Distant Titan Radiometry/Scatterometry Cross-Cal in S05, Rev A

R. West

September 21, 2004

- Sequence: s05
- Rev: 00A
- Observation Id: ti_00a_2
- Target Body: Titan

1 Introduction

This memo describes the third Cassini RADAR activitiy for the s05 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 instrument execution block (IEB).

2 CIMS and Division Summary

CIMS ID	Start	End	Duration	Comments
00AOT_SOUTHWARM003_RIDER	2004-311T16:48:00	2004-311T19:48:00	03:00:0.0	Warmup for calibration and science data collection.
00ATI_SOUTH7CAL002_PRIME	2004-311T19:48:00	2004-311T22:18:00	02:30:0.0	Obtain distant Titan radiometer science and calibration data. One of a set that provides coverage of Titan southern latitude variation along with some obtainable associated longitude variation.

Table 1: ti_00a_2 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. Table 1 shows the CIMS request summary for this observation.

Division	Name	Start	Duration	Data Vol	Comments
a	distant_warmup	-3:00:0.0	03:00:0.0	2.7	Warmup is in separate IEB
b	distant_radiometer	00:00:0.0	02:07:0.0	7.6	Radiometer scan
c	distant_scatterometer	02:07:0.0	00:03:45.0	45.0	Scatterometer on-target stare
d	distant_radiometer	02:10:45.0	00:06:15.0	0.4	Radiometer inbetween Scatt ops
e	distant_scatterometer	02:17:0.0	00:03:45.0	45.0	Scatterometer off-target stare
f	distant_radiometer	02:20:45.0	00:08:30.0	0.5	Radiometer stare
g		02:29:15.0	00:00:45.0	9.0	
Total				110.2	

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	2442927	2442927	3.07	2642
b	2433572	2433572	3.05	2676
c	2428302	2428302	3.05	2698
d	2428164	2428164	3.05	2698
e	2427936	off target	3.05	off target
f	2427800	off target	3.05	off target
g	2427497	2427549	3.05	2702

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

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. 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.

3 Warmup

The radar warmup rider begins at 2004-11-06T16:48:00.000 (-03:00:0.0) and lasts for the standard 03:00:0.0. During the warmup, the IEB will be set for slow speed radiometer only data as shown in table 4.

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	2700.0	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	0.250	no	Kbps - set for slowest burst period
interleave_flag	off	off	no	
interleave_duration (min)	don't care	10.0	no	

Table 4: ti_00a_2 div_a distant_warmup block

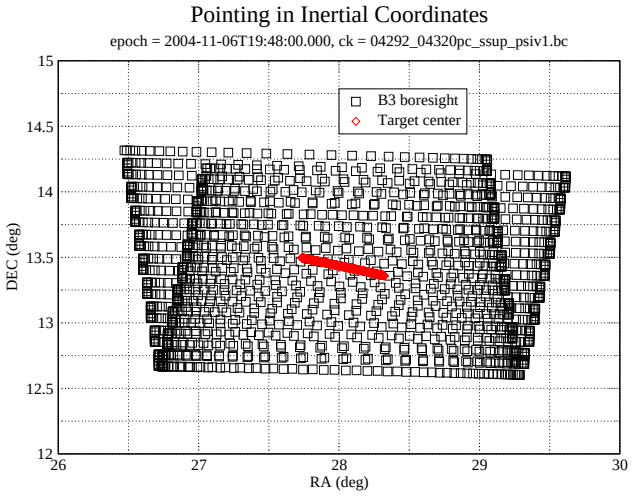

Figure 1: Inbound scan in inertial coordinates

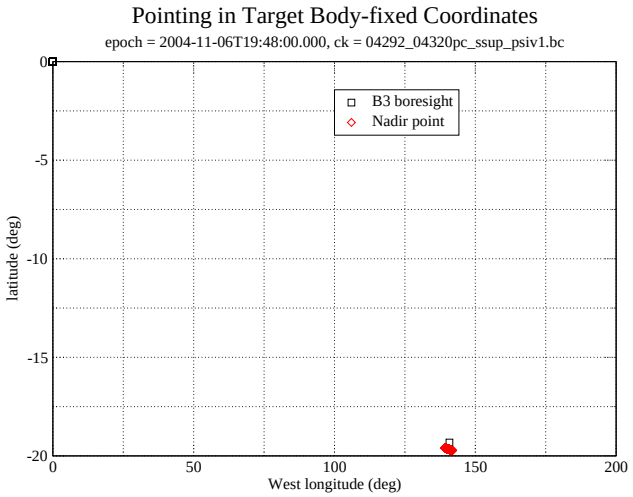

Figure 2: Inbound scan in target body-fixed coordinates

4 Div B: Radiometry Raster Scan

Figures 1 and 2 show the pointing design for the radiometry scan from the merged ckernel. The boresight is pointed most of the time off target, hence the range/altitude plot shows only a few boresight range points. The scans use 1/4 beamwidth spacing to allow for some super-resolution processing of the radiometer data. The angular size of the target is about 2.1 mrad during this division. The beam 3 beamwidth is 6 mrad. The IEB for this division is controlled by a block of keywords as shown in Table 5

5 Div's C,E: Scatterometer Calibration

A scatterometer mode data collection will be performed to calibrate the 117 KHz bandpass radiometrically using Titan as the known target. The calibration consists of two measurements; one with the target centered in the beam, and another off target looking at cold space. The radiometric sensitivity of the receiver is given by,

$$\Delta T = \frac{T_{\rm sys}}{\sqrt{tB}}, \tag{1}$$

where $T_{\rm sys} = T_r + T_a$ is the system temperature (the sum of the receiver noise temperature and the antenna temperature), t is the integration time (the length of the echo window for one burst), and B is the measurement bandwidth (the width of the selected bandpass - 117 KHz for scatterometer mode).

The ΔT that we can achieve is limited by the available data volume which will be about 90 Mbits. Assuming that the IEB runs the radar at 200 Kbps (the target rate for distant scatterometer operations), then the 90 Mbits will last for 7.5 minutes of elapsed time. The time will be divided evenly between the on target and off target measurements giving each 3.75 minutes. The pointing design will provide 5 minutes of on target staring followed by 5 minutes of off-target staring at cold space at least 10 beamwidths away from the target. The actual integration time is much less than the elapsed time due to the burst and pulse duty cycle limits. Dividing the data volume in samples by the sample rate (250 KHz) gives an integration time of 22.5 s for each integration. Assuming a system temperature of 1000 K gives a ΔT of 0.6 K.

The IEB keywords for the scatterometer mode operation are shown in table 6 and the keywords for the radiometer operation inbetween and after the scatterometer integrations are shown in table 7.

6 Revision History

1. Aug 20, 2004: Initial release

Name	Nominal	Actual	Mismatch	Comments
mode	radiometer	radiometer	no	
start_time (min)	varies	0.0	no	
end_time (min)	varies	127.0	no	
time_step (s)	varies	2700.0	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	1.000	no	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: ti_00a_2 div_b distant_radiometer block

2. Sep 21, 2004: Added acronym list

Name	Nominal	c	e	Mismatch	Comments
mode	scatterometer	scatterometer	scatterometer	no	
start_time (min)	varies	127.0	137.0	no	
end_time (min)	varies	130.8	140.8	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	1	1	yes	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	1.20	1.20	no	Set to cover target doppler bandwidth
number_of_pulses	varies	100	100	no	depends on PRF choice (can have more shorter pulses)
n_bursts_in_flight	varies	19	19	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 6: ti_00a_2 div_ce distant_scatterometer block

Name	Nominal	d	f	Mismatch	Comments
mode	radiometer	radiometer	radiometer	no	
start_time (min)	varies	130.8	140.8	no	
end_time (min)	varies	137.0	149.2	no	
time_step (s)	varies	2700.0	2700.0	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	4	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	1.000	1.000	no	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: ti_00a_2 div_df distant_radiometer block

7 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