WIDE BAND SENSITIVITY MEASUREMENTS on the VLBA

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1 Introduction

A series of observations were made between 15 June and 9 July 1995 in an attempt to determine the system temperature, gain, and SEFD (System Equivalent Flux Density) for each antenna of the VLBA as a function of frequency for all bands. Each band was divided evenly into frequencies which extended beyond the nominal bandwidth. This was done to test antenna performance across the full band and especially near the edges of the filters. The complete range of observed frequencies is presented in Table 1. Various sources (see Table 2) were observed with pointing patterns specified in SCHED. Observations at 7mm and 1cm were made using the PTVLBA pointing pattern. This is a 10-point pattern which traces off–source → 1/2 beam → on–source → 1/2 beam → off–source in both azimuth and elevation. All other bands were observed using a 3-point pattern which traced off-source → on–source → off–source in azimuth only.

At all bands up to 2cm, full frequency coverage was obtained. This means that any strong RFI showed up in the original system temperatures. However these were not necessarily consistent from day to day. Many such spikes were edited out of the data, often causing small gaps in the plots. Note that other projects are in progress to do a better job of measuring RFI.

The analysis of the data utilized measurements of system temperature and antenna temperature from the observations as derived by the standard program, TSM. A new program, PLOTBAND, was then used to derive gains and SEFDs. The gain for the antennas was calculated as :

$$GAIN = \frac{T_{ant}}{Flux\ Density}$$

The flux density was calculated using equations from Baars et al (1977, A&A, 61, 99) for most sources. For variable sources (3C84, 3C273), flux densities were estimated from our own observations or from other pointing observations made within a month or so of ours. Program PTANAL was used to derive these flux densities. The SEFD for each antenna was calculated as:

$$SEFD = \left[\frac{T_{sys}}{T_{ant}}\right] \times Flux\ Density$$

The system temperature, gain and SEFD were then plotted as functions of frequency and station.

The plots are intended to provide information for experimental planning purposes. The plots, however, do have various limitations that should be taken into account. The derived flux densities of the variable sources are good to about 5%, which may introduce some error in the gain and SEFD plots. Opacity, gain curve, and spill-over corrections were not made. However, most observations were made at high elevations, so these effects should be minimal. The plots were made with a limited number of data points at each station, not all taken under optimal conditions, which could produce inconsistencies with subsequent observations. In some cases no good data were obtained or the best data were clearly poor. Finally, the measurements will not remain valid indefinitely because receivers are occasionally changed at the stations. All of these factors should be taken into consideration when consulting the plots.

The original goal of this project was to begin the process of maintaining updated calibration information for the full range of frequencies within each band. However, the enormity of such a task had not been fully appreciated. The amount of observation time and data processing (i.e. editing data for bad weather) necessary to maintain dependable information would be too great. Therefore, reliable information on gains will continue to be available only at specific reference frequencies within each band. It will be necessary for observers who use non-standard frequencies to observe calibrators whose flux densities are either determined using the VLBA at a reference frequency or using another instrument such as the VLA or the University of Michigan monitoring program. The reference frequency is given in Table 1 and in the `vlba_gains.key` file from which users normally get gain information.

2 The Data

Before delving into the specific details of each band, there are a couple of universal characteristics of the graphs that are worth noting. One is the result of the fact that the T_{cal}'s used to convert power measurements to antenna and system temperatures are clearly not always correct. The values used are those measured as a function of frequency (over a range that is usually smaller than that measured here) in the lab before the receivers were installed. Errors in T_{cal} show up as compensating errors in T_{sys} and gain that cancel in the SEFD. In the plots, ripples that show up in T_{sys} and gain in areas where the SEFD is smooth are almost certainly the result of imperfect T_{cal}'s. A good example of this is at NL at 6cm. Another factor to consider is the location of the antennas. There are more problems with RFI at KP and LA than at PT or MK due to their proximity to nearby cities. SC has problems related to its low elevation.

Close examination of some of the 20 cm data suggests that measurements made at frequencies where there is not expected to be a significant amount of power getting through the filters, but where there is expected to be significant power elsewhere in the 500-1000 MHz IF, may be corrupted. The total power detectors in the BBC's, which provide all the data used for this memo, may be seeing power that did not originate at the sky frequency expected. This can lead to data that might look ok, or might have very high or very low T_{sys}. There are large variations from one BBC to the next, but the results from one BBC are similar when the frequency is changed. It is difficult distinguish such data from data not subject to this effect and such data have not been edited from the plots. If there is a lot of scatter in any one of the plotted quantities, the data in that vicinity should be considered suspect. For example, at 20 cm at KP, there is an RFI filter that cuts off at about 1333 MHz. All data, some of which looks fine, below about 1300 MHz is probably corrupted.

We believe that this problem affects mainly the 20cm data, but it might well be there at other bands as well.

In all plots, the crosses are RCP data and the circles are LCP data.

7mm: PT seems to be having some problem related to the first LO. It shows up as the ramps in T_{sys} that are correlated with the value of the first LO used. The pattern was consistent on different days. This problem has been reported to the receiver group.

OV has some curious high system temperatures at a few frequencies whose origin has not been determined.

There were clearly problems obtaining consistent data at BR and SC, perhaps because of weather.

HN and BR have lower sensitivities than the others at least partly because of problems with the antenna surfaces. Eventually these will be readjusted.

1cm: The gaps in the plots every 500 MHz represent frequencies that were never scheduled.

Major problems in this band were found at HN and OV. At HN the right circular polarization T_{sys} goes way off scale between 23000—24500 MHz. OV suffers a dip in antenna temperature between 23000—24000 MHz, which is seen in the gain and SEFD measurements. Since it is seen in the SEFD, it is not a T_{cal} problem. Both of these problems are believed to be receiver related and the receiver group has been notified. These problems may have been there a long time, but they do not affect performance at the standard pointing frequencies so they were not caught.

The KP data were obtained in make-up observations with relatively sparse frequency-coverage.

The lower RCP T_{sys} and gain at PT at low frequencies is a T_{cal} problem. The SEFD shows no effect.

At this band, the main problems getting consistent data occured at NL.

2cm: Most of the deviant points in these graphs are intentional. They represent the edges of the four RF filters used to observe in this band. The on-line system chooses which filter to use based on the sky frequency of the first channel. We used higher numbered channels to observe to and beyond the edge of each filter. The gap at 14400—14500 MHz is due to a scheduling error. Efforts were made to bridge this gap during one observing run, but the data from this run were inconsistent with those of the previous run and were not used in the graphs. An exception is at PT.

The gap at PT from 13000—13500 MHz is most likely caused by the antenna not observing when it was scheduled to.

The first time we observed 2cm, BR seemed to be having trouble and the data were discarded. The data present for BR are from another observation day and are incomplete.

There are clear problems with T_{sys} and SEFD at HN above about 14.4 GHz. This could be a weather problem, but other data affected by weather clearly shows the data segmented into the groups of frequencies observed together. Here the curves are smooth. There is no adequate data from another day to check for consistency. Note that the T_{sys} all across the band is above the 75K normally seen at this band at HN.

There have been problems with water in this feed lately and it is likely that is what is happening here.

Note that the on-line system makes the following filter selections based on the frequency of channel 1: Filter 1 for up to 12.9 GHz, Filter 2 for 12.9—13.9 Ghz, Filter 3 for 13.9—14.9 GHz, and Filter 4 for above 14.9 GHz. The on-line system assumes you want an upper sideband first mix and there is no way to override this.

4cm: This is a relatively smooth band. It looks like LA had weather problems when the measurements were made.

The cause of a few rough spots at SC have not yet been identified. The pattern of high T_{sys} problems would suggest some association with a BBC but then a similar effect might be expected at other bands. In fact, there are some similar effects at 6cm, so perhaps there is an IF or BBC problem. This should be pursued some time.

At PT, LCP observations made with the 7.1 GHz front end synthesizer setting did not produce good results. This shows up as a cutoff here at 7.9 GHz and in the SX data at 8.1 GHz (Different frequency sequences were used). RCP is probably ok at the lower frequencies (see the SX data) but do not show here for some unknown reason. The receiver group is looking into the cause of the LCP problem — a mixer is suspect.

4cm with ellipsoid: For dual band 4cm and 13cm (S/X) observations, such as for geodesy and astrometry, an ellipsoid reflector is swung into place over the 4cm feed. This sees radiation reflected by a dichroic reflector which is always in place over the 13cm feed. This dichroic is an array of dipoles on a flat plate. At the standard observing frequency near the center of the 4cm band, the extra reflectors extract a sensitivity penalty of about 20%. Since the dichroic is is a resonant element, it might be expected to further degrade the 4cm response at the extreme frequencies.

Dual band data were not taken during the June-July observations. On 13 Sept, dual band data were obtained and the 4cm results are included here. They look very much like the straight 4cm results. It seems that the dichroic does not degrade the edges of the 4cm band.

Besides the problem (mixer?) in the lower part of the band, PT also had reduced sensitivity at the higher frequencies. It is possible that this is related to the other problem. Measurements will have to be made after the other problem is fixed.

6cm: Again, this is a relatively smooth band. There are some rough spots at SC and OV that do not appear to be related to T_{cal}. The SC deviant points were mentioned under 4cm. NL seems to have a classic case of problems with the T_{cal} values.

13cm: It is worth noting here that the nominal bandwidth for 13cm is 2150—2350 MHz. These plots extend far beyond that, to reveal that observations may be possible between 1950 and 2650 MHz at most stations. The SEFD is the best indicator of performance beyond the nominal band. T_{cal}s are only available between 2100 and 2400 MHz and, judging by the measured system temperatures and gains, the extrapolation to higher frequencies is rather poor. Also, these observations give no information on the polarization performance of the system, which might be rather poor at the higher frequencies.

There are a number of RFI problems in this band and the problems will probably get worse as the number of active users increases. The gaps between 2110—2130 MHz and 2180—2200 MHz that appear at some stations are not due to scheduling errors, but rather to spikes that were probably RFI and that were edited out of the data. At the high frequencies (above 2450 MHz) it is clear that the sites that are relatively exposed to cities (especially KP and LA) have significantly worse problems than the isolated sites.

All sites have a large loss of sensitivity at about 2475 MHz. This is outside the nominal band and, given how consistent it is between sites, may have something to do with the VLBA hardware. Perhaps it is a resonance of some sort.

For those contemplating multifrequency synthesis, note the near overlap of the 13cm and 20cm bands.

Note that all 13cm observations are made with the dichroic plate in place so the sensitivity for dual frequency observations will be the same as those shown here except for a small loss caused by the fact that the focus used for 4/13cm observations is optimized for 4cm.

20cm: The 20cm band is another that has significant RFI problems, especially at the highest and lowest frequencies. In fact, FD, KP, and SC all have special filters to deal with known strong radar signals that can saturate the systems. FD has a filter that passes 1384—1756 MHz which is evident in the data. KP has a filter that passes 1333—1885 MHz. Some data points below 1300 MHz look ok, but, as described earlier in this section, they probably do not actually represent good data at the frequency indicated. At SC, there is an IF filter that passes 665 to 1027 MHz. Used with the 2.4 GHz first LO, this blocks the offending radar signal at about 1.3 GHz. Frequencies below 1400 MHz can be reached with a 2.1 GHz first LO at the risk of saturating the system. Indeed the data below 1400 MHz are relatively poor, although there is no obvious spike at the radar frequency. It should be possible to observe frequencies from 1600 to 1900 MHz at SC using a 2.6 GHz LO, but we did not try. As mentioned earlier, any data at the band edges where there is significant scatter should not be believed.

50cm: Observations at 50cm were made both with and without the 4 MHz narrow band filter. The filtered data are shown in both plots and can be identified in the wide plots as the very close points between 608—614 MHz. Note that the narrow band data shown in the wide band plot has been edited so that the points on the edge of the filters are missing. Only the narrow band data, this time unedited, is shown in a second set of plots. In the wideband plots, the unfiltered data are the more separated points. FD, PT, OV, BR, and MK offer the widest ranges. Unfiltered observations at SC, HN, LA, and KP produced incomprehensible data, most likely because of strong RFI. Observations at these sites without the filter are not recommended. NL data remain at a median between acceptable and incomprehensible. Filtered observations at KP were not obtained because of scheduling problems.

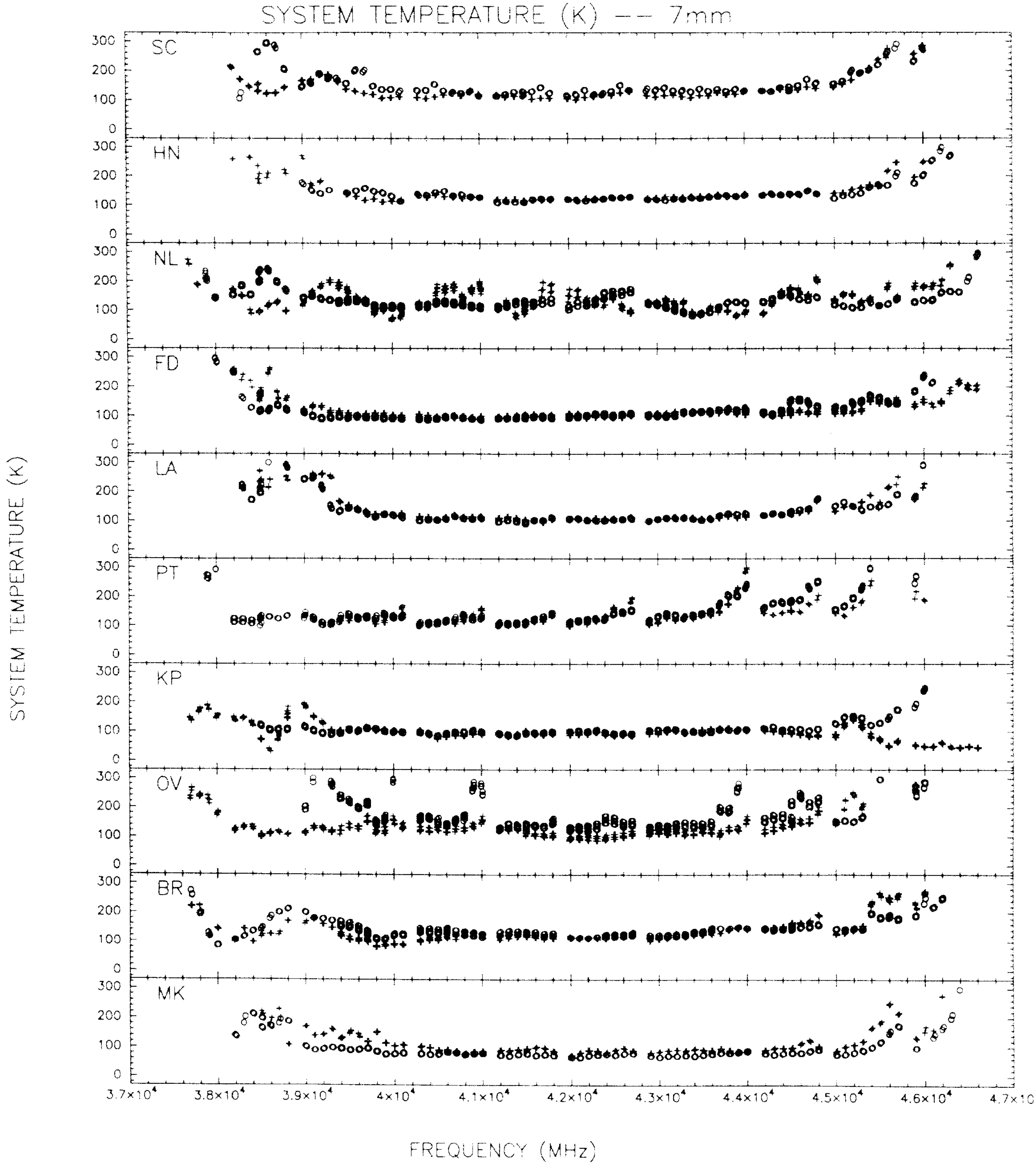
90cm: Observations at 90cm were scheduled for all stations, but no data were ever obtained at SC or MK. Good data were obtained at these sites in regular pointing observations during the same general time period so the systems were working. At all sites, this band is relatively smooth. Problems at specific frequencies at various stations are thought to be mainly due to RFI.

Table 1:
Observed frequencies

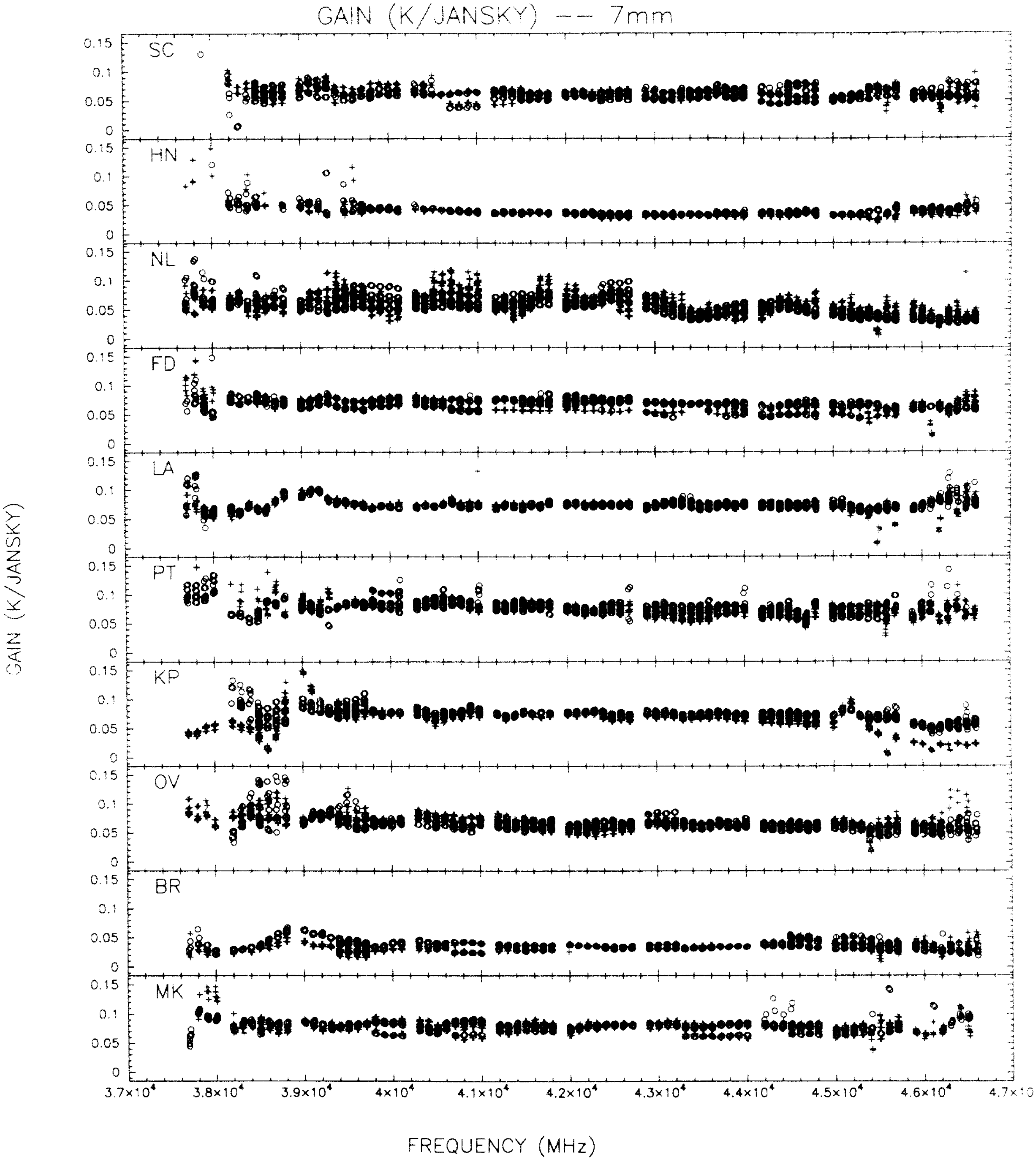
Band	Reference Frequency (MHz)	Nominal Band (MHz)	Frequency Range (MHz)	Bandwidth
7mm	43,212.99	41,000--45,000	39,300--46,700	16
1cm	22,228.99	21,700--24,100	20,500--25,300	16
2cm	15,360.99	12,100--15,400	11,600--16,100	16
4cm	8416.99	8000--8800	7600--9100	16
6cm	4994.99	4600--5100	4400--5300	8
13cm	2266.99	2150--2350	1900--2900	8
20cm	1662.99	1350--1750	1100--1900	8
50cm (without filter)	607.99	595--625	580--640	2
50cm (with filter)	607.99	595--625	608--614	0.25
90cm	325.99	312--342	300--355	2

Table 2:
Observed sources

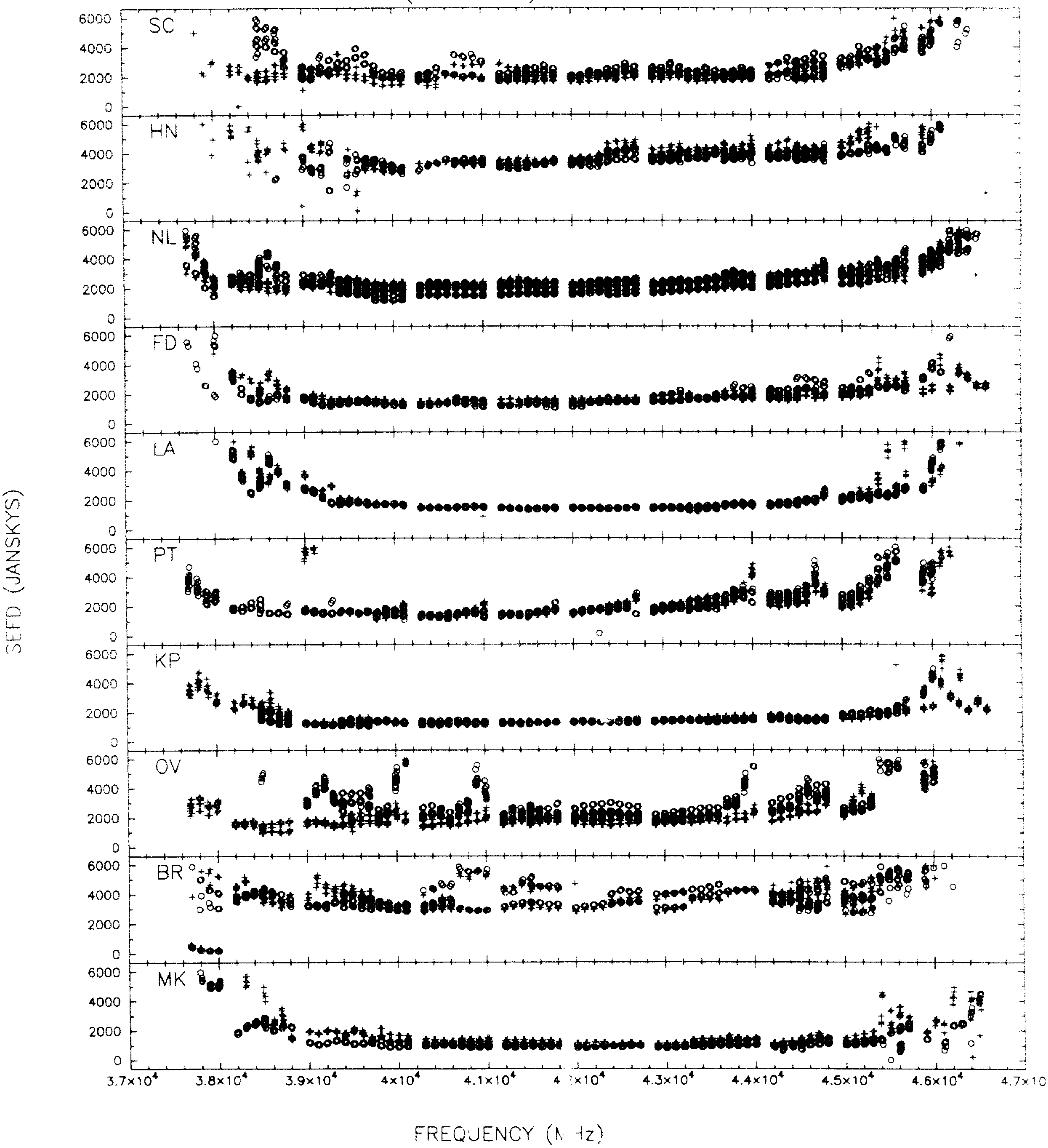
	7mm	1cm	2cm	4cm	6cm	13cm	20cm	50cm	90cm
SC	DR21	3C84 3C273	3C84 3C274	3C84 3C274	3C84 3C274	3C274	3C274 CYGA	3C274	_____
HN	DR21	3C84	3C274	3C84 3C274	3C84 3C274	3C274	3C274 CYGA	3C274	3C274
NL	DR21 3C273	3C84	3C84 3C274	3C84 3C274 CYGA	3C84 3C274	3C274 CYGA	3C274 CYGA	3C274 CYGA	3C274 CYGA
FD	DR21 3C273	3C84	3C84 3C274	3C84 3C274 CYGA	3C84 3C274	3C274 CYGA	3C274 CYGA	3C274 CYGA TAUA	3C274 CYGA
LA	DR21	3C84	3C84 3C274	3C84 3C274 CYGA	3C84 3C274	3C274 CYGA	3C274 CYGA	3C274	3C274 CYGA
PT	DR21	3C84 3C273	3C84 3C274 DR21	3C274 CYGA	3C274	3C274 CYGA	3C274 CYGA	3C274 CYGA TAUA	TAUA CYGA
KP	DR21 3C273	3C273	3C84 DR21	3C84 CYGA	3C84	CYGA	CYGA	_____	TAUA CYGA
OV	DR21 3C273	3C84	3C84 3C274	3C84 3C274 CYGA	3C84 3C274	3C274 CYGA	3C274 CYGA	3C274 CYGA TAUA	TAUA CYGA
BR	DR21 3C273	3C84 3C273	3C84 DR21	3C84 3C274	3C84 3C274	3C274	3C274 CYGA	3C274 CYGA TAUA	TAUA CYGA
MK	DR21 3C273	3C84 DR21 3C273	3C84	3C84 DR21	3C84 DR21	3C274	3C84	3C274	--------

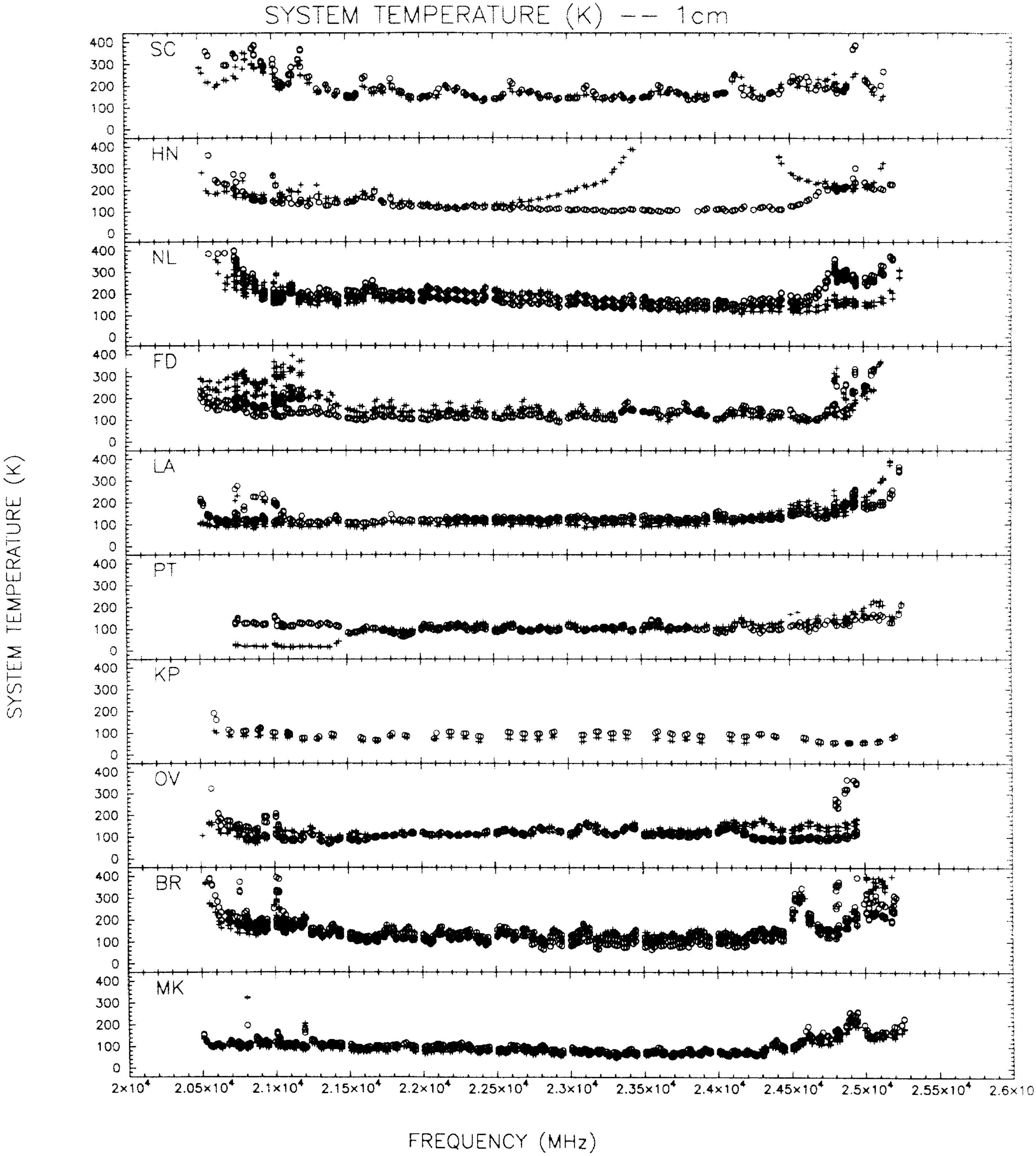


SYSTEM TEMPERATURE (K) -- 7mm
SYSTEM TEMPERATURE (K)
FREQUENCY (MHz)
SC
HN
NL
FD
LA
PT
KP
OV
BR
MK
0
100
200
300
3.7×10⁴
3.8×10⁴
3.9×10⁴
4×10⁴
4.1×10⁴
4.2×10⁴
4.3×10⁴
4.4×10⁴
4.5×10⁴
4.6×10⁴
4.7×10

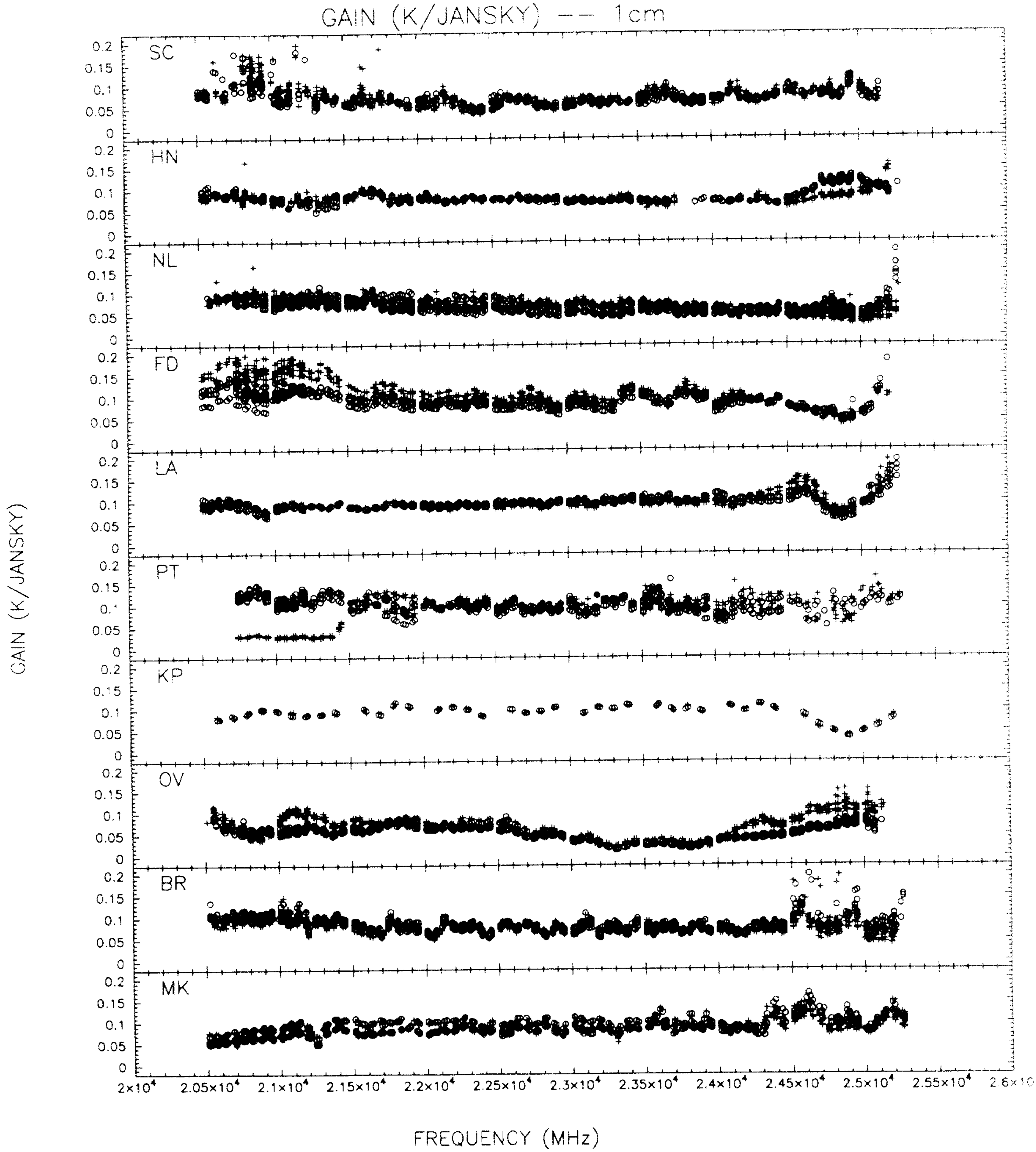

GAIN (K/JANSKY) -- 7mm
SC
HN
NL
FD
LA
PT
KP
OV
BR
MK
GAIN (K/JANSKY)
FREQUENCY (MHz)
0
0.05
0.1
0.15
3.7×10⁴
3.8×10⁴
3.9×10⁴
4×10⁴
4.1×10⁴
4.2×10⁴
4.3×10⁴
4.4×10⁴
4.5×10⁴
4.6×10⁴
4.7×10

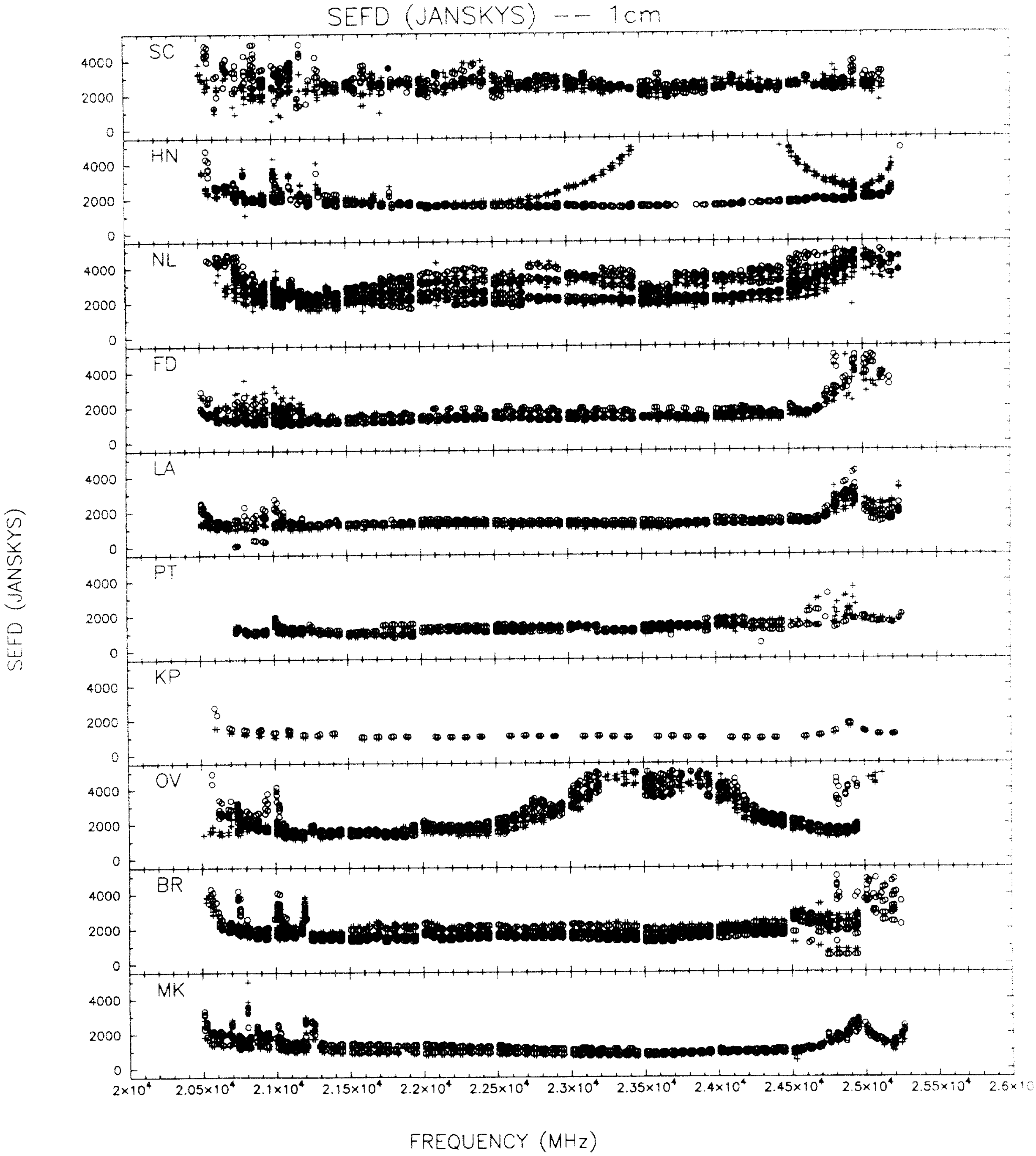
SEFD (JANSKYS) -- 7mm



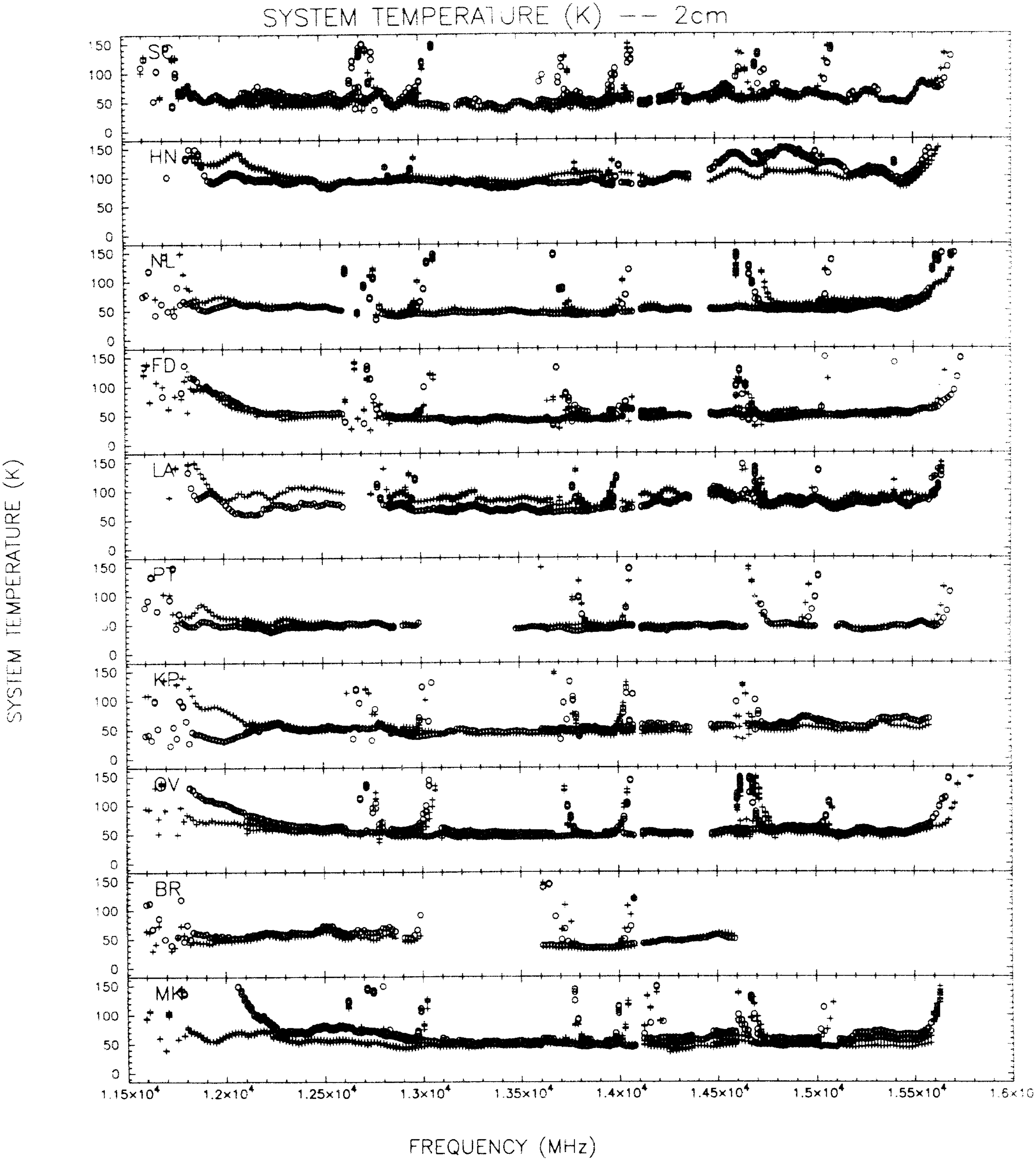


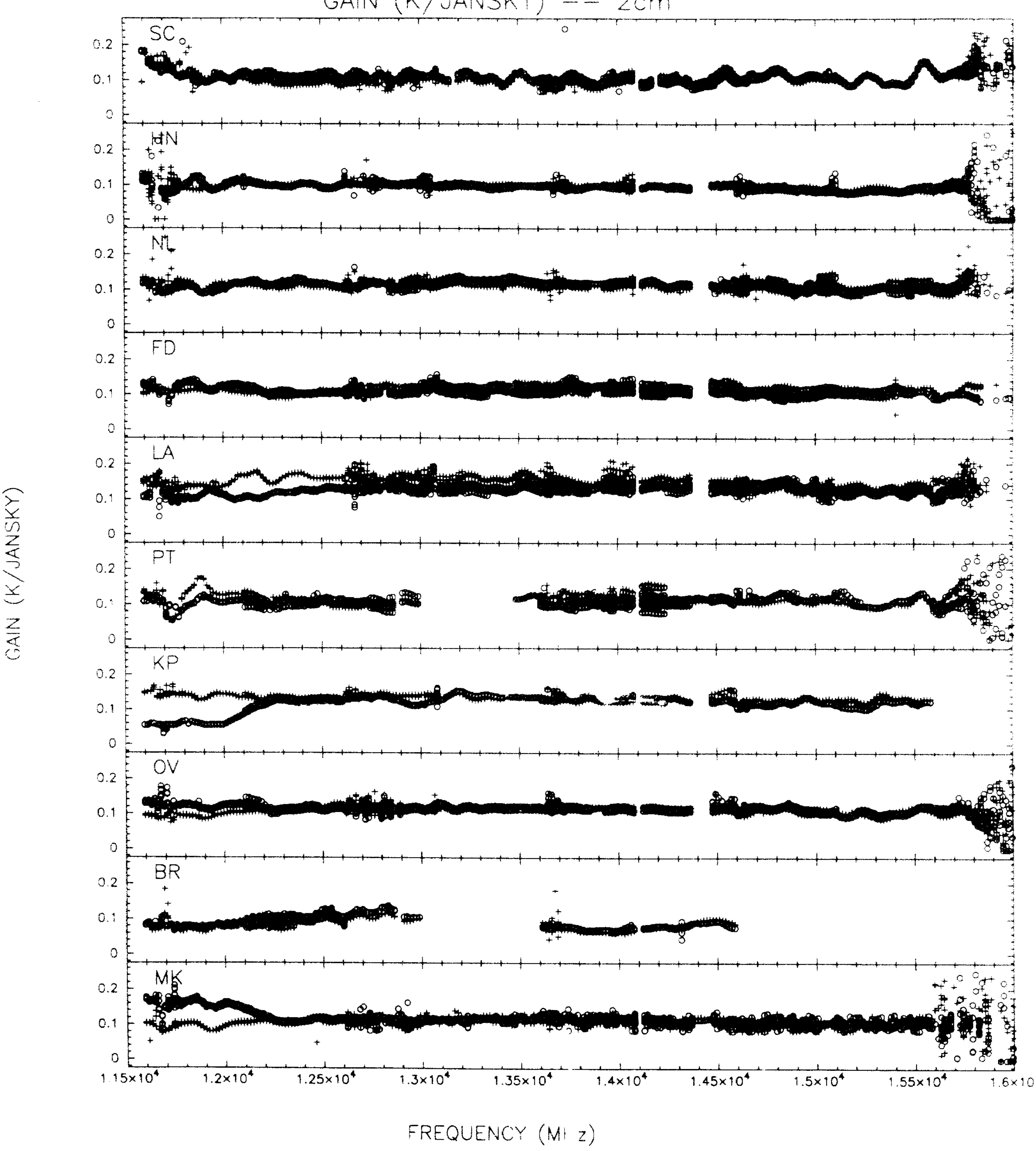
SYSTEM TEMPERATURE (K) -- 1cm
SC
HN
NL
FD
LA
PT
KP
OV
BR
MK
400
300
200
100
0
SYSTEM TEMPERATURE (K)
2×10⁴
2.05×10⁴
2.1×10⁴
2.15×10⁴
2.2×10⁴
2.25×10⁴
2.3×10⁴
2.35×10⁴
2.4×10⁴
2.45×10⁴
2.5×10⁴
2.55×10⁴
2.6×10
FREQUENCY (MHz)

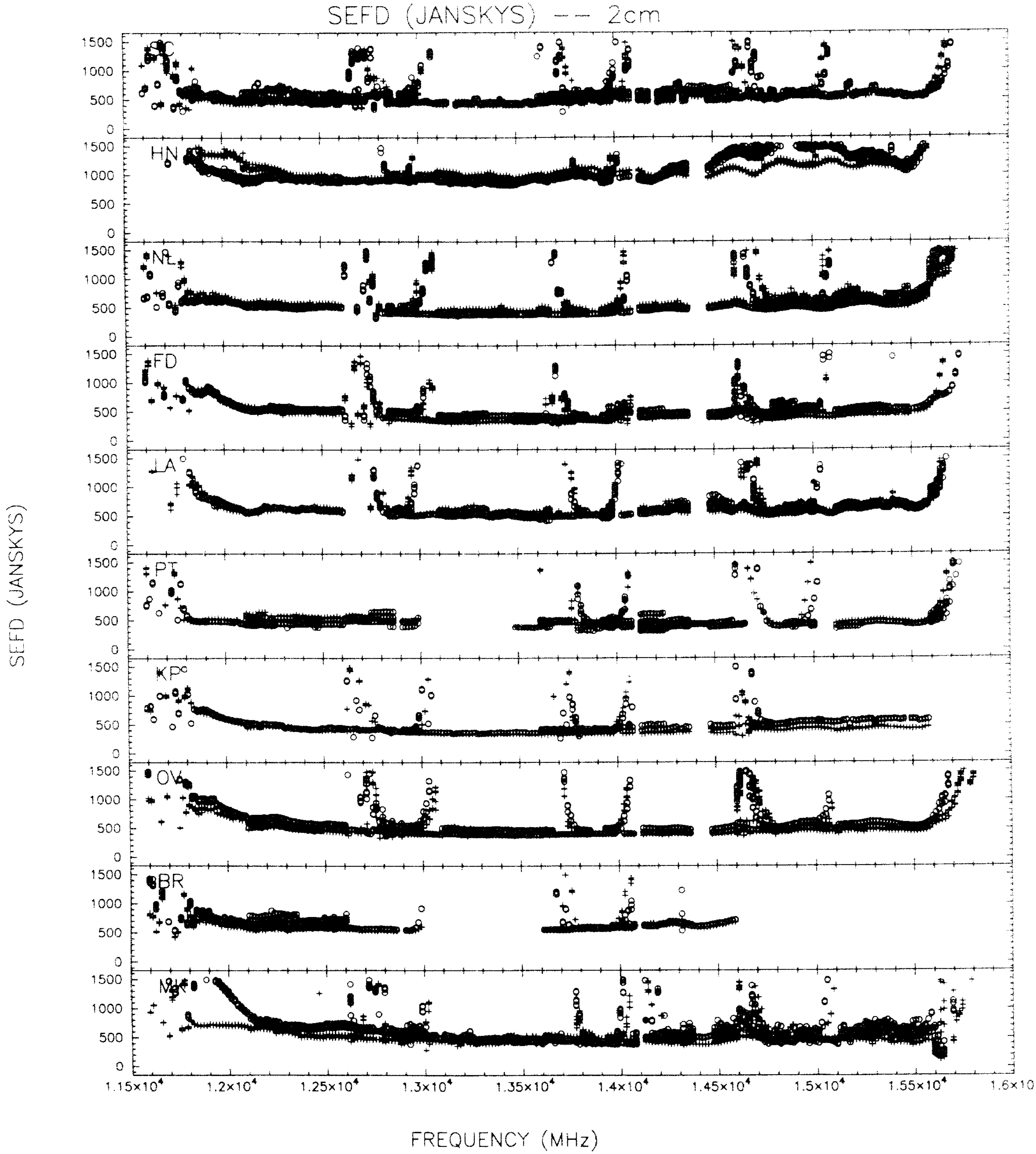

GAIN (K/JANSKY) -- 1cm
SC
HN
NL
FD
LA
PT
KP
OV
BR
MK
GAIN (K/JANSKY)
FREQUENCY (MHz)

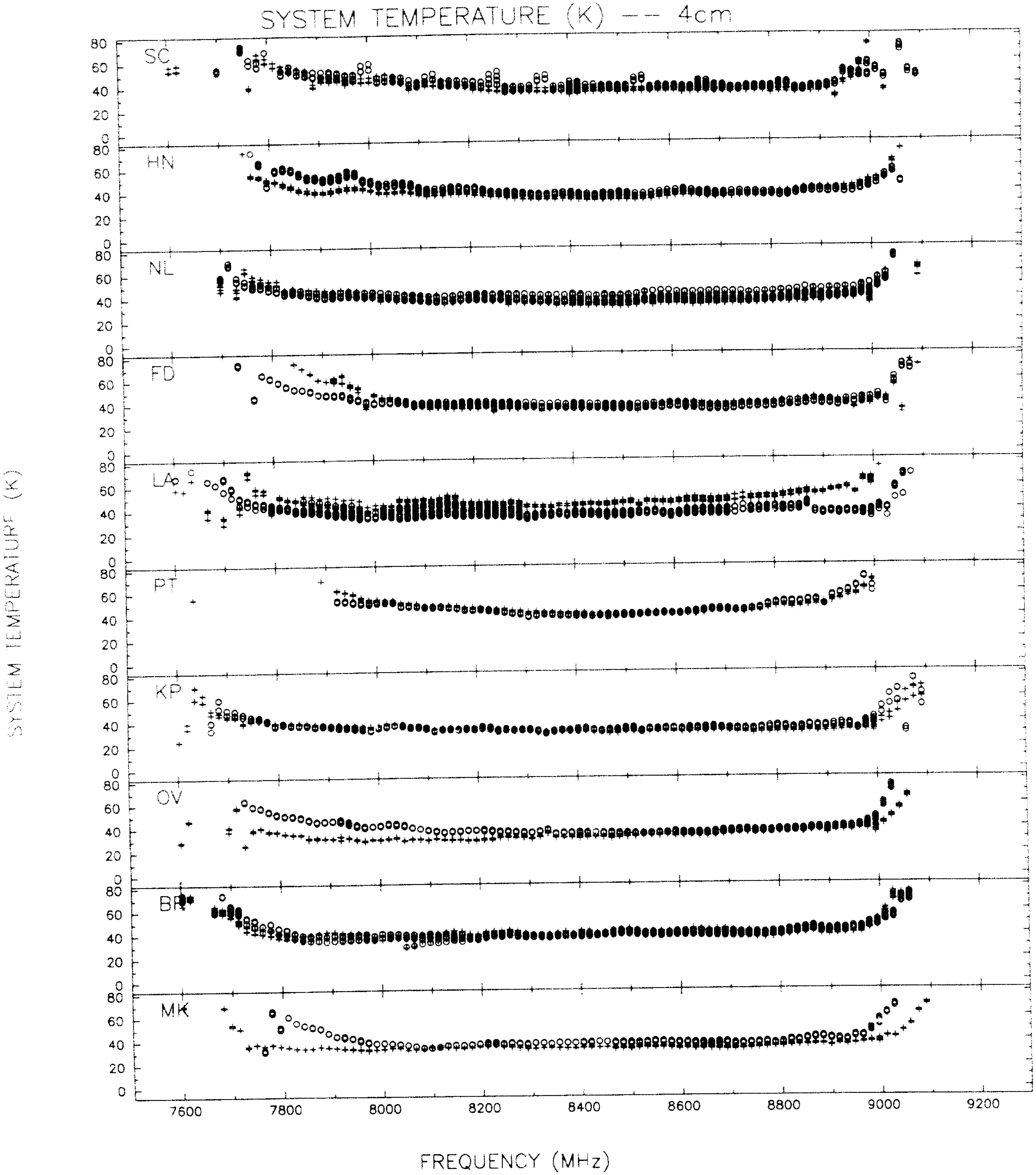


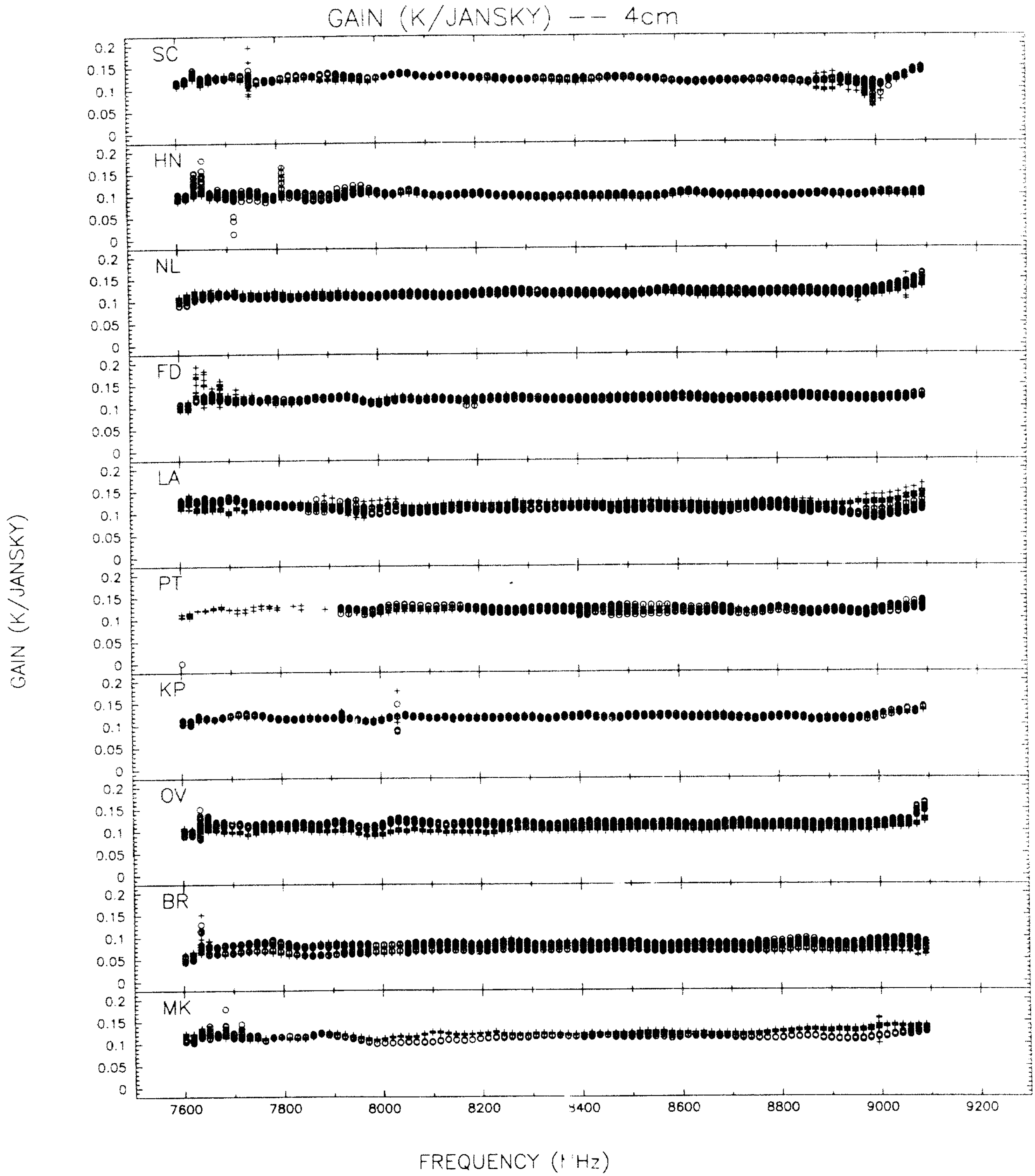
SEFD (JANSKYS) -- 1cm
SC
HN
NL
FD
LA
PT
KP
OV
BR
MK
4000
2000
0
SEFD (JANSKYS)
2×10⁴
2.05×10⁴
2.1×10⁴
2.15×10⁴
2.2×10⁴
2.25×10⁴
2.3×10⁴
2.35×10⁴
2.4×10⁴
2.45×10⁴
2.5×10⁴
2.55×10⁴
2.6×10
FREQUENCY (MHz)

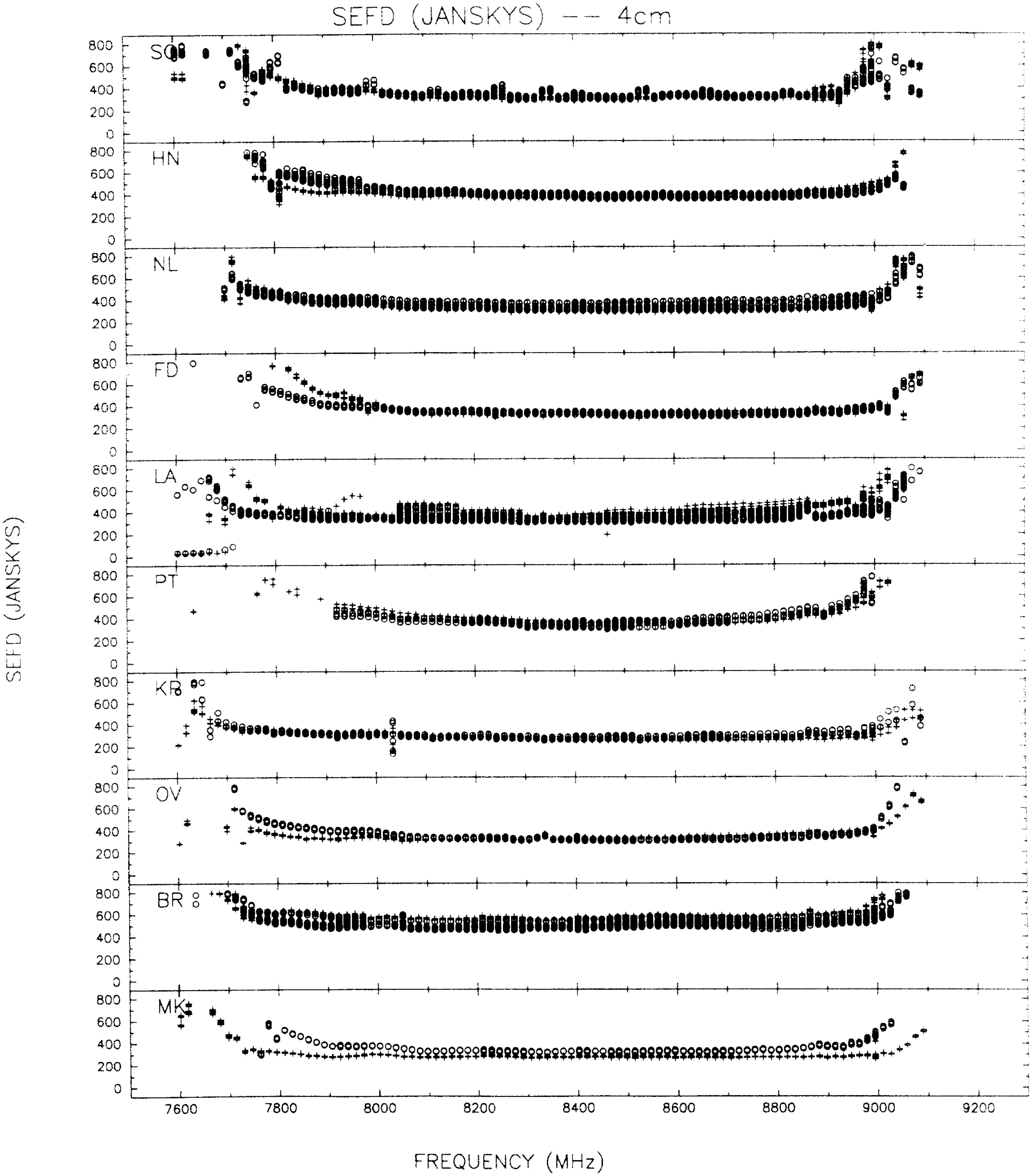

SYSTEM TEMPERATURE (K) -- 2cm
SC
HN
NL
FD
LA
PT
KP
OV
BR
MK
SYSTEM TEMPERATURE (K)
FREQUENCY (MHz)


GAIN (K/JANSKY) -- 2cm
SC
HN
NL
FD
LA
PT
KP
OV
BR
MK
0.2
0.1
0
1.15×10^4
1.2×10^4
1.25×10^4
1.3×10^4
1.35×10^4
1.4×10^4
1.45×10^4
1.5×10^4
1.55×10^4
1.6×10
GAIN (K/JANSKY)
FREQUENCY (MHz)

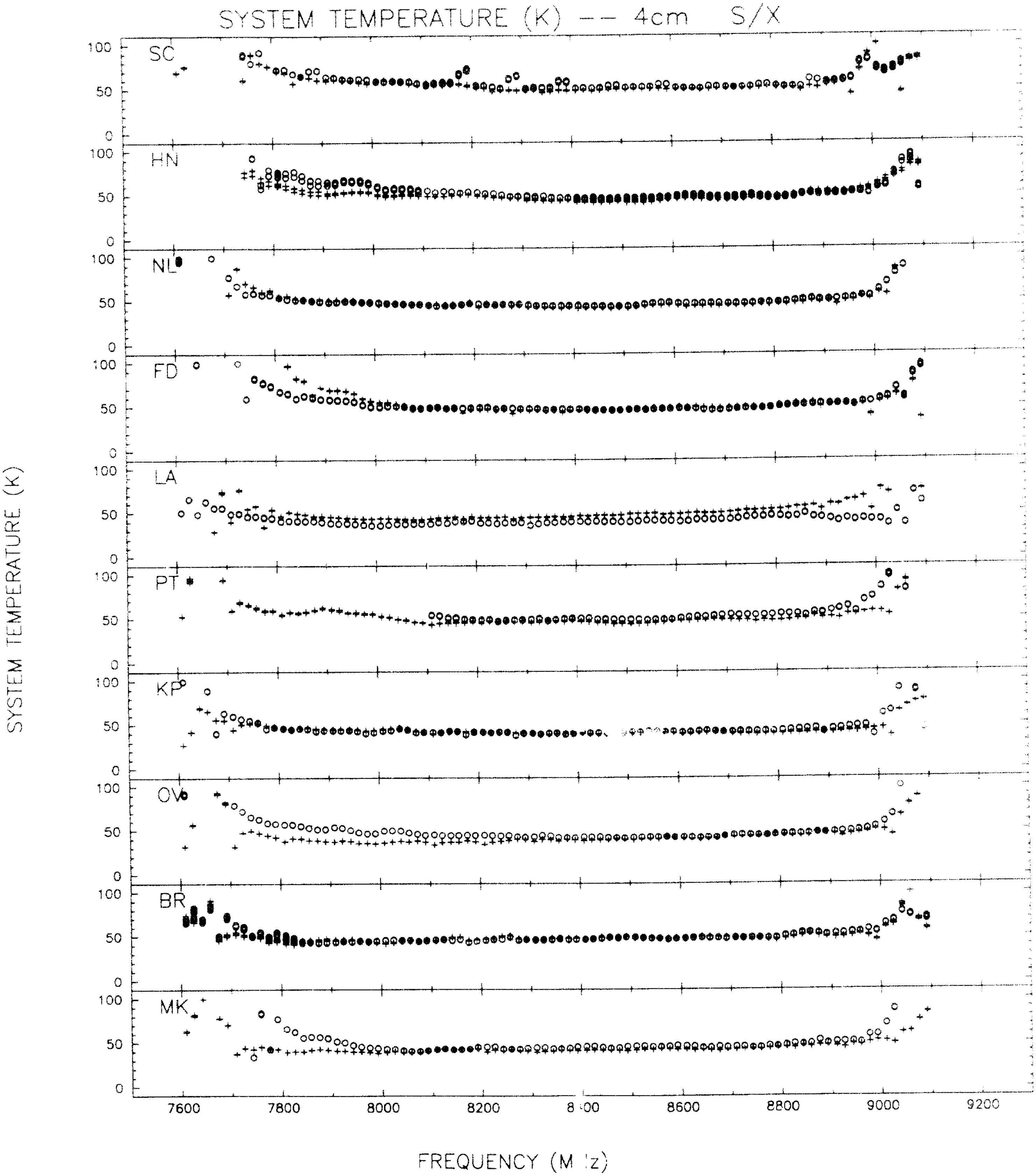

SEFD (JANSKYS) -- 2cm
SEFD (JANSKYS)
FREQUENCY (MHz)
SC
HN
NL
FD
LA
PT
KP
OV
BR
MK
0
500
1000
1500
1.15×10⁴
1.2×10⁴
1.25×10⁴
1.3×10⁴
1.35×10⁴
1.4×10⁴
1.45×10⁴
1.5×10⁴
1.55×10⁴
1.6×10


SYSTEM TEMPERATURE (K) -- 4cm
SYSTEM TEMPERATURE (K)
FREQUENCY (MHz)
SC
HN
NL
FD
LA
PT
KP
OV
BR
MK
7600
7800
8000
8200
8400
8600
8800
9000
9200
0
20
40
60
80

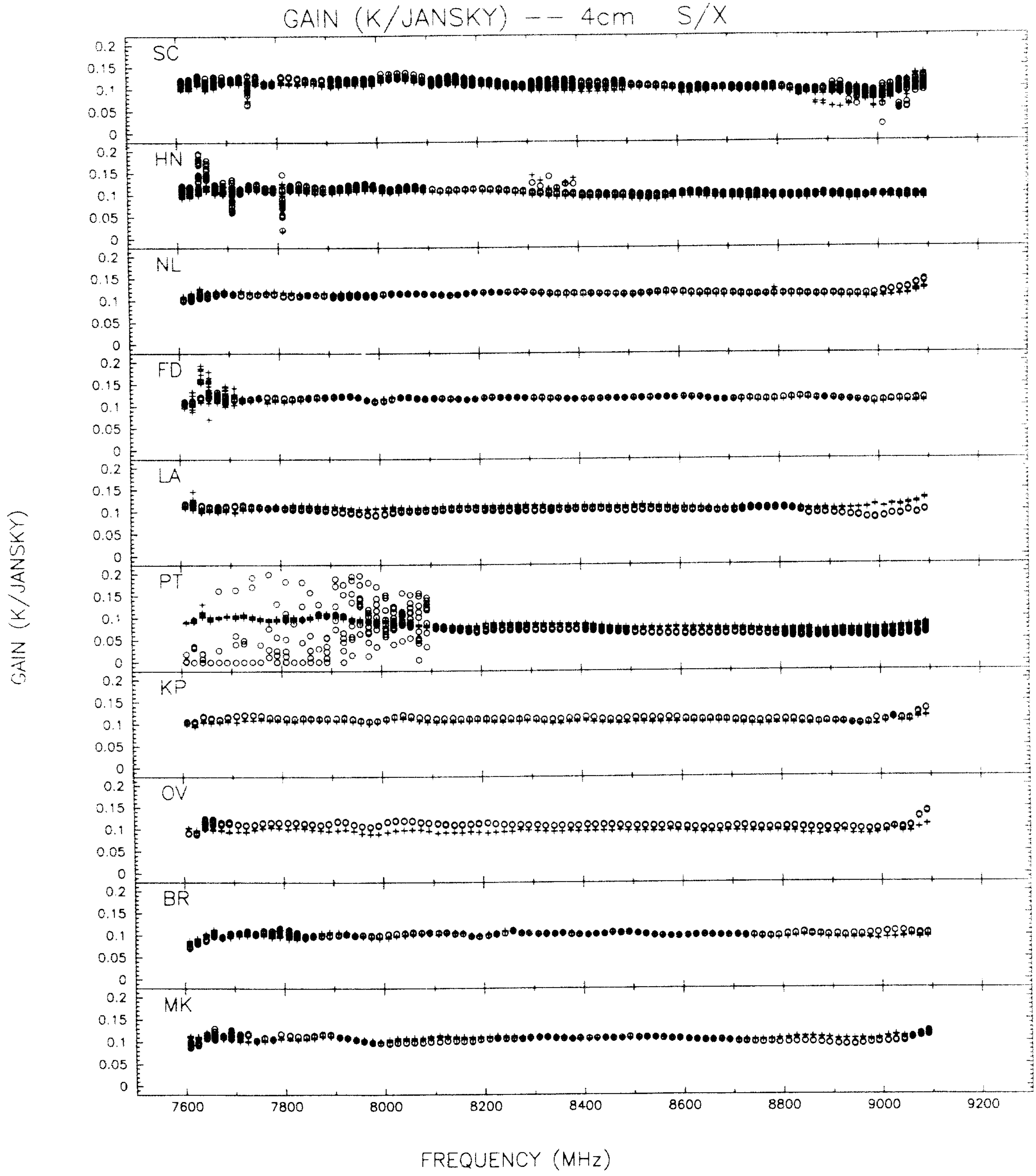

GAIN (K/JANSKY) -- 4cm
SC
HN
NL
FD
LA
PT
KP
OV
BR
MK
0.2
0.15
0.1
0.05
0
GAIN (K/JANSKY)
7600
7800
8000
8200
8400
8600
8800
9000
9200
FREQUENCY (MHz)

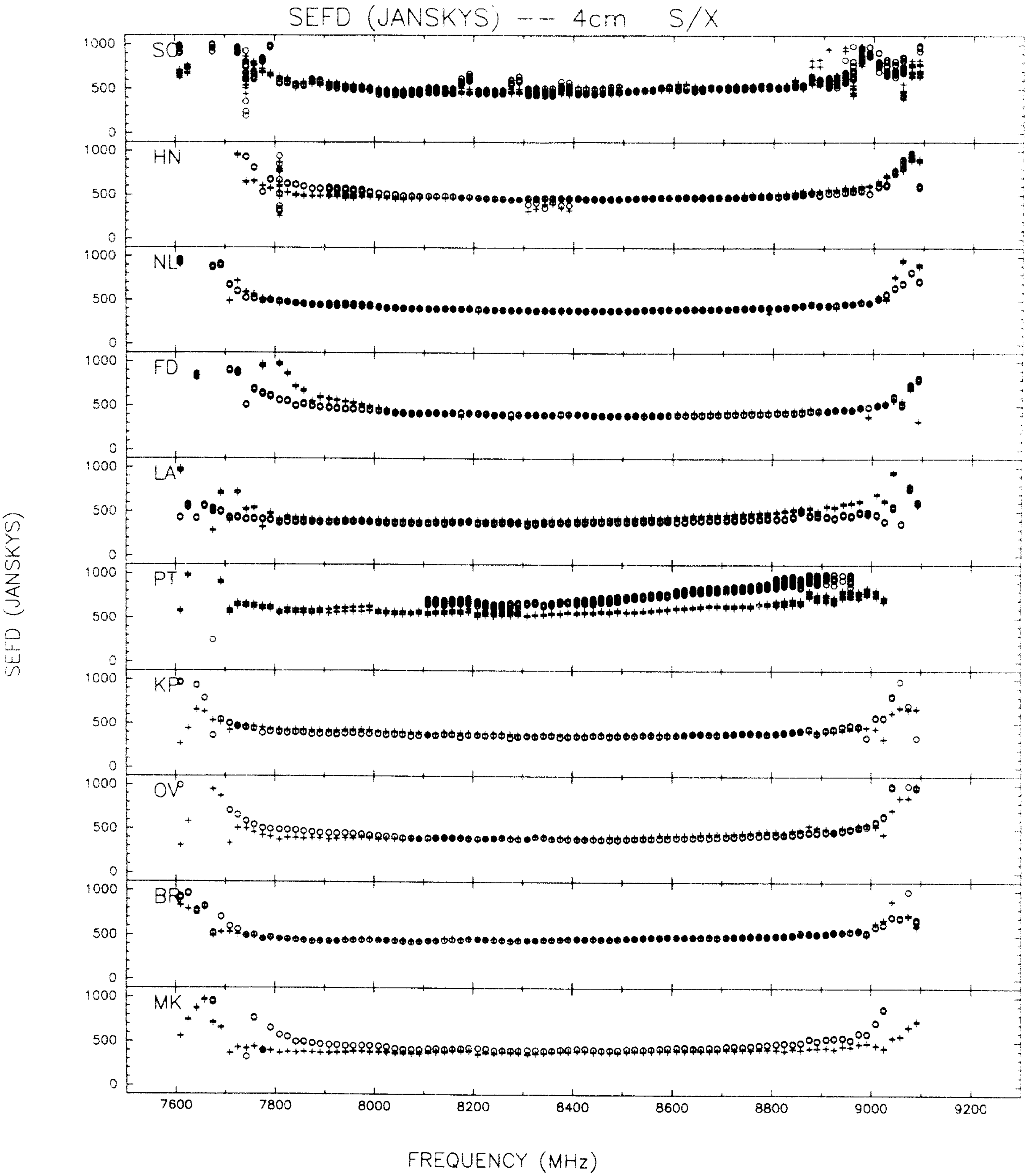


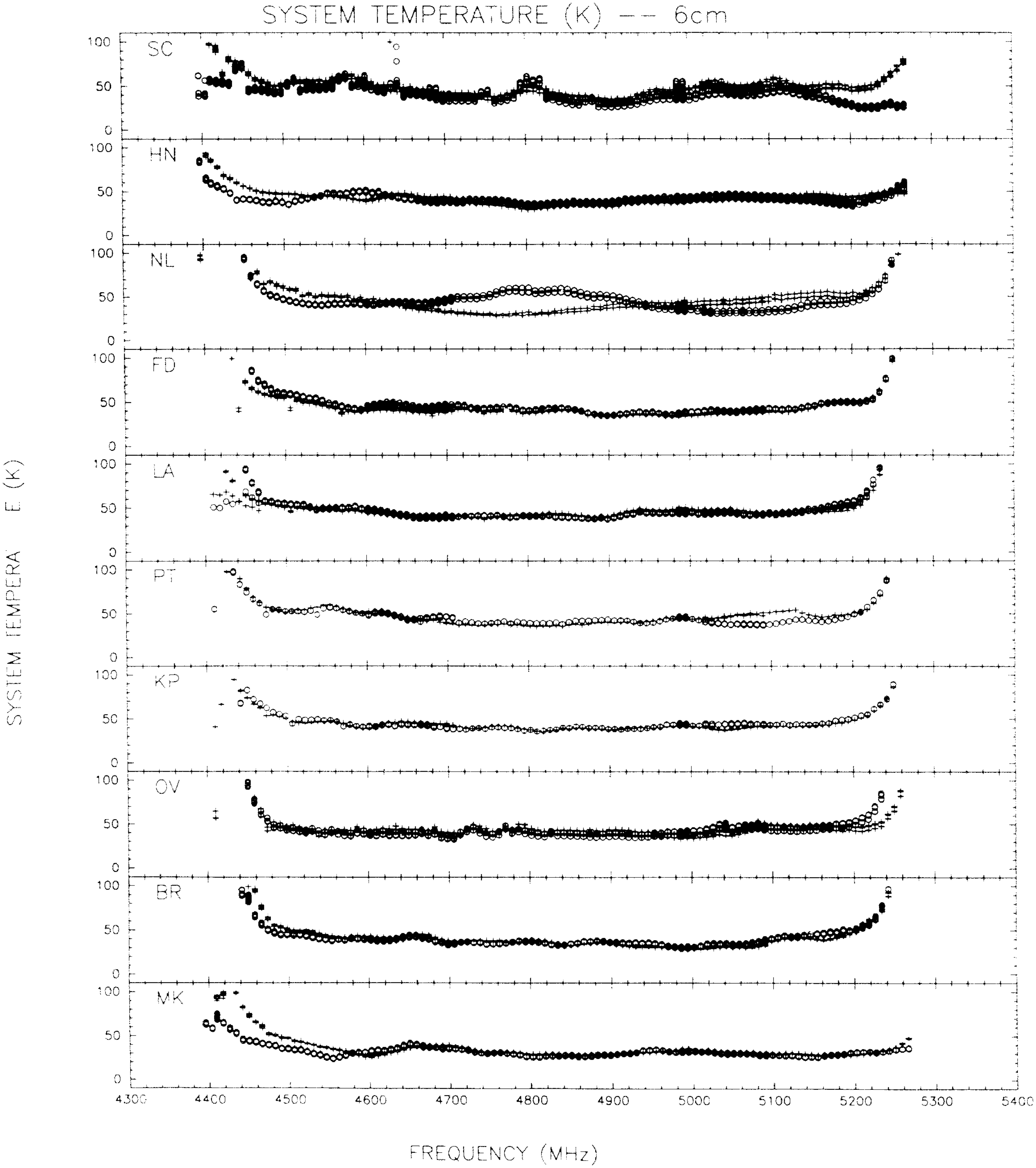
SEFD (JANSKYS) -- 4cm
SC
HN
NL
FD
LA
PT
KP
OV
BR
MK
SEFD (JANSKYS)
0
200
400
600
800
7600
7800
8000
8200
8400
8600
8800
9000
9200
FREQUENCY (MHz)



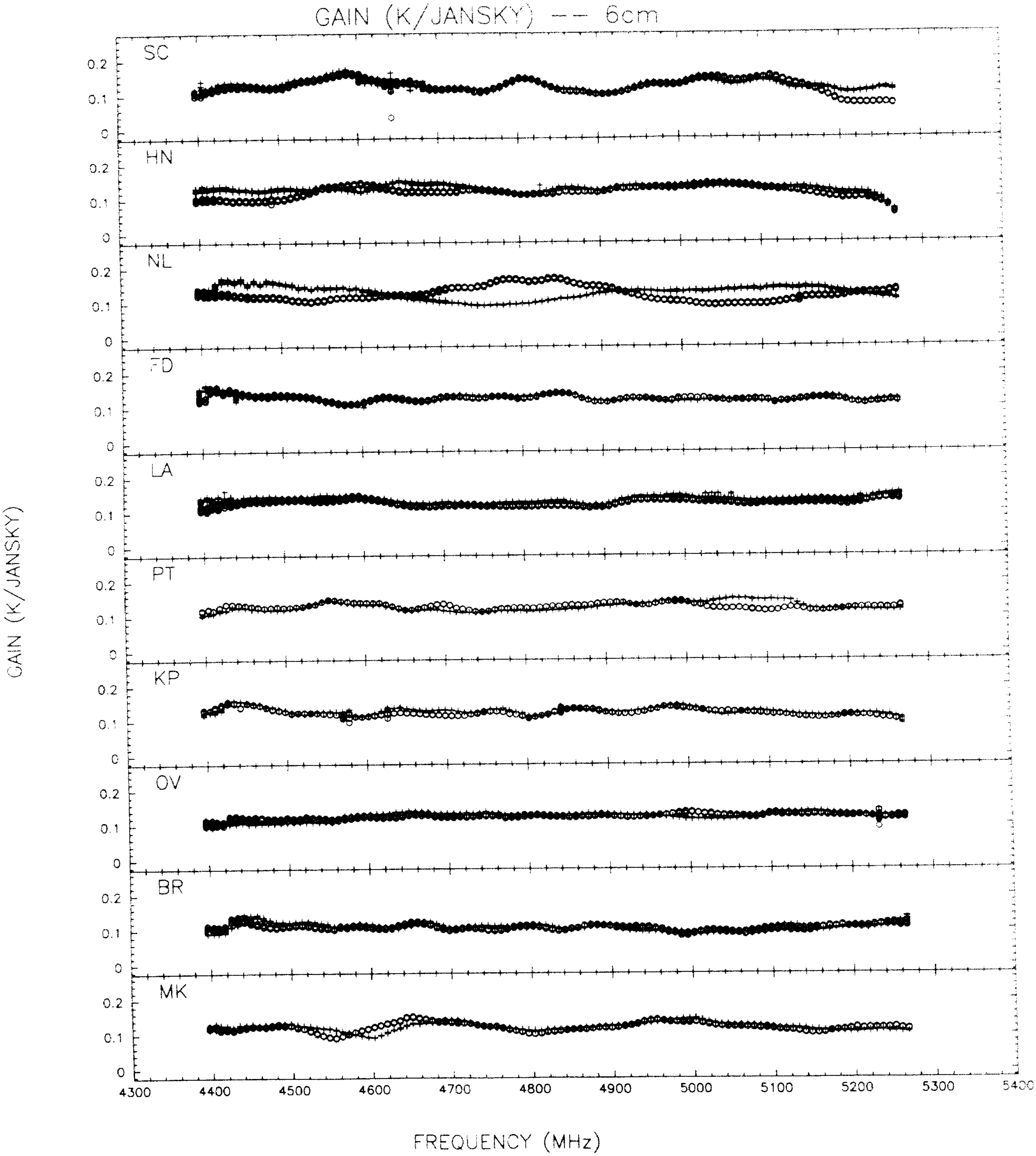
SYSTEM TEMPERATURE (K) -- 4cm S/X
SC
HN
NL
FD
LA
PT
KP
OV
BR
MK
100
50
0
SYSTEM TEMPERATURE (K)
7600
7800
8000
8200
8600
8800
9000
9200
FREQUENCY (M z)

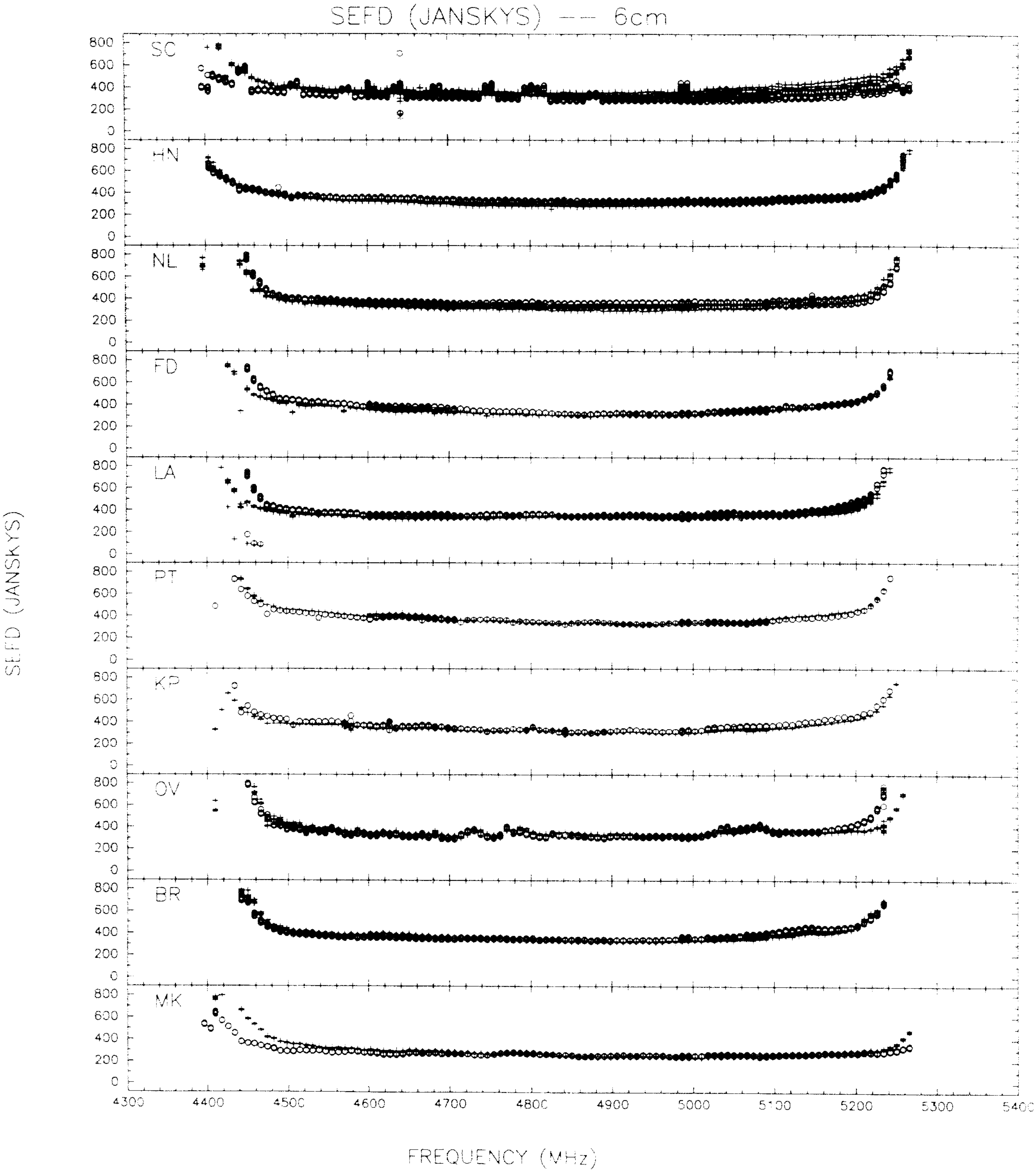

GAIN (K/JANSKY) -- 4cm S/X
SC
HN
NL
FD
LA
PT
KP
OV
BR
MK
GAIN (K/JANSKY)
FREQUENCY (MHz)

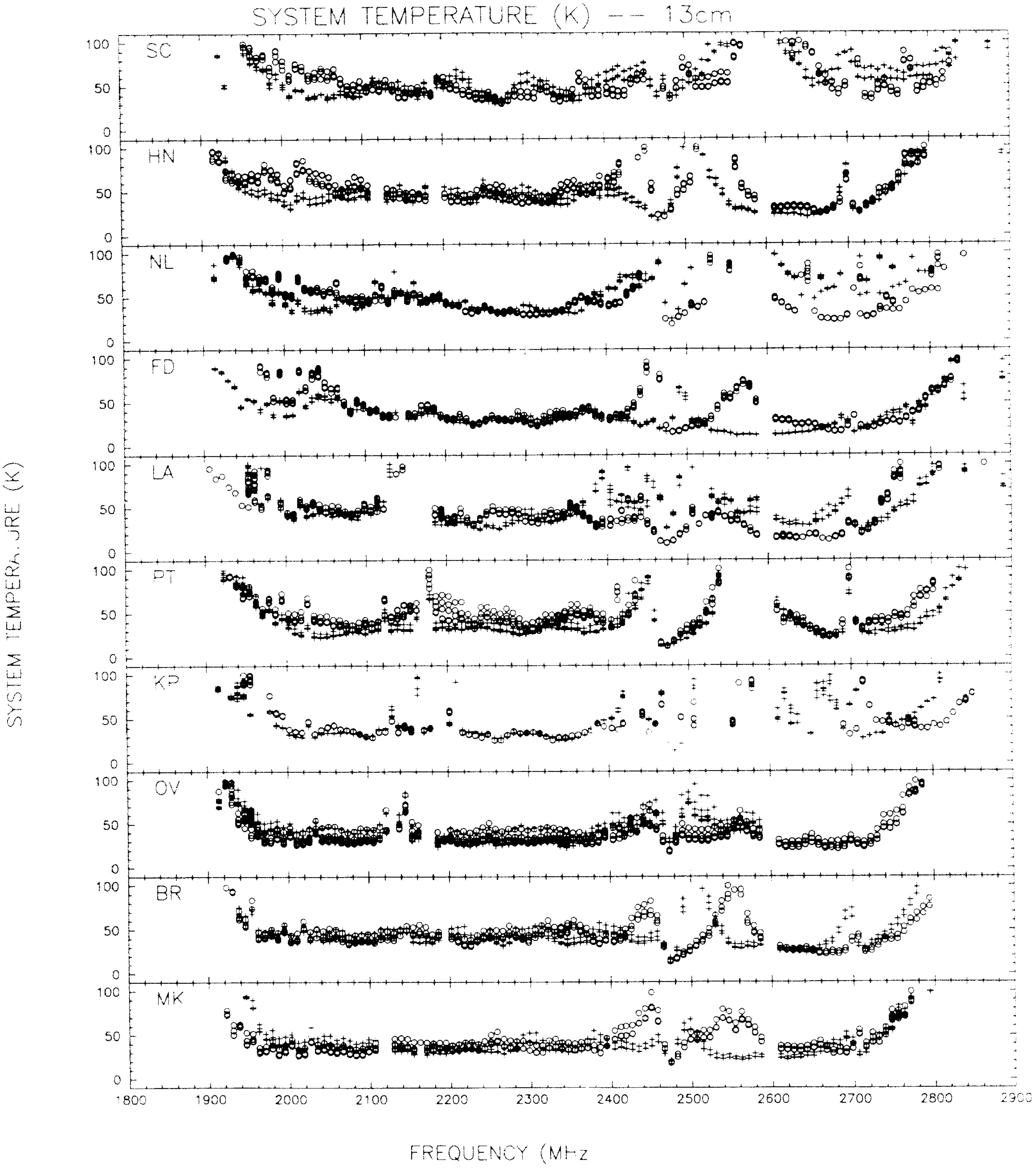

SEFD (JANSKYS) -- 4cm S/X
SEFD (JANSKYS)
SC
HN
NL
FD
LA
PT
KP
OV
BR
MK
1000
500
0
7600
7800
8000
8200
8400
8600
8800
9000
9200
FREQUENCY (MHz)

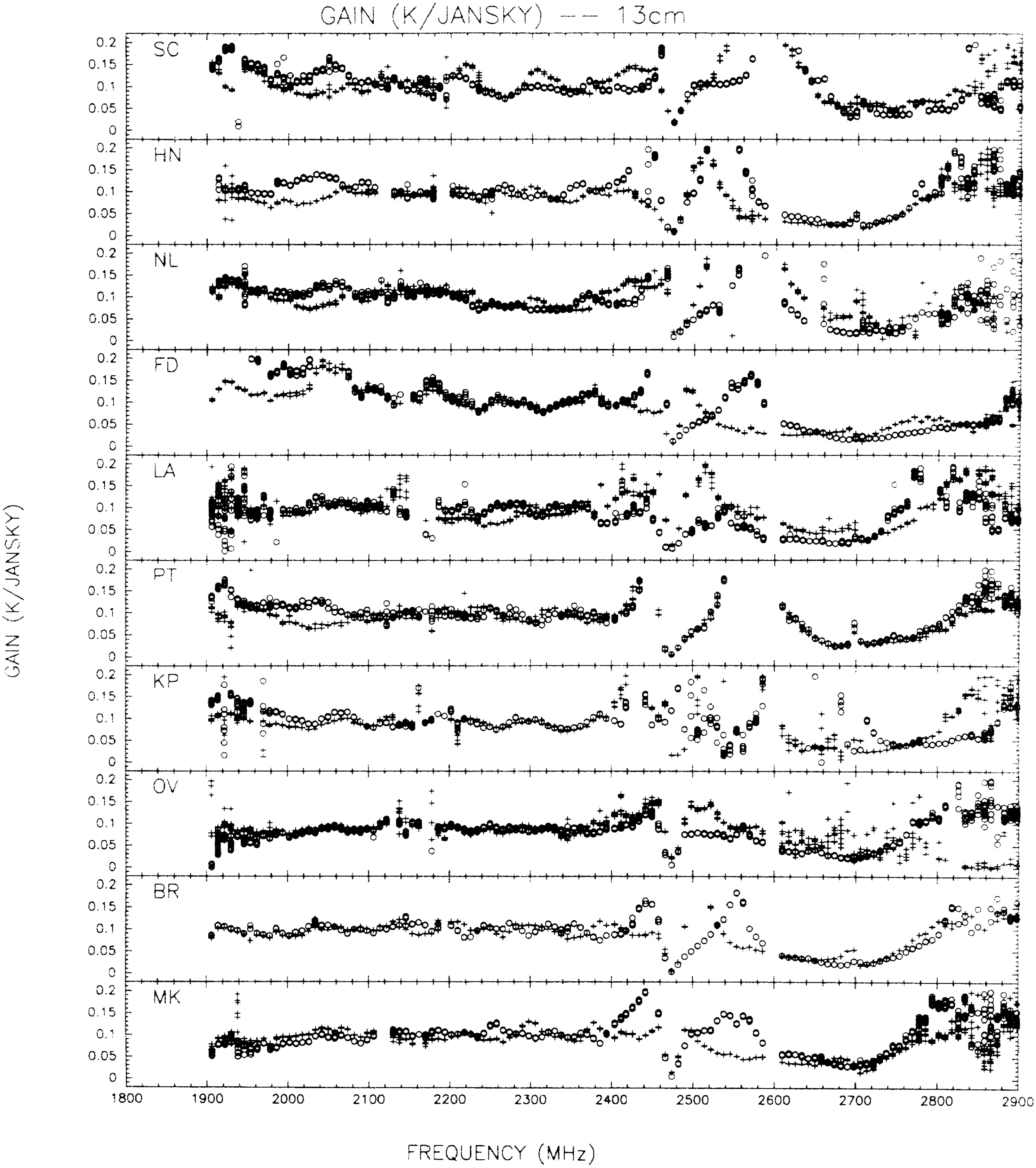


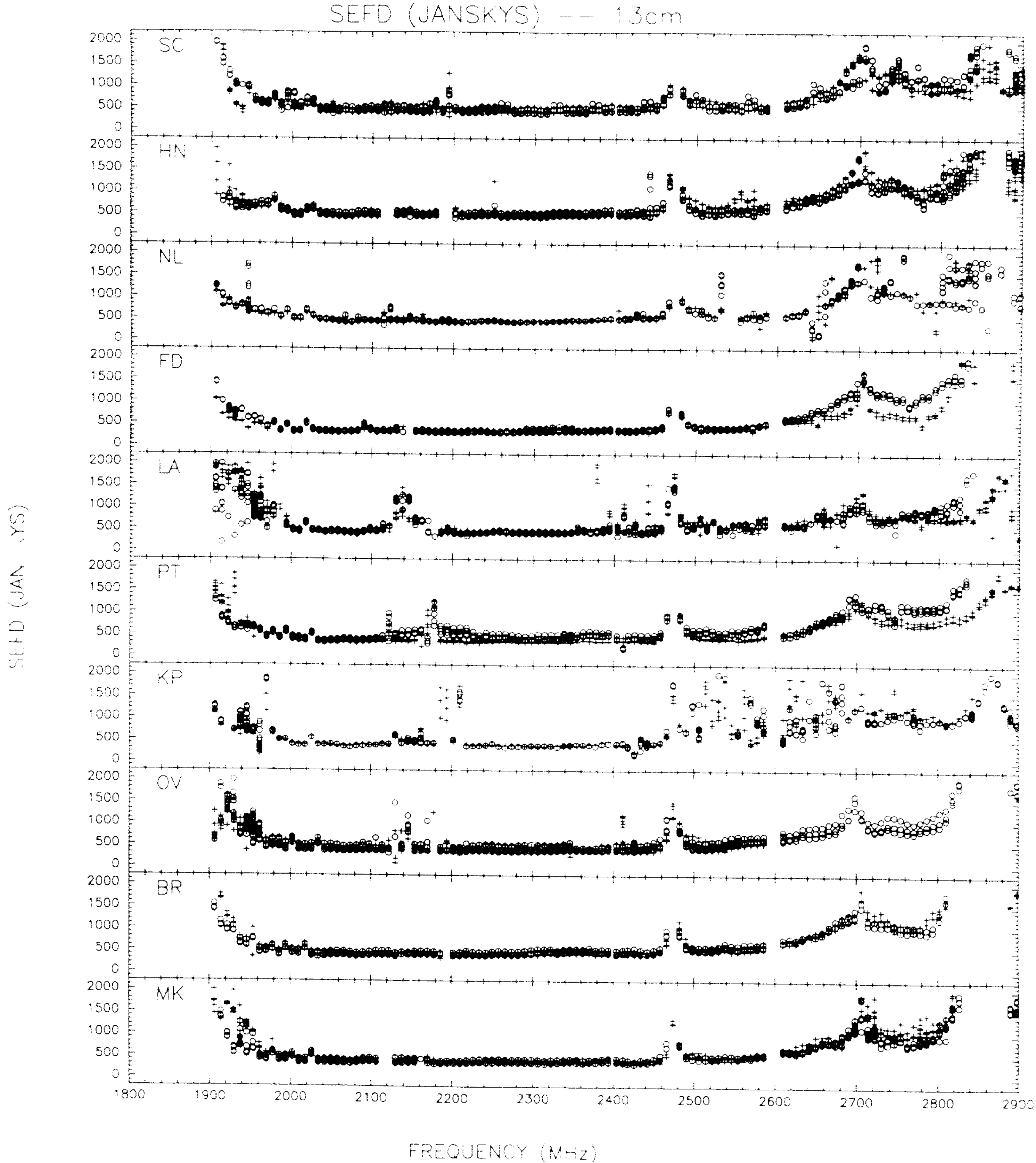
SYSTEM TEMPERATURE (K) -- 6cm
SC
HN
NL
FD
LA
PT
KP
OV
BR
MK
100
50
0
4300
4400
4500
4600
4700
4800
4900
5000
5100
5200
5300
5400
FREQUENCY (MHz)
SYSTEM TEMPERA E (K)


GAIN (K/JANSKY) -- 6cm
SC
HN
NL
FD
LA
PT
KP
OV
BR
MK
0.2
0.1
0
GAIN (K/JANSKY)
4300
4400
4500
4600
4700
4800
4900
5000
5100
5200
5300
5400
FREQUENCY (MHz)

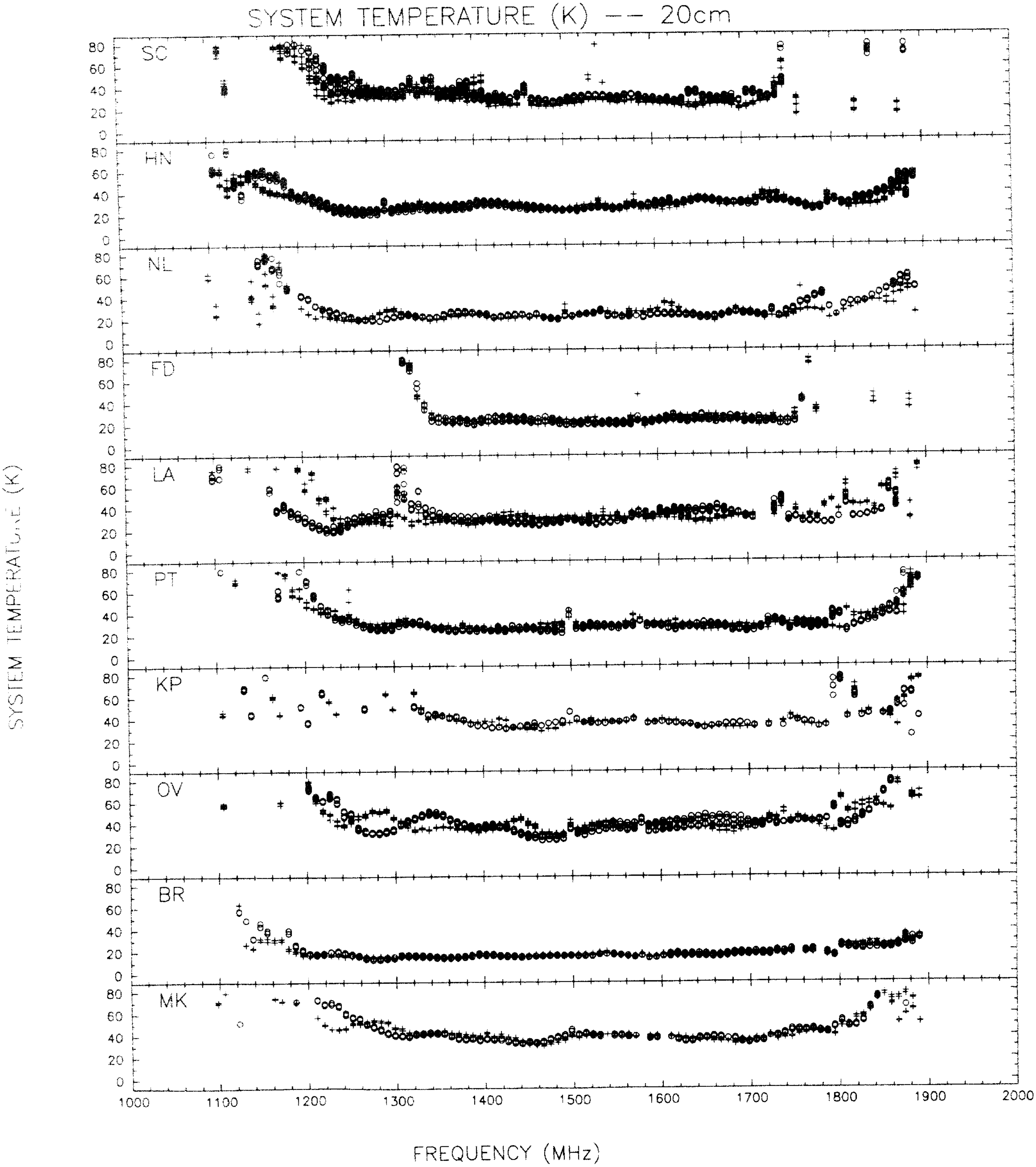

SEFD (JANSKYS) -- 6cm
SC
HN
NL
FD
LA
PT
KP
OV
BR
MK
SEFD (JANSKYS)
FREQUENCY (MHz)
0
200
400
600
800
4300
4400
4500
4600
4700
4800
4900
5000
5100
5200
5300
5400


SYSTEM TEMPERATURE (K) -- 13cm
SC
HN
NL
FD
LA
PT
KP
OV
BR
MK
SYSTEM TEMPERATURE (K)
FREQUENCY (MHz

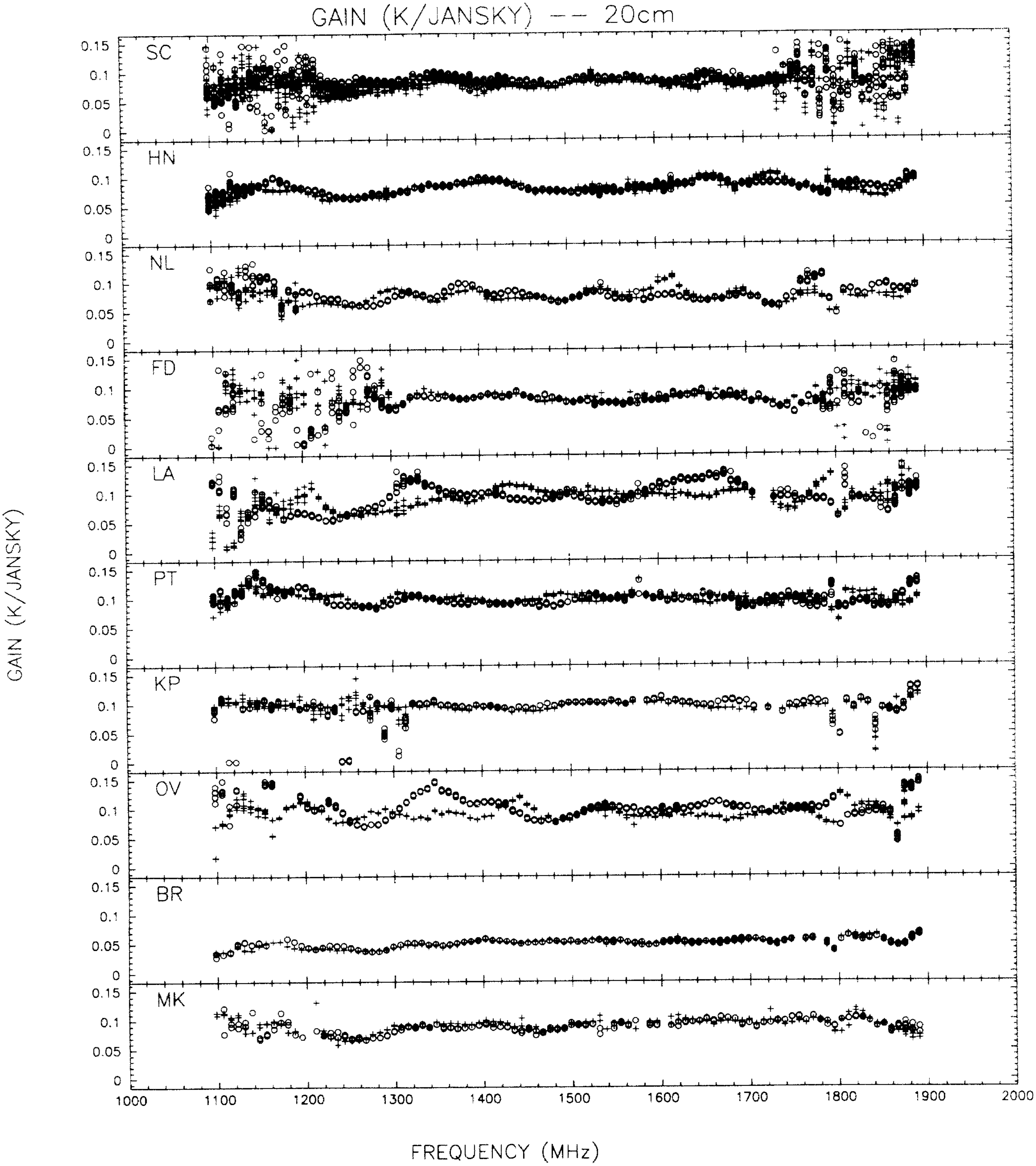

GAIN (K/JANSKY) -- 13cm
SC
HN
NL
FD
LA
PT
KP
OV
BR
MK
GAIN (K/JANSKY)
FREQUENCY (MHz)
1800
1900
2000
2100
2200
2300
2400
2500
2600
2700
2800
2900



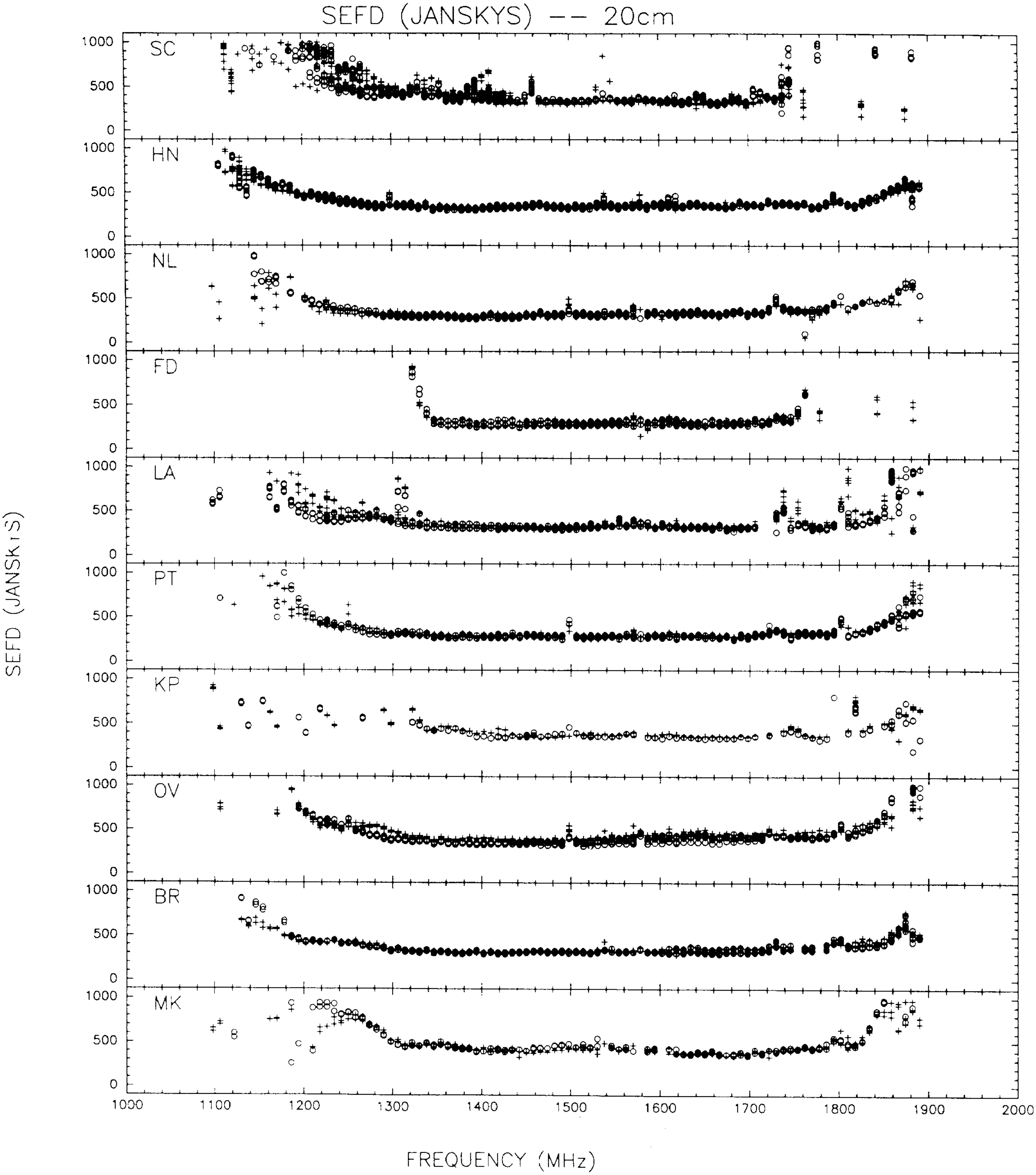
SEFD (JANSKYS) -- 13cm
SC
HN
NL
FD
LA
PT
KP
OV
BR
MK
0
500
1000
1500
2000
1800
1900
2000
2100
2200
2300
2400
2500
2600
2700
2800
2900
SEFD (JANSKYS)
FREQUENCY (MHz)



SYSTEM TEMPERATURE (K) -- 20cm
SC
HN
NL
FD
LA
PT
KP
OV
BR
MK
SYSTEM TEMPERATURE (K)
FREQUENCY (MHz)

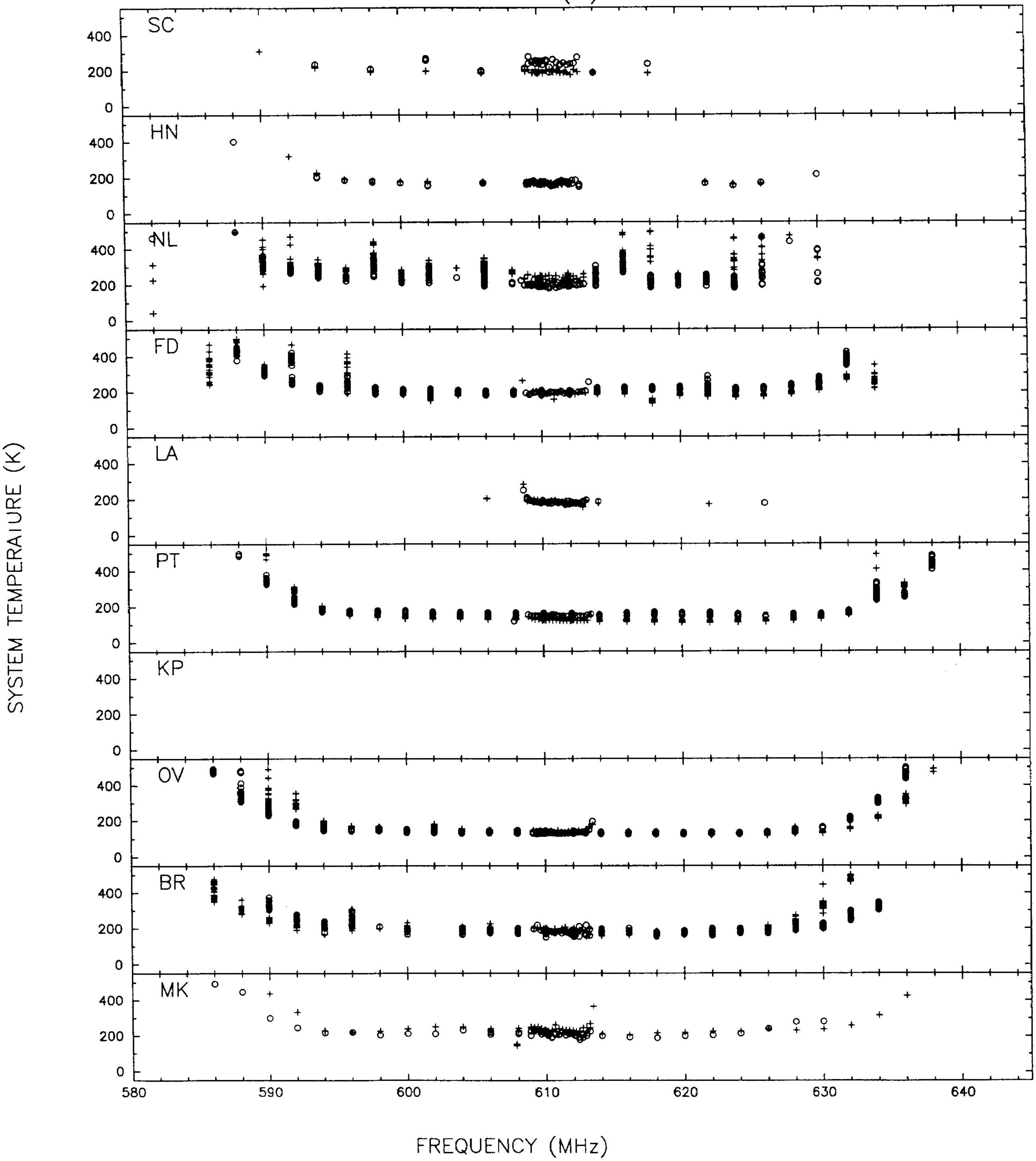


GAIN (K/JANSKY) -- 20cm
SC
HN
NL
FD
LA
PT
KP
OV
BR
MK
0.15
0.1
0.05
0
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000
GAIN (K/JANSKY)
FREQUENCY (MHz)

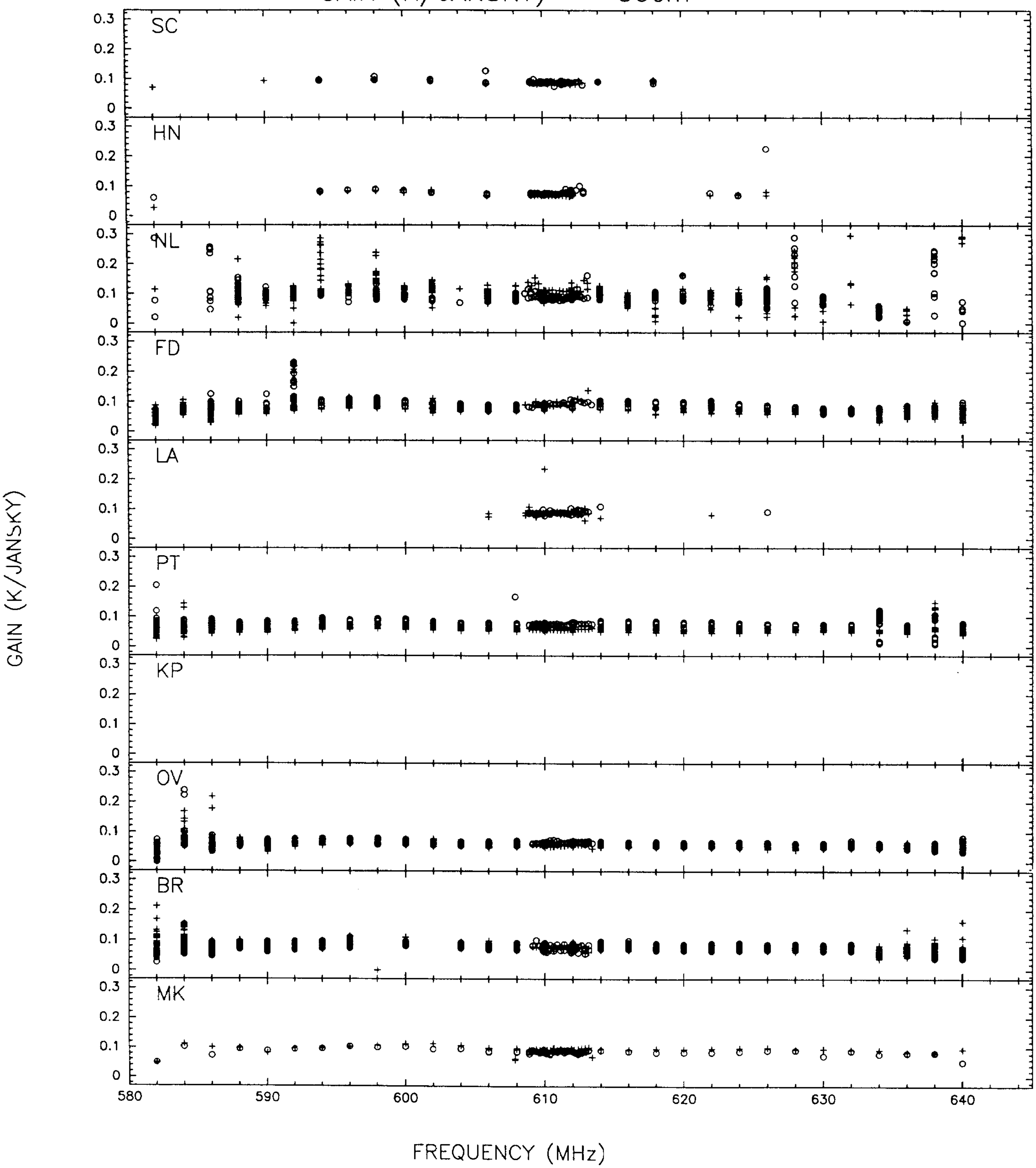


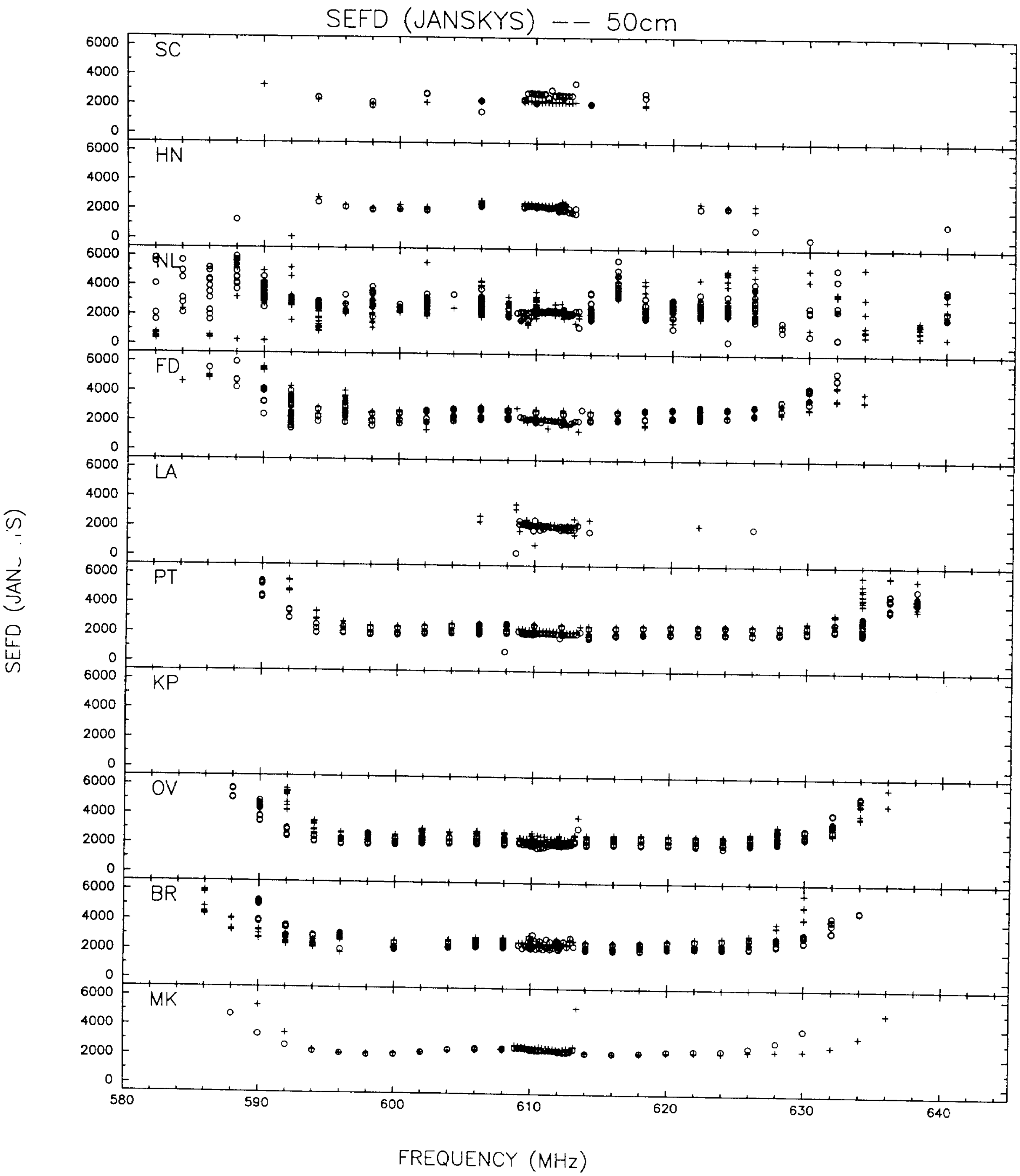
SEFD (JANSKYS) -- 20cm
SC
HN
NL
FD
LA
PT
KP
OV
BR
MK
SEFD (JANSKYS)
FREQUENCY (MHz)

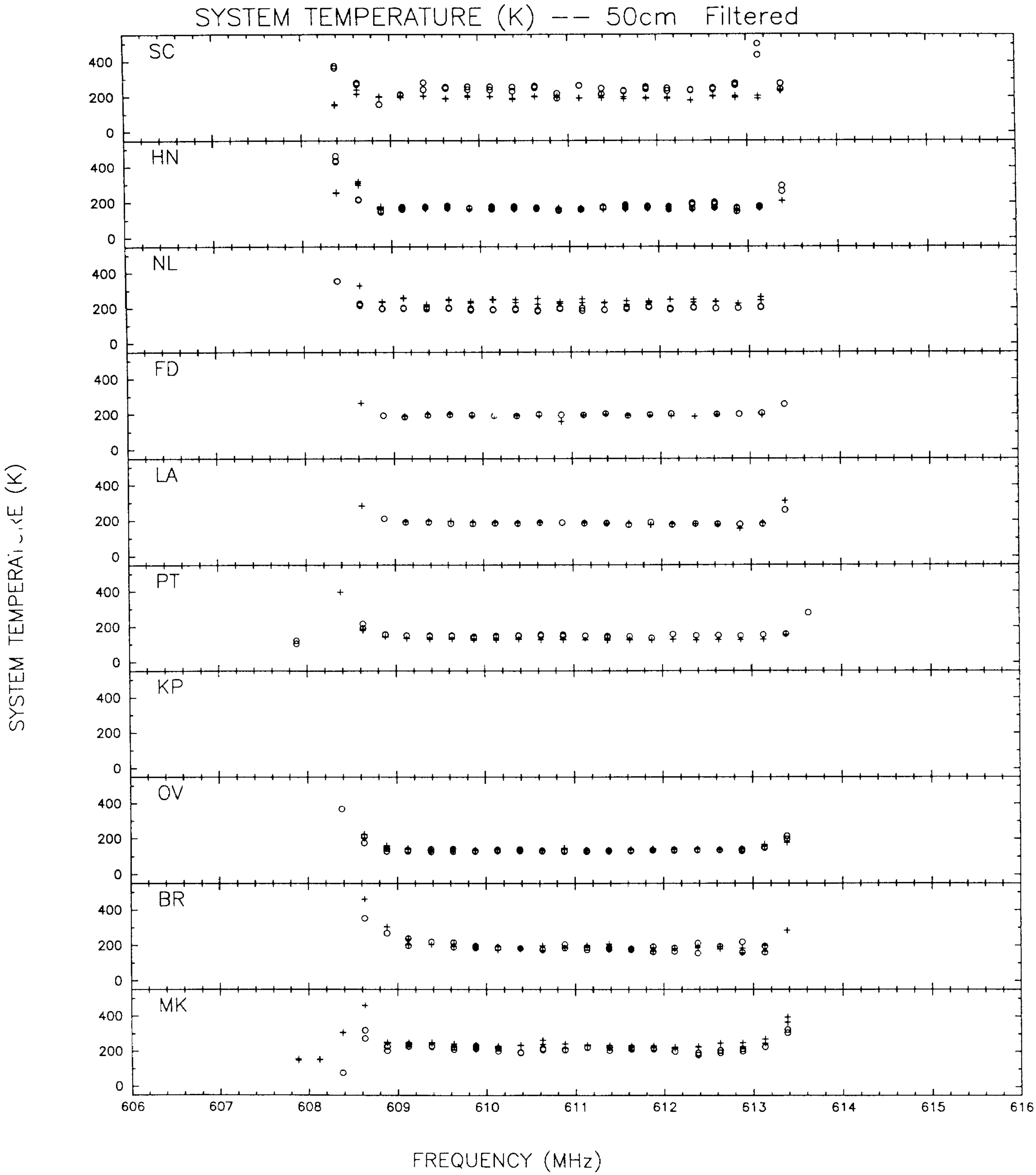
SYSTEM TEMPERATURE (K) -- 50cm



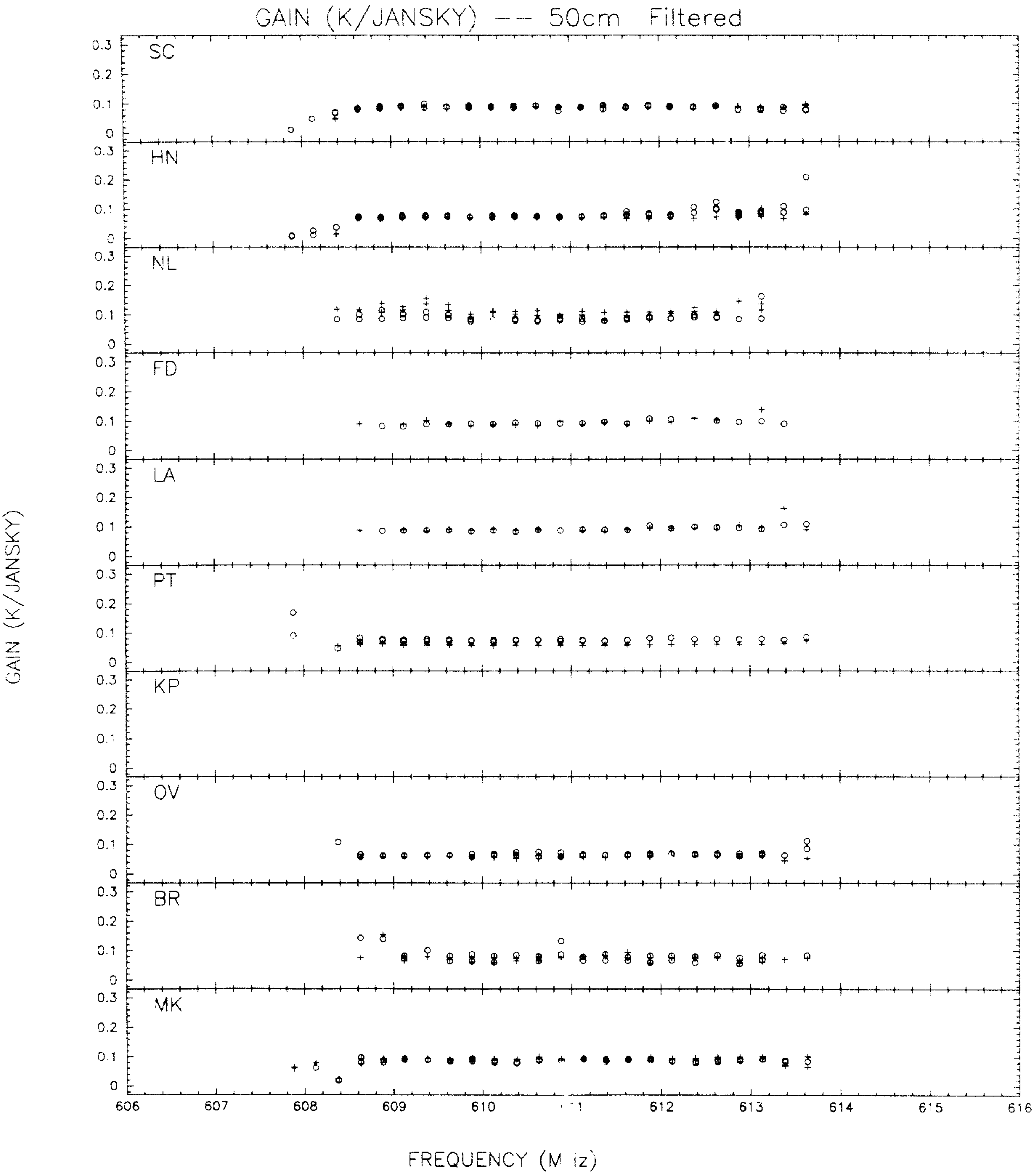
GAIN (K/JANSKY) -- 50cm

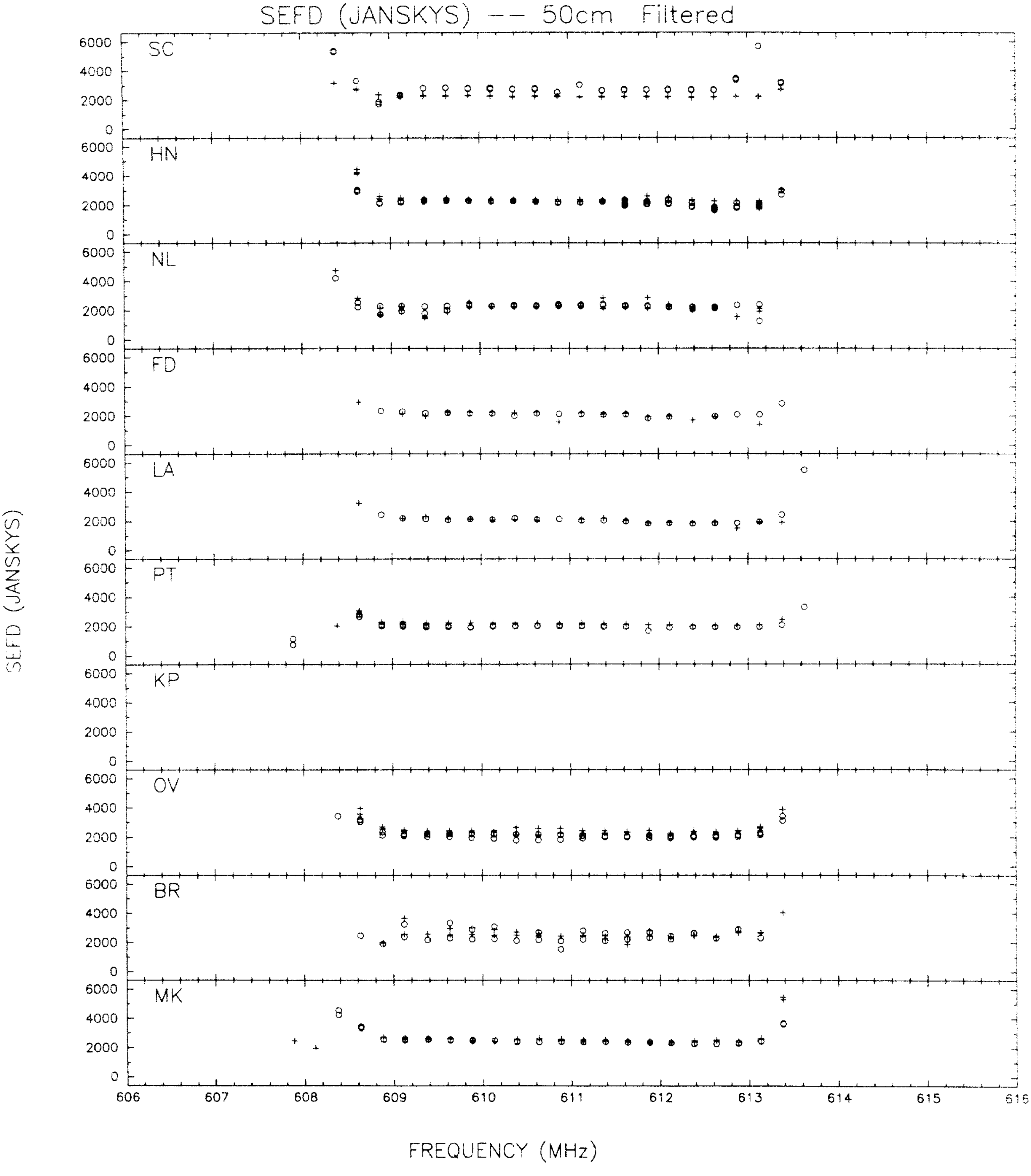



SEFD (JANSKYS) -- 50cm
SC
HN
NL
FD
LA
PT
KP
OV
BR
MK
6000
4000
2000
0
580
590
600
610
620
630
640
SEFD (JANSKYS)
FREQUENCY (MHz)

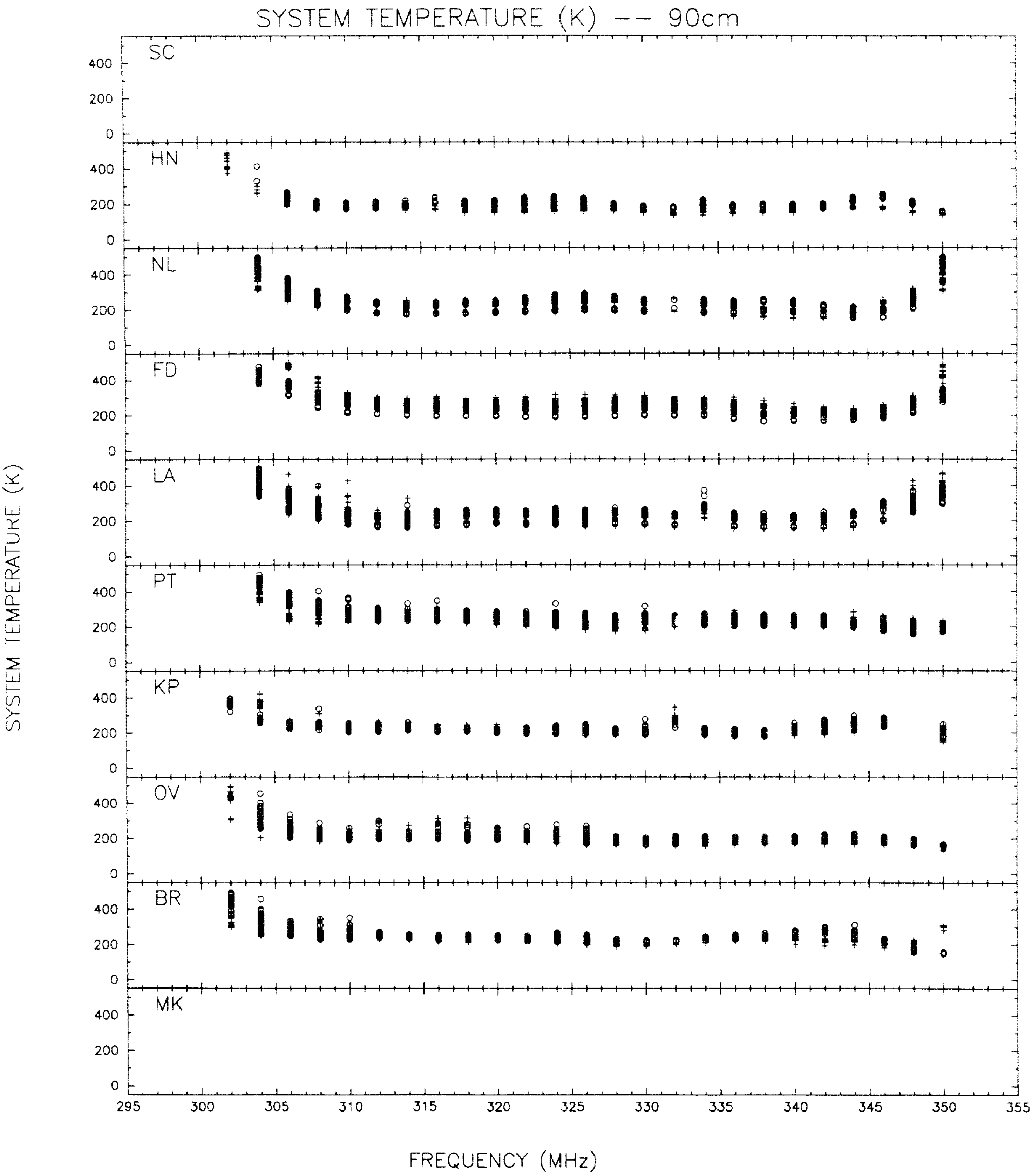


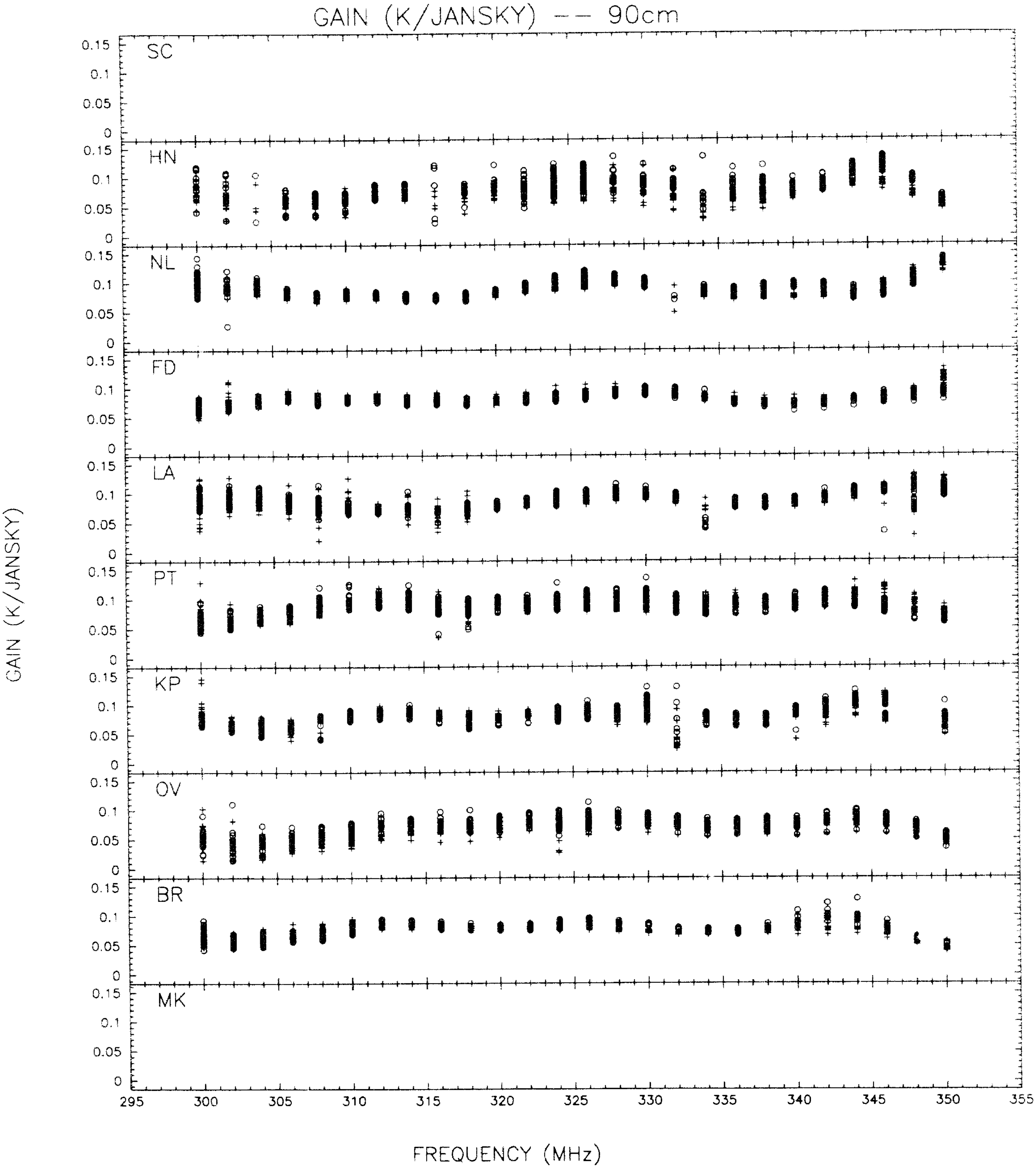
SYSTEM TEMPERATURE (K) -- 50cm Filtered
SC
HN
NL
FD
LA
PT
KP
OV
BR
MK
400
200
0
606
607
608
609
610
611
612
613
614
615
616
SYSTEM TEMPERATURE (K)
FREQUENCY (MHz)

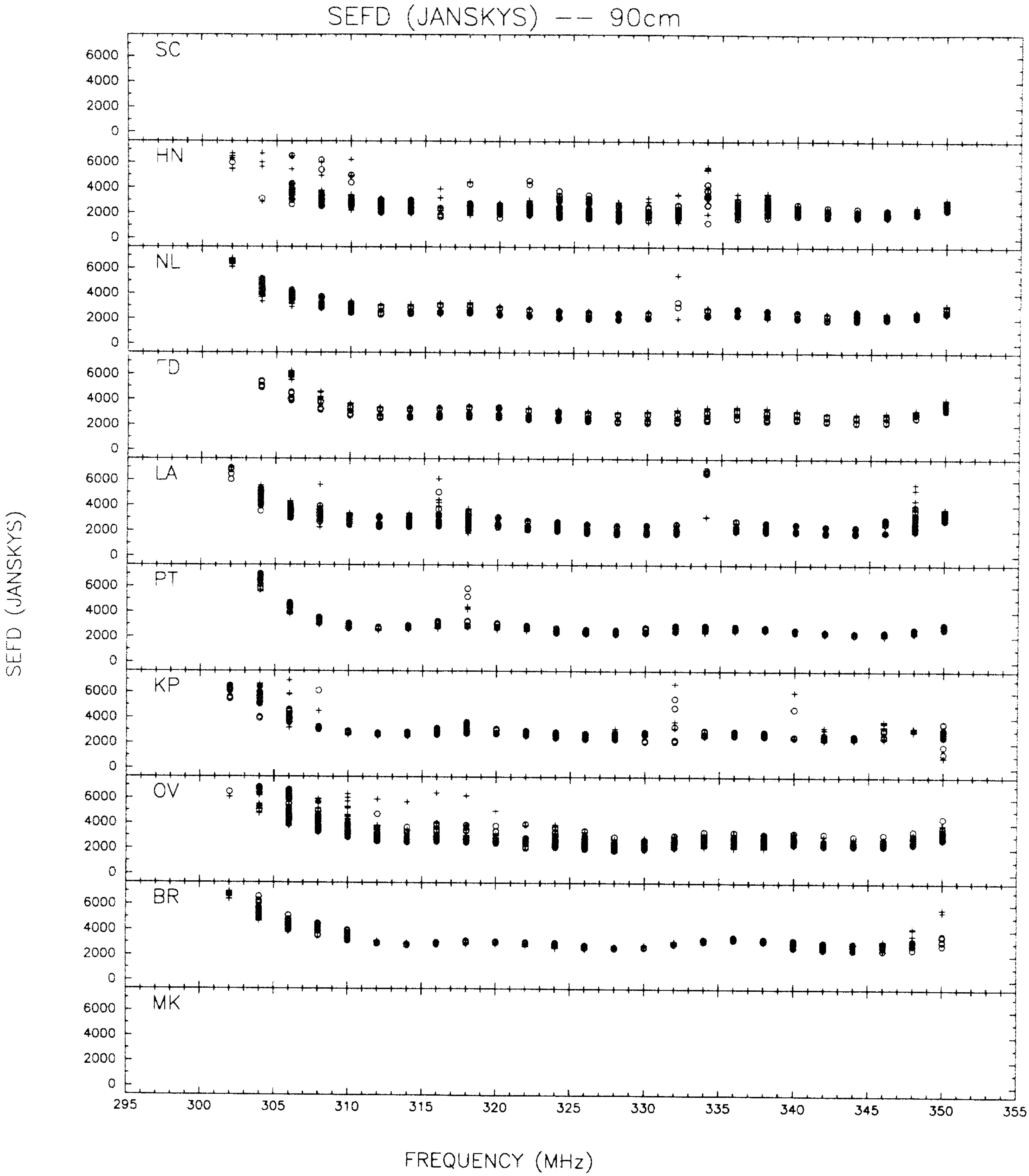

GAIN (K/JANSKY) -- 50cm Filtered
SC
HN
NL
FD
LA
PT
KP
OV
BR
MK
GAIN (K/JANSKY)
FREQUENCY (MHz)



SEFD (JANSKYS) -- 50cm Filtered
SC
HN
NL
FD
LA
PT
KP
OV
BR
MK
SEFD (JANSKYS)
FREQUENCY (MHz)


SYSTEM TEMPERATURE (K) -- 90cm
SC
HN
NL
FD
LA
PT
KP
OV
BR
MK
0
200
400
295
300
305
310
315
320
325
330
335
340
345
350
355
SYSTEM TEMPERATURE (K)
FREQUENCY (MHz)


GAIN (K/JANSKY) -- 90cm
SC
HN
NL
FD
LA
PT
KP
OV
BR
MK
0.15
0.1
0.05
0
295
300
305
310
315
320
325
330
335
340
345
350
355
GAIN (K/JANSKY)
FREQUENCY (MHz)



SEFD (JANSKYS) -- 90cm
SEFD (JANSKYS)
FREQUENCY (MHz)
SC
HN
NL
FD
LA
PT
KP
OV
BR
MK
0
2000
4000
6000
295
300
305
310
315
320
325
330
335
340
345
350
355