Huygens Radio Signal Strength History

R Lorenz 21 September 2012

This dataset (HUYGENS_AGC) is a measure of the signal strength of the Huygens radio signal (Channel B) as measured on the Cassini spacecraft, and is of interest for understanding the Huygens dynamics during descent and at impact, as well as in radio propagation studies.

Huygens transmitted data to the Cassini Orbiter continuously during and after its descent on both Channels A and B, operating at frequencies of 2040 and 2098MHz, respectively. Due to an omitted command in the mission command sequence to the Probe receivers on Cassini, the Channel A receiver was not properly configured and was unable to lock onto the signal.

All data on Channel A, including the signal power and the received frequency, the primary data of the Huygens Doppler Wind Experiment (DWE), were lost. The the Channel A carrier signal, with very high frequency stability due to the DWE Ultra-Stable Oscillator on board Huygens, was fortunately detectable with large radio telescopes on Earth, providing Doppler data to infer the zonal winds. That frequency measurement data is archived on the PDS in the Housekeeping dataset : the relevant path at time of writing is http://atmos.nmsu.edu/PDS/data/hphk_0001/DATA/PDRS/PSAB/

The Channel B receiver on Cassini worked correctly, but was equipped only with a Temperature Controlled Crystal Oscillator (TCXO) frequency reference, so the received frequency measurement is too noisy to be useful in measuring winds (as verified by Dave Atkinson, personal communication). The data is nonetheless archived on the PDS, in the Housekeeping directory. The content of the four receiver status words R6001S, R6002S, R6003S and R6004S and the algorithm by which frequency data (and other receiver performance parameters, such as Viterbi lock etc.) can be reconstructed from the housekeeping telemetry files is described in the Huygens User Manual section 4.2.1-6. The link performance from these data is described by Perez-Ayucar (2005a)

One quantity recorded by the receiver which is of some use in physical studies is the AGC (Automatic Gain Control) setting of the receiver. This gain adapts to compensate for the changing received signal strength, and thus serves as a measure of it. The AGC setting was recorded at some 8 times per second, and the least significant byte (LSB) of the raw value is recorded as bits 0 to 7 of word R5003S and the MSB as bits 0 to 7 of word R5004S, also archived on the PDS in the Huygens Housekeeping data. However, this uncalibrated and disjoint format is inconvenient for general use. The data have been converted by M. Perez-Ayucar of ESA using the receiver specification into a received signal power in dBm, in other words Decibels relative to 1 mW.

The conversion algorithm is described in the INSTRUMENT.CAT file in the HK directory of the archive, specifically http://atmos.nmsu.edu/PDS/data/hphk_0001/CATALOG/INSTRUMENT.CAT, and is repeated here as follows

AGC_raw (digital number) = 256 * HK_PDRS_PSAB_R60047.TAB + HK_PDRS_PSAB_R60037.TAB.

These raw data are calibrated by interpolation of the following data from the PRT#4, day4 flight test

AGC raw DN: 612.9438 607.1000 599.8319 590.6696 580.7143 568.5962 554.3304 536.7500 517.0385 475.5833 448.0714 418.8846 388.2768 357.2596 325.9554 295.4000 266.7857 240.8214 215.3393 193.3482 173.7589 155.5893 140.6538

AGC calibrated dB: -4.6862 -3.6862 -2.6862 -1.6862 -0.6862 0.3138 1.3138 2.3138 3.3138 5 6 7 8 9 10 11 12 13 14 15 16 17 18

The calibrated value of the reconstructed product varies from -117dBm at the start of descent, to about -120dBm at impact (i.e. 3dB down or two times less power) to -129dBm at loss of signal. The transmitted signal power was constant, and even though the range to Huygens decreased (from ~71,500km to ~60,000km) as Cassini flew towards Titan, the elevation of Cassini as seen from Huygens progressively decreased with time and thus the antenna gain decreased.

These signal levels (encoding a data stream of 8192 bits per second) may be compared with a more familiar value - a received wireless internet signal (802.11) is usually within 10dBm of 10 pW (i.e. -80dBm, 10,000 times higher than the Huygens levels, and correspondingly conveying perhaps 1 Mbit/s, a thousand times higher a data rate.) Many GPS receivers are specified to detect signals (which have a low datarate) as low as -159dBm, a thousand times weaker than the Huygens signal. The Huygens signal received by the giant 100m Green Bank radio telescope was 2.8x10^-21W, or -175 dBm (Folkner et al., 2006).

In addition to the slow decline in received signal strength due to the changing Titan-Cassini distance and Cassini elevation angle, during descent there were short-term variations due to the rotation of the probe about its nominally-vertical spin axis, and due to transient deviations from the vertical due to wind shear, turbulence and natural probe motions. These deviations occur because the gain pattern of the antenna has variations with azimuth and elevation (somewhat like the petals on a flower or the spines on a sea urchin) due in part to electromagnetic interaction of the antenna itself with the probe top platform and structures such as the parachute box mounted on it. As the probe motion sweeps a gain lobe through the Huygens-Titan vector, the received signal strength will be increased.

The Channel B antenna gain pattern is described in the file PTA_GAIN_CHB.DAT

Because the antenna pattern was well-documented before launch, the received signal power recovered from the AGC could be used to constrain the elevation and especially the azimuth history of the probe during descent. The azimuth rotation introduces a ‘heartbeat’ pattern that allows a precise measurement of spin rate, and spin direction (which for much of descent was in the direction opposite from that expected - as described in Lebreton et al. (2005) - see also the Supplemental Information to that paper).

An initial analysis of the AGC data is given by Perez-Ayucar et al. (2005a, 2005b). Detailed modeling of the probe attitude history as constrained by the AGC is presented by Dzierma et al. (2007) - an interesting observation is the tilt of the probe early in descent due to wind shear. The spin history using the AGC and DISR data is also discussed in detail by Karkoschka et al. (2007) - interesting (and so far unexplained) short-term changes in spin rate are noted.

A final effect occurs on the surface, where there is no longer any rotational modulation and only a slow elevation change as Cassini set on the horizon as seen from Huygens. However, despite this slowly-changing geometry, sharp dips in signal strength are observed. There are due to multipath, where the elevation is low enough that the direct beam to Cassini, and a corresponding beam reflected from the ground, are comparable enough in intensity that they can interfere. The sharp dips in signal strength correspond to Cassini flying through this interference pattern. The shape of the pattern, and in particular the timing of dips in signal strength, were a powerful constraint on the height of the phase center of the antenna above the ground, and thus showed (Perez-Ayucar et al., 2006) that the probe was resting on the reflecting surface, rather than being embedded in a hole. The depth of the dips is diagnostic of the reflection characteristics of the ground (essentially acting as a bistatic scattering experiment), and provided some (weak) constraints on its roughness and dielectric constant.

The AGC value, converted into received signal power is given in the file as 2 ASCII columns. The first is time after the reference time T0 (when the probe fired the mortar to initiate the parachute sequence) until the signal was lost when Cassini set, 13,050 seconds later. Impact occurred at 8869s. The record starts at 46 seconds, as this is when the transmitters were turned on 13s after the heat shield was jettisoned.

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