Radio Interferometry: Theory, Techniques and Applications,
IAU Coll. 131, ASP Conference Series, Vol. 19, 1991,
T.J. Cornwell and R.A. Perley (eds.)

THE OWENS VALLEY MILLIMETER ARRAY

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ABSTRACT In this paper the telescopes and signal processing systems of the Owens Valley Millimeter Array are briefly described.

INTRODUCTION

The Owens Valley Millimeter Array consists of three 10.4 m diameter telescopes located in a semi-desert region of California at an elevation of 1200 m. During the past four years the system has been substantially upgraded: Dual frequency SIS receivers covering the λ~2.6 mm and λ~1.3 mm bands have been installed and the local oscillator and correlator systems have been replaced. A new computer system has also been installed and the array has been fully automated.

TELESCOPES

The three 10.4 m diameter telescopes (Leighton, 1978) are configured for Naysmith focus operation. A small room located on the alidade platform at one end of the elevation axis provides a laboratory environment for the receiving equipment.

At night the telescopes have surface errors of ~35 μm rms and during the day there is an additional ~35 μm rms warping due to solar illumination. The measured nighttime aperture efficiencies at λ=2.6 mm and λ=1.3 mm are 0.65 and 0.40 respectively. The pointing accuracy of the telescopes is ~6" rms with some larger deviations at sunrise and sunset.

The telescopes can be positioned at any of the 25 stations laid out on a track with an inverted T geometry (200 m east-west and 180 m north-south). The basic station spacing increment is 10 m but a station is provided at 65 m west to allow for 5 m increments. The array has a maximum resolving power of ~2" at λ=2.6 mm and a map with this resolution requires 4 to 6 array configurations depending on the source declination.

RECEIVERS

Each telescope is equipped with a 4.5 K cryostat. The cryostats can accommodate two SIS mixers and are presently configured with one 80 to 115 GHz mixer and one 215 to 270 GHz mixer (Woody, Giovanine and Miller 1989).

The refrigeration system is a closed-cycle arrangement consisting of a Gifford-McMahon 15 K refrigerator and a Joule-Thomson expansion loop as shown in Fig. 1. The cooling capacity of the J-T system is ~1 W with a J-T return pressure of 16 psia.

The SIS mixers use a quarter height rectangular waveguide structure with a corrugated feedhorn and a single adjustable backshort connected to the outside of the cryostat. A computer-controlled stepper motor allows remote tuning of the backshort. The mixers require less than 1 μW of LO power and this is coupled via a ~1% dielectric beamsplitter outside the cryostat. Both Pb alloy and Nb-AlO_x-Nb SIS junctions are used in the mixers. Each mixer is followed by a cooled HEMT IF amplifier operating in the 1.2 to 1.7 GHz band with a noise temperature of ~6 K.

The λ~2.6 mm receivers typically provide double-sideband system noise temperatures (including the effects of the atmosphere) of ~150 K at 100 GHz and ~300 K at 115 GHz. The latter is dominated by the atmospheric opacity in the wings of the 118 GHz O_2 line. At λ~1.3 mm the system temperatures are typically ~400 K.

LOCAL OSCILLATORS

The local oscillator for each λ~2.6 mm receiver is provided by a suite of three U-band Gunn oscillators and a wideband fixed-tuned doubler. These cover the range 85 to 115 GHz. For the λ~1.3 mm band a pair of W-band Gunn oscillators and a tripler provide LO signals in the range 218 to 265 GHz. The oscillators are phase locked to a reference signal in the range 560 to 640 MHz (Padin, Woody and Scott, 1988).

The reference signal is distributed to each telescope in the array via a phase stable link which uses a modulated reflection technique (Swarup and Yang, 1961) to monitor and correct line length variations. In each telescope the phase stable ~600 MHz tone provides a phase reference for a synthesizer operating in the 5.0 to 5.8 GHz band. This synthesizer uses a YIG-tuned oscillator to provide a low phase noise reference for the Gunn oscillator phase lock circuits. Each Gunn oscillator is fitted with a computer-controlled stepper motor drive which is used to adjust the oscillator's mechanical tuning so that the frequency falls within the pull-in range of the phase lock system. An automatic search routine is used to hunt for a phase lock near the expected mechanical tuning position. Fringe rotation and phase switching are applied to the LO via a low frequency reference in the Gunn oscillator phase lock circuits.

The LO system provides an interreceiver phase jitter of 7° rms at 115 GHz, giving a sensitivity degradation of 0.8%. The long-term phase stability is ~20° p-p in 24 hours at 115 GHz.

CORRELATORS

The OVRO Millimeter Array has two correlator systems: A 500 MHz bandwidth analog crosscorrelator for continuum observations and a digital crosscorrelator for spectral line observations. The digital crosscorrelator computes the real crosscorrelation function for signals in up to four frequency bands each up to 128 MHz wide. These bands can be independently positioned anywhere in a 1 to 2 GHz IF band. Two-bit digitization with sampling at the Nyquist rate is used, so the maximum clock rate for the system is 256 MHz. The correlator has a simple serial architecture as shown in Fig. 2. In this arrangement the multipliers and digitizers always operate at the maximum clock rate and the frequency

https://doi.org/10.1017/S0252921100013725 Published online by Cambridge University Press

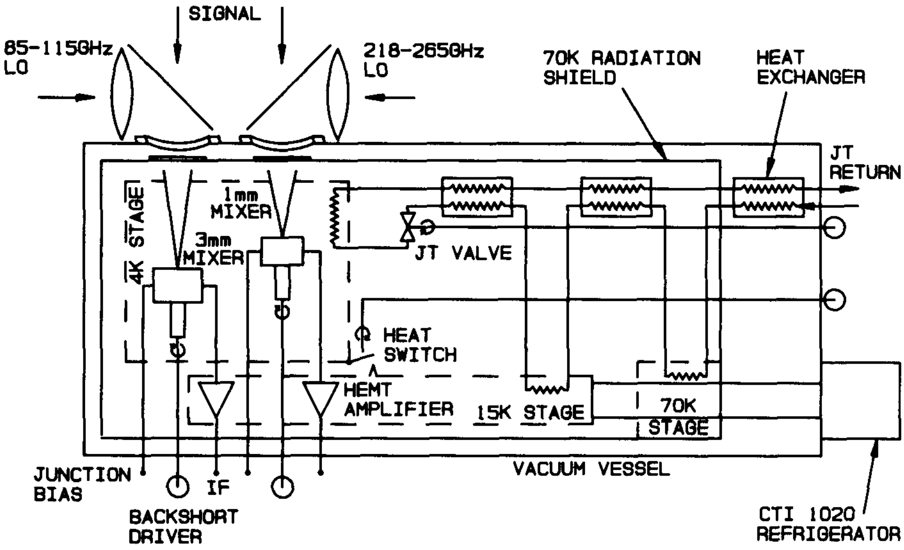

Fig. 1. Cryostat configuration.

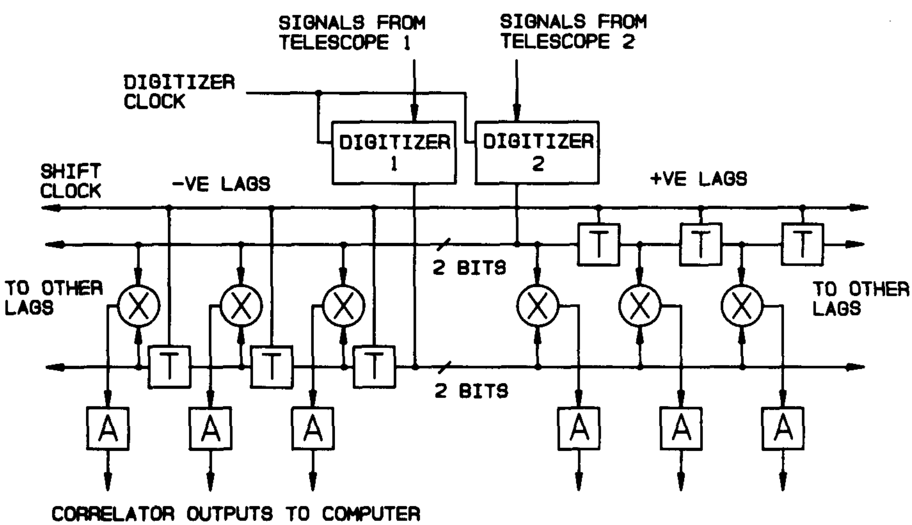

Fig. 2. Digital crosscorrelator architecture. X is a 2-bit multiplier, T is a delay of one shift clock period and A is an accumulator.

resolution of the system is controlled by the digitizer input bandwidth and the correlator shift register clock rate.

The correlator is divided into modules containing 128 lags (64 positive and 64 negative). For each baseline in the array there are four correlator modules which can be associated with independent bands or cascaded to give different resolution options. The four correlator modules fit into a standard VME chassis along with a 68030 processor which controls the operating mode of each module, data integration and phase switch demodulation.

ARRAY CONTROL SYSTEM

The computer system that controls the array consists of a central VAXstation 3100 connected to processors in the telescopes and correlators. The VAXstation handles user interaction, general computing, low duty cycle array control and disk storage. The other processors handle high duty cycle control such as telescope pointing, receiver control and data integration. The key component in the array software is the Central Control Program which runs on the VAXstation. This program interprets and executes commands from interactive sessions and from submitted text files and writes data to disk. The interactive sessions may be from terminals located at the observatory, from remote sessions connected through the network or from dial-in terminals and personal computers. Remote observing is fully supported and since many interactive sessions may be served the array can be monitored from several locations simultaneously.

CONCLUSIONS

During the past four years the sensitivity and stability of the Owens Valley Millimeter Array have been significantly improved and the operation has been fully automated. The instrument can be used to map sources in the 85 to 115 GHz and 218 to 265 GHz bands with a resolution of ~1" in the higher frequency band.

ACKNOWLEDGEMENTS

The Owens Valley Millimeter Array is partially supported by NSF grant AST 87-14405. SIS junctions used in the receivers were provided by R. Miller of AT&T Bell Laboratories and R. LeDuc and B. Bumble of Jet Propulsion Laboratory.

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https://doi.org/10.1017/S0252921100013725 Published online by Cambridge University Press

Ray Norris: How long did it take from starting the development of your receivers through to completion?
Steve Padin: About 2 years for development of the 115 GHz system and about 3 years for the 230 GHz system.