MTI Marker
User Manual

Radar:

Ant Gain 22.02 dBi   Range delay 102.0 [us] Path loss<-> 218.8 dB

Tx Pwr 77.02 [dBm]

RCS -1.93 dBm2

-121.6 [dBm]
Target Return

L-S band

Path loss-> 124.1 dB

Simulated Target

MTI Rx -32.1 dBm
MTI Tx -34.6 dBm

Theoretical values; based on Radar Parameters

Document Characteristics

General
MTI Marker User Manual

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Abstract:	This user manual explains how to work with the MTI Marker (STG882 + antenna). It provides information on the hardware components and instructions on how to use the MTI Setup Assistant in the RASS-S toolbox. Also an introductory section to the RTG1002 is appended.

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006	21-May-19	Appendix 1 added	18-19	EV

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

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

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

GLOSSARY OF TERMS

ACP	Azimuth Change Pulse
ADS-B	Automatic Dependent Surveillance, Broadcast
Annex 10	Aeronautical Telecommunication, *Annex 10 to the Convention on International Civil Aviation*, the principle international document defining SSR
ARP	Azimuth Reference Pulse
ASTERIX	All Purpose Structured Eurocontrol Surveillance Information Exchange, is the standard protocol for ATC data
ATC	Air Traffic Control
COTS	Commercial Off The Shelf
CPU	Computer Processing Unit
CW	Continuous wave
dB	Decibel
Downlink	The signal path from aircraft to ground
FL	Flight Level, unit of altitude (expressed in 100's of feet)
FRUIT	False Replies Unsynchronized In Time, unwanted SSR replies received by an interrogator which have been triggered by other interrogators
GPS	Global Positioning System
ICAO	International Civil Aviation Organization
ICD	Interface Control Document
IE	Intersoft Electronics
IF	Intermediate Frequency
I/O	Input/Output
IP	Internet Protocol
LAN	Local Area Network
LVA	Large Vertical Aperture (antenna)
Monopulse	Radar-receiving processing technique used to provide a precise bearing measurement
MOS	Metal Oxide Semiconductor
MSSR	Monopulse Secondary Surveillance Radar
MTD	Moving Target Detection
MTI	Moving Target Indicator
Multipath	Interference and distortion effects due to the presence of more than one path between transmitter and receiver
NM	Nautical Mile, unit of distance
OEM	Original Equipment Manufacturer
PIN diode	PN diode with Insulating layer between P and N layers
Plot extractor	Signal-processing equipment which converts receiver video into digital target reports suitable for transmission by land lines
PPI	Plan Position Indicator
PRF	Pulse Repetition Frequency
PSR	Primary Surveillance Radar
Radar	Radio Detection And Ranging
Radome	Radio-transparent window used to protect an antenna principally against the effects of weather
RASS-R	Radar Analysis Support Systems – Real-time measurements
RASS-S	Radar Analysis Support Systems – Site measurements
RCS	Radar Cross Section
RDP	Radar Data Processing (system)
RES	Radar Environment Simulator

RF	Radio Frequency	
RFA641	Radar Field Analyser from IE	
RTG698	Radar Target Generator from IE	
RTQC	Real Time Quality Control	
RTT	Radar Test Target	
RX	Receiver	
SAC	System Area Code	
SAT	Site Acceptance Test	
SIC	System Identification Code	
SLS	Side Lobe Suppression, a technique to avoid eliciting transponder replies in response to interrogations transmitted via antenna sidelobes	
SLB	Side Lobe Blanking	
SNR	Signal-to-Noise ratio	
Squitter	Random reply by a transponder not triggered by an interrogation	
SSR	Secondary Surveillance Radar	
STC	Sensitivity Time Control	
STG882	Stationary Target Generator from IE	
TACAN	Tactical Air Navigation	
TCP	Transmission Control Protocol	
TIS-B	Traffic Information Services, Broadcast	
Transponder	Airborne unit of the SSR system, detects an interrogator's transmission and responds with a coded reply stating either the aircraft's identity or its flight level	
TX	Transmitter	
Uplink	Ground-to-air signal path	
UTC	Coordinated Universal Time	

1. INTRODUCTION

Many airfields with primary radar installations use active reflectors in order to check the geographical alignment of the PSR video with the touchdown points, runway crossing points, etc. The active reflector (also known as a stationary target) must produce a "Doppler" shift such that the stationary target passes through the MTI/MTD processor and is presented on the radar screen of the Air Traffic Controller. Without this Doppler signature it would be filtered out as clutter. The MTI Marker is used for Real Time Quality Control (RTQC) checks of the radar system.

The MTI marker simply reflects the energy received from an antenna back towards the radar, the phase of the reflection is inverted at a given rate to simulate Doppler. As such the output power is determined by the input power. Therefore some radar parameters need to be known: Power/antenna gain and also distance between radar and marker. The maximum Radar Cross Section (RCS) of the simulated target is determined by the selection of the marker antenna and can be lowered by inserting attenuators.

2. MODULAR SET-UP

The Intersoft Electronics MTI marker consists of 2 modules:
1. Stationary Target Generator (STG882)
2. Antenna
3. Plastic box (can optionally be used as extra protection against weather conditions)

2.1. Stationary Target Generator (STG882)

In essence, the STG882 can be considered as a mirror for RF. It is installed on a fixed position in the field and accepts signals in L/S/C/X band and reflects them back to the source with or without phase reversal. Phase reversal can be added on the signal to pass through the radar MTI filtering and to be displayed on the PPI of the controller. The STG882 is designed to replace the MTI reflector products suffering from obsolete and heavy batteries. The STG882 can be used to align the radar to the runway.

Figure 1: Stationary Target Generator STG882

A schematic overview of the STG882 is given in the Figure 2 below. The design uses very low power RF MOS switches rather than PIN diodes to save battery power. The battery is a 3.6V lithium battery and it is expected to last for more than 5 years (depending on Doppler settings). Nevertheless, it is advisable to check the battery every year. It is easy accessible at the side of the STG882 enclosure [Figure 1].
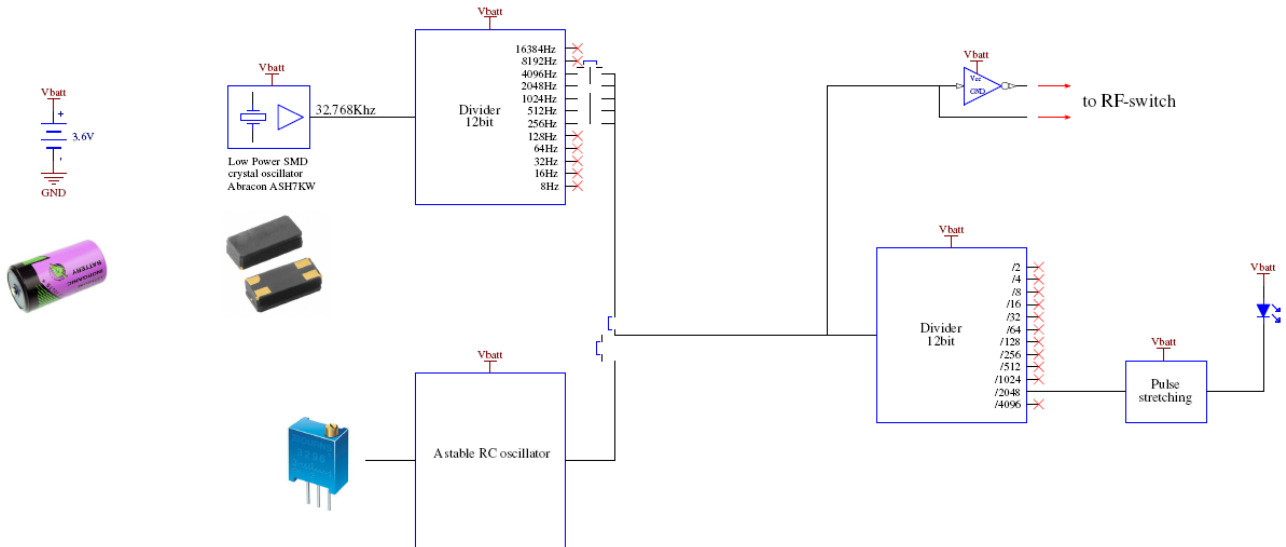

Figure 2: Schematic Overview of STG882

The **phase shifting and switching frequency** will determine the resulting Doppler frequency.

The RF signal will enter the STG882 through the N-type connector on the metal box [Figure 1]. An RF MOS switch will guide the signal to the phase shifter. These phase shifters are responsible for alternating the reflected phase between φ and φ + 180 degrees. Figure 3 shows the MOS switch with two SMA connectors for attaching stubs in order to adjust the reflected signal's phase shift to φ, respectively φ + 180 degrees. The phase reversal is tuned for the desired radar band by using a stub on the incoming RF signal and needs to be specified on order.

The switching frequency is controlled by CMOS logic ICs and is programmable. The user can choose by setting a jumper, between a very stable frequency derived from a 32kHz crystal (jumper 1 on **DV** position) and a continuous variable frequency from a astable RC oscillator (jumper 1 on **CV** position).

With the jumper 2 in the **DV** position, the user can set the doppler frequency to 256, 512, 1024, 2048 or 4096Hz. If the RC oscillator is selected then the frequency can be trimmed with the potentiometer between roughly 200Hz and 3,6KHz.Ideally, the resulting Doppler frequency is nearby the PRF/2. The phase shifting and switching frequency are both set in the factory.
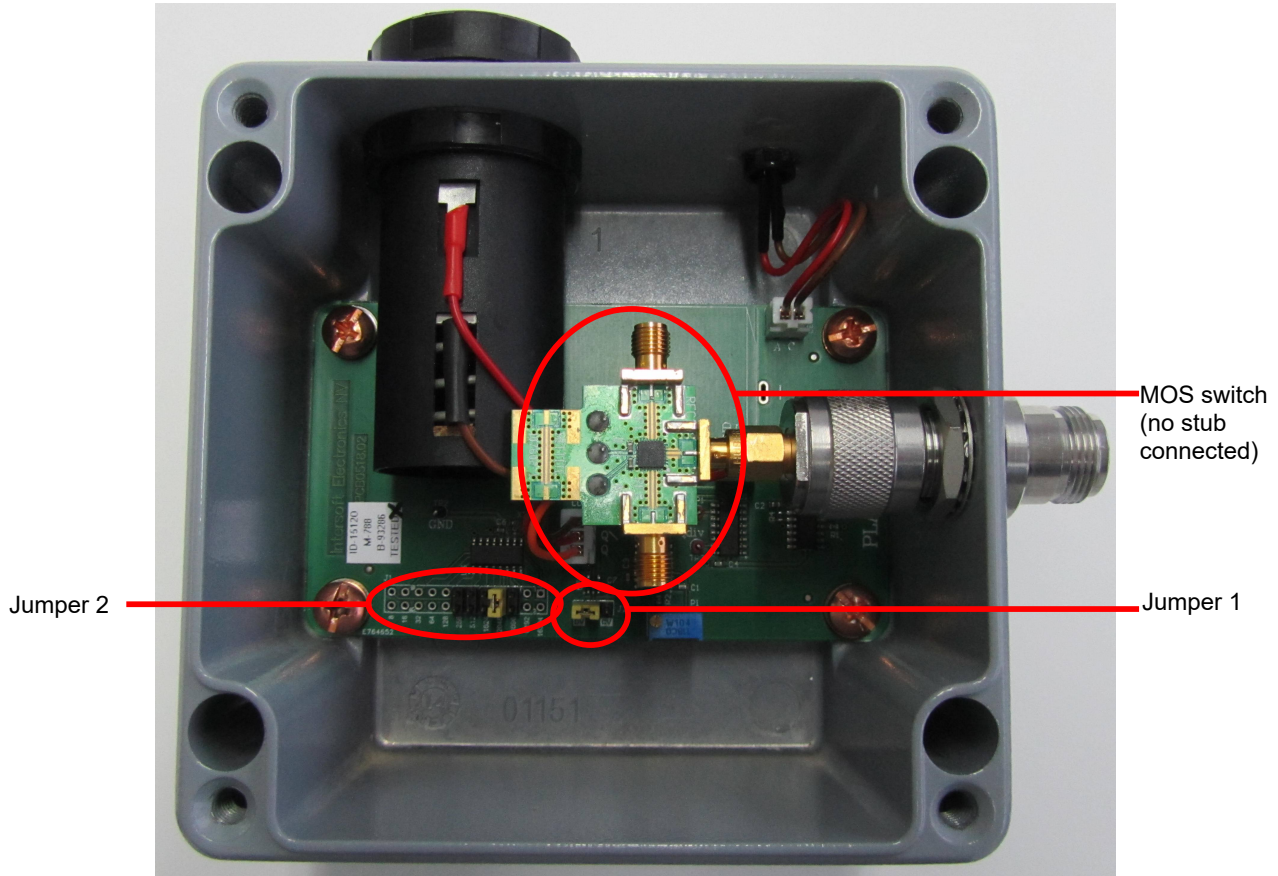
Figure 3: Picture of the STG882

The STG 882 is a passive system and will not amplify the transmitted signal.

The **specifications** of the STG 882 are listed below:

RF switch specification	Value
Maximum allowed input power (no damage)	34 dBm
Maximum input power (1dB compression)	30 dBm
Maximum Switching losses	3 dB
Mechanical specification	**Value**
Battery	Lithium 3.6 V
Dimensions (WxDxH)	120mm x 120 mm x 90 mm
Weight	0.9 kg

Figure 4: Specifications of STG882

2.2. Antenna

The **intended use** of the MTI marker is crucial to determine which antenna is most appropriate to serve your needs. Several parameters will reflect on the antenna choice:

- Polarisation of the PSR antenna

- Distance to the PSR radar

- Required gain

- Mobility of the system

The **polarisation** of the PSR antenna will determine the orientation of the antenna. If possible a standard gain horn antenna is used. This way the exact gain and resulting strength of the target is accurately known. In case a circular polarisation is employed and a strong marker is needed, a parabolic antenna has to be installed.

The **size** of the horn antenna depends on the operating frequency and the required gain. The horn antenna for an L band PSR is larger than for an S band PSR for the same amount of amplification. The size of the horn antenna also reflects on the mobility of the system.

An example which shows how to determine the necessary antenna: For an X-band system a simple 20dB gain horn is sufficient as the high frequency allows a high gain antenna and still preserves a small size while the target RCS needed is usually small on X-band. For L-band being long range radar systems, the marker antenna needs to be much bigger and if the range to the radar is only a few kilometres sometimes the problem is that the received power is more than the MTI marker can handle (typical 20dBm).

2.3. Field Set-up

One has to consider the **elevation** between the MTI marker antenna and the PSR antenna. A PSR antenna typically has 6dB attenuation at horizon level. In case the MTI marker is on a low elevation far away from the radar, this will induce an extra 12dB (6dB up/down) attenuation of the RF signal. Therefore it is advisable to move up in the vertical polar diagram (VPD), for instance by using a telescopic pole [Figure 3].

Although a natural high point in the environment might look tempting for installing the MTI marker, this does not always give the best results. It will definitely maximize the return power towards the radar as you move up in the VPD, but unfortunately the ground clutter will be maximized as well.

Therefore it is advised to **measure a clutter map**. This can be a Built In Test (BIT) function of the radar or one could make use of Intersoft Electronics' hardware and RASS-S software [Figure 5]. Verify the amount of clutter for a few possible locations. If the signal strength of the clutter is calibrated, it can be compared to the calculated power of the MTI marker assistant software for every candidate location.
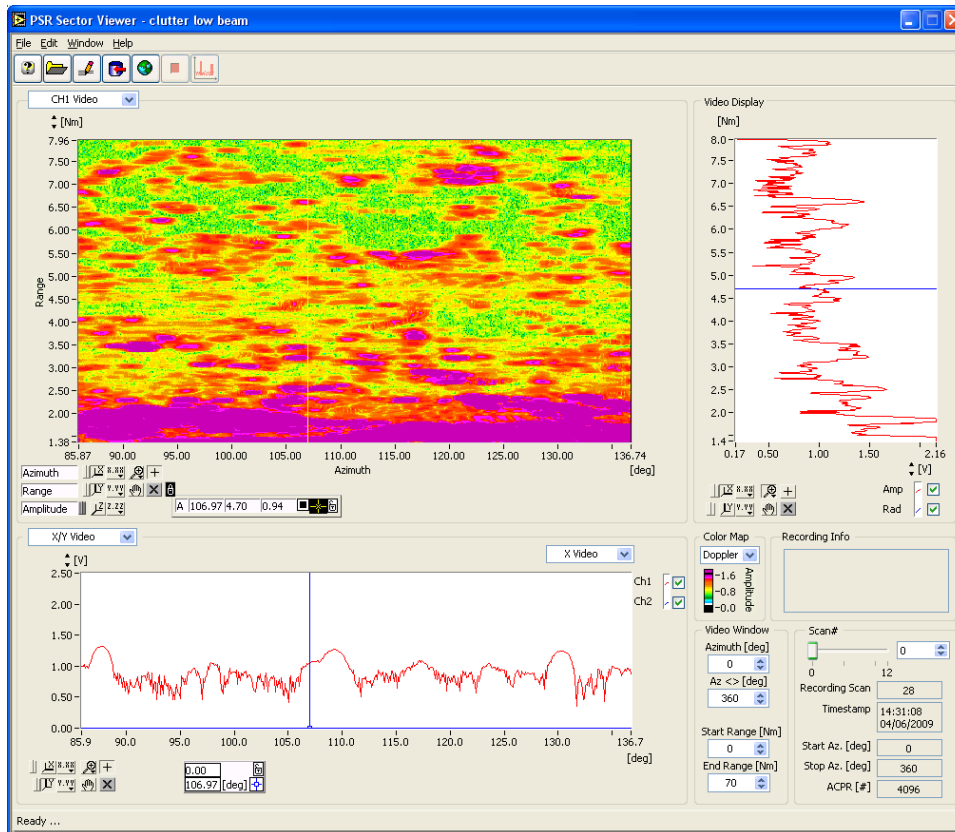
Figure 5: Clutter map example in RASS-S software

A good location would be to pick an area with **direct line of sight** to the radar, where the radar beam still touches the ground but without too much ground clutter. Don't use the tallest building or a tall metal mast. Its strong reflections will mask the generated target. A less massive metal mast or a wooden barn could do just fine. A concrete building could be OK if the walls aren't perpendicular to the signal path. Don't mount it near trees because the combination of rain and wind could create a false (MTI Marker-) target.

If the calculated target return power is stronger then the clutter, the location is good to use.

The RASS-S software can be used to calculate the path losses and resulting performance of MTI Marker set up for your application.

A plastic box is delivered with the STG882 for extra protection against weather conditions, check out Chapter 7 for the installation of the STG882 in the plastic cover.

3. THE MTI SETUP ASSISTANT

The **MTI Setup Assistant** (software tool) can be accessed via the **MTI Marker** button from the **PSR Target Generation** section in the RASS-S toolbox.

Figure 6: PSR Target Generation section with MTI Marker button

In the MTI Setup Assistant we can distinguish:
- some fields to enter parameters
- a VPD curve
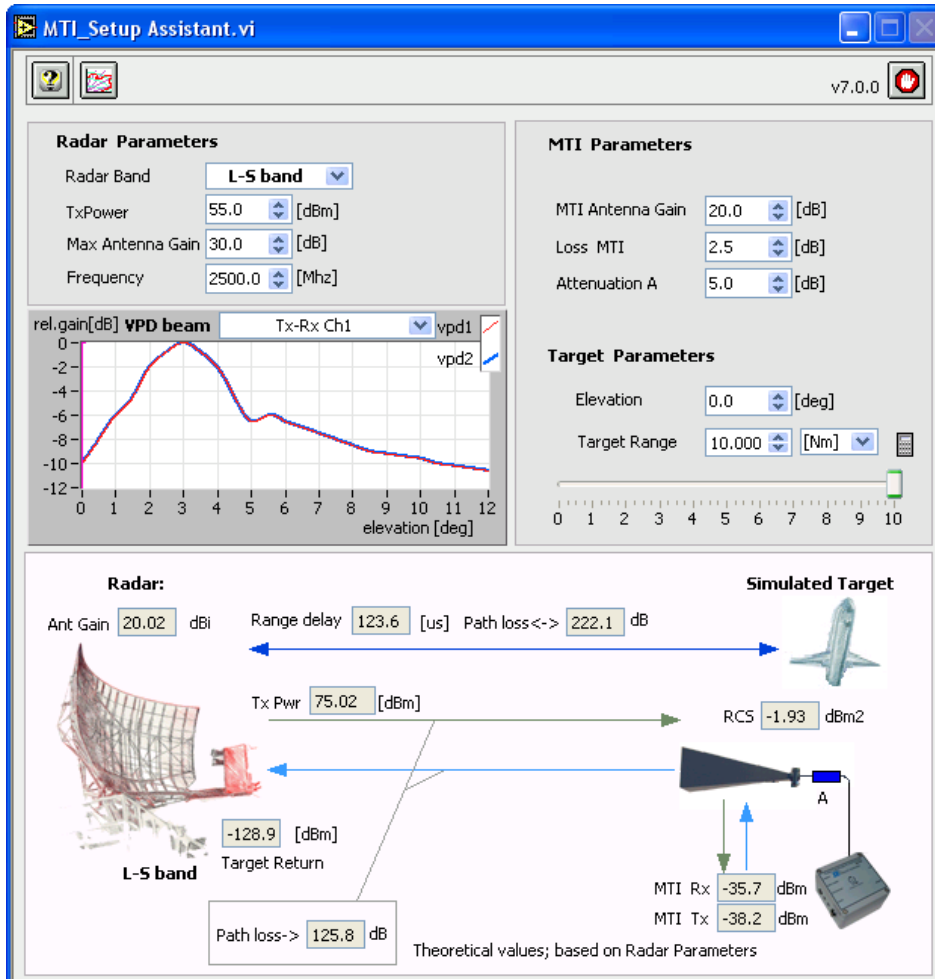- a graphical representation of the setup

Figure 7: MTI Setup Assistant

The MTI Setup assistant needs some parameters of the radar, the MTI and the simulated target. The **radar parameters** include:

- **Radar band**: L-S, C or X

- **Tx Power**: Used to evaluate the theoretical input power of the MTI Marker

- **Max Antenna Gain**: Added to the TxPower to calculate the effective transmitter power

- **Frequency**: Used to calculate the path loss through space

> ☞ **Note: If the exact frequency is not known or if it changes during operation, enter the closest frequency.**

Also the VPD curve can be considered as s radar parameter. Use the **VPD viewer tool** 🖼 in the toolbar to import an existing VPD diagram from text format.

The **MTI Parameters** include:

- **MTI Antenna Gain**: This is typical

    - 10 dB for L-S band

    - 20 dB for C band and X band in mobile setup

    - 24 dB for X band in fixed setup

- **Loss MTI**: Loss induced by the MTI RF components, typical 2,5 dB if no attenuation is used

- **Attenuation A**: Optional attenuation value of attenuator or cable in line with the MTI antenna path, often used to lower the maximum RCS

The **Target Parameters** include:

- **Elevation**

- **Range** of the simulated target

The range can be calculated based on the GPS coordinates of the radar and the MTI Marker using the Calculate Range 🔲 button. This button opens the **Calculate Distances RTG** window in which the coordinates can be entered [Figure 8]. The range can also be set by using the slider.
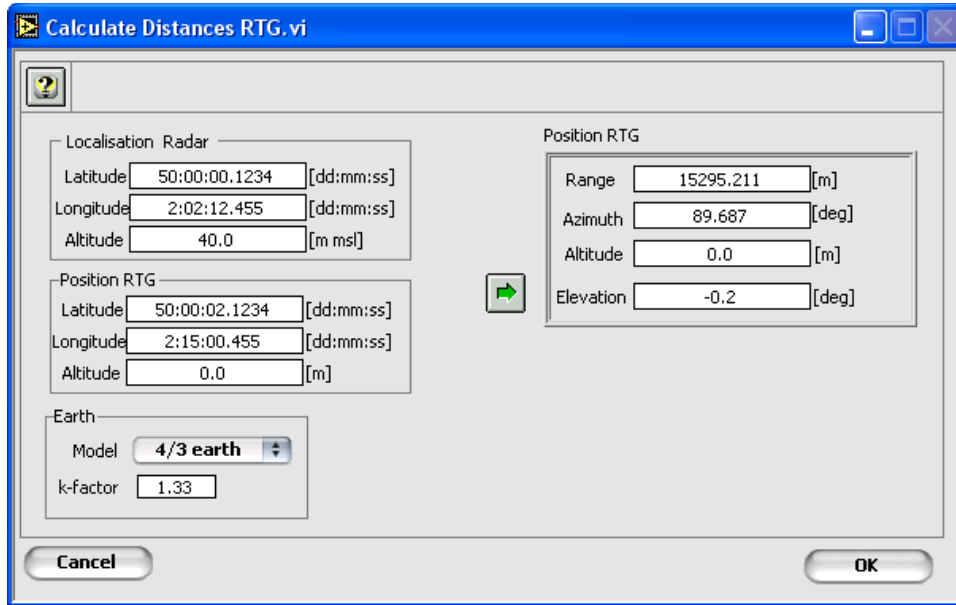
Figure 8: Calculate distances RTG window

The **graphical representation** at the bottom of the MTI Setup Assistant allows for easy analysis of the power levels, path losses, range delay and RCS. Refer to section 4.2Verification of the Power Levels and Matching with Uplink Measurement.

4.   UTILIZATION INSTRUCTIONS

4.1. Verification of the Phase Flipping Rate

If, for example, the radar has a pulse repetition frequency of 240Hz, the rate of phase flipping should be different from 480Hz or 960Hz. If this is not the case, every radar echo would be generated using the same phase shift, no Doppler speed would be measurable and hence no target would be detected.

In order to avoid these situations, it is possible to verify the phase flipping rate. The twelfth bit of the oscillator, which controls the switch of the phase flipping, can be monitored as it is related to the flashing led indicator on the Stationary Target Generator.

Use a stopwatch to measure 10 periods (more accurate then one) of the flashing led indicator on the Stationary Target Generator. Divide the result by 10 and transfer it into a frequency. Multiply the result with 4096 to get the frequency of the phase flipping.

(Example: if the period is 40 seconds , the generated Doppler frequency would be 4096/(40/10) or 1024 Hz).

4.2. Verification of the Power Levels and Matching with Uplink Measurement

Open up the MTI Marker Setup Tool from the RASS-S toolbox, enter the required parameters as described in 3The MTI Setup Assistant and verify the parameters of the setup.

The **path loss** (one way in gray ; two ways in blue) is calculated.

The **target return power** is calculated and it should be above the Minimum Detectable Signal strength of the radar. The corresponding **RCS** of the generated target is also calculated. This RCS doesn't change with the range of the setup. The return power will decrease for sure, but so does the return power of a real aircraft. The only thing that changes the simulated target size is the antenna gain of the MTI marker or additional attenuators put in line between the STG882 and its antenna.

Use the MTI Marker Setup tool to calculate and verify the **power received by the MTI marker**. Verifying the calculated power by an Uplink antenna measurement using the Intersoft RFA641 is advised. Use the antenna of the MTI marker to make the uplink measurement (but use appropriate attenuators and take them into account). Any mistake of the (assumed) antenna gain of the radar antenna or MTI marker will be revealed.

Make sure the Tx power is correct (the radar could be transmitting at half power instead of at peak power) and then adjust the parameters of the MTI antenna gain to **match with the result of the uplink measurement**.

5.   MTI Marker with Optional Test Flight Simulation

The antenna of the MTI Marker can be re-used when the RTG1002 (Radar Target Generator) is added to the set-up. This RTG1002 can be used as a Test Flight Simulator. Adding the RTG1002 to the set-up one can decide to switch to the RTG1002 instead of to the STG882 (Stationary Target Generator).

Often, expensive test flights are used during the SAT procedure of radar systems, since this procedure tests all the important elements of the radar. However a few downsides of this method should be noted: the test flights are very expensive and the Radar Cross Section (RCS) varies with the orientation and type of the aircraft. The latter indicates that the calibration of the RCS is not easy and therefore it is difficult to accurately reproduce a test flight.

For SSR a valuable and much cheaper alternative solution, the Radar Environment Simulator (RES28x) is available to fully test the performance of the radar. For PSR the diversity of systems and the complexity of generating signals that simulate the environment makes it difficult to use a complete RES. The amount of test flights for recurring maintenance procedures and quality control of the PSR can now be reduced significantly by using the new RTG1002 (Radar Target Generator) with programmable RCS. The RTG1002 is able to generate the reflecting signals of an aircraft faithfully and independent of the radar characteristics (frequency, PRF, etc.).

In order to test the complete radar system it is necessary to generate the aircraft signals in the field thereby including the antenna system. The set-up position should be chosen carefully and the site attenuation should be calibrated.

Different test scenarios, in function of range and velocity, can be simulated to test the Doppler MTI function and blind speeds. The accuracy of the radar system can be determined when the simulated trajectory is compared to the output of the radar system (ASTERIX). For this purpose the RASS-S software provides the matching tools. The method described is a feasible, repeatable and low-cost replacement for the expensive test flights and offers a standardized and calibrated maintenance procedure.
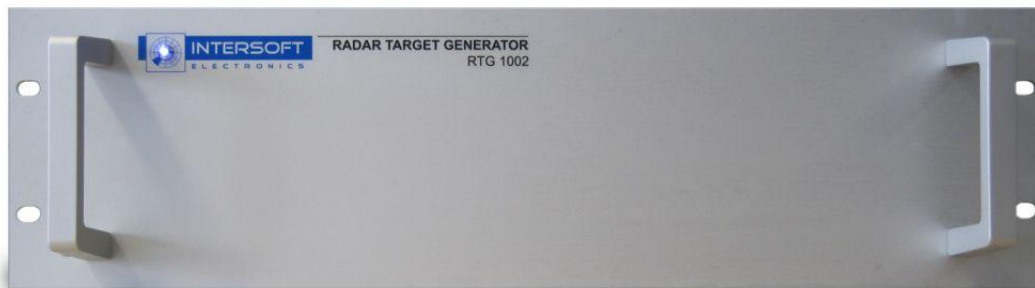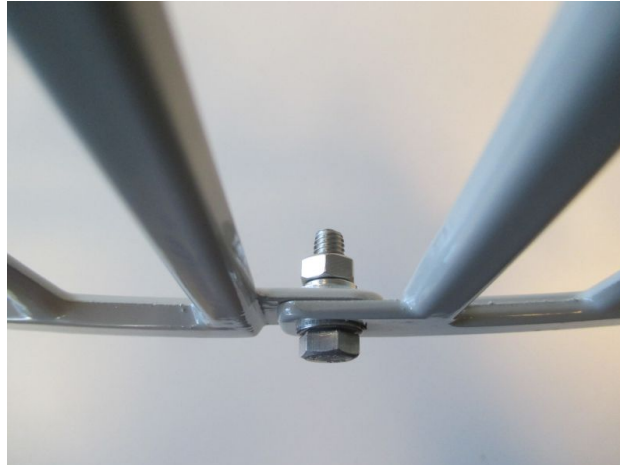

Figure 9: Radar Target Generator RTG1002

6.   APPENDIX 1: ASSEMBLING THE GRID PARABOLIC ANTENNA

Step 1: Combine the 2 antenna halves to compose a parabolic antenna. When the 2 halves are aligned correctly they can be fixed:

Figure 10: Step 1 – Combine the 2 antenna halves

Step 2: Install and fix the feed on the dish antenna:

Figure 11: Step 2 – Install the feed

Step 3: Install and fix the L-bracket on the back of the reflector:

Figure 12: Step 3 – Install the L-bracket

Step 4: Fix the antenna to the supporting pole of your choice:

Figure 13: Step 4 – Fix the antenna to the supporting pole

7. APPENDIX 2: INSTALLING STG882 INTO PLASTIC COVER

Step 1: Remove the lid from the plastic box, remove the split cable gland from the plastic box and remove the bracket from the STG882:

Figure 14: Step 1 - Overview

Step 2: Open the split cable gland, fix the cable grommet around the cable and fix the split cable gland around the cable grommet.
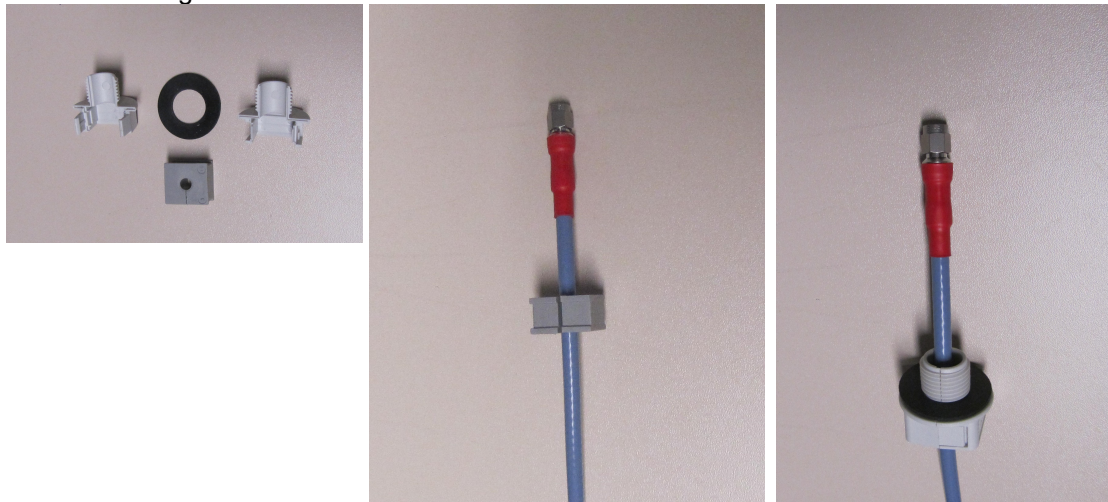

Figure 15: Step 2 – Fixing the cable grommet and cable gland

Step 3: Put the STG882 inside the plastic box, fix the cable to the STG882 using the SMA-N adapter and fix the split cable gland to the plastic box.

Figure 16: Step 3 – Installing the STG inside the plastic cover

Step 4: Close the front side of the plastic box and fix the bracket onto the STG882 (backside of the plastic box).

Figure 17: Step 4 – Fix the bracket