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ESTABLISHED FI NAVIGATION RECEIVERS AND THEIR FUTURE IN FLIGHT INSPECTION

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ABSTRACT

Over a quarter of a century nearly without exception only two types of navigation receivers are used in flight inspection: Collins 51RV5B and Bendix/Honeywell RNA34AF. Both have been developed in a period when position determination during flight inspection was based on landmark-events and manual tracking.
Modern flight inspection systems provide precise high dynamic position determination with accuracies in centimeter range. But still most of the modern flight inspection systems are using these navigation receivers based on analog technique. Today we can observe the obvious impact of the receivers´ internal analog filters to flight inspection measurements. Due to the fact that the internal filters are not long term stable, frequent re-calibration is mandatory. Long warm up time is required because reliable signal output can only be guaranteed for a small temperature range. Other observed unwanted side effects are cross-correlations between input parameters and vulnerability to failures, disturbance and noise. All these effects raise the demand for a digital state-of-the-art flight inspection receiver to obtain repeatable measurement results.

PURPOSE

This paper shows and describes comparisons of output signals of flight inspection receivers either analog or digital. In addition real flight inspection measurement data out of a real calibration task is displayed with a direct comparison between digital and analog techniques. The compared receivers are:
- Bendix/Honeywell RNA34AF
- Collins 51RV5B
- Aerodata AD-RNZ850 (modified Honeywell RNZ-850 B)

BACKGROUND

All flight inspection systems have to use navigation receivers which have to as accurate as described in the regulations. In addition most flight inspection navigation receivers are providing additional special data, to achieve compliance to those regulations. Either FAA, ICAO or any other aviation regulation authority determines the tolerances and the functionality of such flight inspection receivers. Those which were suitable in the past for such tasks are the following competing receivers:
- Bendix/Honeywell RNA34AF
- Collins 51RV5B

Those units are based on analog technique due to their development date, which was a long time ago. New flight inspection receivers which are fulfilling the tolerances according to the dedicated regulations are:
- Honeywell RNA34BF (available earliest end 2006 according to Honeywell Germany)
- Aerodata AD-RNZ850 (modified Honeywell RNZ-850 B)

These both units are working with digital signal processing, which minimizes fault factors like temperature drift or warm up time by its design. The Aerodata modified receiver is using a standard Honeywell RNZ-850 multimode receiver with implemented Aerodata developed filters and signal processing to generate all necessary values and data for flight inspection. Both receivers are with state-of-the-art design. As the Honeywell will be available end of 2006 (according to Honeywell Germany), the Aerodata modified receiver is in use since 2001. Therefore this presentation is focusing on the Aerodata modified Receiver.

SUBJECT

The comparison between the three receivers will be divided in three parts:
- Maintenance and Repair
- Accuracy
- Experience

MAINTENANCE AND REPAIR

The Honeywell as well as the Collins receiver are, as every maintenance shop for such units will assure, today very hard to maintain. Spare parts for the electronic circuit boards are hardly to purchase because of its age and replacements are often even worse or difficult to install because of different sizes.

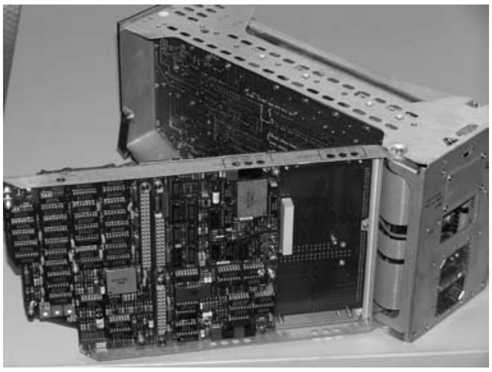

Figure 1: Collins 51RV4B

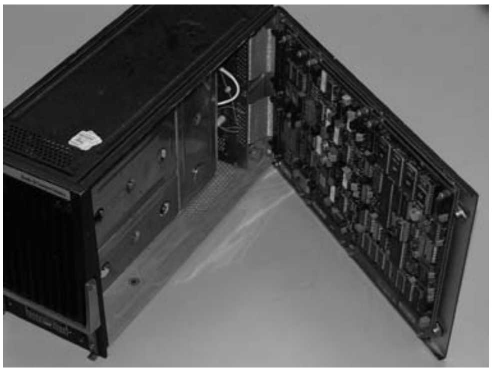

Figure 2: Bendix RNA34AF

The Aerodata modified receiver is much smaller and has implemented the former used large circuit boards on integrated circuits (IC). Due to this much less parts have to be maintained or can become obsolete. As shown in figure 3 only the middle section is performing the functionality of VOR/LLZ and GS, including marker beacon receiver. The upper part contains a DME receiver, the lower part is showing the Flight Inspection Receiver part.

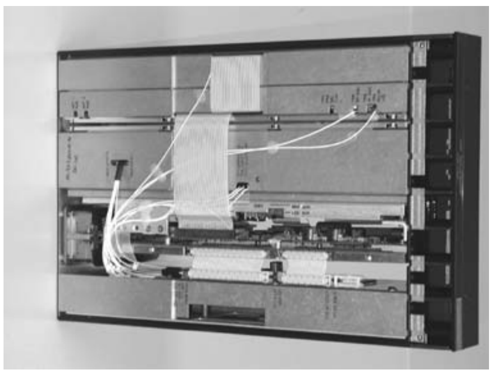

Figure 3: Aerodata AD-RNZ850 (modified Honeywell RNZ-850 B)

The calibration for the RNA34AF has to be performed up to every three month or even more often, depending on each individual unit and on the operators calibration rules. A calibration comprises a lot of different checks and a lot of possibilities to adjust up to ten potentiometers. The equipment for calibration includes many peripheral units like large work bench, spectrum analyzer, oscilloscope, voltmeter, ARINC test set etc. The temperature range has to be noted precisely, because only on this temperature range the calibrated values were applicable.
Exactly the same is applicable for the 51RV5B.
For the AD-RNZ850 a signal generator and a better PC workstation is necessary for re-checking the internal calibration. In the beginning the interval for those re-checks was set to half a year because of insufficient experience with such a new unit. Today, after 5 years of experience, this period was lengthen to one year, because no alteration effects were recognized.
All three units are line replaceable units and are utilized in digital and analog systems. The Aerodata modified receiver is designed for the use in digital systems. On special version it can be connected to analog systems as well. Depending on the version the Honeywell receiver or the Collins receiver are either equipped with an analog or a digital interface. For the following accuracy analysis the Collins receiver with an analog, the Honeywell and the Aerodata modified receiver with a digital interface were used.

ACCURACY ANALYSIS
The comparison of the LLZ deviation accuracy is shown in the following graphics:
The different colors are used to display the following different sum of depth in modulation:
- Magenta graph: 40%
- Blue graph: 36%
- Yellow graph: 44%

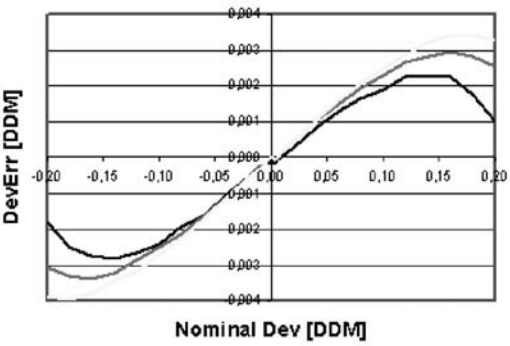

Figure 4: LLZ Deviation Error of 51RV4B

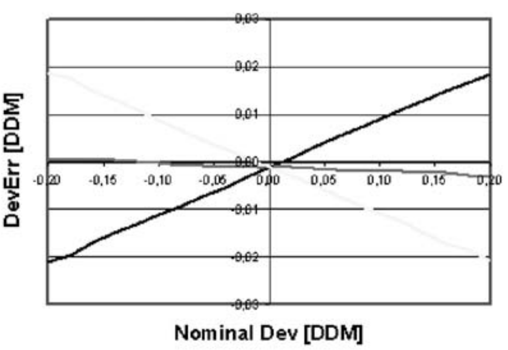

Figure 5: LLZ Deviation Error of RNA34AF

Out of those two graphics it is recognizable that the uncorrected signal of the RNA is much worse than those from the 51RV. This is caused by the manufacture´s philosophy, how to generate such raw signals. The RNA always increases or decreases its SDM to 40%, the 51RV shows the actual signal, not depending on the SDM. The flight inspection software is of course correcting such values of the RNA to achieve the same accurate data as the Collins receiver.
The graphic below shows the values after correction which are comparable to the 51RV as expected.

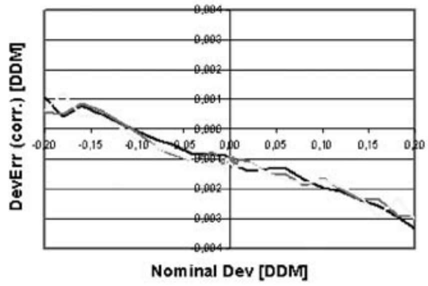

Figure 6: corrected LLZ Deviation Error of RNA34AF

The original signal of the RNZ850 shows nearly the same behavior as the RNA.

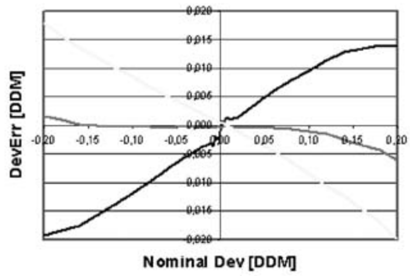

Figure 7: LLZ Deviation Error of original RNZ850

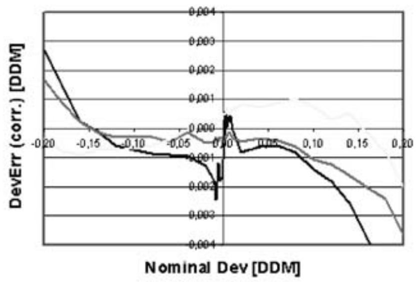

Figure 8: corrected LLZ Deviation Error of original RNZ850

After correction shown in Figure 8 through flight inspection software the RNZ850 achieves the same accuracies as those dedicated flight inspection receivers although it is normal TSO´ed navigation receiver found in many commercial aircrafts all around the world.
Concluding we compare such graphics with those values which are generated by the Aerodata flight inspection part of the receiver. Those values originate from its new developed digital filters:

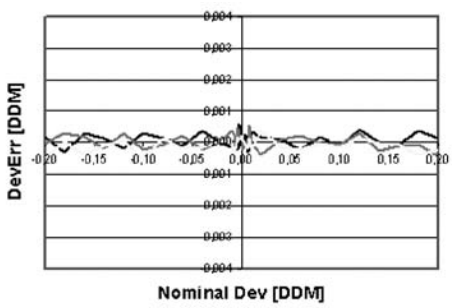

Figure 9: LLZ Deviation Error of AD-RNZ850

This is obvious a good step forward to achieve better accuracies, which is explainable due to its digital filtering. The behavior not influenced by alteration nor by temperature, which is deducted after five years experience.

FIELD EXAMPLE

The following example shows a direct comparison between two of the navigation receivers under investigation.
The flight inspection task was a commissioning of a brand new D-VOR. The flight inspection aircraft was a regular equipped King Air with installed flight inspection system. The used flight inspection receivers were the Bendix RNA34AF and the Aerodata AD-RNZ850.
The following behavior was recognized during that commissioning:
Performing orbit flights at the beginning of the task different bearing values between both receivers were displayed.
On the graphic in figure 10 the following rows are assigned to the following receivers:

First Row: Bearing signal of AD-RNZ850
Second Row: FMDR signal of AD-RNZ850
Third Row: Bearing signal of RNA34AF
Forth Row: FMDR signal of RNA34AF

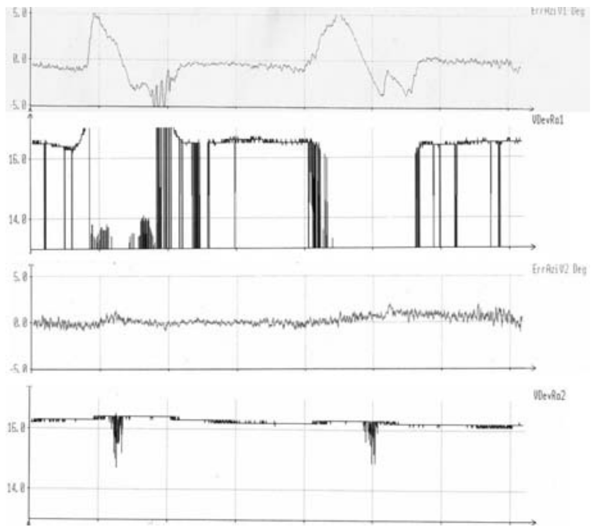

Figure 10: Bearing and FMDR comparison

After exchanging the Aerodata modified flight inspection receiver with a RNA34AF the large bearing error was not recognized on both Bendix receivers. The primary Collins avionic was also showing a large bearing error on that dedicated radials.
The flight inspector in charge has had two different flight inspection receiver with different results, and drawn conclusion was that the Bendix receiver was showing the wrong result.
The solution on the strange situation was originated in the installation on ground. At the VOR station on ground a cable pair was wrongly connected, which causes this particular error.
Due to the design of the Bendix receiver, which was designed in the age of C-VORs, it does not recognize the sharp steps in the frequency modulated phase. The control loop was designed to filter the 30Hz reference, which shall be as stable as possible. Therefore a PLL with along time constant is necessary.
Nowadays D-VORs are state-of-the-art stations. In those VORs the bearing signal is generated through the variable phase in the frequency modulated phase. What formally was a very stable signal, in case of errors at the ground station, can be now a intermittent signal with peaks and steps.
The Aerodata modified receiver is designed for such D-VORs due to its digital filtering and adjustable time constants through software. Of course, all new navigation receivers show this design. The navigation receiver in the cockpit has recognized the bearing error as well and other modern designed avionics would probably do the same.

CONCLUSIONS

The summarization of advantages and disadvantages of those three receivers can be reduced to the comparison between old and new receivers, because the differences between Collins and Bendix receivers are negligible.

Advantages of old receivers:
- Known by nearly all flight inspection units all over the world.
- The accuracy of the dedicated values is still in tolerance according to ICAO or FAA, if the calibration is performed regularly.
- Lots of units are often on stock in every flight inspection company.

Disadvantages of old receivers:
- Calibration has to be accomplished regularly. This is time consuming and increases the possibility of human errors.
- Maintenance is very difficult due to lack of spare parts or obsolete items.
- Space consuming due to its large dimensions.
- No automatic internal calibration possible, due to the adjustment of potentiometers.
- Long warm up periods
- High temperature dependence
- Dependency between field strength, modulation and frequencies

Advantages of new receiver:
- Possibility of showing in parallel highest accurate flight inspection values and values, which are used in regular primary avionics.
- Comprises three flight inspection receivers in one unit (NAV,DME,MKR).
- Internal calibration requires no calibration in the laboratory.
- Nearly no measurable temperature influence.
- Only insignificant dependencies between field strength, modulation and frequencies due to internal calibration.
- Re-programmable according to customer needs.
- Lots of additional flight inspection information values.

Disadvantages of new receiver:
- Only five years experience.
- Since today only 20 units are running on the market.
- More expensive due to combination of flight inspection receiver.

Combining and considering advantages and disadvantages the future belongs to the new digital receiver types. Anyway, the growing impossibility of maintaining the old units will lead to new receivers in any case.

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[1] ICAO, "Manual on Testing Radio Navigation Aids", Document 8071, Vol 1, Fourth Edition 2000
[2] FAA, "U.S. Standard Flight Inspection Manual" Order 8200.1C
[3] T. Heinke, "Multi-Mode Flight Inspection Receiver AD-RNZ850-0100", Aerodata AG, IFIS 2004, Montreal