RADAR Titan Flyby during S56/T65

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- Sequence: s56
- Rev: 124
- Observation Id: t65
- Target Body: Titan
- Data Take Number: 211
- PDT Config File: S56_ssup_psiv1_091026_pdt.cfg
- SMT File: S56_091112.rpt
- PEF File: z0560c.pef

1 Introduction

This memo describes the Cassini RADAR activities for the T65 Titan flyby. This SAR data collection occurs during the S56 sequence of the Saturn Tour. This is a partial radar pass with just ride-along main swath SAR imaging and normal SAR outbound imaging along with a scatteromter/radiometer sweep across Ontario Lacus. 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
124TI_T65WARMUP001_RIDER	2010-012T17:55:36	2010-012T22:55:36	05:00:0.0	
124TI_T65RASAR001_PRIME	2010-012T22:47:36	2010-012T23:10:36	00:23:0.0	
124TI_T65OUTSAR001_PRIME	2010-012T23:10:36	2010-012T23:26:36	00:16:0.0	

Table 1: t65 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. Although the CIMS requests show Low-SAR intervals, in reality the radar will be operated in Hi-SAR mode through most of this flyby.

Division	Name	Start	Duration	Data Vol	Comments
a	Warmup	-5:15:0.0	05:05:0.0	18.2	Warmup
b	standard_radiometer_inbound	-0:10:0.0	00:05:0.0	0.3	Inbound radiometry
c	standard_sar_hi	-0:05:0.0	00:01:0.0	6.0	Ridelaong SAR Turn transition, beam 3 only
d	standard_sar_hi	-0:04:0.0	00:01:0.0	14.0	Left look Ridealong SAR
e	standard_sar_hi	-0:03:0.0	00:04:30.0	63.2	Lef look Ridealong SAR
f	standard_sar_hi	00:01:30.0	00:01:30.0	20.7	Turn from left to right look
g	standard_sar_hi	00:03:0.0	00:03:42.0	51.9	Outbound SAR imaging crossing Ontario right look
h	standard_sar_hi	00:06:42.0	00:01:51.0	26.0	Turn back imaging 5 beams
i	standard_sar_hi	00:08:33.0	00:00:27.0	6.3	Turn back imaging 3 beams
j	standard_scatterometer_outbound	00:09:0.0	00:00:10.0	2.0	Antenna recieve only
k	standard_scatterometer_outbound	00:09:10.0	00:00:10.0	2.0	Resistive load recieve only
l	scatterometer_imaging	00:09:20.0	00:00:30.0	7.5	Ontario scatterometer imaging
m	standard_scatterometer_outbound	00:09:50.0	00:00:2.0	0.5	Ontario Tone observation
n	scatterometer_imaging	00:09:52.0	00:00:6.0	1.5	Ontario scatterometer imaging
o	standard_scatterometer_outbound	00:09:58.0	00:00:2.0	0.5	Ontario Tone observation
p	scatterometer_imaging	00:10:0.0	00:00:6.0	1.5	Ontario scatterometer imaging
q	standard_scatterometer_outbound	00:10:6.0	00:00:2.0	0.5	Ontario Tone observation
r	scatterometer_imaging	00:10:8.0	00:00:20.0	5.0	Ontario scatterometer imaging
s	standard_scatterometer_outbound	00:10:28.0	00:00:7.0	1.8	Antenna recieve only
t	standard_scatterometer_outbound	00:10:35.0	00:00:7.0	1.8	Resistive load recieve only
u	scatterometer_imaging	00:10:42.0	00:00:36.0	9.0	Ontario scatterometer imaging
v	standard_scatterometer_outbound	00:11:18.0	00:00:10.0	2.5	Ontario Tone observation
w	standard_scatterometer_outbound	00:11:28.0	00:00:4.0	1.0	Antenna recieve only
x	standard_scatterometer_outbound	00:11:32.0	00:00:4.0	1.0	Resistive load recieve only
y	standard_sar_hi	00:11:36.0	00:03:24.0	20.4	SAR Turn transition, beam 3 only
z	standard_radiometer_outbound	00:15:0.0	00:05:0.0	0.3	Outbound radiometry
Total				265.3	

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	102526	off target	0.13	off target
b	2428	off target	0.01	off target
c	1456	1868	0.01	2315
d	1322	1601	0.00	2395
e	1215	1416	0.00	2462
f	1109	1135	0.00	2533
g	1215	1250	0.00	2462
h	1736	1823	0.01	2165
i	2104	2356	0.01	1995
j	2201	2515	0.01	1954
k	2238	2563	0.01	1939
l	2276	2611	0.01	1924
m	2390	2759	0.01	1880
n	2397	2769	0.01	1877
o	2421	2800	0.01	1868
p	2428	2811	0.01	1865
q	2452	2843	0.01	1856
r	2460	2854	0.01	1853
s	2539	2959	0.01	1825
t	2567	2995	0.01	1815
u	2595	3031	0.01	1805
v	2742	3209	0.01	1755
w	2783	3261	0.01	1741
x	2800	3281	0.01	1736
y	2817	3299	0.01	1731
z	3717	5062	0.01	1483

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

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.

3 Overview

T65 was originally allocated as a SAR only pass over lake Ontario in the south polar region. The pass begins with left looking ride-along SAR imaging in the vicinity of the southern end of the T7 swath. Right after closest approach, the spacecraft turns to right looking which catches Ontario Lacus. AFter passing over Ontario, the spacecraft turns back, sweeping the radar beams back towards one side of Ontario. Here we begin a special scatterometer radiometer experiment with a sweep back and forth across the short dimension of Ontario. Beam 3 only scatterometery and radiometry data are collected. The pointing is coordinated to pass over the darkest part of Ontario observed in the T57 and T58 SAR swaths. The target area lies at -71.7 latitude, 174.8 West longitude.

4 Mode Specific Operation and Performance

Many details of standard radar sequencing during the 4 main modes (Radiometry, Scatterometry, Altimetry, and SAR) have been discussed in previous sequence memos for prior observations. Refer to these for details. Some selecte performance highlights are illustrated in figures and explained in the following subsections.

4.1 SAR Resolution Performance

For all of the SAR divisions the effective resolution can be calculated from the same equations used in the high-altitude imaging discussion. Figure 1 shows the results from these equations using the parameters from the IEB as generated by RMSS. The calculations are performed for the boresight of beam 3 which is the center of the swath.

Projected range increases with decreasing incidence angle, so the range resolution varies across the swath with better resolution at the outer edge. The SAR pointing profile decreases the incidence angle as time progresses and altitude increases, so there is progressive deterioration of range resolution away from closest approach. The projected range resolution rapidly deteriorates as the incidence angle decreases toward zero at the very beginning and end of the swath.

Azimuth resolution is a function of the synthetic aperture size which is determined by the length of the receive window in each burst (assuming the receive window is always filled with echos). Azimuth resolution deteriorates less quickly because the number of pulses and the length of the receive window are increased as altitude increases which mitigates the increasing doppler bandwidth of the beam patterns. The receive window length increases to fill the round trip time until the science data buffer is filled. At this point it is no longer possible to extend the receive window, and azimuth resolution starts to deteriorate more rapidly.

4.2 Special Scatterometer/Radiometer Observations over Ontario

This observation includes some special scatterometer and radiometer collections over Ontario Lacus. The purpose of these data collections are to better characterize the properties of the lake surface by taking passive and active observations at a variety of incidence and polarization angles. The observations are selected to avoid as much contamination from the "land" areas around the lake as possible. In particular, the central beam twice sweeps over and then dwells a third time on a selected lake target area in the central dark area of the lake as observed in prior SAR swaths (eg.,

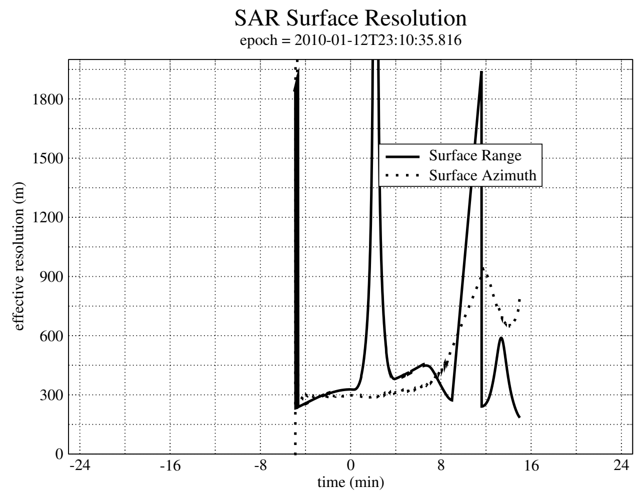

Figure 1: SAR projected range and azimuth resolution. These values are computed from the IEB parameters and are not related to the pixel size in the BIDR file. The pixel size was selected to be always smaller than the real resolution.

T57,T58). Tone scatterometry is used (similar to distant satellite observations) to reliably measure very low backscatter levels. Conicident radiometry is automatically obtained as well. Div's M, O, Q, and V (see table 4) provide IEB parameters for the scatterometer tone observations when passing over the lake target area. The final tone observation (Q) covers the dwell on the lake target area and has the lowest noise equivalent measurement.

Inbetween the tone observations, the radar collects scatterometer imaging data during the remainder of the sweeps back and forth across the lake target area (see table 5). These data can be processed into SAR imagery of the sweep area around the target site. The lower bandwidth and use of the central beam will improve the noise floor of the scatterometer imagery compared to the regular SAR swath collected in division G, however, resolution (about 2 km x 0.5 km) will be inferior.

Receive only data are collected before and after the sweeps across Ontario (div's J and W) to aid in calibrating the scatteormeter data.

5 Revision History

1. Dec 22, 2010: Final release

Name	Nominal	Actual	Mismatch	Comments
mode	scatterometer	scatterometer	no	
start_time (min)	varies	9.8	no	
end_time (min)	varies	9.9	no	
time_step (s)	don't care	4.0	no	Set by valid time calculation
bem	00100	00100	no	
baq	5	5	no	5 - 8 bits straight
csr	0	0	no	0 - fixed attenuator
noise_bit_setting	4.0	4.0	no	Scat signal set higher than ALT/SAR
dutycycle	0.70	0.70	no	
prf (Hz)	1200	3906	yes	
tro	6	6	no	
number_of_pulses	8	0	yes	
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	30.000	250.000	yes	
interleave_flag	off	off	no	
interleave_duration (min)	don't care	10.0	no	

Table 4: t65 Div m standard_scatterometer_outbound block

6 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

Name	Nominal	Actual	Mismatch	Comments
mode	scatterometer	scatterometer	no	
start_time (min)	varies	9.3	no	
end_time (min)	varies	9.8	no	
time_step (s)	varies	4.0	no	
bem	00100	00100	no	
baq	0	5	yes	8-2 used to increase looks and duty cycle - hence SNR
csr	0	0	no	0 - fixed attenuator
noise_bit_setting	4.0	4.0	no	9 dB attenuator
dutycycle	0.35	0.70	yes	
prf (Hz)	1000	2000	yes	1000 Hz is typical, set to balance range/doppler ambiguities
tro	6	6	no	
number_of_pulses	100	0	yes	100 is typical, set to fill echo buffer/round trip time
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	82.000	250.000	yes	82 is typical, set to use available data volume
interleave_flag	off	off	no	
interleave_duration (min)	don't care	10.0	no	

Table 5: t65 Div l scatterometer_imaging block