Improvement of the error budget in flight inspection

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ABSTRACT :

The error budget in Flight Inspection Systems, is composed mainly of the errors due to the "measurement channel" (antennas, receivers…), and the errors due to the "reference channel" (truth system, synchronisation…). For long, the share of the reference channel has been considered as the largest in the error budget because of the difficulties to reach the suitable accuracy, hiding the measurement channel errors.
Nowadays, we do have accurate 3D truth systems based on DGPS (Differential Global Positioning System), infrared or laser trackers, and the most important part of the error budget appears in full light to be due to the measurement channel. We have now to investigate how to improve our measurement channel through calibrated antennas, for instance and certainly using new technologies in digital receivers.
The receivers in use in our systems are mostly analogical equipments derivated from airline products. This paper describes test around two modern digital equipments. The first one is a MMR (Multi Mode Receiver) and the second a laboratory/maintenance equipment.
The purpose of these tests was to highlight new techniques of signals demodulation, the reliability and the easy recording of the measured parameters. DTI/SO2, ground maintenance people and the equipment manufacturer were involved in these experiments. Many in flight records have been performed over traditional or Doppler VORs, mono or bi-frequency ILSs, as well as M type or Null Ref Glide Slope..

OVERVIEW:

Flight Inspection test bench installed in an aircraft includes generally analogical receivers associated with a specific acquisition unit for analog/digital conversion and a computer dedicated for real time signal computation. Main disadvantage of analogical filter technique are temperature and long-term drift.
Our experience has show that usual avionic equipment needs regular calibration (every 3 to 6 months) to guarantee an accuracy of measurement in microampere.
We use daily both receivers. Comparison of the two received signals insures accuracy of measurements. As said before, principal drifts are due to temperature variations and internal element drift of measuring elements (receiver and acquisition unit).
All flight inspection receivers include an AGC (Automatic Gain Control) measurement device. This AGC information allows the determination of the field strength. Further components have to be added like a temperature control for the receiver if the stability of the flight inspection receiver AGC output is not sufficient. All these devices may be simply suppressed with a laboratory receiver.
Using a measuring device able to insure in the same time reception and digital conversion of VHF (Very High Frequency) signal, followed by digital filtering and demodulation, should allow cancellation of all problems known today with classical analogical technology and improve significantly measurement parameters capacity. It also considerably helps aspects of periodic calibration.

SOMETHING NEW ?

Improvement of computation rates and high-speed conversion time of analogical data in digital format allow manufacturers to develop specifics measurement equipments for avionic and electronic laboratories.
We performed in November 2003 a trial with a numerical Multi Mode Receiver (MMR) from French manufacturer in a first time.
On an other hand, a German manufacturer contacted our facilities in mid 2005 and accepted to lend us a pre-serial digital receiver for ground and flight evaluations during last summer and winter.

FIRST TRIAL WITH MULTI MODE RECEIVER (NOVEMBER 2003) :

During this first flight evaluation we have compared raw data of our calibration analogical receivers with a numerical receiver MMR.
The first finding was a low level noise on digital output of the MMR. This noise have 2 microamperes maximum course. However, the average value was identical or close to analogical receiver output signal. A simple digital filter suppresses all high frequency spurious signals (not implemented in raw data of curves below).

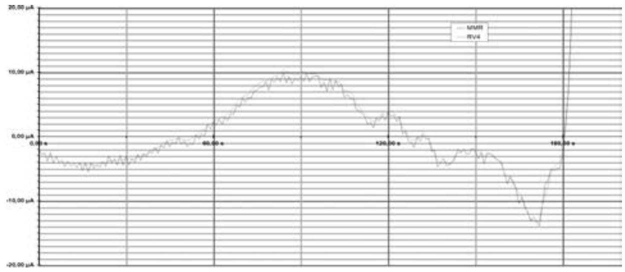


Figure 1 : MMR/51RV4 Localizer comparison (X=time, Y=microampere)

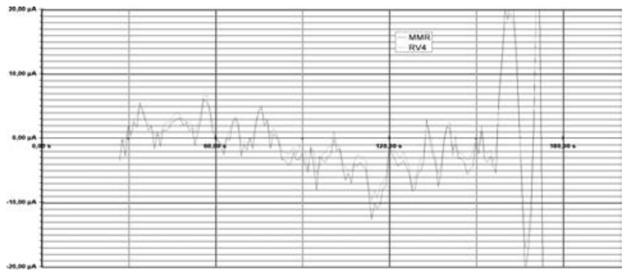


Figure 2 : MMR/51RV4 Glide Slope comparison (X=time, Y=microampere)

SECOND TRIAL WITH EVS-300 RECEIVER (2005-2006):

Since July 2005 we have performed numerous flight hours to evaluate performance of this new generation of receiver. We flew over mono and bi-frequency ILS, M type and Null Ref Glide Slope and traditional and Doppler VOR.
In a first step, same low level noise was observed. The possible origin of this low level noise is the high-speed measurement time (adjusted between 10 and 100 milliseconds) of the receiver. Analogical receiver suppresses automatically these fast variations through natural filtering of electronics demodulation circuits.

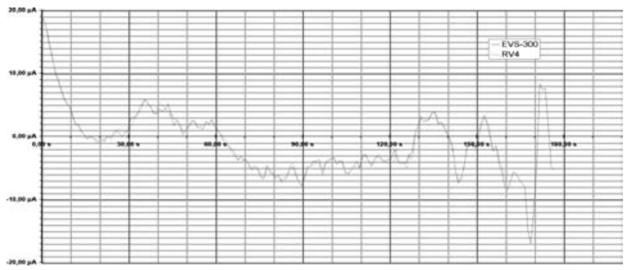
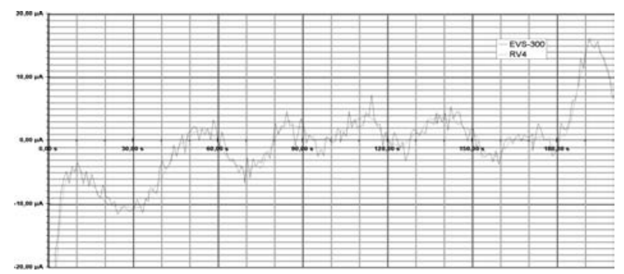


Figure 3 : EVS-300/51RV4 Localizer comparison (X=time, Y=microampere)



FFigure 4 : EVS-300/51RV4 Glide Slope comparison (X=time, Y=microampere)

For coverage measurements, we can see an important difference on high level DDM signal (more than 250 microamperes). It appears whatever ILS inspected. In fact, digital narrow filters reject fully 90Hz and 150Hz of each low frequency measurement (high rejection of 90Hz for 150Hz measurement and conversely). Difference between them are seen with more precision by a numerical receiver, while analogical receiver can not filter totally other side band signal and increase improperly the difference between both signals. Measurements realized with EVS-300 are very closed of field simulations for Thomson 13 antennae and Normarc 12 antennae networks.

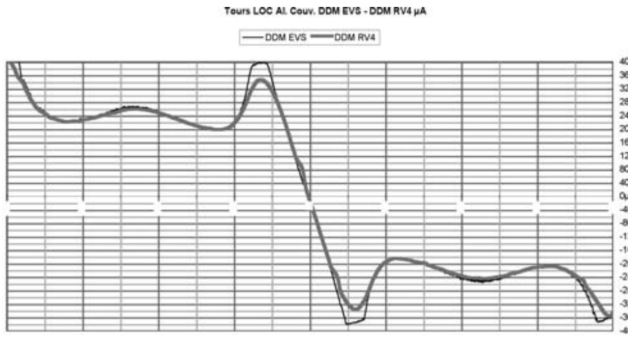


Figure 5 : EVS-300/51RV4 Localizer coverage comparison (X=time, Y=microampere)

We have seen that raw data calculated by digital receivers included low-level noise. A simple algorithm called "recursive digital filtering" allows to obtain the same curve like usual analogical receiver.
A specific presentation will be done during this symposium to cover all filtering aspects on numerical output data.
The range for VOR coverage is the same than range of our airplane receiver. Range for localizer signals at 25 and 17 Nautical miles are also acceptable.
More over, the field strength measure is more precise than all our calibrated AGC measurements.

REAL APPLICATION :

The measuring device at our disposal was not specifically developed for the flight inspection use.
It was initially intended for ground services, anxious to improve significantly their capacity to make several measurements at the same time. It allows us to record all the measurements and to correlate them with the accurate position and time reference.
Consequently, the measuring device is able to replace all VOR, Localiser, Glide Slope, Marker, VHF communications receivers. For ILS particular case, we are now able to measure Clearance and Course signal at the same time.
Further more, it can be connected to a GPS receiver in order to date with precision and to associate each measurement with very accurate DGPS (Differential Global Positioning System) position.
In the particular use in flight inspection of radio-navigation aids, a man-machine interface such as a console remains essential for the technician to fully ensure with the same quality as it exists today, the publication of exploitable results and curves.
However and for specific uses, the equipment tested allows instant visualization in curves forms of the measured values.
All raw data are recorded in digital format. This enables a later post-processing on a computer.
Until now, to measure carrier frequency or sideband modulation levels a spectrum analyser should be used. All those measured data are from now available on the front side of the measuring device.
A rear plug allows to send in real time all parameters to a computer. Moreover, all data recorded can be saved on USB memory storage unit.
However it would be convenient to associate a classical airline receiver to the measuring device in order to ascertain that an airplane equipment receives and decodes appropriately the signals of ground radio-navigation aids. The data stemming from the plane sensor would not be used directly to make a precise measurement, but only to demonstrate a good quality of the received signal.
A fully digital receiver would manage the measuring part entirely and simultaneously.

Position-fixing system :
All calibration bench uses a position-fixing system independent from the inspected facility. The position-fixing system and the flight inspection receiver contribute to the error budget. Time tag of signal impacts directly on precision of measurement.
As said before, the measuring device has a specific input able to receive GNSS (Global Navigation Satellite Service) data. The manufacturer has modified his product to accept our GPS (Global Positioning System) data informations which have been used for ten years by our flight inspection systems. In this way, all navaids data received are recorded with high accuracy GPS position and dating.

Moreover, the identification signal :
Flight inspection of identification signal is required for correctness and clarity.
The digital receiver implemented allows automatic ident decoding in order to facilitate the work of the technician to check the good format of Morse coding for the automatic decoders. It is important to keep in mind that this function is basic on all Airbus planes since the A320, manufactured in our lovely city of Toulouse.

WHY TO USE THE SAME MEASURING EQUIPMENT AT GROUND AND ONBOARD THE CALIBRATION PLANE?

The document 8071, « Manual on testing of radio navigation aids », from ICAO (International Civil Aviation Organization) recommends that results of the flight inspection should be correlated with the results of the ground inspection. Together they form the basis for certification of the facility.
The correct selection and utilization of special ground or flight inspection equipment used to determine the validity of navigation information minimizes the uncertainty of the measurement being performed.
The correlation of air and ground measurement records and equipment stability have allowed some States to extend the interval between flight inspections. This is supported among others by closer tolerances on flight inspection results to ensure operational stability is maintained.
All previous laboratory receivers were not usable on inspection aircraft because of their improper sensitivity threshold, but new generation computes signal with very low level such as –100dBm.
Significant improvement of the accuracy of the signal measurements allows us to foresee a reduction in radio-navigation aids flight inspection costs.
The measurement accuracy on localizer DDM is less than 0.04% and less than 0.08% for glide slope with this digital receiver. Analogical receiver currently implemented on our planes has an accuracy of 2%.
Concerning VOR signal analysis, the manufacturer declares an accuracy better than 0.1°. Analogical receiver performance is 0.5°.
Using the same measuring receiver by the maintenance team on the ground and in the calibration plane allows us to foresee significant benefits:
- improvement of the accuracy of the setting tolerance,
- the exact value for a parameter,
- despite the measurement's uncertainty.

Where there is a difference between the values measured on ground and on the calibration plane, the receivers used by the respective units are swapped to eliminate any doubt and any ambiguity.

CONCLUSIONS :

Digital receivers like MMR are not fully adapted to our needs for flight inspection. They need to be modified to output additive information required for flight inspection.
On the other hand, laboratory numerical receiver is fully compliant with ground and flight inspection tasks. It offers among many output parameters, all information required for calibration. In addition, data are available in different formats and units, displayed in real time on a large

screen, available also on a network connection for external real time computer application and finally recorded onboard for later USB recovery. Do not forget of the ability to associate GPS high precision position and time tag to each measurement dot.
Our trial has demonstrated that the accuracy and reliability of measurement with a frequency output until 100Hz are better than those achieved presently with our Flight Inspection System.
Future flight inspection device will have only little relationship with those used today : an accurate laboratory receiver with performance unknown until today, a DGPS receiver with cent metric precision and a portable computer. Few antennae will remain necessary for signal reception. Autonomous batteries will power all these equipments and flight inspector would carry all his equipments in two portable cases across the world.
Only customs formalities may be able to slow down our new flight inspector of XXIst century.