Ku-band Open Loop Performance Assessment at Higher TDRS Eccentricities

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Two Questions for thie Analysis:

- Can the TDRS network allow the orbits of the TDRS satellites go to a higher eccentricity of 0.0035 without impacting Open Loop operations?
    - TDRS 275 is already at the higher eccentricity
- Can TOPO get some down-track accuracy relief to update their flight rule currently indicating that we can accept only 90 Km of down track error?

Notes on Analysis Method:

- Compared the mean and the standard deviation of the PWRL during the autotrack portion of each event to the Open Loop part of the event.
  - The effect of range can be seen in the results – the Open Loop portions all contained the shortest TDRS ranges.
- Assessed the GNC pointing vector accuracy with respect to the Ku-band, after applying the static bias in PPL #27.
  - Computed the total angle between the Ku-band and the GNC pointing solution from the beginning and end of Autotrack mode just before the start of Open Loop operations.

Ku-band Forward Link Analysis Results:

TDRS ID	Autotrack PWRL (dBm)	Open Loop PWRL (dBm)	GNC Pointing Accuracy (degrees)
046	Median = -48.6 Std Dev = .0998	Median = -48.0 Std Dev = .7220	Median = .1777 Std Dev = .0044
041	Median = -43.4 Std Dev = .0428	Median = -43.22 Std Dev = .2427	Median = .2192 Std Dev = .0255
041	Median = -43.3 Std Dev = .1462	Median = -42.91 Std Dev = .3220	Median = .1793 Std Dev = .0048
275	Median = -44.22 Std Dev = .0772	Median = -46.74 Std Dev = .5435	Median = .2701 Std Dev = .0047
171	Median = -45.1 Std Dev = .3432	Median = -43.88 Std Dev = .7597	Median = .2926 Std Dev = .0116

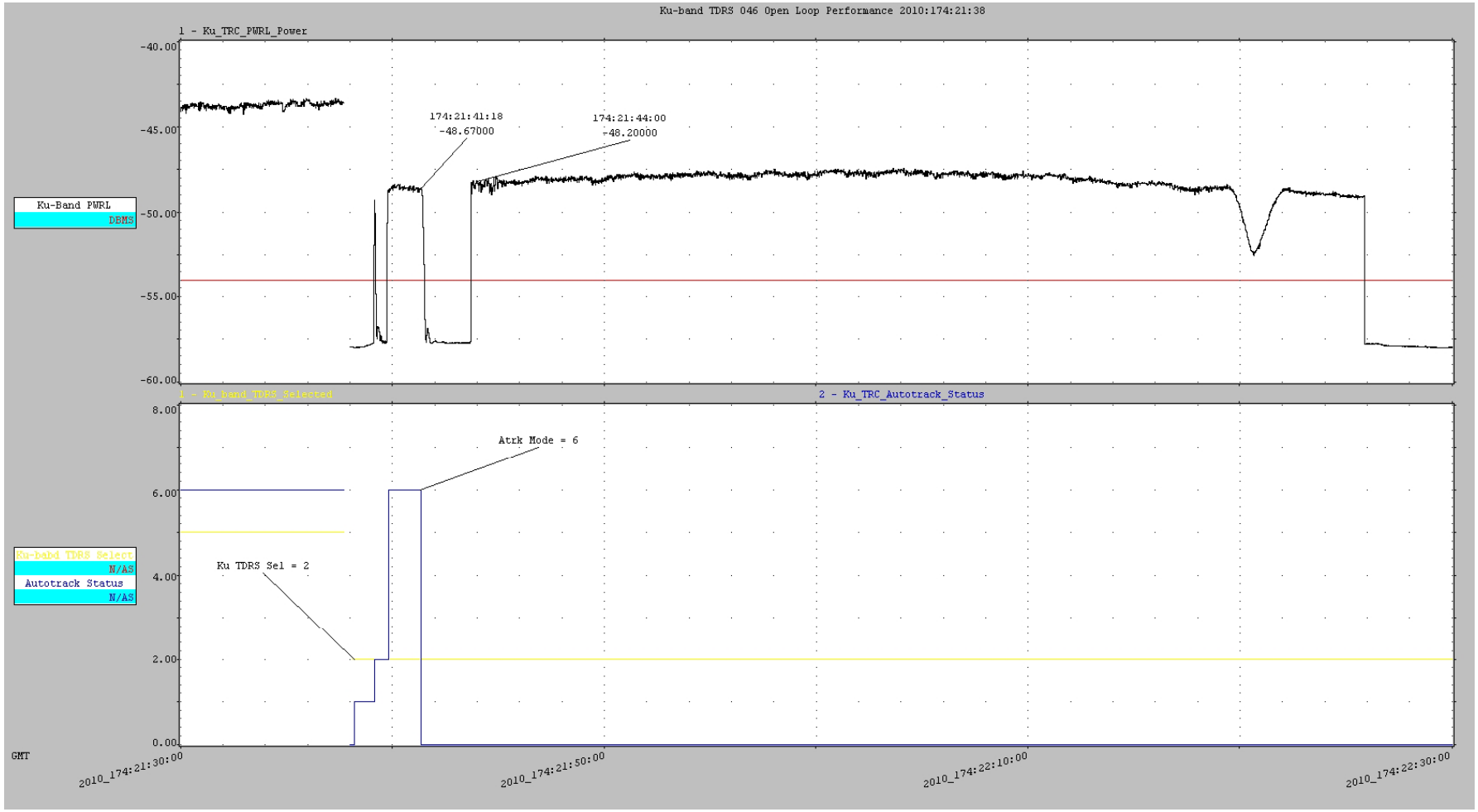
Ku-band Forward Link Analysis Results:

TDRS ID	Autotrack PWRL (dBm)	Open Loop PWRL (dBm)	GNC Pointing Accuracy (degrees)
174	Median = -45.77 Std Dev = .2151	Median = -43.96 Std Dev = .5081	Median = .1626 Std Dev = .0104
275	Median = -44.27 Std Dev = .0737	Median = -47.3 Std Dev = .4949	Median = .3324 Std Dev = .0072
174	Median = -46.38 Std Dev = .3541	Median = -44.56 Std Dev = .3518	Median = .2353 Std Dev = .0126
046	Median = -48.47 Std Dev = ..0664	Median = -48.18 Std Dev = .1270	Median = .1161 Std Dev = .0048
171	Median = -43.41 Std Dev = .1146	Median = -43.07 Std Dev = .6741	Median = .1559 Std Dev = .0044

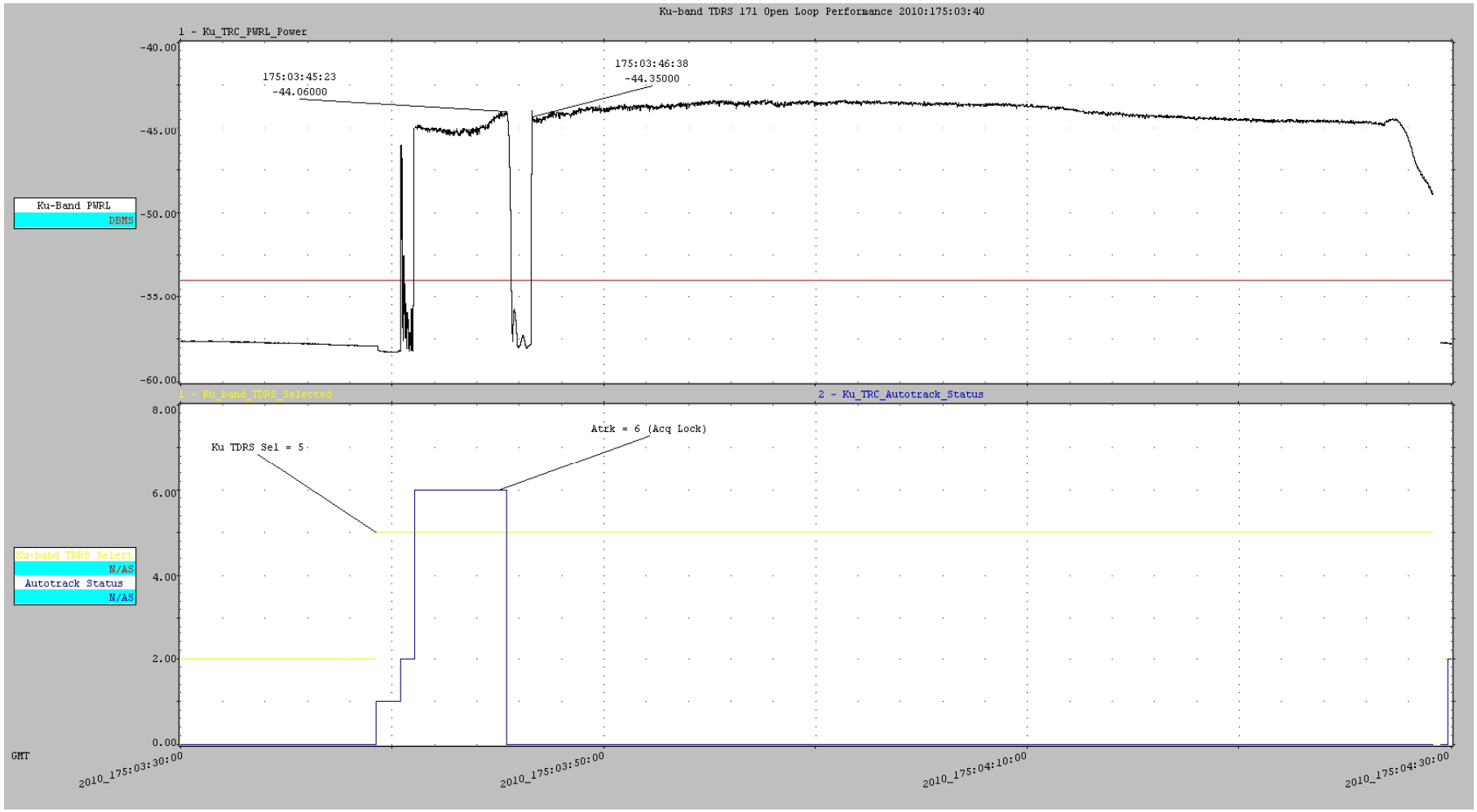
Two Answers Based On Ku-band Forward Link Performance:

- Can the TDRS network allow the orbits of the TDRS satellites go to a higher eccentricity of 0.0035 without impacting Open Loop operations?
  - Yes, the Ku-band maintained forward link lock on TDRS 275 and the on-board state vector was 203 days old.
- Can TOPO get some down-track accuracy relief to update their flight rule indicating that we can accept only 90 Km of down track error?
  - Yes, testing indicates that the Ku-band half-angle value is in excess of 0.4 degrees.
  - Recommend allowing CATO to retain some forward link margin and allowing for a Ku-band half-cone angle of 0.3 degrees.
  - Equates to 219 Km of acceptable down track error assuming TDRS 42,000 Km semi-major axis.

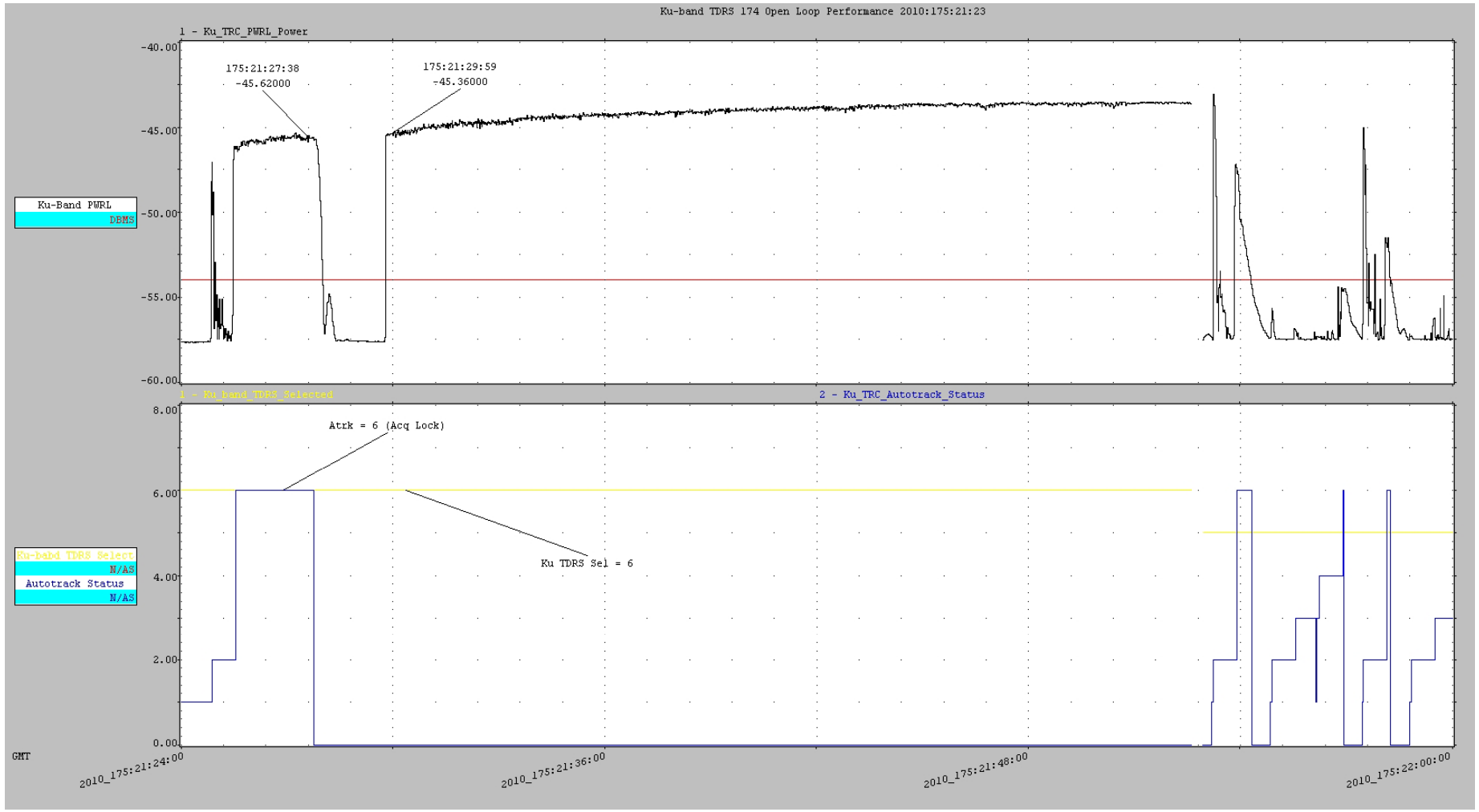
TDRS 046 Open Loop Performance 2010:174:21:38



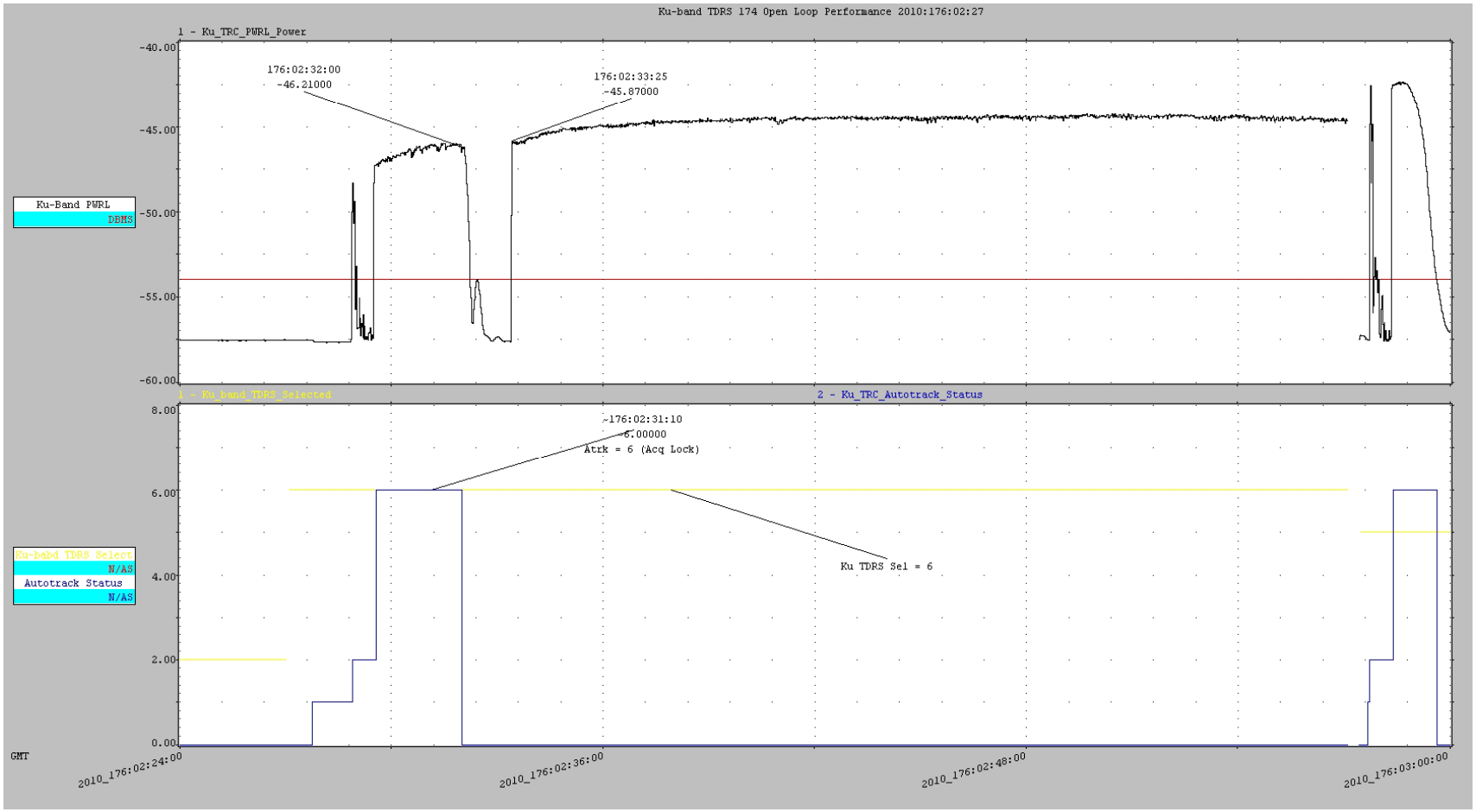
TDRS 171 Open Loop Performance 2010:175:03:40



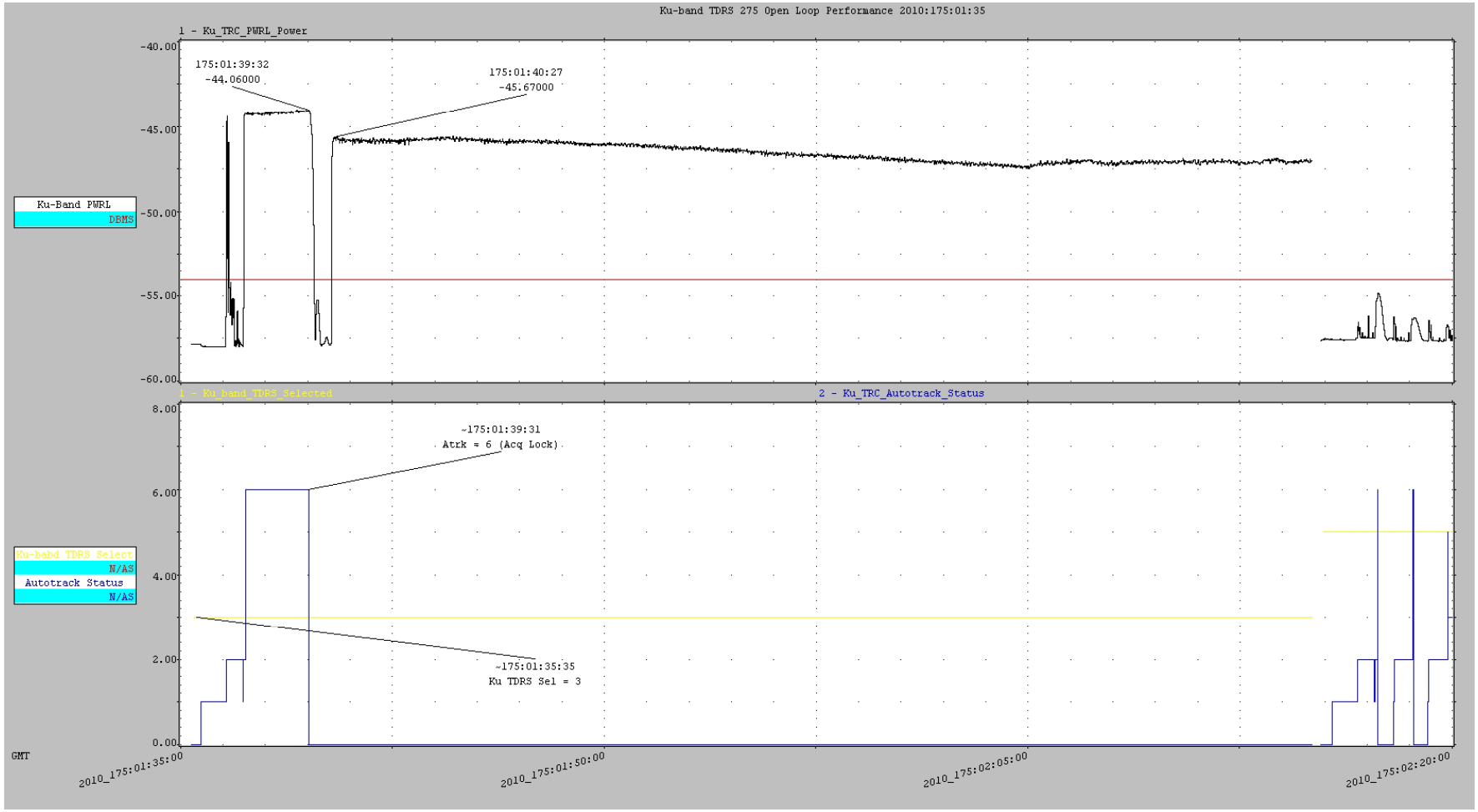
TDRS 174 Open Loop Performance 2010:175:21:23



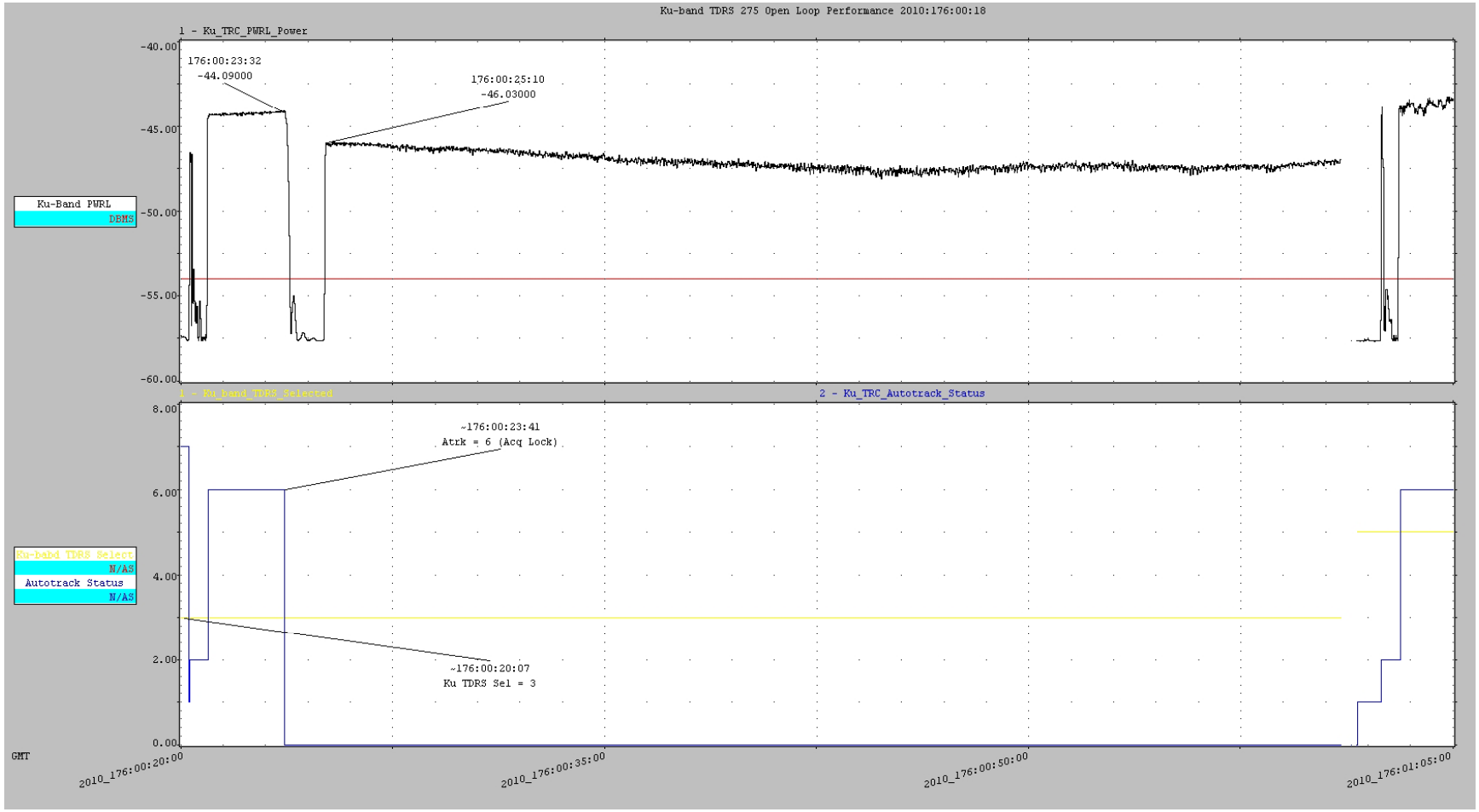
TDRS 174 Open Loop Performance 2010:176:02:27



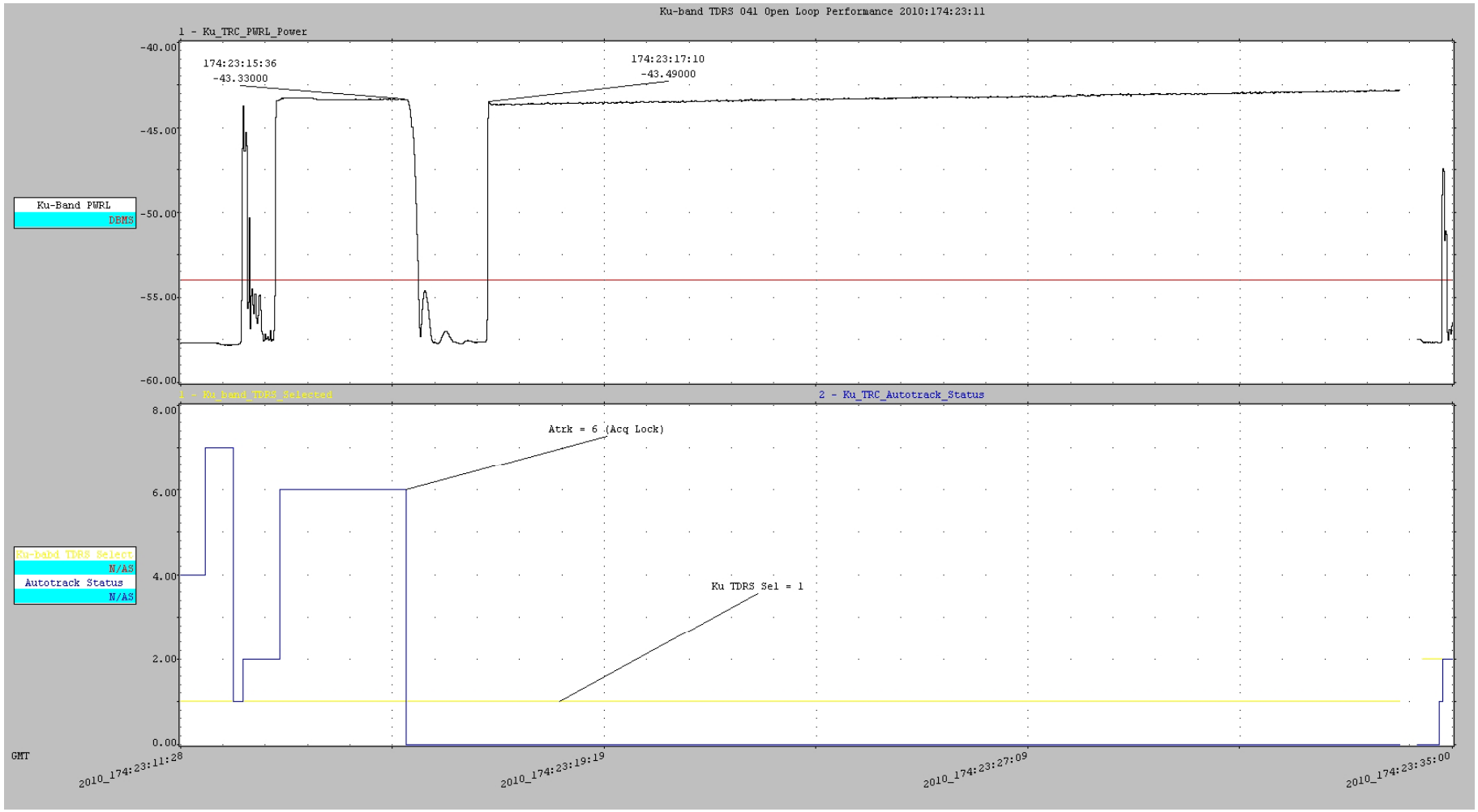
TDRS 275 Open Loop Performance 2010:175:01:35



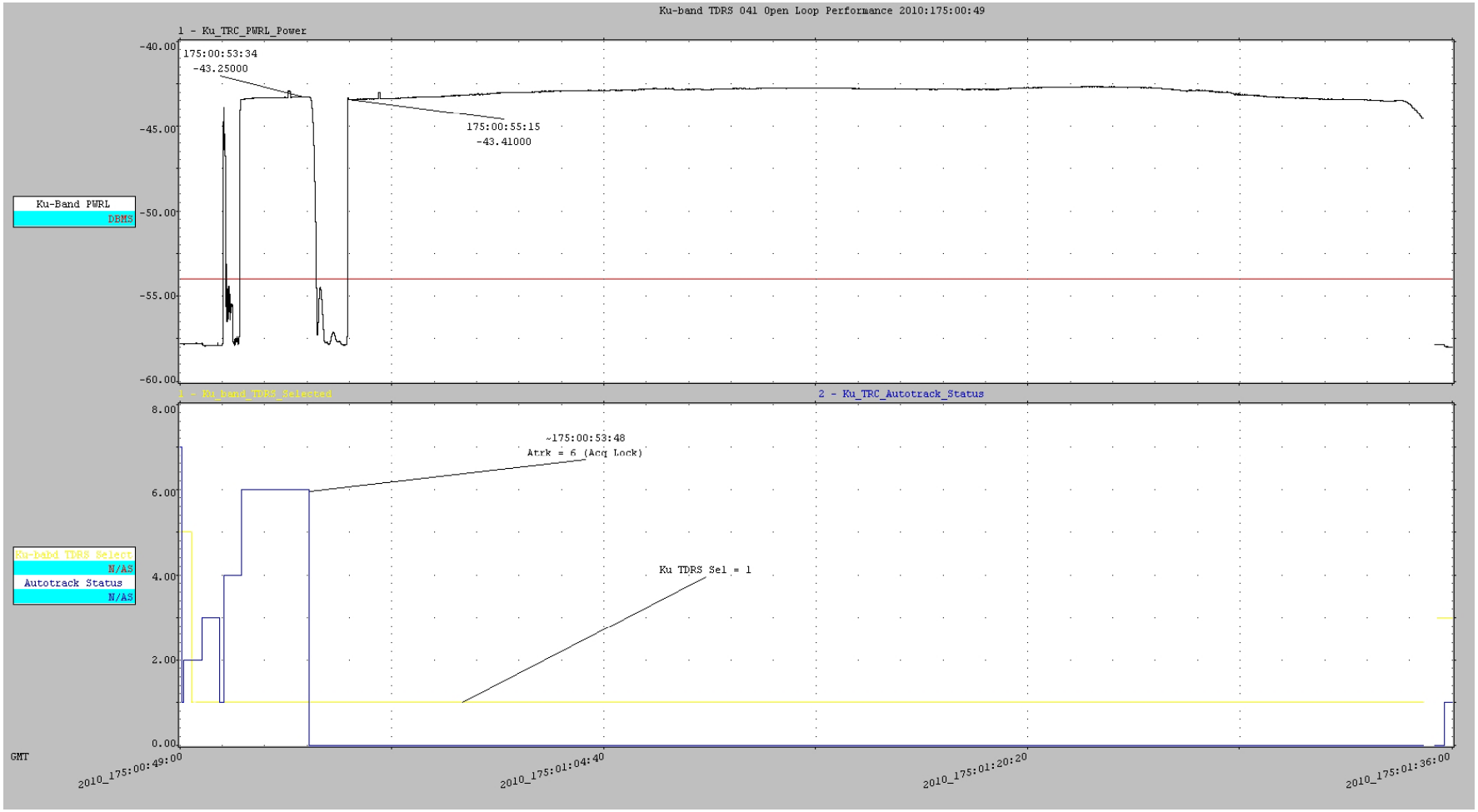
TDRS 275 Open Loop Performance 2010:176:00:18



TDRS 041 Open Loop Performance 2010:174:23:11



TDRS 041 Open Loop Performance 2010:175:00:49



Conclusion

- The test results indicate that the Ku-band link margin can provide the Open Loop capability using TDRS at higher eccentricities.
- TOPO can allow for greater down track error, thereby decreasing the frequency of TDRS state vector uplinks.
  - Acceptable down track error up to 219 Km.

BACKUP CHARTS

- Information about the on-board TDRS State Vectors follows.

TDRS Event Data Supporting Ku-band Open Loop Performance Study

- TDRS 041 event times for this study: 2010:174/23:11 and 2010:175/00:49

T041 State Vector Time: 2010:125:15:00	
Command Parameter	**Value Uplinked**
Slot Number:	5
Satellite ID:	1
Semi-Major Axis	42162335.286948
Inclination	0.006405865
RA of the Asc. Node Time, Coarse	957084451
RA of the Asc. Node Time, Fine	0.0150000
Asc. Node Longitude	5.478852
Mean Motion	0.000072921900
Uplink ID	04112

- Uplink time-tag for this state vector: 2010:125/22:59:35.355
- Means this state vector was approximately 49 days old when we used it for this test.
- Corresponding Cartesian Coordinates for the uplinked state vector:
  - X = 28571043.835546
  - Y = 31009596.079659
  - Z = 269624.461998
  - XDOT = -2261.27667666
  - YDOT = 2083.09333400
  - ZDOT = -1.1795754
  - Longitude = 40.90

TDRS Event Data Supporting Ku-band Open Loop Performance Study

- TDRS 046 event times for this study: 2010:174/21:38 and 2010:182/05:49

T046 State Vector Time: 2010:169:12:00	
Command Parameter	**Value Uplinked**
Slot Number:	2
Satellite ID:	2
Semi-Major Axis	42164862.994569
Inclination	0.197985342
RA of the Asc. Node Time, Coarse	960813137
RA of the Asc. Node Time, Fine	0.010000
Asc. Node Longitude	0.831452
Mean Motion	0.000072917700
Uplink ID	04631

- Uplink time-tag for this state vector: 2010:169/20:50:23.478
- Means this state vector was approximately 5 days old when we first used it.
- Corresponding Cartesian Coordinates for the uplinked state vector:
  - X = 31922369.314769
  - Y = 27488774.152275
  - Z = -1016254.299451
  - XDOT = -1958.30988760
  - YDOT = 2295.56090067
  - ZDOT = 600.59110958
  - Longitude = 45.75

TDRS Event Data Supporting Ku-band Open Loop Performance Study

- TDRS 275 event times for this study: 2010:175/01:35 and 2010:176/00:18

T275 State Vector Time: 2009:336:12:00	
Command Parameter	**Value Uplinked**
Slot Number:	3
Satellite ID:	3
Semi-Major Axis	42161746.628170 m
Inclination	0.199707806^0
RA of the Asc. Node Time, Coarse	943720998
RA of the Asc. Node Time, Fine	0.470000
Asc. Node Longitude	.808583
Mean Motion	0.000072921500
Uplink ID	27562

- Uplink time-tag for this state vector: 2009:336:19:44:46.811
- Means this state vector was approximately 203 days old when we first used it.
- Corresponding Cartesian Coordinates for the uplinked state vector:
  - X = 37856452.203369 m
  - Y = -16536146.011744 m
  - Z = -7853454.334670 m
  - XDOT = 1264.31824289 m/sec
  - YDOT = 2804.14202032 m/sec
  - ZDOT = 206.82545842 m/sec
  - Longitude = 274.93^0

TDRS Event Data Supporting Ku-band Open Loop Performance Study

- TDRS 171 event time for the first event in this study: 2010:175/03:40

T171 State Vector Time: 2010:158:12:00	
Command Parameter	**Value Uplinked**
Slot Number:	1
Satellite ID:	5
Semi-Major Axis	42165880.989196 m
Inclination	0.186804542^0
RA of the Asc. Node Time, Coarse	959895297
RA of the Asc. Node Time, Fine	0.610000
Asc. Node Longitude	.896312
Mean Motion	0.0000729916600
Uplink ID	17129

- Uplink time-tag for this state vector: 2010:159:04:38:38.701
- Means this state vector was almost 16 days old when we first used it.
- Corresponding Cartesian Coordinates for the uplinked state vector:
  - X = -1858951.870836 m
  - Y = -41905183.335015 m
  - Z = -4671842.188735 m
  - XDOT = 3036.49792363 m/sec
  - YDOT = -77.82566208 m/sec
  - ZDOT = -457.43671240 m/sec
  - Longitude = 168.18^0

TDRS Event Data Supporting Ku-band Open Loop Performance Study

- TDRS 171 event time for the second event in this study: 2010:182/03:34

T171 State Vector Time: 2010:174:12:00	
Command Parameter	**Value Uplinked**
Slot Number:	1
Satellite ID:	5
Semi-Major Axis	42164715.406202 m
Inclination	0.187589732^0
RA of the Asc. Node Time, Coarse	961273944
RA of the Asc. Node Time, Fine	0.360000
Asc. Node Longitude	0.893467
Mean Motion	0.000072922300
Uplink ID	17132

- Uplink time-tag for this state vector: 2010:175:17:43:21.029
- Means this state vector was a little more than 6 days old when we used it.
- Corresponding Cartesian Coordinates for the uplinked state vector:
  - X = 9368015.770042 m
  - Y = =40657262.509054 m
  - Z = -6222446.457793 m
  - XDOT = 2961.70165343 m/sec
  - YDOT = 742.34074529 m/sec
  - ZDOT = -349.77818014 m/sec
  - Longitude = 168.43^0

TDRS Event Data Supporting Ku-band Open Loop Performance Study

- TDRS 174 event times for this study: 2010:175/21:23 and 2010:176/02:27

T171 State Vector Time: 2010:158:12:00	
Command Parameter	**Value Uplinked**
Slot Number:	6
Satellite ID:	6
Semi-Major Axis	42165354.819927 m
Inclination	0.175781171^0
RA of the Asc. Node Time, Coarse	959896931
RA of the Asc. Node Time, Fine	0.590000
Asc. Node Longitude	0.947961
Mean Motion	0.000072920300
Uplink ID	17430

- Uplink time-tag for this state vector: 2010:159:04:36:05.386.
- Means this state vector was more than 16 days old when we first used it.
- Corresponding Cartesian Coordinates for the uplinked state vector:
  - X = -4479333.812307 m
  - Y = -41803153.308742 m
  - Z = -3685005.297722 m
  - XDOT = 3023.49225545 m/sec
  - YDOT = -280.23221061 m/sec
  - ZDOT = -465.21366213 m/sec
  - Longitude = 171.75^0