Phase Response of VLBA 16-MHz IF Bands

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1 Introduction

This note reports the results of an investigation of the phase response of the 16-MHz VLBI IF bandpasses of the VLBA and VLA. The measurements made use of existing data from a scientific experiment processed by the VLBA correlator. The investigation was motivated by the launch of the VSOP satellite, but it is relevant for any experiment using 16-MHz bandpasses.

The set of VLBA experiments using 16-MHz bandpasses is rather small. Although this is a standard mode, it allows no speedup in correlation, so almost all VLBA experiments use IF bandpasses of 8 MHz or smaller. Several possible experiments for the bandpass phase measurements were identified by Jon Romney; the most suitable of these took place on 3 August 1996, and included a 22-GHz observation of the calibrator 4C 39.25. This observation used one 16-MHz IF with 2-bit sampling, and was correlated with 512 channels. Relevant characteristics of the experiment are summarized in Table 1. Its good points are that it contained a strong calibrator, has high spectral resolution, and also contains a single VLA antenna (antenna 27 at pad N8) . It suffers the disadvantages of including only one IF per station and of containing no usable data from MK, due to poor recording quality.

Table 1: Experiment Properties

Date	Freq.	N_{IF}	Sampling	Chan/IF	Calibrator	Antennas
3Aug96	22 GHz	1	2-bit	512	4C 39.25	VLBA+Y1

2 Bandpass Measurement

2.1 Procedure

The phase characteristics of the 16-MHz bands for the VLBA antennas and for Y1 were measured in a multi-step process, using FD as the reference antenna, since FD showed the smallest scatter in phase across the bandpass during initial tests. First, the data on the calibrator 4C 39.25 were averaged to 64 spectral channels to reduce the computational load, then fringe-fitted using the AIPS task FRING. The four channels on either end of the band (1–4 and 61–64) were not used in the FRING solution. Second, the resulting SN (solution) table was applied to the CL (calibration) table for the data having the full spectral resolution, using CLCAL. Third, BPASS was used to compute the phase characteristics of the bandpass for the scan on 4C 39.25, with the solutions from the fringe-fit applied to remove the source-dependent phase terms. BPASS solutions were computed both with and without spectral averaging applied, and the results were written in BP (bandpass) tables. Fourth, POSSM was used to plot the bandpass for each station and to compute the final statistics.

2.2 Results

The specification in [1] is for a phase ripple of less than 5° across the lower 80% of VLBA bandpasses, and less than 10° across the upper 20% of the band. Table 2 gives the mean and RMS phases for each station, for the entire bandpass, the lower 80%, and the upper 20%. Table 3 gives values for the same quantities with Hanning smoothing applied in BPASS. Smoothing with a width of four channels was found to reduce the RMS phase variations across the bands by about 10–30%. In all cases, channels 1–10 and 503–512 were not used, in order to eliminate the effects of the band edges. The phase characteristics of the bands between channels 11 and 502 (0.3 MHz to 15.7 MHz) are shown in Figures 1 through 5.

The tables show that the RMS phase variations across the 16-MHz bands are less than 2° for all VLBA antennas except HN and SC. At both of these stations, the signal/noise of the fringe fit is considerably lower than for the other stations, apparently because of resolution of 4C 39.25. Therefore, the intrinsic phase characteristics of the 16-MHz bands at these stations are better than indicated; a higher signal/noise observation would be necessary to isolate the intrinsic properties. The upper 20% of the bands for each station show little increase in phase noise when compared to the lower 80%. At about half of the VLBA stations (notably HN, KP, PT, and SC), there is evidence for a slight roll-off of $\sim 5°$ in the phase in the upper $\sim$ 10% of the band (see figures as well as mean values of lower and upper parts of the bands in Table 2). Even taking this into consideration, it appears that the 16-MHz channels for all VLBA stations meet the phase specification given above.

The VLA (Y1) data were acquired with the VLA filters set to their full bandwidth of 50 MHz. The performance of the 16-MHz VLBI bandpass from Y1 is somewhat worse than for the VLBA stations, and does not meet the VLBA specifications. As Figure 5 shows, there is a phase ripple across the band, with almost two cycles across 16 MHz, and considerable phase noise at the upper end of the band. This may cause a slight degradation in the VLBI data on ground baselines due to the mismatched bandpasses. For space VLBI observations, the phase characteristics are at least as good as the VSOP spacecraft, so the VLA is unlikely to cause significant degradation on the space-ground baseline.

3 Acknowledgments

I thank Jon Romney for identifying the possible experiments for these measurements, and Phil Diamond for communicating the proper inputs for BPASS.

References

[1] VLBA Project Book, Version 7, October 1, 1988.

Table 2: Phase Characteristics of 16-MHz Bandpass — No Smoothing

Antenna	100% of Band		Lower 80%		Upper 20%	
	Mean (deg.)	RMS (deg.)	Mean (deg.)	RMS (deg.)	Mean (deg.)	RMS (deg.)
BR	0.06	1.82	0.02	1.81	0.22	1.86
FD	0.00	0.00	0.00	0.00	0.00	0.00
HN	0.02	3.48	0.76	3.04	−3.16	3.49
KP	−1.06	2.22	−0.46	1.75	−3.59	2.23
LA	0.02	1.51	0.10	1.42	−0.34	1.79
NL	1.01	1.63	1.17	1.57	0.31	1.70
OV	−1.27	1.47	−1.18	1.38	−1.63	1.75
PT	−0.37	2.19	−0.04	1.76	−1.81	3.06
SC	−2.35	5.90	−1.94	5.76	−4.12	6.15
Y27	−2.77	13.7	−1.22	14.0	−9.41	10.1

Table 3: Phase Characteristics of 16-MHz Bandpass — Hanning Smoothing

Antenna	100% of Band		Lower 80%		Upper 20%	
	Mean (deg.)	RMS (deg.)	Mean (deg.)	RMS (deg.)	Mean (deg.)	RMS (deg.)
BR	0.06	1.40	0.02	1.42	0.23	1.34
FD	0.00	0.00	0.00	0.00	0.00	0.00
HN	0.02	2.97	0.76	2.53	−3.15	2.58
KP	−1.05	1.98	−0.46	1.47	−3.58	1.89
LA	0.02	1.07	0.10	0.99	−0.33	1.28
NL	1.01	1.20	1.17	1.17	0.31	1.09
OV	−1.26	1.10	−1.18	1.04	−1.62	1.30
PT	−0.37	1.91	−0.04	1.44	−1.81	2.81
SC	−2.32	4.16	−1.90	4.05	−4.15	4.15
Y27	−2.77	13.4	−1.21	14.0	−9.49	7.29

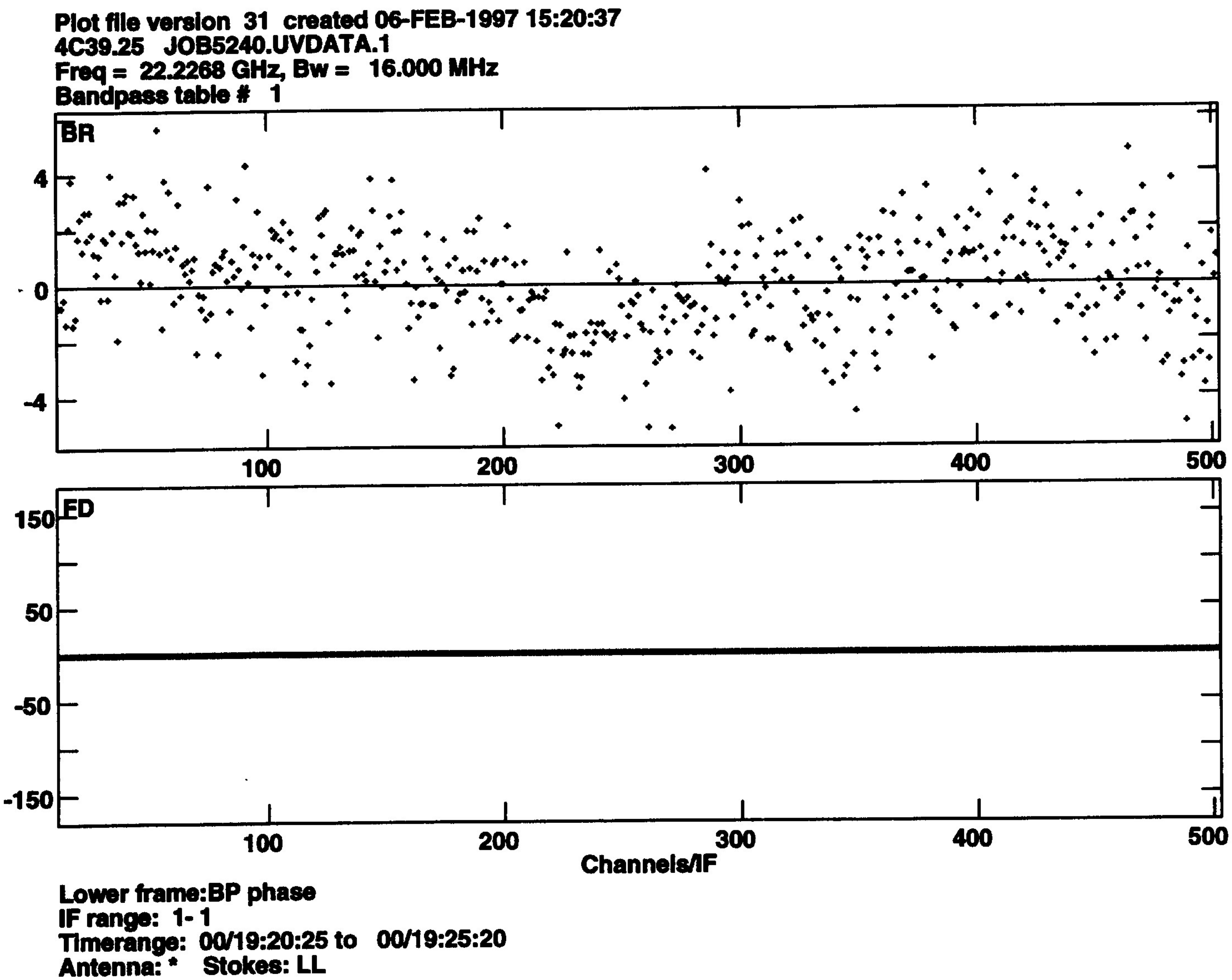

Figure 1: Phase characteristics of 16-MHz bandpasses for BR and FD (reference antenna). Frequencies between 0.3 and 15.7 MHz are plotted.

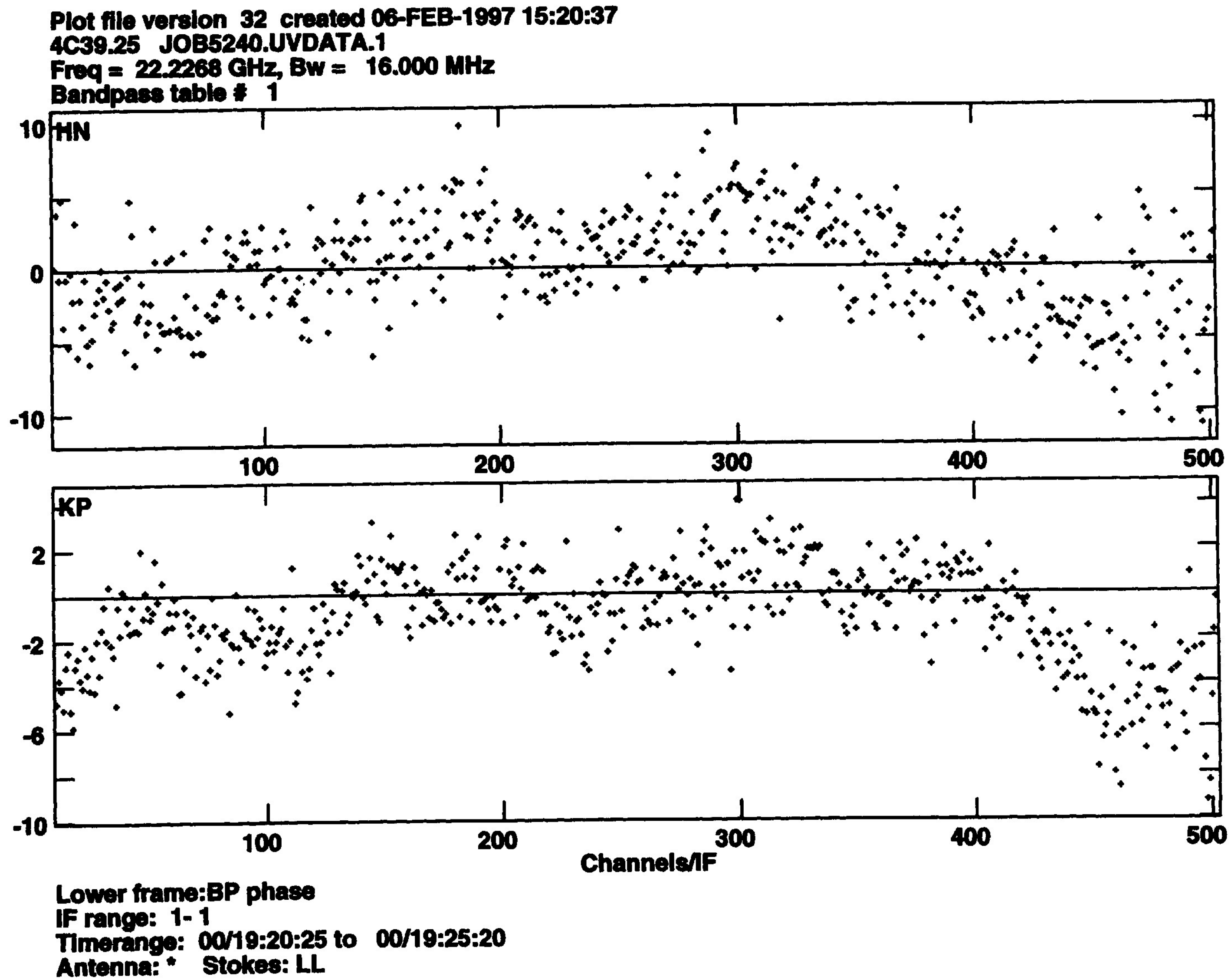

Figure 2: Phase characteristics of 16-MHz bandpasses for HN and KP. Frequencies between 0.3 and 15.7 MHz are plotted.

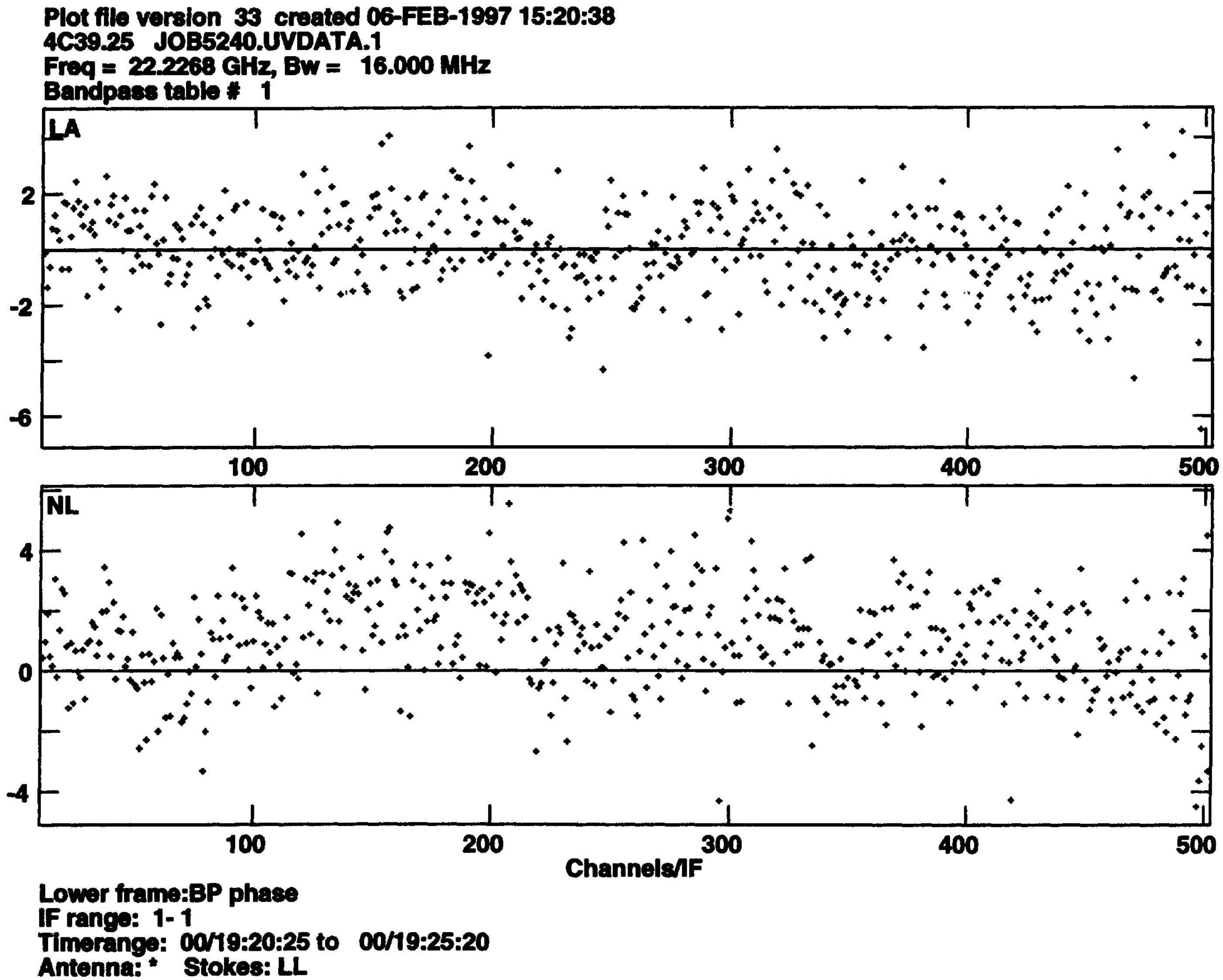

Figure 3: Phase characteristics of 16-MHz bandpasses for LA and NL. Frequencies between 0.3 and 15.7 MHz are plotted.

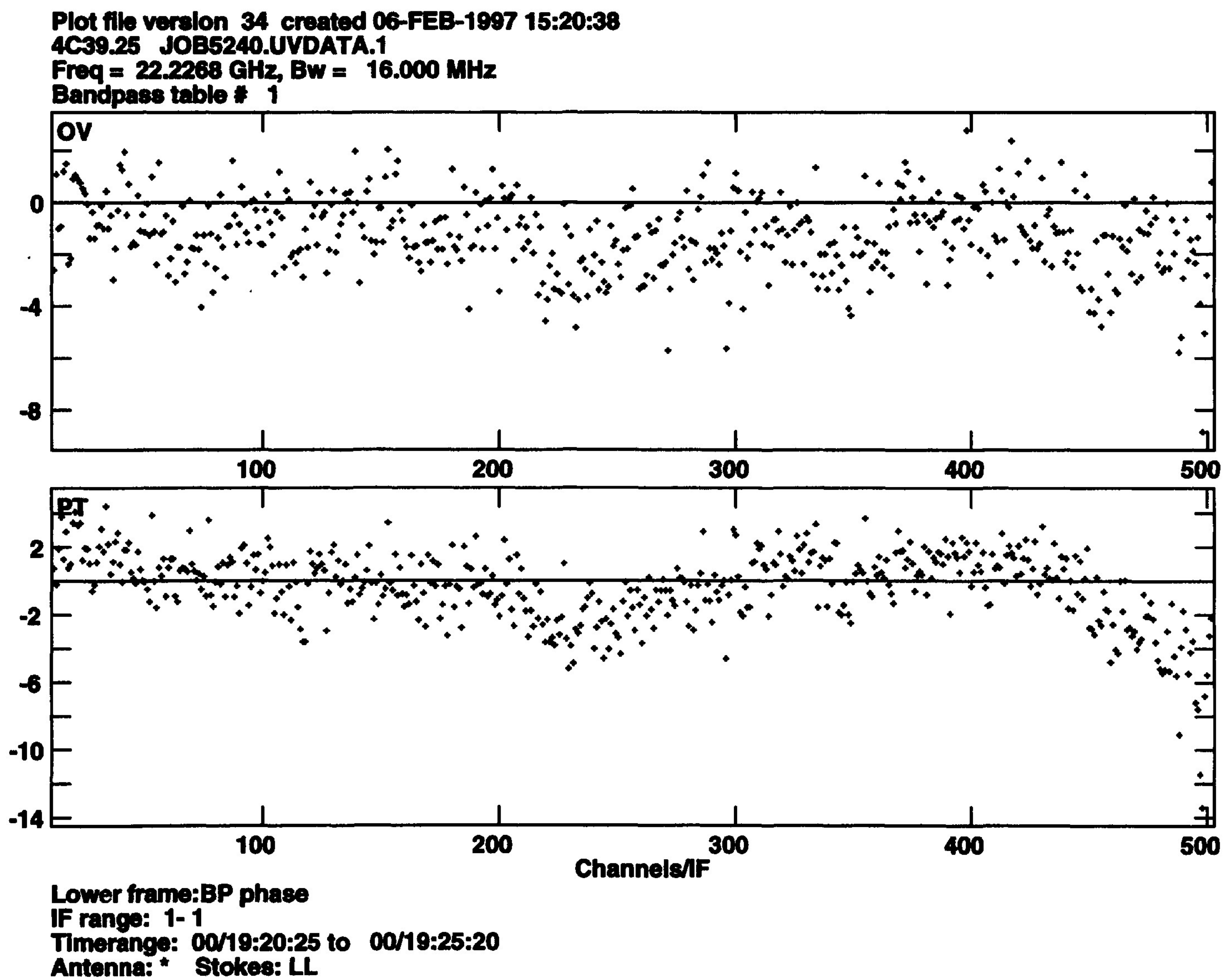

Figure 4: Phase characteristics of 16-MHz bandpasses for OV and PT. Frequencies between 0.3 and 15.7 MHz are plotted.

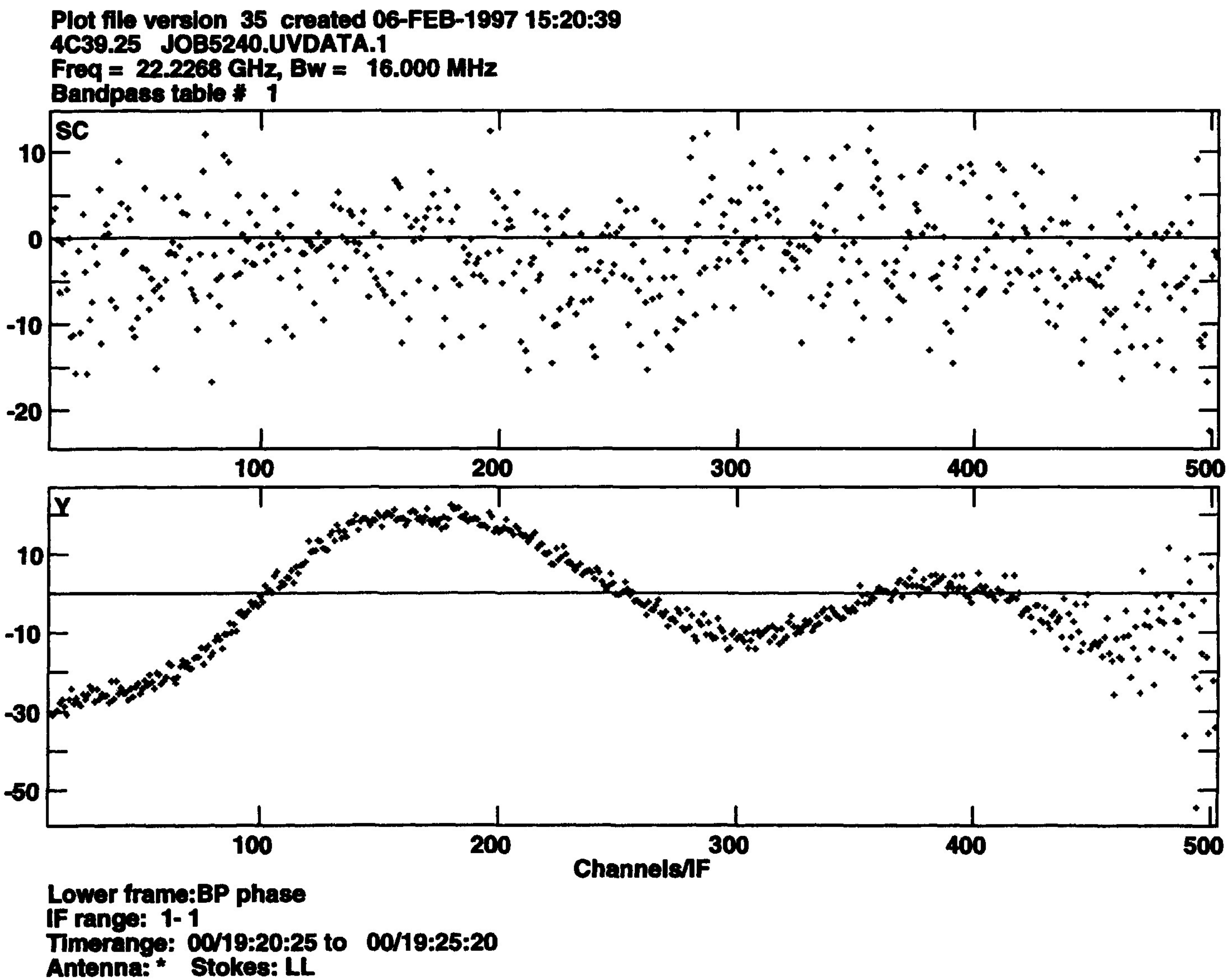

Figure 5: Phase characteristics of 16-MHz bandpasses for SC and Y1. Frequencies between 0.3 and 15.7 MHz are plotted.