

# RADAR Titan Flyby during S15/T8

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- Sequence: s15
- Rev: 017
- Observation Id: t8
- Target Body: Titan
- Data Take Number: 65
- PDT Config File: S15\_ssup\_psiv1\_050809\_pdt.cfg
- SMT File: S15\_SOPU\_2005-07-19\_1.rpt
- PEF File: z0150c.pef

## 1 Introduction

This memo describes the Cassini RADAR activities for the 4th Titan flyby on which SAR data will be acquired. This SAR data collection occurs during the s15 sequence of the Saturn Tour. Two special features of this flyby are imaging of the Huygens Probe landing area, and a modified SAR pointing profile called "pushbroom" that extends the imaging area. A sequence design memo provides the science context of the scheduled observations, an overview of the pointing design, and guidelines for preparing the RADAR IEB.

This SAR data collection will include imaging of the probe landing area.

## 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

| CIMS ID                  | Start             | End               | Duration   | Comments  |
|--------------------------|-------------------|-------------------|------------|---|
| 017OT_TI8P0WARM001_RIDER | 2005-300T21:18:57 | 2005-301T00:18:57 | 03:00:0.0  | Warmup in preparation for T8 flyby. Radiometer calibration data collected.    |
| 017TI_TI8P1RADI001_PRIME | 2005-301T00:18:57 | 2005-301T02:20:57 | 02:02:0.0  | Radiometry during the inbound leg of T8.                                      |
| 017TI_TI8P2SCAT001_PRIME | 2005-301T02:42:57 | 2005-301T03:31:57 | 00:49:0.0  | Collect inbound scatterometry data at 3 different polarization orientations.  |
| 017TI_TI8P3ALTI001_PRIME | 2005-301T03:31:57 | 2005-301T03:48:45 | 00:16:48.0 | Collect altimetry data while maintaining nadir pointing.                      |
| 017TI_TI8P4LSAR001_PRIME | 2005-301T03:48:45 | 2005-301T04:00:57 | 00:12:12.0 | Low Resolution Synthetic Aperture RADAR (SAR) Imaging.                        |
| 017TI_TI8P5HSAR001_PRIME | 2005-301T04:00:57 | 2005-301T04:06:57 | 00:06:0.0  | High Resolution Synthetic Aperture RADAR (SAR) Imaging.                       |
| 017TI_TI8P6LSAR001_PRIME | 2005-301T04:06:57 | 2005-301T04:18:57 | 00:12:0.0  | Low Resolution Synthetic Aperture RADAR (SAR) Imaging.                        |
| 017TI_TI8P7ALTO001_PRIME | 2005-301T04:18:57 | 2005-301T04:35:57 | 00:17:0.0  | Collect outbound altimetry data while maintaining nadir pointing.             |
| 017TI_TI8P8SCAT001_PRIME | 2005-301T04:35:57 | 2005-301T05:24:57 | 00:49:0.0  | Collect outbound scatterometry data at 3 different polarization orientations. |
| 017TI_TI8P9RADO001_PRIME | 2005-301T05:48:57 | 2005-301T09:13:57 | 03:25:0.0  | Radiometry during the outbound leg of T8.                                     |

Table 1: t8 CIMS Request Sequence

| Division | Name                            | Start      | Duration   | Data Vol | Comments                             |
|----------|---------------------------------|------------|------------|----------|--------------------------------------|
| a        | Warmup                          | -9:50:0.0  | 00:20:0.0  | 0.3      | Warmup                               |
| b        | standard_radiometer_inbound     | -9:30:0.0  | 05:30:0.0  | 4.9      | Inbound radiometry scans             |
| c        | standard_radiometer_inbound     | -4:00:0.0  | 02:34:0.0  | 9.2      | Inbound radiometry scans             |
| d        | standard_scatterometer_inbound  | -1:26:0.0  | 00:53:30.0 | 54.6     | Inbound scatterometry scan           |
| e        | standard_altimeter_inbound      | -0:32:30.0 | 00:11:0.0  | 20.5     | Inbound altimetry                    |
| f        | standard_sar_low_inbound        | -0:21:30.0 | 00:04:0.0  | 51.6     | Inbound Low-SAR                      |
| g        | standard_sar_hi                 | -0:17:30.0 | 00:13:30.0 | 194.4    | Hi-SAR at highest data rate possible |
| h        | standard_sar_hi                 | -0:04:0.0  | 00:08:0.0  | 115.2    | Outbound Hi-SAR                      |
| i        | standard_sar_hi                 | 00:04:0.0  | 00:15:0.0  | 216.0    | Outbound Hi-SAR                      |
| j        | standard_altimeter_outbound     | 00:19:0.0  | 00:13:30.0 | 25.1     | Outbound altimetry                   |
| k        | standard_scatterometer_outbound | 00:32:30.0 | 00:17:30.0 | 17.9     | Outbound scatterometer scan          |
| l        | standard_scatterometer_outbound | 00:50:0.0  | 00:30:0.0  | 30.6     | Outbound scatterometer scan          |
| m        | standard_altimeter_outbound     | 01:20:0.0  | 00:25:30.0 | 42.8     | Outbound radiometry                  |
| n        | standard_radiometer_outbound    | 01:45:30.0 | 03:24:30.0 | 12.2     |                                      |
| Total    |                                 |            |            | 795.2    |                                      |

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   | 195589   | off target       | 0.25                 | off target          |
| b   | 188844   | off target       | 0.24                 | off target          |
| c   | 78153    | off target       | 0.10                 | off target          |
| d   | 26791    | 26791            | 0.04                 | 400                 |
| e   | 9196     | 9222             | 0.01                 | 878                 |
| f   | 5772     | 5772             | 0.01                 | 1222                |
| g   | 4598     | 4681             | 0.01                 | 1417                |
| h   | 1587     | 1669             | 0.01                 | 2425                |
| i   | 1587     | 1669             | 0.01                 | 2425                |
| j   | 5031     | 5038             | 0.01                 | 1338                |
| k   | 9196     | 9205             | 0.01                 | 878                 |
| l   | 14877    | 15651            | 0.02                 | 611                 |
| m   | 24795    | 24810            | 0.03                 | 422                 |
| n   | 33276    | 33277            | 0.04                 | 352                 |

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    | a          | b          | Mismatch | Comments                                       |
|---------------------------|------------|------------|------------|----------|--|
| mode                      | radiometer | radiometer | radiometer | no       |  |
| start_time (min)          | -480.0     | -590.0     | -570.0     | yes      | IEB Trigger time is usually later than this    |
| end_time (min)            | -300.0     | -570.0     | -240.0     | yes      |  |
| time_step (s)             | 2700.0     | 2700.0     | 5400.0     | yes      | Used by radiometer only modes - saves commands |
| bem                       | 00100      | 00100      | 11111      | yes      |  |
| baq                       | don't care | 5          | 5          | no       |  |
| csr                       | 6          | 6          | 6          | no       | 6 - Radiometer Only Mode                       |
| noise_bit_setting         | don't care | 4.0        | 4.0        | no       |  |
| dutycycle                 | don't care | 0.38       | 0.38       | no       |  |
| prf (KHz)                 | don't care | 1.00       | 1.00       | 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             | 0.250      | 0.248      | 0.248      | yes      | Kbps - actual data rate may be less            |
| interleave_flag           | off        | off        | off        | no       |  |
| interleave_duration (min) | don't care | 10.0       | 10.0       | no       |  |

Table 4: t8 div\_ab Warmup block

of time are called divisions with a particular behavior defined by a set of division keywords in the config file. Table 2 shows a summary of the divisions used in this observation. Table 3 shows a summary of some key geometry values for each division. Subsequent sections will show and discuss the keyword selections made for each division. Each division table shows a set of nominal parameters that are determined by the operating mode (eg., distant scatterometry, SAR low-res inbound). The actual division parameters from the config file are also shown, and any meaningful mismatches are flagged.

### 3 Warmup and Overview

The radar warmup rider begins at 2005-10-27T21:18:57.000 (-06:56:27.8). During the warmup, the IEB will be set for slow speed radiometer only data as shown in table 4. Division B cycles all 5 beams as the spacecraft slews onto Titan to collect information about spill-over sidelobes.

This observation will be the first full 10-hour radar sequence. The sequence follows the nominal design fairly closely. From -9:30:0.0 to 01:45:30.0, the instrument will operate following the usual full RADAR mode sequence. This means radiometry, altimetry, scatterometry and finally SAR at closest approach, followed by the reverse sequence on the way out. Tables and figures show the parameters and designs during these divisions. Refer to previous Titan flyby sequence design memos for the standard performance tradeoff analyses.

### 4 SAR Imaging

The SAR imaging divisions are shown in tables 5 and 6. The SAR imaging time has been extended on the inbound side to -20 minutes to provide more coverage around the Huygens probe landing area. On the outbound side the profile is extended to 18 minutes to provide more coverage along with using a new pushbroom pointing profile.

| Name                      | Nominal    | Actual  | Mismatch | Comments                              |
|---------------------------|------------|---------|----------|---------------------------------------|
| mode                      | sar1       | sar1    | no       |                                       |
| start_time (min)          | -19.0      | -21.5   | yes      |                                       |
| end_time (min)            | -6.0       | -17.5   | yes      |                                       |
| time_step (s)             | don't care | 7.0     | no       | Set by valid time calculation         |
| bem                       | 11111      | 11111   | no       |                                       |
| baq                       | 0          | 0       | no       | 0 - 8 to 2                            |
| csr                       | 8          | 8       | no       | 8 - auto gain                         |
| noise_bit_setting         | 2.0        | 2.0     | no       |                                       |
| dutycycle                 | 0.73       | 0.70    | yes      |                                       |
| prf (KHz)                 | don't care | 0.00    | no       | RMSS follows profile                  |
| number_of_pulses          | don't care | 0       | no       | RMSS fills round trip time            |
| n_bursts_in_flight        | 1          | 1       | no       |                                       |
| percent_of_BW             | 100.0      | 100.0   | no       |                                       |
| auto_rad                  | on         | off     | yes      |                                       |
| rip (ms)                  | 34.0       | 34.0    | no       |                                       |
| max_data_rate             | 255.000    | 215.000 | yes      | 8 to 2 reduces max data rate possible |
| interleave_flag           | on         | off     | yes      |                                       |
| interleave_duration (min) | varies     | 10.0    | no       |                                       |

Table 5: t8 div\_f standard\_sar\_low\_inbound block

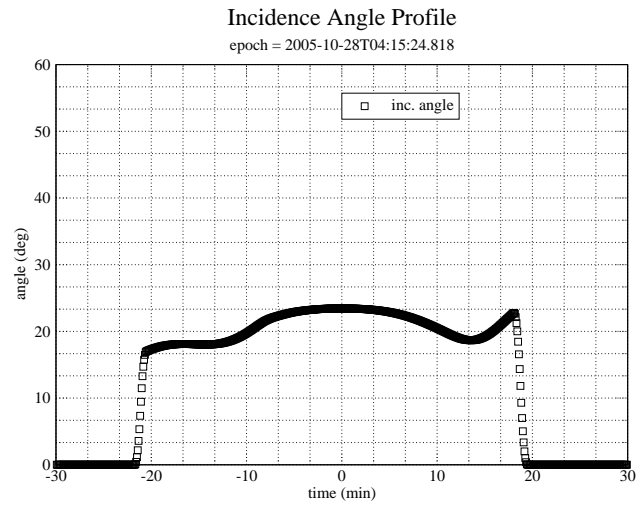


Figure 1: B3 boresight incidence angle during the time around c/a.

| Name                      | Nominal    | g       | h       | i       | Mismatch | Comments  |
|---------------------------|------------|---------|---------|---------|----------|---|
| mode                      | sarh       | sarh    | sarh    | sarh    | no       |   |
| start_time (min)          | -6.0       | -17.5   | -4.0    | 4.0     | yes      |   |
| end_time (min)            | 6.0        | -4.0    | 4.0     | 19.0    | yes      |   |
| time_step (s)             | don't care | 8.0     | 6.0     | 8.0     | no       | Set by valid time calculation unless negative, then time_step is used instead |
| bem                       | 11111      | 11111   | 11111   | 11111   | no       |   |
| baq                       | 0          | 0       | 0       | 0       | no       | 0 - 8 to 2  |
| csr                       | 8          | 8       | 8       | 8       | no       | 8 - auto gain   |
| noise_bit_setting         | 2.0        | 2.0     | 2.0     | 2.0     | no       |   |
| dutycycle                 | 0.73       | 0.70    | 0.70    | 0.70    | yes      |   |
| 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    | 240.000 | 240.000 | 240.000 | yes      | 8 to 2 reduces max data rate possible   |
| interleave_flag           | on         | off     | off     | off     | yes      |   |
| interleave_duration (min) | varies     | 10.0    | 10.0    | 12.0    | no       |   |

Table 6: t8 div\_ghi standard\_sar\_hi block

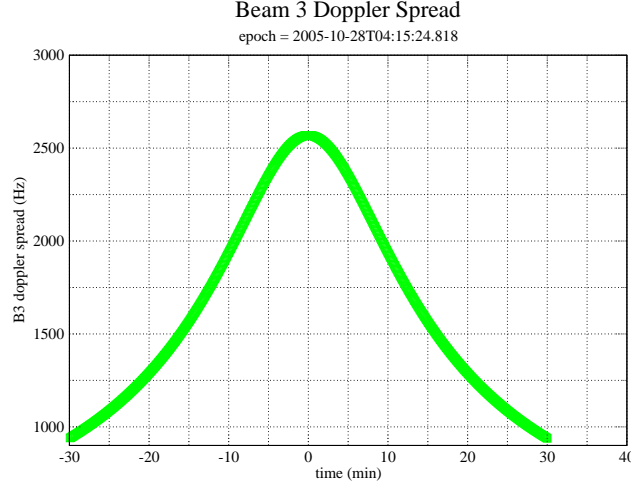


Figure 2: Nadir pointed B3 doppler spread during the time around c/a. Doppler spread is measured within the two-way 3 dB beam pattern.

#### 4.1 PRF and Incidence Angle Profiles

The PRF profile and incidence angle profile (Fig. 1) are optimized for maximum usable 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 T8 flyby will be at 1350 km altitude, and the higher altitude profile used at T3 will be used again here. The optimized profile maximizes usable cross-track width while avoiding gaps in the imaging swath. Unlike the previous SAR imaging passes, this pass will not include any PRF hopping which has not proven necessary.

#### 4.2 Huygens Probe Landing Site Deviation

To ensure that the central beam (Beam 3) is centered over the estimated location of the Huygen's Probe landing site, the inbound SAR incidence angle profile is slightly modified away from the nominal profile. The landing site is close enough to the nominal profile that iso-doppler pointing could still be used. The incidence angle profile deviates for the first 13 minutes from the nominal profile to cross the landing site and smoothly rejoin the nominal profile. The SAR profile is started early at -20 minutes to provide more imaging context around the probe landing site, and based on positive experience with imaging out to 20 minutes in T3. The first few minutes will be in Low-Res SAR mode to preserve more square pixel structure. The actual resolution achieved by Hi-Res SAR and Low-Res SAR modes is similar at this range.

Figures 3 and 4 show the SAR image coverage performance expected from the pulse parameters in divisions G-I 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.

#### 4.3 SAR Resolution Performance

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

$$\delta R_g = \frac{c}{2B_r \sin \theta_i}, \quad (1)$$

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

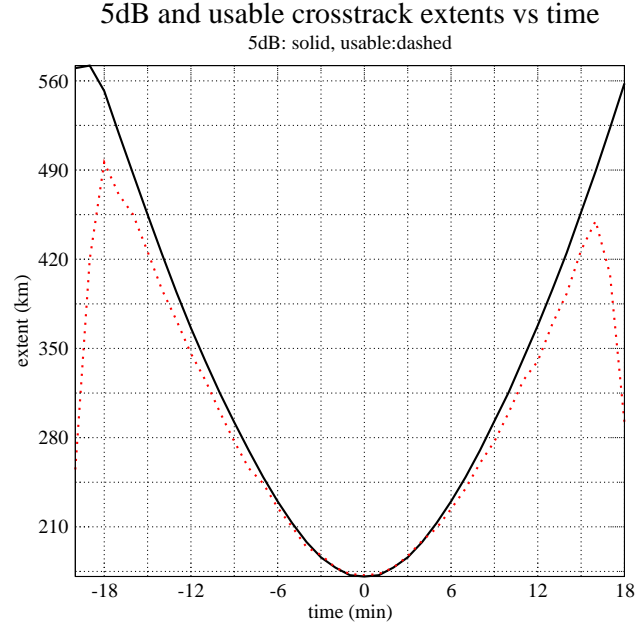


Figure 3: Usable cross track coverage predicted for the parameters in Div's G-I and the 1500 km PRF and incidence angle profiles. Usable image area must have a signal to ambiguity ratio of at least 14 dB, a noise equivalent  $\sigma_0$  of at least -10 dB, and a one way antenna gain of at least -5 dB 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.

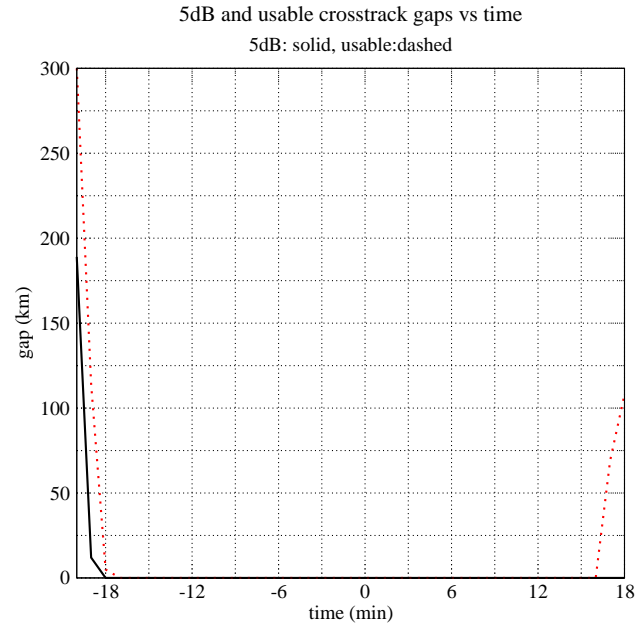


Figure 4: Extent of gaps in the cross-track coverage which do not meet the usable imaging criteria. These gaps occur when the PRF and incidence angle profiles are not optimized for the flyby geometry. The leading cause of gaps is the azimuth offset between beams 2 and 4 and beams 1, 3, and 5. The offset 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.



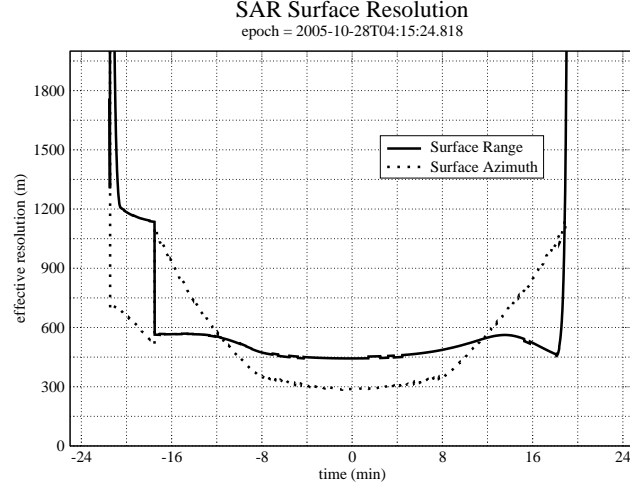


Figure 5: SAR projected range and azimuth resolution. These values are computed from the IEB parameters and are not related to the pixel size in the BIDR file. The pixel size was selected to be always smaller than the real resolution.

where  $\delta R_g$  is the projected range resolution on the surface,  $c$  is the speed of light,  $B_r$  is the transmitted chirp bandwidth,  $\theta_i$  is the incidence angle,  $\delta x$  is the azimuth resolution on the surface,  $\lambda$  is the transmitted wavelength,  $R$  is the slant range,  $\tau_{rw}$  is the length of the receive window,  $v$  is the magnitude of the spacecraft velocity relative to the target body, and  $\theta_v$  is the angle between the velocity vector and the look direction. Figure 5 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.

#### 4.4 Outbound SAR Pushbroom

The outbound segment of SAR will try out a new pointing profile called “pushbroom”. The pitch-over rate is linearly decreased from the nominal profile which allows the swath to move more quickly over the surface. The net effect is to increase coverage at the end of the swath at the expense of looks. The nominal swath design produced more looks than needed, so this represents one way to further optimize the SAR pointing design. Iso-doppler tracking is still maintained, and the same PRF profiles are followed. The pointing deviation will increase the incidence angle away from the nominal profile, and combined with the higher range, there will be some negative impact on SNR and ambiguity performance. Nonetheless, simulation studies indicate that usable coverage should be substantially increased. The end of the T8 swath will serve as a test of these performance tradeoffs.

The pushbroom pointing used on the outbound segment causes some degradation of azimuth ambiguities for the inner beams. The SAR processor can exclude high ambiguity areas. In the future, the PRF profile may be re-optimized for this pushbroom pointing profile.

| Name                      | Nominal    | e         | j         | m         | Mismatch | Comments                                 |
|---------------------------|------------|-----------|-----------|-----------|----------|--|
| mode                      | altimeter  | altimeter | altimeter | altimeter | no       |  |
| start_time (min)          | -30.0      | -32.5     | 19.0      | 80.0      | yes      |  |
| end_time (min)            | -19.0      | -21.5     | 32.5      | 105.5     | yes      |  |
| time_step (s)             | don't care | 12.0      | 12.0      | 26.0      | no       | Set by valid time calculation            |
| bem                       | 00100      | 00100     | 00100     | 00100     | no       |  |
| baq                       | 7          | 7         | 7         | 7         | no       | 7 - 8 to 4                               |
| csr                       | 8          | 8         | 8         | 8         | no       | 8 - auto gain                            |
| noise_bit_setting         | 2.0        | 2.0       | 2.0       | 2.0       | no       |  |
| dutycycle                 | 0.73       | 0.73      | 0.73      | 0.73      | no       |  |
| prf (KHz)                 | 5.00       | 5.00      | 5.00      | 4.00      | yes      |  |
| number_of_pulses          | 21         | 21        | 21        | 17        | yes      |  |
| 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     | 31.000    | 31.000    | 28.000    | yes      | leaving as much data for SAR as possible |
| interleave_flag           | on         | on        | on        | on        | no       |  |
| interleave_duration (min) | varies     | 5.0       | 6.0       | 11.4      | no       |  |

Table 7: t8 div\_ejm standard\_altimeter\_inbound block

## 5 Altimetry

The parameters used by the two standard altimeter segments are shown in table 7.

### 5.1 Div M: Extra Low-Res Altimetry Track

During the wheel to thruster transition after the outbound scatterometry scan, there is a 25 minute segment where the spacecraft is nadir pointed and some form of altimetry can be attempted. The track length is 342 km and the range varies from 25000 km to 33000 km. Normal altimetry ends at 9000 km, so this segment is about 3 times further out, and the  $R^4$  fall off of signal strength will reduce SNR by 19 dB. Figure 6 shows that compressed average pulse envelope for an altimeter burst at 9000 km altitude (taken from T3) has about 25 dB SNR, so there should still be about 6 dB of SNR left at the higher range.  $K_{pc}$  in each range bin in normal altimetry mode at 9000 km is about 0.25, while figure 7 shows the expected  $K_{pc}$  at the higher range as a function of range resolution.  $K_{pc}$  passes through unity at about 180 m range resolution, so the altimeter mode should work with a height resolution somewhat better than 180 m depending on how the processing is performed. To keep the processing options open, the standard altimeter mode will be used for this division. A scatterometer result will still be possible even if altimetry proves impractical. If the altimeter result is good, then future pointing designs may take advantage of this kind of opportunity for more altimetry.

The parameters for division M are shown in table 8. There are some differences from the standard altimetry divisions due to the higher range. The PRF is reduced to 4 KHz to make the PRI long enough to place the receive window within 1024 PRI's (the instruction limit). The number of pulses is reduced to 17 to keep the data rate down. Normally, we would lengthen the burst period, but the burst period is limited to 4 seconds. The same interleaving of occasional shorter pulse trains is used to help identify the leading echo.

## 6 Div's D,K,L: Scatterometry scans

The IEB instructions for the scatterometry divisions are generated by RMSS under the control of the set of config parameters shown in table 9. Although not shown in table 9, scatterometer mode operations use a transmit-receive

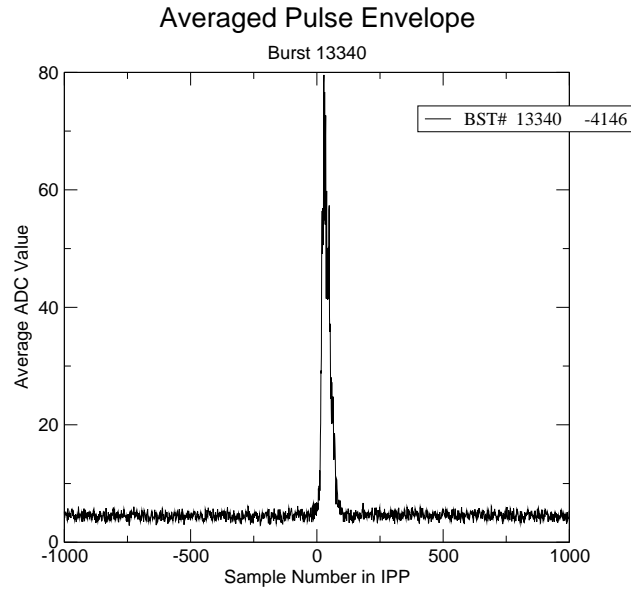


Figure 6: Average of all compressed pulses from an altimeter burst in T3 taken at a range of 9000 km (32 min after closest approach). Note that the plot is in ADC value which is proportional to voltage. To get values proportional to power, the values need to be squared.

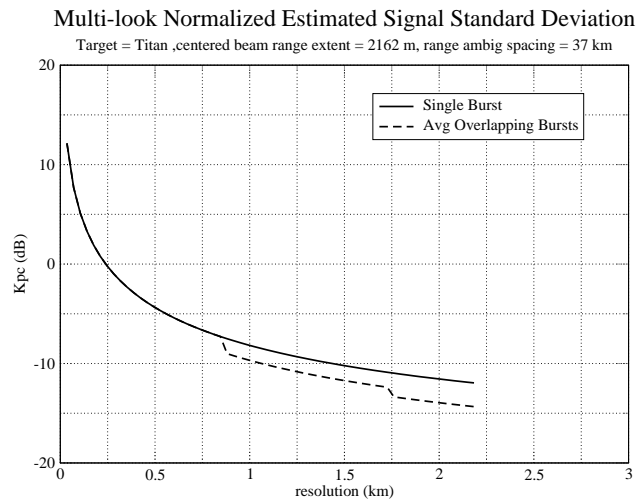


Figure 7: Average of all compressed pulses from an altimeter burst in T3 taken at a range of 9000 km (32 min after closest approach). Note that the plot is in ADC value which is proportional to voltage. To get values proportional to power, the values need to be squared.

| Name                      | Nominal    | Actual    | Mismatch | Comments                      |
|---------------------------|------------|-----------|----------|-------------------------------|
| mode                      | altimeter  | altimeter | no       |                               |
| start_time (min)          | 19.0       | 80.0      | yes      |                               |
| end_time (min)            | 30.0       | 105.5     | yes      |                               |
| time_step (s)             | don't care | 26.0      | no       | Set by valid time calculation |
| bem                       | 00100      | 00100     | no       |                               |
| baq                       | 7          | 7         | no       | 7 - 8 to 4                    |
| csr                       | 8          | 8         | no       | 8 - auto gain                 |
| noise_bit_setting         | 2.0        | 2.0       | no       |                               |
| dutycycle                 | 0.73       | 0.73      | no       |                               |
| prf (KHz)                 | 5.00       | 4.00      | yes      |                               |
| number_of_pulses          | 21         | 17        | yes      |                               |
| 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             | 85.000     | 28.000    | yes      |                               |
| interleave_flag           | on         | on        | no       |                               |
| interleave_duration (min) | varies     | 11.4      | no       |                               |

Table 8: t8 div\_m standard\_altimeter\_outbound block

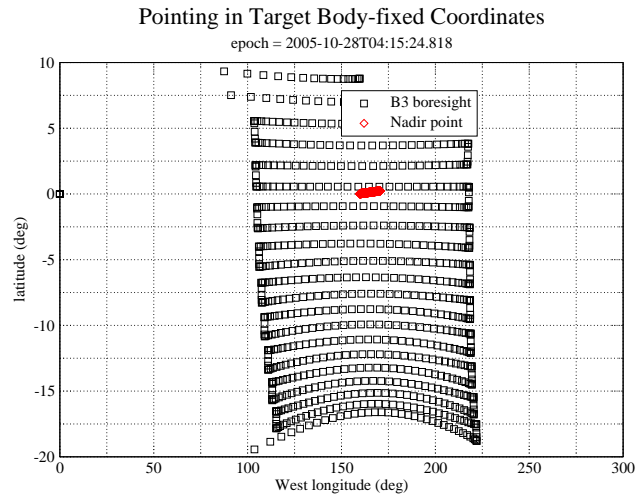


Figure 8: Inbound Scatterometry scan in target body-fixed coordinates

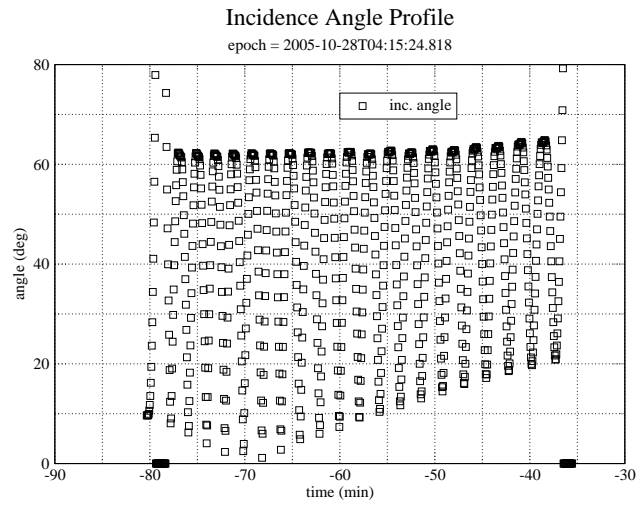


Figure 9: Inbound incidence angle variation during scatterometry scan

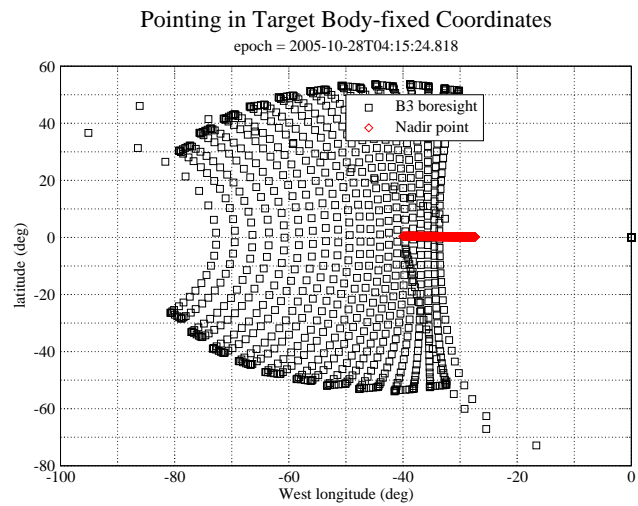


Figure 10: Outbound Scatterometry scan in target body-fixed coordinates

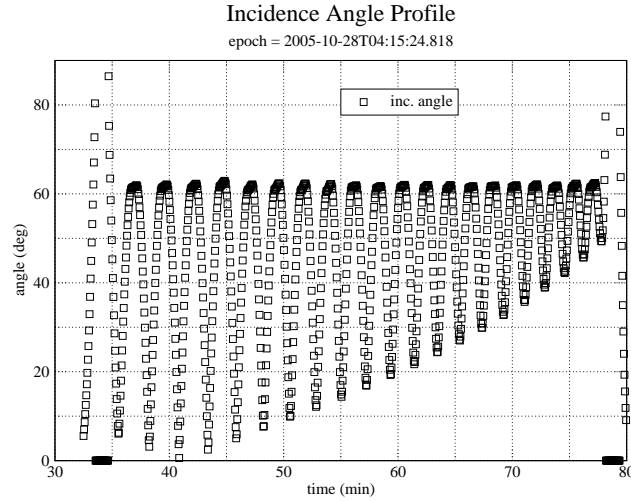


Figure 11: Outbound incidence angle variation during scatterometry scan

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 T8 scatterometry raster scan. 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 T8, this means the inbound scan will be all at the 9 dB attenuator setting while the outbound scan will start with the 15 dB setting and switch to 9 dB after the minimum incidence angle increases above 10 degrees. The switch will be placed in the short bar where the incidence angle is high and the turn rate is low.

## 7 Div's C,M: Radiometry

At the beginning and end of this observation, two pairs of radiometer scans will be performed. Since this is a full pass, there are not enough instructions available to track a range gate for scatterometry, and therefore we will not attempt any compressed scatterometry during the radiometry scans. The parameters for the radiometry scans are shown in table 10.

## 8 Revision History

1. Aug 30, 2005: Added Div F Table
2. Aug 26, 2005: Initial release

| Name                      | Nominal       | d             | k             | l             | Mismatch | Comments                            |
|---------------------------|---------------|---------------|---------------|---------------|----------|-------------------------------------|
| mode                      | scatterometer | scatterometer | scatterometer | scatterometer | no       |                                     |
| start_time (min)          | varies        | -86.0         | 32.5          | 50.0          | no       |                                     |
| end_time (min)            | varies        | -32.5         | 50.0          | 80.0          | no       |                                     |
| time_step (s)             | don't care    | 14.0          | 16.0          | 16.0          | no       | Set by valid time calculation       |
| bem                       | 00100         | 00100         | 00100         | 00100         | no       |                                     |
| baq                       | 5             | 5             | 5             | 5             | no       | 5 - 8 bits straight                 |
| csr                       | 8             | 0             | 0             | 0             | yes      | 8 - auto gain                       |
| noise_bit_setting         | 4.0           | 4.0           | 3.0           | 4.0           | yes      | Scat signal set higher than ALT/SAR |
| dutycycle                 | 0.60          | 0.70          | 0.70          | 0.70          | yes      |                                     |
| prf (KHz)                 | 1.20          | 1.20          | 1.20          | 1.20          | yes      |                                     |
| 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        | 17.000        | 17.000        | 17.000        | yes      |                                     |
| interleave_flag           | off           | off           | off           | off           | no       |                                     |
| interleave_duration (min) | don't care    | 10.0          | 10.0          | 10.0          | no       |                                     |

Table 9: t8 div\_dkl standard\_scatterometer\_inbound block

| Name                      | Nominal    | c          | n          | Mismatch | Comments                      |
|---------------------------|------------|------------|------------|----------|-------------------------------|
| mode                      | radiometer | radiometer | radiometer | no       |                               |
| start_time (min)          | -300.0     | -240.0     | 105.5      | yes      |                               |
| end_time (min)            | -120.0     | -86.0      | 310.0      | yes      |                               |
| time_step (s)             | 2700.0     | 5400.0     | 5400.0     | 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 (KHz)                 | don't care | 1.00       | 1.00       | 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             | 1.000      | 0.992      | 0.992      | yes      |                               |
| interleave_flag           | off        | off        | off        | no       |                               |
| interleave_duration (min) | don't care | 10.0       | 10.0       | no       |                               |

Table 10: t8 div\_cn standard\_radiometer\_inbound block

## 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                                     |