Preliminary S-Band Noise Temperature Statistics at DSS 14 for 1971 and 1972

R. W. D. Booth, M. S. Reid, and T. J. Cullen
Communications Elements Research Section

This article reports on the continuing effort to statistically characterize microwave weather-induced parameters as part of an overall effort to optimize the spacecraft-to-ground communications link. This report considers S-band 1971 and 1972 weather project data only. The statistics of interest are distribution tables for each year, distribution tables for each quarter, and tables of average excess noise temperature duration.

I. Introduction

This article reports on the continuing effort to characterize microwave weather statistics as part of the overall objective to optimize the spacecraft-to-ground communications link. The system operating noise temperature of the S-band systems was monitored and recorded for 1971 and 1972. Excess system noise temperatures were computed from these data. The excess noise temperature is defined as that portion of the total measured system noise temperature which is in excess of that value to be expected on a clear, dry day for the given antenna elevation angle. X- and K-band data will be reported in a subsequent article.

The excess noise temperature distributions for each year and each quarter are tabulated. Estimates of the average duration in time of the periods of excess system temperature have been calculated and are reported. These statistics may be important in planning for critical periods such as planetary encounters, etc.

II. Analysis

The distribution tables were formulated by dividing the total elevation range into four sections; 6–15, 15–25, 25–45, and 45–90 degrees. The excess noise temperature range was divided into sections of 10 K per section. The first section is 0–10 K and, for the accuracy of the measurements, represents the normal, or zero excess, section. The percentage of time the excess system noise temperature fell in each noise temperature section was calculated for each elevation angle section. In addition, these percentages were calculated for the entire elevation angle range of 6–90 degrees.

In addition to the distribution tables, means, standard deviations, and confidence intervals for the means were calculated for each range of elevation angle. The 50 and 95% confidence intervals for the mean were calculated. For these intervals, it was assumed that the distribution of the mean had converged to a gaussian distribution.

Finally, some preliminary estimates of excess noise temperature variations were made. At a fixed elevation angle, the total noise power at the output of the receiver varies with time. The primary contribution to this variation is from atmospheric effects, provided all other effects such as system configuration changes and data handling are removed. One may expect several short-term contributions to the noise received such as clouds and water vapor variations, especially near sunrise and sunset. The noise has a tendency to increase for a while and then decrease. Noise bursts from the transmitter and other ground equipment are excluded. The parameter of interest is the average duration of time that the noise temperature is above some threshold.

An average clear, dry background system temperature as a function of elevation angle was determined for S-band. This is an average baseline background profile. Six additional profiles were generated from this baseline profile. These new profiles were at 1, 2, 3, 4, 5 and 6 dB above the baseline profile. When the measured system temperature crossed one of the thresholds, the time was monitored until the system temperature dropped below the threshold, and these times were used to calculate mean-time durations and standard deviations that the thresholds were exceeded. The total number of events (i.e., number of times that a threshold was crossed) and the average number of events per 24-hour day were also calculated.

III. Tables

The odd-numbered tables from 1 through 19 are distribution tables and the even-numbered tables from 2 through 20 are tables of statistics. The distribution tables list the percentages of time that the excess system noise temperature was between the various 10 K increments, and the antenna elevation angle was between the given limits. For example, in Table 1 the entry 8.6 under 6-15 deg and opposite 0-10 K indicates that for 8.6 percent of the time the excess system noise temperature was between 0 and 10 K, *and* the antenna elevation angle was between 6 and 15 deg. The last column on the right is the total percentage of time the excess system noise temperature was between the indicated values of excess temperature, independent of elevation angle. The row at the bottom indicates the total percentage of time the antenna elevation angle was between the indicated values of elevation angle independent of excess noise temperature.

The statistical tables list the mean and standard deviation of the excess noise temperatures and are given for each elevation angle range. The 50% and 95% confidence intervals are given for the mean value. For example, for Table 2, the value 0.1 under 6-15 and opposite 50% confidence interval, indicates that with probability = 0.5, the actual mean is within plus or minus 0.1 K of the calculated mean value of 8.5 K.

Tables 21 and 22 are tables of the time duration of the periods when the system temperature exceeded the clear, dry weather baseline. Tables 21 and 22 are for all data for 1971 and 1972, respectively. These tables indicate the mean duration of time the system noise temperature was in excess of the indicated threshold. The total number of recorded events is also shown as well as the average number of events per day (equal to the total days of recorded data divided by the total number of recorded events), the mean time-duration of excess system temperature periods and its standard deviation.

In every table a blank indicates either zero or a value less than 0.05. The distribution and the statistical calculations were repeated, both for 1971 and for 1972, on a monthly basis, and these data are available for reference and comparisons.

In order to summarize all the distribution tables in a single figure, the percent of time the excess system noise temperature was greater than 10 K was chosen as a representative number for each table. These values were plotted for each quarter and for the whole calendar year for both 1971 and 1972 and are shown in Fig. 1.

The Goldstone area experienced unusually severe weather conditions, which included a heavy snowstorm in December 1971 (Ref. 1). This is reflected in the high value in Fig. 1 for the winter quarter. The difference, in general, between 1971 and 1972 as seen in Fig. 1 cannot be attributed only to weather conditions, however. The amount of data recorded in each quarter and in each year must be taken into account. Significantly more data were recorded in 1972 than in 1971. For example, for the winter quarter, usable data were recorded for only 9.8% of the possible time in 1971, whereas the figure for 1972 was

22.5%. For the March, April, and May quarter the figures were 4.2% and 29.7% for 1971 and 1972, respectively. For the June, July, August and September, October, November quarters the 1971 and 1972 figures were 2.7%, 25.8% and 4.2%, 28.6%, respectively. Data were recorded for 5.2% of the time in 1971 and 26.6% of the time in 1972. These figures clearly demonstrate the need for more consistent data recording.

In order to estimate the effect of a single period of severe weather, such as the snowstorm in December 1971, the 1971 data were recomputed using only the January through November recordings. These data were compared with the 1972 data and the conclusions are that the effect of the unusual data was to lengthen the average duration of time the excess system noise temperature remained above each of the thresholds and to increase significantly the standard deviations of these periods of excess system temperature, for some thresholds as much as 100 percent.

Other conclusions are that, even omitting December 1971, and if all other effects have been removed, then there were fewer periods of excess system temperature due to inclement weather conditions in 1972 than there were in 1971; the magnitudes of the 1972 excesses were less severe than they were in 1971, and that year-to-year differences must be expected.

Reference

1. Reid, M. S., *An Analysis of System Performance Under the Severe Weather Conditions at Goldstone, December 1971*, Technical Report 32-1526, Vol. XII, pp. 32–37, Jet Propulsion Laboratory, Pasadena, Calif., December 15, 1972.

Table 1. S-band distribution for all data for 1971

Excess noise temperature, K	Antenna elevation angle, deg				
	6–15	15–25	25–45	45–90	6–90
	Percentage of time of excess noise temperature				
0–10	8.6	20.5	44.6	9.4	83.1
10–20	3.4	3.2	4.5	0.9	12.0
20–30	0.2	0.4	0.6	0.2	1.5
30–40	0.1	0.7	[a]	0.2	1.0
40–50	[a]	0.2	0.3	0.4	0.9
50–60	[a]	[a]	[a]	[a]	[a]
60–70	[a]	[a]	[a]	0.3	0.3
70–80	[a]	[a]	[a]	0.2	0.2
80–90	[a]	[a]	0.4	0.1	0.5
90–100	[a]	[a]	0.3	[a]	0.3
100–110	[a]	[a]	[a]	0.3	0.3
Totals	12.3	24.9	50.8	12.0	100.0

[a]Zero or less than 0.05.

Table 2. S-band statistical table for all data for 1971

	Antenna elevation angle, deg				
	6–15	15–25	25–45	45–90	6–90
Mean, K	8.5	6.9	6.3	11.4	7.3
Standard deviation, K	5.2	6.6	11.4	22.3	12.0
50% confidence interval, K	0.1	0.1	0.1	0.3	0.1
95% confidence interval, K	0.2	0.2	0.2	0.8	0.2

Table 3. S-band distribution table for December, January, February, 1971

Excess noise temperature, K	Antenna elevation angle, deg				
	6–15	15–25	25–45	45–90	6–90
	Percentage of time of excess noise temperature				
0–10	7.2	19.6	43.7	3.4	73.9
10–20	2.6	4.3	7.8	1.1	15.8
20–30	0.2	0.9	1.4	0.5	3.0
30–40	0.2	1.4	0.1	0.5	2.2
40–50	[a]	0.4	0.7	0.8	1.8
50–60	[a]	[a]	[a]	[a]	[a]
60–70	[a]	[a]	[a]	0.6	0.6
70–80	[a]	[a]	[a]	0.4	0.4
80–90	[a]	[a]	0.9	0.2	1.2
90–100	[a]	[a]	0.6	[a]	0.6
100–110	[a]	[a]	[a]	0.6	0.6
Totals	10.1	26.6	55.3	8.0	100.0

[a]Zero or less than 0.05.

Table 4. S-band statistical table for December, January, February, 1971

	Antenna elevation angle, deg				
	6–15	15–25	25–45	45–90	6–90
Mean, K	9.6	8.1	8.5	29.7	10.2
Standard deviation, K	5.7	8.7	15.6	33.0	16.7
50% confidence interval, K	0.1	0.1	0.1	0.7	0.1
95% confidence interval, K	0.3	0.3	0.4	2.0	0.3

Table 5. S-band distribution table for March, April, May, 1971

Excess noise temperature, K	Antenna elevation angle, deg				
	6–15	15–25	25–45	45–90	6–90
	Percentage of time of excess noise temperature				
0–10	4.0	8.3	40.4	35.4	88.1
10–20	1.1	3.6	4.3	2.2	11.2
20–30	0.7	[a]	[a]	[a]	0.7
Totals	5.8	11.9	44.8	37.5	100.0

[a]Zero or less than 0.05.

Table 6. S-band statistical table for March, April, May, 1971

	Antenna elevation angle, deg				
	6–15	15–25	25–45	45–90	6–90
Mean, K	9.4	6.4	3.8	3.2	4.2
Standard deviation, K	8.6	5.0	3.4	4.3	4.7
50% confidence interval, K	0.3	0.1	[a]	0.1	[a]
95% confidence interval, K	0.9	0.4	0.1	0.2	0.1

[a]Zero or less than 0.05.

Table 7. S-band distribution table for June, July and August, 1971

Excess noise temperature, K	Antenna elevation angle, deg				
	6–15	15–25	25–45	45–90	6–90
	Percentage of time of excess noise temperature				
0–10	21.7	44.9	24.4	[a]	91.0
10–20	8.9	[a]	[a]	[a]	9.0
Totals	30.6	44.9	24.4	[a]	100.0

[a]Zero or less than 0.05.

Table 8. S-band statistical table for June, July, August, 1971

	Antenna elevation angle, deg				
	6–15	15–25	25–45	45–90	6–90
Mean, K	7.5	5.2	4.1	[a]	5.7
Standard deviation, K	3.4	2.0	1.8	[a]	2.8
50% confidence interval, K[a]	0.1	[a]	[a]	0.1	[a]
95% confidence interval, K[a]	0.2	0.1	0.1	0.2	0.1

[a]Zero or less than 0.05.

Table 9. S-band distribution table for September, October, November, 1971

Excess noise temperature, K	Antenna elevation angle, deg				
	6–15	15–25	25–45	45–90	6–90
	Percentage of time of excess noise temperature				
0–10	8.0	18.6	64.2	3.3	94.1
10–20	3.7	2.2	[a]	[a]	5.9
Totals	11.7	20.8	64.2	3.3	100.0

[a]Zero or less than 0.05.

Table 10. S-band statistical table for September, October, November, 1971

	Antenna elevation angle, deg				
	6–15	15–25	25–45	45–90	6–90
Mean, K	7.7	5.8	4.5	3.4	5.1
Standard deviation, K	3.6	2.6	1.9	0.8	2.6
50% confidence interval, K[a]	0.1	0.1	[a]	[a]	[a]
95% confidence interval, K[a]	0.3	0.2	0.1	0.1	0.1

[a]Zero or less than 0.05.

Table 11. S-band distribution table for all data for 1972

Excess noise temperature, K	Antenna elevation angle, deg				
	6–15	15–25	25–45	45–90	6–90
	Percentage of time of excess noise temperature				
0–10	11.0	14.1	30.3	43.6	99.1
10–20	0.1	0.1	0.2	0.3	0.7
20–30	a	a	a	0.1	0.1
30–40	a	a	a	0.1	0.1
40–50	a	a	a	a	a
50–60	a	a	a	a	a
60–70	a	a	a	a	a
Totals	11.2	14.2	30.6	44.0	100.0

[a]Zero or less than 0.05.

Table 12. S-band statistical table for all data for 1972

	Antenna elevation angle, deg				
	6–15	15–25	25–45	45–90	6–90
Mean, K	1.1	0.8	0.7	0.5	0.7
Standard deviation, K	2.4	2.1	2.0	2.7	2.4
50% confidence interval, K	a	a	a	a	a
95% confidence interval, K	a	a	a	a	a

[a]Zero or less than 0.05.

Table 13. S-band distribution table for December, January, February, 1972

Excess noise temperature, K	Antenna elevation angle, deg				
	6–15	15–25	25–45	45–90	6–90
	Percentage of time of excess noise temperature				
0–10	10.9	13.2	29.3	46.6	100.0
Totals	10.9	13.2	29.3	46.6	100.0

Table 14. S-band statistical table for December, January, February, 1972

	Antenna elevation angle, deg				
	6–15	15–25	25–45	45–90	6–90
Mean, K	0.1	0.1	a	a	a
Standard deviation, K	0.5	0.5	0.1	a	0.3
50% confidence interval, K	a	a	a	a	a
95% confidence interval, K	a	a	a	a	a

[a]Zero or less than 0.05.

Table 15. S-band distribution table for March, April, May, 1972

Excess noise temperature, K	Antenna elevation angle, deg				
	6–15	15–25	25–45	45–90	6–90
	Percentage of time of excess noise temperature				
0–10	10.0	12.5	26.5	50.9	100.0
10–20	a	a	a	a	a
Totals	10.1	12.5	26.5	50.9	100.0

[a]Zero or less than 0.05.

Table 16. S-band statistical table for March, April, May, 1972

	Antenna elevation angle, deg				
	6–15	15–25	25–45	45–90	6–90
Mean, K	0.3	0.2	0.1	0.1	0.1
Standard deviation, K	1.1	0.8	0.5	0.4	0.6
50% confidence interval, K	a	a	a	a	a
95% confidence interval, K	a	a	a	a	a

[a]Zero or less than 0.05.

Table 17. S-band distribution table for June, July, August, 1972

Excess noise temperature, K	Antenna elevation angle, deg				
	6–15	15–25	25–45	45–90	6–90
	Percentage of time of excess noise temperature				
0–10	9.4	13.4	26.4	49.6	98.8
10–20	0.1	a	a	0.5	0.6
20–30	a	a	a	0.3	0.3
30–40	a	a	a	0.2	0.2
40–50	a	a	a	a	a
50–60	a	a	a	a	a
60–70	a	a	a	a	a
Totals	9.5	13.4	26.4	50.7	100.0

[a]Zero or less than 0.05.

Table 18. S-band statistical table for June, July, August, 1972

	Antenna elevation angle, deg				
	6–15	15–25	25–45	45–90	6–90
Mean, K	1.2	0.9	0.5	0.7	0.7
Standard deviation, K	2.3	1.8	1.3	3.7	2.9
50% confidence interval, K	a	a	a	a	a
95% confidence interval, K	0.1	0.1	a	0.1	a

[a]Zero or less than 0.05.

Table 19. S-band distribution table for September, October, November, 1972

Excess noise temperature, K	Antenna elevation angle, deg				
	6–15	15–25	25–45	45–90	6–90
	Percentage of time of excess noise temperature				
0–10	13.7	17.3	38.7	28.0	97.7
10–20	0.3	0.2	0.9	0.5	1.9
20–30	0.1	0.1	a	0.1	0.3
30–40	a	a	a	a	a
40–50	a	a	a	0.1	0.1
50–60	a	a	a	a	a
Totals	14.0	17.6	39.6	28.8	100.0

[a]Zero or less than 0.05.

Table 20. S-band statistical table for September, October, November, 1972

	Antenna elevation angle, deg				
	6–15	15–25	25–45	45–90	6–90
Mean, K	2.2	1.7	1.5	1.6	1.7
Standard deviation, K	3.3	2.9	3.0	4.2	3.4
50% confidence interval, K	a	a	a	a	a
95% confidence interval, K	0.1	0.1	a	0.1	a

[a]Zero or less than 0.05.

Table 21. Average excess noise temperature duration and frequency for S-band data, 1971, all elevation angles

Threshold	Number of events	Average events/ 24-hr day	Mean time duration, min	Standard deviation, min
1 dB	73	1.61	62.1	113.0
2 dB	15	0.33	80.5	143.7
3 dB	3	0.066	243.0	187.2
4 dB	2	0.044	301.5	134.5
5 dB	1	0.022	407.0	
6 dB	1	0.022	301.0	
7 dB	1	0.022	31.0	

Table 22. Average excess noise temperature duration and frequency for S-band data, 1972, all elevation angles

Threshold	Number of events	Average events/ 24-hr day	Mean time duration, min	Standard deviation, min
1 dB	41	0.42	38.8	95.0
2 dB	13	0.13	42.3	73.2
3 dB	5	0.051	22.0	18.9
4 dB	5	0.051	7.0	5.0
5 dB	2	0.021	2.5	1.5

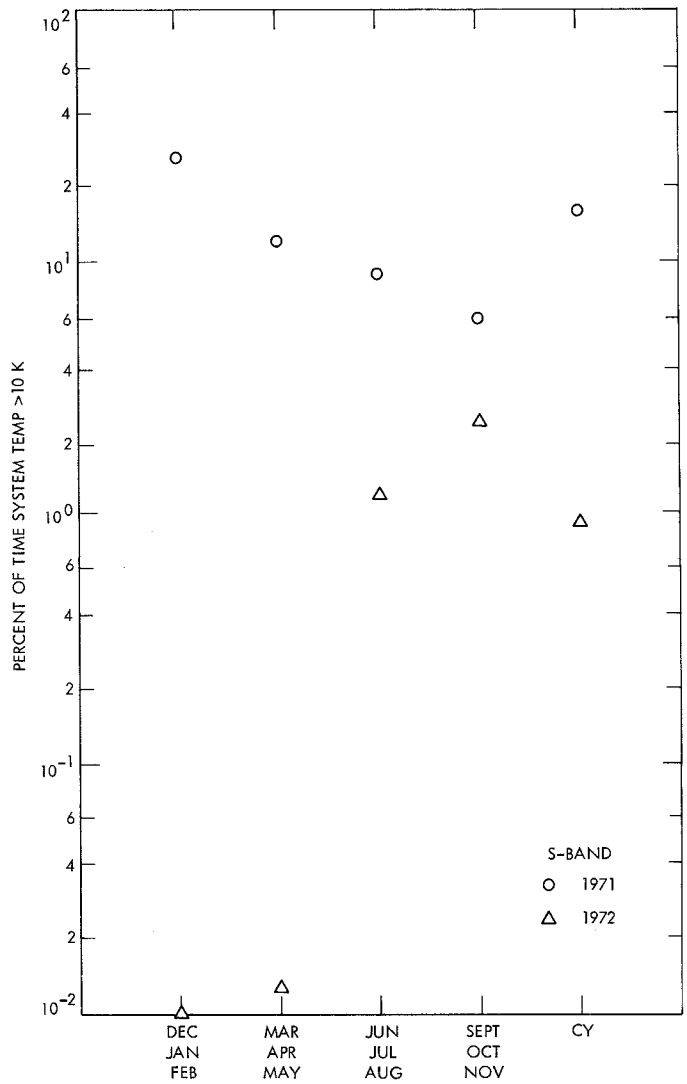

Fig. 1. Percent of time excess system temperature greater than 10 K as a function of time, S-band, 1971 and CY 1972