Rhea Scatterometry Rev 22

R. West

February 9, 2006

- Sequence: s19
- Rev: 022
- Observation Id: rh_022_1
- Target Body: Rhea

1 Introduction

This memo describes one of the Cassini RADAR activities for the s19 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 second Rhea distant scatterometer observation around Nov 27 2005. A short warmup occurs for the first 2 hours using the parameters shown in table 4.

2 CIMS and Division Summary

CIMS ID	Start	End	Duration	Comments
022OT_WARMUP4RH001_RIDER	2006-080T06:20:00	2006-080T09:20:00	03:00:0.0	Warmup for scatterometry and simultaneous radiometry of icy satellite.
022RH_SCATTRAD001_PRIME	2006-080T09:20:00	2006-080T16:40:00	07:20:0.0	Point -Z axis at target and execute raster scan(s) centered on target. Obtain simultaneous scatterometry and radiometry.

Table 1: rh_022_1 CIMS Request Sequence

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.

Division	Name	Start	Duration	Data Vol	Comments
a	distant_radiometer	-2:55:0.0	00:05:0.0	0.3	Warmup
b	distant_radiometer	-2:50:0.0	02:52:0.0	10.2	Blind Radiometry
c	distant_scatterometer	00:02:0.0	00:19:0.0	270.2	Scatterometer target-center stare with chirp
d	distant_scatterometer	00:21:0.0	00:09:0.0	126.9	Scatterometer target-center stare with tone
e	distant_scatterometer	00:30:0.0	00:20:30.0	254.6	Scatterometer corner stares with tone
f	distant_radiometer	00:50:30.0	00:01:6.0	0.1	Radiometer during turn transition
g	distant_scatterometer	00:51:36.0	00:05:30.0	68.3	Scatterometer corner stare with tone
h	distant_radiometer	00:57:6.0	00:01:12.0	0.1	Radiometer during turn transition
i	distant_scatterometer	00:58:18.0	00:05:30.0	68.3	Scatterometer corner stare with tone
j	distant_radiometer	01:03:48.0	00:09:12.0	0.5	Radiometer during turn transition
k	scat_compressed	01:13:0.0	00:24:0.0	5.8	Scatterometer on and off-target receive only compressed
l	distant_radiometer	01:37:0.0	05:38:0.0	20.1	Radiometer during raster scans and final stare
Total				825.4	

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	83685	off target	0.36	off target
b	83400	off target	0.36	off target
c	90759	90759	0.39	2710
d	93366	93366	0.40	2680
e	94701	94701	0.40	2667
f	97972	98133	0.42	2636
g	98156	98308	0.42	2634
h	99090	99245	0.42	2627
i	99297	99449	0.42	2625
j	100256	100412	0.43	2617
k	101906	101906	0.43	2605
l	106468	off target	0.45	off target

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

Name	Nominal	Actual	Mismatch	Comments
mode	radiometer	radiometer	no	
start_time (min)	varies	-175.0	no	
end_time (min)	varies	-170.0	no	
time_step (s)	varies	1800.0	no	Used by radiometer only modes
bem	00100	00100	no	
baq	don't care	5	no	
csr	6	6	no	
noise_bit_setting	don't care	4.0	no	
dutycycle	don't care	0.38	no	
prf (Hz)	don't care	1000	no	
tro	don't care	6	no	
number_of_pulses	don't care	8	no	
n_bursts_in_flight	don't care	1	no	
percent_of_BW	don't care	100.0	no	
auto_rad	on	on	no	
rip (ms)	34.0	34.0	no	starting value for auto-rad
max_data_rate	1.000	0.992	yes	1 Kbps - 1 s burst period which is adequate for slow radiometer scans
interleave_flag	off	off	no	
interleave_duration (min)	don't care	10.0	no	

Table 4: rh_022_1 div_a distant_radiometer block

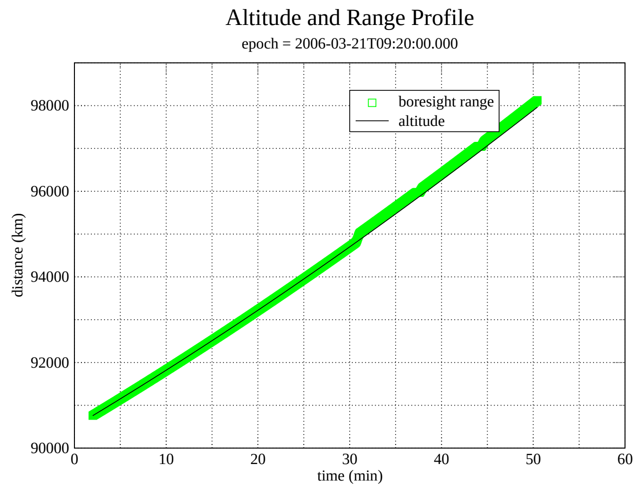

Figure 1: Div's C,D,E: Altitude and range to the boresight point

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 C-Q: Rhea Radiometry/Scatterometry

Rhea is 764 km in radius, which makes it about twice the size of beam 3, so a 5 point scan with scatterometry integration at each scan position will be conducted. Allocated data volume is 750 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 16.1 mrad during this division. The beam 3 beamwidth is 6 mrad.

The division parameters for the radiometer segments are shown in table 5. The division parameters for the compressed scatterometer receive only integrations are shown in table 6 and the two types of target integration divisions are shown in tables 7 and 8.

3.1 Scatterometer Receive Only Measurements

After the actual scatterometer integration, two measurements will be collected in receive only mode. A single division (P) covers the on-target observation and off target observation. Both will last 10 minutes and use the compressed mode to acquire a solid noise measurement without using much data volume. These measurements can then be used to determine system gain and receiver noise temperature for the scatterometer mode right before the actual target 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.

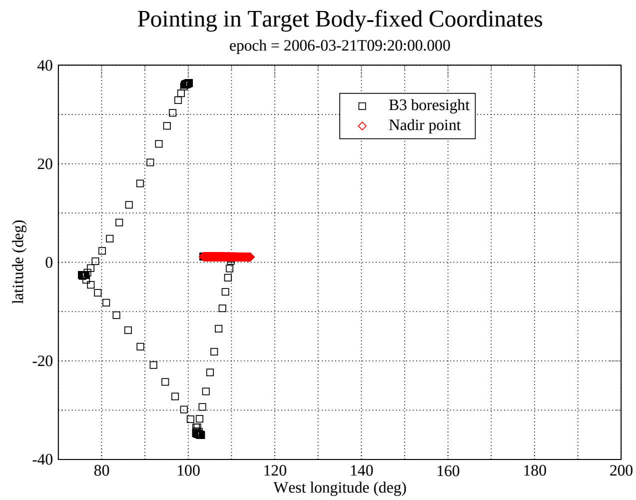

Figure 2: Div's C,D,E: Stare in target body-fixed coordinates

Name	Nominal	Actual	Mismatch	Comments
mode	radiometer	radiometer	no	
start_time (min)	varies	50.5	no	
end_time (min)	varies	51.6	no	
time_step (s)	varies	600.0	no	Used by radiometer only modes
bem	00100	00100	no	
baq	don't care	5	no	
csr	6	6	no	
noise_bit_setting	don't care	4.0	no	
dutycycle	don't care	0.38	no	
prf (Hz)	don't care	1000	no	
tro	don't care	6	no	
number_of_pulses	don't care	8	no	
n_bursts_in_flight	don't care	1	no	
percent_of_BW	don't care	100.0	no	
auto_rad	on	on	no	
rip (ms)	34.0	34.0	no	starting value for auto-rad
max_data_rate	1.000	0.992	yes	1 Kbps - 1 s burst period which is adequate for slow radiometer scans
interleave_flag	off	off	no	
interleave_duration (min)	don't care	10.0	no	

Table 5: rh_022_1 div_f distant_radiometer block

Name	Nominal	Actual	Mismatch	Comments
mode	scat_compressed	scat_compressed	yes	
start_time (min)	varies	73.0	no	
end_time (min)	varies	97.0	no	
time_step (s)	don't care	20.0	no	Set by valid time calculation
bem	00100	00100	no	
baq	3	3	no	3 - PRI summation
csr	1	1	no	1 - Receive only with fixed attenuator set to match Phoebe for easier cross-calibration
noise_bit_setting	4.0	4.0	no	9 dB setting used by all low SNR scatterometry
dutycycle	0.70	0.70	no	
prf (Hz)	1200	1202	yes	Set with num pulses to fill science data buffer
tro	don't care	6	no	automatically set to 6
number_of_pulses	150	150	no	Set with the PRF to fill the science data buffer - Only 2 PRI's worth of data are downlinked.
n_bursts_in_flight	1	1	no	
percent_of_BW	100.0	0.0	yes	
auto_rad	on	on	no	
rip (ms)	34.0	34.0	no	
max_data_rate	8.000	4.000	yes	
interleave_flag	off	off	no	
interleave_duration (min)	don't care	10.0	no	

Table 6: rh_022_1 div_k scat_compressed block

Name	Nominal	c	d	e	Mismatch	Comments
mode	scatterometer	scatterometer	scatterometer	scatterometer	no	
start_time (min)	varies	2.0	21.0	30.0	no	
end_time (min)	varies	21.0	30.0	50.5	no	
time_step (s)	don't care	7.0	8.0	8.0	no	Used when BIF > 1, otherwise set by valid time calculation
bem	00100	00100	00100	00100	no	
baq	5	5	5	5	no	
csr	0	0	0	0	no	0 - normal operation 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	0.70	0.60	0.70	0.70	yes	
prf (Hz)	varies	2700	4808	4808	no	Set to cover doppler spread
tro	6	6	6	6	no	6 - allows for some noise only data in time domain
number_of_pulses	varies	165	240	240	no	depends on PRF choice (can have more shorter pulses)
n_bursts_in_flight	varies	2	2	2	no	Used to increase PRF and data rate at long range
percent_of_BW	0.0	100.0	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	200.000	237.000	235.000	207.000	yes	Kbps - determines burst period
interleave_flag	off	off	off	off	no	
interleave_duration (min)	don't care	10.0	10.0	10.0	no	

Table 7: rh_022_1 div_cde distant_scatterometer block

Name	Nominal	g	i	Mismatch	Comments
mode	scatterometer	scatterometer	scatterometer	no	
start_time (min)	varies	51.6	58.3	no	
end_time (min)	varies	57.1	63.8	no	
time_step (s)	don't care	8.0	8.0	no	Used when BIF > 1, otherwise set by valid time calculation
bem	00100	00100	00100	no	
baq	5	5	5	no	
csr	0	0	0	no	0 - normal operation with fixed attenuator set to match Phoebe for easier cross-calibration
noise_bit_setting	4.0	4.0	4.0	no	Scat signal set higher than ALT/SAR
dutycycle	0.70	0.70	0.70	no	
prf (Hz)	varies	4808	4808	no	Set to cover doppler spread and to allow CSF = integer multiple
tro	6	6	6	no	6 - allows for some noise only data in time domain
number_of_pulses	varies	240	240	no	depends on PRF choice (can have more shorter pulses)
n_bursts_in_flight	varies	2	2	no	Used to increase PRF and data rate at long range
percent_of_BW	0.0	0.0	0.0	no	
auto_rad	on	on	on	no	
rip (ms)	34.0	34.0	34.0	no	
max_data_rate	200.000	207.000	207.000	yes	Kbps - determines burst period
interleave_flag	off	off	off	no	
interleave_duration (min)	don't care	10.0	10.0	no	

Table 8: rh_022_1 div_gi distant_scatterometer block

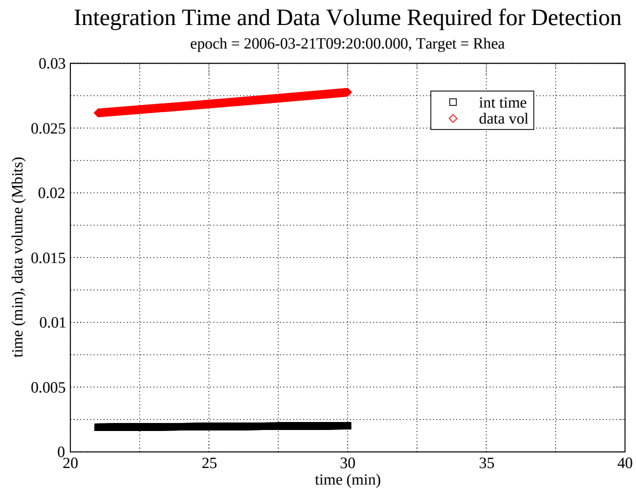

Figure 3: Scatterometry Div D: Detection integration time required for a single point detection using optimal chirp bandwidth

3.2 Scatterometer Performance

The detection performance is shown in figures 3, 4, and 5. Figure 5 shows that range processing is marginal due to high K_{pc}. A chirp division is still included because Rhea may have stronger backscatter than the assumed 0.1 value used in these performance results. Disk integrated results should be very stable.

The maximum doppler spread in Div c is 2710 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 2700 Hz. With this PRF, the range amiguity spacing is 56 km while Dione is 764 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 90759 km range, the range-spread is 53 km. The range ambiguity spacing is larger than the beam size so a chirp division is included.

4 Div Q: Rhea 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 **??**

5 Revision History

1. Feb 9, 2006: Initial Release

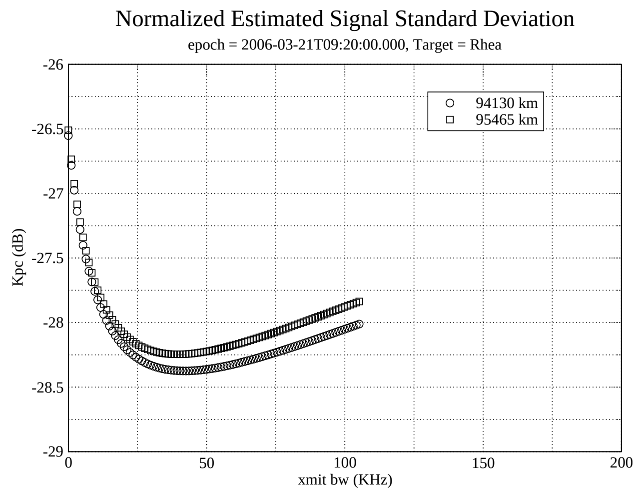

Figure 4: Outbound observation Div D: Normalized estimated signal standard deviation for a disk integrated observation using optimal chirp bandwidth and assuming all the bursts occur at minimum range, and 15 minutes away from minimum range.

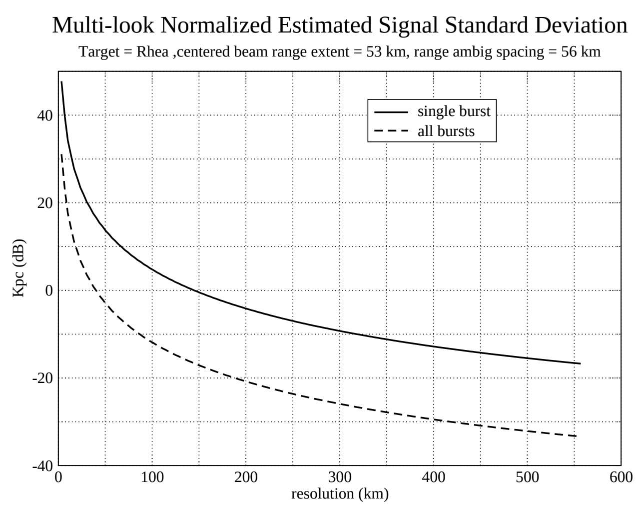

Figure 5: Outbound observation Div C: Normalized estimated signal standard deviation for a range/doppler cell as a function of resolution. Range/doppler resolution elements are both set equal to the specified resolution. Results are shown for a single burst, and for all the bursts in this division. Calculations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

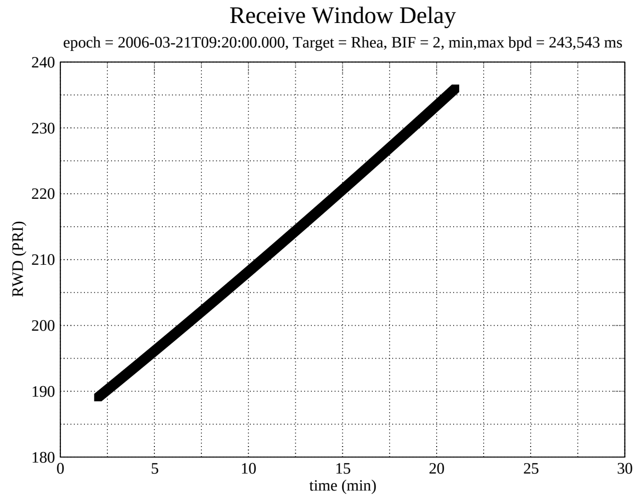

Figure 6: Div F: Inbound scatterometer receive window delay. Subtitle shows the minimum and maximum burst periods that are in principle compatible with the division selected number of bursts in flight.

Name	Nominal	Actual	Mismatch	Comments
mode	radiometer	radiometer	no	
start_time (min)	varies	97.0	no	
end_time (min)	varies	435.0	no	
time_step (s)	varies	1800.0	no	Used by radiometer only modes
bem	00100	00100	no	
baq	don't care	5	no	
csr	6	6	no	
noise_bit_setting	don't care	4.0	no	
dutycycle	don't care	0.38	no	
prf (Hz)	don't care	1000	no	
tro	don't care	6	no	
number_of_pulses	don't care	8	no	
n_bursts_in_flight	don't care	1	no	
percent_of_BW	don't care	100.0	no	
auto_rad	on	on	no	
rip (ms)	34.0	34.0	no	starting value for auto-rad
max_data_rate	1.000	0.992	yes	1 Kbps - 1 s burst period which is adequate for slow radiometer scans
interleave_flag	off	off	no	
interleave_duration (min)	don't care	10.0	no	

Table 9: rh_022_1 div_l distant_radiometer block

6 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