Reducing Test Flights Using Simulated Targets and a Carefully Chosen Set-up

Edition: 001
Date: 18-FEB-09
Status: Released

DOCUMENT DESCRIPTION

Document Title		
Reducing Test Flights: Using Simulated Targets and a Carefully Chosen Set-up		
	Edition	001
	Edition date	18-FEB-09
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	Editor	Marcel Vanuytven

Abstract

At the moment expensive test flights are used during the SAT procedure of PSR radar systems. The method described in this document offers a solution to replace test flights with a standardized and calibrated maintenance procedure.

Keywords

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DOCUMENT STATUS

STATUS			
Working Draft	☐		
Draft	☐		
Proposed Issue	☐		
Released Issue	☑		

ELECTRONIC BACKUP

INTERNAL REFERENCE NAME :	IE-SUP-00043-001 Reducing Test Flights by using Simulated Targets
HOST SYSTEM	**SOFTWARE(S)**
Windows XP Pro	Word 2003

DOCUMENT CHANGE RECORD

The following table records the complete history of the successive editions of the present document.

EDITION	DATE	REASON FOR CHANGE	SECTIONS PAGES AFFECTED	APPROVED BY
001	12-JAN-06	New document	All	EV
001	18-FEB-09	New Layout	All	EV

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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
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
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
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)
RF	Radio Frequency
RTQC	Real Time Quality Control
RX	Receiver
SAC	System Area Code
SIC	System Identification Code
SLS	Side Lobe Suppression, a technique to avoid eliciting transponder replies in response to interrogations transmitted via antenna sidelobes
SLB	Side Lobe Blanking
SNR	Signal-to-Noise ratio

Squitter	Random reply by a transponder not triggered by an interrogation
SSR	Secondary Surveillance Radar
STC	Sensitivity Time Control
TACAN	Tactical Air Navigation
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. Reducing Test Flights by Using Simulated Targets and a Carefully Chosen Set-up

1.1 Introduction

At the moment expensive test flights are used during the SAT procedure of radar systems. 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 made it difficult to use a complete RES28X. The amount of test flights for recurring maintenance procedures and quality control of the PSR can be reduced significantly by using the new RTG698 (Radar Target Generator) with programmable RCS (Radar Cross Section).
The concept that is described hereafter can only replace the test flights in case it consists of the following elements:

1. Target Generator: This equipment should be able to generate the reflecting signals of an aircraft faithfully and independent of the radar characteristics (frequency, PRF, etc.).
2. Calibrated measurement set-up: 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.

The method described in this document offers a solution to replace test flights with a standardized and calibrated maintenance procedure.

1.2 Difference between Test Flights and a Target Generator

Test Flights are commonly used to test the performance of the PSR 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 not without risk.
- The RCS (Radar Cross Section) varies with the orientation and type of the aircraft: calibration of the RCS is not easy.

The latter indicates that it is difficult to accurately reproduce a test flight.
The Intersoft Electronics Radar Target Generator (RTG698) provides the solution to this problem, since it is basically designed to generate true and correct primary radar returns.

1.3 Radar Target Generator: RTG698

The RTG698 was designed to mimic the behaviour of an aircraft. The RTG698 detects and preserves the radar pulse, applies a fixed and highly precise delay and retransmits the pulse with the appropriate power and Doppler shift. The RCS of the generated target is programmable and the RTG698 is capable of generating different Swerling cases which make the simulated trajectory look even more real.
In the software some parameters (such as the antenna gain, power of the transmitter,…) are used to calculate the required target return.
The RTG698 was designed to be used on several frequencies in the L/S-band. It can also be used in the C- or X-band simply by adding a front up/down-convertor which interfaces between the RTG698 and the radar under test.

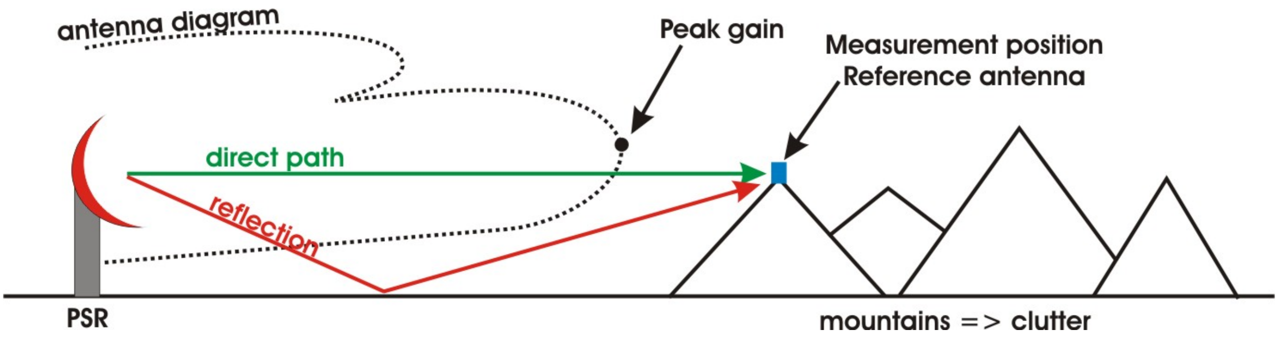
Therefore the RTG698 is a good replacement for a test flight if the set-up in which it is used is carefully chosen and calibrated.

1.4 Field Set-up of the Reference Antenna

A reference antenna needs to be installed in the field to generate the simulated target. A good site for the set-up can only be found after an evaluation of the radar signals in the field using the reference antenna and Rf measurement equipment. Several specifications of the site should be considered:

- The reference antenna needs to have line-of-sight to the radar.
- The elevation angle has to be higher than -2 degrees to the radar horizon to determine the correct antenna gain and to avoid the uncertainty of low elevation sidelobes.
- The set-up should be positioned in the direction of strong clutter to be able to evaluate the sub clutter visibility or radar stability.

First of all the Uplink path (from the PSR to the reference antenna) needs to be checked:



For this purpose the signals received from the radar must be identified and accurately measured. The Radar Field Analyser (RFA641 for L/S-band, RFC709 for C-band, RFX474 for X-band) is perfectly suited for this job.

The Uplink path can be calculated using the following equation:

Tx PWR + Gain – Path loss + Gain(RA) = Rx PWR

Where:
- Tx PWR is the transmitted power of the PSR,
- Gain is the gain of the PSR antenna which is known and can be verified using the RASS-S tools (i.e. solar measurement),
- Path loss is the loss of the uplink path can be determined using the following formula: $P_r = \frac{P_t G_t G_r}{L}\left[\frac{\lambda}{4\pi R}\right]^2$

  Where:
  - P_r is power at the receiving antenna,
  - P_t is transmitted power,
  - G_t is transmitter antenna gain,
  - G_r is receiver antenna gain,
  - L is system losses,

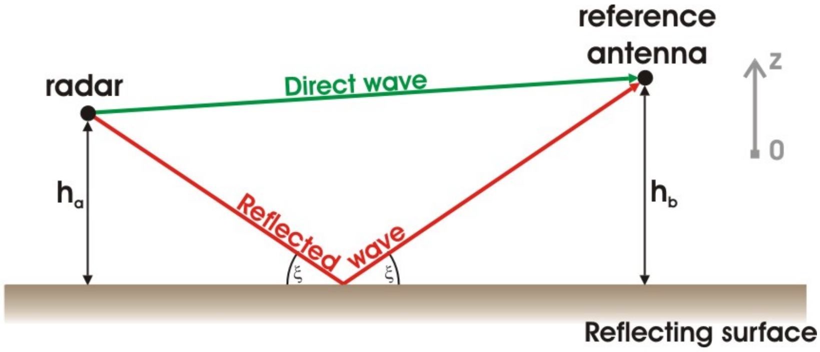
  The factor $\left[\frac{\lambda}{4\pi R}\right]^2$ can be expressed as log:

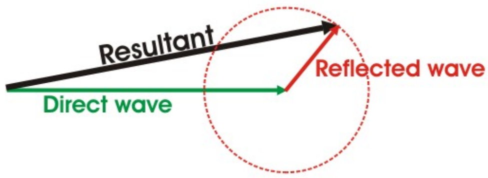
  $$a = -37.801 - 20\log(f) - 20\log(d)$$

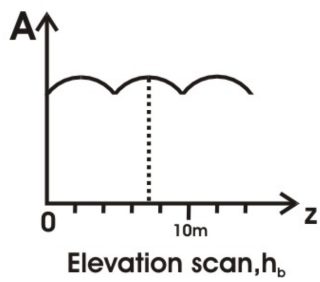
  Where f is the frequency in Megahertz, d is the range in nautical miles and a is the loss in decibels due to the dilution of the signal with range. The path loss is proportional to the range.
- Gain(RA) is the gain of the reference antenna
- Rx PWR is the power received by the reference antenna, this power can be measured using the RTG698.

The Radar Field Analyser measures the antenna diagram and the gain of the radar. It is the absolute value of the gain that is important, so the site attenuation (combination of antenna gain and multipath effect) should be determined as well.

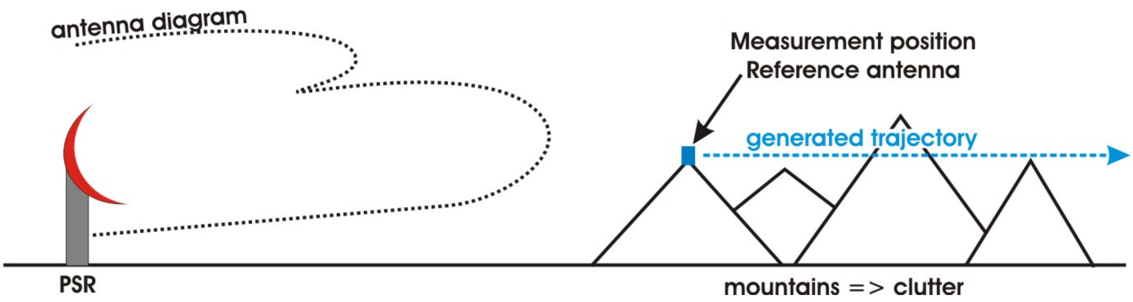
The reflected wave(s) (multipath) causes an uncertainty, which can be determined by changing the height of the reference antenna. If a ground reflection is present the signal changes phase and the received amplitude is varying for different elevations. It is advised not to position the reference antenna in a NULL but preferably close to a maximum (notice that this could be at a lower location). From the maximum variation in amplitude (of the directed wave) the required site attenuation can be calculated.







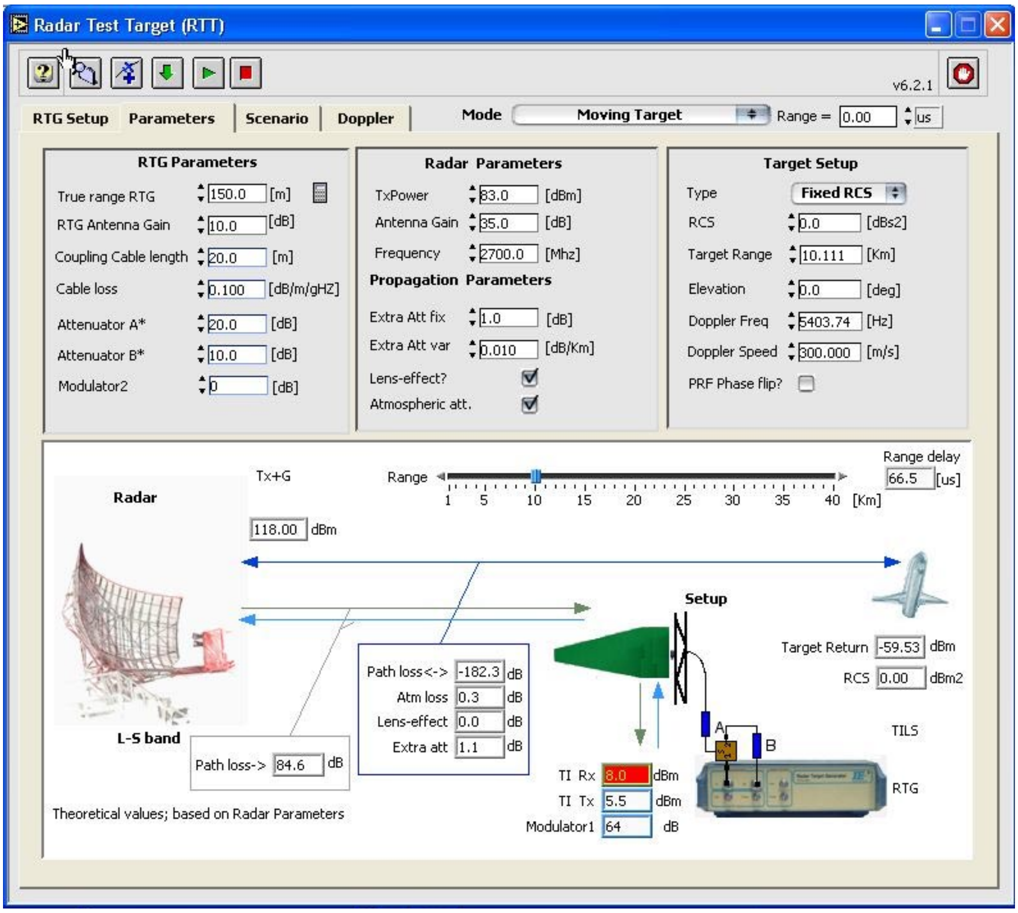
In case the Rx Power is not equal to the expected value +/- 2dB then we can conclude that one of the following elements needs to be checked thoroughly: the transmitter of the radar antenna or the receiving reference antenna. In case the Rx Power is equal to the expected value +/- 2dB, the Uplink path is known and the RTG698 can start simulating a test flight. From the measured power the site attenuation can be calculated which will serve as an input parameter of the RTG698 software.



The target is generated starting at the reference antenna position to the maximum radar range. The RTG698 superimposes the simulated test flight on top of the clutter, so the sub clutter visibility can be determined. Since the clutter strength can be measured (i.e. by using the RASS-S Clutter recording tool), the target strength can be changed to make sure that it’s stronger than the clutter.

1.5 Replacing Test Flights

The RTG698 can generate the correct power since the frequency and gain of the PSR antenna are known, the path loss is determined and the RCS can be chosen. The RTG698 software uses the radar equation to automatically calculate the return power for the different ranges.



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.

1.6 Conclusions

- The method described is a feasible, simple, repeatable and low-cost replacement for the expensive test flights. However more experience will be needed to finalize the concept.
- The radar is tested from top to bottom under operational circumstances. When this method is used it is important to notify the Air Traffic Controller of the simulated test flight that will appear on the screen.
- The antenna used in the RTG698 set-up can be re-used for repeater purposes. The IE MTI Marker is a low-cost Target Generator for a fixed range.
- The test flight can only be simulated in one radial direction. In case the testing procedure requires multiple directions extra antennas will be necessary.
- This simulated test flight is ideal for recurring maintenance tests.