ADS-B 1090ES Extraction

User Manual

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ADS-B 1090ES Extraction **User Manual**	
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Abstract:	ADS-B Extended Squitter (ES) is transmitted on 1090MHz according to the DO-260/ED102 MOPS. ADS-B signals can easily be received on RF using an omni-directional antenna. A portable setup of ADS-B Receiver (ARF800) and associated antenna in combination with the RIM782 or UVR892, performs extraction of the ADS-B signals with an output of ASTERIX CAT021 data for displaying and further analysis. This user manual handles about the DHM, RIM782 and ARF800 for ADS-B extraction.

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Note: This icon to the left of bold italicized text denotes a note, which alerts you to important information.

Caution: This icon to the left of bold italicized text denotes a caution, which alerts you to the possibility of data loss or a system crash.

Warning: This icon to the left of bold italicized text denotes a warning, which alerts you to the possibility of damage to you or your equipment.

GLOSSARY OF TERMS

ADS-B	Automatic Dependent Surveillance, Broadcast
Annex 10	Aeronautical Telecommunication, *Annex 10 to the Convention on International Civil Aviation*, the principle international document defining SSR
ATC	Air Traffic Control
COTS	Commercial Off The Shelf
CPU	Computer Processing Unit
dB	Decibel
FL	Flight Level, unit of altitude (expressed in 100's of feet)
FRUIT	False Replies Unsynchronized In Time, unwanted SSR replies received by an interrogator which have been triggered by other interrogators
GPS	Global Positioning System
ICAO	International Civil Aviation Organization
ICD	Interface Control Document
IE	Intersoft Electronics
IF	Intermediate Frequency
I/O	Input/Output
IP	Internet Protocol
LAN	Local Area Network
LVA	Large Vertical Aperture (antenna)
MSSR	Monopulse Secondary Surveillance Radar
NM	Nautical Mile, unit of distance
OEM	Original Equipment Manufacturer
PPI	Plan Position Indicator
PSR	Primary Surveillance Radar
Radar	Radio Detection And Ranging
RASS-R	Radar Analysis Support Systems – Real-time measurements
RASS-S	Radar Analysis Support Systems – Site measurements
RDP	Radar Data Processing (system)
RF	Radio Frequency
RTQC	Real Time Quality Control
RX	Receiver
SAC	System Area Code
SIC	System Identification Code
SLS	Side Lobe Suppression, a technique to avoid eliciting transponder replies in response to interrogations transmitted via antenna sidelobes
SNR	Signal-to-Noise ratio
Squitter	Random reply by a transponder not triggered by an interrogation
SSR	Secondary Surveillance Radar
STC	Sensitivity Time Control
TACAN	Tactical Air Navigation
TCP	Transmission Control Protocol
TIS-B	Traffic Information Services, Broadcast
Transponder	Airborne unit of the SSR system, detects an interrogator's transmission and responds with a coded reply stating either the aircraft's identity or its flight level
TX	Transmitter
Uplink	Ground-to-air signal path
UTC	Coordinated Universal Time

1. ADS-B 1090 EXTENDED SQUITTER

In recent years, more and more aircraft are being equipped with GPS based navigation tools. This implies that the standard Mode-S reply is enhanced with GPS-based positional information like longitude, latitude and true height; as well as identification information of the targets (downlink format DF17 and DF18).

ADS-B Extended Squitter (ES) is transmitted on 1090MHz according to the DO-260/ED102 MOPS. ADS-B signals can easily be received on RF using an **omni-directional antenna** which is placed at sufficient height to avoid screening from the environment nearby (i.e. buildings, obstacles).

ADS-B can for example be received by the **SLS-antenna** when this has a video output on the radar receiver. This video signal can be connected to Intersoft Electronics' Radar Interface Module (RIM782) or USB Video Recorder (UVR892) to extract the pulses and to make ASTERIX CAT021 data.

In case there is no omni-channel available on the radar receiver -or there is even no radar (yet)- you can simply use a **portable setup of ADS-B Receiver (ARF800) and associated antenna** in combination with the same RIM782 or UVR892. Dependent on height and screening, a maximum range of 300NM can be obtained, while 120NM range is sufficient for analysis with Radar Comparator Dual.

Figure 1.1: ARF800

Applications of the extracted ADS-B data

ADS-B data is an interesting alternative source for situational awareness (**Multi Radar Display MRD3**) and can be used as a separate source of target position information. This source of data can be used as the reference data for comparison with radar data (PSR, SSR, Mode-S), which will be under test. In this way, ADS-B data can assist to calculate the radar's Accuracy and Biases by comparing the radar data to this ADS-B data. (**Radar Comparator Dual or RCD**)

Other Intersoft Electronics ADS-B test tools exist, for example an ADS-B target generator (based on the Radar Environment Simulator or RES). This tool generates the ADS-B 1090ES messages at RF for more than 1024 targets simultaneously, including garbling replies which are always present in the heavily loaded 1090MHz environment. The description of this tool is not part of this document.

This user manual

This user manual focuses on examples of field applications and methods to record ADS-B data for further use, but also includes relative specifications on the ARF800 receiver and GP-1090 antenna. The RCD to make analysis of the data, is not discussed in this user manual.

The **required equipment for extraction of ADS-B replies** and creation of plots from these squitters are listed below:

- **ARF800** and GP-1090 Antenna (in case no SLS-channel of the SSR receiver can be used)
- **RIM782**[1] for sampling of video data, connected with **GPS450** for UTC time synchronization
- RASS-R **Data Handling Module** (DHM) with ADS-B extraction module
- RASS-R **Multi Radar Display 3** (MRD3) to visualize the extracted ADS-B plots
- High end PC or Laptop

Please refer to the relative manuals on the DHM, MRD3, RIM782, RCD for more information on these products.

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1 A UVR892 could be used as alternative.

2.   FIELD APPLICATIONS

As already discussed in the introduction, the two key elements of ADS-B plot extraction are the RASS-R DHM software module and the RIM782 (or UVR892) video recording device. Besides these, an ADS-B receiver and antenna is required to detect ADS-B messages and convert them into video. Examples of various implementation are discussed below.

2.1. Extraction of ADS-B on SLS channel of SSR radar

The **Side Lobe Suppression channel** (SLS or Ω) of a Secondary Surveillance Radar (SSR) can be used to detect the ADS-B messages and convert them to video. Make the following connections as in Figure 2.1:

- The SSR (SLS or Ω) receiver channel output has to be connected to the RIM782[2], for example video channel 1

- The RIM782[2] can have a GPS450 connected for UTC time synchronization

- The RIM782[2] is connected to the PC (laptop or desktop), via a USB-2 cable

- This PC requires as a minimum the RASS-R DHM software to be installed, which will retrieve the video of the ADS-B via the setup as defined in paragraph 2.3. Optionally, the MRD3 and the RCM/D, as well as the RASS-S toolbox, can be installed on the PC.

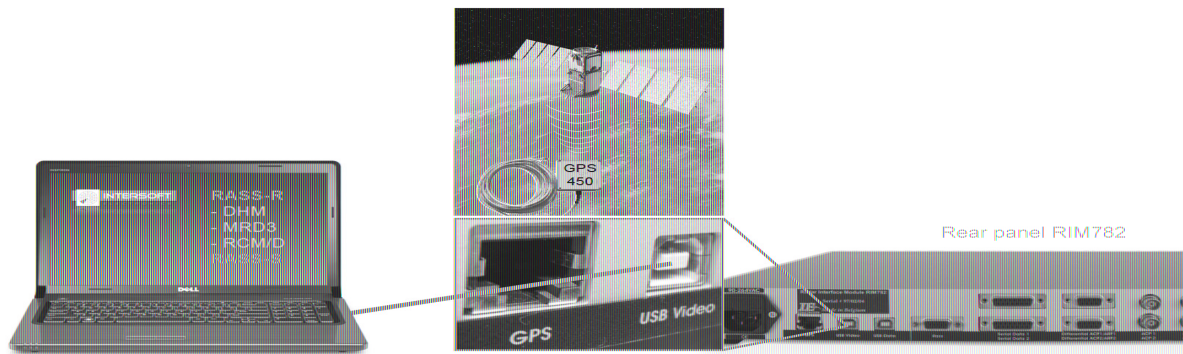Remark that in this application, the ARF800 is not used.

Figure 2.1: SSR SLS Channel Implementation

The maximum obtainable range by using this method will depend on the sensitivity of the radar and screening of the environment. Ranges above 200NM can be expected, but the gaps between detections will increase through garbling with FRUIT.

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2   A UVR892 could be used as alternative.

2.2. Extraction of ADS-B with ARF800 and GP-1090 antenna

In case there is **no omni-channel** and receiver available on the radar, one can use the **portable setup** consisting of the **ARF800 and GP-1090 antenna**. The GP-1090 is an omni-directional antenna and a horizontal coverage of 360 degrees is predicted. Similarly to when an omni-channel is available on the radar, the RIM782[3] is used to perform the ADS-B extraction. Make the following connections as in *Figure 2.2*.

- Connect the GP-1090 ADS-B antenna to the Low Noise Amplifier (LNA) and Filter module.

- From the LNA&Filter module, there is 30m coax cable that must be connected to the ARF800 RF input

- Connect the video-output of the ARF800 to one of the video channels of the RIM782 (preferably channel 1)

- The RB cable (RASS Bus) is used to power the ARF800.

- The RIM782[3] requires a GPS450 connected for UTC synchronous time of detection timestamping of the data

- The RIM782[3] is connected to the PC (laptop or desktop), via USB2 cable

- This PC requires as a minimum the RASS-R DHM software to be installed, which will retrieve the video of the ADS-B via the setup as defined in paragraph 2.3. Optionally, the MRD3 and the RCM/D, as well as the RASS-S toolbox, can be installed on the PC
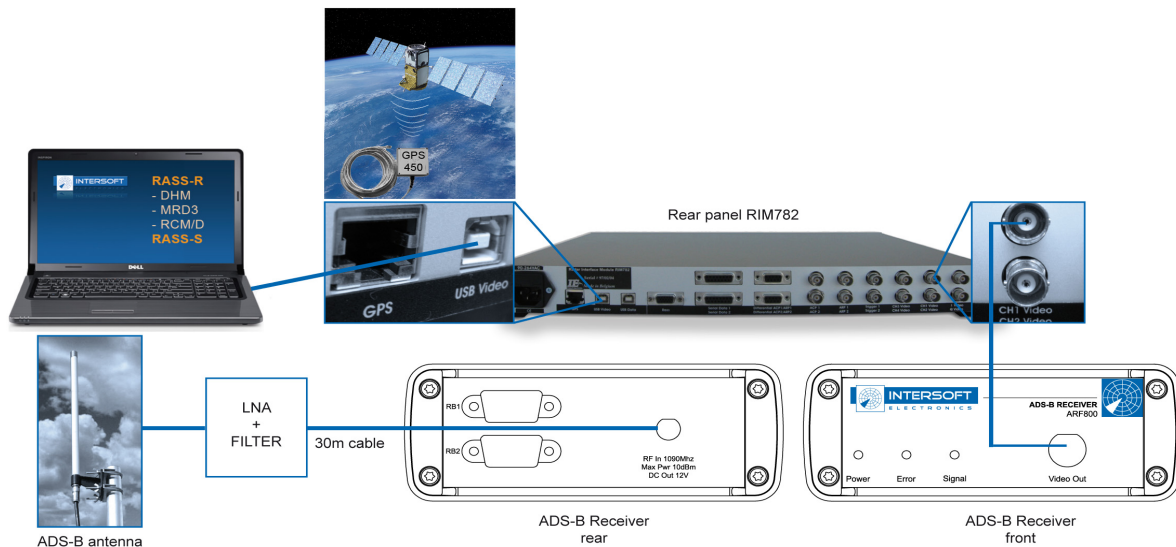

Figure 2.2: ARF800 (with GP-1090 Antenna) Implementation

For an example of obtained range, refer to paragraph 4.2 GP-1090 Performance.

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3   A UVR892 could be used as alternative.

2.3. Configuration of the Data Handling Manager

2.3.1. Getting Started

First launch the RASS-R toolbox. The RASS-R Toolbox window will open (refer Figure 2.3).

Figure 2.3: RASS-R Toolbox

From the RASS-R Toolbox, launch the Data Handling Module. The DHM Configuration Manager window will open (refer Figure 2.4).
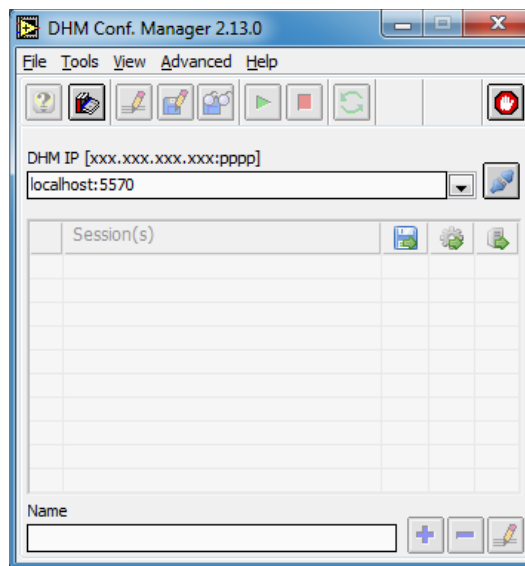

Figure 2.4: DHM Configuration Manager

At this stage, connect to the localhost DHM Background server, by clicking the "Connect" button ⬚ .

Before continuing, a DHM session needs to be created. To create a session, the following step need to be followed:

- Enter your session name in the "Name" field (for this example, the "ADS-B INTERSOFT" is used) and then click the "Create Session" button ⬚ .
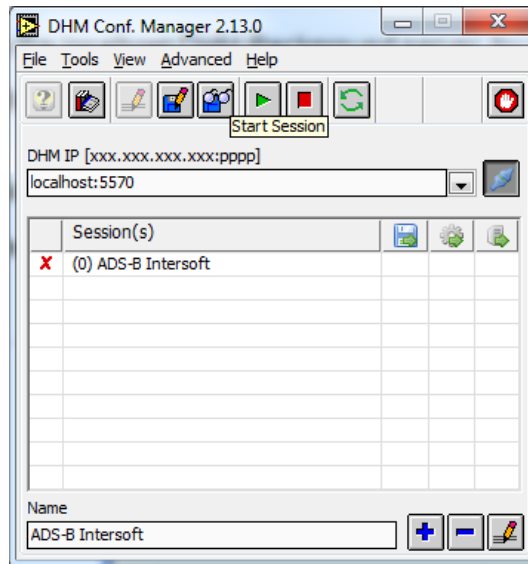
Figure 2.5: DHM Configuration Manager

Your session has been created as shown in Figure 2.5. To edit your session, select your session as shown in Figure 2.5 and click the "Open Session Editor" Button ⬚.

2.3.2.   Configuration of the "ADS-B INTERSOFT" Session

When the DHM Session Editor window is open, the *ADS-BDecoder* modules is the first module to be added for this setup. This module can be located under the "Proprietary Input" list, as part of the "RIM 782[4]" submenu and is called the "*V ADS-BDecoder[43]*". Double click on the menu to add the module as shown in Figure 2.6.
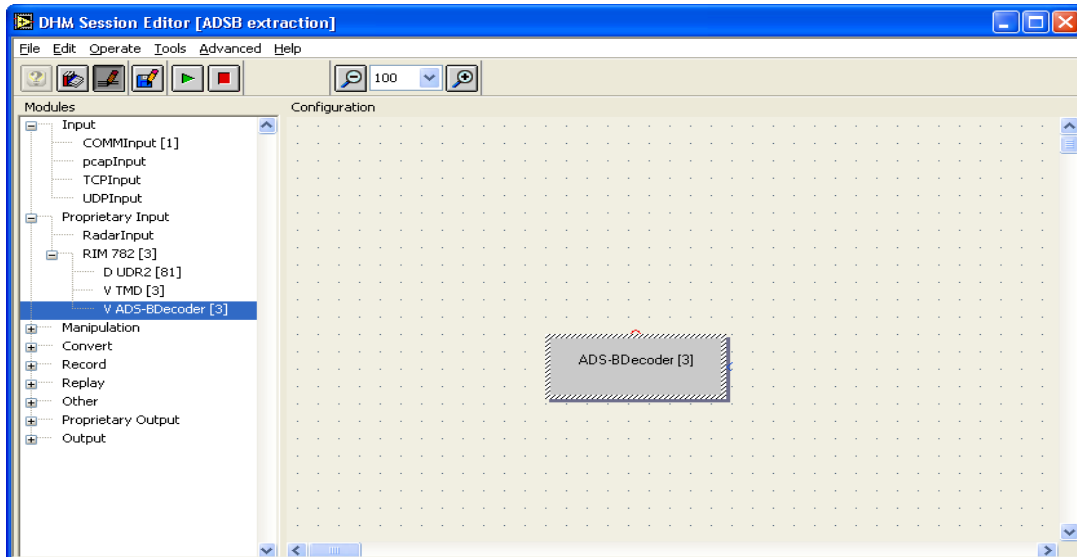

Figure 2.6: ADS-B extraction Session

To define the parameters for the *ADS-BDecoder* module, refer to the DHM User Manual.

After entering the parameters, the ADS-B Decoder module sends the extracted pulses as a bitstream to the ADS-B module. This module will code the individual bits into meaningful data items as described in ASTERIX CAT021. This part of the session is shown in Figure 2.7 and the ADS-B module can be located under the "Manipulation" list.
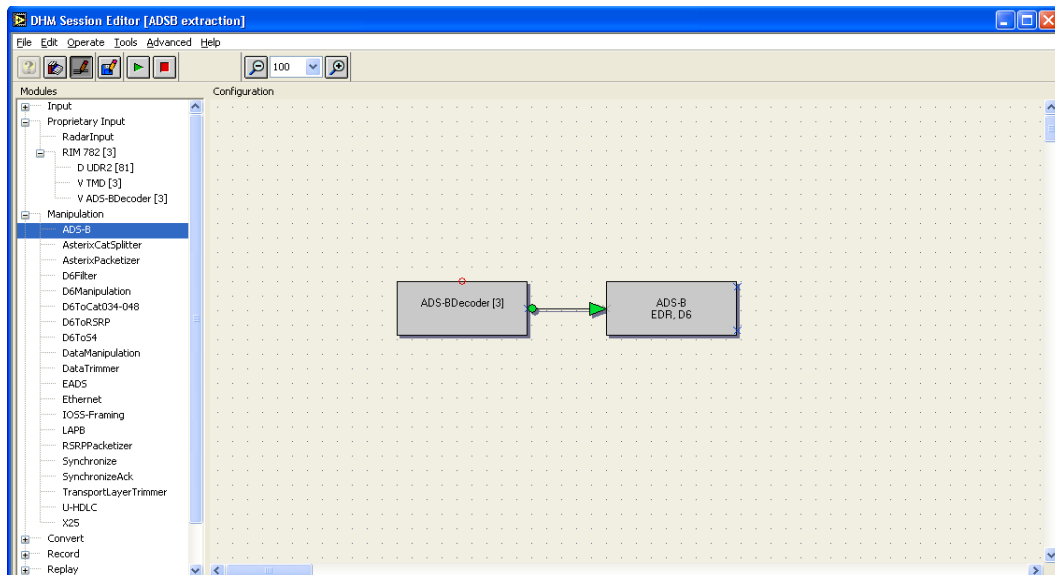

Figure 2.7: ADS-B extraction Session – ADS-B Decoder

To define the parameter for the *ADS-B* module, refer to the DHM User Manual.

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4   A UVR892 could be used as alternative.

The remaining modules to be included within the session will depend on the Users requirements. Figure 2.8 shows three possible implementation examples, they are detailed as follows:

1) The *ADS-B* decoder module can be setup to **output EDR format**. This EDR format contains ASTERIX CAT021. To convert the ASTERIX CAT021 reformated data again, an *AsterixCat021Convert* module is required and can be located under the "Convert" list. Double click on the menu to select the module. To define the parameters for the *AsterixCat021Convert* module, refer to the DHM User Manual. **To display this data on a MRD3**, a *RadarOutput* module is required and can be located under the "Proprietary Output" list. Double click on the menu to select the module. To define the parameters for the *RadarOutput* module, refer to the DHM User Manual.

2) The *ADS-B* module can be setup to **output D6 format**. D6 format is the internal data format used by RASS-R to transport any plot related data (such as target range, azimuth, XY position, longitude, latitude, A-code, S-address, etc) to a client, such as **a MRD3**.
To display the data on a MRD3, a *RadarOutput* module is required and can be located under the "Proprietary Output" list. Double click on the menu to select the module. To define the parameters for the *RadarOutput* module, refer to the DHM User Manual. With this configuration, the MRD3 will not provide any ASTERIX CAT021 data in the display info window.

3) To be able to **analyse** the ADS-B data via tools like for example the **Radar Comparator Mono/Dual** or the RASS-S **Inventory tool**, an S4 file (or D6, see remark below) is required to be recorded. To perform this, the D6 output of the *ADS-B* module must first be converted to S4 format. A *D6ToS4* module is required to perform this convert and can be located under the "Manipulation" list. Double click on the menu to select the module. To define the parameters for the *D6ToS4* module, refer to the DHM User Manual. This S4 output can then be recorded. A *S4Recorder* module is required to perform this recording and can be located under the "Record" list. Double click on the menu to select the module. To define the parameters for the *S4Recorder* module, refer to the DHM User Manual.

For analysis with TRACKAN, it is mandatory to record the D6 data directly from the ADS-B module.
Remark: Radar Comparator, can only input S4 data.

Once your session has been defined, click the "Play" Button ▶ to play your session. The result is shown in Figure 2.8.
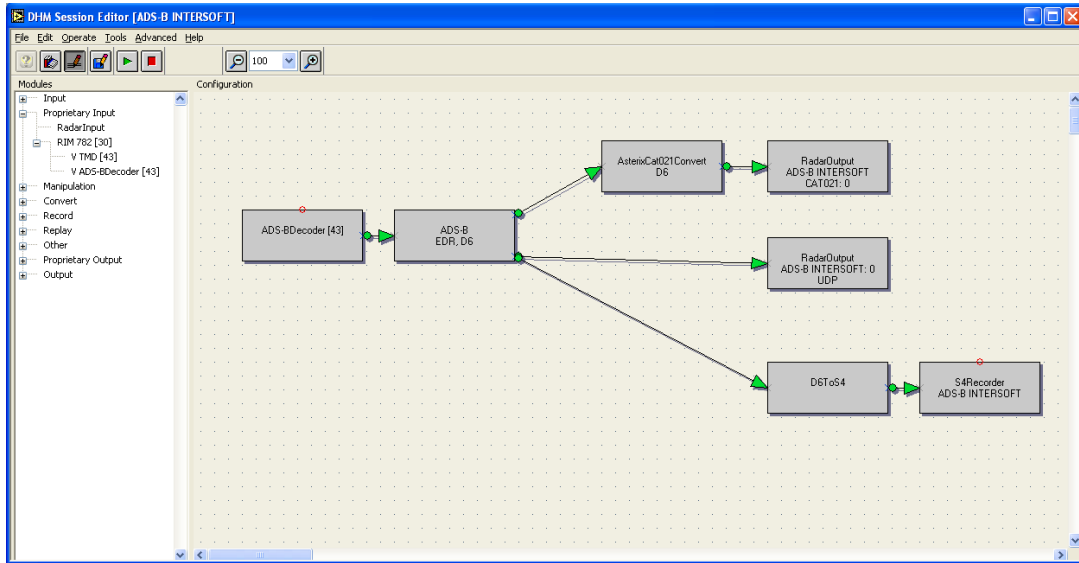
Figure 2.8: ADS-B Session – Final Example

Finally, the user can inspect the running session:

Figure 2.9: Inspect the running session

2.4. Examples of extracted data in MRD3

Refer to the MRD3 user manual for further information on setting up the MRD3. Figure 2.11 Shows the results of extracted ADS-B data as derived from the above mentioned methods. A GP-1090 antenna is located at 10m height, on top of our factory in Belgium. The obtained range, as you can see in Figure 2.11, is almost 180NM.

The figure below shows the Display Info dialog of a selected target in the MRD3, **on the condition that a AsterixCat021Convert** is used (as explained in example 2 above).

```
Display Info (ADSB_IE)

 Text  ▾        1 target(s)           A:----  TRN:----  S:4CA1F4  ▾
-----------------------------------------------------
 Rec. Time & Date:  08:56:07.015 15/09/10
               Cat021, Length = 0044
-----------------------------------------------------
(010)Data Source Identifier
     SAC  = 0x000 , SIC = 000
(040)Target Report Descriptor
     |DCR|GBS|SIM|TST|RAB|SAA|SPI|
     | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
     |ATP|ARC|
     | 1 | 1 |
(030)Time of Day (UTC)
     Time = 08:58:57.2969
(130)Position in WGS-84 Coordinates
     LATITUDE (WGS-84)  = 53.327442 (deg)
     LONGITUDE (WGS-84) = 6.661105 (deg)
(080)Aircraft address
     4CA1F4
(140)Geometric Altitude
     Height = 37962.50 (ft)
(090)Figure of Merrit
     |AC |MN |DC |...|PA |
     | 0 | 0 | 0 |...| 6 |
(210)Link Technology Indicator
```
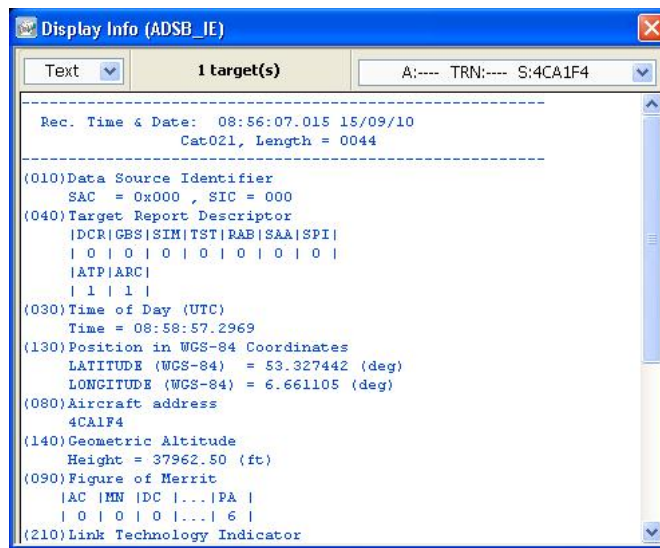
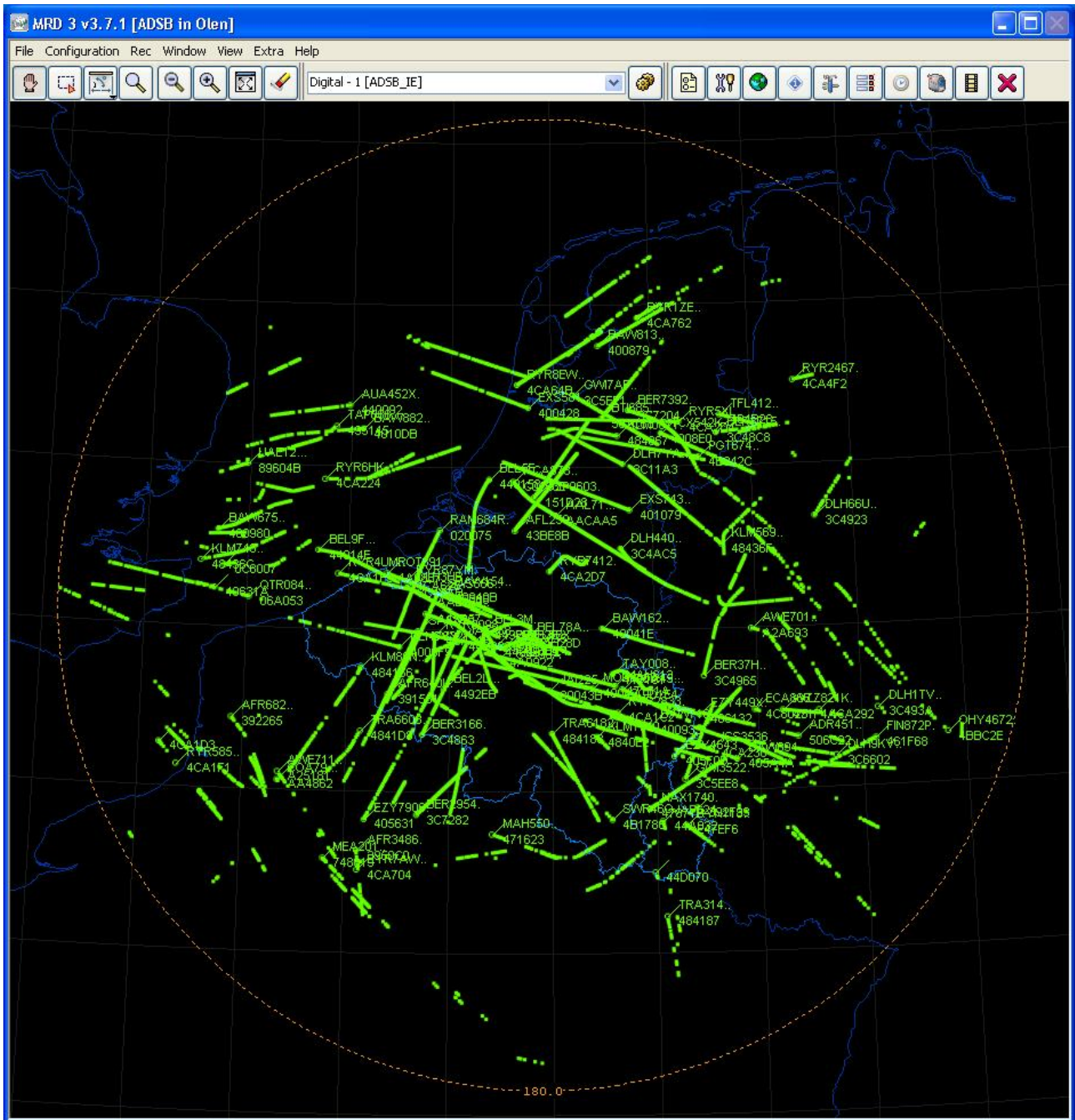*Figure 2.10: ASTERIX CAT021 content of a selected target*

Figure 2.11: ADS-B result in MRD3
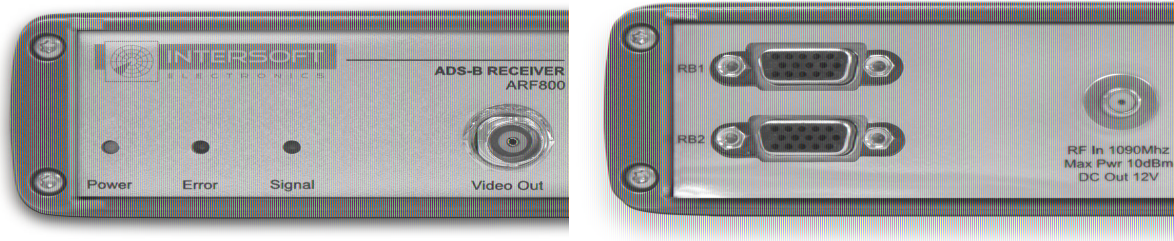
3. ARF800

3.1. Specifications

Figure 3.1: ARF800 front and rear panel

The ARF800 specifications are defined in the table below:

Table 1: ARF800 Specifications

Parameter	Value
Maximum input power (non damaging)	10dBm
Operating Frequency	1090MHz
Bandwidth	10MHz
Dynamic Range	60dB
Video Output Voltage	0 to +2V
Operating Temperature	-40°C to +60°C
Power Consumption	10W
DC-injector on coaxial cable to power LNA&Filter module	12V DC

3.2. Connections

The ARF800 has four external connectors, as defined below:
1. RF in 1090MHz
    a) SMA Female connector
    b) Connect to the LNA&Filter module

2. Video Out
    a) BNC Female connector
    b) Connect to RIM782

3. Power In (RB1)
    a) DB15 Female connector
    b) Connect to 15Vdc power supply

4. Power Out (RB2)
    a) DB15 Female connector
    b) Connect to other RASS equipment which requires power

3.3. Status Indicators

The ARF800 is fitted with three status indicators. These provide the following information:

- Power (**blue**) – this indicates the presence of power to the ARF800 receiver.

- Error (**red**) – this is a warning indicating that there is a shortcut on the 12V DC injected voltage to the LNA&Filter module, or that the LNA&Filter module is not connect at all (based on current measurement).

- Signal (**green**) – this indicates the detection of signal.

3.4. ARF 800 Verification

The ARF800 is a portable device that is specially designed for the ADS-B 1090ES application. The ARF800 is required to convert the RF signals available at the antenna output into a video base band signal, more convenient for further processing. The dynamic range of the RX (noise floor to saturation level) can be measured directly by using the Radar Field Analyser (RFA 641) and the RASS-S software. The dynamic range has been adapted to suit the typical gain and expected power levels for ADS-B squitters in the range of 1 to 200NM from the antenna.

The calibration routine will use the RFA to send RF pulses, with increasing amplitudes, into the ARF800 under test. The video output of these receivers is digitized by the RFA and used to build the calibration table. The RX calibration result consists of a receiver output voltage versus RF input power table and can be seen in Figure 3.2. The ARF800 has a dynamic range of 60dB.

For more information about the calibration of a receiver, please turn to the online user manual of the RASS-S software.
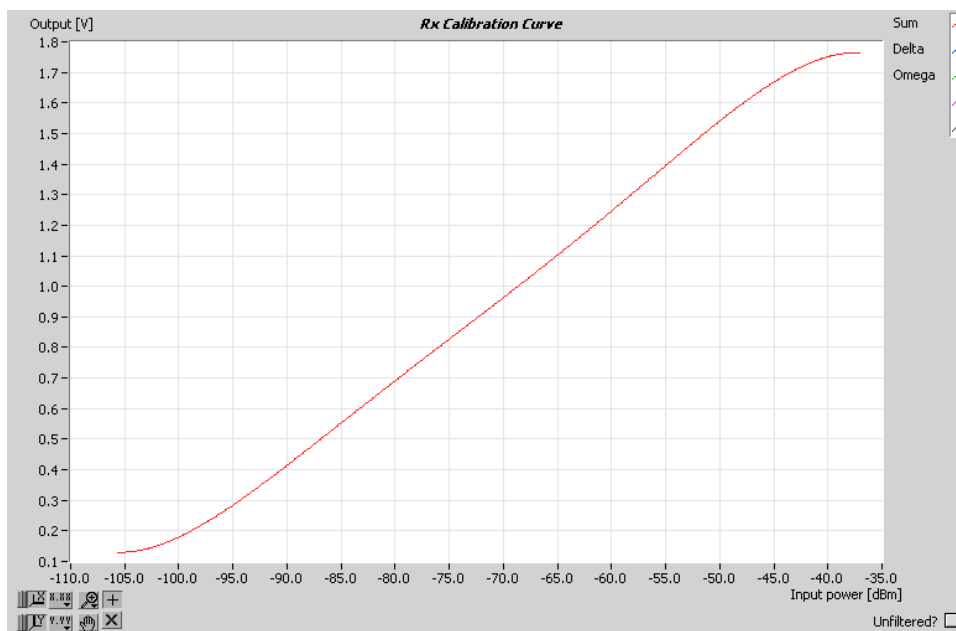

Figure 3.2: ARF800 Calibration Curve

The same RFA setup is used to measure the bandwidth of the receiver under test. Figure 3.3 shows the results with a centre frequency of 1090MHz and the bandwidth of 10MHz.
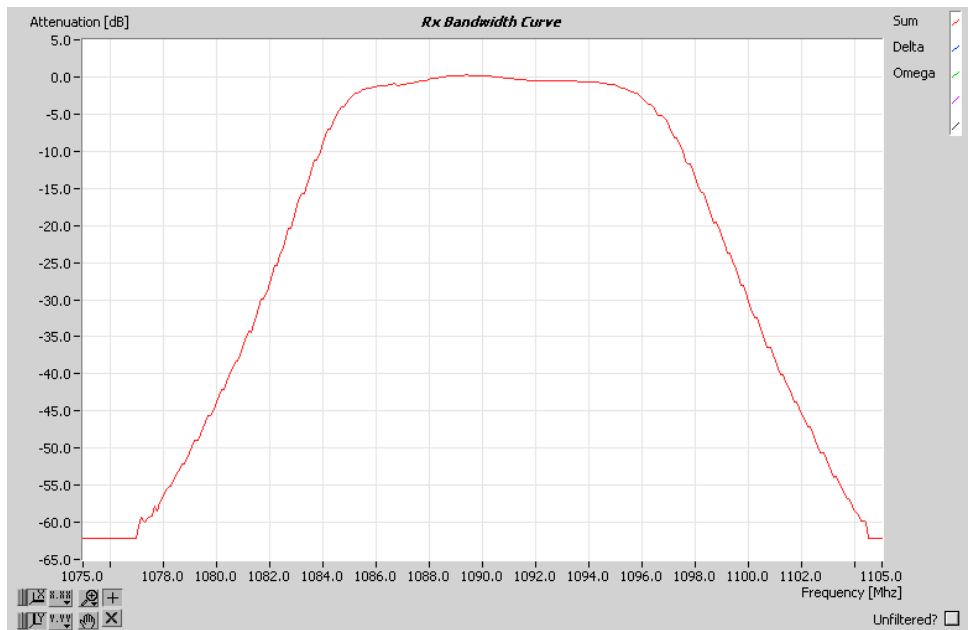
Figure 3.3: ARF800 Bandwidth Curve

For more information about the bandwidth of a receiver, please turn to the online user manual of the RASS-S software.

4. GP-1090 ANTENNA (WITH PRE-AMPLIFIER&FILTER MODULE)

Figure 4.1: GP-1090 Antenna

4.1. Specifications

The GP-1090 Antenna specifications are defined in the table below:

Table 2: GP-1090 Specifications

Parameter	Value
Bandwidth	1070 to 1110MHz
Gain	5dB ±0.5dB
Length	530mm including mast clamp

The AS-1090 Low Noise Pre-Amplifier&Filter module specifications are defined in the table below:

Table 3: AS-1090 Specifications

Parameter	Value
Operating Frequency (filtered)	1090MHz
Bandwidth (3dB)	13MHz
Gain	9dB
Noise Figure	0.9dB
Supply Voltage	+12Vdc over Coax
Power Consumption	80mA
Maximum Input Level	+3dB

4.2. GP-1090 Performance

In LabVIEW, it is possible to generate the Vertical Polar Diagram or VPD from the GP-1090 antenna, in combination with the ARF800 and the RIM782. Below is a theoretical horizontal polar diagram of an omni-directional dipole antenna.
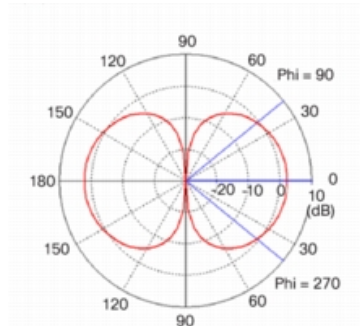

Figure 4.2: Theoretical horizontal polar diagram

Based on 700 000 ADS-B plots containing power in [dBm], together with a correct calibration file of both RIM782 and ARF800, the following VPD is obtained.
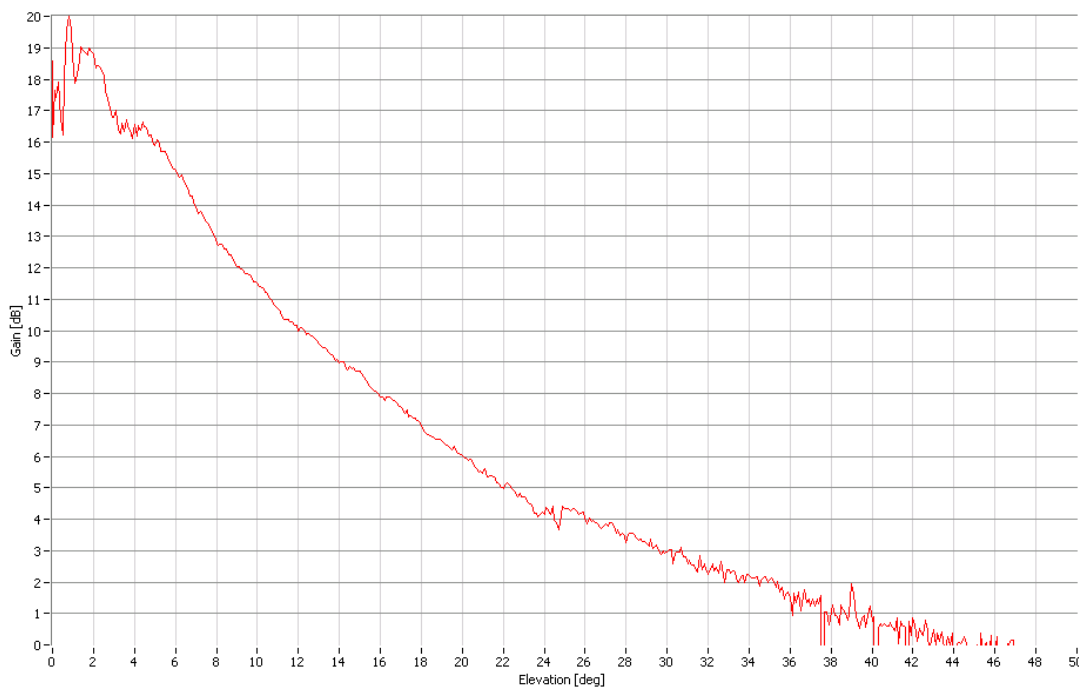

Figure 4.3: GP-1090 (withARF800) VPD Coverage Diagram

As one can see, there is high gain at low elevation, where multipath reception and/or local screening creates variations below 4 degrees elevation. The cone of silence is 46 degrees in elevation.

5.   ANNEXES

Annex 1: Configuration List: ARF800

Check	Qty	Description/Item
		ADS-B Receiver - P800
O	1	ADS-B Receiver Front End - ARF800
O	1	Power supply: 15V-6A DB15HD
O	1	Power cable
		ARF800 Accessories
O	1	Low Noise Pre-Amplifier & Filter module
O	1	GP-1090 Antenna
O	1	30m SMA(m) to SMA(m) low loss cable
O	1	0.45m N(m) to N(m) cable
O	1	N(m) to SMA(f) adapter
		Transport case
O	1	Transport case 430W x 551H x 200D (mm)
O	1	Padlock