退職記念WS＠三鷹
２０１４年６月２日

VLBI研究４０年とこれから

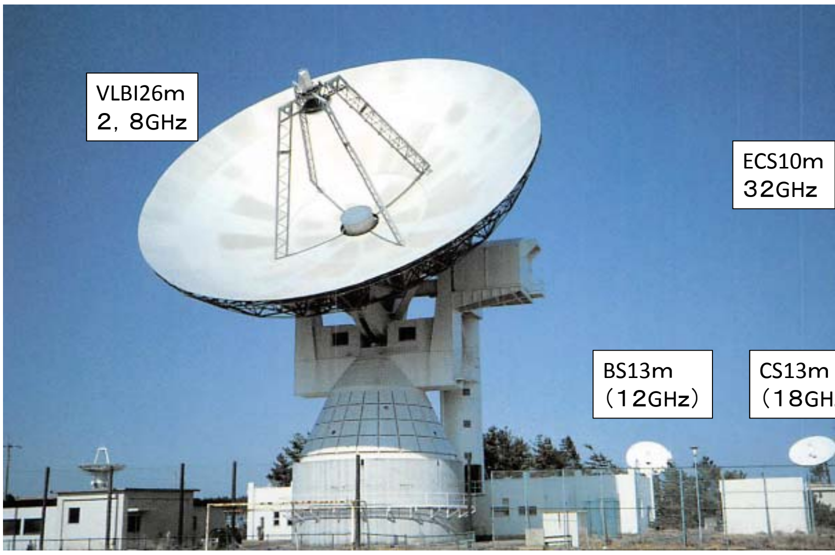
川口則幸

Going to Radio Astronomy

I first worked on the 26-m radio telescope at Kashima station.

The 26-m antenna was already scrapped.

Multi frequency radio observations



The first VLBI experiment in Japan

１９７７年

宇宙電波で地震予知

鹿島など二カ所で

電波研、壮大な実験開始

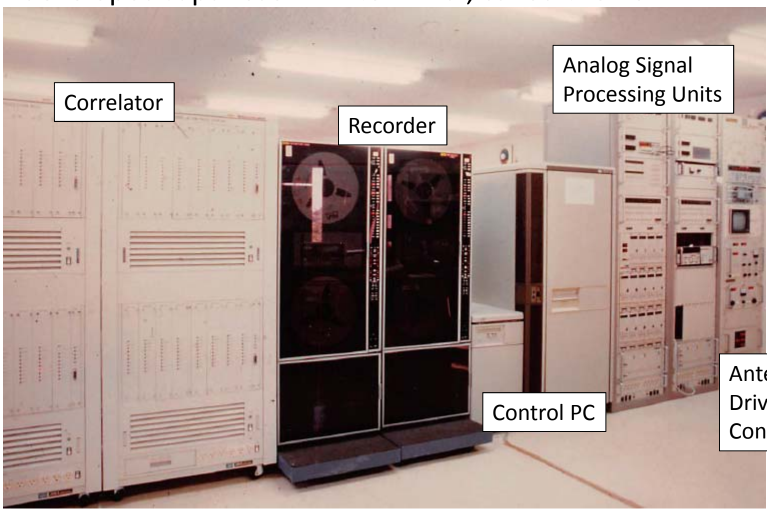
Since 1977 I have been working on VLBI astronomy.

Detection of crustal plate motion

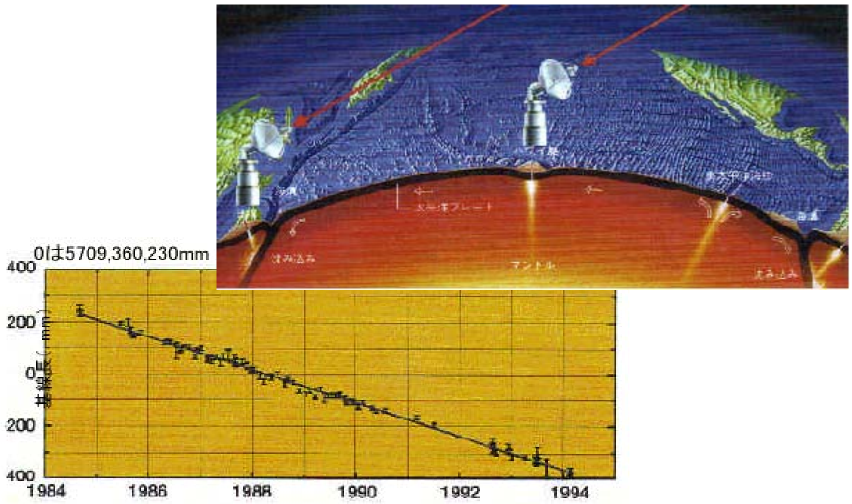
VLBI APPLICATION TO GEODESY

Development of the K3 VLBI Terminal

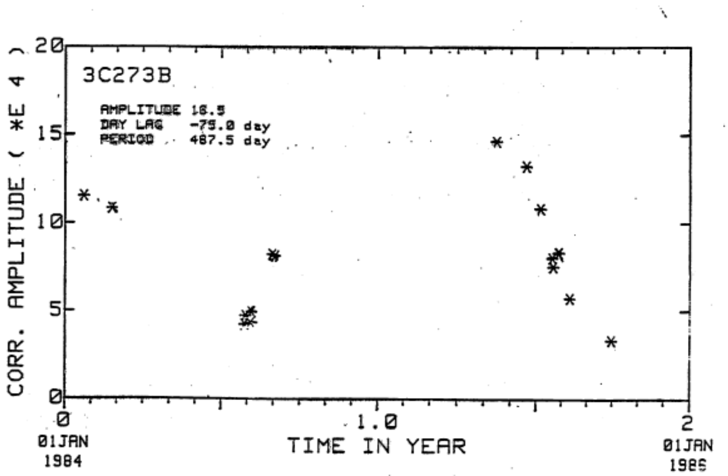
For the use of a Joint US-Japan Geodetic VLBI Observations, I developed Japanese VLBI terminal, called the K3.



Crustal Plate Motion detected

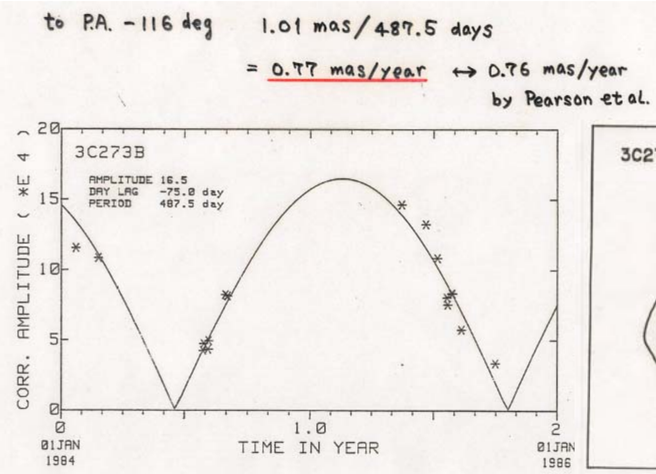


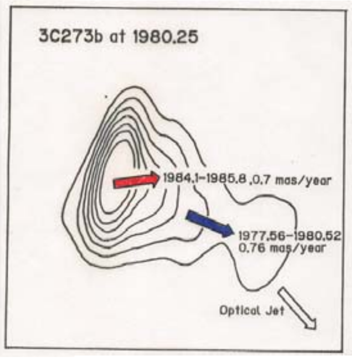
I found systematic changes in the fringe amplitudes observed on 3C273b



Super Luminal Jet Motion was detected.

The change is well fitted to a sinusoidal curve.





Shanghai 6-m telescope

上海天文台６ｍアンテナ
（上海天文台写真提供）

日中VLBI実験

I worked on the 6-m telescope

1985.9

Geodetic Solutions on Kashima-Shanghai Baseline

Repeatability of two times experiments

Table 6

	First 24hour (12 September, 1985)	Second 24hour (17 September, 1985)	Difference	Average
Bx (m)	1150194.27±.08	1150194.35±.11	-0.08	1150194.31±.07
By (m)	1383291.42±.13	1383291.41±.12	+0.01	1383291.42±.09
Bz (m)	-440159.63±.09	-440159.70±.10	+0.08	-440159.66±.07
|B| (m)	1852075.19±.04	1852075.25±.04	-0.06	1852075.22±.03

Accuracy of the baseline length was 4-cm
(Nowadays it is improved to 4-mm)

First launch of the Myu-5 rocket

Wajima-san, He used to work with SHAO.

Kawaguchi

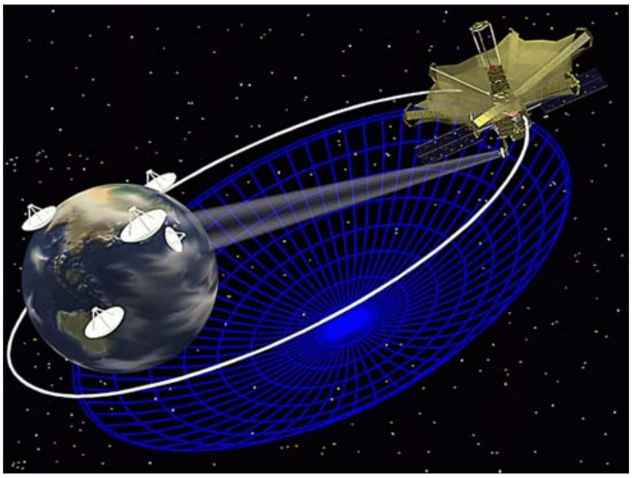
Kobayashi-san, now he is a vice director of NAOJ.

To search for a fine image of AGN

GOING TO SPACE VLBI

BUDGET APPROVED IN 1989
LAUNCHED IN 1997

First space orbiting radio telescope



In 1977.2.17, the space orbiting telescope “HALCA” was launched.

The space VLBI program was performed with an international collaboration.

64m Antenna, Usuda Deep Space Center

I was working at the UDSC for HALCA tracking and data acquisition. It was the largest radio telescope in the eastern Asia before constructing the Tian-Ma 65m.

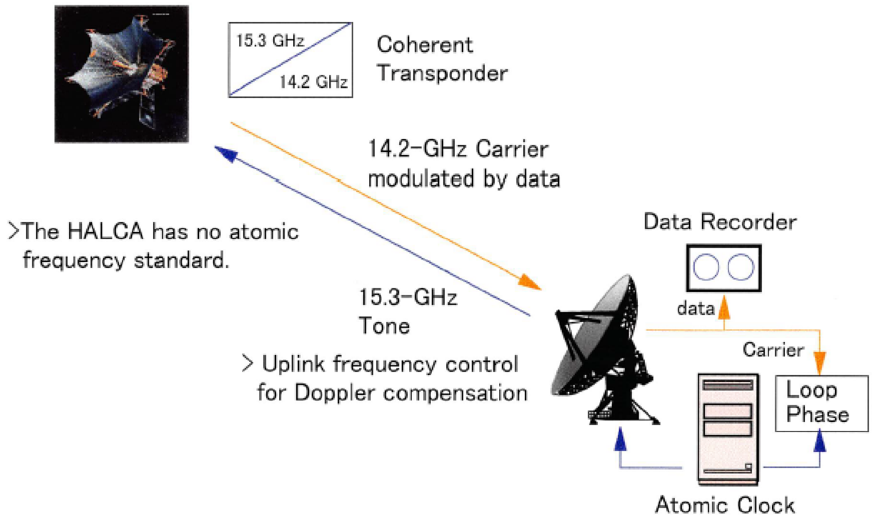
Usuda 10m

Data reception from HALCA

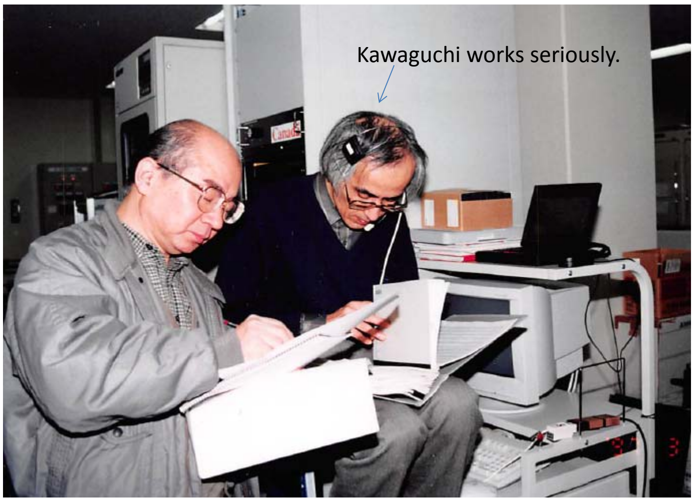
TX：15．3GHz
RX：14．2GHz

Data Rate：128Mbps

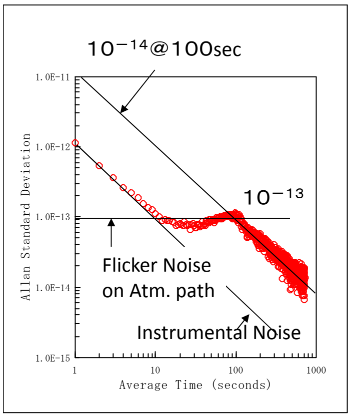
HALCA Phase Transfer System

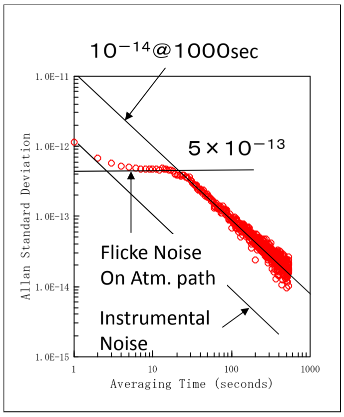


Data receiving in UDSC

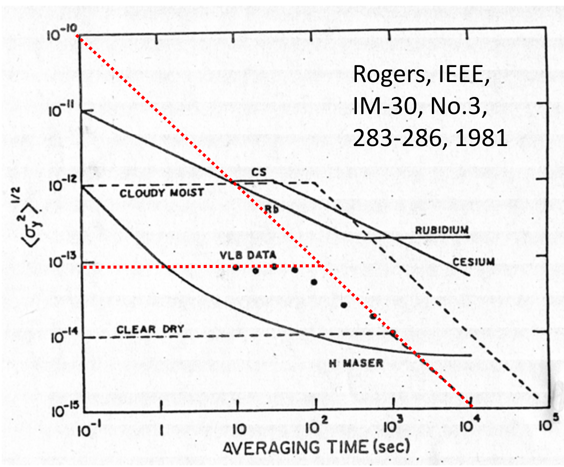


Statistical Analysis of atmospheric phase fluctuations





Establish statistics of Atmospheric path Instability



Also follow 10^{-14} @1000sec model

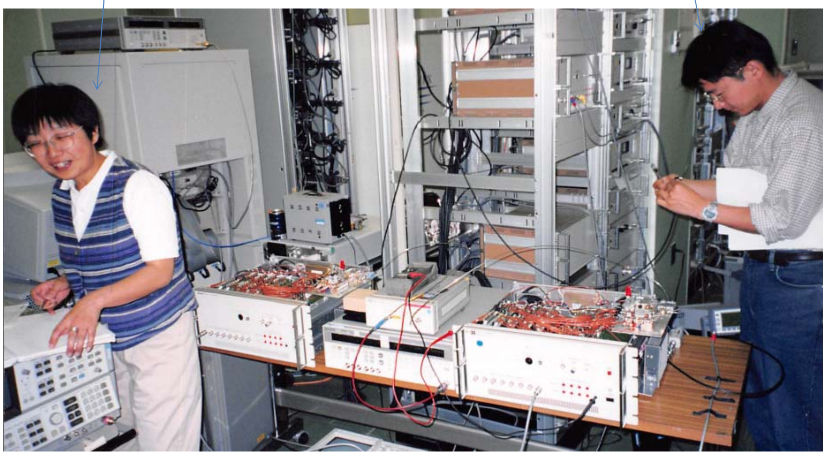
DAS for VLBI

TECHNICAL DEVELOPMENTS

Development of a High Speed ADC

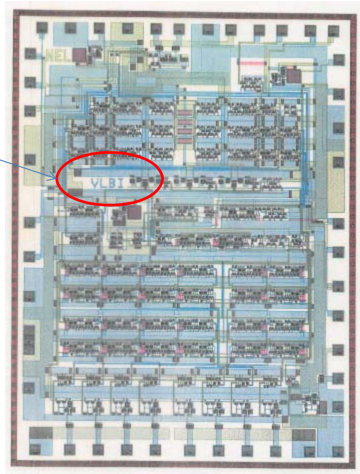
Dr. S. Okumura, she is now a professor of the Nihon Woman's University.

My student, Dr. Kinya Matsumoto, now he is an associate professor of the Tokai University.



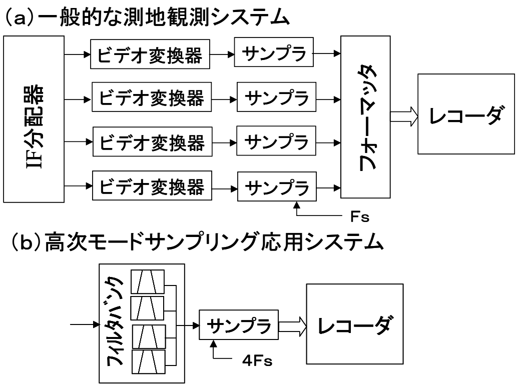
A custom LSI was developed

See this mark.



Simplified Wideband Geodetic VLBI System

- 測地観測には広帯域が必要
- 広帯域(ex. 512MHz)データは全ては記録できない
- 一部の周波数帯のみを記録して合成する(バンド幅合成)



Experimental Results

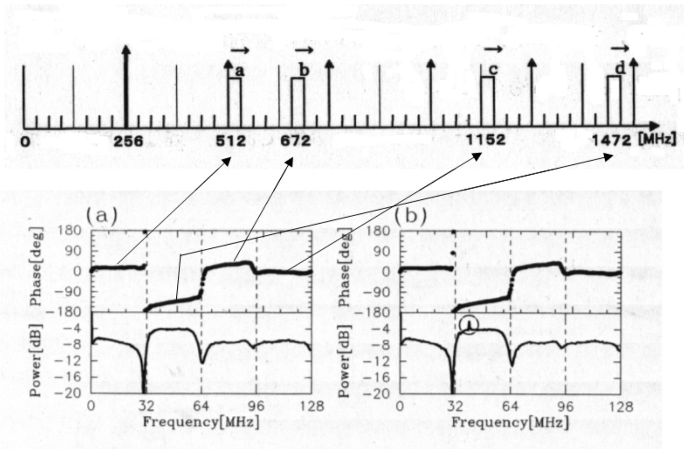


図 36. 相互相関処理結果（白色雑音＋正弦波信号）

From Doctor Thesis (Dr. Suzuyama)

W49N on NRO 45m

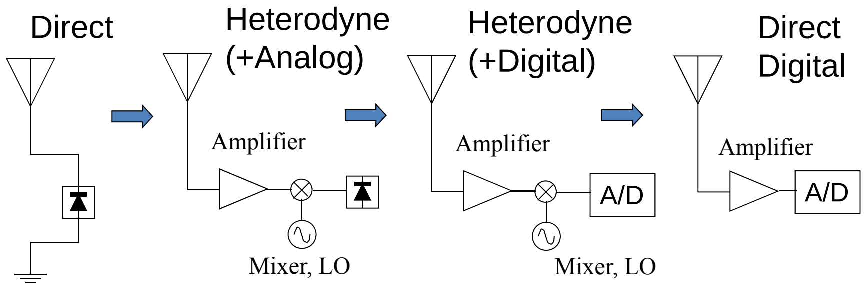
Baseband ... mpled spectrum

LO=(16.8...
2.2-2.6GHzのIF帯に変換してから
8.192GHzでサンプリング、512K点
FFTを行った。図は一部の拡大

...(帯域幅4.096GHz)を
直接8.192GHzでサンプリングし、512K点
FFTを行った。図は一部の拡大
スペクトルは逆順になっている。

Frequency Conversion

The Heterodyne Technology was established in 1918.



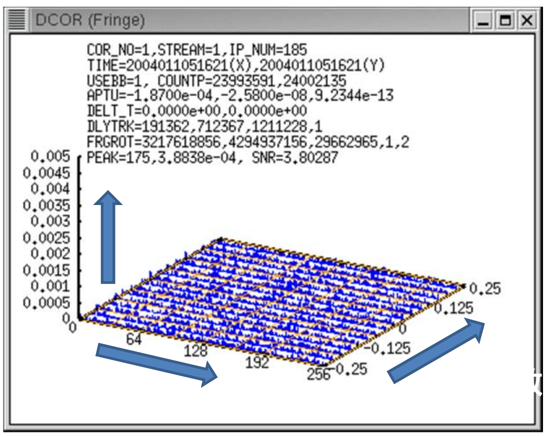
Direct Detection (1887)

Vacuum Tube Amp. (1906)
Heterodyne Detection (1918)

Semiconductor Amplifier (1947)
Digital Processing (1970 ～)

InP HBT Full Digital Receiver (2007?)

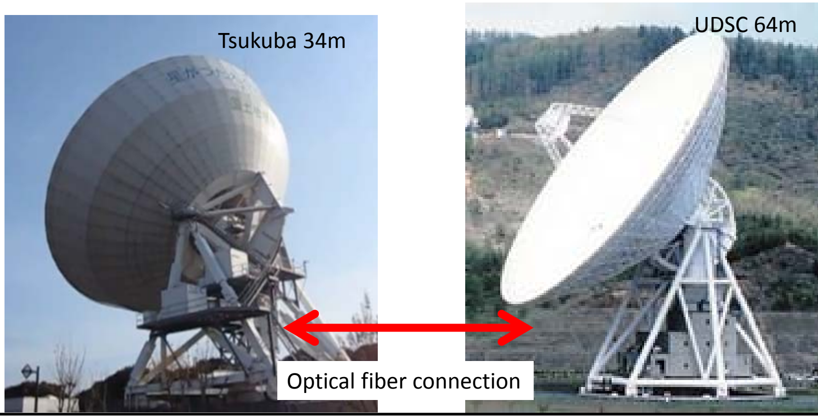
Real time VLBI



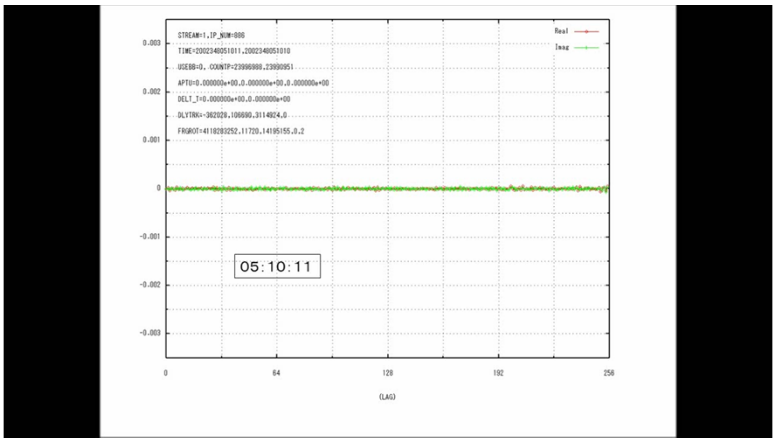
Optical fiber connected real-time VLBI was first realized in the world.

A fixed direction interferometer

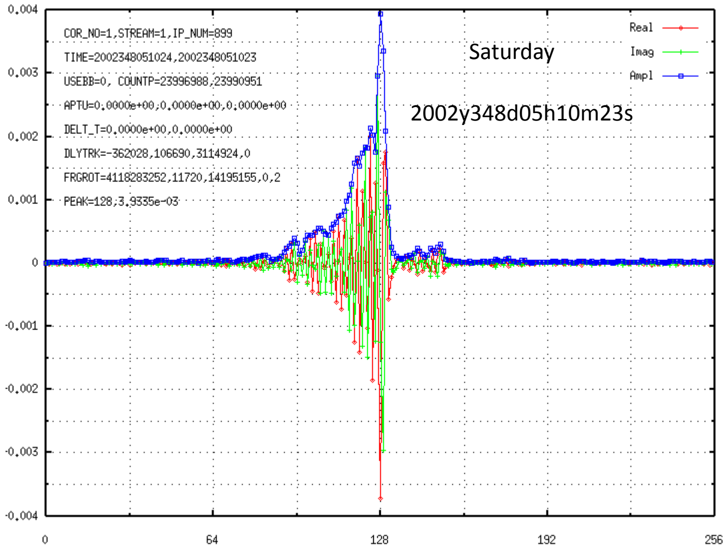
- A parking position of a large telescope is a little bit adjusted from their rest direction.
- While they are at the rest, I made real-time correlation between them. Efficient use of their telescope time!



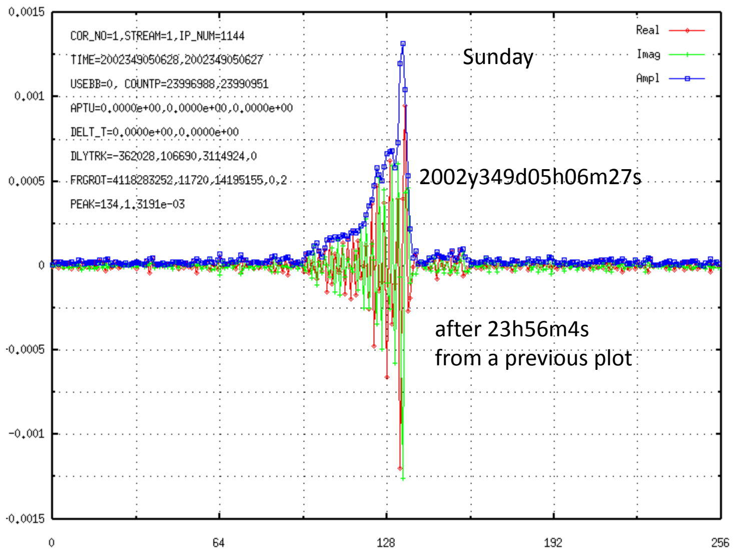
3C84 passed through an VLB Interferometer



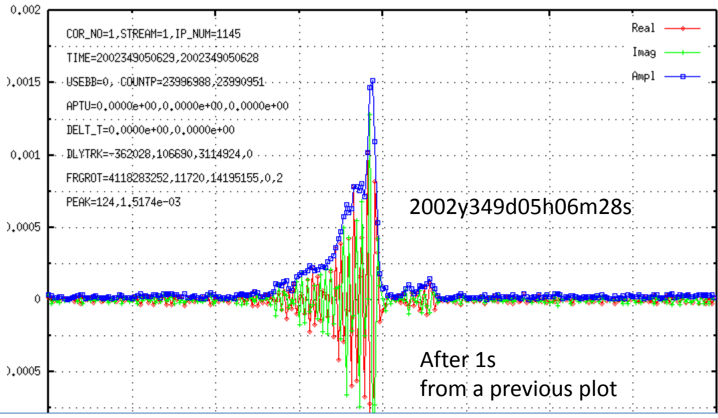
A fringe detected at the center of a correlation window



A fringe position in the next day



One second later

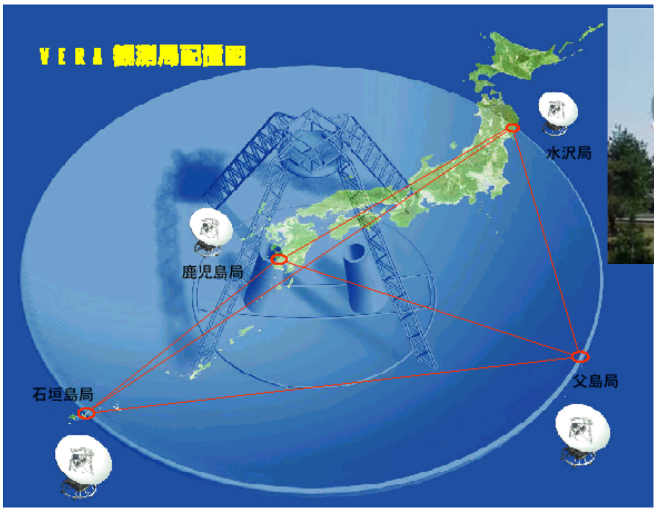


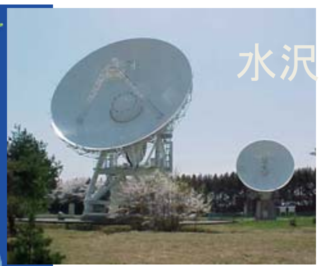
We can know that one revolution of the earth takes a time between 23h56m4s and 23h56m5s. 10µsec accuracy is possible to obtain in this way.

VERA

TO VLBI ASTROMETRY

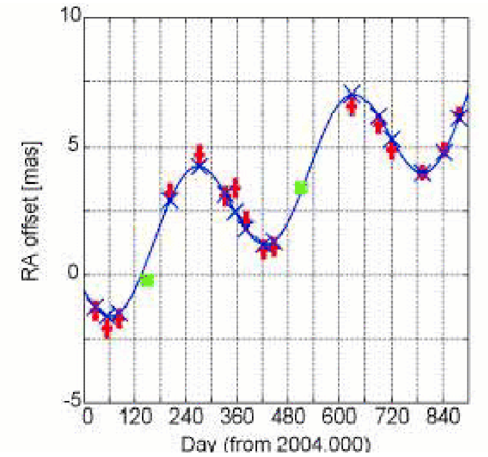
VERA constructed in 2000/2001





VERA Mizusawa Station

Annual Parallax measured for ORION



Measured parallax

π : 2.1 +/-0.1 mas

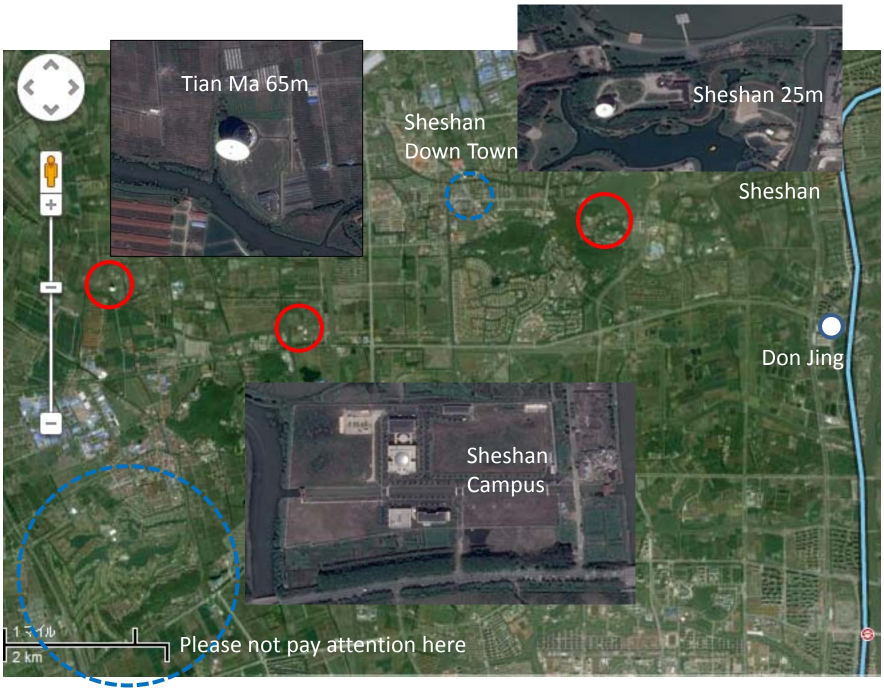
Distance

D : 440 +/- 20 pc

Shanghai Observatory

SHESHAN CAMPUS

Sheshan Campus



Geometry around Sheshan

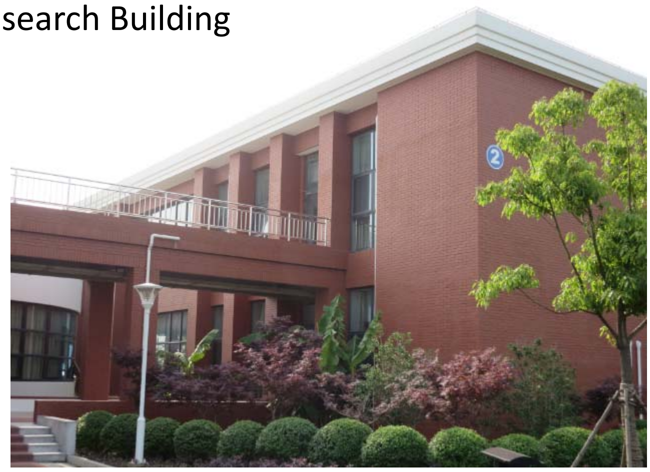
Sheshan Campus

Sheshan Campus

Main Building

Sheshan Campus

Research Building



Sheshan Campus

Dormitory

Sheshan Campus

Dining Hall

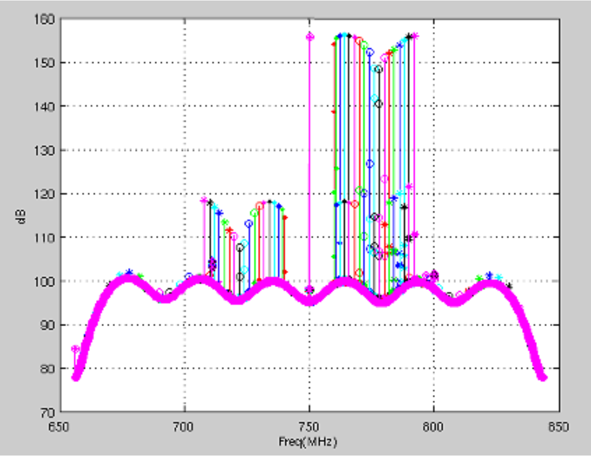
65-m View from Campus

Electric Motor Cycle

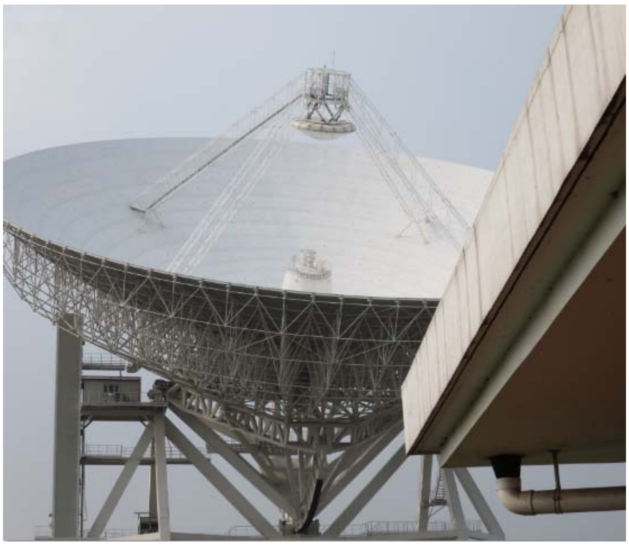
着任後受けた相談

- 月面上ローバーの位置計測精度の検証
- CE3の中国受信局にみられる受信電波強度変動について
- CDASで取得したスペクトルデータに表れる異常なリップルの成因について
- 静止衛星電波の６５mアンテナでの受信について
- 電波天体を用いたホログラフィー計測について
- Active Surface制御におけるActuatorの特性と寿命の検討（共同でAPSJに投稿予定です）
- 広帯域AD変換について
- ６５m用２２／４３GHz帯LNAについて
- ６５mサイトに設置したWVRのデータ解析と今後の開発方針について

Spectrum Ripple on CDAS



Tian Ma 65m (天馬65m）



Feed Horns of 65m

C-band Cooled Receiver

S/X band cooled receiver

Holography Receiver

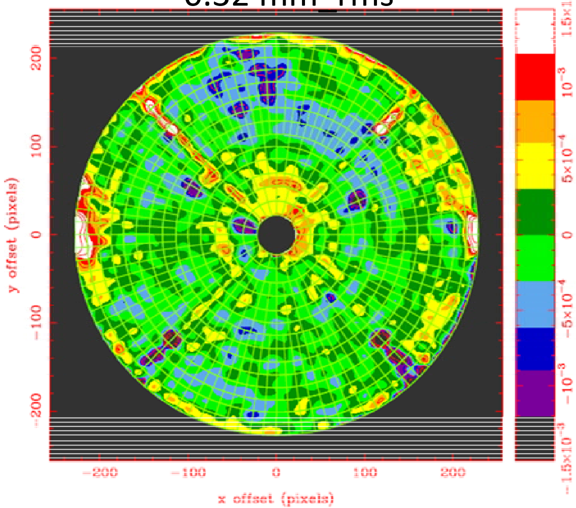
Holography Reference Antenna

1.8-m Dia. Antenna for receiving AsiaSat4
Az=180deg, El=52deg

Absorber on a pannel

Measured Surface Error

0.32 mm rms

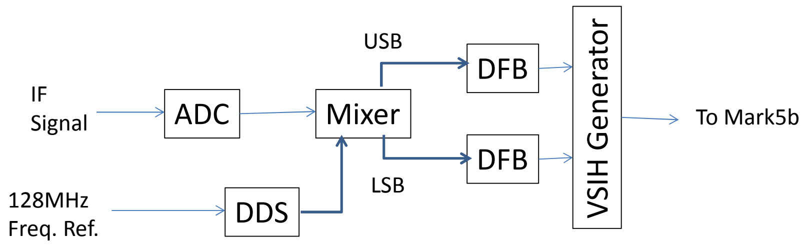


Actuators for Active Surface

Actuator Motion

The maximum stroke is 11 mm for a horizon-to-horizon observation. The life of an actuator is 1550 meter, so that we can expect 100 years or longer life on an active surface control.

DBBC in the CDAS



ADC: Analog¥to¥Digital Converter
DDS: Direct Digital Synthesizer
DF: Digital Filter Bank
VSIH: VLBI Standard Interface on Hardware

Is the ADC on the DBBC is the same as that on DIBAS?

デジタルフィルタの設計

- 広帯域データをデジタルフィルタで情報を圧縮する。
- 処理の順番
  1. 広帯域データをフィルタリングしてから情報圧縮（ダウンサンプリング）
  2. 情報圧縮（ダウンサンプリング）してからフィルタリング
- 通常の処理は1だが、2の手法のほうがフィルタ動作を低速化できるので有利
- 1と2は「ノーブル恒等変換」の関係にある

ノーブル恒等変換の応用

x(n)→ **G(z^U)** → **↓D** →y(n)　通常の考え

から

x(n)→ **↓D** → **G(z)** →y(n)

へ

先にダウンサンプリングすると幸田のフィルタの動作速度を遅くできるので有利

ノーブル恒等変換(2)の数学的証明

$x(n) \to \boxed{\downarrow D} \to \boxed{G(z)} \to y1(m)$ と $x(n) \to \boxed{G(z^D)} \to \boxed{\downarrow D} \to y2(m)$ は等価である。以下、これを証明する。

$$Y_1(z) = G(z)\left\{\frac{1}{D}\sum_{k=0}^{D-1} X\left(W_D^{-k} z^{1/D}\right)\right\}$$

$$Y_2(z) = \frac{1}{D}\sum_{k=0}^{D-1} X\left(W_D^{-k} z^{1/D}\right) G\left\{\left(W_D^{-k} z^{1/D}\right)^D\right\}$$

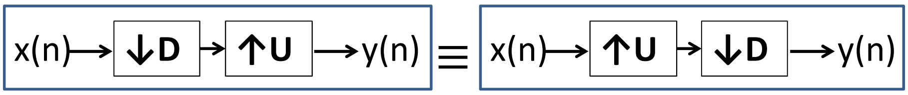
$$= \frac{1}{D}\sum_{k=0}^{D-1} X\left(W_D^{-k} z^{1/D}\right) G\left\{\left(W_D^{-k}\right)^D z\right\}$$

$\left(W_D^{-k}\right)^D = \left(e^{-j\frac{2\pi}{D}}\right)^D = e^{-j2\pi} \equiv 1$ なので

$$Y_2(z) = \frac{1}{D}\sum_{k=0}^{D-1} X\left(W_D^{-k} z^{1/D}\right) G(z) = Y_1(z)$$

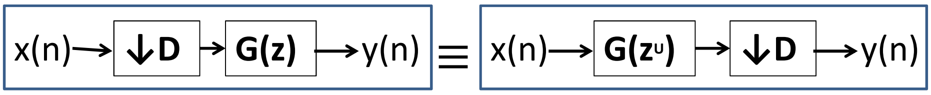
ノーブル恒等変換

(1)

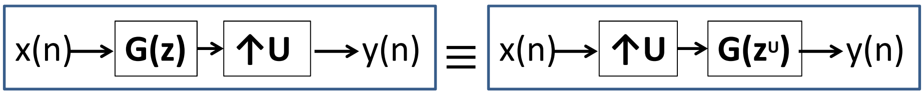


ただし、U と D が「素」である場合

(2)



(3)



My Works in Shanghai

- Holographic surface measurements in different elevation angles
- Actuator life estimation and strategy of active surface control
- 22/43-GHz receivers on 65m
- Digital data processings and the mathematical proof on 'Noble Identity'
  - Digital filtering then down sampling
  - Down sampling then filtering

Sight Seeing

Classical houses looked sunk under water