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The Mark 5B VLBI Data System

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Abstract

The Mark 5B VLBI data system is now being developed at MIT Haystack Observatory. It is based on the same physical platform and uses the same disk-modules as the Mark 5A; it also supports the same maximum data rate of 1024 Mbps. However, the Mark 5B will incorporate a VSI standard interface and command set. This will allow 8-BBC VLBA systems to bypass the existing VLBA formatter and connect directly to the output of VLBA samplers (through a simple interface) at a maximum data rate of 1024 Mbps. For 14-BBC systems with Mark IV formatters, the Mark 5B will allow connection of all 14 BBCs to two Mark 5Bs for a total aggregate data rate of 1792 Mbps. In addition, the Mark 5B is being designed to support all critical functionality of the Mark IV Station Unit so that the Mark 5B may played back directly to the Mark IV correlator through a simple interface. Prototype Mark 5B systems are expected to be available mid-to-late 2004.

1. Mark 5 VLBI Data System

Incorporating primarily low-cost PC-based components, the Mark 5 system [Ref 1] supports data rates up to 1024 Mbps, recording to an array of inexpensive removable IDE/ATA disks. The general goals of the Mark 5 system are:

- Low cost
- Based primarily on unmodified COTS components
- Modular, easily upgradeable
- Robust operation, low maintenance cost
- Easy transportability
- Conformance to VSI specification [Refs 2,3]
- Compatibility with existing VLBI systems during transition
- Flexibility to support e-VLBI
- Minimum of 1 Gbps data rate
- 24-hour unattended operation at 1 Gbps

All but the last goal are clearly achievable with today's technology; 24-hour unattended operation at 1 Gbps is expected to arrive within ~2 years with continued development in high-capacity disk technology.

2. Mark 5 Development Program

The Mark 5 system is being developed in two stages:

1. Mark 5A: The Mark 5A system, in use since late 2002, is intended as a direct replacement for a Mark IV or VLBA magnetic-tape transport at either a station or correlators. It records 8, 16, 32 or 64 tracks from a Mark IV/VLBA formatter, and plays back in the same Mark IV/VLBA format. As such, the Mark 5A is a direct replacement for a Mark IV tape unit at 1024 Mbps and VLBA tape unit at 512 Mbps. Approximately 80 Mark 5A systems have been deployed to stations and correlators around the world.
2. Mark 5B: The Mark 5B is a VSI-compliant system with capability up to 1024 Mbps; no external formatter is necessary, though access to a VSI interface is required. The Mark 5B is expected to be deployed in late 2004.

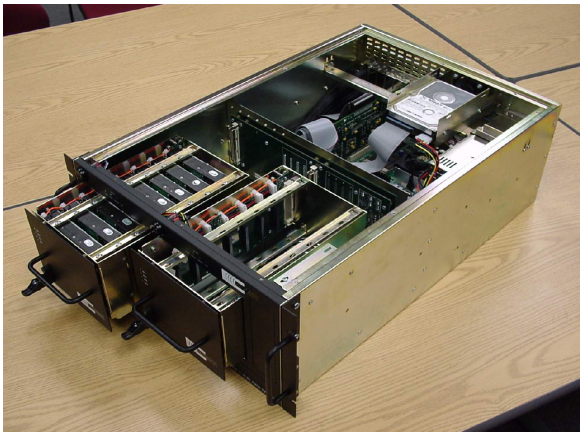

Figure 1. A photograph of the prototype Mark 5A system with its two removable '8-pack' disk modules; the Mark 5B will look the same. A Mark 5A system may be upgraded to a Mark 5B system simply by replacing a Input/Output PCI board in the host PC.

3. Characteristics of the Mark 5B Data System

The Mark 5B system has the following characteristics:

- Uses the same chassis and disk packs as the Mark 5A
- Implements the VLBI Interface Standards (VSI-H, VSI-S and VSI-E)
- Maximum record/playback data-rate is 1024 Mbps (same as Mark 5A)
- Requires new Mark 5B I/O card, currently under design
- Eliminates the need for an external formatter (but requires mating VSI interfaces)
- With a 14-BBC Mark IV or VLBA system, up to 1792 Mbps can be recorded with two parallel Mark 5B systems

- Mark IV Station Unit capabilities are being designed into the Mark 5B so that Mark 5B systems can be connected to Mark IV correlators without the use of a Mark IV Station Unit.
- Built-in phase-cal extraction and state-counting during recording and playback
- Xilinx FPGA design will be updateable via software download from PC; Mark 5A FPGA requires programming from a separate external source

4. Reliability Features

Several features exist in Mark 5 systems to ensure data integrity and continuity in the face of failing or failed data disks:

1. If a disk becomes slow or fails during recording, the recording load is dynamically adjusted among the disks within a module so that no data are lost.
2. If a disk fails or is missing during playback, the Mark 5 will fill any data gaps with a user-specified data pattern that can be detected and cause the data to be invalidated at the correlators.

5. Station Unit Emulation Capability

The Mark IV Station Unit acts as the interface between data from Mark IV/VLBA tape-format data (from either tape or Mark 5A disk systems) and the Mark IV correlator proper. It has several functions:

- Delays the data according to a fifth-order spline polynomial supplied to the Station Unit before presentation of the data to the correlator proper
- Inserts headers into the data stream with model information used by the correlator proper
- Extracts up to two phase-calibration signals from each channel
- Counts state statistics to aid in post-correlation correlation-coefficient normalization

This functionality is being built into the Mark 5B to allow the Mark 5B to connect to a Mark IV correlator without the use of a standard Mark IV Station Unit. The implementation of these functions is aided by an on-board 256 MB memory which will allow dynamic changes in the data-delay at intervals specified by the controlling delay model.

6. Compatibility with Mark 5A

The Mark 5B is being designed so that disk modules recorded on a Mark 5B can be played back on a Mark 5A unit. The playback format on the Mark 5A unit will be in VLBA track format; a list of supported 'compatibility modes' is given in Table 1. Existing Mark 5A units will need to be upgraded to support this compatibility path. This compatibility mode will allow data recorded on Mark 5B systems to be correlated on existing Mark 5A correlators during the transition period to Mark 5B.

Table 1. "VLBA-compatible" modes - Mark 5B disks played on Mark 5A system

#Active DIM Input Bit-streams	Fanout ratio to VLBA-format tracks	#output VLBA tracks
32	1	32
32	2	64
16	1	16
16	2	32
8	1	8
8	2	16
4	1	4
4	2	8
2	2	4

7. VSI Interfaces to Existing Mark IV and VLBA Systems

In order to use the Mark 5B with existing VLBA or Mark IV systems, a VSI interface providing sampled data, clock and 1 pps must be available for connection to the Mark 5B. These interfaces are also being developed at Haystack Observatory as part of the Mark 5B development project:

- VLBA systems (8 BBCs with VLBA formatter): An interface based on the Metsahovi VSI-C converter board will be used. The VSI connector will carry the 2-bit USB and LSB samples from BBCs 1 to 8.
- Mark IV systems (with existing Mark IV formatter): The interface will use the existing samplers, plus 32 MHz and 1pps synthesizers in the Mark IV formatter chassis, and will add a communications and control board. It will support two data modes:

    1. 'Astronomy' mode: 2-bit USB/LSB from BBCs 1 to 8 on VSI output 1; 2-bit USB/LSB from BBCs 9 to 16 on VSI ouput 2; max recording rate 2048 Mbps with two parallel Mark 5B systems
    2. 'Geodetic' mode: 2-bit USB from BBCs 1 to 14 and 2-bit LSB from BBCs 1 and 8

8. Interface to Mark IV Correlator

A Correlator Interface Board (CIM) is necessary to convert the VSI-format output of the Mark 5B system into the form necessary for input into the Mark IV correlator. The CIM will be housed in a separate chassis and connect to the VSI-output connector of the Mark 5B.

9. Summary

The Mark 5B system is the second in the line of Mark 5 VLBI data systems and the first to implement the VSI standard. Built on the same platform as the Mark 5A, the Mark 5B offers both a simple migration path for existing Mark 5A users and an inexpensive VSI-compatible VLBI data system for new installations. In addition, a Mark 5B/Mark 5A compatibility path has been

established to ease in the transition from Mark 5A to Mark 5B. The Mark 5 system is being developed with support from BKG, JPL, KVN, MPI, NASA, JIVE, NRAO and USNO.

References

[1] Whitney, A.R., et. al., "Mark 5", Available from http://web.haystack.mit.edu/mark5/Mark5.htm.

[2] Whitney, A.R., "VLBI Standard Hardware Interface Specification -VSI-H," August 2000, Revision 1.0, Available from http://dopey.haystack.edu/vsi/index.html.

[3] Whitney, A.R., "VLBI Standard Software Interface Specification - VSI-S," February 2003, Revision 1.0 Available at http://dopey.haystack.edu/vsi/index.html.