APPENDIX C

RESOLUTION RESULTS WITH PROCESSING

Tables C.1–C.12 present resolution measurements for the high frequency two-dimensional amplitude-steered array without any time-frequency processing. The array is approximately 10 cm in diameter. There are 392 staves with a center-to-center spacing of 254 μm, and there are 466 rows with a center-to-center spacing of 215.9 μm. The array is designed to steer in the vertical direction to 5° at 5 MHz. Frequencies range from 1 MHz to 5 MHz. The center two staves are used as the transmit array.

Table C.1: Range resolution in mm for angles $5° - 14°$, horizontal angle = $0°$.

Vertical Angle (deg) Range (m)	5	6	7	8	9	10	11	12	13	14
3.0	4.76	5.46	6.34	7.25	8.09	9.01	9.96	11.0	12.0	12.3
3.1	5.02	5.60	6.48	7.36	8.28	9.12	10.1	11.1	12.1	12.4
3.2	5.31	5.75	6.59	7.47	8.31	9.23	10.2	11.2	12.2	12.5
3.3	5.53	5.82	6.74	7.58	8.42	9.34	10.3	11.2	12.2	12.6
3.4	5.57	6.04	6.88	7.76	8.61	9.45	10.4	11.4	12.5	12.7
3.5	5.42	6.23	7.03	7.87	8.75	9.59	10.5	11.5	12.5	12.9
3.6	5.20	6.30	7.25	8.02	8.86	9.78	10.7	11.6	12.6	13.0
3.7	3.59	6.45	7.32	8.20	9.08	9.89	10.8	11.8	12.8	13.1
3.8	3.59	6.63	7.40	8.31	9.12	10.0	11.0	11.9	12.8	13.2
3.9	3.48	6.67	7.51	8.35	9.23	10.1	11.0	12.0	12.9	13.3
4.0	3.52	6.70	7.62	8.46	9.38	10.1	11.1	12.1	13.0	13.4
4.1	3.59	6.96	7.72	8.68	9.52	10.4	11.4	12.3	13.3	13.6
4.2	3.41	7.07	7.87	8.72	9.56	10.5	11.4	12.3	13.3	13.7
4.3	3.48	6.99	7.87	8.75	9.63	10.5	11.4	12.5	13.4	13.8
4.4	3.66	7.18	7.91	8.83	9.74	10.6	11.6	12.5	13.4	13.8
4.5	3.52	7.21	8.13	8.94	9.78	10.6	11.6	12.6	13.5	13.9
4.6	3.59	7.25	8.17	9.01	9.92	10.8	11.7	12.7	13.6	14.1
4.7	3.66	7.36	8.17	9.08	9.92	10.8	11.8	12.7	13.7	14.1
4.8	3.66	7.43	8.28	9.16	10.0	10.9	11.9	12.8	13.7	14.2
4.9	3.66	7.40	8.31	9.23	10.1	11.0	11.9	12.9	13.8	14.2
5.0	3.66	7.43	8.31	9.27	10.1	11.0	11.9	12.9	13.8	14.3

Table C.2: Range resolution in mm for angles $15° - 24°$, horizontal angle = $0°$.

Vertical Angle (deg) Range (m)	15	16	17	18	19	20	21	22	23	24
3.0	13.0	14.3	15.5	16.0	16.8	18.0	18.8	19.5	20.3	21.1
3.1	13.0	14.4	15.6	16.1	17.0	18.1	18.9	19.7	20.5	21.3
3.2	13.1	14.6	15.6	16.2	17.1	18.1	18.9	19.7	20.5	21.3
3.3	13.2	14.6	15.7	16.3	17.1	18.2	19.0	19.7	20.6	21.3
3.4	13.4	14.8	15.9	16.4	17.3	18.3	19.1	19.9	20.7	21.5
3.5	13.5	14.8	15.9	16.5	17.4	18.4	19.2	20.0	20.9	21.6
3.6	13.6	14.9	15.9	16.6	17.5	18.4	19.2	20.0	20.8	21.5
3.7	13.8	15.1	16.1	16.8	17.6	18.5	19.4	20.1	20.9	21.9
3.8	13.9	15.2	16.2	16.9	17.7	18.6	19.4	20.2	21.0	21.9
3.9	14.0	15.3	16.3	17.0	17.8	18.7	19.4	20.3	21.2	21.8
4.0	14.2	15.4	16.3	17.0	17.9	18.7	19.5	20.3	21.1	22.0
4.1	14.4	15.6	16.5	17.2	18.1	18.9	19.7	20.4	21.2	22.1
4.2	14.4	15.6	16.5	17.4	18.1	19.0	19.7	20.5	21.4	22.2
4.3	14.6	15.7	16.6	17.4	18.2	19.0	19.8	20.6	21.4	22.2
4.4	14.6	15.8	16.6	17.5	18.3	19.0	19.8	20.6	21.4	22.3
4.5	14.6	15.9	16.7	17.6	18.3	19.0	19.9	20.7	21.5	22.2
4.6	14.9	16.0	16.8	17.7	18.5	19.3	20.0	20.8	21.7	22.4
4.7	14.9	16.1	16.9	17.8	18.6	19.2	20.0	20.9	21.7	22.6
4.8	15.0	16.2	16.9	17.8	18.6	19.3	20.1	20.9	21.9	22.5
4.9	15.1	16.2	17.0	17.9	18.7	19.4	20.2	21.0	21.8	22.6
5.0	15.1	16.3	17.0	18.0	18.7	19.4	20.1	20.0	21.8	22.7

Table C.3: Range resolution in mm for angles $5° - 14°$, horizontal angle = $15°$.

Vertical Angle (deg) Range (m)	5	6	7	8	9	10	11	12	13	14
3.0	4.65	5.42	6.30	7.18	8.06	8.90	9.81	10.7	11.6	12.1
3.1	5.05	5.60	6.48	7.36	8.20	9.01	9.89	10.8	11.6	12.1
3.2	5.24	5.75	6.67	7.54	8.42	9.27	10.1	11.0	11.8	12.4
3.3	5.57	5.93	6.81	7.73	8.68	9.59	10.6	11.4	12.2	12.8
3.4	5.57	6.23	7.07	7.95	8.90	9.81	10.8	11.5	12.2	12.6
3.5	5.42	6.30	7.25	8.17	9.12	10.0	11.1	12.3	12.5	12.9
3.6	5.46	6.41	7.32	8.35	9.30	10.2	11.5	12.7	14.3	13.1
3.7	5.13	6.59	7.51	8.46	9.45	10.5	11.6	12.9	14.1	13.0
3.8	3.59	6.67	7.62	8.57	9.56	10.7	11.9	13.2	14.7	13.3
3.9	3.63	6.81	7.69	8.68	9.70	10.8	12.1	13.6	15.0	16.0
4.0	3.63	6.96	7.76	8.83	9.81	10.9	12.3	13.8	15.3	16.5
4.1	3.63	6.92	7.80	8.72	9.78	10.8	12.0	13.5	14.9	15.9
4.2	3.66	7.14	8.06	9.01	10.0	11.1	12.4	13.9	15.3	16.1
4.3	3.70	7.29	8.13	9.16	10.1	11.2	12.5	14.0	15.6	16.6
4.4	3.66	7.32	8.28	9.23	10.3	11.3	12.7	14.2	15.8	17.0
4.5	3.74	7.40	8.31	9.27	10.4	11.5	12.8	14.3	16.0	17.8
4.6	3.81	7.54	8.42	9.41	10.4	11.5	12.9	14.3	15.7	16.7
4.7	3.77	7.51	8.50	9.52	10.6	11.6	12.9	14.4	16.0	17.3
4.8	3.77	7.54	8.50	9.56	10.6	11.7	13.1	14.5	16.1	18.0
4.9	3.85	7.69	8.57	9.63	10.7	11.8	13.2	14.6	16.3	18.2
5.0	3.88	7.69	8.68	9.67	10.8	11.9	13.3	14.7	16.5	18.4

Table C.4: Range resolution in mm for angles $15° - 24°$, horizontal angle = $15°$.

Vertical Angle (deg) Range (m)	15	16	17	18	19	20	21	22	23	24
3.0	13.2	21.5	25.6	28.4	22.9	16.0	17.1	18.2	19.0	19.7
3.1	13.0	14.0	25.7	28.3	23.0	16.0	17.0	18.0	18.9	19.6
3.2	13.2	21.3	25.8	28.4	23.0	16.0	17.1	18.0	18.9	19.6
3.3	13.4	22.1	25.9	28.5	23.1	16.1	17.1	18.0	19.0	19.6
3.4	13.1	13.9	25.2	27.8	22.8	15.7	16.9	17.8	18.5	19.4
3.5	13.4	21.3	25.8	28.1	22.9	15.8	16.9	17.8	18.6	19.4
3.6	13.8	21.6	25.9	28.1	22.7	15.8	16.9	17.7	18.6	19.3
3.7	13.4	14.0	23.6	19.6	21.6	15.4	16.5	17.7	18.5	19.0
3.8	13.6	21.2	25.0	20.2	21.8	15.4	16.5	17.7	18.5	19.0
3.9	18.1	22.1	25.5	26.8	21.9	15.5	16.5	17.7	18.5	19.0
4.0	19.0	22.7	26.0	27.3	21.9	15.5	16.6	17.7	18.5	19.2
4.1	14.4	14.3	15.5	15.9	20.5	14.7	16.2	17.3	18.2	18.9
4.2	14.0	14.0	15.2	15.8	11.8	14.5	16.0	17.2	18.0	18.4
4.3	18.1	21.1	15.2	15.6	11.5	14.5	16.0	17.2	18.0	18.4
4.4	19.6	21.9	23.8	15.8	11.5	14.5	16.0	17.2	18.0	18.5
4.5	20.1	22.5	24.8	15.7	11.5	14.5	16.0	17.2	18.0	18.5
4.6	14.3	14.0	14.9	5.60	7.80	13.9	15.6	16.9	17.7	18.4
4.7	18.3	14.1	15.1	5.20	7.54	13.9	15.5	16.9	17.7	18.4
4.8	19.7	21.1	15.1	5.13	7.43	13.8	15.5	16.9	17.7	18.4
4.9	20.3	21.8	15.2	14.0	7.25	13.7	15.6	16.9	17.7	18.4
5.0	20.7	22.4	15.3	14.1	6.74	13.7	15.6	16.9	17.7	18.4

Table C.5: Vertical resolution in degrees for angles $5° - 14°$, horizontal angle = $0°$.

Vertical Angle (deg) Range (m)	5	6	7	8	9	10	11	12	13	14
3.0	0.151	0.167	0.221	0.257	0.283	0.317	0.338	0.374	0.403	0.482
3.1	0.153	0.170	0.223	0.258	0.285	0.320	0.343	0.375	0.404	0.483
3.2	0.155	0.172	0.225	0.259	0.287	0.322	0.343	0.376	0.404	0.486
3.3	0.162	0.174	0.224	0.261	0.288	0.321	0.342	0.378	0.402	0.487
3.4	0.165	0.176	0.228	0.264	0.289	0.324	0.346	0.378	0.406	0.489
3.5	0.178	0.182	0.231	0.265	0.292	0.327	0.344	0.380	0.407	0.484
3.6	0.264	0.181	0.230	0.266	0.291	0.328	0.349	0.380	0.408	0.490
3.7	0.292	0.189	0.237	0.271	0.296	0.327	0.351	0.384	0.407	0.495
3.8	0.298	0.192	0.241	0.274	0.298	0.333	0.353	0.384	0.408	0.498
3.9	0.311	0.197	0.240	0.276	0.299	0.337	0.355	0.385	0.411	0.491
4.0	0.310	0.201	0.244	0.279	0.301	0.339	0.356	0.387	0.413	0.498
4.1	0.299	0.213	0.255	0.287	0.307	0.340	0.357	0.390	0.414	0.506
4.2	0.295	0.225	0.255	0.289	0.307	0.343	0.360	0.391	0.414	0.506
4.3	0.280	0.246	0.259	0.296	0.309	0.350	0.362	0.392	0.417	0.499
4.4	0.265	0.257	0.267	0.297	0.312	0.348	0.362	0.395	0.419	0.505
4.5	0.260	0.266	0.275	0.303	0.317	0.350	0.363	0.397	0.418	0.510
4.6	0.238	0.295	0.281	0.316	0.318	0.358	0.368	0.400	0.420	0.514
4.7	0.229	0.312	0.289	0.321	0.323	0.362	0.369	0.402	0.423	0.508
4.8	0.221	0.327	0.301	0.322	0.328	0.362	0.370	0.405	0.424	0.514
4.9	0.216	0.339	0.315	0.336	0.332	0.363	0.373	0.406	0.425	0.518
5.0	0.213	0.355	0.340	0.343	0.333	0.371	0.373	0.408	0.426	0.520

Table C.6: Vertical resolution in degrees for angles $15° - 24°$, horizontal angle = $0°$.

Vertical Angle (deg) Range (m)	15	16	17	18	19	20	21	22	23	24
3.0	0.521	0.522	0.547	0.604	0.643	0.660	0.688	0.736	0.766	0.799
3.1	0.523	0.523	0.545	0.605	0.642	0.661	0.689	0.732	0.767	0.800
3.2	0.522	0.523	0.548	0.606	0.643	0.661	0.691	0.734	0.768	0.805
3.3	0.523	0.524	0.549	0.606	0.645	0.663	0.691	0.735	0.768	0.802
3.4	0.525	0.525	0.550	0.608	0.647	0.665	0.693	0.739	0.770	0.803
3.5	0.526	0.528	0.549	0.602	0.648	0.667	0.701	0.738	0.773	0.804
3.6	0.530	0.528	0.551	0.610	0.648	0.665	0.695	0.737	0.773	0.805
3.7	0.533	0.529	0.553	0.611	0.649	0.667	0.696	0.742	0.773	0.803
3.8	0.536	0.530	0.552	0.613	0.651	0.666	0.696	0.743	0.773	0.807
3.9	0.536	0.536	0.554	0.614	0.652	0.673	0.704	0.740	0.777	0.812
4.0	0.537	0.534	0.556	0.607	0.653	0.669	0.698	0.743	0.778	0.813
4.1	0.541	0.534	0.558	0.616	0.654	0.671	0.701	0.745	0.776	0.808
4.2	0.542	0.535	0.557	0.613	0.656	0.670	0.701	0.746	0.780	0.811
4.3	0.544	0.541	0.559	0.615	0.657	0.678	0.707	0.745	0.781	0.812
4.4	0.546	0.539	0.560	0.612	0.658	0.673	0.704	0.749	0.784	0.810
4.5	0.547	0.539	0.561	0.621	0.658	0.673	0.706	0.749	0.780	0.811
4.6	0.547	0.541	0.560	0.619	0.661	0.675	0.705	0.748	0.785	0.812
4.7	0.552	0.547	0.565	0.620	0.662	0.682	0.711	0.751	0.788	0.816
4.8	0.553	0.546	0.563	0.613	0.662	0.676	0.709	0.753	0.787	0.817
4.9	0.555	0.545	0.566	0.625	0.664	0.677	0.712	0.753	0.785	0.818
5.0	0.555	0.545	0.563	0.625	0.664	0.680	0.710	0.753	0.788	0.815

Table C.7: Vertical resolution in degrees for angles $5° - 14°$, horizontal angle = $15°$.

Vertical Angle (deg) Range (m)	5	6	7	8	9	10	11	12	13	14
3.0	0.150	0.163	0.216	0.250	0.275	0.298	0.320	0.341	0.357	0.410
3.1	0.153	0.164	0.217	0.251	0.276	0.300	0.322	0.342	0.357	0.413
3.2	0.154	0.165	0.218	0.252	0.275	0.300	0.321	0.343	0.358	0.412
3.3	0.156	0.167	0.220	0.253	0.278	0.304	0.323	0.343	0.358	0.412
3.4	0.168	0.170	0.222	0.254	0.279	0.303	0.322	0.344	0.359	0.412
3.5	0.181	0.173	0.223	0.257	0.280	0.305	0.323	0.345	0.359	0.415
3.6	0.198	0.175	0.226	0.259	0.281	0.306	0.326	0.346	0.360	0.415
3.7	0.294	0.182	0.230	0.261	0.283	0.309	0.327	0.347	0.361	0.415
3.8	0.302	0.185	0.232	0.264	0.286	0.311	0.325	0.347	0.362	0.414
3.9	0.303	0.189	0.236	0.267	0.287	0.313	0.327	0.349	0.362	0.417
4.0	0.310	0.196	0.240	0.270	0.290	0.316	0.330	0.349	0.363	0.418
4.1	0.274	0.212	0.247	0.279	0.295	0.324	0.336	0.357	0.370	0.427
4.2	0.277	0.220	0.250	0.279	0.295	0.321	0.330	0.351	0.364	0.419
4.3	0.266	0.234	0.256	0.283	0.296	0.323	0.334	0.353	0.365	0.420
4.4	0.255	0.250	0.260	0.289	0.299	0.326	0.336	0.354	0.366	0.421
4.5	0.242	0.262	0.267	0.293	0.302	0.330	0.336	0.355	0.367	0.418
4.6	0.216	0.293	0.277	0.300	0.307	0.331	0.337	0.356	0.368	0.422
4.7	0.211	0.313	0.287	0.308	0.310	0.333	0.340	0.358	0.368	0.421
4.8	0.209	0.324	0.300	0.316	0.315	0.340	0.342	0.358	0.369	0.423
4.9	0.197	0.347	0.320	0.321	0.318	0.343	0.344	0.360	0.370	0.424
5.0	0.194	0.431	0.344	0.328	0.325	0.343	0.344	0.361	0.370	0.423

Table C.8: Vertical resolution in degrees for angles $15° - 24°$, horizontal angle $= 15°$.

Vertical Angle (deg) Range (m)	15	16	17	18	19	20	21	22	23	24
3.0	0.423	0.396	0.392	1.880	1.920	1.063	1.010	0.983	0.993	0.999
3.1	0.420	0.396	0.383	0.891	1.595	1.042	0.988	0.964	0.980	0.992
3.2	0.421	0.392	0.377	1.856	1.613	1.055	0.994	0.970	0.985	0.999
3.3	0.421	0.391	0.377	1.879	1.918	1.068	1.001	0.977	0.988	1.002
3.4	0.421	0.396	0.391	0.974	1.586	1.031	0.971	0.955	0.976	0.988
3.5	0.420	0.392	0.380	1.857	1.611	1.044	0.984	0.961	0.979	0.992
3.6	0.420	0.391	0.367	1.912	1.932	1.062	0.996	0.974	0.983	1.001
3.7	0.421	0.399	0.398	1.834	1.571	1.014	0.960	0.951	0.970	0.988
3.8	0.421	0.394	0.385	1.859	1.597	1.035	0.970	0.955	0.975	0.989
3.9	0.421	0.390	0.379	1.877	1.893	1.048	0.978	0.960	0.980	0.992
4.0	0.421	0.388	0.367	1.891	1.922	1.060	0.986	0.966	0.981	0.999
4.1	0.433	0.408	0.399	1.880	1.596	1.030	0.962	0.960	0.974	0.995
4.2	0.423	0.401	0.410	1.042	1.528	0.983	0.941	0.942	0.965	0.984
4.3	0.424	0.398	0.402	1.839	1.554	1.004	0.949	0.946	0.970	0.985
4.4	0.422	0.394	0.390	1.876	1.580	1.019	0.955	0.950	0.969	0.988
4.5	0.422	0.391	0.382	1.886	1.606	1.041	0.965	0.958	0.977	0.992
4.6	0.427	0.407	0.424	0.997	1.456	0.935	0.917	0.930	0.958	0.980
4.7	0.426	0.408	0.418	1.028	1.495	0.950	0.925	0.935	0.961	0.981
4.8	0.425	0.403	0.410	1.042	1.517	0.973	0.930	0.940	0.962	0.986
4.9	0.425	0.398	0.404	1.801	1.539	0.991	0.940	0.946	0.965	0.988
5.0	0.424	0.394	0.397	1.842	1.560	1.007	0.947	0.950	0.971	0.987

Table C.9: Horizontal resolution in degrees for angles $5° - 14°$, horizontal angle $= 0°$.

Vertical Angle (deg) Range (m)	5	6	7	8	9	10	11	12	13	14
3.0	0.239	0.282	0.332	0.382	0.429	0.477	0.525	0.572	0.619	0.671
3.1	0.243	0.284	0.334	0.384	0.432	0.478	0.527	0.575	0.621	0.672
3.2	0.240	0.284	0.333	0.384	0.431	0.478	0.526	0.574	0.620	0.670
3.3	0.237	0.283	0.333	0.383	0.430	0.477	0.525	0.573	0.620	0.670
3.4	0.244	0.287	0.336	0.387	0.434	0.480	0.528	0.576	0.623	0.673
3.5	0.237	0.285	0.335	0.385	0.432	0.479	0.527	0.575	0.621	0.671
3.6	0.227	0.284	0.333	0.383	0.430	0.477	0.525	0.573	0.619	0.669
3.7	0.227	0.289	0.337	0.388	0.435	0.480	0.529	0.576	0.623	0.673
3.8	0.227	0.286	0.334	0.385	0.431	0.479	0.526	0.574	0.620	0.670
3.9	0.230	0.283	0.332	0.382	0.429	0.476	0.524	0.572	0.618	0.668
4.0	0.231	0.279	0.329	0.379	0.427	0.472	0.521	0.570	0.616	0.666
4.1	0.236	0.292	0.340	0.389	0.435	0.483	0.530	0.577	0.622	0.669
4.2	0.236	0.287	0.335	0.385	0.432	0.480	0.526	0.574	0.620	0.671
4.3	0.236	0.279	0.329	0.380	0.428	0.474	0.523	0.571	0.617	0.667
4.4	0.236	0.265	0.326	0.378	0.423	0.472	0.520	0.569	0.615	0.661
4.5	0.237	0.266	0.322	0.374	0.419	0.465	0.517	0.565	0.613	0.659
4.6	0.240	0.269	0.317	0.380	0.425	0.473	0.522	0.571	0.618	0.664
4.7	0.239	0.269	0.316	0.376	0.419	0.468	0.521	0.568	0.614	0.661
4.8	0.239	0.269	0.313	0.361	0.413	0.462	0.516	0.564	0.612	0.659
4.9	0.238	0.268	0.311	0.361	0.412	0.462	0.512	0.561	0.609	0.655
5.0	0.238	0.268	0.316	0.359	0.407	0.457	0.508	0.559	0.606	0.652

Table C.10: Horizontal resolution in degrees for angles $15°-24°$, horizontal angle $= 0°$.

Vertical Angle (deg) Range (m)	15	16	17	18	19	20	21	22	23	24
3.0	0.710	0.761	0.810	0.858	0.907	0.944	0.983	1.034	1.082	1.117
3.1	0.712	0.764	0.813	0.860	0.910	0.946	0.985	1.035	1.085	1.120
3.2	0.711	0.763	0.810	0.858	0.909	0.944	0.983	1.033	1.083	1.117
3.3	0.709	0.761	0.809	0.857	0.908	0.944	0.981	1.032	1.081	1.115
3.4	0.713	0.764	0.813	0.860	0.912	0.948	0.981	1.035	1.084	1.119
3.5	0.710	0.763	0.811	0.858	0.911	0.945	0.981	1.033	1.081	1.115
3.6	0.708	0.761	0.809	0.857	0.909	0.943	0.979	1.030	1.079	1.113
3.7	0.711	0.764	0.811	0.857	0.913	0.946	0.980	1.032	1.083	1.116
3.8	0.709	0.761	0.809	0.858	0.907	0.945	0.979	1.030	1.082	1.114
3.9	0.707	0.759	0.808	0.856	0.905	0.943	0.976	1.029	1.078	1.110
4.0	0.704	0.757	0.806	0.851	0.907	0.941	0.974	1.027	1.079	1.109
4.1	0.712	0.764	0.808	0.855	0.908	0.947	0.978	1.029	1.085	1.109
4.2	0.708	0.761	0.809	0.856	0.907	0.946	0.977	1.030	1.083	1.111
4.3	0.705	0.759	0.809	0.852	0.906	0.942	0.974	1.027	1.081	1.110
4.4	0.702	0.757	0.804	0.850	0.903	0.940	0.972	1.026	1.080	1.106
4.5	0.700	0.753	0.802	0.849	0.902	0.939	0.970	1.025	1.078	1.104
4.6	0.706	0.760	0.808	0.853	0.907	0.944	0.974	1.028	1.083	1.109
4.7	0.702	0.758	0.805	0.851	0.904	0.941	0.972	1.026	1.082	1.107
4.8	0.699	0.755	0.802	0.849	0.904	0.941	0.970	1.024	1.079	1.105
4.9	0.696	0.751	0.801	0.847	0.901	0.940	0.968	1.023	1.077	1.103
5.0	0.694	0.750	0.799	0.844	0.900	0.936	0.966	1.021	1.076	1.102

Table C.11: Horizontal resolution in degrees for angles $5° - 14°$, horizontal angle $= 15°$.

Vertical Angle (deg) Range (m)	5	6	7	8	9	10	11	12	13	14
3.0	0.249	0.295	0.346	0.398	0.447	0.494	0.545	0.594	0.643	0.694
3.1	0.248	0.293	0.345	0.396	0.446	0.494	0.544	0.593	0.642	0.694
3.2	0.246	0.294	0.345	0.397	0.446	0.494	0.544	0.593	0.642	0.693
3.3	0.244	0.293	0.344	0.396	0.446	0.493	0.543	0.593	0.641	0.692
3.4	0.244	0.294	0.345	0.397	0.447	0.494	0.544	0.594	0.642	0.694
3.5	0.237	0.293	0.344	0.396	0.445	0.493	0.542	0.592	0.641	0.692
3.6	0.233	0.291	0.342	0.394	0.443	0.491	0.541	0.591	0.640	0.690
3.7	0.235	0.294	0.344	0.396	0.446	0.493	0.543	0.593	0.641	0.692
3.8	0.239	0.291	0.342	0.394	0.444	0.491	0.540	0.591	0.639	0.690
3.9	0.241	0.288	0.339	0.391	0.441	0.488	0.538	0.589	0.637	0.688
4.0	0.245	0.285	0.336	0.388	0.439	0.486	0.536	0.587	0.635	0.686
4.1	0.245	0.285	0.337	0.389	0.437	0.487	0.536	0.588	0.636	0.687
4.2	0.245	0.288	0.340	0.392	0.442	0.489	0.539	0.590	0.638	0.689
4.3	0.247	0.276	0.336	0.388	0.439	0.486	0.536	0.587	0.636	0.687
4.4	0.248	0.276	0.331	0.384	0.436	0.483	0.533	0.584	0.633	0.684
4.5	0.249	0.277	0.326	0.380	0.432	0.480	0.530	0.581	0.631	0.682
4.6	0.249	0.278	0.322	0.387	0.434	0.484	0.536	0.585	0.636	0.683
4.7	0.249	0.278	0.322	0.382	0.431	0.480	0.532	0.582	0.633	0.680
4.8	0.249	0.279	0.322	0.370	0.426	0.477	0.529	0.579	0.630	0.677
4.9	0.250	0.279	0.322	0.370	0.422	0.474	0.526	0.577	0.627	0.675
5.0	0.250	0.279	0.322	0.371	0.416	0.470	0.521	0.573	0.624	0.673

Table C.12: Horizontal resolution in degrees for angles $15° - 24°$, horizontal angle = $15°$.

Vertical Angle (deg) Range (m)	15	16	17	18	19	20	21	22	23	24
3.0	0.734	0.787	0.840	0.886	0.933	0.973	1.015	1.065	1.114	1.151
3.1	0.734	0.788	0.841	0.887	0.934	0.974	1.015	1.065	1.115	1.151
3.2	0.733	0.786	0.840	0.886	0.934	0.973	1.013	1.064	1.113	1.150
3.3	0.732	0.785	0.839	0.884	0.933	0.972	1.012	1.063	1.111	1.148
3.4	0.733	0.787	0.840	0.886	0.936	0.974	1.013	1.064	1.114	1.149
3.5	0.732	0.785	0.838	0.885	0.934	0.972	1.011	1.060	1.111	1.147
3.6	0.730	0.784	0.835	0.883	0.934	0.971	1.010	1.059	1.109	1.146
3.7	0.731	0.786	0.838	0.885	0.936	0.973	1.010	1.060	1.111	1.147
3.8	0.729	0.783	0.836	0.883	0.931	0.971	1.008	1.058	1.109	1.145
3.9	0.727	0.781	0.834	0.881	0.929	0.969	1.006	1.057	1.111	1.143
4.0	0.725	0.779	0.833	0.879	0.927	0.968	1.004	1.056	1.109	1.140
4.1	0.726	0.780	0.831	0.878	0.931	0.969	1.005	1.057	1.111	1.140
4.2	0.727	0.782	0.835	0.879	0.930	0.971	1.006	1.057	1.113	1.141
4.3	0.724	0.780	0.832	0.877	0.929	0.969	1.004	1.055	1.111	1.139
4.4	0.722	0.777	0.831	0.876	0.927	0.967	1.001	1.054	1.108	1.137
4.5	0.719	0.775	0.829	0.874	0.925	0.965	0.999	1.053	1.107	1.136
4.6	0.723	0.781	0.832	0.878	0.930	0.970	1.003	1.055	1.112	1.139
4.7	0.720	0.778	0.830	0.876	0.928	0.968	1.001	1.054	1.110	1.137
4.8	0.717	0.776	0.828	0.874	0.926	0.966	0.999	1.053	1.107	1.136
4.9	0.715	0.774	0.826	0.872	0.924	0.964	0.997	1.051	1.106	1.134
5.0	0.712	0.771	0.823	0.870	0.922	0.962	0.995	1.050	1.104	1.133

APPENDIX D

RESOLUTION RESULTS WITH PROCESSING

Tables D.1–D.16 present resolution measurements for the high frequency two-dimensional amplitude-steered array, first using the spectrogram and then using the smoothed pseudo-Wigner distribution (SPWD). Horizontal resolution is not expected to be affected by the processing, and so only range and vertical resolutions are given. The array is approximately 10 cm in diameter. There are 392 staves with a center-to-center spacing of 254 μm, and there are 466 rows with a center-to-center spacing of 215.9 μm. The array is designed to steer in the vertical direction to 5° at 5 MHz. Frequencies range from 1 MHz to 5 MHz. The center two staves are used as the transmit array.

Table D.1: Resolution results with spectrogram processing: range resolution in mm for angles $5° - 14°$, horizontal angle $= 0°$.

Vertical Angle (deg) Range (m)	5	6	7	8	9	10	11	12	13	14
3.0	19.0	19.6	19.3	19.4	19.2	20.3	20.3	20.5	20.9	20.7
3.1	19.0	19.6	19.3	19.4	19.2	20.3	20.3	20.5	20.9	20.7
3.2	19.0	19.6	19.3	19.4	19.2	20.3	20.3	20.5	20.9	20.7
3.3	19.0	19.6	19.3	19.4	19.2	20.3	20.3	20.5	20.9	20.7
3.4	19.0	19.6	19.3	19.4	19.2	19.7	20.3	20.5	20.9	20.7
3.5	19.0	19.6	19.3	19.4	19.2	20.2	20.3	20.5	20.9	20.6
3.6	19.0	19.6	19.3	19.4	19.2	20.2	20.3	20.5	20.9	20.6
3.7	18.9	19.6	19.3	19.4	19.2	20.2	20.3	20.5	20.9	20.6
3.8	18.9	19.5	19.3	19.3	19.1	19.6	20.3	20.5	20.9	20.6
3.9	18.9	19.6	19.3	19.3	19.1	19.6	20.3	20.5	20.9	20.6
4.0	18.8	19.5	19.3	19.3	19.1	20.2	20.3	20.4	20.9	20.6
4.1	18.9	19.5	19.2	19.3	19.1	19.6	20.3	20.4	20.8	20.6
4.2	18.9	19.5	19.3	19.3	19.1	19.6	20.3	20.4	20.8	20.6
4.3	18.9	19.5	19.2	19.3	19.1	19.6	20.3	20.4	20.8	20.5
4.4	18.9	19.5	19.2	19.3	19.1	20.1	20.3	20.4	20.8	20.5
4.5	18.9	19.5	19.2	19.3	19.1	19.6	20.3	20.4	20.8	20.5
4.6	18.9	19.4	19.2	19.3	19.1	19.6	20.2	20.4	20.8	20.5
4.7	18.9	19.4	19.2	19.2	19.1	19.6	20.2	20.4	20.8	20.5
4.8	18.9	19.4	19.2	19.3	19.0	19.5	20.2	20.4	20.8	20.5
4.9	18.9	19.4	19.2	19.1	19.0	19.5	20.2	20.3	20.8	20.5
5.0	18.9	19.4	19.2	19.2	19.0	19.5	20.2	20.4	20.8	20.5

Table D.2: Resolution results with spectrogram processing: range resolution in mm for angles $15° - 24°$, horizontal angle $= 0°$.

Vertical Angle (deg) Range (m)	15	16	17	18	19	20	21	22	23	24
3.0	20.9	21.8	22.8	23.0	23.0	24.0	24.4	24.9	25.6	26.6
3.1	20.9	21.7	22.7	23.0	23.0	24.0	24.5	24.9	25.6	26.6
3.2	20.9	21.8	22.7	23.0	23.0	24.0	24.4	24.9	25.6	26.6
3.3	20.9	21.7	22.7	23.0	23.0	24.0	24.4	24.9	25.6	26.6
3.4	20.9	21.7	22.7	23.0	23.0	24.0	24.4	24.9	25.6	26.6
3.5	20.9	21.7	22.7	23.0	23.0	23.9	24.4	24.9	25.6	26.6
3.6	20.9	21.7	22.7	23.0	23.0	24.0	24.4	24.9	25.6	26.6
3.7	20.9	21.7	22.7	23.0	23.0	24.0	24.4	24.9	25.6	26.6
3.8	20.9	21.7	22.7	23.0	23.0	24.0	24.4	24.9	25.6	26.6
3.9	20.9	21.6	22.7	23.0	23.0	24.0	24.4	24.9	25.6	26.6
4.0	20.9	21.7	22.7	23.0	23.0	23.9	24.4	24.9	25.6	26.6
4.1	20.8	21.7	22.6	23.0	23.0	24.0	24.4	24.9	25.6	26.6
4.2	20.8	21.6	22.6	22.9	23.0	24.0	24.4	24.9	25.6	26.6
4.3	20.8	21.6	22.6	22.9	23.0	23.9	24.4	24.9	25.6	26.6
4.4	20.8	21.6	22.6	22.9	23.0	23.9	24.4	24.9	25.6	26.6
4.5	20.8	21.6	22.6	22.9	23.0	23.9	24.4	24.9	25.6	26.6
4.6	20.8	21.6	22.6	22.9	23.0	23.9	24.4	24.9	25.6	26.6
4.7	20.8	21.6	22.6	22.9	23.0	23.9	24.4	24.9	25.6	26.6
4.8	20.8	21.6	22.6	22.9	23.0	23.9	24.4	24.9	25.6	26.6
4.9	20.8	21.6	22.6	22.9	23.0	23.9	24.4	24.8	25.6	26.6
5.0	20.8	21.6	22.6	22.8	22.9	23.9	24.4	24.9	25.6	26.6

Table D.3: Resolution results with spectrogram processing: range resolution in mm for angles $5° - 14°$, horizontal angle $= 15°$.

Vertical Angle (deg) Range (m)	5	6	7	8	9	10	11	12	13	14
3.0	19.0	20.1	19.3	19.4	19.3	19.8	20.5	20.9	21.5	21.5
3.1	19.0	19.7	19.3	19.4	19.3	19.8	20.5	20.9	21.5	21.5
3.2	19.0	19.8	19.3	19.4	19.2	19.8	20.5	20.9	21.5	21.6
3.3	19.0	20.0	19.3	19.4	19.2	19.8	20.5	20.9	21.5	21.5
3.4	19.0	19.5	19.3	19.4	19.2	19.8	20.5	20.9	21.5	21.6
3.5	19.0	19.6	19.3	19.3	19.2	19.8	20.5	20.9	21.5	21.6
3.6	19.0	19.9	19.3	19.4	19.2	19.8	20.5	20.9	21.5	21.5
3.7	19.0	19.3	19.3	19.4	19.2	19.8	20.5	20.9	21.5	21.5
3.8	18.9	19.6	19.3	19.3	19.2	19.7	20.5	20.8	21.5	21.5
3.9	18.9	19.8	19.3	19.3	19.2	19.7	20.5	20.9	21.5	21.5
4.0	18.9	19.6	19.3	19.3	19.2	19.7	20.5	20.8	21.5	21.5
4.1	18.9	19.4	19.2	19.2	19.2	19.7	20.4	20.8	21.4	21.4
4.2	18.9	19.4	19.2	19.2	19.2	19.7	20.5	20.8	21.5	21.5
4.3	18.9	19.4	19.2	19.2	19.2	19.7	20.4	20.8	21.5	21.5
4.4	18.9	19.5	19.2	19.2	19.2	19.7	20.4	20.8	21.5	21.5
4.5	18.9	19.5	19.2	19.2	19.2	19.7	20.4	20.8	21.5	21.5
4.6	18.9	19.3	19.2	19.2	19.2	19.7	20.4	20.8	21.4	21.5
4.7	19.0	19.4	19.2	19.2	19.1	19.7	20.4	20.8	21.4	21.5
4.8	19.0	19.4	19.2	19.2	19.1	19.6	20.4	20.8	21.4	21.5
4.9	19.0	19.4	19.2	19.2	19.1	19.6	20.4	20.8	21.4	21.5
5.0	18.9	19.6	19.2	19.2	19.1	19.6	20.4	20.8	21.4	21.5

Table D.4: Resolution results with spectrogram processing: range resolution in mm for angles $15° - 24°$, horizontal angle $= 15°$.

Vertical Angle (deg) Range (m)	15	16	17	18	19	20	21	22	23	24
3.0	22.4	24.7	25.5	37.0	16.6	19.7	20.8	21.6	22.9	24.3
3.1	22.4	24.5	23.8	22.8	17.8	20.2	21.1	21.7	22.9	24.3
3.2	22.4	24.6	27.2	31.7	17.1	20.1	20.9	21.6	22.9	24.3
3.3	22.4	24.8	26.4	17.9	16.8	19.9	20.9	21.6	22.9	24.3
3.4	22.4	24.4	23.4	22.2	19.3	20.6	21.2	21.8	23.0	24.3
3.5	22.4	24.6	24.0	31.7	18.6	20.4	21.1	21.7	23.0	24.3
3.6	22.5	24.7	26.0	18.2	18.2	20.3	21.1	21.7	22.9	24.2
3.7	22.4	24.4	23.4	21.7	20.2	20.8	21.4	21.8	23.0	24.3
3.8	22.4	24.6	23.6	21.8	19.6	20.7	21.2	21.8	23.0	24.3
3.9	22.5	24.7	23.9	29.0	19.1	20.5	21.2	21.7	22.9	24.2
4.0	22.5	24.9	24.6	18.6	18.6	20.4	21.1	21.7	22.9	24.2
4.1	22.2	24.1	24.2	21.7	20.5	20.9	21.4	21.8	23.0	24.2
4.2	22.4	24.3	23.5	21.5	20.9	21.2	21.5	21.9	23.0	24.3
4.3	22.4	24.4	23.5	21.4	20.7	21.1	21.5	21.9	23.0	24.2
4.4	22.5	24.6	23.6	21.4	20.4	20.9	21.4	21.9	23.0	24.2
4.5	22.5	24.7	23.7	21.3	20.1	20.8	21.3	21.8	23.0	24.2
4.6	22.4	24.1	23.5	21.5	21.5	21.5	21.7	22.0	23.1	24.2
4.7	22.4	24.2	23.5	21.5	21.3	21.4	21.7	22.0	23.0	24.2
4.8	22.4	24.4	23.5	21.3	21.1	21.3	21.6	22.0	23.0	24.2
4.9	22.5	24.5	23.6	21.2	20.9	21.2	21.6	21.9	23.0	24.2
5.0	22.5	24.6	23.6	21.2	20.8	21.1	21.5	21.9	23.0	24.1

Table D.5: Resolution results with spectrogram processing: vertical resolution in degrees for angles $5° - 14°$, horizontal hngle $= 0°$.

Vertical Angle (deg) Range (m)	5	6	7	8	9	10	11	12	13	14
3.0	0.153	0.182	0.230	0.270	0.305	0.344	0.373	0.415	0.447	0.508
3.1	0.156	0.184	0.232	0.271	0.306	0.344	0.374	0.415	0.448	0.509
3.2	0.160	0.186	0.233	0.272	0.306	0.345	0.374	0.415	0.449	0.510
3.3	0.165	0.187	0.233	0.273	0.308	0.346	0.375	0.416	0.449	0.510
3.4	0.169	0.190	0.237	0.275	0.309	0.348	0.377	0.416	0.450	0.510
3.5	0.183	0.193	0.239	0.276	0.310	0.349	0.377	0.416	0.450	0.511
3.6	0.264	0.195	0.239	0.277	0.311	0.350	0.378	0.418	0.452	0.511
3.7	0.290	0.200	0.244	0.280	0.313	0.352	0.380	0.419	0.452	0.512
3.8	0.296	0.205	0.248	0.282	0.315	0.354	0.381	0.419	0.452	0.513
3.9	0.311	0.209	0.248	0.284	0.316	0.355	0.382	0.420	0.454	0.513
4.0	0.309	0.213	0.252	0.286	0.318	0.357	0.383	0.421	0.455	0.514
4.1	0.298	0.223	0.260	0.290	0.321	0.362	0.385	0.422	0.456	0.515
4.2	0.294	0.232	0.261	0.292	0.323	0.361	0.387	0.423	0.456	0.516
4.3	0.281	0.244	0.264	0.297	0.326	0.365	0.389	0.424	0.458	0.517
4.4	0.266	0.255	0.272	0.298	0.327	0.366	0.389	0.425	0.459	0.517
4.5	0.262	0.263	0.278	0.301	0.330	0.369	0.391	0.427	0.459	0.519
4.6	0.241	0.292	0.284	0.310	0.334	0.371	0.394	0.427	0.460	0.520
4.7	0.233	0.311	0.290	0.313	0.338	0.375	0.395	0.428	0.463	0.521
4.8	0.228	0.327	0.300	0.314	0.340	0.378	0.397	0.431	0.463	0.521
4.9	0.221	0.344	0.311	0.323	0.342	0.378	0.399	0.432	0.463	0.523
5.0	0.218	0.366	0.321	0.329	0.346	0.381	0.400	0.432	0.465	0.525

Table D.6: Resolution results with spectrogram processing: vertical resolution in degrees for angles $15° - 24°$, horizontal angle = $0°$.

Vertical Angle (deg) Range (m)	15	16	17	18	19	20	21	22	23	24
3.0	0.564	0.586	0.695	0.747	0.760	0.851	0.885	0.964	1.030	1.124
3.1	0.565	0.586	0.694	0.746	0.759	0.849	0.884	0.963	1.029	1.122
3.2	0.565	0.585	0.695	0.745	0.758	0.850	0.884	0.963	1.028	1.120
3.3	0.565	0.585	0.694	0.745	0.758	0.851	0.884	0.962	1.028	1.119
3.4	0.565	0.585	0.691	0.745	0.758	0.850	0.882	0.961	1.026	1.117
3.5	0.566	0.586	0.691	0.744	0.757	0.847	0.882	0.960	1.026	1.115
3.6	0.566	0.586	0.694	0.744	0.757	0.849	0.882	0.959	1.025	1.115
3.7	0.566	0.585	0.693	0.743	0.756	0.850	0.881	0.958	1.024	1.111
3.8	0.567	0.586	0.689	0.743	0.756	0.845	0.880	0.957	1.023	1.110
3.9	0.567	0.586	0.690	0.742	0.756	0.846	0.880	0.957	1.022	1.109
4.0	0.567	0.586	0.694	0.742	0.755	0.849	0.880	0.956	1.022	1.108
4.1	0.567	0.585	0.687	0.743	0.755	0.847	0.880	0.954	1.021	1.105
4.2	0.568	0.587	0.687	0.740	0.754	0.844	0.878	0.954	1.020	1.103
4.3	0.569	0.587	0.691	0.741	0.754	0.846	0.878	0.953	1.019	1.102
4.4	0.570	0.587	0.690	0.740	0.754	0.846	0.878	0.953	1.019	1.101
4.5	0.570	0.588	0.687	0.739	0.754	0.843	0.877	0.953	1.018	1.100
4.6	0.571	0.587	0.688	0.739	0.752	0.844	0.876	0.951	1.016	1.098
4.7	0.572	0.588	0.689	0.739	0.753	0.845	0.876	0.950	1.016	1.097
4.8	0.572	0.588	0.687	0.738	0.752	0.842	0.875	0.950	1.016	1.096
4.9	0.573	0.589	0.688	0.738	0.753	0.843	0.875	0.950	1.015	1.095
5.0	0.574	0.589	0.688	0.738	0.752	0.845	0.875	0.948	1.015	1.094

Table D.7: Resolution results with spectrogram processing: vertical resolution in degrees for angles $5° - 14°$, horizontal angle = $15°$.

Vertical Angle (deg) Range (m)	5	6	7	8	9	10	11	12	13	14
3.0	0.152	0.119	0.226	0.265	0.295	0.327	0.354	0.390	0.413	0.444
3.1	0.155	0.131	0.227	0.266	0.295	0.328	0.355	0.390	0.412	0.445
3.2	0.158	0.129	0.228	0.267	0.295	0.328	0.355	0.390	0.412	0.443
3.3	0.160	0.126	0.229	0.267	0.296	0.329	0.355	0.390	0.413	0.442
3.4	0.172	0.141	0.231	0.268	0.297	0.330	0.356	0.391	0.412	0.443
3.5	0.184	0.137	0.233	0.270	0.298	0.331	0.357	0.391	0.412	0.441
3.6	0.199	0.131	0.235	0.272	0.299	0.332	0.357	0.391	0.411	0.440
3.7	0.293	0.151	0.238	0.273	0.300	0.333	0.358	0.391	0.412	0.441
3.8	0.301	0.144	0.240	0.275	0.302	0.334	0.359	0.391	0.412	0.439
3.9	0.303	0.138	0.243	0.277	0.303	0.335	0.359	0.391	0.411	0.438
4.0	0.309	0.134	0.246	0.279	0.304	0.337	0.360	0.391	0.411	0.436
4.1	0.293	0.159	0.253	0.285	0.310	0.343	0.367	0.396	0.419	0.447
4.2	0.277	0.151	0.255	0.285	0.308	0.340	0.363	0.392	0.412	0.439
4.3	0.266	0.147	0.260	0.287	0.310	0.342	0.364	0.392	0.411	0.437
4.4	0.256	0.148	0.265	0.291	0.312	0.343	0.365	0.393	0.411	0.435
4.5	0.246	0.141	0.270	0.294	0.314	0.345	0.366	0.393	0.411	0.433
4.6	0.222	0.159	0.278	0.298	0.317	0.347	0.367	0.394	0.412	0.438
4.7	0.217	0.153	0.285	0.302	0.320	0.349	0.369	0.394	0.411	0.436
4.8	0.214	0.148	0.296	0.307	0.322	0.351	0.370	0.394	0.411	0.435
4.9	0.205	0.149	0.304	0.310	0.325	0.353	0.371	0.394	0.411	0.433
5.0	0.200	0.137	0.318	0.315	0.328	0.355	0.372	0.395	0.411	0.432

Table D.8: Resolution results with spectrogram processing: vertical resolution in degrees for angles $15° - 24°$, horizontal angle = $15°$.

Vertical Angle (deg) Range (m)	15	16	17	18	19	20	21	22	23	24
3.0	0.472	0.492	0.614	0.897	1.061	0.973	0.955	1.037	1.065	1.186
3.1	0.477	0.504	0.682	1.488	1.056	0.966	0.958	1.046	1.067	1.188
3.2	0.472	0.496	0.700	0.713	1.101	0.977	0.963	1.048	1.069	1.189
3.3	0.468	0.489	0.699	0.761	1.126	0.986	0.968	1.049	1.071	1.190
3.4	0.475	0.508	0.611	0.477	1.079	0.982	0.971	1.058	1.074	1.191
3.5	0.470	0.500	0.657	0.940	1.133	0.995	0.977	1.061	1.076	1.193
3.6	0.466	0.490	0.650	0.667	1.179	1.016	0.986	1.061	1.081	1.198
3.7	0.474	0.512	0.579	0.562	1.113	1.001	0.985	1.069	1.082	1.195
3.8	0.469	0.504	0.601	1.195	1.167	1.016	0.991	1.072	1.084	1.196
3.9	0.464	0.497	0.637	1.000	1.219	1.027	0.996	1.075	1.086	1.198
4.0	0.460	0.491	1.235	0.691	1.305	1.035	1.001	1.077	1.088	1.198
4.1	0.476	0.510	0.588	0.607	1.292	1.046	1.008	1.078	1.094	1.207
4.2	0.471	0.517	0.566	0.676	1.177	1.032	1.005	1.085	1.093	1.202
4.3	0.466	0.511	0.568	0.669	1.249	1.042	1.011	1.087	1.095	1.203
4.4	0.462	0.505	0.575	1.218	1.323	1.055	1.016	1.090	1.097	1.204
4.5	0.459	0.500	0.590	1.399	1.401	1.069	1.021	1.093	1.098	1.204
4.6	0.472	0.527	0.584	0.736	1.163	1.041	1.016	1.094	1.100	1.207
4.7	0.468	0.522	0.578	0.742	1.219	1.052	1.022	1.096	1.102	1.208
4.8	0.464	0.516	0.573	0.749	1.274	1.067	1.027	1.099	1.104	1.208
4.9	0.461	0.511	0.569	0.753	1.330	1.076	1.032	1.102	1.106	1.209
5.0	0.457	0.503	0.568	0.757	1.389	1.086	1.037	1.104	1.107	1.210

Table D.9: Resolution results with SPWD processing: range resolution in mm for angles $5° - 14°$, horizontal angle $= 0°$.

Vertical Angle (deg) Range (m)	5	6	7	8	9	10	11	12	13	14
3.0	7.40	8.64	8.28	8.72	9.41	10.3	11.1	11.8	12.6	12.5
3.1	7.32	8.64	8.28	8.68	9.41	10.3	11.1	11.8	12.6	12.5
3.2	7.36	8.61	8.24	8.68	9.38	10.2	11.1	11.7	12.6	12.5
3.3	7.25	8.61	8.24	8.68	9.37	10.2	11.1	11.7	12.6	12.4
3.4	7.25	8.57	8.17	8.64	9.30	10.2	11.1	11.7	12.6	12.4
3.5	7.18	8.53	8.17	8.64	9.34	10.2	11.1	11.7	12.6	12.4
3.6	7.03	8.53	8.17	8.64	9.30	10.2	11.0	11.6	12.5	12.4
3.7	6.92	8.46	8.06	8.57	9.23	10.1	11.0	11.6	12.5	12.3
3.8	6.88	8.46	8.06	8.53	9.19	10.1	11.0	11.6	12.5	12.3
3.9	6.45	8.39	8.06	8.50	9.19	10.1	10.9	11.6	12.5	12.3
4.0	6.12	8.39	8.02	8.50	9.16	10.0	10.9	11.9	12.5	12.3
4.1	6.26	8.31	7.91	8.42	9.01	10.0	10.9	11.8	12.4	12.2
4.2	6.63	8.28	7.91	8.42	9.08	9.96	10.8	11.8	12.4	12.2
4.3	6.70	8.20	7.87	8.35	9.05	9.92	10.8	11.8	12.4	12.2
4.4	6.63	8.17	7.80	8.31	9.01	9.89	10.8	11.8	12.3	12.2
4.5	6.77	8.13	7.51	8.35	8.90	9.85	10.7	11.7	12.3	12.2
4.6	6.88	8.06	7.47	8.20	8.94	9.81	10.7	11.7	12.3	12.1
4.7	6.88	8.02	7.43	8.20	8.90	9.78	10.7	11.6	12.3	12.1
4.8	6.92	7.95	7.40	8.20	8.79	9.74	10.6	11.6	12.2	12.1
4.9	6.92	7.91	7.36	8.13	8.75	9.74	10.6	11.6	12.2	12.0
5.0	6.96	7.80	7.32	8.06	8.79	9.70	10.6	11.6	12.2	12.0

Table D.10: Resolution results with SPWD processing: range resolution in mm for angles $15° - 24°$, horizontal angle $= 0°$.

Vertical Angle (deg) Range (m)	15	16	17	18	19	20	21	22	23	24
3.0	13.0	14.4	15.5	15.9	16.6	17.7	18.6	19.2	20.2	20.7
3.1	13.0	14.4	15.5	15.8	16.5	17.7	18.6	19.2	20.1	20.7
3.2	13.0	14.4	15.5	15.8	16.6	17.7	18.6	19.2	20.2	20.7
3.3	13.0	14.4	15.5	15.8	16.5	17.7	18.6	19.2	20.1	20.7
3.4	13.0	14.3	15.5	15.8	16.5	17.7	18.5	19.2	20.1	20.7
3.5	12.9	14.4	15.5	15.8	16.5	17.7	18.5	19.2	20.1	20.7
3.6	13.0	14.3	15.4	15.7	16.5	17.7	18.5	19.1	20.1	20.7
3.7	12.9	14.3	15.3	15.7	16.4	17.7	18.5	19.1	20.1	20.6
3.8	12.9	14.3	15.4	15.7	16.4	17.7	18.5	19.1	20.1	20.6
3.9	12.9	14.3	15.4	15.7	16.4	17.6	18.5	19.1	20.1	20.6
4.0	12.9	14.2	15.3	15.7	16.4	17.6	18.5	19.1	20.1	20.6
4.1	12.8	14.2	15.3	15.7	16.4	17.6	18.5	19.0	20.1	20.6
4.2	12.8	14.2	15.3	15.7	16.4	17.6	18.5	19.0	20.0	20.6
4.3	12.8	14.2	15.3	15.6	16.4	17.5	18.5	19.0	20.0	20.5
4.4	12.7	14.2	15.2	15.6	16.4	17.5	18.4	19.0	20.0	20.5
4.5	12.7	14.1	15.3	15.6	16.3	17.5	18.4	19.0	20.0	20.5
4.6	12.7	14.1	15.2	15.6	16.3	17.5	18.4	19.0	20.0	20.5
4.7	12.7	14.1	15.2	15.5	16.3	17.5	18.3	19.0	20.0	20.5
4.8	12.7	14.1	15.2	15.6	16.3	17.5	18.3	19.0	20.0	20.5
4.9	12.6	14.1	15.2	15.5	16.3	17.5	18.3	19.0	20.0	20.5
5.0	12.6	14.1	15.2	15.5	16.3	17.4	18.3	19.0	19.9	20.5

Table D.11: Resolution results with SPWD processing: range resolution in mm for angles $5° - 14°$, horizontal angle $= 15°$.

Vertical Angle (deg) Range (m)	5	6	7	8	9	10	11	12	13	14
3.0	7.36	10.4	8.35	8.86	9.52	10.6	11.7	12.9	14.0	14.2
3.1	7.40	9.67	8.35	8.86	9.52	10.6	11.7	12.8	13.8	14.2
3.2	7.40	9.92	8.31	8.83	9.52	10.6	11.6	12.8	14.0	14.2
3.3	7.36	10.1	8.02	8.83	9.52	10.6	11.6	12.8	14.0	14.2
3.4	7.25	9.34	7.98	8.79	9.45	10.6	11.6	12.8	13.8	14.2
3.5	7.14	9.52	7.98	8.79	9.45	10.6	11.6	12.7	13.9	14.2
3.6	7.10	9.89	7.95	8.75	9.41	10.5	11.6	12.7	14.0	14.2
3.7	6.96	8.83	7.87	8.72	9.37	10.5	11.5	12.7	13.9	14.2
3.8	6.70	9.23	7.87	8.68	9.37	10.5	11.5	12.7	13.8	14.2
3.9	6.52	9.56	7.84	8.64	9.34	10.4	11.5	12.7	13.9	14.2
4.0	6.12	9.70	7.80	8.64	9.30	10.4	11.5	12.7	13.8	14.2
4.1	6.26	8.57	7.73	8.53	9.23	10.3	11.4	12.5	13.6	13.9
4.2	6.70	8.75	7.73	8.53	9.23	10.4	11.4	12.6	13.8	14.2
4.3	6.77	8.90	7.69	8.53	9.23	10.3	11.4	12.6	13.8	14.2
4.4	6.81	9.23	7.62	8.46	9.19	10.3	11.4	12.6	13.8	14.2
4.5	6.85	9.37	7.62	8.42	9.12	10.3	11.3	12.6	13.7	14.2
4.6	6.99	8.20	7.54	8.39	9.08	10.3	11.3	12.5	13.7	14.1
4.7	6.99	8.90	7.51	8.35	9.05	10.2	11.3	12.5	13.7	14.1
4.8	6.99	8.97	7.43	8.31	9.01	10.2	11.2	12.5	13.7	14.1
4.9	7.14	8.90	7.40	8.28	9.01	10.1	11.2	12.5	13.7	14.1
5.0	7.14	9.52	7.36	8.24	8.94	10.1	11.2	12.4	13.7	14.1

Table D.12: Resolution results with SPWD processing: range resolution in mm for angles $15° - 24°$, horizontal angle $= 15°$.

Vertical Angle (deg) Range (m)	15	16	17	18	19	20	21	22	23	24
3.0	15.7	19.0	18.9	64.6	15.8	12.3	13.8	15.9	16.7	17.2
3.1	15.8	18.7	20.4	18.9	13.9	12.5	14.0	16.0	16.8	17.3
3.2	15.8	18.9	21.0	16.0	14.7	12.7	14.0	15.9	16.7	17.2
3.3	15.8	19.1	19.5	62.7	15.0	12.3	13.8	15.9	16.7	17.2
3.4	15.8	18.7	20.5	20.0	9.37	13.0	14.2	16.0	16.8	17.3
3.5	15.8	18.9	20.8	20.8	8.90	12.8	14.0	15.9	16.7	17.3
3.6	15.9	19.0	21.9	20.3	8.68	12.6	13.9	15.9	16.7	17.2
3.7	15.8	18.6	20.7	18.4	9.92	13.3	14.2	16.0	16.8	17.3
3.8	15.8	18.9	20.9	28.6	9.41	13.1	14.1	15.9	16.7	17.3
3.9	15.9	19.1	21.2	18.9	8.97	12.9	14.1	15.9	16.7	17.2
4.0	15.9	19.3	21.5	19.6	8.61	12.7	14.0	15.8	16.7	17.2
4.1	15.4	18.3	20.7	16.7	9.81	13.3	14.2	15.9	16.7	17.3
4.2	15.7	18.5	15.1	8.94	11.1	13.7	14.4	16.0	16.8	17.3
4.3	15.8	18.7	21.1	9.08	10.5	13.5	14.3	16.0	16.7	17.3
4.4	15.8	18.9	21.3	9.19	9.96	13.3	14.2	15.9	16.7	17.2
4.5	15.9	19.1	21.6	9.41	9.52	13.1	14.1	15.8	16.6	17.2
4.6	15.6	18.2	20.1	15.6	12.3	14.0	14.6	16.1	16.8	17.4
4.7	15.7	18.4	20.4	20.7	11.9	13.9	14.5	16.0	16.8	17.3
4.8	15.7	18.6	20.7	8.64	11.5	13.7	14.5	16.0	16.7	17.3
4.9	15.8	18.7	21.1	8.75	11.0	13.6	14.4	15.9	16.7	17.2
5.0	15.8	18.9	21.4	8.83	10.6	13.5	14.3	15.8	16.7	17.2

Table D.13: Resolution results with SPWD processing: vertical resolution in degrees for angles $5° - 14°$, horizontal angle $= 0°$.

Vertical Angle (deg) Range (m)	5	6	7	8	9	10	11	12	13	14
3.0	0.147	0.184	0.220	0.252	0.286	0.318	0.351	0.384	0.414	0.469
3.1	0.149	0.184	0.221	0.252	0.285	0.317	0.350	0.382	0.412	0.468
3.2	0.150	0.185	0.221	0.252	0.285	0.317	0.348	0.381	0.411	0.468
3.3	0.153	0.185	0.220	0.251	0.284	0.316	0.348	0.381	0.411	0.466
3.4	0.153	0.186	0.222	0.251	0.284	0.316	0.347	0.378	0.408	0.464
3.5	0.160	0.186	0.222	0.251	0.283	0.314	0.345	0.376	0.407	0.462
3.6	0.177	0.186	0.219	0.250	0.281	0.312	0.344	0.376	0.406	0.461
3.7	0.267	0.189	0.221	0.250	0.280	0.312	0.343	0.374	0.403	0.459
3.8	0.276	0.190	0.223	0.250	0.281	0.311	0.341	0.372	0.402	0.458
3.9	0.288	0.190	0.221	0.250	0.280	0.310	0.341	0.370	0.401	0.455
4.0	0.283	0.192	0.222	0.250	0.278	0.310	0.340	0.370	0.400	0.454
4.1	0.270	0.195	0.224	0.249	0.279	0.307	0.335	0.365	0.396	0.452
4.2	0.269	0.196	0.222	0.249	0.278	0.306	0.336	0.365	0.396	0.450
4.3	0.260	0.201	0.224	0.251	0.277	0.307	0.336	0.364	0.394	0.448
4.4	0.249	0.204	0.225	0.249	0.276	0.305	0.333	0.363	0.394	0.448
4.5	0.249	0.203	0.227	0.249	0.278	0.305	0.333	0.363	0.392	0.447
4.6	0.236	0.212	0.227	0.251	0.275	0.303	0.332	0.360	0.390	0.444
4.7	0.230	0.225	0.230	0.251	0.276	0.303	0.330	0.358	0.389	0.443
4.8	0.226	0.226	0.232	0.250	0.276	0.302	0.329	0.358	0.388	0.441
4.9	0.221	0.235	0.235	0.251	0.276	0.302	0.330	0.358	0.386	0.441
5.0	0.218	0.255	0.237	0.255	0.276	0.302	0.329	0.356	0.386	0.440

Table D.14: Resolution results with SPWD processing: vertical resolution in degrees for angles $15° - 24°$, horizontal angle $= 0°$.

Vertical Angle (deg) Range (m)	15	16	17	18	19	20	21	22	23	24
3.0	0.516	0.539	0.568	0.626	0.684	0.717	0.766	0.826	0.873	0.934
3.1	0.515	0.537	0.567	0.624	0.681	0.714	0.762	0.823	0.869	0.930
3.2	0.514	0.535	0.567	0.622	0.679	0.714	0.761	0.821	0.866	0.928
3.3	0.512	0.534	0.566	0.620	0.678	0.712	0.759	0.819	0.864	0.926
3.4	0.509	0.531	0.562	0.617	0.674	0.708	0.755	0.815	0.859	0.922
3.5	0.507	0.530	0.560	0.615	0.672	0.706	0.753	0.813	0.856	0.920
3.6	0.505	0.528	0.560	0.613	0.670	0.706	0.752	0.811	0.854	0.918
3.7	0.503	0.525	0.558	0.610	0.666	0.703	0.747	0.808	0.848	0.913
3.8	0.502	0.523	0.555	0.608	0.664	0.699	0.746	0.806	0.846	0.911
3.9	0.499	0.522	0.554	0.606	0.662	0.697	0.744	0.803	0.844	0.909
4.0	0.498	0.520	0.554	0.604	0.660	0.698	0.741	0.802	0.841	0.907
4.1	0.493	0.514	0.550	0.599	0.653	0.692	0.737	0.797	0.835	0.903
4.2	0.493	0.515	0.548	0.598	0.653	0.689	0.735	0.795	0.832	0.900
4.3	0.491	0.513	0.547	0.596	0.651	0.689	0.733	0.793	0.830	0.898
4.4	0.490	0.511	0.546	0.595	0.648	0.689	0.731	0.791	0.828	0.896
4.5	0.489	0.510	0.545	0.593	0.647	0.686	0.729	0.790	0.826	0.894
4.6	0.486	0.506	0.542	0.589	0.642	0.682	0.725	0.785	0.820	0.890
4.7	0.484	0.504	0.540	0.588	0.640	0.682	0.724	0.783	0.818	0.888
4.8	0.484	0.503	0.540	0.587	0.638	0.679	0.722	0.783	0.816	0.887
4.9	0.483	0.503	0.539	0.584	0.637	0.678	0.720	0.781	0.814	0.885
5.0	0.481	0.500	0.537	0.583	0.635	0.678	0.719	0.779	0.812	0.883

Table D.15: Resolution results with SPWD processing: vertical resolution in degrees for angles $5° - 14°$, horizontal angle = $15°$.

Vertical Angle (deg) Range (m)	5	6	7	8	9	10	11	12	13	14
3.0	0.147	0.104	0.217	0.246	0.276	0.304	0.331	0.357	0.386	0.419
3.1	0.148	0.112	0.217	0.245	0.276	0.304	0.331	0.357	0.388	0.421
3.2	0.148	0.113	0.217	0.245	0.275	0.303	0.329	0.354	0.384	0.416
3.3	0.148	0.112	0.217	0.244	0.273	0.301	0.327	0.351	0.380	0.410
3.4	0.154	0.120	0.216	0.243	0.273	0.300	0.327	0.351	0.383	0.415
3.5	0.159	0.116	0.216	0.243	0.272	0.299	0.325	0.348	0.379	0.408
3.6	0.166	0.115	0.217	0.242	0.271	0.297	0.323	0.346	0.375	0.403
3.7	0.271	0.130	0.216	0.242	0.270	0.296	0.322	0.345	0.377	0.408
3.8	0.280	0.120	0.216	0.241	0.268	0.294	0.320	0.342	0.373	0.401
3.9	0.279	0.118	0.216	0.240	0.267	0.292	0.318	0.339	0.369	0.394
4.0	0.281	0.116	0.216	0.240	0.266	0.291	0.316	0.336	0.365	0.387
4.1	0.265	0.133	0.219	0.243	0.269	0.294	0.319	0.340	0.371	0.399
4.2	0.255	0.126	0.217	0.239	0.264	0.288	0.314	0.334	0.367	0.395
4.3	0.247	0.125	0.217	0.238	0.264	0.286	0.312	0.332	0.364	0.389
4.4	0.243	0.123	0.218	0.238	0.263	0.285	0.310	0.329	0.360	0.382
4.5	0.235	0.119	0.219	0.239	0.262	0.283	0.308	0.326	0.356	0.375
4.6	0.220	0.137	0.220	0.238	0.262	0.283	0.307	0.327	0.362	0.389
4.7	0.216	0.122	0.221	0.237	0.261	0.281	0.306	0.325	0.358	0.383
4.8	0.214	0.122	0.223	0.239	0.260	0.280	0.304	0.323	0.356	0.376
4.9	0.206	0.122	0.224	0.238	0.260	0.278	0.302	0.320	0.354	0.370
5.0	0.201	0.113	0.225	0.237	0.260	0.277	0.300	0.318	0.352	0.362

Table D.16: Resolution results with SPWD processing: vertical resolution in degrees for angles $15° - 24°$, horizontal angle = $15°$.

Vertical Angle (deg) Range (m)	15	16	17	18	19	20	21	22	23	24
3.0	0.438	0.421	0.509	1.084	1.135	0.784	0.788	0.843	0.896	0.977
3.1	0.449	0.444	0.469	0.823	1.210	0.778	0.794	0.850	0.904	0.985
3.2	0.442	0.446	0.502	0.543	1.210	0.780	0.794	0.851	0.905	0.985
3.3	0.434	0.448	0.785	0.621	1.197	0.779	0.795	0.852	0.905	0.985
3.4	0.454	0.459	0.735	0.976	0.783	0.799	0.808	0.863	0.915	0.994
3.5	0.446	0.459	0.446	0.957	0.783	0.800	0.809	0.865	0.916	0.995
3.6	0.435	0.481	0.688	0.979	0.805	0.811	0.814	0.868	0.916	0.996
3.7	0.461	0.492	0.751	0.774	0.858	0.828	0.825	0.877	0.926	1.004
3.8	0.445	0.486	0.732	0.990	0.861	0.831	0.826	0.879	0.926	1.005
3.9	0.433	0.482	0.642	0.989	0.856	0.830	0.827	0.880	0.927	1.005
4.0	0.423	0.761	0.475	0.969	0.851	0.827	0.827	0.879	0.927	1.006
4.1	0.451	0.508	0.746	0.965	0.931	0.865	0.847	0.894	0.934	1.008
4.2	0.467	0.579	0.782	0.933	0.944	0.870	0.854	0.900	0.940	1.019
4.3	0.454	0.587	0.760	0.947	0.947	0.871	0.855	0.900	0.940	1.020
4.4	0.431	0.597	0.754	0.982	0.950	0.872	0.857	0.901	0.940	1.021
4.5	0.418	0.606	0.995	0.999	0.951	0.875	0.858	0.902	0.941	1.021
4.6	0.474	0.601	0.700	1.095	1.001	0.896	0.877	0.915	0.951	1.031
4.7	0.465	0.605	0.980	1.139	1.009	0.899	0.879	0.915	0.951	1.031
4.8	0.452	0.610	1.007	1.145	1.015	0.903	0.880	0.916	0.952	1.032
4.9	0.431	0.617	1.037	1.155	1.018	0.903	0.882	0.917	0.952	1.032
5.0	0.411	0.620	1.060	1.172	1.023	0.904	0.883	0.917	0.952	1.033