RADAR Titan Flyby during S95/T121

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- Sequence: s95
- Rev: 238
- Observation Id: t121
- Target Body: Titan
- Data Take Number: 277
- PDT Config File: S95_sip_port3_160511_pdt.cfg
- SMT File: s95_20160511.smt
- PEF File: z0950b.pef

1 Introduction

This memo describes the Cassini RADAR activities for the T121 Titan flyby. This SAR data collection occurs during the S95 sequence of the Saturn Tour. This is a partial radar pass with both left and right looking SAR 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
238TI_T121WRMUP001_RIDER	2016-207T04:58:23	2016-207T08:52:23	03:54:0.0	
238TI_T121IHSAR001_PRIME	2016-207T08:54:23	2016-207T09:28:23	00:34:0.0	
238TI_T121INALT001_PRIME	2016-207T09:28:23	2016-207T09:40:23	00:12:0.0	
238TI_T121IOSAR001_PRIME	2016-207T09:40:23	2016-207T10:16:23	00:36:0.0	
238TI_T121OTALT001_PRIME	2016-207T10:16:23	2016-207T10:28:23	00:12:0.0	
238TI_T121OHSAR001_PRIME	2016-207T10:50:23	2016-207T11:35:23	00:45:0.0	
238TI_T121OTSCT001_PRIME	2016-207T11:35:23	2016-207T12:13:23	00:38:0.0	

Table 1: t121 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	Warmup	-5:00:0.0	04:02:0.0	14.4	Warmup
b	scatterometer_imaging	-0:58:0.0	00:03:30.0	15.8	Outbound scatterometer imaging
c	scatterometer_imaging	-0:54:30.0	00:02:30.0	11.2	Outbound scatterometer imaging
d	scatterometer_imaging	-0:52:0.0	00:05:30.0	24.8	Outbound scatterometer imaging
e	scatterometer_imaging	-0:46:30.0	00:02:30.0	11.2	Outbound scatterometer imaging
f	scatterometer_imaging	-0:44:0.0	00:14:0.0	63.0	Outbound scatterometer imaging
g	standard_altimeter_inbound	-0:30:0.0	00:10:8.0	20.1	Inbound altimetry
h	standard_scatterometer_inbound	-0:19:52.0	00:00:4.0	0.6	Atmospheric Probe with Chirp
i	standard_scatterometer_inbound	-0:19:48.0	00:00:2.0	0.3	Atmospheric Probe with Tone
j	standard_sar_hi	-0:19:46.0	00:01:10.0	3.5	SAR Turn transition transition from scat, beam 3 only
k	standard_sar_hi	-0:18:36.0	00:02:36.0	34.3	Inbound SAR ping-pong
l	standard_sar_hi	-0:16:0.0	00:10:0.0	138.0	Hi-SAR Main Swath
m	standard_sar_hi	-0:06:0.0	00:02:0.0	27.6	Hi-SAR Main Swath
n	standard_sar_hi	-0:04:0.0	00:20:0.0	276.0	Hi-SAR Main Swath
o	standard_sar_hi	00:16:0.0	00:02:0.0	26.4	Outbound SAR ping-pong
p	standard_sar_hi	00:18:0.0	00:01:18.0	3.9	SAR Turn transition, beam 3 only
q	standard_scatterometer_outbound	00:19:18.0	00:00:4.0	0.6	Atmospheric Probe with Tone
r	standard_scatterometer_outbound	00:19:22.0	00:00:2.0	0.3	Atmospheric Probe with Chirp
s	standard_altimeter_outbound	00:19:24.0	00:09:24.0	18.6	Outbound altimetry
t	standard_scatterometer_outbound	00:28:48.0	00:01:24.0	4.2	Outbound scatterometry during turn to scatterometer imaging
u	scatterometer_imaging	00:30:12.0	00:24:0.0	108.0	Outbound scatterometer imaging
v	scatterometer_imaging	00:54:12.0	00:16:48.0	75.6	Outbound scatterometer imaging
w	scatterometer_imaging	01:11:0.0	00:04:30.0	20.2	Outbound scatterometer imaging
x	scatterometer_imaging	01:15:30.0	00:03:0.0	13.5	Outbound scatterometer imaging
y	scatterometer_imaging	01:18:30.0	00:03:30.0	15.8	Outbound scatterometer imaging
z	scatterometer_imaging	01:22:0.0	00:18:0.0	81.0	Outbound scatterometer imaging
lbrace	scatterometer_imaging	01:40:0.0	00:10:0.0	45.0	Outbound scatterometer imaging
vbar	scatterometer_imaging	01:50:0.0	00:02:0.0	9.0	Outbound scatterometer imaging
rbrace	standard_radiometer_outbound	01:52:0.0	00:23:0.0	1.4	Outbound radiometry
Total				1064.1	

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	95590	off target	0.12	off target
b	16995	17505	0.02	487
c	15866	16421	0.02	513
d	15061	15628	0.02	534
e	13294	13933	0.02	588
f	12494	13336	0.02	617
g	8061	8062	0.01	858
h	4976	4976	0.01	1197
i	4956	4956	0.01	1200
j	4947	4947	0.01	1202
k	4607	4723	0.01	1258
l	3868	3947	0.01	1400
m	1512	1550	0.01	2198
n	1224	1328	0.00	2363
o	3868	3947	0.01	1400
p	4434	4545	0.01	1288
q	4810	4810	0.01	1224
r	4830	4830	0.01	1221
s	4839	4839	0.01	1219
t	7688	7793	0.01	888
u	8123	9676	0.01	853
v	15771	16610	0.02	515
w	21200	22511	0.03	411
x	22658	24114	0.03	392
y	23631	25283	0.03	380
z	24766	25775	0.03	367
lbrace	30608	31053	0.04	318
vbar	33856	35200	0.05	298
rbrace	34506	34990	0.05	295

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

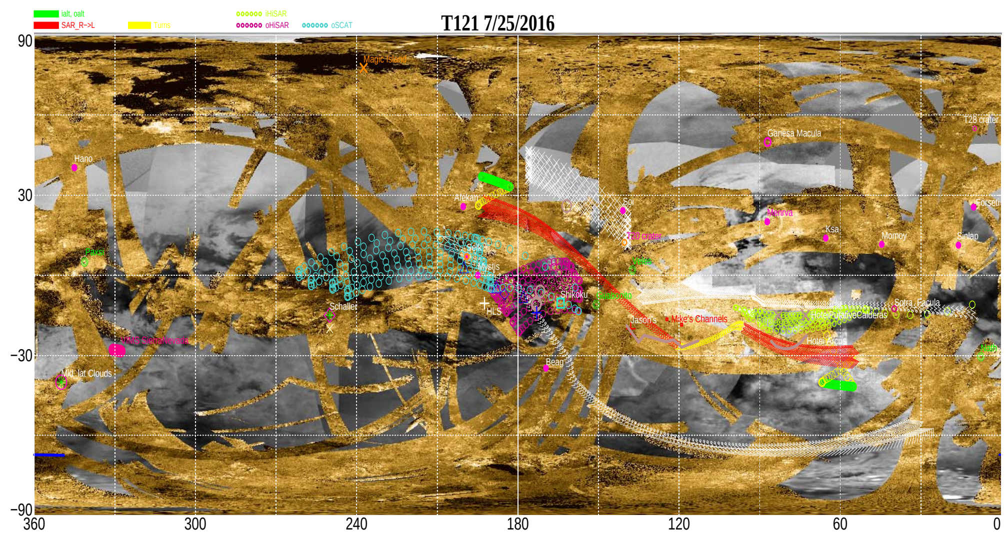

Figure 1: Coverage areas overlaid on Titan map showing prior optical and radar imaging.

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

T121 is a partial pass. The observation starts with inbound high-altitude scatterometer imaging followed by altimetry including atmospheric probe sequences at the end. Following this is the SAR main swath which extends from -18 min to +18 min from closest approach. A turn transition from one side to the other is inserted near close approach to provide more desireable coverage. Another atmospheric probe sequence follows right before the outbound altimetry segment. The observation then concludes with a long high-altitude scatterometer imaging sequence that extends into the time normally used for low resolution scatterometry.

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 T121 data collections on a map of Titan. The red jagged lines show the beam centers of the SAR swath as it sweeps from the southern hemisphere to the northern hemisphere. The lightgreen symbols show the high altitude imaging in the southern hemisphere while the magenta and cyan symbols show the high altitude imaging in the equatorial part of Titan. The darker green symbols show the altimeter tracks.

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 2 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 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 22, 2017: Initial release

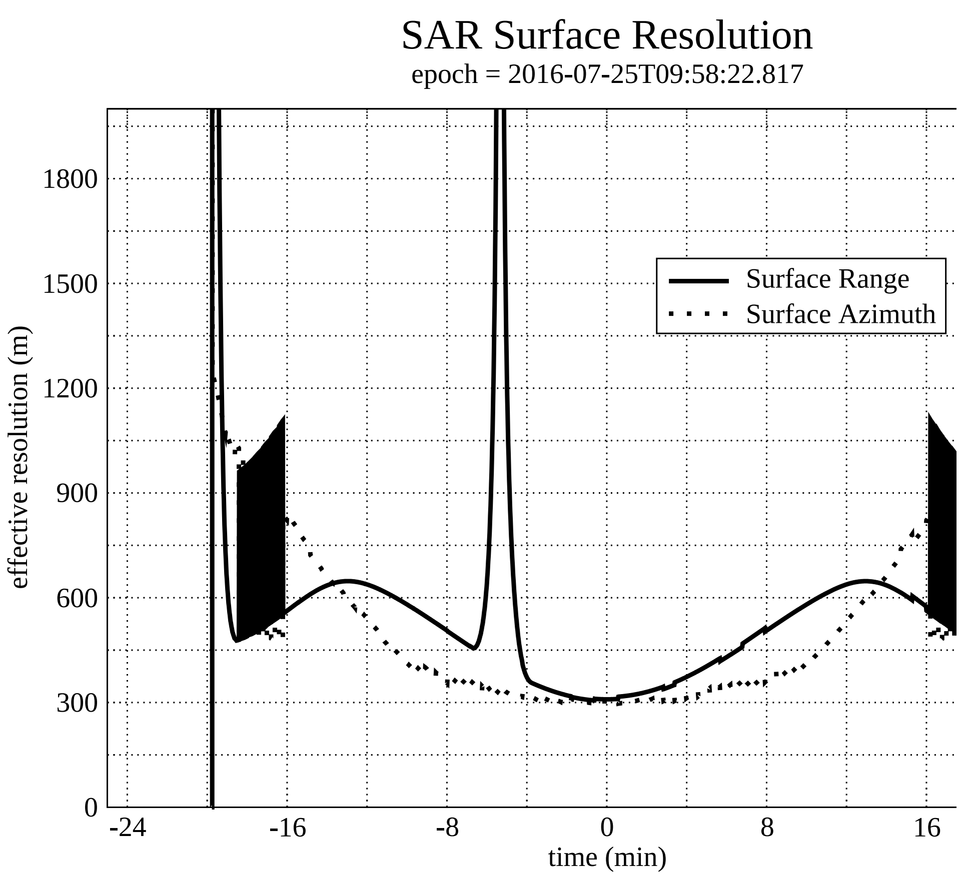

Figure 2: SAR projected range and azimuth resolution. These values are computed from the IEB parameters and are not related to the pixel size in the BIDR file. The pixel size was selected to be always smaller than the real resolution.

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