RADAR Titan Flyby during S28/T25

R. West

February 7, 2007

- Sequence: s28

- Rev: 039

- Observation Id: t25

- Target Body: Titan

- Data Take Number: 120

- PDT Config File: S28_ssup_psiv1_061212_pdt.cfg

- SMT File: s28_smt_061207_gh.rpt

- PEF File: z0280c.pef

1   Introduction

This memo describes the Cassini RADAR activities for the 13th Titan flyby on which SAR data will be acquired. This SAR data collection occurs during the s28 sequence of the Saturn Tour. This is a full radar pass. The SAR profile is pushbroomed on both ends. 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

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

CIMS ID	Start	End	Duration	Comments
039TI_T25WARMUP001_RIDER	2007-052T19:10:12	2007-052T22:25:12	03:15:0.0	Warmup for T25 in-bound radiometry
039TI_T25INRAD001_PRIME	2007-052T22:22:12	2007-053T01:55:12	03:33:0.0	Inbound radiometry of unique terrain at high latitudes
039TI_T25INSCAT001_PRIME	2007-053T01:55:12	2007-053T02:18:12	00:23:0.0	High latitude scatterometry of unique terrain coverage of Titan.
039TI_TI25INALT001_PRIME	2007-053T02:40:12	2007-053T02:54:12	00:14:0.0	Inbound altimetry of the T25 flyby
039TI_TI25ILSAR001_PRIME	2007-053T02:54:12	2007-053T03:03:12	00:09:0.0	Inbound Low-resolution SAR imaging of the T25 flyby
039TI_TI25HISAR001_PRIME	2007-053T03:03:12	2007-053T03:17:12	00:14:0.0	High resolution SAR imaging during the T25 C/A flyby
039TI_TI25OLSAR001_PRIME	2007-053T03:17:12	2007-053T03:26:12	00:09:0.0	Outbound Low-resolution SAR imaging of the T25 flyby
039TI_TI25OTALT001_PRIME	2007-053T03:26:12	2007-053T03:40:12	00:14:0.0	Outbound altimetry of the T25 flyby
039TI_T25OTSCAT001_PRIME	2007-053T04:04:12	2007-053T04:27:12	00:23:0.0	High latitude scatterometry of unique terrain coverage of Titan.
039TI_T25OUTRAD001_PRIME	2007-053T04:27:12	2007-053T07:59:12	03:32:0.0	Inbound radiometry of unique terrain at high latitudes

Table 1: t25 CIMS Request Sequence

Division	Name	Start	Duration	Data Vol	Comments
a	Warmup	-8:00:0.0	03:02:0.0	2.7	Warmup
b	standard_radiometer_inbound	-4:58:0.0	03:36:12.0	12.9	Inbound radiometry
c	standard_scatterometer_inbound	-1:21:48.0	00:03:18.0	5.9	Inbound scatterometry turn to imaging
d	standard_scatterometer_inbound	-1:18:30.0	00:06:30.0	11.7	Inbound scatterometry turn to imaging
e	scatterometer_imaging	-1:12:0.0	00:17:0.0	83.6	Inbound scatterometer imaging
f	standard_scatterometer_inbound	-0:55:0.0	00:02:42.0	4.9	Inbound scatterometry turn from imaging
g	standard_radiometer_inbound	-0:52:18.0	00:20:18.0	1.2	Inbound nadir pointed radiometry - saves data volume
h	standard_altimeter_inbound	-0:32:0.0	00:13:0.0	23.4	Inbound altimetry
i	standard_sar_hi	-0:19:0.0	00:01:36.0	4.8	Hi-SAR Turn transition, beam 3 only
j	standard_sar_low_inbound	-0:17:24.0	00:00:12.0	2.6	Inbound Low-SAR ping-pong
k	standard_sar_hi	-0:17:12.0	00:00:12.0	2.9	Inbound Hi-SAR ping-pong
l	standard_sar_low_inbound	-0:17:0.0	00:00:12.0	2.6	Inbound Low-SAR ping-pong
m	standard_sar_hi	-0:16:48.0	00:00:12.0	2.9	Inbound Hi-SAR ping-pong
n	standard_sar_low_inbound	-0:16:36.0	00:00:12.0	2.6	Inbound Low-SAR ping-pong
o	standard_sar_hi	-0:16:24.0	00:00:12.0	2.9	Inbound Hi-SAR ping-pong
p	standard_sar_low_inbound	-0:16:12.0	00:00:12.0	2.6	Inbound Low-SAR ping-pong
q	standard_sar_hi	-0:16:0.0	00:00:12.0	2.9	Inbound Hi-SAR ping-pong
r	standard_sar_low_inbound	-0:15:48.0	00:00:12.0	2.6	Inbound Low-SAR ping-pong
s	standard_sar_hi	-0:15:36.0	00:31:36.0	451.2	Hi-SAR main swath
t	standard_sar_low_outbound	00:16:0.0	00:02:0.0	25.8	Outbound Low-SAR
u	standard_sar_hi	00:18:0.0	00:01:48.0	5.4	Hi-SAR turn transition to altimetry, B3 only
v	standard_altimeter_outbound	00:19:48.0	00:10:12.0	18.4	Outbound altimetry
w	standard_radiometer_outbound	00:30:0.0	00:24:12.0	1.4	Outbound nadir pointed radiometry - saves data volume
x	standard_scatterometer_outbound	00:54:12.0	00:01:30.0	2.7	Outbound scatterometry turn to imaging
y	standard_scatterometer_outbound	00:55:42.0	00:01:42.0	3.1	Outbound scatterometry turn to imaging
z	scatterometer_imaging	00:57:24.0	00:16:6.0	79.2	Outbound scatterometer imaging
lbrace	standard_scatterometer_outbound	01:13:30.0	00:01:54.0	3.4	Outbound scatterometry turn from imaging
vbar	standard_scatterometer_outbound	01:15:24.0	00:04:36.0	8.3	Outbound scatterometry turn from imaging
rbrace	standard_radiometer_outbound	01:20:0.0	03:30:0.0	12.5	Outbound radiometry scans
Total		3		786.9	

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	165478	off target	0.21	off target
b	102180	off target	0.13	off target
c	26675	off target	0.04	off target
d	25523	25652	0.04	326
e	23256	24059	0.03	357
f	17340	18020	0.02	471
g	16404	16404	0.02	495
h	9427	9427	0.02	794
i	5136	5136	0.01	1242
j	4634	4741	0.01	1329
k	4572	4676	0.01	1341
l	4510	4611	0.01	1352
m	4449	4546	0.01	1364
n	4387	4481	0.01	1376
o	4326	4416	0.01	1389
p	4265	4352	0.01	1401
q	4204	4287	0.01	1414
r	4143	4224	0.01	1427
s	4083	4160	0.01	1440
t	4204	4287	0.01	1414
u	4821	4937	0.01	1295
v	5390	5390	0.01	1202
w	8751	8751	0.01	842
x	17062	17062	0.02	478
y	17583	17699	0.03	465
z	18173	18792	0.03	451
lbrace	23778	24128	0.03	350
vbar	24440	24570	0.03	341
rbrace	26045	off target	0.04	off target

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	-480.0	no	IEB Trigger time is usually later than this
end_time (min)	-300.0	-298.0	yes	
time_step (s)	2700.0	3600.0	yes	Used by radiometer only modes - saves commands
bem	00100	11111	yes	
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	0.248	0.248	no	Kbps - actual data rate may be less
interleave_flag	off	off	no	
interleave_duration (min)	don't care	10.0	no	

Table 4: t25 Div a Warmup block

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   Special Features of this Pass

T25 has two high altitude imaging segments in place of the usual scatterometry scans. The inbound imaging segment consists of two north-south oriented scan lines that cover a feature of interest called the VIMS smile which lies just south of Xanadu. The scan lines extend north and overlap the T13 SAR swath. The outbound imaging segment consists of three scan lines in the north polar area with a little overlap over the T19 SAR swath. The T25 SAR swath is left looking and will overlap with the upcoming T28 SAR swath in the north polar area. The overlap region also will include the T30 altimeter track. These three observations together will provide stereo SAR coverage overlapping an altimeter track in the north polar region where lakes are likely.

4   Warmup and Radiometry

The radar warmup rider begins at 2007-02-21T19:10:12.000 (-08:02:11.8). During the warmup, the IEB will be set to collect 4-second radiometer data on all 5 beams as shown in table 4. Div B covers the inbound radiometry scans with 1-second radiometry.

Name	Nominal	Actual	Mismatch	Comments
mode	radiometer	radiometer	no	
start_time (min)	-300.0	-298.0	yes	
end_time (min)	-120.0	-81.8	yes	
time_step (s)	2700.0	3600.0	yes	Used by radiometer only modes
bem	00100	00100	no	
baq	don't care	5	no	
csr	6	6	no	
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	0.992	0.992	no	
interleave_flag	off	off	no	
interleave_duration (min)	don't care	10.0	no	

Table 5: t25 Div b standard_radiometer_inbound block

5   Div's C-F,X-||: Scatterometry Imaging and Sweeps

In T25, both the inbound and outbound scatterometer raster scans were modified for high-altitude imaging. These imaging segments push the limits more than prior high altitude imaging segments performed in T15 and T19 and cover more area.

The inbound segment starts at -80 minutes with a sweep through nadir to collect some regular low-incidence angle scatterometry. The fast sweep is followed by two scan lines spaced to cover an area below the T13 sar swath and covering part of the VIMS smile. The whole segment is about 25 minutes long and ends at -55 minutes with a turn to nadir pointed altimetry. Div's C and D shown in table 6 provide regular 8-pulse scatterometry during the fast sweep through nadir. The attenuation is set to 15 dB initially to prevent saturation at low incidence angles, and then decreased to 9 dB once the incidence angle rises up again. Div E shown in table 7 provides for a high altitude imaging segment with performance characteristics from segment B of the high altitude imaging presentation made at the T13 science team meeting (see high altitude imaging memo and presentation on radar web page under CRST meetings). Div F also shown in table 6 then provides more regular scatterometry during the turn back to nadir for altimetry, again using 15 dB of attenuation. The outbound segment is similar, starting at 55 minutes and ending at about 76 minutes from c/a. The turn from nadir is covered by Div's X and Y shown in table 8 which step the attenuator from 15 dB to 9 dB to avoid saturation at low incidence angles. Div Z shown in table 9 covers the imaging segment which consists of three scan lines that cover a region next to the T19 swath in the north polar area. This area will not be imaged otherwise during the Tour. Div's { and || shown in table 10 cover the final sweep through nadir before starting the radiometry scans. This sweep again provides low incidence angle regular 8-pulse scatterometry.

The imaging divisions (E,Z) 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 about 2.0 km by 2.5 km.

Name	Nominal	c	d	f	Mismatch	Comments
mode	scatterometer	scatterometer	scatterometer	scatterometer	no	
start_time (min)	varies	-81.8	-78.5	-55.0	no	
end_time (min)	varies	-78.5	-72.0	-52.3	no	
time_step (s)	don't care	8.0	8.0	8.0	no	Set by valid time calculation
bem	00100	00100	00100	00100	no	
baq	5	5	5	5	no	5 - 8 bits straight
csr	0	0	0	0	no	0 - No auto-gain, fixed attenuator set to avoid clipping
noise_bit_setting	4.0	3.0	4.0	3.0	yes	15 dB attenuator
dutycycle	0.70	0.70	0.70	0.70	no	
prf (Hz)	1200	1200	1200	1200	no	
tro	6	6	6	6	no	
number_of_pulses	8	8	8	8	no	
n_bursts_in_flight	1	1	1	1	no	
percent_of_BW	100.0	100.0	100.0	100.0	no	
auto_rad	on	on	on	on	no	
rip (ms)	34.0	34.0	34.0	34.0	no	
max_data_rate	30.000	30.000	30.000	30.000	no	
interleave_flag	off	off	off	off	no	
interleave_duration (min)	don't care	10.0	10.0	10.0	no	

Table 6: t25 Div cdf standard_scatterometer_inbound block
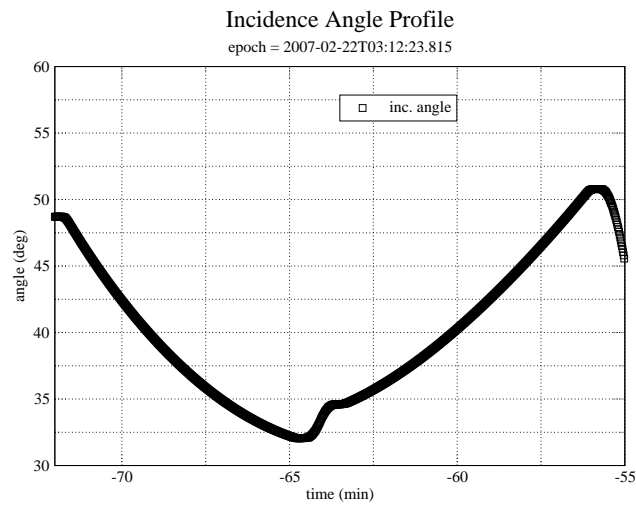
Figure 1: Incidence angle variation during Div E

Name	Nominal	Actual	Mismatch	Comments
mode	scatterometer	scatterometer	no	
start_time (min)	varies	-72.0	no	
end_time (min)	varies	-55.0	no	
time_step (s)	varies	12.0	no	
bem	00100	00100	no	
baq	0	0	no	8-2 used to increase looks and duty cycle - hence SNR
csr	0	0	no	0 - fixed attenuator
noise_bit_setting	4.0	4.0	no	9 dB attenuator
dutycycle	0.35	0.35	no	
prf (Hz)	1000	1000	no	1000 Hz is typical, set to balance range/doppler ambiguities
tro	6	6	no	
number_of_pulses	100	100	no	100 is typical, set to fill echo buffer/round trip time
n_bursts_in_flight	1	1	no	
percent_of_BW	100.0	100.0	no	
auto_rad	on	on	no	
rip (ms)	34.0	34.0	no	
max_data_rate	82.000	82.000	no	82 is typical, set to use available data volume
interleave_flag	off	off	no	
interleave_duration (min)	don't care	10.0	no	

Table 7: t25 Div e scatterometer_imaging block

Name	Nominal	x	y	Mismatch	Comments
mode	scatterometer	scatterometer	scatterometer	no	
start_time (min)	varies	54.2	55.7	no	
end_time (min)	varies	55.7	57.4	no	
time_step (s)	don't care	8.0	8.0	no	Set by valid time calculation
bem	00100	00100	00100	no	
baq	5	5	5	no	5 - 8 bits straight
csr	0	0	0	no	0 - No auto-gain, fixed attenuator set to avoid clipping
noise_bit_setting	4.0	3.0	4.0	yes	15 dB attenuator
dutycycle	0.70	0.70	0.70	no	
prf (Hz)	1200	1200	1200	no	
tro	6	6	6	no	
number_of_pulses	8	8	8	no	
n_bursts_in_flight	1	1	1	no	
percent_of_BW	100.0	100.0	100.0	no	
auto_rad	on	on	on	no	
rip (ms)	34.0	34.0	34.0	no	
max_data_rate	30.000	30.000	30.000	no	
interleave_flag	off	off	off	no	
interleave_duration (min)	don't care	10.0	10.0	no	

Table 8: t25 Div xy standard_scatterometer_outbound block
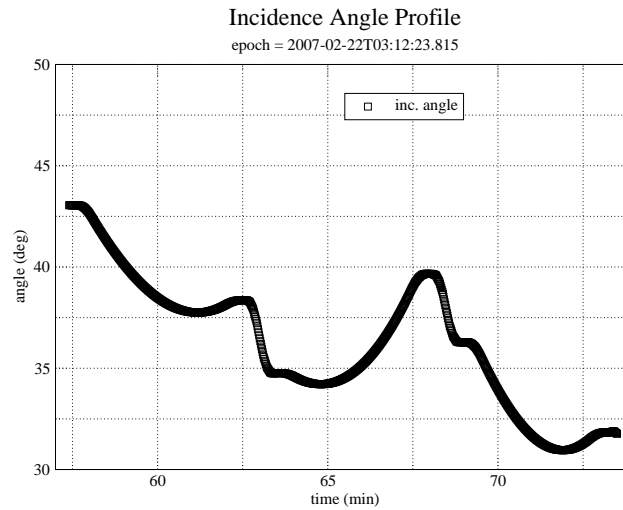
Figure 2: Incidence angle variation during Div Z

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Name	Nominal	Actual	Mismatch	Comments
mode	scatterometer	scatterometer	no	
start_time (min)	varies	57.4	no	
end_time (min)	varies	73.5	no	
time_step (s)	varies	12.0	no	
bem	00100	00100	no	
baq	0	0	no	8-2 used to increase looks and duty cycle - hence SNR
csr	0	0	no	0 - fixed attenuator
noise_bit_setting	4.0	4.0	no	9 dB attenuator
dutycycle	0.35	0.35	no	
prf (Hz)	1000	1000	no	1000 Hz is typical, set to balance range/doppler ambiguities
tro	6	6	no	
number_of_pulses	100	100	no	100 is typical, set to fill echo buffer/round trip time
n_bursts_in_flight	1	1	no	
percent_of_BW	100.0	100.0	no	
auto_rad	on	on	no	
rip (ms)	34.0	34.0	no	
max_data_rate	82.000	82.000	no	82 is typical, set to use available data volume
interleave_flag	off	off	no	
interleave_duration (min)	don't care	10.0	no	

Table 9: t25 Div z scatterometer_imaging block

Name	Nominal	lbrace	vbar	Mismatch	Comments
mode	scatterometer	scatterometer	scatterometer	no	
start_time (min)	varies	73.5	75.4	no	
end_time (min)	varies	75.4	80.0	no	
time_step (s)	don't care	8.0	6.0	no	Set by valid time calculation
bem	00100	00100	00100	no	
baq	5	5	5	no	5 - 8 bits straight
csr	0	0	0	no	0 - No auto-gain, fixed attenuator set to avoid clipping
noise_bit_setting	4.0	3.0	4.0	yes	15 dB attenuator
dutycycle	0.70	0.70	0.70	no	
prf (Hz)	1200	1200	1200	no	
tro	6	6	6	no	
number_of_pulses	8	8	8	no	
n_bursts_in_flight	1	1	1	no	
percent_of_BW	100.0	100.0	100.0	no	
auto_rad	on	on	on	no	
rip (ms)	34.0	34.0	34.0	no	
max_data_rate	30.000	30.000	30.000	no	
interleave_flag	off	off	off	no	
interleave_duration (min)	don't care	10.0	10.0	no	

Table 10: t25 Div lbracevbar standard_scatterometer_outbound block

5.1 PRF and Incidence Angle Choices

Incidence angle variation during the two imaging segments is moderate with higher values than used in normal SAR imaging. (see Figs. 1, 2) The PRF value is set to 1 KHz with a pulse duty cycle of 0.35 in the imaging divisions. This PRF provides for a reasonable balance between range and doppler ambiguities throughout the imaging rasters. Pixel structure is good because both of these imaging segments are positioned close to the iso-doppler point where iso-range and iso-doppler lines are nearly orthogonal. For more technical details on range and doppler ambiguities, refer to the discussion in the T19 sequence design memo.

5.2 SAR-style Scatterometer Resolution Performance

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

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

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

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 division E and figure 4 shows the results for division Z. The calculations are performed for the boresight of beam 3 which is the center of the swath.
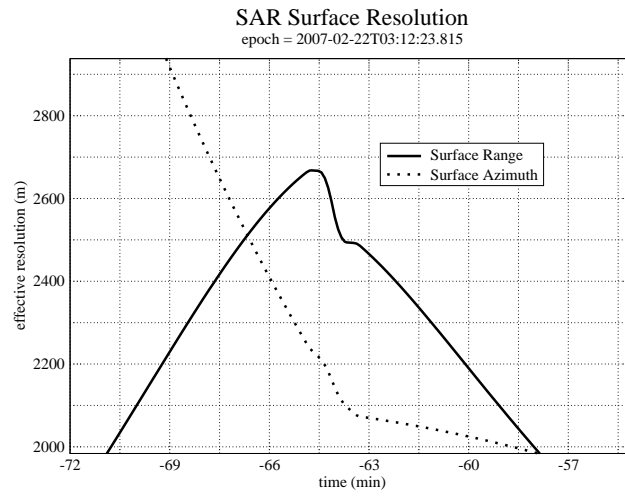
Figure 3: Div E: Projected range and azimuth resolution. These values are computed from the IEB parameters.
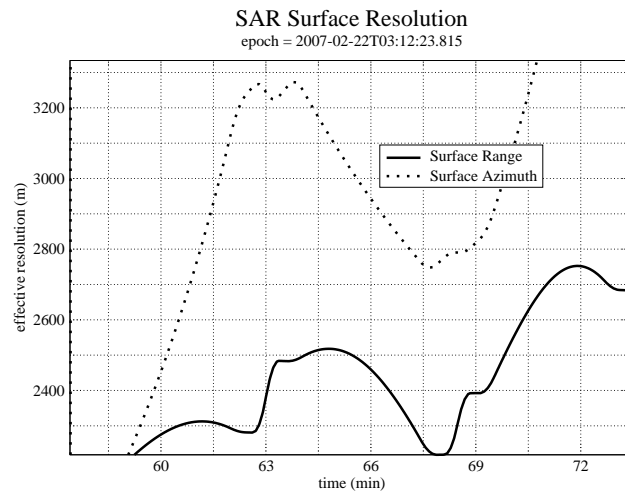

Figure 4: Div Z: Projected range and azimuth resolution. These values are computed from the IEB parameters.
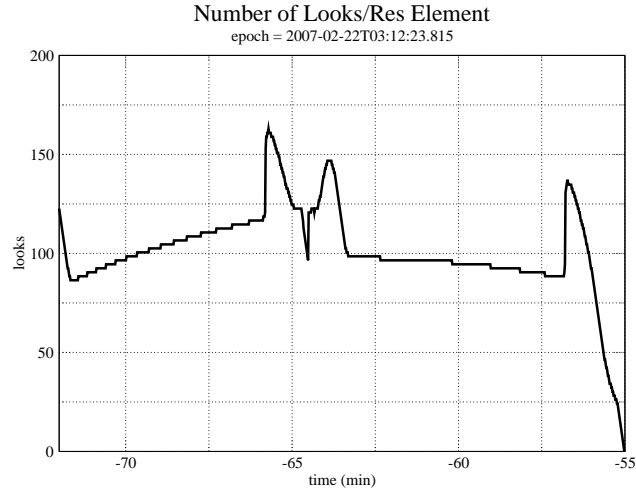
Figure 5: Div E: Number of looks. These values are computed from the IEB parameters.

5.3 SNR and Looks

In scatterometer mode the noise equivalent σ_0 for beam 3 will be generally better than -10 dB in these imaging segments. The number of looks in the inbound segment will be around 100, while in the outbound segment it will be around 60. Looks have been sacrificed in these segments to obtain more coverage area. 8-2 BAQ is used to get more looks out of available data volume.

The resolution of this observation has been improved at the expense of SNR by reducing the pulse duty cycle below 70%, and then increasing the number of pulses until the round trip time or the science data buffer is filled. The ESS limit on the number of pulses also has reduced the duty cycle to permit filling the round trip time or buffer.

During the regular 8-pulse scatterometry divisions the IEB instructions for the scatterometry scans are generated by RMSS under the control of the set of config parameters shown in table 6. Scatterometer mode operations use a transmit-receive window offset (TRO) of 6 which makes the echo window 6 PRI's longer than the number of pulses transmitted. This is done to increase the valid time for an instruction by letting the pulse echos walk through the longer echo window before the range-gate needs to be updated. This is particularly important during Titan scatterometry raster scans where the number of instructions needed to track the varying range can exceed the number available if a smaller TRO value is used. The positive TRO value also guarantees noise-only data in each burst which eliminates the need to insert special noise-only bursts. The PRF of 1.2 KHz is high enough to cover the doppler spread within beam 3, so doppler sharpening could be performed.

To reduce the chance of clipping (saturating) the scatterometry data, a 15 dB attenuator setting is used during the turns across nadir which result in low incidence angles. During the imaging rasters the incidence angle is always higher than 30 degrees, so the 9 dB attenuator setting is used.

6 Div's G,W: Nadir pointed Radiometry

The spacecraft performs a transition from momentum wheel to thruster attitude control at higher ranges just outside of the altimeter segments. During this time, the -Z axis (high gain antenna axis) is pointed at nadir. Normally we take advantage of this time to collect some bonus altimetry albeit at higher altitudes and with slower along track movement. In this flyby, there is not enough data volume allocated to radar to cover the two high-altitude scatterometery imaging segments and also do this bonus altimeter data collection. Therefore, we have sacrificed the bonus altimeter time and instead collect just radiometry at a very low data rate (1 Kbps). The nadir pointed radiometry is still potentially useful for modelling the surface. Table 11 shows the usual radiometer parameters used.
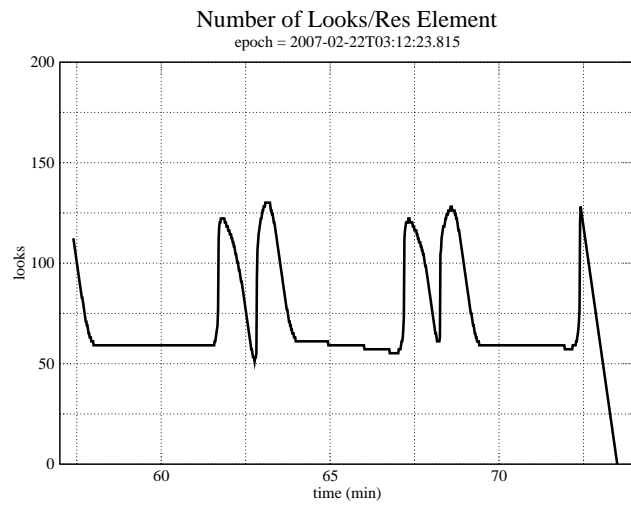
Figure 6: Div Z: Number of looks. These values are computed from the IEB parameters.
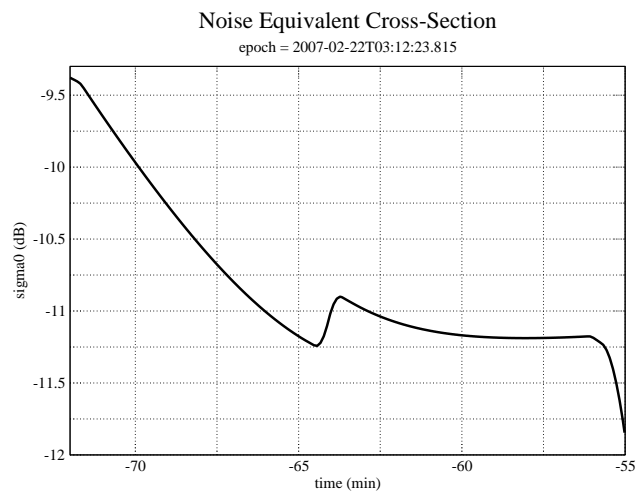

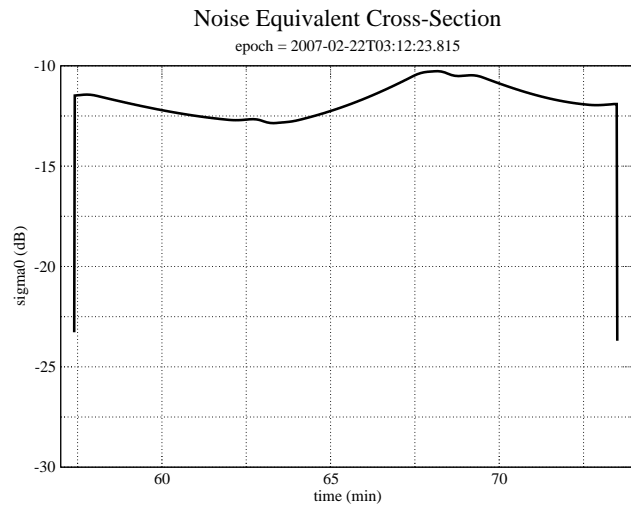Figure 7: Div E: Noise equivalent σ_0. These values are computed from the IEB parameters.

Noise Equivalent Cross-Section

epoch = 2007-02-22T03:12:23.815

Figure 8: Div Z: Noise equivalent σ_0. These values are computed from the IEB parameters.

Pointing in Target Body-fixed Coordinates
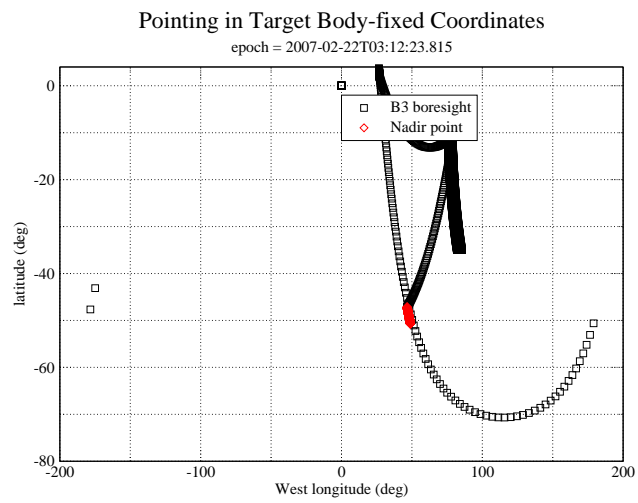
epoch = 2007-02-22T03:12:23.815

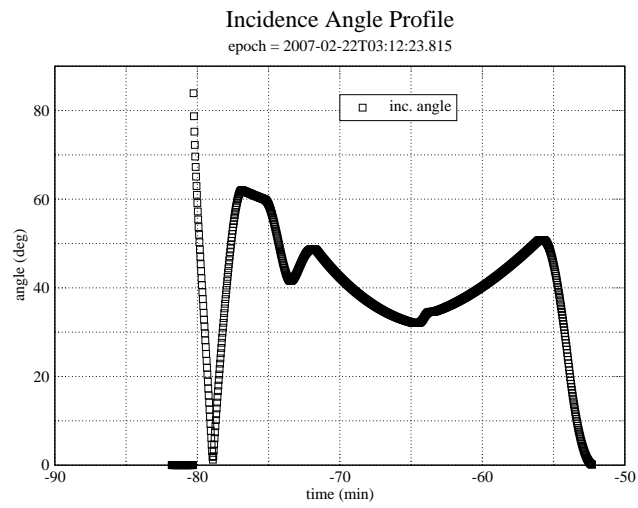Figure 9: Inbound Scatterometry scan in target body-fixed coordinates

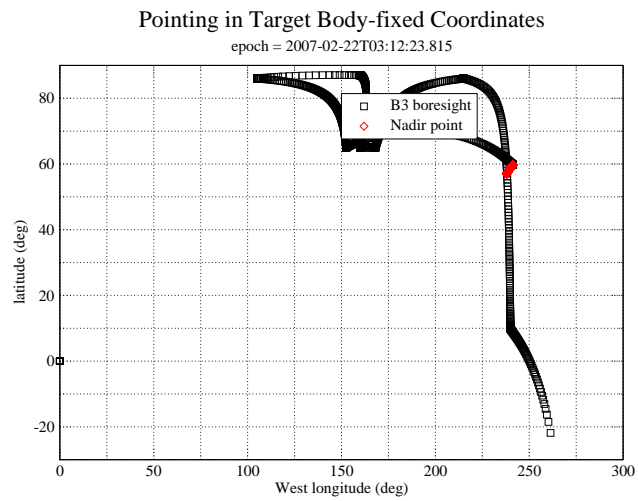Figure 10: Inbound Incidence angle variation during inbound scatterometry

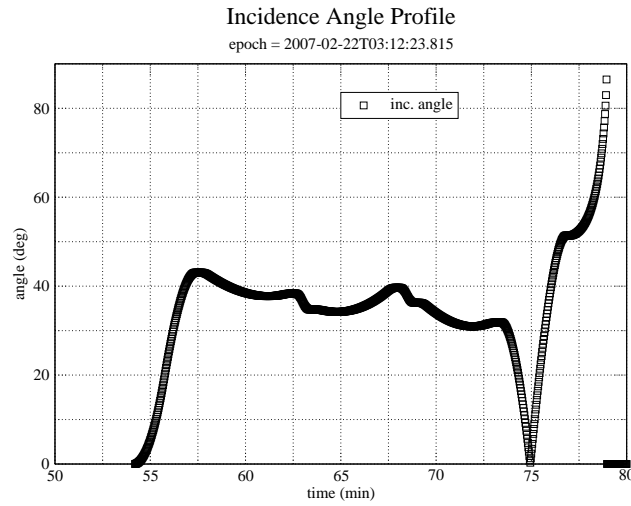Figure 11: Outbound Scatterometry in target body-fixed coordinates

Incidence Angle Profile

epoch = 2007-02-22T03:12:23.815

Figure 12: Outbound Incidence angle variation during scatterometry

Name	Nominal	g	w	Mismatch	Comments
mode	radiometer	radiometer	radiometer	no	
start_time (min)	-300.0	-52.3	30.0	yes	
end_time (min)	-120.0	-32.0	54.2	yes	
time_step (s)	2700.0	360.0	360.0	yes	Used by radiometer only modes
bem	00100	00100	00100	no	
baq	don't care	5	5	no	
csr	6	6	6	no	
noise_bit_setting	don't care	4.0	4.0	no	
dutycycle	don't care	0.38	0.38	no	
prf (Hz)	don't care	1000	1000	no	
tro	don't care	0	0	no	
number_of_pulses	don't care	8	8	no	
n_bursts_in_flight	don't care	1	1	no	
percent_of_BW	don't care	100.0	100.0	no	
auto_rad	on	on	on	no	
rip (ms)	34.0	34.0	34.0	no	
max_data_rate	0.992	0.992	0.992	no	
interleave_flag	off	off	off	no	
interleave_duration (min)	don't care	10.0	10.0	no	

Table 11: t25 Div gw standard_radiometer_inbound block

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Name	Nominal	h	v	Mismatch	Comments
mode	altimeter	altimeter	altimeter	no	
start_time (min)	-30.0	-32.0	19.8	yes	
end_time (min)	-19.0	-19.0	30.0	yes	
time_step (s)	don't care	10.0	10.0	no	Set by valid time calculation
bem	00100	00100	00100	no	
baq	7	7	7	no	7 - 8 to 4
csr	8	8	8	no	8 - auto gain
noise_bit_setting	2.3	2.3	2.3	no	
dutycycle	0.73	0.73	0.73	no	
prf (Hz)	5000	5000	5000	no	
tro	don't care	-6	-6	no	auto set to -6 except interleaved bursts where +6 is used
number_of_pulses	21	21	21	no	
n_bursts_in_flight	1	1	1	no	
percent_of_BW	100.0	100.0	100.0	no	
auto_rad	on	on	on	no	
rip (ms)	34.0	34.0	34.0	no	
max_data_rate	30.000	30.000	30.000	no	
interleave_flag	on	on	on	no	
interleave_duration (min)	varies	8.0	5.0	no	

Table 12: t25 Div hv standard_altimeter_inbound block

7 Div's H,V: Altimetry

The parameters used by the main altimeter segments are shown in table 12. Note that the pulse duty cycle has been increased back to 73% to maximize SNR. Lower pulse duty cycles were used on some previous flyby's to provide more echo separation, but this has been found to be unnecessary.

8 Div's I-U: SAR Imaging

Div's I and U cover the turn transitions with beam 3 only imaging. The data rate has been reduced to 50 Kbps to conserve data volume. This should still provide enough looks during the turn transition because only one beam is used. The SAR swath is pushbroomed at both ends. Div's J-R ping-pong back and forth every 12 seconds between Hi-SAR and Low-SAR with overlapping pixels. This provides a small increase in image quality since the two modes provide rectangular pixels with the short side in different directions. Div S covers the 32 minutes centered on closest approach. Hi-SAR is used throughout to obtain the best resolution possible. At +16 minutes, range and azimuth resolution and SNR favor Low-SAR and the instrument switches to this mode in div T. Targetting of the outbound pushbroom profile ends at +18 minutes. Table 13 shows the standard Hi-SAR divisions, table 14 shows two representative Low/Hi-SAR ping pong divisions, and table 15 shows the B3 only Hi-SAR divisions at the ends. The left look option is selected here to produce a swath that will overlap extensively with the planned T28 swath (also left look) and with the T30 inbound altimeter track. These three observations together will provide stereo SAR coverage overlapping an altimeter track in the north polar region where lakes are likely.

8.1 PRF and Incidence Angle Profiles

The PRF profile and incidence angle profile (Fig. 13) are 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

Name	Nominal	Actual	Mismatch	Comments
mode	sarh	sarh	no	
start_time (min)	-6.0	-15.6	yes	
end_time (min)	6.0	16.0	yes	
time_step (s)	don't care	10.0	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	3.4	yes	
dutycycle	0.70	0.70	no	
prf (Hz)	don't care	0	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	98.0	yes	
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 13: t25 Div s standard_sar_hi block

Name	Nominal	j	k	Mismatch	Comments
mode	sarl	sarl	sarh	yes	
start_time (min)	-19.0	-17.4	-17.2	yes	
end_time (min)	-6.0	-17.2	-17.0	yes	
time_step (s)	don't care	6.0	6.0	no	Set by valid time calculation
bem	11111	11111	11111	no	
baq	0	0	0	no	0 - 8 to 2
csr	8	0	0	yes	8 - auto gain
noise_bit_setting	3.0	2.9	3.4	yes	
dutycycle	0.70	0.70	0.70	no	
prf (Hz)	don't care	0	0	no	RMSS follows profile
tro	don't care	0	0	no	
number_of_pulses	don't care	0	0	no	RMSS fills round trip time
n_bursts_in_flight	1	1	1	no	
percent_of_BW	100.0	100.0	100.0	no	
auto_rad	on	off	off	yes	
rip (ms)	34.0	34.0	34.0	no	
max_data_rate	255.000	215.000	238.000	yes	8 to 2 reduces max data rate possible
interleave_flag	on	off	off	yes	
interleave_duration (min)	varies	10.0	10.0	no	

Table 14: t25 Div jk standard_sar_low_inbound block
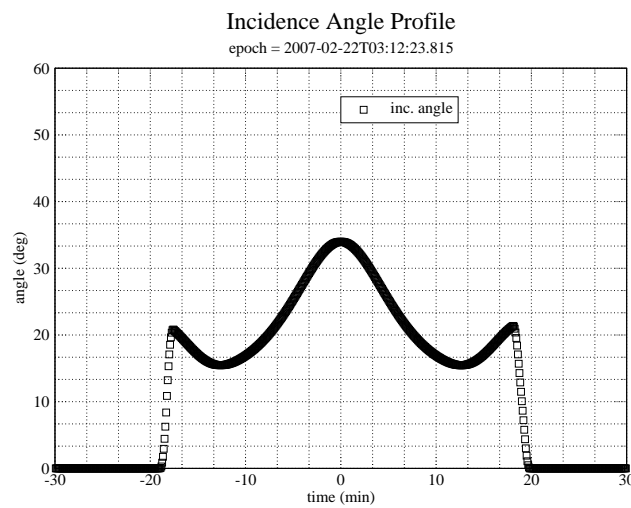
Figure 13: B3 boresight incidence angle during the time around c/a.

| Name	Nominal	i	u	Mismatch	Comments
mode	sarh	sarh	sarh	no	
start_time (min)	-6.0	-19.0	18.0	yes	
end_time (min)	6.0	-17.4	19.8	yes	
time_step (s)	don't care	6.0	6.0	no	Set by valid time calculation unless negative, then time_step is used instead
bem	11111	00100	00100	yes	
baq	0	0	0	no	0 - 8 to 2
csr	8	8	8	no	8 - auto gain
noise_bit_setting	3.0	3.4	3.4	yes	
dutycycle	0.70	0.70	0.70	no	
prf (Hz)	don't care	0	0	no	RMSS follows profile
tro	don't care	0	0	no	
number_of_pulses	don't care	0	0	no	RMSS fills round trip time
n_bursts_in_flight	1	1	1	no	
percent_of_BW	100.0	100.0	100.0	no	
auto_rad	off	off	off	no	Set off for SAR modes to allow minimum burst time
rip (ms)	34.0	34.0	34.0	no	Calculated from radiometer calibration for prior observations
max_data_rate	255.000	50.000	50.000	yes	8 to 2 reduces max data rate possible
interleave_flag	on	off	off	yes	
interleave_duration (min)	varies	10.0	12.0	no	

Table 15: t25 Div iu standard_sar_hi block
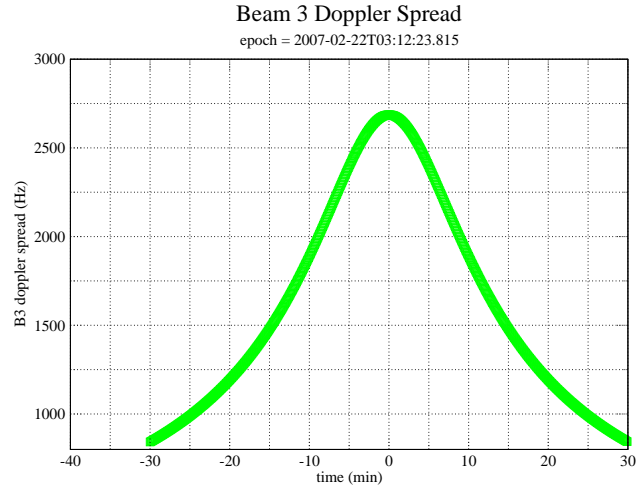
Figure 14: Nadir pointed B3 doppler spread during the time around c/a. Doppler spread is measured within the two-way 3 dB beam pattern.

optimized for a 1500 km flyby. The T25 flyby will be at 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 avoiding gaps in the imaging swath. Unlike some previous SAR imaging passes, this pass will not include any PRF hopping which has not proven necessary.

8.2 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 15 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.

9 Radiometry: Div's B,}

The inbound and outbound radiometry scans both have twin scans with two different polarizations. Their parameters are shown in table 16

10 Revision History
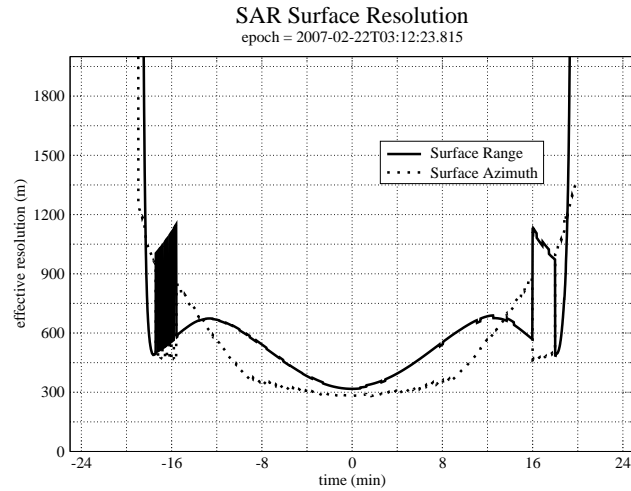
1. Feb 7, 2007: Initial release

Figure 15: 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.

Name	Nominal	b	rbrace	Mismatch	Comments
mode	radiometer	radiometer	radiometer	no	
start_time (min)	-300.0	-298.0	80.0	yes	
end_time (min)	-120.0	-81.8	290.0	yes	
time_step (s)	2700.0	3600.0	2700.0	yes	Used by radiometer only modes
bem	00100	00100	00100	no	
baq	don't care	5	5	no	
csr	6	6	6	no	
noise_bit_setting	don't care	4.0	4.0	no	
dutycycle	don't care	0.38	0.38	no	
prf (Hz)	don't care	1000	1000	no	
tro	don't care	0	0	no	
number_of_pulses	don't care	8	8	no	
n_bursts_in_flight	don't care	1	1	no	
percent_of_BW	don't care	100.0	100.0	no	
auto_rad	on	on	on	no	
rip (ms)	34.0	34.0	34.0	no	
max_data_rate	0.992	0.992	0.992	no	
interleave_flag	off	off	off	no	
interleave_duration (min)	don't care	10.0	10.0	no	

Table 16: t25 Div brbrace standard_radiometer_inbound block

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11 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