Nobeyama 45-m Telescope

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Outline

• Nobeyama 45-m Telescope
• Performance and previous Metrology
• Future Metrology System
Nobeyama 45-m Telescope
Nobeyama 45-m Telescope

- 1350 m altitude
- 45m Diameter (homologous)
- Optics: Beam waveguide
  - Master Collimator
- Pointing accuracy: 2-3"
- Surface accuracy: 100 $\mu$m
- Beam size: 14” @ 115GHz
- $\eta_A$: 0.35 @ 110 GHz
- Receivers (20 – 116 GHz)
- Digital/VLBI Backend
- Open sky policy
Sub Reflector (CFRP honeycomb sandwich)

Main Reflector Panel (CFRP honeycomb sandwich)

Fan

BUS Steel

Fan

Mount Steel

M2/M3 mirror (CFRP honeycomb sandwich)
Current System

- **Antenna:** 45m
- **Optics:** Switch
- **Receiver:**
  - H22: Holography
  - H40
  - Z45
  - T70
  - TZ
  - FOREST
- **IF chain:**
  - New IF
  - Continuum BE
  - SAM45
  - PolariS
  - VLBI BE

Commissioning
OPEN USE
Issues as of 2014

• Large surface errors: 180 µm ($\eta_{A,110\,GHz} : 0.25$)

• High antenna noise temperature: 30 K

• Single pixel Rx only at 3 mm

• Rust on mount structure
Holography

• Measurement
  – Frequency 19.45 GHz (CS satellite)
  – Rx: H22
  – Ref Ant: CS dish (1.8 m)

• Adjustment (700 panels)
  – 2015 sep-oct
  – Motorized part are broken
  – Manually adjusted
Surface Adjustment

Before (2015-06-08)

After (2015-10-05)

- K band Rx at 19.45 GHz using satellite beacon
- Include M1, M2, and beam waveguide optics
  - 180 \( \mu \text{m} \) rms \( \rightarrow \) 100 \( \mu \text{m} \) rms (nominal)
  - \( \eta_A : 0.25 \rightarrow 0.35 \) at 110 GHz
These two mirrors were degraded.
Put (Stick) metal foils to M2 and M3

- Put (Stick) metal foils to M2 and M3 (3 um thick)
- Tsys is reduced by ~ 11K @ 3mm
"FOREST"

FOur beam REceiver System on 45-m Telescope

- 4-beam x 2-pol.(H/V) x 2-sideband = 16 IFs
- Beam separation ~ 50"
- Beam size ~ 14” @ 115GHz
- IF: 4-12 (4-11) GHz ➔ simultaneous $^{12}$CO, $^{13}$CO, $^{18}$O observation
- Dewar rotation system to track same sky position
Paintings

Different thermal behavior?

Before - 2016.06.16 -

After - 2016.08.26 -
Issues

• Large surface errors: 180 μm \( (\eta_{A,110\,\text{GHz}} : 0.25) \)
  – Improved to be 100 μm \( (\eta_{A,110\,\text{GHz}} : 0.35) \)

• High antenna noise temperature: 30 K
  – Reduced to be 19 K (w/o atmosphere)

• Single pixel Rx only at 3 mm
  – Expanded to be 4 pixels

Overall a factor of 10 improvement in 3 mm mapping
  – Painting of mount structure
Performance and Previous Metrology System

Kuno+ 2006, NRO Users Meeting
Pointing error equations

\[ \sigma_{Az}^2 = \sigma_{(mea)}^2 + \sigma_{Az(\text{irreg})}^2 + \sigma_{Az(\text{thermal})}^2 + \sigma_{Az(\text{Sun})}^2 + \sigma_{Az(\text{wind})}^2 \]

\[ \sigma_{El}^2 = \sigma_{(mea)}^2 + \sigma_{El(\text{irreg})}^2 + \sigma_{El(\text{thermal})}^2 + \sigma_{El(\text{Sun})}^2 + \sigma_{El(\text{wind})}^2 \]
Thermal behavior

Observed pointing offsets in azimuth against the temperature at the bottom of the tertiary mirror support tube (Ts)

Ukita 1999
Thermal Metrology

• Before and After thermal metrology implemented

Ukita 1999

Left) Before, Right) After

But, ...
Pointing under Wind

- Homology design – susceptible to wind e.g. pointing offset 0-15” under > 10 m/s wind
Wind metrology

- OPT+CCD/LED sensor experiment
  - OPT at center hub and LED at dish edge
  - Four directions
  - 0.1 sec sampling
  - 100 um or better accuracy
Measurement Setup

Kuno 2006
Four beam pointing monitor Rx

N-STAR (19.45GHz)

Kuno 2006
Pointing error and dish movement
Azimuth/Elevation

Kuno 2006

Sep. 19-24, 2016
Metrology and Control of Large Telescopes
Beam patter @23GHz > 10m/s

Before

After offline correction

Sep. 19-24, 2016

Metrology and Control of Large Telescopes
Future Metrology System
Thermal Metrology

• Re measure the correlation (update current thermal metrology)
• Temperature distribution and pointing errors (after painting)
• Solar irradiation effect
• Simultaneous Inclinometer measurement
Wind Metrology

• Update the previous wind metrology system
• Set more stable LED mount structure
• Enclosure around LET to avoid unwanted sunlight
• Simplify pointing telescopes

• Jupiter or Venus observations with FOREST yields accurate pointing errors in both Az/El.
Metrology goal

Push wind limit further from 3 to 5 m/s by meterology
New Discovery?

TA* ~ 18 K

Automobile Radar at 76 GHz
Now 76-81 GHz is allocated for automotive radars
More to come in WRC-19

• Higher and higher
• IMT, Satellite, Automotive radar
• > 275 GHz application also on the table
Summary

• Nobeyama 45-m telescope (34 yrs old)
  – One of the largest single dish antennas operated at 20-116 GHz.

• Pointing behavior
  – Thermal effect
  – Wind effect
  – Current thermal metrology system
  – Experimental wind metrology system (on hold)
  – Future metrology system under discussion
And more learnt in this WS

- OOF (gravitational/thermal effect)
- Subref position monitor