Radar Field Analyser - RFA641

User Manual

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CONVENTIONS USED

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 t he possibility of damage to you or your equipment.

Glossary of Terms

ACP	Azimuth Change Pulse
ADS-B	Automatic Dependent Surveillance, Broadcast
ARP	Azimuth Reference Pulse
ATC	Air Traffic Control
CW	Continuous wave
dB	Decibel
DME	Distance Measuring Equipment
Downlink	The signal path from aircraft to ground
DSTC	Digital Sensitivity Time Control
FRUIT	False Replies Unsynchronized In Time, unwanted SSR replies received by an interrogator which have been triggered by other interrogators
HPD	Horizontal Polar Diagram
IE	Intersoft Electronics
IF	Intermediate Frequency
LVA	Large Vertical Aperture (antenna)
Monopulse	Radar-receiving processing technique used to provide a precise bearing measurement
MSSR	Monopulse Secondary Surveillance Radar
NM	Nautical Mile, unit of distance
OTD	Out of Tolerance Data
PPI	Plan Position Indicator
PRF	Pulse Repetition Frequency
PSR	Primary Surveillance Radar
Radar	Radio Detection And Ranging
Radome	Radio-transparent window used to protect an antenna principally against the effects of weather
RASS-S	Radar Analysis Support Systems – Site measurements
RCS	Radar Cross Section
RF	Radio Frequency
RX	Receiver
SLS	Side Lobe Suppression, a technique to avoid eliciting transponder replies in response to interrogations transmitted via antenna sidelobes
SLB	Side Lobe Blanking
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
TCAS	Traffic Collision Avoidance System
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
VPD	Vertical Polar Diagram
YIG filter	Yttrium-Iron-Garnet filter

1. Technical Manual RFA641

1.1. General Introduction

The RFA641 is intended for on-site performance checks of (M)SSR ATC radars and primary radars in L and S band. For this purpose, the radar does not have to be taken out of its operational mode. The transmission pattern (power) of the LVA or horn-feed antennas is continuously measured and plotted versus azimuth or time. All antenna measurements are intended to be performed during a regular check-up or maintenance of the radar, often because the antenna is damaged or degraded due to the harsh environment.

Additionally to its primary usage as antenna evaluation tool, the RFA641 can also perform the following tests:

- Uplink (Transmission) antenna diagram: Pulse power = f(Azimuth);
- Generation of test pulses for Downlink (Reception) Antenna Diagram: Rx Pulse power = f(Azimuth);
- Receiver sensitivity sweeps: Receiver Output Voltage = f(Power);
- Receiver bandwidth sweeps: Pow = f(Freq.) and spurious responses;
- STC sweeps: Power = f(delay after trigger);
- Sectorial STC: Power = f(delay after trigger, Azimuth);
- DSTC and sectorial DSTC: same as above for Quantised Video Receivers;
- Transmitter power, spectrum, pulse shape recording, timing, mode and stagger verification;
- FRUIT generation for environment simulation;
- Mode-S interrogation generator for transponder verification;
- Transponder quality verification;
- Target injection for non-pulse-compression primary radars.

The Uplink (Tx) antenna diagram can be measured by using the frequency-controlled receiver input on the RFA641. Using VCO's and filtering techniques, a frequency range from 900 MHz up to 3.0 or 3.5GHz (optional) is covered both in the reception and transmission path. This allows the use of the same instrument on a wide variety of radars. The antenna diagram can be extracted for different radars at any time (e.g. multiple SSRs on one site) by means of the analysis software.

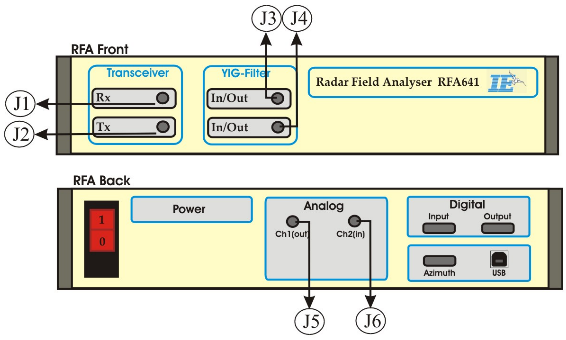
The Downlink (Rx) antenna diagram can be measured with the Radar Interface Module (RIM782) connected to the receiver of the radar and the RFA641 set-up in the field, producing test pulses at a selected frequency. This recording is slaved to the antenna rotation.

1.2. Key Features

- With its measurement frequency tuneable in the 900...3000MHz frequency range, the RFA641 supports both (M)SSR and PSR systems.
- RF receiver for reception of RF interrogations with the purpose to measure the antenna diagram in transmission (uplink).
- RF Tx module for generation of test pulses for reception (downlink) pattern measurements and for receiver measurements (alignment, sensitivity, bandwidth, STC...).
- Data acquisition engine with DSP processing and USB2 interface for direct spooling of the captured pulse data to disk for later analysis. This enables a ‘one button’ semi-automated measurement approach.
- Simple and easy set-up: connect the Radar Field Analyser to the measurement antenna, start up the host computer, take power from a car battery or a UPS and start measuring.
- Highly portable and easily carried by one person.
- Frequency extension available as option.

1.3. Hardware Description

1.3.1. Block Diagram



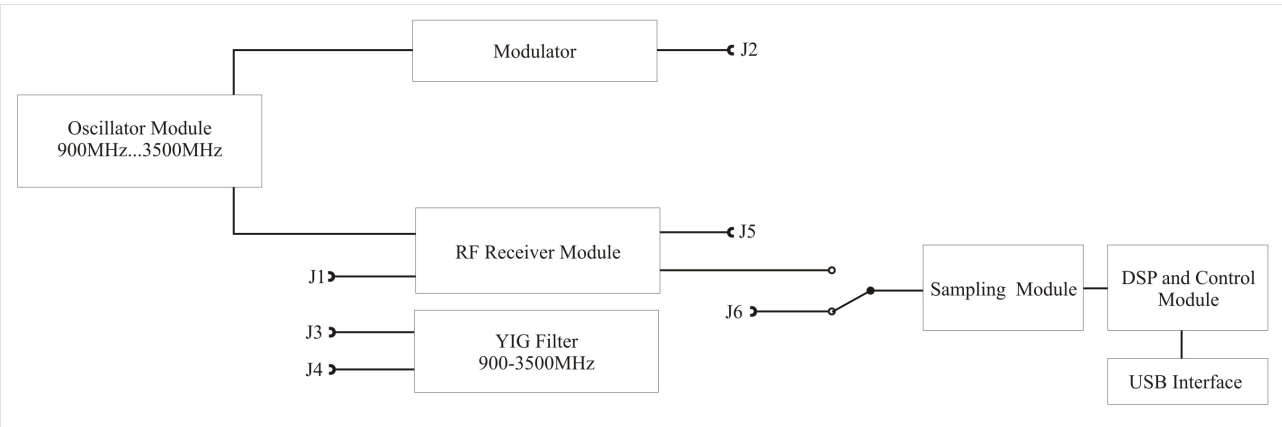


Figure 1: Block Diagram

1.3.2. Connectors and Specifications

Table 1: Interfaces

Name	Specification	Connector Type
Analog	Ch1(out): video output from receiver log amplifier; Ch2(in): video input to acquisition system	2x BNC
Azimuth	TTL input of ACP, ARP, trigger	DB15HD female
Rf	Rx, Tx; 50Ohm	2x BNC
USB	USB2, for remote programming and high speed data throughput, 480Mbit/s transfer rate	USB

Table 2: Transmitter

Name	**Specification**
Frequency Range	900MHz – 3.0GHz Oscillator Synthesiser stabilized; accuracy 100KHz
Optional:	Frequency range up to 3.5GHz
Max. Tx Power At Tx output port	900MHz – 3.0GHz: > 10dBm and < 18dBm
Optional:	3GHz – 3.5GHz: >5dBm and < 15dBm
Amplitude Pulse	900 … 1500MHz: 60dB
Modulation	1500MHz: 50dB
On/off Dynamic Range	> 70dB
Bi phase modulation	0 / 180deg 5deg
RFA Option A: Fruit Reply Code	SSR pulse generator in compliance with Annex 10
Generator	Pulse duration Mode A/C 450ns 100ns Pulse duration Mode-S 500ns 50ns Pulse rise time < 100ns Pulse decay time < 200ns

Table 3: Receiver

Name	**Specification**
Frequency Range	900MHz – 3.0GHz
Optional:	Frequency range up to 3.5GHz
Sensitivity	-75dBm

Table 4: YIG Preselector Filter

Name	**Specification**
Centre Frequency	900MHz – 3.0GHz
Optional:	Frequency range up to 3.5GHz
3 dB Bandwidth	25MHz 2MHz

2. Self-test/Calibration

2.1. Theory

The RFA Self-test tests the most important components and building blocks of the RFA641 and performs a calibration of the transmitter at the selected frequency. It is advised to perform a Self-test/Calibration before any measurements are taken using the RFA641 transmitter.

The two methods for the calibration of the RFA internal transmitter are:

1. **Internal:** The RFA's internal linear receiver is used to measure the relative power level for the modulators. The maximum power is derived from the calibration file.
2. **External:** The log RF module is used to perform absolute power level measurements and is used to build the modulator table.

2.2. Software

2.2.1. Getting Started

The Self-test and Calibration software can be loaded from the RASS-S Toolbox using the ***Uplink***  button.

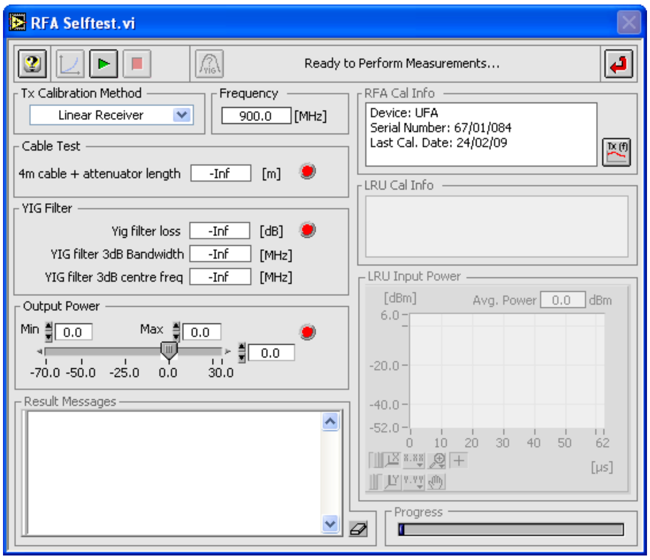


Figure 2: RFA Selftest software

The software will guide you through the necessary set-up and actions to be taken.

When the RFA641 is found, the ***RFA Cal Info*** field will display the device name, serial number and last calibration date as retrieved from the RFAs internal EPROM.

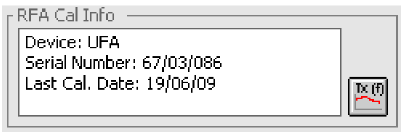


Figure 3: Device information

Choose the calibration method that you want to use by selecting ***Linear Receiver (Internal)*** or ***Log RF Unit (External)*** and select the SSR Downlink frequency (1090 MHz) or the correct PSR frequency.

Figure 4: Selecting the calibration method

When the internal Tx Calibration method is used, the linear receiver will be used to perform VNA measurements, this method is explained in section 2.2.2. . When the external Tx Calibration method is used, the linear receiver will be used to perform the cable measurements and the log RF unit will be used to perform the power measurements, this method is explained in section 2.2.3. .

In case you want to abort the test sequence, you can always hit the ***Abort*** button. It allows ending the sequence at the end of the test that is being executed at the moment you pressed the button.

The two methods implemented are discussed in the next two paragraphs.

2.2.2. Internal Tx Calibration Method

When the internal Tx Calibration method is used, the linear receiver will be used to perform VNA measurements.

1. Click the ***Start*** button to start the test sequence.

Note: The program will guide you through the successive steps and required connections to perform the selftest.

2. First the noise level of the system is measured versus frequency. For this purpose the transmitter is set to maximum power. While input and output are terminated, a frequency sweep over the full RFA641 frequency range is performed to measure the systems noise level.

3. Then the Cable Test is performed. The internal electrical length must be measured first. The program will ask you to connect the 0.5m cable between the attenuators at the Tx and Rx ports of the RFA641.

   Once the connection is made, click ***OK*** to continue the measurement. The electrical length is measured by performing a frequency sweep. The slope of the phase change versus frequency is determined. It is directly corresponding to the length of the cable.

   Once the 0.5m cable length is determined, the program will ask you to replace the 0.5m cable by the 4m antenna cable. Again the VNA measurement is performed to measure the cable length. By subtracting the internal electrical length, the cable length can be determined. The result is displayed in the ***Cable Test*** section.

   The error LED will be red in case the cable length reported is less than 3.5m or more than 4.5m, and an error message is generated, e.g.: “Cable length = 4.7m ... outside 3.5m!!! ... 4.5m!!!”.

   After the 4m cable sweep, the reference level for the selected frequency is measured. This is done using a VNA sweep from 50 MHz below to 50 MHz above the selected selftest frequency. In this step the VNA power is compared with a reference derived from file. The reference power is subtracted from the measured value; this results in the power error vs. frequency being calculated.

4. Now the RFA Selftest program will ask you to insert the YIG filter in the loop. The YIG filters insertion loss will be measured. A frequency sweep will be performed as well. This allows the selftest program

to calculate the 3dB bandwidth and 3dB centre frequency. The results are shown in the ***YIG Filter*** section. An error is indicated in case the YIG filter loss (insertion loss) is higher than 8 dB.

5. The ***Output Power*** slider control is now enabled. The Selftest program sets the modulator voltage and performs a frequency sweep in order to determine the output power (dB) for a number of modulator voltages. The max. output power is read from file and is assumed to be constant over the calibration period.

   The measurement is performed in two steps: The first step decreases the output power starting from max. power until the Rx noise level is hit. Before the second step the program will ask you to remove the 20dB attenuator at the Tx connector. Again the modulator voltage is swept from (max. power -20dB) to min. while the corresponding power level is measured. The resulting maximum and minimum Tx power are indicated in the ***Output Power*** field. The slider allows you to set the output power (i.e. in case you want to check the power level with a spectrum analyser). An error is indicated in case the max. output power is below the specified minimum and in case the dynamic range is not sufficient.

   Even when the max. power is low, the user can use the RFA641 with its limited power. When the modulator sweep is done, the selftest sequence is ended.

6. It is possible to view the YIG filter attenuation vs. frequency by clicking the ***View Filter***  button.

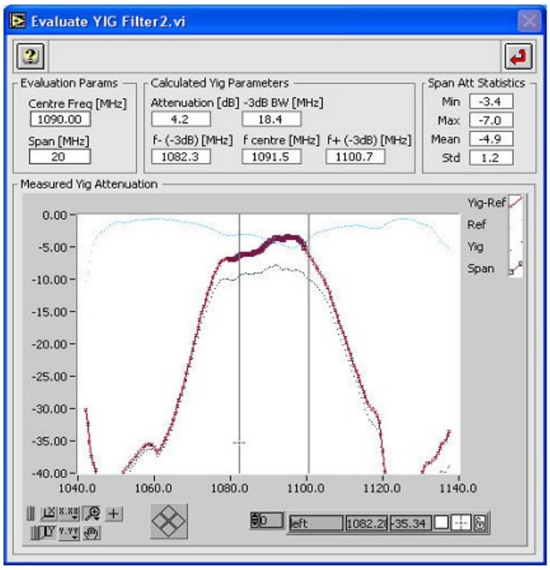


Figure 5: Measured YIG filter attenuation

The ***Evaluate YIG Filter2.vi*** window will pop up, showing the attenuation vs. frequency of the YIG filter, measured using the RFA VNA function. From the measurement data the attenuation, 3dB bandwidth, and 3dB centre frequency are calculated. The ***Span*** parameter is used to determine the frequency span used to calculate the attenuation statistics.

Click the ***Return***  button to return to the Selftest program.

7. Click the ***Return***  button to stop the Selftest function or to return to the calling function.

When the RFA Self-Test/Calibration procedure is performed without problems, you can continue with the measurements, knowing the RFA is performing as expected.

2.2.3. External Tx Calibration Method

When you select the Log RF Unit, immediately the program will ask you to select the LRU499 serial number.

Please make sure to enter the correct serial number, otherwise the power measurements will be incorrect, and as a result the RFA Transmitter calibration will be invalid.

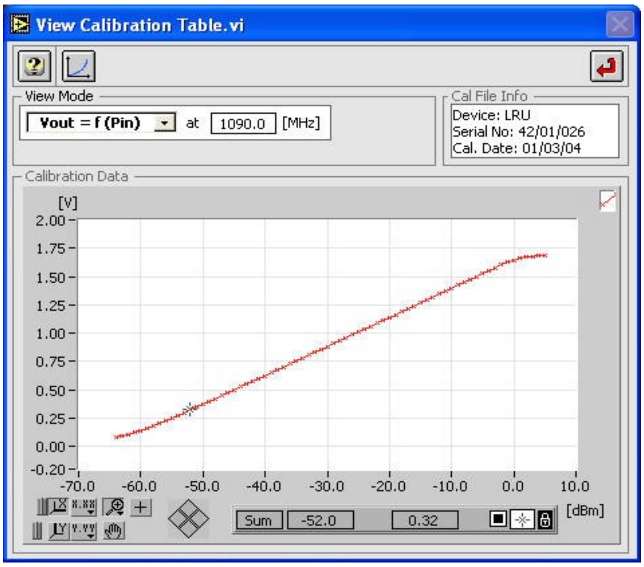


Figure 6: LRU499 Calibration Table

Click ***OK*** to select the LRU499. The dialog will close and the ***View Calibration Table.vi*** will appear. It allows browsing the loaded LRU499 cal table.

Click ***Return***  to return to the RFA Selftest.

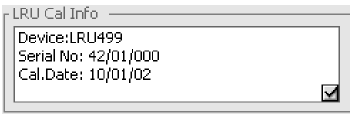
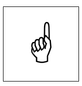


Figure 7: LRU499 Device Information

The cal info of the selected LRU499 is indicated on the RFA Selftest front panel.

When the external Tx Calibration method is used, the linear receiver will be used to perform the cable measurements and the log RF unit will be used to perform the power measurements.

1. Click the ***Start***  button to start the test sequence.



Note: The program will guide you through the successive steps and required connections to perform the selftest.

2. In this section we will omit the explanation of the cable test since the related issues are already explained in section 2.2.2. above. The program will guide you through the successive steps and required connections to perform the selftest. The program first asks you to properly connect the log RF Unit.
   The video connections required at the back of the RFA641 are simplified in the dialog box drawing. The video connector (green breakout box) needs to be connected to the digital input connector. It

provides power to the LRU499. The BNC connector on the breakout box contains the modules video output and needs to be connected to the analogue video input of the RFA641.
First a limited modulator sweep is performed to allow the program to set the power level to +10dBm.

The log RF unit allows viewing the transmitted RF pulse and the received power level at the LRU499 RF input (using the LRU499 calibration file). The pulse shape is displayed in the ***LRU Input Power*** graph, together with its average power level. This way, the Tx modulator calibration process can be viewed.

3. Insert the YIG filter in the RF connections, as explained in the related dialog box that pops up.

4. Once the connections are made, click the ***OK*** button. Now the YIG insertion loss is measured and the result is indicated in the ***YIG Filter*** section. An error is indicated in case the loss is higher than 8dB.

5. Then the YIG filter attenuation versus frequency is measured. This is done in a frequency span from 50 MHz below to 50 MHz above the selected selftest frequency.

   During the frequency sweep, a progress bar indicates the progress and also the pulse amplitude can be viewed in the ***LRU Input Power*** graph.

   Once the YIG Filter sweep is completed, the program continues with the Tx modulator calibration.

   The frequency is reset to the selected selftest frequency and the modulator voltage is swept from maximum to minimum. The LRU499 measures the RF power generated and this way the output power is calibrated.

   The measurement is performed in two steps:

   - First the power is swept from maximum to minimum until the LRU499 noise level is hit.
   - Then the program will ask you to remove the 20dB attenuator at the Tx connector. Again the modulator voltage is swept from max. to min. while the corresponding power level is measured.

   The resulting maximum and minimum power are indicated in the ***Output Power*** section. The slider allows you to set the output power (i.e. in case you want to check the power level with a spectrum analyser). An error is indicated in case the max. output power is below the specified minimum and in case the dynamic range is not sufficient (<60 dB for the frequency range 800...1500 MHz, <50 dB for frequencies above 1500MHz). When the modulator sweep is done, the selftest sequence is ended.

3. When the selftest sequence has ended, it is possible to view the YIG filter attenuation vs. frequency by clicking the ***View Filter*** button as explained in section 2.2.2. above.

4. Click the ***Return*** button to stop the Selftest function or to return to the calling function.

When the RFA Self-Test/Calibration procedure is performed without problems, you can continue with the measurements, knowing the RFA641 is performing as expected.

2.3. Troubleshooting

In case the RFA641 cannot be found, an error message will appear: verify whether the Radar Field Analyser is powered up and properly connected.

3. Uplink

3.1. Theory

The Uplink measurement will provide you with horizontal polar diagrams of any (M)SSR/PSR antenna in its operational environment by recording the pulses of the radar. For this purpose the Radar Field Analyser is set-up in the field with no connection to the radar. An antenna will pick up the radar signal from the air (P1-P2-P3 1030MHz or PSR transmissions) and the Uplink software calculates the HPD antenna diagram from this data.

The pulses can be recorded in a condensed format (pulse mode) or in detail (scope mode). After the recording the HPD can be extracted from the data through fingerprinting (stagger).

When selecting a measurement position for the RFA641 setup, take into account the following guidelines:

- Make sure to have direct line of sight to the radar under test and place the RFA641 at a distance of min. 0.5km and max. 40km.
- Place the antenna at least 1.5m above ground level, preferably even higher. If the radar station remains visible, even when standing behind the antenna, a good measurement result may be expected.
- Choose the correct antenna polarization. All SSRs are vertically polarized. Primary radars can be vertical (most common), horizontal or circular.
- It is advisable to record the antenna signals in both polarization modes. That way, whatever the mode used, or expected, the data is never lost. At the same time the cross polarization is measured, including the effect of the environment. Usually the effect of a high cross polarization is caused by reflections. Therefore it can be used to determine bad positioning of the measuring antenna for reference measurements.
- Beware of nearby buildings or other structures reflecting large portions of the signal. These reflections may influence your measurement.
- The most frequent error is a measurement from a too low elevation angle. The HPD diagram is still correct but doesn't represent the view of the targets and antenna. If in doubt, use an inclinometer to find the elevation angle from the measurement position towards the radar under test.
- Depending on the distance of the RFA641 Uplink setup to the radar system, extra attenuation must be inserted at the Rx input of the RFA641. As a general rule it is best to start with 20dB (SSR) or 40dB attenuation (PSR) between the antenna cable and the YIG input.

3.2. Getting Started

The Uplink is loaded from the RASS-S Toolbox using the ***Uplink*** 

button.

Make the connections as shown in Annex 2: Uplink Connection Diagram.

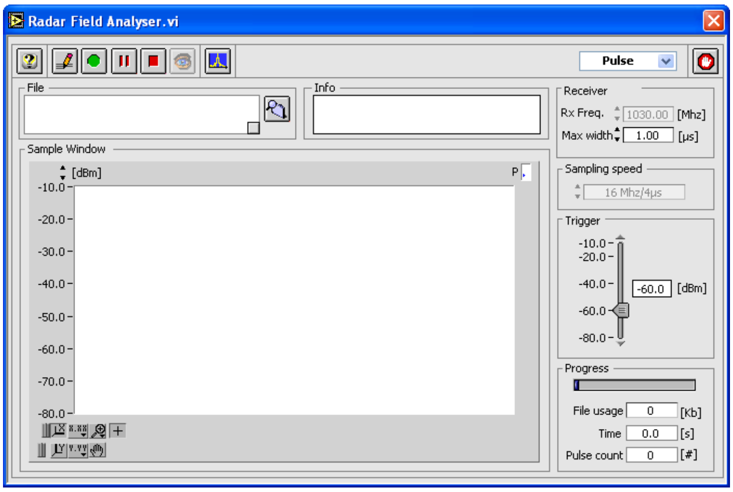


Figure 8: Uplink Software

3.3. Software

1. The RFA Recorder software contains four programs:

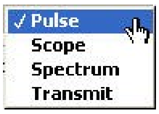


Figure 9: Measurement type selection

- ***Pulse program***: records pulses in a compact format (8 bytes/sample). The data recorded is minimized describing only the amplitude and timing of each pulse in 8 bytes. One should use this program for all Uplink HPD measurements.

- ***Scope program***: records detailed pulse images in 62 samples (128 bytes/pulse). The Scope program logs the complete pulse shape to disk since 128 bytes are used for each pulse. This program can be used to record pulses in special conditions, such as in extreme reflective environments or to completely view the pulses if no oscilloscope is available.

- ***Spectrum program***: scope recording with FFT converts the pulse images into pulse spectrum.

- ***Transmit program***: controls the transmission for the Downlink measurement. The Transmit program is used to transmit pulses or CW using the RFA's transmitter for Downlink purposes.

2. Before starting a recording, first select or create the destination folder by using the ***Find Folder***  button. When clicking this button, a folder dialog will appear asking you to select a folder to store the recordings. By default, the folder dialog will open with the RFA subdirectory of the MSSR or PSR subdirectory of the active campaign folder as the starting point.
In case you want to create a new folder: click the ***New*** button, enter a file name and click ***Create***. Click ***Select*** and the desired folder is selected or created. The ***File*** indicator of the Radar Field Analyser program will show the complete destination path for the pulse recordings, followed by "\none".

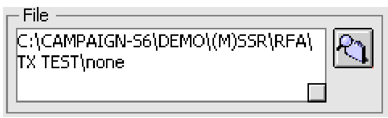


Figure 10: Recording path

3. The less frequently altered Uplink parameters (and in a later stage you will need also the Analysis parameters) can be changed in the preferences window that can be recalled by pressing the ***Parameters*** button. The most commonly adjusted parameters are also put on the RFA Recorder's front panel.

   Only the parameters for Uplink Recording are of importance at this stage. These parameter settings are saved with the recorded data. The range, increment and defaults of the following parameters are shown between square brackets: e.g. [900..3500 , 1 / 1030].

   - Rx Frequency (MHz): [900..3000/3500, 1 / 1030]: This parameter controls the frequency selection setting of the RFA receiver and of the YIG filter. It can be set between 900 and 3500 MHz in case the internal RF circuitry is used. In case the external video input is selected as input source these limits do not exist since the RFA driver will ignore this parameter.
   - Max Pulse width (µs): [1..64, 1 / 1]: This parameter controls the range of the sliding window used to determine the pulse amplitude. The parameter must be set slightly larger than the real pulse width of the recorded pulses. Use the Scope program to verify the pulse width.
   - Trigger level (dBm): [-5..-85, 0.1 / -60]: This level determines the trigger level above which pulses are recorded.

4. First switch to the Scope program using the Program selector as shown in figure 9,in order to measure the complete pulse shape instead of only the pulse amplitude.

   The curve will change appearance:

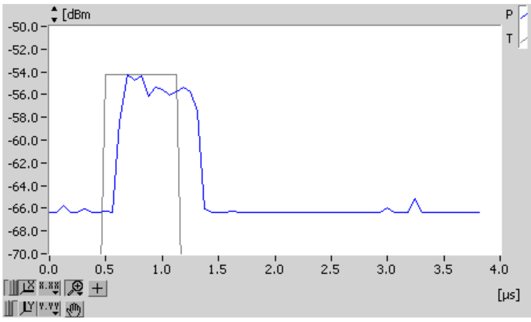


Figure 11: Uplink scope view

   The blue curve is the receiver video signal as it is sampled by the RFA641. The second (grey) curve shows the digital output of the threshold detector. This detector output indicates the pulses and pulse width detected. Using the trigger level slider, the trigger level for pulse detection can be set.

   Position the trigger level such that all pulses are detected properly, but no false triggers occur due to the noise. If the trigger level is too low; only noise will be sampled.

   The default sampling frequency of the scope window is 16 MHz, but if you want to monitor (or record) pulses with longer pulse duration (up to 1ms), you must lower the sampling frequency to 8 MHz or lower. The graph will then show a larger time window of the recorded pulse.

   Now switch back to the pulse program.

5. The last 1024 recorded pulses are now continuously shown (Rx video level output) on the main screen:

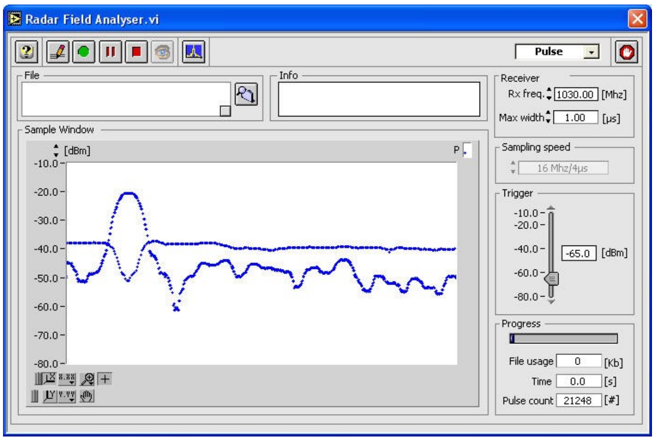


Figure 12: Uplink pulse program

Again, this window allows you to adjust the trigger level, as such that most pulses are detected properly and no noise is recorded.

6. Click the ***Record*** button to start the recording. A file dialog pops up, pointing to the selected destination. The file path indicator will always reflect the latest path used. New files are therefore always created in the last folder that was selected.

   File names for the RFA recordings can be assigned automatically and are put as default name in the file dialog box that is presented when the record button is pressed.

   The default file name is built as follows:

   - Folder name_yymmdd_hhmmss.pls for pulse recordings or
   - Folder name_yymmdd_hhmmss.scp for scope recordings

   Where Folder name consists of the first 14 characters of the selected folder to contain the files, yy for the year, mm for the month, dd for the day, hh for the hour, mm are the minutes and ss the seconds. Since the current time is used in the file name, each time you click the record button, a new file will be created with a different name.

   When you have selected the file name and recording directory, click the ***OK*** button of the file dialog. The recording then starts; the ***time*** indicator and ***Pulse Count*** indicator will start incrementing. While recording, the data graph is not updated. The ***Progress*** slider will slowly fill, until the file usage (given in kB) has reached the maximum size (parameters) or the ***Halt*** button is clicked.

Note: The check box in the File indicator in the Radar Field Analyser.vi allows to automatically assign the default file name.

Note: Several antenna scans are needed to extract a correct HPD. Therefore a proper recording will typically take from 30s to 60s depending on the antenna rotation speed.

In case your radar has a low PRF, it is advised to log more revolutions (i.e. 10 or more). This will allow you later on to interleave multiple HPDs during the extraction phase.

7. Once the recording has been made, the data can be viewed using the ***View*** button.

Clicking this button will evoke the ***View RFA pulses*** window, allowing you to view the recorded pulses and to extract the antenna diagram (this is explained later on).

3.3.1. The Frequency Sweep Function

The RFA Recorder has a frequency sweep mode. This allows you to see pulse power, PRF or pulse count versus frequency.

1. To load this function, click the ***Frequency Sweep***  button on the main RFA recorder screen. The Frequency Sweep window will pop up.

   The function can only be invoked when the RFA641 is set in ***Pulse*** mode.

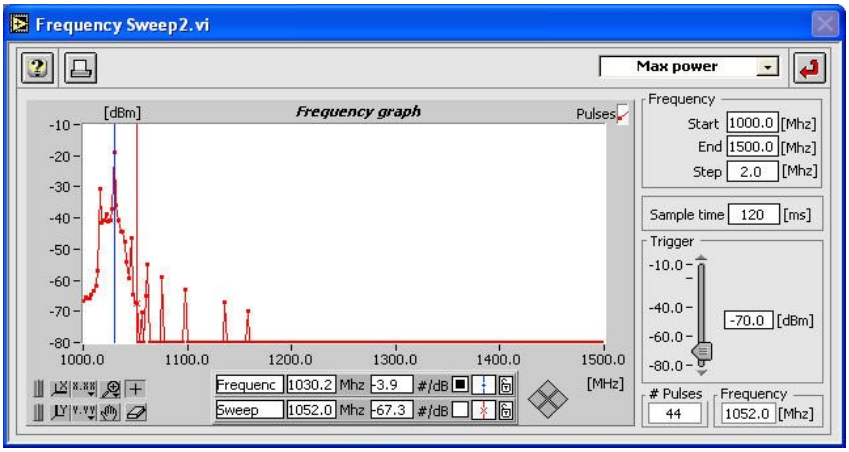


Figure 13: Frequency Sweep function

   The red cursor shows the instantaneous frequency of the RFA receiver.

   The blue cursor can be manually set to a peak in the frequency graph. This way the radar under test can be selected by frequency.

2. Now enter the following parameters:
   - Start frequency: Determines the start frequency for the sweep.
   - End frequency: Determines the end frequency for the sweep.
   - Frequency step: Determines the frequency step for the sweep.
   - Sampling time: Determines how long the frequency remains fixed.

   The ***# pulses*** indicator shows the instantaneous number of received pulses, while the “***Frequency*** indicator shows the instantaneous frequency.

   Select the mode of operation using the Y-scale switch:

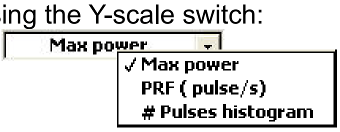


Figure 14: Frequency Sweep Y-Axis selection

   - Max Power mode: maximum power (peak power) received on the scanned frequencies.
   - PRF (pulses/s) mode: received pulses per second on the scanned frequencies.
   - # Pulses histogram mode: the accumulated number of received pulses on the scanned frequencies.

3. The frequency graph has a memory and always retains the highest value. Each time one of the

sweep parameters above explained is changed, the graph is cleared and the frequency sweep starts over from the selected start frequency on.

4. Click the ***Return*** button to close the panoramic sweep window, and to return to the RFA Recorder.

3.3.2. RFA Recorder: Using the External Video Input

The RFA recorder allows the use of the external video input of the Radar Field Analyser as input for the HPD recording. This option is implemented for users who want to perform HPD measurements for radar systems that operate at frequencies outside the RFA frequency range. For this purpose you will need an external RF receiver or in case you have a spectrum analyser available with an analogue video output, you can use this as RF front-end for the HPD measurement, provided its video output level matches the 0...+2V input voltage range of the RFA external video input and the bandwidth (both RF/IF and video) is sufficient.

A receiver calibration curve will be required to define the relationship between the input power level at the receiver or spectrum analyser input (dBm) and its output voltage (V). For a known RF receiver, it is possible to define it by just using a ***slope*** and ***offset*** parameter. For a high quality spectrum analyser the receiver curve will be independent of the frequency used. This allows performing a receiver calibration at a frequency within the RFA frequency range (so using the RFA) and using the resulting calibration table at any other frequency that can be selected on that spectrum analyser.

Depending on the quality of the spectrum analyser, the absolute power level might be changing with the selected frequency. This introduces an offset in power, which is less important for HPD measurements (since we are only interested in the relative power levels), but it is something you must be aware of.

The selected RF/IF and video bandwidth will influence the measurement when wrongly set. They must be set to a sufficient bandwidth to prevent the pulses being smoothed.

Use the scope mode of the RFA recorder program to examine the pulse shape of the pulses received. Verify whether pulses reach their maximum power level within the expected pulse width.

1. Setup the Radar Field Analyser. The only signal connection to be made to the RFA641 is the connection of the spectrum analyser video output to the RFA external video input, available at the back of the RFA, at the analogue input marked CH2. Please verify that the video level signals are within the 0...2V input voltage range. Your spectrum analyser input is assumed to be connected to an appropriate measurement antenna (suitable for the frequency range of interest).

2. Click the ***Parameters*** button. The HPD Preferences window will pop up:

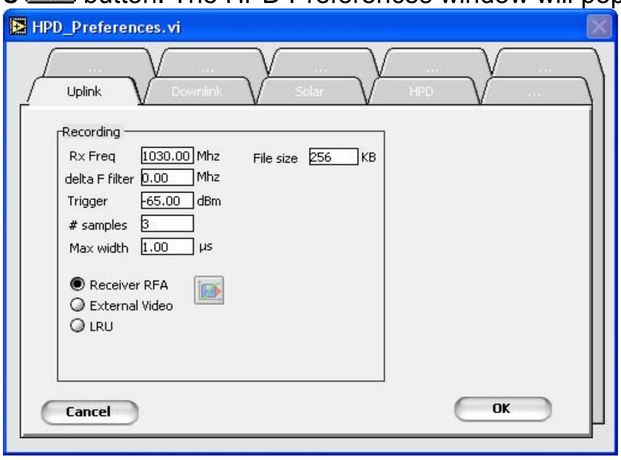


Figure 15: HPD Parameters

Whenever the Radar Field Analyser program is started, it will default to its internal RF circuitry. Therefore the ***External Video*** checkbox is unchecked.

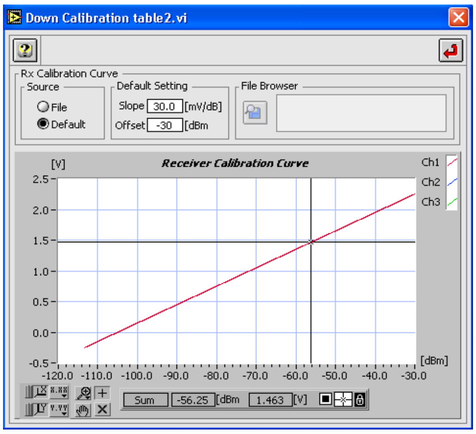


Figure 16: External Receiver Calibration

- To switch to external video, select the ***External Video*** button. The program will prompt you to select a calibration table for the external receiver used. Select the receiver table and click ***OK*** or cancel the file dialog in case you want to define the receiver using a ***Slope*** and ***Offset*** parameter.To use an LRU499 connected to the external video input, select the ***LRU*** button. The program will prompt you to select the LRU calibration file. Enter the serial number and click the ***OK*** button to proceed.

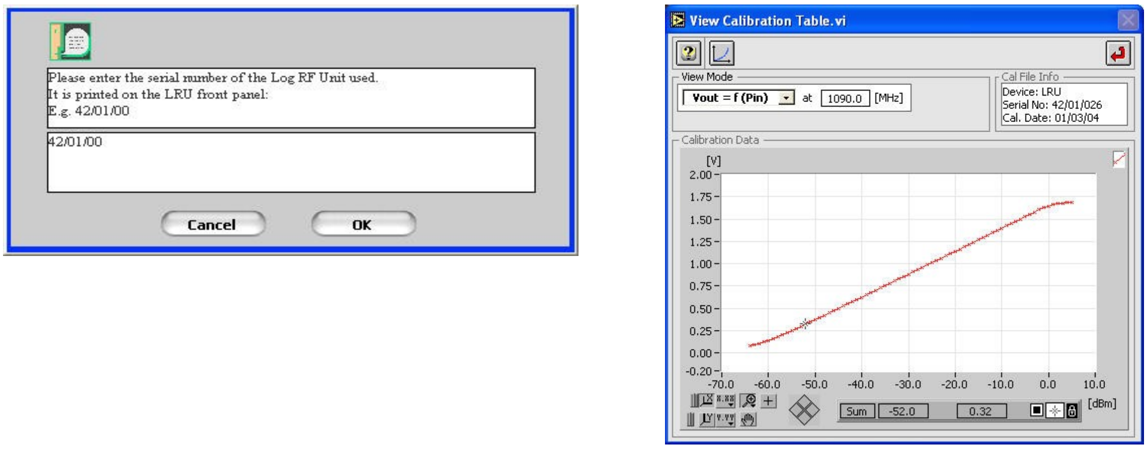


Figure 17: LRU External Calibration

Once the calibration file is selected, hit the ***Return***  button to return to the HPD Preferences window. Click ***OK*** to return to the Radar Field Analyser.vi.

3. The Radar Field Analyser is now switched to the external video input. This is indicated in the receiver control section: ***External Video*** replaces ***Receiver***. The Rx frequency can now be set out of the RFA frequency range since it will be ignored by the RFA641.

   It is advised to set the Rx frequency according to the frequency of the external receiver since it is (together with all other parameters) saved as an attribute to the measurement data file.

   The Y-axis limits as well as the trigger level limits are set according to minimum and maximum of the selected calibration file.

   Both pulse and scope recording functions work in the same way as when using the internal RFA receiver.

3.3.3. View Recorded Pulses

3.3.3.1. RFA Data Analysis: Create HPDs from a Pulse Recording

The View RFA Pulses window shows the pulses as they were recorded in time. Immediately you can recognize the boresights of one or more radars in such a diagram. A measurement using the RFA641 should contain at least three revolutions of the antenna pattern, but preferably more are used.

By selecting a boresight and defining the stagger timing in that boresight; the user can extract the “fingerprint” of the specific radar under test. After this “fingerprinting”, the software will deal with extracting the different HPD curves from the recorded pulses.

The ***View RFA Pulses*** tool can be opened from the RASS-S Toolbox using the ***Uplink*** 

button (select ***View Recorded Pulses***).

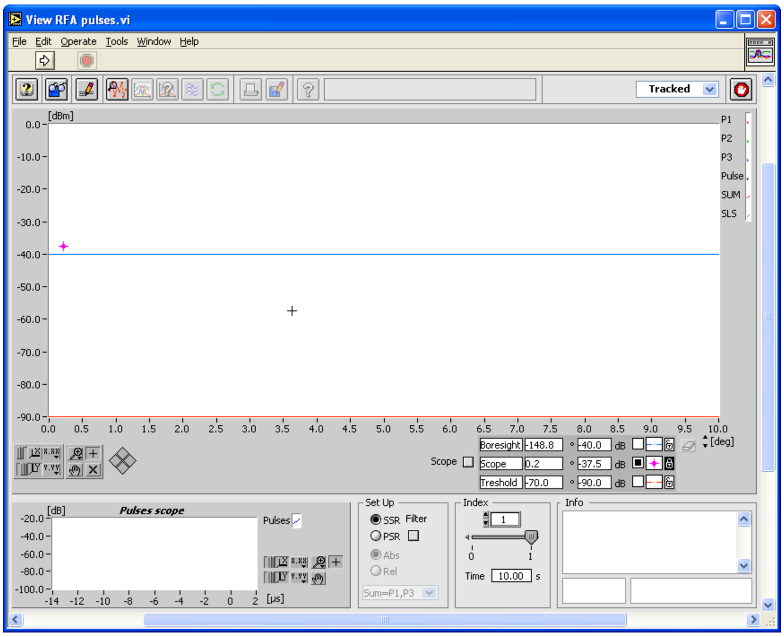


Figure 18: View RFA Pulses software

3.3.3.2. View RFA Pulses

1. Select the measurement type (***SSR*** or ***PSR***) in the ***Set Up*** field at the bottom of the window and click the ***Load***  button.
2. A dialog box will pop up. You will be able to select ***Pulse*** files or ***Scope*** files, as they were recorded with the RFA Recorder.

   If a Pulse file (.pls) is selected, then go straight on to point 2.

   If a scope file is selected (.scp) or if the RFA Recorder is in scope mode when the ***View Data***  button is pressed, the ***View Scope Recording*** window will open first.

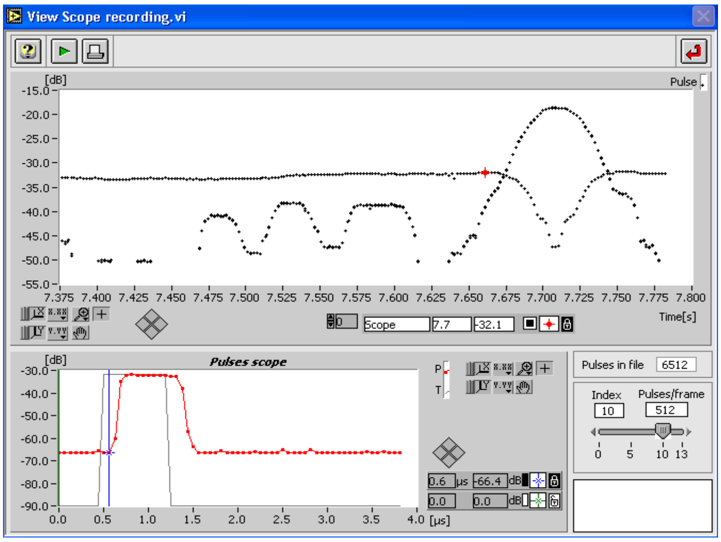


Figure 19: View Scope Recording

The View Scope Recording program reads the consecutive recorded scope waveforms from disk and determines for each of the recorded waveforms the pulses and their amplitudes. This is done using the same algorithm as is performed in the Radar Field Analyser in real-time, when performing pulse recordings. The pulses with their calculated amplitudes are displayed in the ***Pulse*** graph, in frames of a selectable number of pulses (using the ***Pulses/frame*** control).

If required, click the ***Play***  button to convert the Scope file into a Pulse file.

During the conversion process, the Pulse graph will be updated to indicate the progress of the conversion. The program automatically creates a file on disk with the .pls file extension alongside the source file.

Click the ***Return***  button to return to the ***View RFA Pulses*** Window.

In case you click the ***Return*** button without having converted the file, the program will warn and ask again if a pulse conversion must be executed.

2. Now the pulses in the file are read and displayed with a fixed time frame length in the ***View RFA Pulses*** window. The length of the time frame can be selected using the ***Time*** control, which is limited to a maximum of 30s to limit memory size. The ***Index*** slider will select one of the frames to be displayed: if the frame slider is set at 0 and the ***Time*** control at 5 seconds, the data between t=0 and t=5 seconds will be shown. When positioned at 1, the frame between 5 and 10 seconds is shown, etc.

   Depending on whether the data is a PSR or SSR recording, the graphs content will look a little different. If the SSR/PSR switch is set to PSR, a single curve can be recognized (as in figure 20); if the switch is set to SSR you will recognize P1, P2 and P3 (as in figure 21).

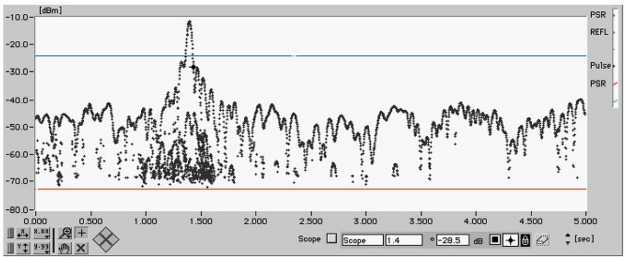


Figure 20: PSR Pulse File example

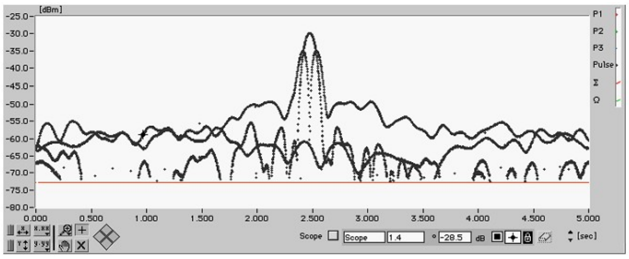


Figure 21: SSR Pulse File example

The graphs X scale can be switched in [seconds], [ms], [µs] or [1/16 µs] using the X scale selector.

If you want to examine each recorded pulse in detail, there is a feature in the RFA software to reconstruct the pulses in detail in the time domain. By using the ✛ cursor, the user can select any pulse on the top graph. The cursor can be moved by selecting the ⊞ cross-cursor from the cursor palette and then selecting the cursor. If the cursor cannot be found, the ⊠ X-cursor will put the cursor in the middle of the graph.
The selected pulse and all pulses within 30 µs before and after the selection are redrawn in the ***Pulses Scope*** graph. This allows you to examine particular cases of reflection or strange swapping of the pulse modes. In many occasions you can record and analyse the creation of erroneous modes at a fixed azimuth direction. This is often caused by the accidental combination of direct and reflected signals.

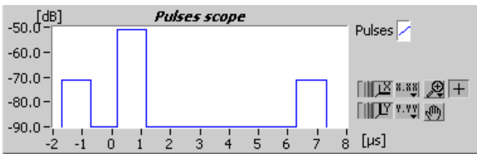


Figure 22: Pulse Scope graph

3. To extract the HPD of a specific radar out of the loaded pulse file, the interrogation timing of that radar must be known. The first step is to select a set of pulses of the radar under test.

   The easiest method to do so is to select a horizontal portion of the SLS pattern using the zoom tool.

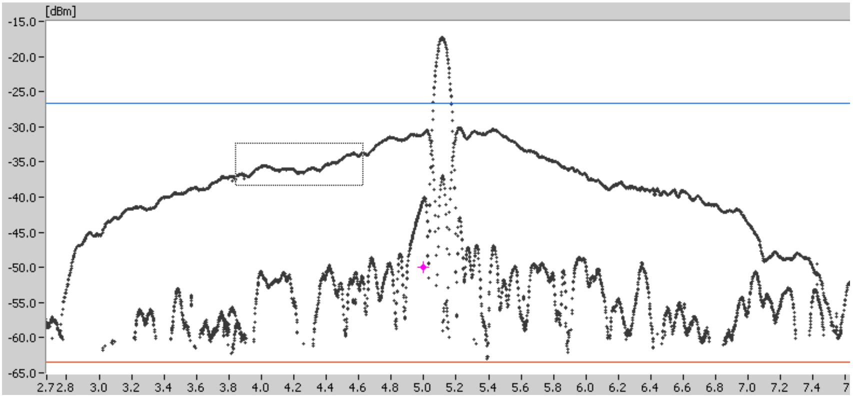


Figure 23: Select Pulses For HPD Extraction

Note: In case your radar system has a low PRF and a large stagger pattern make sure to select enough points of the stagger pattern. Never select a portion with a gap as a wrong period will be measured.

4. Once the pulses for determining the stagger pattern are selected (zoomed in), click the ***Stagger*** button.

   The View Timing window will pop up. The top graph will show all pulses that were located inside the zoomed area, while the bottom part shows the timing pattern (stagger pattern) of the selected pulses.

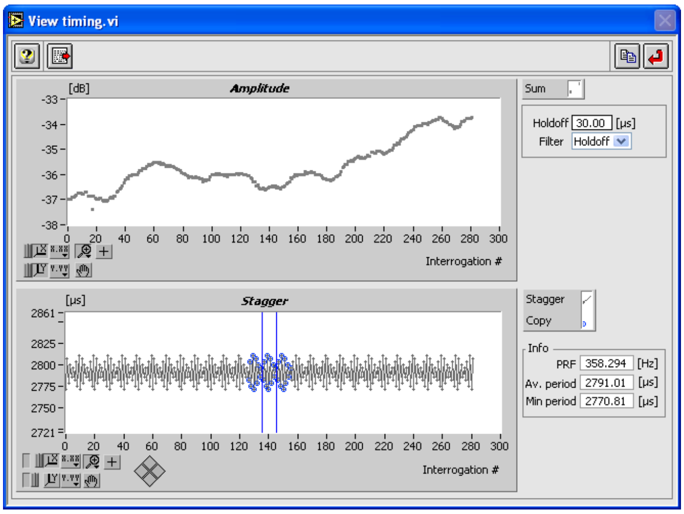


Figure 24: View Timing window: extracting the Stagger pattern

The X-axis shows the pulse index, the Y-axis shows the corresponding time interval between pulses in µs, taking into account the timing filter parameters that can be set using the two controls at the right side of the window.

A number of parameters are calculated from the selected portion of the stagger pattern and are shown in the info fields in the ***View Timing*** window.

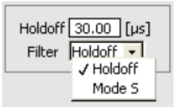


Figure 25: Classical SSR/Mode-S Selection

The ***Filter*** control allows you to select between the timing filter options.

- For mode 1,2A/C only radar systems, select the ***Holdoff*** mode. In this case the ***Holdoff*** control will become visible. Each time a P1 is counted, a hold off time of 30 µs is started, so that P2 and P3 can be skipped. It is default set at 30µs, so that no periods between P1 and P2 or P3 are taken into account.
- For mode-S radar systems, set the filter control to ***ModeS*** to only use the mode A/C interrogation pattern to determine the antenna pattern. In this case the holdoff parameter is dimmed and omitted.

5. Select the stagger pattern.

- If a repetitive stagger pattern can be found by the software: The pattern and the stagger copy to the left and right will be shown in the lower graph in blue In that case, the cursors will automatically be put at the correct positions. In this case, simply click the ***Return*** button to close the Timing window and proceed with section 3.3.3.3. .
- If no pattern can be found automatically: The user must find the repetitive pattern himself: By selecting a number of periods from the bottom graph and clicking the ***Copy*** button, the stagger pattern is copied into the program's memory and can be used to extract this radar's pulses and discriminate them from other radars. There are two possibilities:

  1. If the stagger period is repetitive: Copying this pattern can be done by simply positioning the two vertical cursors such that they contain a repetitive pattern. Then click the ***Copy*** button. The repetitive pattern between the two cursors will be copied to the left and to the right. This can be used to check whether the pattern is really repetitive. If it does not fit immediately, try to shift a cursor one position to the left or right and click the ***Copy*** button again.

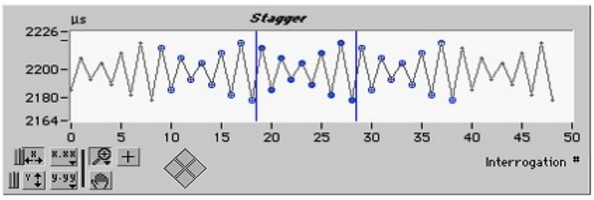


Figure 26: Stagger Pattern Selection

  2. If the stagger period is random (or non-repetitive): In case the pattern is random or non repetitive, we have to select the complete timing of the boresight, as such that the program can calculate the minimum and maximum period of the radar. These two values will then be used to extract the HPD using the ***Triggered*** method. This means that each pulse triggers a new sampling window, which starts at a position Tmin and ends at the occurrence of a new pulse or at T max. The copying can be done by simply positioning the two vertical cursors such that the total stagger pattern falls between the two lines. Mirroring the pattern will again take place when the ***Copy*** button is clicked, but obviously the mirrors will not fit the other pattern.

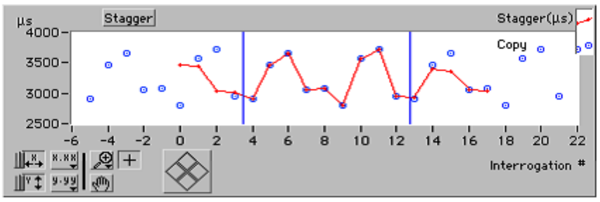


Figure 27: Random Stagger Pattern

Now click the ***Return***  button to return to the ***View RFA Pulses*** window. You have now determined the timing of the mode A/C interrogation pattern of the radar of interest. The next step to proceed to is the actual HPD extraction process.

3.3.3.3. Extracting and Logging the HPD Diagram

1. First select the HPD extraction method. This depends on the kind of stagger pattern of the radar system of interest, as determined in previous section. If the stagger period is repetitive, select the ***Tracked*** method. If the stagger period is random or non-repetitive, select the ***Triggered*** method.

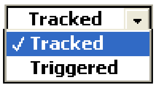


Figure 28: HPD Extraction Method

2. Adjust the HPD Extraction parameters. The HPD extraction processes use a number of preset parameters, which can be adjusted to your own needs, depending on the type of radar. Under normal conditions, this means in 90% of the cases, the parameters are set correctly at default and do not need adjusting. Two basic parameters that will always need adjustment are visible and adjustable as cursors on the pulse graph: the boresight detection level, and the threshold.

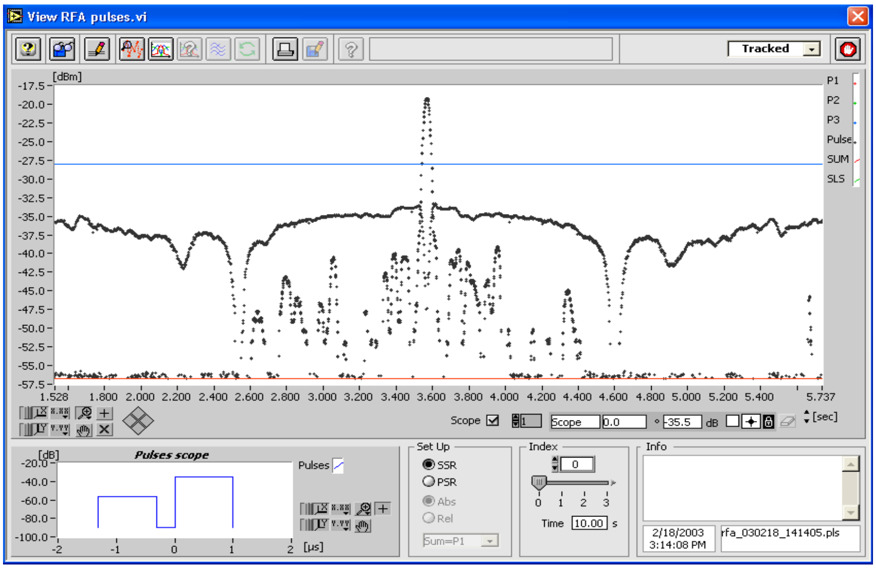


Figure 29: HPD Extraction Threshold Control

3. The red cursor, ***Threshold***, introduces a virtual new trigger level to the pulse file. All pulses below ***Threshold*** (default: -90 dBm) will be cut off. This feature is built in to remove the effects of noise pulses on the extraction algorithms. To set the threshold level make sure one boresight of the radar of interest is shown. Now set the threshold level by moving the red cursor line to the correct level. To

obtain a useful antenna diagram, the pulses shown should at least cover a dynamic range of 40dB.

4. The blue cursor, ***Boresight***, determines the detection of boresight. To have correct boresight detection, this cursor should be set above the sidelobes and lower than the boresight maximum of the radar of interest. When a number (default: 5) of pulses above boresight are detected (taking into account the selected timing and extraction method), boresight is declared. Using the boresight positions, the revolution time is calculated. Figure 29 is a good example of the correct positioning of the ***Threshold*** and ***Boresight*** cursors

5. If you now click the ***HPD***  button, the HPD will be extracted.

6. The HPD graph is drawn in the graph and the scale changes to degrees.

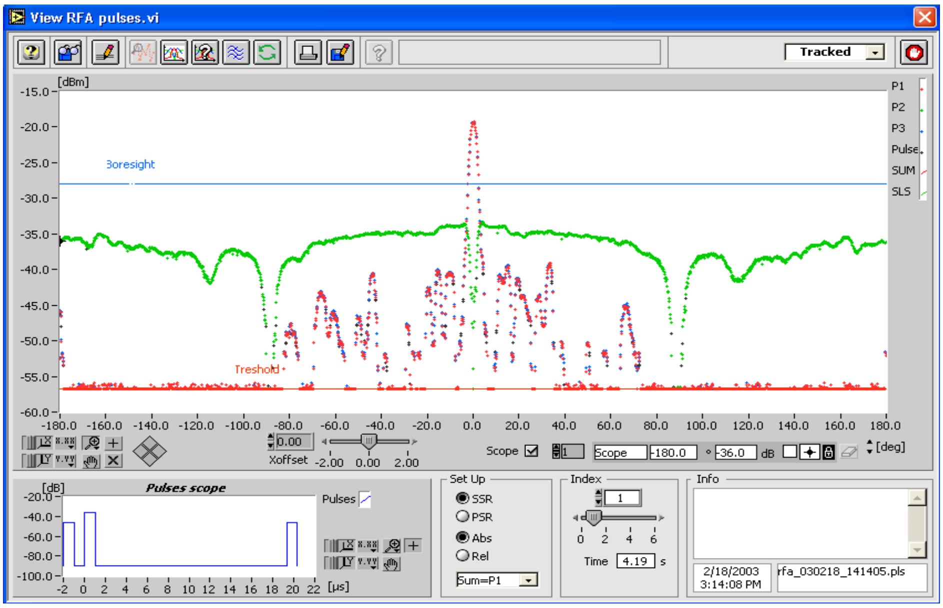


Figure 30: Extracted HPD

7. When the extraction process was successful, the ***Time*** indicator will show the calculated revolution time and the antenna diagram will appear in the graph. If the extraction process was not successful, and the revolution time could not be calculated, the ***Time*** indicator will display its default value (5.00 s) in red.

Figure 31: Revolution Time, Unsuccessful Extraction

8. The ***Index*** slider in the right hand bottom corner of the window indicates the number of revolutions found. The HPD is now shown as amplitude [dB] or [dBm] versus azimuth (°) graph.

9. Depending on the ***Rel/Abs*** switch in the ***Set Up*** field, the graph is shown in an absolute dBm scale or a relative dB scale. In ***Absolute*** position, the dBs are real dBms, received at the RFA input. In ***Relative*** position, the data is shown relative to the maximum value detected in boresight (made equal to 0 dB).

10. The View RFA Pulses program by default assumes that a detected revolution corresponds to 360 degrees. In case you have performed a recording of an antenna with a certain scan width performing a linear scan movement versus time, it is possible to enter a scan width differing from 360 degrees.

    To do this click the ***Parameters***  button and enter the width in the ***Scan Width*** parameter.

Note: For systems containing mode 1 and mode 2 interrogations, the P3 pulse will not be extracted by the current HPD extraction mechanism. Since for mode 1 interrogations P3 might be masked by P2 it is not advisable to use it for the extraction of the Sum diagram. In this case P1 must be used to create the antenna diagram for the Sum channel, P2 is of course used for the extraction of the SLS.

11. If you want to examine each pulse in the HPD graph in detail, the View HPD program contains the feature to reconstruct the pulses in detail in the time domain. This function can be enabled with the ***Scope*** check box of the HPD graph. If this button is checked, the pulses can be selected on the graph by using the cursor and can be examined in detail in the scope graph in the lower left corner. All pulses within 50µs before and after the selection are redrawn in this scope graph. This allows you to examine particular cases of a reflection or strange swapping of the pulse modes.

12. Some simple editing functions for the HPD curve are also available. If, for any reason, the curve still contains erroneous points (due to interference from TCAS, other radars, DME, etc), the user can manually remove any unwanted points. This is done by positioning the cursor on that point and clicking the ***Clear*** button. The unwanted point will disappear from the curve. Make sure the scope function (see above) is disabled in order to remove the points.

13. If the radar uses a large stagger, the points in the graph are not always equidistant in time. If it is required to resample the graph towards equidistant points, which could give you an improvement for OTD calculations and logging of the graph, click the ***Spline*** button. In that case, the HPD graph will be splined using a cubic-spline routine.

14. All editing can be undone. By moving the index slider back and forth, the original HPD will reappear in the graph.

15. The HPD curve will now require a detailed evaluation. This can be done automatically using the ***OTD*** button, which will invoke the following window:

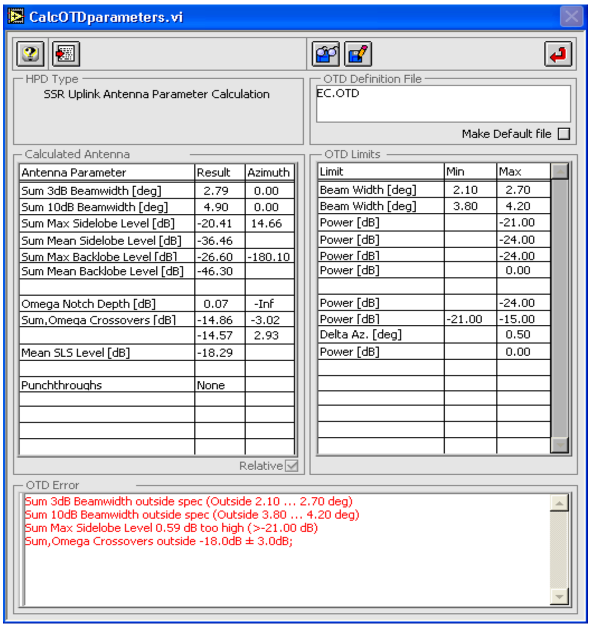


Figure 32: HPD Out of Tolerance Data

16. A number of important parameters are shown. The parameters are checked against the Eurocontrol standards for Radar Performance. If wanted the user can set his own limits for the calculated parameters (as explained in section 3.3.5.). Malfunctions are shown in red.

Caution: Beware the OTD calculations assume equidistant points, so if the stagger period is more than 5% off the average period, use the Spline function before calculating the OTD parameters.

17. Click the ***Return*** button to leave this window.

18. The curve can now also be logged to disk and reviewed later using the View HPD Logfiles function from the Radar Toolbox. Use the ***Save*** button to evoke the Log panel.

Figure 33: Log panel

If no logfile has been selected yet: Open an existing logfile with the ***Open logfile*** button or create a new logfile with the ***New Logfile*** button. In both cases a file dialog will appear. After selecting a logfile (a new or an existing one), use the ***Add logging*** button to add the current data.
If a logfile has already been selected: the logfile string indicates the selected file name. Use the ***Add Logging*** button to append the current data to the logfile.

19. The program will automatically return to View RFA Pulses window.

20. Repeat creating HPD loggings from the different revolutions present, adding them to the same logfile. Use the index to select different revolutions. We have now completed the cycle starting with recording pulses using the Radar Field Analyser up to creating HPD antenna diagrams in an Uplink logfile. If, for any reason, you are not pleased with the extracted HPD diagram (for example if the parameters were not set correctly, or the boresight was not set correctly), you can revert to the original pulse data and reselect the stagger pattern or change any parameter by simply clicking the ***Revert*** button. The graph will revert to the original pulses.

3.3.4. Averaging Multiple HPD Diagrams

In case the interrogations are asynchronous to the revolution, it is possible to interleave multiple HPDs. This way the sample rate can be virtually increased in order to come to a better definition of the actual HPD.

The only requirement is that the recorded RFA pulse file is of sufficient length (# of revolutions recorded).

The View RFA Pulses program is capable of performing this interleave function. The following check list will allow you to perform such action.

1. Perform an antenna diagram extraction as explained above.

2. Once the selected HPD is ready to be inserted into the reference, click the ***HPD*** button again.

The HPD is now transferred to the reference pattern, indicated by ∑ and Ω. The ∑ reference channel will be derived from P1, or P3, or the average level of P1 and P3, depending on the setting of the selector. The result is an overlay of the HPD at index 1 and its copy to the reference. The reference layer is set to connect the diagram dots, to give a visual indication that the copy action was performed correctly.

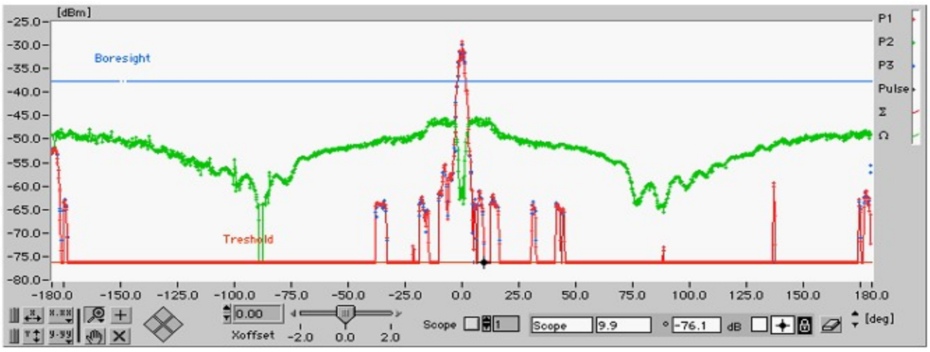


Figure 34: Averaging HPD's

3. Now select the next HPD extracted by changing the index to 2. You will notice that this HPD will be slightly different from the reference.

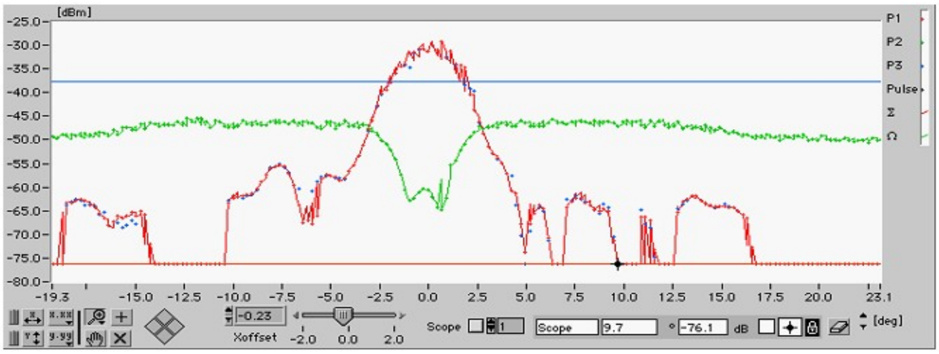


Figure 35: Aligning HPD with Reference

Use the Xoffset control to align the HPD with the reference. Use the boresight and sidelobes to select the best match. Once this is done, you can insert the HPD points in the reference by clicking the HPD button. This can be repeated multiple times, each time increasing the number of samples used to define the HPD diagram.

4. Due to the interleaving of multiple HPDs, the points in the graph are not equidistant in time. Therefore it is required to resample the graph towards equidistant points, in order to ensure correct OTD calculations and correct presentation in the ***View HPD Logfiles*** function by clicking the ***Spline*** button. The new (equidistant) azimuth step can be set using the parameter window. This may take a few seconds to complete. The progress bar will appear to monitor the process. The process also removes eventual abrupt spurious pulses. The number of points for the median filter should be adjusted according to the number of HPDs used for averaging. Click the ***Parameters*** button and change the ***Median Filter # points*** parameter to 2, click ***OK*** to return to the View RFA pulses and again click the ***Spline*** button to perform the cubic spline.

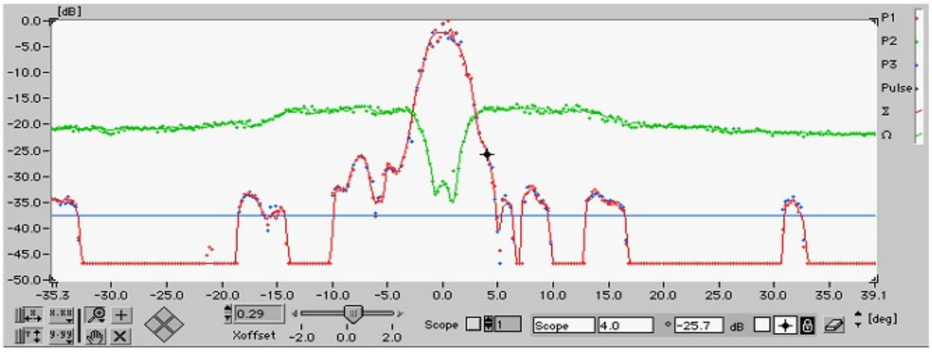


Figure 36: Averaged HPD Result

Since the software doesn't distinguish between single and multiple derived HPDs all other features such as OTD calculation keep on working correctly.

3.3.5. User Defined OTD Limits

The OTD Limits section displays the OTD Limits applied to the calculated antenna parameters. Whenever the program is evoked, it will first read the limits from an ***OTD Definition file***. The OTD error messages will be displayed accordingly.

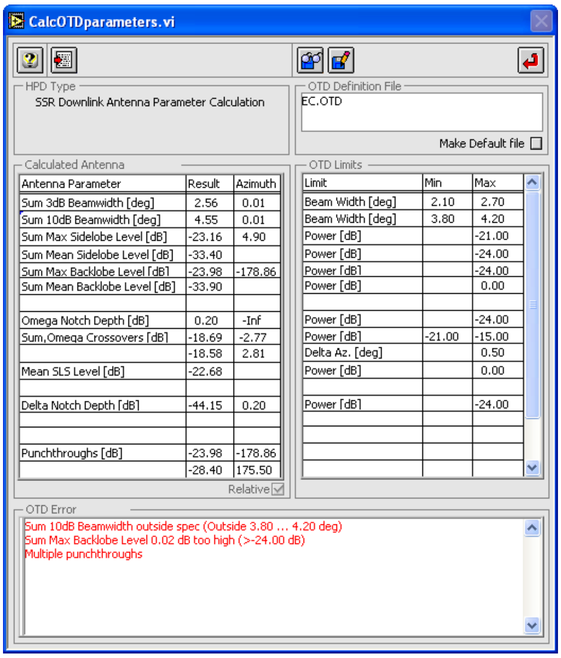


Figure 37: Calculate OTD Parameters window

OTD Definition files are present in the GENERAL\OTD subdirectory of the CAMPAIGN directory. Currently the file 'EC.OTD' is the only file available. This file contains the EC defined parameter limits according to the description in Annex 1: Critical Parameters of SSR Antennas.

The loaded OTD definition file is indicated on the program front panel.

Figure 38: OTD Definition File

The user can change any of these parameters and save the set of limits to a new file in order to create a new OTD definition file. This can be done by clicking the ***Save*** button. In case you want to change the OTD definition file, click the ***Load*** button.

In some cases you might want to set your OTD definition as default calculation. Check the ***Make Default file*** checkbox upon closing the OTD program, the active OTD definition file will be set as the default file to be loaded whenever the OTD program is called.

Figure 39: Make Default File checkbox

The following list describes the OTD limits that can be set by the user. Please note that all limits are defined as relative to the SUM/PSR max power level.

1. SUM/PSR 3dB Beamwidth Min, Max [deg]: Allowed min. and max. for the 3dB beam width
2. SUM/PSR 10dB Beamwidth Min, Max[deg]: Allowed min. and max. for the 10dB beam width
3. Sum/PSR Max sidelobe level [dB(m)]: Allowed max. for the Sum/PSR max. Sidelobe level.
4. Sum/PSR Max Backlobe level [dB(m)]: Allowed max. for the Sum/PSR Backlobe level.
5. Omega Notch Depth [dB(m)]: Allowed max. for the Omega Notch Depth.
6. Sum, Omega Crossovers: Power [dB] min, max: Allowed range for the crossover level.
7. Delta Az [deg] Max: Allowed max. azimuth difference for the crossovers to be recognized as symmetrical.
8. Delta Notch Depth [dB(m)]: Allowed max. for the Delta Notch Depth.
9. Sum, Delta Crossovers
10. Power [dB] Min, Max: Allowed range for the crossover level
11. Azimuth [deg]: Allowed max. azimuth for the crossover position.
12. Delta Az. [deg] Max: Allowed max. azimuth difference for the crossovers to be recognized as symmetrical.

For each of the limits defined the corresponding parameter is checked. In case the calculated antenna parameter is outside the set limits an error message is created in the ***OTD Error Messages*** window. This contains the statements that the parameters are outside specification and displays the parameters result and the set limits. In case of punch-throughs, a list of the punch-throughs is created indicating level and azimuth of each punch-through.

Using the ***Export*** button you can export the OTD parameters, limits and error messages to a tab-separated file.

3.3.6. View HPD Logfiles

To view the measured antenna diagrams, RASS-S contains a universal tool, called View HPD Logging. The program is capable of reading, recognising and displaying Uplink and Downlink HPD logfiles of both (M)SSR and PSR measurements. It is possible to overlay antenna diagrams for comparison in up to five layers.

3.3.6.1. View (M)SSR Uplink Logfiles

To view the measured antenna diagrams, RASS-S contains a universal tool, called View HPD Logging. The program is capable of reading, recognizing and displaying Uplink and Downlink HPD logfiles of both (M)SSR and PSR measurements.

The ***View HPD Curves*** tool can be opened from the RASS-S Toolbox using the ***Uplink***  button (select ***View HPD Logfiles***).

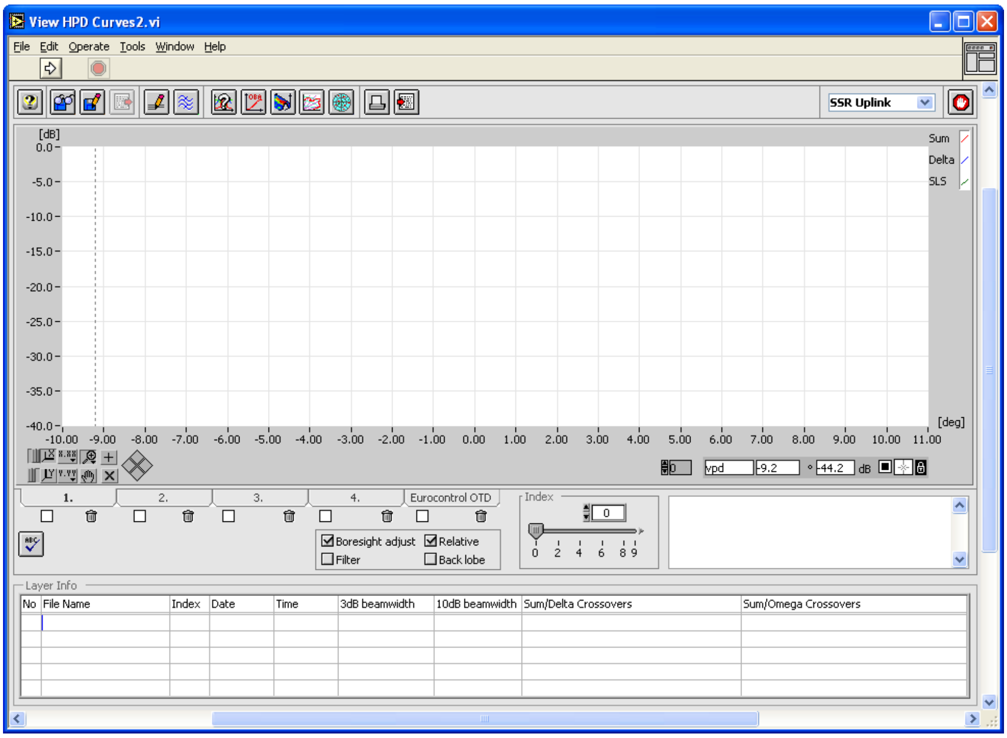


Figure 40: View HPD Logfiles program

1. Use the ***Load***  button to select a downlink logfile, select the file of interest and click the ***OK*** button. The selected file will be displayed in the active layer and its file name will be presented in the ***Layer info*** sub-window, the date and time of the recording is shown and diagram parameters of the selected logging are displayed.

2. It is possible to overlay antenna diagrams for comparison in up to five layers: Select a layer by clicking on a layer tab. The View HPD Logfiles program allows to overlay up to 5 layers. Each of the layers can be temporarily hidden. This is done by means of the check box selectors to select the displaying of the curves. The ***Empty***  button allows clearing the active layer. It is even possible to superimpose SSR Uplink, SSR Downlink, PSR Uplink or PSR Downlink curves on top of each other. Any combination is possible.

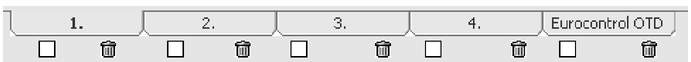


Figure 41: Layer tabs and selectors

3. Click the ***OTD*** button to calculate the OTD parameters. The OTD window will appear. Click the ***Return*** button after inspection.

4. In case you have antenna diagram data available in a TAB-separated file, the ***Import*** function can be used to load this file type into the selected layer. The software expects a diagram defined in

HPD Data SSR 159 degrees

Azimuth[deg]	Sum[dB]	Delta[dB]	SLS[dB]
-90.100	-43.278	13.901	-40.905
-90.000	-43.278	13.901	-40.988
-89.900	-43.278	13.901	-41.080
-89.800	-43.278	13.901	-41.184
-89.700	-43.278	13.901	-41.304

Figure 42: Antenna diagram data in TAB-separated file

four columns: Azimuth [deg], Sum [dB], Delta [dB], SLS [dB]. The data points must be defined equidistant in azimuth.

5. An existing logfile might consist of multiple measurements, from which you may want to select the best ones to be kept in a separate logfile. This operation can easily be performed using the ***Save*** button. Select the diagram you want to transfer to a new or existing logfile using the standard procedure. (Start program and select a curve with the Index control.) Use the Save button to evoke the Log panel. If no logfile has been selected yet: Open an existing logfile with the ***Open logfile*** button or create a new logfile with the ***New Logfile*** button. In both cases a file dialog will appear. The name of the newly selected logfile will be indicated in the ***Current Logfile*** string indicator. Use the ***Add logging*** button to add the current data.
If a logfile has already been selected: In this case the logfile string indicates the selected file name. Use the ***Add Logging*** button to append the current data to the logfile. Use the ***Cancel*** button to cancel the operation.

6. If you recorded multiple HPD diagrams from different elevations, you can stack these on top of each other and create VPD diagrams or 3D diagrams using the following buttons: ***3D*** and ***VPD***. It is also possible to view the data in a polar view mode by clicking the ***Polar View*** button to display the layers in polar mode.

7. The HPD data can be exported using the ***Export*** button. This will evoke a save file dialog, pointing to the “Exports” subdirectory of the active campaign folder. The resulting file consists of a text file containing a table. This table is TAB separated and can be imported by any Spreadsheet program. The file consists of four columns: Azimuth [deg]; Sum Amplitude [dB]; Delta Amplitude [dB]; SLS Amplitude [dB]. The numerical data is converted in a string format with a 3-digit precision.

3.3.6.2. User Defined OTD Limits

(see section 3.3.5 User Defined OTD Limits)

3.4. Troubleshooting

1. No pulses are recorded; the preview window does not show any pulses.
   - Check the antenna connection and the cable between the filter and the receiver.
   - Check the video output on the oscilloscope.
   - Check the frequency settings. Maybe you selected the wrong (PSR) frequency.
2. Lots of pulses are recorded, no boresight can be found in the noise-like pulse distribution.
   - Probably the input amplitude is way too high. Add an external attenuator in the antenna cable.
3. The boresight of the antenna diagram is flattened; side lobes are at less than 20 dB of the boresight.
   - Probably the input amplitude is way too high. Add an external attenuator to the antenna cable.
4. The sample window is not updated at all (***Pulse Count*** does not increase).
   - Lower the trigger value. If this doesn’t help, adjust the frequency and check whether the antenna is properly connected to the equipment

4. Receiver Measurements

4.1. Radar Rx Calibration

4.1.1. Theory

The RF Receiver is needed to convert the very low levels of RF available at the antenna into a video base band signal for further processing. The dynamic range of the Rx (noise floor to saturation level) and the alignment of the monopulse channels can be measured directly.

Also before a Downlink measurement Bandwidth sweep or (D)STC measurement can be performed. The calibration routine will use the RFA641 to send RF pulses with increasing amplitudes into the receiver under test. The video output of these receivers is digitised by the RFA641 and used to build the calibration table(s).

The final Rx calibration result consists of a receiver output voltage versus RF input power table.

4.1.2. Getting Started

The Radar Rx Calibration is loaded from the RASS-S Toolbox using the ***Rx*** button.

Make the connections as shown in Annex 3: Rx, Bandwidth and STC Calibration Connection Diagram.

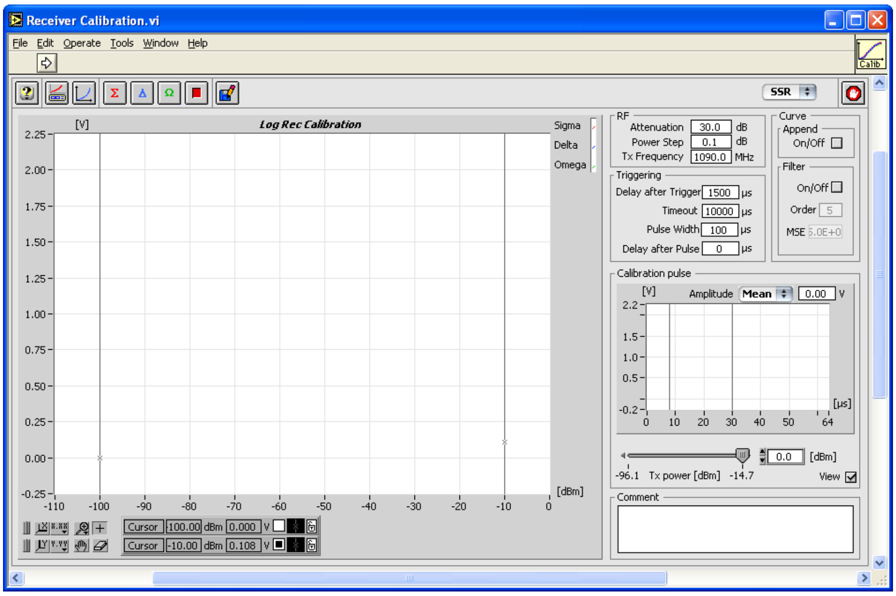


Figure 43: Rx Calibration software

Warning: Make sure the radar Transmitter is switched off on the channel under test and that automatic channel switching is off, before connecting the RFA Tx output to the radars receiver RF Input.

4.1.3. Software

Once the tool is running, the calibration pulse is shown in the ***Calibration Pulse*** graph. As long as no calibration procedure has been started, the tool is in “free run” mode. This means that all parameters can be changed on the fly and their impact on the measurement is shown directly in the calibration pulse graph. Move the slider under the display to change the transmission power of the RFA641 and see the impact on the display.

The output voltage is measured by calculating the mean, max or RMS value of the part of the output pulse selected by the cursors. Therefore it is important to position the cursors correctly. If the measured part between the cursors is not flat (spikes, noise) a beep is produced and the graph will turn red. This does not mean that the calibration is wrong, but that some points in the calibration curve can be erroneous.

1. RF Section: Set the correct ***Extra Attenuation*** value. This value depends on your receivers input range. The output power of the RFA641 for calibration is guaranteed +10dBm at 1090Mhz. If for example the maximum receiver input power is -20 dBm, the external attenuator should be 30dB in order to reach the maximum receiver input power. In most cases, the calibration will be performed through a coupler which is fixed in the antenna chain, typically 20dB or 30dB. This value must also be taken into account. The value of the input coupling factor of the coupler in the receiver chain plus the value of the extra attenuation must be entered in the control.
   Set the ***Power Step*** value to be used. This value will determine the step in transmission power used by the RFA641 to perform the calibration. A typical value of 0.1 dB is sufficient.
   Set the RFA ***Tx frequency*** to be used for calibration. For (M)SSR radars this is always 1090MHz. If a PSR radar is to be calibrated, set the RFA Tx frequency to the PSR operating frequency.

2. Triggering Section: The receiver calibration is performed at a certain time delay after the interrogation trigger pulse: be sure to set the ***Delay after Trigger*** value. If the calibration is performed without applying a trigger pulse, the calibration will use a fixed calibration PRF determined by the ***Timeout*** parameter (PRF=1/Timeout).
   Set the ***Pulse Width*** of the calibration pulse.

Note: When a PSR receiver is being calibrated: make sure the pulse is outside the STC of your receiver by changing the Delay after Trigger parameter.

3. All measurements included in the radar receiver measurements rely on the Radar Field Analyser hardware, especially on its transmitter. In order to verify its behaviour and calibrate the transmitter output power, a selftest function is included in all the programs using the RFA641 transmitter hardware. If you want to verify the operation of the RFA641, click the ***Cal RFA*** button before proceeding with the Receiver Calibration.

4. Verify the correct connections as shown in the connection diagram and click the ***Sum*** button.

5. A dialog box will prompt the user to check the connections of the different channels to the back panel ***Ch 2(in)*** and the ***Tx*** of the RFA641. Confirm the connections by clicking the ***OK*** button.

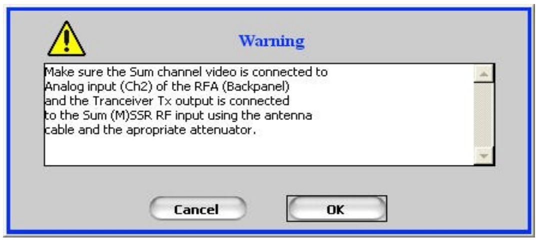


Figure 44: Verifying the connections

The calibration will now be executed.

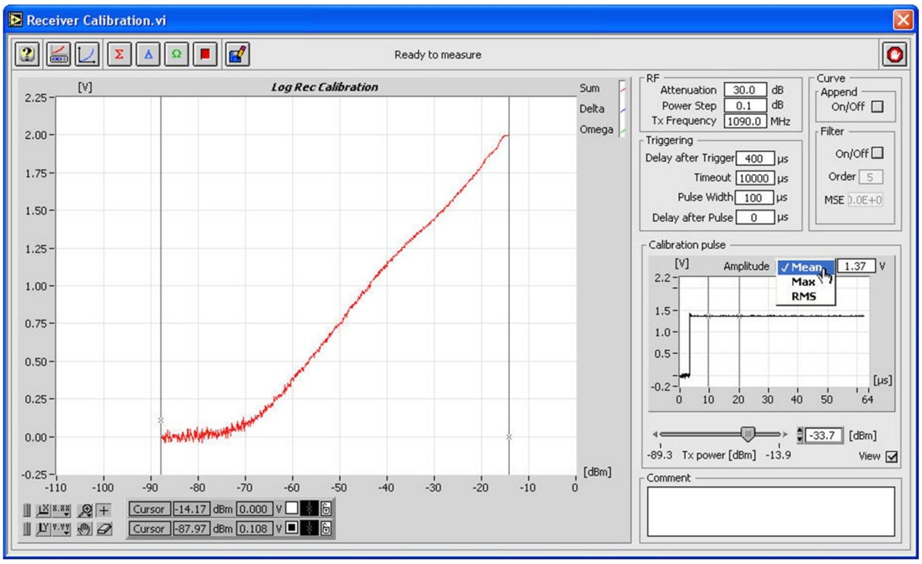


Figure 45: Rx Calibration Example

6. If the noise level of the receiver is not reached during the calibration, the receiver calibration measurement can be performed in successive steps in order to increase the overall dynamic range of the receiver measurement. To do this, check the ***Append*** button and insert an extra attenuator after the first run.
   Enter the correct new attenuation value into the ***Extra Attenuation*** parameter and again click the ***Sum*** button. The software will append the two calibration curves to each other.

7. For MSSR stations: proceed with the measurements of the ***Delta*** and ***Omega*** channels. Press the respective buttons on the software front panel, change the connections as described in the pop-up window and repeat steps 4, 5 and 6.

8. A calibration procedure can always be interrupted by clicking the ***Stop*** button.

9. The user can select a filter option, so that the calibration curves are improved and spikes, due to the operational use of the radar, are removed. To do this, check the ***Filter*** check box on the graph. The filtering is done only for the part of the curves between the cursors. So move the left cursor approximately to the noise floor intercept point before checking the filter box to reduce the curve fitting oscillations. The filter consists of a median filter of order 1 followed by a polynomial fit algorithm, from which the user can alter the default order of 5 to a higher value. The ***MSE*** indicator shows the Mean Squared Error of the curve filtering.

10. Only the part of the curve selected with the cursors on the ***Log Rec Calibration*** graph is saved to disk. Therefore first select the portion of the receiver curve you want to save and click the ***Logging*** button. The VI will prompt a standard file dialog. Fill in the desired calibration file name and save the calibration data on disk.

4.1.4. Troubleshooting

1. A “File not found” message pops up the minute you run the instrument
   - Check whether the RFA641 calibration files are installed correctly.
2. The Calibration Pulse graph turns red and a beep is produced
   - Set the cursors of the Calibration Pulse graph onto the pulse.

4.2. Rx Bandwidth Measurement

4.2.1. Theory

The Rx Bandwidth measurement consists of a frequency sweep. This frequency sweep can be performed with a fixed level (static) or with a variable amplitude pulse (dynamic). This selection can be set by the user. The RFA641 transmitter is set to transmit a pulse at the specified power value and the frequency is swept between two chosen limits. Additionally it is advisable to perform a full bandwidth sweep (900MHz - 3.0/3.5GHz) to check on band spuriousness. The RFA641 continuously samples the output of the radar receiver video signal and uses these values to build a dBm versus frequency table. The resulting bandwidth graph can be analysed to determine the 3dB and 10dB bandwidths of the receiver.

4.2.2. Getting Started

The Rx Bandwidth is loaded from the RASS-S Toolbox using the ***Rx*** button.

Make the connections as shown in Annex 3: Rx, Bandwidth and STC Calibration Connection Diagram.

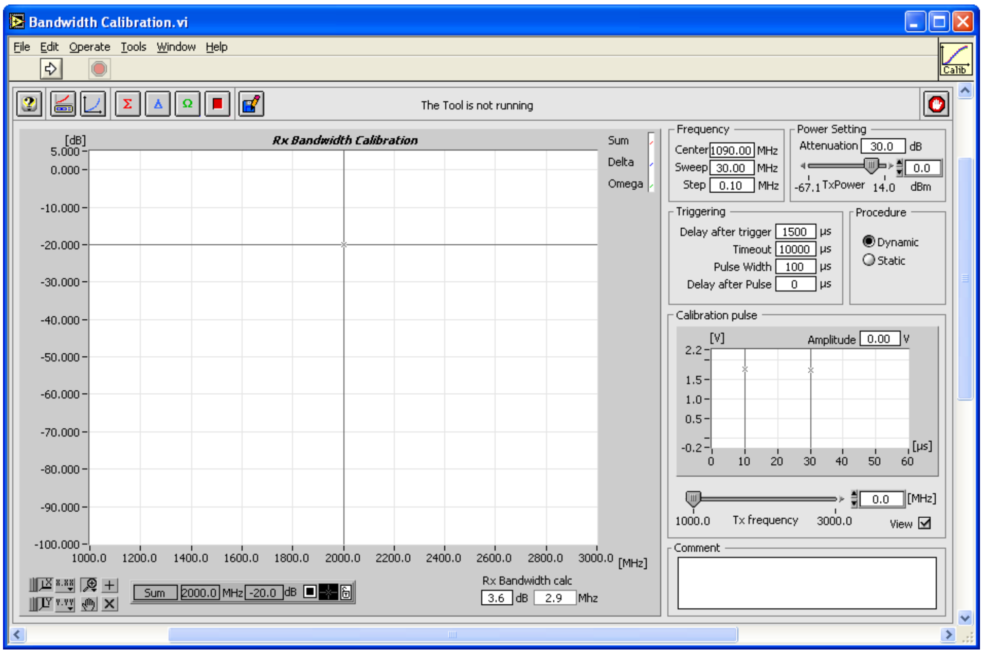
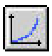


Figure 46: Receiver Bandwidth Measurement software

4.2.3. Software

The software will ask to load the correct receiver calibration file. This is necessary to be able to calculate the exact power level corresponding to the measured pulse amplitudes. This can also be done using the ***Load Rx Calibration***  button. The selected calibration file is then displayed. By clicking ***Cancel*** in the file dialog it is possible to select a default table, in case no receiver calibration file is available. Use ***Slope*** and ***Offset*** to change the default table to your needs.

1. First decide to make a static or dynamic measurement by selecting the corresponding procedure selector.

   When the ***dynamic*** setting is chosen, the pulse amplitude is automatically varied during the calibration procedure according to the receiver's bandwidth curve. Insert the strict minimum extra attenuation. An optimal value is the one where at minimum Tx power the receiver is not saturated in the passband. This way maximum amplitude pulses can be used in the outside of the passband.

   For a ***static*** measurement adjust the settings as needed. Select the correct Tx ***Power*** and ***Attenuation*** value. The ***Power*** control sets the power level present after the extra attenuation at the RFA641's Tx connector, so indicating the power injected in the radars receiver input. The max. output power of the RFA641 is guaranteed +10dBm at 1090Mhz. Choose a level in the linear calibration part of the radar receiver to obtain a satisfactory result. Typically it is set so that the Rx receives a power level of -40 to -50dBm.

   The external attenuator added is typically 30dB in order to reach the maximum receiver input power of about -20dBm. In most cases however, the connection will take place through a fixed coupler already present in the system. This attenuation must also be taken into account, when filling in the ***Attenuation*** parameter. Therefore if the receiver is measured through an extra fixed coupler of 30dB, the transmission power must be set to -50dBm, extra attenuation in this case is 60dB.

2. Set the ***Center Frequency***, the ***Frequency Sweep*** and the ***Frequency Step***. For (M)SSR radars the first is always 1090Mhz. If a PSR radar is to be calibrated, set it to the correct Rx frequency. The

RFA641 frequency ranges from 800 to 3500Mhz. The frequency sweep is usually set to 30MHz, while the step is set at 0.1MHz.

3. Set the ***Trigger*** selection. The Bandwidth measurement is performed at a certain delay after the trigger pulse: be sure to set the ***Delay after Trigger*** value. If the measurement is performed without applying a trigger pulse, the tool will use a PRF of 1/Timeout.

   The ***Calibration Pulse*** field continuously monitors the signal available on the Ch2 video input at the selected frequency. You can control the frequency directly by adjusting the ***Tx frequency*** control and check the pulse shape and amplitude available.

4. Make the correct connections for the calibration of the ∑ channel according to the set-up window and click the ***Sum***  button.

   A dialog box will prompt the user to check the connections of the different channels to the back panel ***Ch2(In)*** and the ***Tx*** of the RFA641. Confirm the connections by clicking ***OK***.

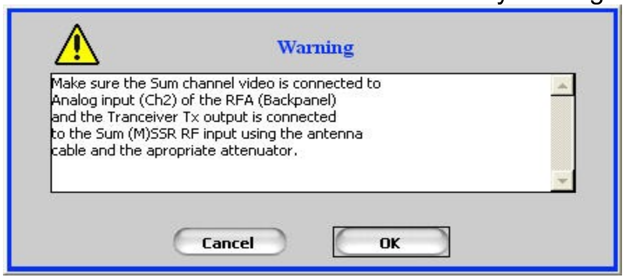


Figure 47: Verifying the connections

Next, the frequency sweep is carried out. The bandwidth curve is measured and the 3dB and 10dB bandwidths can be calculated.

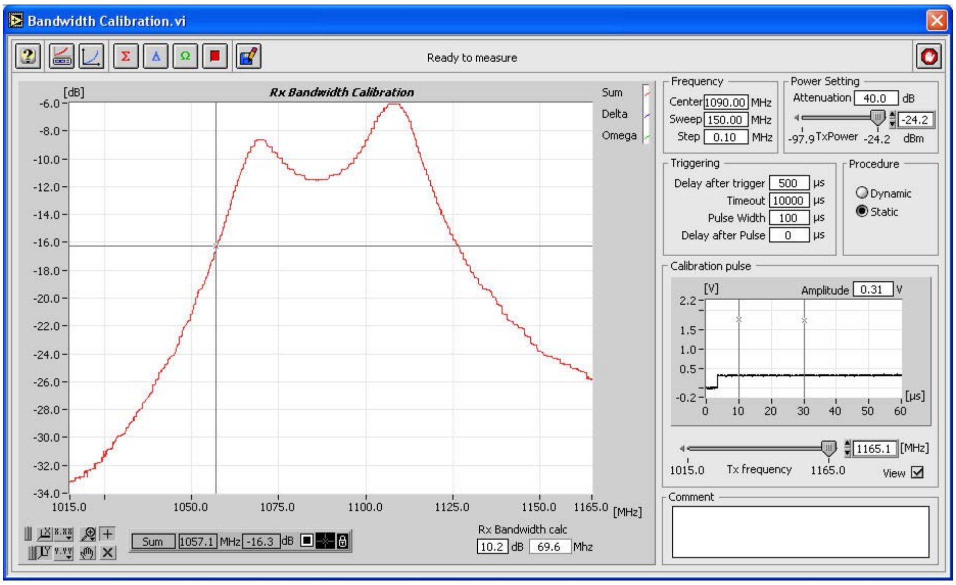


Figure 48: Bandwidth measurement result

Enter 3 dB or 10dB in the ***Rx Bandwidth calc*** field and the respective filter bandwidths will be calculated and displayed.

5. For MSSR stations: make the correct connections to measure the ***Delta***  and ***Omega***  channels and repeat step 4.

6. A measurement can always be interrupted by clicking the ***Stop*** button.

7. When all channels are measured, click the ***Save*** button to save the measurement data to disk. The VI will prompt a standard file dialog, by default pointing to the CALIB subdirectory of the MSSR or PSR subdirectory of the active campaign folder. Type in the desired file name and save the data to disk or select ***Cancel*** if you do not wish to save the results.

4.2.4. Troubleshooting

1. A "File not found" message pops up the minute you run the instrument
   - Check whether the RFA calibration files are installed correctly.

4.3. STC/DSTC Calibration

4.3.1. Theory

The STC measurement result consists of an RF input power versus time table. To be able to measure the gain vs. time delay, the RFA641 needs to be synchronised to the interrogation signal of the radar under test. The position of the RFA641 transmitters output pulse is then altered in discrete steps, ranging from a set maximum (***Stop Delay***) to a minimum (***Start Delay***). The power level for the measurement pulses can be set in the ***Tx power*** control. Make sure that the power of the measurement pulses is within the receiver range.

Two measurement methods are implemented:

1. ***STC:*** Measurement of the STC curve in case the STC is implemented in the receiver and directly measurable at the output of the receiver. The RFA641 will inject pulses of a fixed (selectable) power level into the receiver. These pulses will then be varied in time delay vs. the interrogation trigger. The (M)SSR's analog video output signal is then sampled by the RFA641. This amplitude is passed through the calibration curve in order to build the STC curve: a gain [dB] versus time delay curve.

2. ***DSTC:*** In this case the STC is implemented after the receiver section, by applying a variable threshold when digitising the video. Therefore the video level to be sampled for each of the receivers is the quantised video. The Radar Field Analyser will inject pulses starting from a minimum delay up to a maximum delay. For each delay step the power level injected starts from the selected maximum power level and is decreased down to the DSTC trigger level. Depending on the delay, from a certain RF power level, the pulse will not pass the digitising threshold anymore and disappears at the quantised video output. By presenting the measured threshold level vs. time delay, the Digital STC curve becomes visible.

4.3.2. Getting Started

The STC/DSTC Calibration is loaded from the RASS-S Toolbox using the ***Rx*** button.

In case of an STC measurement make the connections as shown in Annex 3: Rx, Bandwidth and STC Calibration Connection Diagram, in case of a DSTC measurement make the connections as shown in Annex 4: DSTC Calibration Connection Diagram.

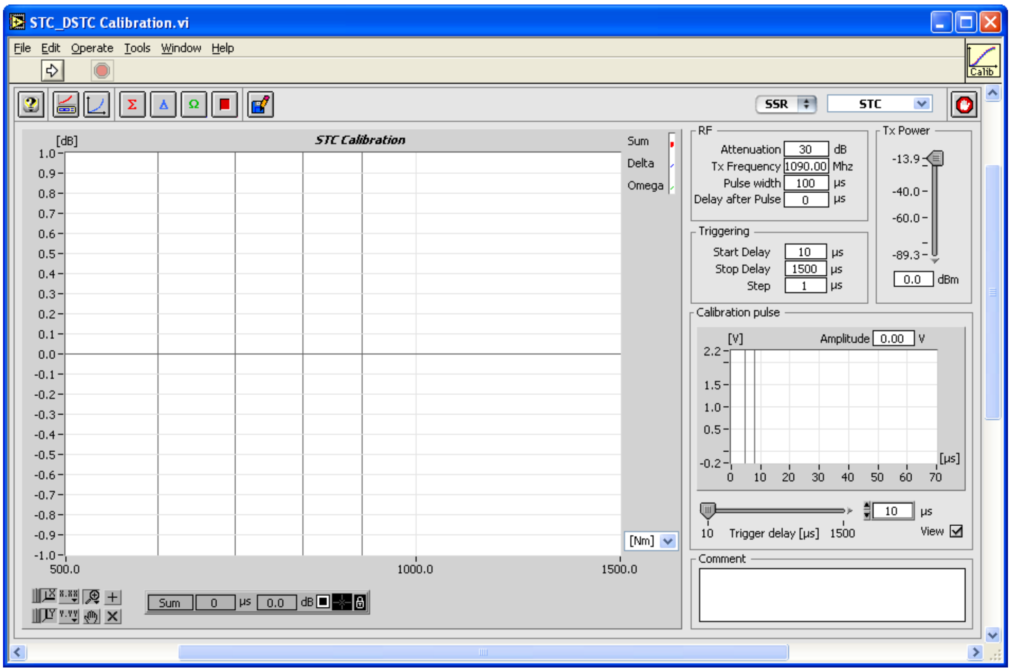


Figure 49: STC/DSTC Calibration software

4.3.3. Software

The software will ask to load the correct receiver calibration file after you have started the tool. This is necessary to be able to calculate the exact power level corresponding to the measured pulse amplitudes.

This can also be done using the ***Load Rx Calibration***  button. The selected calibration file is then displayed. By clicking ***Cancel*** in the file dialog it is possible to select a default table, in case no receiver calibration file is available. Use ***Slope*** and ***Offset*** to change the default table to your needs.

1. Adjust the ***Rf parameters*** and the ***Tx Power*** control as needed. Select the correct ***Tx frequency*** (default 1090MHz). The ***Tx power*** control sets the power level present after the extra attenuation at the RFA641's Tx connector, so indicating the power injected in the radars Rx input. The max. output power of the RFA641 is guaranteed +10dBm at 1090Mhz. Choose a level in the linear calibration part of the radar Rx to obtain a satisfactory result. Typically it is set so that the Rx receives a power level of -40 to -50dBm.

   The external attenuator added is typically 30dB in order to reach the maximum receiver input power of about -20dBm. In most cases however, the connection will take place through a fixed coupler already present in the system. This attenuation must also be taken into account when filling in the ***Attenuation*** parameter. Therefore if the receiver is measured through an extra fixed coupler of 30dB, the transmission power must be set to -50dBm, extra attenuation in this case is 60dB.

   The width of the test pulse can be set using the ***Pulse width*** parameter.

   Delay after Pulse determines the start of the sample window to capture the test pulse at the video level output of the Rx. This is foreseen in case a processing delay exists in the system.

2. Set the Triggering parameters:
   The sweep ***Start Delay*** is used to determine the minimal time between the test pulse and the trigger pulse. The ***Stop Delay*** is used to determine the maximum time between the test pulse and the trigger pulse. The ***Step*** parameter determines the step size of the time sweep.

   The ***Calibration Pulse*** field continuously monitors the signal available on the Ch2 video input at the selected delay. To have an initial idea of the (D)STC range and power levels you can control the time delay of the RF test pulse (and the related measurement window) by adjusting the ***Trigger Delay*** control.

3. If you want to perform the RFA Selftest/Calibration, this is possible by clicking the ***Cal RFA*** button.

4. Click the ***Sum*** button to measure the ∑ channel.

   A dialog box will prompt the user to check the connections of the different channels to the back panel ***Ch2*** and the ***Tx*** of the RFA641. Confirm the connections by clicking the ***OK*** button.

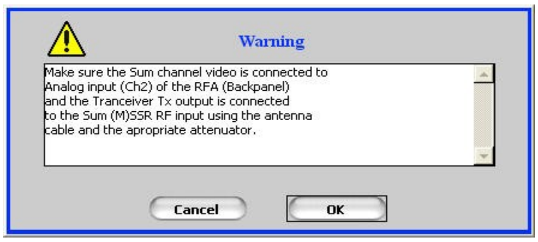


Figure 50: Verifying the connections

While the measurement is performed, the result is immediately visible.

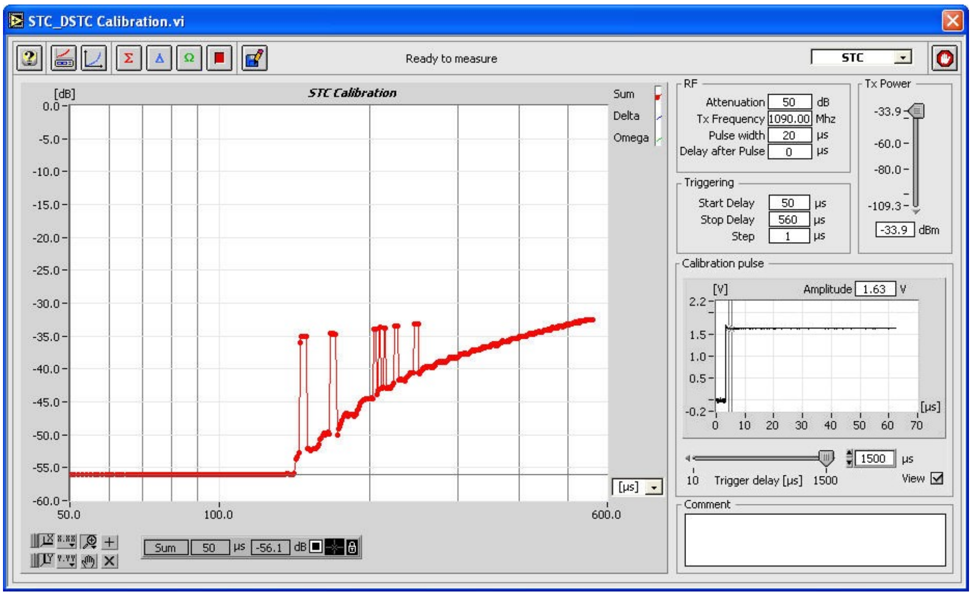


Figure 51: STC measurement result

In case the measurement result is not as expected, the procedure can be halted by pressing the ***Halt*** button.

5. For MSSR stations: proceed with the measurements of the ***Delta*** and ***Omega*** channels. Press the respective buttons on the software front panel, change the connections as described in the pop-up window and repeat step 4.

6. When all channels are measured, click the ***Save*** button to save the measurement data to disk. The VI will prompt a standard file dialog, by default pointing to the CALIB subdirectory of the MSSR or PSR subdirectory of the active campaign folder. Type in the desired file name and save the data on disk or select ***Cancel*** if you do not wish to save the results.

4.4. Sectorial STC

4.4.1. Theory

The Sectorial STC measurement result consists of an RF input power versus time table presented versus azimuth. To be able to measure the gain vs. time delay, the RFA641 needs to be synchronised to the interrogation signal of the radar under test.

The interrogation trigger signal is used both as start of range and as azimuth indicator. Due to limitations of the RFA641 digital input hardware, only two timing signals can be connected simultaneously. Therefore the interrogation count is also used to calculate azimuth.

The RFA641 will inject pulses of a fixed (selectable) power level into the receiver. The (M)SSR's analog video output signal is then sampled by the RFA641. This amplitude is passed through the calibration curve in order to build the STC curve: a gain (dB) versus time delay curve.

4.4.2. Getting Started

The Sectorial STC is loaded from the RASS-S Toolbox using the ***Rx*** button.

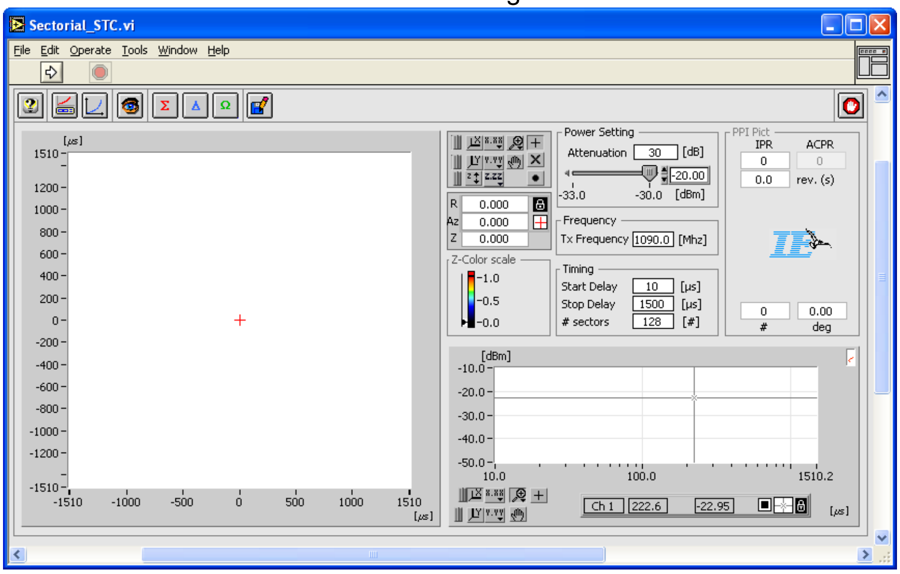


Figure 52: Sectorial STC software

Make the connections as shown in Annex 5: Sectorial STC Calibration Connection Diagram.

Make sure to connect the radar's interrogation trigger signal to the ACP input connection of the RFA641 instead of to the TRIGGER (P1-P3) input. This measurement is repeated for a number of interrogations in each revolution, depending of the number of sectors to be measured.

4.4.3. Software

The program will ask to load the correct receiver calibration file. The receiver calibration file is required in order to be able to calculate the exact power level corresponding to the measured pulse amplitudes. The Down Calibration table2.vi will pop up with a dialog box to select a calibration file. Select the file and click ***OK***. The selected calibration file is then displayed. By clicking ***Cancel*** in the file dialog it is possible to select a default table, in case no receiver calibration file is available. Use ***Slope*** and ***Offset*** to change the default table to your needs. The calibration file can always be reloaded afterwards using the ***Load Rx Calibration*** button.

1. Adjust the Power settings as required. Select the correct ***Tx frequency*** (default 1090MHz) and the correct ***Attenuation*** value. The ***Power*** control sets the power level present after the extra attenuation at the RFA641's Tx connector, so indicating the power injected in the radars receiver input. The max. output power of the RFA641 is guaranteed +10dBm at 1090Mhz. Choose a level in the linear calibration part of the radar receiver to obtain a satisfactory result. Typically it is set so that the receiver receives a power level of -40 to -50 dBm.

   The external attenuator added is typically 30dB in order to reach the maximum receiver input power of about -20dBm. In most cases however, the connection will take place through a fixed coupler already present in the system. This attenuation must also be taken into account when filling in the ***Attenuation*** parameter. Therefore if the receiver is measured through an extra fixed coupler of 30dB, the transmission power must be set to -50dBm, extra attenuation in this case is 60dB.

   The program will synchronize to the ARP and interrogations of the radar. The azimuth information is indicated in the ***PPI Pict*** window. Once the number of interrogations per revolution (IPR) is constant, the azimuth can be calculated correctly and the measurement buttons are enabled.

2. Set the time sweep parameters: The sweep ***Start Delay*** is used to determine the time delay between the first test pulse and the trigger pulse. The ***Stop Delay*** is used to determine the time delay between the last test pulse and the trigger pulse. The RFA641 transmits a set of 128 RF pulses, spread over the selected range from the set minimum (Start Delay) to the set maximum (Stop Delay) to measure the complete STC at once at the azimuth of the interrogation.

3. The ***#sectors*** parameter determines the number of measurements to be executed during one revolution. In fact it acts as a divider for the IPR count, so that each IPR/#sectors amount of triggers a measurement is performed. Each time one of the measurement parameters is changed, the measurement buttons ***Sum***, ***Delta*** and ***Omega*** will be disabled until the next ARP occurs.

4. If you want to perform the RFA Selftest/Calibration, this is possible by clicking the ***Cal RFA*** button.

5. Before starting the measurement it is important to check the position of the output pulse and the setting of the sampling point. Click the ***Preview*** button to open the ***Preview STC.vi*** window.

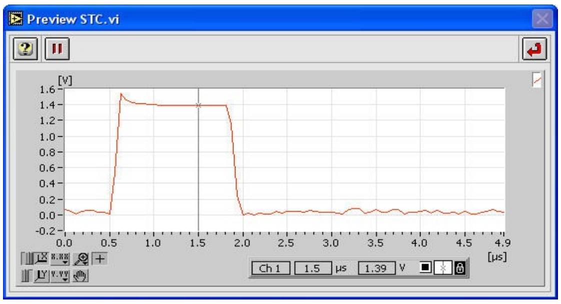


Figure 53: Set sampling point of test pulse

Use the cursor to set the sampling point for the pulse amplitude. Once set, click the ***Return***  button to return to the sectorial STC measurement program.

7. Make the correct connections for measuring the ∑ channel as described in the set-up window and click the ***Sigma***  button. A dialog box will prompt the user to check the connections of the different channels to the back panel Ch2 and the Tx of the RFA641. Confirm the connections by clicking the ***OK*** button.

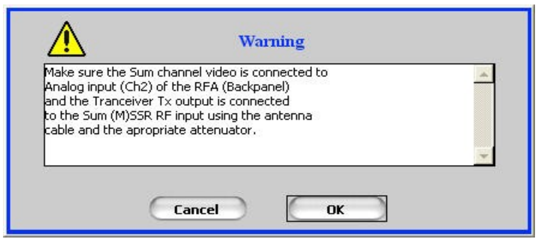


Figure 54: Verifying the connections

Note: The channel selection button is only used to select the correct Rx Calibration table (correct channel). The measurement is a single channel measurement.

8. Upon the ARP following the start of the measurement, the PPI Graph containing the sectorial STC map is updated with the measurement result for the full revolution at once.

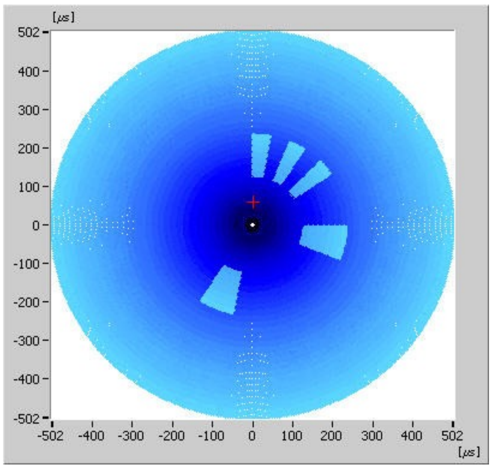


Figure 55: Sectorial STC result

By default the Z-scale (color) is auto scaled on the minimum and maximum of the loaded receiver calibration file. The auto scale pad for the color display also contains a Z-axis auto scale button to allow auto scaling on the Z-axis for the selected zoom in X-direction and Y-direction.

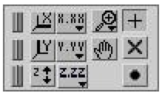


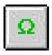
Figure 56: XYZ Graph Controls

If wanted you can set the color scale manually in the ***Z-color scale*** control.

A red cursor is available in the Sectorial STC graph to allow selecting an azimuth. The STC curve for the selected azimuth is then displayed in the STC time graph.

Range, azimuth and power level of the selected point are indicated in the cursor readout.

9. When the channels' STC curve is measured, click the ***Save***  button to save the measurement data to disk. The data will be saved as an S4 plot file, containing one scan with a plot for each measurement point. The following plot information fields are filled in: Range, Azimuth, Power level, Time and Scan Nr. This data file can be viewed using the ***3D View*** function of the Inventory as explained in section 4.6.4. Viewing Sectorial STC and DSTC Measurement Files. The VI will prompt a standard file dialog, by default pointing to the RESULTS subdirectory of the active campaign folder. Type in the desired file name and save the data on disk.

10. For MSSR stations: proceed with the measurements of the ***Delta***  and ***Omega***  channels. Change the connections as described in the pop-up window and repeat steps 7 to 9.

4.5. Sectorial DSTC

4.5.1. Theory

The Sectorial DSTC measurement result consists of an RF input power versus time table presented versus azimuth. To be able to measure the gain vs. time delay, the RFA641 needs to be synchronised to the interrogation signal of the radar under test.

This measurement is repeated for a number of interrogations in each revolution, depending on the number of sectors to be measured. The power level for the measurement pulses can be set in the ***Tx Power*** control. Make sure that the power of the measurement pulses is within the Rx range.

The DSTC is implemented after the Rx section, by applying a variable threshold when digitising the video. Therefore the video level to be sampled for each of the receivers is the quantised video. The Radar Field Analyser will inject pulses starting from a maximum power level, being decreased each second revolution in order to retain the threshold voltage vs range and azimuth.

4.5.2. Getting Started

The Sectorial DSTC is loaded from the RASS-S Toolbox using the ***Rx***  button.

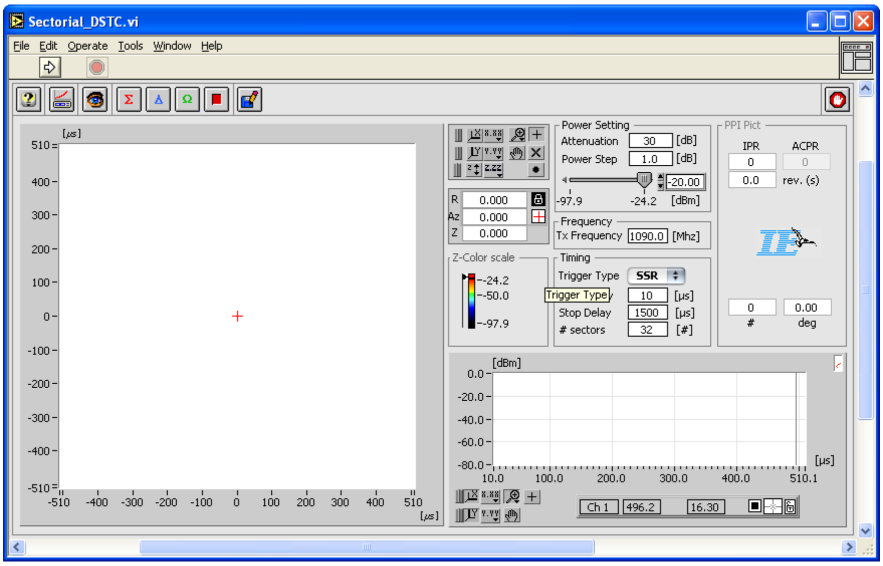


Figure 57: Sectorial DSTC software

Make the connections as shown in Annex 6: Sectorial DSTC Calibration Connection Diagram.

Make sure to connect the radar's interrogation trigger signal to the ACP input connection of the RFA instead of to the TRIGGER (P1-P3) input. Verify that the quantized video output is connected to the RFA's video input.

4.5.3. Software

1. Adjust the settings as needed. Select the correct ***Tx frequency*** (default 1090MHz) and set the ***Power*** and the correct ***Attenuation*** value. The ***Power*** control sets the power level present after the extra attenuation at the RFA641's Tx connector, so indicating the power injected in the radars receiver input. The max. output power of the RFA641 is guaranteed +10dBm at 1090Mhz. The power level control can be used to manually check the operation of the DSTC.

The external attenuator added is typically 30dB in order to reach the maximum receiver input power of about -20 dBm. In most cases however, the connection will take place through a fixed coupler already present in the system. This attenuation must also be taken into account when filling in the ***Attenuation*** parameter.

During the DSTC measurement power will be swept from maximum power to minimum power using the ***Power Step*** value to determine the power levels used. Each other scan the power will be decreased by the value in ***Power Step***.

2. Set the time sweep parameters: The sweep ***Start Delay*** is used to determine the time delay between the first test pulse and the trigger pulse. The ***Stop Delay*** is used to determine the time delay between the last test pulse and the trigger pulse. The RFA641 transmits a set of 128 Rf pulses, spread over the selected range from the set minimum (Start Delay) to the set maximum (Stop Delay) to measure the complete (D)STC at once at the azimuth of the interrogation.

3. The ***#sectors*** parameters determines the number of measurements to be executed during one revolution. In fact it acts as a divider for the IPR count, so that each IPR/#sectors amount of triggers a measurement is performed.

   The interrogation trigger signal is used both as start of range and as azimuth indicator. Due to limitations of the RFA641 digital input hardware, only two timing signals can be connected simultaneously. Therefore the interrogation count is also used to calculate azimuth.

   The program will synchronize to the ARP and interrogations of the radar. The azimuth information is indicated in the ***PPI Pict*** window. Once the number of interrogations per revolution (IPR) is constant, the azimuth can be calculated correctly and the measurement buttons are enabled.

4. Before starting the measurement it is important to check the position of the output pulse and the setting of the sampling point. Click the ***Preview*** button to open the ***Preview STC.vi*** window.

Figure 58: Set sampling point of test pulse

   Use the cursor to set the sampling point for the pulse amplitude. Once set, click the ***Return*** button to return to the sectorial DSTC measurement program.

5. If you want to perform the RFA Selftest/Calibration later on, this is possible by clicking the ***Cal RFA*** button.

6. Make the correct connections for measuring the ∑ channel as described in the set-up window and click the ***Sigma*** button. A dialog box will prompt the user to check the connections of the different channels to the back panel Ch2 and the Tx of the RFA641. Confirm the connections by clicking the ***OK*** button.

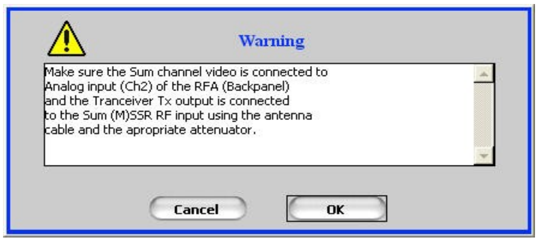


Figure 59: Verifying the connections

Note: The channel selection button is only used to select the correct Rx Calibration table (correct channel). The measurement is a single channel measurement.

Once the measurement is started, the Sum, Delta and Omega buttons are dimmed. The measurement will run through all power levels as determined by the RFA641's power range and the ***Power Step*** value. The number of scans required to perform the measurement can be calculated as: 2*(Pmax-Pmin)/Power Step. Each other scan you will see the power level being updated and a new measurement performed.

For the measurement points exceeding the threshold level (quantised video pulse present), the current Tx power level is filled in. For the measurement points not exceeding the threshold level, the last measured threshold level is retained. This way the DSTC maps are built gradually as the measurement proceeds.

You can await the end of the measurement or in case you decide the measured DSTC curve is sufficient, you can click the ***Stop***  button to halt the measurement sequence.

By default the Z-scale (color) is auto scaled on the minimum and maximum of the loaded receiver calibration file. The auto scale pad for the color display also contains a Z-axis auto scale button to allow auto scaling on the Z-axis for the selected zoom in X-direction and Y-direction.

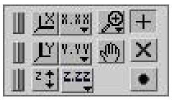
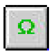


Figure 60: XYZ Graph Controls

If wanted you can set the color scale manually in the ***Z-color scale*** control.

A red cursor is available in the sectorial DSTC graph to allow selecting an azimuth. The DSTC curve for the selected azimuth is then displayed in the DSTC time graph. Range, azimuth and power level of the selected point are indicated in the cursor readout.

7. When the measurement is finished, click the ***Save***  button to save the data to disk. The data will be saved as an S4 plot file, containing one scan with a plot for each measurement point. The following plot information fields are filled in: Range, Azimuth, Power level, Time and Scan Nr. This data file can be viewed using the ***3D View*** function of the Inventory as explained in section 4.6.4. Viewing Sectorial STC and DSTC Measurement Files. The VI will prompt a standard file dialog, by default pointing to the RESULTS subdirectory of the active campaign folder. Type in the desired file name and save the data to disk.

9. For MSSR stations: proceed with the measurements of the ***Delta***  and ***Omega***  channels. Press the respective buttons on the software front panel, change the connections as described in the pop-up window and repeat steps 6 and 7.

4.6. View Rx Calibration

4.6.1. Theory

A universal tool is available to display and print out (to a printer or a report) the measured Rx Calibration, Rx Bandwidth or STC measurement results. Depending on the file type selected, the frontpanel layout of the tool will change to display the correct items.

4.6.2. Getting Started

The ***View Receiver Calibration*** software is loaded from the RASS-S Toolbox using the ***Rx***  button (in the list the software is called ***View Cal, BW, STC Logfiles***).

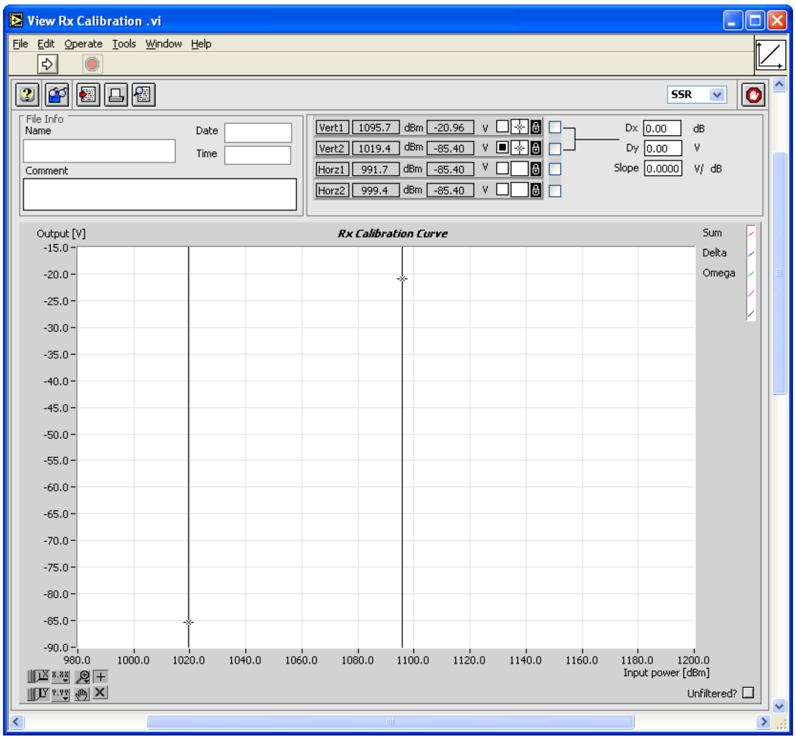


Figure 61: View Receiver Calibration software

4.6.3. Software

1. Click the ***Load***  button to select a receiver measurement file. This can either be a Rx Calibration, Rx Bandwidth or STC measurement result file. Depending on the selected radar type, the dialog will by default point to the CALIB subdirectory of the (M)SSR or PSR directory of the active campaign folder.

In the example of Figure 62 we selected an (M)SSR Radar Rx Calibration file. The calibration data is displayed in the data graph. File name, date and time are default shown.

Four cursors are foreseen to readout specific measurement data if desired. These cursors can be switched on or off with the check mark at the right of the cursor readout. Two vertical and two horizontal cursors are available.

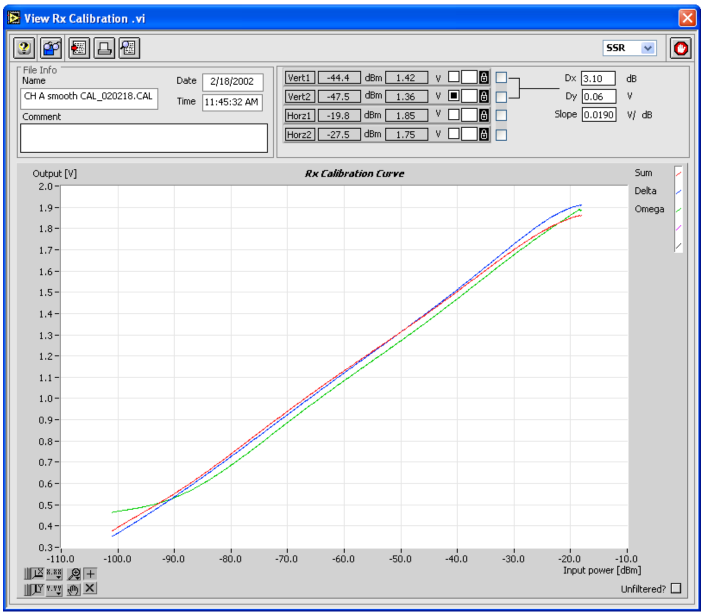


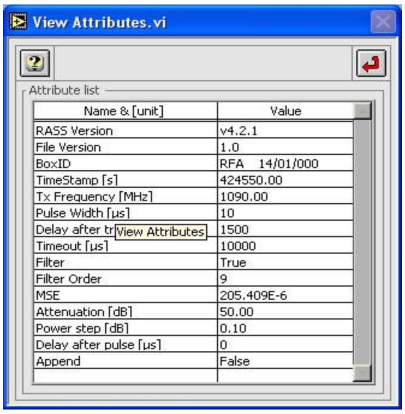
Figure 62: Viewing a receiver calibration result

2. The data can be exported to a spreadsheet formatted text file by clicking the ***Export***  button.
3. A file dialog appears to select destination and file name. The dialog default points to the ***EXPORT*** directory of the active campaign folder.

   Select the destination and file name and click ***OK***.

   The table saved to the text file is TAB separated and can be imported by any spreadsheet program. The numerical data is put to a string format with a 3-digit precision. The file consists of four columns:
   - For Rx Calibration: Power[dBm]; Sum Voltage[V]; Delta Voltage[V]; SLS Voltage[V].
   - For Rx Bandwidth: Frequency[MHz]; Sum Amplitude[dB]; Delta Amplitude[dB]; SLS Amplitude[dB].
   - For STX/DSTC: Time[µs]; Sum Amplitude[dB]; Delta Amplitude[dB]; SLS Amplitude[dB].

4. By clicking the ***View Attributes***  button, the ***View Attributes*** window will open:



Name & [unit]	Value
RASS Version	v4.2.1
File Version	1.0
BoxID	RFA 14/01/000
TimeStamp [s]	424550.00
Tx Frequency [MHz]	1090.00
Pulse Width [µs]	10
Delay after tr View Attributes	1500
Timeout [µs]	10000
Filter	True
Filter Order	9
MSE	205.409E-6
Attenuation [dB]	50.00
Power step [dB]	0.10
Delay after pulse [µs]	0
Append	False

Figure 63: Receiver Calibration file attributes

All related settings used to measure the curve are listed in this window.

4.6.4. Viewing Sectorial STC and DSTC Measurement Files

The sectorial STC and DSTC measurement programs save their data to an S4 plot file. This data can be viewed in the Inventory. Two view methods are important:

- Power vs. time with filtering on azimuth to view the SCT/DSTC curve of a specific sector.
- 3D View of the entire measurement using Power[dBm] as Z-axis.

The following section will explain to you in detail how to use the Inventory to view the STC and DSTC measurement files.

Note: Load the Inventory tool from the Analysis button of the RASS-S toolbox. More information regarding the use of the Inventory is explained in the Inventory manual. This document only describes the use of the Inventory as a sectorial (D)STC result viewer.

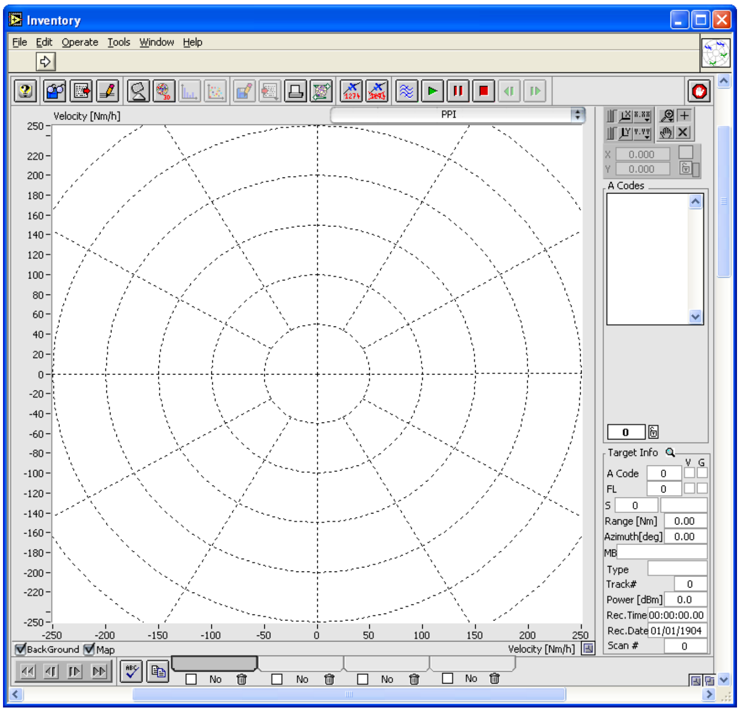


Figure 64: Inventory software

1. Click the ***Load***  button to select a Sectorial STC or DSTC measurement result file.

   The following window will pop up:

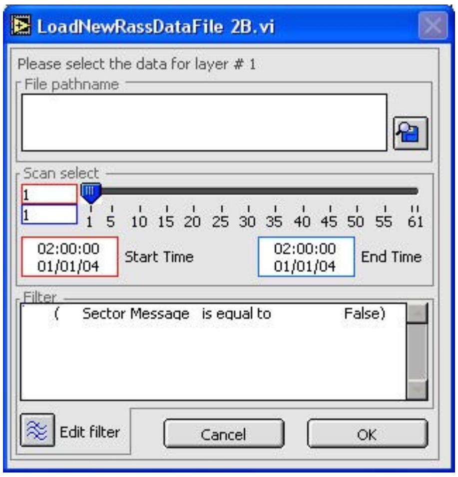


Figure 65: Load S4 File

It allows you to select a file and to load a number of scans out of an S4 plot file.

Click the ***Find File***  button to load the data. By default it will point to the RESULTS directory of the active campaign folder. Select the desired file and click ***OK***. Since only one scan is available, you don't need to alter the default scan selection. Just click ***OK*** and load the file into a layer of the inventory.

Caution: Please beware that in the case you are loading a large number of sectors, it might take several seconds to load the data.

2. The positions of the measurement data are all shown without the power level data. When you want to view the sectorial (D)STC map, click the ***3D View*** button.
3. Select ***Power [dBm]*** as Z-axis. This allows you to view the (D)STC map in the same way the recording tool displays it.

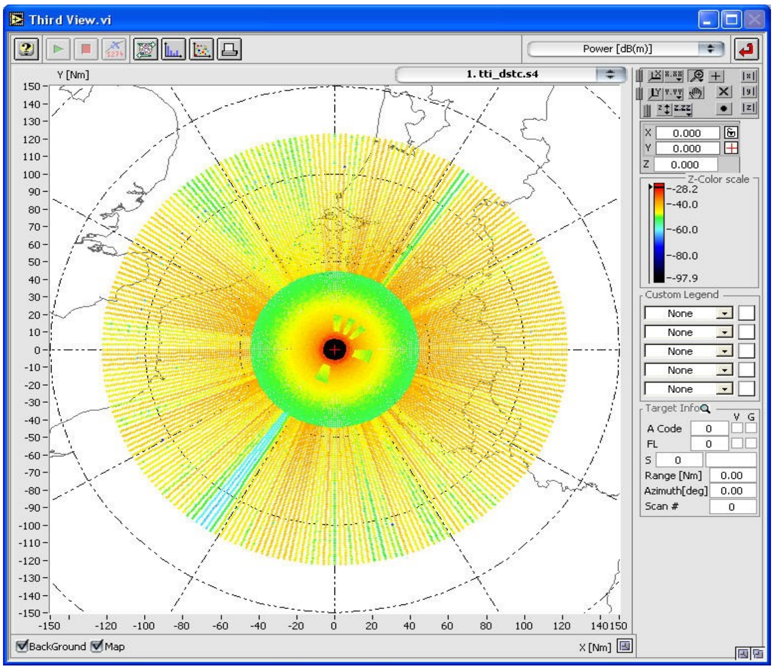


Figure 66: 3D View (Inventory)

For a more detailed explanation of the inventory and the related functions, consult the manual on data analysis.

4. Click ***Return*** to return to the Inventory button and clear the layer to remove the data. This can be done by clicking the ***Empty*** button at the bottom of the inventory window.
5. Again click the ***Load File*** button. In the ***LoadNewRassDataFile.vi*** we will now select the ***Edit Filter*** button.

   The ***Search Editor*** will pop up. The following example shows what will happen when you select the following search criteria:

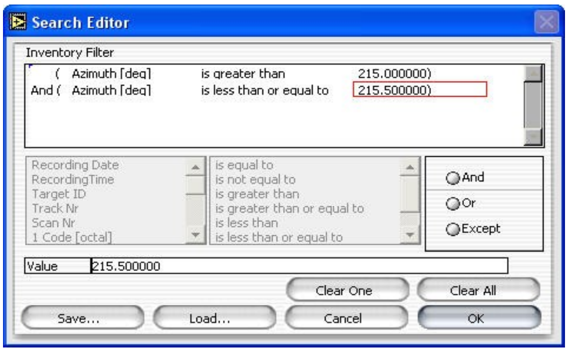


Figure 67: Example filter by radial

The inventory will only display the one STC measurement selected.

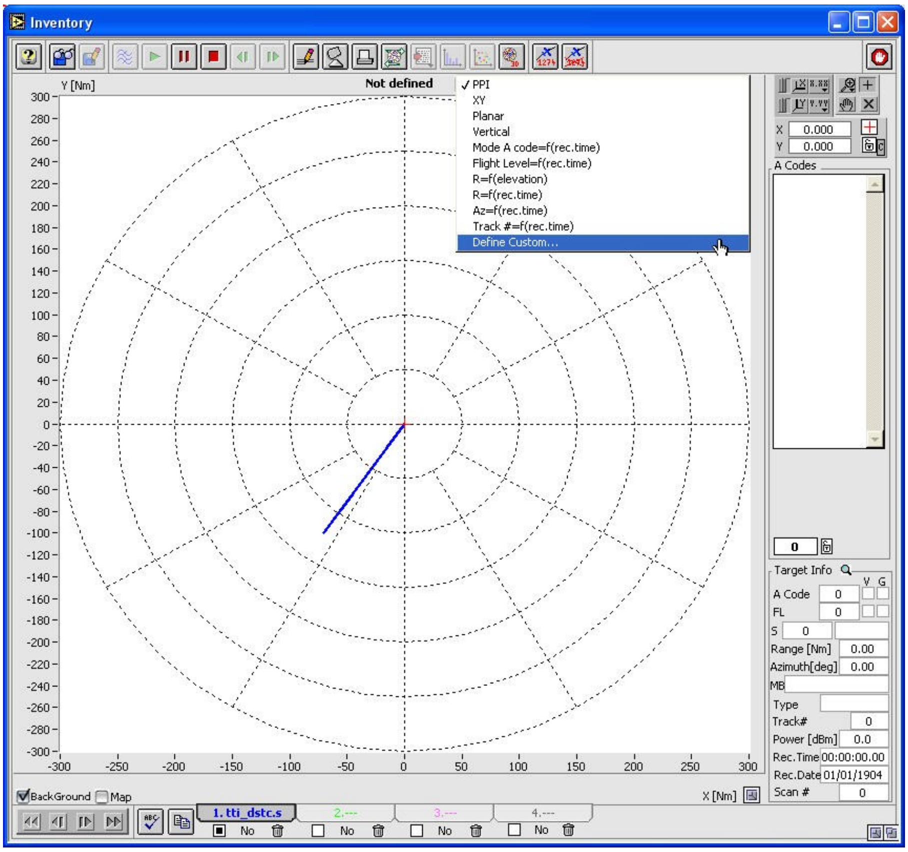


Figure 68: Define custom view

Select ***Define Custom*** from the type menu and select the following axes:

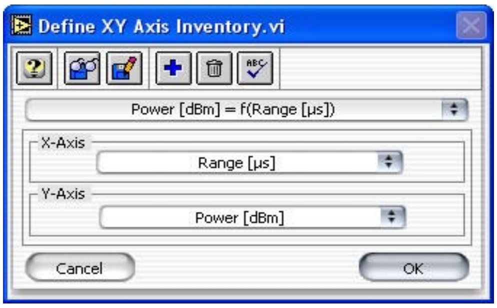


Figure 69: Axis selection

The display changes to the selected graph. It is also recommended to set the X-scale to logarithmic mapping. This can be done in the graphs palette:

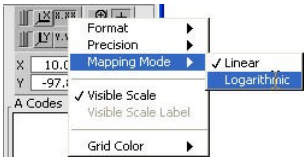


Figure 70: Set X-Axis Scale to Logarithmic

The (D)STC curve of the selected sector can now be viewed like this:

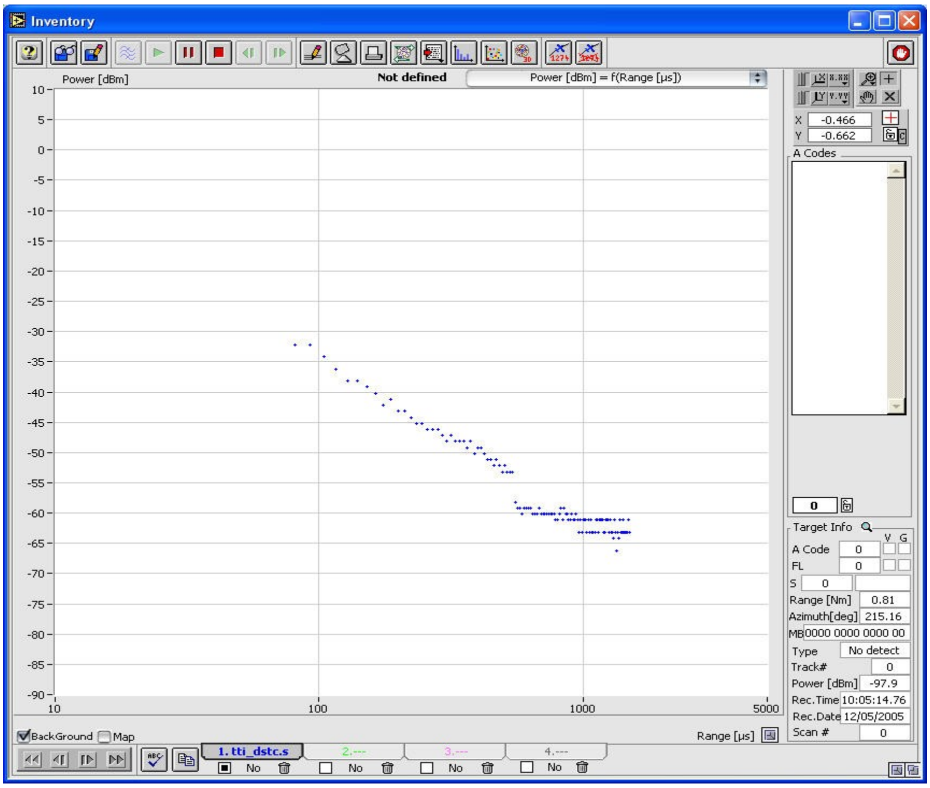


Figure 71: Power vs Time view

5. Downlink Measurement

5.1. Theory

The Downlink measurement enables the user to measure the HPD antenna pattern at reception. The RFA641 is set-up in the field as the RF downlink source transmitting SAM (Synchronous Amplitude Modulated) pulses. In most cases, these pulses are in fact synchronized with the radar's interrogations, to avoid interference with real radar replies and avoid operational impact. The test pulses are then measured at log video level at the output of the (M)SSR or PSR receiver using the RIM782 (further explanation can be found in the RIM782 manual). This chapter will explain the function of the RFA641 in the downlink measurement.

5.2. Getting Started

When the RIM782 is set-up at the radar site according to the RIM782 manual, it is time to set-up the RFA641 in the field (the same location as for an Uplink measurement can be used, tips to find a good location can be found in section 3.1.). The set-up is shown in Annex 7: RFA641 Downlink Connection Diagram. When the RFA641 is set-up, open the Uplink tool from the RASS-S toolbox using the ***Uplink*** button.

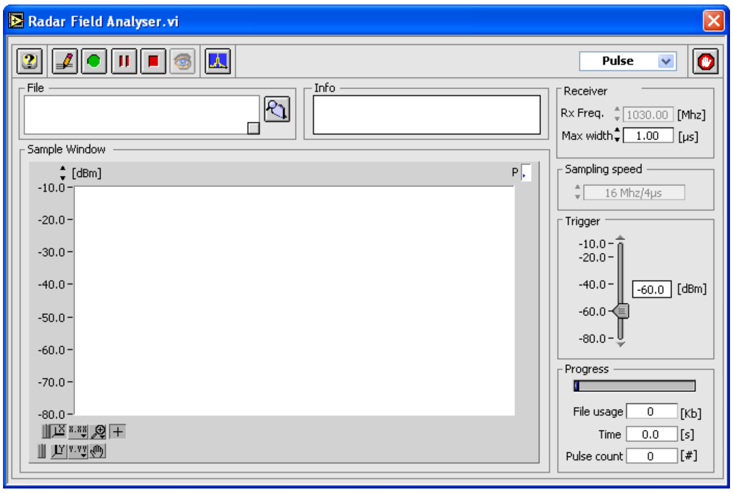


Figure 72: Uplink Software

5.3. Software

1. The Uplink program contains 4 different programs which can be selected via the selector shown in figure 9. For the downlink function the ***Transmit*** program needs to be selected as it transmits pulses or CW using the RFA641's transmitter. As soon as the ***Transmit*** program is selected, the HPD_Preferences window will pop up (this window can also be evoked using the ***Preferences*** button) at the Downlink settings tab.

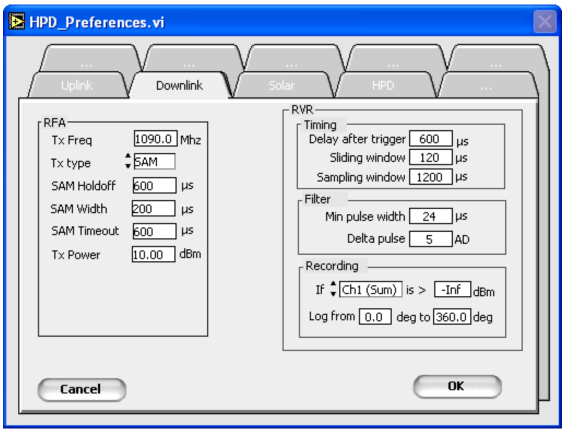


Figure 73: Preferences window

2. Several settings can be changed, such as the width of the pulses, Tx power,... The ***Tx type*** selector can be switched between SAM and CW signals. When you have changed the settings according to your wishes, click ***OK*** to return to the ***Uplink*** program.

3. The Uplink program will show the transmitted signal and warn you of the fact that the RFA is now transmitting.

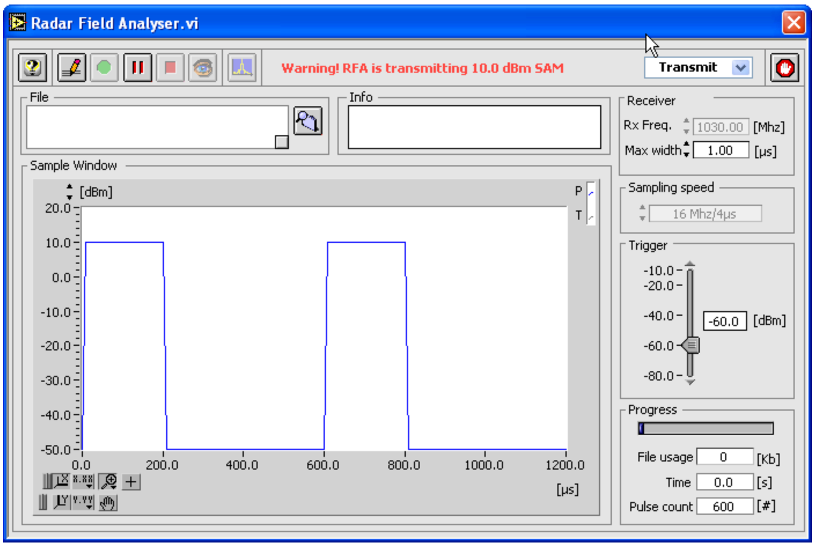


Figure 74: Uplink program transmitting SAM pulses (default settings)

The RFA641 is now transmitting the requested signal, the RIM782 at the radar site can start recording the signal which is picked up by the radar under test.

Caution: Always warn the people at the radar site of the fact that you will be transmitting a signal for test purposes. It is advised to use the antenna cable as on/off switch to guarantee a limited transmission time. Avoid interference to other users on the same frequency.

6. Remote Field Monitor

6.1. Theory

The Remote Field Monitor function is available for both the Radar Field Analyser and the RF Maintenance Unit (RMU484). It consists of a programmable transponder function capable of supporting Mode 1,2,3/A,C interrogation modes. The software supports to set up a fixed target or a target following a programmable radial scenario.

6.2. Getting Started

The ***Remote Field Monitor*** function is loaded from the RASS-S Toolbox using the ***RFM***  button (in the list the function is called ***RFA&RMU Remote Field Monitor for SSR***).

Make the connections as shown in Annex 8: RFM Function Connection Diagram.

The RMU/RFA is connected to the antenna using a 20dB coupler (ZFDC-20-5). The interrogations received from the antenna are injected in the input port of the coupler. The coupler port is connected to the SSR Rx input (RMU) or through the YIG filter to the transceiver Rx port (RFA). Add sufficient attenuation if required to get within the RMU/RFA Rx input range. The Tx output of the RFA/RMU is connected to the Out port of the coupler in order to be able to transmit through the antenna.

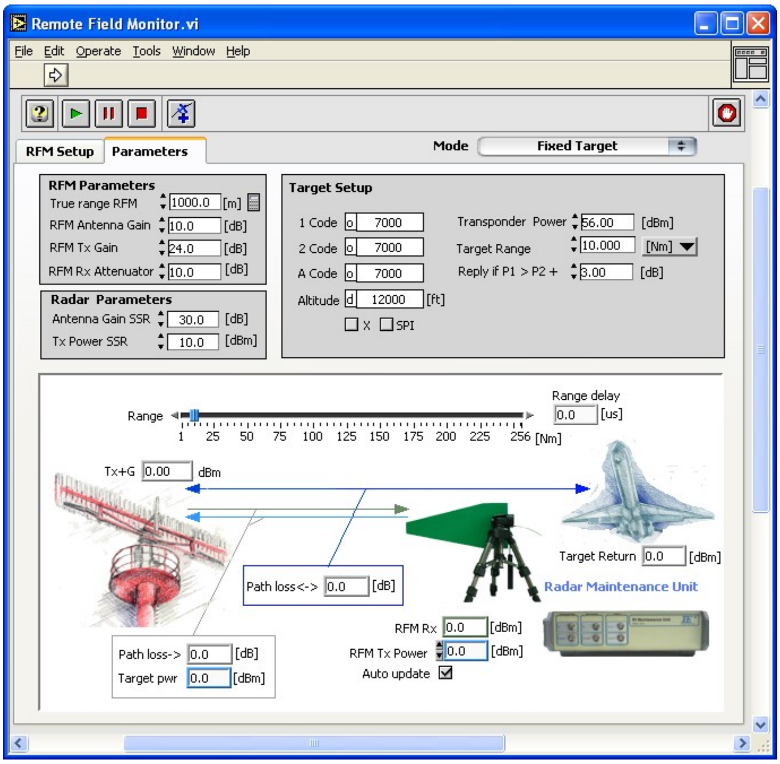


Figure 75: Remote Field Monitor software

6.3. Parameters

The power levels at the different locations will be recalculated in function of the set parameters and the delay of the target.

6.3.1. RFM Parameters

- True Range RFM : Physical range of the RFM
- RFM Antenna Gain : Gain of the external antenna of the RFA or RMU.
- RFM Tx gain: This consists of the gain of the external amplifier if present.
- RFM Rx Attenuator. External attenuator added to the input

6.3.2. Radar Parameters

- Antenna Gain SSR: Antenna gain or the IFF antenna
- TX Power SSR : Tx Power of the interrogator

6.3.3. Target Setup

- 1 Code : Reply Code for Mode1 Interrogations
- 2 Code : Reply Code for Mode2 Interrogations
- 3/A Code: Reply Code for Mode A Interrogations
- Altitude: Generates corresponding reply Code for Mode C Interrogations
- X: Switch X-bit on
- SPI: Switches the SPI bit on
- Transponder Power: Typical transponder power
- Target Range:Actual range of the target. Is used in the radar equation to calculate pathloss. Using the physical range of the RFM the extra delay that is required is calculated in order to generate the target at the correct range.
- Reply condition Sets the power difference between P1 and P2 required to start replying.

6.4. Software

Click the ***Start*** button to start the RFM function.

Using the trigger level, the minimum level for the detection of interrogations can be set. For each valid interrogation detected the beeper will be activated, so you will have an auditive feedback of the RFM operation.

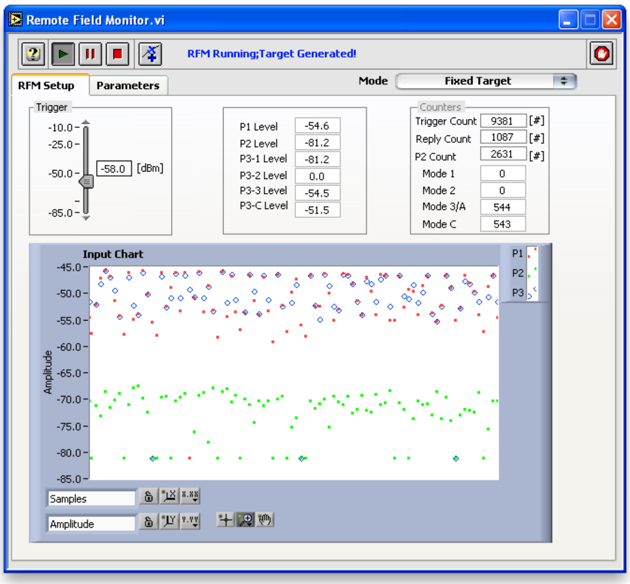
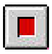


Figure 76: Adjust trigger level (RFM Setup)

A number of indicators display the detected interrogations:

- The level indicators show the instantaneous levels of the interrogation pulses as they are identified as P1, P2 or P3. For P3 the levels are indicated depending on the detected interrogation timing.
- Trigger Count: Each valid pulse is indicated in the trigger count.
- Reply Count: Incremented each time a reply is sent
- P2 Count: Single pulses and pulses that correspond to the 2 microsecond delay for a P2 pulse are counted
- Mode 1,2,3/A,C: Counter for the specific interrogation modes detected (and replies sent).

To stop the RFM operation, click the ***Stop***  button. In case you want the RFM to keep on running but want to disconnect the computer, you can simply click the ***Done***  button. The software will stop without however stopping the device's RFM operation.

The RFM can also operate in a moving target mode where it will fly a simulated target in range from the radar. This is invoked by selecting ***Moving Target*** in the Mode selection on the ***Remote Field Monitor.vi***. When selected the ***Define Speed Scenario*** window will be invoked.

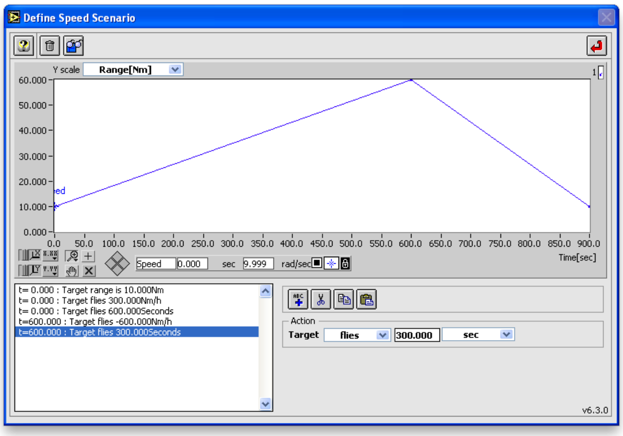


Figure 77: Define Moving Scenario

Define the moving scenario by compiling a series of simple sentences. Once the scenario is complete click the ***Return*** button. Save the scenario when prompted by the LabVIEW dialog boxes. Run the scenario by clicking the ***Start*** button. If a scenario is already running, the RFM should be restarted by clicking the ***Stop*** button and then the ***Start*** button.

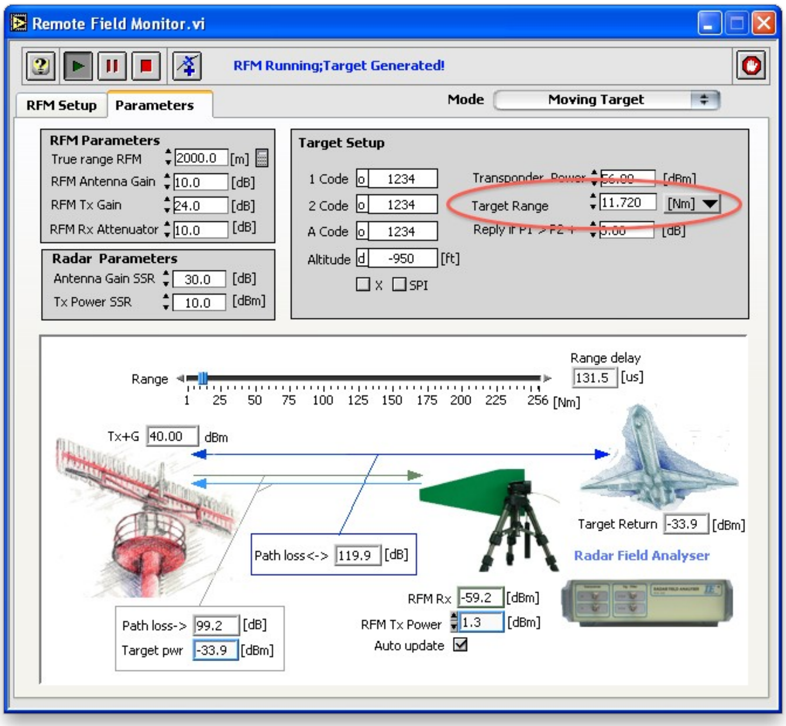


Figure 78: Remote Field Monitor – Moving Scenario

When the scenario is running the ***Target Range*** will change in accordance with the scenario. Path loss parameters will automatically be adjusted to recreate a realistic moving target.

7. Out Beam Interference Generator (FRUIT)

7.1. Theory

The generation of FRUIT can be performed by the RES28x and the RFA641. The RFA Interference Tool is intended for generation of out beam FRUIT and/or CW interference scenarios. The RES Interference tool is intended for generation of in beam FRUIT and/or CW interference scenarios in case where 3 RES channels for target injection are sufficient. This section explains the ***RFA Interference Tool***

All tools have an easy to use identical MMI to enter the interference specifications. After compiling, the scenario is downloaded to the Radar Field Analyser (RFA641) for injecting the interference signals in the RF section of the radar.

7.2. Getting Started

The ***Out-beam Interference Generator (RFA)*** can be loaded from the RASS-S Toolbox using the ***Scenario Generation SSR***  button.

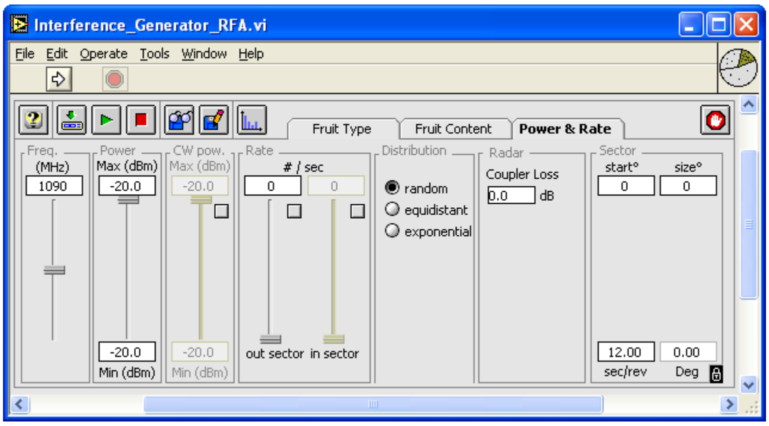


Figure 79: Interference Generator software

When you run the RFA fruit generator and no equipment is connected, you will see a warning message:

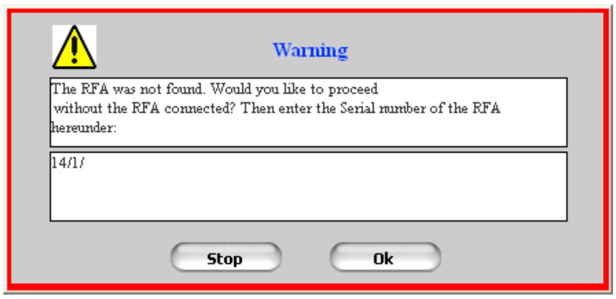


Figure 80: Warning message: RFA not found

Filling in the serial number allows you to perform the scenario generation without the equipment being connected.

Set-up the RFA641 as shown in Annex 9: Out-beam Interference Generation Connection Diagram.

7.3. Software

The Interference Generator software is used to set FRUIT Type, FRUIT Content, and Power and Rate to select the characteristics of the out of beam FRUIT to be generated by the RFA641. The Interference Generator window has three tabs (***Fruit Type***, ***Fruit Content*** and ***Power & Rate***) which can be selected.

At start up the controls on the front panels are in their default setting. The default front panel is the ***FRUIT Type*** panel. All controls can be set in randomly order, no hierarchical or chronological order has to be respected.

Notice that the top row buttons are identical for the three panels. These buttons perform a number of functions to operate the Interference Tool. When the correct settings are made you can download the interference scenario to the RFA641 using the ***Download*** button. Notice that the ***Download*** button is dimmed during the first three revolutions after the start up of the Interference Tool. Therefore no interference scenario can be downloaded to the RFA641 during that time. The scenario can then be started using the ***Play*** button and stopped using the ***Stop*** button.

The ***Save*** button allows the user to save the scenario to disk such that the scenario can be re-loaded in a later stage using the ***Load*** button.

The lock in the right bottom corner must be switched on in case the Interference Generator has to lock onto the ARP signal coming from the radar under test (which is surely the case when a sector is used).

Once an interference scenario is running on the RFA641, the Interference Tool can be stopped using the ***Done*** button (without hitting the ***Stop*** button first), the USB connection can be disconnected and the workstation can be switched off. The RFA641 keeps playing the scenario as long as it is powered.

7.3.1. FRUIT Type

When selecting a FRUIT composition in the ***Fruit Type*** tab, the software will recalculate the ***Fruit Rate Limit*** which is displayed in the left corner of the FRUIT Type window.

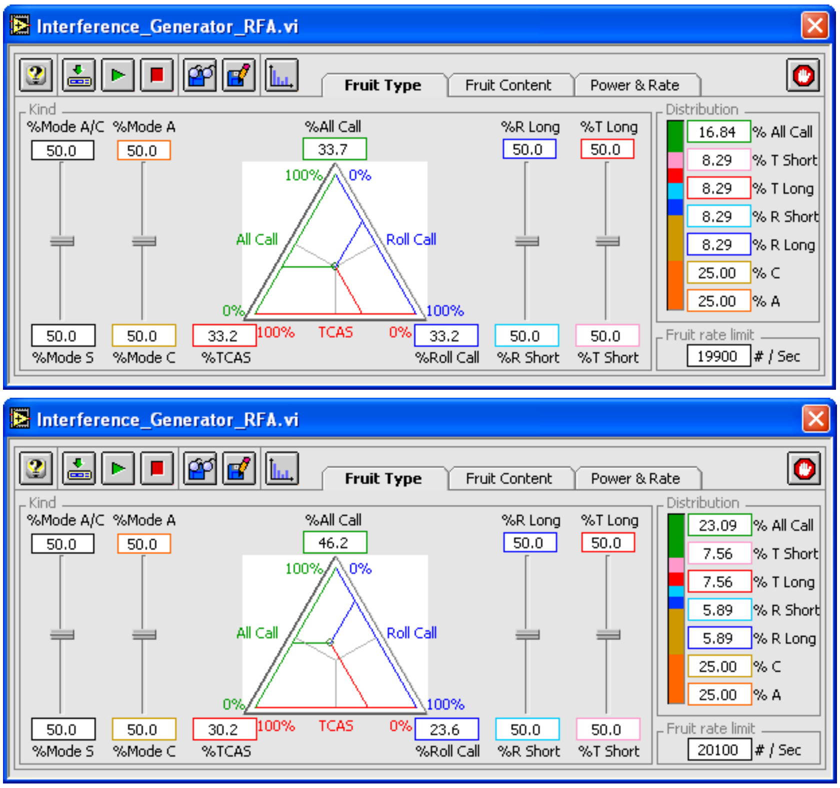


Figure 81: Recalculating Fruit Rate Limit

Calculation of this limit is performed according to the selected percentage of each type of FRUIT and the associated reply duration. In the tests is always a test at maximum rate included.

On the ***FRUIT Type*** panel, the following settings are possible:

- Percentage of Mode S and Mode A/C FRUIT.
- Percentage of Mode A and Mode C FRUIT for the percentage of Mode A/C FRUIT.
- Percentage of All Call, Roll Call and TCAS FRUIT for the percentage of the Mode S FRUIT. The percentages can be changed by moving the intersection point of the green, red and blue line in the triangle.
- Percentage of Long Roll Call and Short Roll Call FRUIT for the percentage of the Roll Call FRUIT.
- Percentage of Long TCAS and Short TCAS FRUIT for the percentage of the TCAS FRUIT.

All percentages are instantaneously calculated and updated when new settings are chosen. The ***Distribution*** indicator displays a graphical overview of all the settings on the FRUIT Type panel.

The ***FRUIT rate limit*** indicator shows the maximal number of FRUITs per second for the chosen settings.

7.3.2. FRUIT Content

The ***Fruit Content*** tab allows you to select the code information contained in the generated FRUITS. For both Mode A en Mode C, a limited code group or the complete code group can be randomly generated. For Mode A FRUITS the possibility is available to generate A codes with a minimum number of bits. For Mode-S, the II code contents can be selected, in percentage. The codes inserted into the II fields to be generated randomly can be selected using a checkbox. The relevant information to these tests is the Mode A information. It is setup so that only A code 7777 is generated. The other settings are left default.

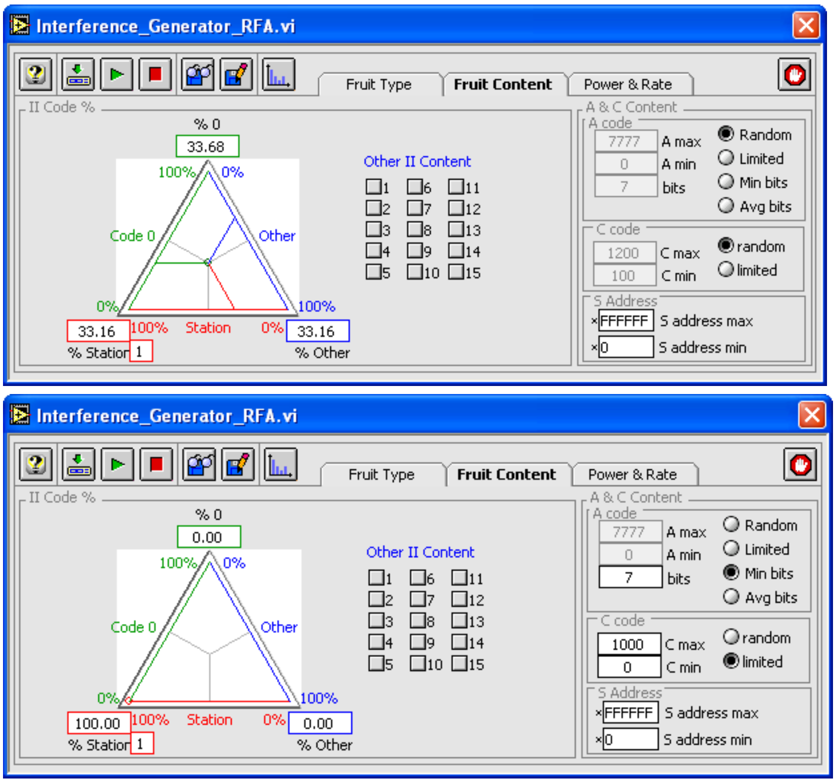


Figure 82: FRUIT Content set-up

On the ***FRUIT Content*** panel, the following settings are possible:

- Percentage of station II code, “0” II code and other II codes in the Mode S FRUIT. The stations II code can be set in the Station II code control at the lower left corner of the triangle. Several other II codes can be selected by clicking their respective check boxes in the ***Other II Content*** control. The percentages can be changed by moving the intersection point of the green, red and blue line in the triangle.
- For the content of the mode A FRUIT, there is a choice between a random distribution using the whole range of legal A codes (***Random***), a random distribution over a limited set of A codes (***Limited***) and a random distribution of A codes with a minimal number of bits set (***Min bits***). The boundaries for the limited set of A codes can be set using the ***A min*** and ***A max*** controls. The minimal number of bits to be set can be selected using the ***bits*** control. When the random button is chosen, the A min, A max and min bits controls are dimmed.
- For the content of the mode C FRUIT, there is a choice between a random distribution using the whole range of legal C codes (***random***) or a random distribution over a limited set of C codes (***limited***). The boundaries of the limited set of C codes can be set using the ***C min*** and ***C max*** controls. When the random option is chosen, the C min and C max controls are dimmed.
- For the content of the Mode-S FRUIT, the S addresses are randomly selected between the ***S address max*** and ***S address min*** parameters.

7.3.3. Power & Rate

The ***Power & Rate*** tab allows you to select ***Generation Frequency***, ***Max. and Min. Reply Power***, ***Max. and Min. CW Power***, ***Reply Rate*** in a defined sector and out of that sector, and ***Reply Distribution vs. time***. CW signals will only be generated in a defined sector.

A sector can be defined at the ***Sector*** section at the right of the window. The dial represents one complete revolution and the instantaneous angle is continuously indicated. The revolution time can be selected (default 12 sec) and at the top portion the start angle and the sector size can be filled in. The selected sector is indicated in green.

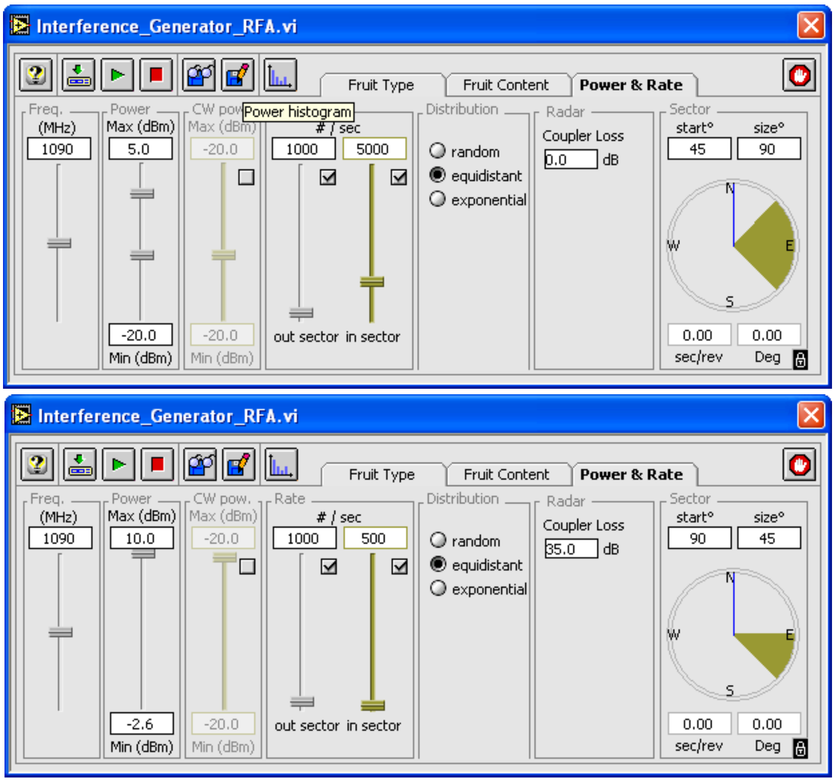


Figure 83: Power & Rate set-up

On the ***Power & Rate*** panel, the following settings are possible:

- Carrier frequency of the FRUIT and CW.
- The FRUIT power is randomly generated, defined by a uniform range distribution between the ***Min*** and ***Max*** boundaries in accordance with a 20 dB/dec propagation law. The minimum and maximum power values are the powers at the radar input. To determine these correctly, the software needs the user to input the coupler loss between the output of theRFA and the input of the Radar.
- The CW interference power is randomly distributed between the ***Min*** and ***Max*** boundaries. When the minimum differs from the maximum, the amplitude of the CW interference signal changes at a 2 KHz rate. CW interference can only be generated “in sector”. The CW interference can be switched off with the check box.
- There are two different sectors for the generation of interference: ***in sector*** and ***out sector***. The ***in sector*** and ***out sector*** FRUIT rates can individually be switched off with their respective check boxes. Notice that the combination of FRUIT and CW is only possible in sector. The time gaps between the FRUITs are then filled with CW interference.
- It is possible to chose between a ***random***, an ***equidistant*** or an ***exponential*** FRUIT distribution in time. The Interference Tool can not generate overlapping FRUIT. Therefore inter arrival times (exponential distribution) smaller than the previous FRUIT length are not possible.
- The ***in sector*** is defined by a ***start*** angle and a ***size*** angle and is represented in a different colour on the azimuth indicator in the ***Sector*** section. The ***out sector*** is then automatically the full circle minus the ***in sector***. The blue line in the azimuth indicator indicates the current azimuth which is also digitally indicated below the analog azimuth indicator. There are two different methods of ACP/ARP generation for the RFA FRUIT generation. Either the revolution speed of the Interference Tool is set with the ***sec/rev*** control. In this case ACP and ARP are generated internally and the Interference Generator runs asynchronous to the radar. The other possibility is to slave the Interference Tool on the ARP/ACP of the radar under test with the ***lock to ARP*** button in the lower right corner of the PPI indicator. In this case the ARP/ACP of the radar under test is used to synchronize the interference scenario. The ARP/ACP of the radar can be fed to the RFA641 through the digital input on the back panel.

8. RFA Transponder Interrogator

8.1. Theory

The Radar Field Analyser RFA641 is used together with the necessary test software to send out interrogations. The output interrogation power level of the RFA641 is limited to 17 dBm (50 mW) minus 10 dB attenuation of the external attenuators. Therefore the real interrogation power send by the device is 7 dBm (5mW). The air link with the transponder will attenuate ± 60 dBm, bringing the power at the input of the transponder at ± -53 dBm, which is comparable with radar operation. In case you want to connect the transponder directly just replace the air link by 60dB of attenuation capable of handling 250W peak power.

8.2. Getting Started

The ***RFA Transponder Interrogator*** is loaded from the RASS-S Toolbox using the ***Transponder***  button.

Make the connections as shown in Annex 10: RFA Transponder Interrogator Connection Diagram.

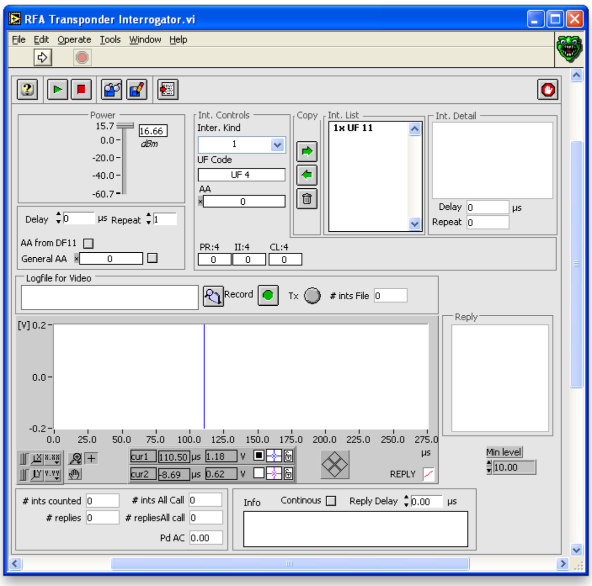


Figure 84: RFA Transponder Interrogator software

8.3. Software

The transponder test software consists of two tools. The ***RFA Transponder Interrogator*** allows to construct an interrogation sequence (schedule) and save it to disk for later use and analysis. The interrogation schedule can be played, and simultaneously the transponder reply video is sampled and stored to disk.

The ***View Transponder Test Data*** program allows to visualise the transponder replies against the sent interrogations.

8.3.1. RFA Transponder Interrogator

1. The ***Power*** control allows to set the Tx Power for the interrogations. The control directly changes the Tx output Power. The Tx Power is not set by the interrogation schedule itself.

2. To define the interrogation schedule, the following general controls are available:
   - Delay: delay between the successive interrogations
   - Repeat: # of interrogations of this type
   - AA: Mode S Aircraft Address Used by default when selecting a Mode S interrogation. This can be user defined or derived from a DF11 reply in case the ***AA from DF11*** check box is checked.

3. For each interrogation a number of detailed specific settings must be defined:

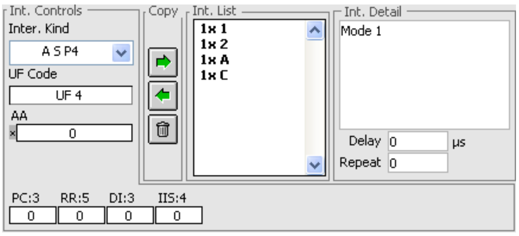


Figure 85: Interrogation Controls

First of all the interrogation controls must be set. These allow you to select the interrogation type:

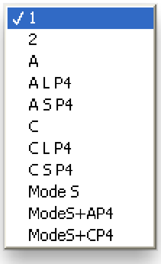


Figure 86: Interrogation Type

The following Uplink formats are supported:

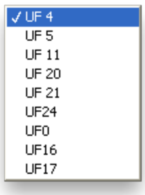


Figure 87: RFA Transponder Tests – Uplink Formats

An aircraft address specific for the interrogation can be entered. Upon changing the UF format, the fields specific for that format will be presented:

1. UF4, 5, 11, 20, 21 specific interrogation fields

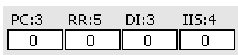


Figure 88: Specific Interrogation Fields

2. UF20,21 additionally the MA data field becomes available

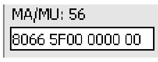


Figure 89: MA Field

3. UF24 specific interrogation fields

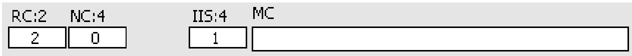


Figure 90: UF24 Fields

5. Now build an interrogation list. A number of controls and related fields are present to allow the user to create an ***Interrogation List***. Once the general parameters, the Interrogation type, format and field data are entered, the interrogation can be entered in the ***Int. List*** by clicking the ***In*** button.

   The interrogation type and number of interrogations are entered in the list, the details of the selected interrogation are copied to the Int. Details, Delay, and Repeat fields.

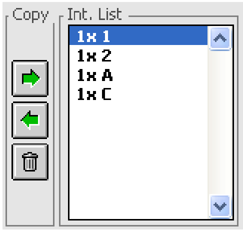


Figure 91: Interrogation List

   To enter an additional interrogation into the list, setup the interrogation parameters and click the ***In*** button again. The interrogation will be added after the last interrogation. If the interrogation is selected (highlighted) in the Interrogation list, pressing the ***In*** button will replace the old interrogation with the new one.

   A selected interrogation can be copied to the interrogation controls using the ***Out*** button. Both general fields (repeat, delay) and interrogation fields (in case of a Mode-S Interrogation) will be copied.

   Pressing the ***Delete*** button removes the selected interrogation from the list.

6. Once a list of interrogations is entered it can be saved to disk by clicking the ***Save*** button and recalled whenever needed. The file will be saved in the ***Interrogations*** subdirectory of the active campaign folder. This way a number of interrogation lists can be created for each specific test you want to perform.

7. When using the tool a next time, the interrogation list can be loaded with the ***Load*** button.

   A file dialog is presented, pointing to the ***Interrogations*** directory of the active campaign folder, listing the interrogation files already created. Select a file and click ***OK*** to load the required interrogation list.

8. An important function of the transponder interrogation tool is sampling, visualising and (when a logfile is selected) logging of the transponder replies. First of all you can play the interrogation list by clicking the ***Start*** button. For each interrogation in the list the data is sampled and displayed in

the ***Reply Video*** window. The last reply will be visible at the end of the sequence.

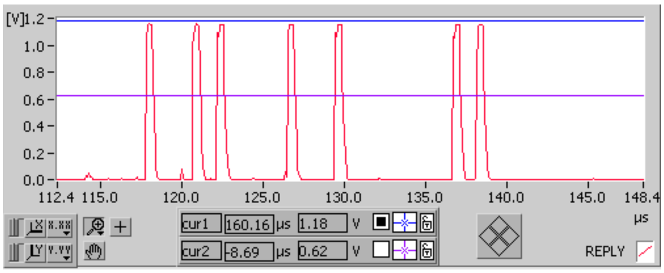


Figure 92: Reply Video window

The sampling window is 256µs. The reply delay can be set according to the range of the transponder under test. In case you want to replay the interrogation list over and over, you can switch on the ***Continuous*** check box. When the end of the list is reached, the program starts over from the beginning.

A number of counters are updated for each interrogation sent out:

- #ints counted : number of interrogations sent
- #replies : # of replies detected.
- #ints All Call: number of All Call Interrogations sent
- #replies All Call: number of All Call Replies detected.
- PdAC: #replies All Call/#ints All Call

The reply is also decoded and the reply data is displayed in the ***Reply*** field.

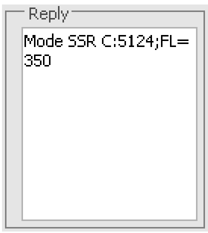


Figure 93: Decoded Reply Video

9. Click the ***Select Folder***  button to select a recording folder. A folder dialog will appear. In case no recording folder was defined yet, use the ***New*** button to create a new folder.

   Select the desired folder and click ***OK***. The logging folder is indicated in the ***Logfile for video*** indicator. Automatically the program is armed for recording, as indicated by the ***Record***  button.

   The ***Ints File*** field indicates the number of interrogations recorded in the logfile. When the ***Start*** button is clicked, the interrogation list is played. For each interrogation the reply video is sampled and stored to a logfile. The logging automatically stops when the last interrogation was sent out. During transmissions the ***Tx Indicator*** will be red.

Figure 94: Reply Video Logging

Each time the ***Start*** button is pressed, a new logfile is automatically created in the logging folder. The file name is automatically created as 'Folder name_yymmdd_hhmmss' where Folder name consists of the first 14 chars of the selected folder to contain the files, put in lowercase, yy for the year, mm for the month, dd for the day, hh for the hour, mm are the minutes and ss the seconds.

10. The last played interrogation schedule and related transponder reply data can be exported to a tab-separated list. By clicking the ***Export***  button, the print tables.vi will pop up containing the following information:

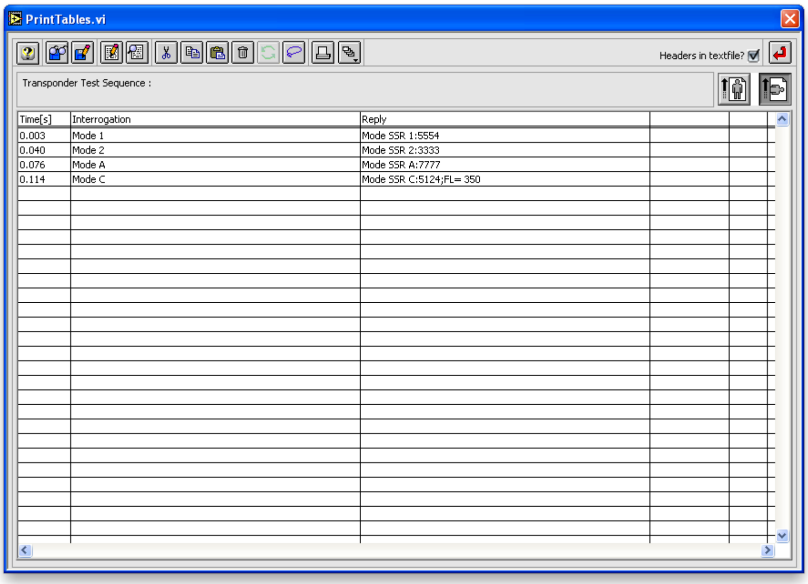


Figure 95: Print Interrogation Tables

8.3.2. Viewing the logged Interrogation-Reply Data

The ***View Transponder Test Data*** program allows to page through the successive interrogations and the corresponding transponder replies. The program can be opened from the RASS-S Toolbox using the ***Transponder***  button.

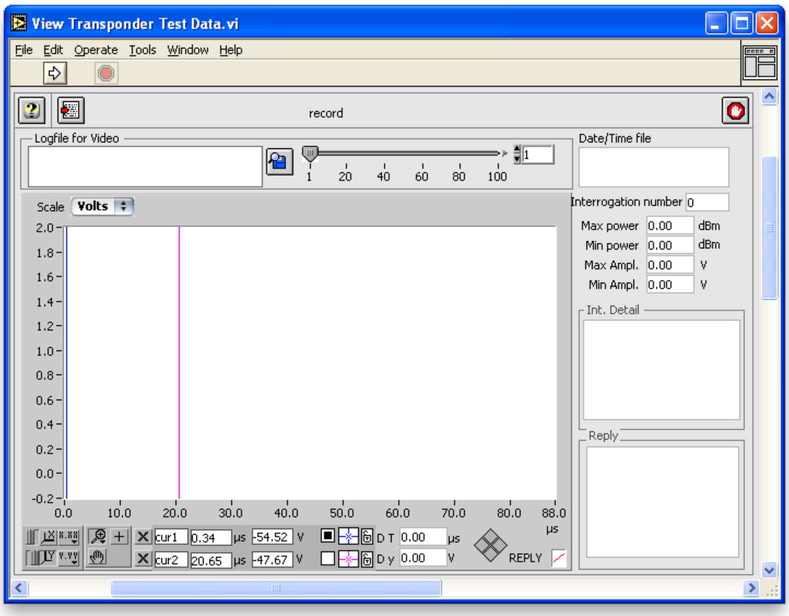


Figure 96: View Transponder Test Data software

1. Load the recorded reply-interrogation file from disk using the ***Load file***  button. A file dialog will pop up, pointing to the ***Interrogations*** subdirectory of the active campaign folder, that normally contains all recording folders available. Open the recording folder of interest and select the file you want to view. Each time the ***Record*** button was pressed in the ***Transponder Interrogator*** software a file was created. Just select the file of interest and click the ***OK*** button.

2. The file is loaded and the index slider is updated according to the number of interrogation-reply pairs available in the logging.

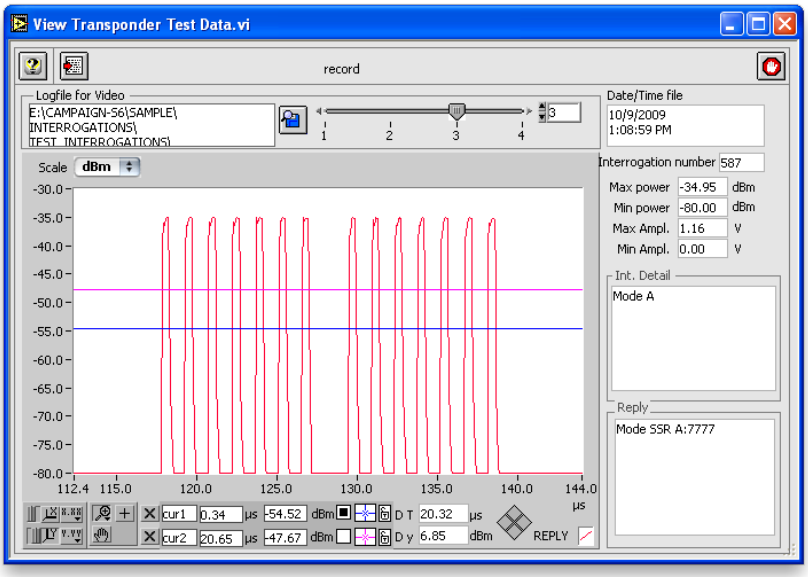


Figure 97: View Interrogation results example

For each index the following information is presented:

- Reply video in Volts or dBm
- Interrogation number
- Max and min reply voltage level and power level.
- Detailed interrogation information.
- Detailed reply information, decoded from the reply video.

The full 256 µs window is stored for each interrogation, so it can contain the full Mode S reply waveform. Video can be viewed in voltage or dBm power according to the receiver used for the logging (RFA receiver). Select the interrogation of interest by moving the index slider. The info will be updated accordingly.

9. RFA for ADS-B Main Control

9.1. Theory

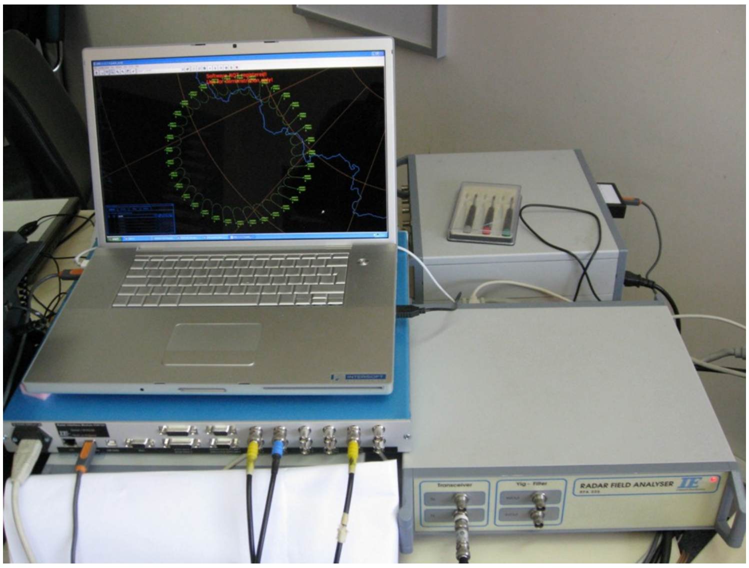


Figure 98: RFA641 connected to RIM782 showing the ADS-B plots on a laptop

As an example a simple scenario with 36 targets in a circle, flying outbound and making predefined movements is shown below.

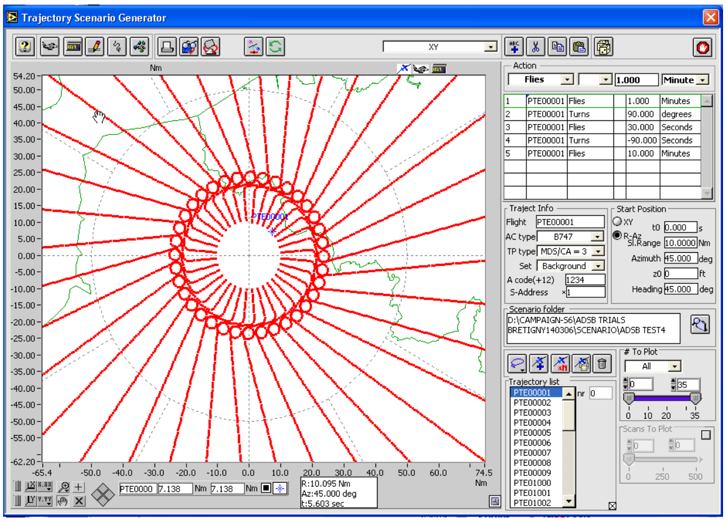


Figure 99: Test scenario definition and transponder properties

Then the scenario is compiled and played using the ***RFA ADSB control*** tool. The output of the ADS-B ground receiver, send using a UDP-Broadcast data stream of ASTERIX cat 21, is recorded using a separate laptop.

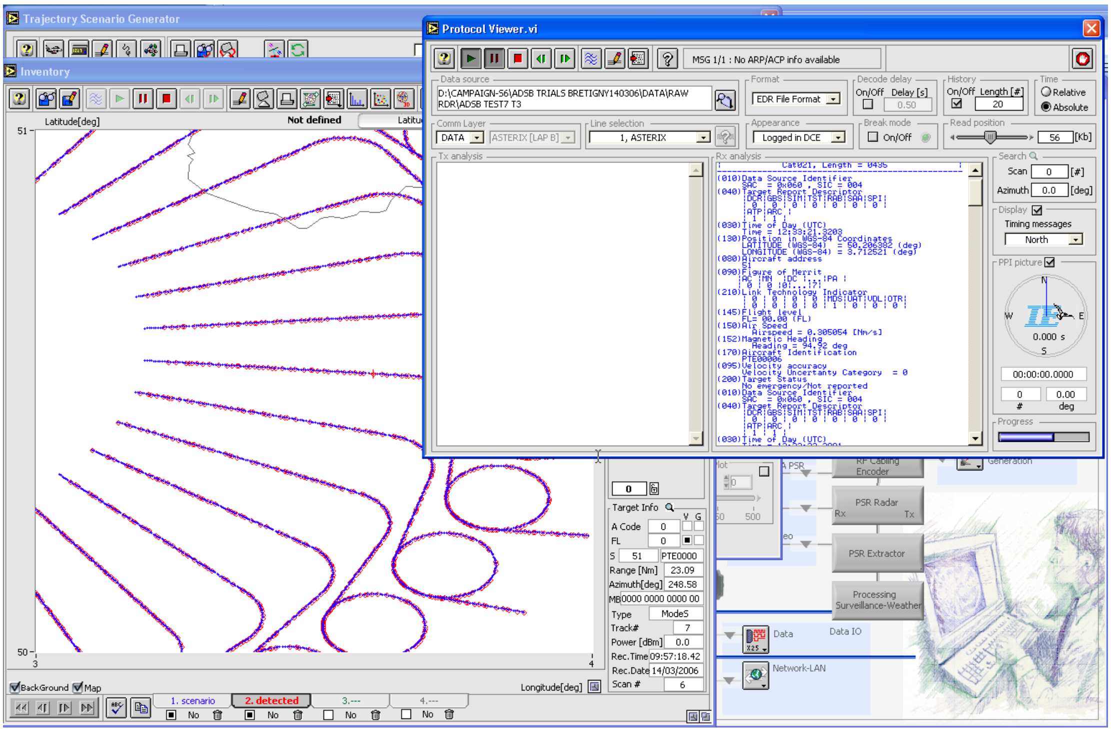


Figure 100: RASS-S analysis tools showing ADS-B cat 21 data of heavily garbled squitter replies

The ASTERIX cat 21 was then converted into an S4 file, allowing it to be visualized and verified in the ***Inventory*** tool. The details of the cat 21 can be verified in the ***Protocol Viewer*** tool and the Pd and Accuracy can be evaluated using the ***Pd and Accuracy tool for ADSB***.

Once the two datasets, scenario and detected ASTERIX are visualized in the Inventory tool, it becomes easy to calculate Pd of detection, accuracy, etc. from this data. Obviously, the tests can be repeated several times, to provide average values of detection probability.

Upon designing the ***RFA ADSB control*** tool, we used the RTCA DO-260 and DO-260A documents, which describe the “Minimum Operational Performance Standards for ADS-B and TIS-B 1090 ES Extended Squitter” as a reference.

In real life, ADS-B ground/airborne receivers have to cope with heavily polluted environments with FRUIT replies, both SSR and Mode S, but also other signal types like DME. Although the possibility of generating these garbling signals is integrated in the RES it was not possible to integrate them in the RFA641 as well, since the RFA has641 only one target generation board.

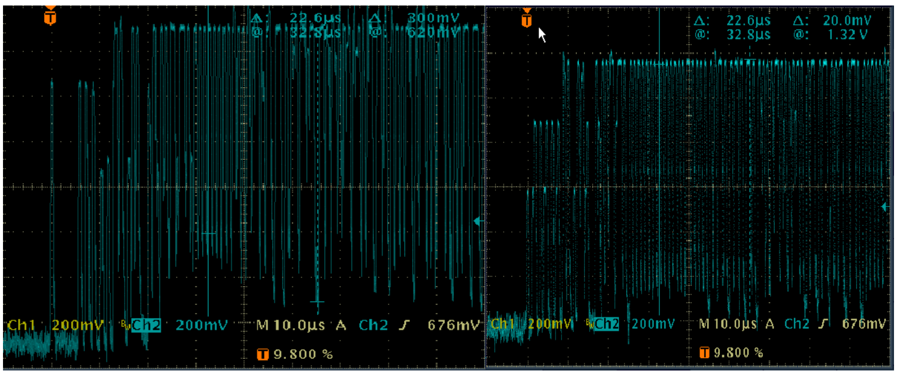


Figure 101: ADS-B extended squitter replies with 9 overlapping SSR replies

Different test scenarios can be generated, (according to RTCA DO260/260A) with different levels of interference signal load, level, power, position in squitter reply, etc… In each of these cases, a different detection level is to be expected.

9.2. Key Specifications

9.2.1. General Specifications

- Max nr of targets : 2048 but limited by sequential nature of ADS-B replies, max. 7500 replies can be generated per second
- Max number of replies 3978 / second
- Nr of independent target generators: 1
- Max nr of overlapping Targets (garbling simulation): 1
- FRUIT generation with 2nd RFA: Up to 22000 Fruits/sec (not simultaneous with ADSB)
- ProgrammableFixed target frequency : 1090 Mhz.
- Target power output: +15..-45dBm at RFA output-30..-90 dBm at ADSB Rx input
- -25..-85 dBm at sensor input
- Full simulation of Horizontal and Vertical Mono-pulse SSR Antenna or ADSB Omni- antenna diagram
- Path Loss simulation with Aircraft antenna modelling

9.2.2. Target Types

- Transponders programmable squitter rates for Airborne/Ground velocity, position and ID squitters.
- Supports DF 11, DF17 and DF18 squitters
- Transponder power programmable
- ICAO Annex 10 am 77 compliant Transponders logic and RF signals
- RTCA DO-260A compliant squitter reports

9.2.3. Scenario

- Simulation of straight flights, turns, accelerations, climbs, descends, static targets, accelerated turns, etc…
- Programmable rates for Velocity, Position and ID reporting in squitters.
- Programmable S address per target
- Programmable TYPE and Subtype values, linked with NIC and Rc
- In flight Code changes, Emergency codes, SPI, etc …
- Programmable Status message squitters
- Automatic Generation of load models and other example scenarios
- Simulation of sensor output data (ASTERIX cat 21)

9.2.4. Recording

(requires additional hardware)

- Using UTC time-stamping (GPS)
- Recording of serial radar data(RDR803 or UDR600)
- Recording of LAN radar data (UDP-IP or TCP-IP) through host-PC LAN port
- Recording of generated video signals (RIM782)

9.2.5. Analysis

- Analysis of Accuracy, Resolution behavior, Pd, Sensitivity
- Automatic comparison
- Visualization of Video data

9.3. Software

9.3.1. Trajectory Scenario Generator

More information regarding the Trajectory Scenario Generator can be found in the RES user manual (section 9.10.4).

9.3.2. Running the Compiled Software

The RFA set-up is shown in Annex 11: RFA for ADS-B Connection Diagram.

1. To run a compiled ADS-B scenario, you have to load the ***RFA ADSB control*** tool from the ***ADS-B Rx***  button of the RASS-S toolbox: make sure the RFA641 is connected to the computer and detected in the RASS-S toolbox!

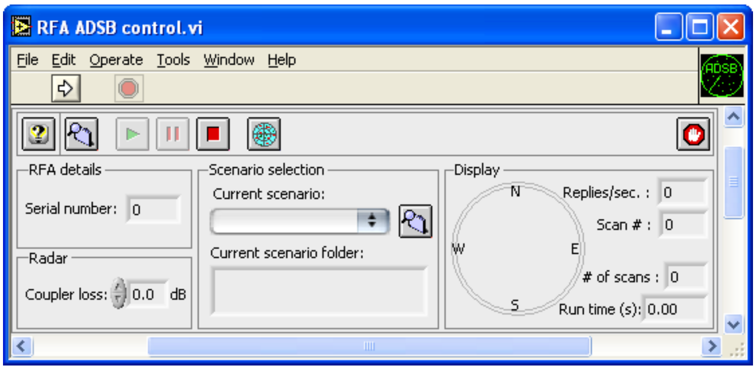
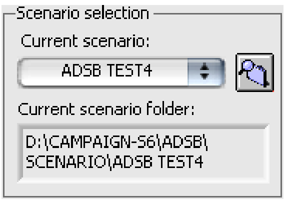


Figure 102: RFA ADS-B Control software

2. Load a scenario using the ***Load scenario***  button .
3. Once the scenario is loaded the scenario name is displayed in ***Current scenario*** and the scenario path under ***Current scenario folder***:



4. Next enter the correct attenuation between the RFA Tx output and the ADSB Rx or radar input in ***Coupler loss***: typically this will be 40 dB.
5. Select if you want to display the targets in the inventory tool (or not) while running the scenario by selecting (deselecting) the PPI button (can't be changed while running).
6. Run the scenario using the ***Play***  button and stop the generation using the ***Stop***  button or pause it using the ***Pause*** button .
7. To select another scenario one can use the ***Load scenario*** button again or select a previous used scenario by clicking on ***Current scenario***.

10. Primary Target Injection

10.1. Theory

The RFA641 will use a number of trigger signals from the radar to generate a simulated target on RF. The TX output of the RFA641 shall be connected to the Radar Under Test (RUT) using a coupler or circulator connected in the reception path of the radar. The RFA641 shall generate a square pulse-shaped return, with a fixed power (depending on the target range) and width. The pulse is created independently from the transmission pulse, so no correlation (e.g. in Doppler speed) between the transmitted pulse and the reception pulse may be expected. Therefore this target injection tool is limited to radars without Doppler processing (although due to the uncorrelated local oscillator of the target generator, the targets generated should pass the Doppler filter banks of such radars).

10.1.1. Calculation of External Attenuation

Please bear in mind to use sufficient attenuation between the radar coupling connection and the RFA641 in order not to damage the RFA641 output. This output can accept no more than 30 dBm (1W) reverse power, so use sufficient attenuation.

A typical application with a 1 MW (60 dBW) power and 30 dB circulator, would still require minimal 30 dB attenuation between the circulator port and the RFA641. From range equation calculations the user can easily determine the exact value required for the external attenuation, but a typical value of 70 dB is acceptable.

The attenuation value is also determined from the dynamic range required for the generation of the scenario. The RFA typically has an output dynamic range of +15 to -45 dB (accurate to 1 dB). This implies that using a 70 dB attenuator, targets between -55 and -115 dBm can be generated.

The following example shows a test flight over 10-100 Nm using a fixed RCS of 1 m^2. Obviously, when RCS is changed or swirling cases are included, the dynamic range may change and the attenuator value should be changed according to the output dynamic range.

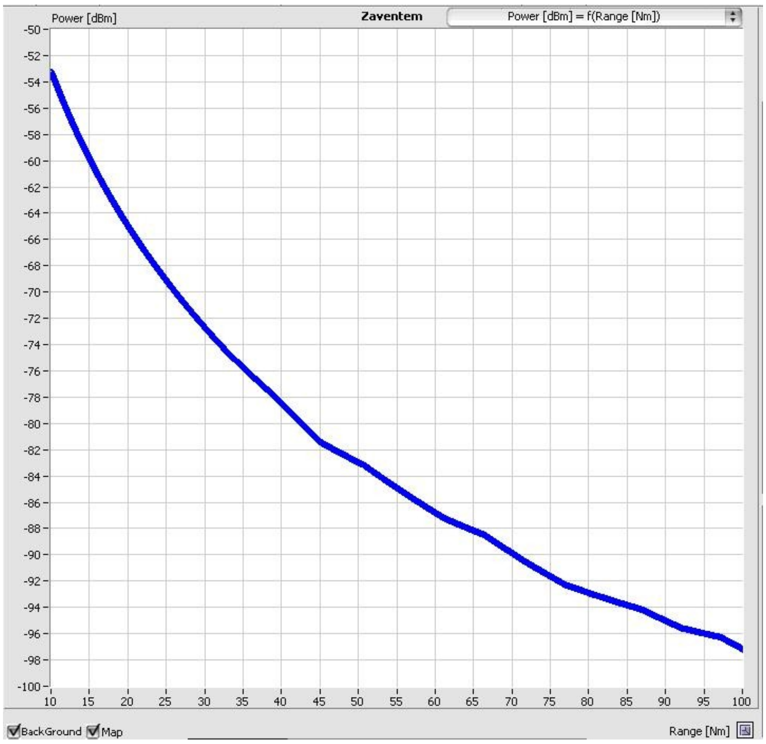


Figure 103: Example test flight

10.1.2. General Concepts

The Target Injection is based on a rather simple principle of generating an echo of precalculated power after a given delay (determined from the target range).

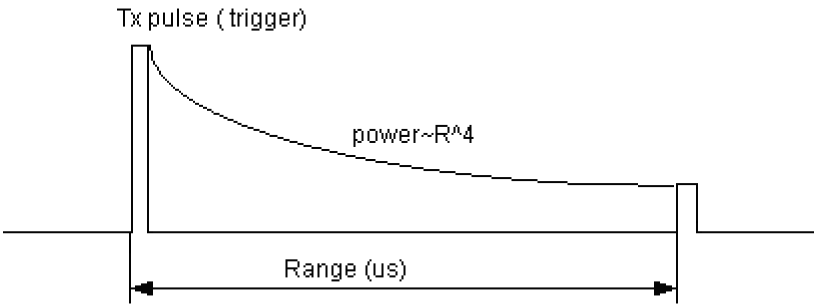


Figure 104: Calculation of echo signal

The azimuth at which the echo is generated is also pre-determined from the scenario, but is recalculated towards the expected interrogation number.

For that purpose, it is important that this target generator can accurately determine the IPR (interrogations per revolutions) of the radar and that this IPR remains stable over time.

The generated target power is precalculated for every azimuth and as such for every interrogation. The power basically is dependant on the range, plus a number of extra programmable parameters.

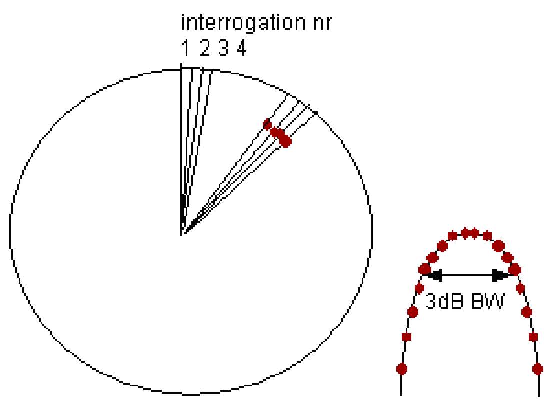


Figure 105: Calculation of target power

The simulator also accurately simulates the horizontal and vertical antenna diagram. The vertical diagram (typically antenna gain versus elevation) can be entered as a VPD diagram (measured as a solar or as import from spreadsheet data) .

The horizontal diagram is calculated as a mathematical parabolic curve with a predefined 3dB beamwidth. Typically, the target is generated over 20 dB dynamic range. Out of beam echos lower than 20 dB are not generated.

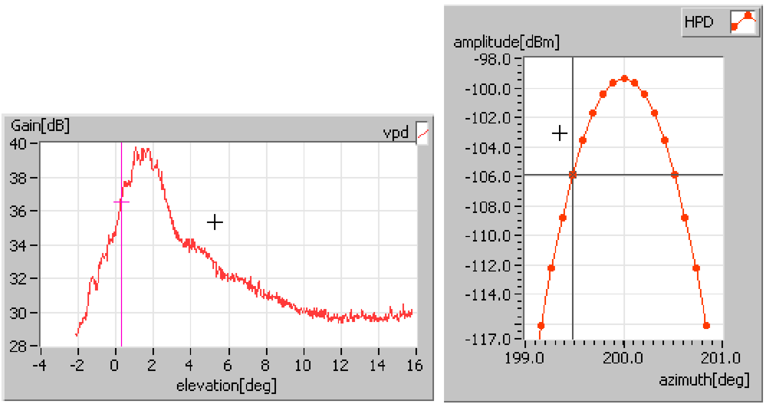


Figure 106: VPD and HPD diagrams

10.1.3. Software Principles

The Target injection tool consists of two software modules, which can both be loaded from the RASS-S toolbox. The first tool is used to create the scenario. This can be performed by opening the ***Trajectory scenario generator*** tool and following the correct instructions for generation of a target generation scenario. All the details of the scenario generator can be found in the RES scenario generation manual.

One should especially take care not to generate overlapping targets, since this it is not possible to generate such targets using this generator.

The PSR target generator typically uses the output (S4TJ) file of the trajectory scenario generator, so the same principles as used for generation of RES targets can be applied. Of course PSR targets do not have an A code or S address, but we advise you to generate a unique A code for every target anyway. This A code can be used for selection of a certain target, e.g. when recording video automatically.

The second tool consist of the actual target injection part and the compiler, which requires a number of steps to be performed:

- Selection of the scenario to be replayed
- Selection of the Vertical diagram of your antenna (Solar curve or import of curve)

- Input of transmission parameters of the radar (power, frequency, gain)
- Input of interfacing parameters of the target injection (beamwidth, pulsewidth, RCS of targets, etc.)
- Booting of RFA641 with automatic detection of IPR (interrogations per revolutions)
- Simulation of one target with live calculation of return power for educational purposes
- Compilation of the scenario with indication of generated power
- Start of scenario replay
- Stop of scenario replay

10.2. Trajectory Scenario Generator

More information regarding the Trajectory Scenario Generator can be found in the RES user manual (section 9.10.4).

10.3. Scenario Replay

10.3.1. Getting Started

The scenario replay requires a number of distinct steps and preparation of a number of files:

- The tool requires a correct Vertical antenna Diagram, in the file format used for PSR vertical diagrams (solars). For this purpose, the solar tool can be used to measure a VPD, or the "View VPD Curves" tool can be used for the editing/importing of any Vertical diagram in the tool.
- The tool requires a site file, which contains the PSR antenna gain (absolute) and the k factor (or vertical earth model). This file can be edited or created from within the replay tool.
- The actual scenario file. This file can be generated by means of the trajectory scenario generator also used for the RES tool. The output file xxx.S4TJ is used to generate the targets. This file can be verified prior to replay using the inventory tool.

The RFA641 set-up is shown in Annex 12: RFA Primary Target Injection Connection Diagram.

Please bear in mind the remarks of section 10.1.1. Calculation of External Attenuation.

Select the software from the ***Scenario Generation***  button on the PSR side of the RASS-S toolbox.

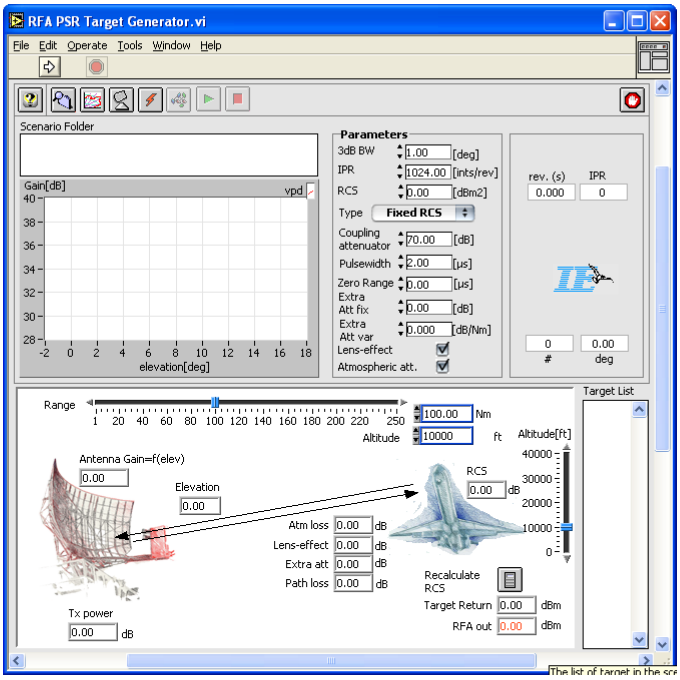


Figure 107: RFA PSR Target Generator

The RFA641 is normally connected to the workstation. If this is not the case, the tool can also be used offline so you can simply check the scenario or use the tool for educational purposes. In case the RFA641 can not be found, following dialog box will be shown:

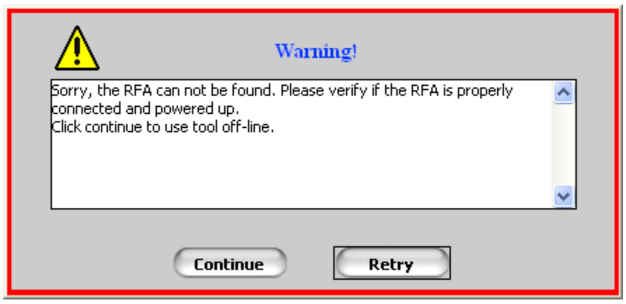


Figure 108: RFA not found warning message

Click on the ***Continue*** button if you want to proceed off line. If not, connect the RFA641 to the USB2 bus and click ***Retry***.

10.3.2. Scenario Selection

Now select a scenario folder ( ) that contains the scenario that was previously compiled in the scenario generator: the file path will appear in the ***Scenario folder*** control.

10.3.3. Vertical Diagram Selection

Next select a Vertical diagram. These can typically be found in the Campaign folder under

PSR:VPD:CURVES and can be evoked using this button: . After selection of the VPD curve, the tool will try to open the ***Site*** file. The site file can be used to enter the Antenna Gain, Frequency of the radar, Tx power and k-factor parameters. These are used to determine the absolute gain of the antenna as a function of elevation of the targets. The gain of Channel 2 and 3 (“Gain Ch2”) is not used in this application, neither is the Rx sensitivity. Select the vertical model (1/1 earth, 4/3 earth, 5/4 earth or custom k factor) to determine the correct vertical refraction. You can save these parameters to the site file for later use using the ***Save*** button. Click ***OK*** once the parameters are set.

Now the selected vertical diagram is shown:

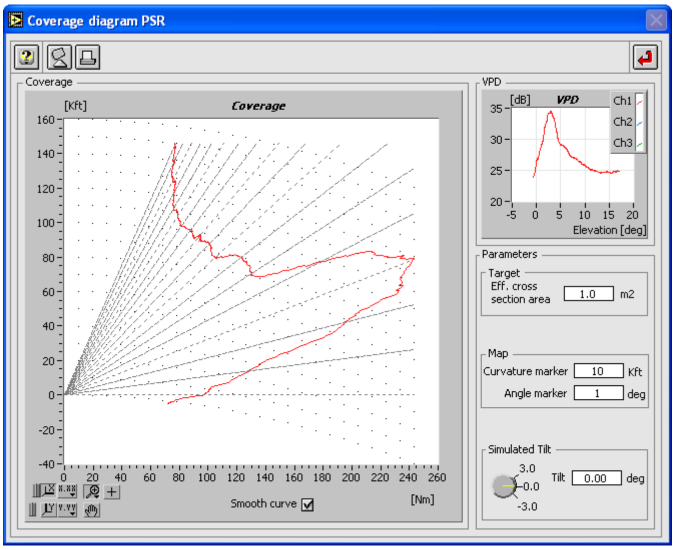


Figure 109: VPD Example

The tilt of the VPD can be modified (electrical tilt) by turning the ***Simulated tilt*** knob on the coverage diagram PSR window. Close this window by clicking the ***Return*** button.

10.3.4. Parameter Setup

Now enter the other parameters for the simulation: IF Tx power, Gain, Frequency or k factor still need modification, you can evoke the site file once more by using the ***Site file*** button. Other parameters should be entered in the main window of the RFA PSR Target Generator.vi:

- ***Tx Power [dBW]*** : the transmit power send by the radar
- ***Gain Ch1***: The absolute maximum gain of the PSR radar antenna. This value is used along with the vertical diagram (VPD) to calculate the radar gain versus elevation.
- ***Tx Frequency [Ghz]***: The frequency of the radar pulse (and receiver); this value is used for the generation of the return signal.
- ***Coverage Model***: A menu selecting the earth model used to determine the earth curvature. The user can select between 4/3 earth, 5/4 earth, 1/1 earth and a custom k factor. The latter can be entered just beneath. The modified earth radius is used to recalculate the target elevation.
- ***3dB Beamwidth***: The beamwidth of the horizontal antenna diagram used for generation of the target return. The tool generates a parabolic curve (in a dB scale) with a 3dB beam as specified.
- ***IPR***: Interrogations per revolutions: The number of interrogations per revolutions for this radar speed.

  The value can be automatically determined by clicking the ***Boot*** button of the tool. In that case the dial will start rotating and the IPR is measured and entered in the parameter set-up. Once booted, this value can not be manually overwritten!
- ***RCS***: Radar Cross Section: The average radar cross section used for the calculation in the radar equation. In case of Fixed RCS, the return power will be stable. If the user selects a Swirling case,

the return power will be variable according to a Raleigh distribution.

- ***Type***: The type of Radar Cross section that is simulated: This selector selects the type of swirling case to be generated. The swirling case changes the RCS according to a statistical function. The distribution is described in many reference works, but we used the distribution from M.I. Skolnik, "Introduction to Radar Systems".
  - ***Fixed RCS*** means the return power is fixed in time and space.
  - ***Swirling type I*** means the reply power of the target changes from scan to scan according to the Rayleigh distribution.
  - ***Swirling type II*** means the reply power of the target changes from reply pulse to reply pulse according to the Rayleigh distribution.
  - ***Swirling type III*** means the reply power of the target changes from scan to scan according to a modified distribution.
  - ***Swirling type IV*** means the reply power of the target changes from reply pulse to reply pulse according to a modified distribution.

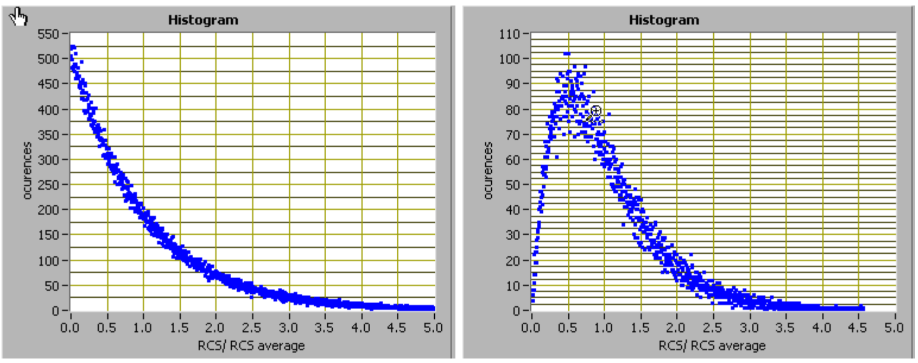


Figure 110: Swirling type I,II (left) and type III,IV (right)

- ***RFA Attenuator***: The attenuation between the RFA641 output (Tx connection) and the input of the radar receiver. This attenuation is added to the calculated return power to determine the RFA641 output power.
- ***Pulsewidth***: The pulsewidth of the generated returns.
- ***Target Zero Range***: The range in µs of the trigger signal. This value is subtracted from the scenario range before the target is being generated. So if you have a pre-trigger, the zero range value should be negative.
- ***Extra Attenuation Fixed***: An extra attenuation (e.g. radome loss) to be added to the radar equation in order to calculate the target return power.
- ***Extra Attenuation Variable***: A variable attenuation value (e.g. atmospheric influence) to be added to the radar equation.
- ***Use Atmospheric attenuation***: Calculated atmospheric loss according to "Radar Range Performance Analysis" by Lamont V.Blake. This calculation uses elevation, frequency and range to determine the atmospheric attenuation of the radar signal. The calculation is performed based on the graphical interpretation of the curves presented in the reference and therefore it has a limited accuracy of 0.1 dB.
- ***Use Lens-effect***: This check box takes the lens effect into account into the radar equation. The lens effect especially is important in low elevations. Calculated lens effect loss; according to "Radar

Range Performance Analysis" by Lamont V.Blake. This calculation uses elevation, frequency and range to determine the lens effect on the radar signal. The calculation is performed based on the graphical interpretation of the curves presented in the reference, and therefore it has a limited accuracy of 0.1 dB.

10.3.5. Determining the Effect of Parameters

The effect of each of these parameters can be verified using the educational simulator in the lower half of the tool. All the calculated values and the parameter values are shown in that display and are recalculated each time you change the ***Range*** and ***Altitude*** of the simulated target.

Beware: Only the Range and Altitude can be modified in this window. All others are indicators of calculated or parameter values.

Change the range or altitude using the sliders or simply by selecting a target in the list.

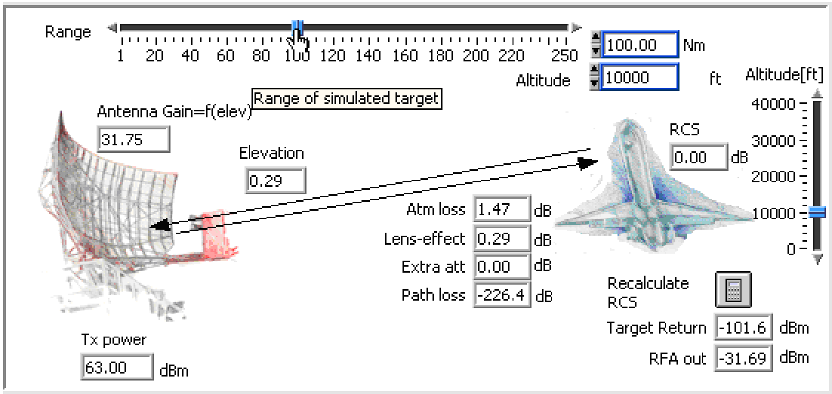


Figure 111: Parameter simulator

In case a swirling case is selected, a recalculation (using the ***Recalculate RCS*** button) generates a new random RCS and as such also modifies the target return power and the RFA output power.

Make sure you “booted” the RFA641 and the dial is rotating. If the dial fails to rotate, make sure you properly connected the trigger signal and the ARP signal.

10.3.6. Compilation of Scenario

Compile the scenario using the ***Compile*** button, the following window will appear:

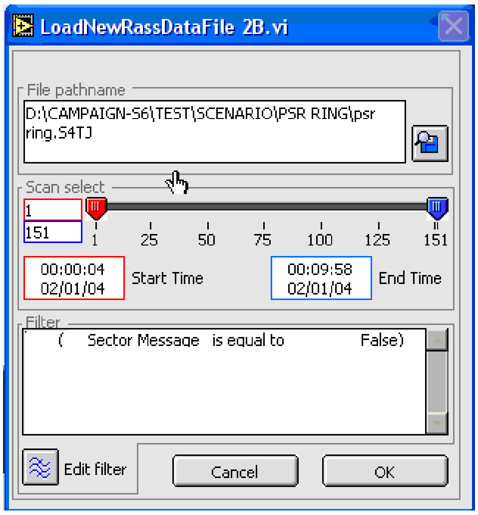


Figure 112: Selecting the scenario

Here you can select the xxx.S4TJ file and optionally select a section of this file. The default filter “Sector message = False” should be used, since the RFA PSR Target Generator does not generate sector messages.

Click the ***OK*** button to continue.

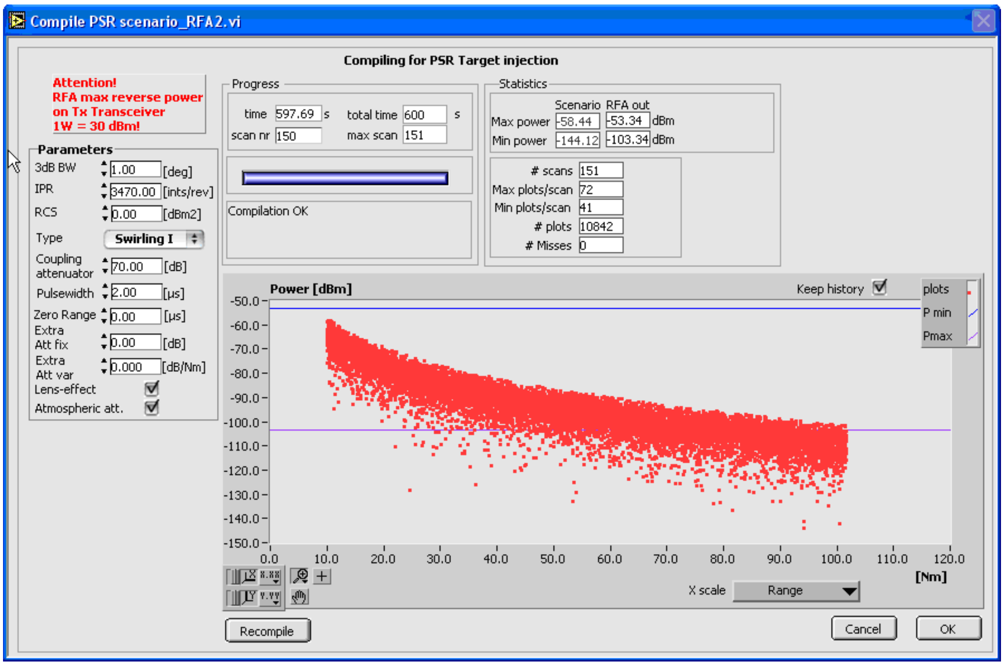


Figure 113: Scenario Compilation

The window will show the compilation process while the scenario is being calculated. If you see that the parameters are wrong or you still want to modify something, you can enter different values in the ***Parameter*** section and recompile the data by clicking the ***Recompile*** button. If you wish to stop the compilation process, use the ***Cancel*** button. The window will also show the maximum output RFA power using the selected Coupling attenuator by means of the upper blue line in the graph. Any target higher than this line will be clipped (creating a square target HPD).

The minimal line is also shown. This is the minimal value the RFA can generate correctly. No target lower than that line is generated.

Obviously, after observing this data , the user can decide to increase or decrease the Coupling attenuator to bring the scenario within the allowed dynamic range.

You can also change the X scale of the power graph to azimuth using the X scale menu.

Use the ***OK*** button to close the compiler window. Now start the replay of the scenario. Do this by clicking the ***Start*** button. The scenario replay can be halted by clicking the ***Stop*** button.

The PSR targets can be recorded using the RIM782 Sector recording tool (explained in the RIM782 manual). Afterwards the scenario can be verified (for example for power) using the Inventory tool (explained in the Inventory manual).

11. Annexes

11.1. Annex 1: Critical Parameters of SSR Antennas

Critical Parameters of SSR Antennas that should be included in the Out-of-Tolerance Detection (OTD): Facility of the Polar Diagram Plotter developed by Intersoft Electronics NV (copied from document 3E/T/322 Eurocontrol Directorate, 6/11/91).

Critical parameters that should be monitored by the OTD are :

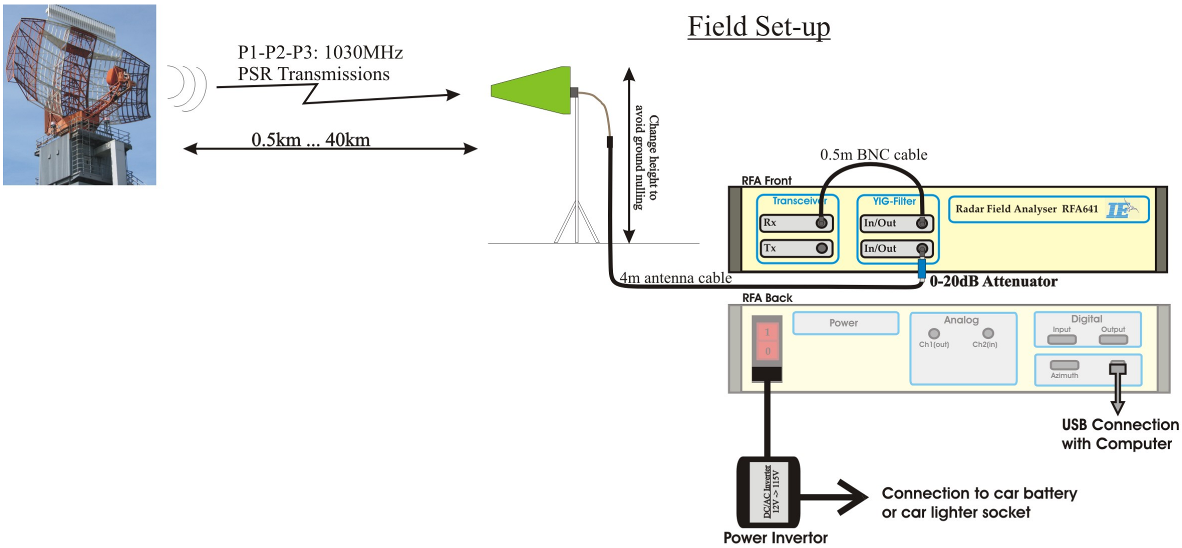
- the presence of sidelobe punch-through (position and level) ;
- the level of the highest ∑ sidelobe (other than the backlobe) (typically <-22 dB)
- the ∑ / Ω cross-over levels (dB) and positions (degrees) (typical level ,-18 dB ± 3 dB)
- the ∑ mainlobe -3 dB beam width (degrees) (typically -2.35° ± 0.25°)
- mean ∑ sidelobe level (typically <-24 dB)
- Ω pattern notch depth , or the highest point within the notch (typically <-24 dB) ;
- the ∑ backlobe level (typically <-24 dB) ;
- the ∑ / ∆ cross-over levels (dB) and positions (degrees), (typically -3 dB ± 0.5 dB, ±1.25° from mainlobe axis) ;

Since there are many different types of SSR antennas (LVAs, hog-through, integrated with PSR, conformal phased array) and different sizes (9 m, 4.5 m, even 2 m) and also variation in parameters between manufacturers, it is expected that a “footprint” is made for each secondary radar site and a given measurement point and that when later measurements show a significant deviation (to be defined for each parameter), than an “alarm” indication is given for the out-of -tolerance parameter(s).

This will also allow the effect on OTD of radar siting and eventual changes in propagation conditions (weather, ground conductivity, local obstructions) to be minimized .

It should be noted that the typical figures given above for levels, beamwidths, positions, etc. are only provisional and might be updated according to experience.

11.2. Annex 2: Uplink Connection Diagram



Set-up Guidelines:

- Make sure to have direct line of sight with the radar under test, avoid fences and wires!
- Change the antenna height to avoid a minimum due to ground reflections
- Make a Scope recording to validate the Transmit pulse and the environment
- Choose the correct antenna polarization (SSR: vertical; PSR: vertical or horizontal)

Horizontal and Vertical polarization

- Choose the opposite antenna polarization and make a recording to evaluate the effects of the environment (such as reflections)

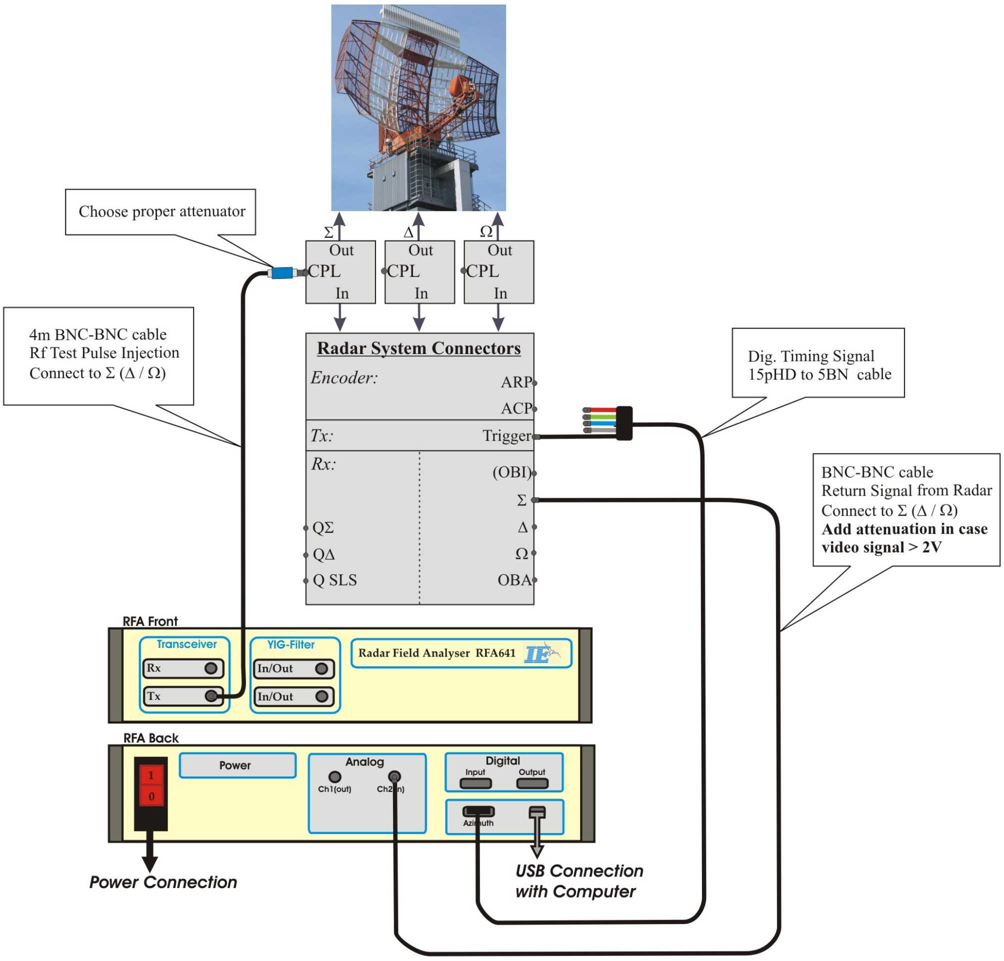
- Avoid nearby buildings or other structures reflecting large signals
- Avoid a low elevation angle versus the radar under test
- Avoid Rx Input saturation (-10dBm)
- Verify the Max. Width parameter

Tips and Tricks:

- Use the Info field to remember the details of the set-up: place, frequency, polarisation,..
- In case the diagram exceeds -10dBm: add attenuation before the YIG-filter
- Max. width pulse parameter: SSR: default 1µs
  PSR: pulsewidth + 20% (check pulsewidth using scope mode)

Figure 114: Uplink Connection Diagram

11.3. Annex 3: Rx, Bandwidth and STC Calibration Connection Diagram

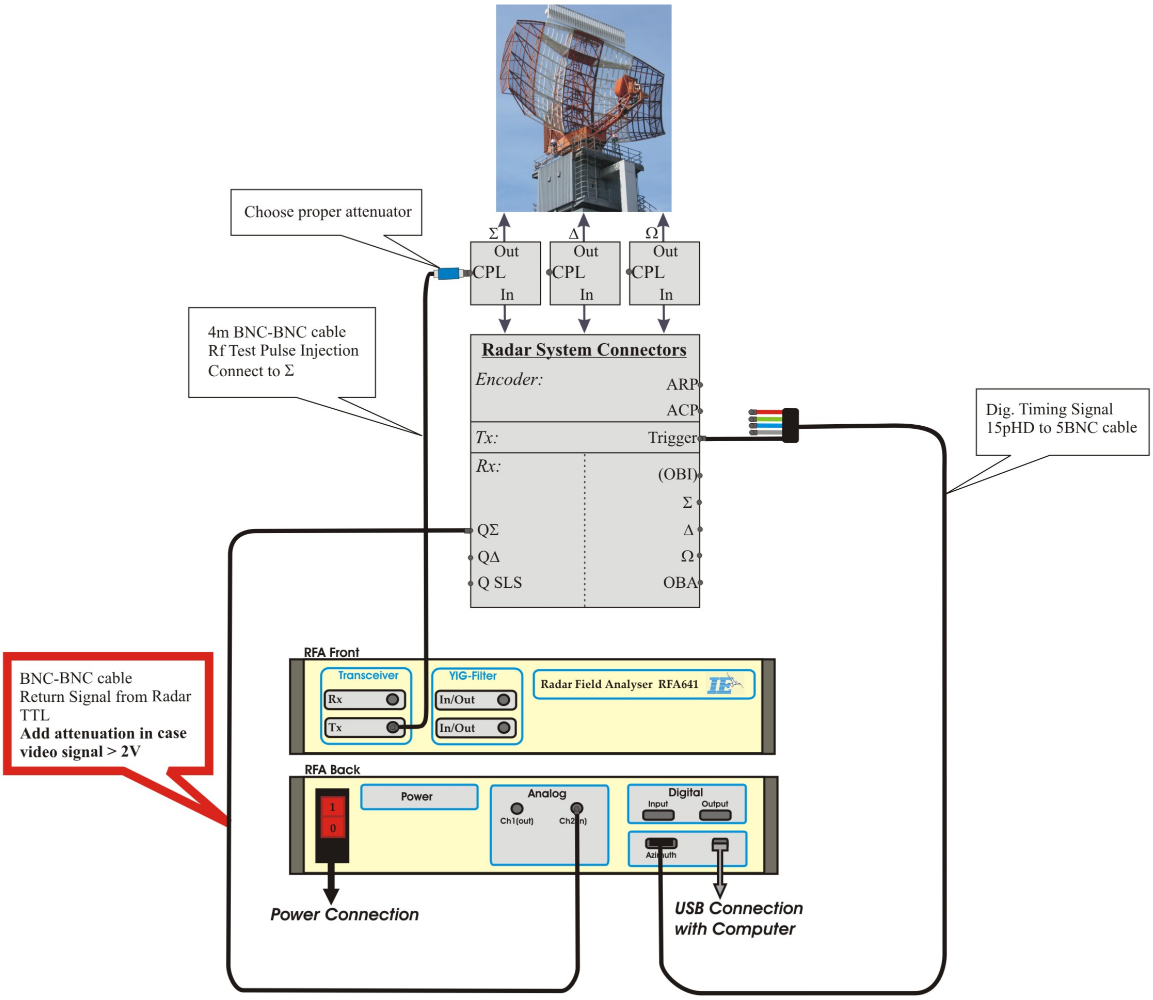


Set-up Guidelines:

- Make sure to switch the Radar transmitter off on the channel under test and turn automatic channel switching off **before** connecting the RFA Tx output to the Radar's Rx Rf input.
- In case you want to perform a Downlink measurement afterwards: use the preferred set-up which includes the RVR.

Figure 115: Rx, Bandwidth and STC Calibration Connection Diagram

11.4. Annex 4: DSTC Calibration Connection Diagram

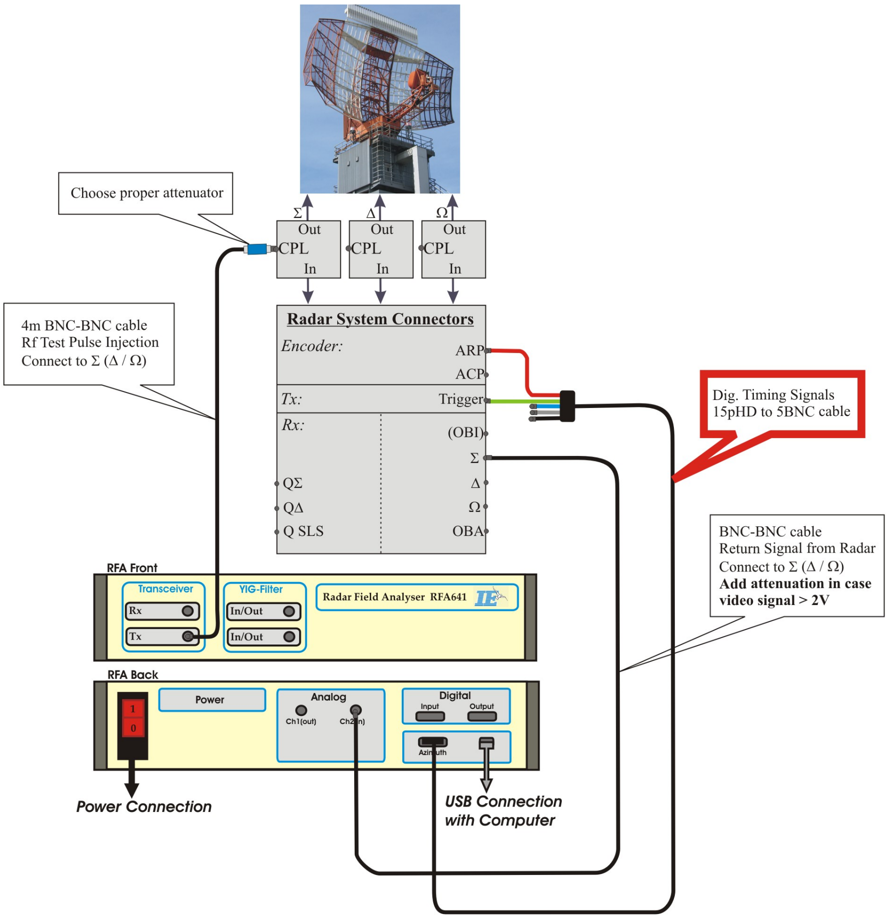


Set-up Guidelines:

- The set-up is the same as set-up 5.1b (Rx Calibration), except for the highlighted connection.
- Make sure to switch the Radar transmitter off on the channel under test and turn automatic channel switching off **before** connecting the RFA Tx output to the Radar's Rx Rf input.

Figure 116: DSTC Calibration Connection Diagram

11.5. Annex 5: Sectorial STC Calibration Connection Diagram

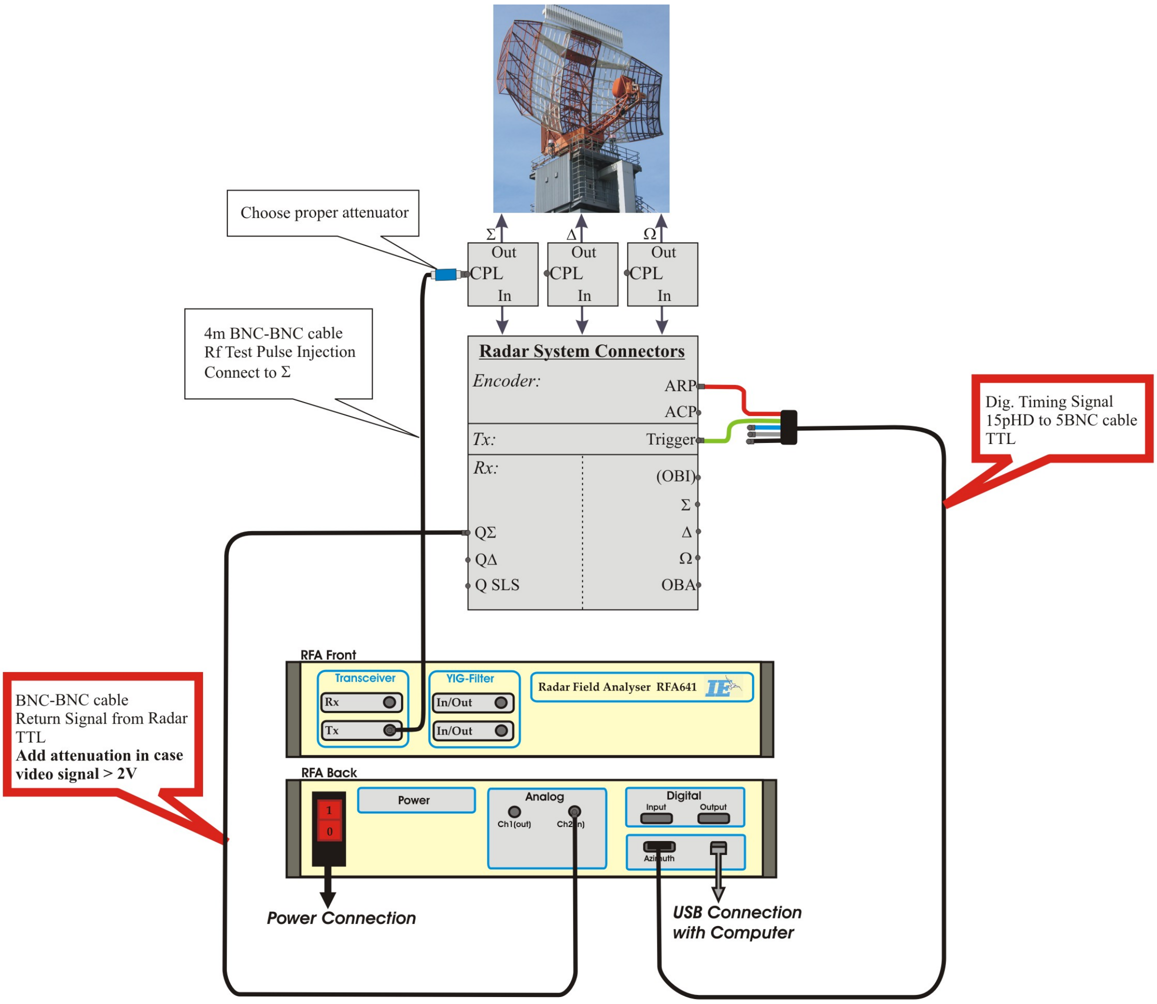


Set-up Guidelines:

- The set-up is the same as set-up 5.1b (Rx Calibration), except for the highlighted connection.
- Make sure to switch the Radar transmitter off on the channel under test and turn automatic channel switching off **before** connecting the RFA Tx output to the Radar's Rx Rf input.

Figure 117: Sectorial STC Calibration Connection Diagram

11.6. Annex 6: Sectorial DSTC Calibration Connection Diagram



Set-up Guidelines:

- The set-up is the same as set-up 5.1b (Rx Calibration), except for the highlighted connection.
- Make sure to switch the Radar transmitter off on the channel under test and turn automatic channel switching off **before** connecting the RFA Tx output to the Radar's Rx Rf input.

Figure 118: Sectorial DSTC Calibration Connection Diagram

11.7. Annex 7: RFA641 Downlink Connection Diagram

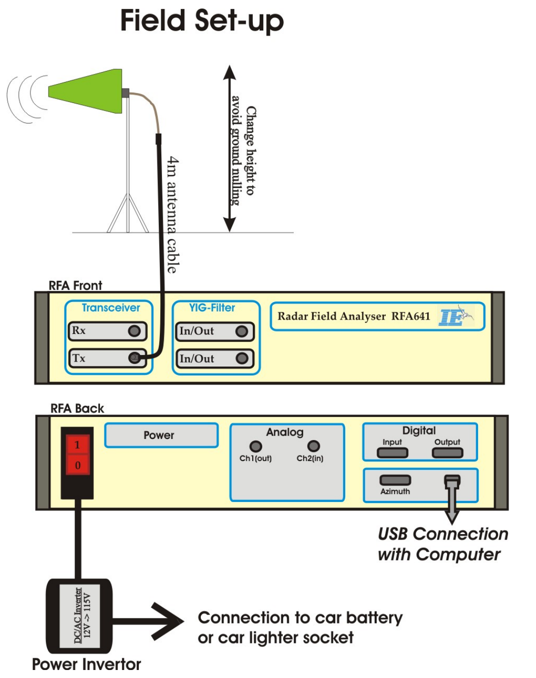
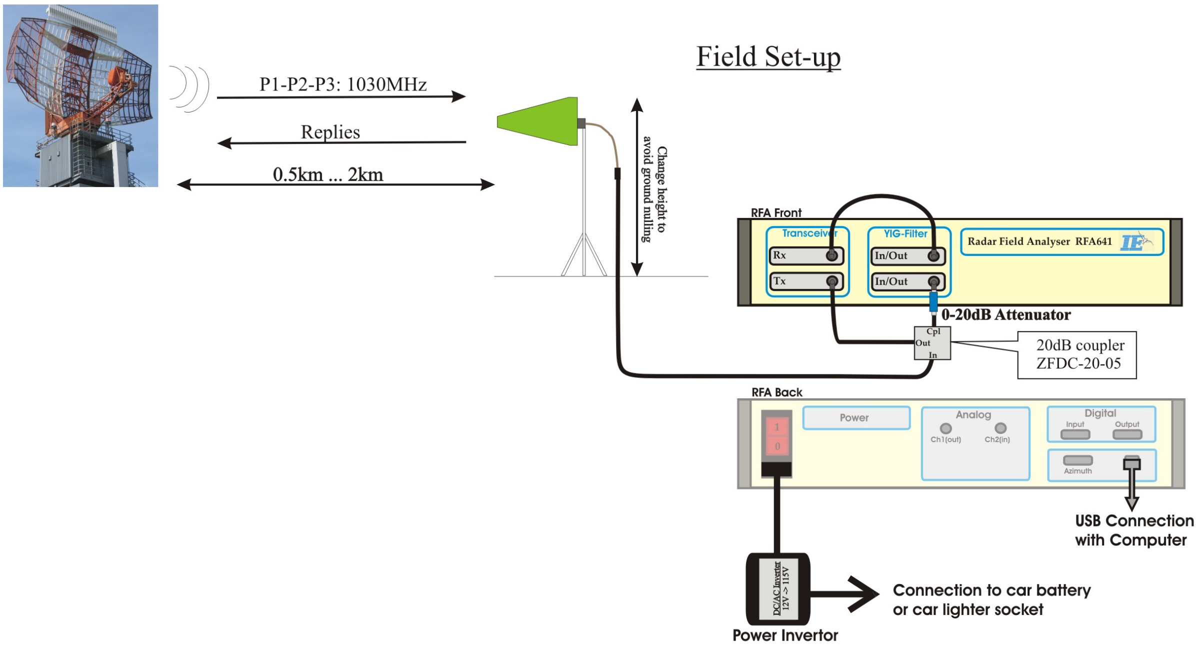


Figure 119: RFA641 Downlink Connection Diagram

11.8. Annex 8: RFM Function Connection Diagram



Set-up Guidelines:

- Make sure to have direct line of sight with the Radar under test, avoid fences and wires!
- Change the antenna height to avoid a minimum due to ground reflections
- Make an Uplink recording to check radar transmissions.
- Choose the vertical antenna polarization

Vertical polarization

⚠

- Avoid nearby buildings or other structures reflecting large signals
- Avoid Rx Input saturation (-10dBm)
- Adjust attenuator to allow input level within -10...-50dBm

Figure 120: RFM Function Connection Diagram

11.9. Annex 9: Out-beam Interference Generation Connection Diagram

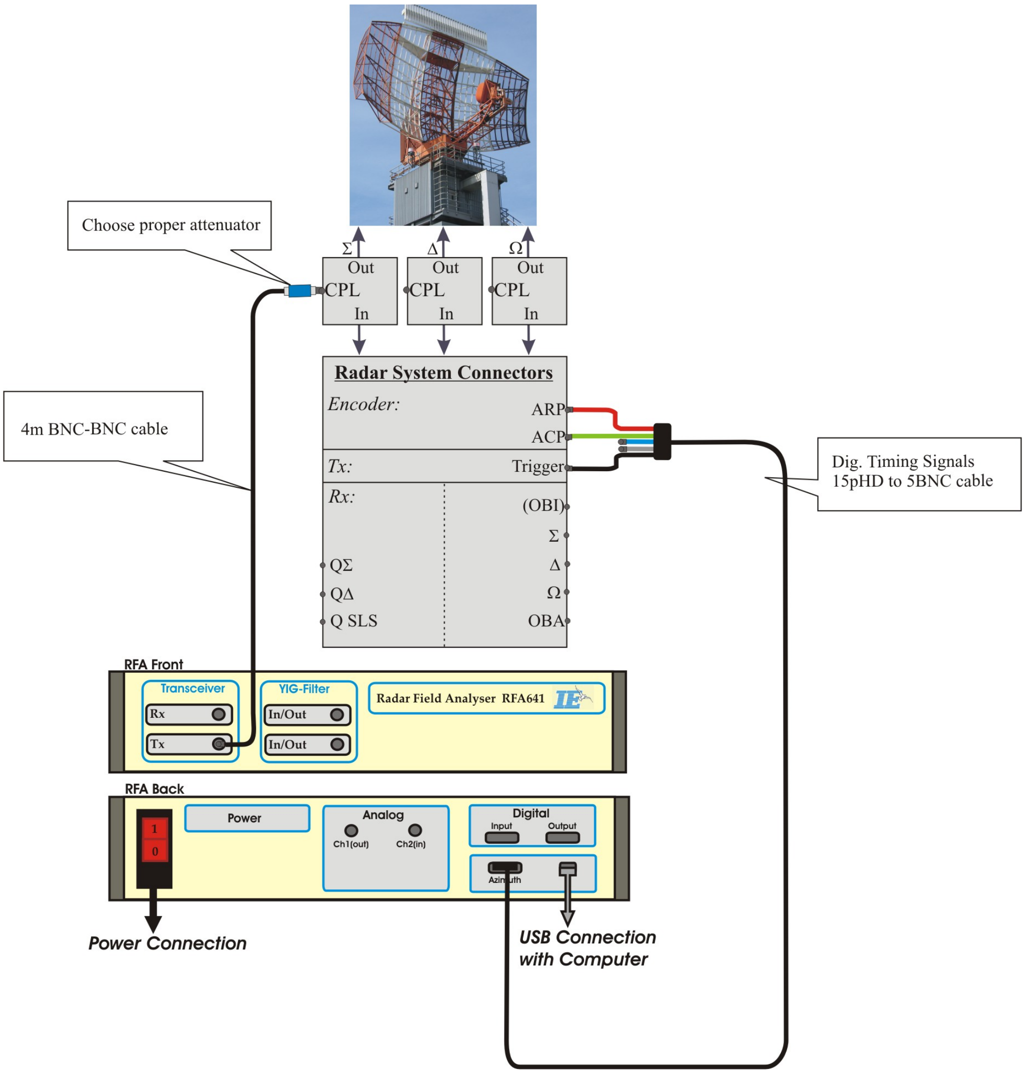
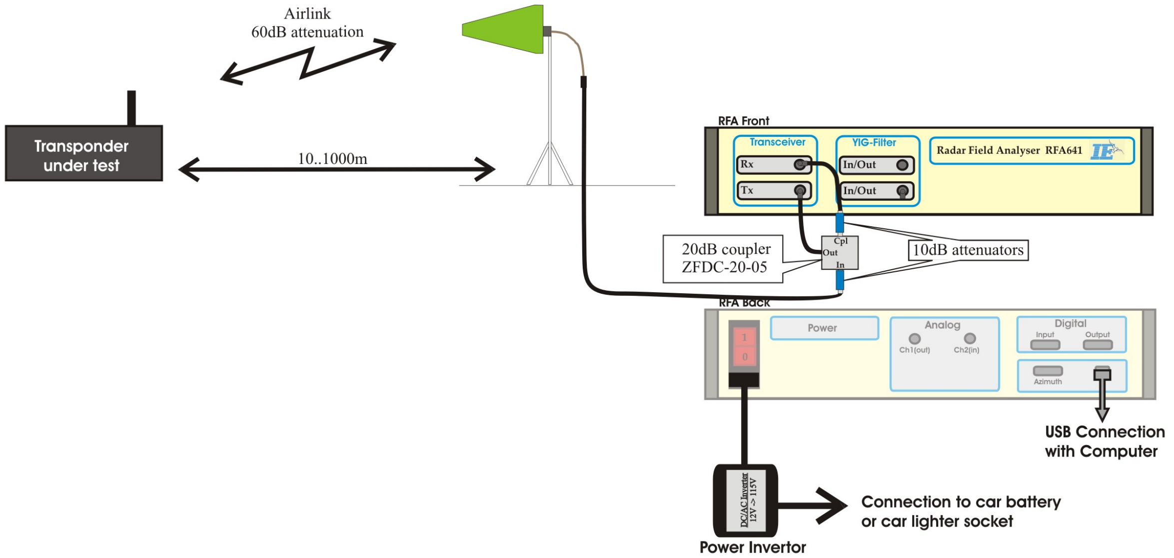


Figure 121: Out-beam Interference Generation Connection Diagram

11.10. Annex 10: RFA Transponder Interrogator Connection Diagram



Set-up Guidelines:

- In case you want to connect the transponder directly, just replace the airlink by 60dB in-line attenuation

⚠
- Make sure not to saturate the Tx output of the RFA with reverse power. It can only accept 30dBm maximum reverse power.

Figure 122: RFA Transponder Interrogator Connection Diagram

11.11. Annex 11: RFA for ADS-B Connection Diagram

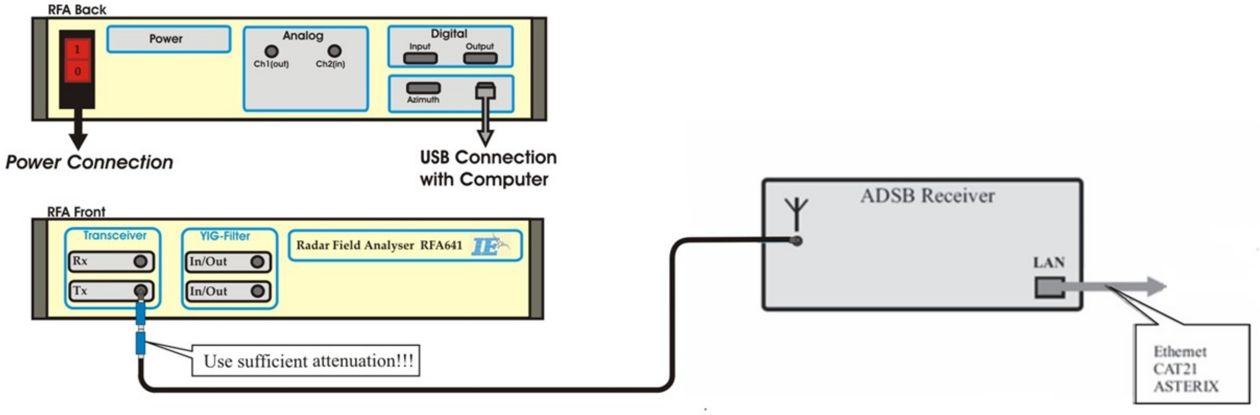
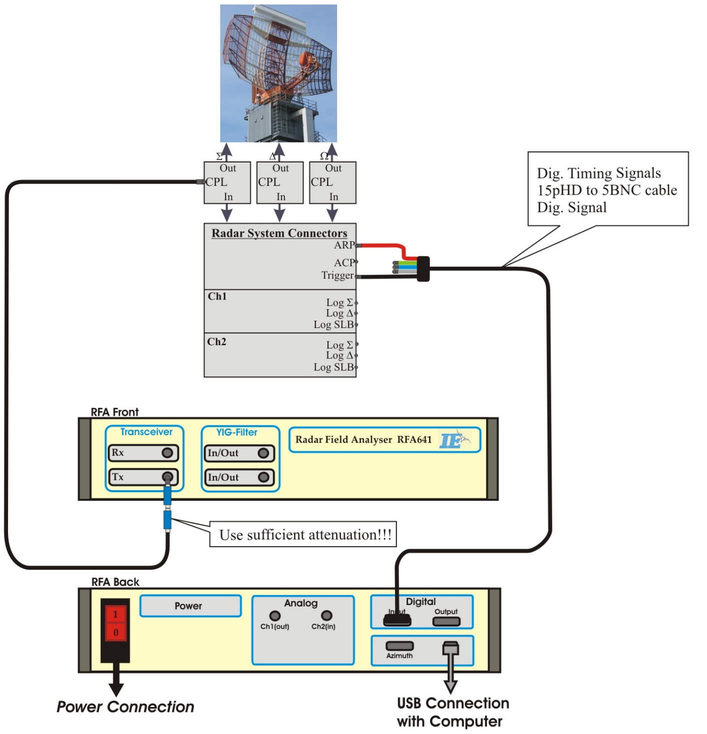


Figure 123: RFA for ADS-B Connection diagram

11.12. Annex 12: RFA Primary Target Injection Connection Diagram



<u>Set-up Guidelines:</u>

- Use sufficient attenuation between the radar coupling connection and the RFA Tx connector in order not to damage the RFA Tx output. This output can accept no more than 30dBm (1W) reverse power. A typical application with a 1MW (60dB) and 30dB circulator would still require minimal 30dB attenuation between the circulator port and the RFA.

Figure 124: RFA Primary Target Injection Connection Diagram

11.13. Annex 13: Configuration List

Check	Qty	Description/Item List
		Radar Field Analyser
O	1	Radar Field Analyser - RFA641
O	1	3.5GHz option
O	1	Mains power cable
O	1	USB cable A to B - 3m
		RFA Accessories
O	1	Log Periodic Antenna 900-3300MHz; LPA114
O	1	Antenna tripod Vanguard Mk-2
O	1	Antenna cable: MCX(m) to BNC(m) RG316 - 1m
O	1	BNC(m) to BNC(m) RG223 - 4m black
O	1	BNC(m) to BNC(m) RG223 - 0.5m black
O	1	BNC(m) to BNC(m) RG223 - 0.16m black
O	1	BNC(m) to BNC(m) RG223 - 0.16m white
O	1	15pHD to 5 BNC(m) cable - 1.8m
O	1	Monitor output Cable: DB9(m) to BNC(m) RG316 - 2m green
O	1	BNC(f) straight adaptor DC-4GHz
O	2	Attenuator 10dB BNC DC-4GHz 50ohm
O	2	Attenuator 20dB BNC DC-4GHz 50ohm
O	1	Directional coupler ZFDC-10-5 BNC
O	1	DC/AC Inverter 12V->115V
O	1	IEC-320 Extension Lead Socket-Plug
O	1	DIN-4165 socket to battery clamps