LWA-1 Antenna Position and Cable Data
Ver. 3

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Contents

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1 Introduction

This memo documents (1) the positions of antennas associated with LWA-1 and (2) the physical lengths and propagation delays of the associated cables, and (3) a model for the loss of these cables. Although some of this information already exists in various LWA engineering memos, it is currently difficult and tedious to identify the most recent and authoritative data. The purpose of this document is to assemble the relevant information into a single document for the mutual convenience of developers and users.

2 Antenna Positions

LWA antennas are grouped into pairs of orthogonally-polarized antennas, referred to as *stands*. There are $N = 256$ stands in the LWA-1 array, numbered 1 through 256. The exists also a Stand 257, which is not part of the LWA-1 array, but is located inside the station perimeter (near the southwest corner) and is identical to the other stands.

Stand positions reported here were extracted from LWA Engineering Memo ARR0003 [1].[1] These are the "as built" positions, as determined by survey measurements. The heights of Stands 223 and 240 were subsequently noted to be in error and have been corrected in the data presented here [2].

Stand positions are reported in Appendix A. The positions are given in a local Cartesian coordinate system, with $+y$ pointing North[2], the $+x$ axis pointing East[3], and the $+z$ axis pointing to Zenith. Relative positions are believed to be accurate to within 2 cm. The location of $x = y = 0$ is marked by a steel center post. z-coordinates refer to the plane of the circuit board inside each stand (which can interpreted as the "feedpoints" of the dipole antennas), with Stand 252 arbitrarily chosen to be the $z = 0$ datum. Note that there is a significant elevation change across the LWA-1 array; it is not safe to assume the stands lie in a best-fit plane, or that such a plane is perpendicular to the z-axis.

The location of the origin of the local coordinate system is not precisely known. The horizontal value being used currently is Latitude 34.070°N, Longitude 107.628°W. The elevation at the LWA-1 site is approximately 7000 ft.

Beyond the 257 stands reported in Appendix A, there is yet another identical stand, located outside the LWA-1 station perimeter fence, referred to variously as the "RTA stand" or the "outrigger". The best known estimate of the position of this stand in the coordinate system described above is $x = +339.61 \pm 0.25$ m, $y = +15.32 \pm 0.25$ m, $z = -0.08 \pm 0.4$ m.

3 Cable Delay

The cables that connect antenna stands to the shelter are of unequal length. (The rest of the signal path is identical between antennas.) These lengths are reported in LWA Engineering Memo RPD0022 [3], and repeated in Appendix B.

The cables are Kingsignal[4] Part Number KSR200DB, which is advertised to have a velocity factor (speed of propagation relative to the speed of light in free space, c) of 0.83. This velocity factor has been confirmed by two of us (Craig and Ellingson) using direct measurement of cables

[1] Specifically, from the spreadsheet `asbuilt.xls`. For those referring back to this file, note that the column headings are wrong; they should be "Stand ID", "x, m", "y, m", and "z, m" respectively.

[2] According to [1]: "directed to the wood post 426.7′ to the north"

[3] According to [1]: "directed 90 degrees to the east of the y-axis".

[4] `http://www.kingsignal.com`

using time-domain reflectometry, and also independently confirmed by one of us (Hartman) using measurement data provided by the supplier as reported in LWA Engineering Memo RPD0026 [4].

When estimating cable propagation delay, it is important to note that coaxial cables are significantly dispersive in the frequency range of interest [5]. The measurements of Craig & Ellingson indicate this additional delay is approximately 3.5 ns in the frequency range of interest. Hartman's fit of the supplier-provided delay measurements (taken at 10 MHz and 80 MHz) to the functional dependence derived in [5] yields the following result for the additional dispersive delay:

$$(2.4 \text{ ns}) \left(\frac{l}{100 \text{ m}}\right) \left(\frac{f}{10 \text{ MHz}}\right)^{-1/2} , \tag{1}$$

where l is cable length and f is frequency. Thus, the analyses agree on the dispersive delay to within roughly 1 ns; i.e., very close agreement relative to what is required for LWA data analysis. However, the latter answer is preferred as it is explicitly in the desired frequency-dependent form.

Combining the above results, the recommended method for computing the total cable propagation time t_c is to use the known length l of the cable from Appendix B in the following expression:

$$t_c = \frac{l}{0.83c} + (2.4 \text{ ns}) \left(\frac{l}{100 \text{ m}}\right) \left(\frac{f}{10 \text{ MHz}}\right)^{-1/2} . \tag{2}$$

4 Cable Loss

It can be shown that the gain (that is, "inverse loss") in a coaxial cable of length l at frequency f can be modeled as follows (see, for example, the last 2 equations in Section 2 of [5]):

$$G(f, l) = e^{-2\alpha_0 l \sqrt{f/f_0}} \quad \text{(linear power units)}, \tag{3}$$

where α_0 is the real part of the propagation constant, and f_0 is the frequency at which a_0 is specified.

Although it has been claimed that the KSR200DB cable used in LWA-1 is essentially the same as Times LMR-200, the cable loss data provided in KSR200DB data sheet indicates that the loss is somewhat higher. For example, the KSR200DB data sheet reports 14.4 dB per 100 m at 150 MHz, whereas Times LMR-200 is 13.1 dB for the same conditions. Independent measurements of KSR200DB loss have not yet been made. However, it is found that $\alpha_0 = 0.00428$ m^{-1} at $f_0 = 10$ MHz gives an excellent fit (within 0.1 dB at 150 MHz) to the 150 MHz, 450 MHz, and 900 MHz values provided in the KSR200DB data sheet.

A Table of Stand Positions

Stand positions in the station local coordinate system (see Section 2) are given below. The columns are as follows: Stand ID, x [m], y [m], z [m].

1	-0.67	-54.63	1.63
2	0.54	-49.33	1.50
3	-2.36	-43.50	1.23
4	1.59	-39.43	1.13
5	-3.19	-31.62	0.93
6	1.87	-26.05	0.72
7	0.03	-16.60	0.45
8	0.38	-10.81	0.25
9	-0.76	-4.40	0.11
10	1.90	0.88	-0.40
11	-0.67	5.67	-0.17
12	-1.33	14.44	-0.52
13	-0.93	19.83	-0.68
14	-0.20	25.22	-0.88
15	1.79	29.77	-1.06
16	2.66	35.47	-1.28
17	-1.42	42.29	-1.40
18	-0.98	47.40	-1.42
19	-2.45	53.44	-1.51
20	7.90	-51.44	1.58
21	-8.85	-53.71	1.57
22	7.09	-46.38	1.44
23	-6.92	-49.12	1.47
24	6.19	-41.31	1.19
25	-3.07	-36.59	1.09
26	4.19	-32.99	0.98
27	-8.18	-32.20	0.96
28	6.96	-26.09	0.79
29	-6.78	-27.39	0.82
30	5.98	-21.09	0.60
31	-3.87	-21.81	0.61
32	4.51	-13.84	0.39
33	-4.94	-14.90	0.42
34	5.39	-8.24	0.19
35	-5.82	-9.96	0.27
36	4.35	-3.51	0.02
37	-7.95	-5.21	0.17
38	7.10	0.98	-0.13
39	-6.80	2.82	-0.10
40	3.36	11.26	-0.44
41	-4.71	8.77	-0.24
42	7.00	15.43	-0.56
43	-5.88	16.55	-0.51
44	4.06	19.53	-0.64
45	-7.73	21.13	-0.73
46	4.95	25.55	-0.86
47	-5.24	25.50	-0.90
48	7.01	30.14	-1.11
49	-4.71	31.33	-1.15

50	7.62	37.09	-1.35
51	-5.87	38.51	-1.25
52	6.05	41.84	-1.42
53	-6.03	44.37	-1.40
54	5.30	54.73	-1.60
55	-7.50	53.57	-1.62
56	13.00	-52.04	1.61
57	-12.85	-50.58	1.49
58	12.50	-46.62	1.42
59	-9.77	-45.09	1.32
60	10.25	-38.33	1.21
61	-10.39	-39.96	1.07
62	9.69	-30.15	0.95
63	-14.82	-30.49	0.90
64	11.74	-24.93	0.73
65	-10.13	-23.70	0.69
66	12.88	-18.20	0.55
67	-10.53	-18.69	0.57
68	9.08	-11.85	0.30
69	-11.11	-13.71	0.43
70	10.52	-7.11	0.17
71	-11.55	-8.71	0.25
72	11.10	-2.06	-0.04
73	-12.12	1.26	-0.10
74	6.63	6.79	-0.25
75	-9.57	6.95	-0.24
76	9.28	10.99	-0.47
77	-9.13	12.91	-0.41
78	11.33	17.90	-0.70
79	-11.05	17.52	-0.63
80	10.76	23.13	-0.85
81	-12.77	24.90	-0.92
82	12.00	30.39	-1.15
83	-10.94	29.41	-1.03
84	13.33	36.03	-1.29
85	-8.66	34.38	-1.18
86	12.01	44.35	-1.55
87	-10.99	41.95	-1.39
88	13.69	51.43	-1.64
89	-15.59	52.33	-1.65
90	18.73	-46.34	1.39
91	-16.14	-46.74	1.39
92	14.55	-42.12	1.28
93	-17.66	-40.97	1.14
94	14.36	-33.78	1.18
95	-16.30	-36.15	1.07
96	16.77	-27.92	0.84
97	-17.47	-26.17	0.80
98	17.42	-20.65	0.61
99	-14.87	-21.90	0.64
100	16.65	-14.89	0.42
101	-15.19	-16.89	0.55
102	13.96	-10.75	0.27
103	-16.19	-11.57	0.43

104	15.71	-5.38	0.09
105	-14.93	-5.03	0.24
106	13.44	2.67	-0.16
107	-16.29	4.02	-0.07
108	13.37	7.67	-0.35
109	-13.52	10.07	-0.51
110	13.79	13.47	-0.54
111	-16.68	15.52	-0.43
112	15.73	22.03	-0.82
113	-16.09	20.98	-0.66
114	16.67	28.59	-1.08
115	-16.44	29.26	-1.01
116	17.96	33.41	-1.30
117	-13.76	33.50	-1.11
118	15.43	40.57	-1.41
119	-15.97	38.32	-1.26
120	17.40	47.88	-1.64
121	-18.96	44.32	-1.47
122	23.55	-44.98	1.27
123	-25.70	-43.34	1.22
124	18.89	-37.03	1.18
125	-22.37	-36.54	1.11
126	20.61	-32.43	0.94
127	-19.67	-32.31	0.99
128	23.43	-25.37	0.73
129	-21.67	-21.14	0.69
130	22.40	-19.86	0.55
131	-19.86	-14.94	0.50
132	21.76	-14.91	0.39
133	-22.71	-10.75	0.40
134	21.94	-7.98	0.18
135	-22.08	-5.28	0.15
136	19.90	-2.69	-0.02
137	-19.65	0.34	0.05
138	19.75	3.62	-0.26
139	-22.37	6.83	-0.14
140	19.50	9.99	-0.42
141	-20.83	11.62	-0.28
142	18.53	15.19	-0.55
143	-20.87	18.75	-0.51
144	20.94	25.29	-0.98
145	-21.59	26.43	-0.76
146	22.72	29.94	-1.18
147	-21.75	31.59	-0.97
148	22.44	35.86	-1.41
149	-20.81	36.64	-1.18
150	24.66	46.16	-1.69
151	-25.04	47.80	-1.44
152	29.06	-38.45	1.11
153	-28.84	-37.45	1.13
154	26.82	-33.13	1.03
155	-27.08	-30.53	0.83
156	28.35	-28.28	0.81
157	-22.83	-26.43	0.80

158	28.13	-23.07	0.63
159	-26.45	-23.01	0.76
160	27.10	-16.73	0.45
161	-24.48	-17.03	0.52
162	25.52	-11.57	0.28
163	-26.55	-7.50	0.28
164	24.92	-2.79	-0.02
165	-28.14	-2.66	0.13
166	25.46	3.75	-0.22
167	-25.56	2.87	0.00
168	24.28	8.60	-0.39
169	-26.03	12.47	-0.19
170	25.16	14.43	-0.59
171	-26.50	17.41	-0.42
172	29.13	22.24	-0.82
173	-25.15	23.01	-0.66
174	26.93	26.74	-1.09
175	-26.49	28.30	-0.83
176	29.11	31.18	-1.26
177	-27.75	33.70	-1.03
178	29.34	37.97	-1.55
179	-30.18	40.32	-1.25
180	35.19	-39.46	1.12
181	-32.85	-41.84	1.18
182	34.39	-32.19	0.91
183	-33.83	-32.41	0.91
184	32.64	-25.66	0.70
185	-31.41	-25.41	0.74
186	32.00	-17.77	0.51
187	-29.42	-17.67	0.57
188	30.67	-11.47	0.28
189	-31.55	-11.58	0.47
190	29.10	-5.39	0.04
191	-35.01	-6.97	0.24
192	30.91	-0.68	-0.03
193	-30.60	1.82	0.01
194	29.71	6.43	-0.33
195	-29.19	8.48	-0.10
196	30.87	11.31	-0.49
197	-33.49	13.13	-0.25
198	31.95	16.22	-0.63
199	-32.46	18.06	-0.36
200	33.04	27.10	-1.08
201	-30.60	25.65	-0.69
202	33.35	35.02	-1.38
203	-32.62	32.47	-1.00
204	33.92	39.96	-1.57
205	-35.12	39.41	-1.22
206	-36.68	-36.47	1.09
207	37.33	-27.26	0.72
208	-39.72	-29.82	0.88
209	35.81	-21.04	0.52
210	-35.52	-22.66	0.71
211	37.04	-14.43	0.36

212	-35.11	-17.61	0.58
213	36.17	-8.45	0.19
214	-37.21	-12.67	0.40
215	38.55	-2.75	-0.01
216	-34.07	-2.05	0.18
217	36.56	3.15	-0.20
218	-35.75	3.78	0.05
219	37.01	10.01	-0.37
220	-36.80	8.84	-0.13
221	38.72	15.91	-0.61
222	-38.94	14.22	-0.30
223	36.74	20.53	-0.18
224	-35.60	22.38	-0.62
225	37.39	30.01	-1.12
226	-35.85	28.46	-0.81
227	43.10	-27.61	0.82
228	-40.56	-22.44	0.71
229	40.88	-22.76	0.59
230	-41.59	-17.38	0.54
231	41.95	-15.76	0.42
232	-44.62	-12.20	0.46
233	40.93	-10.18	0.29
234	-40.82	-8.13	0.31
235	43.98	-2.20	-0.07
236	-39.63	0.27	0.13
237	42.43	3.45	-0.28
238	-41.95	4.71	-0.04
239	41.86	11.13	-0.41
240	-43.20	10.93	-0.18
241	43.55	16.93	-0.68
242	-40.57	20.20	-0.53
243	41.51	23.72	-0.94
244	-39.79	25.17	-0.63
245	46.71	-19.97	0.52
246	-47.73	-16.77	0.59
247	47.38	-12.43	0.28
248	-49.23	-7.21	0.34
249	47.05	-7.39	0.10
250	-48.60	-2.24	0.15
251	49.29	-0.40	-0.16
252	-48.25	2.95	0.00
253	48.66	5.26	-0.28
254	-47.37	13.74	-0.23
255	48.83	11.21	-0.38
256	-47.09	18.72	-0.49
257	-45.58	-44.47	1.30

B Table of Cable Lengths

Cable lengths are given below. The columns are as follows: Stand ID, length [m].

1	138
2	133
3	134
4	126
5	117
6	121
7	105
8	100
9	91
10	86
11	96
12	89
13	83
14	81
15	82
16	77
17	76
18	76
19	74
20	132
21	141
22	131
23	137
24	133
25	122
26	124
27	120
28	116
29	119
30	119
31	120
32	105
33	103
34	92
35	99
36	88
37	101
38	83
39	100
40	94
41	93
42	82
43	92
44	79
45	97
46	76
47	91
48	71
49	87
50	76

51	101
52	71
53	81
54	64
55	78
56	129
57	143
58	126
59	134
60	131
61	130
62	113
63	127
64	113
65	116
66	105
67	113
68	94
69	106
70	91
71	105
72	86
73	114
74	84
75	97
76	74
77	95
78	81
79	106
80	78
81	94
82	66
83	91
84	63
85	89
86	76
87	95
88	57
89	86
90	124
91	137
92	126
93	133
94	110
95	132
96	107
97	123
98	100
99	114
100	91
101	113
102	89
103	111
104	85

105	113
106	86
107	114
108	73
109	100
110	69
111	105
112	82
113	102
114	66
115	96
116	61
117	94
118	67
119	95
120	62
121	94
122	129
123	142
124	114
125	140
126	110
127	127
128	98
129	119
130	96
131	118
132	90
133	119
134	83
135	115
136	81
137	111
138	77
139	121
140	68
141	110
142	64
143	106
144	70
145	114
146	67
147	108
148	66
149	99
150	69
151	101
152	109
153	136
154	106
155	129
156	102
157	123
158	94

159	127
160	90
161	123
162	87
163	120
164	83
165	120
166	72
167	122
168	70
169	120
170	65
171	111
172	52
173	115
174	51
175	110
176	47
177	107
178	50
179	113
180	108
181	141
182	101
183	139
184	99
185	132
186	91
187	130
188	83
189	131
190	88
191	136
192	72
193	124
194	67
195	119
196	62
197	131
198	60
199	128
200	46
201	114
202	44
203	111
204	49
205	117
206	141
207	100
208	145
209	92
210	137
211	82
212	133

213	77
214	135
215	73
216	129
217	71
218	127
219	58
220	126
221	53
222	129
223	57
224	123
225	43
226	116
227	94
228	140
229	89
230	139
231	85
232	144
233	76
234	138
235	71
236	141
237	65
238	146
239	55
240	134
241	52
242	125
243	57
244	125
245	85
246	149
247	81
248	145
249	76
250	145
251	63
252	147
253	59
254	134
255	57
256	131

C Document History

- Version 3 (Dec 12, 2010): Added cable loss data.
- Version 2 (Sep 6, 2010): z-coordinates of stands 223 and 240 corrected per W. Gerstle email dated Sep 3.
- Version 1 (Aug 18, 2010): First version.

References

[1] W. Gerstle & J. Craig, "As-built Surveyed Stand Coordinates," Long Wavelength Array Engineering Memo ARR0003, May 5, 2010.

[2] W. Gerstle, "RE: Antenna Locations", e-mail dated Sep 3, 2010. *This email identifies transcription errors in the z-coordinates of Stands 223 and 240, and provides corrected data.*

[3] J. Craig & A. Martinez, "LWA-1 Cable Lengths," Long Wavelength Array Engineering Memo RPD0022, May 20, 2009.

[4] Burns Industries, "Cable Delay Measurement Matrix," Long Wavelength Array Engineering Memo RPD0026, Sept 21, 2009

[5] S. Ellingson, "Dispersion in Coaxial Cables," Long Wavelength Array Memo 136, June 1, 2008.