Preliminary correlation report for Fall 2019 GMVA session (c192) addressing the "no VLBA fringes" issue

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Summary

As ALMA is used for VLBI at 3mm, it is important to further improve the performance of the VLBA at 3mm. Unfortunately, the last GMVA session of October 2019 (c192) revealed severe problems with the performance of the VLBA and must be regarded as a complete failure. Apparently fringes come and go for individual VLBA stations, while European stations performed well. At the VLBA and at the times, when the fringes are visible, the fringe peak and quality corresponds to expectations. However for the majority of VLBI scans no fringes at the VLBA are visible. It is particularly strange, that even after pointing on strong sources (e.g. 3C84) fringes seem to disappear. This indicates a severe problem in the logic of the pointing system and how the antenna pointing is applied. This needs further checks. Since the effort which is put into GMVA observation is huge, both in terms of manpower and observing time, it will be extremely important to fix these issues, before we can call for a new observing sessions. We recommend to form a task force with the aim to identify and remove possible malfunctions at the VLBA.

Preliminary correlation description

Preliminary correlation of a number of scans targeting four bright sources was performed for all 8 VLBA antennas (Br, Fd, Kp, La, Mk, Nl, Ov, Pt) and two EVN antennas (Ef and On) as reference. The correlated scans included 6 scans targeting 3C345 of c192a experiment, and 15 scans targeting 3C345, 6 scans targeting 1633+38, 23 scans targeting 3C454.4, and 2 scans targeting 3C84 – all the latter of c192b experiment.

The reason for this testing was to check what appeared to be unusually low number of VLBA fringes seen during fringe searching for this session. The results show that, indeed, the number of fringes is much lower than expected and, when fringes are found, the corresponding SNR is also sometimes lower than expected. Worse than that, non-detections, low SNR fringes and high SNR fringes seem to randomly oscillate for each VLBA baseline.

Otherwise the recorded data is be healthy and shows no abnormalities. All correlation weights were either identical or very close to 1.000. All fringes show parallel-hands SNR significantly larger than cross-hands SNR, thus excluding the possibility of a polarization swap.

In the tables 1 – 4 the columns give the number of correlated baselines for different scans (only LL and RR included in this statistics), number of baselines with fringes, and mean SNR for the baselines with fringes. Numbers after slash include only VLBA stations, i. e. exclude Ef and On. For each table the corresponding average SNR for the EfOn baseline is given after the table.

Figures 1 and 2 show the overview of the correlated scans. Each box corresponds to LL (left box) or RR (right box) for each scan and baseline, baselines are designated by combinations of single-letter codes: b,f,k,l,m,n,o,p = Br, Fd, Kp, La, Mk, Nl, Ov, Pt; B = Ef and X = On. Boxes with different shades of green indicate fringes, including even marginal ones with SNR below 7, red boxes indicate no fringes, empty boxes are those with missing data or not correlated, and white space with no boxes corresponds to non-scheduled intervals.

In addition to thorough checking of the vex files and the data, two sanity checks were performed to make sure that the correlation configuration is correct and there is no frequency band misalignment. 1. A separate correlation was performed only for the VLBA stations in the simplest way possible, with no zoom bands, basically correlating stations to each other "as is". 2. In one scan a separate fringe search was performed for each frequency channel of 8 recorded. Neither approach changed the results, and no "empty" frequency bands were found.

Analysis

3C345 and 1633+38 scans, although illustrating the problem, are mostly inconclusive since the sources are relatively weak. But scans targeting brighter 3C454.3 and 3C84 are more revealing. SNR is sometimes higher than 100 for inter-VLBA baselines, and going from 100+ SNR to no fringe in consecutive scans is difficult to explain with weather or similar random factors.

Especially interesting are scans 205 and 206 targeting 3C84 (see table 5). These are "consecutive" (except for pointing, see below) scans of equal length observing the target at a similar high elevation and under similar weather conditions. In scan 205 BrOv SNR (LL/RR) is 143/136, MkOv 54/50 and OvPt 61/53. In 206 none of these fringes are even detected, in fact barely any fringes at all can be seen. On the other hand, there is an EfMk fringe in both 205 and 206 with similar SNR of about 13, and as for EfOv, there is a good fringe in 205, with SNR of about 30, but none in 206. Such behavior is not possible in case of most software-related problems or something along the lines of wrong data structure or correlation misconfiguration. It seems that there is no permanent attenuation or filtering, rather some VLBA antennas just "flicker" on and off. The only significant difference between scans 205 and 206 was that there was a pointing scan before 206 (in "pointing" numbering, i. e. with the pointing scans included, these scans are 618 and 621, with about 4 min pointing reference scans 619-620 on the same source, 3C84). There was no pointing scan before scan 205, and, it is interesting to note, that in the previous scan 204 on 3C454.3 there are also clear fringes for the same baselines BrOv (SNR about 30), MkOv (about 33) and OvPt (about 15), which did not disappear despite slewing to a different source and not repointing.

A similar situation can be observed in scans 161, 165, and 169 targeting 3C454.3 (scans 533, 541, and 548 in the "pointing" numbering). In between these scans another target (CTA102) is observed and VLBA pointing scans performed on 3C454.3. The correlation results are shown in table 6. We again see a sharp contrast between non-detections and SNRs as high as 182.

Table 7 shows another example of fringes appearing, disappearing and rapidly changing SNR for a single baseline MkOv on 3C345. The first scan has a low fringe, the second has a non-detection in LL and marginal detection in RR, then SNR jumps by a factor of 2 for two scans, and then there is a complete non-detection. It is notable that this coming and going of fringes does not seem to depend on the choice of the pointing source, since for UHer we see fringe detections and non-detections in 3 different scans. If UHer were too faint for pointing, then the UT00:00 scan would not have had such a high SNR.

Figure 3 shows fringe SNR vs UT time for 6 baselines based on 3C454.3 scans of c192b. Fringe detections flicker on and off, immediately jumping to high SNRs not even in concert with each other.

Finally, Figure 4 displays full *fourfit* fringe plot for scan 159 ("pointing" No. 528, day 278 UT03:15-22) of c192b, source 3C454.3, baseline FdOv, RR. The amplitude vs time portion of this figure demonstrates that not only between scans, but even within a single scan the amplitude can drift down by a factor of 2. And the smooth fringe rate spectrum indicates that the phase coherence is quite good. It provides evidence against likelihood of low SNR in other scans being due to bad LO stability or similar problems.

Overall we are inclined to believe that all this points towards serious problems with the pointing of the VLBA.

Acknowledgements

Thomas Krichbaum, Helge Rottmann and Jan Wagner contributed to this report by both advice and data analysis. Thomas Krichbaum also wrote the summary and made Figure 3.

Tables

Table 1. c192a scans with 3C345

ant	correlated baselines / VLBA only	found fringes /VLBA only	mean SNR /VLBA only
Br	94/82	22/15	13.9/14.5
Fd	94/82	9/9	13.4/13.4
Kp	94/82	4/4	9.6/9.6
La	94/82	19/15	14.8/15.3
Mk	78/70	18/12	13.2/12.7
Nl	94/82	11/5	10.7/12.4
Ov	94/82	45/34	17.9/18.9
Pt	94/82	11/8	18.5/22.2
Ef	52	27	84.0
On	52	22	100.1

EfOn baseline mean SNR: 333.3

Table 2. c192b scans with 3C345

ant	correlated baselines / VLBA only	found fringes /VLBA only	mean SNR /VLBA only
Br	226/182	9/5	14.8/16.6
Fd	210/166	49/29	12.9/12.0
Kp	198/162	27/16	13.2/15.3
La	220/176	27/19	11.7/12.0
Mk	150/126	27/11	19.5/18.4
Nl	198/154	3/1	8.0/7.4
Ov	226/182	42/32	21.3/19.4
Pt	220/176	14/13	9.6/9.7
Ef	184	56	79.0
On	184	60	75.7

EfOn baseline mean SNR: 177.3

Table 3. c192b scans with 1633+38

ant	correlated baselines / VLBA only	found fringes /VLBA only	mean SNR /VLBA only
Br	100/76	6/2	9.0/11.0
Fd	100/76	18/11	15.1/12.4
Kp	86/66	7/2	12.4/17.1
La	100/76	5/3	10.0/10.2
Mk	54/42	16/8	14.9/11.4
Nl	100/76	0/0	0.0/0.0
Ov	100/76	10/2	23.5/12.1
Pt	100/76	4/4	9.9/9.9
Ef	100	28	39.9
On	100	30	40.4

EfOn baseline mean SNR: 72.1

Table 4. c192b scans with 3C454.3

ant	correlated baselines / VLBA only	found fringes /VLBA only	mean SNR /VLBA only
Br	310/284	17/13	13.8/13.6
Fd	330/296	83/67	22.6/24.0
Kp	310/284	40/27	20.1/20.5
La	330/296	40/33	12.7/13.0
Mk	230/224	60/56	16.7/16.5
Nl	330/296	35/21	13.0/12.7
Ov	310/284	84/70	28.9/29.3
Pt	330/296	67/61	13.2/13.4
Ef	134	38	35.6
On	118	68	31.5

EfOn baseline mean SNR: 75.7 (changing from 260 to 7 due to source elevation)

Table 5. c192b scans with 3C84 (fringe SNR by baseline, LL/RR, 0 = no fringe). No other fringes except those shown.
Scans 205 and 206 in "non-pointing" numbering correspond to scans 618 and 621 in "pointing" numbering.

B = Ef, X = On, b,f,k,l,m,n,o,p = Br, Fd, Kp, La, Mk, Nl, Ov, Pt

day 278	BX	Bb	Bm	Bo	Xb	Xo	bm	bo	bp	fo	fp	mo	op	ko	lo
scan 205 UT09:00-08	0/0	15/15	14/11	32/27	13/10	18/17	16/18	143/136	14/12	11/15	8/11	54/50	61/53	8/0	9/0
scan 206 UT09:15-23	0/0	0/0	13/13	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/9	0/0	0/0	0/0	0/0

Table 6. c192b scans 161, 165 and 169 (consecutive with 3C454.3 as target)
(fringe SNR by baseline, LL/RR, 0 = no fringe). No other fringes except those shown.
Scans 161, 165 and 169 in "non-pointing" numbering correspond to scans 533, 541, and 548 in "pointing" numbering.

b,f,k,l,m,n,o,p = Br, Fd, Kp, La, Mk, Nl, Ov, Pt
(Ef and On did not observe in these scans)

day 278	fk	fl	fm	fn	fo	fp	km	ko	kp	lm	ln	lo	lp	mn	mo	mp	no	op
scan 161 UT03:30-38	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	8/0	0/0	0/0	10/0	9/10	0/0	8/0	0/0	0/0
scan 165 UT04:00-10	21/29	17/12	19/28	11/16	130/182	13/22	17/19	59/58	24/20	10/0	0/0	43/21	9/0	0/0	70/62	11/10	28/24	40/37
scan 169 UT04:30-40	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	19/11	8/0	14/0	19/11	0/0	9/0	17/14	0/0	0/0

Table 7. Example of fringes appearing and disappearing for a single baseline MkOv in c192a. Source 3C345.

UT range (days 276-277)	scan No. "non-pointing"	scan No. "pointing"	SNR LL/RR (0 = no fringe)	preceding pointing source (same for Mk and Ov)
20:30 – 37	09	72	10/11	APLyn
22:00 – 07	15	90	0/8	UHer
00:00 – 07	23	114	22/19	UHer
02:00 – 07	32	139	19/15	V1111Oph
04:00 – 07	41	164	0/0	UHer

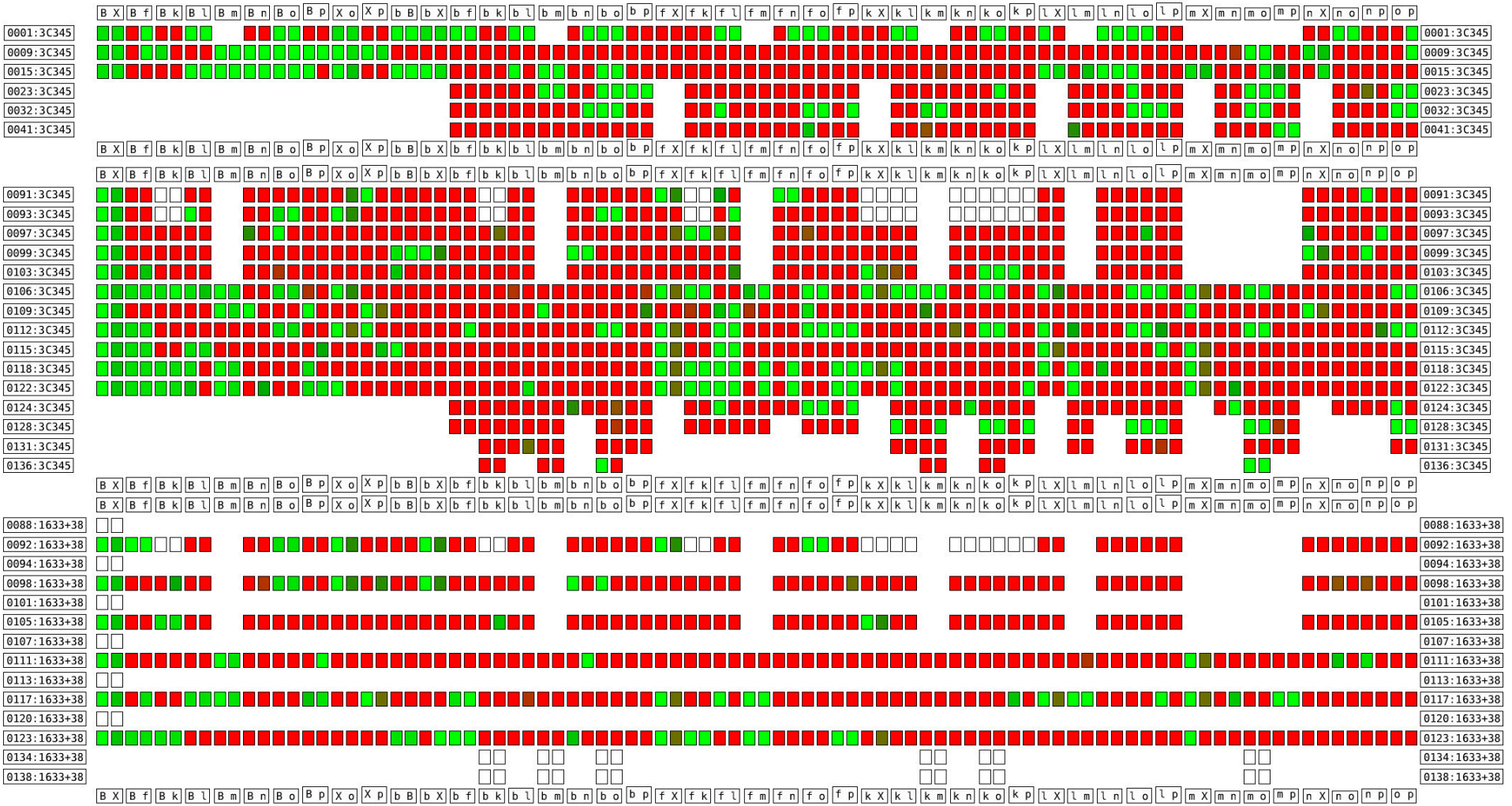

Figure 1. Correlation map of 6 scans targeting 3C345 from c192a, 15 scans also targeting 3C345 from c192b, and 6 scans targeting 1633+38 from c192b. Each box corresponds to LL (left box) or RR (right box) for each scan and baseline, baselines are designated by combinations of single-letter codes: b,f,k,l,m,n,o,p = Br, Fd, Kp, La, Mk, Nl, Ov, Pt; B = Ef and X = On. Boxes with different shades of green indicate fringes, including even marginal ones with SNR below 7, red boxes indicate no fringes, empty boxes are those with missing data or not correlated, and white space with no boxes corresponds to non-scheduled. Scan numbers 1 – 41, 91 – 136, and 88 – 138 are in accordance with "non-pointing" numbering. The corresponding "pointing" numbers are 48 – 164 in c192a, 382 – 465 and 377 – 471 in c192b. UT ranges are d276 18:30 – d277 04:07, d277 17:30 – d278 00:37, and d277 17:15 – d278 00:52.

Figure 2. Correlation map of 23 scans targeting 3C454.3 and 2 scans targeting 3C84, all from c192b. Each box corresponds to LL (left box) or RR (right box) for each scan and baseline, baselines are designated by combinations of single-letter codes: b,f,k,l,m,n,o,p = Br, Fd, Kp, La, Mk, Nl, Ov, Pt; B = Ef and X = On. Boxes with different shades of green indicate fringes, including even marginal ones with SNR below 7, red boxes indicate no fringes, empty boxes are those with missing data or not correlated, and white space with no boxes corresponds to non-scheduled. Scan numbers 125 – 204 and 205 – 206 are in accordance with "non-pointing" numbering. The corresponding "pointing" numbers are 443 – 617 and 618 – 621. UT ranges are d277 23:15 – d278 08:55 and d278 09:00 – 09:23.

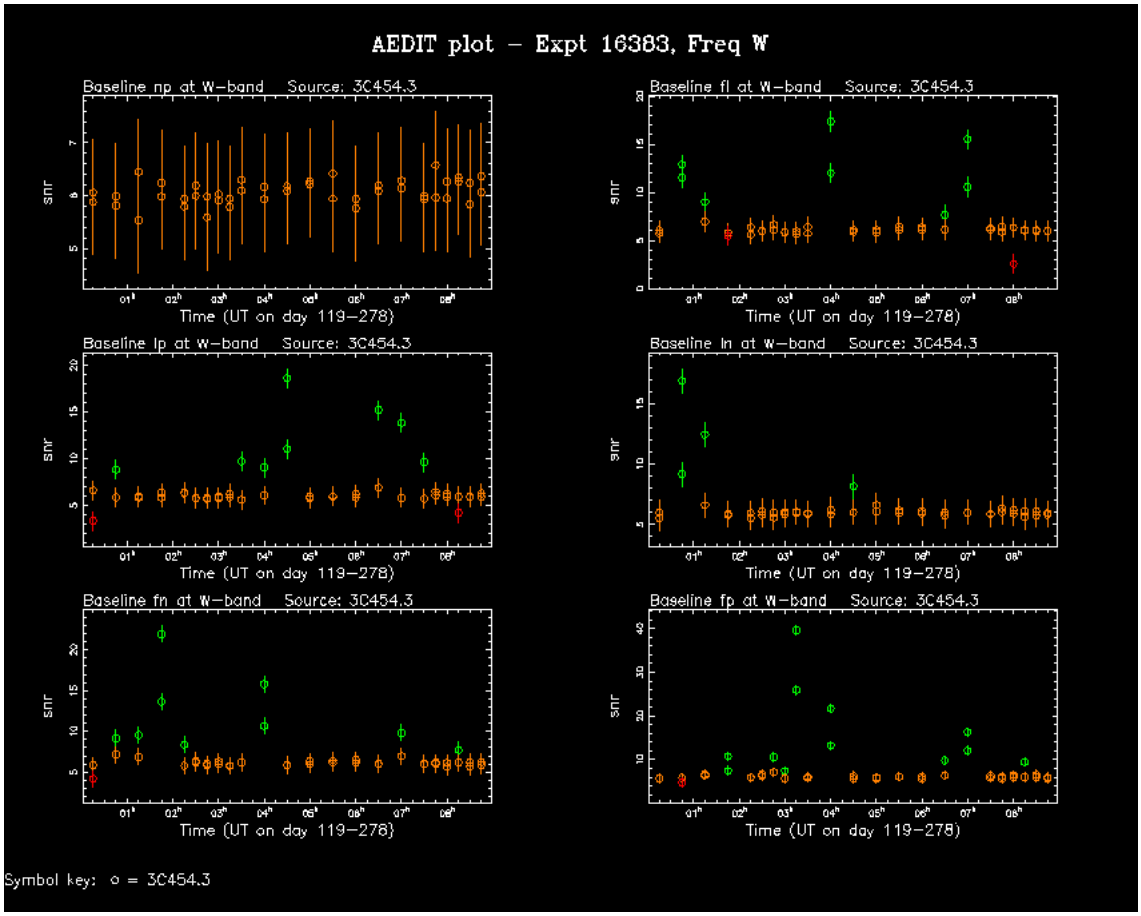

Figure 3. HOPS *aedit* plot based on 3C454.3 scans of c192b for stations f,l,n,p = Fd, La, Nl, Pt, fringe SNR vs UT time for 6 baselines. Fringe detections flicker on and off, immediately jumping to high SNRs.

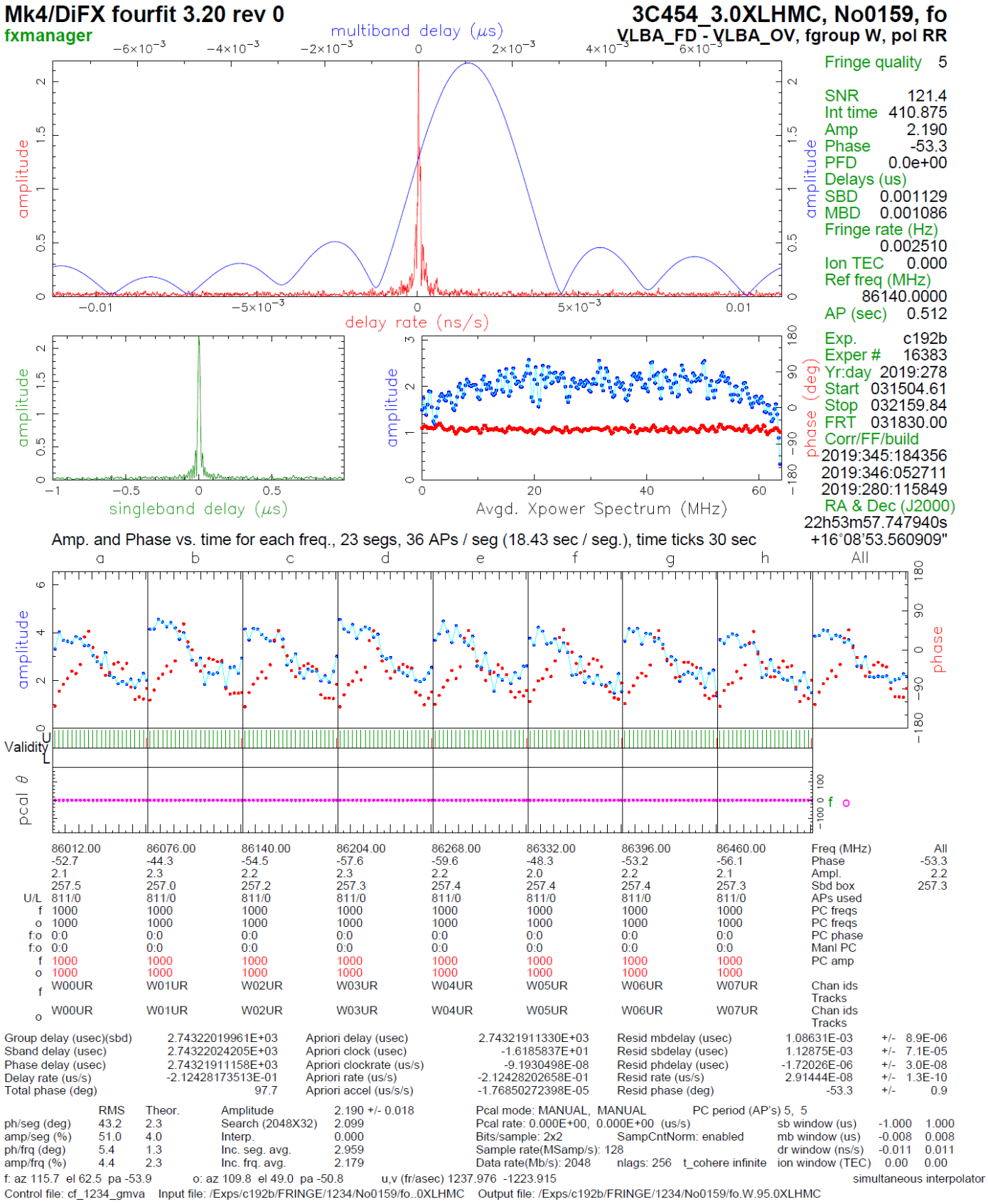

Figure 4. Full *fourfit* fringe plot for scan 159 ("pointing" No. 528, day 278 UT03:15-22) of c192b, source 3C454.3, baseline FdOv, RR. It shows that even during the scan the amplitude can drift down by a factor of two. Note that the overall fringe SNR is quite high, 121. And the smooth fringe rate spectrum demonstrates good phase coherence.