Report (3) 05th Nov 2012	**Lab-based Test for Phase Evaluation Using Libera Singlepass H**	P. Forck W. Kaufmann M. Almalki C. Krüger
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In continuing to investigate Libera Singlepass H unit characteristics, the lab-based testing, presented in the previous report, has been repeated with more data points and larger dynamic range. The aim of these measurements is to characterize the Libera Singlepass H unit.

A great deal of the findings is expected in advance while some observations still need explanation. So, comments from I-tech about some observed behaviors for the unit are required.

In this detailed lab-based measurements, phase measured by Libera Singlepass H system has been evaluated. It is divided into three parts:

1- The phase evaluation for signals superposition.

2- The phase evaluation for signal with noise and phase wrapping

3- The phase evaluation for several bunch shapes (seven bunch shapes).

For these measurements, standard equipments were used in order to perform the phase evaluation shown in figures 1 and 2 in the previous report.

1- Superposition of Signals.

In seeking of more understanding for the unit filtering efficiency, two signals are superposed and their strength is varied. The purpose is to investigate the Libera H capability of filtering and processing of a particular frequency (325 MHz).

The first step is performed by superposing two sinusoidal signals @ 108,4 MHz and 325,2 MHz. Following that, a bunch (Bunch 1) @ 108,4 MHz is generated and superposed with a sinusoidal signal @ 108,4 MHz. The same procedure is repeated with another bunch @ 108,4 MHz (Bunch 2). From the tables 1-1, 1-2, 1-3, 1-4, 1-5 and 1-6 and corresponding plots, figures 1-1 1-2, 1-3, 1-4, 1-5 and 1-6 some remarks can be observed. Appendix 1-1, 1-2 and 1-3 contain all information.

❖ Superposition 108,4MHz & 325,2MHz

1- Amplitude dependence for phase readouts is observed when 108 MHz powers are strong (108 MHz @ 10 & 5 dBm). This behavior disappeared as the 108 MHz power is lower than 0 dBm or 325 signal is strong compare to 108 MHz signal (**?**).
2- The standard deviation records less than 1 ^{o} for all signals where 108 MHz powers are low (- 25 to - 40 dBm).
3- In case of that the both signals power are equal, more than 1 ^{o} standard deviation is measured where the signals' strengh are equal and less than - 15 dBm.
4- The most extreme case where 108 MHz powers are 10 dBm and 325 MHz is -20 dBm, the standard deviation gives ~5 ^{o} .
5- It was expected that the standard deviation increases when 325 MHz signal power decreases. However, it was observed an opposite scenario in some cases (**?**).
6- The standard deviation for phase recorded at 5 dBm power shows strange behavior. Therefore, an explanation is required.
7- It was observed in Lebera phase readouts that there is a phase jump in few degrees around -20 dBm. After this phase jump, the standard deviation almost doubled. However, as the measurements were taken, the phase was always stable and was checked with an external trigger oscilloscope at zero crossing. The reason for this jump has been investigated with the oscilloscope. It was noticed that when the oscilloscope is switched from 10 mV/div to 5 mV/div, there is a jump of ~ 60 ps. At 325 MHz 8,5 ps == 1°, so 60 ps difference means ~7° phase error. This might be an explanation for the phase Jump around -20dBm. However, it does not explain the increasing in standard deviation around this region. The change in standard deviation should be only caused by Libera (**?**).
8- In all cases where 108 MHz input power is 5 dBm, it was observed that there is jump in standard deviation. This becomes clearly noticeable where 325 MHz is low (-5, -10, -15, -20 dBm) (**?**).

Table 1-1, Noise is fixed

325 (dBm)	325 (Vp)	108 (dBm)	108 (Vp)	samples	phase_mean (degree)	st_phase (degree)	st_mean (degree)
10	1	10	1	648	139.821	0.195	0.008
5	0.562	10	1	648	137.663	0.321	0.013
0	0.316	10	1	648	137.962	0.526	0.021
-5	0.178	10	1	648	135.680	0.920	0.036
-10	0.1	10	1	648	135.141	1.592	0.063
-15	0.056	10	1	648	129.510	2.889	0.113
-20	0.032	10	1	648	120.725	4.673	0.184
10	1	5	0.562	648	140.419	0.191	0.007
5	0.562	5	0.562	648	138.687	0.306	0.012
0	0.316	5	0.562	648	139.847	0.525	0.021
-5	0.178	5	0.562	648	138.977	0.914	0.036
-10	0.1	5	0.562	648	140.869	1.712	0.067
-15	0.056	5	0.562	648	139.461	2.870	0.113
-20	0.032	5	0.562	648	137.866	5.438	0.214
10	1	0	0.316	648	140.528	0.130	0.005
5	0.562	0	0.316	648	138.893	0.152	0.006
0	0.316	0	0.316	648	140.111	0.206	0.008
-5	0.178	0	0.316	648	139.496	0.333	0.013
-10	0.1	0	0.316	648	141.743	0.577	0.023
-15	0.056	0	0.316	648	141.213	1.000	0.039
-20	0.032	0	0.316	648	140.937	1.779	0.070
10	1	-5	0.178	648	140.562	0.136	0.005
5	0.562	-5	0.178	648	138.967	0.149	0.006
0	0.316	-5	0.178	648	140.212	0.200	0.008
-5	0.178	-5	0.178	648	139.662	0.338	0.013
-10	0.1	-5	0.178	648	142.102	0.569	0.022
-15	0.056	-5	0.178	648	141.620	1.012	0.040
-20	0.032	-5	0.178	648	141.933	1.757	0.069
10	1	-10	0.1	648	140.566	0.124	0.005
5	0.562	-10	0.1	648	138.963	0.159	0.006
0	0.316	-10	0.1	648	140.222	0.202	0.008
-5	0.178	-10	0.1	648	139.655	0.331	0.013
-10	0.1	-10	0.1	648	142.131	0.562	0.022
-15	0.056	-10	0.1	648	141.735	0.965	0.038
-20	0.032	-10	0.1	648	141.975	1.715	0.067
10	1	-15	0.056	648	140.567	0.123	0.005
5	0.562	-15	0.056	648	138.992	0.155	0.006
0	0.316	-15	0.056	648	140.221	0.208	0.008
-5	0.178	-15	0.056	648	139.681	0.327	0.013
-10	0.1	-15	0.056	648	142.172	0.553	0.022
-15	0.056	-15	0.056	648	141.777	1.019	0.040
-20	0.032	-15	0.056	648	142.016	1.688	0.066
10	1	-20	0.032	648	140.565	0.128	0.005
5	0.562	-20	0.032	648	137.099	0.126	0.005
0	0.316	-20	0.032	648	140.228	0.198	0.008
-5	0.178	-20	0.032	648	137.748	0.173	0.007
-10	0.1	-20	0.032	648	142.183	0.569	0.022

-15	0.056	-20	0.032	648	139.747	0.443	0.017
-20	0.032	-20	0.032	648	141.938	1.683	0.066
10	1	-25	0.018	648	138.582	0.116	0.005
5	0.562	-25	0.018	648	137.091	0.127	0.005
0	0.316	-25	0.018	648	138.364	0.116	0.005
-5	0.178	-25	0.018	648	137.797	0.172	0.007
-10	0.1	-25	0.018	648	140.332	0.247	0.010
-15	0.056	-25	0.018	648	139.770	0.419	0.016
-20	0.032	-25	0.018	648	140.134	0.715	0.028
10	1	-30	0.01	648	138.567	0.116	0.005
5	0.562	-30	0.01	648	137.140	0.130	0.005
0	0.316	-30	0.01	648	138.358	0.113	0.004
-5	0.178	-30	0.01	648	137.793	0.144	0.006
-10	0.1	-30	0.01	648	140.315	0.258	0.010
-15	0.056	-30	0.01	648	139.828	0.316	0.012
-20	0.032	-30	0.01	648	140.113	0.724	0.028
10	1	-35	0.0056	648	138.588	0.111	0.004
5	0.562	-35	0.0056	648	137.149	0.123	0.005
0	0.316	-35	0.0056	648	138.366	0.107	0.004
-5	0.178	-35	0.0056	648	137.803	0.152	0.006
-10	0.1	-35	0.0056	648	140.318	0.188	0.007
-15	0.056	-35	0.0056	648	139.824	0.339	0.013
-20	0.032	-35	0.0056	648	140.207	0.547	0.022
10	1	-40	0.00316	648	138.582	0.114	0.004
5	0.562	-40	0.00316	648	137.149	0.119	0.005
0	0.316	-40	0.00316	648	138.371	0.107	0.004
-5	0.178	-40	0.00316	648	137.791	0.157	0.006
-10	0.1	-40	0.00316	648	140.324	0.193	0.008
-15	0.056	-40	0.00316	648	139.819	0.340	0.013
-20	0.032	-40	0.00316	648	140.186	0.556	0.022

Table 1-2, Noise is varying

325 (dBm)	325 (Vp)	108 (dBm)	108 (Vp)	samples	phase_mean (degree)	st_phase (degree)	st_mean (degree)
10	1	-40	0.00316	648	138.582	0.114	0.004
10	1	-35	0.0056	648	138.588	0.111	0.004
10	1	-30	0.01	648	138.567	0.116	0.005
10	1	-25	0.018	648	138.582	0.116	0.005
10	1	-20	0.032	648	140.565	0.128	0.005
10	1	-15	0.056	648	140.567	0.123	0.005
10	1	-10	0.1	648	140.566	0.124	0.005
10	1	-5	0.178	648	140.562	0.136	0.005
10	1	0	0.316	648	140.528	0.130	0.005
10	1	5	0.562	648	140.419	0.191	0.007
10	1	10	1	648	139.821	0.195	0.008
5	0.562	-40	0.00316	648	137.149	0.119	0.005
5	0.562	-35	0.0056	648	137.149	0.123	0.005

5	0.562	-30	0.01	648	137.140	0.130	0.005
5	0.562	-25	0.018	648	137.091	0.127	0.005
5	0.562	-20	0.032	648	137.099	0.126	0.005
5	0.562	-15	0.056	648	138.992	0.155	0.006
5	0.562	-10	0.1	648	138.963	0.159	0.006
5	0.562	-5	0.178	648	138.967	0.149	0.006
5	0.562	0	0.316	648	138.893	0.152	0.006
5	0.562	5	0.562	648	138.687	0.306	0.012
5	0.562	10	1	648	137.663	0.321	0.013
0	0.316	-40	0.00316	648	138.371	0.107	0.004
0	0.316	-35	0.0056	648	138.366	0.107	0.004
0	0.316	-30	0.01	648	138.358	0.113	0.004
0	0.316	-25	0.018	648	138.364	0.116	0.005
0	0.316	-20	0.032	648	140.228	0.198	0.008
0	0.316	-15	0.056	648	140.221	0.208	0.008
0	0.316	-10	0.1	648	140.222	0.202	0.008
0	0.316	-5	0.178	648	140.212	0.200	0.008
0	0.316	0	0.316	648	140.111	0.206	0.008
0	0.316	5	0.562	648	139.847	0.525	0.021
0	0.316	10	1	648	137.962	0.526	0.021
-5	0.178	-40	0.00316	648	137.791	0.157	0.006
-5	0.178	-35	0.0056	648	137.803	0.152	0.006
-5	0.178	-30	0.01	648	137.793	0.144	0.006
-5	0.178	-25	0.018	648	137.797	0.172	0.007
-5	0.178	-20	0.032	648	137.748	0.173	0.007
-5	0.178	-15	0.056	648	139.681	0.327	0.013
-5	0.178	-10	0.1	648	139.655	0.331	0.013
-5	0.178	-5	0.178	648	139.662	0.338	0.013
-5	0.178	0	0.316	648	139.496	0.333	0.013
-5	0.178	5	0.562	648	138.977	0.914	0.036
-5	0.178	10	1	648	135.680	0.920	0.036
-10	0.1	-40	0.00316	648	140.324	0.193	0.008
-10	0.1	-35	0.0056	648	140.318	0.188	0.007
-10	0.1	-30	0.01	648	140.315	0.258	0.010
-10	0.1	-25	0.018	648	140.332	0.247	0.010
-10	0.1	-20	0.032	648	142.183	0.569	0.022
-10	0.1	-15	0.056	648	142.172	0.553	0.022
-10	0.1	-10	0.1	648	142.131	0.562	0.022
-10	0.1	-5	0.178	648	142.102	0.569	0.022
-10	0.1	0	0.316	648	141.743	0.577	0.023
-10	0.1	5	0.562	648	140.869	1.712	0.067
-10	0.1	10	1	648	135.141	1.592	0.063
-15	0.056	-40	0.00316	648	139.819	0.340	0.013
-15	0.056	-35	0.0056	648	139.824	0.339	0.013
-15	0.056	-30	0.01	648	139.828	0.316	0.012
-15	0.056	-25	0.018	648	139.770	0.419	0.016
-15	0.056	-20	0.032	648	139.747	0.443	0.017
-15	0.056	-15	0.056	648	141.777	1.019	0.040
-15	0.056	-10	0.1	648	141.735	0.965	0.038
-15	0.056	-5	0.178	648	141.620	1.012	0.040
-15	0.056	0	0.316	648	141.213	1.000	0.039
-15	0.056	5	0.562	648	139.461	2.870	0.113
-15	0.056	10	1	648	129.510	2.889	0.113

-20	0.032	-40	0.00316	648	140.186	0.556	0.022
-20	0.032	-35	0.0056	648	140.207	0.547	0.022
-20	0.032	-30	0.01	648	140.113	0.724	0.028
-20	0.032	-25	0.018	648	140.134	0.715	0.028
-20	0.032	-20	0.032	648	141.938	1.683	0.066
-20	0.032	-15	0.056	648	142.016	1.688	0.066
-20	0.032	-10	0.1	648	141.975	1.715	0.067
-20	0.032	-5	0.178	648	141.934	1.757	0.069
-20	0.032	0	0.316	648	140.937	1.779	0.070
-20	0.032	5	0.562	648	137.866	5.438	0.214
-20	0.032	10	1	648	120.725	4.673	0.184

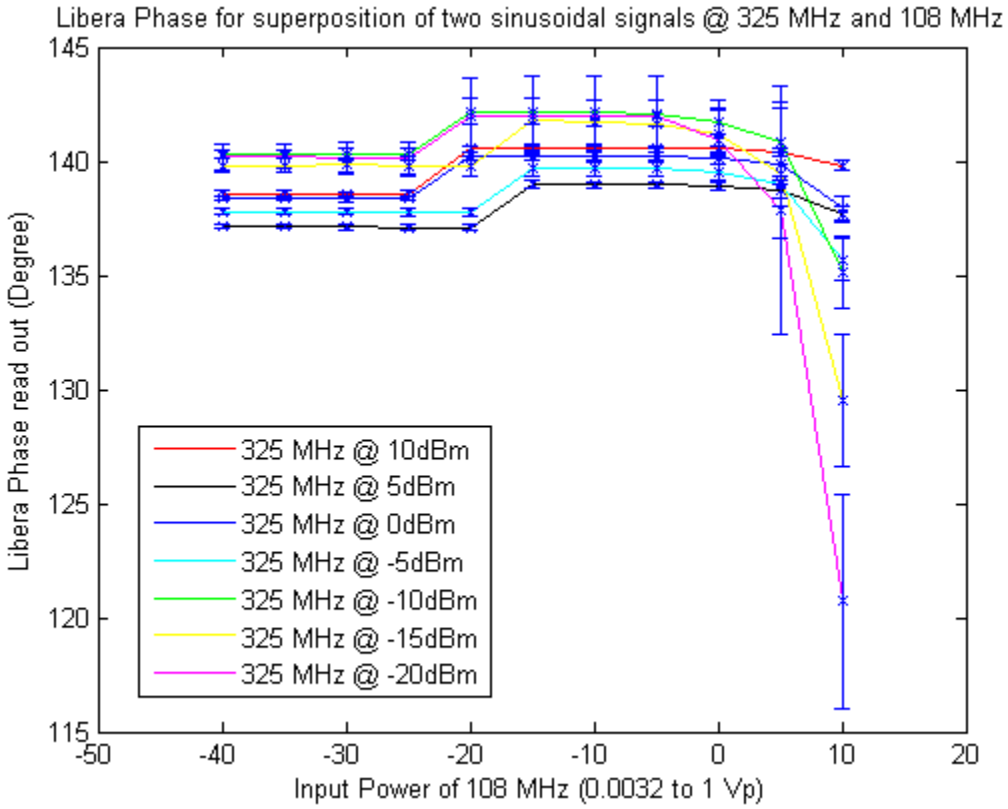

Fig. 1-1

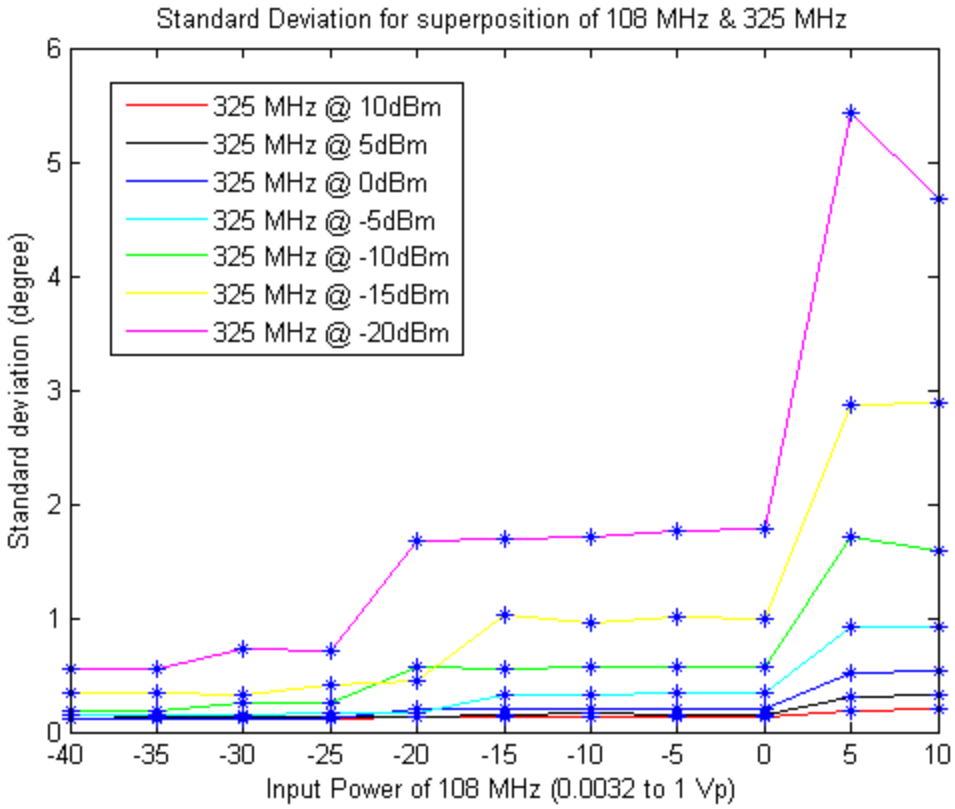

Fig. 1-2

❖ Superposition 108,4MHz & Bunch 1

Table 1-3, Noise is fixed

108 bunch 1 (dBm)	108 bunch 1 (Vp)	108 (dBm)	108 (Vp)	samples	phase_mean (degree)	st_phase (degree)	st_mean (degree)
10	1	10	1	648	95.969	2.179	0.086
5	0.562	10	1	648	93.134	2.352	0.092
0	0.316	10	1	648	87.059	3.304	0.130
-5	0.178	10	1	648	81.428	4.765	0.187
-10	0.1	10	1	648	76.294	6.076	0.239
-15	0.056	10	1	648	69.042	8.501	0.334
-20	0.032	10	1	648	64.314	9.153	0.360
10	1	5	0.562	648	98.938	2.359	0.093
5	0.562	5	0.562	648	97.550	2.787	0.110
0	0.316	5	0.562	648	92.673	4.268	0.168
-5	0.178	5	0.562	648	89.600	7.065	0.278

-10	0.1	5	0.562	648	85.516	11.844	0.465
-15	0.056	5	0.562	648	76.455	17.978	0.706
-20	0.032	5	0.562	648	66.779	28.750	1.129
10	1	0	0.316	648	99.869	2.048	0.080
5	0.562	0	0.316	648	99.491	1.792	0.070
0	0.316	0	0.316	648	96.128	2.398	0.094
-5	0.178	0	0.316	648	95.004	2.817	0.111
-10	0.1	0	0.316	648	94.675	4.449	0.175
-15	0.056	0	0.316	648	90.391	7.153	0.281
-20	0.032	0	0.316	648	84.165	11.465	0.450
10	1	-5	0.178	648	100.380	2.209	0.087
5	0.562	-5	0.178	648	99.958	1.747	0.069
0	0.316	-5	0.178	648	96.987	2.368	0.093
-5	0.178	-5	0.178	648	96.531	2.882	0.113
-10	0.1	-5	0.178	648	97.561	4.685	0.184
-15	0.056	-5	0.178	648	94.563	7.725	0.303
-20	0.032	-5	0.178	648	92.503	13.831	0.543
10	1	-10	0.1	648	100.496	2.130	0.084
5	0.562	-10	0.1	648	100.218	1.680	0.066
0	0.316	-10	0.1	648	97.411	2.313	0.091
-5	0.178	-10	0.1	648	97.489	2.781	0.109
-10	0.1	-10	0.1	648	99.383	4.526	0.178
-15	0.056	-10	0.1	648	97.431	8.167	0.321
-20	0.032	-10	0.1	648	96.971	13.772	0.541
10	1	-15	0.056	648	100.489	2.015	0.079
5	0.562	-15	0.056	648	100.374	1.709	0.067
0	0.316	-15	0.056	648	97.624	2.391	0.094
-5	0.178	-15	0.056	648	97.835	2.867	0.113
-10	0.1	-15	0.056	648	99.975	4.749	0.187
-15	0.056	-15	0.056	648	98.377	8.077	0.317
-20	0.032	-15	0.056	648	97.487	13.726	0.539
10	1	-20	0.032	648	100.480	2.139	0.084
5	0.562	-20	0.032	648	100.553	1.757	0.069
0	0.316	-20	0.032	648	97.807	2.352	0.092
-5	0.178	-20	0.032	648	97.889	3.064	0.120
-10	0.1	-20	0.032	648	100.357	4.789	0.188
-15	0.056	-20	0.032	648	98.892	7.963	0.313
-20	0.032	-20	0.032	648	98.596	15.485	0.608

Table 1-4, Noise is varying

108 bunch 1 (dBm)	108 bunch 1 (Vp)	108 (dBm)	108 (Vp)	samples	phase_mean (degree)	st_phase (degree)	st_mean (degree)
10	1	-20	0.032	648	100.480	2.139	0.084
10	1	-15	0.056	648	100.489	2.015	0.079
10	1	-10	0.1	648	100.496	2.130	0.084
10	1	-5	0.178	648	100.380	2.209	0.087
10	1	0	0.316	648	99.869	2.048	0.080

10	1	5	0.562	648	98.938	2.359	0.093
10	1	10	1	648	95.969	2.179	0.086
5	0.562	-20	0.032	648	100.553	1.757	0.069
5	0.562	-15	0.056	648	100.374	1.709	0.067
5	0.562	-10	0.1	648	100.218	1.680	0.066
5	0.562	-5	0.178	648	99.958	1.747	0.069
5	0.562	0	0.316	648	99.491	1.792	0.070
5	0.562	5	0.562	648	97.550	2.787	0.110
5	0.562	10	1	648	93.134	2.352	0.092
0	0.316	-20	0.032	648	97.807	2.352	0.092
0	0.316	-15	0.056	648	97.624	2.391	0.094
0	0.316	-10	0.1	648	97.411	2.313	0.091
0	0.316	-5	0.178	648	96.987	2.368	0.093
0	0.316	0	0.316	648	96.128	2.398	0.094
0	0.316	5	0.562	648	92.673	4.268	0.168
0	0.316	10	1	648	87.059	3.304	0.130
-5	0.178	-20	0.032	648	97.889	3.064	0.120
-5	0.178	-15	0.056	648	97.835	2.867	0.113
-5	0.178	-10	0.1	648	97.489	2.781	0.109
-5	0.178	-5	0.178	648	96.531	2.882	0.113
-5	0.178	0	0.316	648	95.004	2.817	0.111
-5	0.178	5	0.562	648	89.600	7.065	0.278
-5	0.178	10	1	648	81.428	4.765	0.187
-10	0.1	-20	0.032	648	100.357	4.789	0.188
-10	0.1	-15	0.056	648	99.975	4.749	0.187
-10	0.1	-10	0.1	648	99.383	4.526	0.178
-10	0.1	-5	0.178	648	97.561	4.685	0.184
-10	0.1	0	0.316	648	94.675	4.449	0.175
-10	0.1	5	0.562	648	85.516	11.844	0.465
-10	0.1	10	1	648	76.294	6.076	0.239
-15	0.056	-20	0.032	648	98.892	7.963	0.313
-15	0.056	-15	0.056	648	98.377	8.077	0.317
-15	0.056	-10	0.1	648	97.431	8.167	0.321
-15	0.056	-5	0.178	648	94.563	7.725	0.303
-15	0.056	0	0.316	648	90.391	7.153	0.281
-15	0.056	5	0.562	648	76.455	17.978	0.706
-15	0.056	10	1	648	69.042	8.501	0.334
-20	0.032	-20	0.032	648	98.596	15.485	0.608
-20	0.032	-15	0.056	648	97.487	13.726	0.539
-20	0.032	-10	0.1	648	96.971	13.772	0.541
-20	0.032	-5	0.178	648	92.503	13.831	0.543
-20	0.032	0	0.316	648	84.165	11.465	0.450
-20	0.032	5	0.562	648	66.779	28.750	1.129
-20	0.032	10	1	648	64.314	9.153	0.360

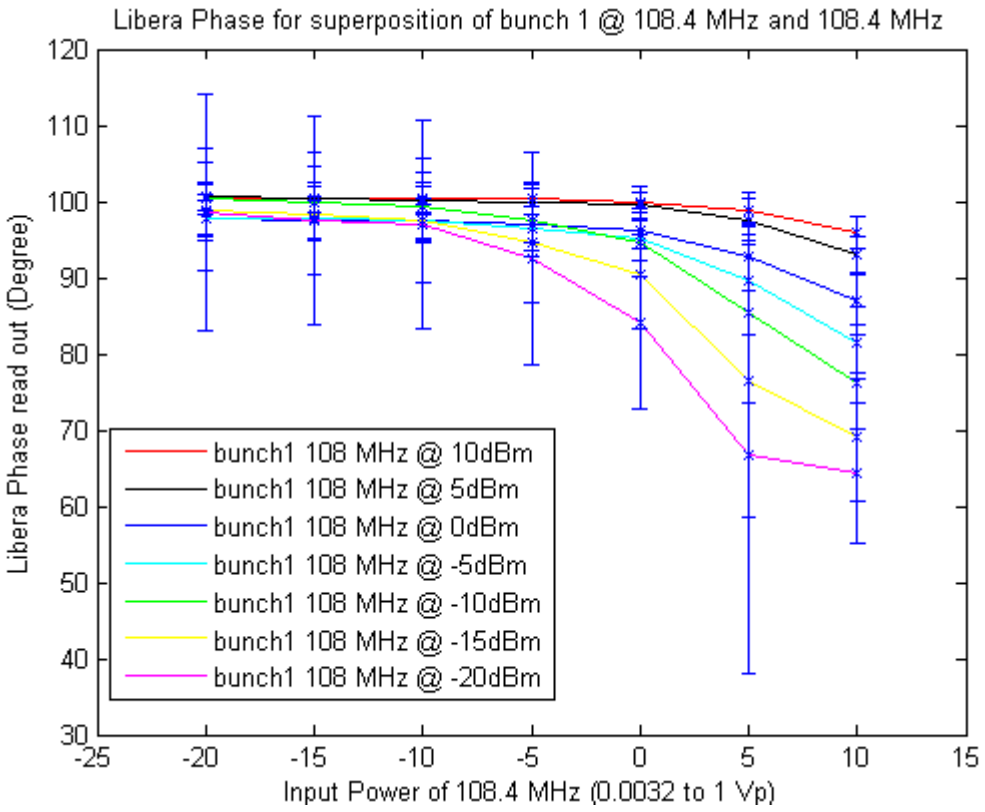
Libera Phase for superposition of bunch 1 @ 108.4 MHz and 108.4 MHz
Libera Phase read out (Degree)
Input Power of 108.4 MHz (0.0032 to 1 Vp)
bunch1 108 MHz @ 10dBm
bunch1 108 MHz @ 5dBm
bunch1 108 MHz @ 0dBm
bunch1 108 MHz @ -5dBm
bunch1 108 MHz @ -10dBm
bunch1 108 MHz @ -15dBm
bunch1 108 MHz @ -20dBm

Fig. 1-3

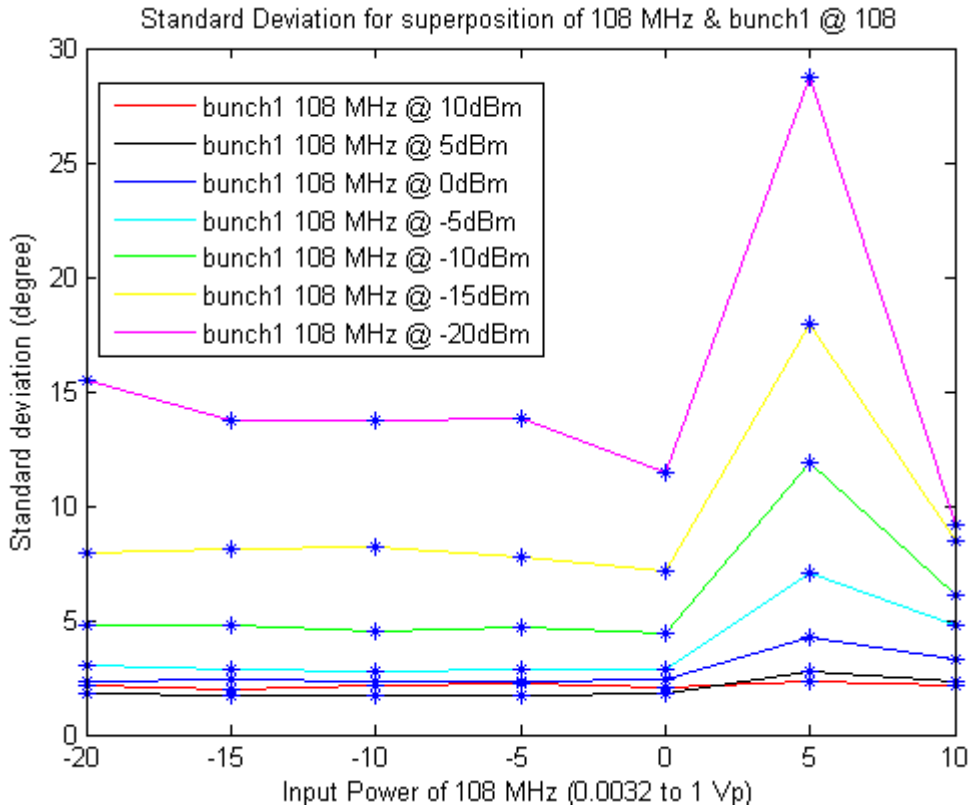
Standard Deviation for superposition of 108 MHz & bunch1 @ 108
Standard deviation (degree)
Input Power of 108 MHz (0.0032 to 1 Vp)
bunch1 108 MHz @ 10dBm
bunch1 108 MHz @ 5dBm
bunch1 108 MHz @ 0dBm
bunch1 108 MHz @ -5dBm
bunch1 108 MHz @ -10dBm
bunch1 108 MHz @ -15dBm
bunch1 108 MHz @ -20dBm

Fig. 1-4

❖ Superposition 108,4MHz & Bunch 2

Table 1-5, Noise is fixed

108 bunch 2 (dBm)	108 bunch 2 (Vp)	108 (dBm)	108 (Vp)	samples	phase_mean (degree)	st_phase (degree)	st_mean (degree)
10	1	10	1	648	136.796	1.531	0.060
5	0.562	10	1	648	134.844	2.189	0.086
0	0.316	10	1	648	124.335	3.330	0.131
-5	0.178	10	1	648	112.591	5.087	0.200
-10	0.1	10	1	648	99.119	7.656	0.301
-15	0.056	10	1	648	83.096	8.763	0.344
-20	0.032	10	1	648	71.846	9.915	0.390
10	1	5	0.562	648	141.308	1.499	0.059
5	0.562	5	0.562	648	142.732	2.196	0.086
0	0.316	5	0.562	648	137.108	3.988	0.157
-5	0.178	5	0.562	648	133.410	6.688	0.263
-10	0.1	5	0.562	648	128.037	12.326	0.484
-15	0.056	5	0.562	648	113.625	22.953	0.902
-20	0.032	5	0.562	648	88.449	44.750	1.758
10	1	0	0.316	648	142.264	1.012	0.040
5	0.562	0	0.316	648	144.367	1.142	0.045
0	0.316	0	0.316	648	140.064	1.554	0.061
-5	0.178	0	0.316	648	138.203	2.435	0.096
-10	0.1	0	0.316	648	136.917	3.987	0.157
-15	0.056	0	0.316	648	131.183	7.053	0.277
-20	0.032	0	0.316	648	124.180	12.283	0.483
10	1	-5	0.178	648	142.834	1.089	0.043
5	0.562	-5	0.178	648	144.927	1.174	0.046
0	0.316	-5	0.178	648	141.140	1.581	0.062
-5	0.178	-5	0.178	648	140.228	2.378	0.093
-10	0.1	-5	0.178	648	140.564	3.920	0.154
-15	0.056	-5	0.178	648	137.658	6.924	0.272
-20	0.032	-5	0.178	648	135.285	12.271	0.482
10	1	-10	0.1	648	142.816	1.017	0.040
5	0.562	-10	0.1	648	145.103	1.207	0.047
0	0.316	-10	0.1	648	141.302	1.584	0.062
-5	0.178	-10	0.1	648	140.786	2.294	0.090
-10	0.1	-10	0.1	648	141.404	3.964	0.156
-15	0.056	-10	0.1	648	139.472	6.577	0.258
-20	0.032	-10	0.1	648	137.936	20.795	0.817
10	1	-15	0.056	648	142.999	1.036	0.041
5	0.562	-15	0.056	648	145.252	1.174	0.046
0	0.316	-15	0.056	648	141.703	1.509	0.059
-5	0.178	-15	0.056	648	141.130	2.268	0.089
-10	0.1	-15	0.056	648	142.261	3.958	0.155
-15	0.056	-15	0.056	648	141.280	6.452	0.253
-20	0.032	-15	0.056	648	141.714	11.495	0.452

10	1	-20	0.032	648	142.901	1.049	0.041
5	0.562	-20	0.032	648	145.296	1.164	0.046
0	0.316	-20	0.032	648	141.670	1.579	0.062
-5	0.178	-20	0.032	648	141.169	2.331	0.092
-10	0.1	-20	0.032	648	142.425	4.041	0.159
-15	0.056	-20	0.032	648	141.596	6.673	0.262
-20	0.032	-20	0.032	648	142.125	16.942	0.666

Table 1-6, Noise is varying

108 bunch 2 (dBm)	108 bunch 2 (Vp)	108 (dBm)	108 (Vp)	samples	phase_mean (degree)	st_phase (degree)	st_mean (degree)
10	1	-20	0.032	648	142.901	1.049	0.041
10	1	-15	0.056	648	142.999	1.036	0.041
10	1	-10	0.1	648	142.816	1.017	0.040
10	1	-5	0.178	648	142.834	1.089	0.043
10	1	0	0.316	648	142.264	1.012	0.040
10	1	5	0.562	648	141.308	1.499	0.059
10	1	10	1	648	136.796	1.531	0.060
5	0.562	-20	0.032	648	145.296	1.164	0.046
5	0.562	-15	0.056	648	145.252	1.174	0.046
5	0.562	-10	0.1	648	145.103	1.207	0.047
5	0.562	-5	0.178	648	144.927	1.174	0.046
5	0.562	0	0.316	648	144.367	1.142	0.045
5	0.562	5	0.562	648	142.732	2.196	0.086
5	0.562	10	1	648	134.844	2.189	0.086
0	0.316	-20	0.032	648	141.670	1.579	0.062
0	0.316	-15	0.056	648	141.703	1.509	0.059
0	0.316	-10	0.1	648	141.302	1.584	0.062
0	0.316	-5	0.178	648	141.140	1.581	0.062
0	0.316	0	0.316	648	140.064	1.554	0.061
0	0.316	5	0.562	648	137.108	3.988	0.157
0	0.316	10	1	648	124.335	3.330	0.131
-5	0.178	-20	0.032	648	141.169	2.331	0.092
-5	0.178	-15	0.056	648	141.130	2.268	0.089
-5	0.178	-10	0.1	648	140.786	2.294	0.090
-5	0.178	-5	0.178	648	140.228	2.378	0.093
-5	0.178	0	0.316	648	138.203	2.435	0.096
-5	0.178	5	0.562	648	133.410	6.688	0.263
-5	0.178	10	1	648	112.591	5.087	0.200
-10	0.1	-20	0.032	648	142.425	4.041	0.159
-10	0.1	-15	0.056	648	142.261	3.958	0.155
-10	0.1	-10	0.1	648	141.404	3.964	0.156
-10	0.1	-5	0.178	648	140.564	3.920	0.154
-10	0.1	0	0.316	648	136.917	3.987	0.157
-10	0.1	5	0.562	648	128.037	12.326	0.484
-10	0.1	10	1	648	99.119	7.656	0.301
-15	0.056	-20	0.032	648	141.596	6.673	0.262

-15	0.056	-15	0.056	648	141.280	6.452	0.253
-15	0.056	-10	0.1	648	139.472	6.577	0.258
-15	0.056	-5	0.178	648	137.658	6.924	0.272
-15	0.056	0	0.316	648	131.183	7.053	0.277
-15	0.056	5	0.562	648	113.625	22.953	0.902
-15	0.056	10	1	648	83.096	8.763	0.344
-20	0.032	-20	0.032	648	142.125	16.942	0.666
-20	0.032	-15	0.056	648	141.714	11.495	0.452
-20	0.032	-10	0.1	648	137.936	20.795	0.817
-20	0.032	-5	0.178	648	135.285	12.271	0.482
-20	0.032	0	0.316	648	124.180	12.283	0.483
-20	0.032	5	0.562	648	88.449	44.750	1.758
-20	0.032	10	1	648	71.846	9.915	0.390

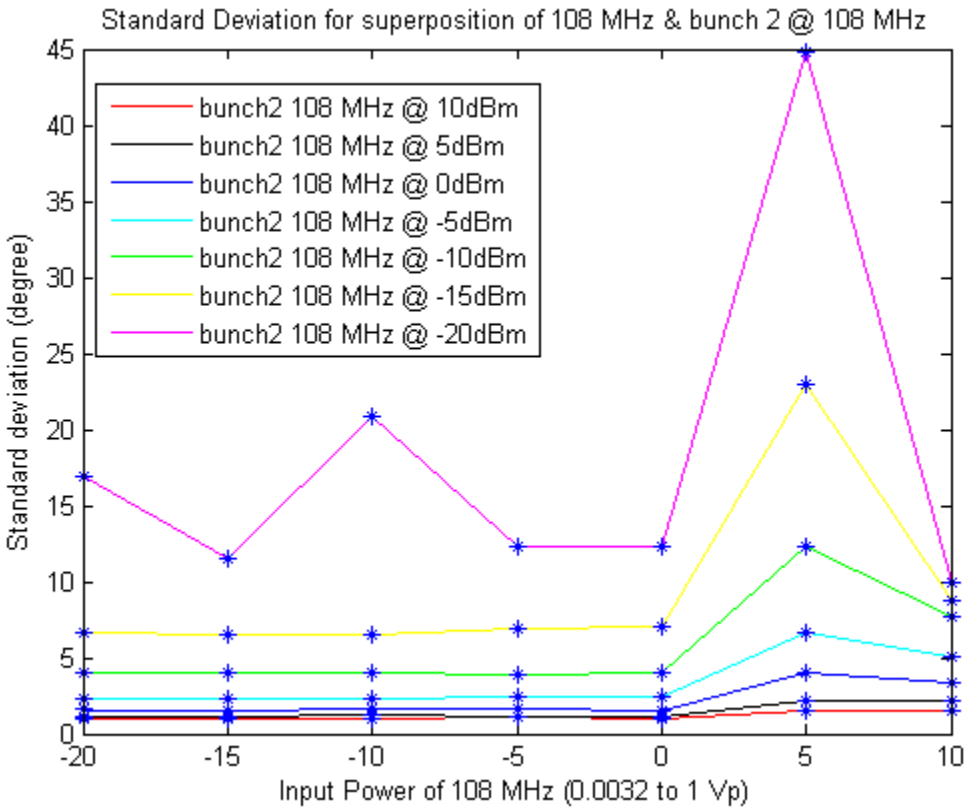

Fig. 1-5

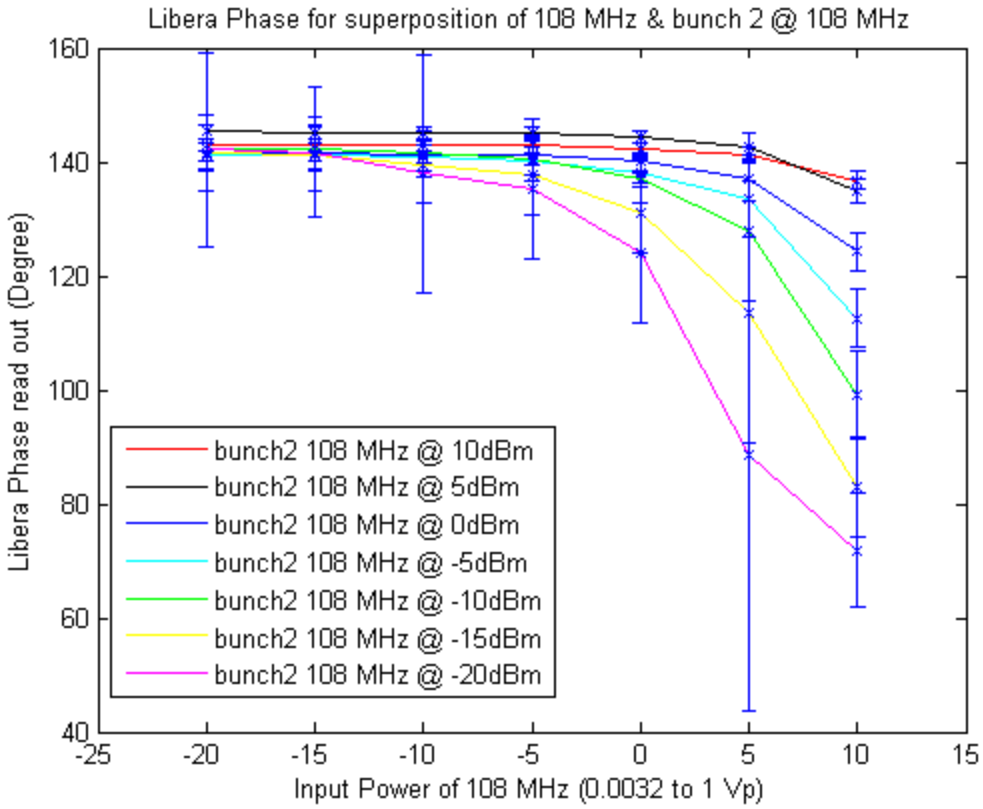
Libera Phase for superposition of 108 MHz & bunch 2 @ 108 MHz
Libera Phase read out (Degree)
Input Power of 108 MHz (0.0032 to 1 Vp)
bunch2 108 MHz @ 10dBm
bunch2 108 MHz @ 5dBm
bunch2 108 MHz @ 0dBm
bunch2 108 MHz @ -5dBm
bunch2 108 MHz @ -10dBm
bunch2 108 MHz @ -15dBm
bunch2 108 MHz @ -20dBm
160
140
120
100
80
60
40
-25
-20
-15
-10
-5
0
5
10
15

Fig. 1-6

2- Superposition of Signals and Noise.

This study is performed to estimate the contribution of noise and its influence on the Libera measured phase. Threrfore, more measurements were taken in different amplitudes to fulfil all parameters that have to be taken into account. Starting with a pure sinusoidal signal @ 325,2 MHz, the signal power is varied and combined with noise levels in range of -35 to 10 dBm. An amplifir is used as a noise source. A similar treatment is performed by combining two different bunches @ 108 MHz separately with noise.

From the tables 2-1, 2-2, 2-3, 2-4, 2-5 and 2-6 and corresponding plots in figures 2-1 2-2 and 2-3 some remarks can be observed. Appendix 2-1, 2-2 and 2-3 contain all information.

1- Phase readout shows amplitude dependence due to noise contribution (**?**). Furthermore, recalling point (1) from the previous section which shows amplitude dependence for phase readouts with strong 108 MHz powers as well.
2- For standard deviation less than 1^{o}, SNR must be more than 20 in case of combining sinusoidal signal @ 325 MHz and noise.
3- In case of bunches (1) and (2) and bunch at phase wrapping, standard deviation of less than 1^{o} never achieved. Acknowledging that even for pure bunch signals, the standard deviation are 1.27^{o} and 2.7^{o} with 10 dBm signal power for bunch (1) and bunch (2) respectively.
9- . Phase readout is amplitude dependence due to noise contribution.

❖ Superposition 325,2 MHz & Noise

Table 2-1, Noise is fixed

325 (dBm)	325 (Vp)	Noise (dBm)	Noise (Vp)	SNR	samples	phase_mean (degree)	st_phase (degree)	st_mean (degree)
10	1	0	0.316	3.16	648	71.66	5.93	0.23
7	0.708	0	0.316	2.24	648	74.20	9.33	0.37
4	0.501	0	0.316	1.59	648	75.10	13.19	0.52
1	0.355	0	0.316	1.12	648	77.92	18.26	0.72
-2	0.251	0	0.316	0.79	648	77.77	34.08	1.34
-5	0.178	0	0.316	0.56	648	72.21	46.68	1.83
-8	0.126	0	0.316	0.40	648	62.92	67.97	2.67
10	1	-5	0.178	5.62	648	72.29	3.26	0.13
7	0.708	-5	0.178	3.98	648	75.91	5.33	0.21
4	0.501	-5	0.178	2.81	648	76.44	7.19	0.28
1	0.355	-5	0.178	1.99	648	79.93	9.22	0.36
-2	0.251	-5	0.178	1.41	648	79.05	16.42	0.65
-5	0.178	-5	0.178	1.00	648	78.93	21.21	0.83

-8	0.126	-5	0.178	0.71	648	77.00	35.55	1.40
10	1	-10	0.1	10.00	648	71.95	1.89	0.07
7	0.708	-10	0.1	7.08	648	75.83	2.98	0.12
4	0.501	-10	0.1	5.01	648	76.06	3.87	0.15
1	0.355	-10	0.1	3.55	648	78.74	5.54	0.22
-2	0.251	-10	0.1	2.51	648	79.33	8.48	0.33
-5	0.178	-10	0.1	1.78	648	79.71	11.38	0.45
-8	0.126	-10	0.1	1.26	648	79.78	16.50	0.65
10	1	-15	0.056	17.86	648	72.61	1.05	0.04
7	0.708	-15	0.056	12.64	648	76.44	1.65	0.06
4	0.501	-15	0.056	8.95	648	76.55	2.23	0.09
1	0.355	-15	0.056	6.34	648	79.54	3.04	0.12
-2	0.251	-15	0.056	4.48	648	79.77	4.82	0.19
-5	0.178	-15	0.056	3.18	648	80.11	6.48	0.25
-8	0.126	-15	0.056	2.25	648	80.95	8.96	0.35
10	1	-20	0.032	31.25	648	72.57	0.59	0.02
7	0.708	-20	0.032	22.13	648	76.03	0.94	0.04
4	0.501	-20	0.032	15.66	648	76.39	1.28	0.05
1	0.355	-20	0.032	11.09	648	78.83	1.74	0.07
-2	0.251	-20	0.032	7.84	648	79.23	2.72	0.11
-5	0.178	-20	0.032	5.56	648	80.01	3.63	0.14
-8	0.126	-20	0.032	3.94	648	80.41	5.09	0.20
10	1	-25	0.018	55.56	648	73.26	0.37	0.01
7	0.708	-25	0.018	39.33	648	76.81	0.53	0.02
4	0.501	-25	0.018	27.83	648	77.16	0.72	0.03
1	0.355	-25	0.018	19.72	648	79.45	0.94	0.04
-2	0.251	-25	0.018	13.94	648	79.83	1.56	0.06
-5	0.178	-25	0.018	9.89	648	80.66	2.05	0.08
-8	0.126	-25	0.018	7.00	648	81.00	2.98	0.12
10	1	-30	0.01	100.00	648	73.02	0.25	0.01
7	0.708	-30	0.01	70.80	648	76.50	0.32	0.01
4	0.501	-30	0.01	50.10	648	76.82	0.42	0.02
1	0.355	-30	0.01	35.50	648	78.99	0.59	0.02
-2	0.251	-30	0.01	25.10	648	79.54	0.85	0.03
-5	0.178	-30	0.01	17.80	648	80.20	1.14	0.04
-8	0.126	-30	0.01	12.60	648	80.61	1.57	0.06
10	1	-35	0.0056	178.57	648	73.77	0.19	0.01
7	0.708	-35	0.0056	126.43	648	77.14	0.19	0.01
4	0.501	-35	0.0056	89.46	648	77.53	0.25	0.01
1	0.355	-35	0.0056	63.39	648	79.60	0.32	0.01
-2	0.251	-35	0.0056	44.82	648	80.09	0.49	0.02
-5	0.178	-35	0.0056	31.79	648	80.92	0.66	0.03
-8	0.126	-35	0.0056	22.50	648	81.10	0.94	0.04

Table 2-2, Noise is varying

325 (dBm)	325 (Vp)	Noise (dBm)	Noise (Vp)	SNR	samples	phase_mean (degree)	st_phase (degree)	st_mean (degree)
10	1	--	--	--	648	75.513	0.146	0.006
10	1	-35	0.0056	178.57	648	73.774	0.188	0.007
10	1	-30	0.01	100.00	648	73.016	0.249	0.010
10	1	-25	0.018	55.56	648	73.258	0.372	0.015
10	1	-20	0.032	31.25	648	72.571	0.594	0.023
10	1	-15	0.056	17.86	648	72.610	1.047	0.041
10	1	-10	0.1	10.00	648	71.948	1.894	0.074
10	1	-5	0.178	5.62	648	72.291	3.256	0.128
10	1	0	0.316	3.16	648	71.664	5.927	0.233
10	1	5	0.562	1.78	648	70.848	10.229	0.402
10	1	10	1	1.00	648	72.77	19.40	0.762
7	0.708	--	--	--	648	77.428	0.095	0.004
7	0.708	-35	0.0056	126.43	648	77.136	0.188	0.007
7	0.708	-30	0.01	70.80	648	76.498	0.316	0.012
7	0.708	-25	0.018	39.33	648	76.811	0.527	0.021
7	0.708	-20	0.032	22.13	648	76.030	0.938	0.037
7	0.708	-15	0.056	12.64	648	76.436	1.650	0.065
7	0.708	-10	0.1	7.08	648	75.832	2.976	0.117
7	0.708	-5	0.178	3.98	648	75.915	5.335	0.210
7	0.708	0	0.316	2.24	648	74.198	9.334	0.367
4	0.501	--	--	--	648	78.022	0.125	0.005
4	0.501	-35	0.0056	89.46	648	77.528	0.249	0.010
4	0.501	-30	0.01	50.10	648	76.819	0.424	0.017
4	0.501	-25	0.018	27.83	648	77.158	0.715	0.028
4	0.501	-20	0.032	15.66	648	76.388	1.279	0.050
4	0.501	-15	0.056	8.95	648	76.549	2.232	0.088
4	0.501	-10	0.1	5.01	648	76.064	3.867	0.152
4	0.501	-5	0.178	2.81	648	76.437	7.187	0.282
4	0.501	0	0.316	1.59	648	75.104	13.187	0.518
1	0.355	--	--	--	648	79.615	0.146	0.006
1	0.355	-35	0.0056	63.39	648	79.604	0.322	0.013
1	0.355	-30	0.01	35.50	648	78.989	0.592	0.023
1	0.355	-25	0.018	19.72	648	79.449	0.937	0.037
1	0.355	-20	0.032	11.09	648	78.829	1.745	0.069
1	0.355	-15	0.056	6.34	648	79.539	3.040	0.119
1	0.355	-10	0.1	3.55	648	78.736	5.540	0.218
1	0.355	-5	0.178	1.99	648	79.932	9.223	0.362
1	0.355	0	0.316	1.12	648	77.921	18.264	0.717
-2	0.251	--	--	--	648	80.034	0.114	0.004
-2	0.251	-35	0.0056	44.82	648	80.089	0.495	0.019
-2	0.251	-30	0.01	25.10	648	79.542	0.854	0.034
-2	0.251	-25	0.018	13.94	648	79.835	1.564	0.061
-2	0.251	-20	0.032	7.84	648	79.226	2.721	0.107
-2	0.251	-15	0.056	4.48	648	79.766	4.823	0.189
-2	0.251	-10	0.1	2.51	648	79.329	8.477	0.333
-2	0.251	-5	0.178	1.41	648	79.053	16.425	0.645
-2	0.251	0	0.316	0.79	648	77.768	34.077	1.339
-8	0.126	--	--	--	648	81.225	0.178	0.007

-8	0.126	-35	0.0056	22.50	648	81.104	0.939	0.037
-8	0.126	-30	0.01	12.60	648	80.611	1.570	0.062
-8	0.126	-25	0.018	7.00	648	80.998	2.978	0.117
-8	0.126	-20	0.032	3.94	648	80.411	5.095	0.200
-8	0.126	-15	0.056	2.25	648	80.949	8.962	0.352
-8	0.126	-10	0.1	1.26	648	79.785	16.503	0.648
-8	0.126	-5	0.178	0.71	648	76.996	35.547	1.396
-8	0.126	0	0.316	0.40	648	62.922	67.967	2.670
-11	0.089	--	--	--	648	82.569	0.186	0.007
-11	0.089	-35	0.0056	15.89	648	82.460	1.383	0.054
-11	0.089	-30	0.01	8.90	648	81.919	2.288	0.090
-11	0.089	-25	0.018	4.94	648	82.656	4.230	0.166
-11	0.089	-20	0.032	2.78	648	81.309	7.300	0.287
-11	0.089	-15	0.056	1.59	648	81.879	14.099	0.554
-11	0.089	-10	0.1	0.89	648	81.099	28.793	1.131
-11	0.089	-5	0.178	0.50	648	72.700	55.153	2.167
-11	0.089	0	0.316	0.28	648	48.789	82.286	3.233
-14	0.063	--	--	--	648	81.442	0.266	0.010
-14	0.063	-35	0.0056	11.25	648	81.453	1.983	0.078
-14	0.063	-30	0.01	6.30	648	80.716	3.509	0.138
-14	0.063	-25	0.018	3.50	648	81.309	5.938	0.233
-14	0.063	-20	0.032	1.97	648	80.221	11.109	0.436
-14	0.063	-15	0.056	1.13	648	81.145	20.161	0.792
-14	0.063	-10	0.1	0.63	648	75.963	42.632	1.675
-14	0.063	-5	0.178	0.35	648	57.543	80.727	3.171
-14	0.063	0	0.316	0.20	648	48.789	82.286	3.233

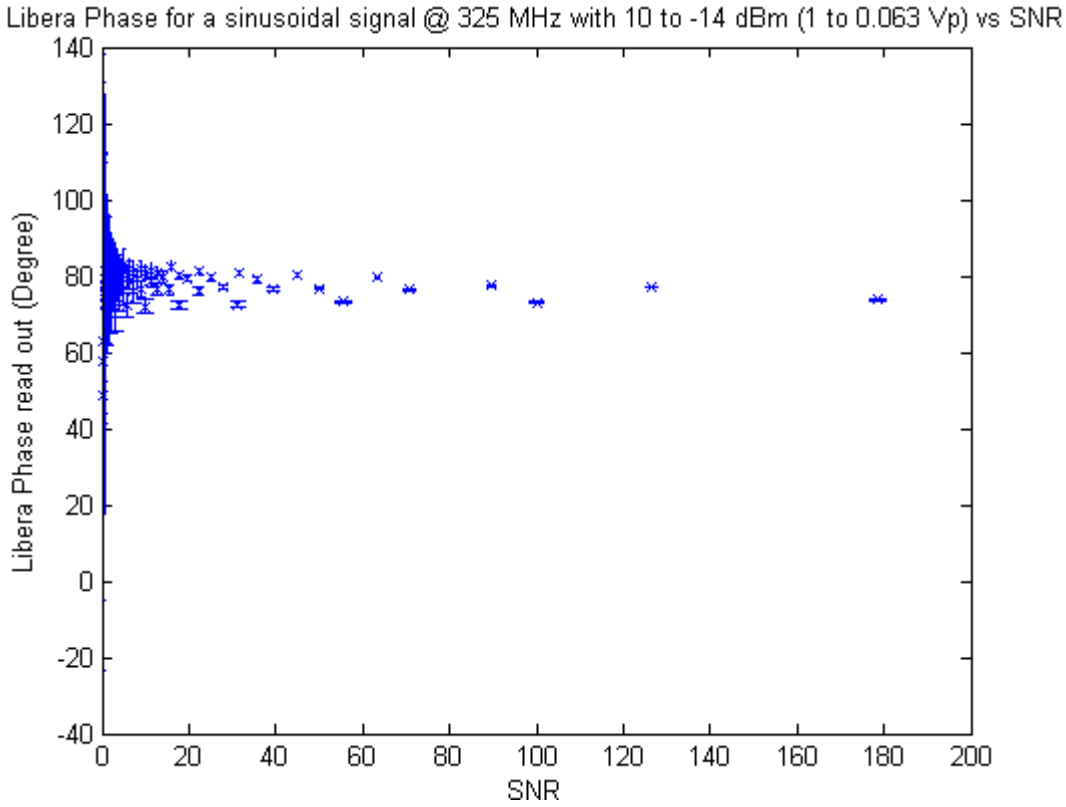

Fig. 2-1

❖ Superposition bunch (1) @ 108.4 MHz & Noise

Table 2-3, Noise is fixed

Bunch 1 (dBm)	Bunch 1 (Vp)	Noise (dBm)	Noise (Vp)	SNR	samples	phase_mean (degree)	st_phase (degree)	st_mean (degree)
10	1	-10	0.1	10.00	648	67.16	12.74	0.50
7	0.708	-10	0.1	7.08	648	73.51	20.64	0.81
4	0.501	-10	0.1	5.01	648	74.25	35.70	1.40
1	0.355	-10	0.1	3.55	648	66.86	58.29	2.29
-2	0.251	-10	0.1	2.51	648	63.01	71.80	2.82
-5	0.178	-10	0.1	1.78	648	49.36	82.18	3.23
-8	0.126	-10	0.1	1.26	648	36.36	99.81	3.92
10	1	-15	0.056	17.86	648	66.20	7.39	0.29
7	0.708	-15	0.056	12.64	648	71.84	11.19	0.44
4	0.501	-15	0.056	8.95	648	72.99	15.92	0.63
1	0.355	-15	0.056	6.34	648	72.28	24.10	0.95
-2	0.251	-15	0.056	4.48	648	71.44	38.57	1.52
-5	0.178	-15	0.056	3.18	648	71.22	51.98	2.04
-8	0.126	-15	0.056	2.25	648	65.38	72.39	2.84
10	1	-20	0.032	31.25	648	66.40	4.23	0.17
7	0.708	-20	0.032	22.13	648	70.13	6.74	0.26
4	0.501	-20	0.032	15.66	648	70.59	9.20	0.36
1	0.355	-20	0.032	11.09	648	71.58	12.29	0.48
-2	0.251	-20	0.032	7.84	648	72.97	19.51	0.77
-5	0.178	-20	0.032	5.56	648	72.47	32.12	1.26
-8	0.126	-20	0.032	3.94	648	76.98	45.86	1.80
10	1	-25	0.018	55.56	648	66.51	2.55	0.10
7	0.708	-25	0.018	39.33	648	69.88	3.86	0.15
4	0.501	-25	0.018	27.83	648	70.73	5.05	0.20
1	0.355	-25	0.018	19.72	648	71.33	7.63	0.30
-2	0.251	-25	0.018	13.94	648	72.82	10.59	0.42
-5	0.178	-25	0.018	9.89	648	72.91	15.18	0.60
-8	0.126	-25	0.018	7.00	648	74.70	21.06	0.83
10	1	-30	0.01	100.00	648	66.56	1.86	0.07
7	0.708	-30	0.01	70.80	648	69.43	2.38	0.09
4	0.501	-30	0.01	50.10	648	69.37	3.10	0.12
1	0.355	-30	0.01	35.50	648	69.57	4.33	0.17
-2	0.251	-30	0.01	25.10	648	72.00	5.72	0.22
-5	0.178	-30	0.01	17.80	648	72.34	8.31	0.33
-8	0.126	-30	0.01	12.60	648	73.26	11.00	0.43
10	1	-35	0.0056	178.57	648	66.55	1.52	0.06
7	0.708	-35	0.0056	126.43	648	69.74	1.74	0.07
4	0.501	-35	0.0056	89.46	648	69.85	2.04	0.08
1	0.355	-35	0.0056	63.39	648	70.18	2.62	0.10
-2	0.251	-35	0.0056	44.82	648	71.76	3.38	0.13
-5	0.178	-35	0.0056	31.79	648	72.24	4.62	0.18
-8	0.126	-35	0.0056	22.50	648	73.26	6.36	0.25

Table 2-4, noise is varying

Bunch 1 (dBm)	Bunch 1 (Vp)	Noise (dBm)	Noise (Vp)	SNR	samples	phase_mean (degree)	st_phase (degree)	st_mean (degree)
10	1	--	--	--	648	66.845	1.275	0.050
10	1	-35	0.0056	178.57	648	66.546	1.524	0.060
10	1	-30	0.01	100.00	648	66.559	1.861	0.073
10	1	-25	0.018	55.56	648	66.508	2.550	0.100
10	1	-20	0.032	31.25	648	66.402	4.232	0.166
10	1	-15	0.056	17.86	648	66.200	7.392	0.290
10	1	-10	0.1	10.00	648	67.161	12.741	0.501
10	1	-5	0.178	5.62	648	67.485	25.576	1.005
10	1	0	0.316	3.16	648	60.941	50.167	1.971
10	1	5	0.562	1.78	648	53.090	72.444	2.846
10	1	10	1	1.00	648	32.807	95.919	3.768
7	0.708	--	--	--	648	69.594	1.290	0.051
7	0.708	-35	0.0056	126.43	648	69.740	1.739	0.068
7	0.708	-30	0.01	70.80	648	69.427	2.384	0.094
7	0.708	-25	0.018	39.33	648	69.879	3.860	0.152
7	0.708	-20	0.032	22.13	648	70.125	6.742	0.265
7	0.708	-15	0.056	12.64	648	71.843	11.189	0.440
7	0.708	-10	0.1	7.08	648	73.508	20.641	0.811
4	0.501	--	--	--	648	69.286	1.233	0.048
4	0.501	-35	0.0056	89.46	648	69.851	2.045	0.080
4	0.501	-30	0.01	50.10	648	69.368	3.097	0.122
4	0.501	-25	0.018	27.83	648	70.726	5.053	0.199
4	0.501	-20	0.032	15.66	648	70.589	9.202	0.362
4	0.501	-15	0.056	8.95	648	72.991	15.925	0.626
4	0.501	-10	0.1	5.01	648	74.253	35.696	1.402
1	0.355	--	--	--	648	69.671	1.289	0.051
1	0.355	-35	0.0056	63.39	648	70.179	2.624	0.103
1	0.355	-30	0.01	35.50	648	69.567	4.328	0.170
1	0.355	-25	0.018	19.72	648	71.332	7.633	0.300
1	0.355	-20	0.032	11.09	648	71.580	12.288	0.483
1	0.355	-15	0.056	6.34	648	72.280	24.098	0.947
1	0.355	-10	0.1	3.55	648	66.864	58.295	2.290
-2	0.251	--	--	--	648	71.152	1.362	0.053
-2	0.251	-35	0.0056	44.82	648	71.762	3.379	0.133
-2	0.251	-30	0.01	25.10	648	71.995	5.716	0.225
-2	0.251	-25	0.018	13.94	648	72.817	10.595	0.416
-2	0.251	-20	0.032	7.84	648	72.969	19.506	0.766
-2	0.251	-15	0.056	4.48	648	71.441	38.571	1.515
-2	0.251	-10	0.1	2.51	648	63.011	71.800	2.821
-5	0.178	--	--	--	648	71.594	1.253	0.049
-5	0.178	-35	0.0056	31.79	648	72.237	4.615	0.181
-5	0.178	-30	0.01	17.80	648	72.341	8.312	0.327
-5	0.178	-25	0.018	9.89	648	72.914	15.181	0.596
-5	0.178	-20	0.032	5.56	648	72.469	32.125	1.262
-5	0.178	-15	0.056	3.18	648	71.220	51.979	2.042
-5	0.178	-10	0.1	1.78	648	49.358	82.178	3.228
-8	0.126	--	--	--	648	71.369	1.355	0.053

-8	0.126	-35	0.0056	22.50	648	73.256	6.357	0.250
-8	0.126	-30	0.01	12.60	648	73.257	10.998	0.432
-8	0.126	-25	0.018	7.00	648	74.697	21.058	0.827
-8	0.126	-20	0.032	3.94	648	76.976	45.862	1.802
-8	0.126	-15	0.056	2.25	648	65.378	72.388	2.844
-8	0.126	-10	0.1	1.26	648	36.362	99.807	3.921

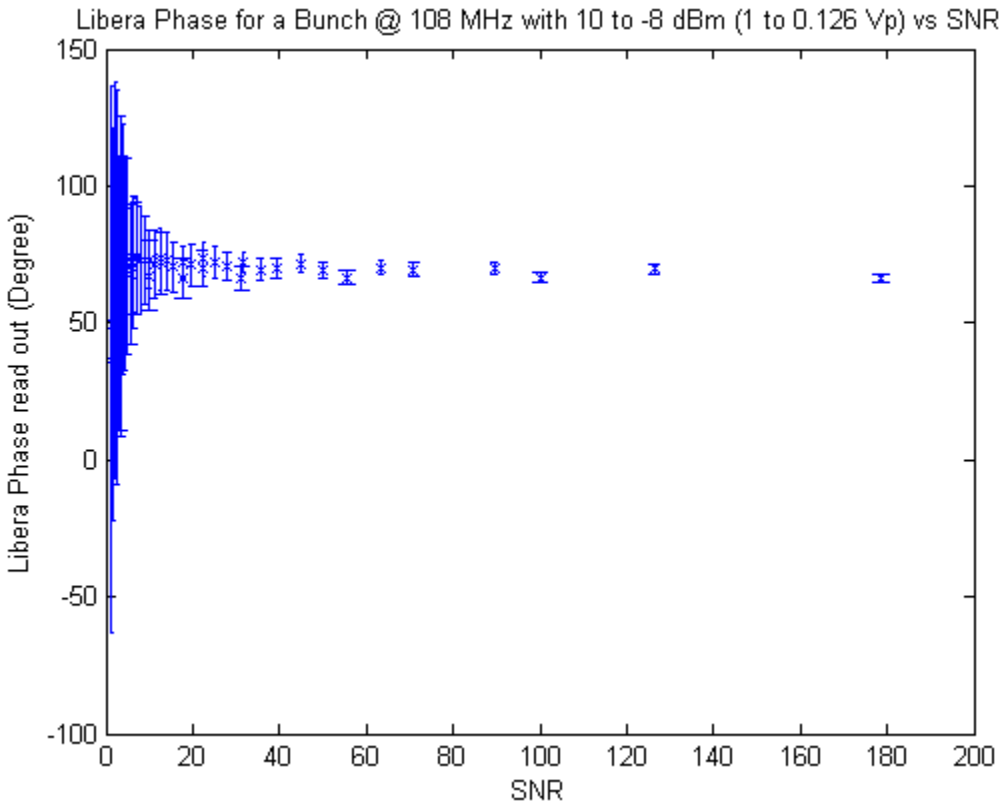

Fig. 2-2

❖ Superposition bunch (2) @ 108.4 MHz & Noise

Table 2-5, Noise is fixd

Bunch 2 (dBm)	Bunch 2 (Vp)	Noise (dBm)	Noise (Vp)	SNR	samples	phase_mean (degree)	st_phase (degree)	st_mean (degree)
7	0.708	-10	0.1	7.08	648	88.31	30.15	1.18
4	0.501	-10	0.1	5.01	648	84.23	39.85	1.57
1	0.355	-10	0.1	3.55	648	76.43	57.37	2.25
-2	0.251	-10	0.1	2.51	648	62.79	72.51	2.85
-5	0.178	-10	0.1	1.78	648	48.85	93.70	3.68
-8	0.126	-10	0.1	1.26	648	38.19	93.42	3.67
7	0.708	-15	0.056	12.64	648	90.23	11.60	0.46
4	0.501	-15	0.056	8.95	648	88.62	17.94	0.70
1	0.355	-15	0.056	6.34	648	88.02	27.40	1.08
-2	0.251	-15	0.056	4.48	648	78.11	53.77	2.11
-5	0.178	-15	0.056	3.18	648	70.48	68.83	2.70
-8	0.126	-15	0.056	2.25	648	54.86	87.35	3.43
7	0.708	-20	0.032	22.13	648	90.57	8.55	0.34
4	0.501	-20	0.032	15.66	648	88.51	12.27	0.48
1	0.355	-20	0.032	11.09	648	90.34	16.72	0.66
-2	0.251	-20	0.032	7.84	648	83.33	36.48	1.43
-5	0.178	-20	0.032	5.56	648	76.70	57.53	2.26
-8	0.126	-20	0.032	3.94	648	67.65	69.64	2.74
7	0.708	-25	0.018	39.33	648	90.74	5.19	0.20
4	0.501	-25	0.018	27.83	648	88.59	6.84	0.27
1	0.355	-25	0.018	19.72	648	89.85	9.62	0.38
-2	0.251	-25	0.018	13.94	648	87.70	14.33	0.56
-5	0.178	-25	0.018	9.89	648	89.09	21.44	0.84
-8	0.126	-25	0.018	7.00	648	83.61	41.78	1.64
7	0.708	-30	0.01	70.80	648	90.19	3.24	0.13
4	0.501	-30	0.01	50.10	648	88.52	3.45	0.14
1	0.355	-30	0.01	35.50	648	89.67	4.59	0.18
-2	0.251	-30	0.01	25.10	648	86.92	6.51	0.26
-5	0.178	-30	0.01	17.80	648	87.82	8.79	0.35
-8	0.126	-30	0.01	12.60	648	89.71	12.49	0.49
10	1	-35	0.0056	178.57	648	89.66	2.86	0.11
7	0.708	-35	0.0056	126.43	648	90.53	2.70	0.11
4	0.501	-35	0.0056	89.46	648	89.05	2.86	0.11
1	0.355	-35	0.0056	63.39	648	89.77	3.12	0.12
-2	0.251	-35	0.0056	44.82	648	87.29	4.12	0.16
-5	0.178	-35	0.0056	31.79	648	88.26	5.06	0.20
-8	0.126	-35	0.0056	22.50	648	89.29	6.75	0.27

Table 2-6, Noise is varying

Bunch 2 (dBm)	Bunch 2 (Vp)	Noise (dBm)	Noise (Vp)	SNR	samples	phase_mean (degree)	st_phase (degree)	st_mean (degree)
10	1	--	--	--	648	89.942	2.693	0.106
10	1	-35	0.0056	178.57	648	89.661	2.864	0.113
10	1	-30	0.01	100.00	648	89.471	2.918	0.115
10	1	-25	0.018	55.56	648	89.621	3.876	0.152
10	1	-20	0.032	31.25	648	89.503	6.152	0.242
10	1	-15	0.056	17.86	648	89.005	7.265	0.285
10	1	-10	0.1	10.00	648	89.680	13.392	0.526
10	1	-5	0.178	5.62	648	87.321	40.850	1.605
10	1	0	0.316	3.16	648	67.659	75.444	2.964
10	1	5	0.562	1.78	648	40.269	99.269	3.900
10	1	10	1	1.00	648	27.569	106.063	4.167
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7	0.708	-35	0.0056	126.43	648	90.535	2.698	0.106
7	0.708	-30	0.01	70.80	648	90.193	3.235	0.127
7	0.708	-25	0.018	39.33	648	90.735	5.193	0.204
7	0.708	-20	0.032	22.13	648	90.570	8.548	0.336
7	0.708	-15	0.056	12.64	648	90.235	11.600	0.456
7	0.708	-10	0.1	7.08	648	88.307	30.154	1.185
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4	0.501	-35	0.0056	89.46	648	89.054	2.863	0.112
4	0.501	-30	0.01	50.10	648	88.524	3.450	0.136
4	0.501	-25	0.018	27.83	648	88.586	6.842	0.269
4	0.501	-20	0.032	15.66	648	88.509	12.271	0.482
4	0.501	-15	0.056	8.95	648	88.624	17.935	0.705
4	0.501	-10	0.1	5.01	648	84.231	39.848	1.565
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1	0.355	-35	0.0056	63.39	648	89.769	3.121	0.123
1	0.355	-30	0.01	35.50	648	89.667	4.592	0.180
1	0.355	-25	0.018	19.72	648	89.849	9.624	0.378
1	0.355	-20	0.032	11.09	648	90.338	16.715	0.657
1	0.355	-15	0.056	6.34	648	88.021	27.403	1.077
1	0.355	-10	0.1	3.55	648	76.425	57.374	2.254
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-2	0.251	-35	0.0056	44.82	648	87.289	4.117	0.162
-2	0.251	-30	0.01	25.10	648	86.918	6.508	0.256
-2	0.251	-25	0.018	13.94	648	87.700	14.326	0.563
-2	0.251	-20	0.032	7.84	648	83.333	36.484	1.433
-2	0.251	-15	0.056	4.48	648	78.106	53.772	2.112
-2	0.251	-10	0.1	2.51	648	62.787	72.513	2.849
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-5	0.178	-35	0.0056	31.79	648	88.257	5.059	0.199
-5	0.178	-30	0.01	17.80	648	87.816	8.793	0.345
-5	0.178	-25	0.018	9.89	648	89.089	21.442	0.842
-5	0.178	-20	0.032	5.56	648	76.696	57.535	2.260
-5	0.178	-15	0.056	3.18	648	70.479	68.828	2.704
-5	0.178	-10	0.1	1.78	648	48.854	93.698	3.681
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-8	0.126	-35	0.0056	22.50	648	89.293	6.754	0.265
-8	0.126	-30	0.01	12.60	648	89.706	12.493	0.491
-8	0.126	-25	0.018	7.00	648	83.609	41.780	1.641
-8	0.126	-20	0.032	3.94	648	67.645	69.636	2.736
-8	0.126	-15	0.056	2.25	648	54.863	87.352	3.432
-8	0.126	-10	0.1	1.26	648	38.191	93.423	3.670

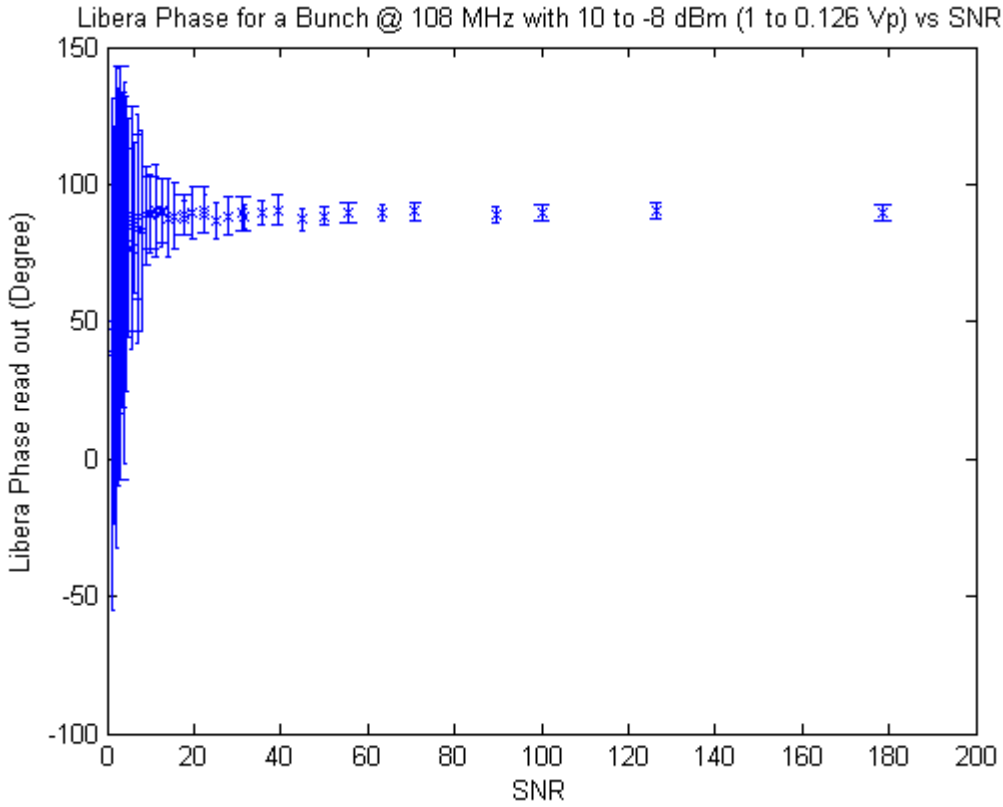


Fig. 2-3

❖ Superposition bunch (7) @ 108.4 MHz & Noise at Phase Wrapping

Remarks:

1- Comparing the highlighted rows in table 2-8 and bunch (7) from table 3-1 where the phase is measured for the same bunch in two conditions. The highlighted rows present the phase wrapping while table 2-9 show the phase with ~ 90^{o}. only small difference for the standard deviation (~ 0.1^{o}) is observed for the two cases.

2- Comparing phase values from table 2-8 where the measured phase represents the phase wrapping to the phases in table 2-6 where the phase not wrapping (~ 90^{o}). They show almost the same values for standard deviation. This proves that Libera algorithm at phase wrapping works efficiently.

Table 2-7, Noise is fixed

Bunchw (dBm)	Bunchw (Vp)	Noise (dBm)	Noise (Vp)	SNR	samples	phase_mean (degree)	st_phase (degree)	Bunch 2 (dBm)
10	1	0	0.316	3.16	648	173.71	55.69	2.19
5	0.562	0	0.316	1.78	648	160.38	81.37	3.20
0	0.316	0	0.316	1.00	648	181.99	84.52	3.32
-5	0.178	0	0.316	0.56	648	171.52	92.48	3.63
-10	0.1	0	0.316	0.32	648	167.12	98.56	3.87
10	1	-5	0.178	5.62	648	175.00	36.44	1.43
5	0.562	-5	0.178	3.16	648	160.69	64.73	2.54
0	0.316	-5	0.178	1.78	648	177.41	75.29	2.96
-5	0.178	-5	0.178	1.00	648	180.38	87.85	3.45
-10	0.1	-5	0.178	0.56	648	175.99	95.60	3.76
10	1	-10	0.1	10.00	648	178.24	13.70	0.54
5	0.562	-10	0.1	5.62	648	165.54	31.68	1.24
0	0.316	-10	0.1	3.16	648	180.11	49.86	1.96
-5	0.178	-10	0.1	1.78	648	170.49	70.16	2.76
-10	0.1	-10	0.1	1.00	648	167.12	81.09	3.19
10	1	-15	0.056	17.86	648	178.74	7.89	0.31
5	0.562	-15	0.056	10.04	648	165.24	16.70	0.66
0	0.316	-15	0.056	5.64	648	179.75	28.06	1.10
-5	0.178	-15	0.056	3.18	648	177.12	48.62	1.91
-10	0.1	-15	0.056	1.79	648	173.61	67.80	2.66
10	1	-20	0.032	31.25	648	178.28	5.94	0.23
5	0.562	-20	0.032	17.56	648	165.58	12.75	0.50
0	0.316	-20	0.032	9.88	648	178.66	18.21	0.72
-5	0.178	-20	0.032	5.56	648	175.59	37.17	1.46
-10	0.1	-20	0.032	3.13	648	178.87	58.63	2.30
10	1	-25	0.018	55.56	648	179.05	3.87	0.15
5	0.562	-25	0.018	31.22	648	165.76	6.88	0.27
0	0.316	-25	0.018	17.56	648	178.31	9.69	0.38
-5	0.178	-25	0.018	9.89	648	175.32	19.12	0.75

-10	0.1	-25	0.018	5.56	648	178.22	36.19	1.42
10	1	-30	0.01	178.57	648	178.55	3.13	0.12
5	0.562	-30	0.01	56.20	648	165.94	3.62	0.14
0	0.316	-30	0.01	31.60	648	176.88	5.06	0.20
-5	0.178	-30	0.01	17.80	648	176.85	8.23	0.32
-10	0.1	-30	0.01	10.00	648	177.35	13.97	0.55
10	1	-35	0.0056	178.57	648	178.91	2.65	0.10
5	0.562	-35	0.0056	100.36	648	166.51	2.77	0.11
0	0.316	-35	0.0056	56.43	648	177.37	3.42	0.13
-5	0.178	-35	0.0056	31.79	648	177.49	4.98	0.20
-10	0.1	-35	0.0056	17.86	648	178.10	8.13	0.32

Table 2-8, Noise is varying

Bunchw (dBm)	Bunchw (Vp)	Noise (dBm)	Noise (Vp)	SNR	samples	phase_mean (degree)	st_phase (degree)	Bunch 2 (dBm)
10	1	--	--	--	648	179.130	2.711	0.107
10	1	-35	0.0056	178.57	648	178.909	2.652	0.104
10	1	-30	0.01	100.00	648	178.550	3.129	0.123
10	1	-25	0.018	55.56	648	179.053	3.869	0.152
10	1	-20	0.032	31.25	648	178.280	5.941	0.233
10	1	-15	0.056	17.86	648	178.740	7.890	0.310
10	1	-10	0.1	10.00	648	178.241	13.696	0.538
10	1	-5	0.178	5.62	648	175.005	36.444	1.432
10	1	0	0.316	3.16	648	173.710	55.690	2.188
5	0.562	--	--	--	648	166.548	2.293	0.090
5	0.562	-35	0.0056	100.36	648	166.511	2.775	0.109
5	0.562	-30	0.01	56.20	648	165.945	3.620	0.142
5	0.562	-25	0.018	31.22	648	165.762	6.879	0.270
5	0.562	-20	0.032	17.56	648	165.577	12.753	0.501
5	0.562	-15	0.056	10.04	648	165.244	16.699	0.656
5	0.562	-10	0.1	5.62	648	165.536	31.677	1.244
5	0.562	-5	0.178	3.16	648	160.689	64.727	2.543
5	0.562	0	0.316	1.78	648	160.383	81.372	3.197
0	0.316	--	--	--	648	177.828	2.329	0.0915
0	0.316	-35	0.0056	56.43	648	177.368	3.417	0.134
0	0.316	-30	0.01	31.60	648	176.878	5.060	0.199
0	0.316	-25	0.018	17.56	648	178.310	9.693	0.381
0	0.316	-20	0.032	9.88	648	178.660	18.206	0.715
0	0.316	-15	0.056	5.64	648	179.747	28.056	1.102
0	0.316	-10	0.1	3.16	648	180.109	49.860	1.959
0	0.316	-5	0.178	1.78	648	177.408	75.292	2.958
0	0.316	0	0.316	1.00	648	181.992	84.521	3.320
-5	0.178	--	--	--	648	177.717	2.253	0.089
-5	0.178	-35	0.0056	31.79	648	177.490	4.984	0.196
-5	0.178	-30	0.01	17.80	648	176.848	8.229	0.323
-5	0.178	-25	0.018	9.89	648	175.325	19.124	0.751
-5	0.178	-20	0.032	5.56	648	175.591	37.165	1.460
-5	0.178	-15	0.056	3.18	648	177.125	48.618	1.910
-5	0.178	-10	0.1	1.78	648	170.485	70.163	2.756

-5	0.178	-5	0.178	1.00	648	180.383	87.851	3.451
-5	0.178	0	0.316	0.56	648	171.521	92.485	3.633
-10	0.1	--	--	--	648	178.773	2.210	0.087
-10	0.1	-35	0.0056	17.86	648	178.096	8.134	0.320
-10	0.1	-30	0.01	10.00	648	177.351	13.970	0.549
-10	0.1	-25	0.018	5.56	648	178.216	36.189	1.422
-10	0.1	-20	0.032	3.13	648	178.872	58.627	2.303
-10	0.1	-15	0.056	1.79	648	173.607	67.802	2.664
-10	0.1	-10	0.1	1.00	648	167.122	81.094	3.186
-10	0.1	-5	0.178	0.56	648	175.993	95.602	3.756
-10	0.1	0	0.316	0.32	648	167.124	98.557	3.872

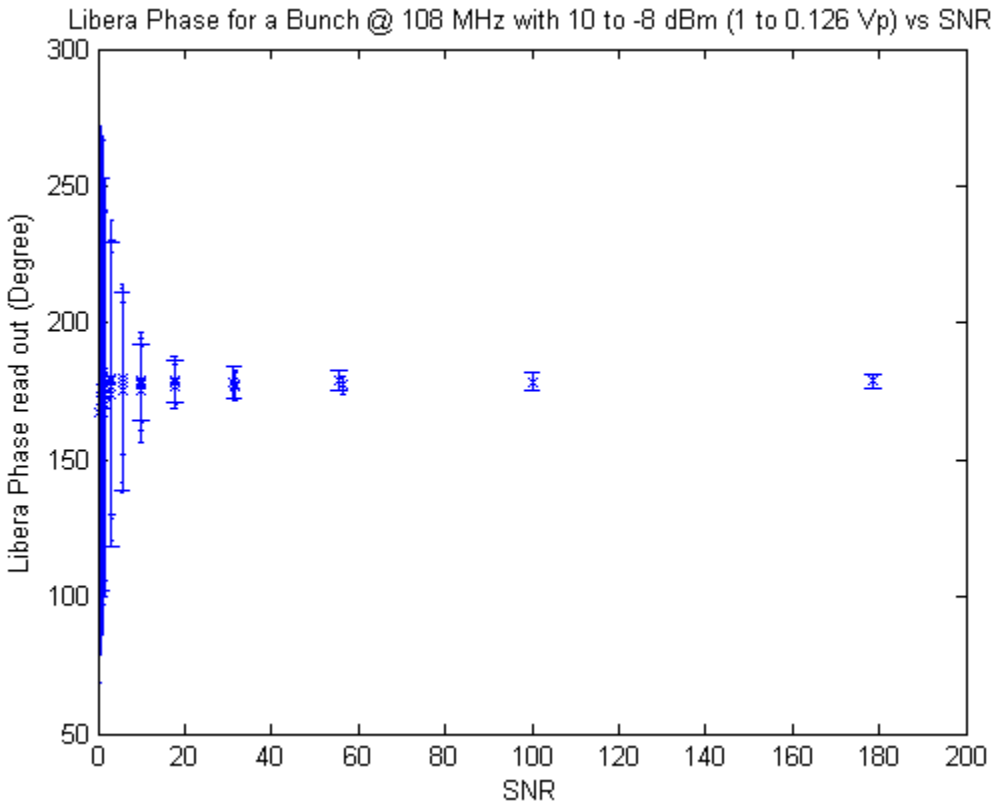


Fig. 2-4

3- The Phase Evaluation for Different Signal Shapes.

Seven different bunch shapes are generated with different levels of amplitudes (10 to -30 dBm). Libera phase readouts are recorded and listed in table 3-1. The oscilloscope was triggered on an external trigger in which signals phases are checked. From table 3-1 and the corresponding plots in appendix 3, some remarks can be observed :

1- The Libera phase readout is dependent on the bunch shapes. Therefore, different bunches gives different phase readout for the third harmonic 325 MHz.
2- The standard deviation is influenced by bunch shapes where in bunch 3, 4, 5 and 7 it exceeds 2 ^{o} even with 10 dBm signal power (**?**).
3- The Libera phase readout is not amplitude dependence
4- The standard deviation of the Libera phase readout shows unexpected behaviour in some shapes (**?**) in which the standard deviation increases with decreasing signal power as it shown in bunches 2, 3, 4, 5 and 7.

Table 3-1, Bunch shapes

Bunch 1					
Signal Power (dBm)	Signal Amplitude (Vp)	Samples	phase_mean (degree)	st_phase (degree)	st_mean (degree)
10	1	648	108.19	1.04	0.04
0	0.316	648	112.22	1.06	0.04
-10	0.1	648	114.98	1.32	0.05
-20	0.032	648	111.53	2.05	0.08
-30	0.01	648	108.75	5.60	0.22
Bunch 2					
Signal Power (dBm)	Signal Amplitude (Vp)	Samples	phase_mean (degree)	st_phase (degree)	st_mean (degree)
10	1	648	138.93	1.34	0.05
0	0.316	648	139.73	1.24	0.05
-10	0.1	648	141.97	1.43	0.06
-20	0.032	648	140.26	3.72	0.15
-30	0.01	570	144.47	11.53	0.48

Bunch 3					
Signal Power (dBm)	Signal Amplitude (Vp)	Samples	phase_mean (degree)	st_phase (degree)	st_mean (degree)
10	1	648	142.53	2.14	0.08
0	0.316	648	145.56	1.99	0.08
-10	0.1	648	148.59	2.12	0.08
-20	0.032	648	149.70	3.55	0.14
-30	0.01	648	146.98	7.53	0.30

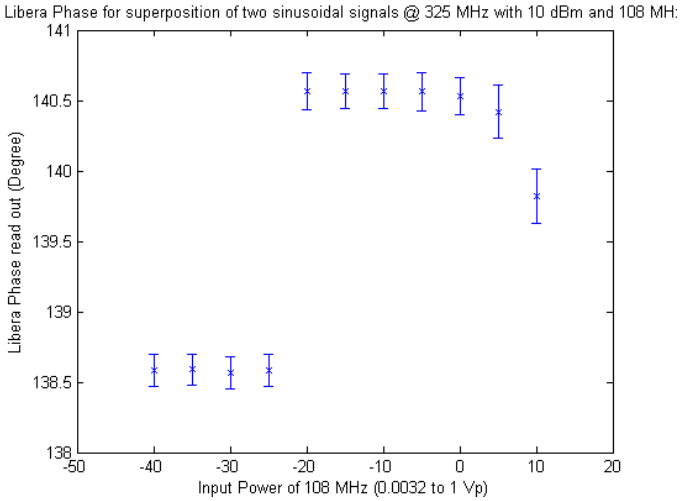
Bunch 4					
Signal Power (dBm)	Signal Amplitude (Vp)	Samples	phase_mean (degree)	st_phase (degree)	st_mean (degree)
10	1	648	129.39	3.77	0.15
0	0.316	648	113.53	2.71	0.11
-10	0.1	648	113.09	2.73	0.11
-20	0.032	648	120.05	3.59	0.14
-30	0.01	648	113.59	8.40	0.33

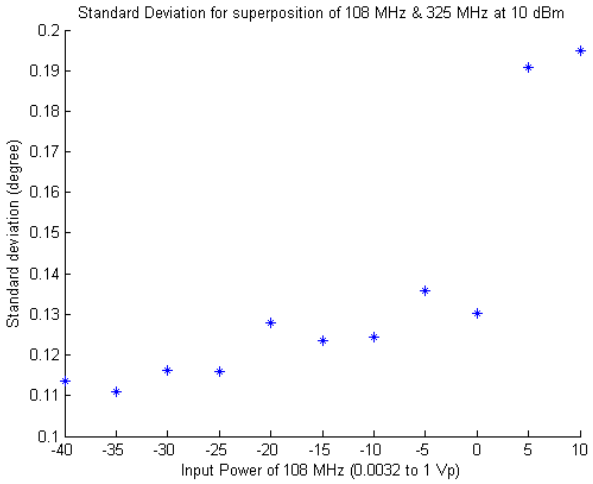
Bunch 5					
Signal Power (dBm)	Signal Amplitude (Vp)	Samples	phase_mean (degree)	st_phase (degree)	st_mean (degree)
10	1	648	118.33	2.22	0.09
0	0.316	648	116.29	1.70	0.07
-10	0.1	648	118.42	1.74	0.07
-20	0.032	648	122.99	2.45	0.10
-30	0.01	648	116.27	5.82	0.23

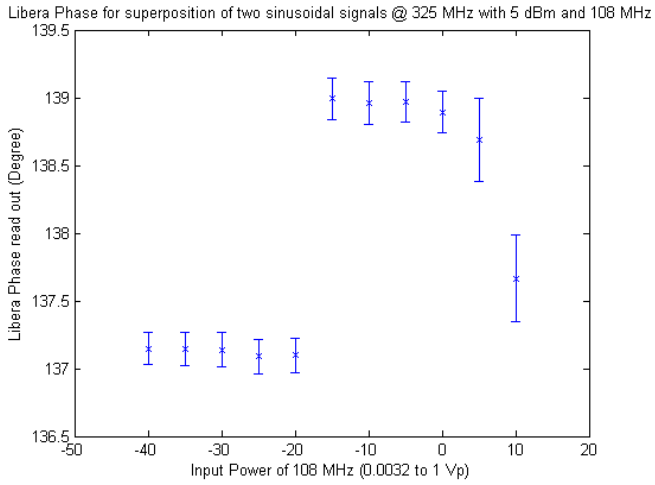
Bunch 6					
Signal Power (dBm)	Signal Amplitude (Vp)	Samples	phase_mean (degree)	st_phase (degree)	st_mean (degree)
10	1	648	98.42	0.85	0.03
5	0.562	648	99.48	0.83	0.03
0	0.316	648	100.50	0.94	0.04
-5	0.178	648	100.26	1.04	0.04
-10	0.1	648	100.57	1.36	0.05
-15	0.056	648	102.57	2.26	0.09
-20	0.032	648	105.04	2.68	0.11
-25	0.018	648	106.44	4.73	0.19
-30	0.01	648	100.49	8.44	0.33

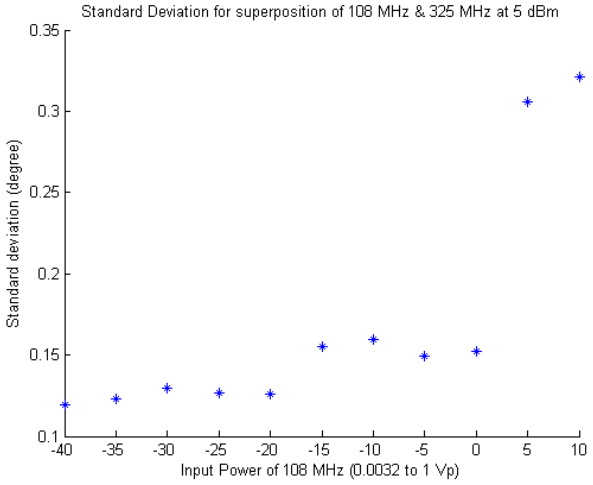
Bunch 7					
Signal Power (dBm)	Signal Amplitude (Vp)	Samples	phase_mean (degree)	st_phase (degree)	st_mean (degree)
10	1	648	90.61	2.70	0.11
5	0.562	648	89.06	2.15	0.08
0	0.316	648	91.60	2.17	0.09
-5	0.178	648	86.87	2.26	0.09
-10	0.1	648	86.38	2.50	0.10
-15	0.056	648	90.81	3.17	0.12
-20	0.032	648	91.41	4.48	0.18
-25	0.018	648	86.34	6.15	0.24
-30	0.01	648	81.65	12.20	0.48

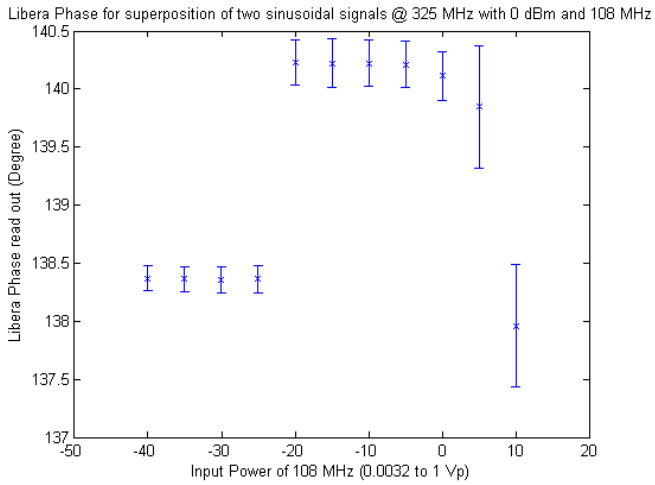
Appendix 1_1 (Superposition of Signals 108,4MHz & 325,2MHz)

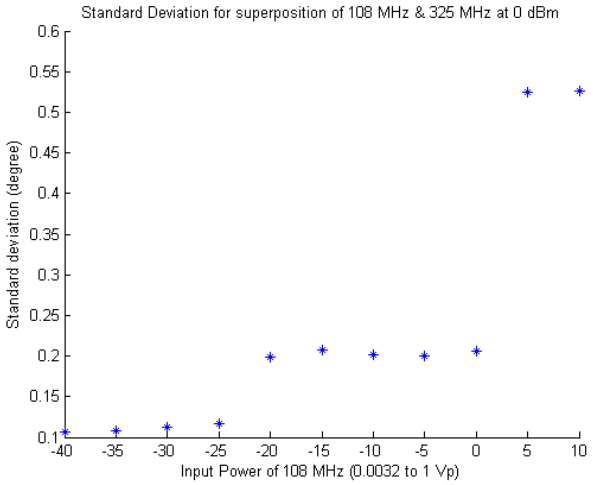


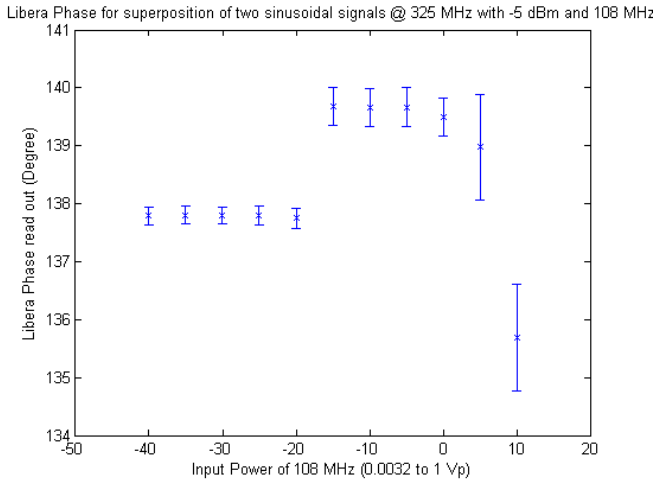


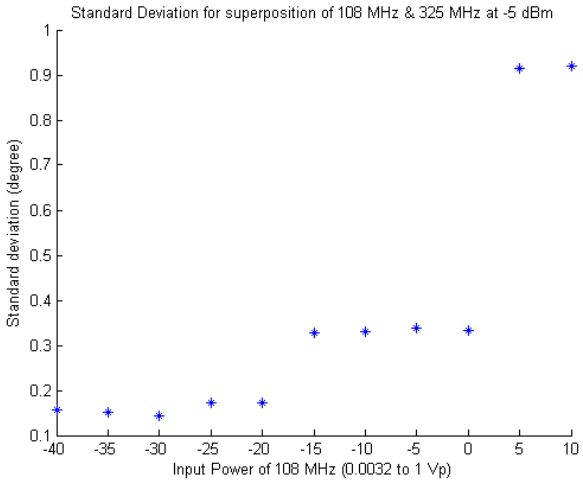


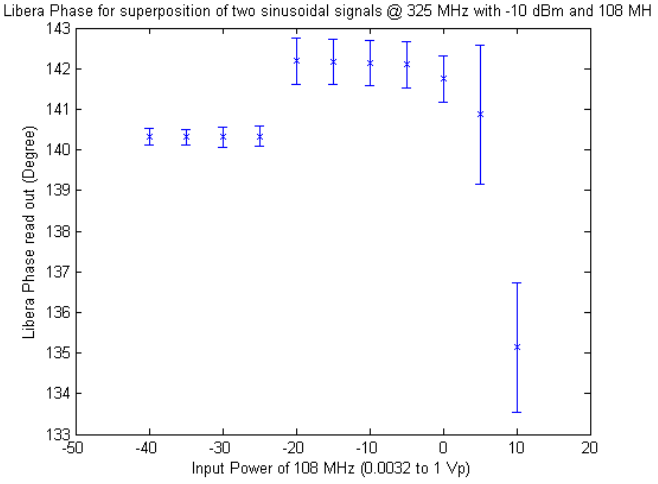


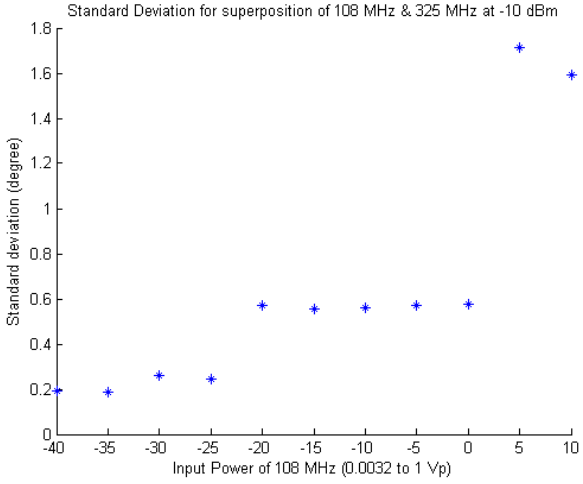


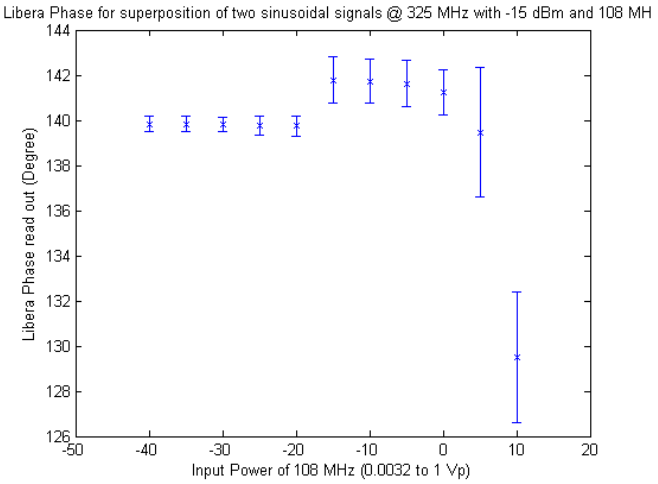


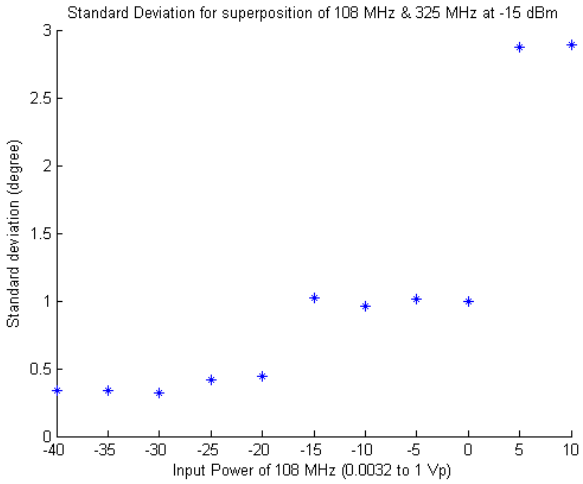

Libera Phase for superposition of two sinusoidal signals @ 325 MHz with -5 dBm and 108 MHz
Libera Phase read out (Degree)
Input Power of 108 MHz (0.0032 to 1 Vp)

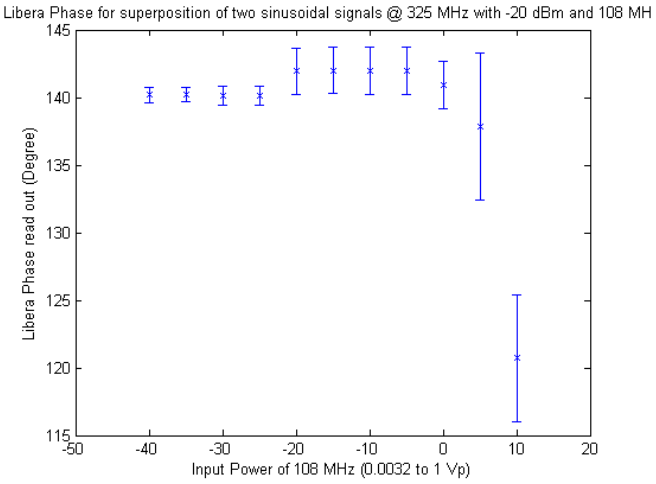

Standard Deviation for superposition of 108 MHz & 325 MHz at -5 dBm
Standard deviation (degree)
Input Power of 108 MHz (0.0032 to 1 Vp)

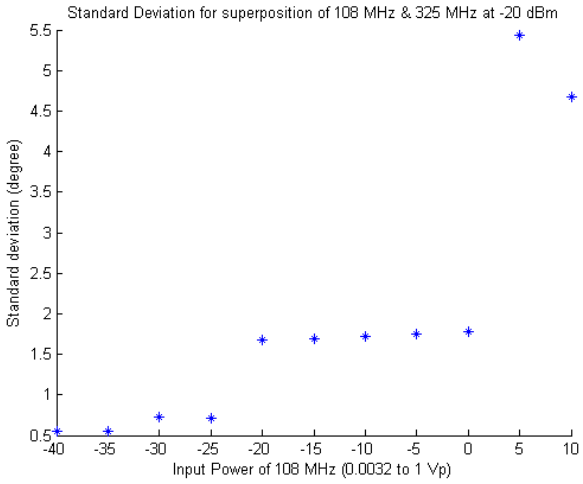

Libera Phase for superposition of two sinusoidal signals @ 325 MHz with -10 dBm and 108 MH
Libera Phase read out (Degree)
Input Power of 108 MHz (0.0032 to 1 Vp)


Standard Deviation for superposition of 108 MHz & 325 MHz at -10 dBm
Standard deviation (degree)
Input Power of 108 MHz (0.0032 to 1 Vp)

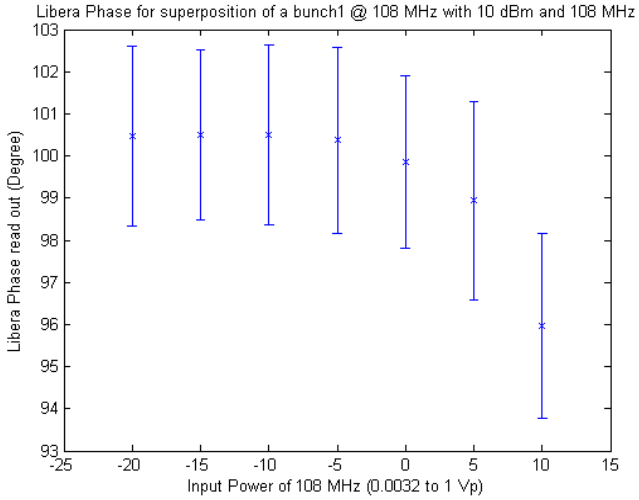

Libera Phase for superposition of two sinusoidal signals @ 325 MHz with -15 dBm and 108 MH
Libera Phase read out (Degree)
Input Power of 108 MHz (0.0032 to 1 Vp)

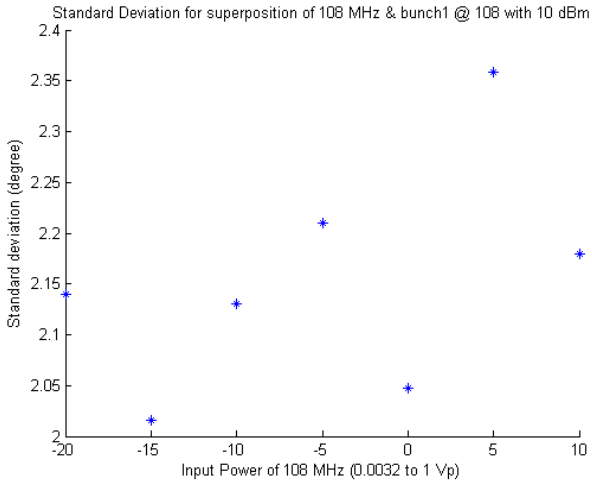

Standard Deviation for superposition of 108 MHz & 325 MHz at -15 dBm
Standard deviation (degree)
Input Power of 108 MHz (0.0032 to 1 Vp)

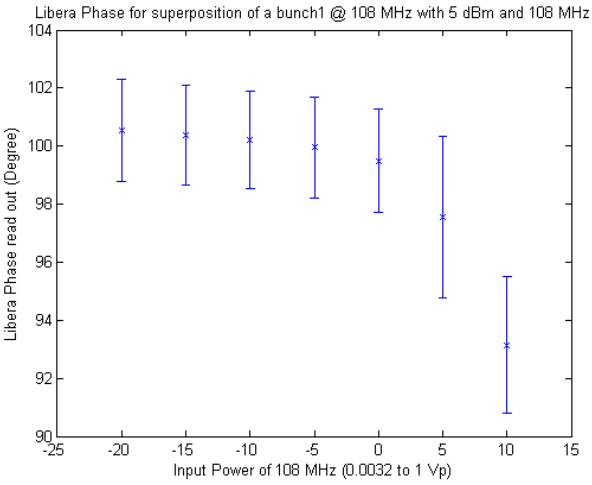

Libera Phase for superposition of two sinusoidal signals @ 325 MHz with -20 dBm and 108 MH
Libera Phase read out (Degree)
Input Power of 108 MHz (0.0032 to 1 Vp)
145
140
135
130
125
120
115
-50
-40
-30
-20
-10
0
10
20

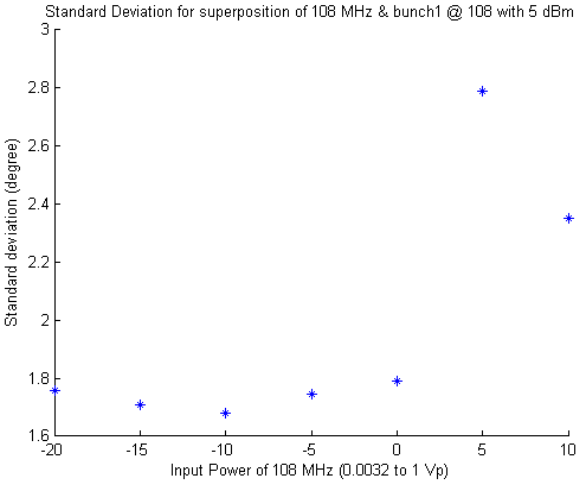

Standard Deviation for superposition of 108 MHz & 325 MHz at -20 dBm
Standard deviation (degree)
Input Power of 108 MHz (0.0032 to 1 Vp)
5.5
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
-40
-35
-30
-25
-20
-15
-10
-5
0
5
10

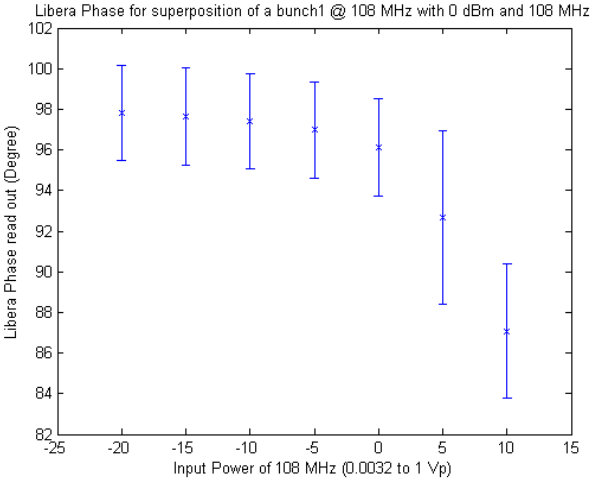
Appemdix 1- 2 (Superposition of Signals 108,4MHz & Bunch (1) @ 108,4MHz)

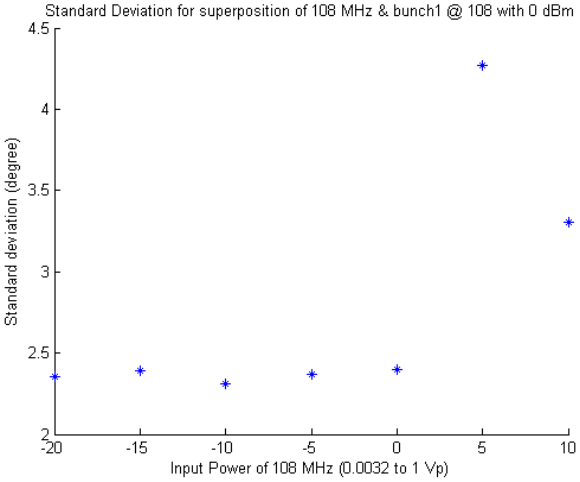


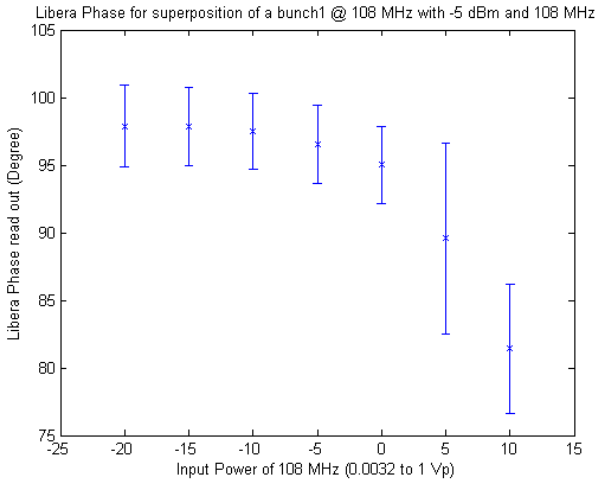


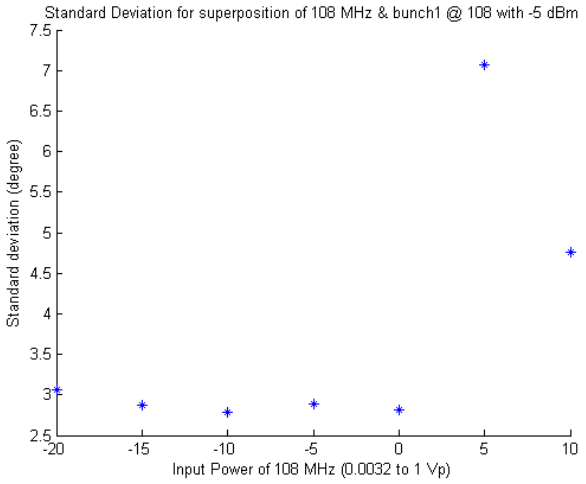


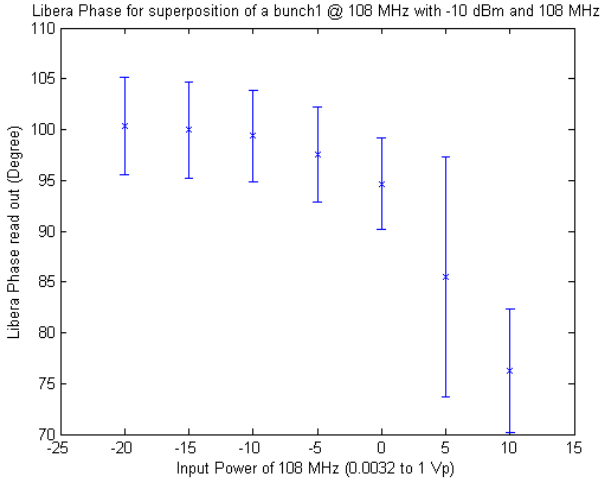


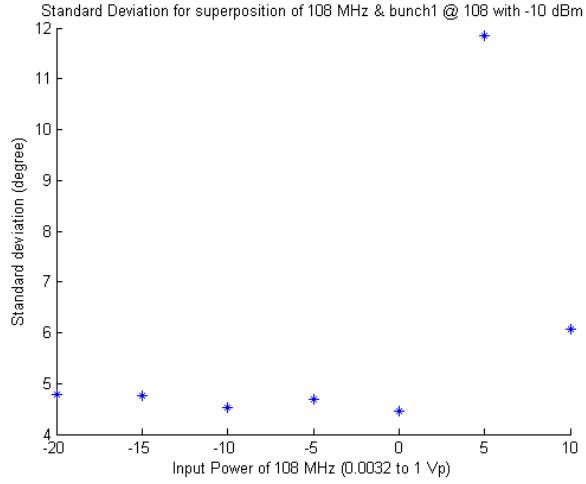


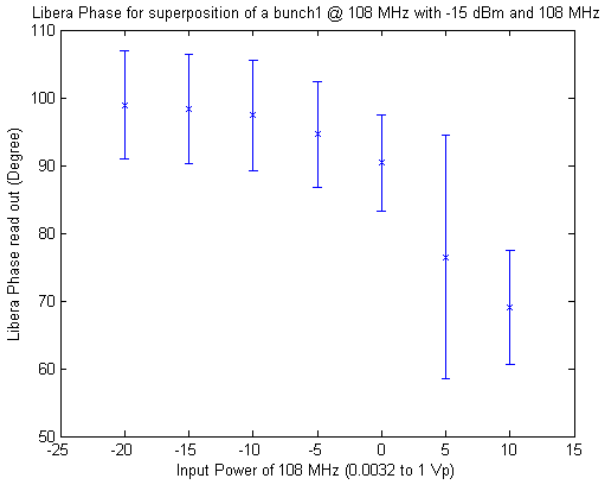


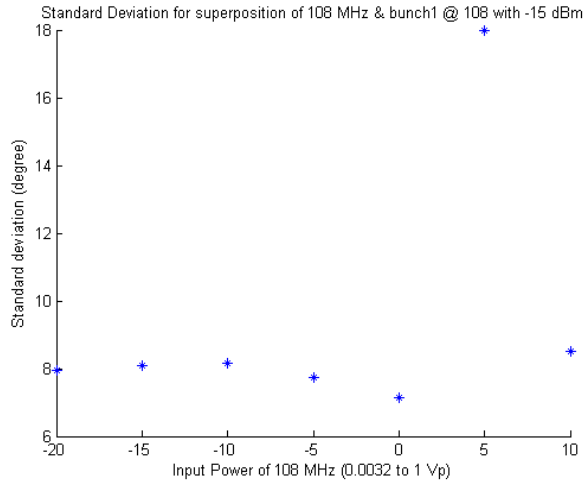

Libera Phase for superposition of a bunch1 @ 108 MHz with -5 dBm and 108 MHz
Libera Phase read out (Degree)
Input Power of 108 MHz (0.0032 to 1 Vp)

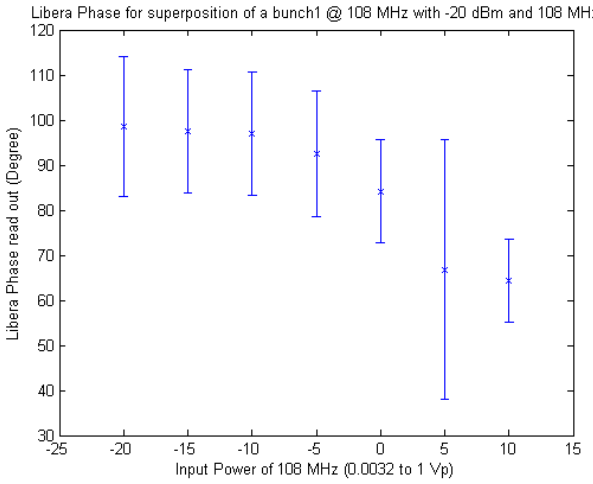

Standard Deviation for superposition of 108 MHz & bunch1 @ 108 with -5 dBm
Standard deviation (degree)
Input Power of 108 MHz (0.0032 to 1 Vp)

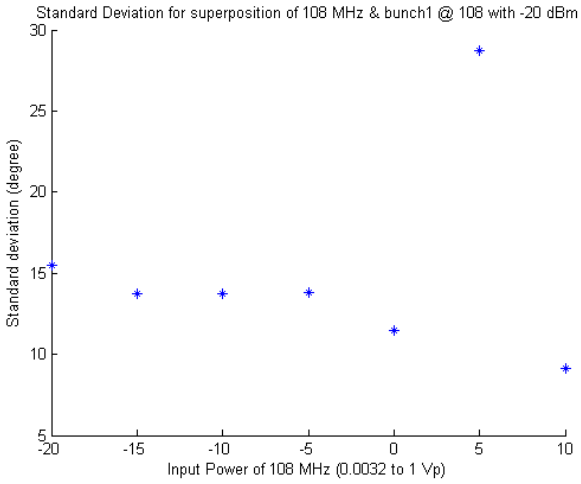

Libera Phase for superposition of a bunch1 @ 108 MHz with -10 dBm and 108 MHz
Libera Phase read out (Degree)
Input Power of 108 MHz (0.0032 to 1 Vp)


Standard Deviation for superposition of 108 MHz & bunch1 @ 108 with -10 dBm
Standard deviation (degree)
Input Power of 108 MHz (0.0032 to 1 Vp)

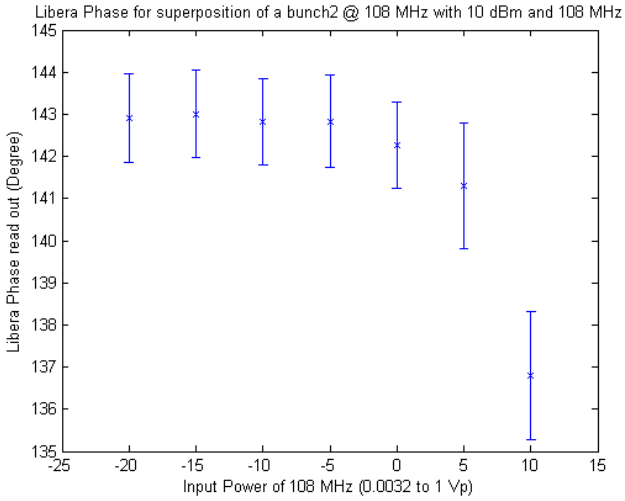

Libera Phase for superposition of a bunch1 @ 108 MHz with -15 dBm and 108 MHz
Libera Phase read out (Degree)
Input Power of 108 MHz (0.0032 to 1 Vp)

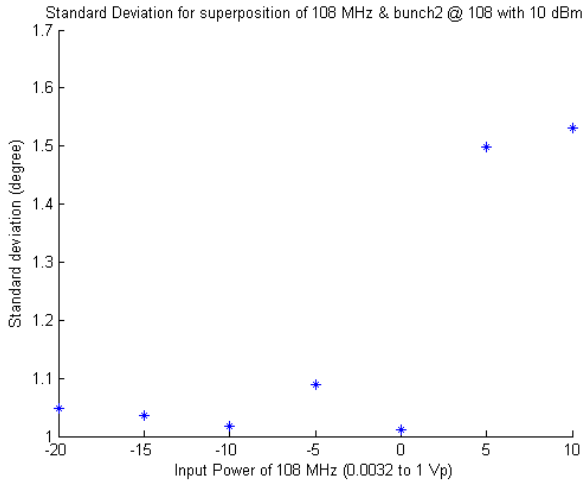

Standard Deviation for superposition of 108 MHz & bunch1 @ 108 with -15 dBm
Standard deviation (degree)
Input Power of 108 MHz (0.0032 to 1 Vp)

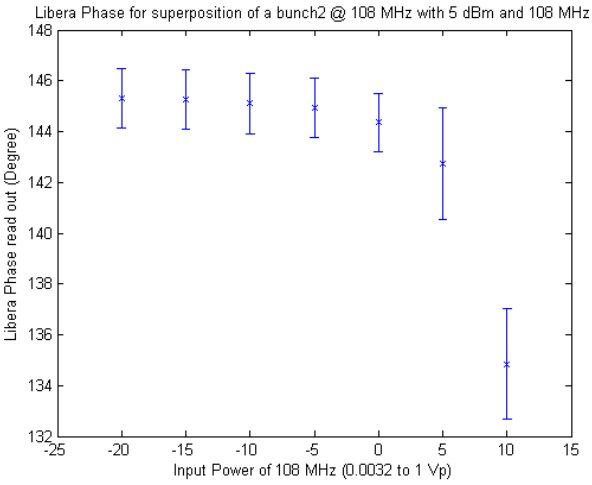

Libera Phase for superposition of a bunch1 @ 108 MHz with -20 dBm and 108 MHz
Libera Phase read out (Degree)
Input Power of 108 MHz (0.0032 to 1 Vp)
120
110
100
90
80
70
60
50
40
30
-25
-20
-15
-10
-5
0
5
10
15

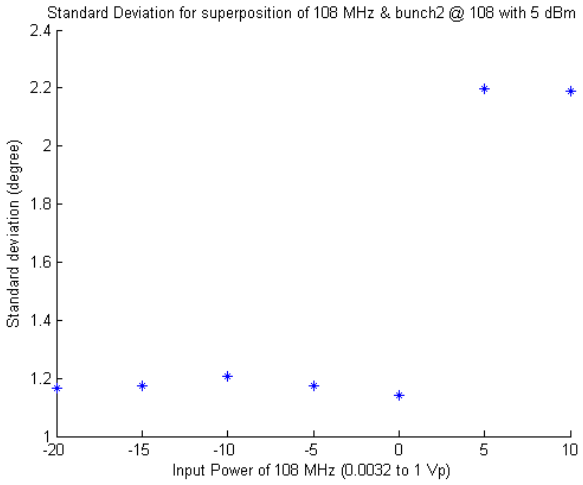

Standard Deviation for superposition of 108 MHz & bunch1 @ 108 with -20 dBm
Standard deviation (degree)
Input Power of 108 MHz (0.0032 to 1 Vp)
30
25
20
15
10
5
-20
-15
-10
-5
0
5
10

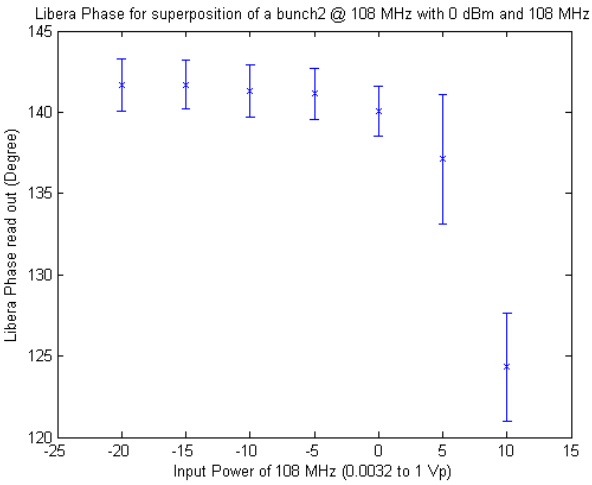
Appendix 1-3 (Superposition of Signals 108,4MHz & Bunch (2) @ 108,4MHz)

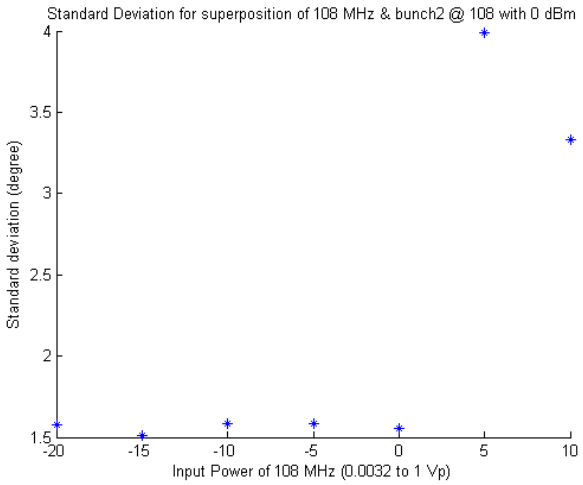


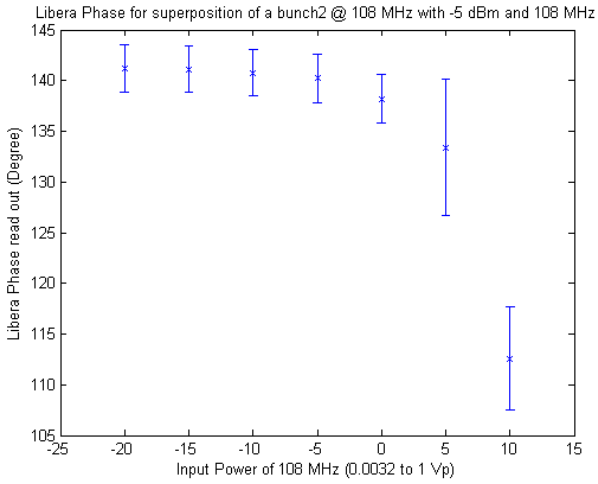


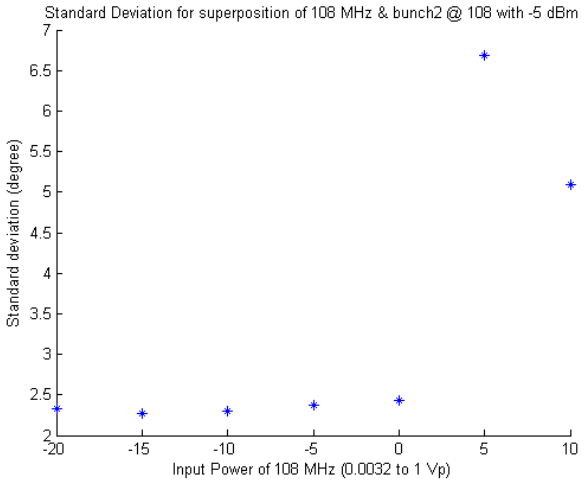


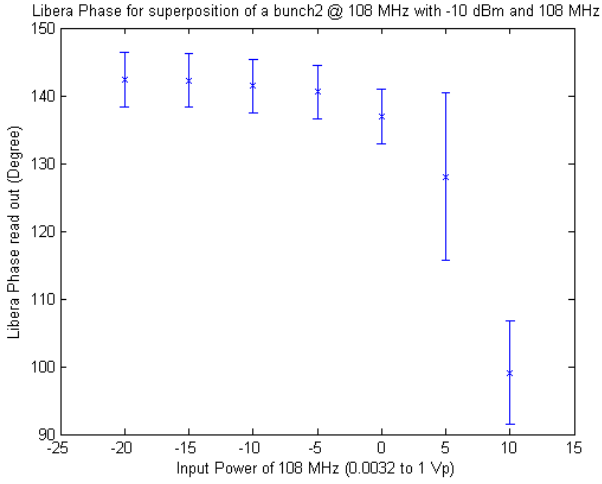


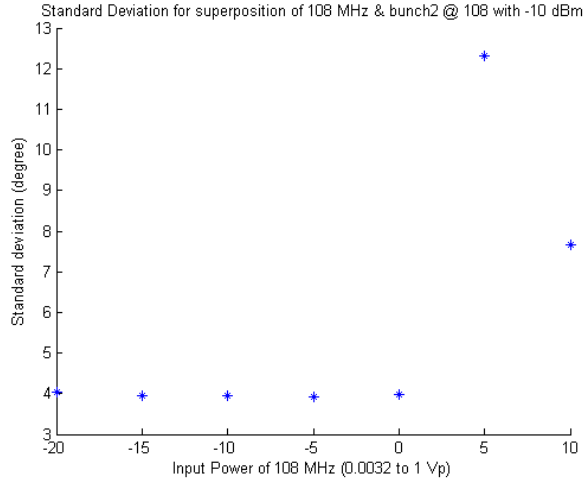


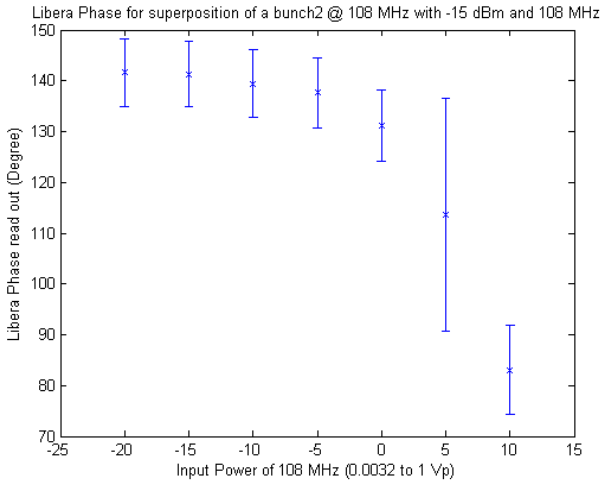


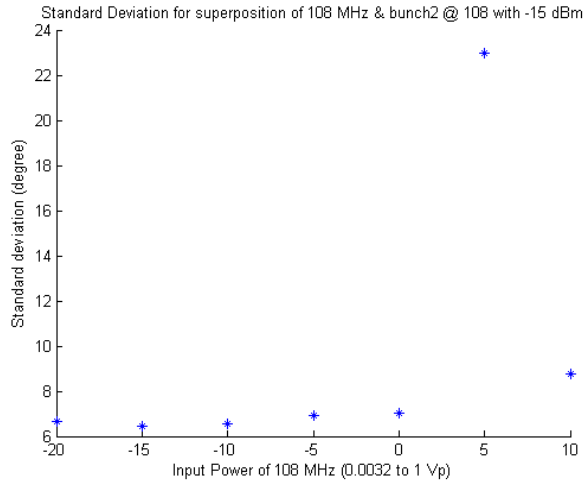

Libera Phase for superposition of a bunch2 @ 108 MHz with -5 dBm and 108 MHz
Libera Phase read out (Degree)
Input Power of 108 MHz (0.0032 to 1 Vp)

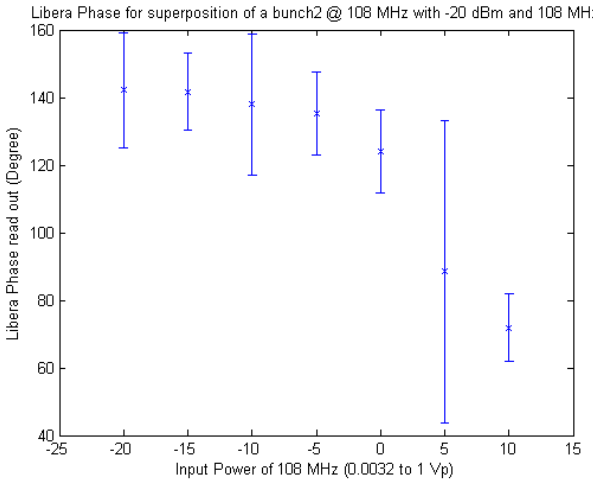

Standard Deviation for superposition of 108 MHz & bunch2 @ 108 with -5 dBm
Standard deviation (degree)
Input Power of 108 MHz (0.0032 to 1 Vp)

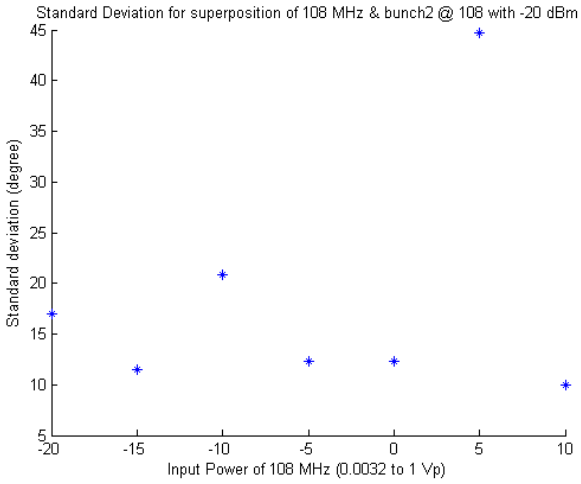

Libera Phase for superposition of a bunch2 @ 108 MHz with -10 dBm and 108 MHz
Libera Phase read out (Degree)
Input Power of 108 MHz (0.0032 to 1 Vp)


Standard Deviation for superposition of 108 MHz & bunch2 @ 108 with -10 dBm
Standard deviation (degree)
Input Power of 108 MHz (0.0032 to 1 Vp)

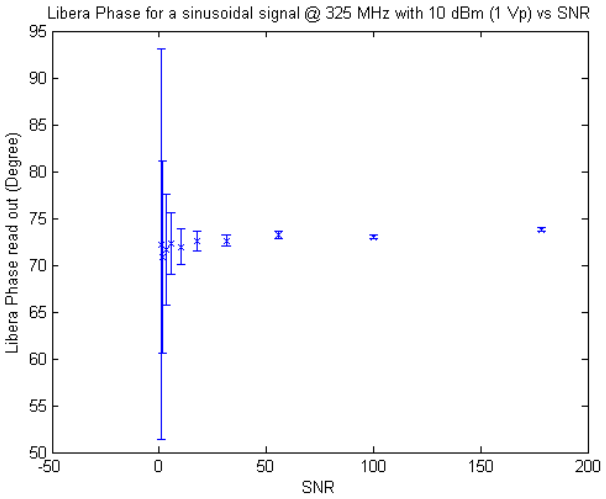

Libera Phase for superposition of a bunch2 @ 108 MHz with -15 dBm and 108 MHz
Libera Phase read out (Degree)
Input Power of 108 MHz (0.0032 to 1 Vp)

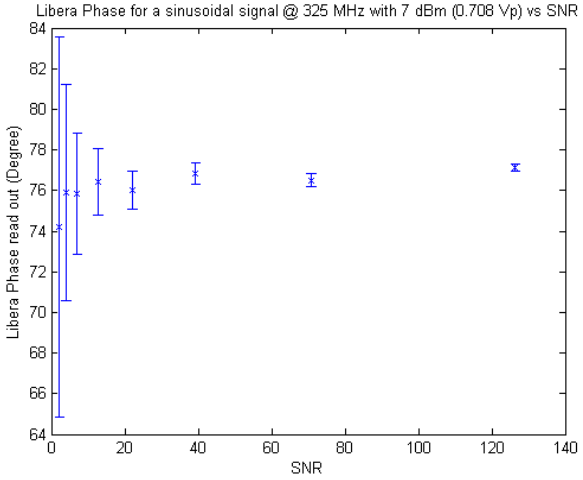

Standard Deviation for superposition of 108 MHz & bunch2 @ 108 with -15 dBm
Standard deviation (degree)
Input Power of 108 MHz (0.0032 to 1 Vp)

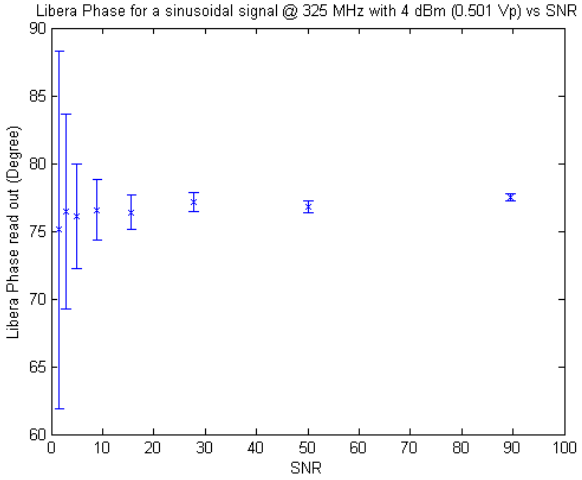

Libera Phase for superposition of a bunch2 @ 108 MHz with -20 dBm and 108 MHz
Libera Phase read out (Degree)
Input Power of 108 MHz (0.0032 to 1 Vp)
160
140
120
100
80
60
40
-25
-20
-15
-10
-5
0
5
10
15

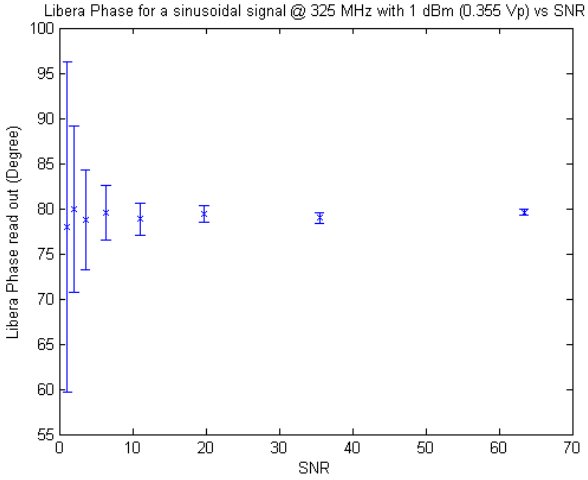

Standard Deviation for superposition of 108 MHz & bunch2 @ 108 with -20 dBm
Standard deviation (degree)
Input Power of 108 MHz (0.0032 to 1 Vp)
45
40
35
30
25
20
15
10
5
-20
-15
-10
-5
0
5
10

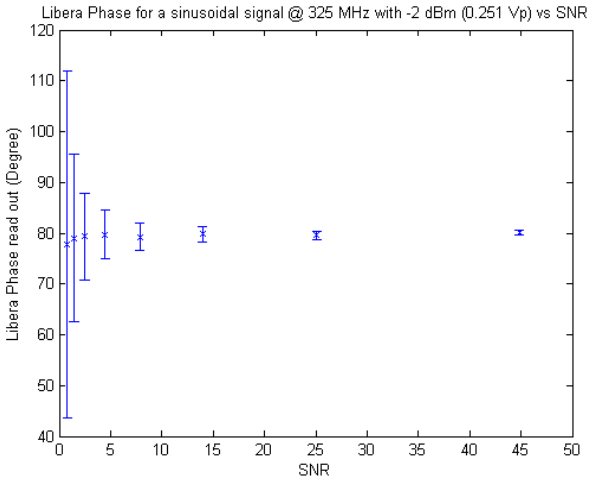
1- Appendix 2 – 1 (Superposition of Signals and Noise 325,2 MHz & Noise)

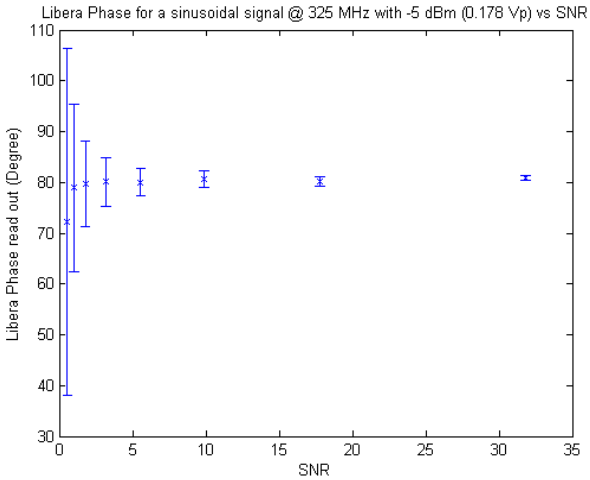


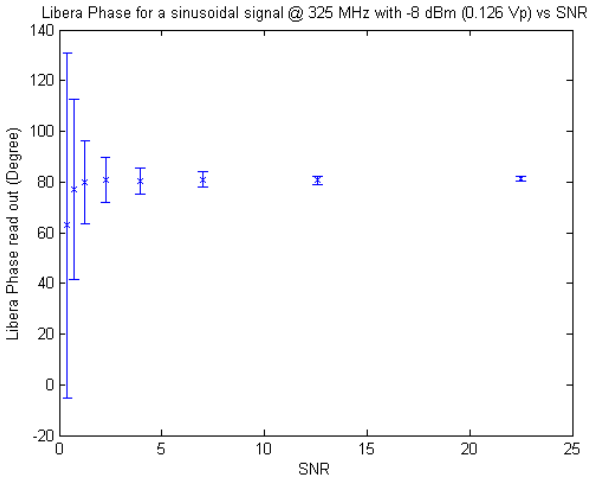


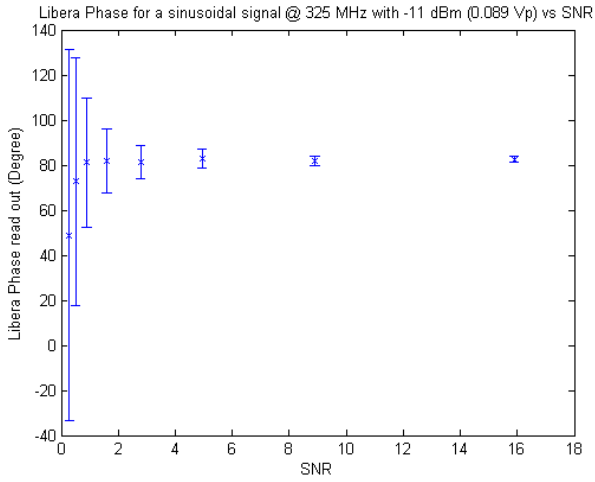


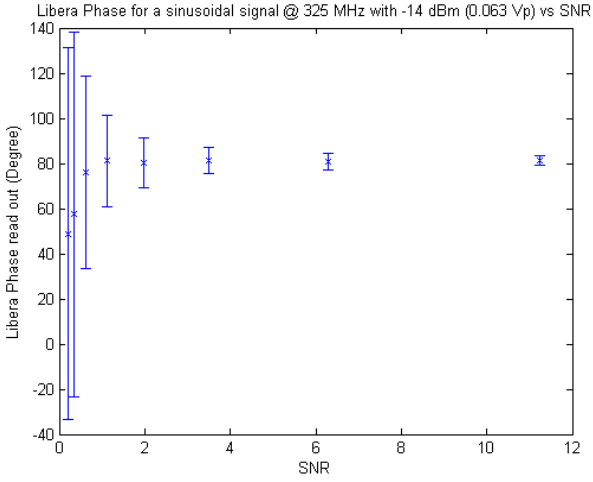


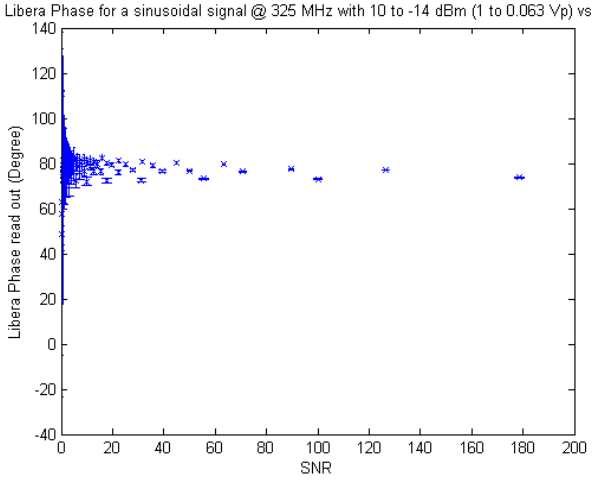


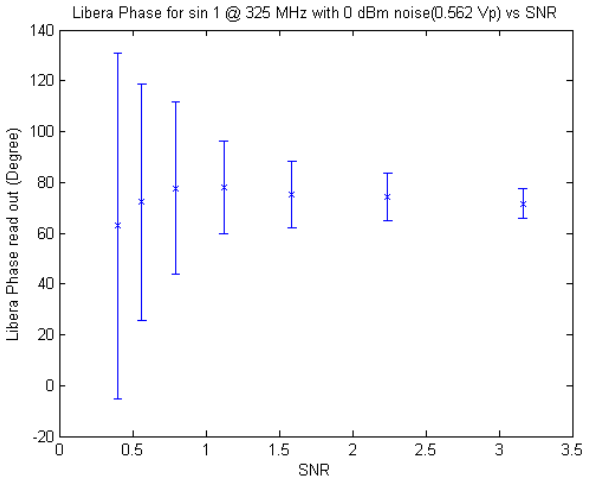


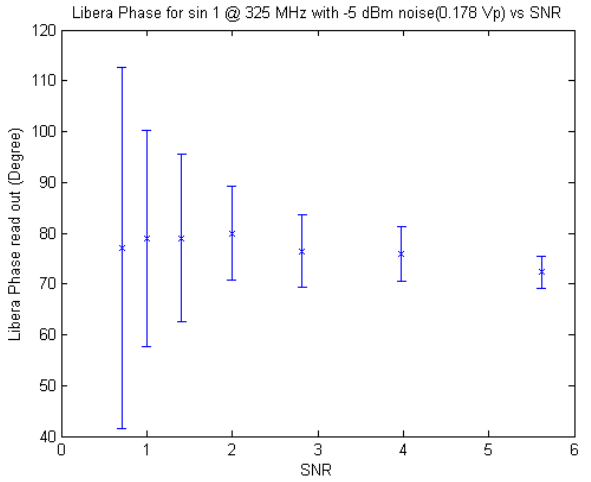

Libera Phase for a sinusoidal signal @ 325 MHz with -8 dBm (0.126 Vp) vs SNR
Libera Phase read out (Degree)
SNR

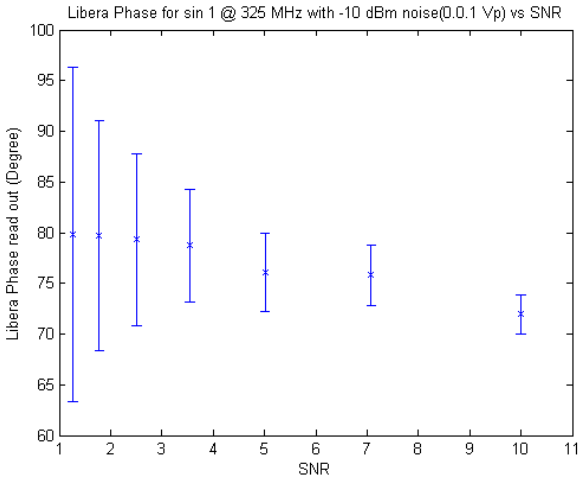

Libera Phase for a sinusoidal signal @ 325 MHz with -11 dBm (0.089 Vp) vs SNR
Libera Phase read out (Degree)
SNR

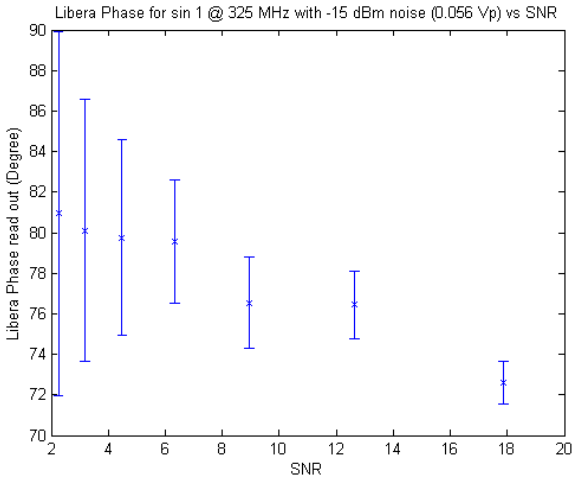

Libera Phase for a sinusoidal signal @ 325 MHz with -14 dBm (0.063 Vp) vs SNR
Libera Phase read out (Degree)
SNR

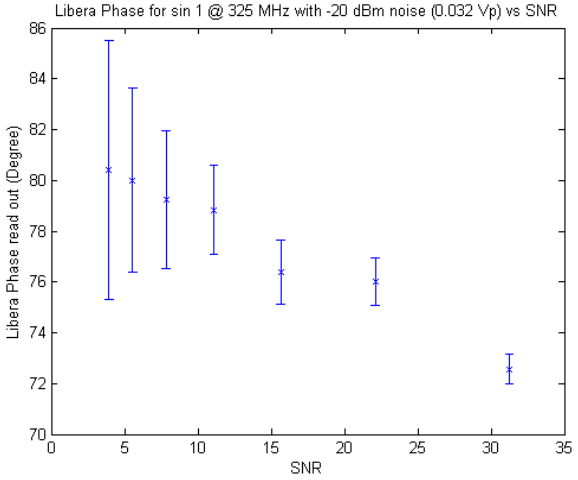

Libera Phase for a sinusoidal signal @ 325 MHz with 10 to -14 dBm (1 to 0.063 Vp) vs SNR
Libera Phase read out (Degree)
SNR

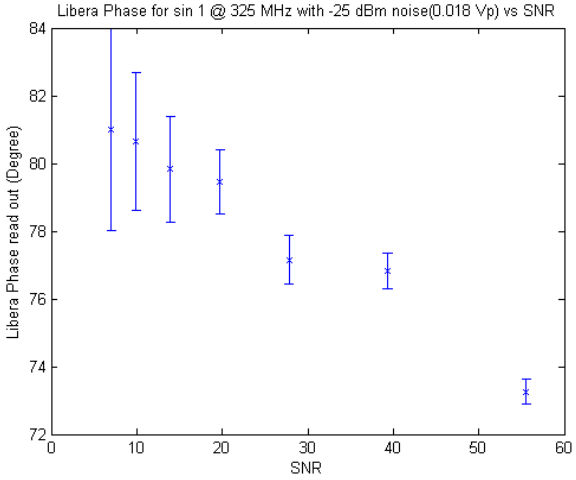

Libera Phase for sin 1 @ 325 MHz with 0 dBm noise(0.562 Vp) vs SNR
Libera Phase read out (Degree)
SNR

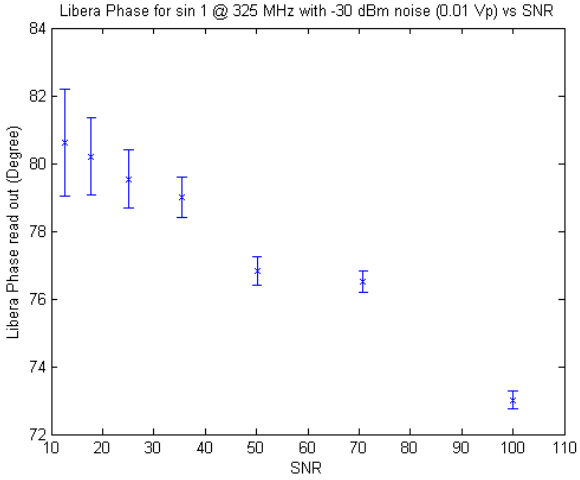

Libera Phase for sin 1 @ 325 MHz with -5 dBm noise(0.178 Vp) vs SNR
Libera Phase read out (Degree)
SNR

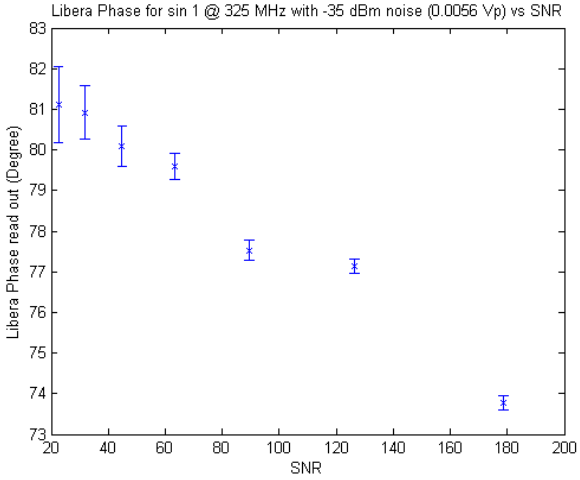

Libera Phase for sin 1 @ 325 MHz with -10 dBm noise(0.0.1 Vp) vs SNR
Libera Phase read out (Degree)
SNR


Libera Phase for sin 1 @ 325 MHz with -15 dBm noise (0.056 Vp) vs SNR
Libera Phase read out (Degree)
SNR

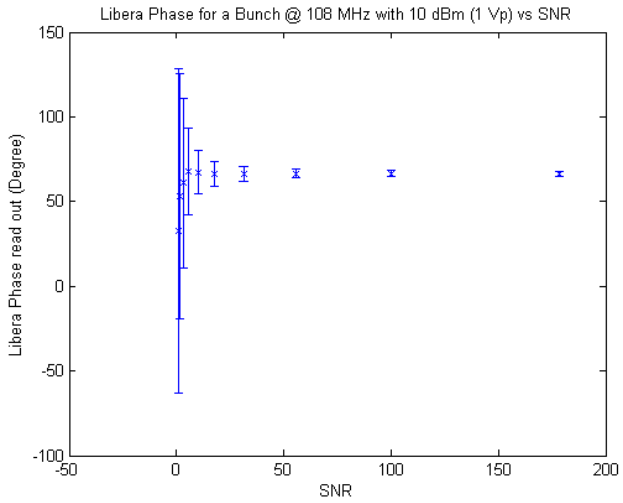

Libera Phase for sin 1 @ 325 MHz with -20 dBm noise (0.032 Vp) vs SNR
Libera Phase read out (Degree)
SNR

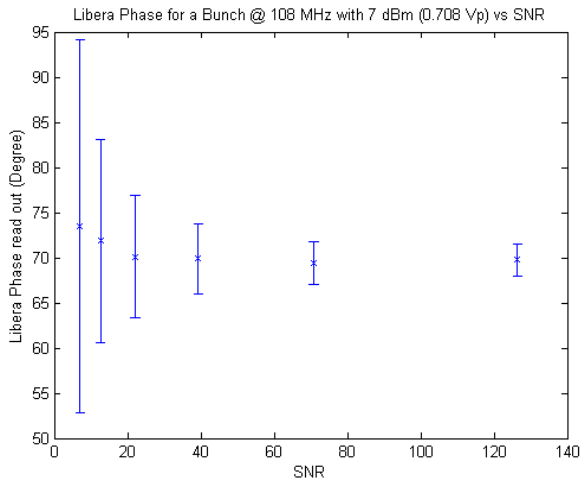

Libera Phase for sin 1 @ 325 MHz with -25 dBm noise(0.018 Vp) vs SNR
Libera Phase read out (Degree)
SNR

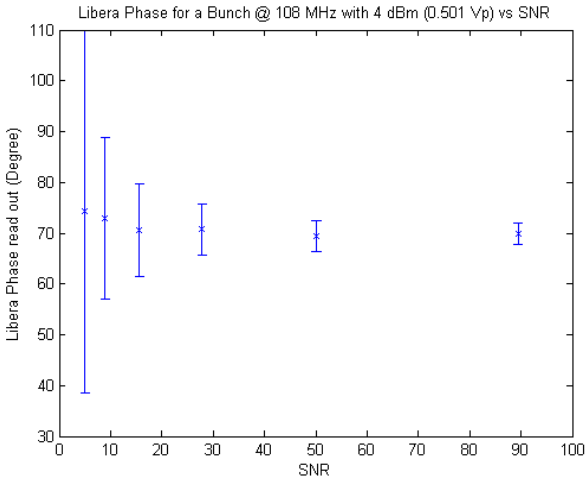

Libera Phase for sin 1 @ 325 MHz with -30 dBm noise (0.01 Vp) vs SNR
Libera Phase read out (Degree)
SNR

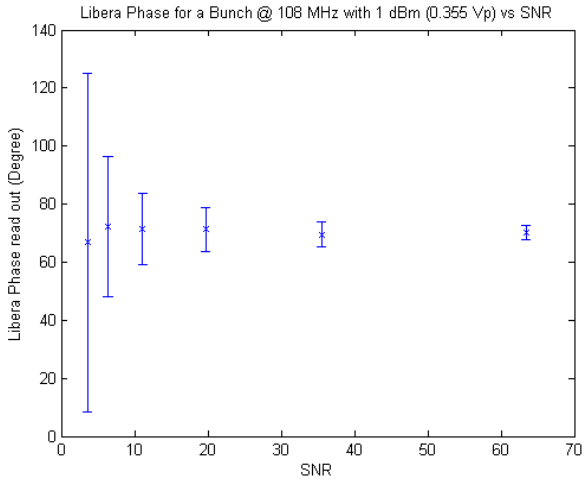

Libera Phase for sin 1 @ 325 MHz with -35 dBm noise (0.0056 Vp) vs SNR
Libera Phase read out (Degree)
SNR

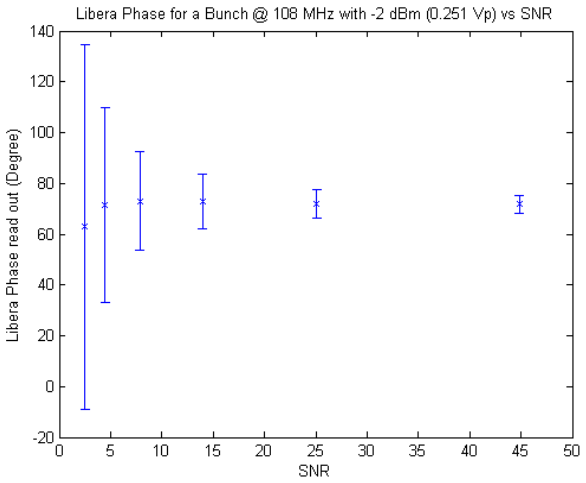
Appendix 2-2 (Superposition of Signals and Noise **Bunch (1) @ 108.4 MHz & Noise**)

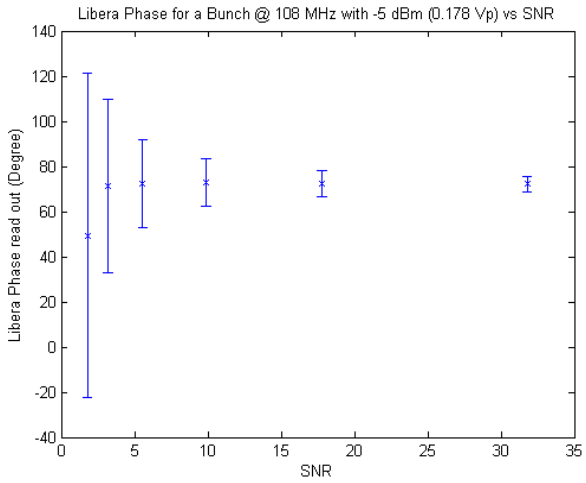


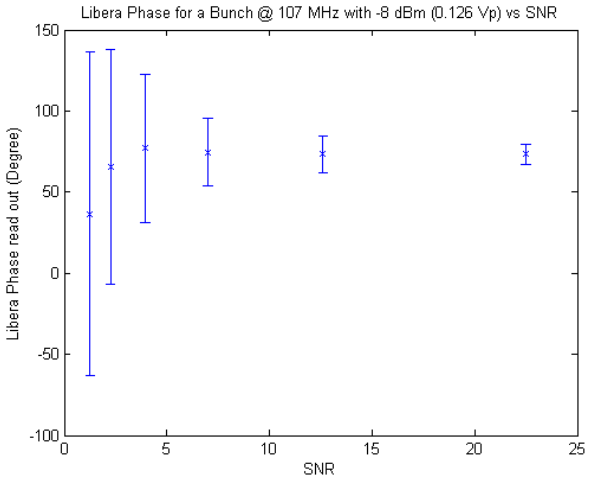


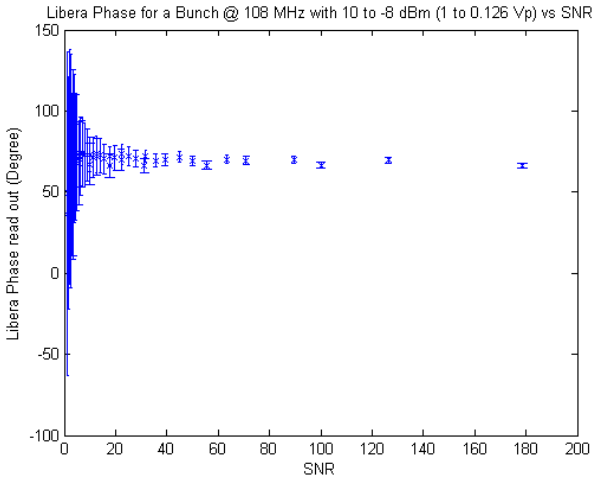


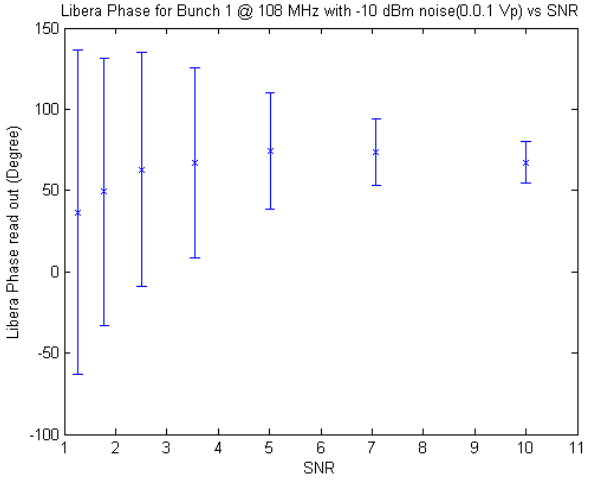


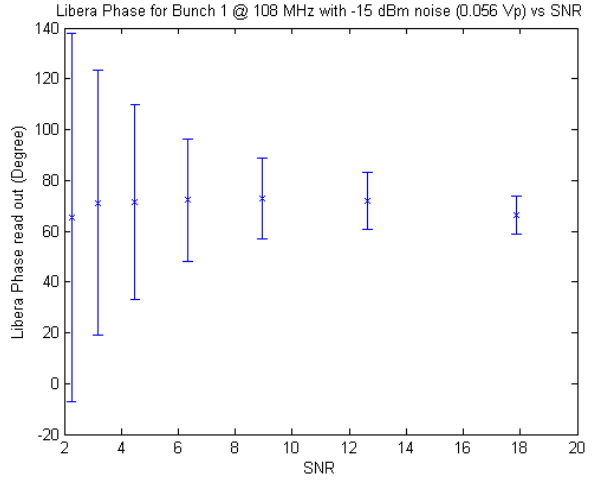


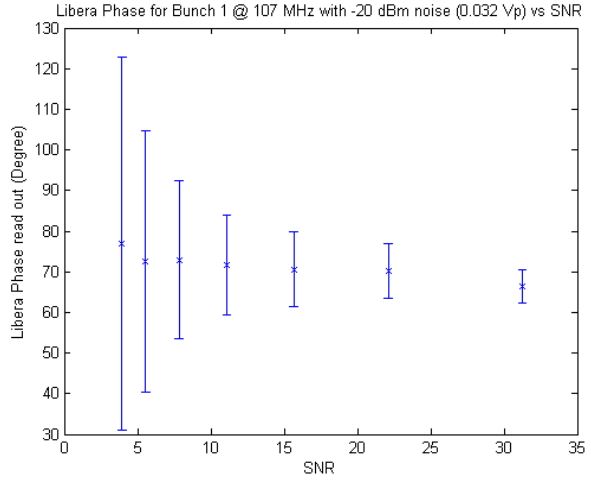


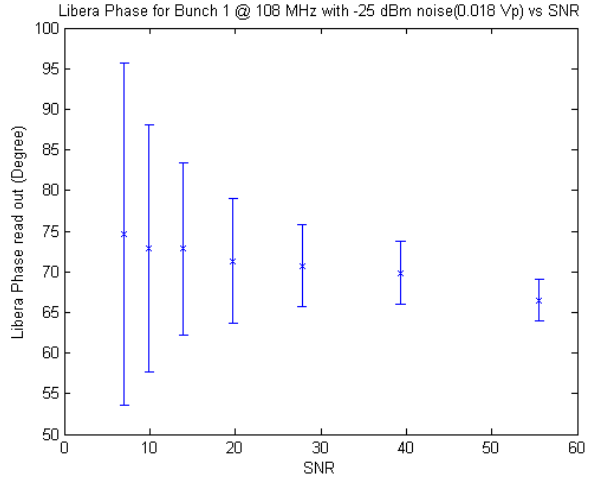

Libera Phase for a Bunch @ 107 MHz with -8 dBm (0.126 Vp) vs SNR
Libera Phase read out (Degree)
SNR

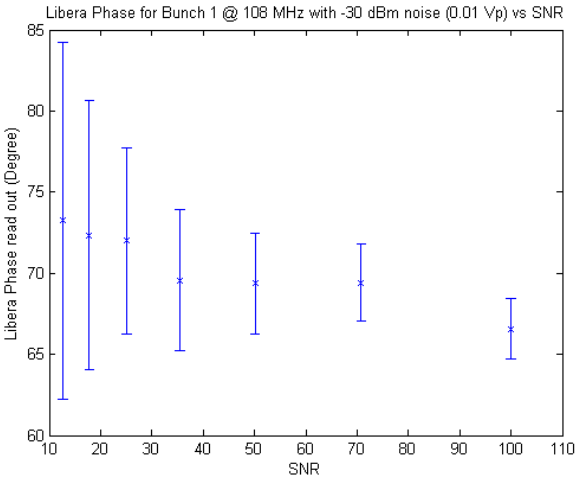

Libera Phase for a Bunch @ 108 MHz with 10 to -8 dBm (1 to 0.126 Vp) vs SNR
Libera Phase read out (Degree)
SNR

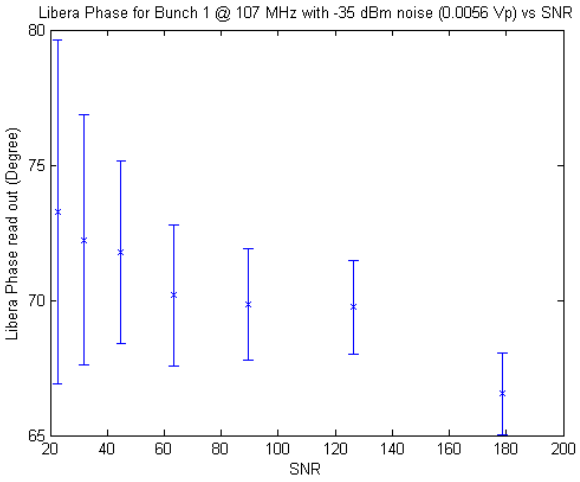

Libera Phase for Bunch 1 @ 108 MHz with -10 dBm noise(0.0.1 Vp) vs SNR
Libera Phase read out (Degree)
SNR

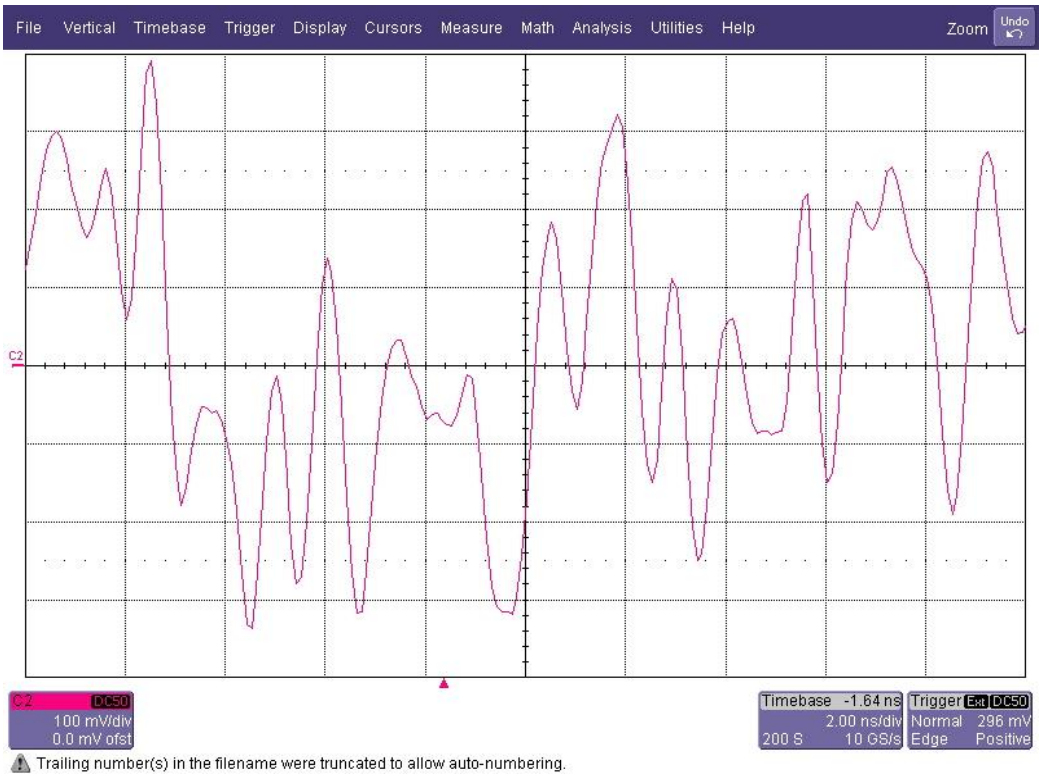

Libera Phase for Bunch 1 @ 108 MHz with -15 dBm noise (0.056 Vp) vs SNR
Libera Phase read out (Degree)
SNR


Libera Phase for Bunch 1 @ 107 MHz with -20 dBm noise (0.032 Vp) vs SNR
Libera Phase read out (Degree)
SNR


Libera Phase for Bunch 1 @ 108 MHz with -25 dBm noise(0.018 Vp) vs SNR
Libera Phase read out (Degree)
SNR

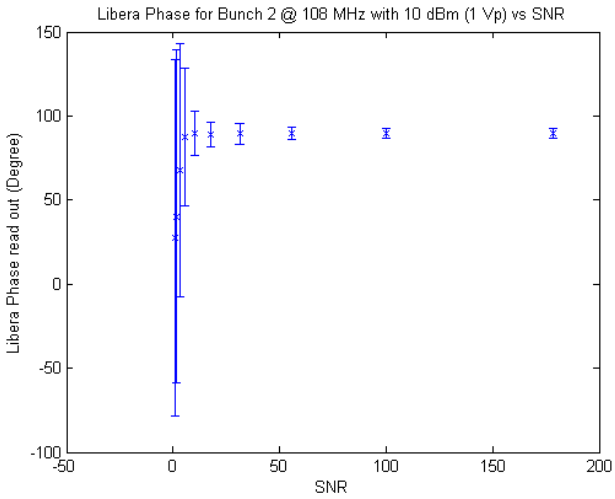


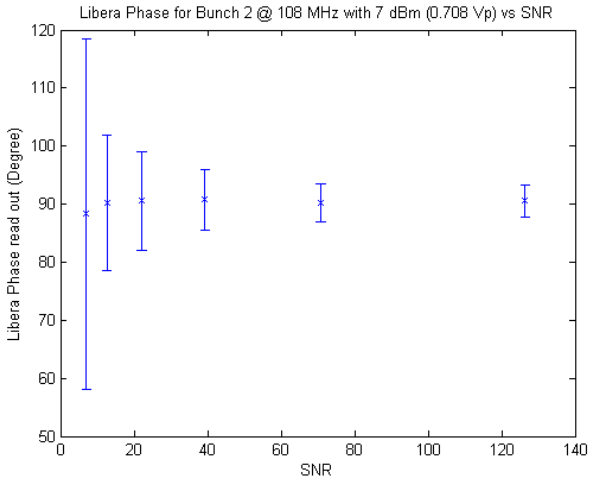


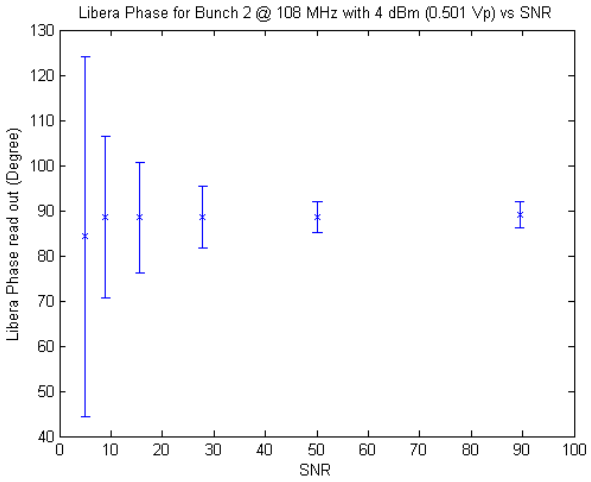


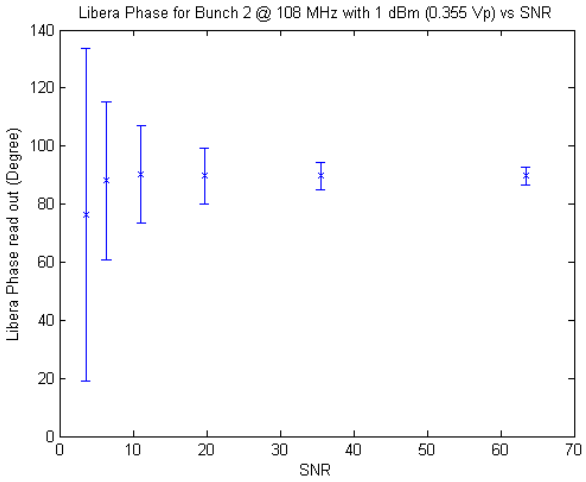
bunch_4dBm_noise_0dBm_

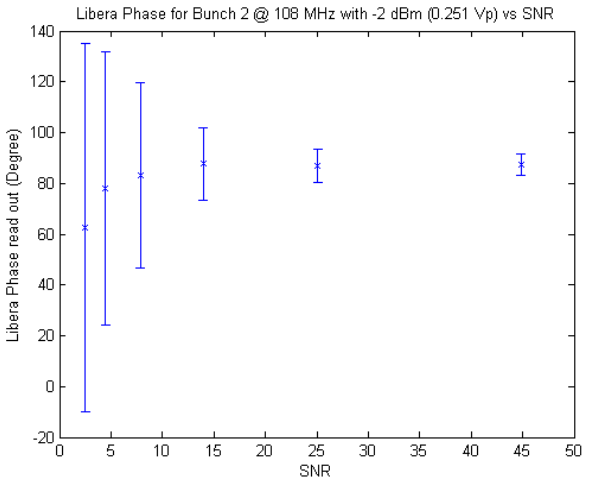
Appendix 2 -3 (Superposition of Signals and Noise Bunch (2) @ 108.4 MHz & Noise)

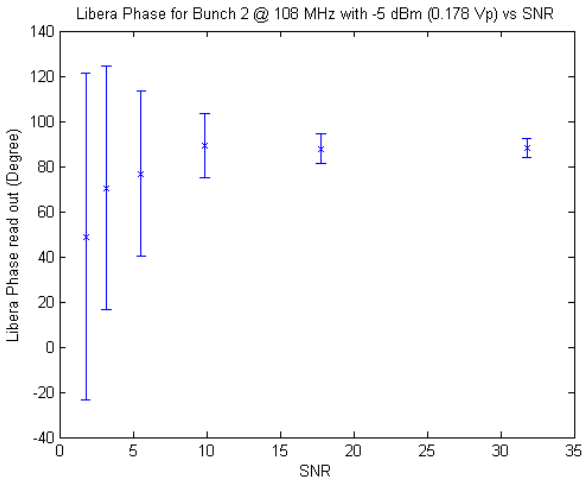


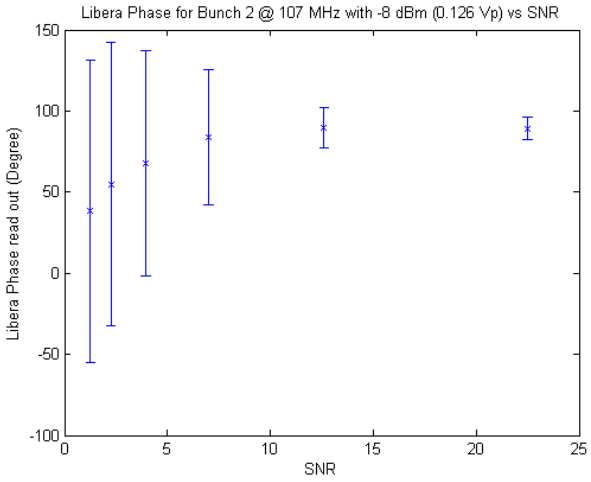


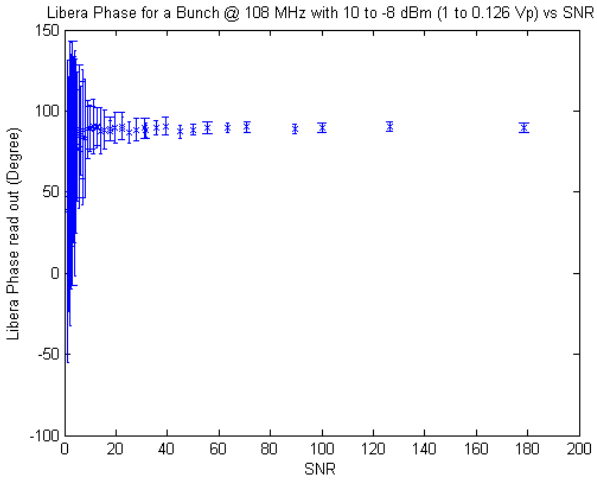


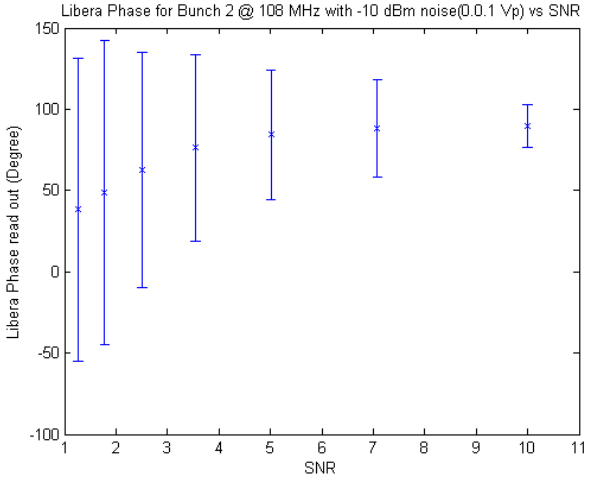


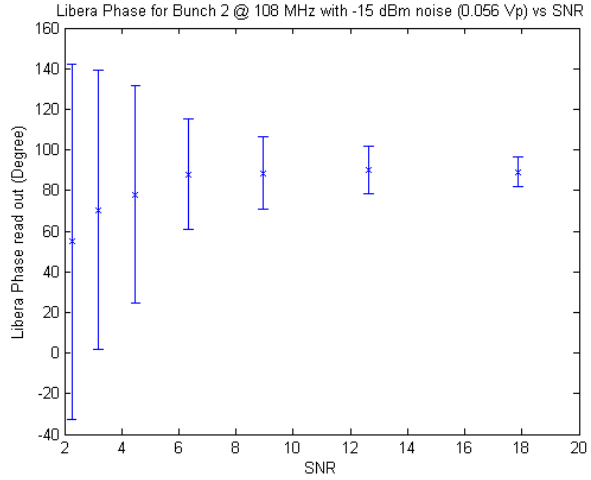


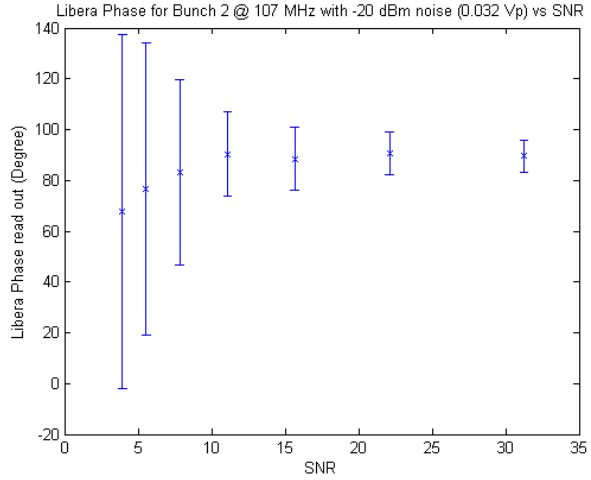


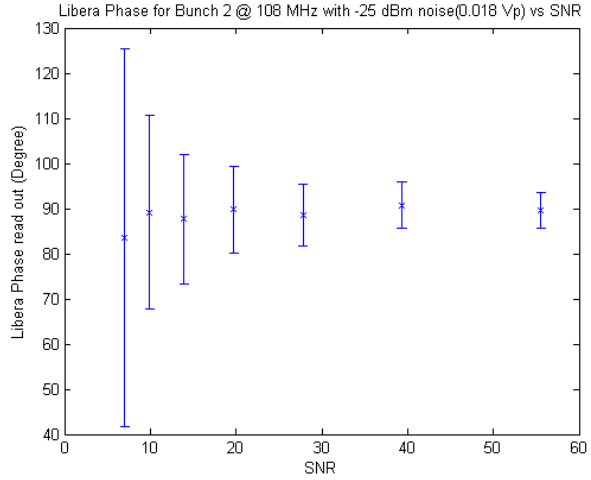

Libera Phase for Bunch 2 @ 107 MHz with -8 dBm (0.126 Vp) vs SNR
Libera Phase read out (Degree)
SNR

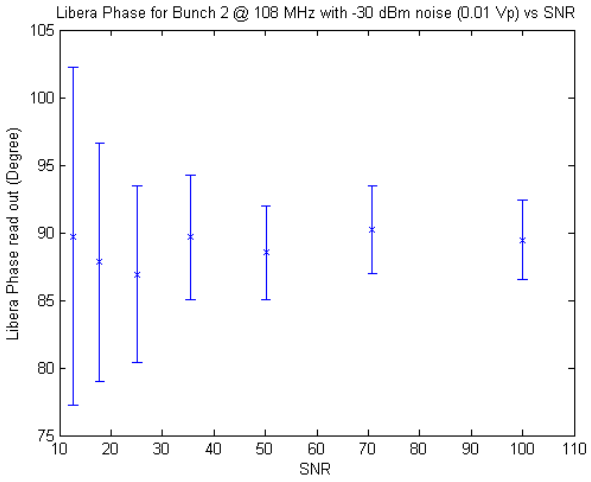

Libera Phase for a Bunch @ 108 MHz with 10 to -8 dBm (1 to 0.126 Vp) vs SNR
Libera Phase read out (Degree)
SNR

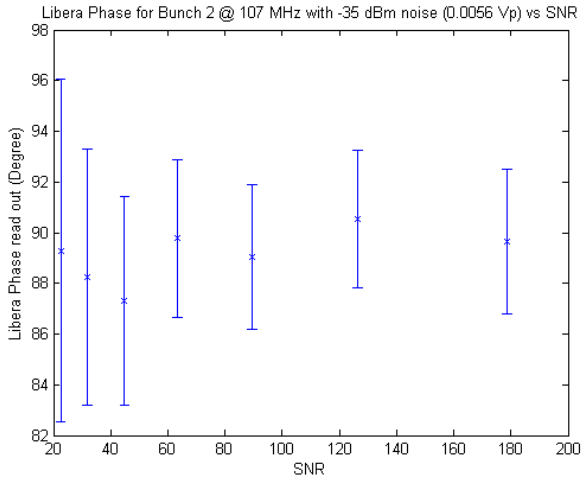

Libera Phase for Bunch 2 @ 108 MHz with -10 dBm noise(0.0.1 Vp) vs SNR
Libera Phase read out (Degree)
SNR


Libera Phase for Bunch 2 @ 108 MHz with -15 dBm noise (0.056 Vp) vs SNR
Libera Phase read out (Degree)
SNR

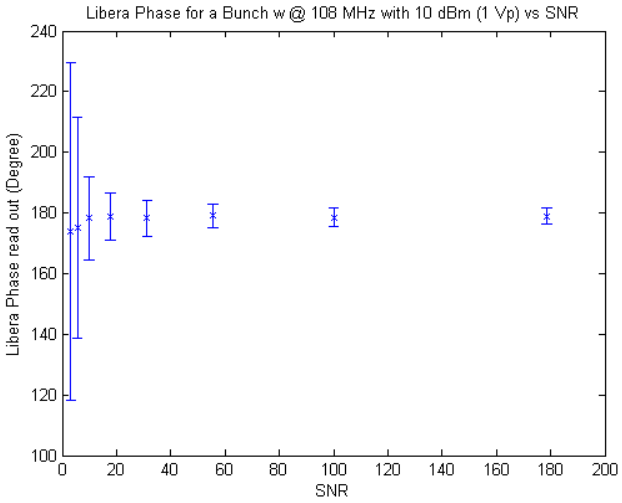

Libera Phase for Bunch 2 @ 107 MHz with -20 dBm noise (0.032 Vp) vs SNR
Libera Phase read out (Degree)
SNR

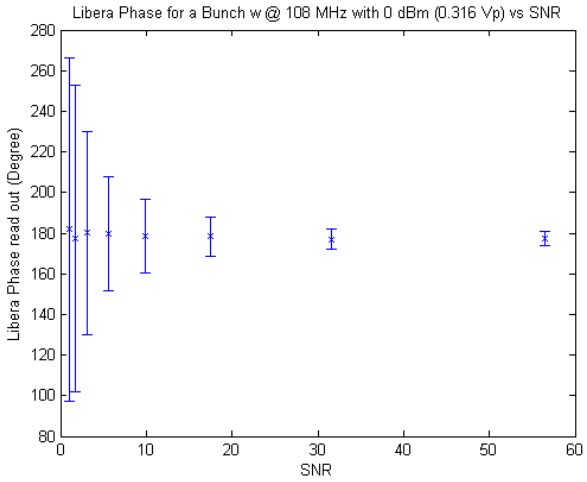

Libera Phase for Bunch 2 @ 108 MHz with -25 dBm noise(0.018 Vp) vs SNR
Libera Phase read out (Degree)
SNR

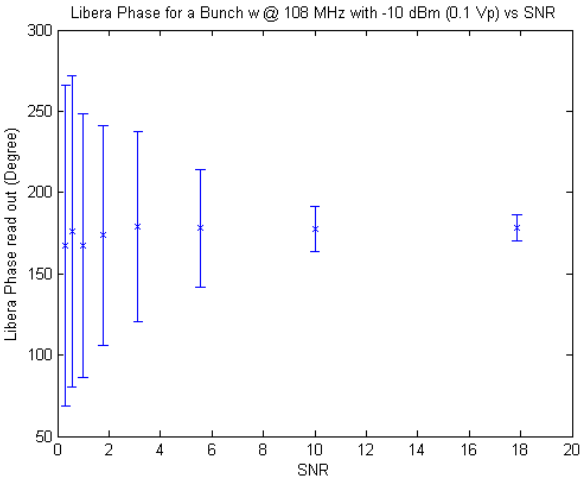

Libera Phase for Bunch 2 @ 108 MHz with -30 dBm noise (0.01 Vp) vs SNR
Libera Phase read out (Degree)
SNR
105
100
95
90
85
80
75
10
20
30
40
50
60
70
80
90
100
110

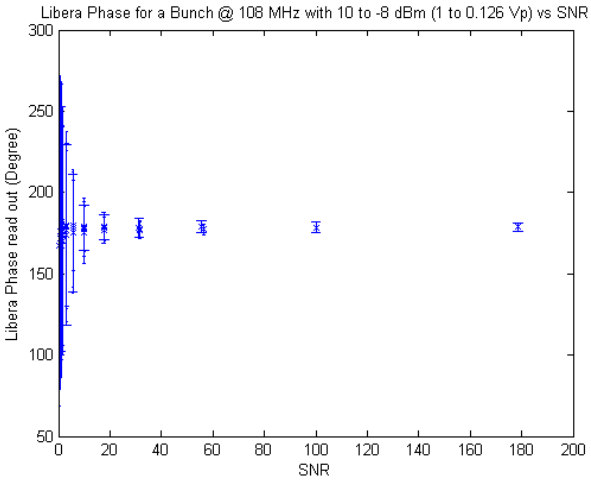

Libera Phase for Bunch 2 @ 107 MHz with -35 dBm noise (0.0056 Vp) vs SNR
Libera Phase read out (Degree)
SNR
98
96
94
92
90
88
86
84
82
20
40
60
80
100
120
140
160
180
200

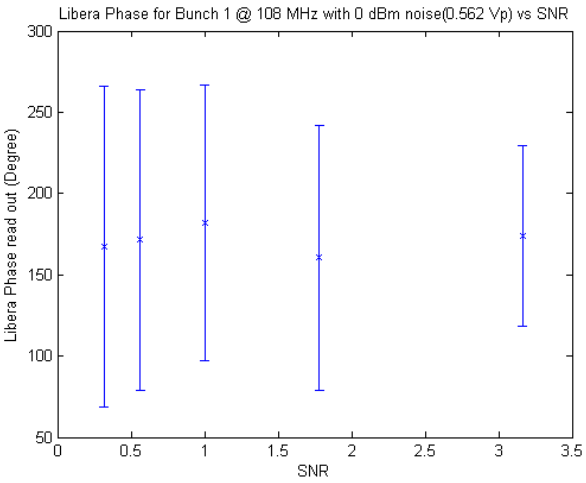
Appendix 2 -4 (Superposition of Signals and Noise Bunch (3) @ 108.4 MHz & Noise at Phase Wrapping)

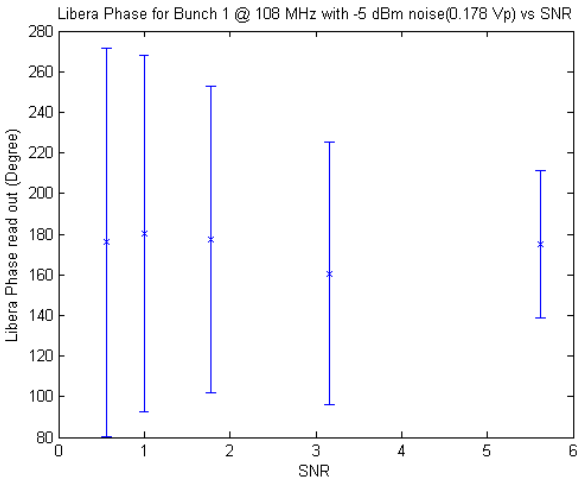


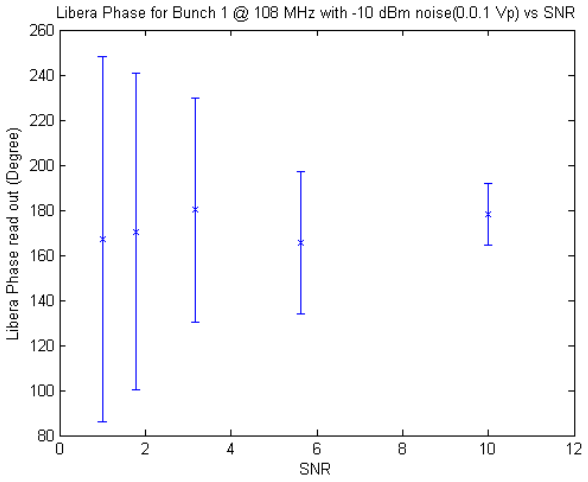


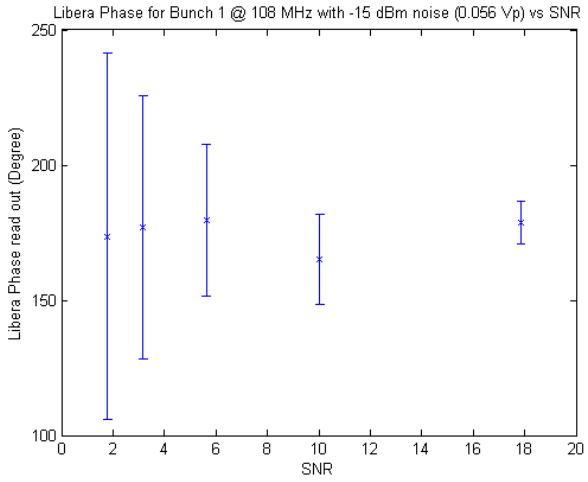


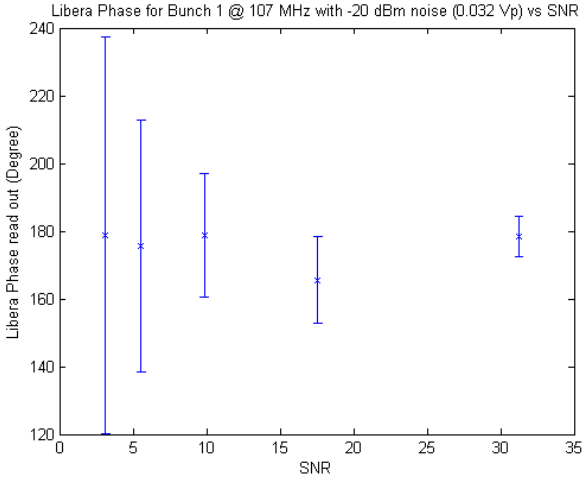


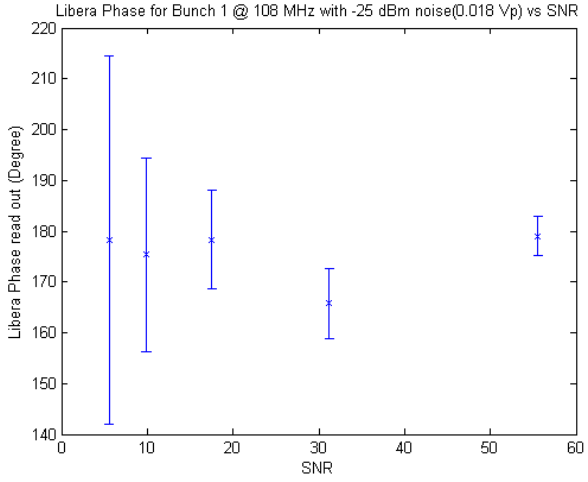


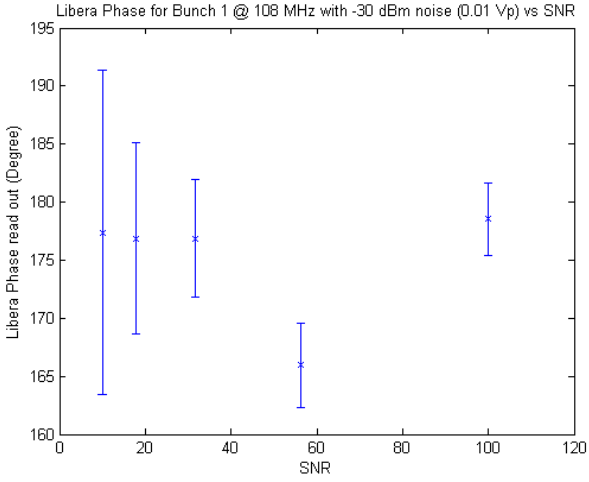


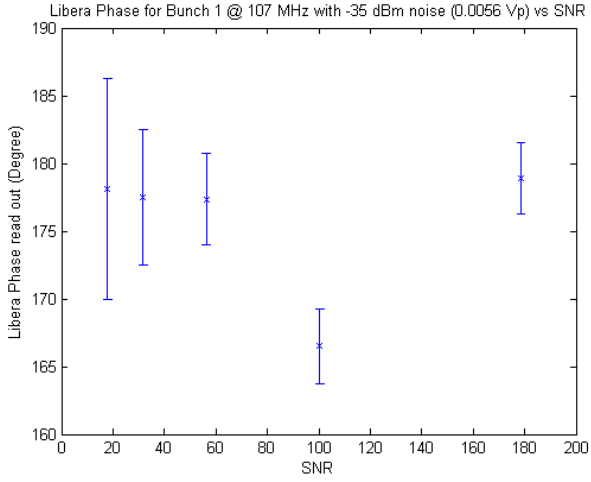

Libera Phase for Bunch 1 @ 108 MHz with -10 dBm noise(0.0.1 Vp) vs SNR
Libera Phase read out (Degree)
SNR


Libera Phase for Bunch 1 @ 108 MHz with -15 dBm noise (0.056 Vp) vs SNR
Libera Phase read out (Degree)
SNR


Libera Phase for Bunch 1 @ 107 MHz with -20 dBm noise (0.032 Vp) vs SNR
Libera Phase read out (Degree)
SNR

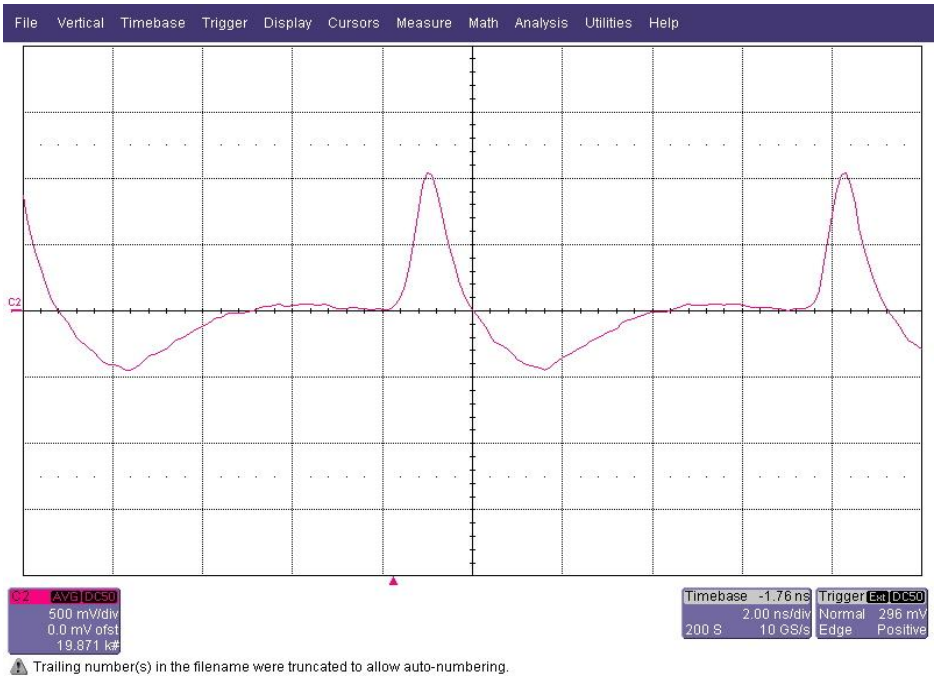

Libera Phase for Bunch 1 @ 108 MHz with -25 dBm noise(0.018 Vp) vs SNR
Libera Phase read out (Degree)
SNR

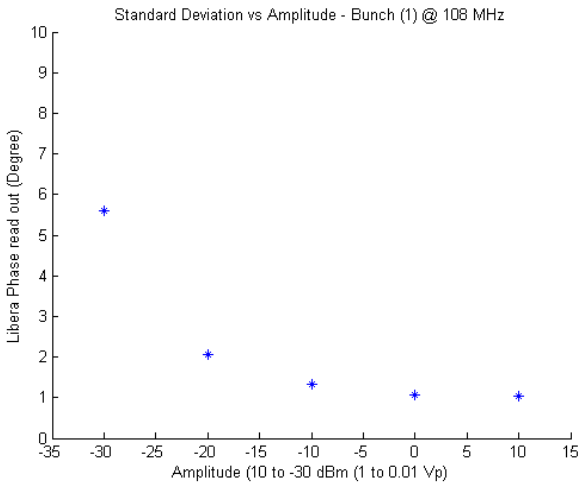

Libera Phase for Bunch 1 @ 108 MHz with -30 dBm noise (0.01 Vp) vs SNR
Libera Phase read out (Degree)
SNR

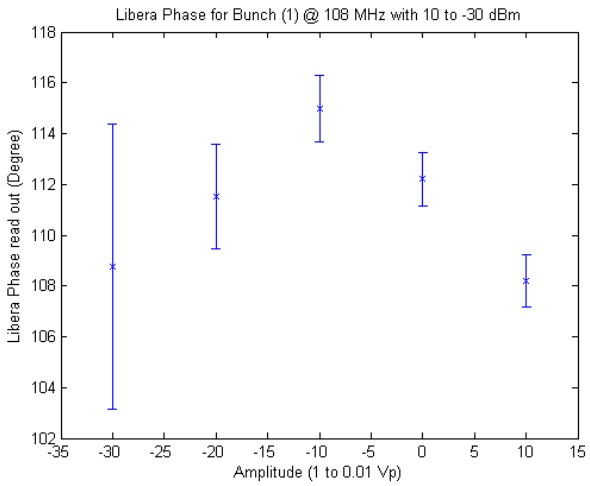

Libera Phase for Bunch 1 @ 107 MHz with -35 dBm noise (0.0056 Vp) vs SNR
Libera Phase read out (Degree)
SNR

Appendix 3 (The Phase Evaluation for Different Signal Shapes Bunches @ 108.4 MHz)

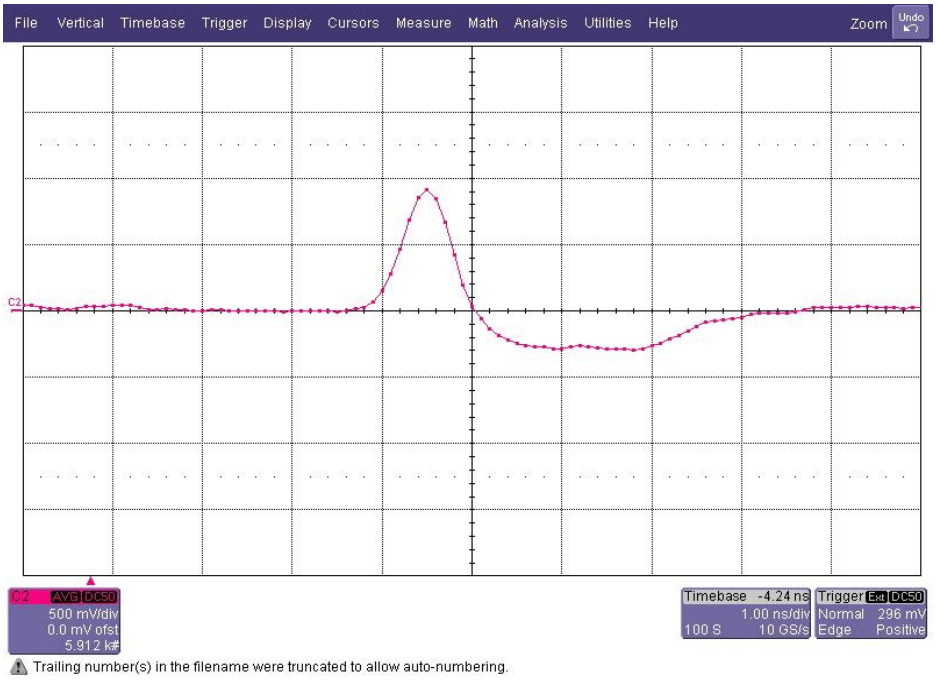
1-Bunch (1)

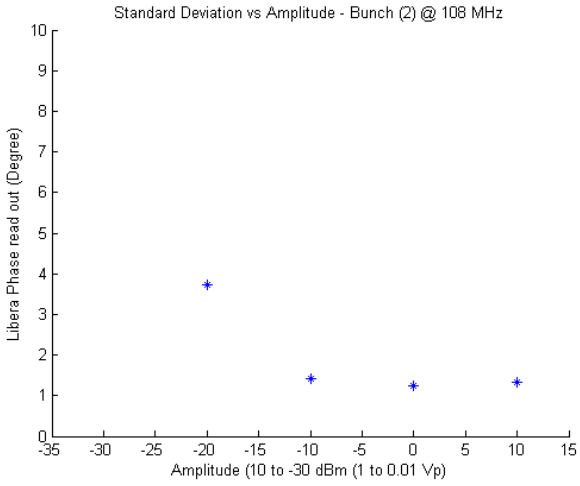


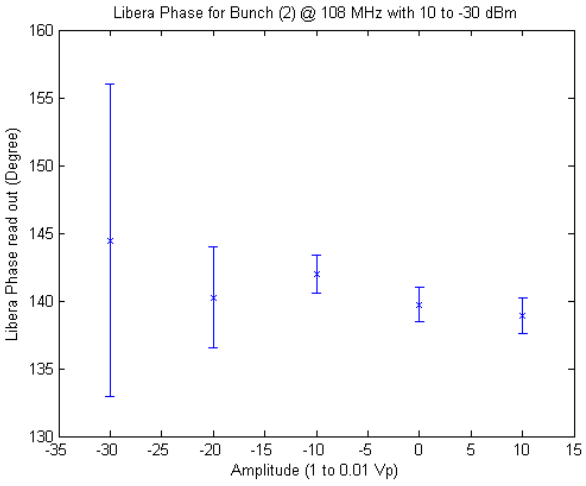




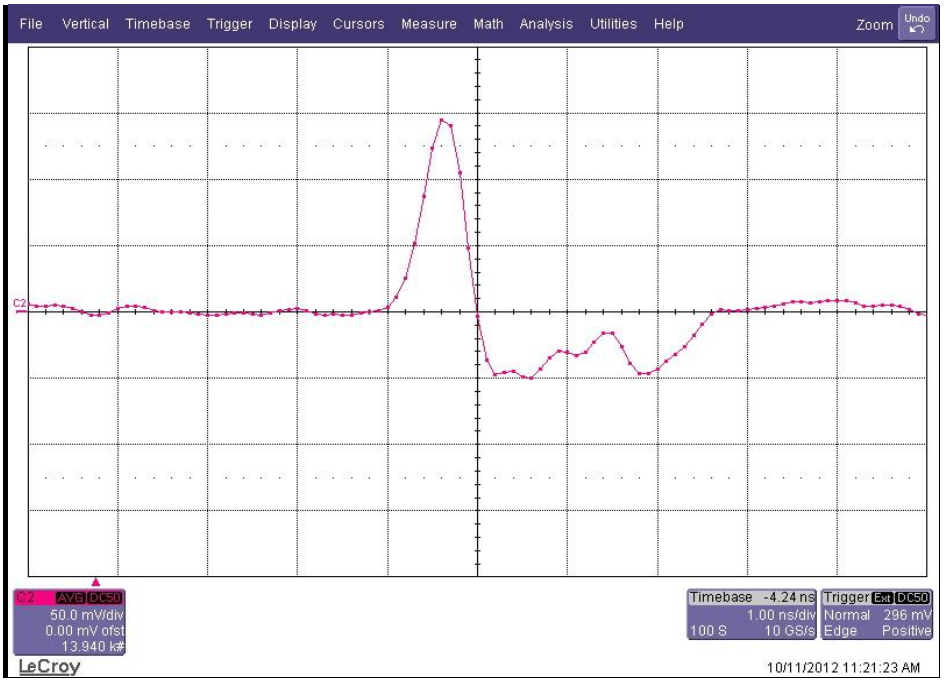
2-Bunch (2)

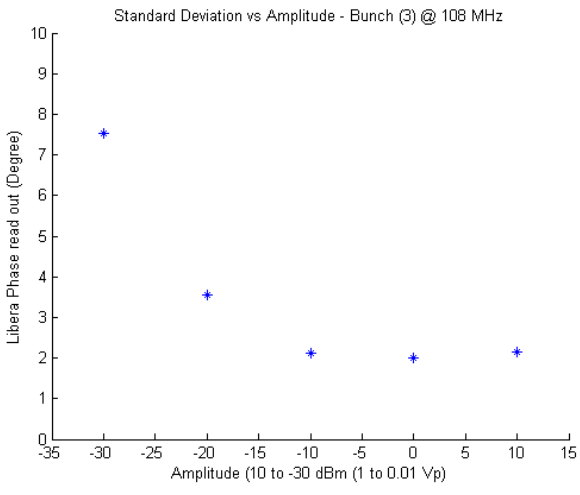

File Vertical Timebase Trigger Display Cursors Measure Math Analysis Utilities Help
Zoom
Undo
C2
C2 AVG DC50
500 mV/div
0.0 mV ofst
5.912 k#
Timebase -4.24 ns
1.00 ns/div
100 S 10 GS/s
Trigger Ext DC50
Normal 296 mV
Edge Positive
Trailing number(s) in the filename were truncated to allow auto-numbering.

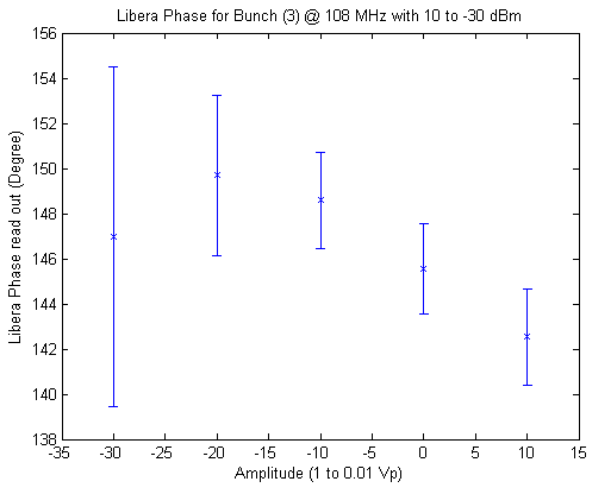

Standard Deviation vs Amplitude - Bunch (2) @ 108 MHz
Libera Phase read out (Degree)
Amplitude (10 to -30 dBm (1 to 0.01 Vp)


Libera Phase for Bunch (2) @ 108 MHz with 10 to -30 dBm
Libera Phase read out (Degree)
Amplitude (1 to 0.01 Vp)

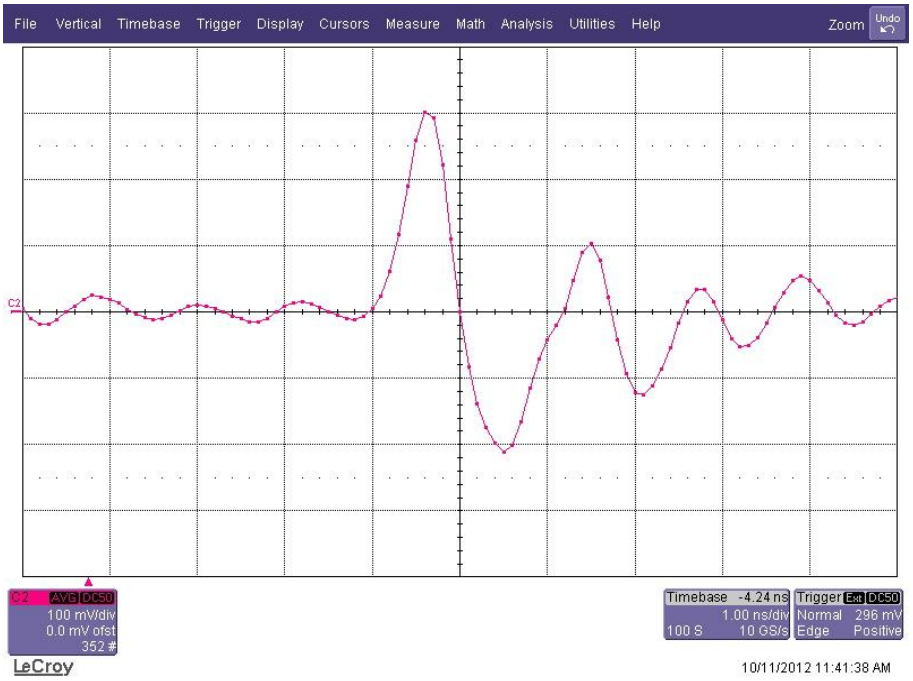
3-Bunch (3)

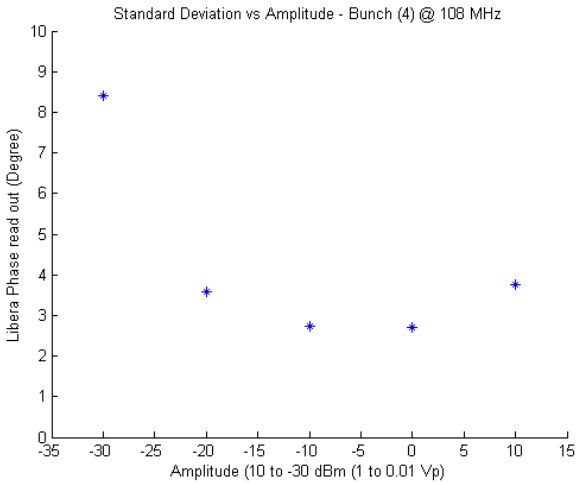

File Vertical Timebase Trigger Display Cursors Measure Math Analysis Utilities Help
Zoom
Undo
C2
C2 AVG DC50
50.0 mV/div
0.00 mV ofst
13.940 k#
Timebase -4.24 ns
1.00 ns/div
100 S 10 GS/s
Trigger Ext DC50
Normal 296 mV
Edge Positive
LeCroy
10/11/2012 11:21:23 AM

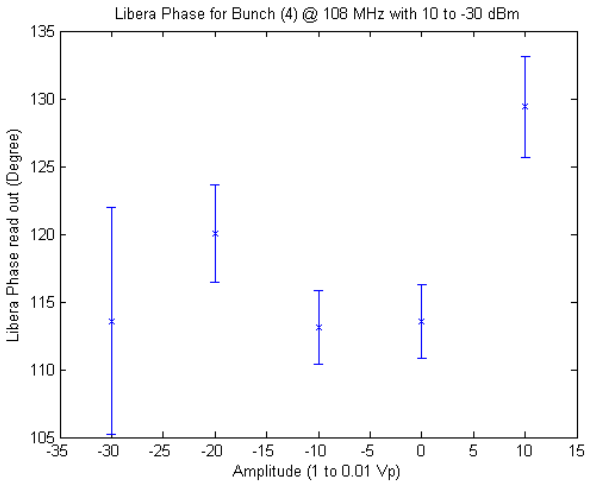

Standard Deviation vs Amplitude - Bunch (3) @ 108 MHz
Libera Phase read out (Degree)
Amplitude (10 to -30 dBm (1 to 0.01 Vp)


Libera Phase for Bunch (3) @ 108 MHz with 10 to -30 dBm
Libera Phase read out (Degree)
Amplitude (1 to 0.01 Vp)

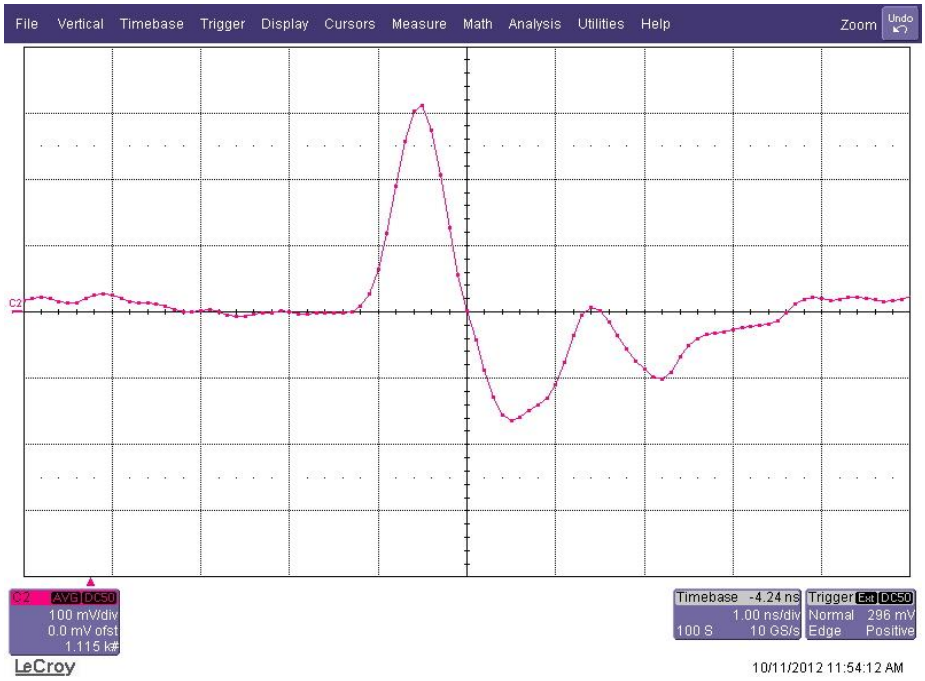
4-Bunch (4)

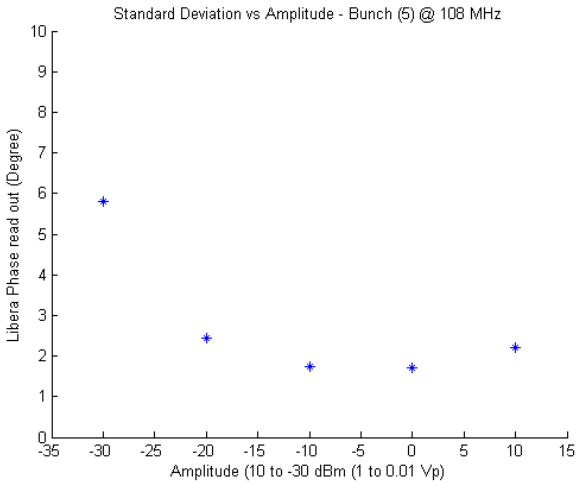

File Vertical Timebase Trigger Display Cursors Measure Math Analysis Utilities Help
Zoom
Undo
C2
C2 AVG DC50
100 mV/div
0.0 mV ofst
352 #
Timebase -4.24 ns
1.00 ns/div
100 S 10 GS/s
Trigger Ext DC50
Normal 296 mV
Edge Positive
LeCroy
10/11/2012 11:41:38 AM

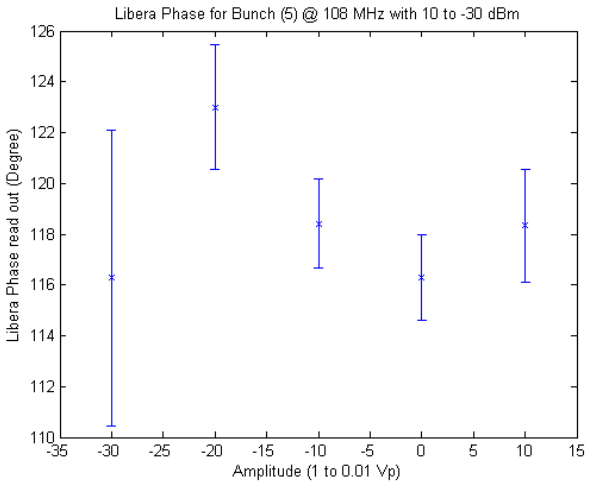

Standard Deviation vs Amplitude - Bunch (4) @ 108 MHz
Libera Phase read out (Degree)
Amplitude (10 to -30 dBm (1 to 0.01 Vp)


Libera Phase for Bunch (4) @ 108 MHz with 10 to -30 dBm
Libera Phase read out (Degree)
Amplitude (1 to 0.01 Vp)

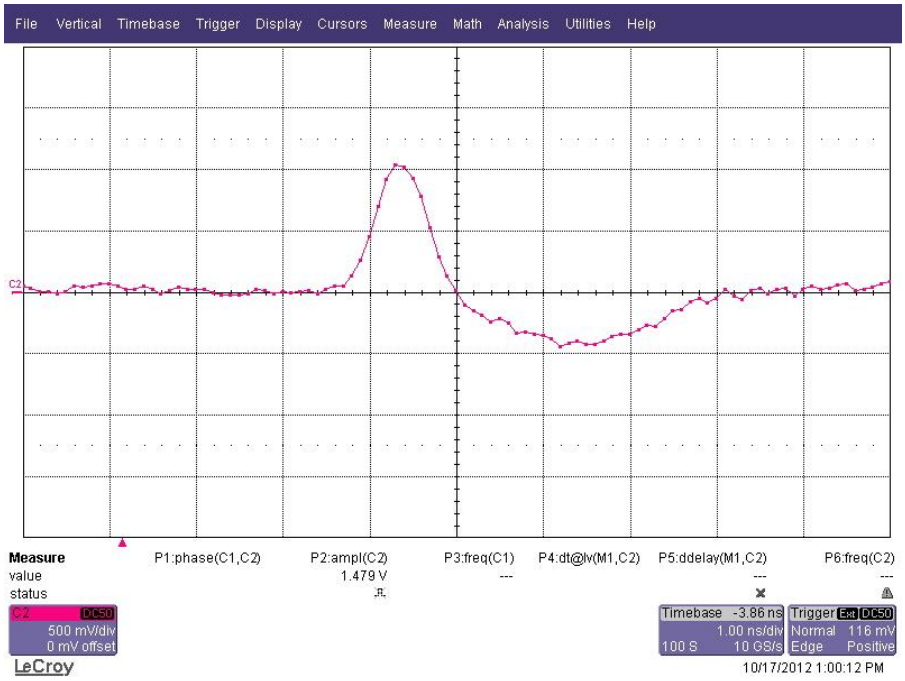
5-Bunch (5)


File Vertical Timebase Trigger Display Cursors Measure Math Analysis Utilities Help Zoom Undo
C2
C2 AVG DC50
100 mV/div
0.0 mV ofst
1.115 kH
Timebase -4.24 ns
1.00 ns/div
100 S 10 GS/s
Trigger Ext DC50
Normal 296 mV
Edge Positive
LeCroy
10/11/2012 11:54:12 AM


Standard Deviation vs Amplitude - Bunch (5) @ 108 MHz
Libera Phase read out (Degree)
Amplitude (10 to -30 dBm (1 to 0.01 Vp)


Libera Phase for Bunch (5) @ 108 MHz with 10 to -30 dBm
Libera Phase read out (Degree)
Amplitude (1 to 0.01 Vp)

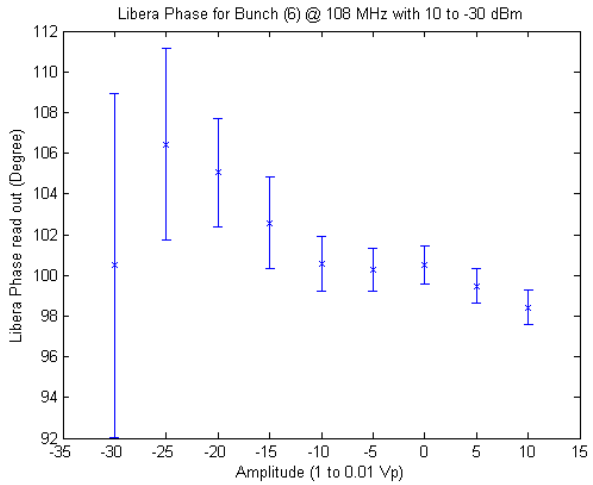
6-Bunch (6)

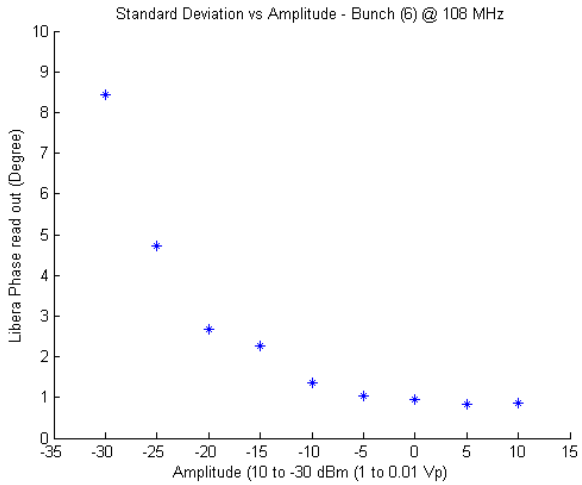

File Vertical Timebase Trigger Display Cursors Measure Math Analysis Utilities Help
C2
Measure
value
status
P1:phase(C1,C2)
P2:ampl(C2)
1.479 V
P3:freq(C1)

P4:dt@lv(M1,C2)
P5:ddelay(M1,C2)

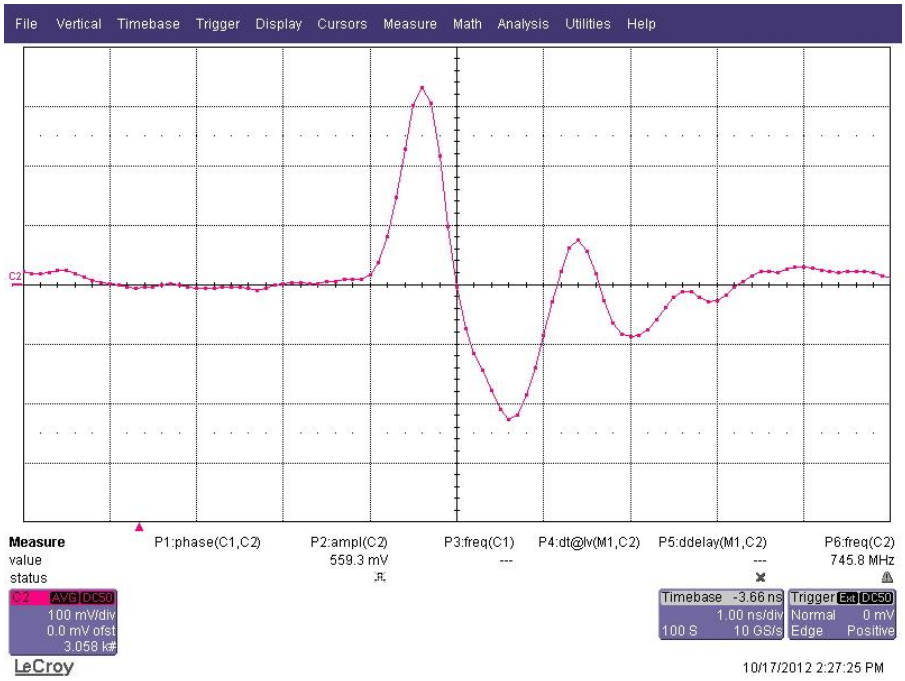
P6:freq(C2)

C2 DC50
500 mV/div
0 mV offset
Timebase -3.86 ns
1.00 ns/div
100 S 10 GS/s
Trigger Ext DC50
Normal 116 mV
Edge Positive
LeCroy
10/17/2012 1:00:12 PM


Libera Phase for Bunch (6) @ 108 MHz with 10 to -30 dBm
Libera Phase read out (Degree)
Amplitude (1 to 0.01 Vp)

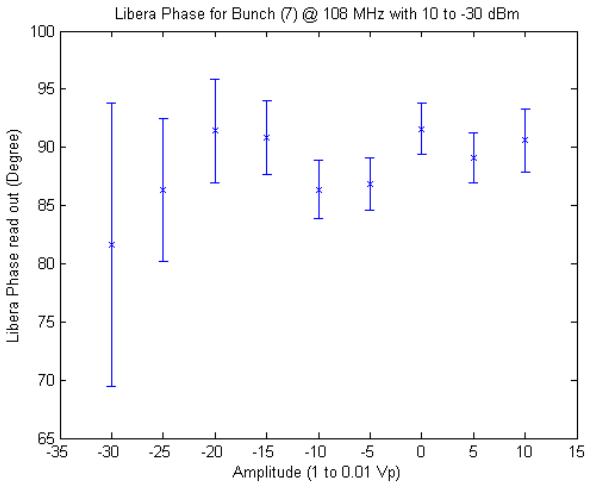

Standard Deviation vs Amplitude - Bunch (6) @ 108 MHz
Libera Phase read out (Degree)
Amplitude (10 to -30 dBm (1 to 0.01 Vp)

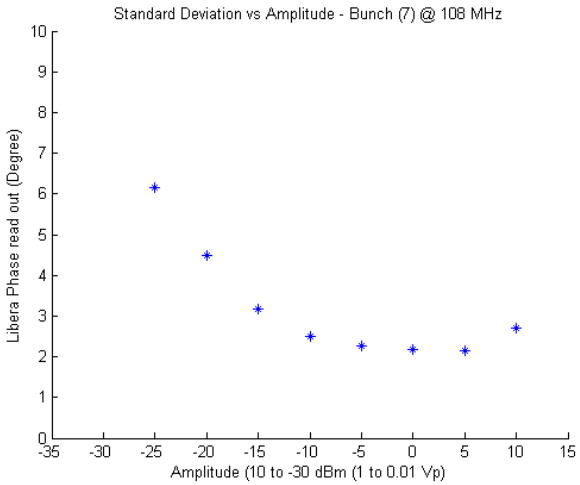
7-Bunch (7)


File Vertical Timebase Trigger Display Cursors Measure Math Analysis Utilities Help
C2
Measure
value
status
P1:phase(C1,C2)
P2:ampl(C2)
559.3 mV
P3:freq(C1)

P4:dt@lv(M1,C2)
P5:ddelay(M1,C2)

P6:freq(C2)
745.8 MHz
C2 AVG DC50
100 mV/div
0.0 mV ofst
3.058 k#
Timebase -3.66 ns
1.00 ns/div
100 S 10 GS/s
Trigger Ext DC50
Normal 0 mV
Edge Positive
LeCroy
10/17/2012 2:27:25 PM


Libera Phase for Bunch (7) @ 108 MHz with 10 to -30 dBm
Libera Phase read out (Degree)
Amplitude (1 to 0.01 Vp)


Standard Deviation vs Amplitude - Bunch (7) @ 108 MHz
Libera Phase read out (Degree)
Amplitude (10 to -30 dBm (1 to 0.01 Vp)