Distant Titan Scatterometry/Radiometry in S20, Rev 23

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- Sequence: s20
- Rev: 023
- Observation Id: ti_023_2
- Target Body: Titan

1 Introduction

This memo describes one of the Cassini RADAR activities for the s20 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.

2 CIMS and Division Summary

CIMS ID	Start	End	Duration	Comments
023OT_RAD01WARM001_RIDER	2006-119T14:14:00	2006-119T17:14:00	03:00:0.0	Warmup for calibration and science data collection.
023TI_SCATT1CAL001_PRIME	2006-119T17:14:00	2006-119T19:14:00	02:00:0.0	Obtain distant Titan scatterometry and radiometer calibration data. Near zero Titan sub-spacecraft latitudes, near zero sub-spacecraft longitude, low phase angle. One of a set that spans the Tour.

Table 1: ti_023_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	03:07:0.0	2.8	Warmup
b	distant_radiometer	00:07:0.0	00:04:0.0	0.2	Off-target engineering test
c	distant_radiometer	00:11:0.0	00:49:0.0	2.9	Radiometer scans
d	distant_radiometer	01:00:0.0	00:04:0.0	0.2	On-target engineering test
e	distant_radiometer	01:04:0.0	00:21:0.0	1.2	On-target radiometer stare
f	distant_scatterometer	01:25:0.0	00:12:0.0	140.4	On-target scatterometer stare
g	distant_radiometer	01:37:0.0	00:11:0.0	0.7	On-target radiometer stare
h	distant_radiometer	01:48:0.0	00:04:0.0	0.2	Off-target engineering test
i	distant_radiometer	01:52:0.0	00:08:0.0	0.5	Closing radiometry
Total				149.2	

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	0	off target	0.00	off target
b	599216	off target	0.75	off target
c	597406	off target	0.75	off target
d	575518	575518	0.72	1102
e	573754	573754	0.72	1100
f	564545	564545	0.71	1090
g	559321	559321	0.70	1084
h	554558	off target	0.70	off target
i	552832	off target	0.70	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	-180.0	no	
end_time (min)	varies	7.0	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	4.0	no	
dutycycle	don't care	0.38	no	
prf (Hz)	don't care	1000	no	
tro	don't care	0	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: ti_023_2 div_a distant_warmup block

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 Warmup

The radar warmup rider begins at 2006-04-29T14:14:00.000 (-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.

4 Div's C,E,I: Radiometry

Figure 1 shows the pointing design for the radiometry scan from the merged ckernel. 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

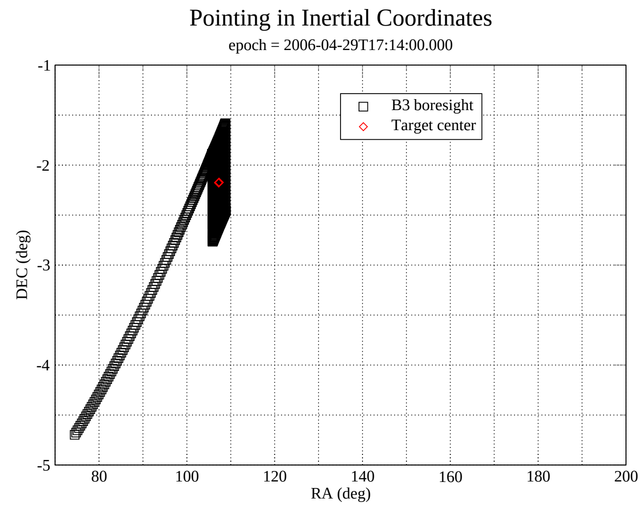

Figure 1: Scan in inertial coordinates

8.7 mrad during this division. The beam 3 beamwidth is 6 mrad. The IEB for this division and the other radiometry divisions is controlled by a block of keywords as shown in Table **??**

5 Div's B,D,H: Engineering Test Segments

Some receive only engineering test segments are inserted into this observation to survey system performance after a 3 hour warmup. Two segments are placed off target at the start and end. One segment is placed at the start of the on-target staring period. These segments cycle all 4 modes in receive only mode collecting compressed mode data over a wide range of attenuator settings. The on and off-target data can then be used to compute system gain and receiver temperature for the 4 modes at various attenuator settings.

6 Div F: Scatterometer Performance

During the scatterometer integration the spacecraft will have beam 3 pointed at the center of Titan. The detection performance is shown in figures 2 and 3. Division parameters are as shown in table 6.

A tone transmission will be used because the signal is too weak to allow for any range compression processing. The PRF will be set higher than the disk bandwidth to allow for doppler processing without any folding of the signal onto itself from the comb pattern generated by the pulsed nature of the signal. The resolution of the signal as a function of doppler will be limited due to the weak signal. This is not a big issue for this observation because its primary purpose is to provide a disk integrated backscatter value for calibration against Earth based radar measurements of Titan. Any doppler spectrum data will be an extra bonus. This observation will also include an upgraded RMSS calculation 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.

The range is large enough that multiple bursts in flight will be needed. Figure 4 shows the receive window delay (RWD) that will be needed for the current pulse parameters shown in table 6. The range of burst periods that are compatible with the number of bursts in flight (giving RWD $\in [0, 1023]$) is also shown. RMSS actually imposes a more strict limit on RWD to accomodate timing constraints in the instrument. 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. The positive TRO value also guarantees noise-only data in each burst which eliminates the need to insert special noise-only bursts.

Name	Nominal	c	e	i	Mismatch	Comments
mode	radiometer	radiometer	radiometer	radiometer	no	
start_time (min)	varies	11.0	64.0	112.0	no	
end_time (min)	varies	60.0	85.0	120.0	no	
time_step (s)	varies	1800.0	1800.0	1800.0	no	Used by radiometer only modes
bem	00100	00100	00100	00100	no	
baq	don't care	5	5	5	no	
csr	6	6	6	6	no	
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 (Hz)	don't care	1000	1000	1000	no	
tro	don't care	0	0	0	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	starting value for auto-rad
max_data_rate	1.000	0.992	0.992	0.992	yes	1 Kbps - 1 s burst period which is adequate for slow radiometer scans
interleave_flag	off	off	off	off	no	
interleave_duration (min)	don't care	10.0	10.0	10.0	no	

Table 5: ti_023_2 div_cei distant_radiometer block

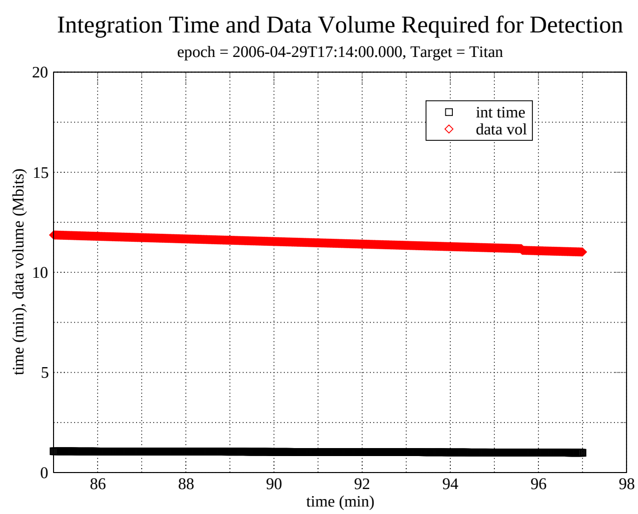

Figure 2: Outbound scatterometry Div F: Detection integration time required for a single point detection using optimal chirp bandwidth

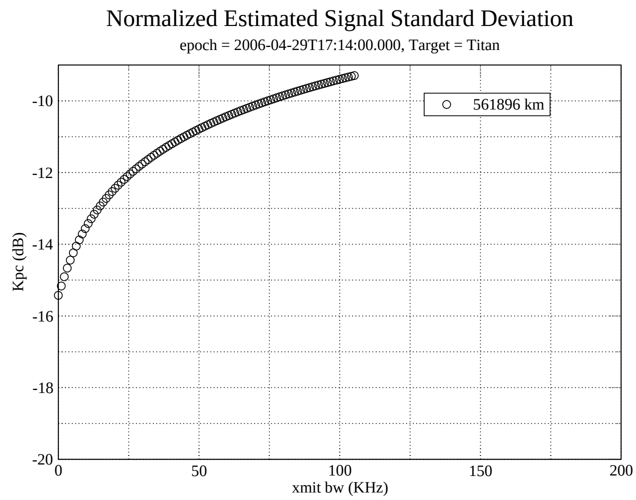

Figure 3: Outbound observation Div F: Normalized estimated signal standard deviation for a disk integrated observation assuming all the bursts occur at minimum range, and 15 minutes away from minimum range.

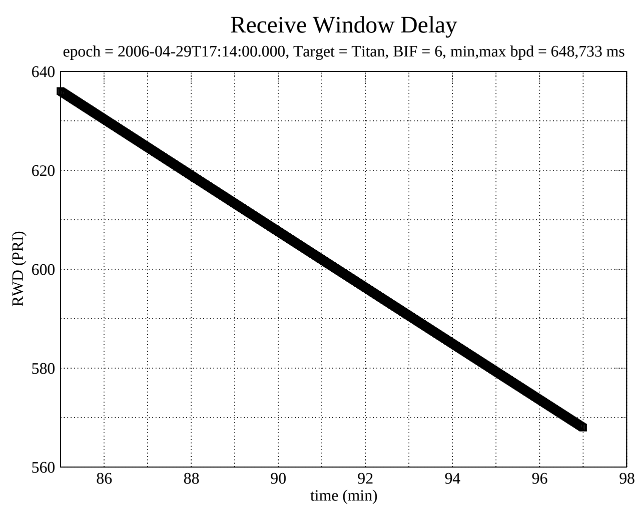

Figure 4: Div C: Outbound scatterometer receive window delay. Subtitle shows the minimum and maximum burst periods that are in principle compatible with the division selected number of bursts in flight.

Name	Nominal	Actual	Mismatch	Comments
mode	scatterometer	scatterometer	no	
start_time (min)	varies	85.0	no	
end_time (min)	varies	97.0	no	
time_step (s)	don't care	14.0	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, 8 - with auto-gain
noise_bit_setting	4.0	4.0	no	Scat signal set higher than ALT/SAR
dutycycle	0.70	0.70	no	
prf (Hz)	varies	1953	no	Set to cover target doppler bandwidth
tro	6	6	no	6 - allows for some noise only data in time domain
number_of_pulses	varies	125	no	depends on PRF choice (can have more shorter pulses)
n_bursts_in_flight	varies	6	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	195.000	yes	Kbps - determines burst period
interleave_flag	off	off	no	
interleave_duration (min)	don't care	10.0	no	

Table 6: ti_023_2 div_f distant_scatterometer block

7 Revision History

1. Mar 29, 2006: Initial release

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