MARK III SYSTEM OVERVIEW

T. A. Clark
NASA/Goddard Space Flight Center

INTRODUCTION

The "Mark III" VLBI system comprises a complete end-to-end VLBI system optimized for both high accuracy geodesy and radio astronomy. It includes the field station electronics for acquiring and recording the VLBI data, the central correlator preprocessing system and a data base/interactive-analysis computer system.

In the past, the earlier Mark I and Mark II VLBI systems were conceived as tape recorders. With these recording systems in hand, the VLBI community started to figure out what to do with them. With Mark III, we started with the requirements of the geodetic and astronomy job, developed the instrumentation to do the job. For that reason, the Mark III is a total system; it is much more than just a tape recorder.

Mark III Data Flow

The entire data flow in the Mark III system from schedule generation through field data acquisition to the analytical production of geodetic and astronomical results is shown in figure 1. One of the key features of the system is the data base concept used to tie together all of the data operations from the beginning to the end. All data is put into the data base so that it is available for later operations and archiving.

The first step in the process of conducting an experiment is to plan the detailed schedule of operations at the VLBI field stations. The program SKED generates the schedules. These schedules are sent to each field station on floppy disks for the station computer. This computer controls the field operations and logs the system status and correlative data during the data acquisition operation. The Mark III wideband VLBI data tapes recorded in the operation are sent to the Mark III correlator, and the station logs (typically on floppy disks) are DE-LOGged into the data base. The paper by Vandenberg, et al.[1] describes these operations in detail.

The schedule, logs, and miscellaneous data in the data base are used to generate the control instructions for the correlator operations which performs the cross-correlation of the VLBI station tapes and the production of the delay and rate observations. Next a string of operations is performed to process the data. The details of the correlator hardware and software are discussed by Whitney[2] and Nesman.[3]

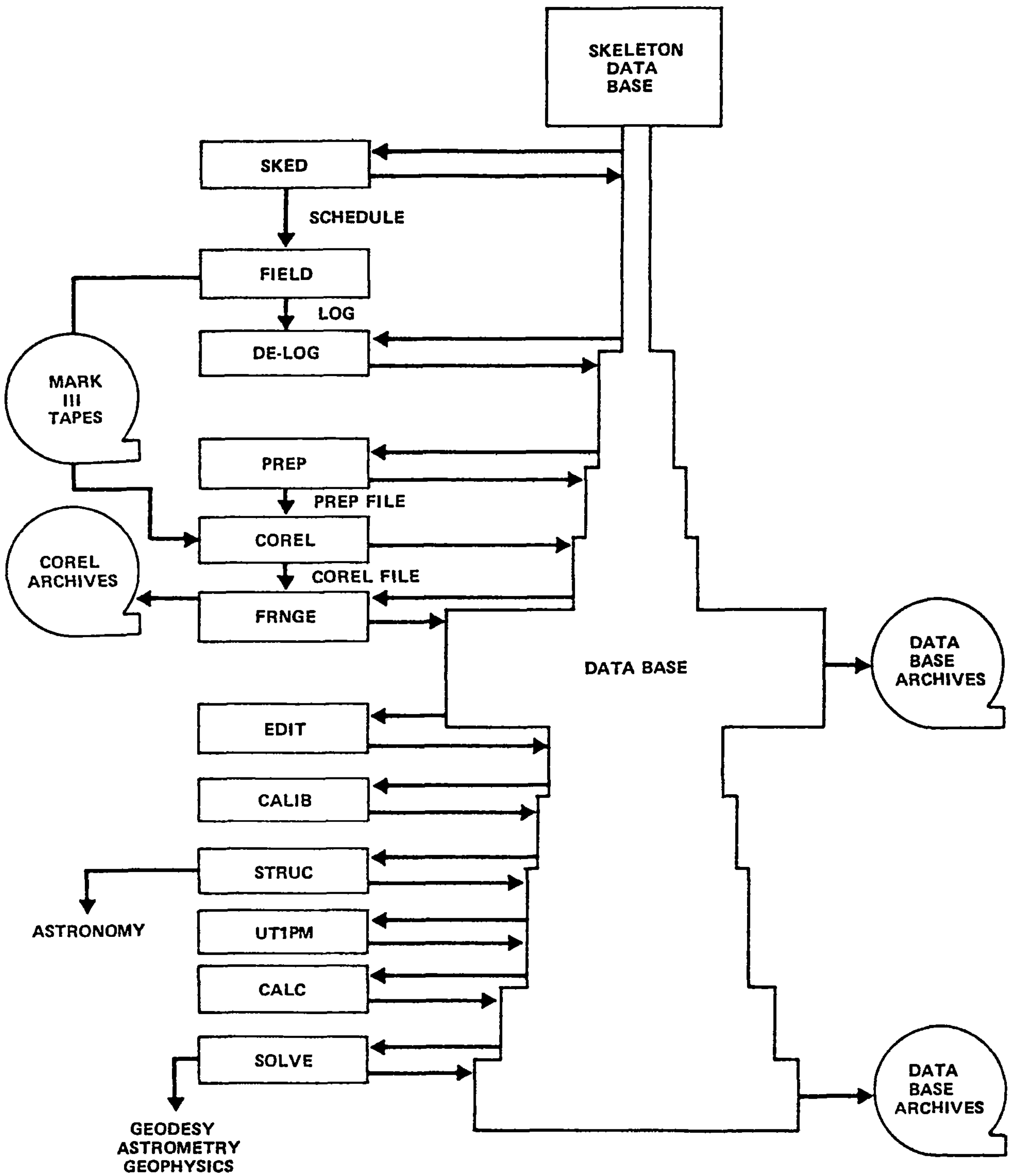

Figure 1. Mark III VLBI data flow.

The edit operation uses data tests and station log information to edit out bad data. Next the propagation and system calibrations are applied, based on station logs of supporting data and calibration data extracted from the VLBI data in the correlator operation. Then corrections are made for the fact that the extra galactic radio sources are not point sources, but have some structure. The STRUC analysis modules can also be used in the analysis of VLBI data to determine the source structure, which is of considerable interest to the astronomy community. Similarly, UT1 and Polar Motion can be put in as a priori values or they can be determined from the analysis of the VLBI data. In doing a geodetic determination, it is necessary to CALCulate a large number of a priori theoretical values of what the observed parameters were expected to be. The details of these models were presented earlier by Ma, et al.[4] In the final step, we SOLVE for the geodetic and astrometric parameters.[5]

One of the things which we have found from our experience with the earlier VLBI systems was that it is necessary to force a degree of discipline on yourselves to maintain the integrity of the data, maintain the quality of data, and to keep records of all the things that have happened to the data in the processing operations. This Mark III Data Base Handler System preserves the integrity of the observations so that information is not lost and can be recovered at any future time.

Figure 1 shows the flow of data and information through the system. The boxes shown are actually the names of computer programs that do the particular jobs. A computer is used for all of these operations. We have removed repetitive manual operations and rely on very heavy computer involvement. Thus, the information is really flowing through a computer system, and there is a very heavy computer structure. The details of the Mark III Data Base Handler System are presented by Ryan, et al.[6]

Mark III VLBI Field Station

A diagram of the Mark III VLBI field station is shown in figure 2. The key features of the system are as follows:

a. The Mark III receiver has very wideband front ends (400 MHz centered at 8.4 GHz, 100 MHz centered at 2.25 GHz) for high delay resolution, uses dual frequencies (8.4 GHz, 2.25 GHz) for extraction of the ionospheric delay, and has continuous system calibration for high accuracy. The details of the receiving system and the continuous calibration method are given by Rogers.[7, 8]

b. The Mark III Data Acquisition Terminal is a very wide bandwidth (112 Mb/s) data system for a significantly improved signal-to-noise ratio. This is especially important for applications utilizing small antennas or weak sources. This terminal contains a computer for automated control and monitoring of the VLBI station in order to facilitate easy field operations. The details of the Mark III Data Acquisition Terminal are given by Rogers,[7], Vandenberg,[1], Hinteregger,[9] and Levine.[10]

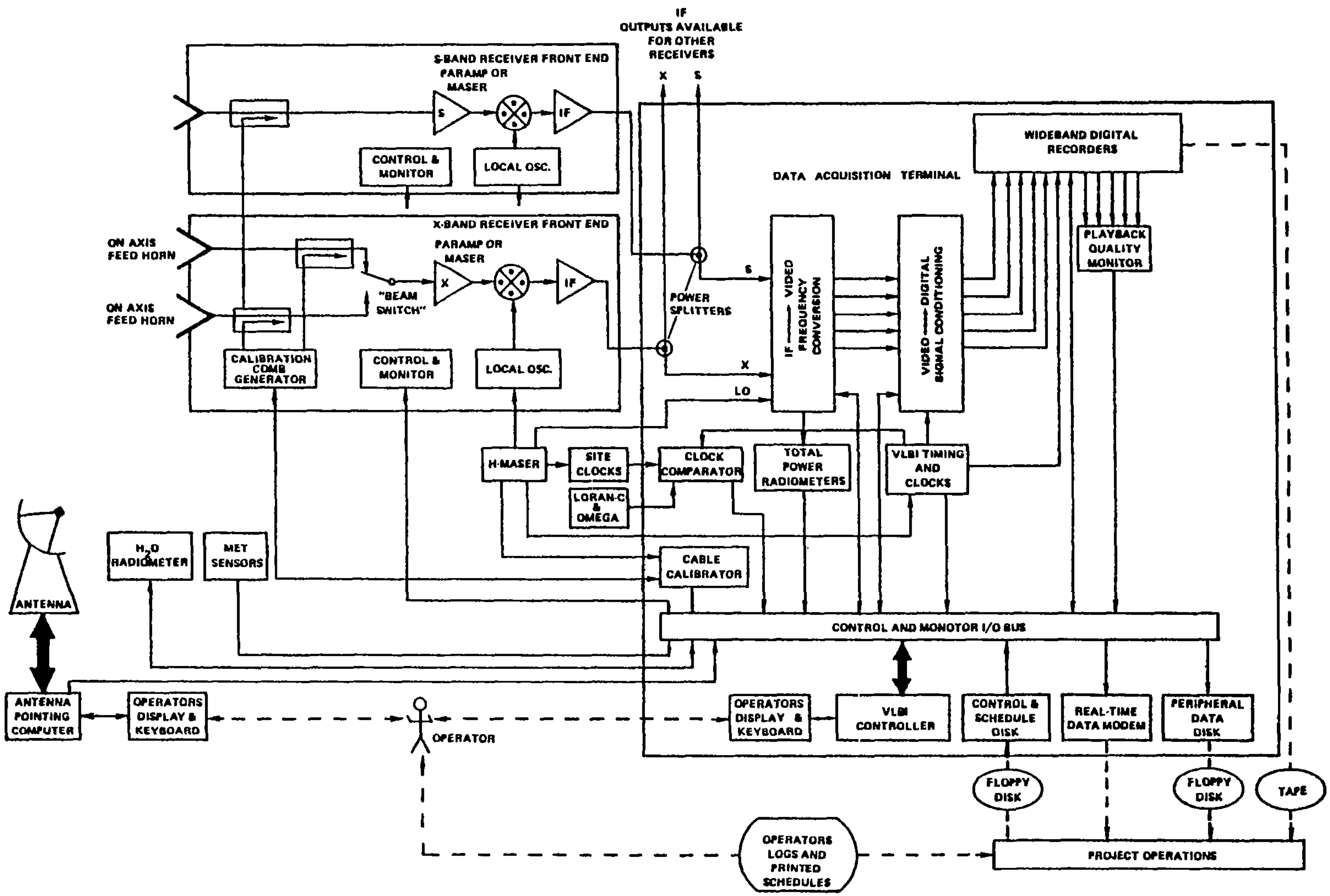

Figure 2. Mark III VLBI field station configuration.

c. A very stable hydrogen maser frequency standard for all frequencies and timing signals in the Mark III field station. Both the NASA NR hydrogen masers, described by Reinhardt,[11] and the SAO VLG masers, described by Vessot,[12] have been used in the Mark III VLBI field stations. They provide a frequency stability of a few parts in 10^{15} for a 100-second period.

d. Tropospheric propagation delay calibrations are determined from measurements at the station with meteorological sensors and microwave water vapor radiometers. The "dry" component of the tropospheric delay is deduced from the meteorological data, and the "wet" component of delay is deduced from water vapor radiometer data. A detailed description of these tropospheric calibration subsystems is given by Resch.[13]

The Mark III VLBI system for the field stations has been developed with stand-alone subsystems to enable the use of the Mark III system in all of the configurations of VLBI stations to be employed by the Crustal Dynamics Project. The three categories of configurations to be used by the Project are:

- Fixed VLBI stations with Mark III VLBI capability permanently located at the station.

- Transportable VLBI stations where a transportable Mark III terminal is brought in and connected to a fixed antenna for a short term VLBI measurement.

- Mobile VLBI stations with the entire VLBI station, including the antenna, on wheels for moving from site to site.

The use of the mobile and transportable stations enables the project to make measurements from a large number of sites with relatively few sets of equipment. The fixed stations form a long-term reference network for tying together the measurements with the mobile and transportable stations.

The status, as of June 1979, of the Mark III VLBI systems/stations is that the development is completed and systems are operating at Haystack Observatory, Massachusetts, and National Radio Astronomy Observatory, West Virginia. Additional Mark III systems are in fabrication for fixed stations at the Owens Valley Radio Observatory, California, the Onsala Space Observatory, Sweden, and the Harvard Radio Astronomy Station, Texas. The first transportable Mark III system is in fabrication and will be deployed first to the Max Planck Institute for Radio Astronomy, West Germany. Similarly, the first Mark III system for a mobile VLBI station is in fabrication and will be installed in the ARIES mobile station (Neill, et al.[14]).

REFERENCES

1. Vandenberg, N., T. Clark, L. Foster, A. Whitney, and G. Lamps, "Automation of the Mark III Field System," Proceedings of Radio Interferometry Techniques for Geodesy Conference, June 1979, in press.

2. Whitney, A., "Mark III Correlator Hardware and Software," Proceedings of Radio Interferometry Techniques for Geodesy Conference, June 1979, in press.

3. Nesman, E., "Correlator Computer Interface and Module Implementation - Mark III Processor," Proceedings of Radio Interferometry Techniques for Geodesy Conference, June 1979, in press.

4. Ma, C., "Geophysical and Astronomical Models Applied in the Analysis of VLBI Data," Proceedings of the Radio Interferometry Techniques for Geodesy Conference, June 1979, in press.

5. Ryan, J. W. and C. Ma., "The Mark III Interactive VLBI Data Analysis System," Proceedings of Radio Interferometry for Geodesy Conference, June 1979, in press.

6. Ryan, J. W., C. Ma, and B. Schupler, "The Mark III Data Base Handler," Proceedings of Radio Interferometry Techniques for Geodesy Conference, June 1979, in press.

7. Rogers, A., "Microwaves to Megabits," Proceedings of Radio Interferometry for Geodesy Conference, June 1979, in press.

8. Rogers, A., "Phase and Group Delay Calibration of a Very Long Baseline Interferometer," Proceedings of Radio Interferometry for Geodesy Conference, June 1979, in press.

9. Hinteregger, H., "The Mark III Wideband Digital Recorder in Perspective," Proceedings of Radio Interferometry for Geodesy Conference, June 1979, in press.

10. Levine, J. and A. Whitney, "Mark III Real-Time Fringe-Detection System," Proceedings of Radio Interferometry for Geodesy Conference, June 1979, in press.

11. Reinhardt, V. and L. Rueger, "The Performance of the NASA Research Hydrogen Masers," Proceedings of Radio Interferometry for Geodesy Conference, June 1979, in press.

12. Vessot, R., "Hydrogen Maser Frequency Standards," Proceedings of Radio Interferometry for Geodesy Conference, June 1979, in press.

13. Resch, G., "Mark III VLBI System - Tropospheric Calibration Subsystems," Proceedings of Radio Interferometry for Geodesy Conference, June 1979, in press.

14. Neill, A., T. Claflin, T. Lockhart, P. MacDoran, D. Morobito, K. Ong, and G. Resch, "Geodetic Measurements with a Mobile VLBI System," Proceedings of Radio Interferometry for Geodesy Conference, June 1979, in press.