VHF testing 05 May 10-12

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Characterization of VAMP03 and VAMP04 at SAO (Kimberk)

LNA gain and noise temperature

Measurements made with noise figure meter at 196 MHz. 3.6V bias applied (~70 mA). Unused inputs/outputs terminated.

Input 1 feeds channel A output directly. Input 2 feeds channel B output directly.

VAMP03

LNA2 ON. LNA1 OFF

Cal \ Output	CH. A	CH. B
ON	19.46 dB / 63.5 K	19.69 dB / 64.8 K
OFF	19.46 dB / 47.2 K	19.68 dB / 49.0 K

Δ_A=16.3 K Δ_B=15.8 K

LNA2 OFF. LNA1 ON.

Cal \ Output	CH. A	CH. B
ON	19.62 dB / 68.3 K	19.32 dB / 66.3 K
OFF	19.61 dB / 47.0 K	19.31 dB / 45.0 K

Δ_A=21.3 K Δ_B=21.3 K

VAMP04

LNA2 ON. LNA1 OFF

Cal \ Output	CH. A	CH. B
ON	19.50 dB / 132.9 K	19.58 dB / 134.5 K
OFF	19.47 dB / 45.5 K	19.54 dB / 47.5 K

Δ_A=87.4 K Δ_B=87.0 K

LNA2 OFF. LNA1 ON.

Cal \ Output	CH. A	CH. B
ON	19.35 dB / 284.5 K	19.44 dB / 285.5 K
OFF	19.31 dB / 46.5 K	19.41 dB / 48.3 K

Δ_A=238.0 K Δ_B=237.2 K

Kim indicates uncertainty in Δ is on the order of ±5 K

VAMP03 G_{LNA1}=19.47±0.17 dB G_{LNA2}=19.57±0.13 dB T_{LNA}=47.1±1.6K
VAMP04 G_{LNA1}=19.38±0.06 dB G_{LNA2}=19.52±0.05 dB T_{LNA}=47.0±1.2K
Attenuation in Q-hybrid cross-paths differ by 0.3,0.1 dB in VAMP03, 04

RX gain and noise temperature

Terminate RX inputs and connect outputs individually to a ZFL-1000LN amplifier (~24 dB), HP8484A sensor and HP436A power meter. Current draw ~0.3 A.

VAMP03

Cal \ Output	LCP	RCP
ON	-29.65	-29.87
OFF	-29.95	-30.17

Δ_{LCP}=0.30 dB Δ_{RCP}=0.30 dB P_{LCPout}=-53.8 dBm P_{RCPout}=-54.0 dBm ± $\Delta G_{ZFL1000}$

For T_{amb}=293 K, T_{cal}=21 K

VAMP04

Cal \ Output	LCP	RCP
ON	-29.82	-29.44
OFF	-29.52	-29.75

Δ_{LCP}=0.30 dB Δ_{RCP}=0.31 dB P_{LCPout}=-53.7 dBm P_{RCPout}=-53.6 dBm ± $\Delta G_{ZFL1000}$

For T_{amb}=293 K, T_{cal}=21-22 K

P-band pass-thru losses

Test at 350 MHz.

VAMP03 Loss:	-3.67 (LCP)	-3.50 (RCP)	
VAMP04 Loss:	-3.67 (LCP)	-3.50 (RCP)	[too good to be true?]

Characterization of VAMP03 and VAMP04 in the AOC lab (Greenhill)

Terminate inputs. Outputs to an Agilent E4419B dual head P/M with a E4413 −70->+20 dBm power head.

Total output power

VAMP03

LCP total:	-55.7±0.02 dBm	RCP total:	-55.9 ±0.03 dBm
3 dB points:	168.0/249.3 MHz		166.0/255.3
Δ_{3dB} :	81.3 MHz		89.3 MHz
ρ_{3dB} :	135.8 dBm/Hz		135.4 dBm/Hz

Preliminary Y-factor Ambient/Cold

$T_{rx} = (T_{amb} - Y{*}T_{cold}) / (Y-1)$

T_1=295K	T_2=77K more or less. Determine via test rig later.		
LCP 2.70±0.03 nW	0.985±0.015 nW	Y=2.74	Trx=48.3K
RCP 2.58±0.03 nW	0.930±0.01 nW	Y=2.77	Trx=47.0K

T_1=295K+cal	T_2=77K+cal
LCP 2.85±0.03 nW	1.17±0.03 nW
RCP 2.72±0.03 nW	1.10±0.03 nW

Bob Hayward advises avoidance of P/M levels above −30 dBm due to nonlinearity (power levels increasingly too large with rising input power). Desirable operating range is −50 to −30 dBm for these power heads.

Final Y-factor Ambient/Cold

Place one ZFL-500 at the output of each VAMP channel. Gain calibration not required.

VAMP03

T=295K	T="77K"	T=295K @ end
LCP 845+-1 nW	320+-0.5 nW	846 nW √
RCP 825+-1 nW	311+-0.5 nW	825 nW √

T=295K+cal	T=77K+cal	T=295K+cal @ end
LCP 897+-1 nW	379+-0.5 nW	897 √
RCP 876+-1 nW	371+-0.5 nW	876 √

Y (amb/cold)	2.64 LCP	2.65 RCP
Y (amb/amb+cal)	1.06 LCP	1.06 RCP
Y (cold+cal/cold)	1.18 LCP	1.19 RCP
Y (amb+cal/cold+cal)	2.37 LCP	2.37 RCP

Ambient/cold measurement:	T_{rx} = 55.9 LCP	55.1 RCP
Addition of cold/cold+cal:	T_{cal}= 23.9 LCP	25.1 RCP

VAMP04

T=295K	T="77K"	T=295K @ end
LCP 863+-1 nW	328+-0.5 nW	---
RCP 892+-1 nW	338+-0.5 nW	---

T=295K+cal	T=77K+cal	T=295K+cal @ end
LCP 922+-1 nW	386+-0.5 nW	923 √
RCP 955+-1 nW	400+-0.5 nW	956 √

Y (amb/cold)	2.63 LCP	2.64 RCP
Y (amb/amb+cal)	1.07 LCP	1.07 RCP
Y (cold+cal/cold))	1.18 LCP	1.18 RCP

T_{rx} will be indentical to VAMP03.

Considerations

- T_{cold} is ~76 K at altitude

- $T_{follow\text{-}on}$ at input due to ambient components has not been taken into account.
  This adds 0.15 dB nominally (directional coupler) + a few hundredths for connector on FE of Rose box and for cable lengths. This needs to be measured in a test rig. Till then,
  T_{ff} = 10 ± 4 K (0.15±0.05 dB).
  T_{cold} = 86±4 K ⇒ T_{RX} = 41 ± 7 K But this is too low. Establish an upper limit.
  T_{cold} = 76 K ⇒ T_{RX} = 58 K

  41 ±7 K < T_{RX} < 58 K

- $T_{cal} = (T_{amb} + T_{RX}) * (Y(amb+cal) - 1)$
  VAMP03: 20.2±0.4 K < T_{cal} < 21.2 K
  VAMP04: 22.8±0.4 K < T_{cal} < 24.7 K

- $T_{cal} = (T_{cold} + T_{RX}) * (Y(cold+cal) - 1)$
  VAMP03: $22.9 < T_{cal} < 24.1$ K LCP 25.4 RCP. This reflects measurement error on Y.
  VAMP04: $22.9 < T_{cal} < 24.1$ K

  Adopt:
  VAMP03: $T_{cal} = 23 \pm 2$ K
  VAMP04: $T_{cal} = 24 \pm 1$ K

- Kimberk measurements of LNA stage with the NF meter $\Rightarrow T_{follow\text{-}on}$ for post-amp stage.
  $T_{LNA} = 47$ K
  $T_{RX} < 58$ K
  $0 < T_{follow\text{-}on} < 11$ K (liberal range)
  Expect $T_{follow\text{-}on}$ of just a few degrees at most, due to 20 dB gain of LNA.

Performance after installation VAMP03 (ant8/W4) VAMP04 (ant26/N12)

VAMP03 Spectrum analyzer sweeps at 4-m RX output

Terminate VAMP03 inputs. (100 kHz RBW on S/A.)

20 MHz ripple detected in VHF bandpass 2 dB p-p for both polarizations
Ripple peaks at ~189, 209, 229, 249 MHz, -93.0 to -91.0 dBm.

Out-of-band baseline: -105 dBm
Peak: -87.3 dBm

10 dB BW (LCP):	157-169 MHz	Δ=112 MHz
6 dB BW (LCP):	164.3-253.7 MHz	Δ=88.7 MHz

3 dB BW cannot be measured due to ripple.

$\int P_\nu$ (6 dB BW)	-64.1 dBm	-143.8 dBm/Hz
$\int P_\nu$ (10 dB BW)	-63.8 dBm	-144.2 dBm/Hz

Remove 4-m RX from signal path. Ripple disappears.

Now, VHF band peak:	195.3 MHz	-87.8 dBm
3 dB BW (LCP):	Δ=72.7 MHz @ -90.2 dBm	
6 dB BW (LCP):	Δ=93.3 MHz @ -93.0 dBm	
$\int P_\nu$ (6 dB BW):	-60.3 dBm	-139.3 dBm/Hz
$\int P_\nu$ (10 dB BW):	-60.0 dBm	-139.6 dBm/Hz

VAMP03 Total Power Measurements

Use 1 MHz filter pak and 2 ZFL-500 amplifiers in series. G=22 dB nominal.

Follow time-series. $\Delta_{cal\ on/off}$=0.24 dB. (0.26 dBm in lab)

Observe periodic & non periodic 1 dB spikes. Kick-test shows this is due to 4-m RX both polz! Remove 4-m RX. Observe 4 dB loss (LCP) across pass-thru used for the P-band and VHF band.

VAMP04 Spectrum analyzer sweeps at 4-m RX output

VAMP04 mounted on antenna 26, pad N12 (?)

Terminate VAMP04 inputs. (100 kHz RBW on S/A.)

20 MHz ripple detected in VHF bandpass 3 dB peak-peak for both polarizations.
Ripple peaks at ~168, 188, 208, 228, 248 MHz.

Remove 4-m RX from signal path.

LCP:
Out-of-band baseline: -105.0 dBm
Peak: -87.5 dBm

3 dB BW (LCP):	Curvature makes characterization difficult. Δ=74.0 MHz @ -89.8 dBm	
6 dB BW (LCP):	164.7-256.4 MHz	Δ=91.7 MHz @ -93.0 dBm
$\int P_\nu$ (3 dB BW)	-60.3 dBm	-139.0 dBm/Hz
$\int P_\nu$ (6 dB BW)	-59.7 dBm	-139.2 dBm/Hz

3 MHz 0.5 dB p-p ripple remains despite removal of 4-m RX.

Now, VHF band peak:	195.3 MHz	-87.8 dBm
3 dB BW (LCP):	Δ=72.7 MHz @ -90.2 dBm	
6 dB BW (LCP):	Δ=93.3 MHz @ -93.0 dBm	
$\int P_\nu$ (6 dB BW):	-60.3 dBm	-139.3 dBm/Hz
$\int P_\nu$ (10 dB BW):	-60.0 dBm	-139.6 dBm/Hz

VAMP04 Total Power Measurements

None. L-band measurements performed instead but no useful data obtained because insufficient absorber was placed in front of the feed.

Performance testing VAMP02 (ant6)

Tens of MHz ripple observed here too. Previsouly missed.

20 MHz, 3 dB p-p. Peaks at 168, 188, 208, 228 MHz (LCP)
18 MHz, 3 dB p-p. Peaks not recorded. RCP.

Remove 4-m RX from signal path. (Set S/A to 30 kHz RBW)

Peak: -98.00 dBm @ 226.3 MHz (flat top makes measurement difficult)
3 dB BW (LCP): Δ=72.0 MHz @ -101.3 dBm (169.6-240.7 MHz)
6 dB BW (LCP): Δ=86.7 MHz @ -104.1 dBm (162.6-249.3 MHz)
$\int P_v$ (3 dB BW): -66.7 dBm -145.3 dBm/Hz
$\int P_v$ (6 dB BW): -66.3 dBm -145.7 dBm/Hz

Add 4-m RX to signal path
Peak: -102.2 dBm @ 226.3 MHz
6 dB BW (LCP): Δ=90.7 MHz @ -107.2 dBm (162.2-252.9 MHz)
$\int P_v$ (6 dB BW): -69.7 dBm -149.3 dBm/Hz
BW through 4-m RX is wider due to peaks in 20/18 MHz ripple (e.g., 248 MHz)

No RCP measurement.

Relative strength of P-band and VHF
Peak: -93 dBm
3 dB BW (LCP): 302.2-340.2 MHz
6 dB BW (LCP): 300.7-341.3 MHz
$\int P_v$ (6 dB BW): -62.4 dBm -138.4 dBm/Hz

No RCP measurement

Residual bandpass ripple after removal of 4-m RX
3 MHz ripple, 1 dB pp.
Stable in amplitude and frequency over at least 3 minutes.
Attenuated by pad at S/A input.

With 4-m RX in signal path, place 3 and 6 dB pads at input and 3 dB pad at output.
18/20 MHz ripple is suppressed. 3 MHz ripple is reduced to 1.5 and 1 dB p-p, respectively.

Climb quad leg. Test padding of cables.

Full suppression of 3 MHz ripple requires 3 dB pad between superflex and heliax or 3 dB pad at VAMP02 output.

Full suppression of 20 MHz ripple requires 3 dB pad at 4-m box output, or bypass switch.

Can we live with the 4-m RX box in the signal path? NB: Instability, 4 dB loss.

First light for VAMP03 (ant 8)

Set spectrum analyzer to RBW 10 kHz and VBW 10 kHz. Span 0.
Insert 1 MHz filter pak in the signal path. Toggle cal with the feeds attached.

Cal	OFF (dBm)	ON (dBm)	Δ (dB)	
LCP:	-69.35	-68.61	0.74	WHAT? 100K sky?
RCP:	-68.6	-68.35	0.25	WHAT? 300K sky?

Swap cables @ RX input

LCP:	-71.50	-71.33	0.17	Order reversed. Feed/cable related?
RCP:	-72.37	-71.65	0.72	Order reversed. Feed/cable related?

Terminate inputs to establish baseline performance

LCP:	-73.71	-73.40	0.31	Nominal.
RCP:	-73.90	-73.52	0.38	Nominal.

Outstanding questions

Why are the cals unequal when mounted and attached to the dipoles?
Should the Q-hybrid preclude inequality?
A source of circular polarization? The sun?
Interaction with the tensioning cables that are parallel to one of the two dipoles?
What might drive the Q-hybrid to not perform a 3 dB split of the input signal paths?

Further testing should be done as follows:

- Night-time total power measurement of VAMP03/04 with a feed attached.
  - Imbalance in cal sq.wave indicates the problem is not astronomical
  - Tilt antenna elevation to rule out polarized RFI. Watch trace on one polz.
  - Optional day-time total power measurement with azimuth rotation of antenna.
- Total power measurement of VAMP03/04 with ONE/THE OTHER RX input terminated.
  - Differing RX temps will enable assessment of Q-Hybrid performance.
- Insert 3 dB SMA pad at both RX inputs simultaneously. Measure Tcal traces. (S/wave)
- Match tests for feeds on antennas 8 and 26.