

## REX Activities in KEM Cruise 1

Ivan Linscott

The REX activities in Loads 16354 to 17331, are associated with four tasks:

1. Solar Conjunction Observations
2. SNR Verification (e.g. Radio Path Characterization)
3. Radio path characterization (misnamed 'Total Electron Counts')
4. Bistatic Dry Run

Each of the tasks was bookended with the REX Test Patterns, that use preset sequences with known response to compare with the REX output and verify performance of the REX process. Since the Test Patterns are run in concert with every REX event, they will not be further described in the four REX measurements to follow.

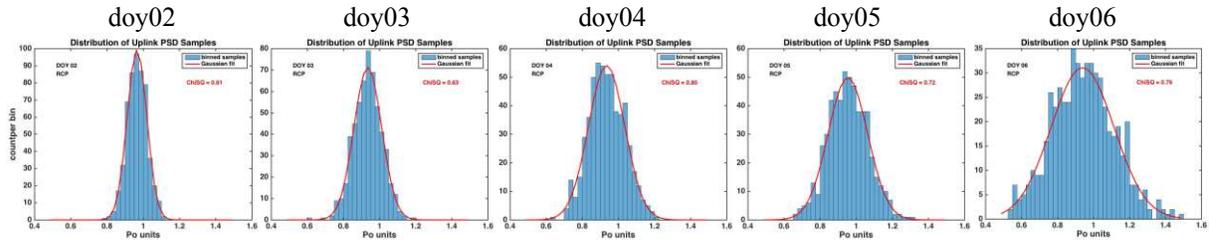
### 1. Solar Conjunction Observations (Load 16354)

In early January of 2017, the New Horizons spacecraft entered solar conjunction, in a manner similar to what is expected during the MU69 Encounter in January 2019, when uplinks transmitted from earth will be used to characterize MU69 and its environment. Transmitting uplinks at or near solar conjunction and through the solar corona is expected to degrade the uplink's stability in both frequency and amplitude. A high stability of the uplinks is necessary for the planned measurements with REX at MU69. Hence determining both the frequency and amplitude stability of uplinks transmitted from earth and received by the New Horizons spacecraft and REX was the objective of the Solar Conjunction Observations.

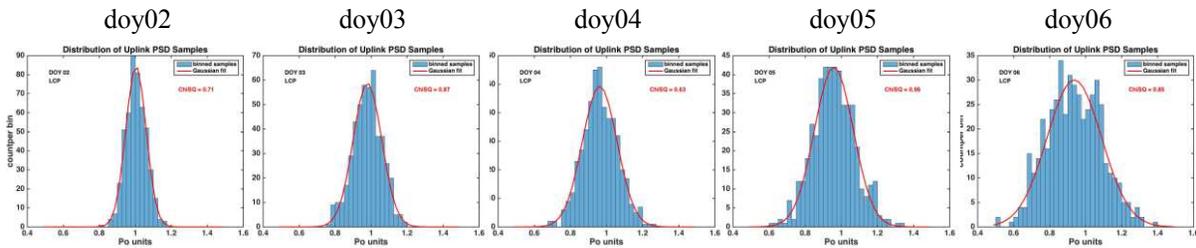
On each of five days as the spacecraft entered into solar conjunction, X-band uplink measurements were made by REX as the earth approached solar conjunction with New Horizons on January 2 to 6, 2017. The earth-sun-spacecraft angle  $\theta_{SEC}$ , changed by  $\sim 1$  degree/day, from  $\sim 5$  degrees to  $\sim 1$  degree, from January 2<sup>nd</sup> to January 6<sup>th</sup>. On each of those days, two X-band uplinks, one in each polarization, were transmitted to New Horizons, and REX recorded the uplink waveforms on the spacecraft for 100 seconds. The REX data characterized the radio path from earth, through the solar corona and out through the solar system to the spacecraft. The distributions of the uplink's amplitude and phase fluctuations was found as a function of  $\theta_{SEC}$ . These distributions evaluate the radioscience utility of the uplinks particularly for navigation and measurements of MU69. The flyby of MU69 is planned for January 1<sup>st</sup>, 2019, close to solar conjunction, when the earth-sun-spacecraft angle will be 6 degrees.

The fluctuations distributions for January 2<sup>nd</sup> to 6<sup>th</sup>, are shown in Figures 1.1, and 1.2. The distributions' standard deviations (STD's), increase linearly with  $\theta_{SEC}$ , from day-of-year 02, (doy02) to doy04, with a marked increase on doy-05 and doy-06. Extrapolating the linear trend indicates that during MU69 encounter, with a  $\theta_{SEC}$  of 6 degrees, the STD's will be comparable to the Pluto flyby, and suitable for the planned Radioscience measurements at MU69.

## Right-Hand Circular Polarization

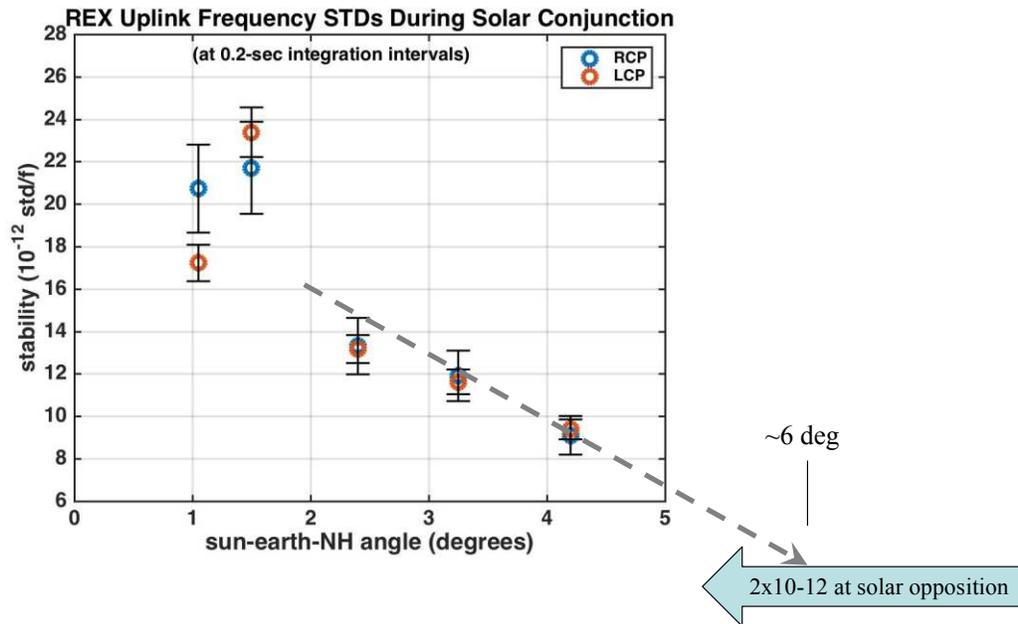


## Left-Hand Circular Polarization



REX Solar Conjunction January 2 to 6, 2017

Figure 1.1. Uplink power distributions during the solar conjunction campaign. The uplinks' power in REX, sampled five times per second, is normalized to the mean. The scale of the horizontal axes is the same in all the plots, showing the power fluctuation distribution's width increases steadily as the angle between the sun and the earth decreases.



REX Solar Conjunction January 2 to 6, 2017

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Figure 1.2. Uplink frequency standard deviations during the solar conjunction campaign. The uplink's frequency is sampled in the REX data at a cadence of 0.2 seconds, and the standard deviation of the distribution of those samples, normalized by the uplink frequency is plotted vs the sun-earth-NH angle. The trend in stability is extrapolated to 6 degrees, the separation angle expected during the MU69 encounter.

The following is the DataTrack listing of the REX data during the Solar Conjunction Campaign.

16354	KARX_1ab_TestPatt_Conj_Start	2017-003_00:13:33	S/C	345,708,333	345,708,635
16354	KARX_1ab_TestPatt_Conj_Start	2017-003_00:13:48	S/C	345,708,348	345,708,650

16354	KARX_19ab_Solar_Conj_Day1	2017-003_00:18:37	S/C	345,708,637	345,803,135
16354	KARX_19ab_Solar_Conj_Day1	2017-003_00:18:52	S/C	345,708,652	345,803,150

16354	KARX_19ab_Solar_Conj_Day2	2017-004_02:33:37	S/C	345,803,137	345,889,535
16354	KARX_19ab_Solar_Conj_Day2	2017-004_02:33:52	S/C	345,803,152	345,889,550

16354	KARX_19ab_Solar_Conj_Day3	2017-005_02:33:37	S/C	345,889,537	345,975,935
16354	KARX_19ab_Solar_Conj_Day3	2017-005_02:33:52	S/C	345,889,552	345,975,950

16354	KARX_19ab_Solar_Conj_Day4	2017-006_02:33:37	S/C	345,975,937	346,062,031
16354	KARX_19ab_Solar_Conj_Day4	2017-006_02:33:52	S/C	345,975,952	346,062,046

16354	KARX_1ab_TestPatt_Conj_End	2017-007_02:28:33	S/C	346,062,033	346,062,335
16354	KARX_1ab_TestPatt_Conj_End	2017-007_02:28:48	S/C	346,062,048	346,062,350

16354	KARX_19ab_Solar_Conj_Day5	2017-007_02:33:37	S/C	346,062,337	346,062,526
16354	KARX_19ab_Solar_Conj_Day5	2017-007_02:33:52	S/C	346,062,352	346,062,526

2. and 3. SNR Verification and Radio Path characterization (Loads 17051, 17258, 17282 and 17300)

Radio path characterization measurements with REX are nominally on a monthly cadence during the New Horizons extended mission. Due to operations constraints such as spacecraft hibernation, and DSN scheduling, the monthly cadence has been irregular. The REX data is from uplinks in both polarizations (RCP and LCP), and recorded and processed as described for the solar conjunctions. The objective is to assess the uplink's frequency and amplitude stability, and to associate the standard deviation measure of the stability distributions with characteristics of the radio path such as multipath propagation. SNR Verification was done on February 26, 2017. The Radio Path Characterization was done on September 30, 2017, October 16, 2017, and November 15, 2017.

The following is the DataTrack listing of the REX data during the Radio Path Characterizations.

02/26/2017:

17051	KARX_1ab_TestPatt	2017-057_11:14:13	S/C	350,413,573	350,413,860
17051	KARX_1ab_TestPatt	2017-057_11:14:28	S/C	350,413,588	350,413,875

17051	KARX_3ab_SNR_Verification	2017-057_11:19:02	S/C	350,413,862	350,414,051
17051	KARX_3ab_SNR_Verification	2017-057_11:19:17	S/C	350,413,877	350,414,051

09/30/2017:

17258	KARX_1ab_TestPatt	2017-273_12:27:33	S/C	369,080,373	369,080,675
17258	KARX_1ab_TestPatt	2017-273_12:27:48	S/C	369,080,388	369,080,690

17258	KARX_3ab_Total_Electron_Counts	2017-273_12:32:37	S/C	369,080,677	369,080,866
17258	KARX_3ab_Total_Electron_Counts	2017-273_12:32:52	S/C	369,080,692	369,080,866

10/16/2017:

17282	KARX_1ab_TestPatt	2017-289_20:00:55	S/C	370,489,975	370,490,277
17282	KARX_1ab_TestPatt	2017-289_20:01:10	S/C	370,489,990	370,490,292

17282	KARX_3ab_Total_Electron_Counts	2017-289_20:05:59	S/C	370,490,279	370,490,468
17282	KARX_3ab_Total_Electron_Counts	2017-289_20:06:14	S/C	370,490,294	370,490,468

11/15/2017:

17300	K1RX_1ab_TestPatt	2017-319_01:21:49	S/C	373,014,829	373,015,131
17300	K1RX_1ab_TestPatt	2017-319_01:22:04	S/C	373,014,844	373,015,146

17300	K1RX_3ab_Total_Electron_Counts	2017-319_01:26:53	S/C	373,015,133	373,015,322
17300	K1RX_3ab_Total_Electron_Counts	2017-319_01:27:08	S/C	373,015,148	373,015,322

#### 4. Bistatic Dry Run (Load 17331)

An Operational Readiness Test, or ORT, was conducted on December 11th, 2017, in preparation for the bistatic radar experiment planned for the MU69 Encounter. The test was planned to validate DSN ground processes, particularly to verify monitoring by the Radioscience Receivers (RSR's), to verify the ability to successfully implement uplink frequency ramping predicts, and to exercise the logistics and coordination within the DSN. The ORT's data is shown in Figure 4.1, as a frequency vs time spectrogram, and illustrates the successful transmissions of six uplinks from the DSN, together with the correct frequency offsets and frequency ramps.

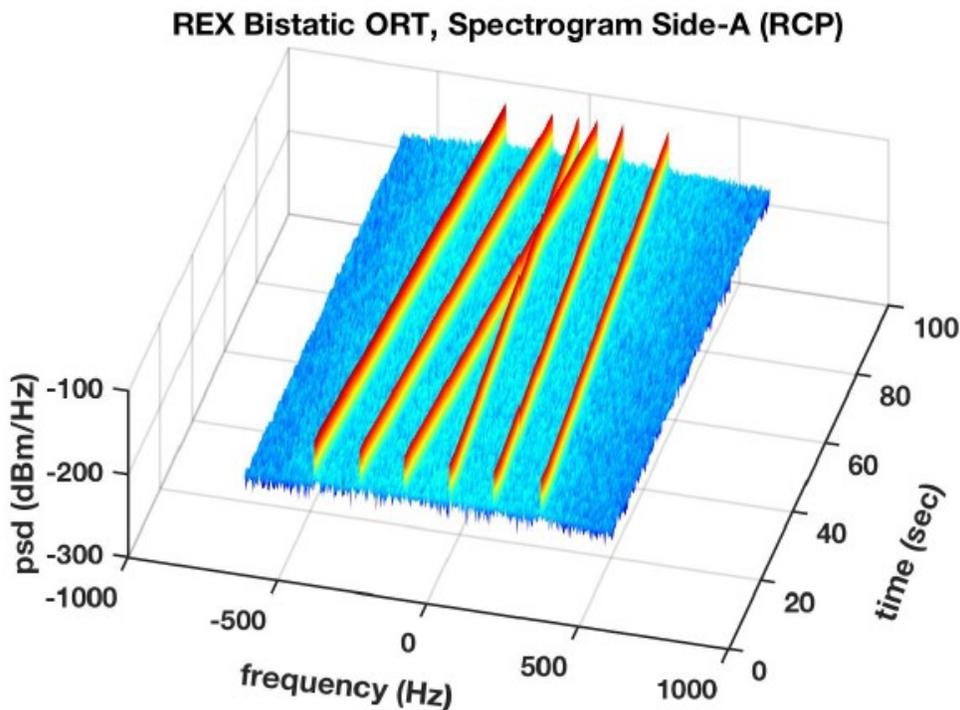


Figure 4.1. Frequency vs time spectrogram of six uplink frequency profiles during the REX Bistatic Dry Run. The frequencies of the five uplink are equally spaced at time zero, but then are ramped linearly, where the three negative offset uplinks ramp up in frequency, while the three uplinks with positive offset ramp down in frequency allowing the two interior frequencies to cross.

The following is the DataTrack listing of the REX data during the Radio Path Characterizations.

17331	K1RX_1ab_TestPatt	2017-345_05:45:52	S/C	375,277,072	375,277,372
17331	K1RX_1ab_TestPatt	2017-345_05:46:07	S/C	375,277,087	375,277,387

17331	K1RX_20ab_MU69_Bistatic-Dry-Run	2017-345_05:50:54	S/C	375,277,376	375,277,867
17331	K1RX_20ab_MU69_Bistatic-Dry-Run	2017-345_05:51:09	S/C	375,277,391	375,277,867