3-Antenna Observation and Raw Data Analysis

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3-Antenna Observation in 2013

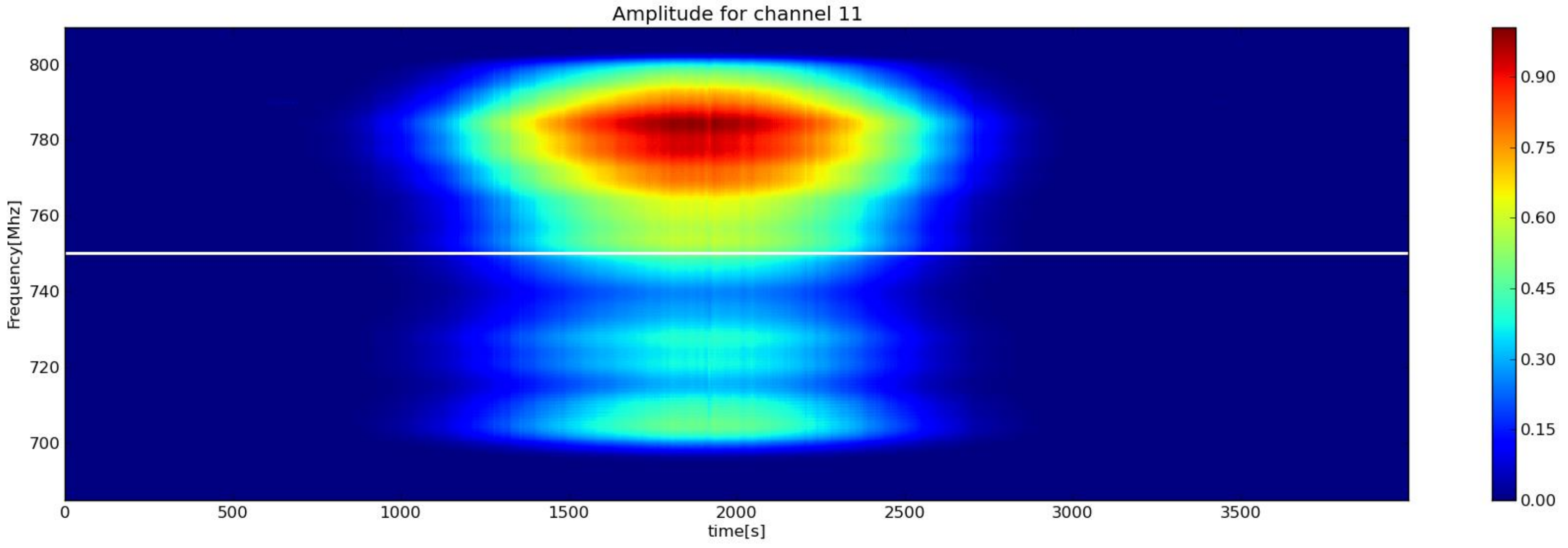
- Location: MingAnTu Observatory (N42.221589 E115.255502)
- Frequency: 685~810MHz
- Integration: 0.5 seconds
- Baseline length A1→A2 ~ 28.9m, A1→A3 ~ 42.9m
- Two polarizations each antenna(Horizon: ch1,3,5; Vertical: ch2,4,6.)
- Source: Sun, Cygnus A, Cassiopeia A.

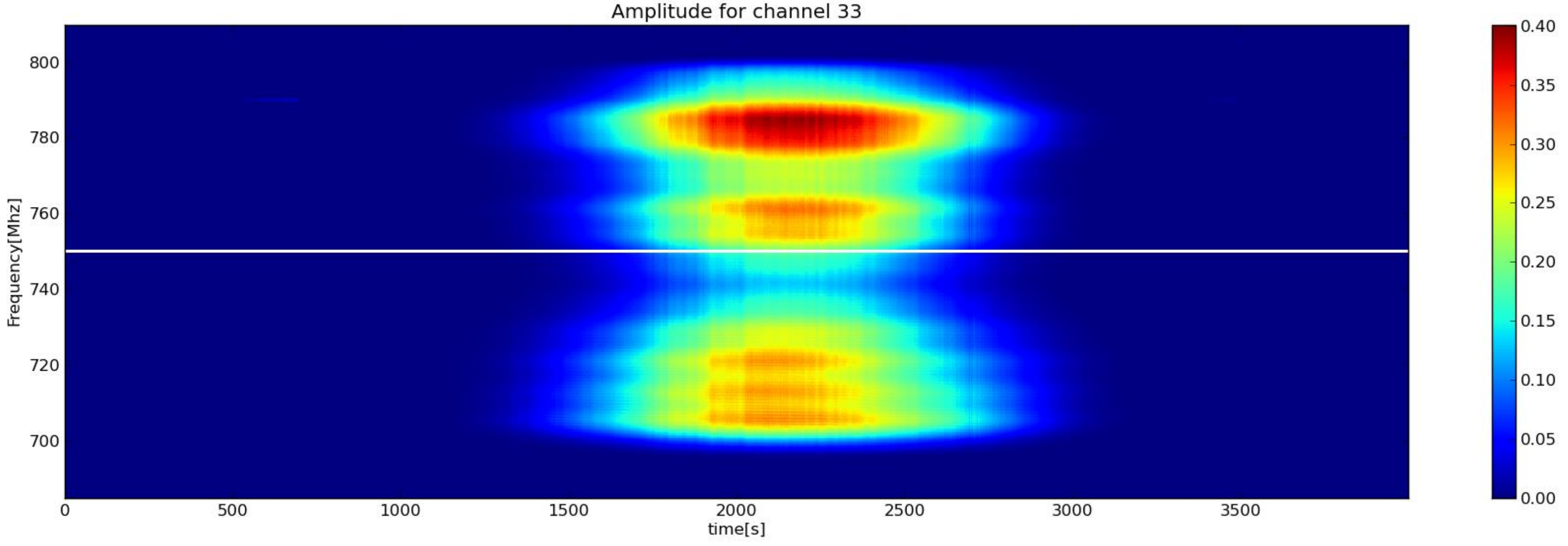
Data preview

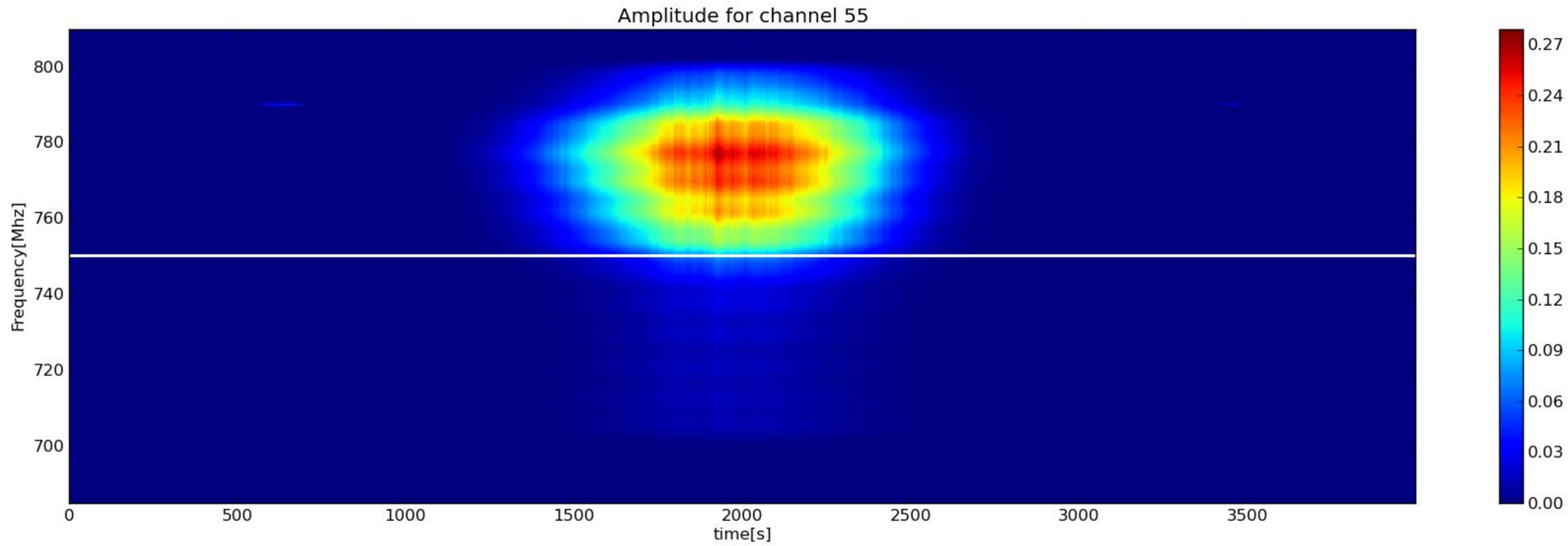
- Sun, Sept. 17th, 2013
- Channel 2 is a useless channel because, by mistake, it actually outputs channel 1's data.

Amplitude of auto-correlation (Ch11, 33, 55; Horizontal)

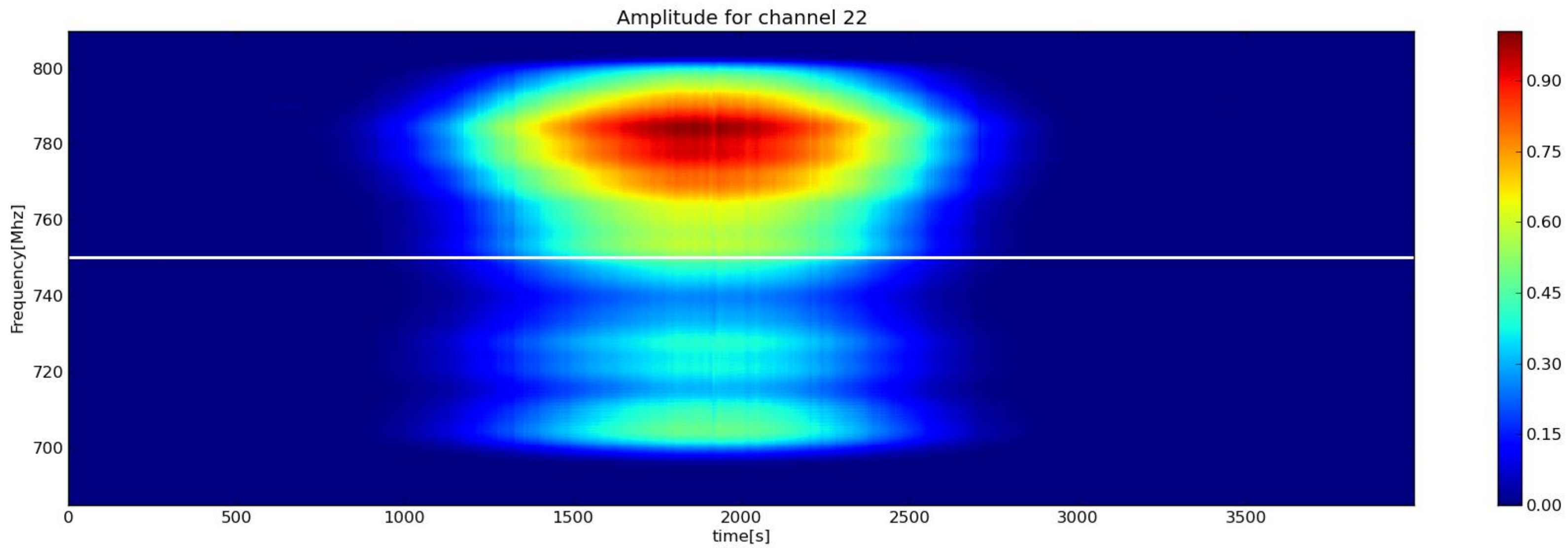
Note: channel 2 is a wrong channel, which by mistake, is actually channel 1's data.

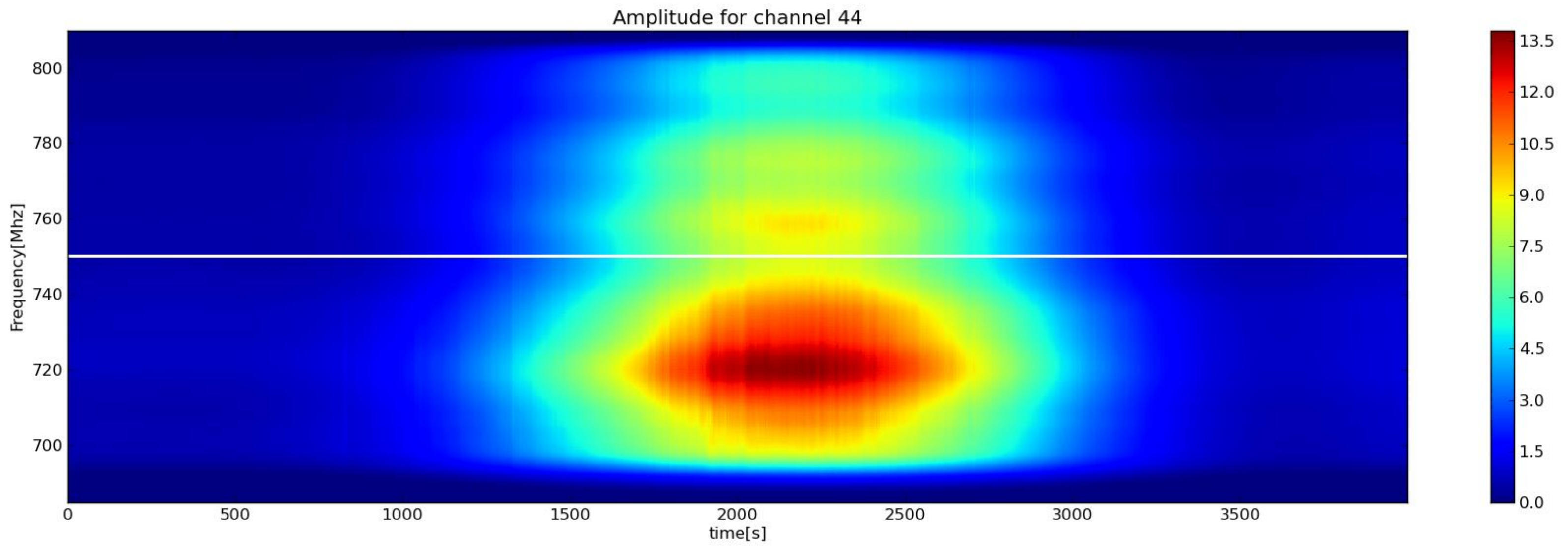




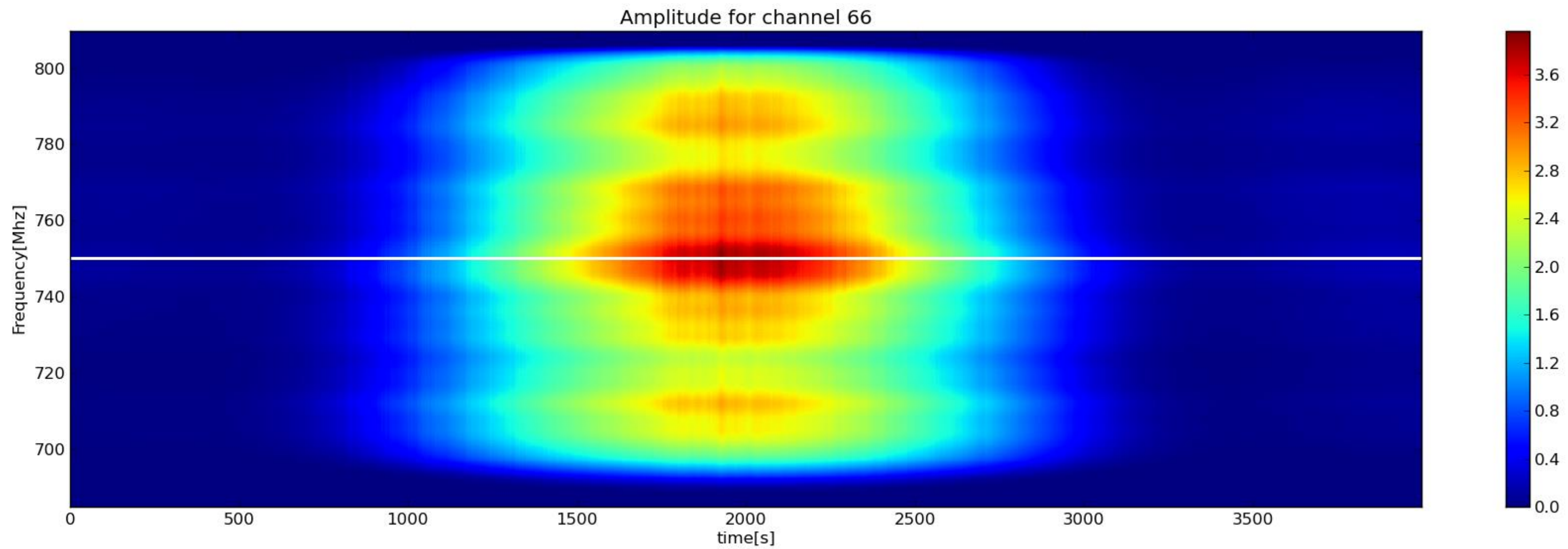


Amplitude of auto-correlation (Ch22, 44, 66; Vertical)



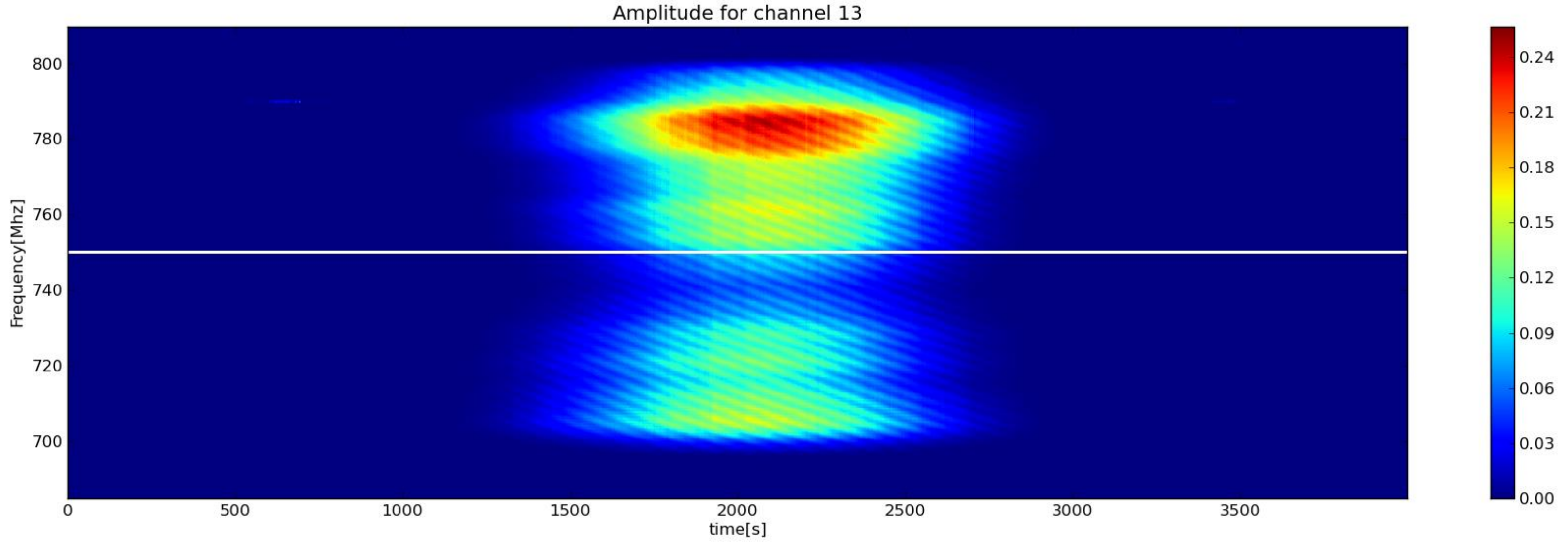


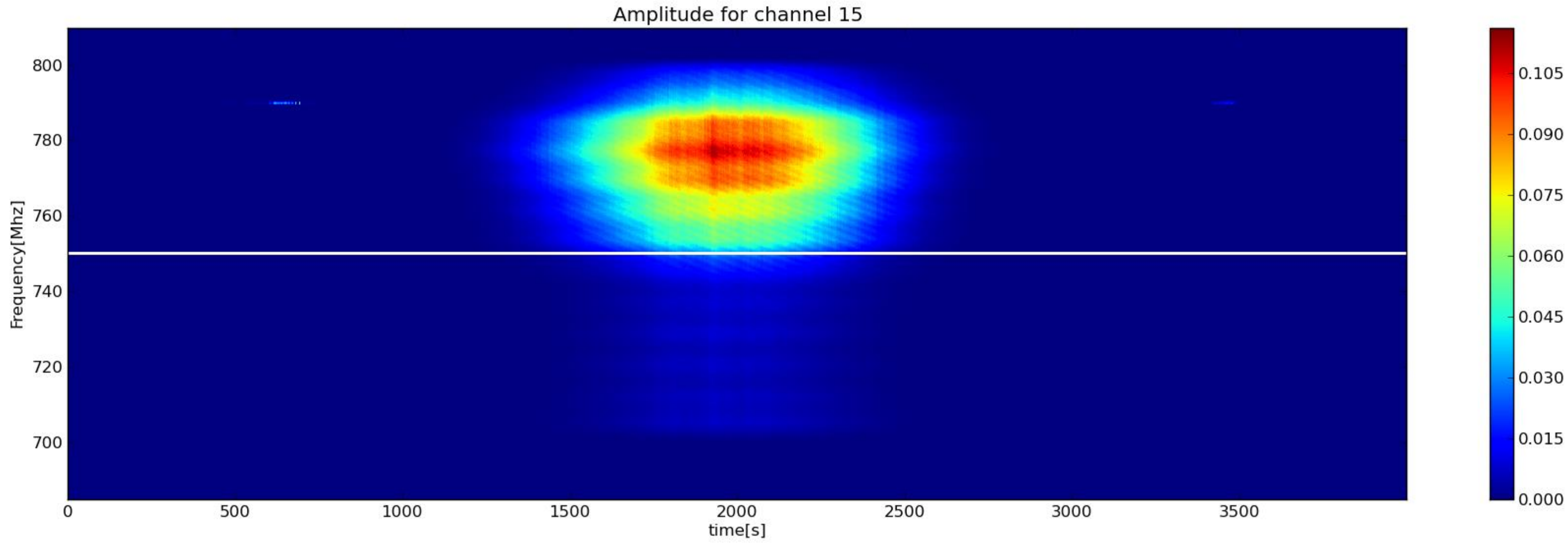
Amplitude for channel 44
Frequency[Mhz]
800
780
760
740
720
700
0
500
1000
1500
2000
2500
3000
3500
time[s]
13.5
12.0
10.5
9.0
7.5
6.0
4.5
3.0
1.5
0.0

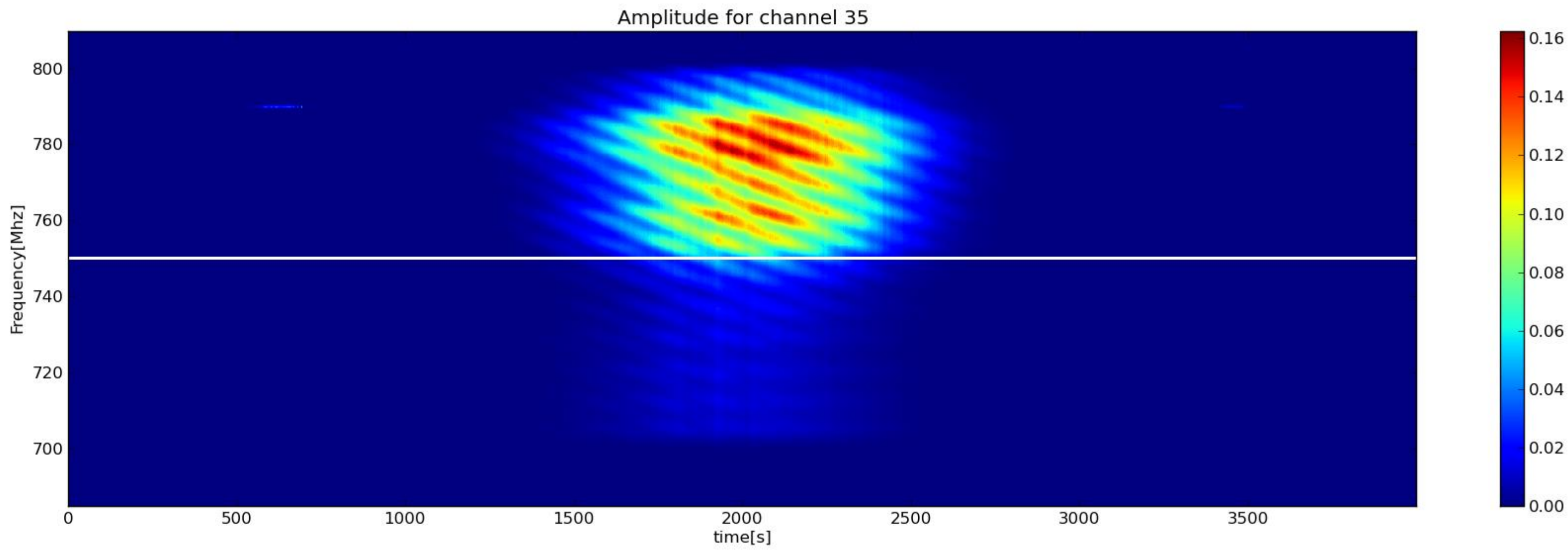


Amplitude for channel 66
Frequency[Mhz]
800
780
760
740
720
700
0
500
1000
1500
2000
2500
3000
3500
time[s]
3.6
3.2
2.8
2.4
2.0
1.6
1.2
0.8
0.4
0.0

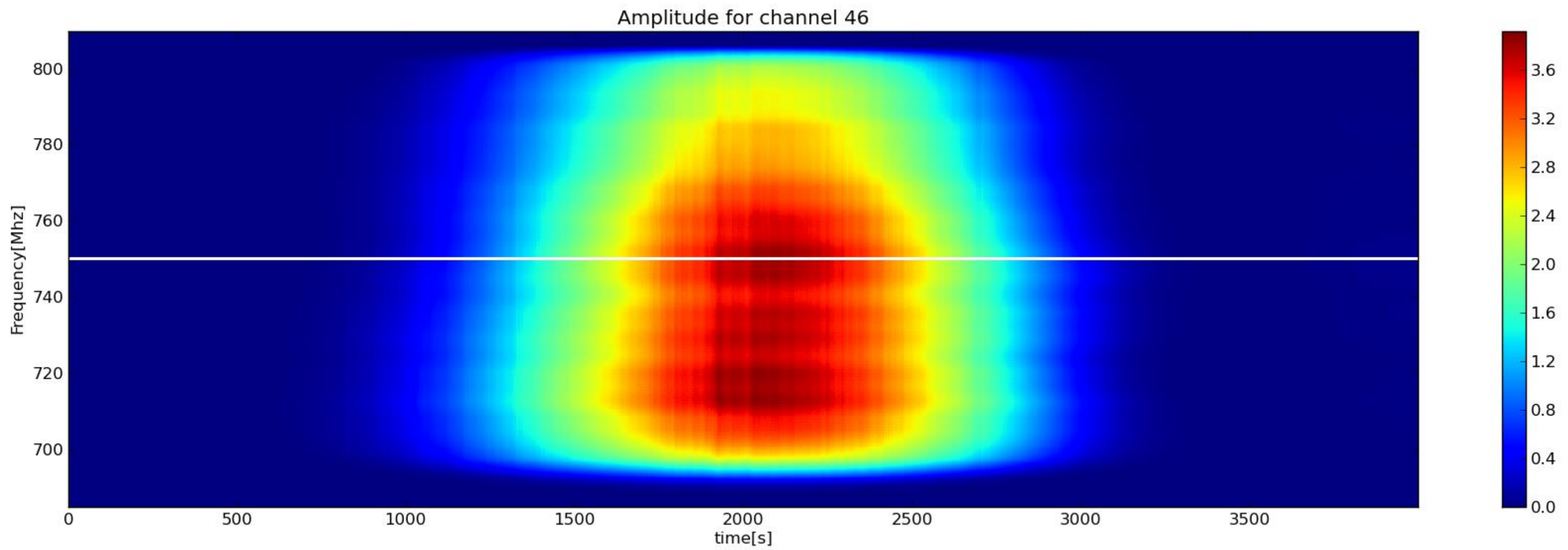
Amplitude of cross-correlation (Ch13, 15, 35; Horizontal)





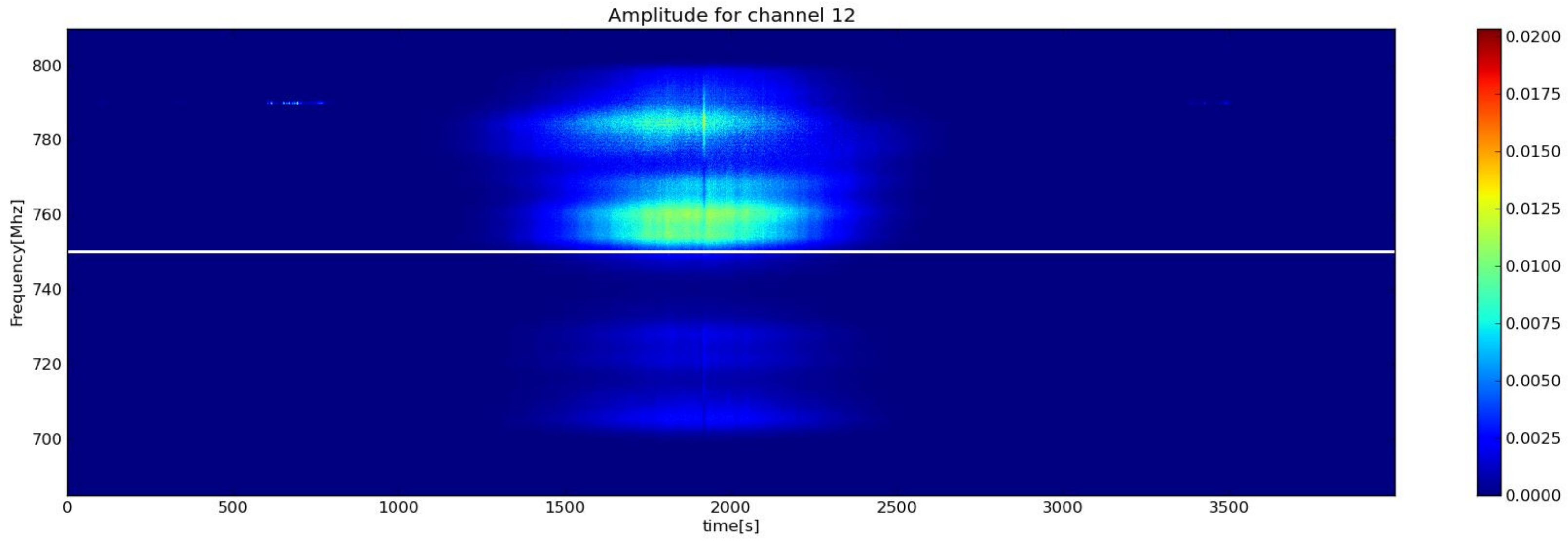


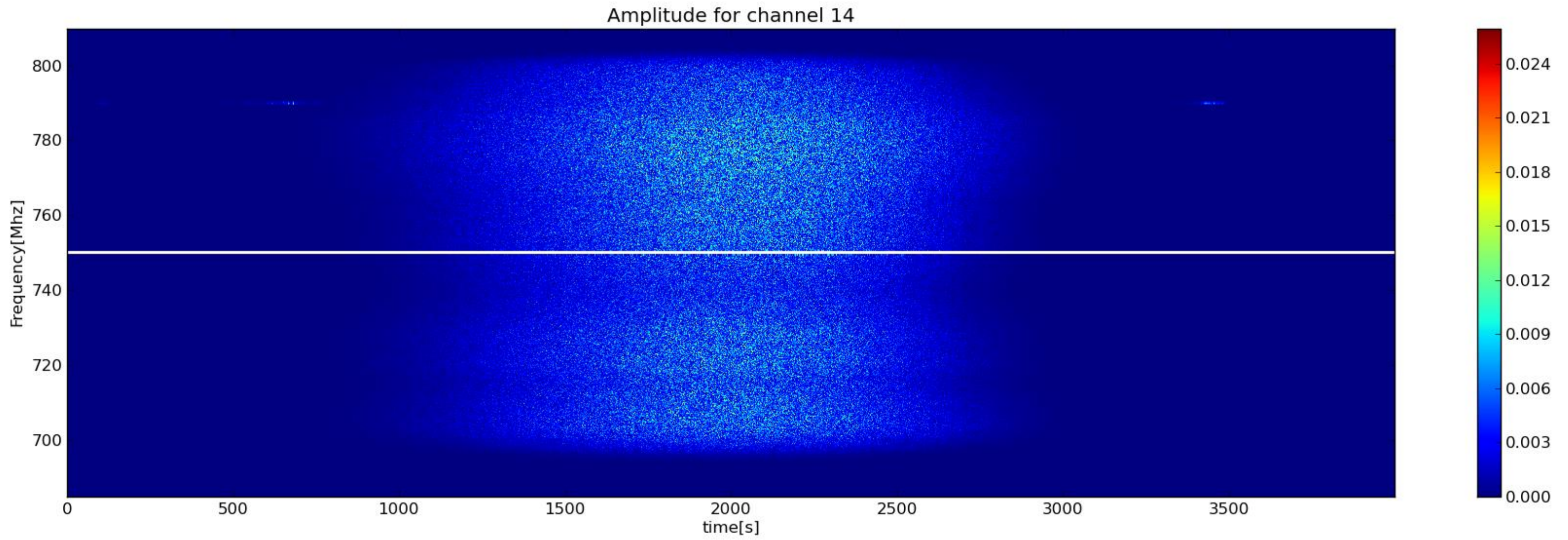
Amplitude of cross-correlation (Ch46; Vertical)

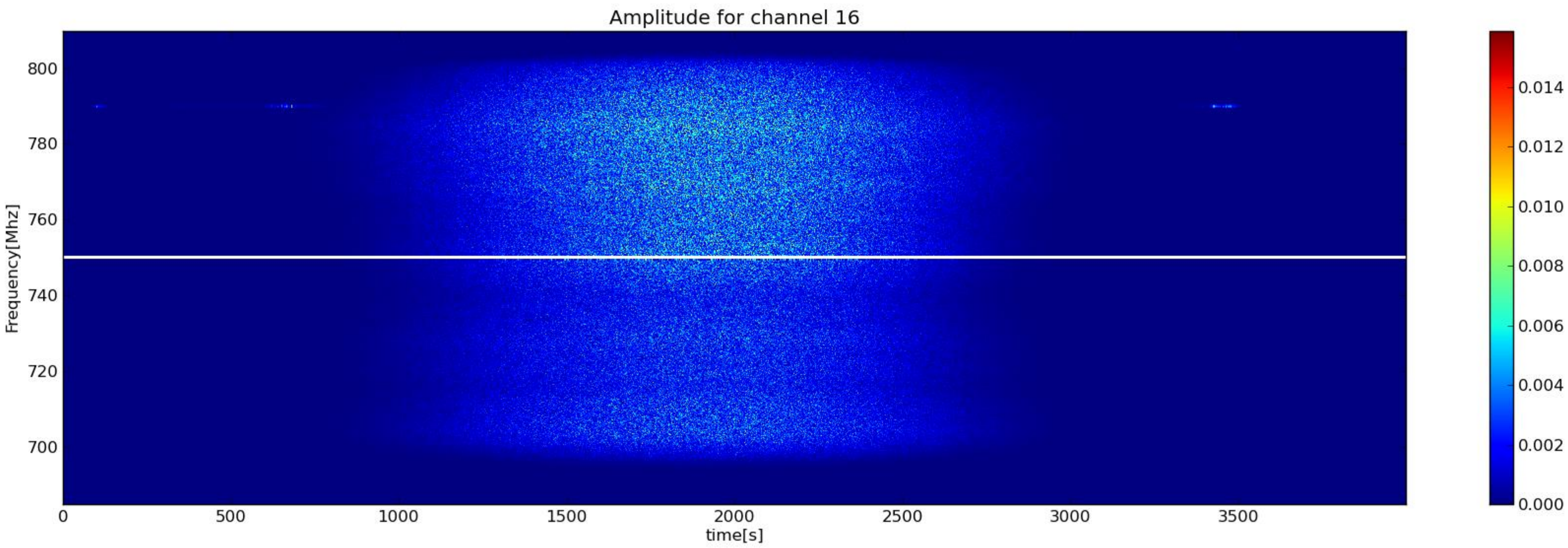


Amplitude of cross-correlation (Ch12, 14, 16)

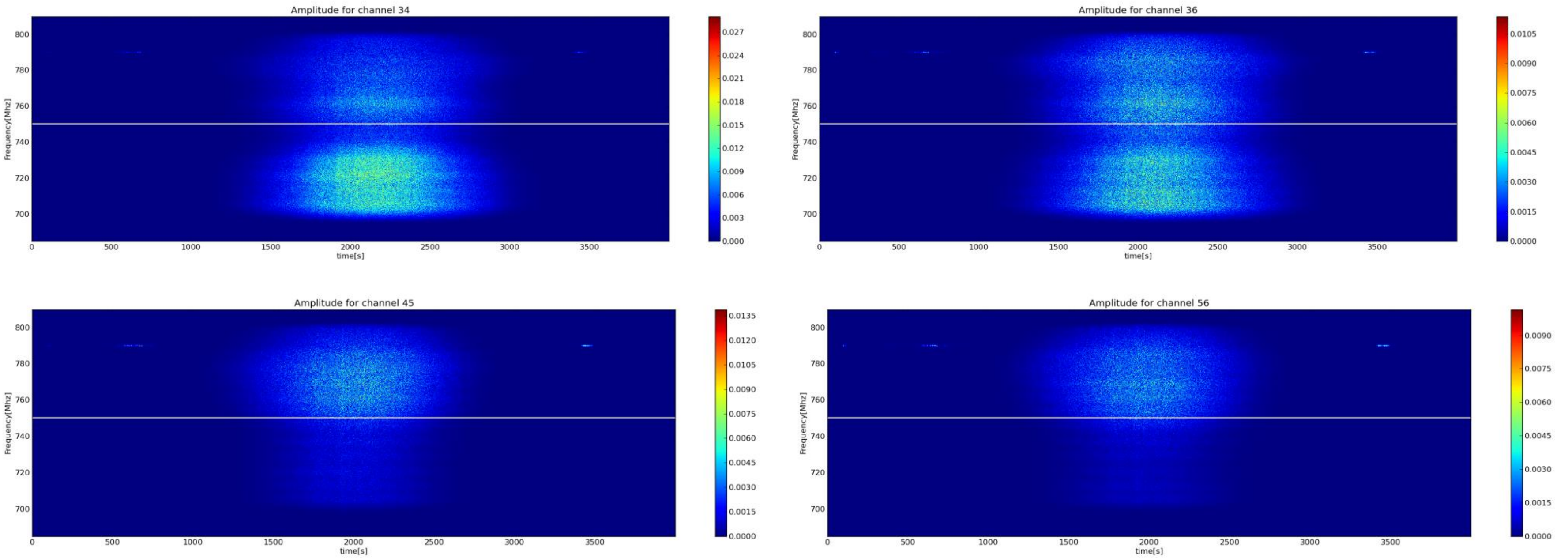
Note: channel 2 is a wrong channel, which by mistake, is actually channel 1’s data.





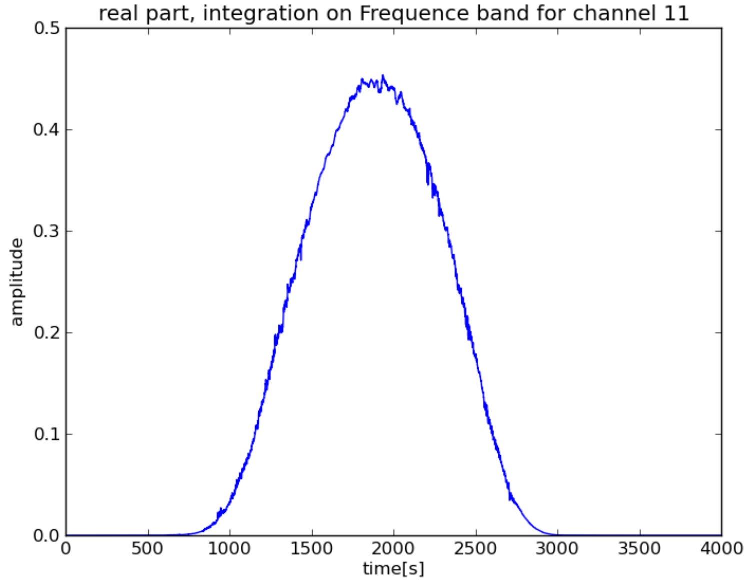


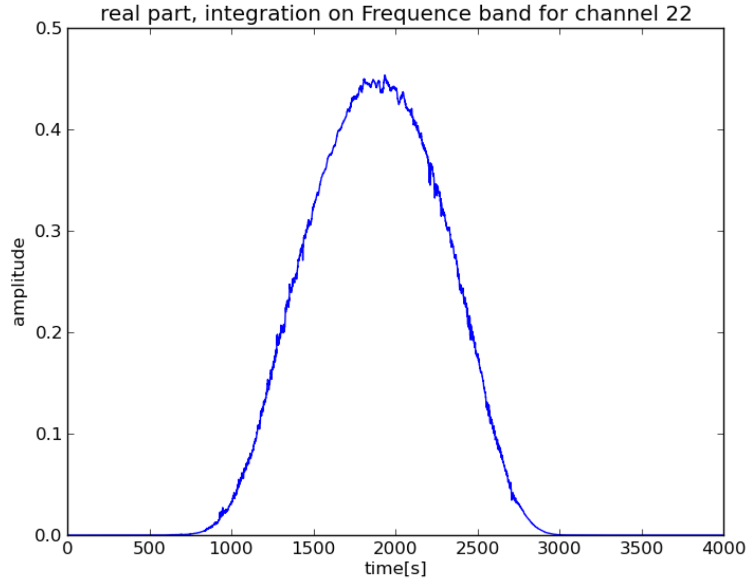
Amplitude of cross-correlation (Ch34, 36, 45, 56)

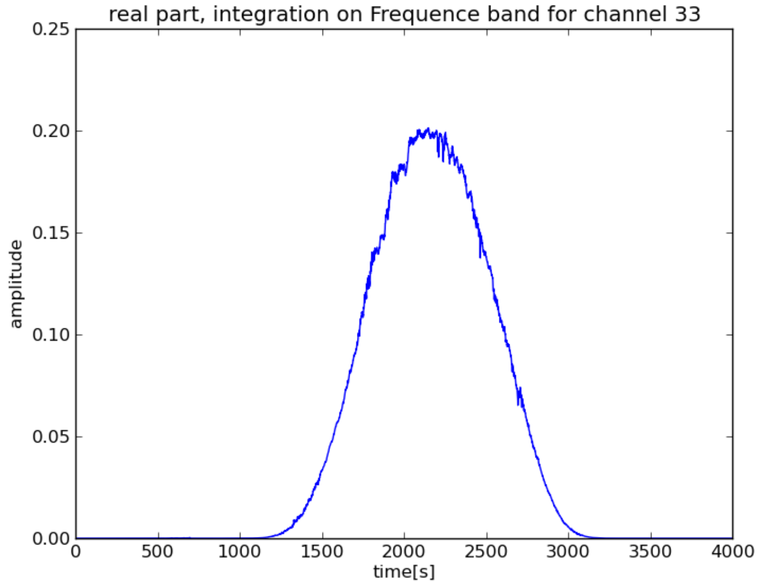


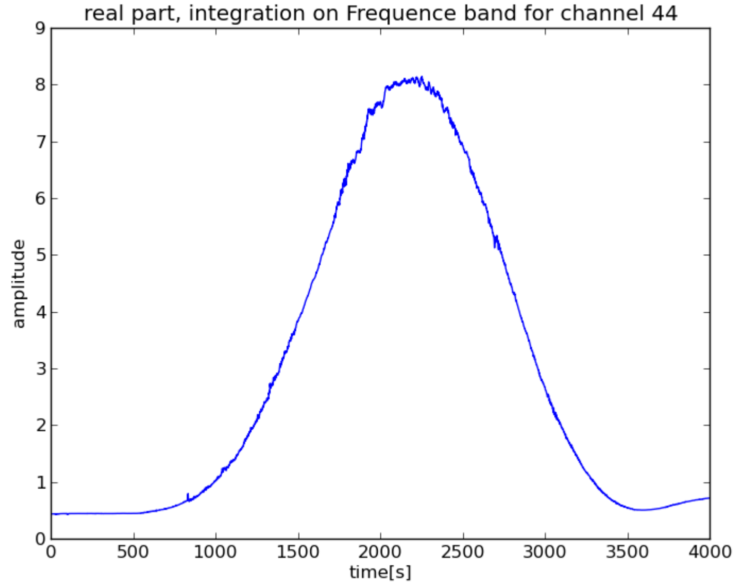
Amplitude of auto-correlation (All channels; Frequency integrated)

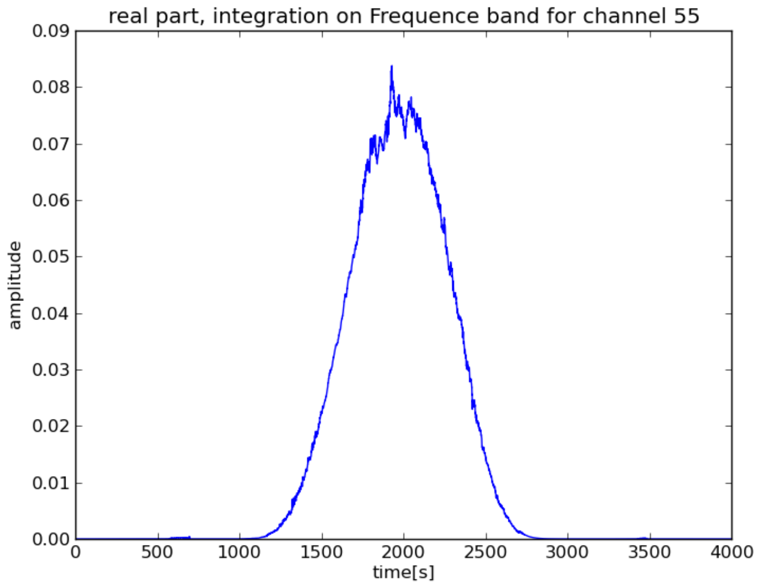
Note: channel 2 is a wrong channel, which by mistake, is actually channel 1's data.

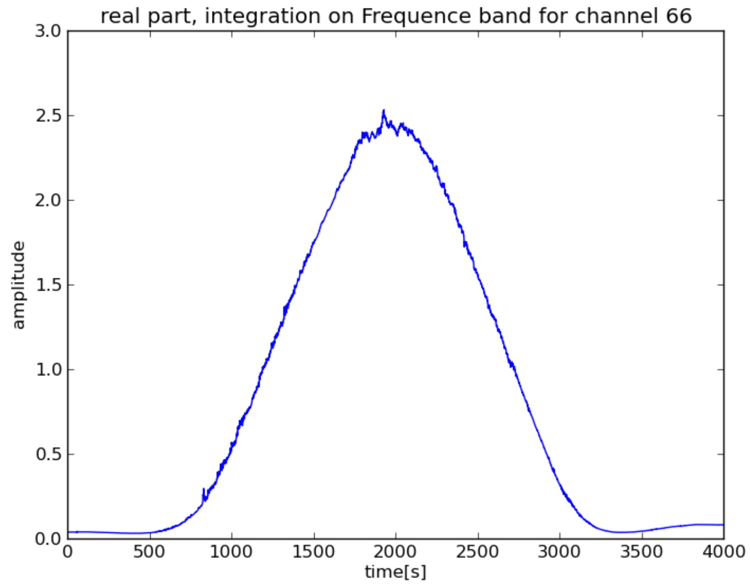




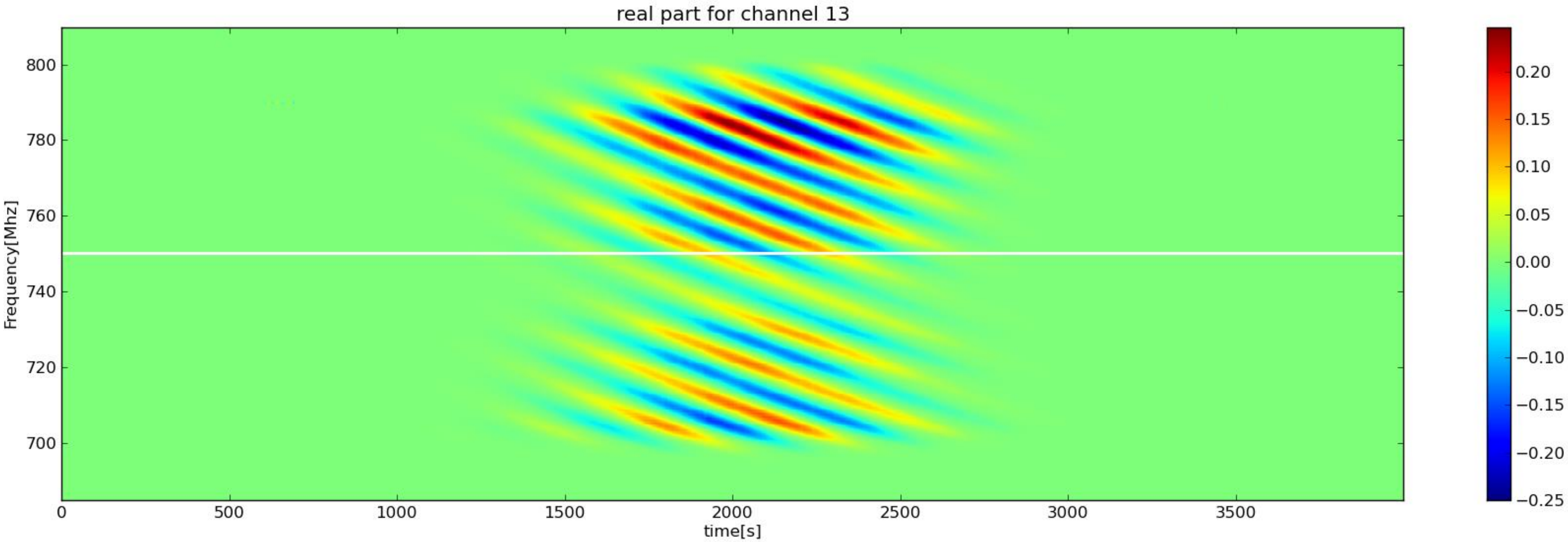

real part, integration on Frequence band for channel 33
amplitude
time[s]

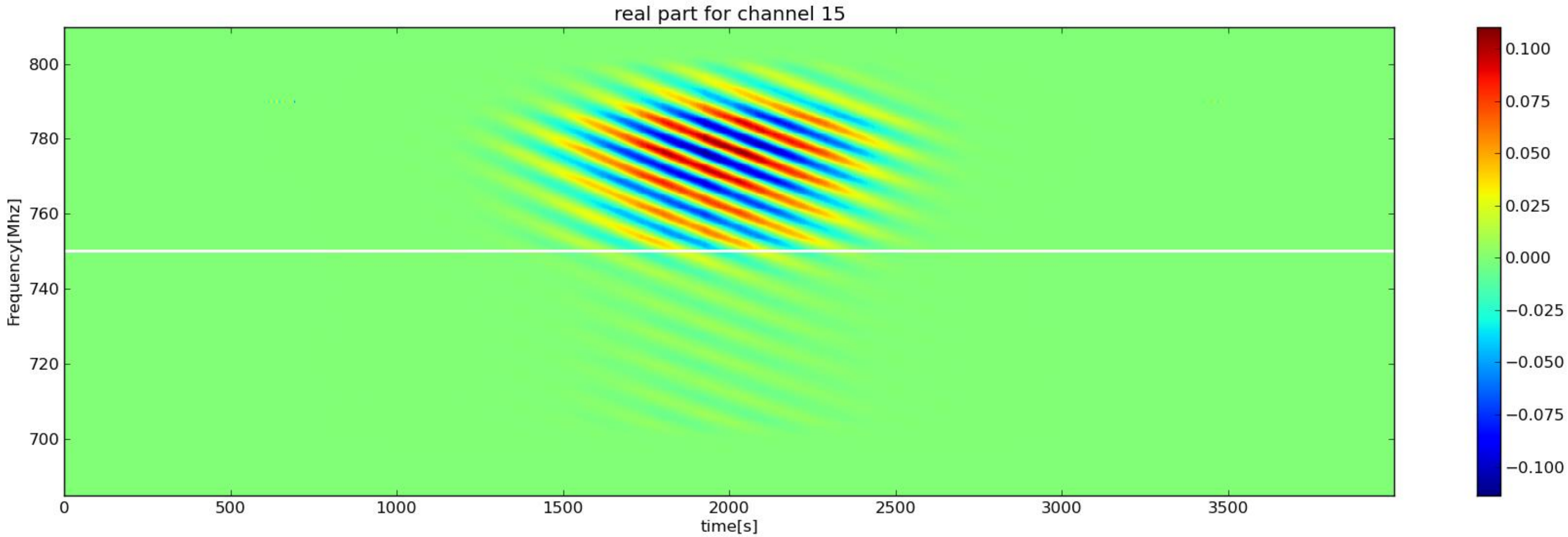

real part, integration on Frequence band for channel 44
amplitude
time[s]

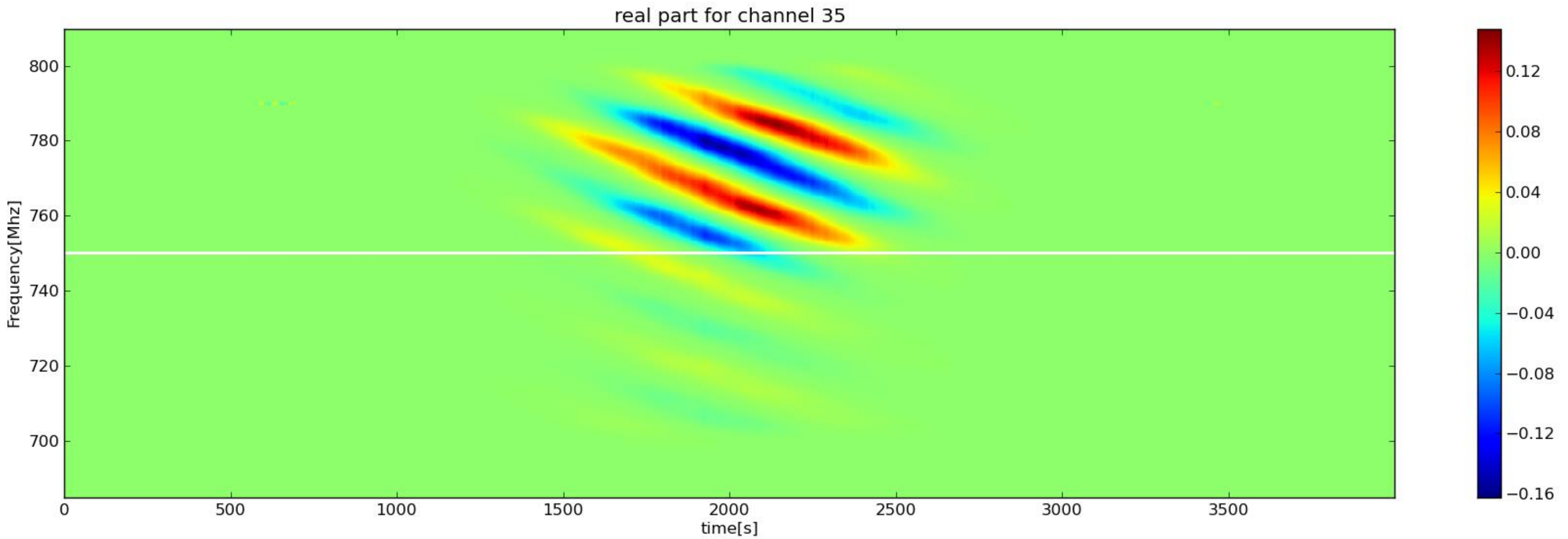

real part, integration on Frequence band for channel 55
amplitude
time[s]

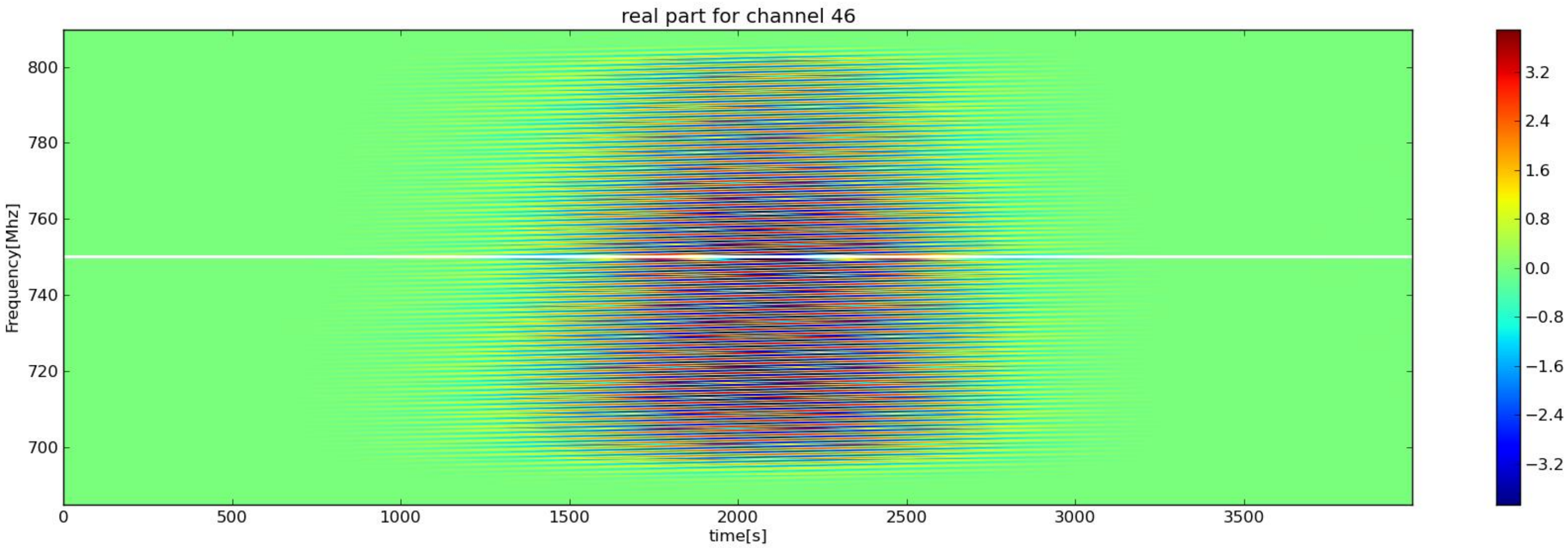

real part, integration on Frequence band for channel 66
amplitude
time[s]

Real part of cross-correlation (ch13, 15, 35, 46)



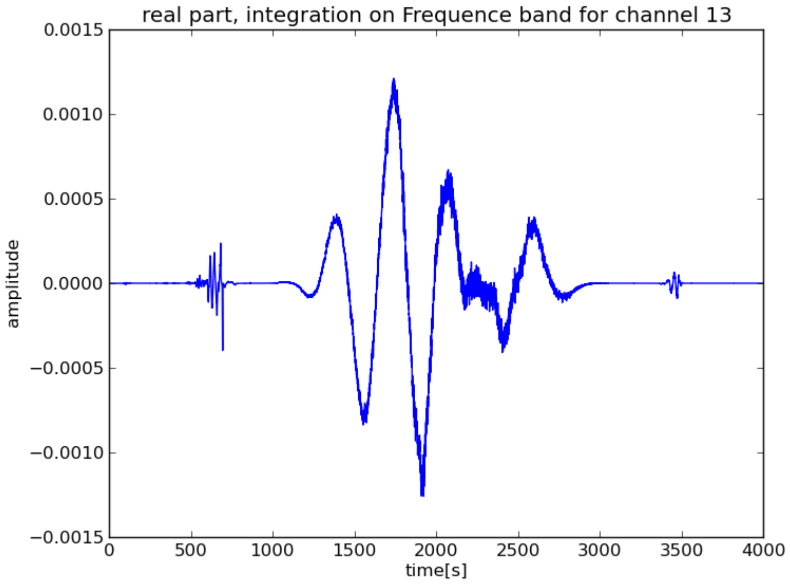

real part for channel 15
Frequency[Mhz]
time[s]
800
780
760
740
720
700
0
500
1000
1500
2000
2500
3000
3500
0.100
0.075
0.050
0.025
0.000
−0.025
−0.050
−0.075
−0.100

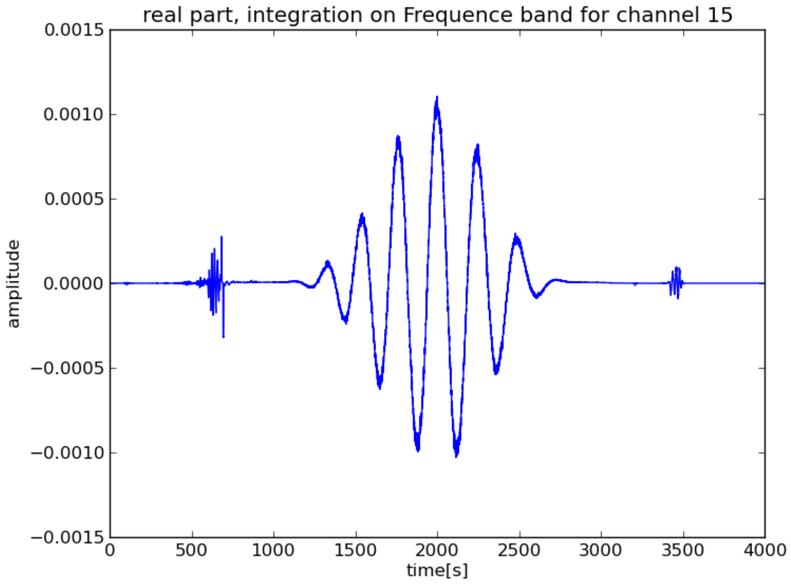

real part for channel 35
Frequency[Mhz]
time[s]
800
780
760
740
720
700
0
500
1000
1500
2000
2500
3000
3500
0.12
0.08
0.04
0.00
−0.04
−0.08
−0.12
−0.16

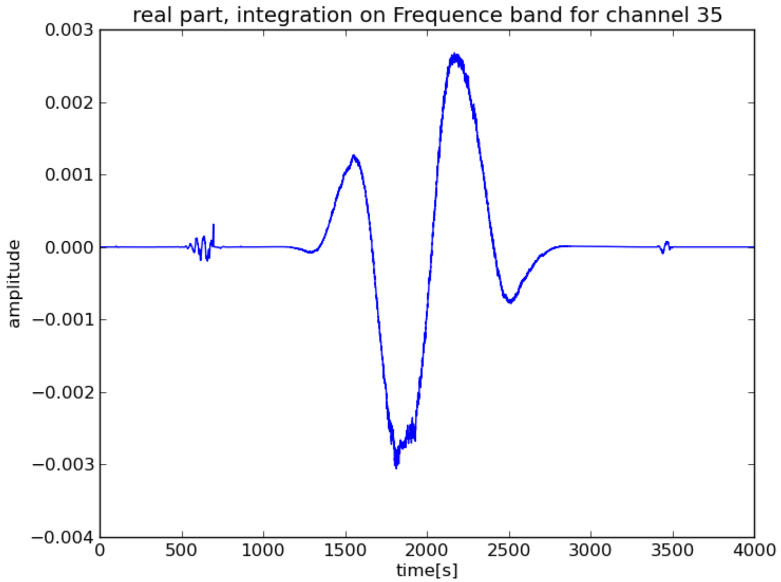


real part for channel 46
Frequency[Mhz]
time[s]
800
780
760
740
720
700
0
500
1000
1500
2000
2500
3000
3500
3.2
2.4
1.6
0.8
0.0
−0.8
−1.6
−2.4
−3.2

Real part of cross-correlation (Ch13, 15, 35; Frequency integrated)

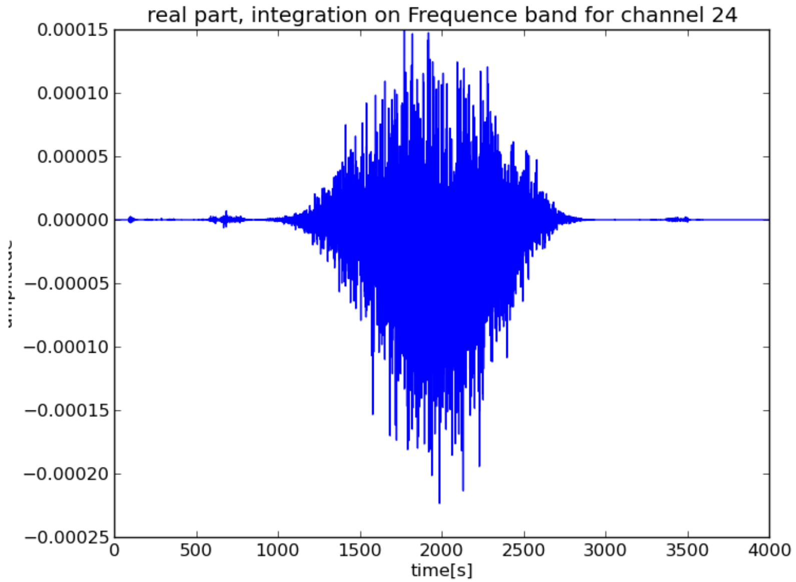


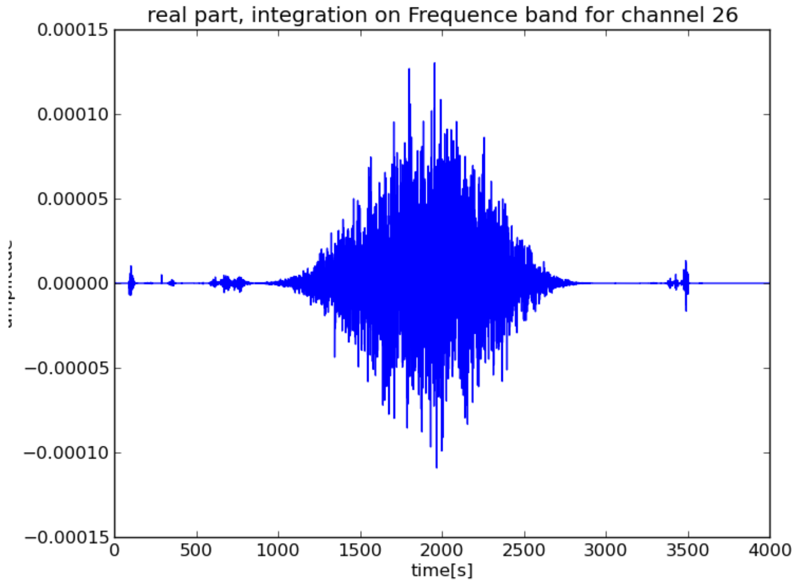


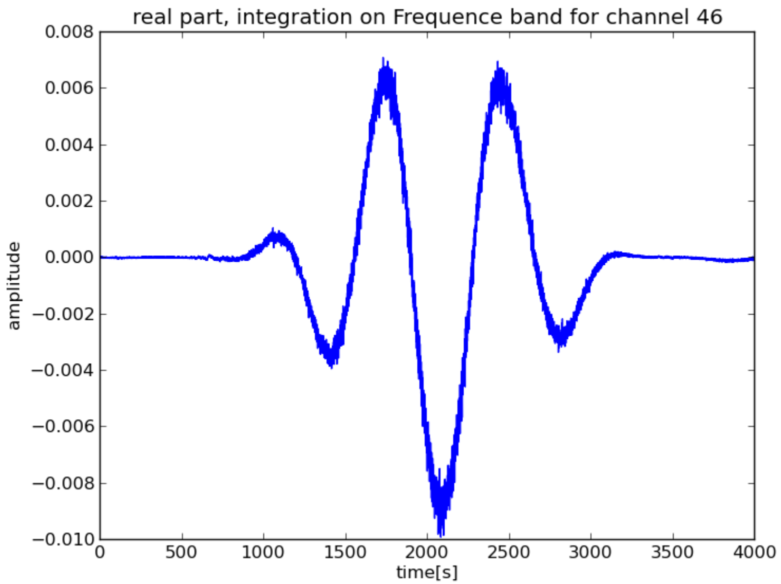


Real part of cross-correlation (Ch24, 26, 46; Frequency integrated)

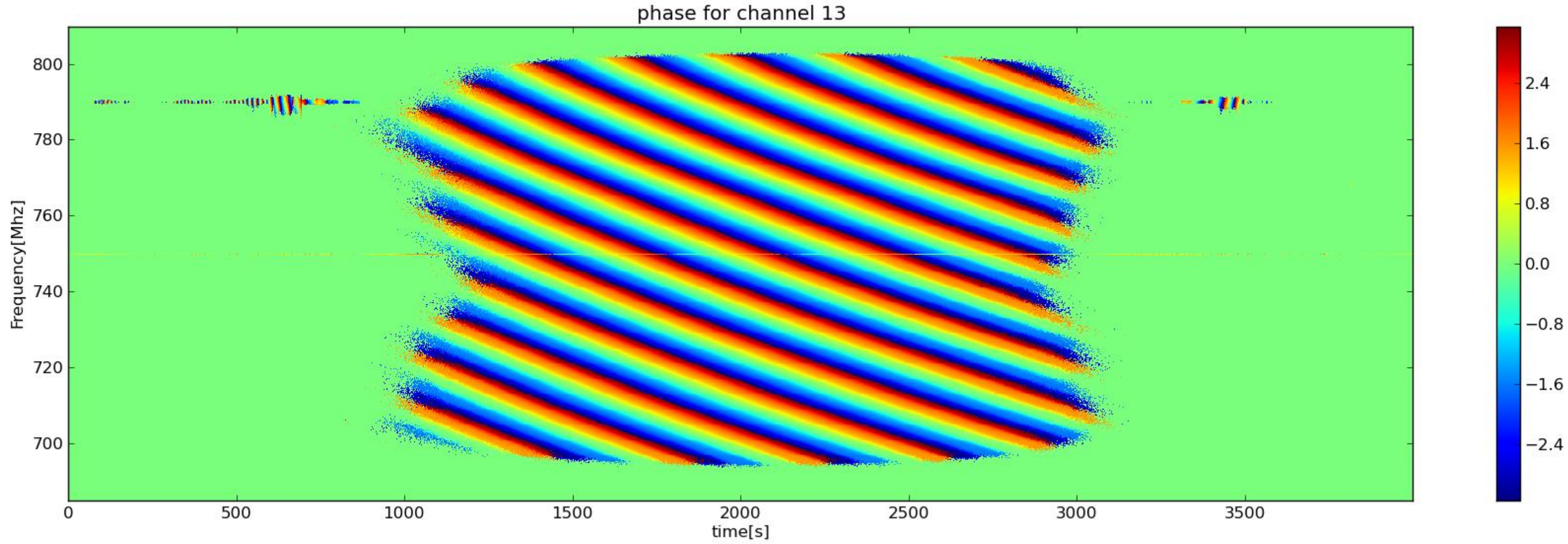
Note: channel 2 is a wrong channel, which by mistake, is actually channel 1's data.

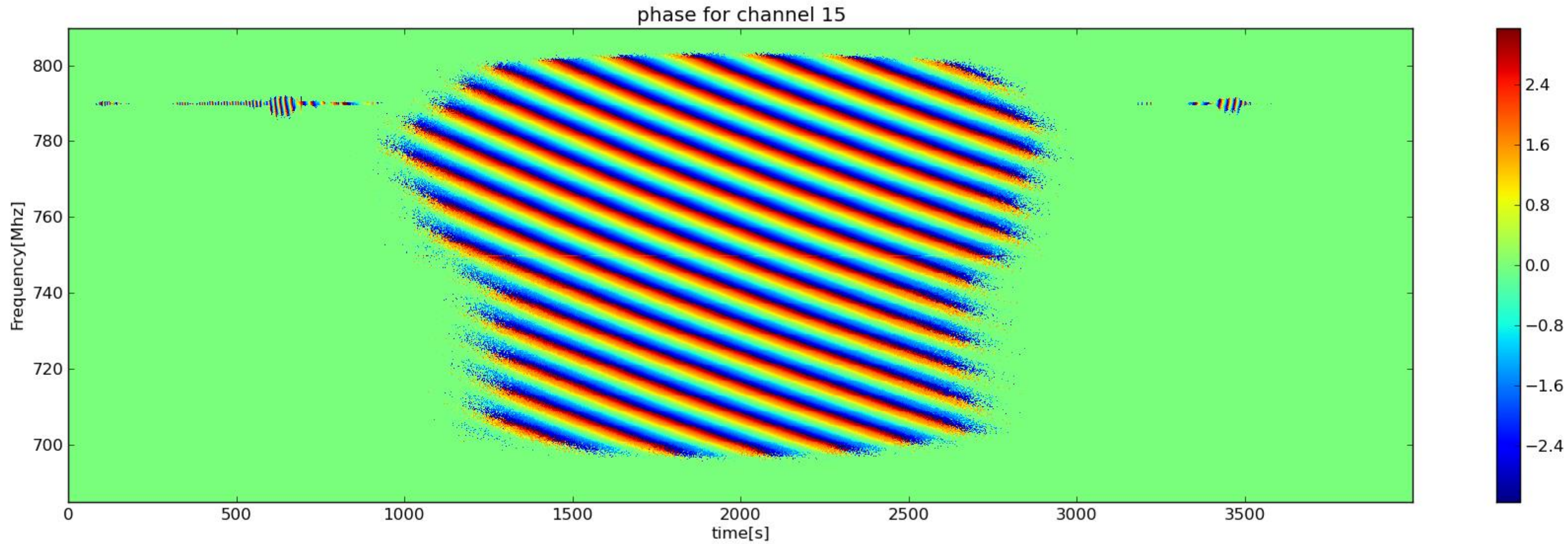

real part, integration on Frequence band for channel 24
amplitude
time[s]

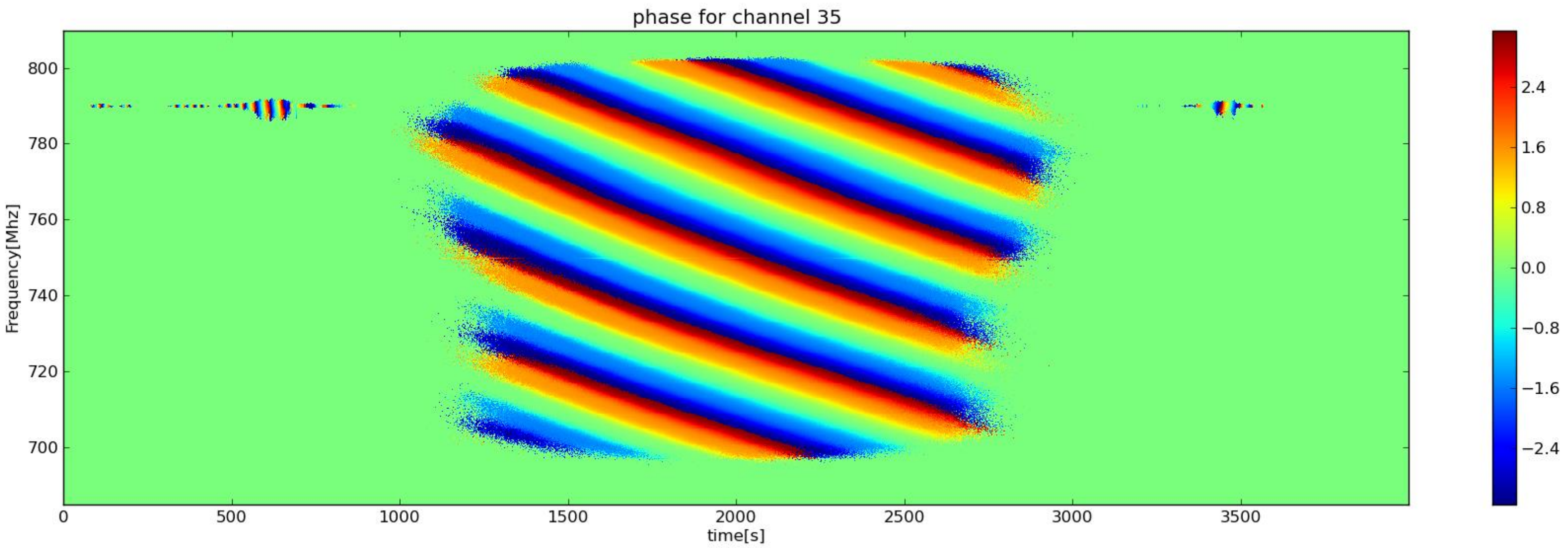

real part, integration on Frequence band for channel 26
amplitude
time[s]

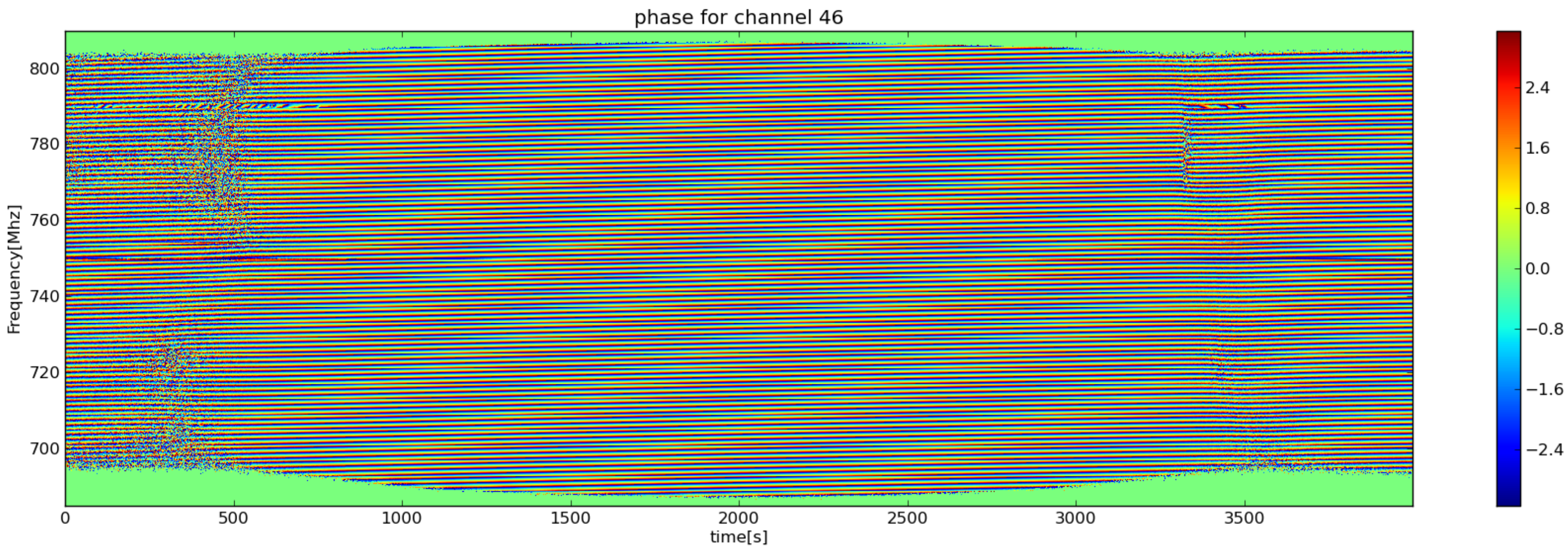

real part, integration on Frequence band for channel 46
amplitude
time[s]

Phase of cross-correlation (Ch13, 15, 35, 46)

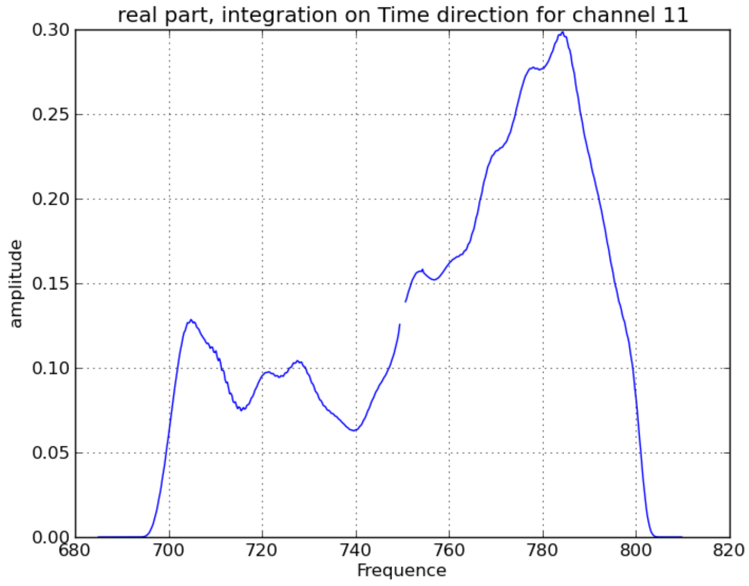


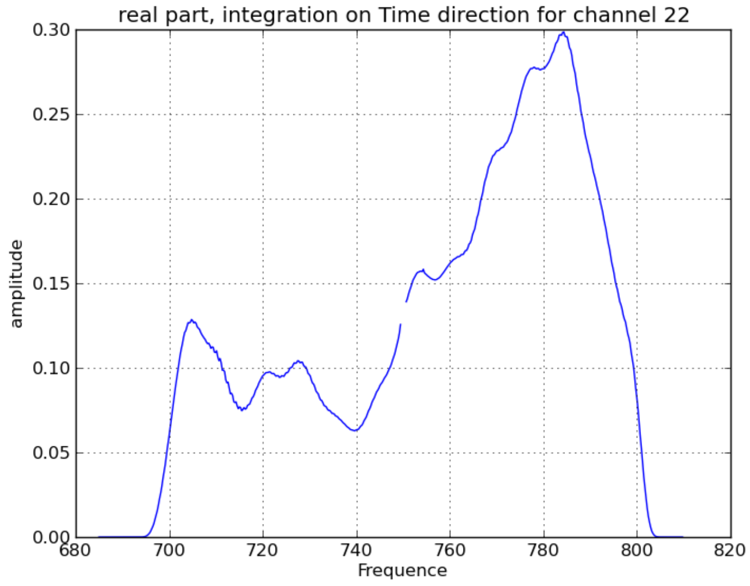


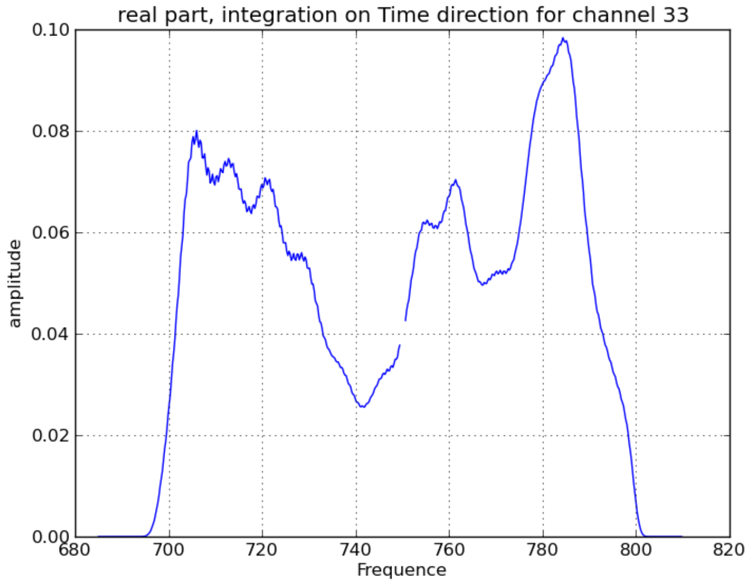

phase for channel 35
Frequency[Mhz]
time[s]
800
780
760
740
720
700
0
500
1000
1500
2000
2500
3000
3500
2.4
1.6
0.8
0.0
−0.8
−1.6
−2.4

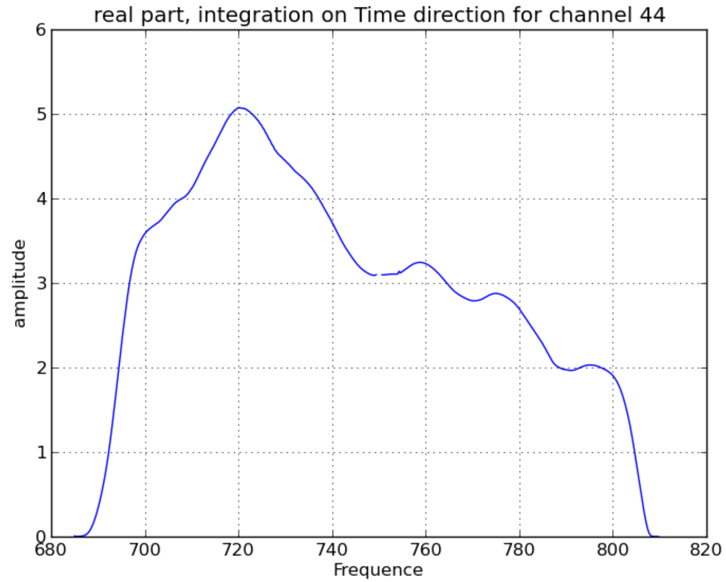

phase for channel 46
Frequency[Mhz]
time[s]
800
780
760
740
720
700
0
500
1000
1500
2000
2500
3000
3500
2.4
1.6
0.8
0.0
−0.8
−1.6
−2.4

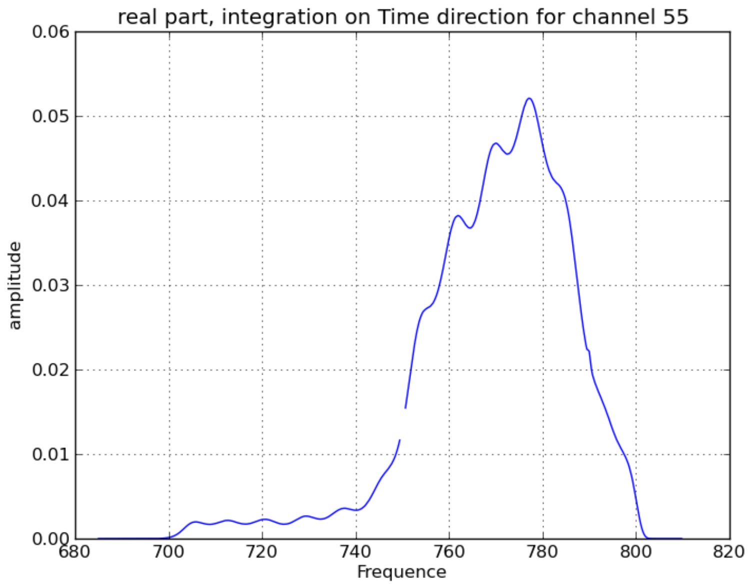
Band pass (All channels)

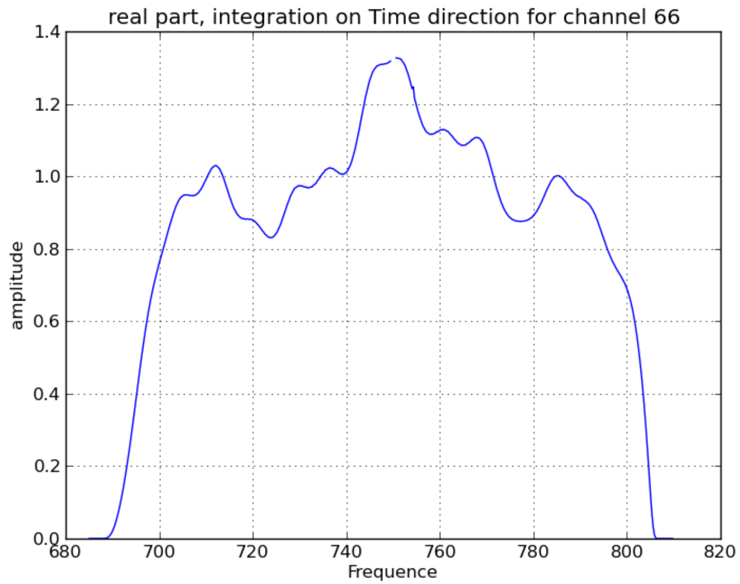





real part, integration on Time direction for channel 33
amplitude
Frequence
0.00
0.02
0.04
0.06
0.08
0.10
680
700
720
740
760
780
800
820


real part, integration on Time direction for channel 44
amplitude
Frequence
0
1
2
3
4
5
6
680
700
720
740
760
780
800
820


real part, integration on Time direction for channel 55
amplitude
Frequence
0.00
0.01
0.02
0.03
0.04
0.05
0.06
680
700
720
740
760
780
800
820


real part, integration on Time direction for channel 66
amplitude
Frequence
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
680
700
720
740
760
780
800
820

Visibility data simulation

- $\text{visibility} = amplitude \cdot \exp(i \cdot phase)$
- A function of time and frequency.

Amplitude part

Related to the source flux, system gain, and beam pattern.

- Source flux F_{source} input as known constant.
- System gain ($G_{amp} \cdot bandpass$)
- beam pattern(Gaussian profile)
  - $\exp\left(-\frac{[\alpha_s\,(t) - \alpha_A\,]^2}{2\pi\sigma^2}\right)$.
  - $\sigma \sim \frac{\lambda}{D} = \frac{c}{\nu D}$, angular resolution.
  - $$\begin{aligned} beampattern &= \exp\left(-\frac{\nu^2 D^2 [\alpha_s(t) - \alpha_A]^2}{2\pi c^2}\right) \\ &= \exp(-a^2\nu^2[\alpha_s(t) - \alpha_A]^2) \end{aligned}$$

Amplitude part

– $beampattern = \exp\left(-\frac{\nu^2 D^2[\alpha_s(t)-\alpha_A]^2}{2\pi c^2}\right)$

$= \exp(-a^2\nu^2[\alpha_s(t) - \alpha_A]^2)$

- Antenna directions not accurate:
  - $\text{beampattern} =$
    $\sqrt{\exp(-a_1^2\nu^2[\alpha_s(t) - \alpha_{A1}]^2) \cdot \exp(-a_2^2\nu^2[\alpha_s(t) - \alpha_{A2}]^2)}$

Phase part

- Geometry delay $e^{i\omega\tau}$
  - $e^{i\cdot 2\pi\nu\cdot\frac{\boldsymbol{B}\cdot\boldsymbol{n}}{c}}$
  - $\mathbf{B}\cdot\mathbf{n} = \mathrm{B}\cdot\cos\theta = \mathrm{B}\cdot(\cos\phi_B\cos\phi_s\cos(\theta_B-\theta_s)+\sin\phi_B\sin\phi_s)$
    - ϕ is declination and θ is azimuth, and B is for Baseline length and s is for Source.
- Instrumental delay Φ_i
  - Differences between frequencies not considered yet
- Total phase
  - $\text{Phase }\Phi = \phi_i + \frac{2\pi\nu B}{c}\cdot(\cos\phi_B\cos\phi_s\cos(\theta_B-\theta_s)+\sin\phi_B\sin\phi_s)$

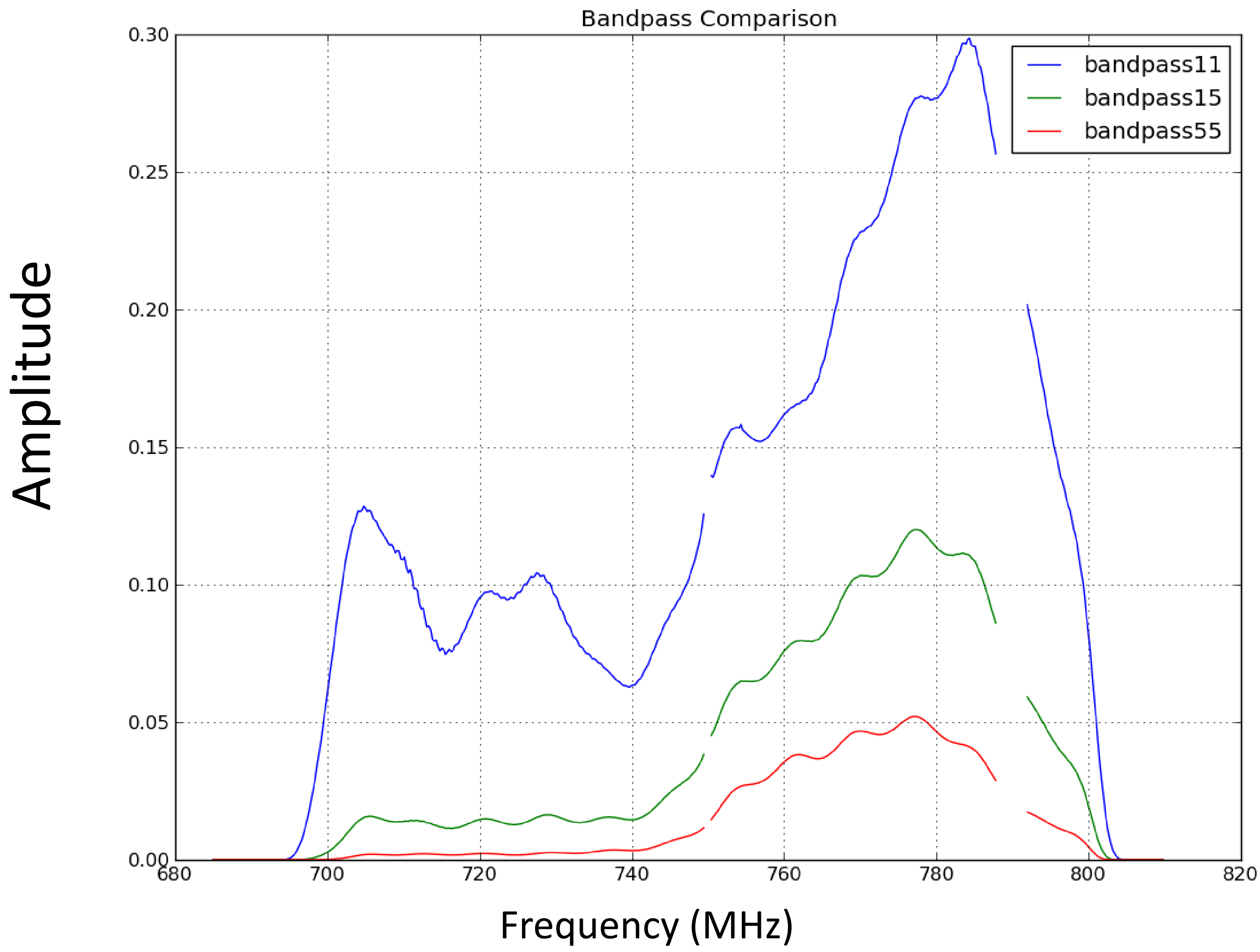
Visibility data simulation

- visibility
- $= amplitude \cdot \exp(i \cdot phase) =$
- $F_{source}\left(A_{gain} e^{i\phi_i}\right)\sqrt{\exp(-a_1^2 \nu^2 [\alpha_s(t) - \alpha_{A1}]^2) \exp(-a_2^2 \nu^2 [\alpha_s(t) - \alpha_{A2}]^2)}$

$$e^{i \cdot \frac{2\pi\nu B}{c} \cdot (\cos\phi_B \cos\phi_s \cos(\theta_B - \theta_s) - \sin\phi_B \sin\phi_s)}$$

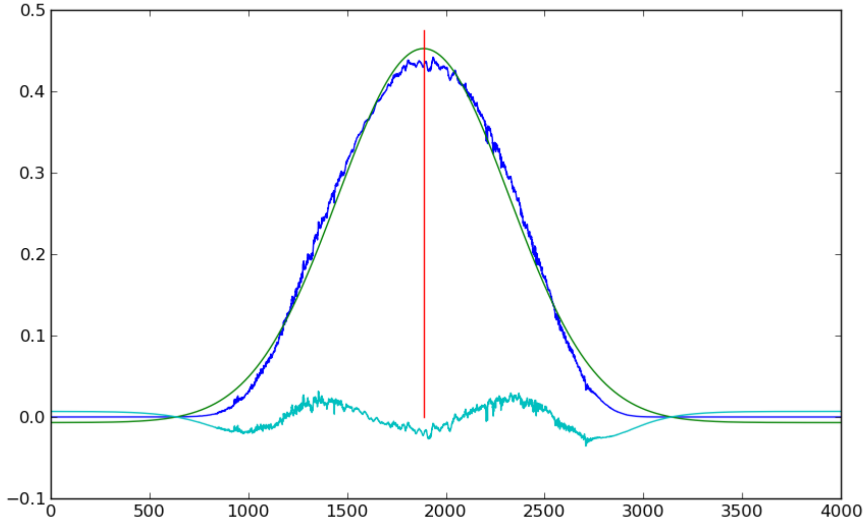
- ALL of the following images are results of observation:
  - Source: Sun.
  - Time: 15:31, Sept. 17th, 2013.
  - Duration: 4000 seconds.
  - Channel 1 and 5.

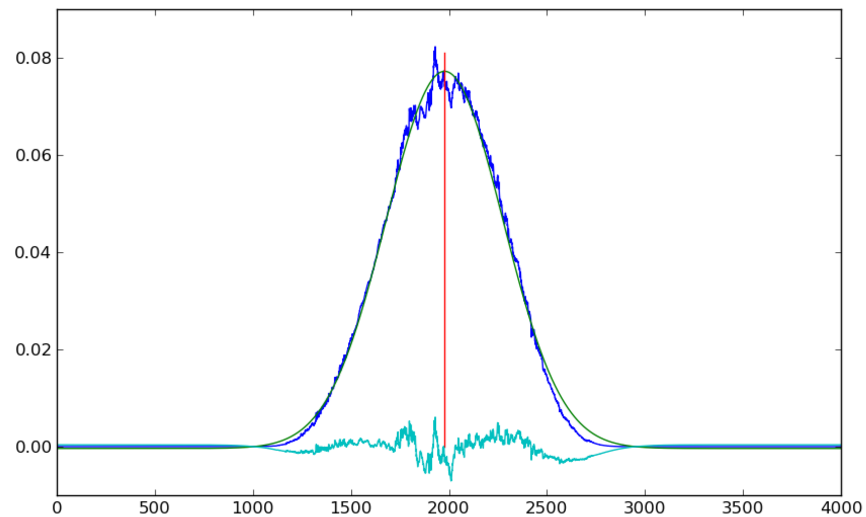
Band pass

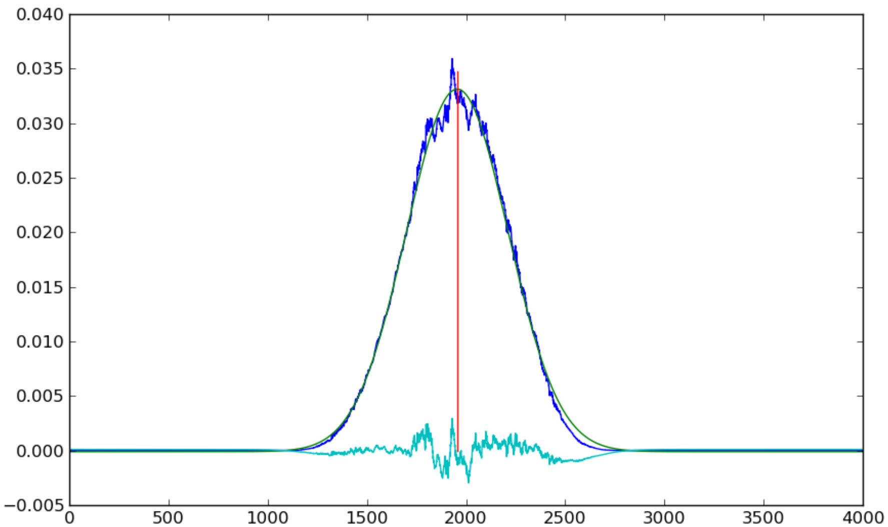


Bandpass Comparison
bandpass11
bandpass15
bandpass55
0.30
0.25
0.20
0.15
0.10
0.05
0.00
680
700
720
740
760
780
800
820
Amplitude
Frequency (MHz)

Beam pattern



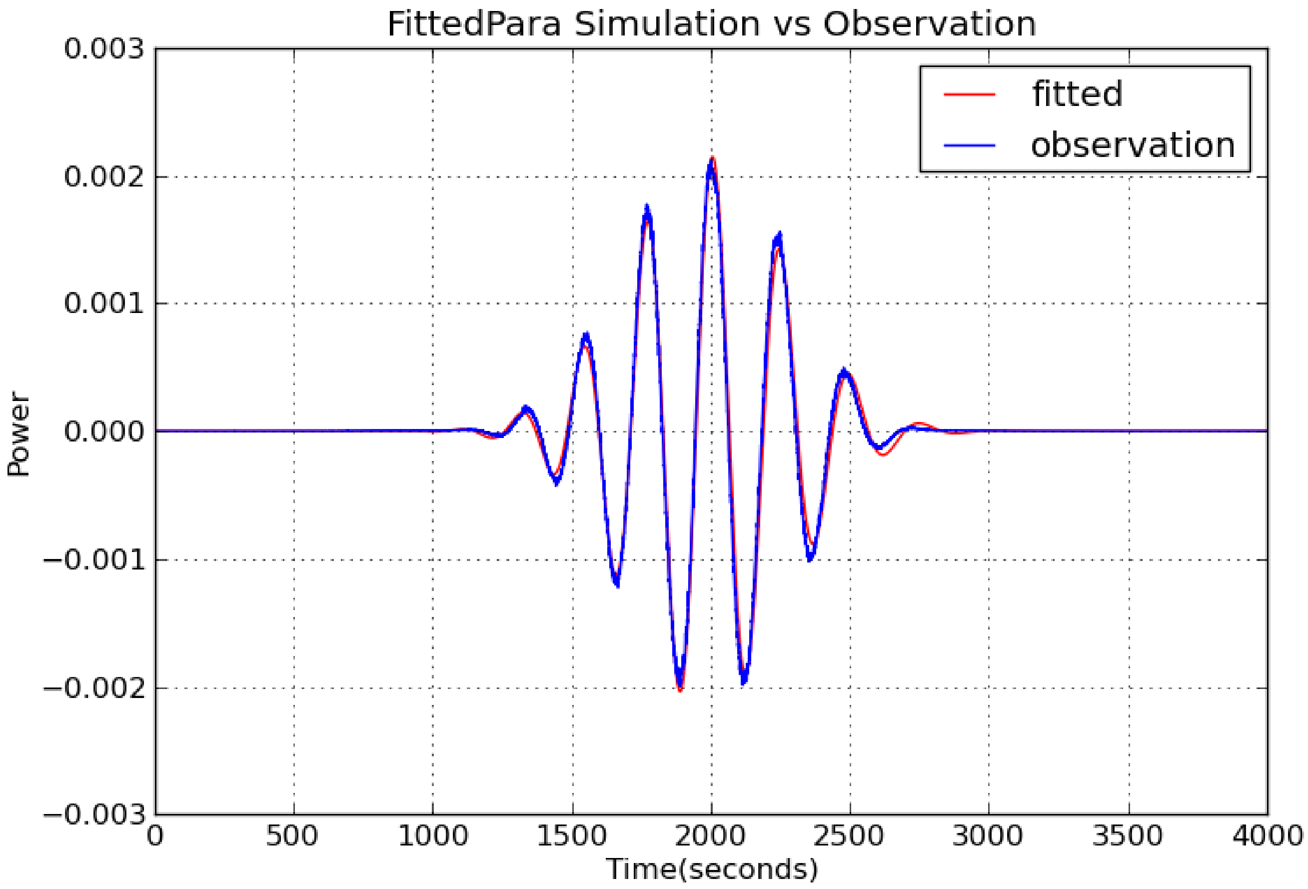




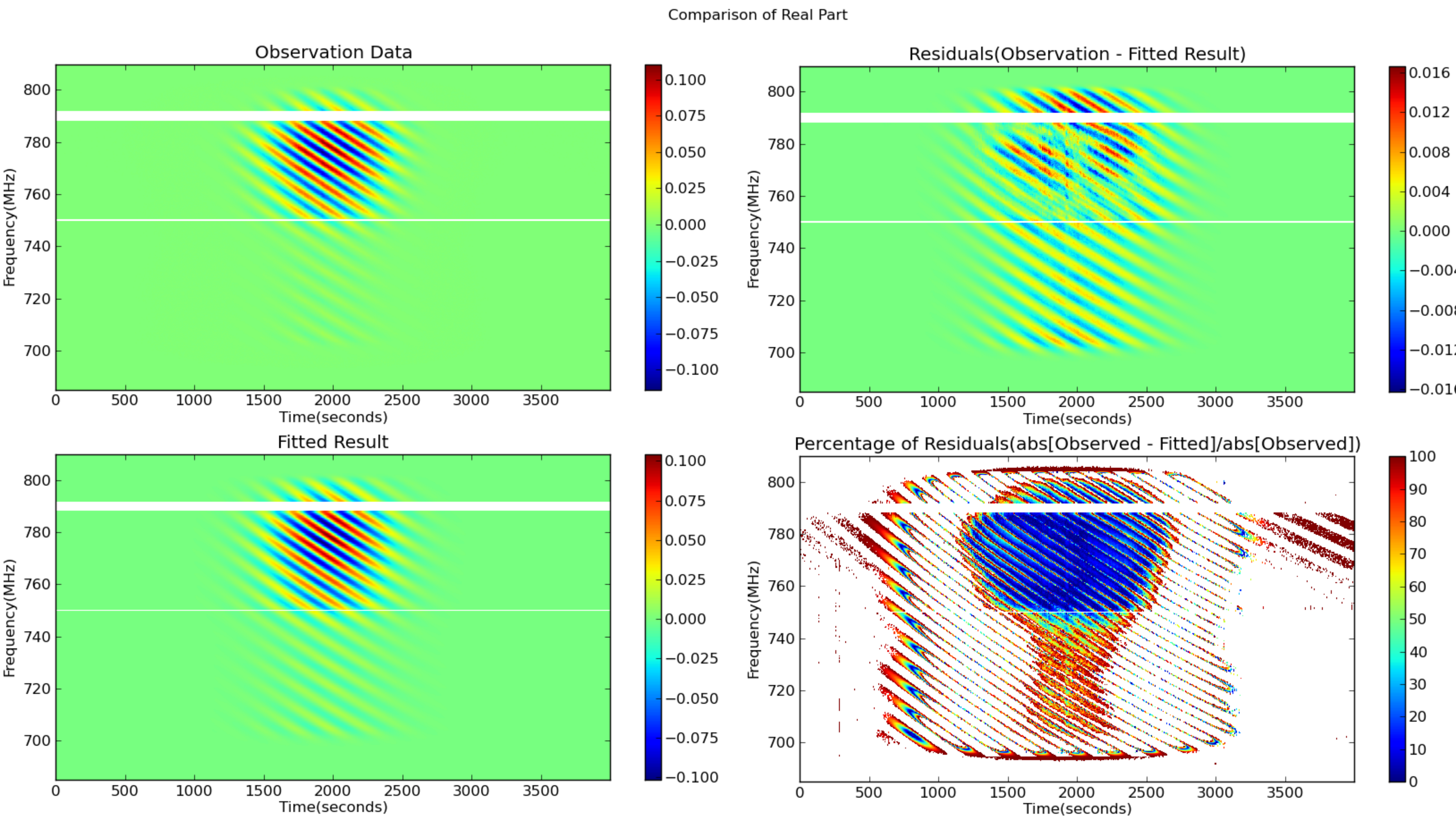
Ch11 | Ch55
Ch15 | note

Blue: Observation;
Green: Gaussian-fitted;
Red: Center;
Cyan: residuals.

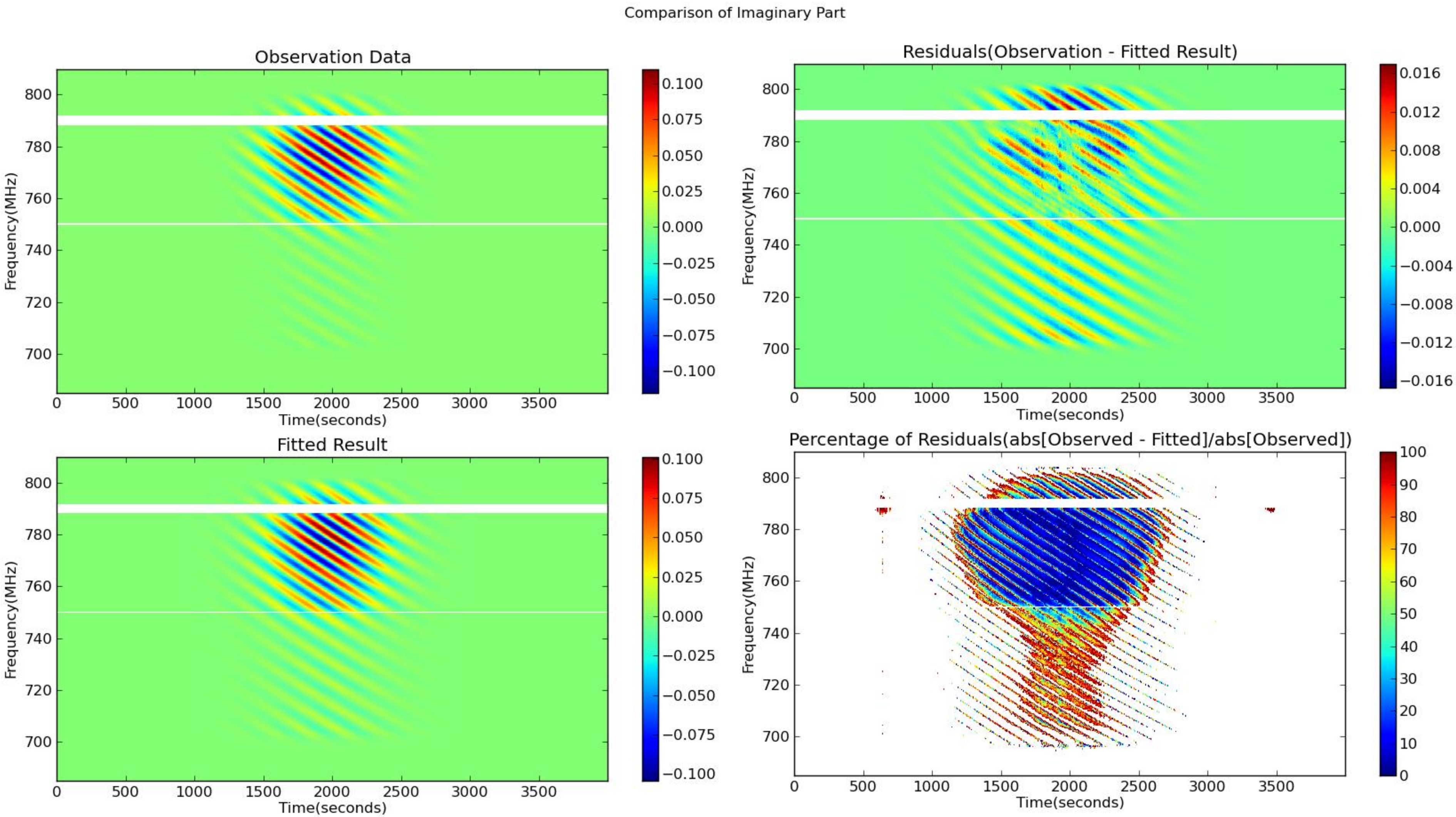
Total Power vs Time



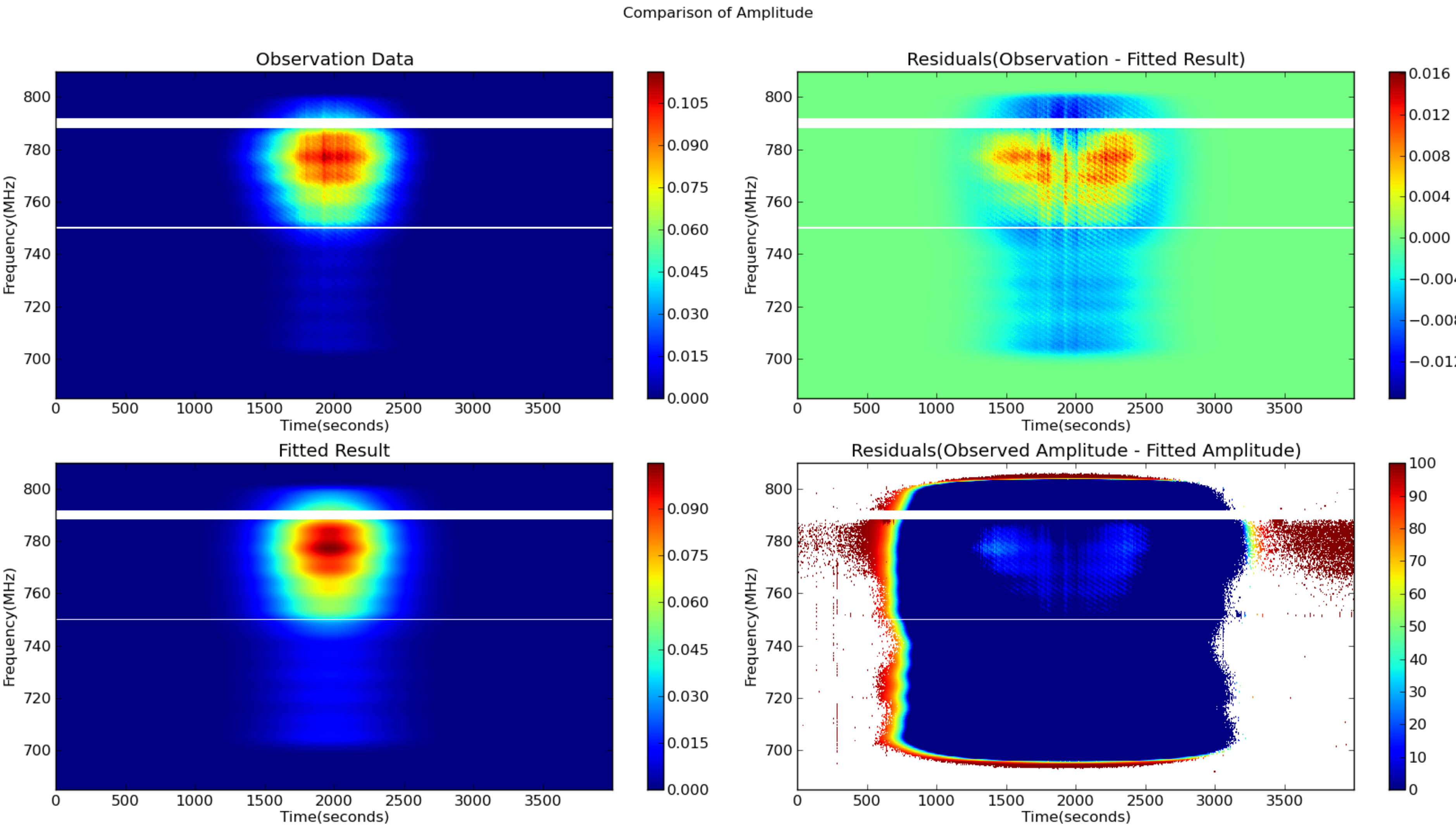
Real part vs Time



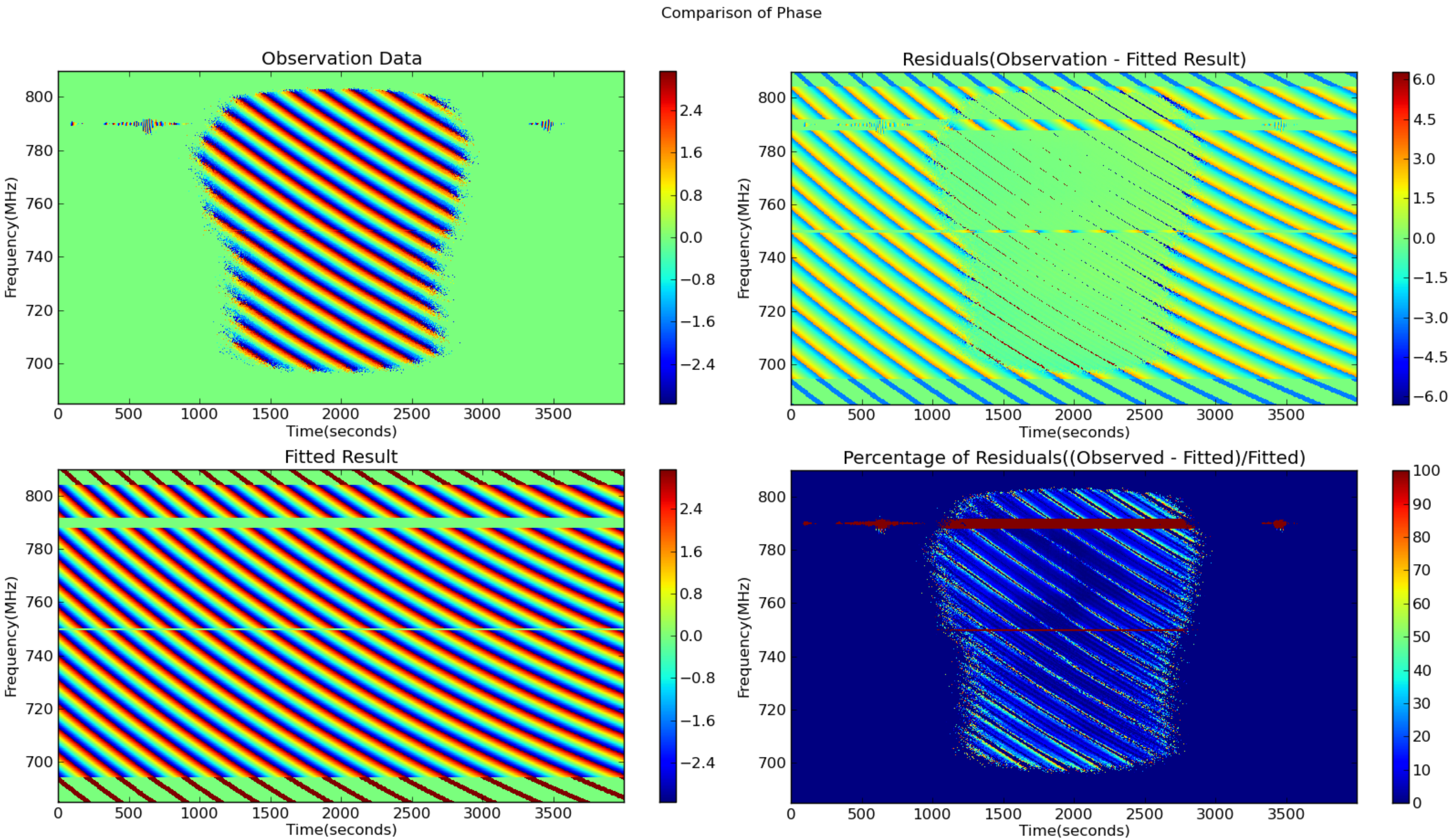
Imaginary part vs Time



Amplitude vs Time



Phase vs Time



ADC non-linearity

- ADC:
  - 4bit out of 14bit
- Input single frequency
- Measure output
- Should be linear