Next Generation Radio Astronomy Receiver Systems at NRAO

SKA2010

Matt Morgan and Rick Fisher

Atacama Large Millimeter/submillimeter Array
Expanded Very Large Array
Robert C. Byrd Green Bank Telescope
Very Long Baseline Array

NRAO

Program Goals

- To develop receivers and wide bandwidth data transport systems which are lower cost, more compact, more reliable, lower weight, more reproducible, and more stable the best current systems.

- To integrate the conversions from RF to baseband, from analog to digital, and from copper to fiber into a single compact package.

- To digitize the signal as close to the antenna feed as possible
  - this inevitably involves transferring some functionality from analog hardware to the digital domain.

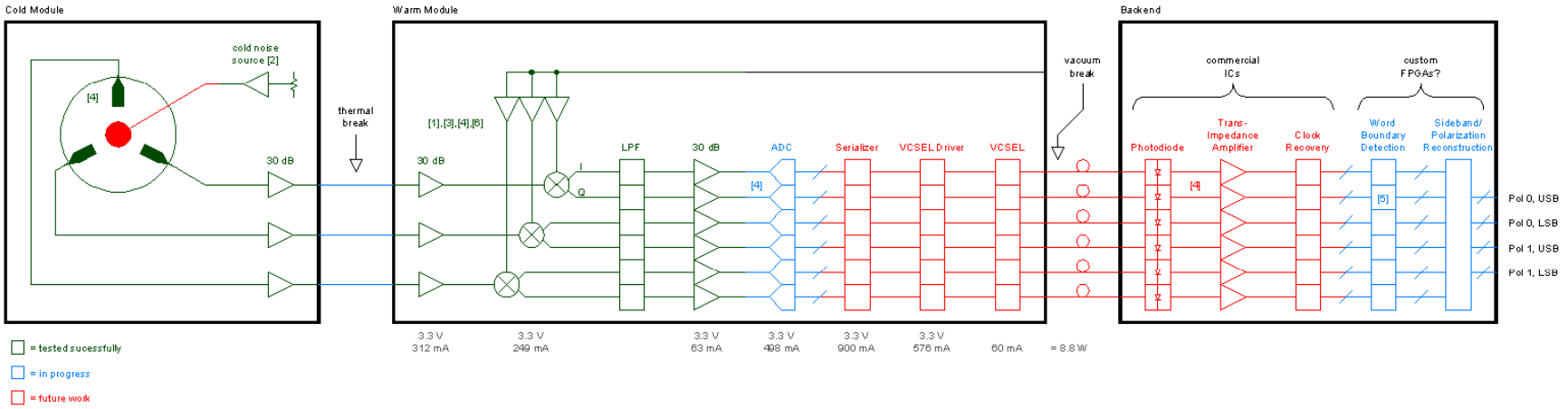
Guiding Principles

- **There will be no compromise in receiver performance** (noise, bandwidth, isolation, stability, etc.)
  - this does not mean all tradeoff's are unchanged, only that a fully re-optimized receiver can do anything our current best receivers can do, probably better, and at less *overall* cost.

- We make small steps, and only spend as much money as is needed at each stage to prove the concept. We do not build costly "demonstrators."

- This is not tied to a specific frequency band, telescope, or application, though large-format focal plane arrays and compact front-ends for small dishes are useful usage cases to remember.

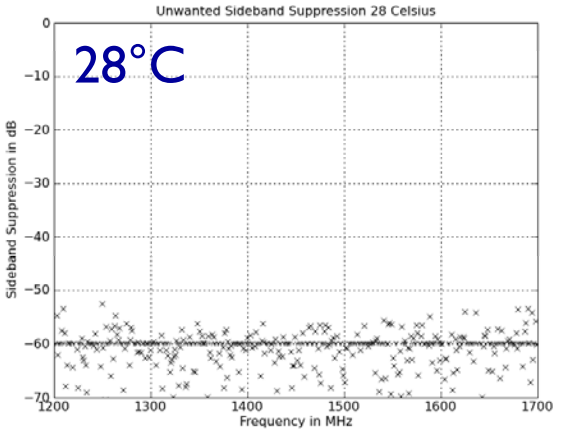
Current Vision

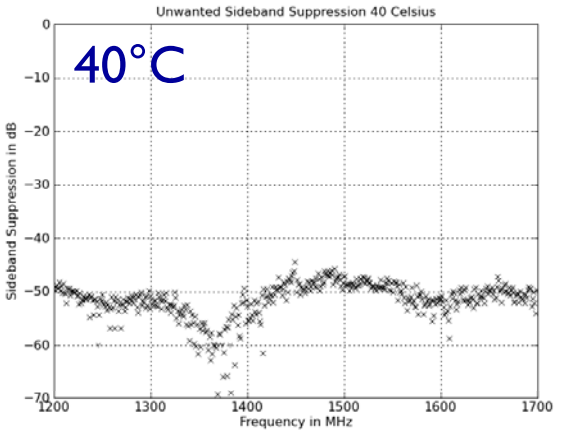


[1] J. Fisher and M. Morgan, "Analysis of a Single-Conversion, Analog/Digital Sideband Separating Mixer Prototype," Electronics Division Internal Report #320, June 2008.
[2] E. Bryerton, "A Cryogenic Integrated Noise Calibration and Coupler Module for the GBT K-Band Focal Plane Array (KFPA)," KFPA Project Critical Design Review, Januray 2009.
[3] M. Morgan and J. Fisher, "Simplifying Radio Astronomy Receivers," NRAO eNews, vol. 2, no. 3, March 2009.
[4] M. Morgan and J. Fisher, Next Generation Radio Astronomy Receiver Systems, Astro2010 Technology Development White Paper, March 2009.
[5] M. Morgan and J. Fisher, "Word-Boundary Detection in a Serialized, Gaussian-Distributed, White-Noise Data Stream," Electronics Division Technical Note #213, October 2009.
[6] M. Morgan and J. Fisher, "Experiments with Digital Sideband-Separating Downconversion," Publications of the Astronomical Society of the Pacific, vol. 122, no. 889, pp. 326-335, March 2010.

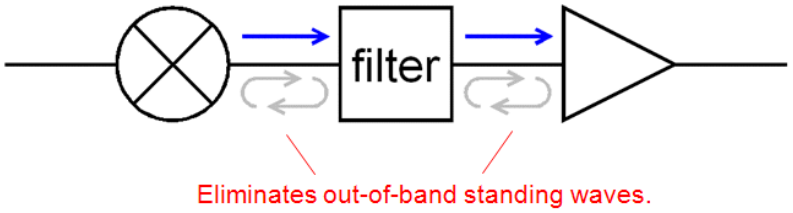
Digital Sideband-Separating Mixer (DSSM)

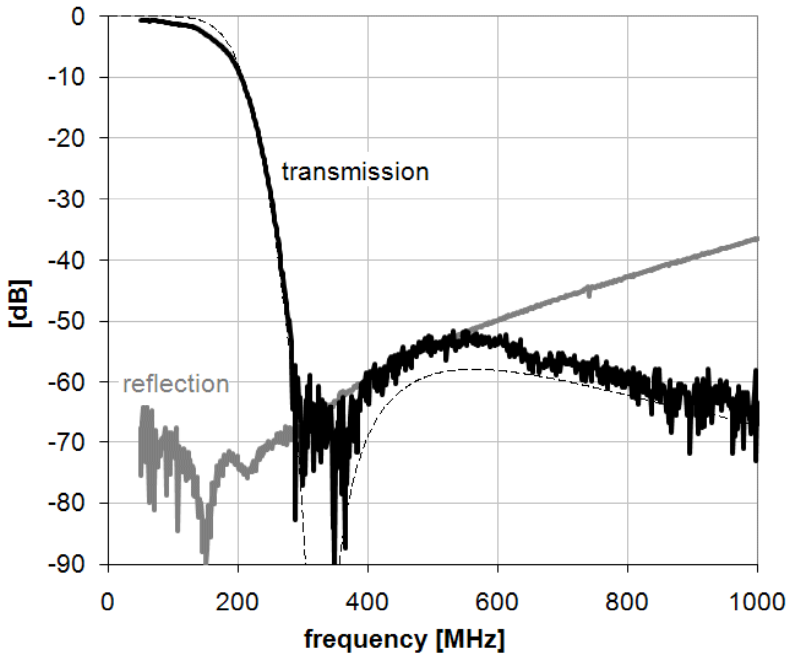
- I- and Q-channels digitized and recombined with calibrated complex weighting coefficients.
- Corrects for LO, RF, and IF analog amplitude and phase errors.
- Extremely stable design: 50 dB sideband-suppression without re-calibration over a 12 °C temperature change.
- No increase in digital data rate: requires two ADC's with half the sample rate for a given processed bandwidth.

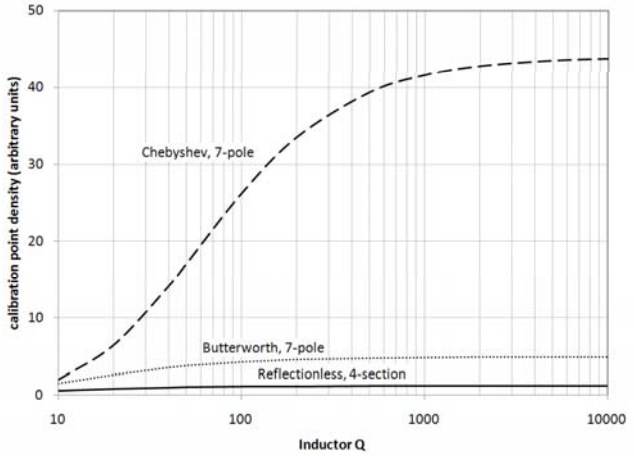




Designed for Calibration Stability



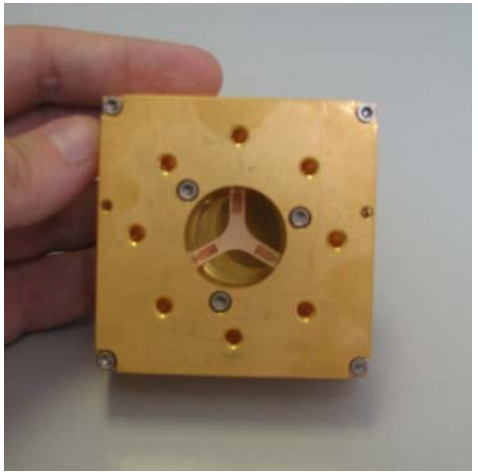


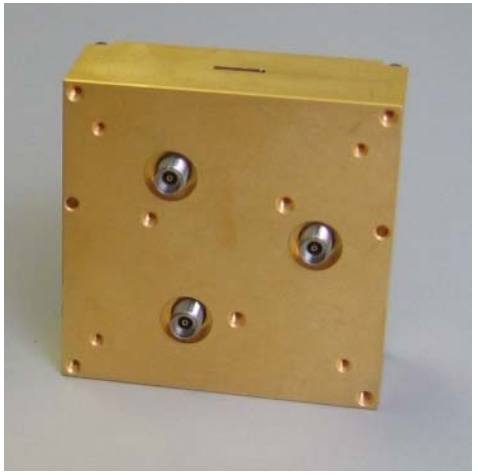


- New filter has differential complex gain slope 45 times better than standard Chebyshev designs with comparable stop-band rejection.
  - fewer calibration points are required
  - calibration is far more stable

Digital Ortho-Mode Transducer (DOMT)

- Planar probe outputs digitized and re-combined with calibrated complex weighting coefficients.
- Corrects for all analog amplitude, phase, and isolation errors.
- Preliminary result: 40 dB polarization isolation dominated by numerical artifacts (no measurable sensitivity to temperature).
- Shown at right: 8-12 GHz cold-module with three-probe OMT and MMIC LNAs.





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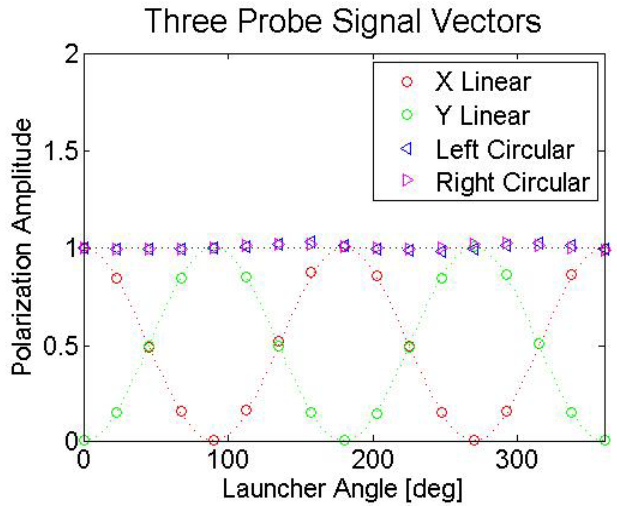
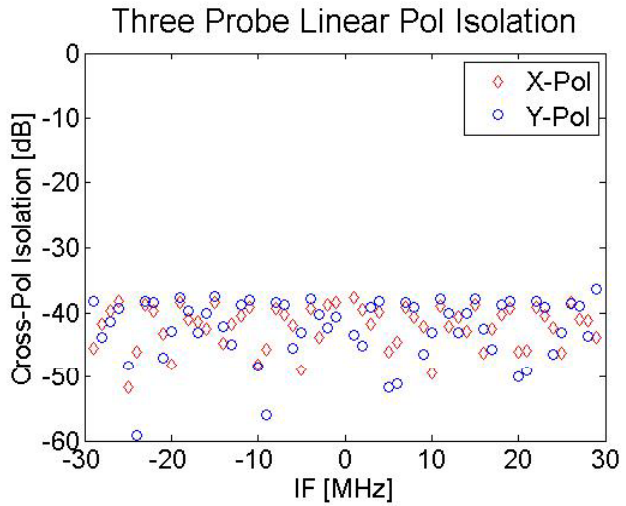
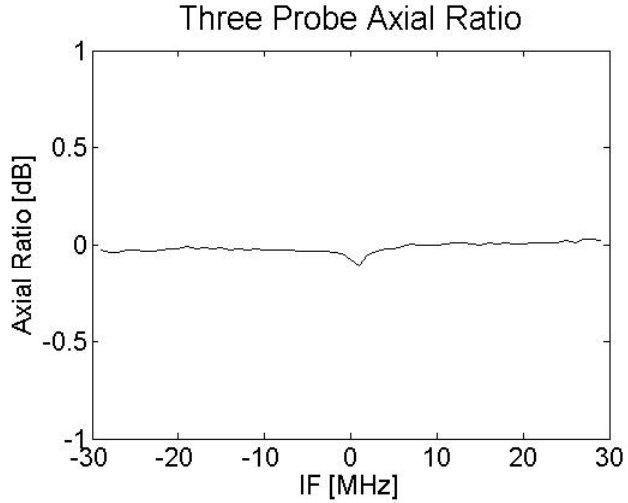
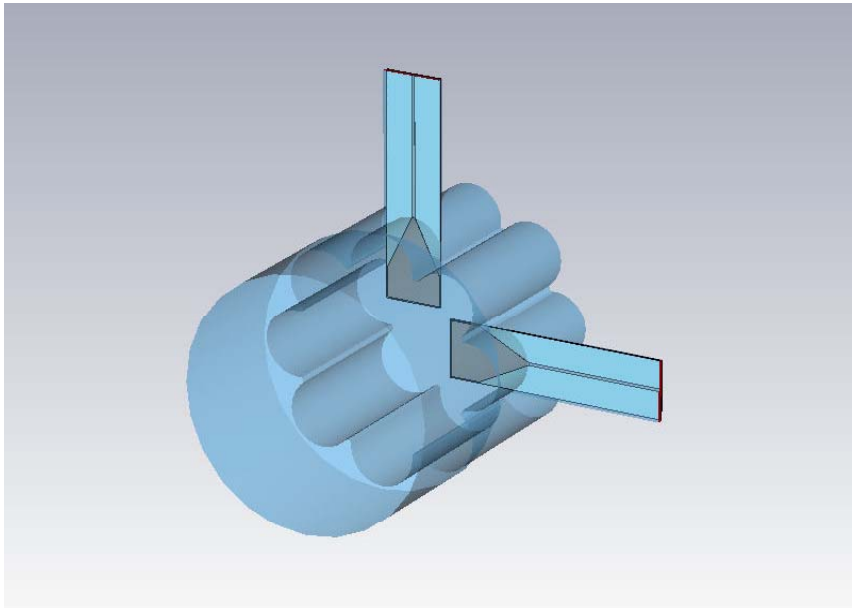






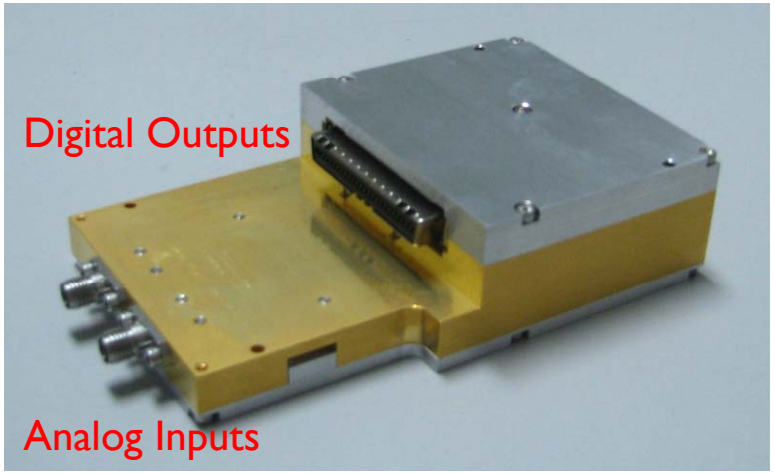
Future Alternative Configuration

- Two-probe configuration has the same number of output channels as a conventional OMT.
- Sacrifices symmetry properties inherent with three or more probes.
- Fluted waveguide cuts off higher-order modes which would tend to make the calibration of this asymmetric OMT unstable.

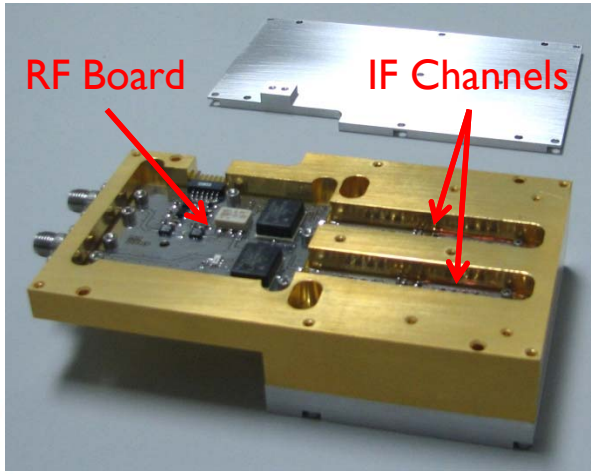


In-Progress: Integrate Analog-to-Digital

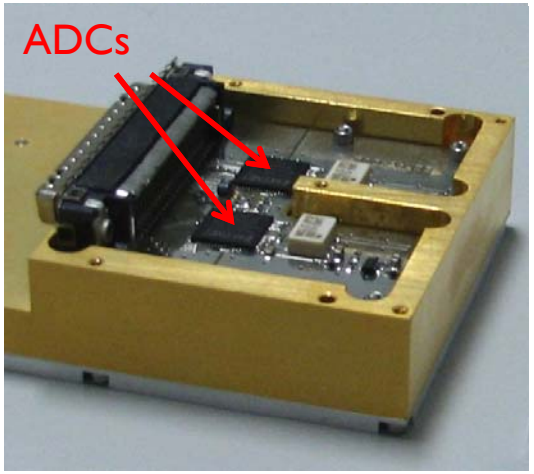
L-Band Module



Analog Side



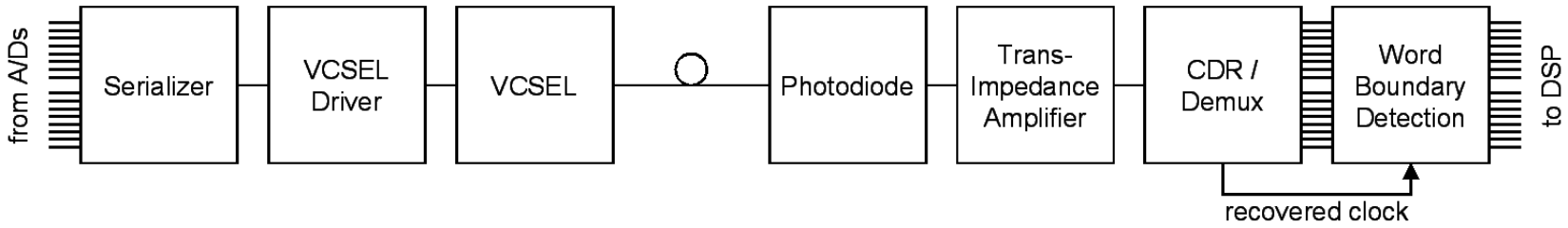
Digital Side

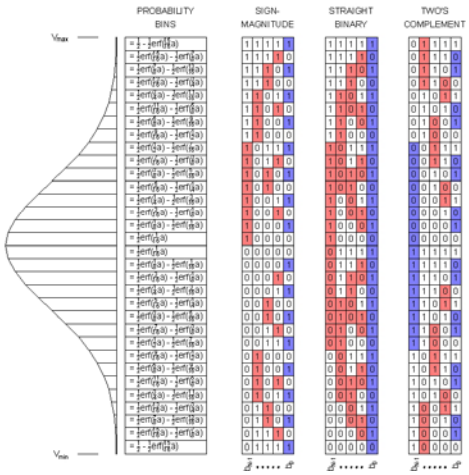


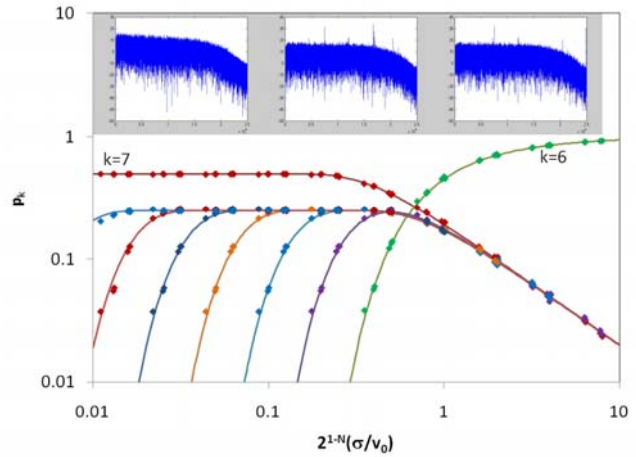
Future: Integrate Copper-to-Fiber

No complex digital logic in the front-end...

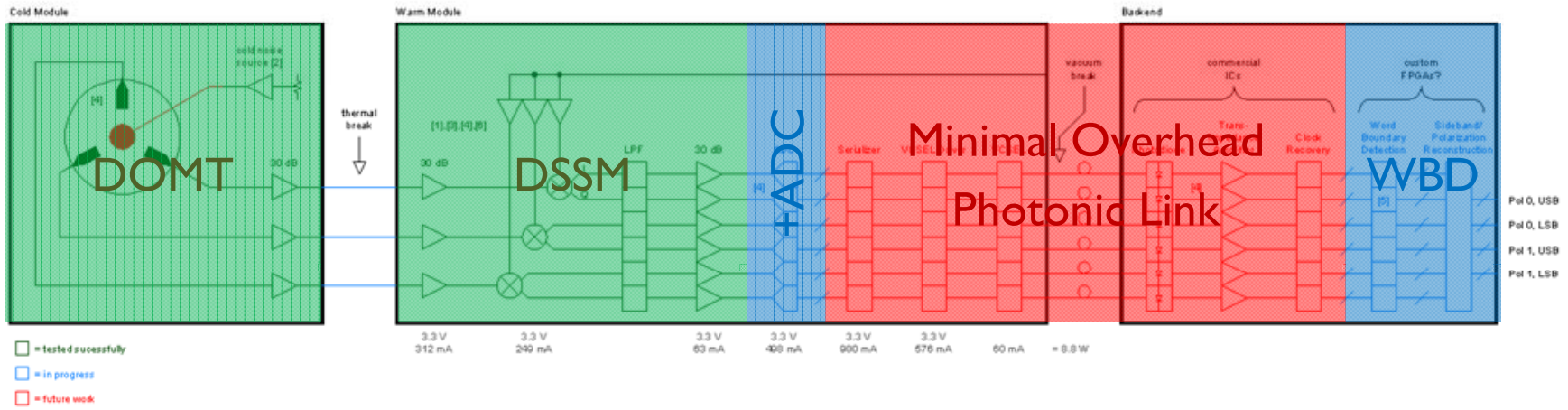
...all overhead for link management is in the back end.







Program Status



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TESTED

IN PROGRESS

UNTESTED

References

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