X-Band Atmospheric Noise Temperature Data and Statistics at Goldstone, DSS 13, 1977–1978

S. D. Slobin, K. B. Wallace, M. M. Franco, and E. M. Andres
Radio Frequency and Microwave Subsystems Section

O. V. Hester
Telecommunications Systems Section

X-band noise temperature data have been taken at Goldstone DSS 13 continuously since August 1975. Presented here are sample data and cumulative distributions of atmospheric noise temperature increase above the quiescent baseline for the calendar years 1977 and 1978. Comparison is made with the existing Deep Space Network noise temperature statistics.

I. Introduction

Reference 1 presents statistics of zenith noise temperature increase above the quiescent (undisturbed) baseline at Goldstone for the period August 1975 through January 1977. Included also are descriptions of elevation angle modelling and determination of atmospheric attenuation values from the given noise temperature increases. This article summarizes the X-band noise temperature statistics for the complete calendar years 1977 and 1978.

II. System Description

X-band atmospheric noise temperature data at DSS 13 (see Fig. 1a) are taken using an X-band noise-adding radiometer and horn antenna (no reflector) with a beamwidth of 15 degrees. Numerous other instruments at the site provide measurements of rainfall, temperature, relative humidity, atmospheric pressure, and solar radiation. Data points are recorded every 2 minutes. The X-band horn is pointed at an elevation angle of 30 degrees and an azimuth of 325-degrees. A complete description of the X-band radiometer system is given in Ref. 2.

The rain gauge at DSS 13 is an MRI (Meteorological Research, Inc.) tipping bucket unit. A funnel collects rain, which is channelled to the tipping bucket. The bucket tips only after it has collected the equivalent of 1/100-inch (0.25 mm) of rain. Each tip empties the bucket and registers as a step on the cumulative rainfall data (see Fig. 1b). A very light rain could continue for an extended period and only be registered as a single step (after 0.01-inch had fallen) in the rain gauge data. Thus, the rain gauge gives inaccurate rain rate values for very light rain. The cumulative amount will be correct, however, to within 0.01-inches. Heavy rains (>10 mm/hr) will cause the bucket to empty more than once during one 2-minute data period. There is little loss of accuracy at these large rates.

III. Noise Temperature and Rainfall Data

Figure 1 shows a five-day segment of raw antenna noise temperature and cumulative rainfall data taken during January 1978. This is typical of a rainy period of the year. The characteristic "spiked" rain signature corresponds almost perfectly to the cumulative rainfall data shown directly below. The intensity of rain, or rain rate (mm/hr), can be determined from the slope of the cumulative rainfall curve. During the period 18-19 hours on day 16 the rain rate is nearly constant (~9 mm/hr), yet the noise temperature exhibits erratic changes. Possible causes of this could be alternate "beading" and "running-off" of raindrops on the antenna horn aperture, cover, or the radiometer "seeing" rain which is not actually falling into the rain gauge. Further investigation of rain and its effects on microwave systems will be carried out. Correlation of rain and noise temperature effects and the development of a weather/microwave model will be the subject of a future DSN Progress Report article. Figure 2 shows the correspondence of rain rate (slope of curve in Fig. 1b) and increased antenna noise temperature for day 16.

As described in Ref. 1, the noise temperature measured at an elevation angle other than zenith is referred to zenith for purposes of statistical consistency. Note in Fig. 1 that the baseline system antenna temperature is approximately 9 kelvins for 30-deg elevation angle. This includes the minimum clear sky contributions from water vapor and oxygen and the noise temperature of the ground, cosmic background, and waveguide. Since the measurement of interest is the *zenith increase* above baseline due to atmospheric variables, the baseline is subtracted from the antenna temperature and the remainder divided by 1/sine (elevation angle) as a "weather-mass" correction. As an example, Fig. 3 shows the zenith equivalence (above baseline) of the data in Fig. 1 from Day 16, 08 hours to Day 17, 08 hours. Times in both figures are referenced to local midnight (PST). The 67 kelvin peak at 30 deg elevation in Fig. 1 becomes a 29 kelvin peak above baseline at zenith $[(67-9) \div 2 = 29]$. Nine-kelvin antenna temperatures in Fig. 1 become equivalent zenith zero-kelvin increases above quiescent baseline in Fig. 3.

Figure 1 also shows typical clear weather (Day 15, 22 hours) and cloudy weather (Day 14, 06 hours) noise temperature measurements. The small noise temperature "humps" occurring at 10-14 hours were probably due to noise diode thermal effects and have since been eliminated and do not appear in the noise temperature statistics.

IV. Noise Temperature Statistics

Statistics have been generated for equivalent zenith X-band atmospheric noise temperature increase above quiescent baseline for various year-quarters and day-quarters at Goldstone. "Equivalent" means that the data are taken at elevation angles other than zenith and are converted to zenith values as described above. Statistics for *system* noise temperature can be obtained by adding the baseline system noise temperature for a particular antenna and elevation angle. Thus, for DSS 14, the 64-meter antenna at Goldstone, approximately 25 K (at zenith) must be added to the atmospheric increase to obtain total system noise temperature. For example, if the *atmospheric* noise temperature increase at *zenith* is 5 K or less, 90% of the time, the total *system* noise temperature *at zenith* would be 30 K or less, 90% of the time. Different antenna elevation angles contribute different ground and clear sky atmospheric contributions and thus the baseline system noise temperature will be a function of elevation angle. A further discussion of elevation angle modelling and attenuation calculation is given in Ref. 1.

Figure 4 shows the cumulative distribution of zenith noise temperature increase for a very wet period in 1978 (first year-quarter, January-March) and for a very dry period in 1977 (second year-quarter, April-June). These curves have 1 K resolution. As an example for reading the curves, for the wet quarter, 95% of the time the zenith noise temperature increase was less than 5 K above the baseline. The wet/dry comparison shows that about 3 times as much data lie above 5 K in the wet quarter as in the dry quarter. Some amount of time the radiometer records values less than the accepted baseline value. This is due primarily to radiometer drift about the "zero-K" point. The baseline could alternatively be defined as that value below which only 5% or 1% of the data lie.

Figure 5 shows a comparison of distribution functions for total-year Goldstone data in 1977 and 1978. In 1978, about 70% more data lie above 5 K than in 1977. Indeed, 1978 was a much wetter year than 1977. Also shown in Fig. 5 is the total-year Goldstone noise temperature distribution function from the DSN Flight Project Interface Design Handbook. The data used to generate the Fig. 5 curve are pre-1970 and it is not known how these data compare descriptively (wet or dry) to the 1977 (very dry) and 1978 (relatively wet) data, although the curve indicates substantially worse weather than in either 1977 or 1978. As has been noted before (Ref. 3) the data appear to be "pessimistic," i.e., they indicate that the weather effects are far worse than they appear to be based on actual measurements.

Since a presentation of distributions for every year/day-quarter for 1977 and 1978 would be prohibitively lengthy, only tables of year-quarter and year-total cumulative distributions are presented. Tables 1 and 2 present the 1977 and 1978 Goldstone cumulative distributions, respectively, up to the 10 K and/or 99% level.

References

1. Slobin, S. D., et al., "X-Band Atmospheric Noise Temperature Statistics at Goldstone DSS-13, 1975-1976," in *The DSN Progress Report 42-38*, Jet Propulsion Laboratory, Pasadena, Calif., Apr. 15, 1977, pp. 70-76.

2. Reid, M. S., et al., "An X-Band Radiometer for the Microwave Weather Project," in *The DSN Progress Report 42-29*, Jet Propulsion Laboratory, Pasadena, Calif., Feb. 15, 1975, pp. 54-59.

3. Greenhall, C. A., "Examination of the DSN X-Band Weather Specifications," in *The DSN Progress Report 42-45*, Jet Propulsion Laboratory, Pasadena, Calif., June 15, 1978, pp. 197-208.

Table 1. Cumulative distribution of zenith atmospheric noise temperature increases above Quiescent Baseline at Goldstone, 1977

TZX[a]	1st year quarter	2nd year quarter	3rd year quarter	4th year quarter	Year total
0	.487	.464	.061	.017	.300
1	.995	.955	.985	.924	.956
2	.999	.980	.992	.951	.976
3	.999	.984	.992	.959	.980
4	1.000	.985	.992	.965	.982
5	1.000	.986	.992	.970	.984
6	1.000	.988	.992	.975	.987
7	1.000	.989	.992	.978	.988
8	1.000	.990	.993	.982	.990
9	1.000	.991	.993	.985	.991
10	1.000	.991	.993	.988	.992

[a]TZX = X-band zenith atmospheric noise temperature increase above quiescent baseline, K; e.g., 2nd year quarter, TZX = 3, 98.4% of data below 3 K increase

Table 2. Cumulative distribution of zenith atmospheric noise temperature increases above quiescent baseline at Goldstone, 1978

TZX[a]	1st year quarter	2nd year quarter	3rd year quarter	4th year quarter	Year total
0	.207	.053	.694	.512	.216
1	.735	.332	.783	.964	.712
2	.879	.947	.945	.980	.931
3	.914	.981	.981	.986	.959
4	.933	.983	.984	.988	.968
5	.949	.986	.987	.990	.975
6	.962	.988	.989	.992	.980
7	.971	.990	.992	.993	.985
8	.979	.992	.994	.993	.988
9	.984	.994	.995	.994	.991
10	.987	.995	.996	.995	.992

[a]TZX = X-band zenith atmospheric noise temperature increase above quiescent baseline, K; e.g., year total, TZX = 5, 97.5% of data below 5K increase.

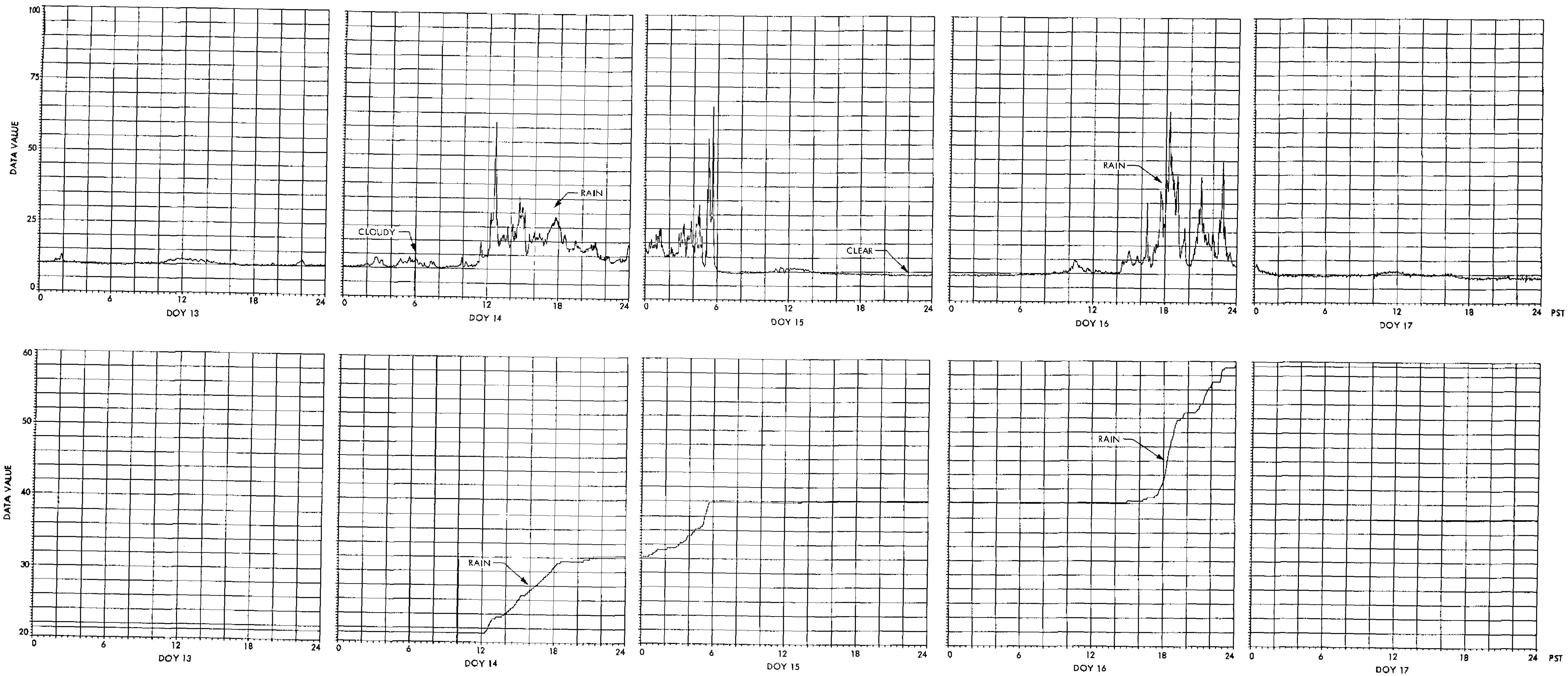

Fig. 1. Raw noise temperature and rainfall data from Goldstone, January 1978, (upper row) X-band antenna noise temperature, K, 30-degree elevation angle, (lower row) cumulative rainfall, mm

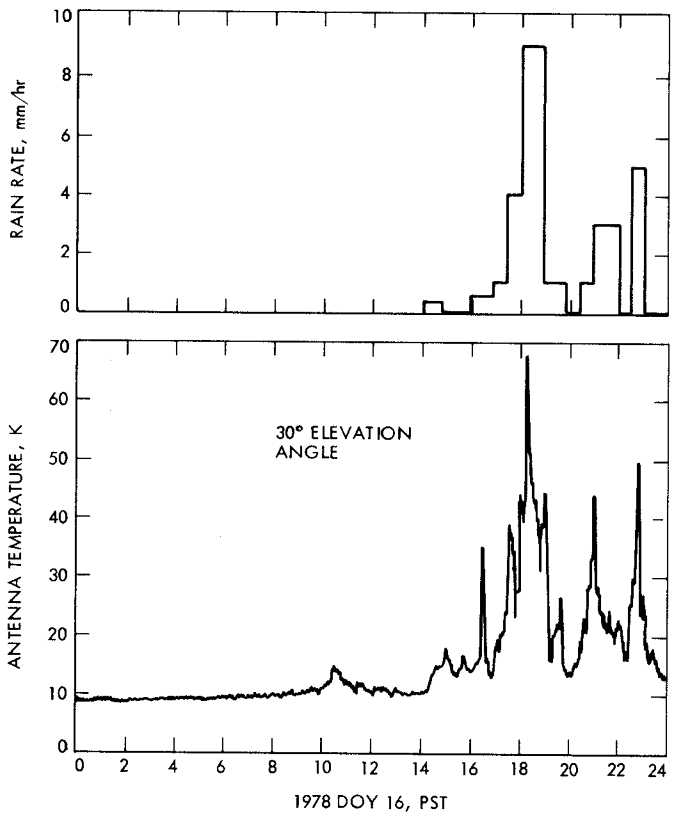

Fig. 2. X-band antenna temperature at Goldstone DSS 13 and corresponding rain rate, January 1978

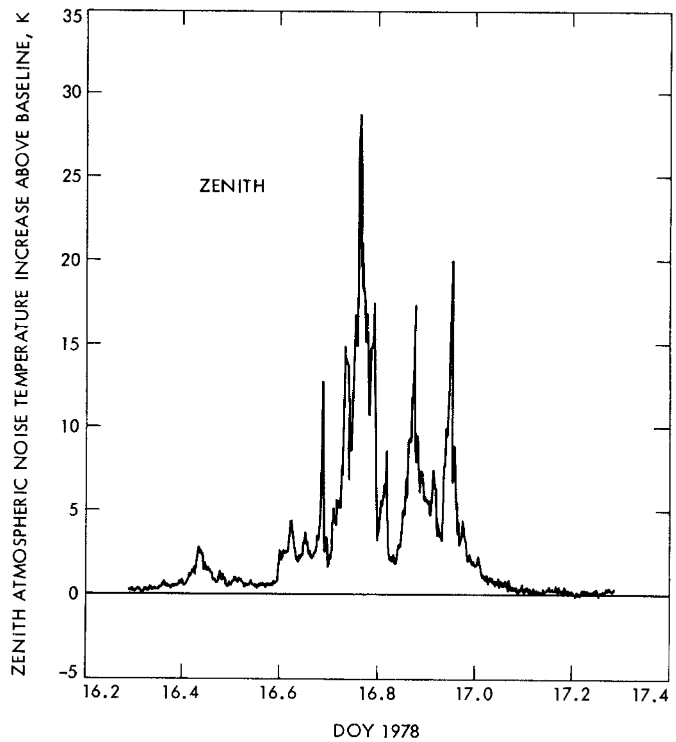

Fig. 3. Zenith equivalent X-band atmospheric noise temperature increase above baseline, K, corresponding to Figs. 1 and 2, January 1978

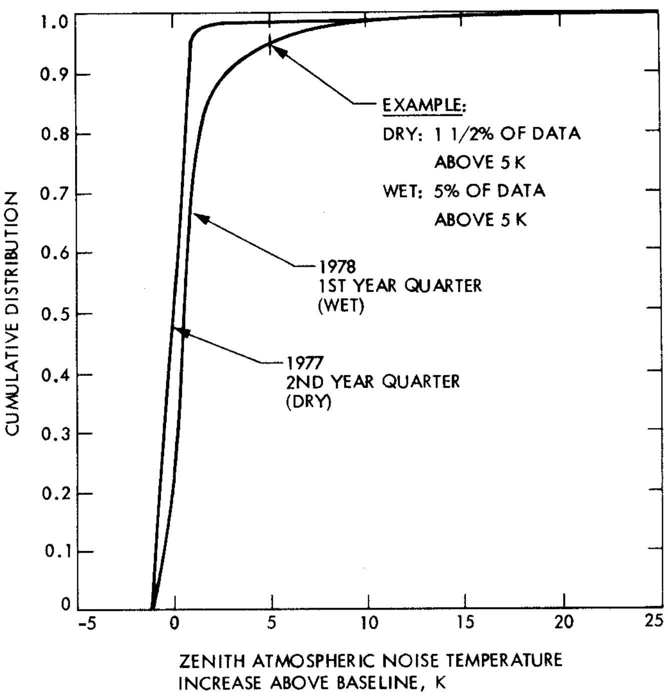

Fig. 4. Wet-quarter/dry-quarter atmospheric noise temperature statistics at Goldstone DSS 13

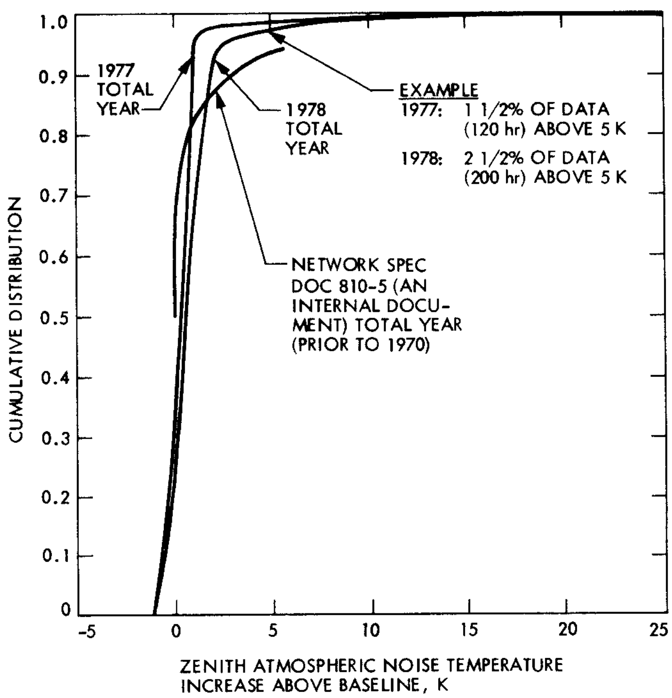

Fig. 5. 1977/1978 atmospheric noise temperature statistics at Goldstone DSS 13 and existing 810-5 distribution

NASA—JPL—Coml., L.A., Calif.