

# Evaluation of the RF Direct sampler “GALAS” for the VGOS Era

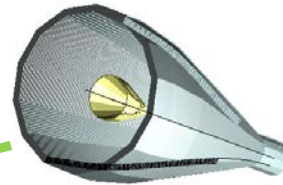
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# Abstract

- Gala-V as a new VGOS project
- New direct sampler: Galas
  - Frequency response
  - Jitter
- Correlation with RF and IF
- Towards a wideband observation
- summary

# Introduction

- Gala-V, new VGOS style
- From 3 GHz to 16 GHz
- Update Kashima 34 meter / Two 1.6 meter



Iguana feed horn  
+ Broad band  
+ Sharp beam width

Optical transfer after LNA etc  
without down converters



Direct sampler  
+ DBBC

# Galas, a new direct sampler

- 16 GHz sampling speed
- 3-bits quantization
- DBBC 2048 MHz, 2-bits
- Four 10 GbE outputs
- Developed by Elecs co, Id.



# Galas: Frequency response

- Measurement

- Capture bit distribution of ADC, which is highly related to frequency and amplitude.

	0	1	2	3
Strong signal	17%	33%	33%	17%
Weak signal	2%	48%	48%	2%

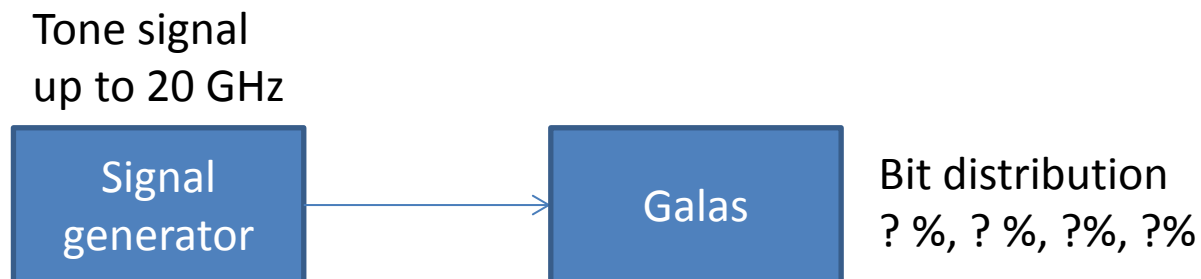
Ex: 2bits sampling

If we input strong signal to a sampler,  
The bit distribution becomes wider

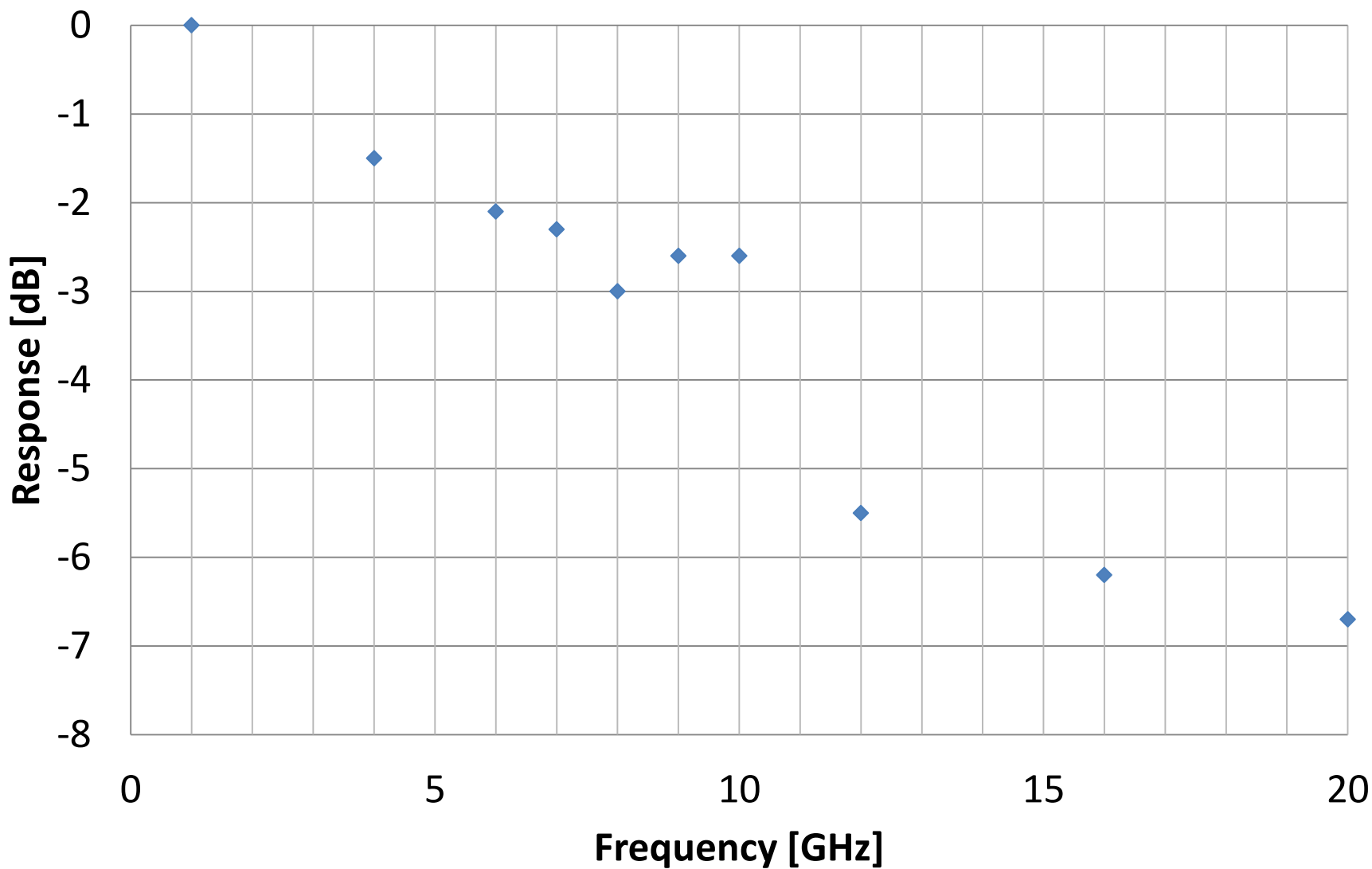
# Galas: Frequency response

- Measurement

- Capture bit distribution of ADC, which is highly related to frequency and amplitude.
- Set bit distribution of **1 GHz as a reference**.
- Change input frequency of the signal generator and take the bit distribution.
- Measure a difference of the amplitude at 1 GHz, considering with a cable attenuation.



# Frequency response of Galas



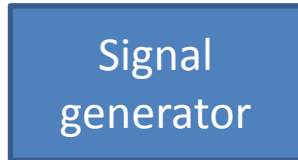
# Frequency response of the Galas

- Every measurements refer 1 GHz.
- Almost linear curve from 1GHz to 20GHz.
- Galas response at 20 GHz is 6.7dB, and the ADC response at 20 GHz is 2.3dB from datasheet.
- This difference maybe be caused by internal cable and micro-strip line.



# Jitter measurement of Galas

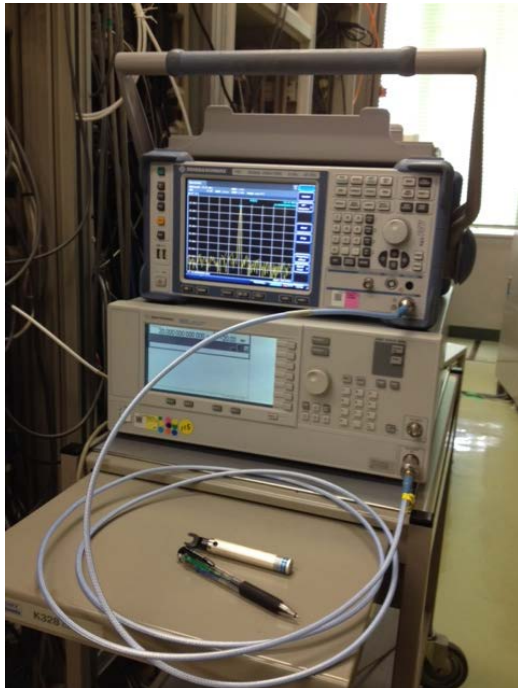
Tone signal  
up to 16 GHz



DBBC 2048Msps\*2bit



Phase calculation by FFT



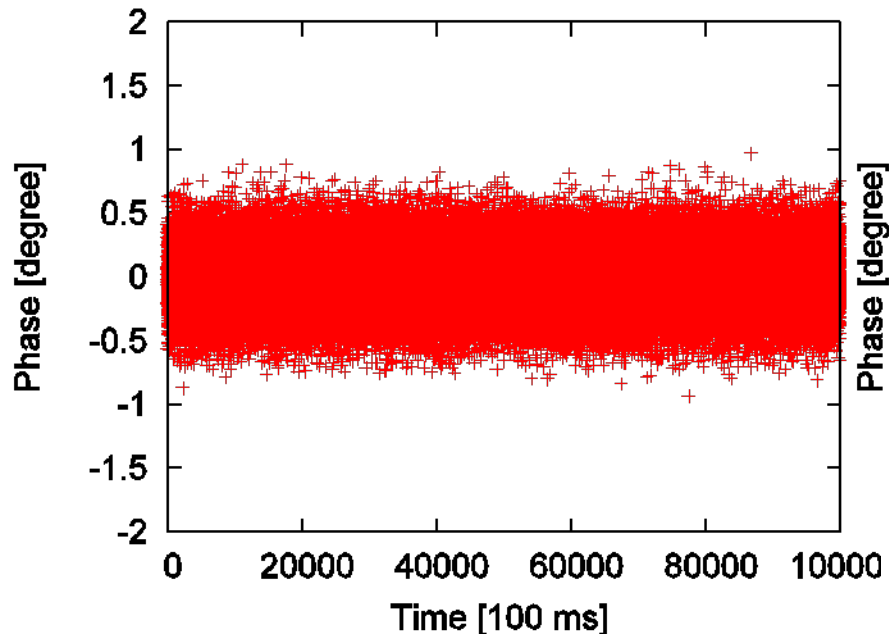
# Jitter measurement

- Signal generator generates tone signal, 1MHz higher than the frequency of the DBBC setting.
- Perform phase calculation per 1 us for 1 sec (about 1 M series)

# Time series of the phase

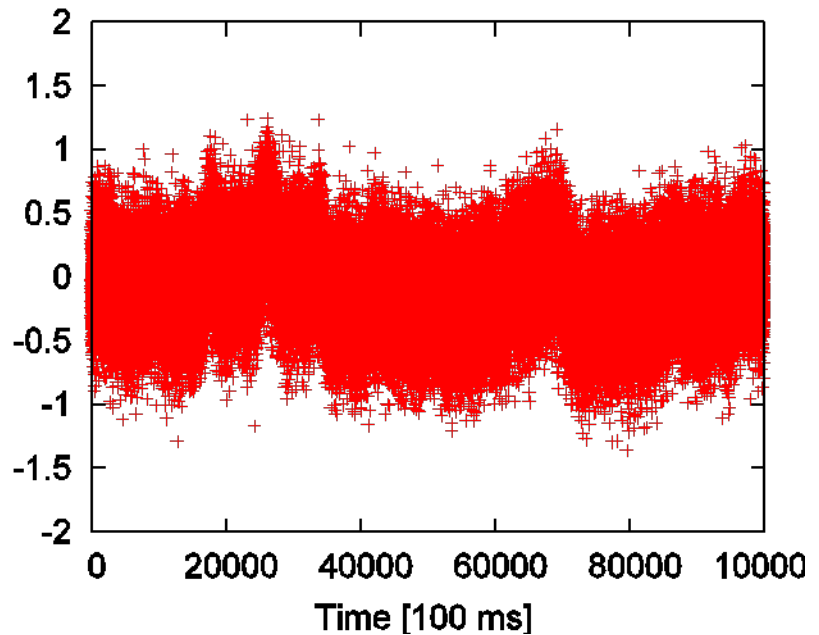
Ex: 1 MHz tone signal

Peak-Peak < 2 degree



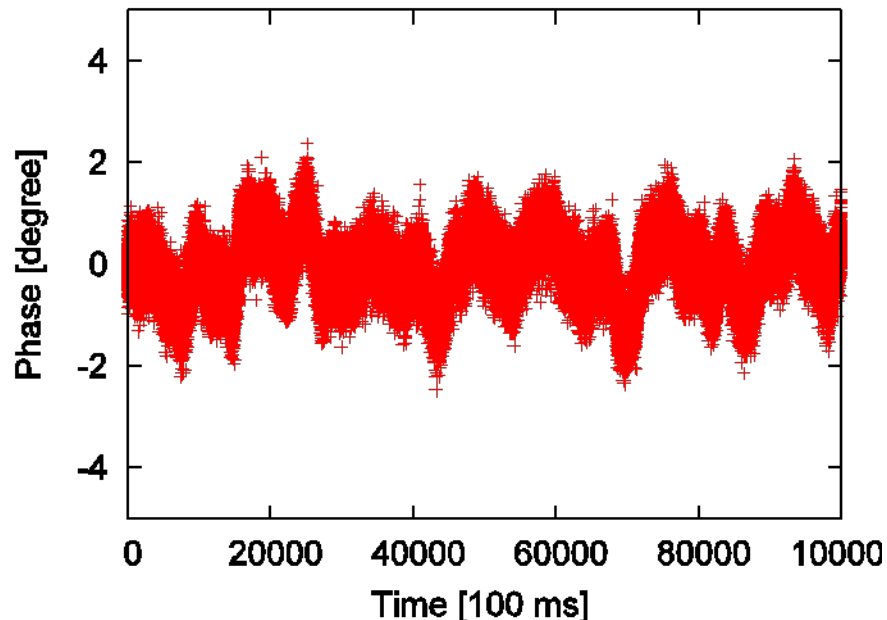
Ex: 2GHz tone signal

Peak-Peak : 2 degree



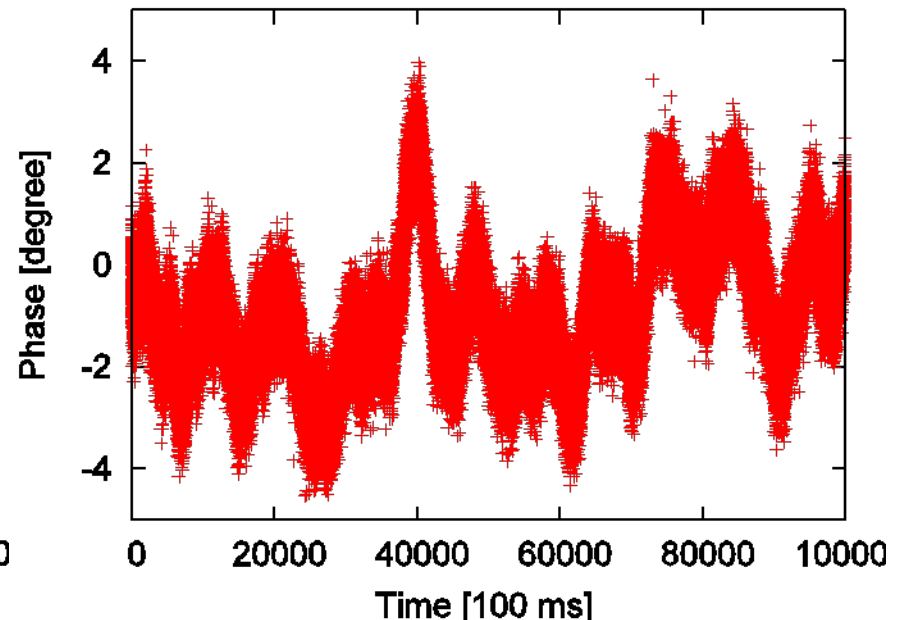
Ex: 7 GHz tone signal

Peak-Peak : 4 degree



Ex: 12 GHz tone signal

Peak-Peak : 8 degree

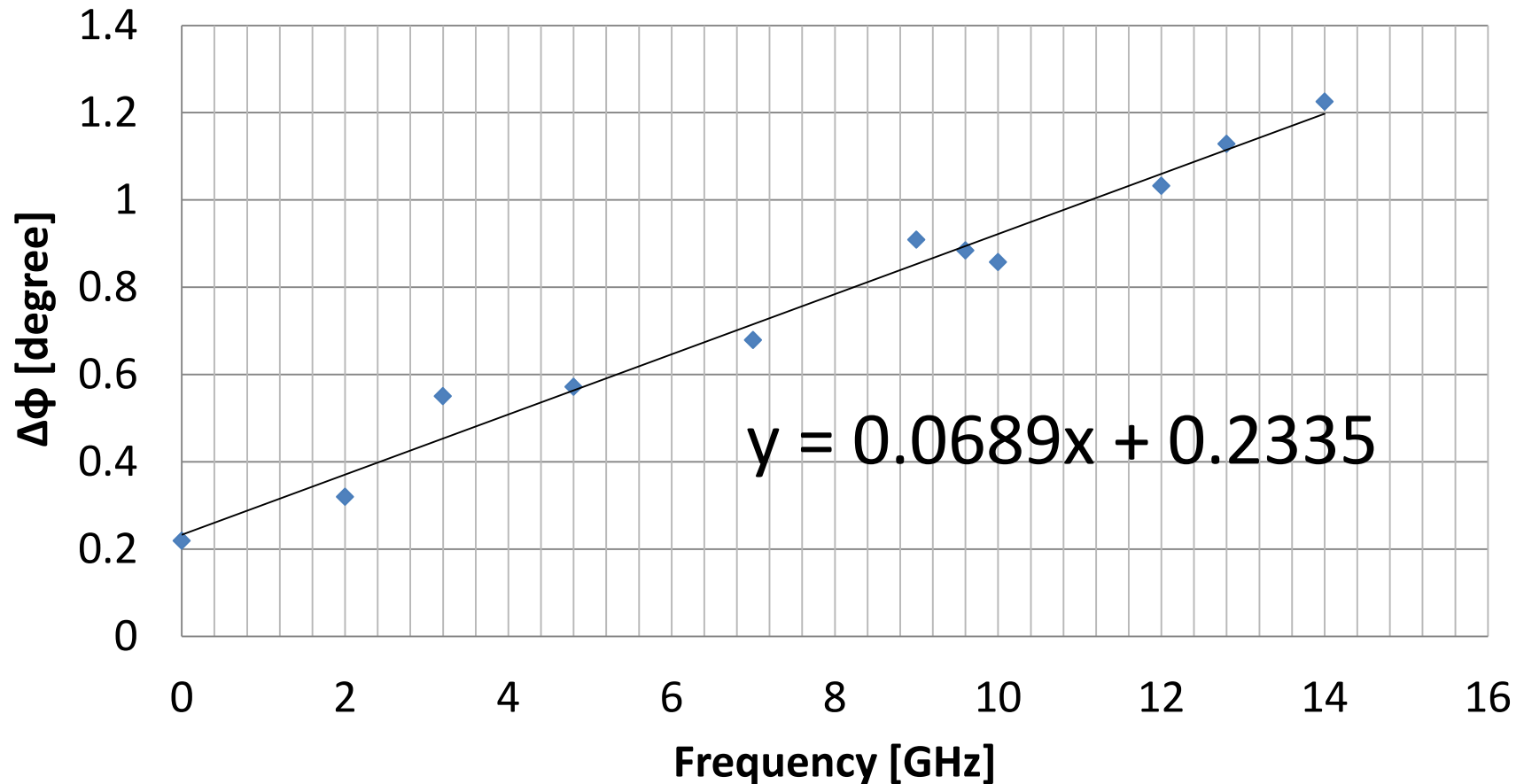


The fluctuation of the phase would depend on a frequency of the tone signal

=> Jitter

# Jitter from phase deviations at each frequencies

## Galas jitter measurement



# Jitter measurement

$$\text{Jitter [sec]} = \Delta\Phi[\text{deg}]/(360*\text{Frequency[Hz]})$$

The Slope is  $0.00689[\text{deg}/\text{GHz}] = 0.191\text{ps}$   
( $1.9139\text{e-}13$ )

The value includes the jitter of the SG itself and the sampler.

If we make a observation with 20 GHz,

$$0.191 [\text{ps}] * 20 [\text{GHz}] = 1.38 [\text{deg}]$$

The phase error is enough small even 20 GHz observation.

# Zero baseline test with RF and IF sampling



1.5 meter antenna on the roof

QRHA Antenna



LNA

4-14GHz

HPF

3GHz filter for RFI

E/O

1-18GHz

Optical-cable

RF signal

E/O

IF signal

Galas

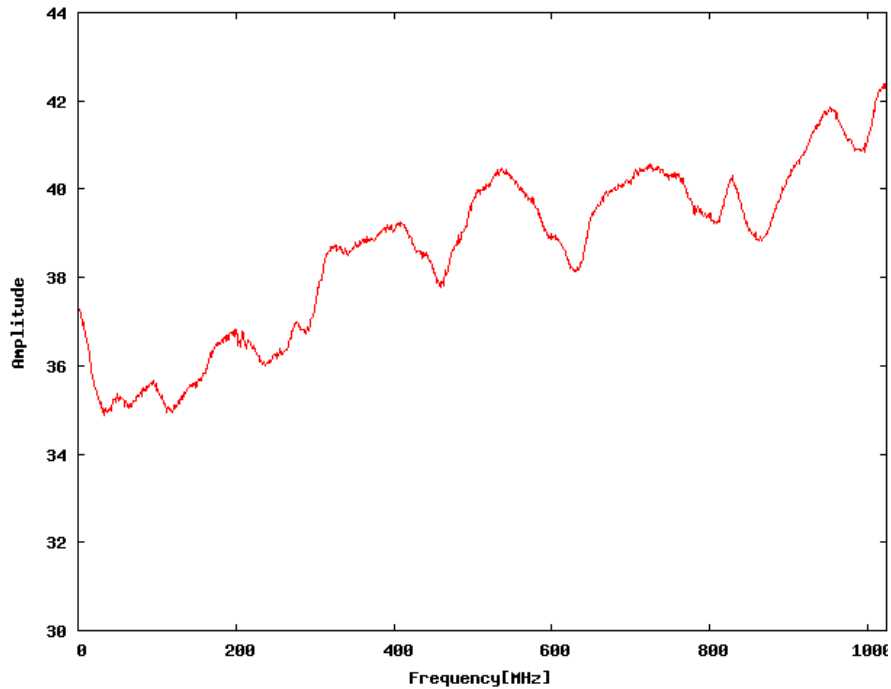
Down-converter

ADS3000+



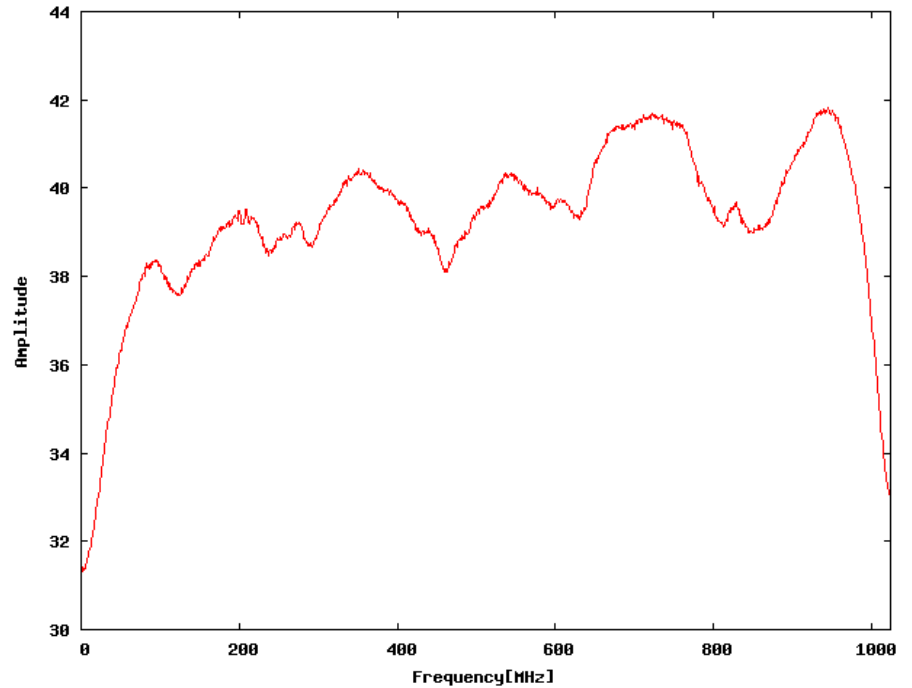
# Gala-V ch1

ADS3000+



0 15.1511  
1 35.0511  
2 34.9134  
3 14.8844

Galas

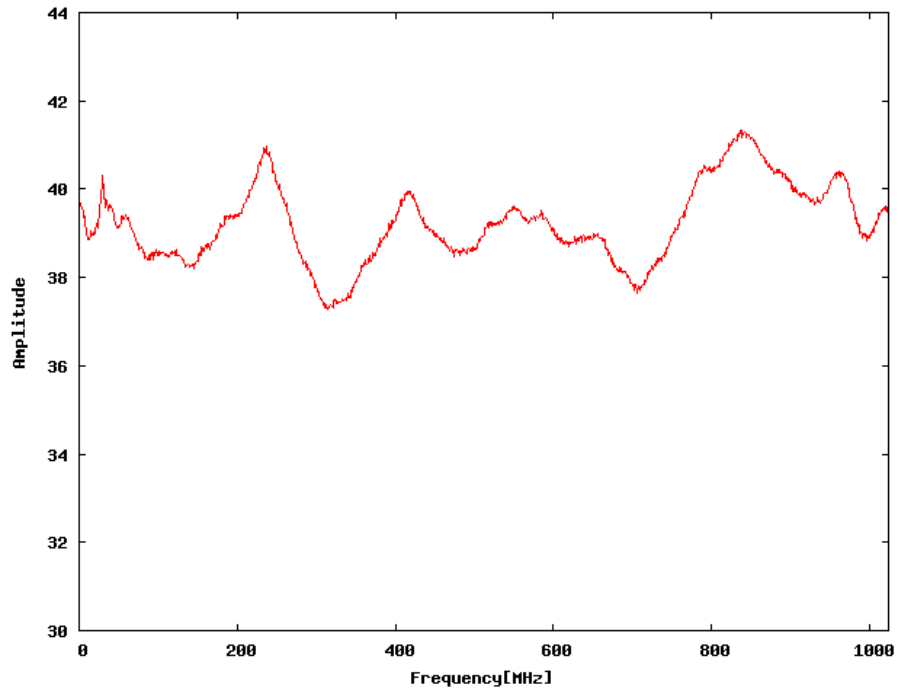


0 17.4352  
1 32.578  
2 32.5267  
3 17.46



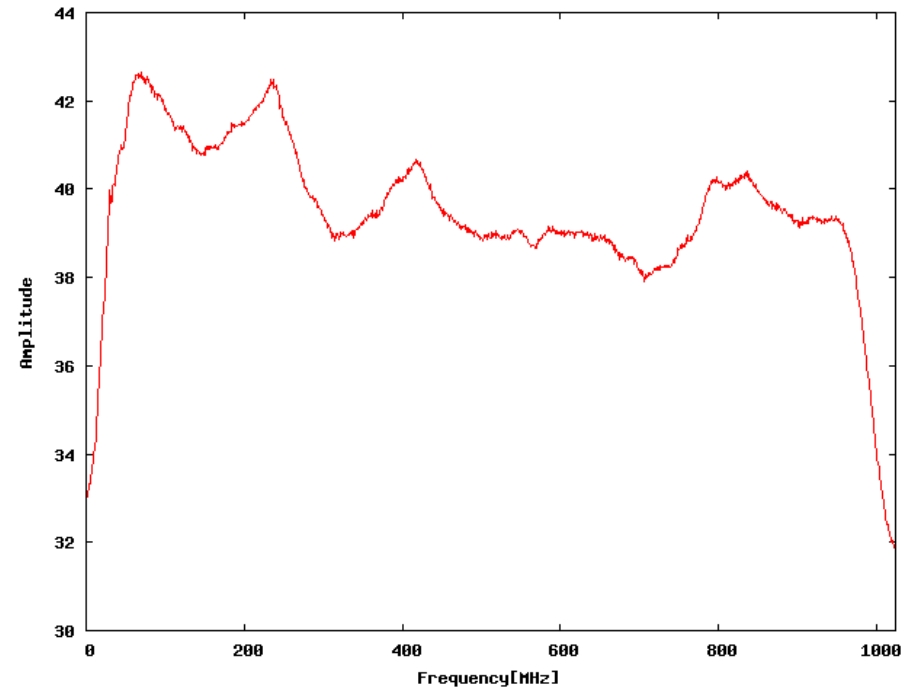
# Gala-V ch2

ADS3000+



0 11.3293  
1 38.7817  
2 38.7979  
3 11.0911

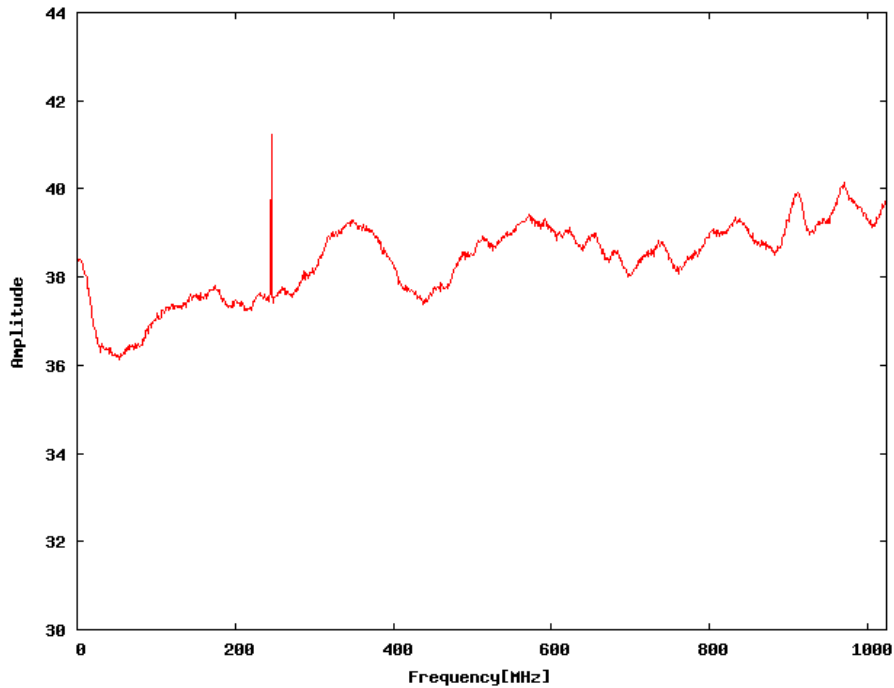
Galas



0 16.5449  
1 33.4445  
2 33.488  
3 16.5225

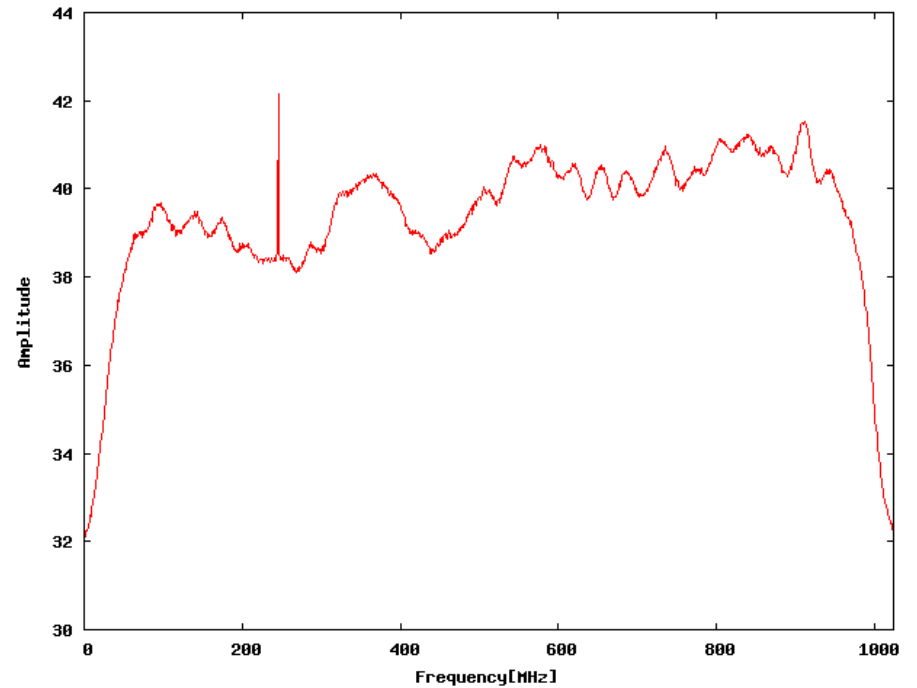
# Gala-V ch3

## ADS3000+



0 10.4744  
1 39.6271  
2 39.6356  
3 10.2629

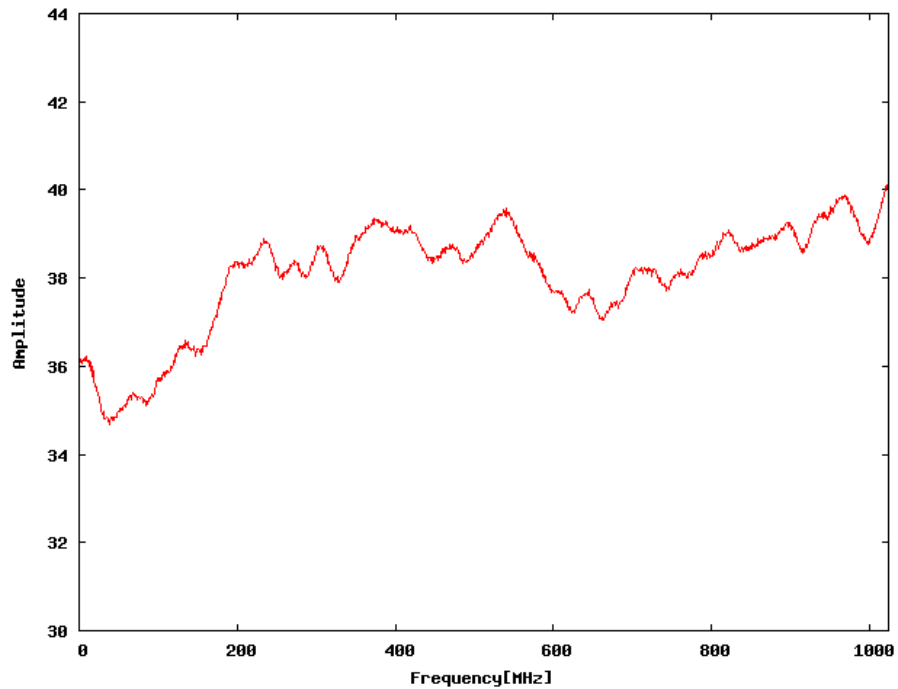
## Galas



0 17.0387  
1 32.9766  
2 32.9549  
3 17.0298

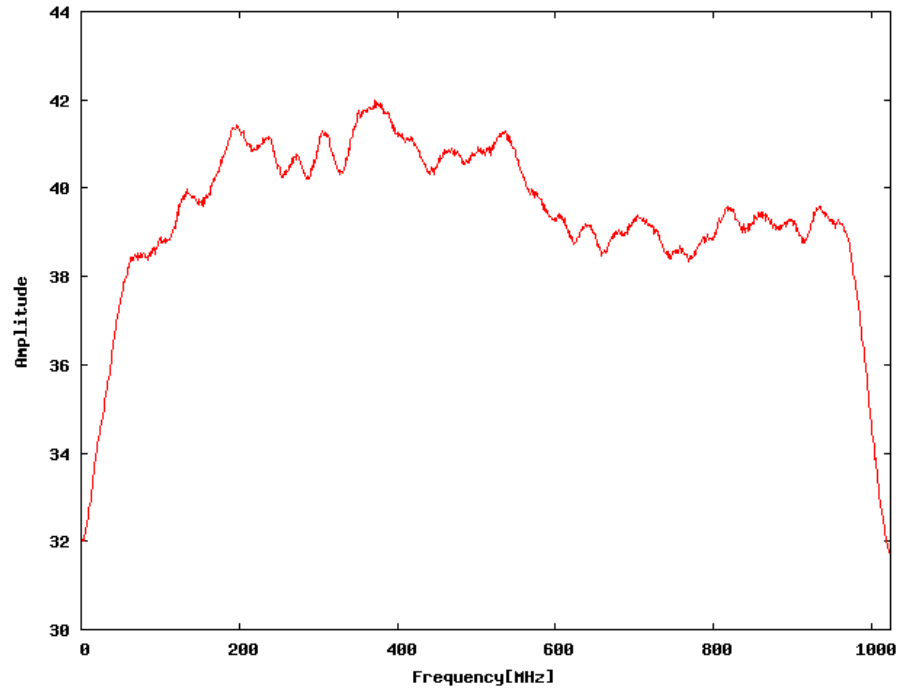
# Gala-V ch4

ADS3000+



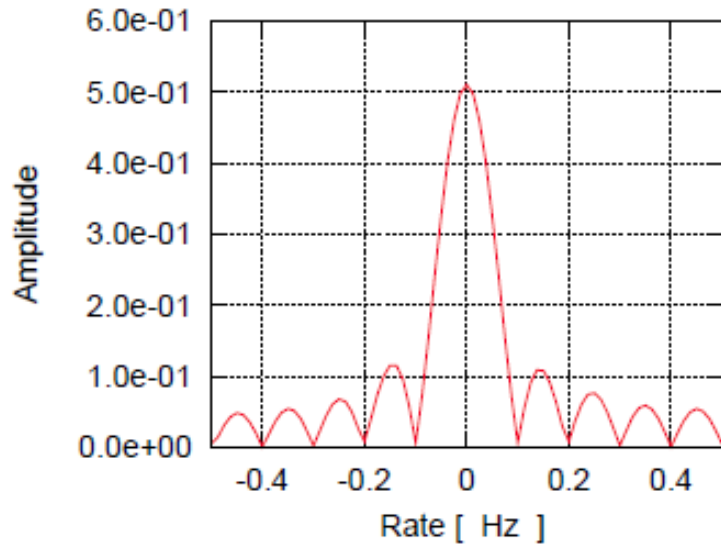
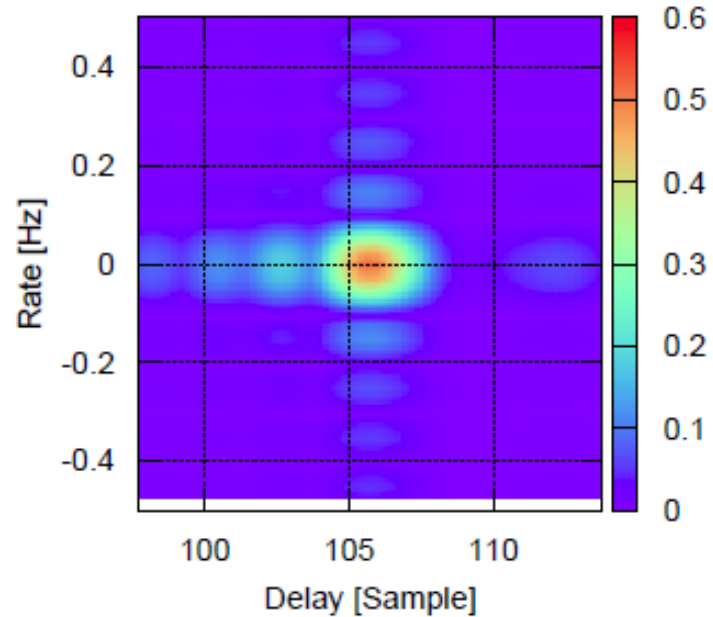
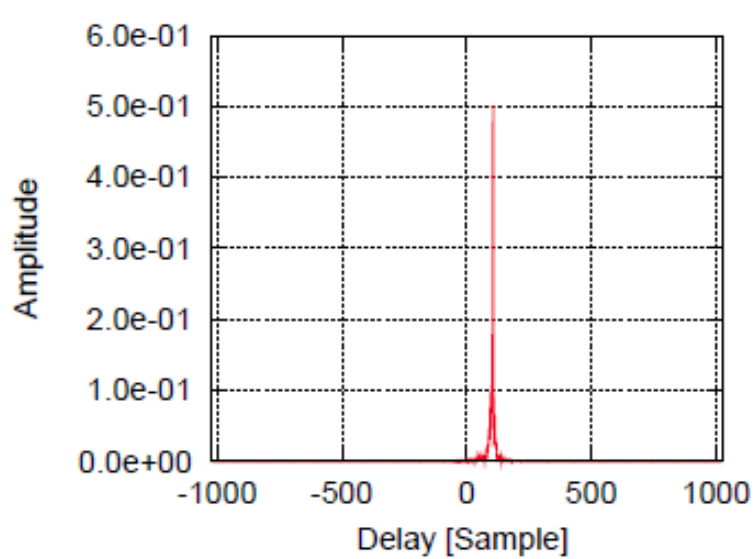
0 13.6814  
1 36.4033  
2 36.4732  
3 13.4421

Galas



0 16.3451  
1 33.6378  
2 33.663  
3 16.3541

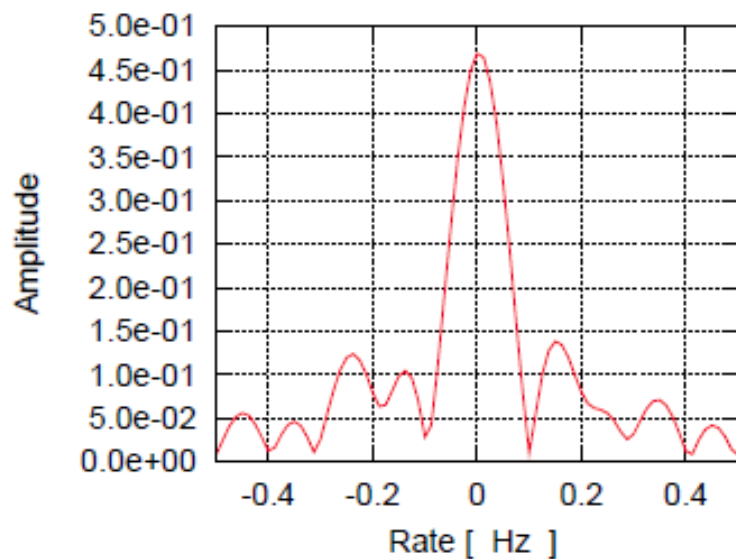
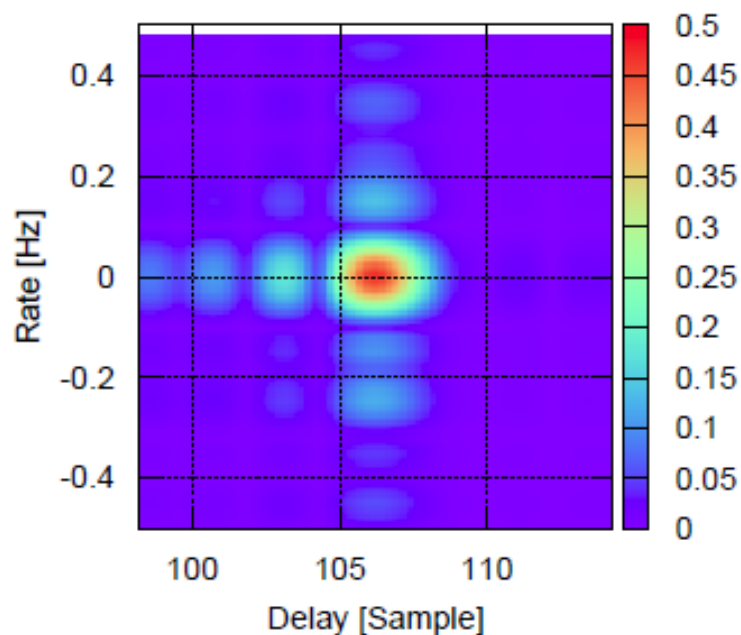
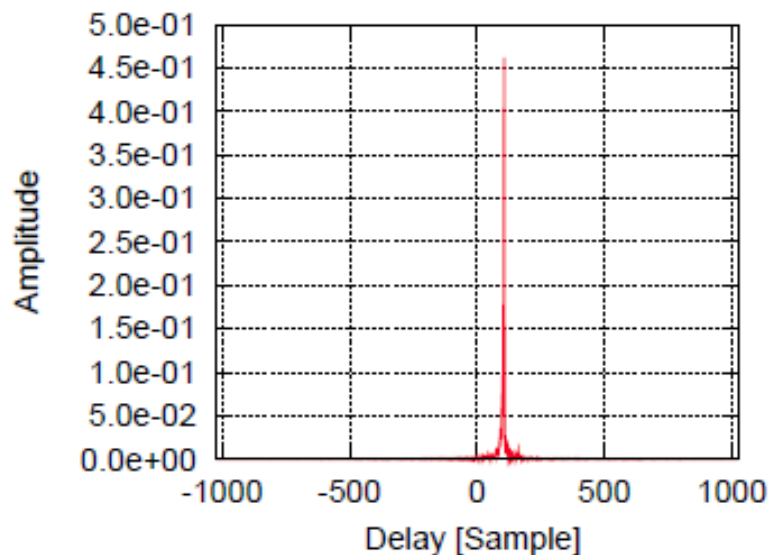
# Correlation result with the 1<sup>st</sup> channel



```

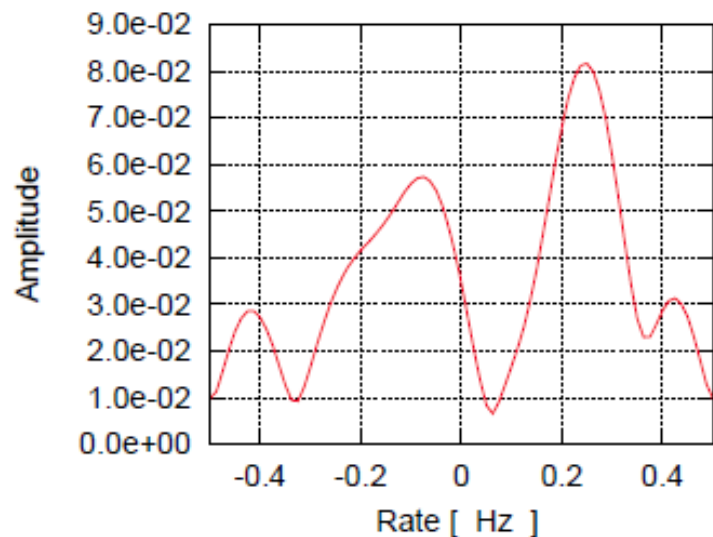
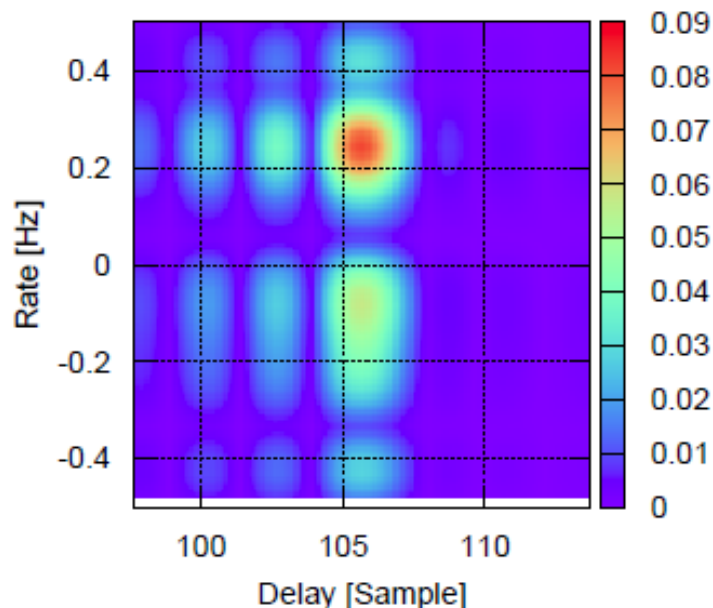
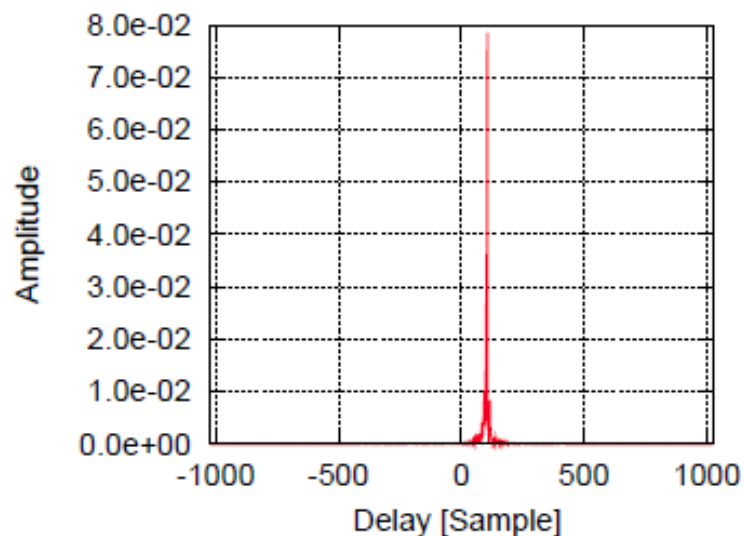
Epoch      : 2013/226 08:30:00
Station-1  : ADS
Station-2  : GAL
Source     : 3C84
Length     : 10.000000 [sec]
Sampling   : 2048000000 [sps]
Frequency  : +8192.000000 [MHz]
Peak Amp   : 51.095119 [ % ]
Peak Phs   : 93.617466 [deg]
Delay      : +105.739639 [spl]
Rate       : -0.074768 [mHz]
SNR        : 1716.283333
    
```

# Correlation result with the 3<sup>rd</sup> channel



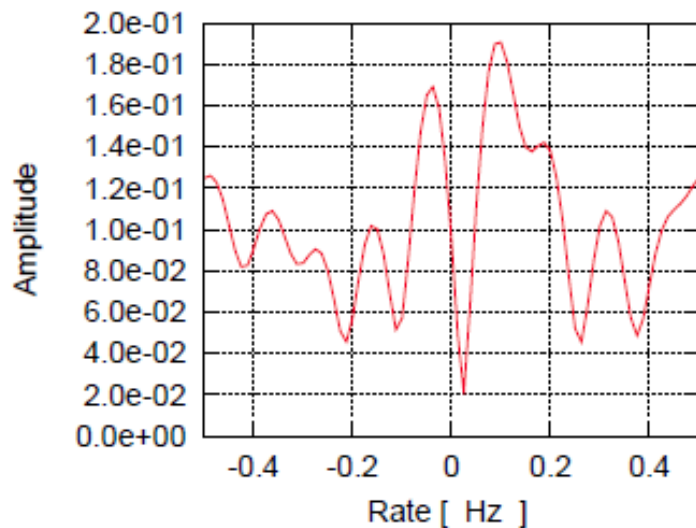
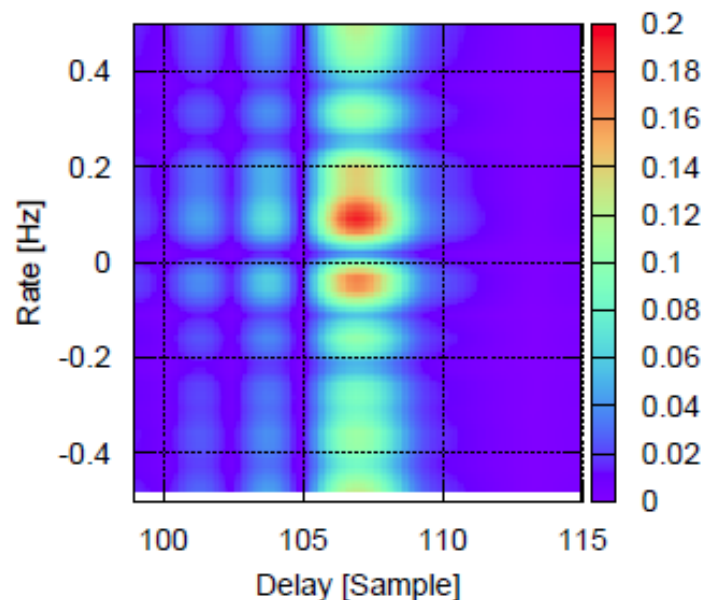
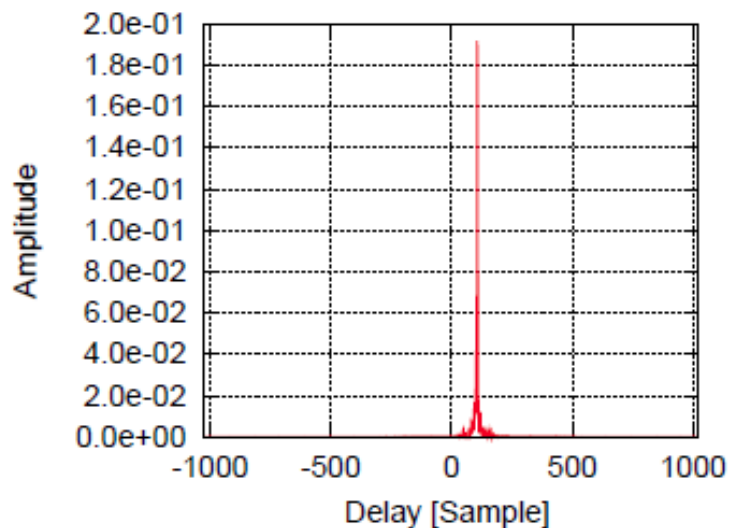
```
Epoch      : 2013/226 08:10:00
Station-1  : ADS
Station-2  : GAL
Source     : 3C84
Length     : 10.000000 [sec]
Sampling   : 2048000000 [sps]
Frequency  : +8192.000000 [MHz]
Peak Amp   : 46.998714 [%]
Peak Phs   : -57.125282 [deg]
Delay      : +106.227661 [spl]
Rate       : +4.156494 [mHz]
SNR        : 1121.830830
```

# Strange Fringe ! with the 2<sup>nd</sup> channel



```
Epoch      : 2013/226 08:02:00
Station-1  : ADS
Station-2  : GAL
Source     : 3C84
Length     : 10.000000 [sec]
Sampling   : 2048000000 [sps]
Frequency  : +8192.000000 [MHz]
Peak Amp   : 8.185559 [%]
Peak Phs   : -43.686509 [deg]
Delay      : +105.669998 [spl]
Rate       : +246.116638 [mHz]
SNR        : 581.165621
```

# Strange Fringe ! with the 4<sup>th</sup> channel



```
Epoch      : 2013/226 08:19:00
Station-1  : ADS
Station-2  : GAL
Source     : 3C84
Length    : 10.000000 [sec]
Sampling  : 2048000000 [sps]
Frequency : +8192.000000 [MHz]
Peak Amp  : 19.189284 [%]
Peak Phs  : -122.332251 [deg]
Delay     : +106.973022 [spl]
Rate      : +94.528198 [mHz]
SNR       : 464.002416
```

# Summary

## Direct sampler Galas:

- Almost linear curve from 1GHz to 20GHz
- Frequency response 6.7dB at 20 GHz
- 0.2 ps jitter
- Detected good fringes with correlation of RF and IF signals (if PLO does not broken.)
- Components of direct sampling system are much less than ever, reliability will be improved.



