

# Warm Front-End Converter Modules



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Atacama Large Millimeter/submillimeter Array

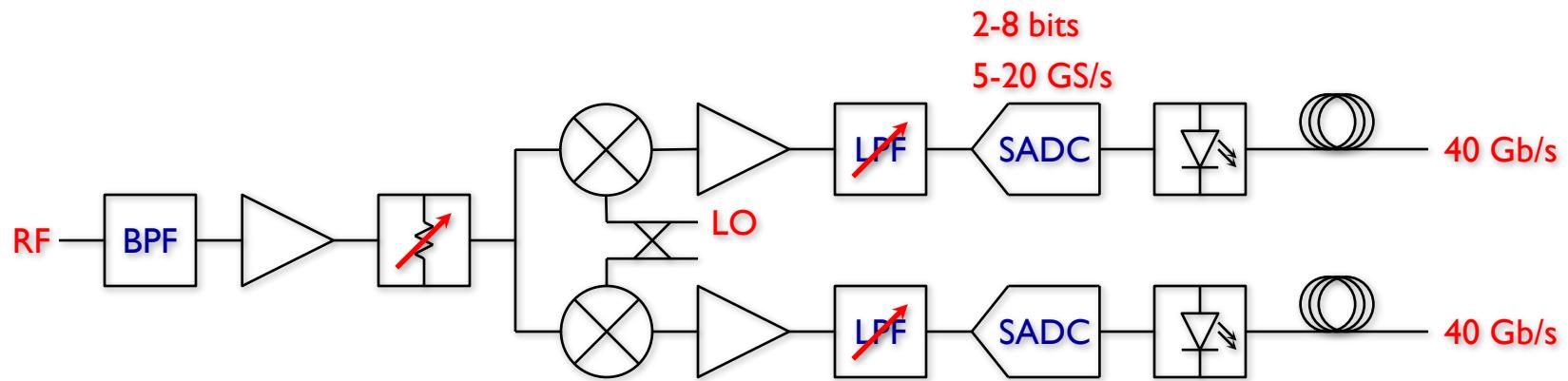
Expanded Very Large Array

Robert C. Byrd Green Bank Telescope

Very Long Baseline Array



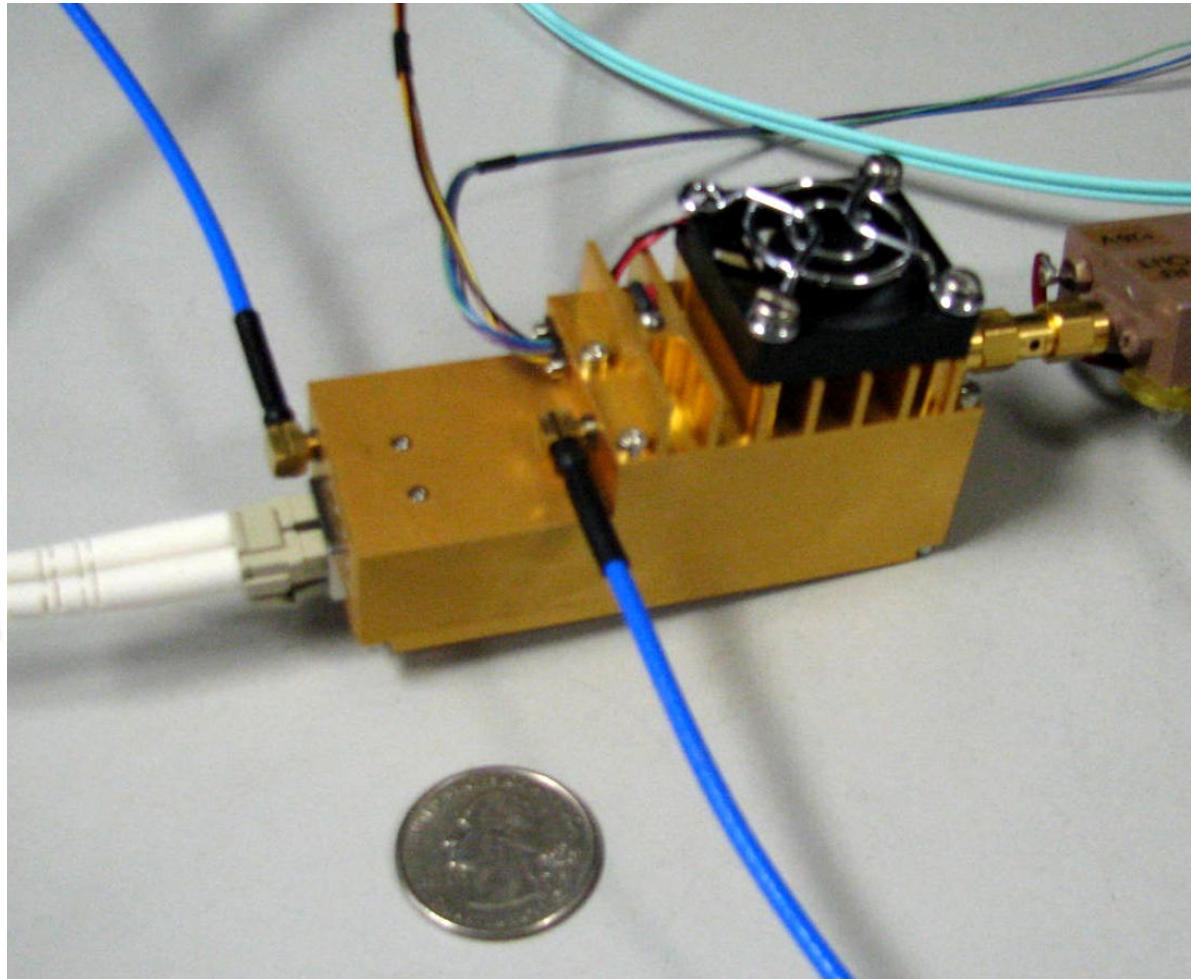
# Front-End Converter Modules (FECMs)



- Integrated Analog-Digital-Photonic
- I/Q downconversion
- Multiple FECMs per antenna
  - RF/LO ranges TBD.
- Switch-selected or simultaneous?
  - fiber cost/maintenance tradeoff
- Variable sample-rate/bit-resolution
  - 2 bit, 20 GHz bandwidth
  - 4 bit, 10 GHz bandwidth
  - 8 bit, 5 GHz bandwidth
  - etc.

# Low-Frequency Prototype

ref. clock



RF input  
1-3 GHz

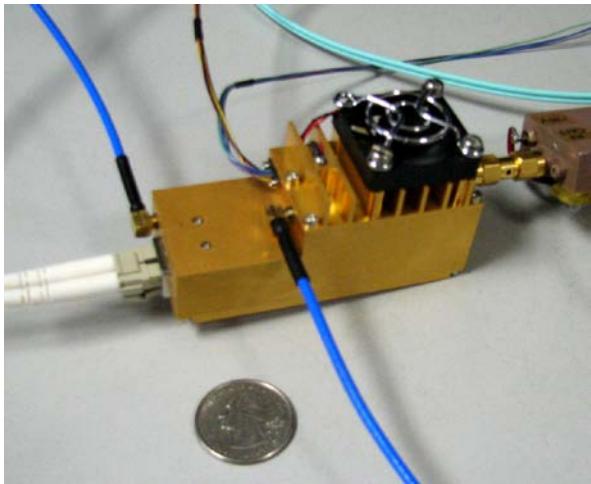
I/Q data out

4 bits/sample

1310nm, 2.5 Gbps

(622 MHz BW)

# Integrated FECMs



- RF/IF Amplification
- Filtering
- Power leveling
- RF-to-baseband conversion
- Analog-to-digital conversion
- Copper-to-fiber conversion

## What it Replaces:

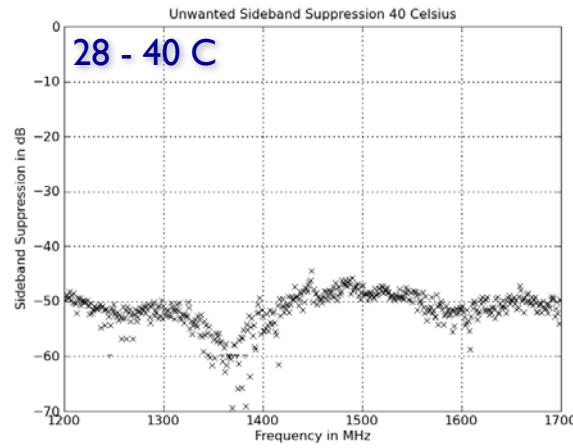
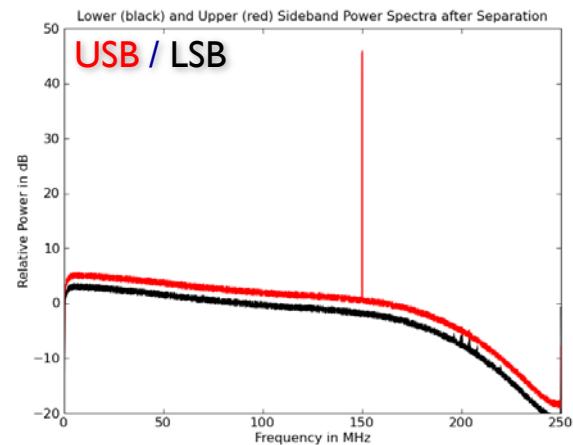
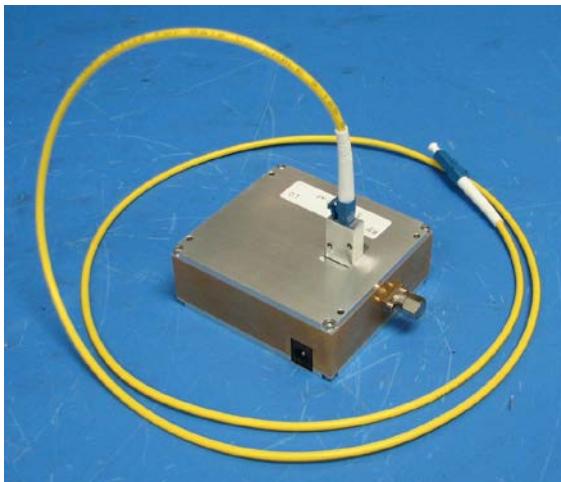
- Warm front-end electronics (RF)
- Warm LO/IF electronics
- Fiber Optic modems
- ADC cards
- Digital data formatters

## System/Operational Benefits:

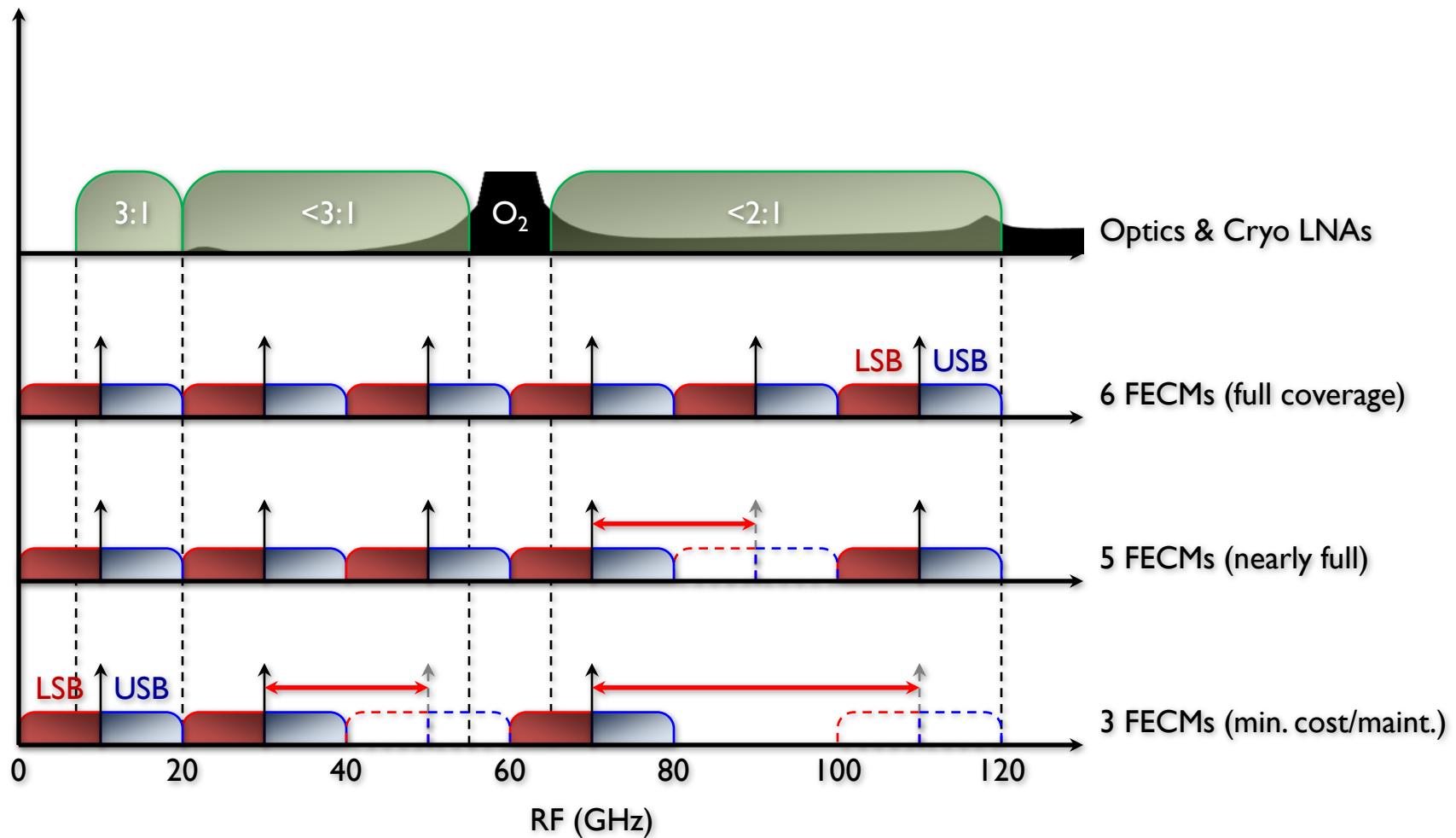
- Modularity / Field-Replaceability
- Mass and power consumption
- Mean-Time-Between-Failures

# Integrated FECM's - cont'd.

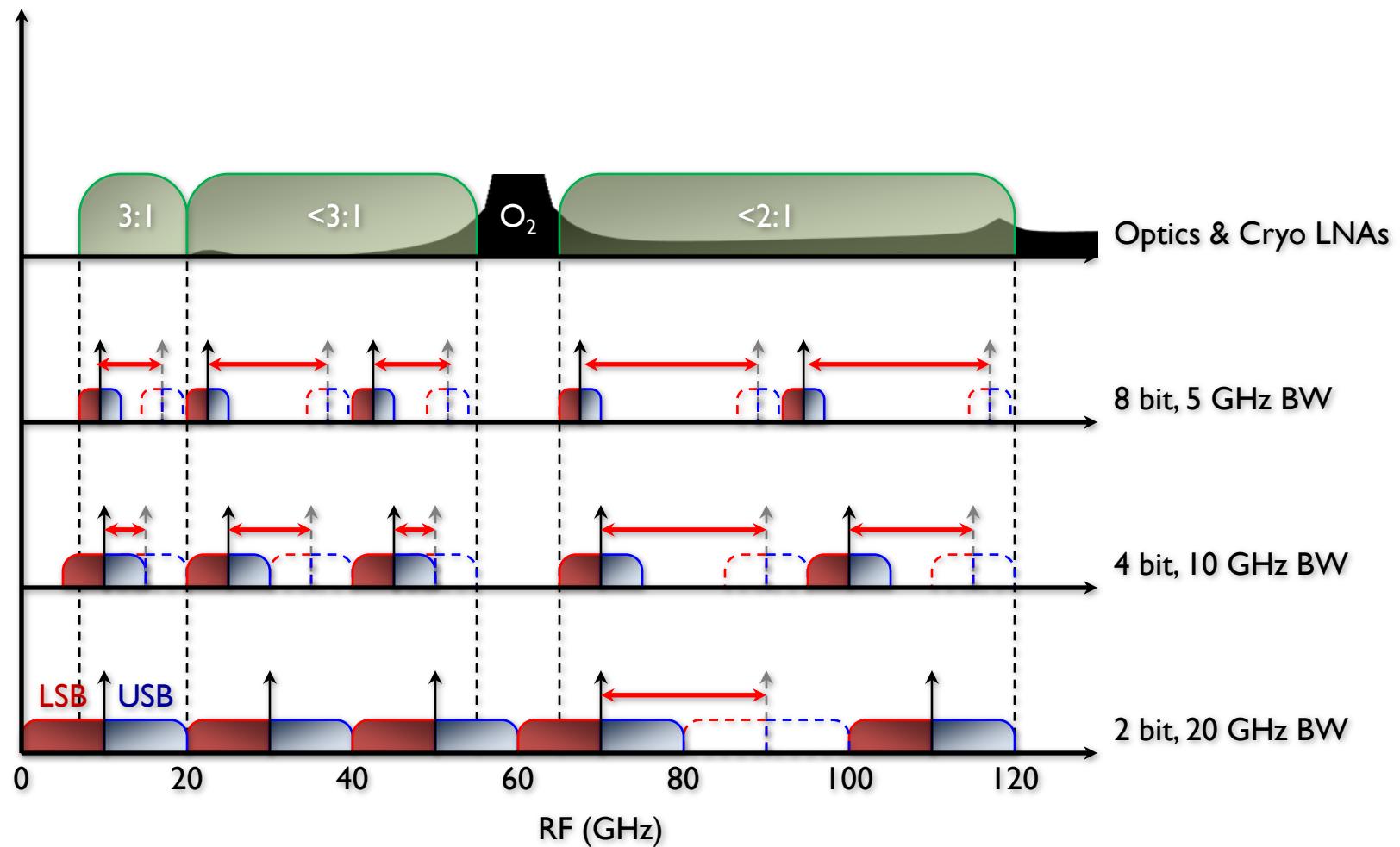
- Stable, precision performance
- Smooth baselines
- Minimal environmental controls required
- Compact, field-replaceable



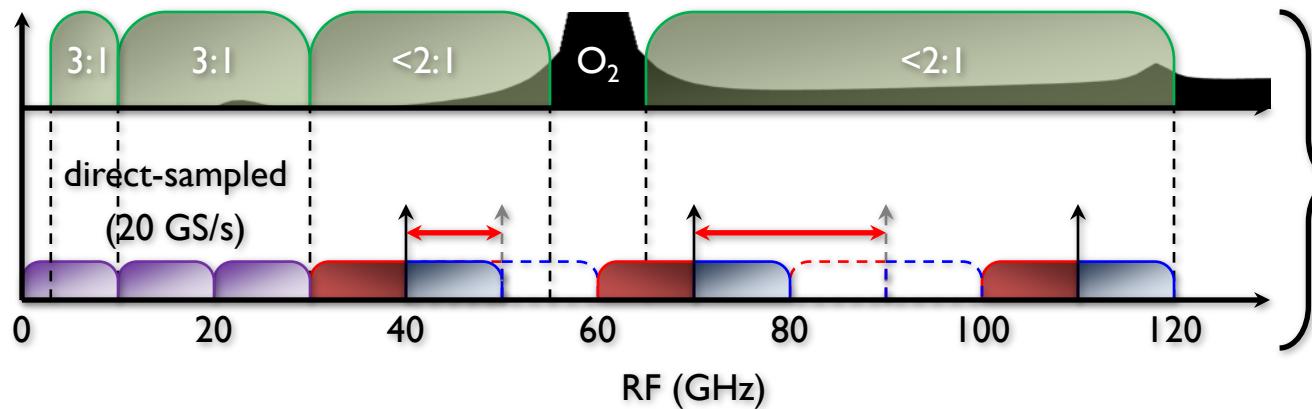
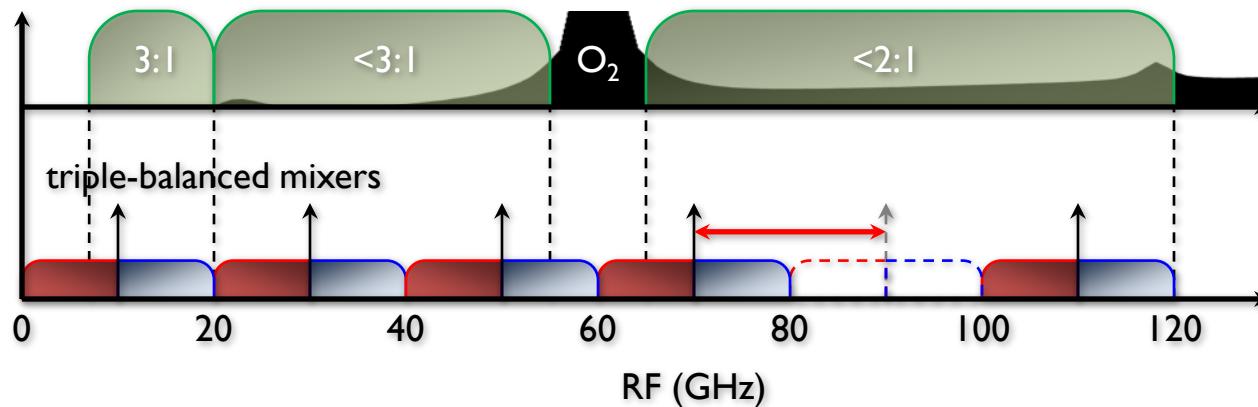
# How Many FECMs?



# Variable Sample Resolution (5 FECMs)



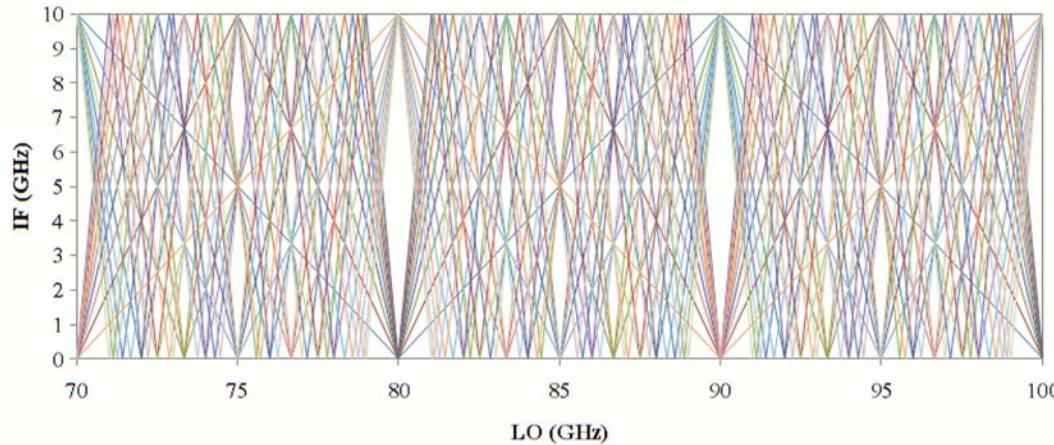
# Triple-Balanced vs. Direct Sampled



This would be my preferred solution.  
- 6 FECMs  
- 3 direct-sampled  
- 9 fibers @ 40 Gbps  
(per polarization)

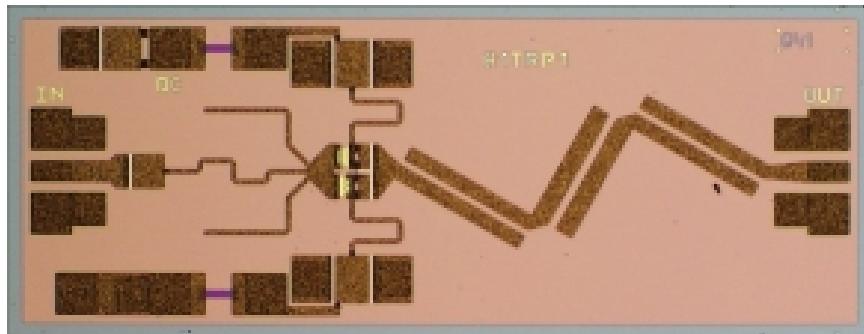
# Commensurate LO/Clock Tuning

- Not required by FECM design, but a good idea:
  - Both the sample clocks and LOs can then all be derived as harmonics of a *single* timing reference distributed to all antennas.
  - Eliminates the chance of spurious mixing products in the output spectrum.

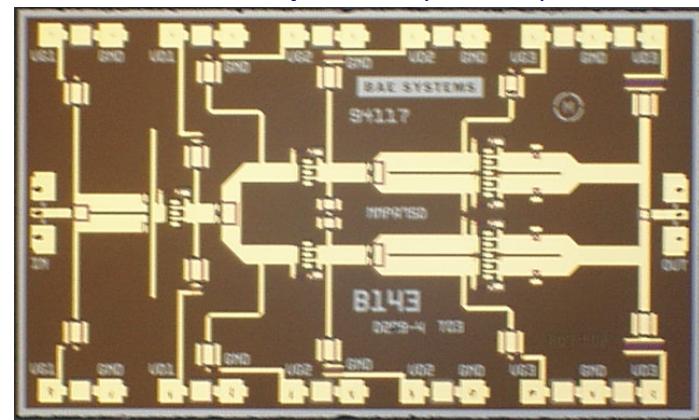


# MMIC Chips Available

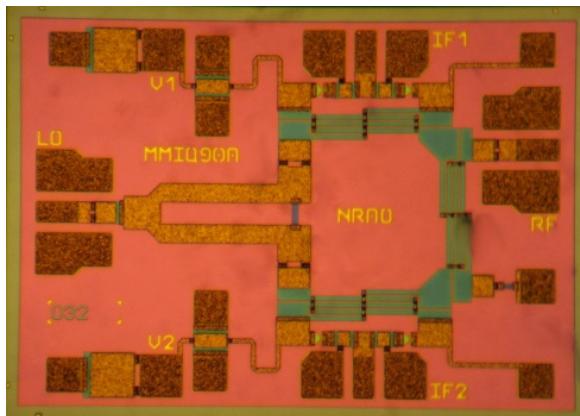
LO Multipliers (ALMA)



LO Amplifiers (ALMA)



60-120 GHz I/Q Mixer

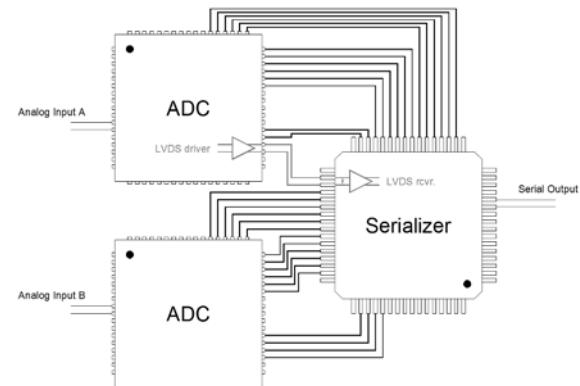


Others...

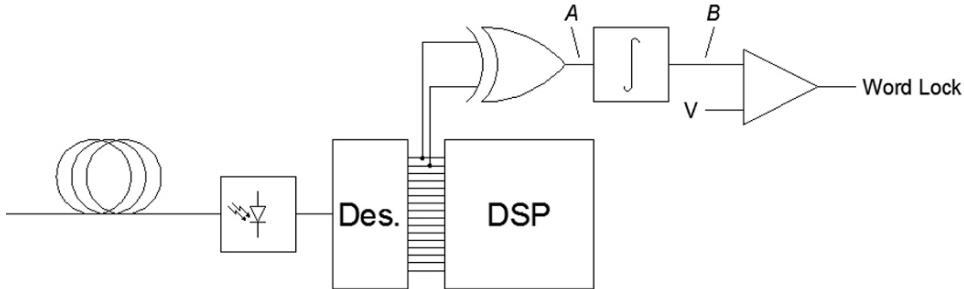
- IF components available commercially.
- Mid-band mixer (30-60 GHz) can be scaled down from the one shown.

# Serial-Output ADC Wanted...

- Integration avoids power consumption in LVDS data transfer between ICs.
- Reduced footprint.
- Dynamically-variable sample-resolution.
  - Implementation should maintain power efficiency by utilizing only those comparators which are needed for the selected resolution.
- Serial rate = 40 Gbps
- Sample rate up to 20 GS/s
- Analog input BW up to 30 GHz
  - to support direct sampling of lower three bands.

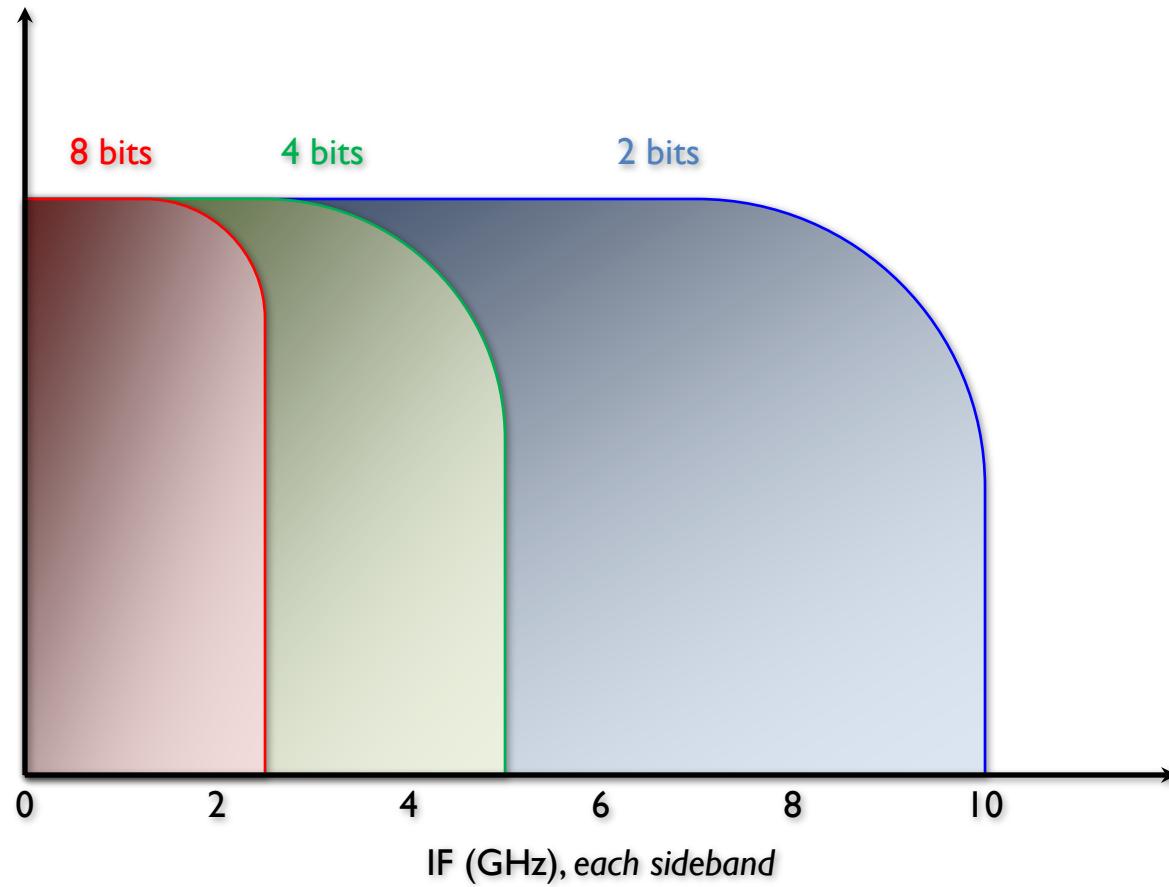


# ...and a De-Serializer...



- 40 Gbps Clock Recovery
- Logic gates for alignment of the MSB in the unformatted bit-stream.
- Additional MSB-detection circuits for determination of resolution.
- see *M. Morgan, J. Fisher, and J. Castro, "Unformatted Digital Fiber-Optic Data Transmission for Radio Astronomy Front Ends," Publications of the Astronomical Society of the Pacific, vol. 125, no. 928, pp. 695-704, June 2013.*

# Step-Tunable Low-Pass Filter



# FECM Interfaces at Each Antenna

## Signal Path:

- 12x RF inputs (both pols)
  - 4x 3.5mm
  - 4x 2.4mm
  - 4x WR-10 (or double-ridged?)
- 18x fiber outputs
  - 6x direct-sampled
  - 12x I/Q data streams
  - 40 Gbps each
  - 1310nm, single-mode

## Auxiliary

- +3.3V,  $\pm 5.0$ V power supplies
- M&C (fiber/ethernet?)
- Time Reference (5 GHz)
  - sample clock and LO derived from this same reference



# FECM Enclosure / Fiber Management

