RADAR Ride-Along Titan Flyby during S24/T18

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- Sequence: s24
- Rev: 029
- Observation Id: t18
- Target Body: Titan
- Data Take Number: 98
- PDT Config File: S24_ssup_psiv1_060725_pdt.cfg
- SMT File: s24_0725_combine_gh.rpt
- PEF File: z0240c.pef

1 Introduction

This memo describes the Cassini RADAR activities for the 8th Titan flyby on which SAR data will be acquired. 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. This ride-along SAR data collection occurs during the s24 sequence of the Saturn Tour. INMS is the prime instrument and their attitude profile keeps the -X axis in the ram (-velocity) direction. The secondary specification doesn't matter to INMS, so radar can ride-along by directing the -Z axis to the normal radar pointing profile. Since this is a secondary specification, the spacecraft will rotate around the X-axis to bring the -Z axis as close as possible to the desired pointing. In practise, this provides usable data for several minutes centered on closest approach. For T18, the time is further constrained by data volume and available time with the beams intercepting the surface. Only SAR data will be acquired in this pass.

2 CIMS and Division Summary

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 throughout 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

CIMS ID	Start	End	Duration	Comments
029OT_WARM4RAS001_RIDER	2006-266T16:54:43	2006-266T18:48:43	01:54:0.0	Warmup for RADAR ride along SAR of Titan with INMS.
029TI_T18RASAR001_INMS	2006-266T18:48:43	2006-266T19:00:43	00:12:0.0	High rate SAR ride along of Titan with INMS.

Table 1: t18 CIMS Request Sequence

Division	Name	Start	Duration	Data Vol	Comments
a	Warmup	-1:55:0.0	01:50:39.0	1.6	Warmup
b	standard_sar_hi	-0:04:21.0	00:08:42.0	124.2	Hi-SAR
c	Closing radiometry	00:04:21.0	00:13:39.0	0.2	Closing radiometry
Total				126.1	

Table 2: Division summary. Data volumes (Mbits) are estimated from maximum data rate and division duration.

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. Subsequent sections will show and discuss the keyword selections made for each division. Each division table shows a set of nominal parameters that are determined by the operating mode (eg., distant scatterometry, SAR low-res inbound). The actual division parameters from the config file are also shown, and any meaningful mismatches are flagged.

3 Warmup and Radiometry

The radar warmup rider begins at 2006-09-23T16:54:43.000 (-02:04:5.8). During the warmup, the IEB will be set to collect 4-second radiometer data on beam 3 as shown in table **??**. Although specified in the IEB, this warmup data will not be returned by the spacecraft because a non-radar telemetry mode will be used for this time.

4 Div B: SAR Imaging

SAR imaging starts at -4.35 minutes and lasts until +4.35 minutes with respect to closest approach. The time range is limited by available data volume at the data rate of Hi-SAR. An alternative would be to use Low-SAR and get twice as many looks. However, the same effect can be achieved by averaging Hi-SAR pixels, so we preserve the option to look at higher resolution data by using Hi-SAR mode. The precise timing of the spacecraft commands that begin and end the radar telemetry mode are uncertain by about 64 seconds. Normally, this uncertainty is taken during warmup or at the beginning of a more extensive radar pass and would not affect the SAR imaging segment. In this ride-along

Div	Alt (km)	Slant range (km)	B3 Size (target dia)	B3 Dop. Spread (Hz)
a	36318	off target	0.05	off target
b	1265	1533	0.00	2368
c	1265	1533	0.00	2368

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

Name	Nominal	Actual	Mismatch	Comments
mode	radiometer	radiometer	no	
start_time (min)	-480.0	-115.0	yes	IEB Trigger time is usually later than this
end_time (min)	-300.0	-4.3	yes	
time_step (s)	2700.0	1800.0	yes	Used by radiometer only modes - saves commands
bem	00100	00100	no	
baq	don't care	5	no	
csr	6	6	no	6 - Radiometer Only Mode
noise_bit_setting	don't care	4.0	no	
dutycycle	don't care	0.38	no	
prf (Hz)	don't care	1000	no	
tro	don't care	0	no	
number_of_pulses	don't care	8	no	
n_bursts_in_flight	don't care	1	no	
percent_of_BW	don't care	100.0	no	
auto_rad	on	on	no	
rip (ms)	34.0	34.0	no	
max_data_rate	0.250	0.248	yes	Kbps - actual data rate may be less
interleave_flag	off	off	no	
interleave_duration (min)	don't care	10.0	no	

Table 4: t18 div_a Warmup block

Name	Nominal	Actual	Mismatch	Comments
mode	sarh	sarh	no	
start_time (min)	-6.0	-4.3	yes	
end_time (min)	6.0	4.3	yes	
time_step (s)	don't care	6.0	no	Set by valid time calculation unless negative, then time_step is used instead
bem	11111	11111	no	
baq	0	0	no	0 - 8 to 2
csr	8	8	no	8 - auto gain
noise_bit_setting	3.0	3.7	yes	
dutycycle	0.70	0.70	no	
prf (Hz)	don't care	5208	no	RMSS follows profile
tro	don't care	0	no	
number_of_pulses	don't care	0	no	RMSS fills round trip time
n_bursts_in_flight	1	1	no	
percent_of_BW	100.0	100.0	no	
auto_rad	off	off	no	Set off for SAR modes to allow minimum burst time
rip (ms)	34.0	34.0	no	Calculated from radiometer calibration for prior observations
max_data_rate	255.000	238.000	yes	8 to 2 reduces max data rate possible
interleave_flag	on	off	yes	
interleave_duration (min)	varies	10.0	no	

Table 5: t18 div_b standard_sar_hi block

observation, there are only 8.7 minutes of SAR, so the precise timing of the telemetry commands will affect the amount of SAR image data collected and the total data volume used. The receive only cal-cycles that are positioned at the beginning and end of active operations may not be captured by the actual data take. If not captured, then we will use an assumed receiver temperature to calibrate the data. A nominal iso-doppler profile is generated and the -Z axis is targetted as the secondary during the ride-along time. -X remains pointing in the ram direction for the prime INMS observation. A single Hi-SAR division (see table **??** covers this time with normal SAR imaging.

4.1 PRF and Incidence Angle Profiles

A fixed PRF of 5.2 KHz is used. Since the spacecraft is not turning to track the target, there is little doppler variation and no need to vary the PRF. Ambiguity performance should be good, however, the number of looks will suffer due to the rapid motion of the beams over the surface. The incidence angle profile (Fig. 1) is optimized for maximum usuable imaging coverage. The Ta profiles were produced for a 950 km flyby which is the most common SAR flyby altitude. The T3 profiles were optimized for a 1500 km flyby. The T17 flyby will be below 1000 km altitude, and the lower altitude profile used at Ta will be used again here. The optimized profile maximizes usable cross-track width while

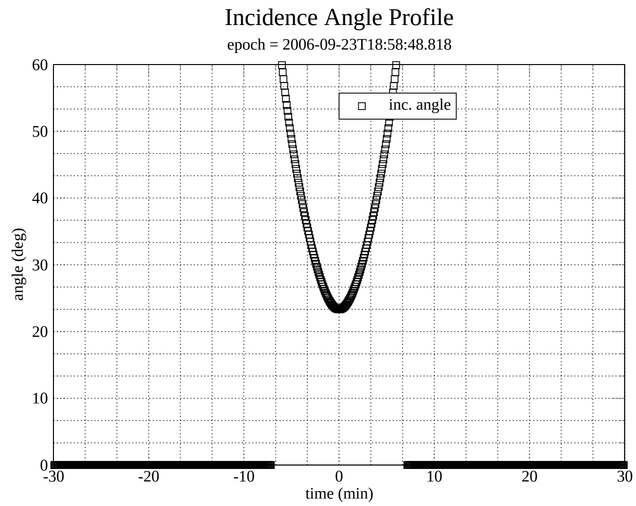

Figure 1: B3 boresight incidence angle during the time around c/a.

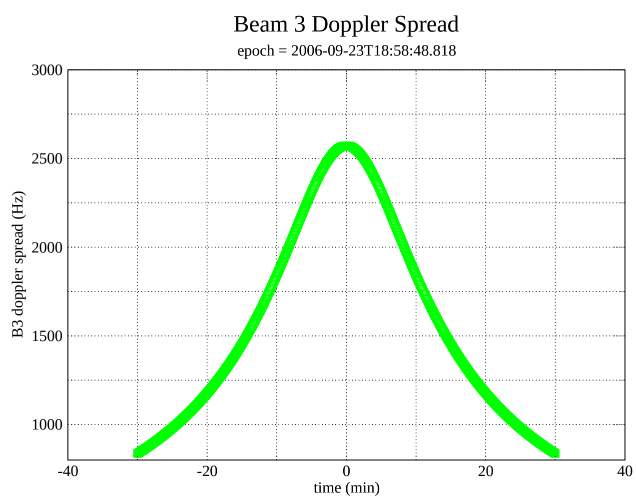

Figure 2: Nadir pointed B3 doppler spread during the time around c/a. Doppler spread is measured within the two-way 3 dB beam pattern.

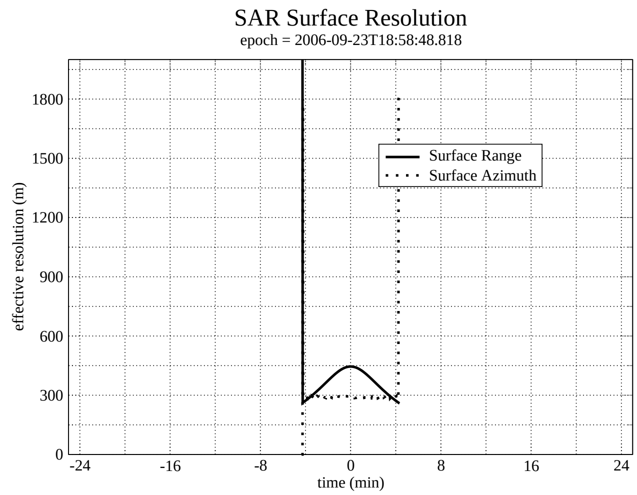

Figure 3: SAR projected range and azimuth resolution. These values are computed from the IEB parameters and are not related to the pixel size in the BIDR file. The pixel size was selected to be always smaller than the real resolution.

avoiding gaps in the imaging swath. The profile is not really followed, so the actual incidence angle will be between 23 and 60 degrees. Unlike some previous SAR imaging passes, this pass will not include any PRF hopping which has not proven necessary.

4.2 SAR Resolution Performance

For all of the SAR divisions the effective resolution can be calculated from the following 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 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 3 shows the results from these equations for the Ta flyby 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.

5 Revision History

1. Aug 22, 2006: Initial release

6 Acronym List

AL	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