MARK III VLBI SYSTEM – TROPOSPHERIC CALIBRATION SUBSYSTEMS*

G. M. Resch

Jet Propulsion Laboratory

ABSTRACT

Tropospheric delay calibrations are implemented in the Mark III system with two subsystems. Estimates of the "dry" component of tropospheric delay are provided by accurate barometric data from a subsystem of surface meteorological sensors (SMS). An estimate of the "wet" component of tropospheric delay is provided by a water vapor radiometer (WVR). Both subsystems interface directly to the ASCII Transceiver bus of the Mark III system and are operated by the control computer. Seven WVR's are under construction and will be used at various radio observatories both as Mark III subsystems and as general observatory calibration tools. These instruments are designed to operate in proximity to a radio telescope and can be commanded to point along the line-of-sight to a radio source. They should provide a delay estimate that is accurate to the ±2 cm level.

*This paper represents the results of one phase of research carried out at the Jet Propulsion Laboratory, California Institute of Technology, under NASA Contract No. 7-100, sponsored by the National Aeronautics and Space Administration.

Any VLBI system that presumes centimeter level accuracy must provide for good tropospheric calibration. In the Mark III data acquisition system, this will be handled by two important subsystems. The first consists of a collection of surface meteorological sensors (SMS). Initally, this package will include an accurate barometer to provide an estimate of the "dry" delay component, a temperature sensor, and a humidity measuring device. The later two measurements could provide an estimate of the "wet" delay component based on a surface model if necessary. Later, we may add a device to estimate cloud cover and a solar hygrometer. Responsibility for this package rests with the group at Goddard Space Flight Center. The second tropospheric calibration subsystem consists of a water vapor radiometer (WVR) that can estimate the "wet" delay component along the line-of-sight of the associated radio telescope. Seven of the WVR's are being constructed at the Jet Propulsion Laboratory (JPL).

The functional description of the WVR is shown in figure 1. Our goal is to provide a ±2 cm delay calibration for all elevations above 20° under most atmospheric conditions. When it is raining, the assumptions on which the algorithms are based will be violated and the instruments will not operate properly. Similarly, a film of liquid H_2O on the cover of the horns (e.g., dew) introduces large errors. More work is needed to define the range of operating conditions and to provide some way to remove the accumulation of liquid H_2O.

- ACCURACY GOAL - ± 2 CM FOR ELEVATIONS ≥ 20° UNDER BOTH CLEAR AND CLOUDY CONDITIONS
- DUAL FREQUENCY DICKE RADIOMETER
  - 21 GHZ AND 31.4 GHZ CHANNELS
  - 200 MHZ BANDWIDTH
  - VARIABLE INTEGRATION TIME (FROM 0.1 SEC)
  - BEAMWIDTH = 8° (BOTH CHANNELS)
  - ALL MICROWAVE ELECTRONICS TEMPERATURE STABILIZED
- INTERFACES READILY TO EITHER A COMPUTER OR A PORTABLE TERMINAL
- CONVERSATIONAL COMMANDS
- REAL-TIME ESTIMATE OF WATER VAPOR CONTENT

Figure 1. WVR functional description.

The instrument consists of two microwave channels, one centered at 21 GHz and the other at 31.4 GHz, to provide an on/off line measurement. Each channel operates double sideband with a total bandwidth of 200 MHz. The effective system temperature in each channel is approximately 1100°K. The microwave module sits on a simple azimuth/elevation positioner and can be pointed to within 1° of a specified position. However, the elevation readout is accurate to ±0.3°. The microwave module contains waveguide loads at ambient temperature and at 100°C in order to provide internal calibration.

Both the microwave and the positions modules are interfaced to a local control panel intended primarily as an aid to troubleshooting. The primary interface to the user will be via a simple serial RS232 line from the microprocessor. However, should a malfunction be suspected, the operator can go to the local control panel and, in principle, determine which module is misbehaving. The microprocessor consists of a single board microcomputer and an analog I/O interface board on which there are 32 multiplexed analog inputs to a 12-bit A/D converter and two 12-bit D/A converters. The control program will reside in ROM (Read Only Memory) and a small amount of RAM (Random Access Memory) will provide space for a data buffer. Note however that the WVR does not provide a capability for storing large amounts of data - that is the responsibility of the user.

Earlier today, Tom Clark described the approach taken to control all of the functions of the Mark III data acquisition system. A microprocessor will control each module and all activity will be coordinated by a central minicomputer. Both the SMS package and the WVR were designed to operate as modules in this system. Since the electrical interface chosen is particularly simple and relatively "universal," the SMS and WVR could also serve as general observatory support instruments. Any microcomputer with an RS232 interface or, for that matter, a portable terminal could be used to control and acquire data from these subsystems.

From independent tests performed during the last several years, we convinced ourselves that the WVR really can measure water vapor. About a year ago, it was realized that what was needed was a clear-cut demonstration that the WVR could improve the quality of VLBI data. To this end, we have concentrated on building seven instruments that will be provided to various installations. Figure 2 shows our construction schedule. The first unit was built from parts cannibalized from the engineering model of a spacecraft radiometer. It was delivered to Project ARIES in early May and is now being tested. Units R2 and R3 were built using microwave components from Sense Systems Inc. (Temple City, California). The hardware has been completed and awaits testing and calibration. Unit R3, the Haystack WVR, was delivered only yesterday; Unit R2 for the Owens Valley Radio Observatory has been completed but is still at JPL. Units R4 through R7 are being constructed from new components and are in various stages of assembly. All hardware will be completed and delivered by October 1979. The design, assembly and fabrication of all WVR hardware has been the responsibility of the Microwave Radiometry Group at JPL under the able direction of Mr. Noboru Yamane.

The software that will reside in the WVR microprocessor which will provide the control and communication features is still in the definition stage. Version 2 of this software is supplied with the WVR that you will see on display. We expect to go through several more versions of this software during the next year as the specifications are refined by feedback from the users of these instruments. More importantly, we expect that these instruments will contribute to increasingly accurate VLBI results during the next year.

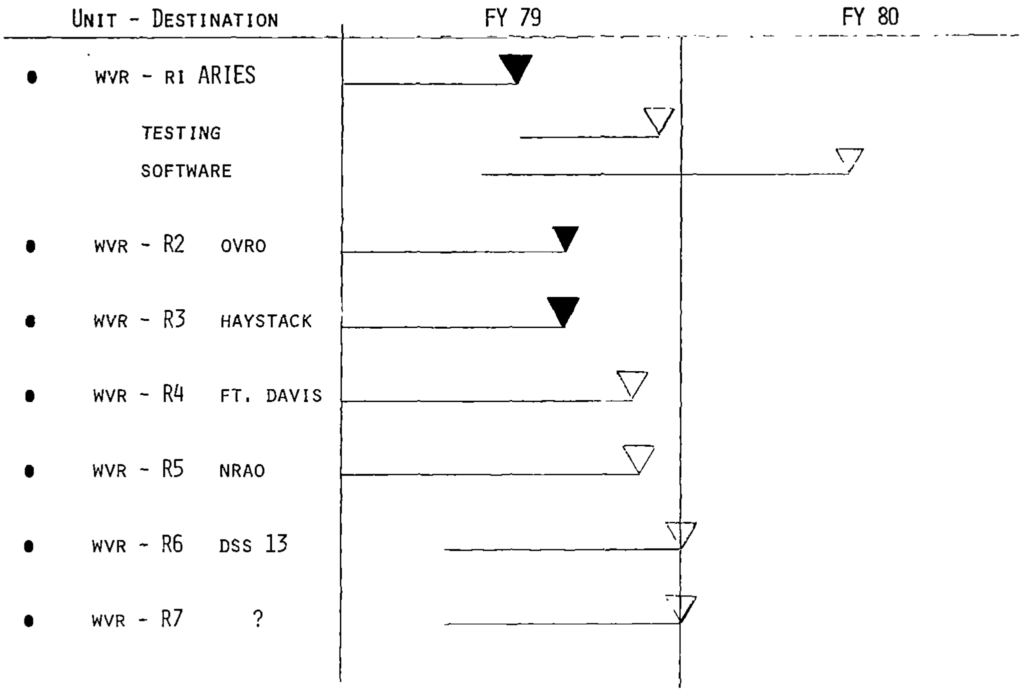

Figure 2. WVR construction.