4T2 SW Manual RF-Analyser

Expert functions using Software Demodulator

Advanced Broadcast Components

Frankfurterstrasse 21
64720 Michelstadt
Germany

Phone: +49 176 618 177 39
Email: info@4T2.eu
Web: www.4T2.eu

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About the Software Demodulator

In addition to standard chipset-, or DSP-based demodulators for digital terrestrial transmissions, Advanced Broadcast Components has designed an entirely software-based demodulator to quantify the properties of the RF-interface of transmission equipment, such as Transmitters or Repeaters.

The advantage of such technology is that the demodulation down to transport stream level can be performed through highly optimised latest generation chip-demodulators, while at the same time the RF properties are evaluated by an independent demodulation algorithm.

Typically parameters such as MER versus Carriers are geometrically derived from the vectors in the I/Q (constellation) domain. As such, these constellation points are already corrected, with the performance of the correction directly influencing the measurement results. The algorithms for correction are almost always company confidential, as these algorithms form the main value of the company implementing them.

With an independent software demodulator running on a standard Windows platform, the correction algorithms can be made public and can be standardised, allowing in the laboratory to perform repeatable measurements of the devices under test.

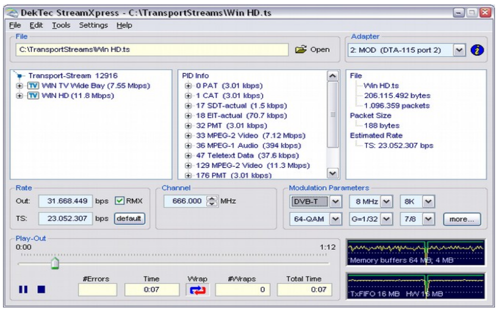
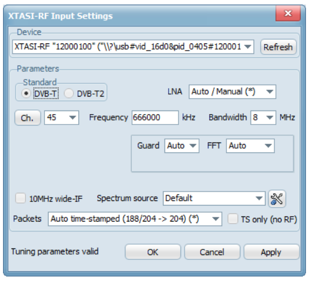
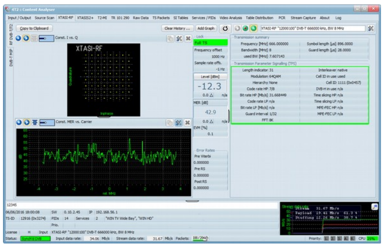
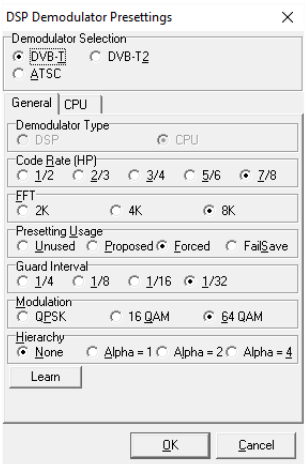
Implementation in the RF-Analyser

The 4T2 RF-Analyser is a Windows application that is running alongside the 4T2 Content Analyser application for enhanced transport stream analysis.
The 4T2 Content Analyser works as the dashboard and control centre. It performs the selection of the RF-input interface, establishes the tuning, displays key performance parameters of the RF-input and performs all transport stream related measurements, including content decoding.

In addition to the key performance parameters of the RF-input in the 4T2 Content Analyser, the 4T2 RF-Analyser makes use of the internal baseband sampler-hardware. It takes the RF samples and applies a demodulator chain (interpolation, I/Q conversion, digital mixing, frequency shifting, symbol detection, pilot synchronisation, amplitude/phase correction, constellation mapping).

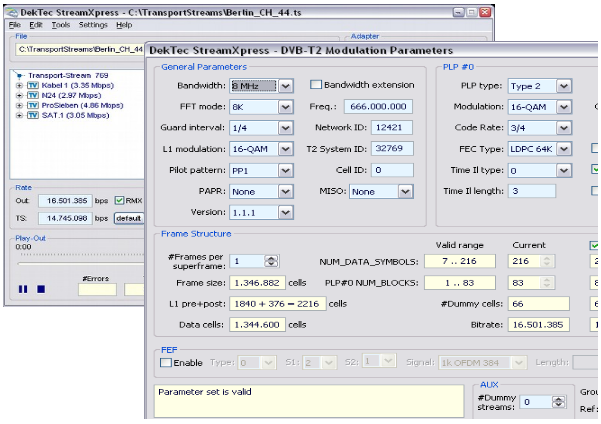
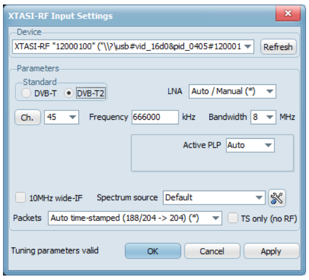
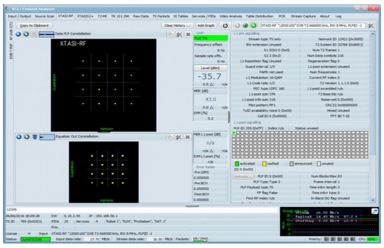
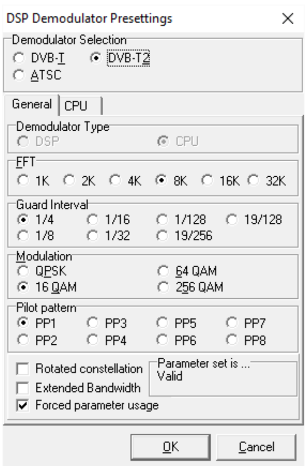
With these algorithms, expert functions are available through the user interface. The following chapters describe how to control the 4T2 RF-Analyser and the measurement results it offers.

Preparations to perform measurements with the 4T2 RF-Analyser (DVB-T)

<table>
<tr><th>application</th><th>action</th></tr>
<tr><td>
</td><td>An RF-signal needs to be applied to the RF-input of the measurement device equipped with 4T2 Content-Analyser and 4T2 RF-Analyser (this example: DVB-T)</td></tr>
<tr><td>
</td><td>In 4T2 Content-Analyser, the XTASI-RF input interface needs to be selected and tuned to the appropriate channel. The transmission standard (DVB-T or DVB-T2) is selected here.</td></tr>
<tr><td></td><td>The 4T2 Content Analyser will lock on the RF-Signal and make all measurements available on the transport level.
In addition to this, key performance parameters are displayed in the XTASI-RF tab.
The modulation parameters are available on the right hand side of the user interface. Some of these parameters are required to pre-set the software demodulator in the RF-Analyser.
There is an automatic interface between the two applications</td></tr>
<tr><td>
</td><td>Software Demodulator Pre-settings can be found in the lower right corner of the 4T2 RF-Analyser application.
In the pop-up dialogue, the OFDM properties can be manually set (copied from the display in the 4T2 Content-Analyser).
However, this is typically not required, as there is an automated interface present between the two applications.

There is one set of settings stored for DVB-T and one for DVB-T2 respectively.
Typically, these settings are unique per country and do not need to be touched again after the initial setup, as they are stored in the laststate file.</td></tr>
</table>

Preparations to perform measurements with the 4T2 RF-Analyser (DVB-T2)

application	action
	An RF-signal needs to be applied to the RF-input of the measurement device equipped with 4T2 Content-Analyser and 4T2 RF-Analyser (this example: DVB-T2)
	In 4T2 Content-Analyser, the XTASI-RF input interface needs to be selected and tuned to the appropriate channel. The transmission standard (DVB-T or DVB-T2) is selected here.
	The 4T2 Content Analyser will lock on the RF-Signal and make all measurements available on the transport level. In addition to this, key performance parameters are displayed in the XTASI-RF tab. The modulation parameters are available on the right hand side of the user interface. Some of these parameters are required to pre-set the software demodulator in the RF-Analyser. There is an automatic interface between the two applications
	Software Demodulator Pre-settings can be found in the lower right corner of the 4T2 RF-Analyser application. In the pop-up dialogue, the OFDM properties can be manually set (copied from the display in the 4T2 Content-Analyser). However, this is typically not required, as there is an automated interface present between the two applications. There is one set of settings stored for DVB-T and one for DVB-T2 respectively. Typically, these settings are unique per country and do not need to be touched again after the initial setup, as they are stored in the last-state file.

With these initial settings done, the 4T2 RF-Analyser gives access to a number of additional measurement results, which are described in the following sections.

Spectrum Analysis

The *Spectrum* analysis menu allows for monitoring the DVB-T signal spectrum. The following figures show typical spectrum displays for off-air measurements and DVB-T live reception.

The Spectrum analysis function does not require the demodulation algorithms to be locked to the input signal for accurate results.

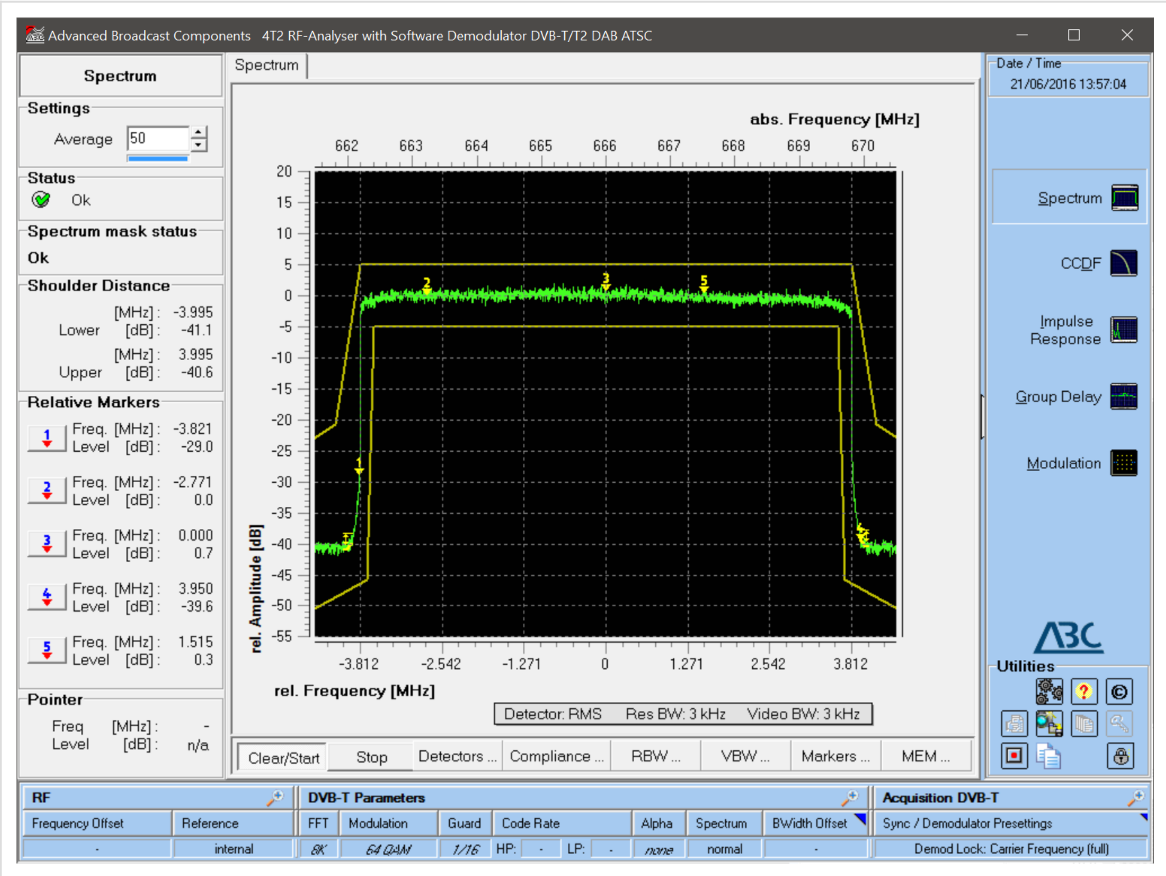


Illustration 1: /Analysis/Spectrum

Background Information

The spectral density of a terrestrial DVB signal is defined as the long-term average of the time-varying signal power per unity bandwidth.

In order to avoid the terrestrial DVB signal interfering with signals in other channels, the transmitted spectrum shall comply with defined spectrum masks.
TR 101 290 defines spectrum masks for critical and non-critical cases.

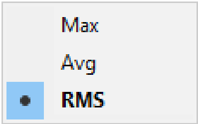
Spectrum Analysis Controls and Displays

Relative values for amplitude and frequency are displayed on the lower and left axis respectively. The 4T2 shifts the top of the DVB-T block automatically to match the line relative to 0 dB.

The *Clear/Start* button starts the spectrum analysis and resets the average counter.

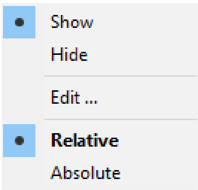
The *Stop* button freezes the display.

Detectors ... opens the following pop-up window:



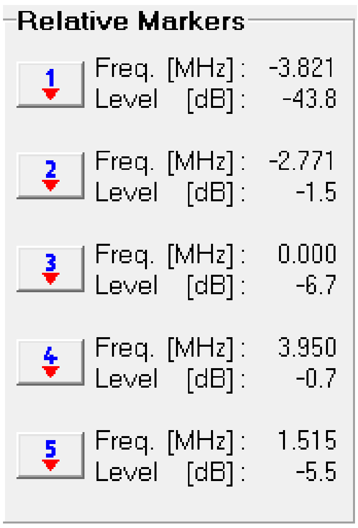
Detector modes: Max for maximum / Avg for average or RMS for root mean square may be selected.

Markers ... opens the following pop-up window:



You may: Show / Hide or Edit markers; they may be located on: Relative or Absolute positions.

Five markers are available within the frequency spectrum. If the markers are hidden, no level measurement results will be available at the bottom left part of the screen. *Edit* opens the marker positioning dialog.

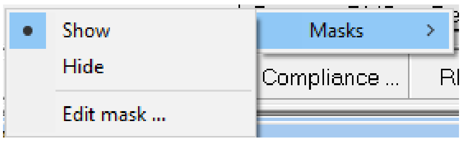


The *Markers* area at the bottom left part of the screen contains 5 result lines for the 5 markers on the spectrum display

.

Relative frequency (see marker description above) plus the corresponding level or level delta (in dB) is displayed in this section.

Compliance ... opens the following pop-up window for mask compliance and trace export properties:



Show / Hide or Edit masks.

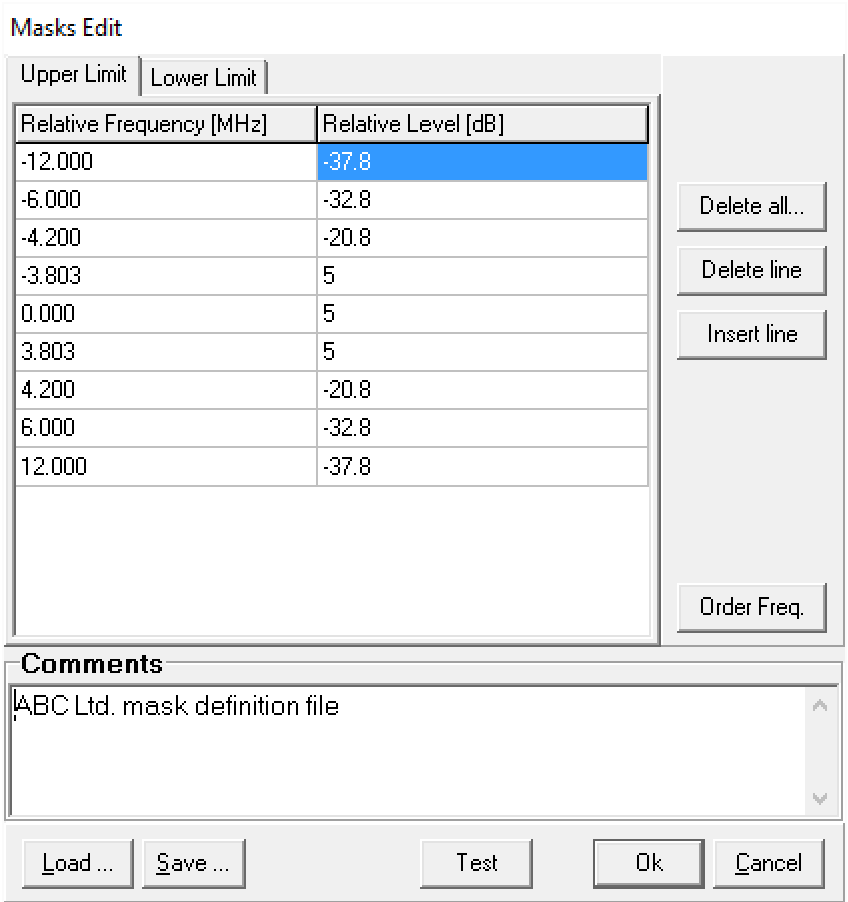
When moving the mouse pointer over *Masks ...* field in the *Show* status, the name of the currently used mask (as determined by the user) is displayed for about three seconds.

Edit may be used to customise spectrum masks according to individual requirements. It opens up the Edit Mask dialogue, allowing defining 8 segments for the lower and upper limits defining the spectrum mask. For this purpose two times 9 points may be set manually. Points 3, 4 and 5 usually define the pass band of the spectrum. Frequency and level offset for low and high mask limit values can be allocated for each of these points.

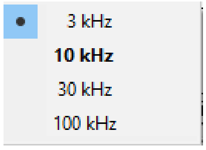
In order to store a defined mask, please click the *Save* button.

To retrieve any previously defined and saved spectrum masks, simply click the *Load* button within the Masks Edit dialogue.

Per default, masks are stored in the \4T2\spectrum\ subfolder.

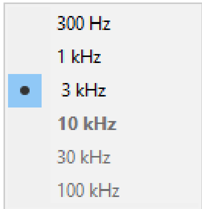


RBW ... allows for setting the resolution bandwidth. When clicking on *RBW ...* the following pop-up window appears:



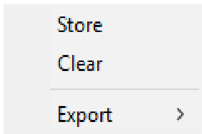
The resolution bandwidth may be selected easily; the default value is displayed in *bold* letters.

VBW ... allows for setting the video bandwidth. When clicking on *VBW ...* the following pop-up window appears:



The video bandwidth may be selected easily; the default value is displayed in *bold* letters. Please note that not every combination of RBW and VBW is possible.

The *MEM ...* button opens a pop up window with the possibilities:



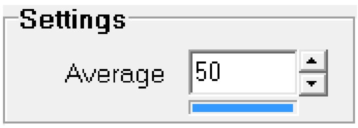
Store or *Clear* and *Export*
Export allows for the detailed processing of trace data with third party applications.

Store allows for storing of the current trace to the background. Stored traces are coloured in blue.

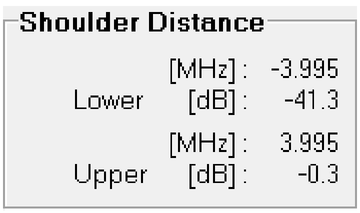
Multiple storing is possible. *Clear* removes all stored curves.

MEM ... provides an easy way to compare results of different measurement situations e.g. for adjustment improvements.

The *MEM ...* function is also available in the *CCDF* and *Group Delay* modes of operation.

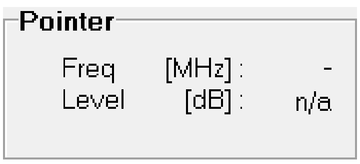


The *Average* selector field allows determining the average number of display points per measurement. If required, please click at either the "increase" or "decrease" arrow to change the setting. You may also type the average number directly. The blue bar indicates the progress of the averaging process. This may be helpful especially if averaging takes place over a higher number of samples.

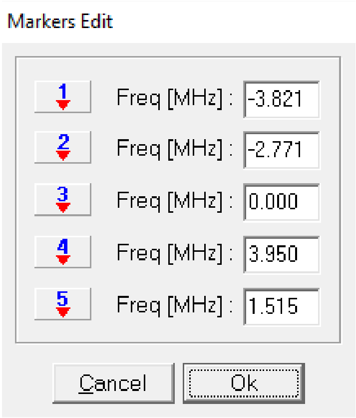


Shoulder Distance automatically positions two shoulder markers at +- 3.995 MHz from center of the DVB signal.

These markers display the lower and the upper shoulder respectively.



The *Pointer* area displays Frequency and Level of the current mouse pointer position in the spectrum diagram.



If you click at any button containing the red arrows in the *Markers* group, the *Set Marker Display* opens up allowing setting the results lines values.

Thus you are able to determine, which frequency and amplitude delta or absolute values you want the 4T2 to display.

Markers may also be shifted manually by setting the mouse pointer close to the marker (selection) and moving the mouse right or left with depressed right mouse key.

Shoulder Distance Measurements

Shoulder distances can be measured using the 4T2 with the built-in markers and mask features. Sample files for 7 MHz and 8 MHz non-critical masks are stored on the hard disk in the sub-folder Spectrum of the application directory.

Fixed Shoulder Markers are used for upper and lower shoulder distance measurements (if required the position of those markers can be edited in the Lastmode.ini file in the application directory).

Using zoom and markers, the shoulder distance verification can be easily performed.

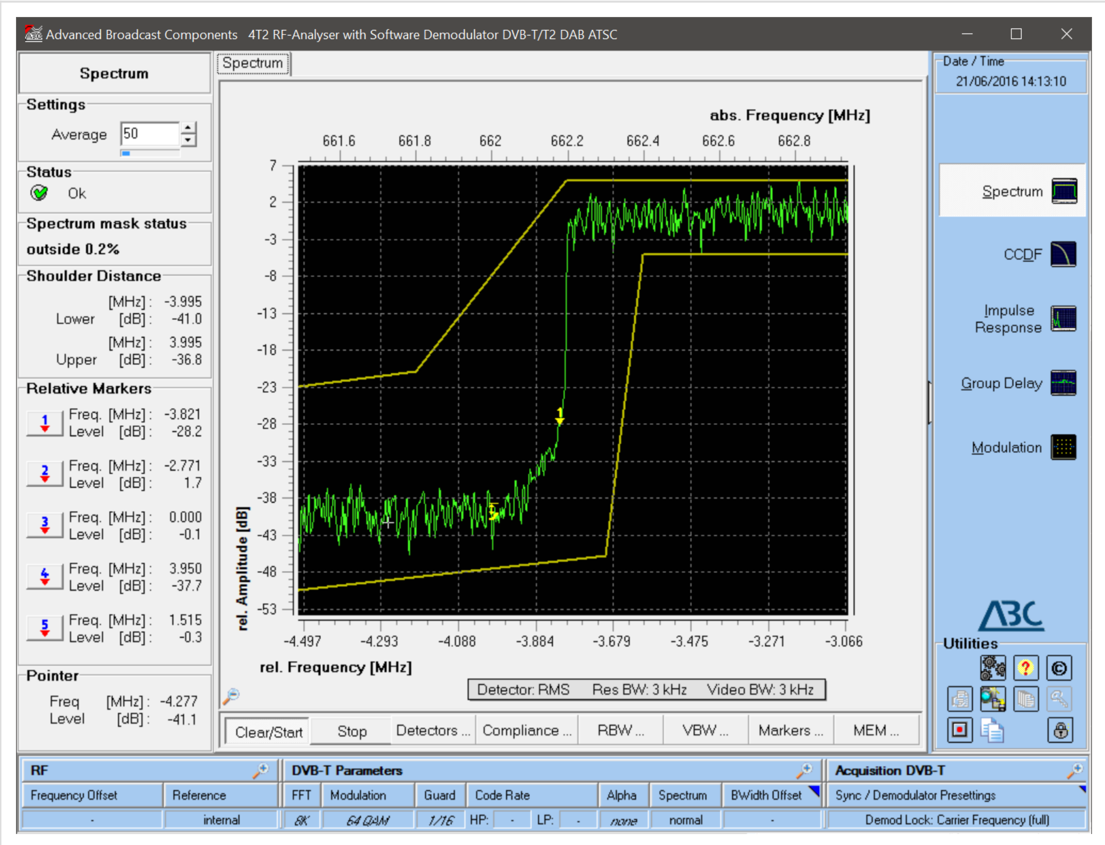


Illustration 2: /Analysis/Spectrum (zoomed to lower shoulder)

Using markers and a zoomed spectrum display, the shoulder distance is available at a glance. As the top area of the DVB-T signal is centred at 0 dB relative, even absolute marker results show already the accurate shoulder distance.

CCDF

CCDF (Complementary Cumulative Distribution Function) is a tool to specify the linearity characteristics of the input signal.

Background Information

CCDF gives information about the amplitude distribution of the signal under test. CCDF curves show the probability (P) of the appearance of peak-to-average ratio (PAR) of the measured signal.

Ideal COFDM signals have a noise-like amplitude distribution identical to a Gaussian response. Any non-linear distortion during the processing chain of the COFDM signal, e.g. compression or clipping effects will result in a deviation from the Gaussian response. The 4T2 RF-Analyser displays the Gaussian curve together with the measured CCDF.

The Crest Factor, as the maximum peak to average ratio in dB is displayed.

The CCDF analysis function does not require the demodulation algorithms to be locked to the input signal for accurate results.

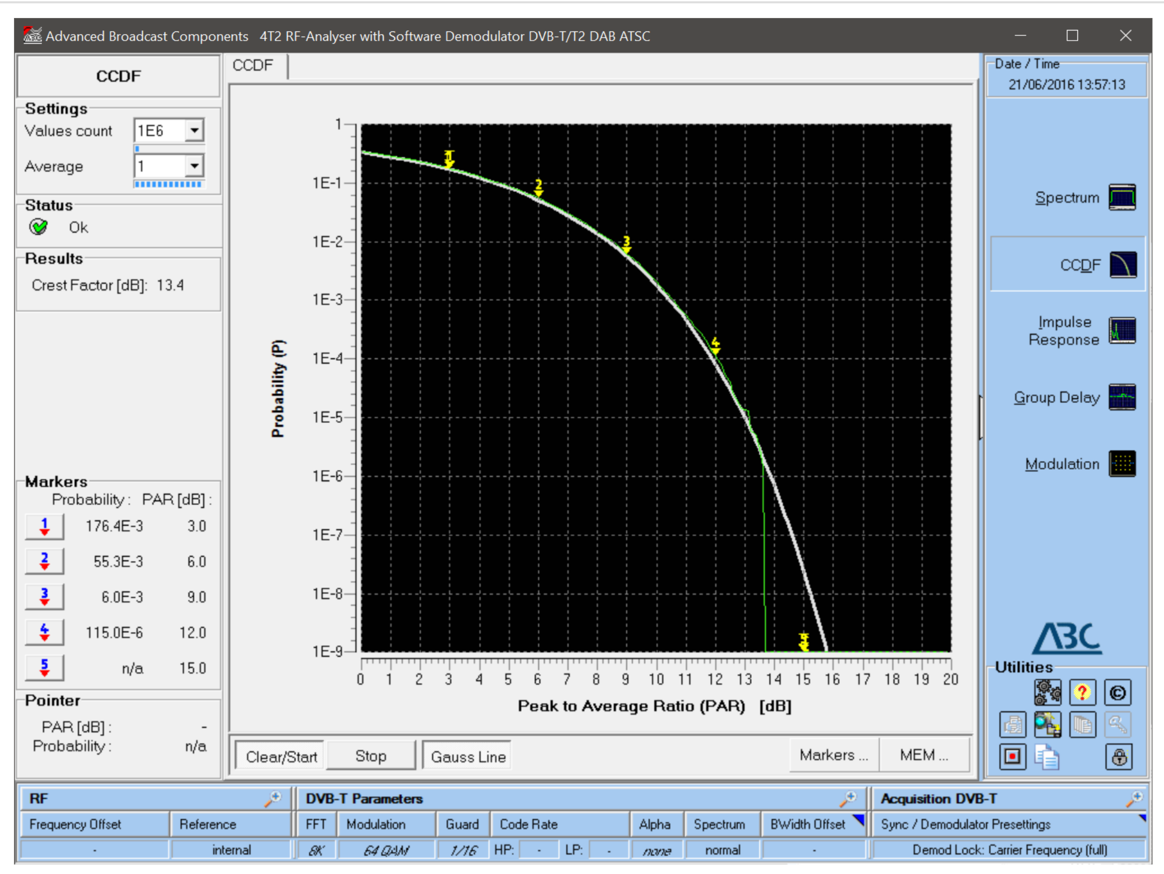


Illustration 3: /Analysis/CCDF

CCDF Controls

The following section explains the various control elements which are available to the user in order to perform CCDF measurements.

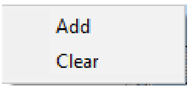
The *Clear/Start* button starts the CCDF analysis and resets the average counter.

The *Stop* button freezes the display.

This item toggles the display of Gauss tolerance field.

The *Markers ...* button opens a pop up window with the possibilities of *Show*, *Hide* or *Edit* markers. The 4T2 provides 5 markers within the CCDF plane. If the Markers are hidden no measurement results will be available at the bottom left part of the screen. *Edit* opens the marker positioning dialogue box.

The *MEM ...* button opens a pop up window with the possibilities:
Add or *Clear*.



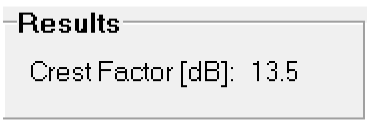
Add allows for storing of the current trace to the background. Stored traces are coloured in blue. Multiple storing is possible. *Clear* removes all stored curves.

MEM ... provides an easy way to compare results of different measurement situations e.g. for adjustment improvements.

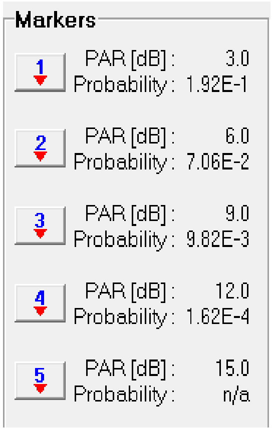
The *MEM ...* function is also available in the *Spectrum*, *Impulse Response*, and *Group Delay* mode of operation.

CCDF Results

Below you will find a list of parameters displayed by the 4T2 *Results* group on the left hand side of the screen while a CCDF analysis is performed:

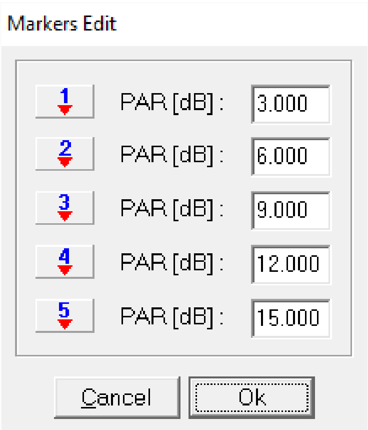


The CREST factor is defined as the ratio of the peak voltage to its root-mean-square value. Since the CREST factor doesn't say how often the peak occurs, the CCDF curves give more complete information about the high signal levels than the CREST factor does.



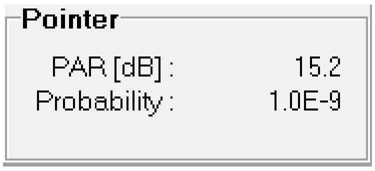
The *Markers* area at the bottom left part of the screen contains five result lines for the five markers on the CCDF display.

The peak to average ratio value (in dB) plus the corresponding probability for each marker point are displayed in this section.



Instead of displaying the PAR and probability of a certain marker, you can click the arrow underneath e.g. the figure 1 marker to open the Markers selection dialog.

If you prefer to display e.g. the difference between marker 1 and marker 2, click *Delta 1-2*.



The *Pointer* area displays PAR and probability of the current mouse pointer position in the CCDF diagram.

Some remarks on CCDF:

- CCDF readout, together with the Crest Factor (CF) is used to assess the quality of DVB-T/T2 power amplifier stages and precorrection.
- A clean sine-wave signal has a Crest Factor of 3 dB.
- An ideal COFDM signal displays a CF of approximately 14.5 dB.
- Very noisy antenna input signals appear like a noise-only signal, similar to the Gaussian reference curve. Make sure that you actually have a receiver lock when measuring those signals.

Impulse Response

The Impulse Response menu enables time domain analysis of the incoming OFDM signal.

It also provides additional information by displaying the corresponding distance (in km) of the received signal on the upper horizontal axis.

The Impulse Response analysis function requires the demodulation algorithms to be locked to the input signal for accurate results.

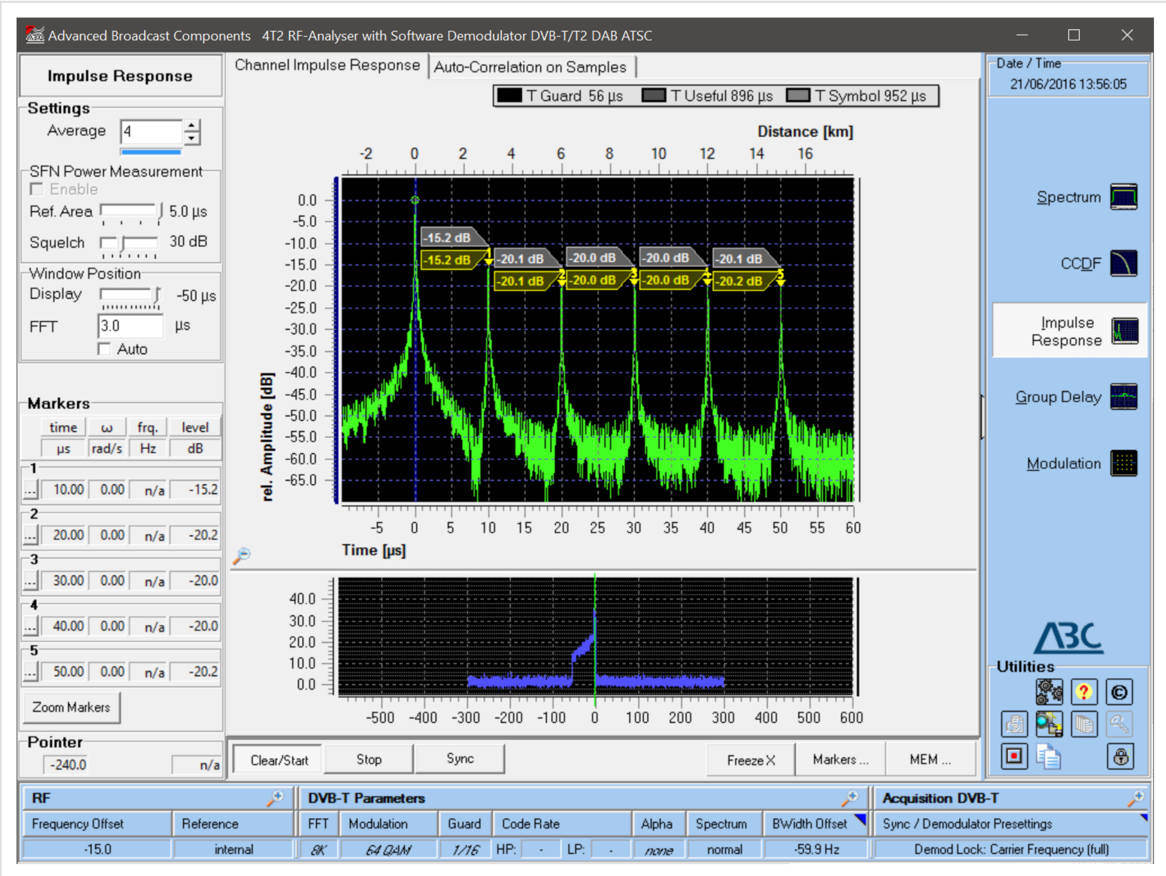


Illustration 4: /Analysis/Impulse Response

Background Information

This measurement may be used in order to analyse the time conditions of several terrestrial DVB signals arriving at the same reception point (resulting in symbol interference), which is particularly useful when monitoring Single Frequency Networks (SFN).

In the Impulse Response screen, the time delay between transmissions in a multi-path environment is displayed.

Two different algorithms are implemented:
Channel Impulse Response, transformation of energy density spectrum into the time domain:

- requires receiver locked state on the incoming terrestrial DVB signal
- delivers precise time and amplitude information
- is restricted to echoes / reflections within the Guard Interval

Auto-Correlation on Samples, IR ~ ACF(F(t)) = IFFT [| FFT (F(t))|²]:

- works on the digitised input signal
- gives precise time information
- is independent from the signal properties i.e. no DVB-T signal has to be present
- delivers any periodic share of the signal as peak in the display, which in case of a DVB-T signal includes: Guard Interval, FFT length, symbol length and combinations thereof
- Peaks due to echoes / reflections are clearly higher in amplitude than peaks due to internal signal periodicity.

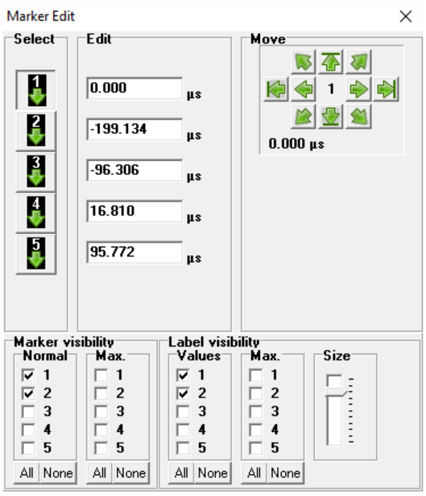
Both algorithms have their advantages and disadvantages. The application shall be chosen according to the input conditions.

Impulse Response Controls and Displays

The *Clear/Start* button starts the impulse response analysis and resets the average counter.

The *Stop* button freezes the display.

Markers ... opens the following dialogue:



The *Marker Edit* dialogue holds tools for sophisticated peak finding on up to 5 markers.

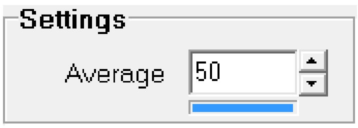
In combination with the user friendly zoom and move functions, echos can be quantified quickly.

Zoomable Labels for values and peaks further add to the versatility of the application.

Zoom Function

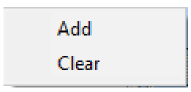
Zoom-in on any time range is performed by dragging the mouse pointer over the area of interest from left to right while holding the left mouse button.

To *Zoom-out* to full span, hold the left mouse button and drag the mouse pointer from right to left.



The *Average* selector field allows determining the average number of display points per measurement. If required, please click at either the "increase" or "decrease" arrow to change the setting.

The *MEM ...* button opens a pop up window with the possibilities:



Add or
Clear.

Add allows for storing of the current trace to the background. Stored traces are coloured in blue.

Multiple storing is possible. *Clear* removes all stored curves.

MEM ... provides an easy way to compare results of different measurement situations e.g. for adjustment improvements.

The *MEM ...* function is also available in the *Spectrum*, *Group Delay*, and *CCDF* mode of operation.

Effect of Software Demodulator settings on Impulse Response results:

There are basically two valid settings for the symbol correction algorithm in the RF-Analyser Software, accessible under SWDemod in Modulation Analysis:

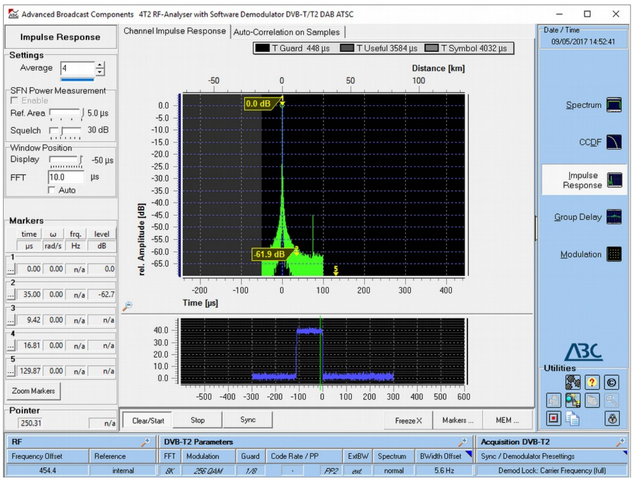
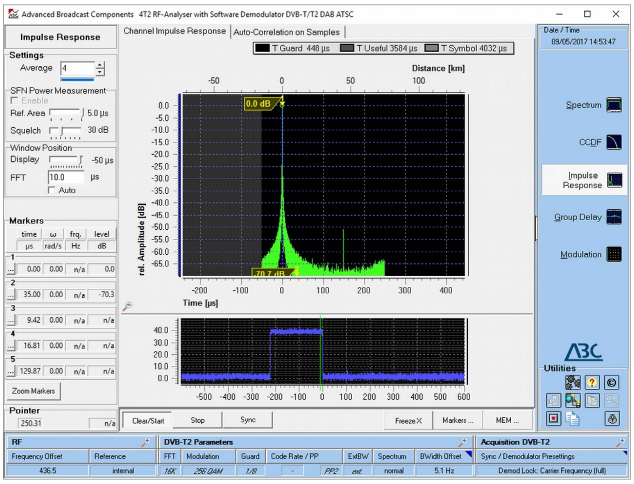
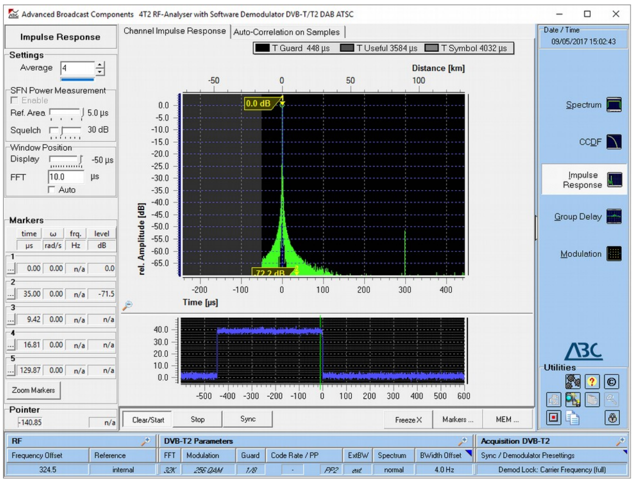
Linear - Single Symbol - Transmitter
This is the right setting for transmitter measurements with direct (cable) connection to the instrument. The correction algorithm is tuned for most accurate MER readings.

Linear - Multi Symbol - Off Air
This is the right setting for field measurements with antenna connection. The correction algorithm spans multiple symbols to improve the stability in presence of echoes in the receiving path.

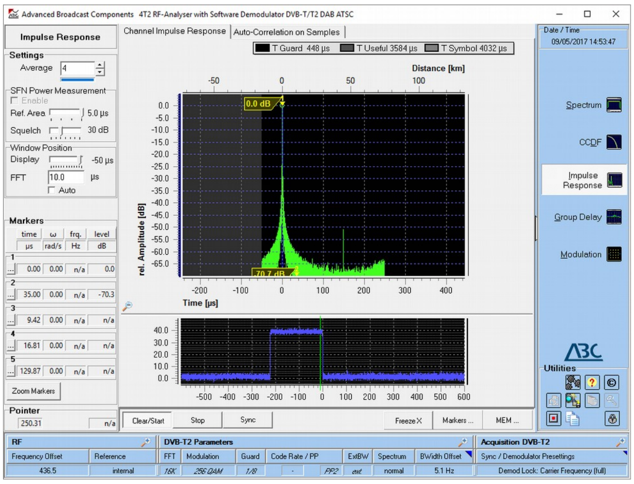
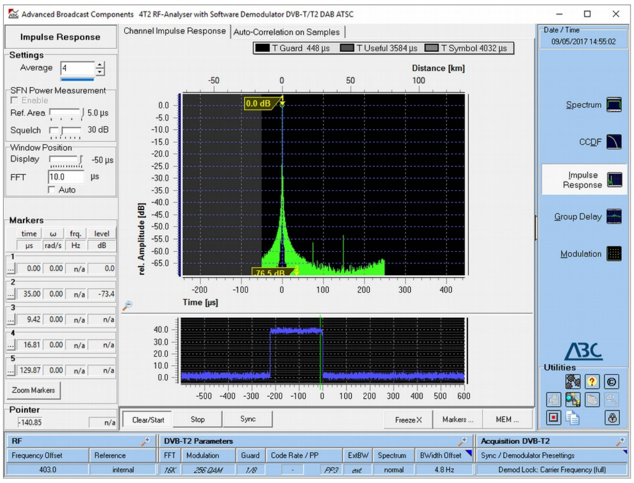
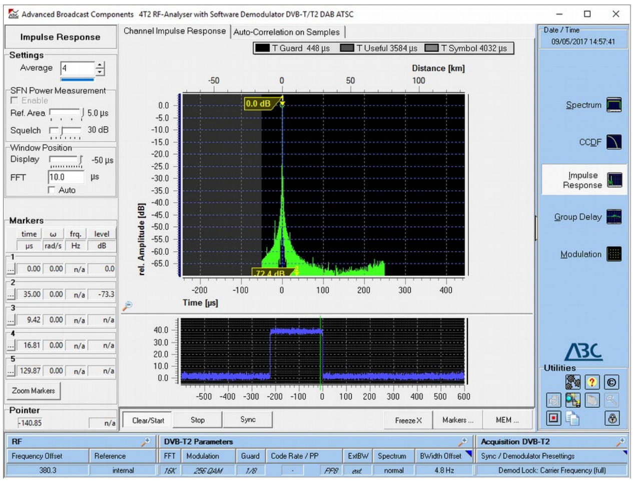
As Impulse Response is the measurement to detect the presence of echoes in the receiving path, this symbol correction algorithm is to be chosen for most accurate measurements.

Please note that depending on pilot patterns and their periodical nature, the impulse response display may show echo-peaks even when only a single transmitter is present.

The following screens show examples of different FFT-lengths and corresponding symbol lengths:

	DVB-T2 8k FFT length, PP2
	DVB-T2 16k FFT length, PP2
	DVB-T2 32k FFT length, PP2

Different Pilot Patterns (PP) result in different Impulse Response displays, even if only a single transmitter is present:

	DVB-T2 16k FFT length, PP2
	DVB-T2 16k FFT length, PP3
	DVB-T2 16k FFT length, PP8

Group Delay

Group delay measures the frequency dependant phase response and transition time of the incoming signal through a device under test (DUT).
The 4T2 RF-Analyser offers graphical displays for phase response, group delay response and amplitude response.
The Group Delay analysis function requires the demodulation algorithms to be locked to the input signal for accurate results.

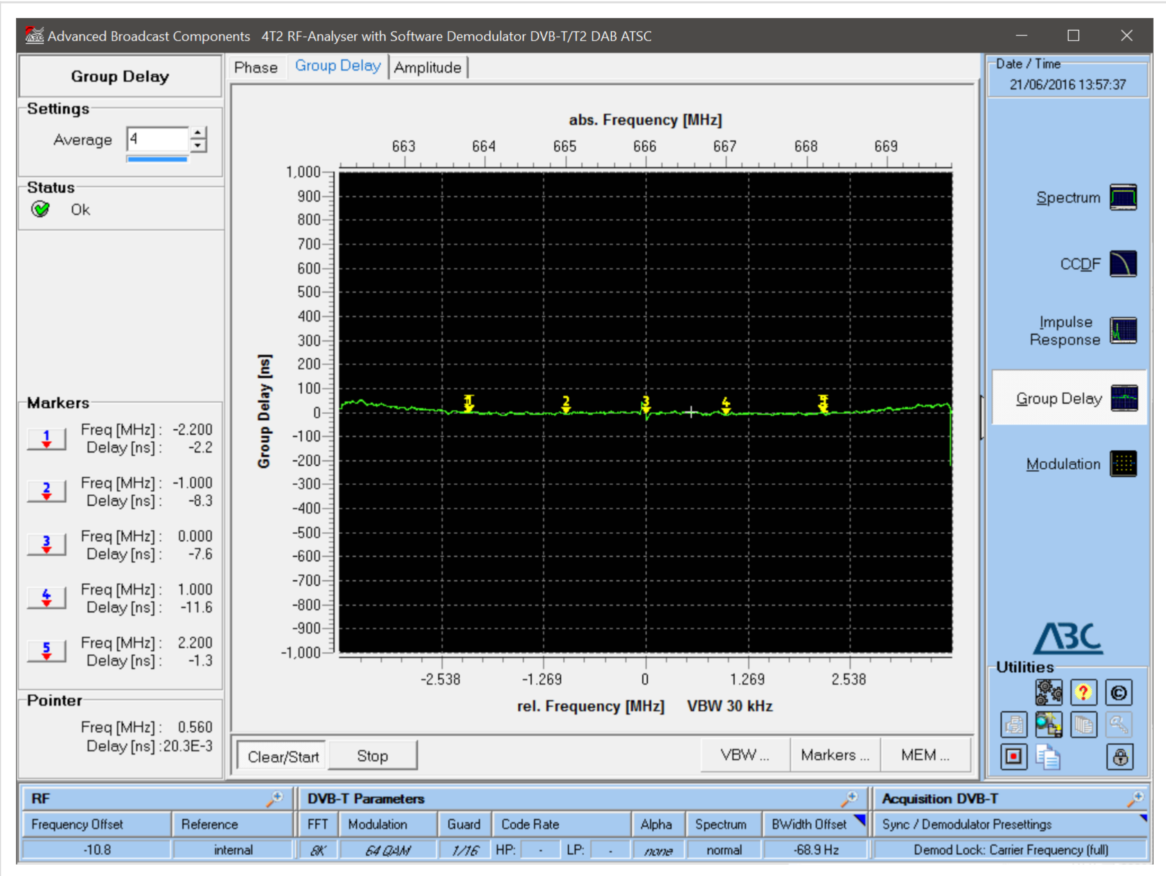


Illustration 5: /Analysis/Group Delay

Background Information

Group delay can be calculated by differentiating the phase response over frequency (d_{phi} / d_f).
It reduces the linear portion of the phase response to a constant value, and transforms the deviations from linear phase into deviations from constant group delay (which causes phase distortion in communication systems).
The average delay represents the average signal transit time through a DUT.

Group Delay Controls

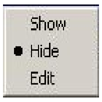
The following section explains the various control elements which are available to the user in order to perform Group Delay measurements.

These buttons are used to toggle the tab-sheet displays between Phase, Group Delay and Amplitude response results.

The *Clear/Start* button starts the group delay analysis and resets the average counter.

The *Stop* button freezes the display.

The *Markers ...* button opens the following pop-up window:



You may:
Show
Hide or
Edit markers.

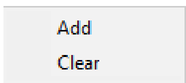
The 4T2 provides 5 markers within the display. If the Markers are hidden, no measurement results will be available at the bottom left part of the screen.

Edit opens the marker positioning dialog.

VBW ... allows for setting the video bandwidth. When clicking on *VBW ...* the following pop-up window appears:

The video bandwidth may be selected easily; the default value is displayed in ***bold*** letters. Please note that not every combination of RBW and VBW is possible.

The *MEM ...* button opens a pop up window with the possibilities:



Add or
Clear.

Add allows for storing of the current trace to the background. Stored traces are coloured in blue.

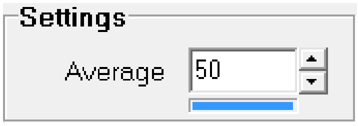
Multiple storing is possible. *Clear* removes all stored curves.

MEM ... provides an easy way to compare results of different measurement situations e.g. for adjustment improvements.

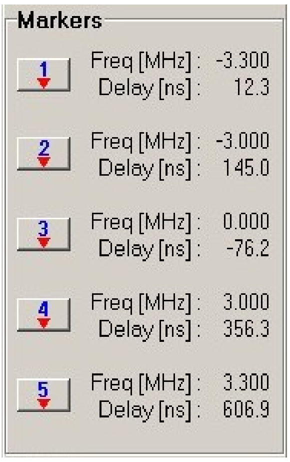
The *MEM ...* function is also available in the *Spectrum*, *Impulse Response*, and *CCDF* mode of operation.

Group Delay Results

Below you will find a list of parameters displayed by the 4T2 *Results* group on the left hand side of the screen while a Group Delay analysis is performed:

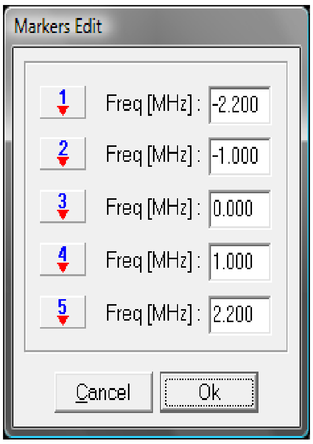


The *Average* selector field allows determining the average number of display points per measurement. If required, please click at either the "increase" or "decrease" arrow to change the setting. You may also type the average number directly. The blue bar indicates the progress of the averaging process. This may be helpful especially if averaging takes place over a higher number of symbols.



The *Markers* area at the bottom left part of the screen contains five result lines for the markers on the Group Delay display.

Depending on the selected results display type (Group Delay or Phase, see 5.5.2), the 4T2 displays either the group delay (in ns) or the phase (in degrees) for each of the defined marker points displayed in this section.



Instead of displaying the delay of a certain marker, you can click the arrow underneath e.g. the figure 1 marker to open the Markers selection dialog.

If you prefer to display e.g. the delay difference (or phase difference) between marker 1 and marker 2, click *Delta 1-2*.

The *Pointer* area displays the group delay (or phase) of the signal at the current mouse pointer position in the diagram.

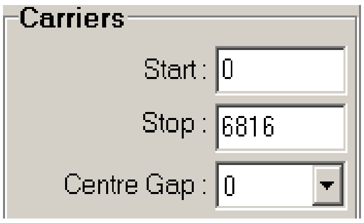
Modulation

The Analysis Modulation menu provides five different display modes which enable to thoroughly analyse the modulation characteristics of the received signal:

- Q vs I (constellation)
- Q vs Carrier
- I vs Carrier
- MER vs Carrier and
- EVM vs Carrier

Modulation Controls

The following section explains the various control elements which are available to perform a modulation analysis.



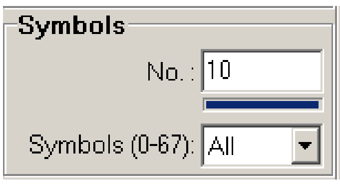
The *Carrier Start* field indicates the first carrier of the range of analysed OFDM-carriers.

The *Carrier Stop* field indicates the last carrier in the range of analysed OFDM-carriers.

By choosing the number of carriers in the *Centre Gap* field, the range for the Carrier Suppression measurement can be selected.

IQ Boundaries determines symbol decision properties and may be beneficial e.g. in low MER environments. Possible values are "Forced", "Squares", "Circles".

IQ Boundaries can remove constellation points from the calculations if they fall outside the decision area. The number and ratio of dropped constellation points related to number of carriers and symbols is displayed under results. Visibility of boundaries can be toggled with the *Boundaries* button below the diagram.



The number of *Symbols* being taken into account for the display of measurement results is entered here. The progress bar is helpful especially in case of a high number of symbols.

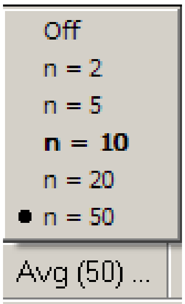
Symbols (0-67) relates to the pilot scheme displayed. Either all 68 pilots are displayed or only a modulo 4 subset, consisting of

- pilots #0,#4,#8, ... (mod 0),
- pilots #1,#5,#9, ... (mod 1),
- pilots #2,#6,#10, ... (mod 2),
- pilots #3,#7,#11, ... (mod 3).

The Precision Mode improves accuracy of the displayed results in 6 MHz channels (typically used in Taiwan; 4T2 with DSP chip-demodulator only).

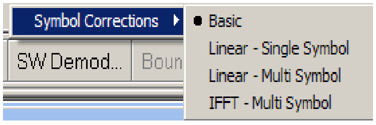
The *Clear/Start* button allows starting a new constellation display.

The *Stop* button freezes (holds) the graphic display.



Avg(.n.) is active at MER vs Carrier and EVM vs Carrier measurements. The value in brackets on the button shows the actual setting.

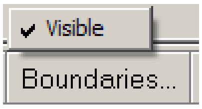
An average of 10 is recommended for most applications



SW Demodulation allows to select 4 different symbol correction methods (channel estimation profiles):

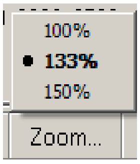
- Basic - according to the symbol gravity point
- Linear - Single Symbol: using pilot carriers on ideal position
- Linear - Multi Symbol: linear interpolation
- IFFT – Multi Symbol: Inverse FFT over all symbols, otimal suited for situations with strong pre – and post-echoes.

Settings are applied when Software Demodulation is activated (see also description of the *Sync* button).



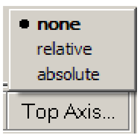
Toggles visibility of IQ Boundaries according to the IQ boundary value selection on the left hand side.

The *Colouring...* button selects between fixed or measurement result depending draw colour of the data points. You may select between Yellow, Result and Rainbow.



The *Zoom...* button allows for scaling the display of constellation points to 100%, 133% and 150%. 100% display concentrates the constellation in the middle of the screen but shows also pixels which appear far away from the centre points. The other modes give a more detailed display of the data carriers.

In the display modes that show data versus carriers, you are able to zoom in on any range of carriers using your left mouse button. Please refer to (*Q vs Carrier / I vs Carrier Display Mode*) for more details.



The *Top Axis...* button is used to adopt the diagram header annotation to the user's requirements. It allows for toggling between the following header scaling:

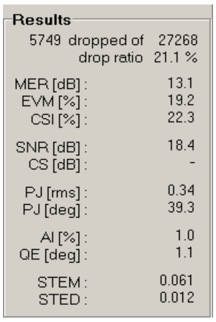
- none: no top axis scale is displayed
- relative: frequency display is zero at the centre position
- absolute: frequency display according to the chosen DVB-T/H channel

Top Axis... it is not available in Q vs I Modulation display mode.

Modulation Results

The 4T2 RF-Analyser measures the following parameters of the OFDM Signal in real-time. The results are displayed for the carrier range from *Start* to *Stop* carrier in the *Carrier* group. The number of symbols taken into account is entered in the *Symbols* box.

Activating IQ Boundaries may lead to dropping of constellation points outside the decision area. The number of dropped symbols as well as the drop ratio is displayed under *Results.*



The *Results* field summarises the modulation analysis.

The *Modulation Error Ratio* (MER) provides a single figure, indicating the quality of the received DVB-T signal. MER is defined as the ratio of I/Q signal power to I/Q noise power; the result is indicated in dB.

MER for digital modulation signals is a substitute to signal to noise ratio (SNR) for analogue signals.

Higher MER values indicate better signal performance.

EVM

The *Error Vector Magnitude* (EVM) is closely related to the MER and can be computed from that figure since both EVM and MER essentially measure the same error characteristics.

EVM is defined as the ratio of the average measured error magnitude to the peak symbol magnitude in percent.

CSI

The *Channel-State Information* (CSI) is defined as the MER in percent.

SNR

SNR or *Signal to Noise Ratio* gives additional information about the quality of the received signal. Since proper SNR measurements require a sound data base, SNR values are displayed only if the number of symbols is >= 20.

CS

The *Carrier Suppression* (CS) is a measure for the rejection of unwanted sinusoidal signals affecting the centre of the analysed OFDM signal. CS is measured in dB; high values indicate high suppression or high signal quality. CS is measured only if the Centre Gap is different from 0.

PJ

The *Phase Jitter* (PJ) of an oscillator occurs due to fluctuations of its phase or frequency. Using such an oscillator to modulate a digital signal results in a sampling uncertainty in the receiver because the carrier regeneration cannot follow the phase fluctuations.

The Phase Jitter is displayed in degrees.

PJ[rms]

The *RMS* (Root Mean Square) *Phase Jitter* parameter is a different representation of the Phase Jitter, indicated as an absolute figure with two decimal places.

AI

The purpose of the *Amplitude Imbalance* (AI) measurement is to separate the QAM distortions resulting from amplitude imbalance of the I and Q signal from all other kinds of distortions.

The AI parameter is expressed as a percentage.

QE

The *Quadrature Error* (QE) parameter describes the distortion of a constellation diagram in case the phases of the two carriers feeding the I and Q modulators are not orthogonal (their phase difference is different from 90°). The QE parameter is indicated in degrees.

STEM

The *System Target Error Mean* (STEM) gives a global indication about the overall distortion present on raw data received by the 4T2, including components like Carrier Suppression, Amplitude Imbalance, Quadrature Error and non-linear distortion. For each point in the constellation graph, the 4T2 computes the distance between their ideal symbol point location and the point corresponding to the mean of the cloud of that particular point.

The result is the Target Error Vector (TEV), whose Root Mean Square (average) value is then determined for all points in the constellation diagram and used to compute the numerical readout given in the System Target Error Mean (STEM) field. It is visualised by the displacement of the centres of the clouds in a constellation diagram from their ideal point.

STED

The *System Target Error Deviation* (STED) is calculated from the STEM value and defines the STE standard deviation.

Modulation Displays

Q vs I Display Mode (Constellation Diagram)

The constellation diagram is ideally suited for assessing the modulation quality of the terrestrial DVB signal at the first glance. It displays the amplitudes of Q(uadrature) and I(nphase) modulated signals in the complex domain. On demand, the symbol decision thresholds can be displayed. Various degrading effects such as noise, interference, I/Q imbalance, and phase jitter may be viewed on the constellation diagram. Each of these effects results in a distinctive cloud shape or other degradation from the sharp constellation point pattern that can be expected for an ideal signal with no or only little modulation errors.

An example constellation diagram for a received 64 QAM modulated DVB-T signal is shown below. Carriers are displayed according to the selected Colour Mode; pilot carriers are displayed in green colour, TPS pilots in blue colour.

The Modulation analysis function requires the demodulation algorithms to be locked to the input signal for accurate results (Demod Lock – Carrier Frequency (full)).

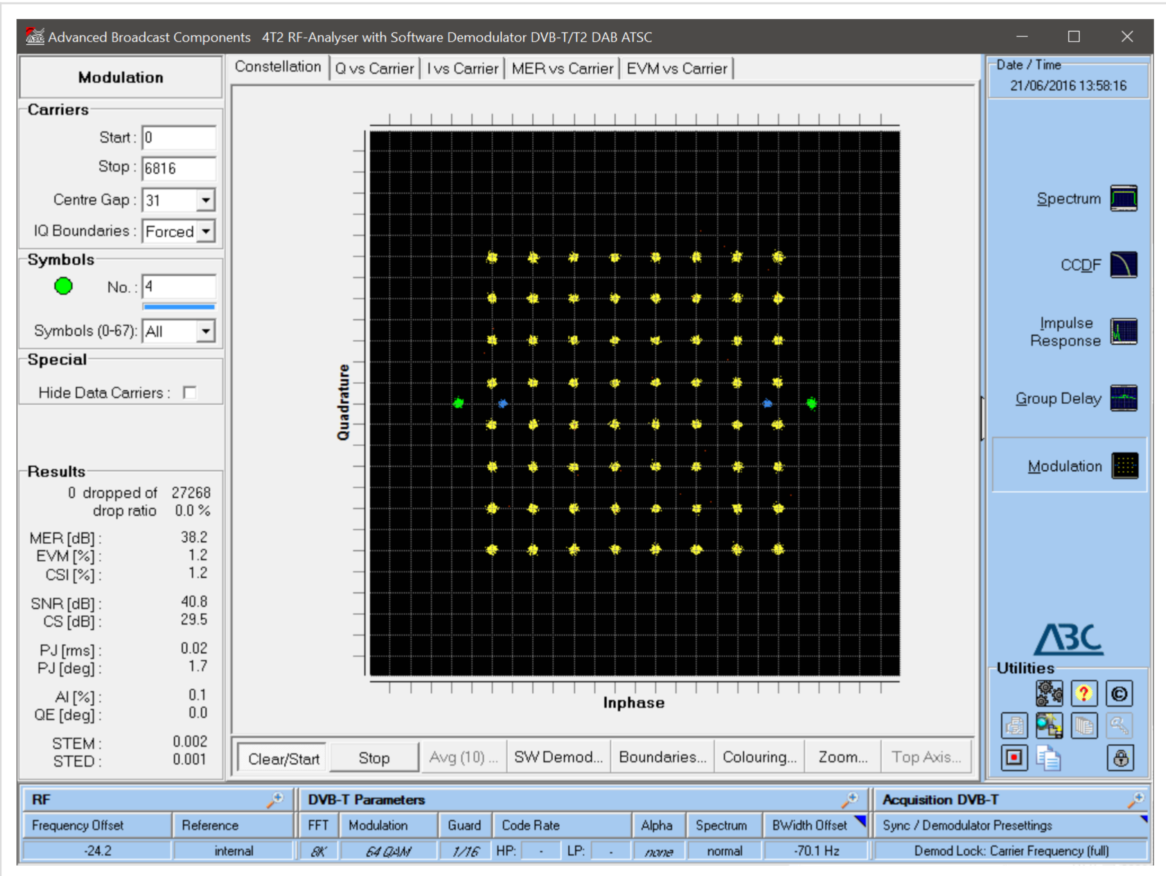


Illustration 6: /Analysis/Modulation/Q vs I display (constellation diagram)

Q vs Carrier / I vs Carrier Display Mode – Zoom Function

In all displays where the number of carriers is indicated on the horizontal axis (Q vs Carrier, I vs Carrier, MER vs Carrier, and EVM vs Carrier), you are able to zoom in on any range of carriers, down to one carrier, by dragging the mouse pointer from left to right over the area of interest while holding the left mouse button down. The exact range of carriers currently being analysed is indicated in the *Carrier Start* and *Carrier Stop* fields. After you have finished analysing a particular section, press the left mouse button and drag the mouse pointer from right to left in order to zoom out again to full span.

A magnifying glass icon at the lower left corner indicates a zoomed display. Clicking on this symbol always zooms back to full span display.

In the Q vs Carrier display the pilots appear on the centre line. Carriers selected in the Centre Gap field appear in red colour.

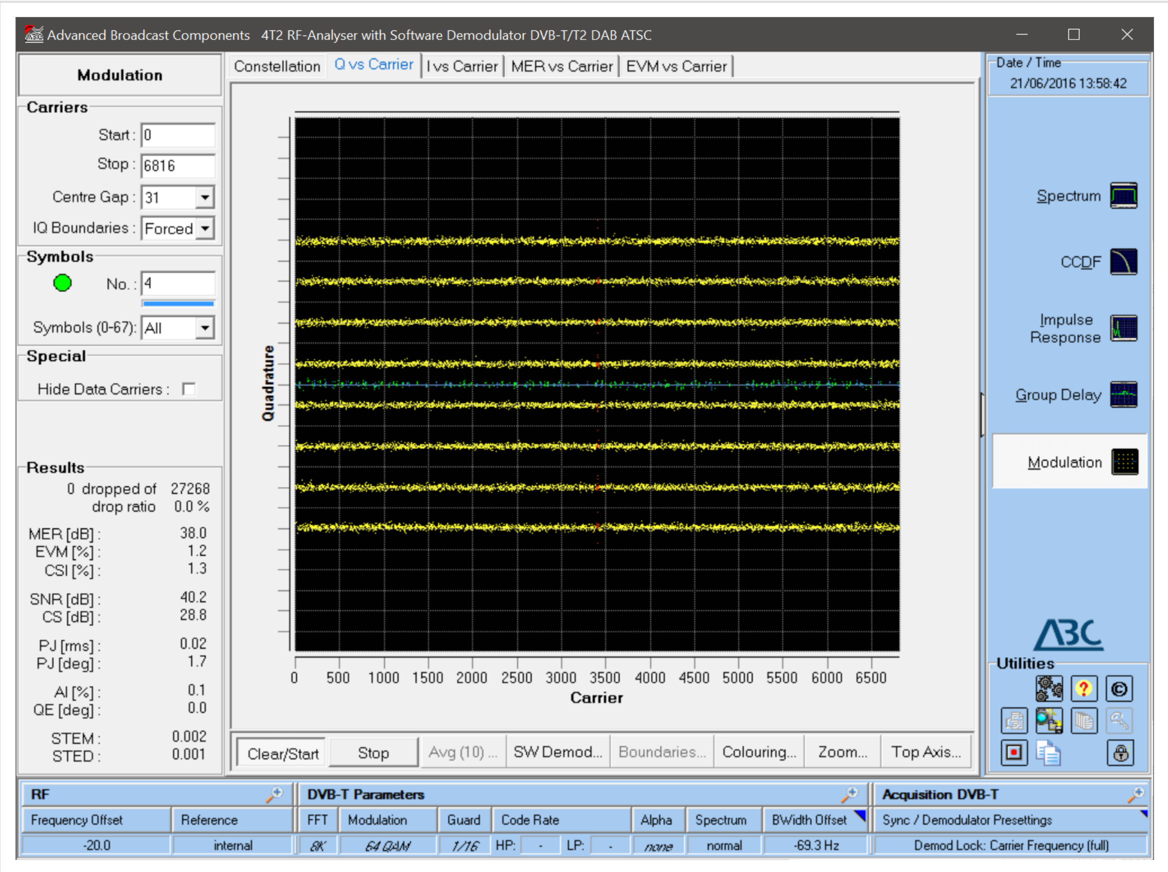


Illustration 7: /Analysis/Modulation/I vs Carriers

MER vs Carrier / EVM vs Carrier in Zoom Mode

The diagram below shows the MER vs Carrier analysis display.

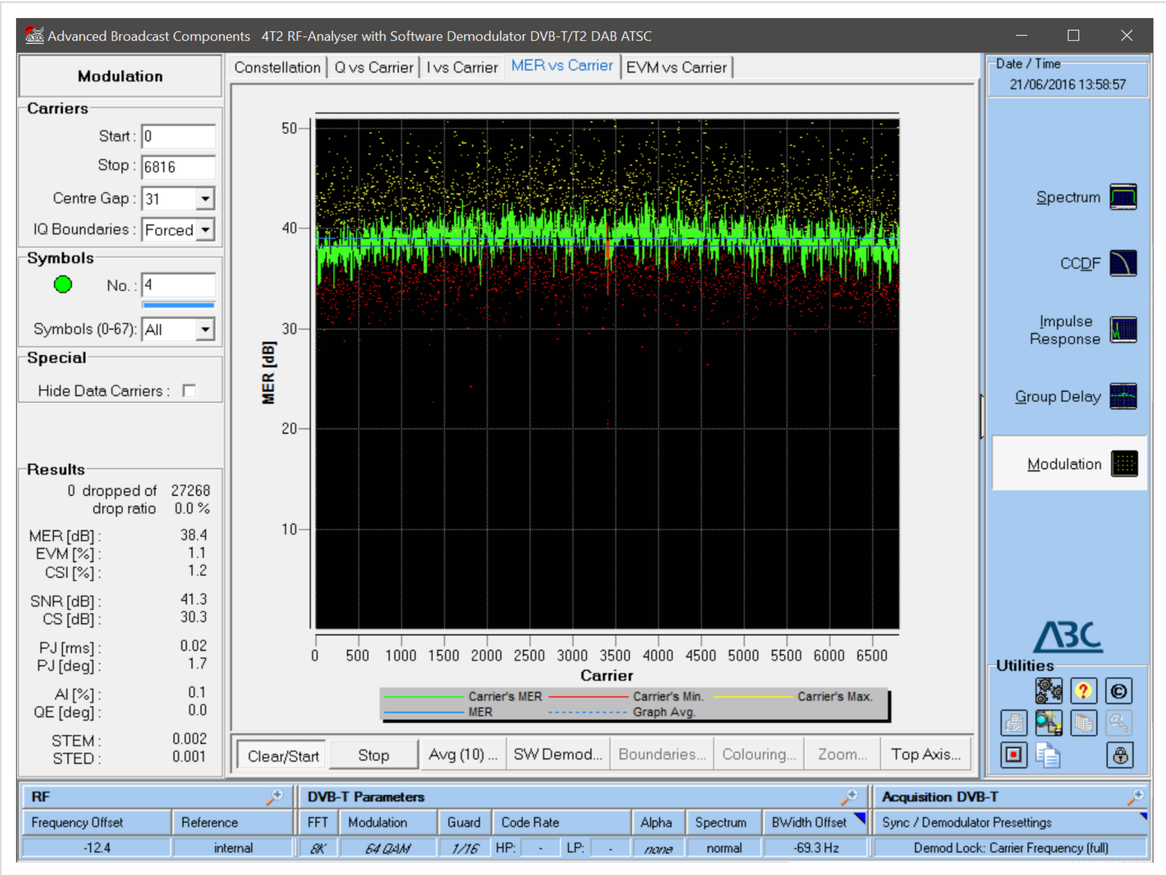


Illustration 8: /Analysis/Modulation/MER vs Carrier

MER vs Carrier gives a variety of information about the MER behaviour of the received signal.
The full information is shown when the averaging function is activated by setting a value different from zero at the *Avg(...)* bar.

A coloured display is shown, the lines having the following meaning:

- steady blue line: true MER value, according to the measured and displayed MER value
- intermittent blue line: "optical" mean value of the MER curve
- green line: MER curve, averaged over the number of symbols, set by *Avg(...)*
- red dots: minimum MER value during one average period
- yellow dots: maximum MER value during one average period

Some hints:

- In the case of software demodulation activated (in the *Sync* pop-up menu) use an adequate low number of symbols in order to have reasonable response times.
- The same applies to the order of average symbols.

The averaging feature is also available at the *EVM vs Carrier* measurement function (not described here in detail).

Coverage

The Coverage function enables the 4T2 to relate OFDM measurement to position data derived from a GPS receiver. The combined data is logged on the 4T2 disk.
The coverage database is in ASCII comma separated values (csv) and may thus be converted to any file format for post-processing, like using coverage prediction software.

There are up to 4 receivers supported, allowing for a maximum of 4 channels to be measured at the same time.

Currently, the application supports Garmin, and Navilock GPS receivers following the NMEA standard.

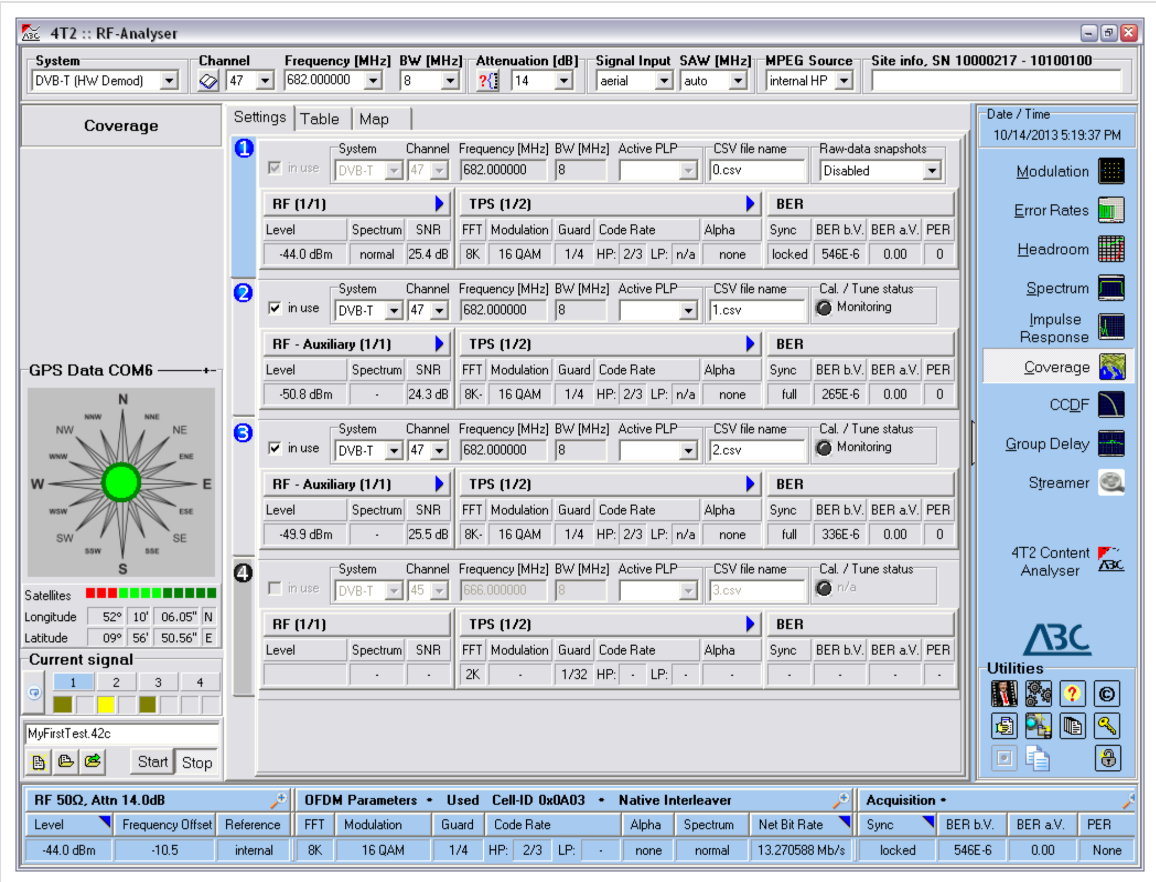


Illustration 9: /Analysis/Coverage (settings display)

Obtaining map information

The process to perform coverage analysis requires very little expert knowledge and can be done in a number of ways, all leading to accurate and reliable results.
The 4T2 can be used to superimpose measurement results on a map of the coverage area, but it is not mandatory to do so. This means that one can perform coverage measurements without loading a map file.
We do, however, encourage to use the map display feature as this is some kind of an online verification during the measurement session.
To use a map for the coverage analysis you will need to have a map-file of sufficient size and resolution in a bitmap format (PNG, JPEG, and BMP supported).

After setting two reference pins, the map is scaled automatically. It is not mandatory to set the reference pins before starting the measurement session. They can be altered during a running measurement session, if necessary.

ABC is providing a **MapMaker** application that enables to obtain up-to-date map data from the internet (Open Street Map Project http://www.openstreetmap.org). The map data is automatically referenced and a loaded map file will immediately display correctly in the RF-Analyser.

Center application screen area

The *Settings* tab holds all settings of the measurement receivers in the 4T2.

Up to 4 receivers are supported under positions 1..4.
The position 1 receiver on the top is always the 4T2 main receiver and thus controlled by the main application settings accessible on the very top of the application-screen.

Raw-data snapshots is a debug tool that allows the storage of IF sample data during the measurement run. This is for ABC internal use, should there be very difficult receiving conditions where more expert opinion is required. ABC has specific proprietary debug tools to work on this data. Please note, that this function stores a lot of data. It is therefore recommended to disable during normal use.

Position 2 to 4 are auxiliary receivers and can be tuned in the corresponding dialogues.

The *Table* tab provides a detailed list of all measurement samples that have been gathered during a measurement session.

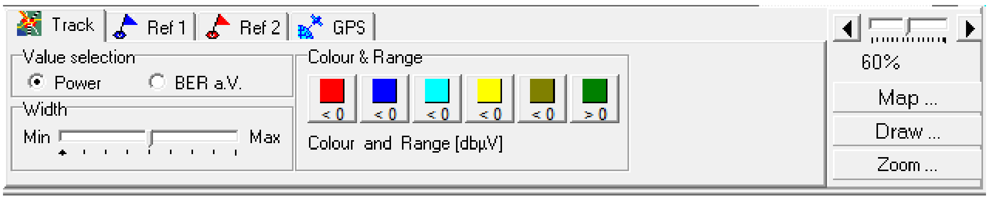
Depending on the position 1..4 selected, the table display changes to the data measured by the corresponding receiver.

The *Map* tab shows the map and the superimposed track herein.

Depending on the position 1..4 selected, the map display changes to the data measured by the corresponding receiver.

The Map tab offers additional tabs for display and documentation:

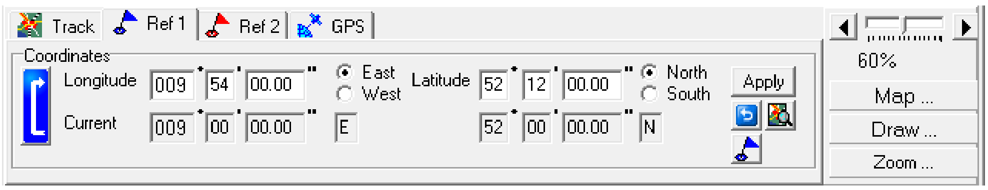
Track Tab-sheet



Properties of the superimposed track can be selected here:

- Value Selection: Colours of the track derived from input level, or bit errors
- Width: Width of the displayed track
- Colour & Range: Selection of colours related to input properties

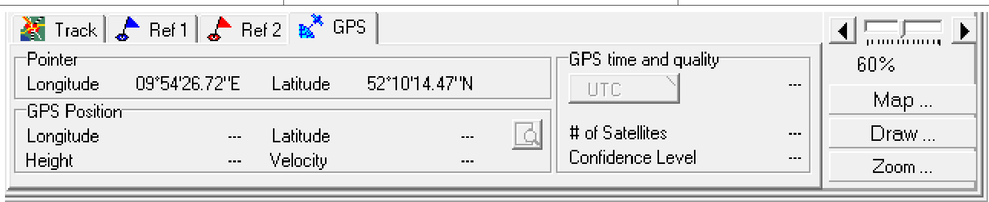
Ref 1/2 Tab-sheet



For manual scaling of displayed map:

- Coordinates: Allows the positioning of reference pins on map, and supports the data acquisition from an attached GPS receiver.

GPS Tab-sheet



Main data display of an attached GPS receiver.

The button *Map* allows the replacement, or selection of a map file.
The button *Draw* allows the selection of values to be drawn on the map.
The button *Zoom* allows the zoom of the map and measurement data according to user requirements.

Left application screen area

GPS Data COMnn displays the GPS communication and indicates traffic on the interface.
While driving, an arrow will point into the direction on the compass dial.

Current position information and the number of satellites received is displayed for data confidence evaluation.

The *Current signal* section allows for a quick evaluation of the reception quality. It can be also used to switch between the receivers. A button to the left of the receiver indicators allows for a complete retune of the receiver front-ends.

Waypoints allows for connection to wheel sensors, should GPS not be available (like in tunnels). As there is additional hardware required, please contact ABC for a further explanation of the usage.

Click the *Start* button to start a measurement.
Click the *Stop* button to terminate the current measurement.

The *File New* dialogue allows creating a new coverage measurement project. You will be asked to save the current settings. Entering a new filename opens a project based on the current settings.

The *File Open* dialogue allows opening an existing coverage measurement project.

The *File Import* dialogue allows opening a legacy single channel coverage project file in the ini format used by RF-Analyser up to 2007.

DVB-T/H Modulation Parameters

Key properties of *2k*, *4k*, and *8k* modulation modes:

channel BW [MHz]	mode [1]	No of carriers [1]	carrier spacing [Hz]	OFDM width [Hz]	FFT length [1]	OFDM [1]	elementary period [1]	symbol length [us]	frame length sym*68 [us]	super frame length fr*4 [us]	guard [1]	guard [us]	Tsymbol [us]	Cmin [1]	Cmax [1]	scattered pilots [1]
	2k	1705	4464,29	7,61	2.048	7/8	7/64	224	15232	60928	1/4	56	280	0	1704	131
											1/8	28	252			
											1/16	14	238			
											1/32	7	231			
8	4k	3409	2232,14	7,61	4.096	7/8	7/64	448	30464	121856	1/4	112	560	0	3408	262
											1/8	56	504			
											1/16	28	476			
											1/32	14	462			
	8k	6817	1116,07	7,61	8.192	7/8	7/64	896	60928	243712	1/4	224	1120	0	6816	524
											1/8	112	1008			
											1/16	56	952			
											1/32	28	924			

channel BW [MHz]	mode [1]	No of carriers [1]	carrier spacing [Hz]	OFDM width [Hz]	FFT length [1]	OFDM [1]	elementary period [1]	symbol length [us]	frame length sym*68 [us]	super frame length fr*4 [us]	guard [1]	guard [us]	Tsymbol [us]	Cmin [1]	Cmax [1]	scattered pilots [1]
	2k	1705	3906,25	6,66	2.048	7/8	1/8	256	17408	69632	1/4	64	320	0	1704	131
											1/8	32	288			
											1/16	16	272			
											1/32	8	264			
7	4k	3409	1953,13	6,66	4.096	7/8	1/8	512	34816	139264	1/4	128	640	0	3408	262
											1/8	64	576			
											1/16	32	544			
											1/32	16	528			
	8k	6817	976,56	6,66	8.192	7/8	1/8	1024	69632	278528	1/4	256	1280	0	6816	524
											1/8	128	1152			
											1/16	64	1088			
											1/32	32	1056			

channel BW [MHz]	mode [1]	No of carriers [1]	carrier spacing [Hz]	OFDM width [Hz]	FFT length [1]	OFDM [1]	elementary period [1]	symbol length [us]	frame length sym*68 [us]	super frame length fr*4 [us]	guard [1]	guard [us]	Tsymbol [us]	Cmin [1]	Cmax [1]	scattered pilots [1]
	2k	1705	3348,21	5,71	2.048	7/8	7/48	298,67	20309,33	81237,33	1/4	75	373	0	1704	131
											1/8	37	336			
											1/16	19	317			
											1/32	9	308			
6	4k	3409	1674,11	5,71	4.096	7/8	7/48	597,33	40618,67	162474,67	1/4	149	747	0	3408	262
											1/8	75	672			
											1/16	37	635			
											1/32	19	616			
	8k	6817	837,05	5,71	8.192	7/8	7/48	1194,67	81237,33	324949,33	1/4	299	1493	0	6816	524
											1/8	149	1344			
											1/16	75	1269			
											1/32	37	1232			

channel BW [MHz]	mode [1]	No of carriers [1]	carrier spacing [Hz]	OFDM width [Hz]	FFT length [1]	OFDM [1]	elementary period [1]	symbol length [us]	frame length sym*68 [us]	super frame length fr*4 [us]	guard [1]	guard [us]	Tsymbol [us]	Cmin [1]	Cmax [1]	scattered pilots [1]
	2k	1705	2790,18	4,75	2.048	7/8	7/40	358,4	24371,2	97484,8	1/4	90	448	0	1704	131
											1/8	45	403			
											1/16	22	381			
											1/32	11	370			
5	4k	3409	1395,09	4,75	4.096	7/8	7/40	716,8	48742,4	194969,6	1/4	179	896	0	3408	262
											1/8	90	806			
											1/16	45	762			
											1/32	22	739			
	8k	6817	697,54	4,75	8.192	7/8	7/40	1433,6	97484,8	389939,2	1/4	358	1792	0	6816	524
											1/8	179	1613			
											1/16	90	1523			
											1/32	45	1478			

Continuous Pilot Carriers (CP) Transmitter Parameter Signalling Carriers (TPS) 2k mode (45 CP, *17 TPS*)	(Carrier indices) 8k mode (177 CP, *68 TPS*)
0 ***34*** 48 ***50*** 54 87 141 156 192 201 ***209*** 255 279 282 333 ***346*** ***413*** 432 450 483 525 531 ***569*** ***595*** 618 636 ***688*** 714 759 765 780 ***790*** 804 873 888 ***901*** 918 939 942 969 984 1050 1101 1107 1110 1137 ***1073*** 1140 1146 1206 ***1219*** ***1262*** 1269 ***1286*** 1323 1377 ***1469*** 1491 ***1594*** 1683 ***1687*** 1704	0 ***34*** 48 ***50*** 54 87 141 156 192 201 ***209*** 255 279 282 333 ***346*** ***413*** 432 450 483 525 531 ***569*** ***595*** 618 636 ***688*** 714 759 765 780 ***790*** 804 873 888 ***901*** 918 939 942 969 984 1050 1101 1107 1110 1137 ***1073*** 1140 1146 1206 ***1219*** ***1262*** 1269 ***1286*** 1323 1377 ***1469*** 1491 ***1594*** 1683 ***1687*** 1704 ***1738*** 1752 ***1754*** 1758 1791 1845 1860 1896 1905 ***1913*** 1959 1983 1986 2037 ***2050*** ***2117*** 2136 2154 2187 2229 2235 ***2273*** ***2299*** 2322 2340 ***2392*** 2418 2463 2469 2484 ***2494*** 2508 2577 2592 ***2605*** 2622 2643 2646 2673 2688 2754 ***2777*** 2805 2811 2814 2841 2844 2850 2910 ***2923*** ***2966*** 2973 ***2990*** 3027 3081 ***3173*** 3195 3387 ***3298*** ***3391*** 3408 ***3442*** 3456 ***3458*** 3462 3495 3564 3600 3609 ***3617*** 3663 3687 3690 3741 ***3754*** ***3821*** 3840 3858 3891 3933 3939 ***3977*** ***4003*** 4026 4044 ***4096*** 4122 4167 4173 4188 ***4198*** 4212 4281 4296 ***4309*** 4326 4347 4350 4377 4392 4458 ***4481*** 4509 4515 4518 4545 4548 4554 4614 ***4627*** ***4670*** 4677 ***4694*** 4731 4785 ***4877*** 4899 ***5002*** 5091 ***5095*** 5112 ***5146*** 5160 ***5162*** 5166 5199 5253 5268 5304 5313 ***5321*** 5367 5391 5394 5445 ***5458*** ***5525*** 5544 5562 5595 5637 5643 ***5681*** ***5707*** 5730 5748 ***5800*** 5826 5871 5877 5892 ***5902*** 5916 5985 6000 ***6013*** 6030 6051 6054 6081 6096 6162 ***6185*** 6213 6219 6222 6249 6252 6258 6318 ***6331*** ***6374*** 6381 ***6398*** 6435 6489 ***6581*** 6603 ***6706*** 6795 ***6799*** 6816

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