Mm VLBI Phase Calibration Generator for KVN

2015.11.24.

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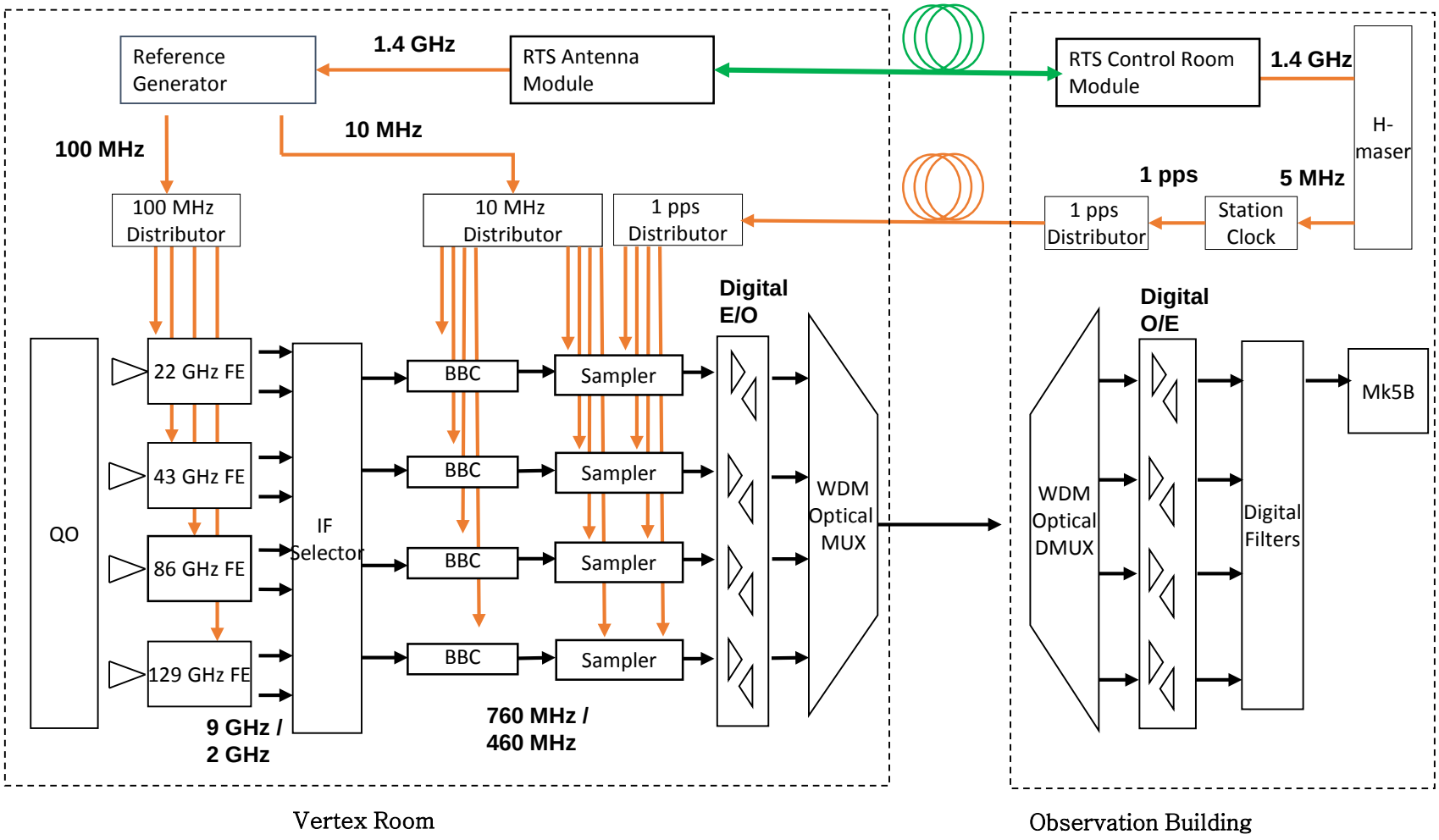
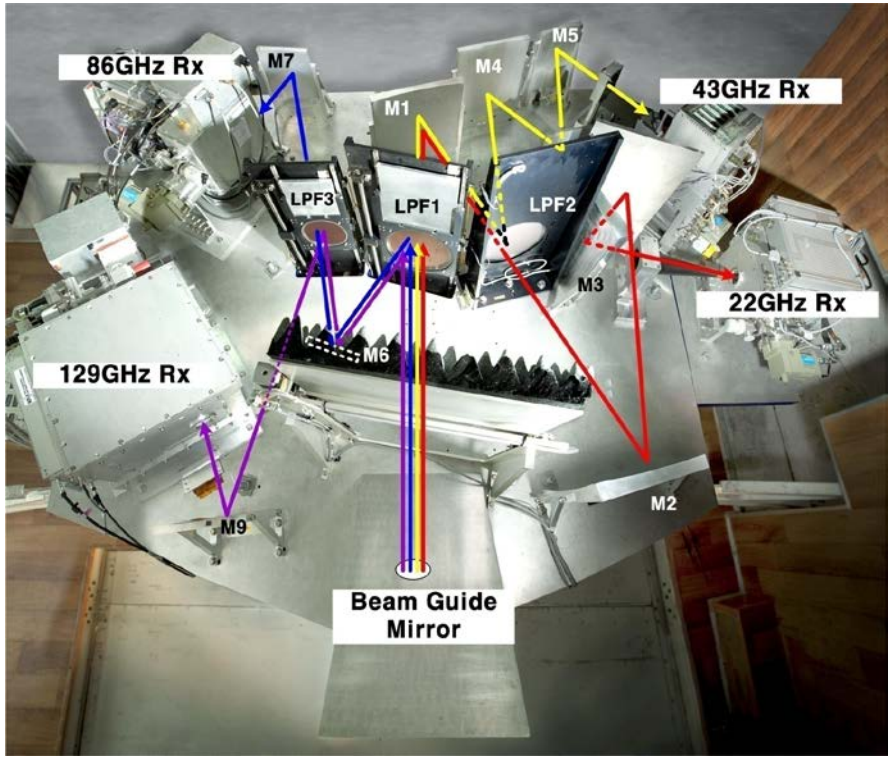
Introduction – KVN(Korean VLBI Network)

- Dish diameter : 21m
- Number of Antenna : 3 ea
- Quasi-optics : 4 band simultaneous observation for mm VLBI
- Observation frequency range and polarization
  - 22 GHz (HEMT) Rx : 21.25-23.25 GHz
  - 43 GHz (HEMT) Rx : 42.11-44.11 GHz
  - 86 GHz (HEMT) Rx : 85-95 GHz
  - 129 GHz (SIS) Rx : 124-142 GHz
- Polarization : dual circular
- 1st IF : 8-10 GHz (8 ch)
- 2nd IF : 500-1000 GHz (4 ch)
- Digital backend : 1 Gsps, ADS-1000 (4 ch)
- Recorder : Mk5B, Mk5B+, Mk6

Introduction - Korean VLBI Network(KVN) System Block Diagram



Introduction-KVN Front End



Item	22 GHz Rx	43 GHz Rx	86 GHz Rx	129 GHz Rx
RF [GHz]	21.25-23.25	42.11-44.11	85-95	124-142
Trx (inc. Q.O. loss)	30~40 K	40~80 K	60~100 K	50~70 K
IF [GHz]	8-10 GHz			
1st Active. component.	InP HEMT LNA (Caltech)	InP HEMT LNA (NRAO)	InP HEMT LNA (UMASS/ JPL)	SIS Mixer
Pol.	LHCP/RHCP			

- 4 band simultaneous observation : Pcal is needed for calibrating 4 receivers LO's phase offset, different delays from antenna focus to each Rx, and each Rx's phase instability

Introduction –Pcal's for geodetic observation

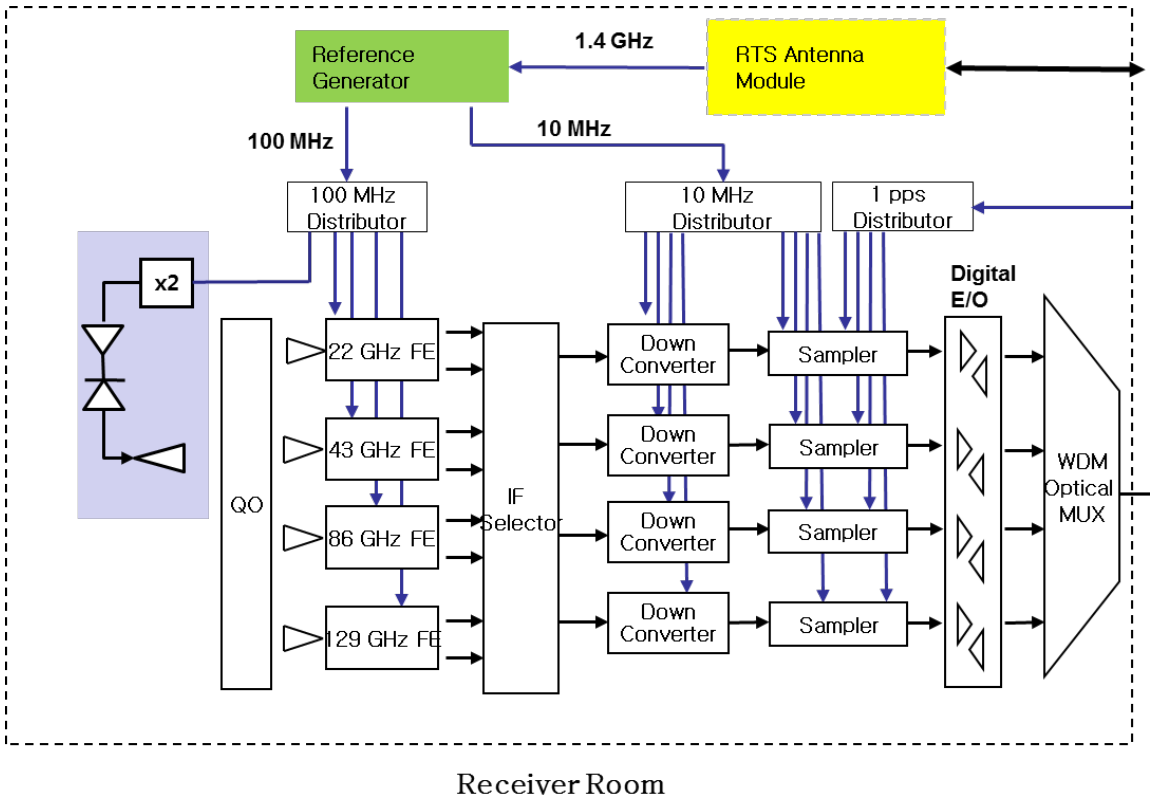
- Pcal generates short impulse to measure phase and group delay in the receiver system
- History & Performances

Item	Key Component	Tone spacing, Stability	Frequency Range	Year
Mark III Pcal	Tunnel diode	1 MHz, ~1.5 ps/°C	-80 dBm @ 2.2GHz, -106 dBm @ 22 GHz	1980's
VLBA Pcal	Tunnel Diode	1/5 MHz, 2 ps/°C	< ~ 40 GHz	1992
Up-converter Pcal	SRD, 17.5 GHz PLO	-	20 GHz band	1999
Digital Phase Calibrator	Logic devices	5/10 MHz, < 1~2 ps/°C (?)	-80 ~ -60 dBm @ 2-14 GHz	~ 2010

- Current Pcal cannot generate 86 and 129 GHz band Pcal. → New Pcal is needed for KVN

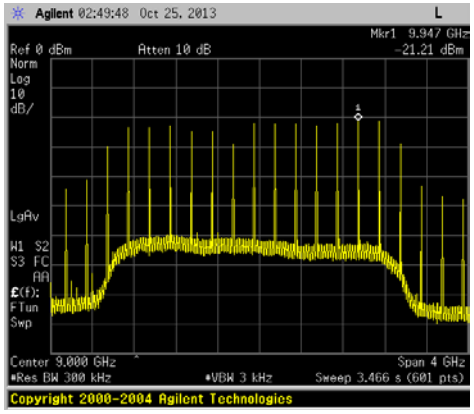
Quasi-optic Pcal for KVN

- KVN tested NLTL comb generator which generates 200 MHz spaced tone signals exceeding 50 GHz. 80 GHz comb signal's output power was measured as about -80 dBm.
- Impulse signals are injected into antenna focus and go through several mirror and quasi-optical filters, and then finally arrive at each receiver's horn input.
- Q.O. Pcal can calibrate 4 receivers LO's phase offset, different delays from antenna focus to each Rx
- Q.O. Pcal needs comb signals and broadband feed from 20 to 142 GHz

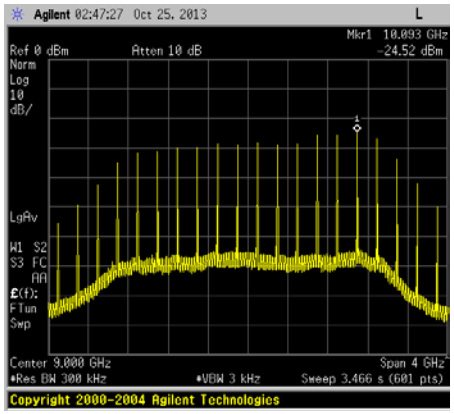


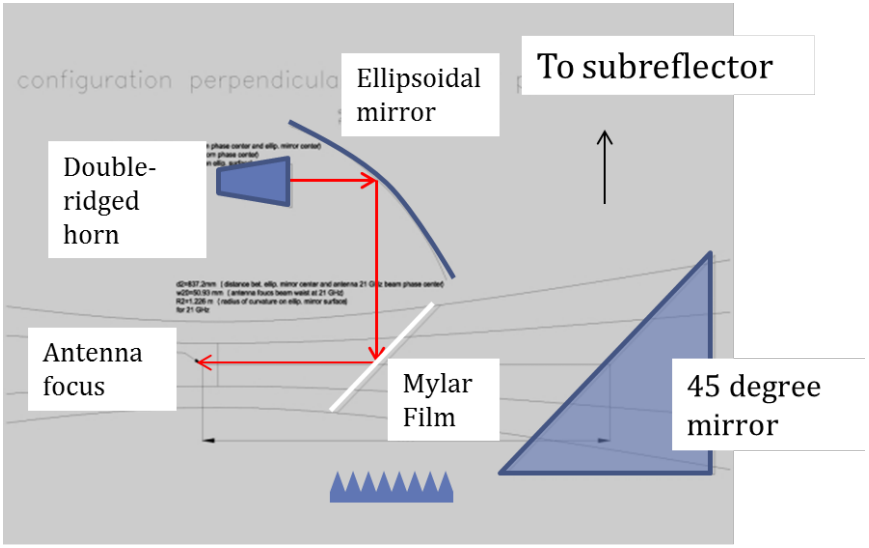
Quasi-optic Pcal Experiment

22GHz Rx's IF

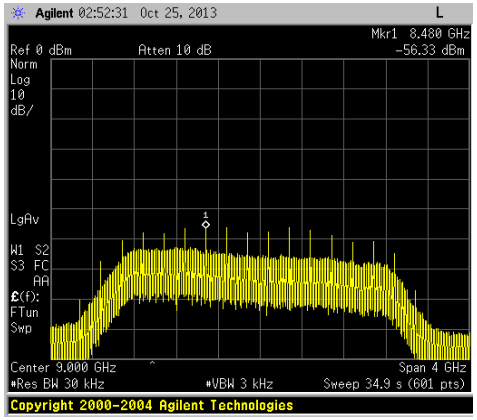


43GHz Rx's IF





86GHz Rx's IF



→ Large Slope more than 30 dB between 22/43 GHz Rx tone signals and 86 GHz Rx's tone signal. We cannot obtain 130 GHz tone signal

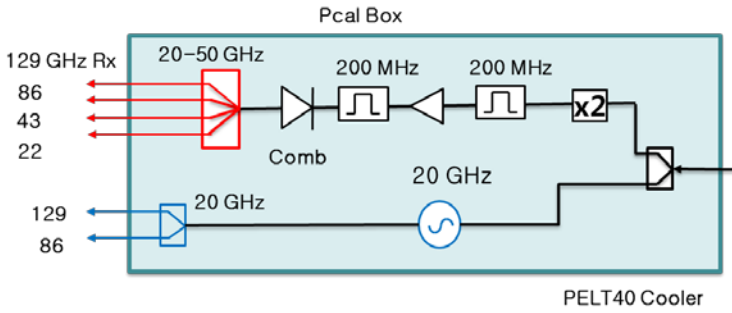
We fabricated Quasi-optical Pcal generator using NLTL comb generator, broadband double-ridged horn, ellipsoidal mirror, and Mylar sheet

Up-conversion Pcal for KVN

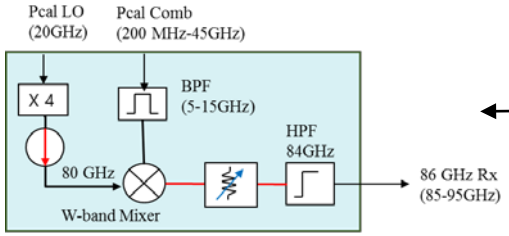
- Up-conversion Pcal can generate 86 GHz and 130 GHz band comb signals by frequency up-conversion.
- Additional LO(Local Oscillator) is used for up-conversion.
- Each frequency band's calibration signals are injected into each receiver's coupling port
- Limits
  - Up-conversion Pcal cannot calibrate 4 receivers LO's phase offset, different delays from antenna focus to each Rx.
- Up-conversion Pcal can only calibrate each receiver's phase instability
- We can control the amplitude of each band's comb signals separately.
- KVN will plan calibrate initial phase of each receiver's output signal using reference source observation

Up-conversion Pcal configuration

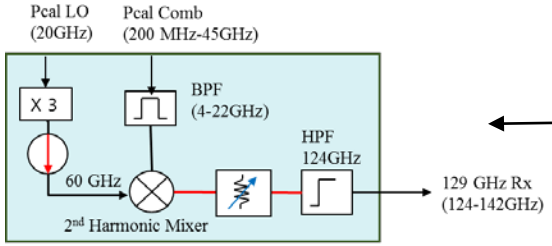
Pcal Main Module

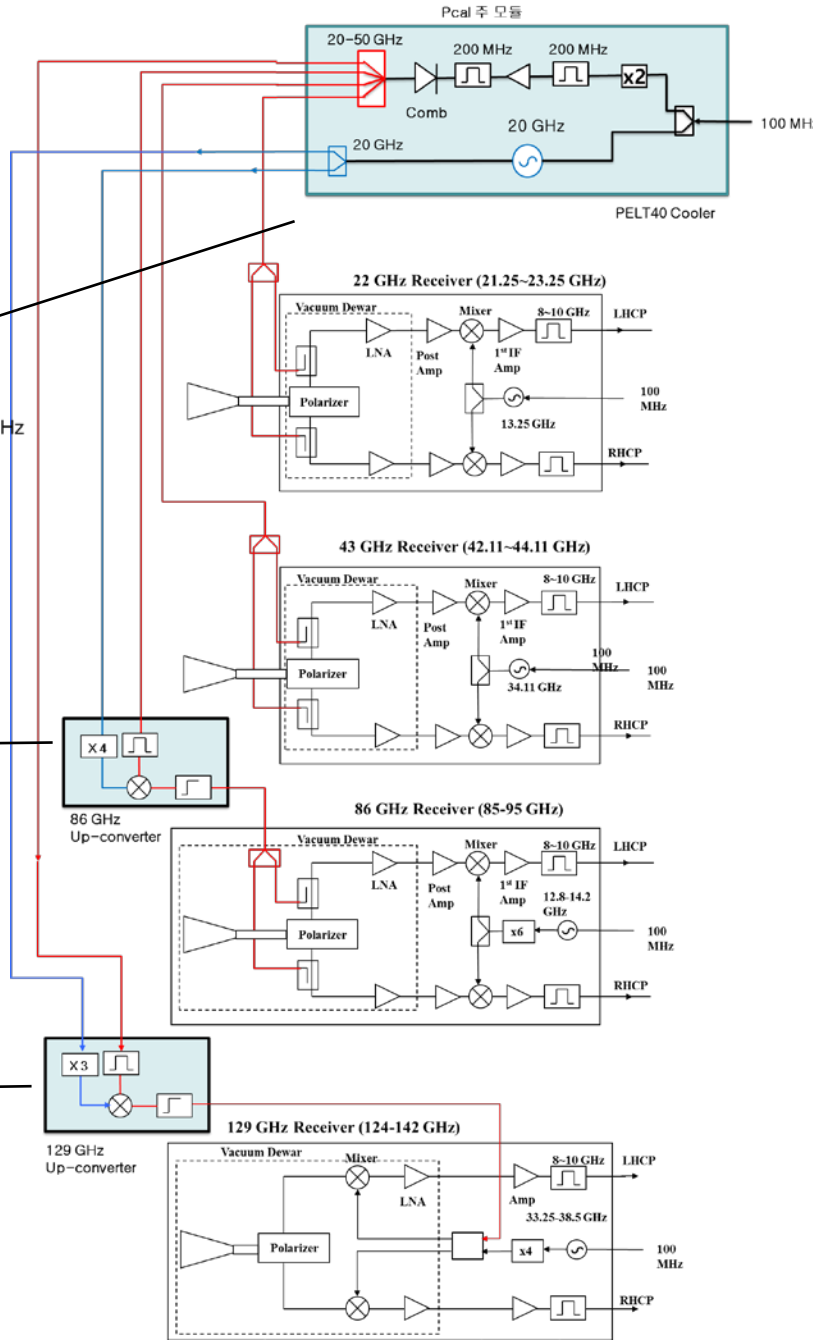


86GHz Pcal Up-converter



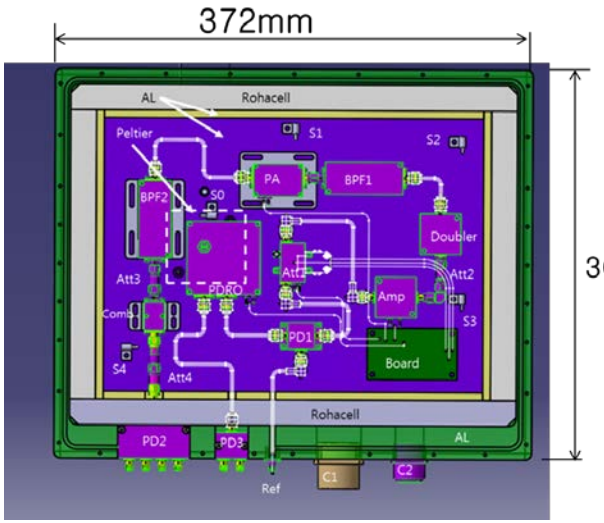
129GHz Pcal Up-converter

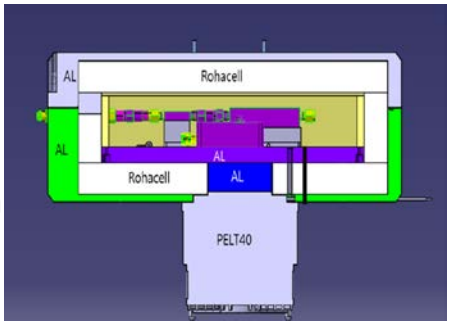




Fabrication and Test of Up-conversion Pcal-Main Module

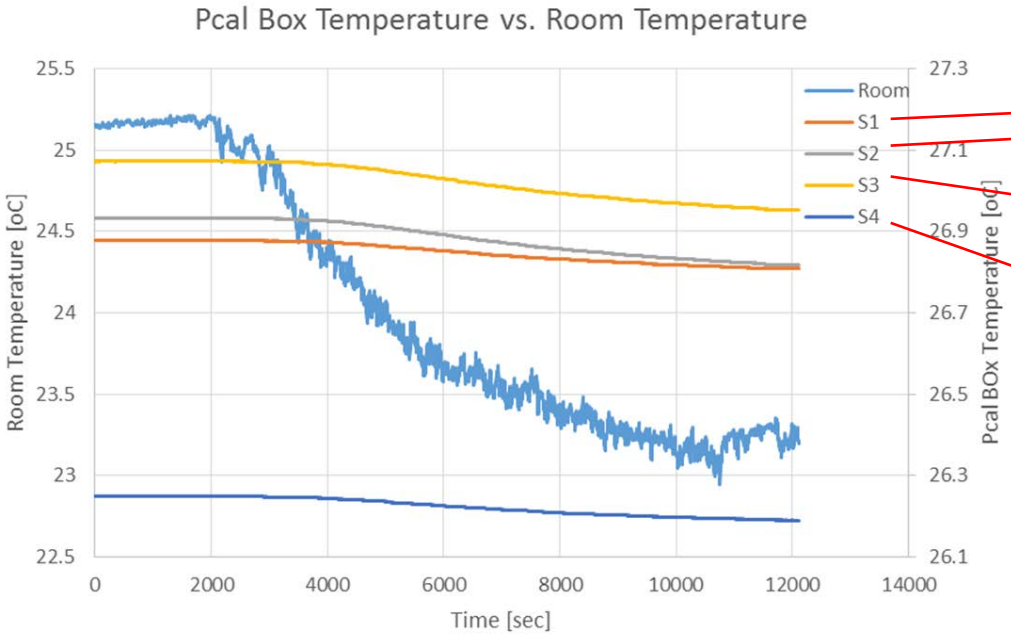
- Comb generator: 7123, Picosecond Labs. NLTL
- 20 GHz Osc. : PDRO (CTI)
- Cooler: Peltier PELT40(including heat sink and fan, by Misumi)
- Temp. Controller: TED8040, Thorlabs
- All RF components are commercial ones

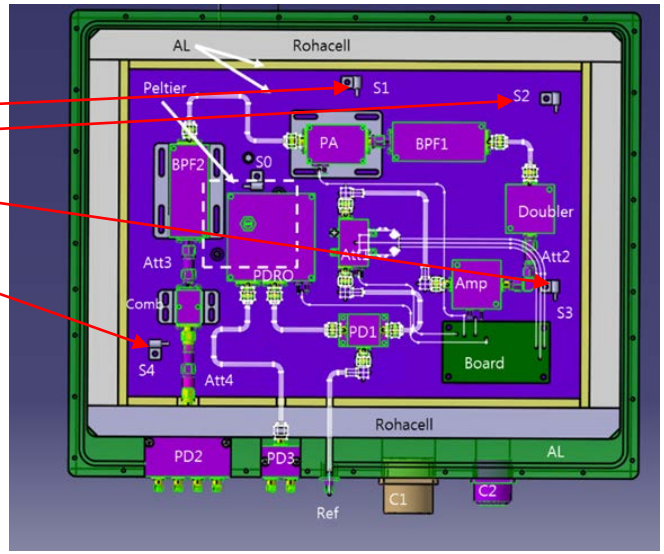




Main module's temperature stability vs. outside temperature

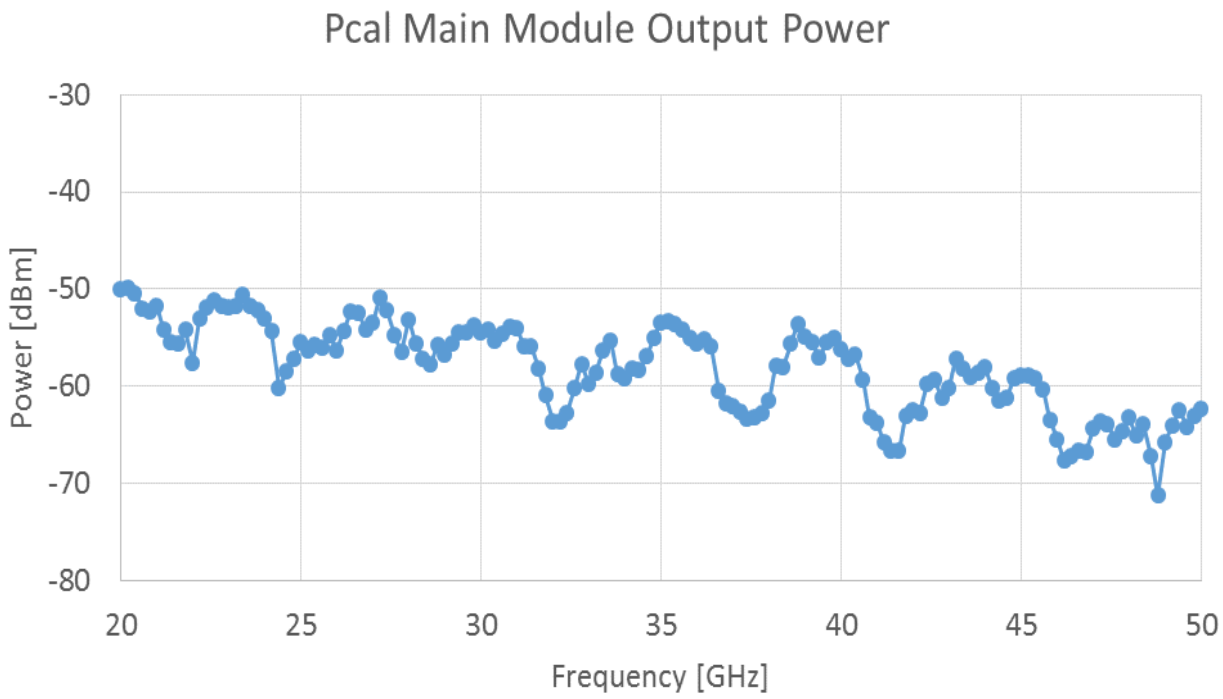
- Inner AL plate's temperature changes 0.03 ~ 0.06 °C when outside temperature changes 1 °C





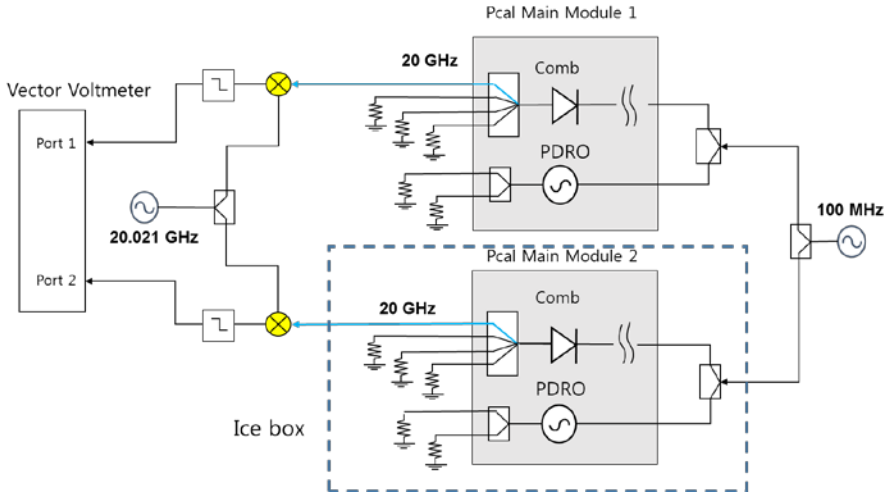
Main module’s output spectrum

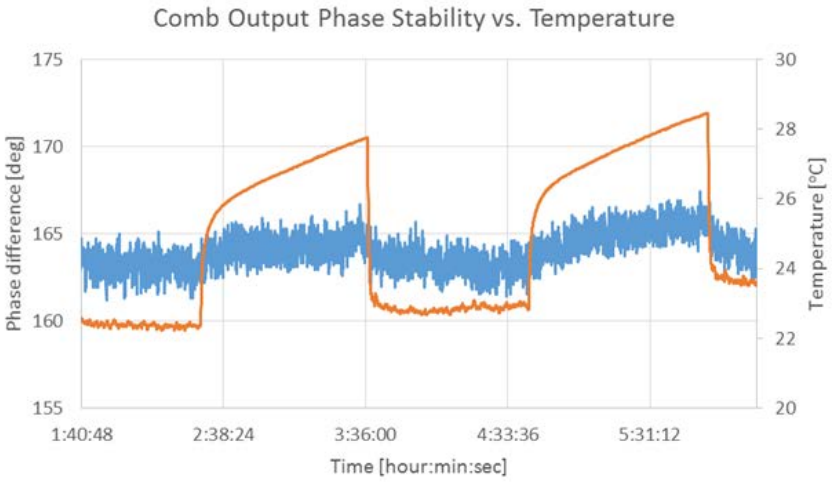
- Output power : -70 ~ -50 dBm @ 20-50 GHz



Main module's phase stability vs temperature

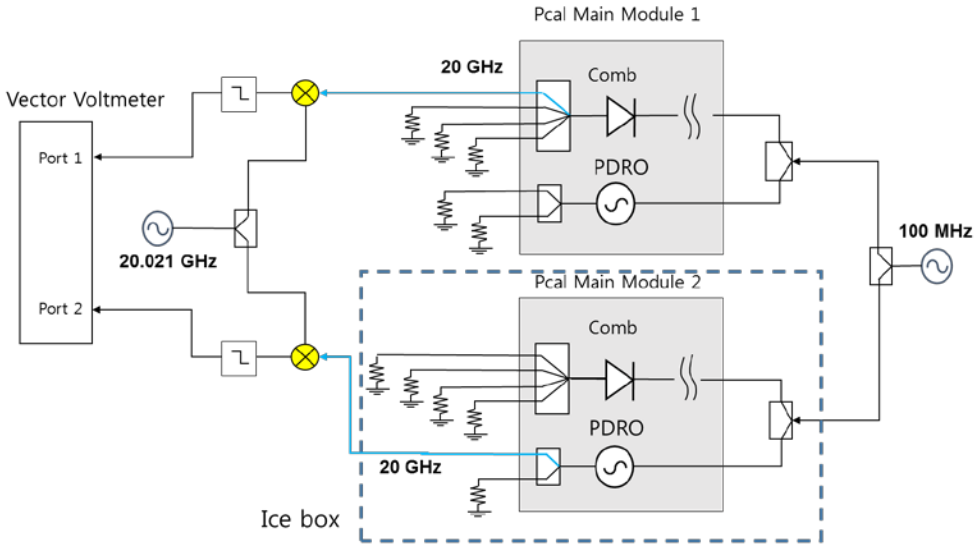
- Two Pcal main modules are prepared.
- Ice box is used for manual temperature change
- Comb output signal's phase stability vs outside's temperature : 0.6 deg/ ^{o}C (0.1 ps/ ^{o}C) @ 20 GHz

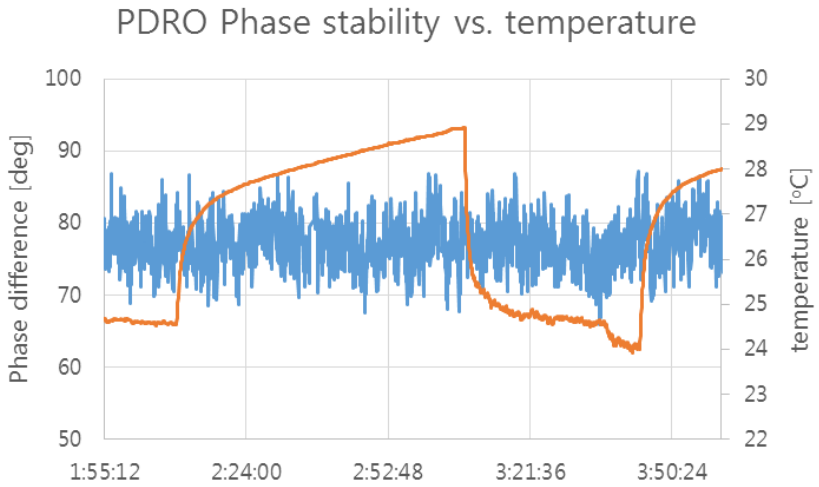




Main module's phase stability vs temperature

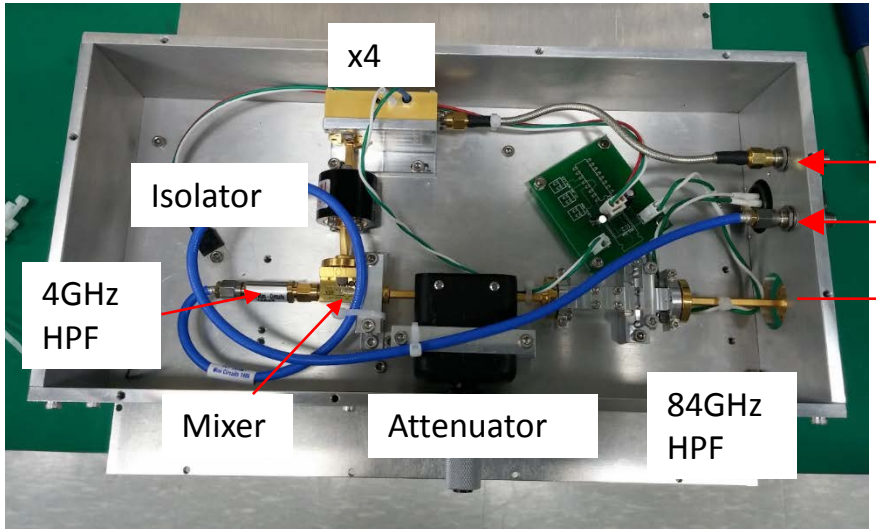
- Two Pcal main modules are prepared.
- Ice box is used for manual temperature change
- PDRO signal's phase changes was not shown when outside's temperature changes (because of large phase noise of oscillator) → < 0.7 deg/ ºC

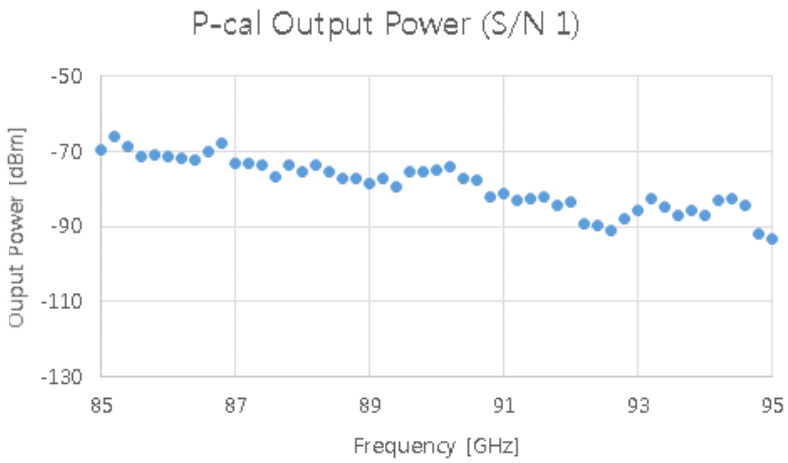




Fabrication and output spectrum of 86 GHz Up-converter

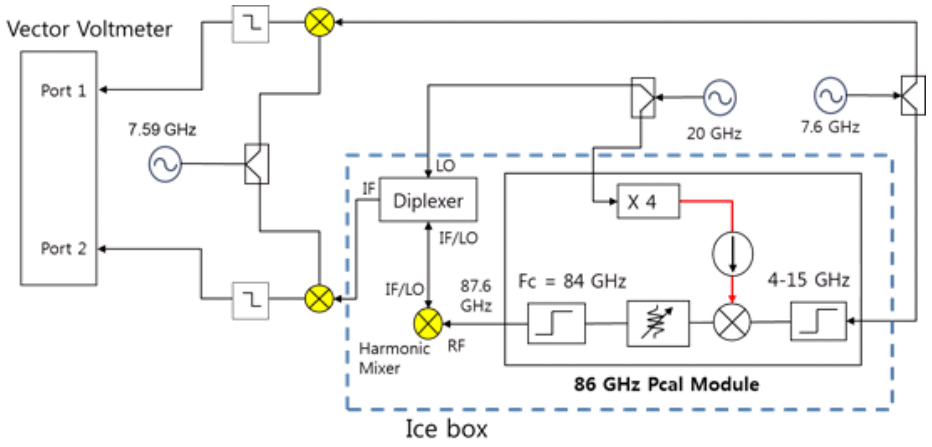
- No temperature control
- Output Power @ 85-95 GHz : -90 ~ -70 dBm

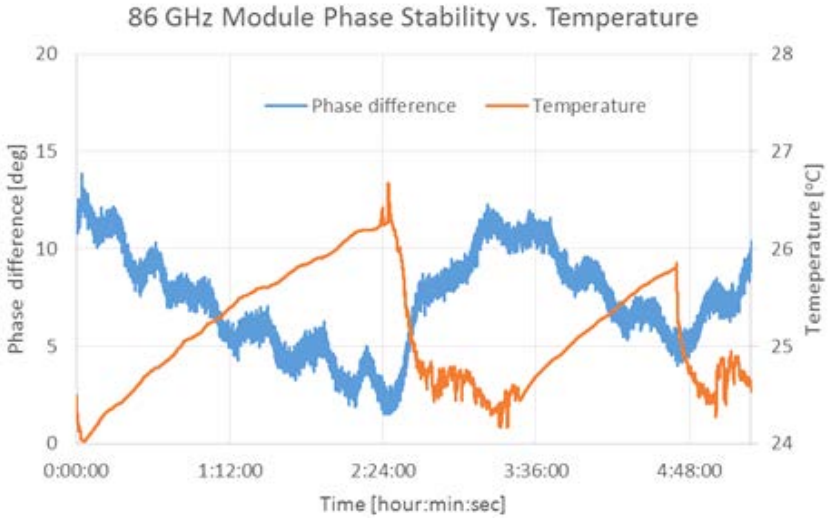




86 GHz Up-converter's phase stability vs temperature

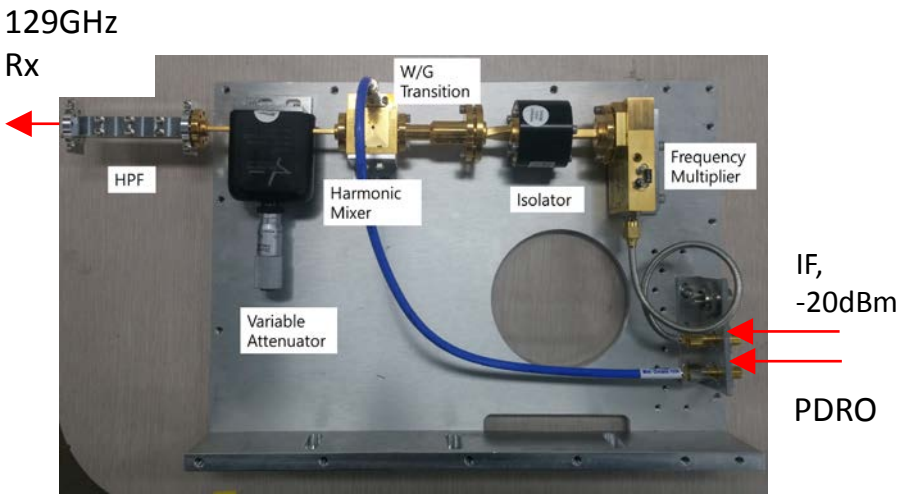
- No temperature control
- Comb output signal's phase stability vs outside's temperature : 5 deg/ ^{o}C @ 86 GHz

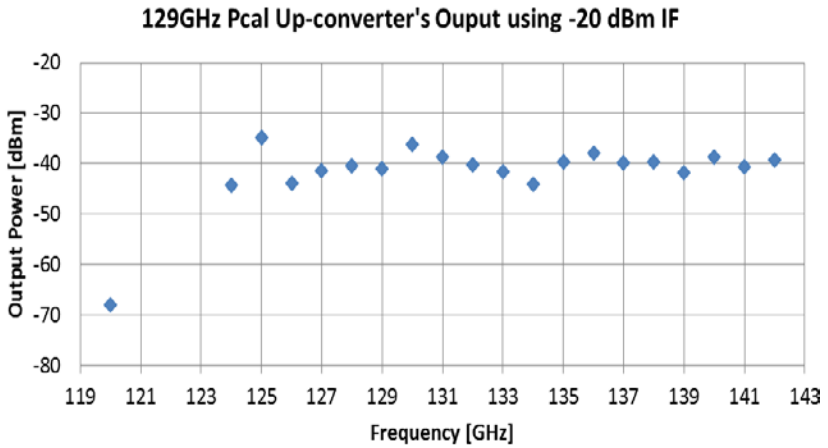




Fabrication and output spectrum of 129 GHz Up-converter

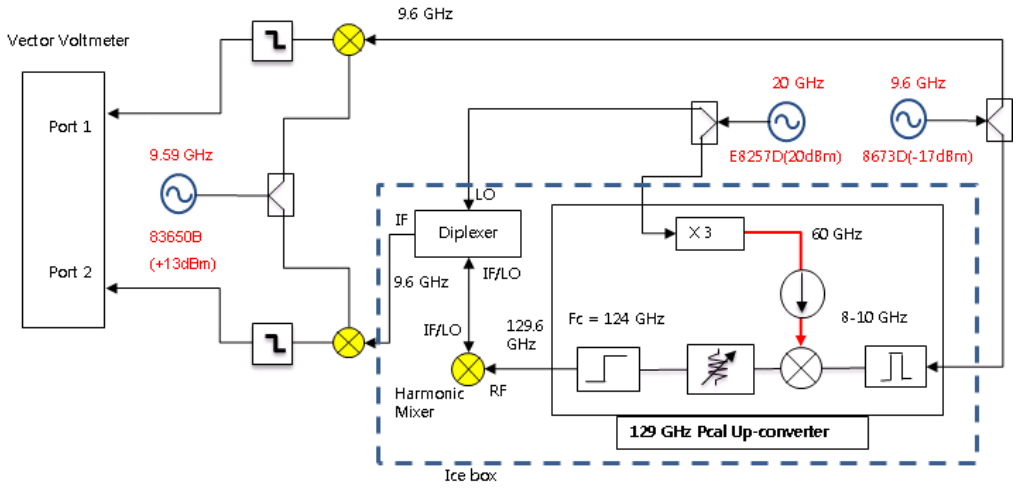
- No temperature control
- Output Power @ 129-142 GHz : -80 ~ -60 dBm (in case of -20 dBm comb signal input)

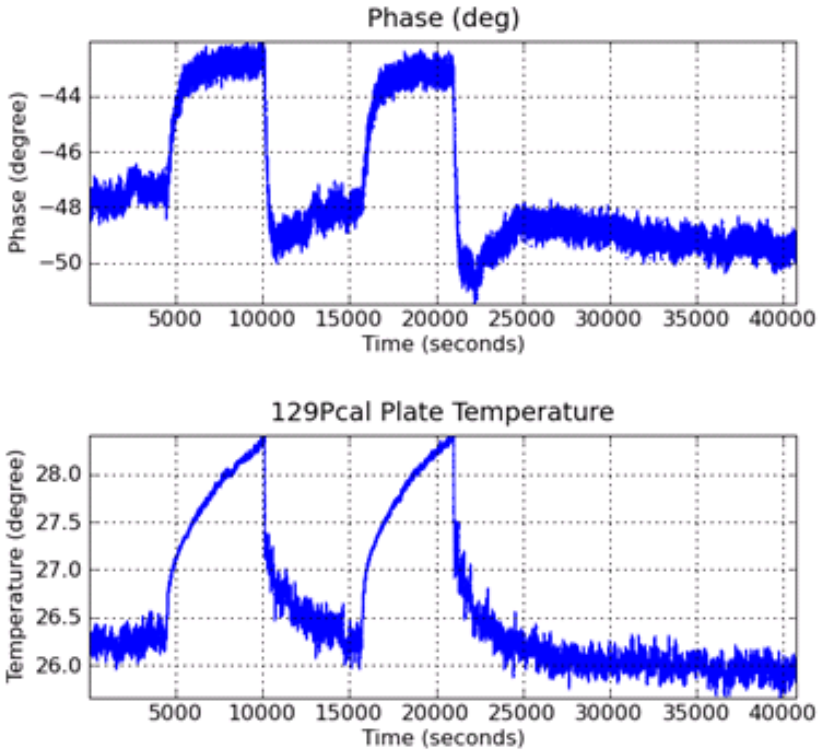




129 GHz Up-converter's phase stability vs. temperature

- No temperature control
- Comb output signal's phase stability vs outside's temperature : 3 deg/ ºC @ 129 GHz





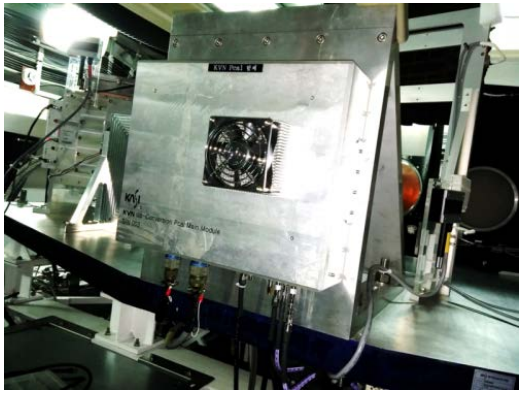
Summary of KVN Up-converter Pcal's stability

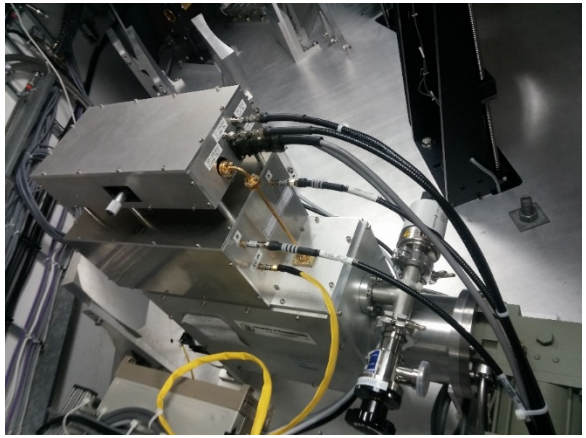
Frequency [GHz]	Phase stability requirement* [deg/℃]	Measured Phase stability** [deg/℃]	Injected signals
22	2.2	0.6 (0.08 ps/℃)	Comb
43	4.3	1.2 (0.08 ps/℃)	Comb
86	8.6	7.8 (0.22 ps/℃)	Up-converted comb
129	12.9	8.0 (0.18 ps/℃)	Up-converted comb

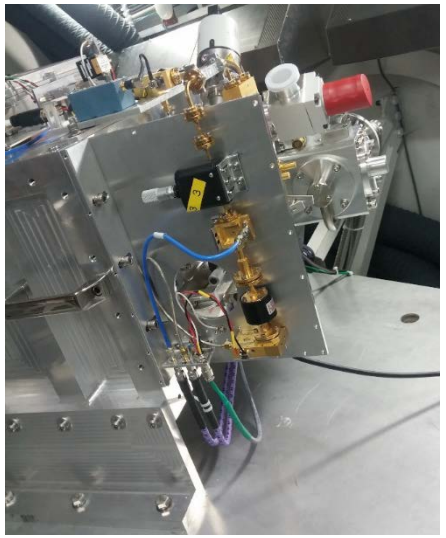
* 95% correlation efficiency

* Excluding transmission cable stability

KVN Up-conversion Pcal experiment-installation







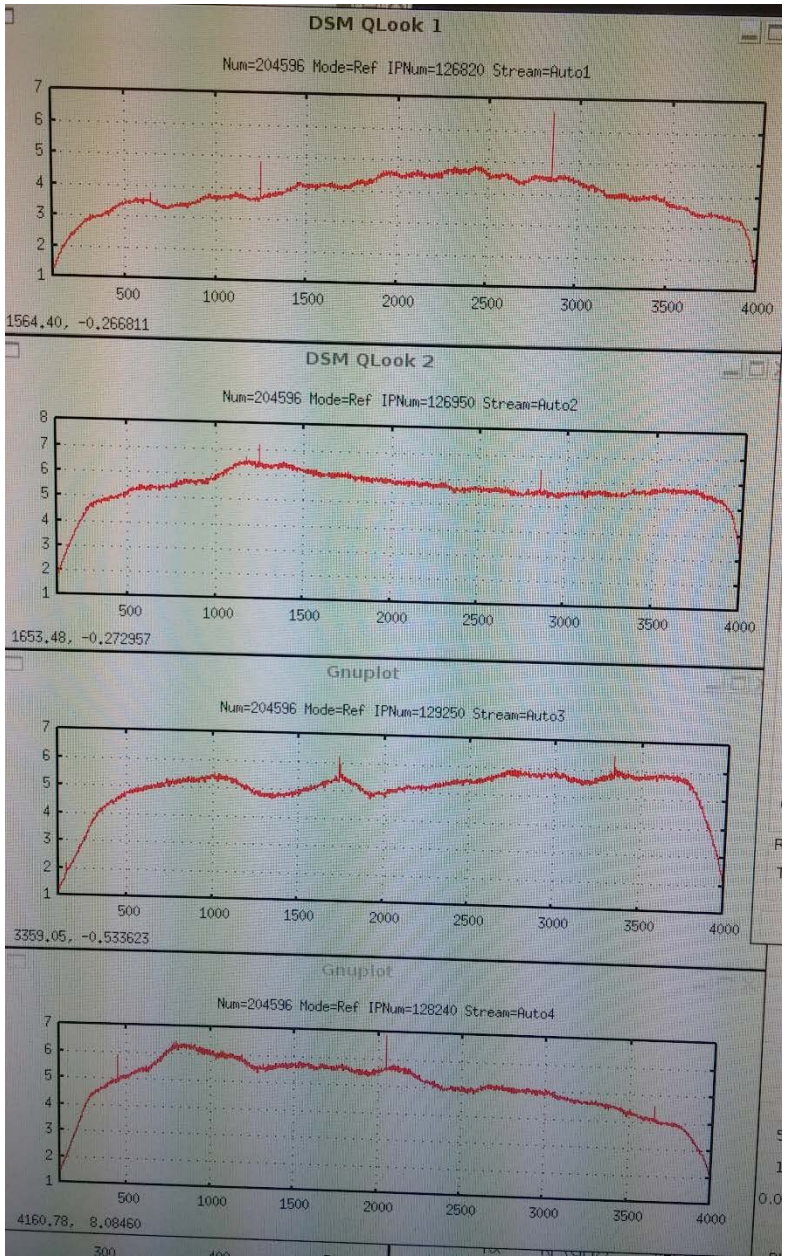
4 frequency pcal tone injection

22 GHz

43 GHz

86 GHz

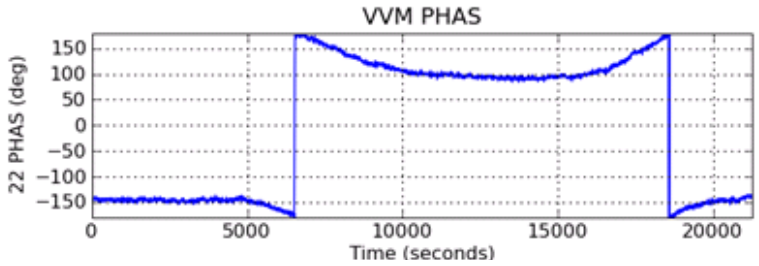
129 GHz



Phase stability measurement of 22, 43, 86 GHz Rx

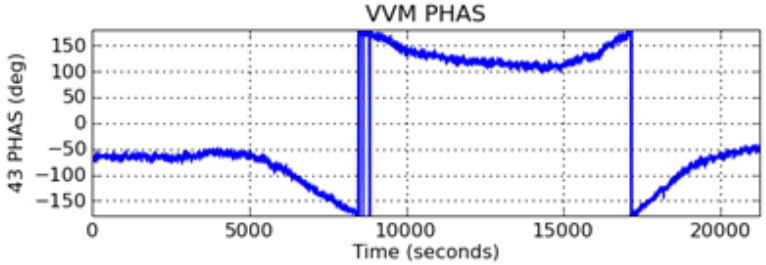
- We measured the phase changes of each receivers by Pcal injction, as the antenna EL angles changes from 90 deg --> 80 deg --> 60 deg --> 40 deg --> 20 deg --> 40 deg --> 60 deg --> 80 deg --> 90 deg

22 GHz



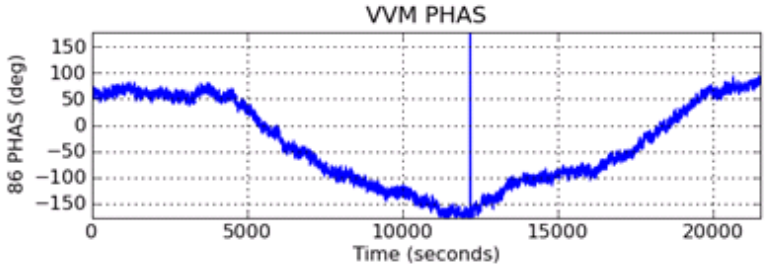
110 deg changes

43 GHz



160 deg changes

86 GHz



230 deg changes

EL:90 deg 40 20 40 80 90

Phase instability due to mainly 1st LO and 2nd LO

Summary & Further works

- Up-converted Pcal configuration was fabricated and tested for KVN mm-VLBI observation
- Pcal LO and fundamental comb are temperature-stabilized using commercial temperature controller(TED8040, Thorlabs)
- 22,43 GHz Pcal and 86 GHz Up-conversion Pcal system was installed on KVN FE.
- 129 GHz Pcal up-converter installation will be complete in the end of 2015.
- Reference source observation is required for calibration of Pcal's LO phase and the difference of path delay before the beginning of each observation.
- Other calibration system have to be checked inc. 100 MHz generator, Round trip system.