# Iapetus Scatterometry Rev 17 (and Titan Radiometry)

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- Sequence: s16
- Rev: 017
- Observation Id: ia_017_1
- Target Body: Iapetus

## 1 Introduction

This memo describes one of the Cassini RADAR activities for the s16 sequence of the Saturn Tour. A sequence design memo provides the science context of the scheduled observations, an overview of the pointing design, and guidlines for preparing the RADAR IEB. This IEB is for the third Iapetus distant scatterometer observation around Nov 12 2005.

## 2 CIMS and Division Summary

Each RADAR observation is represented to the project by a set of requests in the Cassini Information Management System (CIMS). The CIMS database contains requests for pointing control, time, and data volume. The CIMS requests show a high-level view of the sequence design.

The CIMS requests form the basis of a pointing design built using the project pointing design tool (PDT). The details of the pointing design are shown by the PDT plots on the corresponding tour sequence web page. (See https://cassini.jpl.nasa.gov/radar.) The RADAR pointing sequence is ultimately combined with pointing sequences from other instruments to make a large merged c-kernel. C-kernels are files containing spacecraft attitude data.

A RADAR tool called RADAR Mapping and Sequencing Software (RMSS) reads the merged c-kernel along with other navigation data files, and uses these data to produce a set of instructions for the RADAR observation. The RADAR instructions are called an Instrument Execution Block (IEB). The IEB is produced by running RMSS with a radar config file that controls the process of generating IEB instructions for different segments of time. These segments of time are called divisions with a particular behavior defined by a set of division keywords in the config file. Table 2 shows a summary of the divisions used in this observation. Subsequent sections will show and discuss the keyword selections made for each division. Each division table shows a set of nominal parameters that are determined by the operating mode (eg., distant scatterometry, SAR low-res inbound). The actual division parameters from the config file are also shown, and any meaningful mismatches are flagged.

## 3 Div's A,B,D: Initial Radiometry and Titan Scan

This IEB covers two different targets. After the usual three hour warmup covered by division A, there is a distant radiometry raster scan of Titan covered by division B. This scan is part of a series of Titan radiometry scans inserted to provide calibration points periodically during the Tour. Following the Titan scan, the spacecraft will slew to point

| CIMS ID | Start | End | Duration | Comments |
|---|---|---|---|---|
| 017OT_LONGWARM001_RIDER | 2005-316T17:32:00 | 2005-316T20:32:00 | 03:00:0.0 | Warmup for calibration and science data collection. |
| 017TI_LONG2CAL001_PRIME | 2005-316T20:32:00 | 2005-316T21:26:34 | 00:54:34.0 | Obtain distant Titan radiometer science and calibration data. One of a set of near zero titan sub-spacecraft latitudes, fixed phase angle, and varying sub-spacecraft longitudes. |
| 017IA_SCATTRAD001_PRIME | 2005-316T21:26:34 | 2005-317T00:24:00 | 02:57:26.0 | Point -Z axis at target and execute raster scan(s) centered on target. Obtain simultaneous scatterometry and radiometry. |

Table 1: ia_017_1 CIMS Request Sequence

| Division | Name | Start | Duration | Data Vol | Comments |
|---|---|---|---|---|---|
| a | distant_warmup | -4:00:0.0 | 03:17:0.0 | 2.9 | Warmup and initial radiometry |
| b | distant_radiometer | -0:43:0.0 | 00:53:0.0 | 3.2 | Radiometry during Titan raster scan |
| c | scat_compressed | 00:10:0.0 | 00:10:0.0 | 4.2 | Scatterometer off-target receive only compressed |
| d | distant_radiometer | 00:20:0.0 | 00:07:0.0 | 0.4 | Radiometer during turn transition to Iapetus |
| e | scat_compressed | 00:27:0.0 | 00:10:0.0 | 4.2 | Scatterometer on-target receive only compressed |
| f | distant_scatterometer | 00:37:0.0 | 00:26:24.0 | 301.0 | Scatterometer target-center stare with tone |
| g | scat_compressed | 01:03:24.0 | 00:09:36.0 | 4.0 | Scatterometer on-target receive only compressed |
| h | distant_radiometer | 01:13:0.0 | 00:37:0.0 | 2.2 | Radiometer during final stare |
| i | distant_radiometer | 01:50:0.0 | 01:10:0.0 | 4.2 | Radiometer during Iapetus raster scan |
| Total | | | | 326.3 | |

Table 2: Division summary. Data volumes (Mbits) are estimated from maximum data rate and division duration.

| Div | Alt (km) | Slant range (km) | B3 Size (target dia) | B3 Dop. Spread (Hz) |
|---|---|---|---|---|
| a | 415947 | off target | 1.87 | off target |
| b | 417716 | off target | 1.88 | off target |
| c | 418411 | off target | 1.88 | off target |
| d | 418552 | off target | 1.89 | off target |
| e | 418653 | 418653 | 1.89 | 508 |
| f | 418800 | 418800 | 1.89 | 508 |
| g | 419204 | 419204 | 1.89 | 507 |
| h | 419357 | 419357 | 1.89 | 506 |
| i | 419973 | 419973 | 1.89 | 504 |

Table 3: Division geometry summary. Values are computed at the start of each division. B3 Doppler spread is for two-way 3-dB pattern. B3 size is the one-way 3-dB beamwidth

beam 3 at Iapetus. Division D covers the final part of the turn to Iapetus. These division parameters are summarized in table 4.

# 4 Div's C,E,G: Scatterometer Receive Only Measurements

During this observation, three measurements will be collected in receive only mode. One ten minute observation (Div C) is collected before the spacecraft slews on target to provide a cold space reference level. The second and third (Div's E,G) are collected while pointing at the target. Each of these will last 10 minutes and use the compressed mode to acquire a solid noise measurement right before and after the tone integration without using much data volume. These measurements can then be used to determine system gain and receiver noise temperature for the scatterometer mode at the time of the tone measurement. The division PRF and number of pulses (1202 Hz and 150 respectively) are chosen to fill the science data buffer. These parameters give the best performance possible from the compressed mode. Table 5 shows the compressed mode division parameters.

# 5 Div F: Iapetus Scatterometry

Iapetus is 718 km in radius, and the beam is larger than the apparent disk. Thus a single point stare is used. Allocated data volume is 318 Mbits. Figures 1 and 2 show the pointing design for the scatterometry stare from the merged ckernel. The angular size of the target is about 3.4 mrad during this division. The beam 3 beamwidth is 6 mrad. The target integration division is shown in table 6.

## 5.1 Scatterometer Performance

The detection performance is shown in figures 3, 4, and 5. Figure 5 shows that range processing will be impossible due to range ambiguities and weak echo strength. On the other hand, disk integrated results should be very stable.

The maximum doppler spread in Div f is 508 Hz which comes from rotation and spacecraft motion. The PRF needs to be higher than the doppler spread to support potential range-doppler processing, and is set by division parameter to 651 Hz. With this PRF, the range amiguity spacing is 230 km while Iapetus is 718 km in radius. The range-spread of the beam depends on where it is pointed. For target centered pointing the cosine law can be applied to solve the geometry. At 418800 km range, the range-spread is 716 km.

Unfortunately, this is still larger than the range ambiguity spacing, so it will not be possible to collect unambiguous data. Due to the range ambiguity problem (and weak echo strength), a chirp transmission will not be used for this observation. Instead, a tone transmission will be used in all of the scatterometer divisions. Even though a tone transmission is used, the PRF is still set higher than the doppler spread to separate out the grating pattern due to the pulse structure of each burst transmission.

| Name | Nominal | a | b | d | Mismatch | Comments |
|---|---|---|---|---|---|---|
| mode | radiometer | radiometer | radiometer | radiometer | no | |
| start_time (min) | varies | -240.0 | -43.0 | 20.0 | no | |
| end_time (min) | varies | -43.0 | 10.0 | 27.0 | no | |
| time_step (s) | varies | 1800.0 | 1800.0 | 600.0 | no | Used by radiometer only modes - saves commands |
| bem | 00100 | 00100 | 00100 | 00100 | no | |
| baq | don't care | 5 | 5 | 5 | no | |
| csr | 6 | 6 | 6 | 6 | no | 6 - Radiometer Only Mode |
| noise_bit_setting | don't care | 4.0 | 4.0 | 4.0 | no | |
| dutycycle | don't care | 0.38 | 0.38 | 0.38 | no | |
| prf (KHz) | don't care | 1.00 | 1.00 | 1.00 | no | |
| number_of_pulses | don't care | 8 | 8 | 8 | no | |
| n_bursts_in_flight | don't care | 1 | 1 | 1 | no | |
| percent_of_BW | don't care | 100.0 | 100.0 | 100.0 | no | |
| auto_rad | on | on | on | on | no | |
| rip (ms) | 34.0 | 34.0 | 34.0 | 34.0 | no | |
| max_data_rate | 0.250 | 0.248 | 0.992 | 0.992 | yes | Kbps - set for slowest burst period |
| interleave_flag | off | off | off | off | no | |
| interleave_duration (min) | don't care | 10.0 | 10.0 | 10.0 | no | |

Table 4: ia_017_1 div_abd distant_warmup block

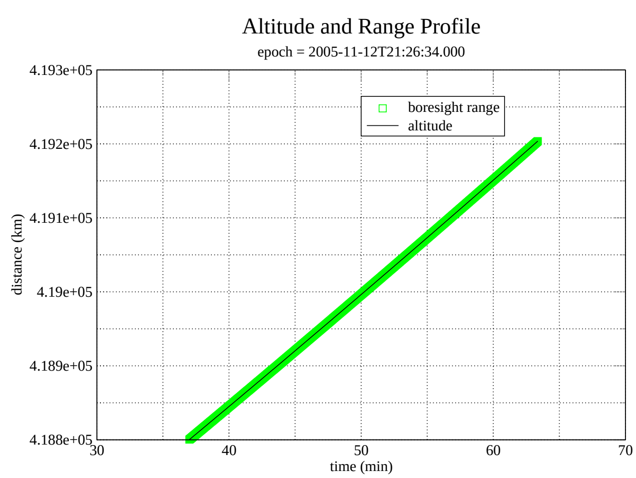


Figure 1: Div D: Altitude and range to the boresight point

| Name | Nominal | c | e | g | Mismatch | Comments |
|---|---|---|---|---|---|---|
| mode | scat_compressed | scatterometer | scatterometer | scatterometer | yes | |
| start_time (min) | varies | 10.0 | 27.0 | 63.4 | no | |
| end_time (min) | varies | 20.0 | 37.0 | 73.0 | no | |
| time_step (s) | don't care | 60.0 | 6.0 | 2.0 | no | Set by valid time calculation |
| bem | 00100 | 00100 | 00100 | 00100 | no | |
| baq | 3 | 3 | 3 | 3 | no | 3 - PRI summation |
| csr | 8 | 1 | 1 | 1 | yes | 1 - Receive only with fixed attenuator set to match Phoebe for easier cross-calibration |
| noise_bit_setting | 4.0 | 4.0 | 4.0 | 4.0 | no | Scat signal set higher than ALT/SAR |
| dutycycle | 0.60 | 0.70 | 0.70 | 0.70 | yes | |
| prf (KHz) | 1.20 | 1.20 | 1.20 | 1.20 | yes | Set with num pulses to fill science data buffer |
| number_of_pulses | 90 | 150 | 150 | 150 | yes | Set to the largest number that the ESS can supply - Only 2 PRI's worth of data are downlinked. |
| n_bursts_in_flight | 1 | 1 | 1 | 1 | no | |
| percent_of_BW | 100.0 | 0.0 | 0.0 | 0.0 | yes | |
| auto_rad | on | on | on | on | no | |
| rip (ms) | 34.0 | 34.0 | 34.0 | 34.0 | no | |
| max_data_rate | 8.000 | 8.000 | 8.000 | 8.000 | no | |
| interleave_flag | off | off | off | off | no | |
| interleave_duration (min) | don't care | 10.0 | 10.0 | 10.0 | no | |

Table 5: ia_017_1 div_ceg scat_compressed block


Figure 2: Div's D: Stare in target body-fixed coordinates

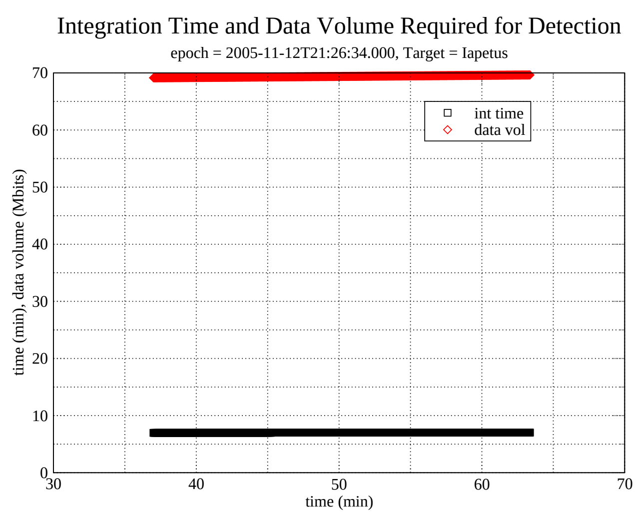


Figure 3: Scatterometry Div F: Detection integration time required for a single point detection using optimal chirp bandwidth

| Name | Nominal | Actual | Mismatch | Comments |
|---|---|---|---|---|
| mode | scatterometer | scatterometer | no | |
| start_time (min) | varies | 37.0 | no | |
| end_time (min) | varies | 63.4 | no | |
| time_step (s) | don't care | 7.0 | no | Used when BIF > 1, otherwise set by valid time calculation |
| bem | 00100 | 00100 | no | |
| baq | 5 | 5 | no | |
| csr | 0 | 0 | no | 0 - normal operation with fixed attenuator set to match Phoebe for easier cross-calibration |
| noise_bit_setting | 4.0 | 4.0 | no | Scat signal set higher than ALT/SAR |
| dutycycle | 0.70 | 0.70 | no | |
| prf (KHz) | varies | 0.65 | no | Set to cover doppler spread and to allow CSF = integer multiple |
| number_of_pulses | varies | 40 | no | depends on PRF choice (can have more shorter pulses) |
| n_bursts_in_flight | varies | 4 | no | Used to increase PRF and data rate at long range |
| percent_of_BW | 0.0 | 0.0 | no | |
| auto_rad | on | on | no | |
| rip (ms) | 34.0 | 34.0 | no | |
| max_data_rate | 200.000 | 190.000 | yes | Kbps - determines burst period |
| interleave_flag | off | off | no | |
| interleave_duration (min) | don't care | 10.0 | no | |

Table 6: ia_017_1 div_f distant_scatterometer block

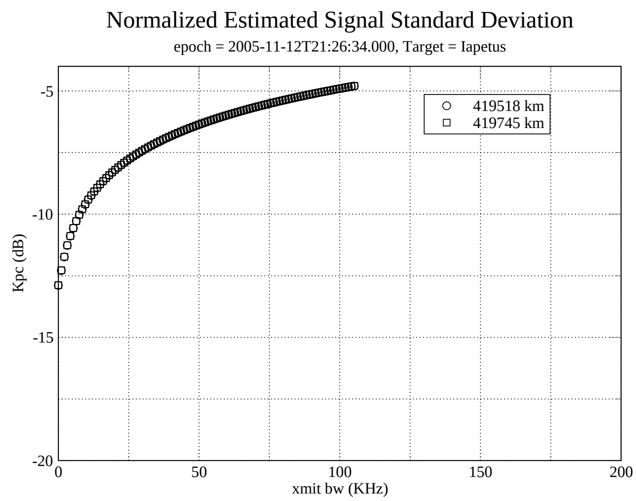


Figure 4: Outbound observation Div F: Normalized estimated signal standard deviation for a disk integrated observation using optimal chirp bandwidth and assuming all the bursts occur at minimum range, and 15 minutes away from minimum range.

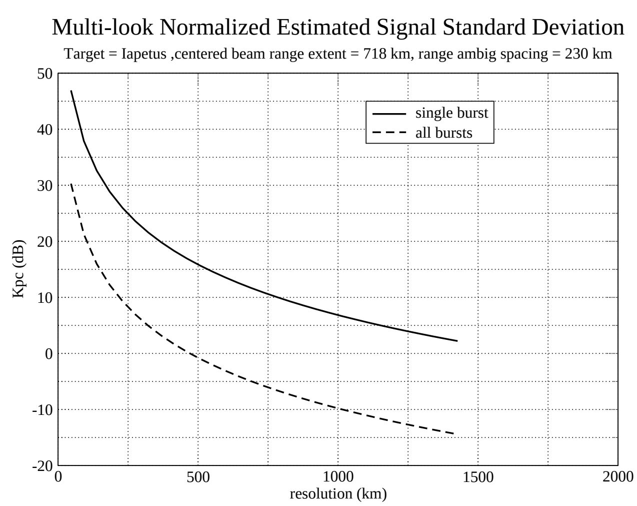


Figure 5: Outbound observation Div F: Normalized estimated signal standard deviation for a range/doppler cell as a function of resolution. Range/doppler resolution elements are both set equal to the specified resolution. Results are shown for a single burst, and for all the bursts in this division. Calculations are performed using the geometry at the start of the division. The presence of ambiguities are not shown.

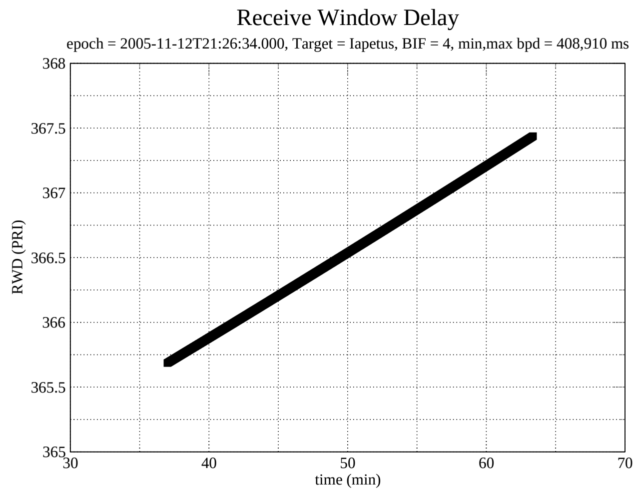


Figure 6: Div F: Inbound scatterometer receive window delay. Subtitle shows the minimum and maximum burst periods that are in principle compatible with the division selected number of bursts in flight.

# 6 Div's H,I: Iapetus Radiometry

Following the scatterometer stare, a raster scan is performed to collect radiometry data. The raster scan allows a precise determination of the peak antenna brightness temperature. This data along with the cold sky data and the internal reference load data will be used to calibrate the radiometer. The radiometer calibration also contributes to the scatterometer calibration. Division parameters for the radiometry raster are shown in table 7

# 7 Revision History

1. Oct 14, 2005: Initial Release

| Name | Nominal | h | i | Mismatch | Comments |
|---|---|---|---|---|---|
| mode | radiometer | radiometer | radiometer | no | |
| start_time (min) | varies | 73.0 | 110.0 | no | |
| end_time (min) | varies | 110.0 | 180.0 | no | |
| time_step (s) | varies | 1800.0 | 1800.0 | no | Used by radiometer only modes |
| bem | 00100 | 00100 | 00100 | no | |
| baq | don't care | 5 | 5 | no | |
| csr | 6 | 6 | 6 | no | |
| noise_bit_setting | don't care | 4.0 | 4.0 | no | |
| dutycycle | don't care | 0.38 | 0.38 | no | |
| prf (KHz) | don't care | 1.00 | 1.00 | no | |
| number_of_pulses | don't care | 8 | 8 | no | |
| n_bursts_in_flight | don't care | 1 | 1 | no | |
| percent_of_BW | don't care | 100.0 | 100.0 | no | |
| auto_rad | on | on | on | no | |
| rip (ms) | 34.0 | 34.0 | 34.0 | no | starting value for auto-rad |
| max_data_rate | 1.000 | 0.992 | 0.992 | yes | 1 Kbps - 1 s burst period which is adequate for slow radiometer scans |
| interleave_flag | off | off | off | no | |
| interleave_duration (min) | don't care | 10.0 | 10.0 | no | |

Table 7: ia_017_1 div_hi distant_radiometer block

# 8 Acronym List

| | |
|---|---|
| AL | Acronym List |
| ALT | Altimeter - one of the radar operating modes |
| BAQ | Block Adaptive Quantizer |
| CIMS | Cassini Information Management System - a database of observations |
| Ckernel | NAIF kernel file containing attitude data |
| DLAP | Desired Look Angle Profile - spacecraft pointing profile designed for optimal SAR performance |
| ESS | Energy Storage System - capacitor bank used by RADAR to store transmit energy |
| IEB | Instrument Execution Block - instructions for the instrument |
| ISS | Imaging Science Subsystem |
| IVD | Inertial Vector Description - attitude vector data |
| IVP | Inertial Vector Propagator - spacecraft software, part of attitude control system |
| INMS | Inertial Neutral Mass Spectrometer - one of the instruments |
| NAIF | Navigation and Ancillary Information Facility |
| ORS | Optical Remote Sensing instruments |
| PDT | Pointing Design Tool |
| PRI | Pulse Repetition Interval |
| PRF | Pulse Repetition Frequency |
| RMSS | Radar Mapping Sequencing Software - produces radar IEB's |
| SAR | Synthetic Aperture Radar - radar imaging mode |
| SNR | Signal to Noise Ratio |
| SOP | Science Operations Plan - detailed sequence design |
| SOPUD | Science Operations Plan Update - phase of sequencing when SOP is updated prior to actual sequencing |
| SSG | SubSequence Generation - spacecraft/instrument commands are produced |
| SPICE | Spacecraft, Instrument, C-kernel handling software - supplied by NAIF to use NAIF kernel files. |
| TRO | Transmit Receive Offset - round trip delay time in units of PRI |