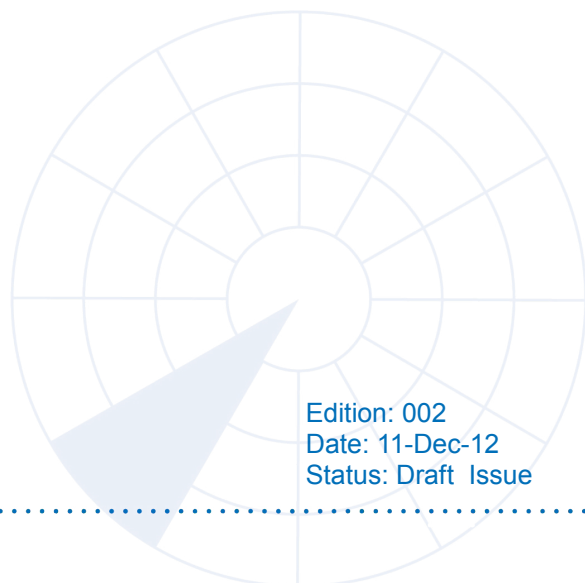
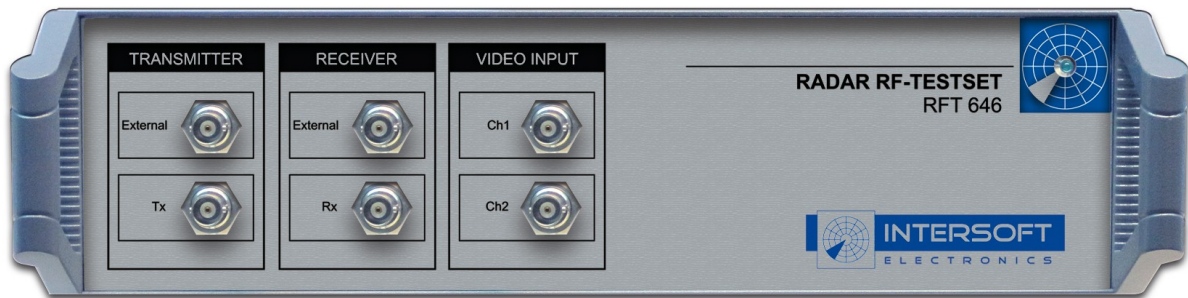


Radar Rf Testset - RFT646

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 the possibility of damage to you or your equipment.



GLOSSARY OF TERMS

CFF	Column Fault Finding measurement
CW	Continuous wave
dB	Decibel
DUT	Device Under Test
FFT	Fast Fourier Transform
IE	Intersoft Electronics
IF	Intermediate Frequency
IFFT	Inverse FFT
LVA	Large Vertical Aperture (antenna)
PSR	Primary Surveillance Radar
PVV	Pulse Vector Voltmeter
Radar	Radio Detection And Ranging
RASS-S	Radar Analysis Support Systems – Site measurements
RF	Radio Frequency
RX	Receiver
SSR	Secondary Surveillance Radar
TX	Transmitter
VNA	Vector Network Analyser
VPD	Vertical Polar Diagram
VSWR	Voltage Standing Wave Ratio (ratio of maximum voltage to minimum voltage on a line)



1. TECHNICAL MANUAL RFT646

1.1. General Introduction

The RFT646 is a versatile dual-channel L/S-band Tx/Rx measuring unit, capable of generating fixed or swept frequency RF test signals in the 700-3500 MHz range. Basically it consists of two phase controlled receivers with digital intermediate frequency measurement channels. Additionally two transmitter channels can provide arbitrary test pulses. A USB interface is used for real-time communication between the DSP controlling the RF-units and the user interface software running on the host computer. The functionality of the unit (as for all RASS-S equipment) can be determined by software.

1.2. Key Features

Following functionalities are available for the RFT646:

- General Vector Network Analysis (VNA): measurement of VSWR, reflective power, forward and reverse transmission
- Dedicated VNA with far field prediction software for (M)SSR LVA antenna
- Dedicated VNA with scanning software for 3D PSR antenna
- Pulse Vector Volt meter

1.3. Hardware Description

1.3.1. Block Diagram

The block diagram below shows the most important building blocks of the RFT646.

The RF front-end consists of two linear receivers for baseband signal processing as is required to perform VNA measurements. Additionally each receiver module has a log receiver channel, whose output is always available at the RFT back panel. A number of switches are put in between to make the ADC input selectable: Lin Rx, Log Rx or the External video input.

Sampling can be triggered in various ways, depending on the DSP program loaded and signals available:

- Analog: a DAC and a comparator allow to trigger at a selectable level. For this purpose, the Reference receiver output can be connected to the trigger circuitry.
- Digital triggering on the external TTL level trigger signal input.
- Internal triggering under software (timer) control.

A Tx output is available to generate a stimulus signal. It can be a swept or a fixed frequency in the range 900 MHz to 3500 MHz. A 63dB digital step attenuator with a 0.5dB step size provides the required power range.

To allow the Rx and Tx frequency to be different, both sections have their own synthesizer module. This makes it possible to add a number of SSR functionalities such as transponder testing, remote field monitor function, etc...



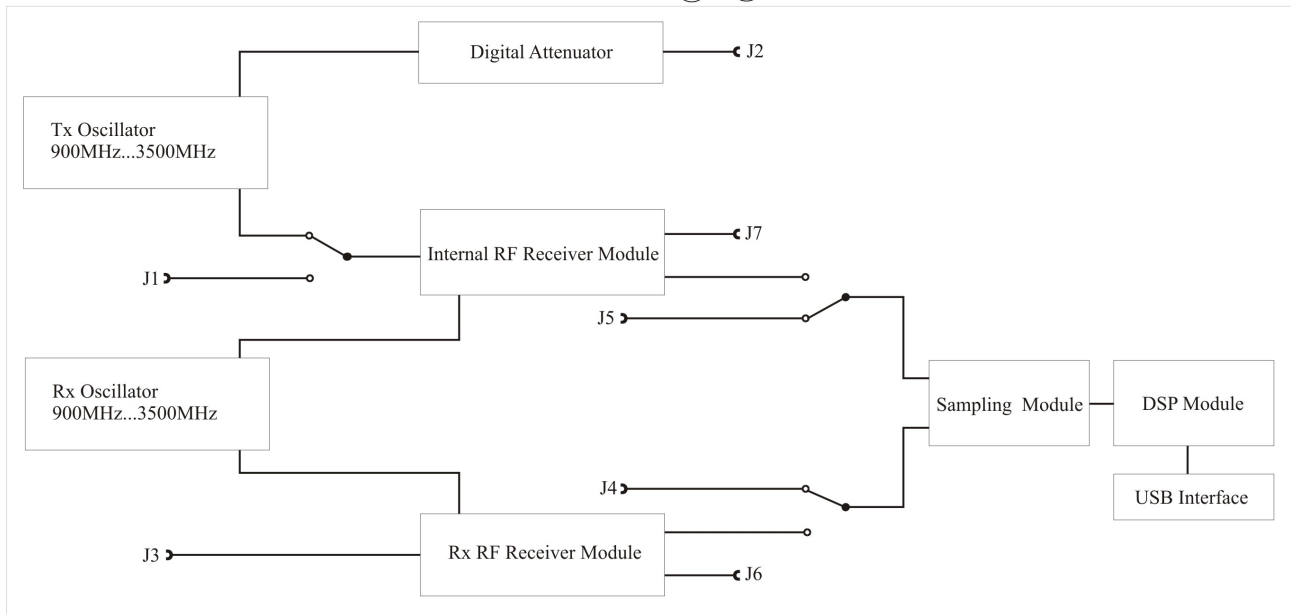
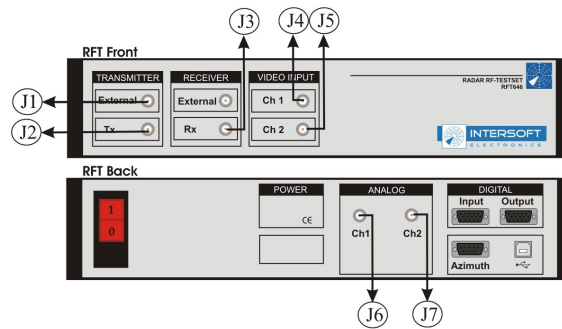


Figure 1: RFT646 Block Diagram

1.3.2. Connectors

1. J1: External Transmitter
 - a) BNC connector
 - b) Frequency range: 900MHz to 3500MHz programmable frequency; synthesizer stabilised; accuracy 100kHz
 - c) Frequency step size: 125kHz
 - d) Max. Tx power: <10dBm
 - e) Modulation range: 60dB
2. J2: Tx
Identical to J1
3. J3: Rx
 - a) BNC connector
 - b) Frequency range: 900MHz to 3500MHz
 - c) Linear sensitivity: -20dBm to -80dBm
 - d) Log sensitivity: -10dBm to -80dBm
4. J4/J5: Ch1/Ch2 Video Inputs
 - a) Analogue video inputs to acquisition system
 - b) BNC connectors
5. J6/J7: Ch1/Ch2 Analogue Outputs
 - a) Analogue video output from Rx
 - b) BNC connectors



2. VECTOR NETWORK ANALYSIS

2.1. Theory

2.1.1. Introduction to VNA

The Vector Network Analyser using the Radar Rf Testset, further called VNA/RFT, is developed for measuring the frequency characteristics of RF single and dual ported devices. The unit can measure both amplitude and phase relation of a DUT (Device Under Test) connected between the input and output port.

It also presents a time domain or distance response curve. A time domain window can be used to single out the response of a specific element in the network. This feature will be very useful for fault finding.

The RFT has two identical input/output channels which makes it possible to use one path to perform the measurement, while the other channel is used as a reference. Since the two channels are identical this will increase system stability and accuracy.

Reflection measurements can be performed using an external directional coupler, to perform SWR and S-parameter measurements. The equipment has an internal modular setup in order to obtain maximum flexibility and future extension provisions.

The unit is operated from a personal computer using virtual front panels. This allows easy access to functions like data storage, hard copy and transfer of data to spreadsheet-like software. The RFT646 is connected to the PC via the USB interface.

The cable set delivered with the Radar Rf Testset is not intended to be of the highest quality for Rf signal connection, since high quality Rf cables are not very handy to work with in the field.



Note: The Radar Rf Testset has a large number and variety of electronic components inside. Therefore we advise the user to allow the system a warm up time of a few minutes in case the maximum accuracy is required.

2.1.2. Basic Concepts of Vector Network Analysis

When dealing with low frequency devices such as transistors and opamps, we usually consider a transfer function of a device as straight forward :

- $F(t) = V_{out}(t) / V_{in}(t)$ in the time domain
- $F(f) = V_{out}(f) / V_{in}(f)$ in the frequency domain

When dealing with RF or microwave energy, we have to be more careful with these assumptions. In fact, this can be compared with light waves. When passing energy to a device, a part of this energy will be transmitted through the device, and a part of the energy is reflected back into the source.



Figure 2: Principle of reflection

This means that an RF device has two transfer functions:

- Transmission function : $F(f) = V_{transmitted} / V_{stimulus}$
- Reflection function : $R(f) = V_{reflected} / V_{stimulus}$



From these functions, several different parameters can be derived:

Table 1: Reflection and transmission parameters

Reflection	Transmission
Input SWR	Gain/attenuation
Return loss	Isolation Input/output
Impedance	Insertion phase
Reflection Coefficient	Group delay
S11,S22	S21,S12

The transmission parameters and reflection parameters are measured separately. Both measurements start with a 'take reference' procedure. The reference from which the (relative) measurement is performed is based upon a physical law.

2.1.2.1. Transmission Parameters

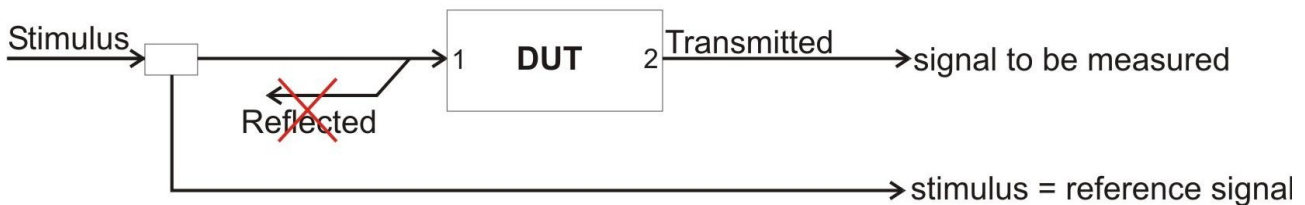


Figure 3: Transmission measurement

In this measurement, it is assumed that the DUT is matched in impedance. The error in matching will reduce the accuracy a little. For instance, a VSWR of 1.5 or a return signal of -14dB on the transmission evokes a measurement uncertainty of 1.6dB.

A VSWR of 3 (-6dB return) evokes a measurement uncertainty of 3.5dB.

2.1.2.2. Reflection Parameters

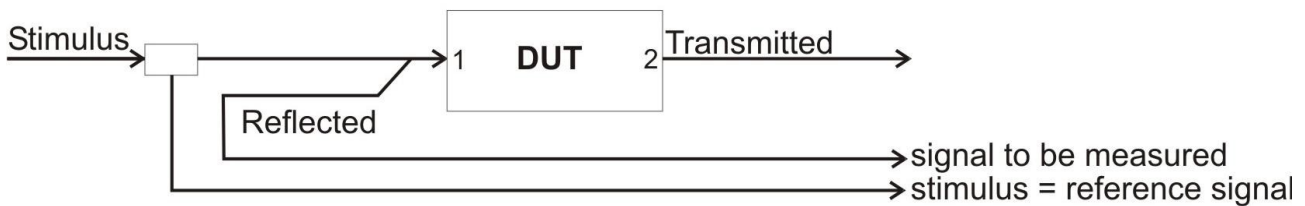


Figure 4: Reflection measurement

In the setup of the transmission measurement, the effect of a small mismatch was negligible. This measurement will focus on the reflection aspect.

First, the reference will be taken with all the energy reflected (open circuit). When the DUT is connected, due to the effect of absorption, the difference with the reference is to be measured. From this measurement all the reflection parameters can be calculated.

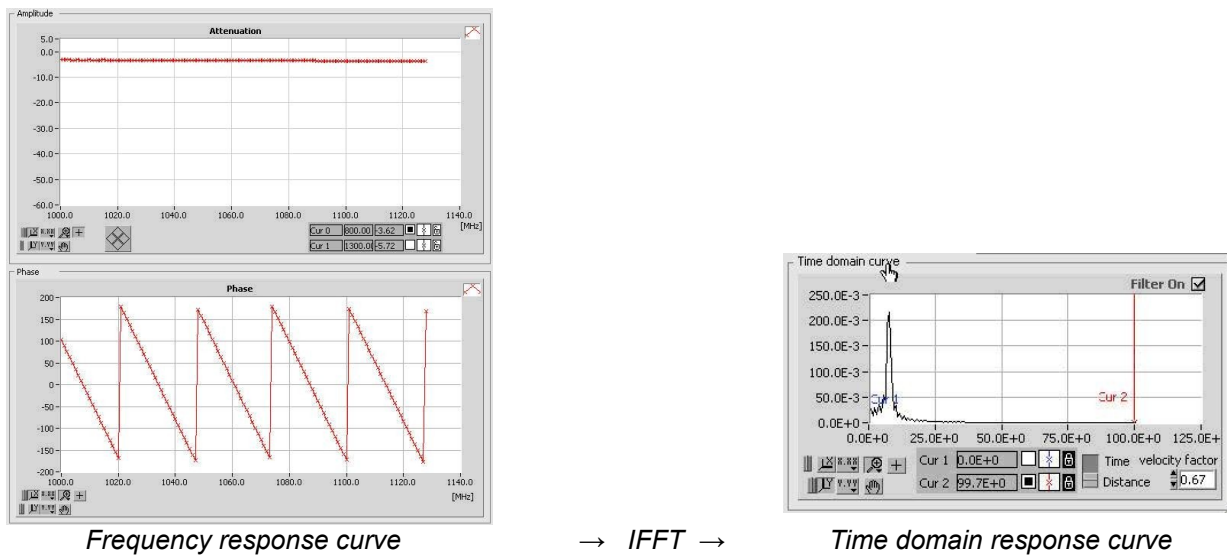


2.1.3. Frequency Domain to Time Domain and Vice Versa

In order to measure all these different parameters of a DUT, the VNA should be able to produce signals with a variety of frequencies to inject into the DUT. By injecting different frequencies and analysing the transmitted signals of the DUT, a frequency response curve can be derived.

The frequency response curve can then be transformed to a time domain curve by calculating the Inverse FFT (IFFT). The most interesting feature of this mathematical approach is that the time domain curve can easily be transformed to a signal amplitude in function of distance or time. By limiting this curve to a section in distance or time the frequency response curve can be recalculated. Doing so the user is able to evaluate the frequency response of a specific part in the transmission chain, for instance the reflection of a rotary joint.

The description of the mathematical formulas can be found in the LabVIEW manual.



2.2. VNA Transmission Measurement

2.2.1. Getting Started

The VNA software is able to deliver information of both amplitude and phase deviation of a device under test. As explained before the measurement is performed by comparing the measurement channel with a reference channel (receiving the stimulus).

The RFT646 contains an internal reference channel, so you will only need to connect the measurement channel.

The connections for the VNA transmission measurement are straight forward. The RFT646 has a coupler and internal RF switch so that the reference signal (derived from the Tx output) is fed through internally.

The only external connections to be made are the ones that are indicated in the connection diagram below. The 10 dB attenuators are default in this setup, they do not only protect the RFT646's receiver, but they also increase the measuring accuracy by improving the VSWR. Further more two RG223 2m cables are used to connect the device under test.

For the reference measurement we connect the cables together with a barrel (as indicated in the figure below), the barrel is later on replaced by the DUT.



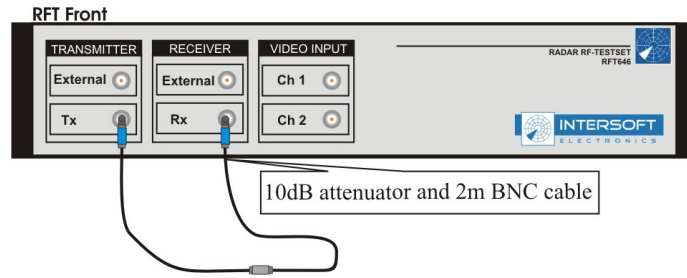


Figure 6: RFT646 connections for VNA transmission measurement

When the connections are made, load the **Vector Network Analysis** tool from the  **VNA** button in the RASS-S toolbox.

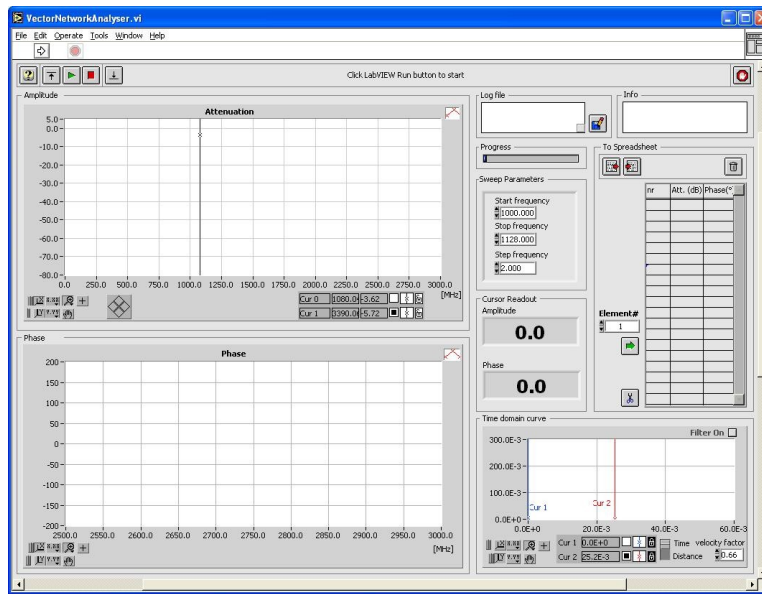


Figure 7: VNA Software

2.2.2. Performing a VNA Transmission Measurement

1. Run the software tool and select the frequency range of interest and the step size. These settings will affect the measurement time!

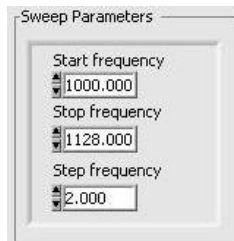




Figure 8: Sweep parameters

2. The first time the tool is started, it will automatically perform a reference measurement, it is therefore important that the device under test is removed and that the Tx and Rx are connected together with a barrel as shown in figure 6. Now start the tool by clicking the  **Start** button. You will notice that the  **Take Reference** button is automatically dimmed as well. When required you can always perform a reference measurement in between measurements by clicking the **Take Reference**

button.

Since the software assumes there is no DUT present, the result of this reference measurement will be accepted by the software as the compensation to be subtracted from the next measurement sweeps, assuming the reference connection corresponds to 0dB attenuation and 0deg phase deviation. Once the reference measurement is performed, you will see the result of the consecutive sweeps. While the reference connections are still in place you will see the stability of the measurement (both in amplitude and phase).

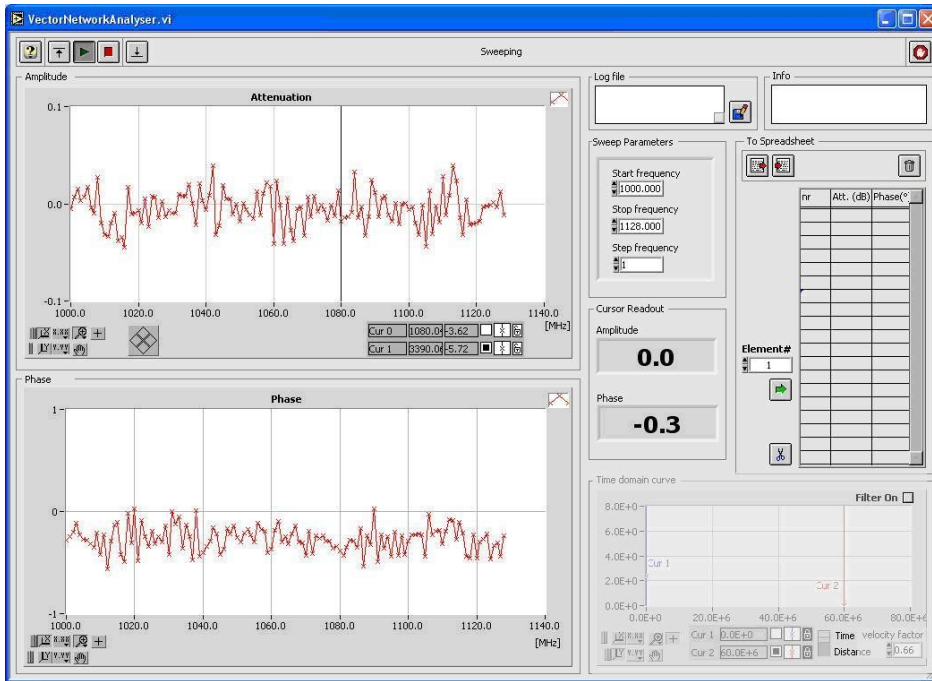


Figure 9: Result of reference measurement: stability of measurement

3. By disconnecting the input of the RFT646 you can verify the noise level. It should be below -55dB.



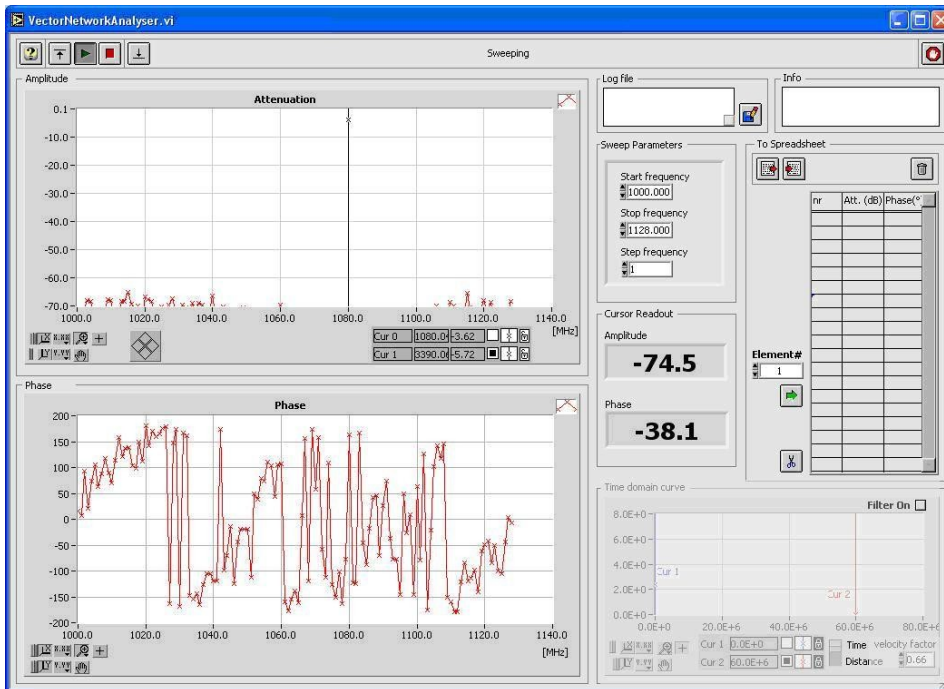


Figure 10: Noise level

- Now the DUT or the transmission chain can be inserted as shown in figure 6. When the DUT is connected, it is probable that a measurement sweep was already taking place. The next sweep provides the correct result.

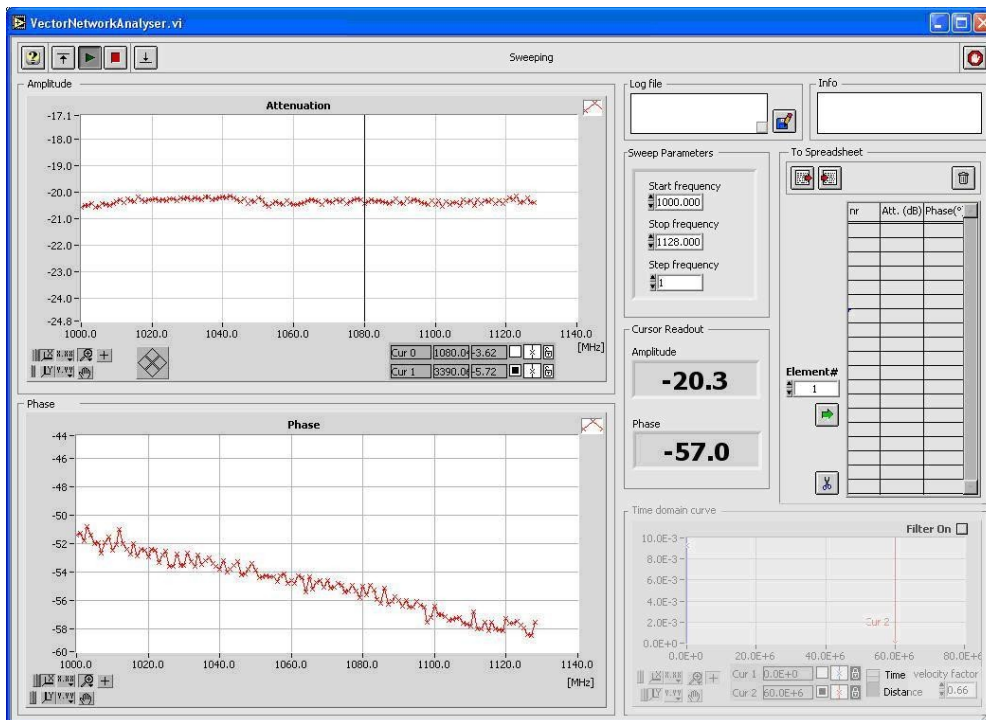




Figure 11: VNA transmission measurement result

The frequency sweep repeats continuously until the  **Stop** button is hit.



5. To save the measurement, click the  **Log curves** button. A pop up dialog appears . The user can create a new logfile or open an existing logfile. **Add logging** will add the graphs' data and the data entered in the **Info** field to the requested logfile.



2.2.3. Example 1: Measuring the loss of a transmission chain

This paragraph shows an example of a transmission measurement. The DUT of the example is a transmission chain containing two 4m BNC RG223 cables, connected with a straight BNC barrel (total of 8m). Replace the BNC barrel in figure 6 with the two 4m cables when the reference measurement is done. The transfer function is presented in the frequency domain like a Bode diagram.

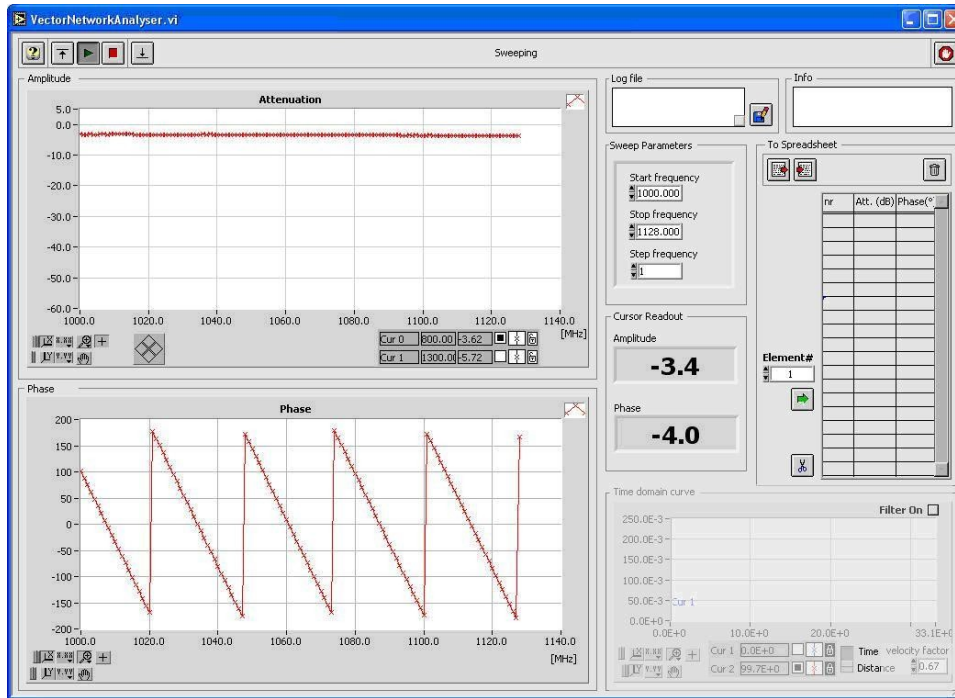


Figure 12: VNA measurement result

The transmission chain had a cable loss of 3.4dB which is acceptable for this type of cabling. The average attenuation is calculated from cursor to cursor in the frequency domain. So it is possible to determine the loss of the transmission line at 1030 MHz in particular.

2.2.4. Example 2: Column Fault Finding measurement (CFF)

In order to calculate the HPD far field behavior of an SSR antenna you can measure the transfer characteristics of the individual elements in certain row of the SSR antenna using the antenna probes. This is done by scanning the elements in a sequence, from the left to the right or vice versa. You can also measure the VPD near field behavior by measuring the elements of a specific column. This is done by scanning the elements in a sequence, from the bottom to the top or vice versa.


The connections are identical as shown in figure 6, the only difference is the DUT itself. Check Annex 6.1. for the full set-up diagram.


The tapering is measured as follows:


1. Follow the steps explained in section 2.2. to perform a transmission measurement.
2. Check the position where the lowest power is expected. This is probably at the end of the column line up (horizontal scan) or at the top of one column (vertical scan). Put the antenna probe in front of the column as shown in Annex 6.1. . If the signal is too low to be measured, then remove the 10dB attenuator at the Tx output to increase the injected power.
3. Hold the antenna probe in position as stable as possible. Each scan has to be performed in the



same way. The more stable a measurement is performed the more repeatable the results will be. A maximum deviation of 1cm is still acceptable.

4. Select the column number you want to measure first. 

Click the  **Add** button. This will add the measured values of the last frequency sweep in the spreadsheet.

5. Then select the column you want to scan next. Repeat the procedure for all the other elements of the antenna.
6. Now it's time to verify the measurement results. In case you have doubt about a specific column measurement you can always repeat the measurement and if necessary replace the previous measurement value with the new result by entering the **Element#** and clicking the **Add** button.
7. Click the  **SaveTapering** button to save the complete table and info data in the selected folder.
8. A dialog box will pop up, pointing by default to the **Network\Tapering** directory of the active campaign folder.
9. To interpret the measured results, use the **Radar Antenna Simulation** software which is explained in section 3. Far Field Simulation of Antenna.

Tips & tricks:

- **Make a measurement in the center column and take reference, unplug the cable and read the dynamic range (>30dB?).**
- **When measuring an additional channel do not take reference again or you will loose the relationship between the two measurements.**

2.3. VNA Reflection Measurement

2.3.1. Getting Started

The VNA reflection setup will make use of an extra coupler. This directional coupler will isolate the energy that is reflected by a DUT or a transmission chain. The VNA software can derive by both amplitude and phase measurement, the physical place and strength of a reflection in a transmission chain. The example in section 2.3.3. will show you how to read the results.

The basic setup of the VNA reflection measurement is shown in figure 13. **Please note that the attenuators can be removed depending on the signal level of the return signal.** In principle the reflected power is measured using this setup. The main advantage is the fact that only one side of the device under test must be connected.

Reflected power of a part of the chain is measured by setting cursors in the time domain filter.



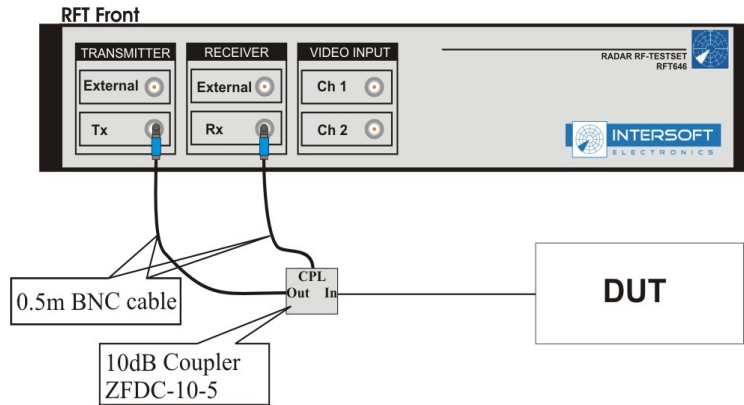


Figure 13: RFT646 connections for VNA reflection measurement

When the connections are made, load the **Vector Network Analysis** tool from the  **VNA** button in the RASS-S toolbox.

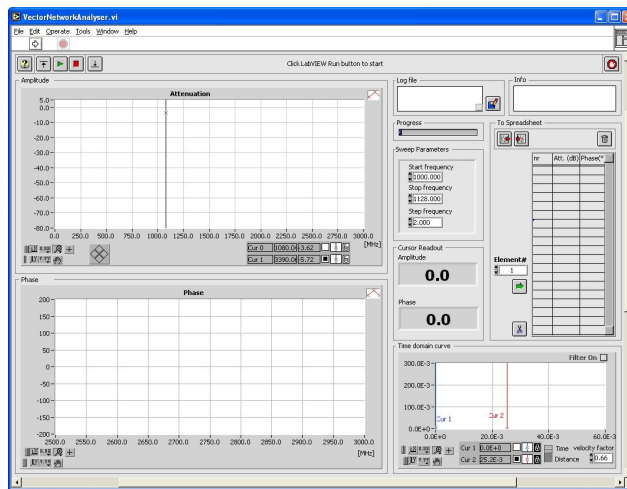




Figure 14: VNA Software

2.3.2. Performing a VNA Reflection Measurement

1. Run the software tool and select the frequency range of interest and the step size. These settings will affect the measurement time!
2. The first time the tool is started, it will automatically perform a **reference measurement**, it is therefore important that the **device under test is removed such that the open end of the coupler's input will reflect maximally** (theoretically 100%). Now start the tool by clicking the  **Start** button. You will notice that the  **Take Reference** button is automatically dimmed as well. When required you can always perform a reference measurement in between measurements by clicking the **Take Reference** button. Since the open end reflects as much as possible, there can not be more energy reflected nor can the reflection of a DUT be faster since the open end is at distance 0. For the software this is the reference, both for amplitude and phase.
3. Now the DUT or the transmission chain can be inserted as shown above. When the DUT is connected, it is probable that a measurement sweep was already taking place. The next sweep provides the correct result.



2.3.3. How to read the results?

2.3.3.1. Measurement Example

In this example you can see the reflections from connectors, cabling and environmental reflections. To demonstrate this function, a calculation of the SWR of a straight BNC jack will be performed. The user can practice on a similar setup, with the equipment available in the RASS-S configuration. It is recommended to use the longest cables as the result will be more obvious.

This example contains one 4m BNC/BNC cable (RFA641 kit), one 2m BNC/BNC cable, 2 straight BNC jacks, and a BNC/MCX antenna cable (RFA641 kit).

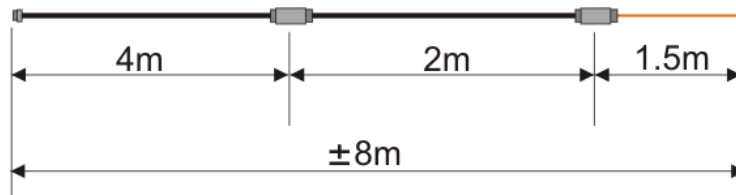


Figure 15: VNA Reflection measurement - Example Set-up

There are two important things about reflections to keep in mind in this measurement:

1. The distance that is displayed is twice as much since the signal travels back.
2. A passive element will meet the reflected signal twice, resulting in double loss figures.

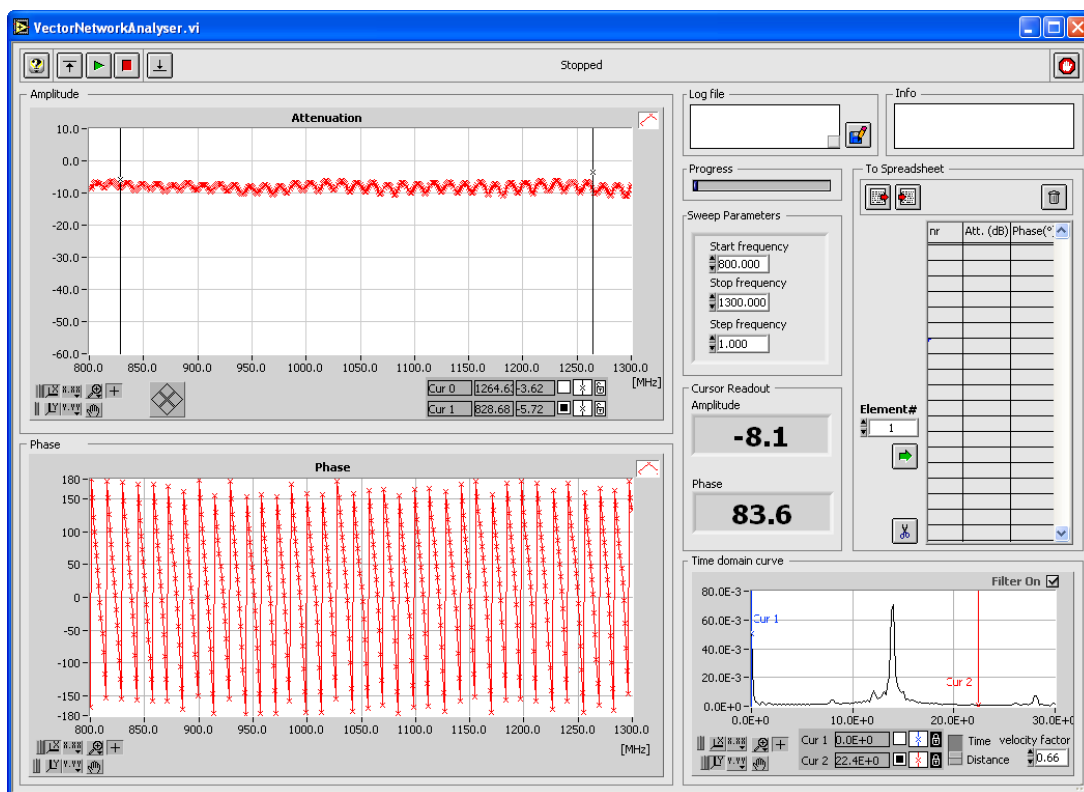


Figure 16: Example measurement result

In the frequency domain the software shows a -8.1 dB attenuation, which means that about 10% of the energy is reflected .

The result (-8.1dB attenuation) is the average of the view in the frequency domain between the frequency cursors. Changing the cursors in the time domain also changes the view in the frequency domain. So the



result of the calculation for the average attenuation is taking into account both the restrictions in frequency as in the time domain. This allows you to isolate a reflection at a certain location.

The time domain curve is continuously updated. Check the **Filter On** check box in the **Time domain Curve** field to enable the time domain filtering between the cursors (only the section between the cursors will be sent through the IFFT). You can see in the time domain window that the graph corresponds to the example.

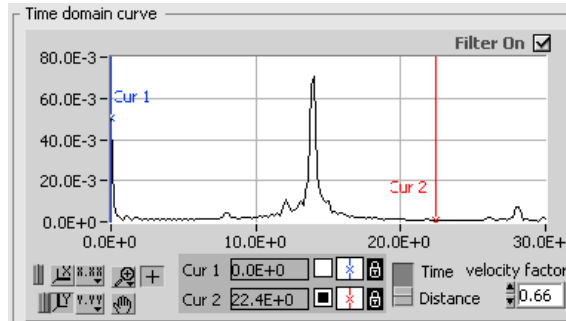


Figure 17: Time domain curve

As a first reflection, the BNC straight connector jack jumps out at a distance of 8m. **Please reconsider that this connector jack was actually after a 4m cable.**

The next reflection, 4m further, is the second BNC jack but also the cable type changes resulting in a bigger impedance mismatch and therefore a greater reflection. Another reflection you can see, is the BNC/MCX connection, resulting in the biggest reflection of all three.

Notice that the velocity factor of the coax had to be inserted. The physical and the electrical length seem to correspond very well.

2.3.3.2. Calculate the VSWR of a Specific Part of the Transmission Chain

In the transmission chain of the example, there were several parts which reflected. It may seem the best solution trying to fix the worst part of the transmission chain, if it is possible to fix of course.

In the time domain you move the cursors to isolate the occurrence you want to focus on. Do not place the cursors too narrow. Keep in mind that because of the bandwidth limitation spreading occurs.

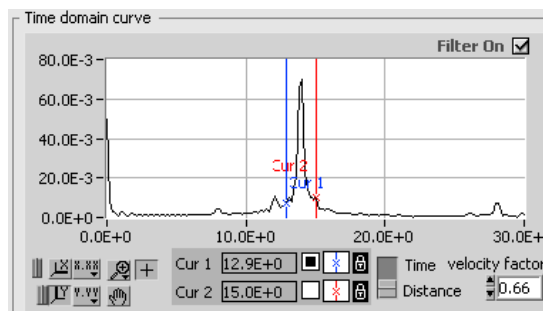


Figure 18: Time domain curve – selection with cursors

This graph shows the isolation of the biggest reflection that occurred due to the cabling. It was the transition from RG223 to RG216 coax cable with a BNC straight jack in between.



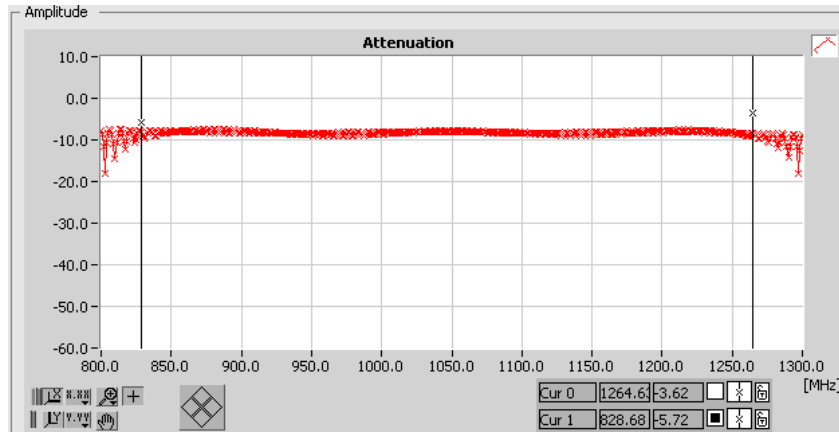


Figure 19: Attenuation of selected reflection

The amount of reflection between the cursors (selected reflection) is shown in the **Amplitude** parameter. This leads to the SWR of the cable connection using the next formula (or a conversion table which is based upon this formula):

$$reflection\ coefficient(VSWR) = \frac{-(10^{\frac{x}{20}} + 1)}{(10^{\frac{x}{20}} - 1)}$$

Where x is the relative amount of reflection in dB shown in the **Amplitude** parameter. In case the relative amount of reflection is -15.7dB, the reflection coefficient (VSWR) is 1.393 .



3. FAR FIELD SIMULATION OF ANTENNA

3.1. Getting Started

A specific software tool allows to investigate the far field behavior of the (M)SSR antenna both for vertical and horizontal directions. The program can use measured or simulated data as an input for the mathematical computations.

The program can be loaded by selecting **Radar Antenna Simulation** from the  **Vector Network Analysis** button in the RASS-S toolbox.

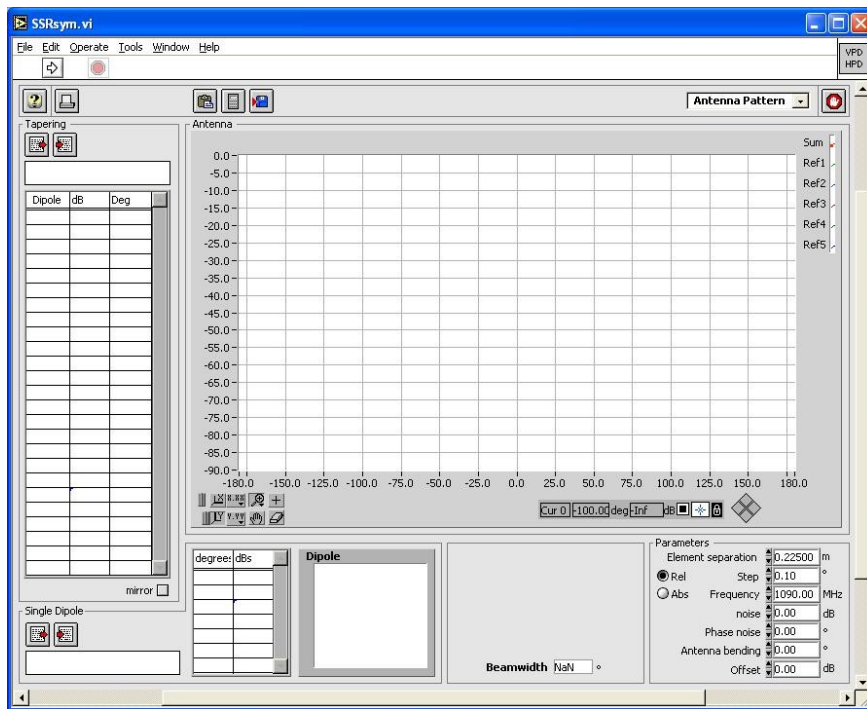



Figure 20: Radar Antenna Simulation Software

3.2. Calculating the Far Field Pattern

Load the measured tapering file using the  **Load Tapering** button in the **Tapering** section. A standard file dialog window will appear, asking to select the tapering file. The file dialog by default points to the **Tapering** subdirectory of the **Network** directory of the active campaign folder.



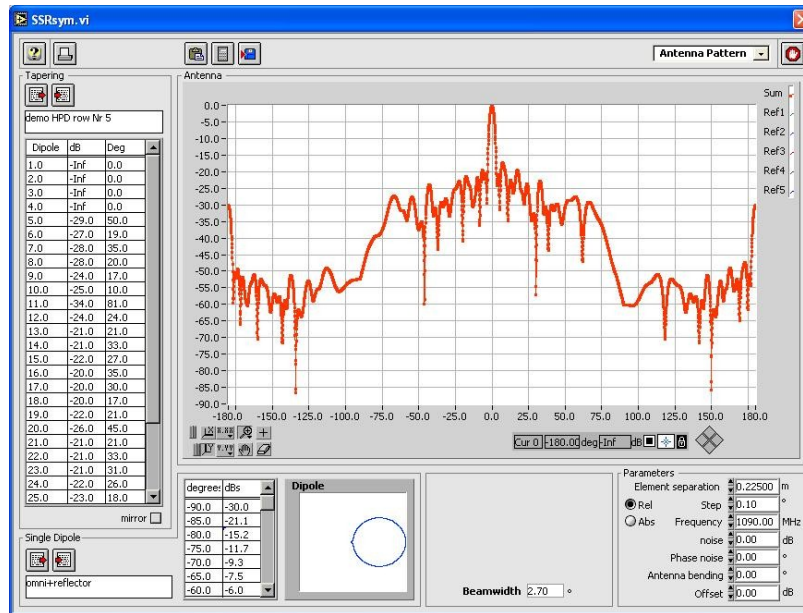


Figure 21: Antenna simulation example after loading a tapering file

The data of the selected tapering file is shown in the spreadsheet form in the **Tapering** section of the software vi. It is possible to save the loaded tapering file again using the **Save Tapering** button. Saving the tapering table can be useful in those cases where the user detects a faulty dipole. If that faulty dipole has a great influence on the resulting antenna diagram the data could be adjusted and saved as a corrected tapering file.

The tapering field also provides a **mirror** option (selector in the **Tapering** section). When the mirror option is selected, the software will mirror the tapering table (except for the last element) and add this internally to the loaded table. This way, only half of the dipole elements need to be entered for simulation, but of course the antenna pattern is then generated assuming that the antenna is perfectly symmetrical. In case all dipoles are measured, the mirror function should be off (default setting).

To be able to perform a mathematical calculation of the antenna pattern, the user should load a dipole element antenna pattern. Depending on the loaded tapering data the dipole information should contain a horizontal or vertical radiation pattern. The RASS-S software contains default radiation patterns for the horizontal and vertical direction. To load a dipole pattern, click the **Load Dipole Data** button in the **Single Dipole** section of the software vi. A standard file dialog window will appear, asking to select the dipole radiation pattern. The radiation patterns that are included by default in the RASS-S software can be found on the **Network >> Dipole** subdirectory of the active campaign folder. When the radiation patterns is selected, the pattern is loaded and shown in the **Single Dipole** section (in the example shown in figure 21 the **omni + reflector** pattern was selected).


You can also enter a know radiation pattern in spreadsheet input. The **Save Dipole Data** button allows you to save a table to disk after you have filled it in to build the custom radiation pattern.



Other important input parameters for the mathematical calculations need to be entered in the **Parameters** section.

Table 2: Parameters for antenna simulation

Element separation	Distance between dipoles
Step	Simulation resolution in degrees
Frequency	Frequency used for simulation
Noise / Phase noise	Phase or amplitude noise can be added mathematically to analyse the influence of manufacturing deviations
Antenna bending	Some (M)SSR antennas are bended in the center to create a split backlobe
Offset	Offset in displayed antenna pattern
Rel/Abs	Relative values of the amplitude related to zero or absolute values can be shown in the graph

Changing any of these parameters will cause a recalculation of the curve. The same can be achieved using the  **Recalc** button.

Both the antenna pattern and the 3dB beamwidth are calculated based on the above mentioned parameters and dipole pattern and displayed (as in figure 21).

The **View** selector in the top right corner of the software vi, allows you to switch between:

1. Antenna Pattern: displays the simulated antenna pattern (rel. gain vs. azimuth).
2. Phase: shows the calculated phase vs. azimuth.
3. Tapering: shows the measured attenuation and phase of each dipole in the graph.

When selecting the **Tapering** displaying method one can easily spot the broken columns since these will pop out of the normal tapering distribution. The example below is a purely graphical representation of the numerical data entered in the tapering table

- the red curve shows the attenuation versus element number, in this example it can be clearly seen that f.e. element number 11 is faulty.
- the green curve shows the measured phase versus element number, one can see that indeed #11 has a phase popping out of the normal readings.

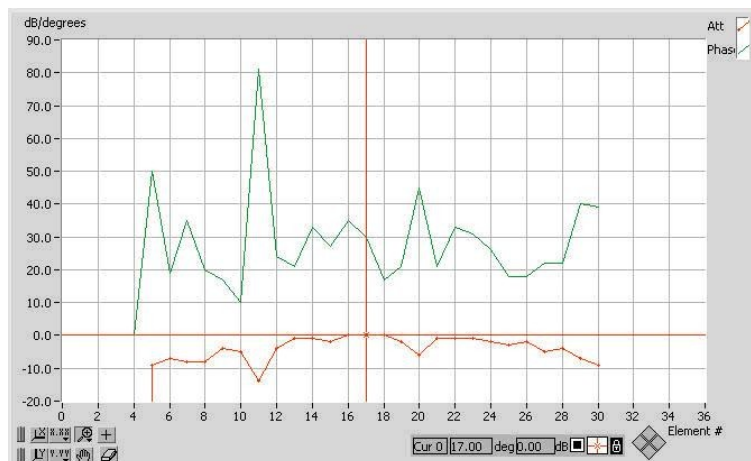


Figure 22: Antenna simulation example after loading a tapering file

Now switch back to the **Antenna Pattern** view. The  **Save HPD Data** button allows you to create a data



file with the same file format as the PSR and/or SSR HPD files.

The **Export VNA data** window will pop up, a type selector allows you to select the resulting diagram type of the export. The resulting file will be placed in the corresponding subdirectory of the active campaign folder. The data can be reviewed using the **View HPD Logfiles** tool. This feature can be useful in comparing the column faultfinding measurement results using the VNA, and the antenna patterns measured with the RFA641 equipment.

4. PULSE VECTOR VOLTMETER

4.1. Getting Started

The Pulse Vector Voltmeter is intended to measure accurately the difference in amplitude and phase between two pulsed Rf signals. In the PVV set-up the Tx output is used as signal source for the measurement, while the external Tx input is used as the reference channel. The device under test can be placed in between the 10dB attenuator present at the Rx input and port 2 of the splitter.

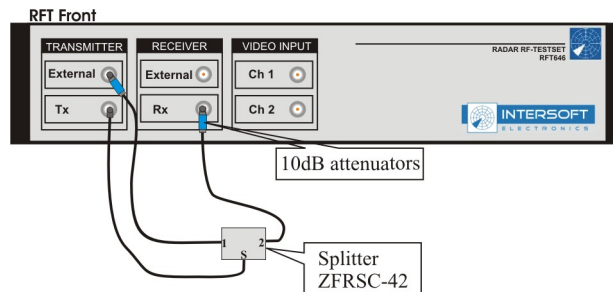


Figure 23: PVV Set-up

Instead of the Tx output, any other pulse RF signal source can of course be used and connected the splitter input. Make sure to add sufficient attenuation in between.

The external trigger input is located at the back of the RFT646. In case you want to use it, you will need the external trigger cable (DB9 to 1 BNC) and connect it to the **Digital Output** connector.

The program can be loaded by selecting **Pulse Vector Voltmeter** from the  **Vector Network Analysis** button in the RASS-S toolbox.



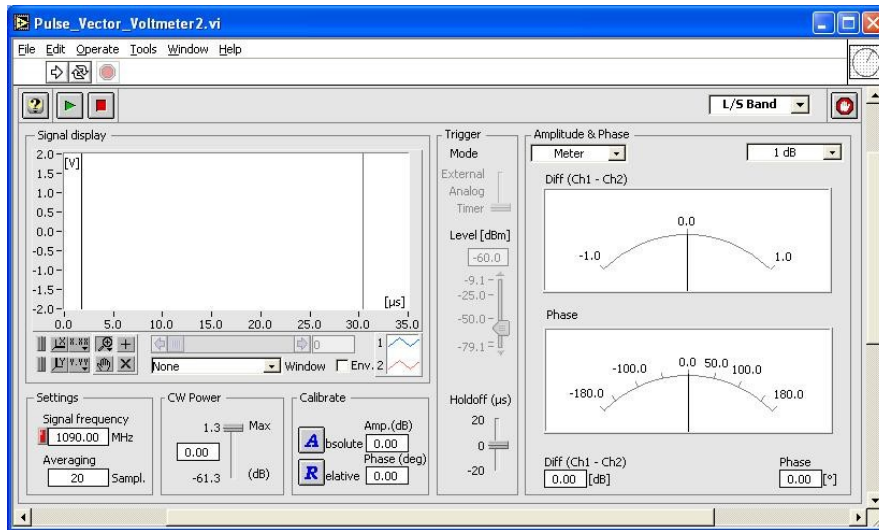



Figure 24: PVV Software

4.2. Using the PVV Software

1. Set the **Signal frequency** control to the Rf-frequency of the signal to be measured. This frequency setting is used to down convert the RF signal to a 2 MHz baseband signal. The baseband signal is then digitised at a 16 MHz rate. Each trigger (on channel 2) results in 512 samples per channel. At a sample rate of 16 MHz, a period of 32 microseconds is covered on each trigger. The last 512 blocks of 512 samples (two channels) are stored in memory and every one of those 512 blocks can be recalled and displayed at all times.
To achieve a higher accuracy, a measurement can be averaged over several consecutive triggers. The number of averages can be set using the **Averaging Samples** control.
2. Three trigger modes are available
 - External: uses a digital trigger connected using the external trigger cable to the digital output connector on the RFT646 back panel. Use this mode in case you have a trigger available for the RF pulses used for the measurement.
 - Analog: in this mode the RFT646 will trigger on a reference signal connected to the External Tx input. The trigger level can be set.
 - Timer: In this mode the RFT646 will generate a CW signal at the Tx Output (Power level can be set with the CW Power control), the internal reference will be used. In this mode the sample windows are started each 4ms.
3. Start measuring by clicking the  **Start** button. The signals present on the two RF channels are both displayed in real time while they are measured. The values of the samples are shown on the display as they are presented to the Analog to Digital Convertors (ADC). All 512 samples per channel are shown on the display but only the samples between the two cursors are used to calculate the difference in phase and amplitude (Rx – Ref).



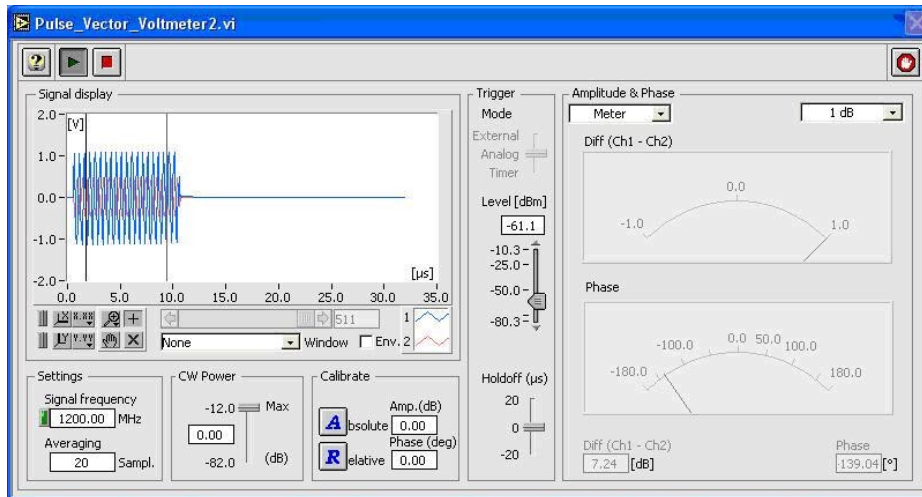



Figure 25: PVV Software Example

4. Once the measurement is stopped with the  **Stop** button, the slider under the display becomes active and the last 512 blocks of 512 samples can be displayed using this slider. It is possible to zoom or pan on the display.
5. With the envelope checkbox (**Env.**) it is possible to switch between the signal as it is been sampled (but down converted to 2 MHz) or the envelope of the baseband signal.

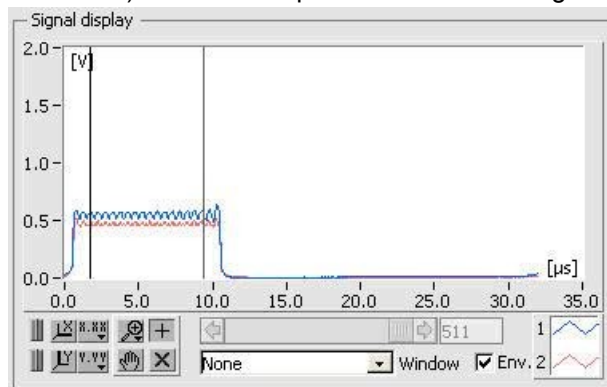


Figure 26: Envelope function

Because further processing of the measurements includes a FFT algorithm, it may be opportune to insert a window function on top of the measured data. A number of different windowing functions are available in the tool:

- None
- Hanning
- Hamming
- Triangle
- Blackman
- Exact Blackman
- Blackman-Harris
- Flat Top

Figure 27: Window functions

The windowing function is applied only between the two cursors. The different windows can be visualized by switching off the envelope option.



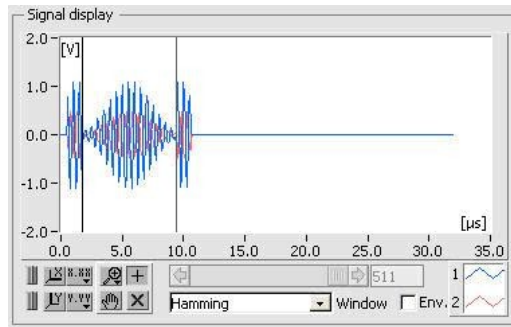
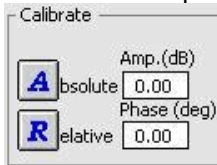


Figure 28: Example of Hamming window

- To use the **Pulse Vector Voltmeter** to its full potential, a calibration of the tool must be built in. There are two possible calibration procedures: a **Relative** and an **Absolute** calibration. To evoke one of the two calibration procedures, push the appropriate button:



The relative calibration procedure measures the difference in phase and amplitude between the two channels at that time (with the preferred averaging) and uses this result as an offset in future measurements. The offsets in phase and amplitude are shown in their respective indicators next to the calibration buttons.

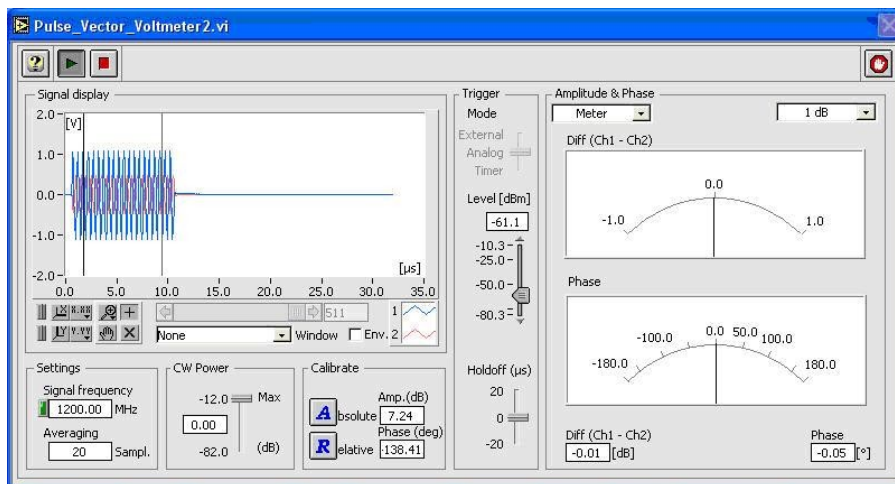


Figure 29: Example of calibration

By simply switching the connecting cables, the absolute calibration procedure enables the de-embedding of the measurement paths from the device under test. After pushing the **Absolute** button, some dialog boxes appear on the screen posing set-up related questions.

It is important to switch the cables as close to the device under test as possible. This way the measuring interface is shifted towards the position where the cables are switched and the measuring path is de-embed from the measurement. Like in the relative calibration, the offsets in phase and amplitude are shown in their respective indicators below the calibration buttons.

Notice that these amplitude and phase offsets are not used to correct the displaying of the two signals. They are only used in the calculation of the phase and amplitude difference between the two channels. Both calibration procedures take into account the same averaging factor as used for the measurements.

Once a calibration procedure is accomplished successfully, the Amplitude and Phase indicator on



the right hand side of the window become active. These indicators show the difference in amplitude and phase between the two channels taken into account the results from the calibration procedure.

- 7. There are two displaying options (selector in the **Amplitude & Phase** section): a meter display and a scope display. The meter display shows the amplitude and phase separately and the scope display shows the result as one vector. Both options also include a digital display. It is possible to choose between different scales.

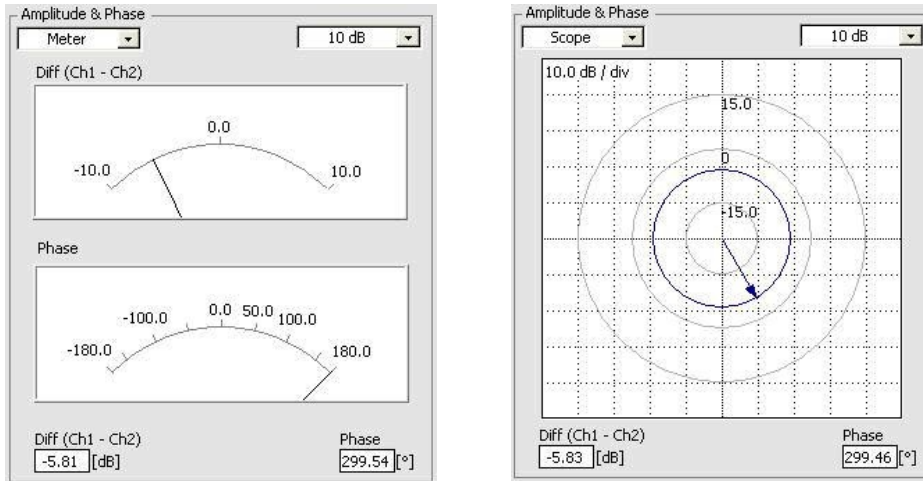


Figure 30: Displaying options: Meter (left) or Scope (right)

5. NEAR FIELD SCAN: RFT646 AND 3D SCAN KIT

5.1. Introduction to Near Field Scan for 3D PSR Radar

This chapter describes the use of the RASS-S Radar RF Testset in order to perform near field scan measurements on 3D PSR radar systems. It explains a user how to use the tool to measure the near field amplitude and phase distribution, calculate the far field pattern and get the phase adjustments necessary to improve and/or tilt the vertical diagram of the PSR 3D long range air defense radar.

The near field scanning tools allow a trained user to perform the necessary measurements to calculate and obtain the VPD from a near field scan in a short time frame.

The **Tune** function is available to focus on improving the side lobe levels for the negative elevation angles, in order to avoid ground reflections and to reduce the interference for the close environment. Another option is to minimize the notches in the main beam. In both cases the result of this calculation is a phase correction table. The phase corrections required for the improvement can be applied using sliding line phase adjusters selected by Intersoft Electronics.

The initial developments of the above mentioned tools were started in the context of a study with the goal to reduce the interference towards the close environment.

5.2. 3D Scan Hardware Set-up

When setting up to perform the **Near Field Scan Transmission Measurement**, please follow the listed instructions and check **Annex 2: 3D Scan Transmission Connection Diagram**:

1. Power up the Radar RF Testset and let it warm up. For transmission measurements it is best to pick a location in the spine.
2. Carry all the encoder stick parts up the spine: 3 pairs of bolts and wingnuts, the encoder stick, 2 aluminium bars, 1 DB9 (f) to RJ45 cable, 2 RJ45 cables 5 m, 2 RJ45 8-way sockets, the tape measure 20m and 2 cramps.
3. Assemble the encoder stick as shown in figure 31 and put the tape measure across the encoder wheel.

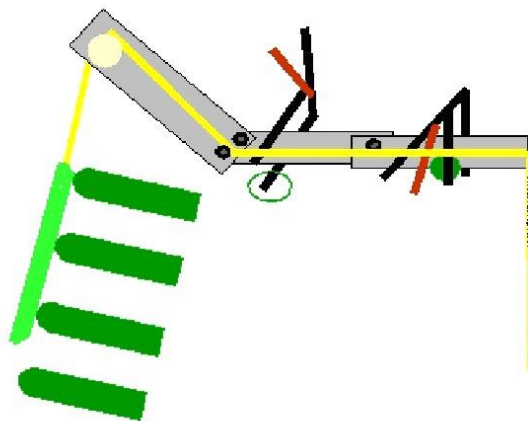


Figure 31: Assembly of 3DS encoder stick


4. Pull out 10m of the tape and throw it down in front of the antenna.
5. Fix the encoder stick to the spine's roof using the cramps. Try to take a location in the horizontal middle of the antenna. Make sure that the tape is "free" when you fasten the cramps. Try to put the encoder wheel in the plane of the antenna surface (see figure 31).
6. [Groundassistance] Carefully connect the antenna scan board to the tape measure.
7. [Groundassistance] Verify whether the tape can move easily.
8. Connect the encoder cable DB9(f) to the encoder output cable's DB9(m) connector. Assemble the cable from the encoder on your way down. Add as much sockets for the RJ45 cable as you need. At the end connect the cable with the DB9 male connector. Plug this cable in the RFT646 digital input.
9. Position the reference dipole to one of the lower rows. Try to take a different position as where the scan will be performed.
10. Extend the cable of the reference dipole and connect it to the RFT646 External Tx input using at least 40dB of attenuation.
11. Extend the cable from the antenna scan board with 5m BNC. Connect the cable to the Rf input Rx of the RFT646 using 60dB of attenuation.
12. Now connect the computer with the USB cable.

The set-up for a **Near Field Scan Receiver Measurement** is similar and shown in **Annex 3: 3D Scan Reception Connection Diagram**.

5.3. Near Field Scan Measurement Software

5.3.1. Getting Started

The **PVV Near Field Scan** tool allows to perform near field measurements. Basically this consist of a pulse vector voltmeter measurement performed for a number of positions. At the end of the measurement, the recorder amplitude and phase, together with the positions are saved to the **VNA Scan File**.

Now select the **RFT646 Near Field Scan** software from the  **VNA PSR** button in the RASS-S toolbox.



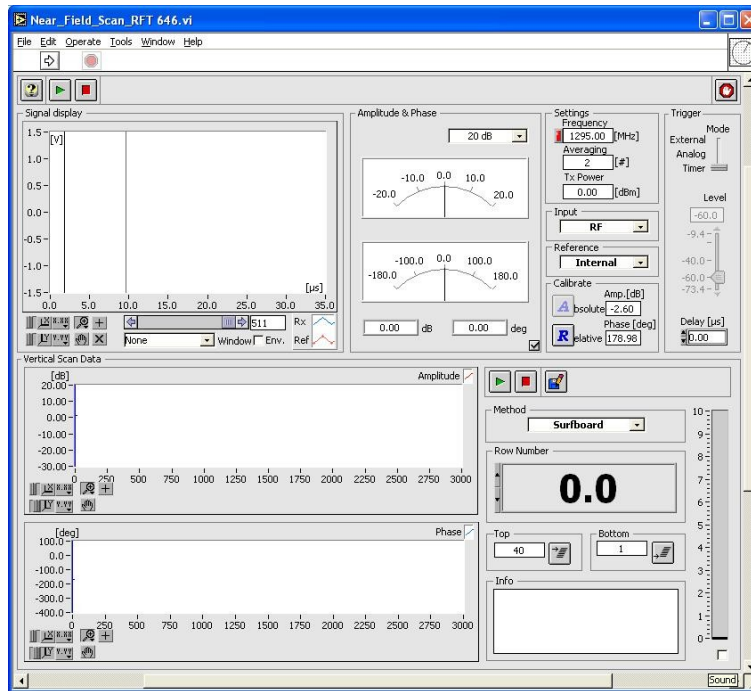


Figure 32: Near Field Scan software

5.3.2. Basic Software Introduction

The tool consists of a Pulse Vector Voltmeter function which allows to sample two signals simultaneously and calculate the amplitude and phase difference. The signal used as a reference can be either an external signal (from the pick-up dipole) or a sample of the stimulus signal generated by the RFT646 and measured internally via a coupler. In both cases the Rx input is the measurement channel.

Once a reference is taken, relative amplitude and phase are calculated for each signal window taken. The cursors on the signal window allow to select the part of the signal used to calculate the amplitude and phase.

The signal sampling can be triggered in three ways:

- **Timer:** This mode is used when the internal RF generator is used to provide the stimulus for the measurement.
- **Analog:** In this case the sampling is triggered by the signal available on channel 2. Since channel 2 is the reference, signal amplitude and phase are constant and therefore triggering is ensured. The trigger sensitivity can be selected using the **Level** control.
- **External:** The trigger is evoked by a digital trigger signal provided by the radar. In this case the analog trigger capability is switched off.

When performing a scan using the surf board antenna, first make sure the program is using the **Surfboard** Method. For this measurement method, in order to be able to measure the position at which a sample is taken, the RF Testset is interfaced to an encoder. By moving the measure tape the encoder provides a number of pulses corresponding to the displacement of the measurement antenna (surf board antenna). This way the position of the board is indicated.

The tool allows to calibrate the encoder position into a row number by identifying top and bottom rows. This is done for ease of use during the measurement and to allow to select samples taking into account the row number later in the analysis phase.

A near field scan measurement consists of taking as much samples (amplitude, phase, position) as possible while slowly moving the surfboard antenna from below the bottom row (row1) up to a bit above the top row (row 40), then waiting a few seconds and repeat (continue) the scan in the downward direction.



During this procedure the **Vertical Scan Data** graph will display the measured samples of amplitude and phase for the different positions of the surfboard. This data is saved to a file on disk when the scan is stopped. This file type is the so called **VNA Scan File**.

In the analysis phase the upward scan will be used to calculate the far field vertical pattern.



NOTE: Please note that a reference file is required to be able to analyse the tapering. This is a near field measurement with all transmitters switched off except one. This measurement has to be performed once. Afterwards the VPD is measured using the transmitters on in the normal operation mode.

5.3.3. Using the Near Field Scan Measurement Software

1. Select the Rf as input. In the case of transmission measurements the surfboard has to be selected as **Method** control.
2. First of all the measurement settings must be entered:
 - Select the correct **frequency**. In case the radar performs a chirp during the pulse transmission, it might be necessary to lower the frequency slightly. Select the frequency setting that gives max. amplitude at the start of the pulse. Normally the **Signal display** shows a 2-3 MHz signal. When the frequency is OK, an indicator will turn from red into green.
 - **Averaging**: This is the number of sample windows that will be averaged to produce an amplitude and phase sample. By default it is set to 2. It is not likely that it needs to be increased.
 - **Tx Attenuation**: This controls the attenuators that are built-in in the Tx outputs of the RF Testset. By default the attenuation is set to 0dB.
 - **Trigger Mode**: Select the 'analog' trigger mode to measure the transmit diagram.
 - **Trigger Level**: The sensitivity of the analog trigger circuitry can be set according to the signal level available at the reference channel.
 - **Delay**: Use this control to adjust the delay after trigger to change the sample position in the pulse.
3. In case the signal level is too low or too high, you can adjust the Rf input attenuation by changing the external attenuators until the **Signal display** shows the signals within range. The signal strength is preferably between 1 and 2 Volt.

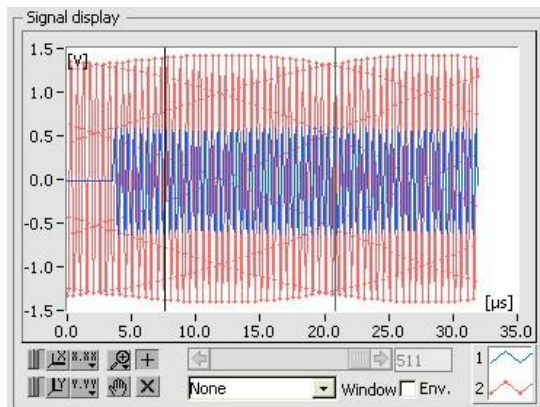




Figure 33: Signal Display

4. Take reference, push the **Relative** button from the **Calibrate** box and verify that the signal is stable (0.1 dB and 3deg phase).
5. Make sure that the encoder cable is connected on the RFT646 backpanel's digital input. Position the antenna scan board on the top row and enter the row number (40) in the dedicated control in the **Top** section of the software. Then push the  **Top Row Assignment** button.



- Bring the antenna scan board down smoothly and position the centre of the antenna scan board on the bottom row. Enter the row number (1) in the dedicated control in the **Bottom** section of the software and push the  **Bottom Row Assignment** button.



Note: While moving the surfboard, make sure to adjust the pulling speed according to the Pulse Rate Indicator at the right bottom of the window. In order to make sure the encoder signals are sampled correctly, the speed should be below 5. The indicator will turn red from 7 and above, indicating speed is too high.

- Deselect the checkbox in the **Amplitude and Phase** window. This will disable the update for this window and doing so speed up the measurement.

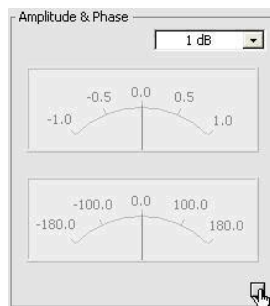



Figure 34: Amplitude and Phase window - deselected

- Position the antenna scan board on the bottom row. When moving, the row indicator will now track the position of the antenna scan board. Start the scan by pushing the  **Start** button and start pulling the antenna scan board slowly upwards.
- The vertical scan data will be updated as you continue with the scan.

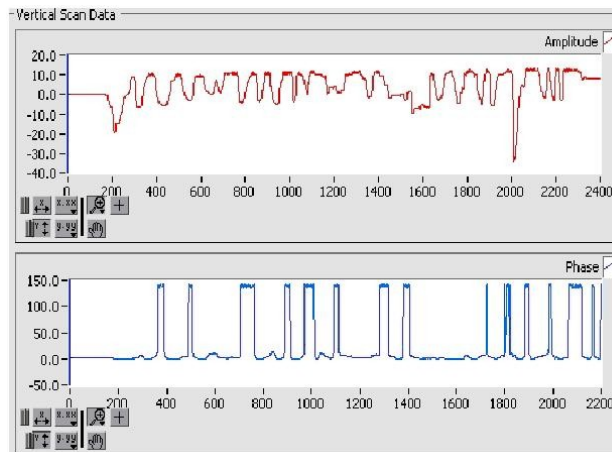



Figure 35: Vertical scan data while performing a near field scan

- Scan the antenna until you reach the top (row number 40.5), and move the scan board back to perform a downward measurement. When the antenna scan board has reached row position 0.5,



push the  **Stop** button to stop the measurement.

11. Save the antenna scan data to a file on the computer hard disk by using the  **Save** button. The **Save File** dialog will point by default to the **NETWORK:VNA_FILE** subdirectory of the active campaign folder.

5.3.4. Calculating the PSR Far Field Diagram

5.3.4.1. View PSR Far Field

Once the antenna tapering is measured, the scan file can be loaded into the **View PSR Far Field** program. This allows to predict the far field from the measured near field. The **View VNA Scan File** function allows to view the measured amplitude and phase versus row number and calculates the tapering. At the same time the resulting antenna diagram is already presented in the **View PSR Far Field** program.

To allow to correct for the measurement probe's (surfboard) calibration, at least once a calibration scan of the surfboard must be performed. This is done by switching off all transmitters except one in the middle. This allows to measure the selectivity of the surfboard.

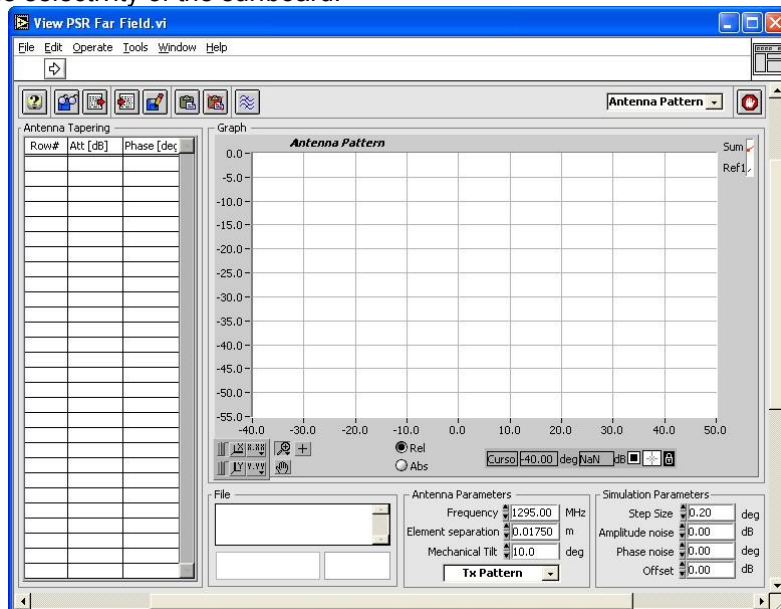



Figure 36: View PSR Far Field software

Open the **View PSR Far Field** program from the  **PSR VNA** button in the RASS-S6 Toolbox.

1. Click the  **Load Scan File** button to select a VNA scan file from disk. A dialog box will pop up, pointing to the **NETWORK:VNA_FILE** subdirectory of the active campaign folder. Select the file of interest and click **OK**.
2. The **View VNA Scan.vi** will pop up. It shows the scan data. Both amplitude and phase are shown versus encoder position or row position. Two cursors are available to select the data part of interest. Make sure to point the cursors to the correct position. During this process, the far field pattern is shown in the far field program.
The horizontal axis represents the encoder position. The file data is combined to 400 samples equally distributed across the antenna surface. In case the encoder is calibrated, the X axis will be converted to row number. The measurement should contain two scans (up and down). In the window of the original VNA data the user can see the repeatability of the measurement for phase and



amplitude by zooming in on a specific part.

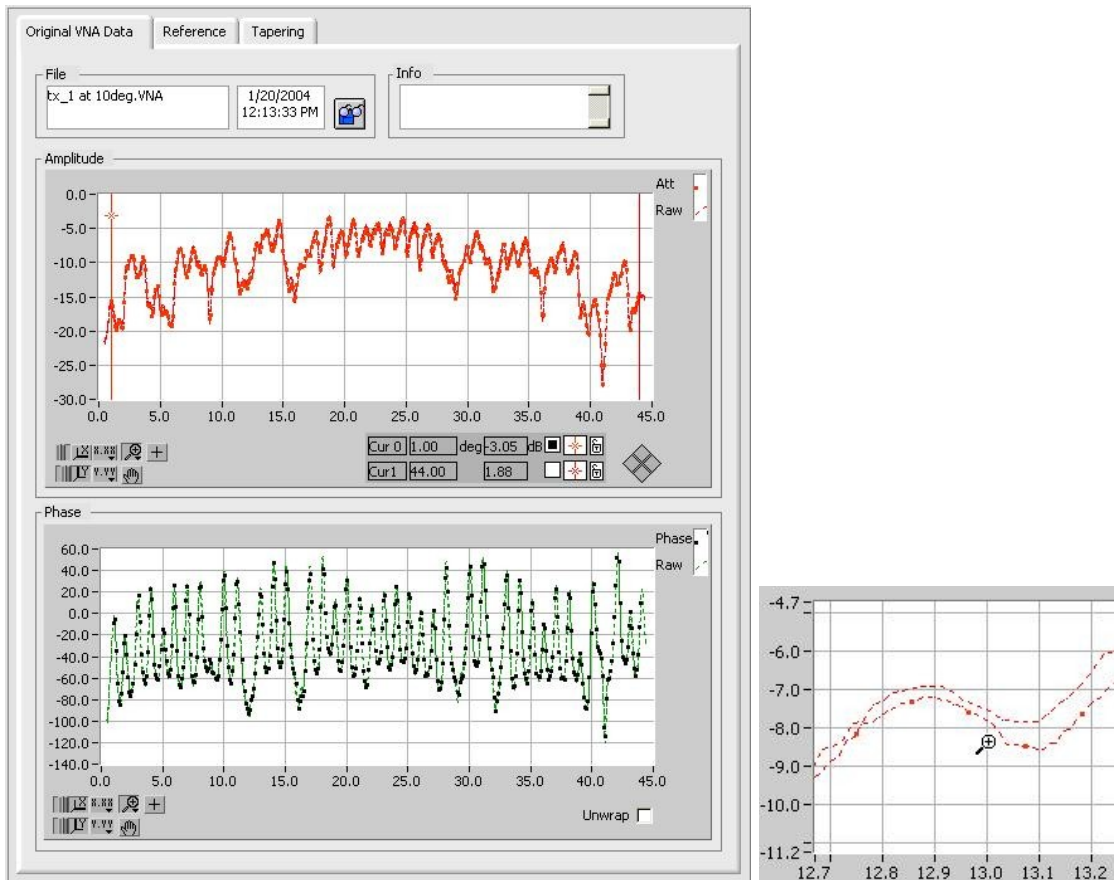



Figure 37: View VNA Scan software result – checking the repeatability in the original data (right)

- The next step is to load the reference file. The **Reference Scan** is a surfboard measurement across the whole antenna array with only one transmitter radiating. This file will be used to process the data with the mathematic operation of deconvolution. To load the reference file click on the **Reference** tab and click the  **Load File** button to select the reference.



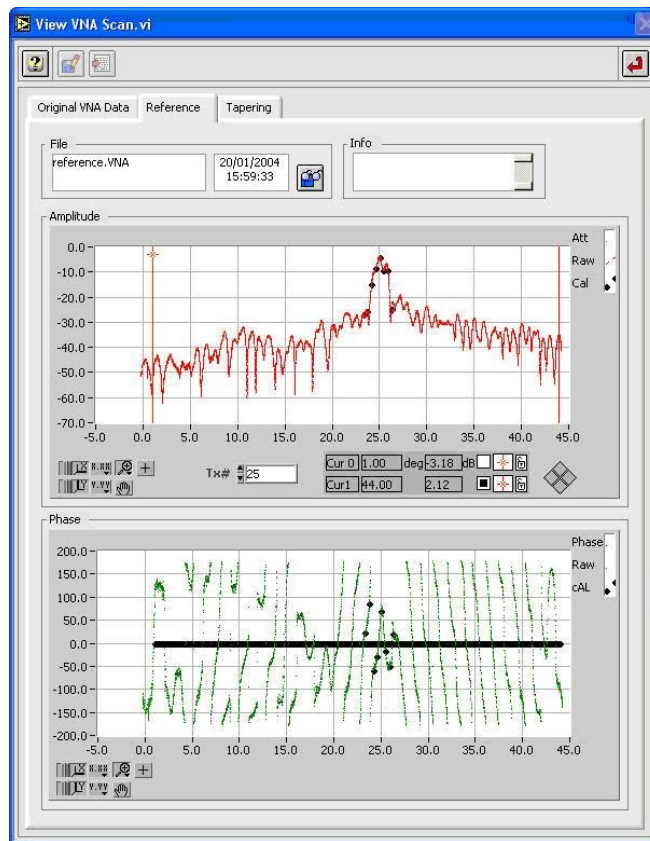


Figure 38: View VNA Scan - Reference file loaded

The reference file is loaded and the samples used as a calibration are indicated as black dots.

4. The result of the deconvolution is shown in the **Tapering** tab. The # of rows of the antenna is listed at the top. If the encoder calibration was performed correctly during the measurement, the software will set the number of rows automatically.



- The **Amplitude and Phase** graph displays the result after calculating out the probe calibration as loaded in the reference. As a result of the deconvolution the energy picked up with the scan board is focused to the corresponding row number, providing a measured tapering table in phase and amplitude. If there are any broken transmitters in the array, they can be detected easily on this graph.

Two cursors are available to indicate the position of row 2 (left cursor) and the position of the second last row (right cursor at #rows-1). These cursor are used to calculate the positions of the row amplitude and row phase values. These are indicated using the red dots on the graph. Purpose of this is to check for rows with problems, f.e. a broken transmitter.

Once both cursors are set correctly, the amplitude and phase tapering becomes visible.

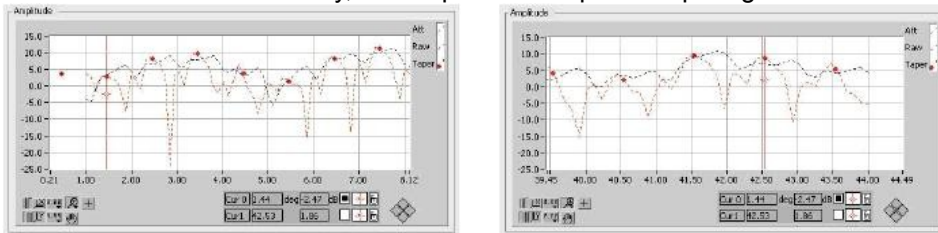


Figure 39: Placing the cursors on row 2 (left) and on the second last row (right)

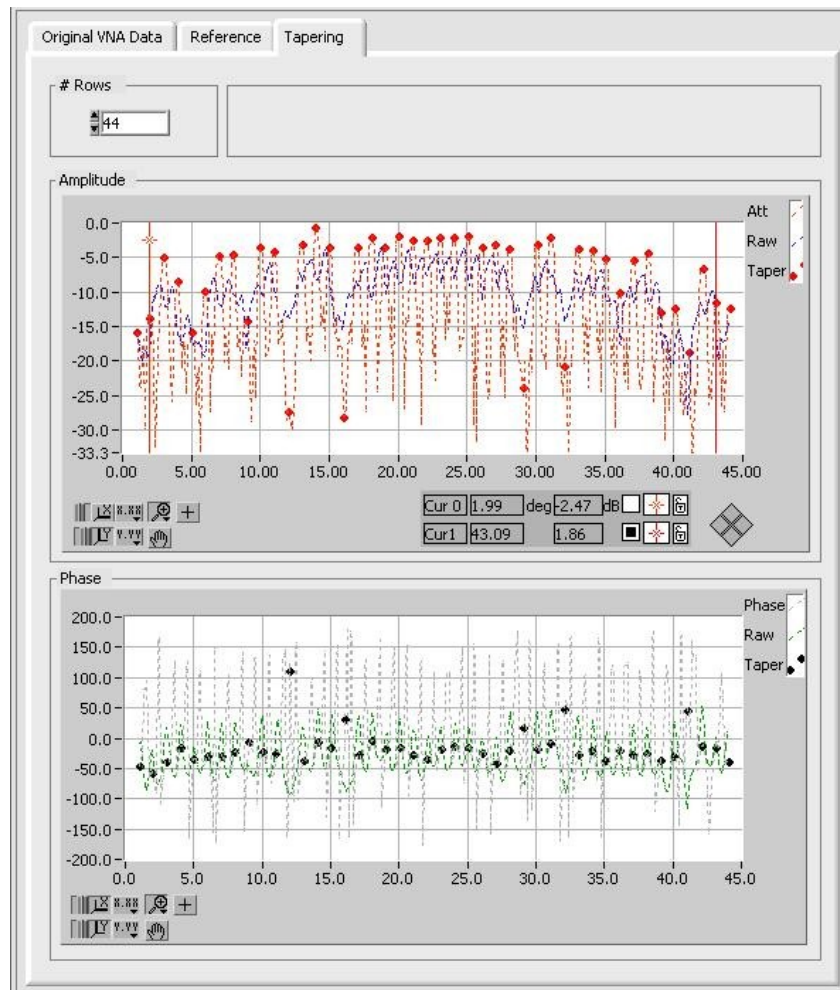




Figure 40: Amplitude and phase tapering result



6. The  **Save** button allows to save the tapering (all 400 points) of the selected tab. When you select the **Original VNA data** tab the uncorrected tapering as was measured is output. When you select the **Tapering** tab, the processed tapering is output to file. An extra button  **Export Tapering** is available in the **Tapering** tab. This allows to save the 40 (Marconi S723) or 44 (FPS117) rows as selected using the cursors to a tab-separated file.
7. The PSR far field diagram is calculated and displayed using the default parameters. Important are the **Frequency** and **Element Separation** parameters. The Frequency shall be set to the Tx Frequency of the radar. Default this is 1295MHz. The element separation must be set according to the distance between two rows, divided by 400/#rows. In case of the S723 this is 0.0175m. The mechanical tilt parameter is added to the X-axis to allow to add a mechanical tilt if necessary.

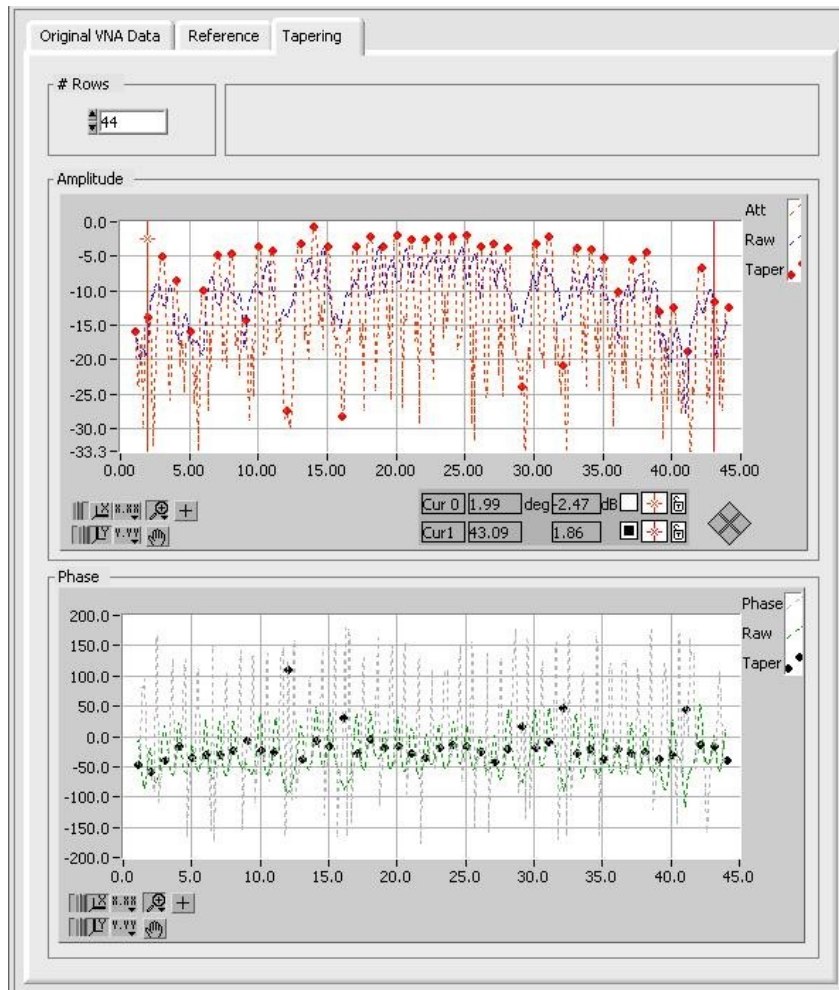






Figure 41: PSR far field diagram

8. The simulation parameters can be altered if required. The step size can be adjusted to 0.05 if you like to draw more dots on the graph. **Amplitude Noise** and **Phase noise** will add extra noise to the tapering table to check antenna pattern dependency on the tapering used. **Offset** can be used to add the gain of the antenna in case you want to save the antenna pattern with its absolute gain.
9. In case you have a tapering available as a tab-separated file, you can load it with the  **Import Tapering File** button. This is useful in case you want to enter the manufacturers theoretical tapering. The  **Save Tapering File** button allows you to save the contents of the **Antenna Tapering** to a



spreadsheet file. In case you want to make changes to the antenna tapering and compare the result with the original antenna diagram, you can use the  **Reference** button to copy the antenna diagram to the graph as a reference. The  **Clear Reference** button allows to remove the reference diagram from the graph.

5.3.4.2. Tune the Vertical Diagram

As a special option, in case sliding line adjusters as selected by IE are installed in the Tx chain, it is possible to tune the transmit pattern. The **Tune Tx Pattern** function takes the measured antenna pattern and uses the current position of the sliding line phase adjusters to calculate a new possible solution for the phase tapering. The goal is to minimize the Tx Power at a selectable elevation section below a selectable max. side lobe level or to reduce the notches in the main beam (for example: IE successfully installed 40 phase adjusters in a Martello S723 and used the software to remove the sidelobes towards the ground).

1. Open the **Tune Tx Pattern** program from the  **Tune Tapering** button in the **View PSR Far Field** program.

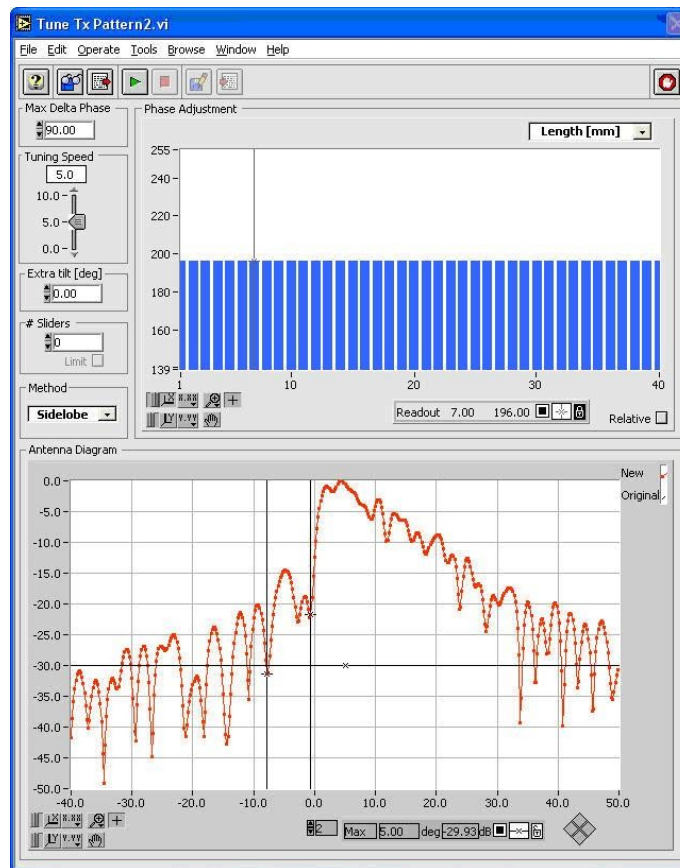




Figure 42: Tune Tx Pattern software

2. The user needs to set the cursors in the negative elevation region of the vertical diagram as the part of the antenna diagram between the cursors will be improved by software simulation in order reduce the sidelobe levels. Initially the position of the phase adjusters is set by default to 196mm, being exactly in the middle of their range.
3. In case you have other settings, you can load the slider position file either using the  **Import slider positions** button or use the  **Load Slider Positions file** button. This loads the slider



positions from a previously saved file. Default location of the slider positions file is in the **NETWORK:TAPERING** subdirectory of the active campaign folder.

- Once the position file is loaded, the mechanical position of the phase adjusters in mm is displayed in the **Phase Adjustment** graph.

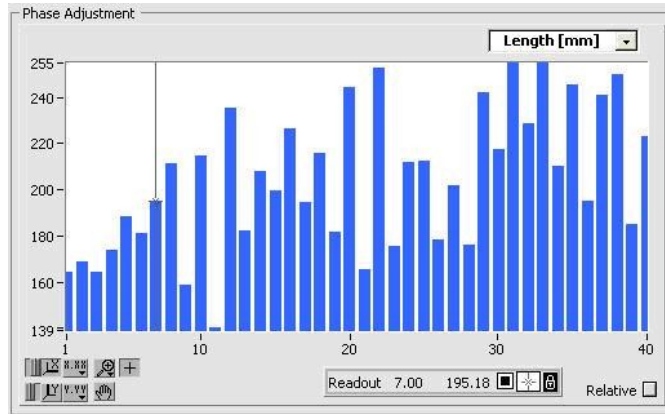



Figure 43: Phase adjustment graph

- It is now necessary to select the region and suppression of the sidelobes as required. The two vertical cursors in the **Antenna Diagram** graph allow to select the elevation part for which the sidelobes need to be reduced (as shown in figure 42). The horizontal cursor allows to select the maximum sidelobe level allowed.

Once the cursors are selected, click the  **Play** button to start the optimisation. The **Antenna Diagram** graph will show the original diagram in reference, together with the antenna diagram as a result of the tapering optimization. Optimization is performed by random changing the phase tapering and retain those changes that have an improvement for the requested elevation section. Figure 44 shows the phase changes required versus the row number to remove the first sidelobe and reduce it below -30dB.

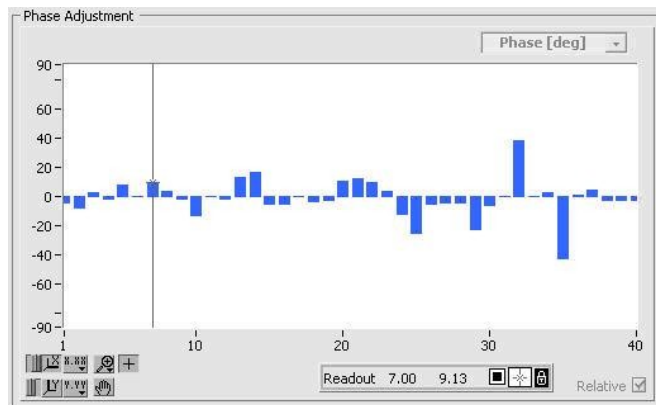


Figure 44: Necessary phase changes to remove sidelobe

The following figure shows the theoretical result in case these changes will be implemented:



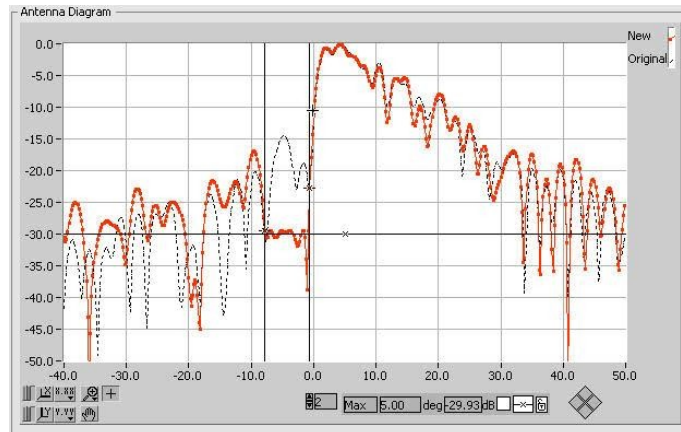







Figure 45: Tuned Antenna Diagram

6. You can stop the adjustment process anytime you want by clicking the  **Stop** button. The program will ask you to save the new positions of the slider as a result of the tuning. This can also be done afterwards using the  **Save** button. The default path to save the slider positions is to the **TAPERING** subdirectory.
7. It is possible to limit the number of phase adjusters to a selectable number. Only that number of phase adjusters with the maximum change are selected in order of magnitude. This can be selected in the **#sliders** section. Check the **Limit** checkbox and enter the number of phase adjusters to be used.
The influence on the antenna diagram is immediately shown. When saving the slider file, the slider positions that are required to change are changed in the slider file, the other ones are left unchanged.
8. Do not forget to export the slider position file (it contains the changes in textual format, with the changed ones marked with an asterix (*)) by clicking the  **Export** button. The **Print Tables** program will open and display the data for export.
9. Click the  **Return** button to return to the **Tune Tx Pattern** program and click the  **Done** button to return to the **View PSR Far Field** program.
10. The original antenna diagram is put in reference while the improved antenna diagram is copied to the **Tx Channel**. Please note that the tapering table is entered in the **Antenna Tapering** table. This way both antenna diagram and tapering table are available for saving to file.
Finally it is time to adjust the sliders. An iterative process of measurement and simulation will lead to successful adjustment to reduce the sidelobes as predicted.

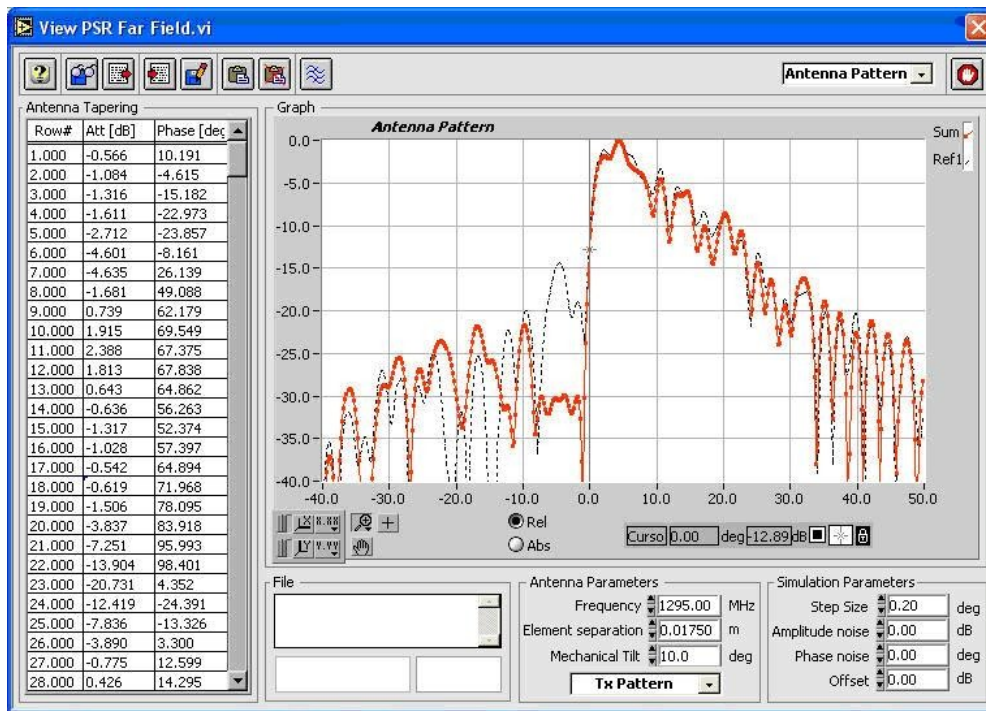
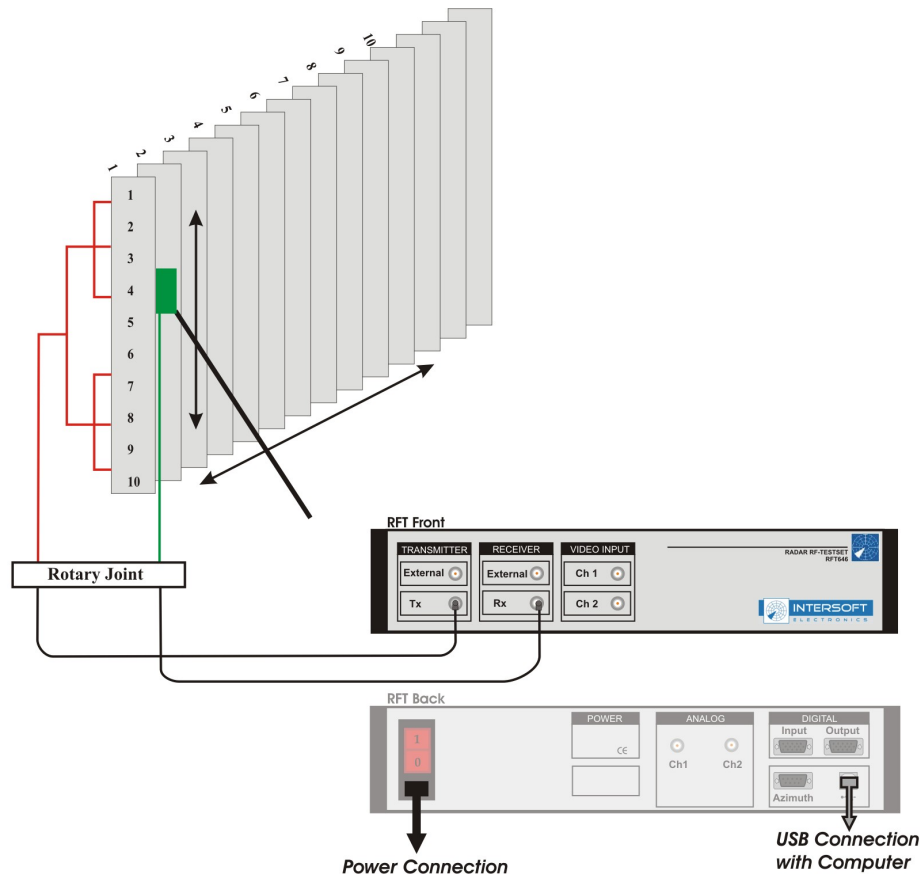


Figure 46: Final tuned antenna pattern

6. ANNEXES

6.1. Annex 1: CFF Connection Diagram



Set-up Guidelines:

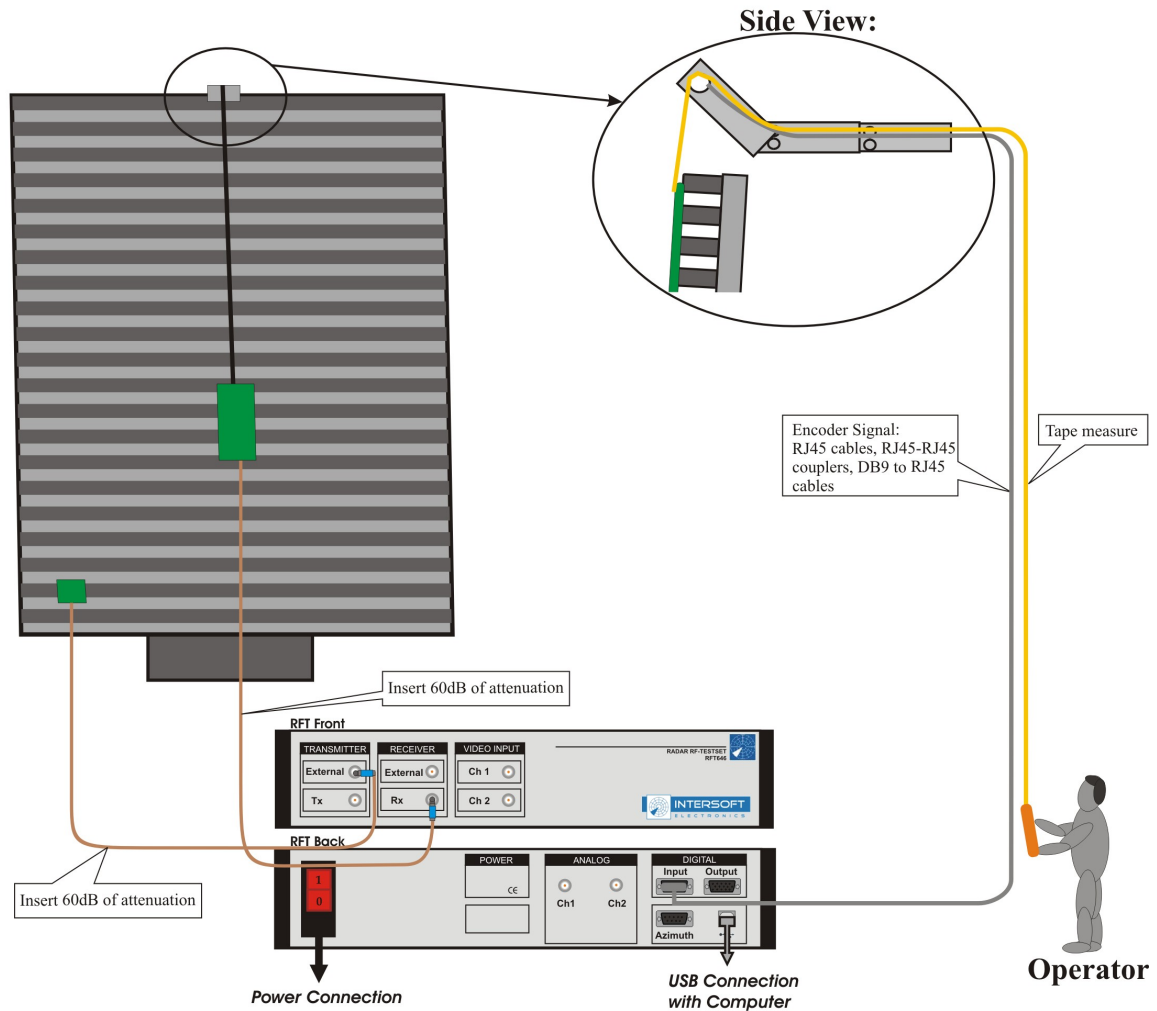
- Make a measurement in the centre column and take reference, unplug the cable and read the dynamic range (>30dB?).
- When measuring an additional channel do not take reference again or you will loose the relationship between the two measurements.

Figure 47: Column Fault Finding connection diagram



6.2. Annex 2: 3D Scan Transmission Connection Diagram

⚠ Avoid walking in the radiation field of the antenna



Set-up Guidelines:

- Make sure the scanboard moves smoothly across the plane of the antennas.
- Use enough attenuation at the beginning of each measurement, then remove attenuation to increase signals but avoid saturation (2V).

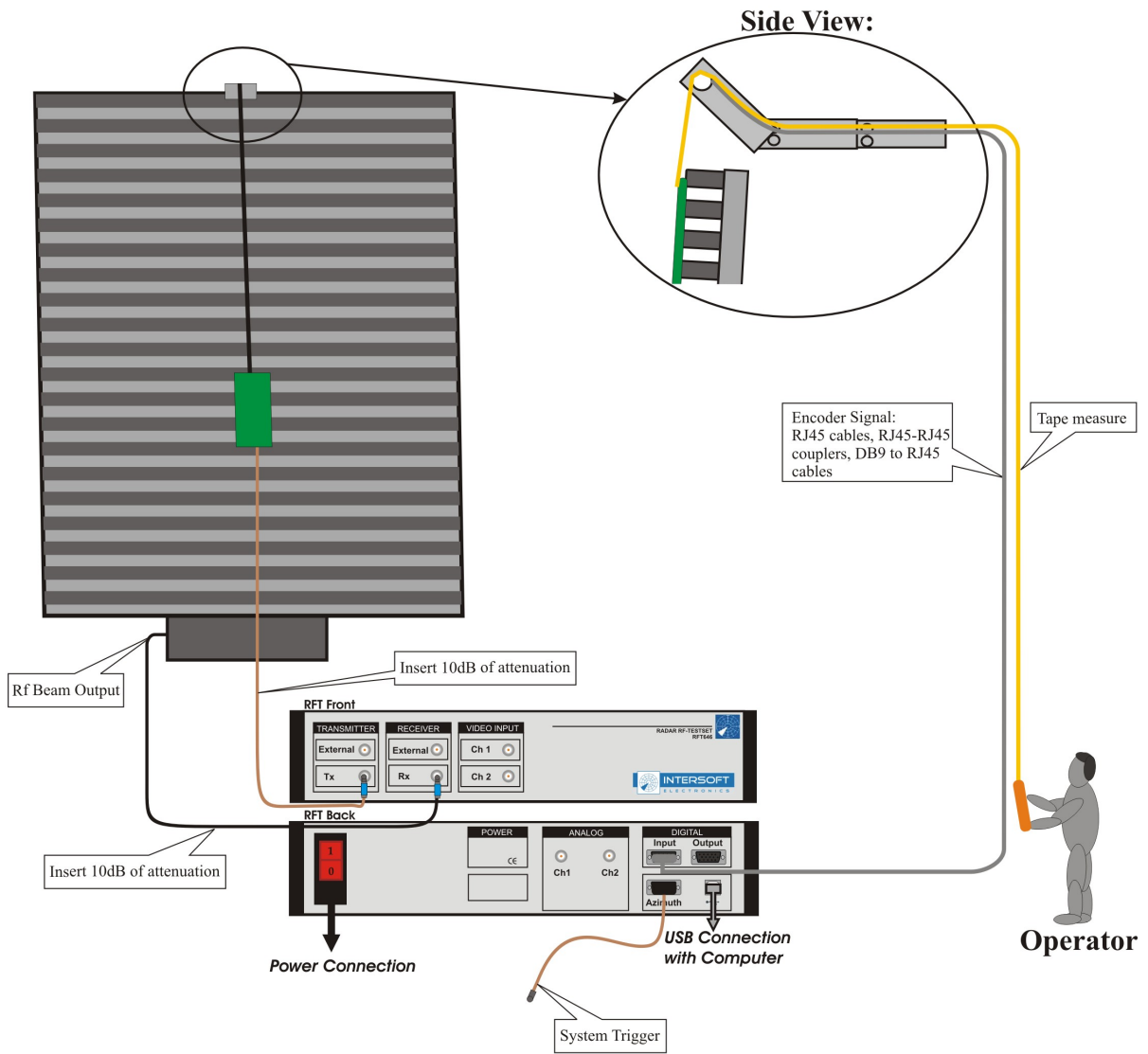
Figure 48: 3D Scan Transmission connection diagram

Tip: Use enough attenuation at the beginning of each measurement, then remove attenuation to increase signals but avoid saturation (2V).



6.3. Annex 3: 3D Scan Reception Connection Diagram

! Make sure to switch the Radar transmitter off



Set-up Guidelines:

- Make sure the scanboard moves smoothly across the plane of the antennas.

Figure 49: 3D Scan Reception connection diagram



6.4. Annex 4: Configuration List: RFT646

Check	Qty	Description/Item List
		Radar Rf Testset
<input type="radio"/>	1	Radar Rf Testset RFT646
<input type="radio"/>	1	Mains power cable
<input type="radio"/>	1	USB cable A to B - 3m
		RFT646 Accessories
<input type="radio"/>	1	2m brown BNC cable
<input type="radio"/>	1	2m red BNC cable
<input type="radio"/>	1	2m blue BNC cable
<input type="radio"/>	1	2m grey BNC cable
<input type="radio"/>	1	0.5m red BNC cable
<input type="radio"/>	1	0.5m blue BNC cable
<input type="radio"/>	1	15pHD to 5 BNC(m) cable
<input type="radio"/>	1	3DS External Trigger Cable
<input type="radio"/>		RFT Accessory Box
<input type="radio"/>	3	BNC(f) to SMA(m) connector
<input type="radio"/>	2	BNC(f) to N(m) connector
<input type="radio"/>	3	BNC(f) straight adaptor DC-4GHz
<input type="radio"/>	3	BNC T adaptor f / f / m
<input type="radio"/>	2	N(f) straight adaptor
<input type="radio"/>	2	10dB BNC Attenuator
<input type="radio"/>	2	20dB BNC Attenuator
<input type="radio"/>	1	Directional coupler ZFDC-10-5 BNC
<input type="radio"/>	1	Power splitter ZFRSC-42 SMA
		Column Fault Finding kit
<input type="radio"/>	1	Dipole antenna probe - mountable
<input type="radio"/>	1	Probe mounting stick



6.5. Annex 5: Configuration List: 3D Scan

Check	Qty	Description/Item List
3D Scan Antenna Kit		
<input type="radio"/>	1	Dipole Antenna Probe
<input type="radio"/>	1	Antenna Scan Board L-Band
<input type="radio"/>	1	Antenna Scan Board S-band
3D Scan Accessories		
<input type="radio"/>	2	Cramp
<input type="radio"/>	2	BNC(m) to BNC(m) RG223 5m black
<input type="radio"/>	1	Velcro Strip hook reel 3m 50 mm.
<input type="radio"/>	1	Velcro Strip loop reel 3m 50mm.
<input type="radio"/>	1	Accessories box
<input type="radio"/>	2	CAT10 Attenuator 10dB BNC 50Ω
<input type="radio"/>	2	CAT20 Attenuator 20dB BNC 50Ω
<input type="radio"/>	3	BNC(f) straight adaptor
<input type="radio"/>	4	RJ45-RJ45 8 way coupler
<input type="radio"/>	4	CAT5 STP patch cord RJ45-RJ45 5m
<input type="radio"/>	1	DB9(m) to RJ45 FTP CAT5 cable 2,5m
<input type="radio"/>	1	DB9(f) to RJ45 FTP CAT5 cable 2,5m
Encoder stick - P577		
<input type="radio"/>	1	Encoder stick
<input type="radio"/>	1	Tape measure Lufkin 20m
<input type="radio"/>	3	Aluminium bar
<input type="radio"/>	1	plastic screen 10m x 50cm
<input type="radio"/>	4	Bolt + wing nut

