June 2017
KOLC(FM) Auxiliary Antenna
Carson City, Nevada Channel 247C
Engineering Study

Facilities Proposed

The proposed modified auxiliary antenna operation will be on Channel 247C (97.3 MHz) with a maximum lobe effective radiated power of 20.5 kilowatts. Operation is proposed with an array comprised of two vertically-polarized log periodic antennas to be mounted on an existing tower with FCC Antenna Structure Registration Number 1011093.

Statement re Directional Antenna Pattern

While the proposed auxiliary antenna facility will operate with a directional antenna, it is not necessary to include a condition on the construction permit requiring proof-of-performance antenna pattern measurements on the Shively 6025 antenna. As is depicted on the attached contour map exhibit, the ERP of the proposed facility has been designed so that even if the auxiliary antenna were to operate omnidirectionally, the auxiliary 60 dBu contour would not exceed the main 60 dBu contour at any azimuth.

In this regard, it should be noted that the proposed auxiliary facility will be located on the same tower as the main KOLC antenna.

RF Exposure Calculations

The power density calculations shown below were made using the techniques outlined in OET Bulletin No. 65. "Ground level" calculations in this report have been made at a reference height of 2 meters above ground to provide a worst-case estimate of exposure for persons standing on the ground in the vicinity of the tower. The equation shown below was used to calculate the ground level power density figures from each antenna.

$$S(\mu W / cm^2) = \frac{33.40981 \times AdjERP(Watts)}{D^2}$$

Where: *AdjERP(Watts)* is the maximum lobe effective radiated power times the element pattern factor times the array pattern factor.

D is the distance in meters from the center of radiation to the calculation point.

Ground level power densities have been calculated for locations extending from the base of the tower to a distance of 1000 meters. Values past this point are increasingly negligible.

The antenna to be used by the auxiliary facility is not a vertical dipole, and use of the dipole element model in FMModel dramatically overstates the ground-level power densities produced by this antenna. The auxiliary facility will utilize a single-level antenna (two antenna elements pointed in opposite directions), and ground level is at least 10 wavelengths away from the antenna. Included with this Engineering Statement is a complete tabulation of the Shively 6025 vertical plane radiation pattern as provided by the antenna manufacturer, along with the calculated ground-level power density from the antenna at 1 meter increments from the antenna. A sample calculation is provided to demonstrate that these calculations were performed correctly using appropriate mathematical principles and the formula from OET Bulletin No. 65. The highest calculated ground level power density from the auxiliary antenna occurs at a distance of 55 meters from the base of the antenna support structure. At this point the power density is calculated to be 67.9 μW/cm², which is 6.8% of 1000 μW/cm² (the FCC standard for controlled environments).

Calculations of the power density produced by the KOLC auxiliary and the other stations at this transmitter site are summarized in the following table:

Call	Avg or Peak ERP Antenna Model	Relative Field	Height AGL	Calculated Max Exposure	Occupational FCC Limit	% of Limit
KOLC(FM) Auxiliary	20.5 kW V SHI 6025-1-V	from manufacturer	38 m	67.9 μW/cm²	1000 μW/cm²	6.8%
K211GA	0.010 kW H SCA CL-FM/1	FMModel Type 1 assumed	25 m	0.2 μW/cm²	1000 μW/cm²	0.02%
KNIS(FM) 217C	67 kW H 67 KW V ERI SHPX-6E	FMModel Type 3	52 m	122.7 μW/cm²	100 μW/cm²	12.3%

K228DA	0.170 kW V SCA (2) CA2V 0.94 wave	FMModel Type 1 assumed 15 m	30.6 μW/cm²	1000 μW/cm²	3.1%
K249ES	0.250 kW H 0.250 kW V SCA (2) CA2CP 0.87 wave	FMModel Type 1 assumed 30 m	10.3 μW/cm²	1000 μW/cm²	1.0%
K263BL	0.099 kW V BEX LOG R-FM-V	FMModel Type 1 assumed 10 m	49.2 μW/cm²	1000 μW/cm²	4.9%
K269DB	0.250 kW H 0.250 kW V Scala (2) CA2CP 0.87 wavelength	FMModel Type 1 assumed 11 m	101.7 μW/cm²	1000 μW/cm²	10.2%
K293CA	0.250 kW H 0.250 kW V SCA (2) CA2CP 0.87 wave	FMModel Type 1 assumed 23 m	18.2 μW/cm²	1000 μW/cm²	1.8%

These calculations show that the maximum calculated power density produced at two meters above ground level by the proposed operation of the KOLC auxiliary and the present operation of the other stations at this site (were their maxima to coincide, which they do not) is 400.8 $\mu W/cm^2$, which is 40% of 1000 $\mu W/cm^2$ (the FCC standard for controlled environments). As was described in the 2005 renewal application BRH-20050601BNL for KOLC, the transmitter site is fenced to prevent public access to any areas which measurements have shown to be above the FCC MPE limit for the general population. This is considered to be a controlled access area. As noted in a report which was included as an exhibit to the 2005 renewal application, Americom engineering staff "erected a new fence to prevent public access to the area where the FCC general public MPE is exceeded. Appropriate signage has been installed to warn members of the general public against attempting to gain access to this area."

Additionally, FM station KNIS, while located close enough to be included as a part of this study, is located on a tower 170 meters from the KOLC tower. The maximum calculated power density from KNIS occurs at a point just 16 meters from that station's tower.

The permittee/licensee in coordination with other users of the site must reduce power or cease operation as necessary to protect persons having access to the site, tower or antenna from radiofrequency exposure in excess of FCC guidelines.

Sample Calculation for Single Shively 6025-1-V antenna

At 55 meters from the base of the antenna support structure, the slant distance to a point 2 meters above ground level is 65.73 meters. This is determined by simple trigonometry, determining the length of the hypotenuse for a right triangle which is 55 meters along the base and 36 meters in height (36 meters being the antenna height above ground, less 2 meters):

$$a^2 + b^2 = c^2$$

$$55^2 + 36^2 = c^2$$

$$c = 65.73 \text{ meters} = \text{hypotenuse}$$

The corresponding depression angle is identical to the angle between the base and hypotenuse, and is determined here as the inverse of the sine of the height over the hypotenuse of the right triangle:

$$\sin(\text{angle}) = \text{opposite} / \text{hypotenuse}$$

$$\sin(\text{angle}) = 36 / 65.73$$

$$\sin(\text{angle}) = 0.5477$$

$$\text{angle} = 33.21 \text{ degrees}$$

From the vertical plane pattern tabulation for the Shively 6025-1-V antenna, the relative field value at a depression angle of 33 degrees is 0.658, and at a depression angle of 34 degrees is 0.640. Interpolating between these two, we arrive at a relative field value of 0.6543 at a depression angle of 33.21 degrees. We use this relative field value to arrive at the adjusted ERP in watts at the depression angle:

$$\text{adjusted ERP} = (\text{watts H} + \text{watts V}) (\text{relative field squared})$$

$$\text{adjusted ERP} = (0 + 20500) (0.6543^2)$$

$$\text{adjusted ERP} = 8{,}776 \text{ watts}$$

By plugging this value into the formula from OET Bulletin 65, we arrive at the calculated ground-level power density:

$$S(\mu W / cm^2) = \frac{33.40981 \times AdjERP(Watts)}{D^2}$$

Where: *AdjERP(Watts)* is the maximum lobe effective radiated power times the element pattern factor times the array pattern factor.

D is the distance in meters from the center of radiation to the calculation point.

Thus, for an adjusted ERP of 8776 kilowatts and a distance of 65.73 meters, S is calculated to equal 67.9 μW/cm².

Antenna: Model 6025-1-V Vertically-polarized single-bay at frequency: 98.1 MHz

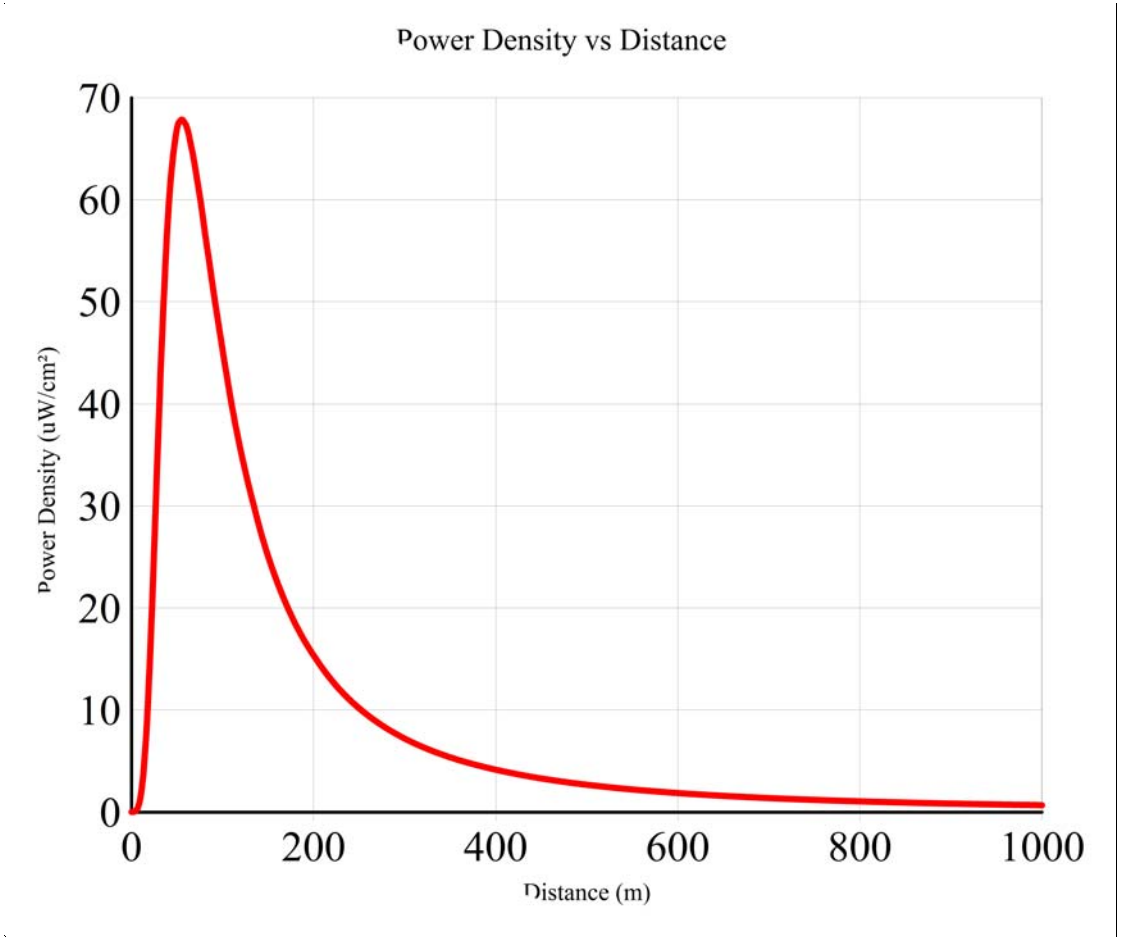
Angle of depression	Relative field	Angle of depression	Relative field	Angle of depression	Relative field	Angle of depression	Relative field
-90°	0.007	-44°	0.474	0°	1.000	46°	0.424
-89	0.009	-43	0.492	1	0.998	47	0.406
-88	0.011	-42	0.510	2	0.996	48	0.389
-87	0.013	-41	0.527	3	0.994	49	0.372
-86	0.015	-40	0.545	4	0.993	50	0.354
-85	0.017	-39	0.563	5	0.991	51	0.338
-84	0.021	-38	0.581	6	0.985	52	0.322
-83	0.024	-37	0.598	7	0.980	53	0.306
-82	0.028	-36	0.616	8	0.975	54	0.289
-81	0.032	-35	0.634	9	0.969	55	0.273
-80	0.036	-34	0.651	10	0.964	56	0.259
-79	0.042	-33	0.668	11	0.955	57	0.244
-78	0.047	-32	0.685	12	0.947	58	0.230
-77	0.053	-31	0.702	13	0.938	59	0.216
-76	0.059	-30	0.719	14	0.929	60	0.201
-75	0.065	-29	0.734	15	0.921	61	0.189
-74	0.073	-28	0.750	16	0.909	62	0.177
-73	0.081	-27	0.766	17	0.897	63	0.164
-72	0.089	-26	0.781	18	0.885	64	0.152
-71	0.097	-25	0.797	19	0.874	65	0.140
-70	0.105	-24	0.811	20	0.862	66	0.130
-69	0.115	-23	0.825	21	0.848	67	0.120
-68	0.125	-22	0.838	22	0.834	68	0.110
-67	0.135	-21	0.852	23	0.820	69	0.100
-66	0.145	-20	0.866	24	0.805	70	0.090
-65	0.156	-19	0.877	25	0.791	71	0.082
-64	0.168	-18	0.889	26	0.775	72	0.074
-63	0.181	-17	0.900	27	0.759	73	0.067
-62	0.193	-16	0.911	28	0.743	74	0.059
-61	0.205	-15	0.923	29	0.726	75	0.051
-60	0.218	-14	0.931	30	0.710	76	0.046
-59	0.232	-13	0.940	31	0.693	77	0.041
-58	0.247	-12	0.948	32	0.675	78	0.035
-57	0.261	-11	0.957	33	0.658	79	0.030
-56	0.276	-10	0.965	34	0.640	80	0.024
-55	0.290	-9	0.970	35	0.623	81	0.021
-54	0.306	-8	0.976	36	0.605	82	0.018
-53	0.322	-7	0.981	37	0.586	83	0.015
-52	0.338	-6	0.986	38	0.568	84	0.012
-51	0.354	-5	0.991	39	0.550	85	0.008
-50	0.370	-4	0.993	40	0.532	86	0.008
-49	0.388	-3	0.995	41	0.514	87	0.008
-48	0.405	-2	0.997	42	0.496	88	0.007
-47	0.422	-1	0.998	43	0.478	89	0.007
-46	0.439	0	1.000	44	0.459	90	0.007
-45	0.456			45	0.441		

Antenna: Model 6025-45 45°-polarized single-bay at frequency: 98.1 MHz

Angle of depression	Relative field	Angle of depression	Relative field	Angle of depression	Relative field	Angle of depression	Relative field
-90°	0.102	-44°	0.664	0°	1.000	46°	0.637
-89	0.110	-43	0.678	1	1.000	47	0.623
-88	0.118	-42	0.691	2	0.999	48	0.609
-87	0.127	-41	0.704	3	0.998	49	0.595
-86	0.135	-40	0.717	4	0.997	50	0.581
-85	0.144	-39	0.729	5	0.995	51	0.567
-84	0.153	-38	0.742	6	0.994	52	0.553
-83	0.163	-37	0.754	7	0.991	53	0.539
-82	0.172	-36	0.766	8	0.988	54	0.525
-81	0.183	-35	0.778	9	0.985	55	0.511
-80	0.193	-34	0.789	10	0.981	56	0.496
-79	0.203	-33	0.801	11	0.977	57	0.482
-78	0.214	-32	0.812	12	0.973	58	0.468
-77	0.225	-31	0.822	13	0.968	59	0.454
-76	0.236	-30	0.833	14	0.963	60	0.440
-75	0.248	-29	0.843	15	0.958	61	0.426
-74	0.260	-28	0.854	16	0.952	62	0.412
-73	0.272	-27	0.863	17	0.946	63	0.399
-72	0.284	-26	0.873	18	0.939	64	0.385
-71	0.296	-25	0.882	19	0.932	65	0.372
-70	0.309	-24	0.891	20	0.925	66	0.358
-69	0.321	-23	0.899	21	0.917	67	0.345
-68	0.334	-22	0.908	22	0.910	68	0.332
-67	0.347	-21	0.915	23	0.901	69	0.319
-66	0.361	-20	0.923	24	0.893	70	0.306
-65	0.374	-19	0.930	25	0.884	71	0.294
-64	0.387	-18	0.937	26	0.874	72	0.281
-63	0.401	-17	0.944	27	0.865	73	0.269
-62	0.415	-16	0.950	28	0.855	74	0.257
-61	0.428	-15	0.956	29	0.845	75	0.245
-60	0.442	-14	0.961	30	0.834	76	0.234
-59	0.456	-13	0.966	31	0.824	77	0.222
-58	0.470	-12	0.971	32	0.813	78	0.211
-57	0.484	-11	0.976	33	0.801	79	0.200
-56	0.498	-10	0.980	34	0.790	80	0.190
-55	0.512	-9	0.984	35	0.778	81	0.180
-54	0.526	-8	0.987	36	0.766	82	0.169
-53	0.541	-7	0.990	37	0.754	83	0.160
-52	0.555	-6	0.993	38	0.742	84	0.150
-51	0.569	-5	0.995	39	0.729	85	0.141
-50	0.583	-4	0.997	40	0.716	86	0.132
-49	0.596	-3	0.998	41	0.703	87	0.123
-48	0.610	-2	0.999	42	0.690	88	0.115
-47	0.624	-1	1.000	43	0.677	89	0.107
-46	0.638	0	1.000	44	0.664	90	0.099
-45	0.651			45	0.650		

KOLC(FM) Auxiliary Antenna
Ground-Level Power Density Calculations
Using Manufacturer's Vertical Plane Pattern

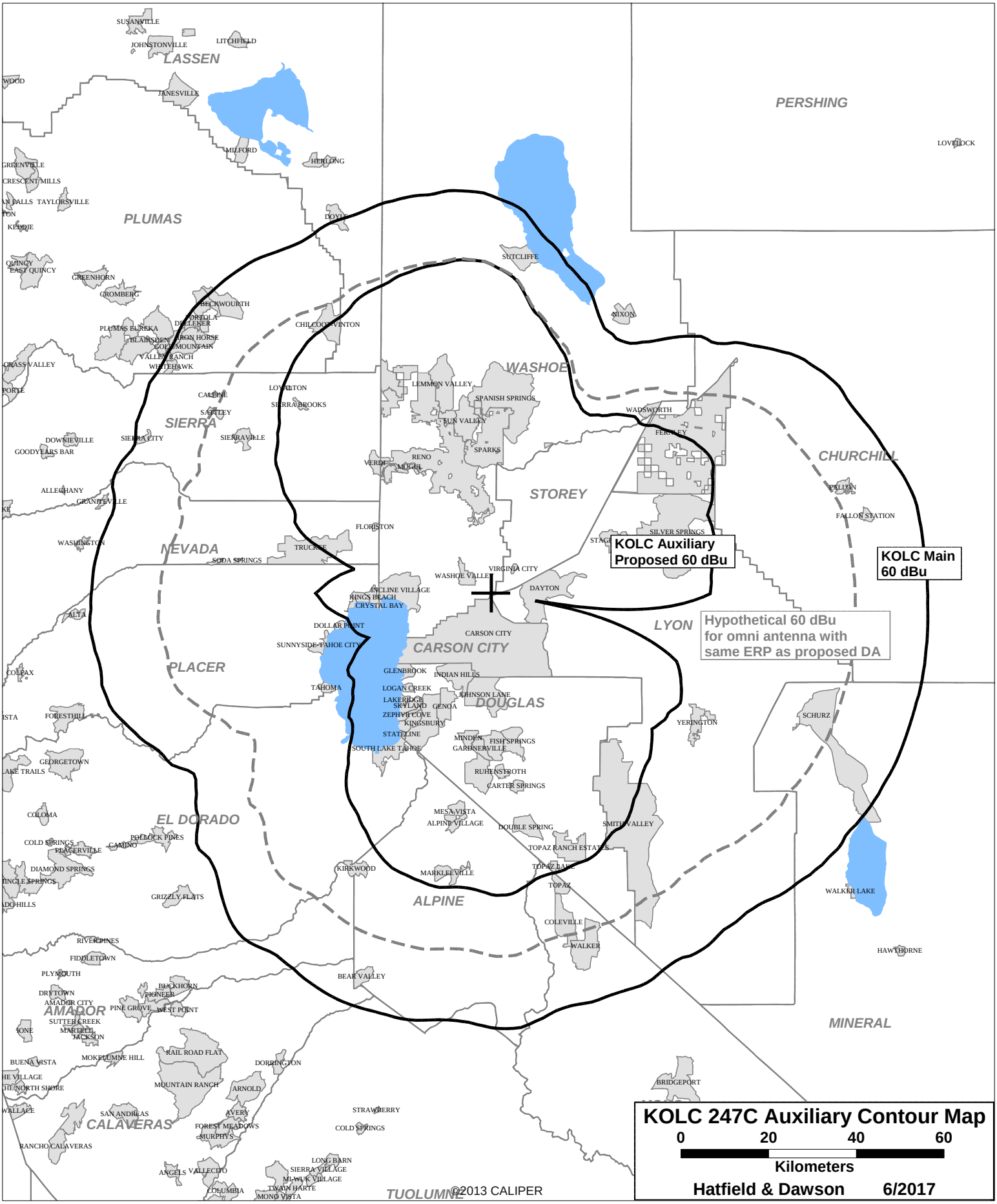
Antenna	SHI6025V			
ERP	0	Watts H (avg)		
	20500	Watts V (avg)		
Antenna AGL	38	meters less 2m is	36	meters above the reference plane
Calculated				
Maximum is	67.85	uW/cm² at	55	meters from the tower



Distance From Tower (meters)	Hypotenuse (meters)	Depression Angle (degrees)	Interp Rel Field	Adjusted ERP (watts)	Power Density uW/cm²
0	36.00	90.00	0.007	1.0	0.03
1	36.01	88.41	0.007	1.0	0.03
2	36.06	86.82	0.008	1.3	0.03
3	36.12	85.24	0.008	1.3	0.03
4	36.22	83.66	0.013	3.5	0.09
5	36.35	82.09	0.018	6.4	0.16
6	36.50	80.54	0.022	10.3	0.26
7	36.67	79.00	0.030	18.5	0.46
8	36.88	77.47	0.038	29.9	0.73
9	37.11	75.96	0.046	43.7	1.06
10	37.36	74.48	0.055	62.4	1.49
11	37.64	73.01	0.067	91.8	2.16
12	37.95	71.57	0.077	123.1	2.86
13	38.28	70.14	0.089	161.8	3.69
14	38.63	68.75	0.103	215.4	4.82
15	39.00	67.38	0.116	276.8	6.08
16	39.40	66.04	0.130	344.5	7.42
17	39.81	64.72	0.143	421.2	8.88
18	40.25	63.43	0.159	516.8	10.66
19	40.71	62.18	0.175	625.8	12.62
20	41.18	60.95	0.190	737.4	14.53
21	41.68	59.74	0.205	860.2	16.55
22	42.19	58.57	0.222	1010.4	18.97
23	42.72	57.43	0.238	1161.6	21.26
24	43.27	56.31	0.254	1326.2	23.67
25	43.83	55.22	0.270	1493.2	25.97
26	44.41	54.16	0.286	1681.5	28.49
27	45.00	53.13	0.304	1891.9	31.21
28	45.61	52.13	0.320	2099.2	33.72
29	46.23	51.15	0.336	2309.6	36.11
30	46.86	50.19	0.351	2524.0	38.40
31	47.51	49.27	0.367	2763.8	40.91
32	48.17	48.37	0.383	3003.5	43.25
33	48.84	47.49	0.398	3242.0	45.42
34	49.52	46.64	0.413	3488.9	47.54
35	50.21	45.81	0.427	3742.7	49.60
36	50.91	45.00	0.441	3986.9	51.39
37	51.62	44.22	0.455	4246.4	53.23
38	52.35	43.45	0.469	4517.2	55.08
39	53.08	42.71	0.483	4787.0	56.77
40	53.81	41.99	0.496	5048.0	58.24
41	54.56	41.28	0.509	5308.6	59.58

42	55.32	40.60	0.521	5568.3	60.80
43	56.08	39.94	0.533	5827.0	61.90
44	56.85	39.29	0.545	6084.3	62.89
45	57.63	38.66	0.556	6340.1	63.78
46	58.41	38.05	0.567	6594.1	64.57
47	59.20	37.45	0.578	6846.1	65.26
48	60.00	36.87	0.588	7099.1	65.88
49	60.80	36.30	0.599	7360.7	66.52
50	61.61	35.75	0.609	7613.8	67.01
51	62.43	35.22	0.619	7856.9	67.36
52	63.25	34.70	0.628	8089.6	67.57
53	64.07	34.19	0.637	8314.0	67.67
54	64.90	33.69	0.646	8543.8	67.77
55	65.73	33.21	0.654	8775.7	67.85
56	66.57	32.74	0.663	8997.6	67.83
57	67.42	32.28	0.670	9211.1	67.71
58	68.26	31.83	0.678	9426.5	67.58
59	69.12	31.39	0.686	9646.5	67.47
60	69.97	30.96	0.694	9862.6	67.30
61	70.83	30.55	0.701	10064.8	67.03
62	71.69	30.14	0.708	10264.2	66.72
63	72.56	29.74	0.714	10453.2	66.33
64	73.43	29.36	0.720	10635.3	65.90
65	74.30	28.98	0.726	10815.3	65.45
66	75.18	28.61	0.733	11003.1	65.04
67	76.06	28.25	0.739	11188.0	64.61
68	76.94	27.90	0.745	11367.1	64.15
69	77.83	27.55	0.750	11536.0	63.63
70	78.71	27.22	0.756	11702.3	63.10
71	79.61	26.89	0.761	11866.0	62.56
72	80.50	26.57	0.766	12027.2	62.01
73	81.39	26.25	0.771	12185.9	61.45
74	82.29	25.94	0.776	12342.2	60.89
75	83.19	25.64	0.781	12496.0	60.32
76	84.10	25.35	0.785	12647.5	59.75
77	85.00	25.06	0.790	12796.6	59.17
78	85.91	24.78	0.794	12928.8	58.53
79	86.82	24.50	0.798	13055.1	57.87
80	87.73	24.23	0.802	13179.5	57.21
81	88.64	23.96	0.806	13303.1	56.57
82	89.55	23.70	0.809	13432.1	55.96
83	90.47	23.45	0.813	13559.2	55.35
84	91.39	23.20	0.817	13684.2	54.74
85	92.31	22.95	0.821	13805.8	54.13
86	93.23	22.71	0.824	13918.9	53.50

87	94.15	22.48	0.827	14030.3	52.88
88	95.08	22.25	0.831	14139.9	52.26
89	96.01	22.02	0.834	14247.9	51.65
90	96.93	21.80	0.837	14354.1	51.04
91	97.86	21.58	0.840	14458.8	50.44
92	98.79	21.37	0.843	14561.8	49.85
93	99.72	21.16	0.846	14663.2	49.26
94	100.66	20.96	0.849	14763.2	48.68
95	101.59	20.75	0.851	14861.6	48.11
96	102.53	20.56	0.854	14958.5	47.54
97	103.46	20.36	0.857	15054.0	46.98
98	104.40	20.17	0.860	15148.1	46.43
99	105.34	19.98	0.862	15239.6	45.88
100	106.28	19.80	0.864	15317.8	45.31


KOLC Auxiliary Proposed 60 dBu
KOLC Main 60 dBu
Hypothetical 60 dBu for omni antenna with same ERP as proposed DA
LASSEN
PLUMAS
SIERRA
WASHOE
PERSHING
CHURCHILL
STOREY
LYON
NEVADA
PLACER
CARSON CITY
DOUGLAS
EL DORADO
ALPINE
AMADOR
CALAVERAS
TUOLUMNE
MINERAL
SUSANVILLE
JOHNSTONVILLE
LITCHFIELD
JANESVILLE
MILFORD
HERLONG
DOYLE
SUTCLIFFE
LOVELOCK
QUINCY
GREENHORN
GROMBERG
BECKWOURTH
PLUMAS EUREKA
CHILCOOT-VINTON
LEMMON VALLEY
SPANISH SPRINGS
SUN VALLEY
WADSWORTH
FERNLEY
NIXON
CALPINE
LOYALTON
SIERRA BROOKS
SATTLEY
DOWNIEVILLE
SIERRA CITY
SIERRAVILLE
GOODYEARS BAR
RENO
SPARKS
VERDI
MOGUL
ALLEGHANY
GRANITEVILLE
FALLON
FALLON STATION
SILVER SPRINGS
STAGE
FLORISTON
WASHINGTON
TRUCKEE
SODA SPRINGS
VIRGINIA CITY
WASHOE VALLEY
DAYTON
INCLINE VILLAGE
KINGS BEACH
CRYSTAL BAY
ALTA
DOLLAR POINT
SUNNYSIDE-TAHOE CITY
CARSON CITY
COLFAX
GLENBROOK
INDIAN HILLS
TAHOMA
LOGAN CREEK
JOHNSON LANE
LAKERIDGE
SKYLAND
GENOA
ZEPHYR COVE
KINGSBURY
FORESTHILL
STATELINE
SOUTH LAKE TAHOE
MINDEN
FISH SPRINGS
GARDNERVILLE
YERINGTON
SCHURZ
GEORGETOWN
RUHENSTROTH
CARTER SPRINGS
COLOMA
MESA VISTA
ALPINE VILLAGE
DOUBLE SPRING
SMITH VALLEY
COLD SPRINGS
PLACERVILLE
POLLOCK PINES
CAMINO
TOPAZ RANCH ESTATES
TOPAZ LAKE
DIAMOND SPRINGS
KIRKWOOD
MARKLEEVILLE
TOPAZ
WALKER LAKE
GRIZZLY FLATS
COLEVILLE
WALKER
RIVER PINES
FIDDLETOWN
HAWTHORNE
PLYMOUTH
BEAR VALLEY
DRYTOWN
BUCKHORN
PIONEER
AMADOR CITY
PINE GROVE
WEST POINT
SUTTER CREEK
MARTELL
JACKSON
MOKELUMNE HILL
RAIL ROAD FLAT
DORRINGTON
BUENA VISTA
MOUNTAIN RANCH
ARNOLD
BRIDGEPORT
SAN ANDREAS
AVERY
STRAWBERRY
FOREST MEADOWS
COLD SPRINGS
MURPHYS
RANCHO CALAVERAS
LONG BARN
SIERRA VILLAGE
MI-WUK VILLAGE
TWAIN HARTE
ANGELS VALLECITO
COLUMBIA
MONO VISTA
©2013 CALIPER
KOLC 247C Auxiliary Contour Map
0 20 40 60
Kilometers
Hatfield & Dawson 6/2017