Development of Integrated Receiver for Radio Astronomy

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Development of Integrated Receiver for Radio Astronomy

- Superconducting Integrated Receiver of 500-650 GHz
- New applications of Integrated Receiver
- Development of flux-flow oscillator (FFO) for 250-400 GHz
- Development and testing circuit including FFO, SIS and Harmonic Mixers.
- Calculation and experimental results
- Summary
Superconducting Integrated Receiver
Superconducting Integrated Receiver with phase-locked FFO

Success in TELIS project: 500-650 GHz

Receiver Microcircuit 4x4 mm
New applications of Integrated Receiver
New applications of Integrated Receiver (1)

“Millimetron” – Russian Space Agency ( > 2017)
12 m cryogenic mirror; $\lambda = 0.01 - 20$ mm.
New applications of Integrated Receiver (2)

ESPRIT – Exploratory Submm Space Radio-Interferometric Telescope

- Telescope sizes ~ 3.5 meter; off-axis
- Number of elements $N = 6$ (15 baselines)
- Projected baselines 200 - 1000 meter
- Frequencies:
  Spots in the range 0.5 – 6 THz
- Front Ends - (0.5 – 1.5 THz): SIS mixers, multiplier LO / $\text{SIR} = \text{FFO} + \text{SIS} + \text{HM}$
  (1.5 – 6 THz) HEB mixers, QCL as LO
- System temperature $< 1000$ K
- IF bandwidth $> 4$ GHz (goal 8 GHz)

The six elements of ESPRIT in an Ariane 5
New applications of Integrated Receiver (3)

Submillimeter Telescope (SMT)  
*Arizona Radio Observatory (ARO)*

Main reflector: paraboloid D=10 m; F/D=0.35. Subreflector: d=0.69 m;  
**SIS-490**: The SORAL 490 GHz single-channel receiver;  
T(DSB) = 110-150 K across its 425 to 500 GHz tuning range.

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15-18 November, 2009  
Wuxi, China
30-cm **PORTable Submillimeter Telescope** (POST)  
*Purple Mountain Observatory (PMO); Nanjing.*  
Site: Delingha of Qinghai province (*altitude ~3200 m*)

**Required parameters:**

- Frequency - 345 GHz  
  \( \text{Tr (DSB)} \leq 100 \text{ K} \)

- IF range - 3.6-4.6 GHz  
  Spectral resolution \( \leq 30 \text{ KHz} \)

- Output power \( \geq 5 \text{ dBm} \)  
  Output frequency - 0.01-1GHz

- Dissipated power at 4.2K stage \( \leq 100 \text{ mW} \)
Integrated Receiver of 345 GHz for POST:

collaboration:

- IREE, Moscow, Russia
- PMO, Nanjing
Development of such Integrated Receiver for POST includes stages:

- New FFO design for 325-365 GHz
- Microcircuit design to pump SIS and Harmonic mixer with FFO power
- Integrated lens-antenna
- Mechanical design for mounting a new receiver at the telescope
- Related stuff and equipment (cables, amplifiers, controlling software, etc.)
Development of Flux-flow oscillator for 250-400 GHz
Flux-flow oscillator as LO

**Working regimes:**
- 400-650 GHz – Fiske steps and flux-flow regime
- 250-400 GHz – Fiske steps regime with low damping

**Josephson equation**

\[ f_{FFO} = \frac{2eV_{FFO}}{hc} \]

(483.6 GHz/mV)
IV-curves of FFO

Resonances at
\[ \omega_n = n \frac{c_0}{2L} \]

Distance between steps
\[ \Delta = \frac{c_0}{2L} \]

FFO Length 700 μm was taken
Development and testing of integrated circuit
Development of testing microcircuit

- FFO + SIS mixer + Harmonic mixer
- Power matching of FFO with mixers is required

1 – FFO
2 – impedance transformer
3 – DC-break
4 – SIS mixer
5,8 – radial stubs
6,9 – mixers output lines
7 – Harmonic mixer
IV-curves of SIS mixer showing pumping by FFO power
FFO and mixers power coupling

1 - FFO - SIS
2 - FFO - HM
3
4
FFO Linewidth measurements

![Diagram showing FFO, PLL, HM, HEMT, Reference, and Spectrum-analizer with frequency ranges and temperatures.]

- FFO: 250-400GHz, T ≥ 4.2 K
- PLL
- HM: IF 0-800 MHz
- HEMT: T = 300K
- Reference: f = 18 GHz
- Spectrum-analizer: IF
Linewidth at best points below 1 MHz in the range 325-365 GHz was obtained.
Measured by integrated receiver a signal of external multiplier (driven by synthesizer)
Summary

- FFO linewidth below 1 MHz was demonstrated in range 325-365 GHz
- Sufficient power matching between FFO and both mixers (SIS and HM) was obtained

*What has to be done:*

- Integrated lens-antenna to be developed
- Circuit design with antenna to be retreated
- FFO design to be improved
- Mechanical construction for mounting receiver into telescope to be realized
Thanx for your attention :)

15-18 November, 2009  Wuxi, China
Phase Noise of the PL FFO

- **Absolute FFO phase noise, \((n = 20)\); SR = 96.7%**
- **R&S Synthesizer at 22 GHz \(n^2\) (\(n = 20\))
- **Phase locked FFO, \(f_{\text{FFO}} = 450\) GHz (\(\delta f_{\text{aut}} = 0.5\) MHz; SR = 97.7%)**
- **R&S Synthesizer at 22 GHz (Specification)**

Phase Noise (dBc/Hz) vs Offset from Carrier (Hz)