X-Band Atmospheric Noise Temperature Statistics at Goldstone DSS 13, 1975–1976

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X-band noise temperature data have been taken at Goldstone DSS 13 for the period August 1975 through January 1977. A description of the experiment is given along with probability density functions for zenith noise temperature increase during all year quarters and day quarters. Elevation angle modeling of the data is described along with a discussion of the problems associated with relating wide beamwidth statistics (this report) to narrow beamwidth antennas.

I. Introduction

X-band noise temperature data have been taken at the Goldstone Venus site (DSS 13) since August 1975. Instrumentation at that site consists of an X-band noise-adding radiometer and a horn antenna (no reflector) with a beamwidth of about 15 deg. Data are being taken continuously to develop X-band noise temperature statistics for the Goldstone complex. The horn is pointed at an elevation angle of 30 deg in the direction of DSS 14 (AZ = 325 deg). This tilt is necessary to keep rainwater from pooling on the aperture diaphragm during rainstorms; the azimuth direction was picked in order to look at weather which was "seen" commonly by both the X-band horn and the DSS 14 64-meter antenna.

Virtually all the data taken from August 1975 through January 1977 has been reduced and analyzed. A data point consists of the equivalent zenith noise temperature integrated over 2 minutes of time and over the 15 deg (±7 1/2 deg) 3-dB beamwidth. A total of 308,200 2-minute data points was considered "good," 7800 were "bad," and the instrument was inoperative for a total time equivalent to 67,300 data points. This amounts to an 80% "good data" return.

II. Description of Results

Data points are classified according to which year and day quarter they belonged. The year quarters are classified:

Year Quarter 1:	Dec, Jan, Feb
Year Quarter 2:	Mar, Apr, May
Year Quarter 3:	Jun, Jul, Aug
Year Quarter 4:	Sep, Oct, Nov

The day quarters are classified:

Day Quarter 1:	0000 to 0600 local time
Day Quarter 2:	0600 to 1200 local time
Day Quarter 3:	1200 to 1800 local time
Day Quarter 4:	1800 to 2400 local time

Noise temperature increases are due to atmospheric changes only, except for rare cases such as water droplets adhering to the aperture diaphragm or an airplane in the beam. The same conditions could exist for a 64-m antenna as well.

The noise temperature statistics are presented in Tables 1 through 5 and Figs. 1 and 2. The tables present the values of normalized probability density functions (percent of time ÷ 100) corresponding to *zenith noise temperature increases above the quiescent baseline* (e.g., 1 = 0 to 1 K, 2 = 1 to 2 K). The zenith X-band quiescent (lowest loss) baseline noise temperature value for Goldstone is approximately 2.5 kelvins (for oxygen and water vapor), which corresponds to approximately 0.043 dB zenith attenuation. Tables 1 through 4 present the probability density functions for each year quarter and each day quarter separately, including the sums over all day quarters. Table 5 presents pdf's for each day quarter, summed over all year quarters, plus the sum over all year and day quarters. Zenith temperature increases greater than 20 K are not shown, both for reasons of clarity and because of the fact that nearly all of the time (> 99%), increases are less than 20 K above the quiescent baseline.

Figure 1 gives a histogram presentation of the data from Table 5 (last column), which is the sum of data for all year quarters and all day quarters. Figure 2 gives the cumulative distribution for the data in Fig. 1. For example, 95.215% of the time the noise temperature increase is 1 K or less, 98.488% of the time 2 K or less, 98.878% of the time 3 K or less, and so forth. Similar figures may be drawn for any year or day quarter data. A system resolution of 1 K covers the entire cumulative distribution range of 0.0 to 0.95 for very low noise temperature increases. Thus "50% weather" at X-band is a concept that cannot be talked about with great precision.

III. Interpretation of the Results

One problem is readily apparent in analyzing the experiment. The difference in beamwidths between the test antenna (15 deg) and a 64-meter antenna (0.04 deg) results in a condition in which the test antenna sees less than or equal to the "amount" of significant weather seen by a 64-m antenna. This means that in a localized weather condition (a rainstorm, for example) which fills a very narrow beam, a wide beam may or may not be filled, resulting in a possibly lower measured antenna temperature. In the case of a widespread weather condition (complete overcast) both beams will be filled and the noise temperature increases will be equal. Data gathered by a wide-beam antenna will be biased toward lower-than-actual values.

Care must be taken in applying these statistics. Modeling techniques to apply wide beam results to narrow beam antennas are being investigated. These will depend on the physical characteristics of rain and clouds, plus associated wind conditions. Wind conditions are important because what a wide-beam antenna sees of a small high noise temperature cell in a 2-minute period as it drifts within the beam, *may* be what a narrow-beam antenna sees *on the average* over a longer *time* period as it drifts in and out of the beam. The ramifications of this are important, and the modeling will be quite difficult.

IV. Elevation Angle Modeling

Elevation angle modeling can be done (with thought and care) as follows. The zenith atmospheric attenuation *increase* may be found from

$$\Delta\mathrm{dB} = 10 \log_{10} \left[\frac{T_P}{T_P - DELTZX}\right]$$

where

T_P = assumed average physical temperature for attenuating elements

$DELTZX$ = zenith noise temperature increase above baseline

For $DELTZX \ll T_P$, ΔdB is insensitive to the choice of T_P, although 265 K to 270 K is a reasonable range for the physical temperature of clouds.

The total zenith atmospheric attenuation becomes:

$$\text{total dB (zenith)} = 0.043 + \Delta\mathrm{dB}$$

At an elevation angle θ, the total atmospheric attenuation becomes (for *uniform* weather over the field of interest)

$$\text{total dB }(\theta) = \frac{\text{total dB, zenith}}{\sin\theta}$$

This approximation is valid for $\theta > 10$ deg. Note that for *scattered* rain and/or clouds, there are nonattenuating spaces between the attenuating elements, and the above expression must be altered considerably based on considerations of percent rain and/or cloud coverage.

For the uniform case, the *total atmospheric noise temperature* may be computed from

$$TX(\theta) = T_P \cdot \left[1 - \frac{1}{L_\theta}\right]$$

where

$L_\theta = 10^{(\text{total dB}, \theta)/10}$

T_P = same assumed physical temperature

Note that as the atmospheric attenuation *increases*, the cosmic background contribution *decreases*. The net cosmic contribution then becomes

$$T_{cosmic,\, \theta} = \frac{2.7}{L_\theta}$$

where L_θ is calculated above. The increase above baseline at elevation θ is *not* $TX(\theta) - T_{baseline}(\theta)$. The *difference* in cosmic contributions must be added back into the above difference.

V. Summary of Data

At Goldstone, there is a zenith X-band noise temperature increase of less than 1 K above the quiescent baseline 95% of the time. The "worst" (highest attenuation) year quarter and day quarter of the year appears, at present, to be the fourth year quarter (Sep, Oct, Nov) in the morning (6 a.m. to noon). The best year quarter/day quarter appears to be the third year quarter (Jun, Jul, Aug) in the morning (6 a.m. to noon). The worst year quarter is the fourth; the best is the third. The worst time of day is the afternoon (noon to 6 p.m.); the best is the evening (6 p.m. to midnight). However, one should take about 10 to 15 years of data before real long-term average statistics may be developed. (Note that 1975-1976 Southern California weather conditions were far "drier" than the long-term average.) These data will be updated quarterly.

Table 1. X-band zenith noise temperature increase — probability density functions.[a] YEAR QUARTER = 1

	Day quarter				
DELTZX[b]	1	2	3	4	All
1	.96813+00	.94814+00	.94851+00	.96614+00	.95765+00
2	.23291-01	.44679-01	.44516-01	.24970-01	.34453-01
3	.33517-02	.17120-02	.34892-02	.56056-02	.35283-02
4	.17043-02	.49705-03	.11256-02	.45298-03	.94180-03
5	.11930-02	.88364-03	.45022-03	.16987-03	.67473-03
6	.34085-03	.13255-02	.22511-03	.56622-04	.49199-03
7	.68170-03	.88364-03	.56278-04	.11324-03	.43576-03
8	.34085-03	.12150-02	.22511-03	.00000	.44982-03
9	.28404-03	.33136-03	.16883-03	.00000	.19680-03
10	.17043-03	.16568-03	.56278-04	.00000	.98398-04
11	.17043-03	.00000	.22511-03	.56622-04	.11245-03
12	.17043-03	.55227-04	.00000	.00000	.56227-04
13	.00000	.55227-04	.16883-03	.00000	.56227-04
14	.11362-03	.00000	.11256-03	.00000	.56227-04
15	.00000	.00000	.00000	.56622-04	.14057-04
16	.56808-04	.00000	.16883-03	.00000	.56227-04
17	.00000	.00000	.00000	.56622-04	.14057-04
18	.00000	.00000	.56278-04	.00000	.14057-04
19	.00000	.00000	.11256-03	.56622-04	.42170-04
20	.00000	.00000	.56278-04	.00000	.14057-04

[a]Percent of time (÷ 100) that noise temperature increase is in range of DELTZX (below). (e.g., .96813 + 00 = .96813 x 10^0).

[b]DELTZX = X-band zenith noise temperature increase above quiescent baseline, 1 = 0 to 1 K, 2 = 1 to 2 K, etc.

Table 2. X-band zenith noise temperature increase — probability density functions. YEAR QUARTER = 2

	Day quarter				
DELTZX	1	2	3	4	All
1	.97982+00	.98621+00	.97688+00	.98177+00	.98117+00
2	.65540-02	.77951-02	.86487-02	.52829-02	.70688-02
3	.16385-02	.18845-02	.31684-02	.18746-02	.21421-02
4	.86237-03	.77094-03	.21408-02	.10225-02	.11996-02
5	.94860-03	.77094-03	.10276-02	.51125-03	.81398-03
6	.94860-03	.17132-03	.42816-03	.42604-03	.49267-03
7	.43118-03	.85660-04	.94194-03	.42604-03	.47125-03
8	.51742-03	.17132-03	.42816-03	.59646-03	.42841-03
9	.25871-03	.00000	.42816-03	.59646-03	.32131-03
10	.25871-03	.00000	.42816-03	.34083-03	.25705-03
11	.17247-03	.00000	.34252-03	.42604-03	.23563-03
12	.34495-03	.00000	.34252-03	.34083-03	.25705-03
13	.25871-03	.85660-04	.85631-04	.34083-03	.19279-03
14	.25871-03	.00000	.85631-04	.42604-03	.19279-03
15	.25871-03	.85660-04	.25689-03	.68166-03	.32131-03
16	.25871-03	.85660-04	.42816-03	.34083-03	.27847-03
17	.00000	.00000	.85631-04	.25562-03	.85683-04
18	.17247-03	.85660-04	.85631-04	.25562-03	.14994-03
19	.25871-03	.00000	.85631-04	.85208-04	.10710-03
20	.34495-03	.17132-03	.17126-03	.85208-04	.19279-03

Table 3. X-band zenith noise temperature increase — probability density functions. YEAR QUARTER = 3

	Day quarter				
DELTZX	1	2	3	4	All
1	.97960+00	.99203+00	.97789+00	.98331+00	.98313+00
2	.10894–01	.63198–02	.11617–01	.87719–02	.94265–02
3	.19702–02	.82689–03	.35527–02	.31126–02	.23854–02
4	.75332–03	.23625–03	.19173–02	.14714–02	.11065–02
5	.69537–03	.00000	.10151–02	.56593–03	.57479–03
6	.23179–03	.59063–04	.11278–02	.73571–03	.54605–03
7	.40563–03	.00000	.33835–03	.28297–03	.25865–03
8	.40563–03	.59063–04	.22557–03	.28297–03	.24428–03
9	.57947–03	.00000	.16918–03	.11319–03	.21555–03
10	.52153–03	.59063–04	.28196–03	.16978–03	.25865–03
11	.34768–03	.59063–04	.33835–03	.56593–04	.20118–03
12	.23179–03	.00000	.22557–03	.56593–04	.12933–03
13	.11589–03	.00000	.56392–04	.56593–04	.57479–04
14	.17384–03	.00000	.56392–04	.11319–03	.86218–04
15	.17384–03	.59063–04	.56392–04	.56593–04	.86218–04
16	.34768–03	.59063–04	.00000	.00000	.10059–03
17	.23179–03	.00000	.56392–04	.11319–03	.10059–03
18	.23179–03	.00000	.00000	.00000	.57479–04
19	.23179–03	.00000	.56392–04	.00000	.71848–04
20	.34768–03	.00000	.00000	.00000	.86218–04

Table 4. X-band zenith noise temperature increase — probability density functions. YEAR QUARTER = 4

	Day quarter				
DELTZX	1	2	3	4	All
1	.92344+00	.91136+00	.91330+00	.92860+00	.91918+00
2	.55902–01	.63683–01	.51913–01	.50648–01	.55507–01
3	.35278–02	.60683–02	.84961–02	.46565–02	.56952–02
4	.18318–02	.17046–02	.31442–02	.20246–02	.21801–02
5	.61058–03	.10909–02	.21742–02	.13160–02	.13013–02
6	.61058–03	.81819–03	.17728–02	.14509–02	.11661–02
7	.61058–03	.34091–03	.14383–02	.87731–03	.81964–03
8	.50882–03	.34091–03	.10035–02	.40491–03	.56614–03
9	.57666–03	.44319–03	.12376–02	.16871–03	.60839–03
10	.57666–03	.37500–03	.10035–02	.13497–03	.52389–03
11	.44098–03	.75001–03	.50174–03	.20246–03	.47319–03
12	.37313–03	.10568–02	.26759–03	.10123–03	.44784–03
13	.78019–03	.95456–03	.23415–03	.26994–03	.55769–03
14	.54274–03	.30682–03	.20070–03	.13497–03	.29575–03
15	.27137–03	.23864–03	.16725–03	.33743–03	.25350–03
16	.20353–03	.68183–04	.10035–03	.13497–03	.12675–03
17	.27137–03	.10227–03	.13380–03	.10123–03	.15210–03
18	.23745–03	.34091–04	.13380–03	.67486–04	.11830–03
19	.23745–03	.34091–03	.23415–03	.33743–04	.21125–03
20	.20353–03	.17046–03	.66899–04	.67486–04	.12675–03

Table 5. X-band zenith noise temperature increase — probability density functions. ALL YEAR QUARTERS

	Day quarter				
DELTZX	1	2	3	4	All year and day quarters
1	.95517+00	.94957+00	.94591+00	.95798+00	.95215+00
2	.30578–01	.37807–01	.34382–01	.28148–01	.32725–01
3	.28445–02	.32218–02	.53973–02	.40937–02	.38952–02
4	.14091–02	.94681–03	.22445–02	.13820–02	.14979–02
5	.81648–03	.74956–03	.13363–02	.75616–03	.91575–03
6	.51359–03	.67066–03	.10639–02	.80831–03	.76531–03
7	.55310–03	.35505–03	.79143–03	.49542–03	.54945–03
8	.44775–03	.46025–03	.55789–03	.31290–03	.44479–03
9	.46091–03	.24985–03	.62276–03	.18252–03	.37938–03
10	.42141–03	.19725–03	.53194–03	.14341–03	.32378–03
11	.31606–03	.30245–03	.37625–03	.16949–03	.29108–03
12	.28972–03	.42080–03	.20759–03	.10430–03	.25510–03
13	.36873–03	.39450–03	.15569–03	.16949–03	.27146–03
14	.31606–03	.11835–03	.12974–03	.14341–03	.17661–03
15	.18437–03	.11835–03	.11677–03	.26075–03	.17007–03
16	.21070–03	.52600–04	.14272–03	.10430–03	.12755–03
17	.15803–03	.39450–04	.77845–04	.11734–03	.98116–04
18	.17120–03	.26300–04	.77845–04	.65187–04	.85034–04
19	.18437–03	.13150–03	.14272–03	.39112–04	.12428–03
20	.21070–03	.92051–04	.64871–04	.39112–04	.10139–03

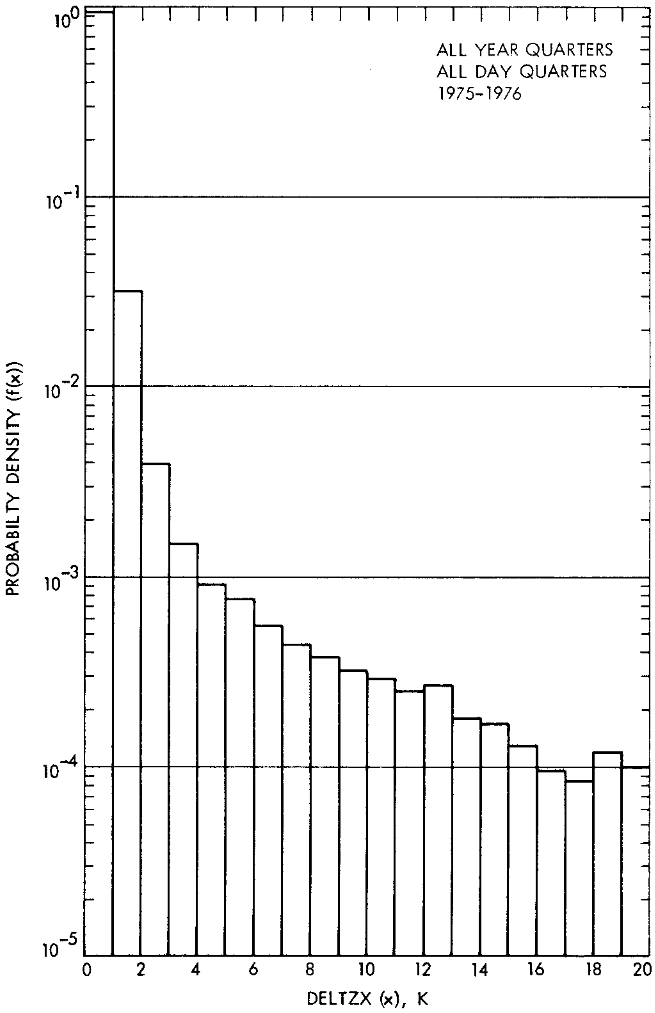

Fig. 1. Probability density histogram of zenith noise temperature increase (DELTZX)

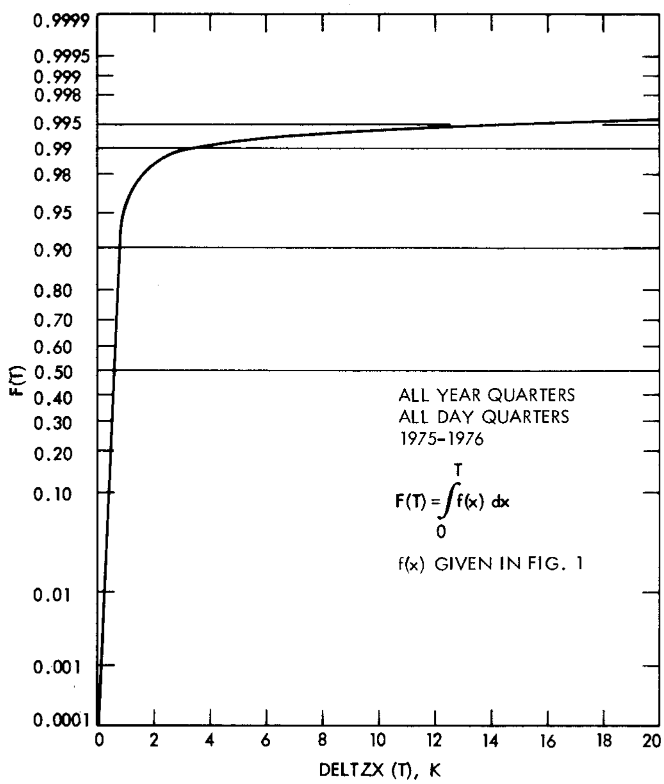

Fig. 2. Cumulative distribution function for zenith noise temperature increase (DELTZX)