Report 01st Oct 2012	**Laboratory Measurements for Phase Evaluation Using Libera Singlepass H**	P. Forck W. Kaufmann M. Almalki
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Web-Link:	http://www-bd.gsi.de/dokuwiki/doku.php?id=projects:bpm-linac	

This report presents the preliminary results for the laboratory phase measurements using Libera Singlepass H. It is divided into four parts:

1- The phase evaluation for signals superposition.

2- The phase evaluation for the four different signal shapes.

3- The phase evaluation for signal with noise.

4- S/N ratio experimental test.

The aim of these measurements is to evaluate the measured phase using Libera Singlepass H by considering some parameters as an attempt to figure out its behaviour.

➢ Superposition of Signals.

In the first part, Libera phase readout is evaluated for a superposition of two signals by varying their strength. The aim is to investigate Libera capability to filter and process a particular frequency (325 MHz). The first phase evaluation is for two sinusoidal signals @ 108,4 MHz and 325,2 MHz. The second is the phase evaluation for a superposition of 108,4 MHz sinusoidal signal and a bunch. The schematic of the two experimental setups are shown in figures 1 and 2.

❖ Superposition 108,4MHz & 325,2MHz

Libera phase readout shows stable measurements with ~ 1 ^{o} standard deviation as long as the 325MHz power is sufficient (+7dBm) which can be seen from table 1. The standard deviation increases to 2.7 when 325 MHz power is -3dBm. Figures 3, 4, 5 and 6 show four cases of 108,4MHz & 325,2MHz superposition.

Table 1: 108.4 MHz & 325.2 MHz

Signal strength	No. Sample	phase (Degree)	σ_dist (Degree)	σ mean
108.4 (+7dBm) & 325.2 (+7dBm)	9923	-108.51	1.14	0.01
108.4 (-3dBm) & 325.2 (+7dBm)	9928	-108.18	0.85	0.01
108.4 (+7dBm) & 325.2 (-3dBm)	9928	-111.50	2.74	0.03
108.4 (-3dBm) & 325.2 (-3dBm)	9928	-111.06	1.92	0.02

❖ Superposition 108,4MHz & Bunch

Table 2 shows ~ 1.5 ^{o} standard deviation for phase readout. It can be easily seen how the signal amplitude enhances the phase reading. Figures 7, 8, 9 and 10 show four cases of 108,4MHz & bunch superposition.

Table 2: 108.4 MHz & Bunch

Signal strength	No. Sample	phase (Degree)	σ_dist (Degree)	σ mean
108.4 (+7dBm) & Bunch(750 mVp)	9928	-19.72	1.15	0.01
108.4 (+7dBm) & Bunch(250 mVp)	9923	-34.39	1.27	0.01
108.4 (-3dBm) & Bunch(750 mVp)	9923	-15.12	1.23	0.01
108.4 (-3dBm) & Bunch(250 mVp)	9923	-22.54	1.56	0.02

Fig. 1, Superposition 108,4MHz + 325,2MHz Setup

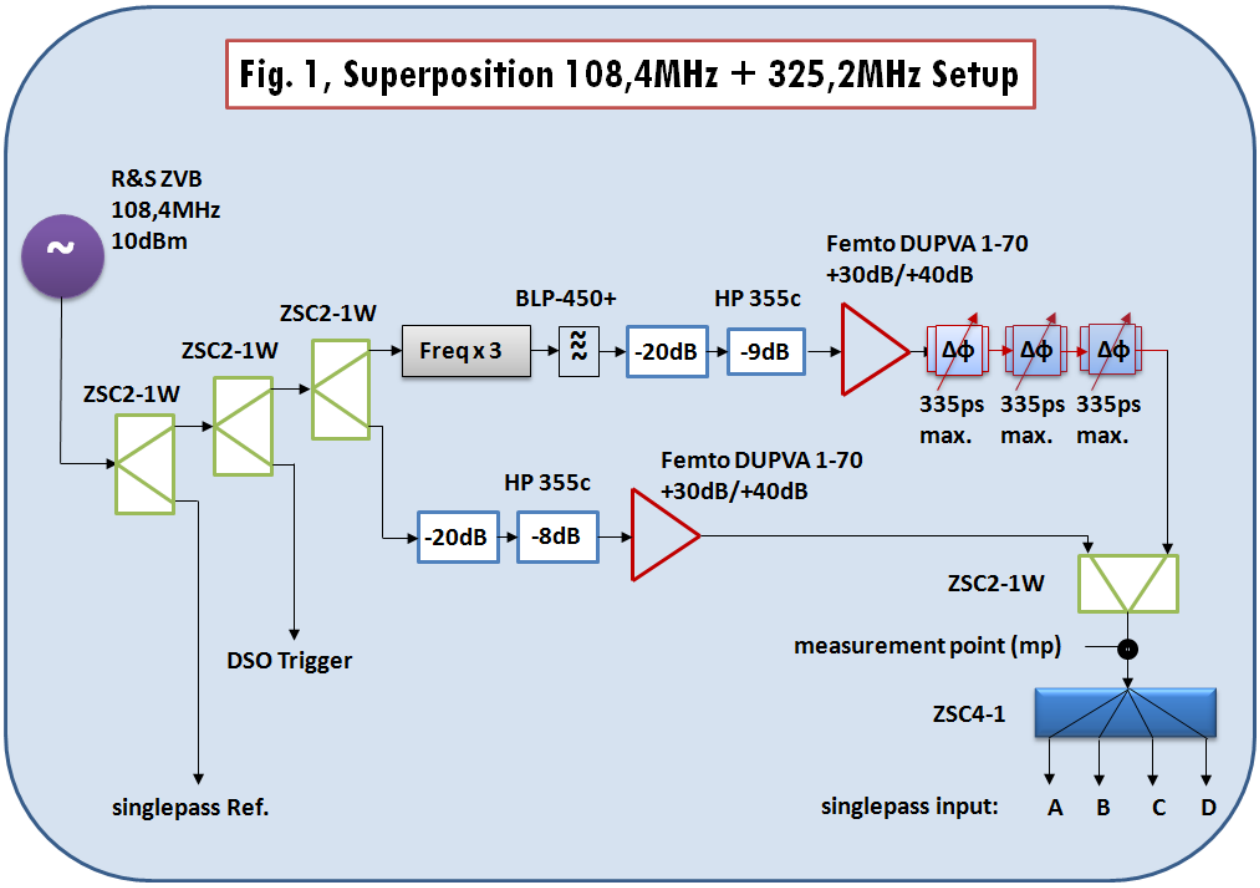


Fig. 2, Superposition 108,4MHz + Bunch Setup

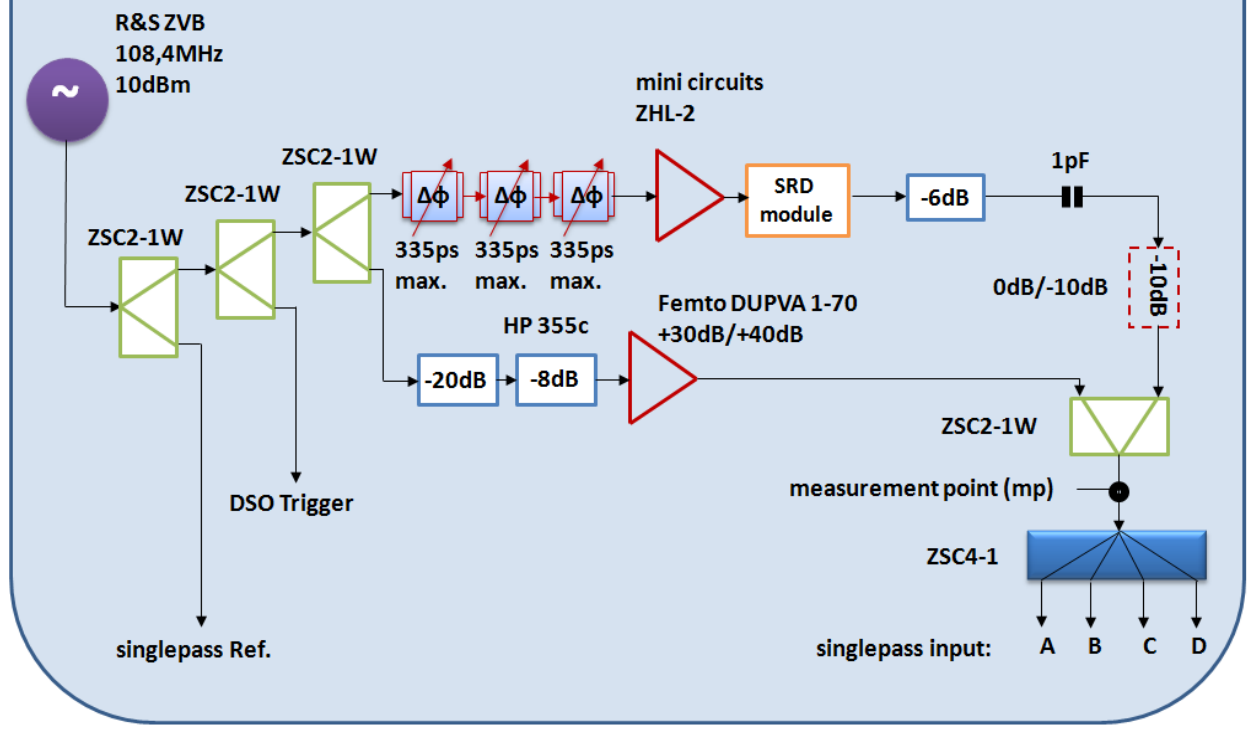


Fig. 3, 108.4 (+7dBm) & 325.2 (+7dBm)

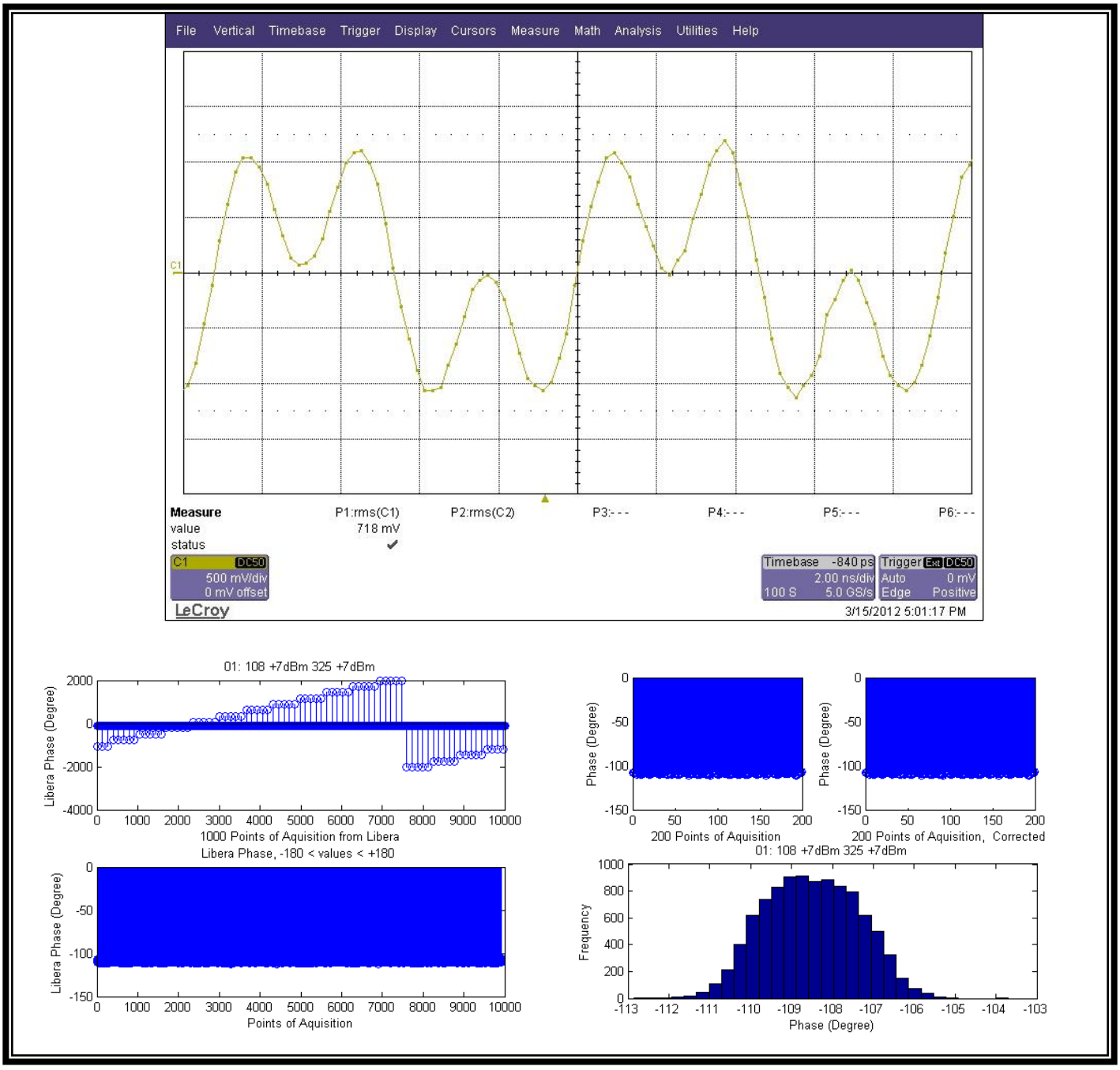


Fig. 4, 108.4 (-3dBm) & 325.2 (+7dBm)

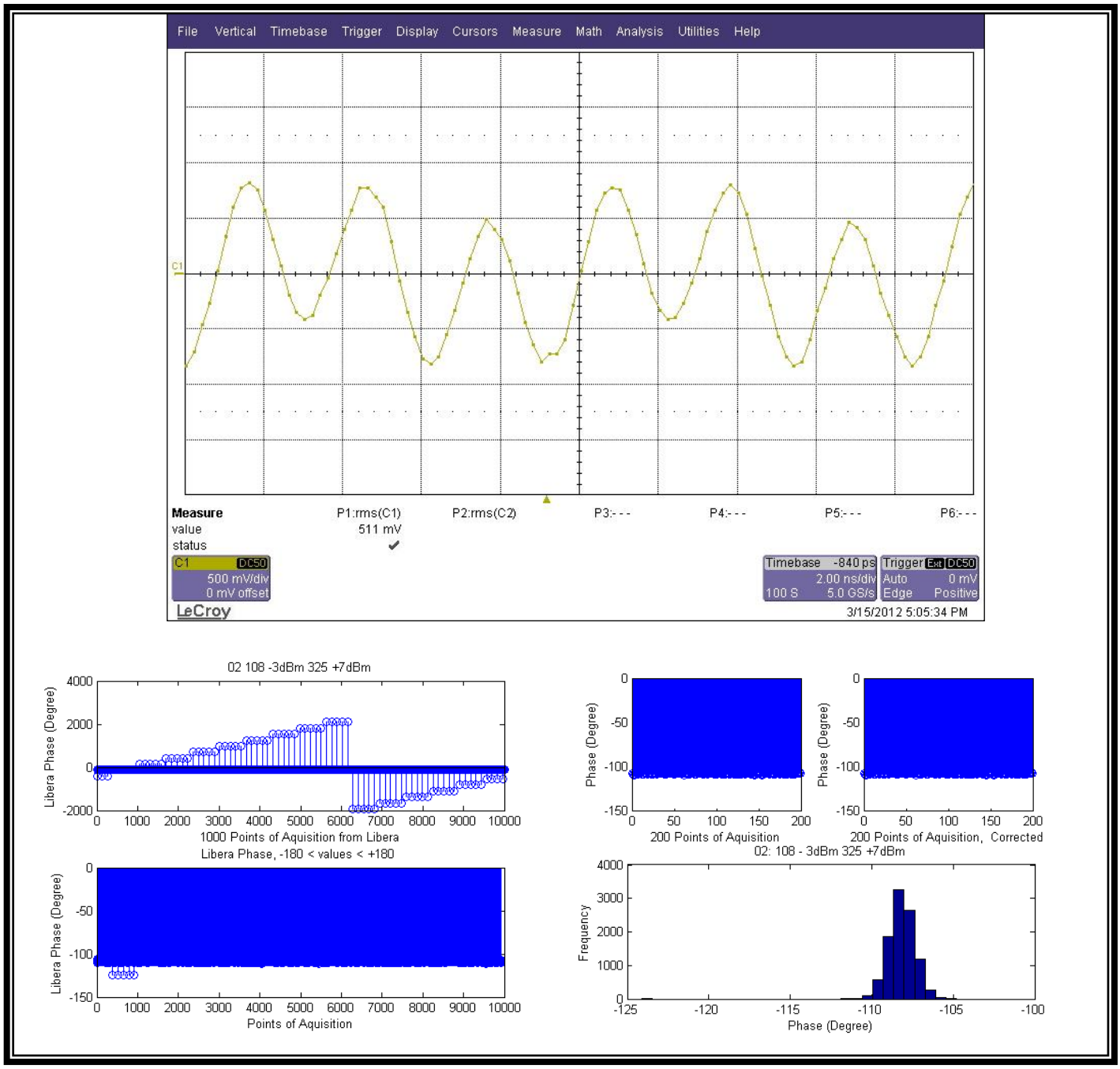


Fig. 5, 108.4 (+7dBm) & 325.2 (-3dBm)

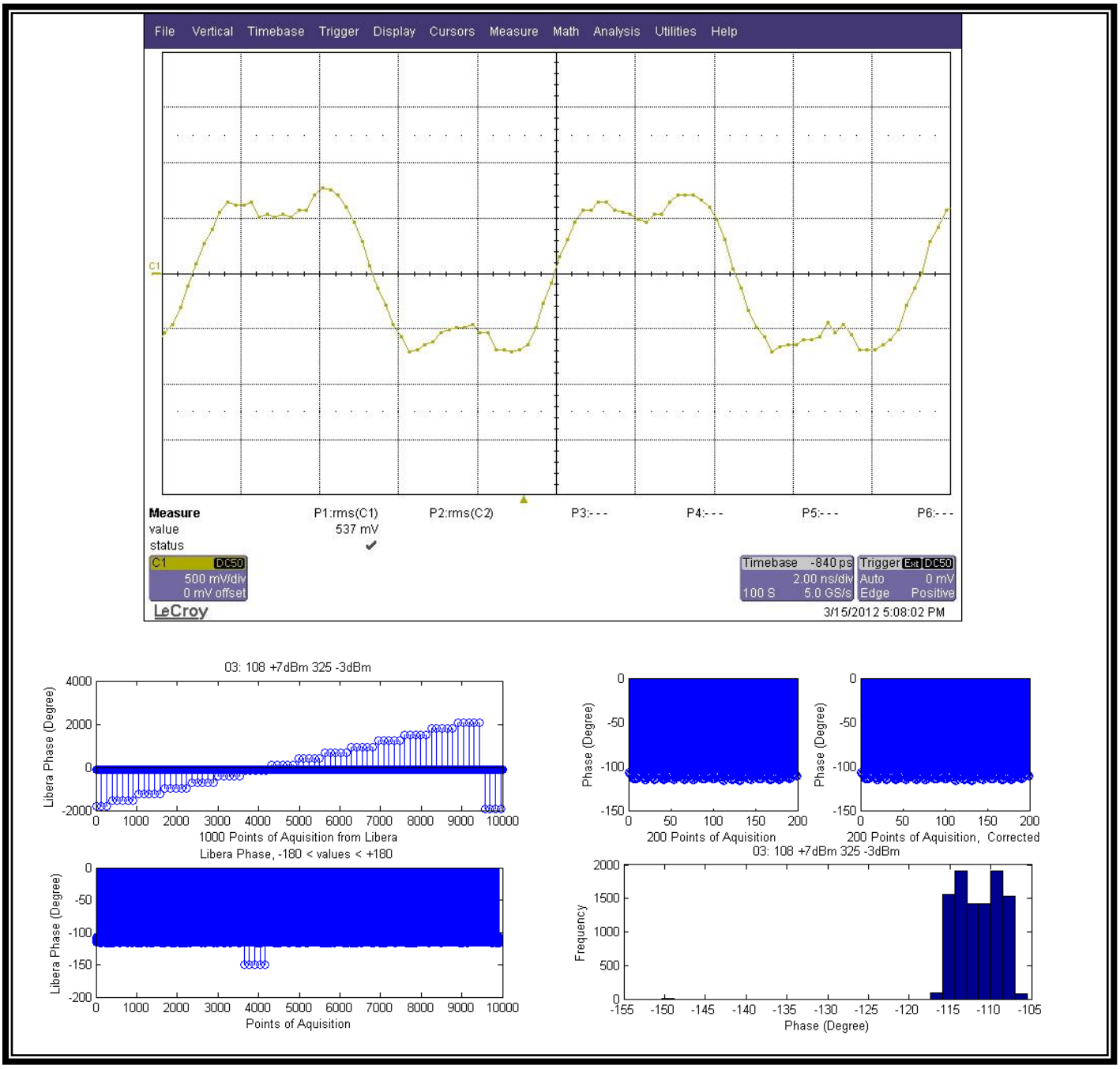


Fig. 6, 108.4 (-3dBm) & 325.2 (-3dBm)

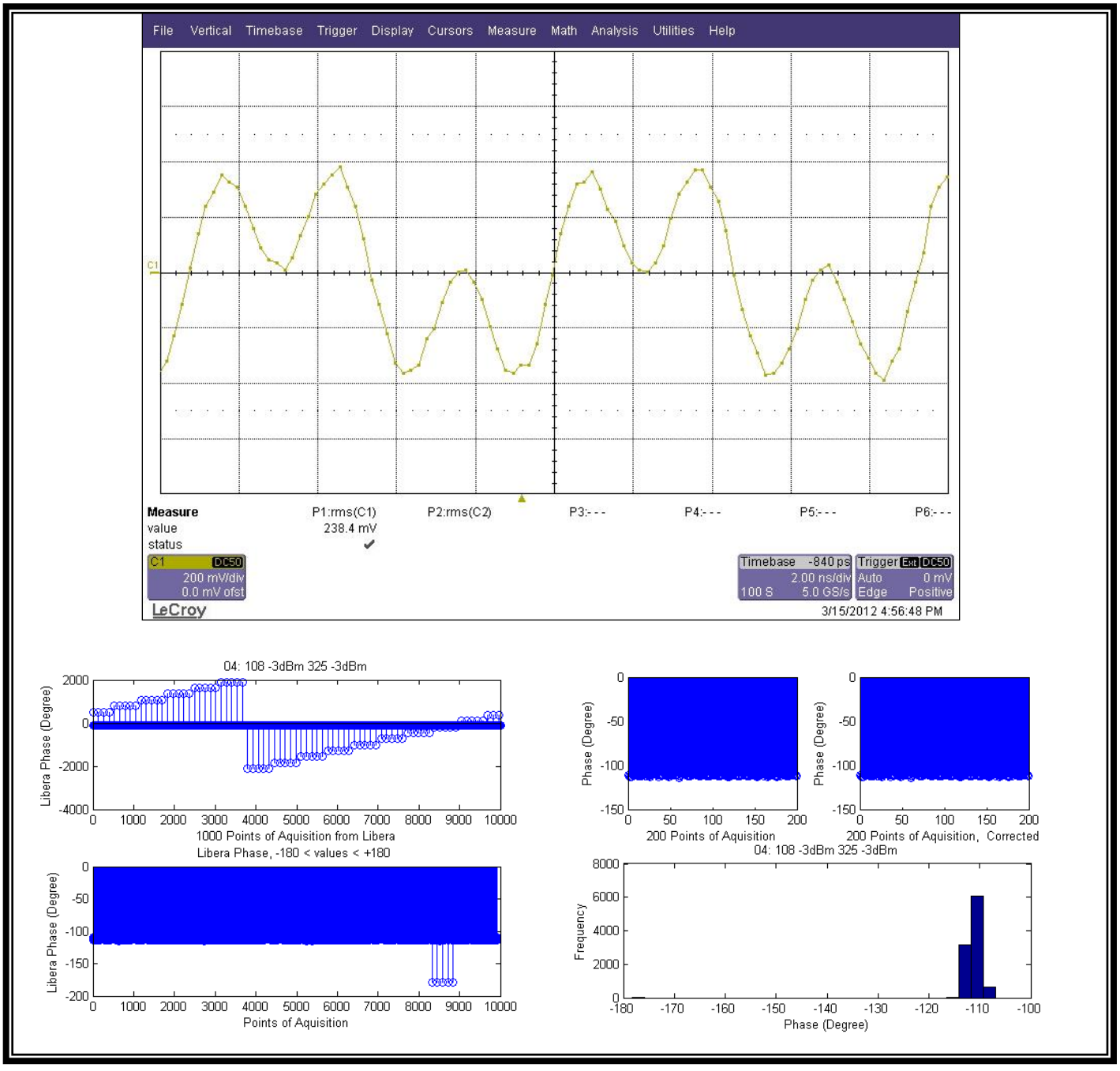


Fig. 7, 108.4 (+7dBm) & Bunch(750 mVp)

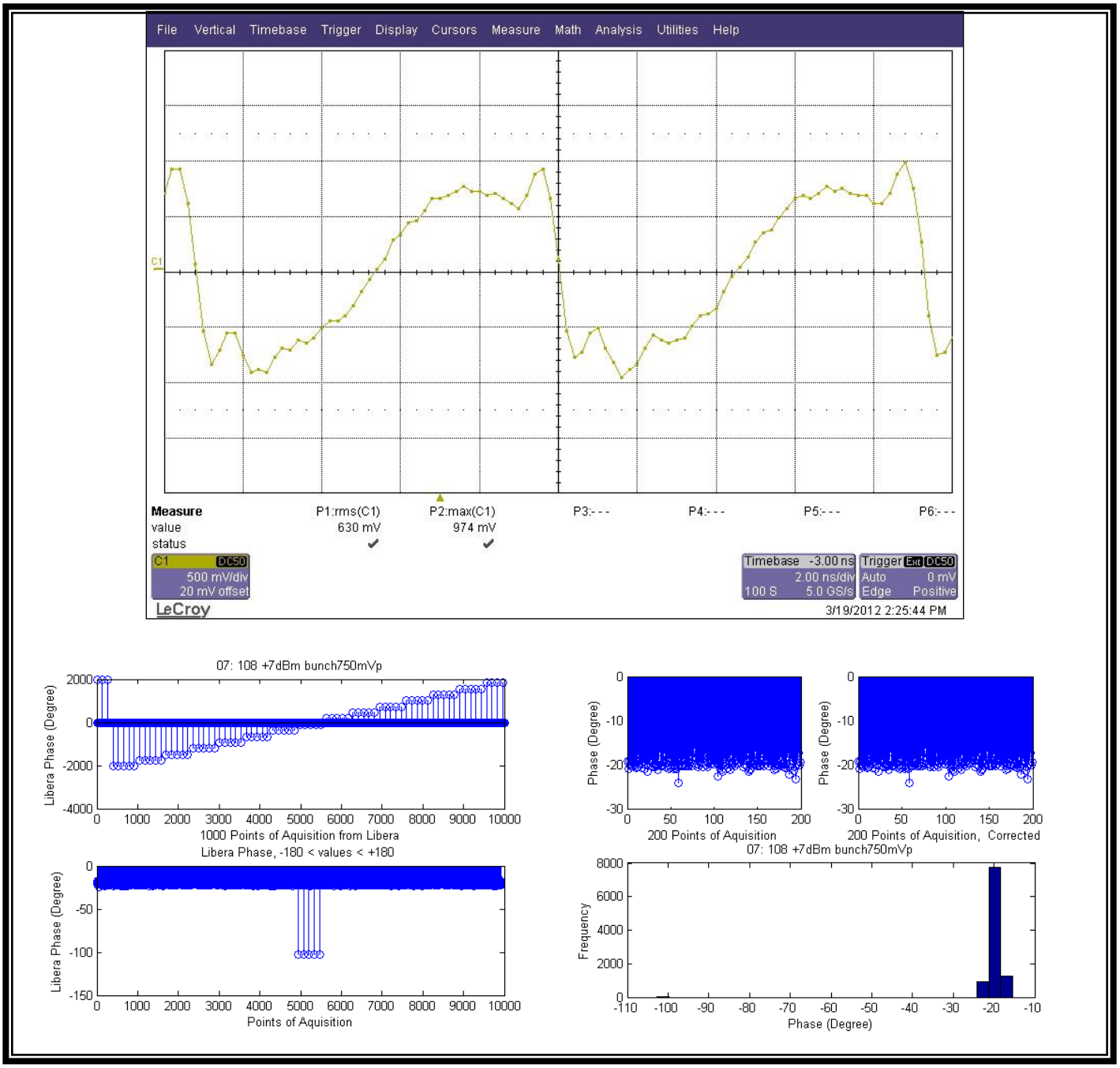


Fig. 8, 108.4 (+7dBm) & Bunch(250 mVp)

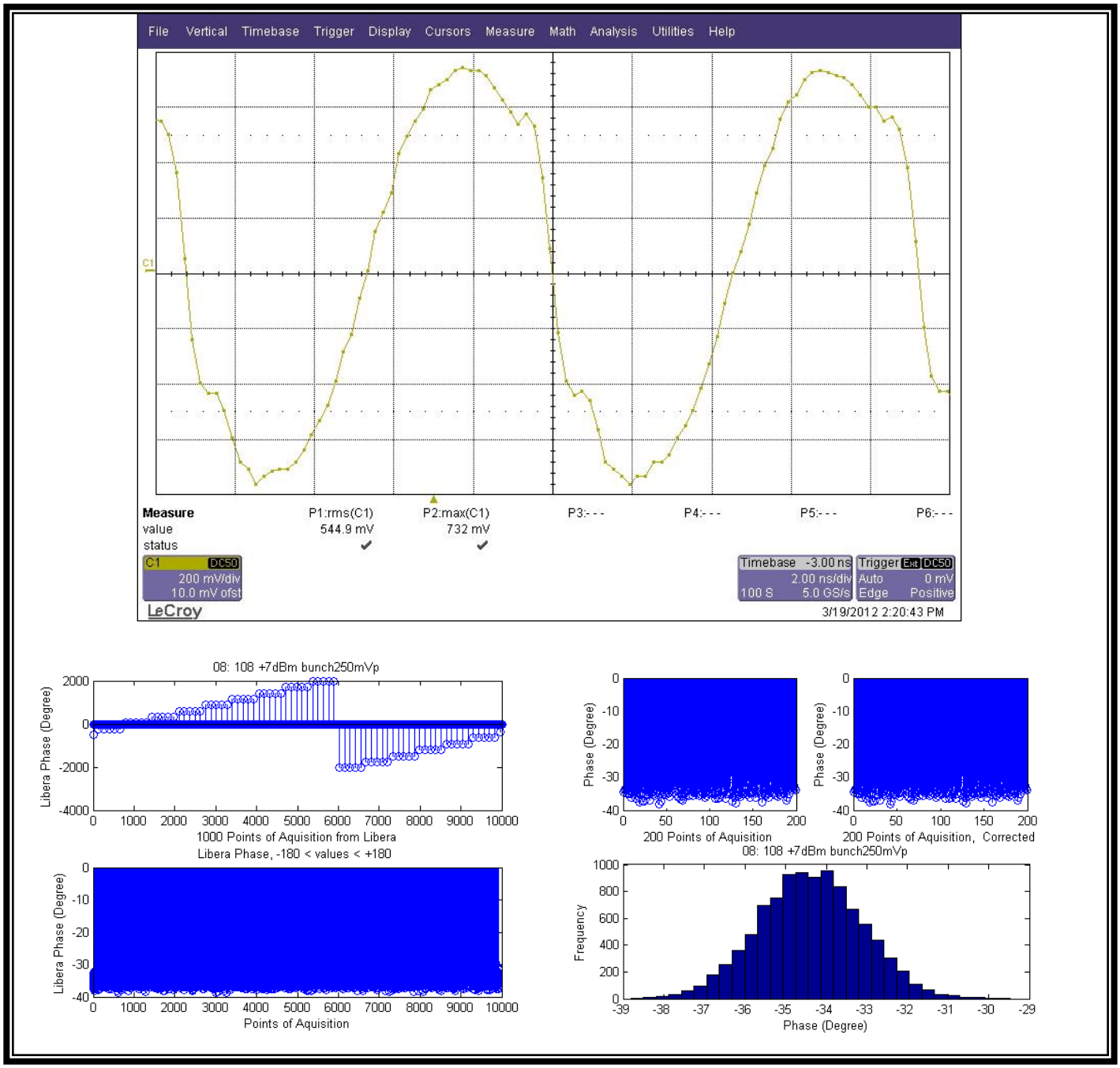


Fig. 9, 108.4 (-3dBm) & Bunch(750 mVp)

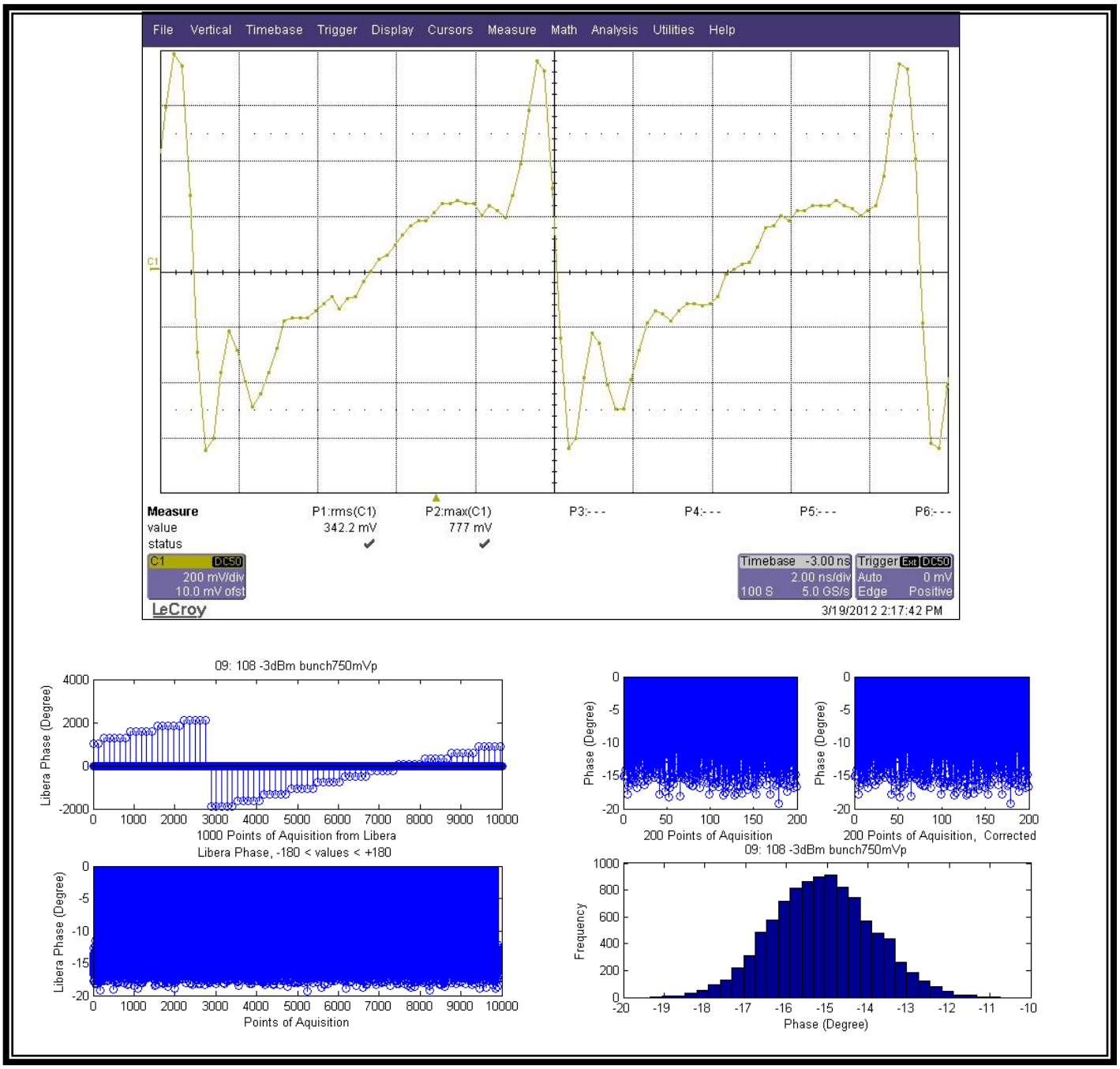
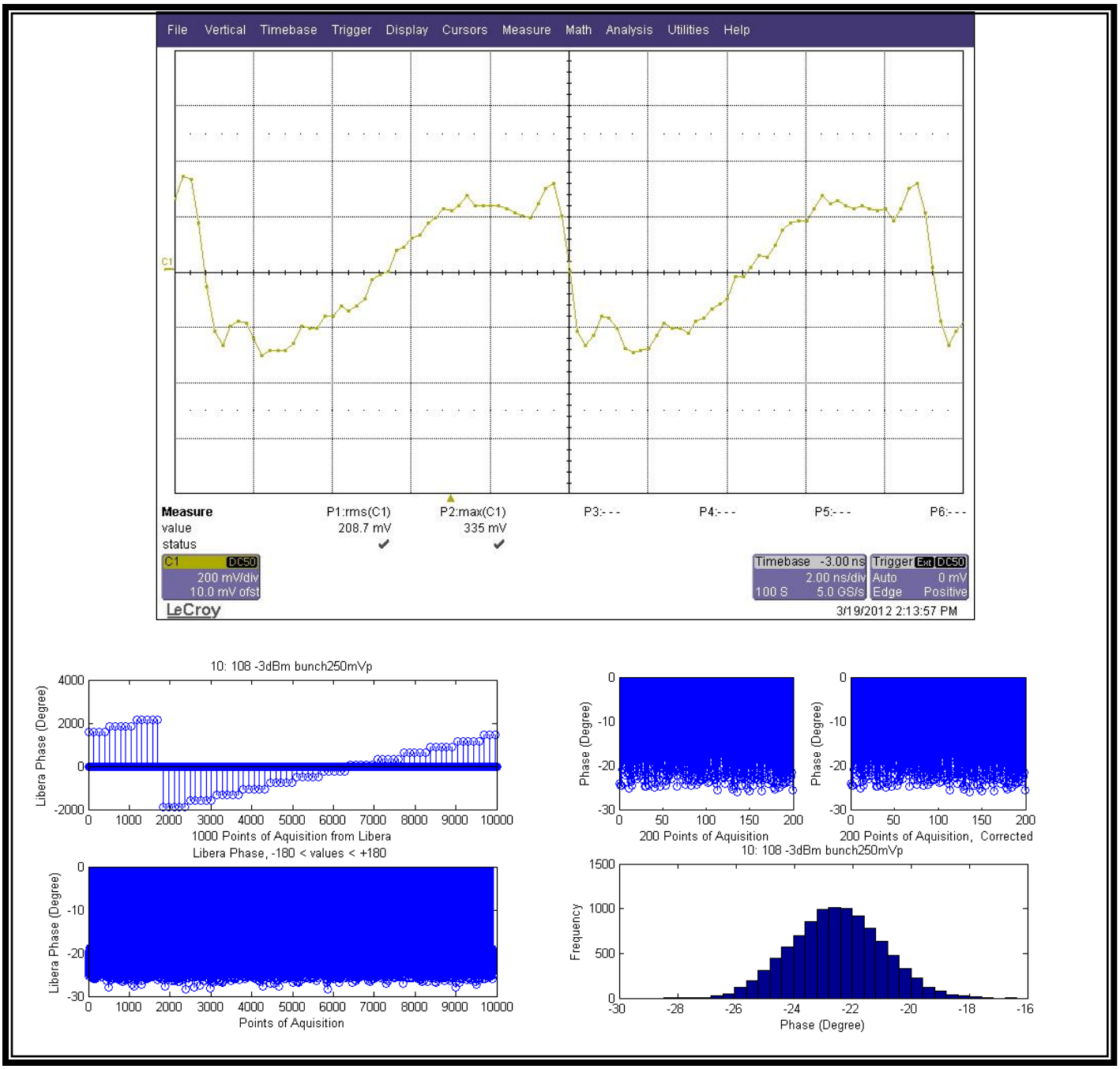


Fig. 10, 108.4 (-3dBm) & Bunch(250 mVp)



➢ Variation of Bunch Shapes.

Four different bunch shapes are generated with different levels of amplitudes. Libera phase readout gives high stability for three shapes regardless to their amplitudes. The standard deviation is ~ 1.5 ^{o} as listed in table 3 where one can see that bunch shape has no considerable effect on the measured phase. This is indeed a point of great advantage. However, this can not be generalized to phase wrapping which can be observed from shape 2. Although, the signal amplitude for shape 3 is relatively high, its standard deviation is 7 ^{o}. Therefore, one can point out that the algorithm of treating such case must be reconsidered. Figure 11, illustrates signal amplitude versus Libera phase readings. Figures 11, 12, 13 and 14 show the signal shape displayed on a scope and Libera phase readings and all collected in figure 15.

A point to mention is that for this test, comparing phase shift with time domain shift for zero crossing point is not here presented.

Table 3: Four Bunch Shapes

Signal amp (mVp)	No. Sample	phase (Degree)	σ_dist (Degree)	σ mean
659	992	-100.73	1.57	0.05
715	992	177.46	7.00	0.22
170	992	-95.46	0.82	0.03
177	992	-112.81	1.40	0.04

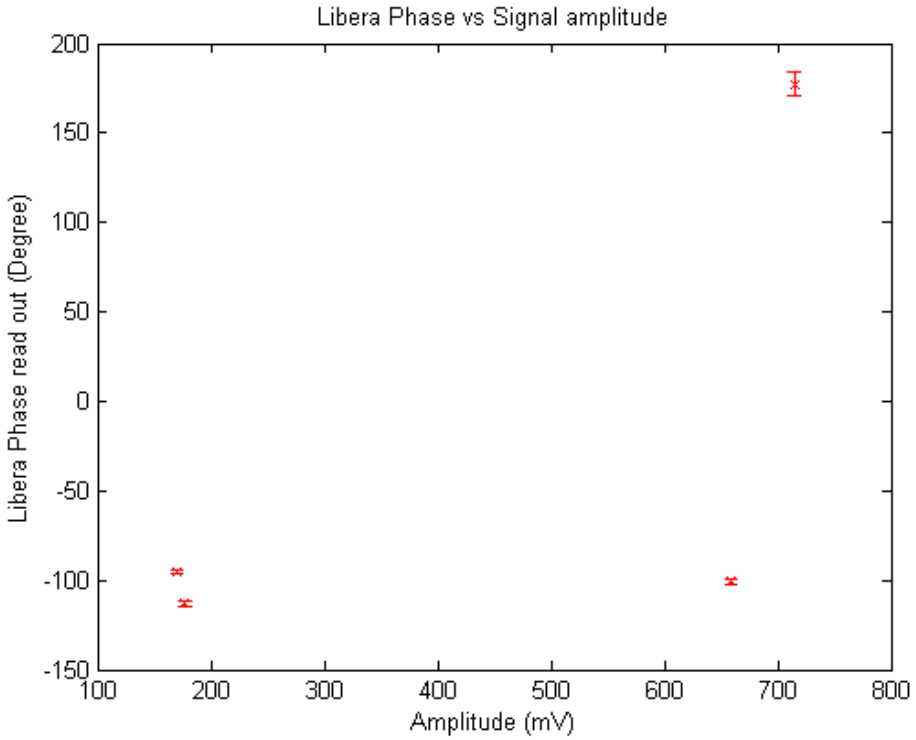


Figure 11, illustrates signal amplitude versus Libera phase readings.

Fig. 11, shape 1

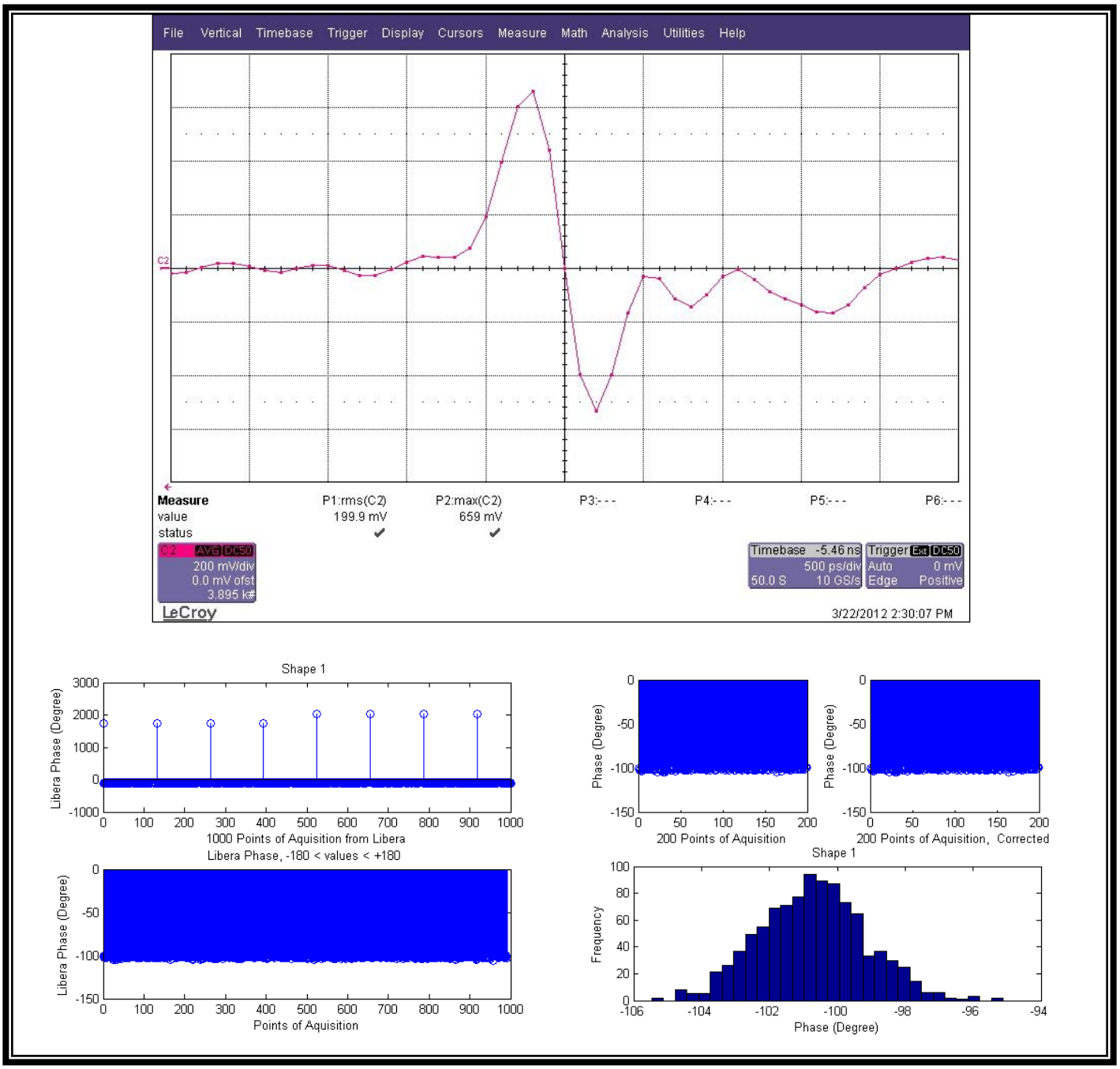


Fig. 12, shape 2

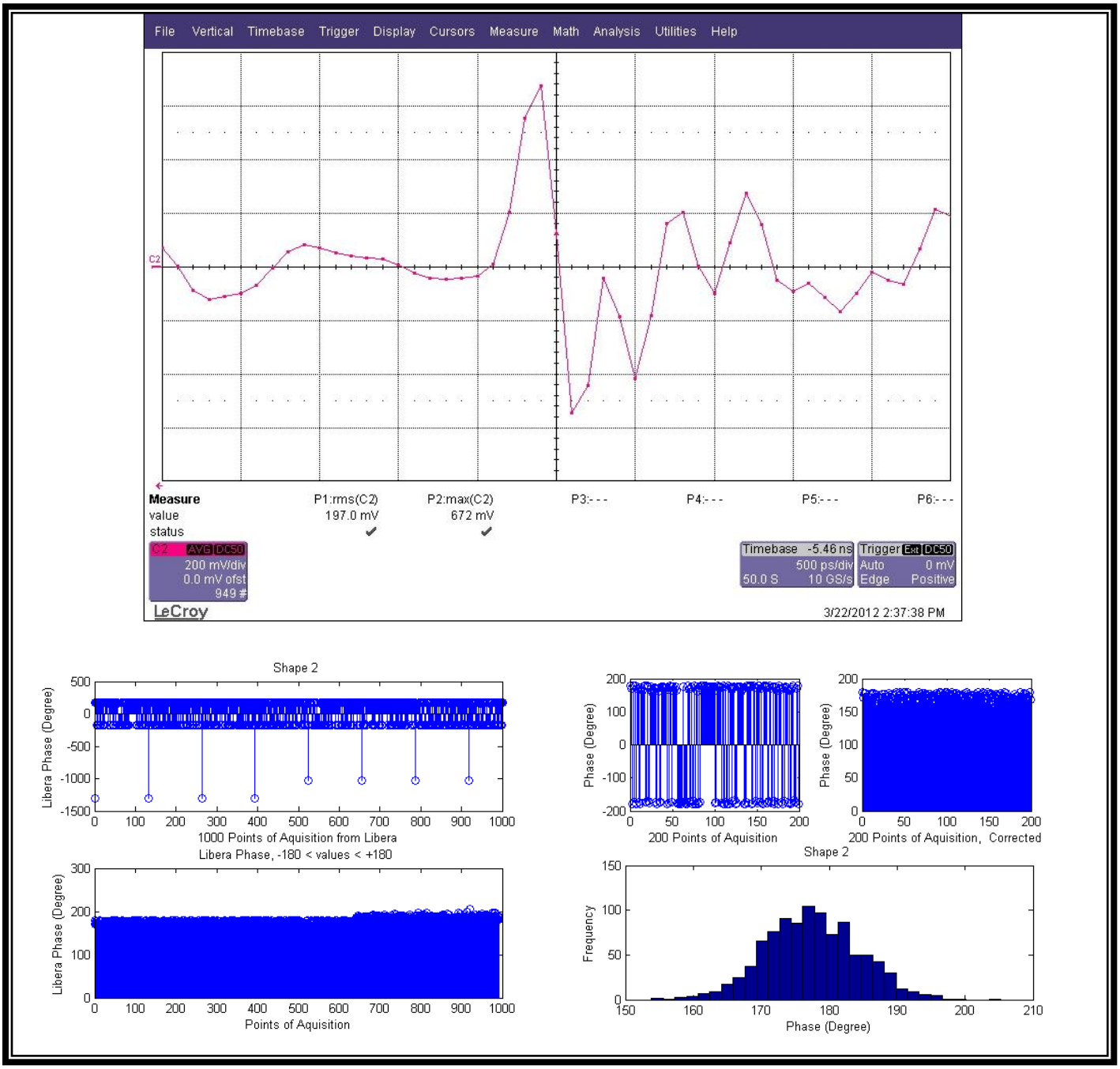


Fig.13, shape 3

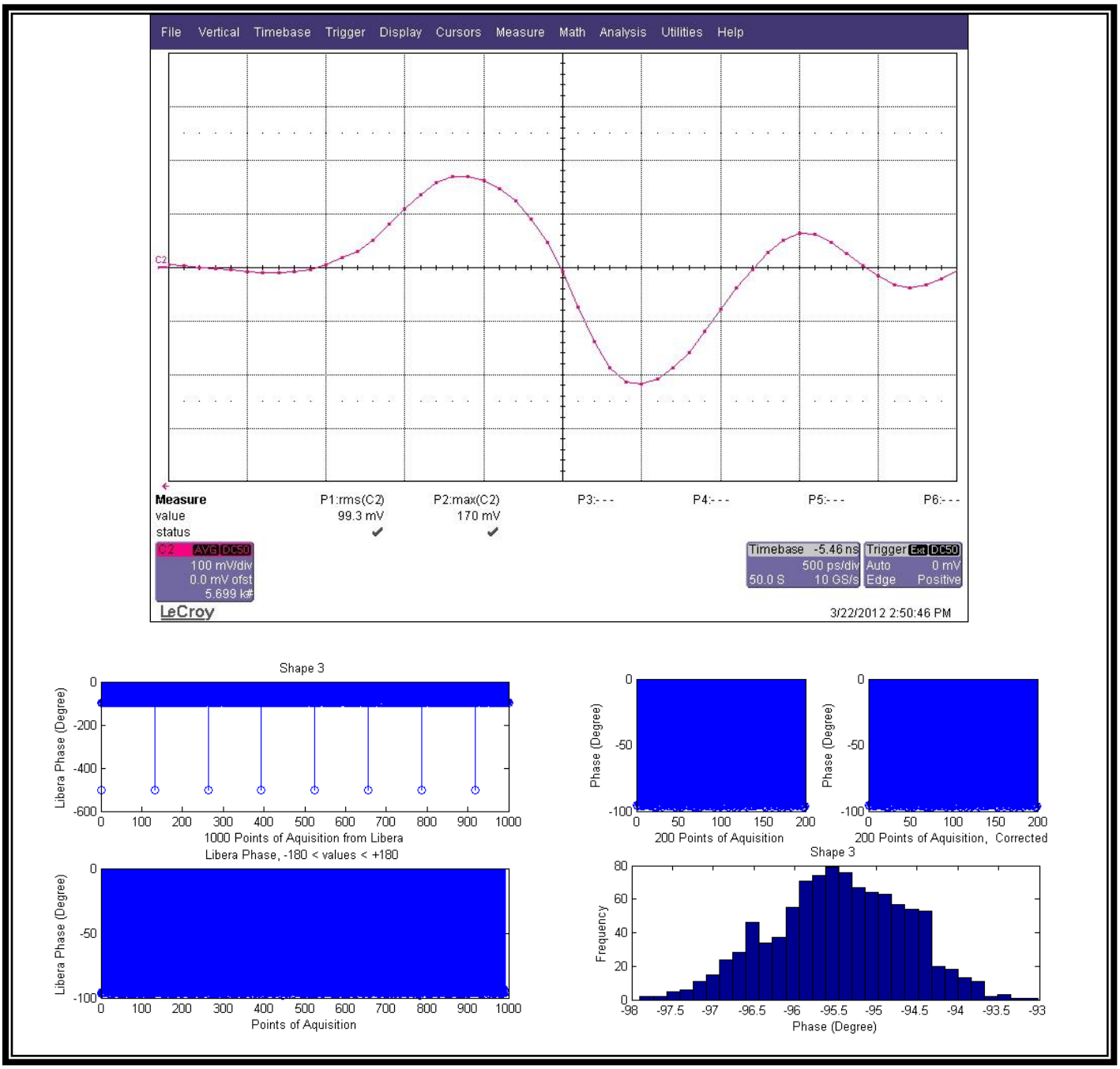
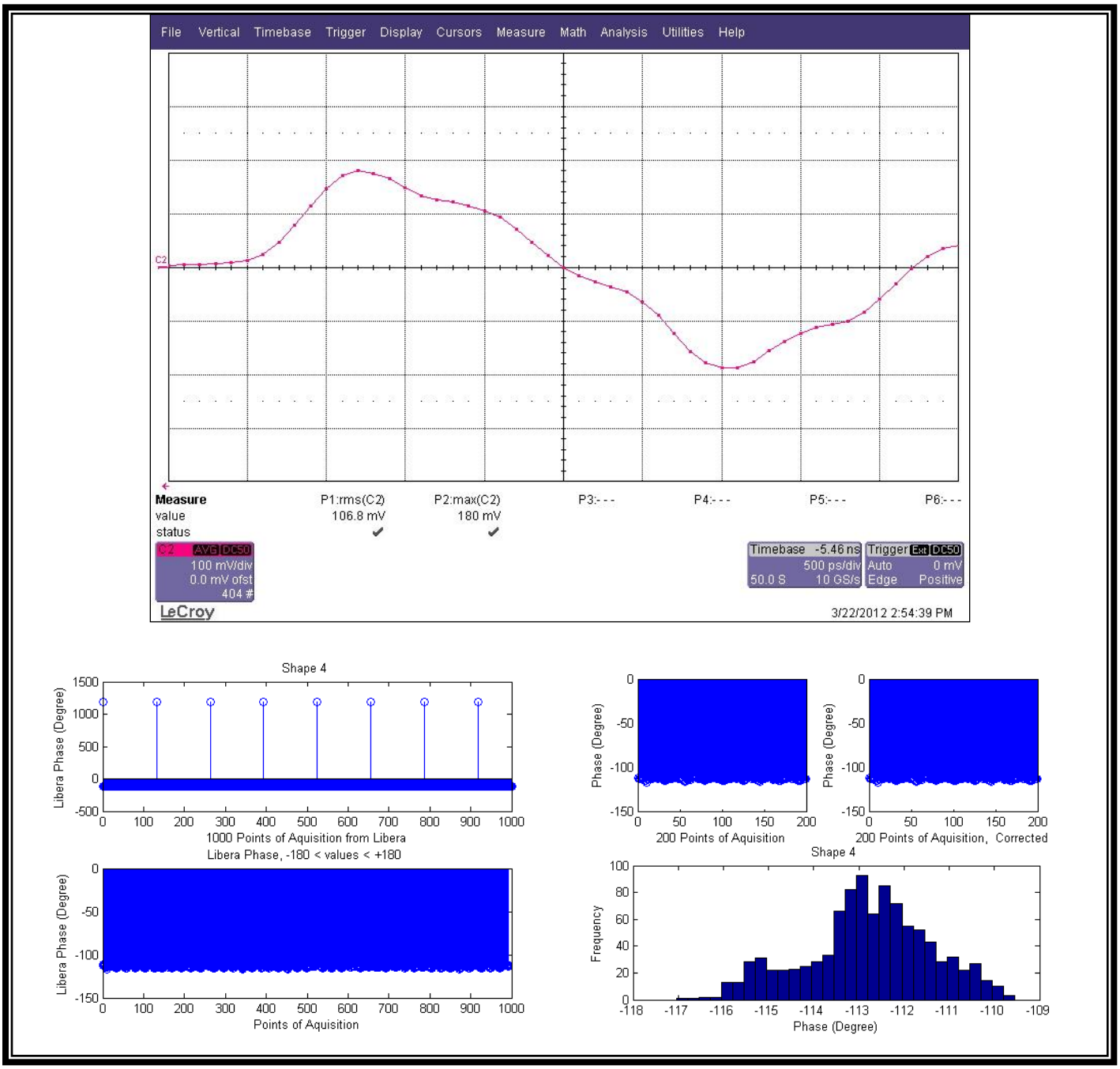


Fig. 14, shape 4



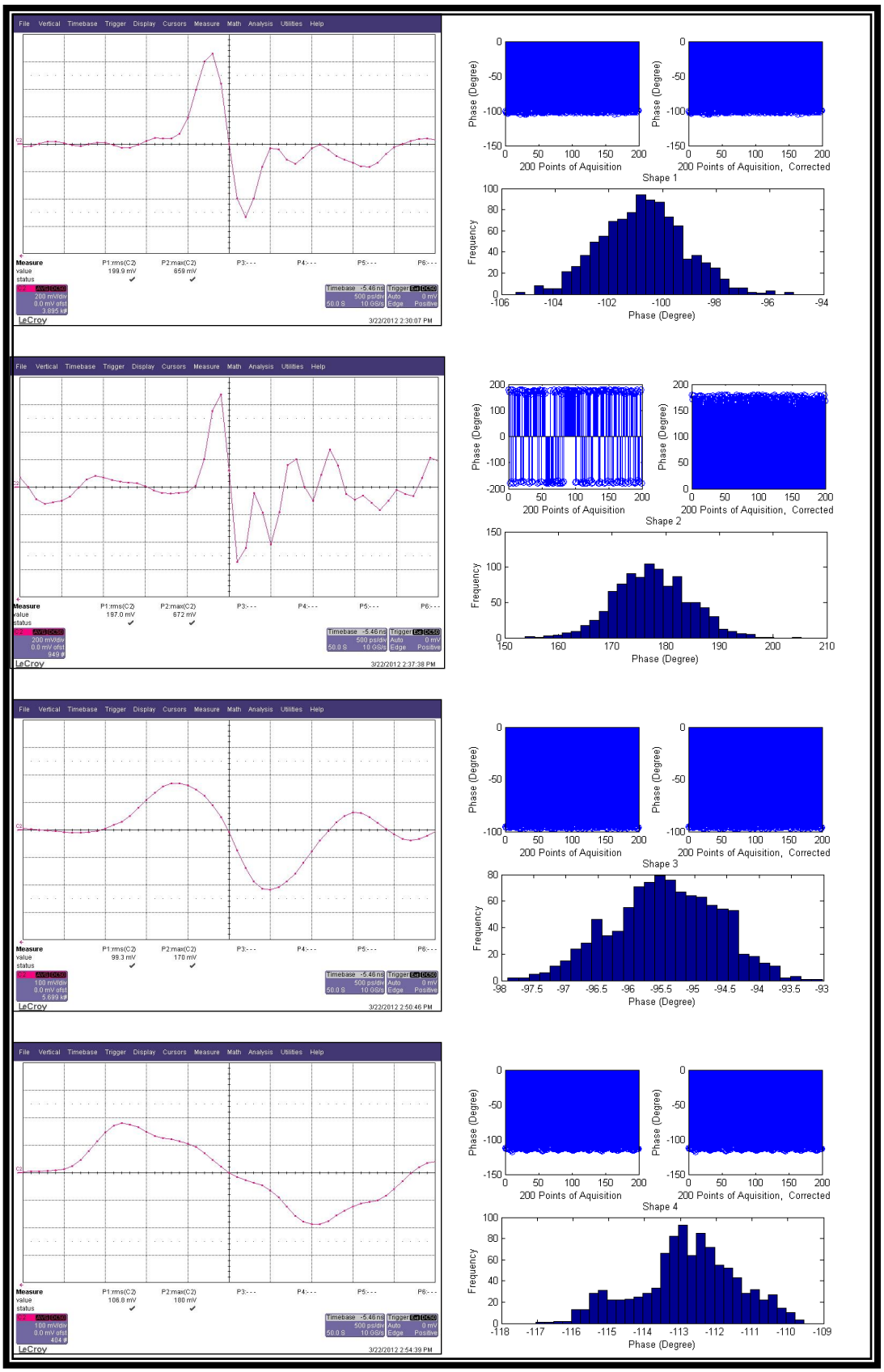


Fig. 15, Four bunches displayed on a scope and Libera phase.

➢ Superposition Bunch & Noise.

A sinusoidal signal @ 325,2 MHz with 400 mVp is combined with three different levels of noise. The noise levels are in 10 dBm step (- 16 dBm, -6 dBm and +3 dBm). A similar treatment is performed by combining 300 mVp bunch with noise. The aim is to investigate the effect of noise on Libera phase readouts. Tables 4 & 5 and figures 15 & 16 show phase recorded and its standard deviation for 400 mVp and 300 mVp. Figures 17, 18, 19, 20, 21, 22, 23 and 24 show 400 mVp @ 325,2 MHz and 300 mVp bunch versus noise level and all collected in figure 24.

- Evaluating the noise tables for 300 mVp bunch and 400 mVp @ 325,2 MHz.

1- These two signals have 100 mVp difference (2.5 dBm).
2- The noise influences phases reading which can be seen by comparing signals have amplitude lower than 400 mVp @ 325,2 MHz (170 mVp & 177 mVp, from table 3). They give stable measurements with standard deviations ~ 1 ^{o} while the situation with adding noise is completely different.
3- As the noise level gets higher, (10 dBm step), the measured phase effected considerably.
4- For -16 dBm noise level, the measured phase for 400 mVp gives a standard deviation of 2.5 ^{o} while gives 17.4 ^{o} for 300 mVp bunch input.
5- The standard deviation increases for both signal phases when the noise level is increased by 10 dBm (-6 dBm) the standard deviations for both signals almost doubled and some phase values have to be corrected.
6- Increasing noise level 10 dBm (3 dBm) gives phases which can not be treated for 300 mVp bunch.

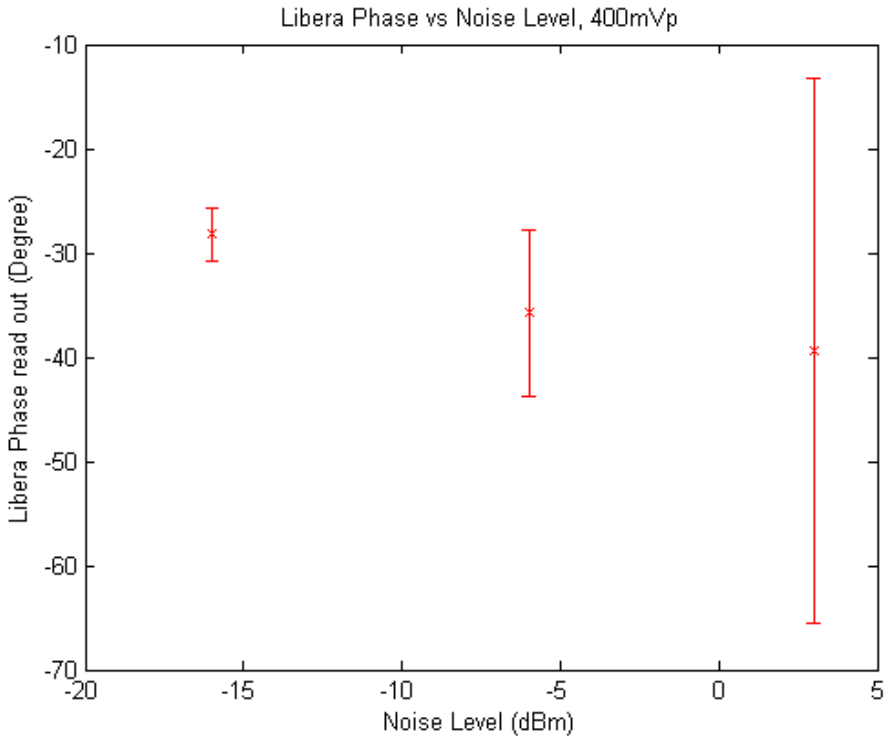


Fig. 15 Libera phase reading and its standard deviation versus noise level for 400 mVp @ 325 MHz.

Table 4: 325Mhz , 400mVp

Noise Level (dBm)	Signal amp (mVp)	No. Sample	phase (Degree)	σ_dist (Degree)	σ mean
0.00	400.00	9928.00	-26.29	1.29	0.01
-16.00	400.00	9928.00	-28.23	2.55	0.03
-6.00	400.00	9928.00	-35.76	7.94	0.08
3.00	400.00	9874.00	-39.40	26.15	0.26

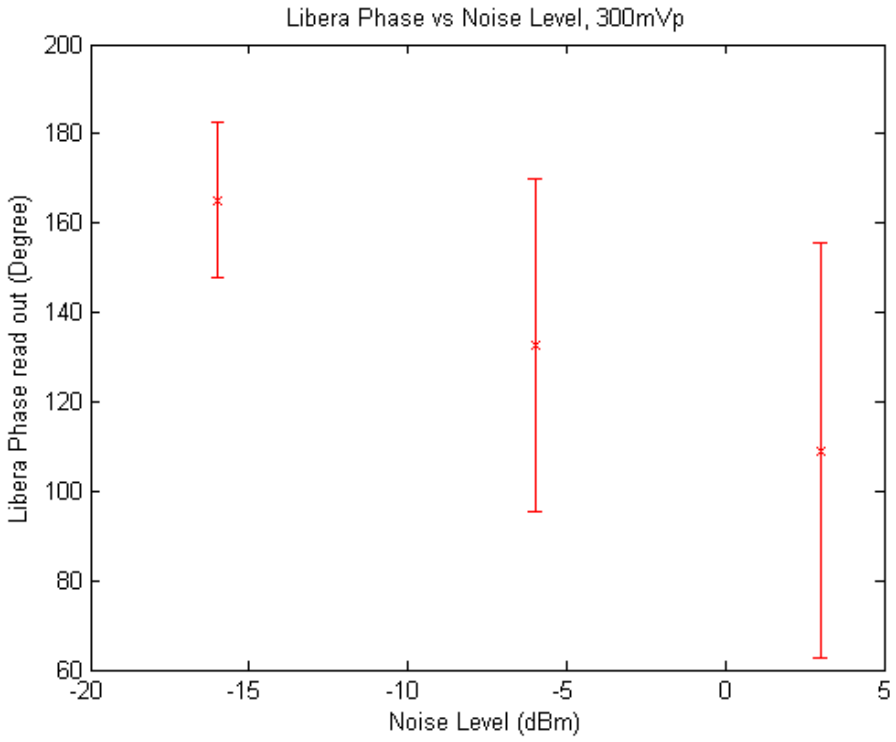


Fig. 16 Libera phase reading and its standard deviation versus noise level for 300 mVp bunch.

Table 5: Bunch , 300mVp

Noise Level (dBm)	Signal amp (mVp)	No. Sample	phase (Degree)	σ_dist (Degree)	σ mean
0.00	300.00	9926.00	166.78	1.05	0.01
-16.00	300.00	9928.00	165.07	17.40	0.17
-6.00	300.00	6113.00	132.77	37.23	0.48
3.00	300.00	5504.00	109.04	46.48	0.63

Fig. 17, 325 MHz signal @ 400mVp.

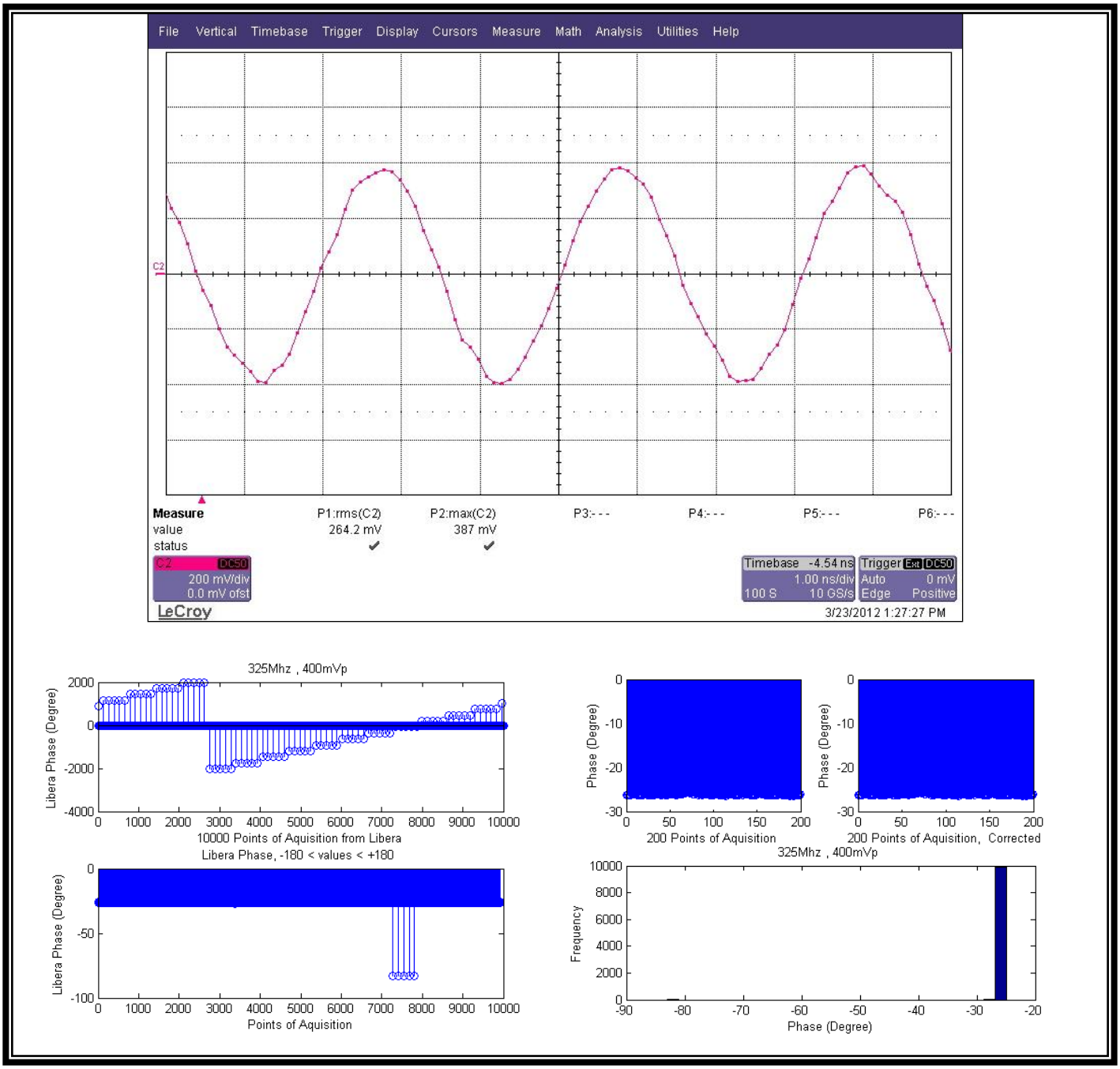


Fig. 18, 325 MHz signal @ 400mVp with -16 dBm noise.

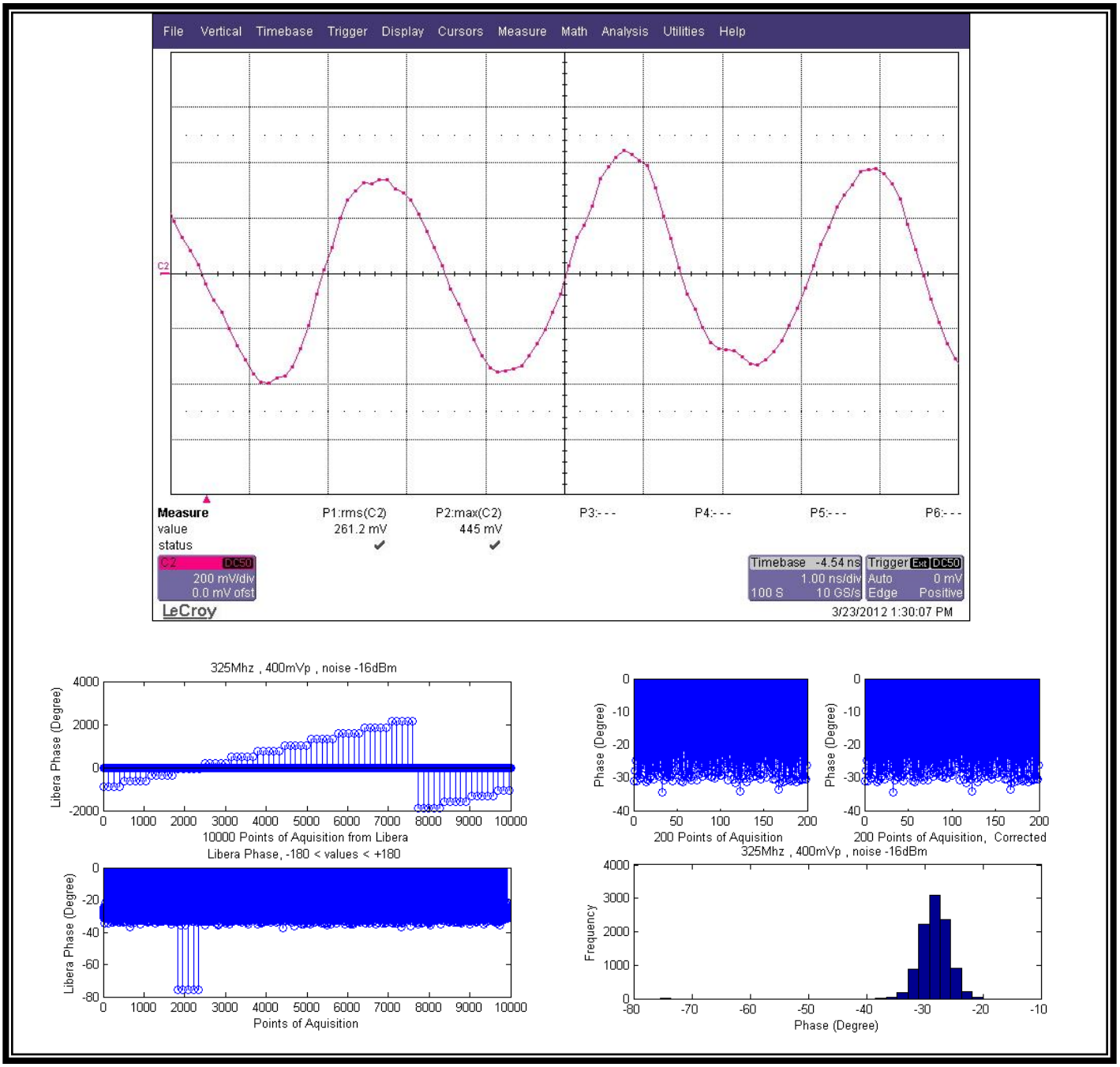


Fig. 19, 325 MHz signal @ 400mVp with -6 dBm noise.

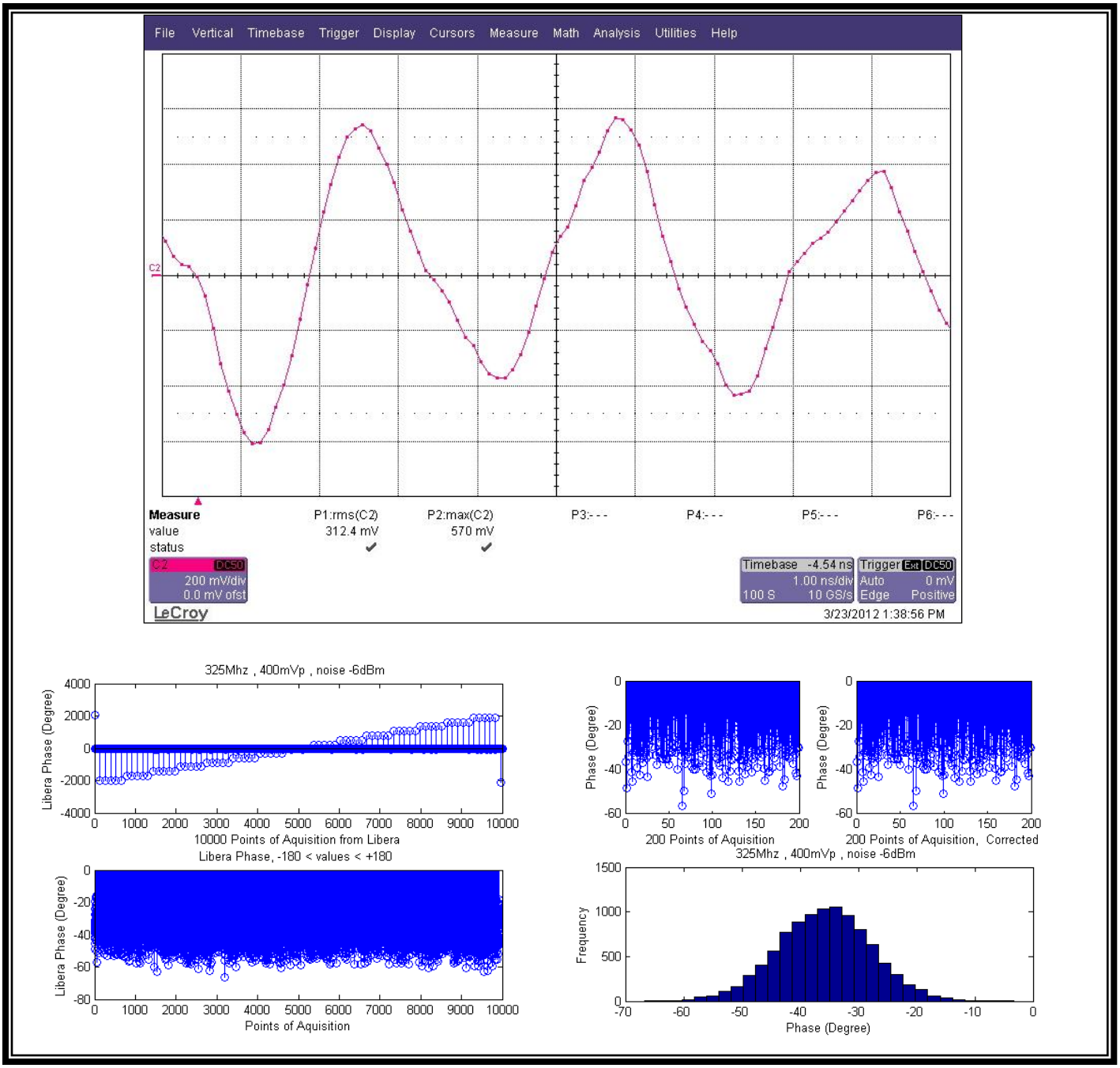


Fig. 20, 325 MHz signal @ 400mVp with +3 dBm noise.

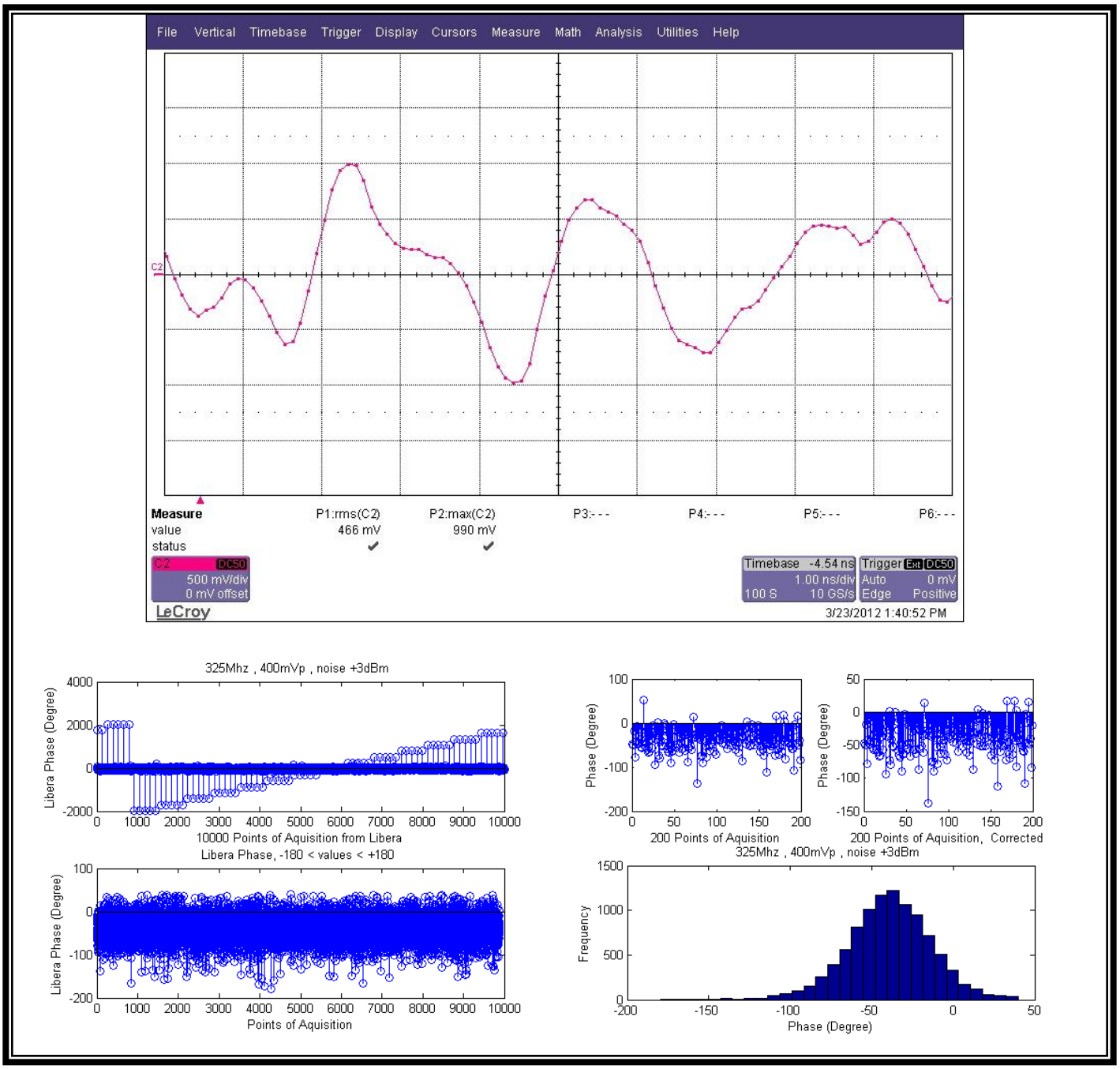


Fig. 21, 300mVp bunch.

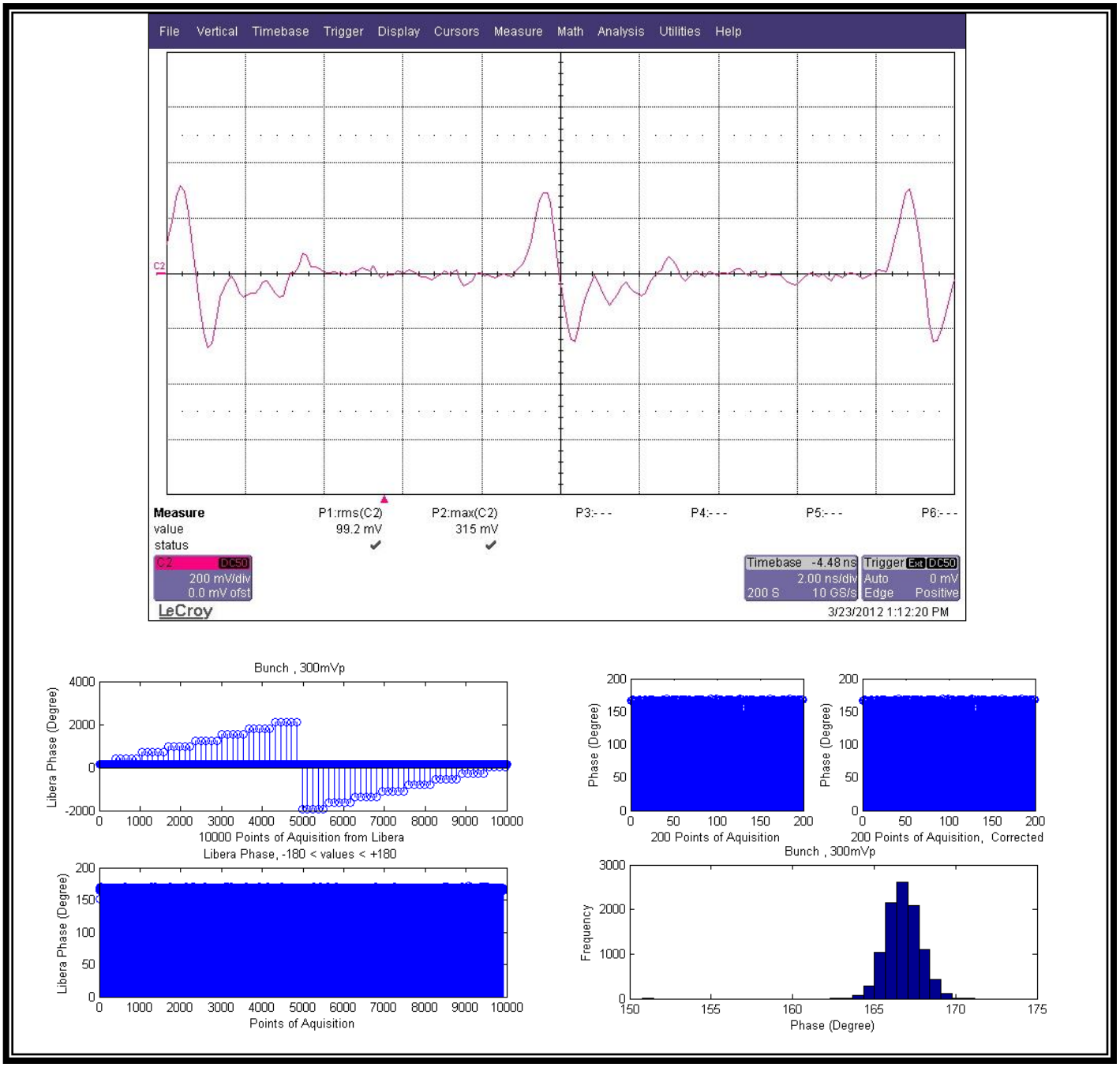


Fig.22, 300mVp bunch with -16 dBm noise.

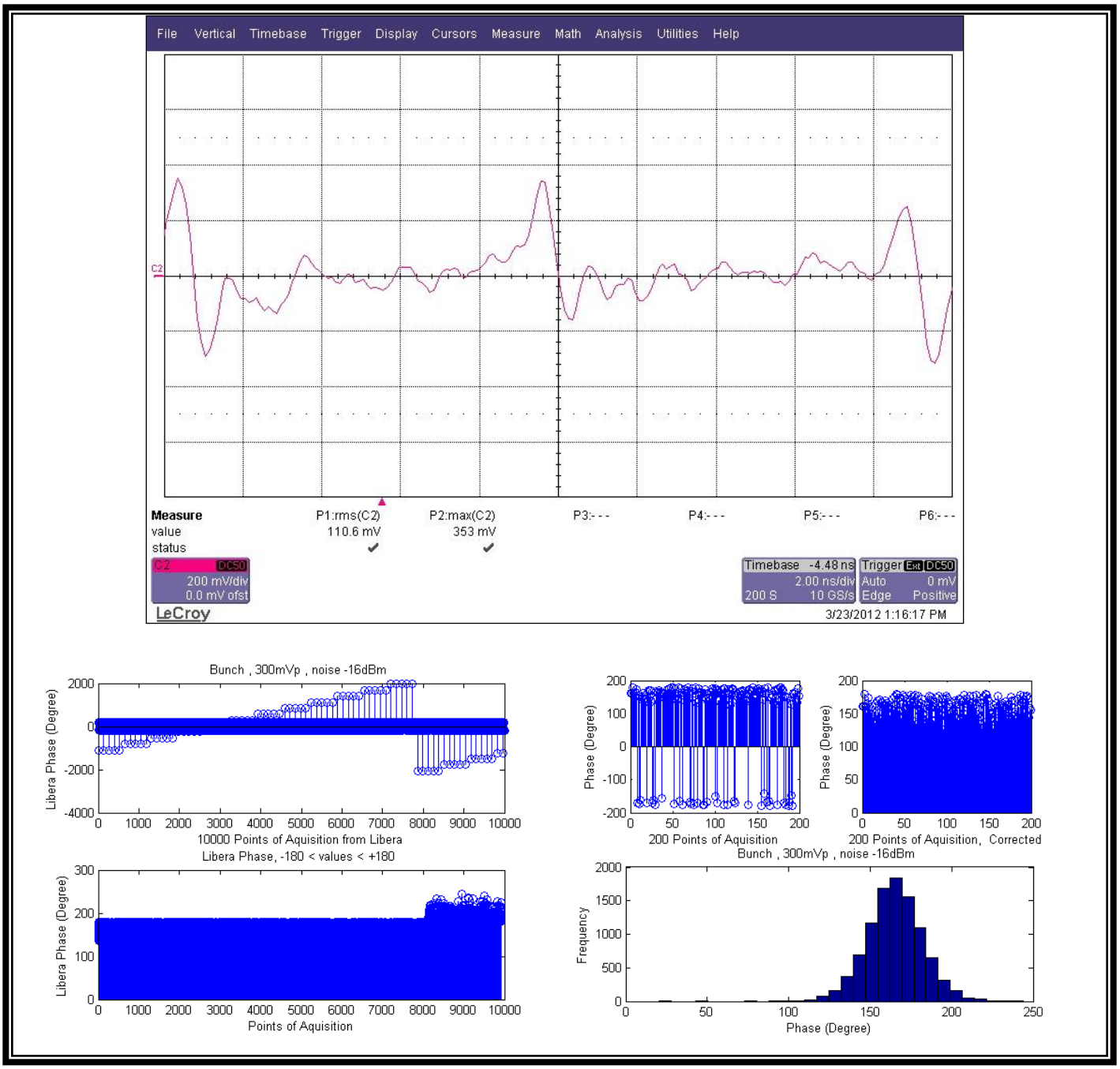


Fig.23, 300mVp bunch with -6 dBm noise.

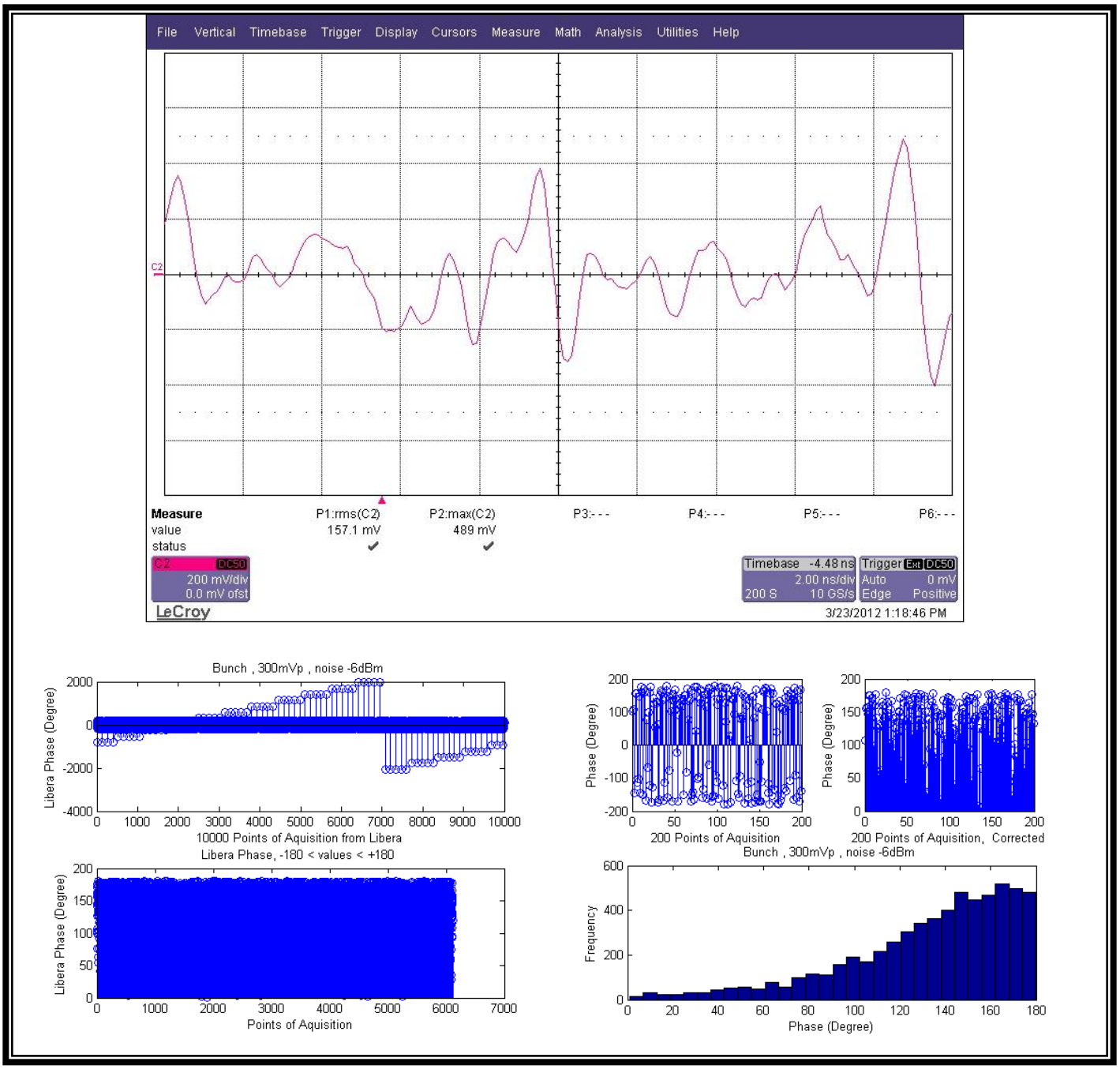
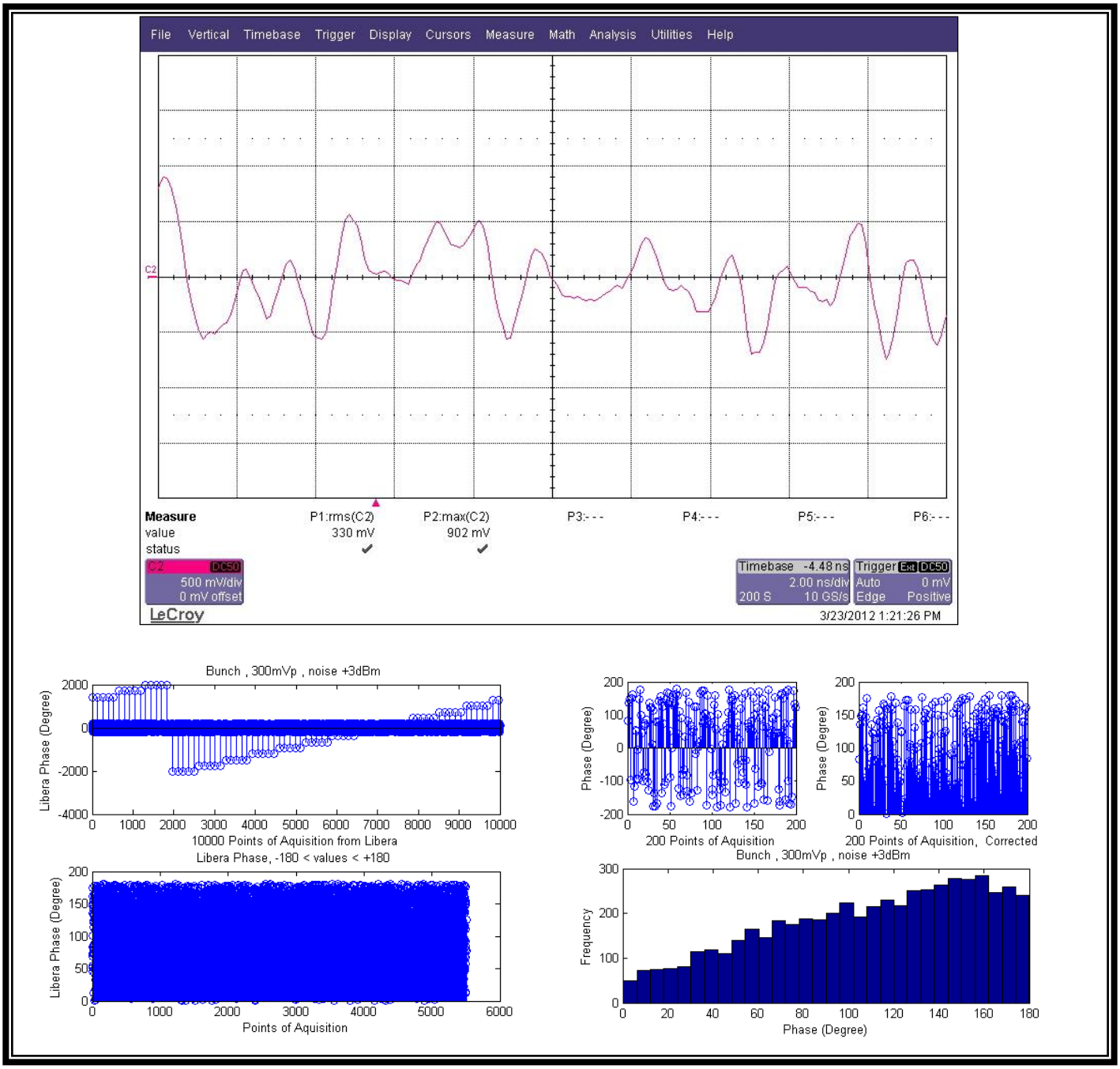


Fig.24, 300mVp bunch with +3 dBm noise.



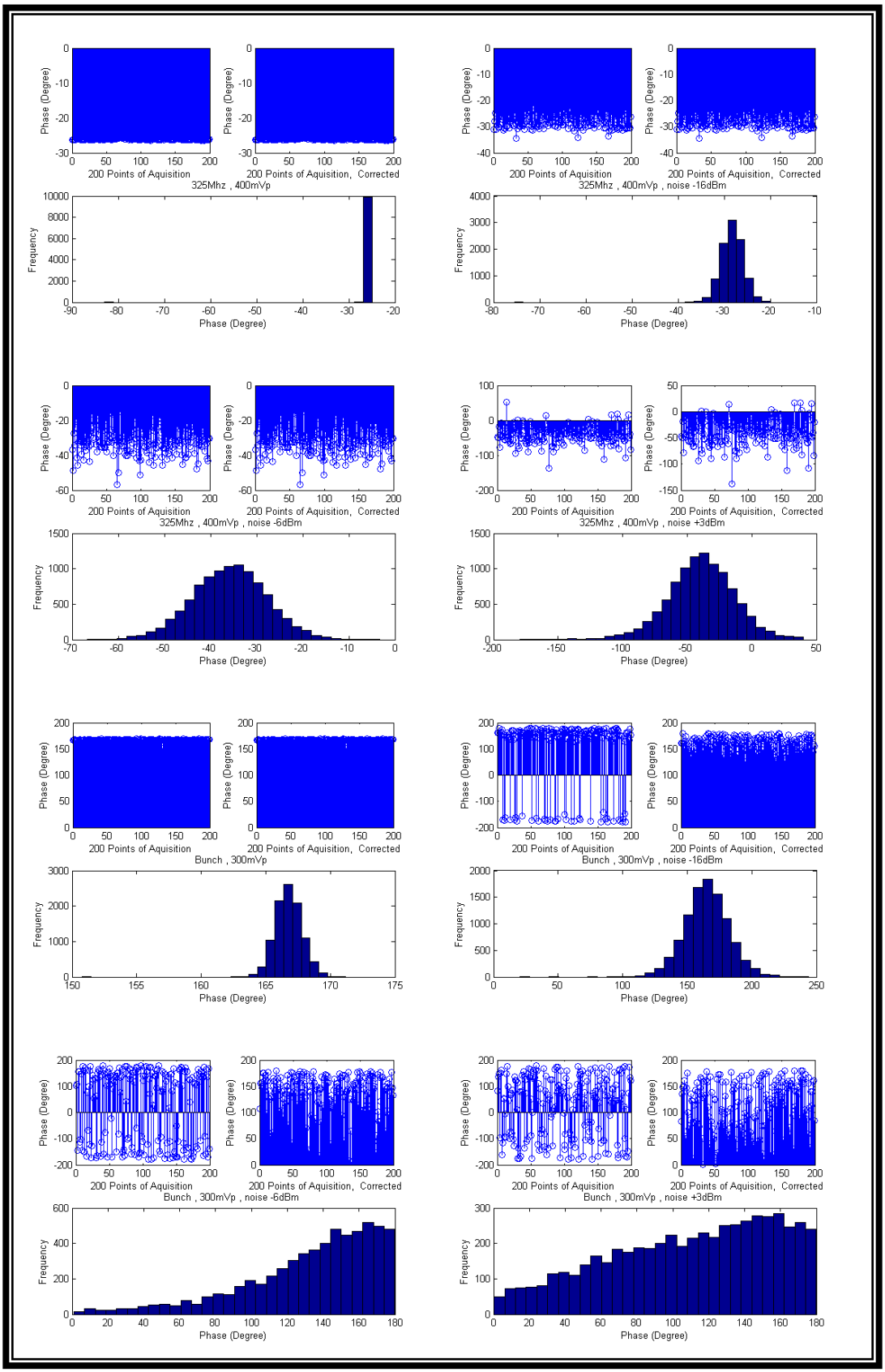
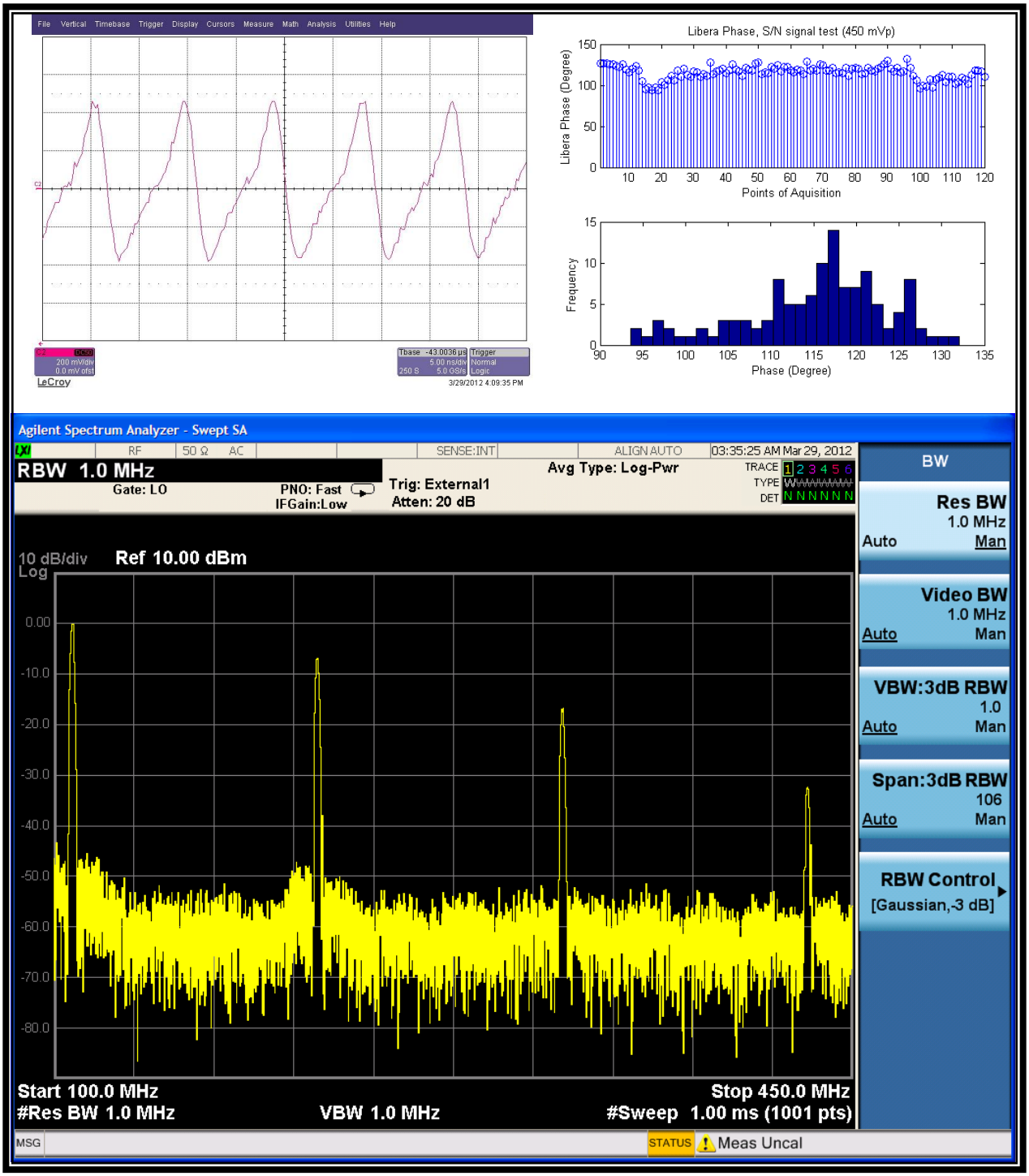


Fig. 25, 400 mVp @ 325,2 MHz and 300 mVp bunch versus noise level and all collected.

➢ S/N ratio experimental test.

A 450 mVp bunch @ 108.4 MHz is formed and then displayed on an oscilloscope. Using a spectrum analyzer, the frequency components are displayed. The power of the third harmonic (325 MHz) is ~ -17 dBm and the the medium noise level is ~60 dBm @ 1MHz resolution bandwidth. The standard deviation for the measured phase is 8.3 ^{o}.



➢ Conclusion

It was shown from those few measurements that the 325 MHz power is critical and it must be strong enough in order to minimize the effect of other signals and noise effect. This effects were particularly strong in such weak signals which confirmed that the Libera Single Pass H is sensitve for noise contribution.

Libera Single Pass H shows great reliabilty to calculate phases with a standard deviation of $< 1.5^{o}$. Such excellence is so promising. This is with one exeption related to the wrapping phase which needs to consider. As a next step, another experimental investigations should be carried out to analyze the limitations of Libera Singlpass H performance in more detail.
