RADAR Titan Flyby during S85/T104

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- Sequence: s85
- Rev: 207
- Observation Id: t104
- Target Body: Titan
- Data Take Number: 261
- PDT Config File: S85_sip_psiv_140611_pdt.cfg
- SMT File: S85_140521.smt
- PEF File: z0850b.pef

1 Introduction

This memo describes the Cassini RADAR activities for the T104 Titan flyby. This SAR data collection occurs during the S85 sequence of the Saturn Tour. This is a partial radar pass with ride-along SAR inbound imaging and normal outbound imaging. 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
207TI_T104WRMUP001_RIDER	2014-232T22:54:09	2014-233T02:09:09	03:15:0.0	
207TI_T104INRAD001_PRIME	2014-233T02:09:09	2014-233T05:54:09	03:45:0.0	
207TI_T104INSCT001_PRIME	2014-233T05:54:09	2014-233T06:57:09	01:03:0.0	
207TI_T104IHSAR001_PRIME	2014-233T06:57:09	2014-233T07:38:09	00:41:0.0	
207TI_T104INALT001_PRIME	2014-233T07:39:09	2014-233T07:54:09	00:15:0.0	
207TI_T104RASAR001_PRIME	2014-233T07:54:09	2014-233T08:09:09	00:15:0.0	
207TI_T104RASAR002_RIDER	2014-233T08:03:09	2014-233T08:09:09	00:06:0.0	
207TI_T104OTSAR001_PRIME	2014-233T08:09:09	2014-233T08:27:09	00:18:0.0	
207TI_T104OTALT001_PRIME	2014-233T08:27:09	2014-233T08:48:09	00:21:0.0	

Table 1: t104 CIMS Request Sequence

Division	Name	Start	Duration	Data Vol	Comments
a	Warmup	-9:20:0.0	03:32:0.0	12.6	Warmup
b	standard_radiometer_inbound	-5:48:0.0	00:03:0.0	0.2	radiometer quick-steps
c	standard_radiometer_inbound	-5:45:0.0	03:10:0.0	11.3	radiometer raster
d	standard_scatterometer_inbound	-2:35:0.0	01:22:0.0	147.6	Inbound scatterometry raster
e	scatterometer_imaging	-1:13:0.0	00:03:12.0	15.4	Inbound scatterometer imaging
f	scatterometer_imaging	-1:09:48.0	00:00:24.0	1.9	Inbound scatterometer imaging
g	scatterometer_imaging	-1:09:24.0	00:07:24.0	35.5	Inbound scatterometer imaging
h	scatterometer_imaging	-1:01:48.0	00:00:18.0	1.4	Inbound scatterometer imaging
i	scatterometer_imaging	-1:01:30.0	00:12:12.0	58.6	Inbound scatterometer imaging
j	scatterometer_imaging	-0:49:18.0	00:00:30.0	2.4	Inbound scatterometer imaging
k	scatterometer_imaging	-0:48:48.0	00:04:48.0	23.0	Inbound scatterometer imaging
l	scatterometer_imaging	-0:44:0.0	00:00:12.0	1.0	Inbound scatterometer imaging
m	scatterometer_imaging	-0:43:48.0	00:14:0.0	67.2	Inbound scatterometer imaging
n	standard_scatterometer_inbound	-0:29:48.0	00:01:36.0	5.8	Inbound scatterometry during turn to alt
o	standard_altimeter_inbound	-0:28:12.0	00:08:12.0	16.2	Inbound altimetry
p	standard_scatterometer_inbound	-0:20:0.0	00:00:4.0	0.6	Atmospheric Probe with Chirp
q	standard_scatterometer_inbound	-0:19:56.0	00:00:2.0	0.3	Atmospheric Probe with Tone
r	scatterometer_compressed	-0:19:54.0	00:12:36.0	2.3	Compressed Scatt/Rad scan
s	standard_sar_hi	-0:07:18.0	00:02:18.0	9.7	SAR Turn transition transition from scat, beam 3 only
t	standard_sar_hi	-0:05:0.0	00:09:0.0	125.3	SAR Ride-along Swath
u	standard_sar_hi	00:04:0.0	00:01:0.0	13.9	SAR Ride-along Swath
v	standard_sar_hi	00:05:0.0	00:01:40.0	7.0	SAR Turn transition transition to scat, beam 3 only
w	standard_scatterometer_outbound	00:06:40.0	00:00:4.0	0.6	Atmospheric Probe with Tone
x	standard_scatterometer_outbound	00:06:44.0	00:00:2.0	0.3	Atmospheric Probe with Chirp
y	standard_altimeter_outbound	00:06:46.0	00:07:14.0	95.5	Outbound close range altimetry
z	standard_sar_hi	00:14:0.0	00:06:0.0	83.5	SAR Main Swath
lbrace	standard_sar_hi	00:20:0.0	00:02:12.0	9.2	SAR Turn transition transition to alt, beam 3 only
vbar	standard_altimeter_outbound	00:22:12.0	00:09:18.0	18.4	Outbound altimetry
rbrace	standard_radiometer_outbound	00:31:30.0	00:04:30.0	0.3	Outbound radiometry
Total				766.8	

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	179427	off target	0.23	off target
b	110916	off target	0.14	off target
c	109945	off target	0.14	off target
d	48385	48521	0.06	160
e	21805	22621	0.03	355
f	20771	21741	0.03	372
g	20641	21701	0.03	374
h	18187	19244	0.03	420
i	18090	19243	0.03	422
j	14165	15415	0.02	525
k	14004	15157	0.02	530
l	12468	13684	0.02	586
m	12404	13648	0.02	588
n	7979	9365	0.01	840
o	7483	7483	0.01	882
p	5000	5000	0.01	1173
q	4981	4981	0.01	1177
r	4971	4971	0.01	1178
s	1734	2764	0.01	2067
t	1344	1746	0.00	2273
u	1212	1323	0.00	2353
v	1344	1409	0.00	2273
w	1616	1616	0.01	2125
x	1628	1628	0.01	2119
y	1634	1634	0.01	2116
z	3309	3309	0.01	1513
lbrace	5000	5013	0.01	1173
vbar	5653	5653	0.01	1080
rbrace	8509	8510	0.01	799

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

T104 is a partial pass. The observation starts with two radiometer scans followed by a scatterometer scan in the southern hemisphere. Following this is a high altitude imaging segment with 9 scan lines providing SAR imaging over the mid latitudes with imaging overlapping the T50 area. This is followed by regular altimetry and an atmospheric probe measurement. After this, a series of turn maneuvers were required to avoid heating constraints which took the radar beams off of Titan, and then back on again to line up for close-in altimetry. During these turn maneuvers, SAR data were collected similar to a ride-along SAR pass around closest approach. This is followed by another atmospheric probe measurement and special close range altimetry using beams 1 and 3 over Kraken Mare. This is followed in turn by regular SAR imaging over Ligeie Mare and outbound altimetry. The radar data collection then ends with 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 T104 data collections on a map of Titan. The red jagged lines show the beam centers of the ride-along SAR swath as it sweeps from the southern hemisphere to the northern hemisphere. The cyan symbols show the high altitude imaging in the southern hemisphere. The green symbols show the altimeter tracks.

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.

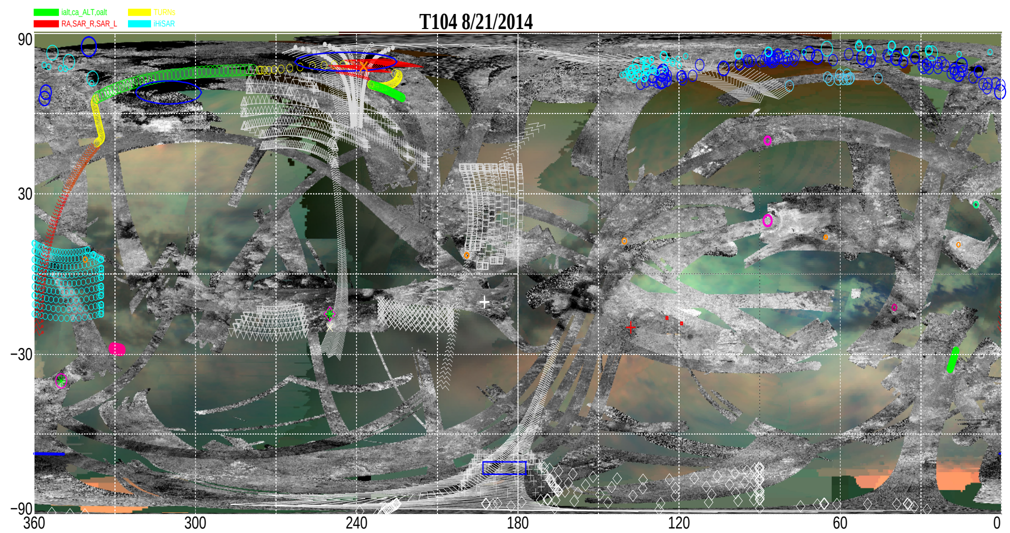

Figure 1: Coverage areas overlaid on Titan map showing prior optical and radar imaging.

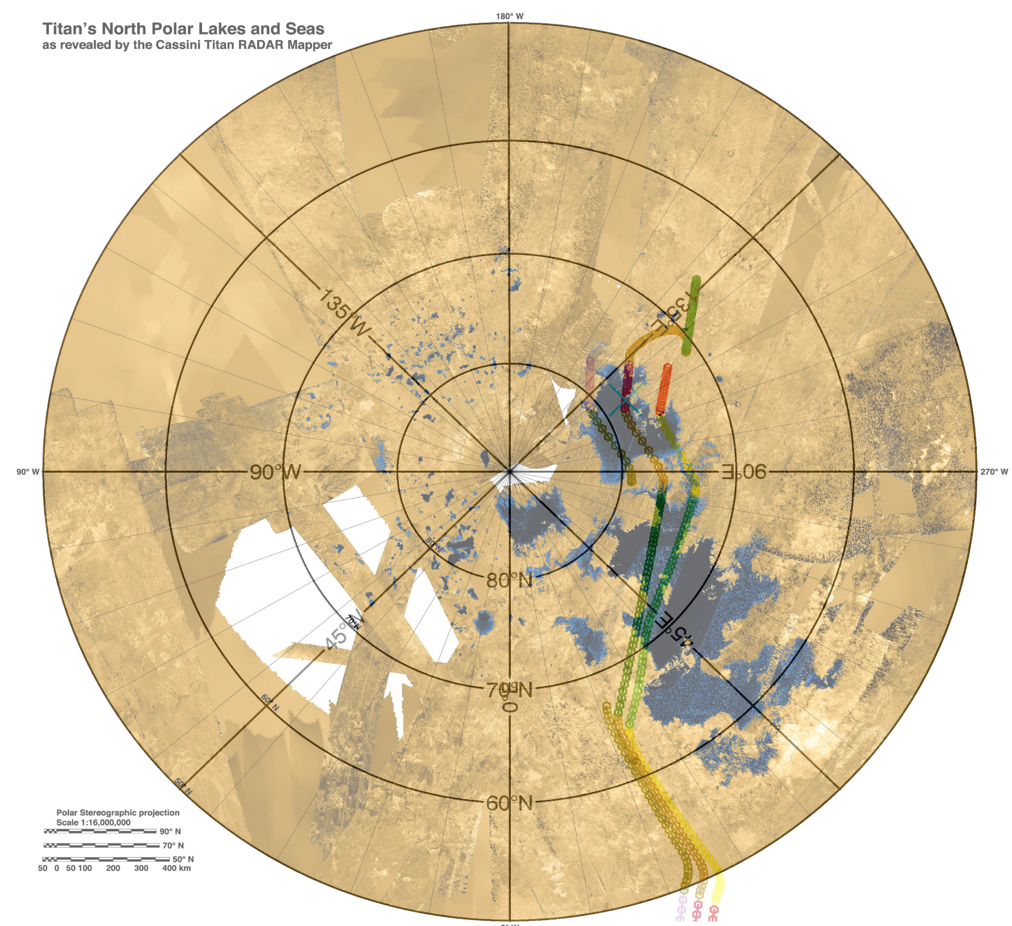

Figure 2: Coverage areas overlaid on polar stereographic Titan map showing prior optical and radar imaging.

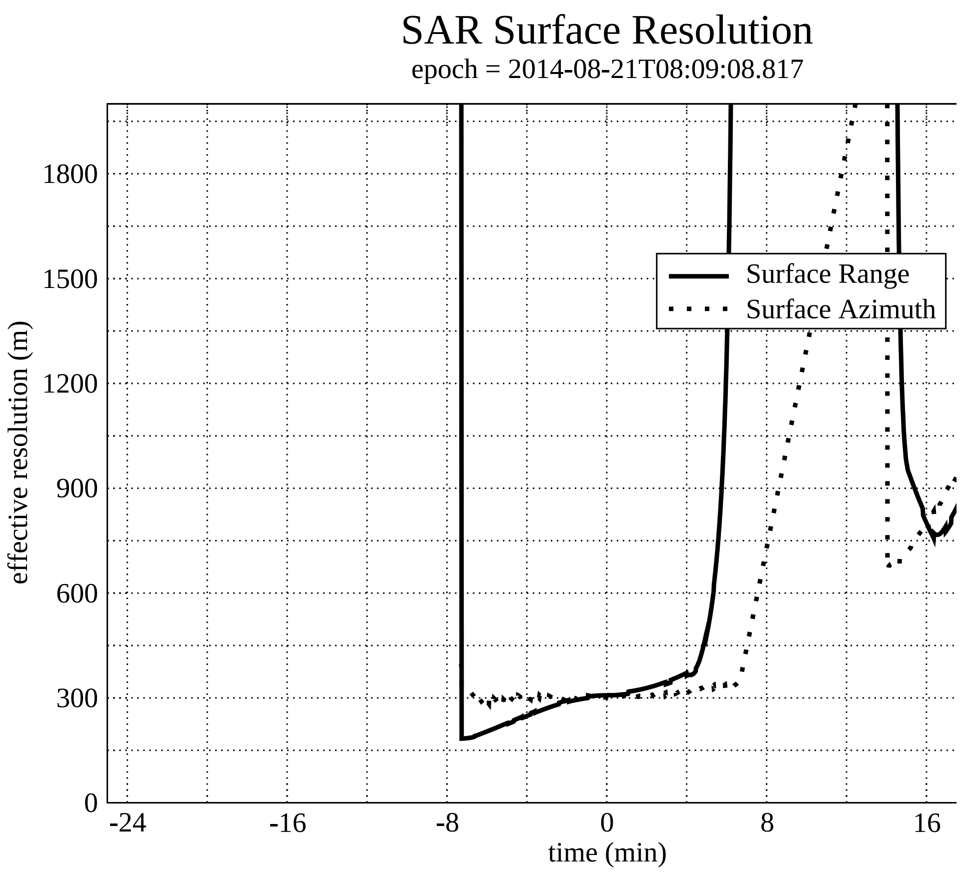

Figure 3: SAR projected range and azimuth resolution. These values are computed from the IEB parameters and are not related to the pixel size in the BIDR file. The pixel size was selected to be always smaller than the real resolution.

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.

5 Revision History

1. Jun 16, 2015: 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