

A study of a RF (radio frequency) direct sampling technique for the geodetic VLBI

NICT :

K. Takefuji, T. Kondo, M. Sekido, R. Ichikawa

GSI :

S. Kurihara, K. Kokado, R. Kawabata

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1. What is a RF direct sampling?
2. We develop a new technique DSAMS.
3. The geodetic VLBI with the DSAMS.
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DSAMS = “Direct Sampling Applied for
Mixed Signals “

A RF direct sampling

1. Never down-convert by analog mixers
 2. A digital sampler which has a high frequency capability is a most important key
- Four necessary components
 - **Antennas, LNAs, the samplers, and(or) optical converters**

We need optical converters in case of the RF signal transfer (Antenna -> lab)

Developments in Japan have the RF direct sampling realize now

Sampler ADX831 (ADX series)

- Elecs Industry corp.
- DC – 30GHz
- Max 8Gsps*3bit
(decimators inside)
- 10GbE connections



ADX831

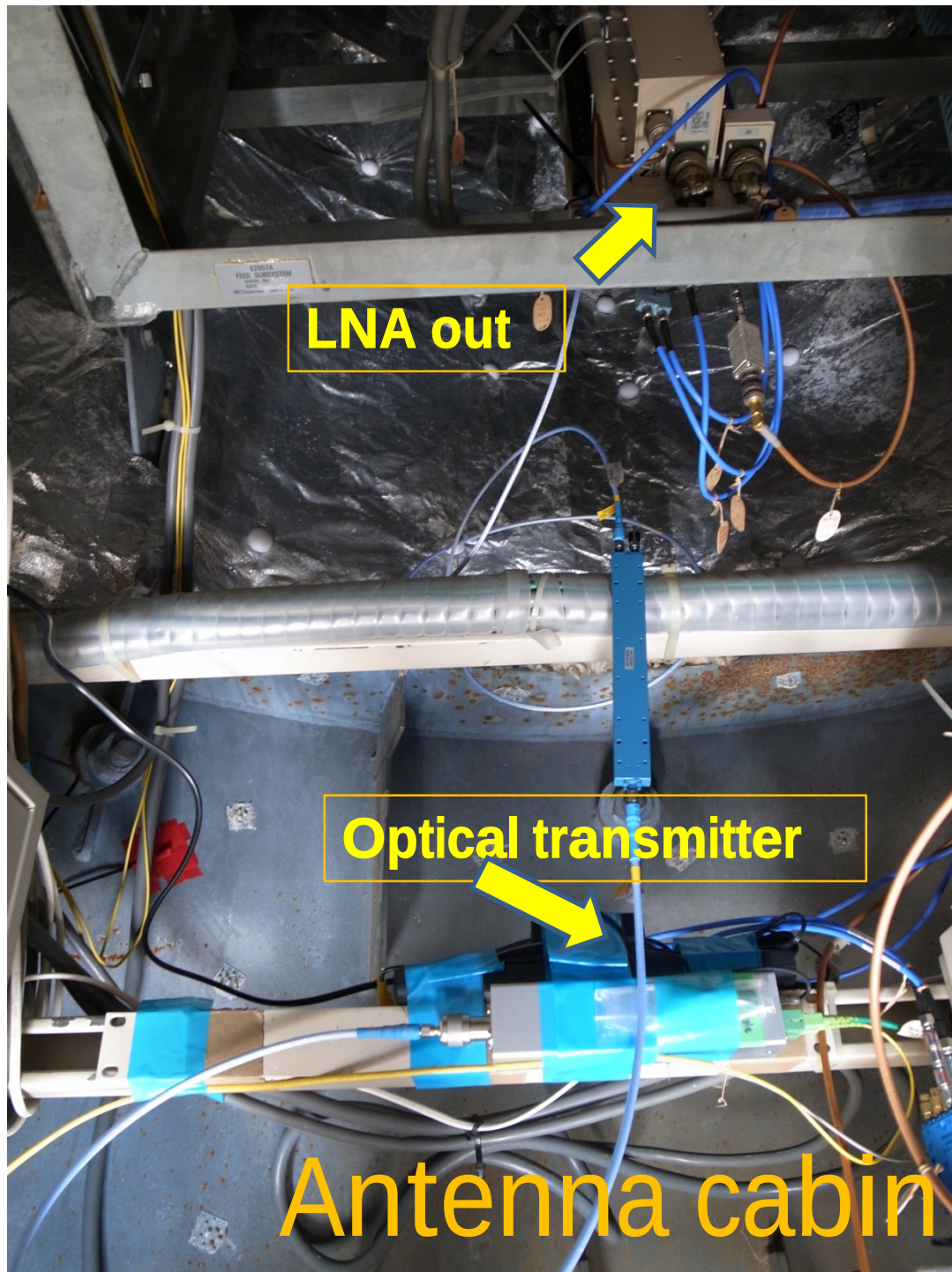
Optical converter E18000

- Toyo technica corp.
- High stability and Low loss
- Wide dynamic range :
Possible to transfer directly
the RF signal just after LNA
(DC - 18GHz)



E18000

A FRING TEST WITH THE RF DIRECT SAMPLING



Installation of the RF direct sampling system

Figure shows the inside of a Kashima11m antenna cabin

- No amplifiers after LNAs
- The RF signal is directly transferred to our lab



The Optical receiver

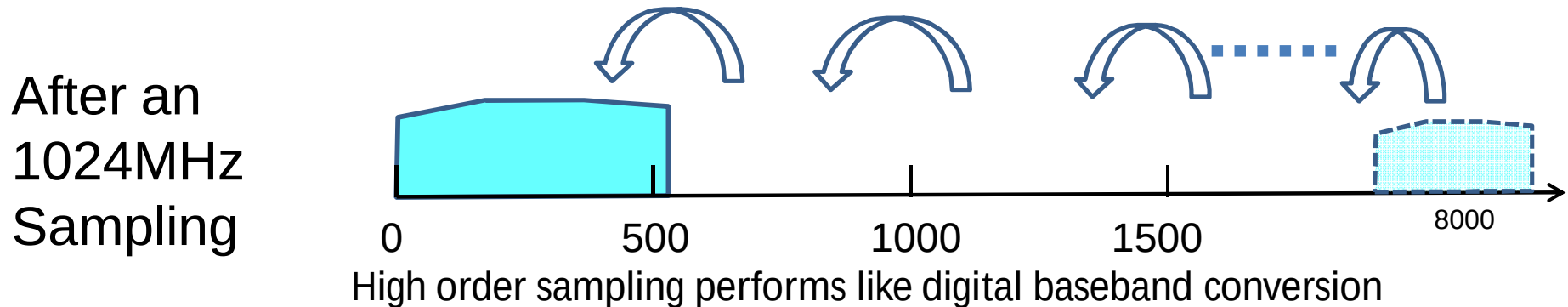
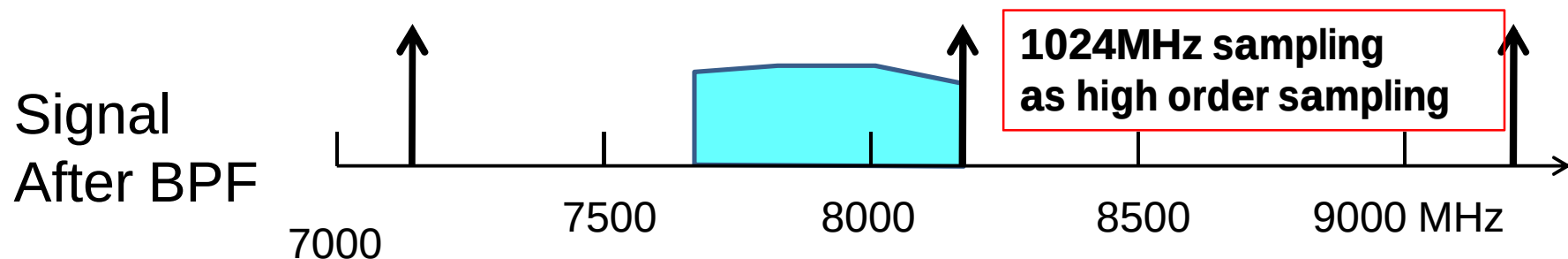
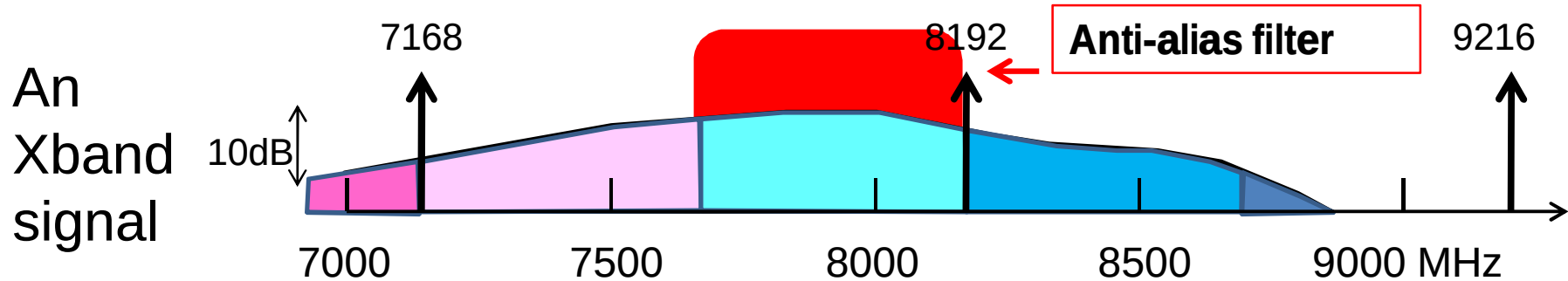
The RF direct sampler

In observation room

According to the Nyquist sampling theorem, it is a necessary to sample at an 18GHz speed to detect a X-band(9GHz).

But we use only an 1GHz sampling speed!! This is called an under sampling or a high order sampling.

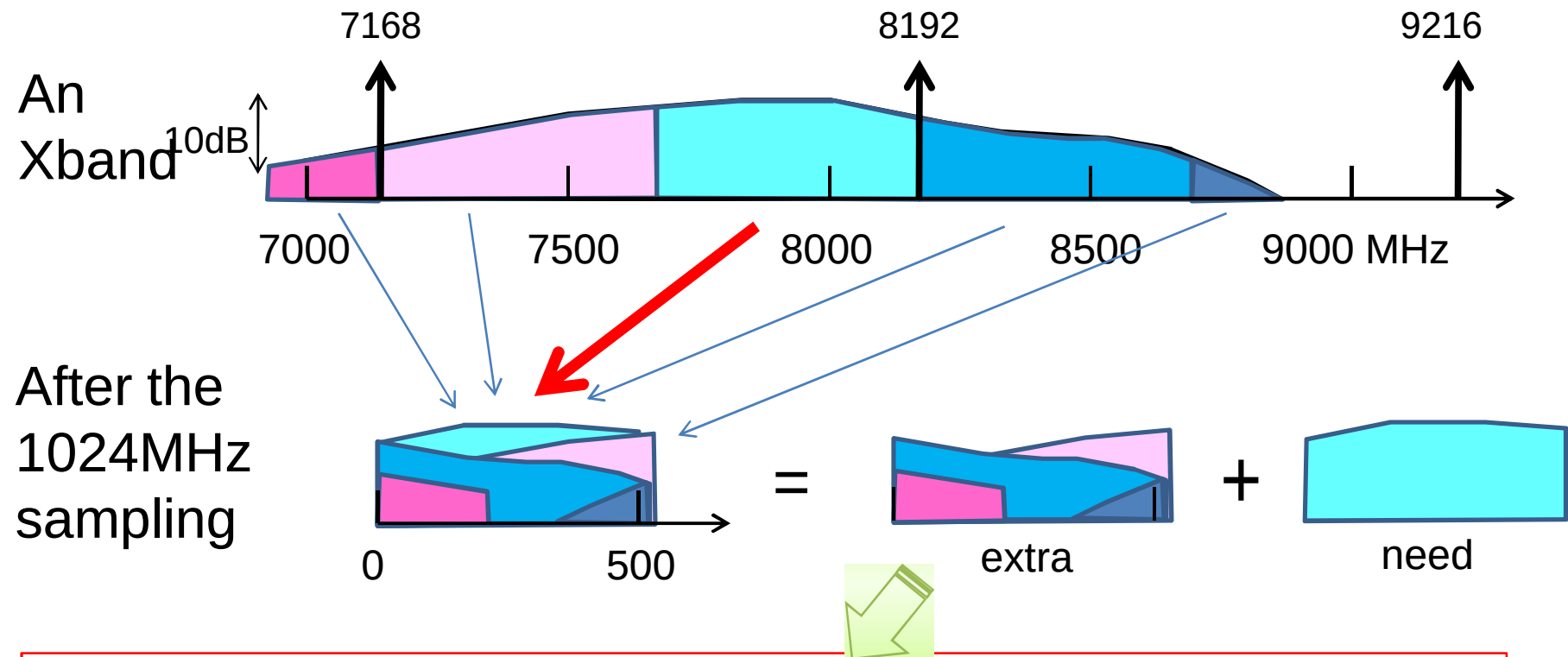
How to perform the RF direct sampling in case of an 1024MHz sampling speed



A rule of sampling

- By digital signal textbooks, “Insert an **anti-aliasing** filter to prevent from an **aliasing** of folded signals”
- You can not make a aliased signal restore to the original signal without anti-filter

The RF direct sampling **without Filter** in case of 1024MHz speed



All bands are overlapped (mixed) !!
Increase Tsys! and Decrease fringe amplitude

Okay, Take it easy!

It's a just fringe test!

We will cover this loss with a
sufficient integration time !

...

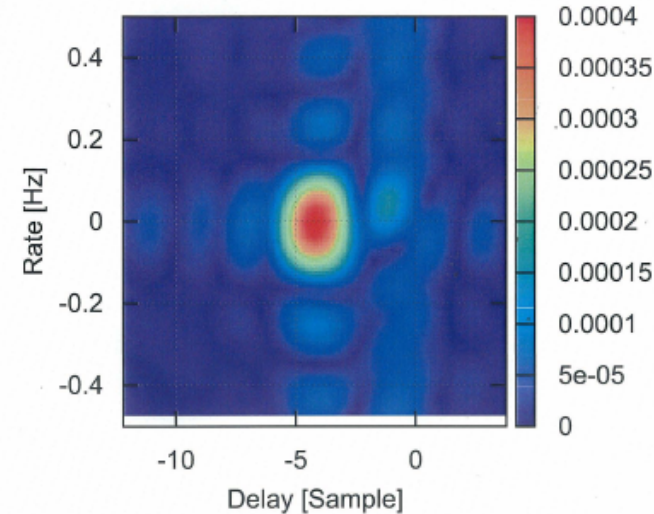
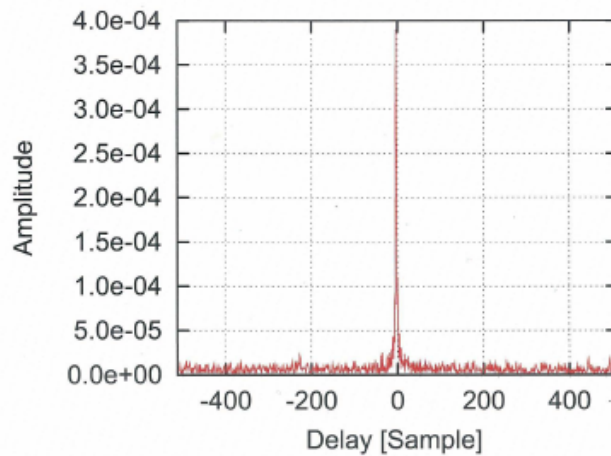
祝：RFダイレクトサンプリングVLBI実験成功! 2011/5/12

2011/5/12

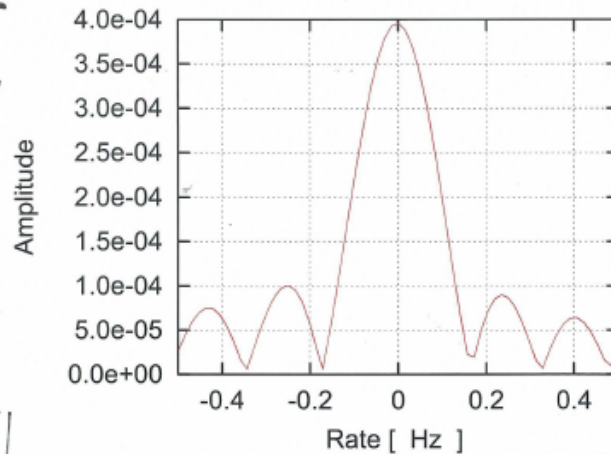
栗原 忍

原田 健一
鈴木 和利

山崎 拓朗



岳藤 一宏



Epoch : 2011/132 07:58:00
 Station-1: TSUKUB32
 Station-2: KASHIM11
 Source : 3C84
 Length : 8.000000 [sec]
 Sampling : 1024000000 [sps]
 Frequency: +8192.000000 [MHz]
 Peak Amp : 0.039585 [%]
 Peak Phs : -133.810336 [deg]
 Delay : -4.195374 [spl]
 Rate : -3.059387 [mHz]
 SNR : 59.974707

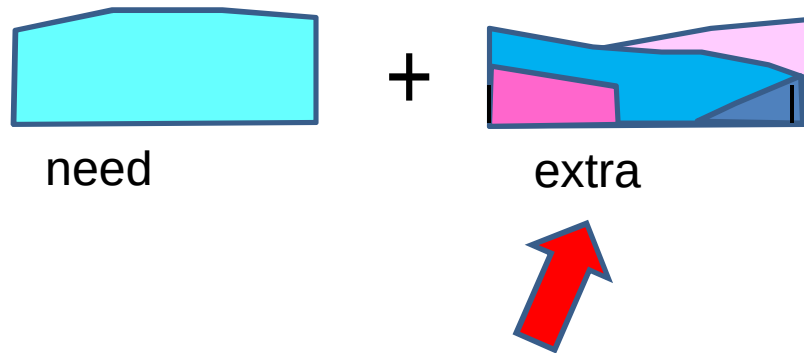
氏原 秀林

中山 貴之 大野 剛元
原田 浩志

熊沢 新樹 関 正衛
辻 真由

You can see this figure in 2011 IVS Annual report

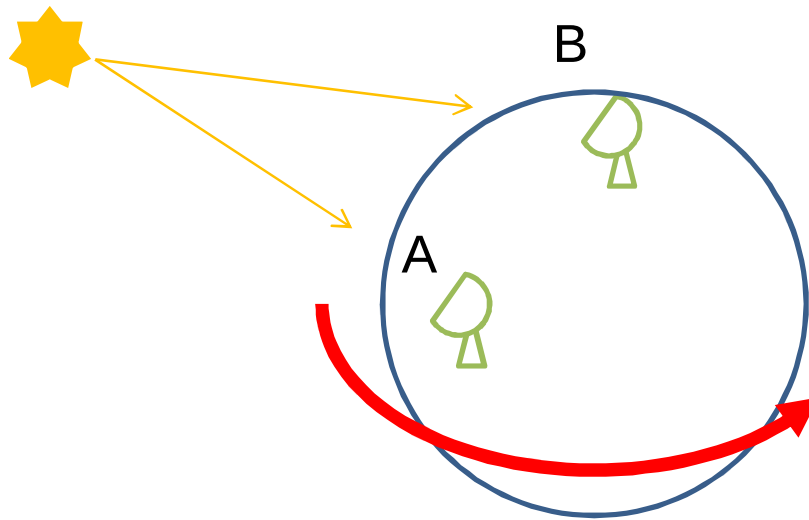
We have doubts about ...



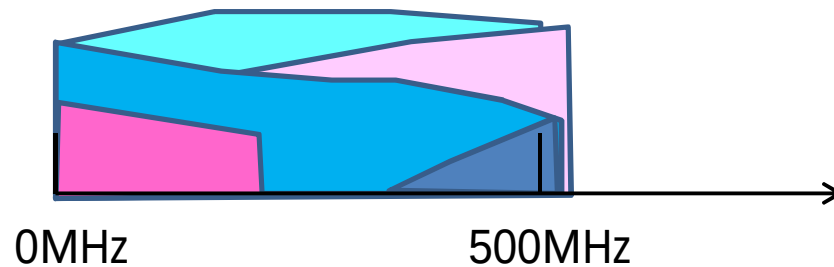
What is this?

It is just interference or noise??

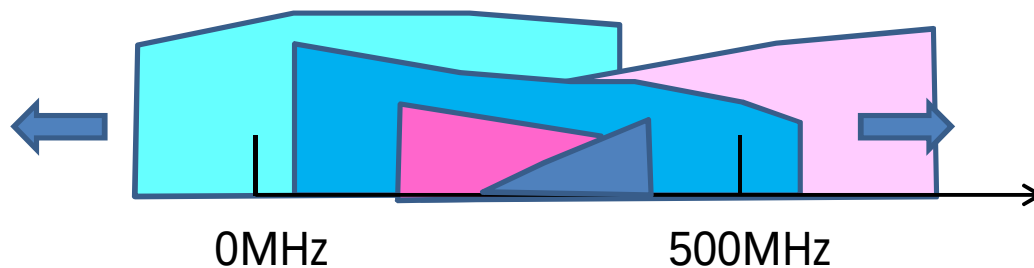
Folded (Aliased) signals must include
signal from radio source !



Rotation of the earth makes Doppler-shift to both station A and B



After sampling at station A as reference

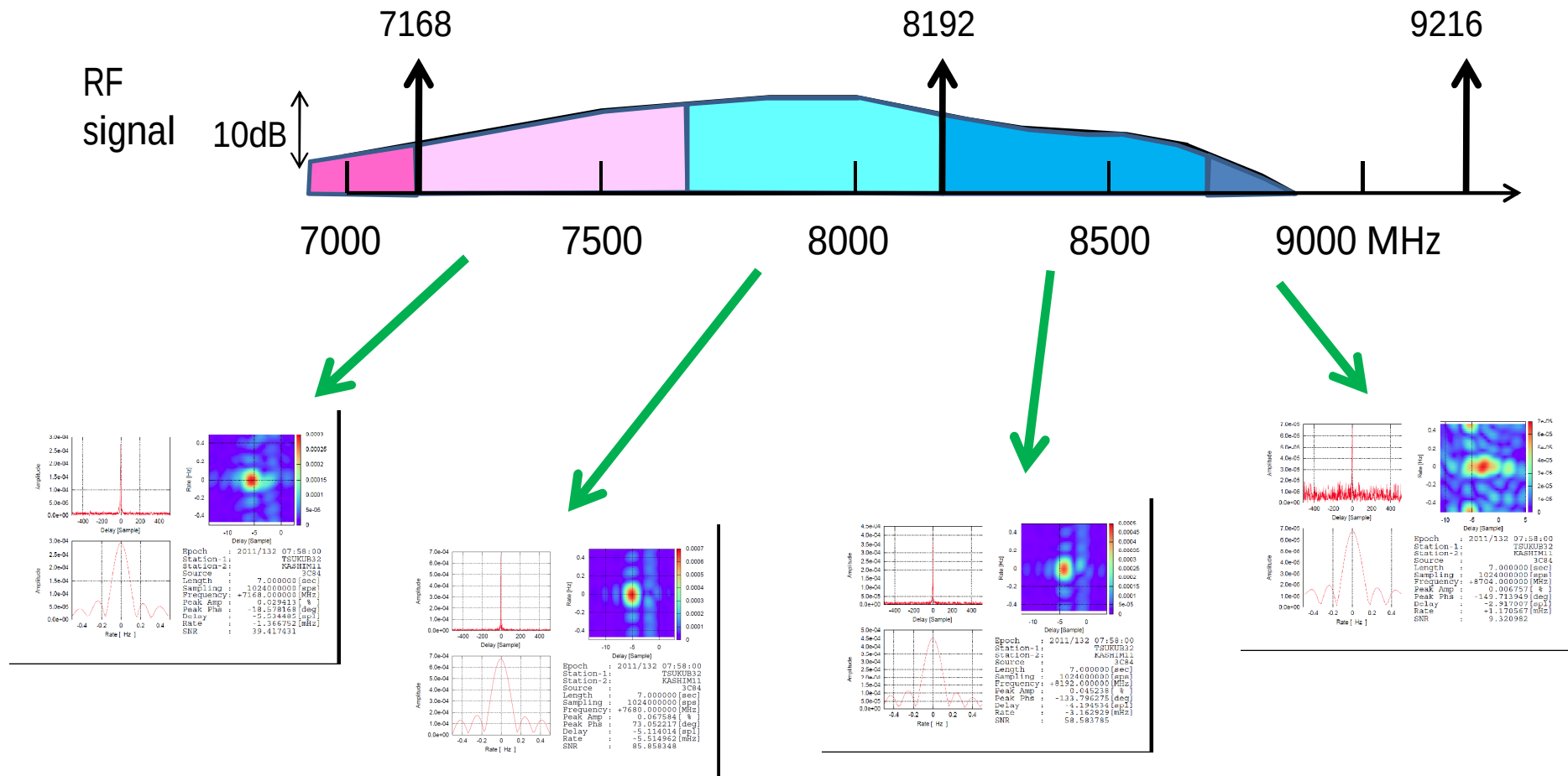


At station B
Each band moves
by Doppler shift

Let's perform correlation to each band properly!

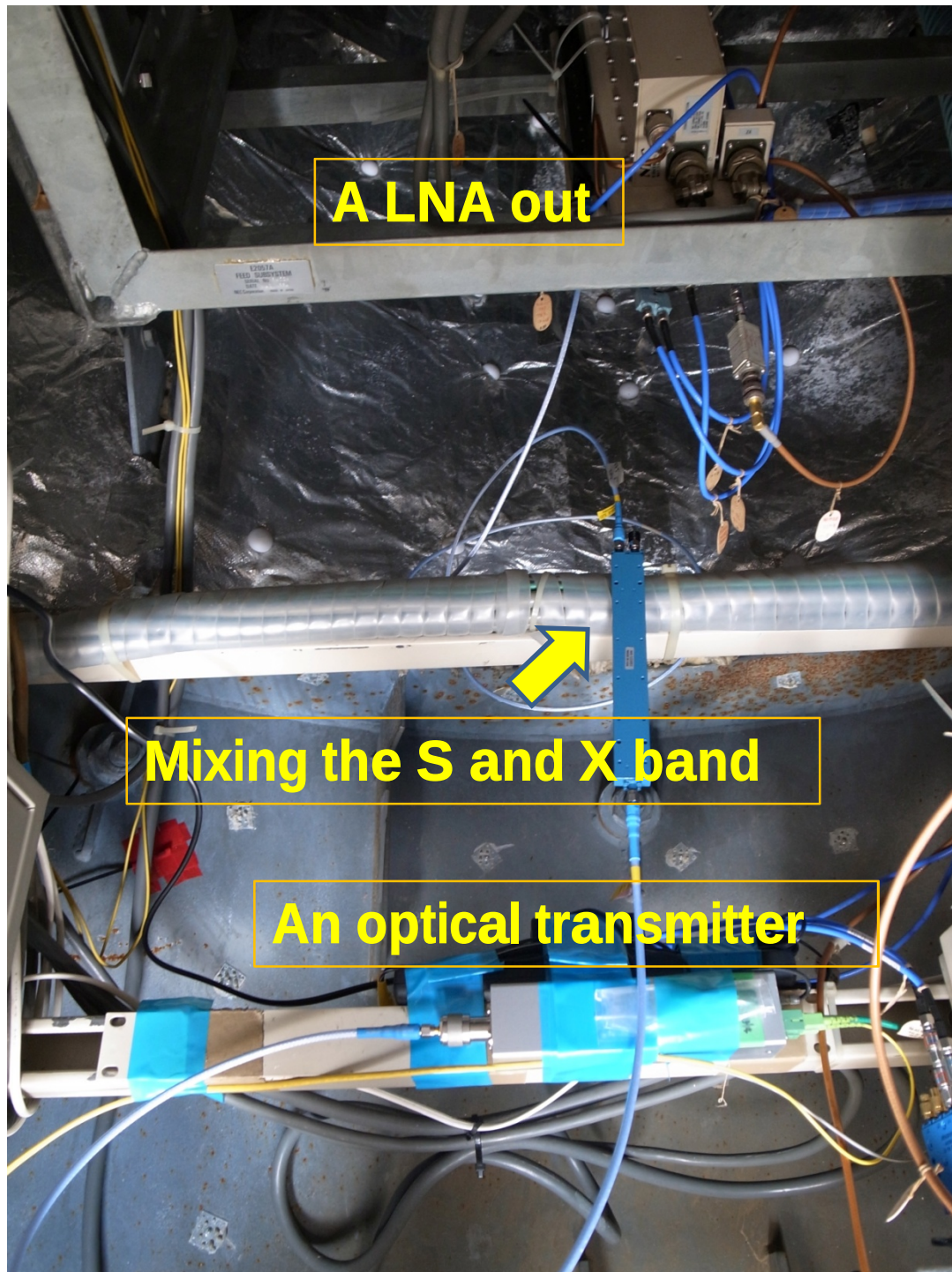
Detected fringes of the mixed X-bands

The first in the world!?

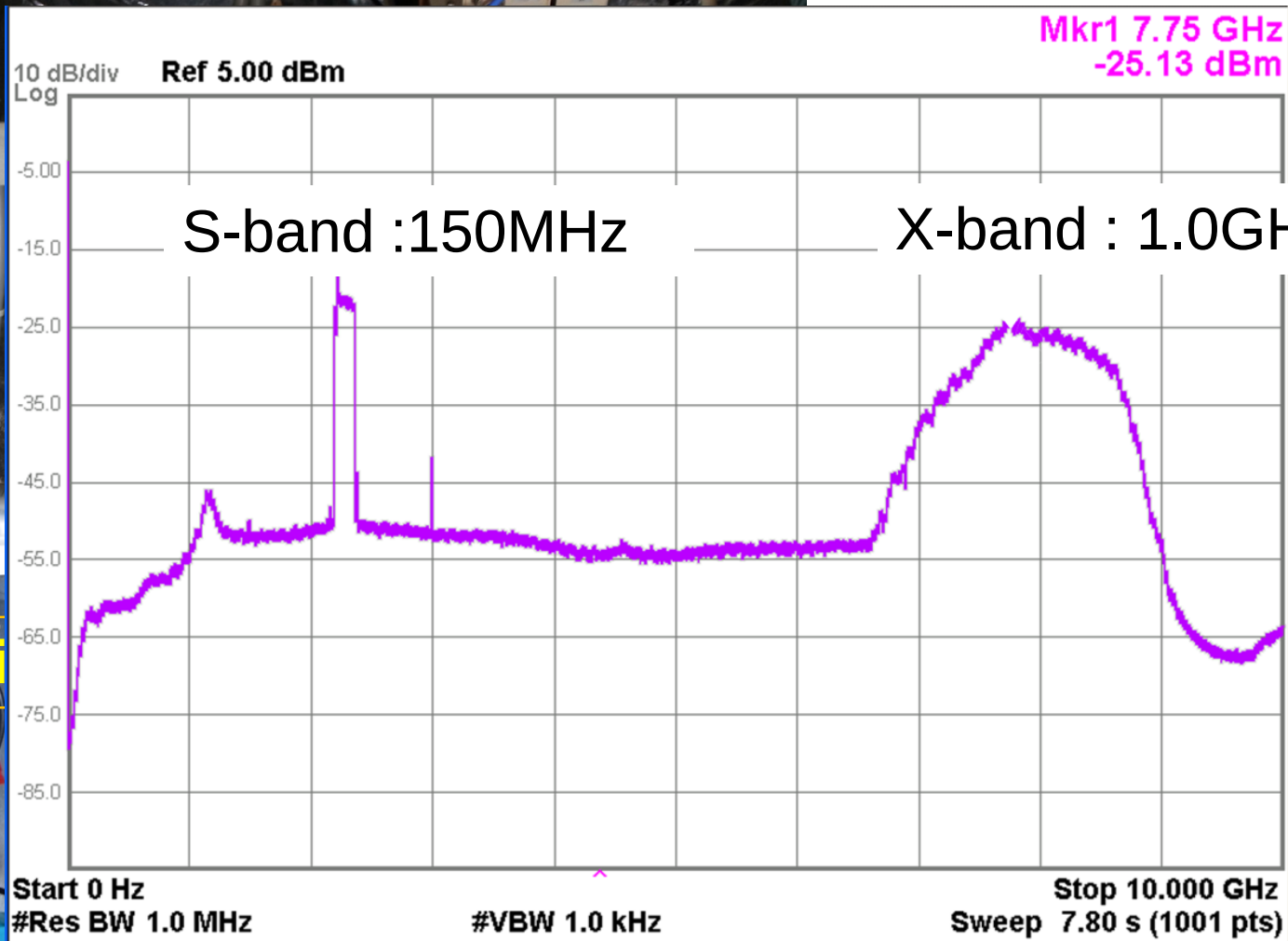


A new VLBI technique has created!?

- We named this technique “**DSAMS**”
- The DSAMS means “**D**irect **S**ampling
Appplied for **M**ixed **S**ignals “
- Next, The DSAMS will be applied for a conventional S/X geodetic VLBI
- The S and X-band are mixed in the RF signal, and are sampled as a single analog stream.



The mixed signal was transferred as the remaining RF signal

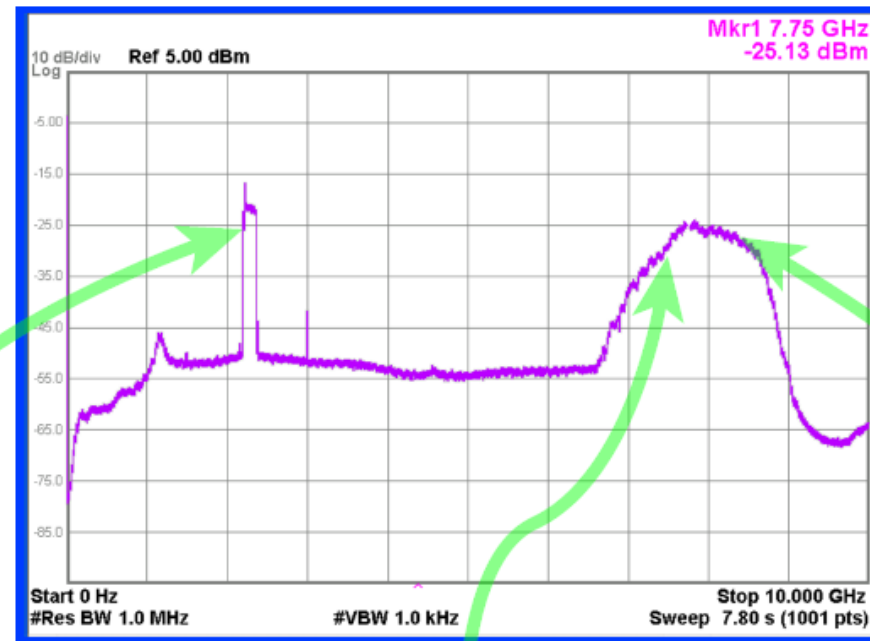


nal was
the
signal

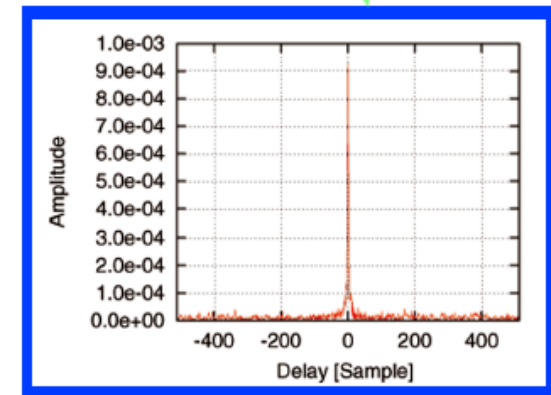
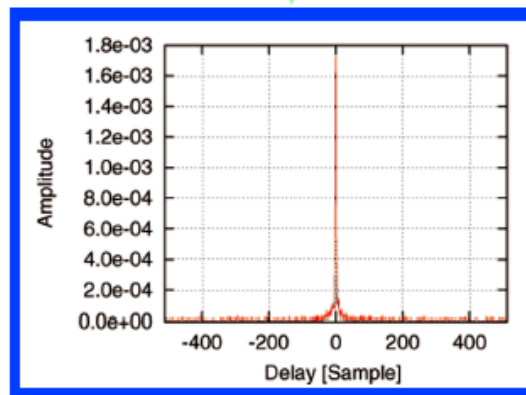
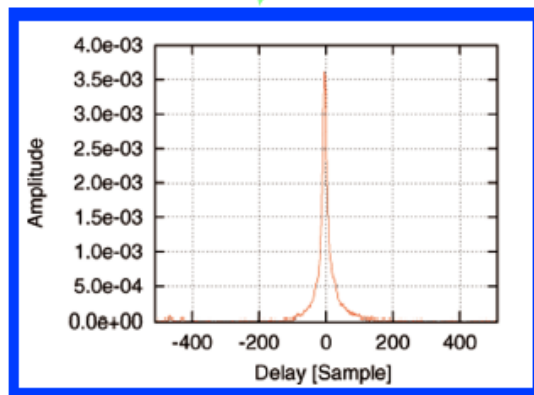
A S+X band spectrum of Kashima11m, DC-10GHz

First fringes in DSAMS

Use of the Kashima11m (NICT) and the Tsukuba32m (GSI) in 24hours geodetic VLBI



S+X Band character
@ Kashima 11m



Correlation by the GICO3

- Four fringes were detected **from single data.**
- Four fringes = One S-band, Three X-bands

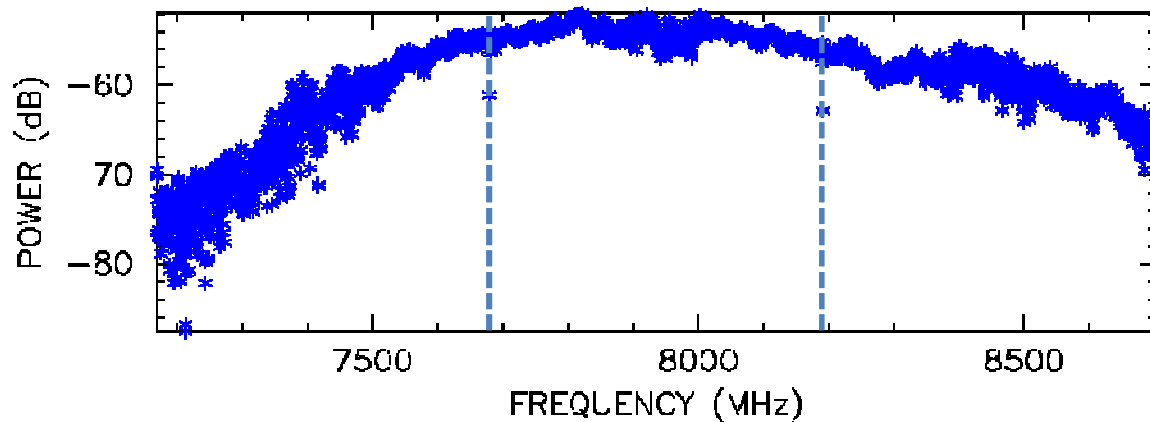
Average In 945scan	S	X-low	X-mid	X-high
SNR	117.2	65.6	145.7	77.7

Ionosphere
correction

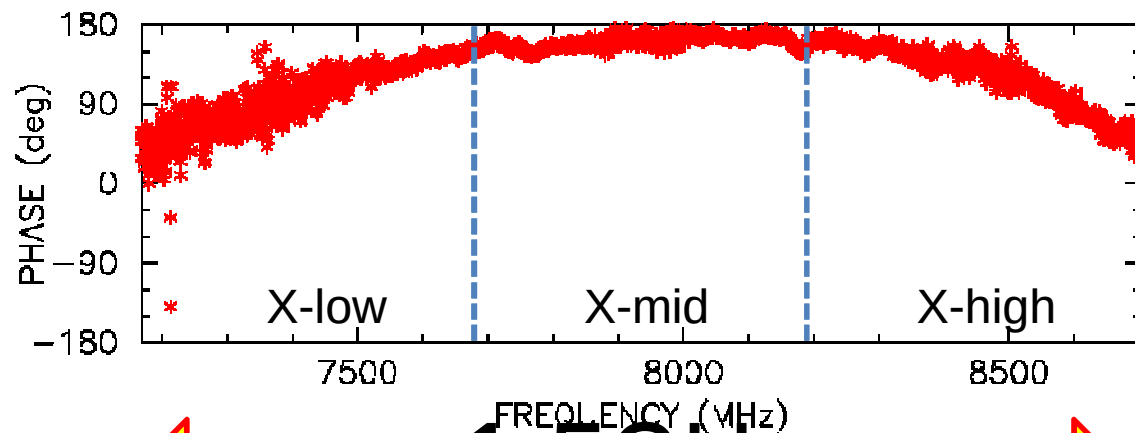
Bandwidth synthesis

Bandwidth synthesis (BWS)

VIDEO CROSS SPECTRUM RF= 7168.0 MHz (POWER)



VIDEO CROSS SPECTRUM RF= 7168.0 MHz (PHASE)

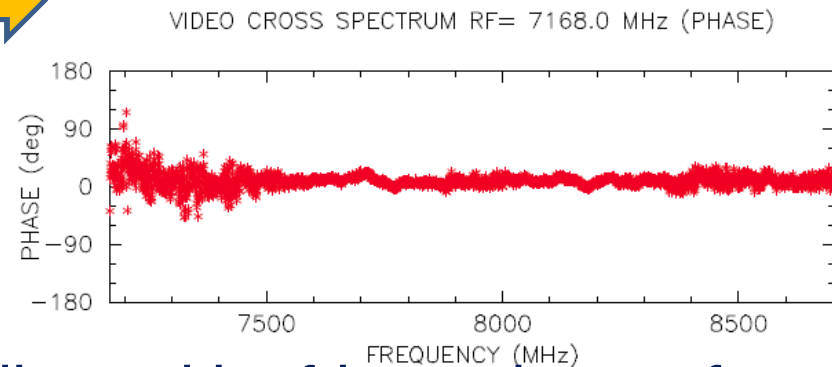
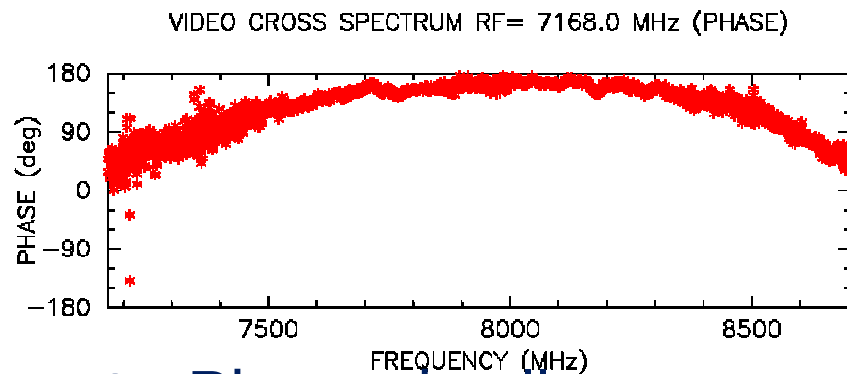
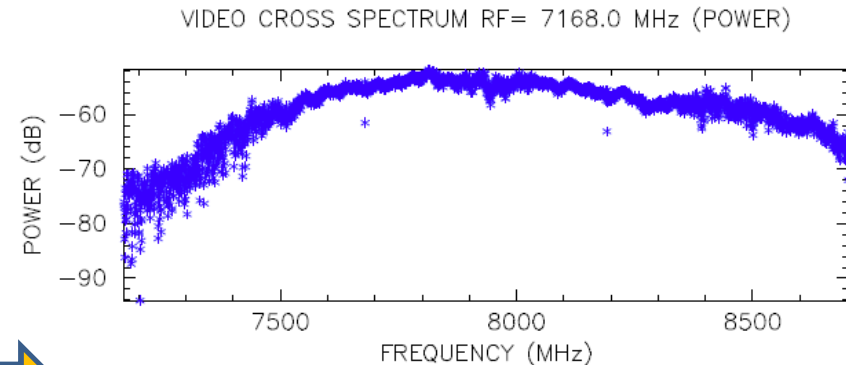
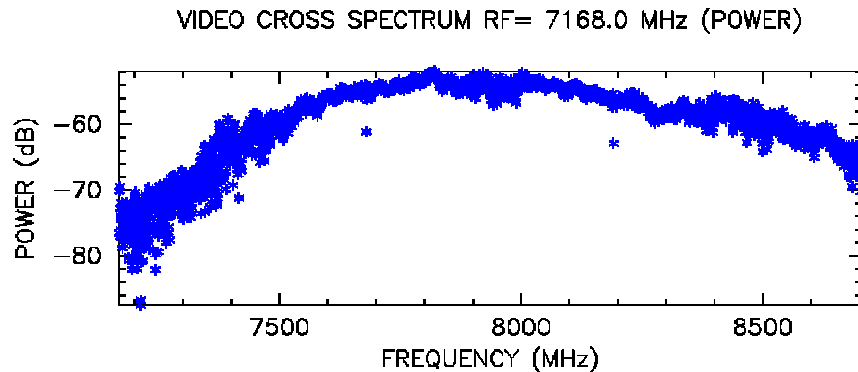


1.5GHz

- Phase differences of band edge were **zero**, to extend bands were quite simple

- An improved bandwidth can cancel out the decreased SNR, **BWS : 11.7%↑**

Band pass calibration (BPC)



- Phases in all scans were calibrated by fringe phase of a strong radio source.
- after BPC improves SNR
 - **BWS & BPC : 24.0%↑ (which compared with X-mid)**

Results of a baseline analysis

Code	Only x-mid		BWS		BWS		BWS&BPC		BWS&BPC	
Iono-correction	No		Yes		No		Yes		No	
Baseline length(mm)	2.71	± 0.94	1.87	± 1.04	2.81	± 0.998	1.71	± 0.94	2.68	± 0.94

✕baseline lengths have an offset of 53812800mm

- Compared above conditions are consistent previous experiments and almost same (A limitation by an atmosphere??)
- Ionosphere correction is effective even 50km of Kashima-Tsukuba baseline (only 1mm)

Summary

- We detected the first fringe with the RF direct sampling
- We developed the DSAMS as new VLBI technique,
 - Correlation, BWS, BPC
- We applied the DSAMS to geodetic S/X VLBI and could obtain baseline even the combined S+X
- We believe the DSAMS VLBI is a simple, reliable, inexpensive.

Future work

- Will we apply the DSAMS to e-VLBI, VLBI2010?
- How about the DSAMS to RAEGE and other X/Ka system?



THANK YOU VERY MUCH.

Contact : takefuji@nict.go.jp