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

<table>
<thead>
<tr>
<th>Cal \ Output</th>
<th>CH. A</th>
<th>CH. B</th>
</tr>
</thead>
<tbody>
<tr>
<td>ON</td>
<td>19.46 dB / 63.5 K</td>
<td>19.69 dB / 64.8 K</td>
</tr>
<tr>
<td>OFF</td>
<td>19.46 dB / 47.2 K</td>
<td>19.68 dB / 49.0 K</td>
</tr>
</tbody>
</table>

$\Delta_A=16.3$ K $\Delta_B=15.8$ K

LNA2 OFF. LNA1 ON.
<table>
<thead>
<tr>
<th>Cal \ Output</th>
<th>CH. A</th>
<th>CH. B</th>
</tr>
</thead>
<tbody>
<tr>
<td>ON</td>
<td>19.62 dB / 68.3 K</td>
<td>19.32 dB / 66.3 K</td>
</tr>
<tr>
<td>OFF</td>
<td>19.61 dB / 47.0 K</td>
<td>19.31 dB / 45.0 K</td>
</tr>
</tbody>
</table>

$$\Delta_A = 21.3 \text{ K} \quad \Delta_B = 21.3 \text{ K}$$

**VAMP04**
LNA2 ON, LNA1 OFF

<table>
<thead>
<tr>
<th>Cal \ Output</th>
<th>CH. A</th>
<th>CH. B</th>
</tr>
</thead>
<tbody>
<tr>
<td>ON</td>
<td>19.50 dB / 132.9 K</td>
<td>19.58 dB / 134.5 K</td>
</tr>
<tr>
<td>OFF</td>
<td>19.47 dB / 45.5 K</td>
<td>19.54 dB / 47.5 K</td>
</tr>
</tbody>
</table>

$$\Delta_A = 87.4 \text{ K} \quad \Delta_B = 87.0 \text{ K}$$

LNA2 OFF, LNA1 ON.

<table>
<thead>
<tr>
<th>Cal \ Output</th>
<th>CH. A</th>
<th>CH. B</th>
</tr>
</thead>
<tbody>
<tr>
<td>ON</td>
<td>19.35 dB / 284.5 K</td>
<td>19.44 dB / 285.5 K</td>
</tr>
<tr>
<td>OFF</td>
<td>19.31 dB / 46.5 K</td>
<td>19.41 dB / 48.3 K</td>
</tr>
</tbody>
</table>

$$\Delta_A = 238.0 \text{ K} \quad \Delta_B = 237.2 \text{ K}$$

Kim indicates uncertainty in $$\Delta$$ is on the order of $$\pm 5 \text{ K}$$

**VAMP03**
$$G_{LNA1} = 19.47 \pm 0.17 \text{ dB} \quad G_{LNA2} = 19.57 \pm 0.13 \text{ dB} \quad T_{LNA} = 47.1 \pm 1.6 \text{ K}$$

**VAMP04**
$$G_{LNA1} = 19.38 \pm 0.06 \text{ dB} \quad G_{LNA2} = 19.52 \pm 0.05 \text{ dB} \quad T_{LNA} = 47.0 \pm 1.2 \text{ K}$$

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**

<table>
<thead>
<tr>
<th>Cal \ Output</th>
<th>LCP</th>
<th>RCP</th>
</tr>
</thead>
<tbody>
<tr>
<td>ON</td>
<td>-29.65</td>
<td>-29.87</td>
</tr>
<tr>
<td>OFF</td>
<td>-29.95</td>
<td>-30.17</td>
</tr>
</tbody>
</table>

$$\Delta_{LCP} = 0.30 \text{ dB} \quad \Delta_{RCP} = 0.30 \text{ dB} \quad P_{LCP_{out}} = -53.8 \text{ dBm} \quad P_{RCP_{out}} = -54.0 \text{ dBm} \quad \pm \Delta G_{ZFL1000}$$

For $$T_{amb} = 293 \text{ K}$$, $$T_{cal} = 21 \text{ K}$$

**VAMP04**

<table>
<thead>
<tr>
<th>Cal \ Output</th>
<th>LCP</th>
<th>RCP</th>
</tr>
</thead>
<tbody>
<tr>
<td>ON</td>
<td>-29.82</td>
<td>-29.44</td>
</tr>
<tr>
<td>OFF</td>
<td>-29.52</td>
<td>-29.75</td>
</tr>
</tbody>
</table>

$$\Delta_{LCP} = 0.30 \text{ dB} \quad \Delta_{RCP} = 0.31 \text{ dB} \quad P_{LCP_{out}} = -53.7 \text{ dBm} \quad P_{RCP_{out}} = -53.6 \text{ dBm} \quad \pm \Delta G_{ZFL1000}$$

For $$T_{amb} = 293 \text{ K}$$, $$T_{cal} = 21 - 22 \text{ K}$$
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 MHz
Δ3dB:  81.3 MHz  89.3 MHz
ρ3dB:  135.8 dBm/Hz  135.4 dBm/Hz

Preliminary Y-factor Ambient/Cold

\[ T_{rx} = \frac{(T_{amb} - Y \cdot T_{cold})}{(Y-1)} \]

\[ T_1=295K \quad T_2=77K \text{ more or less. Determine via test rig later.} \]
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

\[ T_1=295K+\text{cal} \quad T_2=77K+\text{cal} \]
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
\[ T=295K \quad T="77K" \quad T=295K \text{ @ end} \]
LCP 845+-1 nW 320+-0.5 nW 846 nW √
RCP 825+-1 nW 311+-0.5 nW 825 nW √
Considerations

- $T_{\text{cold}}$ is $\sim 76$ K at altitude

- $T_{\text{follow-on}}$ 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, $T_{\text{ff}} = 10 \pm 4$ K (0.15±0.05 dB).
  
  $T_{\text{cold}} = 86\pm4$ K $\Rightarrow T_{\text{RX}} = 41 \pm 7$ K But this is too low. Establish an upper limit.
  
  $T_{\text{cold}} = 76$ K $\Rightarrow T_{\text{RX}} = 58$ K

**41 ±7 K < T_{\text{RX}} < 58 K**

- $T_{\text{cal}} = (T_{\text{amb}} + T_{\text{RX}}) \times (Y(\text{amb+cal}) - 1)$
  
  VAMP03: $20.2\pm0.4$ K $< T_{\text{cal}} < 21.2$ K
  VAMP04: $22.8\pm0.4$ K $< T_{\text{cal}} < 24.7$ K
• \[ T_{\text{cal}} = (T_{\text{cold}} + T_{\text{RX}}) \times (Y_{\text{cold+cal}} - 1) \]

VAMP03: 22.9 < \( T_{\text{cal}} \) < 24.1 K LCP, 25.4 RCP. This reflects measurement error on Y.

VAMP04: 22.9 < \( T_{\text{cal}} \) < 24.1 K

Adopt:

VAMP03: \( T_{\text{cal}} = 23\pm2 \) K

VAMP04: \( T_{\text{cal}} = 24\pm1 \) K

• Kimberk measurements of LNA stage with the NF meter \( \Rightarrow \) \( T_{\text{follow-on}} \) for post-amp stage.

\( T_{\text{LNA}} = 47 \) K

\( T_{\text{RX}} < 58 \) K

\( 0 < T_{\text{follow-on}} < 11 \) K (liberal range)

Expect \( T_{\text{follow-on}} \) 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 \(\Delta=112\) MHz

6 dB BW (LCP): \(164.3-253.7\) MHz \(\Delta=88.7\) MHz

3 dB BW cannot be measured due to ripple.

\[ \int P_\nu (6 \text{ dB BW}) = -64.1 \text{ dBm} \quad -143.8 \text{ dBm/Hz} \]

\[ \int P_\nu (10 \text{ dB BW}) = -63.8 \text{ dBm} \quad -144.2 \text{ dBm/Hz} \]

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

Now, VHF band peak: \(195.3\) MHz, \(-87.8\) dBm

3 dB BW (LCP): \(\Delta=72.7\) MHz @ \(-90.2\) dBm

6 dB BW (LCP): \(\Delta=93.3\) MHz @ \(-93.0\) dBm

\[ \int P_\nu (6 \text{ dB BW}) = -60.3 \text{ dBm} \quad -139.3 \text{ dBm/Hz} \]

\[ \int P_\nu (10 \text{ dB BW}) = -60.0 \text{ dBm} \quad -139.6 \text{ dBm/Hz} \]

**VAMP03 Total Power Measurements**

Use 1 MHz filter pak and 2 ZFL-500 amplifiers in series. \(G=22\) dB nominal.
Follow time-series. $\Delta_{\text{cal on/off}} = 0.24$ 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. $\Delta = 74.0$ MHz @ -89.8 dBm
6 dB BW (LCP): 164.7-256.4 MHz $\Delta = 91.7$ MHz @ -93.0 dBm
$\int P_{\nu}(3 \text{ dB BW})$: -60.3 dBm -139.0 dBm/Hz
$\int P_{\nu}(6 \text{ dB BW})$: -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): $\Delta = 72.7$ MHz @ -90.2 dBm
6 dB BW (LCP): $\Delta = 93.3$ MHz @ -93.0 dBm
$\int P_{\nu}(6 \text{ dB BW})$: -60.3 dBm -139.3 dBm/Hz
$\int P_{\nu}(10 \text{ dB BW})$: -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. Previsously 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)
\[ \int P(3 \text{ dB BW}) \] = -66.7 dBm -145.3 dBm/Hz
\[ \int P(6 \text{ dB BW}) \] = -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)
\[ \int P(6 \text{ dB BW}) \] = -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
\[ \int P(6 \text{ dB BW}) \] = -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.

<table>
<thead>
<tr>
<th>Cal</th>
<th>OFF (dBm)</th>
<th>ON (dBm)</th>
<th>Δ (dB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>LCP</td>
<td>-69.35</td>
<td>-68.61</td>
<td>0.74</td>
</tr>
<tr>
<td>RCP</td>
<td>-68.6</td>
<td>-68.35</td>
<td>0.25</td>
</tr>
</tbody>
</table>

WHAT? 100K sky?

| LCP | -69.35    | -68.61   | 0.74   |
| RCP | -68.6     | -68.35   | 0.25   |

WHAT? 300K sky?

Swap cables @ RX input

| LCP | -71.50    | -71.33   | 0.17   |
| 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   |
| 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 elvation to rule out polarized RFI. Watch trace on one polz.
- 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.