



# APOD Observations with VLBI

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# Outline

1. Background
2. APOD observations with Chinese CEI system
3. APOD observations with IVS VLBI antennas
4. Conclusion and future work

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## 1. Background

## 2. APOD observations with Chinese CEI system

## 3. APOD observations with IVS VLBI antennas

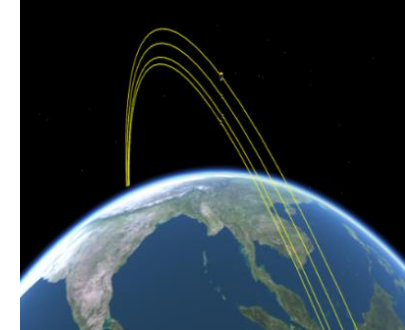
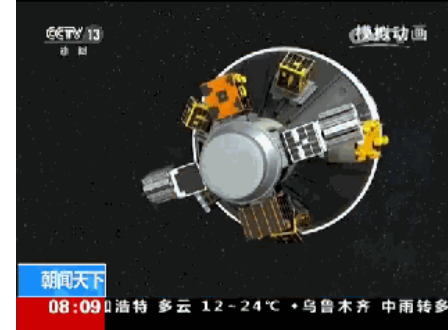
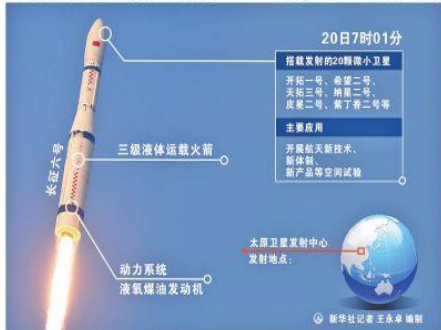
## 4. Conclusion and future work

# 1. Background

On **Sept. 20, 2015**, the Chinese CZ-6 test rocket was launched successfully, and 20 satellites was sent simultaneously into a circular, near-polar and 520 Km altitude orbit. Among these 20 satellites, four CubSats, named with **APOD (Atmospheric density detection and Precise Orbit Determination)**, are projected for **precise orbit determination**, as well as **in-situ atmospheric density detection**.

As user of the APOD, BACC is also responsible for operation, data , as well as payload data processing, data archiving and distribution.

“长征六号”首飞成功 “一箭多星”创新纪录

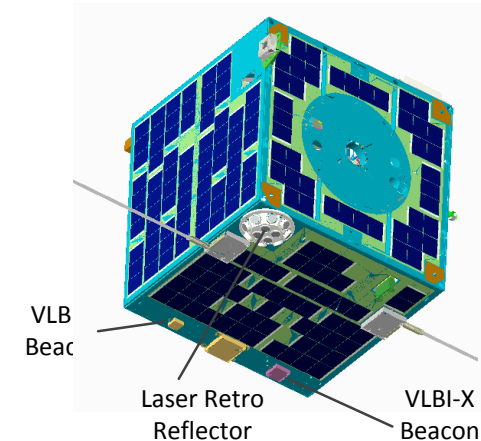
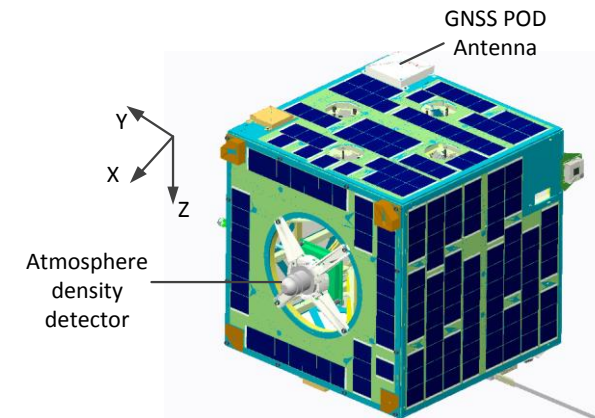




# 1. Background

## ◆ Instrument

- GPS/BDS dual-mode, four-frequency(L1/L2/B1/B3) space-borne receiver
- Laser Retro-Reflector
- Atmospheric density detector
- S/X dual-frequency VLBI beacon



		Nano-satellite	Pico-satellite
GNSS Receiver	Mode	GPS/BDS	
	GPS Frequency/MHz	L1:1575.42, L2:1227.60	
	BDS Frequency/MHz	B1:1561.098, B3:1250.618	
	Sampling Rate/s	8	
VLBI Beacon	S-Band Frequency/MHz	$f_{carrier} = 2262.01$ $f_{s\_dors1} = 2256.87$ $f_{s\_dors2} = 2260.98$ $f_{s\_dors3} = 2263.04$ $f_{s\_dors4} = 2267.15$	-
	X-Band Frequency/MHz	$f_{carrier} = 8424.02$ $f_{x\_dors1} = 8404.87$ $f_{x\_dors2} = 8420.19$ $f_{x\_dors3} = 8427.85$ $f_{x\_dors4} = 8443.66$	-
	Detection Range/km	120 ~ 550	-
	Pressure Measure Range/Pa	$1.0^{-6} \sim 1.0^{-2}$	-
Atmosphere Density Detector	Temperature Range/°C	-20 ~ 60	-
	Sampling Rate/s	1	-
Laser Retro Reflector	Type	Pyramid	Mounted on bottom surface dispersedly
	Number of cube corner prisms	9	11

# Outline

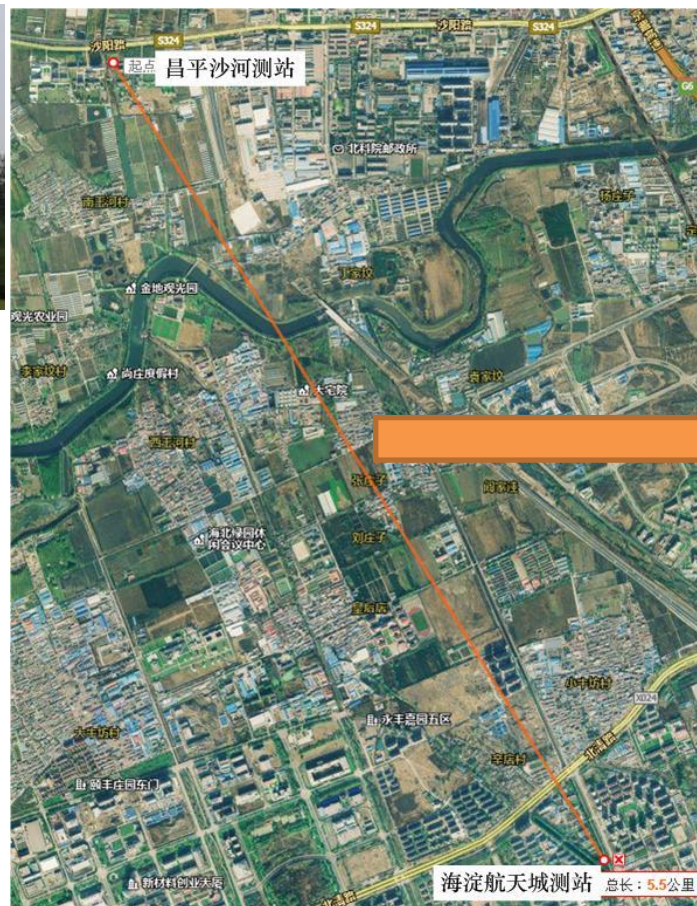
1. Background
- 2. APOD observations with Chinese CEI system**
3. APOD observations with IVS VLBI antennas
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## 2. APOD observations with Chinese CEI system

A CEI constituted by a 3-meter antenna and a 12-meter antenna is conducted on APOD satellite observation.



12 m



5.5 Km



3 m

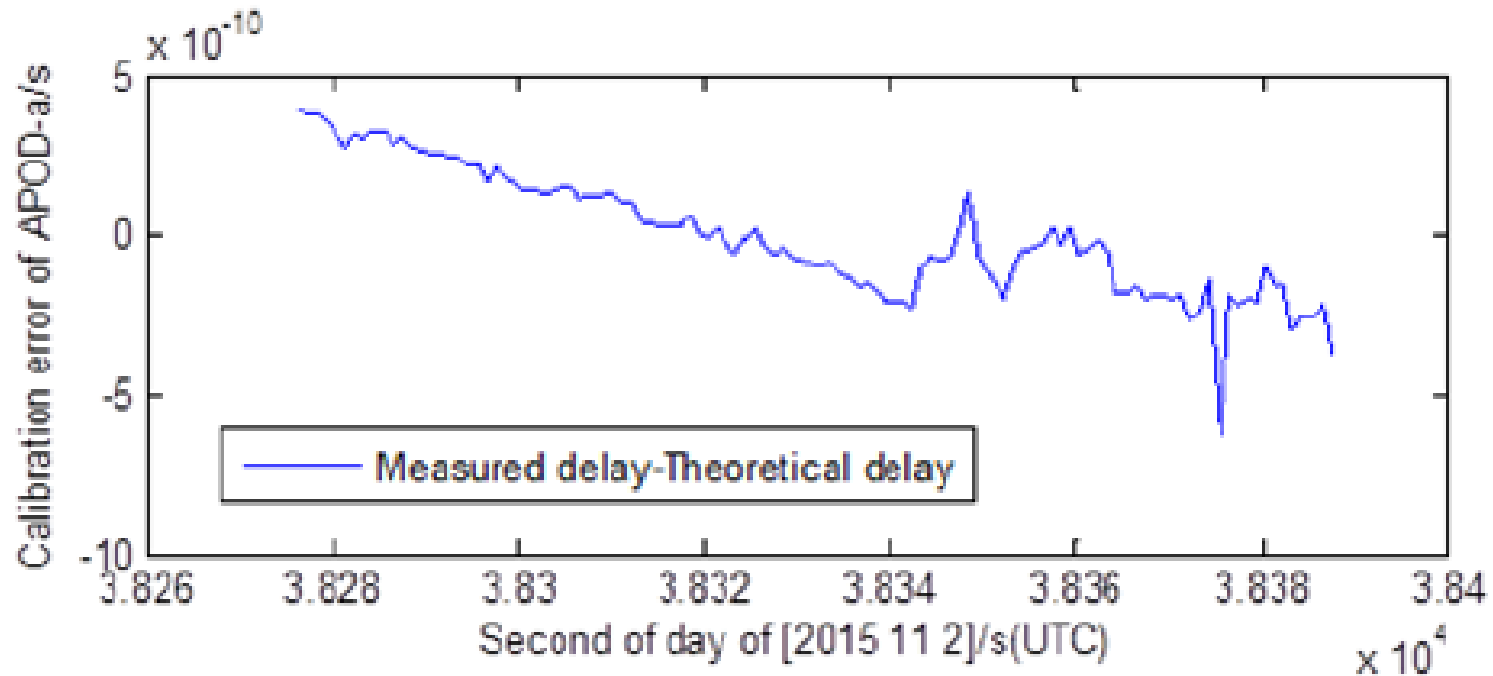
## 2. APOD observations with Chinese CEI system

Epoch: 2016-03-10T11:32:00-11:36:00

Recording signal : 2262MHz, 2267.15MHz, 2256.85MHz

BW: 1 MHz

Quantization digit: 8 bits



O-C of VLBI observations for APOD nano-sat.



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# 3. APOD observations with IVS VLBI antennas

#####Ke+Yg+Hb#####

2016-04-04:

- a) 2016-04-04, 10:04:00 - 10:09:00 UT 0454-234 Ke+Yg+Hb
- b) 2016-04-04, 10:10:49 - 10:12:29 UT APOD Hb+Yg
- c) 2016-04-04, 10:13:29 - 10:17:45 UT APOD Ke+Yg
- d) 2016-04-04, 10:19:00 - 10:24:00 UT 0727-115 Ke+Yg+Hb

#####On+Wz#####

2016-07-14:

- a) 2016-07-14, 06:45:00 - 06:56:00 UT.
- b) 2016-07-14, 15:52:00 - 16:01:00 UT.
- c) 2016-07-14, 17:23:00 - 17:35:00 UT.

2016-07-15:

- d) 2016-07-15, 06:12:00 - 06:22:00 UT.
- e) 2016-07-15, 07:46:00 - 07:54:00 UT.
- f) 2016-07-15, 16:52:00 - 17:02:00 UT.

#####Ke + Yg#####

- g) 2016-07-18, 10:10:00 - 10:20:00 UT:
- h) 2016-07-20, 10:36:00 - 10:46:00 UT:

#####On+Wz+Wn#####

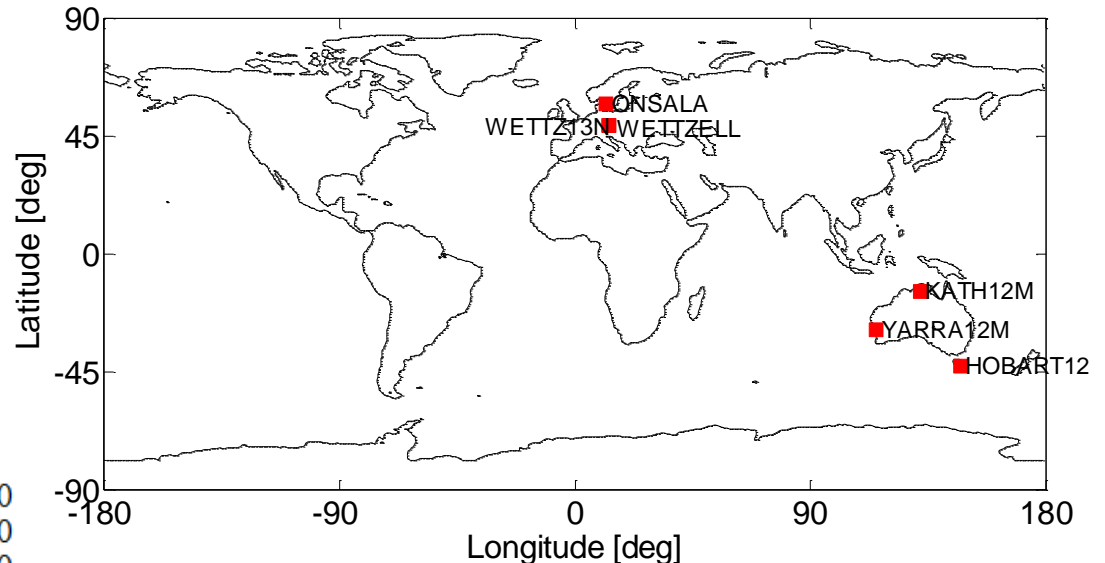
2016-07-25:

- a) 2016-07-25, 06:53:00 - 07:04:00 UT
- b) 2016-07-25, 15:59:00 - 16:09:00 UT

#####On+Wz+Wn#####

- 263a: 2016-09-19, 05:16:02.00 - 05:20:09.00
- 263b: 2016-09-19, 06:50:34.00 - 06:54:36.00
- 263c: 2016-09-19, 15:53:40.00 - 15:58:13.00

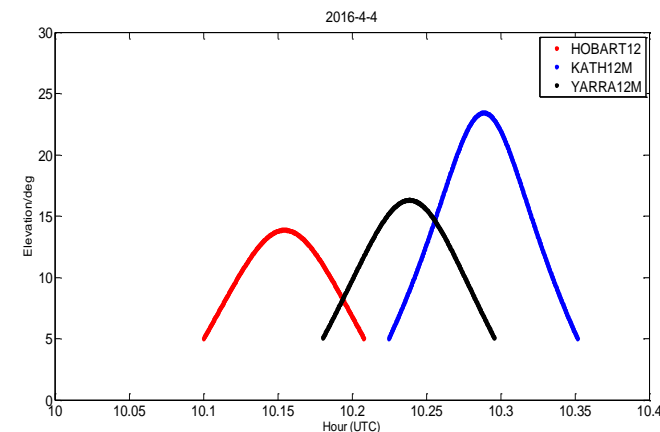
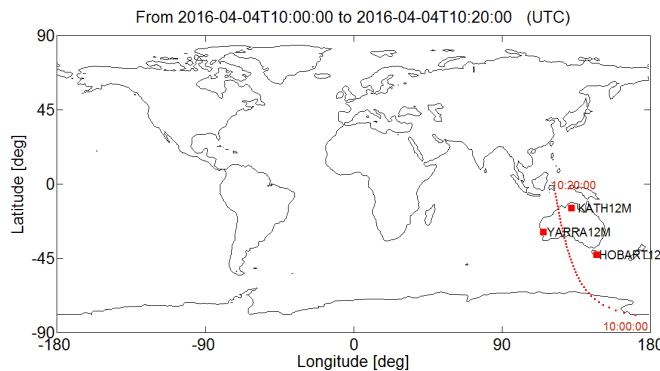
- ① 2016-04-04 Ke-Yg-Hb
- ② 2016-07-14 On-Wz
- ③ 2016-07-15 On-Wz
- ④ 2016-07-18 Ke-Yg
- ⑤ 2016-07-20 Ke-Yg
- ⑥ 2016-07-25 On-Wz-Wn
- ⑦ 2016-09-19 On-Wz-Wn



# 3. APOD observations with IVS VLBI antennas

## ① 2016-04-04 Ke-Yg-Hb

Ra/De input mode; sampling rate is 2 MHz; 1 bit quantization



1) From 10:04:00 to 10:09:00 source 0454-234  
Hobart12- Kath12m -Yarra12m  
1 scan in total, scan length = 5 min

2) From 10:10:49 to 10:12:29 APOD  
Hobart12-Yarra12m  
1 scan per 12 sec, scan length = 6 sec

3) From 10:13:29 to 10:17:45 APOD  
Kath12m-Yarra12m  
1 scan per 12 sec, scan length = 6 sec

4) From 10:19:00 to 10:24:00 source 0727-115  
Hobart12- Kath12m -Yarra12m  
1 scan in total, scan length = 5 min

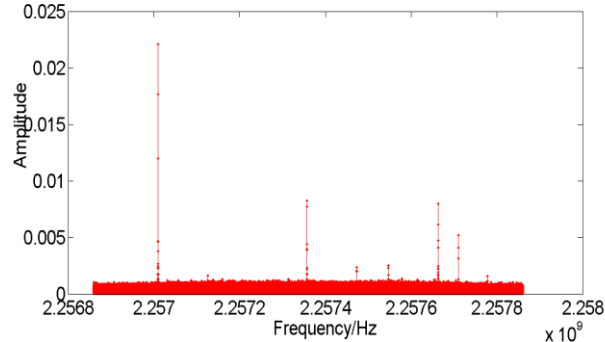
# 3. APOD observations with IVS VLBI antennas

## ① 2016-04-04 Ke-Yg-Hb

Chan12 is scheduled to record APOD s-band DOR (2262-2262/440 MHz)

No APOD DOR signal received.

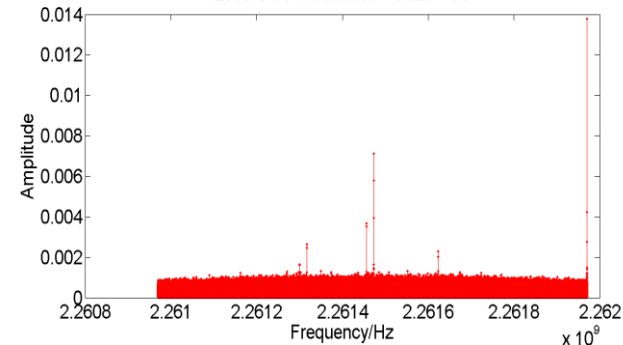
2016-04-04T10:17:07 Chan = 12



Chan13 is scheduled to record APOD s-band DOR (2262-2262/2200 MHz)

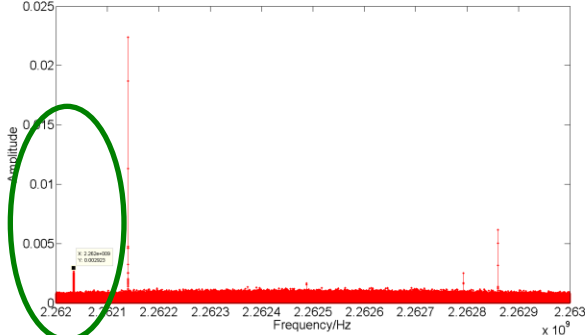
No APOD DOR signal received.

2016-04-04T10:17:07 Chan = 13



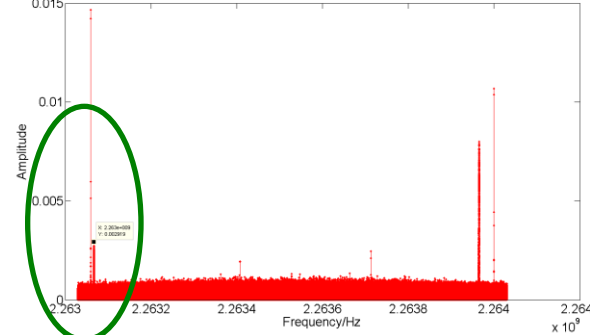
Chan14 is scheduled to record APOD s-band carrier (2262 MHz)

2016-04-04T10:17:07 Chan = 14



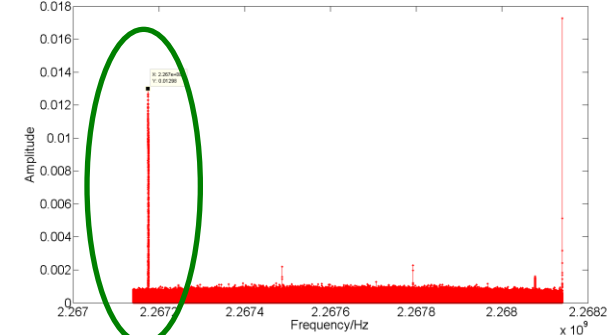
Chan15 is scheduled to record APOD s-band DOR (2262+2262/2200 MHz)

2016-04-04T10:17:07 Chan = 15



Chan16 is scheduled to record APOD s-band DOR (2262+2262/440 MHz)

2016-04-04T10:17:07 Chan = 16

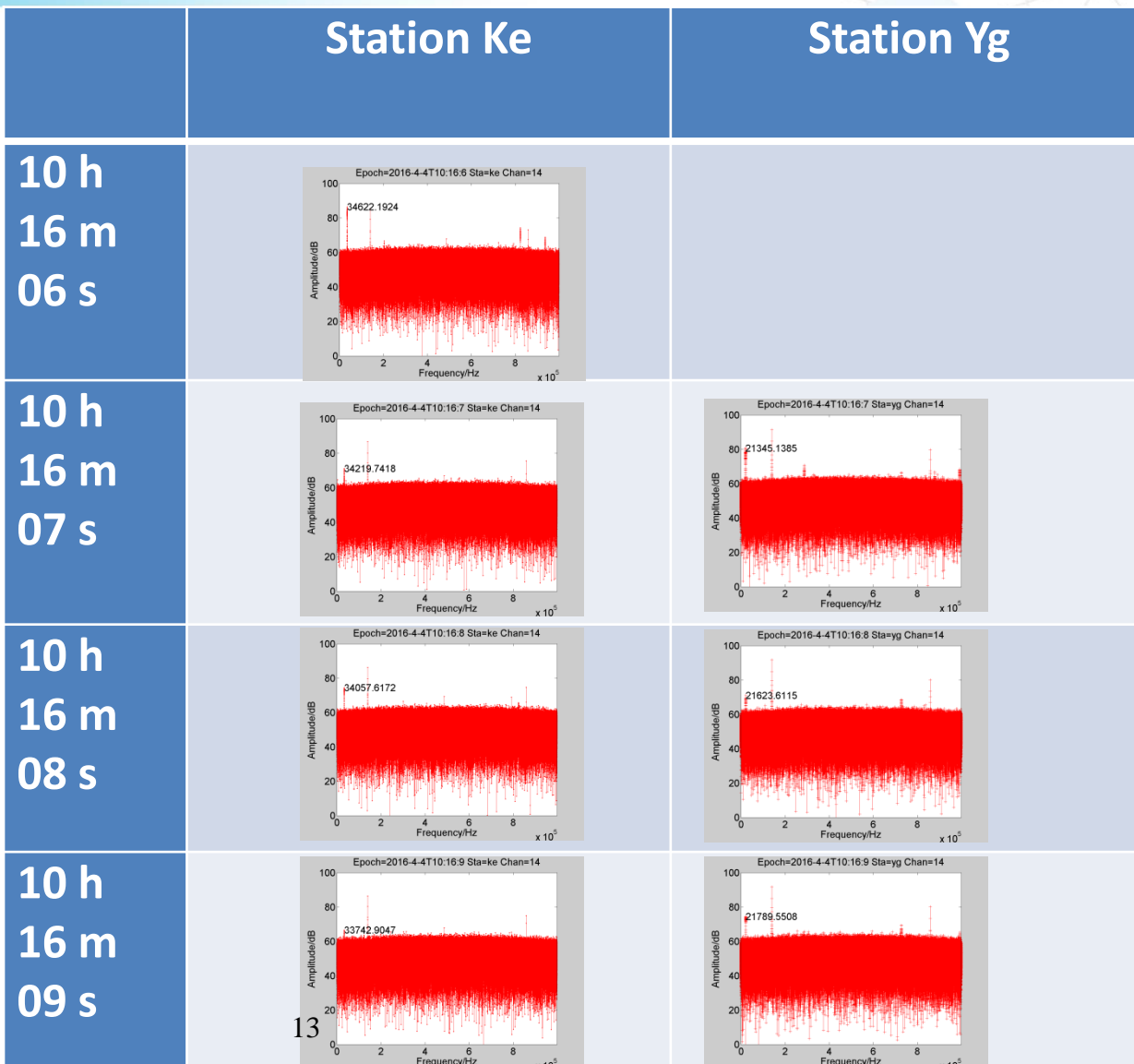




# 3. APOD observations with IVS VLBI antennas

① 2016-04-04 Ke-Yg-Hb

APOD signal  
spectrum within a scan.

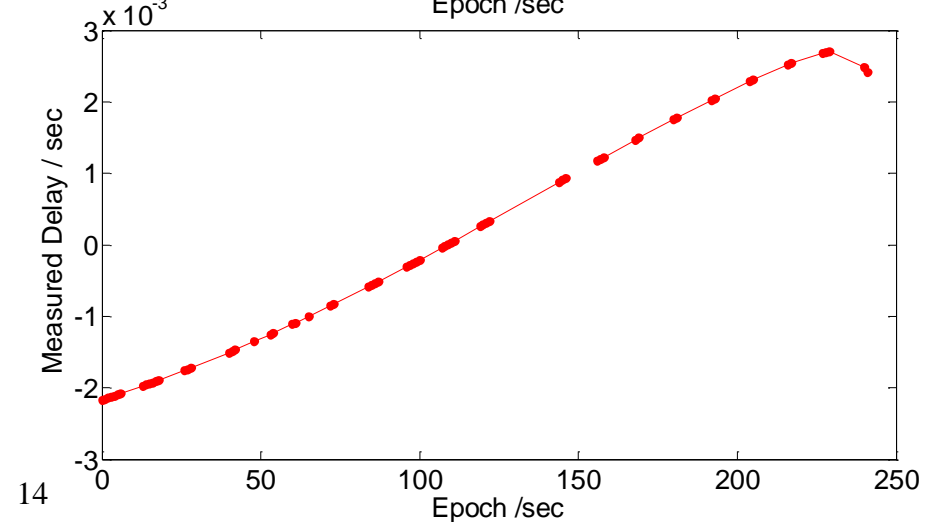
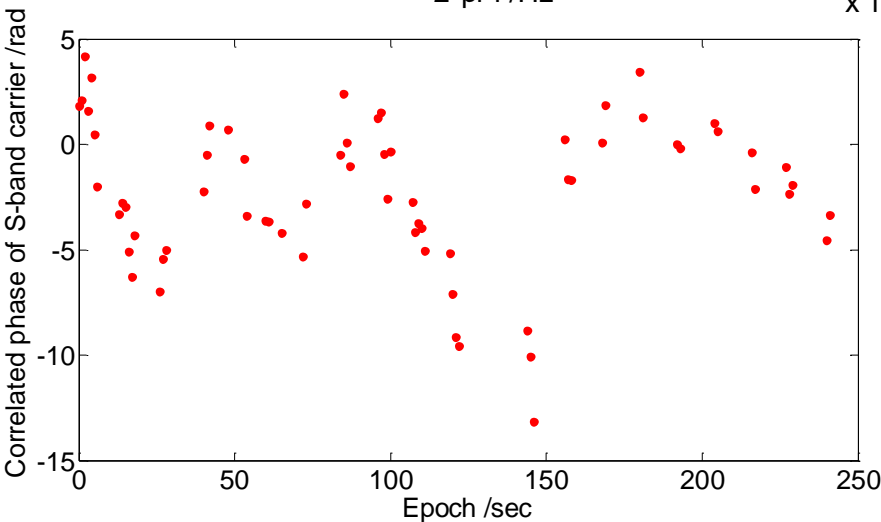
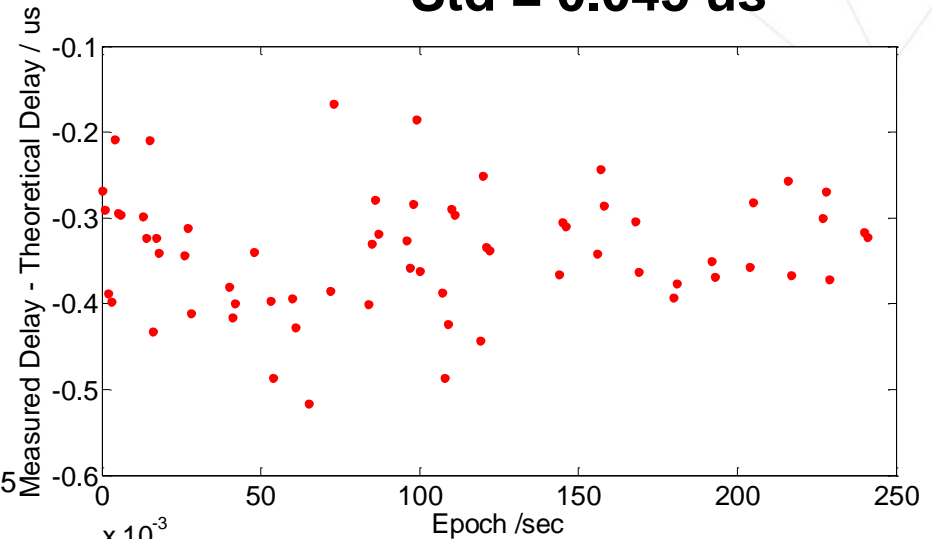
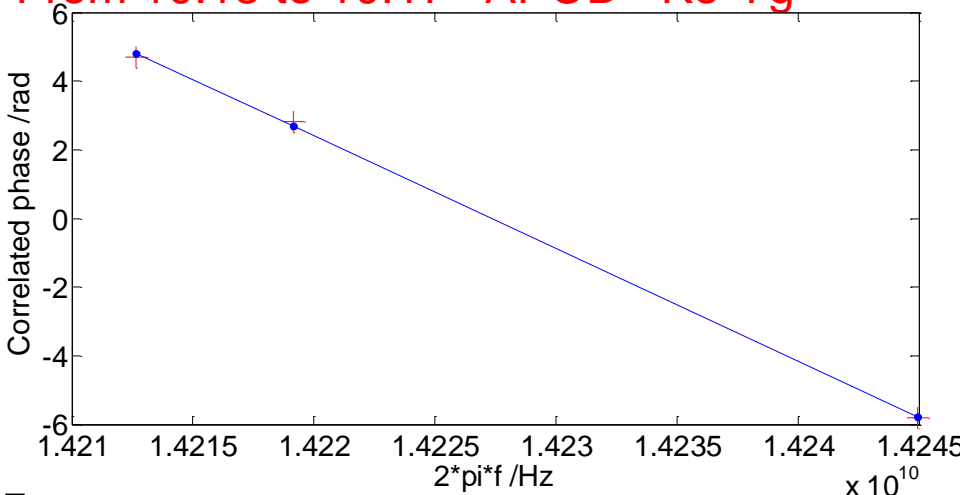


# 3. APOD observations with IVS VLBI antennas

① 2016-04-04 Ke-Yg-Hb

From 10:13 to 10:17 APOD Ke-Yg

Std = 0.045 us

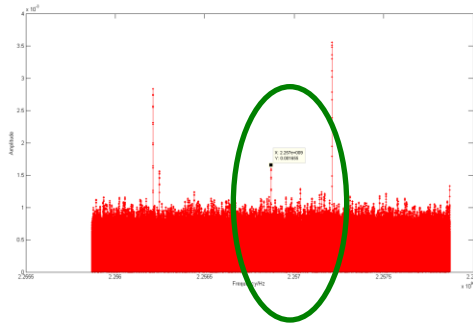


# 3. APOD observations with IVS VLBI antennas

## ④ 2016-07-18 Ke-Yg

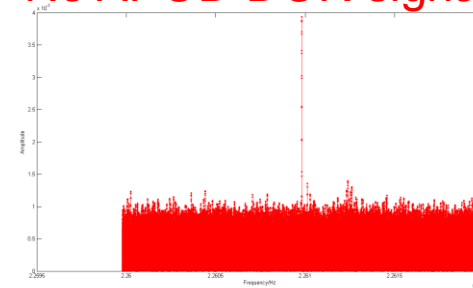
TLE input mode; sampling rate is 4 MHz; Yg didn't get any data

Chan11 is scheduled to record APOD s-band DOR (2262-2262/440 MHz)

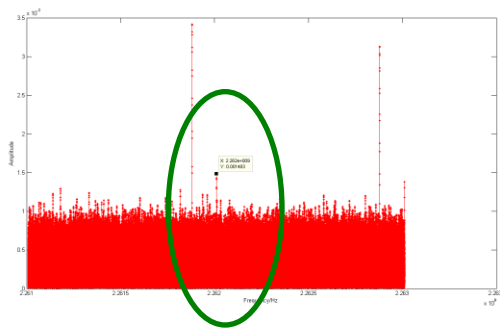


Chan12 is scheduled to record APOD s-band DOR (2262-2262/2200 MHz)

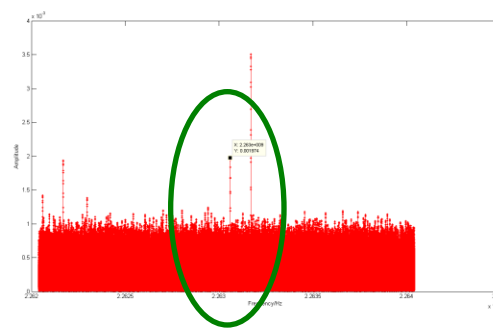
No APOD DOR signal received.



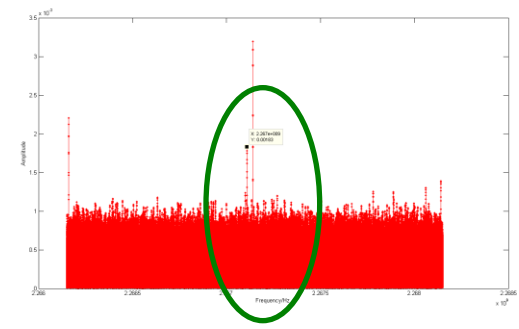
Chan13 is scheduled to record APOD s-band carrier (2262 MHz)



Chan14 is scheduled record APOD s-band DOR (2262+2262/2200 MHz)



Chan15 is scheduled to record APOD s-band DOR (2262+2262/440 MHz)

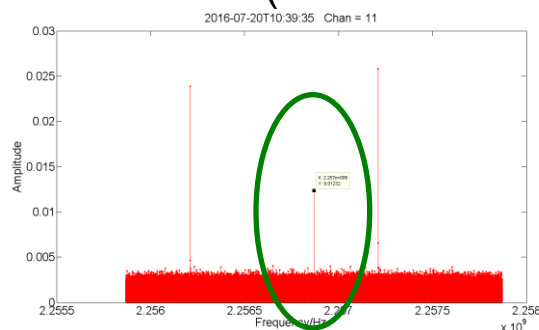


# 3. APOD observations with IVS VLBI antennas

⑤ 2016-07-20 Ke-Yg

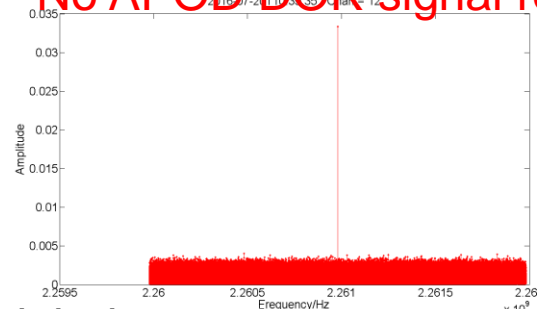
TLE input Mode; sampling rate is 4 MHz

Chan11 is scheduled to record APOD s-band DOR (2262-2262/440 MHz)

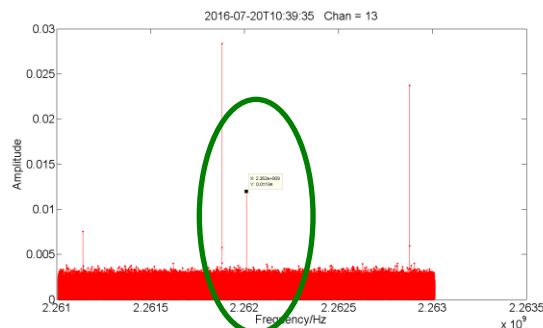


Chan12 is scheduled to record APOD s-band DOR (2262-2262/2200 MHz)

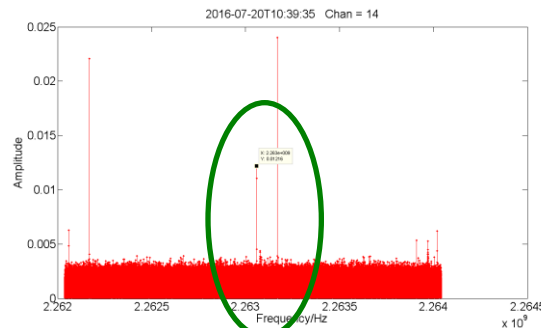
No APOD DOR signal received.



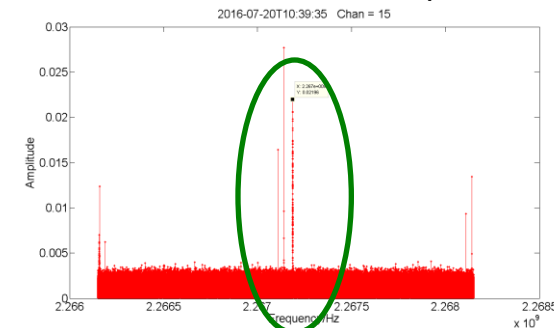
Chan13 is scheduled to record APOD s-band carrier (2262 MHz)



Chan14 is scheduled record APOD s-band DOR (2262+2262/2200 MHz)



Chan15 is scheduled to record APOD s-band DOR (2262+2262/440 MHz)

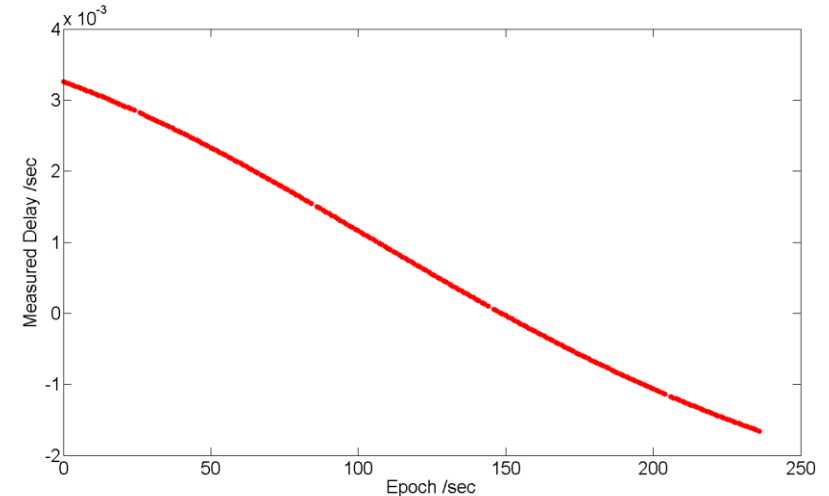
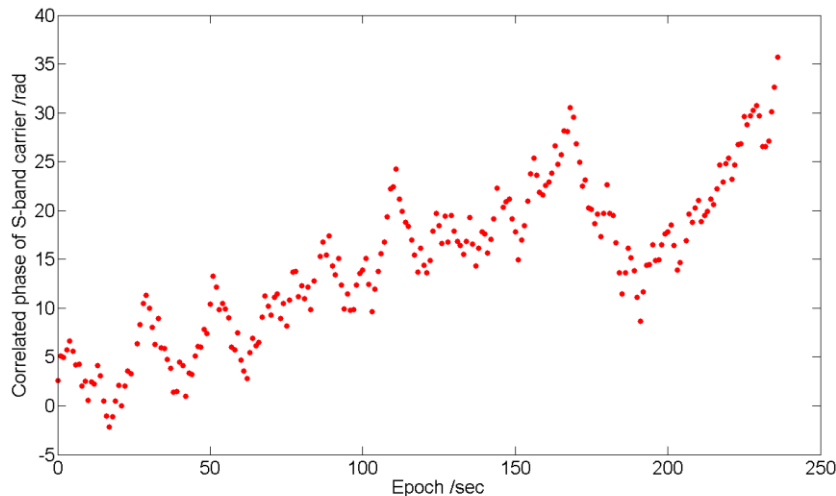
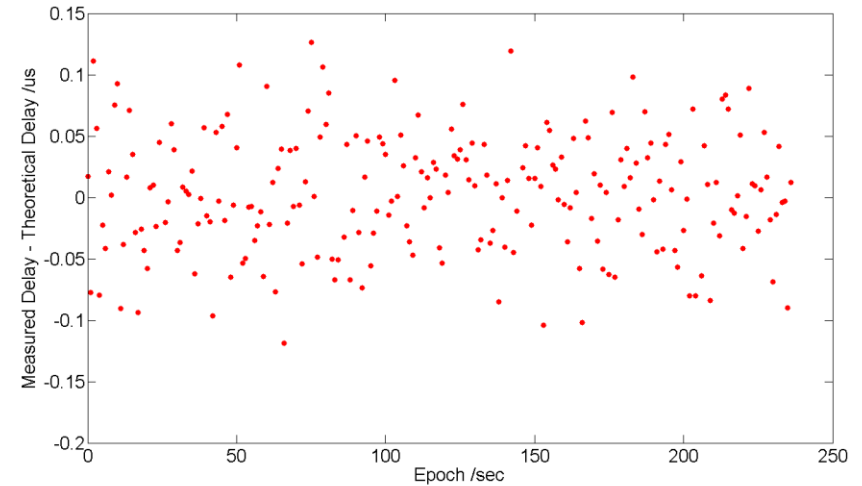
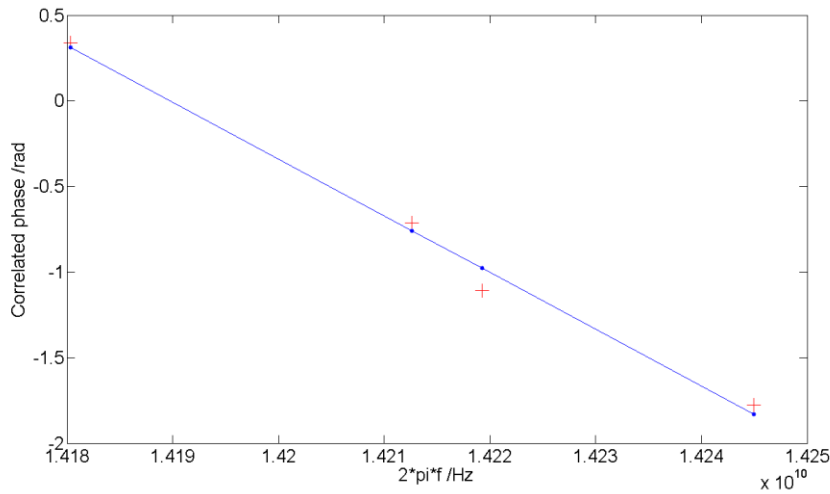




# 3. APOD observations with IVS VLBI antennas

⑤ 2016-07-20 Ke-Yg

Std = 0.04797 us



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## 4. Conclusion and future work

- ◆ Doppler of APOD signal is large and varies quickly, **theoretical delay with very high precision** should be computed for correlation.
- ◆ To observe the LEO satellite with geodetic antennas, it is strongly suggested to update the tracking mode to “**direct Az/EI input**” mode at stations.
- ◆ Analysis of observation data will be carried on; observation of APOD with CEI system will be conducted to check the status of beacon.



# Thank you for your attention!

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