RADAR Titan Flyby during S24/T19

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- Sequence: s24
- Rev: 030
- Observation Id: t19
- Target Body: Titan
- Data Take Number: 100
- 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 9th Titan flyby on which SAR data will be acquired. This SAR data collection occurs during the s24 sequence of the Saturn Tour. This flyby pushbrooms both ends of the SAR pointing profile to acquire more image coverage area. This is a full radar pass with inbound and outbound radiometry, scatterometry, and altimetry, along with closest approach SAR 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 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 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

CIMS ID	Start	End	Duration	Comments
030OT_WARM4TI19001_RIDER	2006-282T09:05:32	2006-282T12:05:32	03:00:0.0	Warmup for RADAR observation of Titan.
030TI_T19INRAD001_PRIME	2006-282T12:05:32	2006-282T16:06:02	04:00:30.0	Radiometry of Titan. -Z scanned over Titan. Y axis controlled for different polarizations.
030TI_T19INSCAT001_PRIME	2006-282T16:06:02	2006-282T16:33:32	00:27:30.0	Scatterometry of Titan. -Z scanned over Titan. Y axis controlled for different polarizations
030TI_T19INALT001_PRIME	2006-282T16:55:32	2006-282T17:10:32	00:15:0.0	Collect altimetry data while maintaining nadir pointing.
030TI_T19INLRES001_PRIME	2006-282T17:10:32	2006-282T17:18:32	00:08:0.0	Low Resolution Synthetic Aperture RADAR (SAR) Imaging.
030TI_T19HISAR001_PRIME	2006-282T17:18:32	2006-282T17:32:32	00:14:0.0	High Resolution Synthetic Aperture RADAR (SAR) Imaging.
030TI_T19OTLRES001_PRIME	2006-282T17:32:32	2006-282T17:40:32	00:08:0.0	Low Resolution Synthetic Aperture RADAR (SAR) Imaging.
030TI_T19OTALT001_PRIME	2006-282T17:40:32	2006-282T17:55:32	00:15:0.0	Collect altimetry data while maintaining nadir pointing.
030TI_T19OTSCAT001_PRIME	2006-282T18:19:32	2006-282T18:40:32	00:21:0.0	Scatterometry of Titan. -Z scanned over Titan. Y axis controlled for different polarizations
030TI_T19OUTRAD001_PRIME	2006-282T18:40:32	2006-282T22:45:32	04:05:0.0	Radiometry of Titan. -Z scanned over Titan. Y axis controlled for different polarizations.

Table 1: t19 CIMS Request Sequence

Division	Name	Start	Duration	Data Vol	Comments
a	Warmup	-8:20:0.0	03:19:0.0	3.0	Warmup
b	standard_radiometer_inbound	-5:01:0.0	03:39:0.0	13.0	Inbound radiometry scans
c	standard_scatterometer_inbound	-1:22:0.0	00:31:0.0	37.2	Inbound scatterometer raster
d	standard_altimeter_inbound	-0:51:0.0	00:19:0.0	35.3	Inbound altimetry
e	standard_altimeter_inbound	-0:32:0.0	00:09:28.0	17.6	Inbound altimetry
f	standard_altimeter_inbound	-0:22:32.0	00:00:16.0	1.0	altimetry test 8-8
g	standard_altimeter_inbound	-0:22:16.0	00:00:8.0	0.5	altimetry test 8-8, and reduced duty cycle
h	standard_altimeter_inbound	-0:22:8.0	00:00:8.0	0.5	altimetry test 8-8, reduced duty cycle and bandwidth
i	standard_sar_hi	-0:22:0.0	00:01:30.0	21.4	Hi-SAR Turn transition, B3 only
j	standard_sar_low_inbound	-0:20:30.0	00:00:12.0	2.6	Inbound Low-SAR ping-pong
k	standard_sar_hi	-0:20:18.0	00:00:12.0	2.9	Inbound Hi-SAR ping-pong
l	standard_sar_low_inbound	-0:20:6.0	00:00:12.0	2.6	Inbound Low-SAR ping-pong
m	standard_sar_hi	-0:19:54.0	00:00:12.0	2.9	Inbound Hi-SAR ping-pong
n	standard_sar_low_inbound	-0:19:42.0	00:00:12.0	2.6	Inbound Low-SAR ping-pong
o	standard_sar_hi	-0:19:30.0	00:00:12.0	2.9	Inbound Hi-SAR ping-pong
p	standard_sar_low_inbound	-0:19:18.0	00:00:12.0	2.6	Inbound Low-SAR ping-pong
q	standard_sar_hi	-0:19:6.0	00:00:12.0	2.9	Inbound Hi-SAR ping-pong
r	standard_sar_low_inbound	-0:18:54.0	00:02:54.0	37.4	Inbound Low-SAR ping-pong
s	standard_sar_hi	-0:16:0.0	00:32:0.0	457.0	Hi-SAR main image segment
t	standard_sar_low_inbound	00:16:0.0	00:02:0.0	25.8	Outbound Low-SAR
u	standard_sar_hi	00:18:0.0	00:01:42.0	24.3	Hi-SAR turn transition to altimetry
v	standard_altimeter_outbound	00:19:42.0	00:10:18.0	19.2	Outbound altimetry
w	standard_altimeter_outbound	00:30:0.0	00:00:16.0	1.0	altimetry test 8-8
x	standard_altimeter_outbound	00:30:16.0	00:00:8.0	0.5	altimetry test 8-8, and reduced duty cycle
y	standard_altimeter_outbound	00:30:24.0	00:00:8.0	0.5	altimetry test 8-8, reduced duty cycle and bandwidth
z	standard_altimeter_outbound	00:30:30.0	00:21:30.0	40.0	Outbound altimetry including wheels transition
lbrace	distant_sar	00:52:0.0	00:11:30.0	51.8	Distant SAR, RTT limited
vbar	distant_sar	01:03:30.0	00:12:30.0	67.5	Distant SAR, buffer limited
rbrace	standard_radiometer_outbound	01:16:0.0	04:04:0.0	14.5	Outbound radiometry scans
Total				890.6	

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	0	off target	0.00	off target
b	98253	off target	0.13	off target
c	25377	26620	0.04	318
d	15114	15115	0.02	510
e	8914	8914	0.01	791
f	5922	5922	0.01	1073
g	5840	5840	0.01	1083
h	5799	5799	0.01	1089
i	5758	5758	0.01	1094
j	5300	5437	0.01	1158
k	5239	5374	0.01	1167
l	5179	5311	0.01	1176
m	5119	5250	0.01	1186
n	5058	5190	0.01	1195
o	4998	5131	0.01	1205
p	4938	5071	0.01	1214
q	4878	5011	0.01	1224
r	4818	4950	0.01	1234
s	3969	4047	0.01	1395
t	3969	4048	0.01	1395
u	4551	4667	0.01	1281
v	5058	5059	0.01	1195
w	8273	8273	0.01	839
x	8358	8359	0.01	832
y	8401	8401	0.01	829
z	8433	8433	0.01	826
lbrace	15445	15445	0.02	500
vbar	19244	19644	0.03	411
rbrace	23387	24358	0.03	343

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	-500.0	yes	IEB Trigger time is usually later than this
end_time (min)	-300.0	-301.0	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	0.250	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: t19 div_a Warmup block

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 2006-10-09T09:05:32.000 (-08:24:34.8). During the warmup, the IEB will be set to collect 1-second radiometer data on all 5 beams as shown in table **??**. Div A covers the turn to Titan and may provide data on the beam spillover sidelobes. This pass begins with two inbound radiometer scans using the usual one-second radiometer only bursts with beam 3 only as shown in Div B (see table **??**). No compressed scatterometry data is collected here due to data volume and instruction count constraints.

4 Div C: Scatterometry Scan

T19 inbound scatterometry covers an area near the equator with the spacecraft on wheel control. The coverage is about half unique, and half overlap with other planned scatteormetry scans. The unique portion covers the VIMS Ta Snail feature.

The IEB instructions for the inbound scatterometry scan are generated by RMSS under the control of the set of config parameters shown in table **??**. Although not shown in table **??**, 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.

Name	Nominal	Actual	Mismatch	Comments
mode	radiometer	radiometer	no	
start_time (min)	-300.0	-301.0	yes	
end_time (min)	-120.0	-82.0	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	1.000	0.992	yes	
interleave_flag	off	off	no	
interleave_duration (min)	don't care	10.0	no	

Table 5: t19 div_b standard_radiometer_inbound block

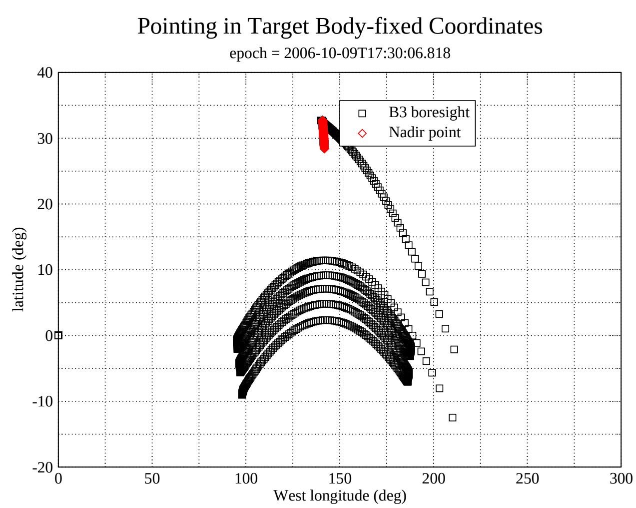

Figure 1: Scatterometry scan in target body-fixed coordinates

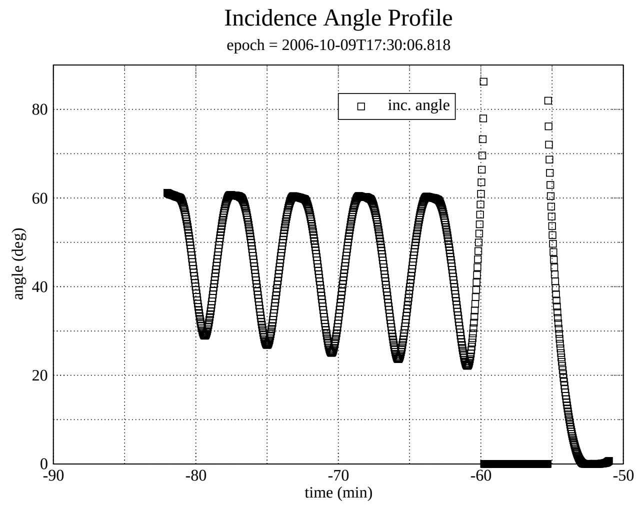

Figure 2: Incidence angle variation during scatterometry scan

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 scatteromtry raster scans. Instead, a fixed attenuator value will be used to keep the signal on-scale over the whole raster scan. Based on experience with T3, a 15 dB attenuator setting will be used for scan lines that go below 10 degrees incidence. For T19, all of the scan lines remain above 20 degrees incidence, so the 9 dB attenuator setting is used throughout.

5 Div's D-H,V: Altimetry

The spacecraft performs a transition from momentum wheel to thruster attitude control outside of the altimeter segments inbound and outbound. During this time, the -Z axis (high gain antenna axis) is pointed at nadir, so we collect data in altimetry mode. The altitude here is higher than the nominal altimetry, so performance will suffer, and pointing performance is not guaranteed. The very beginning of the inbound altimetry track should overlap the edge of the T16 SAR swath near the inbound end. SAR-altimeter overlap is potentially very valuable data since it provides independent height data inside the SAR image. Div's D,E,G,H perform some diagnostic checks to make sure there are no issues with the altimetry data. The parameters used by the main altimeter segments are shown in table **??**.

6 Div's I-U: SAR Imaging

After the altimetry track, there is a 1.5 minute turn transition to the SAR pointing profile during which SAR data is collected in Hi-SAR mode to maximize range resolution and in beam 3 only to maximize the number of looks while the beam is moving rapidly (Div I). This also occurs on the outbound side during the turn to altimetry to pick up imaging during the sweep back to nadir pointing (Div U). A pushbroom profile is used on both inbound and outbound sides to extend the imaging swath. The left look option is selected here to produce a swath that crosses and parallels the T16 swath in the lakes area of the north polar region. The T19 swath passes very close to the north pole and is

Name	Nominal	Actual	Mismatch	Comments
mode	scatterometer	scatterometer	no	
start_time (min)	varies	-82.0	no	
end_time (min)	varies	-51.0	no	
time_step (s)	don't care	12.0	no	Set by valid time calculation
bem	00100	00100	no	
baq	5	5	no	5 - 8 bits straight
csr	0	0	no	0 - No auto-gain, fixed attenuator set to avoid clipping
noise_bit_setting	4.0	4.0	no	9 dB attenuator
dutycycle	0.70	0.70	no	
prf (Hz)	1200	1200	no	
tro	6	6	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	20.000	yes	leaving as much data for SAR as possible
interleave_flag	off	off	no	
interleave_duration (min)	don't care	10.0	no	

Table 6: t19 div_c standard_scatterometer_inbound block

Name	Nominal	e	v	Mismatch	Comments
mode	altimeter	altimeter	altimeter	no	
start_time (min)	-30.0	-32.0	19.7	yes	
end_time (min)	-19.0	-22.5	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	31.000	31.000	yes	
interleave_flag	on	on	on	no	
interleave_duration (min)	varies	8.0	8.0	no	

Table 7: t19 div_ev standard_altimeter_inbound block

likely to uncover more lakes and provide information about the extent of the lakes region. The profile is targetted from -20.5 minutes through +18 minutes. From -20.5 minutes to -18.5 minutes, Div's J-R switch the radar mode back and forth between Low-SAR and Hi-SAR every 12 seconds. During this time, the two SAR modes provide a different balance between range (cross-track) and doppler (along-track) resolution. In Hi-SAR, cross-track resolution is better than along-track resolution. In Low-SAR, along-track resolution is better than cross-track resolution (see Fig. 14). Switching back and forth will let us try out a special kind of processing to enhance resolution. This is a low-risk experiment because the standard SAR processing will still work without modification. This same experiment was tried on T16 and is repeated here. Div S covers most of the SAR swath from -18.5 min to +16 min with Hi-SAR. At +16 minutes, range and azimuth resolution and SNR favor Low-SAR and the instrument switches to this mode for the last two minutes of SAR swath imaging. Targetting of the outbound pushbroom profile ends at +18 minutes. SAR-Hi mode is used during the backsweep to nadir. This extra coverage may provide some stereo opportunities. Table **??** shows the two B3 only Hi-SAR divisions, table **??** shows two representative Low/Hi-SAR ping pong divisions, and table **??** shows the Hi-SAR division that covers the bulk of the swath.

6.1 PRF and Incidence Angle Profiles

The PRF profile and incidence angle profile (Fig. 3) 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 optimized for a 1500 km flyby. The T19 flyby will be at 980 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.

Name	Nominal	i	u	Mismatch	Comments
mode	sarh	sarh	sarh	no	
start_time (min)	-6.0	-22.0	18.0	yes	
end_time (min)	6.0	-20.5	19.7	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	0	8	yes	8 - auto gain
noise_bit_setting	3.0	3.4	3.0	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	238.000	238.000	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 8: t19 div_iu standard_sar_hi block

Name	Nominal	j	k	Mismatch	Comments
mode	sarl	sarl	sarh	yes	
start_time (min)	-19.0	-20.5	-20.3	yes	
end_time (min)	-6.0	-20.3	-20.1	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 9: t19 div_jk standard_sar_low_inbound block

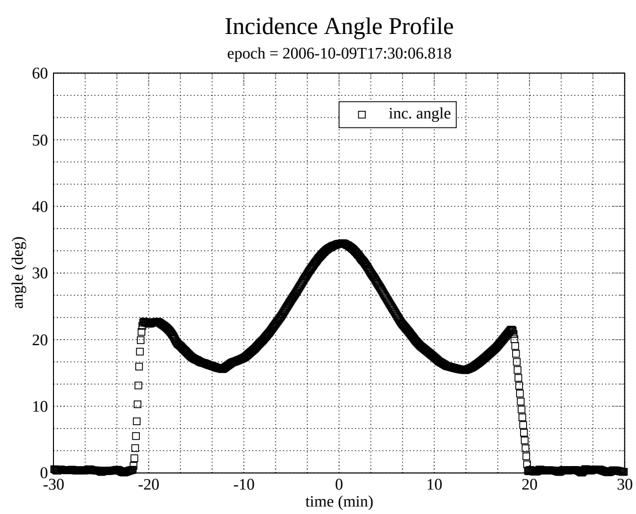

Figure 3: B3 boresight incidence angle during the time around c/a.

Name	Nominal	Actual	Mismatch	Comments
mode	sarh	sarh	no	
start_time (min)	-6.0	-16.0	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	3.0	no	
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 10: t19 div_s standard_sar_hi block

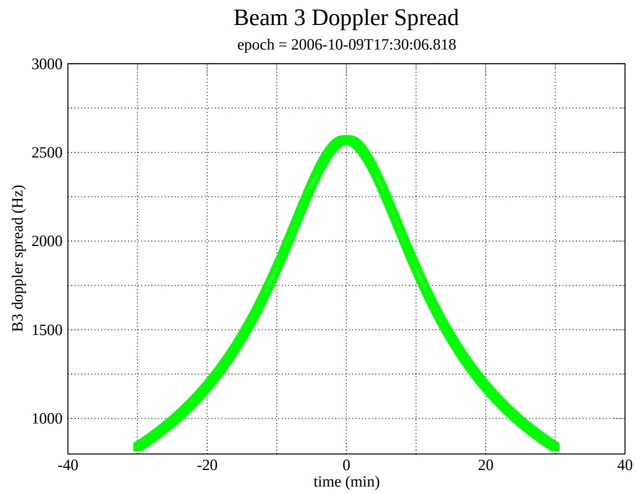

Figure 4: Nadir pointed B3 doppler spread during the time around c/a. Doppler spread is measured within the two-way 3 dB beam pattern.

6.2 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 14 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.

7 Div's {,‖: High Altitude Imaging

From 55 min to 76 minutes, the pointing design slews beam 3 about 10 beamwidths around the normal iso-doppler attitude for an incidence angle of 35 degrees. This design allows 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's { and ‖ covers the imaging time with scatterometer divisions that push against the 7% duty cycle limit, the 32 Kbyte size of the science

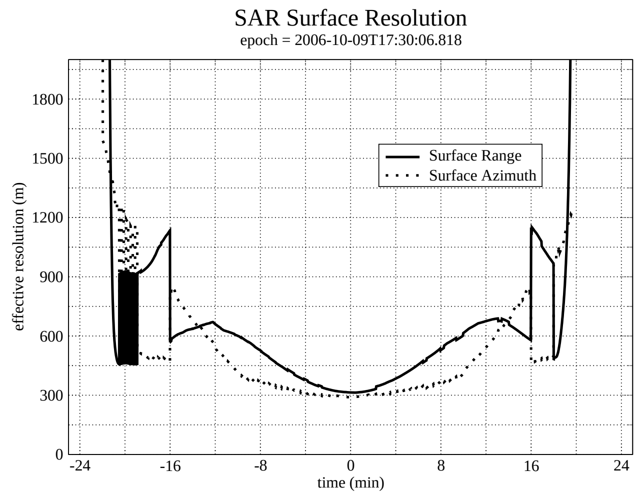

Figure 5: SAR projected range and azimuth resolution. These values are computed from the IEB parameters and are not related to the pixel size in the BIDR file. The pixel size was selected to be always smaller than the real resolution.

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 which is different from the T15 design where SNR was maximized. Resolution in this segment will be about 2.0 km by 2.5 km. Div { covers the ranges where the receive window length is round trip time limited while div || covers the later ranges that are limited by the buffer size. Table **??** shows the scatterometer parameters used.

7.1 PRF and Incidence Angle Choices

RMSS does not support all of the SAR options in scatterometer mode, so this high-res scatterometer profile uses a nearly constant incidence angle (see Fig. 6) and PRF. The PRF value is set to 1 KHz in division { and 800 Hz in division || to adequately space the range and doppler ambiguities. Doppler ambiguities occur at intervals equal to the PRF, so the PRF needs to be set higher than the doppler spread within the beam footprint. The doppler spread during divisions { and || varies from about 505 Hz to about 460 Hz as range varies from 16500 km to 23000 km. At the same time the PRF needs to be low enough to keep the range ambiguities outside of the beam footprint. Assuming a locally flat surface, range ambiguities have an angular spacing of,

$$\alpha = \frac{c}{2Rf_p \tan\theta_i}, \tag{3}$$

where α is the angular spread from the spacecraft position, c is the speed of light, θ_i is the incidence angle, R is the range to the surface, and f_p is the PRF. If we set the angular spread equal to the beamwidth θ_{bw}, then f_p should lie between the two limits,

$$f_p(max) = \frac{c}{2R_{\text{max}}\theta_{\text{bw}} \tan\theta_i} = 1442Hz, \tag{4}$$

and

$$f_p(min) = \text{max doppler spread} = 505Hz, \tag{5}$$

where R_{max} is 23000 km, θ_{bw} is 6 mrad for beam 3, and θ_i is about 37 degrees at 26000 km. This simple calculation shows the range of PRF values that might be acceptable. Figures 7 and 8 show the actual layout of the beam footprint and the iso-range and iso-doppler contours at the start and end of divisions W and X respectively. The iso-range and iso-doppler contour lines are spaced by one ambiguity to provide a way to judge potential ambiguity issues. The PRF values were chosen to balance the spacing of range and doppler ambiguities at the two endpoints.

Name	Nominal	lbrace	vbar	Mismatch	Comments
mode	scatterometer	scatterometer	scatterometer	no	
start_time (min)	varies	52.0	63.5	no	
end_time (min)	varies	63.5	76.0	no	
time_step (s)	don't care	4.0	6.0	no	Valid time calculation used
bem	00100	00100	00100	no	
baq	0	0	0	no	0 - 8-2 used to keep data rate within limits
csr	0	0	0	no	0 - Fixed attenuator
noise_bit_setting	4.0	4.0	4.0	no	Set for 9 dB attenuator
dutycycle	varies	0.35	0.18	no	
prf (Hz)	varies	1000	800	no	Manually set to balance range/doppler ambiguity spacing
tro	6	6	6	no	6 - scatt mode only allows 6 for now
number_of_pulses	varies	99	96	no	Manually set to fill RTT or buffer or exhaust ESS
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	varies	75.000	90.000	no	Kbps - set as high as possible to maximize looks
interleave_flag	off	off	off	no	
interleave_duration (min)	don't care	10.0	10.0	no	

Table 11: t19 div_lbracevbar distant_sar block

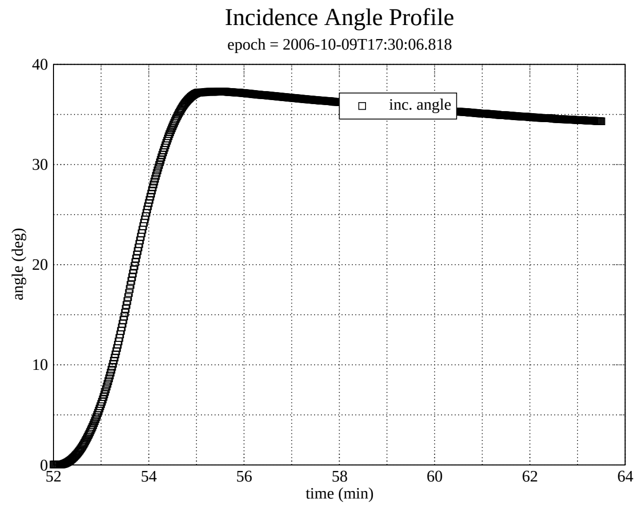

Figure 6: Incidence angle variation during Div {

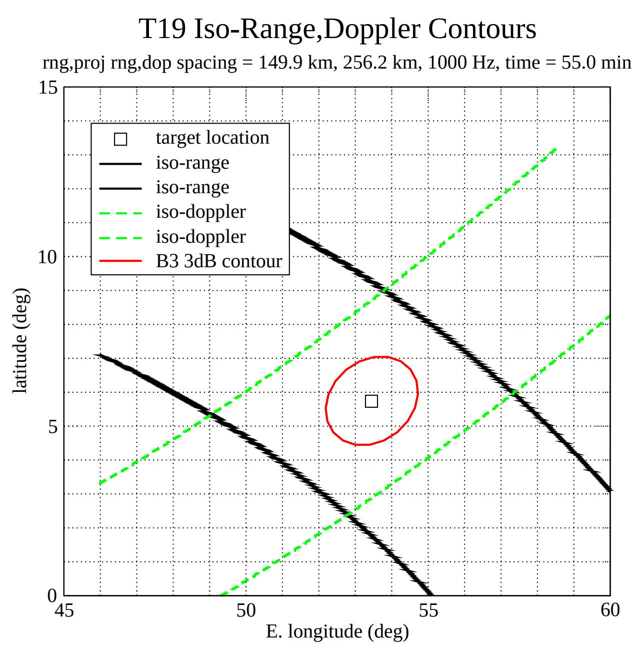

Figure 7: Surface Contours showing imaging geometry and ambiguity spacing at the start of Div {.

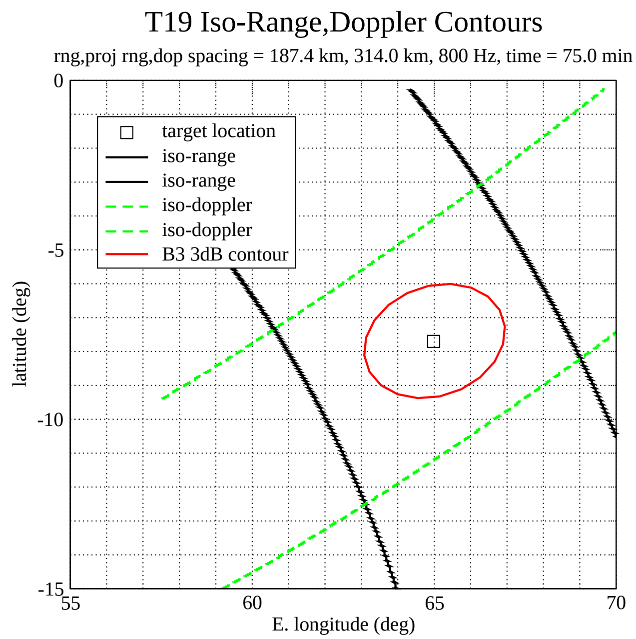

Figure 8: Surface Contours showing imaging geometry and ambiguity spacing at the end of Div ||.

7.2 SAR-style Scatterometer Resolution Performance

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

$$\delta R_g = \frac{c}{2B_r \sin\theta_i}, \tag{6}$$

$$\delta x = \frac{\lambda R}{2\tau_{rw} v \sin\theta_v}, \tag{7}$$

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 **??** shows the results from these equations for division { and figure **??** shows the results for division ||. The calculations are performed for the boresight of beam 3 which is the center of the swath.

7.3 SNR and Looks

Noise performance will be better in this segment than it was in the T12 high altitude imaging because of the lower altitude range. In scatterometer mode the noise equivalent σ_0 for beam 3 will be better than -10 dB in division {, and better than -7 dB in division ||. The number of looks will vary from 250 to 350. 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. Division || needed to be reduced to an 18% pulse duty cycle to allow the science data buffer to be filled using a PRF of 800 Hz. This reduced the noise equivalent to about -7 dB at the end, but it offers the possibility of obtaining noise only data from the range compressed data since the range extent of the pulses are less than half of the range extent of the beam. This may prove useful in validating the noise subtraction technique applied to the regular SAR data.

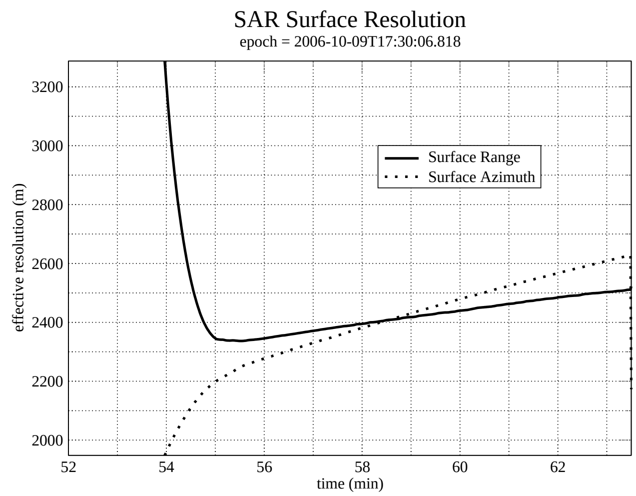

Figure 9: Div {: Projected range and azimuth resolution. These values are computed from the IEB parameters.

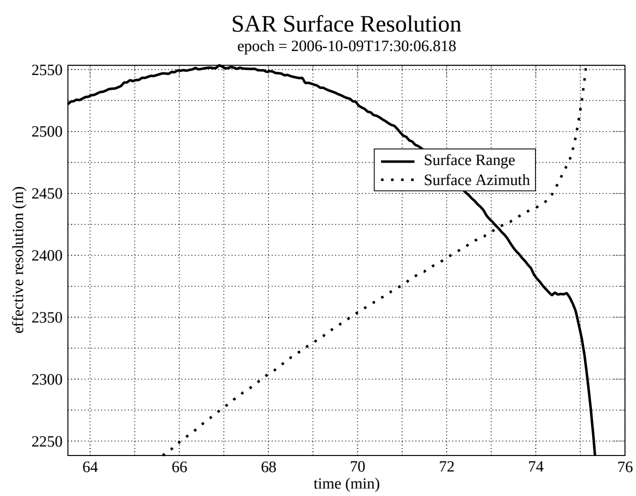

Figure 10: Div ||: Projected range and azimuth resolution. These values are computed from the IEB parameters.

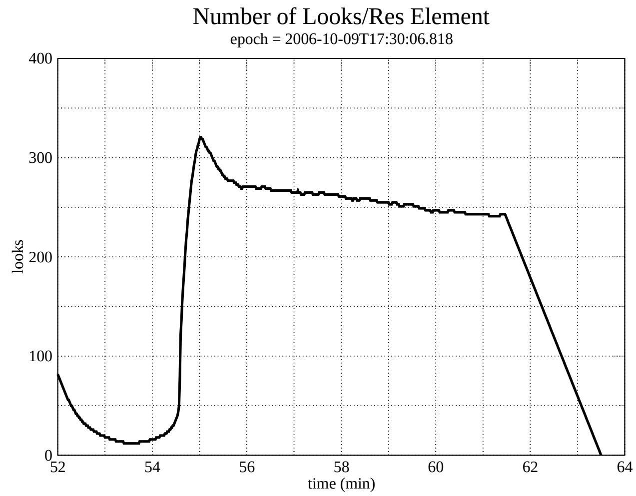

Figure 11: Div {: Number of looks. These values are computed from the IEB parameters.

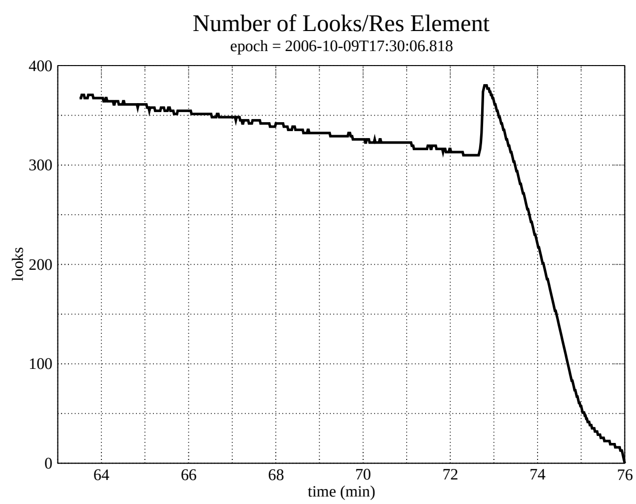

Figure 12: Div ||: Number of looks. These values are computed from the IEB parameters.

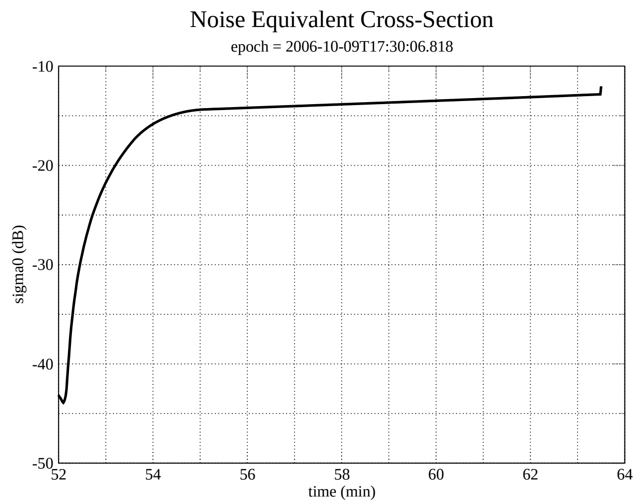

Figure 13: Div {: Noise equivalent σ_0. These values are computed from the IEB parameters.

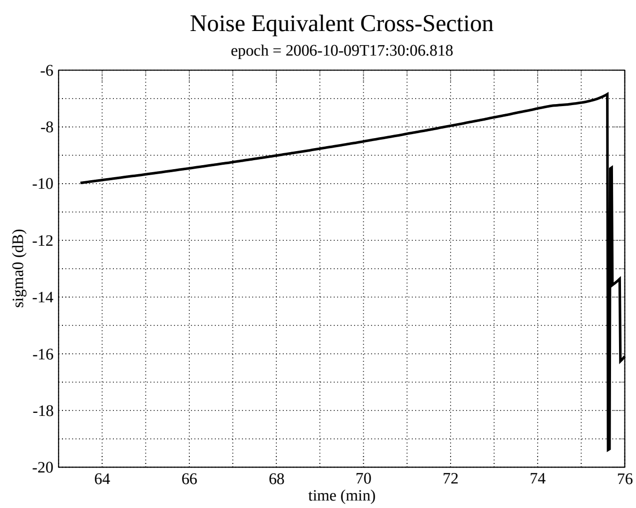

Figure 14: Div ||: Noise equivalent σ_0. These values are computed from the IEB parameters.

8 Revision History

1. Aug 22, 2006: 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