S-Band Microwave Weather Project Data for CY 1971

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The Weather Project forms part of an overall Radio Systems Development Project which seeks to optimize the spacecraft-to-ground communications link. The objective of the Weather Project is the statistical prediction of the performance of the DSN at X-band, and in the future at K-band. Previous articles have discussed the general approach of the Weather Project, the measurements, calibrations, equipment, methods and the analysis of the calendar year (CY) 1971 X-band data. This article reports on the analysis of the S-band data for CY 1971. These results are presented in tabular form. Cumulative frequency distribution of percentages of excess system temperature is tabulated as a function of time (whole year and quarterly periods) and of antenna elevation angle (four elevation ranges and for all elevation angles); averages, standard deviations, and confidence limits are also tabulated.

I. Introduction

The Weather Project forms part of an overall Radio Systems Development Project which seeks to optimize the spacecraft-to-ground communications link. The objective of the Weather Project is the statistical prediction of the performance of the DSN at X-band, and in the future at K-band. Previous articles (Refs. 1 and 2) discussed the general approach of the Weather Project, the measurements, the calibrations, equipment, methods, and the analysis of the X-band data for calendar year (CY) 1971. This article reports on the analysis of the S-band data for CY 1971. These results are presented in tabular form. Cumulative frequency distribution of percentages of excess system temperature is tabulated as a function of time (whole year and quarterly periods) and of antenna elevation angle (four elevation ranges and for all elevation angles); averages, standard deviations, and confidence limits are also tabulated.

II. Discussion of the Tables

The results for the S-band data for CY 1971 are presented in tabular form. Table 1 is a cumulative frequency distribution of percentages of excess system temperature, which is that component of temperature due to atmospheric conditions and other unknowns as a function of antenna elevation angle. The excess system temperatures have been divided into increments of 10 K. Four antenna elevation angle ranges have been considered: 6 to 14.99 deg, 15 to 24.99 deg, 25 to 44.99 deg, and 45 to 90 deg.

The table consists of percentages of time that the excess system temperature was less than the nominal magnitude for the various antenna elevation angles. Thus, for 81.1% of the time that the antenna's elevation angle was in the range 15 to 25 deg. the excess system temperature was under 10 K. The column on the right lists percentages for all elevation angles.

The frequency distribution shown in Table 1 is for the whole of calendar year 1971. The table lists percentages of time, in each antenna elevation angle range, that the excess system temperature was less than the value given in the left hand column. Tables 2 through 5 are similar tables for quarterly periods. Table 4, for example, is the frequency distribution for June through August 1971.

The total number of minutes of good data recorded in each category is listed at the bottom of each of the above tables. In Table 1, for example, which refers to the whole of calendar year 1971, the total number of minutes of good data recorded is listed as 73,857 out of a possible 529,000 minutes. This means that good data were obtained for only 14% of the year. The reasons for missing or bad data are several. Normally data were recorded only when the station was tracking spacecraft. Thus the number of minutes of recorded data at S-band is considerably less than the number of minutes of X-band data. Unusable or "bad" data were recorded when the system suffered from S-band transmitter noise bursts, or when calibration was lost due to equipment failure, operator error, etc.

The usable or "good" data, however, are also subject to some error. The most common sources of error in these data are inaccuracies in the scale calibrations due to drifts in the equipment and an insufficiently determined fair weather baseline. These sources of error are under investigation.

Table 6 shows averages, standard deviations, and confidence intervals on measured excess system temperatures for the whole year and for the year divided into separate quarters. In each period the data have been divided into the same antenna elevation intervals as in the previous tables. The results have been computed taking one data point per minute of recorded data. The mean values of the excess system noise temperature for the various periods and elevation angles are shown in the second column. The next column lists the standard deviation of the data. As in the case of the X-band data (Ref. 1), there is a considerable spread in the data, as seen in the standard deviation column. The next two columns list the 95% and 50% confidence intervals, computed from the measured data, on the mean values of the excess system temperatures. These confidence intervals were calculated assuming all errors are random and neglecting the effects of any bias in any of the measurements. Bias errors would degrade the calculations by widening the intervals for a fixed confidence.

As with the X-band data the S-band sample mean converges as $\sigma/\sqrt{N}$ if the data are gaussian distributed, which, again, is only approximately true in this case.

It must be noted that:

(1) Measured results are based on one year of data only. It is not possible to derive meaningful statistics from one year of recorded data.

(2) The underlying data for the measured results are only approximately gaussian distributed (as indicated by a test for normality), and, therefore, the use of confidence intervals is suspect.

(3) More measured data are required before meaningful statistics can be deduced.

(4) A more accurate baseline must be determined.

References

1. Reid, M. S., and Booth, R. W. D., "Preliminary Analysis of the Microwave Weather Project Data for CY 1971," in *The Deep Space Network Progress Report*, Technical Report 32-1526, Vol. XI, pp. 111–120. Jet Propulsion Laboratory, Pasadena, Calif., Oct. 15, 1972.

2. Reid, M. S., "Tracking and Ground Based Navigation: A Description of the Weather Project," in *The Deep Space Network Progress Report*, Technical Report 32-1526, Vol. X, pp. 116–122. Jet Propulsion Laboratory, Pasadena, Calif., Aug. 15, 1972.

Table 1. S-band cumulative percentage probabilities of excess system temperature for CY 1971

Excess system temperature less than, K	Range of antenna elevation angle, deg				
	6–15	15–25	25–45	45–90	6–90
10	61.12	81.10	90.48	96.13	86.93
20	98.52	97.26	98.73	97.81	98.22
30	99.67	98.22	99.34	98.22	98.90
40	100.00	99.76	99.37	98.54	99.30
50	100.00	100.00	99.75	98.77	99.57
60	100.00	100.00	99.75	98.78	99.58
70	100.00	100.00	99.75	99.19	99.68
80	100.00	100.00	99.75	99.43	99.74
90	100.00	100.00	99.91	99.59	99.86
100	100.00	100.00	100.00	99.59	99.90
110	100.00	100.00	100.00	100.00	100.00

Antenna elevation angle was: 6–15 deg 11.4% of the time
                                 15–25 deg 17.2% of the time
                                 25–45 deg 46.3% of the time
                                 45–90 deg 25.1% of the time

Total time of good data recorded was 73,857 out of a possible 529,000 minutes.

Table 2. S-band cumulative percentage probabilities of excess system temperature for CY 1971 (December, January, February)

Excess system temperature less than, K	Range of antenna elevation angle, deg				
	6–15	15–25	25–45	45–90	6–90
10	54.57	79.58	86.34	92.38	81.96
20	98.19	94.83	97.60	93.95	96.49
30	99.42	96.63	98.75	95.07	97.77
40	100.00	99.55	98.80	95.96	98.58
50	100.00	100.00	99.52	96.59	99.14
60	100.00	100.00	99.52	96.64	99.14
70	100.00	100.00	99.52	97.76	99.35
80	100.00	100.00	99.52	98.43	99.47
90	100.00	100.00	99.83	98.88	99.71
100	100.00	100.00	100.00	98.88	99.79
110	100.00	100.00	100.00	100.00	100.00

Antenna elevation angle was: 6–15 deg 13.4% of the time
                                 15–25 deg 18.4% of the time
                                 25–45 deg 49.8% of the time
                                 45–90 deg 18.4% of the time

Total time of good data recorded was 36,355 out of a possible 129,750 minutes.

Table 3. S-band cumulative percentage probabilities of excess system temperature for CY 1971 (March, April, May)

Excess system temperature less than, K	Range of antenna elevation angle, deg				
	6–15	15–25	25–45	45–90	6–90
10	63.86	86.68	94.40	98.17	95.00
20	93.89	100.00	100.00	100.00	99.81
30	100.00	100.00	100.00	100.00	100.00

Antenna elevation angle was: 6–15 deg 3.04% of the time
                                 15–25 deg 7.83% of the time
                                 25–45 deg 32.6% of the time
                                 45–90 deg 56.5% of the time

Total time of good data recorded was 19,946 out of a possible 133,400 minutes.

Table 4. S-band cumulative percentage probabilities of excess system temperature for CY 1971 (June, July, August)

Excess system temperature less than, K	Range of antenna elevation angle, deg				
	6–15	15–25	25–45	45–90	6–90
10	58.27	80.00	100.00	0.00	78.38
20	100.00	100.00	100.00	0.00	100.00

Antenna elevation angle was: 6–15 deg 28.2% of the time
                                 15–25 deg 49.2% of the time
                                 25–45 deg 22.6% of the time
                                 45–90 deg   0% of the time

Total time of good data recorded was 3,937 out of a possible 132,900 minutes.

Table 5. S-band cumulative percentage probabilities of excess system temperature for CY 1971 (September, October, November)

Excess system temperature less than, K	Range of antenna elevation angle, deg				
	6–15	15–25	25–45	45–90	6–90
10	78.85	82.54	95.18	100.00	90.82
20	100.00	99.96	100.00	100.00	99.99
30	100.00	100.00	100.00	100.00	100.00

Antenna elevation angle was: 6–15 deg 13.8% of the time

15–25 deg 18.2% of the time

25–45 deg 64.0% of the time

45–90 deg 4.0% of the time

Total time of good data recorded was 13,619 out of a possible 132,500 minutes.

Table 6. Averages, standard deviations, and confidence intervals on excess system temperature for CY 1971

Period	Range of antenna elevation angles, deg	Excess noise temperature mean value, K	Standard deviation, K	95% Confidence interval, K	50% Confidence interval, K
CY 1971	6–15	9.07	5.33	±0.11	±0.04
	15–25	7.37	5.66	±0.10	±0.03
January	25–45	6.32	5.74	±0.06	±0.02
through	45–90	6.39	9.26	±0.13	±0.04
December	All angles	6.83	6.80	±0.05	±0.02
	6–15	9.78	5.56	±0.16	±0.06
	15–25	7.94	6.87	±0.16	±0.06
December	25–45	7.06	7.55	±0.11	±0.04
January	45–90	8.54	15.06	±0.36	±0.12
February	All angles	7.86	9.16	±0.09	±0.03
	6–15	9.22	6.06	±0.48	±0.17
	15–25	6.33	3.40	±0.17	±0.06
March	25–45	5.56	2.30	±0.06	±0.02
April	45–90	5.18	1.34	±0.02	±0.01
May	All angles	5.52	2.30	±0.03	±0.01
	6–15	9.17	4.93	±0.29	±0.10
	15–25	7.00	4.00	±0.18	±0.06
June	25–45	5.00	3.33	±0.22	±0.08
July	45–90	0	0	0	0
August	All angles	7.16	4.12	±0.13	±0.04
	6–15	7.12	4.08	±0.18	±0.06
September	15–25	6.75	3.81	±0.15	±0.05
October	25–45	5.48	2.14	±0.05	±0.02
November	45–90	5.00	3.33	±0.28	±0.10
	All angles	5.92	2.89	±0.05	±0.02