RADAR Titan Flyby during S47/T50

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- Sequence: s47
- Rev: 102
- Observation Id: t50
- Target Body: Titan
- Data Take Number: 181
- PDT Config File: S47_ssup_ssg_081027_pdt.cfg
- SMT File: S47_psiv_081021.rpt
- PEF File: z0470d.pef

1 Introduction

This memo describes the Cassini RADAR activities for the T50 Titan flyby. This SAR data collection occurs during the S47 sequence of the Saturn Tour. This is a full radar pass with a ride-along SAR swath at closest approach. 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
102TI_T50WARMUP001_RIDER	2009-037T23:05:51	2009-038T03:20:51	04:15:0.0	
102TI_T50INRAD001_PRIME	2009-038T03:20:51	2009-038T06:50:51	03:30:0.0	
102TI_T50INSCAT001_PRIME	2009-038T06:50:51	2009-038T07:38:51	00:48:0.0	
102TI_T50IHISAR001_PRIME	2009-038T07:39:51	2009-038T08:20:51	00:41:0.0	
102TI_T50INALT001_PRIME	2009-038T08:20:51	2009-038T08:38:51	00:18:0.0	
102TI_T50RASAR001_PRIME	2009-038T08:38:51	2009-038T09:02:51	00:24:0.0	
102TI_T50OUTALT001_PRIME	2009-038T09:02:51	2009-038T09:20:51	00:18:0.0	
102TI_T50OHISAR001_PRIME	2009-038T09:20:51	2009-038T09:40:51	00:20:0.0	
102TI_T50OUTSCT001_PRIME	2009-038T10:02:32	2009-038T10:50:51	00:48:19.0	
102TI_T50OUTRAD001_PRIME	2009-038T10:50:51	2009-038T14:50:51	04:00:0.0	

Table 1: t50 CIMS Request Sequence

Division	Name	Start	Duration	Data Vol	Comments
a	Warmup	-9:45:0.0	07:45:0.0	27.7	Warmup
b	standard_scatterometer_inbound	-2:00:0.0	00:49:30.0	89.1	Inbound scatterometry raster
c	scatterometer_imaging	-1:10:30.0	00:04:0.0	21.6	Inbound scatterometer imaging
d	scatterometer_imaging	-1:06:30.0	00:04:30.0	24.3	Inbound scatterometer imaging
e	scatterometer_imaging	-1:02:0.0	00:02:0.0	10.8	Inbound scatterometer imaging
f	scatterometer_imaging	-1:00:0.0	00:12:0.0	46.8	Inbound scatterometer imaging
g	scatterometer_imaging	-0:48:0.0	00:02:0.0	7.8	Inbound scatterometer imaging
h	scatterometer_imaging	-0:46:0.0	00:02:30.0	9.8	Inbound scatterometer imaging
i	scatterometer_imaging	-0:43:30.0	00:02:0.0	7.8	Inbound scatterometer imaging
j	scatterometer_imaging	-0:41:30.0	00:03:30.0	13.7	Inbound scatterometer imaging
k	scatterometer_imaging	-0:38:0.0	00:07:0.0	27.3	Inbound scatterometer imaging
l	standard_altimeter_inbound	-0:31:0.0	00:13:6.0	24.4	Inbound altimetry
m	standard_scatterometer_inbound	-0:17:54.0	00:00:4.0	0.6	Atmospheric Probe with Chirp
n	standard_scatterometer_inbound	-0:17:50.0	00:00:2.0	0.3	Atmospheric Probe with Tone
o	standard_sar_hi	-0:17:48.0	00:01:0.0	3.6	Hi-SAR Turn transition, beam 3 only
p	standard_sar_low	-0:16:48.0	00:00:42.0	2.5	SAR-Low Turn transition, beam 3 only
q	standard_radiometer_outbound	-0:16:6.0	00:10:54.0	0.6	Outbound radiometry scans
r	standard_sar_hi	-0:05:12.0	00:10:24.0	147.3	Hi-SAR Main Swath
s	standard_radiometer_outbound	00:05:12.0	00:09:48.0	0.6	Outbound radiometry scans
t	standard_sar_low	00:15:0.0	00:01:0.0	3.6	SAR-Low Turn transition, beam 3 only
u	standard_sar_hi	00:16:0.0	00:01:0.0	3.6	Hi-SAR Turn transition, beam 3 only
v	standard_scatterometer_outbound	00:17:0.0	00:00:4.0	0.6	Atmospheric Probe with Tone
w	standard_scatterometer_outbound	00:17:4.0	00:00:2.0	0.3	Atmospheric Probe with Chirp
x	standard_altimeter_outbound	00:17:6.0	00:13:54.0	25.9	Outbound altimetry
y	scatterometer_imaging	00:31:0.0	00:08:0.0	31.2	Outbound scatterometer imaging
z	scatterometer_imaging	00:39:0.0	00:11:0.0	59.4	Outbound scatterometer imaging
lbrace	scatterometer_imaging	00:50:0.0	00:22:0.0	21.1	Outbound scatterometer imaging
vbar	standard_scatterometer_outbound	01:12:0.0	00:46:0.0	82.8	Outbound scatterometry raster
rbrace	standard_radiometer_outbound	01:58:0.0	04:02:0.0	14.4	Outbound radiometry scans
Total		2		709.2	

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	203340	off target	0.26	off target
b	40370	off target	0.05	off target
c	22934	23195	0.03	359
d	21528	22597	0.03	381
e	19948	21161	0.03	410
f	19246	20302	0.03	424
g	15046	16267	0.02	532
h	14349	15767	0.02	555
i	13478	14849	0.02	586
j	12783	13923	0.02	613
k	11571	12440	0.02	668
l	9164	9286	0.01	808
m	4817	4817	0.01	1291
n	4796	4796	0.01	1295
o	4786	4786	0.01	1297
p	4472	4617	0.01	1355
q	4255	5009	0.01	1398
r	1436	1965	0.01	2386
s	1436	1965	0.01	2386
t	3918	4940	0.01	1471
u	4224	4365	0.01	1405
v	4534	4534	0.01	1343
w	4555	4555	0.01	1339
x	4566	4566	0.01	1337
y	9164	9510	0.01	808
z	11917	12644	0.02	651
lbrace	15745	16846	0.02	511
vbar	23461	24563	0.03	351
rbrace	39665	40331	0.05	203

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

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.

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

T50 has both inbound and outbound radiometry and scatterometry raster scans as well as both inbound and outbound high altitude imaging segments. The inbound high altitude imaging segment covers the VIMS cloud source and mountains area just east of the T7 SAR swath. The outbound high altitude image segment covers area just north of T8 amongst the equatorial dunes. The SAR swath is a ride-along swath that crosses the west end of T8 and heads south towards the end of the T7 SAR swath. There are also two sweep turns with imaging data before and after the ride-along swath. Atmospheric probes are inserted with the sweep turns when close to nadir pointing.

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 selected performance highlights are illustrated in figures and explained in the following subsections.

4.1 High Altitude Imaging

The high altitude imaging segments are designed to optimize range-doppler ambiguities, resolution, number of looks and noise-equivalent cross-section. These segments push against the 7% duty cycle limit, the 32 Kbyte size of the science data buffer, the round trip time limitation, and the number of pulses that the ESS can put out. To allow the best possible azimuth resolution, the duty cycle is reduced to allow a longer pulse train while still remaining below the 7% duty cycle limit. This trades SNR for resolution as was done in T19. Resolution in these segments will be in the 1 to 2 km range. For more technical details on range and doppler ambiguities, refer to the discussion in the T19 sequence design memo.

4.2 SAR-style Scatterometer Resolution Performance

Since SAR processing will be applied to this segment, the effective resolution can be calculated from the same equations,

$$\delta R_g = \frac{c}{2B_r \sin\theta_i}, \tag{1}$$

$$\delta x = \frac{\lambda R}{2\tau_{rw} v \sin\theta_v}, \tag{2}$$

where δR_g is the projected range resolution on the surface, c is the speed of light, B_r is the transmitted chirp bandwidth, θ_i is the incidence angle, δx is the azimuth resolution on the surface, λ is the transmitted wavelength, R is the

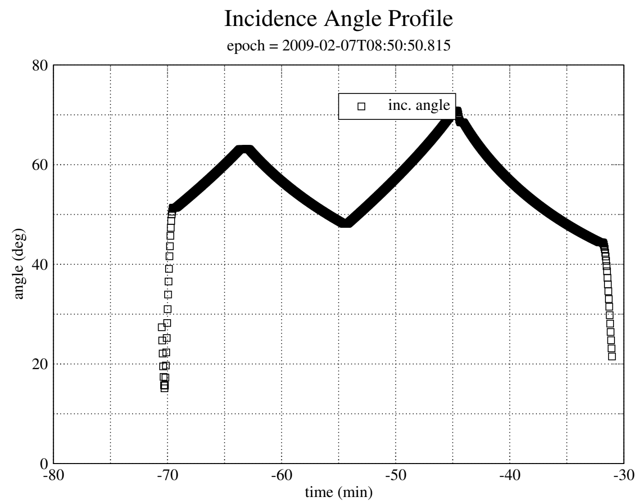

Figure 1: Incidence angle variation during Inbound scatterometer imaging.

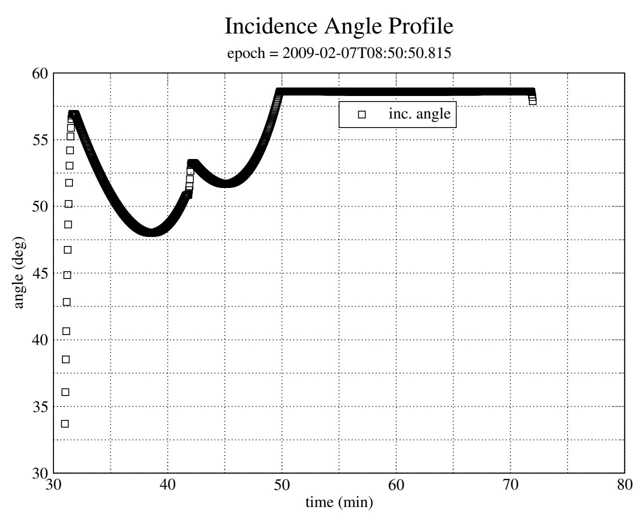

Figure 2: Incidence angle variation during Outbound scatterometer imaging.

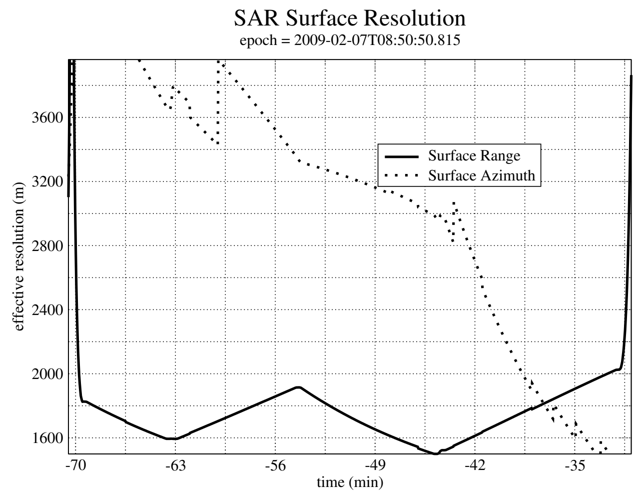

Figure 3: Inbound Scatterometer imaging projected range and azimuth resolution. These values are computed from the IEB parameters.

slant range, τ_{rw} is the length of the receive window, v is the magnitude of the spacecraft velocity relative to the target body, and θ_v is the angle between the velocity vector and the look direction. Figure 4 shows the results from these equations for the scatterometer imaging time. The calculations are performed for the boresight of beam 3 which is the center of the swath.

4.3 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 7 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.

4.4 Atmospheric Probes

Atmospheric probe measurements were inserted to look for signals from preciptation above the surface. Details are provided in prior sequence memos starting with T30.

5 Revision History

1. Feb 9, 2008: Initial release

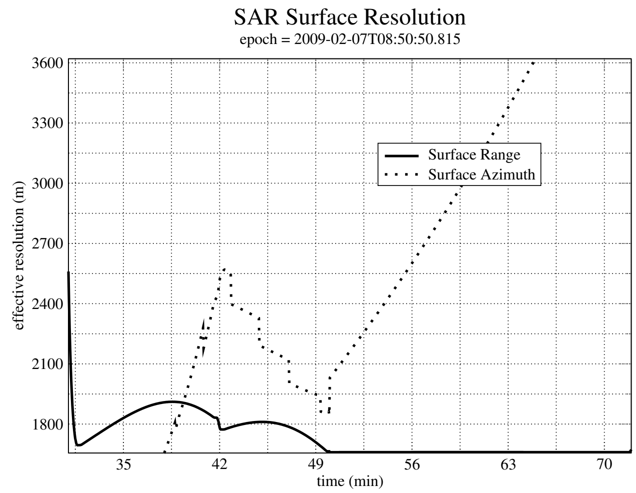

Figure 4: Outbound Scatterometer imaging projected range and azimuth resolution. These values are computed from the IEB parameters.

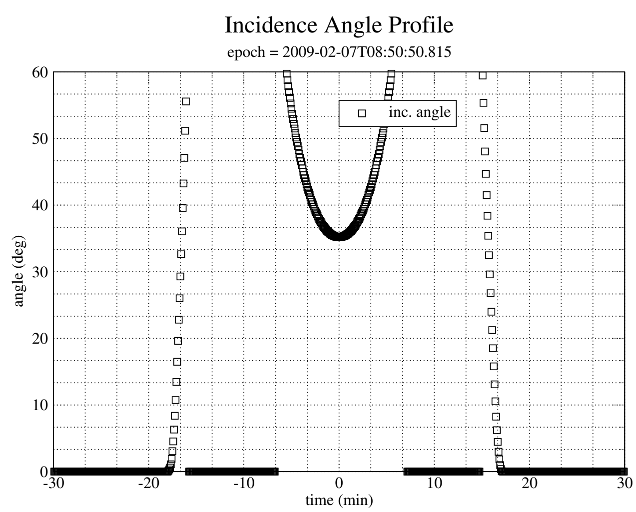

Figure 5: B3 boresight incidence angle during the time around c/a.

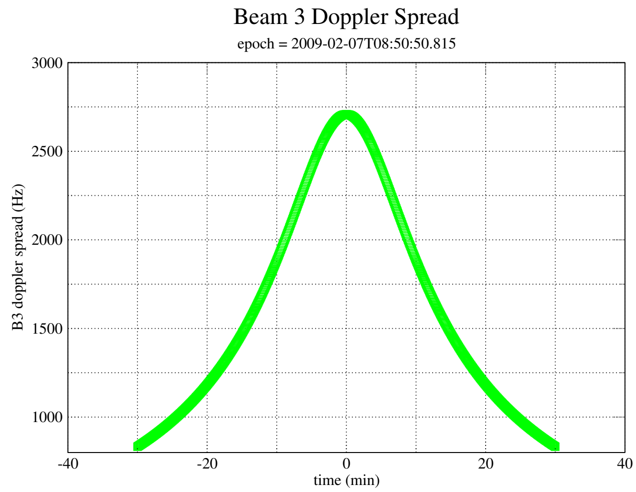

Figure 6: Nadir pointed B3 doppler spread during the time around c/a. Doppler spread is measured within the two-way 3 dB beam pattern.

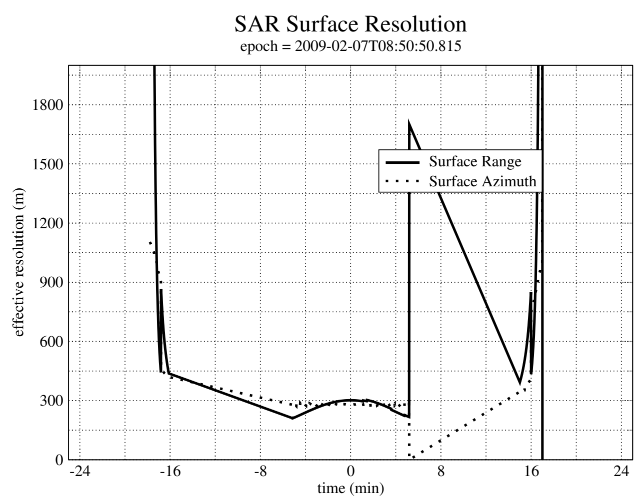

Figure 7: SAR projected range and azimuth resolution. These values are computed from the IEB parameters and are not related to the pixel size in the BIDR file. The pixel size was selected to be always smaller than the real resolution.

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