WVR’s for Quasar network

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Structure of presentation

- **Main tasks**
- **Technical features**
- **Retrieval algorithm**
- **Metrology problems**
- **Preliminary results: comparison ZWD of GNSS, WVR, VLBI**
- **Nearest plans**
WVR’s - additional instruments for "Quasar“ colocation sites

WVR’s will be used for:

- practically real-time ZWD monitoring,
- IWV / PWV monitoring
- VLBI data processing
WVR prototypes are installed in “Svetloe” observatory

WVR1 (since 2011)

WVR2 (June) 2013

Operation mode:
- zenith direction (WVR2)
- fully steerable (WVR1, WVR3, 4, 5)

WVR’s provide quasi-real time data rate: one count every 6 seconds
Basic requirements for WVR

- **Presence of precise MW thermostable reference loads**
- **Maximum temperature stability of all RF units**
- **Temperature control (and logging) of all critical points**
- **Total gain variation control of the RF units**
- **Operation mode:** “total power” + fast switching (1kHz) of input signals
- **Guaranteed linearity of square low detector for input signals**
- **“Industry” - standard electronics – cheap and reliable**
- **Unified design of radiometric units**
- **Remote access and control facilities**
Unified thermo stable radiometric blocks

1. DAS module: 16bit resolution ADC, 100kHz data rate, data processing (1s integration for all signals etc.)
2. Ferrite X-switch driver, 3 precise digital thermostat drivers, 3 temperature sensors.
3. RS 485

Up to 20 parameters are placed into WVR log-file, 5MB/d
**WVR3 design – particular attention on temperature stability**

**WVR3. (New!)**

<table>
<thead>
<tr>
<th>Specifications</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency bandwidth 3 dB, GHz</td>
<td></td>
</tr>
<tr>
<td>Channel A</td>
<td>20.7±0.25</td>
</tr>
<tr>
<td>Channel B</td>
<td>31.4±0.25</td>
</tr>
<tr>
<td>Noise temperature, at the input, K,</td>
<td></td>
</tr>
<tr>
<td>A</td>
<td>150</td>
</tr>
<tr>
<td>B</td>
<td>280</td>
</tr>
<tr>
<td>Gain, up to Sq. law detector, dB</td>
<td></td>
</tr>
<tr>
<td>A</td>
<td>65</td>
</tr>
<tr>
<td>B</td>
<td>65</td>
</tr>
<tr>
<td>Brightness temper. sensitivity, mK, t = 1s (Ta=10K)</td>
<td></td>
</tr>
<tr>
<td>A</td>
<td>12</td>
</tr>
<tr>
<td>B</td>
<td>25</td>
</tr>
<tr>
<td>Relative gain instability, 24 h, , % , less than</td>
<td></td>
</tr>
<tr>
<td>HPBW(-3dB) / BW(-35dB)</td>
<td>0.03</td>
</tr>
<tr>
<td>Angular resolution Az, El, arc min.</td>
<td>6° / 22°</td>
</tr>
</tbody>
</table>
“Tip-cal.” is used for accurate measurement of calibration signals

WVR 1 in “Svetloe”

Temperature of “Cold” loads:

Channel A “Cold” load: \( T_{CA} = 313.02 \pm 0.02 \text{ K (r.m.s. , on 1.5 year interval)} \)

Channel B “Cold” load: \( T_{CB} = (313.38 \pm 0.02) \text{ K (r.m.s. , on 1.5 year interval)} \)

\[
\tau = f\left(\frac{1}{\cos(Z)}\right) \quad \text{opacity, “tip-cal.”}
\]

Calibration signals referred to the WVR input:

\[
T_{KA} = T_{CA} + T_{recA} (T_{amb})
\]

\[
T_{KB} = T_{CB} + T_{recB} (T_{amb})
\]

\( T_{recA} (T_{amb}) \) – receiver noise temperature depends on \( T_{amb} \).
Tip-cal. results made during the period of 10 months

### Ambient temperature interval:

\[ \text{T}_{\text{amb}}: -20^\circ\text{C} \div +20^\circ\text{C} \]

### Mean value of calibration signal \( T_{kA}, K, \) channel A

\[ y = 0.0498x + 430.22 \]
\[ R^2 = 0.8942 \]

### WVR1:

\[ T_{kA} = 0.0498 \cdot T_{\text{amb}} + 430.22 \]

August 2012 – June 2013

### Ambient temperature interval:

\[ \text{T}_{\text{amb}} : -20^\circ\text{C} \div +20^\circ\text{C} \]

### Mean value of calibration signal

\[ T_{\text{rec.A}} (T_{\text{amb}}) = (0.0498 \cdot T_{\text{amb}} + 430.22) - T_{cA} \]
Retrieval algorithm

\[
\{T_{bA}, T_{bB}\} \rightarrow IWV(P, T) \rightarrow ZWD \\
ZWD = \left(0.106 + \frac{1722}{T_{eff}}\right) \cdot IWV \quad [1,2],
\]

L: [cm], IWV: [g/cm²], meteo: P: [hPa], T: [K]

\(T_{eff}, [K]\) – atmosphere mean temperature (model based on radiosonde profiles)

Now \(T_{eff}\) can be measured (!) by T-profiler (MTP-5, ATTEX)

Capacitive rain sensor data are used for WVR data correction

Reference:


Metrology: mean atmosphere temperature measurement + calibration IWV

“Svetloe”
27 Feb 2014, (UT: 05:20), T(h)

Atmosphere temperature profiler MTP-5:

http://mtp5.ru/

Measurements of T(h) with MTP-5:

T(h) → Teff
Data processing: structure of software package

- Meteo parameters + rain intensity
  2014-02-19 00:00:00 ...
  2014-02-19 00:01:00 ...

- WVR's data
  2014-02-19 00:00:00 ...
  2014-02-19 00:00:05 ...

Software

- ASCll
- Java
- XML

- Loader
- Publisher
- Compiler

- Data base (binary)

- Source data format
- Algorithm for calculating ZWD, ZDD, IWV, etc...
- Report format

The magnitudes of ZWD, ZDD, IWV, etc.

2014-02-19 00:00:00 ...
2014-02-19 00:01:00 ...
...
r.m.s. of \( dL \sim 3 \text{ mm} \) \hspace{1cm} (dL= ZWD(WVR1)- ZWD(GNSS))
"Svetloe" ZWD (WVR1- GNSS)
Bias: 1mm, r.m.s. ~ 5 мм, (~25% data removed)
Small temperature dependence

Interval: from 2013-01-13 to 2013-11-11 (301 days)
(~20% data removed : rainfall, snowfall, maintenance)
Experimentally confirmed results

WVR1:

- *Stable metrological parameters for a year period*
- *large interval between calibrations*
- *low operational expenses*
- *continuous, reliable, maintenance-free operation for several months interval*

Nearest plans:

- Installation MTP-5 in “Zelenchukskaya”
- Installation WVR’s in “Zelenchukskaya” and “Badary”
Thank you for your attention!