Iapetus Scatterometry Rev B

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- Sequence: s07
- Rev: 00B
- Observation Id: ia_00b_1
- Target Body: Iapetus

1 Introduction

This memo describes one of the Cassini RADAR activities for the s07 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 one of two Iapetus distant scatterometer observations arond Jan 1 2005. One is at the very end of rev B, the other (ia_00c_1) is at the very start of rev C. These observations were modified by the trajectory change made to raise the flyby altitude for this Iapetus flyby. The trajectory change was made to reduce uncertainties in the Huygens probe trajectory. The usual warmup parameters are used during the first three hours as shown in table 4

2 CIMS and Division Summary

CIMS ID	Start	End	Duration	Comments
00BOT_WARM4IA001_RIDER	2004-366T01:45:00	2004-366T04:29:00	02:44:0.0	Warmup for scatterometry and simultaneous radiometry of icy satellite.
00BIA_SCATTRADL001_PRIME	2004-366T04:29:00	2004-366T08:00:00	03:31:0.0	Point -Z axis at target and execute raster scan(s) centered on target. Obtain simultaneous scatterometry and radiometry.

Table 1: ia_00b_1 CIMS Request Sequence

Division	Name	Start	Duration	Data Vol	Comments
a	distant_warmup	-3:00:0.0	03:00:0.0	2.7	Warmup
b	distant_radiometer	00:00:0.0	02:22:30.0	8.5	Radiometer during initial stare and raster scan
c	distant_scatterometer	02:22:30.0	00:01:0.0	0.0	Scatterometer zero data fill
d	distant_scatterometer	02:23:30.0	00:04:30.0	54.0	Scatterometer center point stare with full chirp
e	distant_scatterometer	02:28:0.0	00:04:30.0	54.0	Scatterometer center point stare with tone
f	distant_scatterometer	02:32:30.0	00:04:48.0	0.0	Scatterometer zero data fill
g	distant_scatterometer	02:37:18.0	00:04:12.0	50.4	Scatterometer corner point stare with tone
h	distant_scatterometer	02:41:30.0	00:04:48.0	0.0	Scatterometer zero data fill
i	distant_scatterometer	02:46:18.0	00:04:12.0	50.4	Scatterometer corner point stare with tone
j	distant_scatterometer	02:50:30.0	00:04:54.0	0.0	Scatterometer zero data fill
k	distant_scatterometer	02:55:24.0	00:04:6.0	49.2	Scatterometer corner point stare with tone
l	distant_scatterometer	02:59:30.0	00:04:54.0	0.0	Scatterometer zero data fill
m	distant_scatterometer	03:04:24.0	00:04:6.0	49.2	Scatterometer corner point stare with tone
n	distant_radiometer	03:08:30.0	00:11:30.0	0.7	Closing radiometry
o		03:20:0.0	03:00:0.0	2.7	
Total				321.7	

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	174198	off target	0.79	off target
b	158670	off target	0.72	off target
c	147542	off target	0.67	off target
d	147468	147468	0.67	681
e	147137	147137	0.66	682
f	146807	146807	0.66	684
g	146456	146505	0.66	686
h	146151	146199	0.66	687
i	145803	145851	0.66	689
j	145500	145548	0.66	690
k	145148	145196	0.66	692
l	144855	144902	0.65	694
m	144506	144553	0.65	695
n	144215	144262	0.65	697
o	143406	off target	0.65	off target

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

Name	Nominal	Actual	Mismatch	Comments
mode	radiometer	radiometer	no	
start_time (min)	varies	-180.0	no	
end_time (min)	varies	0.0	no	
time_step (s)	varies	1800.0	no	Used by radiometer only modes - saves commands
bem	00100	00100	no	
baq	don't care	5	no	
csr	6	6	no	6 - Radiometer Only Mode
noise_bit_setting	don't care	4	no	
dutycycle	don't care	0.38	no	
prf (KHz)	don't care	1.00	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	
max_data_rate	0.250	0.248	yes	Kbps - set for slowest burst period
interleave_flag	off	off	no	
interleave_duration (min)	don't care	10.0	no	

Table 4: ia_00b_1 div_a distant_warmup block

Name	Nominal	Actual	Mismatch	Comments
mode	radiometer	radiometer	no	
start_time (min)	varies	0.0	no	
end_time (min)	varies	142.5	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	no	
dutycycle	don't care	0.38	no	
prf (KHz)	don't care	1.00	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: ia_00b_1 div_b distant_radiometer block

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. Table 1 shows the CIMS request summary for this observation.

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 B: Iapetus Radiometry

Following the warmup, the spacecraft will stare at Iapetus for about 20 minutes to avoid unfavorable geometry and a constraint violation. Then 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 are shown in table 5. The scan is shown in figure 1.

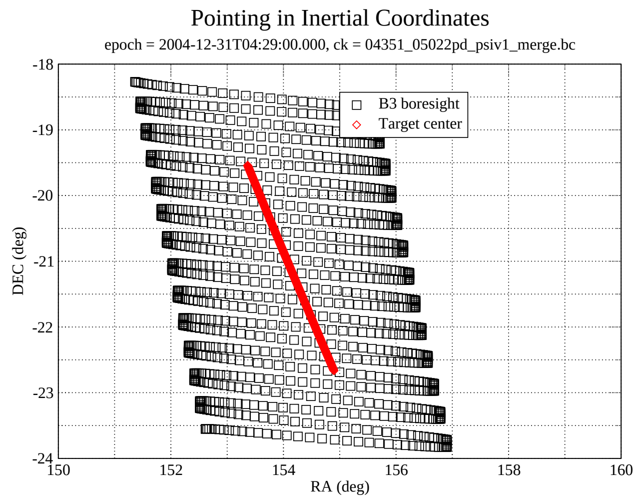

Figure 1: Div B: Radiometer raster scan in inertial coordinates

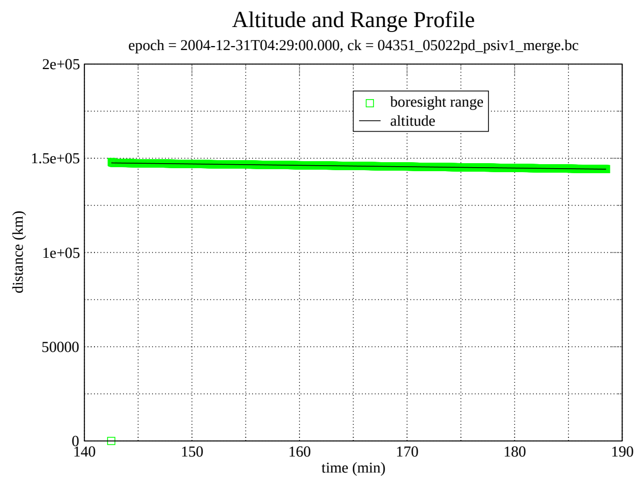

Figure 2: Div's C-M: Altitude and range to the boresight point

4 Div's C-M: Iapetus Scatterometry

Iapetus is a large body (718 km radius), and has been observed by radar from the Earth. This makes it particularly valuable for calibration purposes. The inbound observation in rev B is close enough that the beam is smaller than the apparent disk, so a five point stare is used to provide better coverage of the visible disk.

Figures 2 and 3 show the pointing design for the scatterometry stare from the merged ckernel. The angular size of the target is about 9.3 mrad during this division. The beam 3 beamwidth is 6 mrad.

The scatterometer stares are all covered by divisions C-M which control the usage of data volume and the chirp bandwidth. This observation will also include an upgraded RMSS calculation (as used on ti_00a_1) that will make the chirp start frequency an integer multiple of the PRF. This is done to keep the echo peak from being split in the frequency domain by the comb pattern due to the pulsed nature of the signal.

Div's C,D,E control the first central stare. Division C is a time filler with the BAQ mode set to 8 to 0 (ie., no data is collected). Time fillers are used when the instrument is kept in scatterometer mode, but no data is collected due to limitations on data volume. Division D specifies a full chirp data collection during the central stare. This data collection will provide the opportunity to do range and doppler processing on the central area. Division E is just like division D except a tone transmission is used instead. These division parameters are shown in table 6.

Name	Nominal	c	d	e	Mismatch	Comments
mode	scatterometer	scatterometer	scatterometer	scatterometer	no	
start_time (min)	varies	142.5	143.5	148.0	no	
end_time (min)	varies	143.5	148.0	152.5	no	
time_step (s)	don't care	16.0	45.0	45.0	no	Used when BIF > 1, otherwise set by valid time calculation
bem	00100	00100	00100	00100	no	
baq	5	2	5	5	yes	2 - 8 to 0
csr	0	0	0	0	no	0 - Normal Operation, 8 - with auto-gain
noise_bit_setting	4	4	4	4	no	Scat signal set higher than ALT/SAR
dutycycle	0.70	0.70	0.70	0.70	no	
prf (KHz)	varies	0.80	0.80	1.25	no	Set to cover target doppler bandwidth
number_of_pulses	varies	40	40	40	no	depends on PRF choice (can have more shorter pulses)
n_bursts_in_flight	varies	1	2	3	no	Used to increase PRF and data rate at long range
percent_of_BW	0.0	100.0	100.0	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	200.000	200.000	200.000	no	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 6: ia_00b_1 div_cde distant_scatterometer block

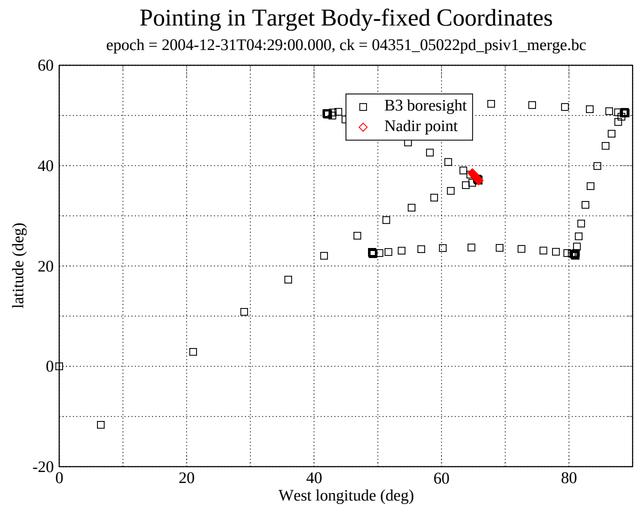

Figure 3: Div's C-M: Inbound stare in target body-fixed coordinates

Following the central stare, there are four stares spaced around the perimeter to provide more coverage of the surface. Each has a time filler followed by a division which specifies a tone transmission. Table 7 shows the parameters used for each of the four corner stares.

The maximum doppler spread in Div d is 682 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 800 Hz. With this PRF, the range amiguity spacing is 187 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 147468 km range, the range-spread is 182 km. Thus, the target centered stare will allow unambiguous range-doppler processing (except for the unavoidable North-South ambiguity) while the edge aligned stares will suffer from range ambiguities. The centered point may provide a sharper look at the incidence angle dependence of the surface backscatter. The corner points will suffer from range ambiguities, so a tone transmission is used on all of them.

The detection performance for the central stare is shown in figures 4, 5, and 6. Figure 6 shows that it will be difficult to resolve range doppler cells because the normalized standard deviation increases to 0 dB (unity SNR) when the resolution gets down to the range ambiguity spacing.

5 Revision History

1. Nov 17, 2004: Added Kpc vs resolution plot, fixed Kpc calculation
2. Nov 12, 2004: Initial Release

Name	Nominal	f	g	Mismatch	Comments
mode	scatterometer	scatterometer	scatterometer	no	
start_time (min)	varies	152.5	157.3	no	
end_time (min)	varies	157.3	161.5	no	
time_step (s)	don't care	16.0	45.0	no	Used when BIF > 1, otherwise set by valid time calculation
bem	00100	00100	00100	no	
baq	5	2	5	yes	2 - 8 to 0
csr	0	0	0	no	0 - Normal Operation, 8 - with auto-gain
noise_bit_setting	4	4	4	no	Scat signal set higher than ALT/SAR
dutycycle	0.70	0.70	0.70	no	
prf (KHz)	varies	0.80	1.25	no	Set to cover target doppler bandwidth
number_of_pulses	varies	40	40	no	depends on PRF choice (can have more shorter pulses)
n_bursts_in_flight	varies	1	3	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	200.000	200.000	no	Kbps - determines burst period
interleave_flag	off	off	off	no	
interleave_duration (min)	don't care	10.0	10.0	no	

Table 7: ia_00b_1 div_fg distant_scatterometer block

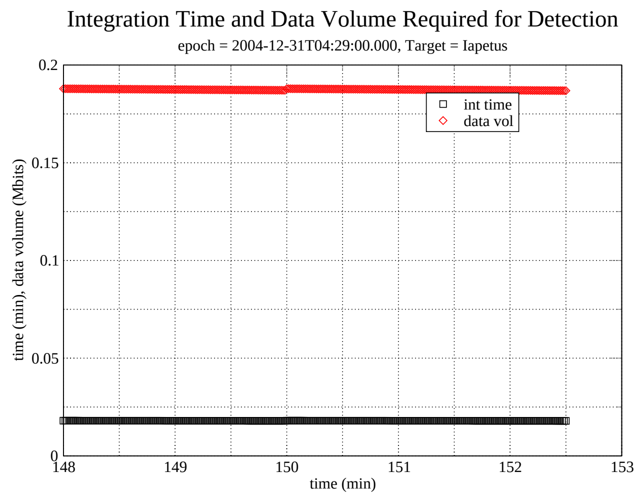

Figure 4: Scatterometry Div E: Detection integration time required for a single point detection using optimal chirp bandwidth

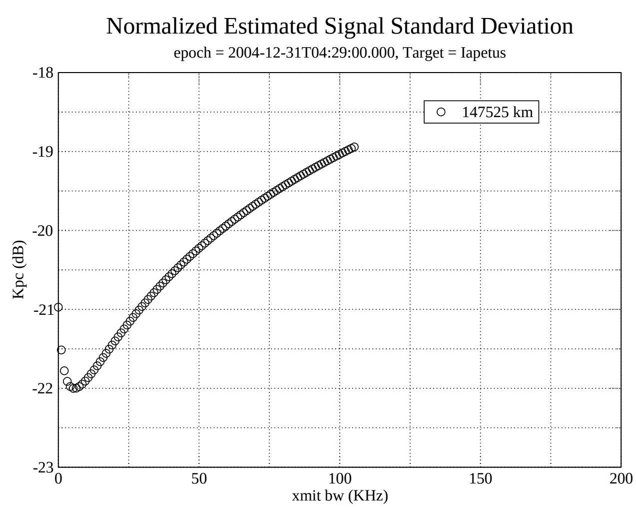

Figure 5: Inbound observation Div E: Normalized estimated signal standard deviation for a disk integrated observation assuming all the bursts occur at minimum range, and 15 minutes away from minimum range.

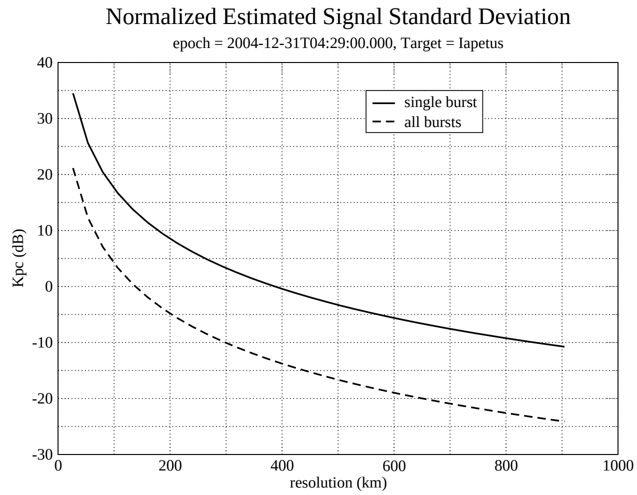

Figure 6: Outbound observation Div D: Normalized estimated signal standard deviation for a range/doppler cell as a function of resolution. Range/doppler resolution elements are both set equal to the specified resolution. Results are shown for a single burst, and for all the bursts in this division. Calculations are performed using the geometry at the start of the division. The presence of ambiguities are not shown.

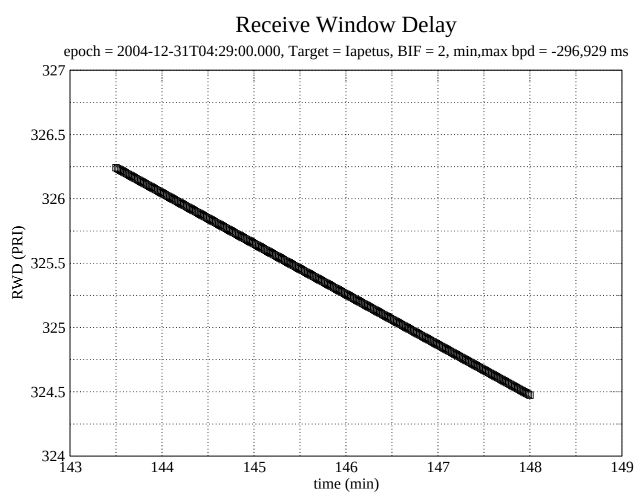

Figure 7: Div D: Inbound scatterometer receive window delay. Subtitle shows the minimum and maximum burst periods that are in principle compatible with the division selected number of bursts in flight.

6 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