High-End Flight Inspection Receiver

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ABSTRACT

The calibration of navigation aids requires highly accurate navigation receivers.

The combination of a modern (cost-saving) mass-produced airborne navigation receiver, together with modern digital hardware and sophisticated signal processing software allows the precision analysis of the whole spectrum of signal parameters necessary for flight inspection.

The Aerodata flight inspection receiver AD-RNZ850-0100 incorporates three navigation units and the signal processing hardware in one housing resulting in space and weight reduction compared to standard flight inspection equipment. A Field Programmable Gate Array design enables new functionality such as digital filtering and modulation frequency measurement and gives the flexibility to implement hard- and software extensions, such as customer specific interface protocols. Furthermore, temperature compensation shortens warm-up time and guarantees high precision over the full temperature range.

This paper gives an overview of the functionality, the technical and economical impacts and experience gained so far by using this receiver for ILS, VOR, Marker and DME calibration.

OVERVIEW

Standard Flight Inspection Receivers (e.g. RNA34AF) are based on conservative analog filter technique with all known disadvantages such as temperature and long term drift. Due to low integration rate a couple of receivers (NAV, DME, Marker) are required to collect all flight inspection data. This approach was cost intensive and required a lot of space and weight, which is always rare in aircraft installations. Current technology allows the integration of all such units into one slim housing.

Aerodata's new flight inspection receiver is based on Honeywell's Navigation unit RNZ-850 which is part of the Primus II Radio System and often used in business aircrafts. Aerodata's modification offers:

- Access to all required flight inspection parameters via ARINC-429 and RS-232 interface (option),
- ARINC-429 output format compatible to RNA34AF (NAV-Receiver) and
- high performance and instant data access due to multi-dimensional factory calibration.

STRUCTURE

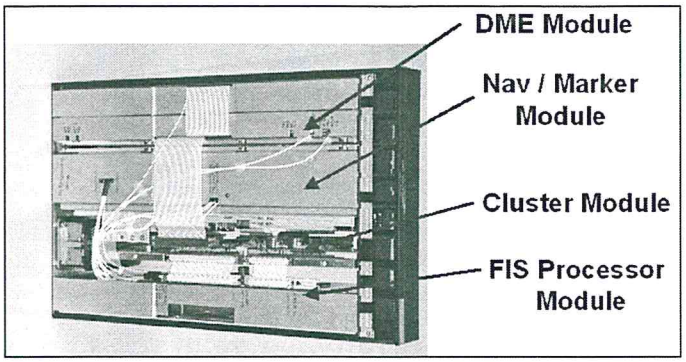

Figure 1: Overview

Honeywell Multi Mode Receiver

The used Honeywell Receiver in its original configuration is an integration of VOR, DME, Glide Slope, Marker Beacon and ADF functionality in one unit.

The modules communicate via high speed bi-directional radio system bus (RSB).

The navigation unit and additional units are controlled by a compact radio management unit (RMU).

A VHF communication unit, a transponder with mode A/C and mode S functionality and furthermore a MLS and TCAS unit may be connected to the receiver.

FIS Processor Module

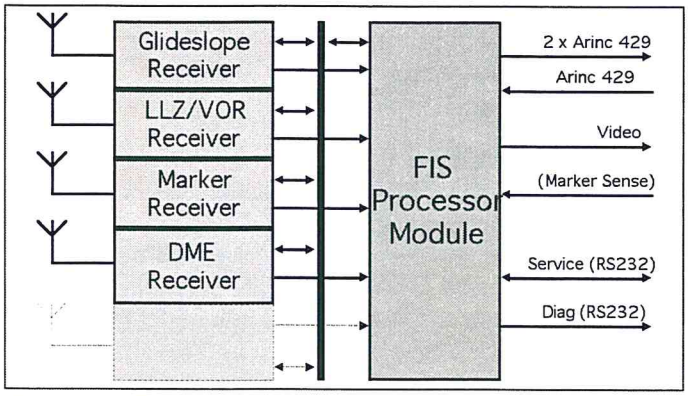

Figure 2: Receiver Structure

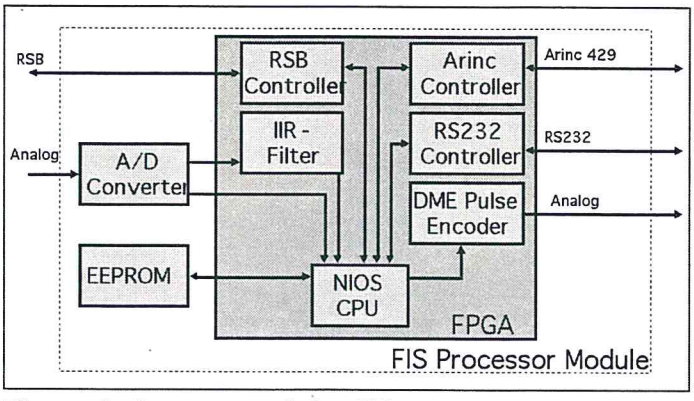

Figure 3: Structure of the FIS processor module

The modification philosophy on that receiver is to keep all original hardware as it is and to get the required additional flight inspection information by means of high-impedance taps on internal signals (e.g. AGCs, demodulator outputs). Where possible existing test points were used. All signal processing is done on a single board FIS module which is mounted on the RNZ850's spare ADF frame. This installation also enables easy access to the tray connector pins since the ADF provisions are used to interface and to supply the FIS module with power.

Thus a minimum of modifications on the original RNZ850 is needed and all signal taps are made on a non-interference basis due to their high impedance nature.

The Power supply philosophy inside the RNZ850 is unchanged. The new signal processing unit is powered via the spare ADF power pins.

The main functionality of Aerodata's FIS Processor Module is realized by means of on an Altera Stratix™ Field Programmable Gate Array (FPGA) including the 32-bit NIOS™ CPU as part of a System on Programmable Chip solution. Stratix FPGAs are optimized to address the challenges of high-bandwidth systems. Stratix devices offer very high core performance and memory capacity, functionality for clock management and digital signal processing (DSP) applications with remote system upgrade capabilities.

Interfaces

In addition to the CPU the FPGA design includes the following serial controllers:

- ARINC-429,
- Radio System Bus (RSB) and
- RS-232.

The ARINC-429 interface is the main link to the Flight Inspection System. It offers:

- Provision of all measured parameters,
- Tuning of the Nav/DME,
- Marker High/Low sensitivity switching and
- Receiver self test.

Thus no RSB interface is required to operate the AD-RNZ850-0100. The RS-232 interfaces are used for service and calibration and may optionally be used as the main interface to the receiver (in addition to the ARINC-429 interface).

For compatibility with RNA34AF analogue outputs are available at the tray connector.

IIR-Filter

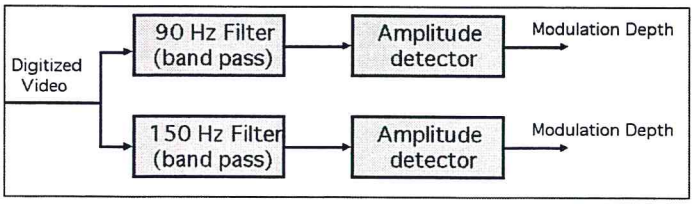

Figure 4: Filter Structure

$$H_*(z) = \frac{a_0 + a_1 z + a_2 z^2 + \ldots a_{m+1} z^m}{1 + b_1 z + b_2 z^2 + \ldots a_{m+1} z^m}$$

For separation of the 90Hz and 150Hz frequencies of the low pass filtered demodulated ILS localizer and Glide-Slope

signals two digital infinite impulse response (IIR) filters are part of the FPGA design. They are designed as cascaded 6th order Chebychev band pass filters. Furthermore each filter suppresses the 1020Hz identification signal.

Filter characteristics (see figures 5.8):

- Center frequency: 90/150Hz
- Group Delay: < 70ms
- sampling rate: 7200Hz
- resolution: 28 Bit
- stop band attenuation: >60dB
- crosstalk attenuation: >60dB

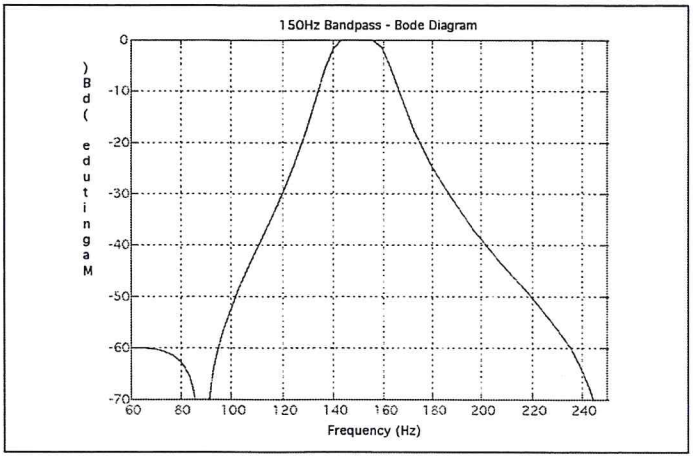

Figure 7: Characteristic of the 90Hz-Filter

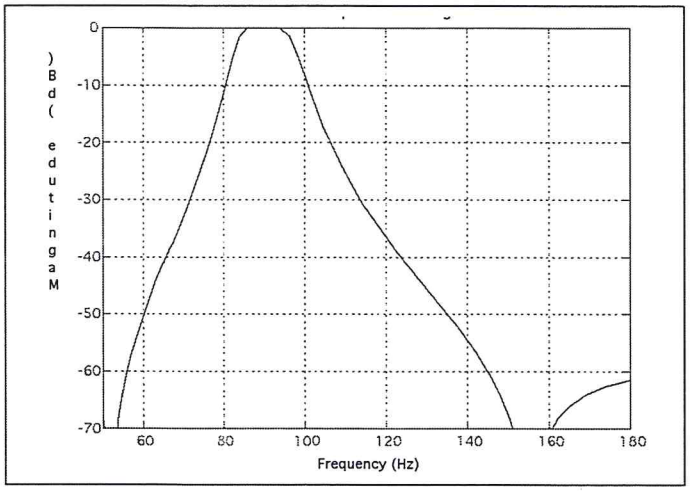

Figure 5: Characteristic of the 90Hz-Filter

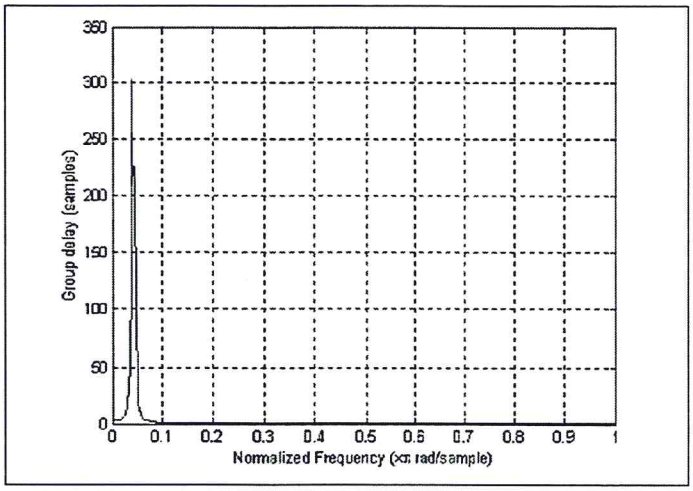

Figure 8: 150Hz-Filter Group Delay

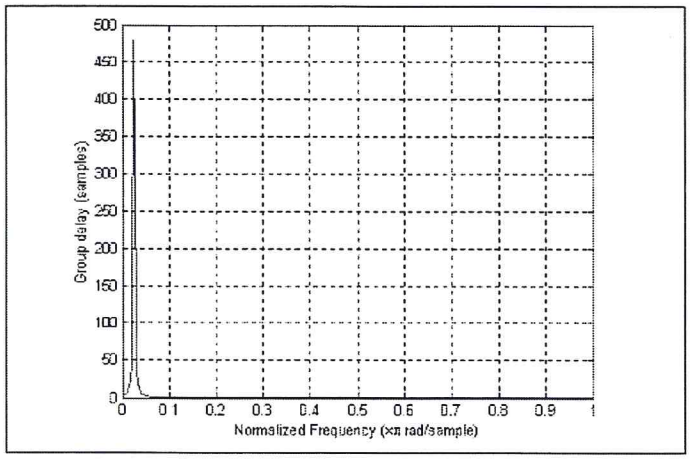

Figure 6: 90Hz-Filter Group Delay

FUNCTIONALITY

Data processing and Calibration

Flight Inspection parameters are calculated from the digitized analogue data and the digital output of the navigation modules. In order to compensate influences such as temperature drift, RF-filter characteristics a multidimensional correction is implemented. The correction data is applied and stored in an EEPROM.

As shown in Figure 9 the calibration data are determined as part of the production process.

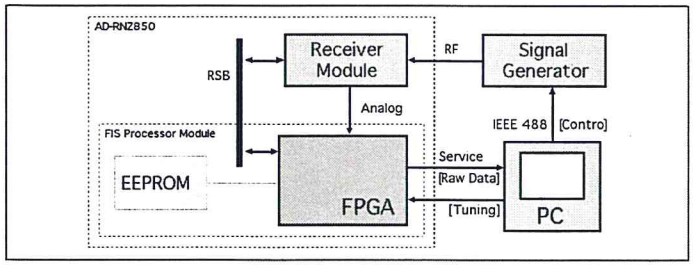

Figure 9: Factory Calibration Procedure

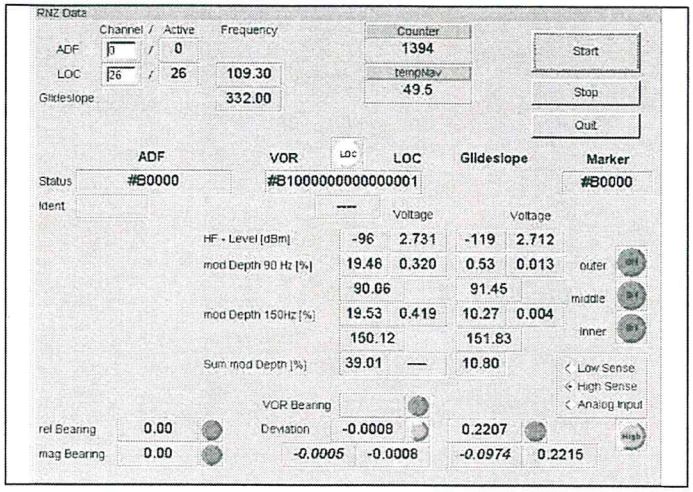

Figure 10: Screenshot of Calibration Program

Parameters

The following parameters and signals are accessible via analogue and digital interfaces:

Navigation Receiver Parameters

Input	Digital	Analog
Tuning	X	
Output	**Digital**	**Analog**
Echo Frequency	X	
Deviation / Bearing	X	
Modulation Depths	X	(X)
Modulation Frequencies	X	
RF Power	X	
VOR FM Deviation Ration	X	
Video		X
Audio		X

Figure 11: ILS and VOR parameters

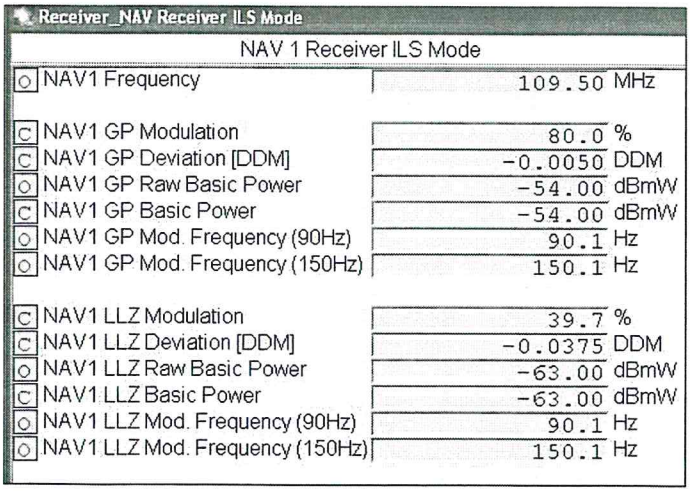

Figure 12: ILS parameters (displayed in Flight Inspection System)

Marker Beacon Receiver Parameters

Input	Digital	Analog
Sensitivity	X	X
Output	**Digital**	**Analog**
Lamps	X	X
RF Power	X	X
Sensitivity	X	X
Audio		X

Figure 13: Marker parameters

DME Transceiver Parameters

Input	Digital	Analog
Tune Frequency	X	
Output	**Digital**	**Analog**
Echo Frequency	X	
Distance	X	
RF Power	X	X
SquitterRate	X	X
Range Reply Efficiency	X	X
Ground Speed	X	
Station ID	X	
Time To Station	X	
Video		X
Audio		X

Figure 14: DME parameters

Auxiliary Parameters

Input	Digital	Analog
Analog Signal		2
Output	**Digital**	**Analog**
Receiver Status	X	
Timer	X	
Temperature	X	

Figure 15: Auxiliary parameters

TECHNICAL DATA

Name	**AD-RNZ-850-0100**		
Function	Flight Inspection VOR / LLZ / GP / MKR / DME Receiver		
Supply voltage	28 V DC		
cont. Power	33 W		
max. Power	33 W		
Weight	5.0 kg		
Dimensions (max)	W: 226.1 mm	H: 85.9 mm	L: 355.9 mm
Mounting	Tray, Part No. 7510124-9XX		
Inputs	ARINC429 , RS232 , RSB		
Outputs	ARINC429 , RS232 , RSB		
	Temperature	Humidity	Altitude
Calibrated Operation	+15 °C ... +40 °C	<95% non condensing	15000ft
Operation	+10 °C ... +60 °C	<95% non condensing	15000ft
Storage	-40 °C ... +85 °C	<95% non condensing	70000ft

Detailed Component Data

Data Output	Unit	Accuracy (95%)	Restriction
Azimuth (Bearing)	deg	+/- 0.3	0...-100dBm, 25...35% mod.
30Hz Modulation	%	+/- 1.0	-30...-100dBm, 25...35%mod.
9960Hz Modulation	%	+/- 1.0	-30...-100dBm, 25...35%mod.
FMDR	-	+/- 0.1	0...-100dBm
AGC	dBm	+/- 2 dB	-100...-20dBm

Data Output	Unit	Accuracy (95%)	Restriction
LLZ Deviation	ddm	0.0010 0.0016 0.0100	-20...-100dBm, 0.000...0.020 ddm 0.020...0.200 ddm 0.200...0.250 ddm
Modulation 90Hz	%	+/- 0.5	> -70dBm
Modulation 150Hz	%	+/- 0.5	> -70dBm
Sum of Modulation	%	+/- 1 add. 2 %	0...0.25ddm -90dBm..-100dBm
AGC	dBm	+/- 2 dB	-100...-20 dBm
GP Deviation	ddm	0.0017 0.0100	-20...-100dBm, 0.000..0.200 ddm 0.200..0.250 ddm
Modulation 90Hz	%	+/- 0.5	-70dBm
Modulation 150Hz	%	+/- 0.5	> -70dBm
Sum of Modulation	%	+/- 1 add. 2 %	0...0.250 ddm -70dBm..-100dBm
AGC	dBm	+/- 2dBm	-93...-64 dBm
Lamp on / off	-	+/- 6 dB	-61...-35 dBm
AGC	dBm	+/- 2 dB	-68...-38 dBm
Distance	NM	+/- 0.1	0...-90 dBm
AGC	dBm	+/- 2 dB	-90...-30 dBm
Squitter Rate	Hz	+/- 5	0 – 2800 Hz
Interrogation Rate	Hz	+/- 1	0 – 30 Hz
Reply Rate	Hz	+/- 1	0 – 30 Hz

FLIGHT TEST RESULTS

Aerodata has undertaken some significant flight tests with AD-RNZ850-0100 in order to demonstrate integrity and to compare the results with the RNA-34AF NAV receiver. The following plots show the comparison results:

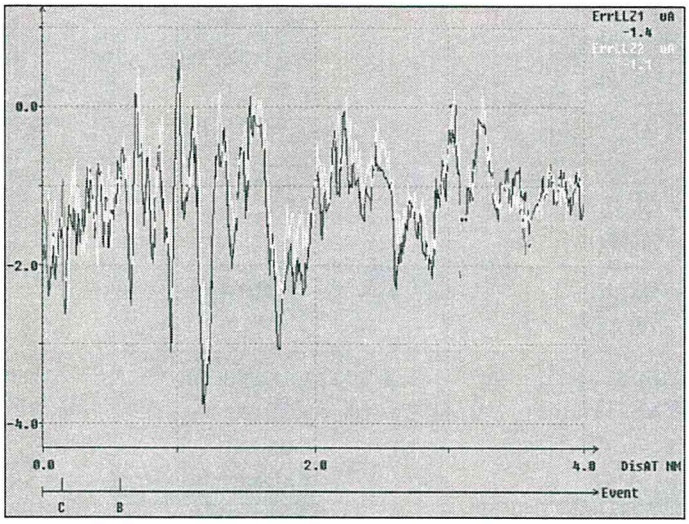

Figure 16: LLZ deviation versus distance to threshold (black: AD-RNZ850, white: RNA-34F)

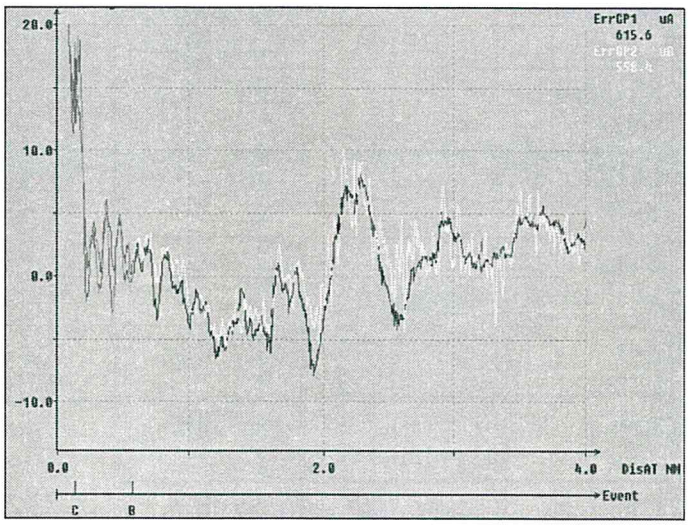

Figure 17: GP deviation versus distance to threshold (black: AD-RNZ850, white: RNA-34F)

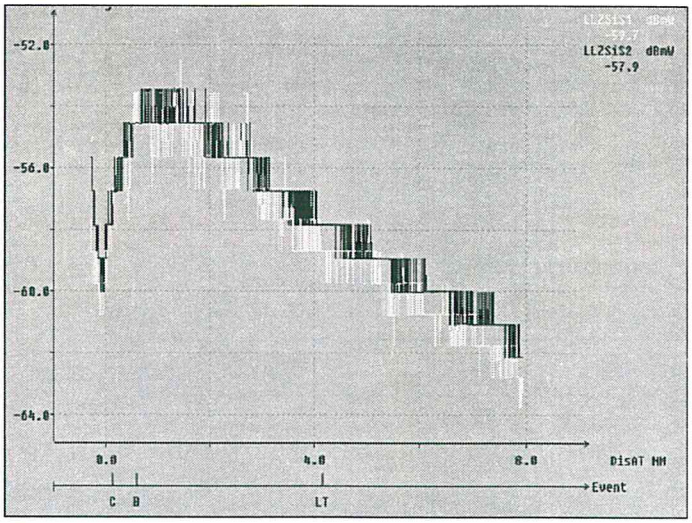

Figure 18: LLZ signal in space versus distance (white: AD-RNZ850, black: RNA-34F)

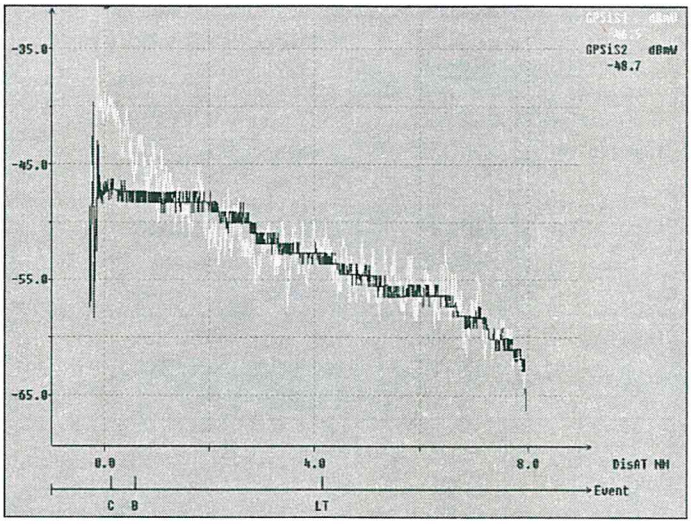

Figure 19: GP signal in space versus distance (white: AD-RNZ850, black: RNA-34F)

The flight test has shown, that the parameters measured by the compared receivers do not deviate significantly. The saturation behavior of the AD-RNZ850 is less pronounced.

SUMMARY

The structure, functionality and technical data of a flight inspection multimode receiver based on a modern commercial airborne navigation receiver was described. Aerodata's new Nav-Receiver AD-RNZ850-0100 is a compact state of the art Flight Inspection receiver with integrated ILS, VOR, Marker and DME receiver units. Its small dimensions and weight makes it ideal for integration in small aircrafts. Standard serial interfaces allow for easy connection to any Flight Inspection System or computer. The digital filter design and complex onboard calibration guarantee accurate data over a wide temperature range.