

OBSERVATION OF THE HAKUTO-R MOON LANDING, 2023 April 25

Station: EB3FRN

Location: 41.12255N, 1.001841E / JN01mc / 160m ASL

Antenna: 1.5m offset dish, RHCP feedhorn

G/T: 19.5dB

Converter: Kuhne KU LNC 8085 C PRO2 (7800MHz LO, 600MHz IF)

Receiver: SDR Airspy R2

Samplerate: 156.250ksps (2.5msps, decimated /16)

Freq referece: HP Z3805 GPSDO

Software: Arch Linux, airspy_rx and Baudline:

Ephemeris JPL Horizons

Trcking source: Moon

HAKUTO-R Freq: 8492.500MHz

Abstract

The HAKUTO-R spacecraft Moon landing attempt was observed from EB3FRN amateur-DSN station on 2023 April 25.

Baudline, a software package designed for scientific visualization of the spectral domain, was used for signal analysis processing and display. Following spacecraft LOS (Loss of Signal) at the expected touchdown time (16:44:00 UTC) the observation file was saved to the computer hard disk.

Unfortunately, Baudline does not natively manage the recordings timestamping and this was the source of an error in an earlier preliminary analysis we made public where the timestamps are over 70 seconds in the past due to a scripting error.

To correct the original timestamping error, two different sources were utilized: a "live" screenshot taken during the reception of the spacecraft signal [8], and the AMSAT-DL Bochum Observatory timestamping (which is gratefully acknowledged). This error being fixed with the proper time reference allowed for the time to be recalculated and for the original observation record to be properly timestamped.

A thorough analysis of the Doppler frequency shift present in the records has revealed an unexpected behavior in the signal just before LOS, where it traces a helix-like figure. In addition, the analysis of the signal using a RBW (Resolution Bandwidth) of less than 0.2Hz has revealed the presence of side tones located at $\pm 4\text{Hz}$ from the main carrier frequency.

With these findings, further analysis of the last 8 minutes of the mission has been conducted in an effort to gain more information about the last seconds of the mission prior to LOS.

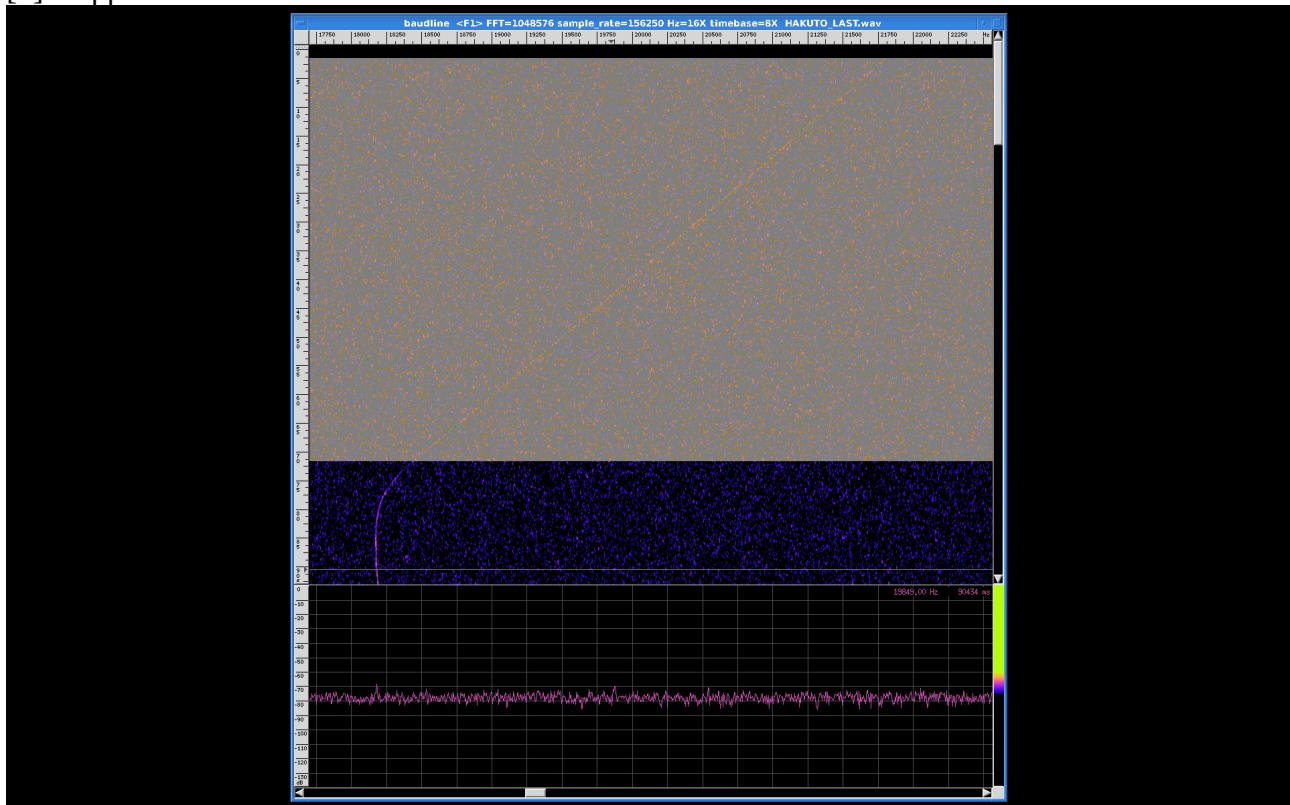
This report provides a summary of the analysis of the Doppler frequency shift data for each event, with the full set of analysed data available in an attached spreadsheet.

Please note that the signal is very weak with a very marginal SNR, this results in an observation error of ± 0.5 seconds in the timestamps and $\pm 1\text{Hz}$ in the frequencies.

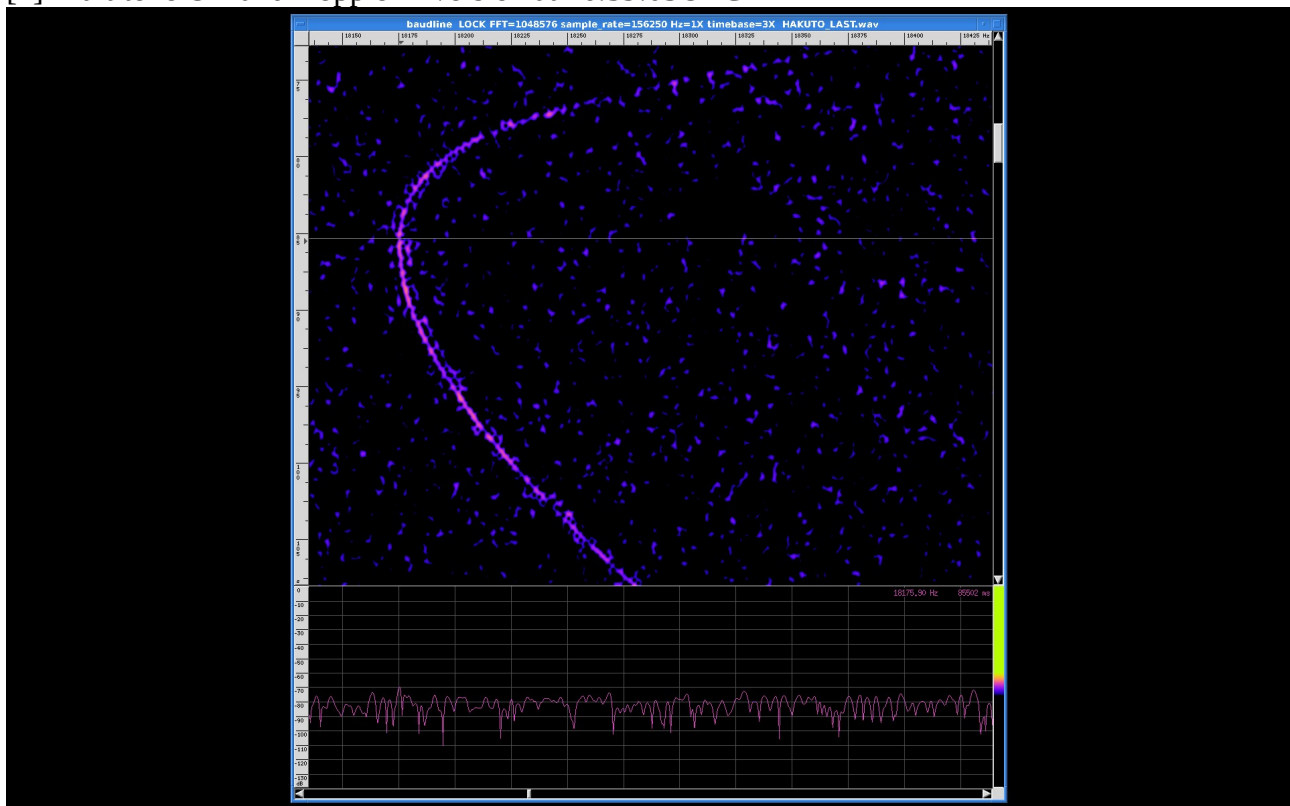
The timeline in the screenshots is oriented vertically with older events located at the top and newer events located at the bottom.

TIMESTAMP UTC	FREQ 8492.5xxxxx kHz	DELTA T MM:SS	DELTA F Hz	DOPPLER Hz/S	COMMENT
16:37:33,301	22762,47				
16:38:51,190	19081,89	01:17,889	-3680,580	-47,254	[1] [C]
16:39:02,769	18821,41				
16:39:03,775	18819,63	00:01,006	-1,780	-1,780	MULTITONE ON
16:39:04,772	18819,03	00:00,997	-0,600	-0,602	
16:39:05,197	18819,03	00:00,425	0,000	0,000	DOPPLER INVERSION [2]
16:39:05,768	18819,63	00:00,571	0,600	1,051	
16:39:06,774	18820,82	00:01,006	1,190	1,183	
16:39:29,447	18951,35				
16:40:22,280	19481,83	00:52,833	530,480	10,031	[3] [D]
16:40:25,795	19502,4				
16:40:26,792	19505,68	00:00,997	3,280	3,290	
16:40:27,788	19507,76	00:00,996	2,080	2,088	
16:40:32,608	19518,19				
16:43:32,034	19746,48	02:59,426	228,290	1,272	[4][E]
16:43:33,357	19747,67	00:01,323	1,190	0,899	
16:43:33,610	19747,67	00:00,253	0,000	0,000	DOPPLER INVERSION MULTITONE OFF [5]
16:43:34,317	19745,88	00:00,707	-1,790	-2,532	
16:43:34,969	19744,390	00:00,652	-1,490	-2,285	
16:43:35,314	19743,8	00:00,345	-0,590	-1,710	
16:43:35,413	19743,8	00:00,099	0,000	0,000	DOPPLER INVERSION 1st HALF PERIOD [6]
16:43:35,513	19744,39	00:00,199	0,590	2,965	
16:43:36,310	19747,37	00:00,996	2,980	2,992	
16:45:04,981	18327,89	00:01,540	-28,610	-18,578	
16:45:06,522	18299,28	00:01,541	-28,610	-18,566	
16:45:08,080	18273,05	00:01,558	-26,230	-16,836	
16:45:07,337	18203,91				2nd to LAST PERIOD
16:45:08,840	18175,3	00:01,503	-28,610	-19,035	[7][F] LOS

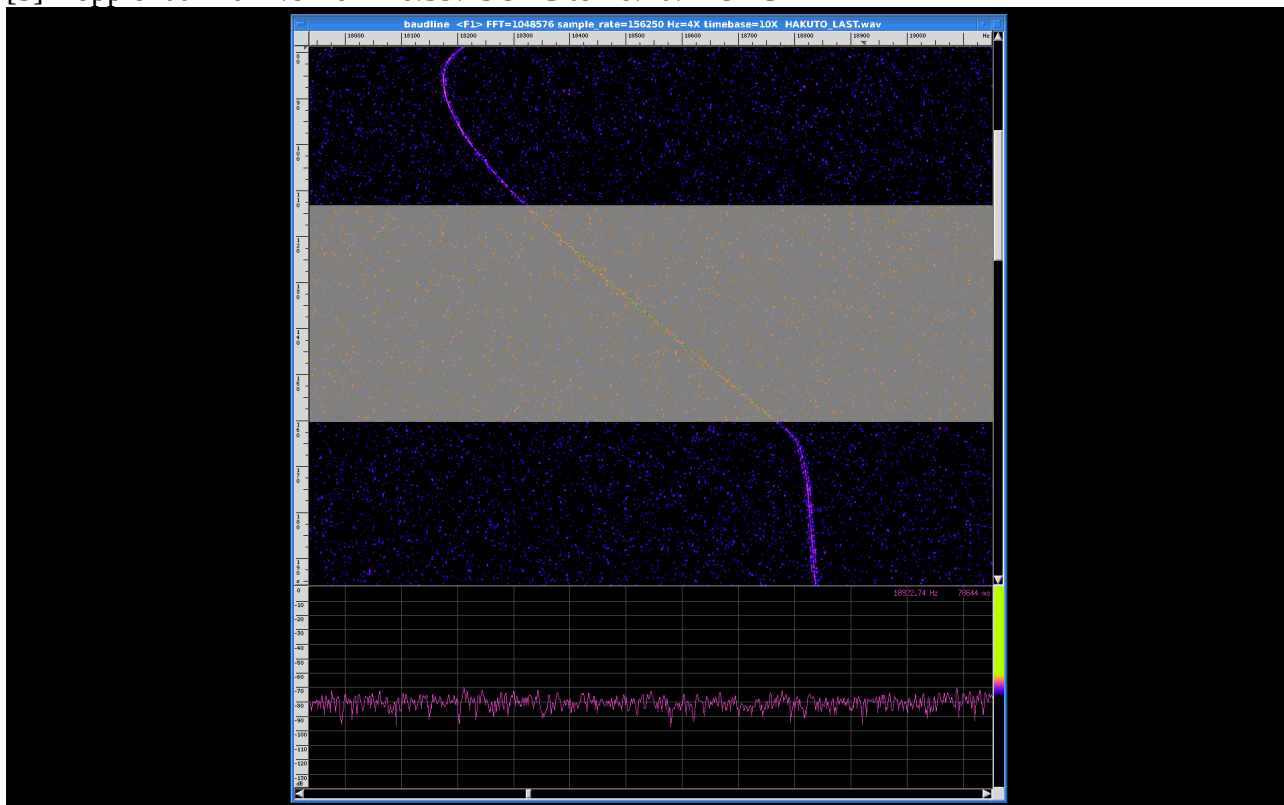
[1] Doppler at -47.254Hz/s at 16:37:54UTC to 16:38:51UTC



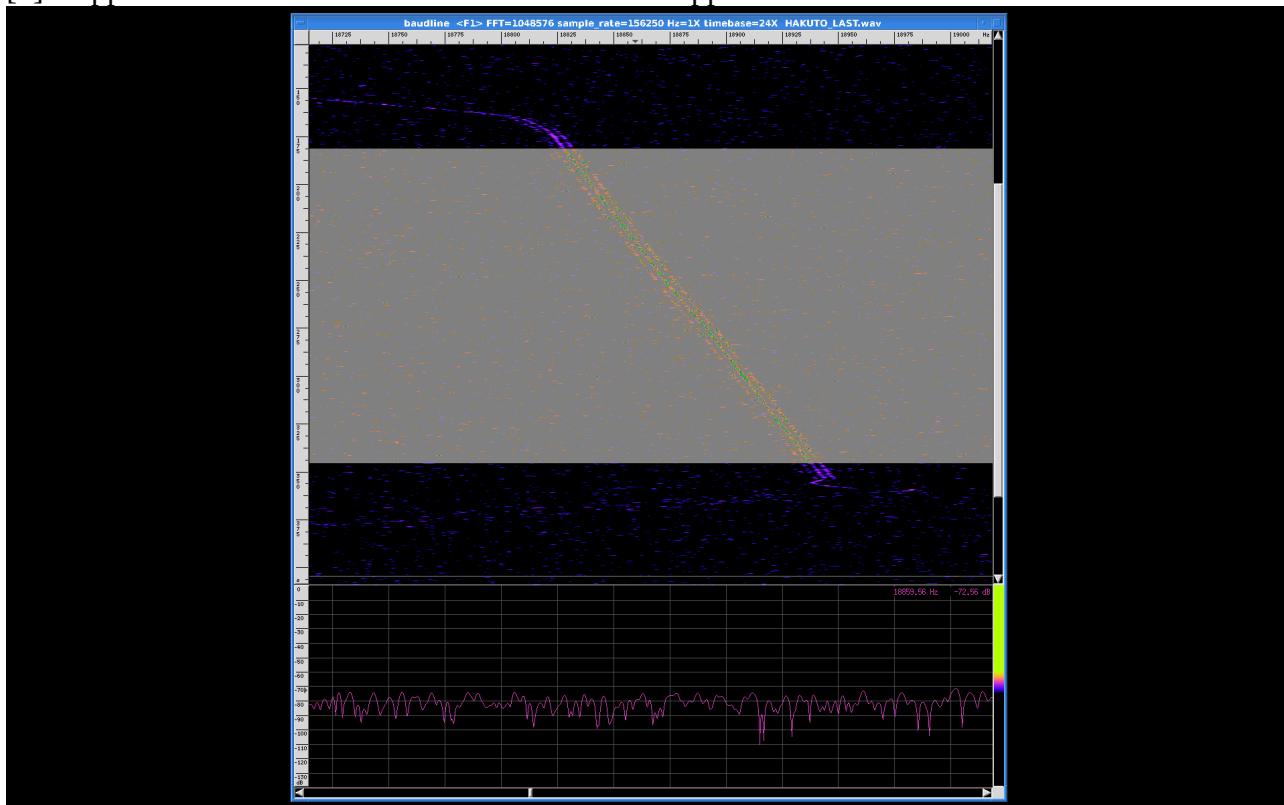
[2] Multitone ON and Doppler inversion at 16:39:05UTC



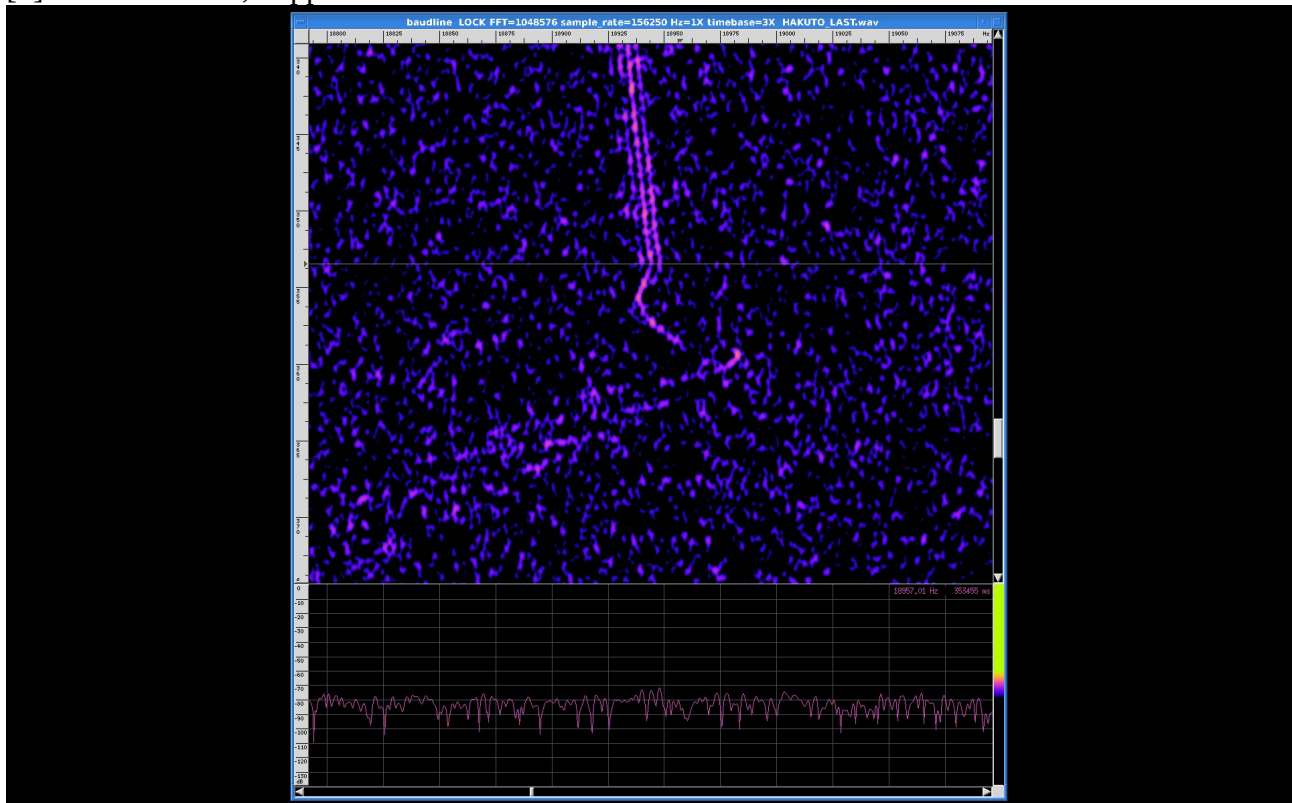
[3] Doppler at +10Hz/s from 16:39:29UTC to 16:40:22UTC



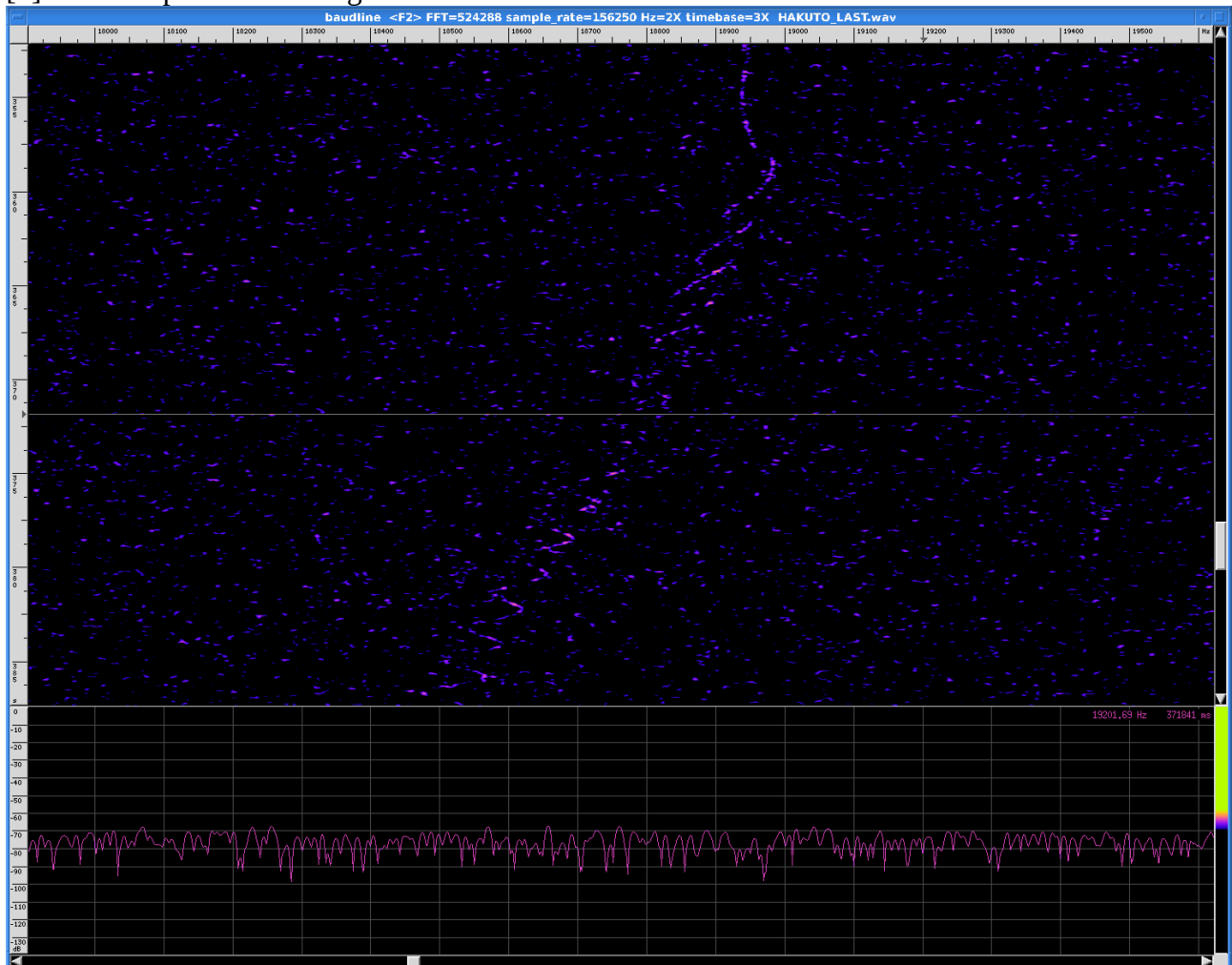
[4] Doppler decrease from +10Hz/s to +1.272Hz/s doppler from 16:40:32UTC to 16:43:32UTC



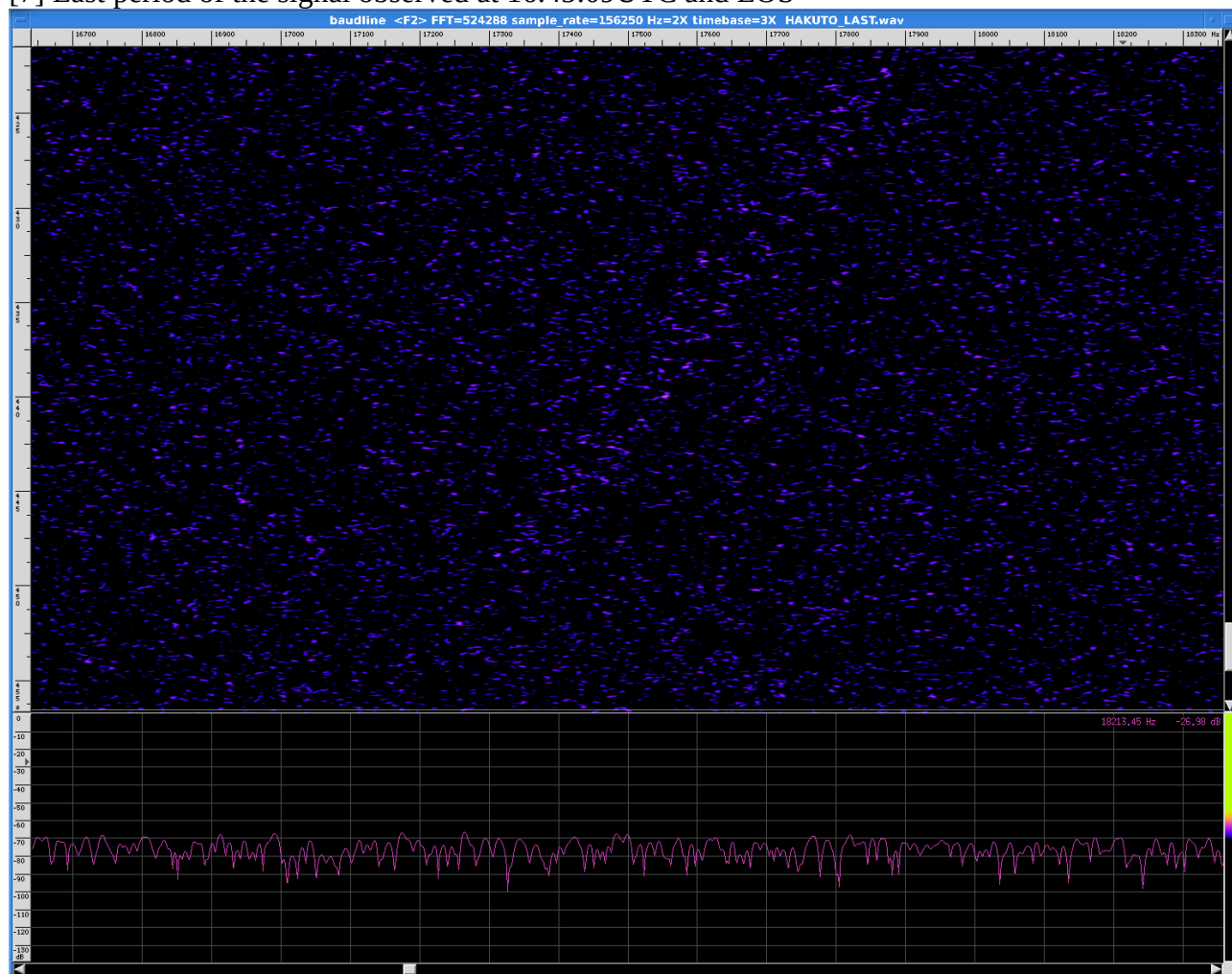
[5] Multitone OFF, doppler inversion and SC starts to turn to himself at 16:43:33UTC



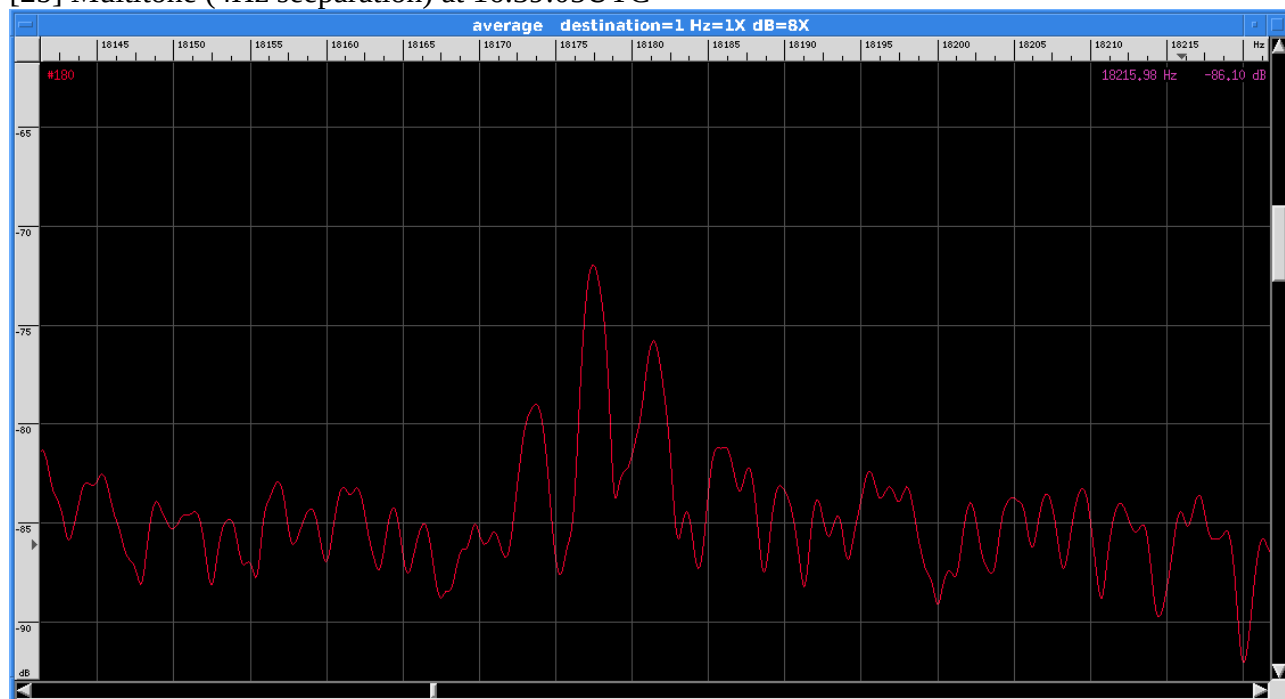
[6] First full period of the signal at 16:43:39UTC



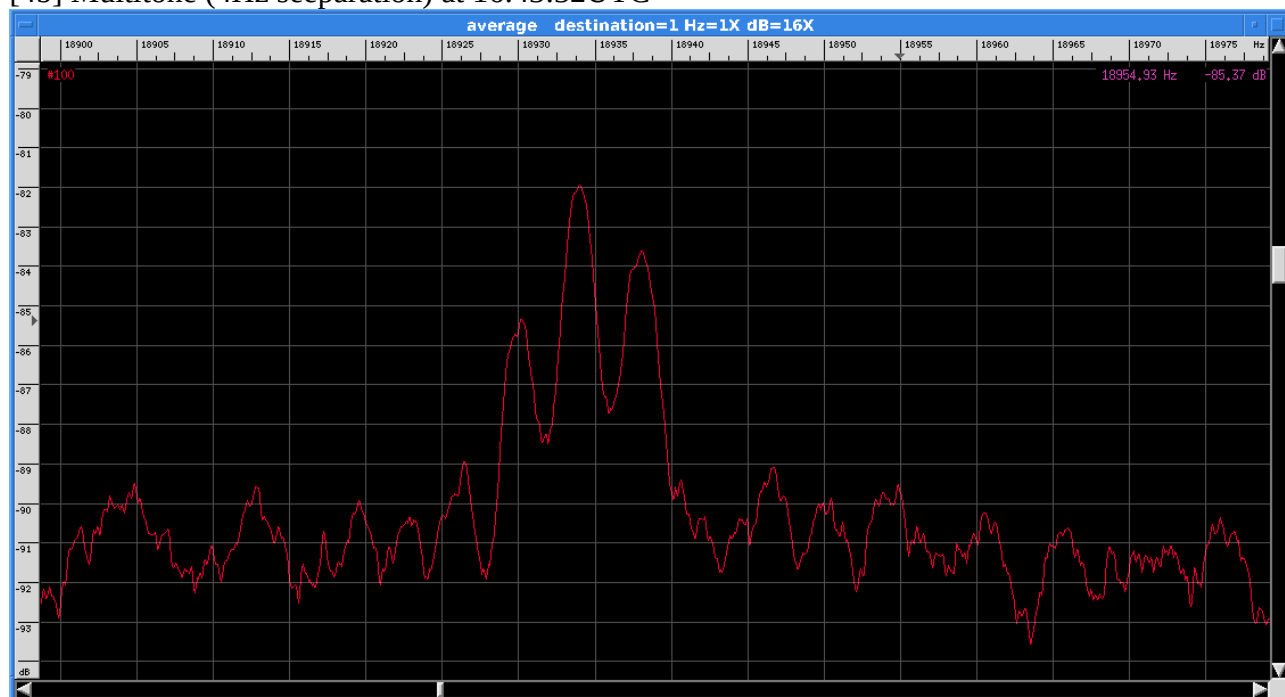
[7] Last period of the signal observed at 16:45:09UTC and LOS



[2b] Multitone (4Hz seeparation) at 16:39:05UTC



[4b] Multitone (4Hz seeparation) at 16:43:32UTC



[8] Screenshot performed while the signal from the spacecraft was being received

