VLBA Memo 83: North Liberty Rail Maintenance, July 2010

Bob Broilo

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1 Introduction

The original grout under the azimuth rail at the North Liberty, Iowa VLBA antenna has been steadily failing. In 2002, one major repair and many spot repairs were performed (VLBA Antenna Memo #38). In 2008, more areas of failing grout were found, both visually and by measuring deflection under load (VLBA Antenna Memo #73).

On July 19th, 2010, a maintenance crew from the VLA consisting of Johnny Gonzales, Gerald O'Connell, and Bob Broilo arrived at the site. We were joined by site technicians Mike Burgett and D. J. Beard. Our goals were to stabilize the rail condition, perform maintenance on the rail splices, and improve the rail flatness.

This report is more elaborate (tedious) than a normal VLBA maintenance report. This is to document specific strategies and provide tiresome details of rail and splice phenomena which may prove important someday[1].

2 Strategy

17 of the bolts[2] had previously been spot repaired, and 6 splices at 2 bolts per splice, leaving 91 bolts remaining with original grout. We had 30 units of Dayton-Superior Turbo Grout Epoxy at 0.5ft^3 each to use. From previous experience, each 0.5ft^3 fills an average of 1.6 bolts that have been cleaned for spot repair. Thus we estimated that had enough to replace the grout between approximately 50 bolts.

The strategy for the maintenance is:

1. Measure the rail height under load to determine the areas where the rail has sunk over time, indicating areas of deterioration and their severity.

2. Visually inspect the rail grout to identify areas of deterioration that are still supporting the rail but are expected to fail the soonest.

[1] the reader may find slight consolation in the fact that it was much more tedious to write than it will be to read.

[2] "Bolt" in this report can refer to an area of rail between two bolts when talking about amount of grout (one bolt's worth), but rail height measurements are taken at each bolt location.

3. Mechanically remove the weak grout, leaving solid original grout.
4. Replace the removed grout with high-strength epoxy grout.
5. Re-shim and re-torque the splices.

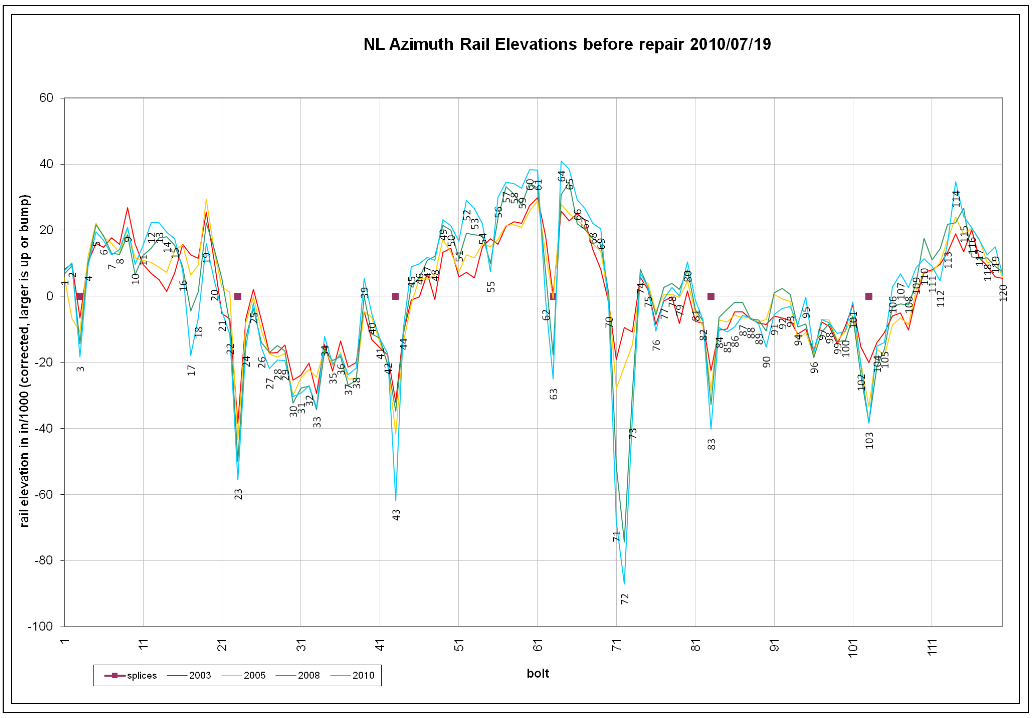


Figure 1: Rail height since last repair

Figure 1 shows rail heights since the last grout repair. Bolts 3, 23, 43, 63, 83, and 103 are splices. The splices already have plates and grout under them. The splices usually start to sag because the shims get pushed out, corrode away, or the rail wears.

Some areas of grout deterioration are clearly seen in the rail height data at bolts 17, 55, 72, and possibly 30-33. Corroborating these with visual inspections we see obvious problems at bolts 17, 55 (figure 2) and 72 (figure 3). Bolts 30-33 look good externally, and bolts 19-20 have visible grout problems that are not yet causing the rail to sag (figure 4).

The exact condition of the old grout is unknown until it is being demolished. It is important to remove all the bad grout, and the volume of grout removed varied from bolt to bolt as the demolition occurred.

For example, the grout at bolt 72 was in very poor condition. When hit with the tools, it fell out with little effort and in large pieces. A lot of grout is gone by the time the area is clean and solid (Figure 5).

Compare this to an area of more solid grout which can only be chiseled away slowly (figure 6).[3] Much more volume of new grout will be needed to fill

[3] Note that this area was not completely cleaned yet when the photo was taken. We remove as much of the old grout from under the support plates at each bolt as possible.

Figure 2: Bolts 17 and 55 before repair

Figure 3: Bolt 72 area before repair

Figure 4: Bolts 31 and 19 before repair

Figure 5: Bolt 72 after grout removal

Figure 6: Bolt 91 after grout removal

the hole under bolt 72 than bolt 91.

It is true in this specific example that the area around bolt 72 was clearly worse than bolt 91. These locations were chosen to illustrate the hole size. But more often, an area that looks solid by visual inspection and measurement will fall apart readily. This makes it tricky to try to estimate the exact number of bolts to remove the old grout from.

If more grout is removed than can be replaced with the new grout, the antenna would be in an unusable condition. The rail alone cannot support the weight of the wheel. So we did the demolition/removal and pours in segments to avoid removing more grout than we could replace. The measurements and visual inspection help to ensure that the areas most in need of immediate repair are done first.

The epoxy grout must have a dry surface to bond to. The technique of removing and pouring in segments gives more flexibility when dealing with periods of poor weather.

3 Splices

Figure 7: Splice shim migration

The rail splices flex, wear and loosen up as the wheels ride over them. They require regular re-torquing and re-shimming. At North Liberty, the splices had been re-torqued in 2008, yet by the time of our visit many of the bolts had loosened to the point that they could be removed by hand. The rail height data show a steady sinking of the splices since they had been shimmed in 2002. The shims corrode, deform, or migrate out from under the rail. See figure 7 for examples of shim migration.

The splice bars are covered by a rubbery coating, which was applied when the splices were improved in the 1990s in an attempt to prevent moisture from penetrating the rail components. Unfortunately, this coating began to conceal a major problem developing at this site.

The splice bars were all cracked, and some even completely broken (figures 8 and 9). Some were bent (figures 10 and 11). Some of the cracks appear to be caused by the way the slots for the rail clips were cut. They originate at the corners of the saw lines. But other cracks in bolt holes seem to

Figure 8: Splice bar typical cracks at North Liberty antenna

Figure 9: Splice bar typical cracks at North Liberty antenna

Figure 10: Bent Splice bar from North Liberty antenna

Figure 11: Bent Splice bar from North Liberty antenna

hint that there may be breakage occurring at other sites where the bars were cut smoothly.

Luckily, the VLA site had a full set (6 pairs) of splice bars. After minor modifications to the slots to fit the Foster rail clips (with smooth rounded cuts to prevent cracking), they were shipped to us at the North Liberty site. The new splice bars improved the rail flatness dramatically as seen in the pre-shimming measurements in figure 12.

We attempted to improve the rail flatness even more by re-shimming the splices. We took fine measurements of the loaded splice and included three bolts to each side to get an approximate slope. These measurements are plotted as the “reading” lines in figure 10. The “theor” lines are the calculated slopes. The shallower dips on these newer readings show that the new splice bars support the splices better than the cracked and broken bars.

The amount of shim we added is to the immediate right of the charts. The green triangles are the results of our efforts. Despite expending quite a bit of effort and time fitting the shims under the rail, they did not reduce the depth of the dips much. This may be a sign that the rails have worn significantly at the splices. Adding more shim would require a great deal of force and may damage the rail, so we chose not to on this trip. However, the amount of shim we added will support the rail and reduce flexing.

4 Trip Log

Inventory of previously repaired splices, 10-16, 20-22, 27-29, 32-35, 36-40, 51-53, 68-70, 79-81, 93-93, 107-109, 117-120

2010-07-17 - 2010-07-18 travel

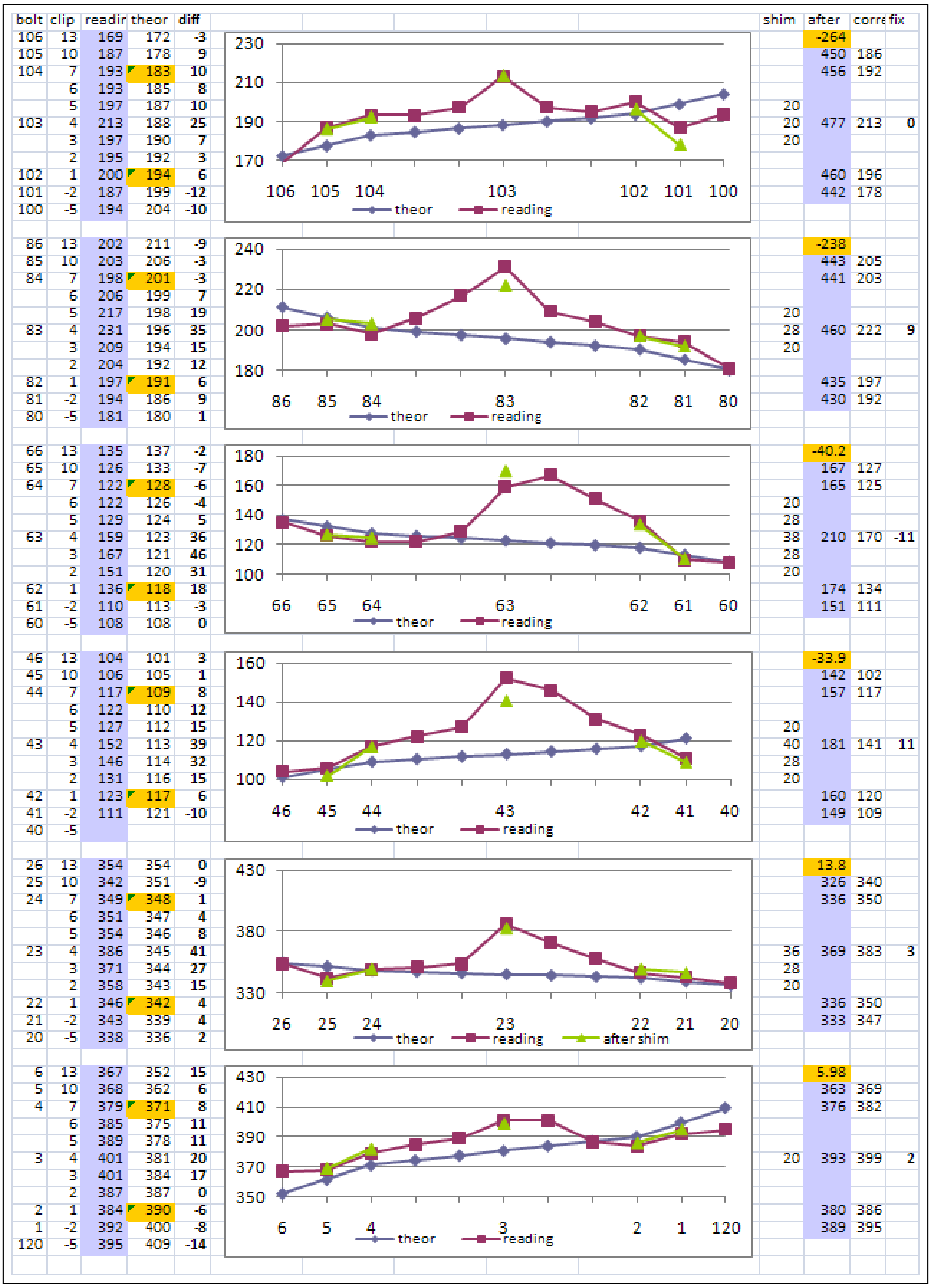
2010-07-19 lots of rain
: shot rail with optical level - plotted (figure 1) and identified bad spots
: broke out 16-20, 54-56, 61-62, 70-74 (11 bolts)
: unbolted splices 23, 43 - some bars broken, most cracked: ordered 6 sets from VLA

2010-07-20 mist, fog, some lightning slowing work
: unbolted splices 3, 103
: broke out 16-20, 89-93, 53-54, 29-32 (4+4+1+3=12 bolts)
: cleaned up 70-74, 29-32, 16-20

2010-07-21 sunny
: cleaned up 70-74, 29-32, 16-20
: formed where needed
: poured - 11 units

2010-07-22 sunny
: unbolted splices 63, 83
: cleaned under splices with water and air
: Tried to re-align splice at 43 with new splice bars

2010-07-23 rain, occasional t-storms
: installing new splice bars - 43 is better but still mismatched
: initial torquing



bolt	clip	readir	theor	diff	shim	after	corre	fix
106	13	169	172	-3		-264		
105	10	187	178	9		450	186	
104	7	193	183	10		456	192	
	6	193	185	8				
	5	197	187	10	20			
103	4	213	188	25	20	477	213	0
	3	197	190	7	20			
	2	195	192	3				
102	1	200	194	6		460	196	
101	-2	187	199	-12		442	178	
100	-5	194	204	-10				
86	13	202	211	-9		-238		
85	10	203	206	-3		443	205	
84	7	198	201	-3		441	203	
	6	206	199	7				
	5	217	198	19	20			
83	4	231	196	35	28	460	222	9
	3	209	194	15	20			
	2	204	192	12				
82	1	197	191	6		435	197	
81	-2	194	186	9		430	192	
80	-5	181	180	1				
66	13	135	137	-2		-40.2		
65	10	126	133	-7		167	127	
64	7	122	128	-6		165	125	
	6	122	126	-4	20			
	5	129	124	5	28			
63	4	159	123	36	38	210	170	-11
	3	167	121	46	28			
	2	151	120	31	20			
62	1	136	118	18		174	134	
61	-2	110	113	-3		151	111	
60	-5	108	108	0				
46	13	104	101	3		-33.9		
45	10	106	105	1		142	102	
44	7	117	109	8		157	117	
	6	122	110	12				
	5	127	112	15	20			
43	4	152	113	39	40	181	141	11
	3	146	114	32	28			
	2	131	116	15	20			
42	1	123	117	6		160	120	
41	-2	111	121	-10		149	109	
40	-5							
26	13	354	354	0		13.8		
25	10	342	351	-9		326	340	
24	7	349	348	1		336	350	
	6	351	347	4				
	5	354	346	8				
23	4	386	345	41	36	369	383	3
	3	371	344	27	28			
	2	358	343	15	20			
22	1	346	342	4		336	350	
21	-2	343	339	4		333	347	
20	-5	338	336	2				
6	13	367	352	15		5.98		
5	10	368	362	6		363	369	
4	7	379	371	8		376	382	
	6	385	375	11				
	5	389	378	11				
3	4	401	381	20	20	393	399	2
	3	401	384	17				
	2	387	387	0				
2	1	384	390	-6		380	386	
1	-2	392	400	-8		389	395	
120	-5	395	409	-14				

Figure 12: Low spots at splices and shimming attempts

2010-07-24 shot splices w/ level - new bars help a lot
shim splices
re-torque
shot w/ level again - shims helped some but did not fix splices
completely re-torque

2010-07-25 broke out 4-10, 74-79, 84-89, 96-97, 104-107, 109-113 (24 bolts)
started cleaning and forming

2010-07-26 finished cleaning and forming
poured (12 units, batches of 2 work best)
broke out 24-25, 35-36, 40-41, 56-61 (8 bolts)
cleaned, formed
poured 5 units

2010-07-27 shot rail w/ level, looks much better but not flat due to splices
and some deformation at clip 72
final torquing of splices
cleanup, packing

5 Results and Recommendations

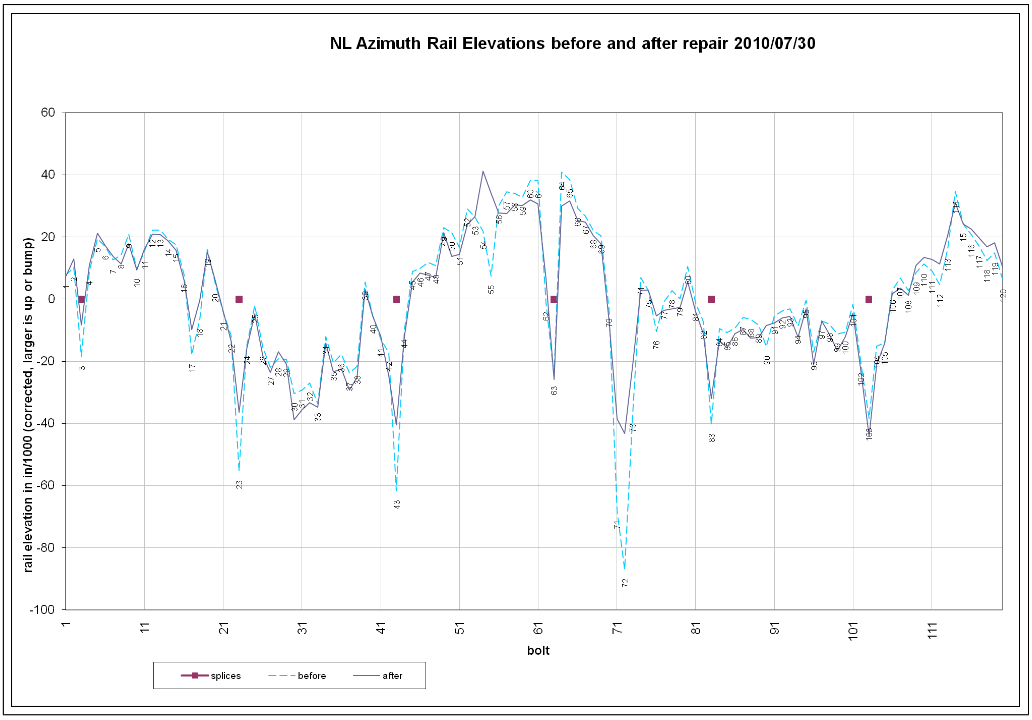


Figure 13: Rail height before and after repair

We used 28 0.5ft^3 units of grout to repair 55 bolts in 4.5 days, or approximately 2 bolts/unit and 12 bolts/day. The before and after rail elevations are in figure 13. The holes due to grout and splice deterioration have been improved to about half of their earlier depth.

The area around bolt 72 has been deformed by the wheels during the time when the old grout was not supporting it. A grouting plate similar to the type used at the Mauna Kea VLBA site might be able to correct this, but may not be worth the effort. The dip is about the same depth as the splices. The plate would take several days to install, and great care must be taken during the installation to avoid worsening the problem. For example, at Mauna Kea we had problems with thermal expansion warping the rail while the grout cured.

A similar but smaller dip was left in the Hancock, NH rail after a large area of grout had catastrophically failed and been repaired there. Recently, another area was repaired at Brewster, WA (see VLBA Antenna Memo 82), but we do not have before and after measurements to know if there was a residual dip.

After the rail grout has been stabilized we should revisit these areas and attempt to correct them. Meanwhile, the next time there is a severe grout failure of this nature, we should determine where in the rail system the deformation is occurring.

The bolts with high-strength grout are 1-25, 27-41, 42-44, 51-64, 68-81, 82-97, 102-113, and 117-120. This is 95 bolts total. The bolts with original grout are 120-1, 41-42, 44-51, 64-68, 81-82, 97-102, and 113-117, or 25 total. These will need attention in the next few years. If weather allows, we will repair these on the way back from the Hancock, NH antenna in late September.

We do not know how many sites have cracked or broken splice bars, so we need to keep a few sets of spare splice bars handy for field replacement. A set should be taken on each rail job.