Temperature Stabilization in the receiver cabin of KVN antenna

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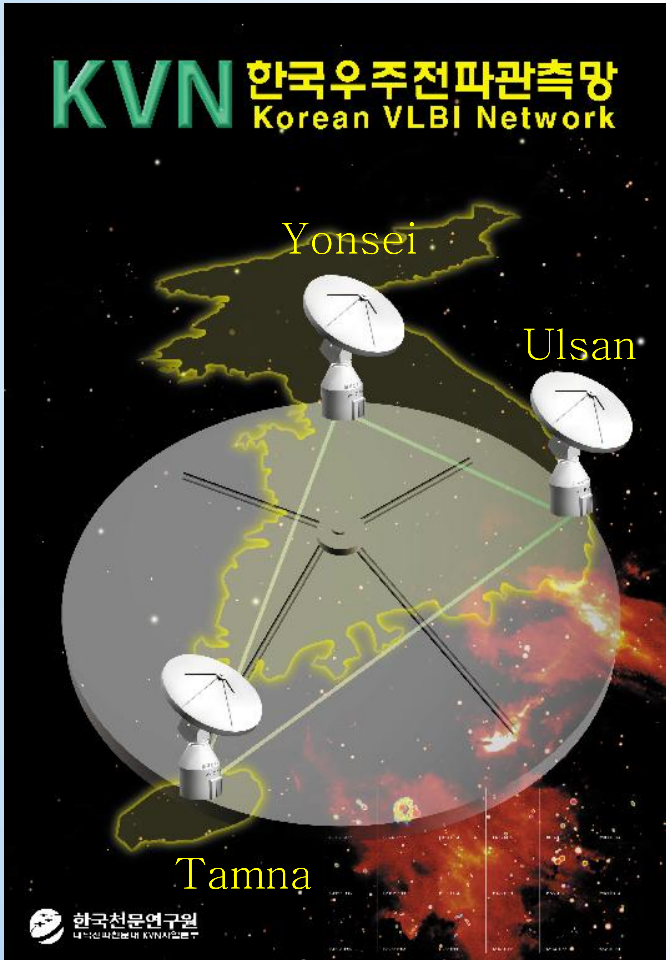
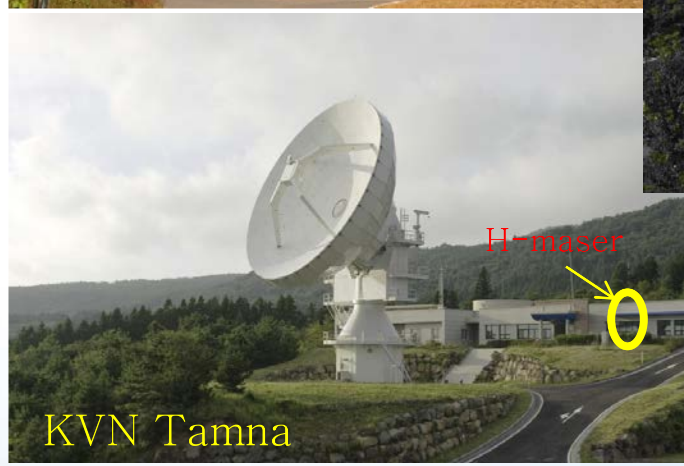
4th IVTW in Auckland, NZ

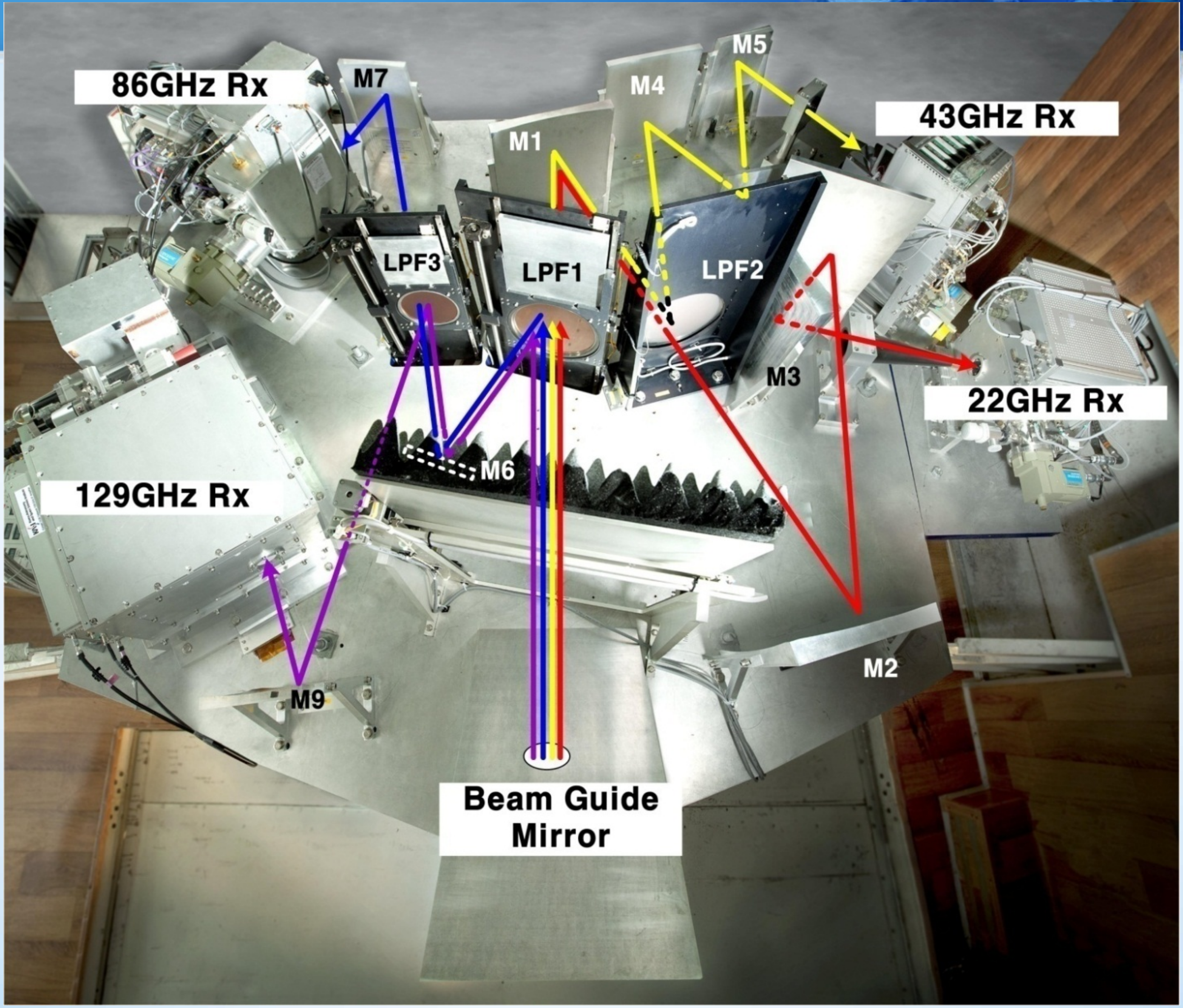
KASI 한국천문연구원
Korea Astronomy & Space Science Institute

KVN 21m Radio Telescopes





KVN 4 channel Receiver



Phase stability in mm VLBI

- Atmospheric fluctuation
  - ✓ *4 channel receiver system*
- Instrumental phase noise due to ~
  - Cable length variation due to Mechanical vibration and temp.
    - ✓ ***RTS*** *: Phase stabilization from phase error due to cable length variation*
  - Characteristic change of Rx components due to Temp. variation
    - ✓ *Ultra wide band* ***phase calibration*** *(22GHz ~ 130GHz)*
  - Difficulties
    - ✓ P-cal., RTS components itself,
    - ✓ cables after P-cal. or RTS

*** Temperature stabilization in receiver cabin and H-maser room with new HVAC**

within +-0.5degC

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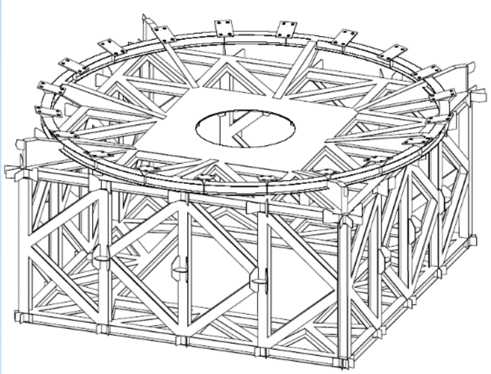
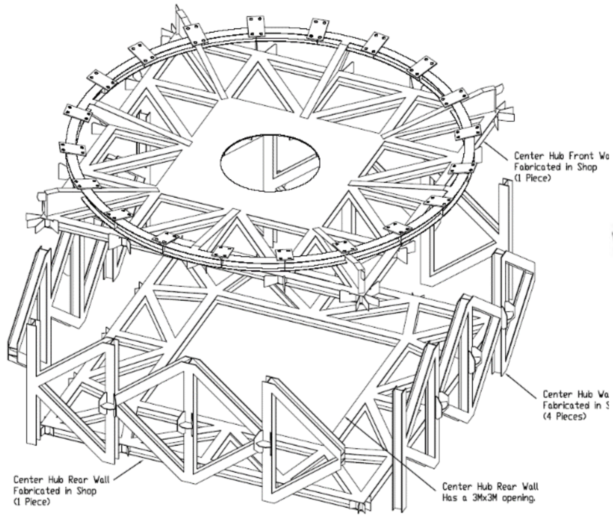
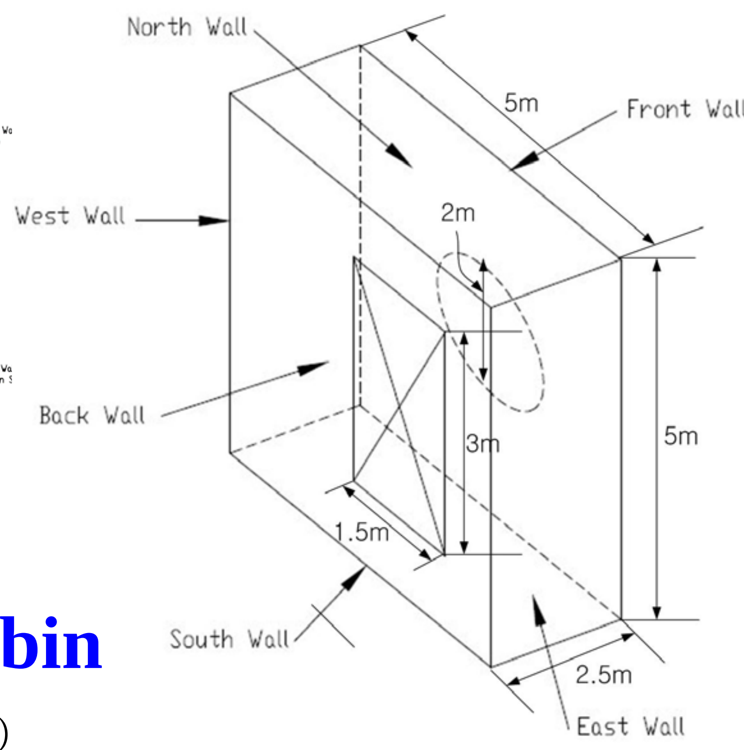
Structure of receiver cabin



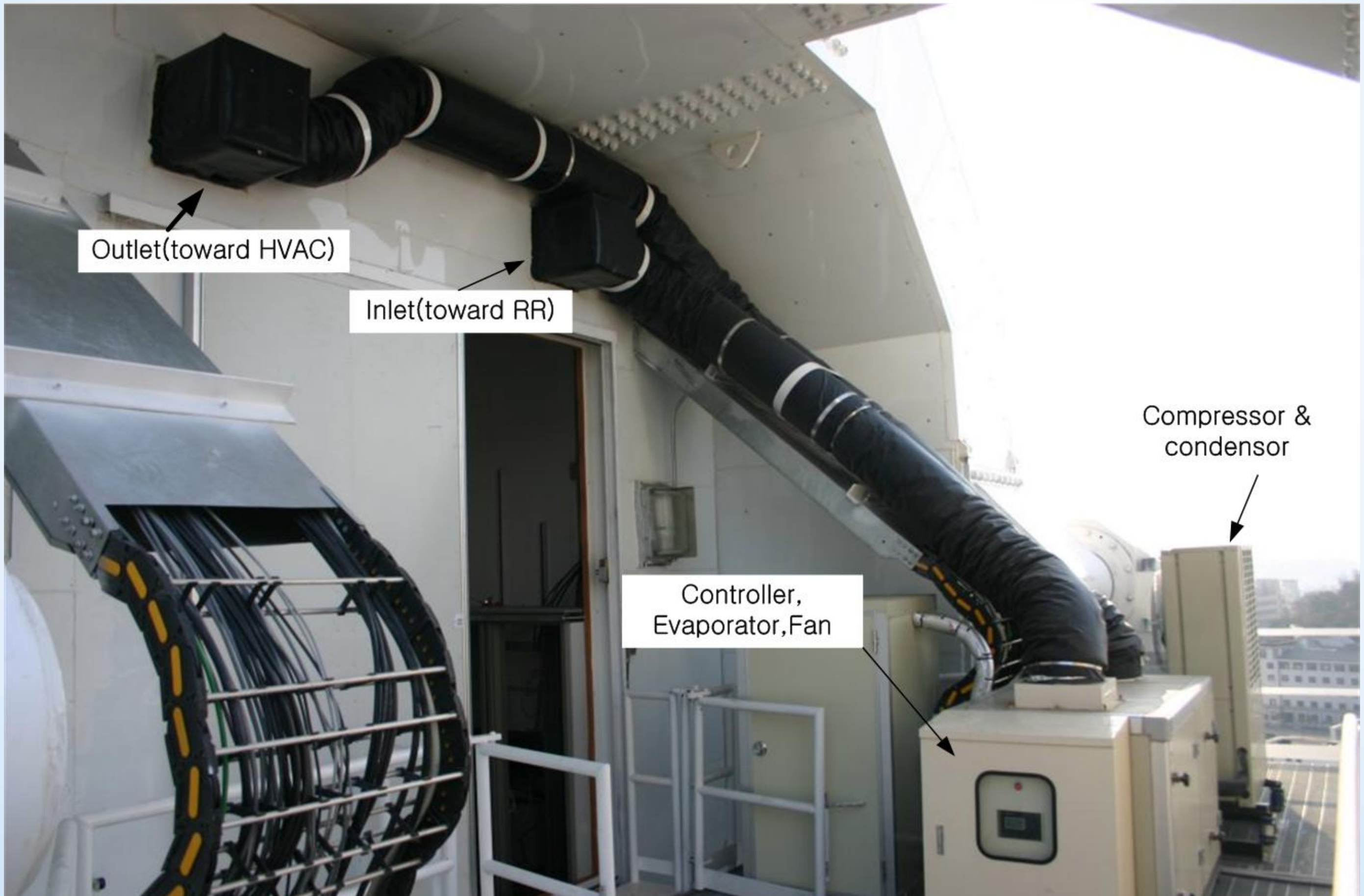




Thermal weakness in Receiver Cabin

1. A big hole for vertex window (about 2m radius)
2. A big door (3m x 1.5m)
3. Two in/outlet holes for cables
4. Limitation of performance of insulation material
5. Thermal transmission through steel structure

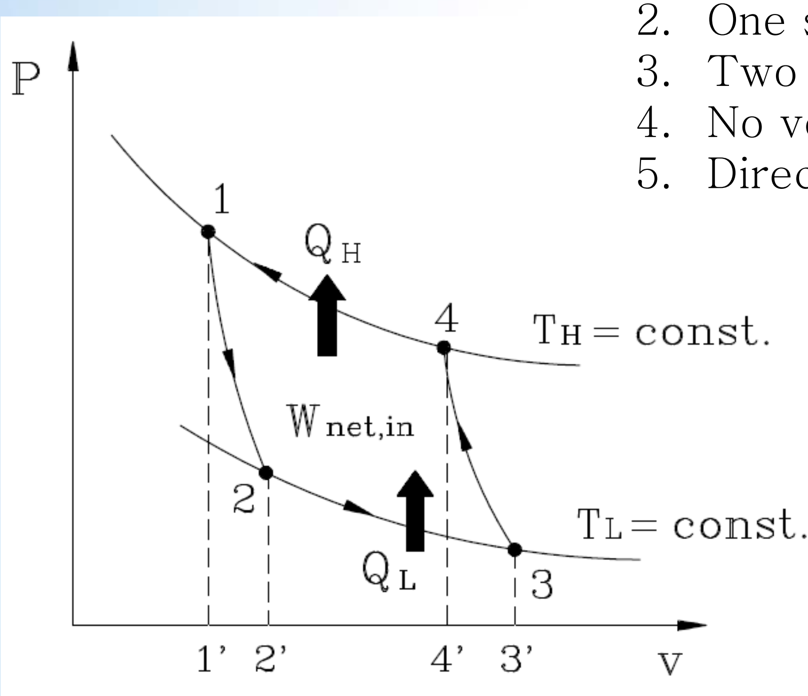
Old Rx room HVAC

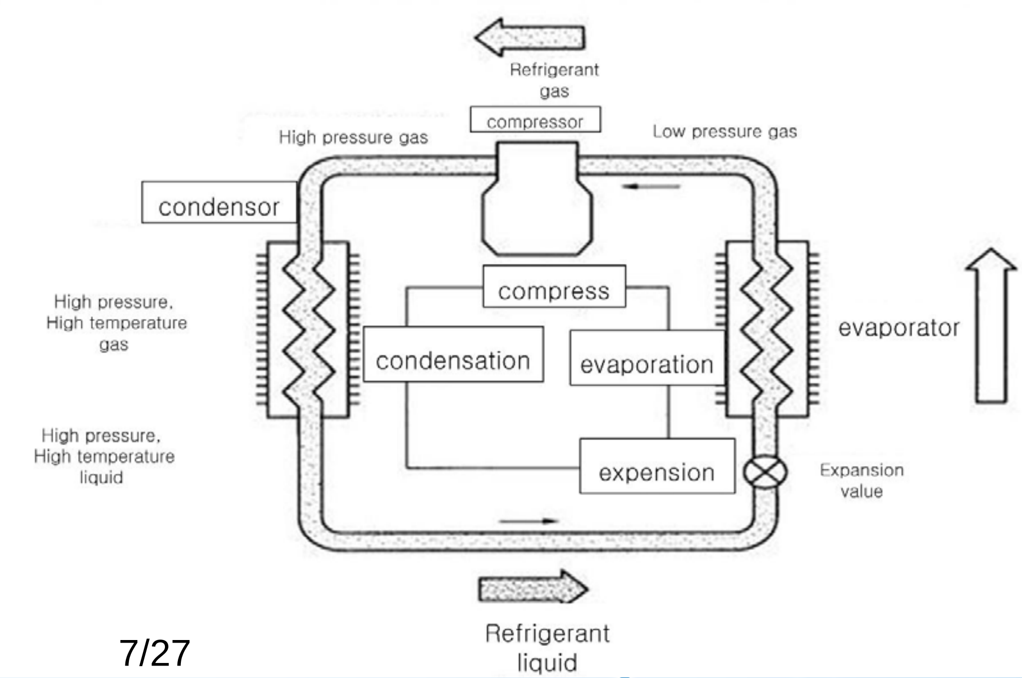


Conventional Refrigerator using reversal Carnot Cycle

Old Rx room HVAC

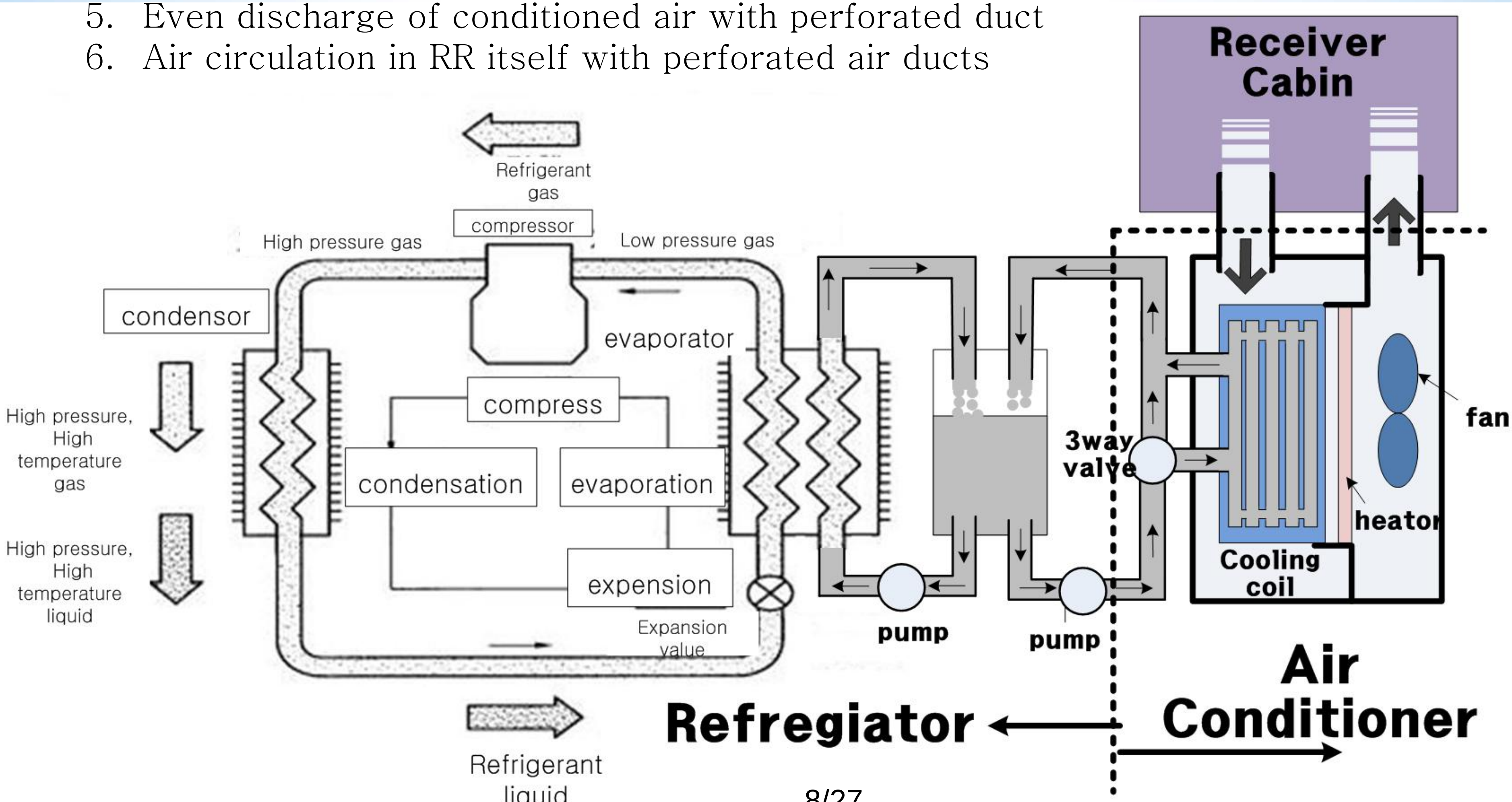
1. Temp. control range : <+ −2 degC
2. One step refrigeration, On/Off control of compressor
3. Two step On/Off control of Heaters
4. No ventilation in receiver cabin in itself
5. Direct heat exchange at evaporator



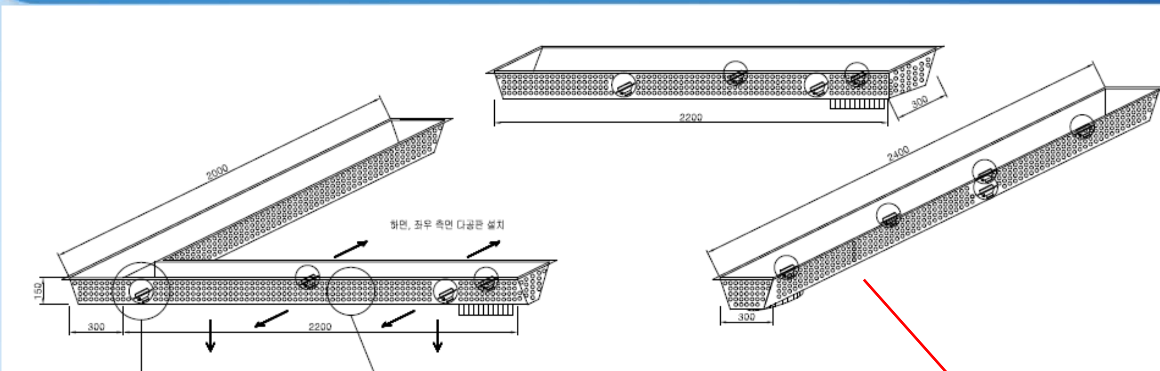


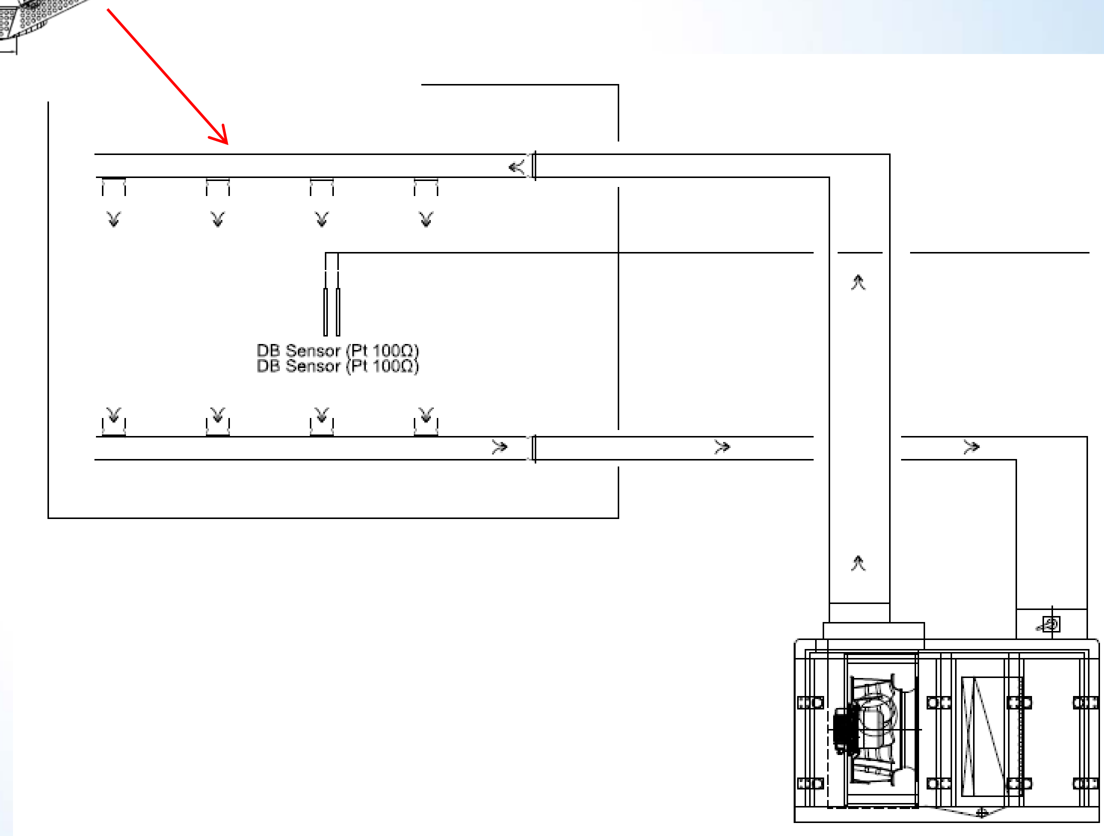
New Rx room HVAC

1. Temp. control range : <+ -0.5 degC
2. Indirect heat exchanger at evaporator
3. PID control for 3 way water valve
4. PID control for heater
5. Even discharge of conditioned air with perforated duct
6. Air circulation in RR itself with perforated air ducts

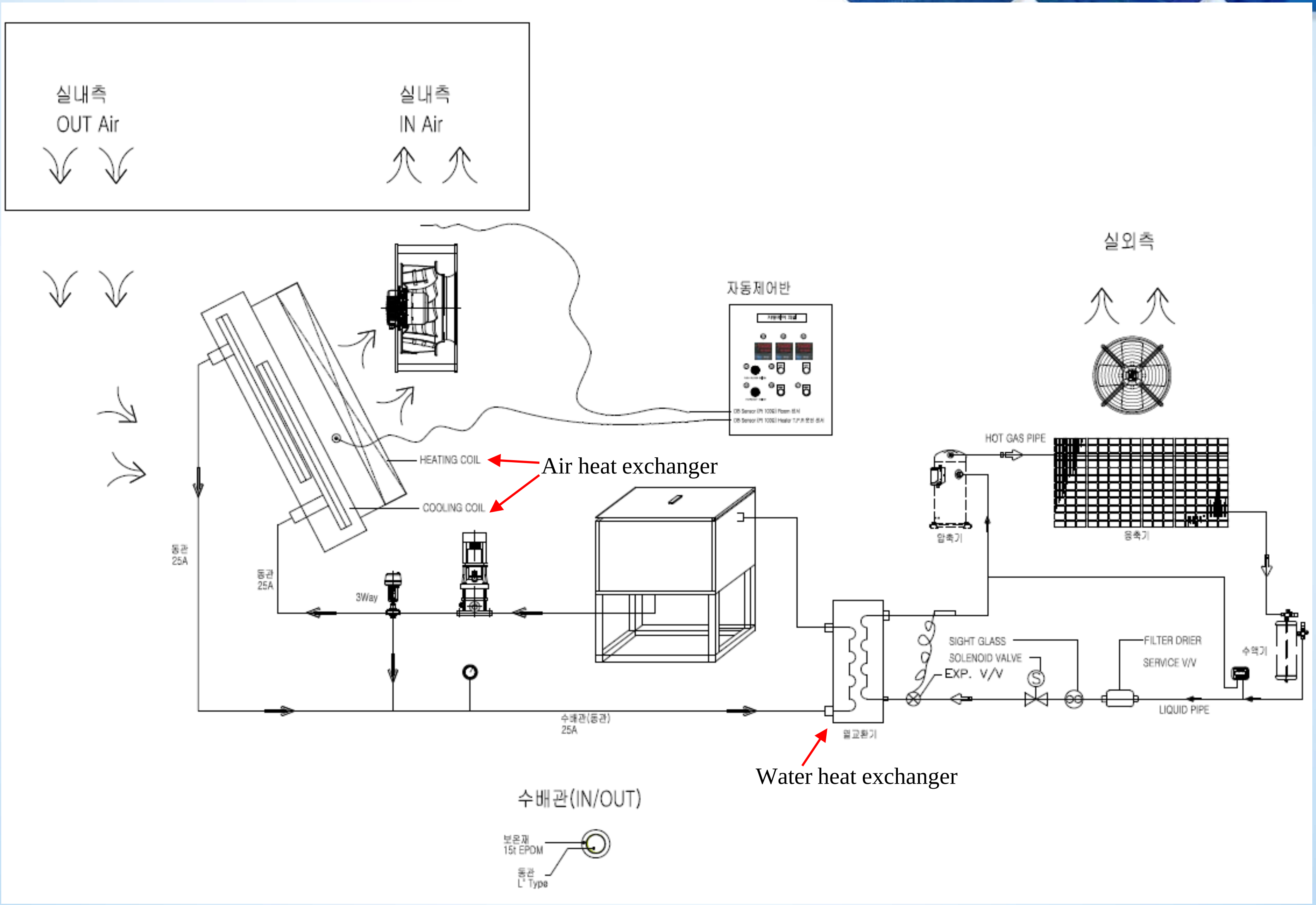


Perforated ducts for Even discharge





Airflow diagram of new HVAC



Heat load (Total refrigeration capacity = heat load + control capacity)

due to power load, radiation and convection

power load	load capacityW)
Vacuum monitor	200
power supply for 22,43, 86 GHz Rx	500
conoller power for quasi optics	200
Total power detector	200
bias power for 129GHz Rx	500
monitor system for Rxs	300
Temp. monitor system	200
Base band converter	500
IF signal selector	500
frequency synthesizer	500
M&C computr for Rxs	500
Digital Sampler x 4ea	800
Digital signal optical transmitter	300
4channel receiver	1,000
lights and etc.	1,000
total	7,000

Heat load from power usage
(heat from inside)

material	K	area [m^2]	air temp.	surface Temp. [k]	Temp. Diff. [k]	radiation rate	total radiation heat work rate [w]	natural convection coefficient	total convection heat work rate [w]
urethan	0.2	91.3	23	27	2	0.85	1,107	4.5	822
steel	4.3	1.1	23	27	2	0.85	13	4.5	10
styroform	0.6	0.8	23	38	15	0.85	76	4.5	53
aluminum	46.9	2.4	23	38	15	0.95	229	4.5	159
total							1,425		1,043

K : Thermal transmitteny [$W/m^2 \cdot K$]

Heat load from radiation and convection
(heat from outside)

(7kw + 1.4kw + 1kw) x 1.2 (reserve rate) =

11.3kw

control capacity

to control air state from 38 °C(80% relative humidity) to 26 °C(60% relative humidity) within 15min

(1) 38°C(80% relative humidity) air enthalpy =

i_{38_80} = 0.24cal/J x 38°C +(597kcal/kg

+ 0.441kcal/(kg°C) x 38°C) x 0.03kg = 27.53kcal/kg

(2) 23°C(60% relative humidity) air enthalpy =

i_{23_60} = 0.24cal/J x 23°C +(597kcal/kg

+ 0.441kcal/(kg°C) x 23°C) x 0.015kg = 14.62kcal/kg

(3) Difference of enthalpy = $i_{38\_80} - i_{23\_60}$ = 12.9kcal/kg = **53kJ/kg**

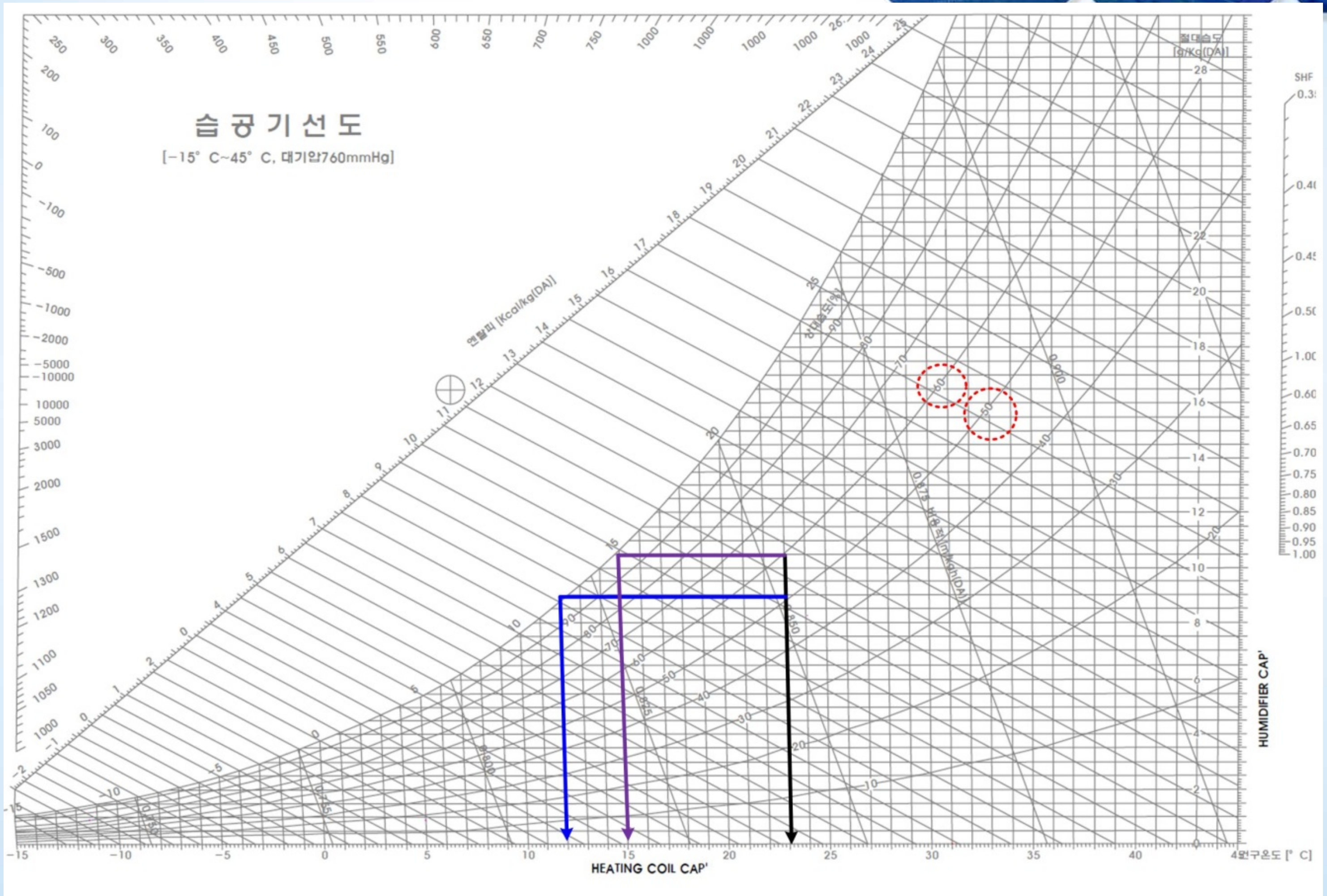
(4) **Control capacity** : Refrigeration capacity to control air state from 38 °C(80% relative humidity) to 26 °C (60% relative humidity) within 15min

1.2kg/m³ x 100m³ x **53kJ/kg** = 6,360kJ → 6,360kJ/15min = 7.06kJ/s = **7.06kw**

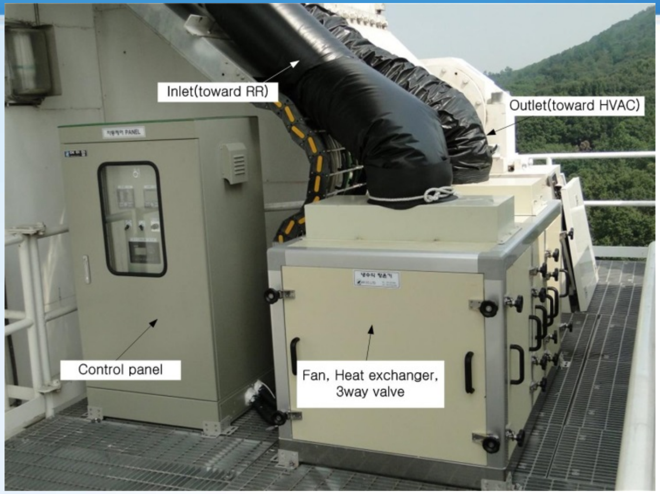
Total refrigeration capacity = heat load + control capacity

= 11.3kw + 7.06kw = 18.36kw =18.36kw x 1RT/4kw **= ~5RT**

Psychrometric chart for KVN HVAC
(temp: 23degC, Humidity control < 60% : water < 15degC)



New Rx room HVAC system



Air heat exchanger and air blower


Compressor, condenser and water heat exchanger

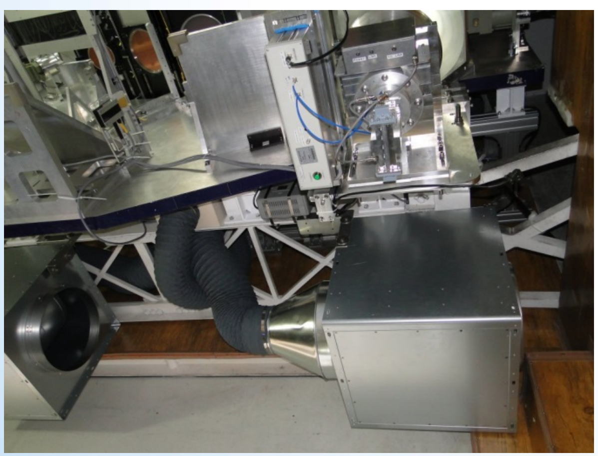

Perforated air duct in receiver cabin


Distribution box for air ducts

Ideas for air circulation and ventilation

Air distribution box in RR for air discharge

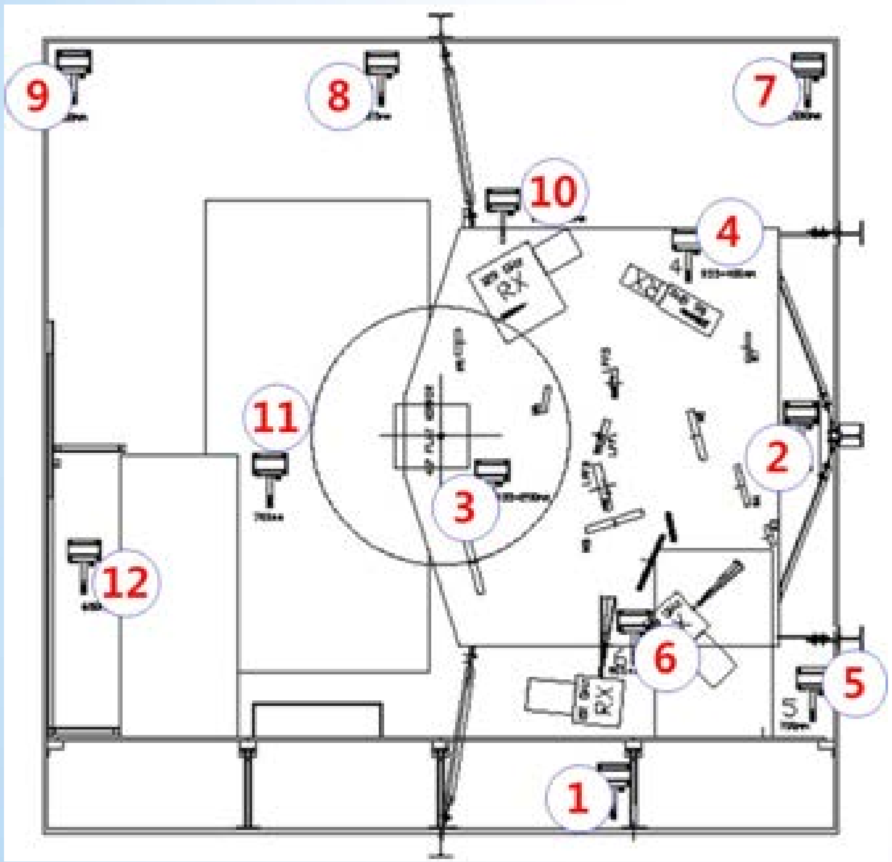
Inlet box for even air suction in receiver cabin



Blowers in RR air circulation in receiver cabin

Perforated air ducts for air circulation

Temperature sensors in receiver cabin




① 1580mm


② 750mm


③ 955+290mm


④ 955+400mm(86GHz)


⑤ 700mm


⑥ 955+450mm(43GHz)


⑦ 1530mm


⑧ 1620mm

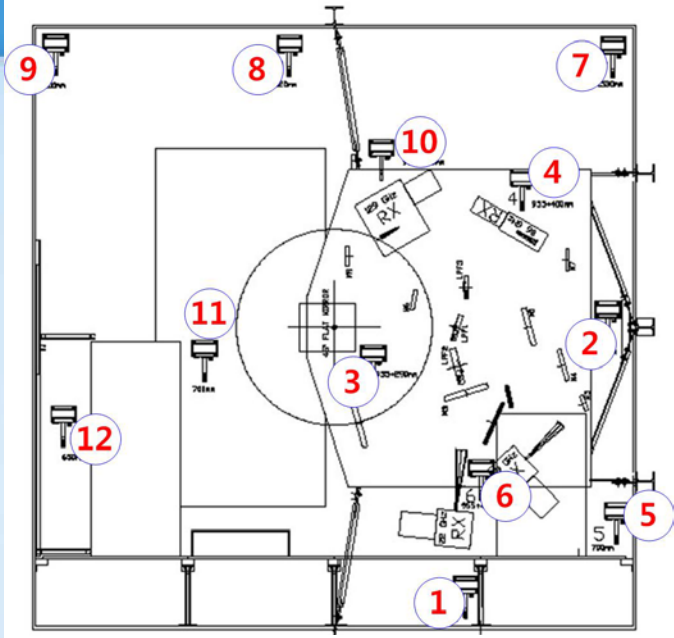

⑨ 1200mm


⑩ 955+490mm(129GHz)

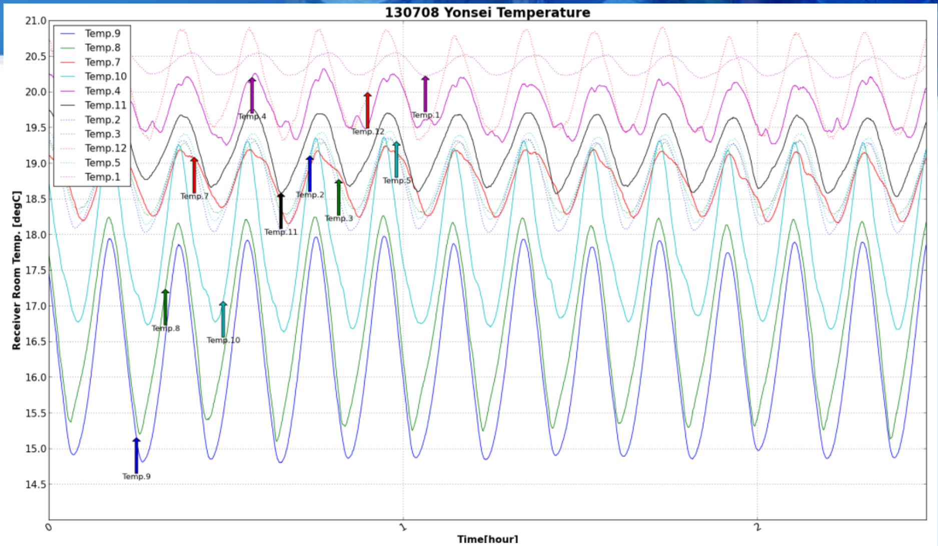

⑪ 700mm(디지털 랙앞)


⑫ 650mm(디지털 랙뒤)

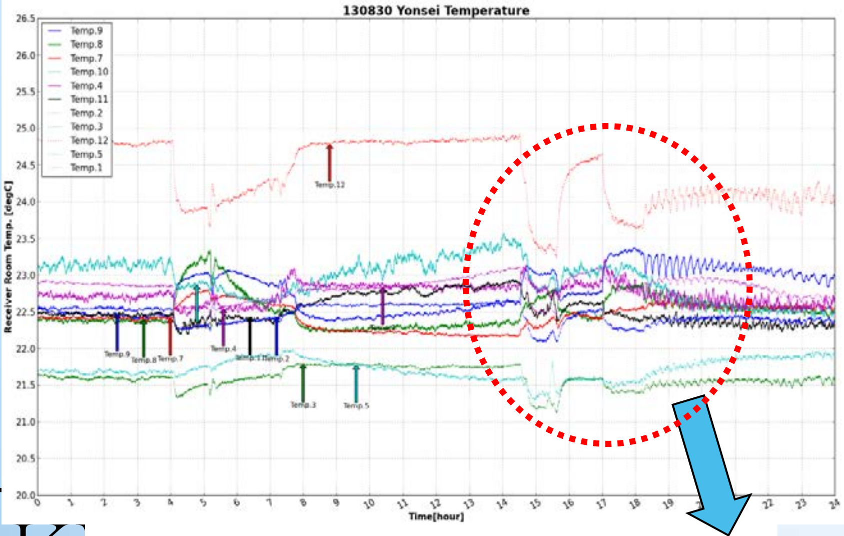
Monitoring Temp. in RR



Position of Temp. sensors in receiver room

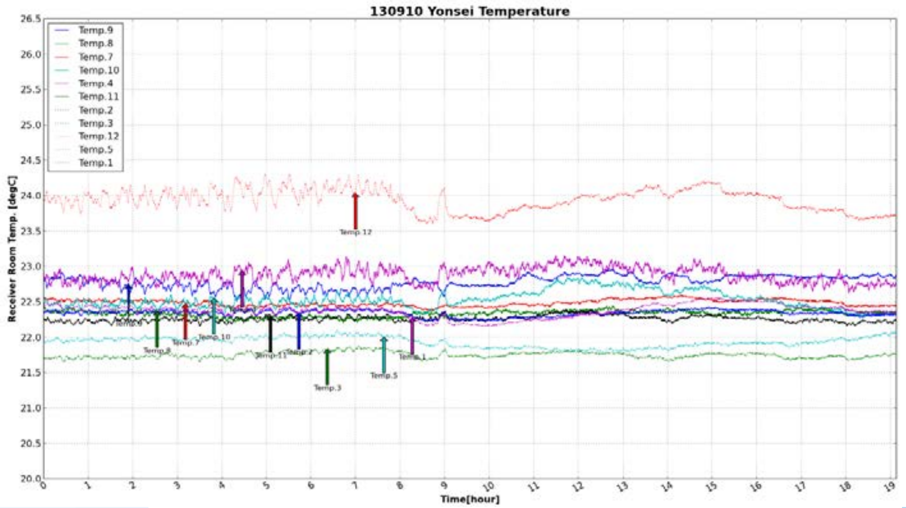


Temperature in RR with old HVAC (stow position)



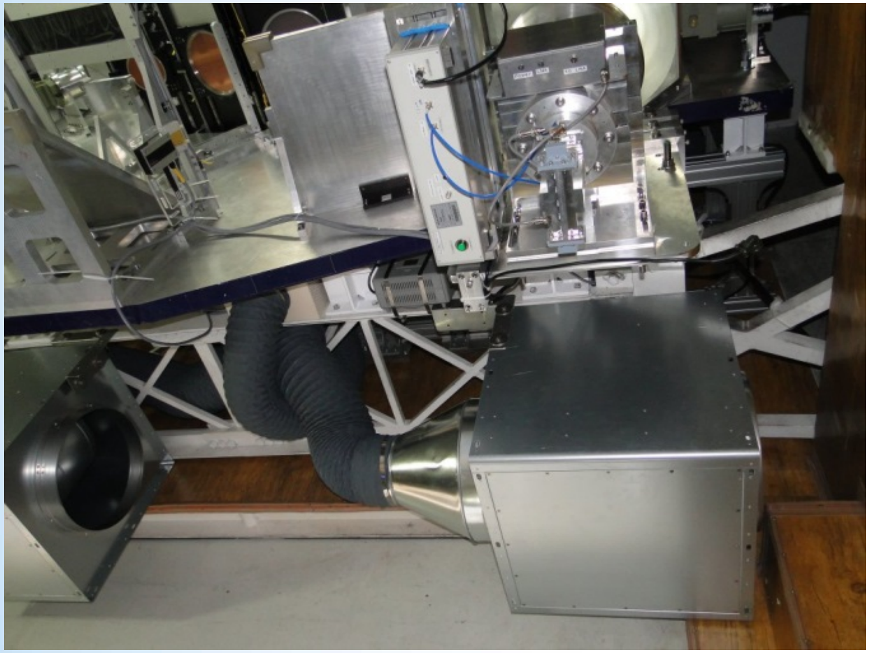
Temperature in RR with new HVAC (stow

Before air circulation



Temperature in RR with new HVAC (stow position)

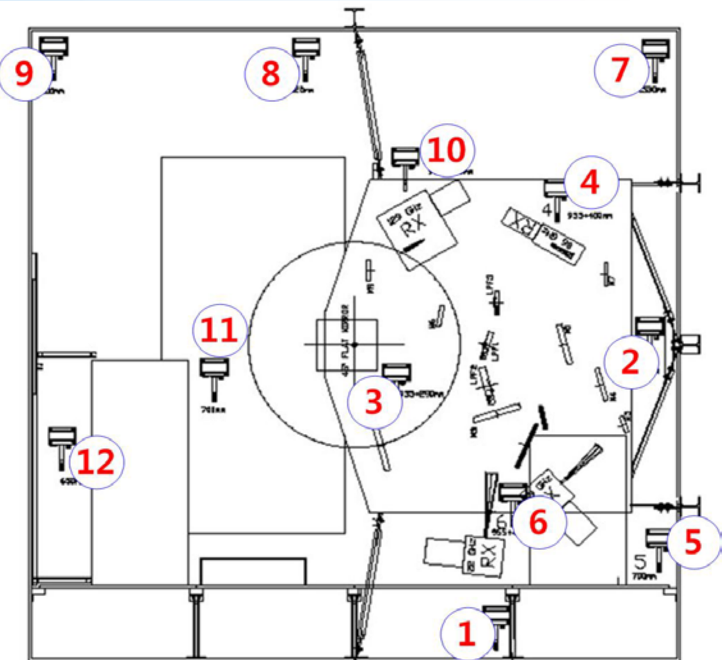
Air circulation with blower and ducts



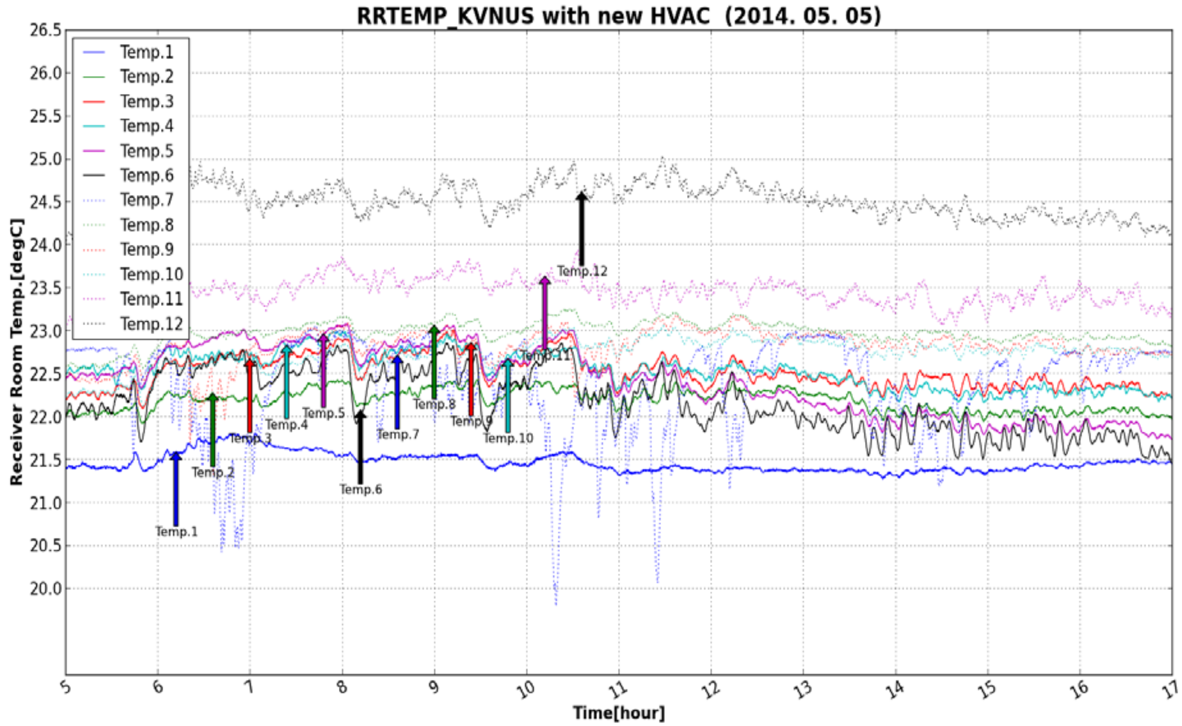
Blowers in RR air circulation in receiver cabin

Perforated air ducts for air circulation

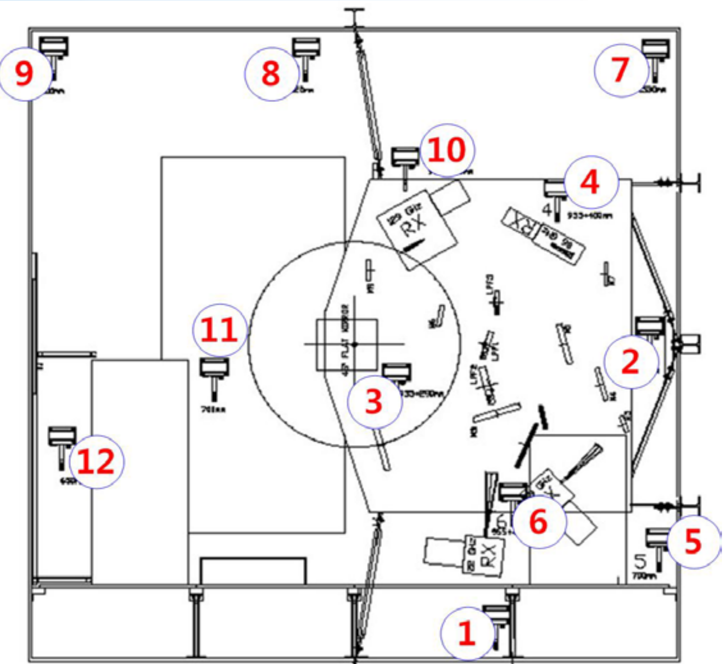
Ulsan receiver room Temp. w/ new HVAC and Vent.



수신기방내 온도센서 위치



Ulsan receiver room Temp. w/ new HVAC and Vent.



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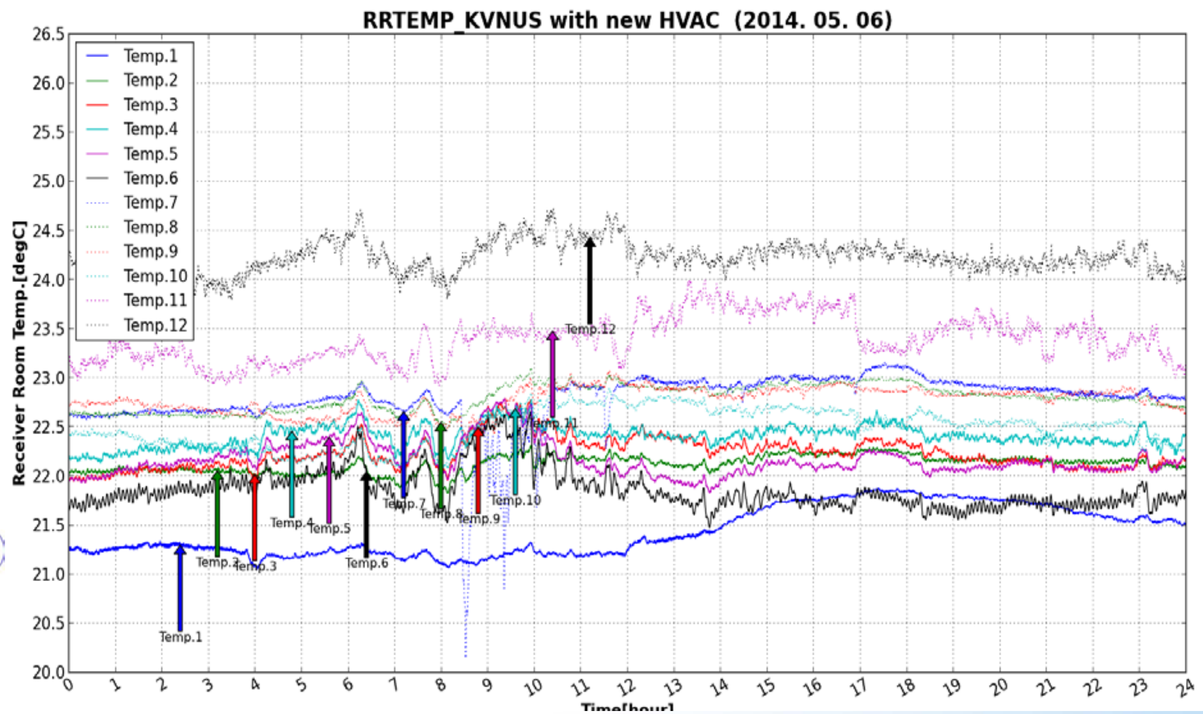
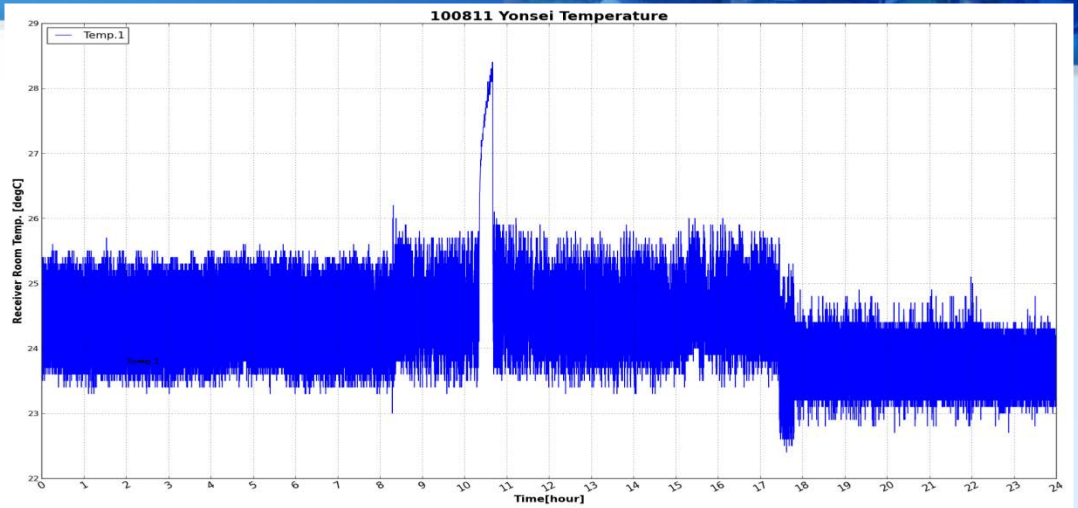


Yonsei H-maser room HVAC

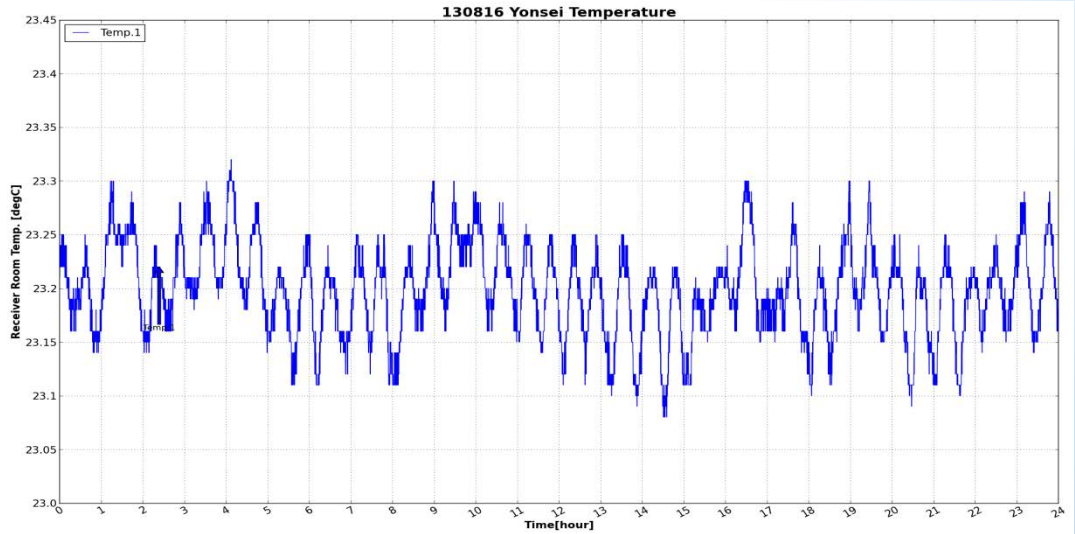
수소시계실 **HVAC** 공조기, 제어기

수소시계실 다공판 토출덕트

수소시계실 용 냉수식 컴프레서

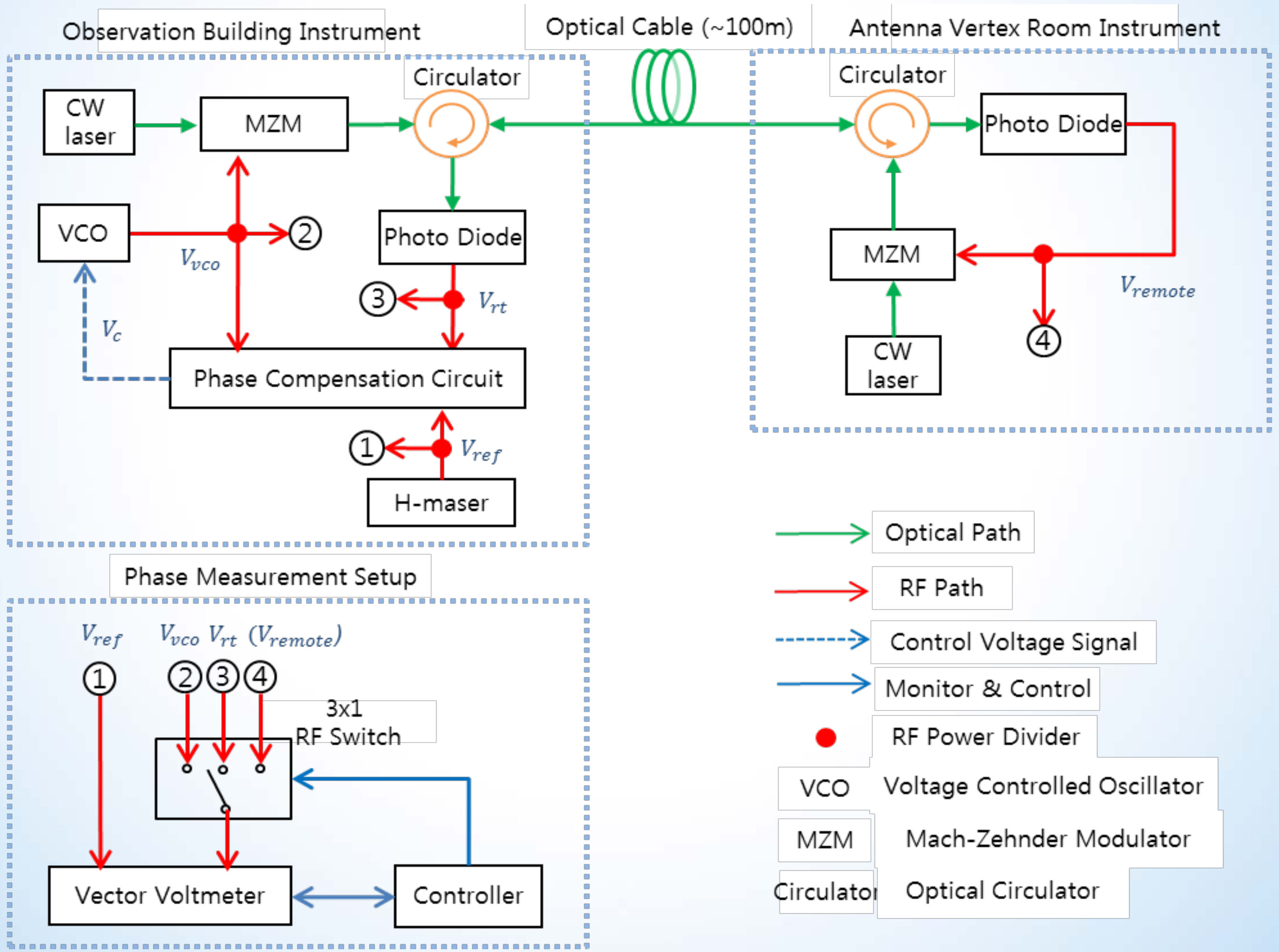


수소시계실내 온도 (**old HVAC ➔ +-1.5degC)**

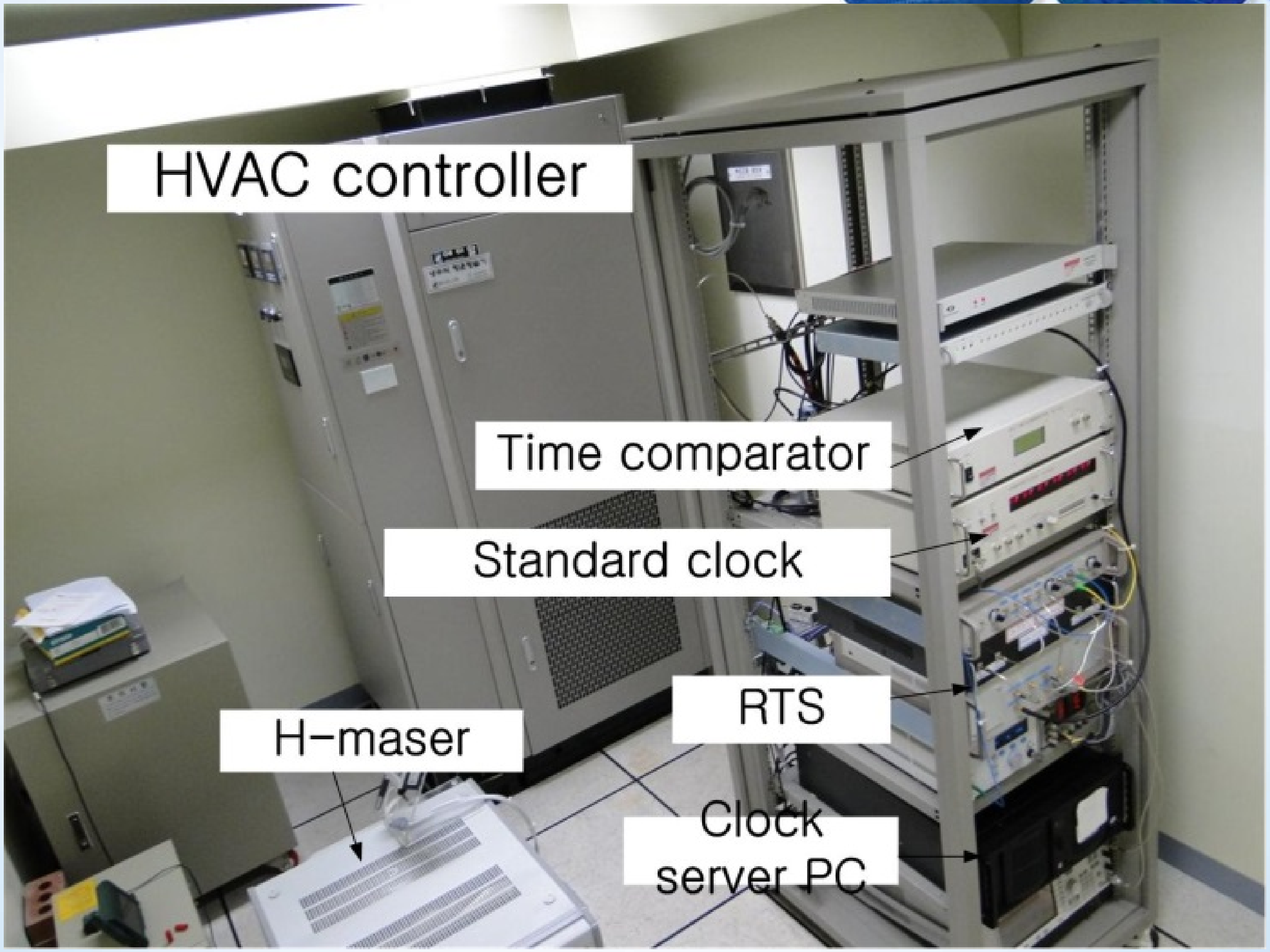


수소시계실내 온도 (**new HVAC ➔ +-0.1degC)**

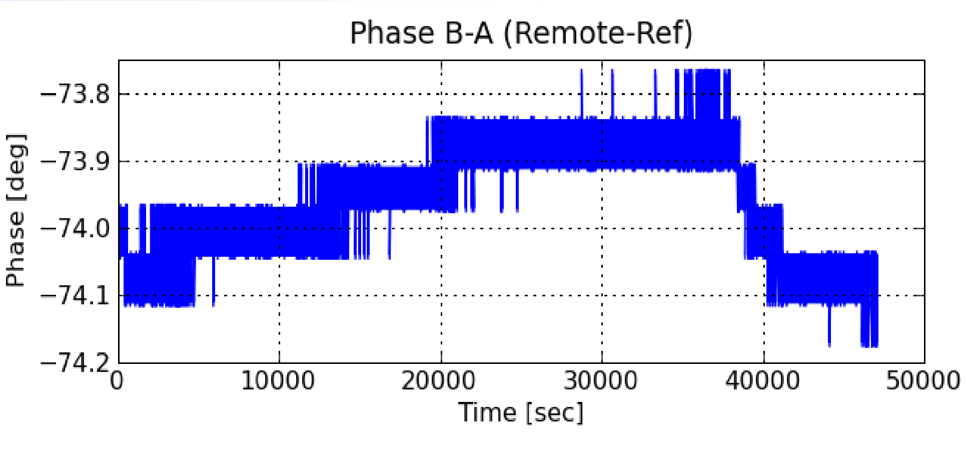
Round Trip Monitor system for phase noise monitoring



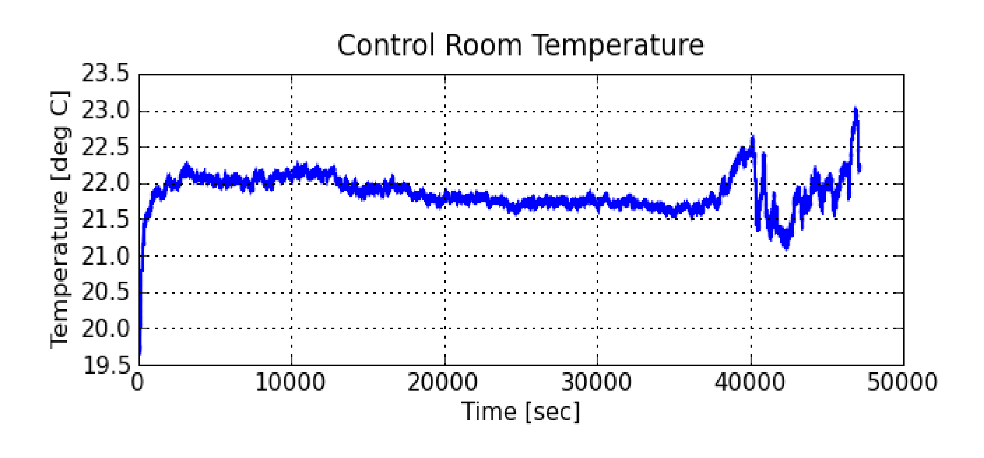
Installation of clock related instruments in H-maser room after temperature stabiization



Temp., phase variation with old HVAC

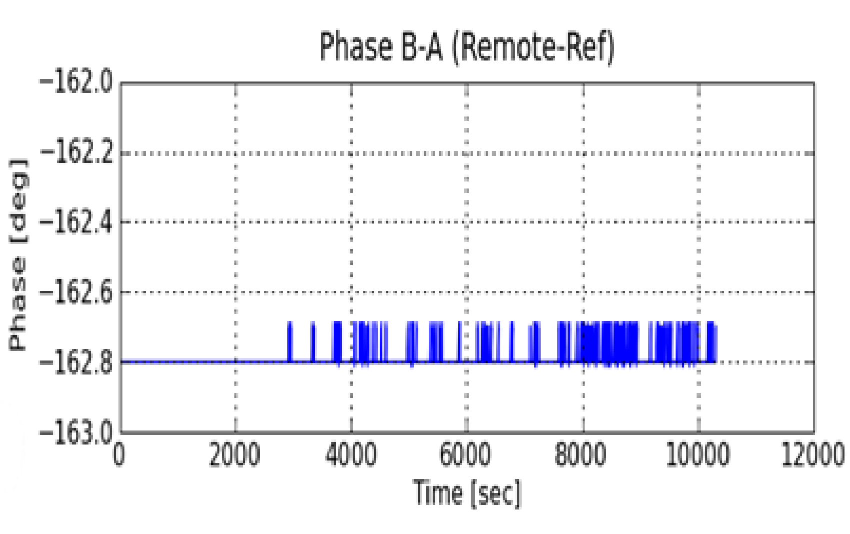


Phase difference b/w H-maser and RR reference signal : <0.4deg @1.4GHz)

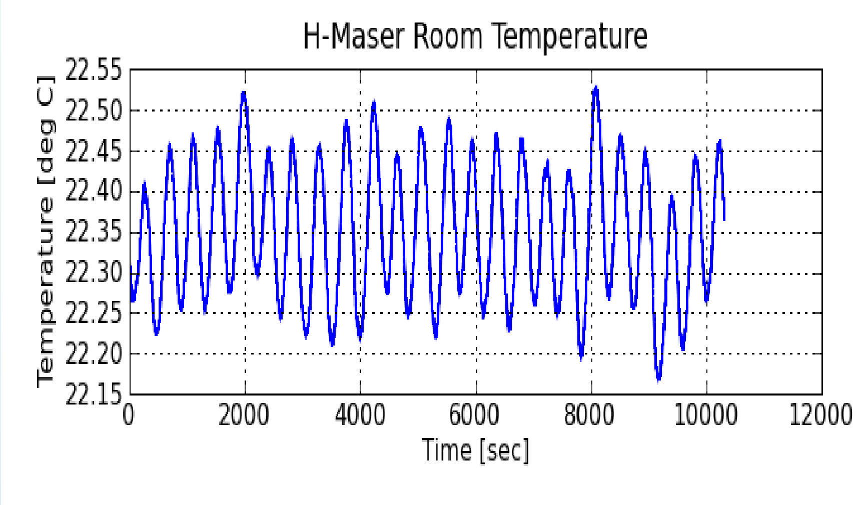


Temperature variation at H-maser :
< +- 2degC

Temp., phase variation with new HVAC

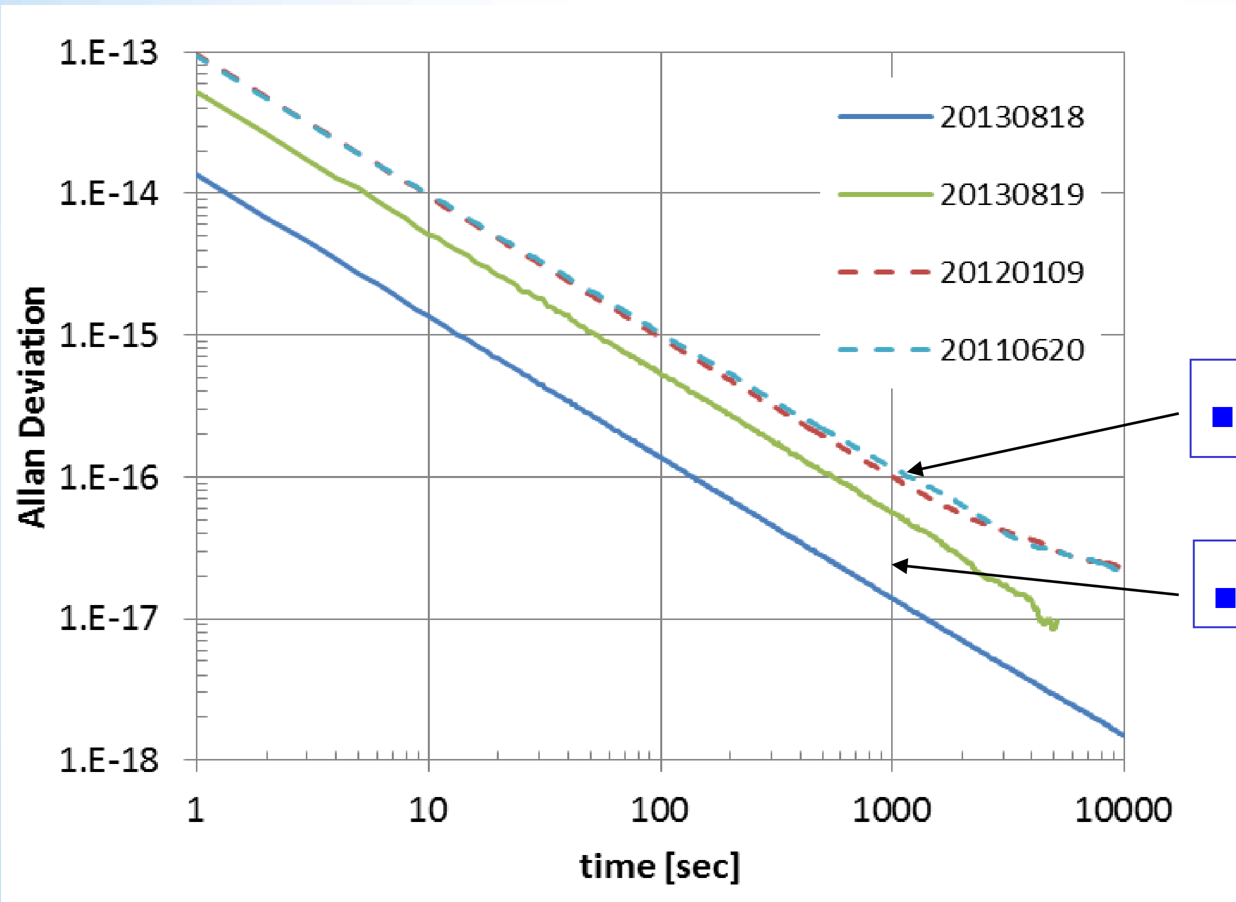


Phase difference b/w H-maser and RR reference signal : <0.1deg @1.4GHz)



Temperature variation at H-maser :
< +-0.1degC

Alan deviations for phase noise



■ AD: 1x 10^{-16}/1000s

■ AD: 2x 10^{-17}/1000s

Alan deviations of phase noise is improved twice.

Summary

- Indirect heat exchanging with water as intermediate material
- PID controller of three way water valve to stabilize temp. of cooling coil (water)
- PID controller of heater for stabilization of final air temperature
- Perforated duct, duct distribution box for in/outlet
- Perforated ducts and blower for air circulation
- Temperature sensor and monitor
- New HVAC for receiver cabin: < + - 0.5degC/per channel (24h operation)
- New HVAC for H-maser room: < + - 0.1degC/per channel (24h operation)
- Relative humidity ratio : < 60%
- Phase stabilization of RTS : Allen deviation : $1x10^{-16}$/1000s → $2x10^{-17}$/1000s

Thank you for your attention

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