Periodic Variations in the Signal-to-Noise Ratios of Signals Received From the ICE Spacecraft

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Data from the ICE probe to comet Giacobini-Zinner are analyzed to determine the effects of spacecraft rotation upon the signal-to-noise ratio (SNR) for the two channels of data. In addition, long-term variations from sources other than rotation are considered. Results include a pronounced SNR variation over a period of three seconds (one rotation) and a lesser effect over a two-minute period (possibly due to the receiving antenna conscan).

I. Introduction

The use of a former Earth satellite to probe the tail of the comet Giacobini-Zinner has recently been accomplished. The probe, known as International Cometary Explorer (ICE), transmits data from two 4-lobed antennas mounted on a boom emanating from the top of the spacecraft. Figure 1 shows the positions of the probe relative to the Earth and the probe's two antennas. The rotation of the probe causes a rotating doughnut-shaped antenna pattern, with a small skew angle, to be observed from the Earth station(s).

The spacecraft transmits identical data symbols on two S-band carriers: channel A at 2270 MHz and channel B at 2217 MHz. This article examines the received symbol signal-to-noise ratios (SNRs) for channels A and B in order to determine the periodic components of the SNR time variations.

II. Description of Data

The experiment was based on data received from ICE at DSS-14 from 1125 Z to 1203 Z on 1985 DOY 148. The detected symbol streams quantized to 8 bits at the output of the symbol synchronizer assemblies (SSAs) were recorded simultaneously for channels A and B on the Telemetry Processing Assembly (TPA) computers using software developed for symbol stream combining (Ref. 1). Initial processing was to estimate the symbol SNRs as a function of time for the two channels using the moment method (Refs. 2, 3). This processing also produced sample absolute moments and sample second moments for the two channels. These data were produced by summing over 57 data symbols, received from the probe at a rate of 1024 symbols per second (symb/s). This pre-sum interval is short enough that the actual SNR is almost constant within it, yet long enough to make subsequent processing tractable.

III. Short-Term Variation

The rate of rotation of the spacecraft is known to be about 19.65 rpm, or 0.3275 Hz, and each channel's antenna consists of four approximately equally spaced lobes. Therefore, peaks and troughs in the received SNR occur at about 1.31 Hz or four times the rotational rate.

The first step in the data analysis was to accurately determine the frequency of the dominant periodic component. This was done by calculating the energy at closely spaced frequencies near 1.31 Hz, for a data record 83 seconds in length. The final estimate of the true dominant frequency, averaged over the first (absolute) and second moment streams of the A and B channels, was 1.3108 Hz. Thus, 0.3277 Hz or one-fourth of the dominant frequency was the actual rotational frequency. Note that this result assumes that the symbol rate was exactly 1024 symb/s.

The next step was to determine the Fourier coefficients of each data stream at harmonics of the fundamental, 0.3277 Hz. Reconstruction of the time functions of the four statistics from these harmonics resulted in smoothed estimates of the periodic time variations. Then smoothed estimates of the symbol SNR were determined at each time step of the reconstructed A and B channels using the unbiased moment method (Refs. 2, 3).

The relative magnitudes of the first 20 Fourier coefficients of the A- and B-channel second moment data determined which of the coefficients were statistically significant. Using the average SNR estimates and the mean square levels of the input data, the statistics were calculated for the Fourier coefficients at frequencies with no non-random energy. In the second moment data, the means and standard deviations of the amplitude of Fourier coefficients with noise only were 1.21 and 0.48 for channel A, and 0.86 and 0.34 for channel B. The decision to use the fourth and eighth harmonics of the 0.3277 Hz fundamental was based on the data in Table 1. Harmonics four and eight are greater than the mean plus three standard deviations, and are clearly significant. Some others were of borderline significance, but were not used.

The resultant A- and B-channel SNRs, reconstructed using the fourth and eighth harmonics, are illustrated in Fig. 2. The A-channel SNR was on the average 1.5-dB stronger than the B-channel SNR. The variations ranged over approximately 1.4 dB peak-to-peak for the A-channel and 2.0 dB for the B-channel. This effect was obviously due to the combined probe rotation effect and the 4-lobed antenna pattern. The short-term variations of the A and B channels were nearly in phase.

IV. Long-Term Variation

A 24-minute span of data (472 spacecraft rotations) was used to determine if other, long-term, variations in SNR existed. The observation of the symbol error rate (SER) by J. W. Layland had shown a variation with a principal period of about two minutes. The mean SNR of each rotation was found for channels A and B; Fourier analysis of this 472-point data stream yielded a strong variation with a period of 132 s (frequency 0.00758 Hz). This variation is shown in Fig. 3.

Table 2 lists the Fourier coefficients for the first 20 harmonics of the 0.00758 long-term fundamental frequency. The first harmonic is in general one order of magnitude larger than any other harmonic; statistical analysis of these coefficients was not necessary since the first harmonic so clearly dominated all other harmonics listed.

The A-channel mean SNR varied over a range of about 0.3 dB peak-to-peak while the B-channel mean SNR varied over a range of about 0.6 dB. The reconstruction using the first harmonic of 0.00758 Hz was sufficiently accurate to represent the long-term variation in SNR. The variations of the two channels were in phase. The 132-s period is consistent with the conscan period of the ground-based antenna system of approximately 128 seconds.

V. Conclusions

There are significant short-term and long-term variations in the SNR of signals received from the ICE spacecraft. The dominant short-term effects are at 1.31 Hz and 2.62 Hz, the fourth and eighth harmonics of the spacecraft rotation rate. The dominant long-term effect is at 0.00758 Hz, which is approximately the receiving antenna conscan rate. The short-term variations of period 3.05 seconds are much greater than the long-term effect. Short-term variations are 1.4 dB peak-to-peak for the A channel and 2.0 dB for the B channel, whereas long-term variations are 0.3 dB for the A channel and 0.6 dB for the B channel.

References

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2. Vo, Q., "Signal-to-Noise Ratio and Combiner Weight Estimation for Symbol Stream Combining," *TDA Progress Report 42-76*, Jet Propulsion Laboratory, Pasadena, CA, February 15, 1984, pp. 86–98.

3. Layland, J.W., "On S/N Estimation," *Space Program Summary 37-48*, Volume III, Jet Propulsion Laboratory, Pasadena, CA, Dec. 31, 1967, pp. 209–212.

Table 1. Fourier coefficients of short-term variation of ICE SNR, f_1 = 0.3277 Hz (1125 Z, DOY 148)

Channel	Harmonic = n	A_n	B_n	Magnitude
A, Sum of Absolutes	0	20.423	0.000	20.423
	1	-0.020	0.041	0.045
	2	0.009	-0.064	0.065
	3	0.080	-0.028	0.085
	4	-0.037	-0.357	0.359
	5	0.060	-0.034	0.069
	6	0.075	-0.007	0.075
	7	0.035	-0.004	0.036
	8	-0.153	0.067	0.167
B, Sum of Absolutes	0	14.959	0.000	14,959
	1	0.023	0.065	0.068
	2	0.083	-0.071	0.109
	3	0.023	-0.058	0.063
	4	-0.268	-0.489	0.558
	5	0.066	0.026	0.071
	6	0.044	0.006	0.044
	7	0.004	0.015	0.015
	8	-0.080	0.028	0.084
A, Sum of Squares	0	545.348	0.000	545.348
	1	-0.929	1.089	1.431
	2	1.001	-2.813	2.986
	3	4.201	-0.924	4.302
	4	-1.580	-15.649	15.729
	5	2.908	-2.095	3.584
	6	2.596	-0.603	2.665
	7	2.236	-1.104	2.494
	8	-6.899	2.229	7.250
B, Sum of Squares	0	308.269	0.000	308.269
	1	0.389	1.886	1.925
	2	2.872	-2.692	3.936
	3	0.474	-2.151	2.203
	4	-9.818	-16.780	19.441
	5	1.990	1.068	2.259
	6	1.182	0.197	1.198
	7	0.420	0.380	0.566
	8	-2.975	1.141	3.186

Table 2. Fourier coefficients of long-term variation of ICE SNR, f_1 = 0.007576 Hz (1125 Z to 1149 Z, DOY 148)

Channel	Harmonic = n	A_n	B_n	Magnitude
A	0	1.3800	0.0000	1.3800
	1	-0.0094	-0.0183	0.0205
	2	-0.0019	0.0004	0.0020
	3	-0.0001	0.0006	0.0006
	4	0.0044	-0.0034	0.0056
	5	-0.0033	0.0020	0.0038
	6	-0.0006	-0.0007	0.0009
	7	0.0019	0.0043	0.0048
	8	0.0007	-0.0030	0.0031
	9	-0.0025	-0.0018	0.0031
	10	0.0002	0.0006	0.0006
	11	0.0020	0.0000	0.0020
	12	-0.0009	0.0010	0.0013
	13	-0.0007	0.0037	0.0038
	14	0.0006	-0.0016	0.0017
	15	-0.0037	-0.0011	0.0038
	16	-0.0027	0.0027	0.0038
	17	0.0022	-0.0021	0.0030
	18	-0.0021	0.0015	0.0026
	19	-0.0005	0.0008	0.0010
	20	-0.0025	0.0029	0.0038
B	0	0.9500	0.0000	0.9500
	1	-0.0182	-0.0301	0.0352
	2	-0.0004	0.0020	0.0021
	3	0.0005	-0.0020	0.0021
	4	-0.0013	0.0023	0.0026
	5	0.0021	0.0010	0.0023
	6	0.0000	-0.0009	0.0009
	7	0.0048	-0.0019	0.0052
	8	-0.0010	-0.0007	0.0012
	9	0.0015	0.0002	0.0015
	10	-0.0027	-0.0020	0.0034
	11	-0.0029	-0.0020	0.0035
	12	0.0033	0.0006	0.0033
	13	0.0032	-0.0012	0.0034
	14	0.0012	0.0010	0.0015
	15	0.0013	0.0006	0.0015
	16	-0.0009	0.0022	0.0024
	17	-0.0001	0.0009	0.0010
	18	-0.0004	-0.0014	0.0014
	19	-0.0022	-0.0002	0.0022
	20	0.0002	-0.0028	0.0028

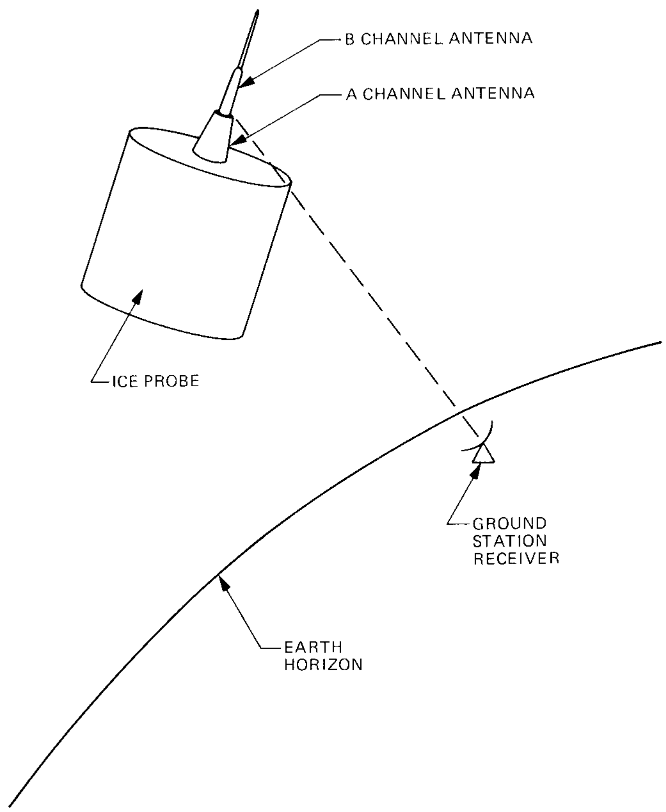

Fig. 1. ICE spacecraft orientation

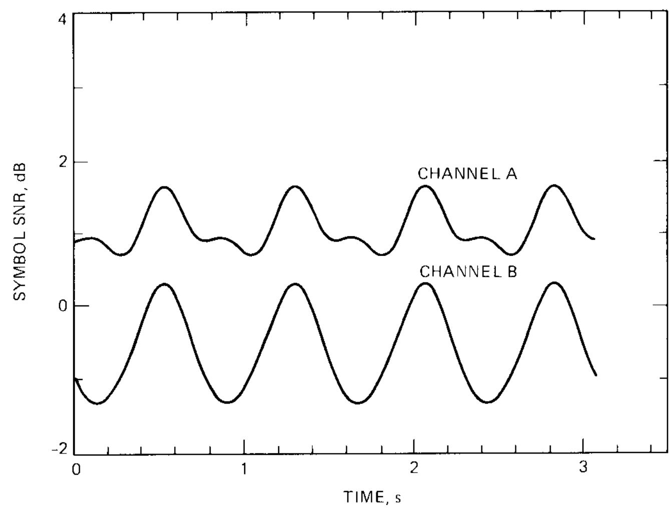

Fig. 2. SNRs for channels A and B vs time (1125 Z, DOY 148)

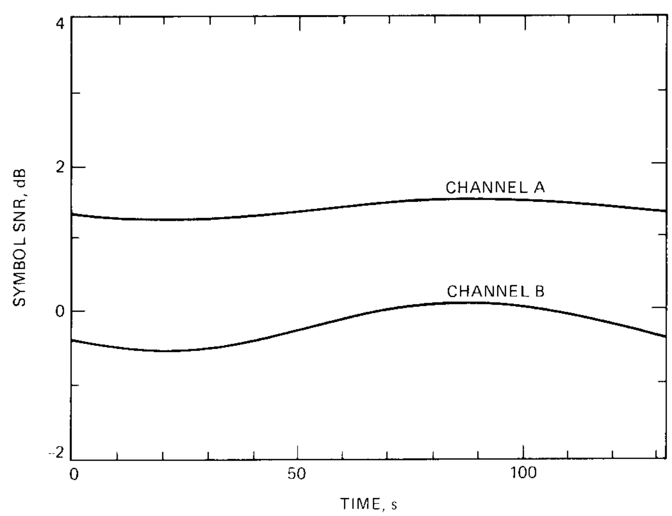

Fig. 3. SNRs for channels A and B vs time (1125 Z to 1149 Z, DOY 148)