National Radio Astronomy Observatory

Charlottesville, Virginia

To: Addressee May 3, 1976

From: A. M. Shalloway

VLA ELECTRONICS MEMO #138

Subject: Modes, Sub-arrays and integration times of the VLA Delay-Multiplier System

1. INTRODUCTION

In determining modes and sub-arrays to be available to astronomers, an almost infinite number of combinations could be proposed. In an effort to come up with a practical system, a study was made with the help of S. Weinreb, R. Escoffier and E. Greisen. The modes, sub-arrays, and integration times proposed in this memo should cover a large percentage of VLA usage. If there is a particular type of observation that would require two or more configurations and thus a longer observation time, but the observation only occurred a few percent or less of the total VLA observation time, then the longer time required is justifiable over complicating an already complicated VLA.

2. MODES

Twenty-one modes are shown in Table 1. This is a revised listing from VLA Electronics Memoranda #134 - Computer Control and Processor for VLA Digital Delay-Multiplier System, A. M. Shalloway. In general the table is self-explanatory; however, the following will aid in understanding the table.

MNEMONIC is an abbreviated symbol for reference purposes. These are proposed by Barry Clark and Larry D'Addario based on the following:

C = continuum

1,2,3,4 = line, number of spectra per baseline

P = polarization

A,B,C,D = specified IF signal is processed

\+ = indicated IF signals summed after FFT processing

In some cases the mnemonics would normally be more than three characters, these cases are as follows:

8\. 1AC+ 9. 1BD+ 10. 1AB+ 11. 1CD+ 16. 2AC+BD+ 17. 4ABCD

20\. CP/2CD 21. CQ/2AB

MODE NO. is a column of numbers by which modes will be referenced. It also is probably indicative of the approximate number of programs or variations on a program (sub routines) requried in the synchronous and asynchronous computers.

CONFIGURATION MULT. is a column indicating the number of different configurations (connections) required of the delay-recirculator-driver-multiplier system.

CONFIGURATION MEM. is a column indicating the number of different memory configurations and/or microcomputer and FFT programs or sub-routines required.

NO. OF BANDS defines the operation in terms of the number of frequency bands.

DESCRIPTION gives additional information about the mode and in some cases the purpose of the mode.

MULTIPLIER & MEMORY QUADRANTS lists which continuum and/or spectral bands appear in which quadrant of the multipliers and which quadrant of the memory. A,B,C and D refer to and are the same nomenclature as used for the IF bands where: A&B are left polarization and C&D are right polarization. Of course, A,B,C, and D will not necessarily be 50 MHz, but will be of the bandwidth selected for the continuum or spectral observation. In the continuum section, S and C refer to sine and cosine. Note that each continuum multiplication, for example SxS, represents four multiplications: RSxRS, LSxLS, RSxLS and LSxRS.

In case it is helpful in understanding the various modes, I have included corrected copies of the mode block diagram from VLA Electronics Memo No. 133 - The Combined Continuum-Spectral Line Digital Delay and Multiplier System - R. Escoffier. These appear as Figures 1 through 5.

The 1/2 τ delay of B and D in modes 10 and 11 are produced by synchronous computer programming to supply a delay to delay lines B and D to produce a 1/2 τ delay from A and C. τ = sample period.

The increase in sensitivity due to oversampling in modes 10 and 11 produces a relative sensitivity of .88 compared to a normal relative sensitivity of .81. This reduces the observation time by 16.2%. The increase in sensitivity due to combining two different polarizations in modes 8, 9 and 16 produces a relative sensitivity of 1.146 and a reduction in observation time of 50.0%

Modes 10 and 11 oversample by shifting the sample point in time. This method is described in an article "Quantization Noise of Correlation Spectrometers" by F. K. Bowers and R. J. Klingler. Mode 3 oversamples by phase shifting every frequency by 90° (using sine and cosine). I do not know how much increase in sensitivity this produces, but it is probably in the same ballpark as modes 10 and 11.

3. SUB-ARRAYS

As a compromise between complexity, cost, and what really seemed desirable, a set of three sub-array setups is proposed. They are listed in Table 2.

The first four columns have the same meanings as in the mode Table 2, except the number column was started at 1 again.

NO. OF QUADRANTS indicates the number of quadrants used on the continuum or spectral line portion of the sub-array.

The remainder of columns are self-explanatory.

The number os sub-arrays -groups of antennas- can be as many as desired, or as many as we are willing to program for in the synchronous and asynchronous computers.

4. LOCATION OF PROCESSING

In all of the above, certain operations were assumed to be done in the synchronous or asynchronous computers. These include:

A. Discarding any sets (8 ea.) of continuum baselines and any sets of spectral line baselines not desired. They may not be desired because the antennas are not in operation; in modes 1 and 2 either quadrants 2 and 4 or 1 and 3 respectively are not used; or the sets composed of antennas in different sub-arrays must be discarded.

B. In mode 3 and 16, quadrants 1 and 2 are added together and quadrants 3 and 4 are added together. In modes 8, 9, 10 and 11, quadrants 1 and 2 are added to 3 and 4.

If it is desired that some of these items be accomplished by the memory-microcomputer-FFT-Modcomp system, I would appreciate being notified as soon as it is determined. Hereafter, the memory-microcomputer-FFT system will be referred to as the MAC system (Multiplier-Memory Automatic Control system). It might be helpful if Barry Clark gave a name to the Modcomp associated with the MAC system since programming-wise it is part of the synchronous computer system.

MODE & CONFIGURATION				NO. OF BANDS	DESCRIPTION	MULTIPLIER & MEMORY QUADRANTS			
MNEMONIC	NUMBER	MULTIPLIER	MEMORY			1	2	3	4
					CONTINUUM				
CP	1	1	1	2		S×S & S×C		S×S & S×C	
CQ	2	1	1	2			C×C & C×S		C×C & C×S
C	3	1	1	2	OVERSAMPLED-SENSITIVITY INCREASE	S×S & S×C	C×C & C×S	S×S & S×C	C×C & C×S
					SPECTRAL LINE				
1A	4	2	2	1	MAXIMUM RESOLUTION	← A×A →			
1B	5	3	2	1	" "	← B×B →			
1C	6	4	2	1	" "	← C×C →			
1D	7	5	2	1	" "	← D×D →			
1AC	8	6	3	1	SUM OF POLARIZATIONS-MAXIMUM SENSITIVITY	A×A + C×C			
1BD	9	7	3	1	" " " " "	B×B + D×D			
1AB	10	8	3	1	$A=B+\frac{1}{2}\gamma$ OVERSAMPLED-SENSITIVITY INCREASE	A×A + B×B			
1CD	11	9	3	1	$C=D+\frac{1}{2}\gamma$ " " "	C×C + D×D			
2AC	12	6	3	2	TWO POLARIZATIONS -OR- TWO WAVELENGTHS	A×A		C×C	
2BD	13	7	3	2	" " " " "	B×B		D×D	
2AB	14	8	3	2	TWO CLOSE FREQUENCY BANDS	A×A		B×B	
2CD	15	9	3	2	" " " "	C×C		D×D	
2++	16	10	4	2	SUM OF POLARIZATIONS-MAXIMUM SENSITIVITY	A×A + C×C		B×B + D×D	
4	17	10	4	4		A×A	C×C	B×B	D×D
PAC	18	11	4	4	POLARIZATION SPECTRA	A×A	A×C	C×A	C×C
PBD	19	12	4	4	" "	B×B	B×D	D×B	D×D
					CONTINUUM & SPECTRAL LINE				
CP2	20	13	5	2 & 2		S×S & S×C	C×C	S×S & S×C	D×D
CQ2	21	14	6	2 & 2		A×A	C×C & C×S	B×B	C×C & C×S

TABLE 1 MODES OF OBSEVATION

SUB-ARRAY & CONFIGURATION				CONTINUUM		SP LI		
MNEMONIC	NUMBER	MULTIPLIER	MEMORY	NO. OF QUADRANTS	APPLICABLE MODES	NO. OF QUADRANTS	NO. OF B.W.'s	APPLICABLE MODES
X	1	6 THRU 9	3	—	—	4	2	12, 13, 14, 15
	2	10	4	—	—	4	4	17
	3	13, 14	5, 6	2	20, 21	2	2	20, 21

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TABLE 2 SUB-ARRAYS

FIGURE 1 CONTINUUM MODE

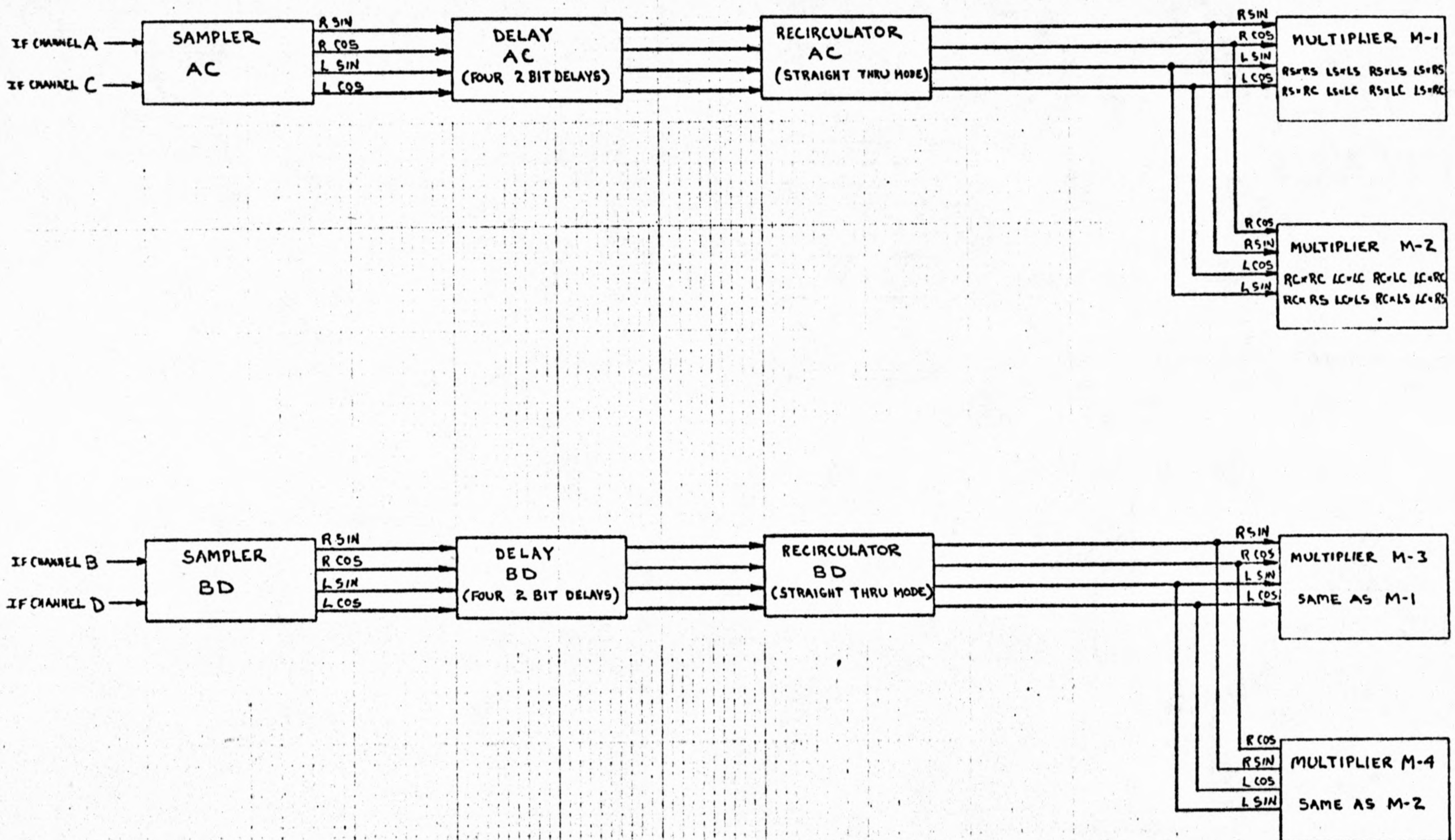
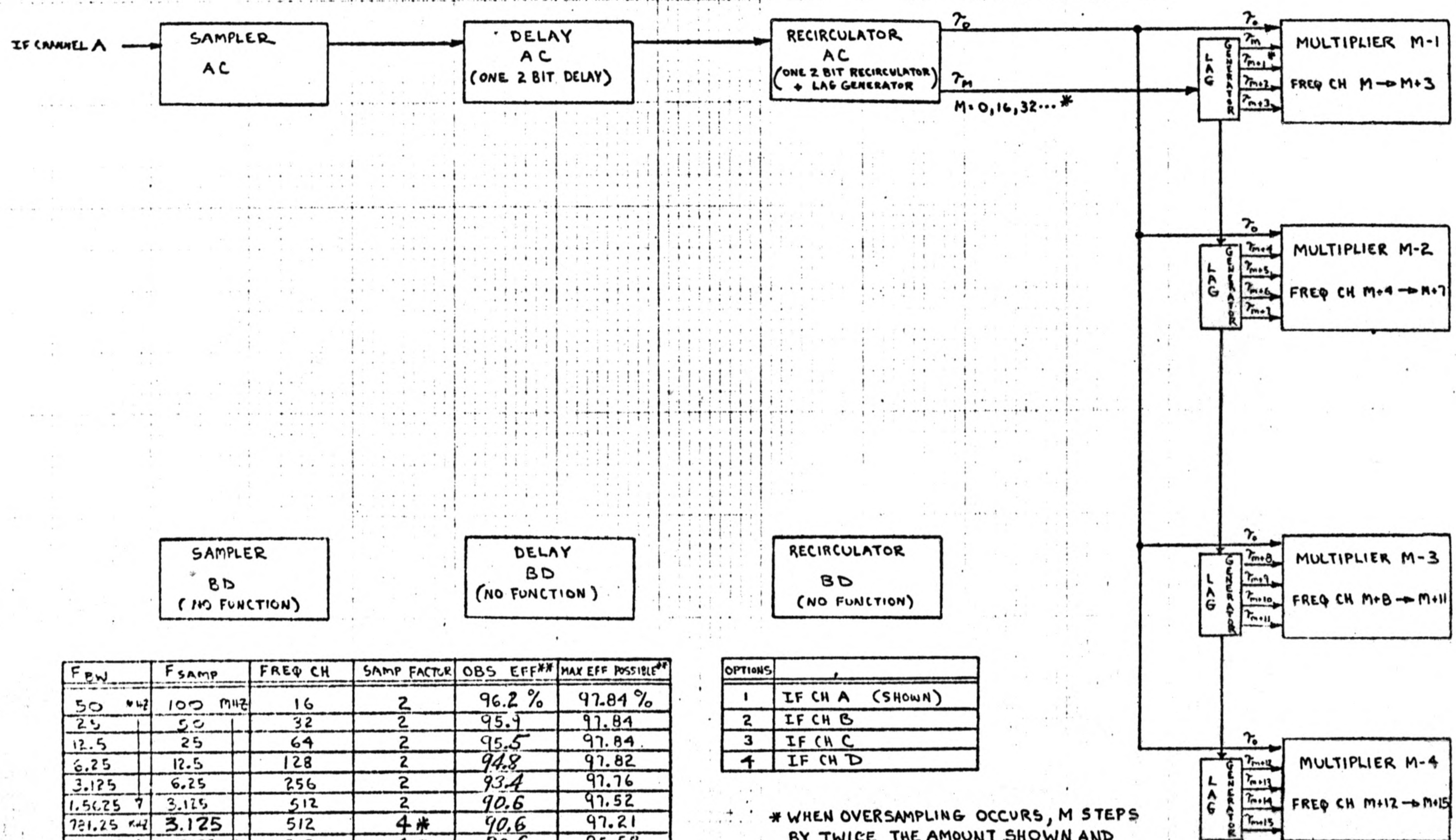


FIGURE 2 SINGLE BAND SPECTRAL LINE MODE



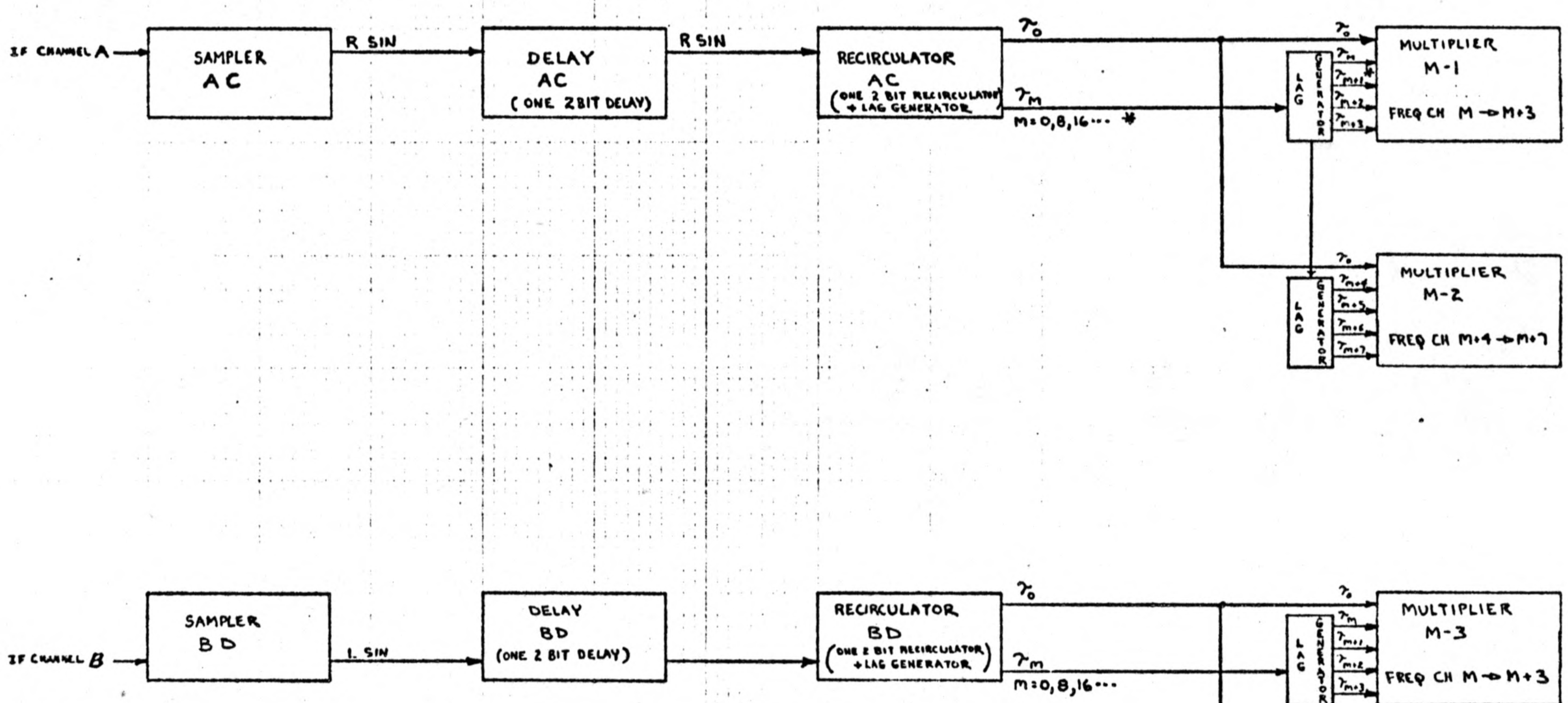
F_{BW}	F_{SAMP}	FREQ CH	SAMP FACTOR	OBS EFF**	MAX EFF POSSIBLE**
50 MHz	100 MHz	16	2	96.2 %	97.84 %
25	50	32	2	95.9	97.84
12.5	25	64	2	95.5	97.84
6.25	12.5	128	2	94.8	97.82
3.125	6.25	256	2	93.4	97.76
1.5625	3.125	512	2	90.6	97.52
781.25 KHz	3.125	512	4*	90.6	97.21
390.625	1.5625	512	4*	90.6	95.58
195.3125	781.25 KHz	512	4*	90.6	95.32
97.65625	390.625	512	4*	90.6	92.80

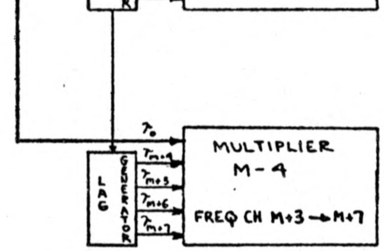
OPTIONS	
1	IF CH A (SHOWN)
2	IF CH B
3	IF CH C
4	IF CH D

* WHEN OVERSAMPLING OCCURS, M STEPS BY TWICE THE AMOUNT SHOWN AND τ_{M+N} INTO MULTIPLIERS BECOMES τ_{M+2N}.

** APPLIES TO FIG 2 THRU 5.

FIGURE 3 DUAL BAND SPECTRAL LINE MODE



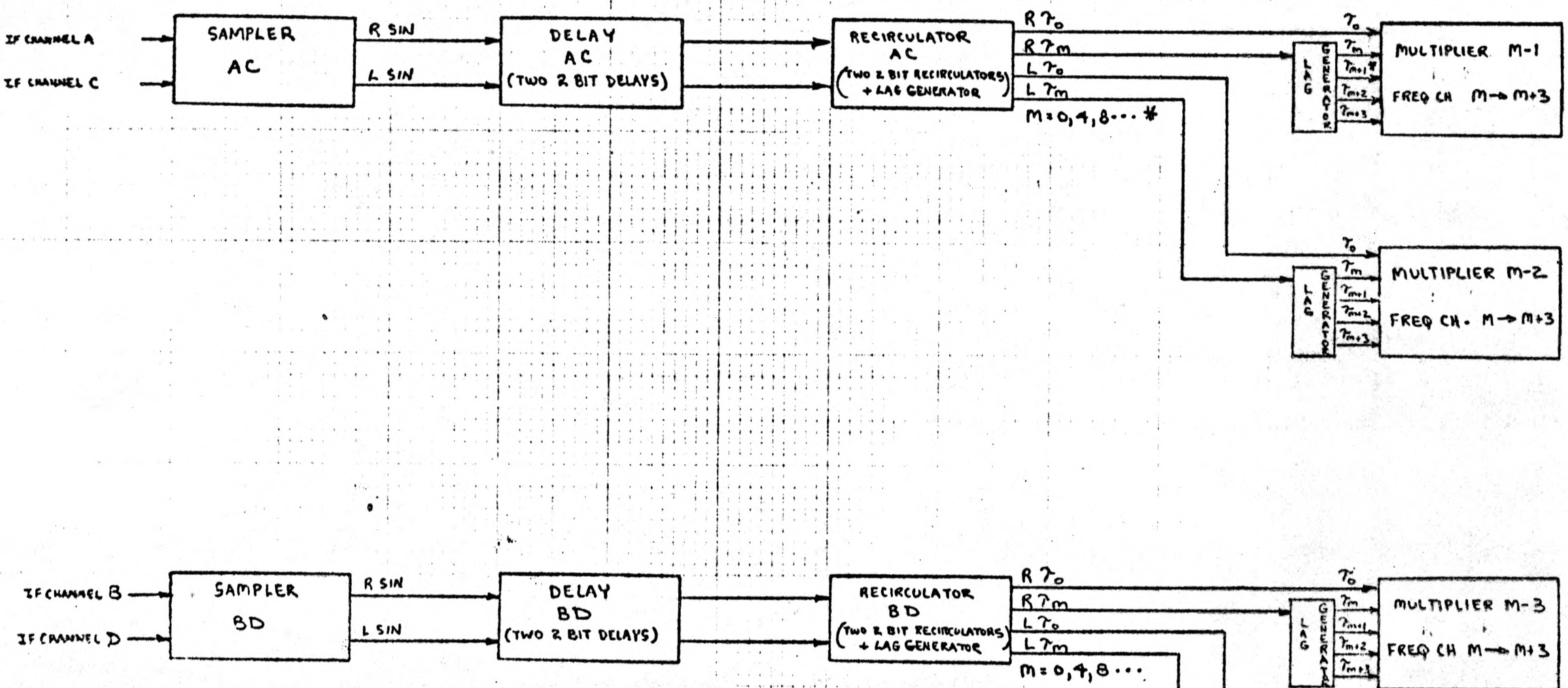


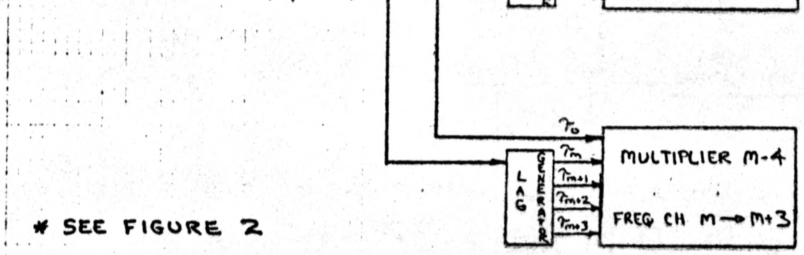
F_{BW} / IF CH	F_{SAMP}	FREQ CH / IF CH	SAMP FACTOR	BW CAPACITY	FREQ CH CAP
50 MHZ	100 MHZ	8	2	100 MHZ	16
25	50	16	2	50	32
12.5	25	32	2	25	64
6.25	12.5	64	2	12.5	128
3.125	6.25	128	2	6.25	256
1.5625	3.125	256	2	3.125	512
781.25 KHZ	3.125	256	4 *	1.5625	512
390.625	1.5625	256	4 *	781.25 KHZ	512
195.3125	781.25 KHZ	256	4 *	390.625	512
97.65625	390.625	256	4 *	195.3125	512

OPTIONS	
1	IF CH A and C
2	B and D
3	A and B (SHOWN)
4	C and D

* SEE FIGURE 2

FIGURE 4 FOUR BAND SPECTRAL LINE MODE



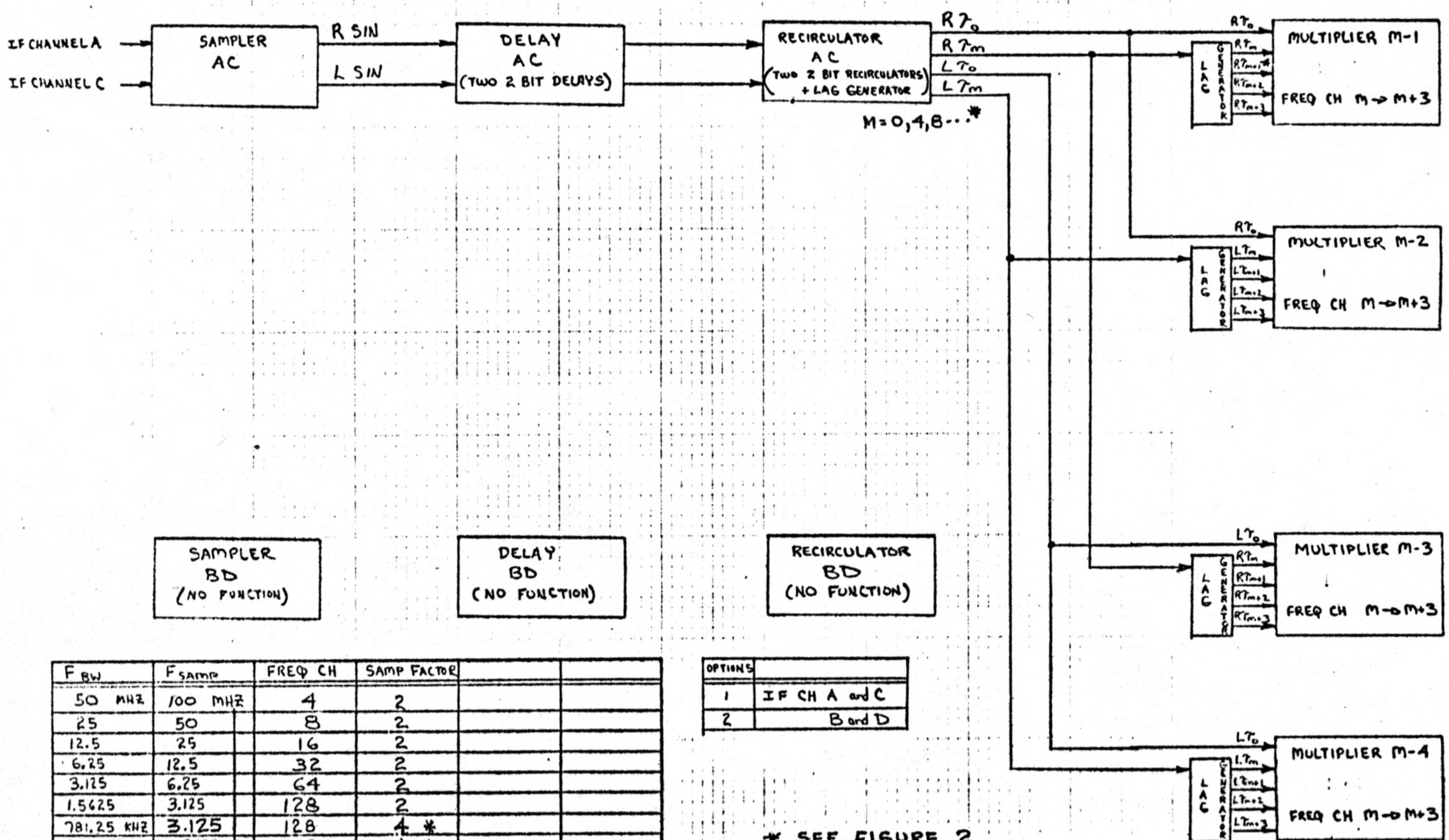


F_{BW}/IF CH	F_{SAMP}	FREQ CH/IF CH	SAMP FACTOR	BW CAPACITY	FREQ CH CAP
50 MHZ	100 MHZ	4	2	200 MHZ	16
25	50	8	2	100	32
12.5	25	16	2	50	64
6.25	12.5	32	2	25	128
3.125	6.25	64	2	12.5	256
1.5625	3.125	128	2	6.25	512
781.25 KHZ	3.125	128	4 *	3.125	512
390.625	1.5625	128	4 *	1.5625	512
195.3125	781.25 KHZ	128	4 *	781.25 KHZ	512
97.65625	390.625	128	4 *	390.625	512

* SEE FIGURE 2

FIGURE 5

POLARIZATION SPECTRAL LINE MODE



F_{BW}	F_{samp}	FREQ CH	SAMP FACTOR		
50 MHZ	100 MHZ	4	2		
25	50	8	2		
12.5	25	16	2		
6.25	12.5	32	2		
3.125	6.25	64	2		
1.5625	3.125	128	2		
781.25 KHZ	3.125	128	4 *		
390.625	1.5625	128	4 *		
195.3125	781.25 KHZ	128	4 *		
97.65625	390.625	128	4 *		

OPTIONS	
1	IF CH A and C
2	B and D

* SEE FIGURE 2

4. INTEGRATION TIMES

Maximum and minimum integration times are shown in Table 3. Integration time is equal to the dump time between MAC and Core A and B computers.

TABLE 3

A. CONTINUUM MODES

min. = 312.5 msec. max. = 10 sec.

B. SPECTRAL LINE MODES

B.W. In MHz	Integration Time	
	Min.	Max.
50	1.25 sec.	10 sec.
25	1.25 sec.	20 sec.
12.5	1.25 sec.	40 sec.
6.25	2.5 sec.	40 sec.
3.125	5 sec.	40 sec.
1.5625 thru .09765625	10 sec.	40 sec.

C. MORE THAN ONE B.W. AT A TIME OR MODES 20 & 21

min. and max. = 10 sec.

In the processing of continuum data in A and C in Table 3, the data received from the multiplier is integrated for 312.5 msec. on the integrating memory. The mean and mean square are then formed for ten seconds from these 312.5 msec integrations and then sent to core A & B computers:

$$\overline{X} = \frac{1}{N}\sum_{i=1}^{N} X_i \quad ; \quad \overline{X^2} = \frac{1}{N}\sum_{i=1}^{N} X_i^{\,2}$$