New way of ILS calibration using the availability of high precision digital receiver

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ABSTRACT

During an ILS Flight Check, we use to measure global error which is the difference between ILS signal (Localizer or Glide DDM) and the reference (trajectography).
When the MLS was defined by ICAO, the terms of pilotable error (**PFE** : Path Following Error) and noise error (CMN Command Motion Noise) appeared. The MLS flight check introduced the frequency filtering of the global error.
Most of the Flight Inspection Services in the word still use analogical receiver like the Collins 51 RV4 that we have in our Bench. This type of receiver has an important time constant value so it was impossible to apply a similar process on the ILS error.
If we use a numeric receiver for example the Rohde&Schwarz EVS300, we can try to extrapolate the filtering process of the MLS on ILS values. This presentation will present a new way of ILS flight check and propose numeric filters which can applied and also the type of tolerances who will be associated with these new parameters.

INTRODUCTION

ILS was defined after the World War II and at this time we only spoke about global error. At the beginning of the eighties the MLS was defined by ICAO, the error had to be decomposed in low frequency signal the PFE and high frequency signal the CMN. The purpose of this document is to proceed a numeric filtering to ILS curves given by a very precise numeric receiver. On the other hand, the DDM from the EVS-300 is very noisy so for a flight check exploitation we have to filtered it. The goal of filtering is also to simulate the respond of an analogical receiver. We cannot do this processing with an analogical receiver like the Collins 51RV4, because the DDM signal is already filtered by the electronics demodulation devices. The only element we can measure is the time constant of this type of receiver.

DEFINIFION IN ICAO ANNEXE 10

The ICAO don't use the terms of PFE and CMN for ILS or VOR but in the paragraph 2.1.7 of Supplement C, we can read "Owing to the complex frequency components present in the IL s beam bend structures, measured values of bends are dependent on the frequency response of the airborne receiving and recording equipment. It is intended that beam measurements be obtained by using a total time constant (in seconds) for the receiver DDM output circuits and associated recording equipment of 92.6/V, where V is the velocity in km/h of the aircraft or ground vehicle as appropriate."
So for this study we keep that value of 92.6/V, which give 0.33 seconds for a aircraft speed approach of 150 knots.

FILTERS CONSTRUCTION:

We have to filter curves in distance (Nm), but the time constant to apply is in seconds so we are going to calculate filter parameters for an average speed 150 knots in this study.
We bolt filters in using the Draft MLS 8071. The filters are numeric and recursive
The PFE filter is a Low Pass filter and his general equation is :

$$Y_n = A.Y_{n-1} + B.Y_{n-2} + C(X_n + 2X_{n-1} + X_{n-1})$$

where A, B and are function of the corner frequency and sample period.
The CMN filter has to be a Side Band filter. We build it by a combination of a Low Pass Filter on the output of the receiver with a high corner

frequency to cut very high frequency on DDM, essentially internal noise of the receiver and a High Pass Filter.
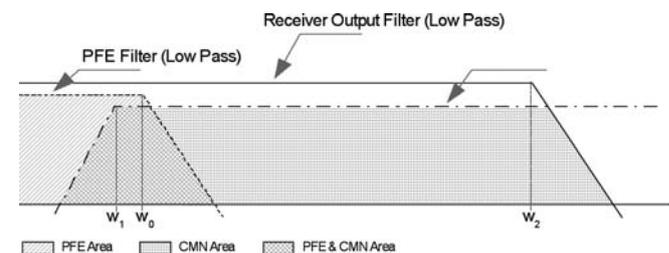The general equation of the receiver filter is :

$$Y_n = A.Y_{n-1} + B(X_n + X_{n-1})$$

where A, B and are function of the corner frequency (wc=10 rad/s) and sample period.
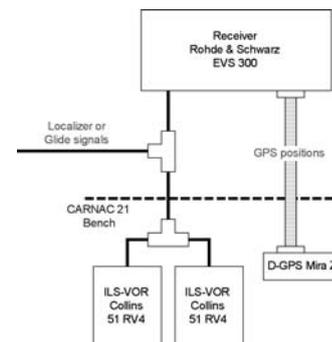The general equation of the CMN filter is :

$$Y_n = A.Y_{n-1} + B(X_n - X_{n-1})$$

where A, B and are function of the corner frequency and sample period.

MEASUREMENTS

At this time, we performed two ILS flight checks with full trajectography (Périgueux and Tours). The EVS was in parallel on the Localizer or Glide signals and connected to our D-GPS for recording WGS-84 positions.

After the flight, we extracted the values of the EVS 300 by the USB port and the values for the Collins 51RV4 by the CARNAC 21 Bench. All these values are back–processing by Excel, to calculate Errors, PFE&CMN and compare curves from the EVS-300 (raw and filtered) and from the 51RV4. This type of process can be implemented on Calibration Bench to be done in Real Time in the same way as in MLS.
The first step consisted to synchronise EVS300 and 51RV4 data. On EVS300 data we have GPS positions. So we can calculate for each EVS-300 value a position in spherical coordinates (Azimuth, Site and Distance) like it was given by the CARNAC 21 Bench. After that, we can compare two receivers curves. After that point, we can also try different type of filtering. For simplification I only present the results from MLS type filters

SYNCHRONISATION OF RAW AND FILTERED DATAS

As we know, recursive numeric filtering introduces a delay on the output data, so we have to resynchronise filtered data with row data. We can make it easily if we know the caracterics of the filter and the speed of the plane (Ground speed for approach, Vertical Speed for Glide slice and Azimuthal speed for Localizer Coverage).

RESULTS AND CURVES

The following curves show the filtering of the Localizer Axis of Périgueux. The corner frequency for PFE is 3 rad/s corresponding at the time constant of 92,6/V with an aircraft speed of 150 Knots.
The CMN is obtained by filtering at 10 rad/s of the EVS-300 DDM signal and after that a high pass filtering with a corner frequency at 2 rad/s.
Figure 3 and 4 represent the difference between PFE or CMN and Collins 51 RV4, the filtered curves are not re-synchronised.
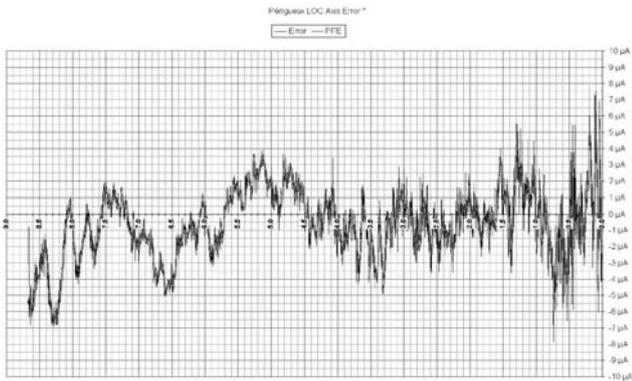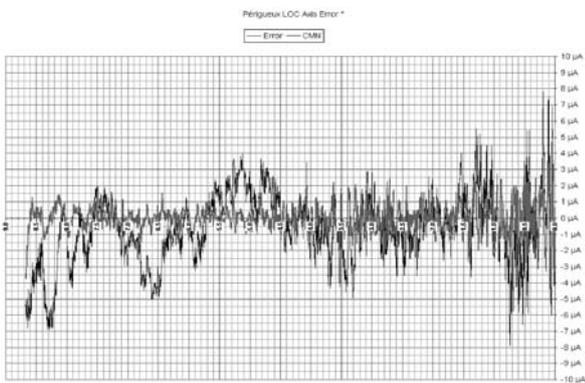
The next curves show the filtering for a Glide Slope Approach. We keep the same values of corner frequency for the PFE (Figure 5) and CMN (Figure 7).

Figure 7 and 8 represent the difference between PFE or CMN and Collins 51 RV4, for the Glide Path of Tours, the filtered curves are not re-synchronised.

Figure 1 : EVS300 (Error-PFE)

Figure 2 : EVS300 (Error – CMN)
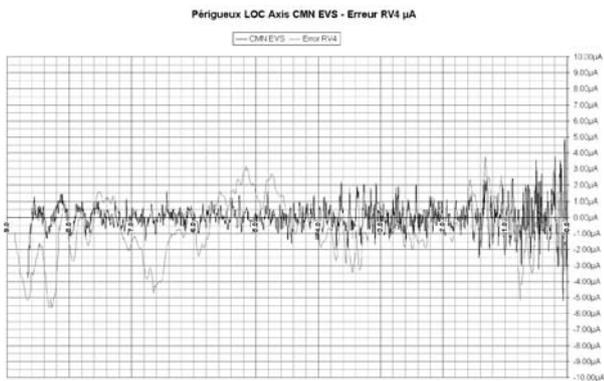
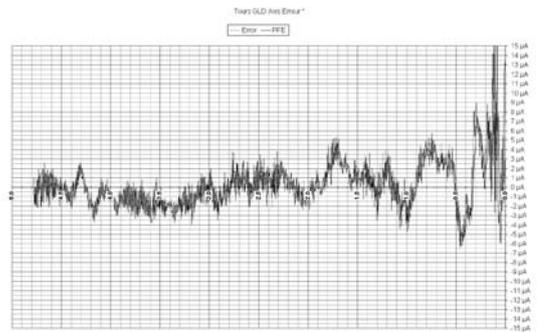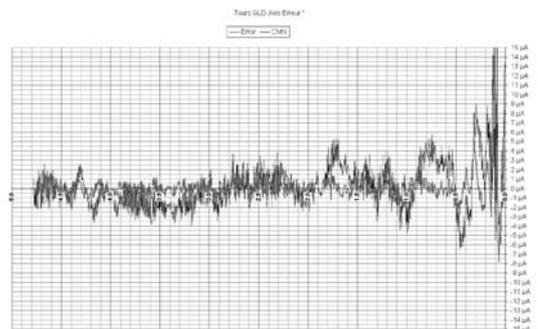**Figure 3 : EVS300 (PFE) – Collins 51 RV4 (Error)**
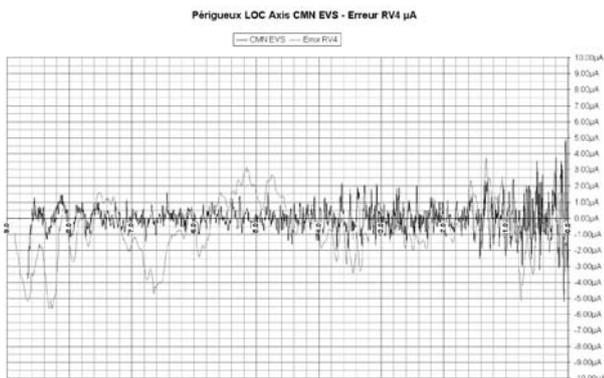
Figure 4 : EVS300 (CMN) – Collins 51 RV4 (Error)

Figure 5 : EVS300 (Error-PFE)

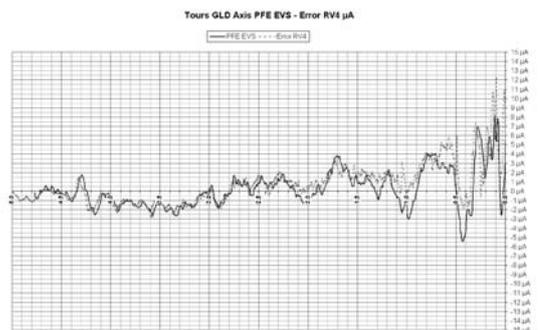
Figure 6 : EVS300 (Error-CMN)

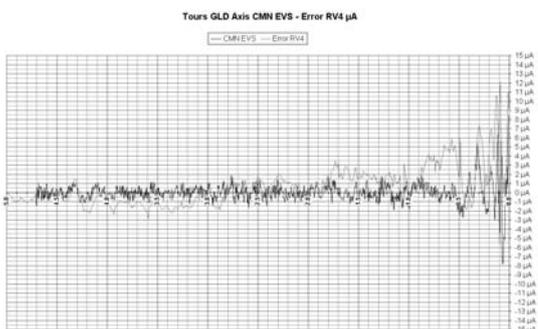**Figure 7 : EVS300 (PFE) – Collins 51 RV4 (Error)**

Figure 8 : EVS300 (CMN) – Collins 51 RV4 (Error)

We can also filter the DDM curves for example Localizer Coverage, in this case we print filtered curves before and after re-synchronisation. In this case the corner frequency is 0.5 rad/s for having an important delay to make up
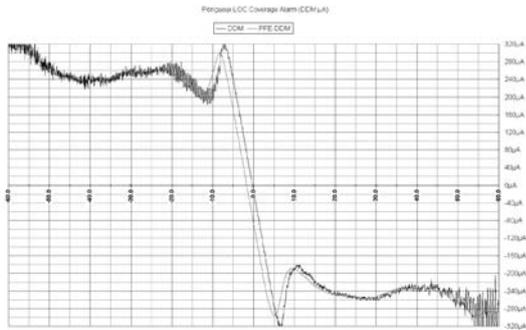

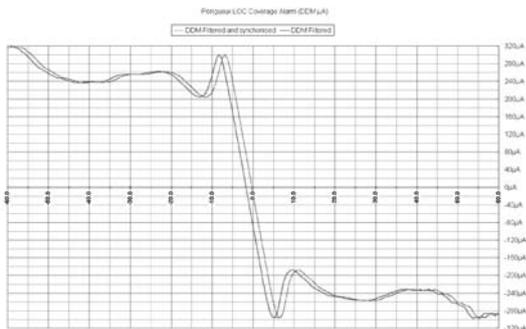
Figure 9 : EVS300 (DDM-DDM Filtered)

Figure 10 : EVS300 (DDM Filtered – DDM Filtered and synchronised)

CONCLUSION:

The aim of this study is to try to filter EVS300 curves for two different goals, make an exploitation of EVS300 in flight checks and separate different components of the global error in ILS or VOR.
We see that we can reproduce curve look a like analogical receiver Collins. We also
introduce a new way of process on ILS and VOR measurements. In this topic I don't want to speak yet about tolerance but if we want to apply this process totally we have to define new values of tolerance for ILS, especially for CMN. Now we have planned to make some other flights to improve our experience.