Near Term SMA Upgrades

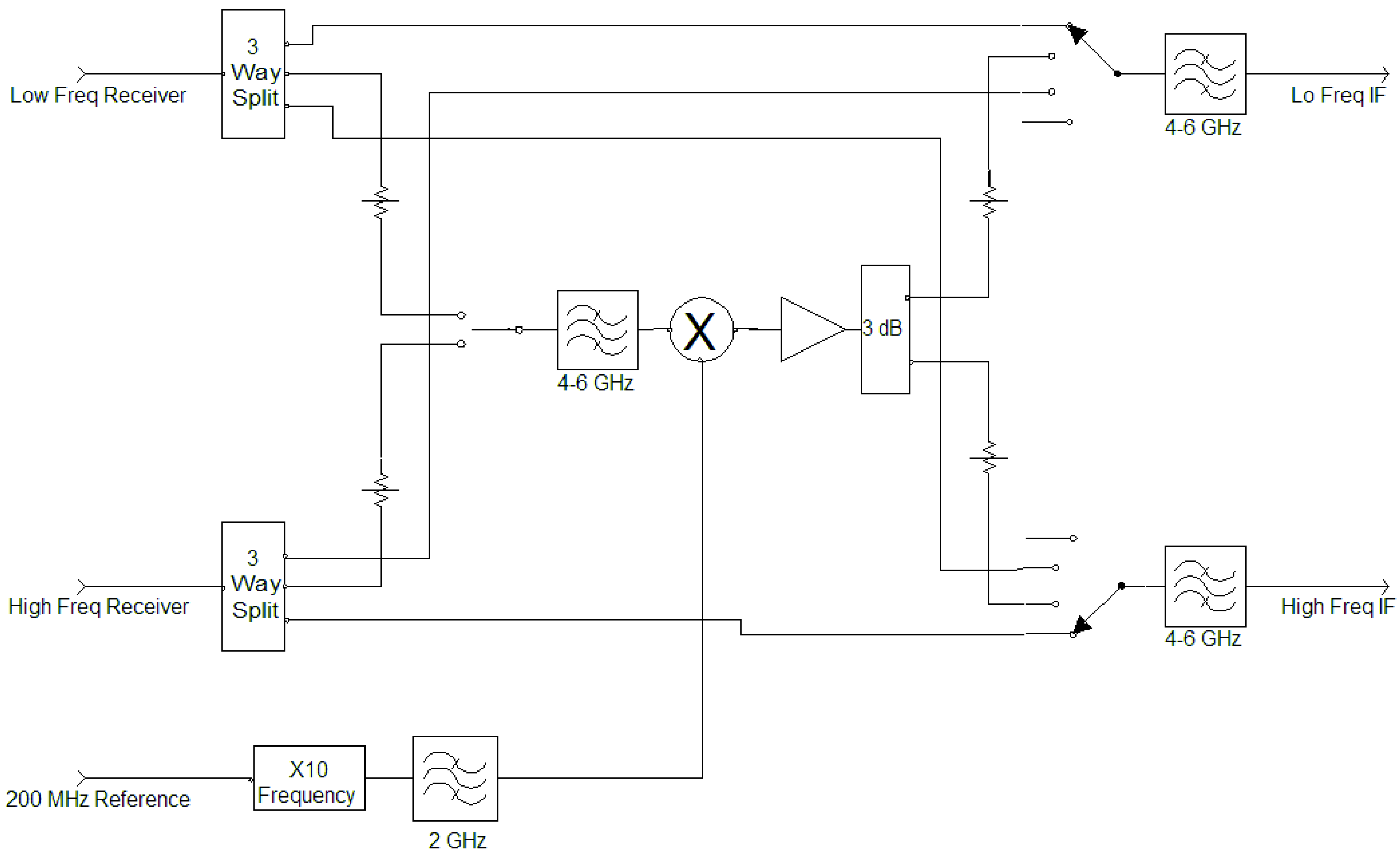
Robert W. Wilson

Double Bandwidth with One Receiver

(Better continuum sensitivity, more instantaneous spectral coverage)

- Minimal changes are required.
  - Remove 3.75-6.25 GHz filter in dewar.
  - Replace isolators at LNA input, replace a few commercial amplifiers (most will be ok).
  - Downconverter to convert 6-8 GHz to 4-6 Ghz needed.
  - LO can be derived from 200 Mhz reference in cabin.
  - Switches needed to feed either the high or low frequency receiver to the downconverter and feed its output to the other IF system.
- Engineering personnel are available.
- One or two chunks will be lost because of MRG leakage into the IF at 6-8 GHz.

Bandwidth Doubling Processor



Complete 400 GHz Receiver Installations

(Better polarization measurements, new spectral band)

- Presently 4 are installed and working.
- We expect to have 6 by the end of the year, all by the middle of 2008.
- The present 400 Ghz receivers are not performing as well as expected. This is being investigated.
- We need the Todd Hunter replacement in the receiver lab to speed this along.

Improvements to 600 GHz Receivers

(Improved sensitivity is critical for calibration)

- Remove Martin-Puplett diplexer and use VDI multiplier with one tuner (Phase Shifter).
- Replace Teflon lens with a cooled quartz lens.
- Replace JPL “long junction” mixer with University of Cologne SIS mixer.
- Install quartz window.

Other Receiver Improvements

(Improved sensitivity)

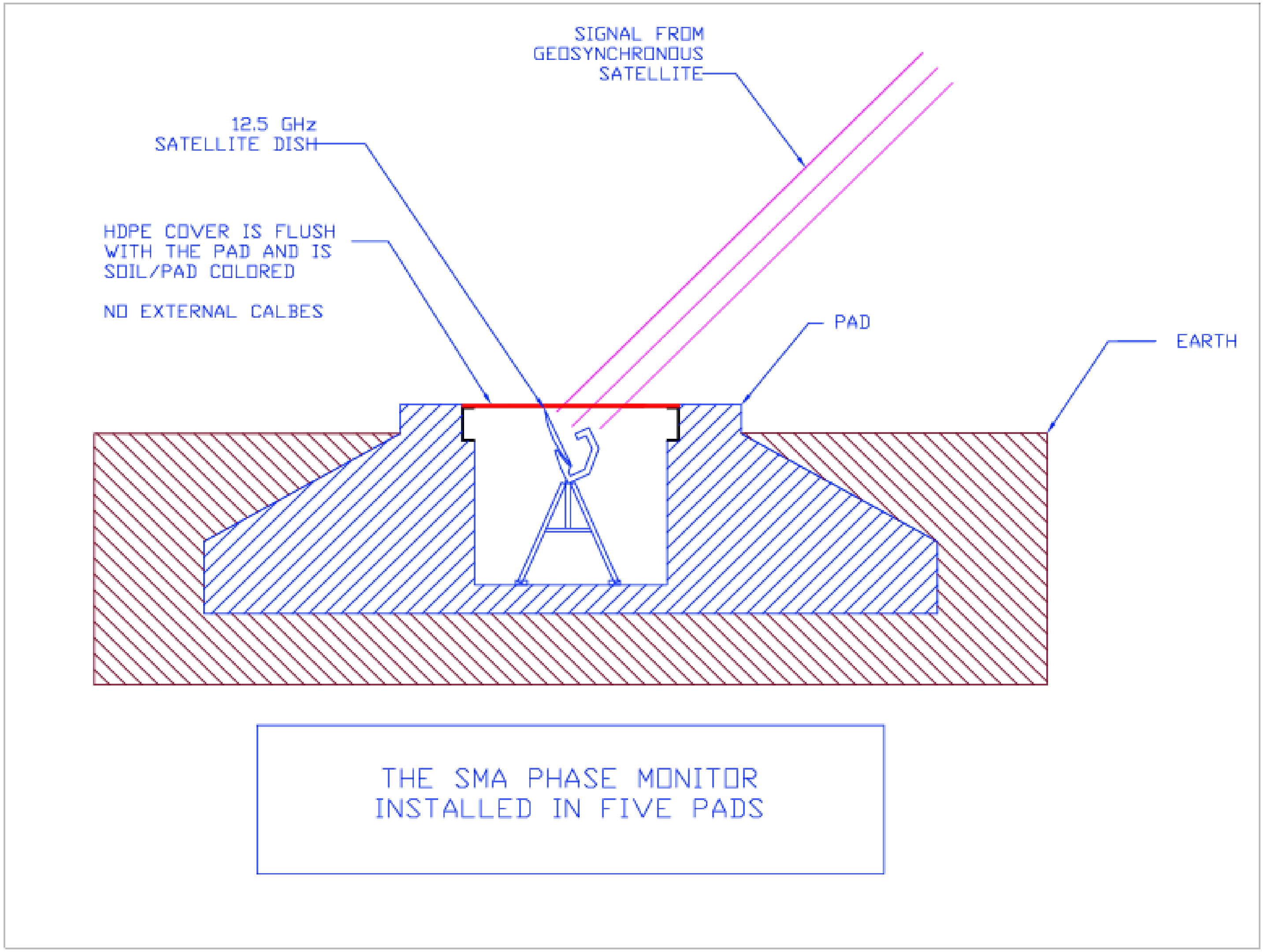
- For comparison, the “top of dewar” receiver noise temperatures are: 200 GHz 50-60K, 300 GHz 60-80K, 400 GHz ~80-130K**
- Replace Teflon windows with coated quartz to reduce loss and improve bandwidth. (3K)
- Install wire grid polarizers to terminate feed horn cross polarization in a cold absorber (10K)
- Cool the Teflon lens to 45K (3K)
- Start using VDI tunerless multipliers on the 230 receivers
  - Less loss from LO coupler
  - No spares for Millitech multipliers and they cannot be repaired
  - Easier and more reliable tuning

Atmospheric Phase Monitor I

(More efficient observing)

- Four satellites available with 48°-53° elevation angles.
  - Echostar 5, Galaxy 27, Galaxy 13, Galaxy 10R
- Each transmits at ~12 Ghz with~20kW ERIP with two polarizations interleaved over 500 MHz bandwidth
- Expect to measure relative delays of 3.5 µm over time scales from 0.1 to 1000 seconds (good for 600 GHz).
- Use SMA pads and optical fibers for stability.
- 3 receivers for phase closure and 2-d u-v coverage.
- Remove phase change from calculated orbital motion.

Phase Monitor Antenna in an SMA Pad



Atmospheric Phase Monitor II

(More efficient observing)

- Use inexpensive satellite TV components
  - LNB – Invacom QPH-031 provides horn, orthomode transducer, LNA and quadrature hybrid to allow four polarizations to be observed. Noise figure 0.4 dB, price $79 ea. for 1-9.
- Data may be used to
  - Choose optimal observing frequency and project for current conditions (Phase stability and τ are only weakly correlated.)
  - Chose optimal time of observing calibrators
  - Determine Phase stability trends at the site
- Monitor will run 24/7 and produce uniform data for the Mauna Kea community in real time.

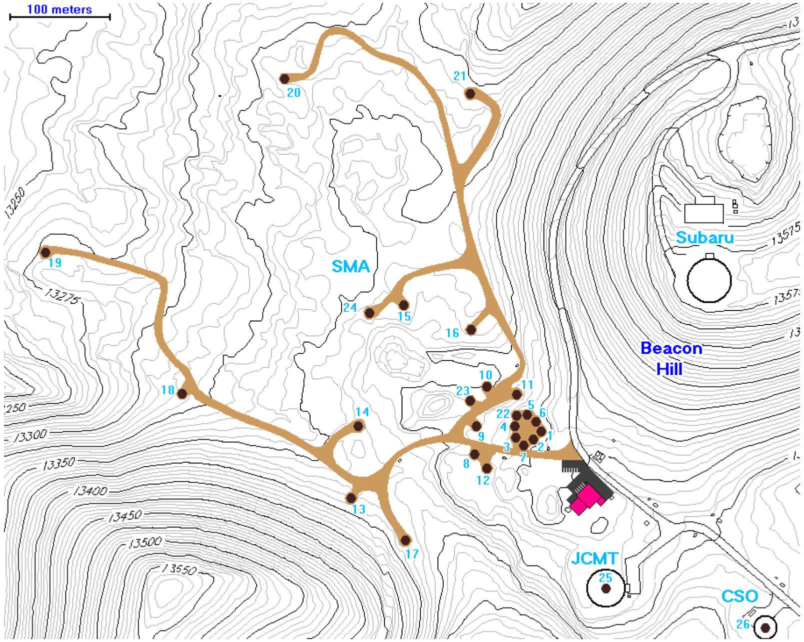
Scott Paine's water vapor measurement plans

- I'll have 2 or 3 slides from Scott here on Tuesday

eSMA

(Increased sensitivity and spatial resolution)

- Max Baseline, Aeff.
  - SMA 508 m 161 m^2
  - SMA+CSO 782 m 201 m^2
  - SMA+JCMT 624 m 238 m^2
  - eSMA 782 m 278 m^2
- RMS flux in one 8h track
  - SMA 0.551 mJy 1.00
  - SMA+CSO 0.519 mJy 0.94
  - SMA+JCMT 0.393 mJy 0.71
  - eSMA 0.375 mJy 0.68



Assumptions about eSMA Telescopes

Telescope	E_{app}	A_{app}	T_{Rx}	Bw (Hz)	#Sb	#Pol
SMA	0.71	28.3	80	$2x10^9$	2	2
CSO	0.71	85.0	80	$2x10^9$	2	1
JCMT	0.55	176.7	80	$2x10^9$	2	2

eSMA Progress

- CSO and JCMT can be used very much like SMA antennas.
  - Optical fibers are in place and connected.
  - JCMT and CSO bought IF/LO equipment like the SMA's from us and have an SMA style VME Bus control computer.
  - JCMT and CSO can be commanded in position like another SMA telescope.
  - 10 station correlator code has been written and works.
  - We can now work with 2 different LO multiplications after the Gunns.
  - Polarization settings to match the SMA's are known for the JCMT and CSO.

eSMA Telescope Specific Problems

- JCMT
  - Can fit a baseline, but changes by ~1 cm between sessions. This might be an elevation or other internal effect. No successful multi-quasar baseline tracks have been observed yet.
  - Axes don't intersect (not orthogonal to baseline terms).
  - The cab moves wrt. the telescope, changing the path length.
  - Slews much slower than the SMA, increasing calibration overhead.
  - T_{Rx} at 345 GHz is currently 2X that of an SMA receiver.
  - Fringes have not been seen yet at 345 GHz.
- CSO
  - Baseline fits have a 120 deg. quasi-sinusoidal residual with ~1 hour period. The same oscillations are seen on the beacon.
  - Polarization can be tracked only by manually rotating the receiver.
  - Slews much slower than the SMA, increasing calibration overhead.
  - Fringes have not been seen yet at 345 GHz.

eSMA Operational Problems

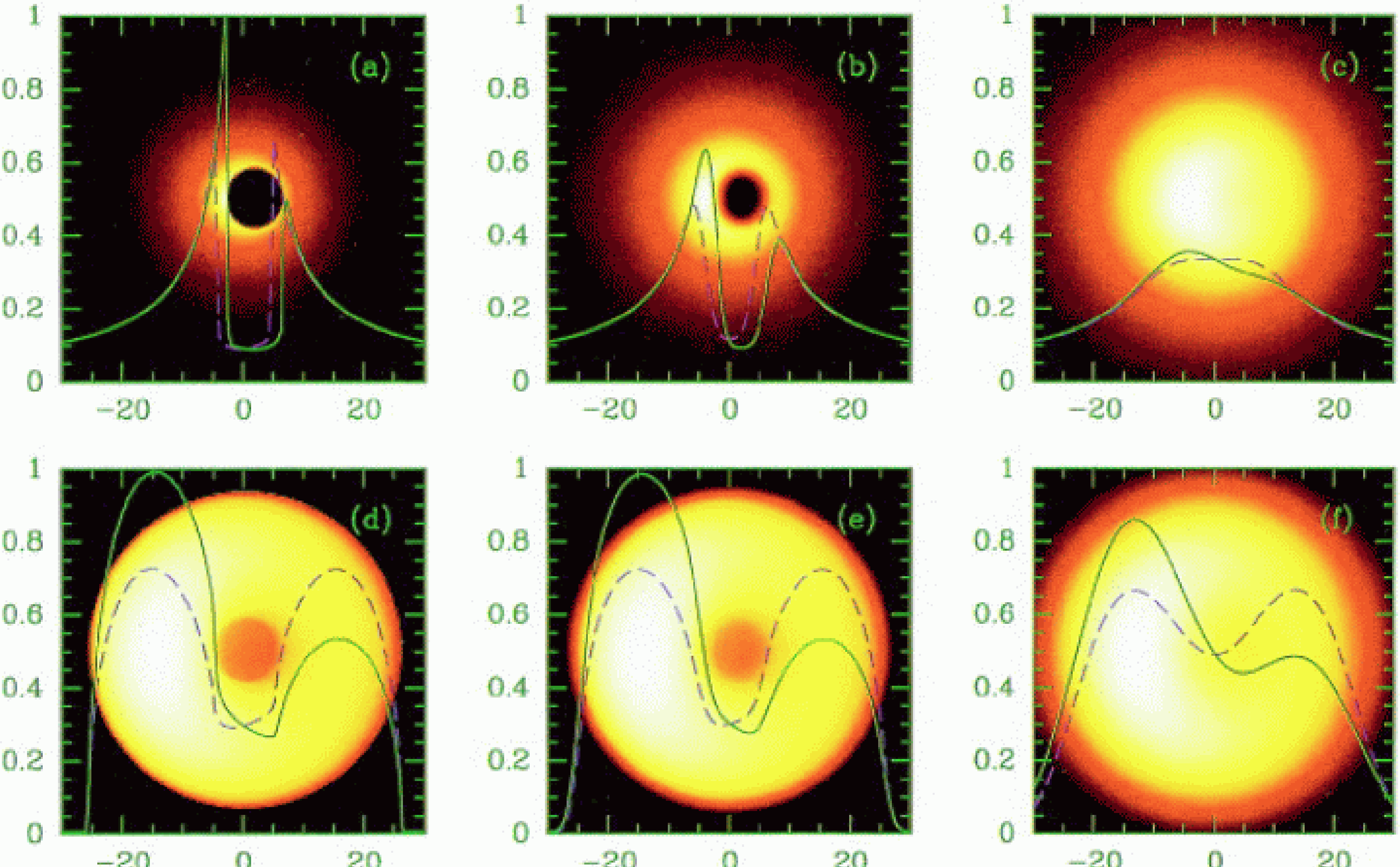
- JCMT and CSO have generally had separate problems, so simultaneous testing is not fruitful.
- Different scheduling methods and priorities make testing hard.
- We have been running daytime tests, but only < 1 night in 2 months have been devoted to eSMA tests.
- There is no specification for how well the eSMA must work before science observations can be done.
- We have little progress from the last 2 years' efforts.

Sub-mm VLBI from Mauna Kea

- The science target is the SMBH in Sgr A* at 800 µm
  - 20 µas resolution can resolve and image the structure of emission at the event horizon scale
  - At longer wavelengths GC is optically thick and image is blurred by scattering.
  - Sgr A* is obscured by dust in the optical and near IR.

Ray tracing model

Falcke et al. ApJ 528, L13 (2000)



←Maximally rotating SMBH, with envelope of radiating gas in free-fall

←Non rotating SMBH, medium has uniform emissivity from Keplerian shells

↑ Simulated "actual" intensity

↑ observation λ=0.6 mm

↑ observation λ=1.3 mm

Horizontal axis in these simulations is in units of the gravitational radius, about 5 μas.

Sub-mm VLBI from Mauna Kea

- Our effort is centered on the SMA, using the eSMA antennas and connections.
  - Jonathan Weintroub leading our effort with many external and internal collaborators.
  - VLBI Program PI: Shep Doeleman, MIT-Haystack
  - IR&D funding for hardware based on wider CfA interest.
  - We can currently reference the eSMA to a high quality installed MASER
  - Co-phasing the SMA+CSO+JCMT will give 3.3x the effective area of the JCMT alone at 345 GHz.

Hardware for Phasing, Summing and Recording the eSMA for VLBI

- CASPER (Center for Astronomy Signal Processing and Electronics Research) at Berkeley supplies
  - FPGA boards
  - Design flow software
  - Astronomy macros
- MIT-Haystack Mark5b Digital Backend (CASPER based also)
- Use IF from existing “Correlator 1st downconverter” output
- Use a correlator in an FPGA based on a CASPER design for calibrating the system and dynamic atmospheric tracking.
- We either have or have on order enough hardware to process 1 GHz of bandwidth (4 Gbit/sec.).
- Many of the problems of the eSMA will be present here also, but should have a common solution and phases may be corrected by the correlator.

Successful 1.3mm VLBI Observations

April 9 & 10, 2007 with JCMT, SMTO and 1 CARMA Antenna

Source	Flux (Jy)	SMTO-CARMA	SMTO-JCMT	CARMA-JCMT
1058+013	3.4 (3 Apr)			
1334-127	4.9 (31 Mar)			
3C273	12.2 (4 Apr)			
3C279	9.4 (4 Apr)			
Sgr A*	2.4 (10 Apr)			
1749+-96	6.4 (4 Apr)			
1921-293	4.0 (12 Apr)			
BL-Lac	2.9 (18 Apr)			

Quasar fluxes from Mark Gurwell, Sgr A* measured by CARMA during VLBI