

L404B On Sky Phase Stability

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Abstract This memo describes the results of on the sky testing of the L404B LO compared to the L404A in terms of phase stability. No significant difference between the L404A and L404B are found.

1 Background

L404B synthesizers have been deployed across the full VLBA array, with one L404B replacing both the old L104.1 and L104.2. The L404 went through two revisions: an L404A and an L404B. During the deployment it was requested that the one L404A at Los Alamos (LA) remained, becoming the last station to go to an L404B. On Feb 21 2025 a final on sky test comparing the L404B phase noise to the L404A phase noise was conducted (exp code TL017B) and the results thereof are described here. After this date the Los Alamos site and thus all VLBA stations transitioned to using the L404B.

2 Experiment Setup

The on sky test (TL017B) ran on Feb 21 2025, and observed 12 different setups/bands as described in table 1. Of these data taken, the 'U', '4cm-Rbbdd' and 'L' setup data are examined here. 'U' for its relatively long 18 minute scan to check for any phase jumps or unexpected slopes, 'L' for a low synthesizer frequency and '4cm-Rbbdd' as it allows for simultaneous comparison between the L404B and L104.3 on the same baseline. Each setup observed the source 3C84. It should be noted that 3C84 is resolved on VLBA scales and this complicates analysis slightly.

Setup	Band	Sky Freq (GHz)	L404 Freqs (GHz)	Bandwidth	Scan Length
SX	SX	8.5/2.3	9.4/2.9	4 × 32 MHz per pol	3 × 3 min
U	2cm	12.6	12.1	2 × 16 MHz per pol	1 × 18 min
X	4cm	8.4	7.9	2 × 16 MHz per pol	1 × 3 min
C	6cm	4.2/7.8	8.6/3.6	2 × 16 MHz per pol	1 × 3 min
S	13cm	2.2	3.1	2 × 16 MHz per pol	1 × 3 min
L	20cm	1.4	2.1	2 × 16 MHz per pol	1 × 3 min
6cm-HIGH	6cm	7.0	7.9/7.6	2 × 16 MHz per pol	8 × 3 min
6cm-LOW	6cm	4.7	4.1/3.9	2 × 16 MHz per pol	8 × 3 min
4cm-Rbbdd	4cm	8.2	7.4/9.6(L104.3)	4 × 16 MHz RCP	8 × 3 min
4cm-RLbd	4cm	8.2	7.4	2 × 16 MHz per pol	8 × 3 min
thermal.2cm	2cm	15.2	14.6	2 × 16 MHz per pol	4 × 15 min
thermal.20cm	20cm	1.6	2.4	2 × 16 MHz per pol	4 × 15 min

Table 1: The setups used in the TL017B L404B test. Setups 'U', 'L' and '4cm-Rbbdd' are examined in this document.

3 ‘U’ Setup Analysis

3.1 Phase Stability

The data were loaded into AIPS using task FITLOAD with default parameters except for CLINT 0.1 in case short timerange solution intervals might be used. AIPS task POSSM was used to check data for RFI free spectral channels (no RFI was seen), then the AIPS task VPLOT was used to make plots and export the phase data with respect to time for a single 0.25 MHz bandwidth spectral channel (spectral channel 30) of IF 2 in RCP. As shown in Figure 1 no phase jumps are seen during the scan, and the longer term phase stability of baselines to the L404A station (LA) looks by eye to be very similar to L404B - L404B stations. Note no fringe fitting was performed so baselines were selected here to have both similar baseline length and that happened to not wrap in phase throughout the scan.

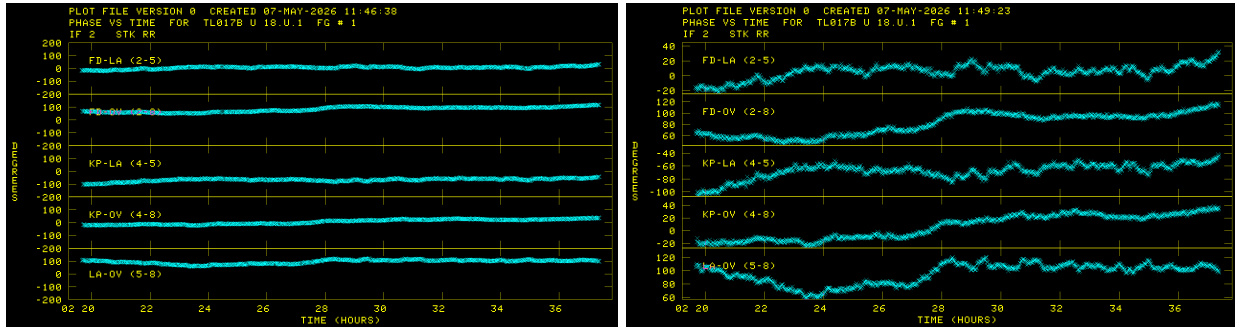


Figure 1: Phase vs time for a single RCP, 0.25 MHz spectral channel (30) in IF two for baselines to the L404A station (LA) and similar baseline length non L404A stations using the ‘U’ setup described in Table 1. The left shows the data for the full 360° phase range, and the right panel shows the same data with autoscaling applied.

3.2 Phase RMS

To investigate the phase stability further VPLOT was then used to export phase rms vs time for 30 s averaging periods (solint=0.5). This averaging was chosen to show fairly smooth lines. The resulting plot is shown in Figure 2. Note all baselines to MK and SC have been excluded here as they show much higher phase rms as the source is resolved. The plot is fairly messy and it is clear source structure is playing a major role in phase rms (remember phase rms is essentially 1/SNR, and longer baselines will have less signal for a resolved source). Still there is no major difference between the L404A - L404B baselines (baselines to LA) and L404B - L404B baselines.

BL	U (Prms)	L (Prms)	4cm-Rbbdd
FD-KP	0.90	1.71	0.85
FD-PT	1.40	1.45	1.20
KP-OV	1.40	—	1.11
KP-PT	1.55	1.66	1.15
OV-PT	1.58	—	1.36
LA-OV	1.50	—	1.52
LA-PT	1.67	1.58	1.44
FD-LA	1.61	1.78	1.45
KP-LA	1.90	2.02	1.36

Table 2: Median Phase RMS for all baselines with length below 1200 km for all the setups analysed here.

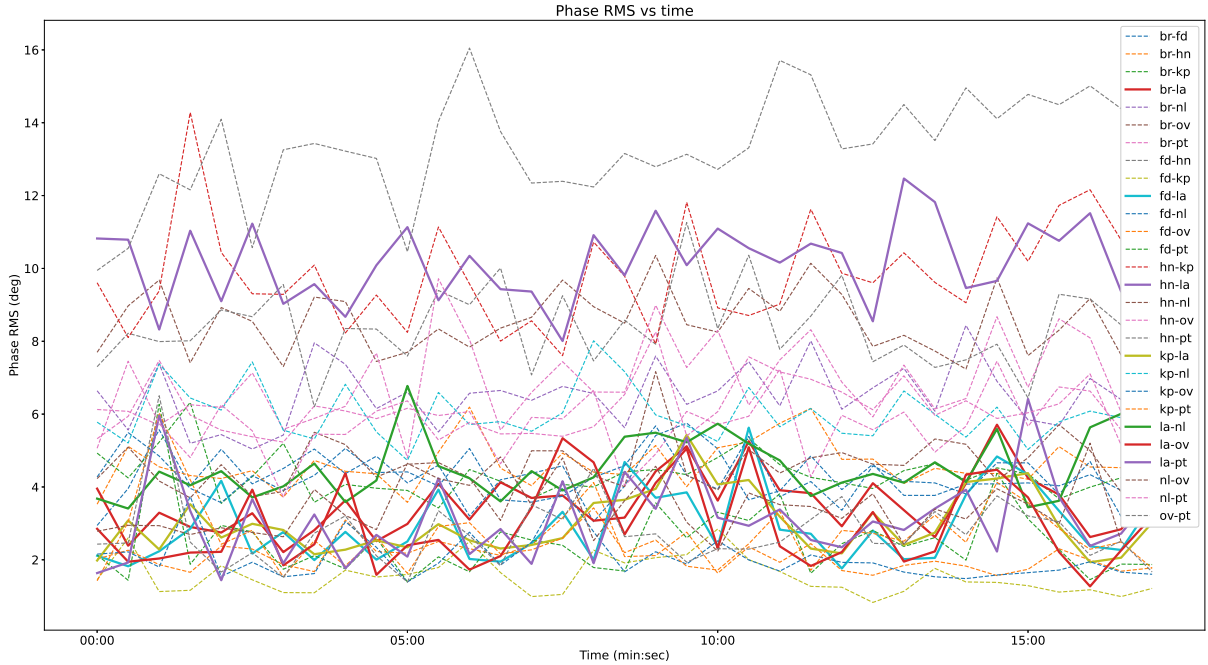


Figure 2: Phase RMS vs Time for all baselines in the TL017B L404 test using setup ‘U’ as described in Table 1. The solid bold lines are for baselines to the L404A station Los Alamos (LA).

In an attempt to disentangle source structure from this analysis the median rms was calculated for the full scan for each baseline and plotted against the associated baseline length. The result is shown in Figure 3. Note that there will be additional effects due to source structure and baseline direction not accounted for in this as the source is not a gaussian (it has a complicated morphology and multiple components). Still as seen in Figure 3 the median phase rms is very comparable for L404A-L404B baselines and L404B-L404B baselines of similar baseline lengths. As the median phase rms of L404B-L404B baselines is comparable to or better than that of the L404A-L404B baselines at similar baselinge lengths this is a pretty good indication that the L404B performance is as good or better than the L404B performance. There is little apparent difference in structure detected on baselines of length < 1200 km. So the median phase rms on these baselines can be compared quantitatively. Table 2 shows these. Taking the average and stderror gives average phase rms of 1.67 ± 0.15 deg for L404A-L404B baselines and 1.37 ± 0.25 deg for L404B-L404B baselines.

4 ‘L’ Setup Analysis

A similar analysis as described in Section 3 was performed. Unfortunately OV had some issues at L-band during this time and has thus been excluded from this analysis. A solint of 0.1 min = 6 seconds was used for the averaging time given the shorter scan. Here IF 1 spectral channel 30 was used to avoid some RFI seen in IF 2. Figure 4 shows the median phase rms vs baseline length for this setup. Note again that the L404B-L404B performance appears as good or better than the L404A-L404B phase rms. Again for baseline lengths below 1200 km the structure appears quite stable allowing quantitative analysis, however here the lack of OV is felt more acutely. Taking the average and stderror gives average phase rms of 1.79 ± 0.18

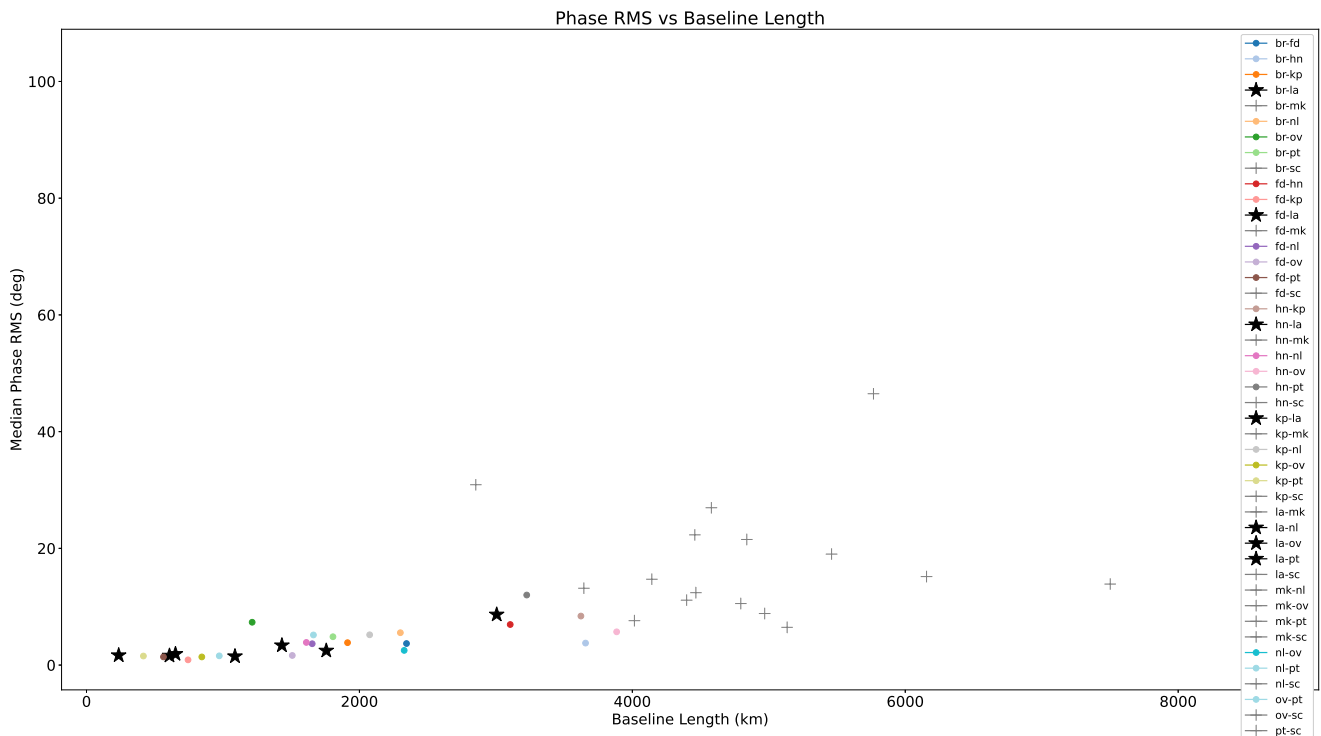


Figure 3: Median Phase RMS vs baseline length for all baselines in the T1017B L404 test using setup 'U'. Solid points are L404B-L404B baselines, black stars are L404A-L404B baselines (baselines to LA) and grey pluses are baselines to MK and SC. Note the MK-SC baseline has been excluded entirely as it is further off the scale.

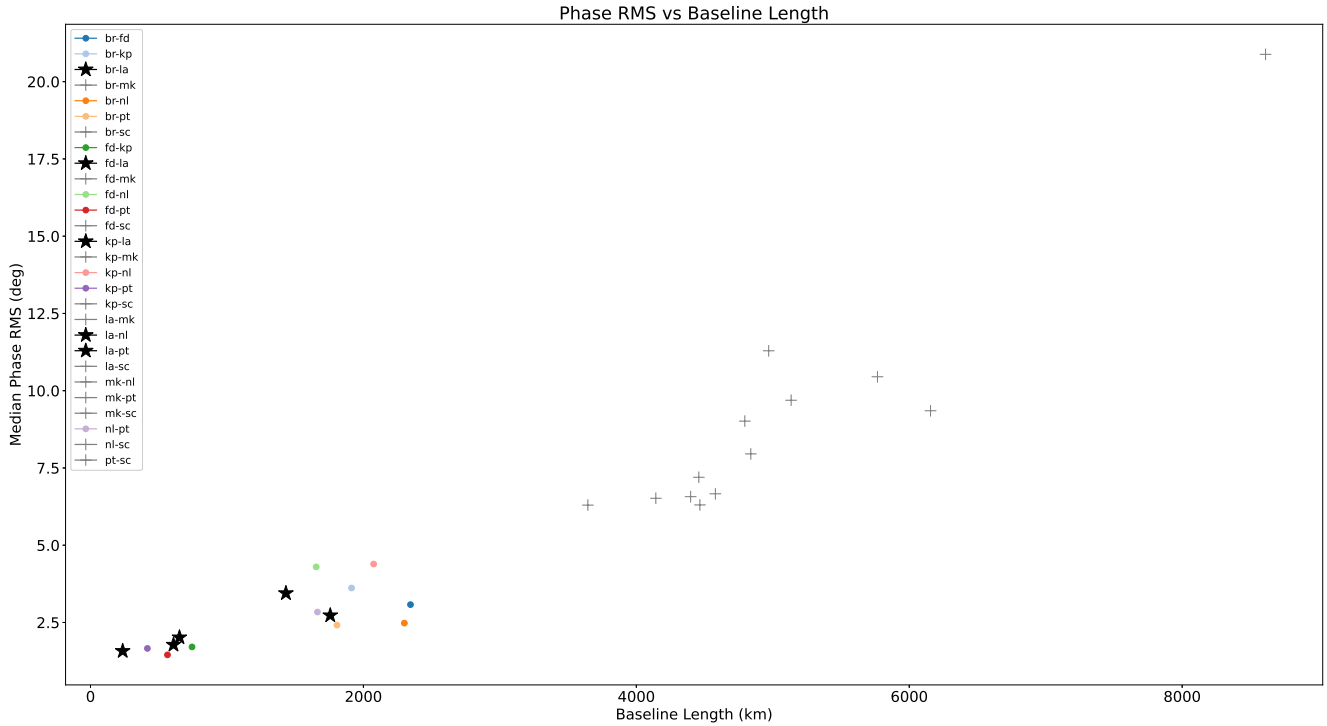


Figure 4: Median Phase RMS vs baseline length for all baselines in the T1017B L404 test using setup ‘L’. Solid points are L404B-L404B baselines, black stars are L404A-L404B baselines (baselines to LA) and grey pluses are baselines to MK and SC. Note the MK-SC baseline has been excluded entirely as it is further off the scale, and OV has been excluded due to L band issues at the site.

deg for L404A-L404B baselines and 1.60 ± 0.11 deg for L404B-L404B baselines. Again the phase rms for L404B-L404B is comparable to or better than for the L404A-L404B baselines.

5 ‘4cm-Rbbdd’ Setup Analysis

A similar analysis as described in Section 3 was performed. As this setup was run for eight three minute scans separated in time, a solint of 0.5 min = 30 seconds was again used for the averaging time. Note that for following analysis the gaps between scans were removed. No sign of jumps or ramps was seen at the start or end of scans. Here IF 1 spectral channel 30 was used. Figure 5 shows the median phase rms vs baseline length for this setup. Note again that the L404B-L404B performance appears as good or better than the L404A-L404B phase rms. Again for baseline lengths below 1200 km the structure appears quite stable allowing quantitative analysis. Taking the average and stderror gives average phase rms of 1.44 ± 0.06 deg for L404A-L404B baselines and 1.13 ± 0.17 deg for L404B-L404B baselines. Again the phase rms for L404B-L404B is comparable to or better than for the L404A-L404B baselines.

This setup is special as it uses the L104_3 for the upper two IFs (IF 3 and 4). While the frequencies are not identical (≈ 8.2 and ≈ 8.8 GHz respectively) this does still allow for a simultaneous comparison of phase stability at similar frequencies for the same baselines between the old L104_3 and the L404A (at LA)

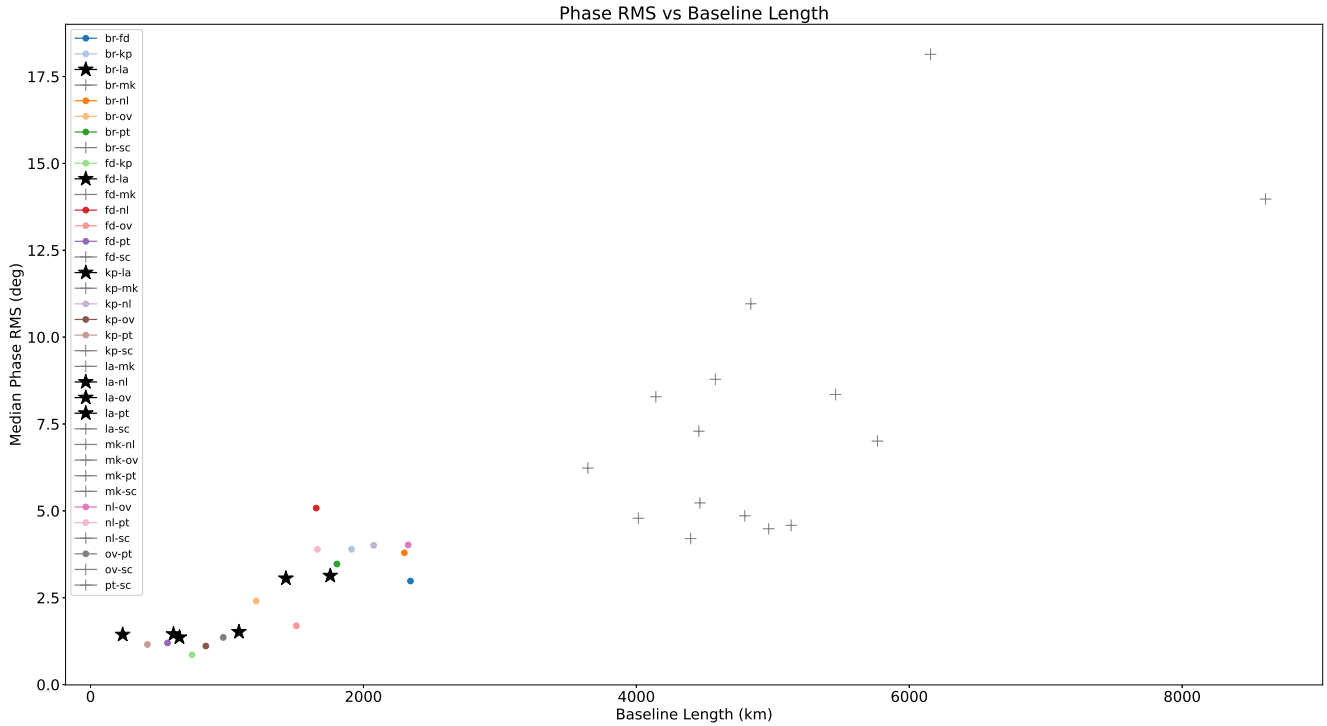


Figure 5: Median Phase RMS vs baseline length for all baselines in the Tl017B L404 test using setup ‘4cm-Rbbdd’. Solid points are L404B-L404B baselines, black stars are L404A-L404B baselines (baselines to LA) and grey pluses are baselines to MK and SC. Note the MK-SC baseline has been excluded entirely as it is further off the scale.

and L404B (at other stations). SC and MK have once again been excluded from the analysis due to the extremely long baseline lengths and associated lower SNR as the source is resolved out. Figure 6 shows the comparison between the L404A and L104.3 at Los Alamos (LA). There appears to be a good agreement on phase noise comparing these two synthesizers across various baselines.

Similarly Figure 7 shows the comparison between the L404B and L104.3 at Pie Town (PT). There appears to be a good agreement on phase noise comparing these two synthesizers across various baselines, with perhaps a slight improvement in phase noise visible in the L404B data. Please note again that the setup used sets sky frequencies of ≈ 8.2 and ≈ 8.8 GHz and thus some difference is expected.

6 Acknowledgements

Thanks to Eric Greisen for adding the ability to output data from the AIPS task VPLOT in support of these analyses, and to Lilia Tremou for sanity checking.



Figure 6: Phase RMS vs time, calculated over 30 second solution intervals, comparing the phase rms of the L404A at Los Alamos (solid lines) with the L104.3 (dashed lines) by plotting spectral channel 30 of IFs 1 and 3 respectively. Note the setup ends up with sky frequencies of around 8.2 and 8.8 GHz for the L404A and L104.3 respectively so the data are not quite one to one. Note also these data come from 8, 3 minute scans with gaps removed here.



Figure 7: Phase RMS vs time, calculated over 30 second solution intervals, comparing the phase rms of the L404A at Pie Town (solid lines) with the L104.3 (dashed lines) by plotting spectral channel 30 of IFs 1 and 3 respectively. Note the setup ends up with sky frequencies of around 8.2 and 8.8 GHz for the L404A and L104.3 respectively so the data are not quite one to one. Note also these data come from 8, 3 minute scans with gaps removed here.