Time and Frequency Transfer and Related Activities in NMIJ

National Metrology Institute of Japan (NMIJ)

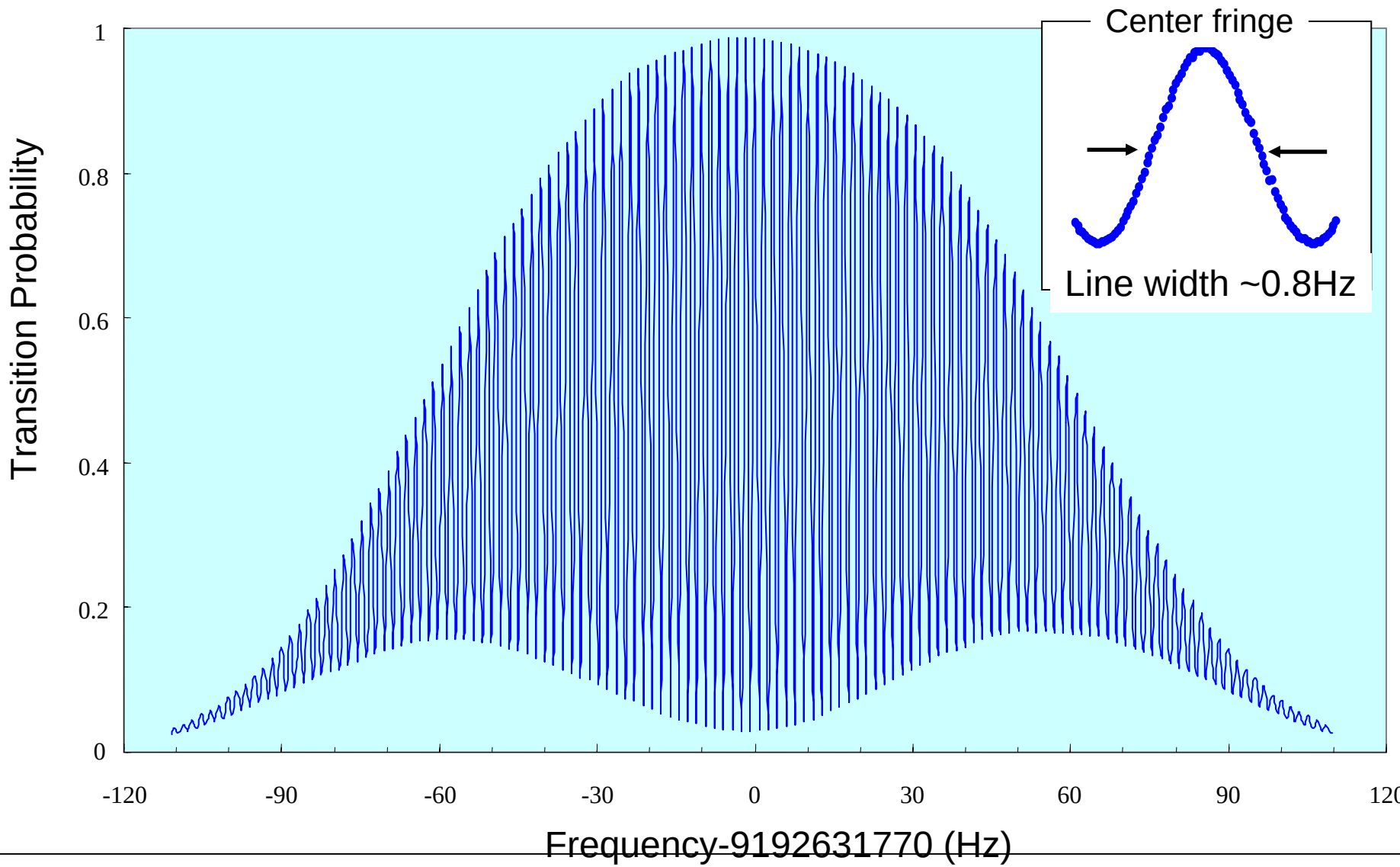
Recent activities on T&F in NMIJ

- The evaluation results of NMJI-F1 have been reported in the Circular-T
- Cryogenic sapphire oscillators have been operating at NMIJ.
  $\sim 10^{-15} - 10^{-16}$ @1 s
- Optical lattice clock research with the collaboration of Prof. Katori of Tokyo Univ. has been started.
  $\sim 10^{-16} - 10^{-17}$@1 s will be realized in near future

- The precise time and frequency transfer techniques became highly significant item at NMIJ.

Atomic fountain frequency standard in NMIJ (NMIJ-F1)

Ramsey resonance in NMIJ-F1



Uncertainty of NMIJ-F1

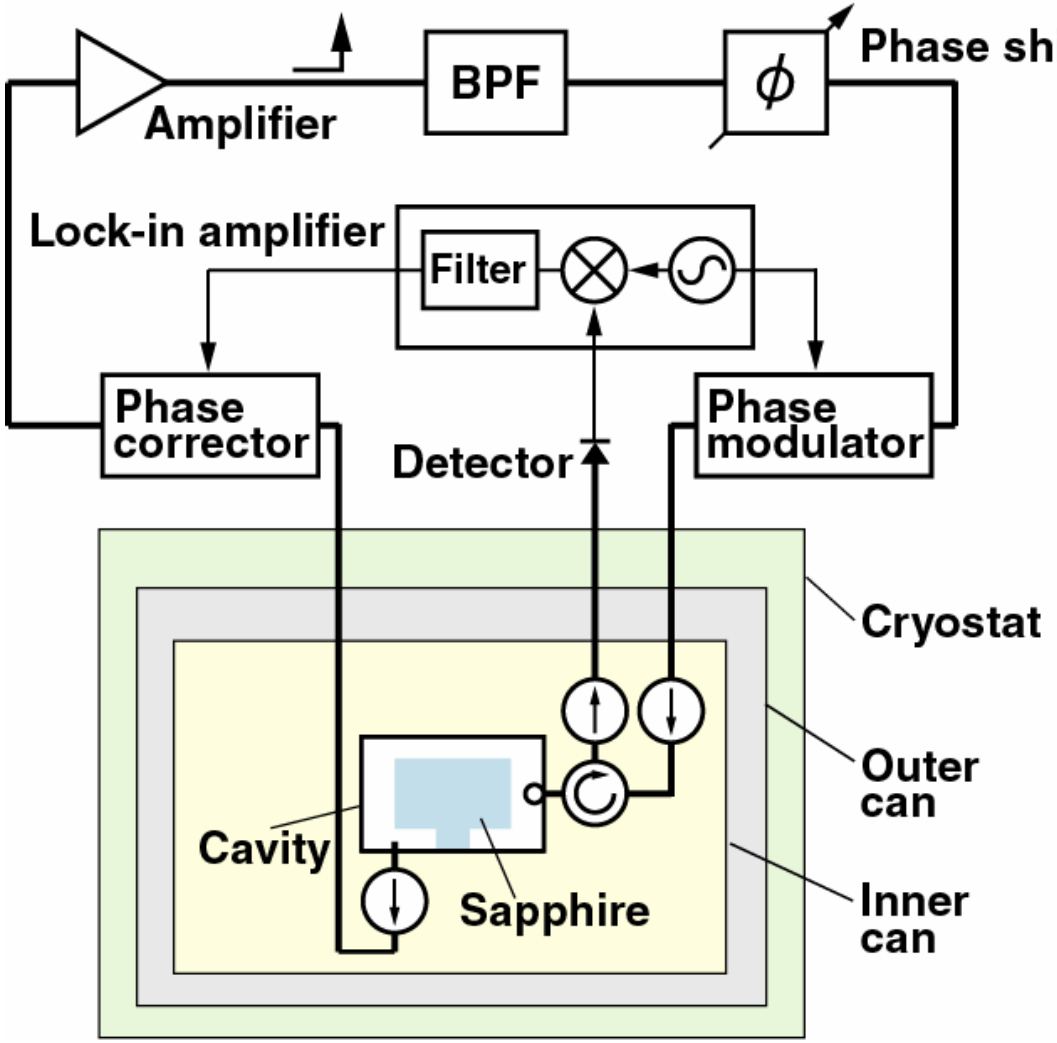
Frequency biases and uncertainties in NMIJ-F1 (x 10^{-15})

Source of uncertainty	Bias	Uncertainty
2nd order Zeeman	185.2	0.7
Blackbody radiation	-18.0	1.4
Gravitation	1.6	0.1
Cold collisions	0.0	3.3
Distributed cavity phase	-	1.2
Total	168.8	3.8

Comparison with NMIJ-F1 and UTC (x 10^{-15})

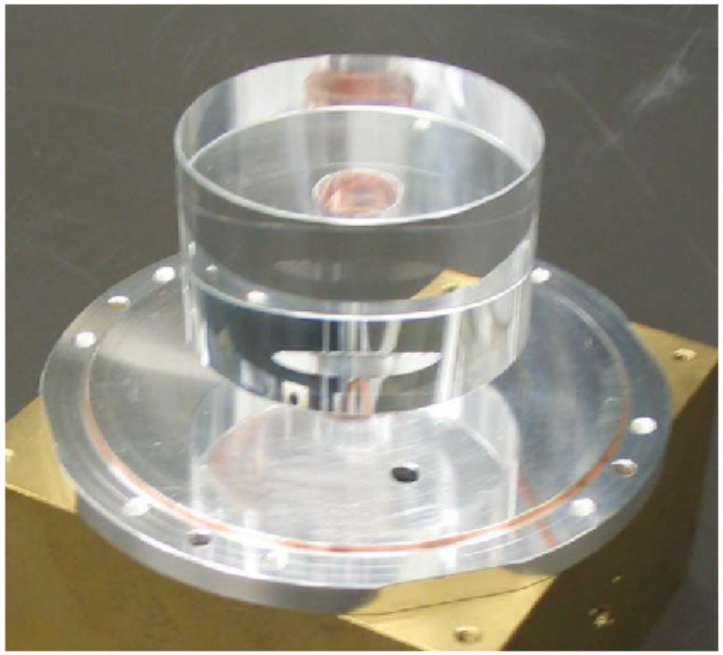
Period (MJD)	y(NMIJ-F1)-y(UTC)	Uncertainty
53549-53559	5.8	5.0
53589-53599	-9.2	5.1
53629-53639	-7.2	5.3

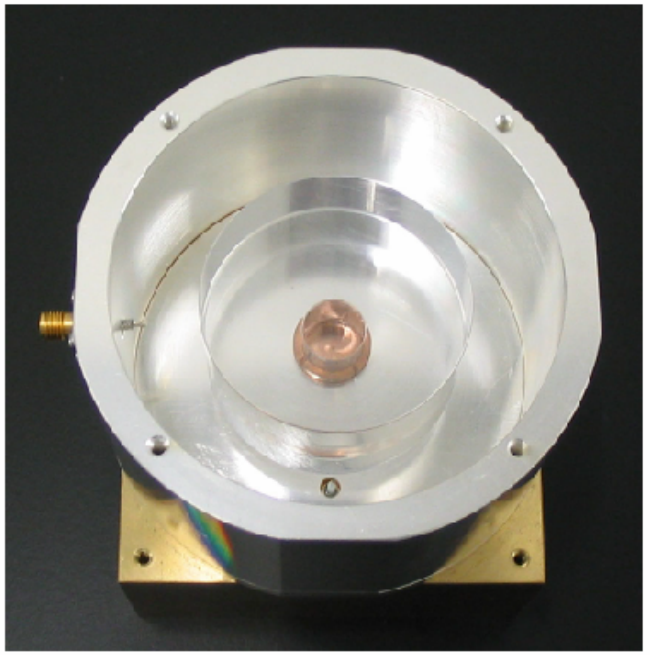
Cryogenic Sapphire Oscillator



- Pound-type frequency stabilization
- Discriminator signal

Sapphire-loaded cavity



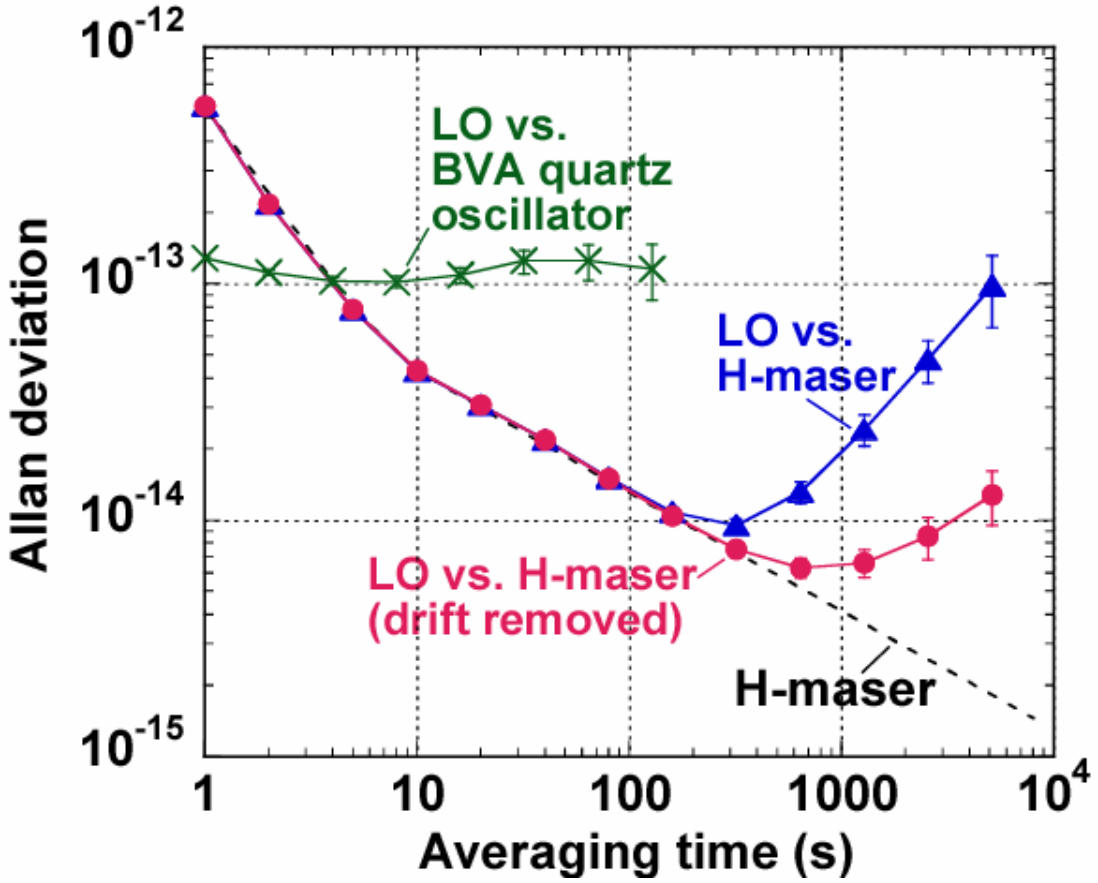


- 5 cm diameter, 3 cm long
- Coupling to the resonator

  Primary input port: magnetic field loop probe from the side of the cavity

  Output port: straight antenna probe from the bottom

Frequency stability of the local oscillator at 9.192 GHz



- **Estimated frequency stability at 1 s:**

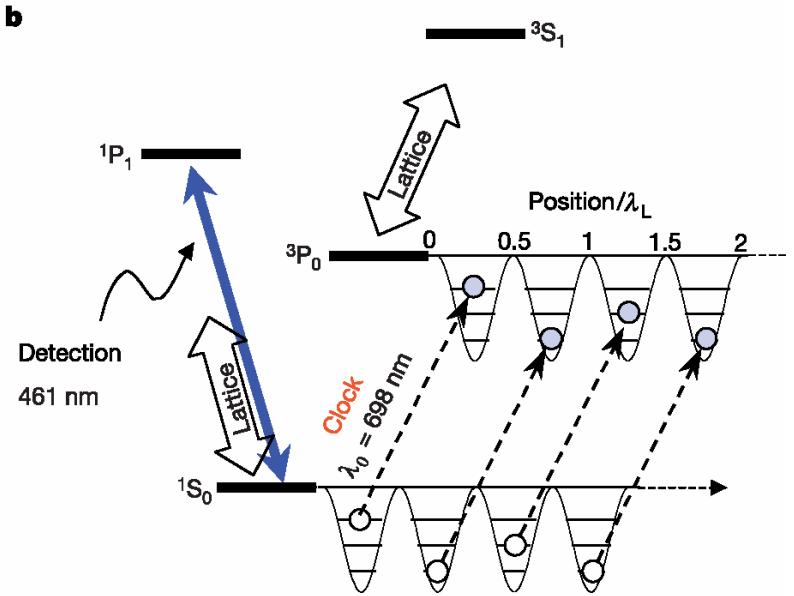
$\sigma_{yCSO}(\tau) = 6 \times 10^{-15}$

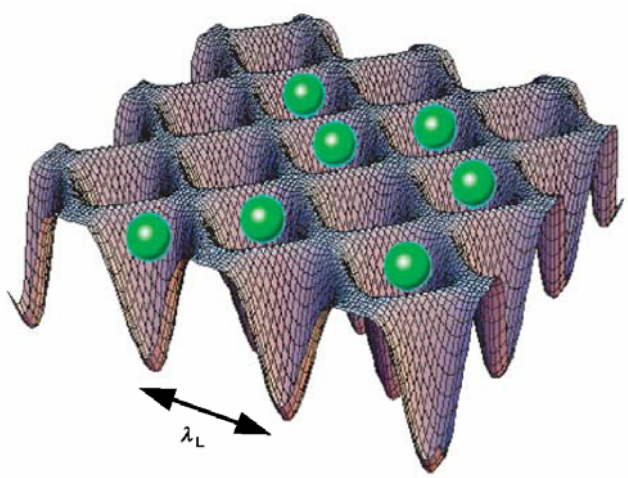
$\sigma_{ySynthesizer}(\tau) = 5 \times 10^{-15}$

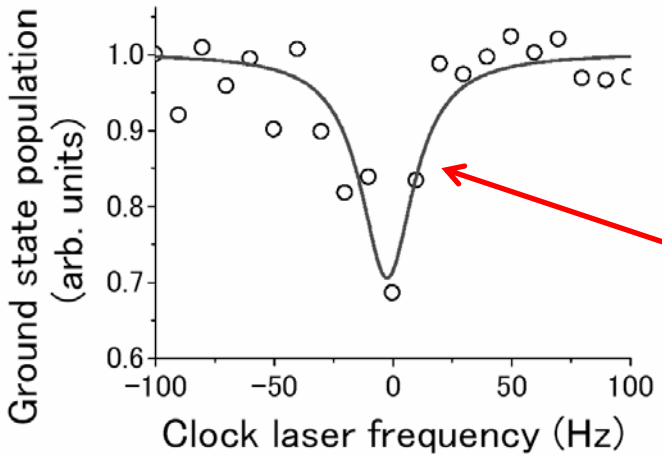
$\sigma_{yLO}(\tau) = 8 \times 10^{-15}$

The 2nd one has been constructed successfully. It will be reported in the next EFTF by Dr. Watabe.

Optical lattice clock







Reference : M. Takamoto, F.-L. Hong, R. Higashi & H. Katori, Nature 435, 321 (2005).

Line width: 27 Hz
（limited by probe laser line width)

Time transfer at NMIJ

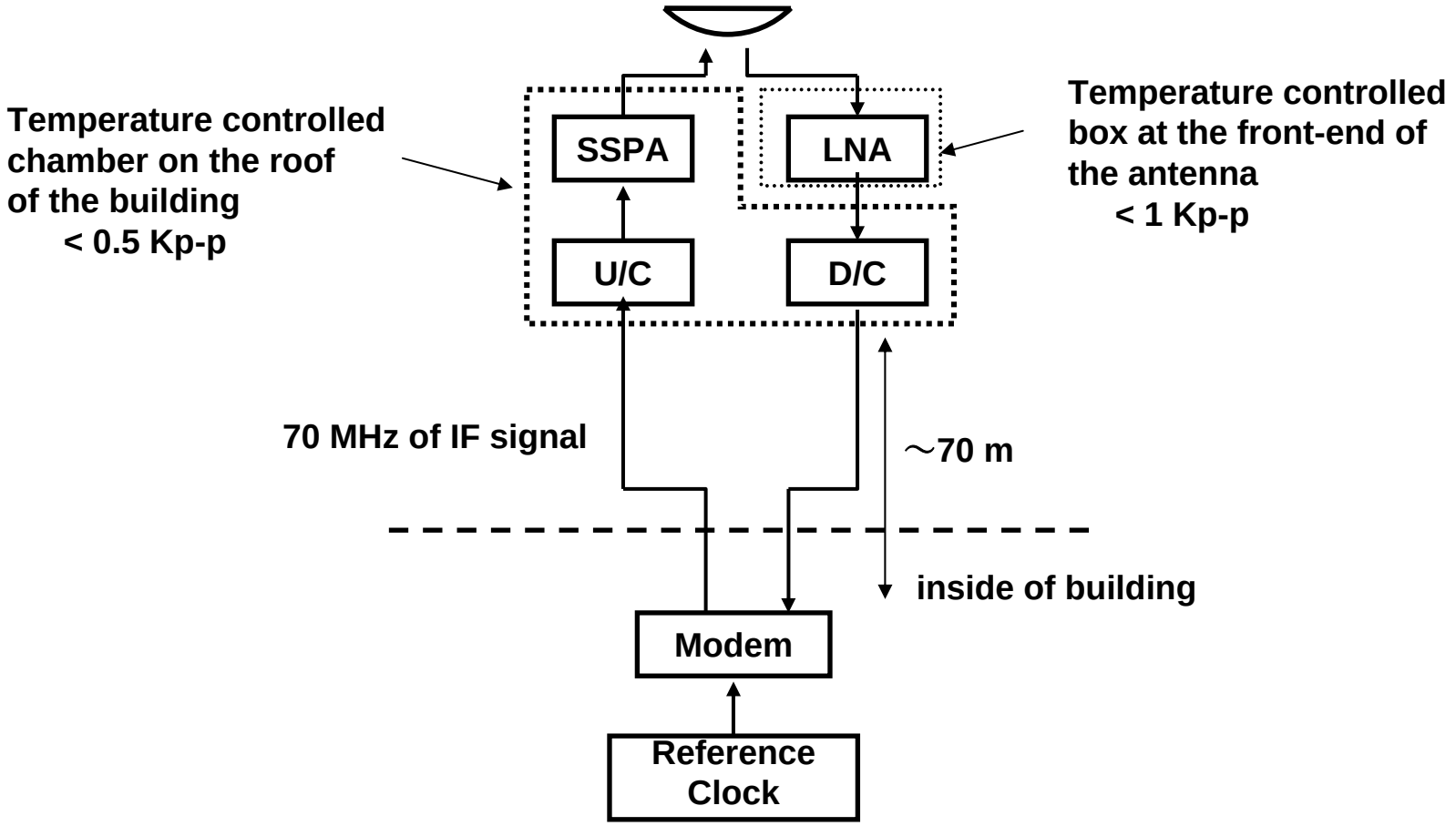
- **JCSAT-1B link among Pacific-rim region NMIs**
  This link was interrupted due to the satellite trouble, but it was restarted since October 20, 2005.
  - 1.8 m dish antenna with 4 W SSPA
  - multi-channel TWSTFT modem

- **Preparation for another link**
  A new earth station for PAS-4 will be installed at NMIJ by the end of March 2006.
  - 2.4 m dish antenna with 10 W SSPA
  - Devices of ODU, such as SSPA, U/C and D/C. will be temperature stabilized within 0.5 K
  - Devices in the front-end of the antenna, such as LNA, will be temperature stabilized within 1 K
  - multi-channel TWSTFT modem

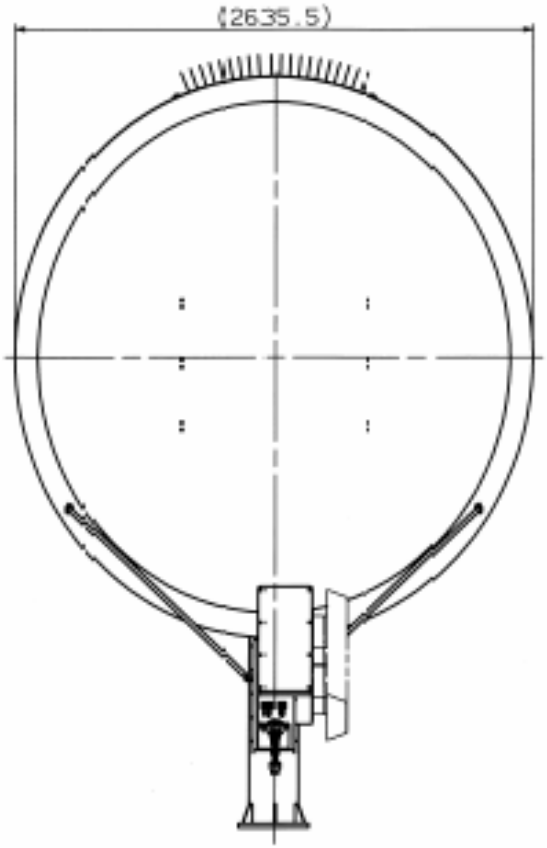
- **Basic study for precise time and frequency transfer**
  Basic research on precise time and frequency transfer has been started to realize highly precise time and frequency transfer, such as 10^{-16} level.

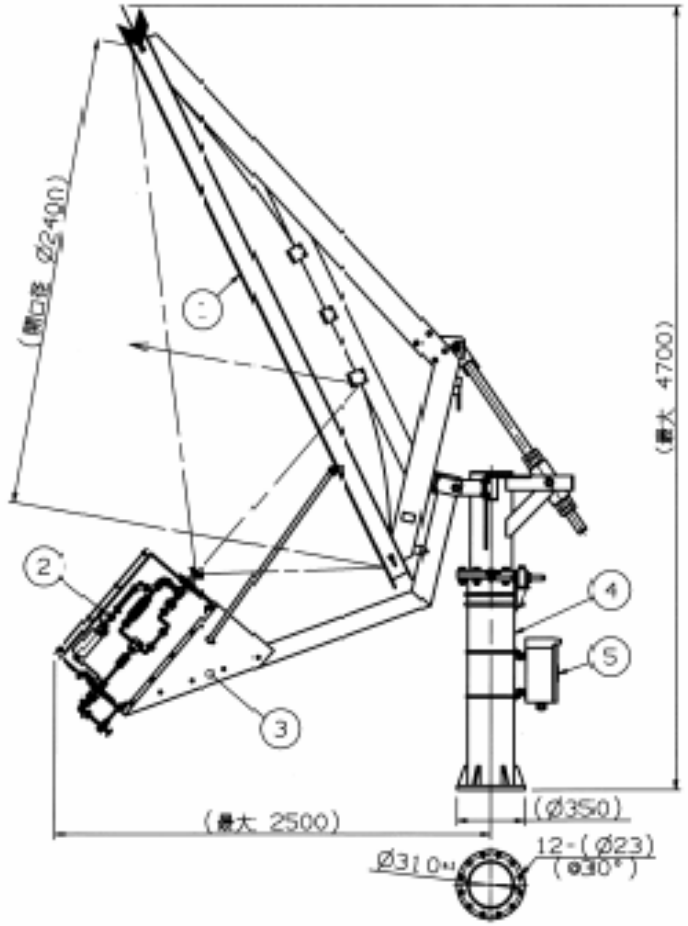
1.8 m dish antenna for JCSAT-1B

Configuration of the new antenna

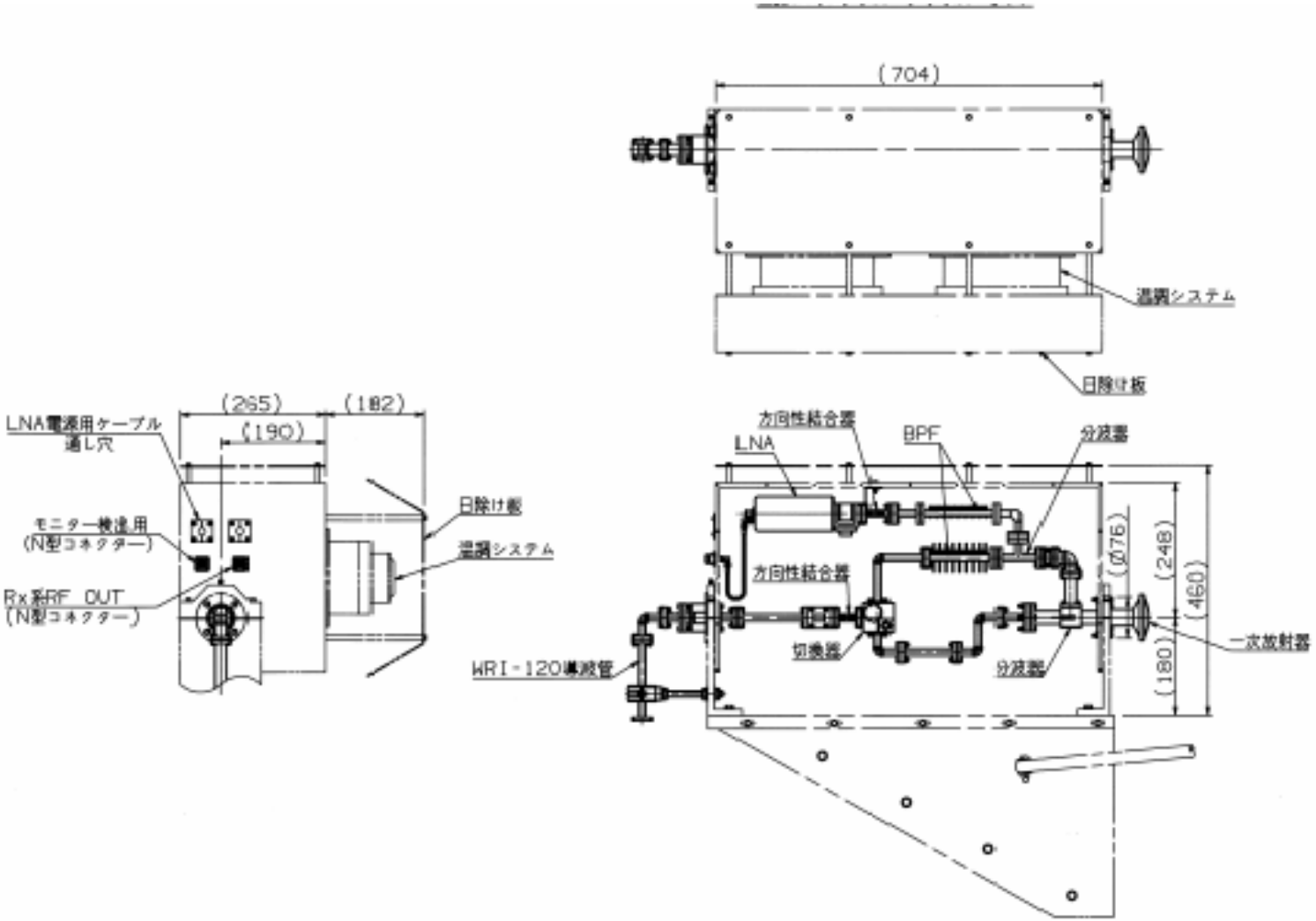


Dish of the antenna





Front-end of the antenna



Location of the new earth station