Phase Solution Analysis for the Simultaneous Dual Frequency VLBI Observations

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Korean VLBI Network (KVN)
Difficulties in mm VLBI
Phase Referencing Techniques

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1st Experiment
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Korean VLBI Network (KVN)

- The First VLBI facility in Korea
- Dedicated millimeter VLBI system
- Multi-Frequency Simultaneous Observation at 22, 43, 86, 129 GHz
- Fast switching & multi-freq. phase referencing
Difficulties in Ground-based VLBI System

• Heavy data load
• Operation & maintenance of distant stations
• Only highly bright & compact sources can be observed

But the largest difficulties come from

1. Unpredictable fluctuations in independent frequency standards
2. Highly irregular refraction effects in the atmosphere

(Dr. Sasao)

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Difficulties in mm-VLBI

Pico Veleta – Onsala Baseline

VLBI phase time series

Source: BL Lac
Frequency: 86 GHz

(Dr. A. Roy)
Phase Referencing Methods

- Fast Switching
- Water Vapor Radiometer
- Dual Beam Correction (VERA)
- Paired/Clustered Antennas
- Multi-Frequency Phase Referencing

(Dr. A. Roy)

(Dr. Asaki)

(VSOP)

(VERA)
Multi-Frequency Phase Referencing

• Basic Idea
  - Using the fringe phase of a source at a lower freq. in order to calibrate the phase of the same source at higher one.
  - The *non-dispersive nature* of the water vapor-induced excess path delay in the troposphere over the wide range of radio frequency.

\[
\frac{\partial \phi_{\text{high}}}{\partial t} = \left( \frac{v_{\text{high}}}{v_{\text{low}}} \right) \times \frac{\partial \phi_{\text{low}}}{\partial t}
\]

(Dr. Han)
Multi-Frequency Phase Referencing

- Multi-Frequency Phase Referencing will enable mm-VLBI (Dr. Sasao)

1) to essentially resolve the reference source problem and nearly always find a reference source for a target
   ∴ target source = reference source

2) to get a perfect phase compensation without any loss of coherence
   ∴ sky condition is exactly same

3) to integrate mm VLBI fringes as long as a single-dish telescope does

4) to detect and image as many sources as cm VLBI does
VERA Experiment

- The first experiment with a dual-freq. simultaneous observation using VERA

- Observation
  - 2005 Apr 15 (UT 14 ~ 21 hour)
  - Bandwidth 128 MHz, LL, Dual Mode Setting
  - Target Sources
    - 22 GHz with Beam A NRAO512
    - 43 GHz with Beam B 3C345
  - Separation Angle < 0.5 degree

- Testing the feasibility of the multi-frequency phase referencing
- Phase solution transfer from lower freq. to higher one
- Atmospheric delay compensation between 22 & 43 GHz
1st VERA Dual-Frequency Experiment

- Dual Mode Setting

NRAO 512
α = 16:40:29.6
δ = +39:46:46
beam A
(22 GHz)

3C345
α = 16:42:58.8
δ = +39:48:37
beam B
(43 GHz)
Phase Solutions with Solution interval 30sec

Red lines ~ 22GHz (NRAO512)  Green line ~ 43GHz (3C345)
Phase Solutions at Mizusawa-Iriki Baseline -2-

Time (sec)

Phase (deg)

-200  -150  -100  -50  0  50  100  150  200

22GHz Phases (NRAO512)

43GHz Phases (3C345)

Connected Phases and Differential Phases

Time (sec)

65200 65400 65600 65800 66000 66200 66400 66600 66800

0 00 500 0 500 0 500 0 500 0 500

Connected Phase at 22GHz

Connected Phase at 43GHz

Differential Phases

Connected Phases and Differential Phases

Time (sec)

68600 68800 69000 69200 69400 69600 69800 70000

-400 -200 0 200 400 600 800

Connected Phase at 22GHz

Connected Phase at 43GHz

Differential Phases

Connected Phases and Differential Phases

Time (sec)

70200 70400 70600 70800 71000 71200 71400 71600

-800 -600 -400 -200 0 200 400 600

Connected Phase at 22GHz

Connected Phase at 43GHz

Differential Phases

Connected Phases and Differential Phases

Time (sec)

73400 73600 73800 74000 74200 74400 74600

-800 -600 -400 -200 0 200 400 600

Connected Phase at 22GHz

Connected Phase at 43GHz

Differential Phases

Connected Phases and Differential Phases

Time (sec)

75000 75200 75400 75600 75800 76000 76200 76400

-600 -400 -200 0 200 400 600 800

Connected Phase at 22GHz

Connected Phase at 43GHz

Differential Phases

Connected Phases and Differential Phases

Time (sec)

Phase Solutions -2-
• Both of fringe phases at 22 & 43 GHz show a typical behavior of the phases in VLBI, which is the flicker freq. noise for short time scale and white phase noise for a longer time scale.

• The differential phases are inversely proportional to $\tau$, that means the effect of atmospheric fluctuation is effectively removed.
22GHz (NRAO512) → 3C345 → NRAO512 → …

Beam A: 3C345 → NROA512 → 3C345 → NRAO512 → …

Beam B: NROA512 → 3C345 → NRAO512 → 3C345 → …
• We were not able to get fringe phases of NRAO512 at 43 GHz (yellow scans) because it was not bright enough at this frequency.

• However, the other scans which are NRAO512 (22GHz) and 3C345 (43GHz) were observed and showed the repeatability of these experiments very well.
DISCUSSION & SUMMARY

• VLBI phases are suffering from many of effects such as, troposphere, ionosphere, sec Z effect, source structure, uncertainties of the source/station coordinates, clock offsets and instrumental delays and so on.

• We made a dual-frequency simultaneous observation at 22 & 43 GHz using VERA and analyzed phase solutions to test the feasibility of multi-frequency phase referencing for KVN.

• From the 1st experiment, we found some drift/sinusoidal tendency at differential phases. We have investigated what kind of effect could cause such a specific tendency.
Multi-freq. Phase Referencing vs Fast Frequency Switching

- Good possibility of Multi-freq. phase referencing technique with a strong correlation of phases at different frequencies

DISCUSSION & SUMMARY

(Middelberg et al)
The performance of multi-freq. phase referencing in KVN is expected to be much higher than this experiment because of using same source.

VLBI Imaging at higher freq. will be able to have a good chance with multi-freq. phase referencing:
- AGNs: Core shift, accretion, jet formation, black-holes etc…
- Masers: multi-line observation, environmental studies of evolved stars etc…

Multi-freq. phase referenced observation between KVN + VERA is near at hand.

Multi-frequency phase referencing in KVN is feasible.

The correlation between different frequencies of KVN is expected to be better than this experiment ($\rho > 0.96$).