RADAR Titan Flyby during S82/T98

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- Sequence: s82
- Rev: 201
- Observation Id: t98
- Target Body: Titan
- Data Take Number: 257
- PDT Config File: S82_sip_psiv_131112_pdt.cfg
- SMT File: s82_psiv_datapol_131111.rpt
- PEF File: z0820b.pef

1 Introduction

This memo describes the Cassini RADAR activities for the T98 Titan flyby. This SAR data collection occurs during the S82 sequence of the Saturn Tour. This is a complete radar pass with SAR imaging over Lake Ontario. 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
201TI_T98WARMUP001_RIDER	2014-033T10:12:38	2014-033T13:12:38	03:00:0.0	
201TI_T98INRAD001_PRIME	2014-033T13:12:38	2014-033T16:57:38	03:45:0.0	
201TI_T98INSCAT001_PRIME	2014-033T16:57:38	2014-033T18:00:38	01:03:0.0	
201TI_T98IHISAR001_PRIME	2014-033T18:00:38	2014-033T18:41:38	00:41:0.0	
201TI_T98INALT001_PRIME	2014-033T18:42:38	2014-033T18:54:38	00:12:0.0	
201TI_T98INOSAR001_PRIME	2014-033T18:54:38	2014-033T19:30:38	00:36:0.0	
201TI_T98OUTALT001_PRIME	2014-033T19:30:38	2014-033T19:47:38	00:17:0.0	
201TI_T98OHISAR001_PRIME	2014-033T20:09:38	2014-033T20:30:38	00:21:0.0	
201TI_T98OUTSCT001_PRIME	2014-033T20:30:38	2014-033T21:27:38	00:57:0.0	
201TI_T98OUTRAD001_PRIME	2014-033T21:27:38	2014-034T01:12:38	03:45:0.0	

Table 1: t98 CIMS Request Sequence

Division	Name	Start	Duration	Data Vol	Comments
a	Warmup	-9:00:0.0	03:10:0.0	11.3	Warmup
b	standard_radiometer_inbound	-5:50:0.0	00:05:0.0	0.3	radiometer quick-steps
c	standard_radiometer_inbound	-5:45:0.0	03:32:0.0	12.6	radiometer raster
d	standard_scatterometer_inbound	-2:13:0.0	00:58:0.0	90.5	Inbound scatterometry raster
e	scatterometer_imaging	-1:15:0.0	00:25:12.0	90.7	Inbound scatterometer imaging
f	scatterometer_imaging	-0:49:48.0	00:10:18.0	37.1	Inbound scatterometer imaging
g	scatterometer_imaging	-0:39:30.0	00:09:54.0	35.6	Inbound scatterometer imaging
h	standard_scatterometer_inbound	-0:29:36.0	00:01:24.0	2.5	Inbound scatterometry during turn to alt
i	standard_altimeter_inbound	-0:28:12.0	00:10:12.0	20.2	Inbound altimetry
j	standard_altimeter_inbound	-0:18:0.0	00:08:0.0	105.6	Inbound high rate altimetry
k	standard_altimeter_inbound	-0:10:0.0	00:10:0.0	132.0	Inbound high rate altimetry
l	standard_scatterometer_inbound	00:00:0.0	00:00:4.0	0.6	Atmospheric Probe with Chirp
m	standard_scatterometer_inbound	00:00:4.0	00:00:2.0	0.3	Atmospheric Probe with Tone
n	standard_sar_hi	00:00:6.0	00:01:6.0	2.6	SAR Turn transition transition from scat, beam 3 only
o	standard_sar_hi	00:01:12.0	00:03:48.0	50.2	Hi-SAR Main Swath
p	standard_sar_hi	00:05:0.0	00:11:0.0	145.2	Hi-SAR Main Swath
q	standard_sar_pingpong	00:16:0.0	00:02:30.0	33.0	Outbound SAR ping-pong
r	standard_sar_hi	00:18:30.0	00:04:2.0	9.7	SAR Turn transition transition to scat, beam 3 only
s	standard_scatterometer_outbound	00:22:32.0	00:00:4.0	0.6	Atmospheric Probe with Tone
t	standard_scatterometer_outbound	00:22:36.0	00:00:2.0	0.3	Atmospheric Probe with Chirp
u	standard_altimeter_outbound	00:22:38.0	00:10:22.0	20.5	Outbound altimetry
v	scatterometer_imaging	00:33:0.0	00:01:12.0	4.0	Outbound scatterometer imaging
w	scatterometer_imaging	00:34:12.0	00:06:48.0	24.5	Outbound scatterometer imaging
x	scatterometer_imaging	00:41:0.0	00:11:0.0	39.6	Outbound scatterometer imaging
y	scatterometer_imaging	00:52:0.0	00:28:0.0	100.8	Outbound scatterometer imaging
z	standard_scatterometer_outbound	01:20:0.0	00:55:0.0	85.8	Outbound scatterometry raster
lbrace	standard_radiometer_outbound	02:15:0.0	03:45:0.0	13.4	Outbound radiometry
Total				1069.4	

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	174161	off target	0.22	off target
b	112410	off target	0.14	off target
c	110781	off target	0.14	off target
d	41597	42766	0.06	243
e	22667	23519	0.03	395
f	14494	15450	0.02	573
g	11190	12083	0.02	706
h	8070	9120	0.01	909
i	7636	7636	0.01	947
j	4590	4590	0.01	1346
k	2519	2519	0.01	1891
l	1236	1236	0.00	2526
m	1236	1236	0.00	2526
n	1236	1236	0.00	2526
o	1257	1308	0.00	2512
p	1595	1698	0.01	2309
q	4032	4137	0.01	1459
r	4732	4863	0.01	1320
s	5912	5912	0.01	1138
t	5932	5932	0.01	1135
u	5942	5942	0.01	1134
v	9132	9132	0.01	828
w	9510	9829	0.02	802
x	11668	12304	0.02	683
y	15202	15510	0.02	551
z	24293	24700	0.03	373
lbrace	42245	43518	0.06	242

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

T98 is a complete pass. The observation starts with two radiometer scans followed by a scatterometer scan in the northern hemisphere. Following this is a high altitude imaging segment with 9 scan lines providing SAR imaging over the mid latitudes imaging one of the craters. This is followed by regular altimetry, highrate altimetry and an atmospheric probe measurement. After this, SAR imaging is performed over the southern latitudes imaging lake Ontario followed by another atmospheric probe measurement and eventually turning back to nadir for an altimeter track. This is followed by a high altitude imaging segment with 6 scan lines over the south pole. The radar data collection then ends with normal outbound scatterometry and radiometry.

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 Coverage Layout

Figure 1 shows the layout of the different T98 data collections on a map of Titan. The SAR swath occurs from 1.2 min to 18.5 min and is shifted to higher incidence angles by 3 degrees to center it on lake Ontario. Figure 2 shows a polar stereographic projection of the beam 1,3,5 tracks during the SAR observation. The high altitude scatterometer imaging of the South polar area is also shown on this figure.

4.2 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 3 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 and during the close approach altimetry segment.

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

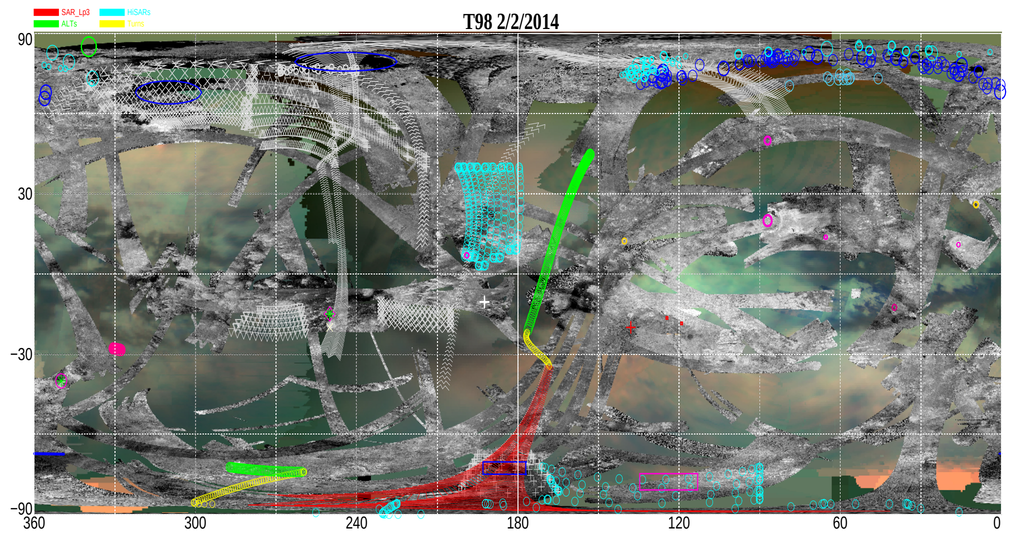

Figure 1: Coverage areas overlaid on Titan map showing prior optical and radar imaging.

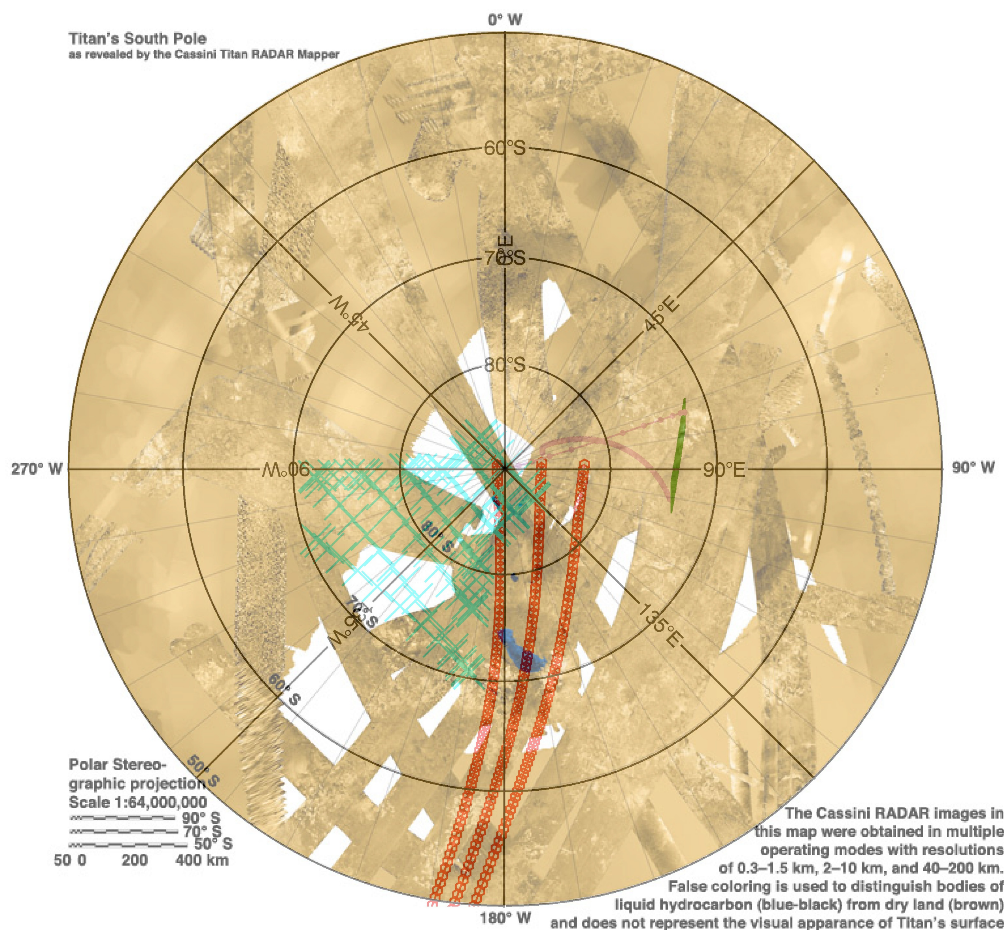

Figure 2: Coverage areas overlaid on polar stereographic Titan map showing prior optical and radar imaging.

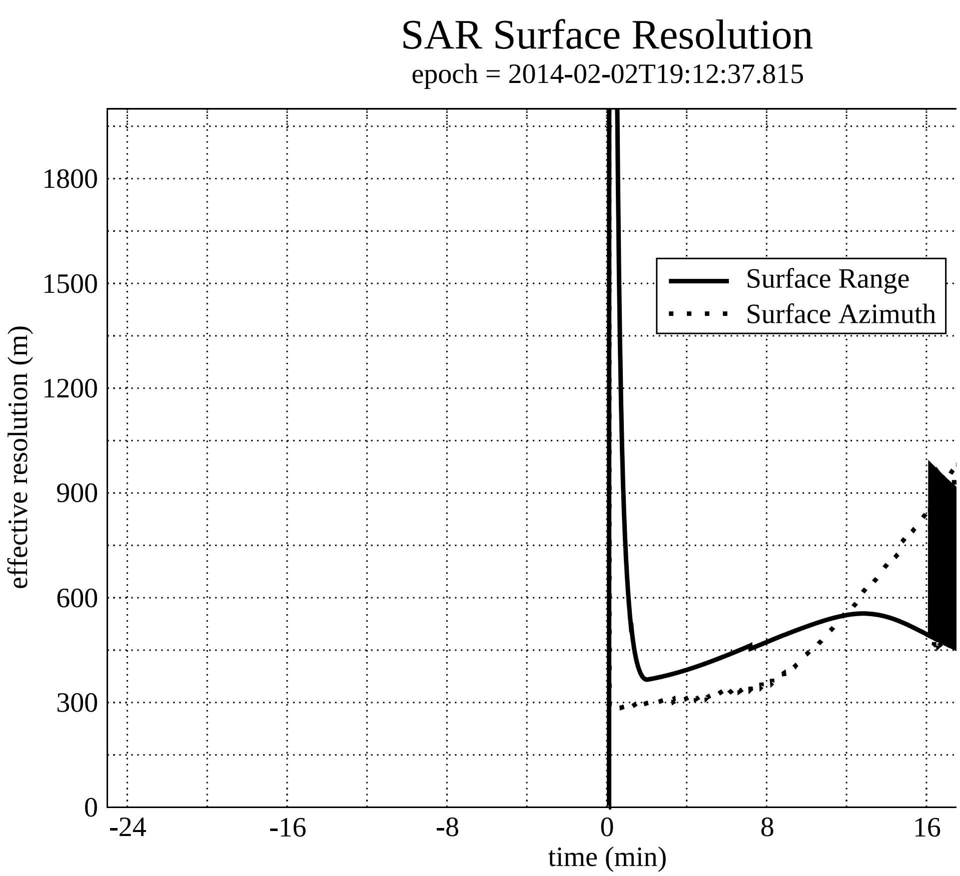

Figure 3: SAR projected range and azimuth resolution. These values are computed from the IEB parameters and are not related to the pixel size in the BIDR file. The pixel size was selected to be always smaller than the real resolution.

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.

5 Revision History

1. Nov 21, 2014: Final release

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