

Geodetic and Maidenhead Locator System Conversion

Extending the definition of Maidenhead grid locators from the currently defined 8 characters to 16 characters improves location precision to within inches.

A geodetic system is a coordinate system used to locate places on the Earth using a set of reference points. Specifically, latitude and longitude coordinates used together locate places on Earth's surface, for example the coordinate set (34.065380 N, 84.554930 W). The Maidenhead Locator System, see Figure 1, uses the geodetic latitude and longitude numbers expressed differently as alternating pairs of letters and numbers.¹ This limits

the number of characters needed for radio transmission, for example EM42uf.

It is common in the Amateur Radio world to represent geographical locations using the first two or three Maidenhead pairs. Additional accuracy is gained by including additional pairs. Up to eight characters has been ratified, although several online conversion tools extend the system into smaller squares. It is interesting to note that the extended system results are not always compatible.

Two things are discussed in this paper.

- 1) The algorithm proposed for additional character pairs beyond the defined eight.
- 2) The precision gained by adding additional character pairs.

Proposed Algorithm

The proposed algorithm is simple. Continue the original pattern until the necessary precision is reached. Table 1

¹Notes appear on page 35

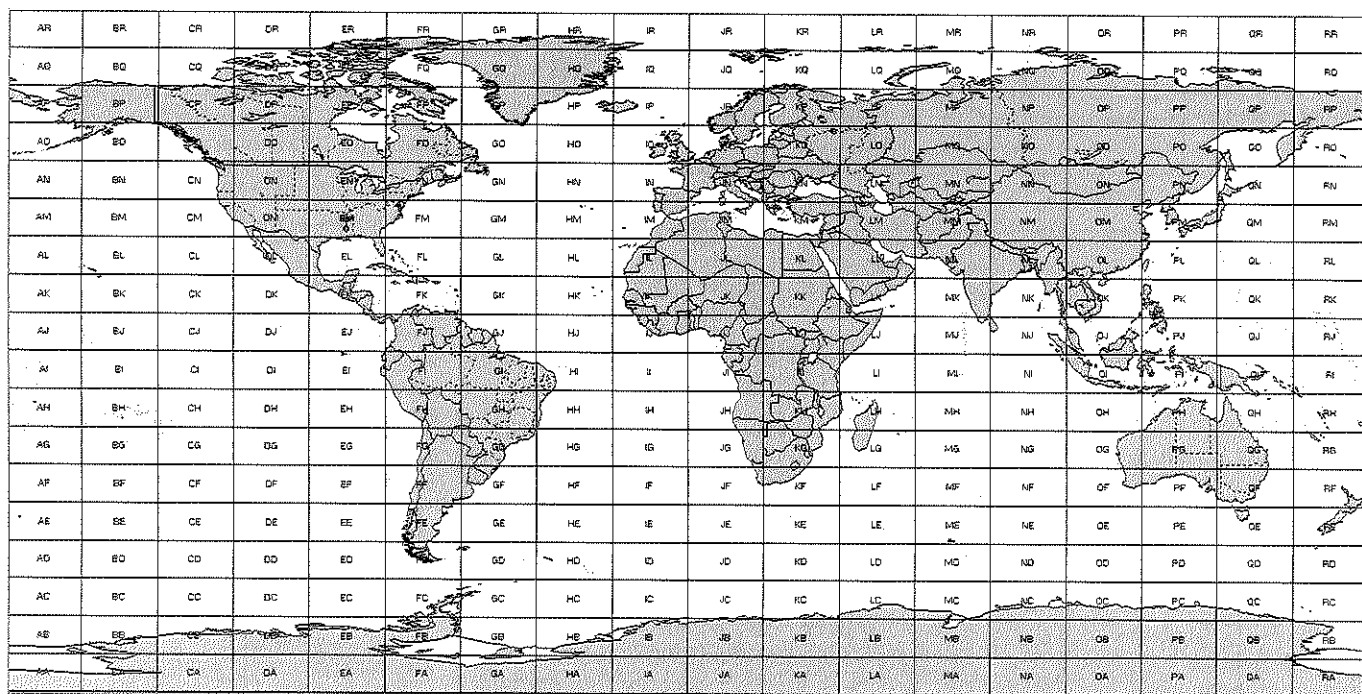


Figure 1 — This map, generated using DX Atlas 2.3 (Alex Shovkoplyas, VE3NEA, www.dxatlas.com), illustrates the two character Maidenhead grid squares.

shows sixteen characters and *number of bins* in degrees. Characters one through eight are defined. I am proposing a definition for characters nine through sixteen. Notice that the first two characters encode eighteen bins of 20 degrees of longitude, and 10 degrees of latitude respectively. Characters 3 and 4 encode ten bins of two degrees of longitude, and one degree of latitude respectively. Characters 5 and 6 encode twenty four bins of five minutes of longitude, and 2.5 minutes of latitude respectively, expressed in degrees. Last, characters seven and eight encode ten bins of 30 seconds of longitude and 15-seconds of latitude respectively, expressed in degrees. Since it is difficult to see the relationship between the elements when expressed in degrees, we transformed the numbers by multiplying them by 3600 to express the values in *seconds*, as shown in Table 2.

Table 3 shows the two important relationships used to codify the algorithm. The values for characters 9 through 16 in Table 2 are calculated from the relationships detailed in Table 3. For example, the number of bins alternates between 24 and 10 based upon the pairs. Numbered pairs have ten bins tagged zero through nine, and the lettered pairs use letters *a* through *x*. Furthermore, the character 9, longitude number of 1.25 (Table 2), was calculated by dividing 300, the character 5 number, by 240.

Tables 13 through 28 represent each of the sixteen characters, and are calculated from the Table 2 values. These Tables are similar to those introduced by Edmund Tyson, N5JTY, in the January 1989 *QST*. There, additional calculations are also given in milliseconds. Note that the number of bins is twice what I show in Table 1 to account for positive and negative coordinates. The positive numbers represent the northern hemisphere and the eastern half of the globe. The negative numbers represent the southern hemisphere and the western half of the globe.

Algorithm Implementation

I chose to implement the algorithm in a *Microsoft Excel* spread sheet, although any other program or language can be used. You can download my spread sheet from the *QEXfiles* web page. Table 4 shows an example for entering decimal latitude and longitude numbers into the spreadsheet to obtain the 16 character Maidenhead grid square. The spread sheet uses color to enhance readability. Anything related to latitude is orange and anything related to longitude is green. Grid square information has a yellow background and lettered in red. This example shows that entering a latitude of 34.065380 and a longitude of -84.554930 results a 16 character Maidenhead grid

locator of EM74rb35jq85av30.

The algorithm and calculations in degrees are shown in the left two columns of Table 5. Columns three and four show the algorithm and calculations in milliseconds. It is interesting to note that the calculations take fewer steps when performed in milliseconds.

It is also comforting to see that the calculations in degrees and in milliseconds produce the same result. The fifth column, labeled *Accuracy*, is used to verify my code. Values 15 and 16 are the same as the original latitude and longitude values.

Just in case you do not have your

Table 1 – Degrees

Characterization of grid characters by degrees.

Character	Longitude	Latitude	Character	Number of bins
1	20	10	2	18
3	2	1	4	10
5	0.0833333	0.0416667	6	24
7	0.0083333	0.0041667	8	10
9	0.0003472	0.0001736	10	24
11	0.0000347	0.0000174	12	10
13	0.0000014	0.0000007	14	24
15	0.0000001	0.0000001	16	10

Table 2 – Seconds

Characterization of grid characters by seconds.

Character	Longitude	Latitude	Character	Number of bins
1	72000	36000	2	18
3	7200	3600	4	10
5	300	150	6	24
7	30	15	8	10
9	1.2500000	0.6250000	10	24
11	0.1250000	0.0625000	12	10
13	0.005208333	0.002604167	14	24
15	0.000520833	0.000260417	16	10

Table 3.

Character relationships.

Relationships 1

Since	Character 1	to	Character 5	in seconds	is equal to	240
and	Character 2	to	Character 6	in seconds	is equal to	240
therefore	Character 5	to	Character 9	in seconds	is equal to	240
and	Character 6	to	Character 10	in seconds	is equal to	240
and	Character 9	to	Character 13	in seconds	is equal to	240
and	Character 10	to	Character 14	in seconds	is equal to	240

Relationships 2

Since	Character 1	to	Character 3	in seconds	is equal to	10
and	Character 2	to	Character 4	in seconds	is equal to	10
therefore	Character 9	to	Character 11	in seconds	is equal to	10
and	Character 10	to	Character 12	in seconds	is equal to	10
and	Character 13	to	Character 15	in seconds	is equal to	10
and	Character 14	to	Character 16	in seconds	is equal to	10

Table 4

Coordinate to Maidenhead sixteen-character conversion.

	Latitude	Longitude	Maidenhead Grid
Enter in decimal degrees:	34.065380		
Enter longitude in decimal degrees:		-84.554930	
			EM74rb35jq85av30

Table 5
Algorithm and calculations example – coordinates to Maidenhead

LONGITUDE

<i>Algorithm and calculations in degrees</i>		<i>Algorithm and calculations in milliseconds</i>		<i>Accuracy</i>
-84.554930	Longitude degrees	Longitude milliseconds	-304397748	
E	Character 1 from Table 13	Character 1 from Table 13	E	
-80	Extract value 1	Extract value 1	-288000000	-80.00000000
-4.55493	Remaining lon degrees	Remaining lon milliseconds	-16397748	
7	Character 3 from Table 15	Character 3 from Table 15	7	
-4	Extract value 3	Extract value 3	-14400000	-84.00000000
-0.55493	Subtract	Remaining lon milliseconds	-1997748	
-33.2958	Remaining lon minutes			
r	Character 5 from Table 17	Character 5 from Table 17	r	
-30	Extract value 5	Extract value 5	-1800000	-84.50000000
-3.2958	Subtract			
-197.748	Remaining lon seconds	Remaining lon milliseconds	-197748	
3	Character 7 from Table 19	Character 7 from Table 19	3	
-180	Extract value 7	Extract value 7	-180000	-84.55000000
-17.748	Remaining lon seconds	Remaining lon milliseconds	-17748	
j	Character 9 from Table 21	Character 9 from Table 21	j	
-17.5	Extract value 9	Extract value 9	-17500	-84.55486111
-0.248	Remaining lon seconds	Remaining lon milliseconds	-248	
8	Character 11 from Table 23	Character 11 from Table 23	8	
-0.125	Extract value 11	Extract value 11	-125	-84.55489583
-0.123	Remaining lon seconds	Remaining lon milliseconds	-123.00	
a	Character 13 from Table 25	Character 13 from Table 25	a	
-0.11979	Extract value 13	Extract value 13	-125	-84.55493056
-0.00321	Remaining lon seconds	Remaining lon milliseconds	2.00	
3	Character 15 from Table 27	Character 15 from Table 27	3	
-0.003125	Extract value 15	Extract value 15	1.562	-84.55493012
-0.00008	Remaining lon seconds	Remaining lon milliseconds	0.438	

LATITUDE

34.065380	Latitude degrees	Latitude milliseconds	122635368	
M	Character 2 from Table 14	Character 2 from Table 14	M	
30	Extract value 2	Extract value 2	108000000	30.00000000
4.06538	Remaining lat degrees	Remaining lat milliseconds	14635368	
4	Character 4 from Table 16	Character 4 from Table 16	4	
4	Extract value 4	Extract value 4	14400000	34.00000000
0.06538	Subtract	Remaining lat milliseconds	235368	
3.9228	Remaining lat minutes			
b	Character 6 from Table 18	Character 6 from Table 18	b	
2.5	Extract value 6	Extract value 6	150000	34.04166667
1.4228	Subtract			
85.368	Remaining lat seconds	Remaining lat milliseconds	85368	
5	Character 8 from Table 20	Character 8 from Table 20	5	
75	Extract value 8	Extract value 8	75000	34.06250000
10.368	Remaining lat seconds	Remaining lat milliseconds	10368	
q	Character 10 from Table 22	Character 10 from Table 22	q	
10	Extract value 10	Extract value 10	10000	34.06527778
0.368	Remaining lat seconds	Remaining lat milliseconds	368	
5	Character 12 from Table 24	Character 12 from Table 24	5	
0.3125	Extract value 12	Extract value 12	312.5	34.06536458
0.0555	Remaining lat seconds	Remaining lat milliseconds	55.50	
v	Character 14 from Table 26	Character 14 from Table 26	v	
0.05469	Extract value 14	Extract value 14	54.69	34.06537978
0.00081	Remaining lat seconds	Remaining lat milliseconds	0.810	
0	Character 16 from Table 28	Character 16 from Table 28	0	
0	Extract value 16	Extract value 16	0	34.06537978
0.0008100	Remaining lat seconds	Remaining lat milliseconds	0.8100	

Table 6
Coordinate conversion: Degrees-Seconds to Decimal Degrees.

	<i>Latitude</i>	<i>Longitude</i>
Enter degrees:	38	-102
Enter minutes:	18.67625998	17.50775174
Coordinates in decimal degrees:	38.311271	-102.2917959

Table 7

Coordinate conversion: Degrees-Minutes-Seconds to Decimal Degrees

	Latitude	Longitude
Enter degrees:	38	-102
Enter minutes:	18	17
Enter seconds:	40.57559896	30.46510428
Coordinates in decimal degrees:	38.311271	-102.2917959

Table 8

Maidenhead to coordinate conversion.

Enter grid locator: EM91ad60mw45qt80

	Decimal degrees	Degrees	Minutes	Degrees	Minutes	Seconds
Latitude:	31.128920		7.735200	31	7	44.111979
Longitude:	-81.945670	-81	56.740200	-81	56	44.411979

coordinates in decimal form, or you do not know how to convert degrees-minutes or degrees-minutes-seconds to decimal, Tables 6 and 7 are included as separate spreadsheet tabs to facilitate the conversions. You then must copy the calculated decimal solution to the spreadsheet Table 4.

To convert a Maidenhead grid locator into coordinates, use the *Grid to Degree Converter* spreadsheet tab. Type the grid locator into the yellow box and read the result in decimal degrees, degrees-minutes, and degrees-minutes-seconds to the right. This is illustrated in Table 8. [Table 8 builds the latitude and longitude systematically starting from the corner nearest to 0 deg latitude by 0 deg longitude of the ever decreasing size of grid squares, rather than reporting the center coordinator of those squares. The author welcomes reader inputs.—Ed]. The algorithm and calculations are shown in Table 9.

Maidenhead Grid Precision

How precise are the Maidenhead grid pairs? In other words, how close to the precise geo-location are you in relation to the number of grid pairs? How precise is precise enough? How does this vary with changes in latitude since as you relocate closer to the poles, longitude lines converge, or get closer together?

The spreadsheet tab labeled *Accuracy* shows the results in miles and feet for each pair of grid characters at latitude 34, see Table 10. Notice that with four characters, or two pairs, the location is within 32.1 miles. The location is within about one-third of a mile when eight characters are included in the calculation. With twelve characters, the precision is within about 12 feet, while a 16 character calculation gets you within one inch.

Table 9

Algorithm and calculations example – Maidenhead to coordinates.

Get # characters	16
Extract character 1	E
Extract character 2	M
Extract character 3	9
Extract character 4	1
Extract character 5	a
Extract character 6	d
Extract character 7	6
Extract character 8	0
Extract character 9	m
Extract character 10	w
Extract character 11	4
Extract character 12	5
Extract character 13	q
Extract character 14	t
Extract character 15	8
Extract character 16	0
Calculate character 1 value	-288000000
Calculate character 2 value	108000000
Calculate character 3 value	0
Calculate character 4 value	3600000
Calculate character 5 value	-6900000
Calculate character 6 value	450000
Calculate character 7 value	-90000
Calculate character 8 value	0
Calculate character 9 value	-13750
Calculate character 10 value	13750
Calculate character 11 value	-625
Calculate character 12 value	312.5
Calculate character 13 value	-36.45838
Calculate character 14 value	49.479173
Calculate character 15 value	-0.520833
Calculate character 16 value	0
Add longitudes together	-295004412
Add latitudes together	112064112
Convert lon to decimal degrees	-81.94566999
Convert lat to decimal degrees	31.12891999
Longitude degrees	-81
Latitude degrees	31
Longitude minutes	-56.74019965
Latitude minutes	7.735199653
Lon Mins	-56
Lat Mins	7
Lon Secs	-44.41197921
Lat Secs	44.11197917

Table 10**Precision based upon number of Maidenhead characters.**

<i>Latitude 1</i>	<i>Longitude 1</i>	<i>Latitude 2</i>	<i>Longitude 2</i>	<i>Distance in miles</i>	<i>Distance in feet</i>	<i>Grid characters</i>
34.065380	-84.554930	30.000000	-80.000000	387.5939897	2046496.2659	2
34.065380	-84.554930	34.000000	-84.000000	32.1297237	169644.9411	4
34.065380	-84.554930	34.041667	-84.500000	3.5496850	18742.3367	6
34.065380	-84.554930	34.062500	-84.550000	0.3456742	1825.1599	8
34.065380	-84.554930	34.065278	-84.554861	0.0080980	42.7576	10
34.065380	-84.554930	34.065365	-84.554896	0.0022294	11.7711	12
34.065380	-84.554930	34.065380	-84.554931	0.0000354	0.1871	14
34.065380	-84.554930	34.065380	-84.554930	0.000017	0.0900	16

Table 11**Distance between two Maidenhead locaters.**

		<i>Latitude decimal</i>	<i>Longitude decimal</i>	<i>Miles</i>
Enter grid square 1:	EM42uf13fd66rq60	32.221470	-90.323030	
Enter grid square 2:	EM31id77sc01go90	31.154541	-93.268740	
Calculated miles				188.3716945

Table 12**Grid 1 – Grid 2 algorithm.***Grid 1 algorithm and calculations*

Get # characters	16
Extract character 1	E
Extract character 2	M
Extract character 3	4
Extract character 4	2
Extract character 5	u
Extract character 6	f
Extract character 7	1
Extract character 8	3
Extract character 9	f
Extract character 10	d
Extract character 11	6
Extract character 12	6
Extract character 13	r
Extract character 14	q
Extract character 15	6
Extract character 16	0
Calculate character 1 value	-288000000
Calculate character 2 value	108000000
Calculate character 3 value	-36000000
Calculate character 4 value	7200000
Calculate character 5 value	-900000
Calculate character 6 value	750000
Calculate character 7 value	-240000
Calculate character 8 value	45000
Calculate character 9 value	-22500
Calculate character 10 value	1875
Calculate character 11 value	-375
Calculate character 12 value	375
Calculate character 13 value	-31.25004
Calculate character 14 value	41.666672
Calculate character 15 value	-1.562499
Calculate character 16 value	0
Add longitudes together	-325162907.8
Add latitudes together	115997291.7
Convert lon to decimal degrees	-90.32302995
Convert lat to decimal degrees	32.22146991
Longitude degrees	-90
Latitude degrees	32
Longitude minutes	-19.38179688
Latitude minutes	13.28819444
Lon Mins	-19
Lat Mins	13
Lon Secs	-22.90781254
Lat Secs	17.29166667

Grid 2 algorithm and calculations

Get # characters	16
Extract character 1	E
Extract character 2	M
Extract character 3	3
Extract character 4	1
Extract character 5	i
Extract character 6	d
Extract character 7	7
Extract character 8	7
Extract character 9	s
Extract character 10	c
Extract character 11	0
Extract character 12	1
Extract character 13	g
Extract character 14	o
Extract character 15	9
Extract character 16	0
Calculate character 1 value	-288000000
Calculate character 2 value	108000000
Calculate character 3 value	-43200000
Calculate character 4 value	3600000
Calculate character 5 value	-4500000
Calculate character 6 value	450000
Calculate character 7 value	-60000
Calculate character 8 value	105000
Calculate character 9 value	-6250
Calculate character 10 value	1250
Calculate character 11 value	-1125
Calculate character 12 value	62.5
Calculate character 13 value	-88.54178
Calculate character 14 value	36.458338
Calculate character 15 value	0
Calculate character 16 value	0
Add longitudes together	-335767463.5
Add latitudes together	112156349
Convert lon to decimal degrees	-93.26873987
Convert lat to decimal degrees	31.15454138
Longitude degrees	-93
Latitude degrees	31
Longitude minutes	-16.12439236
Latitude minutes	9.272482639
Lon Mins	-16
Lat Mins	9
Lon Secs	-7.46354178
Lat Secs	16.34895834

Distance Between Grids

Use the spreadsheet tab named *Grid to Grid Distance* to determine the distance from one Maidenhead grid locator to another. Enter the two grids in the yellow boxes near the top. The coordinates are calculated in decimal degrees and the distance in miles is given. This distance is calculated by the Spherical Law of Cosines with the law rearranged so that latitude can be used directly rather than the co-latitude. An example is shown in Table 11. The Grid 1 and Grid 2 algorithms calculations are shown in Table 12. Units of milliseconds are used in most steps for accuracy and ease of translating into other programming languages.

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Notes

¹ www.arri.org/grid-squares.

² E. H. Tyson, N5JTY, "Conversion between Geodetic and Grid Locator Systems", QST, Jan 1989, pp. 29 – 30, 43.

Table 13 – Longitude.

18 bins of 20 degrees (72000000 ms).

Degrees	Letter	Milliseconds
-180		-648000000
-160	A	-576000000
-140	B	-504000000
-120	C	-432000000
-100	D	-360000000
-80	E	-288000000
-60	F	-216000000
-40	G	-144000000
-20	H	-72000000
0	I	0
20	J	72000000
40	K	144000000
60	L	216000000
80	M	288000000
100	N	360000000
120	O	432000000
140	P	504000000
160	Q	576000000
180	R	648000000

Table 14 – Latitude.

18 bins of 10 degrees (36000000 ms).

Degrees	Letter	Milliseconds
-90		-324000000
-80	A	-288000000
-70	B	-252000000
-60	C	-216000000
-50	D	-180000000
-40	E	-144000000
-30	F	-108000000
-20	G	-72000000
-10	H	-36000000
0	I	0
10	J	36000000
20	K	72000000
30	L	108000000
40	M	144000000
50	N	180000000
60	O	216000000
70	P	252000000
80	Q	288000000
90	R	324000000

Table 15 – Longitude.

20 bins of 2 degrees (7200000 ms).

Degrees	Letter	ms
-20		-72000000
-18	0	-64800000
-16	1	-57600000
-14	2	-50400000
-12	3	-43200000
-10	4	-36000000
-8	5	-28800000
-6	6	-21600000
-4	7	-14400000
-2	8	-7200000
0	9	0
2	0	7200000
4	1	14400000
6	2	21600000
8	3	28800000
10	4	36000000
12	5	43200000
14	6	50400000
16	7	57600000
18	8	64800000
20	9	72000000

Table 16 – Latitude.

20 bins of 1 degree (3600000 ms).

Degrees	Number	ms
-10		-36000000
-9	0	-32400000
-8	1	-28800000
-7	2	-25200000
-6	3	-21600000
-5	4	-18000000
-4	5	-14400000
-3	6	-10800000
-2	7	-7200000
-1	8	-3600000
0	9	0
1	0	3600000
2	1	7200000
3	2	10800000
4	3	14400000
5	4	18000000
6	5	21600000
7	6	25200000
8	7	28800000
9	8	32400000
10	9	36000000

Table 17 – Longitude.**48 bins of 5 minutes (300000 ms).**

Minutes	Letter	ms
-120		-7200000
-115	a	-6900000
-110	b	-6600000
-105	c	-6300000
-100	d	-6000000
-95	e	-5700000
-90	f	-5400000
-85	g	-5100000
-80	h	-4800000
-75	i	-4500000
-70	j	-4200000
-65	k	-3900000
-60	l	-3600000
-55	m	-3300000
-50	n	-3000000
-45	o	-2700000
-40	p	-2400000
-35	q	-2100000
-30	r	-1800000
-25	s	-1500000
-20	t	-1200000
-15	u	-900000
-10	v	-600000
-5	w	-300000
0	x	0
5	a	300000
10	b	600000
15	c	900000
20	d	1200000
25	e	1500000
30	f	1800000
35	g	2100000
40	h	2400000
45	i	2700000
50	j	3000000
55	k	3300000
60	l	3600000
65	m	3900000
70	n	4200000
75	o	4500000
80	p	4800000
85	q	5100000
90	r	5400000
95	s	5700000
100	t	6000000
105	u	6300000
110	v	6600000
115	w	6900000
120	x	7200000

Table 18 – Latitude.**48 bins of 2.5 minutes (150000 ms).**

Minutes	Letter	ms
-60.0		-3600000
-57.5	a	-3450000
-55.0	b	-3300000
-52.5	c	-3150000
-50.0	d	-3000000
-47.5	e	-2850000
-45.0	f	-2700000
-42.5	g	-2550000
-40.0	h	-2400000
-37.5	i	-2250000
-35.0	j	-2100000
-32.5	k	-1950000
-30.0	l	-1800000
-27.5	m	-1650000
-25.0	n	-1500000
-22.5	o	-1350000
-20.0	p	-1200000
-17.5	q	-1050000
-15.0	r	-900000
-12.5	s	-750000
-10.0	t	-600000
-7.5	u	-450000
-5.0	v	-300000
-2.5	w	-150000
0.0	x	0
2.5	a	150000
5.0	b	300000
7.5	c	450000
10.0	d	600000
12.5	e	750000
15.0	f	900000
17.5	g	1050000
20.0	h	1200000
22.5	i	1350000
25.0	j	1500000
27.5	k	1650000
30.0	l	1800000
32.5	m	1950000
35.0	n	2100000
37.5	o	2250000
40.0	p	2400000
42.5	q	2550000
45.0	r	2700000
47.5	s	2850000
50.0	t	3000000
52.5	u	3150000
55.0	v	3300000
57.5	w	3450000
60.0	x	3600000

Table 19 – Longitude.**20 bins of 30 seconds (30000 ms).**

Seconds	Number	ms
-300		-300000
-270	0	-270000
-240	1	-240000
-210	2	-210000
-180	3	-180000
-150	4	-150000
-120	5	-120000
-90	6	-90000
-60	7	-60000
-30	8	-30000
0	9	0
30	0	30000
60	1	60000
90	2	90000
120	3	120000
150	4	150000
180	5	180000
210	6	210000
240	7	240000
270	8	270000
300	9	300000

Table 20 – Latitude.**20 bins of 15 seconds (15000 ms).**

Seconds	Number	ms
-150		-150000
-135	0	-135000
-120	1	-120000
-105	2	-105000
-90	3	-90000
-75	4	-75000
-60	5	-60000
-45	6	-45000
-30	7	-30000
-15	8	-15000
0	9	0
15	0	15000
30	1	30000
45	2	45000
60	3	60000
75	4	75000
90	5	90000
105	6	105000
120	7	120000
135	8	135000
150	9	150000

Table 21 – Longitude.
48 bins of 1.25 seconds (1250 ms).

Seconds	Letter	ms
-30.00		-30000
-28.75	a	-28750
-27.50	b	-27500
-26.25	c	-26250
-25.00	d	-25000
-23.75	e	-23750
-22.50	f	-22500
-21.25	g	-21250
-20.00	h	-20000
-18.75	i	-18750
-17.50	j	-17500
-16.25	k	-16250
-15.00	l	-15000
-13.75	m	-13750
-12.50	n	-12500
-11.25	o	-11250
-10.00	p	-10000
-8.75	q	-8750
-7.50	r	-7500
-6.25	s	-6250
-5.00	t	-5000
-3.75	u	-3750
-2.50	v	-2500
-1.25	w	-1250
0.00	x	0
1.25	a	1250
2.50	b	2500
3.75	c	3750
5.00	d	5000
6.25	e	6250
7.50	f	7500
8.75	g	8750
10.00	h	10000
11.25	i	11250
12.50	j	12500
13.75	k	13750
15.00	l	15000
16.25	m	16250
17.50	n	17500
18.75	o	18750
20.00	p	20000
21.25	q	21250
22.50	r	22500
23.75	s	23750
25.00	t	25000
26.25	u	26250
27.50	v	27500
28.75	w	28750
30.00	x	30000

Table 22 – Latitude.
48 bins of 0.625 seconds (625 ms).

Seconds	Letter	ms
-15.000		-15000
-14.375	a	-14375
-13.750	b	-13750
-13.125	c	-13125
-12.500	d	-12500
-11.875	e	-11875
-11.250	f	-11250
-10.625	g	-10625
-10.000	h	-10000
-9.375	i	-9375
-8.750	j	-8750
-8.125	k	-8125
-7.500	l	-7500
-6.875	m	-6875
-6.250	n	-6250
-5.625	o	-5625
-5.000	p	-5000
-4.375	q	-4375
-3.750	r	-3750
-3.125	s	-3125
-2.500	t	-2500
-1.875	u	-1875
-1.250	v	-1250
-0.625	w	-625
0.000	x	0
0.625	a	625
1.250	b	1250
1.875	c	1875
2.500	d	2500
3.125	e	3125
3.750	f	3750
4.375	g	4375
5.000	h	5000
5.625	i	5625
6.250	j	6250
6.875	k	6875
7.500	l	7500
8.125	m	8125
8.750	n	8750
9.375	o	9375
10.000	p	10000
10.625	q	10625
11.250	r	11250
11.875	s	11875
12.500	t	12500
13.125	u	13125
13.750	v	13750
14.375	w	14375
15.000	x	15000

Table 23 – Longitude.
20 bins of 0.125 seconds (125 ms).

Seconds	Number	ms
-1.250		-1250
-1.125	0	-1125
-1.000	1	-1000
-0.875	2	-875
-0.750	3	-750
-0.625	4	-625
-0.500	5	-500
-0.375	6	-375
-0.250	7	-250
-0.125	8	-125
0.000	9	0
0.125	0	125
0.250	1	250
0.375	2	375
0.500	3	500
0.625	4	625
0.750	5	750
0.875	6	875
1.000	7	1000
1.125	8	1125
1.250	9	1250

Table 24 – Latitude.
20 bins of 0.0625 seconds (62.5-ms).

Seconds	Number	ms
-0.6250		-625.0
-0.5625	0	-562.5
-0.5000	1	-500.0
-0.4375	2	-437.5
-0.3750	3	-375.0
-0.3125	4	-312.5
-0.2500	5	-250.0
-0.1875	6	-187.5
-0.1250	7	-125.0
-0.0625	8	-62.5
0.0000	9	0.0
0.0625	0	62.5
0.1250	1	125.0
0.1875	2	187.5
0.2500	3	250.0
0.3125	4	312.5
0.3750	5	375.0
0.4375	6	437.5
0.5000	7	500.0
0.5625	8	562.5
0.6250	9	625.0

Table 25 – Longitude.**48 bins of 0.005208 seconds (5.208 ms).**

Seconds	Number	ms
-0.12500016		-125.00016
-0.11979182	a	-119.79182
-0.11458348	b	-114.58348
-0.10937514	c	-109.37514
-0.1041668	d	-104.1668
-0.09895846	e	-98.95846
-0.09375012	f	-93.75012
-0.08854178	g	-88.54178
-0.08333344	h	-83.33344
-0.0781251	i	-78.1251
-0.07291676	j	-72.91676
-0.06770842	k	-67.70842
-0.06250008	l	-62.50008
-0.05729174	m	-57.29174
-0.0520834	n	-52.0834
-0.04687506	o	-46.87506
-0.04166672	p	-41.66672
-0.03645838	q	-36.45838
-0.03125004	r	-31.25004
-0.0260417	s	-26.0417
-0.02083336	t	-20.83336
-0.01562502	u	-15.62502
-0.01041668	v	-10.41668
-0.00520834	w	-5.20834
0	x	0
0.00520834	a	5.20834
0.01041668	b	10.41668
0.01562502	c	15.62502
0.02083336	d	20.83336
0.0260417	e	26.0417
0.03125004	f	31.25004
0.03645838	g	36.45838
0.04166672	h	41.66672
0.04687506	i	46.87506
0.0520834	j	52.0834
0.05729174	k	57.29174
0.06250008	l	62.50008
0.06770842	m	67.70842
0.07291676	n	72.91676
0.0781251	o	78.1251
0.08333344	p	83.33344
0.08854178	q	88.54178
0.09375012	r	93.75012
0.09895846	s	98.95846
0.1041668	t	104.1668
0.10937514	u	109.37514
0.11458348	v	114.58348
0.11979182	w	119.79182
0.12500016	x	125.00016

Table 26 – Latitude.**48 bins of 0.002604 seconds (2.604-ms).**

Seconds	Number	ms
-0.062500008		-62.500008
-0.059895841	a	-59.895841
-0.057291674	b	-57.291674
-0.054687507	c	-54.687507
-0.05208334	d	-52.08334
-0.049479173	e	-49.479173
-0.046875006	f	-46.875006
-0.044270839	g	-44.270839
-0.041666672	h	-41.666672
-0.039062505	i	-39.062505
-0.036458338	j	-36.458338
-0.033854171	k	-33.854171
-0.031250004	l	-31.250004
-0.028645837	m	-28.645837
-0.02604167	n	-26.04167
-0.023437503	o	-23.437503
-0.020833336	p	-20.833336
-0.018229169	q	-18.229169
-0.015625002	r	-15.625002
-0.013020835	s	-13.020835
-0.010416668	t	-10.416668
-0.007812501	u	-7.812501
-0.005208334	v	-5.208334
-0.002604167	w	-2.604167
0	x	0
0.002604167	a	2.604167
0.005208334	b	5.208334
0.007812501	c	7.812501
0.010416668	d	10.416668
0.013020835	e	13.020835
0.015625002	f	15.625002
0.018229169	g	18.229169
0.020833336	h	20.833336
0.023437503	i	23.437503
0.02604167	j	26.04167
0.028645837	k	28.645837
0.031250004	l	31.250004
0.033854171	m	33.854171
0.036458338	n	36.458338
0.039062505	o	39.062505
0.041666672	p	41.666672
0.044270839	q	44.270839
0.046875006	r	46.875006
0.049479173	s	49.479173
0.05208334	t	52.08334
0.054687507	u	54.687507
0.057291674	v	57.291674
0.059895841	w	59.895841
0.062500008	x	62.500008

Table 27 – Longitude.**20 bins of 0.000520833 seconds (0.520833 ms).**

Seconds	Number	ms
-0.005208330		-5.20833
-0.004687497	0	-4.687497
-0.004166664	1	-4.166664
-0.003645831	2	-3.645831
-0.003124998	3	-3.124998
-0.002604165	4	-2.604165
-0.002083332	5	-2.083332
-0.001562499	6	-1.562499
-0.001041666	7	-1.041666
-0.000520833	8	-0.520833
0.000000000	9	0
0.000520833	0	0.520833
0.001041666	1	1.041666
0.001562499	2	1.562499
0.002083332	3	2.083332
0.002604165	4	2.604165
0.003124998	5	3.124998
0.003645831	6	3.645831
0.004166664	7	4.166664
0.004687497	8	4.687497
0.005208330	9	5.20833

Table 28 – Latitude.**20 bins of 0.0002604 seconds (0.2604 ms).**

Seconds	Number	ms
-0.000260417		-0.260417
-0.000234375	0	-0.23437503
-0.000208333	1	-0.20833336
-0.000182292	2	-0.18229169
-0.000156250	3	-0.15625002
-0.000130208	4	-0.13020835
-0.000104167	5	-0.10416668
-0.000078125	6	-0.07812501
-0.000052083	7	-0.05208334
-0.000026042	8	-0.02604167
0.000000000	9	0
0.000026042	0	0.02604167
0.000052083	1	0.05208334
0.000078125	2	0.07812501
0.000104167	3	0.10416668
0.000130208	4	0.13020835
0.000156250	5	0.15625002
0.000182292	6	0.18229169
0.000208333	7	0.20833336
0.000234375	8	0.23437503
0.000260417	9	0.2604167