VLBA Scientific Memo no. 17.

VLBA 3mm Specs & Status

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Introduction

This memo seeks to set the target specs for the completed 3mm VLBA system, and summarizes the current status of the antennas and receivers in Table 1. Comments are welcome to: `vdhawan@nrao.edu`. The memo may also be viewed from the VLBA home page, at

`http://www.nrao.edu/vlba/html/3MM/scimemo17.html`

Prototype VLBA 3mm dual-polarization receivers, covering nominally 80-90 GHz, have been in use on the antennas at Pie Town (since 1996 December) and Los Alamos (April 1998). Participation is routine in the Coordinated Millimeter VLB Array. These sessions are scheduled in MK3 mode by Haystack Observatory in several sessions, amounting to 15-20 days per year.

First VLBA-only fringes were reported in late April, and can be viewed at:

`http://www.nrao.edu/vlba/html/3MM/3mm.html`

Requirements

Minimum Coverage: 84.0 - 95.5 GHz

This band should have the best performance, as it includes the methanol masers at 84.5 & 95.1GHz, and other Galactic lines including HCO+ (89.19), SiO (86.243), HCN (88.63), HNC (90.66). At 18-20% efficiency, (Table 1) the 25m VLBA antennas will have comparable sensitivity to existing 12-15m millimeter antennas, for galactic absorbtion-line studies.

Easily Attainable: 80 - 96 GHz

This extended band is available from amplifier and polarizer, see below. There is no strong argument for going down to 80 GHz, other than the small but cumulative benefits of better efficiency, phase stability and opacity for continuum compared to 95GHz; and a wider span for possible redshifted lines. Minor costs are expected from hardware redesign, and little or no penalty from degraded mid-band performance.

Action Item: Detail cost estimates.

[1]Acknowledgement: Comments from NRAO staff and colleagues have been incorporated.

Amplifier Specs

Band : 80-96 GHz; Gain : >33dB; Tamplifier : ~45K; Input ret.loss : >10 dB, 15dB preferable.

M. Pospieszalski's prototypes met or exceeded these specs, though not in exactly this band. [The return-loss spec was driven by the assumed un-availability of low-loss coolable isolators. J.Webber has information on new designs for waveguide band isolators that may relax this criterion.]

Action Item: We need to better understand the noise budget of the PieTown receiver, i.e., why 50K amplifiers (in CDL bench test) give over 150K (on telescope). See Table 1 notes.

Other Hardware

These do not appear to be severely limiting.

Polarizer

The present units go from 75-95 with 1dB ellipticity, and to 96 with 2dB. The design is a scaled version of the 12-15.4GHz polarizer, which NRAO has permission to build from Atlantic Microwave specs. It can be re-centered at 88GHz with modest effort.

Spacek Mixers

These cover 80-90 now; can do 85-95; and can probably do 80-96.

Retrofit four Receivers

The prototype, somewhat ad-hoc specification was 80-90GHz. About $18K per receiver is required for RF filters, LO multipliers and filters, and miscellaneous components.

Action Item: Detailed respec & cost.

Antenna Efficiency

Before any panel adjustments, the efficiencies at 86.2GHz are: PieTown 12%; LosAlamos 18%, where 100%=5.65Jy/K. (Table 1.)

Action Item: The difference between the antennas needs to be understood; e.g. whether the sub- or main reflector is the cause. The efficiencies of LA and PT are indistinguishable at 7mm.

Dual-frequency requirement (on wish-list)

The option to allow simultaneous observation at 3mm and another band (as done at S/X) has not been discussed recently, and so is included here. The expense probably rules it out for now.

Optics: dichroic & ellipsoid, plus retraction mechanism for stowing. S/X indications are \$10-15K per antenna.

Which bands to pair?

3mm + 2cm: Will work only for continuum sources. Simultaneous operation would need an additional 2cm converter module, as 3mm now uses 2cm converter module as IF. (~\$15K per antenna)

3mm + 1.3cm: Can work even when source is present only at 86GHz, using 22GHz water-vapour radiometry for phase correction. Will need an additional 2-16GHz synthesizer. (~\$15K per antenna)

Feed location constraints : 2cm is probably OK, 1.3cm needs to be explored (S.Srikanth)

In summary, the cost, not including design, is ~\$30K per antenna, half for the optics and half for extra electronics, either a 2-16GHz synthesizer, or 2cm converter.

Action Item: Watch results of water-vapour radiometry tests on VLA. Do VLBA tests.

Related Developments

Ongoing efforts are merely listed here, to be discussed elsewhere.

- Pointing: Present rms is 5-7", with occasional systematic deviations upto 30" from rail and thermal effects. Tests indicate improvements from a combination of enhanced pointing model, and offsets referenced to 1.3cm or 7mm.
- 512 MHz Wideband Recording: nearly ready to test.
- Holography & Metrology

Interference

Emission from Cloud Profiling Radars at 94GHz is not a problem yet. We may need notch filters eventually, but the frequency is not certain. Example specs for the radars seem to be 1-2KW, 1-2m dia dish, 94-95GHz. [J.B.Mead et al., Proc.IEEE 82 no.12 Dec 1994 p1891]. Vehicle Radars at 75GHz should not be a problem.

The protected band (passive Earth Exploration Satellite, Radio Astronomy and Space Research) is 86-92 GHz, for the time being. Methanol masers lie outside of any protection here.

ITU-R Footnote S5.149 lists radioastronomical spectral line bands at 93.07 - 93.27 GHz (1-0 lines of N2H+); 97.88 - 98.08 GHz (2-1 line of CS).

Other current allocations include 76-81GHz: Radiolocation; 81-84GHz: Satellite downlinks; 84-86: Broadcasting Satellite; 92-95: Satellite uplinks.

Action Item: Get details on projected activity in these bands, and proposed allocation changes.

Appendix: Status of Antennas & Calibration, 1998 May

Calibration was based on the planets, the moon, and atmospheric transparency as consistency checks on the primary calibration by hot/cold load. 7mm data were taken simultaneously, as a sanity check, and to measure the opacity.

The efficiency difference between PT and LA is under investigation.

We urgently need to resolve why amplifiers with noise under 50K result in a Tsys on telescope of 150K or more at PT - a detailed breakdown of the noise added by the polarizer, horn, mixer, etc. is needed. 22K is from the atmosphere and about 25K comes from the high Tcal, at 50% duty cycle. Prior to telescope installation, the 2 channels at PT gave TRx/Tcal at 86.2GHz of 78K/49K; 87K/37K, (M. Balister). These amplifiers had ~34dB gain, 46K noise as tested at the CDL, including window, cold horn and room temperature mixer with noise of 1500K (M. Pospieszalski).

There seems to have been a gradual increase of Tsys since installation. (Could this be due to the slow leak in the vacuum window?)

The LA amplifiers were not expected to be optimal - they were prototypes of the MAP amplifiers, designed for higher frequency, (J.Campbell, 86GHz VLBA Prototype Project Review, 1998Mar26).

Ant	freq	Pol	SEFD	TsysZ	TcalHC	Eff	EffMoon	TcalTAB
LA	86.24	R	5200	165	23.	18%	53%	12.8
LA	86.24	L	8400	230	37.	16%	54%	23.6
PT	86.24	R	9400	195	47.	12%	50%	43.7
PT	86.24	L	8200	175	52.	12%	48%	36.7
LA	43.12	R	1050	95		51%	60.1%	8.21
LA	43.12	L	1200	112		53%	59.6%	6.51
PT	43.12	R	1050	98		53%	60.3%	2.14
PT	43.12	L	1020	94		52%	61.0%	2.80

Notes:

SEFD is System Equivalent Flux Density, Jy.

TsysZ is Zenith System temperature, K, with Tatmosphere of 15K, 5% zenith opacity at 7mm; 22K, 7% opacity at 3mm. All Tsys measurements are SSB, 16MHz BW.

TcalHC are the calibration temperature values, based on Hot/Cold load measurements, (D. Bagri)

Efficiency on a point source, at elevation 45°, opacity corrected, assuming 5.65 Jy/K = 100%. Antenna gain curves are in the file available to astronomers via anonymous ftp to: ftp.aoc.nrao.edu

EffMoon is the ratio [Antenna temp on moon] / [moon temp]. Assuming the small-scale dish surface errors are the same at PT and LA, (as seems to be indicated by the holography), the scatter in Moon efficiencies reflects errors in the Tcal values, rather than differences in the fraction of beam lying on the moon.

TcalTAB is the cal value in the table used by VLBA Operations. The 7mm values are reasonably consistent across the array and R/LCP. I think most were measured in the field, with hot/cold loads, (G. Petencin.) The 3mm table values are clearly wrong, the hot-cold calibration is much more consistent. It is not clear why the Tcals in the field are systematically more than the laboratory measurements.