Observation Overview

First of all … THANK YOU! for Rev 273

- S99 Rev 274 RSS observations
  - Include
    - Gravity observation (24hrs in duration)
    - Periapse ring occultation
    - Distant ingress and egress ring occultations
  - 2-way/3-way mode
  - Periods of Telemetry OFF, Ranging OFF, 2-way/3-way mode (during occultations)
  - Playbacks planned during gravity observation when TLM is not off
  - 11 tracks scheduled
    - 8 DSN, 3 ESA
    - No, not a record!
    - Rev 028 in 2006 on DOY 258-260 (9/15-17) was the record with 12 tracks
      - Saturn rings and atmospheric occultations
      - DSN only

Science Highlights

Gravity Observation - From Luciano Iess

Rev 274 is the second of six orbits devoted to the determination of Saturn's gravity field and the mass of the B ring. The spacecraft will collect gravity and magnetic field data from a distance as close as 3000 km from the cloud level. Those data are crucial to build interior models of the planet and to determine the depth of zonal winds.

The Cassini radio science investigation will measure Saturn gravity field and the ring mass by means of range rate measurements enabled by the onboard X band (7.2-8.4 GHz) radio system, and the antennas of NASA's Deep Space Network and ESA's tracking network. The gravity determination is obtained by fitting the radial velocity of the spacecraft with accuracies of about 0.05 mm/s (at a time scale of 60 s) with a model of the spacecraft dynamics. Due to the large Doppler rate, the measurements are aided by predictions obtained from a model of the orbital dynamics.

Cassini orbital geometry is crucial for the gravity experiment. The highly eccentric 6-day orbit has a pericenter close to Saturn's clouds, within the inner edge of the rings. With Cassini passing between the rings and the planet, Cassini will be able to disentangle the strong acceleration due to Saturn's oblateness from that due to tiny pull of the rings. In addition, going close to Saturn Cassini will be affected by tiny density inhomogeneities inside the planet, thus providing clues on their structure.

Cassini gravity passes will be able to provide the density distribution inside Saturn. In particular, it will tell us how massive the core is (we are expecting something like 20 Earth masses of heavy elements in the central part of the planet). The gravity field of Saturn as measured by Cassini depends on how mass is distributed inside the planet. We may imagine that layers of different densities give different contributions to the total gravity. However, it is only the fast rotation of the planet that makes the shape oblate and generates sufficient latitudinal gravity variations to allow inferring the density profile at depth. We know the planet's bulk density from it's mass and radius. (Radius gives us the volume.) The gravity field yields the density as a function of radius in the H/He envelope of the planet. So, in a sense, since we know the density of the whole planet, and the density of the H/He envelope, we can infer that we are, or are not, "missing" mass in the deep interior of the planet, based on how dense the H/He mixture would be extended to very deep interior conditions. If we are missing mass, one can calculate out how much that is, and that is the core mass.

Science Highlights Cont’d

Gravity Observation Cont’d - From Luciano Iess

The tiny pull of the hemispherically asymmetric gravity field we’ll also allow Cassini to tell us how deep the winds are inside Saturn. We know that the winds at the cloud level are up to 300 km/h strong, but we do not know if the flow goes down to just 100, or 1000, or even 10000 km. This is another important science goal of the Grand Finale.

The mass of the rings (concentrated mostly in the B ring) remains uncertain. Its value, generally expressed in terms of Mimas masses, bears crucial information on how and when the rings formed, and their relation with Saturn and its moons. Models predict that a large ring mass implies that the rings are old, dating back to the formation of the Saturnian system 4.5 billion years ago. A small mass implies that the rings are much younger, possibly formed by the impact with a comet.

By the end of July Cassini will tell us a lot about the interior structure and the formation of the Saturnian system. We are anxious to analyse the data, and proud to be part of this endeavor which sees the effort of so many people in the Project and the DSN.

Science Highlights Cont'd

Ring Occultations - From Essam Marouf

The Rev 274 RSS periapse, ingress, and egress ring occultations are the second group in a unique Grand Finale (Proximal Orbits) campaign of Cassini radio occultations of Saturn's ring system. The campaign takes advantage of occultation track geometry that systematically sweeps across the ring system. Collectively, the occultation tracks capture a spread in: 1) Earth relative longitude , and 2) inertial ring longitudes. The first allows characterization of the virtual azimuthal ring asymmetry due to gravitational wakes known to permeate Rings A and B. The second allows characterization of true azimuthal ring asymmetry driven by ring dynamics, including sharp edges and resonant interaction with the satellites and with Saturn's interior structure. Also unique about the campaign is that the rings are close to their maximum opening angle (B~26-27°) as seen from the Earth, possible only near the 2017 epoch of the Proximal Orbits. The large *B*-angle allows maximum penetration of the radio signals of optically thick features, especially Ring B, the many density and bending waves everywhere, confined optically thick ringlets including the Ring C plateaus. Radio occultations enjoy the advantage of measurements using three coherent observation wavelengths (0.94, 3.6, and 13 cm; Ka-, X-, and S-band), allowing not only profiling of ring structure but also constraining the structures physical properties.

The Grand Finale campaign includes ring occultations on the 6 RSS gravity orbits (Revs 273, 274, 275, 278, 280 and 284) and two on Rings segments (Revs 276 and 282). The 6 on the gravity orbits include never before attempted close occultations observing the rings from a distance < ~1 RS near orbit periapse. Dubbed "periapse ring occultations," they start almost immediately after Cassini dives through the ring plane and are short in duration (< 26 m) but cover the complete main ring system. High spatial resolution scattered and direct signals measurements are expected because of the small HGA footprint and the small Fresnel scale, respectively. The collective ring coverage of the RSS Grand Finale occultations is unprecedented in the Cassini Mission.

DSN and ESA Antennas

- DSN Coverage

		Pre	BOT	EOT	Post				
17	135	0140	0310	0620	0635	DSS-55 CAS	RSS GRAV/OCC L3	7171 N750	1A1
17	135	0415	0545	1415	1430	DSS-25 CAS	TP RSS GRAVOC L3	7171 N748	1A1
17	135	0505	0550	1130	1145	DSS-84 CAS	RSS GRAV/OCC	7171 0142	1A1
17	135	0820	0950	2245	2300	DSS-35 CAS	TP RSS GRAVOC L3	7172 N750	1A1
17	135	0845	0945	2245	2300	DSS-43 CAS	RSS GRAV/OCC L3	7172 1647	1A1
17	135	1745	1830	0005	0020	DSS-74 CAS	RSS GRAV/OCC	7173 0142	1A1
17	135	2055	2225	0620	0635	DSS-55 CAS	RSS GRAV/OCC L3	7172 N750	1A1
17	135	2125	2225	0620	0635	DSS-63 CAS	RSS GRAV/OCC L3	7172 1647	1A1
17	136	0115	0200	0820	0835	DSS-84 CAS	RSS GRAV/OCC	7172 0142	1A1
17	136	0410	0540	0800	0815	DSS-25 CAS	RSS GRAV/OCC L3	7172 N748	1A1
17	136	0440	0540	0800	0815	DSS-14 CAS	RSS GRAV/OCC L3	7172 1647	1A1

- DSS-55, DSS-25, DSS-35, DSS-74 and DSS-63 will be providing the uplink

- Goldstone DOY 136 supports don't fully cover the exit baseline
  - They originally ended at 0840, but were shortened during integration when the Rings TWT considered removing the 40min turn at the end
  - The time was not shorterend, but the coverage was not reinstated
  - Coverage is OK as is. Will not request extending

DSN and ESA Antennas Cont'd

Receivers scheduled

- 2 closed-loop receivers per antenna
- DSN Open-loop receivers (RSRs, WVSRs, VSRs, PRSRs)
- PRSR at Malargue and New Norcia
- Open-loop data are prime for occultations. Closed-loop data are prime for gravity
    - Gravity will also use open-loop data
- Only RCP will be recorded
    - 2-way/3-way and 1-way modes

S99 Rev 274 Open-Loop Receiver Assignment

DSS Prdx Mode	Operator (S) Scripted By	Ops Machine	Open-loop Receiver	Channels	Subchannels	Bandwidths KHz
DOY 135						
35 1-/2-way	Elias/Danny/ Clement (S)Elias	rsops1	RSR1	RSR1A -> XRCP RSR1B -> KRCP	1, 2, 3, 4 1, 2, 3, 4	1, 16, 50, 100 1, 16, 50, 100
35 1-/2-way	Danny (S)Danny	rsops4	WVSR1	WVSR1A -> XRCP WVSR1B -> KRCP	1, 2, 3, 4 1, 2, 3, 4	1, 16, 50, 100 1, 16, 50, 100
35 1-/2-way	Danny (S)Danny	rsops4	WVSR2 Precision Mode	WVSR2A -> XRCP WVSR2B -> KRCP	1, 2, 3, 4 1, 2, 3, 4	1, 16, 50, 100 1, 16, 50, 100
43 1-/3-way	Elias/ Danny (S)Elias	rsops1	RSR2	RSR2A -> XRCP	1, 2, 3, 4	1, 16, 50, 100
55 1-/2-/3-way	Clement (S)Clement	rsops1	RSR2 RSR1	RSR2A -> XRCP RSR1B -> KRCP	1, 2, 3, 4 1, 2, 3, 4	1, 16, 50, 100 1, 16, 50, 100
55 1-/2-/3-way	Danny/Aseel (S)Danny	rsops4	WVSR1	WVSR1A -> XRCP WVSR1B -> KRCP	1, 2, 3, 4 1, 2, 3, 4	1, 16, 50, 100 1, 16, 50, 100
55 1-/2-/3-way	Danny/Aseel (S)Danny	rsops4	WVSR2 Precision Mode	WVSR2A -> XRCP WVSR2B -> KRCP	1, 2, 3, 4 1, 2, 3, 4	1, 16, 50, 100 1, 16, 50, 100
DOY 136						
84 2-/3-way	Aseel	rsops6/ psdg5	PRSR 168.96.250.72	PRSR -> XRCP	1, 2, 3, 4	1, 16, 50, 16
14 2-/3-way	Elias/Clement (S)Elias	rsops2	RSR3	RSR3A -> XRCP RSR3B -> SRCP	1, 2, 3, 4 1, 2, 3, 4	1, 16, 50, 16 1, 16, 50, 100
14 1-way	Jay/Danny (S)Jay	rsops5	WVSR2	WVSR2A -> XRCP WVSR2B -> SRCP	1, 2, 3 4, 5, 6, 7 8 1, 2, 3 4, 5, 6, 7	1, 16, 50 1, 16, 50, 100 (with offset) 16 (with offset) 1, 16, 50 1, 16, 50, 100 (with offset)

STILL BEING WORKED

S99 Rev 274 Open-Loop Receiver Assignment

DSS Prdx Mode	Operator	Ops Machine	Open-loop Receiver	Channels	Subchannels	Bandwidths KHz
25 2-/3-way	Elias/Danny (S)Elias	rsops2	RSR1	RSR1A -> XRCP RSR1B -> KRCP	1, 2, 3, 4 1, 2, 3, 4	1, 16, 50, 16 1, 16, 50, 100
25 2-/3-way	Elias (S)Elias	rsops2	RSR2 Precision Mode	RSR2A -> XRCP RSR2B -> KRCP	1, 2, 3, 4 1, 2, 3, 4	1, 16, 50, 16 1, 16, 50, 100
25 1-way	Jay/Danny (S)Danny	rsops3	VSR1	VSR1A -> KRCP	1, 2, 3, 4	1, 16, 50, 100 (with offset)
43 2-/3-way	Elias/Clement (S)Clement	rspos1	RSR1	RSR1A -> XRCP RSR1B -> SRCP	1, 2, 3, 4 1, 2, 3, 4	1, 16, 50, 16 1, 16, 50, 100
43 1-way	Jay/Danny (S)Jay	rsops4	WVSR1	WVSR1A -> XRCP WVSR1B -> SRCP	1, 2, 3 4, 5, 6, 7 1, 2, 3 4, 5, 6, 7	1, 16, 50 1, 16, 50, 100 (with offset) 1, 16, 50 1, 16, 50, 100 (with offset)
35 2-/3-way	Elias/Danny (S)Clement	rsops1	RSR2	RSR2A -> XRCP RSR2B -> KRCP	1, 2, 3, 4 1, 2, 3, 4	1, 16, 50, 16 1, 16, 50, 100
35 1-way	Jay/Danny (S)Jay	rsops4	WVSR2	WVSR2A -> XRCP WVSR2B -> KRCP	1, 2, 3 4, 5, 6, 7 1, 2, 3 4, 5, 6, 7	1, 16, 50 1, 16, 50, 100 (with offset) 1, 16, 50 1, 16, 50, 100 (with offset)

STILL BEING WORKED

WVSR1A at Goldstone unavailable (being used by VLBI)
PRSR1 at Madrid is backup
VSR1 at Canberra is backup
No precision mode recordings at DSS-35 on DOY 129

Don't record
Same fgain throughout (use TLM off fgain)
Re-set fgain when TLM is off at xx:xx:xx and don't change

DSN Open-Loop Receiver Status

Email from Danny on 4/12

Goldstone

RSR1 – Green (X-band power jumps observed on RSR1A)
RSR2 – Green with date rate != num_samples warnings
RSR3 – Green
VSR1A – "Orange" - DP Internal Error Error may occur; try restarting; reliability in question
VSR1B – "Red" - DP Internal Error Error may occur; try restarting; reliability in question
WVSR1 – Green w/ with fgain bug
WVSR2 – Green w/ with fgain bug
No PRSR

Canberra

RSR1 – Green
RSR2 – Green
VSR1 – Green
PRSR1 –Red
WVSR1 – Green w/ with fgain bug
WVSR2 – Green w/ with fgain bug

Madrid

RSR1A – Red but can be used by overriding dig vfy test
RSR1B - Green
RSR2A – Green
RSR2B – Digitizer test fails due to unknown cause. Can be used by overriding dig vfy test
VSR1 – Red
PRSR1 – Green
WVSR1 – Green w/ with fgain bug
WVSR2 - Green w/ with fgain bug

Real-Time Support

RSSG will be in Ops Room at 6:30 pm on Sunday, May 14 (135/0130)

- Last post-cal ends at 1:35 am on Tuesday, May 16 (136/0835)
- 31 hours
    - Rev 273 was 37 hours
- Will send engineering team support schedule soon

NOA support?

ACE support?

Predicts

- Last NAV OD delivery was on May 9
  - No other deliveries planned before the Rev 274 observations
- RSS will not be modifying the uplink predicts
- Lu: Can you please ask SPS to provide uplink predicts by early tomorrow morning
- Elias and Danny will generate and verify the open-loop downlink predicts
- RSS usually uses three sets of downlink predicts in the open-loop receivers for occultations:
  - #1: Coherent (2-way/3-way)
  - #2: 1-way coherent:1-way predicts offset in real-time to coherent downlink frequency
  - #3: 1-way (no offset): For 1-way baseline and when the DST loses lock (for example, dense ring regions)
- If an additional receiver is available, will record in high precession mode for gravity
  - Did that during Rev 273

Post Rev 273 Comments

- High signal dynamics around periapse
  - Ka-band (and X-band?) Signal drifting in and out of 1 KHz open-loop recordings
    - Large drift in part due to not using coherent predicts with correct uplink ramps?
      - Can’t generate coherent predicts with ESA. Instead use 3-way with DSN when the stations are coherent with ESA
  - DSN closed-loop receivers maintained lock
  - Now have ESA uplink ramps so we’re starting to look into this more

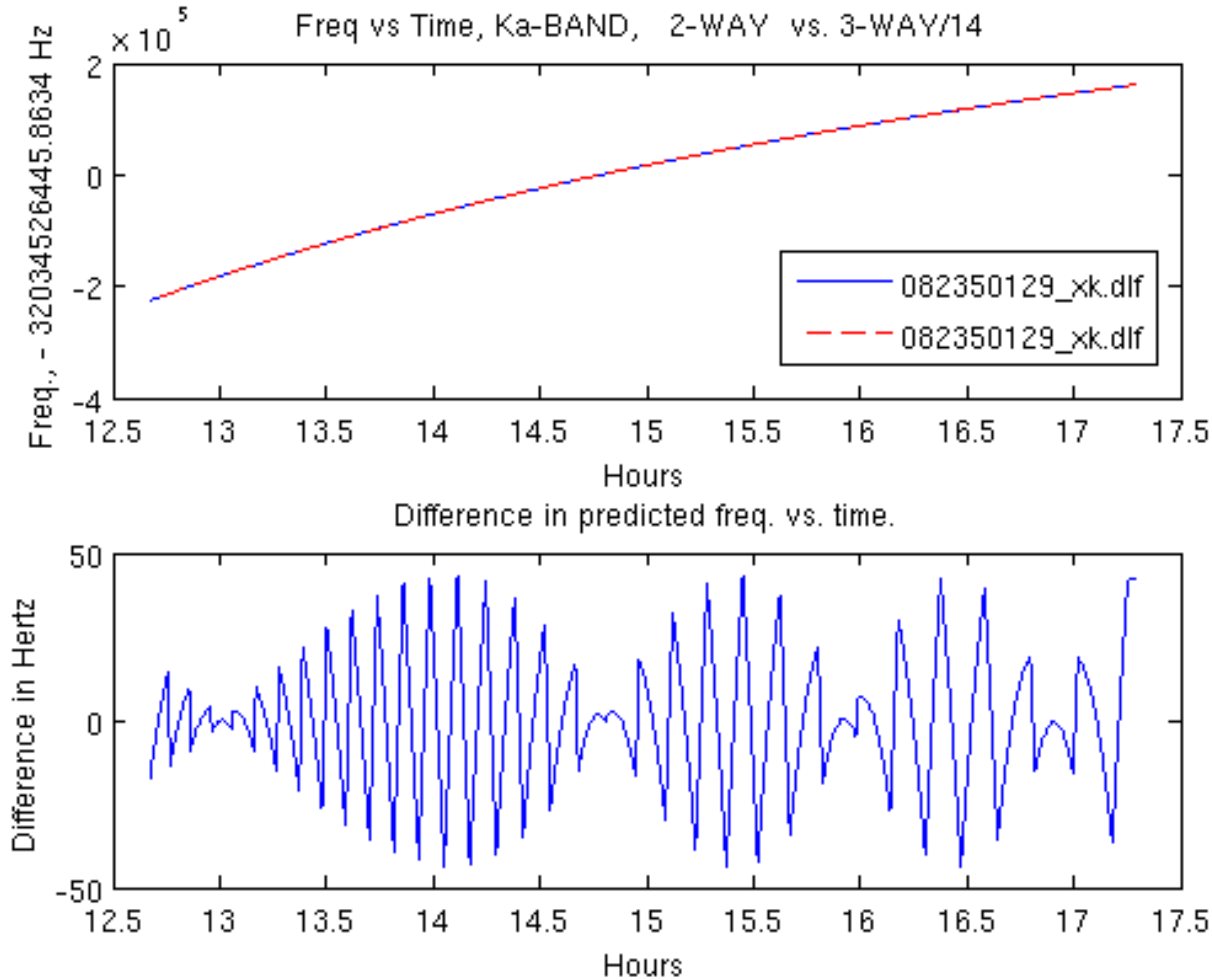
- DSS-55 required clarification about uplink ramp and no sweep

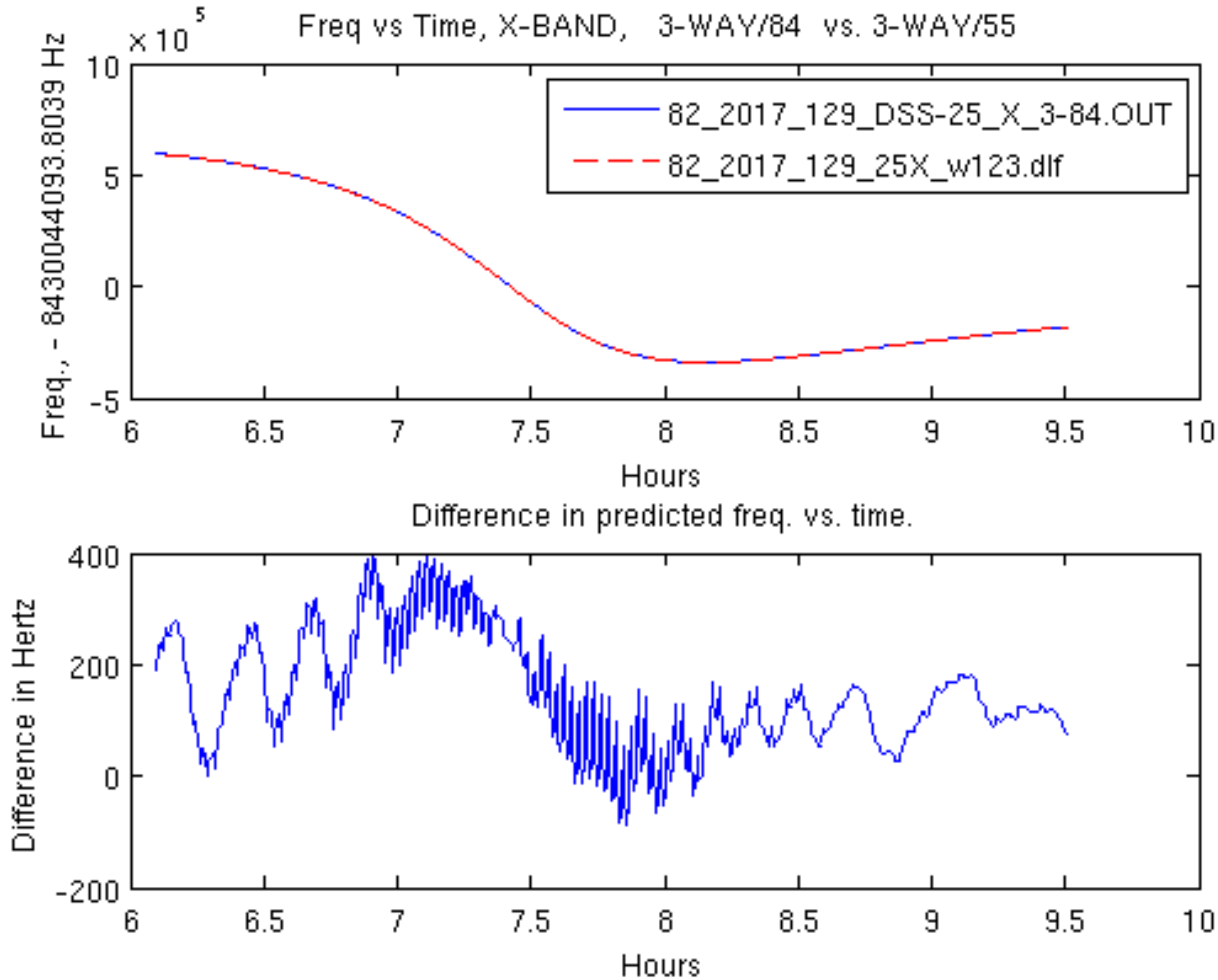
- Some stations had SNT enabled when they should’ve been disabled

- DSS-25 wanted to disable Monopulse at switch from 3-way/55 to 3-way/14
  - Told them thought it was unnecessary
  - They requested widenning carrier loop bandwidth
  - Is this needed?

- To discuss with engineering team
  - Shifts, disk space, scripts, recording bandwidths,

- Any others?


Freq vs Time, Ka-BAND, 2-WAY vs. 3-WAY/14
× 10^5
Freq., - 32034526445.8634 Hz
2
0
-2
-4
082350129_xk.dlf
082350129_xk.dlf
12.5
13
13.5
14
14.5
15
15.5
16
16.5
17
17.5
Hours
Difference in predicted freq. vs. time.
Difference in Hertz
50
0
-50
12.5
13
13.5
14
14.5
15
15.5
16
16.5
17
17.5
Hours


Freq vs Time, X-BAND, 3-WAY/84 vs. 3-WAY/55
× 10^5
Freq., - 8430044093.8039 Hz
82_2017_129_DSS-25_X_3-84.OUT
82_2017_129_25X_w123.dlf
10
5
0
-5
6
6.5
7
7.5
8
8.5
9
9.5
10
Hours
Difference in predicted freq. vs. time.
Difference in Hertz
400
200
0
-200
6
6.5
7
7.5
8
8.5
9
9.5
10
Hours

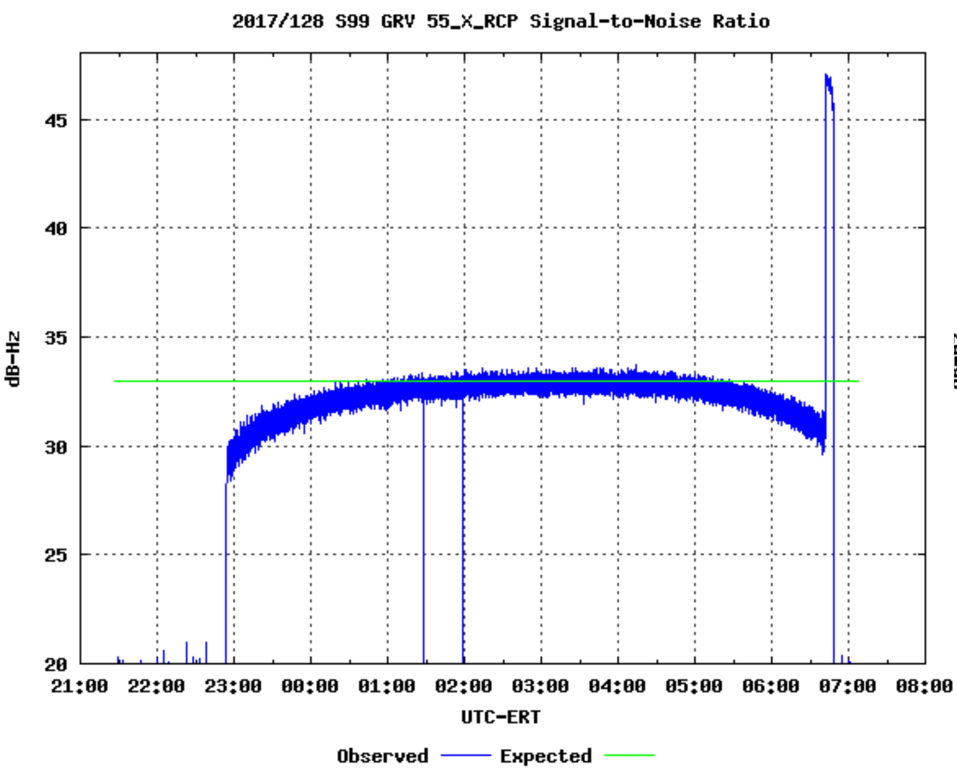
ORTs

None planned between Rev 273 and 274, but Rev 273 provide good antenna pointing data to assess the pointing models

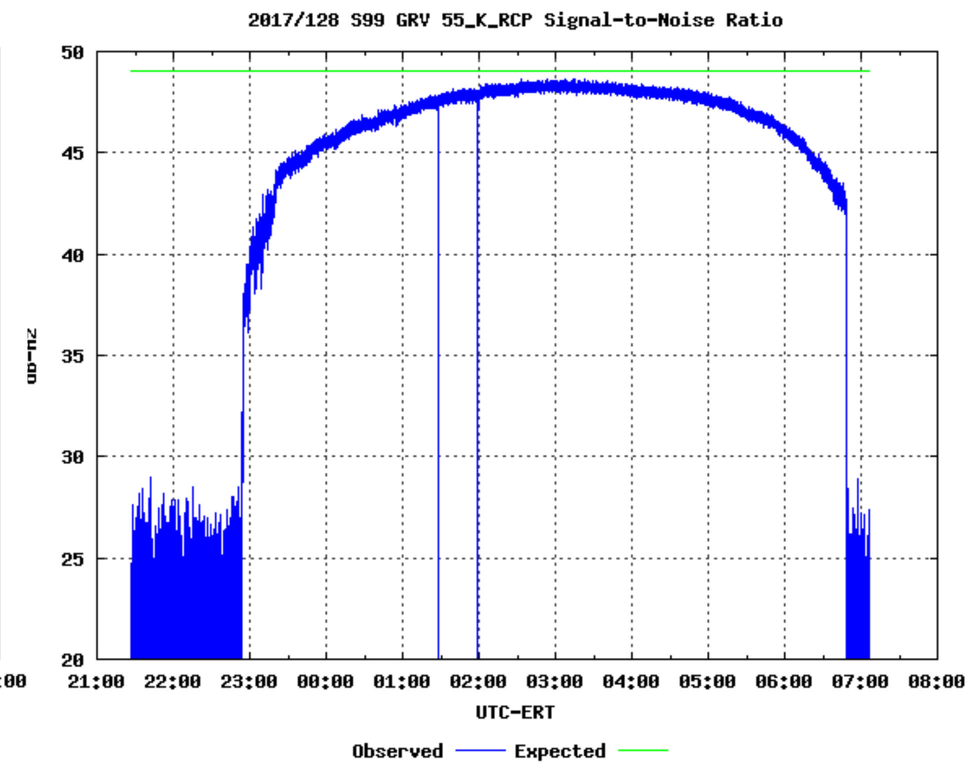
- Tracks from rise to set at all complexes
- Good weather

Example: DSS-55 on DOY 128

55X



55Ka



Misc

Uplink Strategy

- DSS-55, 18 kW, ramped, sweep
- DSS-25, 18 kW, ramped, no sweep
  - Uplink transfer between Madrid and Goldstone not possible
    - ~5min gap in uplink due to transmitter elevation limits

      DSS-55 transmitter off limit: 135/06:02:15 ERT

      DSS-25 transmitter on limit: 135/06:07:10 ERT
    - Timeline has DSS-55 stopping the uplink at 135/060200, and DSS-25 starting at 135/061000
      - 8 minute coherent gap
- DSS-35, 18 kW, ramped, no sweep
  - Uplink transfer from DSS-25
- DSS-74, 18 kW, ramped, no sweep
  - Uplink transfer from DSS-35
  - To close uplink gap between Canberra and Madrid
- DSS-63, 18 kW, ramped, sweep
  - Sweep to ensure DST lock at occultation egress

DSS-43 declared red as soon as we completed Rev 273 support

- DOY 129/2200z, SPC-40 declared DSS-43 MSI (Master Equatorial Servo Interface) RED
- Impact to Rev 274?

Misc Cont'd

Subreflectors at DSN and ESA
- Fixed or moving?
- ESA asked if can compare data with fixed from DOY 129 with data from moving from previous supports

BLF
- Checked with Telecom prior to Rev 273 if an update is needed, and they said no
- Do we need to check again?

DKF
- Does not have the correct uplink or AOS/LOS times. Use times in RSS timeline
- DKF has playback times

DSS-35 will be prime (2-way) during closest approach period

Monopulse
- Per timeline
  - Stations to enable and disable Monopulse only when requested by RSS
- Rising stations - Wait for ~10 degrees elevation to enable Monopulse

4th Order Blind Pointing Models
- Data sent to David
- Graham Baines at Canberra has been checking the DSS-35 pointing model

Misc Cont'd

Timeline
- There will be a v2
- Comments are welcome

Doppler Dynamics
- NOA-s will check accelerations during periapse period
- Need to increase carrier loop bandwidth around periapse?
- Preference is to keep the same bandwidths throughout the support

Rev 274 is shared with CDA
- They picked

NOPEs
- Any other red/orange equipment?

RSSG
Ops room displays
- Started by first shift, updated as needed by later shifts

Danny
- Please check open-loop receivers status, availability and disk space