RADAR Titan Flyby during S08/T3

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November 24, 2004

- Sequence: s08
- Rev: 003
- Observation Id: t3
- Target Body: Titan
- Data Take Number: 30
- PDT Config File: S08_ssup_psiv1_041111_pdt.cfg
- SMT File: s08_ssup_2004-11-11.rpt
- PEF File: z0080c_full.pef

1 Introduction

This memo describes the Cassini RADAR activities for the second Titan flyby on which SAR data will be acquired. The second SAR data collection occurs during the s08 sequence of the Saturn Tour. 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 SAR data collection was added to the Tour plan after a trajectory change was made which altered the science plan. The timeline will include SAR imaging, altimetry, and an outbound scatterometry scan on thrusters, but no radiometry only scans. Based on early results from the Ta flyby which show stronger than expected backscatter, the normal SAR swath will be extended to 20 minutes on either side of closest approach.

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
003TI_T3WARMUP001_RIDER	2005-046T02:12:53	2005-046T06:19:53	04:07:0.0	Collect altimetry data while maintaining nadir pointing.
003TI_T3INLSAR001_PRIME	2005-046T06:37:53	2005-046T06:50:53	00:13:0.0	Low Resolution Synthetic Aperture RADAR (SAR) Imaging.
003TI_T3HISAR001_PRIME	2005-046T06:50:53	2005-046T07:04:53	00:14:0.0	High Resolution Synthetic Aperture RADAR (SAR) Imaging.
003TI_T3OTLSAR001_PRIME	2005-046T07:04:53	2005-046T07:17:53	00:13:0.0	Low Resolution Synthetic Aperture RADAR (SAR) Imaging.
003TI_T3OUTALT001_PRIME	2005-046T07:17:53	2005-046T07:29:53	00:12:0.0	Altimetry taken during the outbound trajectory of T3
003TI_T3OUTSCAT001_PRIME	2005-046T07:29:53	2005-046T08:07:53	00:38:0.0	Outbound Scatterometry during Ta flyby

Table 1: t3 CIMS Request Sequence

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

The radar warmup rider begins at 2005-02-15T02:12:53.000 (-04:44:59.8) and RADAR will collect 15 minutes of data after turn on. The rest of the warmup time is a rider while the ORS instruments collect data. During the warmup, the IEB will be set for slow speed radiometer only data as shown in table 4.

4 Div's B,H: Standard Altimeter

From -0:31:0.0 to -0:21:30.0, and from 00:21:0.0 to 00:32:30.0, the instrument will operate in Altimeter mode. The division keywords are shown in Table 5 The altimeter track is also targeted by an ISS observation for later comparison.

There is an issue with the pointing accuracy for altimetry. Nominally, the beam 3 boresight should be pointed at the nadir point to within a fraction of one beamwidth. However, the project predicts that pointing near Titan closest approach will not be that accurate. The problem is most acute for Ta which has the highest uncertainties in the position of Titan. Examination of the altimeter pointing in Ta using the reconstructed ckernel and a preliminary reconstructed ephemeris shows that the beam 3 boresight wandered around the edge of the two-way beam pattern (see Fig. 1). Later Titan flyby's will have better pointing accuracy. The main problem is the bias rather than the wandering around, so the same 2 mrad thruster pointing deadbands used in Ta should work for T3.

Division	Name	Start	Duration	Data Vol	Comments
a	Warmup	-6:40:0.0	06:09:0.0	5.5	
b	standard_altimeter_inbound	-0:31:0.0	00:09:30.0	17.1	Inbound altimetry over bright-dark transition
c	standard_sar_hi	-0:21:30.0	00:00:30.0	4.5	Inbound Hi-SAR, Beams 3,4,5
d	standard_sar_hi	-0:21:0.0	00:07:0.0	63.0	Inbound Hi-SAR with reduced data rate
e	standard_sar_hi	-0:14:0.0	00:28:0.0	428.4	Hi-SAR at highest data rate possible
f	standard_sar_hi	00:14:0.0	00:06:30.0	58.5	Outbound Hi-SAR with reduced data rate
g	standard_sar_hi	00:20:30.0	00:00:30.0	4.5	Outbound Hi-SAR, Beams 3,4,5
h	standard_altimeter_outbound	00:21:0.0	00:11:30.0	20.7	Outbound altimetry
i	standard_scatterometer_outbound	00:32:30.0	00:31:30.0	56.7	Outbound scatterometer scan
j	standard_radiometer_outbound	01:04:0.0	00:06:0.0	0.4	Outbound off-target radiometry
Total				659.3	

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	132704	off target	0.17	off target
b	8858	8858	0.01	913
c	5917	5917	0.01	1242
d	5768	5799	0.01	1264
e	3797	3866	0.01	1663
f	3797	3866	0.01	1663
g	5620	5656	0.01	1288
h	5768	5768	0.01	1264
i	9337	9338	0.01	875
j	19675	off target	0.03	off target

Table 3: Division geometry summary. Values are computed at the start of each division. B3 Doppler spread is for one-way 3-dB pattern.

Name	Nominal	Actual	Mismatch	Comments
mode	radiometer	radiometer	no	
start_time (min)	-480.0	-400.0	yes	Different due to incomplete RADAR pass
end_time (min)	-300.0	-31.0	yes	Different due to incomplete RADAR pass
time_step (s)	2700.0	2700.0	no	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	no	
dutycycle	don't care	0.38	no	
prf (KHz)	don't care	1.00	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	0.250	no	Kbps - actual data rate may be less
interleave_flag	off	off	no	
interleave_duration (min)	don't care	10.0	no	

Table 4: t3 div_a Warmup block

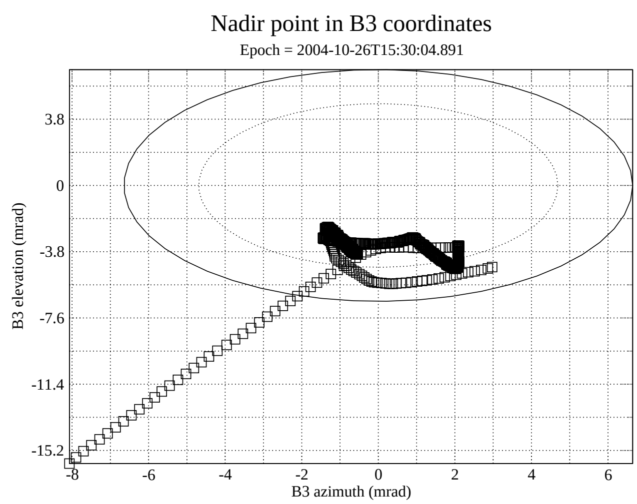

Figure 1: Altimetry pointing performance during Ta using reconstructed ckernel and preliminary reconstructed ephemeris

Name	Nominal	b	h	Mismatch	Comments
mode	altimeter	altimeter	altimeter	no	
start_time (min)	-30.0	-31.0	21.0	yes	
end_time (min)	-19.0	-21.5	32.5	yes	
time_step (s)	don't care	2.0	2.0	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	2	2	no	
dutycycle	0.73	0.73	0.73	no	
prf (KHz)	5.00	5.00	5.00	no	
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	leaving as much data for SAR as possible
interleave_flag	on	on	on	no	
interleave_duration (min)	varies	6.7	6.4	no	

Table 5: t3 div_bh standard_altimeter_inbound block

The PRF and number of pulses are fixed at 5 KHz and 21 pulses respectively. Unlike the SAR modes which fill the round trip time, the number of pulses in Altimeter mode is limited by the size of the science data buffer (16 K words = 32 Kbytes). The PRF value chosen is high enough to cover the doppler spread within beam 3 thus allowing for doppler beam sharpening (see Table 3 and figure 3). Assuming a locally flat surface, then range ambiguities are spaced according to,

$$\cos\theta = \frac{2a}{c\tau_{\text{pri}} + 2a}, \tag{1}$$

where θ is angular separation to the first range ambiguity, a is the altitude above the surface, c is the speed of light, and $\tau_{\text{pri}} = 1/\text{PRF}$ is the pulse repetition interval. Using the values specified above and a minimum altitude of 5000 km, the first range ambiguity is about 18 one-way beamwidths away from the nadir point and should not be an issue.

Given the pulse timing parameters, the burst rate is then determined by the division data rate. For Altimetry, the nominal design rate is 30 Kbps. The actual value can be adjusted to make tradeoffs in data volume usage. For the T3 flyby, the SAR modes are favored by pushing the instrument to the limits imposed by the geometry during the closest approach time. Available data is insufficient to push SAR to the limit for the entire SAR swath, so it will be throttled back during the higher altitude areas. Altimetry will be kept at the nominal value of 30 Kbps.

RMSS sets the transmit-receive window offset (TRO) to -6 for normal Altimeter operations. The negative TRO value means that the echo window is 6 PRI's shorter than the number of pulses transmitted. This setting increases the valid time of each radar instruction because the range-gate can vary by 6 PRI's before the echo window will see an empty PRI interval. Unlike the scatterometer mode, the negative TRO setting eliminates any noise only segments in the burst which makes the data collection more efficient. Although the Altimeter mode does not need so much noise only data (for noise subtraction and radiometric calibration) it is still desirable to occasionally see where exactly the pulse train lies in the range-gate. Therefore the interleave option will be used to insert some positive TRO bursts that will show the beginning or the end of the pulse train. The interleave keywords for this division are set to generate 2 or 3 special bursts spaced evenly in time. During the special interleaved bursts, RMSS programs 9 transmit pulses and a TRO of +6 giving an echo window 15 PRI's long. The division keyword for number of pulses is not used for these interleaved bursts.

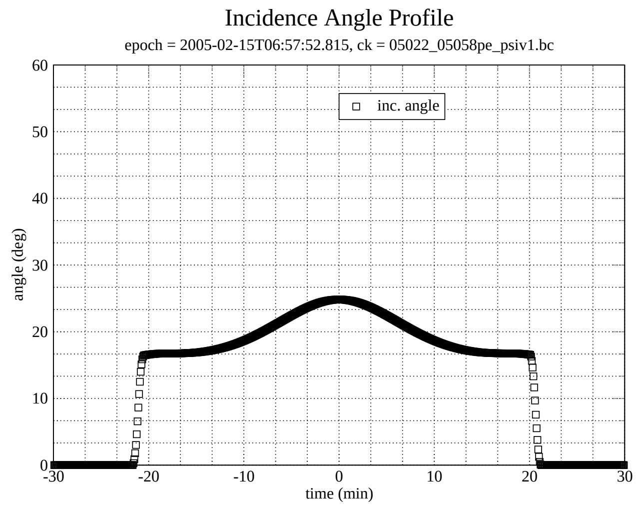

Figure 2: B3 boresight incidence angle during the time around c/a.

5 Div's C-G: Hi-Res SAR

Figure 2 shows the incidence angle profile during the hour centered on closest approach (c/a) which covers the SAR and altimeter intervals. Due to stronger than expected backscatter levels during the Ta data collections, the T3 strategy is to push SAR imaging out to 20 minutes before and after c/a. This means extending the operating altitude for SAR from 4000 km to about 5000 km. High-Res SAR will be started as soon as the beams move away from nadir point. The pointing design targets a newly optimized desired look angle profile (DLAP) from -20 minutes to +20 minutes with respect to closest approach.

The IEB instructions for the Hi-Res SAR interval are generated by RMSS under the control of five divisions in the config file as shown in table 6 and table 7.

Auto-Rad is set off for high-res SAR to allow the minimum burst period possible. As for Ta, the radiometer integration period is set to 34 ms (see Ta sequence design memo). When beam 3 approaches nadir pointing, beams 1 and 2 cross the nadir point and are no longer useful for SAR imaging. For these time intervals lasting about 30 seconds at the beginning and end of the SAR time, divisions C and G specify operation with beams 3,4,5 leaving out beams 1 and 2. The central division E specifies operation at the maximum data rate possible in 8-2 BAQ. This provides the most looks during the critical closest approach time when looks are in short supply. During the other SAR divisions (C,D,F,G) the data rate is slowed down to fit the total data collected within the RADAR allocation for T3. Slowing down the data rate is accomplished by increasing the burst period. This reduces the number of looks while retaining the best resolution possible. At higher altitudes, there are more looks, so this is the logical place to make the tradeoff between looks and data volume.

5.1 PRF and Incidence Angle Profiles

The PRF profile (Fig. 4) and incidence angle profile (Fig. 2) 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 Ta flyby was at 1200 km c/a altitude, however, the same PRF and incidence angle profiles still give the same performance. T3 is higher with a c/a altitude above 1500 km, and a new optimized profile is generated for it.

In principle another tradeoff could be made in the SAR profiles between looks and SAR processing difficulty vs. incidence angle and cross-track extent. Higher incidence angles usually lead to better quality images as long as the signal to noise ratio remains adequately high. However, increasing the incidence angle would increase range ambiguities and actually reduce the usable cross-track area. To counter the range ambiguities problem which reduces usable cross-track area, the PRF could be reduced at the expense of azimuth ambiguities. The current profile design is conservative in that the area within the 5 dB one-way beam patterns will generally satisfy the ambiguity requirement (minimum 14 dB total signal to ambiguity ratio). There is not enough time to study this tradeoff for T3, so the

Name	Nominal	c	d	e	Mismatch	Comments
mode	sarh	sarh	sarh	sarh	no	
start_time (min)	-6.0	-21.5	-21.0	-14.0	yes	Extended 40 minute profile, starts as soon as beam 3 leaves nadir point
end_time (min)	6.0	-21.0	-14.0	14.0	yes	Go to 5 beams as soon as possible
time_step (s)	don't care	2.0	2.0	2.0	no	Set by valid time calculation unless negative, then time_step is used instead
bem	11111	00111	11111	11111	yes	
baq	0	0	0	0	no	0 - 8 to 2
csr	8	8	8	8	no	8 - auto gain
noise_bit_setting	2	2	2	2	no	
dutycycle	0.73	0.73	0.73	0.73	no	
prf (KHz)	don't care	0.00	0.00	0.00	no	RMSS follows profile
number_of_pulses	don't care	0	0	0	no	RMSS fills round trip time
n_bursts_in_flight	1	1	1	1	no	
percent_of_BW	100.0	100.0	100.0	100.0	no	
auto_rad	off	off	off	off	no	Set off for SAR modes to allow minimum burst time
rip (ms)	34.0	34.0	34.0	34.0	no	Calculated from radiometer calibration for prior observations
max_data_rate	255.000	150.000	150.000	255.000	yes	8 to 2 reduces max data rate possible
interleave_flag	on	off	on	on	yes	
interleave_duration (min)	varies	60.0	60.0	60.0	no	

Table 6: t3 div_cde standard_sar_hi block

Name	Nominal	f	g	Mismatch	Comments
mode	sarh	sarh	sarh	no	
start_time (min)	-6.0	14.0	20.5	yes	Leave max rate as late as possible
end_time (min)	6.0	20.5	21.0	yes	
time_step (s)	don't care	2.0	2.0	no	Set by valid time calculation unless negative, then time_step is used instead
bem	11111	11111	00111	yes	
baq	0	0	0	no	0 - 8 to 2
csr	8	8	8	no	8 - auto gain
noise_bit_setting	2	2	2	no	
dutycycle	0.73	0.73	0.73	no	
prf (KHz)	don't care	0.00	0.00	no	RMSS follows profile
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	150.000	150.000	yes	8 to 2 reduces max data rate possible
interleave_flag	on	on	on	no	
interleave_duration (min)	varies	60.0	60.0	no	

Table 7: t3 div_fg standard_sar_hi block

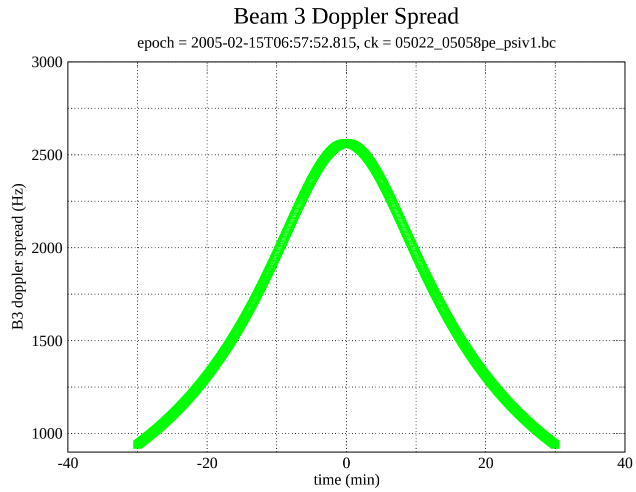

Figure 3: Nadir pointed B3 doppler spread during the time around c/a. Doppler spread is measured within the on-way 3 dB beam pattern.

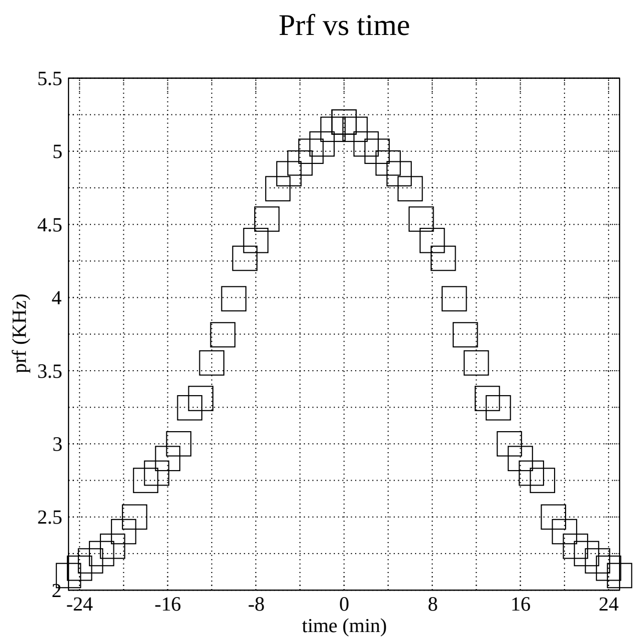

Figure 4: PRF profile used during the SAR divisions. This profile along with the incidence angle profile is optimized to provide the most usable cross-track width while maintaining adequate SNR and signal to ambiguity ratio inside of the 5 dB one-way beam patterns.

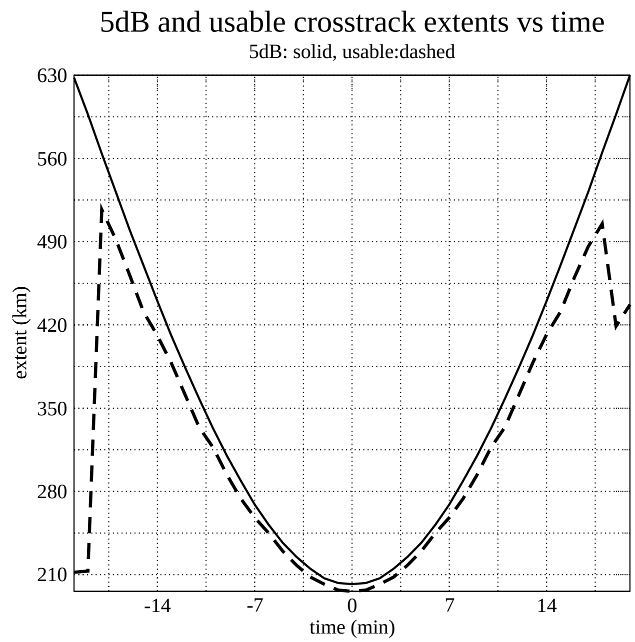

Figure 5: Usable cross track coverage predicted for the parameters in Div's C-G and the 1500 km PRF and incidence angle profiles. Usable image area must have a signal to ambiguity ratio of at least 14 dB, a noise equivalent σ_0 of at least -10 dB, and a one way antenna gain of at least -5 dB relative to the beam maximum gain. The large drop at the ends are due to the absence of beams 2 and 4 which are offset from beams 1, 3, and 5.

conservative optimized profile will be used.

The PRF profile is parameterized as a function of time with respect to c/a while the incidence angle profile is parametrized with respect to altitude above the sub-spacecraft point. These parameterizations are needed to allow the same profiles to be used for a group of flyby's with similar c/a altitudes. The PRF profile primarily covers the doppler spread of the beams (see figure 3) which varies with the changing angle between the spacecraft velocity vector and the look direction, but does not strongly depend on c/a altitude. The incidence angle profile on the other hand controls the balance between signal to noise ratio (SNR) and cross-track coverage which varies with altitude regardless of the time at which a particular altitude occurs.

Figures 5 and 6 show the SAR image coverage performance expected from the pulse parameters in divisions C-G and the PRF and incidence angle profiles applied to this flyby geometry. Calculation of ambiguities assumes a Venus backscatter model for the Titan surface. Once actual data on the Titan backscatter response is obtained, this calculation can be updated. However, it is unlikely that changes in the model function will have much affect on the selection of parameters. Most of the constraints come from the evolution of the flyby geometry, the shape and position of the beam patterns, and the location of range ambiguities.

5.2 PRF Hopping

The normal PRF profile is interrupted at the start of SAR divisions D, E, and F to insert some PRF hops (plus and minus 10 percent). These steps in PRF will be used to resolve potential integer ambiguities in the doppler centroid where our knowledge of the doppler centroid is off by a multiple of the PRF. These special instructions proved useful on the Ta flyby by allowing the doppler centroid program to estimate attitude biases. If only the reconstructed ckernel is used, then the doppler tracking algorithm introduces unacceptable large errors. Therefore, PRF hopping will be included again for T3.

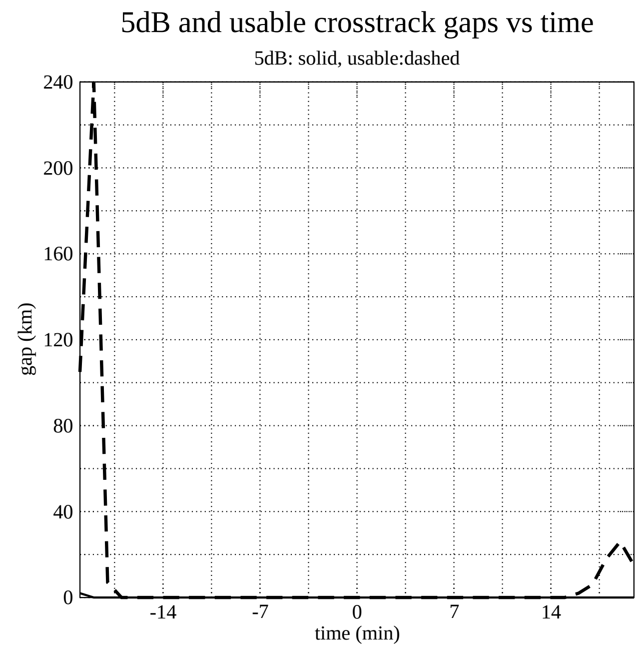

Figure 6: Extent of gaps in the cross-track coverage which do not meet the usable imaging criteria. These gaps occur when the PRF and incidence angle profiles are not optimized for the flyby geometry. The leading cause of gaps is the azimuth offset between beams 2 and 4 and beams 1, 3, and 5. The offset causes beams 2 and 4 to lead/lag the other beams on the surface. Thus they pass with a different incidence angle which can lead to gaps unless the incidence angle profile is adjusted to avoid this problem.

5.3 Data Rate

The three Hi-SAR divisions are needed to manage data volume usage. The total data volume allocation for T3 is insufficient to allow SAR imaging at the max data rate possible. The data rate for SAR is most easily reduced by slowing down the burst period which reduces the number of looks. An alternative would be to shorten the pulse train at the expense of azimuth resolution, however, RMSS does not support this modification at present. For T3 the max data rate for SAR will be maintained around closest approach where the number of looks is already low. Away from closest approach, the number of looks increases, and it is possible to give up some looks without too much degradation of the image. The outer two SAR divisions will be used to reduce the SAR data rate.

5.4 SAR Resolution Performance

For all of the SAR divisions the effective resolution can be calculated from the following equations,

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

$$\delta x = \frac{\lambda R}{2\tau_{rw} v \sin\theta_v}, \tag{3}$$

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 7 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

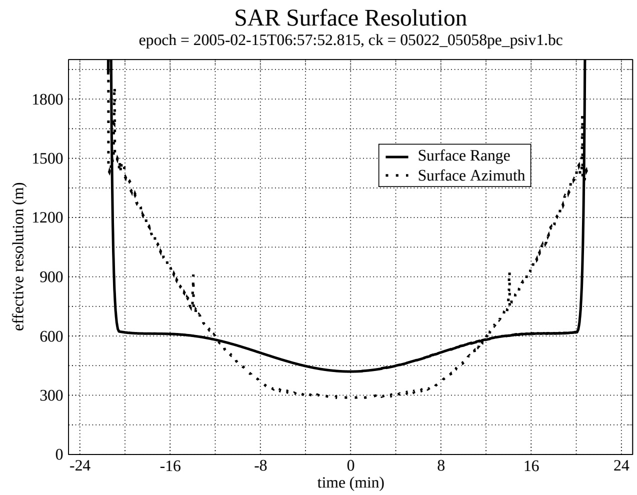

Figure 7: SAR projected range and azimuth resolution. These values are computed from the IEB parameters and are not related to the pixel size in the BIDR file. The pixel size was selected to be always smaller than the real resolution.

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.

6 Div I: Outbound Scatterometer Scan

The T3 radar observation ends with a thruster driven scatterometry scan that goes pole to pole. A scan line at the beginning and end sweeps off the limb to provide radiometer calibration points on cold sky. The outbound scatterometry scan starts at 2005-02-15T07:29:53.000 (00:32:0.2) with a duration of 38 min. Figures 8 and 9 show the pointing design for the scatterometry scan from the merged ckernel. Figure 10 shows the incidence angle coverage of this scan.

The IEB instructions for this scatterometry block are generated by RMSS under the control of the set of config parameters shown in table 8. Although not shown in table 8, 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.

During Ta, the scatterometry scans suffered from clipping during the center of the scan lines. The clipping occurred because RMSS placed all of the instruction boundaries near the outer edges of the scan where they were most needed to track the rapidly varying range. Thus, the auto-gain algorithm did not have an opportunity to see the higher signal levels near the center of the scan lines where the incidence angle dropped close to nadir pointing. To prevent this problem from recurring, auto-gain will not be used for the T3 scatteromtry raster scan. Instead, a fixed attenuator value will be used to keep the signal on-scale over the whole raster scan. From the Ta results, the fixed attenuator value is determined to be 12 dB instead of the usual 9 db used in distant scatterometer observations.

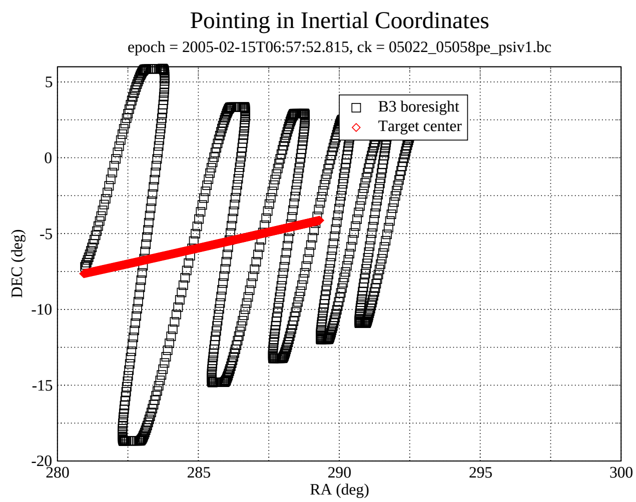

Figure 8: Scatterometry scan in inertial coordinates

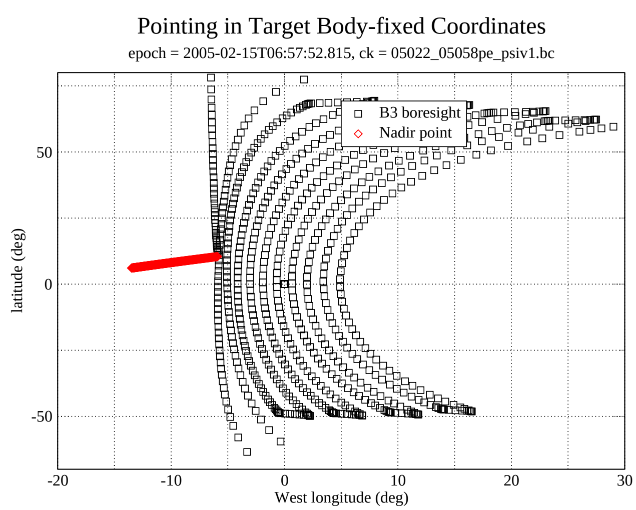

Figure 9: Scatterometry scan in target body-fixed coordinates

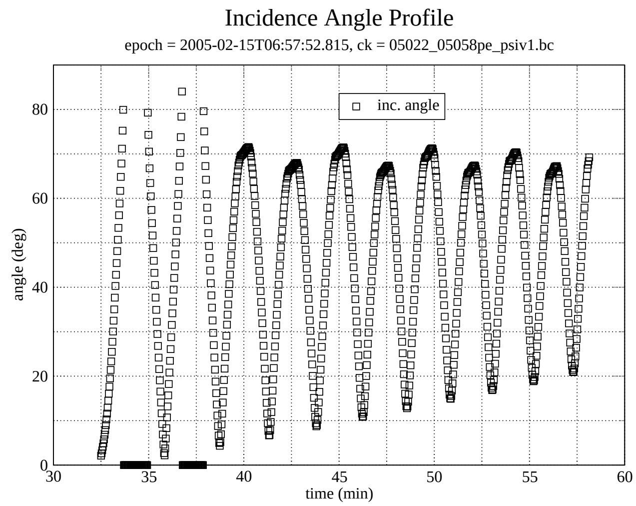

Figure 10: Incidence angle variation during scatterometry scan

Name	Nominal	Actual	Mismatch	Comments
mode	scatterometer	scatterometer	no	
start_time (min)	varies	32.5	no	
end_time (min)	varies	64.0	no	
time_step (s)	don't care	5.0	no	Set by valid time calculation
bem	00100	00100	no	
baq	5	5	no	5 - 8 bits straight
csr	8	0	yes	8 - auto gain
noise_bit_setting	4	4	no	Scat signal set higher than ALT/SAR
dutycycle	0.60	0.60	no	
prf (KHz)	1.20	1.20	no	
number_of_pulses	8	8	no	
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	30.000	30.000	no	leaving as much data for SAR as possible
interleave_flag	off	off	no	
interleave_duration (min)	don't care	10.0	no	

Table 8: t3 div_i standard_scatterometer_outbound block

Name	Nominal	Actual	Mismatch	Comments
mode	radiometer	radiometer	no	
start_time (min)	120.0	64.0	yes	
end_time (min)	300.0	70.0	yes	
time_step (s)	2700.0	2700.0	no	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	no	
dutycycle	don't care	0.38	no	
prf (KHz)	don't care	1.00	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	1.000	1.000	no	leaving as much data for SAR as possible
interleave_flag	off	off	no	
interleave_duration (min)	don't care	10.0	no	

Table 9: t3 div_j standard_radiometer_outbound block

7 Div J: Outbound Radiometry

After the scatterometer scan is finished, the spacecraft moves the radar borsight away from Titan, and the instrument finishes in radiometer only mode with parameters as shown in table 9.

8 Revision History

1. Nov 24, 2004: Added SAR resolution plot, estimate of scatt attenuator
2. Nov 19, 2004: Initial release

9 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