Plateau de Bure / NOEMA Phasing Plans

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From Stars to Black Holes:
mm-VLBI with ALMA and other Telescopes
ESO Garching, June 27th - 28th 2012

- Plateau de Bure Interferometer today:
  Switching to phased array mode, observing techniques
- Calibration
  Effective system temperature in phased array mode
- VLBI with NOEMA
  Capabilities and timescales

Geographical Overview

IRAM 30-M

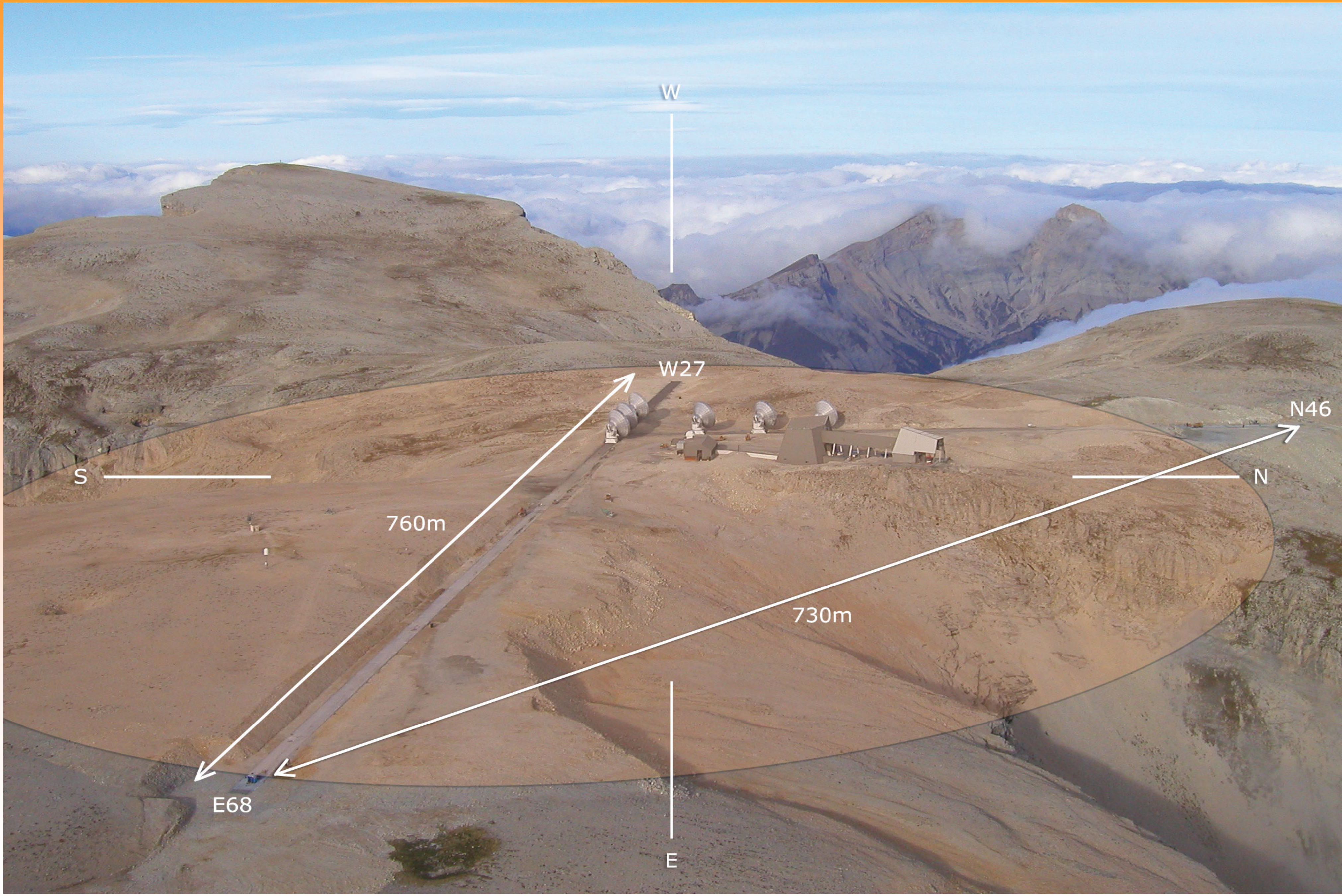
Pico Veleta

Sierra Nevada, Spain

Alt. 2850m

IRAM Plateau de Bure Interferometer

IRAM Plateau de Bure: synthesis antenna



IRAM Plateau de Bure: receiver tuning ranges

	Band 1	Band 2	Band 3	Band 4
RF range*/[GHz]	80–116	129–174	201–267	277–371
T_{rec}/[K] LSB	40–55	30–50	40–60	30–50
T_{rec}/[K] USB	40–55	40–80	50–70	30–50
G_{im}/[dB]	-10	-12 ... -10	-12 ... -8	-20
RF LSB/[GHz]	80–104	129–165	201–264	277-359
RF USB/[GHz]	104–116	164–174	264–267	289-371

* center of the 4.2-7.8 GHz IF band;

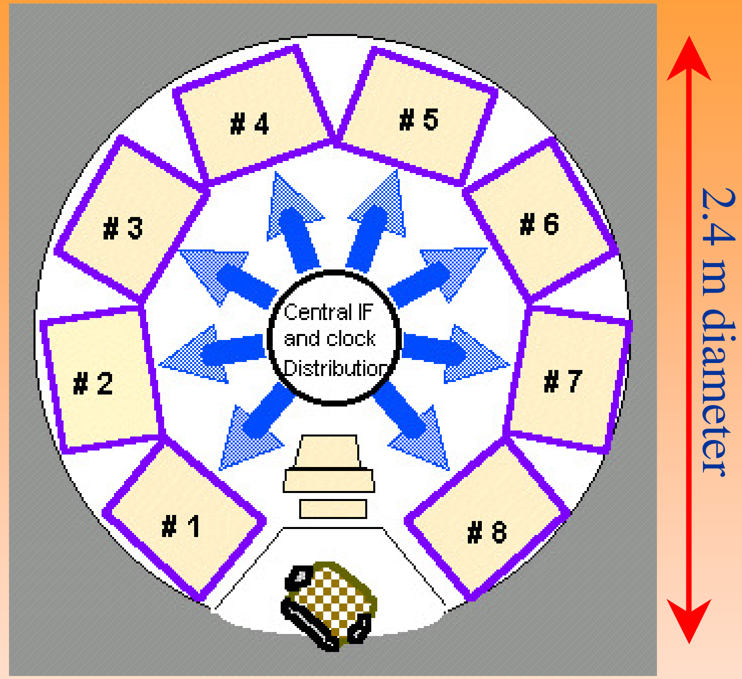
All bands are in dual polarization.

Filter wheels: Currently we have lambda/4 plates installed for band 1 and band 3

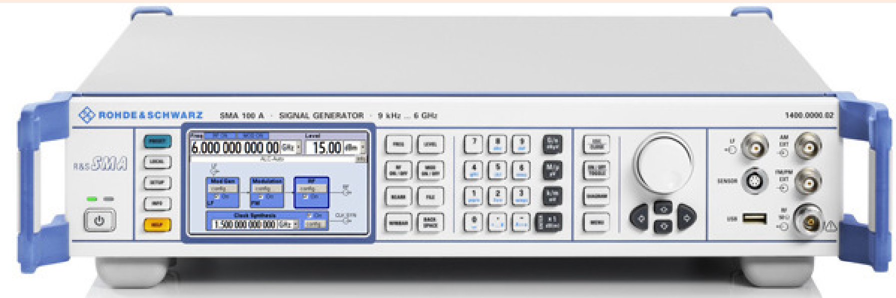
Plateau de Bure VLBI equipment today

EFOS-38 maser (T4Science), with low phase noise quartz

Mark4 Formatter + Mark5A recorder



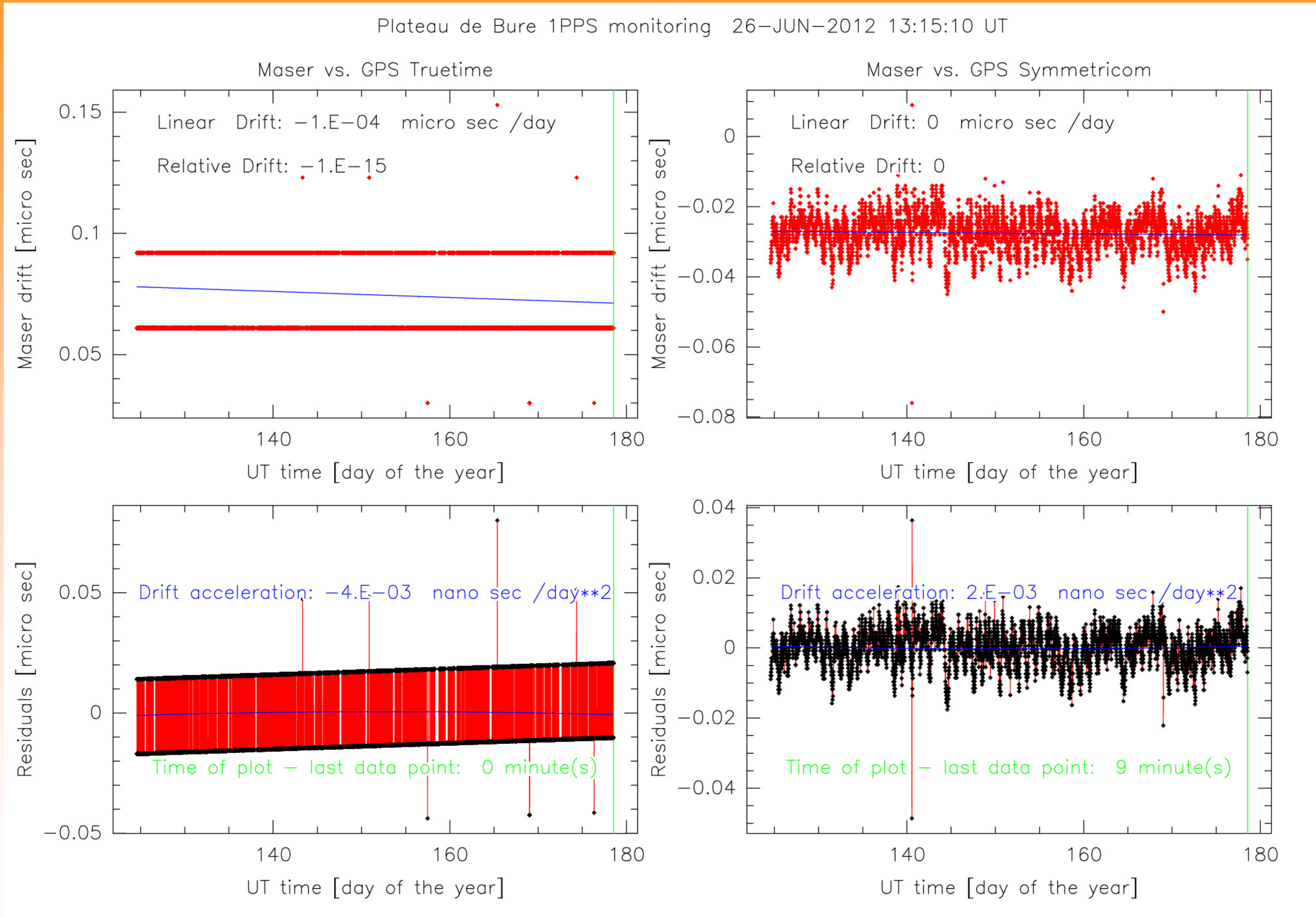
Narrow-band correlator (2000)



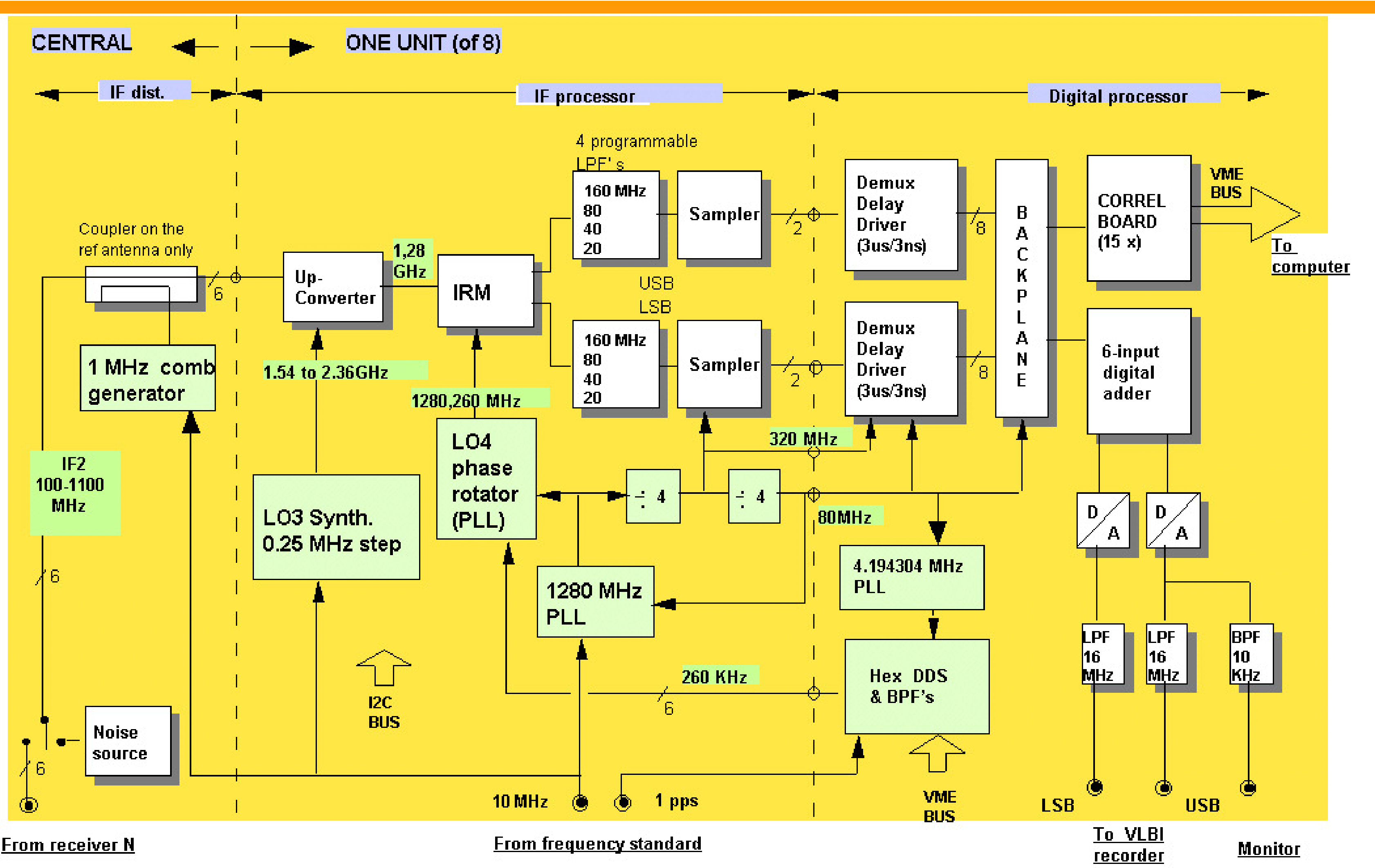
Rohde & Schwarz SMA100 B22 frequency generator

You can visit our vintage Mark4B tape recorder in the “Deutsches Museum” in München.

Plateau de Bure VLBI equipment today (II)

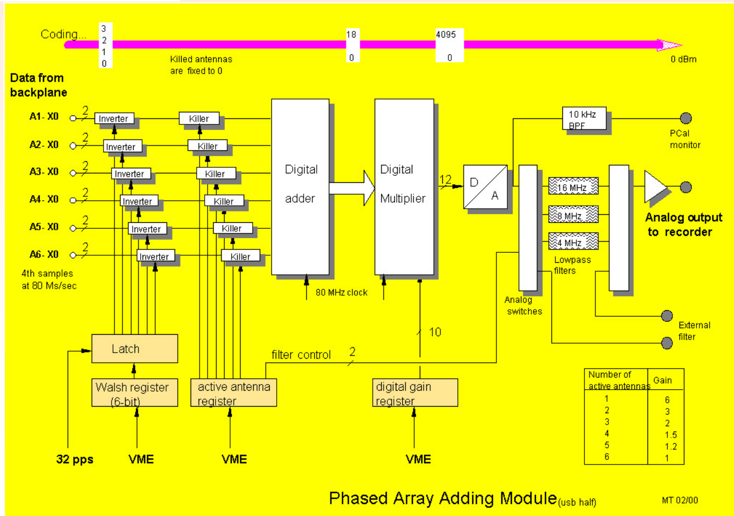


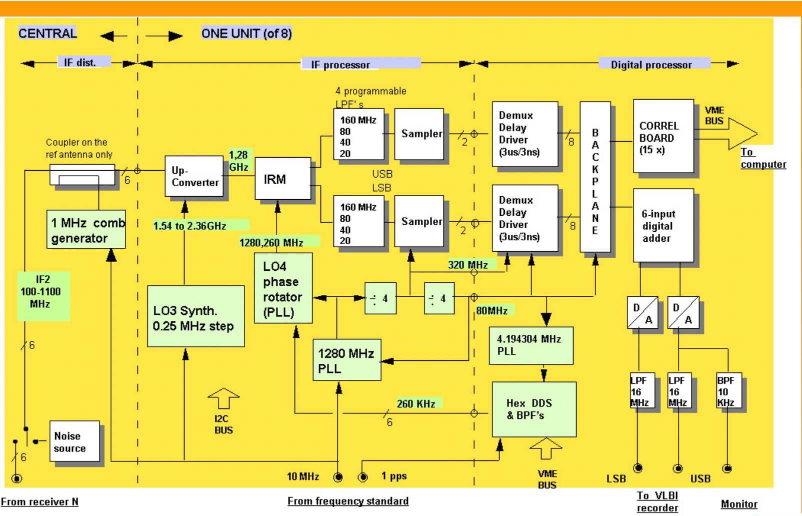
Two GPS receivers monitor the maser drift.



One Narrow-Band correlator unit

Half of one Adder Module

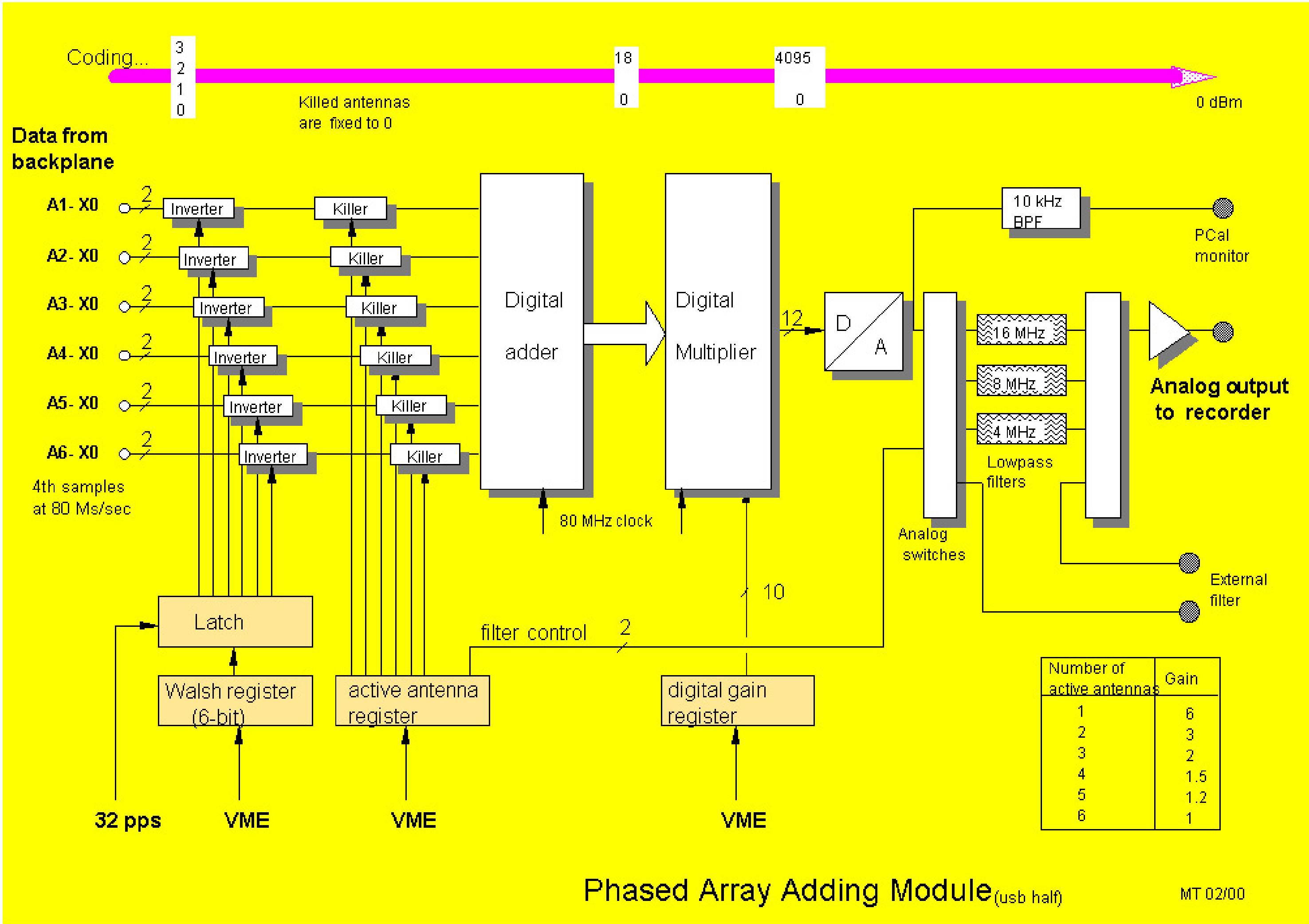




One
Narrow-Band
correlator unit

Note: this backend is limited to 128 MHz (1 Gbit/sec, all 8 units) in VLBI mode.

Half of one Adder Module



Phasing the phased array

Phasing = align phases of all antennas and spectral units to the **reference antenna**.
On Bure that is done **once** integrating over 2 minutes before a VLBI scan is started.

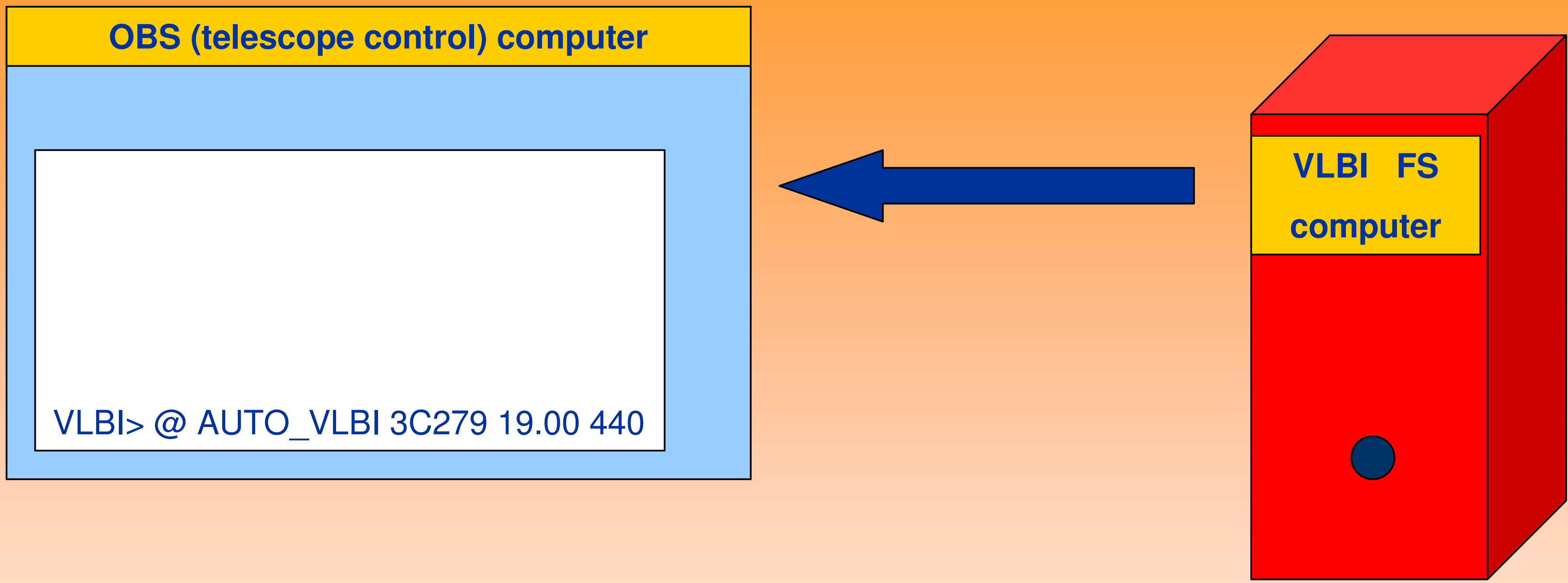
Phasing on an **external point-like continuum calibrator** is required if the science target:

- has an extended component resolved by the local interferometer,
- is a maser,
- is too weak.

Many science targets are strong quasars, which allow to phase directly on them.

Note: Phasing is a function of time and target position, and needs to be redone frequently.

Observing in VLBI mode



- macro calls are inserted into the Field System (FS) schedule and sent to the telescope control computer running OBS.
- this macro handles calibration, pointing, focus, phasing and next VLBI scan start, and keeps track of available time
- by modifying macro key variables, the observer can adapt the observing strategy in real time, or even de-activate the macro to type commands by hand.
- if necessary, the reception in OBS can be put on hold without stopping the FS.

Practical Aspects

- **Phased array operation:** preferentially in compact configuration (less phase noise)
- **Pointing / focus:** use backend WIDEX! (3.6 GHz vs. 128 MHz bandwidth)
- **Limitations at millimeter wavelengths:** mainly due to meteorological conditions (wind speed, precipitation)
- **Flexible calibration strategy:** very useful during instable afternoons.
- **Reference antenna:** compromise between

    - short baselines to all other antennas

    - minimal shadowing by other antennas

Practical Aspects (detail)

Choice of reference antenna:
Example in compact 6 antenna D configuration

BL	Length[m]
1 2	73.32
1 3	59.80
2 3	23.99
1 4	32.01
2 4	94.48
3 4	86.74
1 5	66.38
2 5	87.00
3 5	64.01
4 5	97.02
1 6	39.99
2 6	61.81
3 6	39.04
4 6	72.00
5 6	32.11

Connected baseline lengths [m] for all possible reference antenna choices

								Average [m]
A1	0.00	73.32	59.80	32.01	66.38	39.99		**45.25**
A2	73.32	0.00	23.99	94.48	88.00	61.81		**56.94**
A3	59.80	23.99	0.00	86.74	64.00	39.04		**45.60**
A4	32.01	94.48	86.74	0.00	97.02	72.00		**63.71**
A5	66.38	88.00	64.00	97.02	0.00	32.11		**57.92**
A6	39.99	61.81	39.04	72.00	32.11	0.00		**40.93**

System Temperature

Required: a system temperature that includes the phase noise.

From the parallel running cross-correlations and autocorrelations we have

- Tsys [Kelvin] for each antenna i
- Efficiency E (in Kelvin/Jansky) for each antenna i
- phases P averaged over the desired time resolution per antenna i, relative to the reference antenna

$$T_{sys} = N_{ant} \cdot \sum_{i=1}^{N_{ant}} E_i \cdot \left(\sum_{i=1}^{N_{ant}} \sqrt{\frac{E_i}{T_{sys\ i}}} \cdot cos P_i \right)^{-2}$$

- if the source is too weak, extended or a line source: use the latest available point-source phasing efficiency instead.

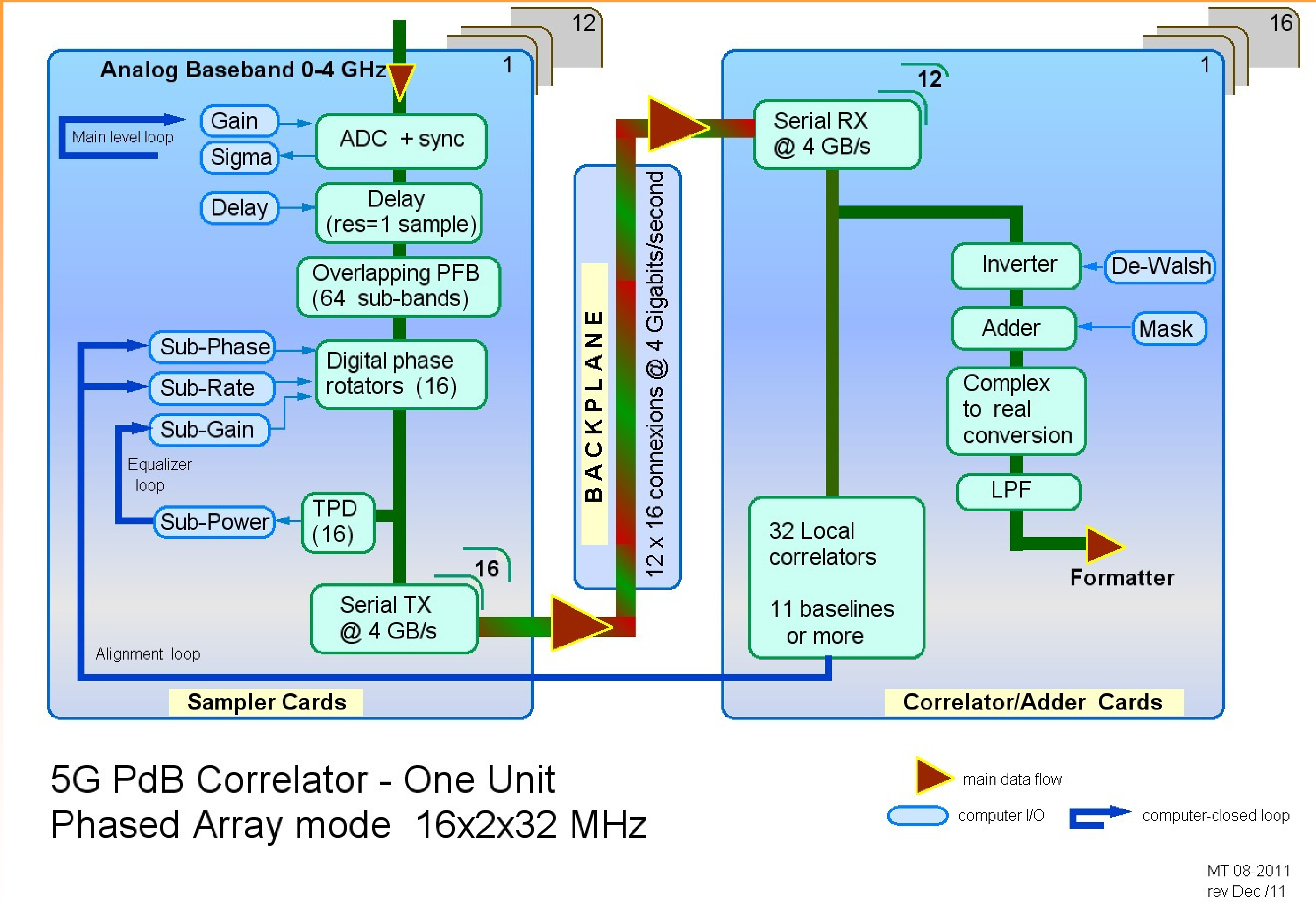
NOEMA

Northern **E**xtended **M**illimeter **A**rray:

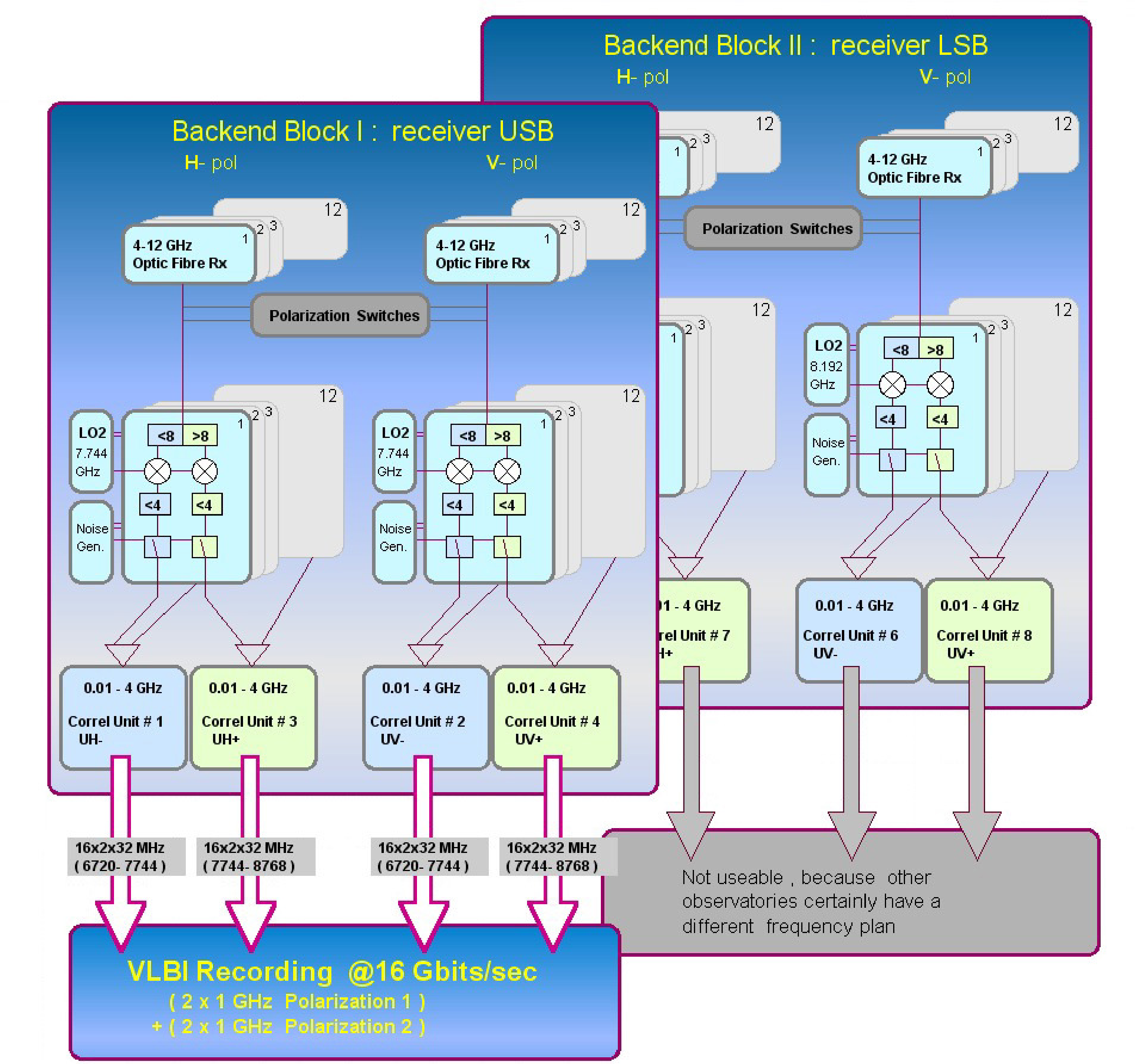
Planned extension of the present-day Plateau de Bure Interferometer

	PdBI	NOEMA
antennas	6	10 (12 ?)
baselines	15	45 (66 ?)
bandwidth	2 x 3.6 GHz	2 x 16 GHz
max. baseline	760 m	1600 m

In 2015 (?): The 5th generation correlator on Bure



In 2015 (?): The 5th generation correlator on Bure



In 2015 (?): The 5th generation correlator on Bure

- Correlator with FPGA technology, fully re-programmable
- can morph into a large-band phased array machine for up to 12 antennas with 2 x 2 GHz bandwidth (16 Gbits/sec data rate)
- autocorrelations in 32 MHz sections for calibration
- integrated cross-correlator for phasing
- fully digital output

Thank you!