Long-term stability of an SiGe HBT-based active cold load

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Radiometer calibration onboard a satellite

Reference sources

External target:
- cold sky, pole...

Internal reference:
- passive termination, noise diodes ...

**Cold source:** Low value of noise temperature (< target brightness temperature) + Long-term stability

Alternative solution: Active Cold Load (ACL)

=> Significant improvement (> 40%) in radiometric resolution has been reported at L-band (with traditional noise injection radiometer)
### Active cold loads

<table>
<thead>
<tr>
<th>Year</th>
<th>Author</th>
<th>Technology</th>
<th>Frequency</th>
<th>Noise temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td>1981</td>
<td>R.H. Frater</td>
<td>GaAs MESFET</td>
<td>1.4 GHz</td>
<td>50 K</td>
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<td>1997</td>
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<td>P.M. Buhles</td>
<td>0.15 μm GaAs MHEMT</td>
<td>2-10 GHz, 10-26 GHz</td>
<td>90 K, 125K</td>
</tr>
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<td>2009</td>
<td>N. Skou</td>
<td>GaAs PHEMT</td>
<td>10.69 GHz</td>
<td>77 K</td>
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<td>2010</td>
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-> several technologies, topologies and frequency ranges: **FET-based ACL**

**SiGe HBT**: low cost, low excess noise: feasibility ?
I – ACL implementation

1. Topology
2. Results

II – Radiometer for long-term stability measurements

1. Test-bed
2. Characteristics

III – Stability results

1. Short-term
2. Long-term

Conclusion
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Technical specifications:

- Frequency band: 1400 – 1427 MHz
- Return loss > 30 dB
- Noise temperature < 80 K
- Stability: to be evaluated

Active device:

SiGe HBT from Infineon Technologies (BFP640 – SOT343 package)

\[ T_{\text{min}} < 40 \text{ K} \]
Electrical circuit:

- 0.635 mm alumina substrate
- Surface Mount Components
- 50 Ω microstrip lines

Bias stability:
- Resistive collector-to-base circuit
- Adjustable voltage regulator
2. Results

For \( I_c = 5.6 \) mA and \( V_{cc} = 1.12 \) V

- Sensitivity test of temperature variations: \( \approx 0.3 \) K/°C
  (ex: GaAs FET-based ACL: 0.35 and 0.38 K/°C)

Reflection coefficient < -35 dB
Noise temperature < 66 K
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1. Test-bed

Dedicated radiometer: two-load radiometer with noise injection

- measurements errors due to power gain variations are reduced

![Diagram of a radiometric setup](attachment:image.png)

**Typical measurement cycle**

- $V_0$
- $V_1$
- $V_2$

$\tau_0$, $\tau_1$, $\tau_2$
1. Test-bed

- DAQ U2351A from Agilent
- Thermistors for temperature control
1. Test-bed

**Coaxial switch:**
- Insertion loss: 0.04 dB
- Isolation: > 120 dB

**LNA + Filter:**
- Gain: > 60 dB
- Noise Bandwidth: 60 MHz
- Noise temperature: 40 K

![Diagram showing the test-bed setup with LNA, Filter, Coaxial switch, and DAQ device connected through Thermistors and Command circuit.](image-url)
1. Test-bed

Square-law detector:
- Tunnel diode
- Responsivity: 1 mV/µW à 1.4GHz
- Noise: 2 nV/√Hz à 100Hz
Radiometer for long-term stability measurements

1. Test-bed

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Low-noise voltage amplifier:
- Gain: 80 dB
- Noise floor: 1 nV/√Hz
1. Test-bed

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- Noise floor: 1 nV/VHz

Low-pass filter (RC circuit)
- Time constant: 5 ms
Radiometer for long-term stability measurements

1. Test-bed

Noise injection:
- Excess noise ratio of 15.6 dB at 1.4 GHz
- Coupler: 16 dB
- Noise temperature: \( T_2 \approx 280K \)
1. Test-bed

-> in order to limit the impact of temperature variations, we realize temperature stabilized enclosure:

- ACL temperature $\approx 38.4^\circ C$

- ACL temperature variations:
  $< 0.01 ^\circ C$ during 1 day
  $< 0.03 ^\circ C$ during 4.5 months

10 mm- thick aluminum enclosure
+ 50 mm-thick extruded polystyrene
+ Temperature control circuit
2. Characteristics

ACL noise temperature:

\[ T_n = T_0 - L \left( \frac{V_0 - V_1}{V_2 - V_1} \right)^2 T \]

Important characteristics:

- low value for L
- \( V_0 \) and \( V_2 \) close
- smallest variance values; depend on integration time
2. Characteristics

Allan variance:

\[ \sigma^2_y(\tau) = \frac{1}{2} \langle (\bar{y}_{n+1} - \bar{y}_n)^2 \rangle \]

Conditions:
- \( T^\circ_{\text{amb}} \approx 38.4°C \)
- Maximum deviation < 0.01°C
- Period = 150 min

Optimum integration time:
\( \tau_0 = 50 \text{ s} \)
\( \tau_1 = 15 \text{ s} \)
\( \tau_2 = 30 \text{ s} \)

- Sensitivity < 31mK
- Stability < 25mK for a total integration time of 95s
I – ACL implementation

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Conclusion
1. Short-term

Characteristics:

- Mean: 87.48 K
- Standard deviation: 32 mK
- Maximum deviation: 0.205 K
2. Long-term

ACL noise temperature:
- Maximum deviation < 0.35 K
- Slope : -2.1 mK/day

⇒ extrapolated stability < 1 K/year
I – ACL implementation

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Conclusion
Conclusion

**ACL**

- Reflection coefficient < -35 dB
- Noise temperature < 66 K

**Radiometer**

- Sensitivity < 31 mK
- Stability < 25 mK for a total integration time of 95 s
- Long-term stability (4.5 months):
  - Gain: maximum deviation < 0.03 dB
  - Receiver noise temperature: maximum deviation < 1 K
  - Physical temperature variations < 0.03°C

**Long term stability** (4.5months)

- Maximum deviation < 0.35 K
- Slope: -2.1 mK/day ➞ extrapolated stability < 1 K/year

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Thank you for your attention