NATIONAL RADIO ASTRONOMY OBSERVATORY
SOCORRO, NEW MEXICO
VERY LARGE ARRAY PROJECT

VLA TEST MEMORANDUM NO. 121

# APPLICATION OF MEASURED SYSTEM TEMPERATURES TO VLA DATA

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## 1.0 SUMMARY OF OBSERVATIONS

Test observations were scheduled for 8 hours on 1977 December 19. Sources 3C84 and DA267 were observed; 3C84 set during the period, and DA267 transmitted. Observations were made at all four bands, with 2 cm and 1.3 cm concentrated during the setting of 3C84. Antennas 1, 2, 4, 6, 7, 8, and 9 were operating at 6 cm; antennas 2, 6, 7, 8, and 9 were operating at 20 cm; and antennas 4, 7, 8, and 9 were operating at 2 cm and 1.3 cm. Antenna 4 was actually operating at 20 cm but the data had to be totally discarded as explained below.

The tests had several objectives, the primary one being to apply the measured system temperatures to the visibility data at 6 cm and 20 cm to repeat the experiment reported in VLA Test Memorandum 119. In addition, the elevation dependence of visibility data at 2 cm and 1.3 cm was to be investigated, including the effects of system temperature, atmospheric extinction, and antenna efficiency. The latter topic is discussed in VLA Test Memorandum No. 122.

## 2.0 CLOSURE PROPERTIES

The program ANTSOL, which solves for individual antenna amplitudes and phases from the redundant correlator data, was run on 5-minute scan averages of the raw data. After the solution is made, the program compares the correlation predicted from the solution to the actual visibility data; the differences are closure errors. In general, the closure errors on this data were small and infrequent once no-fringe data and other obvious glitches were eliminated from the data. In particular, 6 cm, 2 cm, and 1.3 cm had "typical" closure errors (phase < 6d, amplitude < 8%). One exception was the scans when 3C84 was setting (elevation < 11d), when there was a notable lack of phase closure at 1.3 cm, possibly due to an imperfect refraction correction. The phase closure errors at 20 cm were the worst of all bands, but only in amplitude (phase ~ 0d, amplitude < 20%). Antenna 4 at 20 cm contaminated the solution so badly that its data had to be totally flagged. Both IFs A and C acted this way. There has been a weak birdie reported in antenna 4, channel C (Maintenance Report 1064); the lack of closure with channel A indicates there may be a weaker birdie there too.

The closure errors described above were those which occurred over scan averages. In general, averaging for less than a scan makes the closure errors considerably worse in that they are reported for almost every correlator but are not generally higher in value.

## 3.0 MEASURED SYSTEM TEMPERATURES

The system temperatures measured by the monitor system (which can also be thought of as the "apparent" system temperatures) are shown in Figures 1 to 9, and Table 1. The measurements are stable with a few exceptions:

20 cm -- Antenna 7A had a very high system temperature and it was unstable. Antenna 6 shows an increase in system temperature toward low elevations which is much steeper than the other antennas; this behavior has been noticed before.

6 cm -- All antennas have "reasonable" system temperatures. The rms of the average temperature is markedly smaller for antennas 7, 8, and 9 (rms ~ 3%) than for the first 6 antennas (rms ~ 10%). Also, the measured system temperature itself is systematically lower for antennas 7, 8, and 9 (Tsys ~ 40 K) than for antennas 1, 2, 4, and 6 (Tsys ~ 75 K). This supports the conclusions reached by M. Sinclair, and is also correlated with the change of manufacturer for the paramps.

2 cm -- Antenna 4 had very high system temperatures (4A ~ 1000 K, 4C ~ 500 K); 4C was stable whereas 4A had an erratic cal value. Antennas 8, 9, and 7C had system temperatures on the order of 200 K. Antenna 7A has a very low cal value, giving an abnormal measured temperature of only 29 K.

1.3 cm -- Antenna 4 had very high system temperatures, as at 1.3 cm (4A ~ 4500 K, 4C ~ 1200 K), but both values were very stable. Antennas 7, 8, and 9 had system temperatures on the order of 400 K.

## 4.0 APPLICATION OF MEASURED SYSTEM TEMPERATURES

The program ANTSOL was run on the raw data to obtain the solutions for the antenna amplitudes. Then, the program GTTSYS was run to fill the gain table with the measured system temperatures. Then ANTSOL was run again. The two sets of solutions, raw data and data with system temperatures applied, constitute the values analyzed below.

There are two regimes over which the system temperature application may be examined. One is the time variations observed in the visibility data, and the other is the variations in the observed amplitude from one antenna-IF to another. In general, neither one of these regimes is significantly affected by the application of the measured system temperatures. Figures 10 to 13 show the raw data: scan averages plotted as a function of time or elevation. Figures 14 to 17 are plots of the data with system temperature applied.

The time variations are indicated by the rms of the scan averages listed in Tables 2 to 5, one for each frequency (these are averages of the data points plotted in the figures). The percentage rms is not significantly different for the raw data and the data corrected by the system temperatures. The correction does remove gross effects such as the changes at low elevations, but the minor ripples in amplitude seen for various antenna-IFs are not reflected in the system temperatures. The situation is worst for antennas 7, 8, and 9 because the system temperatures are very stable, and have no effect whatsoever on the amplitudes other than scaling them.

The variations in amplitude from one antenna-IF to another are made even larger by the system temperature correction (with the curious exception of 1.3 cm). The tables give the overall average amplitude for each antenna-IF before and after the system temperature application. Over all bands, the correction brings the amplitudes into fairly good order-of-magnitude agreement, indicating that the gross effects of the system temperature correction (i.e., over hundreds of degrees) is correct.

Except for the problems already noted above concerning the measured system temperatures, no antennas appear to be particularly bad when the system temperature correction is applied. Rather, there seems to be a general lack of agreement between the amplitude of the raw data and the system temperature for that antenna-IF. For each band, the over-all averages of the amplitudes have somewhat higher, but not extraordinarily higher, rms values after the system temperature application. The system temperature correction appears to have simply redistributed the contributions to the rms differently among the antenna-IFs. The actual temperatures of the calibration signals are known to about 10%, but the variations among the antenna-IFs show a typical rms of 20 to 30%, indicating that the uncertainties in absolute temperature cannot account for the variations in the corrected antenna amplitudes.

The calculation of the average amplitude by band was done for all operating antennas, and also for antennas 7, 8, and 9 alone. The rms variations among antenna-IFs are very similar for both groups of antennas.

The results of this test may be compared to those reported in VLA Test Memorandum 119; there the discrepancies introduced by the system temperature correction were more striking. The conclusion to be drawn from the new data is similar to that drawn from the data presented in Memorandum 119: the system temperature measurement and correction does not account for the temporal variations in the antenna amplitudes, nor does it account for the variations of amplitude from antenna-IF to antenna-IF, and probably should not be applied to the data until the variations are understood. The system temperature measurement may be incorrect (i.e., the "apparent" Tsys is not the true Tsys), and there may be other factors contributing to the final antenna amplitudes.

The observations reported in this memorandum were designed to investigate only the variations in system temperature; other effects (such as individual antenna efficiency) could contribute to the observed differences in antenna amplitude and also need to be investigated.

## TABLE I

## MEASURED SYSTEM TEMPERATURES

(Averages over all monitor data)

### 20 cm

| IF | (TP/cal)*Tcal | | Tsys(K) | rms(%) |
|---|---|---|---|---|
| 2A | 2.64 | ± .06 | 105 | 2.46 |
| 2C | .67 | .04 | 27 | 5.28 |
| 4A | 1.28 | .07 | 51 | 5.32 |
| 4C | 1.38 | .07 | 55 | 4.86 |
| 6A | 2.10 | .20 | 84 | 9.67 |
| 6C | 1.56 | 1.84 | 62 | 117.62 |
| 7A | 6.81 | 1.64 | 272 | 24.13 |
| 7C | 2.17 | .06 | 87 | 2.89 |
| 8A | 1.09 | .15 | 44 | 13.82 |
| 8C | 1.70 | .11 | 68 | 6.32 |
| 9A | 1.31 | .05 | 52 | 3.82 |
| 9C | .93 | .04 | 37 | 4.27 |

### 6 cm

| IF | (TP/cal)*Tcal | | Tsys(K) | rms(%) |
|---|---|---|---|---|
| 1A | 1.86 | ± .19 | 74 | 10.13 |
| 1C | 1.73 | .78 | 69 | 45.06 |
| 2A | 2.47 | .30 | 99 | 12.34 |
| 2C | 1.33 | .14 | 53 | 10.79 |
| 4A | 2.34 | .25 | 93 | 10.73 |
| 4C | 1.44 | .09 | 57 | 6.16 |
| 6A | 1.61 | .24 | 64 | 14.97 |
| 6C | 2.17 | .95 | 87 | 43.86 |
| 7A | .89 | .03 | 36 | 3.65 |
| 7C | 1.12 | .05 | 45 | 4.17 |
| 8A | .93 | .03 | 37 | 2.82 |
| 8C | .93 | .03 | 37 | 3.46 |
| 9A | 1.20 | .04 | 48 | 3.49 |
| 9C | .88 | .03 | 35 | 3.49 |

### 2 cm

| IF | (TP/cal)*Tcal | | Tsys(K) | rms(%) |
|---|---|---|---|---|
| 4A | 26.21 | ± 38. | 1048 | 147.75 |
| 4C | 13.55 | .35 | 542 | 2.62 |
| 7A | .72 | .02 | 29 | 2.41 |
| 7C | 6.28 | .20 | 251 | 3.17 |
| 8A | 4.23 | .10 | 169 | 2.34 |
| 8C | 6.89 | .28 | 276 | 4.07 |
| 9A | 7.07 | .09 | 283 | 1.21 |
| 9C | 4.20 | .12 | 168 | 2.93 |

### 1.3 cm

| IF | (TP/cal)*Tcal | | Tsys(K) | rms(%) |
|---|---|---|---|---|
| 4A | 114.04 | ±8.17 | 4562 | 7.17 |
| 4C | 28.99 | .55 | 1160 | 1.90 |
| 7A | 9.91 | .56 | 396 | 5.67 |
| 7C | 11.02 | .89 | 441 | 8.12 |
| 8A | 10.53 | .41 | 421 | 3.92 |
| 8C | 7.83 | 1.27 | 313 | 16.20 |
| 9A | 9.80 | .19 | 392 | 1.93 |
| 9C | 7.42 | .60 | 297 | 8.08 |

# TABLE 2

## AVERAGE ANTENNA POWER AMPLITUDES *1000/Jy FOR 20 cm

11 5-minute scans on DA267

### RAW DATA

| IF | Amp | | rms | %rms |
|---|---|---|---|---|
| 2A | 210 | ± | 8 | 4 |
| 2C | 260 | | 17 | 6 |
| 6A | 105 | | 5 | 4 |
| 6C | 197 | | 12 | 6 |
| 7A | 122 | | 18 | 15 |
| 7C | 148 | | 21 | 14 |
| 8A | 316 | | 30 | 10 |
| 8C | 239 | | 16 | 7 |
| 9A | 231 | | 9 | 4 |
| 9C | 243 | | 18 | 7 |

Average of above: 207 ± 62 (30%)

### DATA x Tsys

| IF | Amp | | rms | %rms |
|---|---|---|---|---|
| 2A | 551 | ± | 10 | 2 |
| 2C | 173 | | 3 | 2 |
| 6A | 227 | | 7 | 3 |
| 6C | 237 | | 5 | 2 |
| 7C | 321 | | 51 | 16 |
| 8A | 342 | | 33 | 10 |
| 8C | 405 | | 32 | 8 |
| 9A | 300 | | 18 | 6 |
| 9C | 224 | | 22 | 10 |

Average of above: 308 ± 109 (35%)

## TABLE 3

## AVERAGE ANTENNA POWER AMPLITUDES *1000/Jy FOR 6 cm

10 5-minute scans on DA267

### RAW DATA

| IF | Amp | | rms | %rms |
|---|---|---|---|---|
| 1C | 340 | ± | 6 | 2 |
| 2A | 255 | | 9 | 3 |
| 2C | 325 | | 5 | 2 |
| 4A | 214 | | 4 | 2 |
| 4C | 378 | | 4 | 1 |
| 6A | 340 | | 23 | 7 |
| 6C | 277 | | 2 | 1 |
| 7A | 381 | | 13 | 3 |
| 7C | 377 | | 3 | 1 |
| 8A | 366 | | 8 | 2 |
| 8C | 475 | | 4 | 1 |
| 9A | 225 | | 5 | 2 |
| 9C | 307 | | 5 | 2 |

Average of above: 328 ± 69 (21%)

### DATA x Tsys

| IF | Amp | | rms | %rms |
|---|---|---|---|---|
| 1C | 508 | ± | 34 | 7 |
| 2A | 631 | | 17 | 3 |
| 2C | 448 | | 7 | 2 |
| 4A | 508 | | 9 | 2 |
| 4C | 546 | | 5 | 1 |
| 6A | 519 | | 17 | 3 |
| 6C | 635 | | 27 | 4 |
| 7A | 335 | | 9 | 3 |
| 7C | 422 | | 10 | 2 |
| 8A | 337 | | 6 | 2 |
| 8C | 438 | | 6 | 1 |
| 9A | 270 | | 7 | 2 |
| 9C | 266 | | 3 | 1 |

Average of above: 451 ± 119 (26%)

## TABLE 4

## AVERAGE ANTENNA POWER AMPLITUDES *1000/Jy FOR 2 cm

14 5-minute scans on DA267

### RAW DATA

| IF | Amp | | rms | %rms |
|---|---|---|---|---|
| 4A | 10 | ± | 4 | 44 |
| 4C | 31 | | 2 | 6 |
| 7A | 52 | | 5 | 9 |
| 7C | 51 | | 4 | 8 |
| 8A | 59 | | 3 | 6 |
| 8C | 67 | | 4 | 5 |
| 9A | 29 | | 2 | 7 |
| 9C | 38 | | 3 | 7 |

Average of above: 42 ± 17 (40%)

### DATA x Tsys

| IF | Amp | | rms | %rms |
|---|---|---|---|---|
| 4A | 177 | ± | 139 | 78 |
| 4C | 417 | | 23 | 6 |
| 7C | 315 | | 24 | 7 |
| 8A | 244 | | 14 | 6 |
| 8C | 451 | | 22 | 5 |
| 9A | 203 | | 14 | 7 |
| 9C | 155 | | 11 | 7 |

Average of above: 280 ± 109 (39%)

## TABLE 5

## AVERAGE ANTENNA POWER AMPLITUDES *1000/Jy FOR 1.3 cm

14 5-minute scans on DA267

### RAW DATA

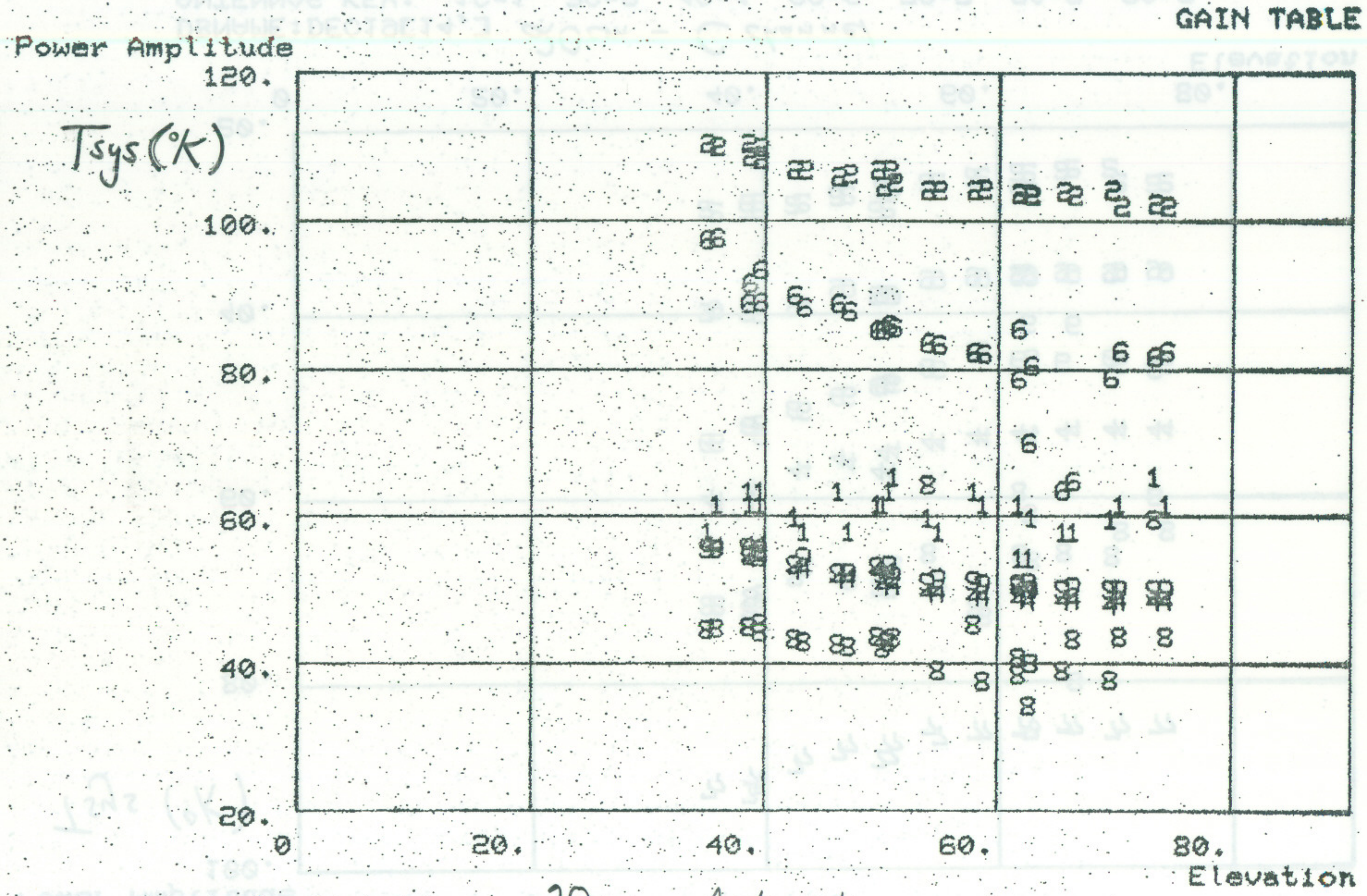
| IF | Amp | | rms | %rms |
|---|---|---|---|---|
| 4C | 8 | ± | 1 | 6 |
| 7A | 23 | | 2 | 7 |
| 7C | 31 | | 3 | 9 |
| 8A | 26 | | 2 | 6 |
| 8C | 33 | | 2 | 5 |
| 9A | 26 | | 2 | 7 |
| 9C | 43 | | 3 | 7 |

Average of above: 27 ± 10 (39%)

### DATA x Tsys

| IF | Amp | rms | %rms |
|---|---|---|---|
| 4C | 233 | 14 | 6 |
| 7A | 221 | 15 | 7 |
| 7C | 318 | 29 | 9 |
| 8A | 269 | 19 | 7 |
| 8C | 254 | 39 | 15 |
| 9A | 247 | 17 | 7 |
| 9C | 303 | 18 | 6 |

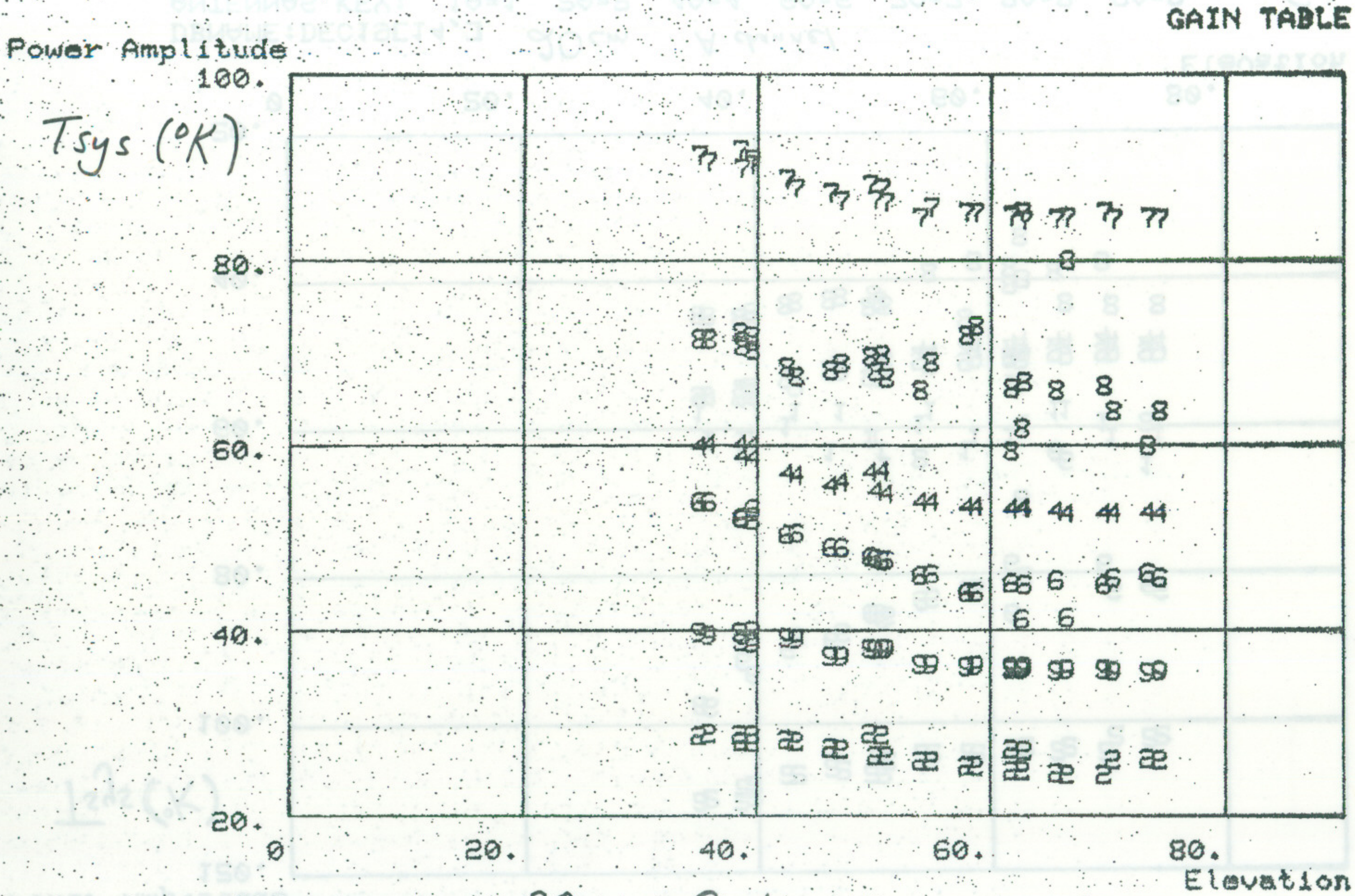
Average of above: 263 ± 37 (14%)



DBNAME:DEC19E14,J 20cm A channel

ANTENNAS KEY: 1A=1 2A=2 4A=4 6A=6 7A=7 8A=8 9A=9

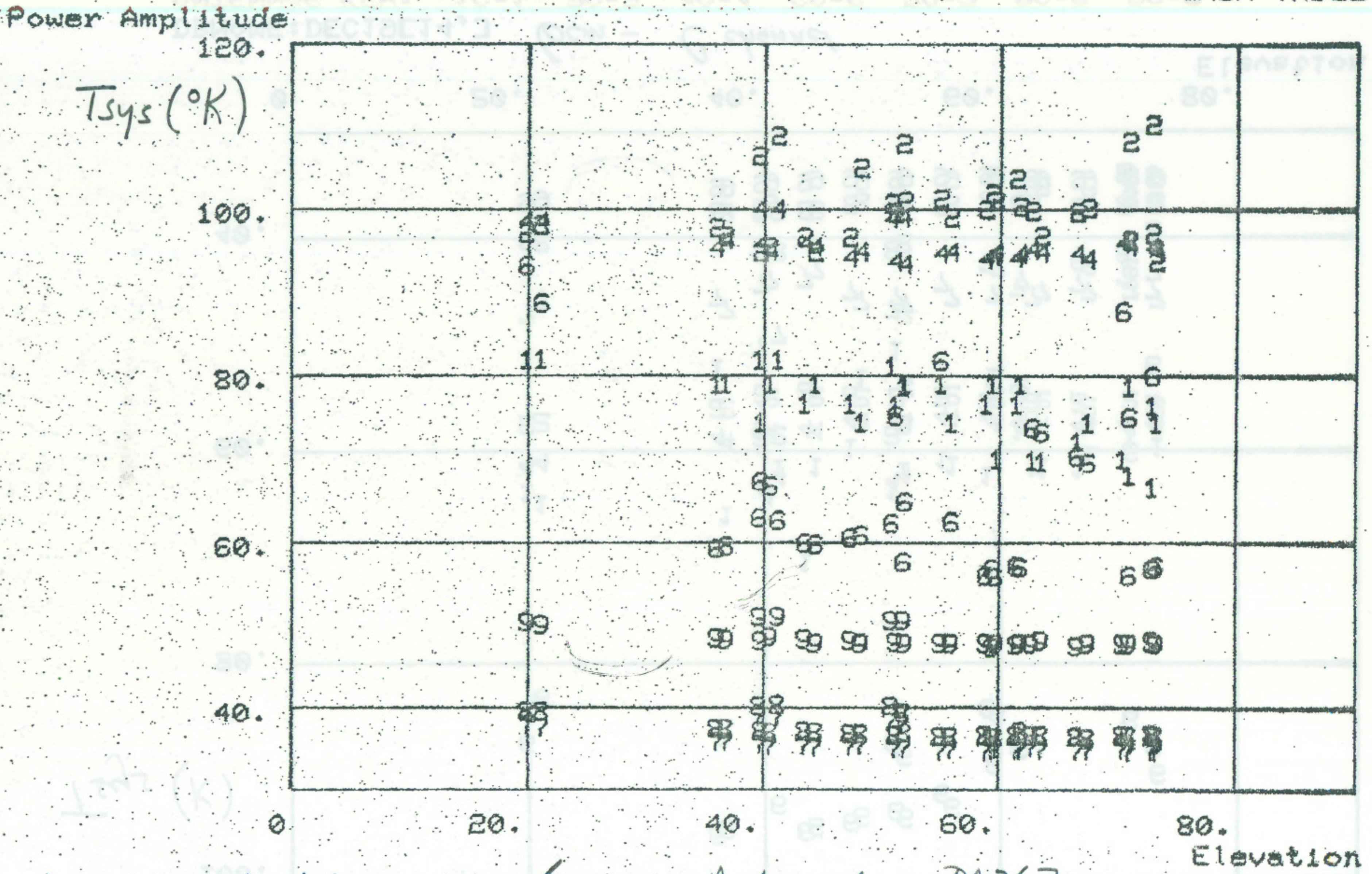
Fig. 1



DBNAME:DEC19[14,] 20cm - C channel
ANTENNAS KEY: 1C=1 2C=2 4C=4 6C=6 7C=7 8C=8 9C=9

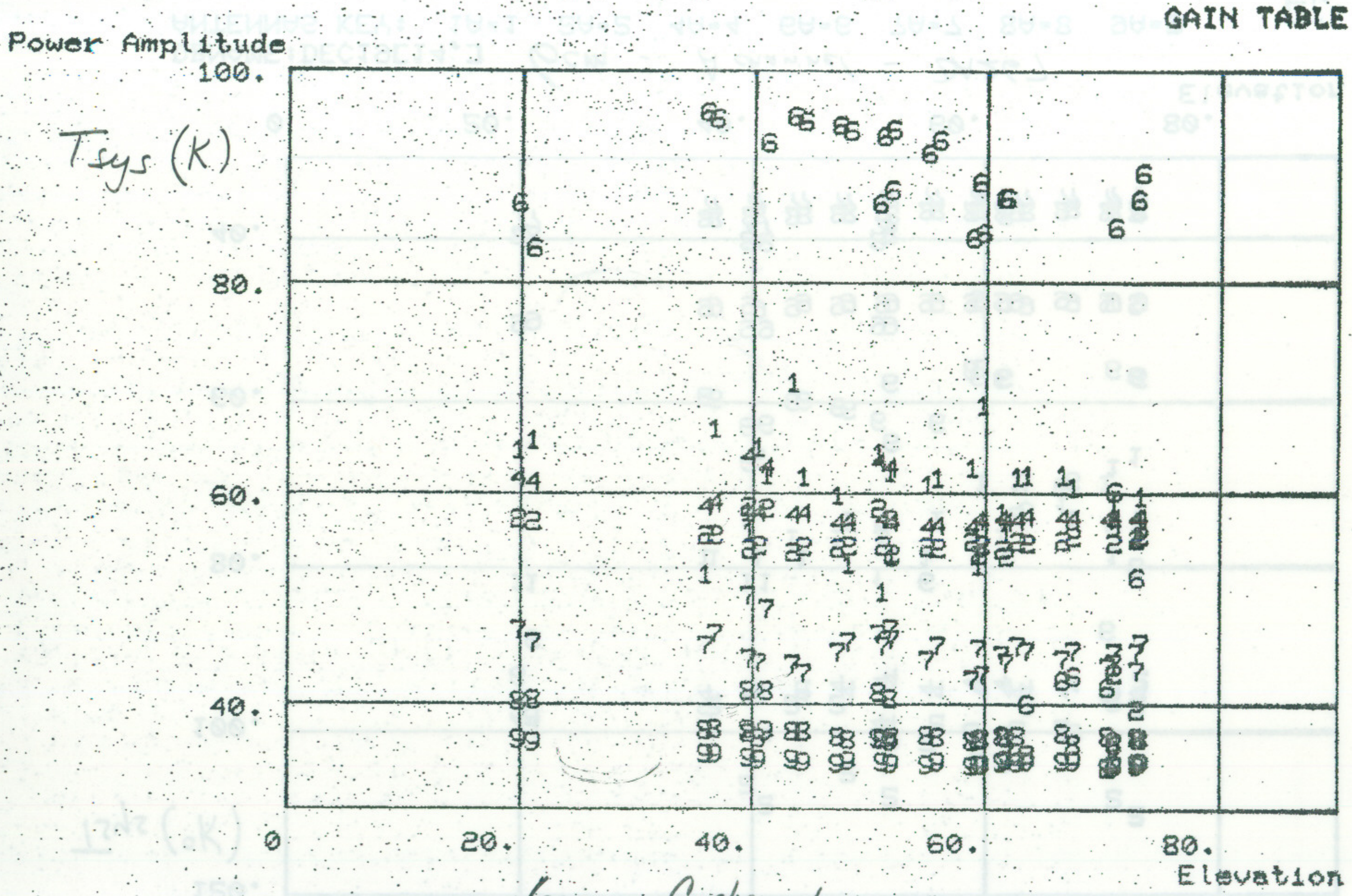
Fig.2

**GAIN TABLE**



DBNAME:DEC19[14,] 6cm - A channel - DA267
ANTENNAS KEY: 1A=1 2A=2 4A=4 6A=6 7A=7 8A=8 9A=9

Fig. 3

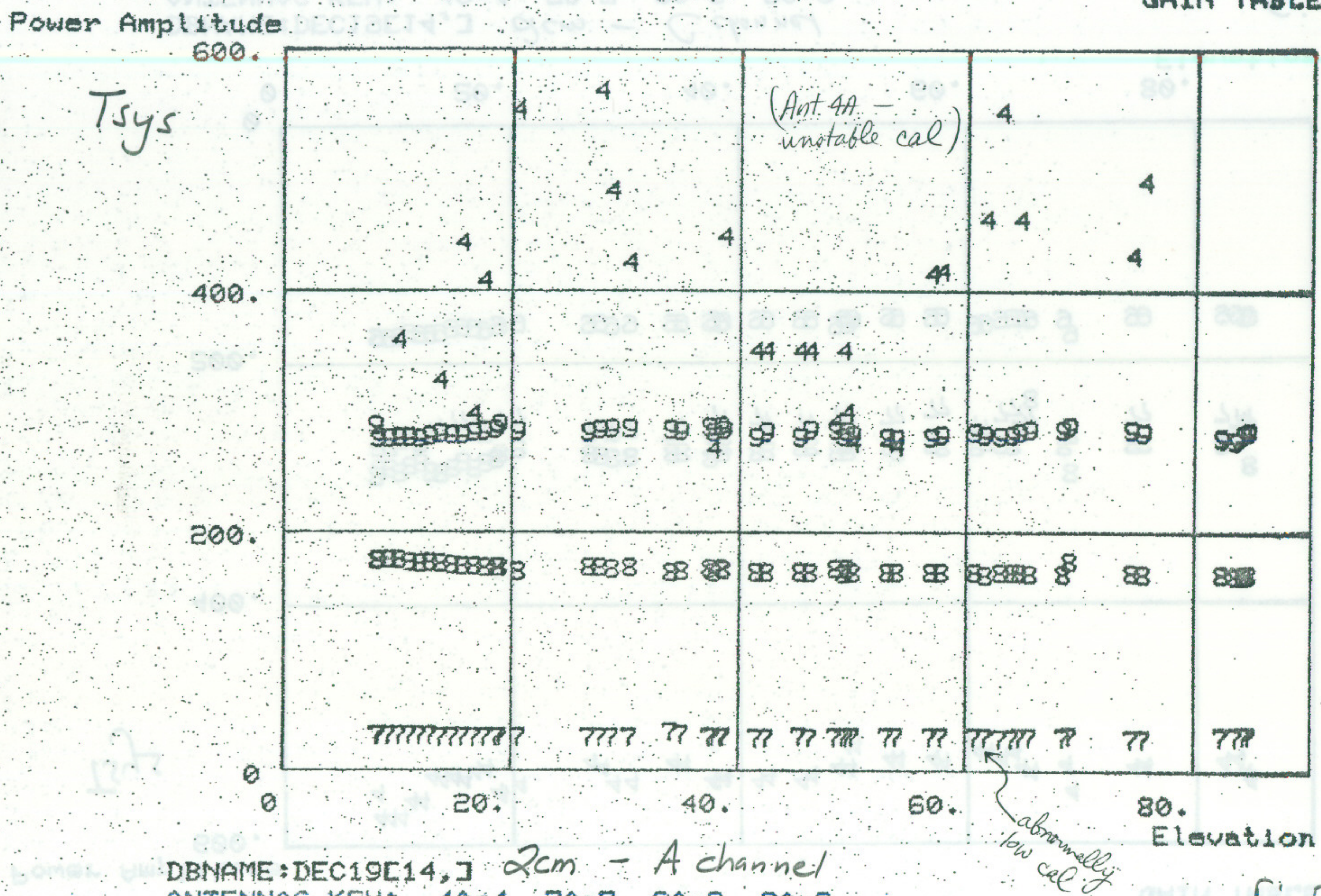


DBNAME:DEC19E14,J 6cm - C channel

ANTENNAS KEY: 1C=1 2C=2 4C=4 6C=6 7C=7 8C=8 9C=9

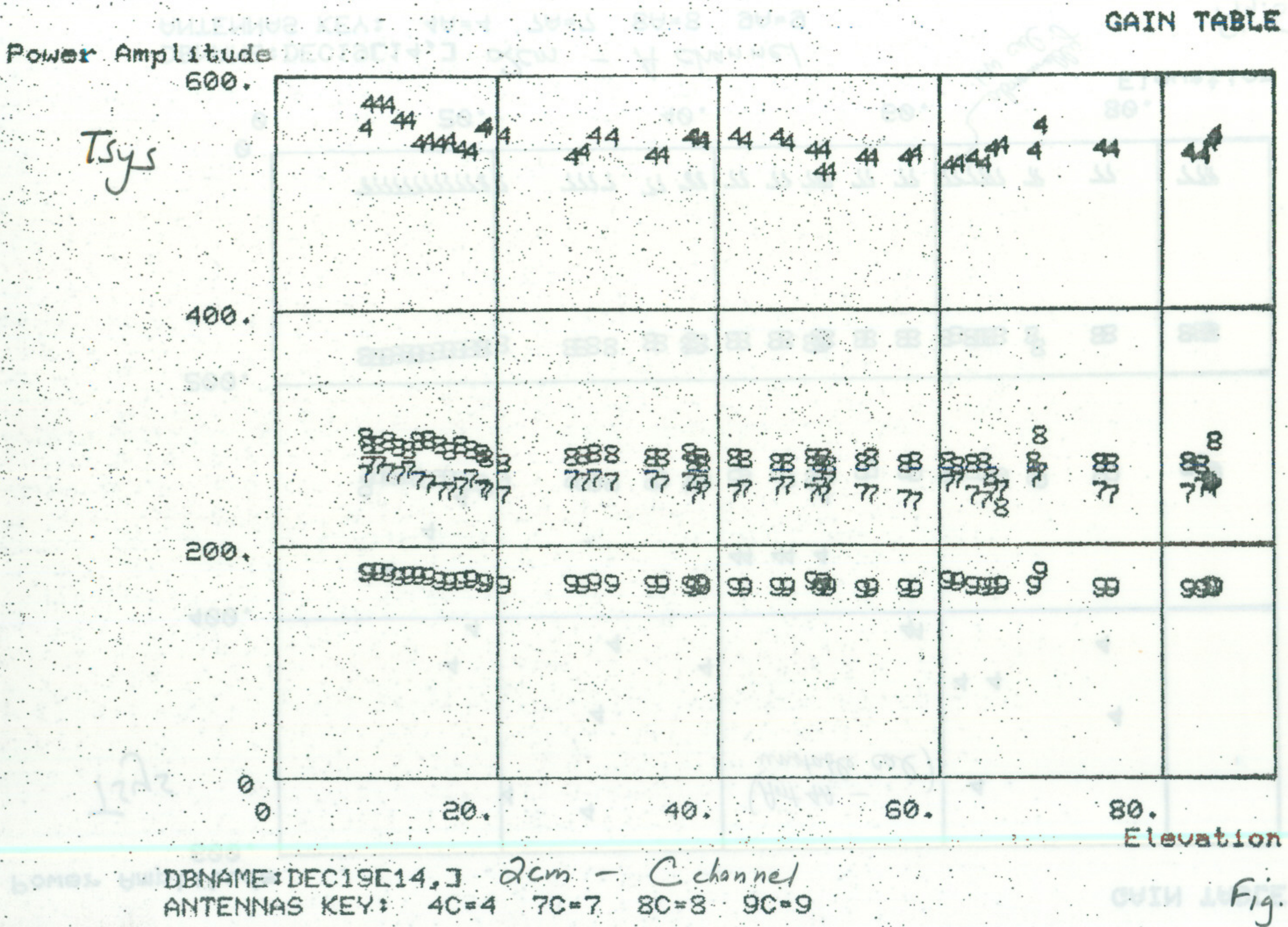
Fig.4

GAIN TABLE



DBNAME:DEC19[14,] 2cm – A channel
ANTENNAS KEY: 4A=4 7A=7 8A=8 9A=9

Fig.5

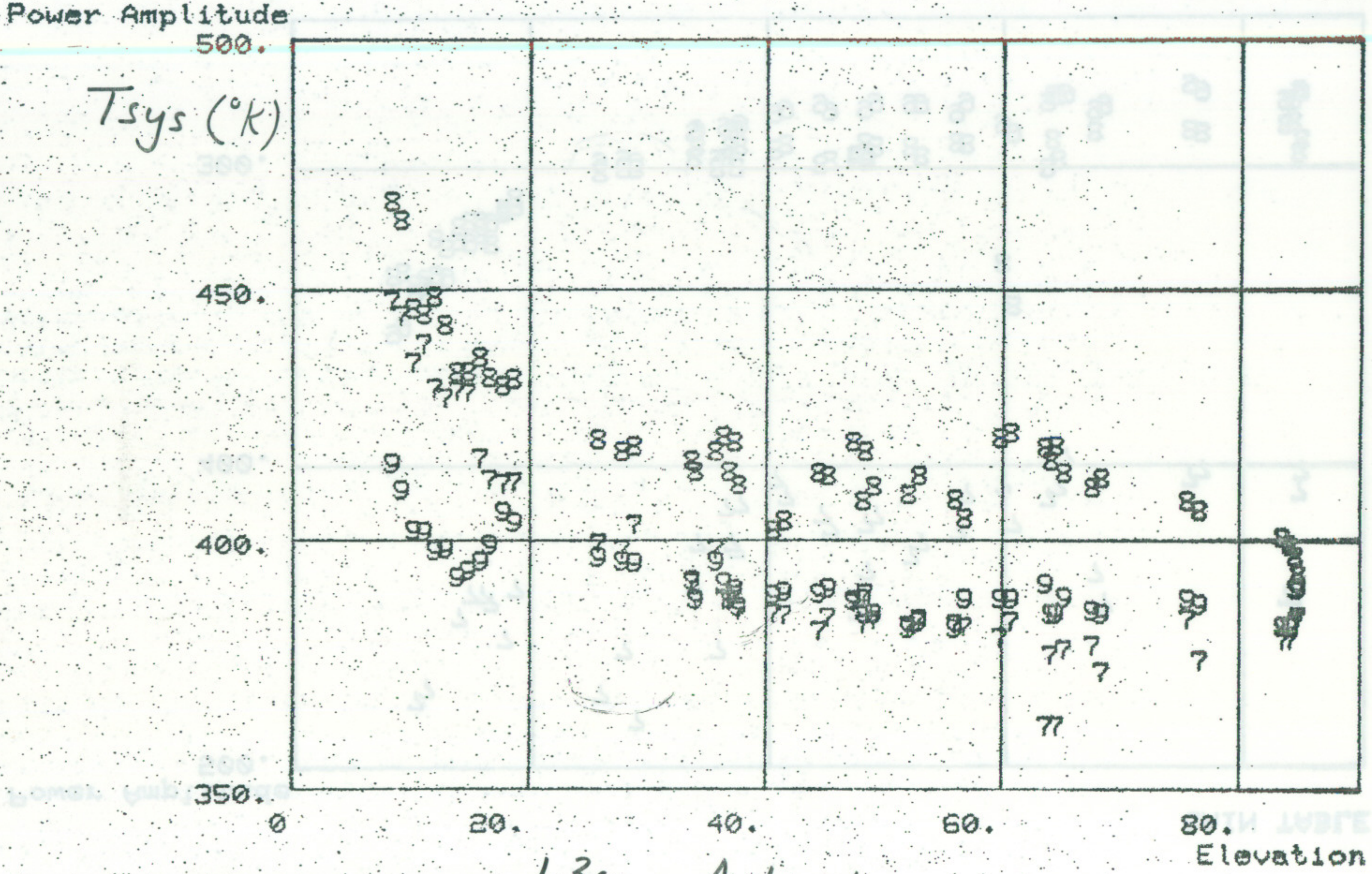


Tsys

2cm – C channel

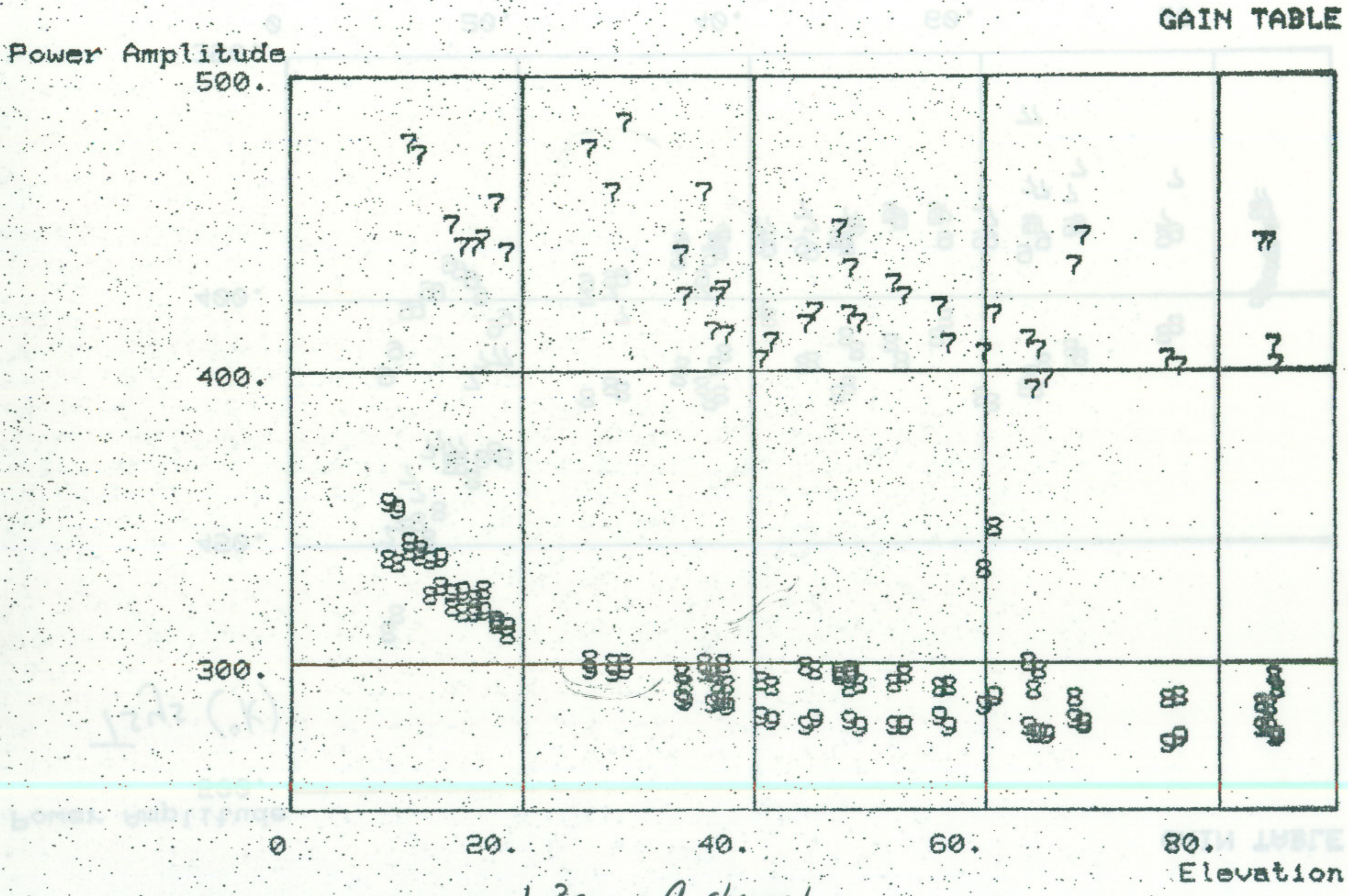
Fig. 6

**GAIN TABLE**



DBNAME:DEC19[14,] 1,3cm – A channel
ANTENNAS KEY: 4A=4 7A=7 8A=8 9A=9

Fig. 7



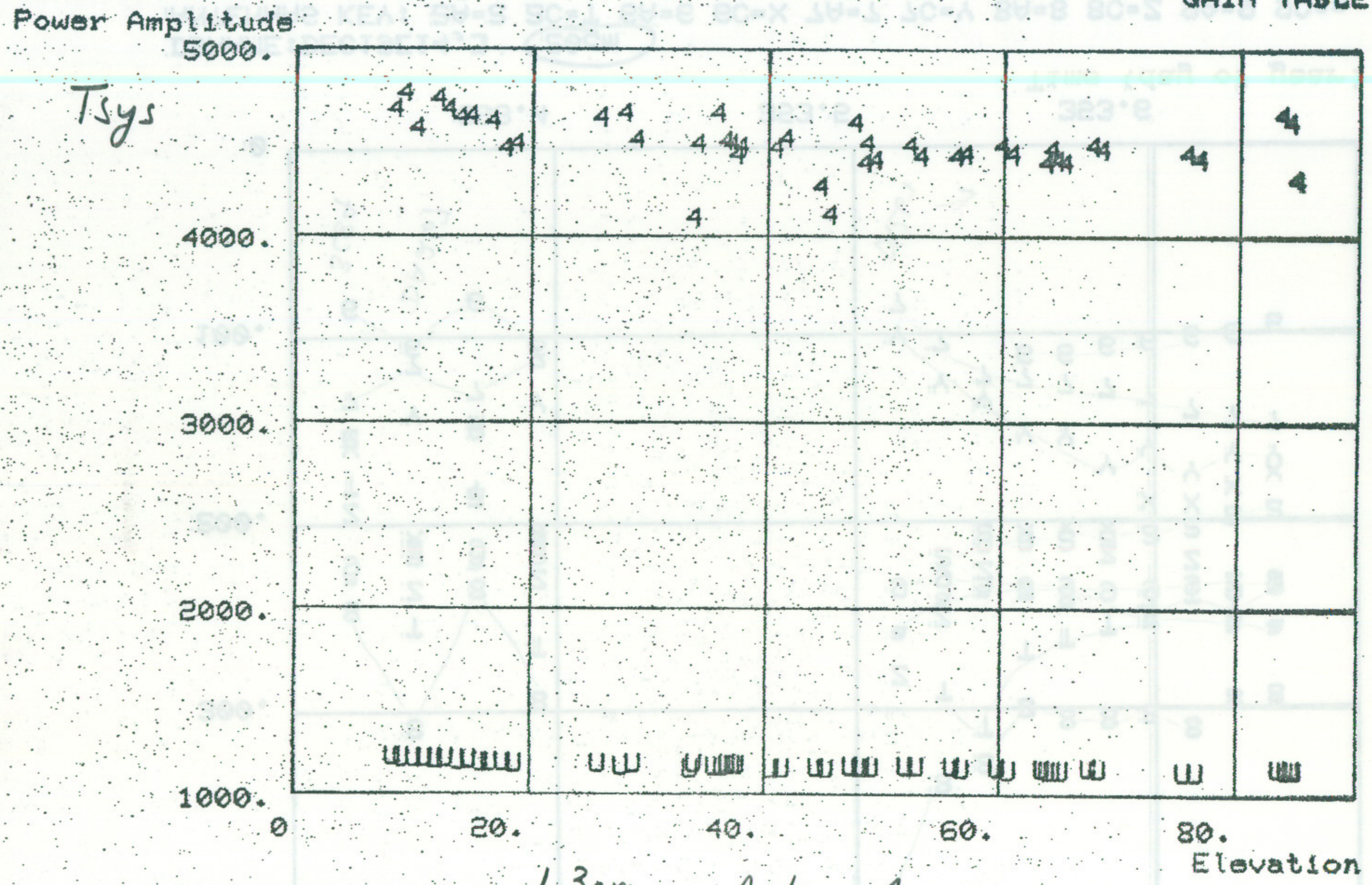
DBNAME:DEC19[14,]

1.3cm - C channel

ANTENNAS KEY: 4C=4 7C=7 8C=8 9C=9

Fig. 8

GAIN TABLE

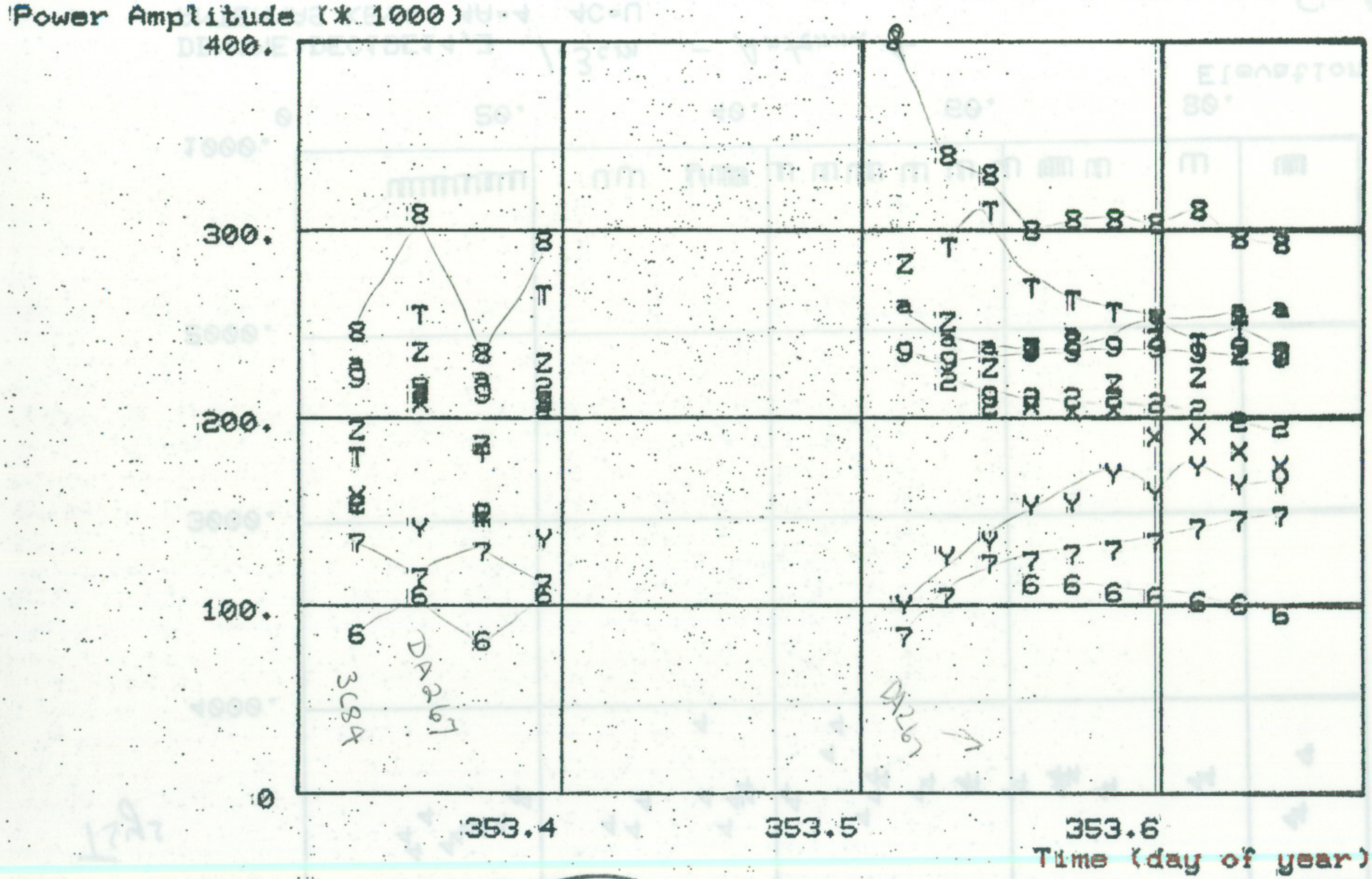


DBNAME:DEC19[14,] 1.3cm - Antenna 4
ANTENNAS KEY: 4A=4 4C=U

Fig. #9

RAW DATA

**ANTENNAS CALIBRATION FILE**



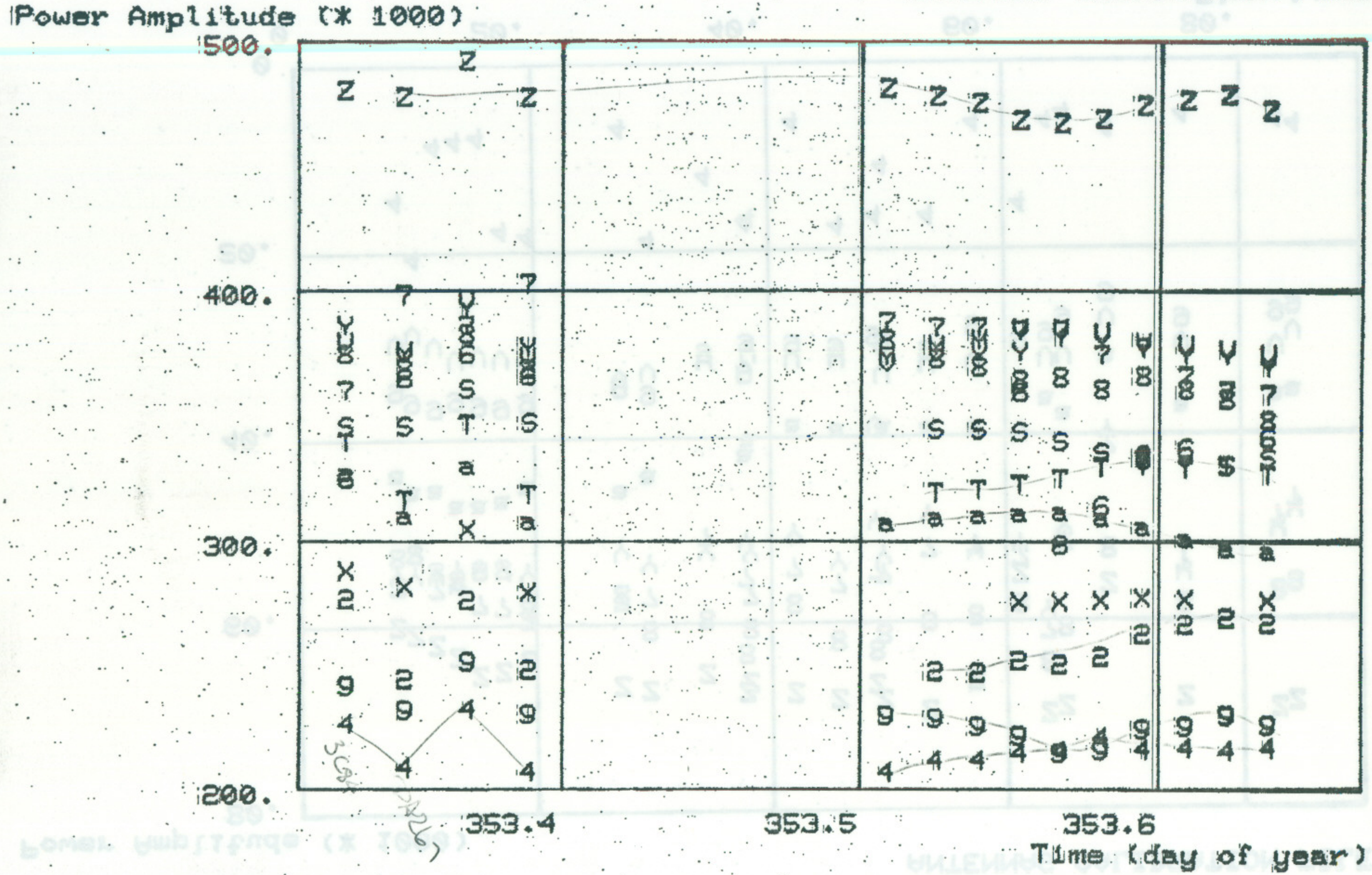
DBNAME:DEC19[14,] 20cm

ANTENNAS KEY: 2A=2 2C=T 6A=6 6C=X 7A=7 7C=Y 8A=8 8C=Z 9A=9 9C=a

Fig. 10

RAW DATA

ANTENNAS CALIBRATION FILE



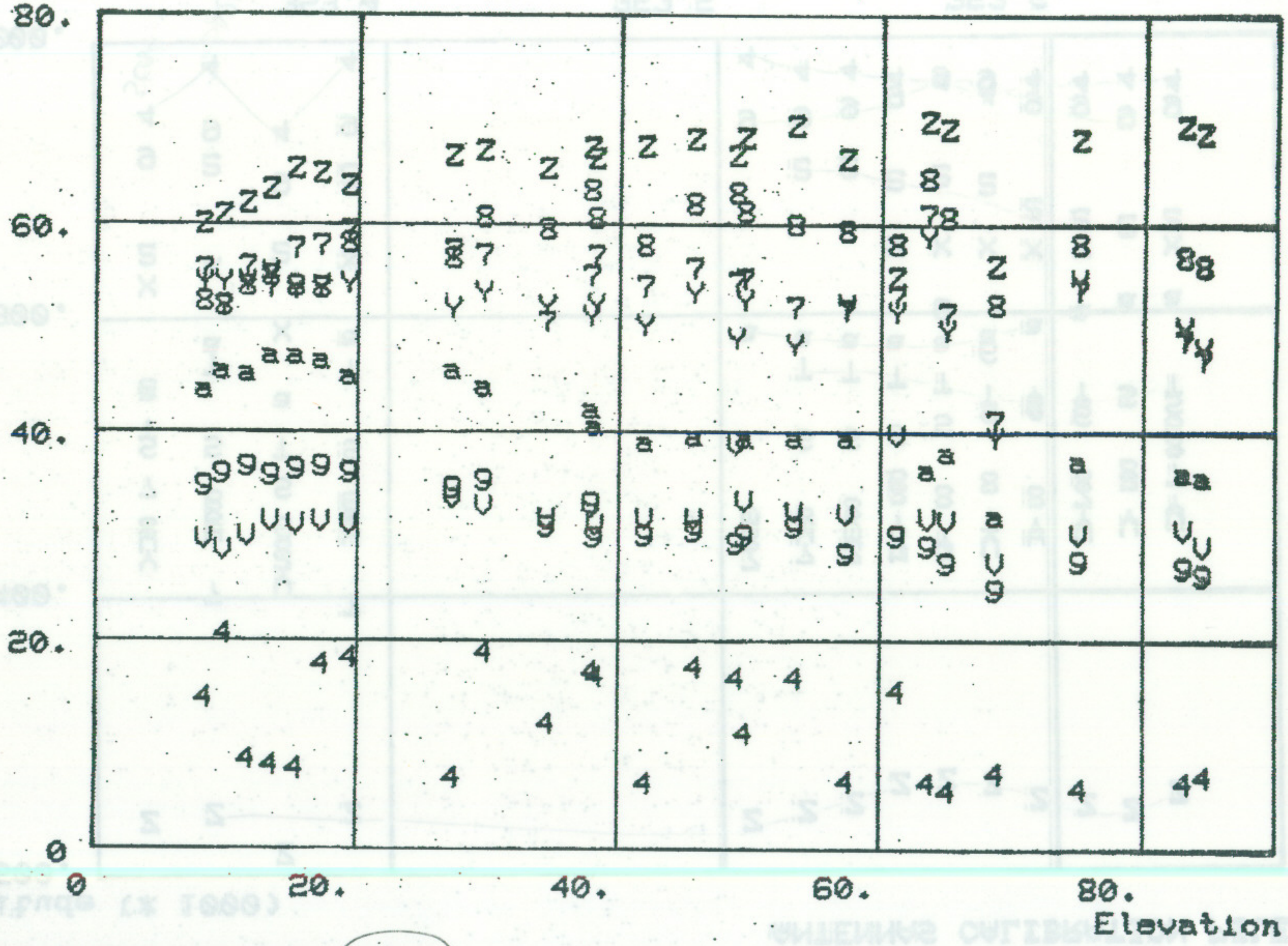
DBNAME:DEC19[14,] 6cm
ANTENNAS KEY: 1A=1 1C=S 2A=2 2C=T 4A=4 4C=V 6A=6 6C=X 7A=7 7C=Y
8A=8 8C=Z 9A=9 9C=a

Fig. 11

RAW DATA

ANTENNAS CALIBRATION FILE

Power Amplitude (* 1000)



DBNAME:DEC19[14,] 2cm
ANTENNAS KEY: 4A=4 4C=V 7A=7 7C=Y 8A=8 8C=Z 9A=9 9C=a

Fig. 12

RAW DATA

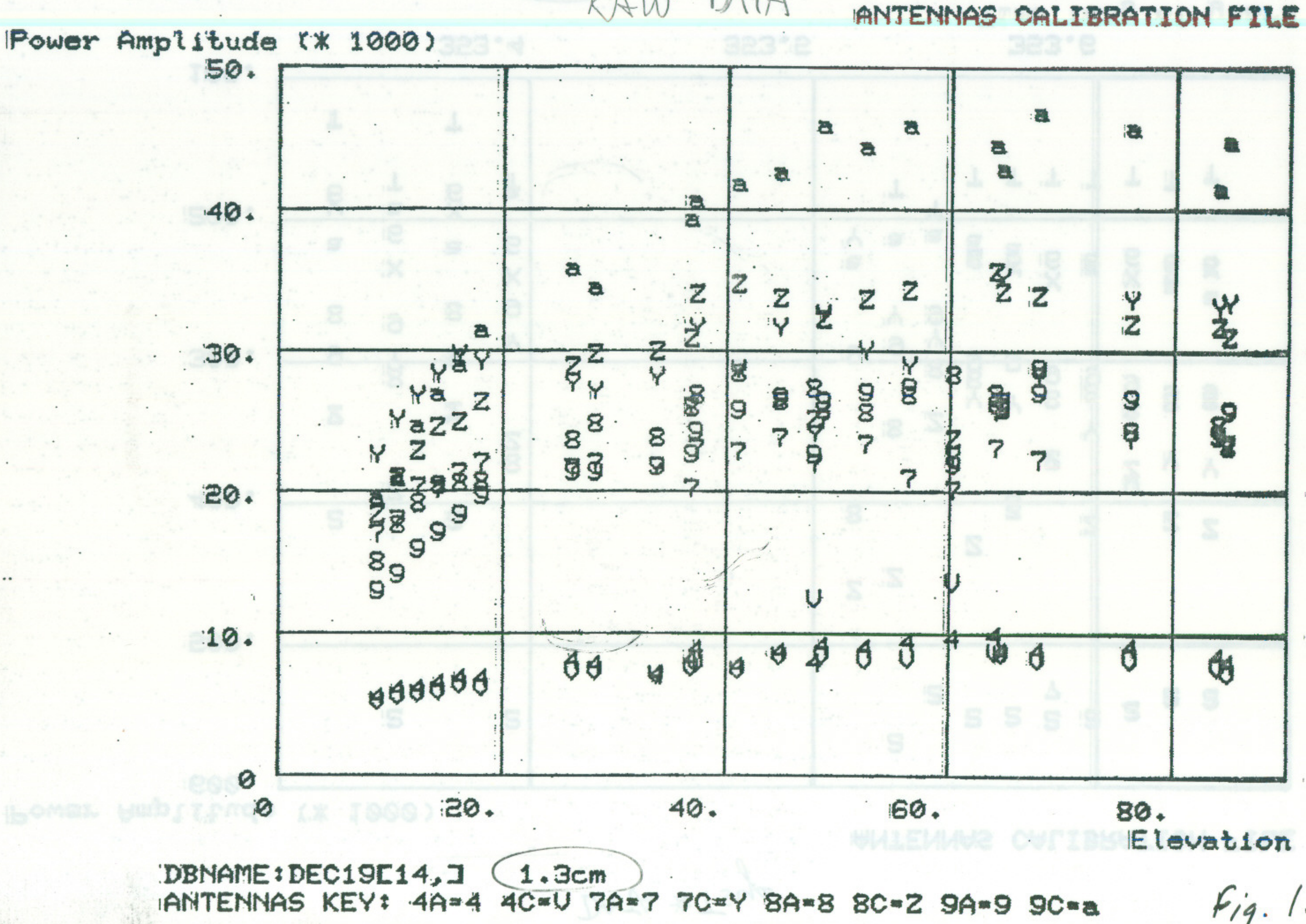
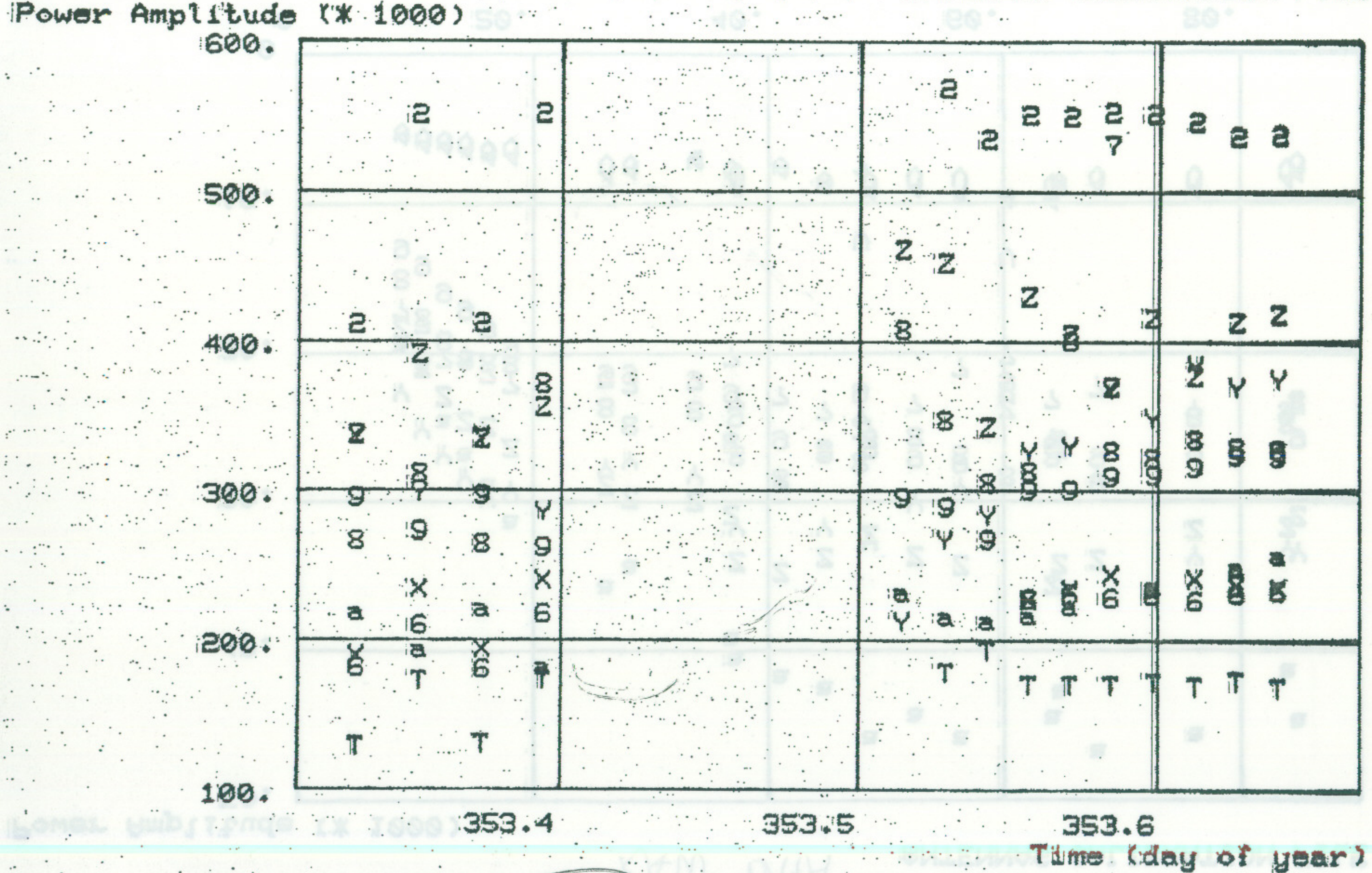


Fig. 13

DATA *Tsys

ANTENNAS CALIBRATION FILE



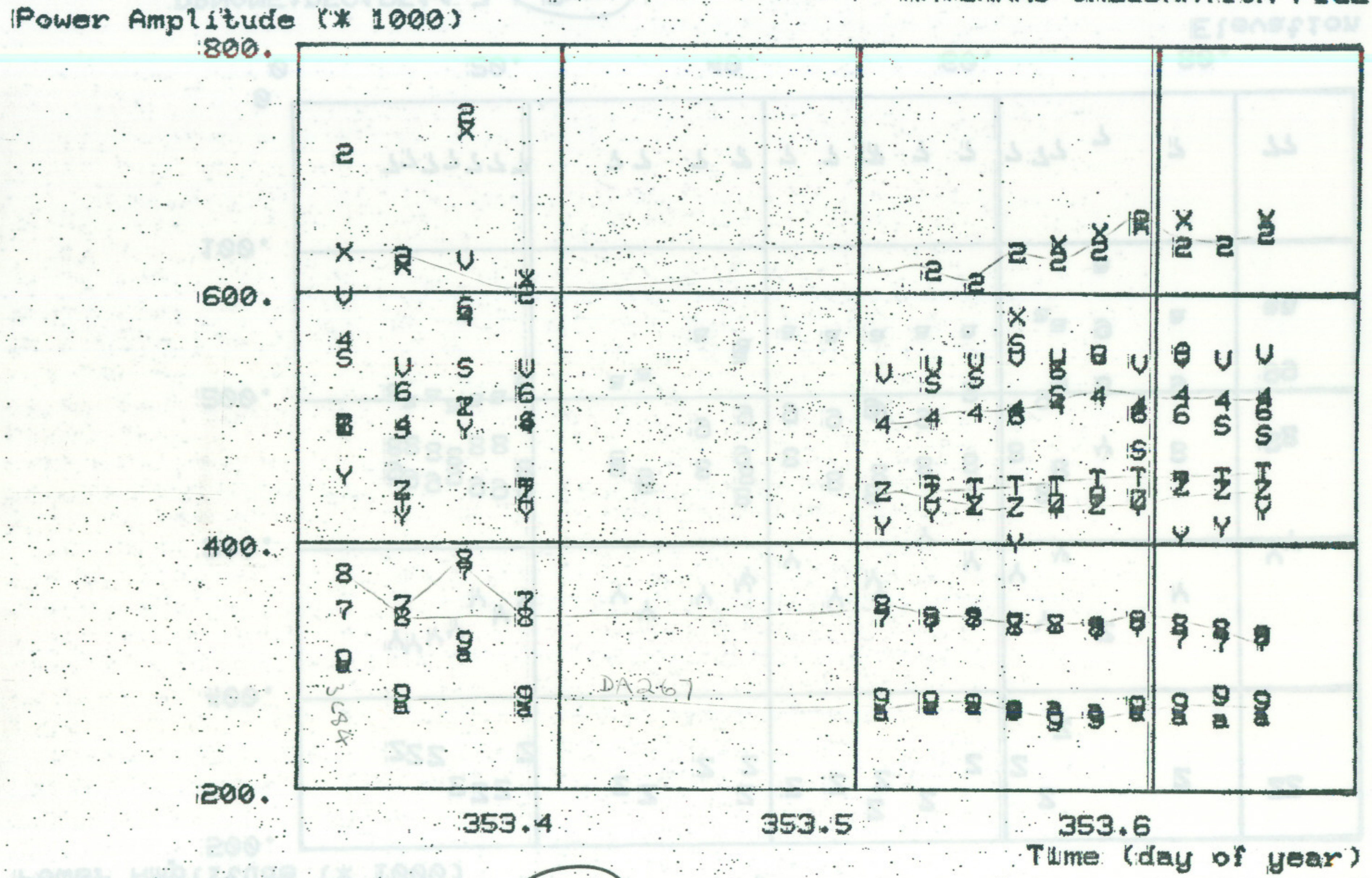
DBNAME:DEC19[14,] 20cm

ANTENNAS KEY: 2A=2 2C=T 6A=6 6C=X 7A=7 7C=Y 8A=8 8C=Z 9A=9 9C=a

Fig. 14

DATA × Tsys

ANTENNAS CALIBRATION FILE

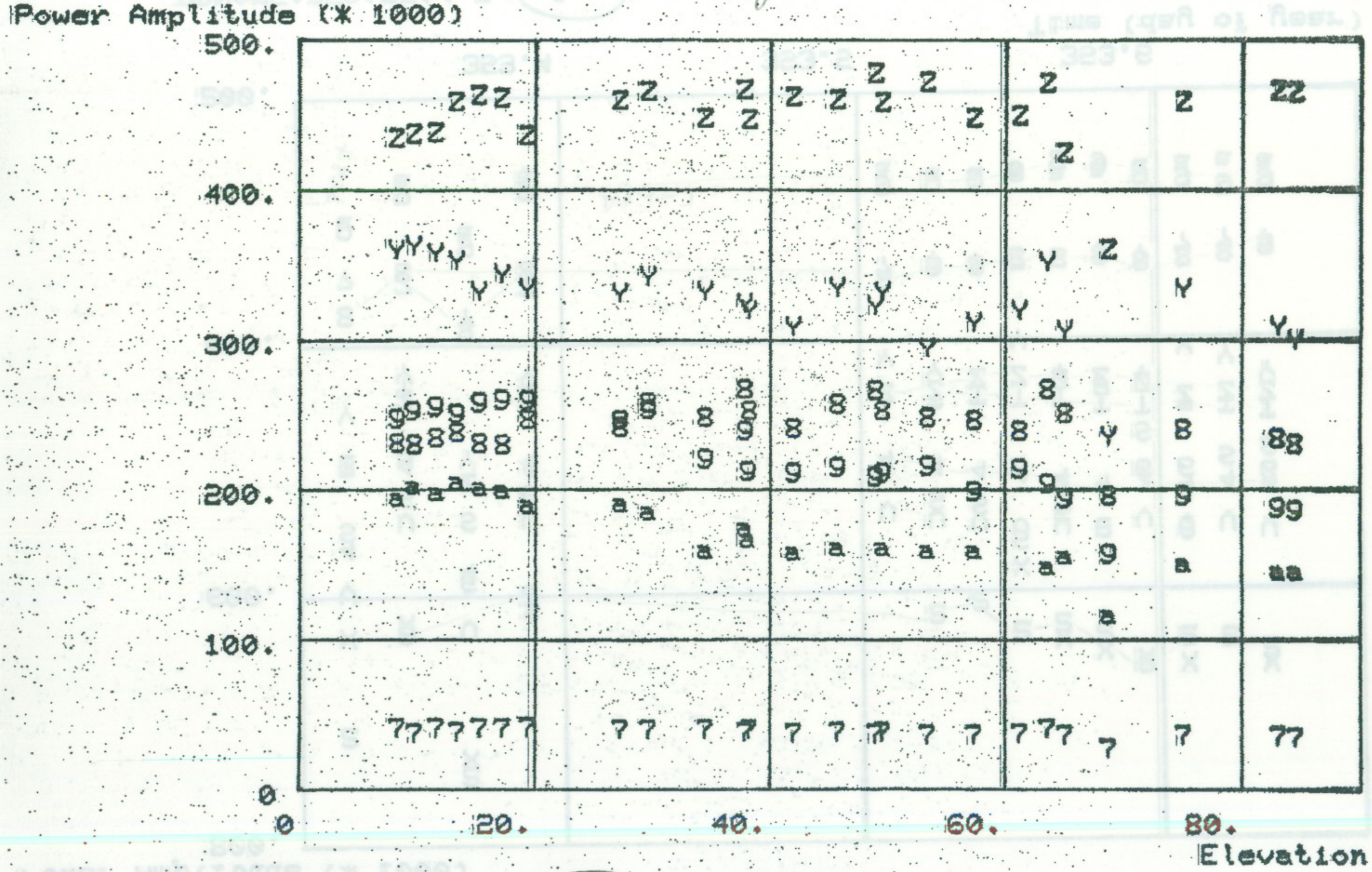


DBNAME:DEC19[14,] (6cm)
ANTENNAS KEY: 1A=1 1C=S 2A=2 2C=T 4A=4 4C=V 6A=6 6C=X 7A=7 7C=Y
8A=8 8C=Z 9A=9 9C=a

Fig. 15

DATA × Tsys

ANTENNAS CALIBRATION FILE



DBNAME:DEC19[14,] 2cm

ANTENNAS KEY: 7A=7 7C=Y 8A=8 8C=Z 9A=9 9C=a

Fig. 16

DATA × Tsys

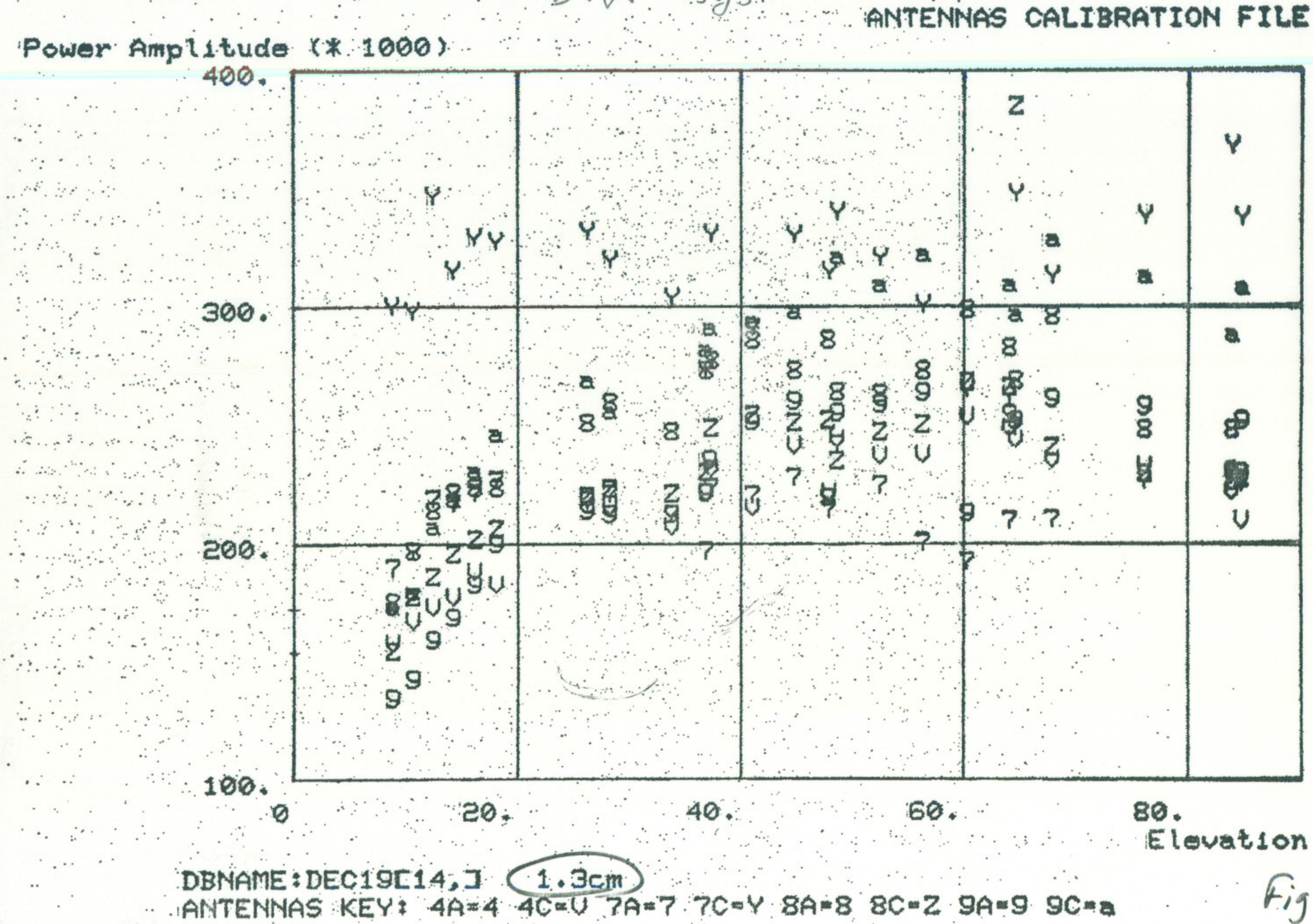


Fig. 17