

Report (4) 18 th Dec 2012	Experimental test of "Libera Single Pass H" for beam phase and "Time of Flight" measurements. – Nov 2012 Experiment –	P. Forck W. Kaufmann M. Almalki C. Krüger
Copies to:	P. Forck, M. Almalki, M. Schwickert, L. Groening, W. Kaufmann, P. Kowina, C. Krüger, G. Clemente, R. Singh, K. Lang, A. Reiter, W. Vinzenz GSI B. Baricevic, M. Znidarcic, R. Hrovatin I-Tech C. Simon CEA	
Web-Link:	http://www-bd.gsi.de/dokuwiki/doku.php?id=projects:bpm-linac	

➤ Introduction

In order to improve Libera single pass H performance, a new unit has been customized for UNILAC. In the previous unit only the third harmonic (325.2 MHz) was processed since it was customized for P-LINAC frequencies (325.2 MHz and 650.4 MHz). The main difference, however, between the units is the front-end analogue filter. In the new unit, the RF front-end filtering has been changed to cover the first (108.4 MHz) and second harmonic (216.8 MHz). Figure 1 shows the impedance response for the new unit. Furthermore, the other change is the ADC full scale where it was changed from 16 dBm (4 Vpp) to -5 dBm (0.355 Vpp).

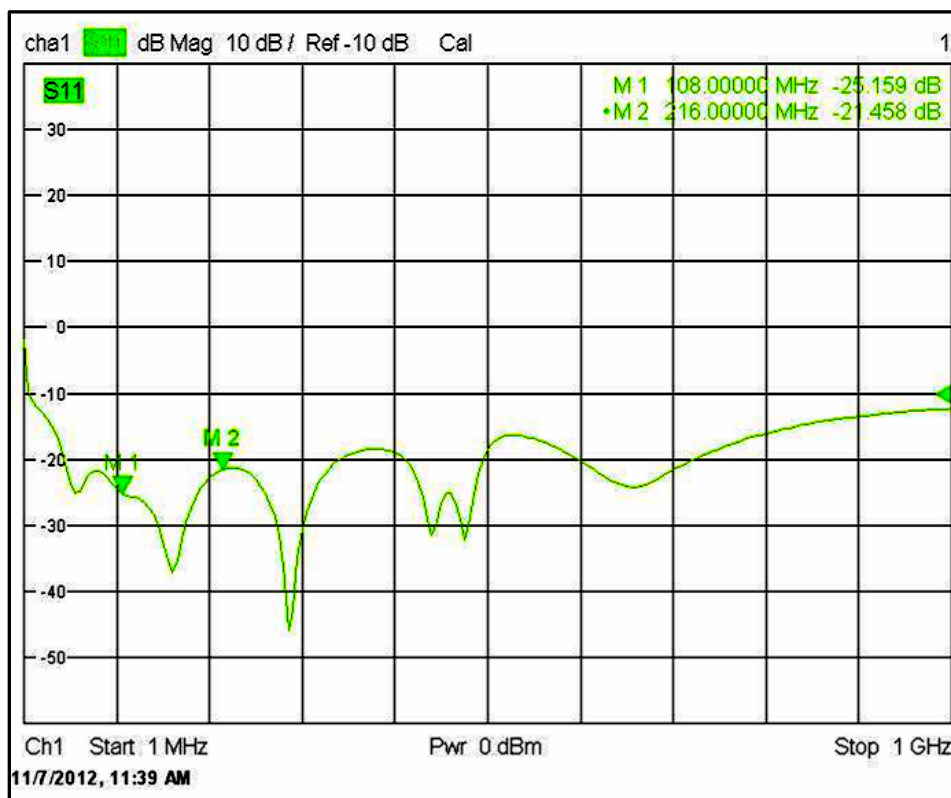


Figure1: the input matching at 108.408 MHz and 216.8 MHz points are at -25 dB and -21 dB return loss for the new unit.

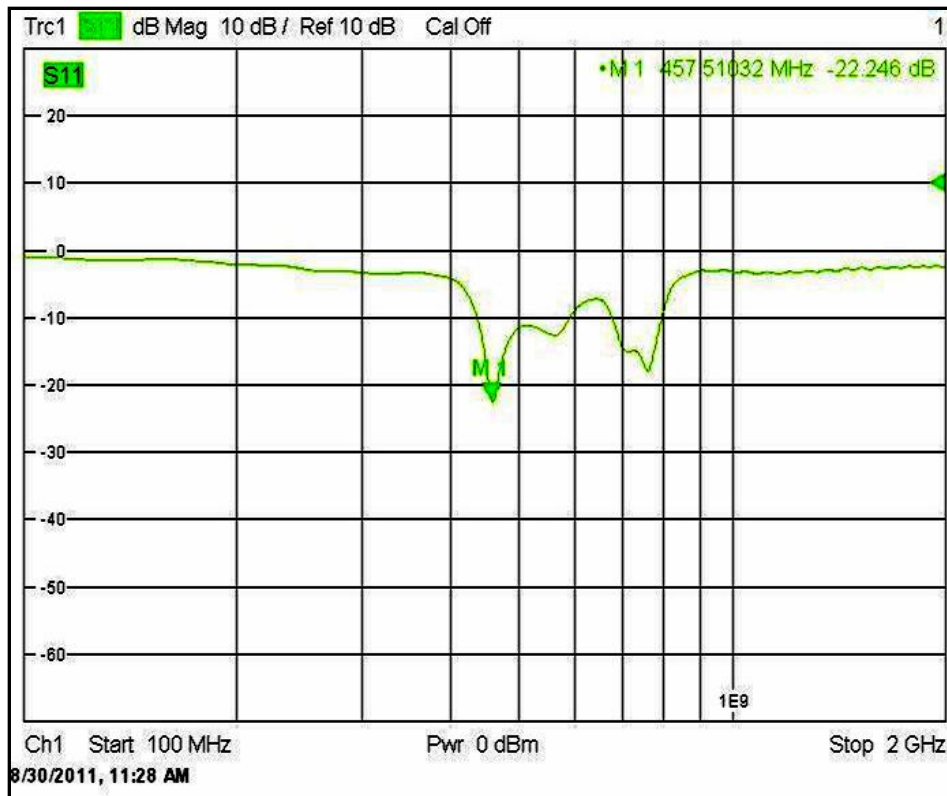


Figure 2: the input matching at 108MHz and its harmonics is not optimal for the old unit

For the purpose of a comparative measurement, this experiment was carried out with the same experimental setup for March 2012 experiment to test and to compare the new and old units' performance with flexibility to change signal amplitude using a switchable pre-amplifier. The first section describes the performance test for the two units. The second section shows phase evaluation from different bunch shapes using the new unit and comparing Libera H measurements with time-domain data and FFT calculations. The third section reports the Libera H position determination test comparing with profile grid measurements.

In summary, this report presents the experimental results and it is divided into three sections:

- 1- Performance test (Comparison between the Old Unit and the New Unit).
- 2- Phase Evaluation (Seven Bunch Shapes)
- 3- Beam Position test.

➤ Part 1 : Performance test (Comparison between the Old Unit and the New Unit).

Three different bunch shapes are formed and their phases have been measured using the old and new Libera H units. The purpose is to compare the two units' performance for different bunch shapes with different amplitudes. The bunches amplitude was varied using a pre-amplifier and the step size for gain variation was 6 dB. The maximum input amplification for the new unit is 44 dB while it is 50 dB for the old unit. For all bunches, bunch streams from time domain data were stored for FFT calculations. The results of phase evaluation are summarized in Tables 1-1 and 1-2 for the new and the old unit respectively.

Figures 1-1, 1-2 and 1-3 show Libera H phase versus signal amplitude (amplification) for three bunch shapes. More visualizing plots about the three shapes can be found in appendix 1.

Observations and Results

- 1- The new unit gives stable phase measurements in comparison to the old unit. This can be seen in figures 1-1, 1-2 and 1-3.
- 2- For shape 1, Libera H new unit measured phase with standard deviation less than 1° for 44 to 26 dB amplification.
- 3- The measurements at higher amplitude levels show a better phase reading but the standard deviation sometime is fluctuating.
- 4- The Libera H new unit shows more fluctuation in phase readings for shape 2 and 3 in comparison with shape 1.
- 5- When looking at bunch position information, it was observed for shape 1 that the bunch position was almost the same for all measurements taken at different amplification levels. It is, however, not the case for shape 2. This might explain phase fluctuation for shape 2 and 3.
- 6- In shape 3, unexpected phase reading was noticed at 44 dB (**red readout in** Table 1-1). The bunch position information revealed that the bunch position for this case in particular was different from the position of the rest of bunch amplitude levels.
- 7- Bunch position could be an explanation for the unexpected phase reading mentioned in point 6 and phase readout fluctuation mentioned in point 4 and 5.

Table 1-1: Libera single pass H readout (The New Unit)

Shape No.	Amplifi. (dB)	Signal Amp Libera H (mV)	No. of Samples	Phase Mean (deg.)	St. of Phase (deg.)	St. of Mean (deg.)	1 st Harmo. 108.4 (MHz)	St. of Phase (deg.)	St of Mean (deg.)	2 nd Harmo. 216.8 (MHz)	St. of Phase (deg.)	St. of Mean (deg.)
Shape 1	44	1228.78	516	164.88	0.67	0.03	164.89	0.69	0.03	-72.21	1.44	0.06
	38	594.82	516	164.10	0.69	0.03	164.10	0.69	0.03	-79.43	1.49	0.07
	32	301.58	516	164.43	0.73	0.03	164.43	0.71	0.03	-83.32	1.78	0.08
	26	153.91	516	166.76	0.94	0.04	166.76	0.88	0.04	-82.33	2.54	0.11
	20	76.75	516	163.91	1.51	0.07	163.94	1.51	0.07	-85.88	4.64	0.20
	14	38.87	516	165.16	2.53	0.11	165.16	2.64	0.12	-84.90	8.40	0.37
Shape 2	44	909.93	516	-35.63	1.15	0.05	-35.63	1.15	0.05	-129.98	2.62	0.12
	38	440.10	516	-37.73	1.35	0.06	-37.73	1.35	0.06	-139.52	2.88	0.13
	32	224.00	516	-36.62	0.96	0.04	-36.62	0.96	0.04	-141.56	3.63	0.16
	26	110.30	516	-33.62	1.53	0.07	-33.62	1.53	0.07	-138.75	7.81	0.34
	20	55.24	516	-35.60	2.44	0.11	-33.85	7.55	0.33	-138.63	30.32	1.33
	14	28.23	516	-35.55	3.93	0.17	-36.31	22.91	1.01	-121.56	59.62	2.62
Shape 3	44	1130.60	516	-17.38	0.58	0.03	-17.38	0.57	0.03	-80.33	1.18	0.05
	38	929.09	516	-5.70	1.28	0.06	-5.71	1.23	0.05	-68.66	2.49	0.11
	32	455.70	516	-7.03	1.51	0.07	-7.05	1.42	0.06	-76.84	2.83	0.12
	26	227.74	516	-6.36	1.27	0.06	-6.36	1.26	0.06	-80.23	3.54	0.16
	20	116.23	516	-4.34	1.53	0.07	-4.34	1.53	0.07	-79.03	10.63	0.47
	14	58.48	516	-7.62	2.36	0.10	-7.62	2.36	0.10	-47.47	75.32	3.32

Table 1-2: Libera single pass H readout (The Old Unit)

Shape No.	Amplifi. (dB)	Signal Amp Libera H (mV)	No. of Samples	Phase Mean (deg.)	St. of Phase (deg.)	St. of Mean (deg.)
Shape 1	50	800.91	516	-112.41	4.45	0.20
	44	463.84	516	-115.05	6.56	0.29
	38	244.96	516	-127.94	12.12	0.53
	32	149.11	516	48.94	153.11	6.74
Shape 2	50	200.27	516	-92.51	23.27	1.02
	44	118.97	516	-95.43	44.40	1.95
	38	112.40	516	-103.05	60.11	2.65
Shape 3	44	212.16	516	-33.51	23.61	1.04
	38	132.48	516	-41.99	38.52	1.70
	32	107.99	516	-51.39	40.09	1.77
	26	102.67	516	-54.17	47.28	2.08
	20	103.18	516	-52.04	46.78	2.06
	14	99.76	516	-59.16	48.31	2.13

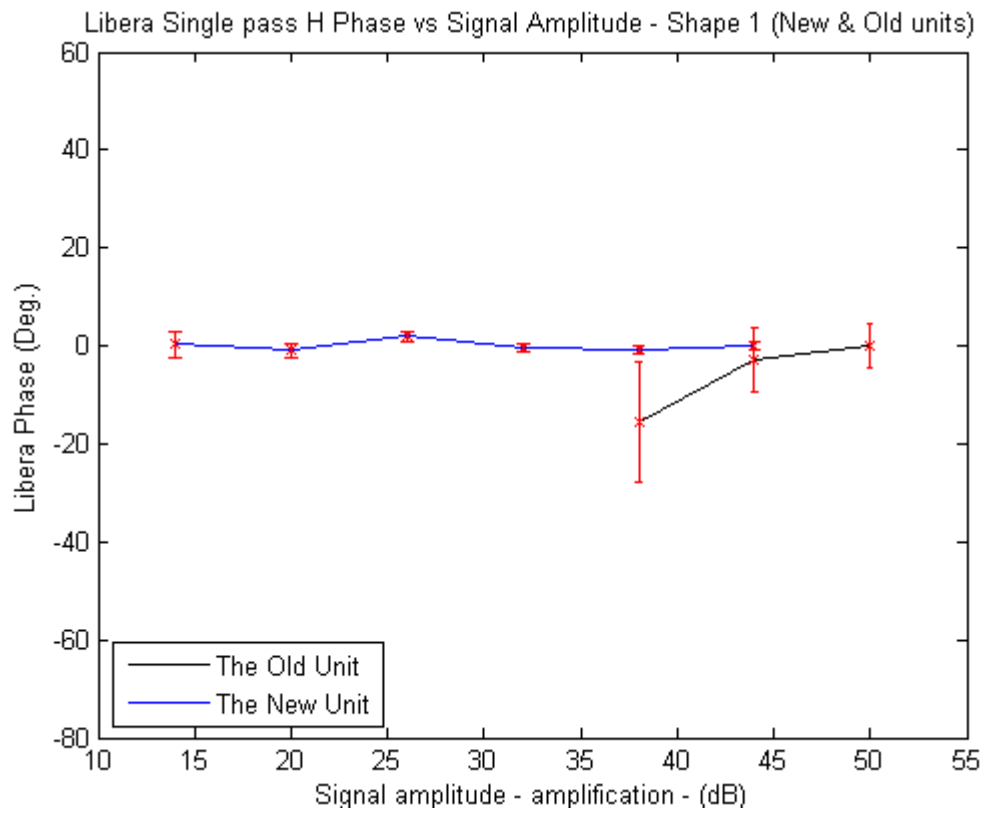


Figure 1-1: shape (1), Libera single pass H readout.

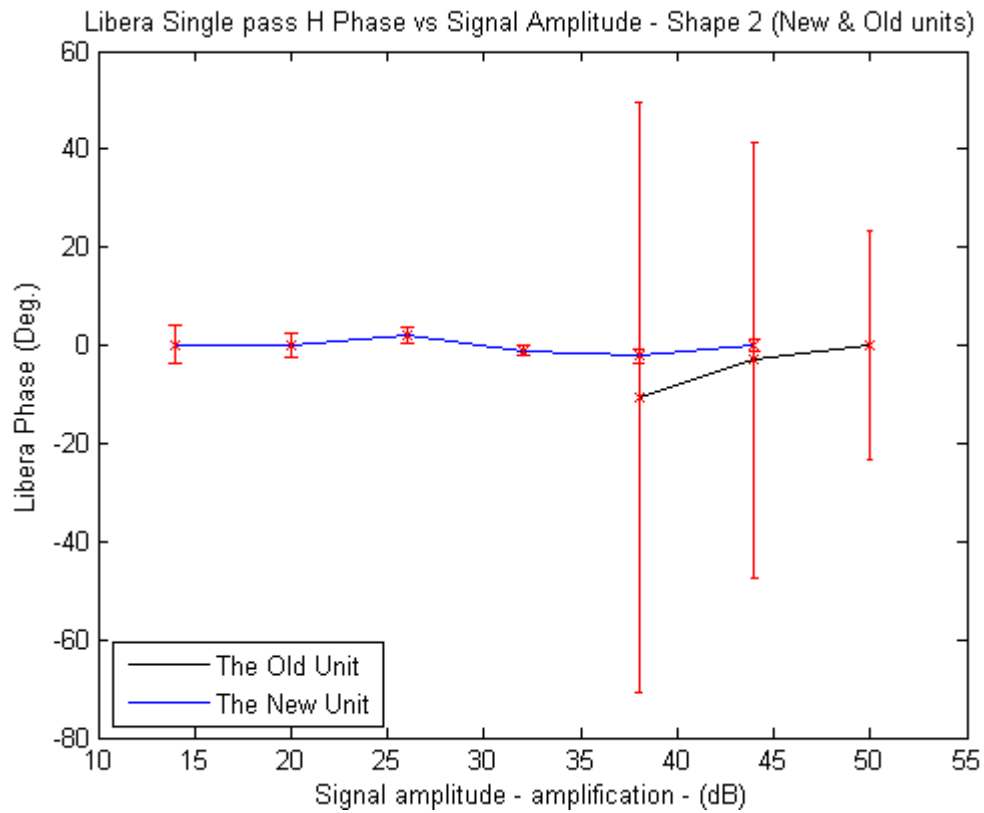


Figure 1-2: shape (2), Libera single pass H readout.

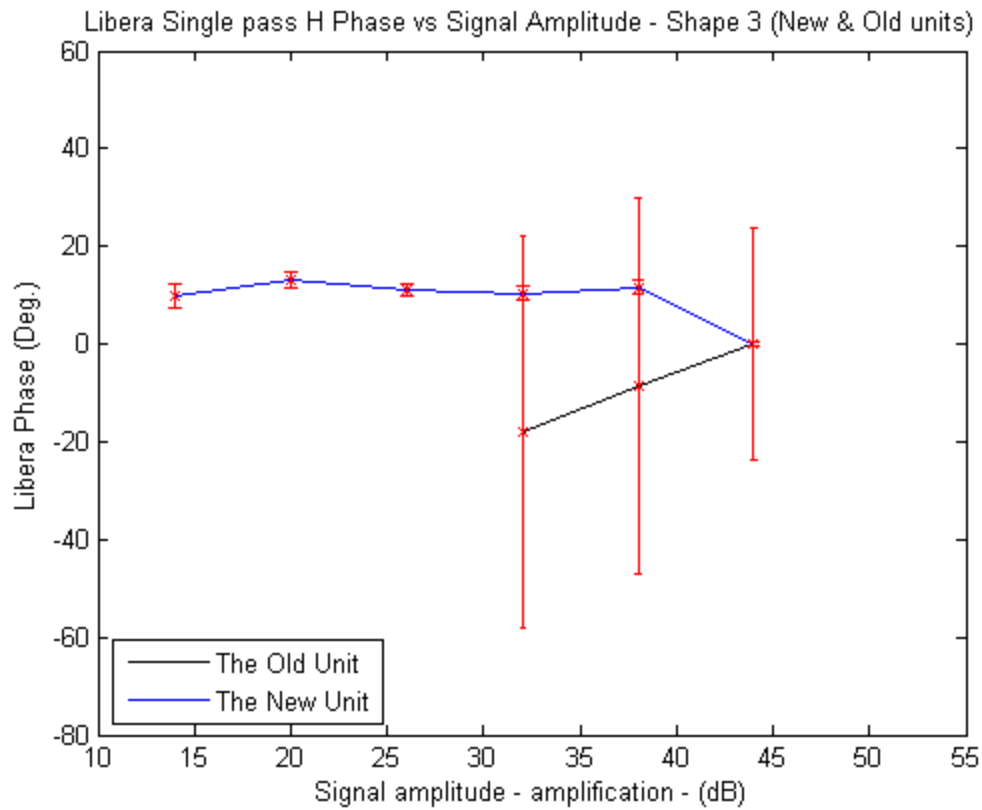


Figure 1-3: shape (3), Libera single pass H readout.

➤ **Part 2 : Phase Evaluation (Seven Bunch Shapes)**

1- Libera single pass H measurements (from BPM and Phase probe).

With the aim to get a better understanding of the Libera H characteristics and, in particular, its act with different bunch shapes to find possible gain improvements, systematic measurements were carried out at three amplitude levels 44, 32 and 20 dB. This section presents Libera H phase evaluation for the experimental results for seven bunch shapes. Then, Libera H results were compared with the time-domain processing along with the FFT analytical calculations.

From the oscilloscope, time-domain data were taken for all bunches. The phase was evaluated in time domain based on time differences determined by zero crossing points in respect to the first bunch shape. From time-domain data, the phase were calculated using FFT for one bunch. In addition, for each bunch shape, a stream of bunches were stored for further calculations (16000000 samples corresponding to 177000 bunches). For memory limitation, 30000 bunches were used for FFT calculations.

Three things shall be pointed out: first, the amplitude level detected by Libera H is influenced by the bunch shape. For example, Libera H records 1.05 V for shape 1 after 44 dB pre-amplification while it is 0.577 V for shape 7. Second, all bunches were triggered on the RF acceleration frequency. However, in time domain processing, zero crossing points were determined in respect to bunch 1.

In order to have a base for further investigations, the phase for each bunch shape were measured by Libera H using two methodes. First, as Libera H the input signals come from the BPM (four PUs). Second, the input signals were taken from phase probe and splited into four cables before they feed to Libera H.

Observations and Results

- **Libera H measurements,**

1- Very good agreement between BPM and phase probe readouts with only one exption appears with shape 7 (blue readout in Table 2-1 & 2-2). All results are summarized in tables 2-1, 2-2, 2-3 and 2-4. For all bunch shapes, Libera H phase readout and the standard deviation versus signal amplification can be seen in Figures 2-1, 2-2 and 2-3 using BPM and 2-4, 2-5 and 2-6 using phase probe.

2- With 44 dB and 32 dB pre-amplification, Libera H readouts show good resolution with standard deviation less than 1° for most of shapes (only two cases) shown in table 2-1 and 2-3.

3- Table 2-3 and 2-6 summarize Libera H results in respect to shape 1. More plots about this section can found in appendix 2.

Table 2 -1: Libera H phase readout using BPM signals

Shape No.	Amplifi. (dB)	Signal Amp Libera H (mV)	No. of Samples	Phase Mean (deg.)	St of Phase (deg.)	St of Mean (deg.)	1 st Harmo. 108.4 (MHz)	St of Phase (deg.)	St of Mean (deg.)	2 nd Harmo. 216 (MHz)	St of Phase (deg.)	St of Mean (deg.)
1	44	1050.46	516.00	-12.87	0.57	0.03	-12.84	0.44	0.02	-75.46	0.87	0.04
2	44	1023.43	516.00	-13.45	0.67	0.03	-13.48	0.54	0.02	-76.92	1.11	0.05
3	44	982.78	516.00	-10.22	0.82	0.04	-10.15	0.57	0.03	-72.91	1.39	0.06
4	44	936.09	516.00	-7.82	0.87	0.04	-7.75	0.64	0.03	-70.34	1.49	0.07
5	44	860.35	516.00	-3.87	0.70	0.03	-3.85	0.67	0.03	-70.92	1.90	0.08
6	44	858.56	516.00	-1.98	1.09	0.05	-1.87	0.69	0.03	-65.35	1.91	0.08
7	44	577.11	516.00	16.91	0.89	0.04	16.91	0.89	0.04	-157.58	6.36	0.28
1	32	258.06	516.00	-17.74	0.72	0.03	-17.74	0.64	0.03	-94.18	2.05	0.09
2	32	248.49	516.00	-13.66	0.72	0.03	-13.65	0.67	0.03	-88.46	2.15	0.09
3	32	241.29	516.00	-10.33	0.87	0.04	-10.31	0.75	0.03	-83.86	2.41	0.11
4	32	227.46	516.00	-8.05	0.80	0.04	-8.06	0.78	0.03	-82.78	3.04	0.13
5	32	213.24	516.00	-4.91	0.82	0.04	-4.94	0.79	0.03	-81.02	3.48	0.15
6	32	201.30	516.00	-1.30	0.97	0.04	-1.30	0.97	0.04	-80.34	4.32	0.19
7	32	139.62	516.00	16.45	1.36	0.06	16.45	1.36	0.06	-123.74	20.29	0.89
1	20	66.29	516.00	-18.04	1.70	0.07	-18.10	2.16	0.10	-96.12	6.83	0.30
2	20	62.67	516.00	-15.00	1.60	0.07	-15.12	2.33	0.10	-91.37	7.72	0.34
3	20	61.52	516.00	-11.81	1.83	0.08	-11.81	1.83	0.08	-87.79	8.78	0.39
4	20	59.13	516.00	-8.59	1.95	0.09	-8.59	1.95	0.09	-84.10	12.38	0.54
5	20	55.52	516.00	-5.85	2.13	0.09	-7.56	3.68	0.16	-81.71	13.10	0.58
6	20	50.64	516.00	-2.40	2.03	0.09	-2.40	2.03	0.09	-88.50	19.43	0.86
7	20	35.67	516.00	15.89	3.61	0.16	21.18	5.48	0.24	93.60	60.76	2.67

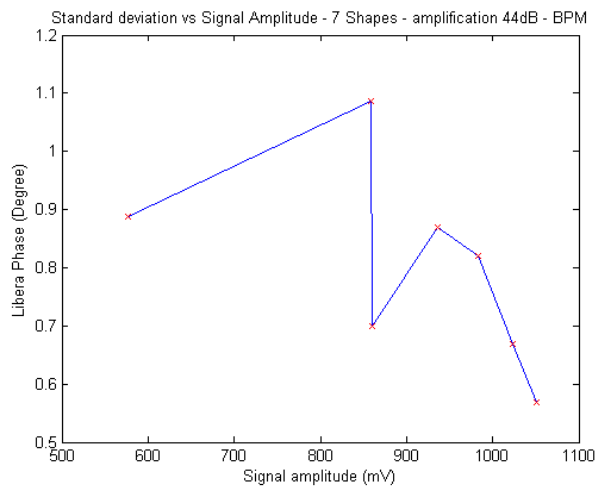
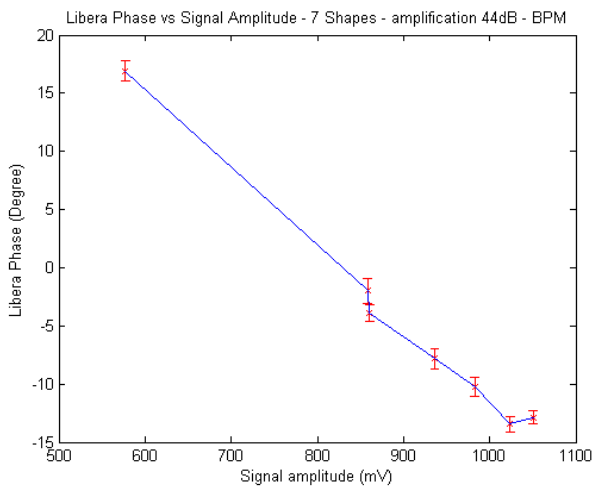


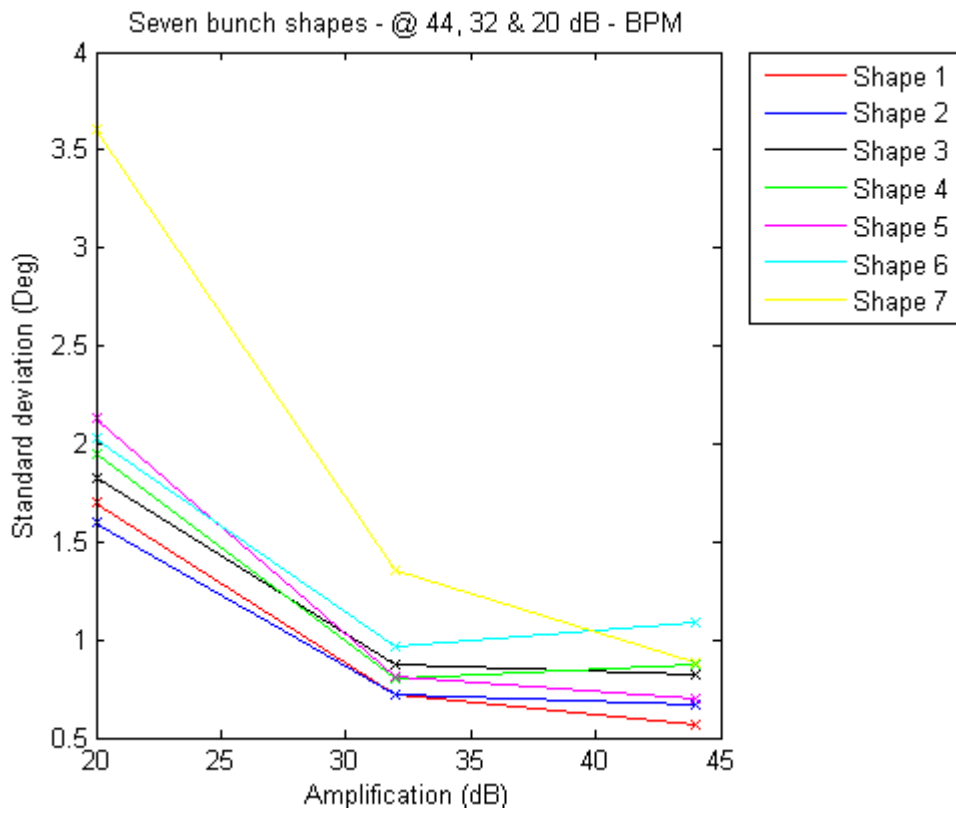
Figure: 2 -1, (left), Libera H phase readout versus BPM signals for all bunch shapes - and (right), the standard deviation.

Table 2 -2: Libera H phase readout using BPM signals

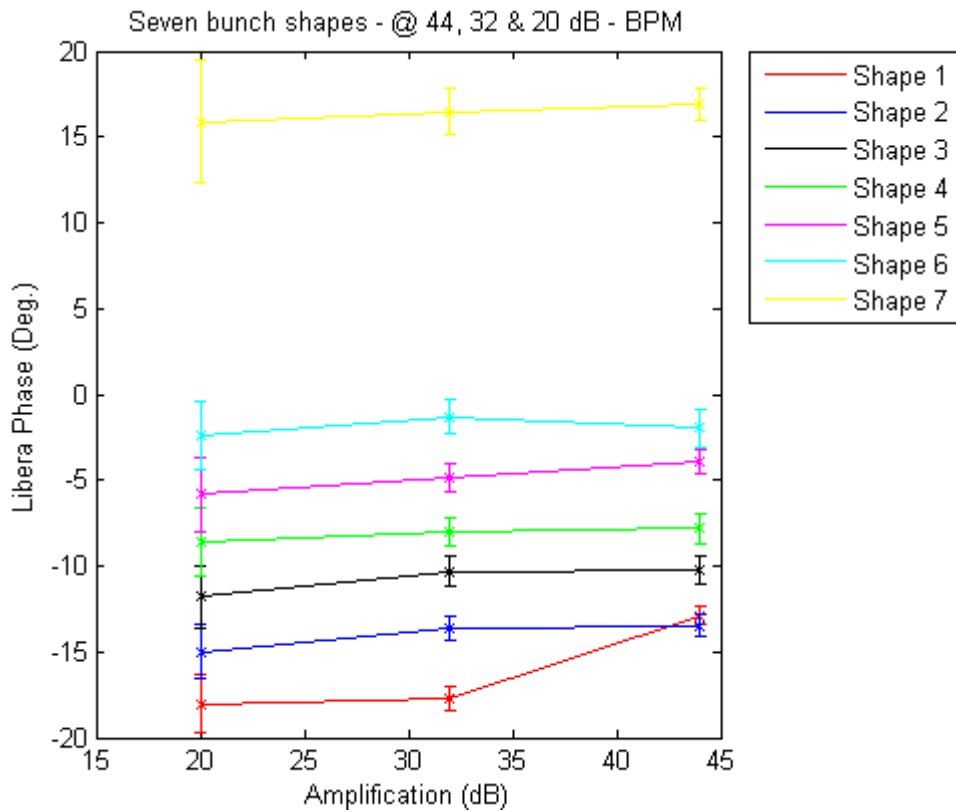
Shape No.	Amplifi. (dB)	Signal Amp Libera H (mV)	No Samp.	Phase Mean (deg.)	St of Phase (deg.)	St of Mean (deg.)	1 st Harmo. 108.4 (MHz)	St of Phase (deg.)	St of Mean (deg.)	2 nd Harmo. 216 (MHz)	St of Phase (deg.)	St of Mean (deg.)
1	44	1050.46	516	-12.87	0.57	0.03	-12.84	0.44	0.02	-75.46	0.87	0.04
	32	258.06	516	-17.74	0.72	0.03	-17.74	0.64	0.03	-94.18	2.05	0.09
	20	66.29	516	-18.04	1.70	0.07	-18.10	2.16	0.10	-96.12	6.83	0.30
2	44	1023.43	516	-13.45	0.67	0.03	-13.48	0.54	0.02	-76.92	1.11	0.05
	32	248.49	516	-13.66	0.72	0.03	-13.65	0.67	0.03	-88.46	2.15	0.09
	20	62.67	516	-15.00	1.60	0.07	-15.12	2.33	0.10	-91.37	7.72	0.34
3	44	982.78	516	-10.22	0.82	0.04	-10.15	0.57	0.03	-72.91	1.39	0.06
	32	241.29	516	-10.33	0.87	0.04	-10.31	0.75	0.03	-83.86	2.41	0.11
	20	61.52	516	-11.81	1.83	0.08	-11.81	1.83	0.08	-87.79	8.78	0.39
4	44	936.09	516	-7.82	0.87	0.04	-7.75	0.64	0.03	-70.34	1.49	0.07
	32	227.46	516	-8.05	0.80	0.04	-8.06	0.78	0.03	-82.78	3.04	0.13
	20	59.13	516	-8.59	1.95	0.09	-8.59	1.95	0.09	-84.10	12.38	0.54
5	44	860.35	516	-3.87	0.70	0.03	-3.85	0.67	0.03	-70.92	1.90	0.08
	32	213.24	516	-4.91	0.82	0.04	-4.94	0.79	0.03	-81.02	3.48	0.15
	20	55.52	516	-5.85	2.13	0.09	-7.56	3.68	0.16	-81.71	13.10	0.58
6	44	858.56	516	-1.98	1.09	0.05	-1.87	0.69	0.03	-65.35	1.91	0.08
	32	201.30	516	-1.30	0.97	0.04	-1.30	0.97	0.04	-80.34	4.32	0.19
	20	50.64	516	-2.40	2.03	0.09	-2.40	2.03	0.09	-88.50	19.43	0.86
7	44	577.11	516	16.91	0.89	0.04	16.91	0.89	0.04	-157.58	6.36	0.28
	32	139.62	516	16.45	1.36	0.06	16.45	1.36	0.06	-123.74	20.29	0.89
	20	35.67	516	15.89	3.61	0.16	21.18	5.48	0.24	93.60	60.76	2.67

Table 2-3:

Shape No	Libera H				Libera H				Libera H			
	44 dB from BPM (-17.74 is taken)				32 dB from BPM				20dB from BPM			
	Amp mV	Phase deg.	Phase - Ref(1) deg.	Phase - Ref(1) ns	Amp mV	Phase deg.	Phase - Ref(1) deg.	Phase - Ref(1) ns	Amp mV	Phase deg.	Phase - Ref(1) deg.	Phase - Ref(1) ns
1	1050.459	-12.87	0.00	0.00	258.06	-17.74	0.00	0.00	66.29	-18.04	0.00	0.00
2	1023.426	-13.45	4.29	118.41	248.49	-13.66	4.08	104.47	62.67	-15.00	3.04	77.65
3	982.7774	-10.22	7.52	201.15	241.29	-10.33	7.41	189.56	61.52	-11.81	6.23	159.45
4	936.093	-7.82	9.92	262.59	227.46	-8.05	9.69	247.92	59.13	-8.59	9.45	241.80
5	860.3462	-3.87	13.87	363.61	213.24	-4.91	12.83	328.33	55.52	-5.85	12.19	311.90
6	858.5626	-1.98	15.76	411.96	201.30	-1.30	16.44	420.47	50.64	-2.40	15.64	400.09
7	577.115	16.91	34.65	895.12	139.62	16.45	34.19	874.78	35.67	15.89	33.93	867.93



Figures 2-2: the standard deviation versus signal amplification



Figures 2-3: Libera H phase readout and the standard deviation versus signal amplification

Table 2 -4: Libera H phase readout using Phase probe signals

Shape No.	Amplifi. (dB)	Signal Amp Libera H (mV)	No. of Samples	Phase Mean (deg.)	St of Phase (deg.)	St of Mean (deg.)	1 st Harmo. 108.4 (MHz)	St of Phase (deg.)	St of Mean (deg.)	2 nd Harmo. 216 (MHz)	St of Phase (deg.)	St of Mean (deg.)
1	44	1468.73	516.00	-64.99	0.62	0.03	-64.96	0.46	0.02	166.81	1.03	0.05
2	44	1425.84	516.00	-61.53	0.62	0.03	-61.50	0.44	0.02	171.44	0.79	0.03
3	44	1366.42	516.00	-58.71	0.86	0.04	-58.73	0.82	0.04	173.62	2.00	0.09
4	44	1301.45	516.00	-55.69	0.74	0.03	-55.65	0.59	0.03	176.52	1.33	0.06
5	44	1224.64	516.00	-53.40	0.81	0.04	-53.39	0.78	0.03	165.88	6.82	0.30
6	44	1191.54	516.00	-49.71	0.71	0.03	-49.71	0.71	0.03	112.85	5.43	0.24
7	44	448.10	516.00	-64.46	2.72	0.12	-62.89	3.38	0.15	68.73	14.51	0.64
1	32	370.71	516.00	-63.68	0.75	0.03	-63.65	0.53	0.02	161.32	1.15	0.05
2	32	351.44	516.00	-60.00	0.67	0.03	-59.96	0.46	0.02	165.76	1.10	0.05
3	32	323.46	516.00	-54.24	0.77	0.03	-54.22	0.63	0.03	171.26	1.87	0.08
4	32	312.54	516.00	-51.69	0.75	0.03	-51.85	0.84	0.04	173.21	2.89	0.13
5	32	290.72	516.00	-48.96	0.83	0.04	-49.04	0.84	0.04	170.67	3.45	0.15
6	32	292.78	516.00	-48.84	0.70	0.03	-48.84	0.70	0.03	168.68	3.19	0.14
7	32	113.90	516.00	-61.41	2.91	0.13	-50.71	3.32	0.15	53.49	14.64	0.64
1	20	95.96	516.00	-63.24	1.10	0.05	-63.34	0.93	0.04	155.04	3.10	0.14
2	20	93.19	516.00	-59.91	1.07	0.05	-59.98	0.96	0.04	159.72	3.89	0.17
3	20	84.15	516.00	-53.45	1.24	0.05	-49.85	9.58	0.42	162.02	26.48	1.17
4	20	81.49	516.00	-51.14	1.44	0.06	-51.14	1.44	0.06	152.50	11.83	0.52
5	20	78.24	516.00	-48.54	1.35	0.06	-49.53	1.47	0.06	121.53	8.41	0.37
6	20	78.66	516.00	-47.85	1.38	0.06	-47.85	1.38	0.06	154.44	44.89	1.98
7	20	31.22	516.00	-59.78	3.98	0.18	74.75	93.24	4.10	36.11	50.71	2.23

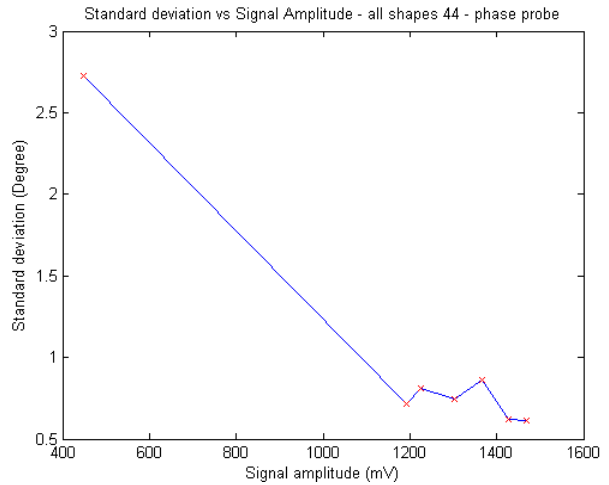
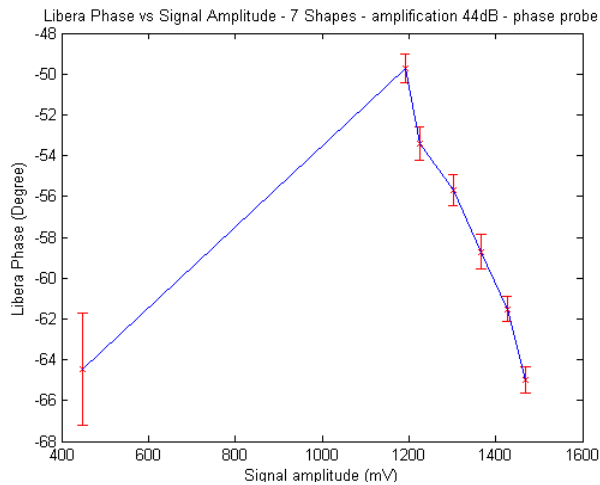


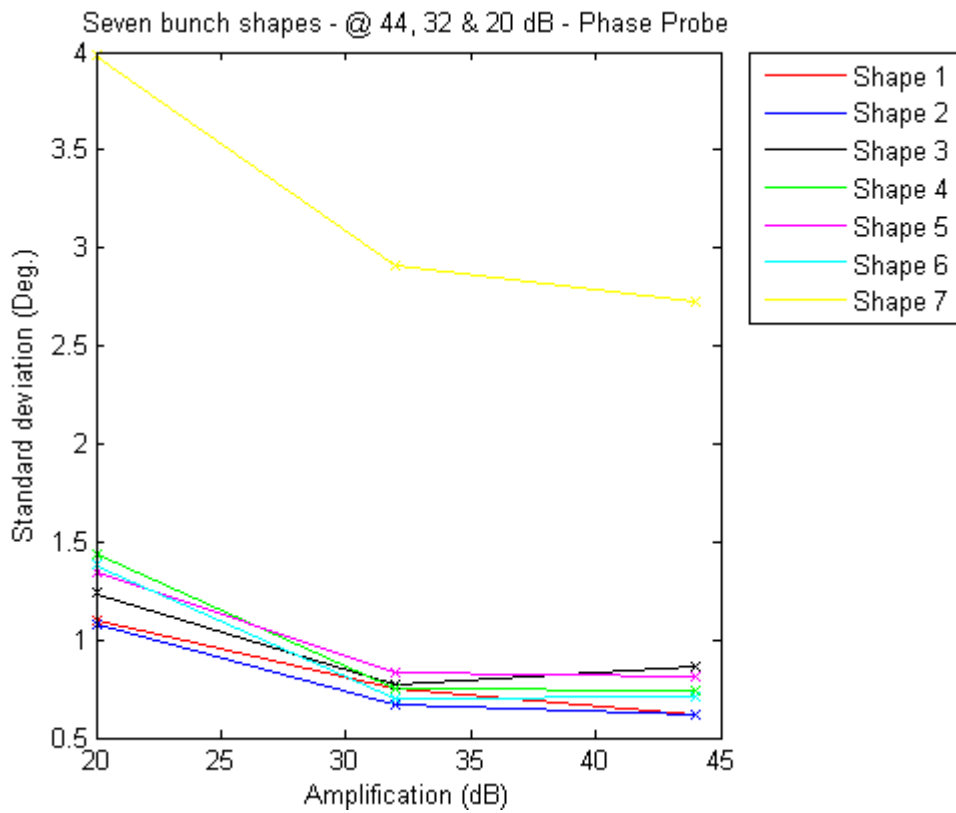
Figure 2 -4, (left), Libera H phase readout versus phase probe signals for all bunch shapes - and (right), the standard deviation.

Table 2 -5, Libera H phase readout using Phase probe signals

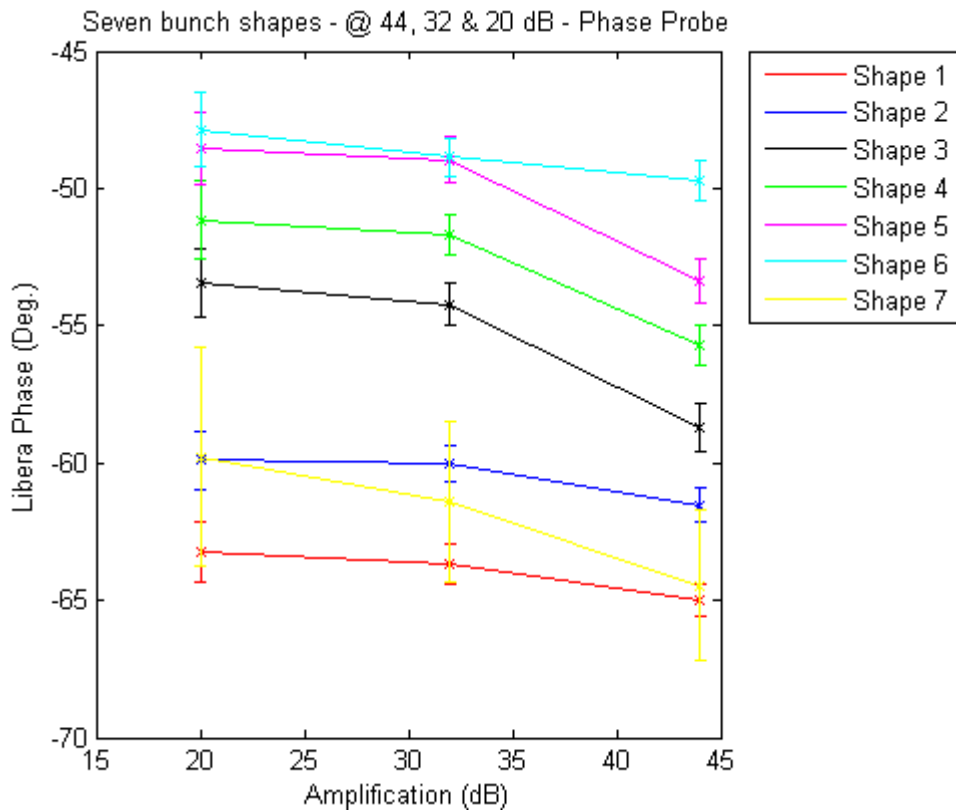
Shape No.	Amplifi. (dB)	Signal Amp Libera H (mV)	No Samp.	Phase Mean (deg.)	St of Phase (deg.)	St of Mean (deg.)	1 st Harmo. 108.4 (MHz)	St of Phase (deg.)	St of Mean (deg.)	2 nd Harmo. 216 (MHz)	St of Phase (deg.)	St of Mean (deg.)
1	44	1468.73	516	-64.99	0.62	0.03	-64.96	0.46	0.02	166.81	1.03	0.05
	32	370.71	516	-63.68	0.75	0.03	-63.65	0.53	0.02	161.32	1.15	0.05
	20	95.96	516	-63.24	1.10	0.05	-63.34	0.93	0.04	155.04	3.10	0.14
2	44	1425.84	516	-61.53	0.62	0.03	-61.50	0.44	0.02	171.44	0.79	0.03
	32	351.44	516	-60.00	0.67	0.03	-59.96	0.46	0.02	165.76	1.10	0.05
	20	93.19	516	-59.91	1.07	0.05	-59.98	0.96	0.04	159.72	3.89	0.17
3	44	1366.42	516	-58.71	0.86	0.04	-58.73	0.82	0.04	173.62	2.00	0.09
	32	323.46	516	-54.24	0.77	0.03	-54.22	0.63	0.03	171.26	1.87	0.08
	20	84.15	516	-53.45	1.24	0.05	-49.85	9.58	0.42	162.02	26.48	1.17
4	44	1301.45	516	-55.69	0.74	0.03	-55.65	0.59	0.03	176.52	1.33	0.06
	32	312.54	516	-51.69	0.75	0.03	-51.85	0.84	0.04	173.21	2.89	0.13
	20	81.49	516	-51.14	1.44	0.06	-51.14	1.44	0.06	152.50	11.83	0.52
5	44	1224.64	516	-53.40	0.81	0.04	-53.39	0.78	0.03	165.88	6.82	0.30
	32	290.72	516	-48.96	0.83	0.04	-49.04	0.84	0.04	170.67	3.45	0.15
	20	78.24	516	-48.54	1.35	0.06	-49.53	1.47	0.06	121.53	8.41	0.37
6	44	1191.54	516	-49.71	0.71	0.03	-49.71	0.71	0.03	112.85	5.43	0.24
	32	292.78	516	-48.84	0.70	0.03	-48.84	0.70	0.03	168.68	3.19	0.14
	20	78.66	516	-47.85	1.38	0.06	-47.85	1.38	0.06	154.44	44.89	1.98
7	44	448.10	516	-64.46	2.72	0.12	-62.89	3.38	0.15	68.73	14.51	0.64
	32	113.90	516	-61.41	2.91	0.13	-50.71	3.32	0.15	53.49	14.64	0.64
	20	31.22	516	-59.78	3.98	0.18	74.75	93.24	4.10	36.11	50.71	2.23

Table 2-6;

Shape No	Libera H				Libera H				Libera H			
	44 dB from Phase Probe				32 dB from Phase Probe				20dB from Phase Probe			
	Amp mV	Phase deg.	Phase - Ref(1) deg.	Phase - Ref(1) ns	Amp mV	Phase deg.	Phase - Ref(1) deg.	Phase - Ref(1) ns	Amp mV	Phase deg.	Phase - Ref(1) deg.	Phase - Ref(1) ns
1	1468.725	-64.99	0.00	0.00	370.71	-63.68	0.00	0.00	95.96	-63.24	0.00	0.00
2	1425.842	-61.53	3.46	118.41	351.44	-60.00	3.68	94.10	93.19	-59.91	3.33	85.25
3	1366.424	-58.71	6.28	201.15	323.46	-54.24	9.44	241.47	84.15	-53.45	9.79	250.55
4	1301.449	-55.69	9.30	262.59	312.54	-51.69	11.99	306.75	81.49	-51.14	12.10	309.58
5	1224.643	-53.40	11.59	363.61	290.72	-48.96	14.73	376.72	78.24	-48.54	14.70	376.02
6	1191.536	-49.71	15.28	411.96	292.78	-48.84	14.84	379.64	78.66	-47.85	15.39	393.70
7	448.0994	-64.46	0.53	895.12	113.90	-61.41	2.27	58.02	31.22	-59.78	3.47	88.69



Figures 2-5: the standard deviation versus signal amplification.



Figures 2-6: Libera H phase readout and the standard deviation versus signal amplification.

- Time-domain measurements,

From the oscilloscope, the data in time-domain are used as depicted in figure 2-7 and 2-8. The results of phase differences from zero crossing in respect to shape 1 are summarized in Table 2-1.

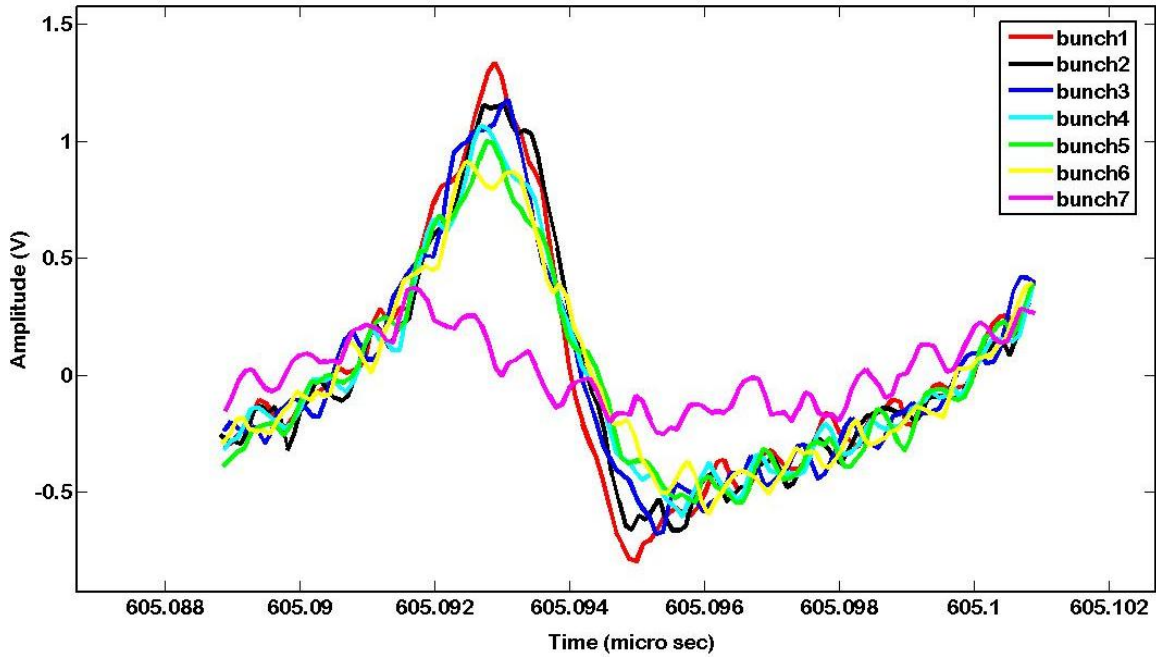


Figure 2-7: Seven bunch shapes reproduced from time-domain data from the oscilloscope.

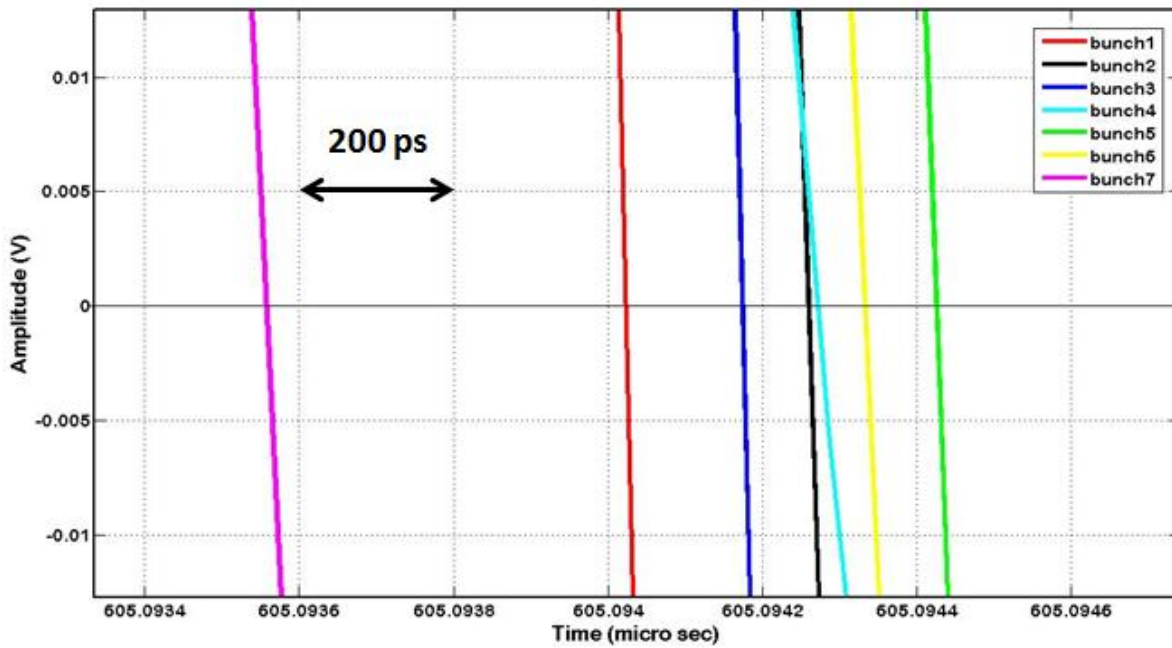


Figure 2-8: magnifying zero-crossing points, bunch 1 is chosen as reference shape.

Table 2-7: Time-domain quantities according to report 2 (06 September 2012), Zero-starting (Zs), Maximum (Max), Minimum (Min) and Zero-ending (Ze) with Zero-crossing (Zc) @ 108.408 MHz

Shape No.	Zc – Max (ns)	Zc – Zs (ns)	Max – Zs (ns)	Min – Zc (ns)	Min – Max (ns)	Min – Zs (ns)	Ze – Min (ns)	Ze – Zc (ns)	Ze – Max (ns)	Zc – Zc (1) (ps)	Zc – Zc (1) (deg.)
1	1.13	3.52	2.39	0.94	2.07	4.46	5.04	5.99	7.12	0.00	0.00
2	1.26	3.42	2.16	0.64	1.89	4.05	5.07	5.71	6.96	238	9.31
3	1.11	3.67	2.57	1.17	2.27	4.84	4.40	5.57	6.67	147	5.74
4	1.55	3.42	1.87	1.41	2.96	4.83	4.27	5.68	7.23	244	9.55
5	1.60	3.62	2.02	1.42	3.02	5.04	4.16	5.58	7.18	397	15.53
6	1.84	3.79	1.94	1.72	3.56	5.50	3.67	5.39	7.23	309	12.07
7	1.91	3.76	1.86	1.80	3.71	5.57	3.53	5.34	7.24	-468	-18.30

$360^\circ = 9.21 \text{ ns @ } 108.408 \text{ MHz}$

- [FFT calculations and comparison to Libera H,](#)

1- FFT calculations revealed an interesting aspect when the two methods were applied on time domain-data to calculate phase for each harmonic. The first is similar to what has been done in the previous report in which a single bunch was extracted from time-domain data and its interpolated curve was Fourier transformed after zero padding as it summarized in table 2-8. The second method is by taking the Fourier transformation for a stream of bunches (30000 bunches), table 2-9. An agreement between the two methods is observed. Libera H measurements, time-domain data and FFT calculations are summarized in table 2-10. Figures 2-9 and 2-10, show time-domain data versus Libera H, FFT calculations from BPM. Figure 2-11 and 2-12 time-domain data versus Libera H, FFT calculations from phase probe .

Table 2-8: FFT phase calculations using a single bunch.

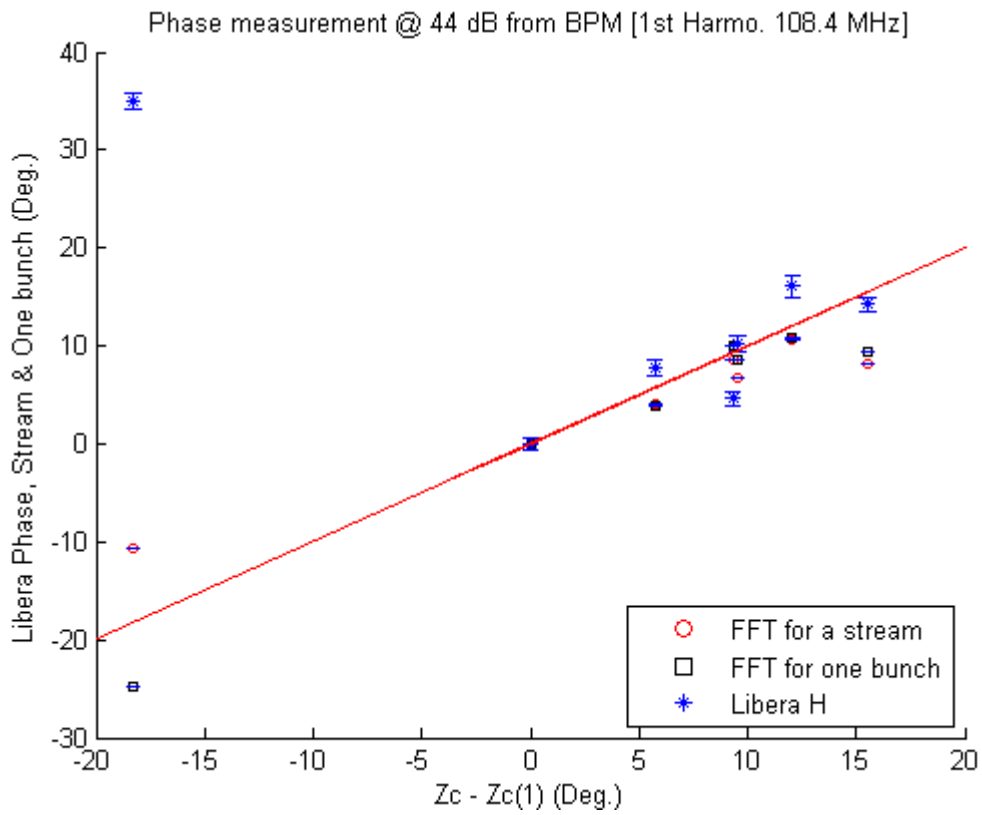
Shape No	1 st Harmo. 108.4 (MHz)	2 nd Harmo. 216.8 (MHz)	3 rd Harmo. 325.2 (MHz)	4 th Harmo. 433.6 (MHz)	5 th Harmo. 542 (ns)	6 th Harmo. 650.4 (MHz)	7 th Harmo. 758.8 (MHz)	8 th Harmo. 867.2 (MHz)	9 th Harmo. 975.6 (MHz)	Phase(1 st Harmo.) +117.88 (deg.)	Time diff from(1 st Harmo.) (ps)
1	-117.88	174.82	107.50	52.85	-1.87	-151.24	105.68	61.75	55.58	0.00	0.00
2	-107.96	-168.27	125.26	87.83	-11.91	151.82	125.11	65.46	46.85	9.92	253.77
3	-113.93	176.54	110.09	18.13	-116.38	-165.37	128.25	43.53	2.89	3.95	100.96
4	-109.24	-175.64	105.35	7.09	-122.43	-142.90	-64.44	108.73	95.96	8.63	220.83
5	-108.38	-176.84	107.31	-12.93	-80.72	178.01	102.73	145.25	15.01	9.50	243.03
6	-107.06	-173.23	111.24	6.57	-125.65	-89.83	-9.54	158.48	-11.47	10.81	276.60
7	-142.44	103.13	63.43	31.93	59.27	97.51	62.93	100.39	108.08	-24.68	-628.40

Table 2-9; FFT phase calculations using a single bunch.

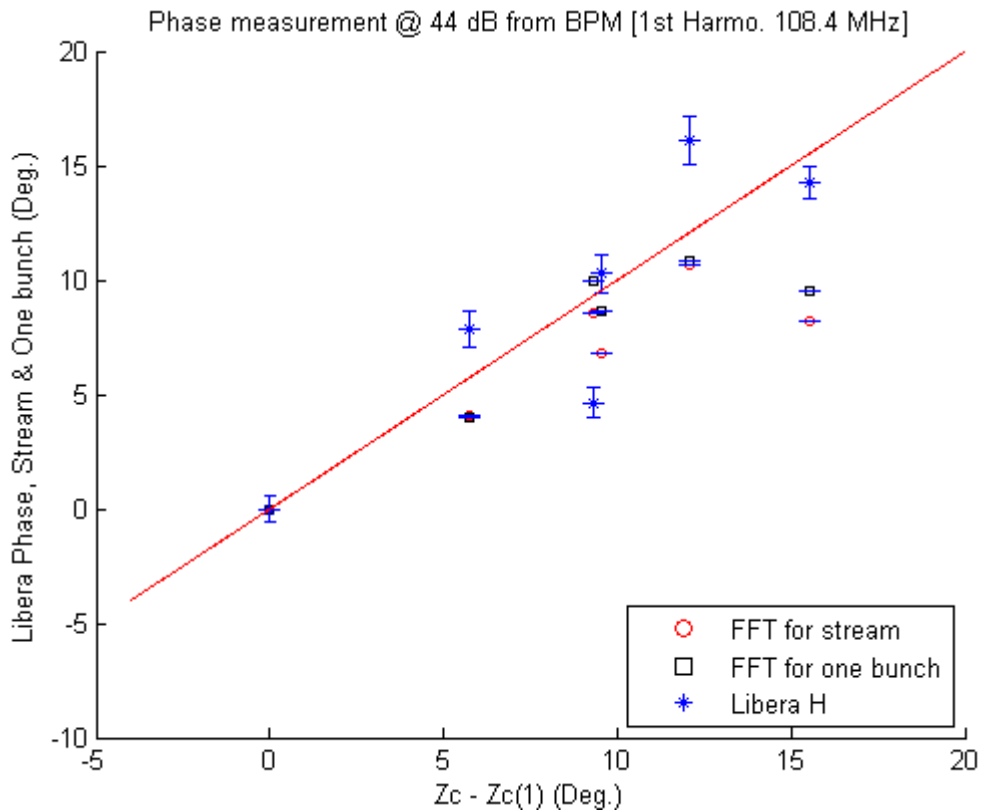
Shape No	1 st Harmo. 108.4 (MHz)	2 nd Harmo. 216.8 (MHz)	3 rd Harmo. 325.2 (MHz)	Phase(1 st Harmo.) +116.85 (deg.)	Time diff from(1 st Harmo.) (ps)
1	-116.85	174.46	109.66	0.00	0.00
2	-108.30	-171.32	128.82	8.54	218.57
3	-112.73	176.69	107.65	4.12	105.42
4	-110.07	-181.22	107.92	6.78	173.37
5	-108.68	-179.25	101.55	8.17	209.03
6	-106.18	-177.96	98.33	10.67	273.01
7	-127.44	77.81	61.70	-10.59	-270.97

Table 2-10;

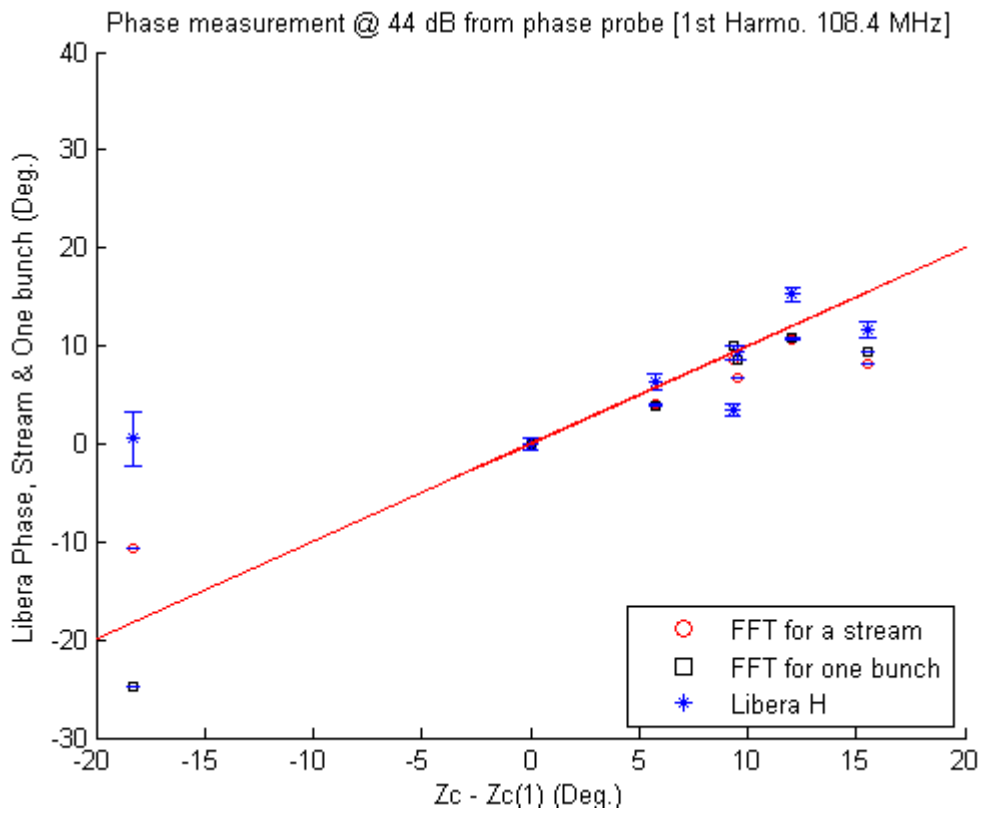
Shape No	Libera H (PUs)			Stream			One bunch			Time domain	
	Phase readout from (PUs)	Phase(1 st Harmo.) +18.08 (deg.)	Timediff from(1 st Harmo.) (ps)	Calcula. Phase	Phase(1 st Harmo.) +116.85 (deg.)	Timediff from(1 st Harmo.) (ps)	Calcula. Phase	Phase(1 st Harmo.) +117.88 (deg.)	Timediff from(1 st Harmo.) (ps)	Phase(1 st Harmo.) +117.88 (deg.)	Timediff from(1 st Harmo.) (ps)
1	-18.08	0.00	0.00	-116.85	0.00	0.00	-117.88	0.00	0.00	0.00	0.00
2	-13.45	4.63	118.45	-108.30	8.54	218.57	-107.96	9.92	253.77	9.31	238.00
3	-10.22	7.86	201.09	-112.73	4.12	105.42	-113.93	3.95	100.96	5.74	147.00
4	-7.82	10.26	262.49	-110.07	6.78	173.37	-109.24	8.63	220.83	9.55	244.00
5	-3.87	14.21	363.54	-108.68	8.17	209.03	-108.38	9.50	243.03	15.53	397.00
6	-1.98	16.10	411.89	-106.18	10.67	273.01	-107.06	10.81	276.60	12.07	309.00
7	16.91	34.99	895.16	-127.44	-10.59	-270.97	-142.44	-24.68	-628.40	-18.30	-468.00



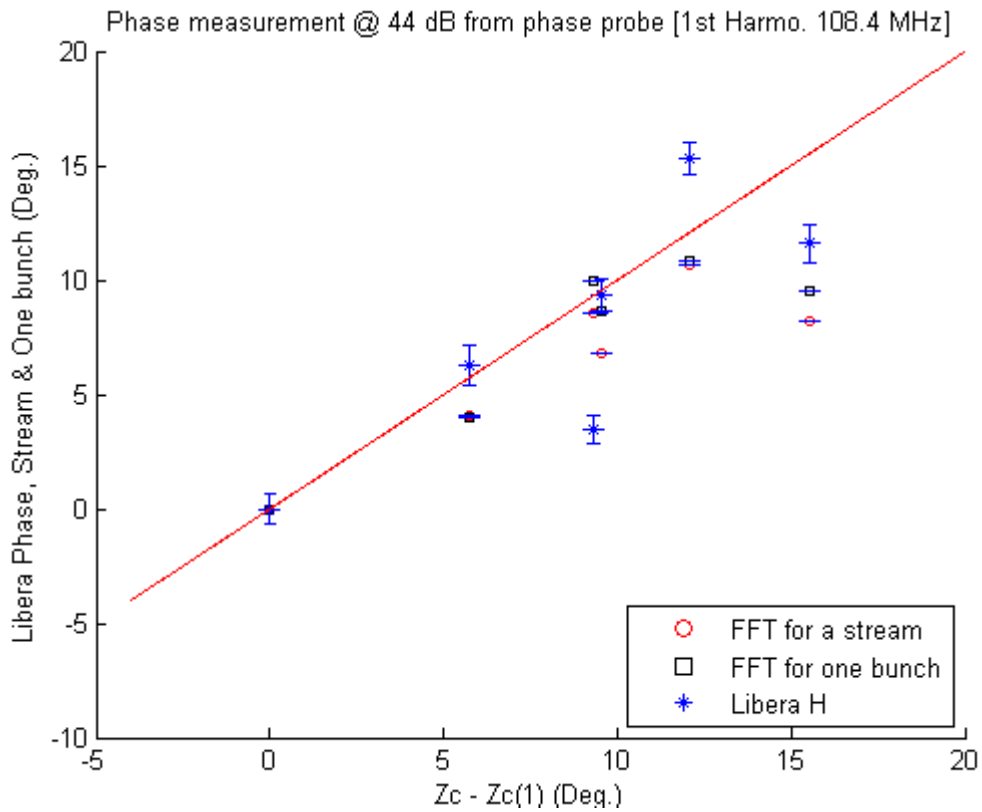
Figures 2-9: time-domain data versus Libera H, FFT calculations from BPM.



Figures 2-10: time-domain data versus Libera H, FFT calculations from BPM (shape 7 is excluded).



Figures 2-11: time-domain data versus Libera H, FFT calculations from phase probe.



Figures 2-12: time-domain data versus Libera H, FFT calculations from phase probe (shape 7 is excluded).

➤ **Part 3 : Beam Position test.**

Using the input amplification of 44 dB, the beam positions were measured by BPM (four PU electrodes) installed on the beam line and connected to Libera H. The aim of this experiment is to test Libera H position determination in comparison to grid profile measurements. The grid is placed between the BPM and the phase probe. Due to the preparation condition, only a number of beam positions were taken along x and y axes but not diagonally. After that, beam positions at -5, -3, 0, 3, 5 mm were set along x and y axis using (SEM) profile grid. The same settings were then repeated and the beam positions were measured by Libera H. This section discusses the results.

Observations and Results

1- Changing the beam position in y axis showed a coupling between axes. This influenced the output phase measured by Libera H as it shown in figure 3-2.

2- A summary of measurement is given in table 3-1.

Table 3-1:

X (mm)	Y (mm)	Phase Mean (deg.)	St of Phase (deg.)	Libera X (mm)	St. X (mm)	Libera Y (mm)	St. Y (mm)
0 (-0.05)	0 (0.03)	-30.2502	0.85	-0.04	-0.16	-0.07	-0.39
0 (0.19)	-5 (-5.00)	-28.462	0.52	-0.21	-0.13	-4.56	-0.28
0 (0.16)	-3 (-3.05)	-29.259	0.54	-0.17	-0.13	-2.82	-0.31
0 (-0.16)	3 (3.04)	-30.9785	0.99	0.03	0.18	3.43	0.59
0 (-0.23)	5 (4.96)	-31.6263	0.66	0.10	0.13	4.95	0.33
0 (0.10)	0 (0.01)	-30.6184	0.43	-0.04	-0.13	0.12	0.33
-5 (-4.96)	0 (-0.11)	3.831072	0.43	-4.03	-0.11	-1.04	-0.25
-3 (-2.96)	0 (0.26)	-9.63001	0.46	-2.46	-0.17	-0.60	-0.42
3 (2.99)	0 (-0.21)	-53.8679	0.72	2.49	0.13	0.94	0.34
5 (5.02)	0 (-0.66)	-72.2603	0.70	4.22	0.14	2.02	0.37

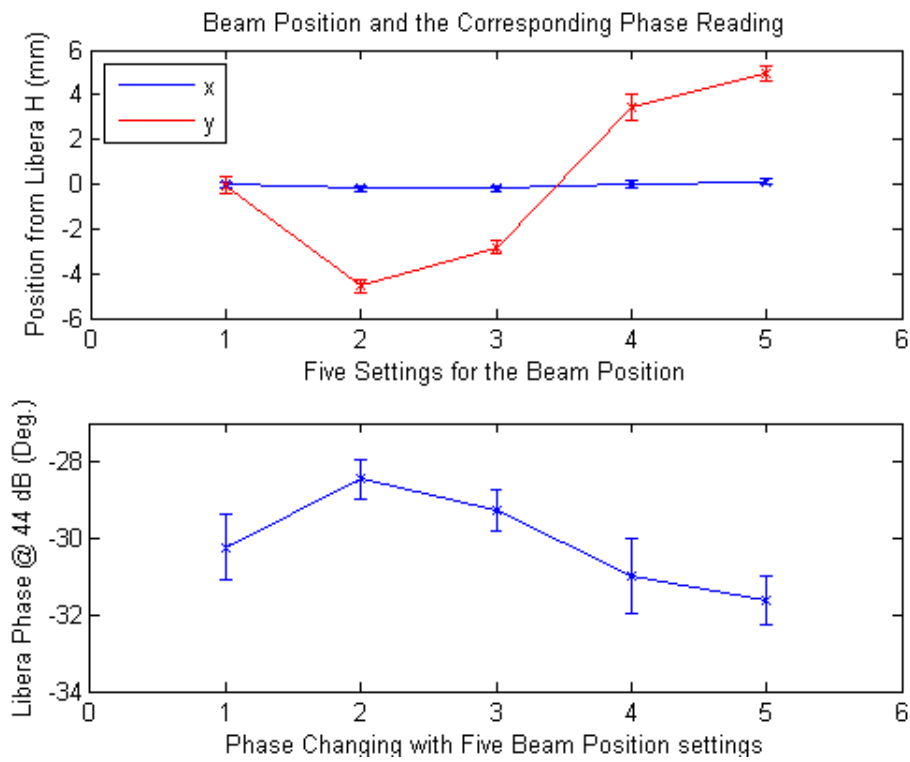


Figure 3-1, (up) beam position reading using Libera H, horizontal position (x) is fixed and vertical position is varied. (Down) the corresponding phase readout from Libera H.

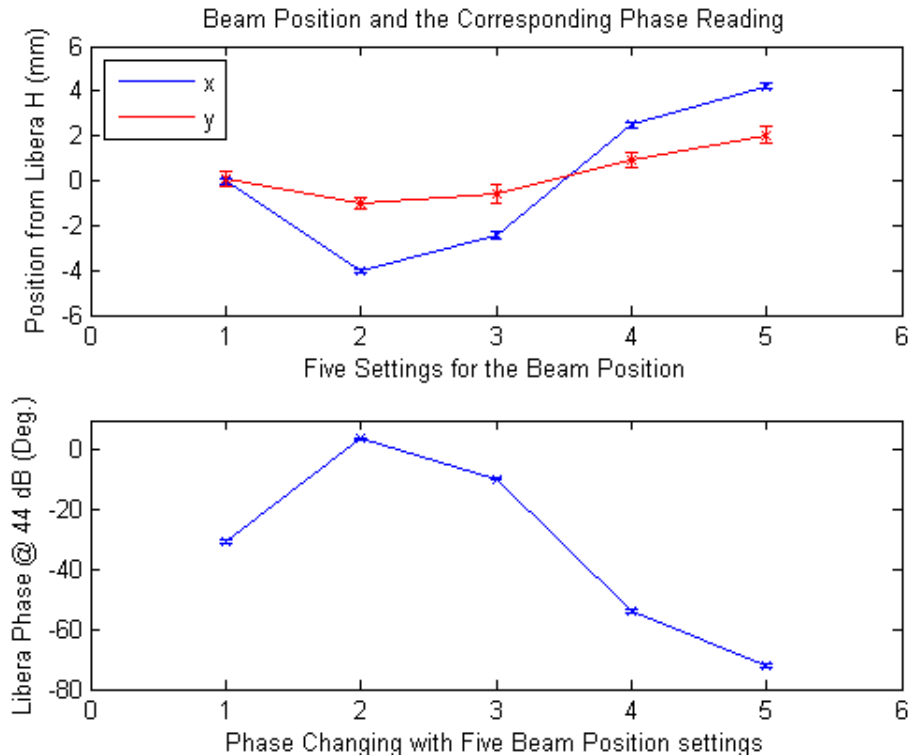
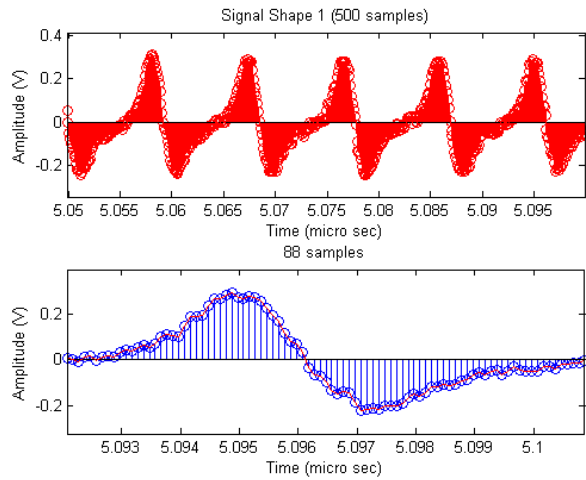


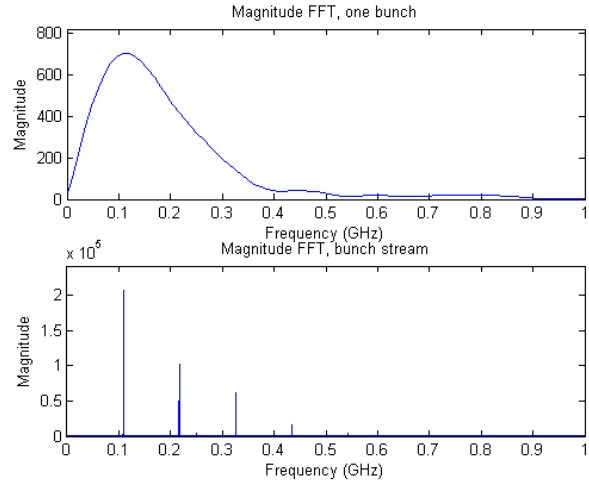
Figure 3-2, beam position reading using Libera H, vertical position (x) is fixed and horizontal position is varied. (Down) the corresponding phase readout from Libera H.

Appendix 1

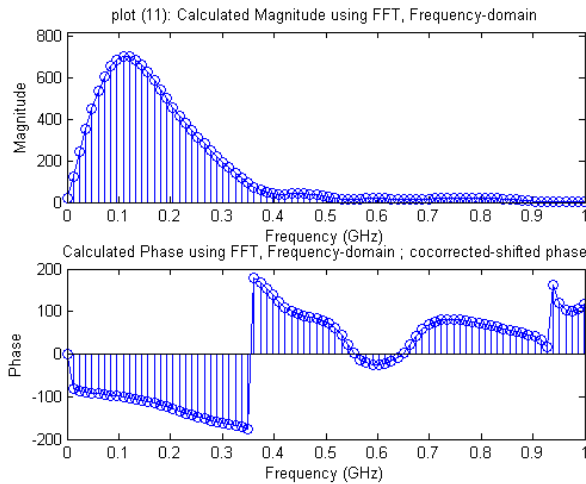
Shape 1



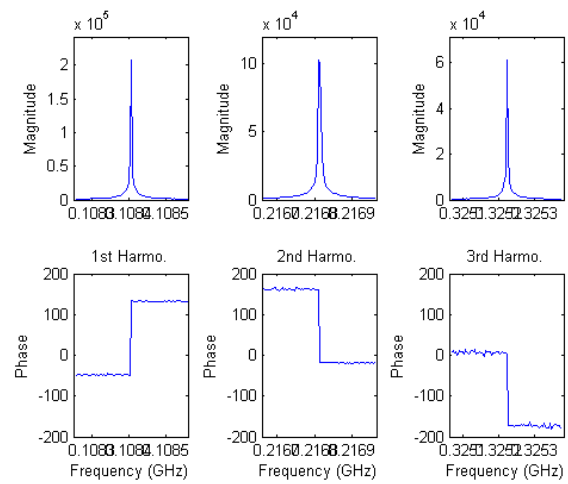
Plot 1-1, Time-domain data for a single bunch & for a sequence of bunches.



Plot 1-2, Amplitude spectrum using FFT for a single bunch (up) & a sequence (down).

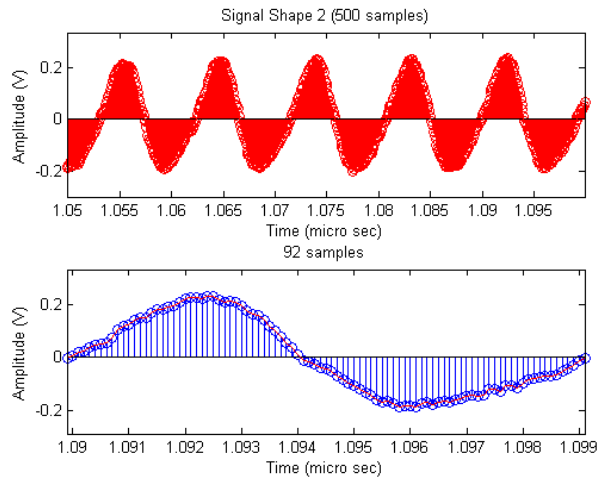


Plot 1-3, Amplitude (up) & phase (down) spectrums from FFT for a a single bunch.

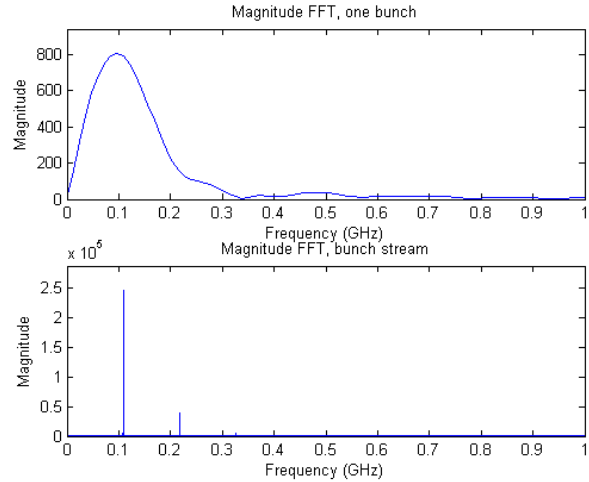


Plot 1-4, Amplitude (up) & phase (down) spectrums from FFT for a sequence of bunches.

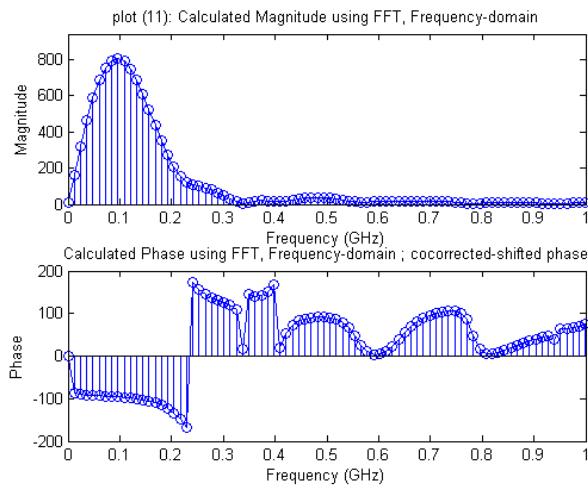
Shape 2



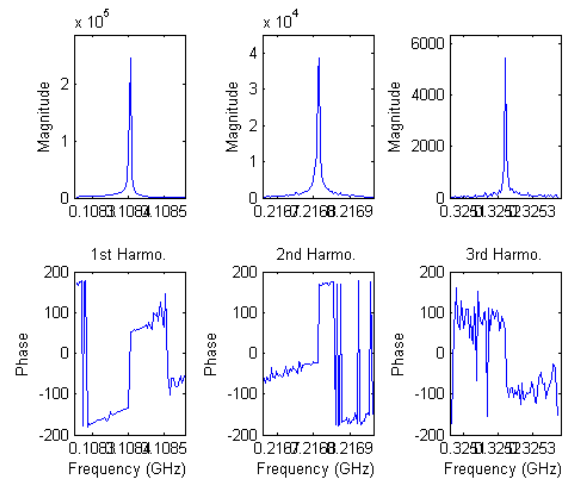
Plot 1-5, Time-domain data for a single bunch & for a sequence of bunches.



Plot 1-6, Amplitude spectrum using FFT for a single bunch (up) & a sequence (down).

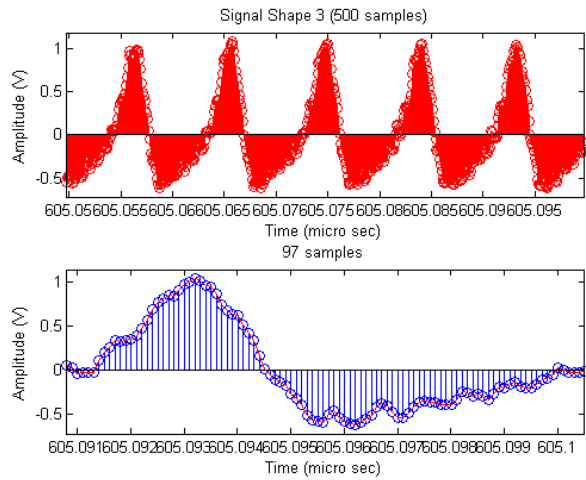


Plot 1-7, Amplitude (up) & phase (down) spectrums from FFT for a a single bunch.

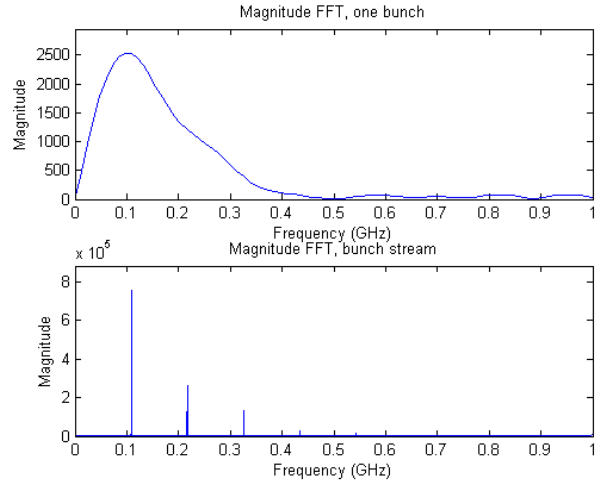


Plot 1-8, Amplitude (up) & phase (down) spectrums from FFT for a sequence of bunches.

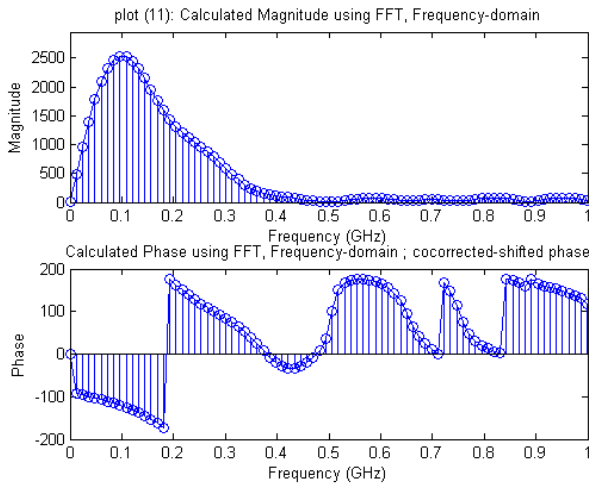
Shape 3



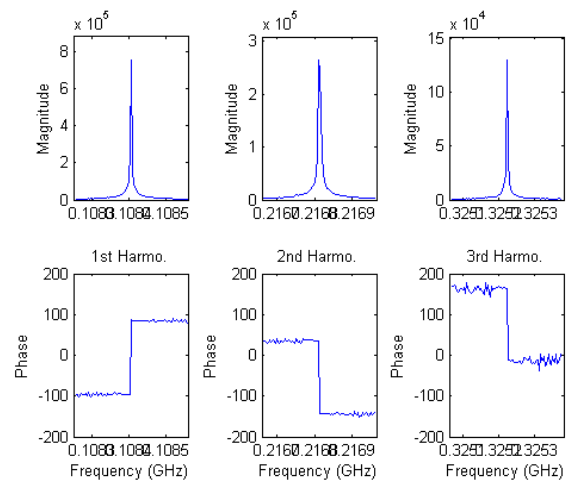
Plot 1-9, Time-domain data for a single bunch & for a sequence of bunches.



Plot 1-10, Amplitude spectrum using FFT for a single bunch (up) & a sequence (down).



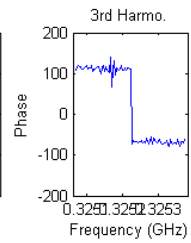
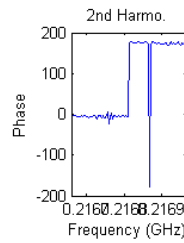
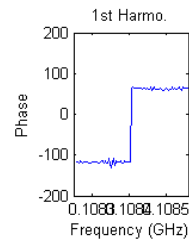
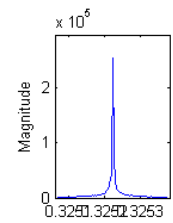
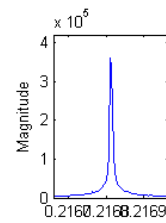
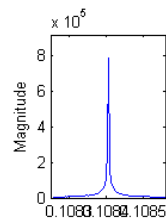
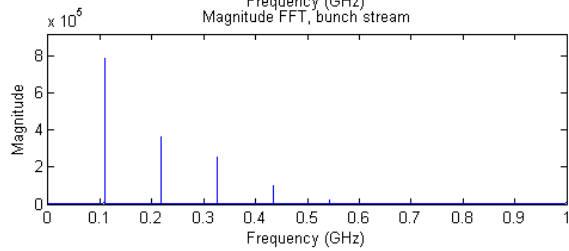
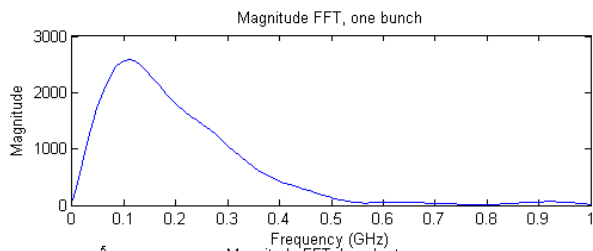
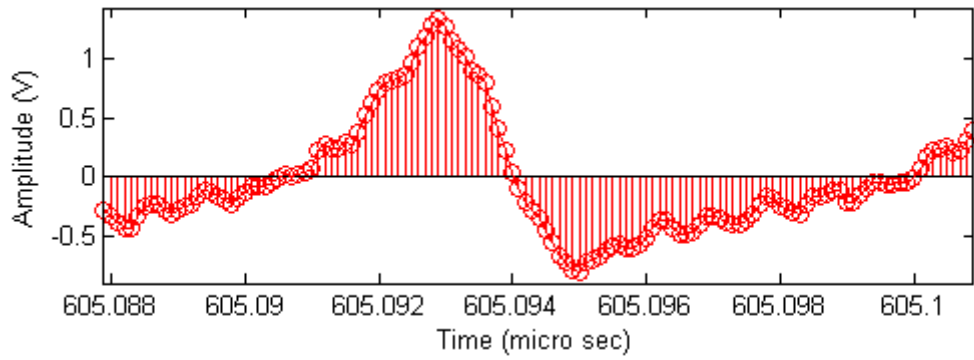
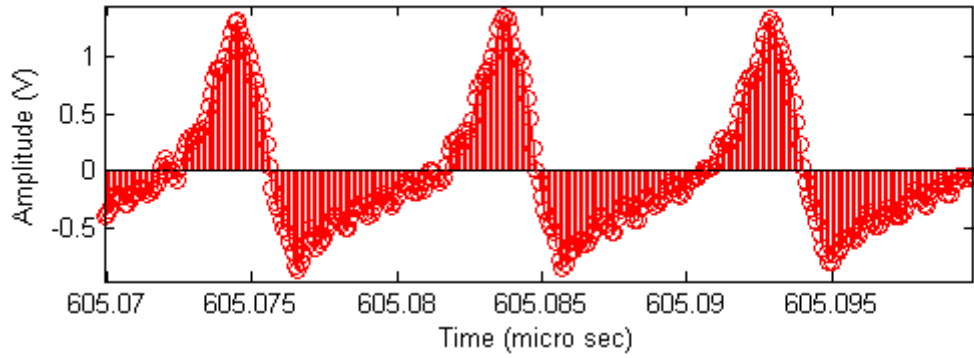
Plot 1-11, Amplitude (up) & phase (down) spectrums from FFT for a single bunch.



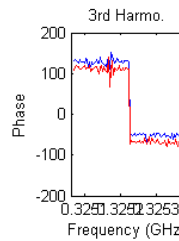
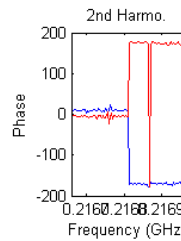
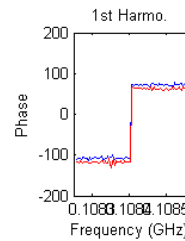
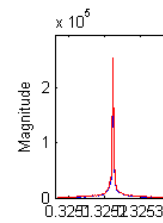
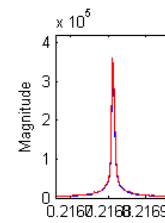
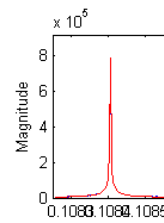
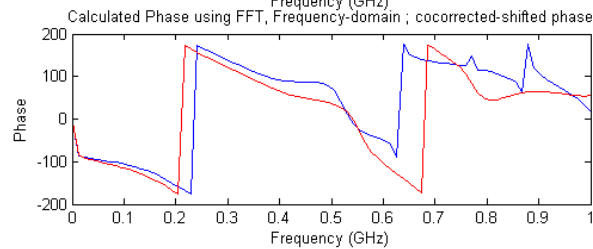
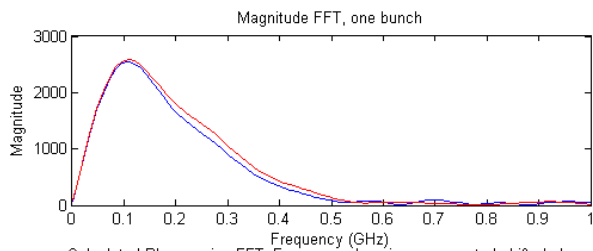
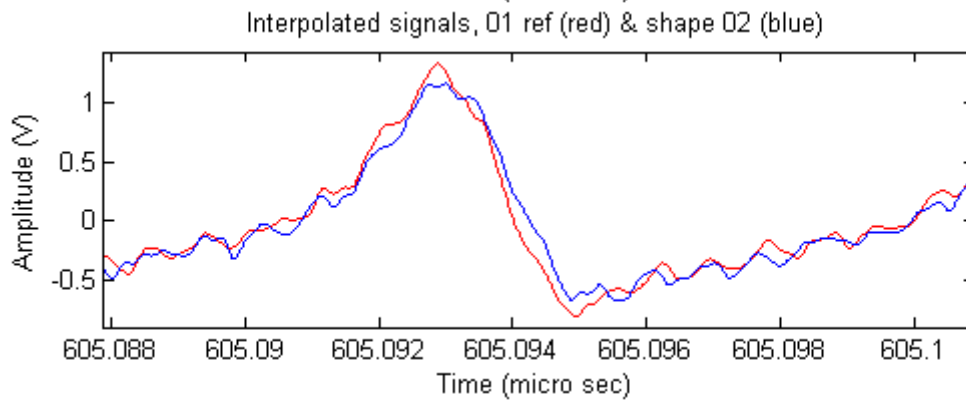
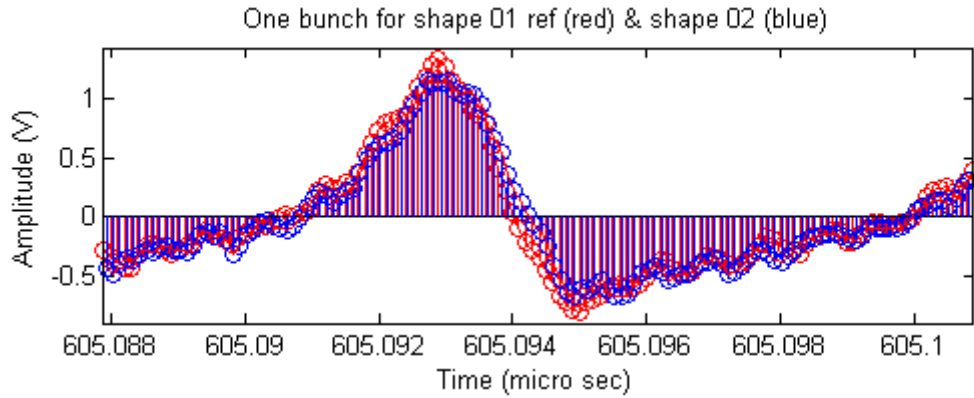
Plot 1-12, Amplitude (up) & phase (down) spectrums from FFT for a sequence of bunches.

Appendix 2

Signal Shape 1 - ref - (300 samples)

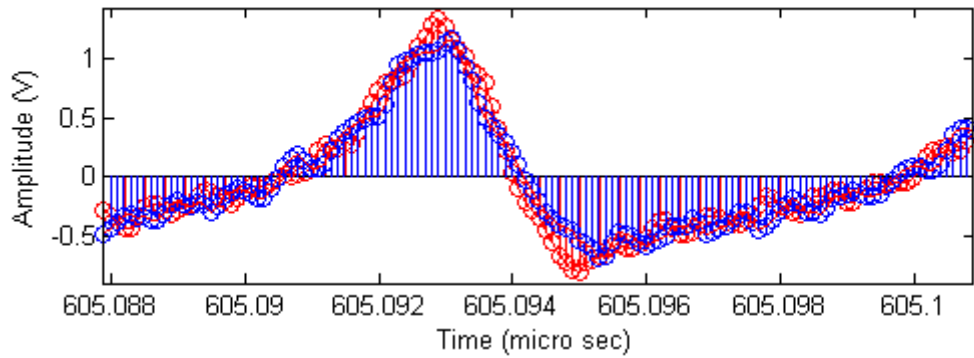


Shape 2

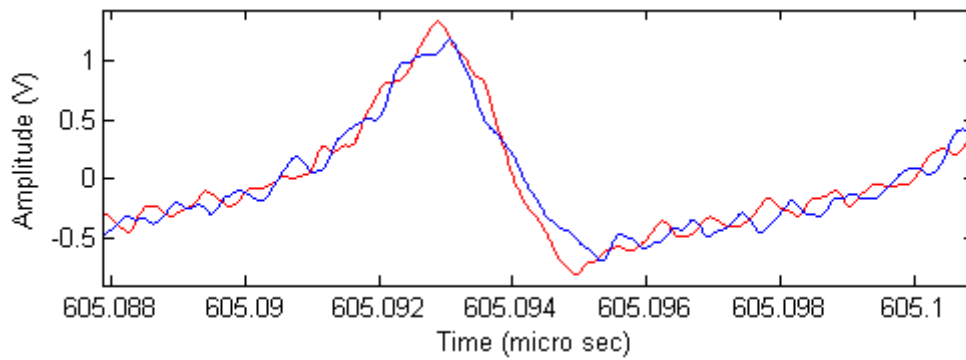


Shape 3

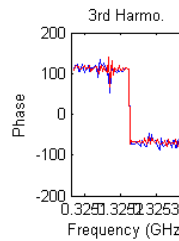
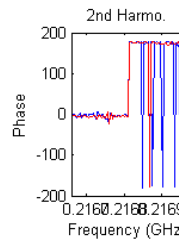
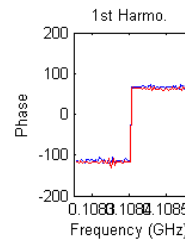
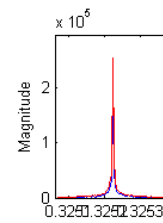
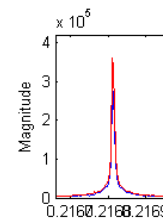
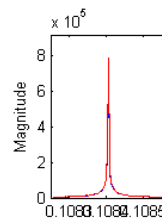
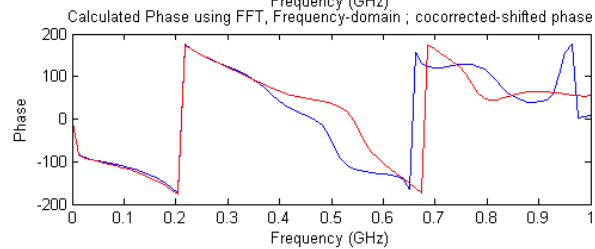
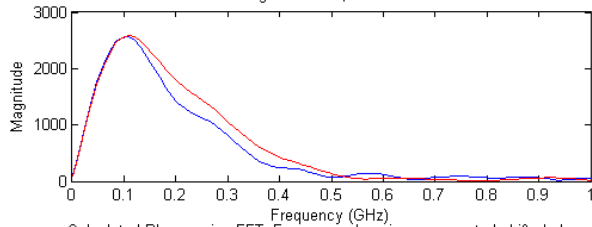
One bunch for shape 01 ref (red) & shape 03 (blue)



Interpolated signals, 01 ref (red) & shape 03 (blue)

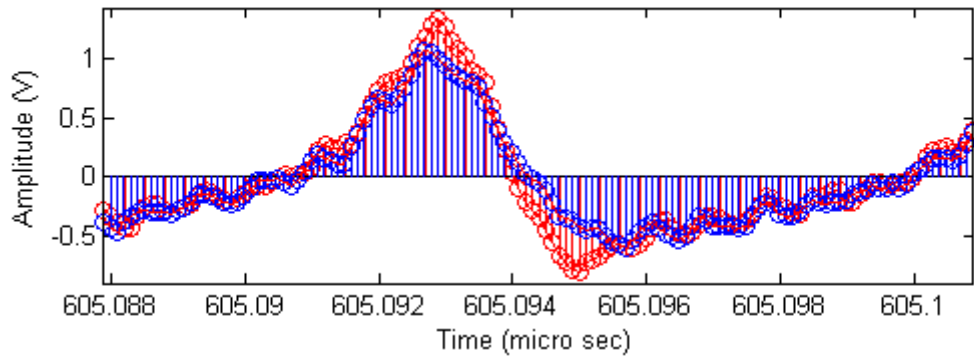


Magnitude FFT, one bunch

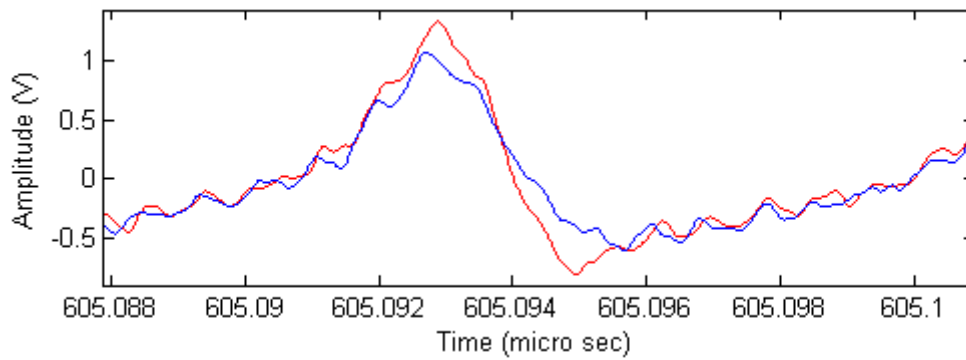


Shape 4

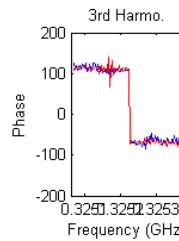
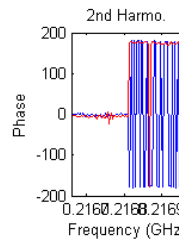
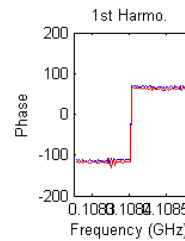
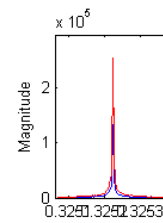
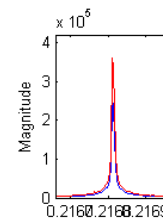
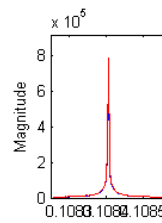
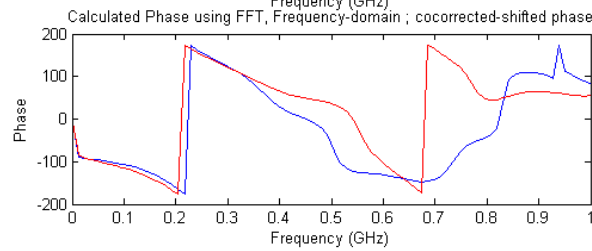
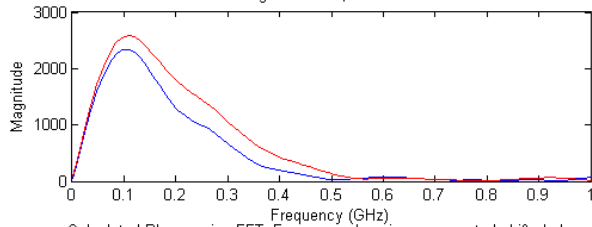
One bunch for shape 01 ref (red) & shape 04 (blue)



Interpolated signals, 01 ref (red) & shape 04 (blue)

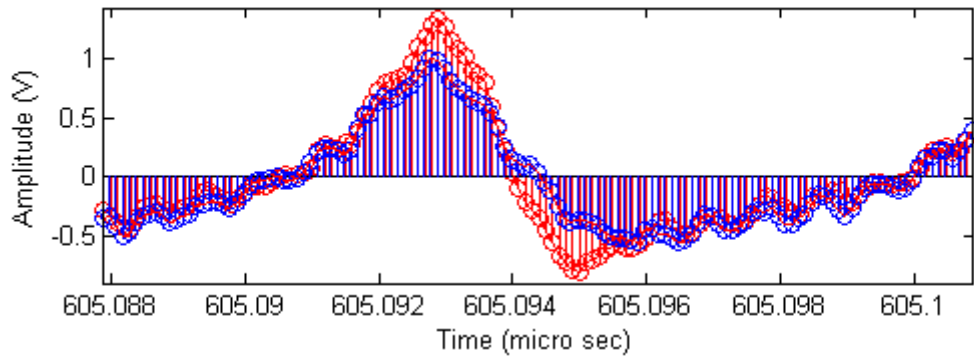


Magnitude FFT, one bunch

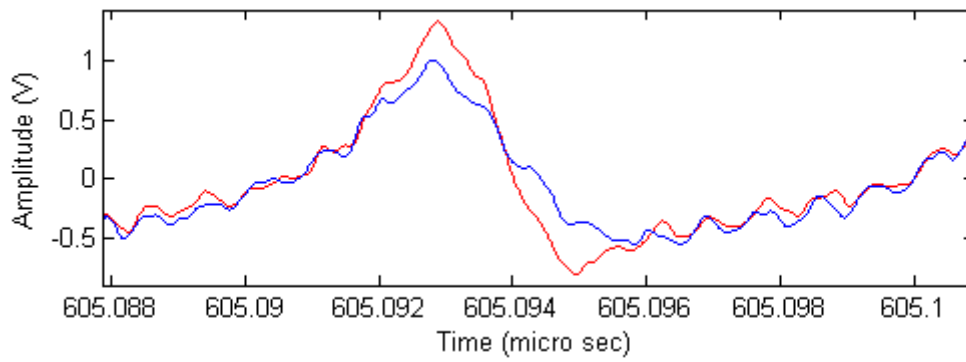


Shape 5

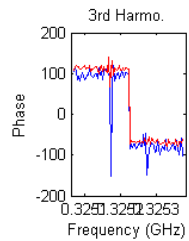
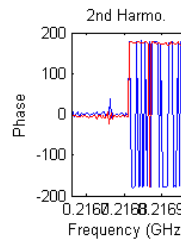
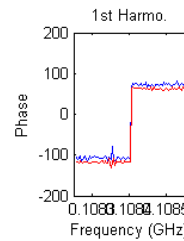
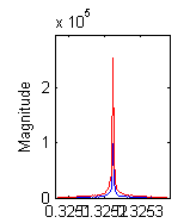
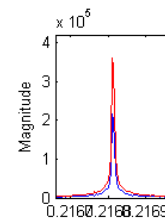
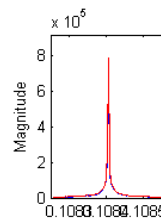
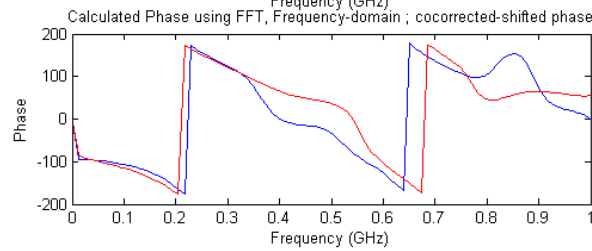
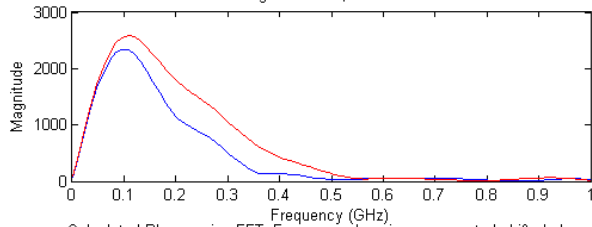
One bunch for shape 01 ref (red) & shape 05 (blue)



Interpolated signals, 01 ref (red) & shape 05 (blue)

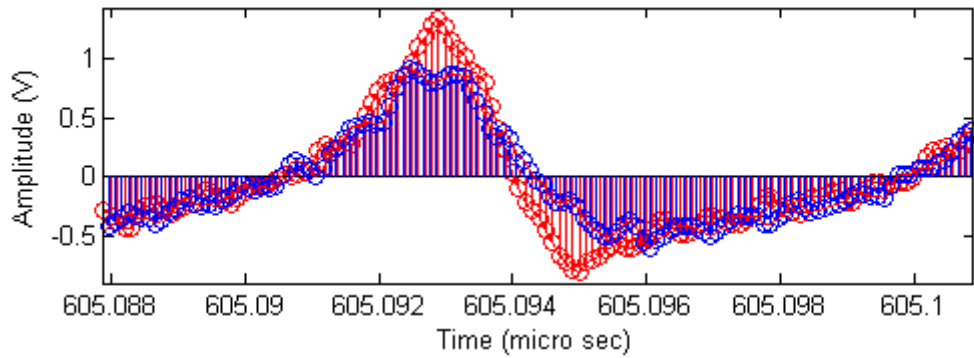


Magnitude FFT, one bunch

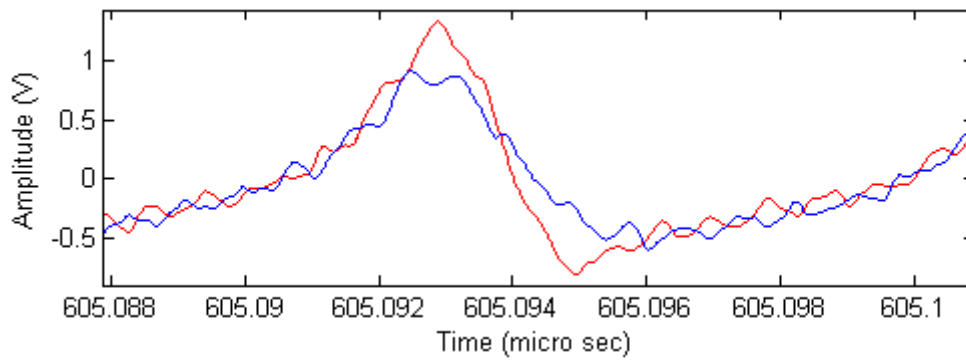


Shape 6

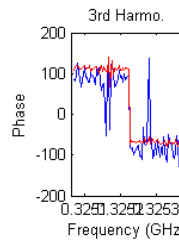
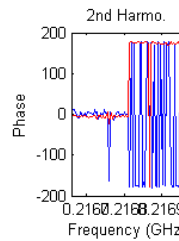
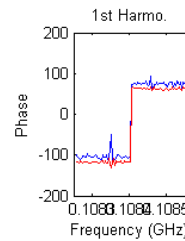
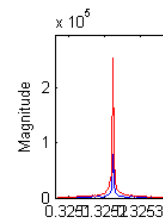
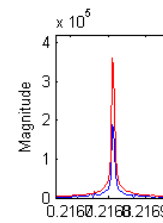
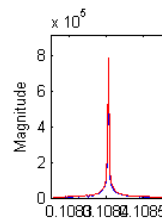
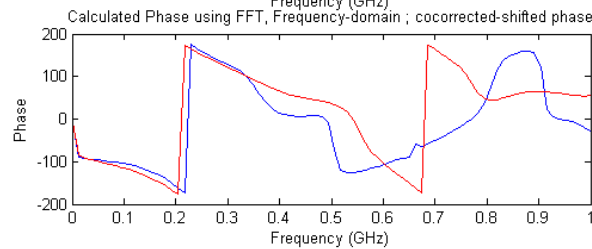
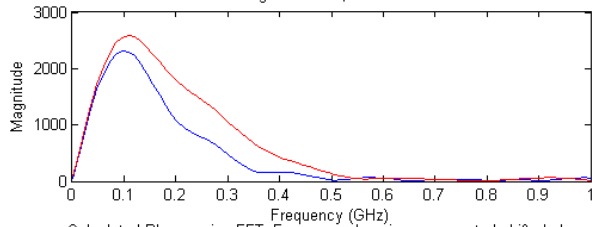
One bunch for shape 01 ref (red) & shape 06 (blue)



Interpolated signals, 01 ref (red) & shape 06 (blue)

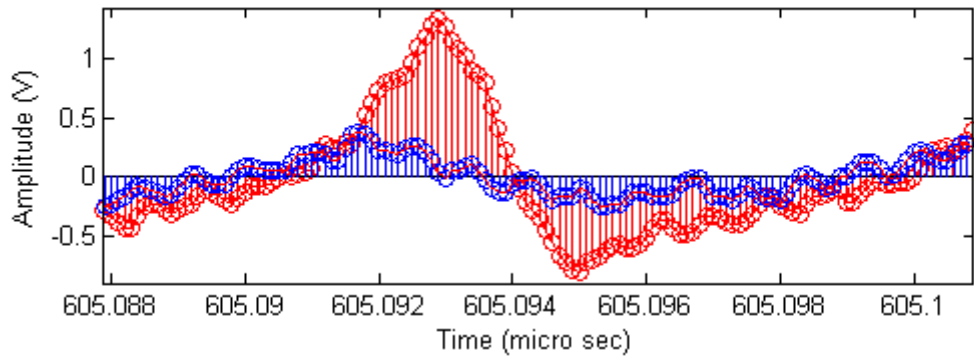


Magnitude FFT, one bunch

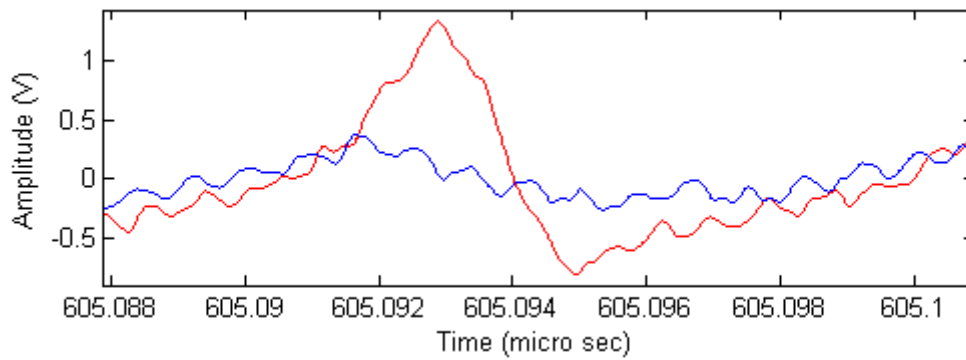


Shape 7

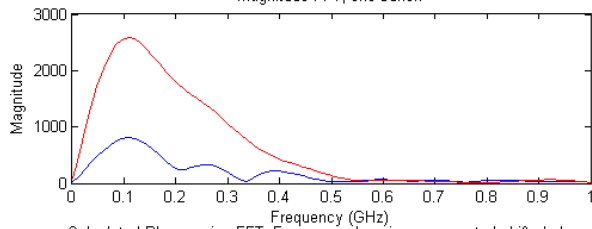
One bunch for shape 01 ref (red) & shape 07 (blue)



Interpolated signals, 01 ref (red) & shape 07 (blue)



Magnitude FFT, one bunch



Calculated Phase using FFT, Frequency-domain ; cocorrected-shifted phase

