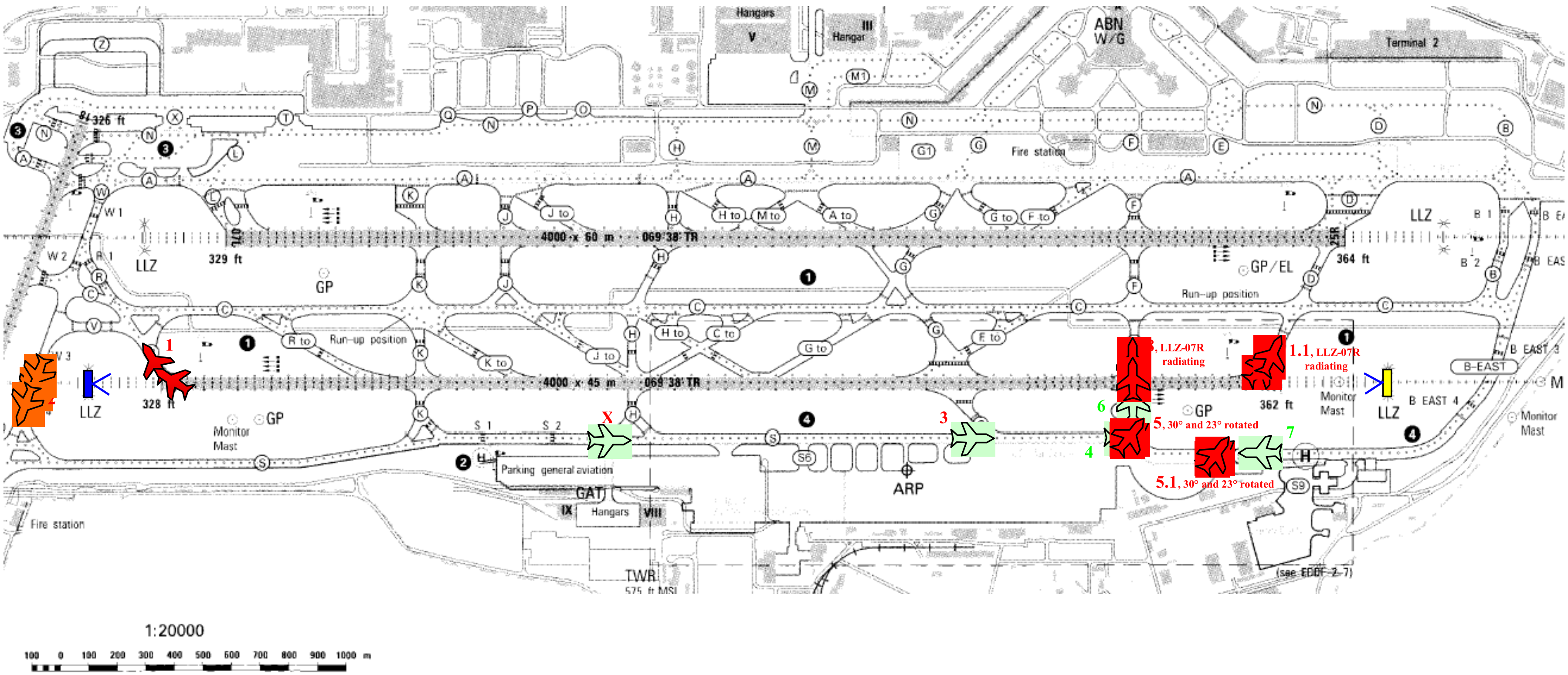


Figure 7 Test positions for B747 at Frankfurt airport

6.2 Toulouse campaigns

Upon the predictions of theoretical analysis and simulation, DSNA/DTI defined the positions for the aircraft as indicated in the following Tables and Figures.

Measurements were conducted for A380 only

- by flight check
- by ground vehicle, equipped with field receiver as described in Annex E.

All ground measurements were conducted with the ILS receiver in motion along the runway centreline while the aircraft hold in steady position.

Annexes E and F provides detailed information on the ILS characteristics and measurement and recording equipments.

Complementary ground measurements were also conducted with a vehicle equipped with the DFS recording equipment and with a maintenance vehicle of the SNA/Sud.

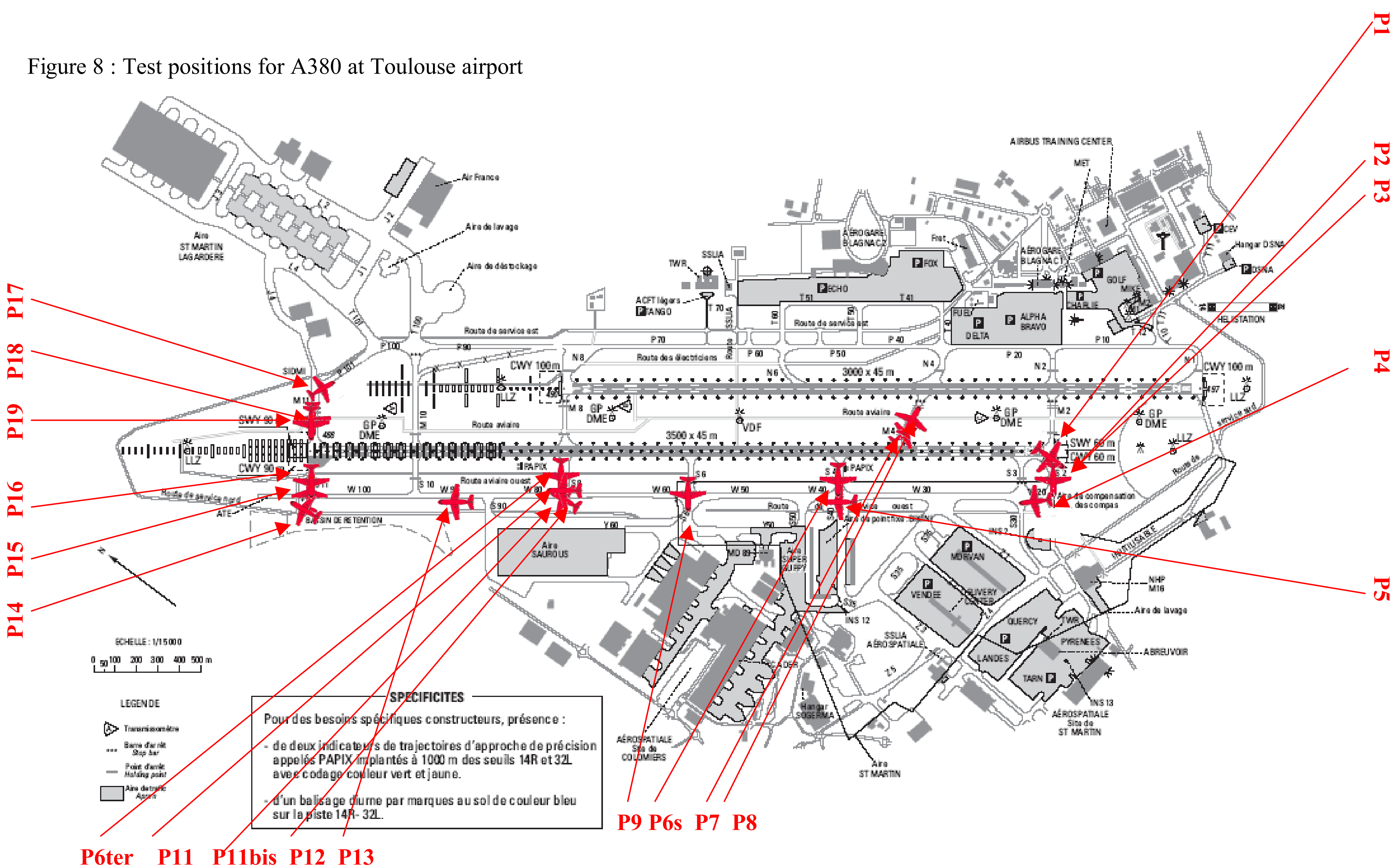
The following Table and Picture illustrates the test positions within the runway layout of Toulouse airport. Test positions for the Glide Path system are in blue colour.

Position number	A380 location	Distance from runway axis	Magnetic heading	Objectives
P0	Abreuvoir			Reference recording
P1	On the runway axis taking a turn on the right	Maximum shift of the tail fin to the left side of the axis	180° (in the direction of the south)	Assessment of effect on following aircraft by previous landing aircraft leaving the RWY axis close to the stop-end
P2	Taking runway exit on S2	Tail fin at the runway border 22.5m from axis	234°	Assessment of effect on following aircraft by previous landing aircraft leaving the RWY axis close to the stop-end
P3	Taking runway exit on S2	Tail fin at 90m	234°	MLS/AZ sensitive area confirmation
P4	On W20	A/C axis at 200m	317°	ILS/LOC sensitive area confirmation
P5	Intersection S4/S40 W30/W40	A/C axis at 200m	324°	ILS/LOC sensitive area confirmation
P7	M4	Tail fin at 60m	114°	MLS/AZ sensitive area confirmation
P8	M4	Nose at 90m from RWY14L centre line	84° (according to taxiway axis)	ILS/LOC French sensitive area confirmation
P12	Intersection S8/W60/W80	A/C axis at 200m	354°	ILS/LOC sensitive area confirmation
P16	S11	Nose at 90m	054°	MLS/AZ sensitive area confirmation
P19	M11	Nose at 90m	234°	MLS/EL sensitive area confirmation
P6 quat	S4	Tail fin at 22.5 m	234°	ILS critical area confirmation

P6	S4	Tail fin at 60m	234°	MLS/AZ sensitive area confirmation ILS critical area confirmation
P6 Bis	S4	Tail fin at 80m	234°	MLS/AZ sensitive area confirmation ILS critical area confirmation
P6 Ter	S8	Tail fin at 60m	234°	MLS/AZ sensitive area confirmation ILS critical area confirmation
P9	S6	Tail fin at 120m	234°	ILS/LOC UK sensitive area confirmation
P11	Intersection S8	A/C tail at 160m	324°	ILS/LOC sensitive area confirmation
P11 Bis	Intersection S8	A/C axis at 180m	354°	ILS/LOC sensitive area confirmation
P13	sur W90 à 90m au sud de S10	A/C axis at 200m	324°	ILS/LOC sensitive area confirmation
P14	S11	Tail at 200m	354°	ILS/LOC sensitive area confirmation
P15	S11	Tail at 60m	234°	ILS/LOC sensitive area confirmation
P17	P101	Tail at 250m	114°	ILS/LOC French sensitive area confirmation
P18	M11	Nose at 150m	234°	ILS/GP sensitive area confirmation

Table 3 Summary of A380 tests scenarios - ILS Toulouse

Figure 8 : Test positions for A380 at Toulouse airport



6.3 Heathrow campaign

The OUILS prediction tool was used to predict Flight Inspection results for an A380 positioned at various locations around Runway 27L at Heathrow Airport. These predictions are then compared with actual test data in order to verify and validate the models accuracy.

The runway is equipped with a 24 element LPD antenna array localizer from Park Air Systems, Norway.

Flight Inspection was carried out by Flight Precision Limited (Teesside, England) using the Flight Inspection System (FIS) developed by Aerodata.

Ground Inspection was carried out using an ARTUS ILS measurement system associated to a 2-element Yagi antenna. These measurements were not intended to validate the modelling tool.

The table below gives the location of the A380 selected for the start of A380 operations at Heathrow and which were modelled using the OHIO tool.

Position	Description	Nose Wheel Distance from 27L Threshold	Nose Wheel Distance from Runway	Angle wrt Runway
A1	Taxiway A heading towards Threshold	824m	192m	0.0 deg
A2	Taxiway A heading towards Threshold	788m	212m	23 deg
A3	Taxiway A heading towards Threshold	754m	249m	45 deg
B1	Taxiway A turning into Link 33	1542m	192m	0.0 deg
B2	Taxiway A turning into Link 33	1500m	229m	45.0 deg
B3	Taxiway A turning into Link 33	1500m	270m	81.8 deg
C1	Taxiway A turning into Link 34	1684m	192m	0.0 deg
C2	Taxiway A turning into Link 34	1644m	229m	45.0 deg
C3	Taxiway A turning into Link 34	1650m	273m	90.0 deg
Airbus 122	122m from Runway Centre Line at Link 29	864m	122m	0.0 deg
P17	South of 27L Threshold	123m	292m	-110.0deg
F	Crossing Runway from Taxiway R to Taxiway W	1753m	159m	56.0 deg
G	Crossing Runway from Taxiway R to Taxiway W	1507m	203m	56.0 deg

Table 4. A380 Positions Modelled Prior to Tests at Heathrow

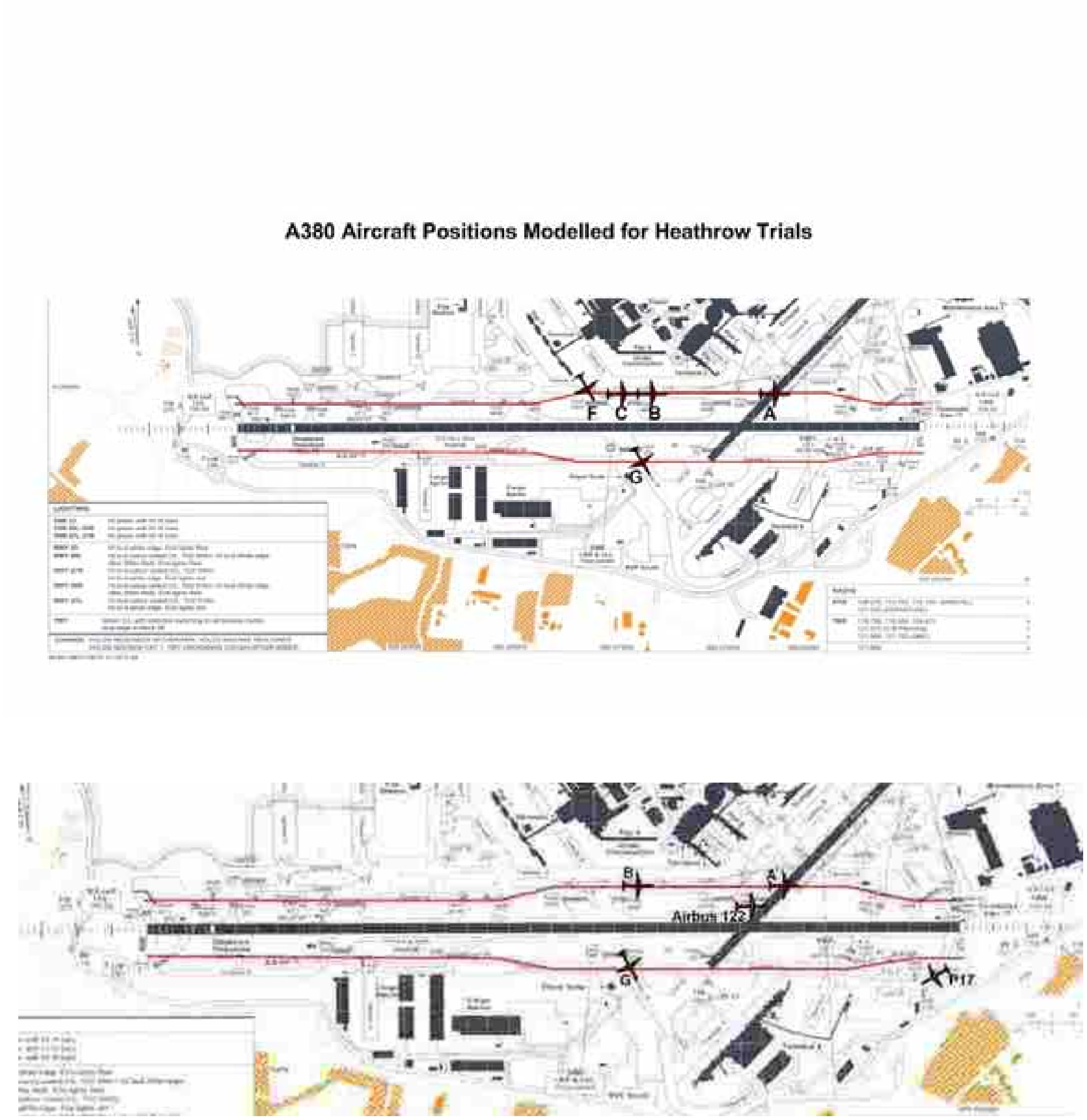


Figure 9 : B1, B2, Airbus122, A1, A2, P17 and G with an additional G+20m position. Modelled results only produced prior to ground and flight inspection.

7 Result analysis

7.1 Frankfurt results

7.1.1 Summary of tests A380 - ILS conducted Frankfurt 29./30.10.2005

The A380 Frankfurt test results are presented in Annex C.

7.1.1.1 A380 on TWY parallel to the runway

An A380 travelling on the taxiway parallel to the runway at a distance of 200 m (CL to CL) does not cause out-of-tolerance distortions for up to CAT III operation, see records of P-X, P-3, P-4.
Distortion is highest when the airplane has travelled about 3/4 of the distance from the Localizer to the threshold. Angles of about 30° of the airplane towards the runway within this area seem to be critical and are likely to exceed the CAT III tolerance limits. There is no effect to CAT II or CAT I for this situation however.

7.1.1.2 A380 in the rear of the Localizer antenna

The measurement with the A380 stationery at 190 m in the rear of the antenna shows no out of tolerance condition, however a small course line shift can be observed. The theory upon this situation is that high course line shifts will be observed when altering the distance of the airplane in small increments such as of decimetres, resp. fractions of the wavelength. The measured course line shift therefore is just a momentum and should not be considered for definition of the protection area. Further investigations have to be done. However the criticality is said for orthogonal positions of the airplane and not for slant orientations.

7.1.1.3 A380 departing the RWY at RWY stop-end (260m in front of the LLZ)

Departing the runway by the A380 at a distance of 260 m from the Localizer causes out-of-tolerance signal distortions of **90 µA**. Depending of the speed of the departure the signal distortion will be of the bend following type. The distortion can be found at any distance of the whole approach because it results in a shift of the mean course-line, see record P-1.

7.1.1.4 A380 crossing the runway (900m in front of the LLZ)

Crossing the runway by the A380 at a distance of 900 m from the Localizer causes out-of-tolerance signal distortions of **20 µA**. Depending on the speed of the crossing the signal distortion will be of the bend following type. The distortion can be found at any distance of the whole approach because it results in a shift of the mean course-line, see record P-8.
CAT I operation seems all right, provided the Sensitive Area is cleared from the crossing A380 before the approaching airplane reaches 2 NM from threshold, see record P-8.

7.1.1.5 A380 in front and in the rear and/or aside the Glide Path antenna

An A380 at 190 m in the rear and/or 150m aside the Glide Path antenna does not cause out-of-tolerance conditions of the Glide Path equipment.
An A380 at 270 m in front of the Glide Path antenna does cause out-of-tolerance conditions of the Glide Path equipment, bend amplitude is out-of-tolerance for CAT III.

The following table and picture illustrates the results of the A380 test campaign conducted 29./30.10.2005.

7.1.2 Summary of tests A380-ILS Frankfurt by table and picture

Test Position	*Distortion Amplitude/DDM*	*Result*	*Note*
0	1,5 / -2 µA	Static Distortion: In-Tolerance	Reference Record, no airplane
Pos. 1:	100 / -30 µA	Out-of-tolerance for CAT I - III	Critical Area affected
Pos. 2:	-1,5 / -3,5 µA	Course-line shift by 2,5 µA, structure not affected, In-Tolerance*)	*) In-Tolerance, however open for final decision
Pos. X:	1,5 / -2,5 µA	In-Tolerance for CAT I - III	No major effect from A380
Pos. 3:	1,5 / -2,5 µA	In-Tolerance for CAT I - III	No major effect from A380
Pos. 4:	2 / -3 µA	In-Tolerance for CAT I - III	No major effect from A380
Pos. 5:	7 / -2,5 µA *) 4 / -2 µA	Potential Out-of-tolerance for CAT III, In-Tolerance for CAT I - II	*) Dependency of recording speed observed
Pos. 6:	2,5 / -2,5 µA	In-Tolerance for CAT I - III	In-Tolerance for both, LLZ (FC measurement only) and **GP**
Pos. 7:	2,5 / -2,5 µA	In-Tolerance for CAT I - III	In-Tolerance for both, LLZ (FC measurement only) and **GP**
Pos. 8:	16 / -20 µA	Out-of-tolerance for CAT II/III	Critical Area affected In-tolerance condition for CAT I under S/A procedure
Pos. 9:	±20 µA bend, -25 µA angle shift	Out-of-tolerance CAT III for GP	Critical Area **GP** affected

Table 5 Summary of tests A380 - ILS Frankfurt

DFS Deutsche Flugsicherung | dgac DSNA | NATS | Luchtverkeersleiding Nederland Air Traffic Control the Netherlands

Airplane red coloured = ILS out-of-tolerance / Airplane green coloured = ILS in tolerance

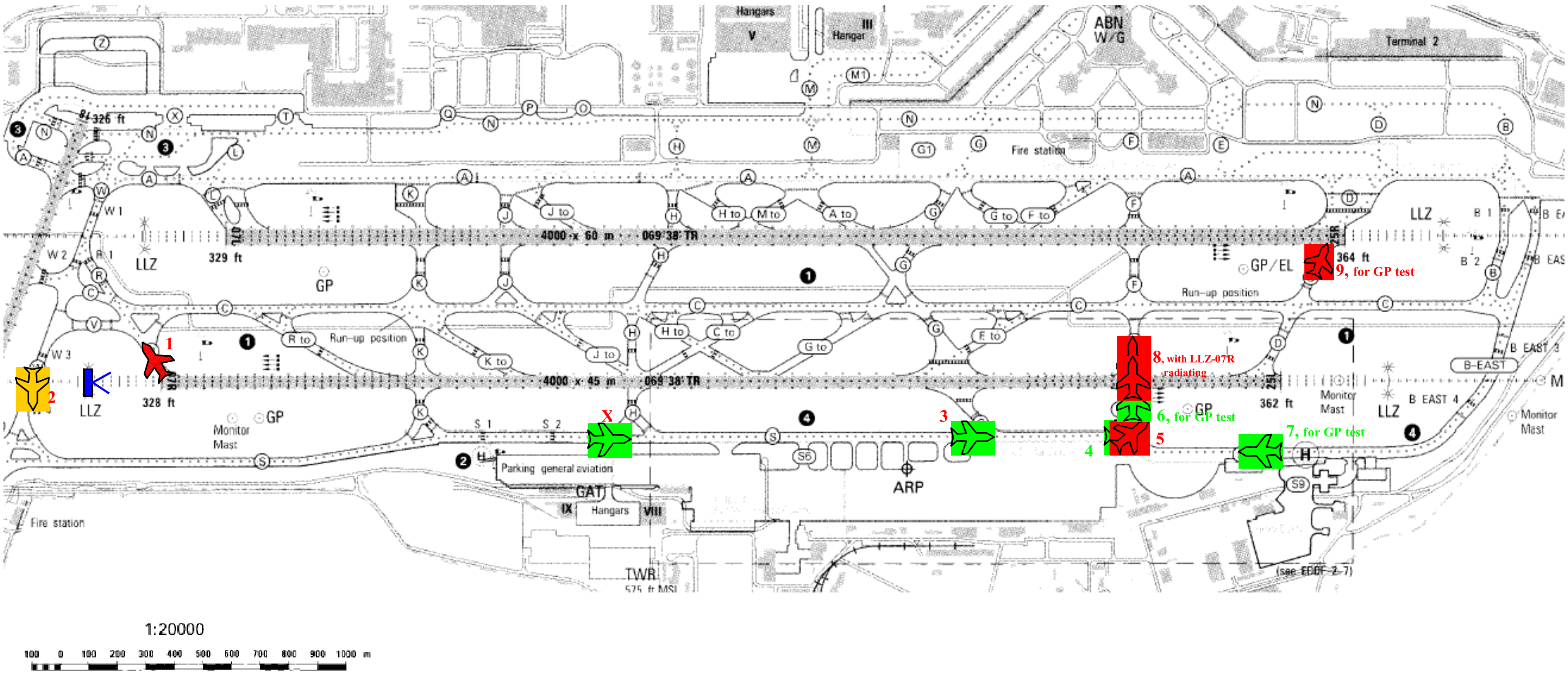


Figure 10 : Summary of results for A380 test campaign at Frankfurt airport

7.1.3 Summary of tests B747 - ILS conducted Frankfurt 08./09.04.2006

The B747 Frankfurt test results are presented in Annex D.

7.1.3.1 B747 on TWY parallel to the runway

An B747 travelling on the taxiway parallel to the runway at a distance of 200 m (CL to CL) does not cause out-of-tolerance distortions for up to CAT III operation, see records of P-5. Even if the airplane is rotated to angles of 23° or 30° towards the RWY centreline at this distance, no out-of-tolerance conditions occur.
An B747 travelling on the taxiway 'Whisky' slant in the rear of the LLZ antenna at a distance of 190 m (CL to CL) does not cause out-of-tolerance distortions for up to CAT III operation, see records of P-2.

7.1.3.2 B747 departing the RWY at RWY stop-end (260m in front of the LLZ)

Departing the runway by the B747 at a distance of 260 m from the Localizer (in case of RWY 25L) and/or at a distance of 380 m from the Localizer (in case of RWY 07R) cause out-of-tolerance signal distortions. Depending of the speed of the departure the signal distortion will be of the bend following type. The distortion can be expected at any distance of the whole approach because it results in a shift of the mean course-line, see record P-1.

7.1.3.3 B747 crossing the runway

Crossing the runway by the B747 at a distance of 900 m from the Localizer causes signal distortions of 8 µA. Depending on the speed of the crossing the signal distortion will be of the bend following type. The distortion will be found at any distance of the whole approach because it results in a shift of the mean course-line, see P-8. Due to the relative small distortion amplitude however, CAT I to CAT II operations are permissible as long as an approaching aircraft is outside 2 NM from threshold when the RWY crossing takes place.

7.1.4 Summary of tests B747 - ILS Frankfurt by table and picture

The following table and picture illustrates the results of the A380 test campaign conducted 29./30.10.2005.

Test Position	*Distortion Amplitude / DDM*	*Result*	*Note*
Pos. 1:	45 / -5 µA	Out-of-tolerance for CAT I - III	Critical Area affected
Pos. 1.1:	5 / -20 µA	Out-of-tolerance for CAT II - III	Critical Area not affected Sensitive Area affected
Pos. 2:	<+/- 1 µA	In-Tolerance for B747	
Pos. 5:	2 / -1,7 µA *) 1,6 / -1,7 µA	In-Tolerance for B747	*) light dependency of recording speed observed
Pos. 8:	7 / -8 µA	In-Tolerance for B747 for CAT I – II under S/A procedure	Sensitive Area
Pos. 8.1:	1 / -3 µA	In-Tolerance for B747	Not checked with A380

Table 6 Summary of tests B747 - ILS Frankfurt

Airplane red coloured = ILS out-of-tolerance / Airplane green coloured = ILS in tolerance / Airplane orange coloured = ILS in tolerance for CAT I operation

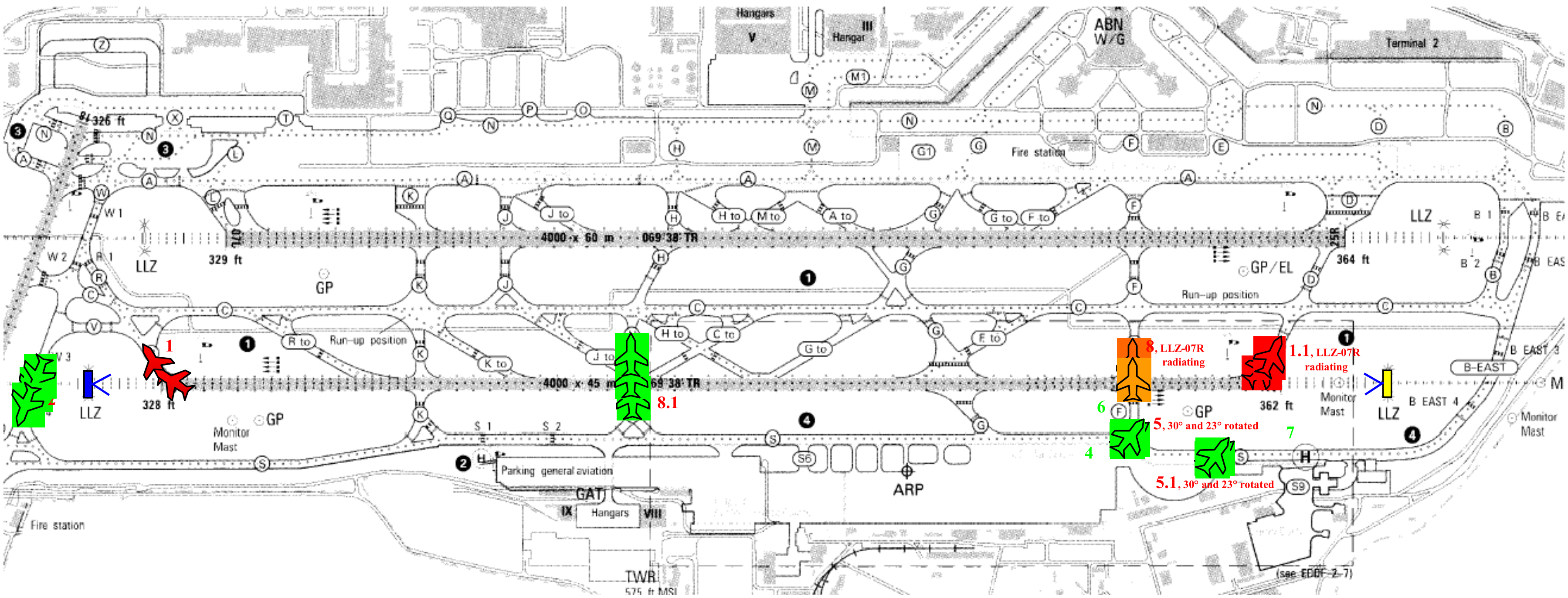


Figure 11 : Summary of results for B747 test campaign at Frankfurt airport

7.2 Toulouse results

7.2.1 Summary of the tests conducted in Toulouse

In general the measurements have been made with a vehicle speed of 40 km/h. When a specific different speed was used this is mentioned.

All the measurements made in Toulouse was using the A380 at a fixed position.
The A380 Toulouse test results are presented in Annex G.

7.2.1.1 P1 (A380 fin at 710m from Localizer, 5m from C/L and 21° orientation towards runway centreline) :

The A380 is turning to clear the runway after a long landing and roll out. The fin is rotated and at 5m from runway centreline. The filtered data (after the application of the speed relevant ICAO low pass filter) show an error less than +/- 2 µA. Flight checks data show errors within +/- 3µA.

7.2.1.2 P2 (A380 fin at 608m from localizer, 29m from C/L and 83° orientation towards runway centreline) :

The A380 is leaving the runway after a long landing and roll out. The fin is almost perpendicular to the runway axis at 29 m from runway centreline. The ground filtered data (after the application of the speed relevant ICAO low pass filter) show an error from 25 µA to 90µA. A large error (20µA) is also recorded during the flight check aircraft during the entire approach.

7.2.1.3 P3 (A380 fin at 603m from localizer, 92.6m from C/L and 90° orientation) :

The A380 is leaving the runway after a long landing and roll out. The fin is perpendicular to the runway axis at 92.6 m from runway centreline. The ground filtered data (after the application of the speed relevant ICAO low pass filter) show an error within +/- 3µA. Flight checks data show errors within +/- 3µA.

7.2.1.4 P4 (A380 fin at 662m from localizer, 198m from C/L and parallel to runway centreline i.e. 5°orientation) :

The A380 is on a parallel taxiway and close to the Localizer. The ground filtered data (after the application of the speed relevant ICAO low pass filter) show an error within +/- 3µA. Flight checks data show errors within +/- 3µA.

7.2.1.5 P5 (A380 fin at 1531m from localizer, 198m from C/L and parallel to runway centreline) :

The A380 is on a parallel taxiway. The ground filtered data (after the application of the speed relevant ICAO low pass filter) show an error within +/- 3µA. Flight checks data show errors within +/- 2µA.

7.2.1.6 P6 (A380 fin at 1579m from localizer, 57m from R/W C/L and 90° orientation)

The A380 is clearing the runway at 1579 m from localizer on a perpendicular exit taxiway and its fin is at 57m from runway centreline. The ground filtered data (after the application of the speed relevant ICAO low pass filter) show an error up to 50µA. Flight checks data show errors reaching 7µA after threshold and a constant 2µA bias before threshold.

7.2.1.7 P6bis (A380 at 1579m from localizer, 83m from R/W C/L and 90° orientation)

The A380 is clearing the runway at 1579 m from localizer on a perpendicular exit taxiway and its fin is at 83m from runway centreline. The ground filtered data (after the application of the speed relevant ICAO low pass filter) show an error up to 30µA. Flight checks data show errors reaching 8µA after threshold and a constant 3µA bias before threshold.

7.2.1.8 P6ter (A380 fin at 2909m from localizer, 56m from Runway C/L and 90° from Runway C/L)

The A380 is clearing the runway at 2900 m from localizer on a perpendicular exit taxiway and its fin is at 56m from runway centreline. The ground filtered data (after the application of the speed relevant ICAO low pass filter) show an error up to 40µA. Flight checks data show errors reaching 4µA after threshold and within +/- 3 µA before threshold.

7.2.1.9 P6quat (A380 fin at 1579m from localizer, 21m from Runway C/L and 90° from runway C/L) :

The A380 is clearing the runway at 1579 m from localizer on a perpendicular exit taxiway and its fin is at 21m from runway centreline. The ground filtered data (after the application of the speed relevant ICAO low pass filter) show an error larger than 50µA. Flight checks data show errors reaching 8µA after threshold and a constant 2µA bias before threshold.

7.2.1.10 P7 (A380 fin at 1313m from localizer, 69m from C/L and 42° orientation) :

The A380 is on a high speed exit. The fin is oriented at 42° relative to RW C/L and at 69m from RW C/L. The ground filtered data (after the application of the speed relevant ICAO low pass filter) show an error larger than 40µA. Flight checks data show a constant 4µA error up to threshold and an increase of this error after threshold to reach 10 µA.

7.2.1.11 P8 (A380 fin at 1247m from localizer,173m from C/L and 60° orientation)

The A380 is on a high speed exit. The fin is oriented at 42° relative to RW C/L and at 173m from RW C/L. The ground filtered data (after the application of the speed relevant ICAO low pass filter) show an error within+/- 3µA. Flight checks data show a constant 2µA error up to threshold and an increase of this error after threshold to reach 6 µA.

7.2.1.12 P9 (A380 fin at 2267m from localizer, 116m from R/W C/L and 90° orientation)

The A380 is clearing the runway at 2200 m from localizer on a perpendicular exit taxiway and its fin is at 111m from runway centreline. The ground filtered data (after the application of the speed relevant ICAO low pass filter) show an error up to 10µA. Flight checks data show errors reaching 5µA after threshold and a constant 2µA bias before threshold.

7.2.1.13 P11 (A380 fin at 2870m from localizer, 159,5m from runway C/L and parallel to runway C/L)

The A380 is holding on a parallel taxiway and is parallel to the taxiway and runway centrelines. The axis of the taxiway is at 160m from runway centreline. The filtered error is within +/- 3µA as recorded by the SNA/SUD maintenance vehicle. Flight checks data show errors within +/- 2µA.

7.2.1.14 P11 bis (A380 fin at 2860m from localizer, 180,5m from C/L and 30° orientation towards runway centreline) :

The A380 is holding on a parallel taxiway after a turn initiation and is presenting a 30° heading. Two vehicle ground speeds were tested (15 and 40 km/h). The filtered data (after the application of the speed relevant ICAO low pass filter) show an error within +/- 5 µA for the 40km/h speed and within +/- 2.5 µA for the 15 km/h speed. Flight checks data show errors within +/- 2µA.

7.2.1.15 P12 test point (A380 fin at 2888m from localizer, 200m from runway C/L and 30° orientation relative to runway C/L)

The A380 is holding on a parallel taxiway after a turn initiation and is presenting a 30° heading. The filtered data (after the application of the speed relevant ICAO low pass filter) show an error within +/- 2.5 µA. Flight checks data show an error within + /- 1µA up to threshold.

7.2.1.16 P13 test point (A380 fin at 3426m from localizer, 200m from runway C/L and parallel to runway C/L)

The A380 is holding on a parallel taxiway and is parallel to the taxiway and runway centrelines The filtered data (after the application of the speed relevant ICAO low pass filter) show an error within +/- 2.5 µA. Flight checks data show errors within +/- 2µA.

7.2.1.17 P14 test point (A380 fin at threshold, 200m from runway C/L and 30° orientation relative to runway C/L)

The A380 is holding at threshold on a parallel taxiway after a turn initiation and is presenting a 30° heading. The flight check data (limited to approach up to threshold) show an error within +/- 2.5 µA. The ground filtered data (after the application of the speed relevant ICAO low pass filter) show an error within +/- 2.5 µA except between the threshold and the touch down zone where the error is higher than 40 µA. It has to be noticed that the antenna height on the vehicle is 4m and that the vehicle speed in this area is still low as the vehicle is accelerating. Flight checks data show errors within +/- 2µA.

7.2.1.18 P15 test point (A380 fin at threshold, 46m from Runway C/L and 90° from Runway C/L)

The A380 is holding after runway crossing with its tail fin at 46m from runway centreline. The filtered data (after the application of the speed relevant ICAO low pass filter) show an error within +/- 2.5 µA. Flight checks data show errors within +/- 2µA.

7.2.1.19 P16 (A380 at threshold, nose at 90 m from Runway C/L and 90° from Runway C/L)

The A380 is holding at 90m stop at threshold before lining up. The filtered data (after the application of the speed relevant ICAO low pass filter) show an error within +/- 2.5 µA. Flight checks data show an error within +/- 3µA up to threshold.

7.2.1.20 P17 (A380 fin at 2267m from localizer, 111m from R/W C/L and 90° orientation)

The A380 is clearing the runway at 2200 m from localizer on a perpendicular exit taxiway and its fin is at 111m from runway centreline. The flight check data (limited to approach up to threshold) show an error within +/- 2 µA. The ground filtered data (after the application of the speed relevant ICAO low pass filter) show an error higher than 40 µA between the threshold and the touch down zone. It has to be noticed that the antenna height on the vehicle is 4m and that the vehicle speed in this area is still low as the vehicle is accelerating. Recording systems failure after the Touchdown point did not allow to record any data after this point.

7.2.1.21 P18 (A380 at threshold, nose at 150 m from Runway C/L and 90° from Runway C/L)

The A380 is holding at 150m stop at threshold before lining up. The filtered data (after the application of the speed relevant ICAO low pass filter) show an error within +/- 2.5 µA. Flight checks data show errors within +/- 2µA until threshold.

7.2.1.22 P19 (A380 at threshold, nose at 90 m from Runway C/L and 90° from Runway C/L)

The A380 is holding at 90m stop at threshold before lining up. The filtered data (after the application of the speed relevant ICAO low pass filter) show an error within +/- 2.5 µA. Flight checks data show an error within +/- 3µA up to threshold.

7.2.2 Summary of tests A380-ILS Toulouse by table

Position number	*Observed Distortion*	*Results*	*Note*
P0	+2 / -2 µA	Static Distortion: In-Tolerance	Reference Record, no airplane
P1	+/- 2 µA (ground) +/- 3 µA (flight)	In Cat. III Tolerances	Critical or sensitive areas not affected
P2	25 to 90µA (ground) 20 µA (flight)	Outside Cat. I Tolerances	Critical and sensitive areas affected
P3	+/- 3 µA (ground) +/- 3 µA (flight)	In Cat. III Tolerances	Critical or sensitive areas not affected
P4	+/- 3 µA (ground) +/- 3 µA (flight)	In Cat. III Tolerances	Critical or sensitive areas not affected
P5	+/- 3 µA (ground) +/- 2 µA (flight)	In Cat. III Tolerances	Critical or sensitive areas not affected
P7	More than 40 µA (ground) 4 µA before threshold and 10 µA after threshold (flight)	In Cat. I tolerances Outside Cat.III	Sensitive areas affected
P8	+/- 3 µA (ground) 2 µA before threshold and 6 µA after threshold (flight)	In Cat. I tolerances Outside Cat.III for flight measurement	Sensitive areas affected (based on flight) and not affected (based on ground)
P12	+/- 2.5 µA (ground) +/- 1 µA (flight)	In Cat. III Tolerances	Critical or sensitive areas not affected
P16	+/- 2.5 µA (ground) +/- 3 µA (flight)	In Cat. III Tolerances	Critical or sensitive areas not affected
P19	+/- 2.5 µA (ground) +/- 3 µA (flight)	In Cat. III Tolerances	Critical or sensitive areas not affected
P6 quat	+/- 50 µA (ground)	In Cat. I tolerances	Sensitive areas affected

	2 µA before threshold and 8 µA after threshold (flight)	Outside Cat.III	Critical area not affected
P6	+/- 50 µA (ground) 2 µA before threshold and 7 µA after threshold (flight)	In Cat. I tolerances Outside Cat.III	Sensitive areas affected Critical area not affected
P6 Bis	+/- 30 µA (ground) 3 µA before threshold and 8 µA after threshold (flight)	In Cat. I tolerances Outside Cat.III	Sensitive areas affected Critical area not affected
P6 Ter	+/- 40 µA (ground) 3 µA before threshold and 4 µA after threshold (flight)	In Cat. I tolerances Outside Cat.III	Sensitive areas affected Critical area not affected
P9	+/- 10 µA (ground) 2 µA before threshold and 5 µA after threshold (flight)	In Cat. I tolerances Outside Cat.III	Sensitive areas affected Critical area not affected
P11	+/- 3 µA (ground) +/- 2 µA (flight)	In Cat. III Tolerances	Critical or sensitive areas not affected
P11 Bis	+/- 5 µA (ground at 40km/h) +/- 2.5 µA(ground at 15km/h) +/- 2 µA (flight)	No margin for Cat.III tolerance	Sensitive areas just affected
P13	+/- 2.5 µA (ground) +/- 2 µA (flight)	In Cat. III Tolerances	Critical or sensitive areas not affected
P14	+/- 2.5 µA (ground) +/- 2.5 µA (flight)	In Cat. III Tolerances	Critical or sensitive areas not affected
P15	+/- 2.5 µA (ground) +/- 2 µA (flight)	In Cat. III Tolerances	Critical or sensitive areas not affected
P17	No data after TDP (ground) +/- 2 µA before threshold (flight)	In Cat. I tolerances No conclusions for Cat. III	Critical areas not affected No conclusions for sensitive area
P18	+/- 3 µA (ground) +/- 3 µA (flight)	ILS/GP sensitive area confirmation	Critical or sensitive areas not affected

Table 7 Summary of A380 tests results - ILS Toulouse

7.3 *Heathrow results*

7.3.1 Summary of tests conducted at Heathrow

The results obtained from measurements at Heathrow Runway 27L show that the predictions obtained from the OUILS model are validated by flight measurements. In particular, low frequency bends are very accurately indicated by the model. High frequency anomalies predicted by the model will need some further explanation.

All the measurements at Heathrow were made using the A380 at fixed positions. Dimensions given are for the aircraft nose wheel with respect to runway threshold to aid aircraft positioning during the tests. Full diagrams of these positions and plotted results can be found in Annex 11.

7.3.1.1. Position A1 On Parallel Taxiway 192m North of Runway 27L, 0.0 deg with respect to runway, 824m from and heading towards threshold.

Flight checks data shows errors within +/- 4µA including existing static bends.
Ground Test Data shows errors within +/- 3µA but these results are not used for validation of the simulation tool and are for reference only.

7.3.1.2. Position A2 On Parallel Taxiway 212m North of Runway 27L, turning east-north-east on a heading of 23.0 deg with respect to runway, 788 m from threshold.

Flight checks data shows errors within +/- 4.5µA including existing static bends.
Ground Test Data shows errors within +/- 5µA but these results are not used for validation of the simulation tool and are for reference only.

7.3.1.3. Position B1 On Parallel Taxiway 192m North of Runway 27L, 0.0 deg with respect to runway, 1542m from and heading towards threshold.

Flight checks data shows errors within +/- 3µA including existing static bends.
Ground Test Data shows errors within +/- 3µA but these results are not used for validation of the simulation tool and are for reference only.

7.3.1.4. Position B2 On Parallel Taxiway 229m North of Runway 27L, turning north-east on a heading of 45.0 deg with respect to runway, 1500 m from threshold and heading for stand..

Flight checks data shows errors within +/- 5µA including existing static bends.
Ground Test Data shows errors within +/- 4µA but these results are not used for validation of the simulation tool and are for reference only.

7.3.1.5. Position Airbus122 On Parallel Taxiway 122m North of Runway 27L, 0.0 deg with respect to runway, 864m from and heading towards threshold.

Flight checks data shows errors within +/- 3.5µA including existing static bends.
Ground Test Data shows errors within +/- 3.5µA but these results are not used for validation of the simulation tool and are for reference only.

7.3.1.6. Position P17 292m South of Runway 27LTthreshold and back set by 123m, leaving runway with tail towards runway and at -110.0 deg.

Flight checks data shows errors within +/- 3µA including existing static bends.
Ground Test Data shows errors within +/- 3µA but these results are not used for validation of the simulation tool and are for reference only.

7.3.1.7. Position G Crossing Runway north to south at an angle of 56.0 deg with respect to runway, 1753m from Threshold and 159m south of the Runway.

Flight checks data shows errors within +/- 7µA including existing static bends.
Ground Test Data shows errors within +/- 7µA but these results are not used for validation of the simulation tool and are for reference only.

7.3.1.8. Position G+20 Crossing Runway north to south at an angle of 56.0 deg with respect to runway, 1753m from Threshold and 159m south of the Runway.

Flight checks data shows errors within +/- 6µA including existing static bends.
No Ground Test carried out.

7.3.2 Summary of tests A380-ILS Heathrow by table

A summary of the findings for the tests at Heathrow can be found in Table below.

Position	Description	Results Summary
A1	Taxiway A heading towards Threshold	In-tolerance for CATIII operations
A2	Taxiway A heading towards Threshold	On limit of tolerance for CATIII operations
A3	Taxiway A heading towards Threshold	Not tested
B1	Taxiway A turning into Link 33	In-tolerance for CATIII operations
B2	Taxiway A turning into Link 33	On limit of tolerance for CATIII operations
B3	Taxiway A turning into Link 33	Not tested
C1	Taxiway A turning into Link 34	Not tested
C2	Taxiway A turning into Link 34	Not tested
C3	Taxiway A turning into Link 34	Not tested
Airbus 122	122m from Runway Centre Line at Link 29	In-tolerance for CATIII operations
P17	South of 27L Threshold	In-tolerance for CATIII operations
F	Crossing Runway from Taxiway R to Taxiway W	Not tested

G	Crossing Runway from Taxiway R to Taxiway W	Out-of-tolerance for CATIII operations
G+20	Crossing Runway from Taxiway R to Taxiway W 20 m further	Out-of-tolerance for CATIII operations

Table 8. A380 Positions for Tests at Heathrow

8 Conclusions

1. Three simulation tools have been evaluated during the study.
2. To fully take into account the dynamic ILS receiver behaviour, simulations tools need to integrate the receiver capture effect associated with the dynamic Doppler shift, which has been highlighted during Frankfurt and Toulouse ground measurements campaigns.
3. At least two simulation tools have been demonstrated as including a realistic receiver dynamic behaviour, (OHIO University and ATOLL).
4. In general, simulation tools assume an omni directional receiving antenna pattern. The ATOLL tool has tailored the receiving antenna pattern with the DFS and DSNA ground antenna pattern.
5. It has been demonstrated that simulation tools limiting the A380 to its tail fin provide good correlation with the observed A380 effects on ILS Localizer signal if filtered data and maximum amplitude of raw data are analysed. Nevertheless in some specific evaluations (envelope of raw data, A380 close to the localizer antenna -typically below 1000 m) simplified models may not be fully representative. This is true in particular for the definition of the ILS localizer critical area. The more complex simulation tool from IHSS (NAVCOM Consult) could not be validated so far in this measurement activity due to missing authorisation by NAVCOM. It is intended to do this in an update version of the report.
6. The ILS Localizer array antenna pattern performances are a key element in the determination of the A380 error contribution as the signal in space characteristics are affected by the presence of the A380 tail fin and may differ from one system to another.
7. The ILS airborne receiver characteristics are a key element as they drive directly the performances of the system in presence of multipath. The ground measurement campaigns illustrate this point showing different behaviour for different receivers in the same environment. The current ILS receiver MOPS are not clearly specifying some important characteristics of the receivers and this may conduct to large performances differences for different receiver facing multipath.
8. Parallel or orthogonal orientations of the A380 relative to the runway centreline are less critical than other angle orientations. For example, some tests have been conducted in Toulouse and Heathrow to assess such situations. The exact results are obviously highly dependant on ILS LLZ antenna performances and longitudinal position of the A380.
9. Airplane positions which are not in parallel or orthogonal orientation towards the runway centreline should require in some cases a larger LSA. Tests conducted in Frankfurt revealed that a 30° towards-runway-oriented A380 at 210 m aside runway centreline and at a distance of 3620 m from LLZ may create worst case out-of-tolerance bends on that airport at a specific speed (and not at another speed). The same scenario in Toulouse at 180m from centreline and 2855m from LLZ confirms that the

generated bend leave no more margins for static multipath. Considering the better signal-in-space conditions in favour of the direct signal between threshold and touch-down zone (as the receiver is airborne), a reduction of the LSA lateral dimension around the threshold area is anticipated.

10. An A380 on the runway, departing the runway or crossing it, causes higher signal distortion along all the approach path, than the current wide body aircraft.
11. Sensitive Area size in the rear of the LLZ antenna clearly depends on antenna type and has still to be investigated further on a local basis.
12. Critical and Sensitive Area of the Glide path equipment was not investigated in detail in this effort. Three tests were conducted in Frankfurt in order to validate the modelling tools for Glide Path equipment. This validation is still pending.
13. Any other modelling tool could be validated in the future as long as the predictions match with all the measurements as contained within this report.

9. Recommendations

1. The management of LSA as defined in ICAO Standards should be interpreted as “the LSA has to be cleared from the aircraft tail during ILS operations”. (Conclusion #5)

2. An LSA (Localizer Sensitive Area) covering the whole runway and having a width of 190 m either side of the runway centreline (consistent with Annex 14 code F recommendation for runway/taxiway separation design) is a first typical value and does not require any additional specific analysis to secure ILS CATIII operations, provided the A380 airplane is in parallel or orthogonal orientation towards the runway and static multipath induce less than a maximum +/- 3µA bend and using an ILS LLZ wide aperture array. In other cases (e.g. higher static multipath or smaller ILS LLZ antenna aperture) the LSA value will be derived from a specific analysis taking care of the exact static multipath error). An 150 m wide LSA will be the minimum value and could be used providing a specific analysis taking into account the ILS LLZ antenna performances and the static actual multipaths.

3. Where layout of the airport and operational procedures allow different orientations than parallel or orthogonal, wider LSA extending up to 250 m either side of the runway centreline in some portions (between ¾ of runway length and Touch Down Zone) represents a first typical value to secure ILS CATIII operations assuming static multipath induce less than a maximum +/- 3µA bend and the use of an ILS LLZ wide aperture array. Dependant upon further analysis necessary to cover the receiver behaviour and most critical orientation, the value of 250 m could be adjusted. In other cases (e.g. higher static multipath or smaller ILS LLZ antenna aperture) the LSA value will be derived from a specific analysis taking care of the exact static multipath error. A smaller LSA width could be used providing a specific analysis taking into account the ILS LLZ antenna performances and the static actual multipaths and other considerations.

4. Critical areas dimensions could have to be extended up 1000m from LLZ antenna to cover specific situations. The additional B747 measurements conducted in Frankfurt indicate a necessity to extend the critical area up to 500m from LLZ antenna for this type of aircraft. To overcome those specific situations alternative operational mitigations should be implemented

   In a more general sense,

5. The operational procedures to manage the critical areas need to be harmonized at an international level.

6. In order to get a more accurate predictability of the multipath impact on aircraft behaviour, revision and improvement of the existing ILS airborne receiver standards addressing in particular the filtering characteristics (EUROCAE or RTCA MOPS) could be considered.

7. ICAO should introduce within the DOC 8071 a specification for antenna to conduct ground measurements that fits typical aircraft antenna. Depending on the outcome of the implementation of the recommendation above that ground measurement filtering characteristics be updated to be consistent.

8. Simulation tools should implement a receiver model that address the dynamic Doppler effect.

ANNEX A Ground test set : DFS measurement configuration

Measurement Equipment

[1] ILS field receiver, Type EVS-200 of Rhode&Schwarz
Raw data acquisition at 33 Hz for DDM and RF-Level

[2] Antenna HF-108 (see photo)
Directivity: gain is 1.2 at 112 MHz, front to rear and right/left ration is 6 dB

[3] Notebook PC for recording with ILMA (ILS Measurement Application)
Post processing and filtering evaluation by help of Excel

ILS systems operational / Frankfurt southern runway

LLZ-25L: Antenna type is Dipole/Reflector 21/7 element wide aperture, 2-frequency system
Width adjusted to 2,87°, frequency is 110.70 MHz
Runway length is 4000 m and distance from threshold to Localizer antenna is 261,6 m

LLZ-07R: Antenna type is Dipole/Reflector 21/7 element wide aperture, 2-frequency system
Width adjusted to 2,80°, frequency is 110.95 MHz
Runway length is 4000 m and distance from threshold to Localizer antenna is 379,2 m

Signal filtering criteria / measurement speed

Effects of Receiver Speed on Runway Ground check Measurements

It is a common practice to ground-check course line position and structure of the ILS DDM signal of a CAT III ILS by driving a measurement vehicle along the runway centreline. For this measurement a field receiver together with an appropriate antenna is installed in a vehicle and the DDM is recorded while driving down the runway at a specified speed. The recording is then evaluated with respect to course line position and structure, i.e. bends and scalloping. Course line position and course structure have to fulfil the requirements of para. 3.1.3.4 of ICAO SARPS, Annex 10, otherwise the ILS may no longer be used for CAT III operations. Therefore rigorous measurement techniques become an essential issue.

Since such a measurement is a dynamic one, the dynamic behaviour of the receiver itself, the sample rate and the correct filtering of the recorded DDM must be considered. These measurement parameters, beside capture effect and antenna pattern of the receiver equipment, play a major role in the evaluation of the recorded DDM curve. A wrong interpretation of the measurement especially in a strong multipath environment can easily jeopardize ILS CAT III performance.
Figure 11 shows a measurement where a large aircraft is close to the border of the ILS Sensitive Area. The aircraft causes substantial in-beam reflections of the ILS signal.

Measured on runway centreline, DDM distortions in form of DDM oscillations with increasing frequency can be observed. For evaluation purposes the receiver's raw data were recorded only and thereafter a filtered DDM curve was calculated, employing a digital filter algorithm. The filter algorithm had been adapted to the vehicle/receiver speed at each case.

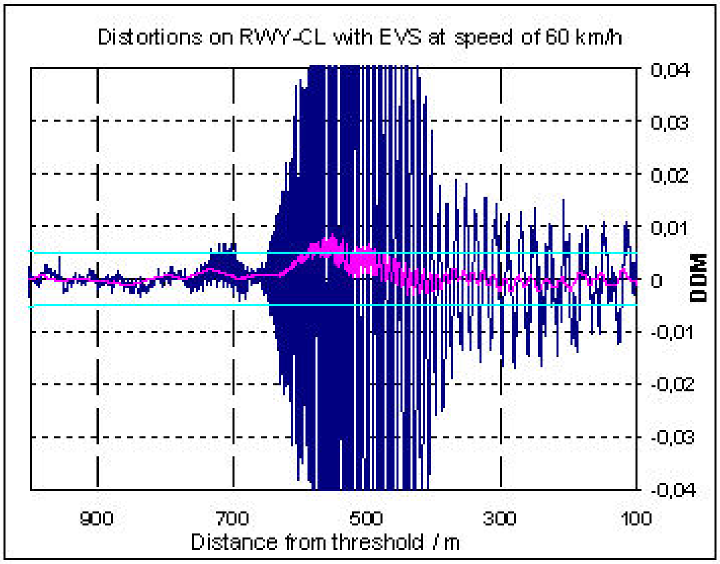


Figure A.1 Distortion measured on RWY centreline with a speed of **60 km/h**

(Receiver EVS 200), with raw data in blue (big amplitudes) and filtered data in red (small amplitudes).

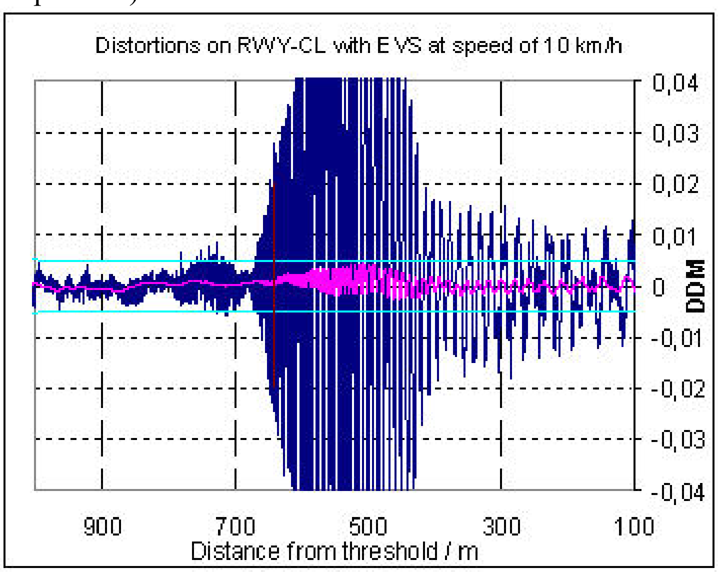


Figure A.2 Distortion measured on RWY centreline with a speed of **10 km/h**

(Receiver EVS 200), with raw data in blue (big amplitudes) and filtered data in red (small amplitudes)

Although the filter was adjusted to the receiver's speed, the filtered data showed a different magnitude: With the low speed of 10 km/h the DDM distortions are within the 5µA tolerance limit while the same scattering source measured at a speed of 60 km/h causes distortion amplitudes exceeding the 5µA limit.
The above example illustrates the difficult situation of the ILS engineer or inspector to evaluate ILS performance in the presence of a reflecting object, respectively to dimension the size of the ILS Sensitive Area.

References

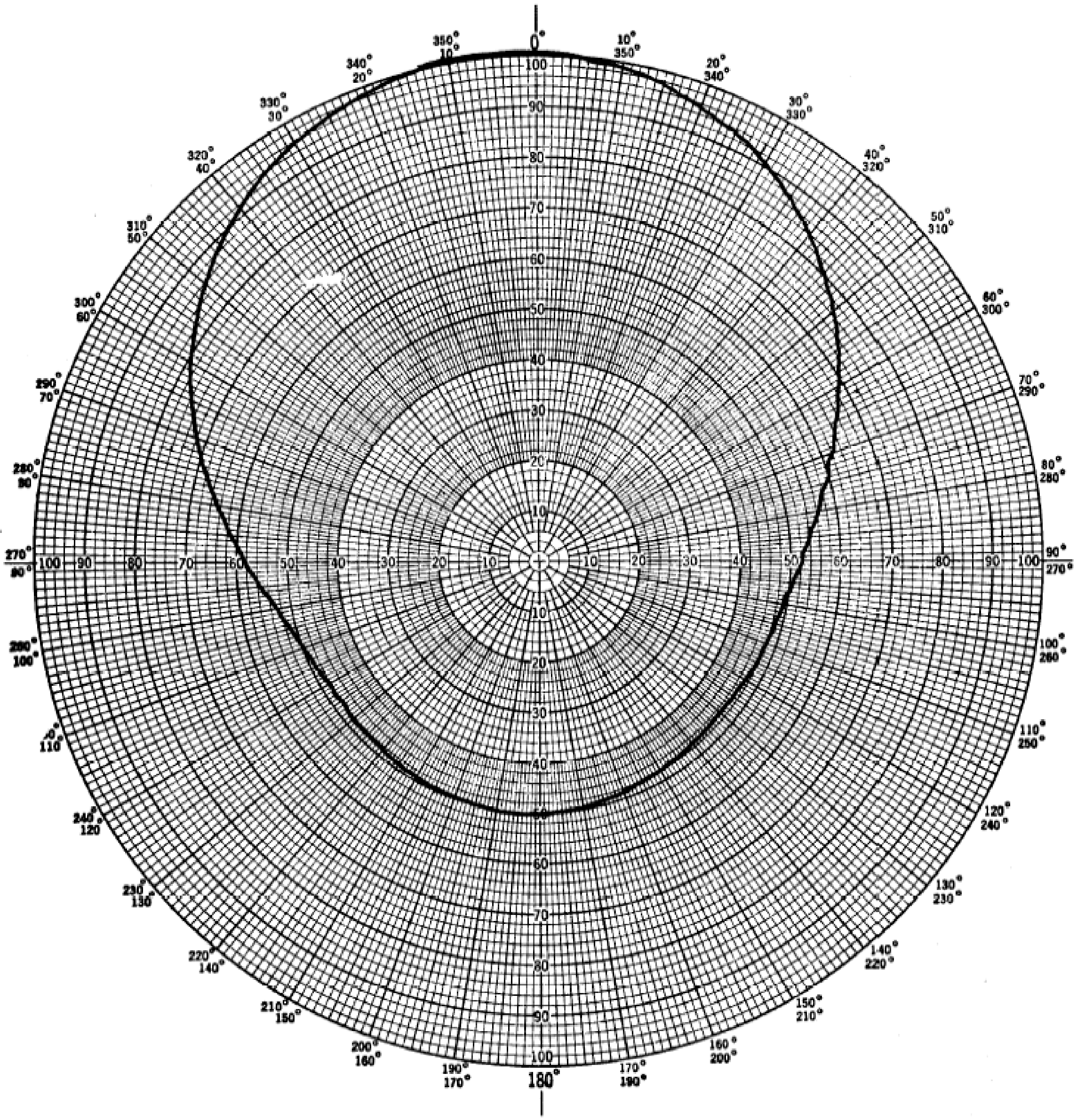
[1] ICAO: *Annex 10 to the Convention of International Civil Aviation*, Volume I: Radio Navigation Aids, Montreal, 2003

Figure A.3 Measurement vehicle and receiver antenna, typ HF-108

Postfach 801469 · D-81614 München · Telefon (089) 4129-0

ROHDE&SCHWARZ

Objekt / Object	HF 108 E-Field Pattern	Diagramm / Pattern	Azimuth ~~Elevation~~
		Frequenz / Frequency	110 MHz



Bemerkung / Remark	Id. 4061.0506.02 Ser.Nr. 9400781/001	Bearbeiter / Operator	[illegible]
		Datum / Date	12.6.07

096.5970-0783

ANNEX B : Frankfurt ILS characteristics

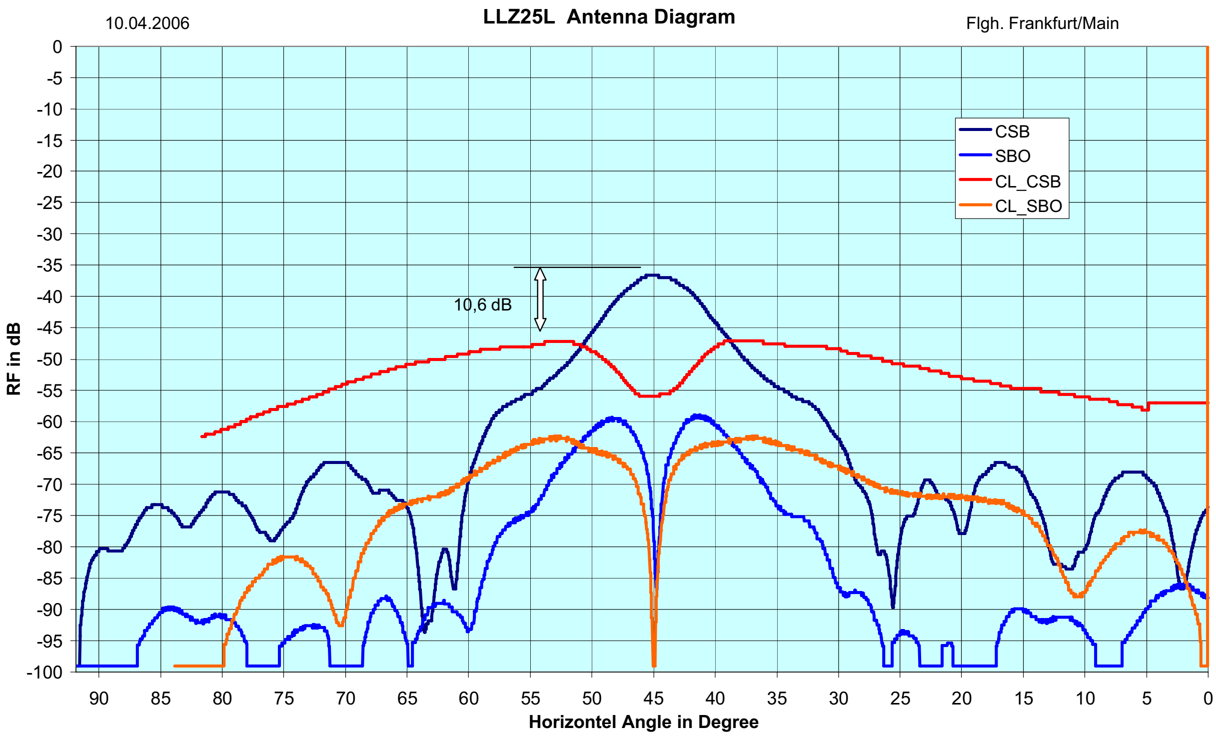


Figure B.1 Antenna pattern, CSB/SBO Course and Clearance

ANNEX C: A380 Frankfurt test campaign

1. Dynamic Measurements, A380 steady in test position

The following records show the measurement of the DDM signal, raw data (blue) and filtered data (red) taken during the runway check. During this measurement method the A380 airplane was steady positioned on the determined position while the receiver, mounted in a vehicle was driven along the runway. On the left-hand side (distance 4000 m) there is the RWY-stopend and consequently, on the right hand side with distance "0" there is the threshold. The radiating Localiser is at the left-landside and in case of LLZ-25L radiating, the threshold (0 m) is 4000 plus 261,6 m distant from the Localiser antenna. In case of LLZ-07R radiating, the threshold (0 m) is 4000 plus 379,2 m distant from the Localiser antenna.
The filtered DDM data are calculated from the DDM raw data according to ICAO, Annex 10, Attachment C, para. 2.1.7. The raw data have been recorded a t a rate of 33 per second and driving speed on runway centreline was 60 km/h.
The graph shows the tolerance limits for the *Course Structure* in accordance with ICAO, Annex 10, para. 3.1.3.4.
The graph contains event markings (as vertical brown lines) in order to coincide object positions with measurement event.
The ground measurement was followed by the flight-check measurement. Flight-check generally was performed by flying inbound from 8 NM on the Glidepath angle down to the threshold and over the runway in 50 ft height. The record of the flight to each of the A380 test positions is added to the graph of the ground-measurement.

Reference Record (no airplane near the runway)

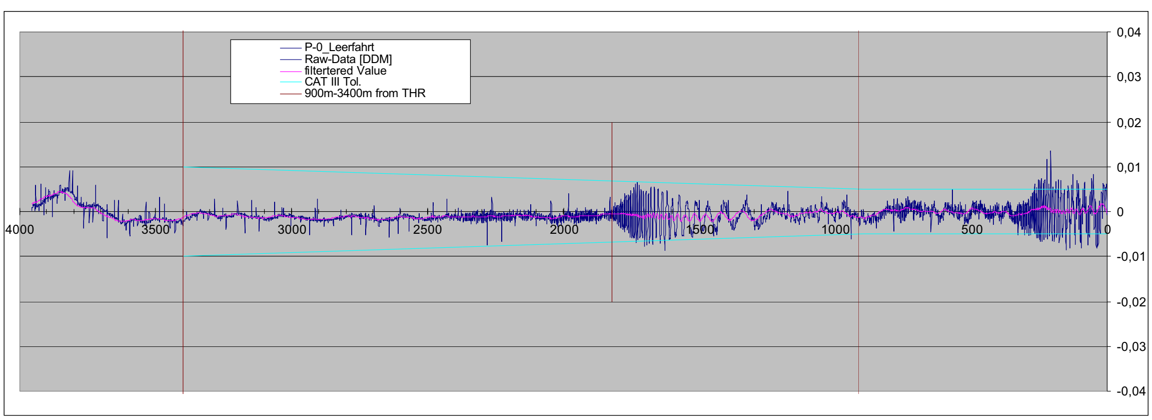


Figure C.1 Reference Record / Ground measurement
No airplane near the runway, Markers from left to right: ILS point E, GP-antenna 26L, ILS point D. The two Glidepath installations GP 26L and GP 25L cause some distortions as can be seen.
The next figure shows the Reference record by flight check.

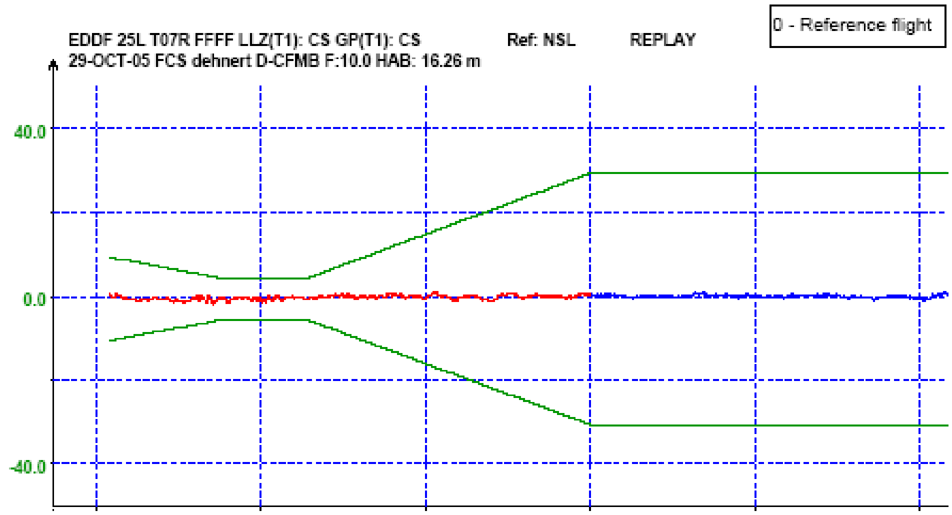


Figure C.2 Reference Record / Flight Check measurement

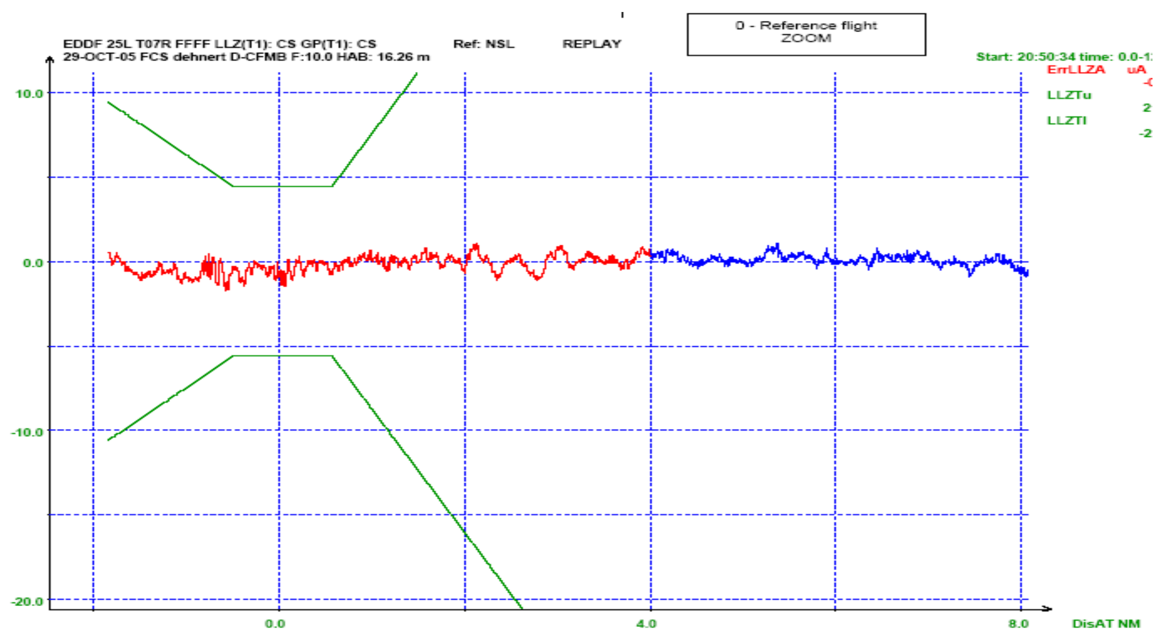


Figure C.3 Reference Record / Flight Check measurement / Zoomed in

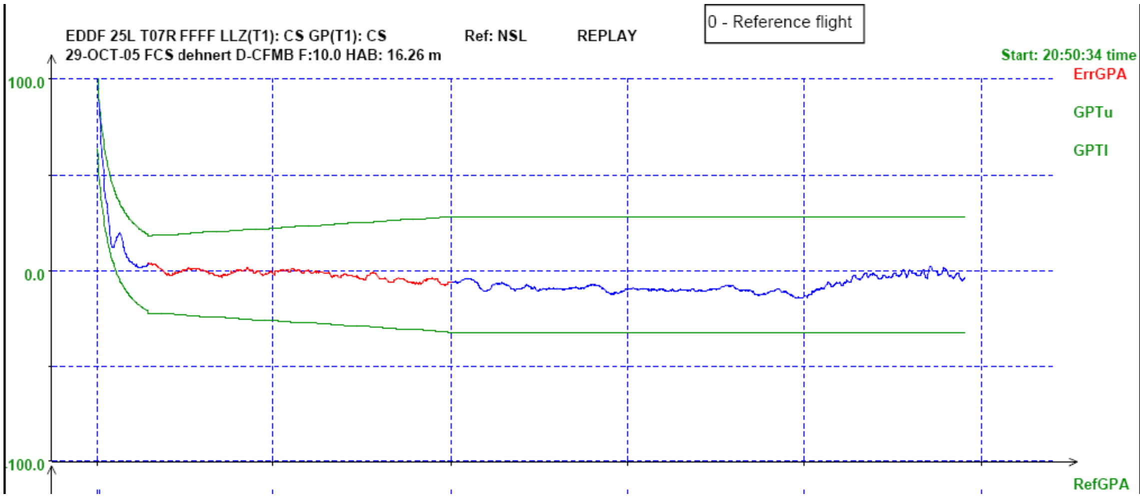


Figure C.4 : Reference record / Flight check measurement Glide Path

P-2 Record

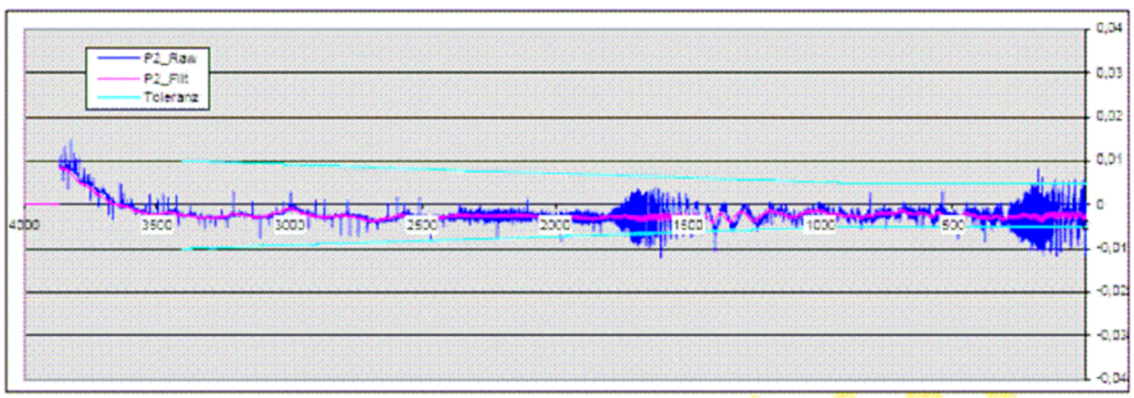


Figure C.5 : P-2 ground record

Airplane tail 190m rear of the localizer antenna and 0 m from runway centreline

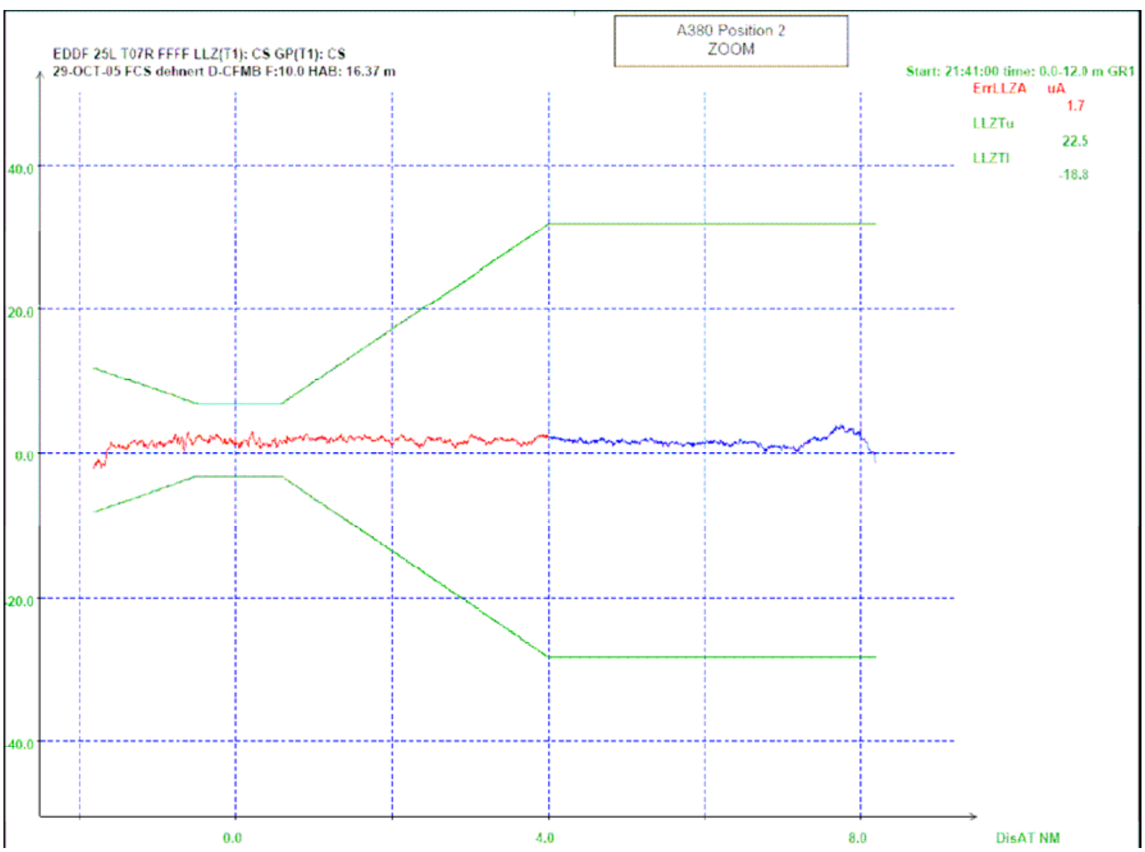


Figure C.6 : P-2 Flight record

P-X Record

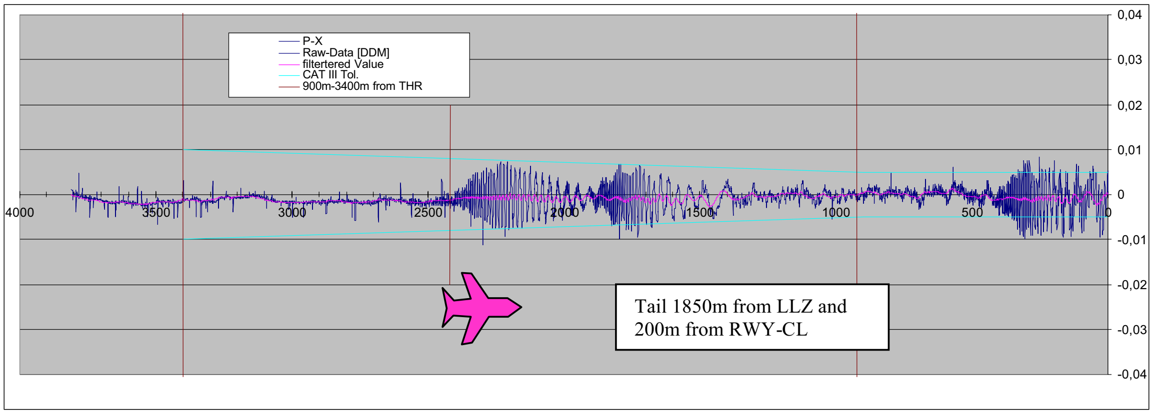


Figure C.7 P-X Ground Record

Airplane tail 1850 m from LLZ and 200m from RWY-CL), Markers von left to right: ILS point E, Tail of A380, ILS point D

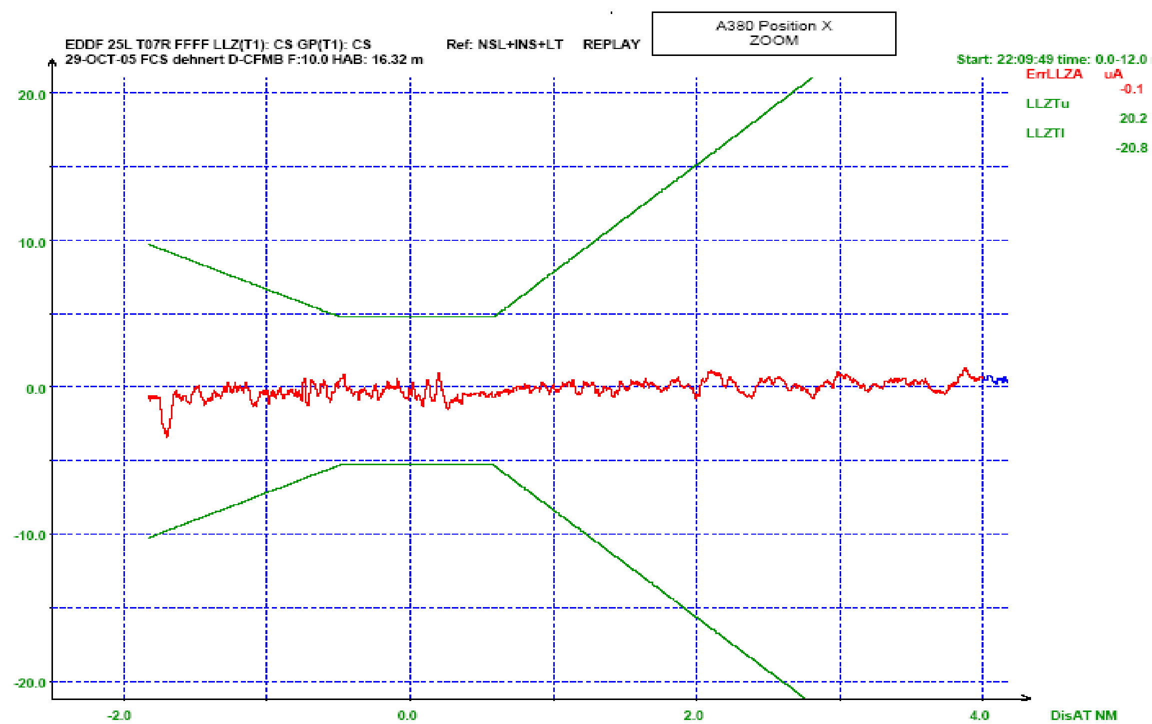


Figure C.8 P-X Flight Record

P-3 Record

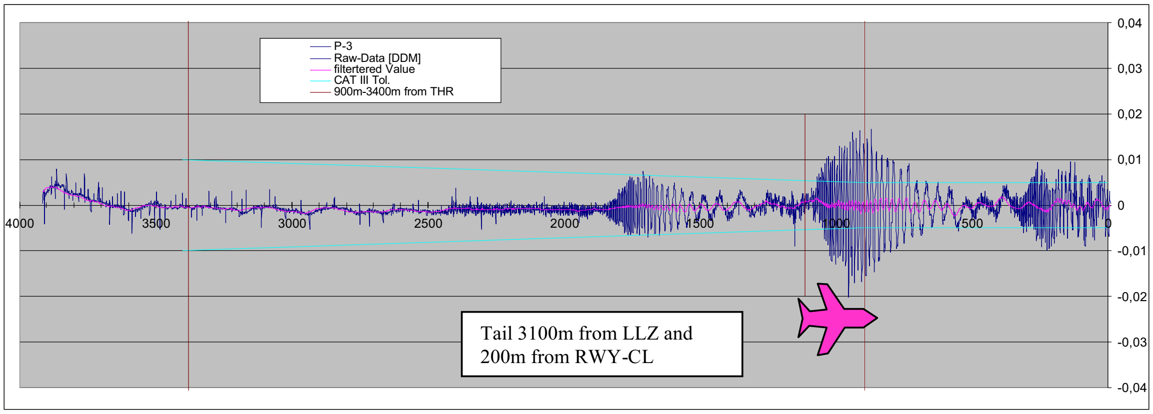


Figure C.9 P-3 Ground Record

Airplane tail 3100 m from LLZ and 200m from RWY-CL), Markers von left to right: ILS point E, Tail of A380, ILS point D

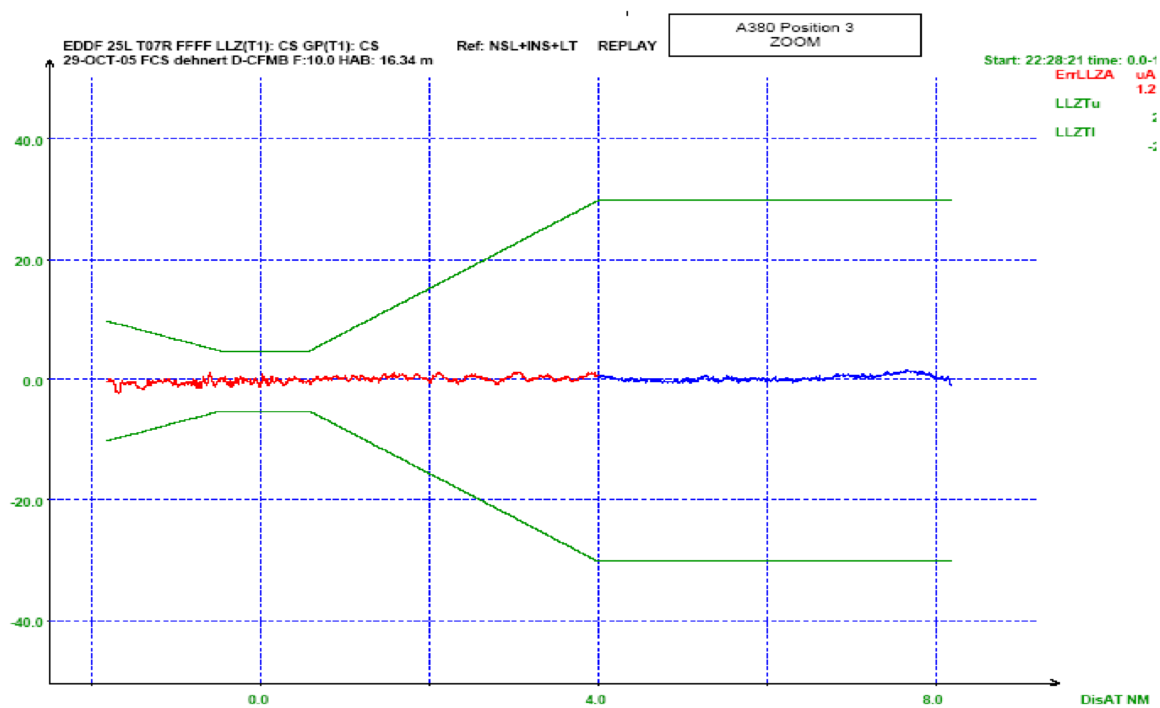


Figure C.10 P-3 Flight Record

P-4 Record

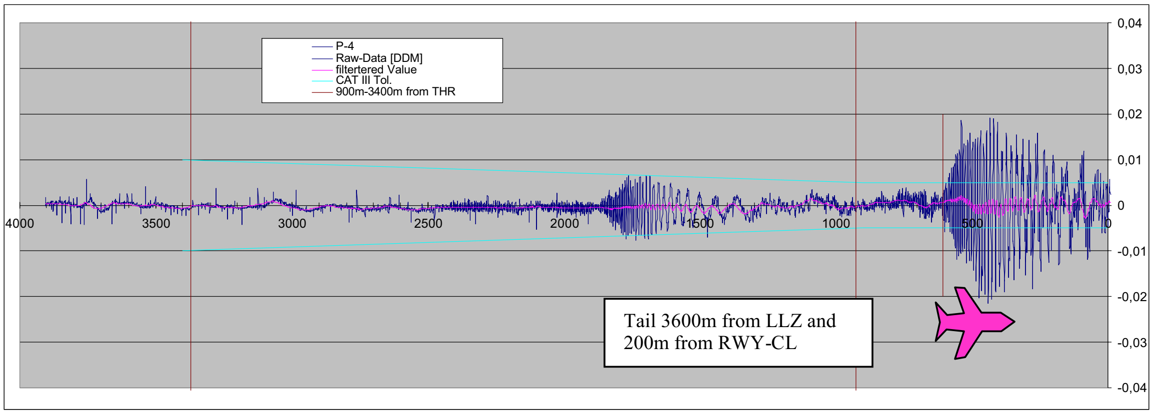


Figure C.11 P-4 Ground Record

Airplane tail 3600 m from LLZ and 200m from RWY-CL). Markers from left to right: ILS point E, ILS point D, Tail of A380

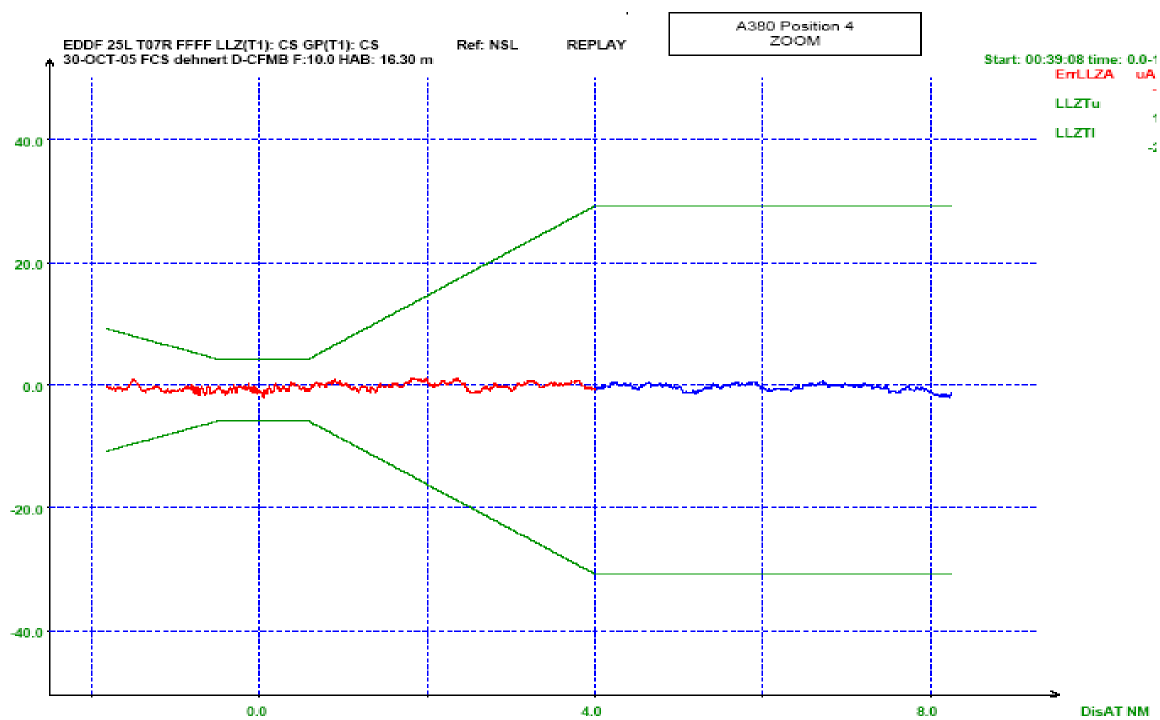


Figure C.12 P-4 Flight Record

P-5 Record

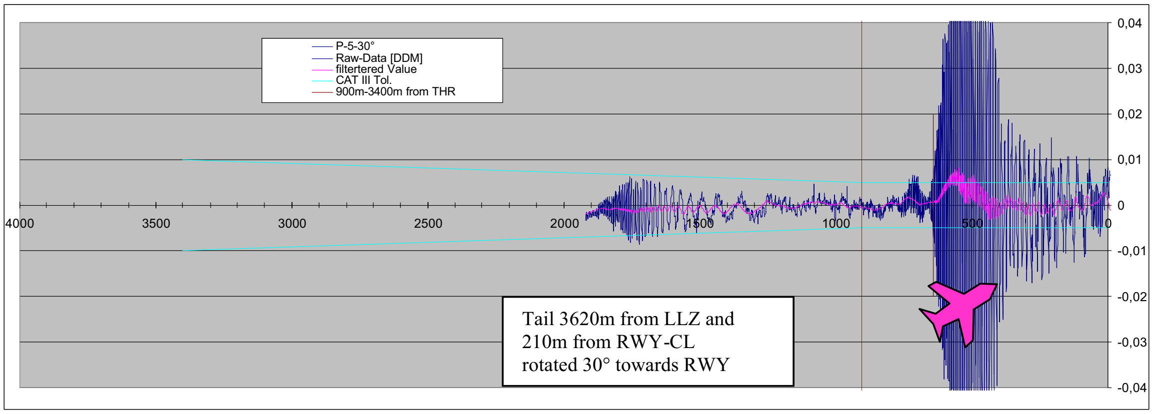


Figure C.13 P-5 Ground Record with airplane at 30° rotated to RWY

Airplane tail 3620 m from LLZ and 210m from RWY-CL, Markers from left to right: ILS point D, Tail of A380

P-5 Record (10 km/h)

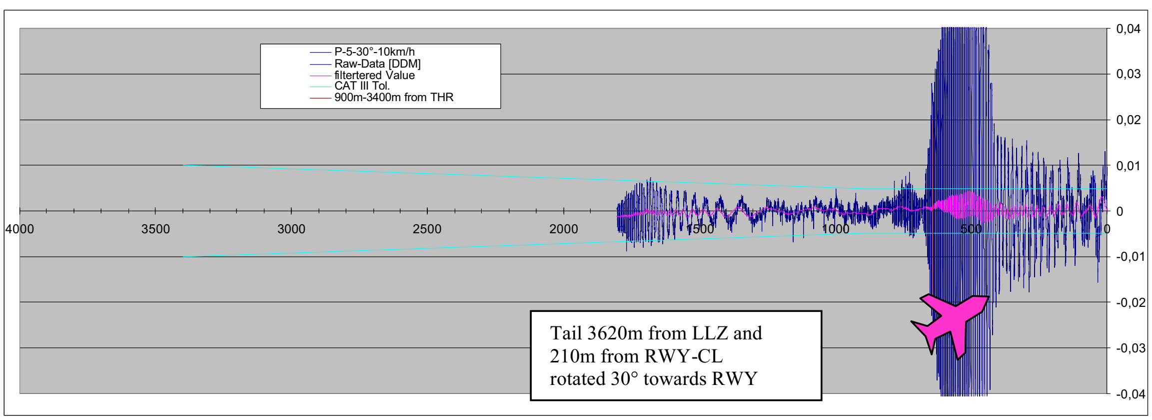


Figure C.14 P-5 Ground Record at 10 km/h and with airplane at 30° rotated to RWY

Airplane tail 3620 m from LLZ and 210m from RWY-CL, Markers from left to right: ILS point D, Tail of A380

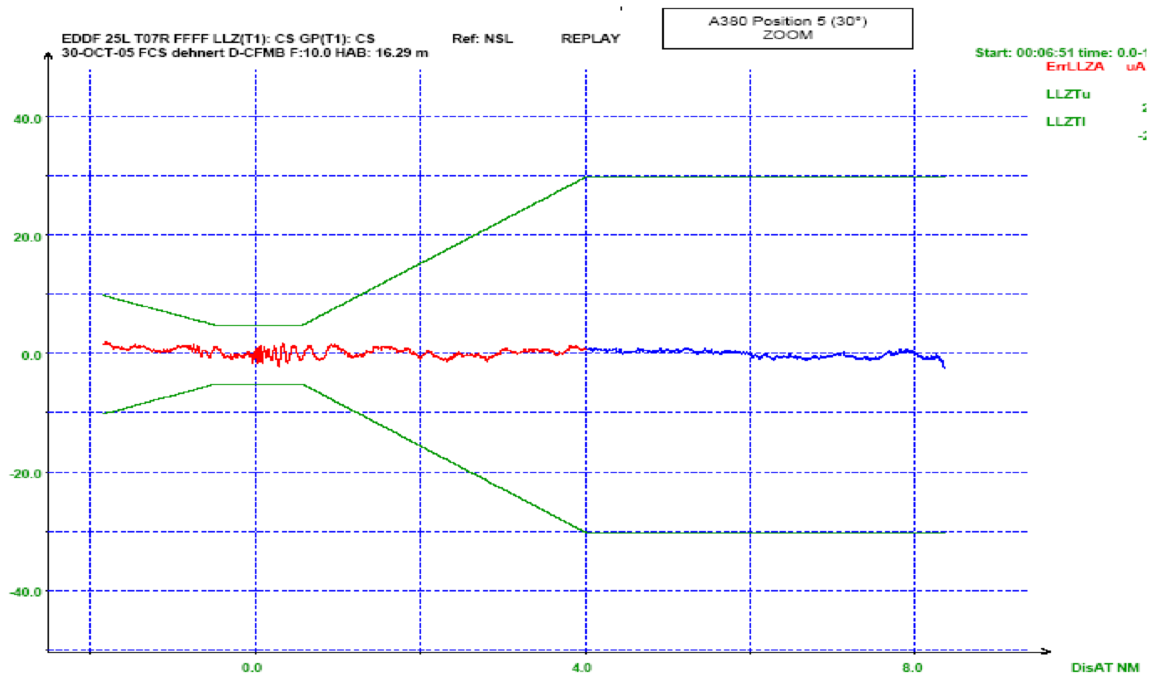


Figure C.15 P-5 Flight Record

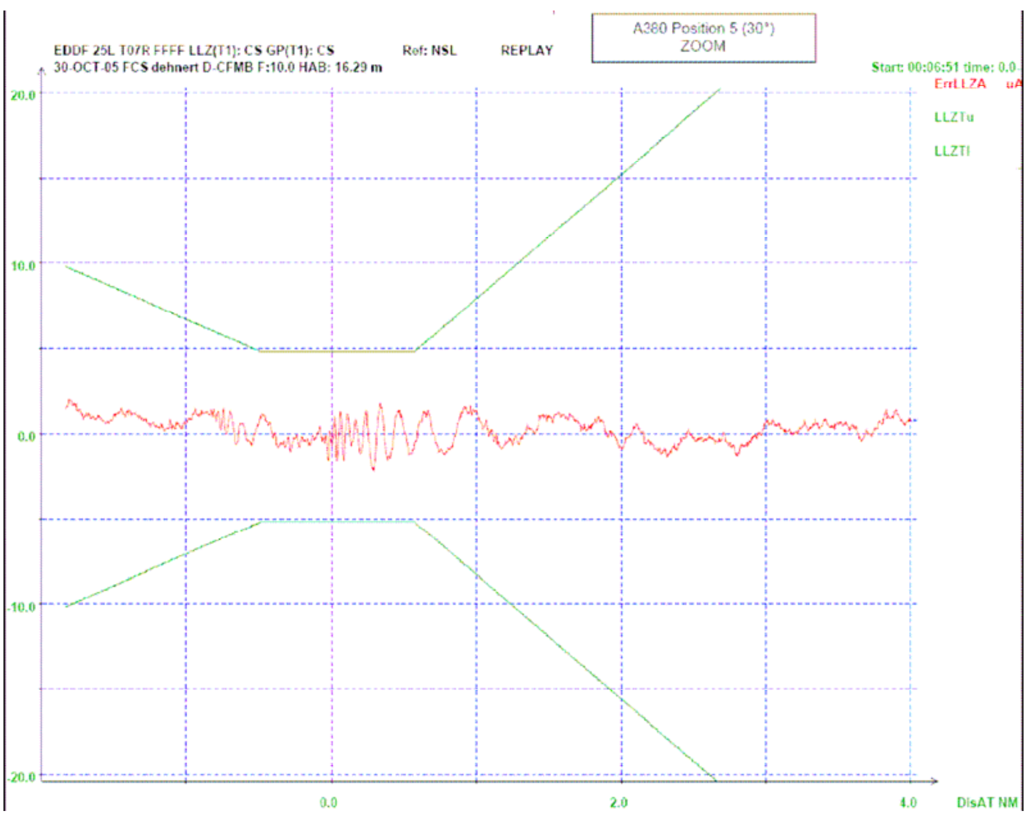


Figure C.16 P-5 Flight record / Zoom in

P-6 record

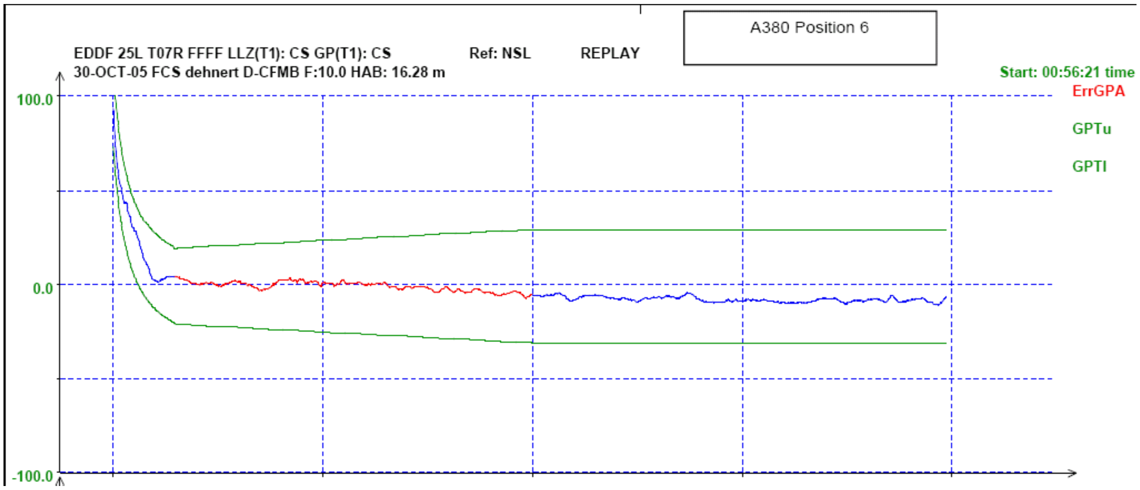


Figure C.17 : P6 – GP Flight record with airplane at 180m rear of GP antenna

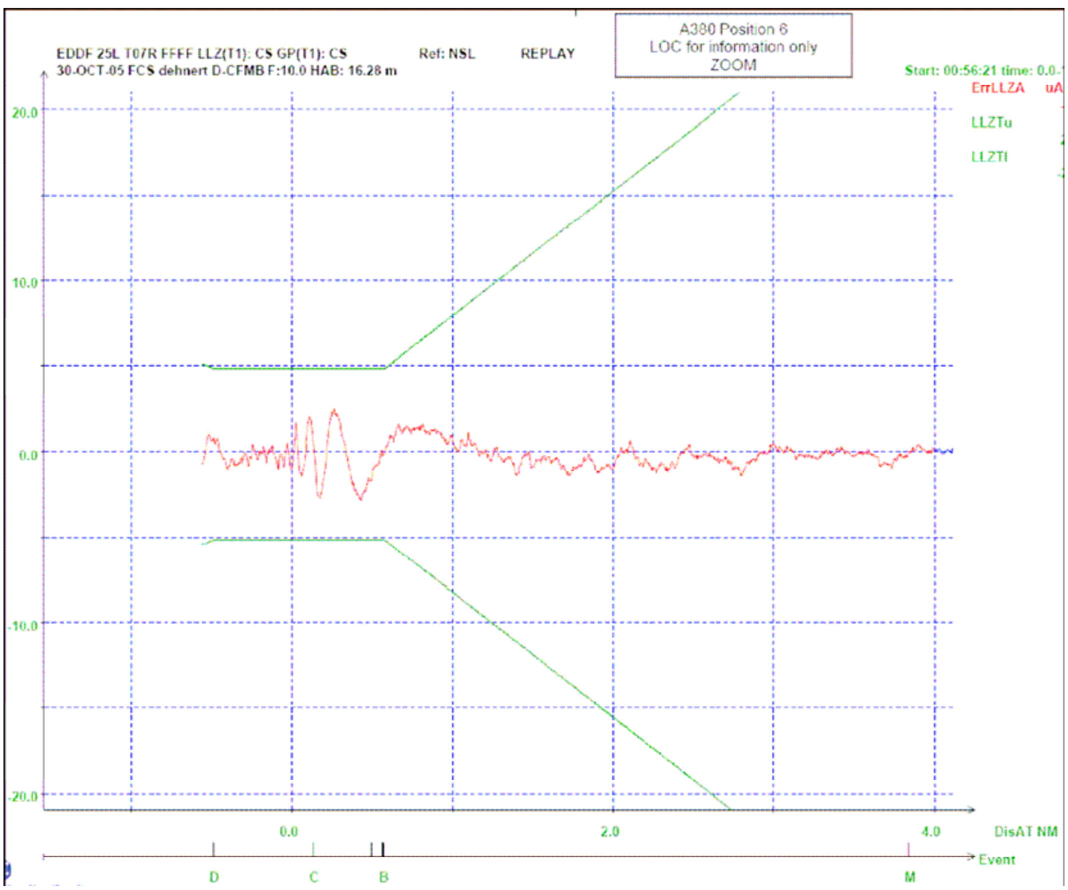


Figure C.18 : P-6 LLZ Flight record with airplane orthogonal to RW; Aircraft nose at 3740m from Localizer and 150 m from runway centreline

P-7 records :

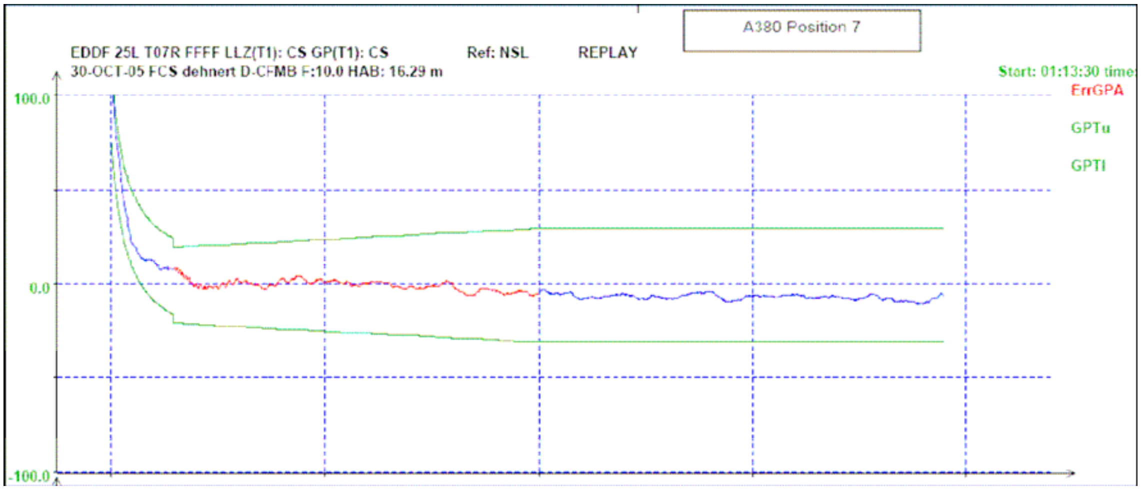


Figure C.19 : P-7 GP flight record with airplane 150m aside and 150m in front of GP antenna

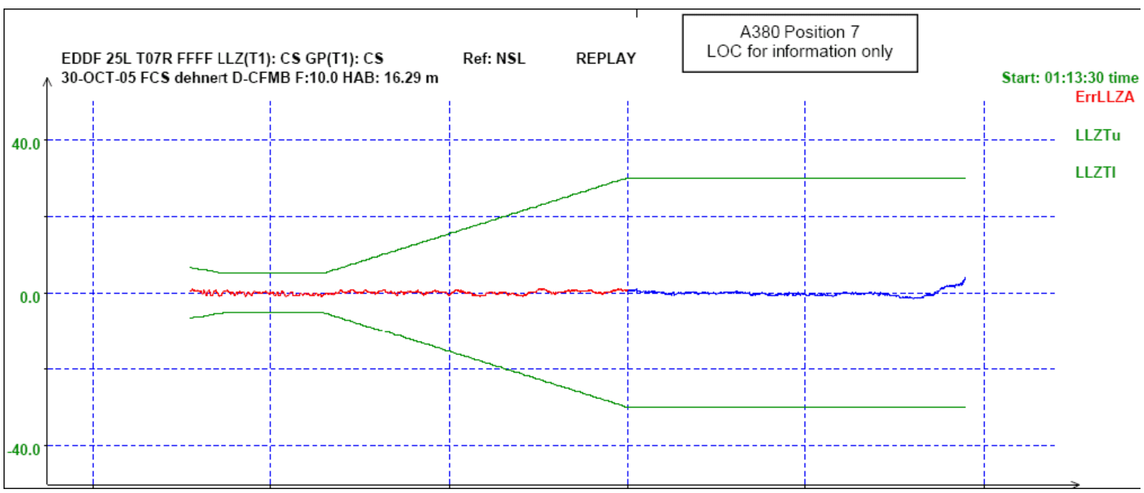


Figure C.20 : P-7 LLZ flight record with airplane 150m aside and 150m in front of GP antenna

P-9 record :

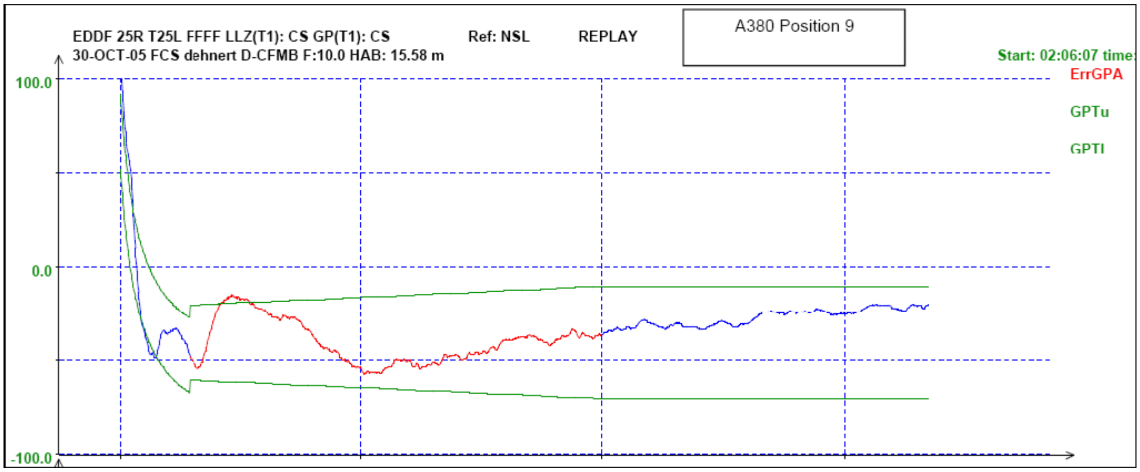


Figure C.21 : P-9 GP Flight record with airplane at 270 m in front of GP antenna

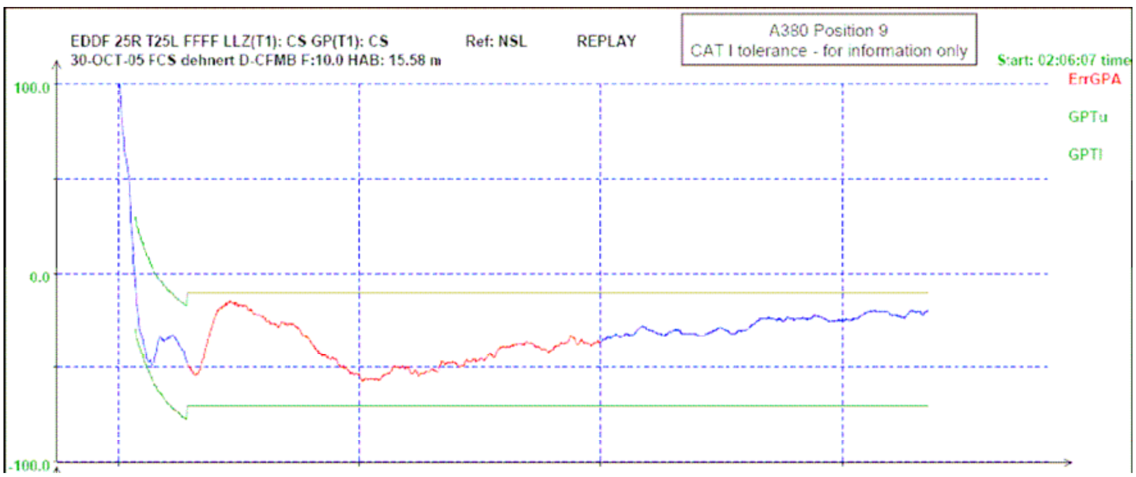


Figure C.22 : P-9 GP Flight record with Cat.I tolerance limits

2. Static Measurements, while A380 in motion

The following records show the measurement of the DDM signal with the receiver steady on ground, receiving antenna was the opposite LLZ antenna (i.e. on extended RWY centreline). During the measurement the A380 was towed at a speed of 15 km/h between the defined positions and the resulting DDM and RF-level recorded over the elapsing time (X-axis in seconds).
Shown are raw data in light blue colour and filtered values in dark blue. For this record the filter is due to correct for noise and high frequency peaks. The raw data are not expected to have an impact on the CDI.
Flight-check measurement have also been recorded during this test sequence with both, the A380 in motion and the flight-check airplane in approach. The records of the flight-check measurements are illustrated as well.

P-1 Record (A380 departing the RWY via 'Romeo')

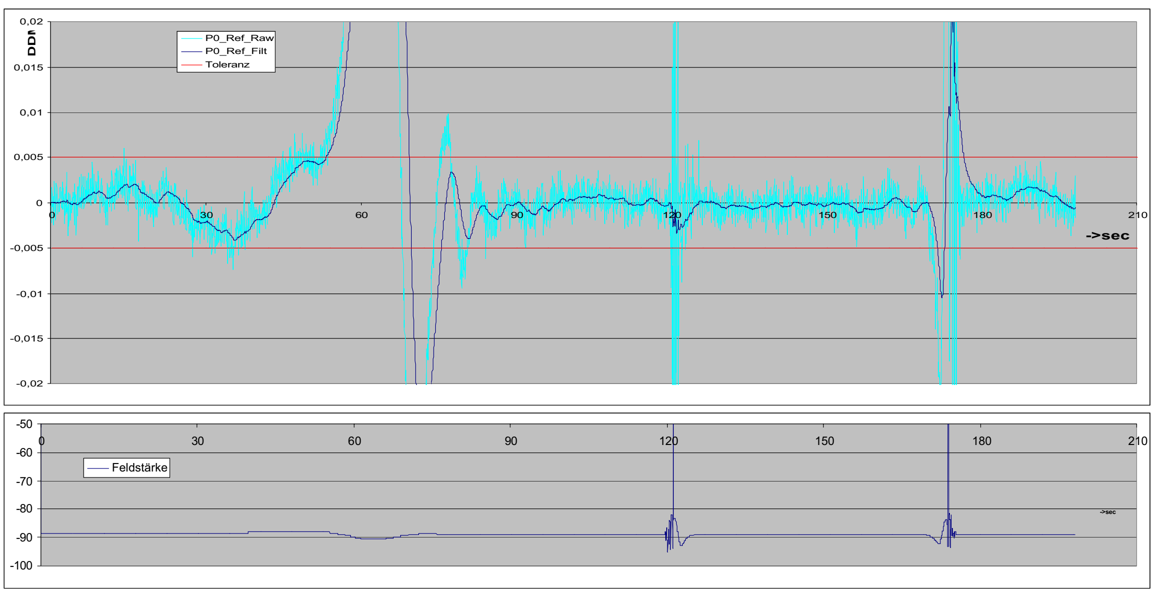


Figure C.23 P-1 Ground-Record (A380 departing the RWY via 'Romeo')

The A380 departs the RWY via TWY 'Romeo' at a speed of 15 km/h, starting 100 m (related to the nose tip of the airplane) in front of the RWY-stop end, i.e. starting at 362 m in front of the radiating Localizer antenna and coming 300m approx. close to the antenna.
It can be assumed, that the airplane turned in to north at about 30 sec. and reached a distance offset from RWY-CL at another 30 sec. Distortion disappeared when the tail of the A380 was about 150 m away from RWY-centreline.
The distortion peaks at 120 sec. and at 170 sec. are caused by the flight-check airplane flying over the receiver antenna (at the time of 120 sec.) and flying over the transmitting LLZ antenna (at the time of 170 sec.). These distortions therefore are not caused by the A380.

The next figure shows the record of the flightcheck aircraft for this test item.

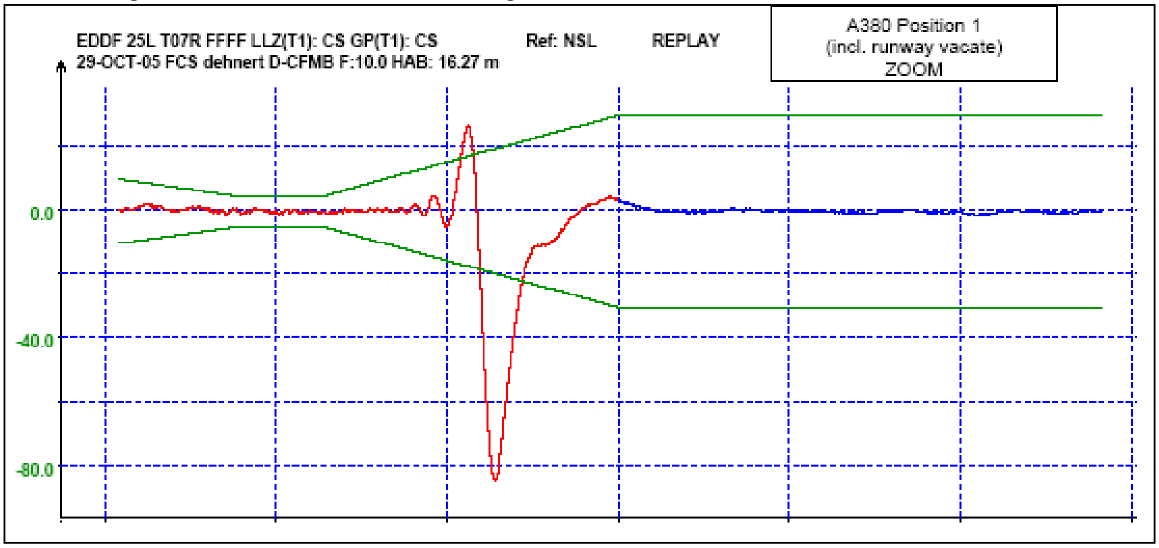


Figure C.24 P-1 Flight-Record (A380 departing the RWY via ‘Romeo’)

P-8 Record (A380 crossing the RWY via 'Foxtrot')

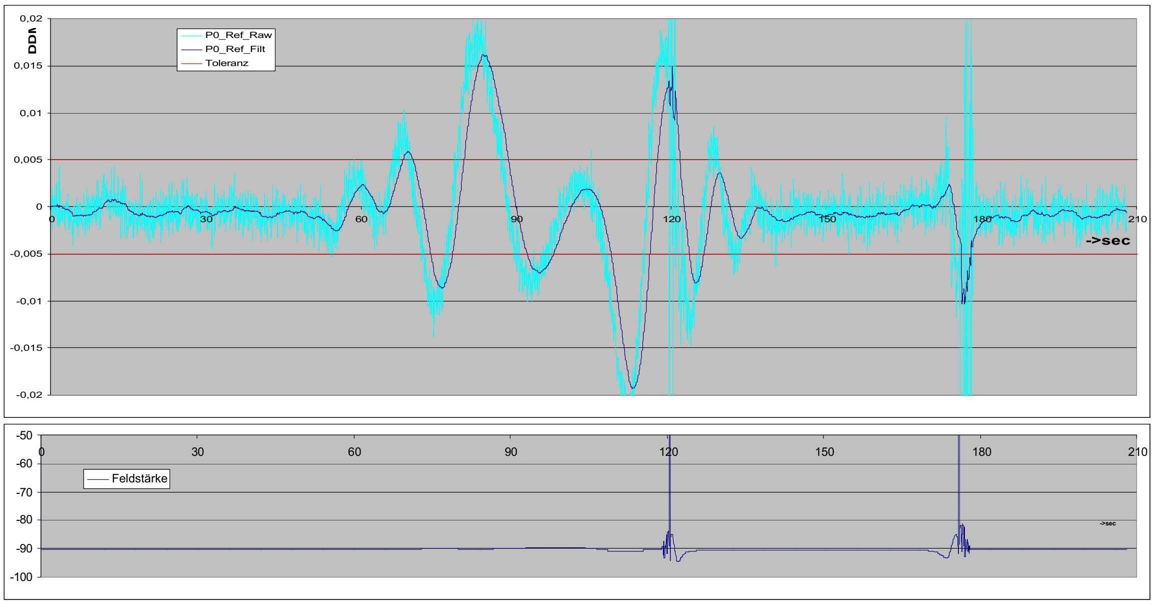


Figure C.25   P-8 Ground-Record (A380 crossing the RWY via 'Foxtrot')

The A380 is crossing the RWY via TWY 'Foxtrot' from south to north at a speed of 15 km/h, starting 150 m (related to the nose tip of the airplane) away from RWY centreline.
It can be assumed, that the tail of the airplane was above RWY-centreline after about 100 sec. and again 150 m away from the RWY-CL at about 140 sec.
The distortion peaks at 120 sec. and at 170 sec. again are caused by the flight-check airplane flying over the receiver antenna (at the time of 120 sec.) and flying over the transmitting LLZ antenna (at the time of 170 sec.). These distortions therefore are not caused by the A380.
During this measurement Localizer 07R was radiating and thus the distance between the crossing A380 and the LLZ antenna was 900 m! (520 m + 380 m)

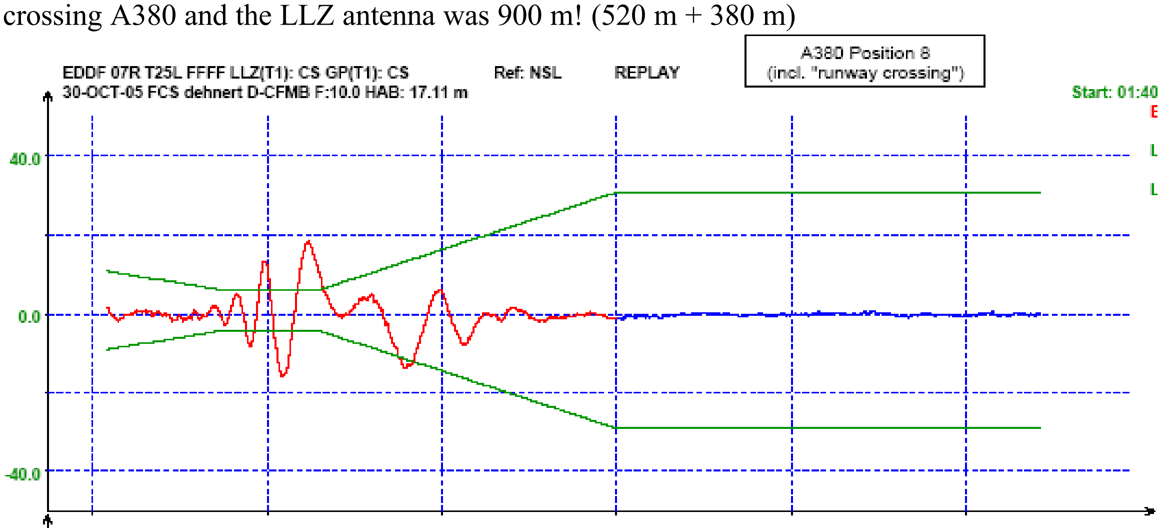


Figure C.26   P-8 Flight-Record (A380 crossing the RWY via 'Foxtrot')

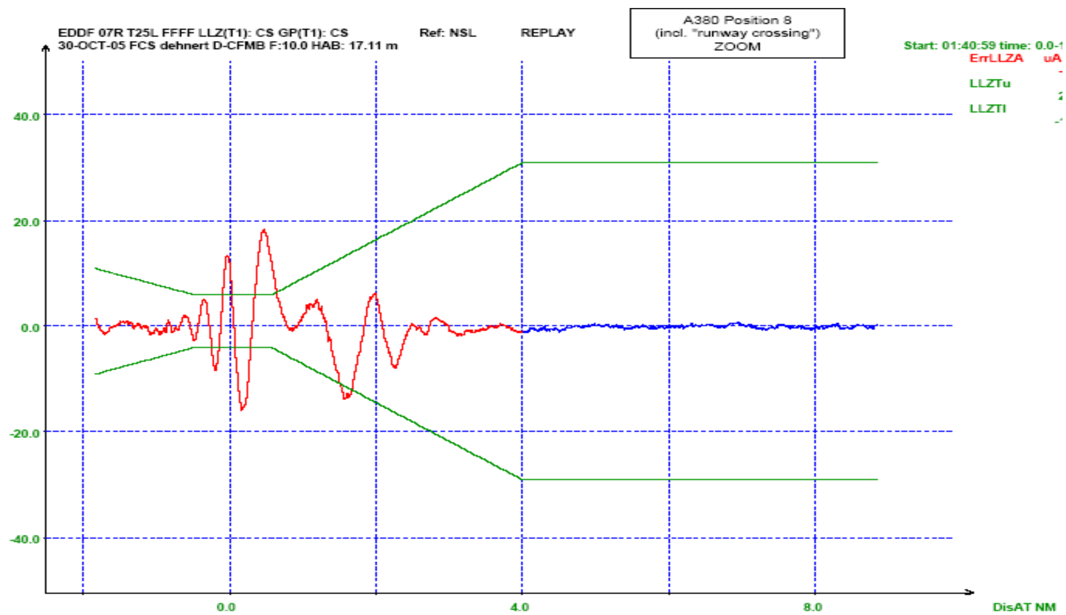


Figure C.27 P-8 Flight-Record (A380 crossing the RWY via 'Foxtrot'), zoomed in

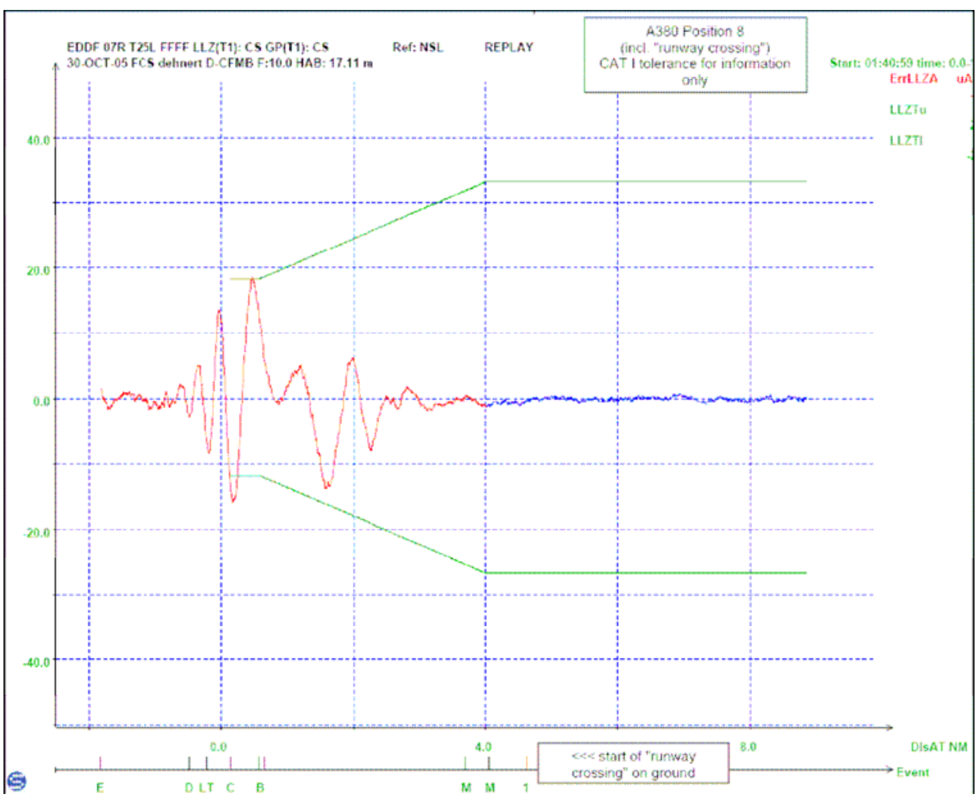


Figure C.28 : P-8 GP Flight record with Cat.I Tolerances

ANNEX D: B747 Frankfort test campaign

1. Dynamic Measurements, B747 steady in test position

P-5 Record (B747)

Dynamic measurements, with B747 steady, only the positions P-5 and P-5.1 were conducted:

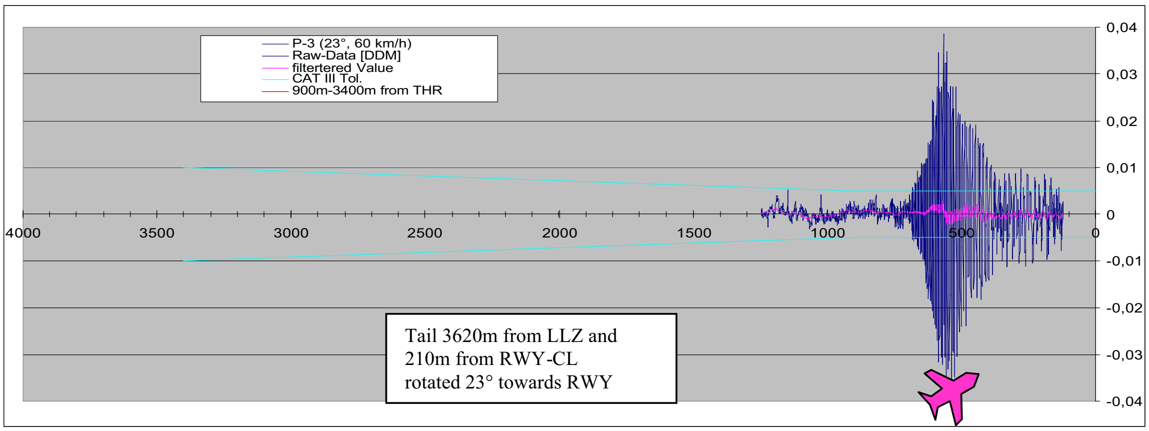


Figure D.1 P-5 Ground Record with airplane at 23° rotated to RWY, measured at 60 km/h

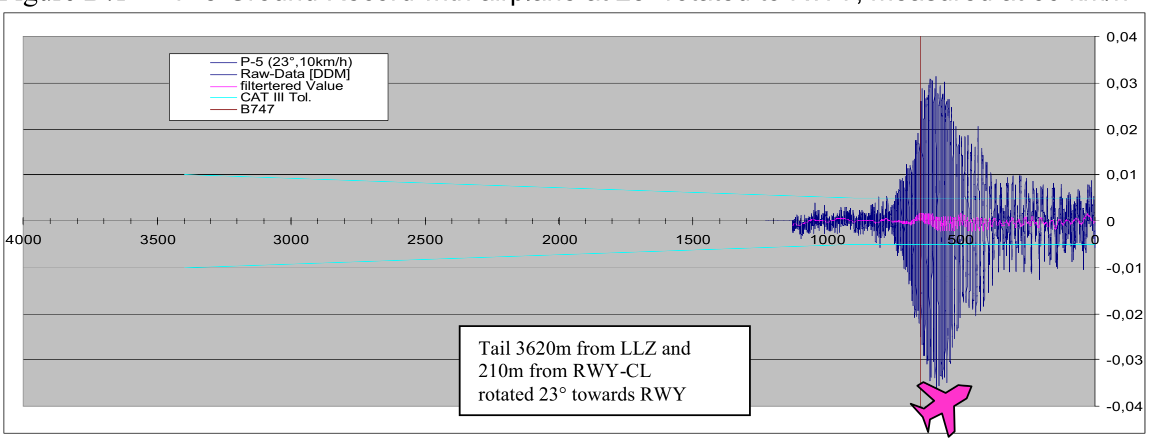


Figure D.2 P-5 Ground Record with airplane at 23° rotated to RWY, measured at 10 km/h

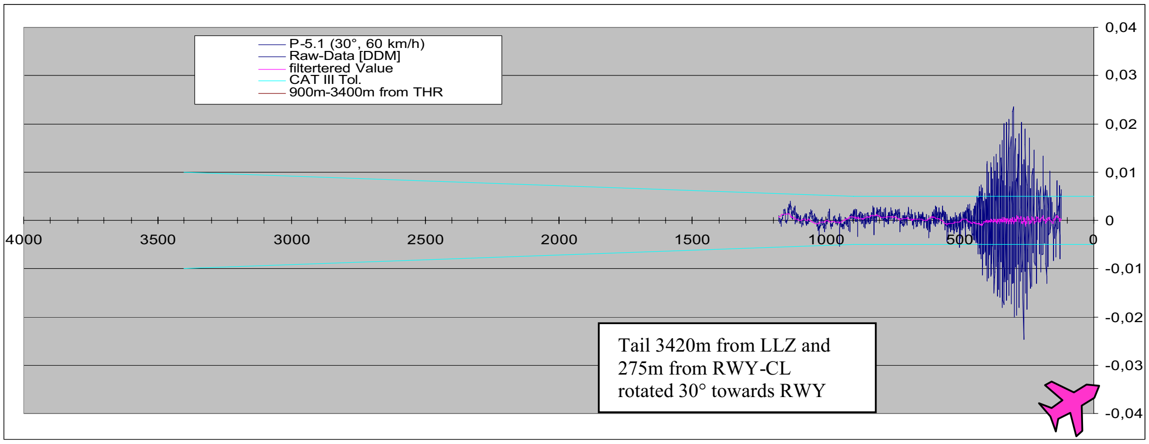


Figure D.3 P-5 Ground Record with airplane at 30° rotated to RWY, measured at 60 km/h

2. Static Measurements, while B747 in motion

Static measurements, with B747 motion were conducted for the P-1, P-2, P8 and P1.1:

P-1 Record (B747 departing the RWY via 'Romeo')

This measurement was performed in the same manner as P-1 with the A380: LLZ 25L was operational and the B747 was towed from a position 100 m (related to the nose tip of the airplane) in front of the RWY stop-end, which is 362 m in front of the radiating Localizer. The towing speed however was about 25 km/h, 10 km/h faster.
In the following figure both curves, the A380 trial as well as the B747 trial are shown in one diagram.
The difference between the two distortion amplitudes are 1 to 2, in other words the distortion amplitude of the B747 is nearly precisely half of the one of the A380!
Anyhow it should be noticed that the distortion amplitude is out-of-tolerance for the B747 as well.

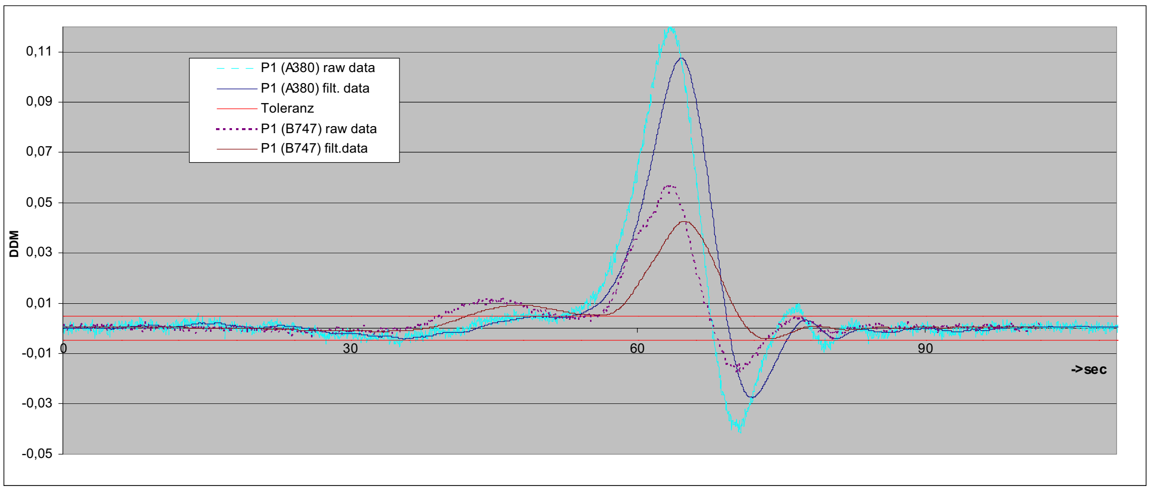


Figure D.4 P-1 Ground Record with B747 departing RWY via 'Romeo'

P-8 Record (B747 crossing RWY via 'F') with LLZ-25L operational

This measurement was performed in the same manner as P-8 with the A380. The B747 was towed from a position 150 m (related to the nose tip of the airplane) away from the RWY centreline.
During this measurement Localizer 07R was radiating and thus the distance between the crossing airplane and the LLZ antenna was 900 m (520 m + 380 m).
The towing speed however was about 25 km/h, 10 km/h faster.
In the following figure both curves, the A380 trial as well as the B747 trial are shown in one diagram.
The difference between the two distortion amplitudes again is about 1 to 2, in other words the distortion amplitude of the B747 is nearly half of the one of the A380, as could have learned in the example above!
A crossing of the B747 at that distance from radiating Localizer however is acceptable for CAT I operation and will be acceptable for CAT II/III operation as well under the procedure for Sensitive Areas. Therefore this distance from Localizer belongs to Sensitive Area in case of B747.

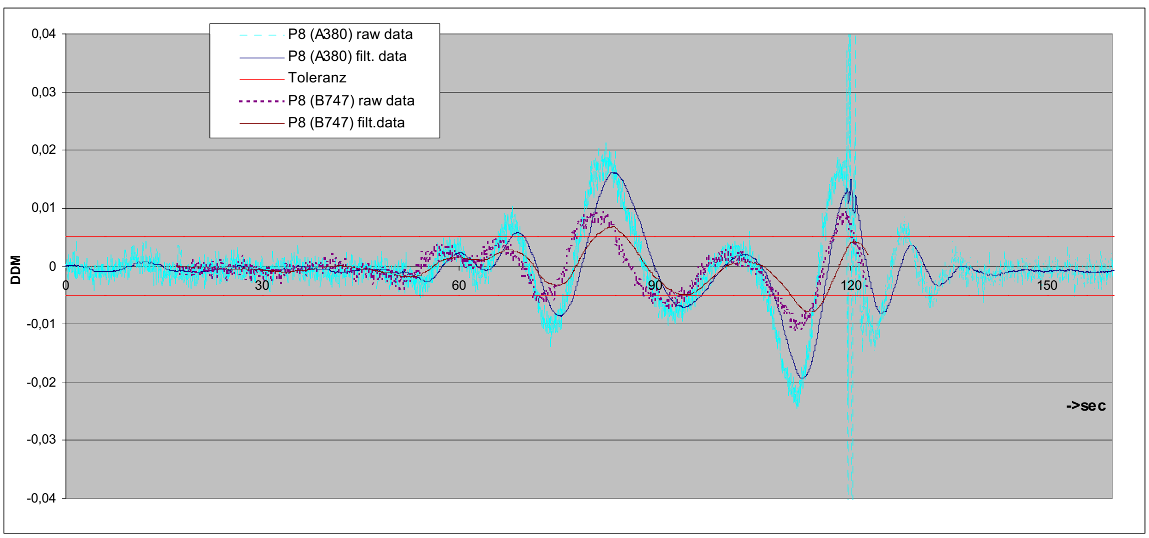


Figure D.5 P-8 Ground Record with B747 crossing the RWY via 'Foxtrot'

P-8.1 Record (B747 crossing RWY via ‘H’) with LLZ-25L operational

P-8.1 Record (B747 crossing RWY via ‘H’) with LLZ-25L operational

This measurement was performed incidentally when a B747 was crossing the RWY via ‘Hotel’.
During this measurement Localizer 07R was radiating and thus the distance between the crossing airplane and the LLZ antenna was 2680 m (2300 m + 380 m).
A crossing of the B747 at that distance from radiating Localizer is acceptable, no out-of-tolerance distortion occurs, see diagram below.

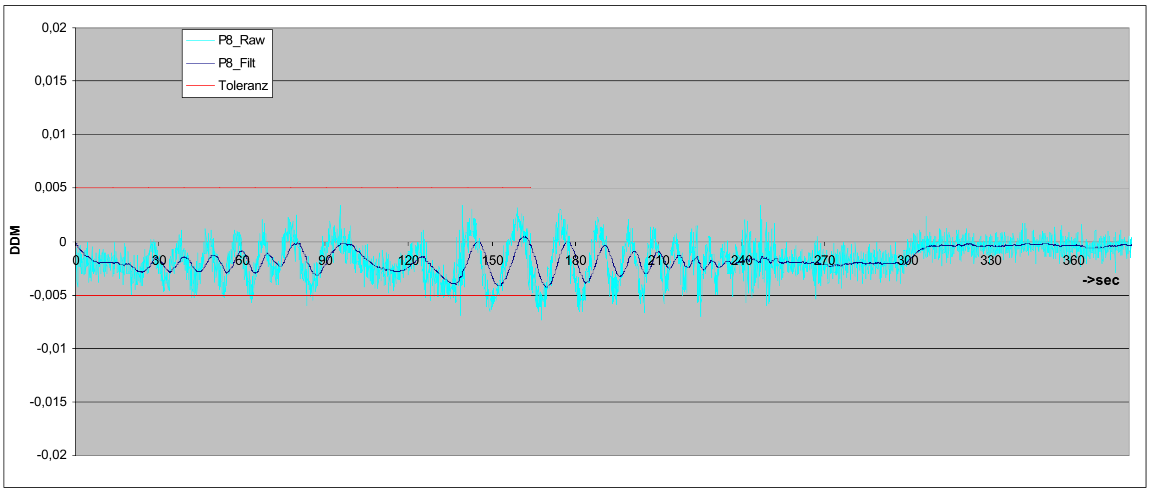


Figure D.6 P-8 Ground Record with B747 crossing the RWY via ‘Hotel’

P-2 Record (B747 passing rear of LLZ antenna via ‘Whisky’)

This measurement was performed in order to check the Sensitive Area in the rear of the Localizer antenna.
The B747 was towed on TWY ‘W’, which is 190 m distant from the antenna und at an horizontal angle of 70 degrees against the extended RWY centreline.
The test with the A380 was done in a different manner: The A380 was positioned orthogonal to the extended RWY centreline. This A380 trial caused a shift of the Localizer course line along the whole approach path.
With the B747 towed on ‘Whisky’, no distortions can be observed.

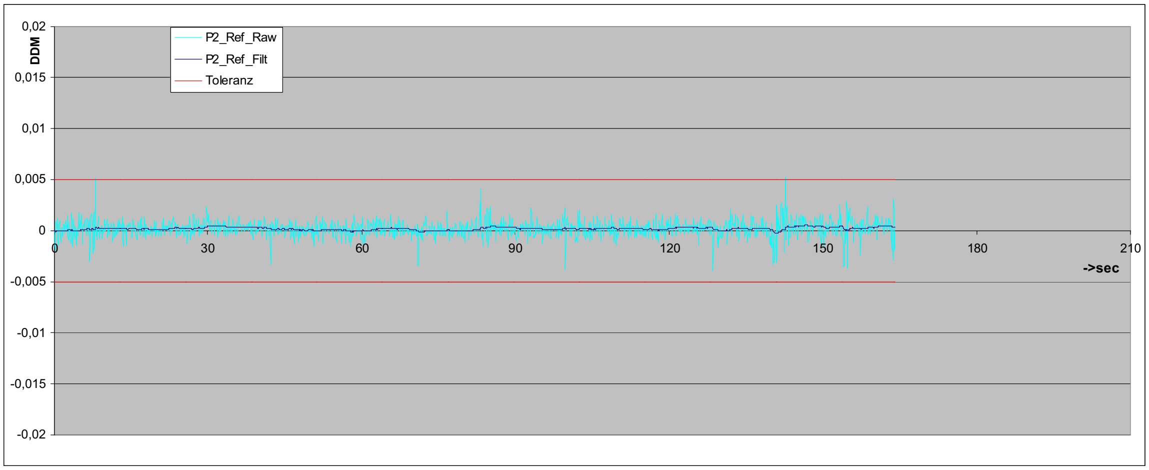


Figure D.7 P-2 Ground Record with B747 passing in the rear of LLZ via ‘Whisky’

P-1.1 Record (B747 departing the RWY via 'Delta')

This measurement was performed in order to check the Critical Area of the Localizer antenna. The B747 was towed on TWY 'D, which starts about 380 m distant from the antenna of LLZ 07R und at a horizontal angle of 65 degrees against the extended RWY centreline.

This test was not done with the A380. However the B747 leaving the RWY at the distance of 380 m slant to the LLZ cause distortion unacceptable for CAT II/III operation under the present procedure for Sensitive Areas.

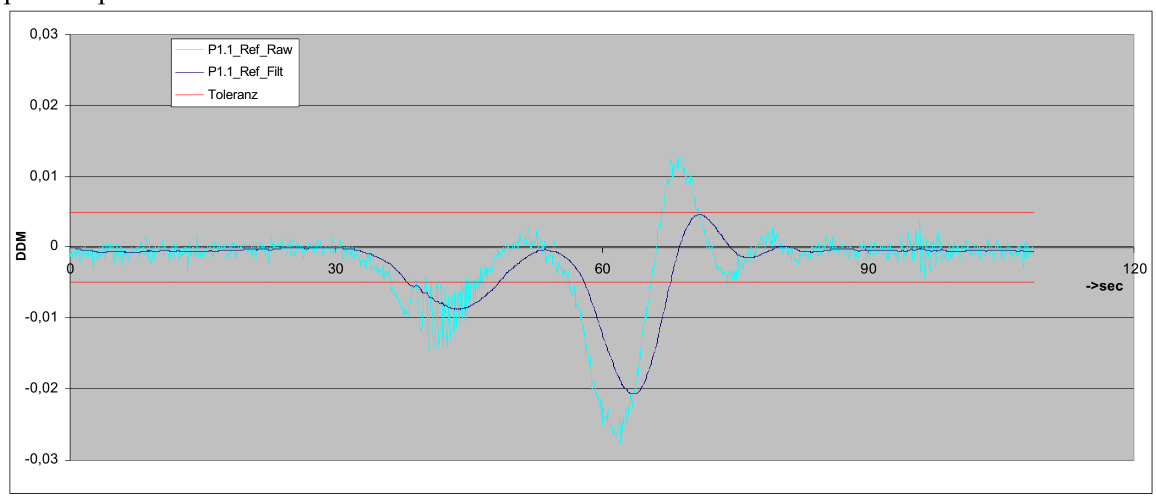
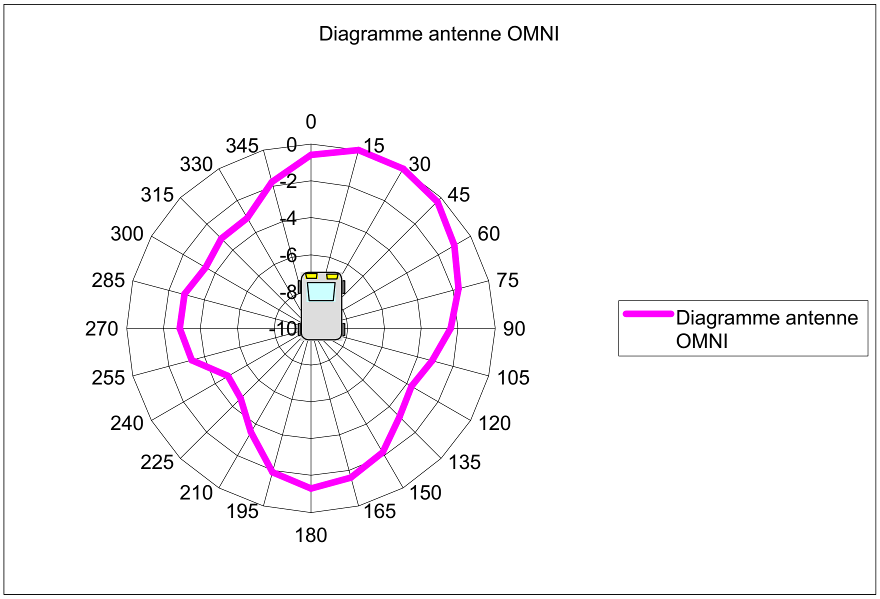


Figure D.8 P-1.1 Ground Record with B747 departing the RWY via 'Delta'

ANNEX E : Toulouse DSNA and SNA/Sud Test set up

DSNA Measurement Equipment

- ILS field receiver, Artus 324
  Raw data acquisition at 10 Hz for DDM and RF-Level
- Antenna :type Scala (see photo)
  Directivity: see diagramm
- Post processing and filtering evaluation DTI Software



Measured diagram of the antenna at 4m high on vehicle

SNA/Sud Measurement Equipment

- ILS field receiver, Artus 324
  Raw data acquisition at 10 Hz for DDM and RF-Level
- Antenna :type Yagi (see photo)
  Directivity: see diagram
- Post processing and filtering evaluation SNA/sud Software

SNA/Sud maintenance vehicle equipped with a Yagi antenna which is 45° turned towards the A380 obstacle (to the right side)

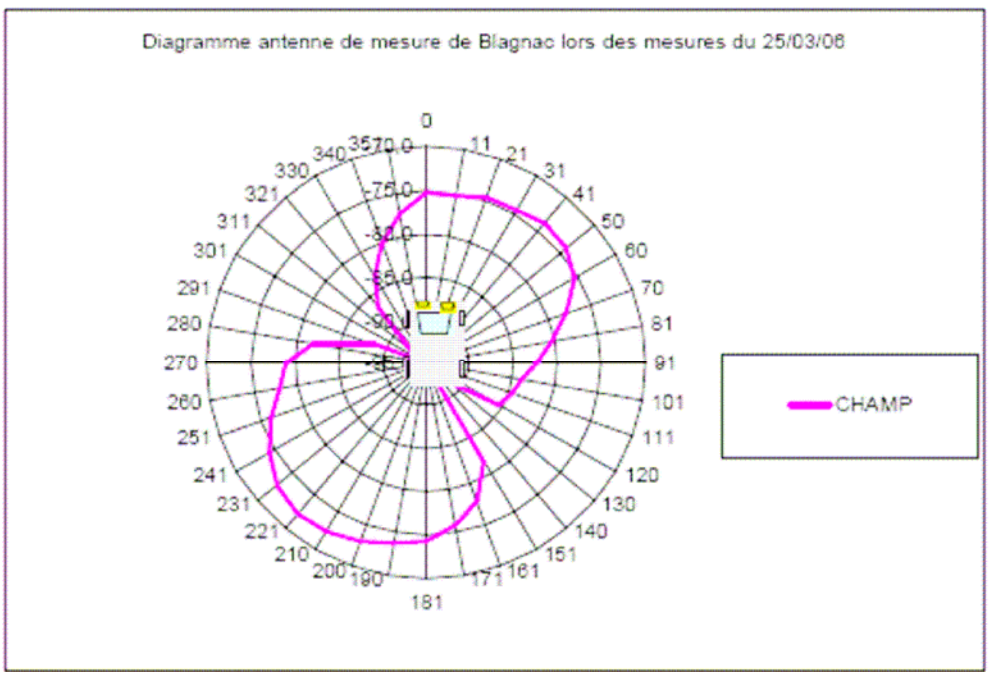
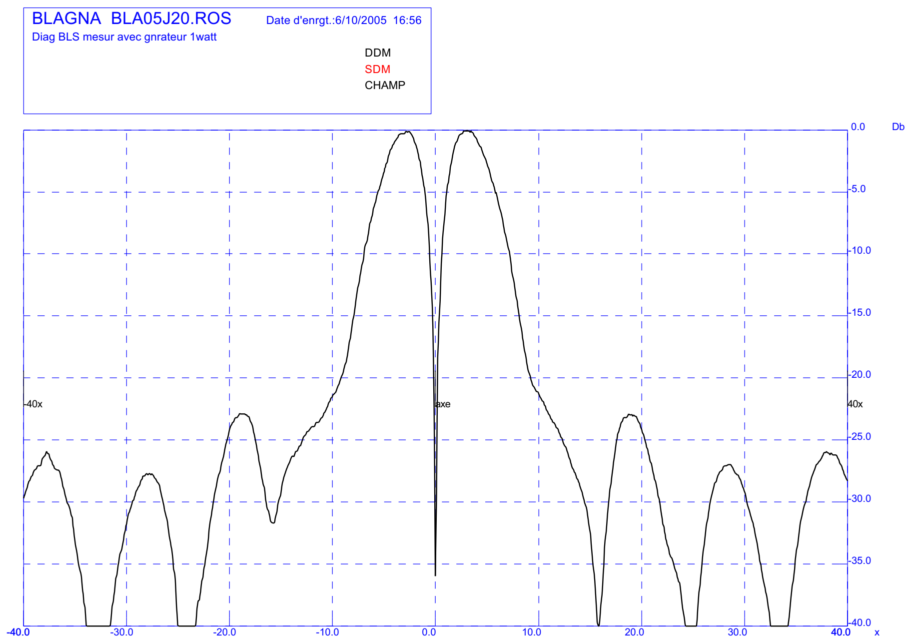
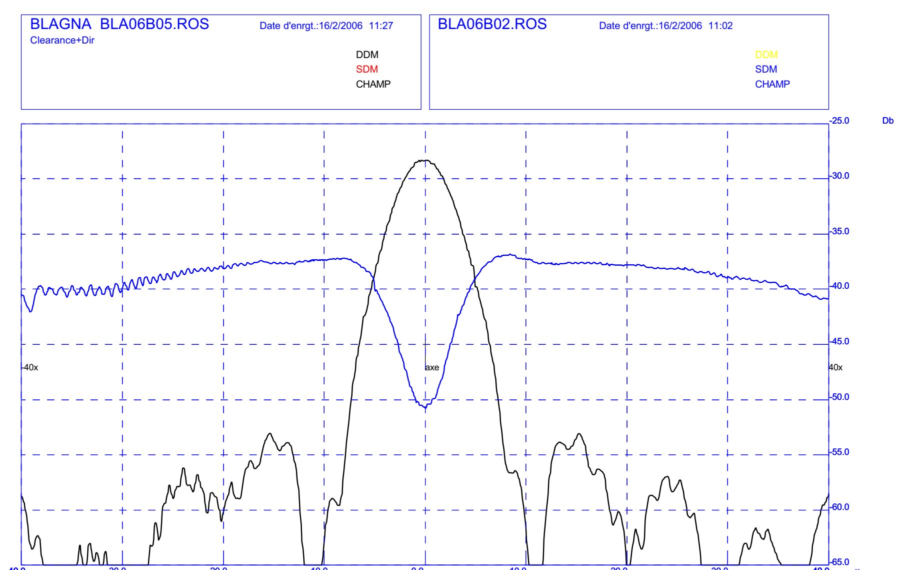


Diagram of the Yagi antenna

ANNEX F : Toulouse Blagnac ILS 14R characteristics

SBO Pattern of 25 antennas array at Toulouse BLAGNAC



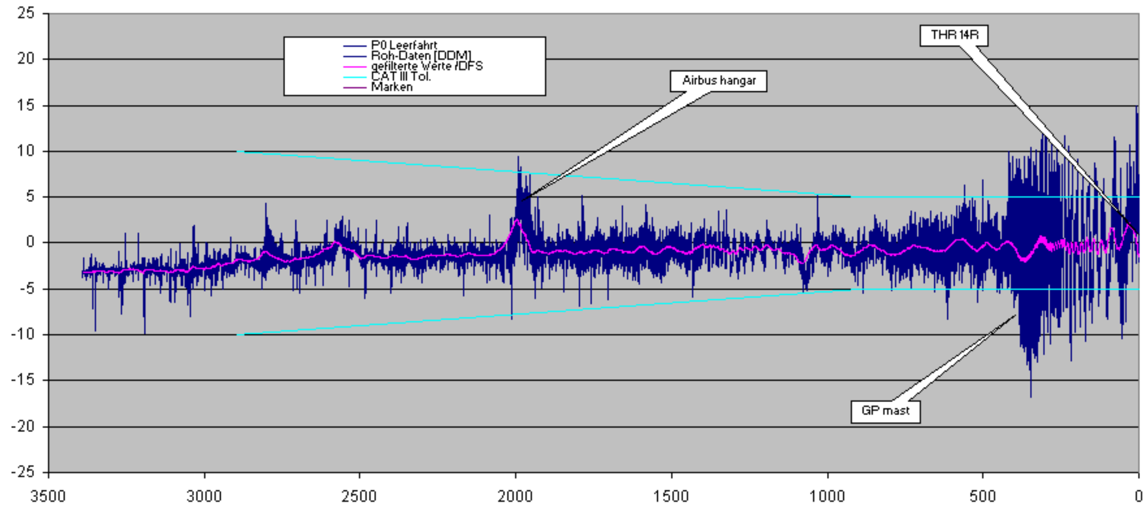


CSB pattern of the course and clearance

ANNEX G: A380 Toulouse test campaign

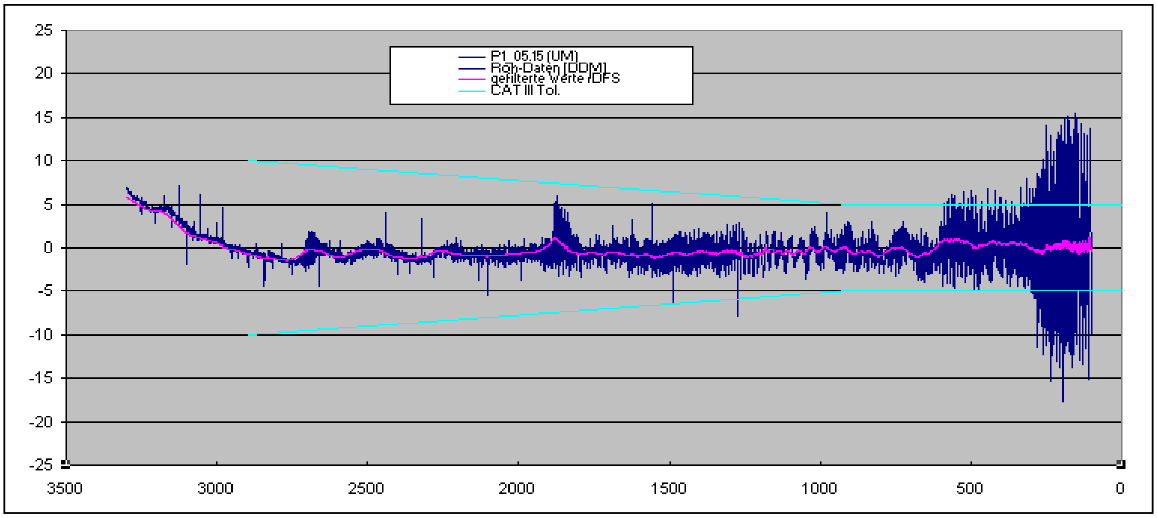
Toulouse Airport

Reference record without A380

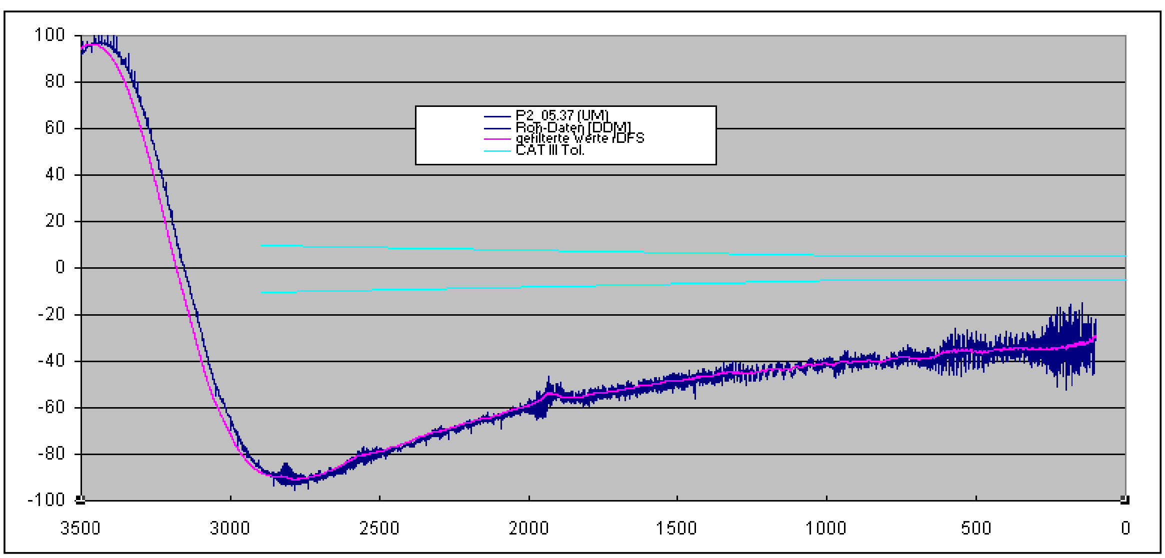


Measurements with DFS receiver and DSNA antenna

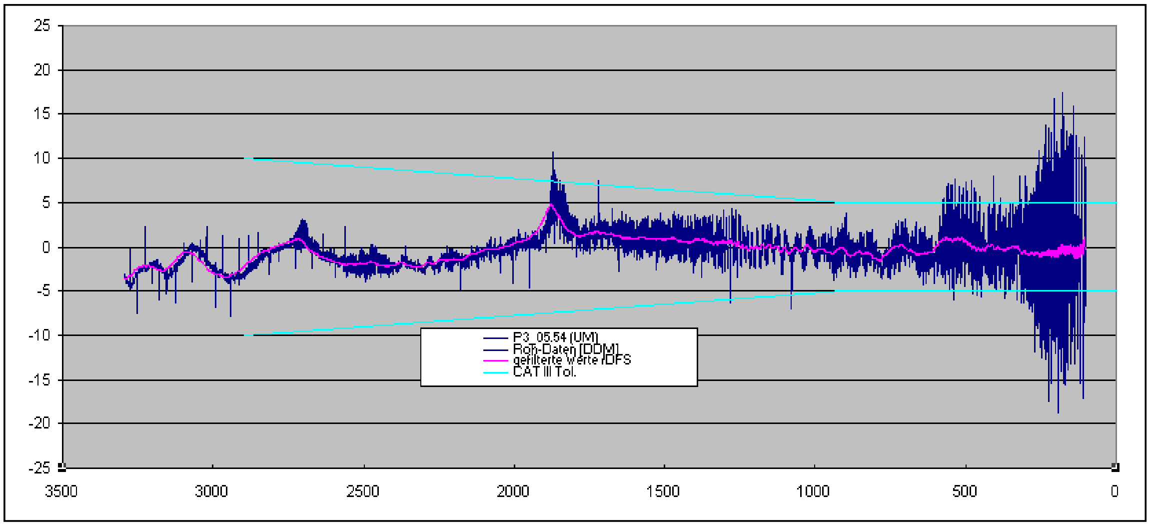
P1: Tail : Forward = 710, sideway = -5, rotation = 21°
Measurements with DFS receiver and DSNA antenna



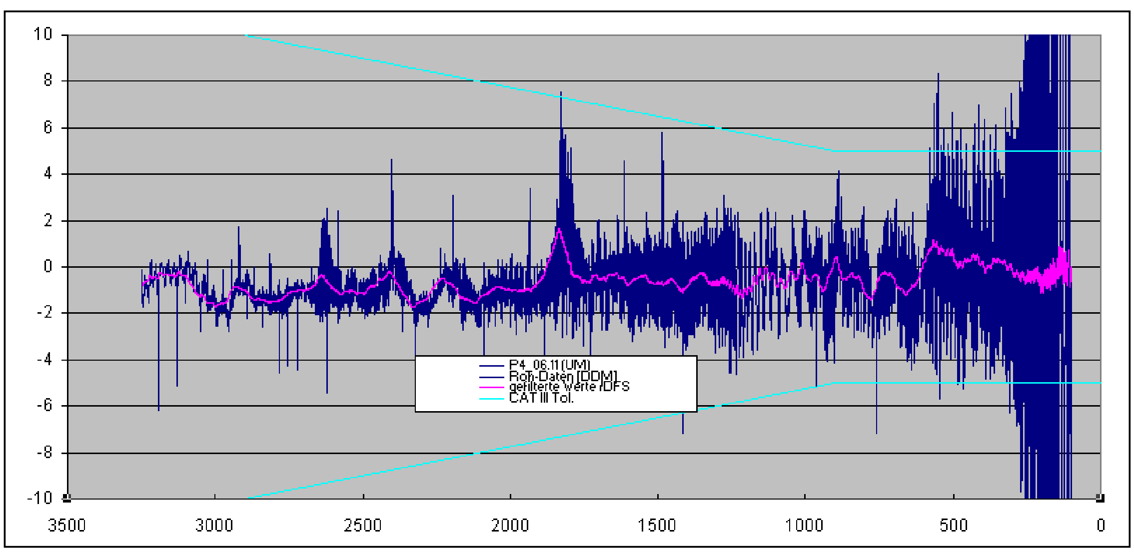
P2: Tail: Forward = 608, sideway = 29, rotation = 83°
Measurements with DFS receiver and DSNA antenna



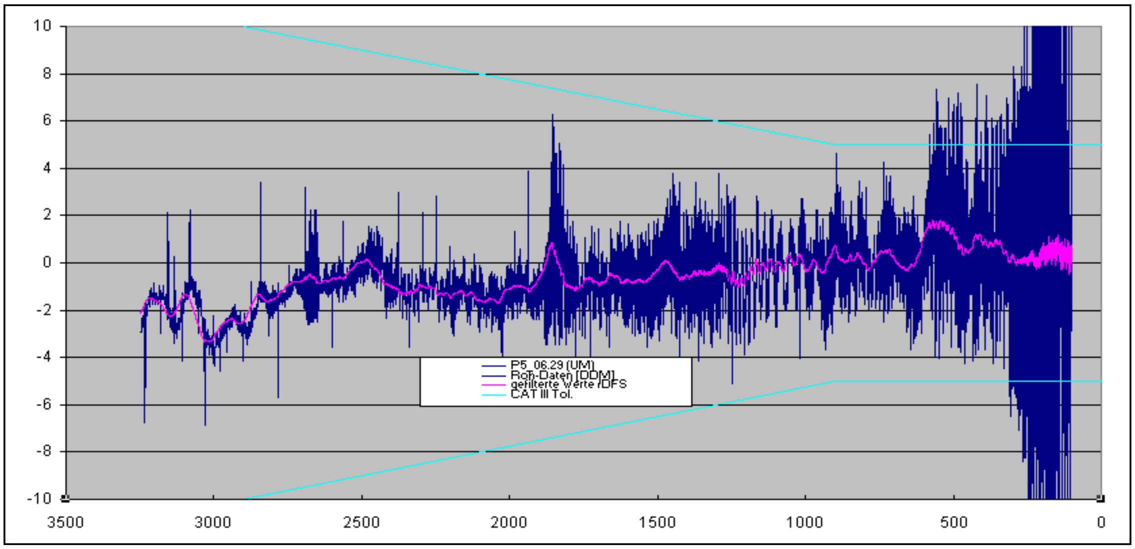
P3: Tail: Forward = 603, sideway = 93, rotation = 90°
Measurements with DFS receiver and DSNA antenna



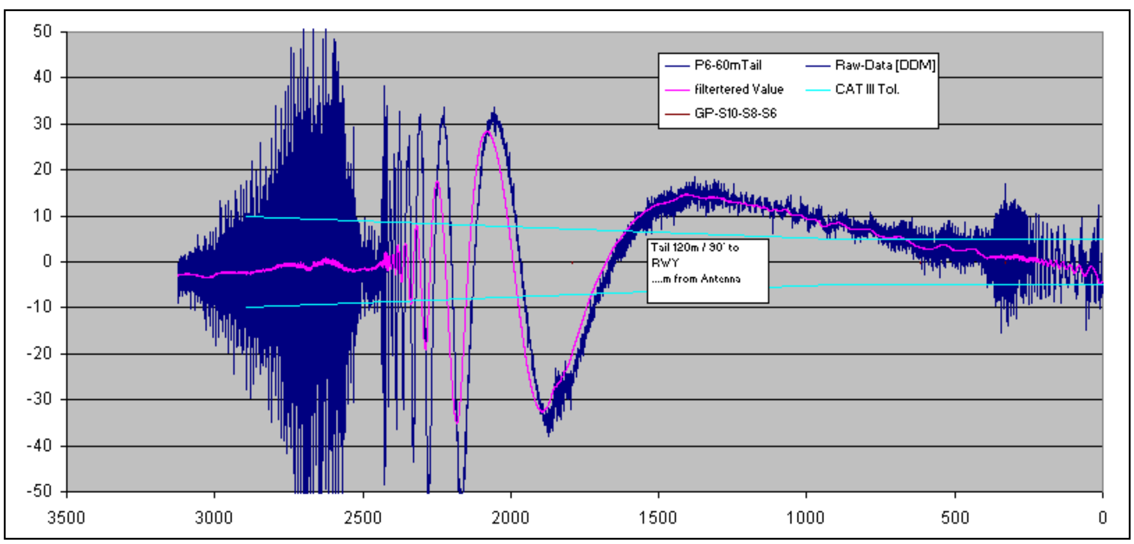
P4: Tail : Forward = 662m, sideway = 198m, rotation = 5°
Measurements with DFS receiver and DSNA antenna



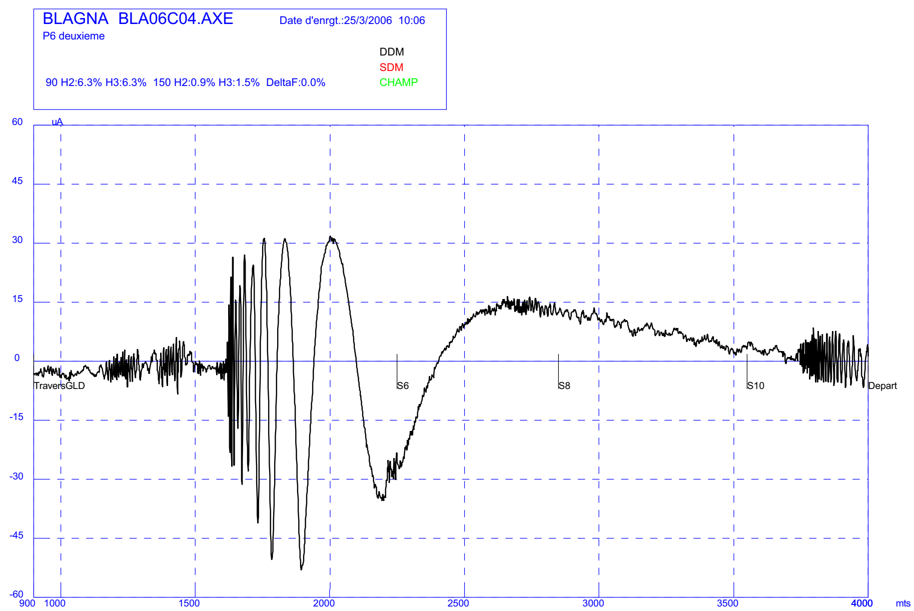
P5: Tail : Forward = 1531m, sideway = 198m, rotation = 0°
Measurements with DFS receiver and DSNA antenna



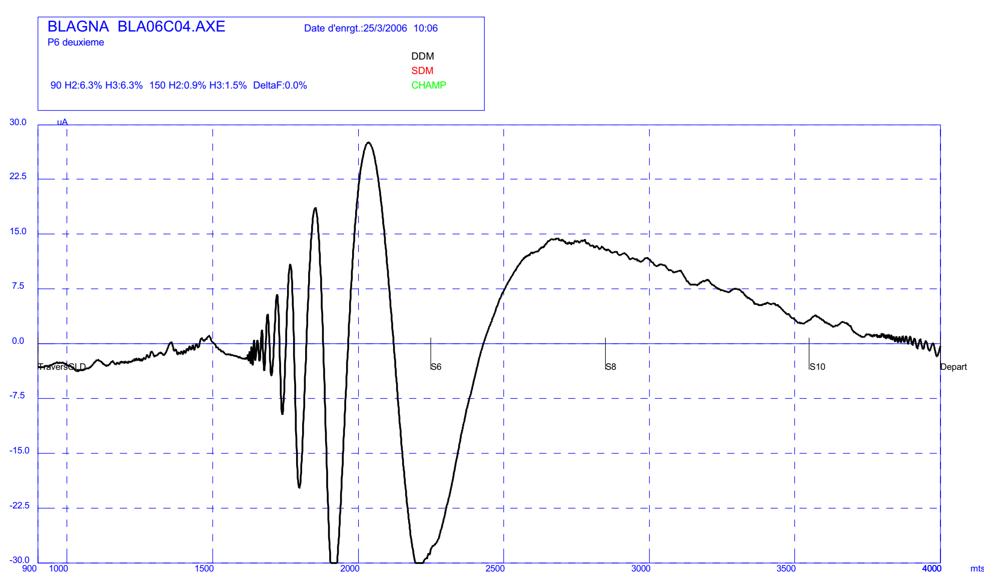
P6: Tail: Forward = 1579m, sideway = 57m, rotation = 90°
Measurements with DFS receiver and DSNA antenna



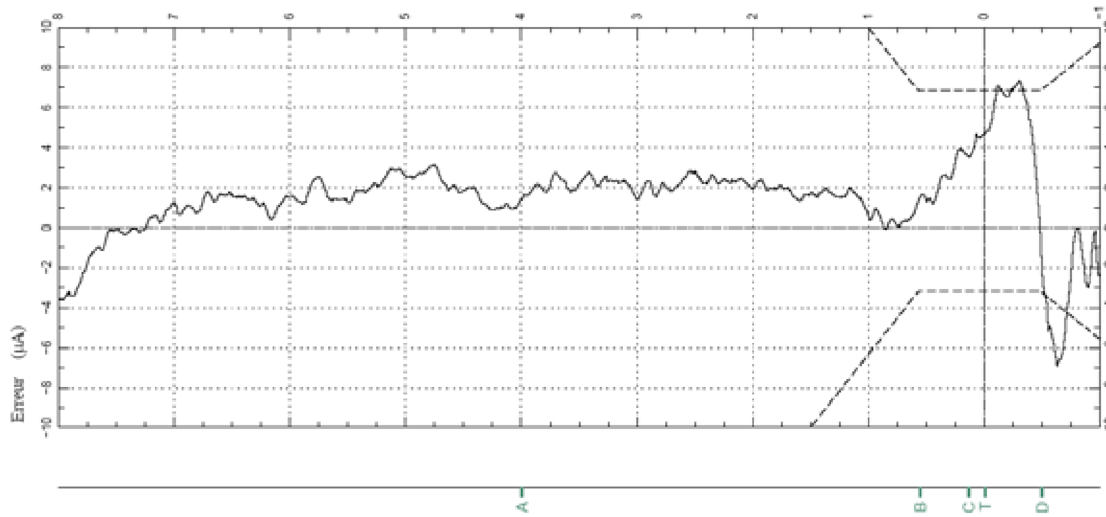
Measurements with DSNA receiver antenna



Raw data

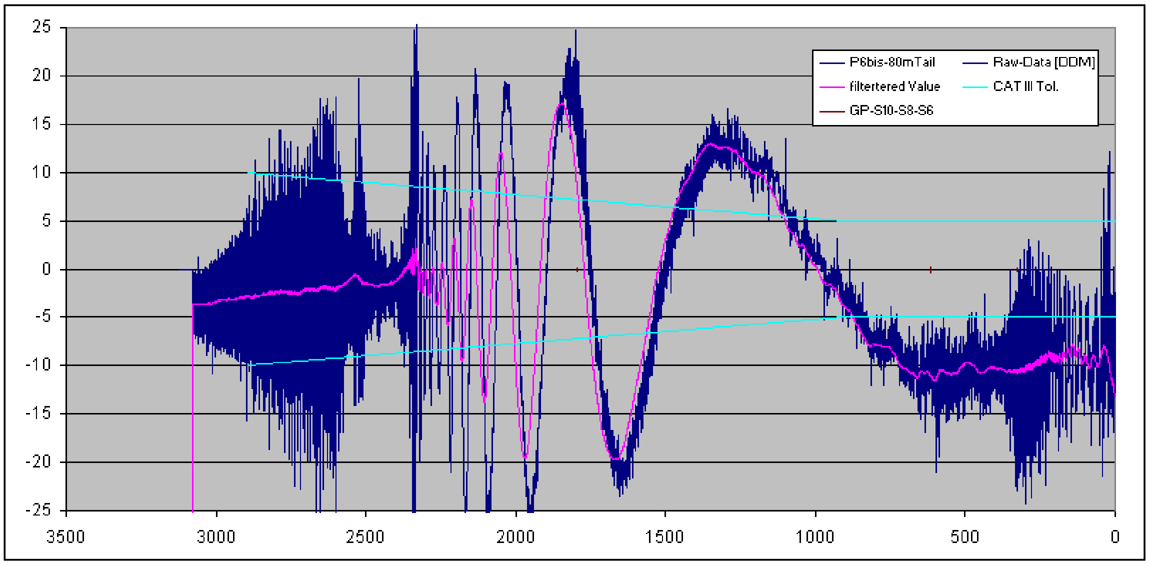


Filtered data

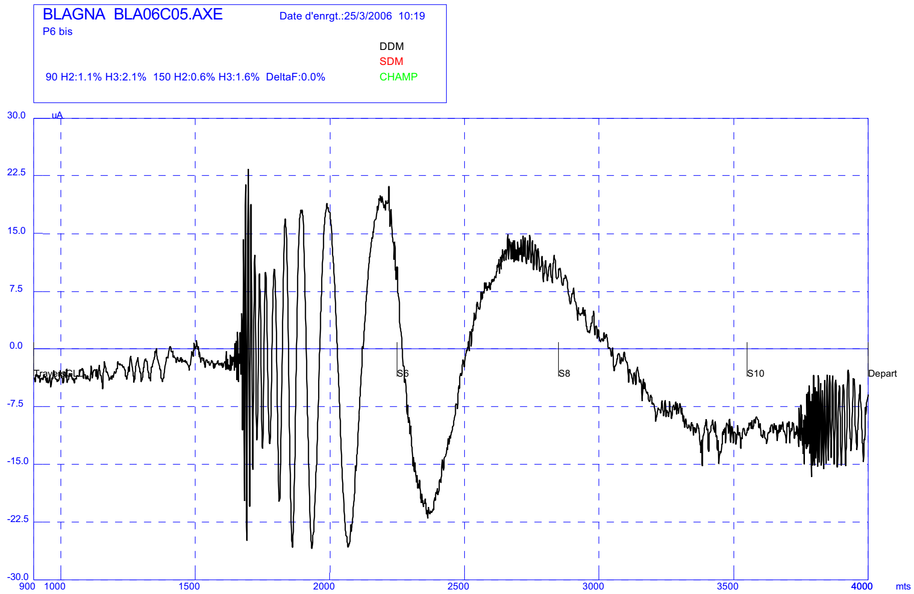


DSNA flight check data

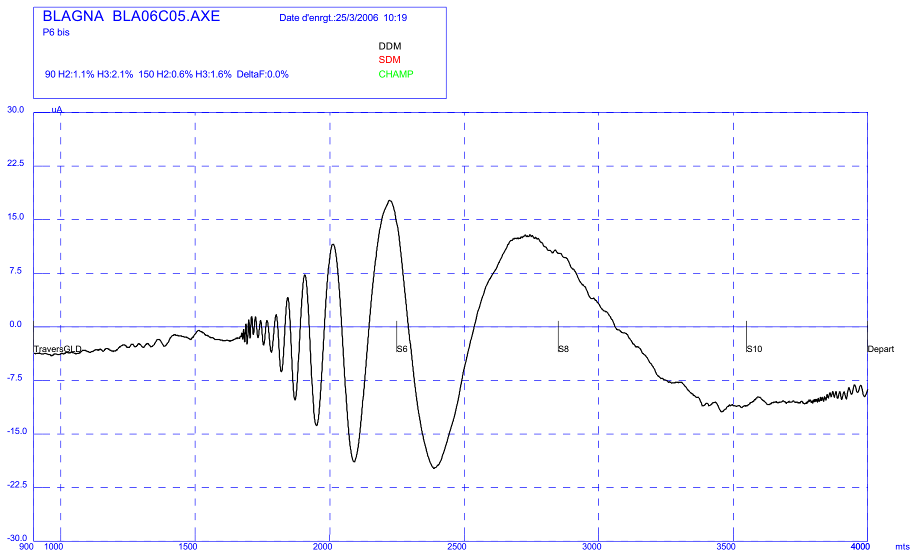
P6 bis: Tail: Forward = 1579m, sideway = 83m, rotation = 90°
Measurements with DFS receiver and DSNA antenna



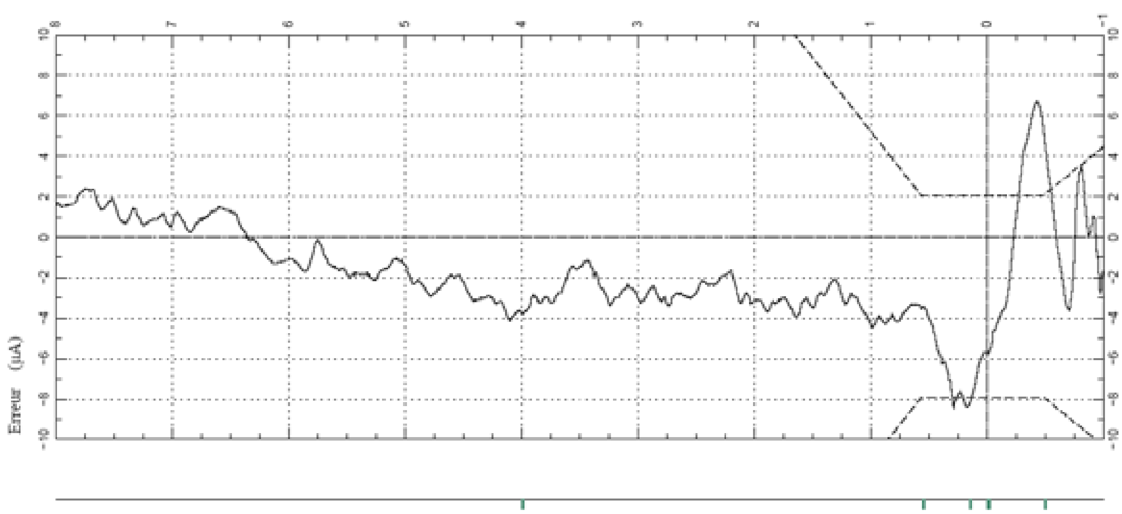
Measurements with DSNA receiver antenna



Raw data

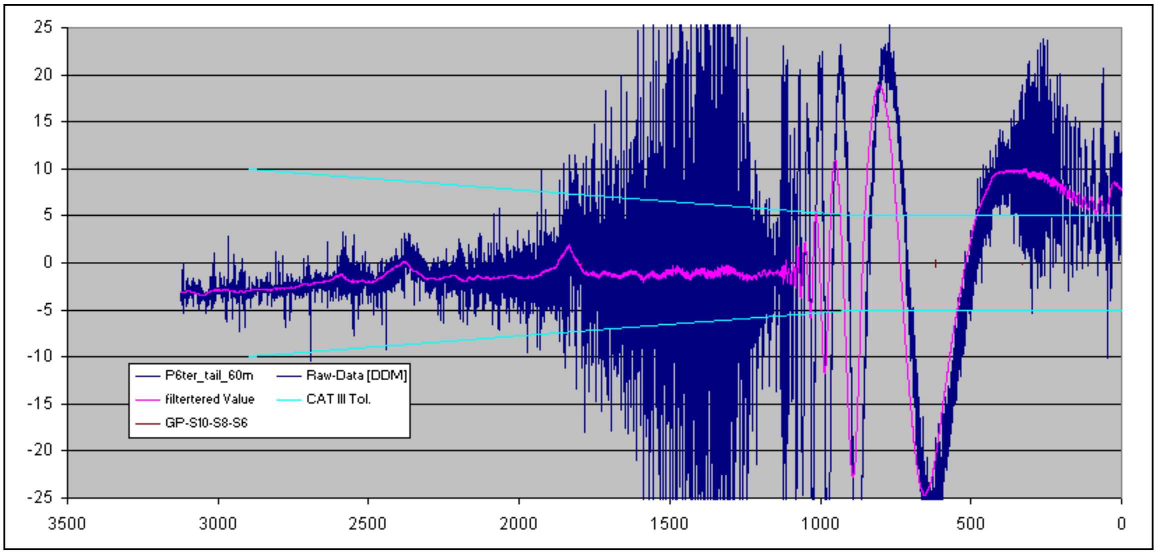


Filtered data

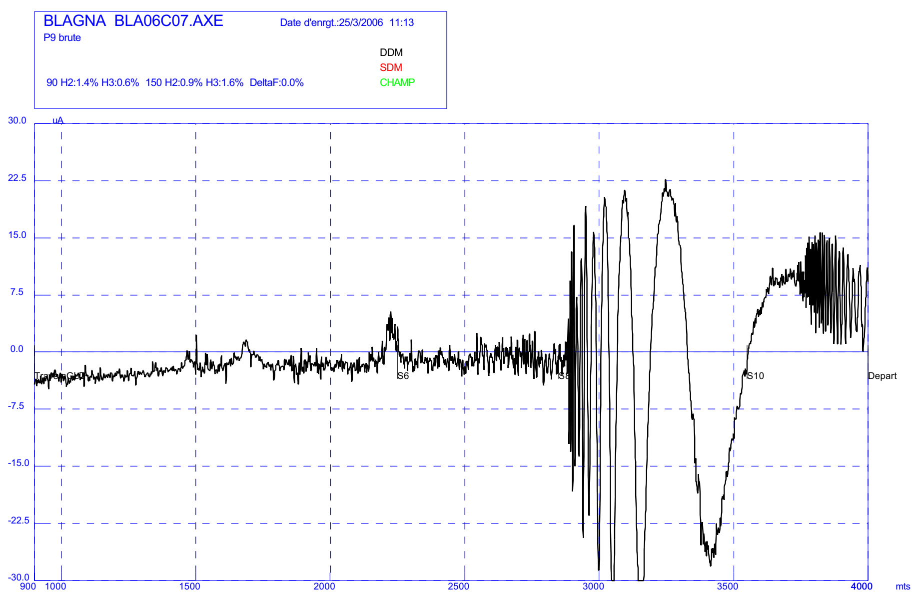


DSNA flight check data

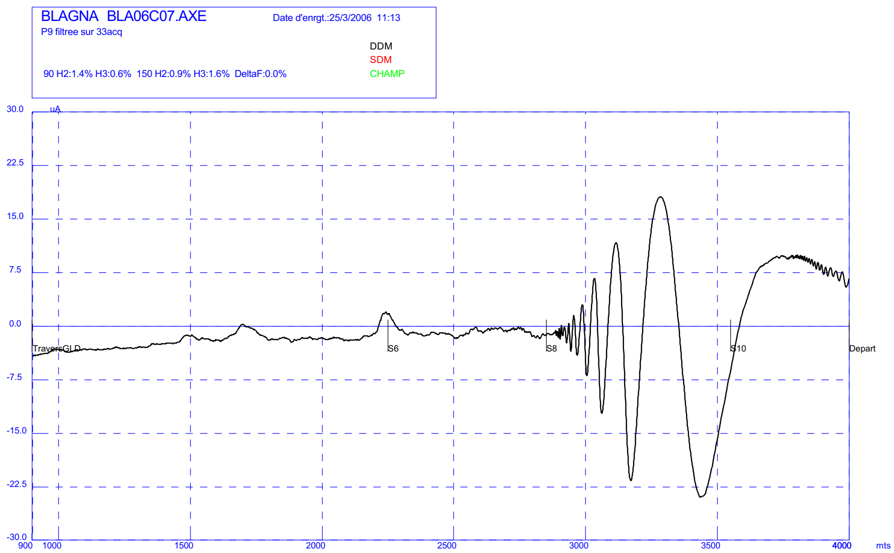
P6 ter: Tail: Forward = 2909m, sideway = 56m, rotation = 90°
Measurements with DFS receiver and DSNA antenna



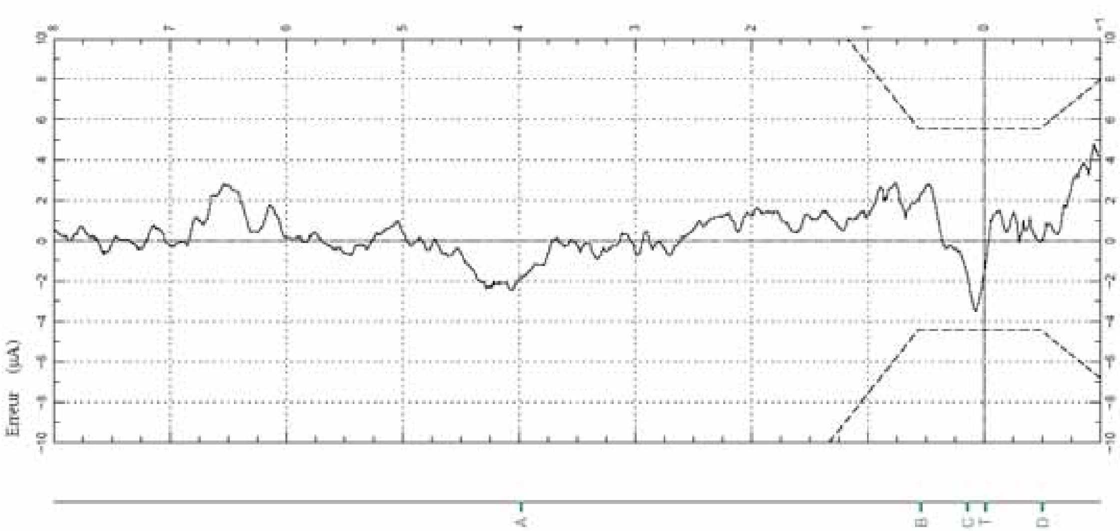
Measurements with DNSA receiver antenna



Raw data

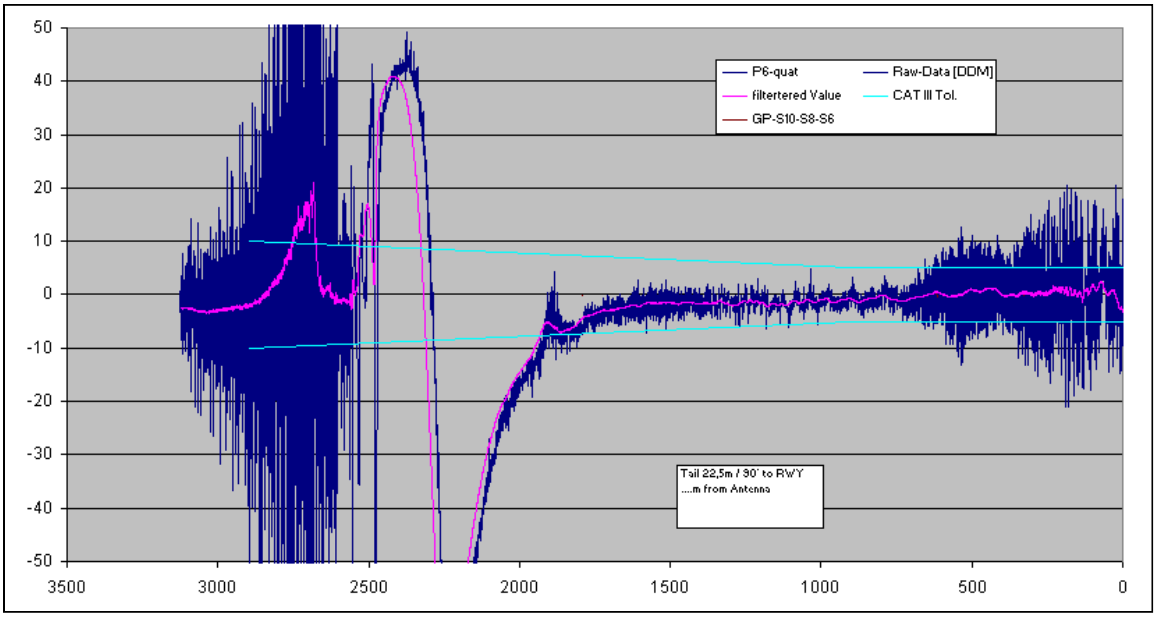


Filtered data

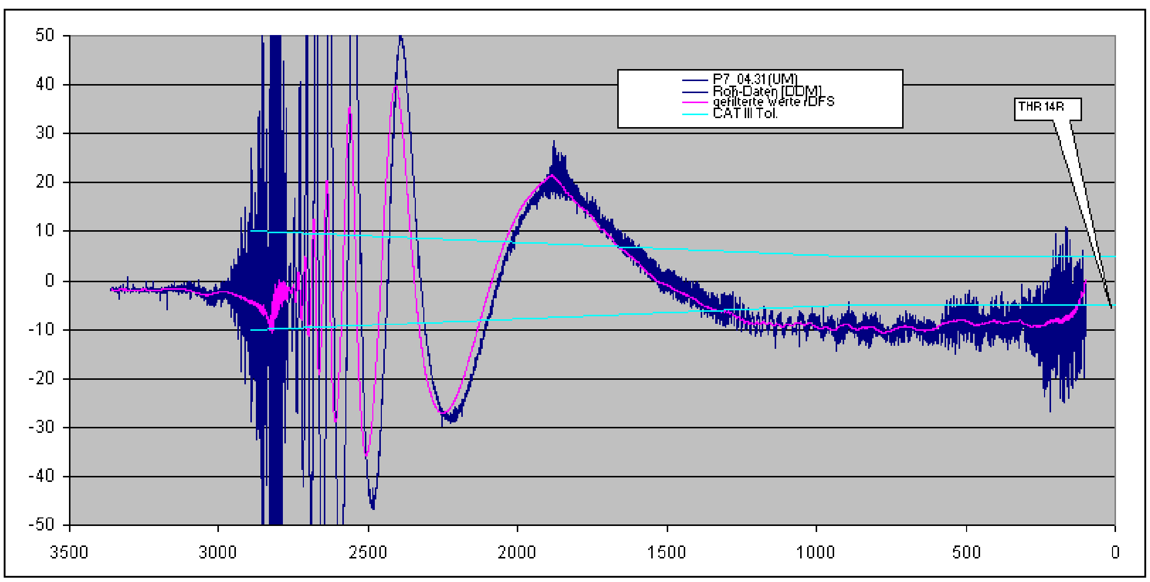


DSNA flight check data

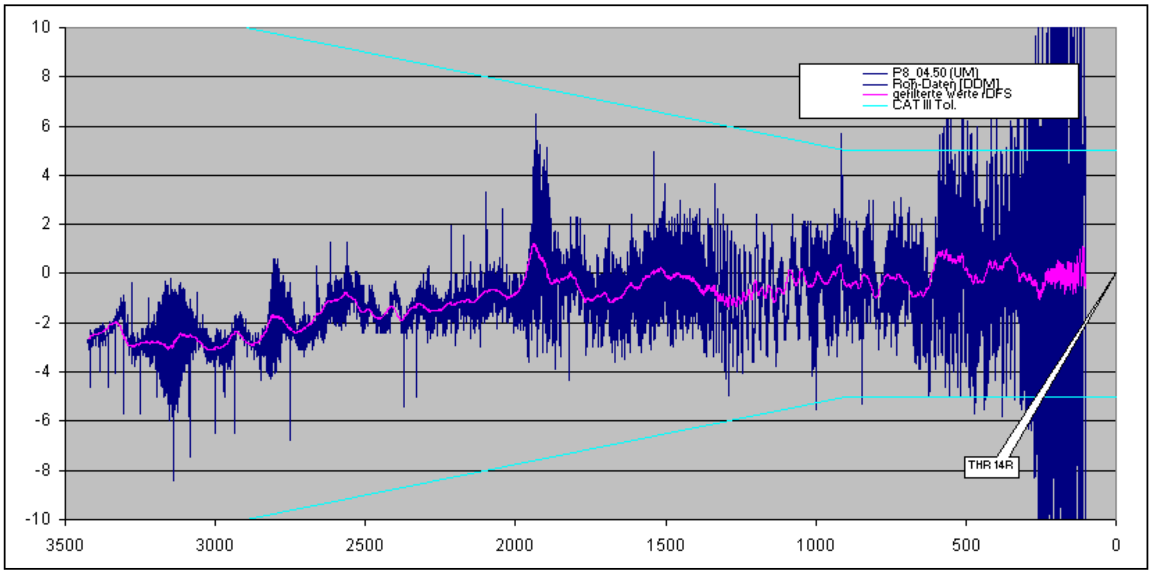
P6 quad: Tail: Forward = 1579m, sideway = 21m, rotation = 90°
Measurements with DFS receiver and DSNA antenna



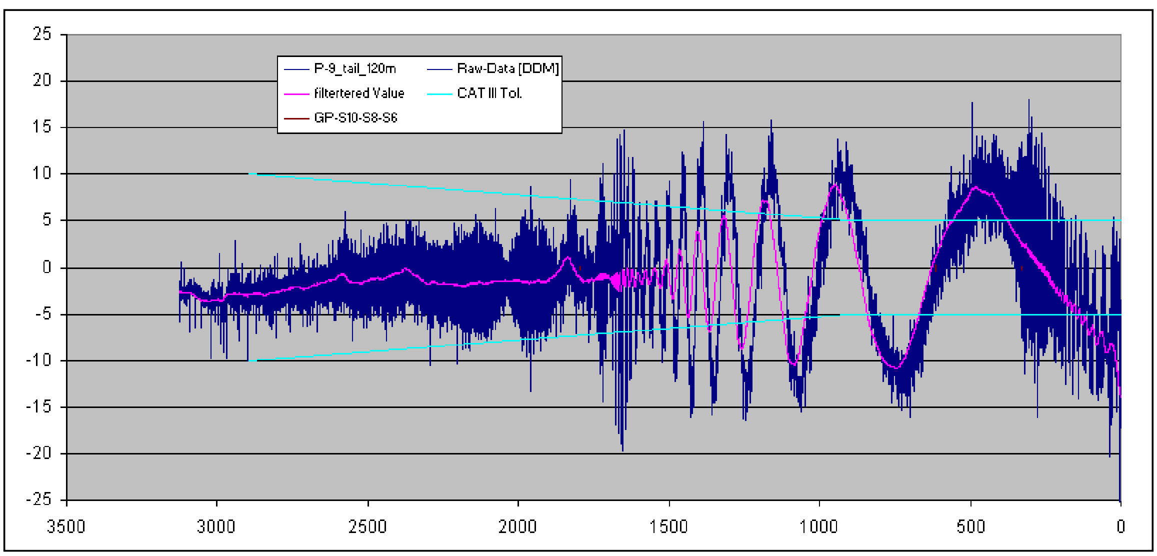
P7: Tail: Forward = 1313m, sideway = -69m, rotation = 42°
Measurements with DFS receiver and DSNA antenna



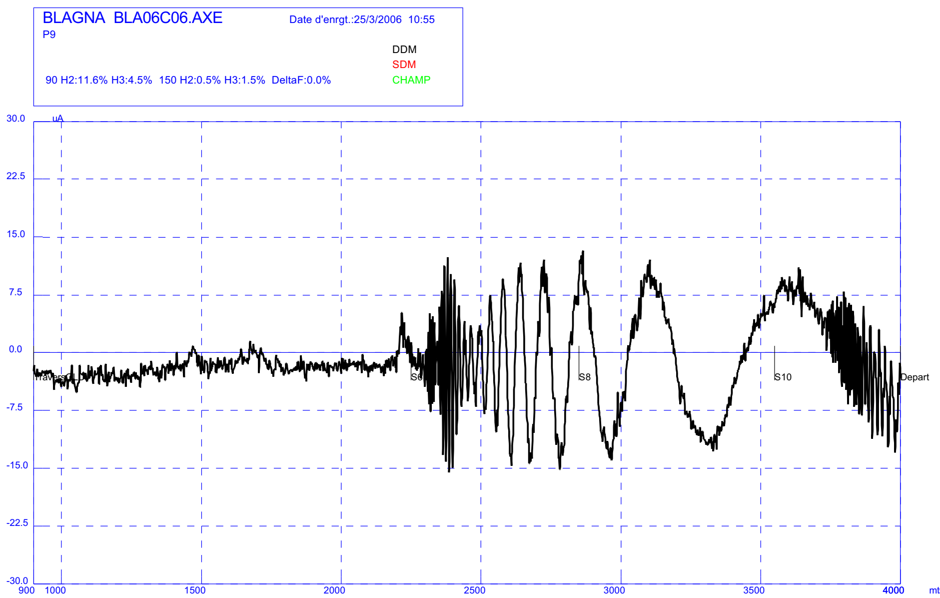
P8: Tail: Forward = 1247m, sideway = -173m, rotation = 60°
Measurements with DFS receiver and DSNA antenna



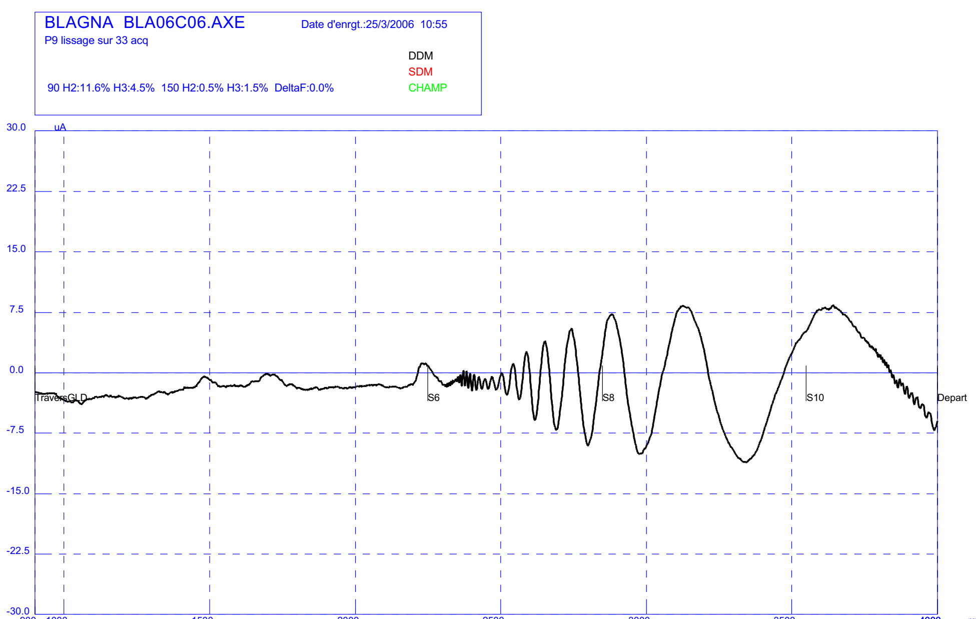
P9: Tail: Forward = 2267m, sideway = 116m, rotation = 90°
Measurements with DFS receiver and DSNA antenna



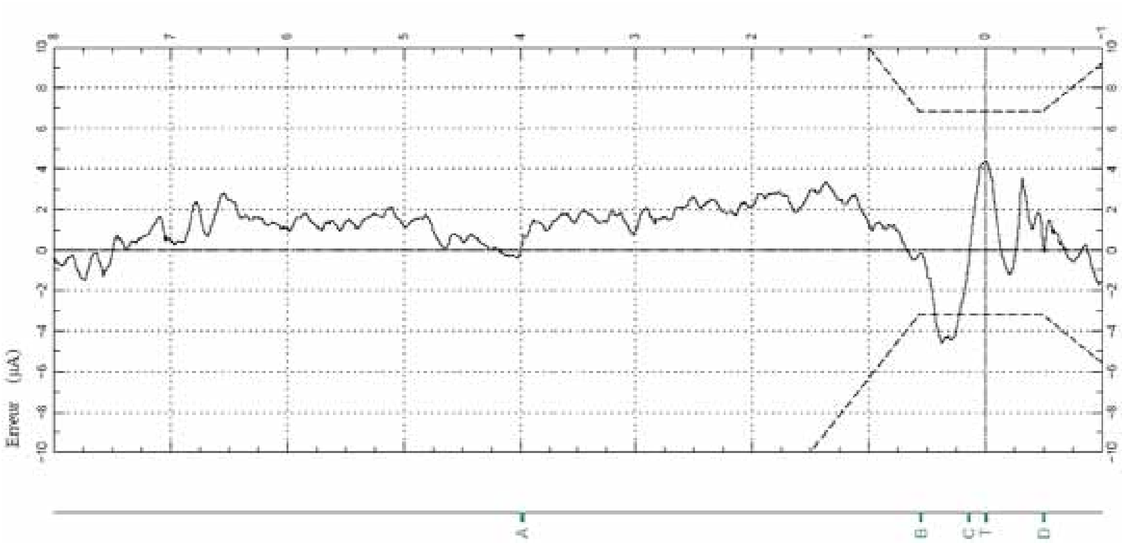
Measurements with DNSA receiver antenna :



Raw data

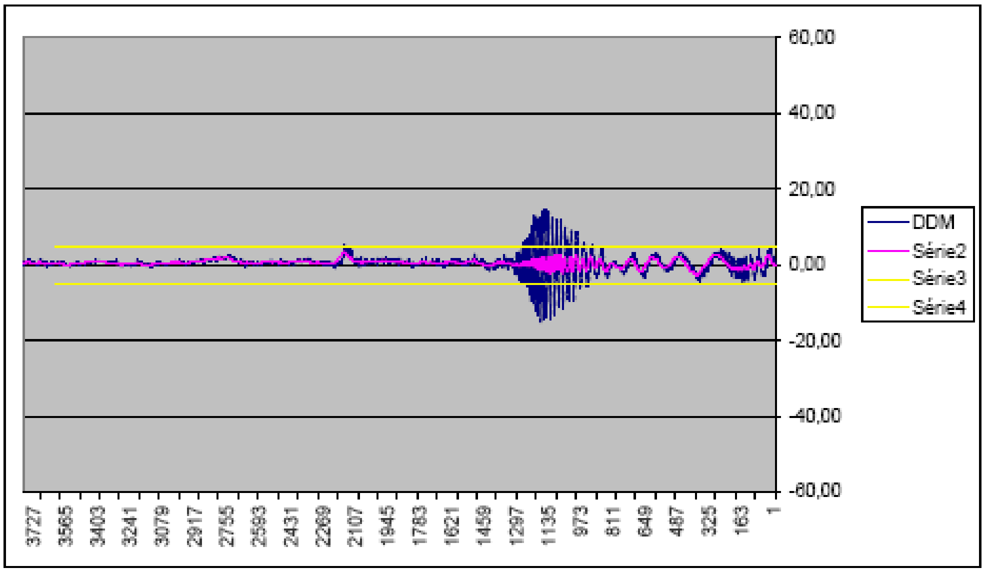


Filtered data

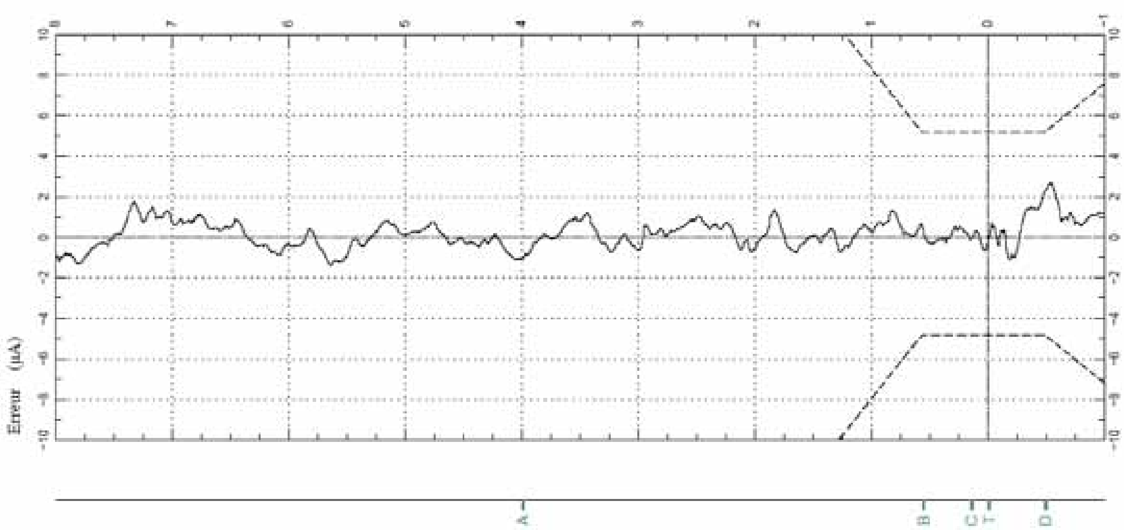


<u>**DSNA flight check data**</u>

P11: Tail: Forward = 2870m, sideway = 156m, rotation = 0°
Measurements with SNA/Sud receiver antenna :

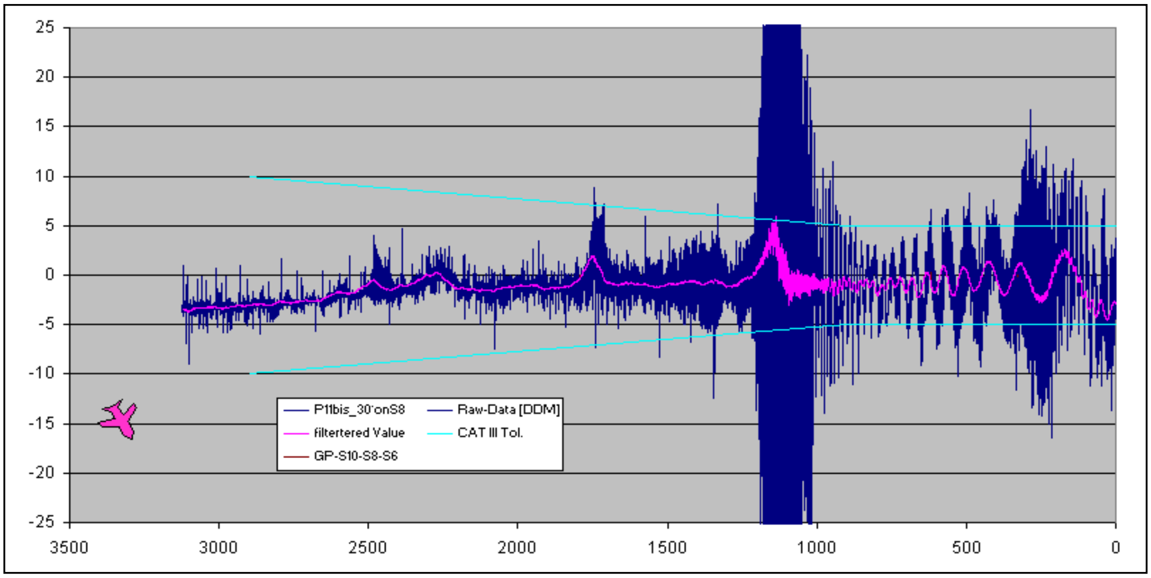


SNA/SUD maintenance vehicle results

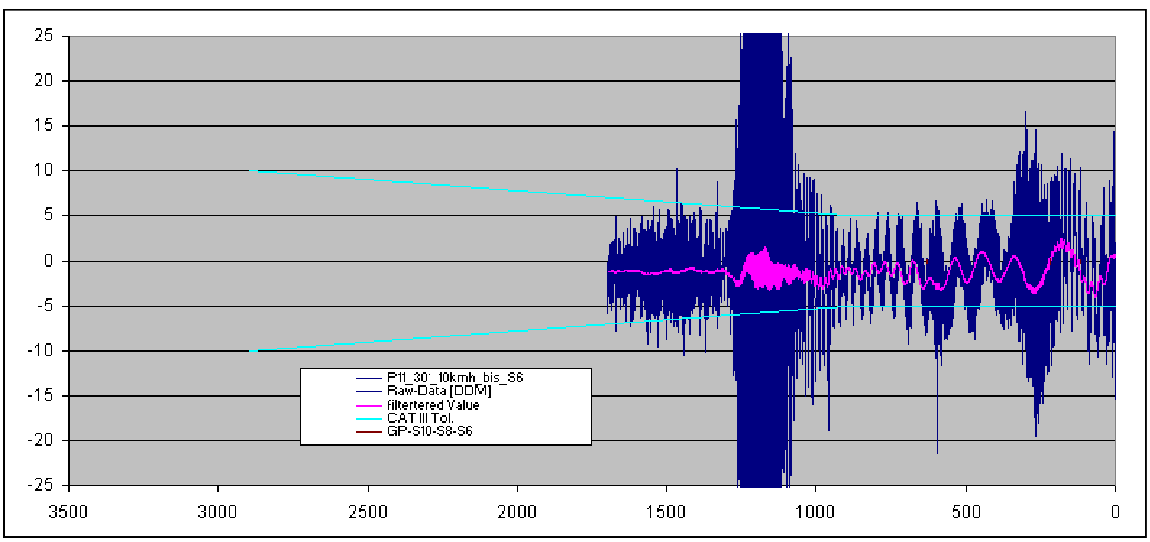


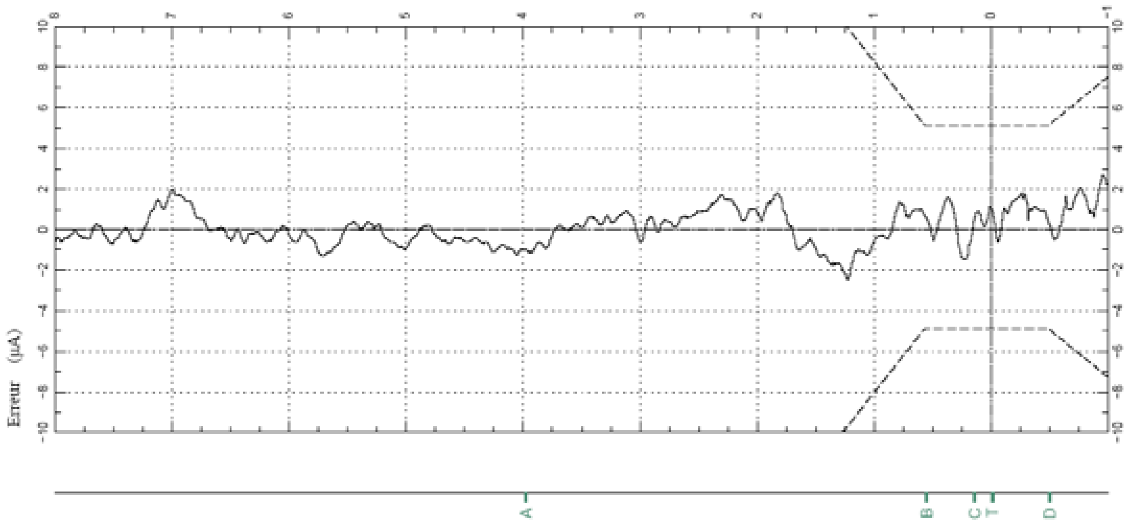
DSNA Flight check data

P11 bis at 40 km/h: Tail: Forward = 2860m, sideway = 178m, rotation = -30°
Measurements with DFS receiver and DSNA antenna :



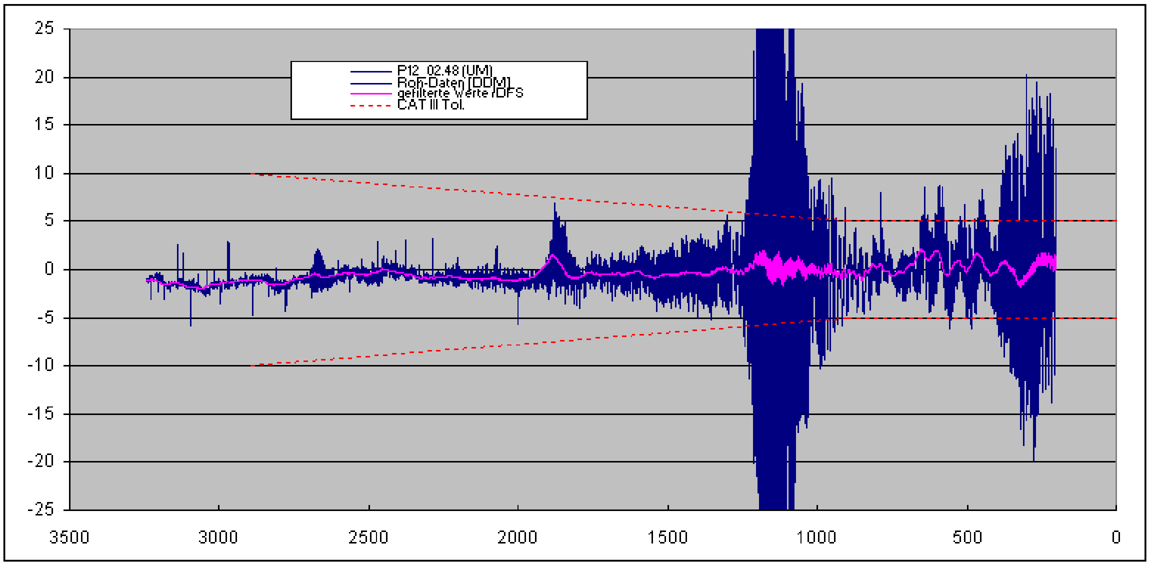
P11 bis at 13 km/h: Tail: Forward = 2860m, sideway = 178m, rotation = -30°
Measurements with DFS receiver and DSNA antenna:



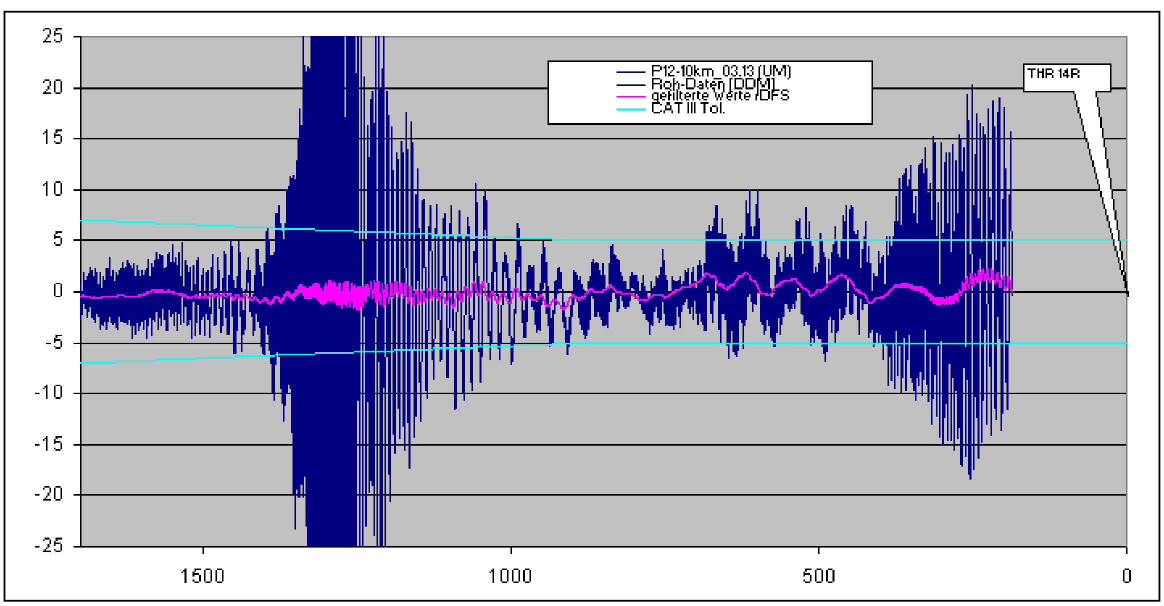


DSNA Flight check data

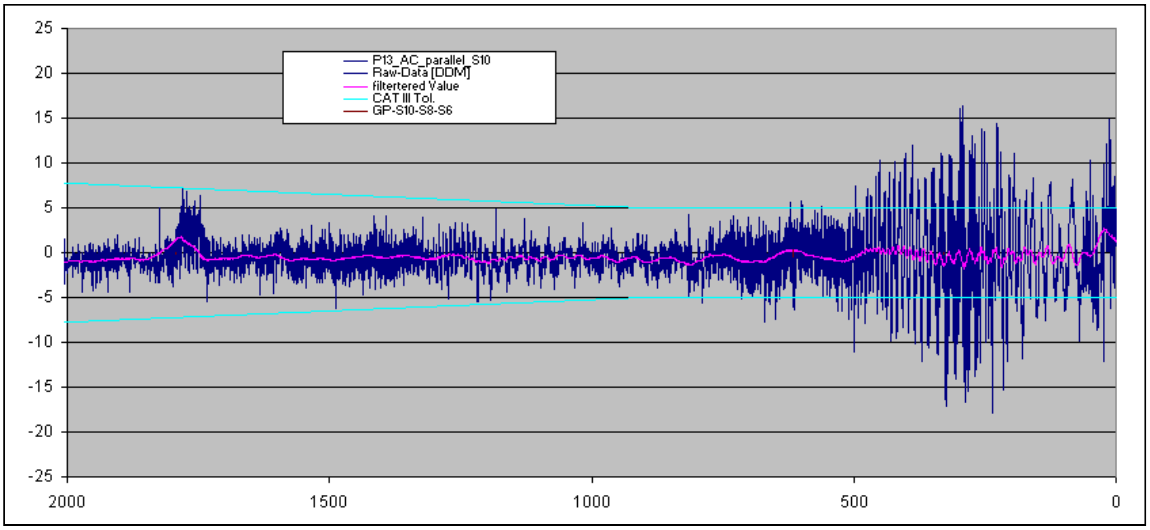
P12 at 40 km/h: Tail: Forward = 2890m, sideway = 178m, rotation = -30°
Measurements with DFS receiver and DSNA antenna:

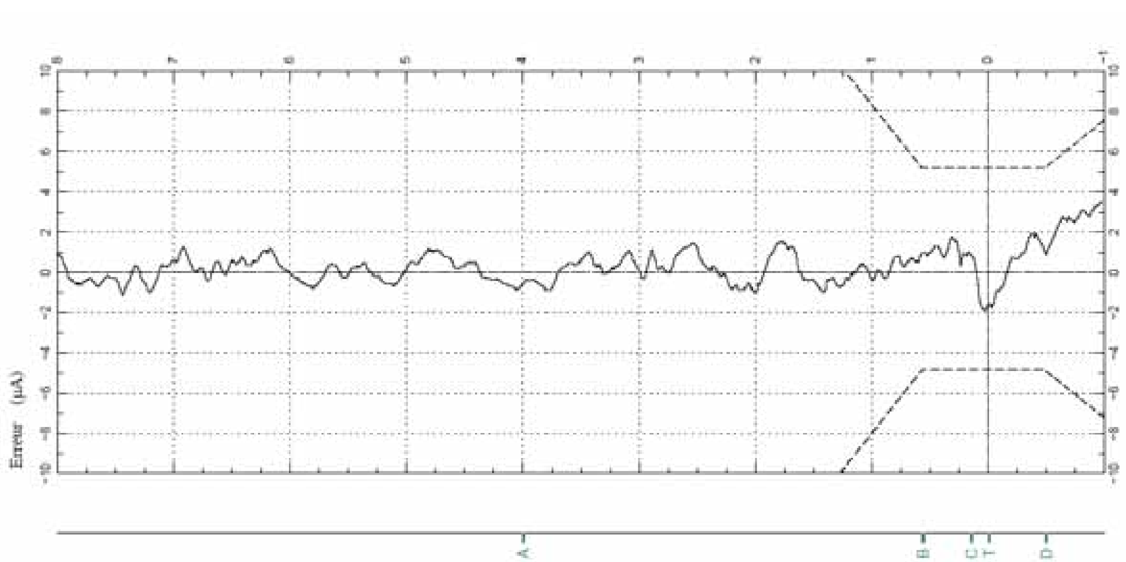


P12 at 10 km/h: Tail: Forward = 2890m, sideway = 178m, rotation = -30°
Measurements with DFS receiver antenna :



P13: Tail: Forward = 3426m, sideway = 196m, rotation = 0°
Measurements with DFS receiver and DSNA antenna:

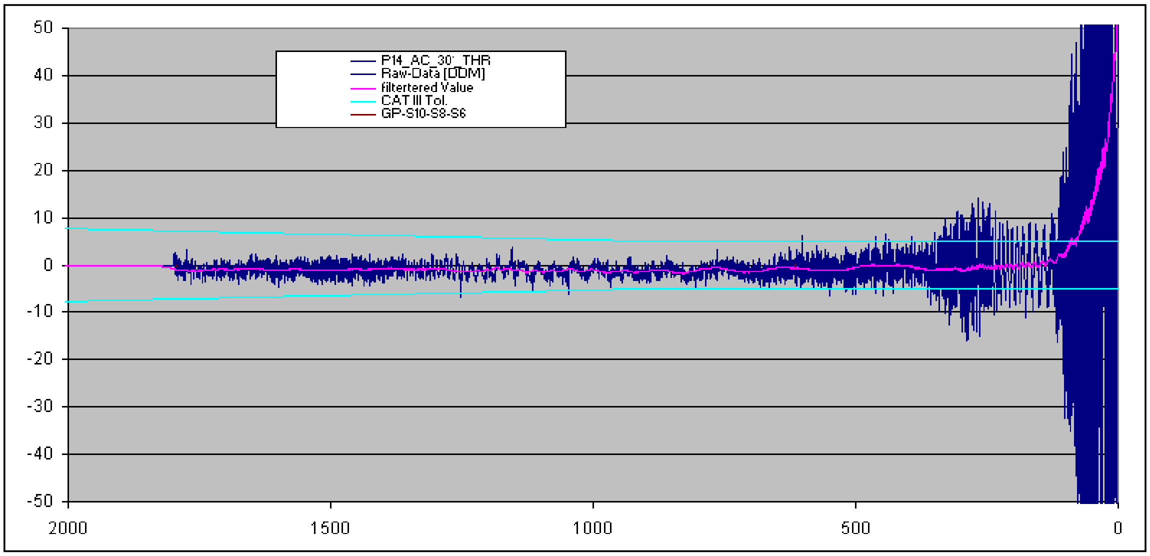


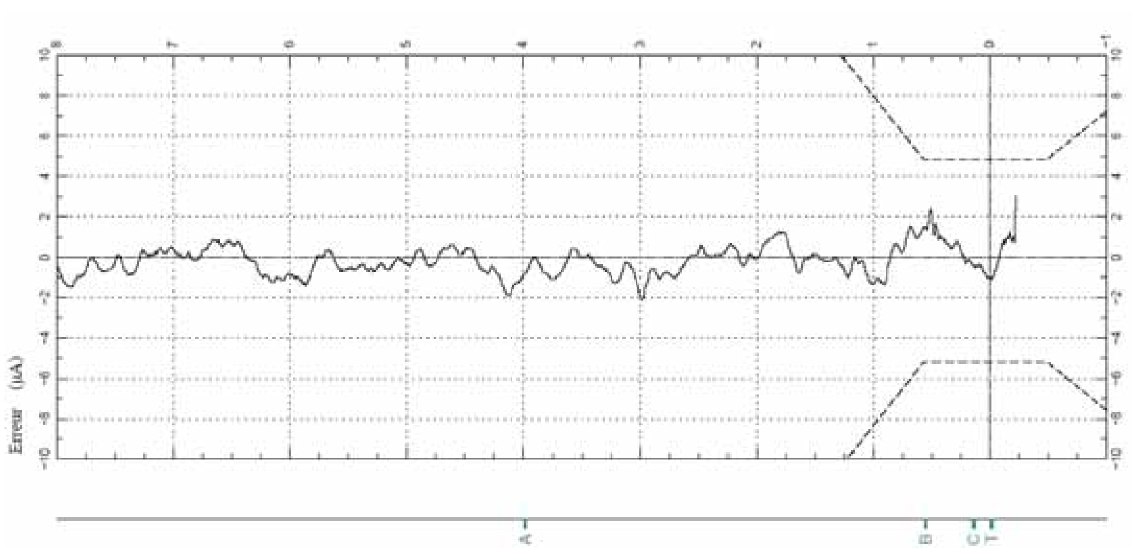


<u>**DSNA flight check data**</u>

P14: Tail: Forward = 4013m, sideway = 194m, rotation = -30°

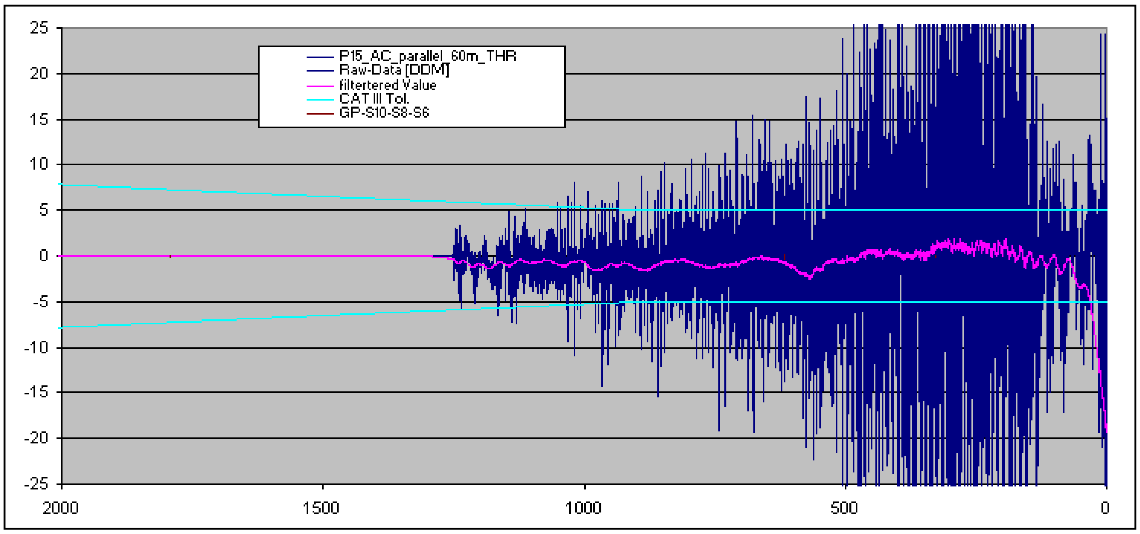
Measurements with DFS receiver and DSNA antenna:

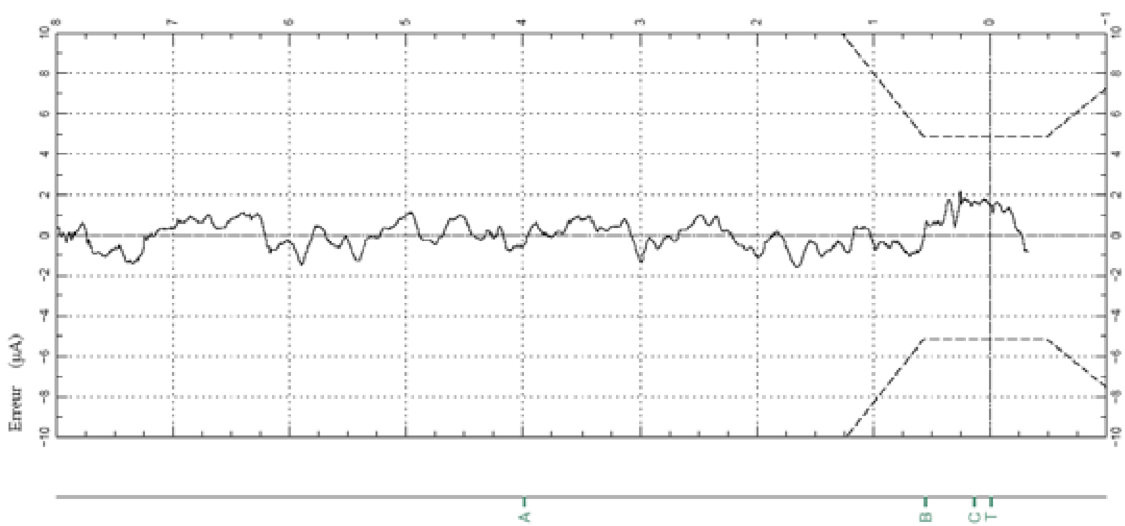




<u>**DSNA flight check data**</u>

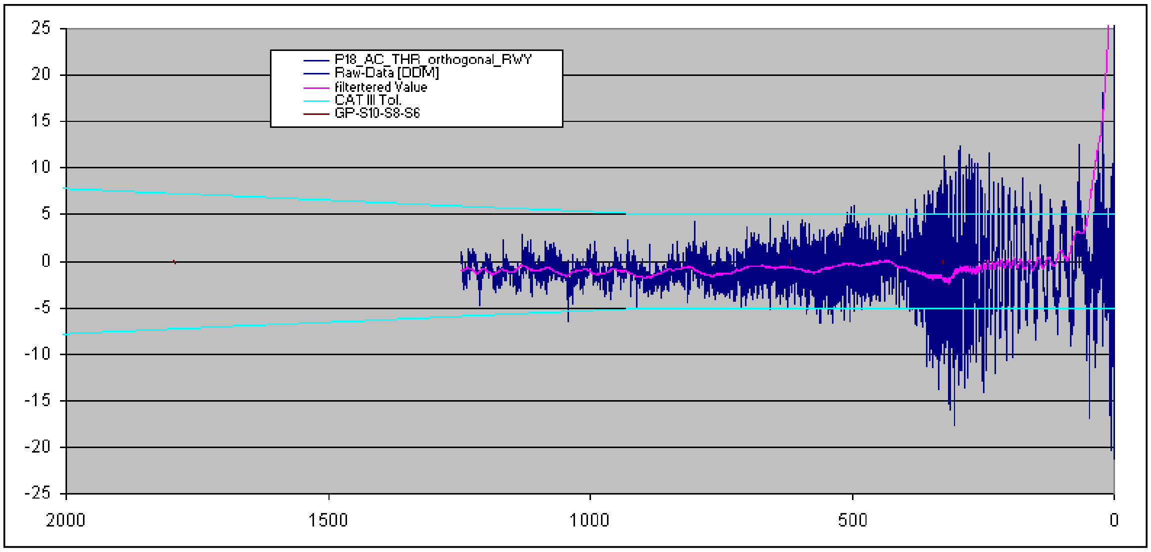
P15: Tail: Forward = 4068m, sideway = 51m, rotation = 90°
Measurements with DFS receiver antenna :





<u>**DSNA flight check data**</u>

P18: Tail: Forward = 4068m, sideway = 51m, rotation = 90°
Measurements with DFS receiver antenna :



ANNEX H : Heathrow ILS 27L Characteristics and test set-up

Measurement Equipment

Flight Precision Limited - Teesside, England

- Beech King Air 200 Flight Inspection Aircraft

Actual Aircraft used for A380 measurements was G-FPLB

- ILS Receiver Type RNA 34AF (Flight Inspection Receiver)
- Antenna type Chelton A39H-3AD (Stags Head), Localiser Top Antenna.
- Aerodata Flight Inspection System (FIS)
- Laser Tracker, GPS and Inertial reference systems

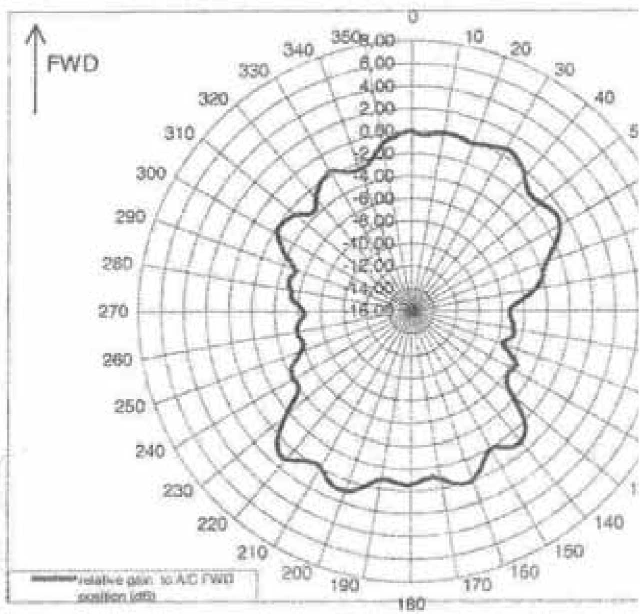
Antenna and Aircraft calibrated and software compensated to give an omni-directional receiving pattern. See Polar Diagram of Antenna below.

All approaches were from 5NM to Land and Roll Out to assess Cat III b tolerances along the runway. As the aircraft passed the laser tracker (positioned at the Glide Path site) for the roll out portion of the flight, inertial referencing was relied upon along the runway. Because of this, some of the results show a structure veering off from centreline. This should be ignored.

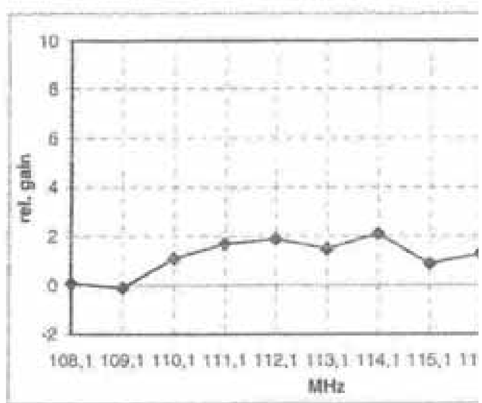
Bearing (Angle betw. A/C FWD position and TX)	relative gain to A/C FWD position (dB)	softw. corr. value related to bea-ring
0	0,00	0,00
10	0,08	0,08
20	-0,15	-0,15
30	0,58	0,58
40	-0,53	-0,53
50	-1,20	-1,20
60	-0,93	-0,93
70	-3,30	-3,30
80	-4,85	-4,85
90	-7,28	-7,28
100	-6,88	-6,88
110	-7,40	-7,40
120	-5,63	-5,63
130	-4,35	-4,35
140	-0,85	-0,85
150	-1,90	-1,90
160	-0,07	-0,07
170	-0,95	-0,95
180	-0,63	-0,63
190	-0,88	-0,88
200	1,00	1,00
210	-0,08	-0,08
220	1,03	1,03
230	-1,70	-1,70
240	-4,00	-4,00
250	-5,65	-5,65
260	-5,72	-5,72
270	-6,50	-6,50
280	-5,22	-5,22
290	-5,10	-5,10
300	-2,43	-2,43
310	-2,65	-2,65
320	-2,90	-2,90
330	-1,60	-1,60
340	-2,52	-2,52
350	-0,85	-0,85

LLZ Top

Antenna type:	Chelton A39H-3AD	A/C type:	B200
Antenna position:	top	A/C call sign:	G-FPLB
Ant. height above GND:	3,18 m	Date:	23.02.2004
Polarisation:	horizontal	Cal. location:	THR 26, EDV
Cal. RF freq. (Pattern):	108,5 MHz		



Freq. in MHz	overall gain versus freq. (dB)	TX-ant. rel. gain to meas. freq 108.5 MHz. (dB)	cable loss rel. to meas. freq 108.5 MHz. (dB)	RX-ant. rel. gain to meas. freq 108.5 MHz. (dB)	soft-ware corr. value
108,1	-93,8	0	0	0,1	0,1
109,1	-94,0	0	0	-0,1	-0,1
110,1	-92,8	0	0	1,1	1,1
111,1	-92,2	0	0	1,7	1,7
112,1	-92,0	0	0	1,9	1,9
113,1	-92,4	0	0	1,5	1,5
114,1	-91,8	0	0	2,1	2,1
115,1	-93,0	0	0	0,9	0,9
116,1	-92,6	0	0	1,3	1,3
117,1	-91,8	0	0	2,1	2,1
117,9	-92,0	0	0	1,9	1,9



Absolute antenna gain of antenna in FWD direction at 108,5 MHz : -5,62 dBi

Characteristics of Chelton A39H-3AD fitted to Flight Inspection Aircraft G-FPLB used for A380 Trials at London Heathrow Airport

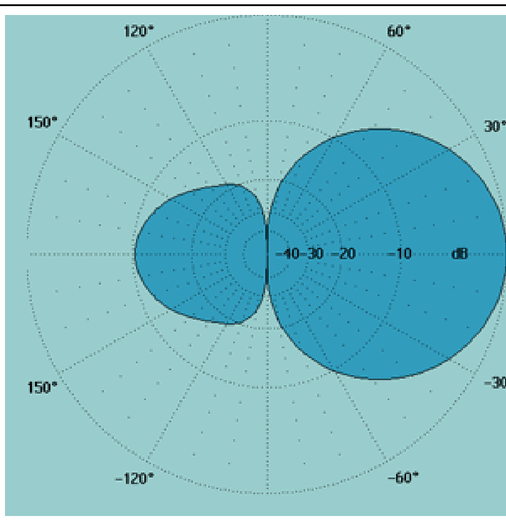
Ground Test Vehicle

Ground test vehicle supplied by ARTUS for the purpose of MLS Ground Testing but also fitted with an ILS capability
.

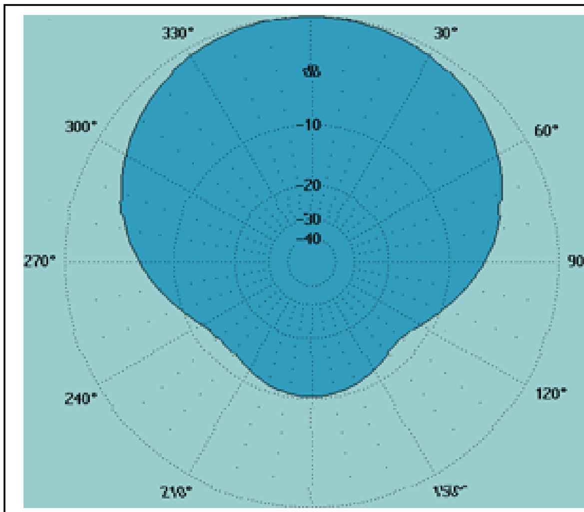
- ILS Field Receiver type ARTUS
  using ICAO Filters
- Antenna type Skymasts S2Y 112
  (see polar diagram below)
- Notebook PC for recording and
  analysing data
- Vehicle Speed 40 mph (65 km/hr)

ILS/MLS Test Vehicle

Yagi Antenna Polar Diagrams supplied by Skymasts



S2Y e field



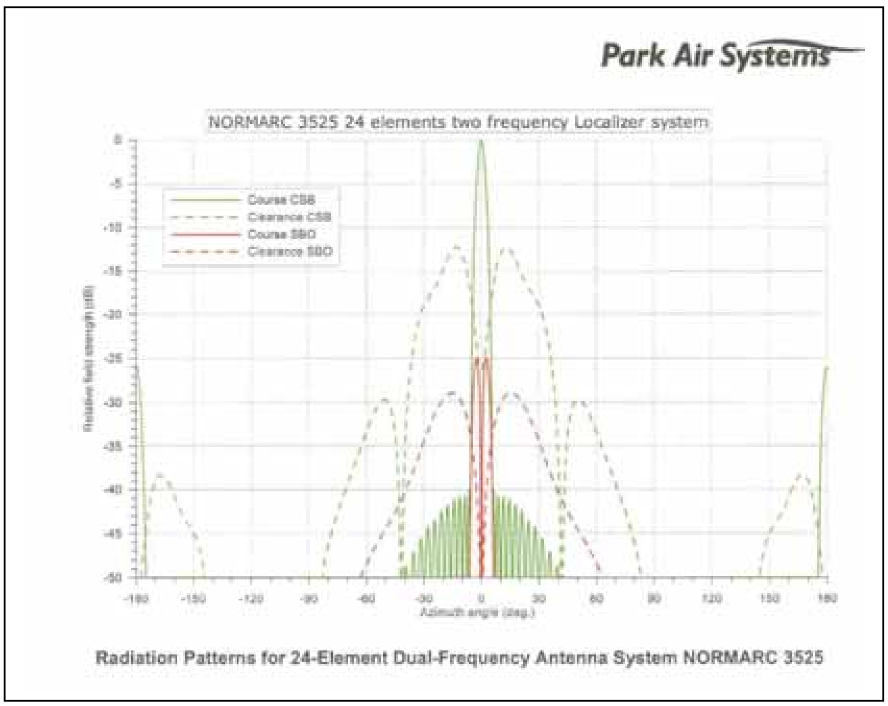
S2Y h field

ILS system (Localiser), Heathrow Runway 27L

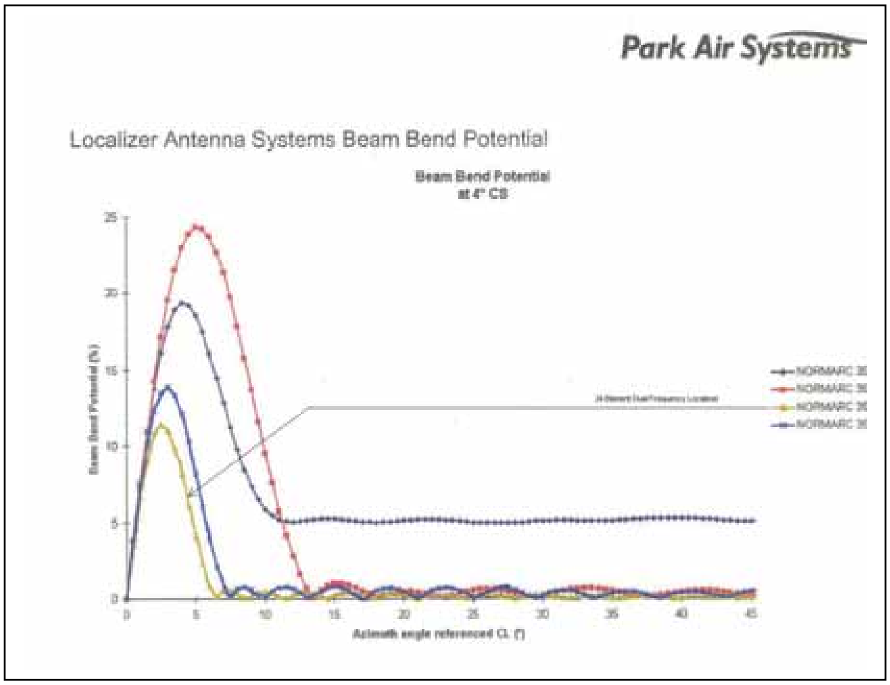
Park Air Systems 7000A, 24 element (8 element clearance) Log Periodic Dipole Array

- 24/8 element (8 element clearance) Log Periodic Dipole Array
- Width adjusted to 3.04°, frequency is 109.5 MHz
- Runway Length is 3657m and distance from Localiser to Threshold is 3953m

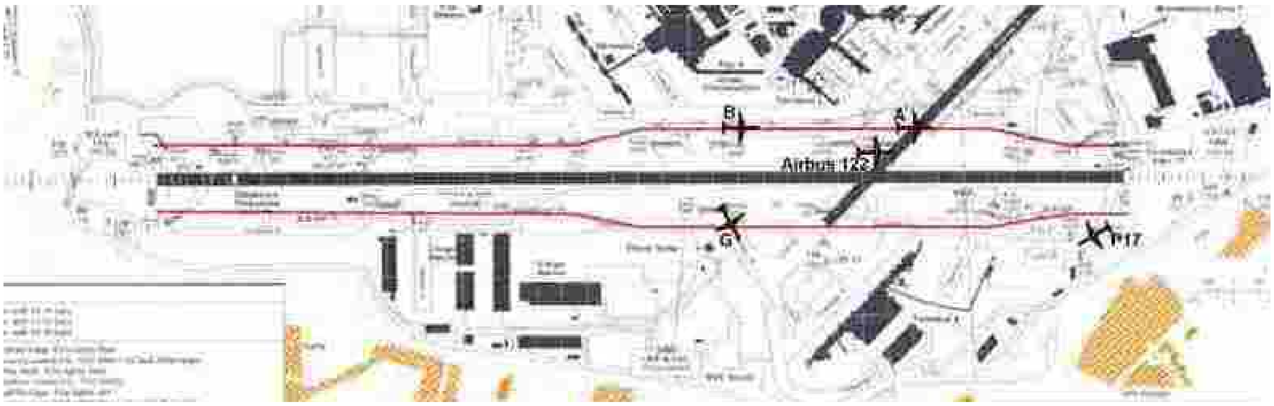
Park Air System, 24 antenna array - localiser CSB - SBO patterns of the course and clearance



Park Air System, 24 antenna array - localiser
Beam Bend Potential

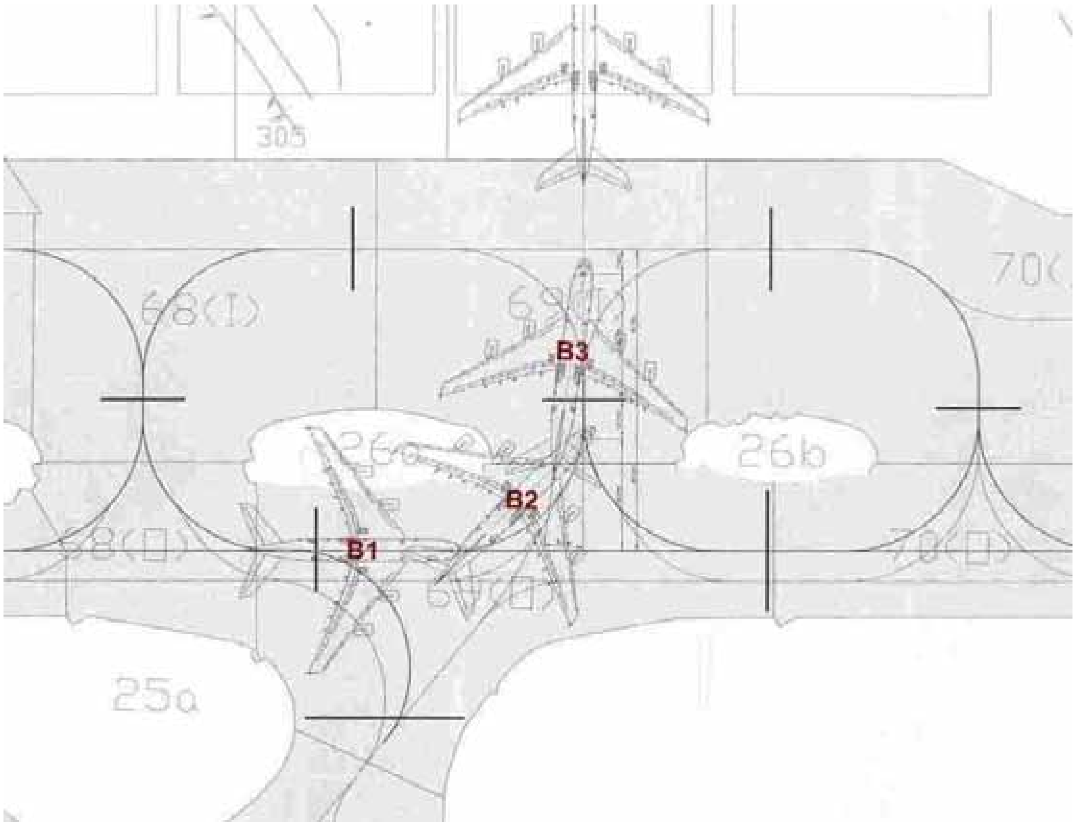


ANNEX I : Heathrow campaign results with A380

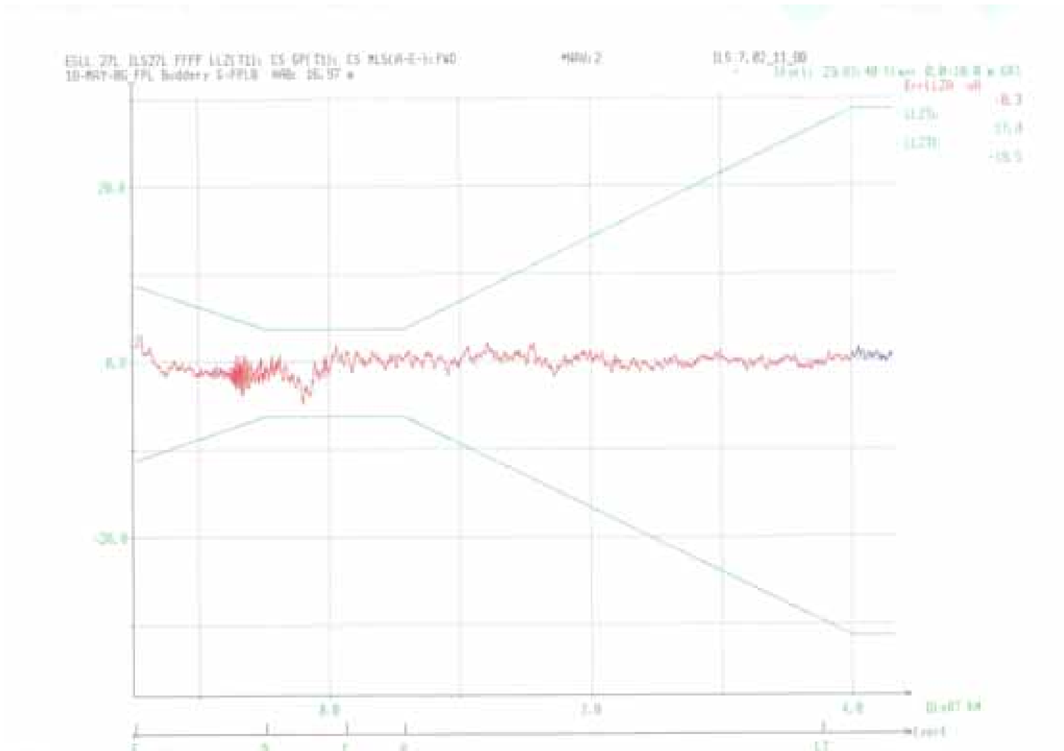


Actual Positions Tested with Flight and Ground Inspection Measurements Produced

B1, B2, Airbus122, A1, A2, P17 and G with an additional G+20m position

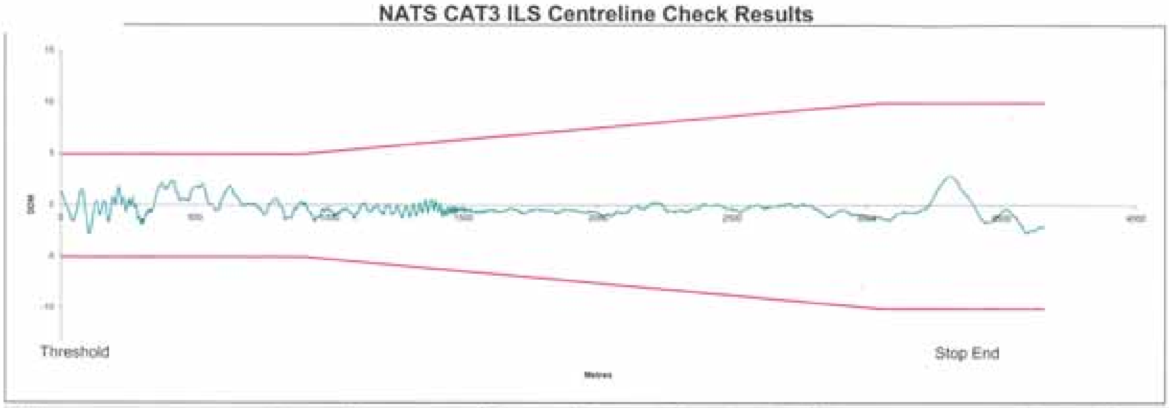


Positions B1, B2 and B3



Actual Flight Inspection Structure Plot for 27L Localiser with A380 at Position B1

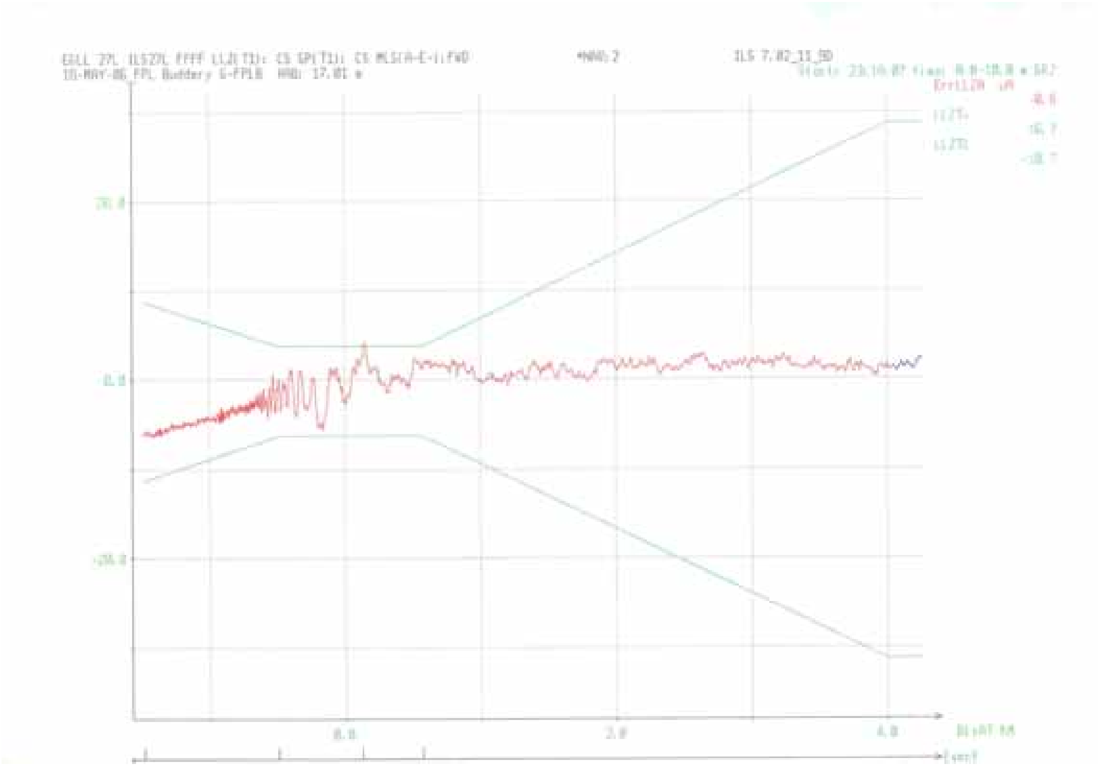
NATS CAT3 ILS Centreline Check Results



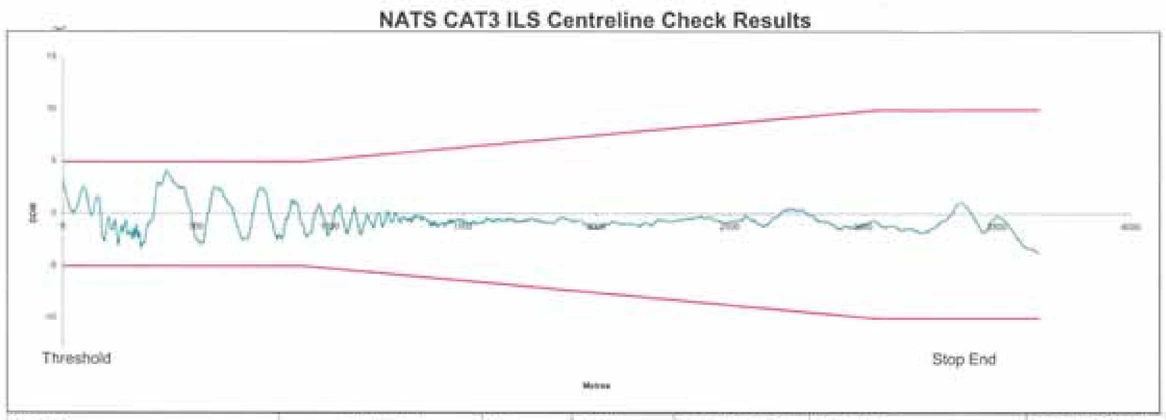
Station	Runway	Tx	Ident	Completed By	Signature	Date of Check
HEATHROW	27L	TX2	ILL	KJM		19-May-06

	Value	Tolerance	Result
Threshold to Point D			
Mean Alignment	0.2 uA 150Hz		
Bend Amplitude	-2.7 uA at 104m	'+/- 5 uA	Pass
Point D to Point E			
Max Bend Amplitude	-1.5 uA at 944m	Linear increase +/-5 @Pt d to +/-10 @ Pt E	Pass
Max % of Tol Bend Amp	-1.5 uA at 944m		Pass
Point D to Stop End			
Max Bend Amplitude	2.9 uA at 3303m	'+/-10 uA	Pass

Ground Inspection Plot for 27L Localiser with A380 at Position B1



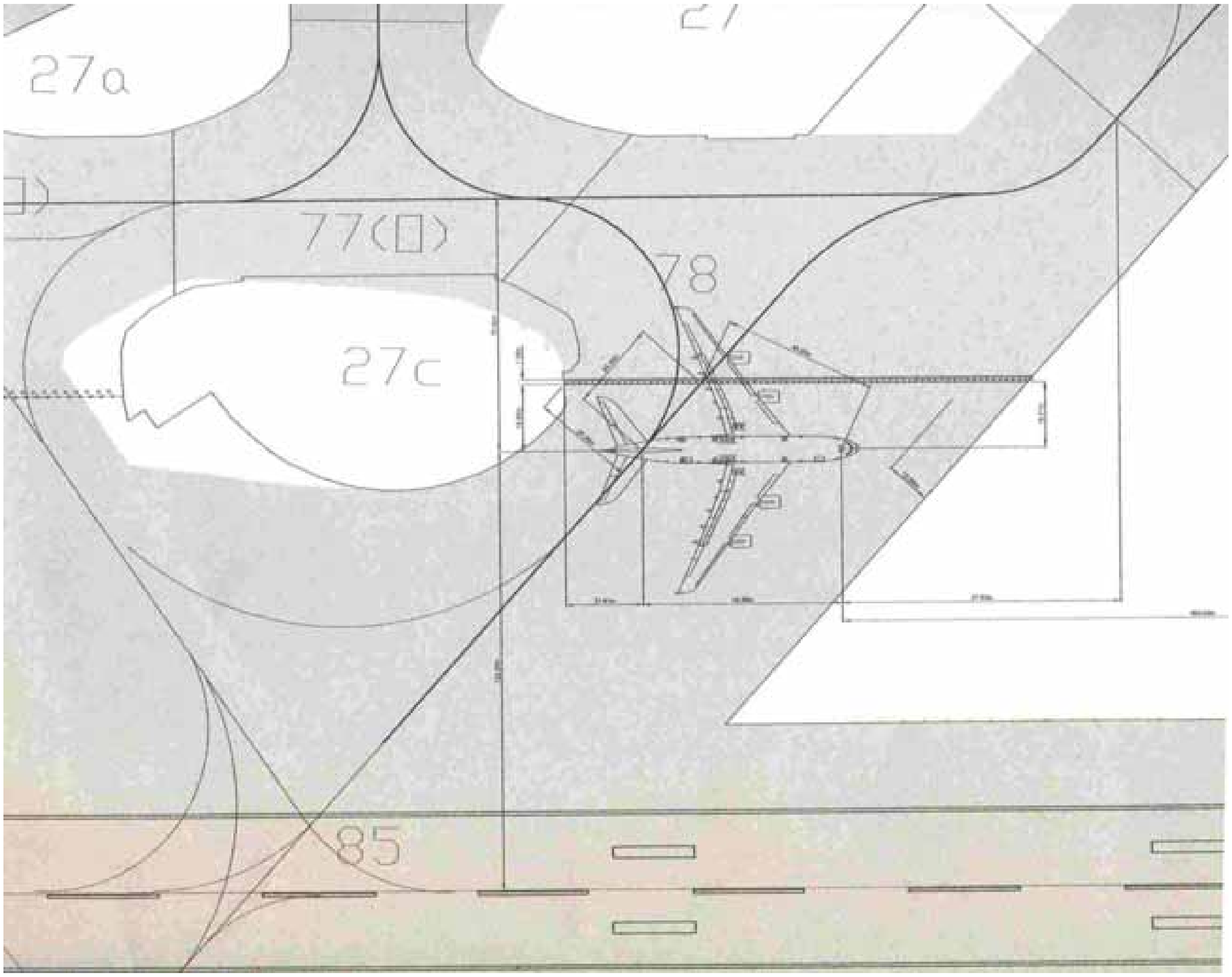
Actual Flight Inspection Structure Plot for 27L Localiser with A380 at Position B2



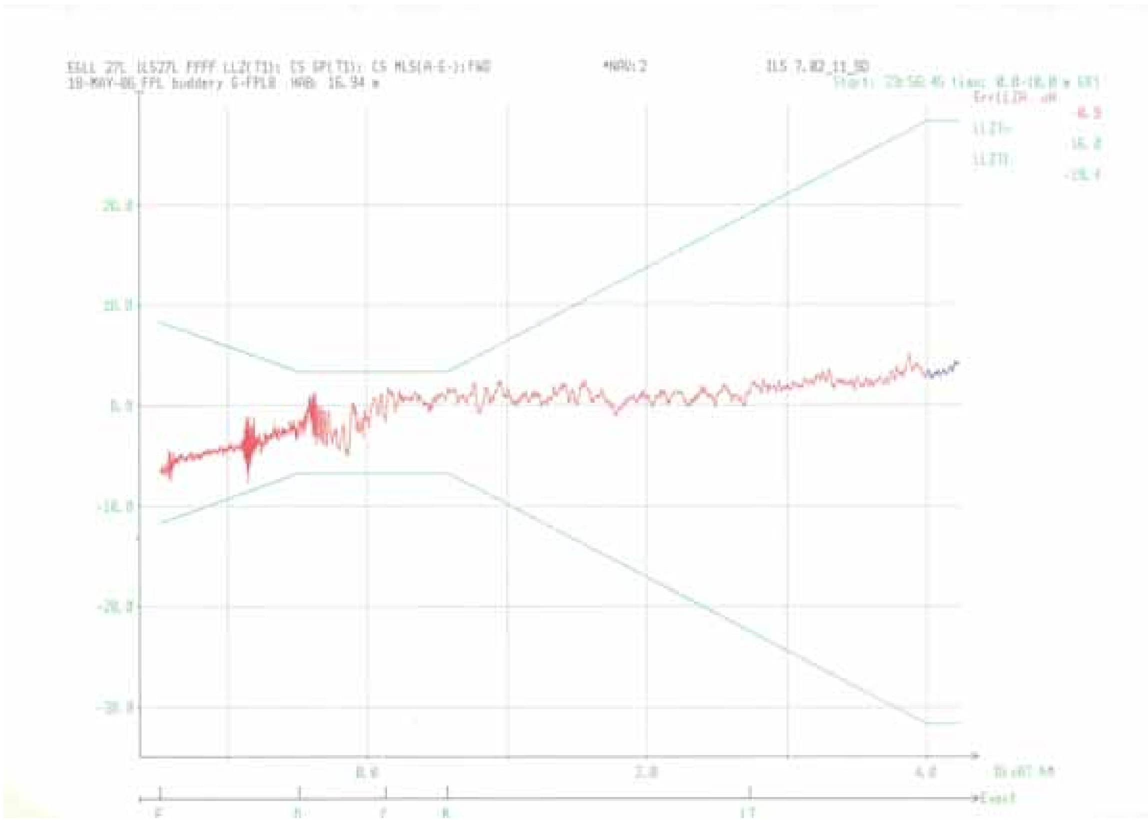
Station	Runway	Tx	Ident	Completed By	Signature	Date of Check
HEATHROW	**27L**	**TX2**	**ILL**	**KJM**		**19-May-06**

	Value	Tolerance	Result
Threshold to Point D			
Mean Alignment	0.2 uA 150Hz		
Bend Amplitude	4.2 uA at 393m	'+/- 5 uA	**Pass**
Point D to Point E			
Max Bend Amplitude	-2.2 uA at 913m	Linear increase +/-5 @Pt d to +/-10 @ Pt E	**Pass**
Max % of Tol Bend Amp	-2.2 uA at 913m		**Pass**
Point D to Stop End			
Max Bend Amplitude	-3.7 uA at 3655m	'+/-10 uA	**Pass**

Ground Inspection Plot for 27L Localiser with A380 at Position B2

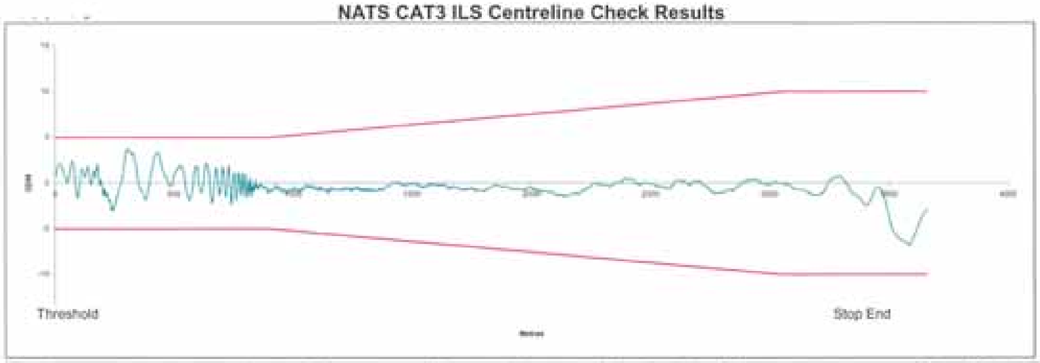


Position Airbus122



Actual Flight Inspection Structure Plot for 27L Localiser with A380 at Position Airbus122

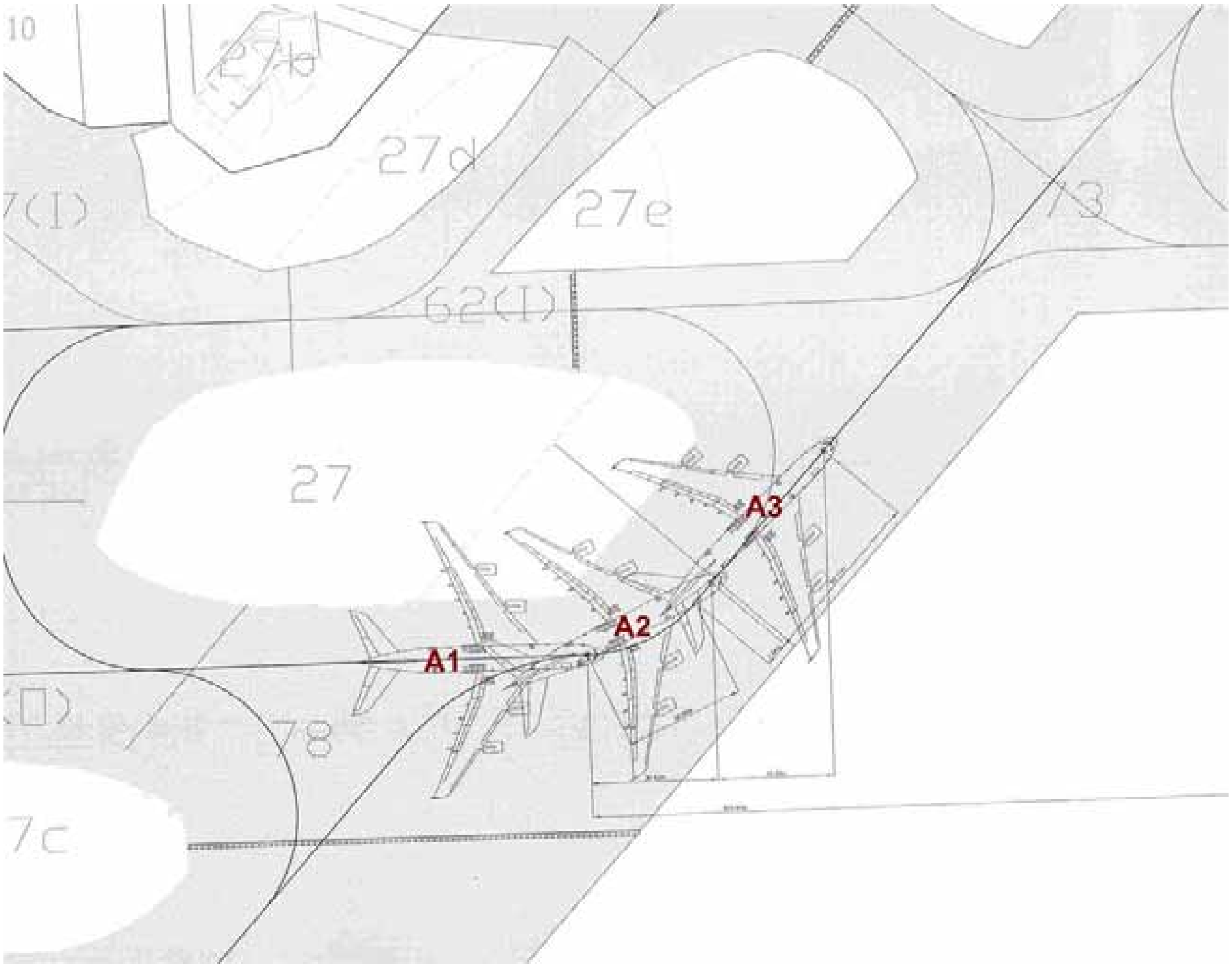
NATS CAT3 ILS Centreline Check Results



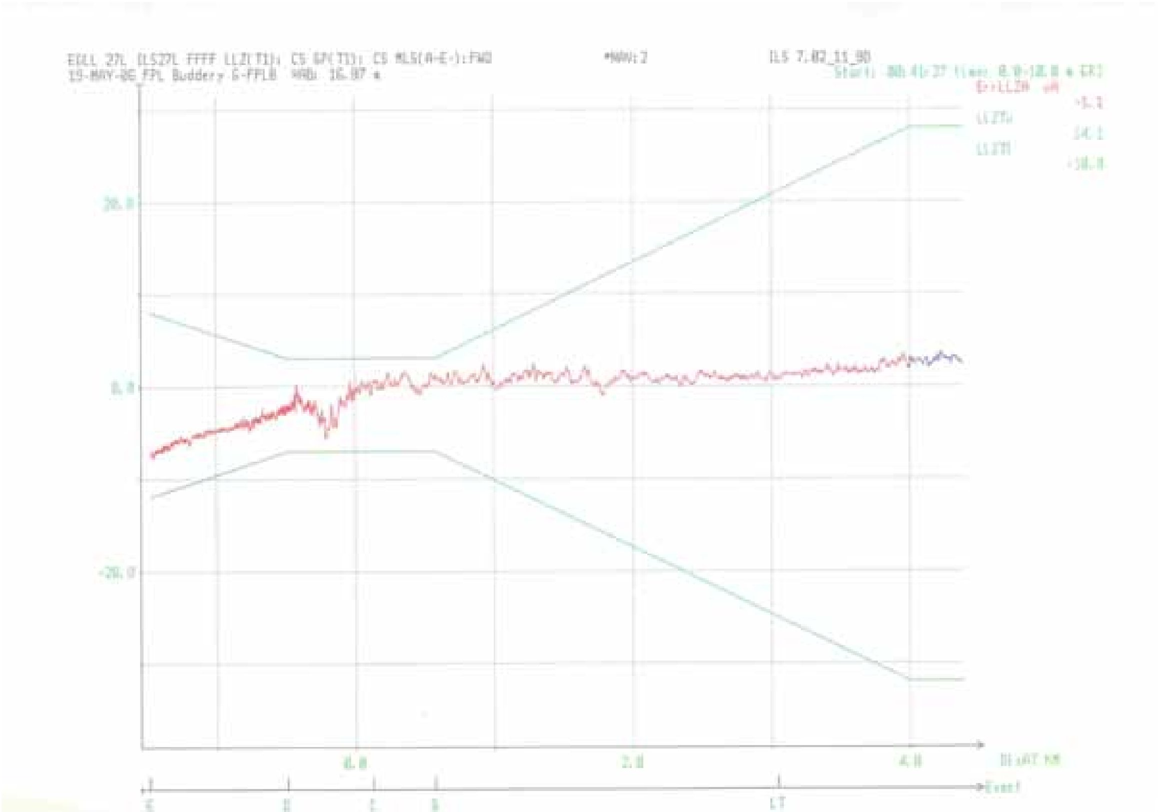
Station	Runway	Tx	Ident	Completed By	Signature	Date of Check
HEATHROW	**27L**	**TX2**	**ILL**	**KJM**		**19-May-06**

	Value	Tolerance	Result
Threshold to Point D			
Mean Alignment	0.4 uA 150Hz		
Bend Amplitude	3.8 uA at 303m	'+/- 5 uA	**Pass**
Point D to Point E			
Max Bend Amplitude	-1.5 uA at 2140m	Linear increase +/-5 @Pt d to +/-10 @ Pt E	**Pass**
Max % of Tol Bend Amp	-1.1 uA at 969m		**Pass**
Point D to Stop End			
Max Bend Amplitude	-6.8 uA at 3586m	'+/-10 uA	**Pass**

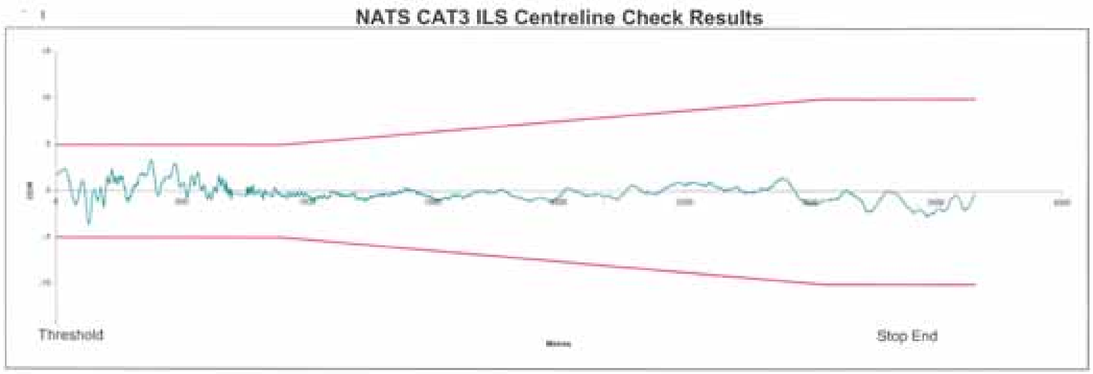
Ground Inspection Plot for 27L Localiser with A380 at Position Airbus122



Positions A1 and A2



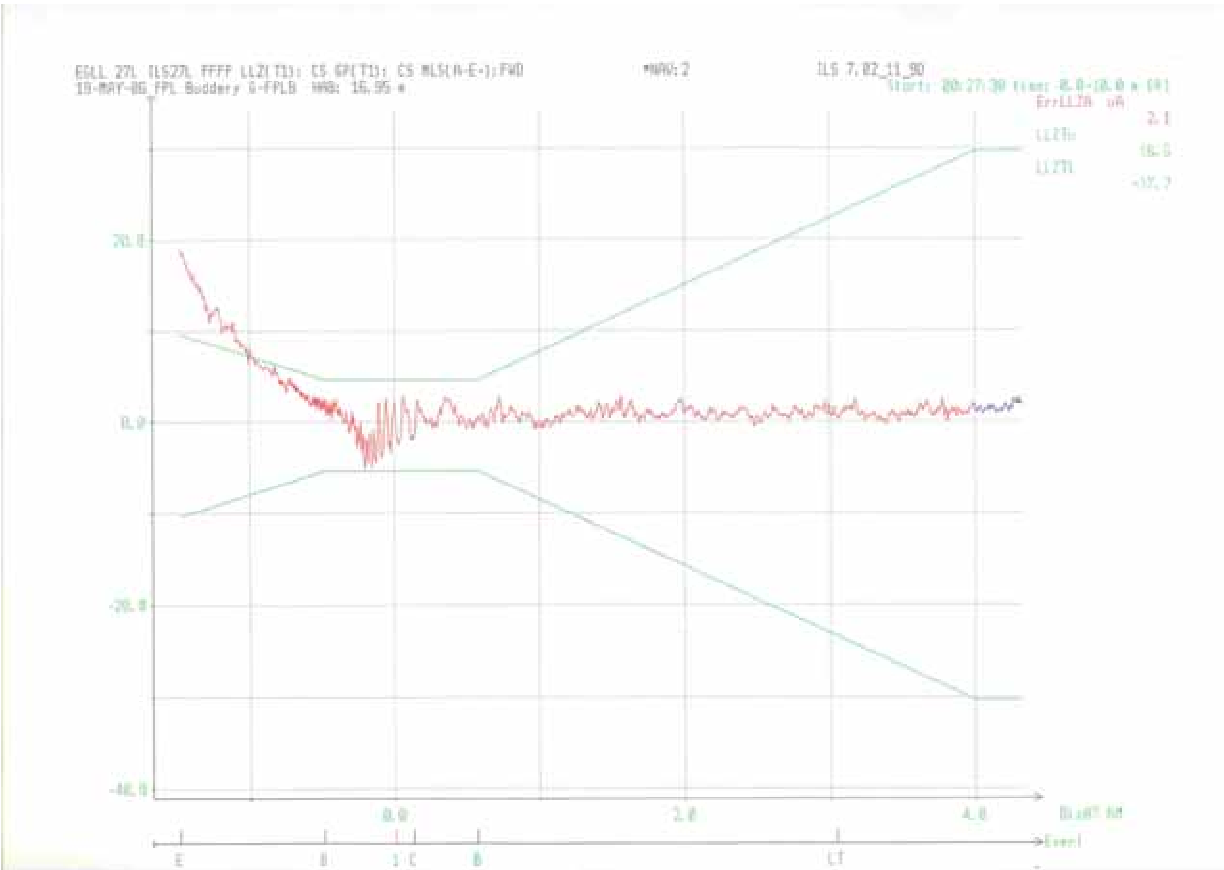
Actual Flight Inspection Structure Plot for 27L Localiser with A380 at Position A1



Station	Runway	Tx	Ident	Completed By	Signature	Date of Check
HEATHROW	**27L**	**TX2**	**ILL**	**KJM**	K. J. M. (signature)	**19-May-06**

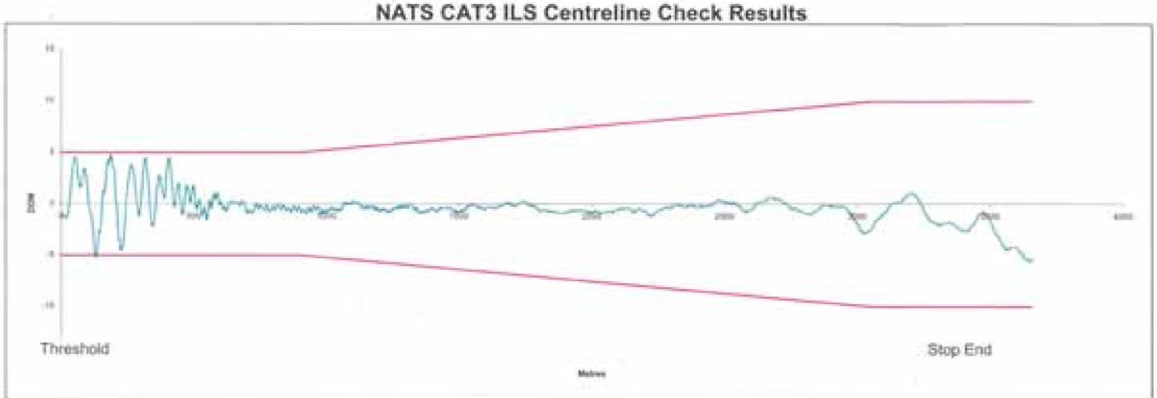
	Value	Tolerance	Result
Threshold to Point D			
Mean Alignment	0.5 uA 150Hz		
Bend Amplitude	-3.6 uA at 130m	'+/- 5 uA	**Pass**
Point D to Point E			
Max Bend Amplitude	1.5 uA at 2887m	Linear increase +/-5 @Pt d to +/-10 @ Pt E	**Pass**
Max % of Tol Bend Amp	-1.1 uA at 1030m		**Pass**
Point D to Stop End			
Max Bend Amplitude	-2.6 uA at 3463m	'+/-10 uA	**Pass**

Ground Inspection Plot for 27L Localiser with A380 at Position A1



Actual Flight Inspection Structure Plot for 27L Localiser with A380 at Position A2

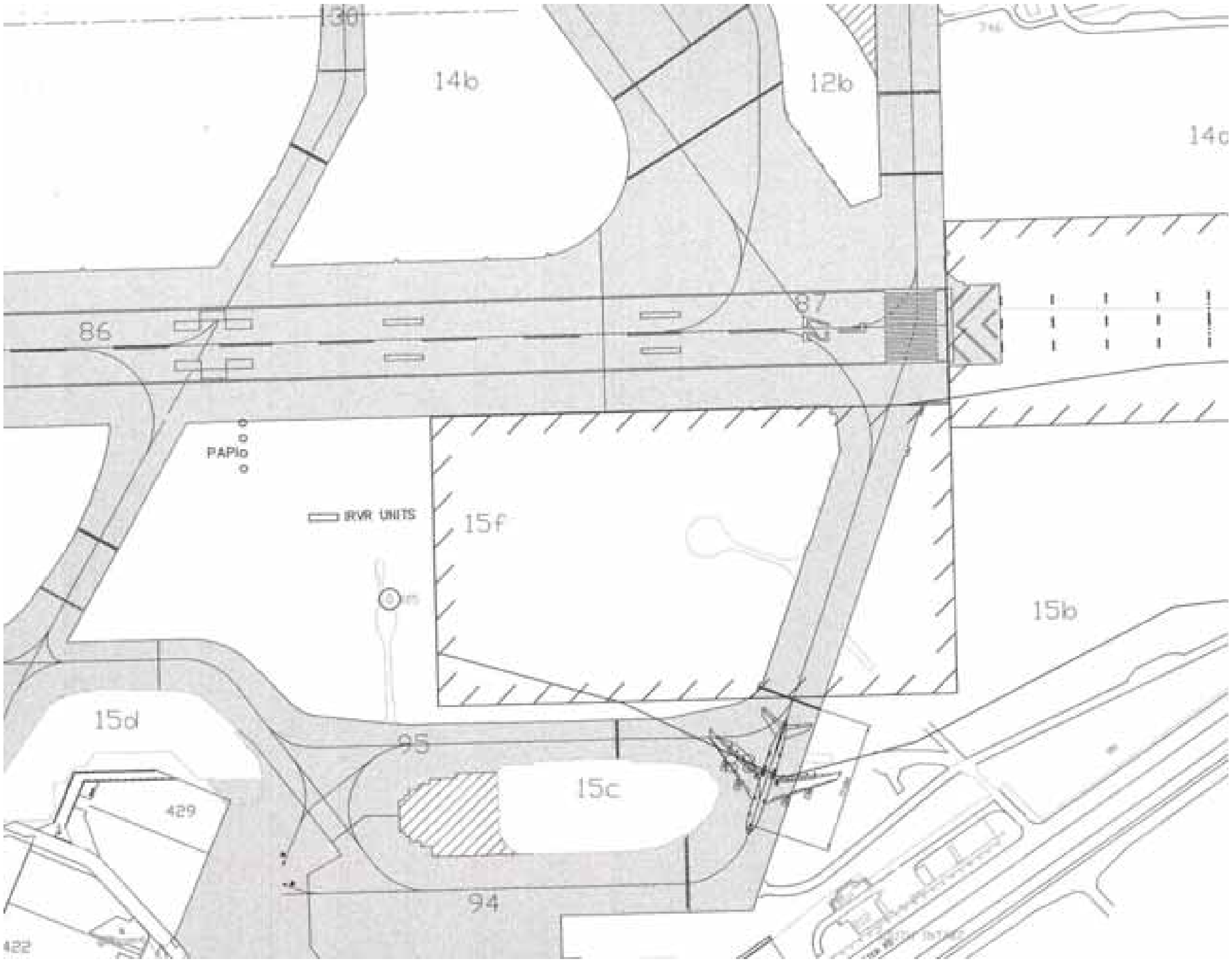
NATS CAT3 ILS Centreline Check Results



Station	Runway	Tx	Ident	Completed By	Signature	Date of Check
HEATHROW	27L	TX2	ILL	KJM		19-May-06

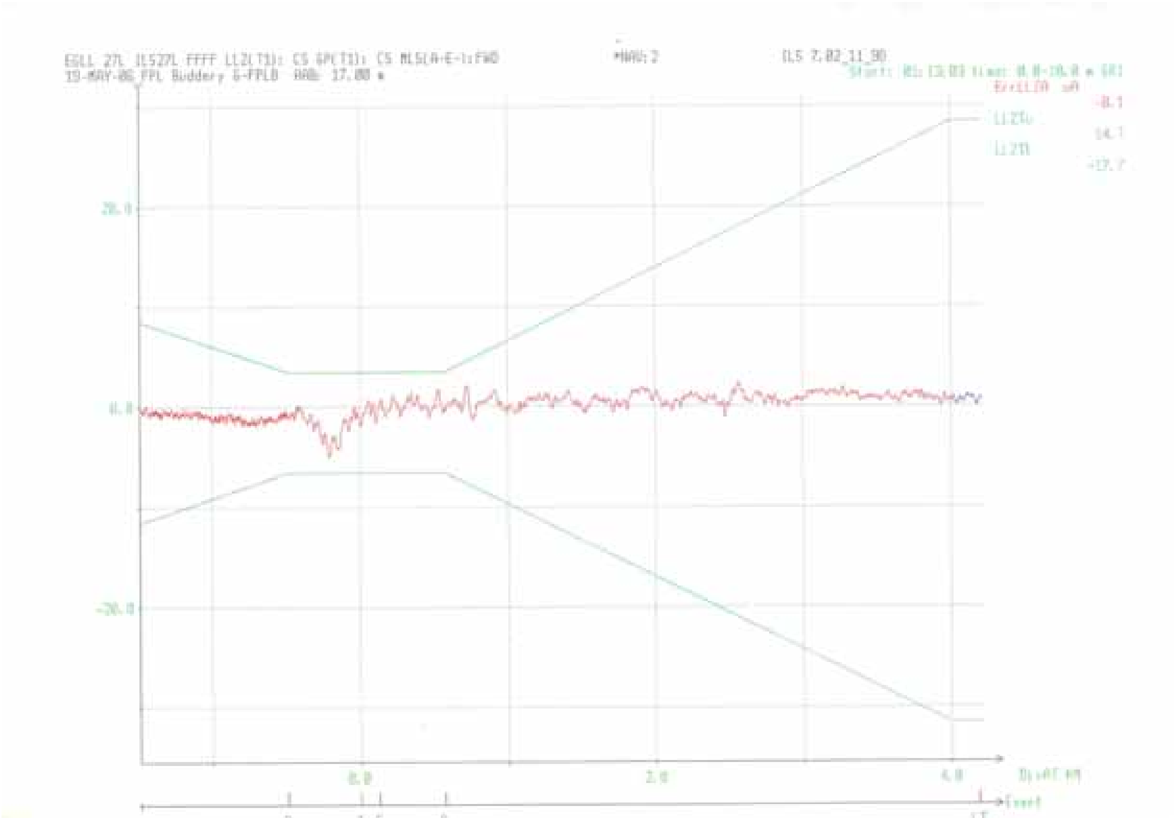
	Value	Tolerance	Result
Threshold to Point D			
Mean Alignment	0.3 uA 150Hz		
Bend Amplitude	-5.3 uA at 132m	'+/- 5 uA	Fail
Point D to Point E			
Max Bend Amplitude	-2.9 uA at 3031m	Linear increase +/-5 @Pt d to +/-10 @ Pt E	Pass
Max % of Tol Bend Amp	-2.9 uA at 3031m		Pass
Point D to Stop End			
Max Bend Amplitude	-5.6 uA at 3649m	'+/-10 uA	Pass

Ground Inspection Plot for 27L Localiser with A380 at Position A2



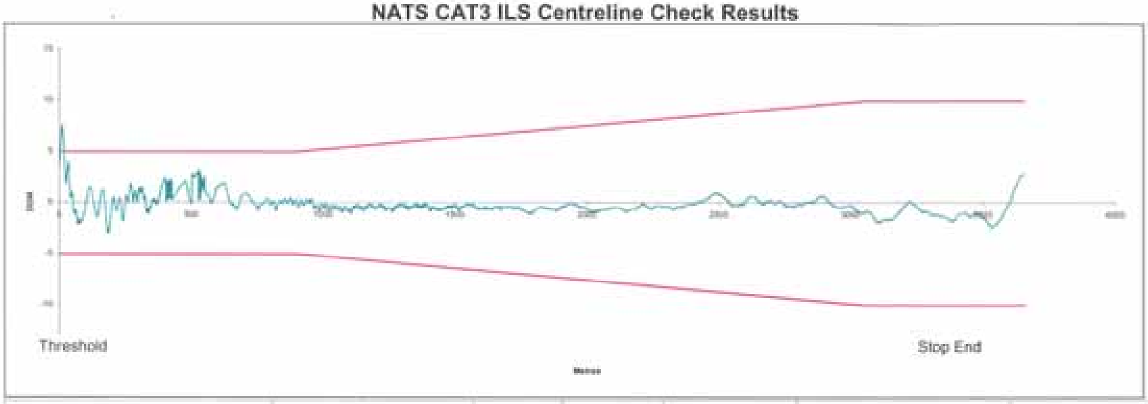
Position P17

Actual Flight Inspection Structure Plot for 27L Localiser with A380 at Position P17



Actual Flight Inspection Structure Plot for 27L Localiser with A380 at Position P17

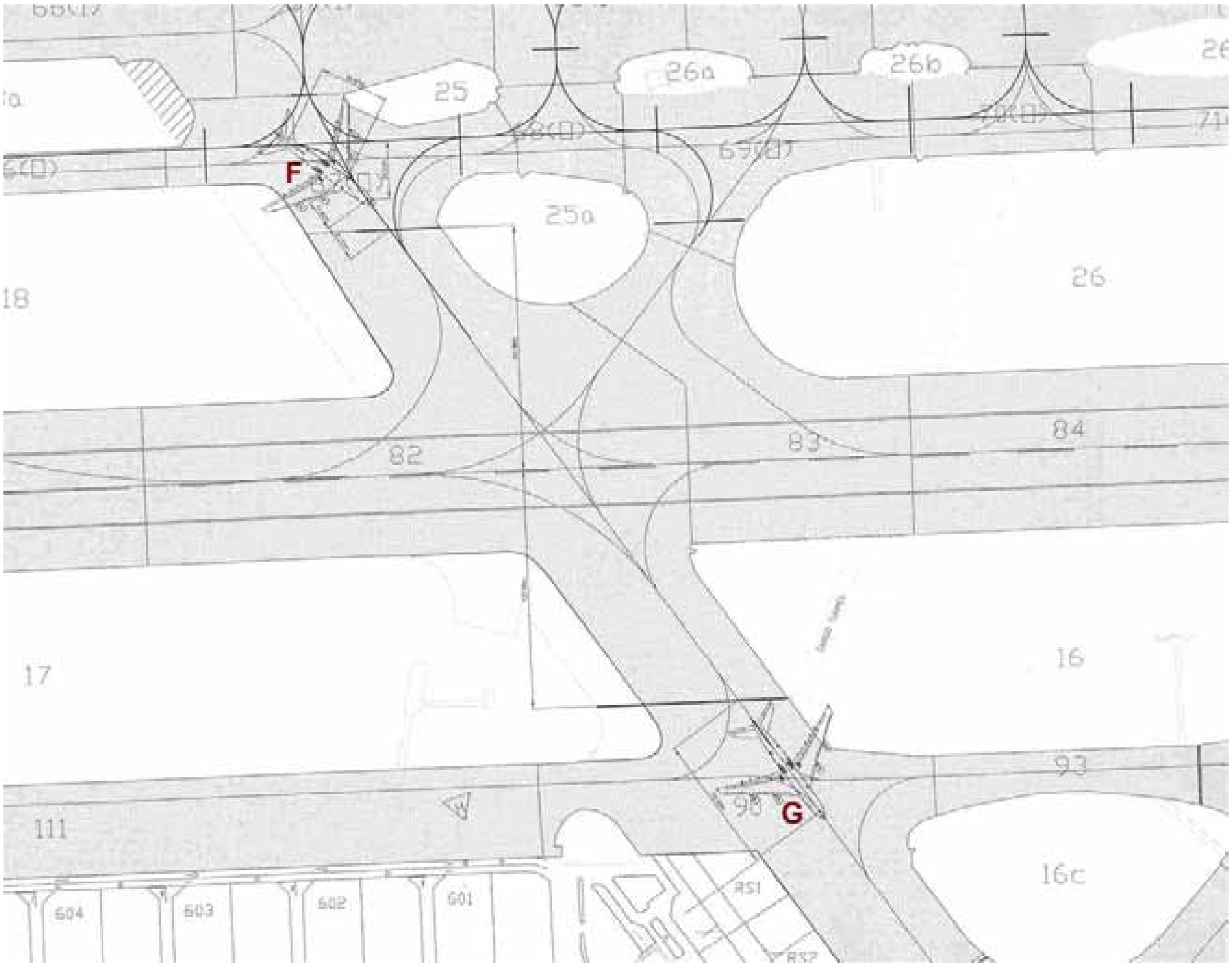
NATS CAT3 ILS Centreline Check Results



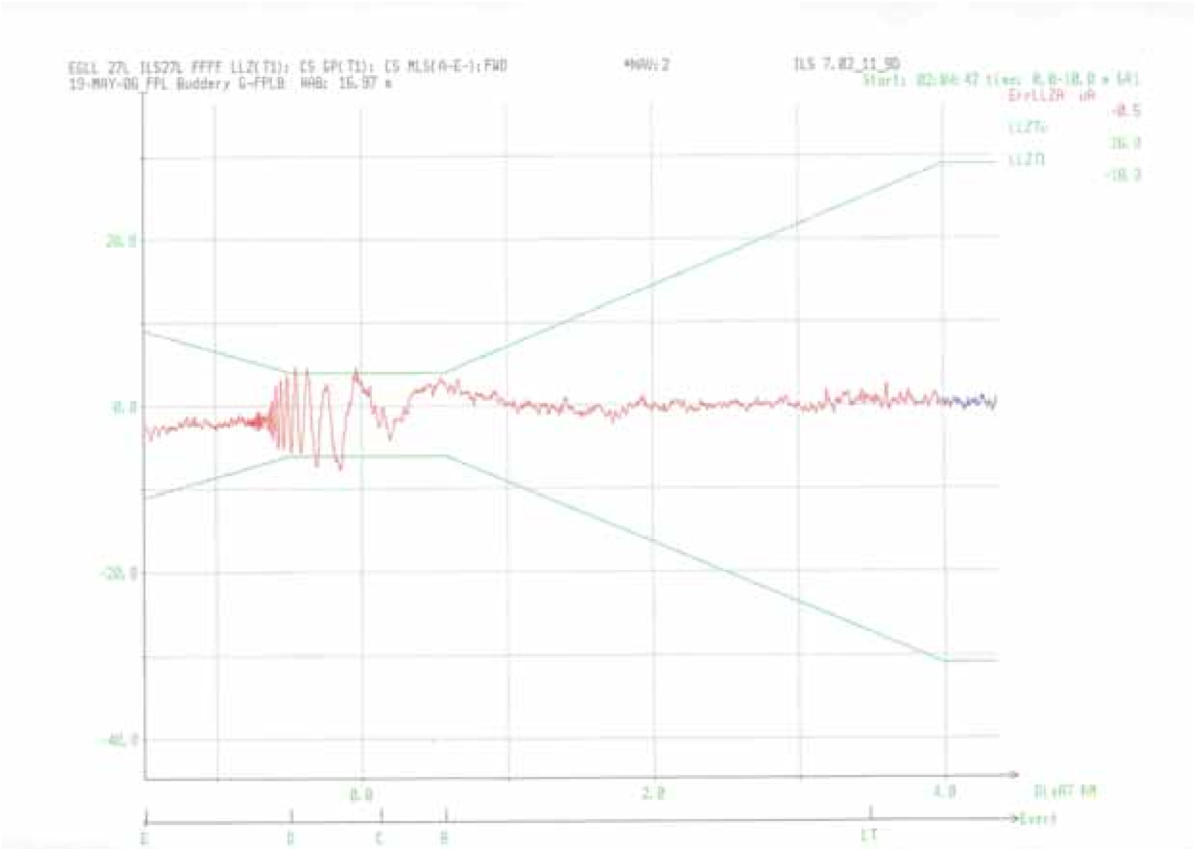
Station	Runway	Tx	Ident	Completed By	Signature	Date of Check
HEATHROW	**27L**	**TX2**	**ILL**	**KJM**		**19-May-06**

	Value	Tolerance	Result
Threshold to Point D			
Mean Alignment	0.6 uA 150Hz		
Bend Amplitude	7.7 uA at 10m	'+/- 5 uA	**Fail**
Point D to Point E			
Max Bend Amplitude	-1.1 uA at 1104m	Linear increase +/-5 @Pt d to +/-10 @ Pt E	**Pass**
Max % of Tol Bend Amp	-1.1 uA at 1104m		**Pass**
Point D to Stop End			
Max Bend Amplitude	2.9 uA at 3658m	'+/-10 uA	**Pass**

Ground Inspection Plot for 27L Localiser with A380 at Position P17

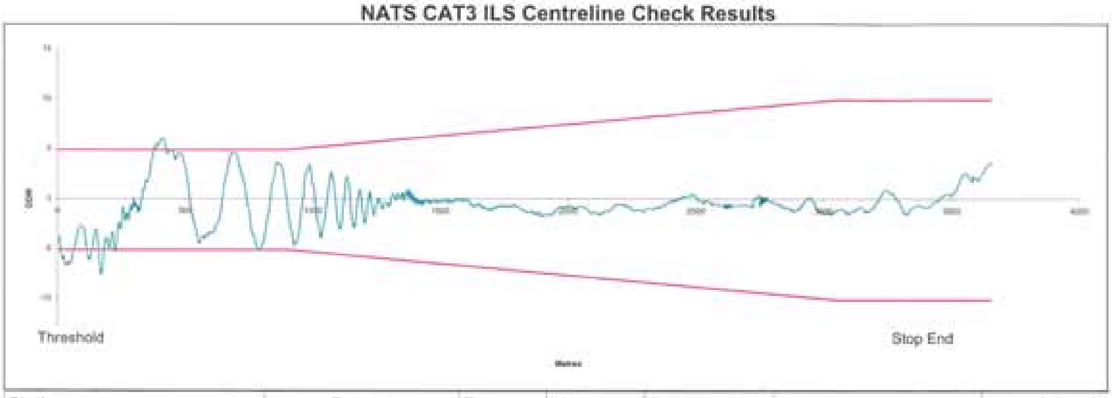


Positions F and G



Actual Flight Inspection Structure Plot for 27L Localiser with A380 at Position G

NATS CAT3 ILS Centreline Check Results



Station	Runway	Tx	Ident	Completed By	Signature	Date of Check
HEATHROW	27L	TX2	ILL	KJM		19-May-06

	Value	Tolerance	Result
Threshold to Point D			
Mean Alignment	0.8 uA 90Hz		
Bend Amplitude	-7.4 uA at 171m	'+/- 5 uA	Fail
Point D to Point E			
Max Bend Amplitude	-4.6 uA at 927m	Linear increase +/-5 @Pt d to +/-10 @ Pt E	Pass
Max % of Tol Bend Amp	-4.6 uA at 927m		Pass
Point D to Stop End			
Max Bend Amplitude	3.7 uA at 3650m	'+/-10 uA	Pass

Ground Inspection Plot for 27L Localiser with A380 at Position G

ANNEX J : Comparison of A380 ILS disturbance with OHIO simulations for London cases

1. THE OUILS ILS MODEL USED BY NATS

1.1 The ILS model used by NATS for the initial report is known as the Ohio University ILS model (OUILS). This is an earlier version of the IPPM/OUILS model used by Park Air Systems. It is a two-ray model that calculates the difference in path length between signals arriving at an aircraft direct from the radiating antenna and those reflected from buildings and structures. The direct and reflected radio signals are then combined to determine the signal being received by an aircraft. OUILS was written in the Fortran programming language. Subsequent modelling has been carried out using the latest version of OUILS. This version is Windows Based and provides a much friendlier user interface that enables quicker data entry and processing.

1.2 The input to the model is provided through the use of a data file, containing the following information:-

- The antenna signal distribution data for the Course signal (includes CSB and SBO signal strengths and phases);
- The antenna signal distribution data for the Clearance signal (includes CSB and SBO signal strengths and phases);
- Antenna radiation pattern (Log-Periodic antenna);
- ILS Localiser frequency;
- ILS Localiser Sector Width;
- Details of signal “reflectors”.

1.3 Each reflector is constructed from a number of rectangular reflecting plates. The size, location (in three dimensions relative to the position of the ILS antenna array) and orientation of each plate is individually specified. Using a large number of small plates allows complex shapes to be constructed.

1.4 The output of the model is in the form of a data file. This file contains two series of numbers that identify:-

a) Aircraft distance from the ILS Antenna array;
b) Calculated offset from ideal approach line.

1.5 It should be noted that the ILS model is normally used to determine the static effect of a building or development on the ILS Localiser guidance beam. However, by carrying out a series of runs with an object being “stepped” by a small amount between each run, it is possible to build up a representation of the effects of a slowly moving object on the ILS Localiser beam. It is also possible to iterate a large number of locations in one run to give an indication of scatterer locations and their respective effect on the Localiser signal in space.

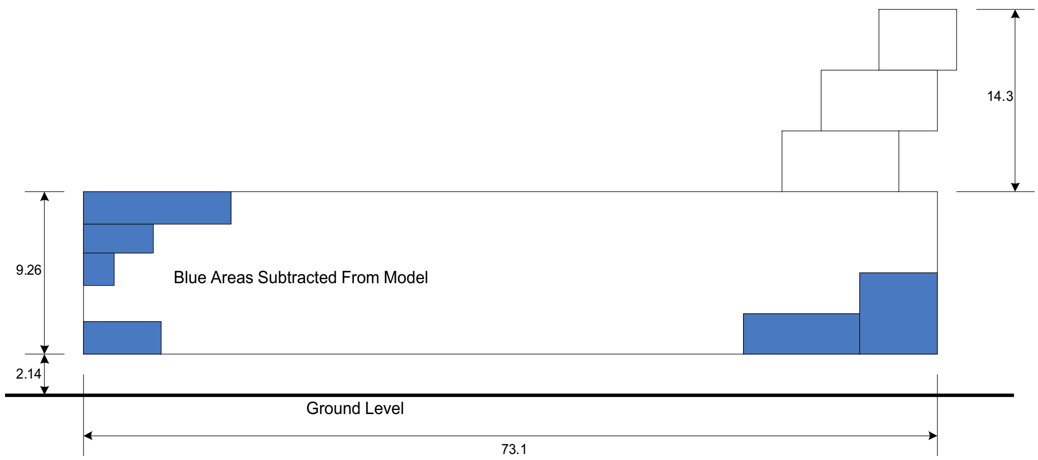
1.6 The ILS receiver system on an aircraft making an approach will be moving. The speed of the aircraft will determine whether the receiver has time to react to signals whose magnitudes are rapidly changing (i.e. noise spikes). The faster the receiver is moving, the less likely that the changes will be visible on the cockpit display. The aircraft system therefore has a degree of "in-built" hysterisis. It is possible to simulate this effect within the ILS model by passing the results through a "low-pass" filter. However, using the filter can lead to the masking of some reflections and will result in a small reduction in the magnitude of the calculated bends. In order to determine the "worst case" scenario, the results from the model have not been passed through this filter.

1.7 The model assumes that each reflecting plate is a perfect reflector, i.e. it reflects 100% of the radio energy received by the plate. Although it is not possible to change the value of the reflection coefficient (1.00), it is possible to simulate a reduction in this coefficient by reducing the total area of the reflector. Taking such an approach could lead to other problems and so is not recommended and has not been used here. The results are therefore "worst case".

2. THE NATS VERSION OF THE AIRBUS A380 MODEL

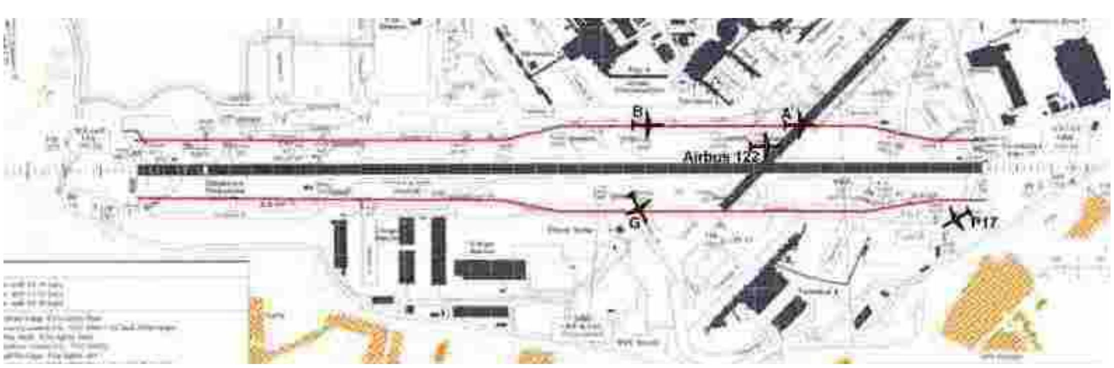
A380 on its Maiden Flight – April 26th 2005

2.1 A line drawing showing the size of the NATS representation of the Airbus A380 aircraft used within the OUILS model is shown in Figure Two below:-



NATS model of A380 Airbus (not to scale)

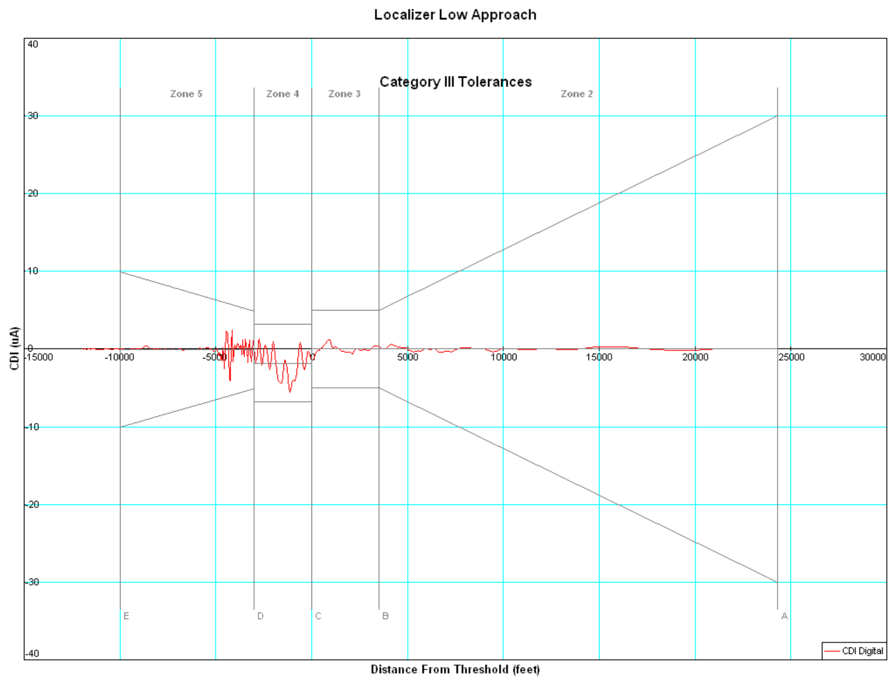
2.2 A data file containing the above model of the Airbus A380 is provided as a standard template within the latest version of the OUILS model.



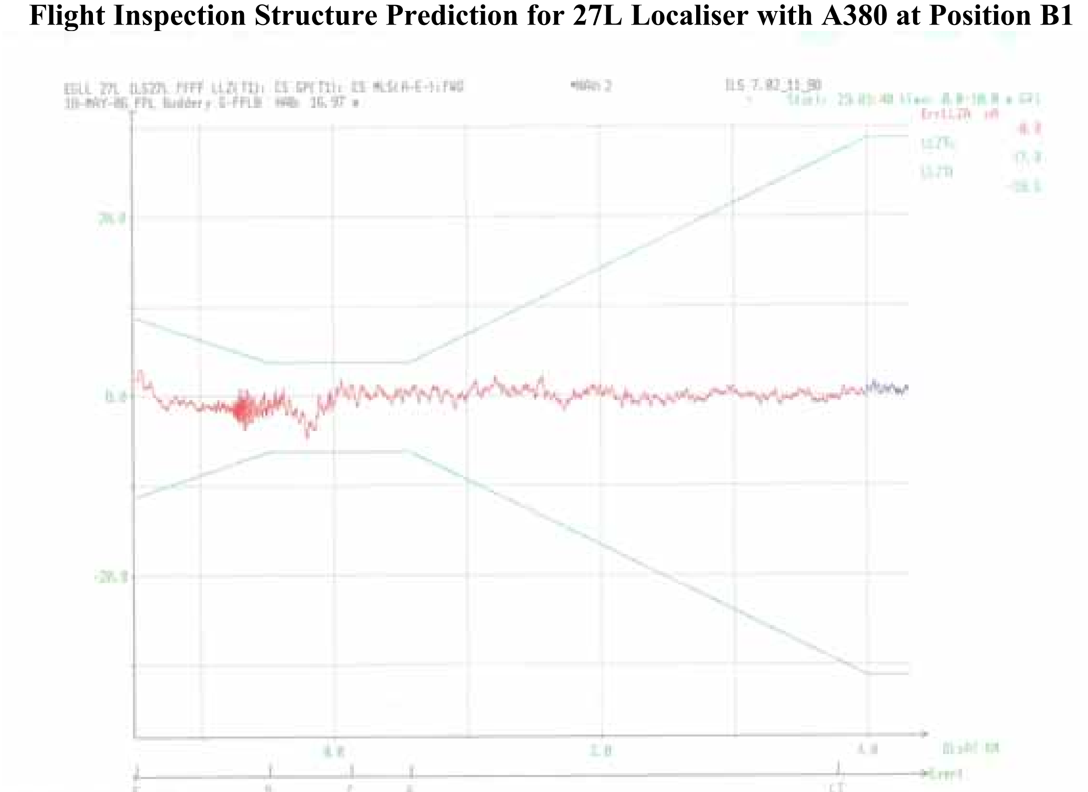
Actual Positions Tested with Flight and Ground Inspection Measurements Produced

B1, B2, Airbus122, A1, A2, P17 and G with an additional G+20m position

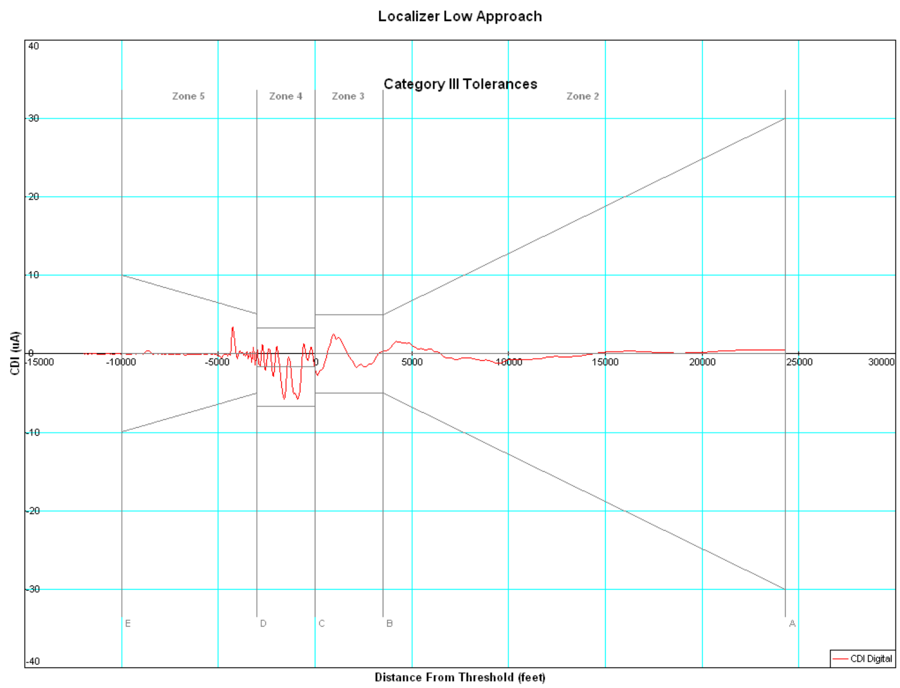
Positions B1 and B2



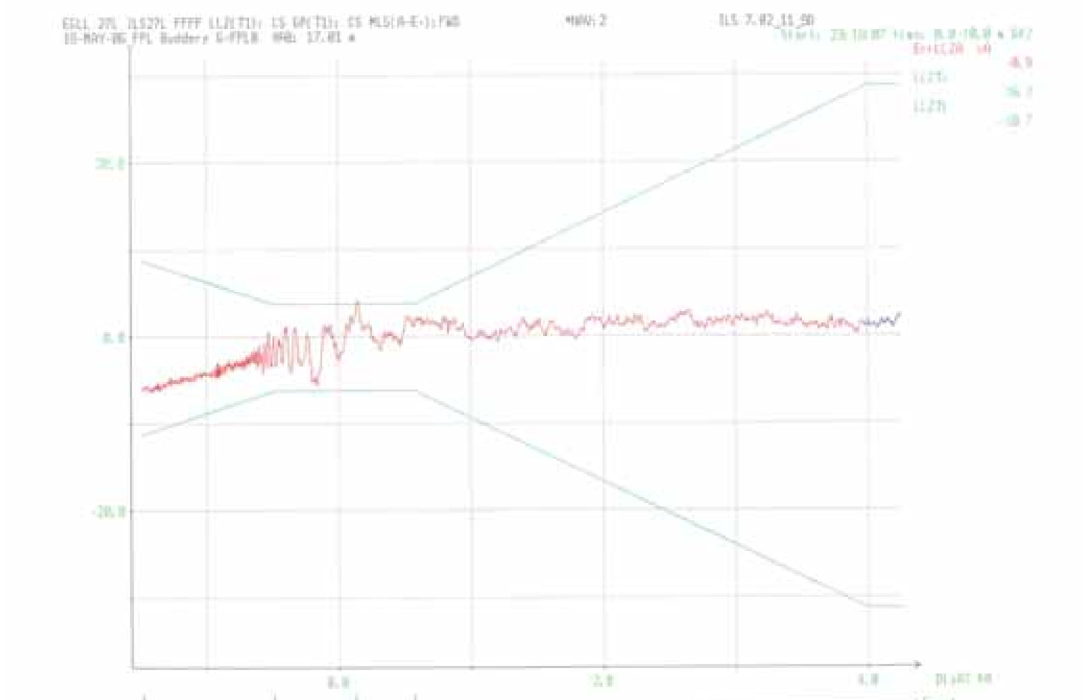
Flight Inspection Structure Prediction for 27L Localiser with A380 at Position B1



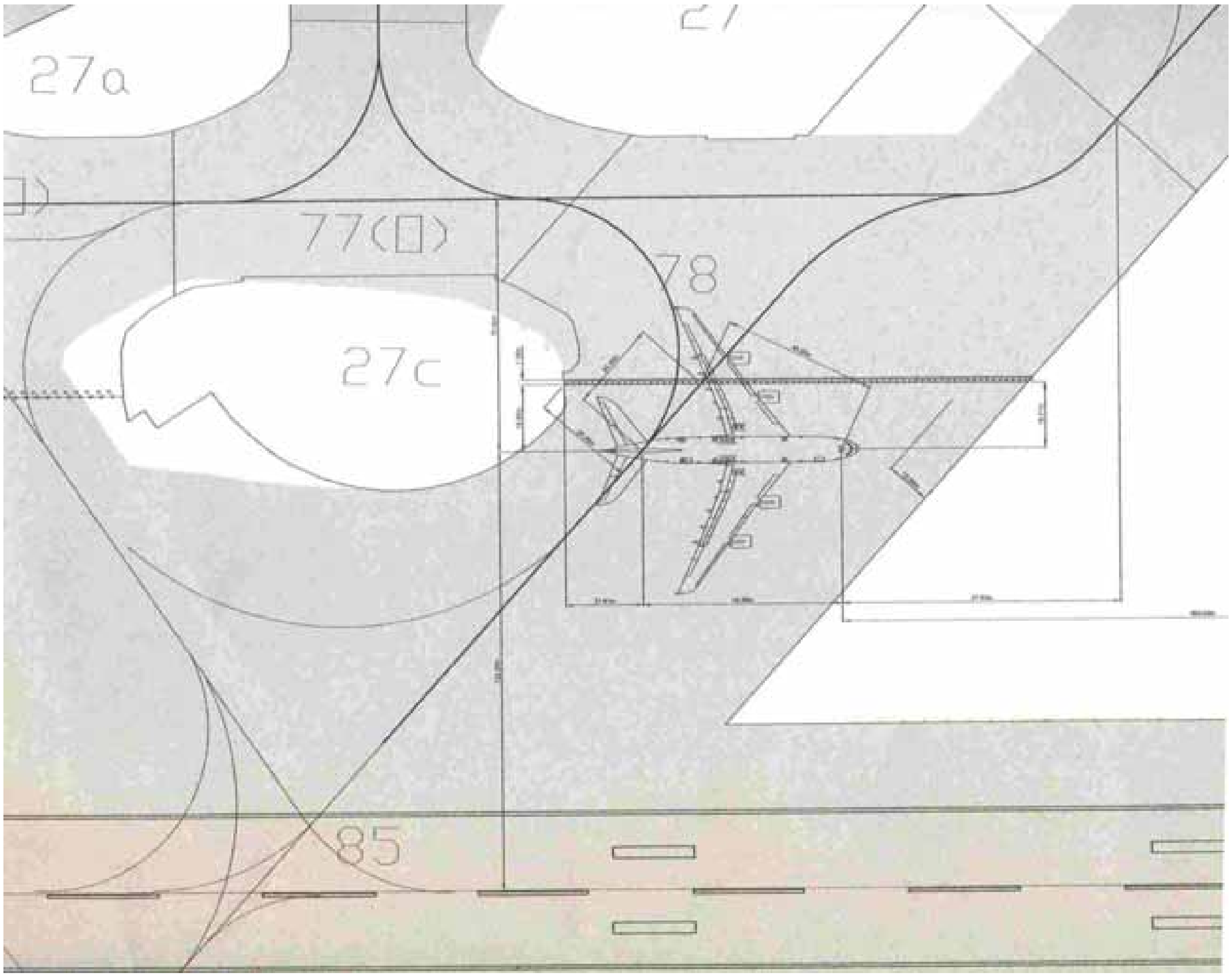
Actual Flight Inspection Structure Plot for 27L Localiser with A380 at Position B1



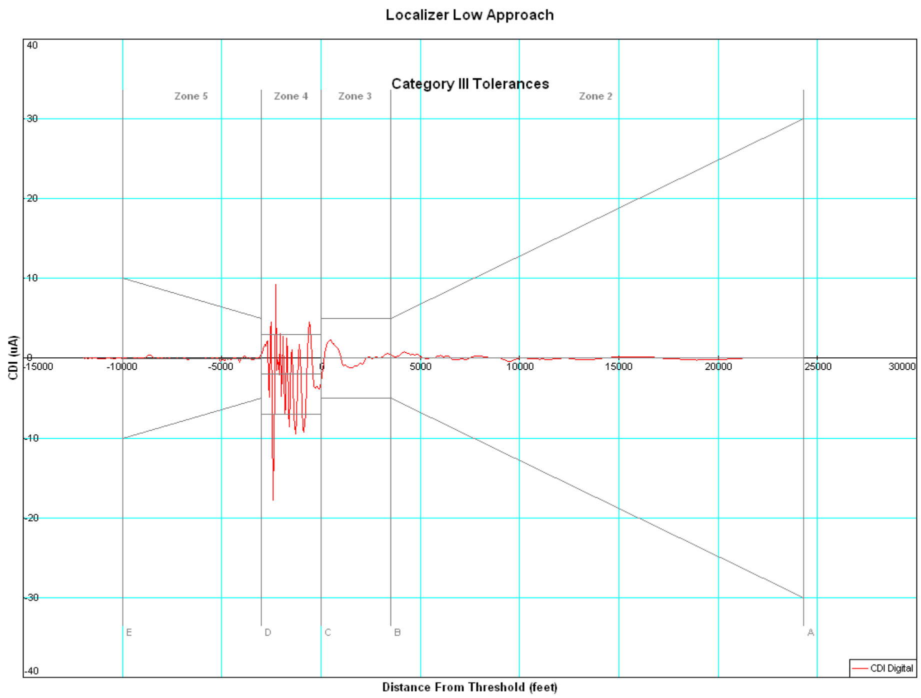
Flight Inspection Structure Prediction for 27L Localiser with A380 at Position B2



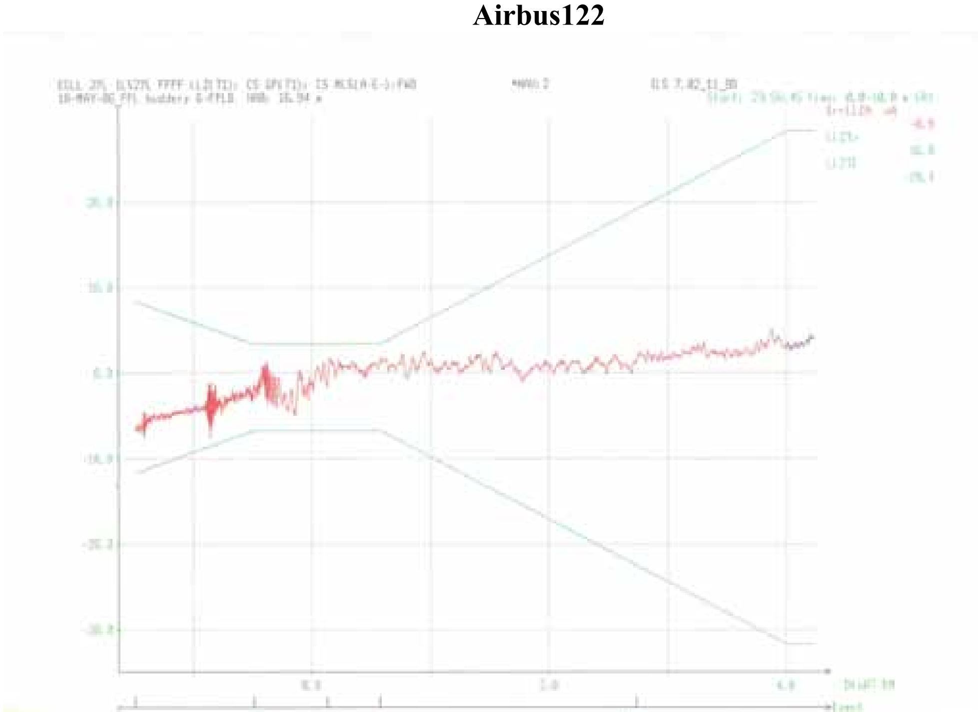
Actual Flight Inspection Structure Plot for 27L Localiser with A380 at Position B2



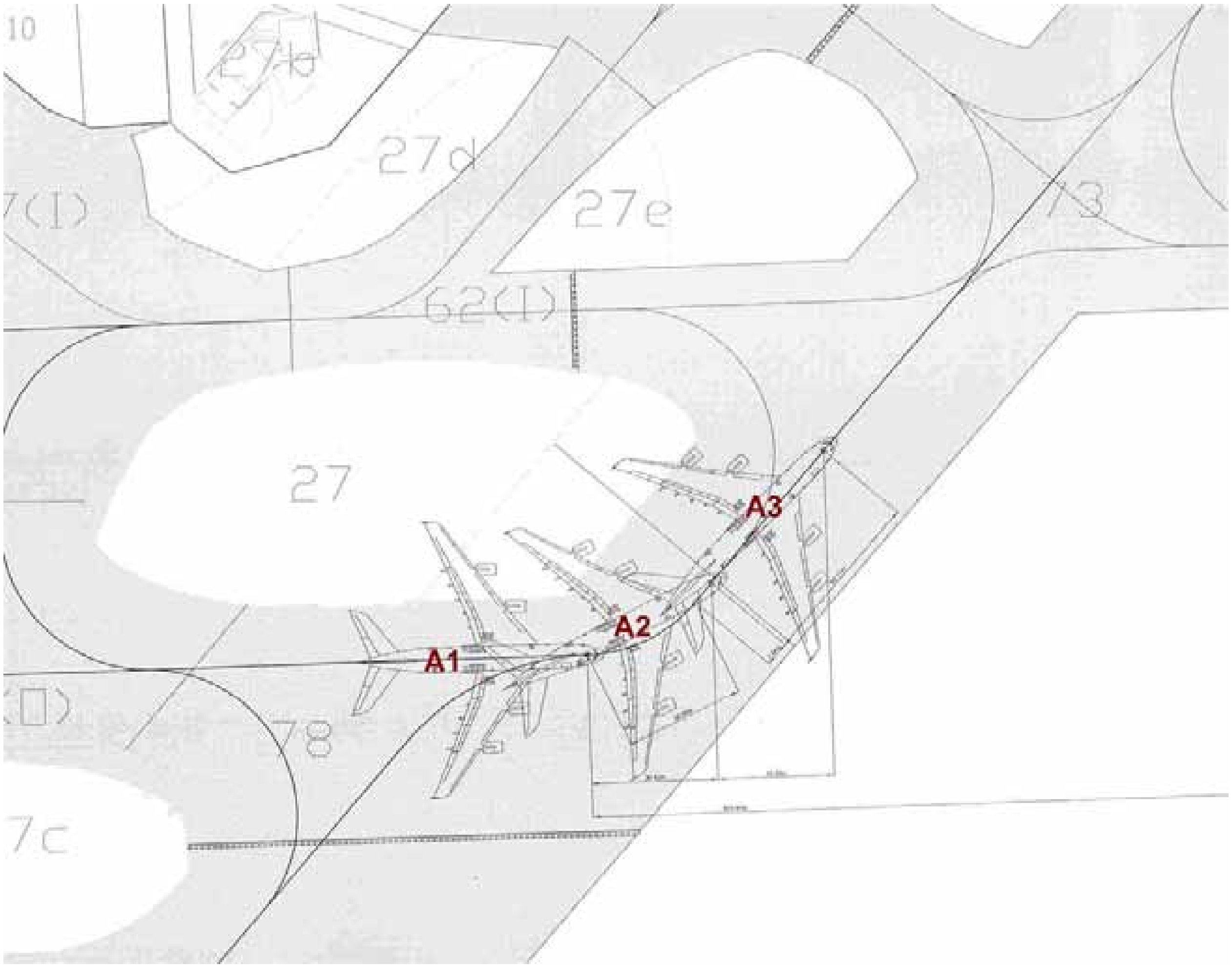
Position Airbus122



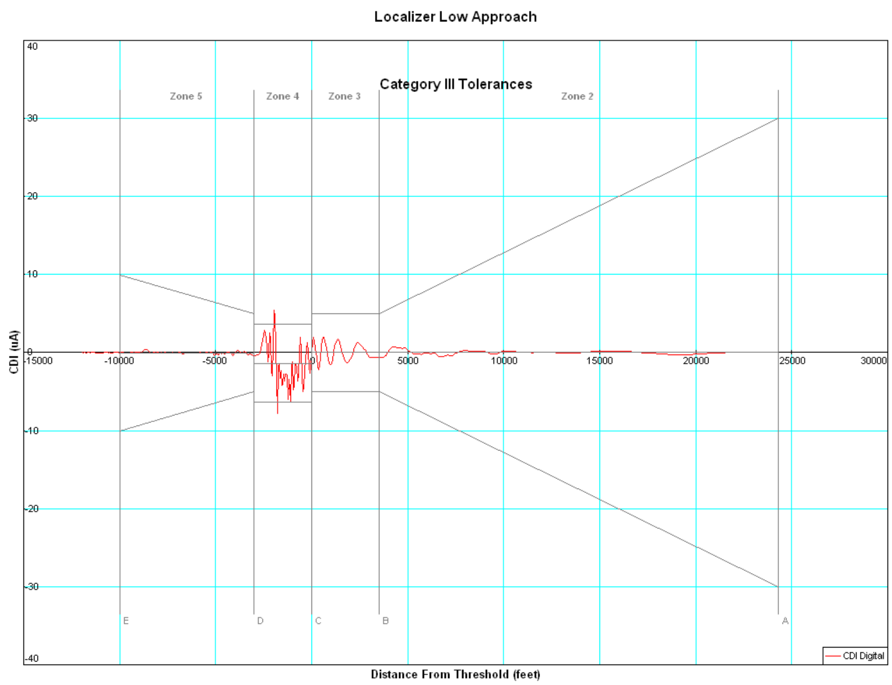
Flight Inspection Structure Prediction for 27L Localiser with A380 at Position Airbus122



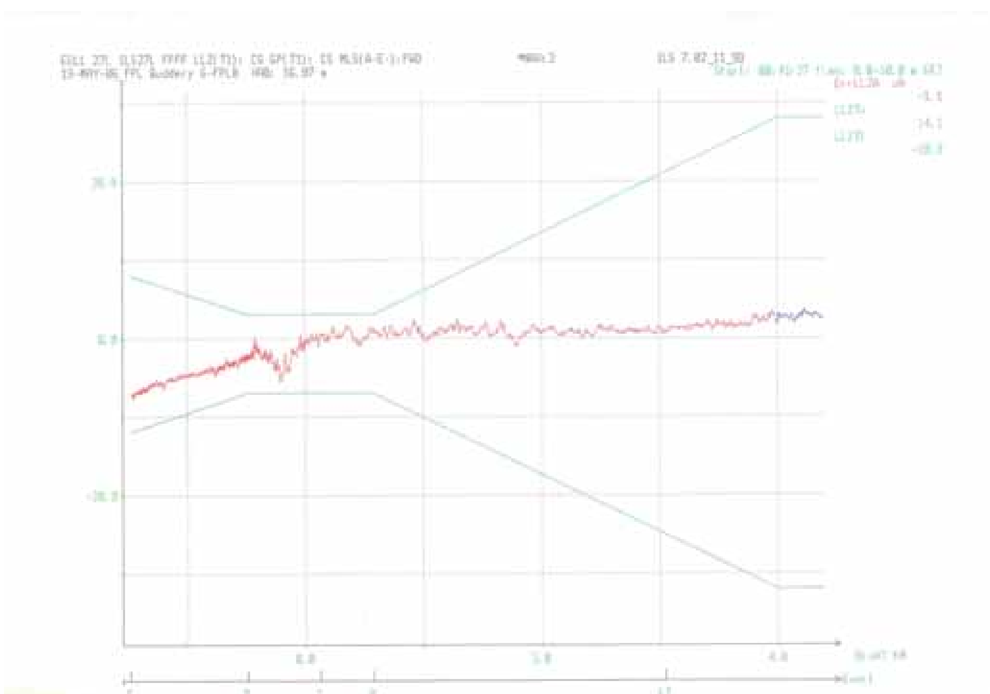
Actual Flight Inspection Structure Plot for 27L Localiser with A380 at Position Airbus122



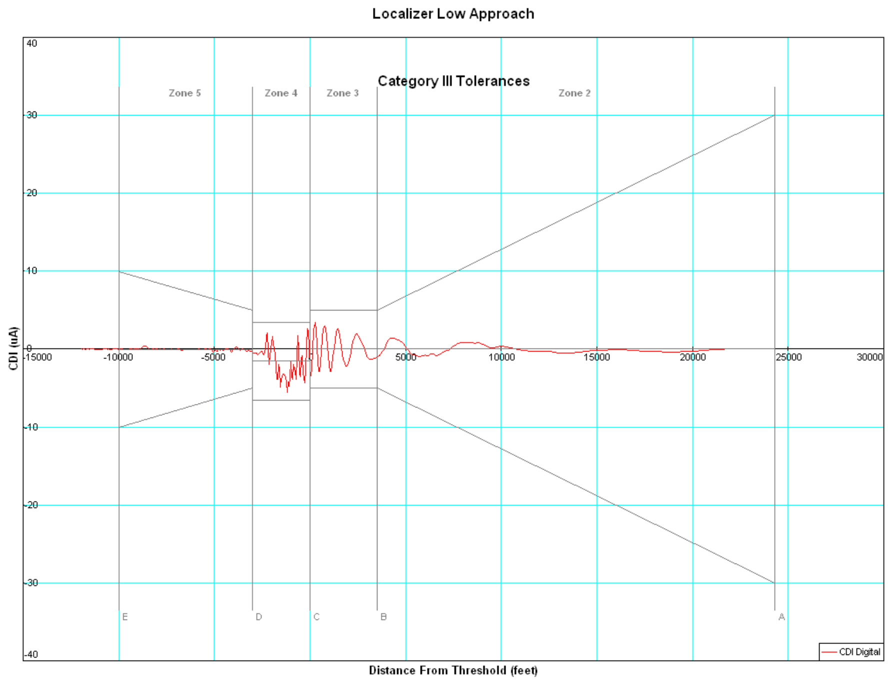
Positions A1 and A2



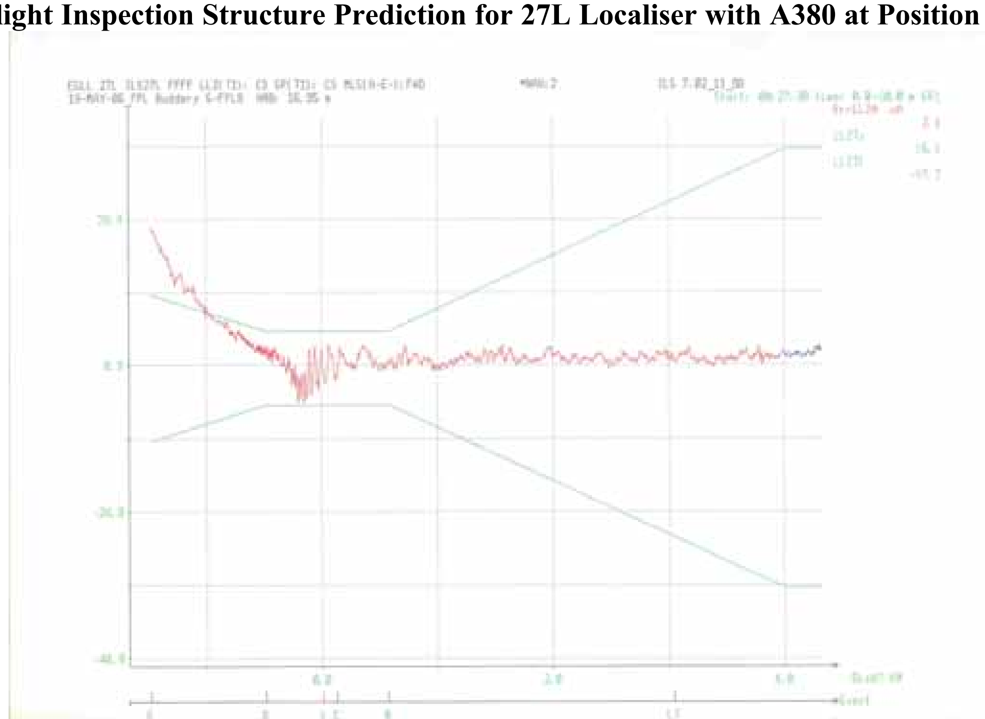
Flight Inspection Structure Prediction for 27L Localiser with A380 at Position A1



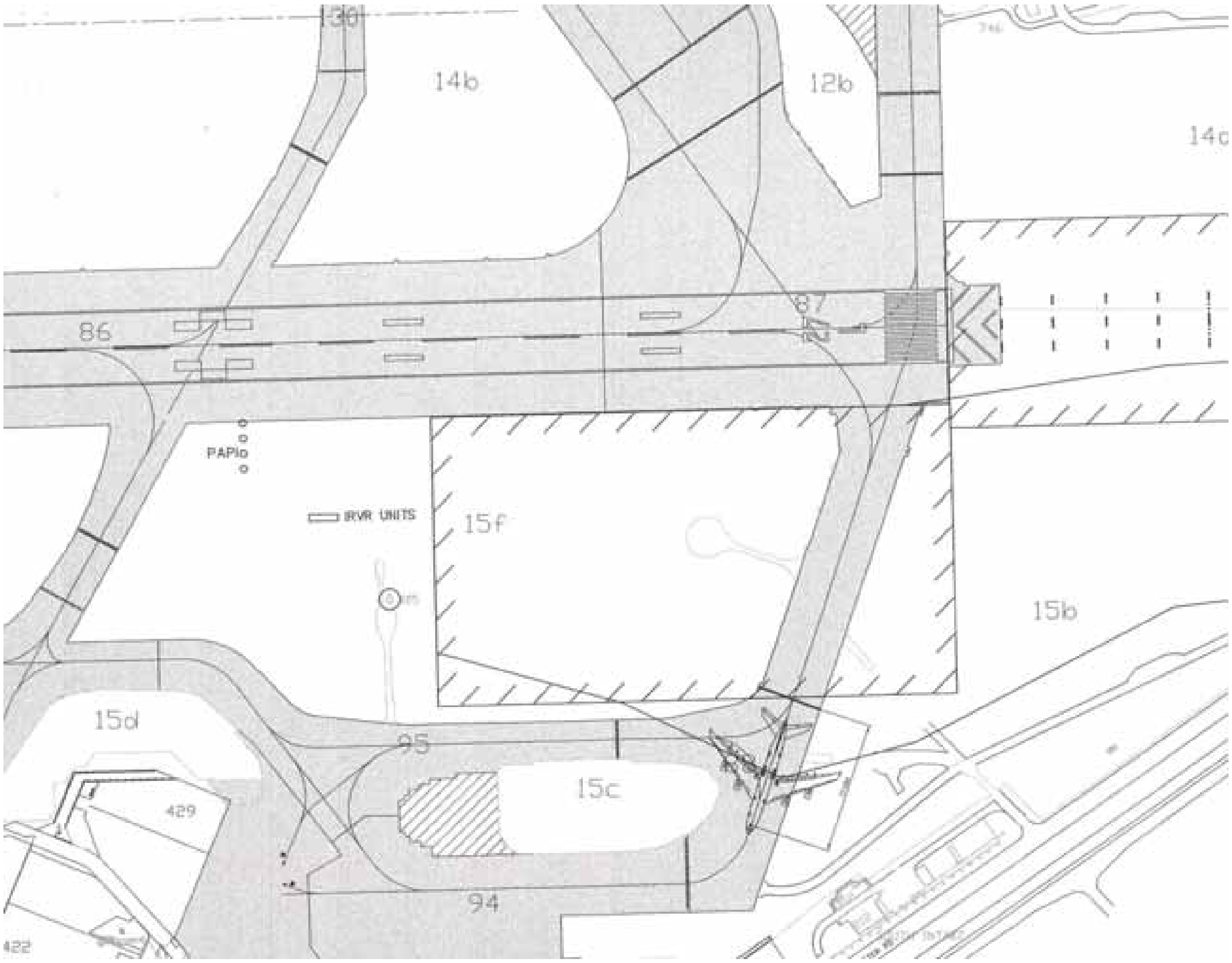
Actual Flight Inspection Structure Plot for 27L Localiser with A380 at Position A1



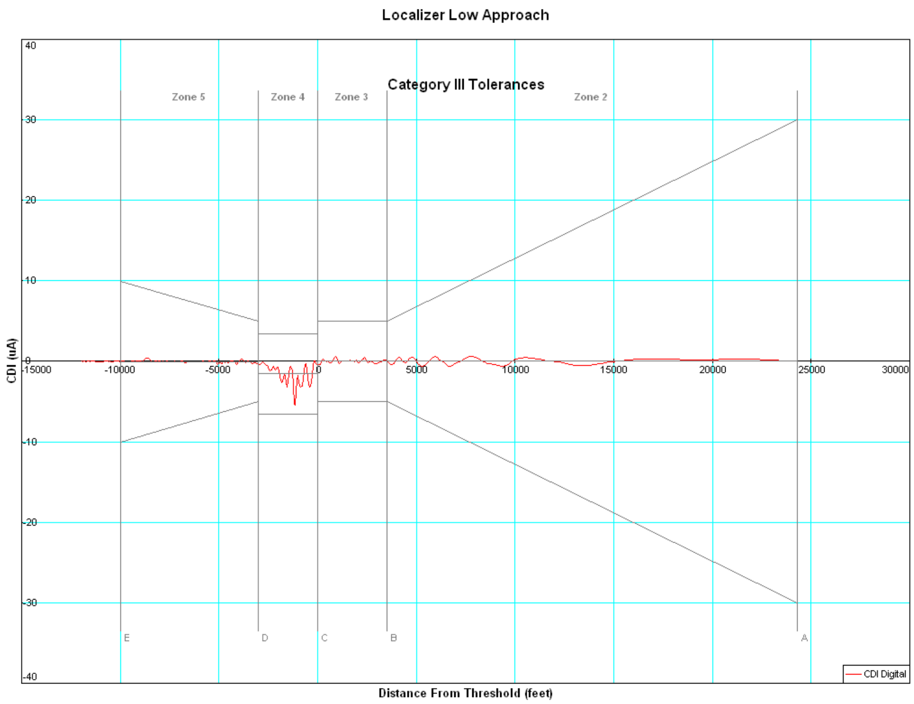
Flight Inspection Structure Prediction for 27L Localiser with A380 at Position A2



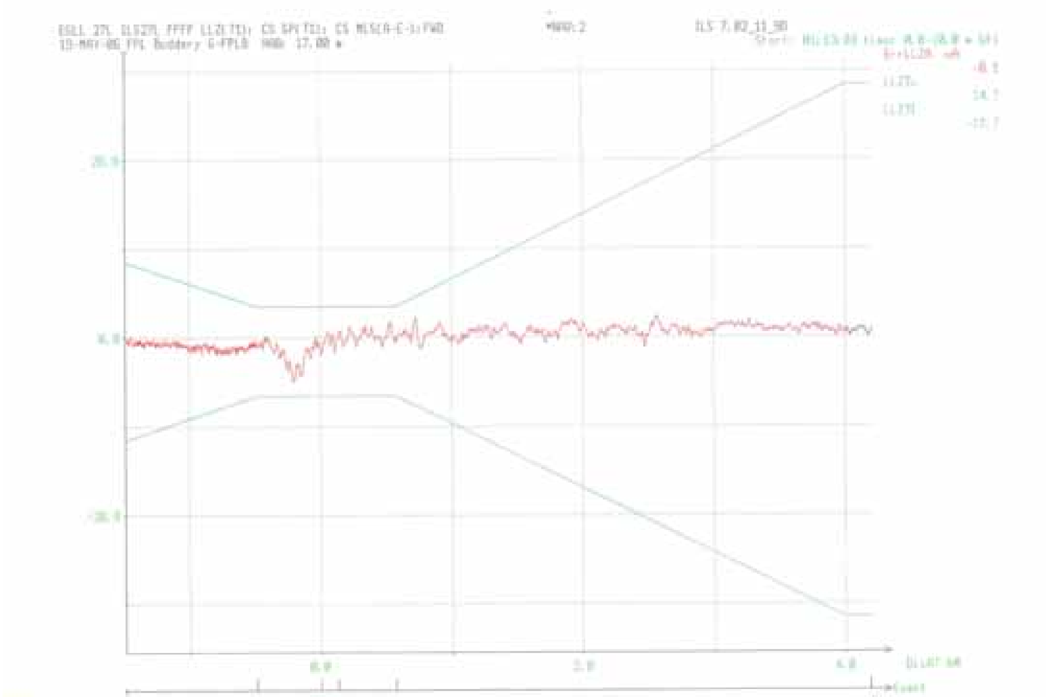
Actual Flight Inspection Structure Plot for 27L Localiser with A380 at Position A2



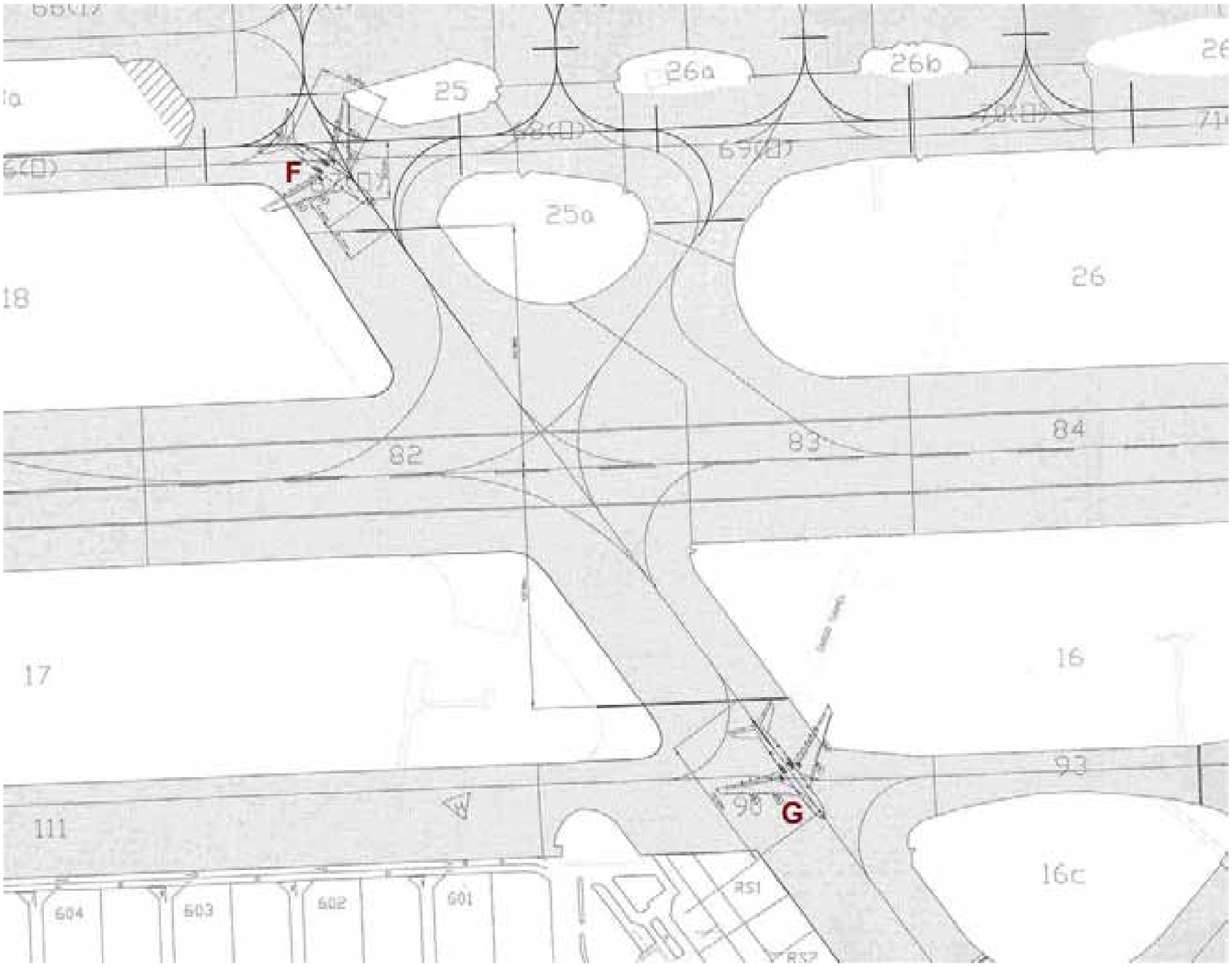
Position P17



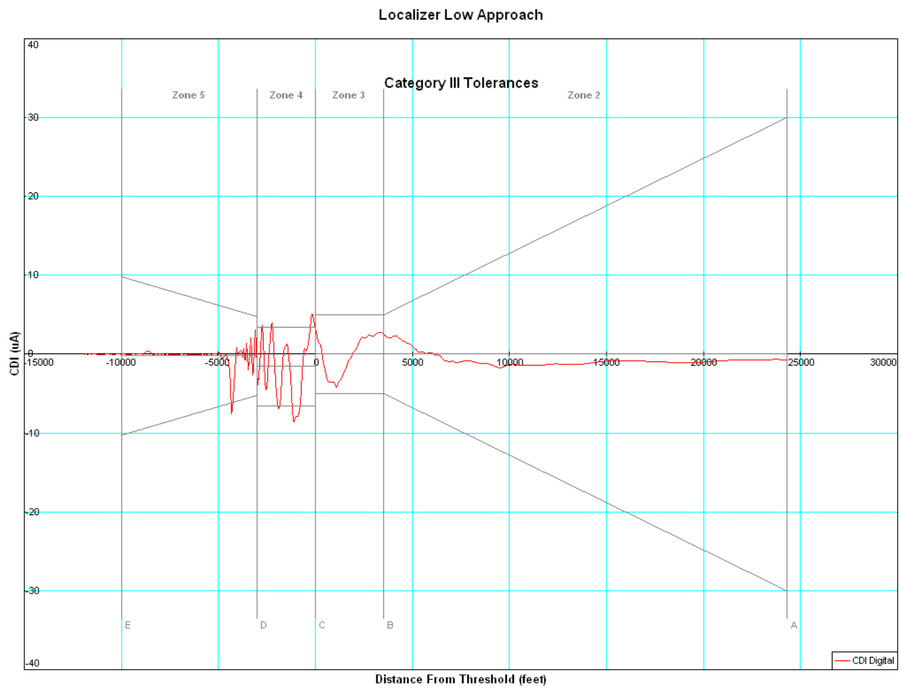
Flight Inspection Structure Prediction for 27L Localiser with A380 at Position P17



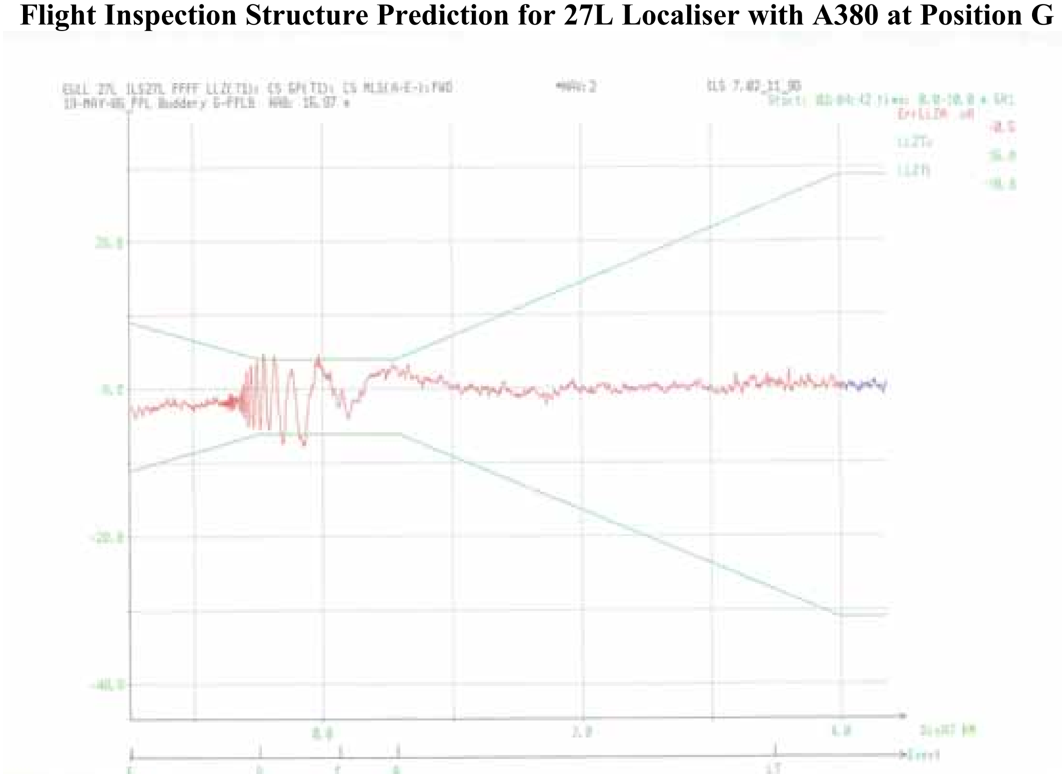
Actual Flight Inspection Structure Plot for 27L Localiser with A380 at Position P17



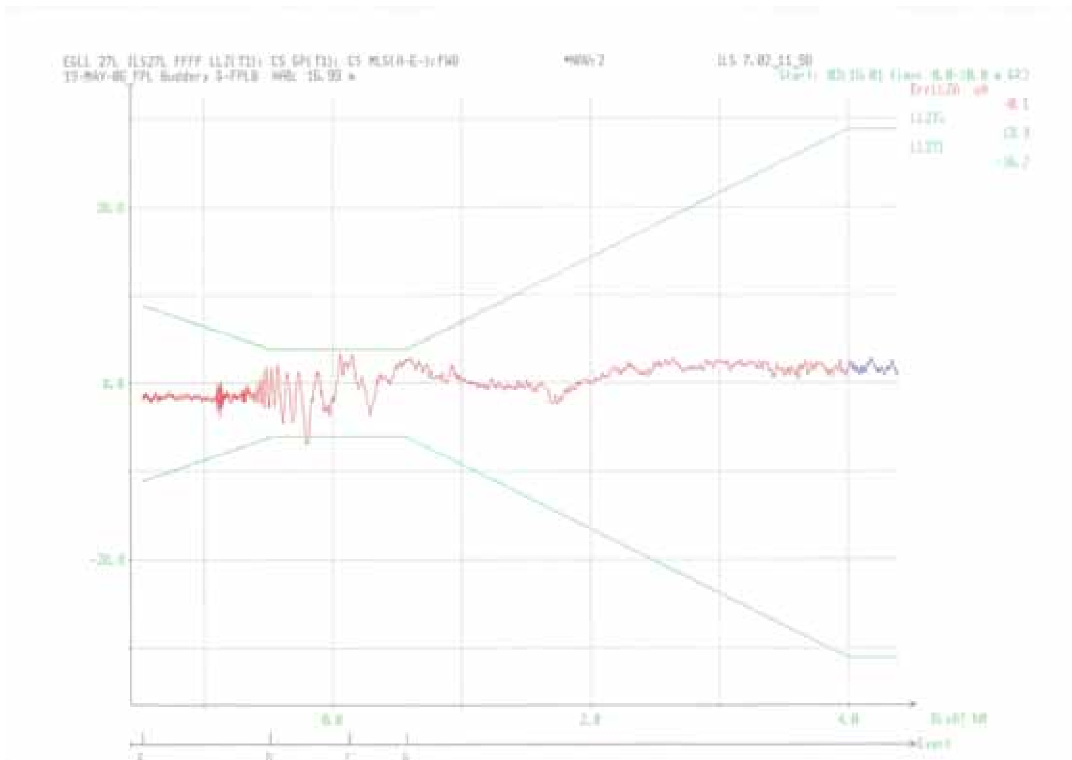
Positions F and G



Flight Inspection Structure Prediction for 27L Localiser with A380 at Position G



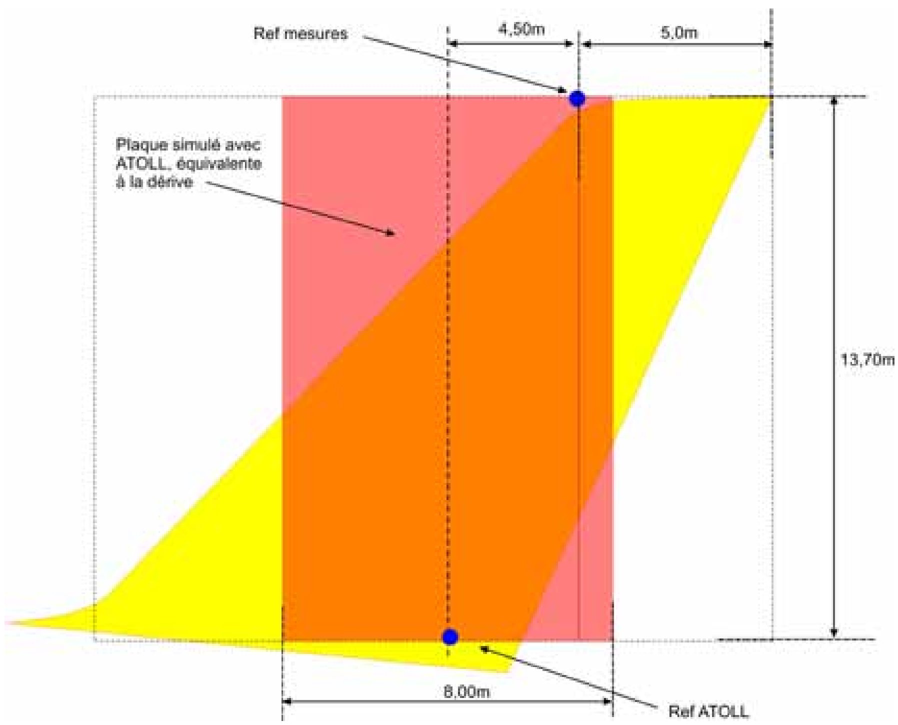
Actual Flight Inspection Structure Plot for 27L Localiser with A380 at Position G



Actual Flight Inspection Structure Plot for 27L Localiser with A380 at Position G+20

ANNEX K : Comparison of A380 ILS disturbance with ATOLL simulations for Toulouse and Frankfurt A380 cases

Simulation of A380 tail is made by the following rectangular metallic sheet

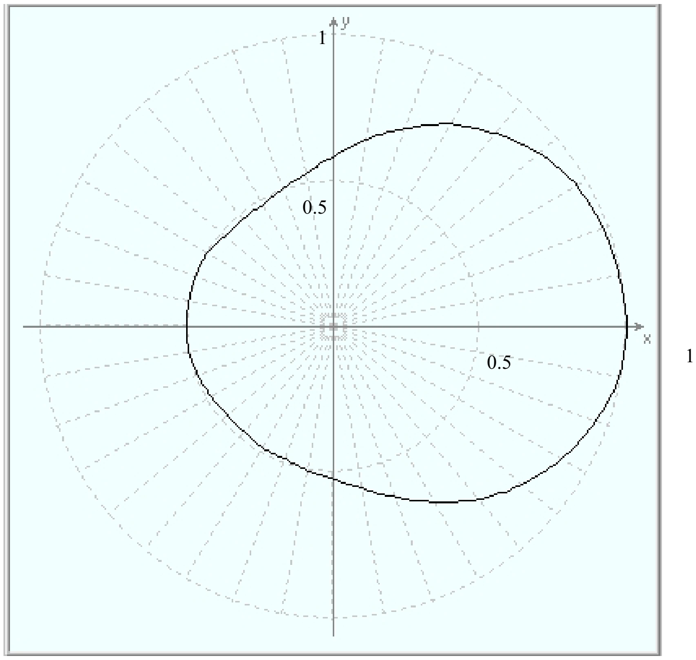


Simulation conditions:
Receiver features close to EVS200 (to be confirmed)
Receiver speed: 40km/h or 10km/h when mentioned.
Antenna height above the ground: 4m

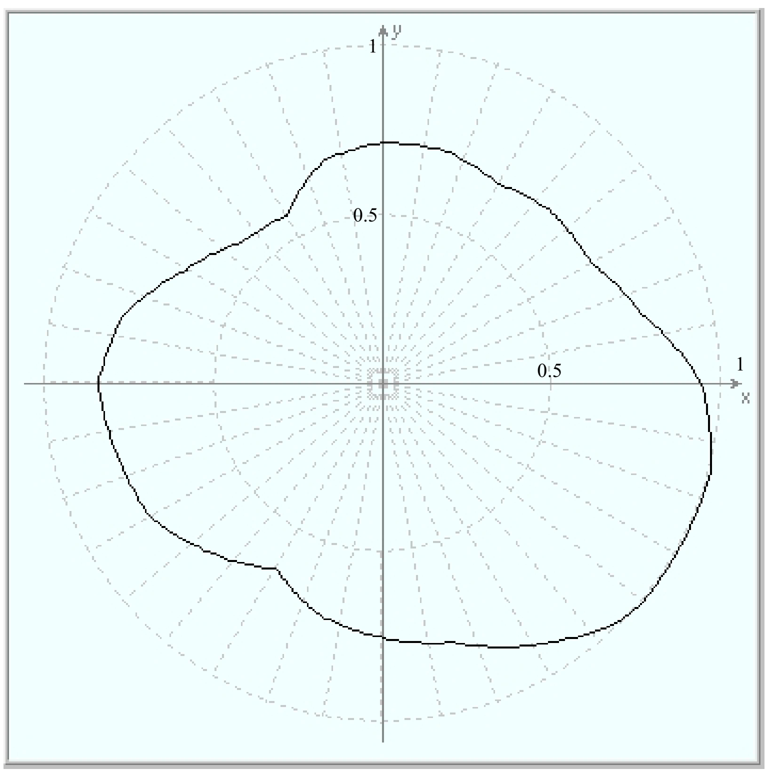
Raw data with omni directional antenna= green curves
Raw data with DFS or DSNA receiver antenna= orange curves

Data with DFS or DSNA antenna filtered using ICAO time constant = blue curves

Simulated DFS receiver antenna pattern



Simulated DSNA receiver antenna pattern



Simulation evaluation versus measurements

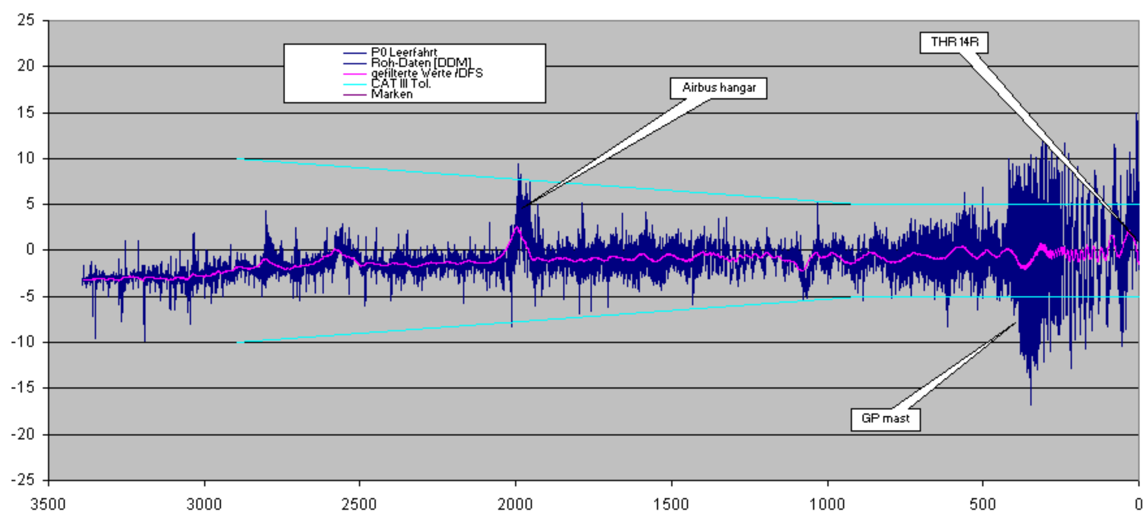
The comparison between simulations and measurements are made on the filtered curves. Filtered curves are obtained by filtering the raw data (output at measurement receiver) applying ICAO recommendation for evaluating roughness and bends.

The raw data have therefore been filtered using a low pass filter of the first order with a time constant adjusted to the speed of the measurement vehicle according to ICAO recommendation.

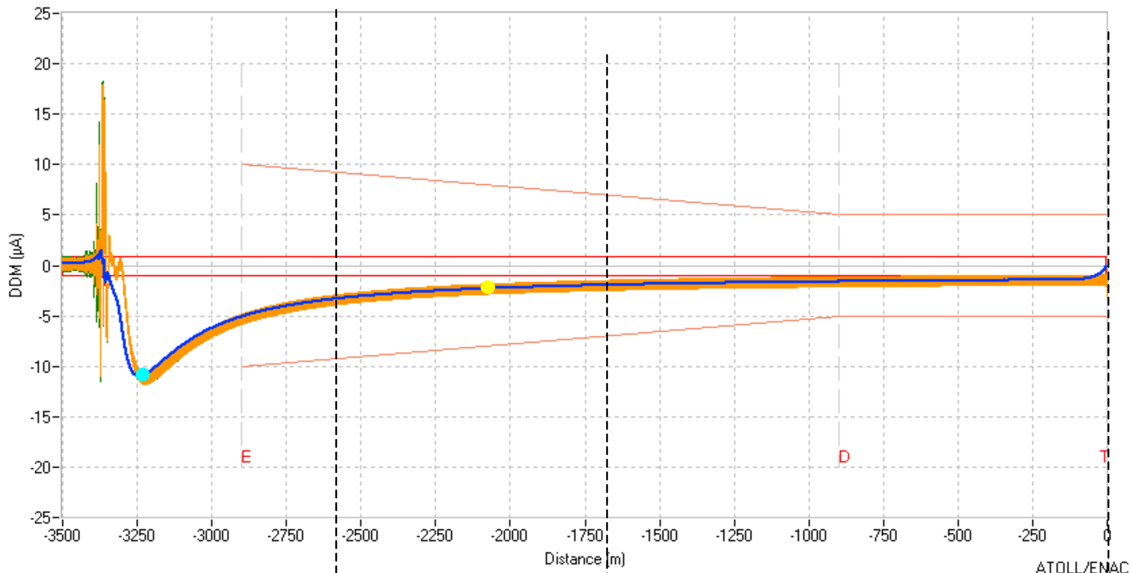
$$\tau = 92{,}6/V \quad \text{with } V \text{ in km/h}$$

Toulouse Airport

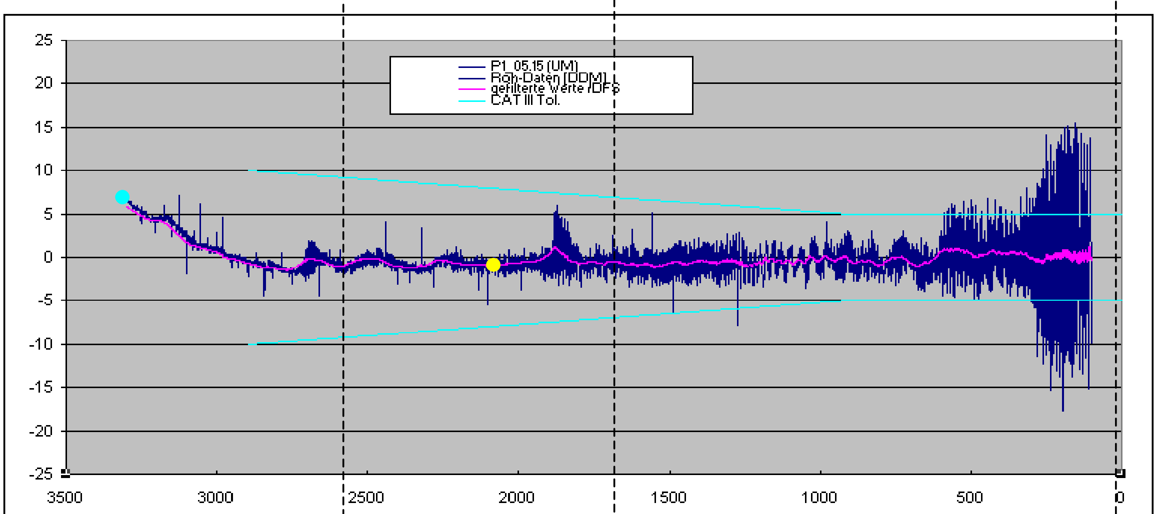
Reference record without A380



P1: Tail : Forward = 710, sideway = -5, rotation = 21°
Simulation and measurements with DFS receiver antenna



Disturbance amplitude: T1=-11µA, T2=-2µA

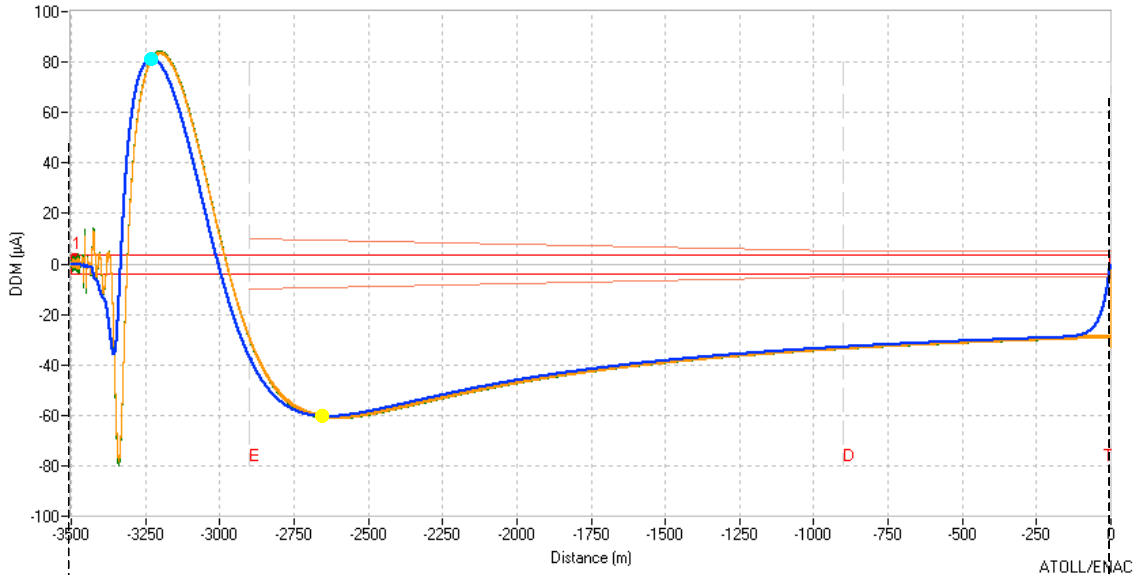


Disturbance amplitude **with** A380: T1=+6 µA, T2=-0.9µA
Disturbance amplitude **without** A380 at same points: T1=-3µA, T2=-1.4µA

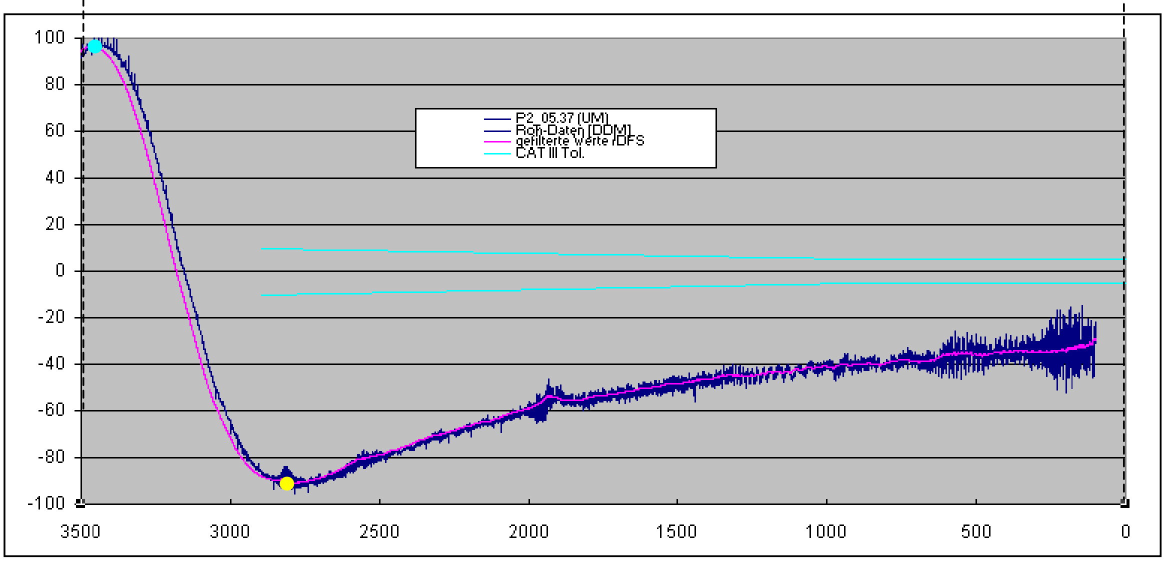
Disturbance amplitude with A380 **only**: T1=3µA, T2=0.5µA

Difference between simulation and measurements:
T1: -11 – 3 = -14µA
T2: -2 – (-0.5) = -1.5µA

P2: Tail: Forward = 608, sideway = 29, rotation = 83°
Simulation and measurements with DFS receiver antenna



Disturbance amplitude: T1=80µA, T2=-60µA

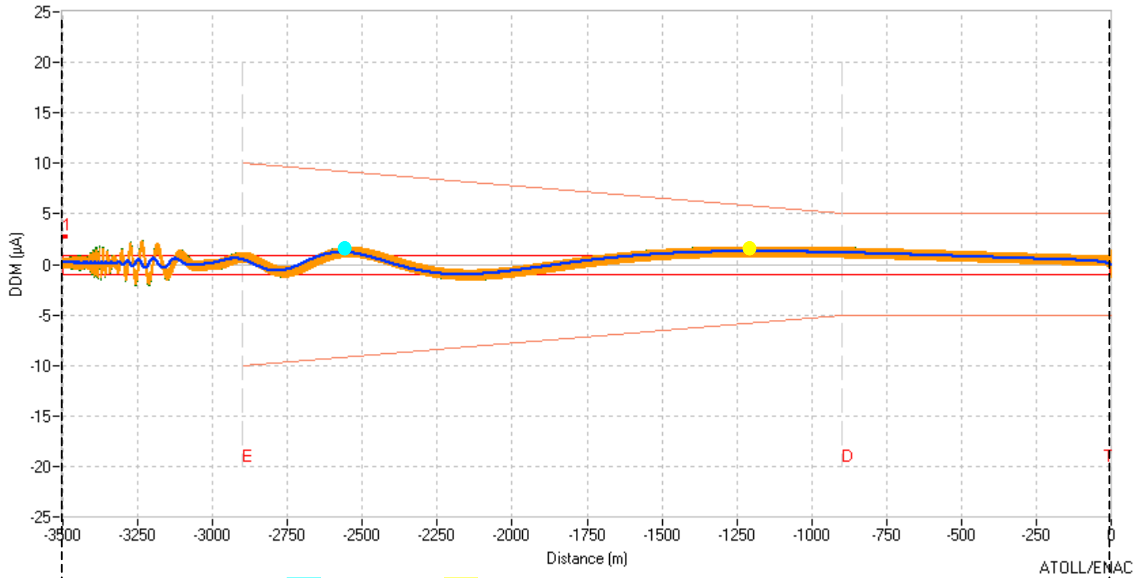


Disturbance amplitude **with** A380: T1=+96 µA, T2=-90µA
Disturbance amplitude **without** A380 at same points: T1=-3µA, T2=-2 µA

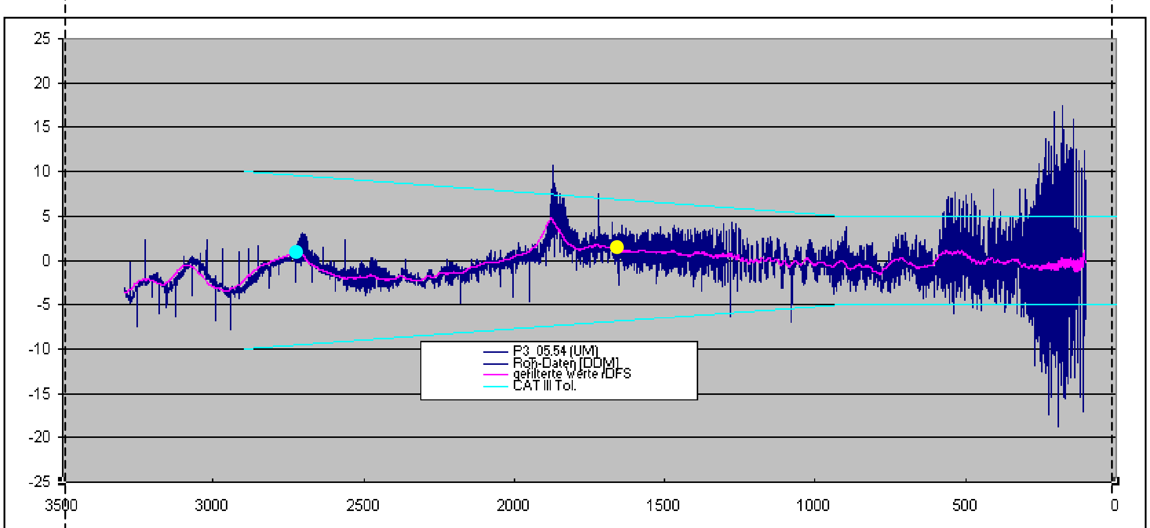
Disturbance amplitude with A380 **only**: T1=99µA, T2=-88µA

Difference between simulation and measurements:
T1: 80 – 99 = -19µA
T2: -60 – (-88) = 28µA

P3: Tail: Forward = 603, sideway = 93, rotation = 90°
Simulation and measurements with DFS receiver antenna



Disturbance amplitude: T1 = 1.2µA, T2 = 1.3µA

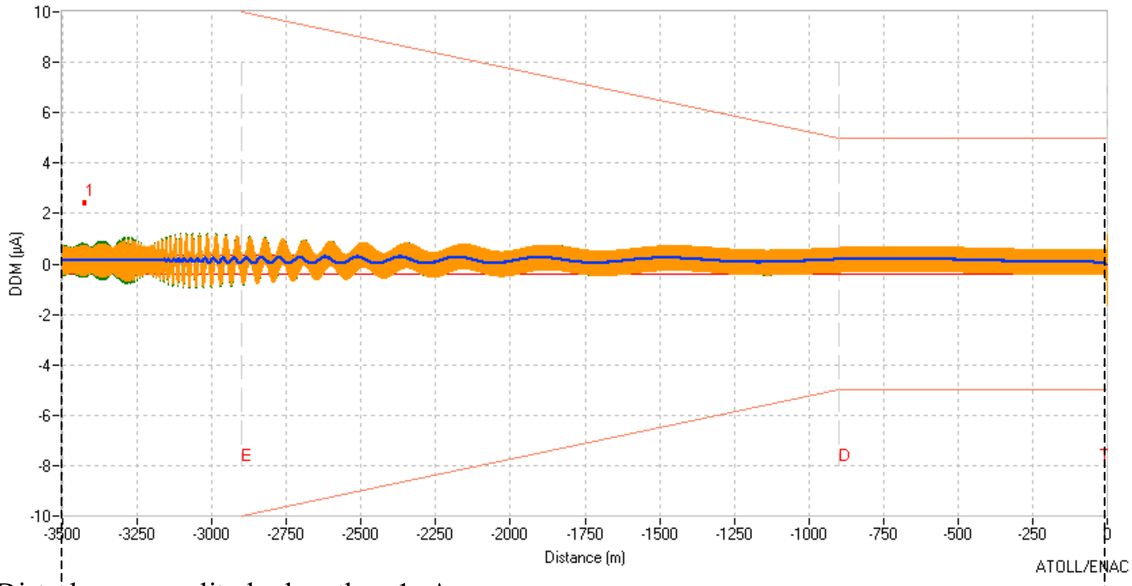


Disturbance amplitude **with** A380: T1 = +0.7 µA, T2 = 1.2µA
Disturbance amplitude **without** A380 at same points: T1=-1.4µA, T2=-0.6µA

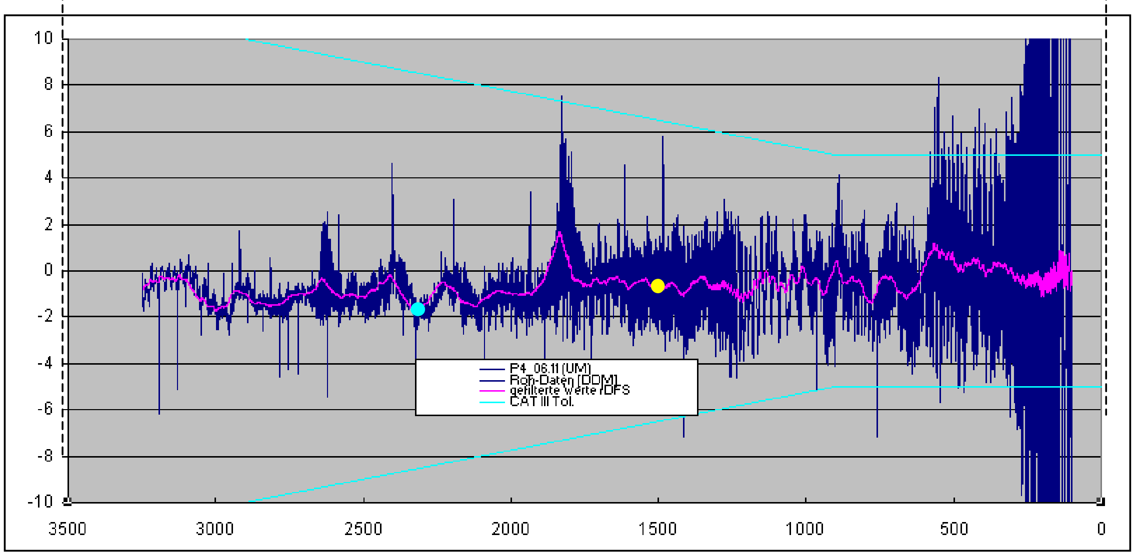
Disturbance amplitude with A380 **only**: T1 = 2.1µA, T2 = 1.8µA

Difference between simulation and measurements:
T1: 1.2 – 2.1 = -0.9µA
T2: 1.3 – (1.8) = -0.5µA

P4: Tail : Forward = 662m, sideway = 198m, rotation = 5°
Simulation and measurements with DFS receiver antenna



Disturbance amplitude: less than 1µA

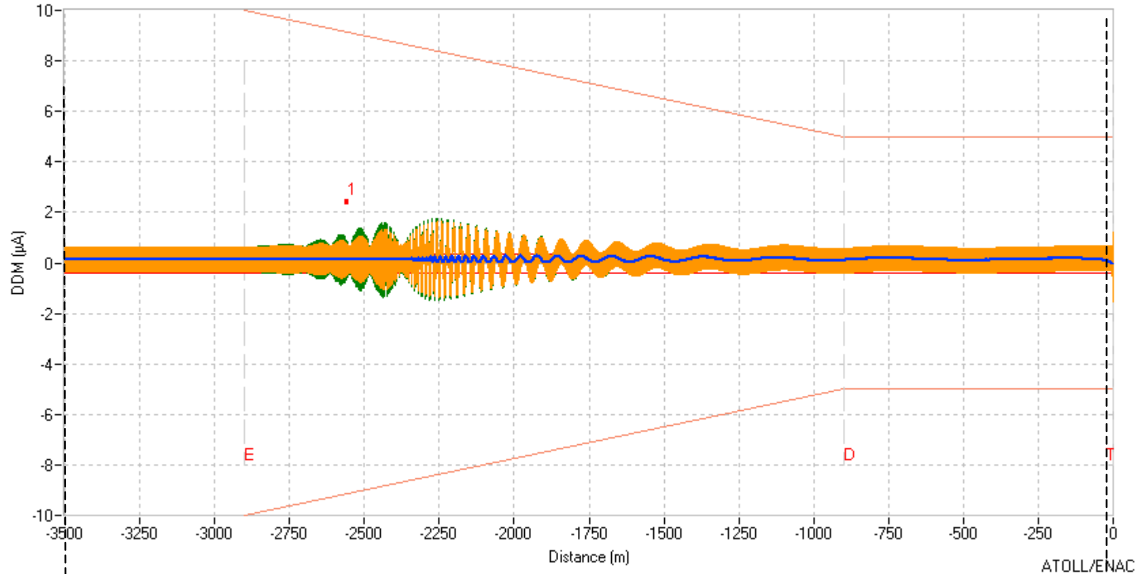


Disturbance amplitude **with** A380: T1 = -1.5 µA, T2 = -0.4µA
Disturbance amplitude **without** A380 at same points: T1=-1.4µA, T2=-1µA

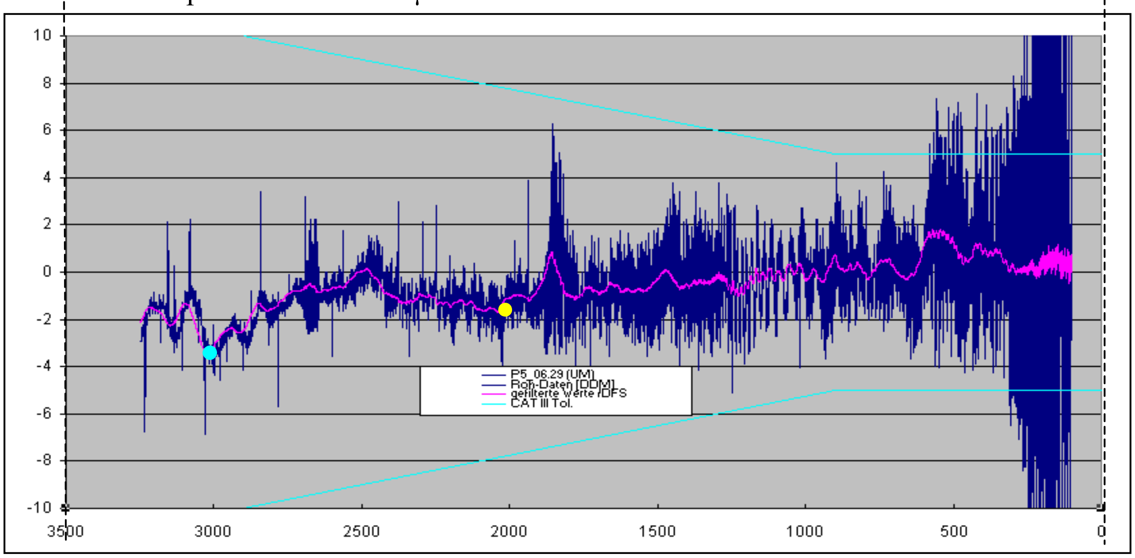
Disturbance amplitude with A380 **only**: T1 = -0.1µA, T2 = 0.6µA

Difference between simulation and measurements:
T1: 0 – (-0.1) = 0.1µA
T2: 0 – (0.6) = -0.6µA

P5: Tail : Forward = 1531m, sideway = 198m, rotation = 0°
Simulation and measurements with DFS receiver antenna



Disturbance amplitude: less than 1µA

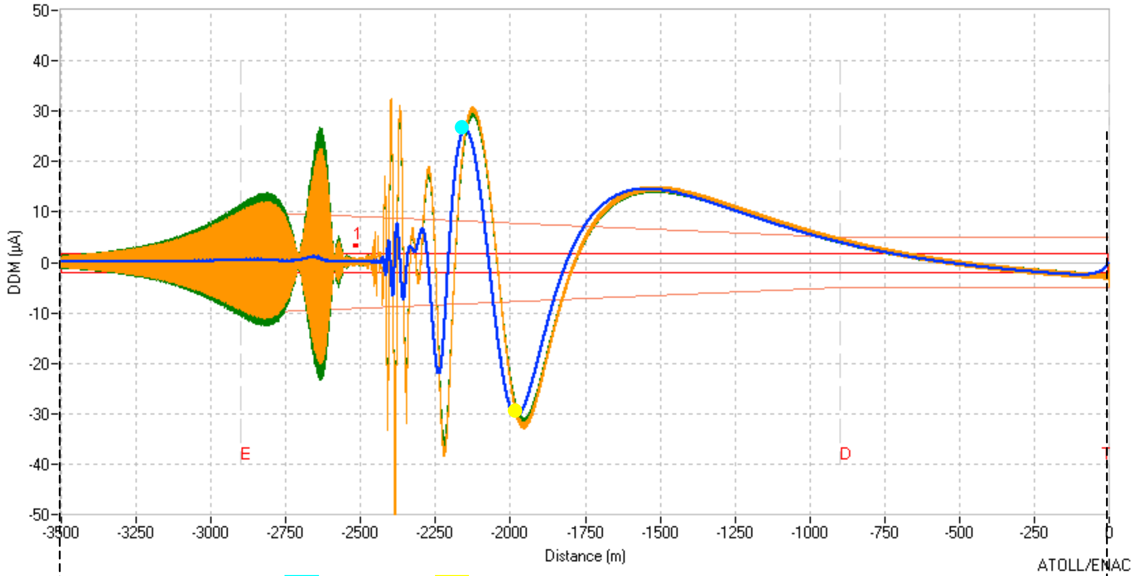


Disturbance amplitude **with** A380: T1 = -3 µA, T2 = -1.5µA
Disturbance amplitude **without** A380 at same points: T1=-3µA, T2=-1.5µA

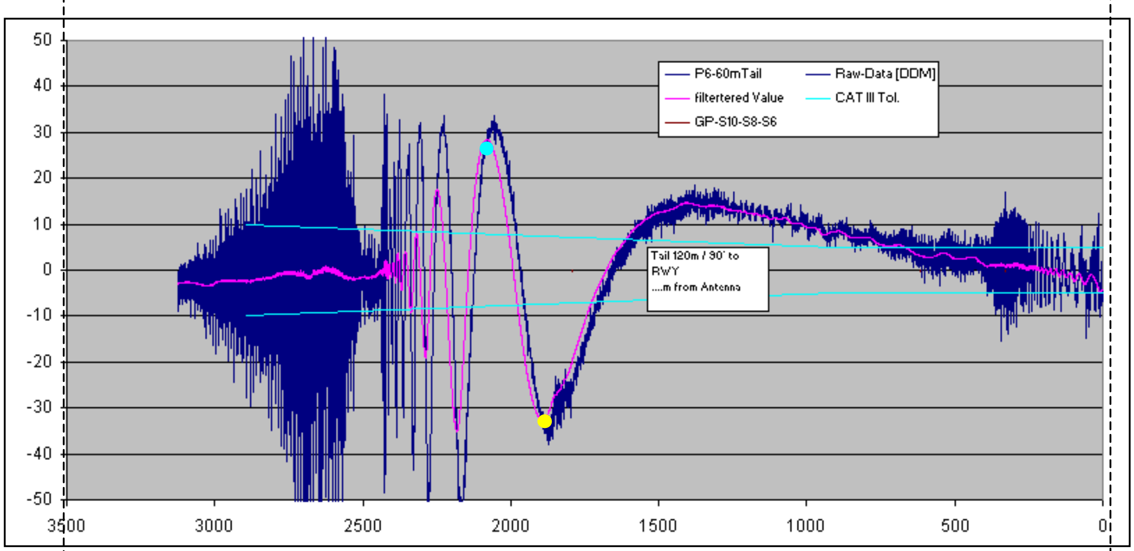
Disturbance amplitude with A380 **only**: T1 = -0.0µA, T2 = 0.0µA

Difference between simulation and measurements:
T1: 0 – (0.0) = 0.0µA
T2: 0 – (0.0) = 0.0µA

P6: Tail: Forward = 1579m, sideway = 57m, rotation = 90°
Simulation and measurements with DSNA receiver antenna (orange = raw data)



Disturbance amplitude: T1 = 26µA, T2 = -29µA

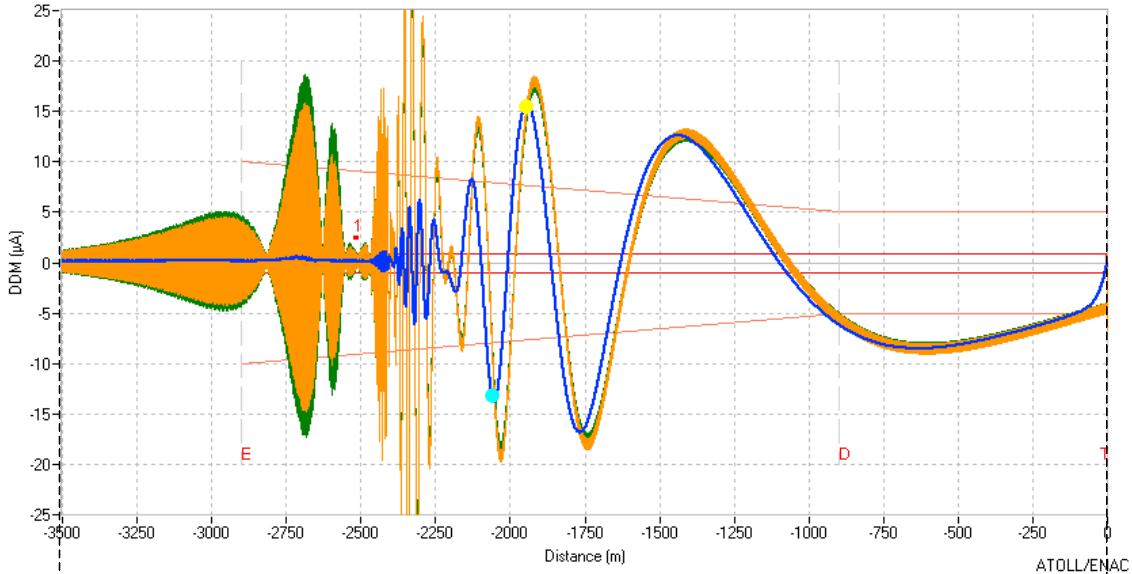


Disturbance amplitude **with** A380: T1 = 27 µA, T2 = -31µA
Disturbance amplitude **without** A380 at same points: T1=-1µA, T2=-1µA

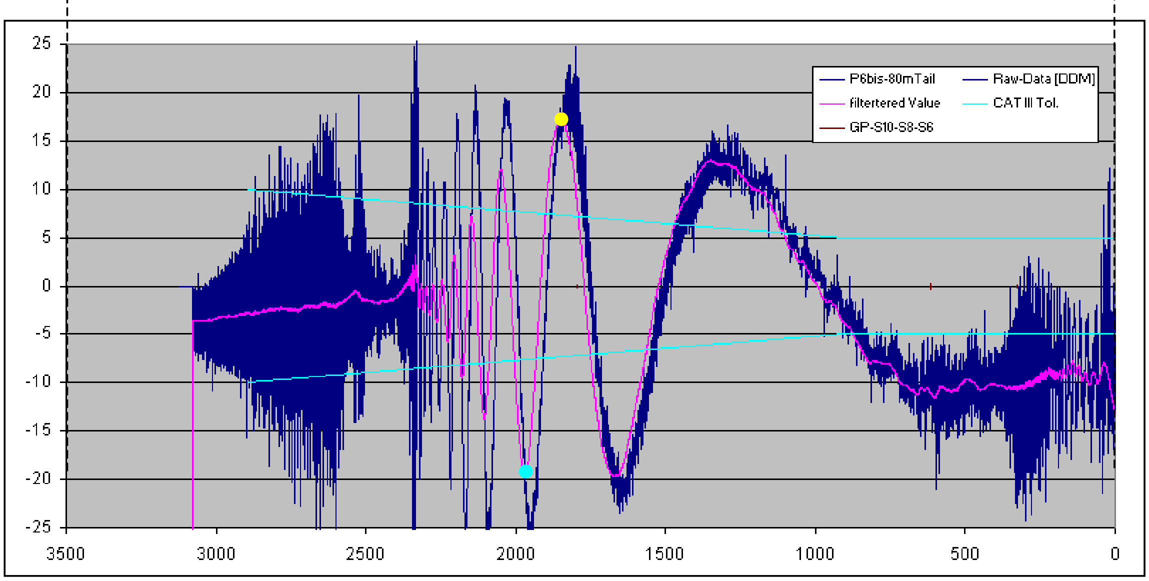
Disturbance amplitude with A380 **only**: T1 = 28µA, T2 = -30 µA

Difference between simulation and measurements:
T1: 26 – (28) = -2µA
T2: -29 – (-30) = 1µA

P6 bis: Tail: Forward = 1579m, sideway = 83m, rotation = 90°
Simulation and measurements with DSNA receiver antenna



Disturbance amplitude: T1 = -13µA, T2 = +15µA

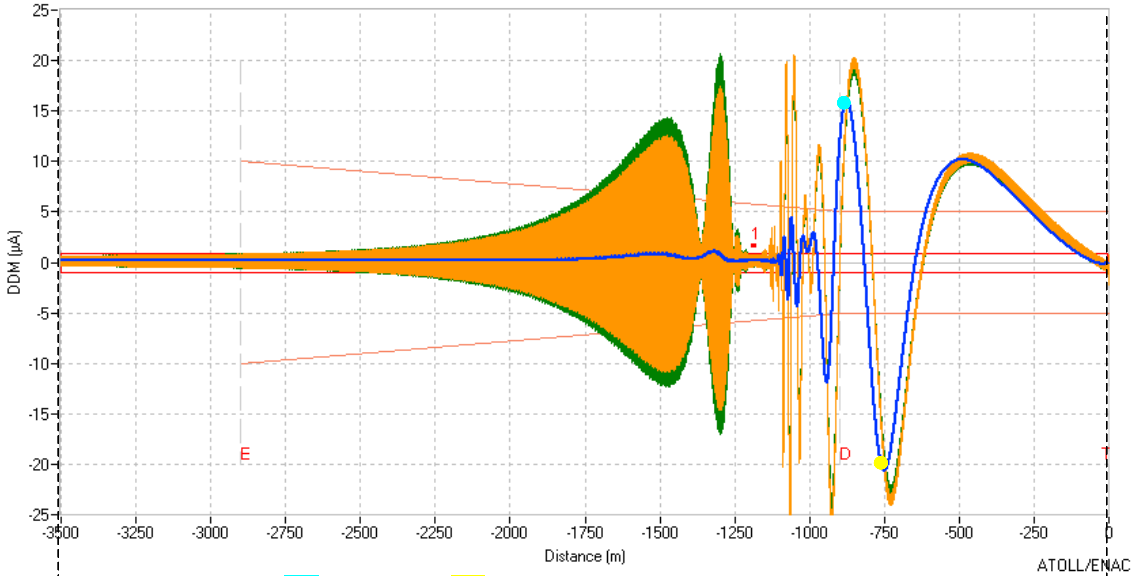


Disturbance amplitude **with** A380: T1 = -19 µA, T2 = 17µA
Disturbance amplitude **without** A380 at same points: T1=-1µA, T2=-1µA

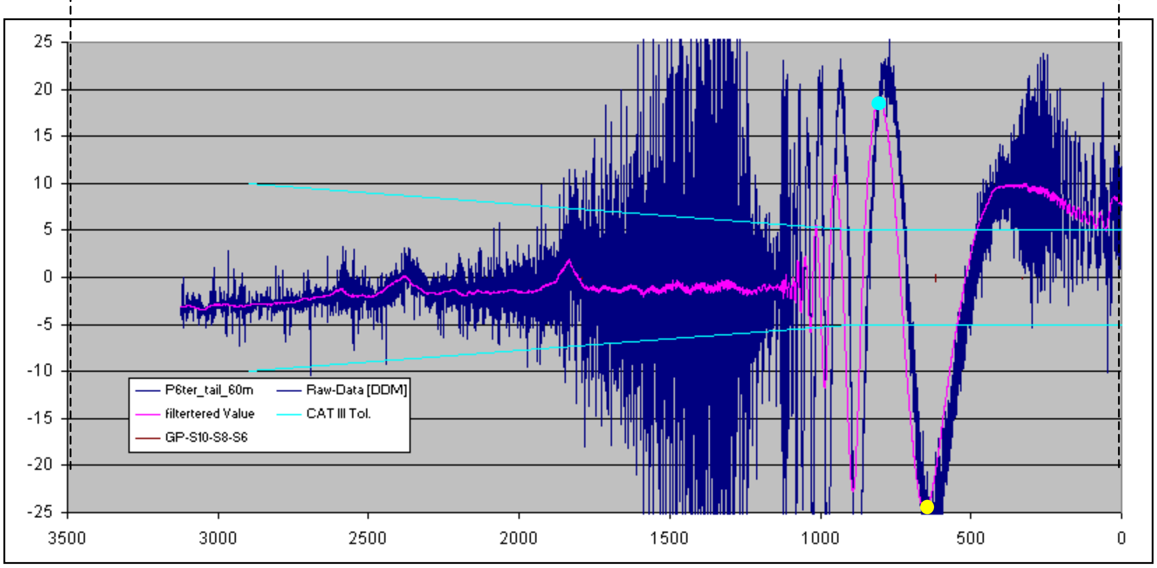
Disturbance amplitude with A380 **only**: T1 = -18µA, T2 = 18 µA

Difference between simulation and measurements:
T1: -13 – (-18) = +5µA
T2: +15 – (18) = -3µA

P6 ter: Tail: Forward = 2909m, sideway = 56m, rotation = 90°
Simulation and measurements with DSNA receiver antenna (orange = raw data)



Disturbance amplitude: T1 = +16µA, T2 = -20µA

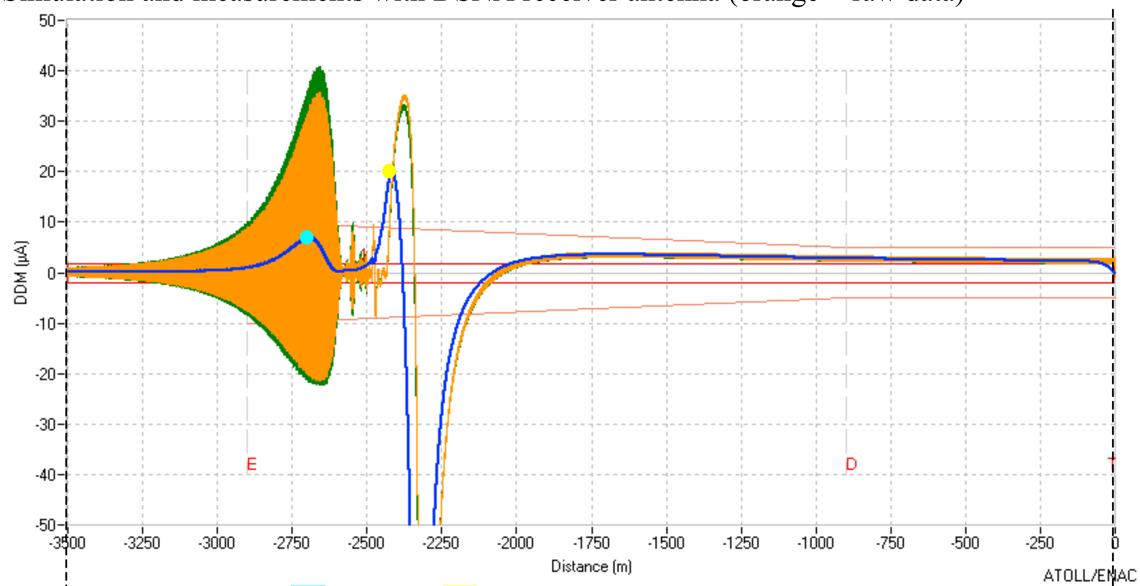


Disturbance amplitude **with** A380: T1 = +18 µA, T2 = -24µA
Disturbance amplitude **without** A380 at same points: T1=-1µA, T2=-1µA

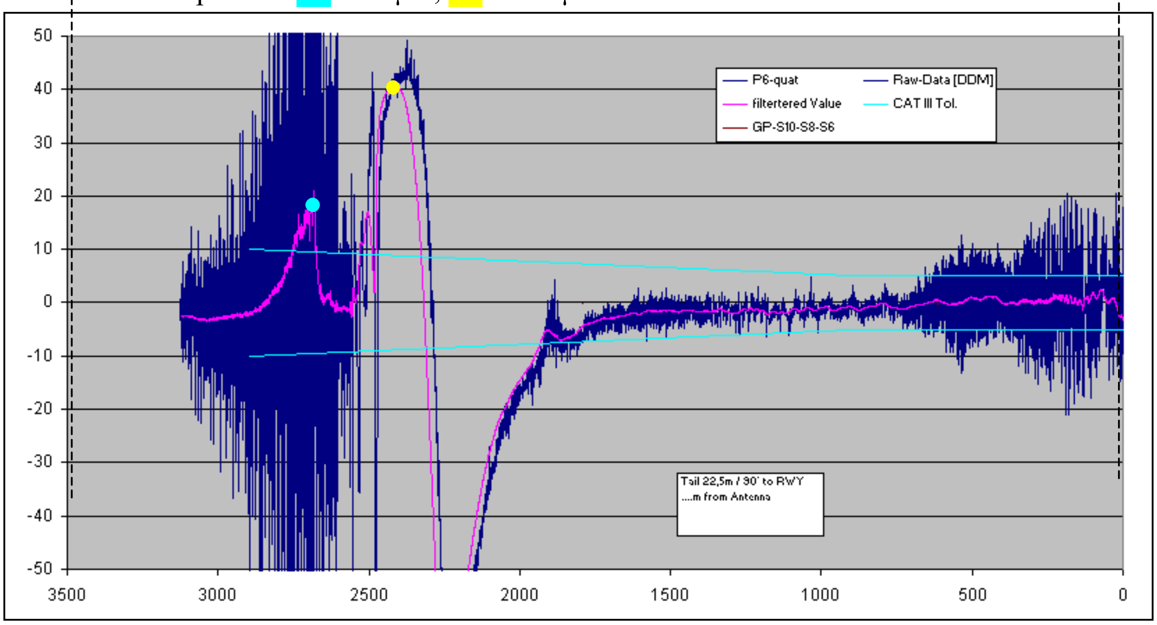
Disturbance amplitude with A380 **only**: T1 = +19µA, T2 = -23 µA

Difference between simulation and measurements:
T1: +16 – (+19) = -3µA
T2: -20 – (-23) = +3µA

P6 quad: Tail: Forward = 1579m, sideway = 21m, rotation = 90°
Simulation and measurements with DSNA receiver antenna (orange = raw data)



Disturbance amplitude: T1 = +7µA, T2 = +19µA

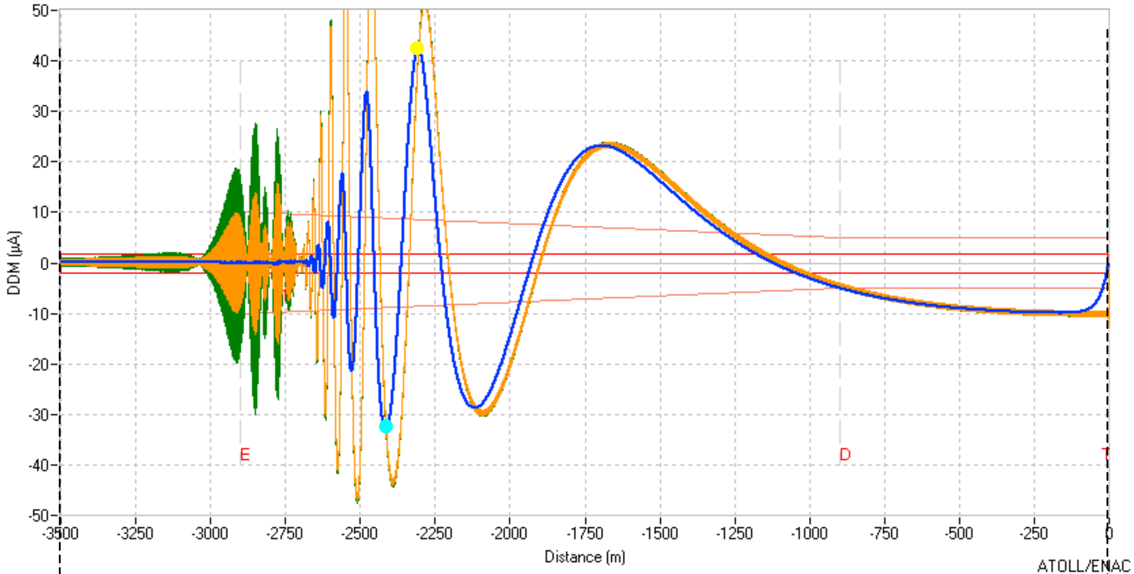


Disturbance amplitude **with** A380: T1 = +20 µA, T2 = +40µA
Disturbance amplitude **without** A380 at same points: T1=-2µA, T2=-2µA

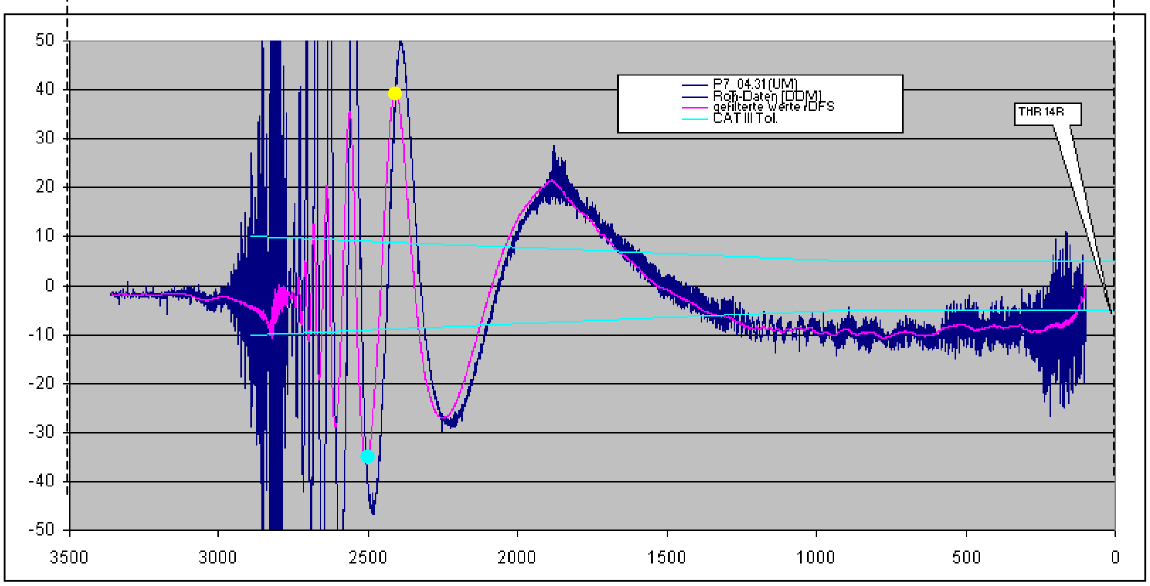
Disturbance amplitude with A380 **only**: T1 = +22µA, T2 = +42 µA

Difference between simulation and measurements:
T1: +7 – (+22) = -15µA
T2: +19 – (+42) = -23µA

P7: Tail: Forward = 1313m, sideway = -69m, rotation = 42°
Simulation and measurements with DFS receiver antenna (orange = raw data)



Disturbance amplitude: T1 = -33.5µA, T2 = +43µA

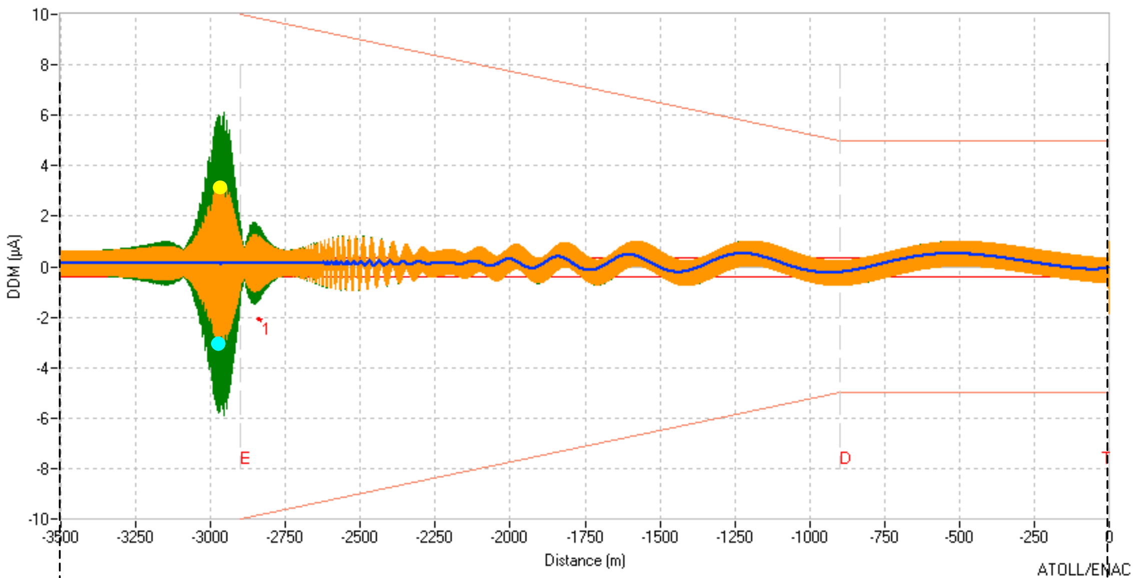


Disturbance amplitude **with** A380: T1 = -34 µA, T2 = +39µA
Disturbance amplitude **without** A380 at same points: T1 = -1.0µA, T2 = -1.5µA

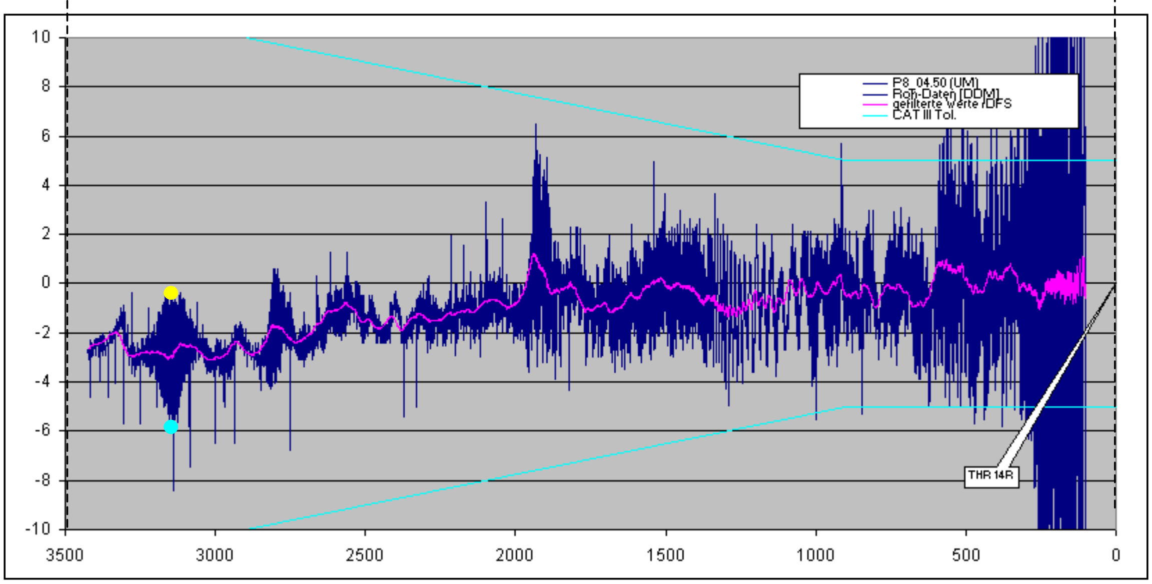
Disturbance amplitude with A380 **only**: T1 = -33µA, T2 = +40.5 µA

Difference between simulation and measurements:
T1: -33.5 – (-33) = -0.5µA
T2: +43.0 – (+40.5) = -2.5µA

P8: Tail: Forward = 1247m, sideway = -173m, rotation = 60°
Simulation and measurements with DFS receiver antenna (orange = raw data)
NOTE: for this point DDM values for checkpoints (T) are on DFS antenna raw data because the filtered curves show no errors.

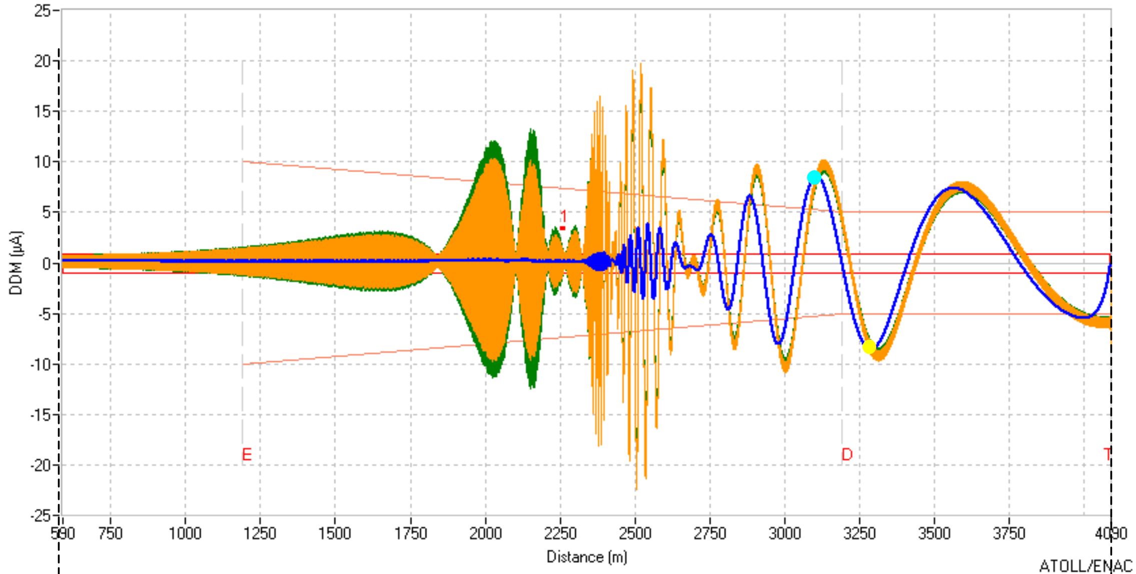


Disturbance amplitude: T1 = -3.0µA, T2 = +3.0µA

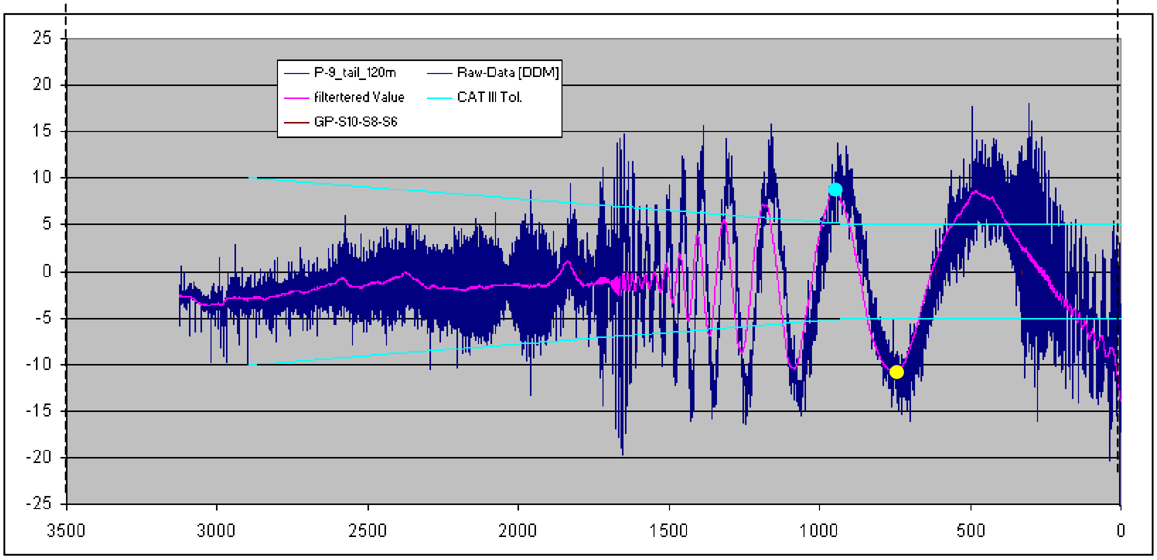


Disturbance amplitude **with** A380: T1 = -5.5 µA, T2 = -0.5µA
Disturbance amplitude **without** A380 at same points: T1 = -3.0µA, T2 = -3.0µA
Disturbance amplitude with A380 **only**: T1 = -2.5µA, T2 = +2.5 µA
Difference between simulation and measurements:
T1: -3.0 – (-2.5) = -0.5µA
T2: +3.0 – (+2.5) = +0.5µA

P9: Tail: Forward = 2267m, sideway = 116m, rotation = 90°
Simulation and measurements with DSNA receiver antenna (orange = raw data)



Disturbance amplitude: T1 = +8µA, T2 = -9µA

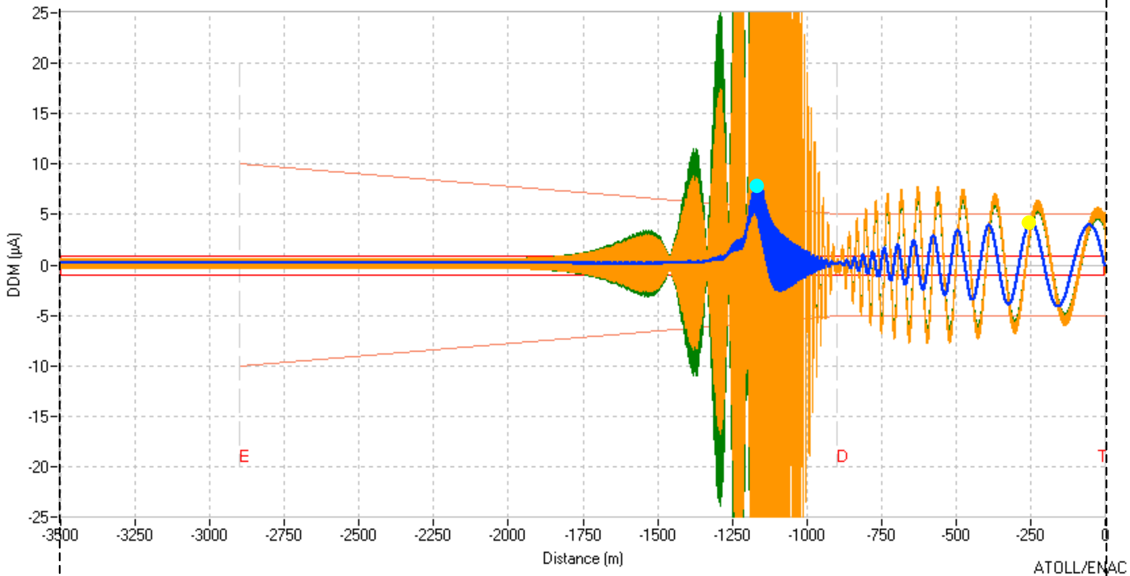


Disturbance amplitude **with** A380: T1 = +8 µA, T2 = -11µA
Disturbance amplitude **without** A380 at same points: T1=-1µA, T2=-1µA

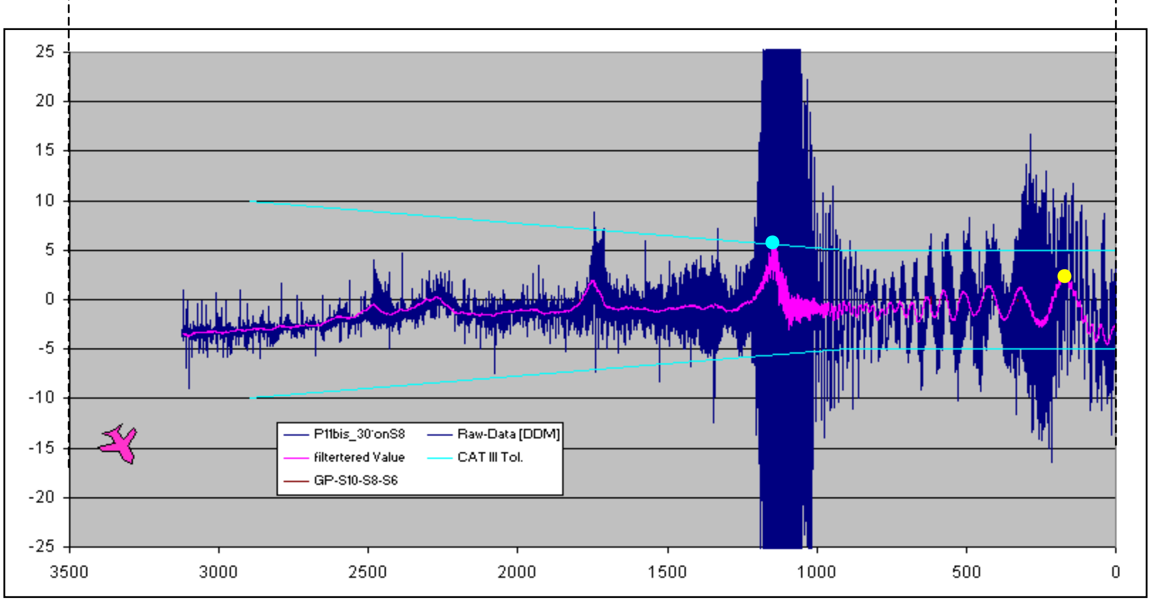
Disturbance amplitude with A380 **only**: T1 = +9µA, T2 = -10 µA

Difference between simulation and measurements:
T1: +8 – (+9) = -1µA
T2: -9 – (-10) = +1µA

P11 bis at 40 km/h: Tail: Forward = 2860m, sideway = 178m, rotation = -30°
Simulation and measurements with DSNA receiver antenna (orange = raw data)



Disturbance amplitude: T1 = +8.0µA, T2 = +4.0µA

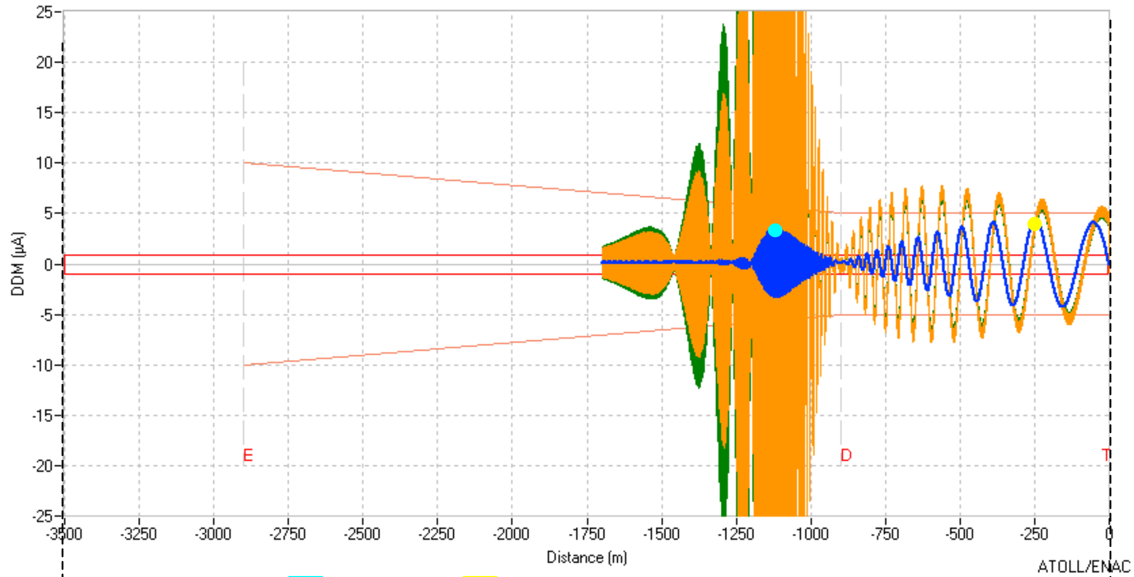


Disturbance amplitude **with** A380: T1 = +6 µA, T2 = +2µA
Disturbance amplitude **without** A380 at same points: T1 = -1µA, T2 = 0µA

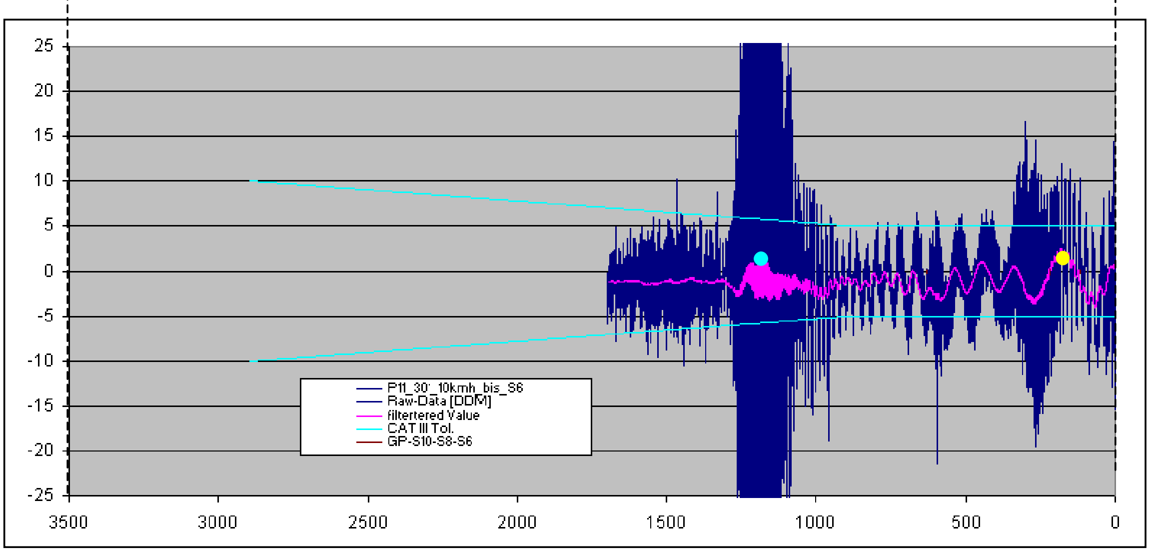
Disturbance amplitude with A380 **only**: T1 = +7µA, T2 = +2 µA

Difference between simulation and measurements:
T1: +8.0 – (+7) = -1µA
T2: +4.0 – (+2) = +2µA

P11 bis at 13 km/h: Tail: Forward = 2860m, sideway = 178m, rotation = -30°
Simulation and measurements with DSNA receiver antenna (orange = raw data)



Disturbance amplitude: T1 = +3.5µA, T2 = +4.0µA

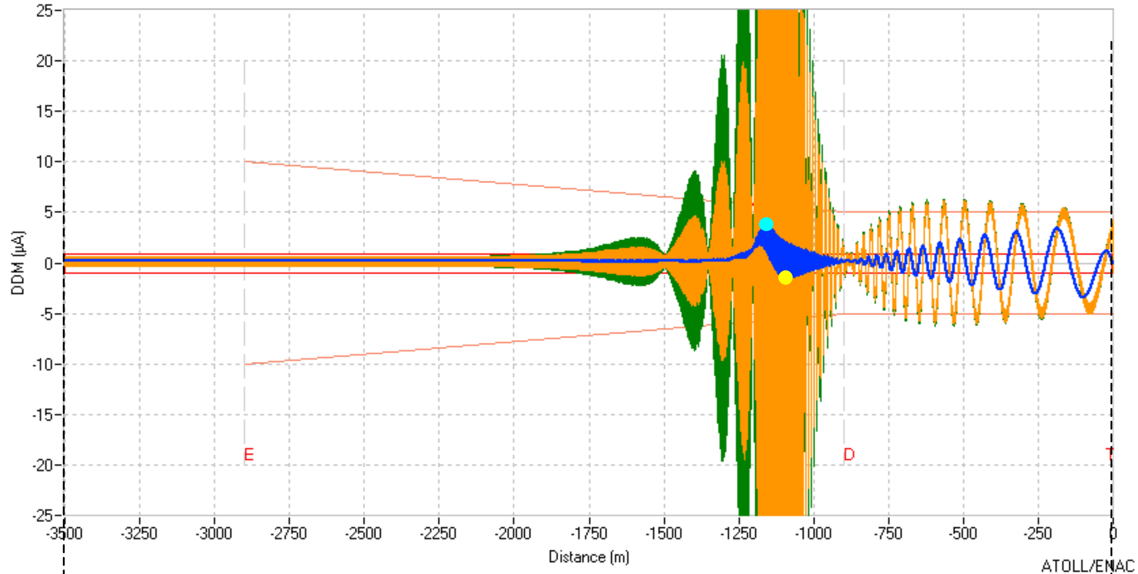


Disturbance amplitude **with** A380: T1 = +1 µA, T2 = +2µA
Disturbance amplitude **without** A380 at same points: T1 = 0µA, T2 = 0µA

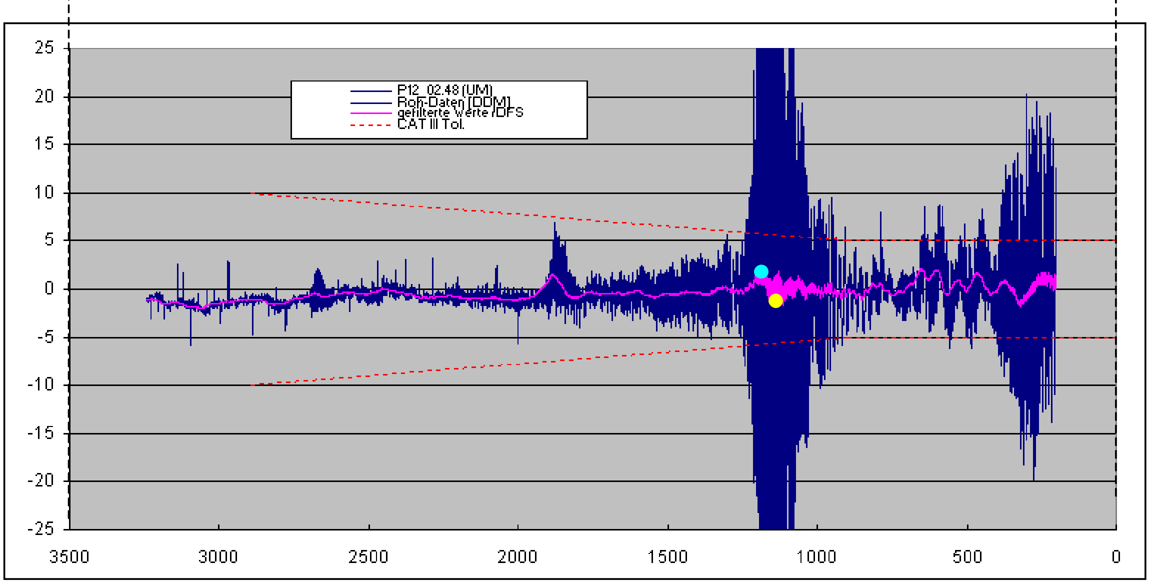
Disturbance amplitude with A380 **only**: T1 = +1µA, T2 = +2 µA

Difference between simulation and measurements:
T1: +3.5 – (+1) = +2.5µA
T2: +4.0 – (+2) = +2.0µA

P12 at 40 km/h: Tail: Forward = 2890m, sideway = 178m, rotation = -30°
Simulation and measurements with DFS receiver antenna (orange = raw data)



Disturbance amplitude: T1 = +3.5µA, T2 = -1.5µA

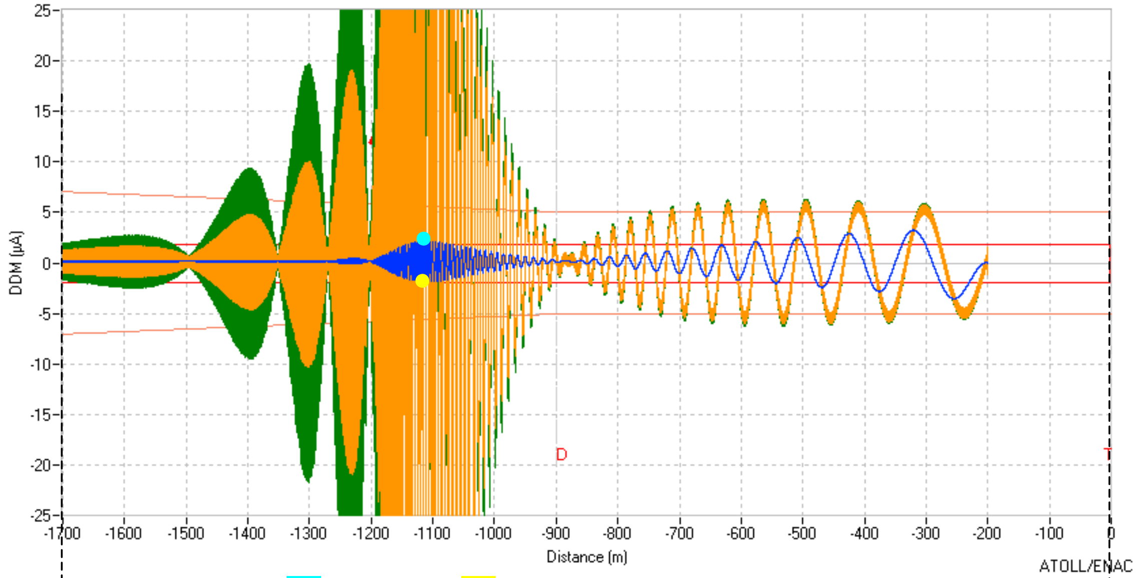


Disturbance amplitude **with** A380: T1 = +1.5 µA, T2 = -1µA
Disturbance amplitude **without** A380 at same points: T1 = 0µA, T2 = -0.5µA

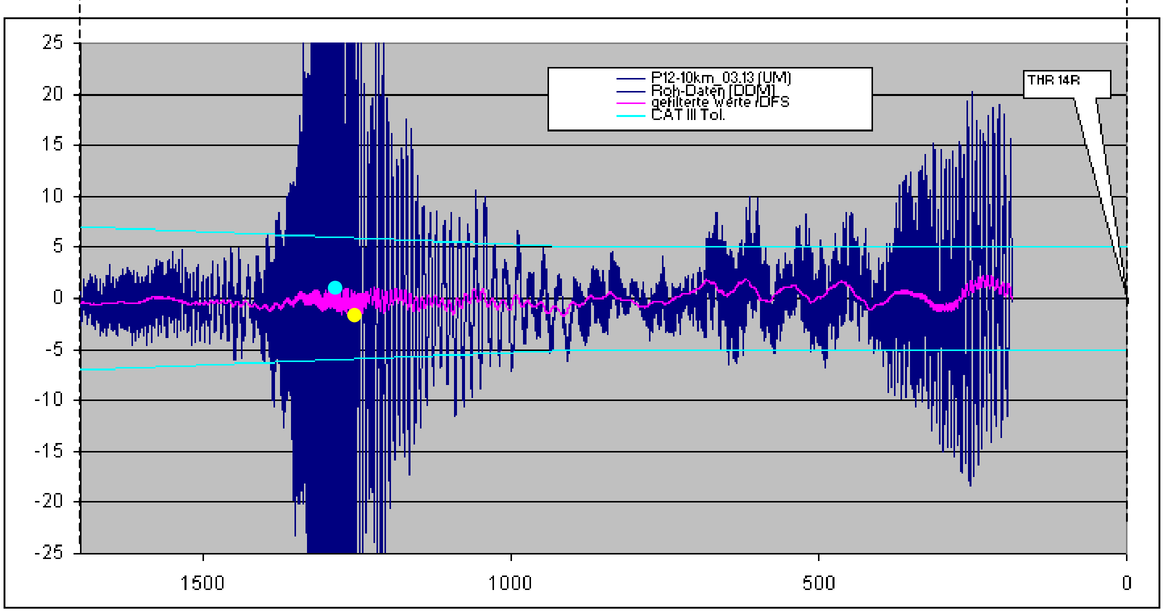
Disturbance amplitude with A380 **only**: T1 = +1.5µA, T2 = -0.5 µA

Difference between simulation and measurements:
T1: +3.5 – (+1.5) = +2.0µA
T2: -1.5 – (-0.5) = -1.0µA

P12 at 10 km/h: Tail: Forward = 2890m, sideway = 178m, rotation = -30°
Simulation and measurements with DFS receiver antenna (orange = raw data)



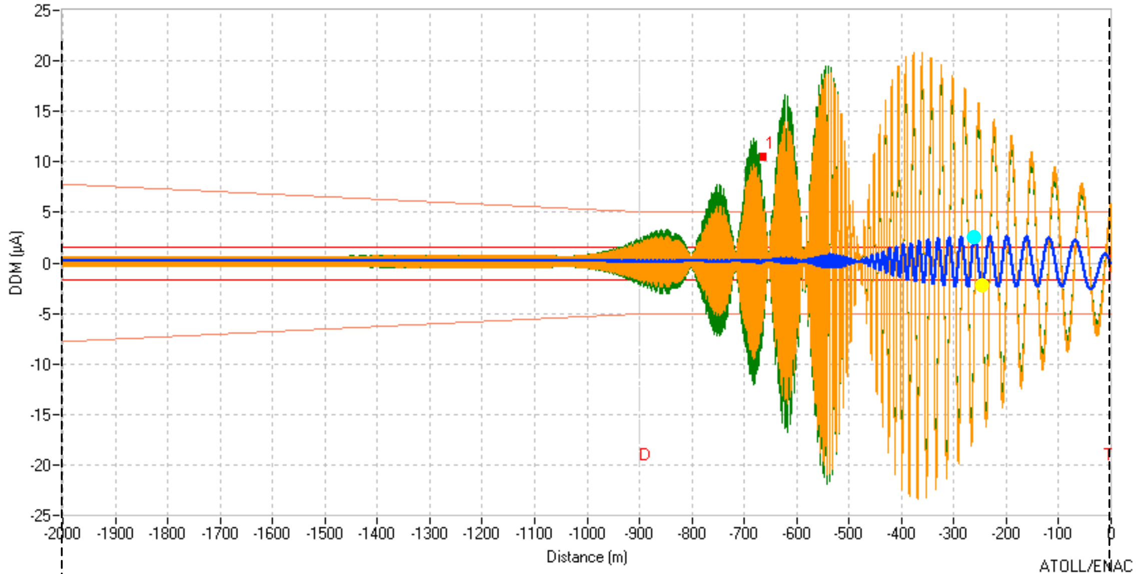
Disturbance amplitude: T1 = +2.0µA, T2 = -2.0µA



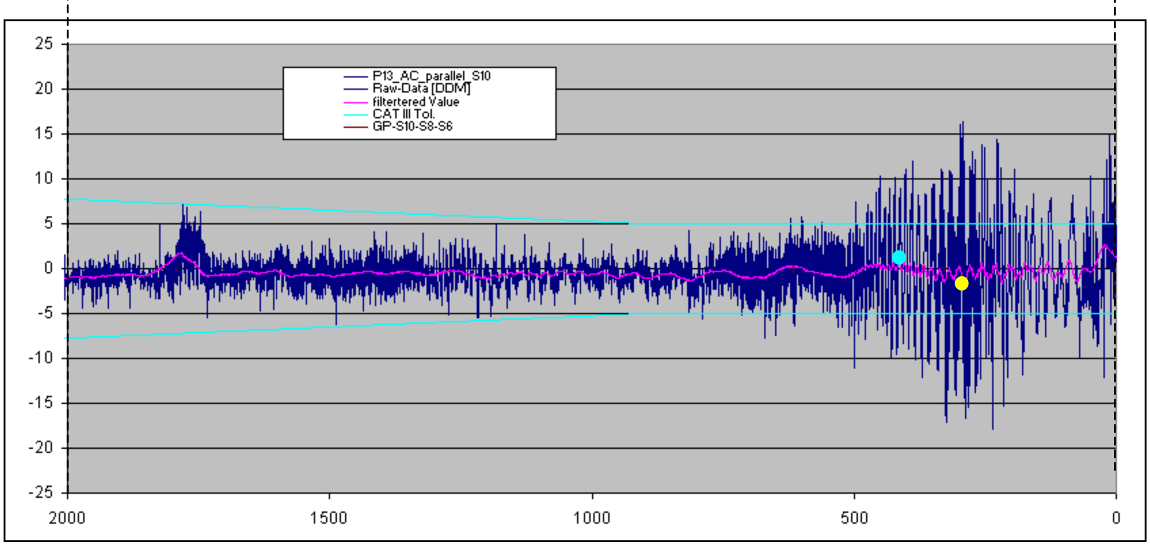
Disturbance amplitude **with** A380: T1 = +1.0 µA, T2 = -1.0µA
Disturbance amplitude **without** A380 at same points: T1 = -1.0µA, T2 = -0.5µA

Disturbance amplitude with A380 **only**: T1 = +2.0µA, T2 = -0.5 µA
Difference between simulation and measurements:
T1: +2.0 – (+2.0) = +0.0µA
T2: -2.0 – (-0.5) = -1.5µA

P13: Tail: Forward = 3426m, sideway = 196m, rotation = 0°
Simulation and measurements with DSNA receiver antenna (orange = raw data)



Disturbance amplitude: T1 = +2.5µA, T2 = -2.0µA

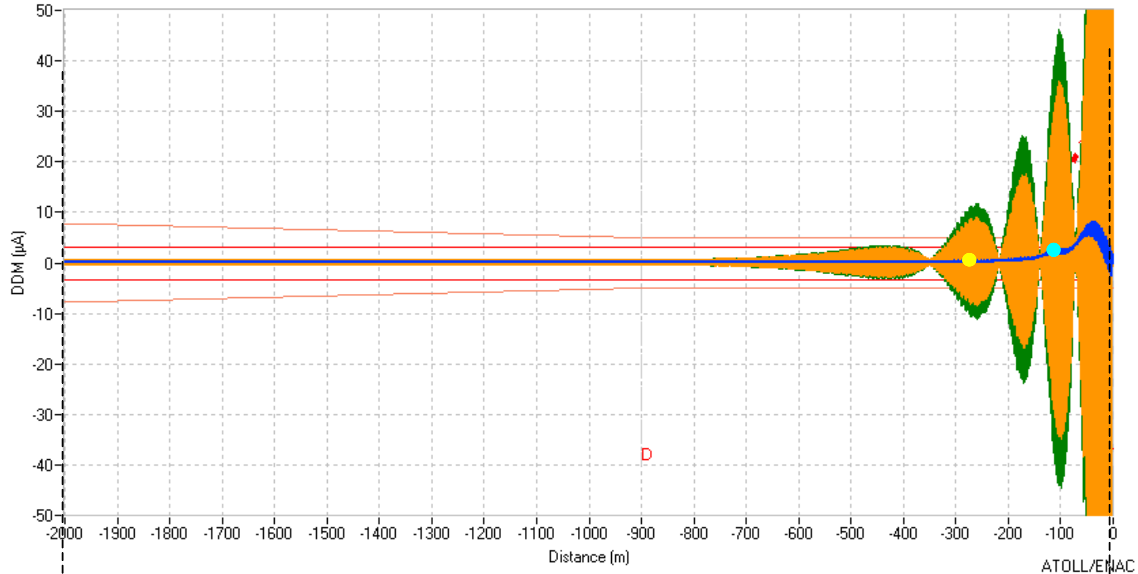


Disturbance amplitude **with** A380: T1 = +0.5µA, T2 = -1.5µA
Disturbance amplitude **without** A380 at same points: T1 = -0.0µA, T2 = -0.5µA

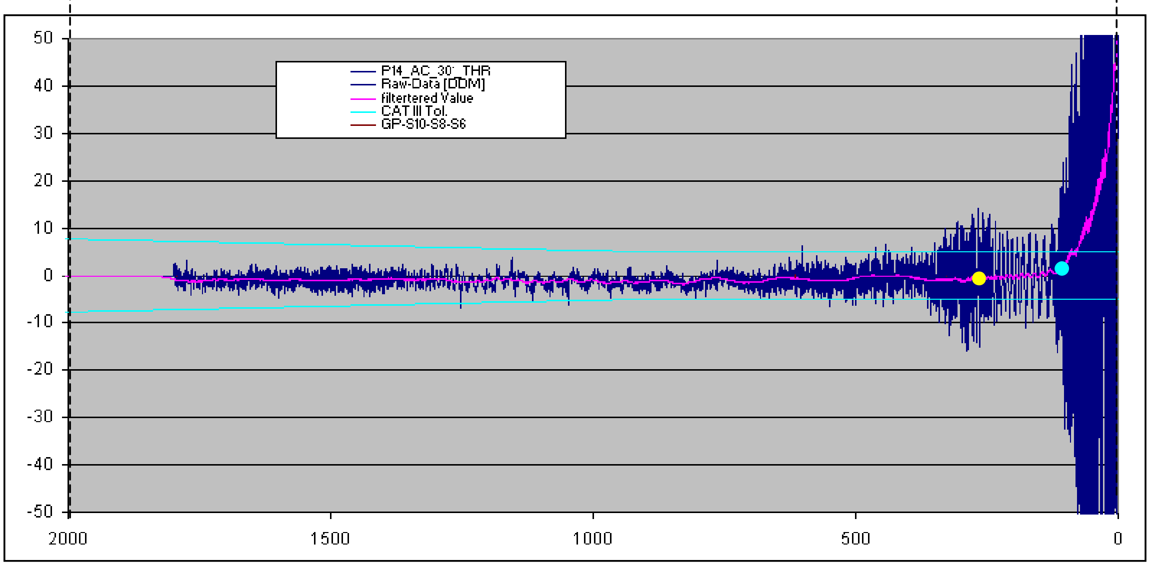
Disturbance amplitude with A380 **only**: T1 = +0.5µA, T2 = -1.0µA

Difference between simulation and measurements:
T1: +2.5 – (+0.5) = +2.0µA
T2: -2.0 – (-1.0) = -1.0µA

P14: Tail: Forward = 4013m, sideway = 194m, rotation = -30°
Simulation and measurements with DSNA receiver antenna (orange = raw data)



Disturbance amplitude: T1 = +2.5µA (100m), T2 = 0.5µA (280m)

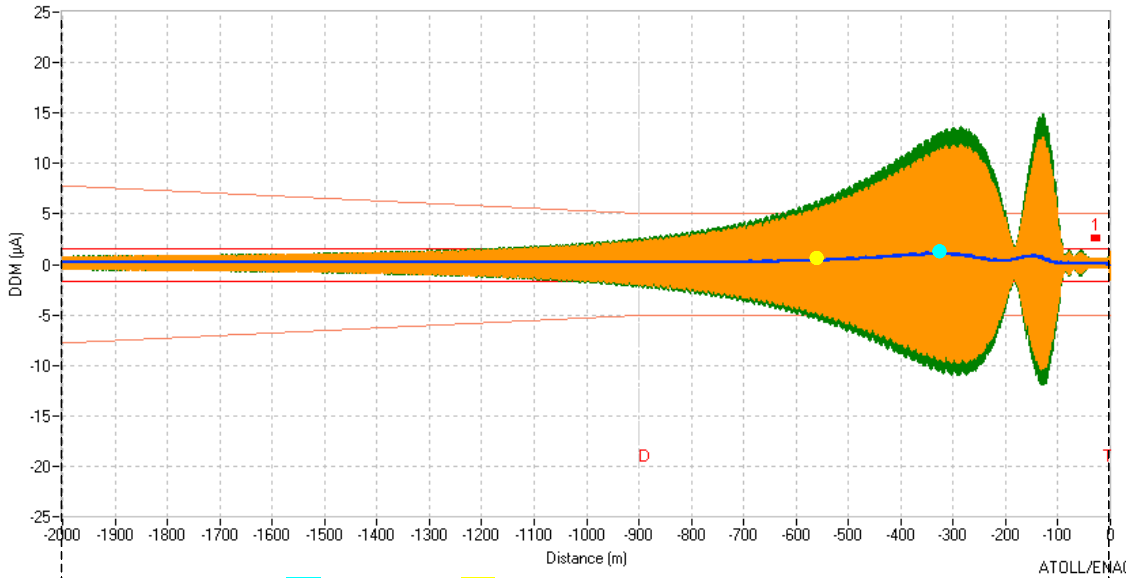


Disturbance amplitude **with** A380: T1 = +2.5µA (100m), T2 = -0.5µA (280m)
Disturbance amplitude **without** A380 at same points: T1 = -0.0µA, T2 = -0.0µA

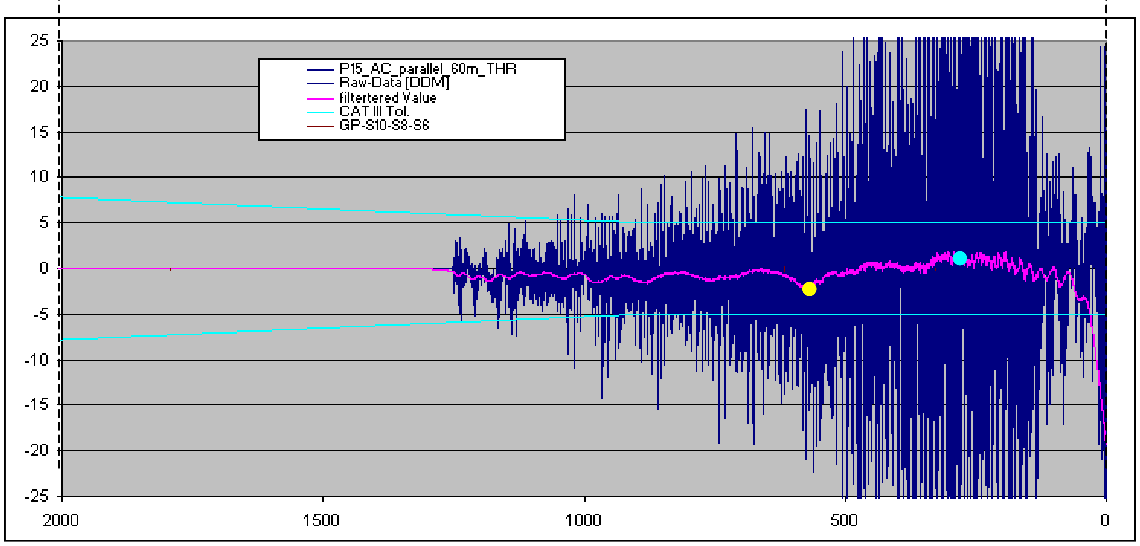
Disturbance amplitude with A380 **only**: T1 = +2.5µA, T2 = -0.5µA

Difference between simulation and measurements:
T1: +2.5 – (+2.5) = +0.0µA
T2: +0.5 – (-0.5) = +1.0µA

P15: Tail: Forward = 4068m, sideway = 51m, rotation = 90°
Simulation and measurements with DSNA receiver antenna (orange = raw data)



Disturbance amplitude: T1 = +1.5µA, T2 = 0.5µA (580m)

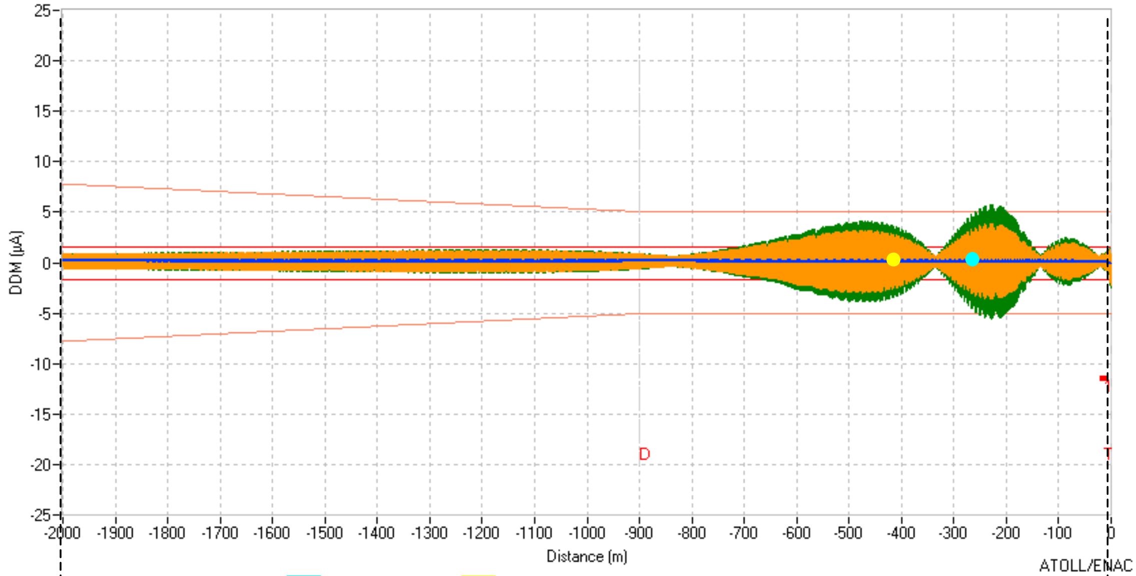


Disturbance amplitude **with** A380: T1 = +1.5µA, T2 = -2.0µA (580m)
Disturbance amplitude **without** A380 at same points: T1 = -0.0µA, T2 = +0.5µA

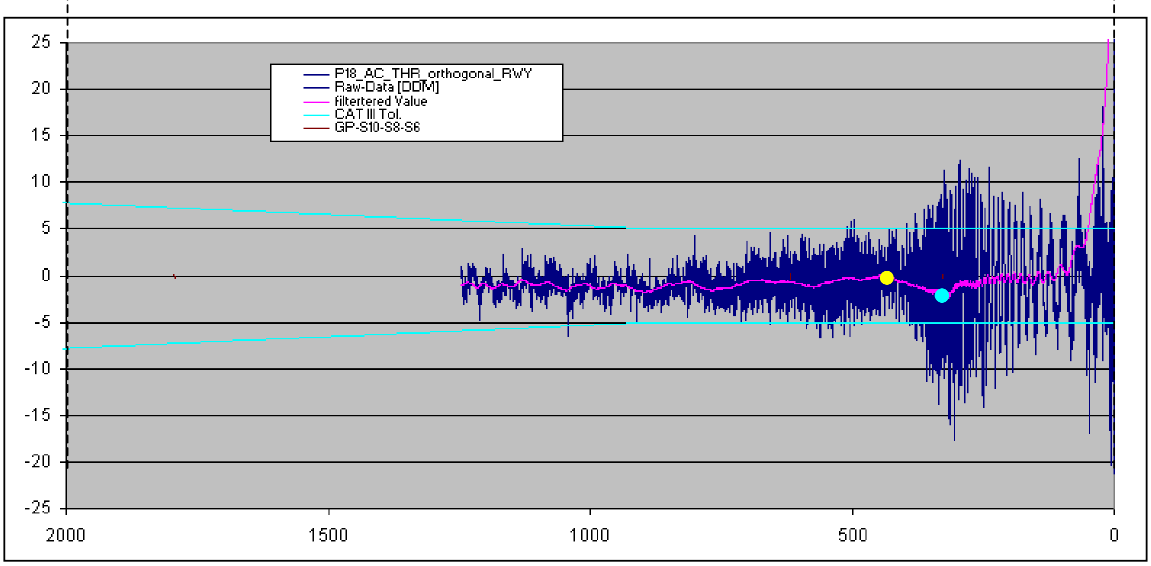
Disturbance amplitude with A380 **only**: T1 = +1.5µA, T2 = -2.5µA

Difference between simulation and measurements:
T1: +1.5 – (+1.5) = +0.0µA
T2: +0.5 – (-2.5) = +3.0µA

P18: Tail: Forward = 4068m, sideway = 51m, rotation = 90°
Simulation and measurements with DSNA receiver antenna (orange = raw data)



Disturbance amplitude: T1 = +0.0µA, T2 = 0.0µA



Disturbance amplitude **with** A380: T1 = -2.0µA, T2 = 0.0µA (580m)
Disturbance amplitude **without** A380 at same points: T1 = -0.0µA, T2 = -0.5µA

Disturbance amplitude with A380 **only**: T1 = -2.0µA, T2 = +0.5µA

Difference between simulation and measurements:
T1: +0.0 – (-2.0) = +2.0µA
T2: +0.0 – (+0.5) = -0.5µA

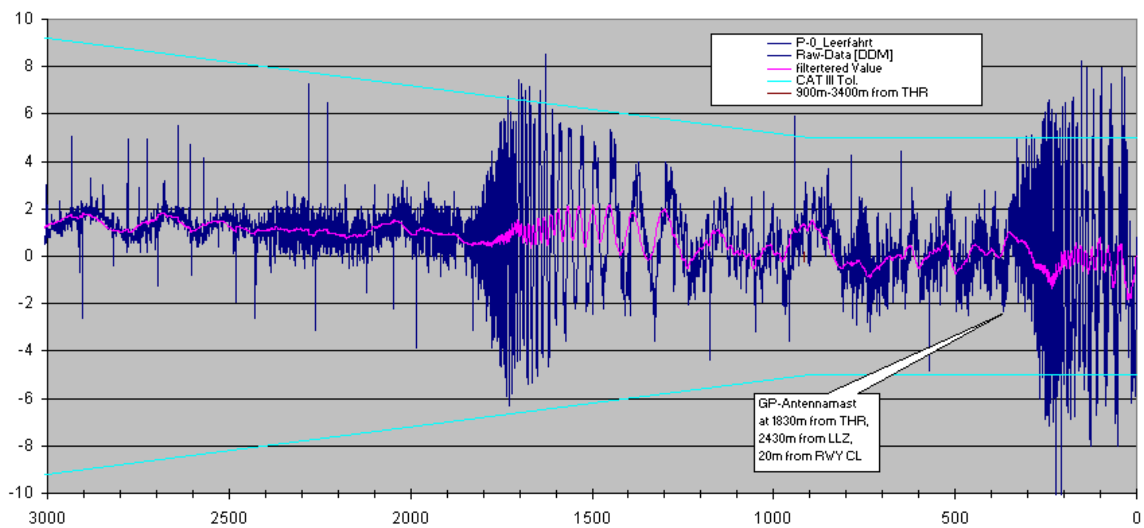
Frankfurt Airport

Simulation conditions:
Receiver features close to EVS200 (to be confirmed)
Receiver speed: 60km/h or 10km/h when mentioned.
Antenna height above the ground: 4m

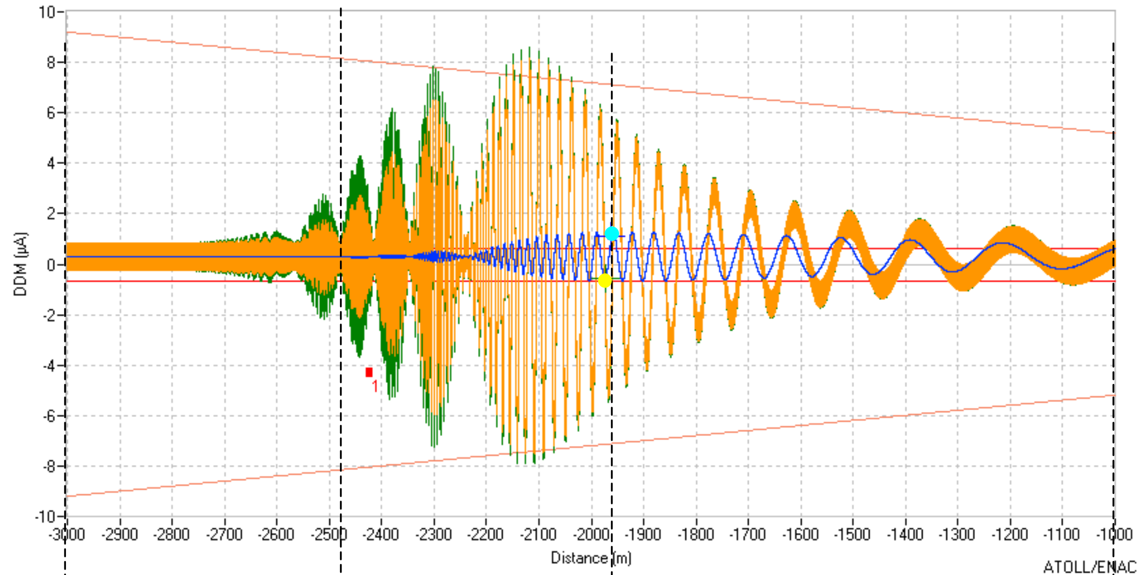
Raw data with omnidirectionnal antenna= green curves
Raw data with DFS receiver antenna= orange curves

Data with DFS antenna filtered using ICAO time constant = blue curves

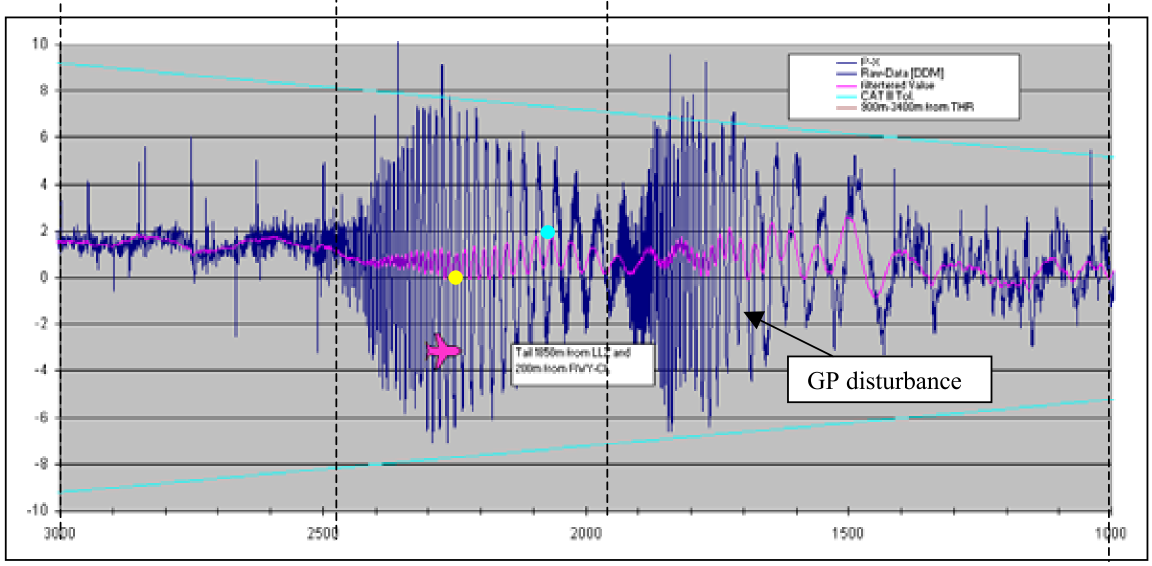
Reference record without A380



PX: Tail : Forward = 1836, sideway = -200, rotation = 0°
Simulation and measurements with DFS receiver antenna (orange = raw data)



Disturbance amplitude: T1 = +3.5µA, T2 = +4.0µA



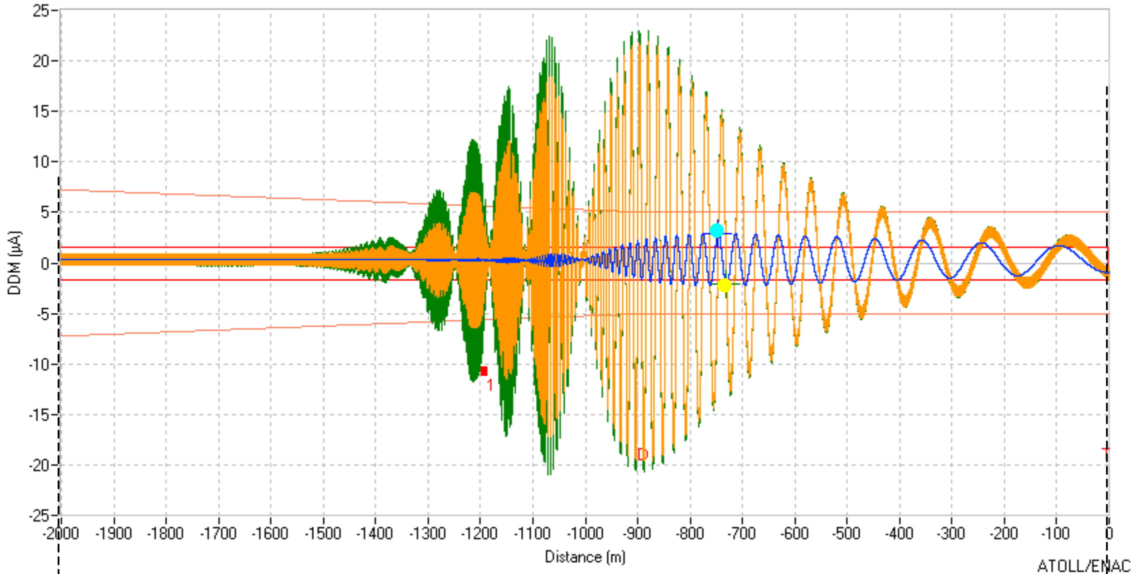
Disturbance amplitude **with** A380: T1 = +1.5µA, T2 = 0.0µA
Disturbance amplitude **without** A380: T1 = +1.0µA, T2 = 1.0µA

Disturbance amplitude with A380 **only**: T1 = 0.5µA, T2 = -1.0µA

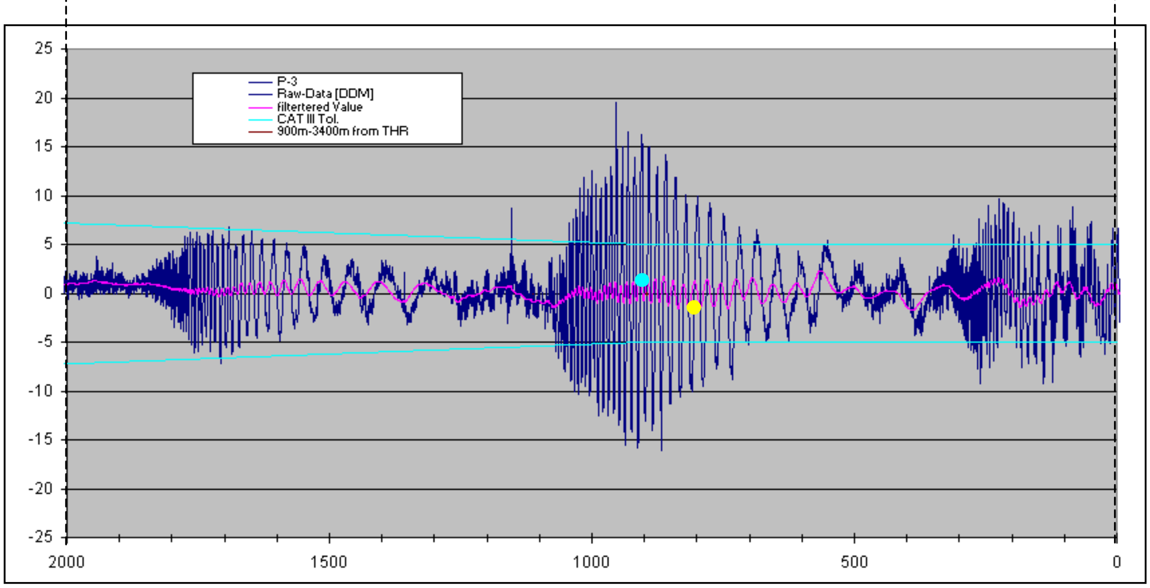
Difference between simulation and measurements:
T1: 0.5 – 1 = -0.5µA
T2: -1 – (-0.6) = -0.4µA

P3: Tail: Forward = 3067, sideway = -200, rotation = 0°

Simulation and measurements with DFS receiver antenna (orange = raw data)



Disturbance amplitude: T1 =+2.5µA, T2=-2.5µA



Disturbance amplitude **with** A380: T1 =+2.0µA, T2=-1.0µA

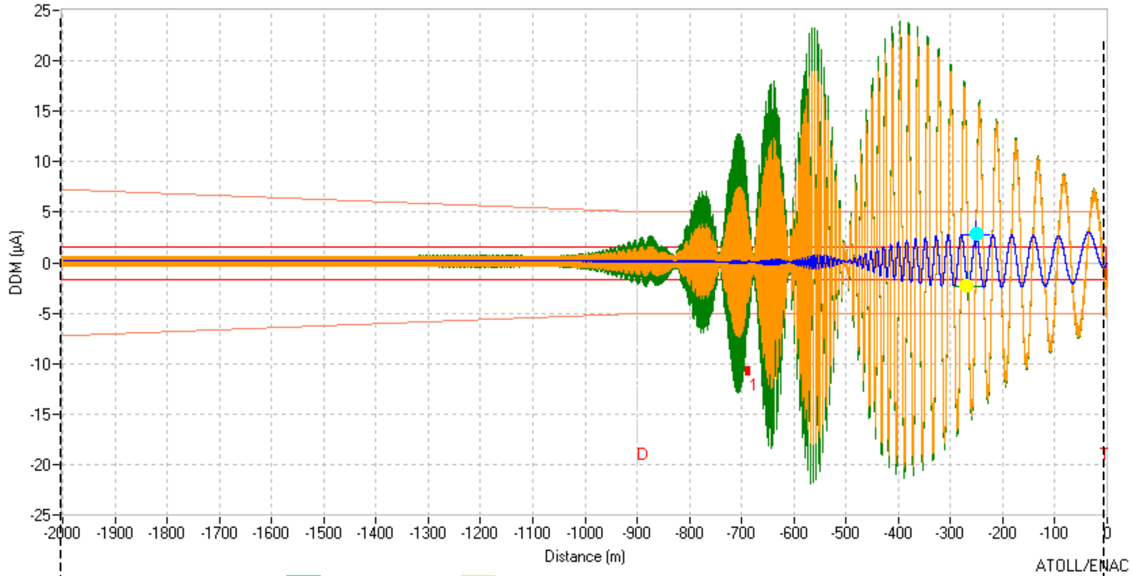
Disturbance amplitude **without** A380 at same points: T1 =0.0µA, T2=0.0µA

Difference between simulation and measurements:

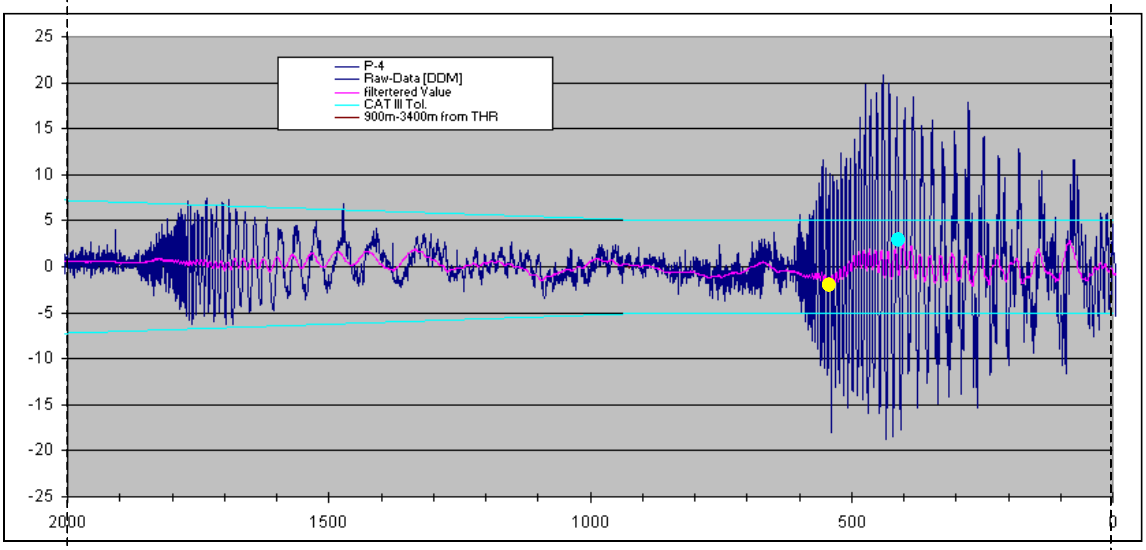
T1: 2.5 – 2.0 = 0.5µA

T2: -2.5 – (-1.0) = -1.5µA

P4: Tail: Forward = 3572, sideway = -200, rotation = 0°
Simulation and measurements with DFS receiver antenna (orange = raw data)



Disturbance amplitude: T1 = +2.5µA, T2 = -2.5µA



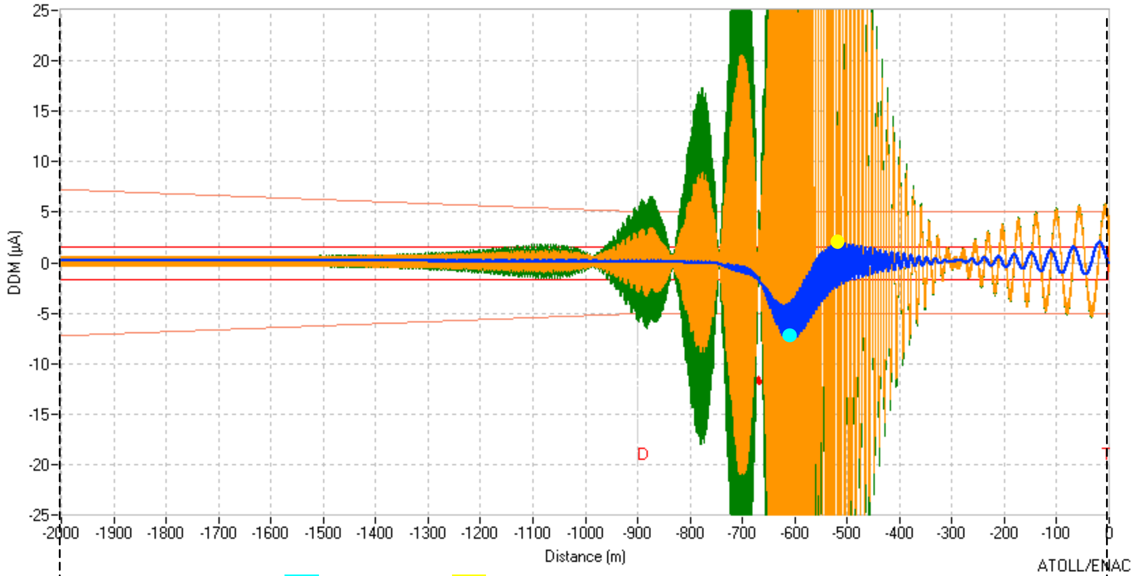
Disturbance amplitude **with** A380: T1 = +2.0µA, T2 = -2µA
Disturbance amplitude **without** A380 at same points: T1 = 0.0µA, T2 = 0.0µA

Difference between simulation and measurements:
T1: 2.5 – 2.0 = 0.5µA
T2: -2.5 – (-2.0) = -0.5µA

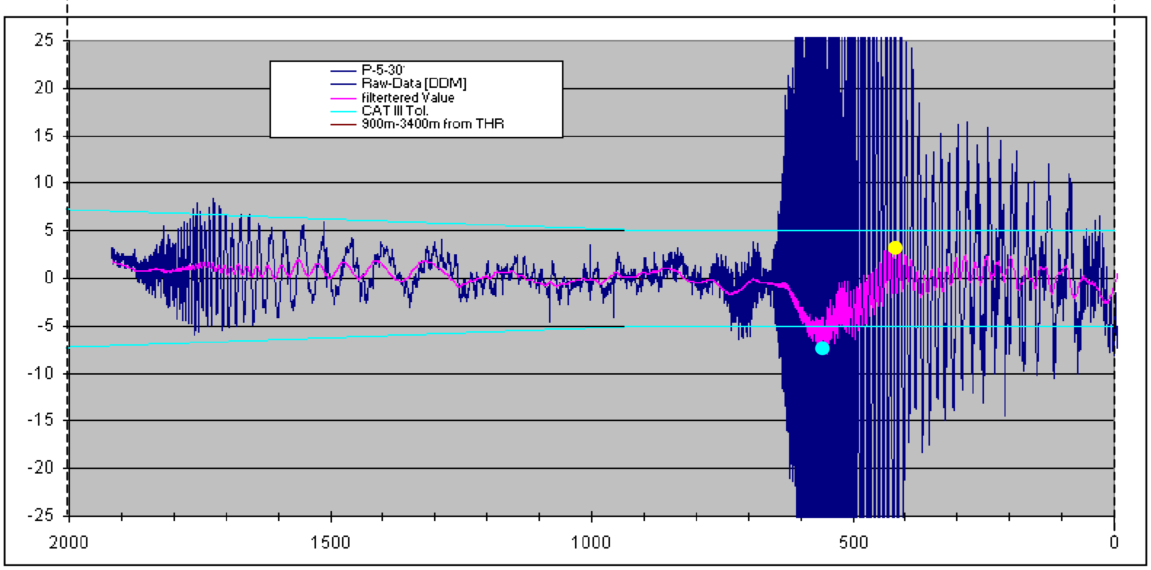
P5 30° at 60 km/h

Tail : Forward = 3588m, sideway = -219m, rotation = 30°

Simulation and measurements with DFS receiver antenna (orange = raw data)



Disturbance amplitude: T1 = -7.5µA, T2 = +2.0µA



Disturbance amplitude **with** A380: T1 = -7.5 µA, T2 = +3µA

Disturbance amplitude **without** A380 at same points: T1 = 0µA, T2 = 0µA

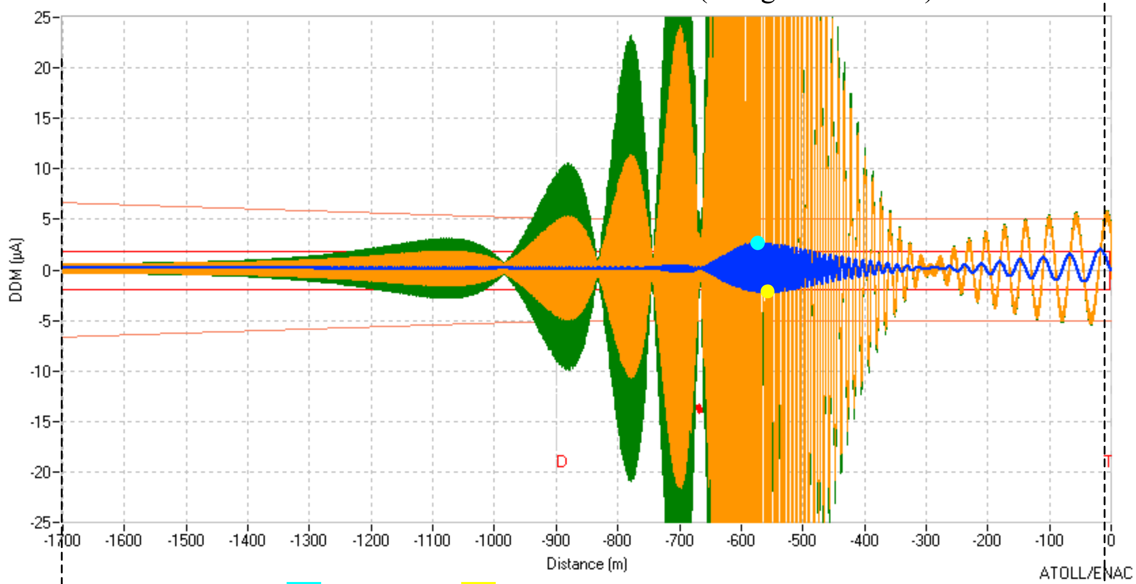
Disturbance amplitude with A380 **only**: T1 = -7.5µA, T2 = +3 µA

Difference between simulation and measurements:

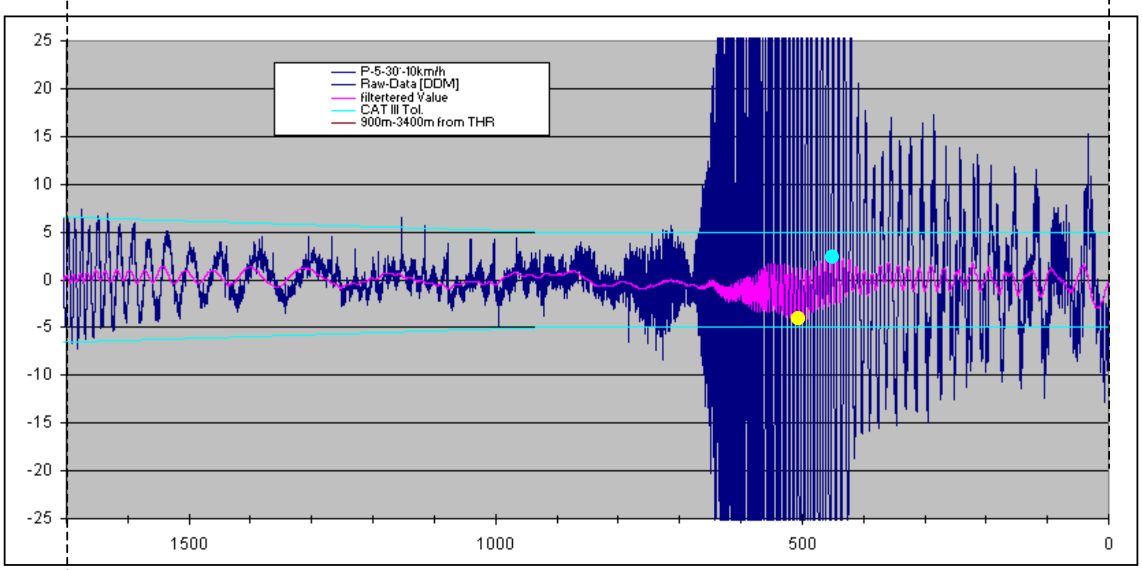
T1: -7.5 – (-7.5) = +0.0µA

T2: +2.0 – (+3) = -3.0µA

P5 30° at 10 km/h
Tail : Forward = 3588m, sideway = -219m, rotation = 30°
Simulation and measurements with DFS receiver antenna (orange = raw data)



Disturbance amplitude: T1 = +3.0µA, T2 = -2.0µA



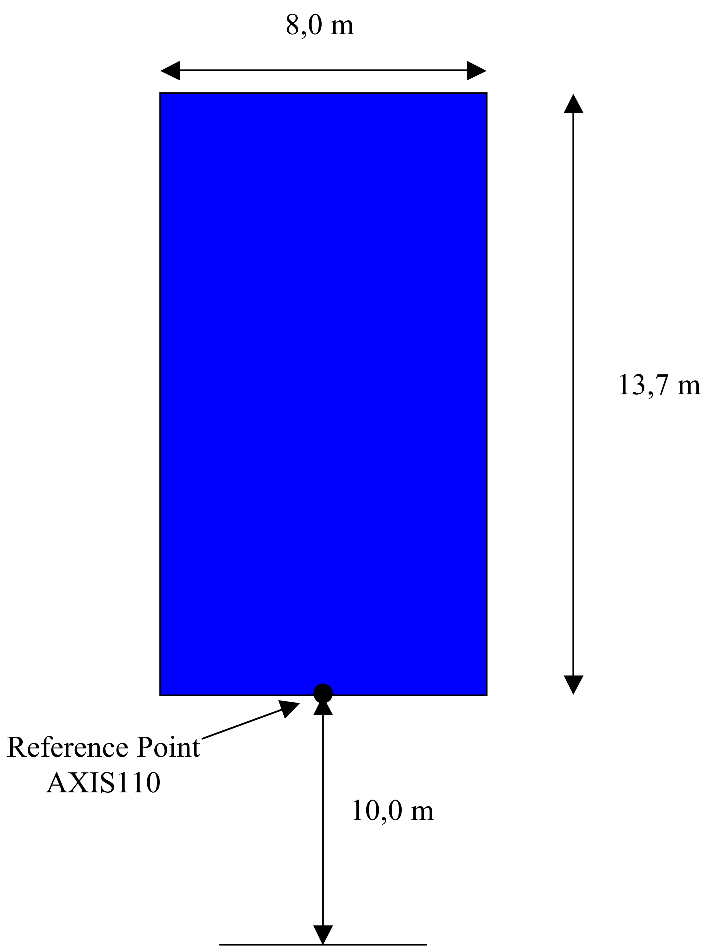
Disturbance amplitude **with** A380: T1 = +2.0 µA, T2 = -4µA
Disturbance amplitude **without** A380 at same points: T1 = 0.5µA, T2 = 0µA

Disturbance amplitude with A380 **only**: T1 = +1.5µA, T2 = -4.0 µA
Difference between simulation and measurements:
T1: +3.0 – (+1.5) = +1.5µA
T2: -2.0 – (-4.0) = +2.0µA

ANNEX L : Comparison of A380 ILS disturbance with AXIS 110 (R40) simulations for Toulouse and Frankfurt A380 cases

Model of the tail

The A380 tail is modelled by a rectangular metallic sheet as defined by:



Simulation conditions

Receiver characteristics: as implemented in AXIS 110 R40.
Receiver speed: 40km/h (Toulouse), 60 km/h (Frankfurt) or 10km/h when mentioned.

Antenna height above the ground: 4m.
Antenna pattern: omnidirectional, as implemented in AXIS 110 R40.

Only the filtered case has been simulated using the ICAO time constant.

Simulation evaluation versus measurements

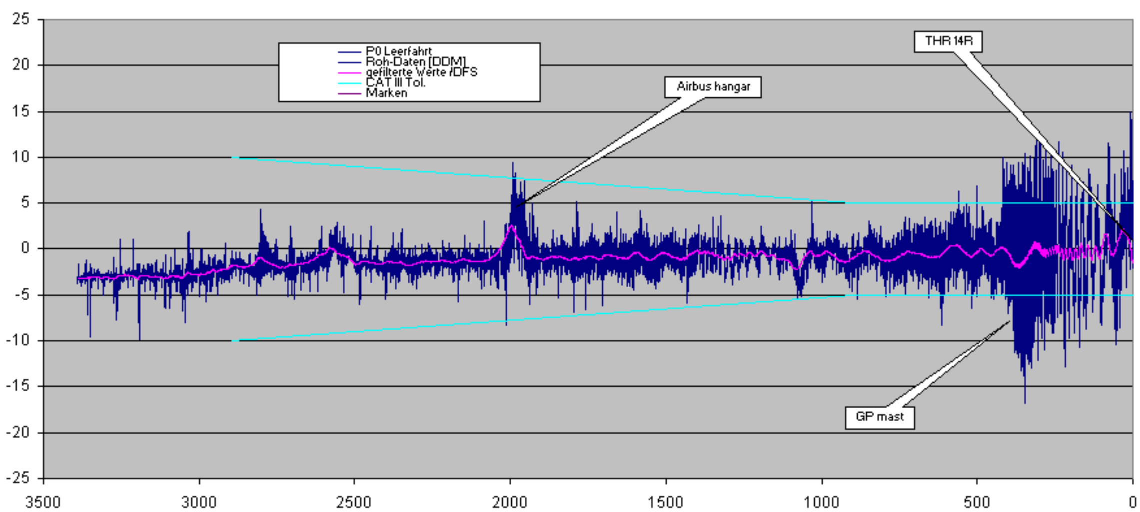
The comparison between simulations and measurements are made on the filtered curves. Filtered curves are obtained by filtering the raw data (output at measurement receiver) applying ICAO recommendation for evaluating roughness and bends.

The raw data have therefore been filtered using a low pass filter of the first order with a time constant adjusted to the speed of the measurement vehicle according to ICAO recommendation.

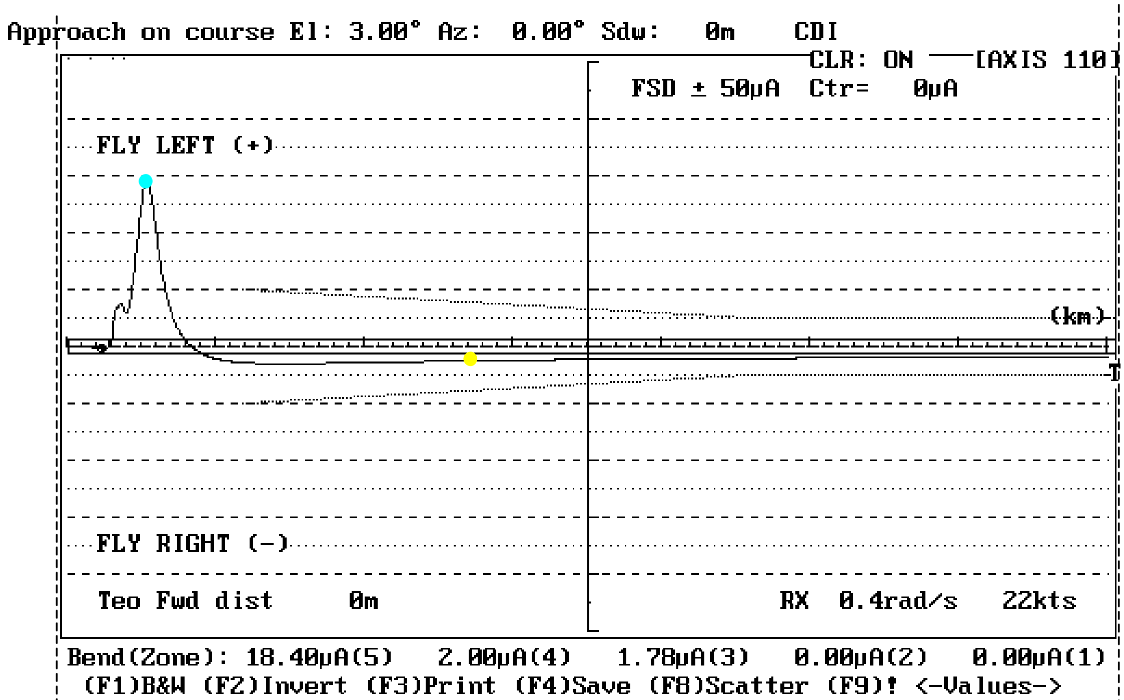
$$\tau = 92{,}6/V \quad \text{with } V \text{ in km/h}$$

Toulouse Airport

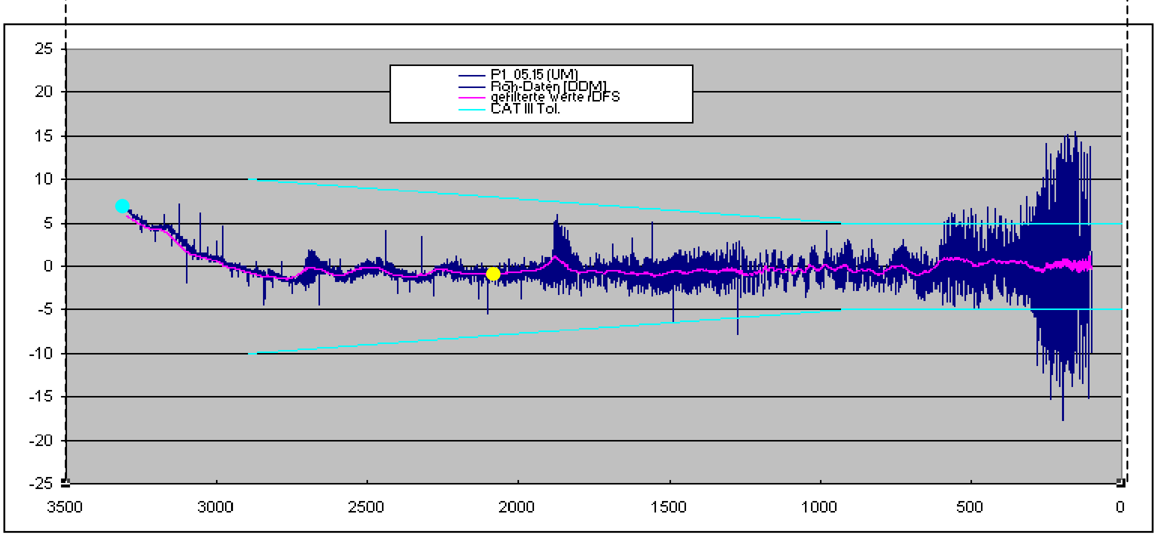
Reference record without A380



P1: Tail : Forward = 710m, Sideway = 5m, Rotation = 21°



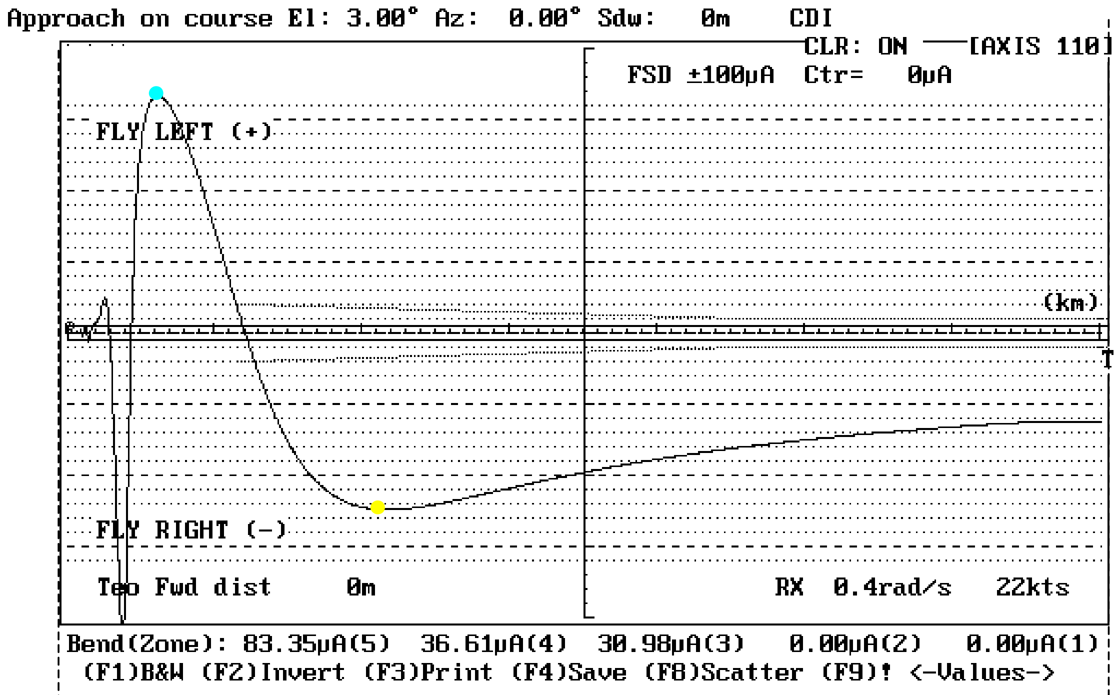
Disturbance amplitude: T1 = 29,3µA, T2 = -2,4µA



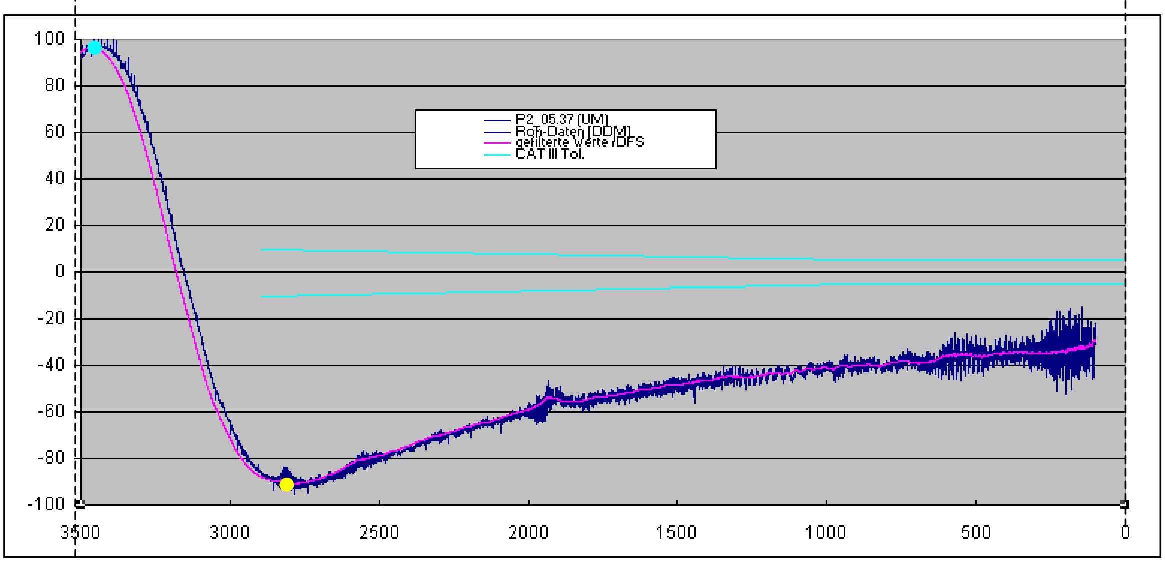
Disturbance amplitude **with** A380: T1 = 6,0 µA, T2 = -0,9µA
Disturbance amplitude **without** A380 at same points: T1 = -3µA, T2 = -1,4µA
Disturbance amplitude with A380 **only**: T1 = 9,0µA, T2 = -0,5µA
Difference between simulation and measurements:
T1: 29,3 – 9,0 = 20,3µA, T2: -2,4 – (-0,5) = -2,9µA

Simulation within tolerances and measurements within tolerances.

P2: Tail: Forward = 608m, Sideway = -29m, Rotation = 83°



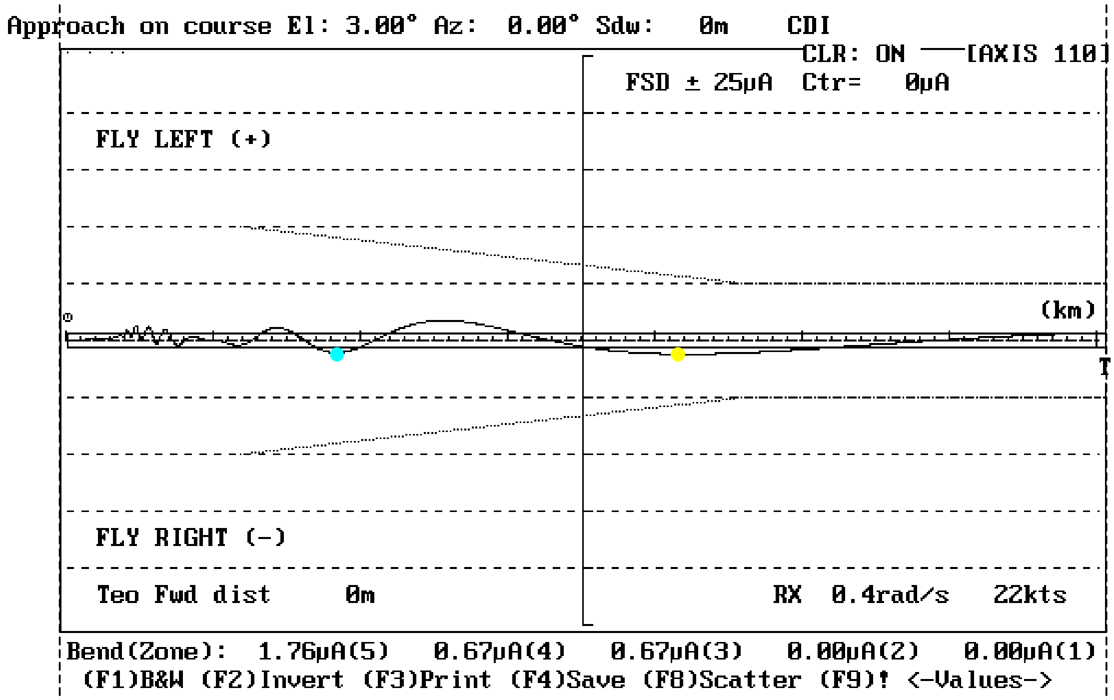
Disturbance amplitude: T1 = 83,3µA, T2 = -62,1µA



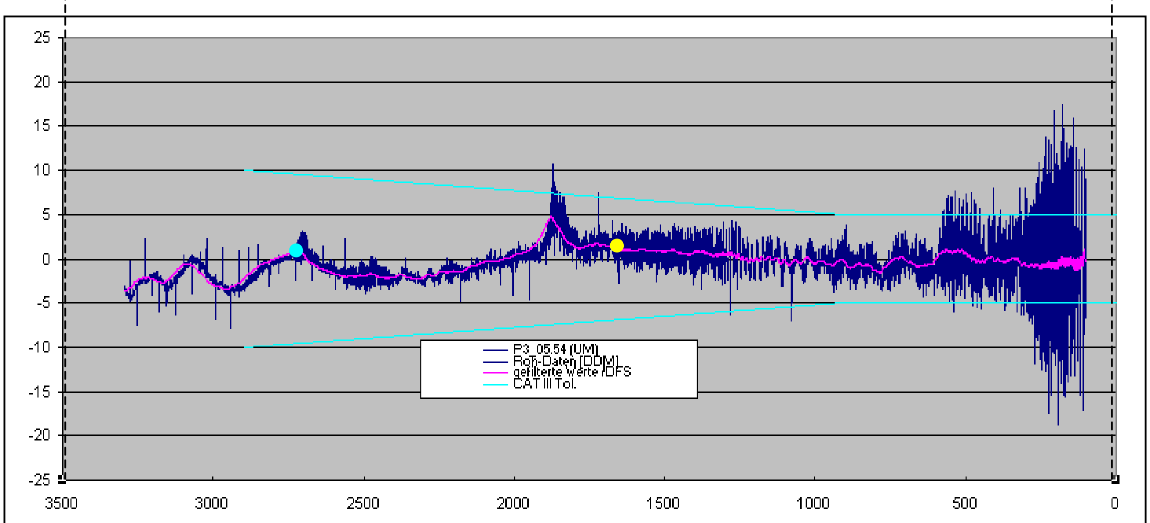
Disturbance amplitude **with** A380: T1 = 96,0 µA, T2 = -90,0µA
Disturbance amplitude **without** A380 at same points: T1 = -3,0µA, T2 = -2,0 µA
Disturbance amplitude with A380 **only**: T1 = 99,0 µA, T2 = -88,0µA
Difference between simulation and measurements:
T1: 83,3 – 99,0 = -15,7µA, T2: -62,1 – (-88,0) = 25,9µA

Simulation outside tolerances and measurements outside tolerances.

P3: Tail: Forward = 603m, Sideway = -93m, Rotation = 90°



Disturbance amplitude: T1 = -1,1µA, T2 = -1,2µA

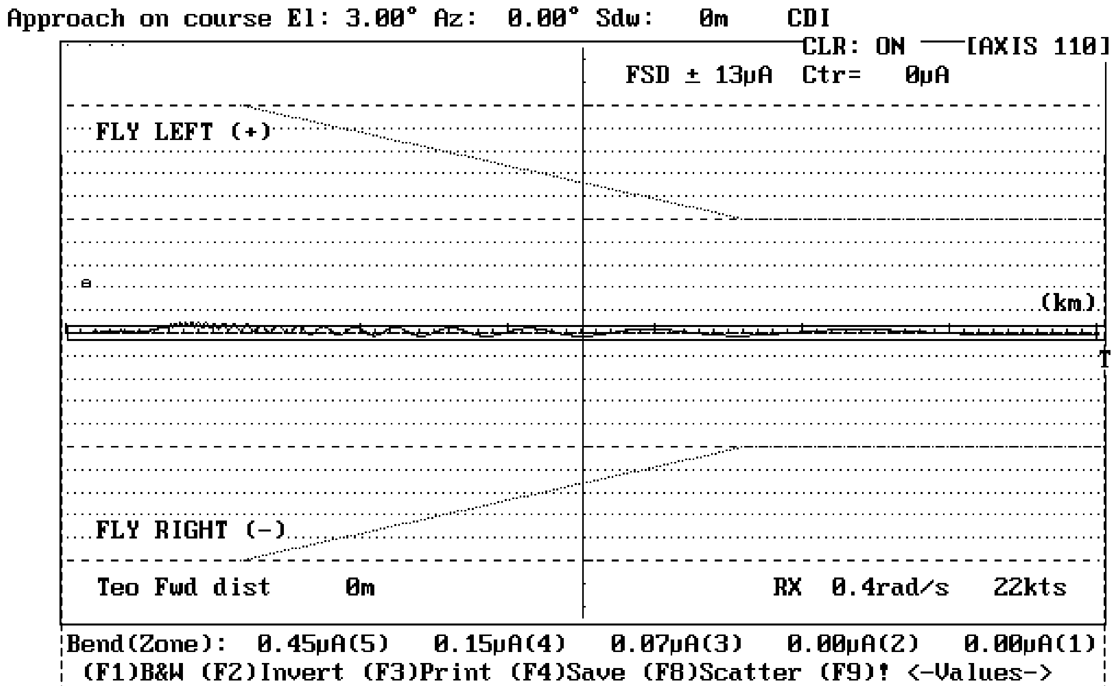


Disturbance amplitude **with** A380: T1 = 0,7 µA, T2 = 1,2µA
Disturbance amplitude **without** A380 at same points: T1=-1,4µA, T2=-0,6µA
Disturbance amplitude with A380 **only**: T1 = 2,1µA, T2 = 1,8µA

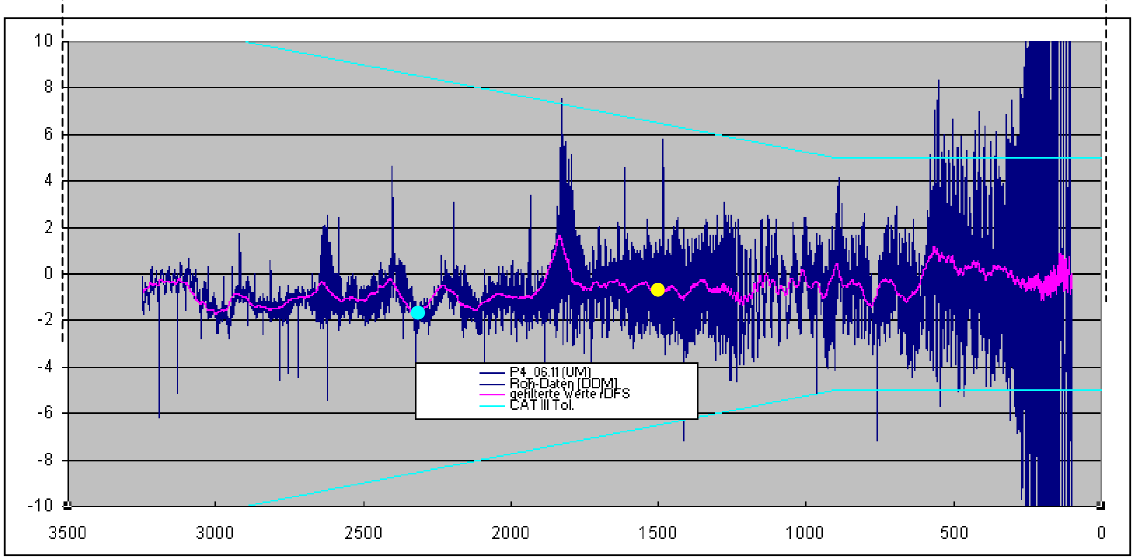
Difference between simulation and measurements:
T1: -1,1 – 2,1 = -3,2µA, T2: -1,2 – 1,8 = -3,0µA

Simulation inside tolerances and measurements inside tolerances.

P4: Tail: Forward = 662m, Sideway = -198m, Rotation = 5°



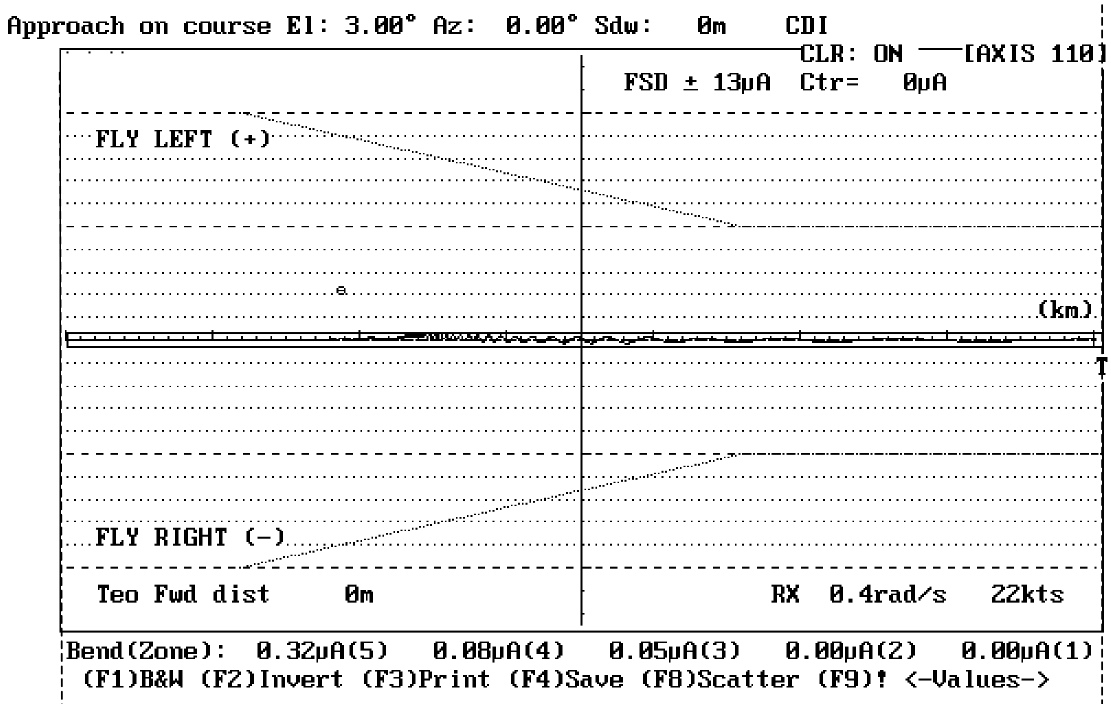
Disturbance amplitude: less than 1µA



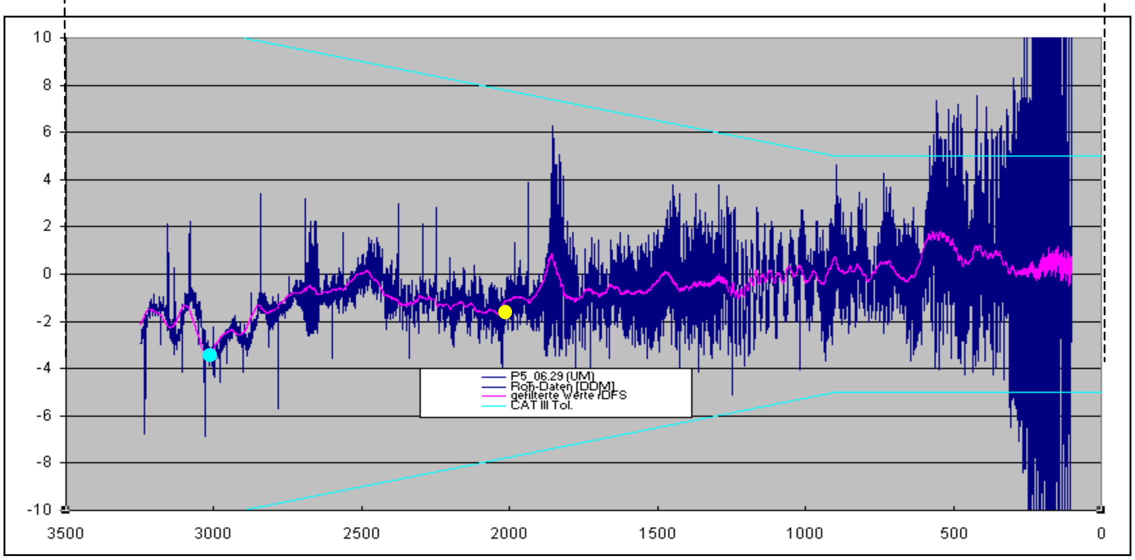
Disturbance amplitude **with** A380: T1 = -1,5 µA, T2 = -0,4µA
Disturbance amplitude **without** A380 at same points: T1 = -1,4µA, T2 = -1,0µA
Disturbance amplitude with A380 **only**: T1 = -0,1µA, T2 = 0,6µA
Difference between simulation and measurements:
T1: 0,0 – (-0,1) = 0,1µA, T2: 0,0 – (0,6) = -0,6µA

Simulation inside tolerances and measurements inside tolerances.

P5: Tail : Forward = 1531m, Sideway = -198m, Rotation = 0°



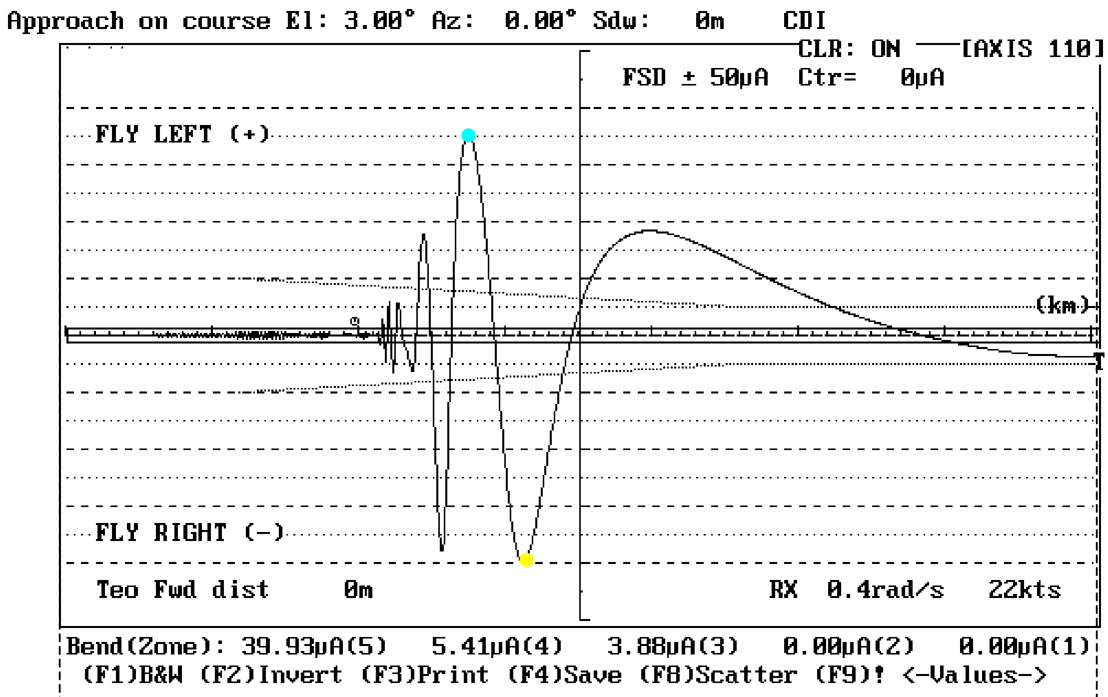
Disturbance amplitude: less than 1µA



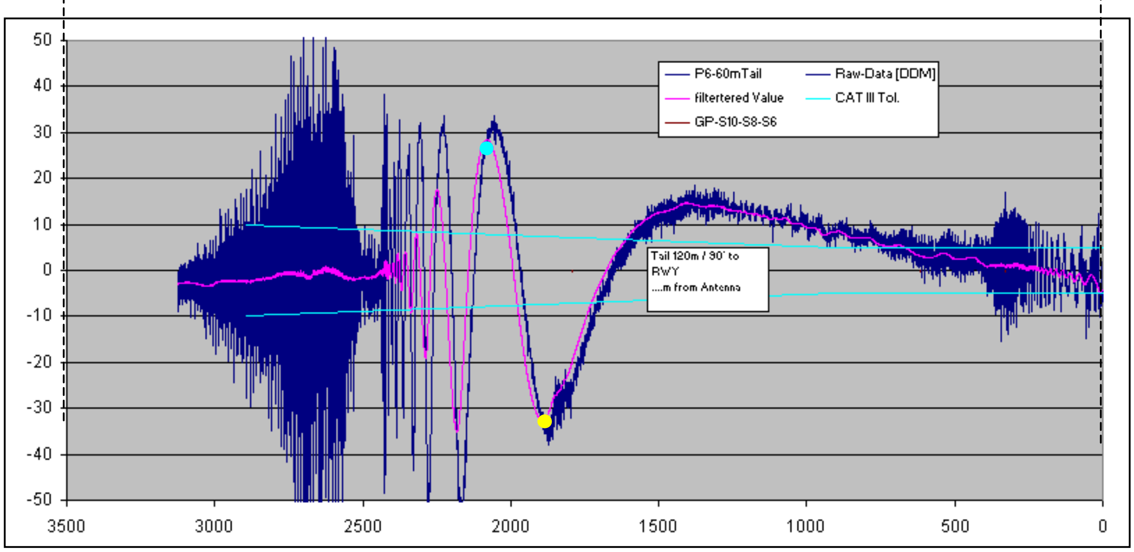
Disturbance amplitude **with** A380: T1 = -3,0 µA, T2 = -1,5µA
Disturbance amplitude **without** A380 at same points: T1 = -3,0µA, T2 = -1,5µA
Disturbance amplitude with A380 **only**: T1 = -0,0µA, T2 = 0,0µA
Difference between simulation and measurements:
T1: 0,0 – 0,0 = 0,0µA, T2: 0,0 – 0,0 = 0,0µA

Simulation inside tolerances and measurements inside tolerances.

P6: Tail: Forward = 1579m, Sideway = -57m, rotation = 90°



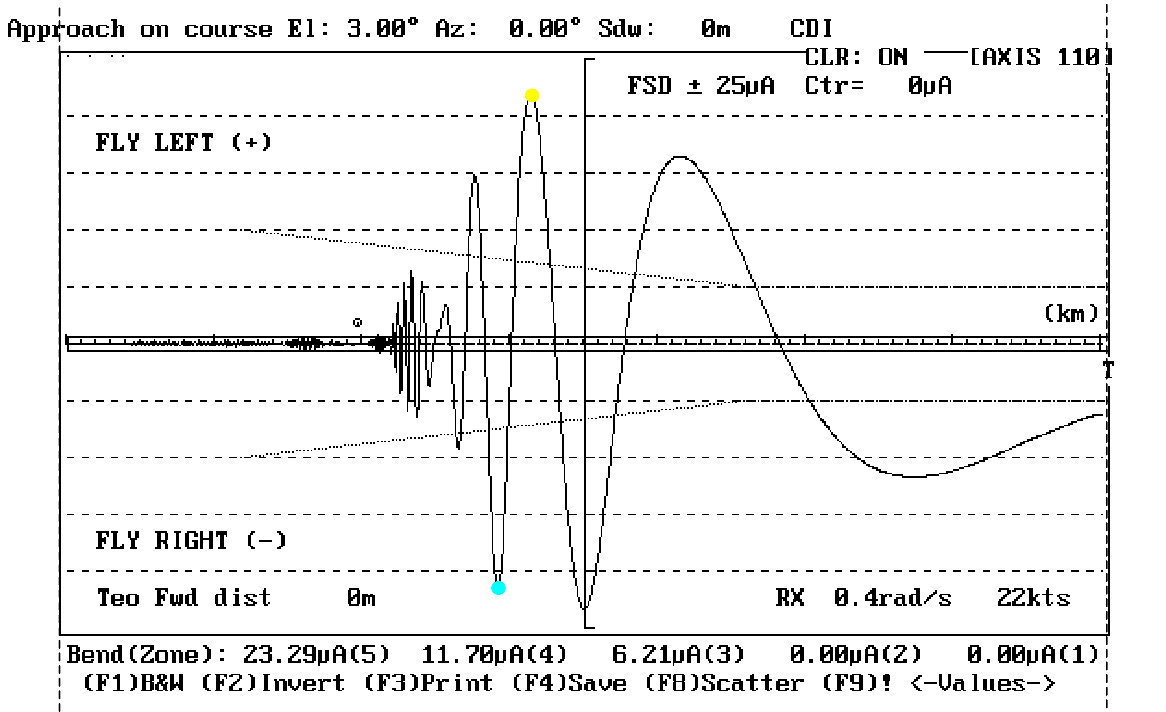
Disturbance amplitude: T1 = 35,3µA, T2 = -39,8µA



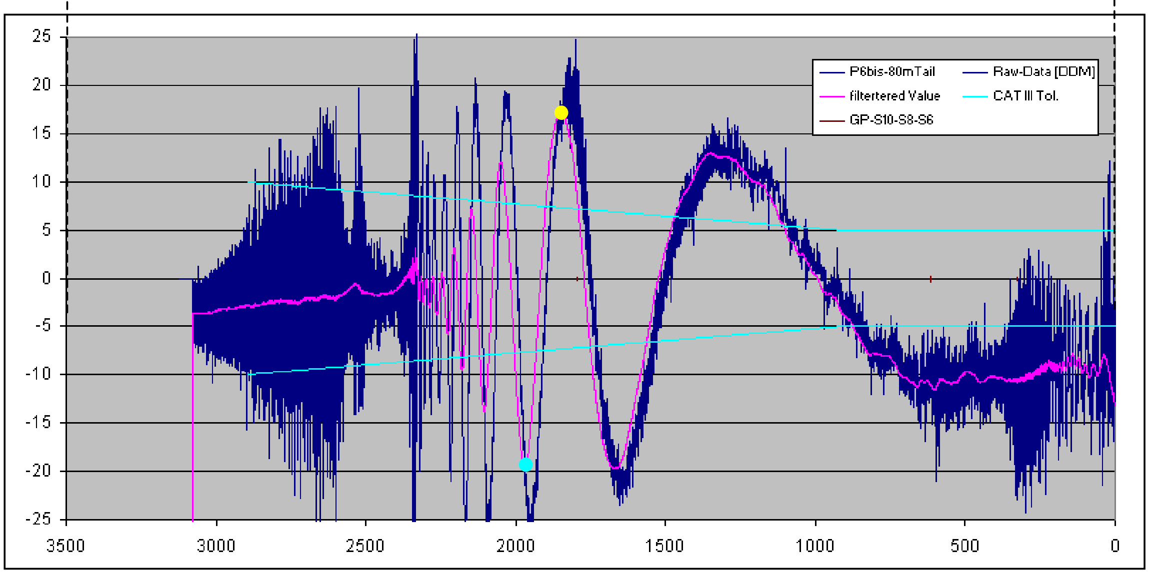
Disturbance amplitude **with** A380: T1 = 27,0 µA, T2 = -31,0µA
Disturbance amplitude **without** A380 at same points: T1 = -1,0 µA, T2 = -1,0µA
Disturbance amplitude with A380 **only**: T1 = 28,0µA, T2 = -30,0 µA
Difference between simulation and measurements:
T1: 35,3 – (28,0) = 7,3µA, T2: -39,8 – (-30,0) = -9,8µA

Simulation outside tolerances and measurements outside tolerances.

P6 bis: Tail: Forward = 1579m, Sideway = -83m, Rotation = 90°

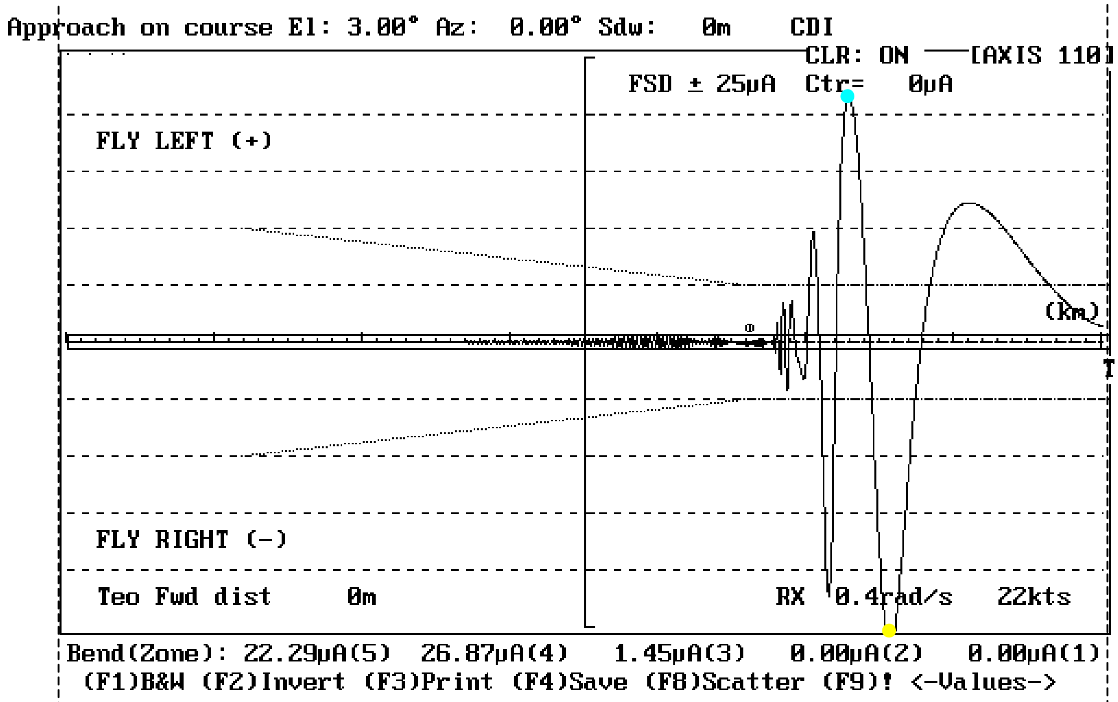


Disturbance amplitude: T1 = -21,7µA, T2 = 21,9µA

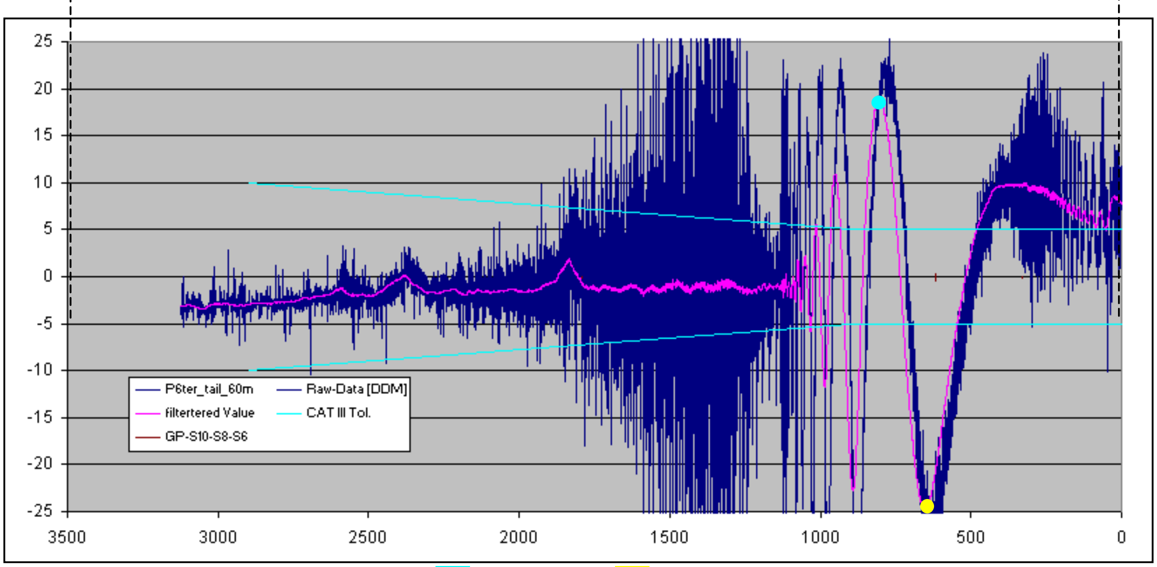


Disturbance amplitude **with** A380: T1 = -19,0 µA, T2 = 17,0µA
Disturbance amplitude **without** A380 at same points: T1 = -1,0µA, T2 = -1,0µA
Disturbance amplitude with A380 **only**: T1 = -18,0µA, T2 = 18,0µA
Difference between simulation and measurements:
T1: -21,7 – (-18,0) = -3,7µA, T2: 21,9 – 18,0 = 3,9µA
Simulation outside tolerances and measurements outside tolerances.

P6 ter: Tail: Forward = 2909m, Sideway = -56m, Rotation = 90°



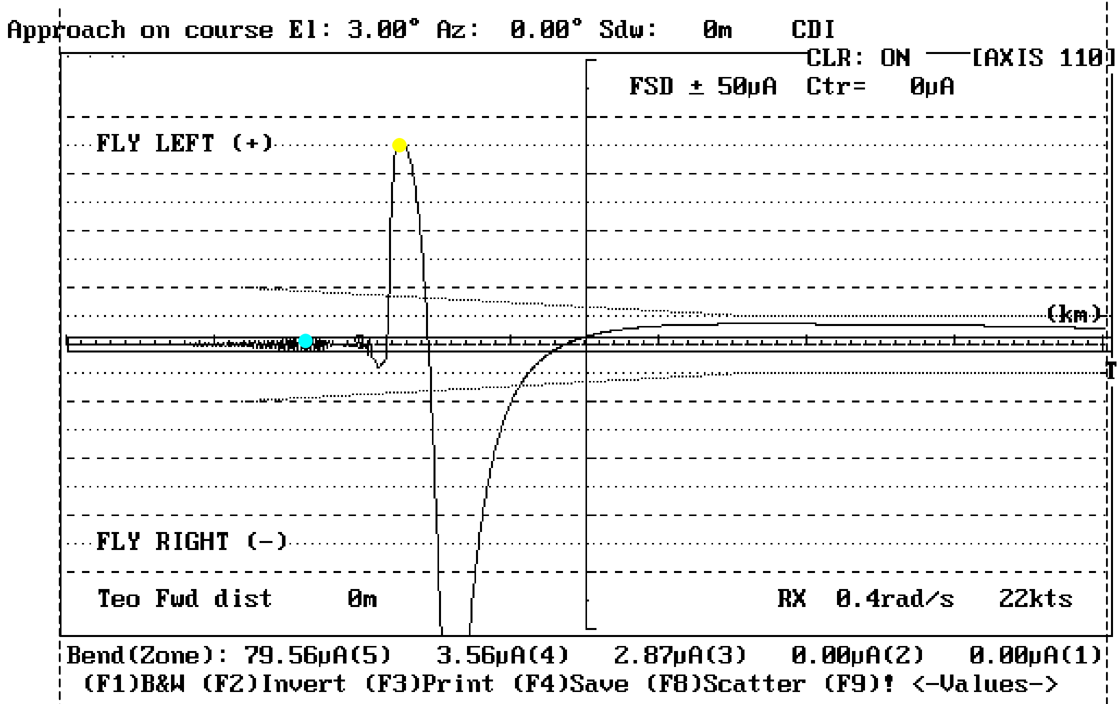
Disturbance amplitude: T1 = 21,6µA, T2 = -26,8µA



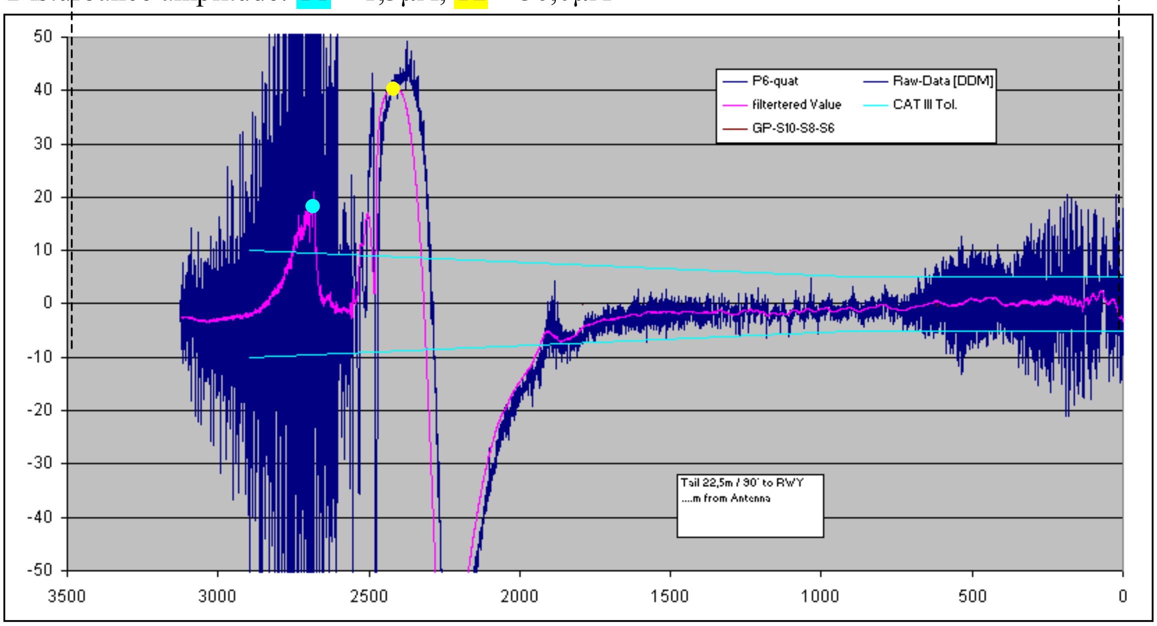
Disturbance amplitude **with** A380: T1 = 18,0 µA, T2 = -24,0µA
Disturbance amplitude **without** A380 at same points: T1 = -1,0µA, T2 = -1,0µA
Disturbance amplitude with A380 **only**: T1 = 19,0µA, T2 = -23,0 µA
Difference between simulation and measurements:
T1: 21,6 – 19,0 = 2,6µA, T2: -26,8 – (-23,0) = -3,8µA

Simulation outside tolerances and measurements outside tolerances.

P6 quad: Tail: Forward = 1579m, Sideway = -21m, Rotation = 90°

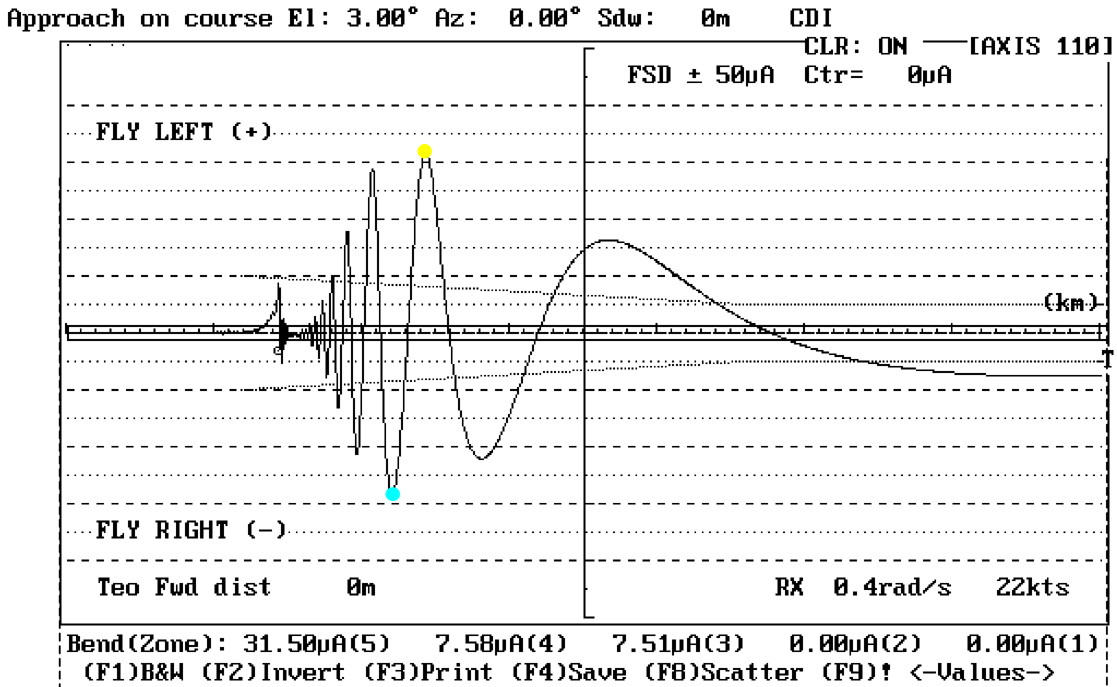


Disturbance amplitude: T1 = 1,3µA, T2 = 36,0µA

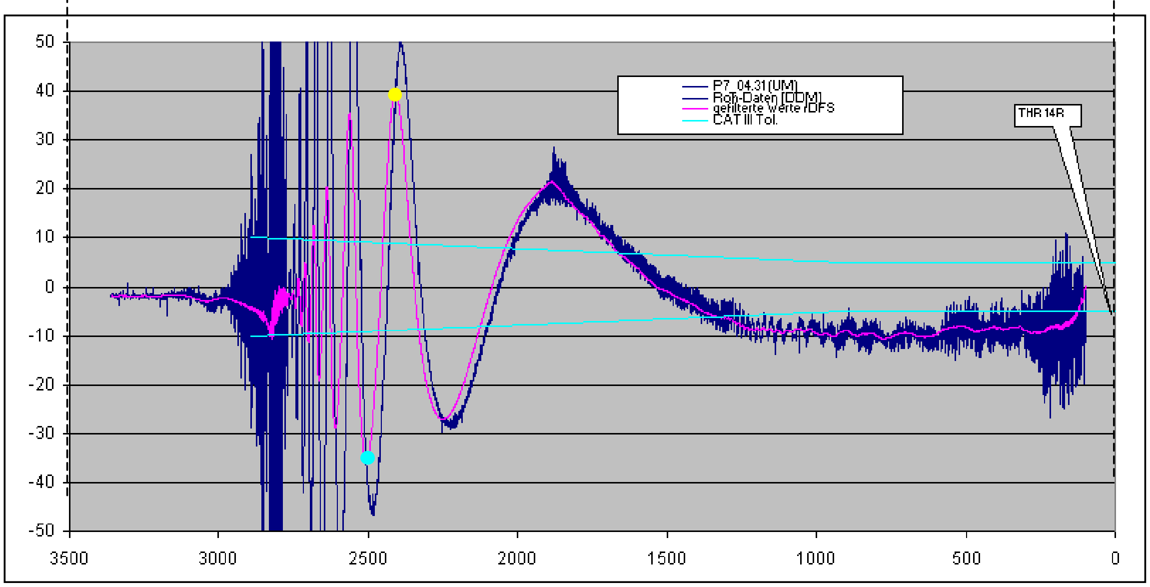


Disturbance amplitude **with** A380: T1 = 20,0µA, T2 = 40,0µA
Disturbance amplitude **without** A380 at same points: T1 = -2,0µA, T2 = -2,0µA
Disturbance amplitude with A380 **only**: T1 = 22,0µA, T2 = 42,0µA
Difference between simulation and measurements:
T1: 1,3 – 22,0 = 20,7µA, T2: 36,0 – 42,0 = -6,0 µA
Simulation outside tolerances and measurements outside tolerances.

P7: Tail: Forward = 1313m, Sideway = 69m, Rotation = -42°

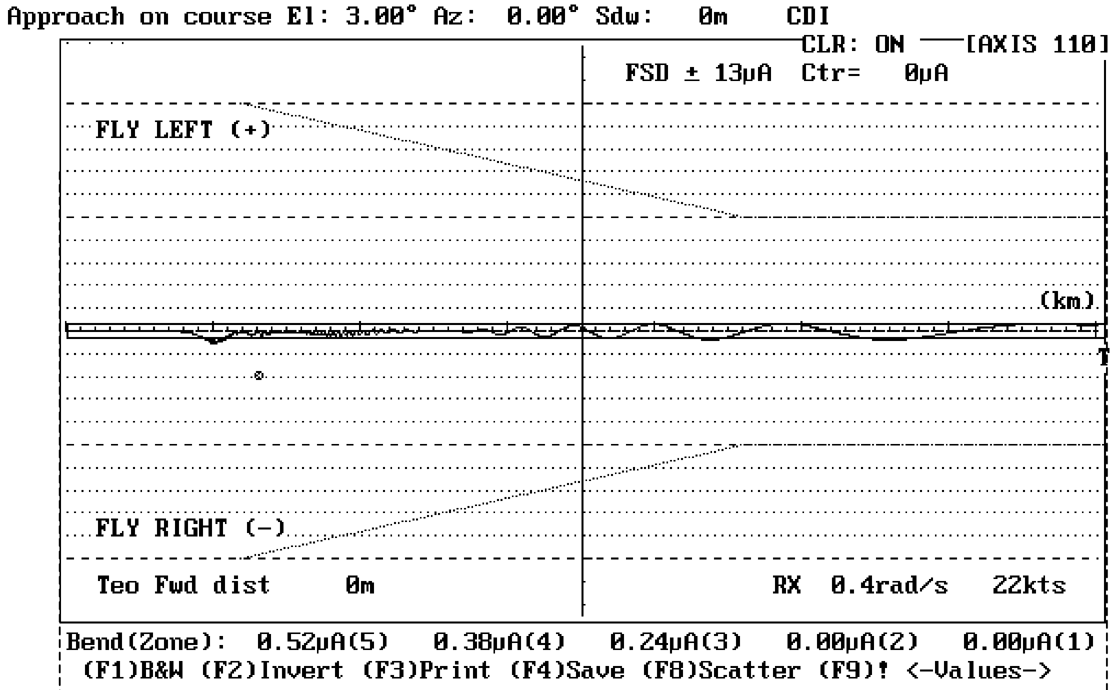


Disturbance amplitude: T1 = -28,3µA, T2 = 31,5µA

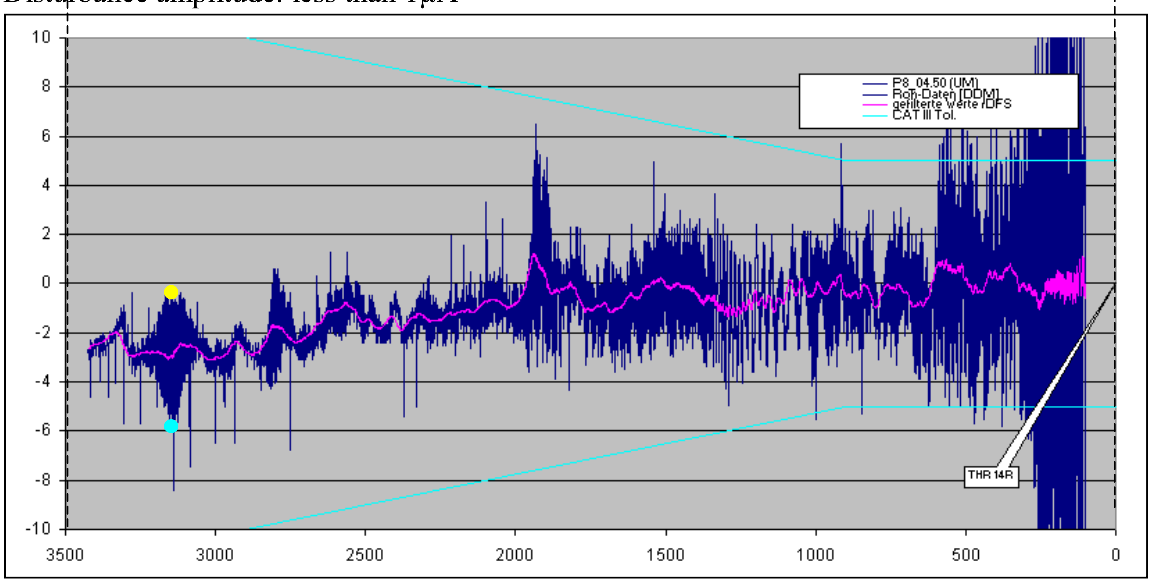


Disturbance amplitude **with** A380: T1 = -34,0 µA, T2 = 39,0µA
Disturbance amplitude **without** A380 at same points: T1 = -1,0µA, T2 = -1,5µA
Disturbance amplitude with A380 **only**: T1 = -33,0µA, T2 = 40,5 µA
Difference between simulation and measurements:
T1: -28,3 – (-33,0) = 4,7µA, T2: 31,5 – 40,5 = -9,0µA
Simulation outside tolerances and measurements outside tolerances.

P8: Tail: Forward = 1247m, Sideway = 173m, Rotation = -60°



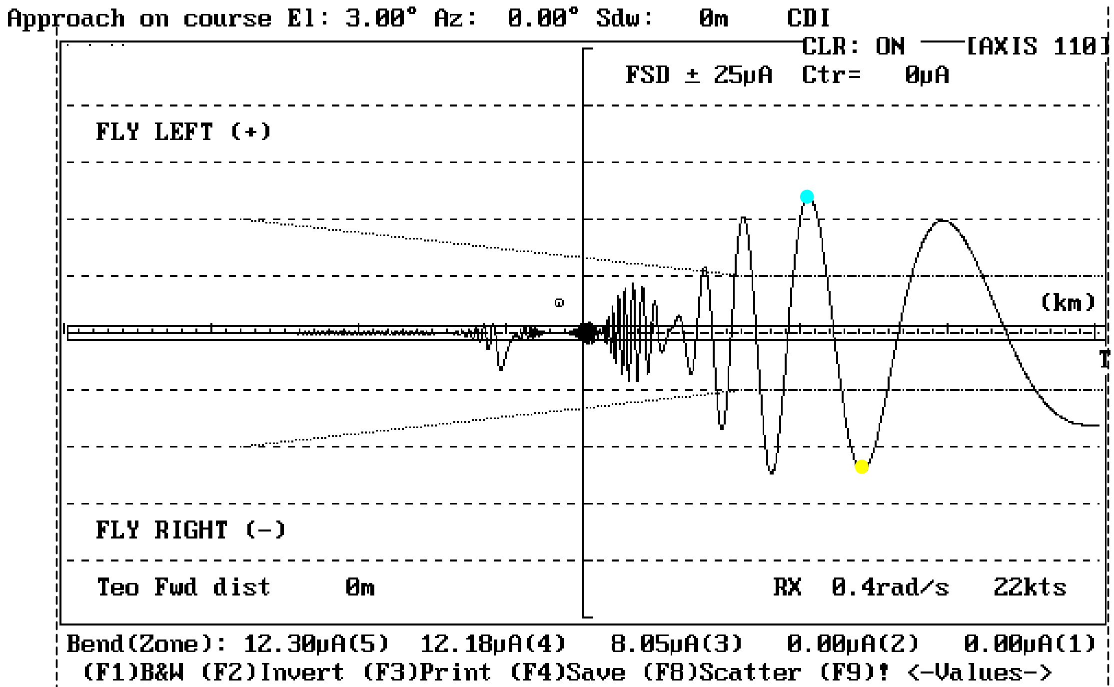
Disturbance amplitude: less than 1µA



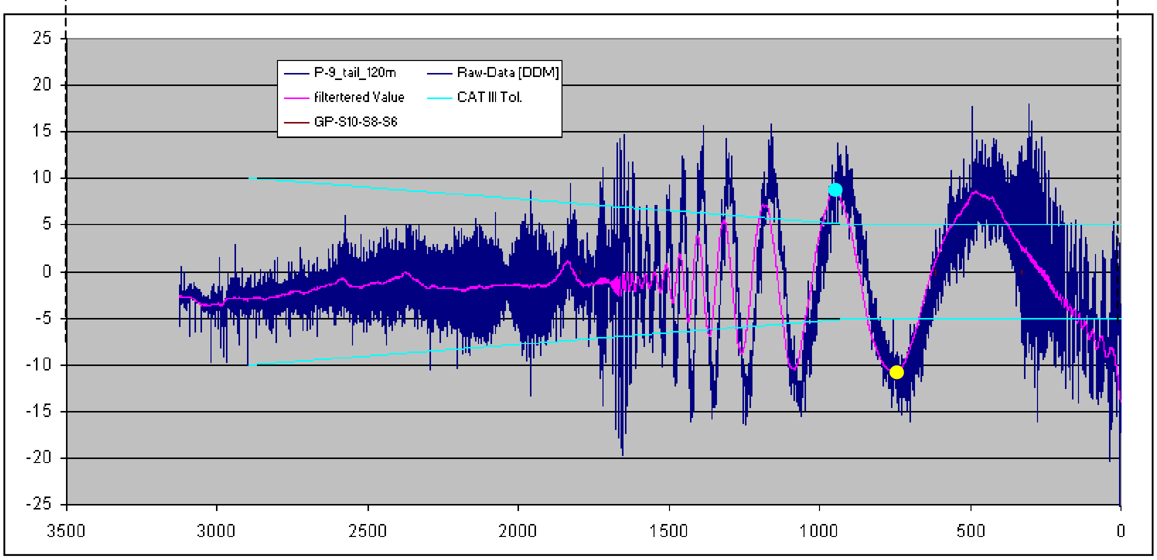
Disturbance amplitude (raw data) **with** A380: T1 = -5,5 µA, T2 = -0,5µA
Disturbance amplitude (raw data) **without** A380 at same points: T1 = -3,0µA, T2 = -3,0µA
Disturbance amplitude with A380 (raw data) **only**: T1 = -2,5µA, T2 = 2,5 µA
Difference between simulation and measurements:
T1: ?µA, T2: ?µA

Simulation inside tolerances and measurements inside tolerances.

P9: Tail: Forward = 2267m, Sideway = 116m, Rotation = 90°

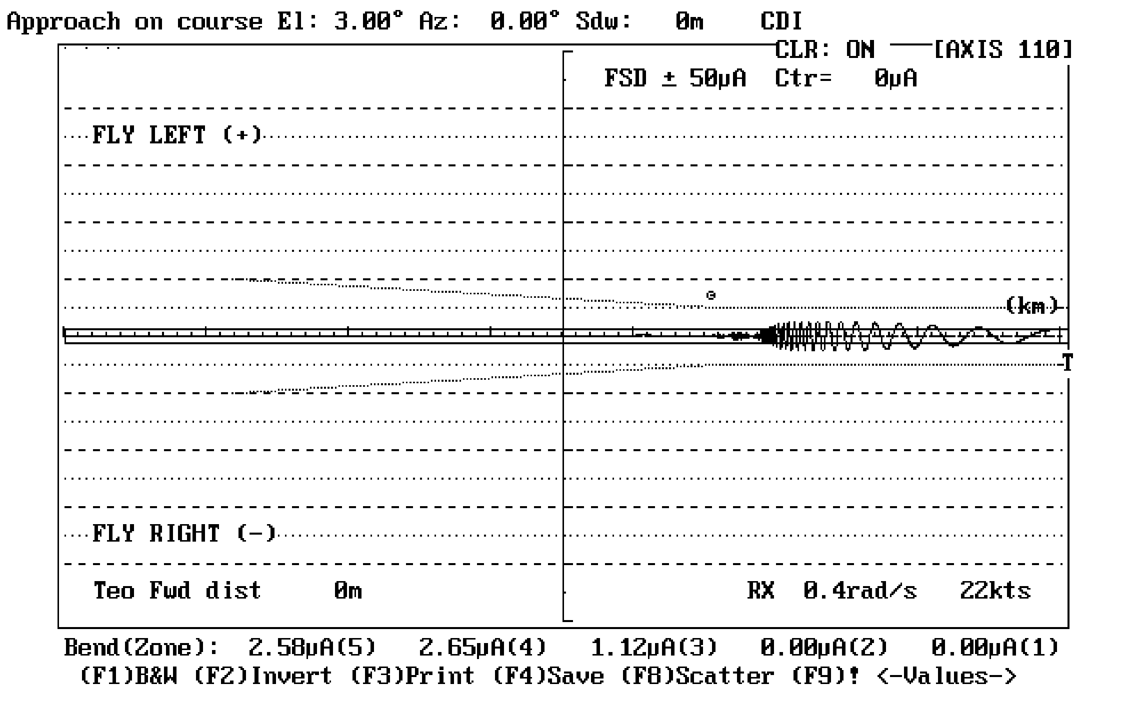


Disturbance amplitude: T1 = 12µA, T2 = -12,1µA

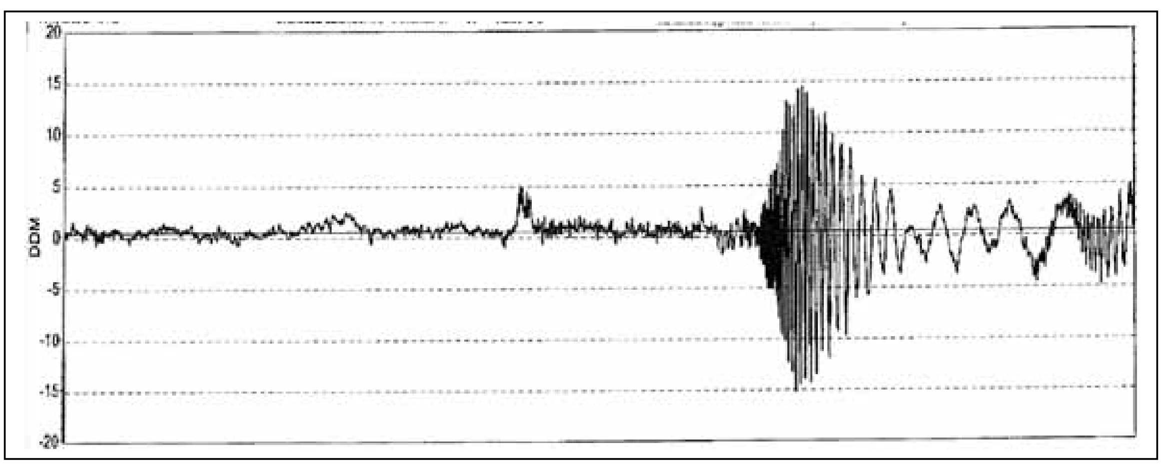


Disturbance amplitude **with** A380: T1 = 8,0 µA, T2 = -11,0µA
Disturbance amplitude **without** A380 at same points: T1 = -1,0µA, T2 = -1,0µA
Disturbance amplitude with A380 **only**: T1 = 9,0µA, T2 = -10,0µA
Difference between simulation and measurements:
T1: 12,0 – 9,0 = 3,0µA, T2: -12,1 – (-10,0) = -2,1µA
Simulation outside tolerances and measurements outside tolerances.

P11: Tail: Forward = 2870, Sideway = -159, rotation = 0°

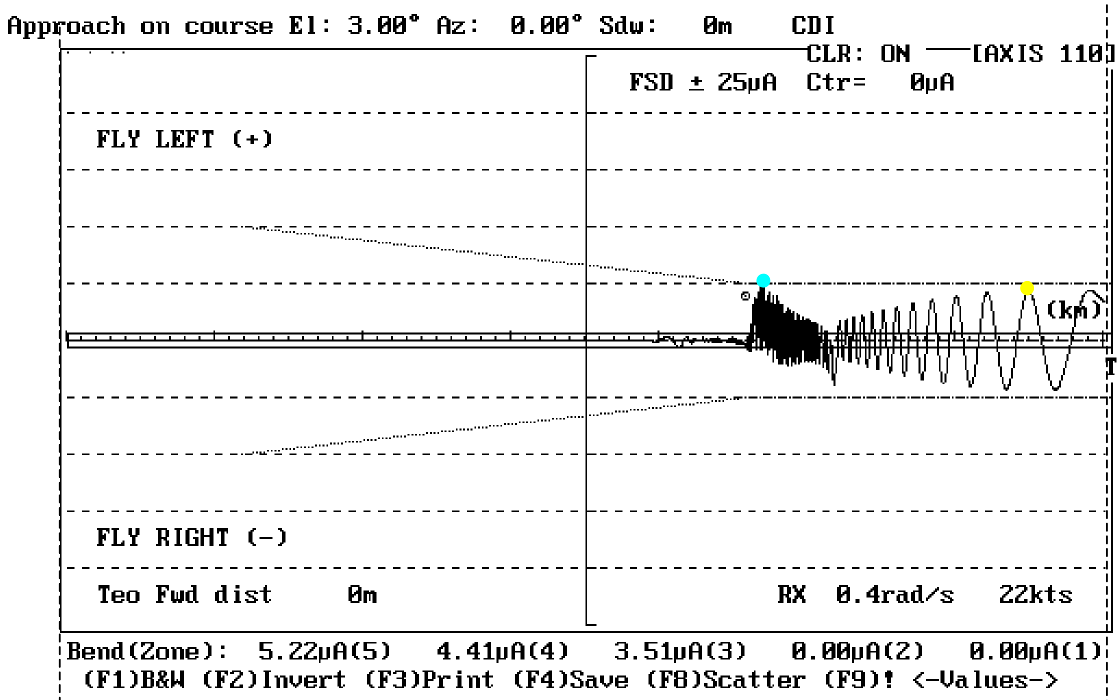


Measurement with ARTUS receiver and dipole antenna turned 45° to get approximately the same attenuation to the direct and reflected signal.

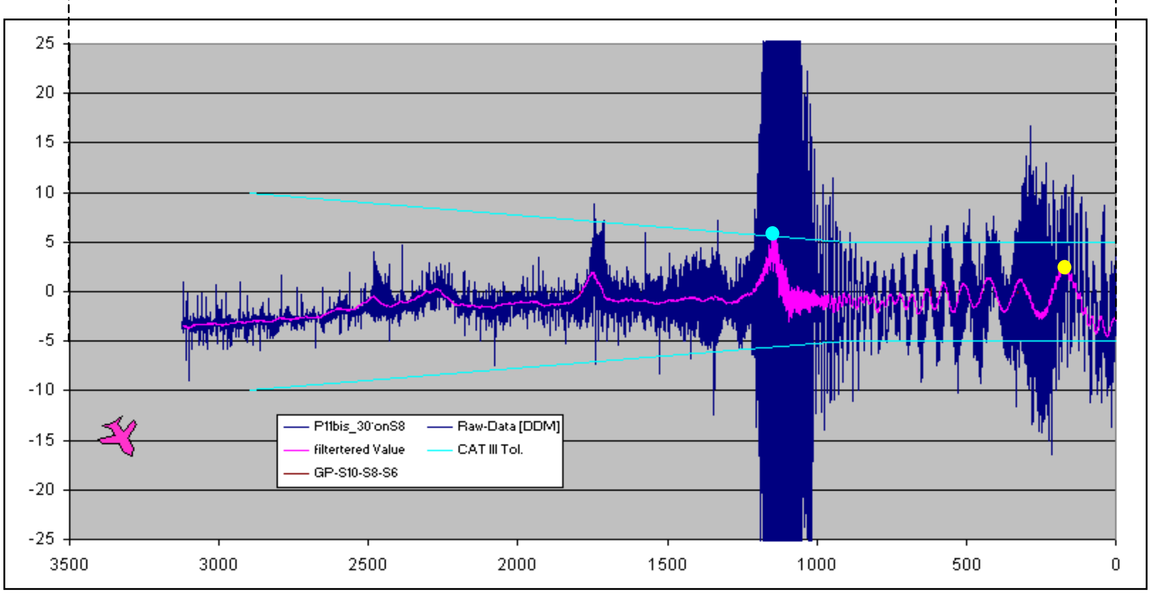


NOTE :
At 40km/h the ARTUS receiver filters out the high frequency bend components. The records made with this receiver can therefore not be considered as raw data.
Applying ICAO filtering to this data can lead to underestimate the disturbance.

P11 bis at 40 km/h: Tail: Forward = 2886m, Sideway = -178m, Rotation = 30°

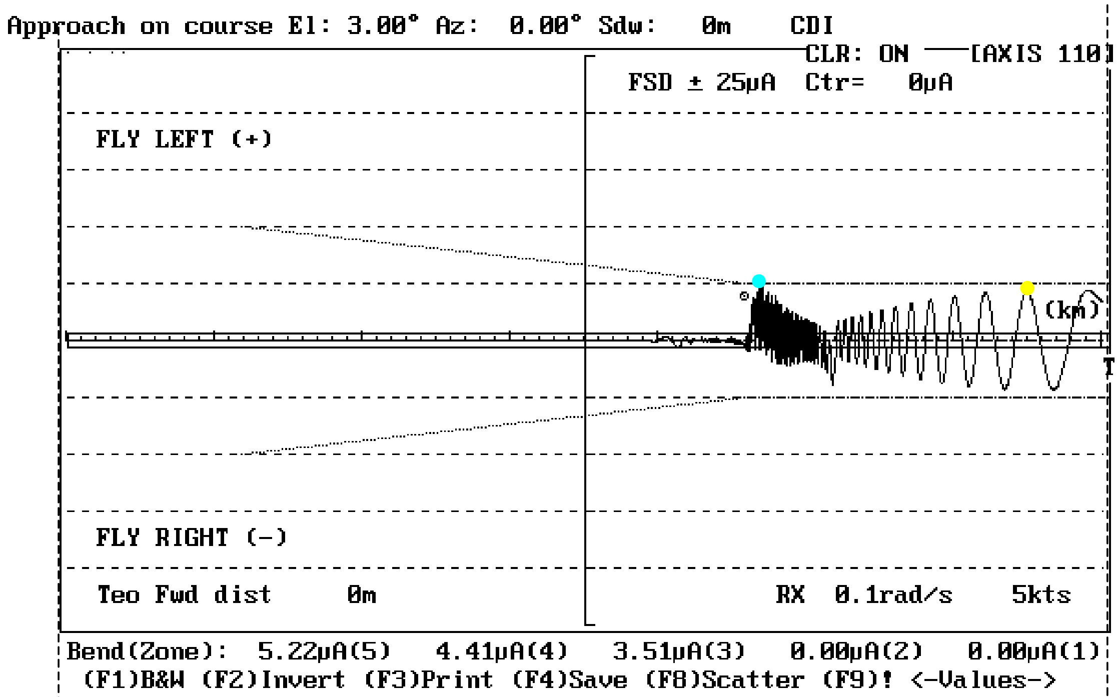


Disturbance amplitude: T1 = 5,2µA, T2 = 4,3µA

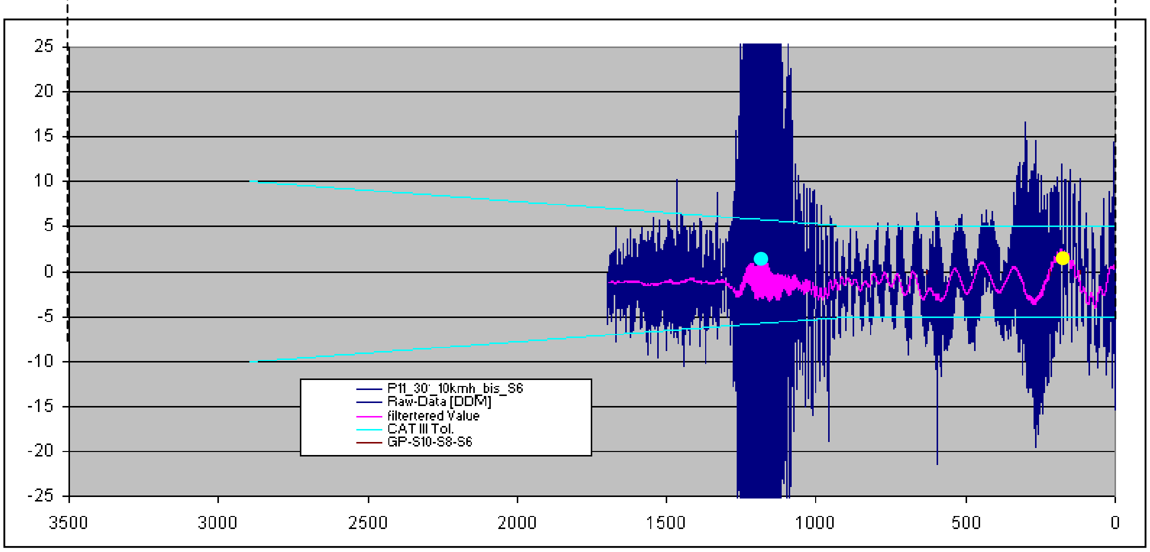


Disturbance amplitude **with** A380: T1 = 6,0 µA, T2 = 2,0µA
Disturbance amplitude **without** A380 at same points: T1 = -1,0µA, T2 = 0,0µA
Disturbance amplitude with A380 **only**: T1 = 7,0µA, T2 = 2,0 µA
Difference between simulation and measurements:
T1: 5,2 – 7,0 = -1,8µA, T2: 4,3 – 2,0 = 2,3µA
Simulation (just) outside tolerances and measurements outside tolerances.

P11 bis at 10 km/h: Tail: Forward = 2886m, Sideway = -178m, Rotation = 30°



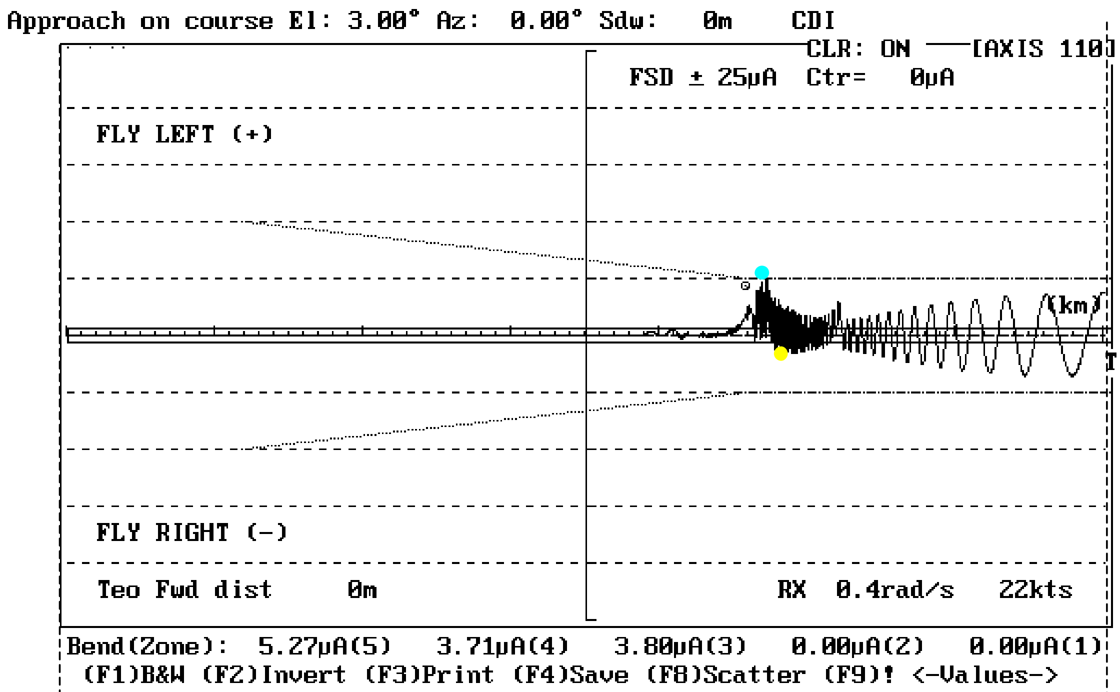
Disturbance amplitude: T1 = 5,3µA, T2 = 4,3µA



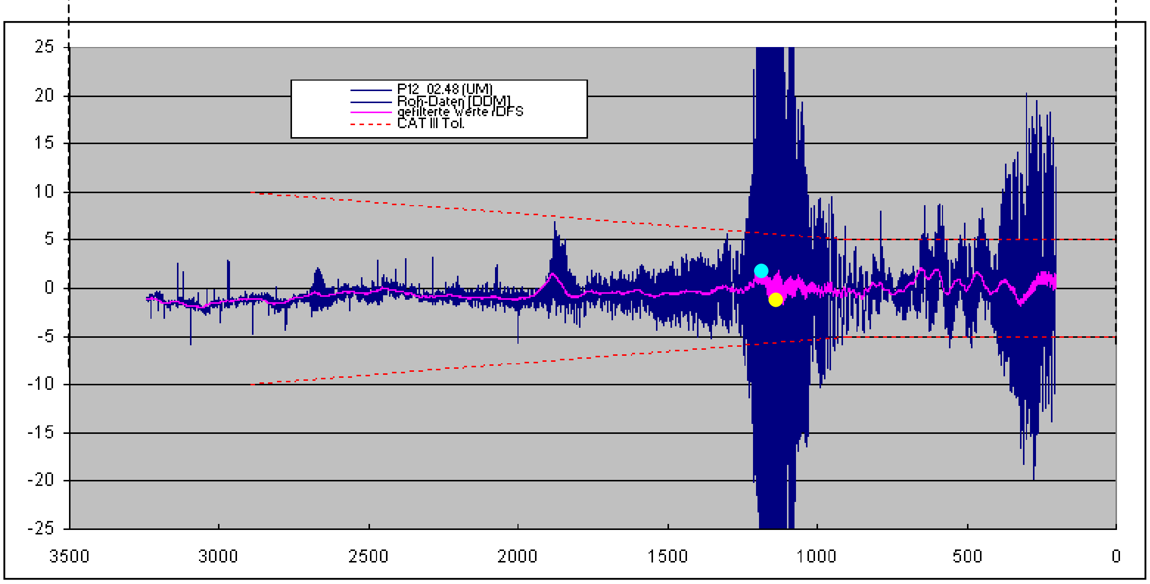
Disturbance amplitude **with** A380: T1 = 1,0 µA, T2 = 2,0µA
Disturbance amplitude **without** A380 at same points: T1 = 0,0µA, T2 = 0,0µA
Disturbance amplitude with A380 **only**: T1 = 1,0µA, T2 = 2,0 µA
Difference between simulation and measurements:
T1: 5,3 – 1,0 = 4,3µA, T2: 4,3 – 2,0 = 2,3µA

Simulation (just) outside tolerances and measurements inside tolerances.

P12 at 40 km/h: Tail: Forward = 2889m, Sideway = -193m, Rotation = 31°

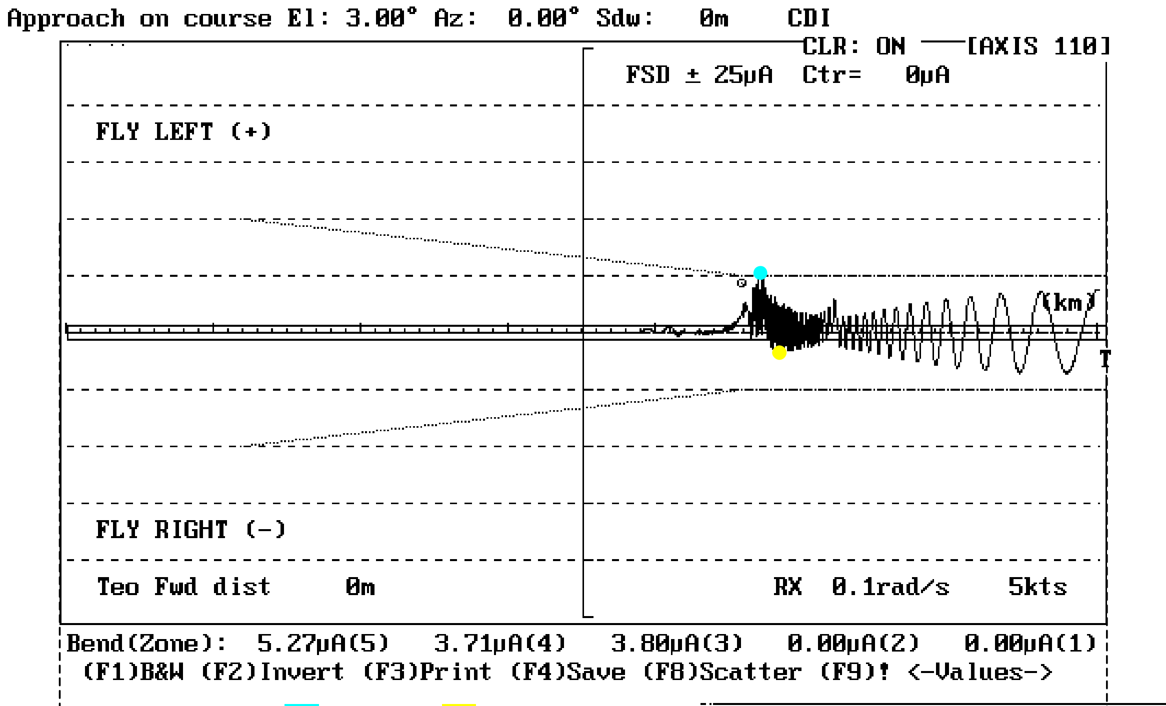


Disturbance amplitude: T1 = 5,3µA, T2 = -1,5µA

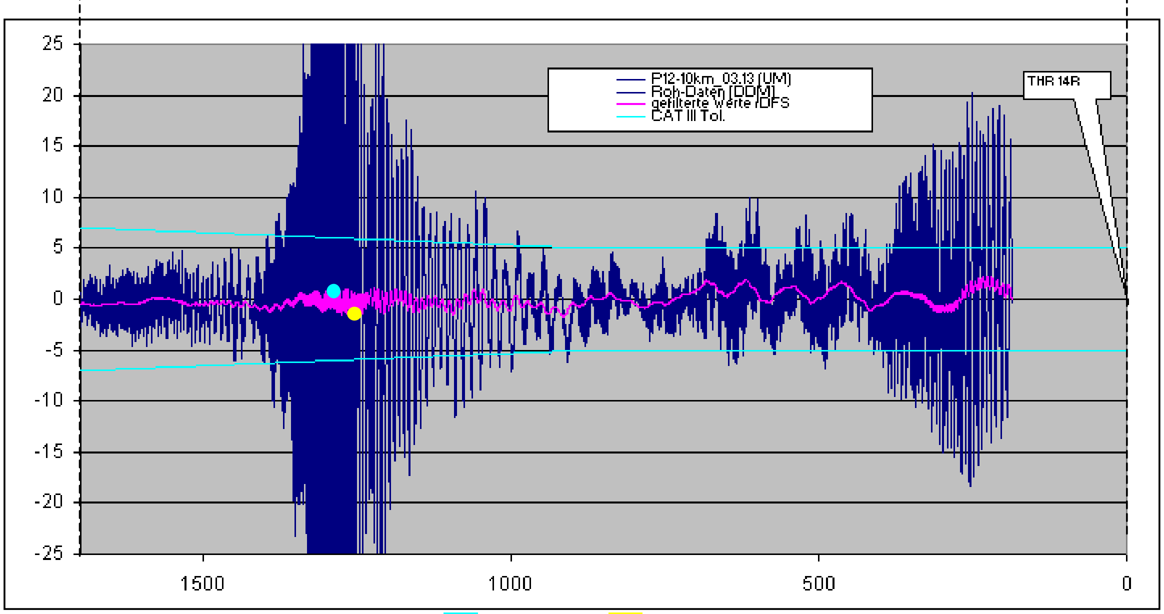


Disturbance amplitude **with** A380: T1 = 1,5 µA, T2 = -1,0µA
Disturbance amplitude **without** A380 at same points: T1 = 0,0µA, T2 = -0,5µA
Disturbance amplitude with A380 **only**: T1 = 1,5µA, T2 = -0,5µA
Difference between simulation and measurements:
T1: 5,3 – 1,5 = 3,8µA, T2: -1,5 – (-0,5) = -1,0µA
Simulation (just) outside tolerances and measurements inside tolerances.

P12 at 10 km/h: Tail: Forward = 2889m, Sideway = -193m, rotation = 31°

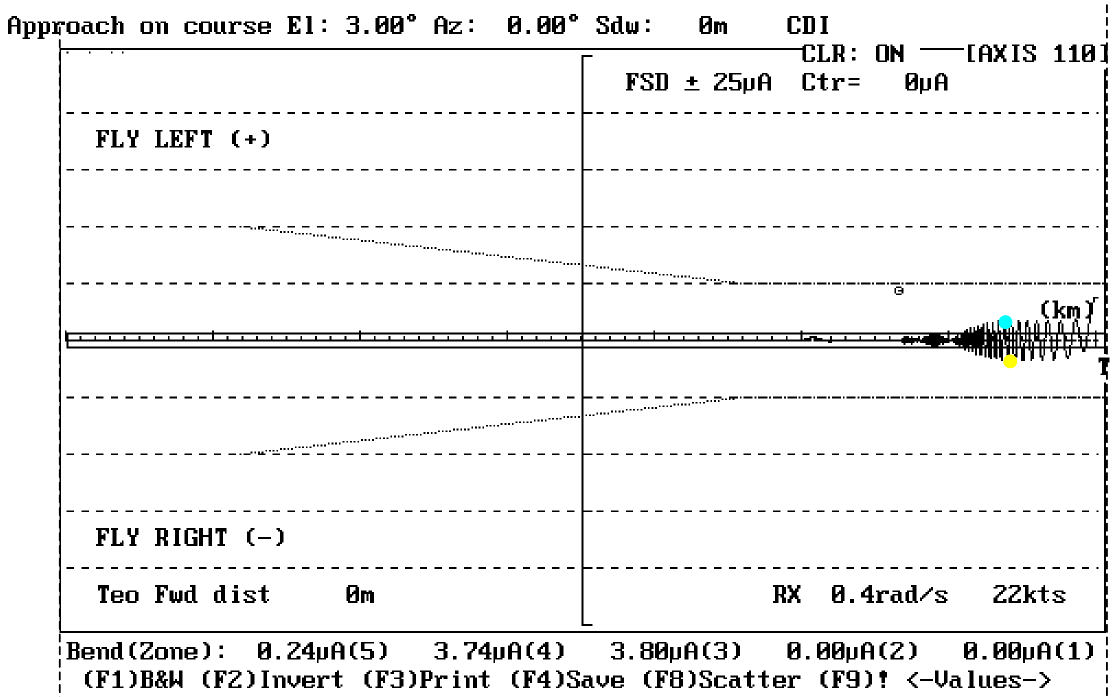


Disturbance amplitude: T1 = 5,3µA, T2 = -1,5µA

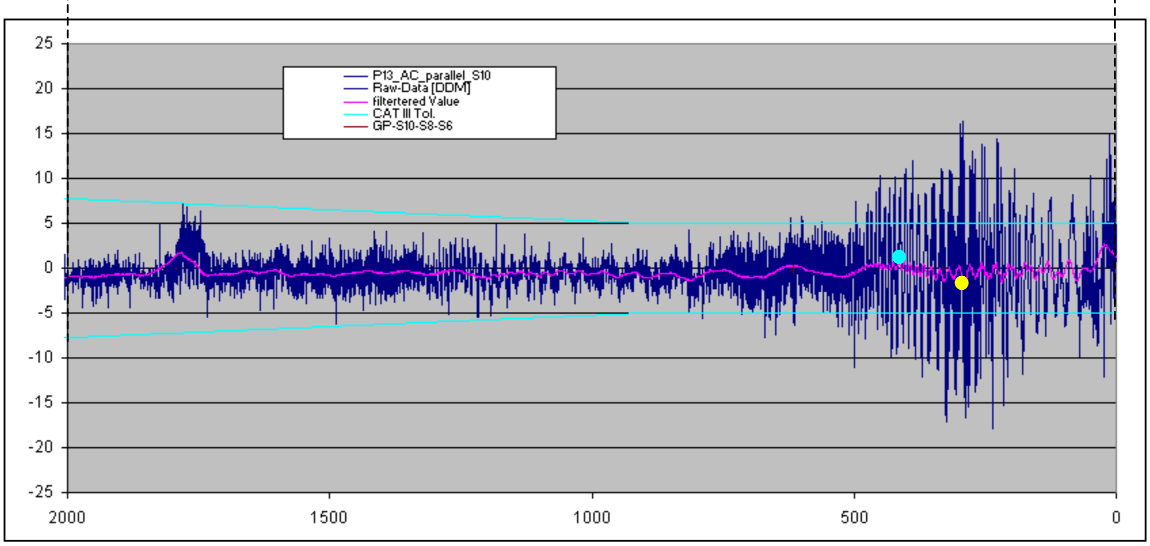


Disturbance amplitude **with** A380: T1 = 1,0 µA, T2 = -1,0µA
Disturbance amplitude **without** A380 at same points: T1 = -1,0µA, T2 = -0,5µA
Disturbance amplitude with A380 **only**: T1 = 2,0µA, T2 = -0,5µA
Difference between simulation and measurements:
T1: 5,3 – 2,0 = 3,3µA, T2: -1,5 – (-0,5) = 2,0µA
Simulation (just) outside tolerances and measurements inside tolerances.

P13: Tail: Forward = 3426m, Sideway = -196m, Rotation = 0°



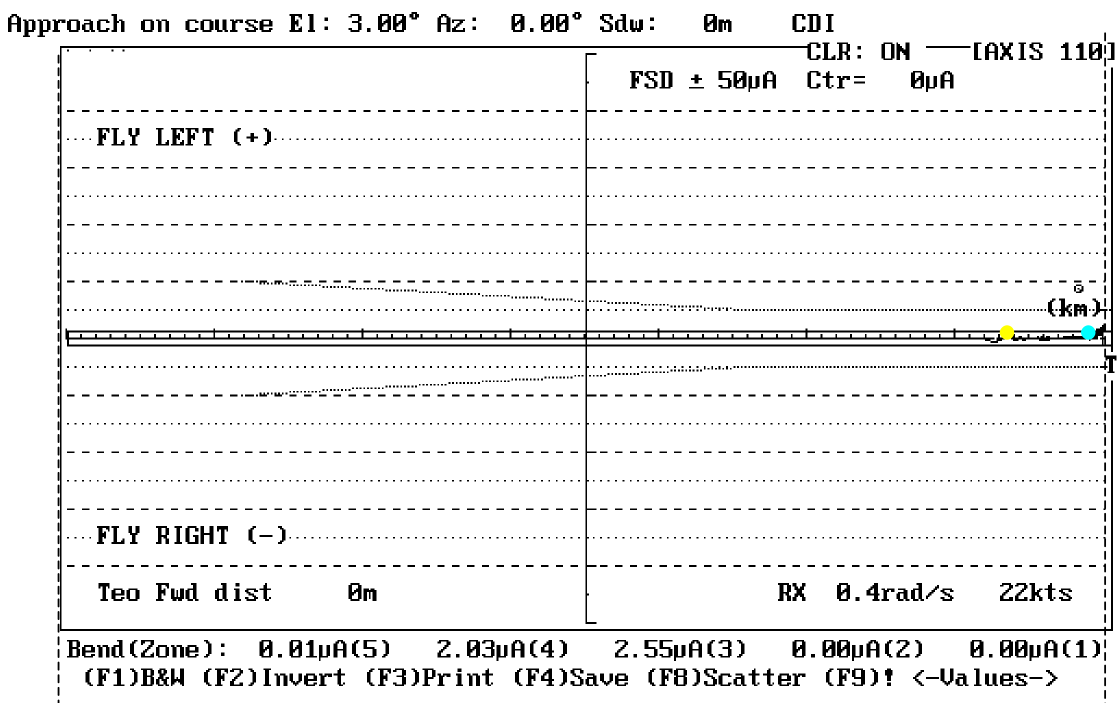
Disturbance amplitude: T1 = 1,7µA, T2 = -1,7µA



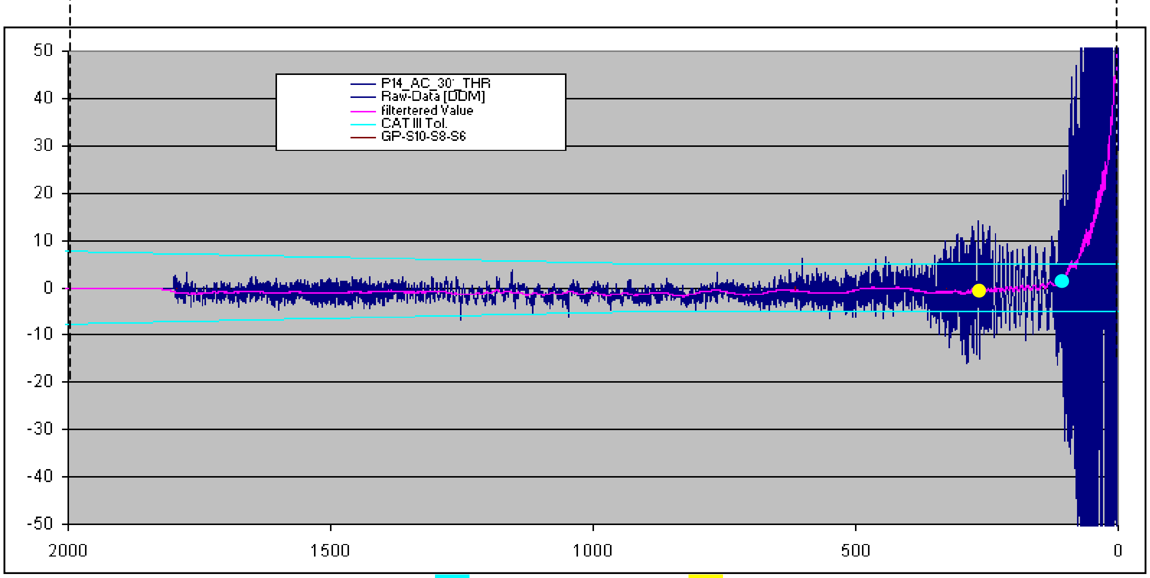
Disturbance amplitude **with** A380: T1 = 0,5µA, T2 = -1,5µA
Disturbance amplitude **without** A380 at same points: T1 = 0,0µA, T2 = -0,5µA
Disturbance amplitude with A380 **only**: T1 = 0,5µA, T2 = -1,0µA
Difference between simulation and measurements:
T1: 1,7 – 0,5 = 1,2µA, T2: -1,7 – (-1,0) = -0,7µA

Simulation inside tolerances and measurements inside tolerances.

P14: Tail: Forward = 4013m, Sideway = -194m, Rotation = 30°



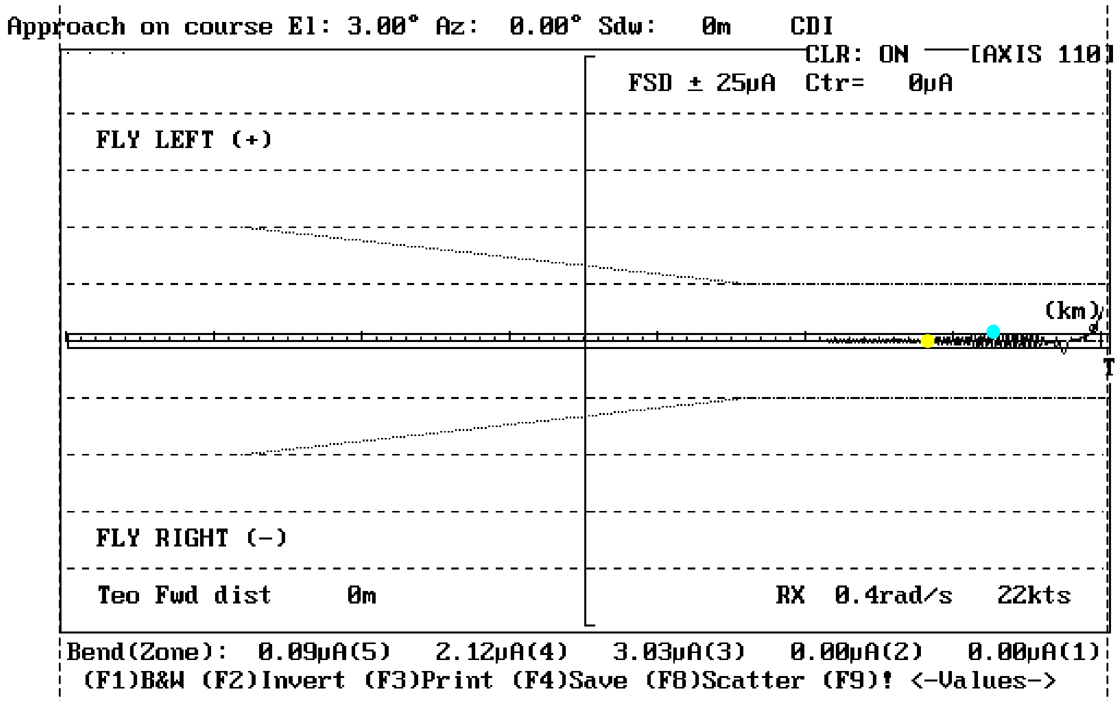
Disturbance amplitude: T1 = 0,2µA (100m), T2 = 0,5µA (280m)



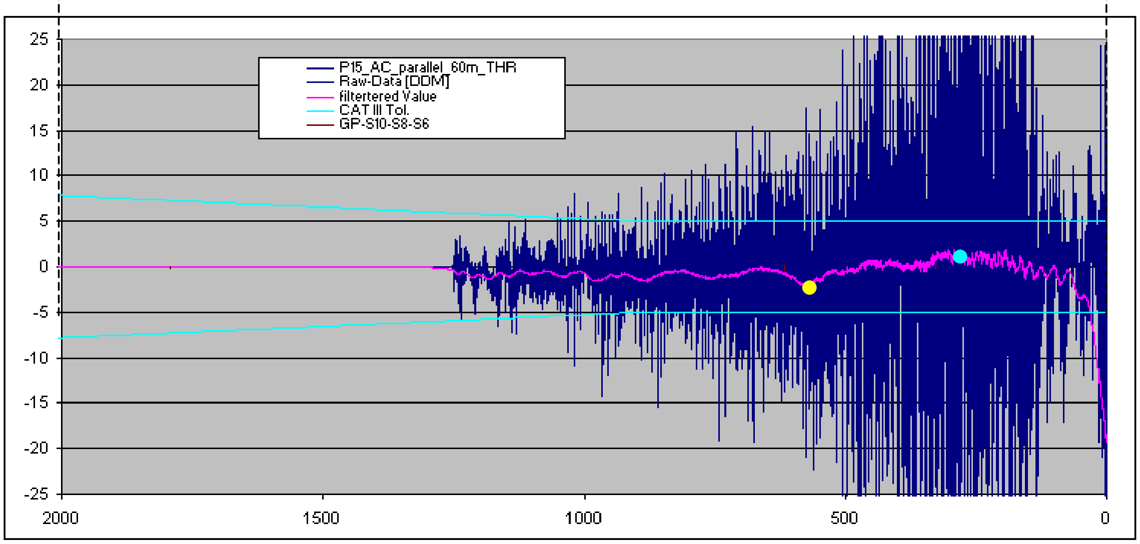
Disturbance amplitude **with** A380: T1 = 2,5µA (100m), T2 = -0,5µA (280m)
Disturbance amplitude **without** A380 at same points: T1 = 0,0µA, T2 = 0,0µA
Disturbance amplitude with A380 **only**: T1 = 2,5µA, T2 = -0,5µA
Difference between simulation and measurements:
T1: 0,2 – 2,5 = -2,3µA, T2: 0,5 – (-0,5) = 1,0µA

Simulation inside tolerances and measurements inside tolerances.

P15: Tail: Forward = 4068m, Sideway = -51m, Rotation = 90°

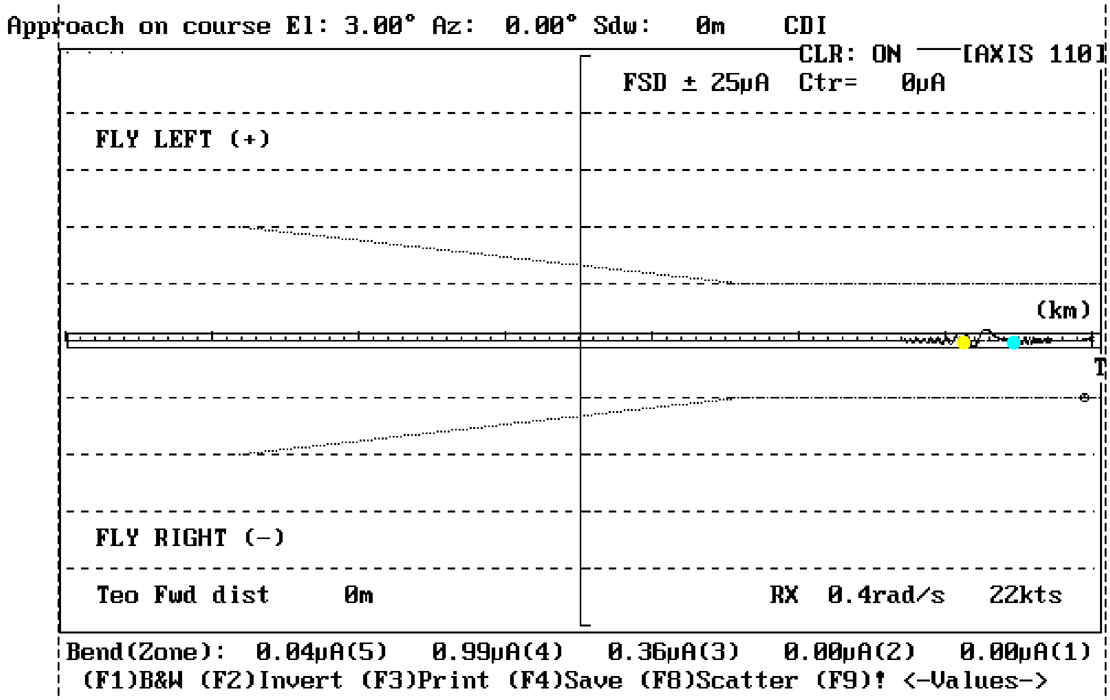


Disturbance amplitude: T1 = 0,5µA, T2 = -0,2µA (580m)

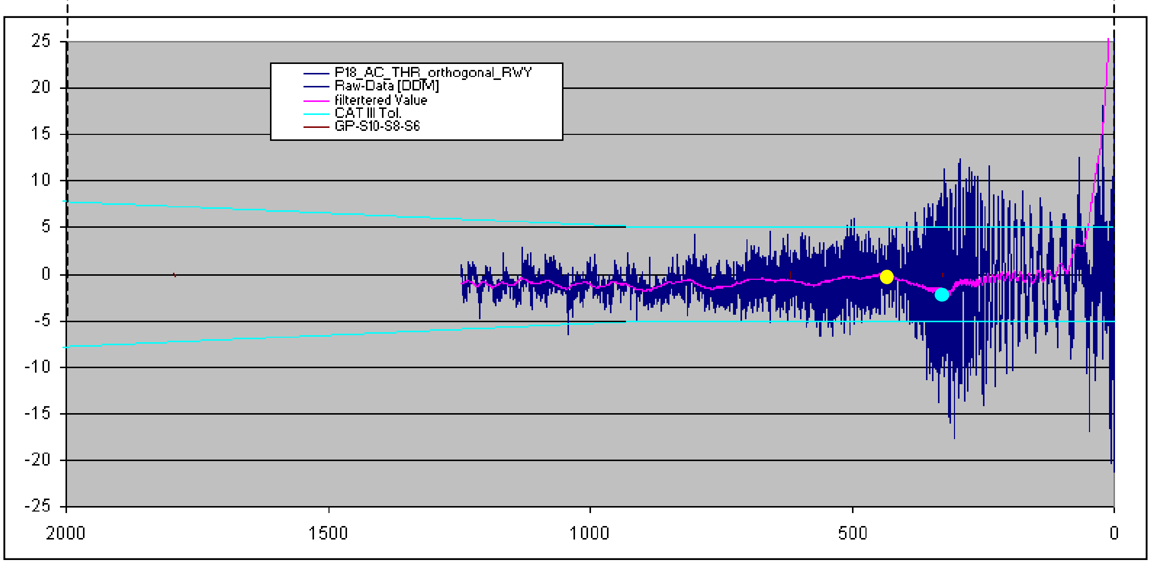


Disturbance amplitude **with** A380: T1 = 1,5µA, T2 = -2,0µA (580m)
Disturbance amplitude **without** A380 at same points: T1 = 0,0µA, T2 = 0,5µA
Disturbance amplitude with A380 **only**: T1 = 1,5µA, T2 = -2,5µA
Difference between simulation and measurements:
T1: 0,5 – 1,5 = -1,0µA, T2: -0,2 – (-2,5) = 2,3µA
Simulation inside tolerances and measurements inside tolerances.

P18: Tail: Forward = 4068m, sideway = 221m, rotation = 90°



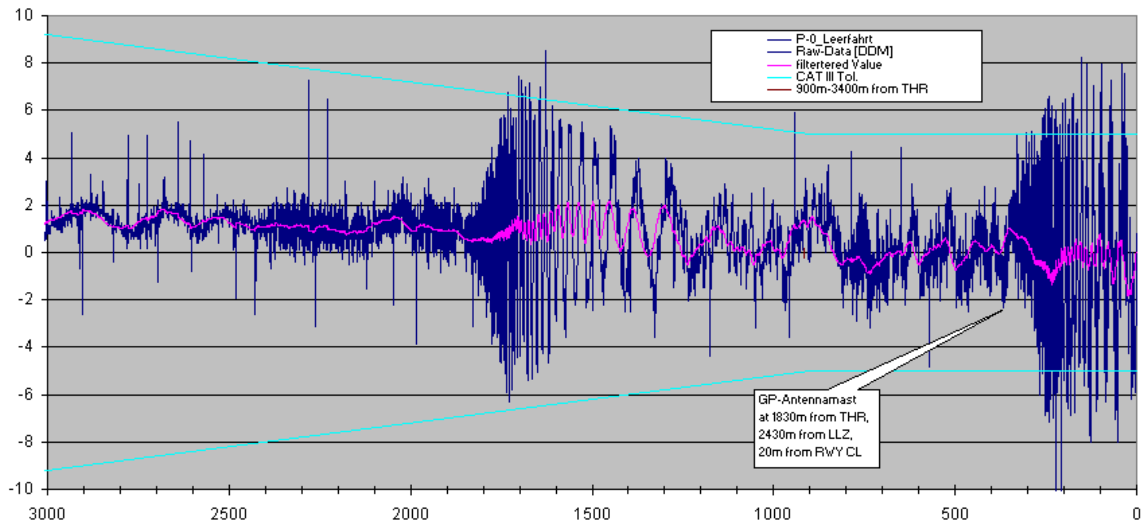
Disturbance amplitude: T1 = -0,2µA, T2 = -0,4µA



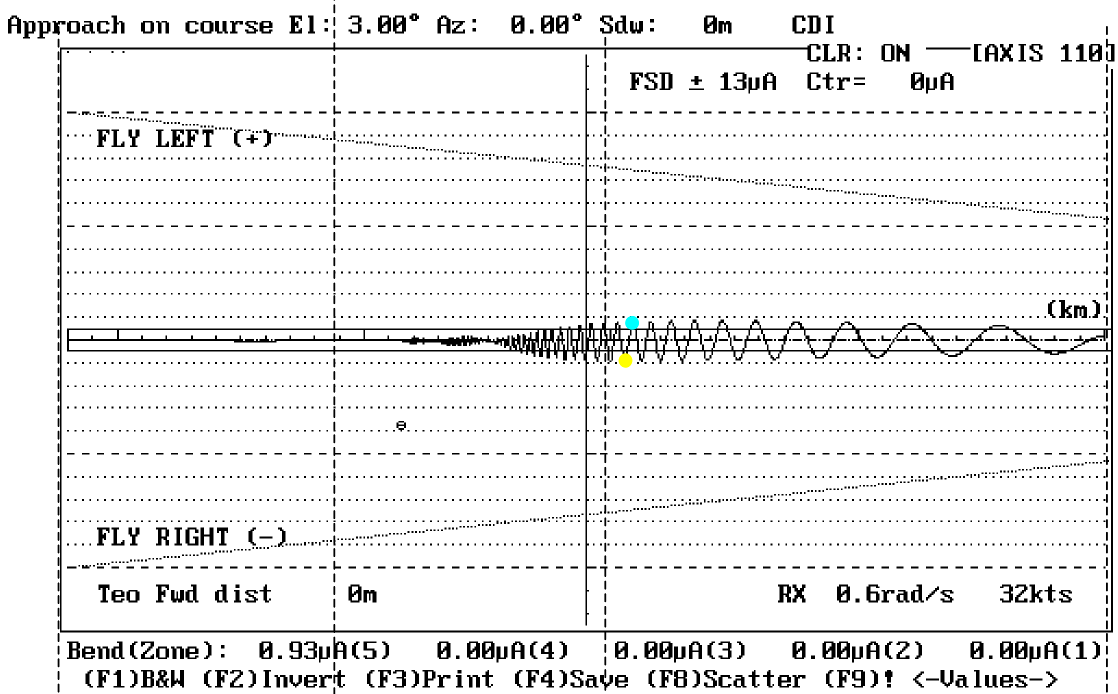
Disturbance amplitude **with** A380: T1 = -2,0µA, T2 = 0,0µA (580m)
Disturbance amplitude **without** A380 at same points: T1 = -0,0µA, T2 = -0,5µA
Disturbance amplitude with A380 **only**: T1 = -2,0µA, T2 = 0,5µA
Difference between simulation and measurements:
T1: -0,2 – (-2,0) = 1,8µA, T2: -0,4 – 0,5 = -0,9µA
Simulation inside tolerances and measurements inside tolerances.

Frankfurt Airport

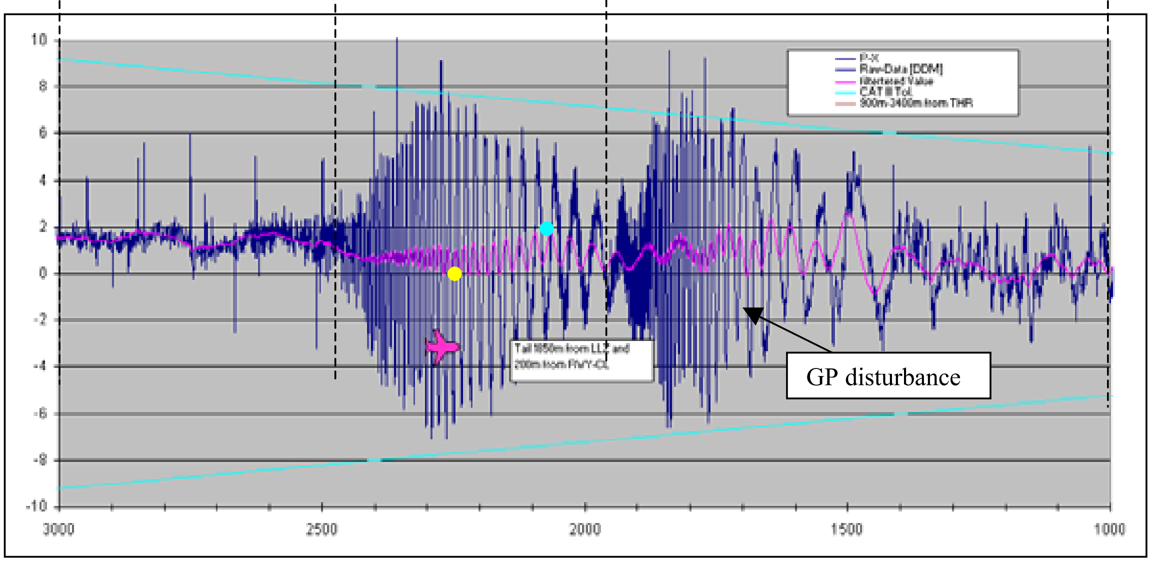
Reference record without A380



PX: Tail : Forward = 1836m, Sideway = 200m, Rotation = 0°



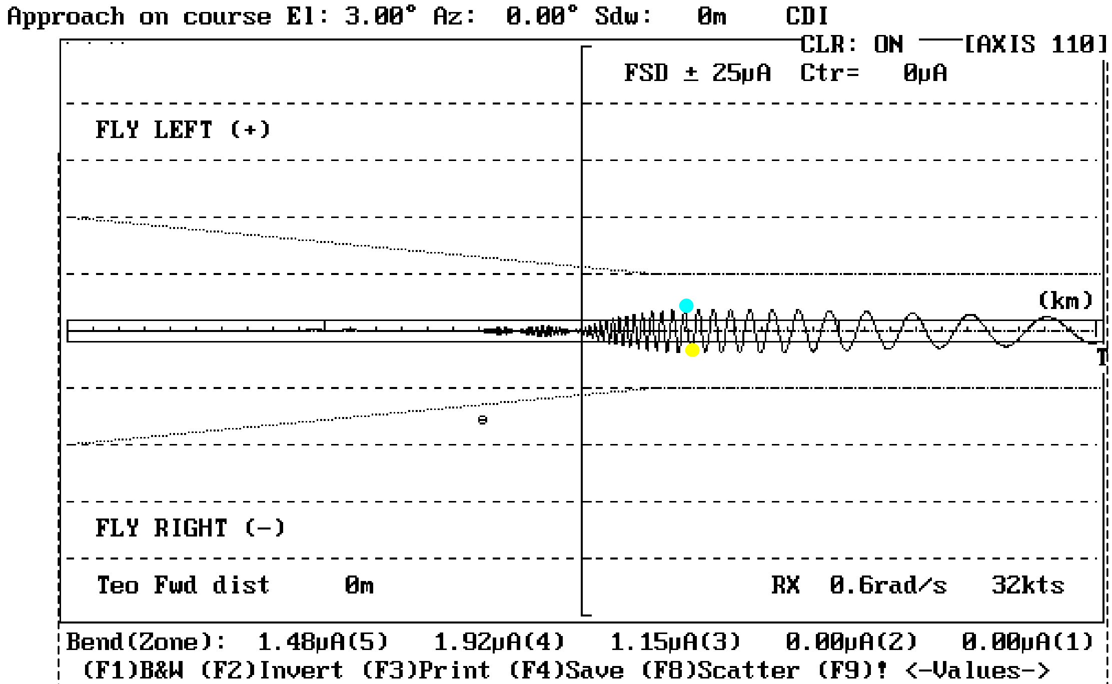
Disturbance amplitude: T1 = 0,8µA, T2 = -0,9µA



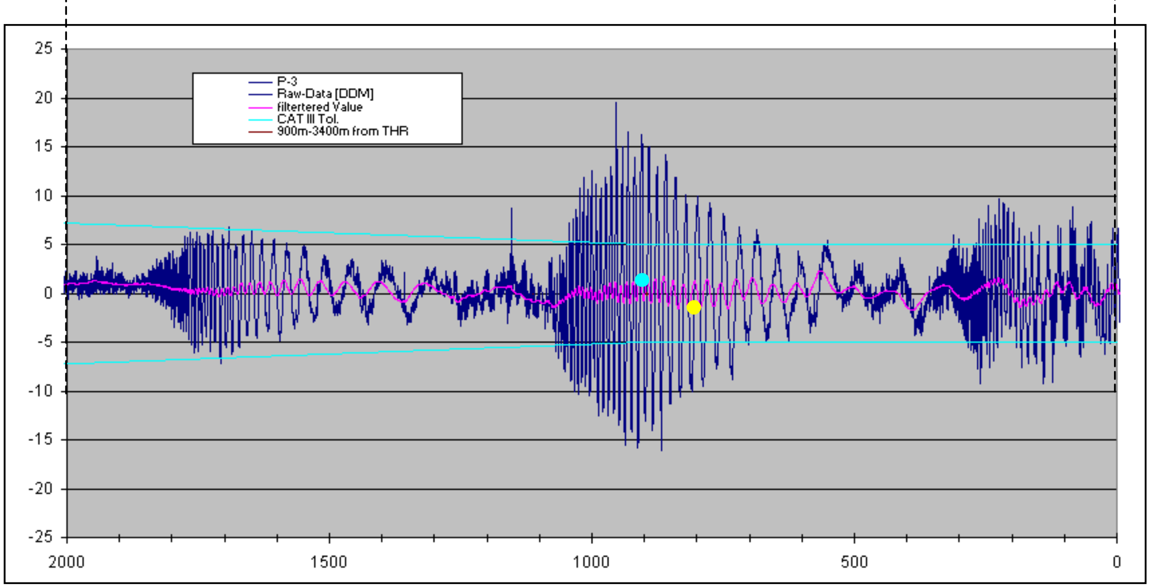
Disturbance amplitude **with** A380: T1 = 1,5µA, T2 = 0,0µA
Disturbance amplitude **without** A380: T1 = 1,0µA, T2 = 1,0µA
Disturbance amplitude with A380 **only**: T1 = 0,5µA, T2 = -1,0µA
Difference between simulation and measurements:
T1: 0,8 – 0,5 = 0,3µA, T2: -0,9 – (-1,0) = 0,1µA

Simulation inside tolerances and measurements inside tolerances.

P3: Tail: Forward = 3067, Sideway = 200m, rotation = 0°

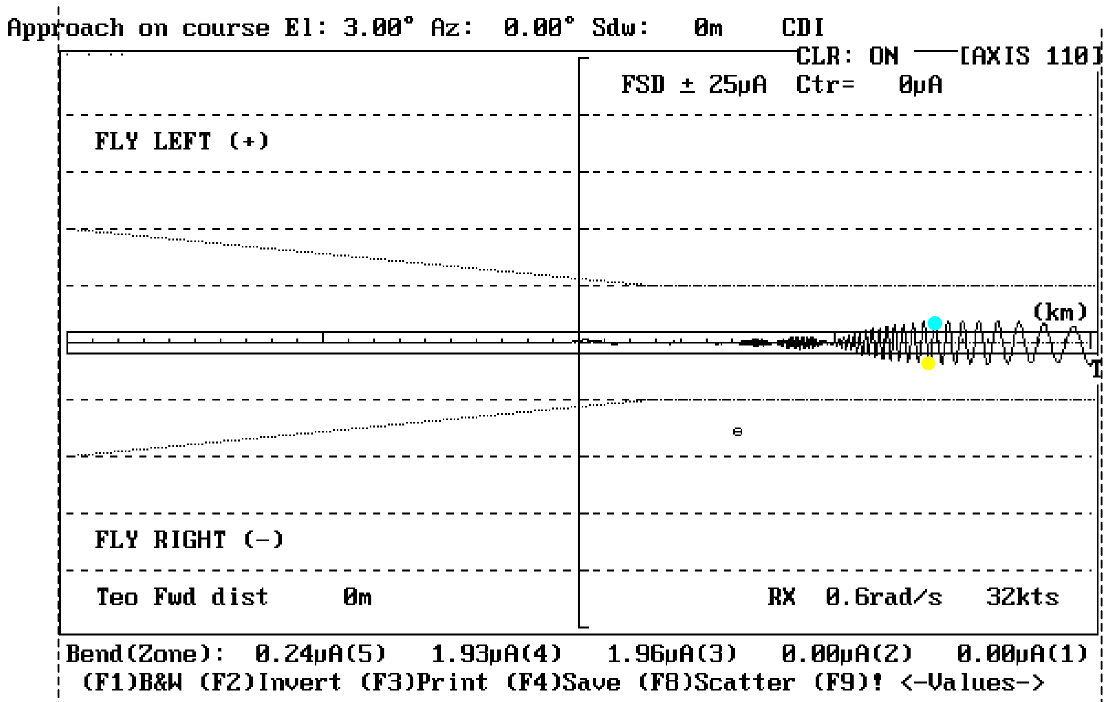


Disturbance amplitude: T1 =1,8µA, T2=-1,9µA

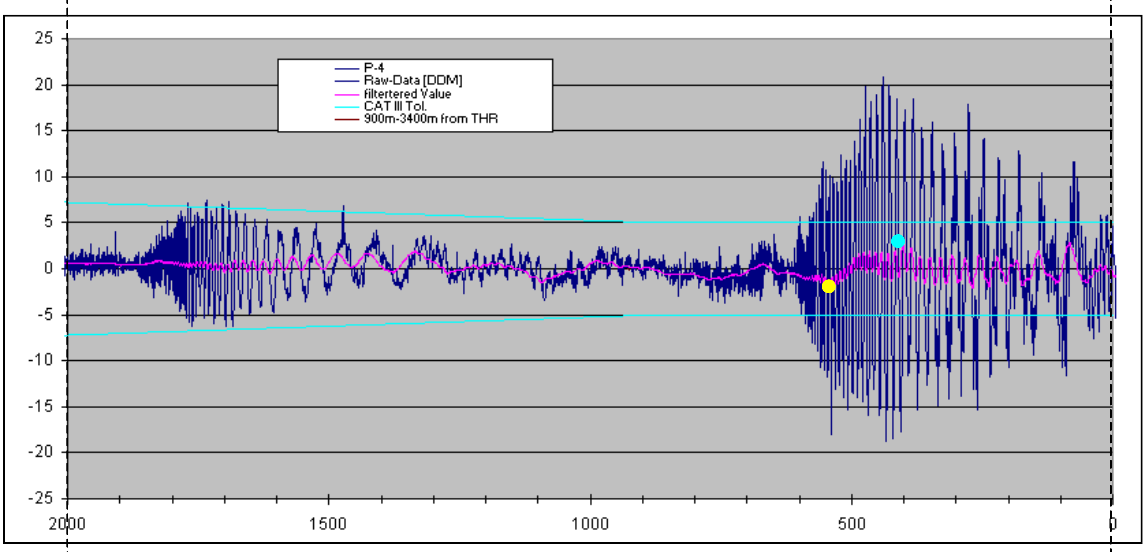


Disturbance amplitude **with** A380: T1 =2,0µA, T2=-1,0µA
Disturbance amplitude **without** A380 at same points: T1 =0,0µA, T2=0,0µA
Difference between simulation and measurements:
T1: 1,8 – 2,0 = -0,2µA, T2: -1,9 – (-1,0) = -0,9µA
Simulation inside tolerances and measurements inside tolerances.

P4: Tail: Forward = 3572, Sideway = 200m, Rotation = 0°



Disturbance amplitude: T1 = 1,8µA, T2 = -1,8µA

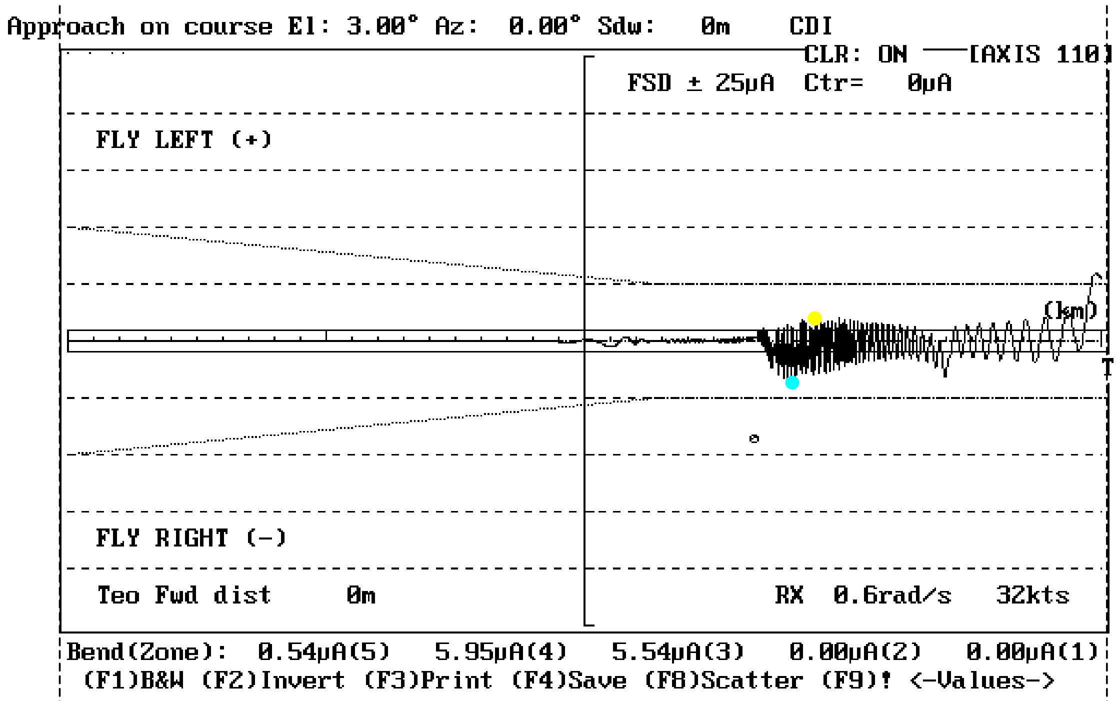


Disturbance amplitude **with** A380: T1 = 2,0µA, T2 = -2,0µA
Disturbance amplitude **without** A380 at same points: T1 = 0,0µA, T2 = 0,0µA
Difference between simulation and measurements:
T1: 1,8 – 2,0 = -0,2µA, T2: -1,8 – (-2,0) = 0,2µA

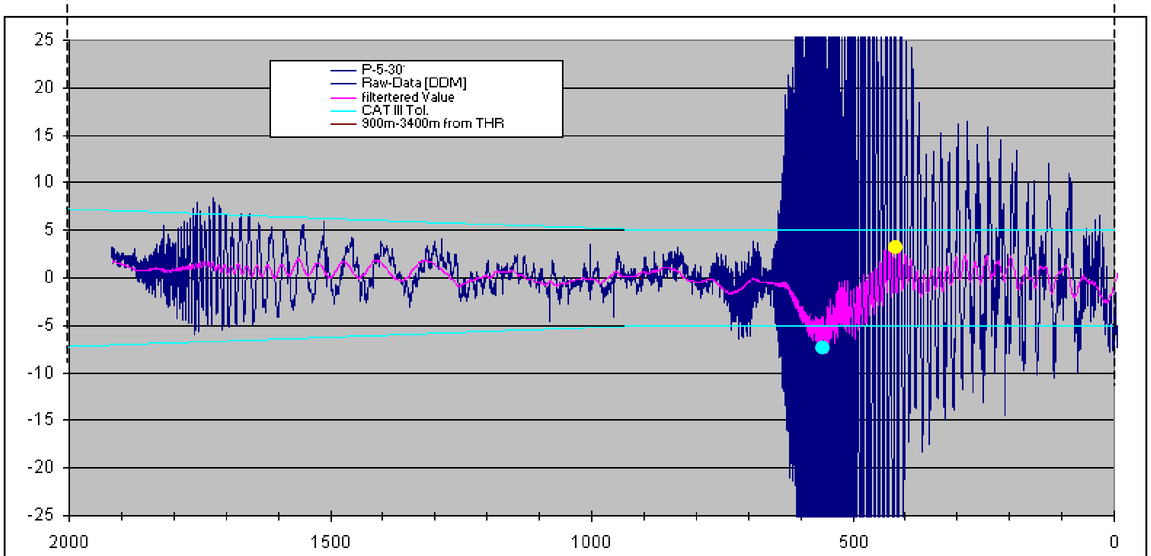
Simulation inside tolerances and measurements inside tolerances.

P5 30° at 60 km/h

Tail : Forward = 3588m, Sideway = 219m, rotation = 30°



Disturbance amplitude: T1 = -4,0µA, T2 = 2,0µA



Disturbance amplitude **with** A380: T1 = -7,5 µA, T2 = 3,0µA

Disturbance amplitude **without** A380 at same points: T1 = 0,0µA, T2 = 0,0µA

Disturbance amplitude with A380 **only**: T1 = -7,5µA, T2 = 3,0 µA

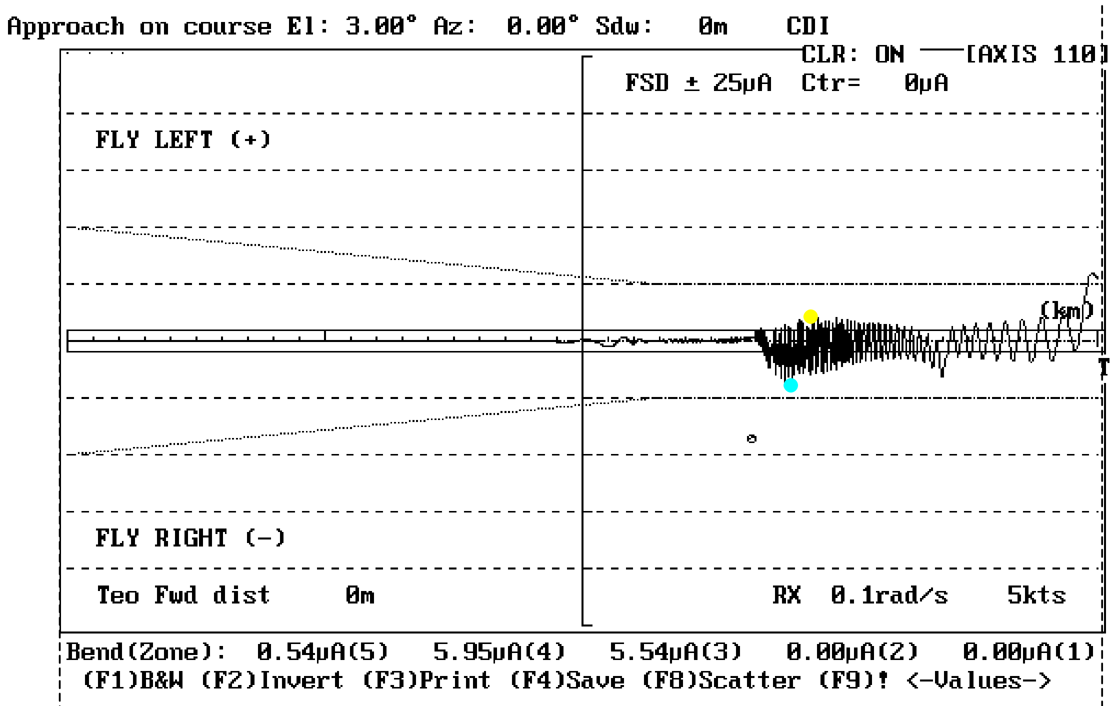
Difference between simulation and measurements:

T1: -4,0 – (-7,5) = 3,5µA, T2: 2,0 – (3,0) = -1,0µA

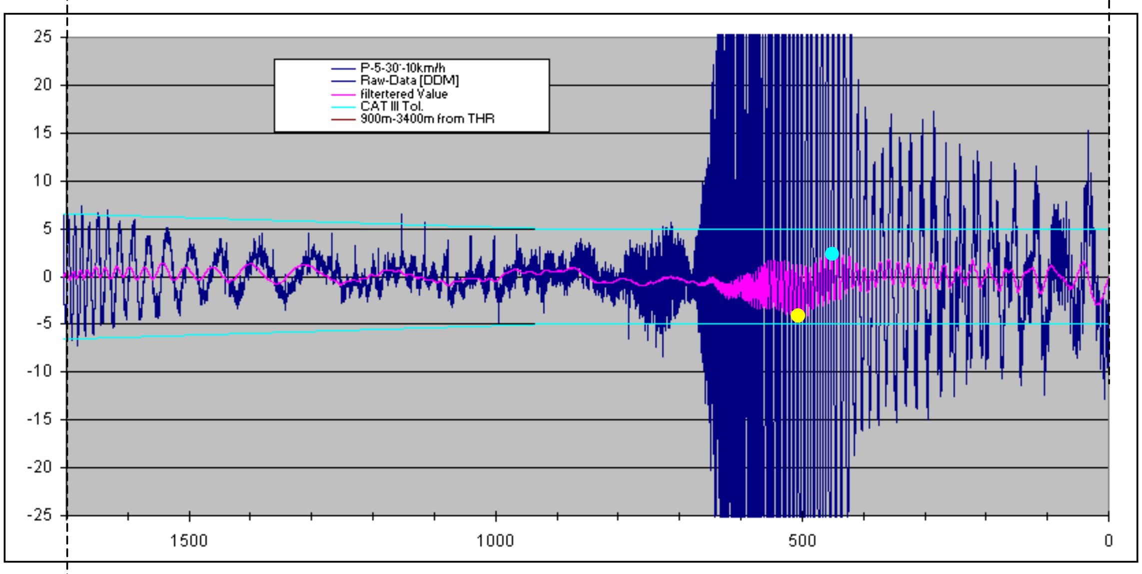
Simulation inside tolerances and measurements outside tolerances.

P5 30° at 10 km/h

Tail : Forward = 3588m, Sideway = 219m, Rotation = 30°



Disturbance amplitude: T1 = -4,0µA, T2 = 2,0µA



Disturbance amplitude **with** A380: T1 = 2,0 µA, T2 = -4,0µA

Disturbance amplitude **without** A380 at same points: T1 = 0,5µA, T2 = 0,0µA

Disturbance amplitude with A380 **only**: T1 = 1,5µA, T2 = -4,0 µA

Difference between simulation and measurements:

T1: -4,.0 – 1,5 = 2,5µA, T2: 2,0 – (-4.0) = 6,0µA

Simulation inside tolerances and measurements inside tolerances.

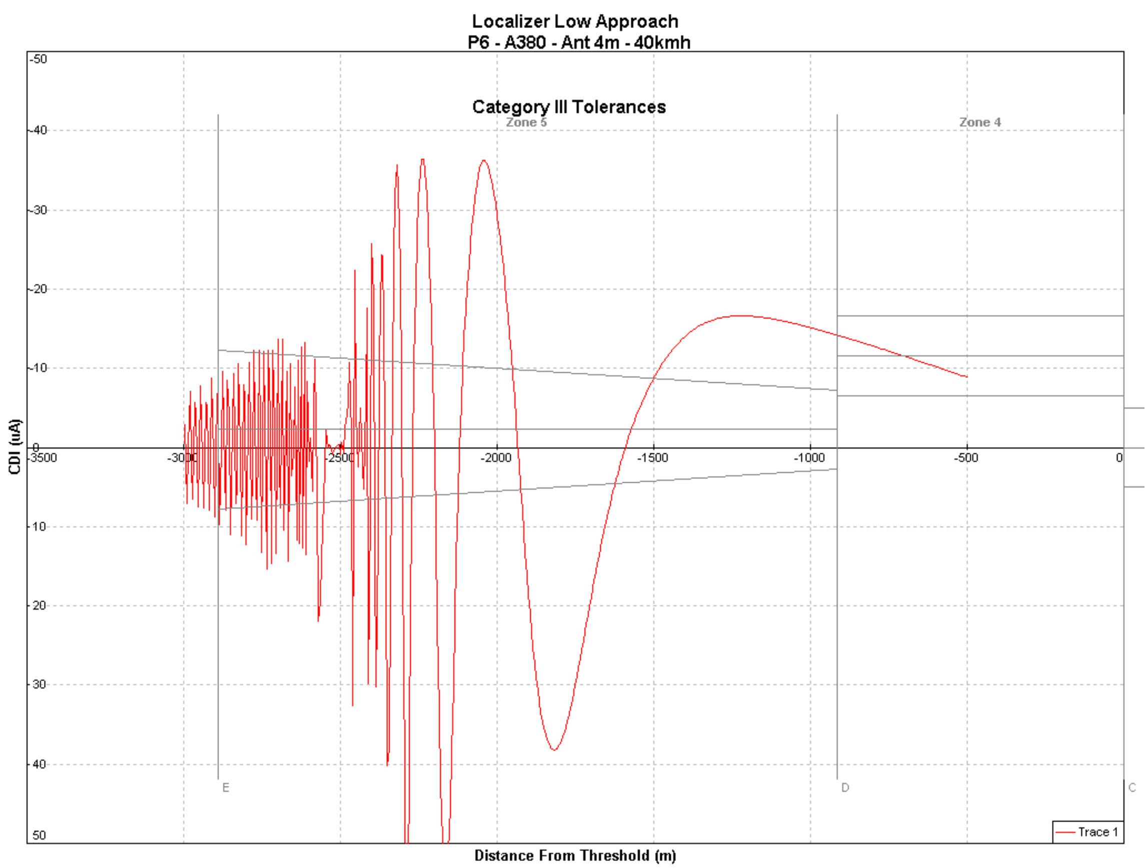
ANNEX M : Comparison of A380 ILS disturbance with NAVCOM simulations for Frankfurt A380 cases

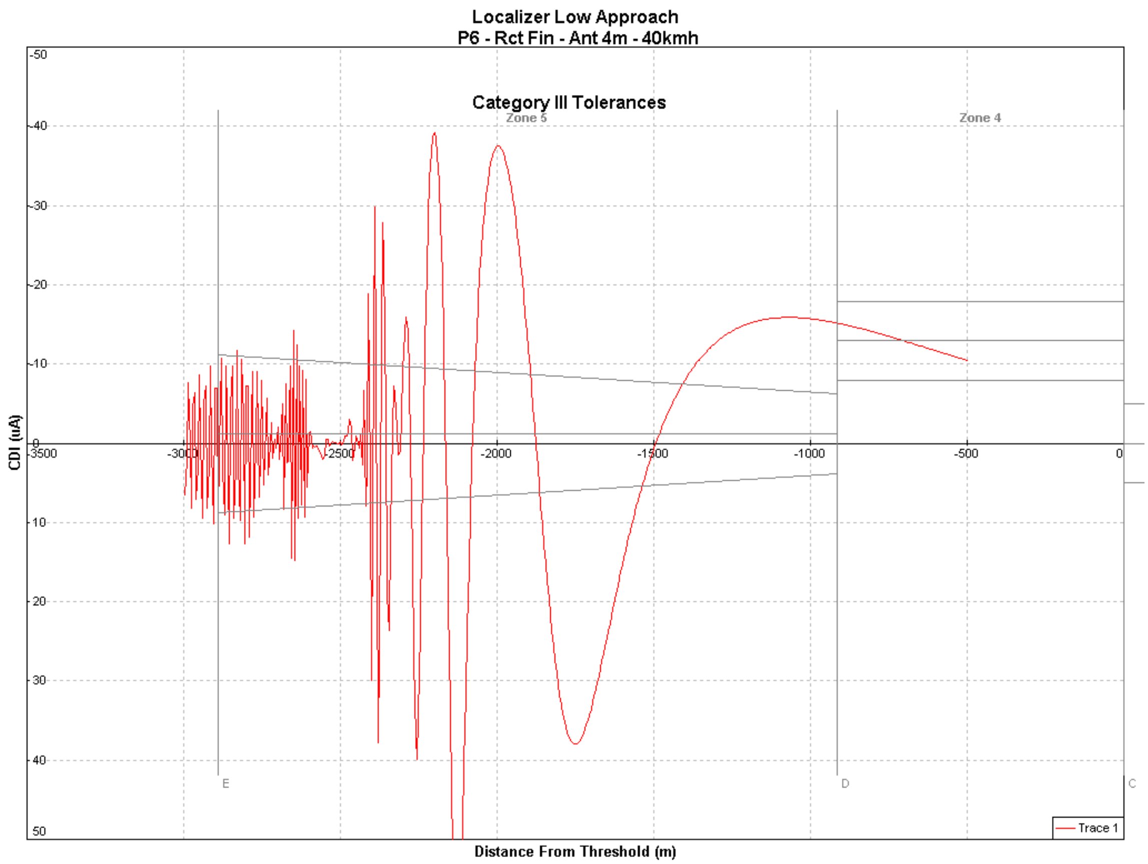
To be added with NavCom authorisation

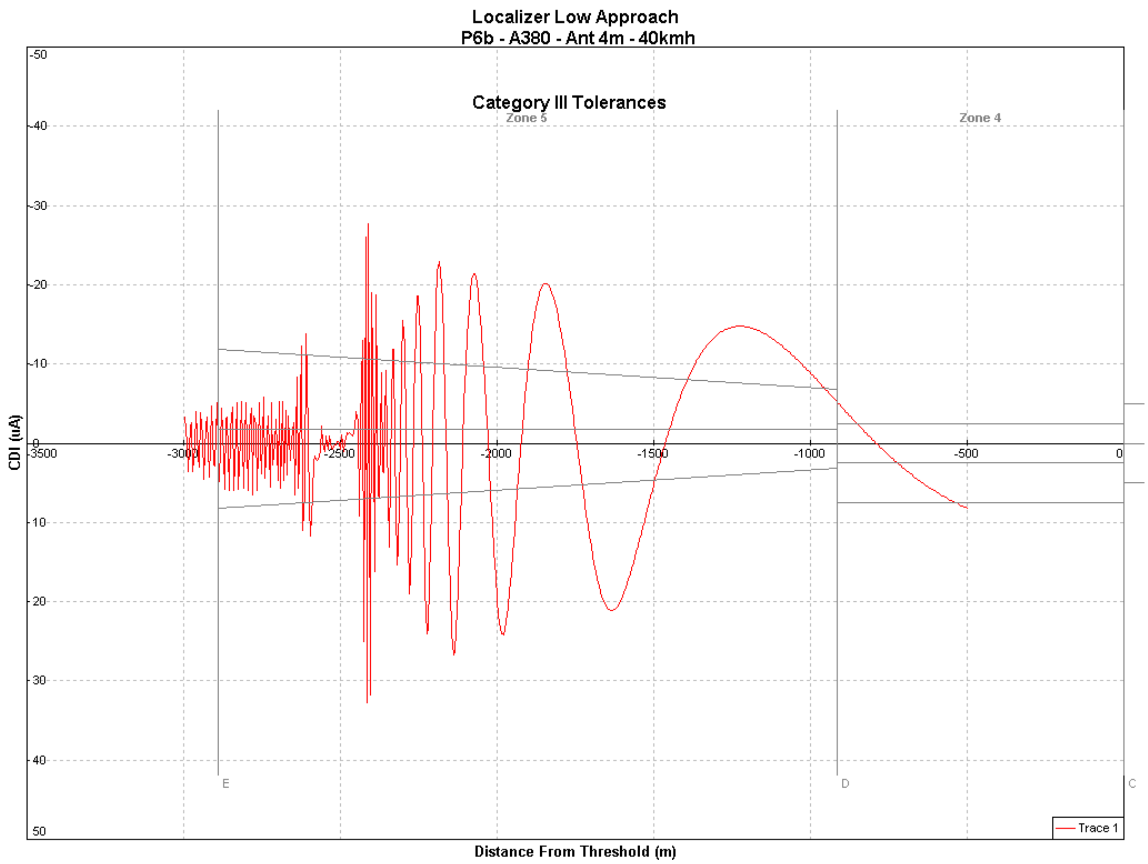
ANNEX N : Comparison of A380 ILS disturbance with OHIO simulations for Toulouse and Frankfurt A380 cases

Raw data prediction results are provided for several measurement points at Toulouse and one point at Frankfurt

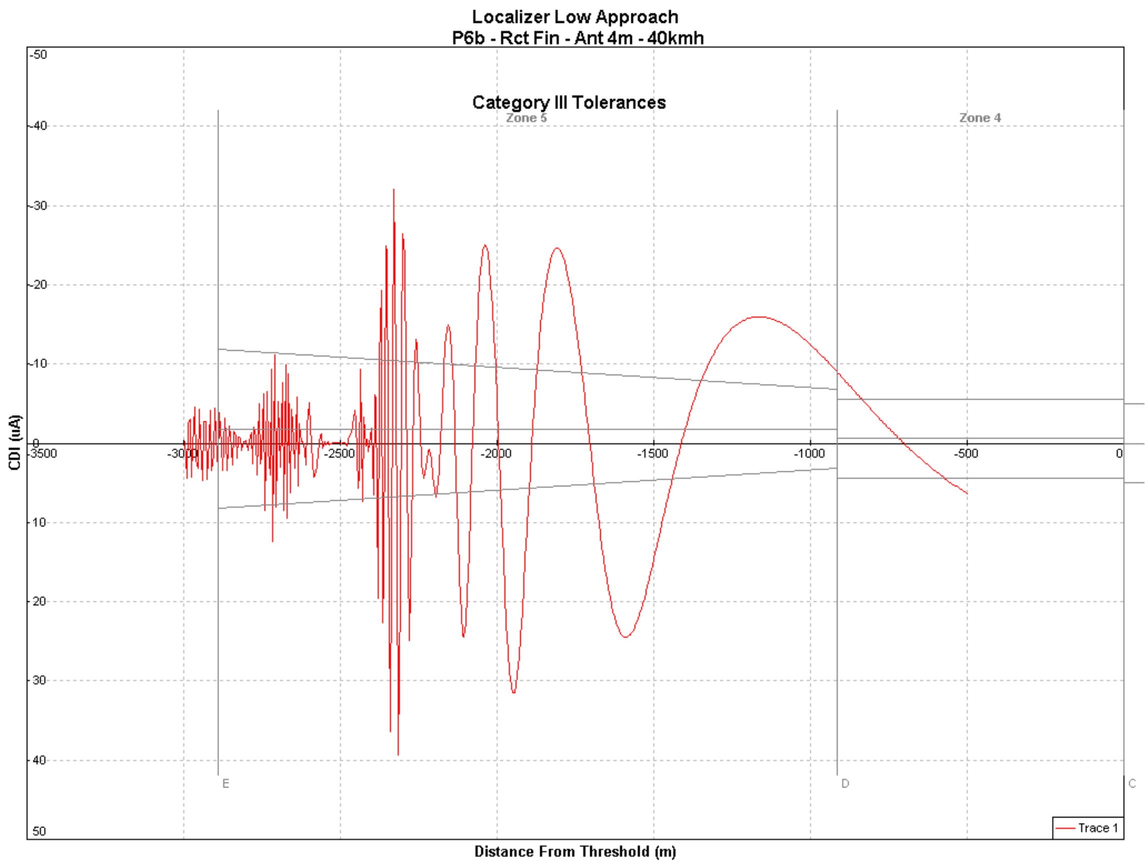
<u>Toulouse :</u>

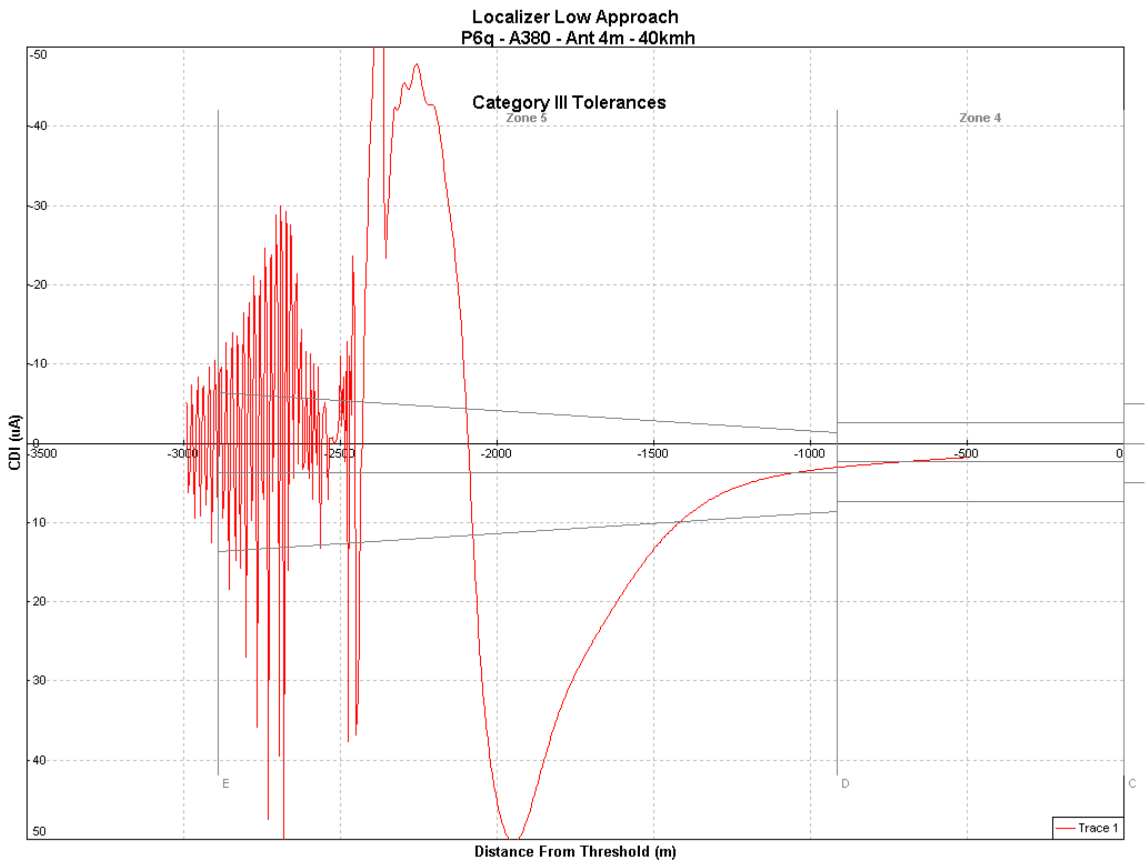



Localizer Low Approach
P6 - Rct Fin - Ant 4m - 40kmh
Category III Tolerances
Zone 5
Zone 4
CDI (uA)
Distance From Threshold (m)
Trace 1
E
D
C
-3500
-3000
-2500
-2000
-1500
-1000
-500
0
-50
-40
-30
-20
-10
10
20
30
40
50

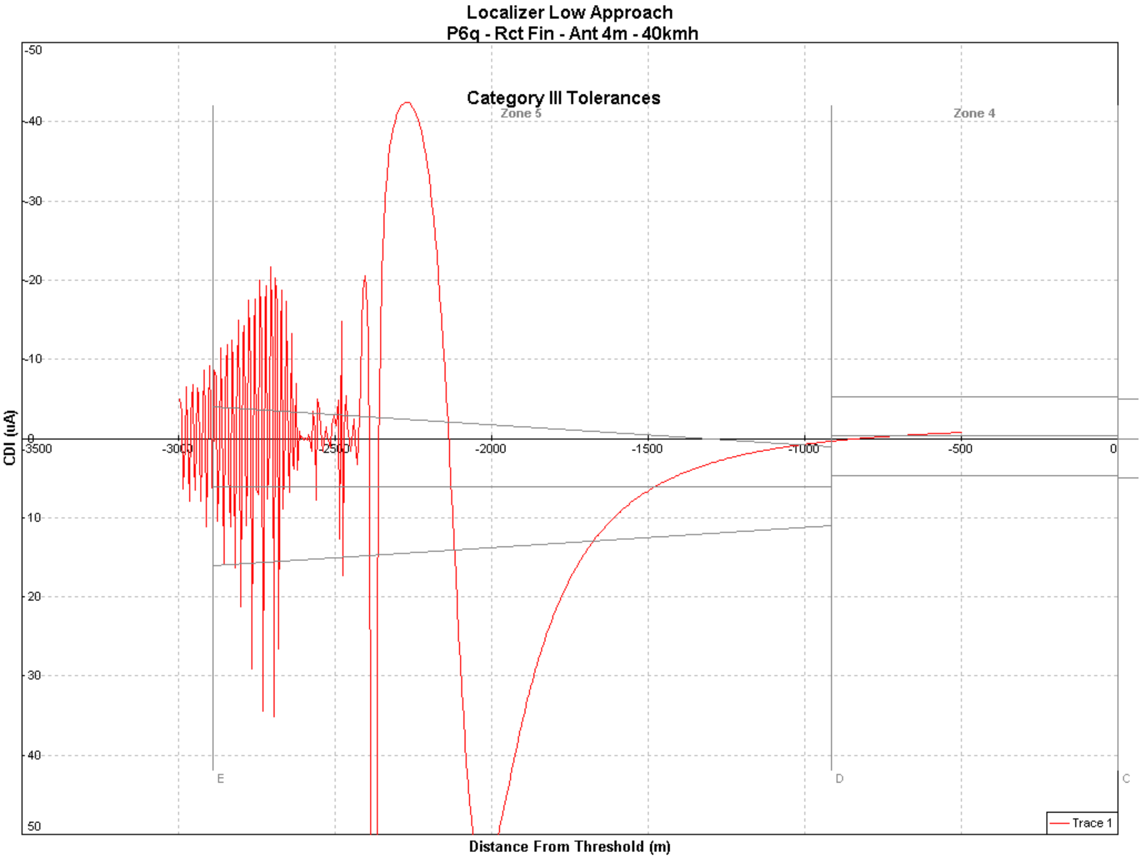


Localizer Low Approach
P6b - A380 - Ant 4m - 40kmh
Category III Tolerances
Zone 5
Zone 4
CDI (uA)
Distance From Threshold (m)
Trace 1

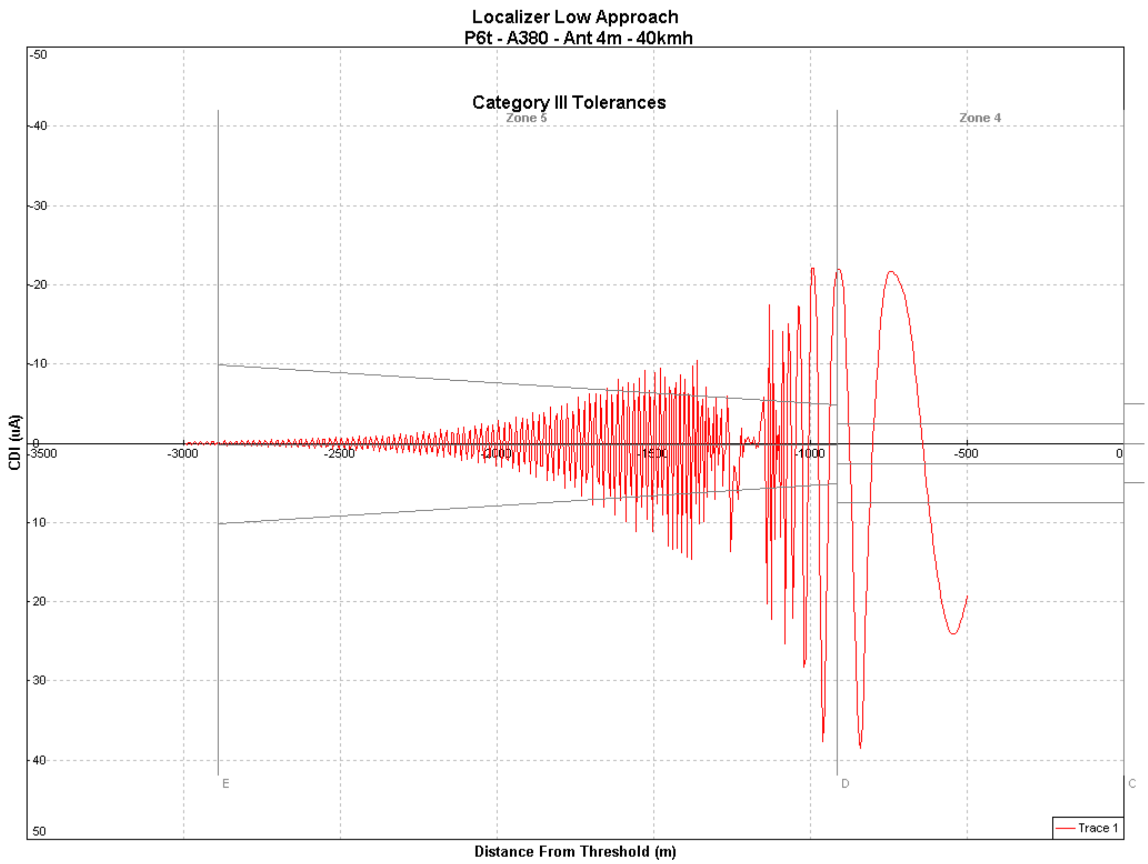

Localizer Low Approach
P6b - Rct Fin - Ant 4m - 40kmh
Category III Tolerances
Zone 5
Zone 4
CDI (uA)
Distance From Threshold (m)
-50
-40
-30
-20
-10
0
10
20
30
40
50
-3500
-3000
-2500
-2000
-1500
-1000
-500
0
E
D
C
Trace 1



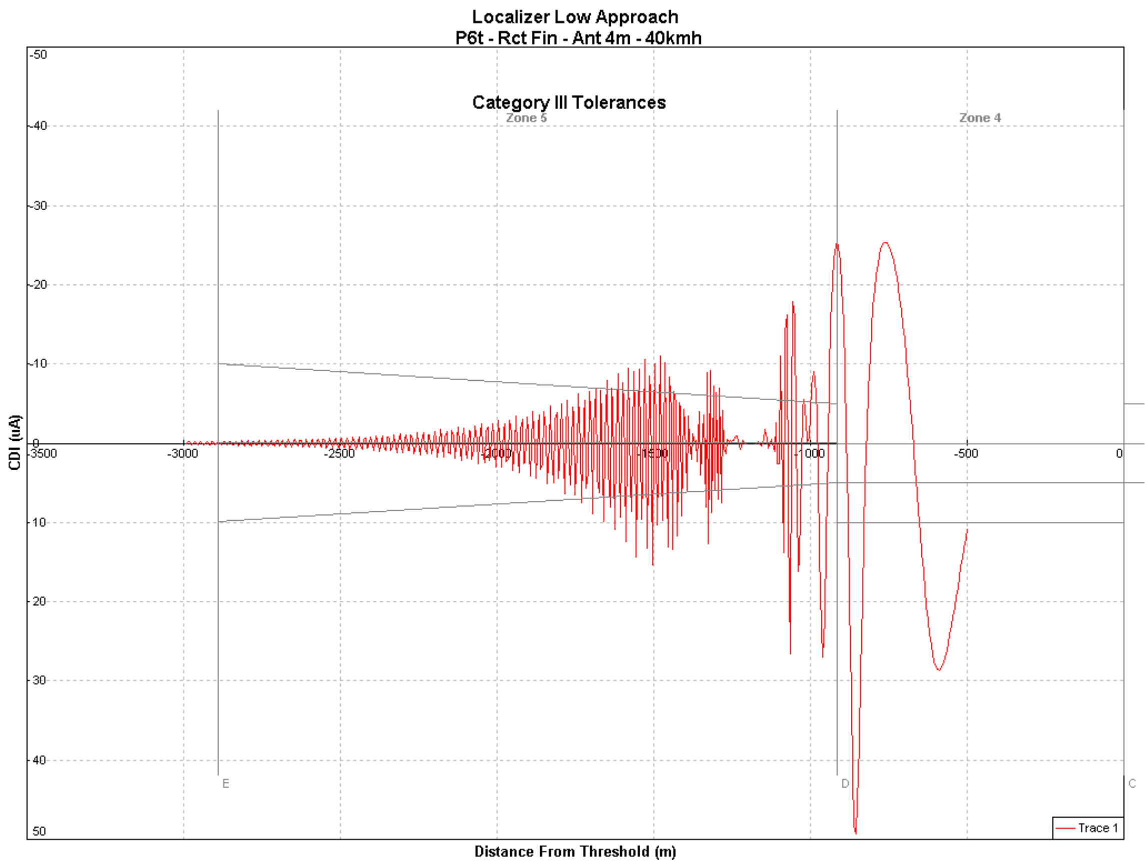
Localizer Low Approach
P6q - A380 - Ant 4m - 40kmh
Category III Tolerances
Zone 5
Zone 4
CDI (uA)
Distance From Threshold (m)
Trace 1

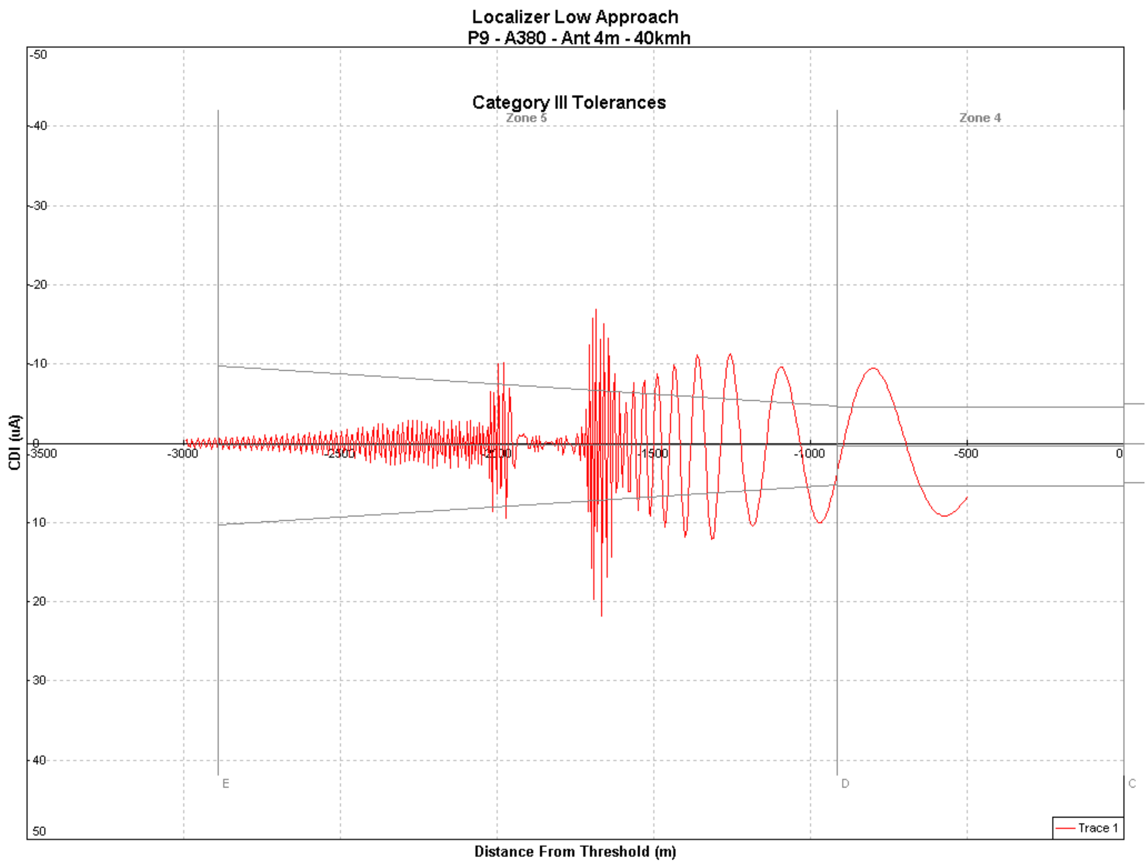


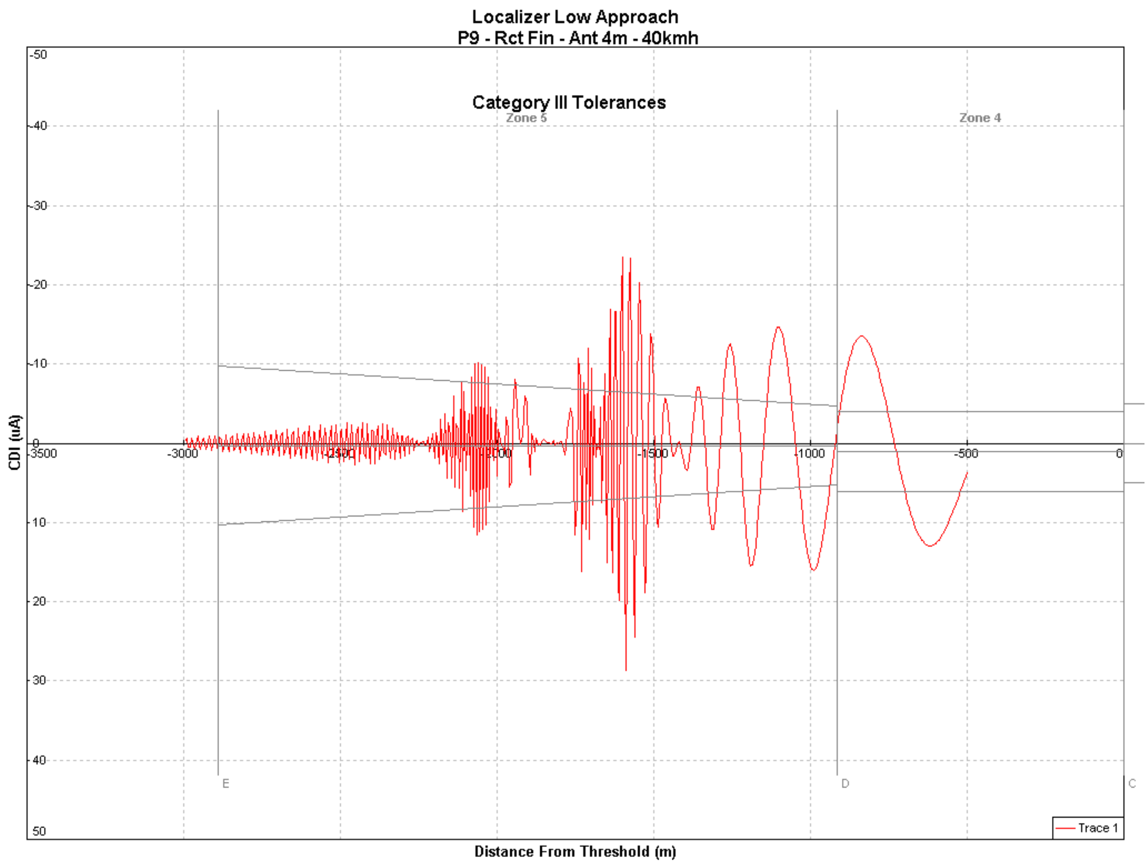
Localizer Low Approach
P6q - Rct Fin - Ant 4m - 40kmh
Category III Tolerances
Zone 5
Zone 4
CDI (uA)
Distance From Threshold (m)
E
D
C
Trace 1

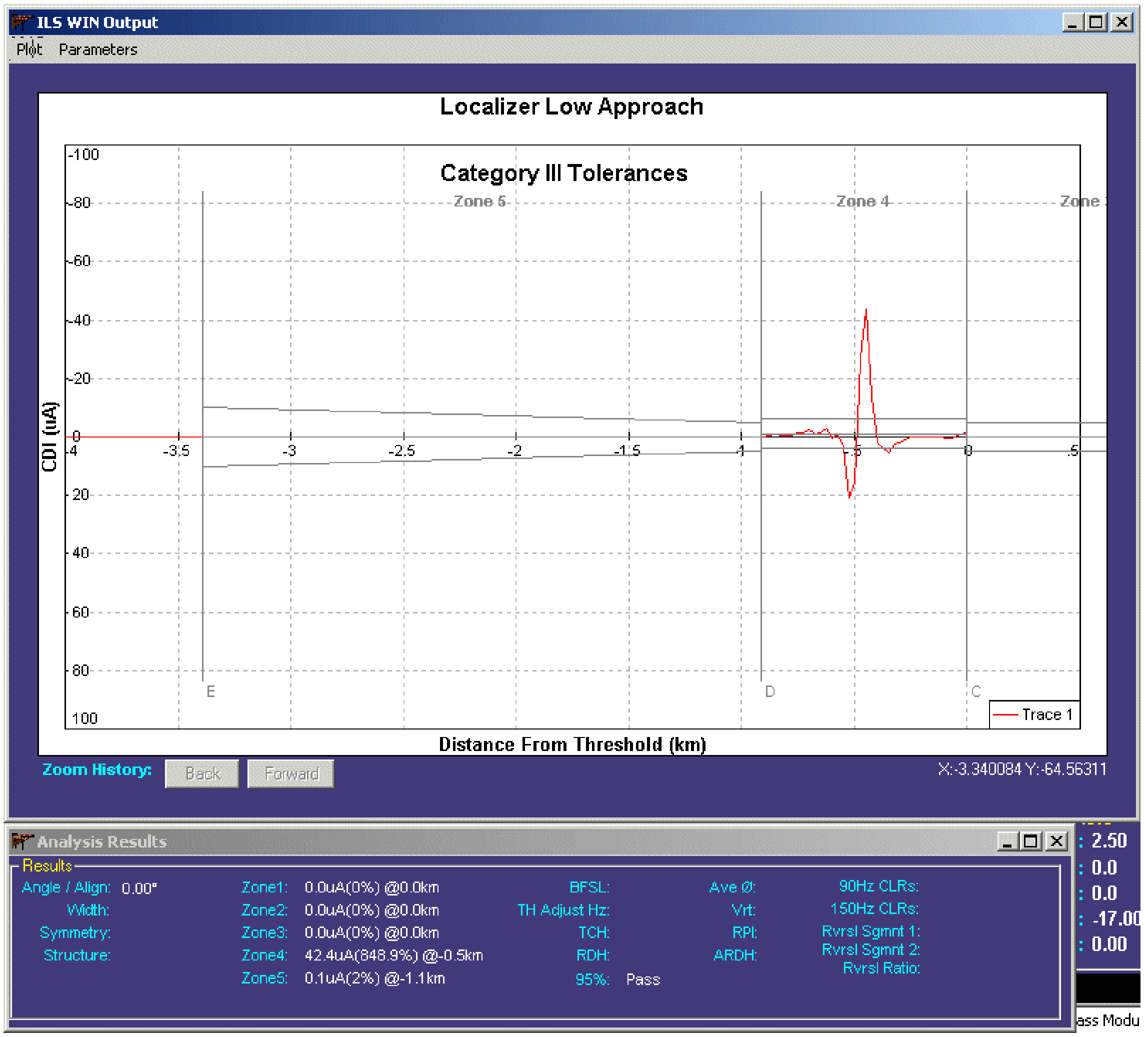


Localizer Low Approach
P6t - A380 - Ant 4m - 40kmh
Category III Tolerances
Zone 5
Zone 4
CDI (uA)
Distance From Threshold (m)
Trace 1

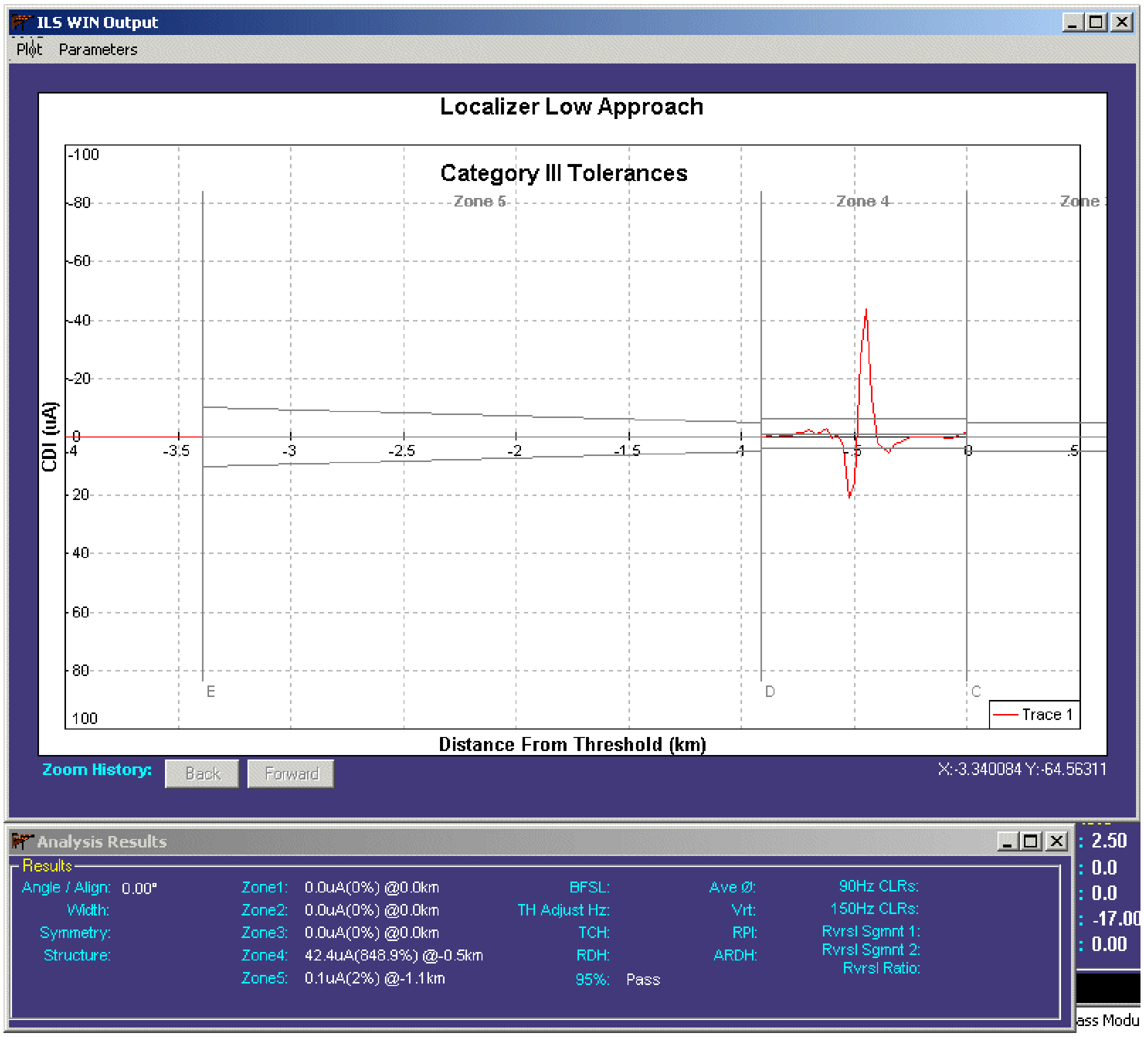

Localizer Low Approach
P6t - Rct Fin - Ant 4m - 40kmh
Category III Tolerances
Zone 5
Zone 4
CDI (uA)
Distance From Threshold (m)
Trace 1
-50
-40
-30
-20
-10
0
10
20
30
40
50
-3500
-3000
-2500
-2000
-1500
-1000
-500
0
E
D
C

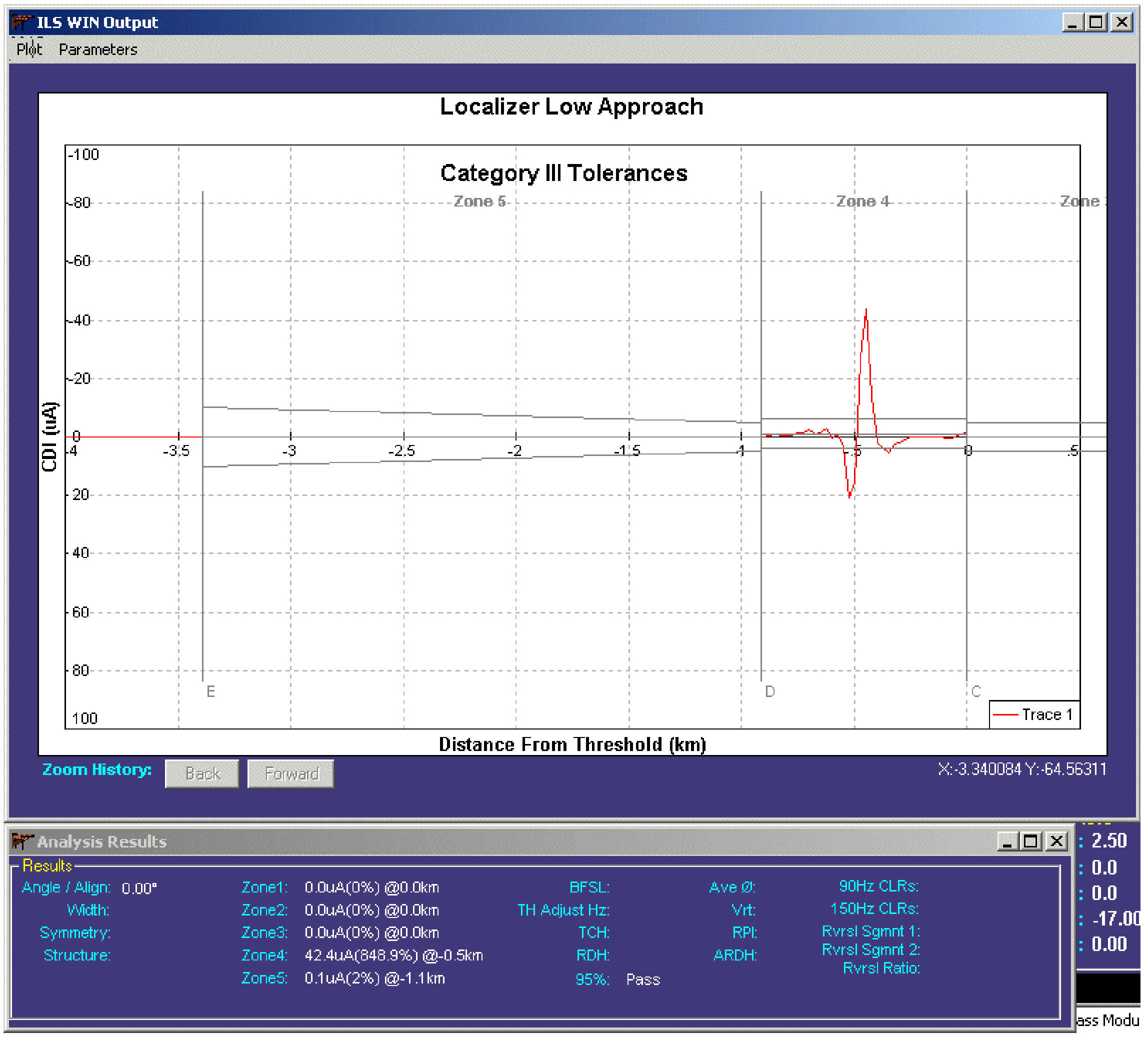

Localizer Low Approach
P9 - A380 - Ant 4m - 40kmh
Category III Tolerances
Zone 5
Zone 4
CDI (uA)
Distance From Threshold (m)
E
D
C
Trace 1


Localizer Low Approach
P9 - Rct Fin - Ant 4m - 40kmh
Category III Tolerances
Zone 5
Zone 4
CDI (uA)
Distance From Threshold (m)
Trace 1
E
D
C

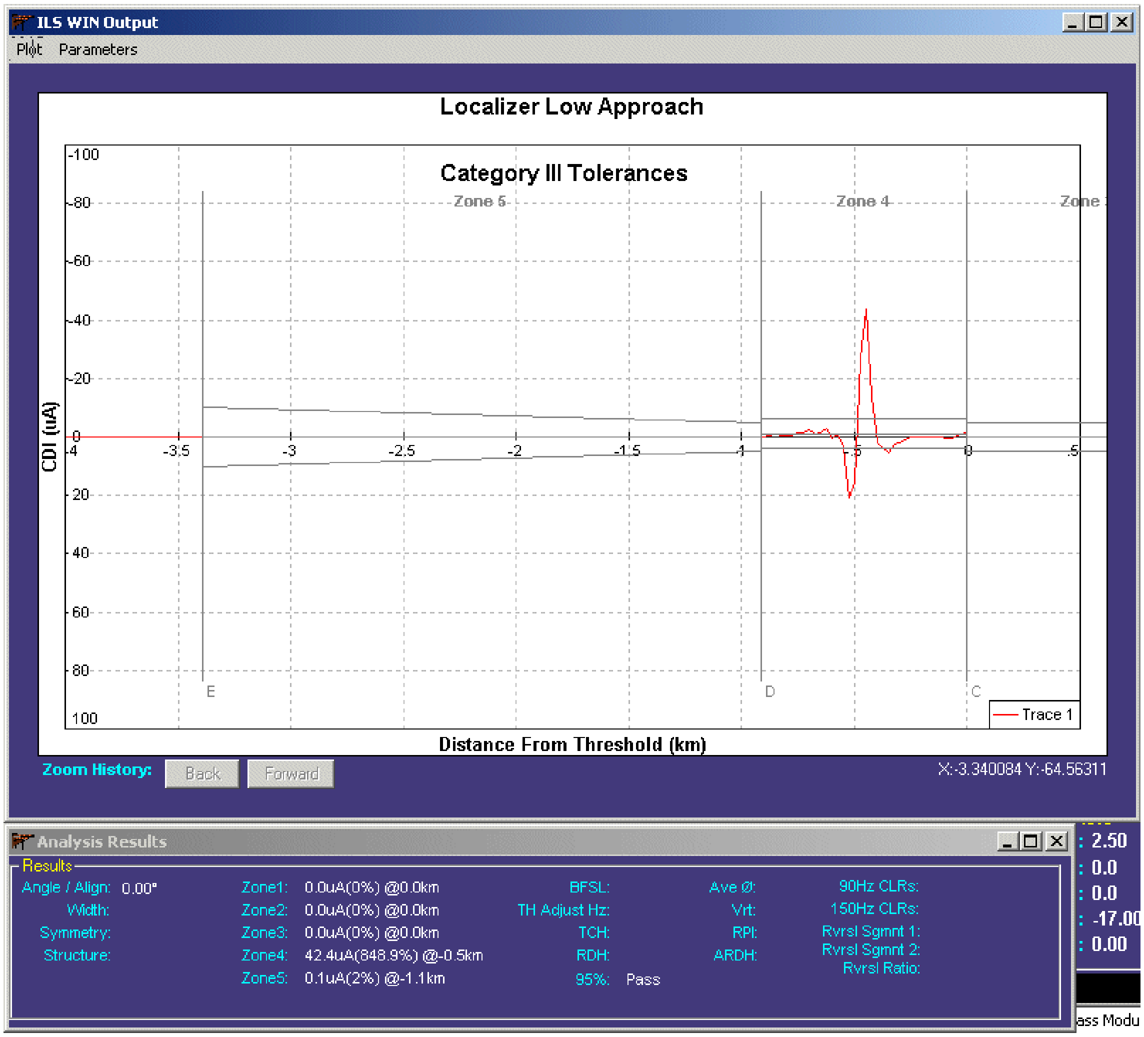

ILS WIN Output
Plot
Parameters
Localizer Low Approach
Category III Tolerances
Zone 5
Zone 4
CDI (uA)
Distance From Threshold (km)
Trace 1
E
D
C
Zoom History:
Back
Forward
X:-3.340084 Y:-64.56311
Analysis Results
Results
Angle / Align: 0.00°
Width:
Symmetry:
Structure:
Zone1: 0.0uA(0%) @0.0km
Zone2: 0.0uA(0%) @0.0km
Zone3: 0.0uA(0%) @0.0km
Zone4: 42.4uA(848.9%) @-0.5km
Zone5: 0.1uA(2%) @-1.1km
BFSL:
TH Adjust Hz:
TCH:
RDH:
95%: Pass
Ave Ø:
Vrt:
RPI:
ARDH:
90Hz CLRs:
150Hz CLRs:
Rvrsl Sgmnt 1:
Rvrsl Sgmnt 2:
Rvrsl Ratio:
: 2.50
: 0.0
: 0.0
: -17.00
: 0.00

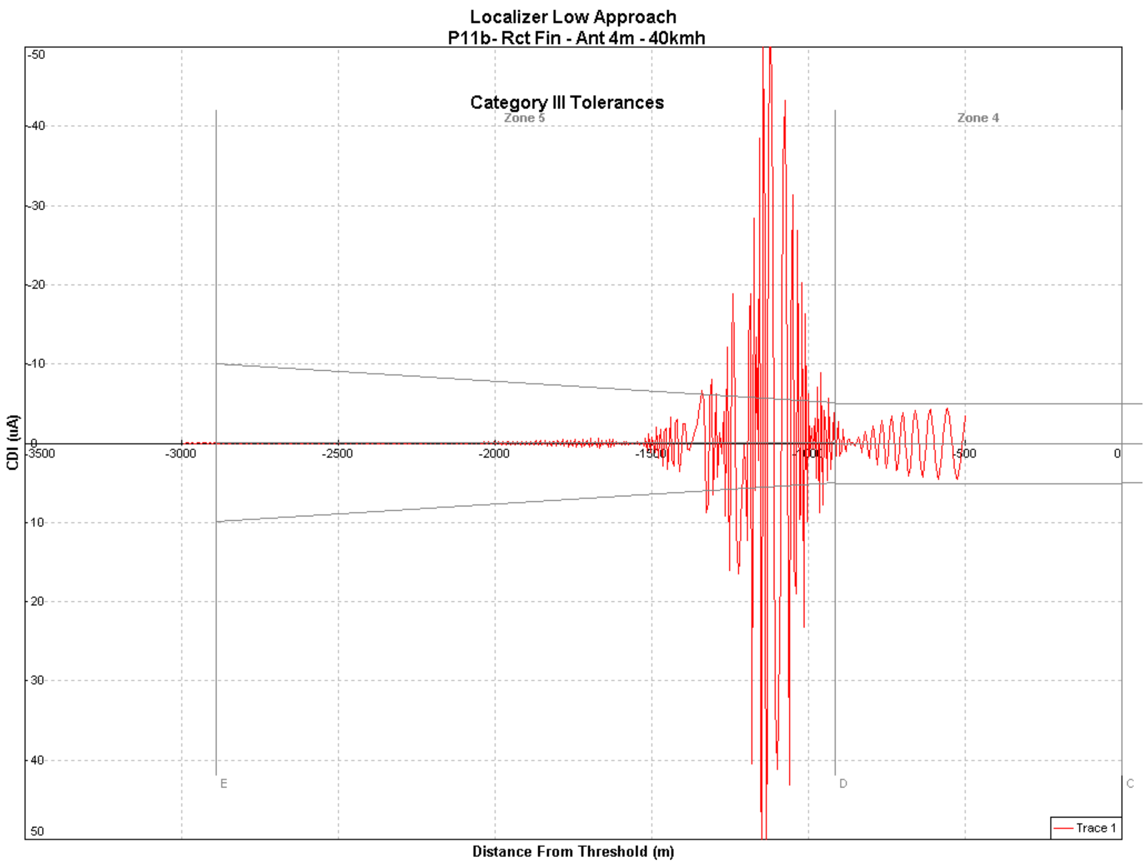
P11

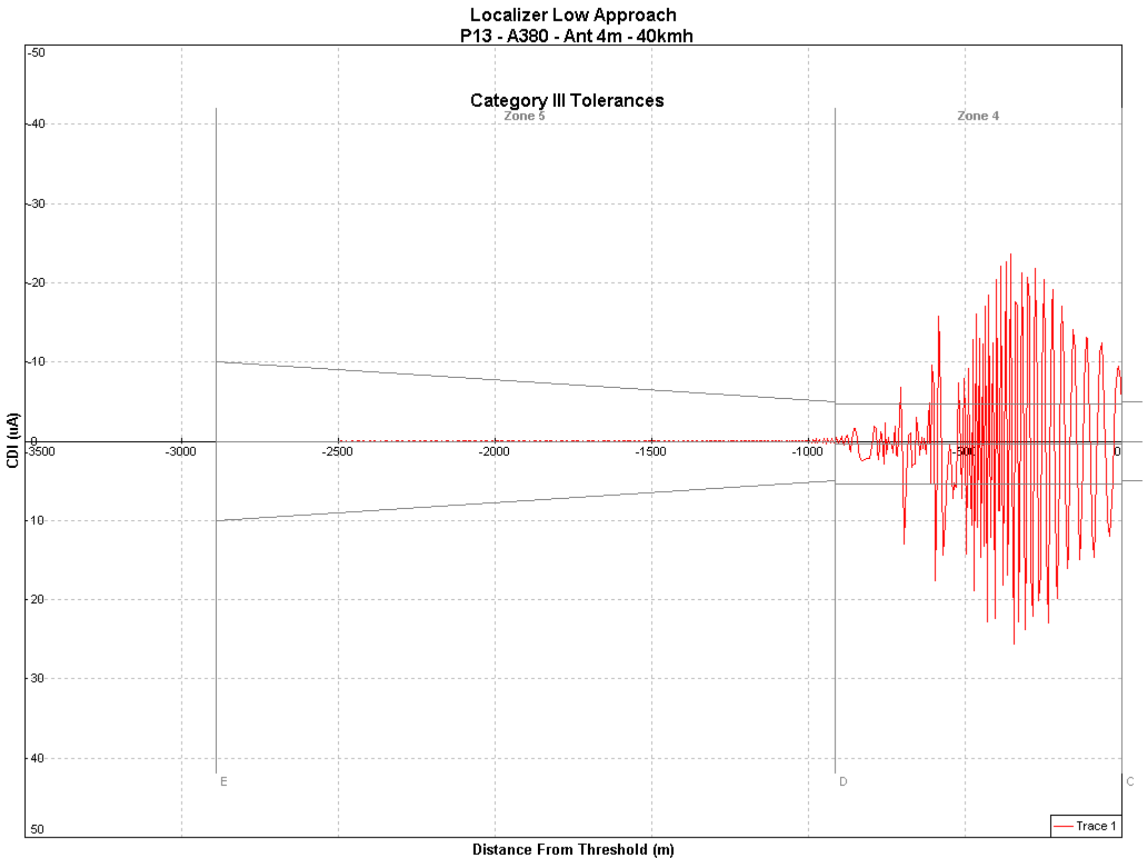

ILS WIN Output
Plot Parameters
Localizer Low Approach
Category III Tolerances
Zone 5
Zone 4
CDI (uA)
Distance From Threshold (km)
Trace 1
Zoom History: Back Forward
X:-3.340084 Y:-64.56311
Analysis Results
Results
Angle / Align: 0.00°
Width:
Symmetry:
Structure:
Zone1: 0.0uA(0%) @0.0km
Zone2: 0.0uA(0%) @0.0km
Zone3: 0.0uA(0%) @0.0km
Zone4: 42.4uA(848.9%) @-0.5km
Zone5: 0.1uA(2%) @-1.1km
BFSL:
TH Adjust Hz:
TCH:
RDH:
95%: Pass
Ave Ø:
Vrt:
RPI:
ARDH:
90Hz CLRs:
150Hz CLRs:
Rvrsl Sgmnt 1:
Rvrsl Sgmnt 2:
Rvrsl Ratio:

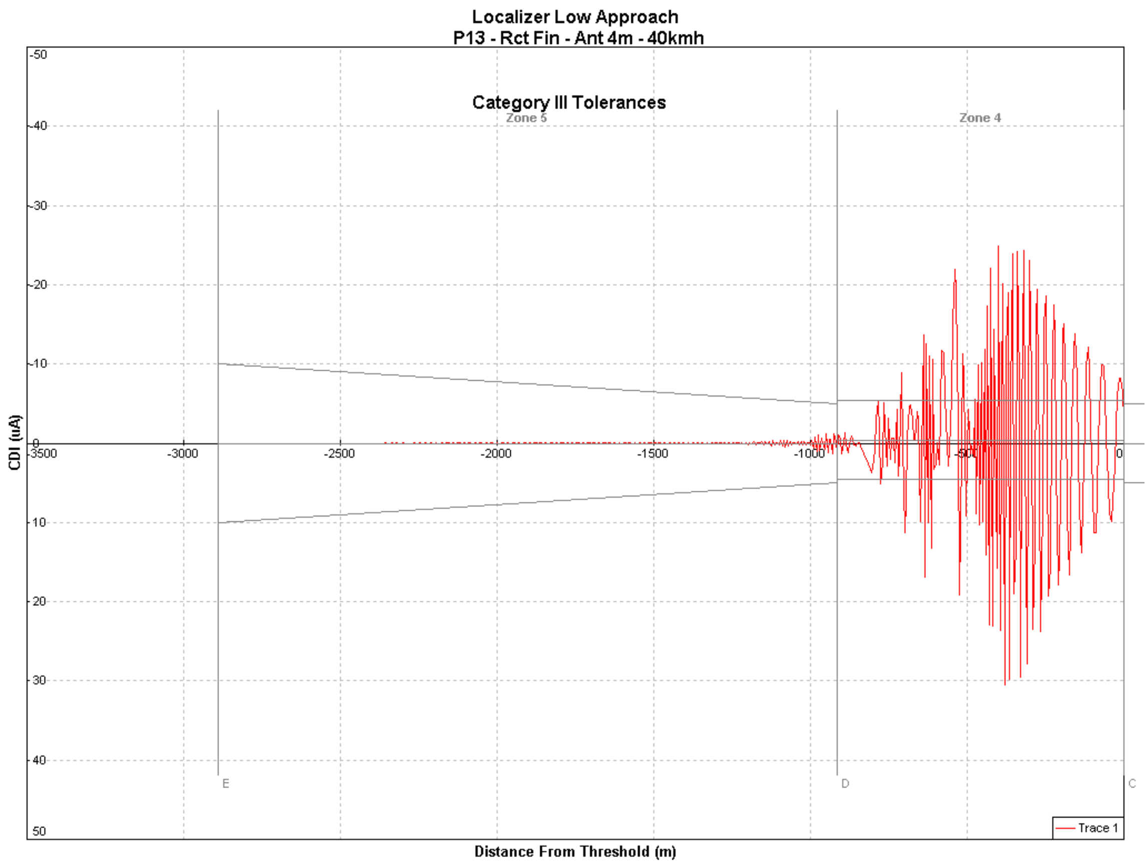

ILS WIN Output
Plot Parameters
Localizer Low Approach
Category III Tolerances
Zone 5
Zone 4
CDI (uA)
Distance From Threshold (km)
Trace 1
Zoom History: Back Forward
X:-3.340084 Y:-64.56311
Analysis Results
Results
Angle / Align: 0.00°
Width:
Symmetry:
Structure:
Zone1: 0.0uA(0%) @0.0km
Zone2: 0.0uA(0%) @0.0km
Zone3: 0.0uA(0%) @0.0km
Zone4: 42.4uA(848.9%) @-0.5km
Zone5: 0.1uA(2%) @-1.1km
BFSL:
TH Adjust Hz:
TCH:
RDH:
95%: Pass
Ave Ø:
Vrt:
RPI:
ARDH:
90Hz CLRs:
150Hz CLRs:
Rvrsl Sgmnt 1:
Rvrsl Sgmnt 2:
Rvrsl Ratio:
: 2.50
: 0.0
: 0.0
: -17.00
: 0.00

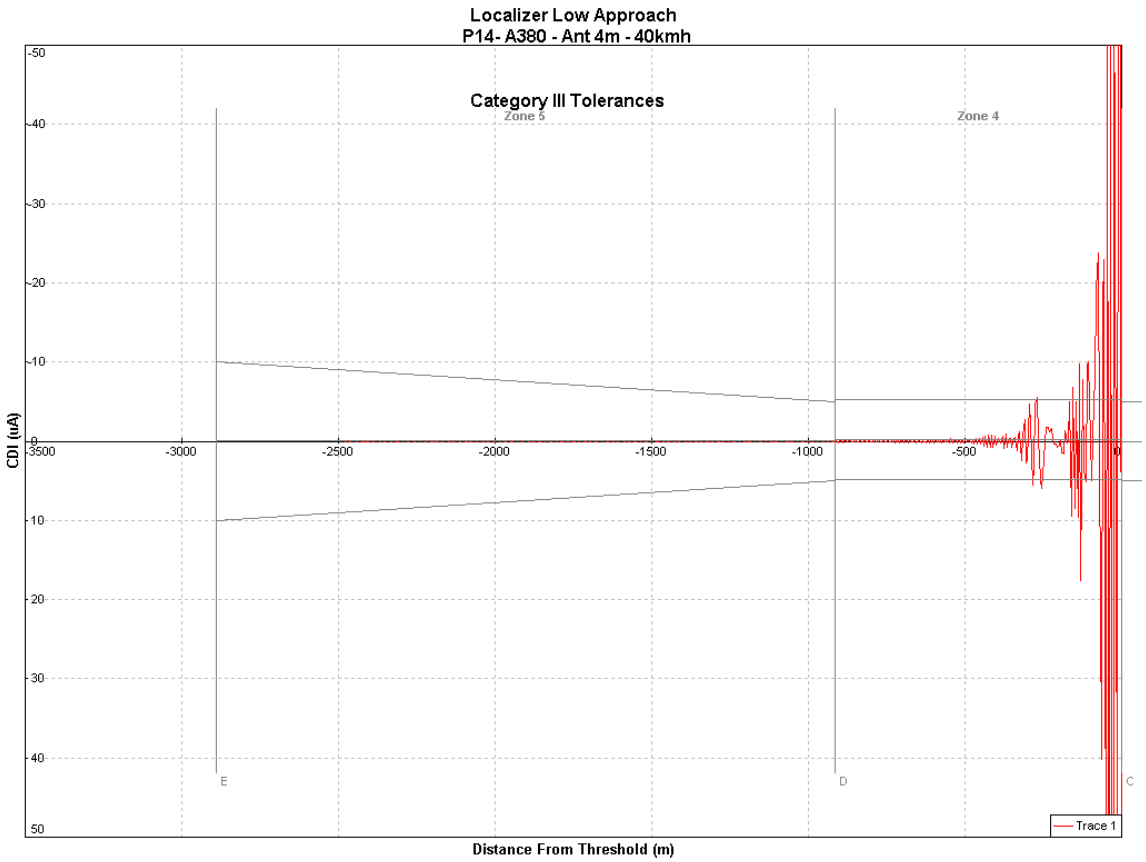
P11 BIS


ILS WIN Output
Plot Parameters
Localizer Low Approach
Category III Tolerances
Zone 5
Zone 4
CDI (uA)
Distance From Threshold (km)
Trace 1
Zoom History: Back Forward
X:-3.340084 Y:-64.56311
Analysis Results
Results
Angle / Align: 0.00°
Width:
Symmetry:
Structure:
Zone1: 0.0uA(0%) @0.0km
Zone2: 0.0uA(0%) @0.0km
Zone3: 0.0uA(0%) @0.0km
Zone4: 42.4uA(848.9%) @-0.5km
Zone5: 0.1uA(2%) @-1.1km
BFSL:
TH Adjust Hz:
TCH:
RDH:
95%: Pass
Ave Ø:
Vrt:
RPI:
ARDH:
90Hz CLRs:
150Hz CLRs:
Rvrsl Sgmnt 1:
Rvrsl Sgmnt 2:
Rvrsl Ratio:

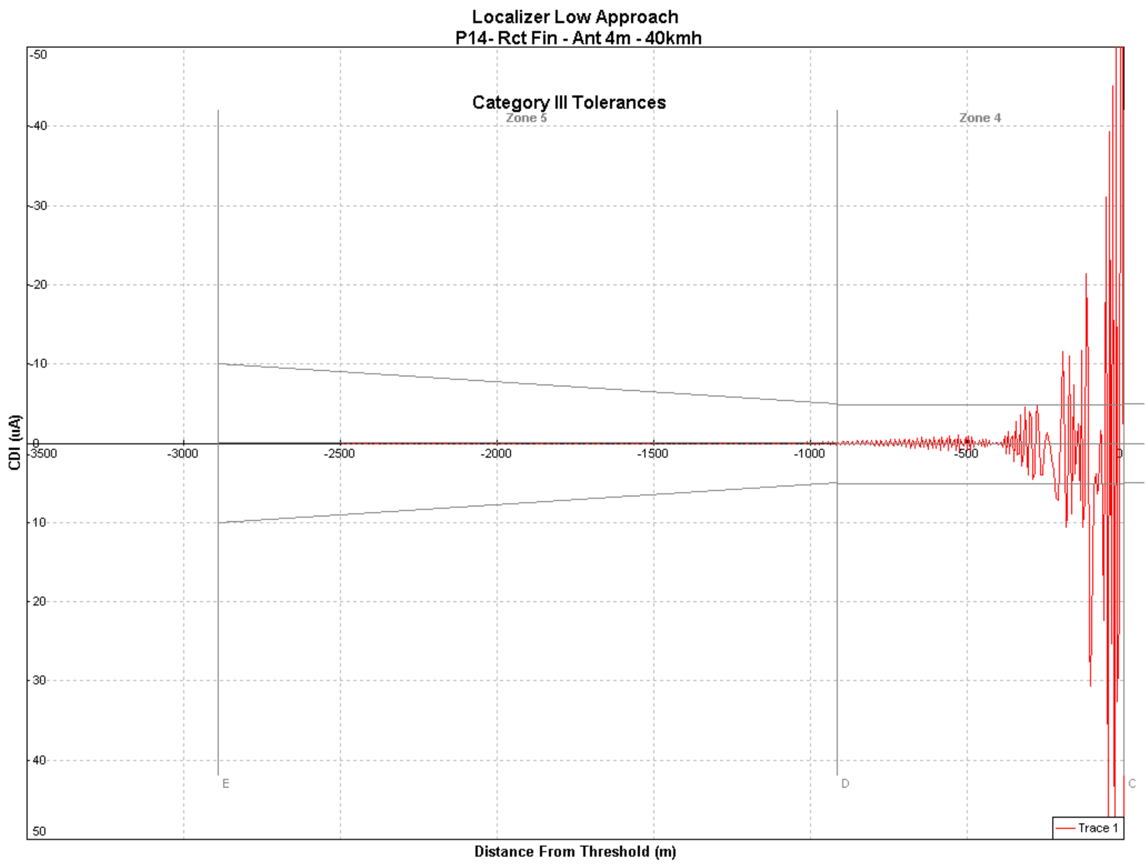

Localizer Low Approach
P11b- Rct Fin - Ant 4m - 40kmh
Category III Tolerances
Zone 5
Zone 4
CDI (uA)
Distance From Threshold (m)
E
D
C
Trace 1
-50
-40
-30
-20
-10
0
10
20
30
40
50
-3500
-3000
-2500
-2000
-1500
-1000
-500
0


Localizer Low Approach
P13 - A380 - Ant 4m - 40kmh
Category III Tolerances
Zone 5
Zone 4
CDI (uA)
Distance From Threshold (m)
Trace 1
E
D
C

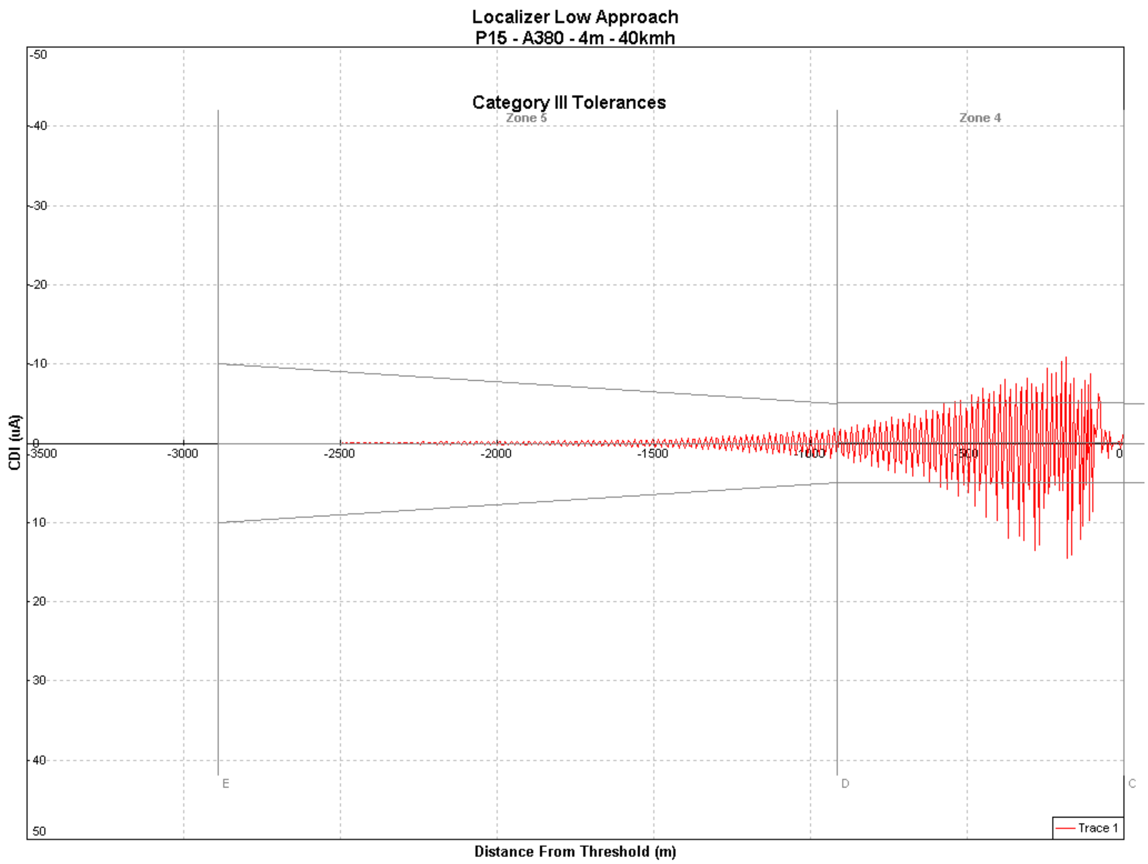

Localizer Low Approach
P13 - Rct Fin - Ant 4m - 40kmh
Category III Tolerances
Zone 5
Zone 4
E
D
C
CDI (uA)
Distance From Threshold (m)
Trace 1
-50
-40
-30
-20
-10
0
10
20
30
40
50
-3500
-3000
-2500
-2000
-1500
-1000
-500
0

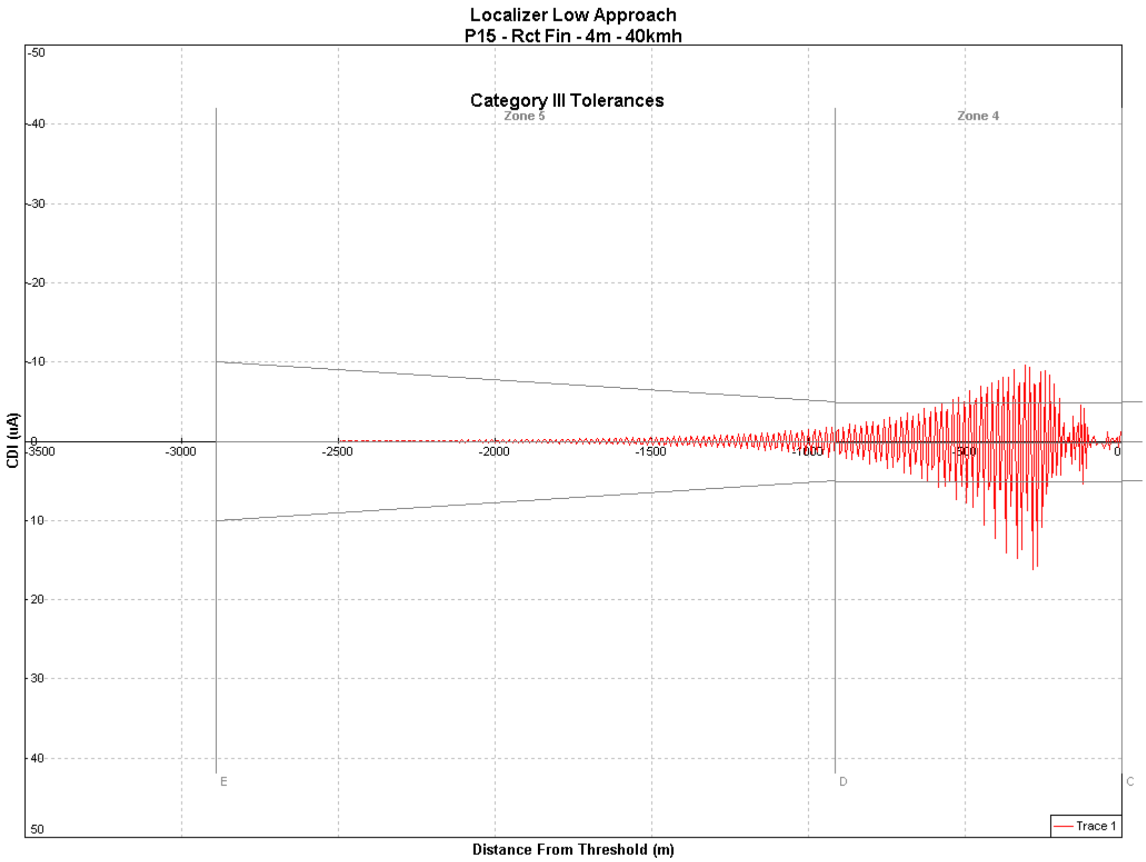


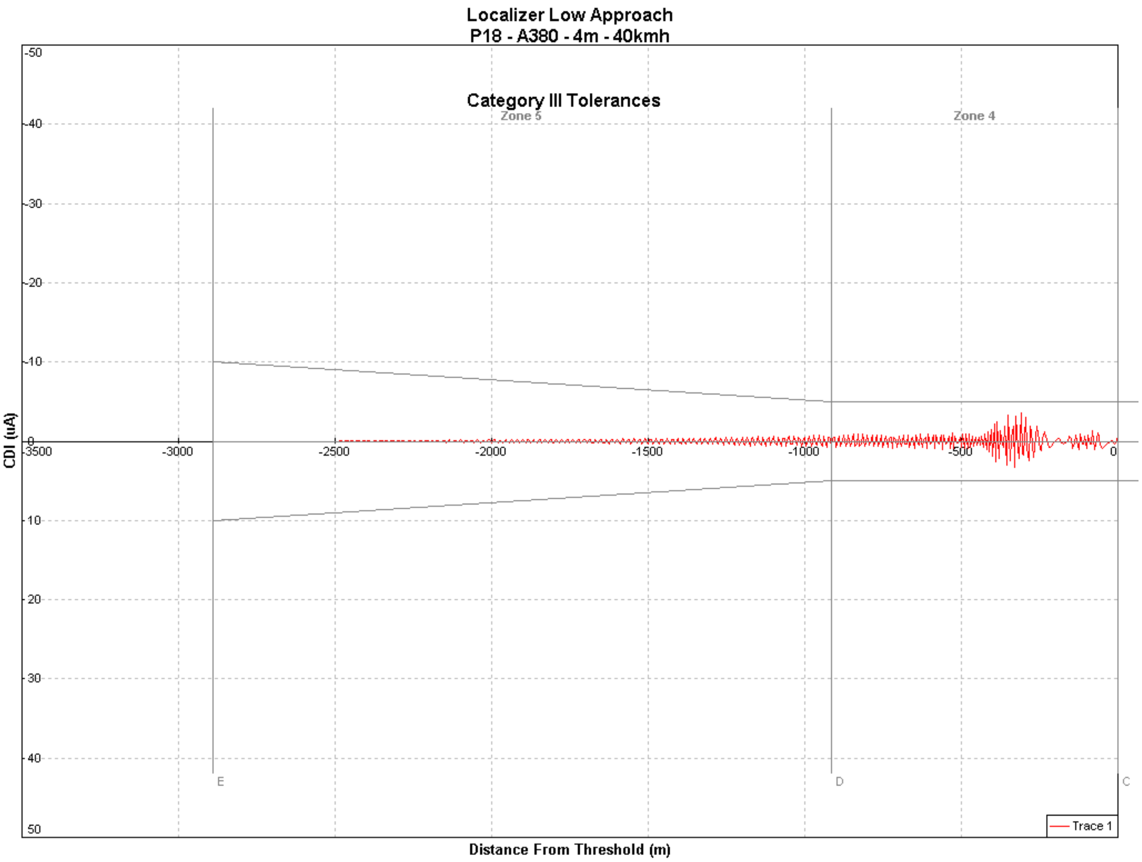
Localizer Low Approach
P14- A380 - Ant 4m - 40kmh
Category III Tolerances
Zone 5
Zone 4
CDI (uA)
Distance From Threshold (m)
Trace 1



Localizer Low Approach
P14- Rct Fin - Ant 4m - 40kmh
Category III Tolerances
Zone 5
Zone 4
CDI (uA)
Distance From Threshold (m)
E
D
C
Trace 1

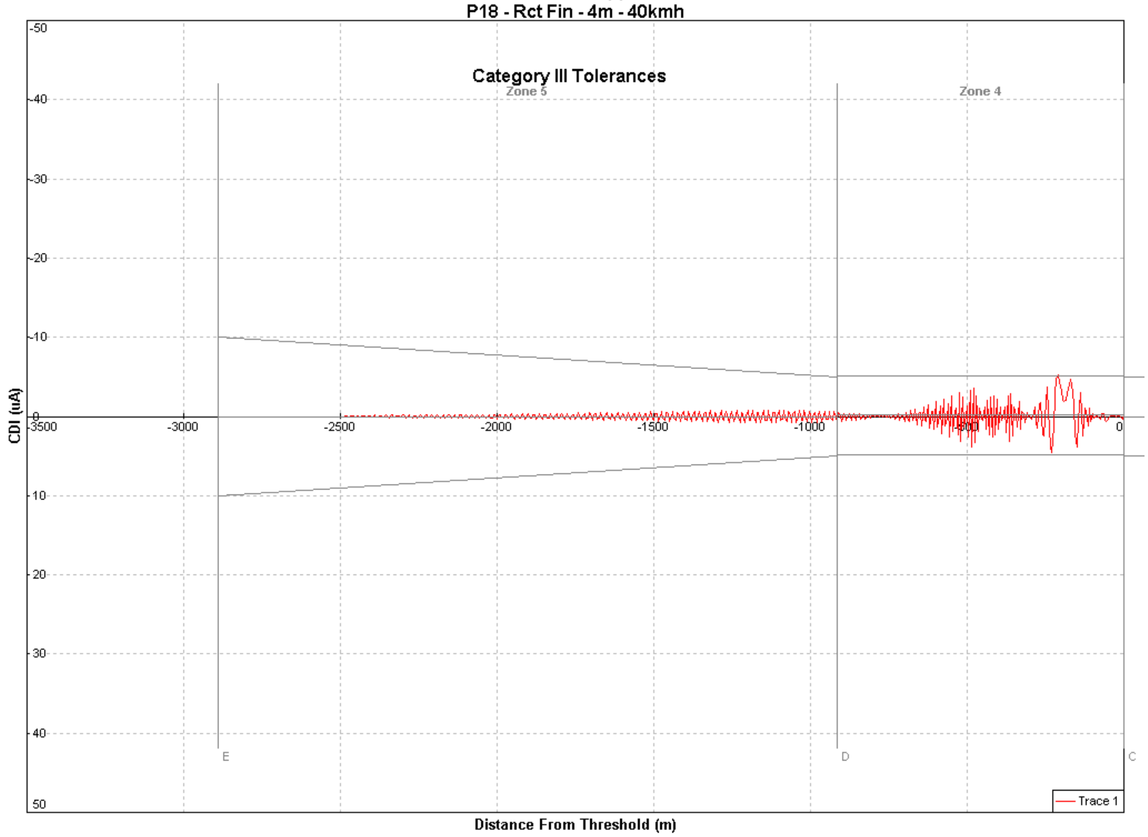

Localizer Low Approach
P15 - A380 - 4m - 40kmh
Category III Tolerances
Zone 5
Zone 4
CDI (uA)
Distance From Threshold (m)
E
D
C
Trace 1


Localizer Low Approach
P15 - Rct Fin - 4m - 40kmh
Category III Tolerances
Zone 5
Zone 4
CDI (uA)
Distance From Threshold (m)
E
D
C
Trace 1

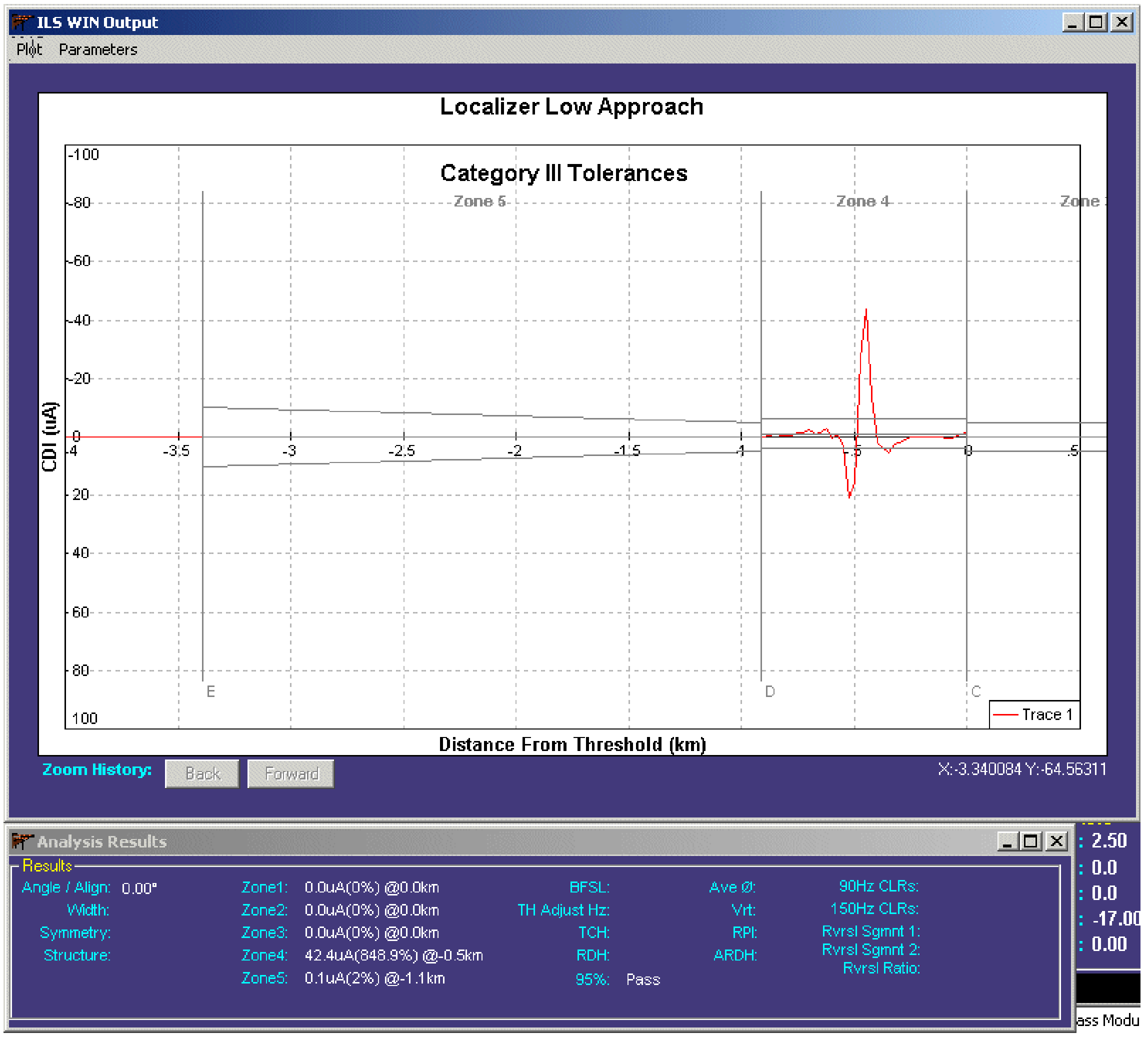


Localizer Low Approach
P18 - A380 - 4m - 40kmh
Category III Tolerances
Zone 5
Zone 4
CDI (uA)
-50
-40
-30
-20
-10
0
10
20
30
40
50
-3500
-3000
-2500
-2000
-1500
-1000
-500
0
E
D
C
Trace 1
Distance From Threshold (m)

Localizer Low Approach
P18 - Rct Fin - 4m - 40kmh



Frankfurt : P-5



ANNEX O : Receiver behaviour analysis results

Preface

These results are extracted from the DFS study "Scientific investigations on ILS receivers" performed by Dr. Jochen Bredemeyer, FCS Flight Calibration Services, Braunschweig, Germany.

The study mainly contains of a comparison between the Rohde&Schwarz EVS200 and Bendix RNA-3AF in case of typical ILS interference situations. To do so, a specially designed ILS generator was used to feed the receivers with artificially interfered RF Signals according to geometric conditions.

In this case, all geometric prerequisits and assumptions are taken from the A380 at Position 5, turn 23°, at Frankfurt airport during the measurement campaign.

ILS Bandpass Signal Synthesis

Due to the motion of the receiver at constant velocity v there is a time-dependent threshold distance following

$$x(t) = x_0 - v \cdot t - x_r \quad (1)$$

where x_0 is the initial distance and $x_r = 500m$ the distance f the A380.

During motion, the Doppler shift towards the A380 decreases due to its lateral distance $y_r = 200m$ so the difference in Doppler shift against the LLZ antenna is given by

$$\Delta f(t) = \frac{f_0 \cdot v}{c_0} \cdot \frac{x(t)}{\sqrt{x^2(t) + y_r^2}} \quad (2)$$

with f_0 = 110.7 MHz and the speed of light c_0.

For the following we assume that f_1 is an intermediate frequency (IF) which is either used for simulation purposes (f_1=1 kHz) and for the generation of the real RF signal to be fed into the ILS receiver. Its angular frequency is then given by

$$\omega_r(t) = 2\pi \cdot f_1 + 2\pi \cdot \Delta f(t). \quad (3)$$

Since the momentary frequency is time-varying according equation (2) we need its integral to obtain the momentary phase

$$\phi_r(t) = \int \omega_r(t)dt + \psi_r = 2\pi \left(f_1 t + \frac{f_0}{c_0} \cdot \sqrt{x^2(t) + y_r^2} \right) + \psi_r \quad (4)$$

where ψ_r is the initial phase.

ILS modulation signals CSB und SBO generally are given by

$$\begin{aligned} U_{mod}^{CSB}(t) &= \frac{SDM}{2} \cdot (\sin(3\Omega \cdot t) + \sin(5\Omega \cdot t)) \quad (5) \\ U_{mod}^{SBO}(t) &= \frac{DDM}{2} \cdot (\sin(3\Omega \cdot t) - \sin(5\Omega \cdot t)) \end{aligned}$$

with

$$\Omega = 2\pi \cdot 30\text{Hz} \ . \quad (6)$$

The direct signal on centerline reaching the receiver is pure CSB at the constant Doppler shift

$$\Delta f_{max} = \frac{f_0 \cdot v}{c_0} \tag{7}$$

so that the bandpass signal phase can be written as

$$\phi_d(t) = 2\pi f_1 t + 2\pi \int \Delta f_{max} dt + \psi_d = 2\pi \cdot (f_1 + \Delta f_{max})t + \psi_d \ . \tag{8}$$

The combined ILS bandpass signal then consists of the direct portion

$$\begin{aligned} U_d^{CSB}(t) &= \left(1 + U_{mod}^{CSB}(t)\right) cos(\phi_d(t)) \\ U_d^{SBO}(t) &= 0 \quad \text{(on centerline)} \end{aligned} \tag{9}$$

and the reflection

$$\begin{aligned} U_r^{CSB}(t) &= \left(1 + U_{mod}^{CSB}(t)\right) cos(\phi_r(t)) \\ U_r^{SBO}(t) &= U_{mod}^{SBO}(t)) cos(\phi_r(t)) \ . \end{aligned} \tag{10}$$

We introduce $SDM = 0.4$ for ILS LOC and DDM_r as the deviation at A380's position so the single modulation depths are given by

$$\begin{aligned} m_{r90} &= \frac{SDM + DDM_r}{2} \\ m_{r150} &= \frac{SDM + DDM_r}{2} \ . \end{aligned} \tag{11}$$

Furthermore, we assume the A380 acts as a time/distance-varying reflector $a_r(t)$. By means of simplicity, the reflection coefficient curve follows a Gaussian pulse shape with a half-amplitude distance of 200m and a maximum of 0.3 as shown in figure 1.

> Important: This simple A380 reflection simulation is not to replace any other complex model but to obtain a roughly acceptable interfered bandpass signal. The patterns of both the LLZ and the receiving antenna are not considered.

According to these definitions, we can compose the complete bandpass signal containing both the direct and the reflected signal. Hence, the final composite bandpass signal results in:

$$\begin{aligned} U_{ILS}(t) &= U_d^{CSB}(t) + a_r\left(U_r^{CSB}(t) + U_r^{SBO}(t)\right) \\ &= (1 + 0.2 \cdot (\sin(3\Omega \cdot t) + \sin(5\Omega \cdot t))) \cos(\phi_d(t)) \\ &+ \ a_r(1 + m_{r90} \cdot \sin(3\Omega \cdot t) + m_{r150} \cdot \sin(5\Omega \cdot t)) \cos(\phi_r(t)) \end{aligned} \tag{12}$$

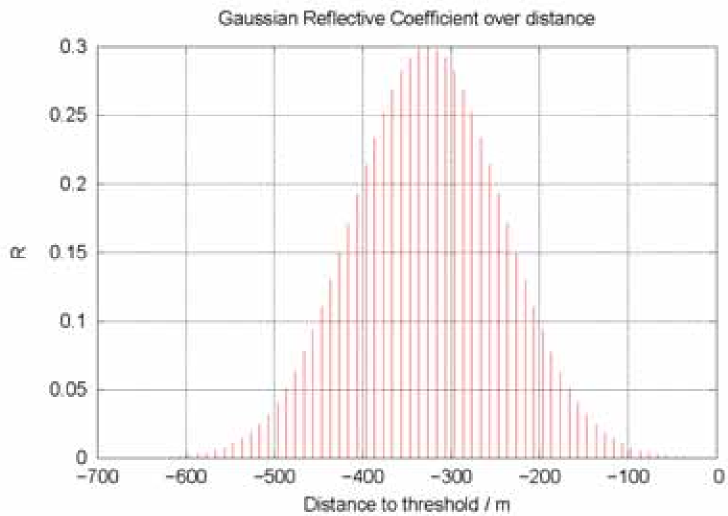


Figure 1: Simple A380 reflection at P5 as a Gaussian Impuls with maximum 0.3

Demodulation and Bias effect

A rather generalized form of equation (12) can be written as

$$y(t) = s_d(t) \cdot \cos(\phi_d(t)) + s_r(t)\cos(\phi_r(t)) \tag{13}$$

where

$$\begin{aligned} s_d(t) &= 1 + 0.2 \cdot (\sin(3\Omega \cdot t) + \sin(5\Omega \cdot t)) \\ s_r(t) &= a_r(1 + m_{r90} \cdot \sin(3\Omega \cdot t) + m_{r150} \cdot \sin(5\Omega \cdot t)) \end{aligned} \tag{14}$$

comply with the definitions of the preceding section.

In information theory the baseband of an amplitude modulated signal is identical to the *absolute value of the complex envelope* of the bandpass signal:

$$|y_T(t)| = \sqrt{s_d^2(t) + s_r^2(t) + 2s_d(t)s_r(t)\cos(\phi_d(t) - \phi_r(t))} \tag{15}$$

The argument of the cosine function then contains the time-varying difference frequency which is multiplied by the modulations signals $s_d(t)$ and $s_r(t)$ itselves. In other terms, this multiplication means another AM with difference frequency modulating the 90Hz and 150Hz sidebands so more lines appear in the baseband spectrum.

The following figures show how the interference affects both the bandpass (at IF $f_1 = 1\,\text{kHz}$) and the baseband signal at three distinguished distances to the runway threshold at a ground speed $v = 60\,\text{km/h}$:

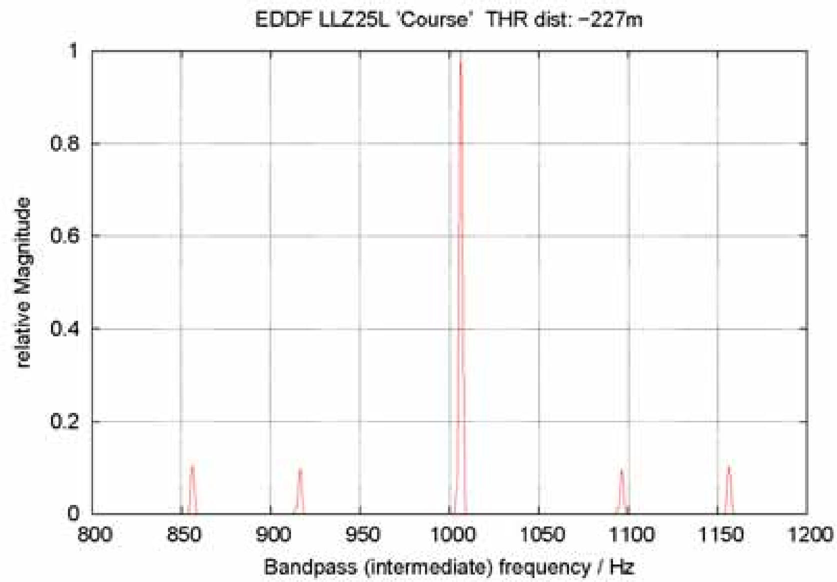


Figure 2: ILS bandpass spektrum (v=60km/h ≙ 17m/s)

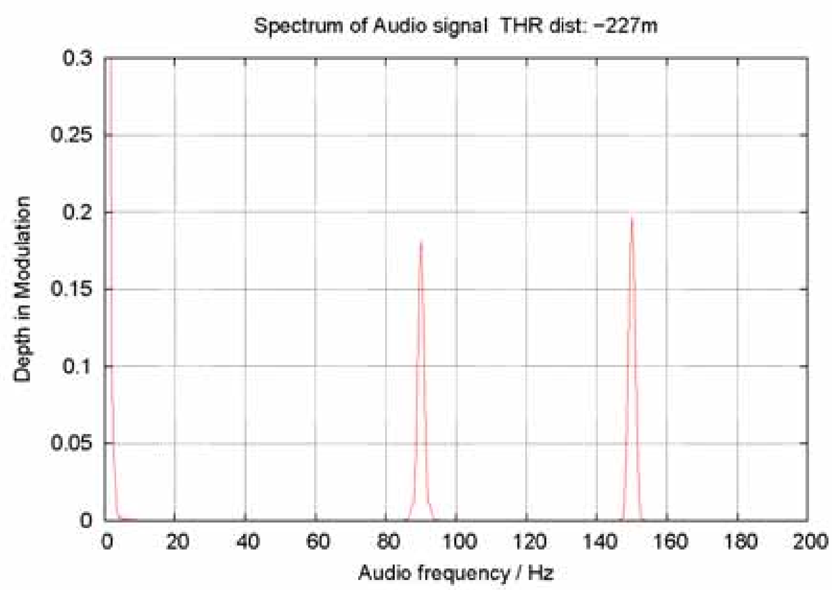


Figure 3: AF (baseband) spectrum (v=60km/h ≙ 17m/s)

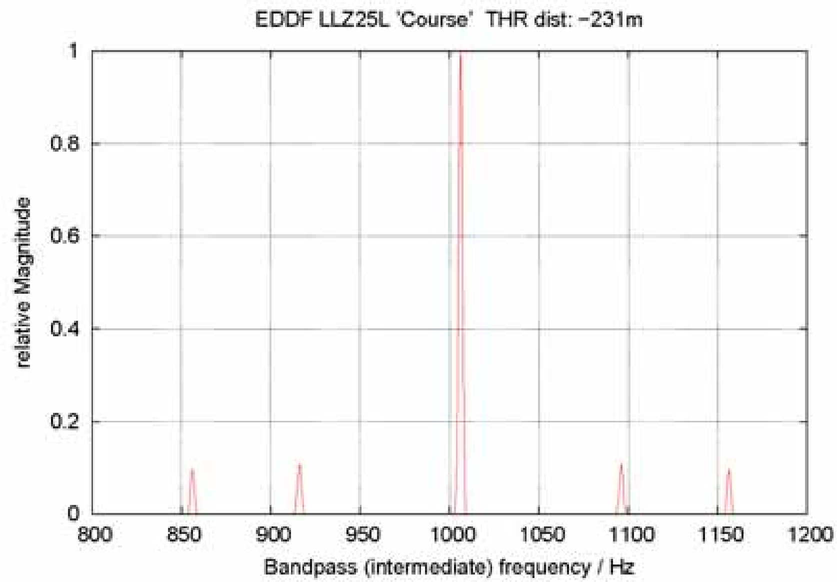


Figure 4: ILS bandpass spektrum (v=60km/h ≙ 17m/s)

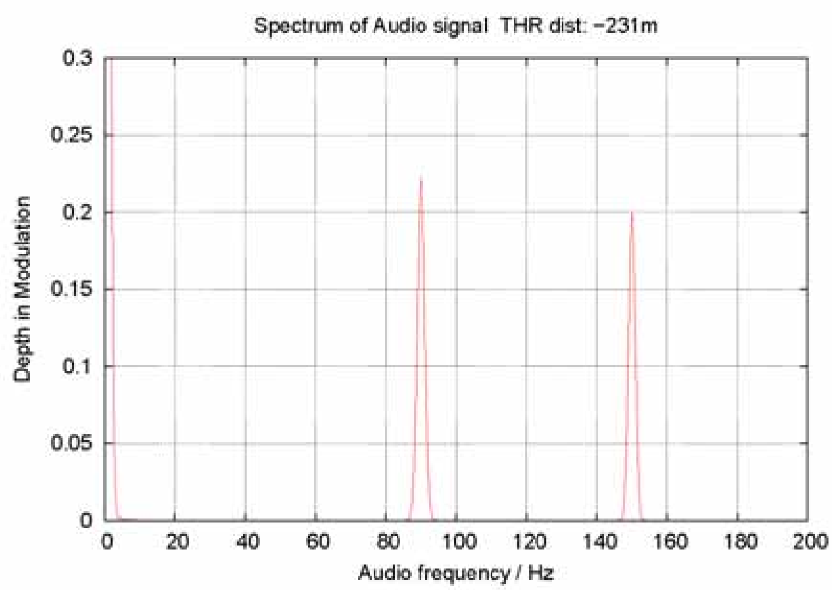


Figure 5: AF (baseband) spectrum (v=60km/h ≙ 17m/s)

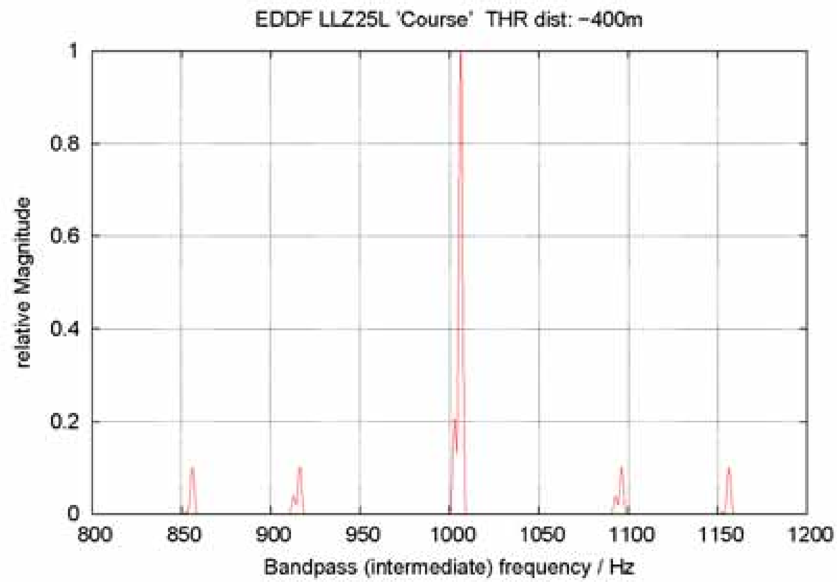


Figure 6: ILS bandpass spektrum (v=60km/h ≙ 17m/s)

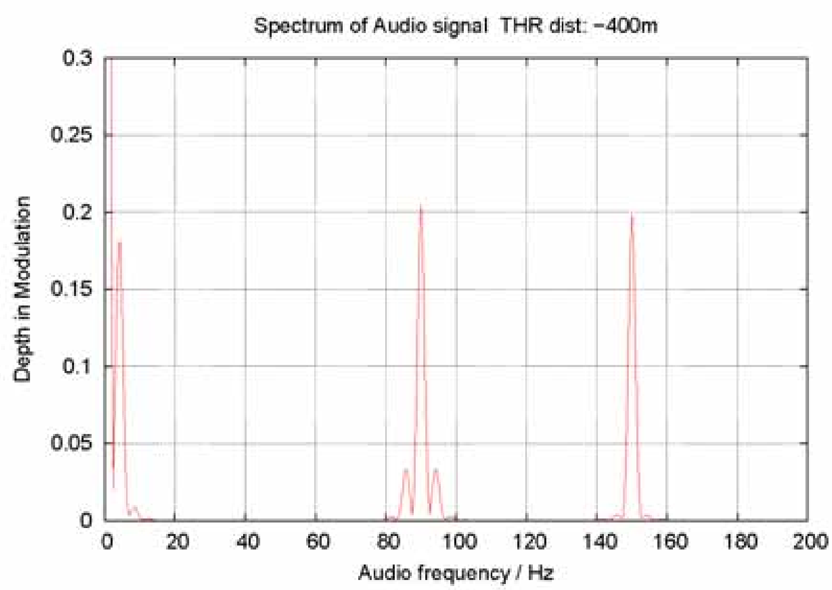


Figure 7: AF (baseband) spectrum (v=60km/h ≙ 17m/s)

The pumping effect of the sidebands which can be observed in figures 2 to 5 is what typically causes scallopings in case of a pure in-beam reflection with only a small difference in Doppler shift. The corresponding pumping sideband amplitudes which can be easily identified in the frequency domain induce the DDM scalloping. The more the difference in Doppler shift increases while passing by the A380 the more those two symmetrical AM lines of the 90 Hz sideband appear. It is now acting as a carrier itself with two sub-sidebands at the differential Doppler frequency. This is due to the multiplication with the cosine function of equation (15) (see figure 7). However, the other two terms $s_d^2(t)$ and $s_r^2(t)$ then cause the bias effect since they describe the amplitudes of the 90 Hz and 150 Hz lines without deviation. Figure 7 shows the remaining bias effect which mostly influences the 90 Hz due to the A380 being placed left of the runway.

To derive the resulting DDM from equation (12) we apply IIR-type digital sideband filters according to the general transfer function

$$H(z) = \frac{B(z)}{A(z)} = \frac{b(1) + b(2)z^{-1} + \cdots + b(n+1)z^{-1}}{1 + a(2)z^{-1} + \cdots + a(n+1)z^{-1}} \quad (16)$$

where the polynoms $A(z)$ and $B(z)$ contain appropriate numbers to obtain 90 Hz and 150 Hz filters.

Finally, the resulting DDM curve of the simulation is shown in figure 8 where the bias effect is clearly observable. The filtered curve is generated according to the velocity-dependent ICAO filter time constant.

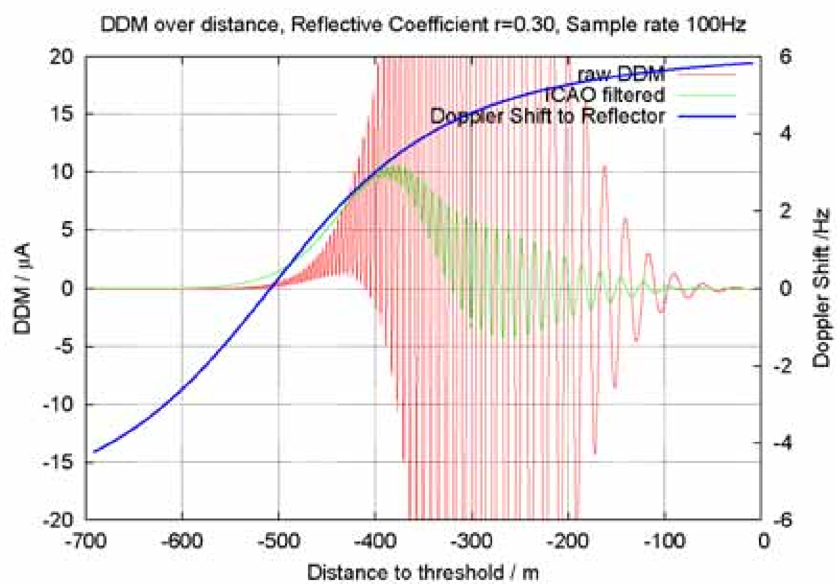


Figure 8: Distorted DDM of simulated A380 at Position 5 (v=60km/h ≙ 17m/s)

Receiver measurements

The ILS generator now synthesizes interfered RF signals to be fed into the receivers under test.

In figure 9 the results of the Rohde&Schwarz EVS200 are shown according to the simulated signal described in the sections above while figure 10 shows the corresponding behaviour of the Bendix RNA34-AF which is integrated in a laboratory flight inspection system of FCS. Assuming a higher speed during landing we obtain the curve for v=117 kn ≙ 60 m/s to be viewed in figure 11. All diagrams show the receiver raw DDM data, the correctly applied ICAO filter and the AGC voltage which tries to adapt to the oscillating power within the receiver bandwidth.

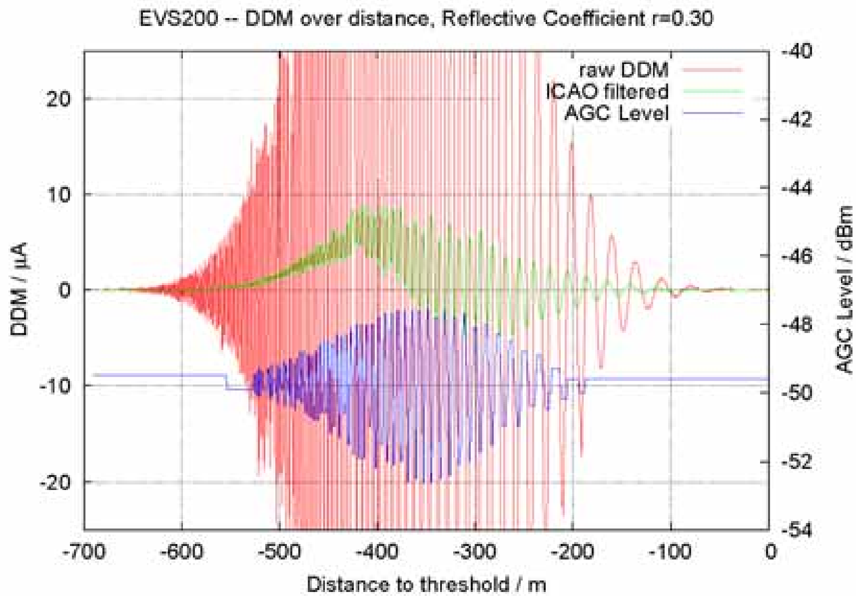


Figure 9: Measurement with synthesized ILS signal fed into EVS200, v=60km/h ≙ 17m/s

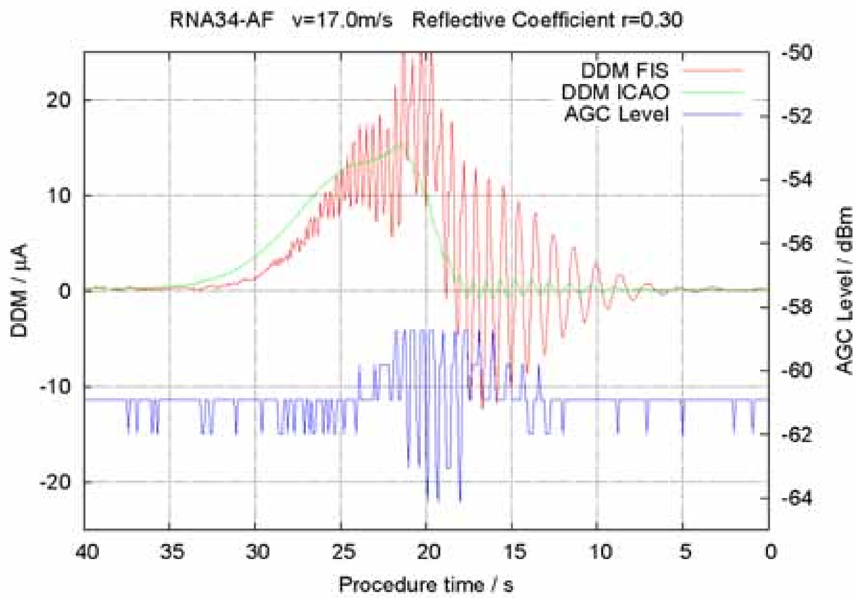


Figure 10: Measurement with synthesized ILS signal fed into RNA34-AF, v=60km/h ≙ 17m/s

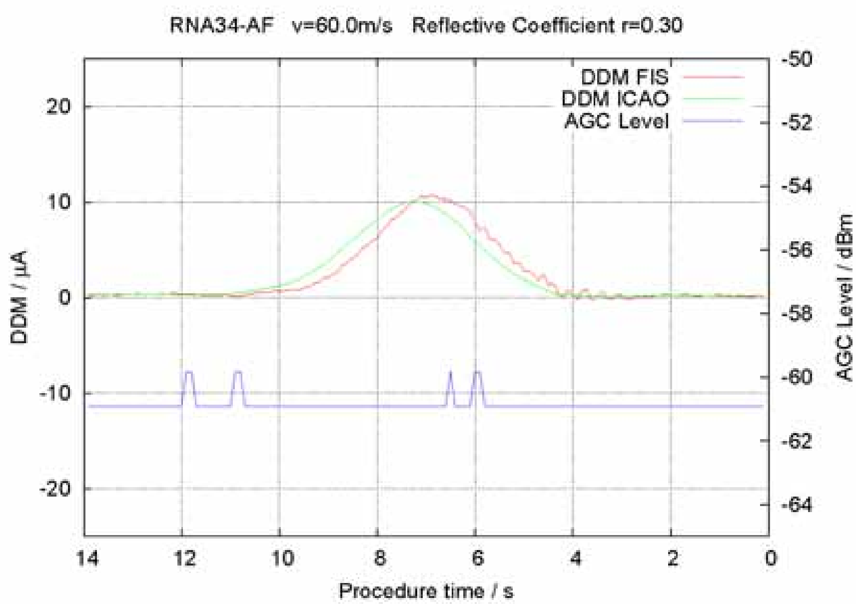


Figure 11: Measurement with synthesized ILS signal fed into RNA34-AF, v=117kn ≙ 60m/s