VLB ARRAY MEMO No. 78-A

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I. The Array Record System

The digital output of the I.F. samplers at each antenna must be stored for post observation shipment to the VLBA processor where correlation with data from all the antennas will take place. This storage will be on magnetic tape with wide band digital tape recorders required at each antenna for storage and similar units at the processor required for playback.

The maximum bit rate of 200M bps produced at each antenna and the need to observe for 24 hours a day sets the upper limit on the antenna record system data rate and storage capacity at 200M bps and 2 x 10^{13} bits/day. The need to record data at this high rate and in this volume with a minimum of operator intervention over 24 hours puts difficult requirements on the record system.

The two systems most investigated to meet the VLBA record system requirements are those systems already used in VLBI experiments, the MK II and MK III VLBI recorders.

The MK II system uses consumer type video cassette recorders (VCR's) modified to record digital data. These systems have proven reliability records and are inherently inexpensive.

The MK III system uses broad band instrumentation recorders that can take data at up to a 224M bps rate. This recorder is a 28-track machine which will require digital division of the four 50M bps bands into the 28 up to 8M bps recorder tracks.

Neither type recorder, however, is directly applicable to the VLBA. The MK II system suffers from low bandwidth (4M bps per recorder) while the MK III system will record only about 7.5 minutes of full bandwidth data on a 9200-ft. reel of 1 inch tape. Work at various institutions is proceeding, however, to improve both systems. A MK II recorder has been made to work at a data rate of 12M bps and NRAO is investigating recording up to 12.5M or 16M bps on these recorders and a high density moving head system is under design for upgrading the recording volume per reel of the MK III recorder.

Of these two possible recorders, NRAO proposes to use the less expensive MK II recorder in building the VLBA, keeping in mind possible improvements in the MK III recorder and other wideband recorders before actual VLBA development begins.

At a data rate of 12.5M bps, each antenna will require eight recorders to keep up with a 100M bps data rate output of the samplers. Lower sample rates can be handled by dropping recorders off line or by increasing the bits per sample. Eight recorders will produce up to 48 four-hour tape cassettes per day per antenna. To reduce the bookkeeping required to keep this many tape cassettes straight and to reduce operator intervention to a minimum, NRAO proposes to develop, for the VLB Array, a rack based recorder system using eight video cassette recorders plus one floating spare in an integrated rack assembly (see Figure 1). This rack will have a rack based automatic cassette changer plus a rack based cassette storage area, all under control of a central microprocessor. The tape storage area will be a dismountable bin which can be shipped, cassettes in place, to the correlator for processing. Two such racks will be used per antenna so that 100% redundancy is provided when operating at the normal 100M bps rate. The maximum 100 MHz bandwidth, requiring 200M bps storage, will be accommodated by using both racks simultaneously and accepting the lower reliability. A similar rack based playback system at the processor will complement the antenna record system requiring only insertion of the cassette-loaded bins to process one day's worth of observations for a given antenna. Cassette changes, recorder operations, data synchronism, automatic spare recorder replacement for a defective unit, etc. will all be done under microprocessor control requiring a minimum of operator intervention.

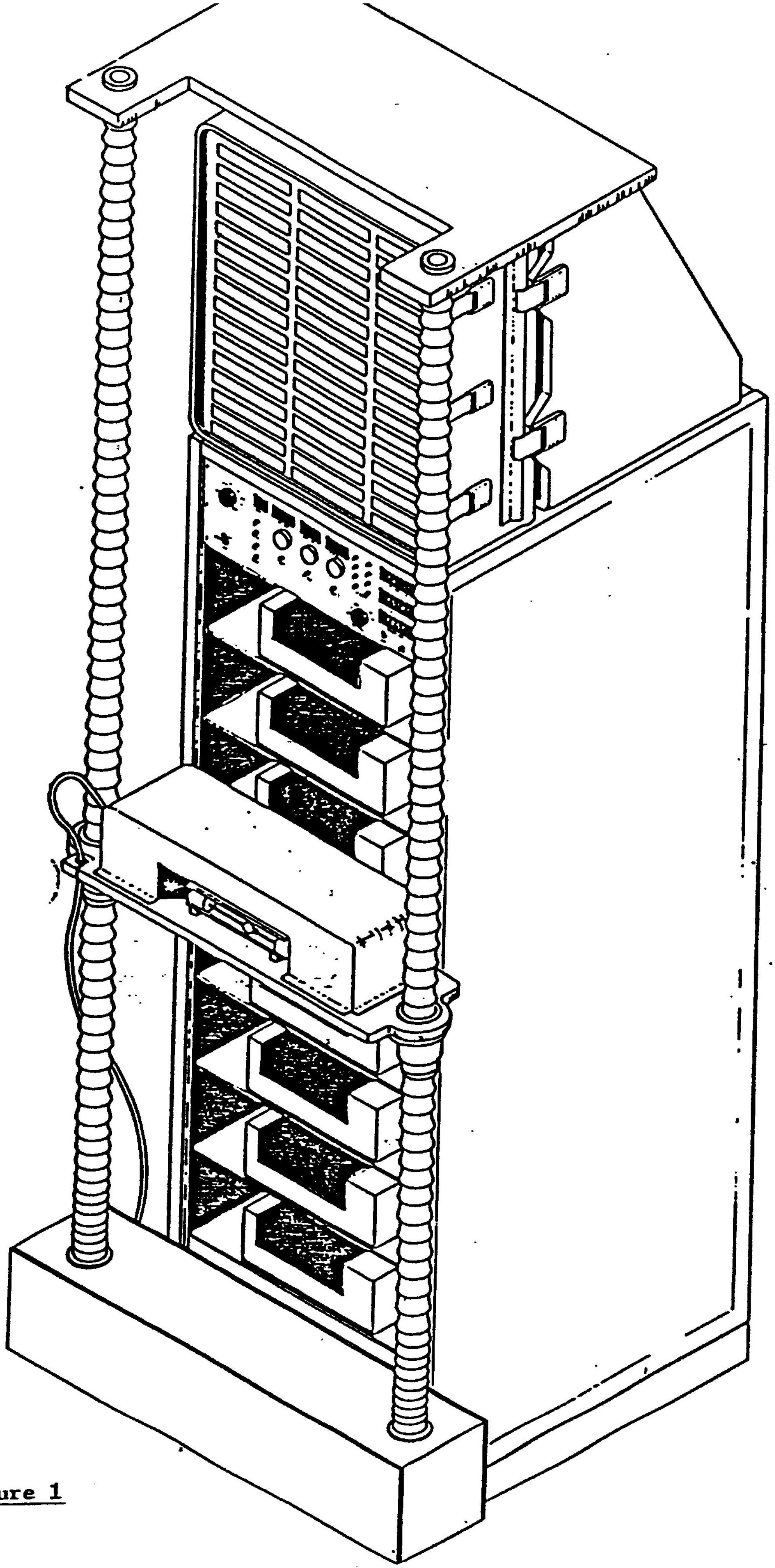

Figure 1

The sampler outputs at any antenna will be recorded on the various tape recorders in 10,000 bit swatches with each swatch having its own time code and check sum encoded. By breaking the data into such swatches, the four I.F. bands can be multiplexed between the various recorders whereby one-eighth of any I.F.'s data will be recorded on any given machine. Such an arrangement will require little digital circuitry to produce and to unscramble and yields a more graceful recorder system failure sequence, since a failure of one recorder will then result in loss of 1/8 of each I.F.'s data rather than eliminating a large percentage of one I.F.'s data.

II. Playback System

The playback system will be, like the record system, based on consumer type video cassette records. Rack based playback stations, each with 8 playback recorders plus one floating spare, a rack wide automatic cassette changer, and a central cassette storage bin will be required to service the antennas of the VLBA. The cassette bin, which holds one day's worth of observational results for one antenna at 100M bps sampling, will be loaded into a playback rack where cassette shuttling, recorder operation, recorder time synchronism, etc. will be controlled by a central microprocessor. Since the order of the cassettes in the bins will have been under software control at each antenna, little bookkeeping will be required to keep the large number of cassettes produced by the VLBA in their proper order. Twenty such racks will be provided at the processor to allow processing of 10 antennas' data at a 200M bps data rate in one pass. Fourteen of these racks will be used in supporting a 100M bps, 14-antenna observation.

Although 126 recorders will be required at the processor to support a 14-antenna array, a more or less modular rack design as above should make the operational process at the correlator more reasonable. The inexpensive nature of the cassette recorders will also make sparing, both at the rack level and at the individual recorder level, economical.

The playback cassette units could be modified to play back at a speed 10 to 15% higher than the record speed, allowing some processing time edge over the observing time. This edge will help reduce the possibility of tape backlogs accumulating due to correlator usage delays and inefficiencies. Except for this possible modification to the cassette recorder servo electronics, there will be no difference between an antenna recorder rack and a playback rack.

III. Recorder/Playback System Cost Estimate

A) Recorders

Each antenna will require one recorder rack plus one spare rack plus 10% spares of individual video cassette recorders and electronics. The table below estimates the recorder system cost per antenna:

20	video cassette recorders	$ 16k
2	recorder racks with electronics	43k
	spare rack electronics	4k
		$ 63k

B) Playback

Twenty playback racks, plus two spares, will be required at the processor. These 20 racks will allow processing of a 10-antenna, 100 MHz bandwidth observation. To process a 14-antenna, 50 MHz observation, only 14 of these racks are used. The table below estimates the playback system cost, including a 60-day supply of tape cassettes, bins and spares:

218	video cassette recorders	$ 175k
22	playback racks with electronics	429k
	spare rack electronics	45k
	spare recorder parts (heads, etc)	45k
60-day tape supply		380k
60-day cassette bin supply		75k
		$1,321

C) Development and Construction

The tables below summarize the development cost and man-power and the construction man-power required for the VLBA record/playback system.

Development

Item	Cost	Man-Months
Home video recorder upgrade	$ 12k	12
Automatic cassette changer	8k	8
Read/write electronics	3k	4
Rack microprocessor control	4k	4
System interface	2k	4
Documentation	-	6
	$ 29k	38

Construction

Item	Man-months
Home video recorder modifications	20
Automatic cassette changer	15
Rack electronics	12
Rack integration	6
	53

IV. Recorder/Playback System Alternatives and Comparisons

Various methods were considered in investigating how to get the remote antenna data to the processor for correlation for the VLBA. The most attractive method, real time transmission via satellite or land lines, is not practical at this time because of high cost and there seems only a slight chance at this time that direct transmission of VLBA data will ever be economically practical. However, this option, possibly using NRAO's own satellite, will be kept open.

Of recording mediums presently available or projected, only magnetic storage seems to be practical because of data storage density, storage medium cost, and storage medium reusability. Thus, most of the investigation for a VLBA data transmission system centered on magnetic tape recorders.

Tape recorders studied include wide band instrumentation recorders (specifically the MK III recorder), modified consumer type video recorders (specifically the MK II recorder), analog and digital television recorders, and projected high density digital recorders.

The television recorders suffer at present from high cost, lack of specifications (for digital TV), and the universality of 90 minute reel/cassette record times.

The array construction and operational costs of 5 possible remaining systems are summarized in Table I. These five recorder systems include:

1) The Ampex AVRX wide band digital recorder.
2) A MK III instrumentation recorder using movable heads to yield a 12-times increase in tape bit density (i.e., 336 tracks across the 1" tape).
3) A MK III instrumentation recording using movable heads to yield a 36-times increase in tape bit density.
4) A MK III instrumentation recorder using movable heads to yield a 20-times increase in tape bit density.
5) Multiple consumer type video cassette recorders (VCR) modified to record 12.5M bps.

It should be noted that none of these possible record systems have been demonstrated as yet, although the Ampex AVRX recorder has been demonstrated in a breadboard stage.

The chart is based on the following:

1) The processor will have the following number of playback stations,

AVRX	16
All MK III	16
VCR	22

allowing 14-antenna, 100M bps, or 10-antenna, 200M bps operation for all approaches except the AVRX. The AVRX system was considered too expensive to extend to 200M bps. In addition, all MK III systems will require extra operator time, not shown in the chart, for additional antenna visits and for extra tape changes at the processor to support 200M bps operation. The VCR system will require additional operator time to load two tape bins per antenna per day.

2) Operational cost is based on the operation of 10 antennas at 100M bps assuming that this will be the most common mode of operation.

3) Automatic cassette changers for the AVRX and VCR recorders are assumed.

4) Multiple MK III recorders are required at each antenna to allow 12 hours between tape changes. The resulting 2 tape changes per day at each antenna and the 3 to 8 tape changes per day at the processor result in the increase in operator time shown. No redundancy in antenna recorders is provided and recorder failures will result in additional antenna visits per day.

	Ampex AVRX	Moving Head MK III (12X)	Moving Head MK III (36X)	Moving Head MK III (20X)	12.5 Bit VCR
Recorder and electronics cost/array (including spares)	$5,956 k	$3,116 k	$2,002 k	$2,556 k	$1,496 k
60-day tape supply	$1,950 k	$1,248 k	$ 415 k	$ 750 k	$ 486 k
60-day shipping container supply	$ 75 k	$ 60 k	$ 20 k	$ 30 k	$ 75 k
TOTAL CONST. COST	$7,981 k	$4,424 k	$2,437 k	$3,336 k	$2,057 k
Maintenance cost/yr.	$2,200 k	$ 103 k	$ 103 k	$ 103 k	$ 158 k
Tape cost/yr.	$ 23 k	$ 30.4 k	$ 10.1 k	$ 18 k	$ 15 k
Tape shipping cost/yr.	$ 237 k	$ 246 k	$ 82 k	$ 152 k	$ 138 k
TOTAL OPERATING COST	$2,460 k	$ 379.4 k	$ 195.1 k	$ 273 k	$ 311 k
Operator time/yr. (in man years)	2.3	5.4	4.8	4.9	2.3
Technician time/yr. (in man years)	0.1	0.1	0.1	0.1	1.5
TOTAL OPERATING MANPOWER (in man years/year)	2.4	5.5	4.9	5.0	3.8