Interoffice

National Radio Astronomy Observatory

Charlottesville, Virginia

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To: VLBA Working Group

From: R. P. Escoffier

VLB ARRAY MEMO No. 44

Subject: Recording Systems

Here are three attachments that may be of interest to the VLBA Working Group. First, I have compiled a chart comparing the various characteristics of recording systems that will meet the VLBA recorder requirements. The second is a drawing of a recorder rack I would like to propose for the VLBA proposal. This drawing, together with the third attachment, is more or less self-explanatory.

The last attachment is a draft of the recorder section of the proposal. This draft assumes some array characteristics, such as the 4-band, 25M bps maximum sampling rate per band, I.F. configuration and a 10-antenna processor, which will have to be corrected when the final specifications of the VLBA are decided upon.

The attached draft does not include any discussion or cost estimates of the I.F. electronics.

The cost estimates of the two charts do not reflect usage of a rack such as is shown in the figure. For example, the 1.3 man-years per year tabulated in the 16M bps MK II column is operator time required just in changing cassettes in an array requiring 140 cassette recorders. This time would be mostly eliminated by use of the automatic cassette changer. The most misleading aspect to the charts is, however, that their cost estimates do not include recorder associated electronics or the proposed automatic cassette changer. A quick comparison between the chart estimate and the draft estimate will demonstrate this fact. Perhaps a chart revision reflecting actual VLBA requirements should be made later.

Attachments

TABLE I

Recorders	MK II	MK III	Ampex AVRX	Moving Head MK III (X10)	Moving Head MK III (X20)	16M Bit MK II	20M Bit MK II
Unit Price	$800	$35K (3)	$100K (6)	$35K (3)	$35K (3)	$800	$800
Head Price	$75 (1)	$15K R&W $7.5K R (3)	$12K (6)	$10K (5)	$7K (7)	$75 (1)	$75 (1)
Tape Price (per reel/cass.)	$15 (1)	$170 (4)	$200 (6)	$170 (4)	$170 (4)	$15 (1)	$15 (1)
Data Rate	4M bit	112M bit	106M bit	112M bit	112M bit	16M bit	20M bit
Record Time (per reel/cass.)	4 hr.	13 min.	90 min.	2.2 hr.	4.3 hr.	4 hr.	4 hr.
10^{10} bits/reel, cass.	5.2	8.7	57	87	170	23	29
Pounds/10^{13} bits (8)	110 (9)	1,380 (10)	55	138 (10)	70 (10)	25 (9)	20 (9)
10^6 bits/sq. in.	10	0.8	20	8	15	47	60
Ave. head life	2,000 hr. (2)	15,000 hr. (5)	1,000 hr. (6)	6,000 hr. (5)	3,000 hr. (7)	2,000 hr. (2)	2,000 hr. (2)
Ave. tape life	300 passes (2)	500 passes (5)	1,000 passes (6)	50 passes (11)(5)	50 passes (11)(7)	300 passes (2)	300 passes (2)

Notes, Sources:
(1) NRAO
(2) Panasonic
(3) Honeywell
(4) 3M
(5) Haystack
(6) Ampex
(7) JPL
(8) 10^{13} bits ≈ 24 hr. @ 112M bit
(9) 0.58 lb/cassette
(10) 12 lb/reel
(11) 1 pass = complete record or playback pass

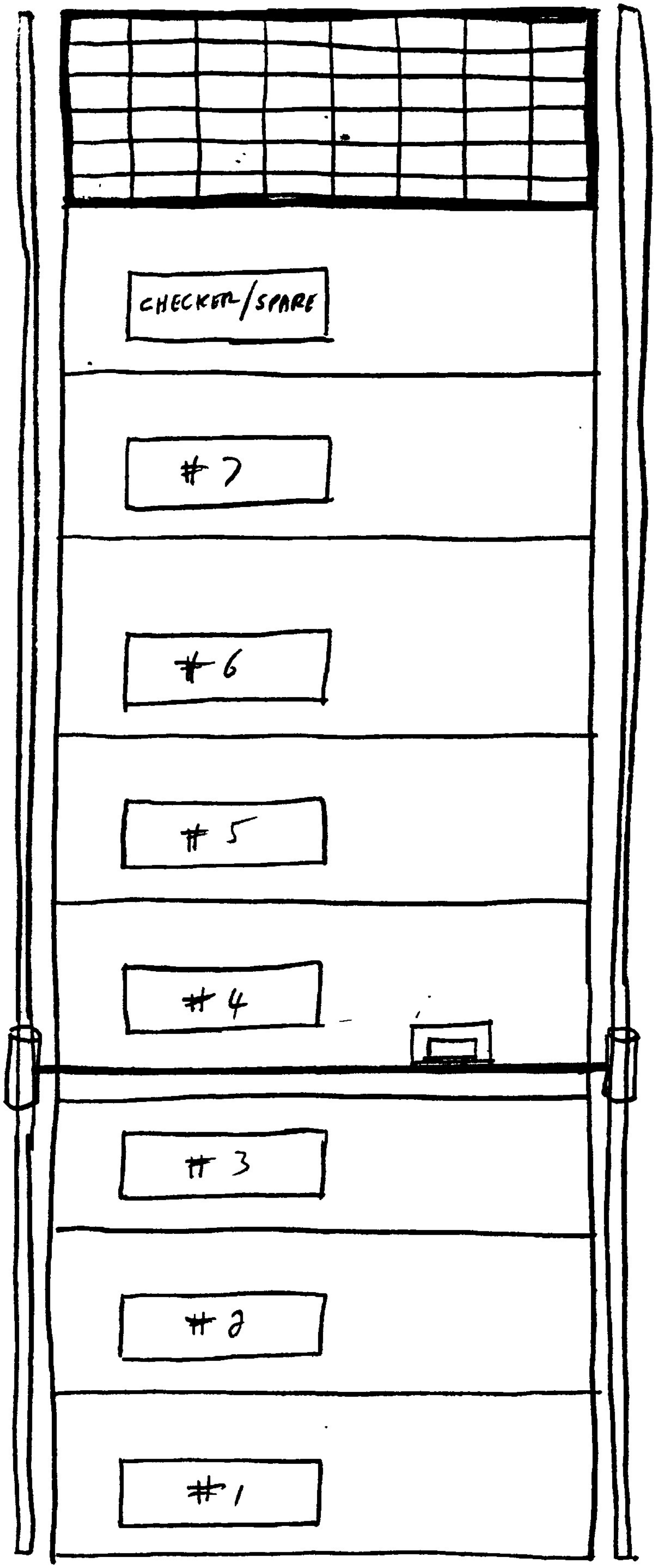
TABLE II

VLBA Cost [Number/Array]	MK II [560]	MK III [20]	Ampex AVRX [20]	Moving Head MK III (10X) [20]	Moving Head MK III (20X) [20]	16M Bit MK II [140]	20M Bit MK II [100]
Cost/Array (No spares)	$448K (28=112M bit)	$700K	$2 Meg.	$700K	$700K	$112K (7=112M bit)	$80K (5=100M bit)
40-day tape supply	$1 meg.	$7.5 Meg.	$1.3 Meg.	$743K	$380K	$253K	$180K
Spares	$50K	$500K (7)	$1.5 Meg. (7)	$500K (7)	$500K (7)	$80K (7)	$56K (7)
Total Const. Cost	$1.5 Meg.	$8.7 Meg.	$4.8 Meg.	$1.9 Meg.	$1.6 Meg.	$445K	$316K
Head Cost/yr.	$184K	$131K	$2.1 Meg.	$292K	$409K	$46K	$33K
Tape Cost/yr.	$61K	$275K	$23K	$270K	$139K	$15K	$11K
Shipping Cost/yr. (1)	$142K	$1.9 Meg.	$70K	$193K	$98K	$35K	$25K
Motor, Break Cost/yr.	- (3)	$63K (2)	$100K (4)	$63K (2)	$63K (2)	- (3)	- (3)
Replacement Cost/yr.	$448K (1 yr. life)	$70K (10 yr. life)	$200K (10 yr. life)	$70K (10 yr. life)	$70K (10 yr. life)	$112K (1 yr. life)	$80K (1 yr. life)
Total Op. Cost/yr.	$835K	$2.4 Meg.	$2.5 Meg.	$890K	$780K	$208K	$150K
Operator time/yr. changing & cataloging tapes (in man years)	5.1 (5)	20 (6)	0.5 (5)	2.0 (6)	1.0 (6)	1.3 (5)	0.9 (5)
Technician Time/yr. (in man years)	5.6	0.1	0.1	0.1	0.1	1.5	1
Total Operator Time/yr. (in man years)	10.7	20	0.6	2.1	1.1	2.8	1.9

NOTES: (1) Ave. shipping price - 20¢/lb. (4) Guess (6) 3 min./reel change

(2) Honeywell (3) Throw-away (5) 30 sec./cass. change (7) Includes 100% redundancy at each ant.

11-30-81
RPE



112 MBIT RECORDER RACK

7 RECORDERS @ 16 MBIT EA

1 RECORDER TO VERIFY TAPES & SUBSITUTE FOR DEFICTIVE UNIT.

AUTOMATIC CASSETTE CHANGER CAN LOAD TAPES AND SHUTTLE TAPES TO CHECKER UNIT

TAPE STORAGE AT TOP OF RACK WILL HOLD 48 TAPES AND IS A SHIPPABLE UNIT.

RACK MICROPROCESSOR WILL CONTROL CASSETTE CHANGER, RECORDERS, SELF VERIFICATION, AND SELF SUBSITUTION.

SELF TEST WILL CONSIST OF SHUTTLING RECORDED TAPES INTO THE CHECKER UNIT FOR REWIND AND SPOT HEADER AND CHECKSUM VERIFICATION.

SELF SUBSTITUTION WILL OCCUR IF BAD RECORDER IS FOUND. FROM THAT POINT ON THE SUSPECTED BAD RECORDER AND THE CHECKER ARE PARALLED, BOTH PRODUCING TAPES. ALSO UNITS WILL THEN DO THEIR OWN REWIND & SPOT HEADER AND CHECKSUM VERIFICATION.

RACK MICROPROCESSOR TO MAIN COMPUTER COMM. NEED ONLY CONVEY:

1) BANDWIDTH BEING USED
2) START/STOP
3) TIME

DRAFT R. Escoffier
12/16/81

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 100M 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 100M bps and 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 realiability records and are inherently inexpensive.

The MK III system uses broad band instrumentation recorders that can take up to a 112M bps rate. This recorder is a 28-track machine which will require digital division of the four 25M bps bands into the 28 up to 4M 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 13 minutes of full bandwidth data on a 9600-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 16 or 20M 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 before actual VLBA development begins.

At a data rate of 16M bps, each antenna will require seven recorders to keep up with the 100M bps data rate of the samplers. Lower sample rates can be handled by dropping recorders off line. Seven recorders will produce up to 42 four-hour tape cassettes per day per antenna. To reduce the bookkeeping required to keep these 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 7 video cassette recorders plus one floating spare in an integrated rack assembly. 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. A similar rack based playback system at the processor will complement the antenna record system requiring only insertion of the cassette-loaded bin 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.

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 swatching, the four I.F.

bands will be able to be multiplexed between all 7 recorders. Thus, one-seventh 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 will make fitting 4 bands into 7 recorders easy. Also, a failure of one recorder will then result in loss of 1/7 of each I.F.'s data rather than eliminating a large percentage on one I.F.'s data.

II. Playback System

The playback system will be, like the record system, based on consumer type video cassette records. A rack based playback station with 7 playback recorders plus one floating spare, a rack wide automatic cassette changer, and a central cassette storage bin will be required to service each antenna in the VLBA. The cassette bin, which holds one day's worth of observational results for one antenna, 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 straight.

Although 80 recorders will be required at the processor to support a 10-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 will 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 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:

18	video cassette recorders	\$ 15K
2	recorder racks with electronics	54K
	spare rack electronics	4K
	spare recorder parts (heads, etc.)	2K
	power supplies, rack, etc.	5K
		\$ 80K

B) Playback

The correlator playback system will require 10 recorder racks, plus 2 spares plus 10% spares of individual recorders and electronics. Also included in this estimate is a 40-day supply of cassettes. The table below estimates the playback system cost:

106	video cassette recorders	\$ 85K
12	playback racks with electronics	324K
	spare rack electronics	24K
	spare recorder parts (heads, etc.)	12K
	power supplies, racks, etc.	30K
40-day tape supply		253K
		\$728K