A Broadband Receiver for FAST

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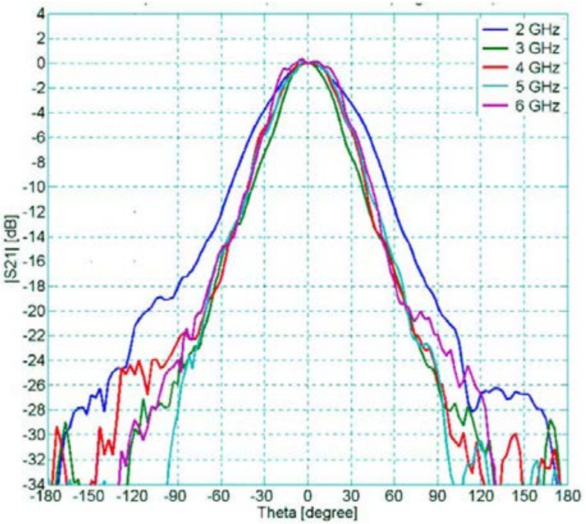
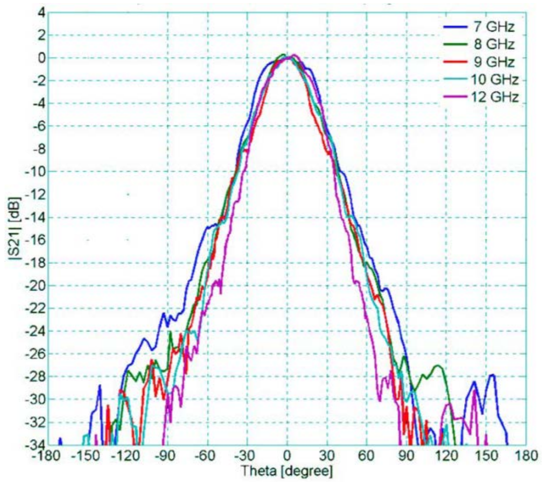
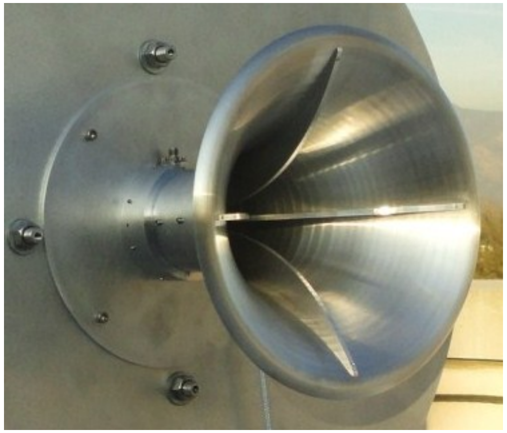
Wideband Antenna Feeds

Ahmet Agiray Ph.D. thesis at http://radiometer.caltech.edu or IEEE AP

- Quad-Ridge Flared Horn (QRFH) antenna feeds cover 6:1 frequency ranges and have been designed and tested on several antennas with varying F/D illumination angles and giving ~ 60% efficiency
- The feed can be scaled to for different 6:1 ranges. A 10cm diameter feed cover 4 to 24 GHz (SKA?) and a 1.5m diameter would cover 0.27 to 1.62 GHz (FAST)
- Patterns are fairly constant as required for an efficient feed for a parabolic reflector.
- Square implementations are easier to fabricate for low frequencies.







Circular Quadruple-Ridged Flared Horn Achieving Near-Constant Beamwidth Over Multi-Octave Bandwidth: Design, Measurements and System Performance

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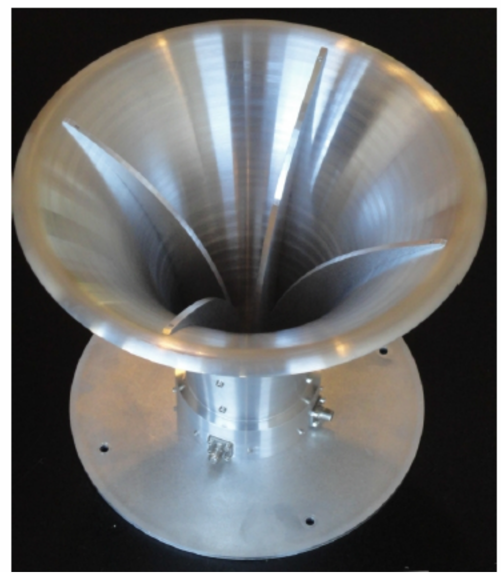
William A. Imbriale, *Life Fellow, IEEE,* Christopher Beaudoin, *Member, IEEE*

***Abstract*—A circular quadruple-ridged flared horn achieving almost-constant beamwidth over 6:1 bandwidth is presented. This horn is the first demonstration of a wideband feed for radio telescope reflector antennas which can accommodate different optical configurations. Measurements of stand-alone horn performance reveal excellent return loss performance as well as very stable radiation patterns over 6:1 frequency range. In addition, system performance of the quad-ridge horn on a radio telescope is presented which shows an average aperture efficiency of 70%. Design approach and modal analysis are detailed with particular attention devoted to design insights gained from analysis, fabrication and measurements of the horn presented herein.**

***Index Terms*—wideband feed, constant-beamwidth horn, feed for radio telescope, quad-ridge, ridged horn.**

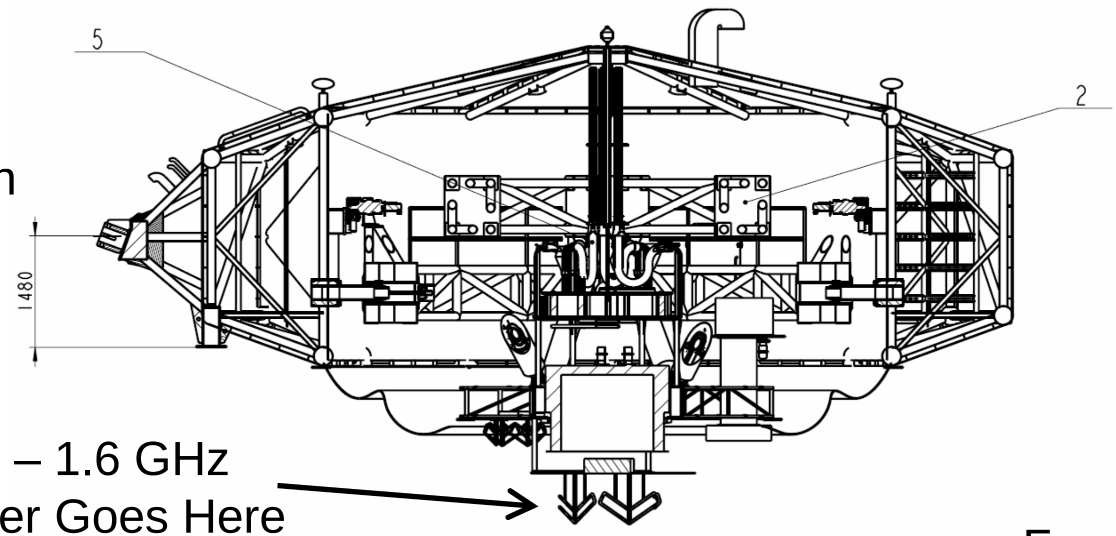
I. Introduction

EFFICIENT reflector antenna feeds with bandwidth much greater than an octave would greatly benefit radio astronomy as well as other applications in communications and defense systems. The very wide bandwidth provides system



Mounting of Broadband Feed and Receiver at FAST Focal Region

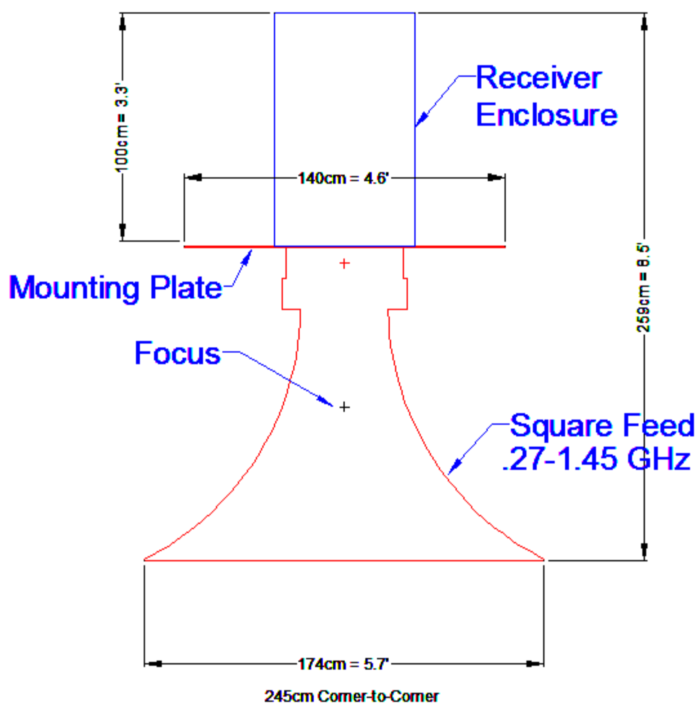
Focus Cabin



0.27 – 1.6 GHz
Receiver Goes Here

Feed 1.45m Square

Feed and Receiver
Not to Scale



Proposed 0.27 to 1.62GHz Receiver for FAST
Start June 2014, Complete June 2016
Design, Fabricate, and Test Receiver at Caltech
Deliver Designs to NAOC with Option to Deliver Hardware

1) **Feed Aperture Efficiency** - Greater than 60% for illumination of a F/D=0.461 ideal parabolic reflector.

2) **Feed Spillover Noise** - Less than 10K noise from 300K radiation outside of 64 degree angle subtended by the reflector in the 0.5 to 1.62 GHz range; less than 15K in the 0.27 to 0.5 GHz range.

3) **Noise Goals** at 1.42 GHz

LNA Noise - 4K
Noise at Dewar Input Coax – 13K
Noise at Feed Aperture - 20K
Tsys - 35K

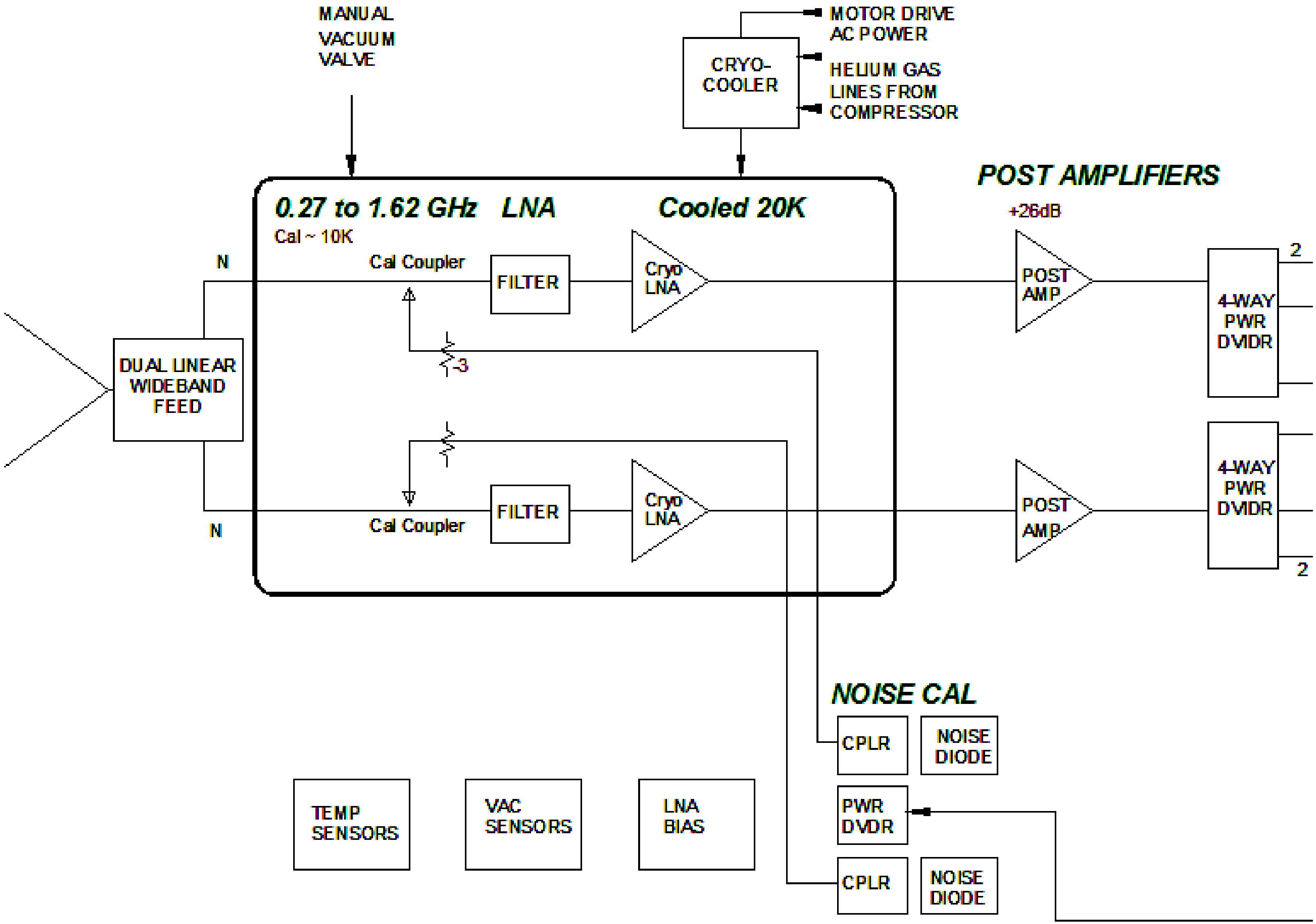
4) **LNA Gain Compression, P1dB** - > -39dBm referred to input

5) **Noise Calibration Signal** - 20 +/- 5K

6) **System Mass** - < 100 kg excluding cryogenic compressor

7) **Feed Size** - 1.45m square x 1.2m long

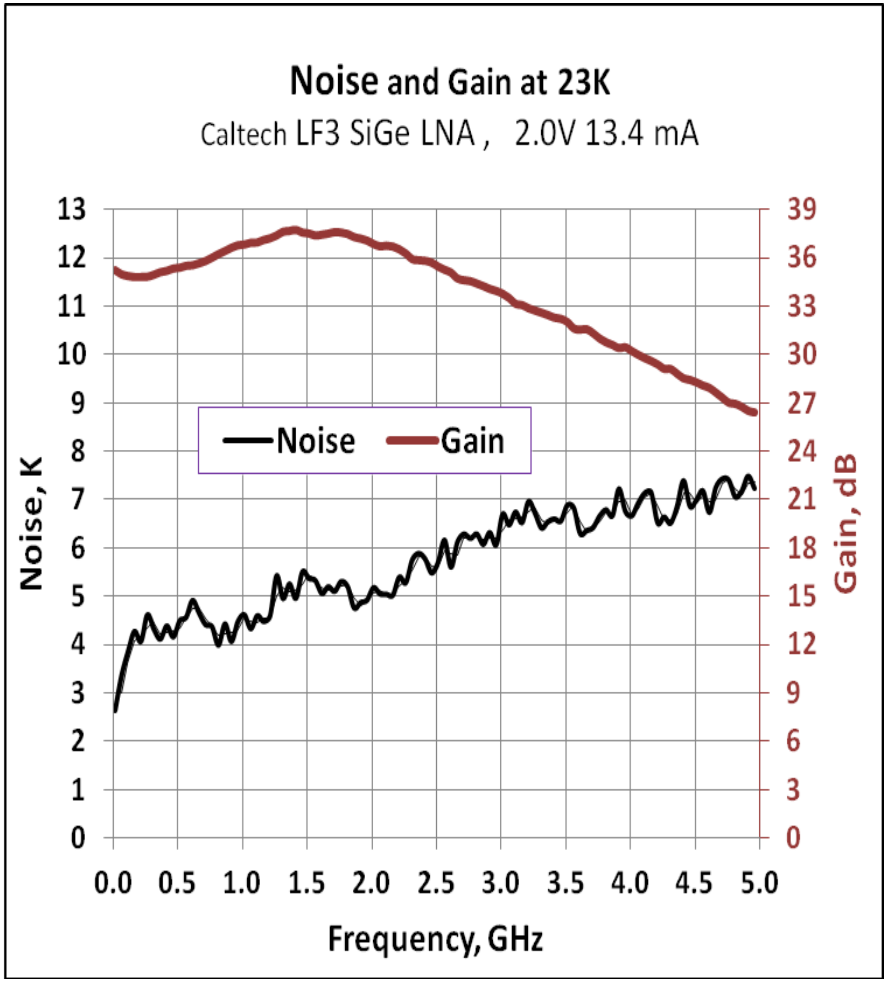
FAST Front-End



New SiGe Cryogenic LNA. LF3, for FAST 0.27 – 1.62 GHz Receiver

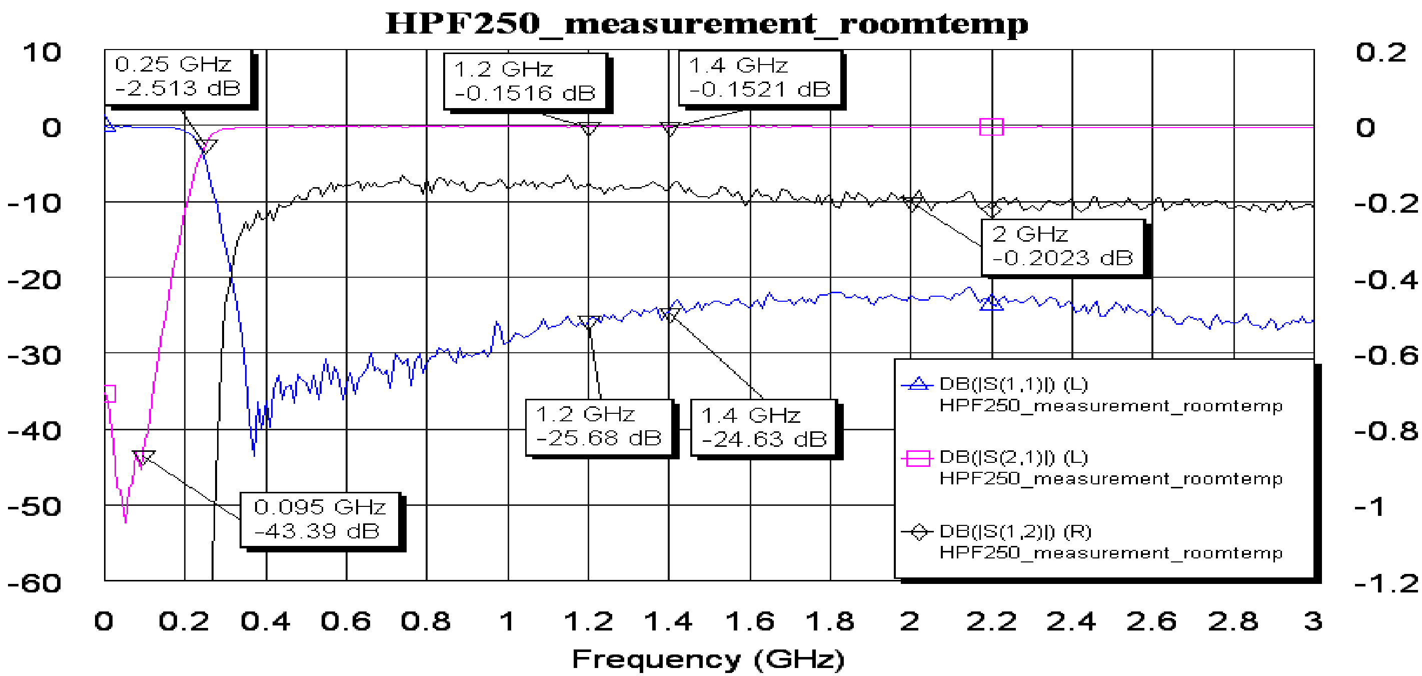
Performance Summary, 2V, 13mA Bias

Parameter	At 24K
Noise Temperature	<5.5 K
Gain =20log|S21|	36 +/-2 dB
IRL=-20log|S11|	>10
ORL=-20log|S22|	>14
Gain Compression, Output P1dB	-5 dBm
Gain Compression, Input P1dB	-41 dBm
Input P1dB at 2.5V Supply	-39 dBm
Maximum Power Output	+3 dBm = .002W



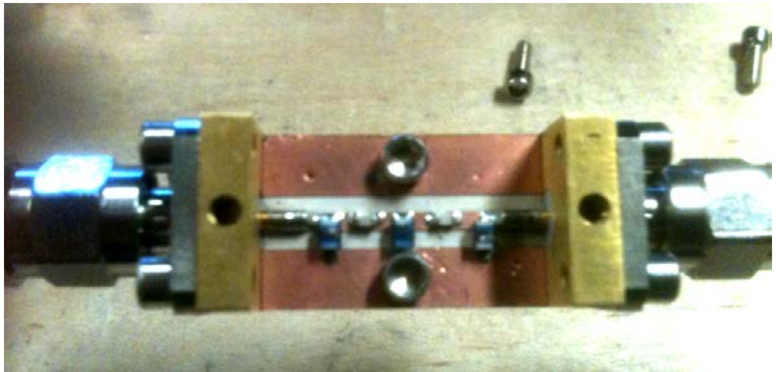
Cryogenic High-Pass Filter*

Loss of 0.15 dB at 300K is expected to decrease at 20K and, as is, would only add 0.7K to receiver noise. The filter provides 43dB attenuation in the FM band at 95 MHz



***Design and measurement for cryogenic cooled HPF with 250MHz cutoff frequency**

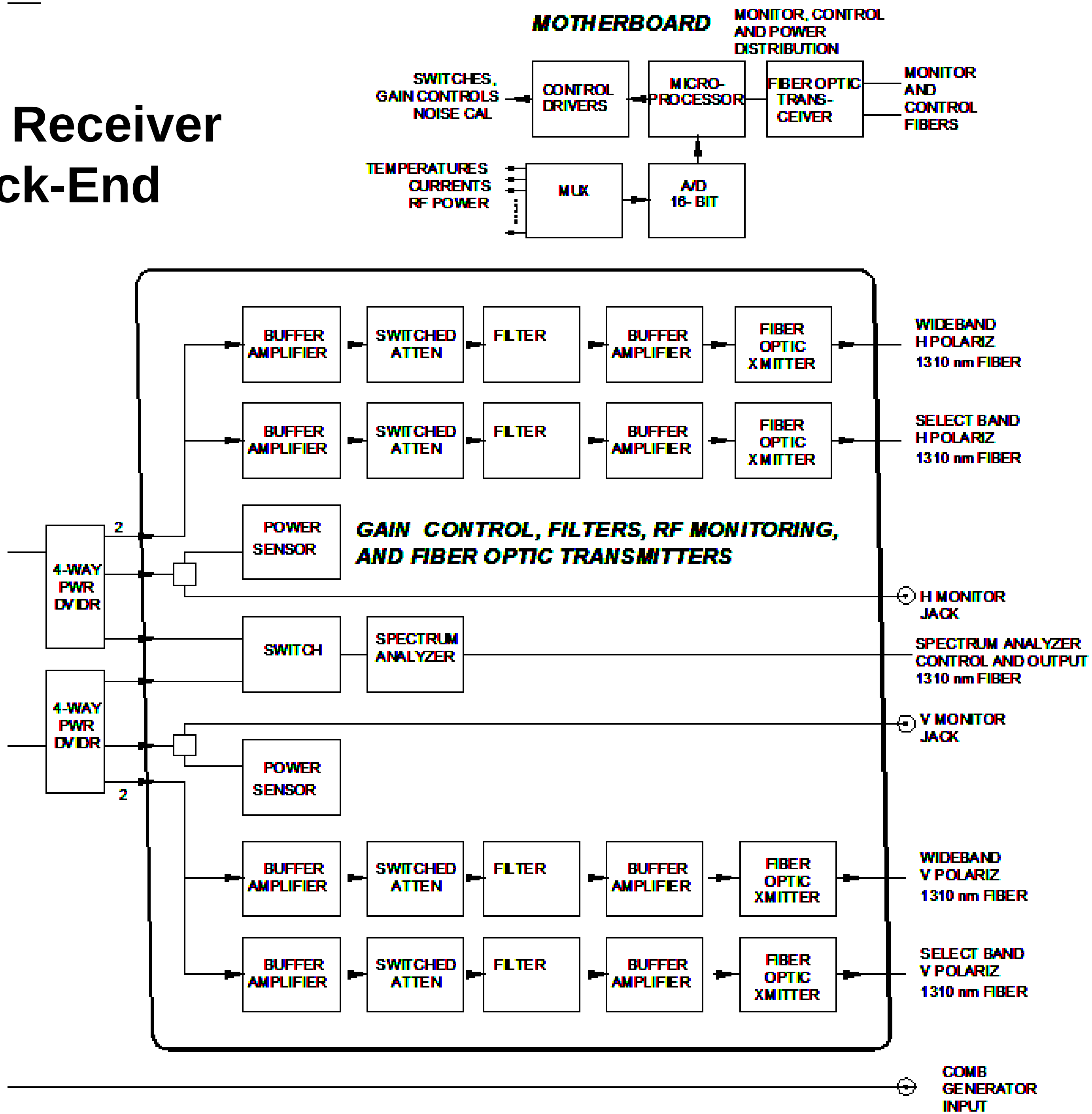
Liu Hongfei and Sander Weinreb
September 4 2013
http://radiometer.caltech.edu



Components Other Than LNA Determine System Noise

Component	**Remarks**	**LNA at 300K**	**LNA at 20K**	**LNA and Feed at 20K**
LNA	LNA measured at connector	33	4	4
Sky	Background + atmosphere	4	4	4
Spillover & Blockage	Reduce with offset antenna	10	10	4
Feed loss	Estimate	7	7	0
LNA to feed loss	20cm of 1cm diameter foamed coax, .04 dB	0	4	0
Vacuum feedthru	Glass/Kovar bead, 0.05 dB	0	3	2
Pre-LNA RFI Filter	0.1 dB Loss	7	0	0
Calibration coupler	0.1 dB Loss	7	0	0
Coax in dewar	10cm or .141 SS/BeCu .09 dB at 190K	0	3	0
Total	**Estimate, +/- 5K**	**68**	**35**	**20**

FAST Receiver Back-End



Caltech EE Ph.D. Theses on Instrumentation for Radio Astronomy, 2003-2013

Thesis links at http://radiometer.caltech.edu

Matthew Morgan – *Millimeter-Wave MMICs and Applications,* 2003
Mixers, multipliers, LNA's, switches, and multi-chip modules

Joseph Bardin - *Silicon-Germanium Heterojunction Bipolar Transistors For Extremely Low-Noise Applications,* 2009
SiGe transistor theory, modeling, cryogenic tests, amplifiers

Glenn Jones - *Instrumentation for Wide Bandwidth Radio Astronomy,* 2009
Radio telescope system tests, spectral lines, pulsars, and RFI mitigation

Damon Russell - *Technology Advances for Radio Astronomy,* 2012
Cryogenic wafer probe station, noise parameters, SiGe MMIC designs

Ahmed Akgiray - *New Technologies Driving Decade-bandwidth Radio Astronomy: Quadruple-Ridged Flared Horn & Compound-Semiconductor LNAs,* 2013, 6:1 bandwidth feeds, 1-20 and 3-50 GHz HEMT LNA's

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