

**MASSACHUSETTS INSTITUTE OF TECHNOLOGY**  
**HAYSTACK OBSERVATORY**  
*WESTFORD, MASSACHUSETTS 01886*

*Telephone: 978-692-4764*  
*Fax: 781-981-0590*

21 June 2006

TO: Mark 5 group  
 FROM: Alan R. Whitney  
 SUBJECT: Mark 5A+ playback modes with Mark 5B recordings

The Mark 5A+ is a ‘compatibility’ extension of the Mark 5A Xilinx code to allow playback of recordings made with Mark 5B. The output of the Mark 5A+ is standard VLBA-format output ‘tracks’ that can be correlated on Mark 4 or VLBA correlators with Mark 5A+ playback units. Playback modes of Mark 5A disks are unaffected.

Operating modes

Table 1 shows the ‘compatibility’ modes supported by Mark 5A+. Each Mark 5B bit-stream is a sign or magnitude bit stream at the sample rate.

# Mk5B recorded DIM bit-streams	Fanout ratio to VLBA-format tracks	#output VLBA tracks	#Mark5B disk frames per VLBA track frame	Reference Figure# in this memo	Reference Table # in this memo
2	4	8	2	1	3
4	2	8	2	1	4
8	1	8	2	1	5
4	4	16	4	2	4
8	2	16	4	2	5
16	1	16	4	2	6
8	4	32	8	3	5
16	2	32	8	3	6
32	1	32	8	3	7
16	4	64	16	4	6
32	2	64	16	4	7

Table 1: ‘Compatibility’ modes implemented in Mark 5A+.

Track mapping

The mapping from baseband-channel sign and magnitude bit-streams to Mark 5B bit-streams is detailed in Table 2 for the Mark 4 VSI formatter and the Metsahovi VSI-C board. When played back on the Mark 5A+, each of the Mark 5B bit-streams are reconstructed into 1, 2 or 4 VLBA-format tracks (‘fanout’) according to operator instruction.

The detailed mapping of these bit-streams to track numbers is, of course, important for properly setting up for correlation. Unfortunately, no single track mapping from the Mark 5B bit streams to VLBA output tracks results in track assignments that can be accommodated at all correlators, most particularly the VLBA correlator, which expects particular track ordering. Therefore, in addition to the default track mapping, additional optional mappings are provided to deal with this issue. Figures 1 through 4 show the available mappings from Mark 5B 32-bit data words to output tracks for each of these cases of 8, 16, 32 and 64 output tracks, respectively. In each case, Map 0 is the mapping used by normal Mark 5A operation, while the other maps are specially designed for Mark 5A+ to accommodate VLBA-correlator requirements. Tables 3 through 7 show the resulting track assignments as a function of the number of recorded Mark 5B bit streams, the VLBA fan-out ratio, and the selection of the track mapping option. Table 8 shows the recommended track mapping option as a function of the number of Mark 5B bit-streams and the number of playback tracks; these values should always be used except for testing or extraordinary circumstances.

### Generation of VLBA tape frames

On startup, the Mark 5A+ waits for the first Mark 5B disk-frame number evenly divisible by 16 and starts generating VLBA tape frames from that point. This guarantees that the VLBA tape frame will be properly registered to the Mark 5B data. The VLBA-format time-code in the Mark 5B Disk Frame Header is used directly to generate the time-code in the corresponding VLBA tape track frame headers. The auxiliary-data field in all VLBA tape frame headers for all tracks generated by Mark 5A+ is identically zero.

### Data invalidation

The Mark 5A+ keeps a continuous eye open for the Mark 5B fill pattern, which marks invalid data. If fill pattern is recognized, the data in all VLBA output tracks are marked invalid by inverting the data parity bit in exactly the same manner that the Mark 5A manages invalid data.

### Support of correlation modes at VLBA correlator

Table 9 lists the most commonly used VLBA recording modes (provided courtesy of Jon Romney) as well as other modes recorded with Mark 4 formatters. All of the most commonly used VLBA mode, plus a number of additional modes, are supported by Mark 5A+ with output track mappings compatible with the VLBA correlator.

### Mark 5A+ usage

In order to play Mark 5B data on the Mark 5A+ system, you must first know two important pieces of information: 1) the number of bit-streams recorded on the Mark 5B recording, and 2) the number of VLBA tracks you wish to create in the playback (equivalent to fanout ratio). Then, using Table 8, determine the recommended track-map option, designated  $m$ . Playback of Mark 5B data on the Mark 5A+ system is setup by the 'mode=' command:

mode = mark5a+m : #tracks            (example: 'mode = mark5a+2 : 32');

For example, to play a Mark 5B recording with 16 recorded bit-streams fanned out to 32 VLBA-format tracks, Table 8 recommends  $m=2$ . Thereafter, playback is managed in the same way as for a standard Mark 5A recording. Of course, the proper track mappings must be specified in the correlator control files. The 'mode' must be set before queries such as 'scan\_check?' and 'track\_check?' are used. Furthermore, care must be exercised since some of the returned

parameters may be different; for example, there will be no track numbers returned by ‘track\_check?’ since the Mark 5A+ sets the auxiliary data field identically to zero.

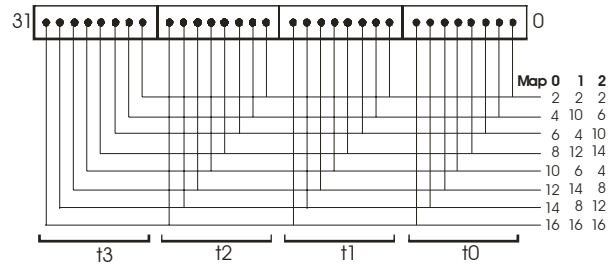


Figure 1: Mapping of bits in FPDP word to tracks for all cases of 8 output tracks; 3 mapping options are available. Output track groups are duplicated in the same manner as Mark 5A.  $t_0 - t_3$  refer to output-track clock cycles.

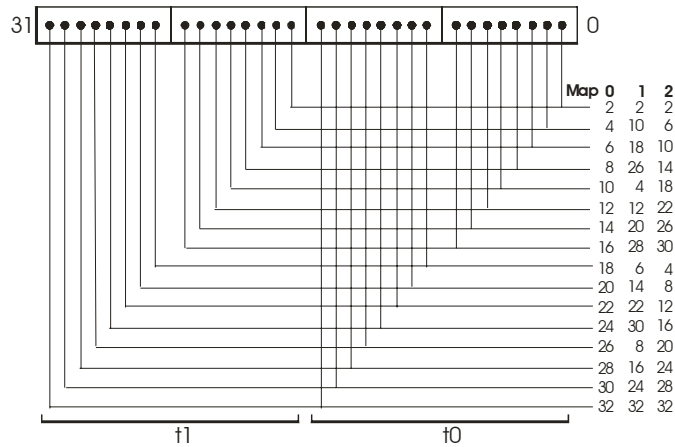


Figure 2: Mapping of bits in FPDP word to tracks for all cases of 16 output tracks; 3 mapping options are available. Output track groups are duplicated in the same manner as Mark 5A.  $t_0 - t_1$  refer to output-track clock cycles.

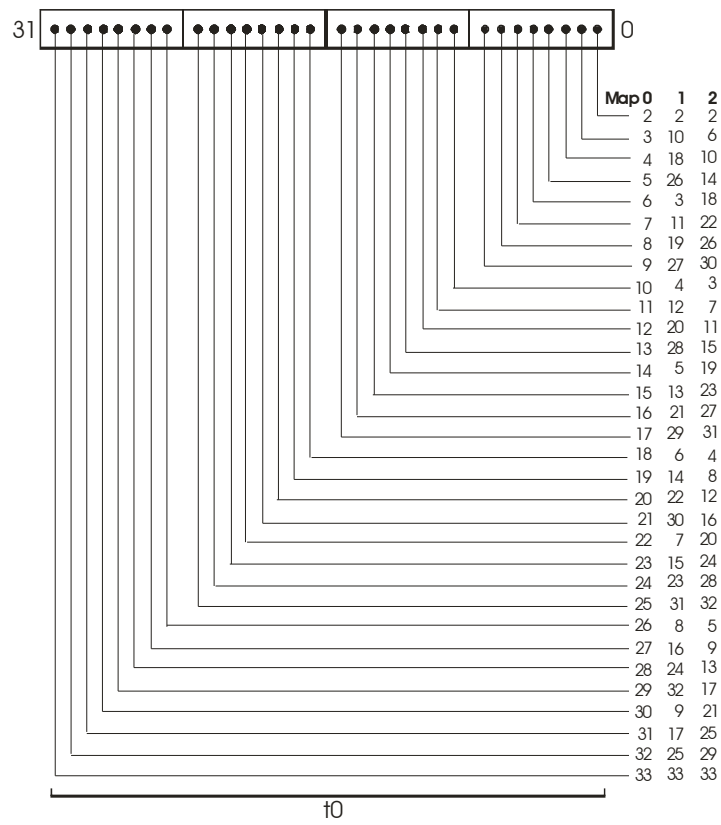


Figure 3: Mapping of bits in FPDP word to tracks for all cases of 32 output tracks; 3 mapping options are available. Headstack 1 output is duplicated to Headstack 2 (as in Mark 5A).  $t_0$  refers to a single output-track clock cycle.

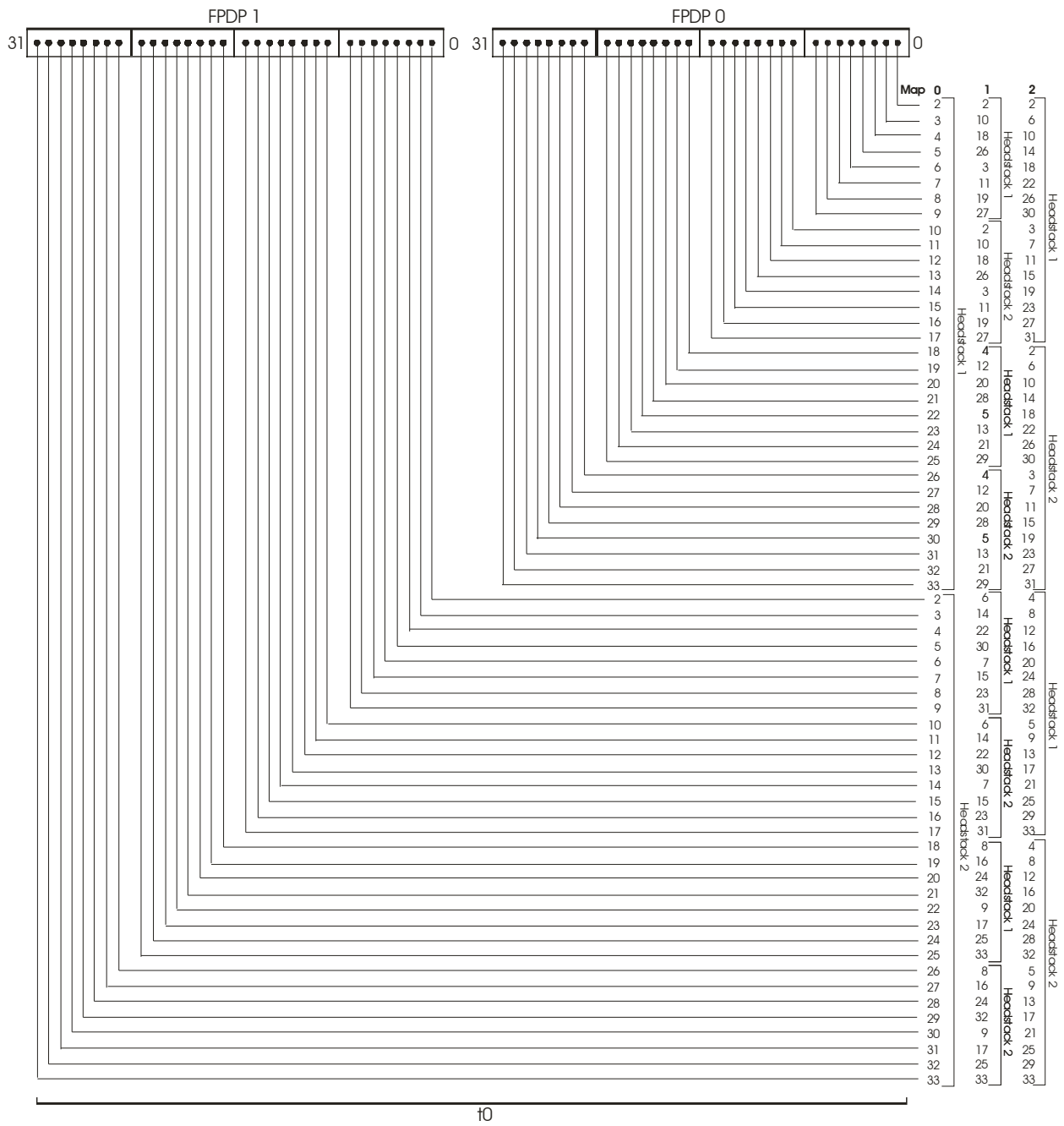


Figure 4: Mapping of bits in two consecutive FPDP words to output tracks for all cases of 64 output tracks; 3 mapping options are available.  $t_0$  refers to a single output-track clock cycle.

Mark 5B bit-stream #	Mk4 VSI formatter			Metsahovi VSI-C board
	VSI1 output	VSI1 output	VSI2 output	
	'Astronomy' mode	'Geodesy' mode	All modes	
0	1US	1US	9US	1US
1	1UM	1UM	9UM	1UM
2	2US	2US	10US	2US
3	2UM	2UM	10UM	2UM
4	3US	3US	11US	3US
5	3UM	3UM	11UM	3UM
6	4US	4US	12US	4US
7	4UM	4UM	12UM	4UM
8	5US	5US	13US	5US
9	5UM	5UM	13UM	5UM
10	6US	6US	14US	6US
11	6UM	6UM	14UM	6UM
12	7US	7US	-	7US
13	7UM	7UM	-	7UM
14	8US	8US	-	8US
15	8UM	8UM	-	8UM
16	1LS	1LS	9LS	1LS
17	1LM	1LM	9LM	1LM
18	2LS	8LS	10LS	2LS
19	2LM	8LM	10LM	2LM
20	3LS	9US	11LS	3LS
21	3LM	9UM	11LM	3LM
22	4LS	10US	12LS	4LS
23	4LM	10UM	12LM	4LM
24	5LS	11US	13LS	5LS
25	5LM	11UM	13LM	5LM
26	6LS	12US	14LS	6LS
27	6LM	12UM	14LM	6LM
28	7LS	13US	-	7LS
29	7LM	13UM	-	7LM
30	8LS	14US	-	8LS
31	8LM	14UM	-	8LM

Table 2: Mapping of baseband-channel sample streams to Mark 5B bit-streams for both Mark 4 VSI formatter (modified Mark 4 formatter) and the Metsahovi VSI-C board connected to VLBA samplers.  
[Example: '4UM' is BBC4, USB, magnitude]

Mk5B bit-stream#	Fanout 4 (8 output tracks)		
	Map 0	Map 1	Map 2
0	2,6,10,14	2,4,6,8	2,10,4,12
1	4,8,12,16	10,12,14,16	6,14,8,16

Table 3: Track mapping options for playback of recordings with 2 Mark 5B bit-streams. Recommended mapping is shaded and is compatible with track mappings required by VLBA correlator.

Mk5B bit-stream#	Fanout 2 (8 output tracks)			Fanout 4 (16 output tracks)		
	Map 0	Map 1	Map 2	Map 0	Map 1	Map 2
0	2,10	2,6	2,4	2,10,18,26	2,4,6,8	2,18,4,20
1	4,12	10,14	6,8	4,12,20,28	10,12,14,16	6,22,8,24
2	6,14	4,8	10,12	6,14,22,30	18,20,22,24	10,26,12,28
3	8,16	12,16	14,16	8,16,24,32	26,28,20,32	14,30,16,32

Table 4: Track mapping options for playback of recordings with 4 Mark 5B bit-streams. Recommended mappings are shaded and are compatible with track mappings required by VLBA correlator.

Mk5B bit-stream#	Fanout 1 (8 output tracks)			Fanout 2 (16 output tracks)			Fanout 4 (32 output tracks)		
	Map 0	Map 1	Map 2	Map 0	Map 1	Map 2	Map 0	Map 1	Map 2
0	2	2	2	2,18	2,6	2,4	2,10,18,26	2,4,6,8	2,3,4,5
1	4	10	6	4,20	10,14	6,8	3,11,19,27	10,12,14,16	6,7,8,9
2	6	4	10	6,22	18,22	10,12	4,12,20,28	18,20,22,24	10,11,12,13
3	8	12	14	8,24	26,30	14,16	5,13,21,29	26,28,20,32	14,15,16,17
4	10	6	4	10,26	4,8	18,20	6,14,22,30	3,5,7,9	18,19,20,21
5	12	14	8	12,28	12,16	22,24	7,15,23,31	11,13,15,17	22,23,24,25
6	14	8	12	14,30	20,24	26,28	8,16,24,32	19,21,23,25	26,27,28,29
7	16	16	16	16,32	28,32	30,32	9,17,25,33	27,29,31,33	30,31,32,33

Table 5: Track mapping options for playback of recordings with 8 Mark 5B bit-streams. Recommended mappings are shaded and are compatible with track mappings required by VLBA correlator.

Mk5B bit-stream#	Fanout 1 (16 output tracks)			Fanout 2 (32 output tracks)			Fanout 4 (64 output tracks) [hdstk]	
	Map 0	Map 1	Map 2	Map 0	Map 1	Map 2	Map 0	Map 1
0	2	2	2	2,18	2,6	2,4	2,18[1], 2,18[2]	2,4,6,8[1]
1	4	10	6	3,19	10,14	6,8	3,19[1], 3,19[2]	10,12,14,16[1]
2	6	18	10	4,20	18,22	10,12	4,20[1], 4,20[2]	18,20,22,24[1]
3	8	26	14	5,21	26,30	14,16	5,21[1], 5,21[2]	26,28,20,32[1]
4	10	4	18	6,22	3,7	18,20	6,22[1], 6,22[2]	3,5,7,9[1]
5	12	12	22	7,23	11,15	22,24	7,23[1], 7,23[2]	11,13,15,17[1]
6	14	20	26	8,24	19,23	26,28	8,24[1], 8,24[2]	19,21,23,25[1]
7	16	28	30	9,25	27,31	30,32	9,25[1], 9,25[2]	27,29,31,33[1]
8	18	6	4	10,26	4,8	3,5	10,26[1], 10,26[2]	2,4,6,8[2]
9	20	14	8	11,27	12,16	7,9	11,27[1], 11,27[2]	10,12,14,16[2]
10	22	22	12	12,28	20,24	11,13	12,28[1], 12,28[2]	18,20,22,24[2]
11	24	30	16	13,29	28,32	15,17	13,29[1], 13,29[2]	26,28,20,32[2]
12	26	8	20	14,30	5,9	19,21	14,30[1], 14,30[2]	3,5,7,9[2]
13	28	16	24	15,31	13,17	23,25	15,31[1], 15,31[2]	11,13,15,17[2]
14	30	24	28	16,32	21,25	27,29	16,32[1], 16,32[2]	19,21,23,25[2]
15	32	32	32	17,33	29,33	31,33	17,33[1], 17,33[2]	27,29,31,33[2]

Table 6: Track mapping options for playback of recordings with 16 Mark 5B bit-streams. Recommended mappings are shaded and are compatible with track mappings required by VLBA correlator.

Mk5B bit-stream#	Fanout 1 (32 output tracks)			Fanout 2 (64 output tracks)		
	Map 0	Map 1	Map 2	Map 0	Map 1	Map 2
0	2	2	2	2[1], 2[2]	2,6[1]	2,4[1]
1	3	10	6	3[1], 3[2]	10,14[1]	6,8[1]
2	4	18	10	4[1], 4[2]	18,22[1]	10,12[1]
3	5	26	14	5[1], 5[2]	26,30[1]	14,16[1]
4	6	3	18	6[1], 6[2]	3,7[1]	18,20[1]
5	7	11	22	7[1], 7[2]	11,15[1]	22,24[1]
6	8	19	26	8[1], 8[2]	19,23[1]	26,28[1]
7	9	27	30	9[1], 9[2]	27,31[1]	30,32[1]
8	10	4	3	10[1], 10[2]	2,6[2]	3,5[1]
9	11	12	7	11[1], 11[2]	10,14[2]	7,9[1]
10	12	20	11	12[1], 12[2]	18,22[2]	11,13[1]
11	13	28	15	13[1], 13[2]	26,30[2]	15,17[1]
12	14	5	19	14[1], 14[2]	3,7[2]	19,21[1]
13	15	13	23	15[1], 15[2]	11,15[2]	23,25[1]
14	16	21	27	16[1], 16[2]	19,23[2]	27,29[1]
15	17	29	31	17[1], 17[2]	27,31[2]	31,33[1]
16	18	6	4	18[1], 18[2]	4,8[1]	2,4[2]
17	19	14	8	19[1], 19[2]	12,16[1]	6,8[2]
18	20	22	12	20[1], 20[2]	20,24[1]	10,12[2]
19	21	30	16	21[1], 21[2]	28,32[1]	14,16[2]
20	22	7	20	22[1], 22[2]	5,9[1]	18,20[2]
21	23	15	24	23[1], 23[2]	13,17[1]	22,24[2]
22	24	23	28	24[1], 24[2]	21,25[1]	26,28[2]
23	25	31	32	25[1], 25[2]	29,33[1]	30,32[2]
24	26	8	5	26[1], 26[2]	4,8[2]	3,5[2]
25	27	16	9	27[1], 27[2]	12,16[2]	7,9[2]
26	28	24	13	28[1], 28[2]	20,24[2]	11,13[2]
27	29	32	17	29[1], 29[2]	28,32[2]	15,17[2]
28	30	9	21	30[1], 30[2]	5,9[2]	19,21[2]
29	31	17	25	31[1], 31[2]	13,17[2]	23,25[2]
30	32	25	29	32[1], 32[2]	21,25[2]	27,29[2]
31	33	33	33	33[1], 33[2]	29,33[2]	31,33[2]

Table 7: Track mapping options for playback of recordings with 32 Mark 5B bit-streams. Recommended mappings are shaded. Mapping to 64 output tracks is compatible with track mappings required by VLBA correlator, but mapping to 32 output tracks is not.

#Mk5B bit-streams	#output tracks				fanout ratio		
	8	16	32	64	1	2	4
2	1	-	-	-	-	-	1
4	2	1	-	-	-	2	1
8	0	2	1	-	0	2	1
16	-	0	2	1	0	2	1
32	-	-	2	2	2	2	-

Table 8: Recommended Mark 5A+ track-mapping option as a function of the number of recorded Mark 5B DIM input bit-streams and # of output tracks or fanout ratio (i.e. #output-trks/#bit-streams). All recommended track mappings except the case of 32 bit-streams played back to 32 tracks (fanout ratio 1) are compatible with track mappings required by the VLBA correlator. All recommended track mappings are compatible with the Mark 4 correlators.

Most common VLBA modes	Total (Mbps)	#chns	b/s	Total BW (MHz)	Sample Rate (Ms/s)	Track Rate (Mbps)	#Mark5B bitstreams	#tracks	Fan-Out (tks/bitstream)	Mk5A+ trk map option	VLBA Usage	Other usage
256-8-2	256	8	2	64	16	8	16	32	2	2	39.3%	
128-8-1	128	8	1	64	16	4	8	32	4	1	17.0%	RDV
128-4-2	128	4	2	32	16	4	8	32	4	1	17.0%	
256-4-2	256	4	2	64	32	8	8	32	4	1	5.4%	
128-8-2	128	8	2	32	8	4	16	32	2	2	4.9%	
64-2-2	64	2	2	16	16	4	4	16	4	1	2.4%	
128-4-2	128	4	2	32	16	8	8	16	2	2	1.8%	
128-4-1	128	4	1	64	32	8	4	16	4	1	1.8%	
128-2-2	128	2	2	32	32	8	4	16	4	1	1.8%	
128-8-2	128	8	2	32	8	8	16	16	1	0	1.5%	
32-8-2	32	8	2	8	2	2	16	16	1	0	1.5%	
64-4-2	64	4	2	16	8	4	8	16	2	2	1.3%	
16-4-2	16	4	2	4	2	2	8	8	1	0	1.3%	
512-8-2	512	8	2	128	32	8	16	64	4	1	1.1%	
64-8-1	64	8	1	32	8	2	8	32	4	1	0.6%	
32-1-2	32	1	2	8	16	4	2	8	4	1	0.5%	
128-8-1	128	8	1	64	16	8	8	16	2	2	0.3%	
64-8-2	64	8	2	16	4	4	16	16	1	0	0.3%	
512-16-1	512	16	1	256	32	8	16	64	4	1	0.2%	
Other modes												
1024-16-2	1024	16	2	256	32	16	32	64	2	2		R&D
512-16-1	512	16	1	256	32	16	16	32	2	2		
512-16-2	512	16	2	128	16	16	32	32	1	2		
512-16-2	512	16	2	256	16	8	32	64	2	2		
256-16-1	256	16	1	128	16	8	16	32	2	2		R1
128-16-1	128	16	1	64	8	8	16	16	1	0		R4

Table 9: List of most commonly used recording modes, listing the Mark5A+ track mapping option to be used with each mode (shaded). The most commonly used VLBA modes are for the period 2005.01.01 to 2006.04.07 (provided courtesy Jon Romney, NRAO). Note that some recording modes can be supported with more than one fan-out value (i.e. 512-16-2); the track mapping option changes if a different fan-out value is used.