RADAR Titan Flyby during S09/T4

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- Sequence: s09
- Rev: 005
- Observation Id: t4
- Target Body: Titan
- Data Take Number: 48
- PDT Config File: S09_ssup_psiv1_050107_pdt.cfg
- SMT File: S09_2005-01-20.rpt
- PEF File: z0090d.pef

1 Introduction

This memo describes the Cassini RADAR activities for the third Titan flyby on which RADAR data will be acquired. The third SAR data collection occurs during the s09 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 RADAR data collection includes only radiometry and scatterometry. RADAR will not operate at the closest approach time, therefore no altimeter or SAR data can be collected. The radiometry scans will include compressed scatterometry for the first time. Following the two radiometry/compressed scatterometry scans, there will be a small scatterometry scan. All of these scans are executed on momentum wheel control.

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. Table 1 shows the CIMS request summary for this observation. Although the CIMS requests show Low-SAR intervals, in reality the radar will be operated in Hi-SAR mode throughout this flyby.

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

CIMS ID	Start	End	Duration	Comments
005TI_WARMUPT4001_RIDER	2005-090T11:20:16	2005-090T14:35:16	03:15:0.0	
005TI_T4RADIOM001_PRIME	2005-090T14:35:16	2005-090T19:35:16	05:00:0.0	Execute 4-hour period acquiring Radiometry data of Titan; design of raster scan TBD will incorporate different polarization orientations.

Table 1: t4 CIMS Request Sequence

Division	Name	Start	Duration	Data Vol	Comments
a	Warmup	-9:20:0.0	03:50:0.0	3.4	
b	scatterometer_compressed	-5:30:0.0	04:02:0.0	79.9	Inbound radiometry and compressed scatterometry
c	standard_scatterometer_inbound	-1:28:0.0	00:38:12.0	75.6	Inbound scatterometer scan
d	standard_scatterometer_inbound	-0:49:48.0	00:01:3.0	1.9	Attenuator test at edge of scan line
e	standard_scatterometer_inbound	-0:48:45.0	00:04:45.0	9.4	Rest of scatterometer scan
f	standard_radiometer_outbound	-0:44:0.0	00:14:0.0	0.8	Inbound radiometer
Total				171.0	

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

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. Table 3 shows a summary of some key geometry values for each division. 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.

Div	Alt (km)	Slant range (km)	B3 Size (target dia)	B3 Dop. Spread (Hz)
a	188212	off target	0.24	off target
b	109683	off target	0.14	off target
c	27931	off target	0.04	off target
d	15237	16587	0.02	744
e	14894	16210	0.02	757
f	13347	off target	0.02	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)	-480.0	-560.0	yes	Different due to incomplete RADAR pass
end_time (min)	-300.0	-330.0	yes	Different due to incomplete RADAR pass
time_step (s)	2700.0	3600.0	yes	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	4.0	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 - actual data rate may be less
interleave_flag	off	off	no	
interleave_duration (min)	don't care	10.0	no	

Table 4: t4 div_a Warmup block

3 Warmup

The radar warmup rider begins at 2005-03-31T11:20:16.000 (-08:44:59.8). During the warmup, the IEB will be set for slow speed radiometer only data as shown in table 4.

4 Div B: Compressed Scatterometry

From -5:30:0.0 to -1:28:0.0, the instrument will operate in compressed scatterometer mode. The division keywords are shown in Table 5

The scan designs are normal radiometer only scans, and radiometer data will be collected just as for the Ta flyby. The compressed scatterometer mode will sum 75 pulses worth of echo data into two pulses of data space. This limits the data rate to less than 5 Kbps which is within the data rate requested for the radiometry scans.

Operating the compressed scatterometer mode during the radiometry scans uses a lot of IEB instructions to track the range-gate variation. In fact, scatterometry during the radiometry scans uses even more instructions than a scatterometer only scan because the radiometer scans turn around on cold space. This means the scan motion has time to accelerate before hitting the limb of the target resulting in very high range rates in the outer part of the scan lines. Another factor is the greater range which reduces the angular size of the target which also increases the range rates for a given angular scan rate. During T4, there are plenty of instructions to spare because there is no altimetry or SAR. Future passes, however, may not be able to afford the instructions to track scatterometry all the way across every radiometry scan line.

Name	Nominal	Actual	Mismatch	Comments
mode	scatterometer_compressed	scatterometer_compressed	no	
start_time (min)	varies	-330.0	no	
end_time (min)	varies	-88.0	no	
time_step (s)	don't care	3.0	no	Set shorter to increase instructions tracking range-gate
bem	00100	00100	no	
baq	3	3	no	5 - 8 bits straight
csr	8	0	yes	8 - auto gain
noise_bit_setting	4.0	4.0	no	Scat signal set higher than ALT/SAR
dutycycle	0.60	0.60	no	
prf (KHz)	1.20	1.00	yes	
number_of_pulses	90	75	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	no	
percent_of_BW	100.0	100.0	no	
auto_rad	on	on	no	
rip (ms)	34.0	34.0	no	
max_data_rate	6.000	5.500	yes	
interleave_flag	off	off	no	
interleave_duration (min)	don't care	10.0	no	

Table 5: t4 div_b scatterometer_compressed block

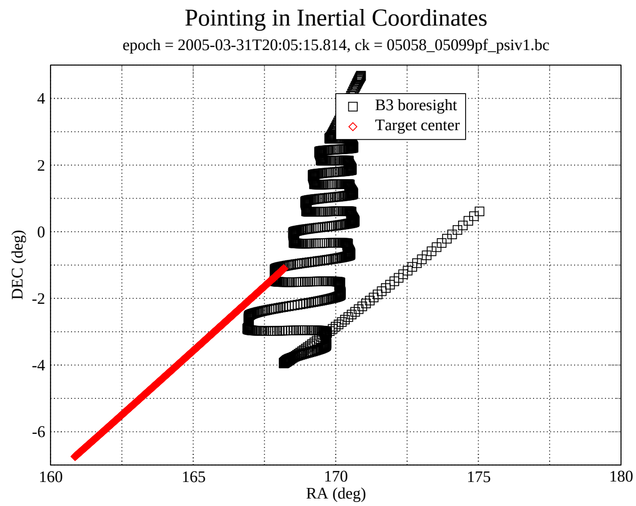

Figure 1: Scatterometry scan in inertial coordinates

5 Div's C-E: Inbound Scatterometer Scan

The T4 radar observation ends with a wheel driven scatterometry scan. A scan line at the beginning and end sweeps off the limb to provide radiometer calibration points on cold sky. Figures 1 and 2 show the pointing design for the scatterometry scan from the merged ckernel. Figure 3 shows the incidence angle coverage of this scan.

The IEB instructions for this scatterometry block are generated by RMSS under the control of the set of config parameters shown in table 6. Although not shown in table 6, scatterometer mode operations use a transmit-receive window offset (TRO) of 6 which makes the echo window 6 PRI's longer than the number of pulses transmitted. This is done to increase the valid time for an instruction by letting the pulse echos walk through the longer echo window before the range-gate needs to be updated. This is particularly important during Titan scatterometry raster scans where the number of instructions needed to track the varying range can exceed the number available if a smaller TRO value is used. The positive TRO value also guarantees noise-only data in each burst which eliminates the need to insert special noise-only bursts. The PRF of 1.2 KHz is high enough to cover the doppler spread within beam 3, so doppler sharpening could be performed.

To prevent clipping from occurring, auto-gain will not be used for the T4 scatteromtry raster scan. Instead, a fixed attenuator value will be used to keep the signal on-scale over the whole raster scan. The T3 scatterometer scans used 22 dB and 18 dB attenuator settings. For T4, the scatterometer scan is at higher incidence angle (always above 35 degrees) so the attenuator is set to 15 dB.

Division D is positioned at the outer edge of a scan line and this time is used to run a series of attenuator tests designed to examine the calibration of the internal attenuators.

6 Div F: Final Radiometry

After the scatterometer scan is finished, the spacecraft moves the radar borsight away from Titan, and the instrument finishes in radiometer only mode with parameters as shown in table 7.

7 Revision History

1. Jan 28, 2005: Minor division parameter adjustments, changed attenuator and added text on range-gate tracking
2. Jan 27, 2005: Initial release

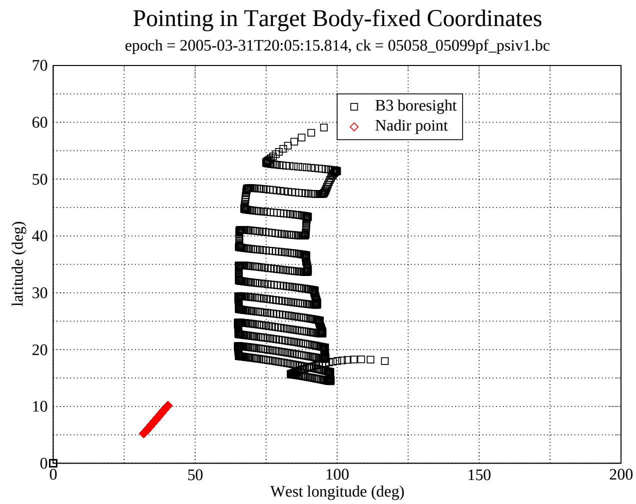

Figure 2: Scatterometry scan in target body-fixed coordinates

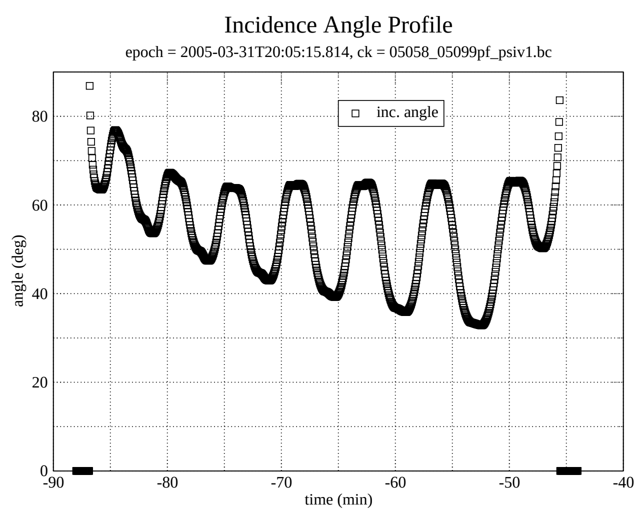

Figure 3: Incidence angle variation during scatterometry scan

Name	Nominal	c	e	Mismatch	Comments
mode	scatterometer	scatterometer	scatterometer	no	
start_time (min)	varies	-88.0	-48.8	no	
end_time (min)	varies	-49.8	-44.0	no	
time_step (s)	don't care	3.0	3.0	no	Set by valid time calculation
bem	00100	00100	00100	no	
baq	5	5	5	no	5 - 8 bits straight
csr	8	0	0	yes	0 - No auto-gain, fixed attenuator set to avoid clipping
noise_bit_setting	4.0	3.1	3.1	yes	15 dB attenuator
dutycycle	0.60	0.70	0.70	yes	
prf (KHz)	1.20	1.20	1.20	no	
number_of_pulses	8	8	8	no	
n_bursts_in_flight	1	1	1	no	
percent_of_BW	100.0	100.0	100.0	no	
auto_rad	on	on	on	no	
rip (ms)	34.0	34.0	34.0	no	
max_data_rate	30.000	33.000	33.000	yes	
interleave_flag	off	off	off	no	
interleave_duration (min)	don't care	10.0	10.0	no	

Table 6: t4 div_ce standard_scatterometer_inbound block

Name	Nominal	Actual	Mismatch	Comments
mode	radiometer	radiometer	no	
start_time (min)	120.0	-44.0	yes	
end_time (min)	300.0	-30.0	yes	
time_step (s)	2700.0	1800.0	yes	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 (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	1.000	0.992	yes	
interleave_flag	off	off	no	
interleave_duration (min)	don't care	10.0	no	

Table 7: t4 div_f standard_radiometer_outbound 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