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*"S" INDICATES SUPERSEDES EARLIER PAGE. "A" INDICATES ADDED PAGE

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Section 15 - MPRF BIT CALIBRATION AND TEST MODE

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PREFACE

This document contains the PSP Computer Program Development Specification for the Programmable Signal Processor (PSP) unit of the F-15 AN/APG-63 Radar. The document is divided into sixteen (16) sections, with each section specifying an individual mode of the PSP operation. It must be noted that the Air-to-Air LPRF Search and Acquisition Mode and LPRF Track Mode, Sections 6 and 7 respectively, have been deleted per augmentations to RCP/CCP 613A. However, the sections numbers are retained to preserve the continuity of this document. Also updating of the HPRF RAM Single Target Track (STT) Mode, Section 13, has been deferred until a future date.

A block diagram is included in most sections to illustrate all of the processing steps within that mode. The processing steps are then specified in detail with an "Inputs - Processing - Outputs" format.

The page numbering is of the form SN - PN.

where:

SN = section number and
PN = page number within the section.

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SECTION 1

HPRF RANGE-WHILE-SEARCH MODE

1.0 INTRODUCTION

The HPRF Range-While-Search (RWS) mode is used for two purposes: 1) to search for targets in a multiple target environment; and 2) to resolve the range of the detected targets. This is accomplished by a three phase FM ranging scheme. The doppler shifts from the three phases are correlated to identify targets. The correlated doppler shifts are also used to compute the range of the targets. To enhance target detection, this mode employs:

a) a 512 - point FFT for spectral computation for each phase,
b) a 16-3-16 sliding window for spectral noise estimation,
c) CFAR detection,
d) doppler shift centroiding,
e) azimuth centroiding, and
f) IFF target correlation.

The confirmed targets are displayed on the Vertical Situation Display (VSD) unit in the cockpit.

A functional block diagram showing the detailed data processing scheme is given in Figure 1.1. Digitized target signals are sent from the A to D convertor in the ARSP (039 unit) to the Programmable Signal Processor (PSP). The returns from two subbands (SB1 and SB2) are processed in two separate channels. The signals are amplitude weighted before the Fast Fourier Transfer (FFT) process. Later, the two 512 filter results are combined into a single 512 filter data base. From this, the magnitude in each filter is computed and compared with the threshold level for target hit/miss detection. The threshold level is adjusted for every filter according to the noise levels in an ensemble of adjacent bins. Filter centroiding, range resolving, and azimuth centroiding are performed to resolve closely spaced targets and to avoid false correlation starts due to a strong or wide target. When IFF interrogation is active, detected radar targets are correlated with the IFF targets from the IFF Reply Evaluator (IRE) before being sent to the VSD for display. The confirmed targets and tracks are displayed (in search) at various intensity levels on the VSD with the most recent data at the brightest intensity level so that the track and heading can be easily identified on the display. For manual acquisition, the Digital Scan Convertor in the PSP can also search for stored targets within the designated acquisition corral (correlation gate) commanded by the pilot. A correlated target is sent to the RDP for target acquisition PRF and elevation designation.

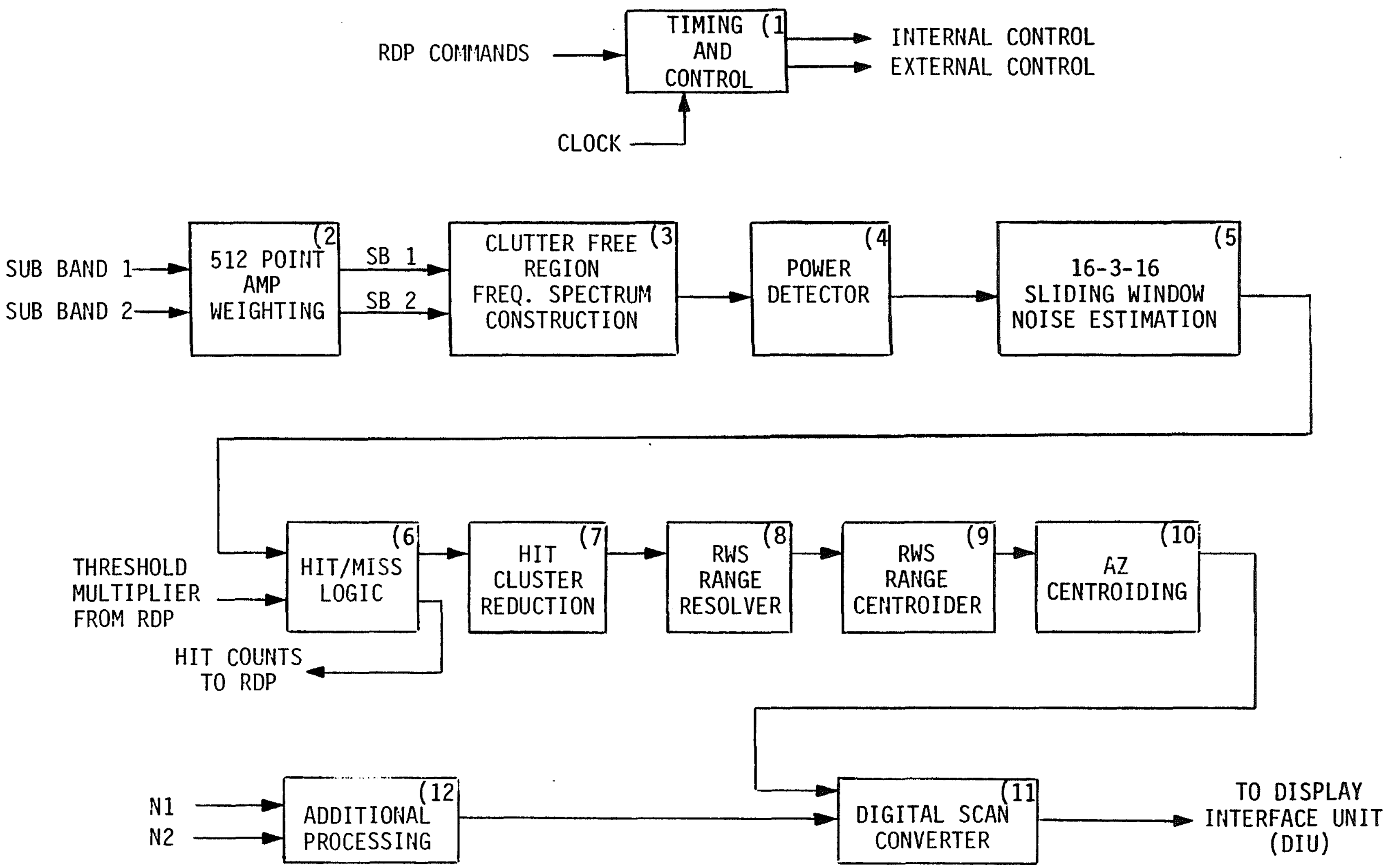


Figure 1.1 - RWS FUNCTION DIAGRAM

1.1 Timing and Control (T&C)

The Timing and Control function (T&C) shall be accomplished by special Timing-and-Control modules (TC1 and TC2) and by the software in the PSP. T&C modules shall operate in real time and have close tolerance requirements on their high speed timing. The T&C functional requirements described here cover both the hardware and the software. Some of the T&C function may involve RDP, RSP and other hardware modules in the PSP. Only the T&C functions required in the PSP software control are discussed in detail here.

1.1.1 Inputs

- Mode control command indicating HPRF RWS search mode from RDP
- PRF command and Processing Phase command from RDP
- Manual acquisition and cursor position command from RDP
- 20 MHz clock reference frequency from T&C module
- Range, azimuth and border scaling from RDP
- Target heading compensation and $\Delta\phi$ angle from RDP
- ECM Tag from RDP
- VCO positions A, B and C

1.1.2 Processing

Timing and Control functions are divided into three major categories.

i) System related T&C functions

ii) RWS and PRF related T&C functions

iii) Internal Timing

a) The system related T&C functions shall include the following:

- PRF generating command
- System timing sequence control
- Clock generation for internal PSP processing
- Flag generation

Fundamental control of the radar system parameters is derived from the 20 MHz master clock timing signals in conjunction with the timing generating Modules. The shortest time interval is 50 nsec. A timing and control table is sent from the RDP to the PSP Bulk Memory via "C" Memory at the program startup phase of the HPRF RWS mode. The RDP then selects the table to be used at any particular point in time via the Mode Command. The PSP transfers the RDP selected Timing Generator control table(s) to "C" Memory. Each table has the information necessary to control the time history of all the Time Generator outputs. This timed sequence of output signals routed to the various radar units yields the radar operation (waveform) desired. (Figure 1.1.1).

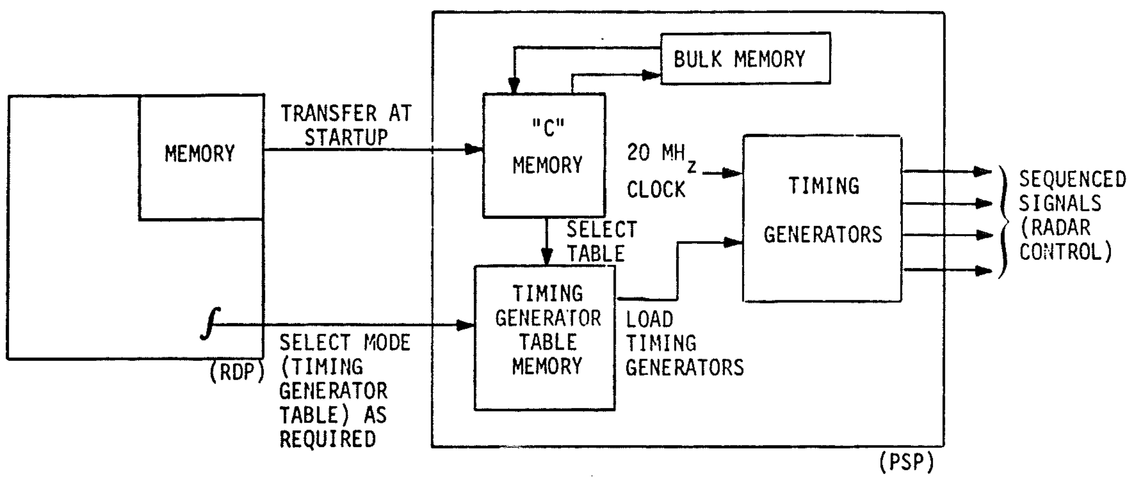


Figure 1.1.1 - TIMING GENERATOR SCHEME

b) <u>RWS and PRF Related T&C Function</u>

This T&C function shall generate the RWS and PRF related signals which are synchronous with the signal detection process. The T&C function shall divide a single RSP cycle into four different phases. The first phase (phase D) of the 4.301 MS "dead time" and three phases of 8.602 MS each are for signal transmission and detection. (Figure 1.1.2). Each phase of phases C, B, and A has 512 sample times and uses different frequency ramping function for range resolving. The time sequence for phase change is controlled by the T&C function by counting the 512 sampling intervals before switching. Detailed time sequence are shown in Figure 1.1.2.

c) <u>Internal Timing</u>

Timing of the PSP internal processing is derived from a self-contained clock with a frequency of 35.7 MHz. The 35.7 MHz signal is then divided by five to generate a signal of 7.14 MHz yielding a basic clock cycle of 140 nano seconds for PSP data processing. Based on this clock cycle, the T&C function generates flags, sets control indicators, transfers mode commands from the RDP and performs other services as required to implement the data flow and detailed data processing for the HPRF RWS search mode operation. For example, the timing of FFT filter initialization, the controlling sliding window for noise estimation and the initiation straight-line-scanning all are commanded for T&C function for each phase of the data processing.

d) HPRF RWS Search Mode and System Parameter Control

The following parameters are set for HPRF RWS Search Mode and Track Test (BIT).

1) Mode Control Word
*2) Subband Thresholds
*3) VCO Positions A, B & C
For Track Test (BIT), the cm bit in PSP1 will be set; insert the following VCOs for the different phases.
Phase C = $0004\ 1072_8$
Phase B = $0004\ 1561_8$
Phase A = $0004\ 1325_8$
4) Number of Amplitude Weights, $N_W = 8$
5) Filter Number, $N_F = 512$
6) Number of Range Bins, $N_{RB} = 48$, for 100 mile range
7) Number of Samples, $N_S = 512$, for filter processing
8) HIT/MISS Detection Threshold Level
9) DSC Mode Control Word
10) Correlation Gate Size
*11) Target Heading Compensation
*12) Range, azimuth and border scaling from RDP.

Parameters with asterisks require update every PSP cycle.

1.1.3 Outputs

- Sample Enables
- Process Sync
- Processing Clock
- Pause and Process Time
- Flags

HPRF RWS SEARCH, ACQUISITION 1, AND BURST RANGING

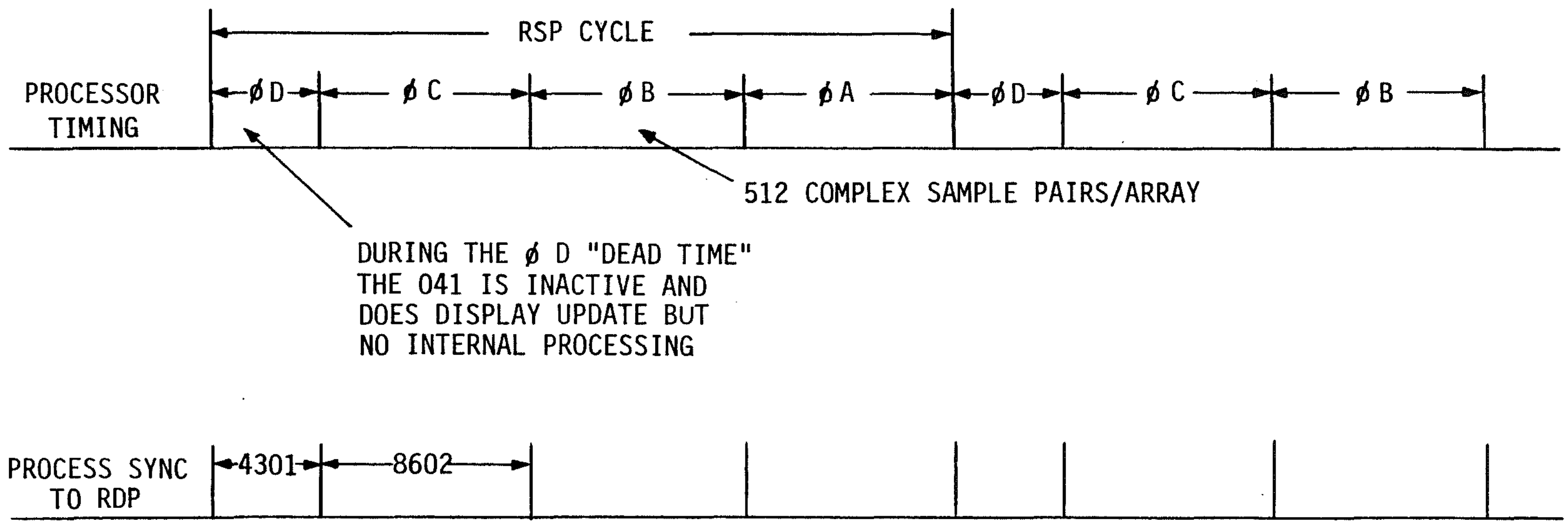


FIGURE 1.1.2 - HPRF RWS PHASE SEQUENCE

1.2 Amplitude Weighting

1.2.1 Inputs

- Two sequences of 512 I/Q samples that are associated with the frequency bands, SB1 and SB2, of the radar return signal:

  $$\{S(i,j) \mid i = 1, 2; j = 0, \ldots, 511\}$$

  SB1 and SB2 are equal in bandwidth and disjoint. Together they span the processed clear region of the radar signal spectrum. They are referred to as sub-band 1 and sub-band 2 respectively.

1.2.2 Processing

Amplitude weighting takes place just before the FFT is applied to the two input sequences. This ensures that the FFT output for each of the sequences satisfies a desired peak mainlobe to peak side-lobe ratio. The procedure requires that precomputed weights be stored in the PSP. Each of the 512 samples from SB1 and SB2 are weighted as follows:

$$S_W(i,j) = A(j) \cdot S(i,j)$$

where:	S	input I/Q sample
	S_W	weighted I/Q sample
	$i = 1,2$	sub-band index
	$j = 0, \ldots, 511$	sample index
	A	weights as shown in Table 2.2.1 The weights are real and symmetrical.

1.2.3 Outputs

- Two sequences of 512 weighted I/Q samples associated with SB1 and SB2 respectively:

  $$\{S_W(i,j) \mid i = 1, 2; j = 0, \ldots, 511\}$$

TABLE 1.2.2.1 - KAISER AMPLITUDE WEIGHTS

FOR F-15 HPRF RANGE-WHILE-SEARCH

$N_p = 512$

SAMPLE NUMBER n	AMPLITUDE WEIGHTS A(n)
0	.233398
1	.236816
2	.240723
3	.244141
4	.248047
5	.251953
6	.255371
7	.259277
8	.263184
9	.267090
10	.270508
11	.274414
12	.278320
13	.282227
14	.286133
15	.290039
16	.293945
17	.297852
18	.301758
19	.305664
20	.309570
21	.313477
22	.317383
23	.321289
24	.325195
25	.329102
26	.333008
27	.337402
28	.341309
29	.345215
30	.349121

SAMPLE NUMBER n	AMPLITUDE WEIGHTS A(n)
31	.353027
32	.357422
33	.361328
34	.365234
35	.369629
36	.373535
37	.377441
38	.381836
39	.385742
40	.389648
41	.394043
42	.397949
43	.402344
44	.406250
45	.410645
46	.414551
47	.418457
48	.422852
49	.426758
50	.431152
51	.435059
52	.439453
53	.443359
54	.447754
55	.451660
56	.456055
57	.459961
58	.464355
59	.468262
60	.472656
61	.476563

TABLE 1.2.2.1 - KAISER AMPLITUDE WEIGHTS
FOR F-15 HPRF RANGE-WHILE-SEARCH
$N_p = 512$

SAMPLE NUMBER n	AMPLITUDE WEIGHTS A(n)
62	.480957
63	.485352
64	.489258
65	.493652
66	.497559
67	.501953
68	.505859
69	.510254
70	.514160
71	.518555
72	.522461
73	.526855
74	.530762
75	.535156
76	.539063
77	.543457
78	.547363
79	.551758
80	.555664
81	.560059
82	.563965
83	.568359
84	.572266
85	.576172
86	.580566
87	.584473
88	.588867
89	.592773
90	.596680
91	.601074
92	.604980

SAMPLE NUMBER n	AMPLITUDE WEIGHTS A(n)
93	.608887
94	.613281
95	.617188
96	.621094
97	.625000
98	.629395
99	.633301
100	.637207
101	.641113
102	.645020
103	.648926
104	.653320
105	.657227
106	.661133
107	.665039
108	.668945
109	.672852
110	.676758
111	.680664
112	.684570
113	.687988
114	.691895
115	.695801
116	.699707
117	.703613
118	.707031
119	.710938
120	.714844
121	.718750
122	.722168
123	.726074

TABLE 1.2.2.1 - KAISER AMPLITUDE WEIGHTS
FOR F-15 RANGE-WHILE-SEARCH
$N_p = 512$

SAMPLE NUMBER n	AMPLITUDE WEIGHTS A(n)
124	.729492
125	.733398
126	.736816
127	.740723
128	.744141
129	.748047
130	.751465
131	.754883
132	.758789
133	.762207
134	.765625
135	.769043
136	.772461
137	.776367
138	.779785
139	.783203
140	.786621
141	.790039
142	.792969
143	.796387
144	.799805
145	.803223
146	.806641
147	.809570
148	.812988
149	.816406
150	.819336
151	.822754
152	.825684
153	.829102
154	.832031

SAMPLE NUMBER n	AMPLITUDE WEIGHTS A(n)
155	.834961
156	.838379
157	.841309
158	.844238
159	.847168
160	.850098
161	.853027
162	.855957
163	.858887
164	.861816
165	.864746
166	.867676
167	.870605
168	.873047
169	.875977
170	.878906
171	.881348
172	.884277
173	.886719
174	.889160
175	.892090
176	.894531
177	.896973
178	.899414
179	.901855
180	.904297
181	.906738
182	.909180
183	.911621
184	.914063
185	.916504

TABLE 1.2.2.1 - KAISER AMPLITUDE WEIGHTS
FOR F-15 HPRF RANGE-WHILE-SEARCH
$N_p = 512$

SAMPLE NUMBER n	AMPLITUDE WEIGHTS A(n)
186	.918457
187	.920898
188	.923340
189	.925293
190	.927734
191	.929688
192	.931641
193	.934082
194	.936035
195	.937988
196	.939941
197	.941895
198	.943848
199	.945801
200	.947754
201	.949219
202	.951172
203	.953125
204	.954590
205	.956543
206	.958008
207	.959961
208	.961426
209	.962891
210	.964355
211	.966309
212	.967773
213	.969238
214	.970215
215	.971680
216	.973145

SAMPLE NUMBER n	AMPLITUDE WEIGHTS A(n)
217	.974609
218	.975586
219	.977051
220	.978516
221	.979492
222	.980469
223	.981934
224	.982910
225	.983887
226	.984863
227	.985840
228	.986816
229	.987793
230	.988770
231	.989746
232	.990234
233	.991211
234	.992188
235	.992676
236	.993652
237	.994141
238	.994629
239	.995117
240	.995605
241	.996582
242	.997070
243	.997070
244	.997559
245	.998047
246	.998535
247	.998535

TABLE 1.2.2.1 - KAISER AMPLITUDE WEIGHTS
FOR F-15 HPRF RANGE-WHILE-SEARCH
$N_p = 512$

SAMPLE NUMBER n	AMPLITUDE WEIGHTS A(n)
248	.999023
249	.999512
250	.999512
251	.999512
252	.999512
253	.999512
254	.999512
255	.999512

1.3 Clutter Free Region Frequency Spectrum Construction

Target detection and range rate determination all depend on the frequency content of the radar return signal. The signals of interest fall in the clutter-free doppler region. To construct the discrete frequency spectrum of this region, each of the two weighted sample sequences from 1.2.3 are transformed by a Fast Fourier Transform algorithm. The results are two discrete frequency spectra.

$$\{F(i,k) \mid i = 1, 2; k = 0 \ldots, 511\}$$

Only the 1st 256 elements of $\{F(1,k)\}$ and the last 256 elements of $\{F(2,k)\}$ have meaningful data. These elements are combined to form the frequency spectrum of the clutter free region.

1.3.1 Inputs

- Two sequences of 512 weighted I/Q samples corresponding to SB1 and SB2 of the radar return signal:

  $$\{S_W(i,j) \mid i = 1, 2; j = 0, \ldots, 511\}$$

- Phase rotation constants:

  $$\{W^m \mid m = 0, \ldots, 511\}$$

  where:

  $$W = \exp(-j2\pi/512)$$

1.3.2 Processing

The Discrete Fourier Transform (DFT) of each input sequence is given by:

$$F(i,k) = \sum_{n=0}^{511} S_W(i,n) \cdot W^{nk}$$

where:	i	sub-band index
	k	filter number
	n	sample number
	F	filter value; a complex number

Because of the symmetry of W^m in the complex plane, only the first 256 phase constants need be stored in the PSP. The remaining 256 constants are the complex conjugates of the stored constants. The Fast Fourier Transform (FFT) is an algorithm that executes the DFT mentioned above. The design of the FFT is left to the programmer. The frequency spectrum of the clear region is given by:

$$F_{cl}(k) = \begin{cases} F(1,k) & k = 0,\ 255 \\ F(2,k) & k = 256,\ 511 \end{cases}$$

1.3.3 Outputs

- The discrete frequency spectrum of the clear region:

$$\{F_{cl}(k) \mid k = 0, \ldots, 511\}$$

1.4 Power Detector

Power Detector's function is to compute the signal power at each discrete frequency of the spectrum given by section 1.3.3.

1.4.1 Input

- The discrete frequency spectrum of the clear region:

$$\{F_{cl}(k) \mid k = 0, \ldots, 511\}$$

1.4.2 Processing

The signal power at each discrete frequency is given by:

$$P(k) = |F_{cl}(k)|^2$$

1.4.3 Output

- The power spectrum of the clear region:

$$\{P(k) \mid k = 0, \ldots, 511\}$$

1.5 Noise Estimate

This subfunction determines a background noise power estimate for each doppler cell in the processed region. The noise estimates are used in the Detection Thresholding function.

1.5.1 Inputs

Inputs to the Noise Estimate subfunction are:

- $P(k)$ Power array of all doppler clear filters
- ϕ Current FM phase

1.5.2 Processing

The noise estimate is computed as described here. A "16-3-16" sliding window filtered average and an overall "long ensemble" average of ΔN doppler cells forms two estimates, the largest of which is output as the noise estimate.

Ensemble Averages are computed for each doppler cell by comparing the average power in two groups of 16 contiguous filters positioned symmetrically about the cell under consideration. Neither group shall contain the filters directly adjacent to the cell under consideration. The largest of these two groups averages is taken as the Ensemble Average (EA). The Ensemble Average noise estimate is determined as expressed mathmetically here.

$$EA(k) = (1/16)\ \mathrm{MAX}\left[\sum_{j=k-17}^{k-2} P(j),\ \sum_{j=k+2}^{k+17} P(j)\right]$$

where: k is the doppler filter index, EA(k) is the estimate for the k th doppler filter, and P(j) is the power output of the j th doppler filter.

NOTE: The above equation is calculated for the index "k" (the doppler filters) over all 512 filters.

A least value for the noise estimate shall be computed as the Long Ensemble Average (LEA) as detailed here.

$$LEA = \left\{ \frac{1}{\Delta N} \left[\sum_{j=512-\Delta N}^{511} P(j) \right] \right.$$

ΔN is 128.

Then the noise estimate for each cell shall be the larger.

$$N(k) = MAX \left[EA(k), \; LEA \right]$$

1.5.3 Outputs

Outputs from the Noise Estimate subfunction are:

- N(K) Ensemble Average noise estimates for all doppler clear filters.

1.6 Hit/Miss Logic

The Hit/Miss logic identifies those cells in the 512 filters that have valid target information. The identification depends on the noise estimate of the cells and a threshold multiplier. The latter is computed in the RDP and is based on a constant false alarm probability. If the ratio of the filter signal power to its noise power estimate exceeds the square of the threshold multiplier, that cell is declared a hit, otherwise it is declared a miss.

1.6.1 Input

- Signal power of the filter cells:

  $\{P(j) \mid j = 0, \ldots, 511\}$

- Noise estimates of the filter cells:

  $\{N(j) \mid j = 0, \ldots, 511\}$

- Signal detection threshold multipliers (from RDP):

  K_{SUB1} (for detection in the first 256 cells),

  K_{SUB2} (for detection in the last 256 cells).

1.6.2 Processing

The Hit/Miss Logic in this report is based on the signal power of the filters. This differs from the Hit/Miss Logic in the MPRF Search & Acquisition mode where the logic is based on the magnitude of the filter signals. To accomodate this difference the threshold multipliers used in this report are:

$$KP_{SUB1} = K^2_{SUB1}$$
$$KP_{SUB2} = K^2_{SUB2}$$

For the processing, an array $\{H(j) \mid j = 0, \ldots, 511\}$ is set aside to hold the Hit/Miss information. The hit counts in subband 1 and subband 2 are placed in COUNT 1 and COUNT 2 respectively. The following steps describe the Hit/Miss Logic:

a) for j = 0 to 255

if $(P(j) \geq KP_{SUB1} \times N(j)$ then $H(j) = 1$; a hit

else $H(j) = 0$; a miss

b) $$\text{COUNT1} = \sum_{j=0}^{255} H(j)$$

c) for j = 256 to 511

if $(P(j) \geq KP_{SUB2} \times N(j)$ then $H(j) = 1$; a hit

else $H(j) = 0$; a miss

d) $$\text{COUNT2} = \sum_{k=256}^{511} H(j)$$

1.6.3 Outputs

- The hit counts in subband 1 and subband 2: COUNT 1, COUNT 2 to RDP.
- Hit/Miss array: $\{H(j) \mid j = 0, \ldots, 511\}$

1.7 Hit Cluster Reduction

A strong radar return signal from a single or multiple target(s) can cause the signal levels of a cluster of filters to exceed a given CFAR threshold. This forces a string of ones to be entered in the CFAR Hit-array (H-array). Hit Cluster Reduction is the process of shrinking these clusters in the H-array. The reduction rules are given in section 1.7.2.

After the reduction process a set of "coarse" hit filter numbers is defined as follows:

$$\{J_c = k \mid H(k) = 1\}$$

The set of coarse hit filter numbers is reported to the Range Resolver Logic.

1.7.1 Input

- CFAR hit data: $\{H(j) \mid j = 0, \ldots, 511\}$
- Filter Signal powers: $\{P(j) \mid j = 0, \ldots, 511\}$

1.7.2 Processing

The H-array is scanned to identify hit clusters. Three reduction rules are imposed on the cluster upon identification and these are:

	BEFORE			AFTER		
RULES	H(j-2)	H(j-1)	H(j)	H(j-2)	H(j-1)	H(j)
R1	0	1	0	0	1	0
R2	1	1	0	0	1	0
R3	1	1	1	0	1	0

Where H(j) is the current element under examination.

The Hit Cluster Reduction (HCR) rules are implemented in the following algorithm:

Step 0: Set $j = 0$.

Step 1: If $(H(j) = 1)$ then do Step 2, else increment j and repeat Step 1 until $j = 511$.

Step 2: Increment j ; end HCR if $j = 511$.

Step 3: If $(H(j) = 1)$ then do Step 4, else increment j and go to Step 1.

Step 4: Increment j ; if $j = 511$ then apply R2 and end HCR.

Step 5: If $(H(j) = 1)$ then apply R3, else apply R2.

Step 6: Go to Step 1.

The following example illustrates a typical reduction process.

Example:

Let $H(k) = 0$ for $24 < k$ and $k < 15$

k	15	16	17	18	19	20	21	22	23	24	25
H(k) Before	1	1	1	1	1	0	1	1	1	1	0
Rules	R3			R2			R3			R1	
H(k) After	0	1	0	0	1	0	0	1	0	1	0

Then $J_c = \{16, 19, 22, 24\}$

1.7.3 Output

- The set of coarse hit filter numbers.

1.8 Range Resolver Logic

The dwell time (time-on-target) is divided into three phases, (C,B,A). In phases B and A, the carrier frequency is linearly modulated. The modulation in B is twice as fast as that in A. In the presence of a target the doppler shift of the return signal in the phase C carries the target closing velocity information while the doppler shift in phases A and B carry the target range information. A linear relationship between the doppler shifts in the three phases allows individual target identification in a multiple target search environment.

The RDP can request two modes of operation, Search Mode or Acquisition I Mode. In the Search Mode, the Range Resolver Logic computes the ranges of all the targets that satisfy condition C.1 given in section 1.8.2. In the RWS Acquisition I Mode the logic first executes the Search Mode. Then it identifies a target whose range falls within an RDP specified range window. This target is passed on to the RDP.

1.8.1 Input

- The coarse hit filter number pairs for the three phases (Output of section 1.7):

1.8.1.1 HPRF RWS Acquisition I Mode

- Mode Control Word for RDP (PSP Word 1).
- Coarse Range B from RDP (PSP Word 2).

1.8.2 Processing

The unit of measure for the doppler shift is given in terms of a filter index (k).

Let the three most-recent input sets be defined as F_A, F_B, & F_C. These sets may contain hits at locations defined by the indices k_A, k_B, or k_C, where $k_A \in F_A$, $k_B \in F_B$, $k_C \in F_C$. Then a target is identified if the following condition holds:

$$C.1: \left| k_A - \mathrm{Int}\left[(k_C + k_B)/2 + 1/2 \right] \right| \leq 1$$

$$k_B \leq k_A \leq k_C, \text{ and } (k_C - k_B) \leq 48$$

A coarse range is computed for each target which satisfies C.1. The coarse range r_C is defined below.

$$r_C = (k_C - k_B)$$

where

r_C is the coarse range number

The range is given in terms of an integer multiple of $R_R \approx 2$ nautical miles. (This range resolution follows from the parameters of the FM ranging scheme.)

There can be more than one target or target JEM returns in the same range interval, each with a different closing velocity. Thus, each target is identified by its range and doppler shift pair (r, k_C).

1.8.2.1 Search Mode

The logic identifies all the targets and computes their ranges.

1.8.2.2 HPRF Acquisition I Mode

The logic selects a single target from the entire set of targets that have been identified by the condition C.1 above. This target must meet two additional tests in the following order:

Test 1: The target range must be greater than or equal to the RDP command "Coarse Range B".

Test 2: The target must have the minimum range of all targets passing test #1.

(Should two targets "tie" for minimum range, the target with highest doppler index (k_C) is selected.)

The target that is selected is then reported to the RDP in terms of its range-doppler coordinates (r, k_C).

1.8.3 Output

1.8.3.1 Search Mode

- The set of all target ranges (coarse range numbers) and paired doppler filter number (unambiguous velocity):

  $$\{r(i)\ k_C(k) \mid i = \text{target index}\},$$

  This set is sent to the range centroiding function, Section 1.9.

1.8.3.2 HPRF Acquisition I Mode

- (Same as above plus):
- The target range-doppler coordinates that satisfies Test 1 and Test 2 in section 1.8.2.2.

1.9 Range Centroiding

The Centroiding function processes the range doppler pairs from the Range Resolver function to eliminate the multiple range resolutions from a target's JEM returns. The range, doppler pairs are centroided in range only. The doppler filter associated with the centroided range is reported out of the centroiding function, i.e. no attempt is made to pick out the skin return from the JEM returns.

1.9.1 Inputs

- The set of all target ranges (coarse range numbers) and paired doppler filter number (unambiguous velocity):

$$\{r(i),\ k_C(i) \mid i = \text{target index}\}$$

1.9.2 Processing

For any coarse range number with more than one associated doppler filter number, the set of (coarse range number, doppler filter number) pairs where the coarse range numbers are equal are reduced to a subset of one (coarse range number, doppler filter number) pair. The rule(s) by which the doppler shift data is reduced is left to detailed program design consideration.

The coarse range numbers are arranged in order of increasing value then scanned to identify adjacent hits. [Adjacent hits are two target ranges whose coarse range numbers differ by one.] Three centroiding rules are applied to adjacent hits upon identification. These rules are as described in Figure 1.9.1.

	BEFORE			AFTER		
RULES	C.R.#-2	C.R.#-1	C.R.#	C.R.#-2	C.R.#-1	C.R.#
R1	0	1	0	0	1	0
R2	1	1	0	0	1	0
R3	1	1	1	0	1	0

Figure 1.9.1 - RWS RANGE CENTROIDING RULES

1.9.3 Outputs

- The set of velocity reduced, range centroided (Coarse range number, doppler filter number) pairs to the Azimuth Centroiding function, section 1.10.

1.10 Azimuth Centroiding

The technique of Azimuth Centroiding of radar target samples is designed to improve the radar azimuth resolution so that closely spaced radar targets can be resolved. At the same time, this technique prevents the initiation of false targets from any strong target which can yield radar returns in several adjacent range azimuth elements. Azimuth Centroiding replaces the currently used method of inhibiting all adjacent azimuth hits from a strong target except the initial hit.

1.10.1 Inputs

- Centroided unambiguous ranges from the Range Centroider
- Antenna "Video Azimuth" from RDP
- Azimuth Centroider Inhibit flag from RDP

1.10.2 Processing

The initial phase of the Azimuth Centroiding function is the tagging of each target range (coarse range number) with an azimuth value from the RDP. If the Az Centroider Inhibit flag is set (i.e. logical "1"), the azimuth centroiding procedure is NOT performed. The azimuth value tagged to the target and the coarse range number of the target are output. If the Az Centroider Inhibit flag is reset (i.e. logical "0"), the azimuth centroider procedure is performed as described in the following paragraphs.

Centroiding is performed when a target generates two or more sucessive hits in the same range cell or are range cell $\pm K_1$. [K_1 is the half width of the data collection gate shown in Figure 1.10.1]. The multiple hits from the single target would be detected over successive Azimuth Centroiding cycles. The one range and azimuth computed by this function for the multiple hits is an average of the targets input coarse range numbers and tagged azimuth positions over a number of RWS phases. The azimuth centroiding is accomplished by establishing azimuth centroider "tracks" for each target. Associated with each track are:

R_0 = Range bin of the track initiator

R_C = Current range bin of the track

AZ_0 = Azimuth of the track initiator

AZ_C = Current azimuth

N_H = Hit counter

N_M = Miss counter

A schematic diagram showing possible radar samples from a strong target or multiple targets is illustrated in Figure 1.10.1. These samples straddle several range bins and azimuth elements.

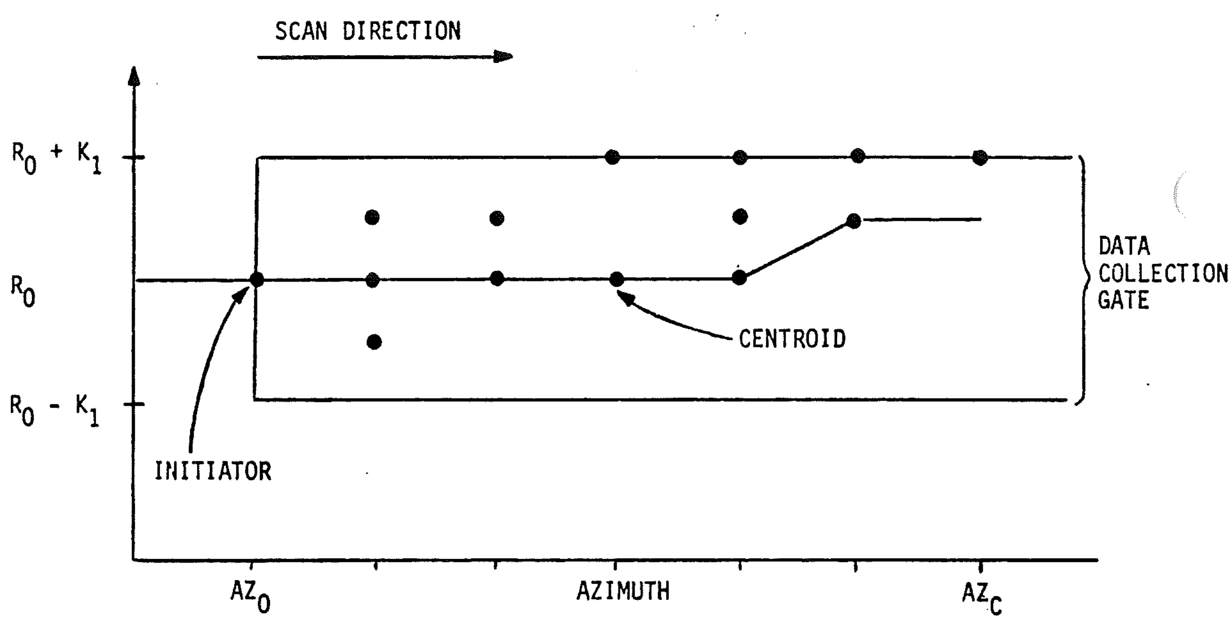


Figure 1.10.1 - AZIMUTH CENTROIDING

For Azimuth Centroiding, the target samples along each azimuth element within $R_C + K_1$ and $R_C - K_1$ range bins are candidates for correlation with a track, where K_1 represents the half-width of the data collection gate. Track correlation, initiation, and termination are performed as follows.

1.10.2.1 Track Correlation

1) For each track, a search is made for hit(s) within the data collection gate ($\pm K_1$ range bins about the current target range bin, R_C).

2) Only one hit is allowed to correlate with a given track. If more than one hit is found in the data collection gate, the hit in range bin R_C is chosen as the correlated hit; if such a hit does not exist, the hit with the closest range is chosen as the correlated hit.

3) If a correlated hit is found, the track range R_C is set equal to the range bin of the correlated hit, the track azimuth AZ_C is set to the current video antenna azimuth, and the track miss counter N_M is set to zero. The correlated hit is deleted from the hit list.

4) If no correlated hit is found, the track miss counter N_M is incremented by one.

5) In all cases, the track hit counter N_H is incremented by one to indicate the total number of azimuth elements since the initiator.

1.10.2.2 Track Initiation

1) Any uncorrelated hits remaining in the hit list after track correlation is performed are used to initiate new tracks.

2) The track parameters for each new track are initialized as follows:

$R_0 = R_C$ = range bin of uncorrelated hit

AZ_0 = current video antenna azimuth

$N_H = 1$

$N_M = 0$

1.10.2.3 Track Termination

1) If the miss counter for a track equals N_S misses, the track is terminated.

2) If the hit counter for a track equals N_{Max}, the track is terminated.

3) If $|R_0 - R_C|$ for a track exceeds R_{Max}, the track is terminated.

4) A centroided target position is computed for each terminated track and sent to the Display Processing function.

   a) The centroided range of the target is the average of the range bin of the initiator and the range bin of the last hit in the track:

   $$R = IPO[(R_0 + R_C)/2 + 0.5]$$

   b) The centroided azimuth of the target is the average of the azimuth of the initiator and the azimuth of the last hit in the track:

   $$Az = IPO[(Az_0 + Az_C)/2 + 0.5]$$

1.10.2.4 Azimuth Centroider Parameters Values

Parameter values for the HPRF Range-While-Search Mode are as follows:

K_1 = 1 range bin

N_S = 3 misses

N_{Max} = 10 hits

R_{Max} = 5 range bins

1.10.3 Outputs

- Coarse range number and azimuth of centroided targets to Display Processing.

1.11 Digital Scan Converter Function

The Digital Scan Converter (DSC) in the Programmable Signal Processor (PSP) performs interface functions between the radar, the IFF Reply Evaluator (IRE) and the Vertical Situation Display (VSD) for the target display. It performs the function of data formatting and display symbology terms of position, duration/intensity and symbol generation. The DSC also correlates radar targets with the target designator (corral) and with IFF targets. In multi-target situations, the DSC determines the sequencing of multi-target display and target disposition.

The DSC software specification for HPRF search mode is the same as that in the MPRF search mode. The same software design is used for both modes.

1.11.1 Inputs

- IFF data from IRE.
- Mode X Ident Command from EWWS.
- Acquisition Symbol position (in DSC Word 1) from RDP.
- Antenna Elevation caret position and Antenna Azimuth caret position (in DSC Word 2) from RDP.
- Display mode parameters and Display aging parameters (in DSC Word 3) from RDP.
- BIT Window data (in DSC Word 4 and 5) from RDP.
- Azimuth Heading compensation (in PSP Word 5 Bits 0-3) from RDP.

If the Azimuth Centroider Inhibit flag is 0, then for each terminated azimuth track in the Azimuth Centroider:

- Centroided Azimuth
- Centroided unambiguous range
- Hit Count

If the Azimuth centroider Inhibit flag is 1, then for each valid hit:

- Azimuth tagged to target.
- Unambiguous range of target.

1.11.2 Processing

1.11.2.1 Overview

This section contains an overview and three subsections which describe the key data processing functions of the Digital Scan Converter. The overview covers the general approach of data processing for input data from RDP and PSP (see Section 1.11.1). The three key processing functions, target correlation, aging/erasing and heading compensation are discussed in detail in three separate subsections. Data processing logic as well as inputs and outputs is specified in each subsection. The final outputs of the DSC and VSD via Display Interface Unit (DIU) are listed in section 1.11.3 at the end of this function specification section.

The data processing functions of the Digital Scan Converter are shown in the following functional block diagram, Figure 1.11.2. The Digital Scan Converter (DSC) receives its control words, and cursor position from the RDP, target hits from Azimuth Centroid Processor section 1.10, and the IFF data from the IRE Word Buffer. First, it reformats the 24-bit data words into 48 bit DSC memory words (Figure 1.11.3A) to be stored in the PSP Bulk Memory for data processing and target correlation. If a manual acquisition is requested from the Radar Data Processor (RDP 081 Unit), the DSC shall search its target memory for targets which lie within the correlation azimuth and range window of the cursor as positioned by the pilot. If a target is found, the elevation bar of the antenna and the PRF are sent to the RDP so that the radar parameters can be set for target acquisition. For radar target and IFF target correlation, the DSC either performs or bypasses the target/IFF correlation as commanded by the RDP. The output display data consisting of 128 48-bit target data words and six other target words are sent to the VSD via the Display Interface Unit (DIU).

For target and display data storage, the DSC shall maintain three separate memories. A small target table (32 word x 48 bits) is required to store the new target data as sent-in by the Azimuth Centroiding Processor (Section 1.10). These new targets will then merge into a large 192 word x 48 bits Master Target Memory (TM1) in the PSP Bulk Memory for target correlation and data processing. This Master Target Memory TM1 operates in a "first-in first-out" (FIFO) manner. When there are more targets than the memory storage, the oldest targets in TM1 are deleted. The FIFO operation can be achieved by using a cyclic target address table for target deletion without the actual shifting of all target data in the TM1 memory. The targets in the TM1 memory are used by the Correlation Logic.

Those targets which lie within the current range and azimuth bound are selected by Vertical Situation Display (VSD). This target data then is rescaled for 11 bits azimuth data (TM1 data format) to 9 bits azimuth data (TM2 data format) and 12 bits range data to 9 bits range data to fit the VSD data word format. The rescaled target table consisting of at most 128 target and 6 DSC target words (Figure 1.11.3) is transferred to VSD Display Data Memory (TM2). This data is sent from DSC to DIU for VSD display (Figure 1.11.4).

The three important functions in the DSC (target correlation, aging/erasing and heading compensation) are discussed in detail in Sections 1.11.2.2 to 1.11.2.4.

1.11.2.2 <u>Target Correlation</u>

The DSC Correlation Logic must perform two basic types of target correlations in both azimuth (X) and range (Y). The first type is correlation of cursor with radar targets. The second type is the correlation of new radar targets with current IFF targets. Target correlation logic and its window sizes are shown in Figure 1.11.5 and Table 1.11.1.

1.11.2.2.1 <u>Inputs</u>

- Target Correlation Mode (in PSP Word 1) from RDP.
- Acquisition Symbol position (in DSC Word 1) from RDP.
- IFF target data from IRE (Figure 1.11.1).
- IFF target correlation (in DSC Word 3) from RDP.

TABLE 1.11.1 - CORRELATION WINDOW

a.

AZIMUTH CORRELATION WINDOW	
MODE	X WINDOW
Cursor Correlation	$\pm 4^{\circ}$ or ± 16 Azimuth bins
IFF Narrow Target Correlation (Wide Target bit = 0)*	$\pm 4^{\circ}$ or ± 16 Azimuth bins
IFF Wide Target Correlation (Wide Target bit = 1)*	$\pm 8^{\circ}$ or ± 32 Azimuth bins

* IRE Reply Word Bit 11

b.

RANGE CORRELATION WINDOW		
MODE	Y WINDOW	RANGE
MPRF & RWS Acq	± 12 Bins	$\pm$ Selected range $\div$ 40 or 0.25 nm
LRS IFF (Short Range Detect bit = 0)**	± 6 Bins	± 2 nm
SRS IFF (Short Range Detect bit = 0)**	± 24 Bins	$\pm .5$ nm

** PSP Word 1 Bit 9

TABLE 1.11.2 - IFF CORRECT CODE/CORRELATION STATUS LOGIC

CORRECT CODE = 1 (from RDP) OR CORRELATE = 0 (from IRE)		CORRECT CODE = 0 (from RDP) OR CORRELATE = 1 (from IRE)	
IRE REPLY CORRELATES WITH* ONE OR MORE RADAR TARGETS	IRE REPLY FAILS TO CORRELATE WITH ANY RADAR TARGETS	IRE REPLY CORRELATES WITH* ONE OR MORE RADAR TARGETS	IRE REPLY FAILS TO CORRELATE WITH ANY RADAR TARGETS
TAG RADAR TARGET(S) WITH IRE REPLY IFF CODE	INSERT IRE REPLY X, Y POSITION IN MEMORY WITH IFF CODE AND SET NON-CORRELATION BIT	TAG RADAR TARGET(S) WITH IRE REPLY IFF CODE	DROP THIS IRE REPLY

* THE RADAR TARGET'S X,Y POSITION FALLS WITHIN THE IRE REPLY'S CORRELATION WINDOW.

IRE REPLY IFF STATUS	IFF CODE
NO DATA (NULL)	0 0
HIGH CONFIDENCE	0 1
LOW CONFIDENCE	1 0
MODE X	1 1

IFF REPLY WORD FROM PSP TO DSC

0	1 2	11	12	13	14	23
INVALID	IFF CODE MSB LSB	IFF TARGET RANGE MSB LSB	WIDE TARGET	CORRELATE	OVERLOAD	IFF TARGET BEARING (AZIMUTH) MSB LSB

Figure 1.11.1

IFF REPLY WORD FROM IRE VIA PSP

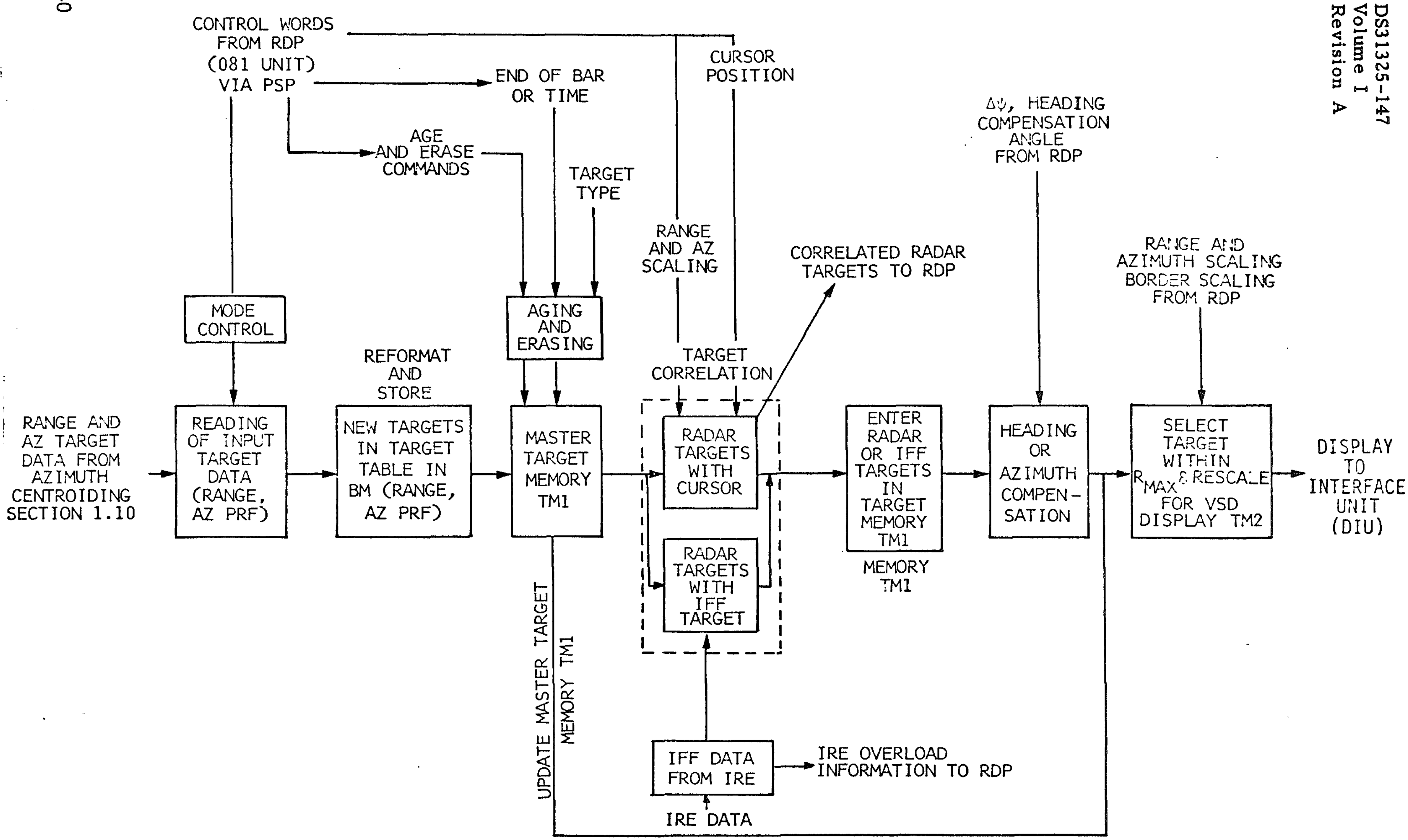


FIGURE 1.11.2 - DIGITAL SCAN CONVERT FUNCTION DIAGRAM HPRF RWS SEARCH

		0–3	4–5	6–16	17–28	29–31	32–33	34	35	36	37–44	45–47
1 to 128	TARGET WORD	4 BITS WORD CODE	IFF CODE	11 BITS AZIMUTH POSITION (X)	12 BITS RANGE POSITION (Y)	3 BITS EL	PRF	NON CORRELATED IFF TARGET	TARGET ERASED	SYNTHETIC TARGET	8 BITS SPARE	3 BITS INT

A. Target Word Format

		0–3	4–5	6–8	9–14	15–23	24–44	45–47
129	RNG/VEL SCALE	0 1 0 0	0 0	RNG/ VEL SCALE	0 0 0 0 0 0	0 0 0 0 0 0 0 0 0	SPARES	1 1 1
130	CURSOR POSITION	0 1 0 1	0 0	X POSITION		Y POSITION	SPARES	1 1 1
131	ANT. AZ. POSITION	0 1 0 1	0 0	X POSITION		1 0 0 0 1 0 1 1 0	SPARES	1 1 1
132	ANT. EL. POSITION	0 1 0 1	0 0	1 0 0 0 1 0 1 1 0		Y POSITION	SPARES	1 1 1
133	BIT WORD #1	0 1 0 1 or 0 0 0 0	0 0	1st CHARACTER	2nd CHARACTER	3rd CHARACTER	SPARES	1 1 1
134	BIT WORD #2	0 1 0 1 or 0 0 0 0	0 0	4th CHARACTER	5th CHARACTER	6th CHARACTER	SPARES	1 1 1

B. Display Symbol Word Formats

Figure 1.11.3 - DSC BULK MEMORY WORDS

WORD	NAME	BIT POSITION 0 1 2 3	4 5	6 7 8 9 10 11 12 13 14	15 16 17 18 19 20 21 22 23	24 - 44	45 46 47
1	MPRF TGT/IFF or	0 0 0 1	IFF CODE	X POSITION	Y POSITION	NOT USED	INTENS.
	HPRF TGT/IFF or	0 0 1 1	IFF CODE	X POSITION	Y POSITION		INTENS.
	UNCORRELATED IFF or	0 0 1 0	IFF CODE	X POSITION	Y POSITION		1 1 1
128	BLANK	0 0 0 0	THESE BIT POSITIONS MAY BE RANDOMLY SET.				0 0 0
129	RNG/VEL SCALE	0 1 0 0	0 0	RNG/VEL SCALE 0 0 0 0 0 0	0 0 0 0 0 0 0 0 0	NOT USED	1 1 1
130	CURSOR POSITION	0 1 0 1	0 0	X POSITION	Y POSITION		1 1 1
131	ANT. AZ. POSITION	0 1 0 1	0 0	X POSITION	1 0 0 0 1 0 1 1 0		1 1 1
132	ANT. EL. POSITION	0 1 0 1	0 0	1 0 0 0 1 0 1 1 0	Y POSITION		1 1 1
133	BIT WORD #1	0 1 0 1 or 0 0 0 0	0 0	1st CHARACTER	2nd CHARACTER 3rd CHARACTER		1 1 1
134	BIT WORD #2	0 1 0 1 or 0 0 0 0	0 0	4th CHARACTER	5th CHARACTER 6th CHARACTER		1 1 1

Figure 1.11.4 - DSC TO VSD DIGITAL DATA (HPRF SEARCH)

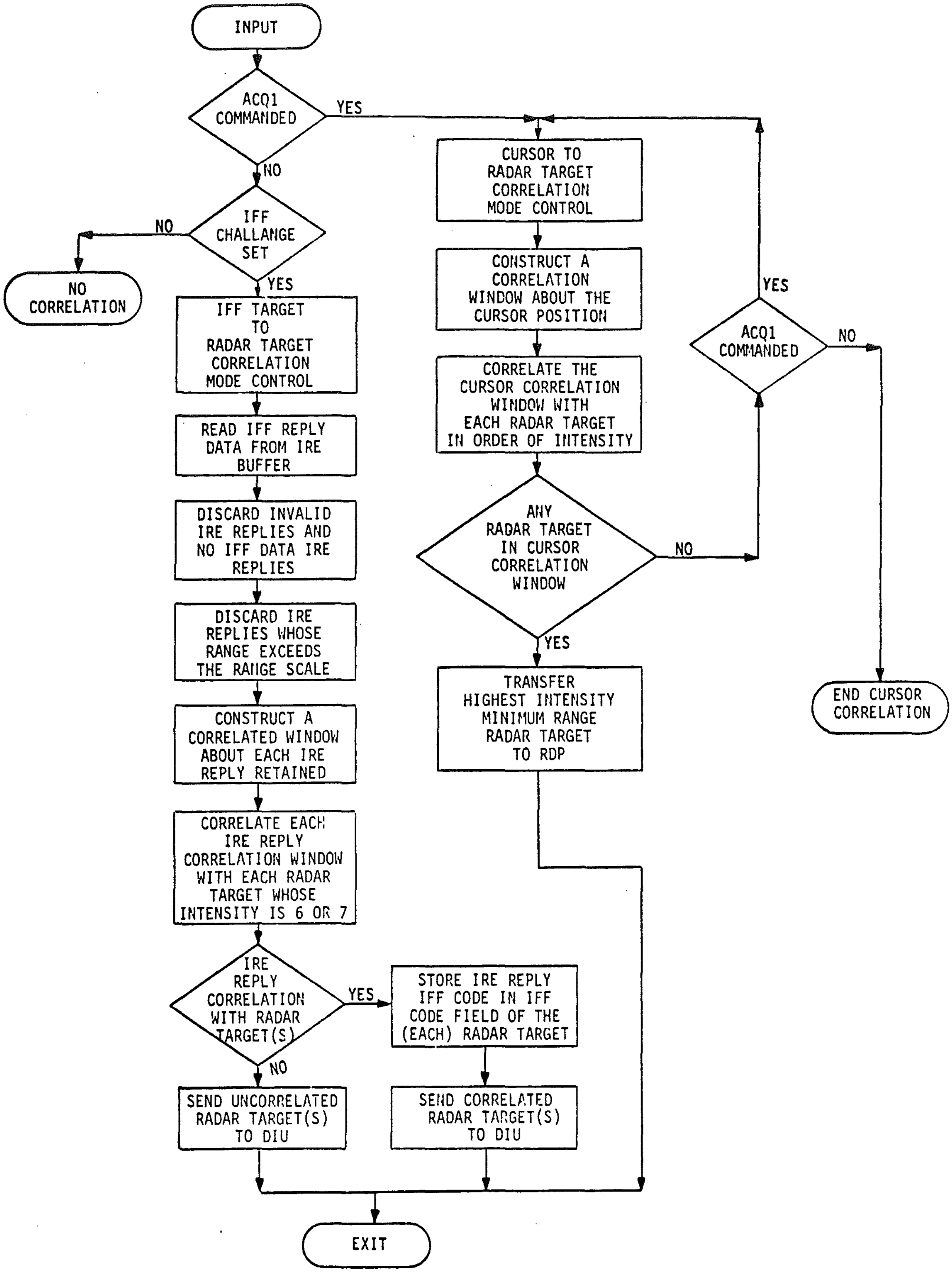
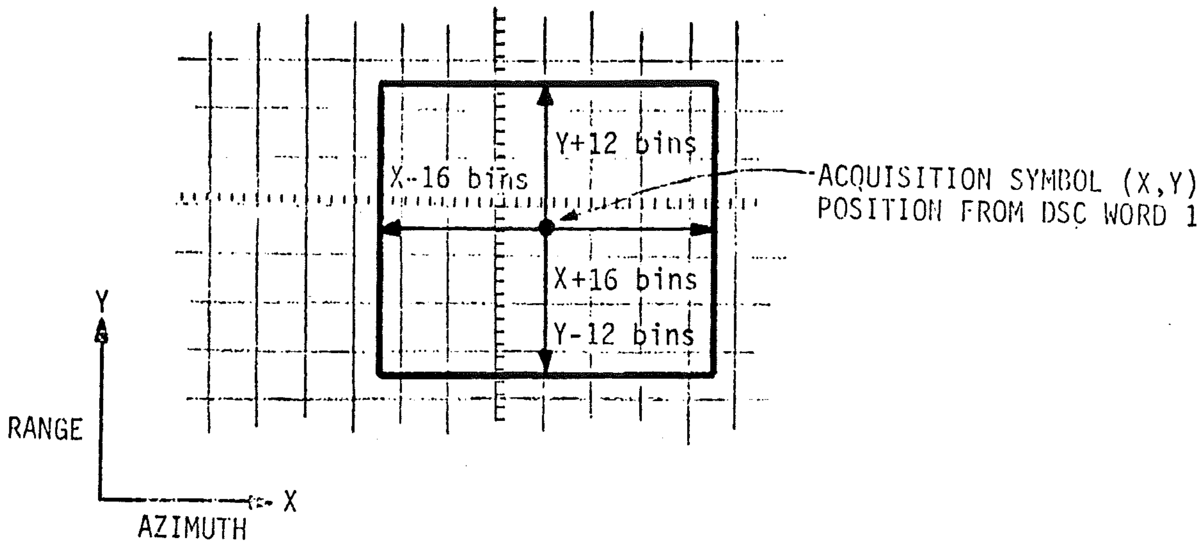


Figure 1.11.5 - CORRELATION LOGIC

1.11.2.2.2 Processing

Cursor Correlation Logic

When cursor correlation is commanded, from the RDP (via PSP Word 1, Submode Code Signal), the DSC must search for a correlation with all targets in the TM1 Memory in the order of target intensity. (Figure 1.11.3). First the correlation window (box) is constructed from the Acquisition Symbol X (azimuth) and Y (range) positions as follows:



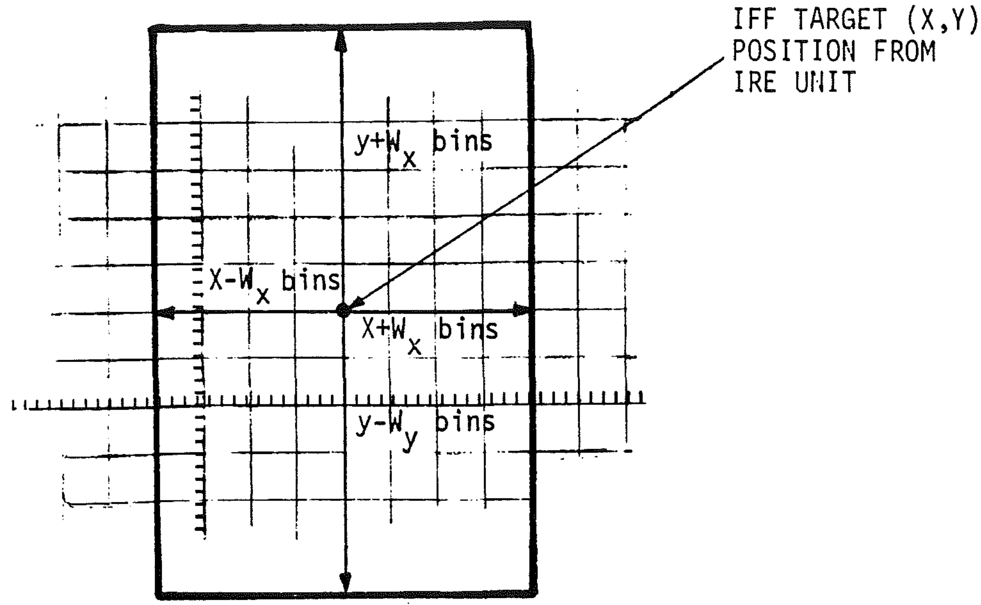
Targets with an intensity of seven are not correlated. Therefore, on the first memory readout cycle, targets with an intensity of six are examined to determine if any fall within the correlation window. On the second memory readout cycle, correlation is performed on targets with an intensity of five. On the third memory readout cycle, correlation is performed on intensity four targets and so on down to intensity zero. When a cursor correlation is made, the X (azimuth), Y (range) position, intensity, El Bar number, PRF and Synthetic Target Status of the correlated target is stored. The correlated target with the highest intensity AND minimum range is selected and sent to the RDP via IDA. If no correlation has been made after zero intensity targets are searched, the DSC Tag (IDA Word 1 Bit 10) is set to zero and the (intensity) counter starts over at six.

IFF Target Correlation Logic

If cursor correlation has NOT been commanded and the IFF challange bit (DSC Word 3 Bit 23) is set, the DSC must do IFF Target correlation for both CORRECT CODE and NON-CORRECT CODE targets. In the former case, if a correlation does not occur with any memory radar target, The IFF target is entered into the memory. In the latter case, if a correlation does not occur with any memory radar target, the IFF target is dropped. In both cases, the IFF code is entered into the memory radar target IFF field when a correlation does occur. Table 1.11.2 summarizes the IFF correct code correlation logic.

Each IFF Target received from the IRE unit (see Figure 1.11.1) is checked to determine if it is a candidate for correlation. An IFF Target is NOT correlated with memory radar targets if (1) the invalid bit is set, (2) the IFF code field is zero, or (3) the IFF Target range exceeds the selected range scale. All other IFF Targets received from the IRE unit are candidates for correlation with the memory radar targets. If the OVERLOAD bit of any of the IFF Targets retained for correlation is set, then the IFF Overload Bit (IDA Word 1 Bit 9) is set to logical "1" for the RDP.

A correlation window is constructed around each IFF Target retained for correlation with the memory radar targets. The correlation window (box) is constructed from the IFF Target X (azimuth) and Y (range) position as follows:



where W_X is the half-size of the correlation window in Azimuth and W_Y is the half-size of the correlation window in Range. The possible values of W_X and W_Y are specified in Table 1.11.1a and b respectively. [Note: W_X can have one of two values based on the setting of the WIDE TARGET bit in the IRE Reply Word and W_Y can assume one of two values based on the setting of the SHORT RANGE DETECT bit in PSP Word 1.]

After forming a correlation window about an IFF Target X,Y position, the memory makes one circulation. During this circulation, the IFF target is correlated, in range and azimuth, with each target in the memory which has an intensity of 6 or 7, i.e. each intensity 6 or intensity 7 target X,Y position is checked to determine if it falls within the IFF Target correlation window. [Note: Jammers and non-correlated IFF Targets in the memory are NOT correlated with the "new" IFF Target].

When an IFF Target correlation is made, the IFF Target IFF Code is written into the memory radar target IFF Code field. The IFF Target can correlate with any number of memory radar targets. If no IFF Target correlation is made, the IFF Target is either inserted into the memory as a non-correlated IFF Target or dropped as indicated by the logic in Table 1.11.2.

The IFF correlation cycles are timed not to occur at the same time as the VSD readout cycles.

1.11.2.2.3 Outputs

- DSC Tag or IFF Overload Bit to RDP via IDA.
- ECM Tag, PRF and El Bar Number of cursor correlated radar target to RDP via IDA.
- Unambiguous Range and MPRF Code of cursor correlated radar target to RDP via IDA.
- IFF Code of each correlated IFF Target to IFF Code field of correlated memory radar target(s) in Master Target Memory TM1.
- Non-correlated IFF Targets with correct code to Master Target Memory TM1.

1.11.2.3 Target Age.Erase Logic

Target Aging and Erase Logic is required to control the display intensity of targets sent to the VSD. This logic changes (ages) the display intensity or erases the displayed targets according to the "AGE" or "ERASE" commands, respectively, sent to the RDP. When a target is first detected, the target's display intensity is set at the maximum brightness of the eight state intensity level scale (3 bits); then the intensity level is decreased in accordance with the Aging and Erase Logic, which is further illustrated and discussed in MPRF Search, Section 4.16.2.3.

1.11.2.4 Heading or Azimuth Compensation

The heading or azimuth compensation is required to correct the azimuth error due to the time lag between the time of data collection and the target displayed on VSD. This azimuth compensation can also improve the azimuth accuracy in target correlation.

1.11.2.4.1 Inputs

- End-of-elevation-bar signal or time signal from RDP.
- Azimuth compensation angle $\Delta\psi$ for time period as specified by the RDP.
- Target azimuth angle from the Master Target Memory TM1.

1.11.2.4.2 Processing

A fixed amount of azimuth compensation in binary hits shall be added to all radar/IFF targets in the Master Target Memory TM1 at the end of a specific time period. This azimuth compensation angle is predicted by the RDP due to the change of relative positions between the target and the own aircraft during maneuvers. No elevation compensation is required.

1.11.2.4.3 Outputs

- Azimuth compensated target data to update the target azimuth position of all targets stored in the Master Target Memory TM1.

1.11.3 Outputs

- VSD Digital Data for MPRF Search Modes consists of 128 48-bit target data, one range/velocity scale word, one cursor position word, two antenna position words and two bit-words and sent to Display Interface Unit at a 60 HZ rate.
- Radar target within the cursor range/azimuth boundary to RDP via IDA.
- IFF overload Bit to RDP via IDA.

1.12 Additional Processing (TBS)

Reference PSP-18 Volume 2, DS31325-147
(PSP Computer Program Development Specification)

SECTION 2

HPRF $\dot{R}$ SEARCH & ACQUISITION MODE

2.0 INTRODUCTION

The purpose of the HPRF $\dot{R}$ Search/Acquisition Mode is to search the radar environment and detect nose-aspect targets through the extraction and processing of target doppler frequency data. The following major processing functions comprise this mode:

a) Timing and control
b) FFT doppler filter processing
c) Post detection integration
d) Noise estimation
e) Hit/Miss logic
f) Hit cluster reduction
g) $\dot{R}$ data search
h) Azimuth centroiding
i) Display processing

A functional block diagram of the HPRF $\dot{R}$ Search/Acquisition Mode is shown in Figure 2.1. The PSP receives I/Q data from the radar clutter-free spectrum region. This spectral region is separated into two frequency subband channels by analog filters in the 039 unit. The input I/Q data is amplitude weighted and resolved into an array of 512 discrete doppler filters. The detected power level in each filter is processed by post detection integration to enhance the signal-to-noise characteristics of target returns in the array. Two separate estimates of background noise, an ensemble average and a time average, are calculated for alternate use in establishing the target detection threshold. The RDP commands two levels of thresholding in the HPRF $\dot{R}$ mode. Data crossing the higher threshold is output to Hit Cluster Reduction for pre-display processing. Data crossing each threshold is separately counted and sent to the RDP. These counts are used by the RDP for determining the optimum threshold level. If an acquisition mode has been selected, the first doppler hit in the reduced array that exceeds a predetermined $\dot{R}$

value is output to the RDP. A centroiding function is applied to the hit array to prevent multiple azimuth display of strong targets. For interface with the Vertical Situation Display (VSD), the PSP display processing functions consist of hit data reformating, intensity aging, target/cursor correlation, and display scaling symbology.

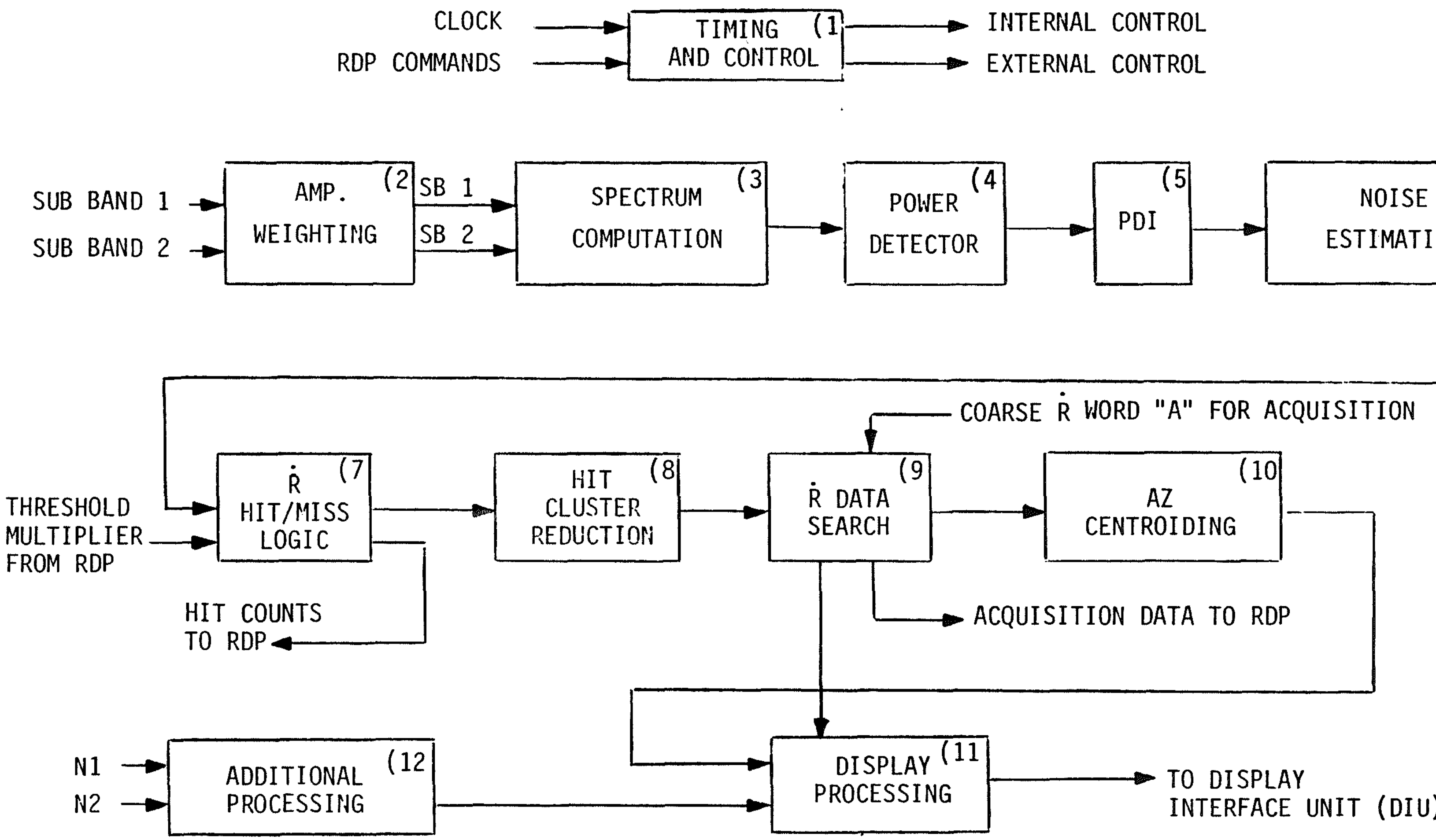


Figure 2.1 - HPRF Ṙ SEARCH AND ACQUISITION FUNCTION DIAGRAM

2.1 Timing and Control

The purpose of this section is to provide an overview of Timing and Control (T&C) for the HPRF Ṙ Search and Acquisition Mode. This function consists of the following:

- Initialization and regulation of mode configuration
- Generation of the radar system clocks
- Reception and distribution of external control commands and programmable timing sequences.

T&C is concerned with the communication among the RDP, PSP, and associated radar system units. This interaction of devices involves both hardware and software with the basic function interface illustrated in the block diagram of Figure 2.1.1. Two PSP hardware units provide the switchboard function for the decoding and routing of T&C data: the Timing and Control module and part of the Input Data Conditioner modules.

The Timing and Control module (Figure 2.1.2) consists of a parameter receiver, two dual-memory event generators, and a 20 MHz oscillator with associated logic circuitry for generation of the radar clocks. The Parameter Receiver accepts P-BUS data from the CIU and distributes the control words to the event memories and a parameter register. Operation of each event memory and the parameter register is accomplished in alternate load/execute sequence with the A/B memory select (EOP2) provided in concurrence with the process sync. This double buffered configuration provides continuous generation of timing and radar event parameters.

In the HPRF Ṙ Search mode, Event Generator #1 (EG1) is clocked at the A/D sample enable rate (60 KHz). The primary function of EG1 in this mode is to provide the event interval timing for Event Generator #2 (EG2). The selection of the EG1 interval count is done based on the event sequence requirements for the mode. An interval count of 64 is used in this discussion to illustrate correct timing of the oscillator change command. The time interval for EG2 event sequencing therefore would be $64/60 \times 10^3$ Hz = 1.0667 ms. Details of event timing from the T&C module are found in the processing portion of this section.

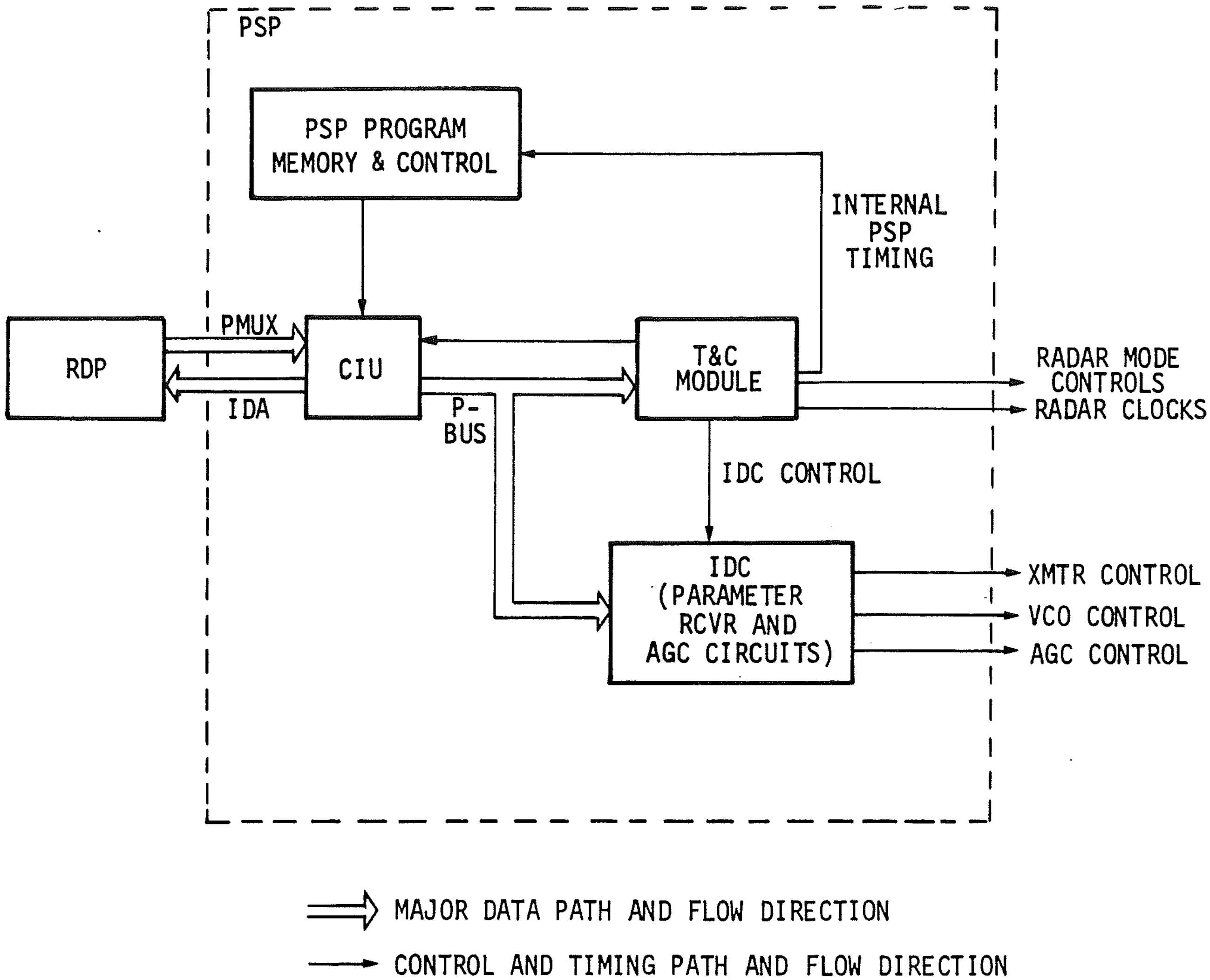


Figure 2.1.1

TIMING AND CONTROL - HPRF $\dot{R}$ SEARCH AND ACQUISITION

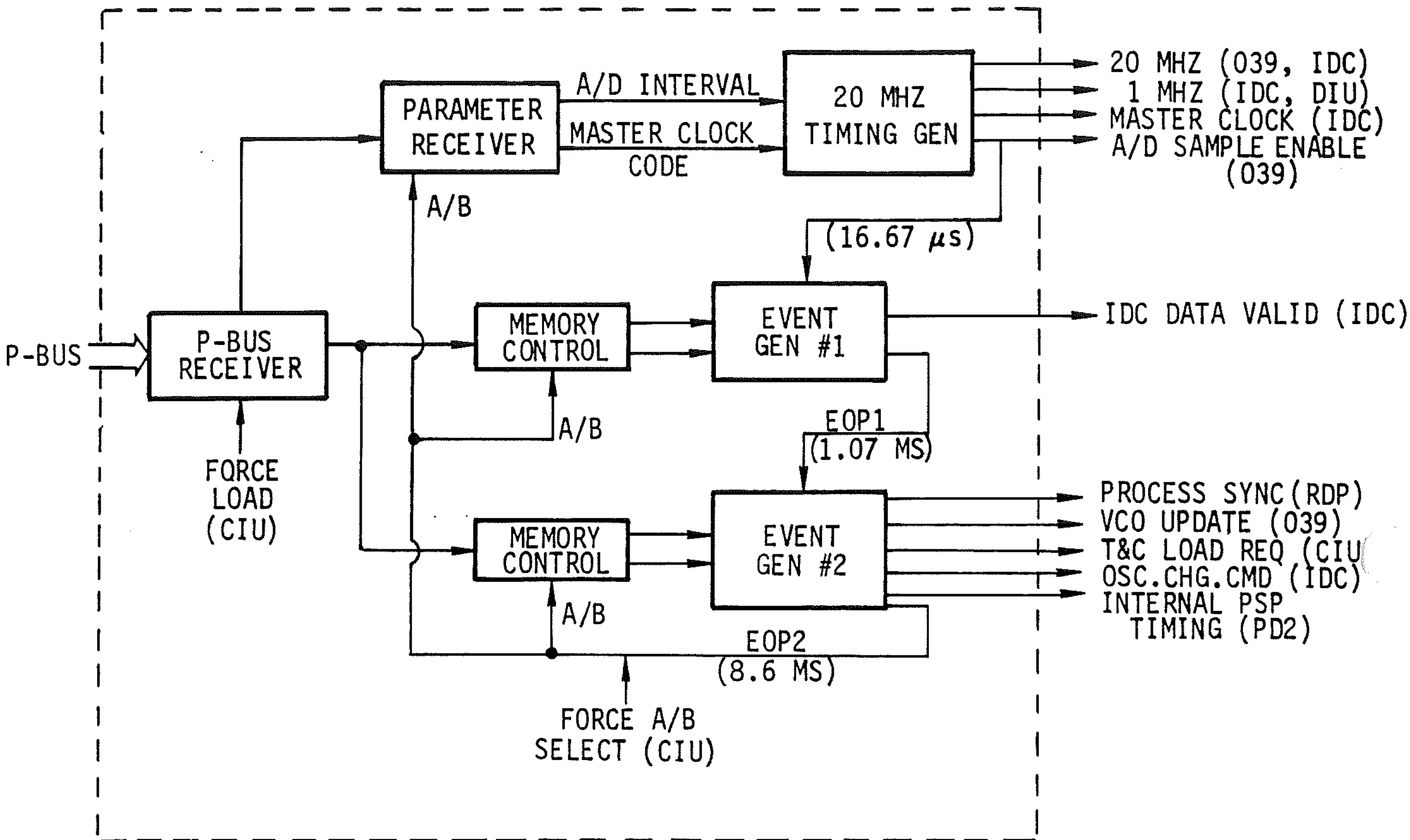


Figure 2.1.2

FUNCTIONAL BLOCK DIAGRAM - T & C MODULE

HPRF $\dot{R}$ SEARCH & ACQUISITION

The Input Data Conditioner (IDC) for the HPRF $\dot{R}$ Search and Acquisition mode is represented in Figure 2.1.3. The IDC parameter receiver accepts the appropriate P-BUS control words and distributes them to double buffered holding registers. Register switching (A/B select) is provided by the T&C module as in a programmable-delay oscillator change pulse. Other IDC parameters provided for this mode include AGC circuit gain limits, HPRF data bypass, and the VCO frequency command and user code. It should be noted that the internal control parameters interface with hardware circuitry within the IDC prior to output to associated radar units. With the exception of the VCO data delay, which is a hardware function of the T&C module, the IDC parameters are software controlled.

2.1.1 Inputs

The primary data input to the Timing and Control (T&C) function are the P-BUS control words. For the HPRF $\dot{R}$ Search mode, the following words apply:

- T&C Event Generator Control Word 1
- T&C Event Generator Control Word 2
- T&C Parameter (Internal) Control Word 1
- IDC External Control Word
- IDC Internal Control Word
- IDC VCO Control Word

The content and destination of each control word is listed in the block diagrams of the preceding section. Three additional Timing and Control inputs are provided independent of the P-BUS data - two software controlled T&C initialization functions and an IDC control signal from the A/D converter:

- T&C Force Load } From CIU
- Force A/B Select } From CIU
- HPRF Signal Level } From 039

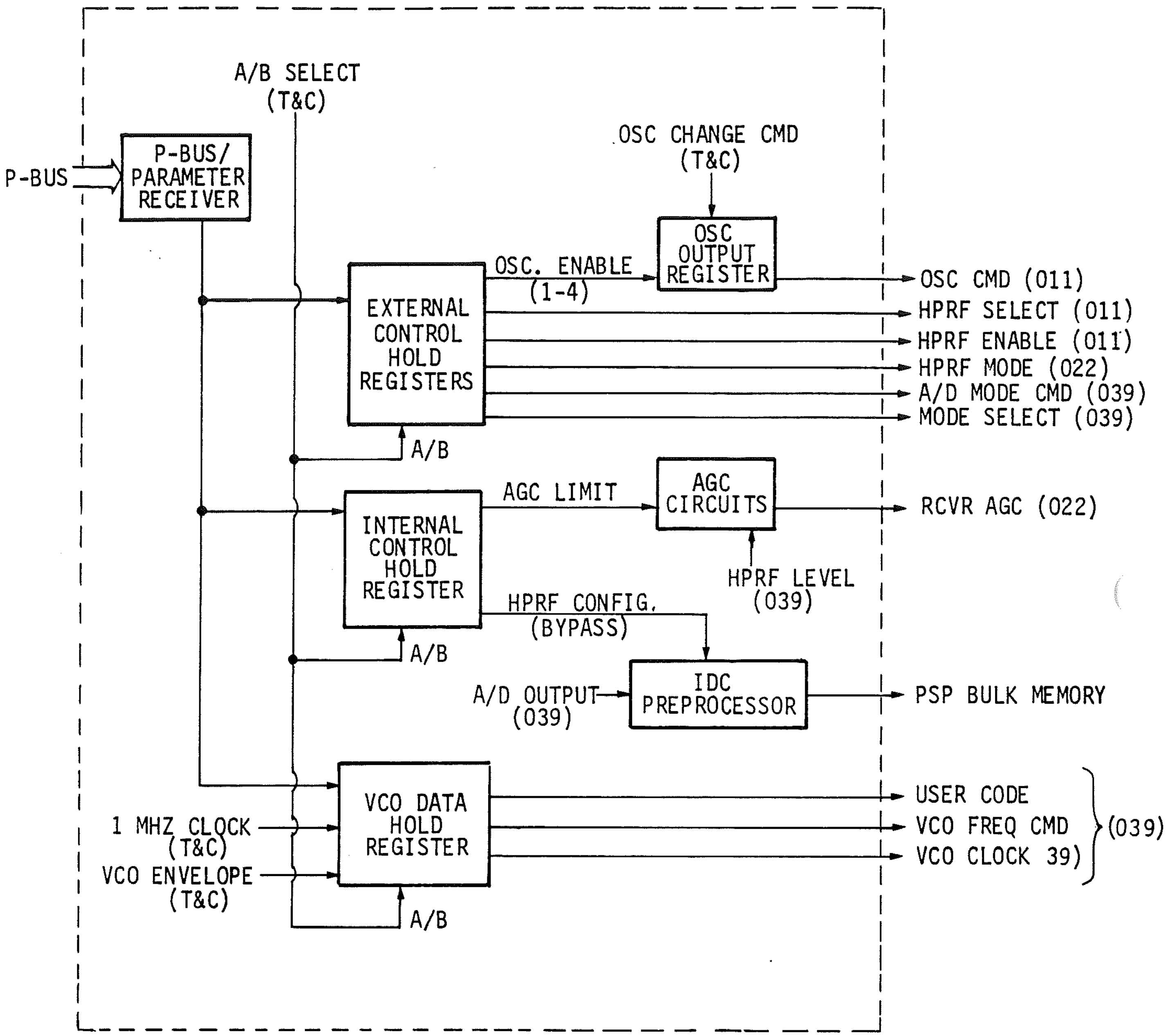


Figure 2.1.3

FUNCTIONAL BLOCK DIAGRAM - INPUT DATA CONDITIONER (IDC)

HPRF Ṙ SEARCH & ACQUISITION

2.1.2 Processing

The T&C function process cycle is performed once per 8.6 millisecond phase period in the HPRF $\dot{R}$ Search and Acquisition mode. Upon receipt of a mode change indication from the RDP, the PSP software will interrupt the current processing phase with a T&C force load. This operation loads the T&C module event memories and IDC holding registers with the event parameters to be generated during the initial phase of the new mode. Since the event generators are double buffered, the memory output registers currently in the execute configuration is inhibited during the mode change. A completion of forced load, the CIU outputs a FORCE A/B SELECT to the T&C module which initiates the output of the initial phase events. Analysis of both the hardware and data collection specifications for HPRF $\dot{R}$ Search mode indicates that three phase periods are necessary to properly configure the system and process the first data sample. The time line of the T&C events required during mode initialization is presented in the following subsections. Output parameters have been separated into four functional categories to assist the reader in following the event sequence:

- Front End Control and PRF Change
- RDP-PSP Control and PRF Change
- VCO and AGC Control
- Data Collection and Processing

2.1.2.1 Front End Control & PRF Change

Included in the forced load from the CIU are the event parameters necessary to properly configure the radar front end (Transmitter, Receiver, and Analog Processor) for HPRF operation. Figure 2.1.4 illustrates a typical start-up process. It should be noted that the time line is expressed in EG2 event increments (1.07 ms.). For the initial phase following the forced load (PHASE 0) - HPRF ENABLE, and HPRF MODE are set high to command HPRF to the transmitter and receiver. The Analog Processor HPRF configuration is established by setting the proper codes for MODE SELECT (11), and A/D MODE COMMAND (10). The states of the above event parameters remain unchanged while an HPRF mode is selected.

For the illustrated example, the Transmitter at mode change is operating at HPRF #4 - indicated by the state of OSC #4 ENABLE (1) and the HPRF SELECT code (11). A PRF change requires the appropriate oscillator to be stabilized prior to the output of the select code update. To select HPRF #3, the OSC CHANGE CMD is output to the IDC by T&C Event Generator #2 at 4.3 ms. before the succeeding phase. This signal gates OSC #3 ENABLE (set true at start of phase) from the oscillator output register. The PRF change cycle is then completed by HPRF SELECT code (10) generated at the start of PHASE I. Oscillator turnoff is controlled by the T&C module hardware and is not a programmable event.

2.1.2.2 RDP - PSP Command Data Transfers

The data transfer timeline for the HPRF $\dot{R}$ Search and Acquisition mode is represented in Figure 2.1.5. Included in the FORCE LOAD events to be generated during PHASE 0 is the initial PROCESS SYNC to the RDP (081 unit). The receipt of this signal initiated a COMMAND DATA (PMUX) transfer to the CIU. This serial message transfer of one to sixteen 24-bit words, clocked at a 1 MHz rate, is completed within 1 ms.

Included in the PMUX transfer is the control data for the T&C events that is to be generated during the following phase. The T&C and IDC control words, reformatted to 32 bits by the CIU are transferred via the P-BUS upon receipt of a T&C LOAD REQUEST. Clocked at 7.14 MHz the T&C LOAD is completed within 300 μs. The request is shown to be generated at 7.47 ms. into the phase period. This is the final programmable event interval that accomodates a T&C LOAD before end of phase. The execution of the T&C events loaded from the RDP-PSP command data transfer is initiated by the internal A/B SELECT which in turn regenerates the transfer cycle.

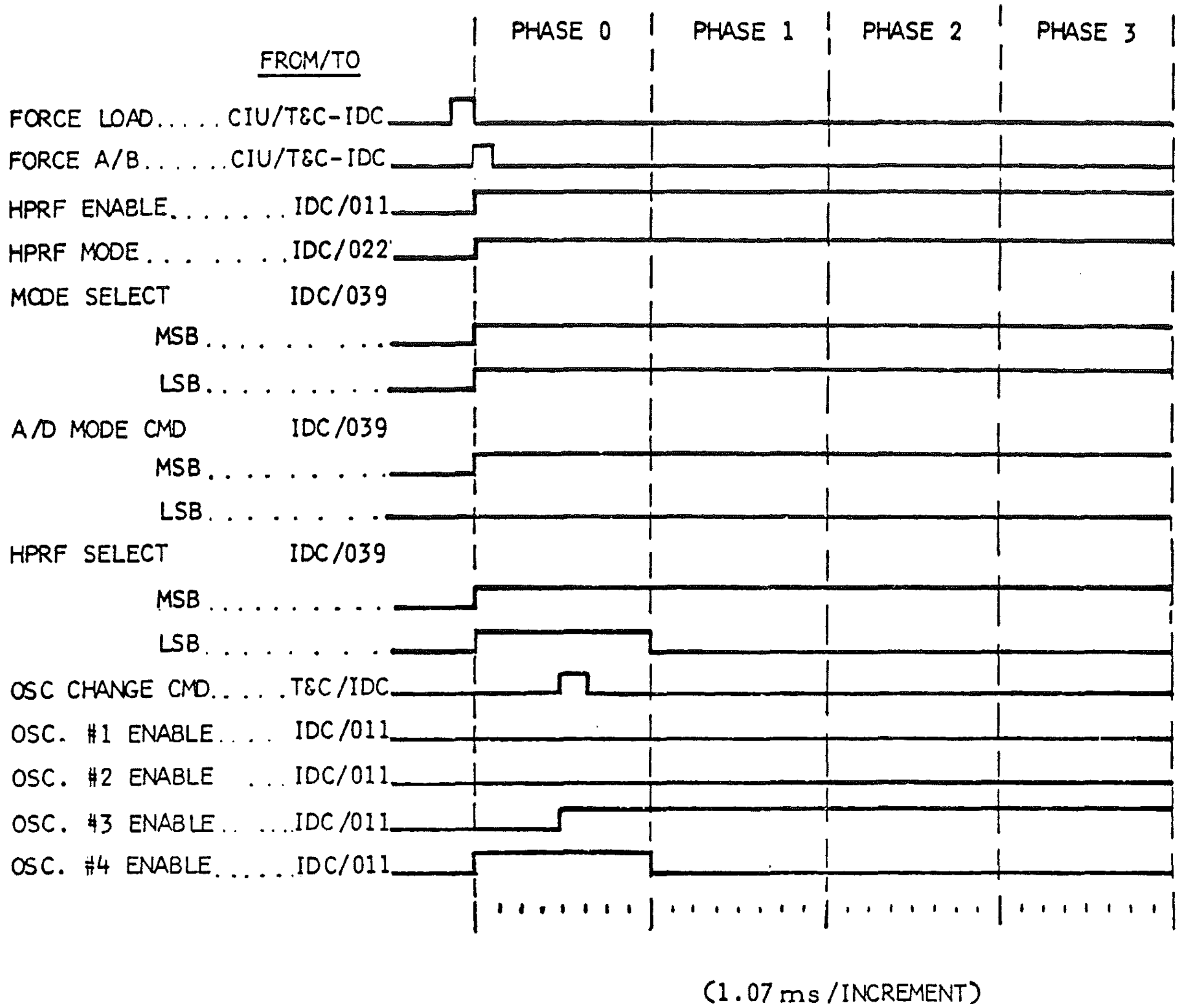


Figure 2.1.4

Front End Control and PRF Change

HPRF $\dot{R}$ Search and Acquisition

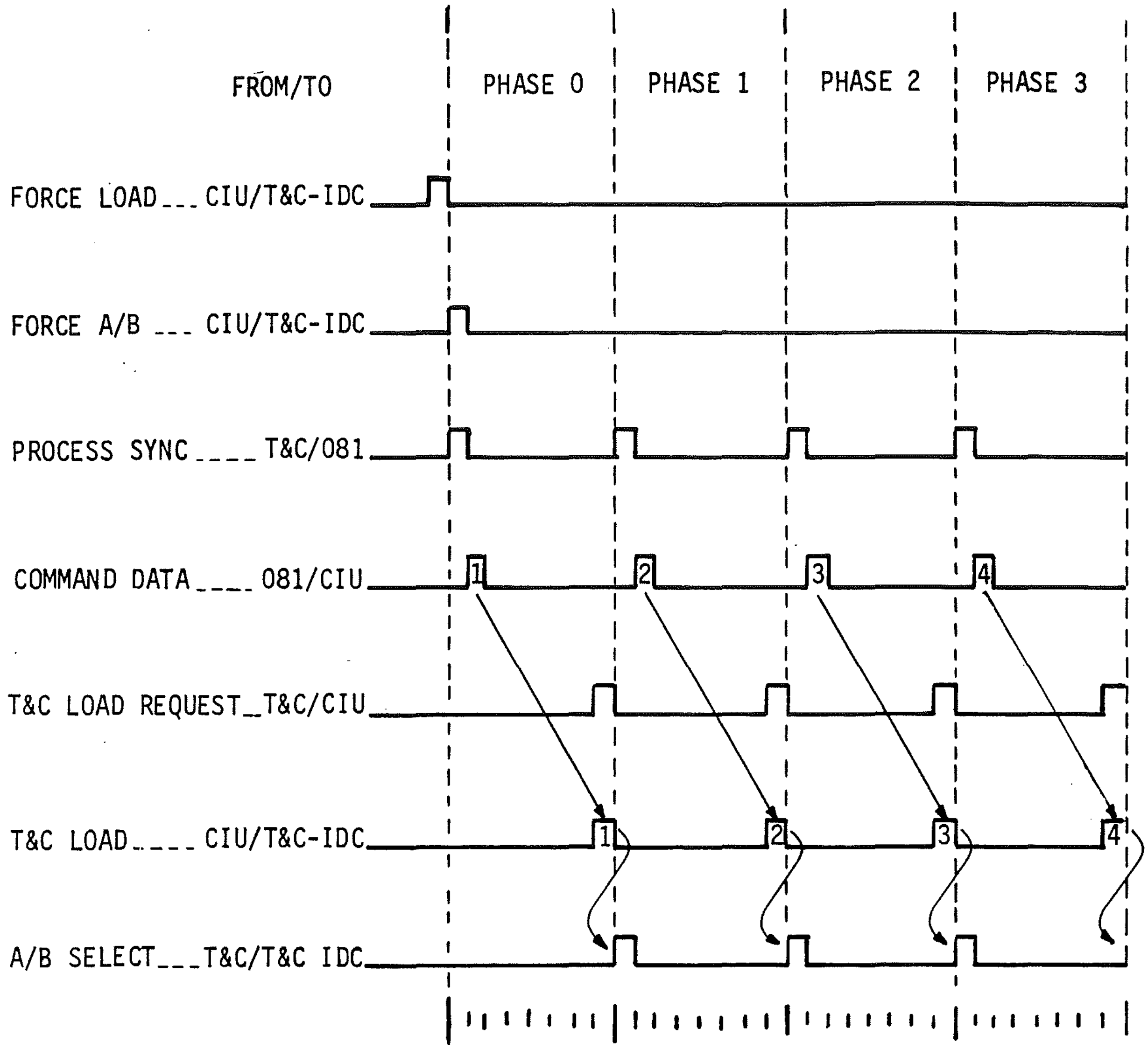


Figure 2.1. 5

COMMAND DATA TRANSFERS

HPRF Ṙ SEARCH & ACQUISITION

2.1.2.3 VCO & AGC Control

The initial VCO frequency command following power up or mode change is input to the IDC parameter receiver by the CIU FORCE LOAD. This 16-bit serial data is gated to the 039 unit by a 20 μs VCO ENVELOPE which is delayed approximately 7 msec from the start of phase (refer to Figure 2.1.6). The envelope delay is a T&C module hardware function and is not controllable by the PSP software. A 3-bit user code (100 for non-FMR modes) establishes the proper 039 holding register for the command data. The updated register is not executed until the VCO UPDATE COMMAND is received from T&C Event Generator #2 at the start of the following phase. Including the RDP-PSP/T&C data transfer cycle, a VCO frequency change therefore requires two phase periods for implementation.

The IDC control parameters include a maximum value for receiver gain. This RDP-controlled limit is input to the AGC receiver control logic once per phase. For HPRF modes, the AGC function examines threshold data over three consecutive phases. If the status of HPRF LEVEL (2-bits) is unchanged for two of the three phases, the current AGC level is changed by one 11 db step. The calculated level is then compared against the AGC LIMIT. The larger value, corresponding to a lower gain setting, is output to the Receiver. In the example of Figure 2.1.6, an AGC LIMIT code of 00 - corresponding to 0 db of attenuation, was input at mode change. This allows the full receiver gain range of 44 db for AGC computation. During the first three phases the threshold level was exceeded twice - resulting in an increase in AGC from 22 db to 33 db. This update is output to the Receiver during PHASE 3.

2.1.2.4 Data Collection and Processing

With the radar having been configured for HPRF $\dot{R}$ Search operation during PHASE 0, the data sampling cycle is initiated at PHASE 1 as shown in Figure 2.1.7. The A/D SAMPLE ENABLE pulse and the MASTER CLOCK are input to the Analog Processor (039 unit) from T&C Event Generator #2. The 60 KHz A/D enable rate produces the

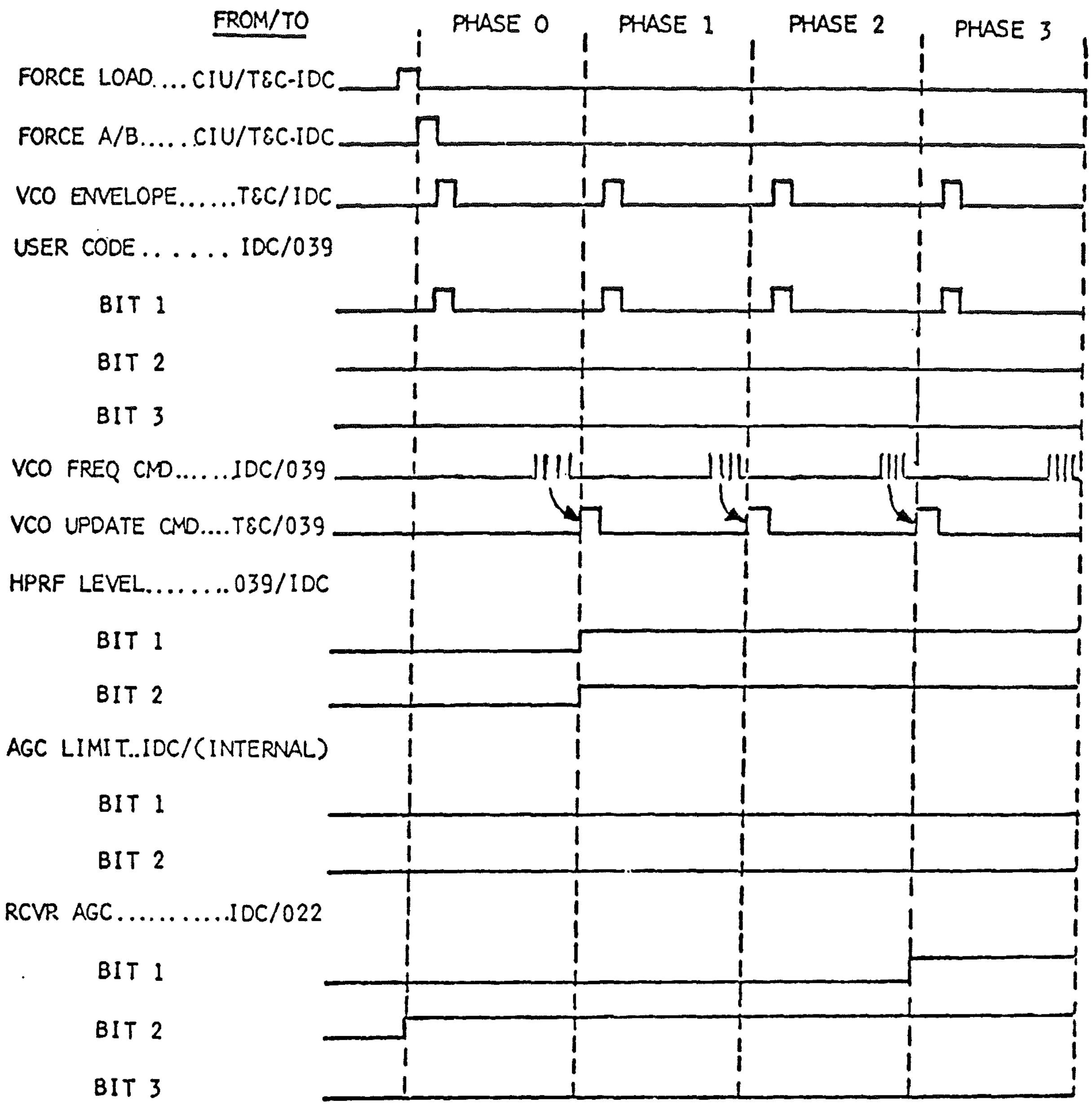


Figure 2.1.6

VCO & AGC CONTROL
HPRF $\dot{R}$ SEARCH & ACQUISITION

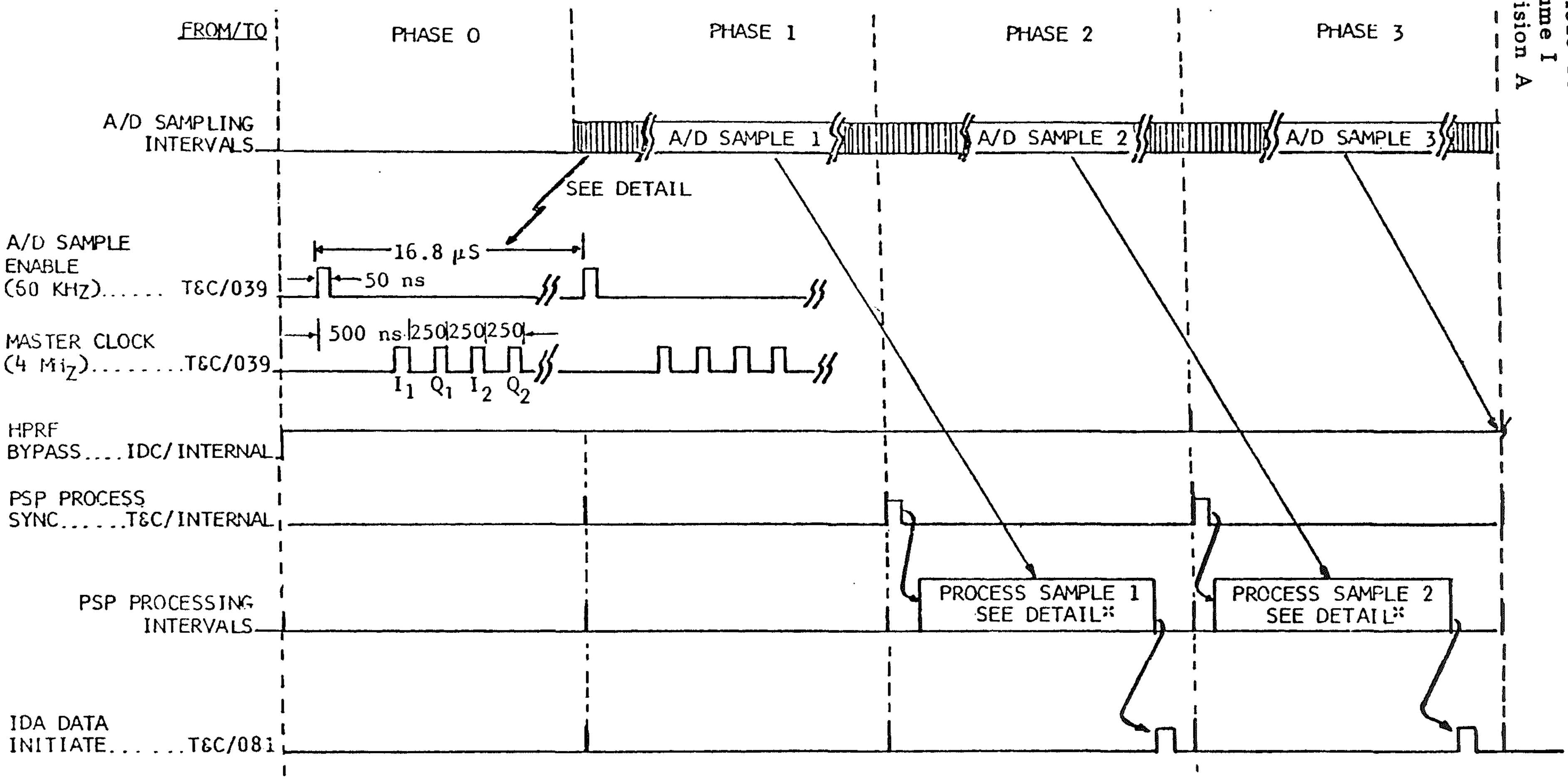
requisite 512 data samples per phase period. I/Q data are clocked from the 039 sample and hold circuits in sequence as detailed in the illustration. The nine-bit A/D data words are routed through the appropriate IDC processing circuits by HPRF BYPASS for reassembly into the PSP Bulk Memory format.

Processing of the first data sample is initiated by PSP PROCESS SYNC at the start of PHASE 2. Configuration of the process sequence for the HPRF $\dot{R}$ Search and Acquisition mode (see detail Figure 2.1.7) is maintained by the PSP software. Upon completion of the process cycle, IDA INITIATE enables the PSP-RDP data transfer.

2.1.3 Outputs

The Timing and Control function provides the following output categories:

- Radar Configuration Commands
- Radar Event Commands
- Data Transfer Commands
- Data Processing Commands
- Radar System Clocks



*SEE DETAIL HPRF Ṙ SEARCH PROCESS SEQUENCE

AMPLITUDE WEIGHTING	FILTER FORMULATION	POWER DETECTION	PDI	NOISE ESTIMATE	HIT/MISS LOGIC	HIT CLUSTER REDUCTION	DATA SEARCH ACQUISITION	AZIMUTH CENTROID	DISPLAY PROCESS

Figure 2.1.7

DATA COLLECTION AND PROCESSING

HPRF Ṙ SEARCH & ACQUISITION

2.2 Amplitude Weighting

2.2.1 Inputs

- Two sequences of 512 I/Q samples that are associated with the frequency bands, SB1 & SB2 of the radar return signal:

$$\{S(i,j) \mid i = 0, \ldots, 511, j = 1,2\}$$

SB1 and SB2 are equal in bandwidth and immediately adjacent to each other in frequency. Together they span the processed clear region of the radar signal spectrum. They are referred to as subband 1 and subband 2 respectively.

2.2.2 Processing

Amplitude weighting takes place just before the FFT is applied to the two input sequences. This ensures that the FFT output for each of the sequences satisfies a desired peak mainlobe to peak side-lobe ratio. The procedure requires that precomputed weights be stored in the PSP. Each of the 512 samples from SB1 and SB2 are weighted as follows:

$$S_w(i,j) = A(i) \bullet S(i,j)$$

where: $S(i,j)$ = input I/Q sample

$S_w(i,j)$ = weighted I/Q sample

$j = 1,2$ = subband index

$i = 0, \ldots, 511$ = sample index

$A(i)$ are amplitude weights as shown in Table 2.2.1, which are symmetrical.

2.2.3 Outputs

- Two sequences of 512 weighted I/Q samples associated with SB1 and SB2 respectively:

$$\{S_w(i,j) \mid i = 0 \ldots, 511, j = 1,2\}$$

TABLE 2.2.2.1 - KAISER AMPLITUDE WEIGHTS
FOR F-15 HPRF $\dot{R}$ SEARCH AND ACQUISITION

$N_P = 512$

SAMPLE NUMBER n	AMPLITUDE WEIGHTS A(n)
0	.233398
1	.236816
2	.240723
3	.244141
4	.248047
5	.251953
6	.255371
7	.259277
8	.263184
9	.267090
10	.270508
11	.274414
12	.278320
13	.282227
14	.286133
15	.290039
16	.293945
17	.297852
18	.301758
19	.305664
20	.309570
21	.313477
22	.317383
23	.321289
24	.325195
25	.329102
26	.333008
27	.337402
28	.341309
29	.345215
30	.349121
31	.353027
32	.357422
33	.361328
34	.365234
35	.369629
36	.373535
37	.377441
38	.381836
39	.385742
40	.389648
41	.394043
42	.397949
43	.402344
44	.406250
45	.410645
46	.414551
47	.418457
48	.422852
49	.426758
50	.431152
51	.435059
52	.439453
53	.443359
54	.447754
55	.451660
56	.456055
57	.459961
58	.464355
59	.468262
60	.472656
61	.476563

TABLE 2.2.2.1 - KAISER AMPLITUDE WEIGHTS FOR F-15 HPRF $\dot{R}$ SEARCH AND ACQUISITION

$N_p = 512$

SAMPLE NUMBER n	AMPLITUDE WEIGHTS A(n)
62	.480957
63	.485352
64	.489258
65	.493652
66	.497559
67	.501953
68	.505859
69	.510254
70	.514160
71	.518555
72	.522461
73	.526855
74	.530762
75	.535156
76	.539063
77	.543457
78	.547363
79	.551758
80	.555664
81	.560059
82	.563965
83	.568359
84	.572266
85	.576172
86	.580566
87	.584473
88	.588867
89	.592773
90	.596680
91	.601074
92	.604980
93	.608887
94	.613281
95	.617188
96	.621094
97	.625000
98	.629395
99	.633301
100	.637207
101	.641113
102	.645020
103	.648926
104	.653320
105	.657227
106	.661133
107	.665039
108	.668945
109	.672852
110	.676758
111	.680664
112	.684570
113	.687988
114	.691895
115	.695801
116	.699707
117	.703613
118	.707031
119	.710938
120	.714844
121	.718750
122	.722168
123	.726074

TABLE 2.2.2.1 - KAISER AMPLITUDE WEIGHTS FOR F-15 HPRF Ṙ SEARCH AND ACQUISITION

$N_P = 512$

SAMPLE NUMBER n	AMPLITUDE WEIGHTS A(n)
124	.729492
125	.733398
126	.736816
127	.740723
128	.744141
129	.748047
130	.751465
131	.754883
132	.758789
133	.762207
134	.765625
135	.769043
136	.772461
137	.776367
138	.779785
139	.783203
140	.786621
141	.790039
142	.792969
143	.796387
144	.799805
145	.803223
146	.806641
147	.809570
148	.812988
149	.816406
150	.819336
151	.822754
152	.825684
153	.829102
154	.832031

SAMPLE NUMBER n	AMPLITUDE WEIGHTS A(n)
155	.834961
156	.838379
157	.841309
158	.844238
159	.847168
160	.850098
161	.853027
162	.855957
163	.858887
164	.861816
165	.864746
166	.867676
167	.870605
168	.873047
169	.875977
170	.878906
171	.881348
172	.884277
173	.886719
174	.889160
175	.892090
176	.894531
177	.896973
178	.899414
179	.901855
180	.904297
181	.906738
182	.909180
183	.911621
184	.914063
185	.916504

TABLE 2.2.2.1 - KAISER AMPLITUDE WEIGHTS
FOR F-15 HPRF R SEARCH AND ACQUISITION

$N_p = 512$

SAMPLE NUMBER n	AMPLITUDE WEIGHTS A(n)
186	.918457
187	.920898
188	.923340
189	.925293
190	.927734
191	.929688
192	.931641
193	.934082
194	.936035
195	.937988
196	.939941
197	.941895
198	.943848
199	.945801
200	.947754
201	.949219
202	.951172
203	.953125
204	.954590
205	.956543
206	.958008
207	.959961
208	.961426
209	.962891
210	.964355
211	.966309
212	.967773
213	.969238
214	.970215
215	.971680
216	.973145

SAMPLE NUMBER n	AMPLITUDE WEIGHTS A(n)
217	.974609
218	.975586
219	.977051
220	.978516
221	.979492
222	.980469
223	.981934
224	.982910
225	.983887
226	.984863
227	.985840
228	.986816
229	.987793
230	.988770
231	.989746
232	.990234
233	.991211
234	.992188
235	.992676
236	.993652
237	.994141
238	.994629
239	.995117
240	.995605
241	.996582
242	.997070
243	.997070
244	.997559
245	.998047
246	.998535
247	.998535

TABLE 2.2.2.1 - KAISER AMPLITUDE WEIGHTS FOR F-15 HPRF $\dot{R}$ SEARCH AND ACQUISITION

$N_p = 512$

SAMPLE NUMBER n	AMPLITUDE WEIGHTS A(n)
248	.999023
249	.999512
250	.999512
251	.999512
252	.999512
253	.999512
254	.999512
255	.999512

2.3 Spectrum Computation

The spectrum of the clutter free region is formed in this section. This is accomplished in two steps. First, a Fast Fourier Transform is applied to the two sets of weighted samples from section 2.2.2. The results are two spectra each spanning * KHz.

$$\{F(k,j) \mid k = 0, \ldots, 511,; j = 1,2\}$$

where: k is the discrete frequency index, and

j is the subband index.

Only the first 256 elements of $\{F(k,1)\}$ and the last 256 elements of $\{F(k,2)\}$ have meaningful data. In the second step, these elements are combined to form the desired spectrum.

2.3.1 Inputs

- Two sequences of 512 weighted I/Q samples corresponding to SB1 and SB2 of the radar return signal:

$$\{S_w(i,j) \mid i = 0, \ldots, 511; j = 1,2\}$$

- Phase rotation constants:

$$\{W^m \mid m = 0, \ldots, 511\}$$

where:

$$W = \exp(-j2\pi/512)$$

2.3.2 Processing

The Discrete Fourier Transform (DFT) of each input sequence is given by:

$$F(k,j) = \sum_{n=0}^{511} S_w(n,j) \bullet W^{nk}$$

where: j = subband index

k = filter number

n = sample number

F = filter value; a complex number

* Classified parameter value

Because of the symmetry of W^m in the complex plane, only the first 256 phase constants need be stored in the PSP. The remaining 256 constants are the complex conjugates of the stored constants. The Fast Fourier Transform (FFT) is an algorithm that executes the DFT mentioned above. The design of the FFT is left to the programmer.

The frequency spectrum of the clear region is formed as follows:

$$F_{c1}(k) = \begin{cases} F(k-1) & k = 0, \ldots, 255 \\ F(k,2) & k = 256, \ldots, 511 \end{cases}$$

2.3.3 Outputs

- The discrete frequency spectrum of the clear region:
  $\{F_{c1}(k) \mid k = 0, \ldots, 511\}$

2.4 Power Detector

Power Detector's function is to compute the signal power at each discrete frequency of the spectrum computed in section 2.3.3.

2.4.1 Inputs

- The discrete frequency spectrum of the clear region:
  $\{F_{c1}(k) \mid k = 0, \ldots, 511\}$

2.4.2 Processing

$$P(k) = |F_{c1}(k)|^2$$

2.4.3 Output

- The power spectrum of the clear region:
  $\{P(k) \mid k = 0, \ldots, 511\}$

2.5 Post Detection Integration (PDI)

The purpose of Post Detection Integration (PDI) is to improve target detection against background noise by reducing the variability of the noise. The PDI function accumulates the input samples into a weighted "running average." The resultant output, both for noise only and with signal present, has reduced fluctuation. The overlap of the probability density functions of the signal and background noise is considerably reduced; thus minimizing noise threshold crossings (false alarms) while enhancing the target signal characteristics. When the radar is in the HPRF $\dot{R}$ mode a feedback type PDI technique is employed. In this approach, a 5/8 feedback factor is applied to the input signal.

2.5.1 Inputs

- Mode control from RDP indicating HPRF $\dot{R}$ Search
- The power spectrum of the clear region:

  $\{P(k,n) \mid k = 0, \ldots, 511; n = \text{sample index}\}$

2.5.2 Processing

Figure 2.5.2.1 illustrates the feedback PDI mechanization. An initial value of PDI power, $P_{PDI}(k,0)$, is applied to reduce the signal buildup time during the first time constant duration.

For HPRF $\dot{R}$ Search, the PDI power level is calculated for each filter as follows:

$$P_{PDI}(k,n) = P(k,n) + 5/8\ P_{PDI}(k,n-1)$$

where:

k	=	filter index
n	=	sample index
$P_{PDI}(k,0)$	=	initial PDI value 128
P_{PDI}	=	integrated signal power.

2.5.2.1

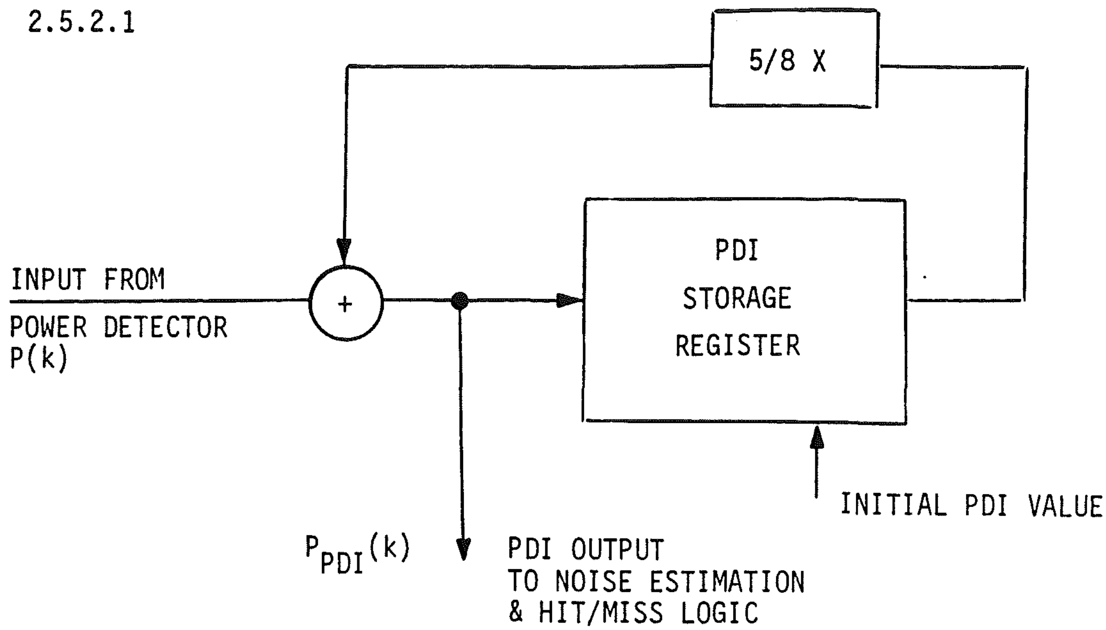


Figure 2.5.2.1 - 5/8 FEEDBACK PDI

2.5.3 Output

A continuous sequence of integrated power levels for each filter:

$$\left\{P_{PDI}(k) \mid k = 0, \ldots, 511\right\}$$

2.6 Noise Estimate

This subfunction determines two background noise estimates for each processed doppler cell. For HPRF $\dot{R}$ Search, both a sliding window "ensemble average" estimate and a "time average" estimate are computed at all times. Either estimate is RDP selectable via the Hit/Miss logic for use in threshold detection. Figure 2.6.1 illustrates the noise estimate subfunction's relationship to the overall detection process.

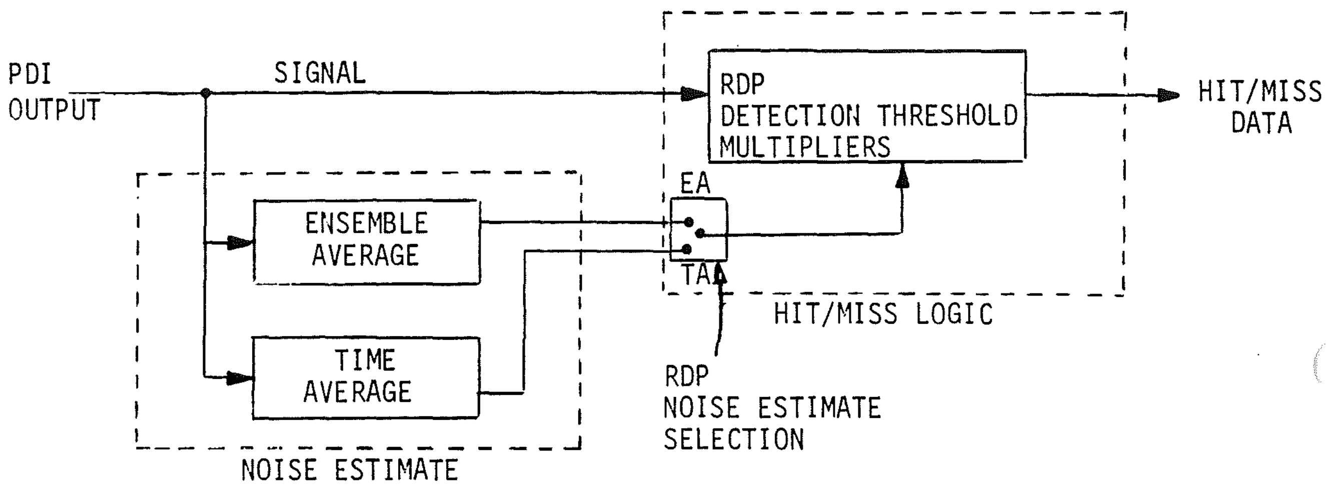


Figure 2.6.1 - $\dot{R}$ SEARCH MODE NOISE ESTIMATES

2.6.1 Inputs

Inputs to the Noise Estimate subfunction are:

- Mode control from RDP indicating HPRF $\dot{R}$ Search
- Integrated power levels for all clear region doppler filters:

$$\{P_{PDI}(k) \mid k = 0, \ldots, 511\}$$

2.6.2 Processing

2.6.2.1 Ensemble Average (EA)

The Ensemble Average noise estimate is computed as described here. A "16-3-16" sliding window average and an overall "long ensemble" average of ΔN doppler cells forms two estimates, the largest of which shall be output as the Ensemble Average noise estimate. Sliding Window averages are computed for each doppler cell by comparing the average power in two groups of 16 contiguous filters positioned symmetrically about the cell under consideration. Neither group contains the filters directly adjacent to the cell under consideration. The largest of these two group averages is taken as the Sliding Window (SLW) Average. The Sliding Window Average noise estimate is expressed mathematically as follows:

$$SLW(k) = (1/16)\ \mathrm{MAX}\left[\sum_{j=k-17}^{k-2} P_{PDI}(j),\ \sum_{j=k+2}^{k+17} P_{PDI}(j)\right],$$

where: k is the doppler filter index, SLW(k) is the estimate for the k-th doppler filter, $P_{PDI}(j)$ is the PDI output of the j-th doppler filter.

Note: The above equation is calculated for the doppler filter index "k" that runs over all 512 filters.

The Long Ensemble Average (LEA) is computed by the following equation:

$$LEA = \left\{ \frac{1}{\Delta N} \left[\sum_{j=512-\Delta N}^{511} P_{PDI}(j) \right] \right.$$

where: ΔN is 128.

The Ensemble Average noise estimate for each cell is the larger of the SLW and LEA.

2.6.2.2 Time Average

In the current 041 unit, the time average noise estimate is performed by processing every third PDI sample in a second feedback loop using a feedback factor of 7/8. For implementation in the PSP, a delayed time average estimate using each PDI sample is calculated. This approach maintains a background noise level which is unaffected by the presence of a signal. The time delay is introduced by selecting the third average prior to the current filter sample for output to the Hit/Miss logic. The Time Average noise estimate logic is shown in Figure 2.6.2.2.1.

Since every PDI sample is utilized in the delayed time average, a different feedback coefficient must be applied to produce the same time constant. The feedback coefficient has been determined to be 23/24.

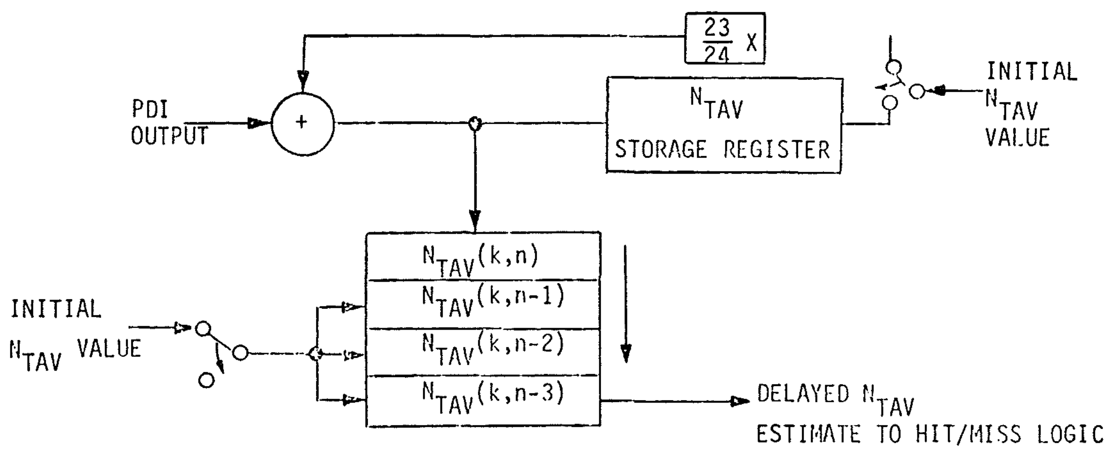


FIGURE 2.6.2.2.1 - TIME AVERAGE NOISE ESTIMATE

The computation of the time average noise estimate for HPRF $\dot{R}$ Search is expressed as follows:

$$N_{TAV}(k,n) = \frac{1}{24} P_{PDI}(k,n) + \frac{23}{24} N_{TAV}(k,n-1)$$

where : k = filter index

n = sample index

P_{PDI} = integrated power level

N_{TAV} = time averaged noise estimate

Note: While the current time average is computed continuously, the delayed estimate $N_{TAV}(k,n-3)$ is used in the Hit/Miss logic for threshold detection. In addition, both the feedback loop and the delay registers are initialized to prevent false alarm at the start of the computational cycle.

2.6.3 Outputs

Outputs from the Noise Estimate subfunction are:

- $N(k)$ — Ensemble Average noise estimates for all clear region doppler filters.
- $N_{TAV}(k,n-3)$ — Delayed Time Average noise estimates for all clear region doppler filters.

2.7 $\dot{R}$ Hit/Miss Logic

The Hit/Miss logic identifies those cells in the 512 filters that have valid target information. The identification depends on the noise estimate of the cells and a threshold multiplier. The latter is computed in the RDP and is based on a constant false alarm probability. In HPRF $\dot{R}$ Search mode, the noise estimate is either the ensemble average or delayed time average as selected by the RDP. If the doppler filter PDI power level exceeds the threshold level, that cell is declared a hit, otherwise it is declared a miss. An additional scale factor of 3/4 is applied to the threshold level for subband 1 and subband 2. Hits crossing this lower threshold are counted, and the count is sent to the RDP for threshold adjustment purposes. Figure 2.7.1 is a block diagram of the Hit/Miss Logic.

2.7.1 Input

- Mode control from RDP indicating HPRF $\dot{R}$ Search
- Integrated signal power of the filter cells:
  $\{P_{PDI}(k) \mid k = 0, \ldots, 511\}$
- Noise estimates of the filter cells:
  $\{N(k) \mid k = 0, \ldots, 511\}$, or
  $\{N_{TAV}(k,n-3) \mid k = 0, \ldots, 511\}$, as commanded by RDP.
- Signal detection threshold multipliers (from RDP):
  K_{SUB1} (for detection in the first 256 cells),
  K_{SUB2} (for detection in the last 256 cells).
- Noise selection (EA or TA) from RDP.

2.7.2 Processing

The Hit/Miss logic in this mode is based on the signal power of the filters. This differs from the current RSP design where the logic is based on the magnitude of the filter signals. To accomodate this difference the threshold multipliers used in this mode are:

$$\left.\begin{aligned} KP_{R1} &= K_{SUB1}^2 \\ KP_{R2} &= K_{SUB2}^2 \end{aligned}\right\}\text{ for target hit detection} \qquad \left.\begin{aligned} KP_{SUB1} &= (3/4)K_{SUB1}^2 \\ KP_{SUB2} &= (3/4)K_{SUB2}^2 \end{aligned}\right\}\text{ for statistical "hit count" detection}$$

For processing, an array $\{H(k) \mid k = 0, \ldots, 511\}$ is set aside to hold the resolved* $\dot{R}$ Hit/Miss information. The number of resolved $\dot{R}$ hits is placed in COUNT R. A second array $\{SH(k) \mid k = 0, \ldots, 511\}$ holds the x 3/4 threshold $\dot{R}$ Hit/Miss information. The hit counts in this second array are kept separate for subband 1 and subband 2, and are placed in COUNT 1 and COUNT 2 respectively. The following steps describe the Hit/Miss Logic.

a) For k = 0 to 255,
If $\left[P_{PDI}(k) \geq KP_{R1} \times N'(k)\right]$ then H(k) = 1, a hit
else H(k) = 0, a miss
If $\left[P_{PDI}(k) \geq KP_{SUB1} \times N'(k)\right]$ then SH(k) = 1, a hit
else SH(k) = 0, a miss

b) $\text{Count 1} = \sum_{k=0}^{255} SH(k)$

c) For k = 256 to 511
If $\left[P_{PDI}(k) \geq KP_{R2} \times N'(k)\right]$ then H(k) = 1, a hit
else H(k) = 0 a miss
If $\left[P_{PDI}(k) \geq KP_{SUB2} \times N'(k)\right]$ then SH(k) = 1, a hit
else SH(k) = 0, a miss

where $N'(k) = N(k)$ or $N_{TAV}(k,n-3)$ as commanded by the RDP.

d) $\text{COUNT 2} = \sum_{256}^{511} SH(k)$

e) $\text{COUNT R} = \sum_{0}^{511} H(k)$

2.7.3 Outputs

- Resolved $\dot{R}$ Hit/Miss array, $\{H(k) \mid k = 0, \ldots, 511\}$, to hit cluster reduction.
- Resolved $\dot{R}$ hit count, COUNT R, to RDP.
- Hit counts in subband 1 and subband 2, COUNT 1 and COUNT 2, to RDP.

* The term "resolved" is used here to designate those hits which cross the higher target detection threshold KP_{R1} or KP_{R2}.

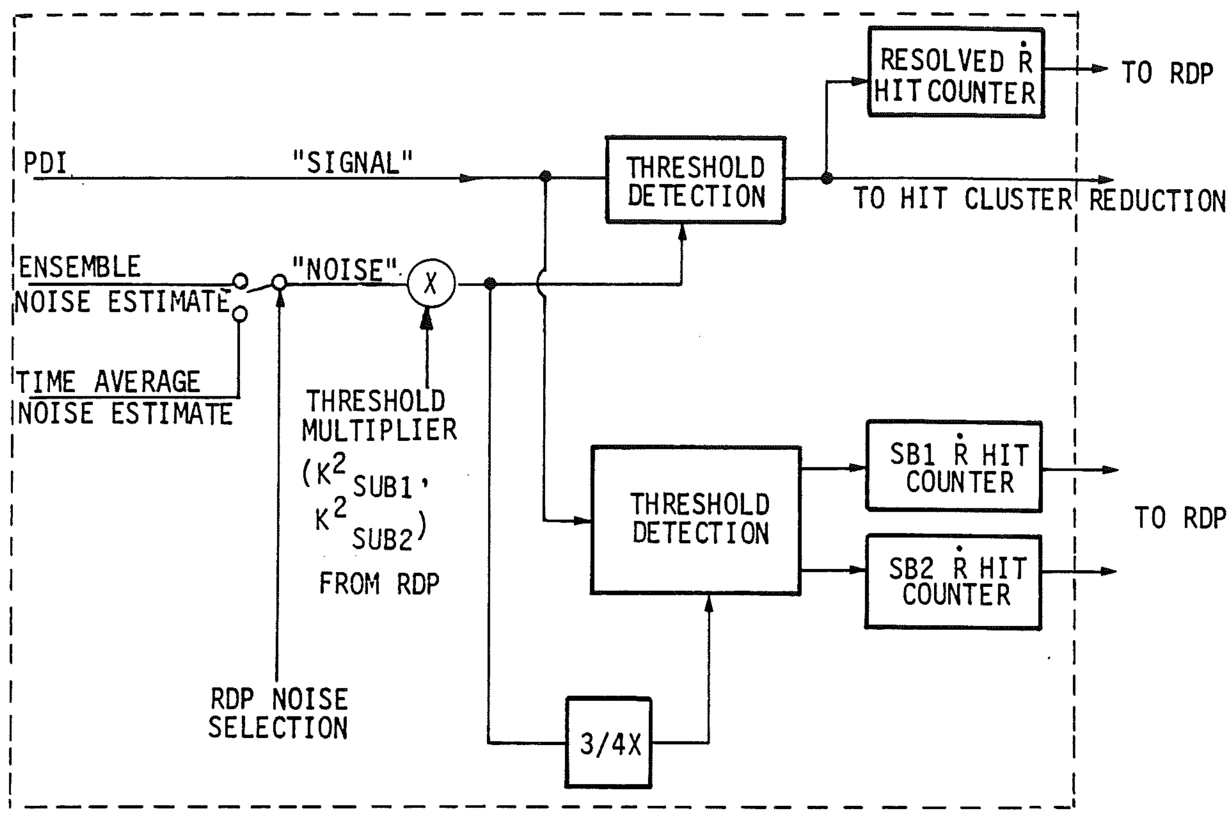


Figure 2.7.1 - HIT/MISS LOGIC

2.8 Hit Cluster Reduction

A strong radar return signal from a single or multiple target(s) can cause the signal levels of a cluster of filters to exceed a given CFAR threshold. This forces a string of one to be entered in the Resolved $\dot{R}$ Hit/Miss Array (H-array). Hit Cluster Reduction is the process of shrinking these clusters in the H-array. The reduction rules are given in section 2.8.2.

A set of filter numbers is defined:

$$J_c = \{k | H(k) = 1\}$$

The set is formed after the reduction process. The elements of J_c are called the coarse-hit filter numbers.

2.8.1 Input

- Resolved $\dot{R}$ Hit/Miss Array: $\{H(j) \mid j = 0, \ldots, 511\}$

2.8.2 Processing

The H-array is scanned to identify hit clusters. Three reduction rules are imposed on the cluster upon identification and these are:

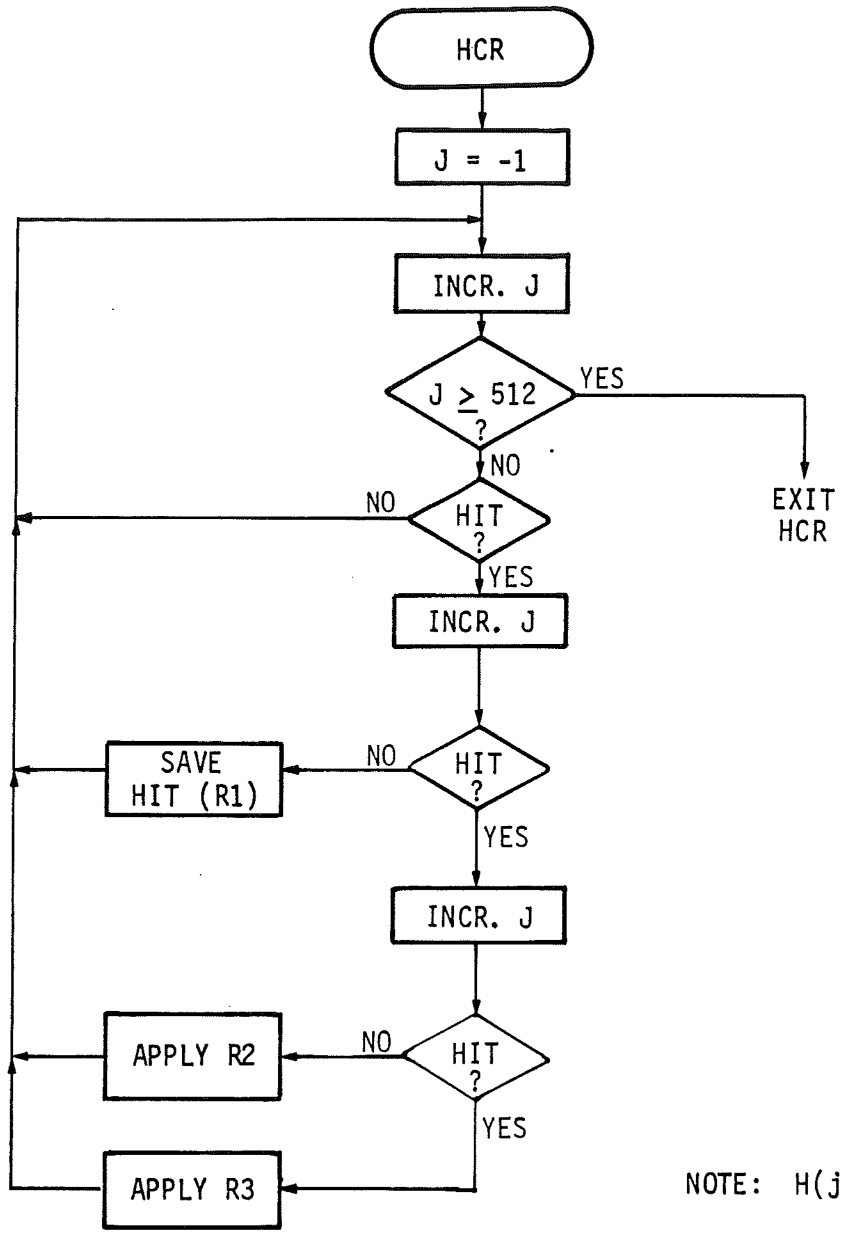
	BEFORE			AFTER		
RULES	H(j-2)	H(j-1)	H(j)	H(j-2)	H(j-1)	H(j)
R1	0	1	0	0	1	0
R2	1	1	0	0	1	0
R3	1	1	1	0	1	0

Where H(j) is the current element under examination.

Then the coarse hit filter numbers are defined as follows:

$$J_c = \{k \mid H(k) = 1\}$$

An implementation of the Hit Cluster Reduction (HCR) rules is represented in the flow diagram of Figure 2.8.2.1.



NOTE: H(j) = 0 for J > 511

Figure 2.8.2.1 - HIT CLUSTER REDUCTION

The following example illustrates a typical reduction process:

Example:

Let H(k) = 0 for 24 < k and k < 15 and k = 20

k	15	16	17	18	19	20	21	22	23	24	25
H(k) BEFORE	1	1	1	1	1	0	1	1	1	1	0
RULES	R3			R2			R3			R1	
H(k) AFTER	0	1	0	0	1	0	0	1	0	1	0

$\{J_c = 16, 19, 22, 24\}$

2.8.3 Output

The set of coarse filter hits, J_c, as the reduced hit array

$\{H(k) \mid k = 0, \ldots, 511\}$.

2.9 $\dot{R}$ Data Search

This section operates in three modes:

1) Search Mode,
2) Acquisition I Mode, and
3) Acquisition II Mode.

In the Search Mode, an array is set aside to collect the doppler frequency shifts of all the identified targets. In the Acquisition I and II Modes, this array is examined to determine the smallest doppler shift beyond a minimum frequency given by the RDP. This minimum frequency is designated by the command "Coarse Range Rate ($\dot{R}$) A."

2.9.1 Input

- The reduced hit array from Hit Cluster Reduction subfunction:

  $\{H(k) \mid k = 0, \ldots, 511\}$

- Coarse $\dot{R}$ A for Acquisition I and II modes from RDP.
- Mode select word from RDP.

2.9.2 Processing

2.9.2.1 Search Mode Processing

The action of this mode is to place the doppler frequency shifts of identified targets into an array (D) as follows:

$$D = \{k_i \mid H(k_i) = 1\}$$

where: i is the target index

k_i is the i-th target doppler shift index.

2.9.2.2 Acquisition I and II Modes Processing

The logic of Acquisition I & II modes is to identify the target in the array (D) that has the smallest doppler shift beyond the Coarse $\dot{R}$ A. This doppler shift is designated by F.

2.9.3 Outputs

2.9.3.1 Search Mode

- The doppler shift of identified targets:

$$D = \{k_i \mid H(k_i) = 1\}$$

2.9.3.2 Acquisition I & II Modes

- The array (D) as in the Search Mode.
- The smallest doppler $\geq$ the Coarse $\dot{R}$ (i.e., F)

2.10 AZIMUTH CENTROIDING

The technique of azimuth centroiding of radar target samples is designed to improve the radar azimuth resolution so that closely spaced radar targets can be resolved. At the same time, this technique prevents the initiation of false targets from any strong target which can yield radar returns in several adjacent doppler azimuth elements. Azimuth centroiding replaces the currently used method of inhibiting all adjacent azimuth hits from a strong target except the initial hit.

2.10.1 Inputs

- The set of coarse filter hits from Hit Cluster Reduction.
- Antenna "Video Azimuth" (DSC Word 2) from RDP.
- Azimuth Centroider Inhibit flag from RDP.

2.10.2 Processing

The initial phase of the Azimuth Centroiding function is the tagging of each target doppler (coarse filter hit) with an azimuth value from the RDP. If the Az Centroider Inhibit flag is set (i.e. logical "1"), the azimuth centroiding procedure is NOT performed. The azimuth value tagged to the target doppler and the coarse filter number of the target are output. If the Az Centroider Inhibit flag is reset (i.e. logical "0"), the azimuth centroiding procedure is performed as described in the following paragraphs.

Centroiding is performed when a target generates two or more successive hits in the same doppler cell or one doppler cell $\pm K_1$. [K_1 is the half width of the data collection gate shown in Fiugre 2.10.1]. The multiple hits from the single target would be detected over successive Azimuth Centroiding cycles. The one doppler and azimuth computed by this function for the multiple hits is an average of the target's input doppler and tagged azimuth positions over a number of phases. The azimuth centroiding is accomplished by establishing azimuth centroider "tracks" for each target. Associated with each track are:

$\dot{R}_o$ = Doppler bin of the track initiator

$\dot{R}_c$ = Current doppler bin of the track

AZ_o = Azimuth of the track initiator

AZ_c = Current azimuth of the track

N_H = Hit counter

N_M = Miss counter

A schematic diagram showing possible radar samples from a strong target or multiple targets is illustrated in Figure 2.10.1. These samples straddle several doppler bins and azimuth elements.

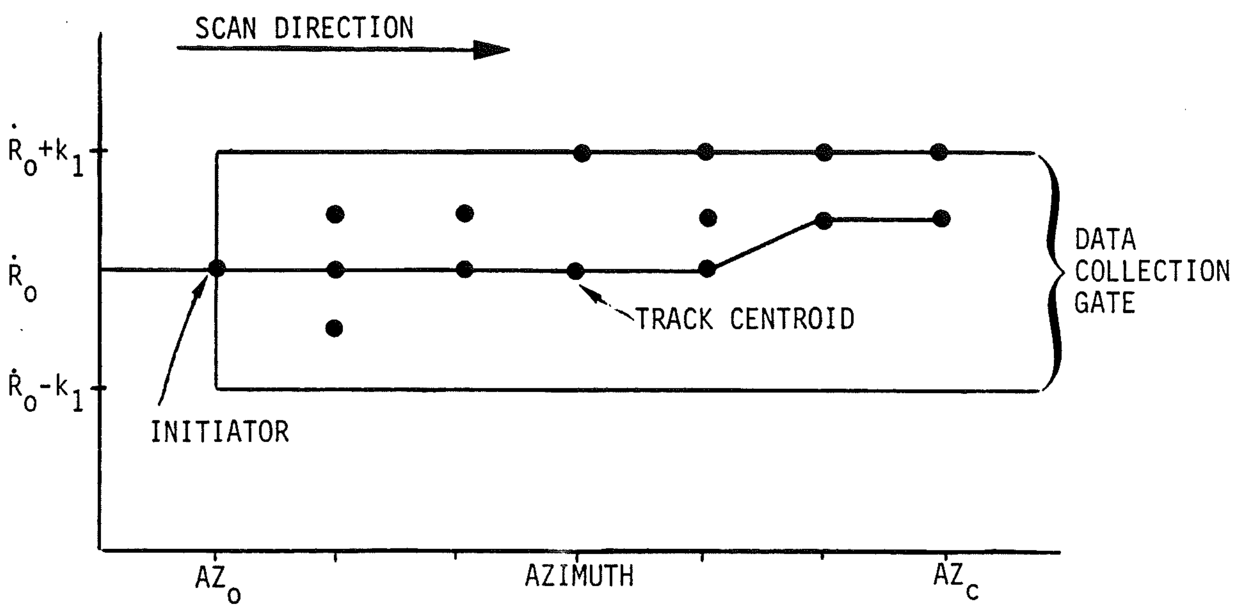


Figure 2.10.1 - AZIMUTH CENTORIDING

For azimuth centroiding, the target samples along each azimuth element within $\dot{R}_c+k_1$ and $\dot{R}_c-k_1$ doppler bins are candidates for correlation with a track, where k_1 represents the half width of the data collection gate. Track correlation, initiation and termination are performed as follows.

2.10.2.1 Track Correlation

1) For each track, a search is made for doppler hit(s) within the data collection gate ($\pm k_1$ doppler bins about the current target doppler bin, $\dot{R}_c$).

2) Only one hit is allowed to correlate with a given track. If more than one hit is found in the data collection gate, the hit in doppler bin $\dot{R}_c$ is chosen as the correlated hit; if such a hit does not exist, the hit with the highest doppler is chosen as the correlated hit.

3) If a correlated hit is found, the track doppler, $\dot{R}_c$, is set equal to the doppler bin of the correlated hit, the track azimuth, AZ_c, is set to the current video antenna azimuth and the track miss counter, N_M, is set to zero. The correlated hit is deleted from the hit list.

4) If no correlated hit is found, the track miss counter N_M is incremented by one.

5) In all cases, the track hit counter N_H is incremented by one to indicate the total number of azimuth elements since the initiator.

2.10.2.2 Track Initiation

1) Any uncorrelated hits remaining in the hit list after track correlation is performed are used to initiate new tracks.

2) The track parameters for each new track are initialized as follows:

$\dot{R}_o = \dot{R}_c$ = doppler bin of uncorrelated hit

AZ_o = current video antenna azimuth

N_H = 1

N_M = 0

2.10.2.3 <u>Track Termination</u>

1) If the miss counter for a track equals N_S misses, the track is terminated.

2) If the hit counter for a track equals N_{MAX}, the track is terminated.

3) If $|\dot{R}_o - \dot{R}_c|$ for a track exceeds $\dot{R}_{MAX}$, the track is terminated.

4) A centroided target position is computed for each terminated track and sent to the Display Processing function.

a) The centroided doppler of the target is the average of the doppler bin of the initiator and the doppler bin of the last hit in the track:

$$\dot{R} = IPO[(\dot{R}_o + \dot{R}_c)/2 + 0.5]$$

b) The centroided azimuth of the target is the average of the azimuth of the initiator and the azimuth of the last hit in the track:

$$Az = IPO[(Az_o + Az_c)/2 + 0.5]$$

2.10.2.4 Azimuth Centroider Parameter Values

Parameter values for the HPRF $\dot{R}$ Search and Acquisition Mode are as follows:

k_1 = 1 doppler bin

N_S = 3 misses

N_{MAX} = 10 hits

$\dot{R}_{MAX}$ = 5 doppler bins

2.10.3 Outputs

- The doppler filter number and azimuth of centroided targets to Display Processing.

2.11 Display Processing

The Display Processing shall perform an interface functions between the radar and the VSD for target and BIT Window Display. Inputs from the Azimuth Centroiding logic and from the RDP shall be processed and formatted for display. Target storage is provided in order to allow a target's recent position history to be displayed. Also, other stored parameters (elevation, PRF) concerning a particular target may be recalled at the RDP's request.

Outputs from this function which are destined for the VSD, are sent via the Display Interface Unit (DIU) hardware module in the PSP.

2.11.1 Inputs

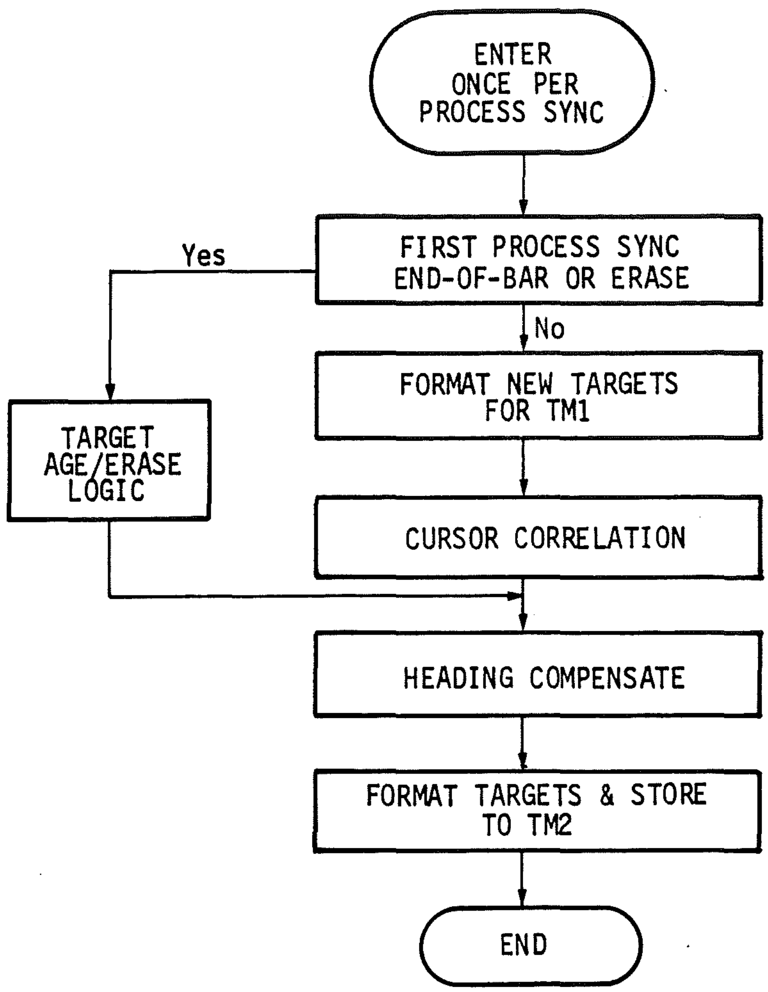
- Display Control words from RDP via DSC Words.
- Mode control ($\dot{R}$ Search, $\dot{R}$ Acq. I, $\dot{R}$ Acq. II) from RDP.
- Centroided target coordinates (doppler frequency index, azimuth) from Azimuth Centroiding subsection 2.10.
- Heading compensation angle ($\Delta\psi$) from RDP.

2.11.2 Processing

The Display Processing program shall be entered once per process synch interval. New inputs from the RDP, and new targets from Azimuth Centroiding shall be processed along with previously stored data to produce 1) a new image output for the VSD, and 2) the necessary stored target information for the RDP. The program shall establish two blocks of memory for use in this processing.

A "working" memory called TM1 shall contain up to 128 targets and shall be manipulated as required during the processing to form the new desired VSD images. A second storage memory called TM2 shall be provided to store the VSD images from one process synch to the next. TM2 is directly accessed by the DIU module for output to the VSD.

Figure 2.11.2.1 is an overall block diagram of the Display Processing program. Subsequent sub-paragraphs discuss each of the processing operations shown in the diagram.



DISPLAY PROCESSING LOGIC

Figure 2.11.2.1

2.11.2.1 Formatting Targets

Incoming target data points are given in terms of $\dot{R}$/Azimuth coordinates. $\dot{R}$ is expressed in units of doppler filter number ($0 \rightarrow 511$), azimuth is expressed in "display units" where the LSB is $120^0/496$. Output targets are stored in TM2 with both coordinates in display units. The necessary translation from doppler filter number (F) to y-axis display unit (Y) is illustrated in Figure 2.11.2.1.1. The following equation accomplishes the projection of filter number onto the display axis as shown in the figure.

$$Y = \mathrm{IPO}\left[(F + 11)\left(\frac{496}{522}\right) - 248 + .5\right]$$

Note that input targets with filter numbers ($0 \rightarrow 11$) are discarded.

Additional information which must be carried with each target in the mode is:

PRF (current HPRF in use)	(2 bits)
Elevation scan bar number	(3 bits)
Intensity code = 111 initially	(3 bits)
Synthetic target identifier	(1 bit)

The format of TM2 storage is dictated by the DIU module requirements. Figure 2.11.2.1.2a shows the format for TM2 targets. Figure 2.11.2.1b shows the set of words which must be sent to display symbology other than targets (i.e., cursor, antenna position markers, range scale, etc.). The PSP program must form this group of words (from RDP inputs) each process synch time.

The specific format of TM1 is to be left to the programmer in order to allow the most efficient processing of the data. However, the TM1 memory is intended to carry up to 128 of the most recent targets. This means that the targets must be located in memory, or tagged in order of recency, so that overflows of target data can be resolved in favor of more recent targets by discarding the "oldest" targets.

(NOT TO SCALE)

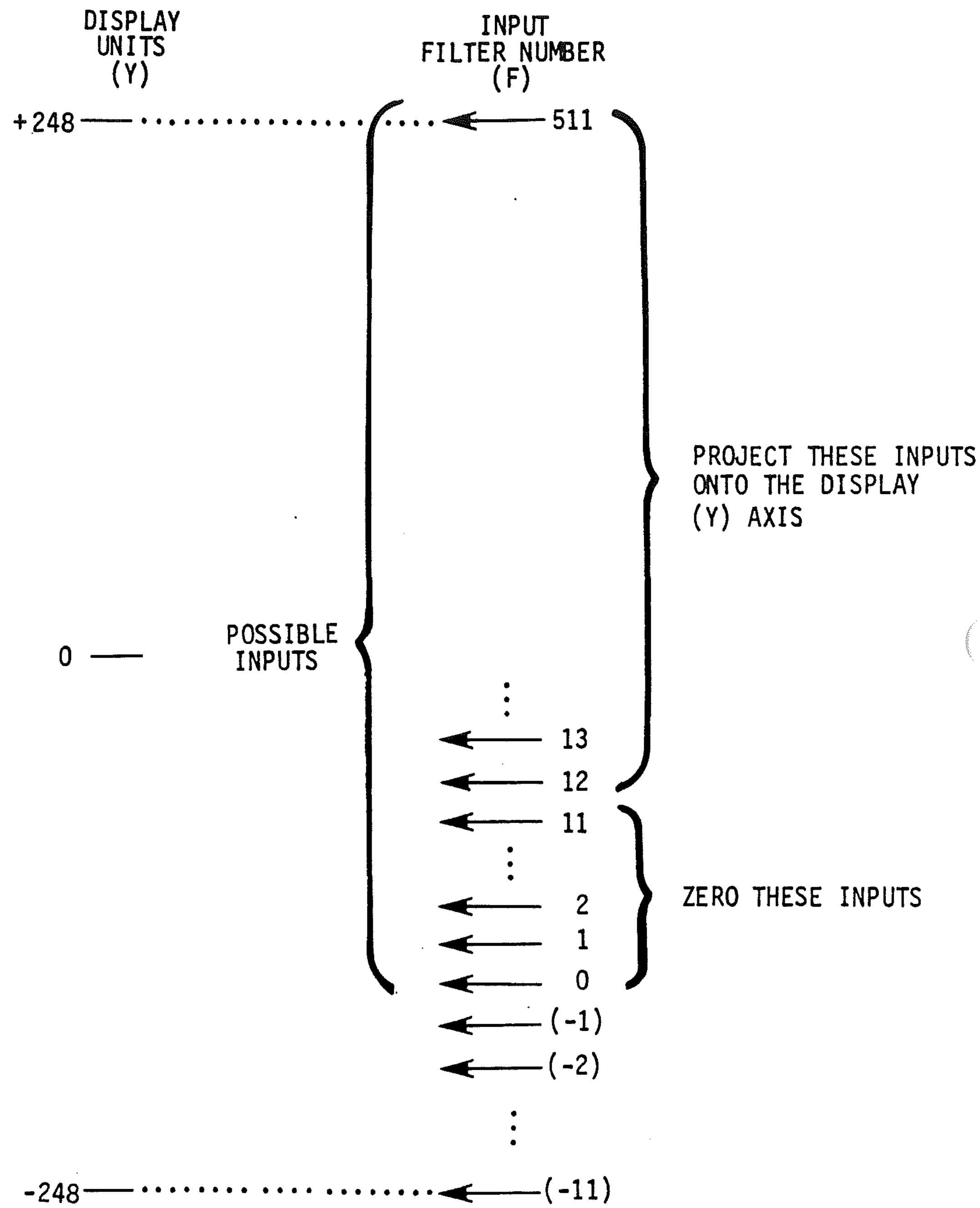


Figure 2.11.2.1.1

$\dot{R}$ SEARCH MODE DISPLAY SCALING

BIT POSITION

WORD #	PURPOSE	0–3	5	16	28	31	33				44	47
1 TO 128	TARGET WORDS	4 BITS WORD CODE (0011)	IFF CODE (00)	11 BITS AZIMUTH POSITION (X)	12 BITS RANGE POSITION (Y)	3 BITS EL BAR	PRF	0	0	SYNTHETIC TARGET	8 BITS SPARE	3 BITS INTENSITY

a) Target Words

		0 3	5		14	23	24 to 44	45 46 47
129	RNG/VEL SCALE	0 1 0 0	0 0	RNG/VEL SCALE	0 0 0 0 0 0	0 0 0 0 0 0 0 0 0	NOT USED	1 1 1
130	CURSOR POSITION	0 1 0 1	0 0	X POSITION		Y POSITION		1 1 1
131	ANT AZ POSITION	0 1 0 1	0 0	X POSITION		1 0 0 0 1 0 1 1 0		1 1 1
132	ANT EL POSITION	0 1 0 1	0 0	1 0 0 0 1 0 1 1 0		Y POSITION		1 1 1
133	BIT WORD #1	0 1 0 1 or 0 0 0 0	0 0	1st CHARACTER	2nd CHARACTER	3rd CHARACTER		1 1 1
134	BIT WORD #2	0 1 0 1 or 0 0 0 0	0 0	4th CHARACTER	5th CHARACTER	6th CHARACTER		1 1 1

b) Display Symbol Word

FIGURE 2.11.2.1.2 - TM2 BULK MEMORY WORDS (HPRF Ṙ SEARCH MODE)

2.11.2.2 Cursor Correlation

This function is performed in order to report stored parameters concerning a selected target to the RDP. The purpose is to allow the RDP to optimize the probability of acquiring a particular target by use of the stored parameters (elevation bar#, PRF, and synthetic target identification bit). Whenever the RDP commanded mode is "$\dot{R}$ Acq. I", the PSP program shall search the TM1 memory for a target which lies within a predetermined $\dot{R}$/Azimuth window. The window size is given as $\pm$ 16 Azimuth (X) display units by $\pm$ 12 $\dot{R}$(Y) display units centered about a point designated by the RDP. (The RDP designates the center of the cursor correlation window by the control words "Acquisition Symbol X" and "Acquisition Symbol Y"). The search for the targets begins with targets of intensity code = 6, and sequentially searches throughout decreasing intensity codes until a target is found. If no target is found, the search begins again with the intensity code = 6 targets and continues until, 1) a target is found, or 2) the $\dot{R}$ Acq. I mode is deselected. When a correlated target is found, its parameters are reported to the RDP via the next scheduled IDA transmission.

2.11.2.3 Target Age/Erase Logic

Target Aging and Erase Logic is required to control the display intensity of targets sent to the VSD. This logic changes (ages) the display intensity or erases the displayed targets according to the "AGE" or "ERASE" commands, respectively, sent to the RDP. When a target is first detected, the target's display intensity is set at the maximum brightness of the eight state intensity level scale (3 bits); then the intensity level is decreased in accordance with the Aging and Erase logic, which is further illustrated and discussed in MPRF Search, section 4.16.2.3.

2.11.2.4 Heading Compensation

Targets are displayed in the "X" dimension in terms of ownship aircraft horizon stabilized coordinates. Therefore, stored targets must be compensated for ownship heading changes in order to continually be displayed at the proper azimuth. A heading compensation increment ($\Delta\psi$) is supplied by the RDP each process synch interval. The increment is expressed in azimuth display units ($120^{O}/496$). The increment is applied to each target in TM1. Targets are tested after each heading compensation update to determine if the maximum azimuth limits ($\pm 60^{O}$) have been exceeded. All targets exceeding these limits are eliminated.

2.11.3 Outputs

- VSD data in the form of 134 48-bit.
- Bulk Memory words as shown in Figure 2.11.2.1.2a & b.
- Radar target data from the cursor correlation window:
    - Elevation Bar Number
    - PRF
    - Synthetic Target Identifier
    - Target Doppler Filter Number.

2.12 Additional Processing (TBS)

Reference PSP-18 Volume 2 DS31325-147
(PSP Computer Program Development Specification)

SECTION 3

HPRF TRACK MODE

3.0 INTRODUCTION

In the HPRF Track Mode, the PSP is programmed to process two sets of samples taken from Track 1 and Track 2 channels respectively. The objective of the processing is to use the radar sum (Σ) and the radar difference (Δ) signals embedded in these samples to compute the target tracking errors in azimuth, elevation and velocity. In the Fast Track Mode, the errors are computed once every 8.602 msec., while in the Slow Track Mode, the errors are computed once every 34.408 msec. The time line for either mode of processing is divided into four phases. The Σ & Δ data in two of the phases yields the azimuth tracking error, and the Σ & Δ data in the other two phases yields the elevation tracking error. The same data used in the angle errors computation are manipulated to yield the target velocity tracking error. RDP receives these errors at the frequency specified by the track mode.

A Hit/Miss logic is included to test if the target doppler shift lies in an 11-cell "speed gate". A positive result confirms that the tracking is indeed "on target". This logic is used to validate the tracking errors that are sent to the RDP.

The functional diagram of the HPRF Track Mode is shown in Figure 3.1.1. The data processing for this mode as explained above is performed by the four modules:

a) Data Sorting,
b) Spectrum Computation
c) A/A HPRF Track Discriminants,
d) Signal/Noise Computation & Hit/Miss Logic

In addition to the tracking errors, the following information is also obtained for the RDP:

a) azimuth Angle Ratio Threshold, ART (Az),
b) elevation Angle Ratio Threshold, ART (El),
c) signal and noise information pertaining to the 11-cell "speed gate".

The HPRF Track Mode is supported by the Timing and Control and the Display Processing modules. The former provides all the switching functions for the HPRF Track data processing, while the latter module is used to format the range-azimuth coordinates of the tracked target for the VSD. The details of each functional module in Figure 3.1.1 are discussed in the following sections.

3.1 Timing and Control (T&C)

Timing and Control is concerned with the communication between the RDP, the PSP, and the rest of the Radar System. Generally, the interaction between these devices begins with the RDP selecting a mode of operation (i.e., HPRF Track). This action causes the Radar System to transmit and receive pulses at a mode-determined PRF. The Radar System gathers samples from the radar return signal for storage in the PSP. When a complete set of samples is ready, the PSP is alerted to begin processing the set. The PSP processing program is dictated by the mode words given by the RDP. After the PSP is through with the processing, the RDP must be ready to accept the results. This interaction is repeated until the RDP selects another mode of operation.

The communication between RDP, PSP and the rest of the Radar is established through the timing functions. Figure 3.1.2 shows a list of the major timing functions related to HPRF Track Mode. The details of these functions and the T&C module are discussed in Section 3.1.2.

3.1.1 Input

- Mode Command from RDP (HPRF Track Mode)
- PRF Command from RDP
- Angle Identification Code for RDP
- Track Mode from RDP (Fast or Slow)
- 20 MHz reference frequency (internal to PSP)
- 7.14 MHz reference frequency (internal to PSP)

3.1.2 Processing

The timing signals can be divided into two groups:

a) Radar System timing functions, and

b) the PSP timing functions.

The first group of signals is generated by a 20 MHz clock in the T&C module while the second group is generated by a 7.14 MHz clock internal to the PSP.

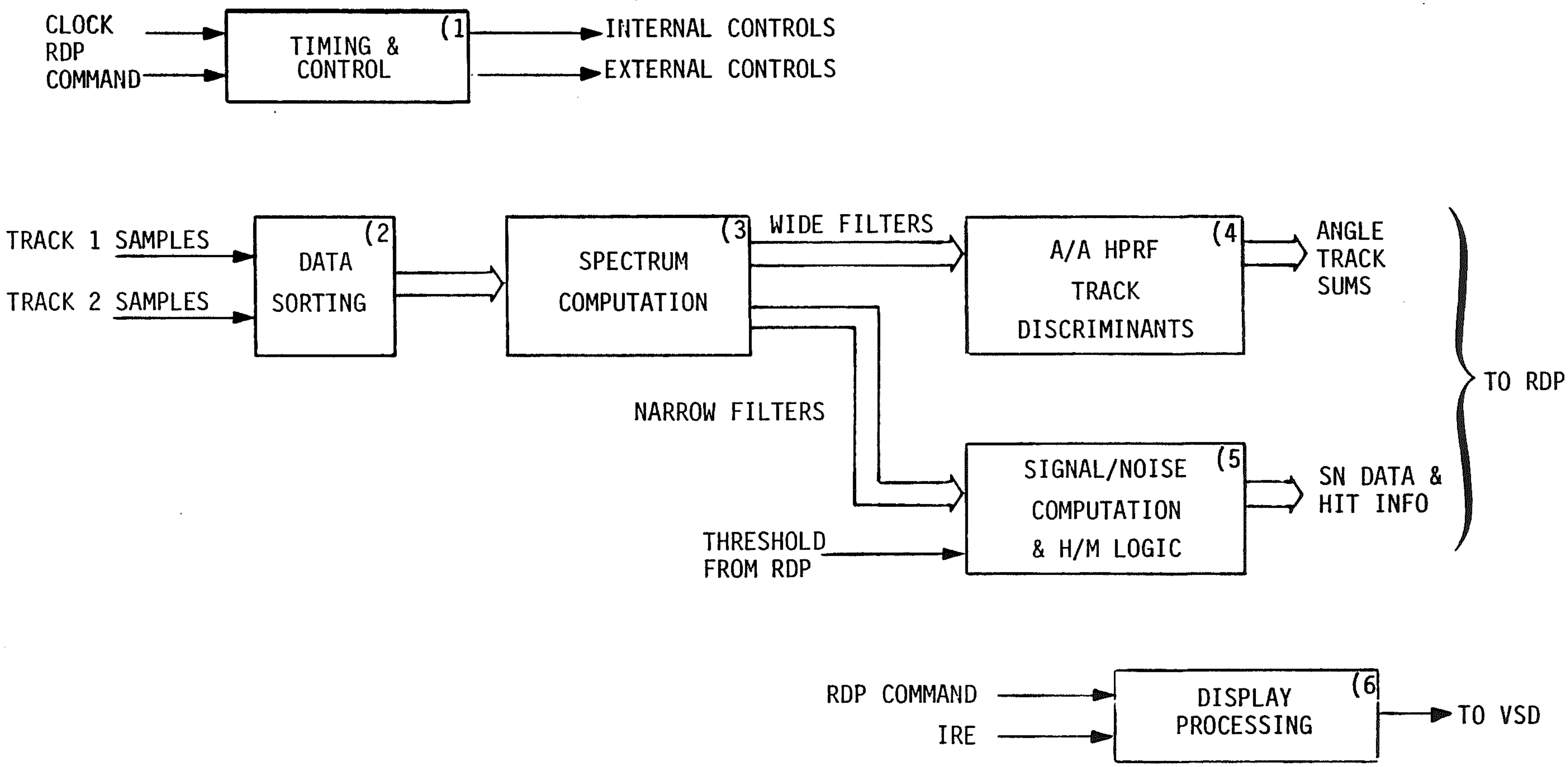


Figure 3.1.1 - HPRF TRACK FUNCTION DIAGRAM

3.1.2.1 T&C Module

The T&C module and its interface between the RDP and the PSP is shown in Figure 3.1.3. The module consists of:

1) a 20 MHz clock,
2) a current control table buffer, and
3) timing generators.

RDP can place a control table at any time into the current control table buffer through Memory C. The content of the buffer and the 20 MHz clock determines the Radar System timing functions to be formed by the timing generators.

3.1.2.2 HPRF Track Timing Functions

The major timing functions used in the HPRF Track Mode are described below:

Timing Functions	Descriptions
Radar Transmit Pulses	These pulses are generated by the Radar exciter unit (001). The exciter generates several HPRF's in response to commands from the RDP. These commands are routed through the PSP unit.
A/D Sampling Syncs*	These pulses are used in gathering the samples from the radar return signal. 512 pulses take place every 8.602 msec. These pulses and the radar transmit pulses are not synchronized. The next three Radar timing functions listed below are synchronized to this signal.
Angle Sequence Syncs*	These pulses are used to identify a group of samples with a radar Angle Ident Code. In the Fast Track Mode, the Angle Sequence Syncs occur once every 128 sampling syncs, while in the Slow Track Mode they occur once every 512 sampling syncs.

*These signals are derived from the 20 MHz clock in T&C.

Timing Functions	Descriptions
Process Syncs*	These syncs occur once every 512 sampling syncs. They alert the PSP to begin processing the samples prepared by the Radar System. They are also sent to the RDP to allow it to synchronize with the processing.
IDA Data Valid Syncs*	These pulses appear after the PSP has finished one batch of data processing. They alert the RDP to accept the PSP output. These syncs occur once every 512 sampling syncs.
PSP Processing Clocks	These pulses are generated by the 7.14 MHz clock within PSP. They are used for the PSP processing. These pulses are not synchronized to the processing syncs generated by the T&C module.

3.1.3 Outputs

- Radar System timing functions
- PSP timing functions

*These signals are derived from the 20 MHz clock in T&C.

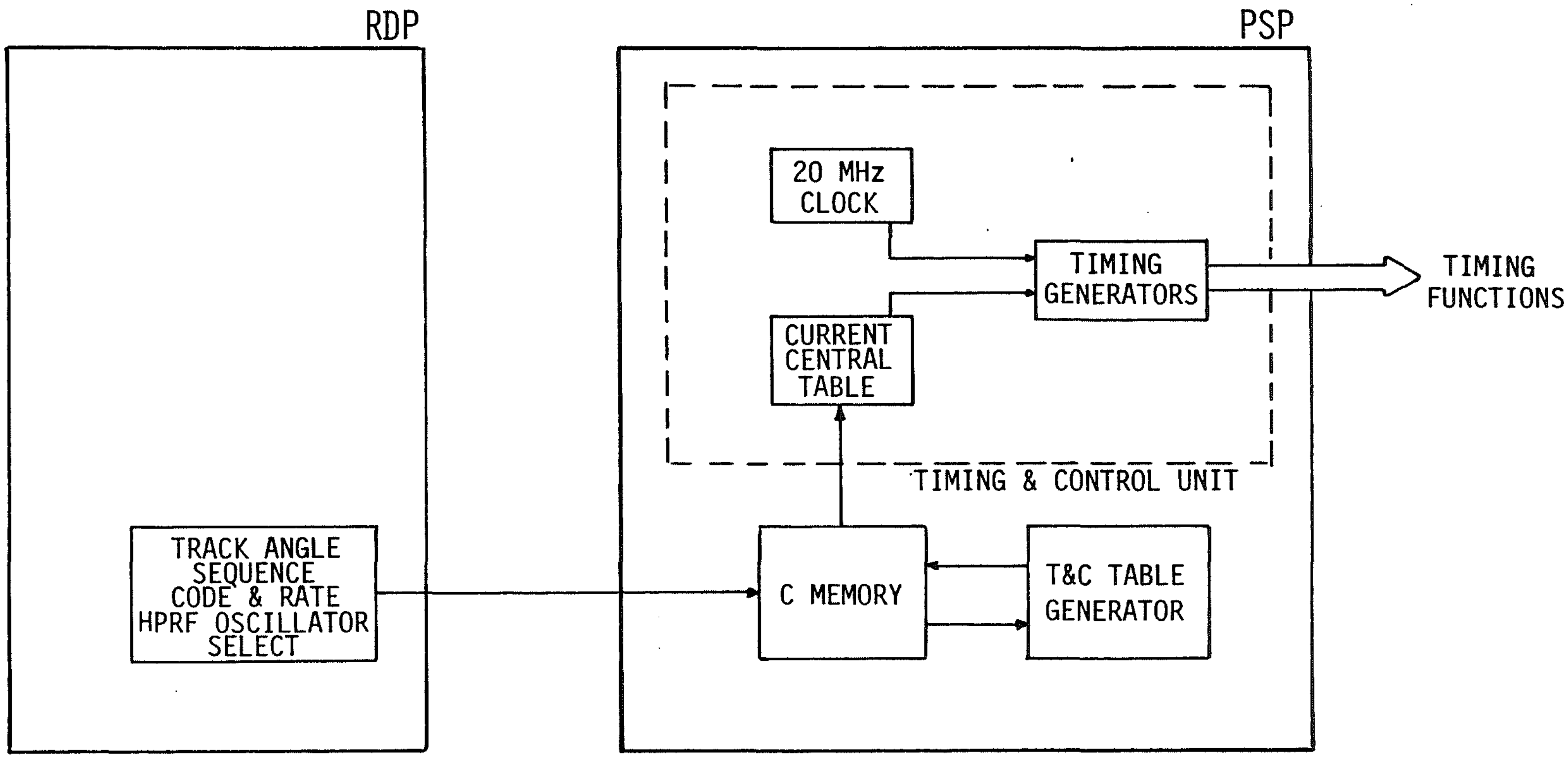


Figure 3.1.3 - INTERFACE BETWEEN THE RDP, PSP AND THE T&C MODULE

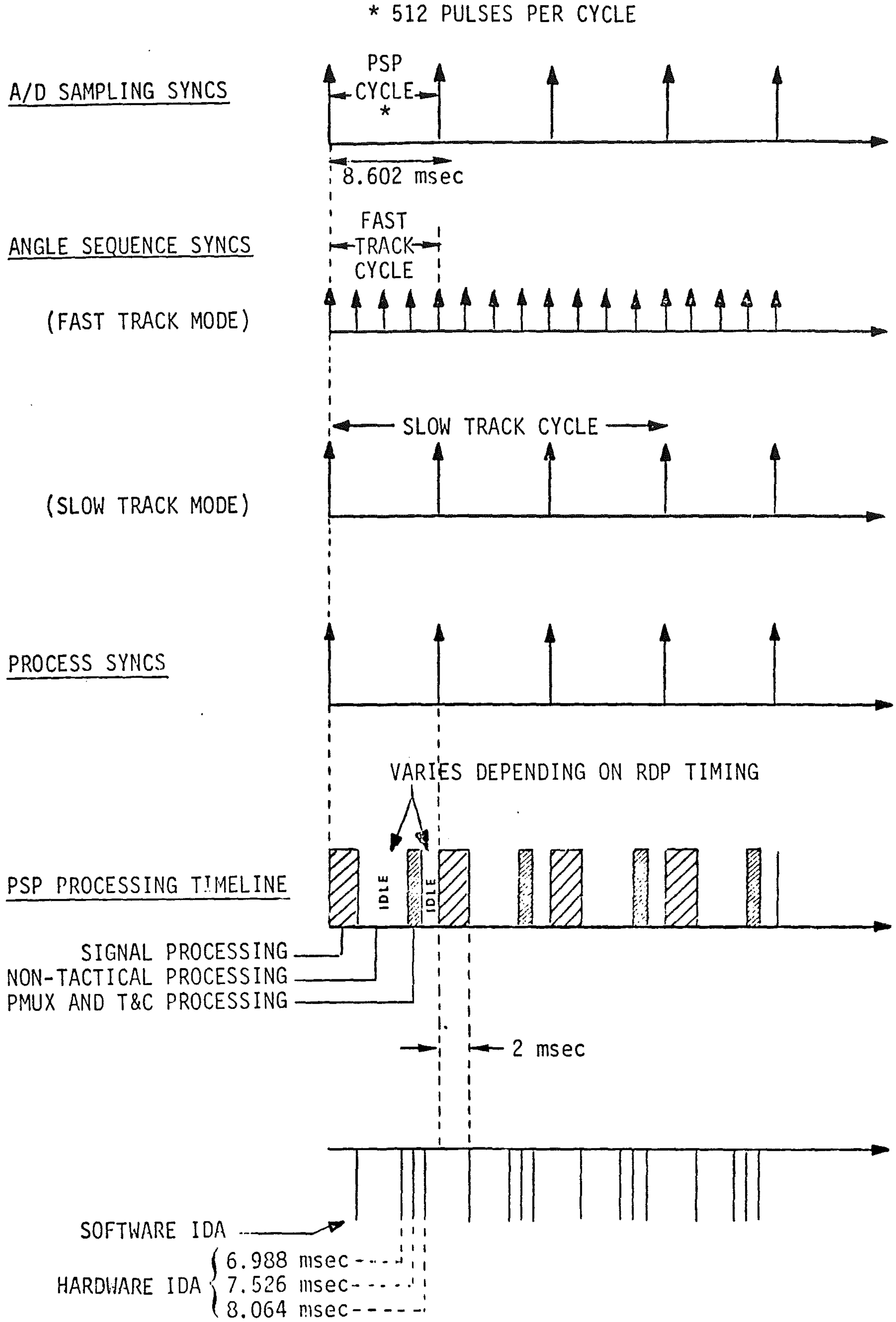


Figure 3.1.2 - HPRF TRACK TIMING FUNCTIONS

3.2 Data Sorting

Two sets of 512 time-ordered samples are taken from Track 1 and Track 2 channels respectively. The samples are collected over an 8.6 msec. period. The purpose of Data Sorting is to sub-divide both of the sets into 5 groups each. Four of the groups are formed by selecting the first 128 samples, the second 128 samples, and so on. The fifth group is formed by selecting every fourth sample from the entire set of 512. A total of 10 groups of 128 samples is output to the spectrum computation function for each 8.6 msec. period.

3.2.1 Input

- Two sets of 512 samples from Track 1 and Track 2:

  $\{S(i,T) \mid i = 0, \ldots, 511;\ T = 1,2\}$

  where: i is the sample number
  T is the track index.

3.2.2 Processing

The definitions below describe the groups of samples for each track, T = 1,2:

a) $\{S_g(i,T) \mid S_g(i,T) = S(i + 128 \times (g-1), T);\ g = 1,2,3,4\}$

b) $\{S_5(i,T) \mid S_5(i,T) = S(4i,T);\ i = 0, \ldots, 127\}$

3.2.3 Output

- Ten groups of samples as defined in 3.2.2:

  $\{S_g(i,T) \mid g = 1,2,3,4,5\}$

  "g" is called a group index.

3.3 Spectrum Computation

The frequency spectrum is computed for each group of samples defined in section 3.2.2. This is done by passing the weighted samples of each group through a Fast Fourier Transform.

Two types of filters, narrow and wide, result from the computations. The filters computed for the S_5-samples are the narrow ones; the filters for the other groups of samples are the wide ones. The S_5 samples are taken over a period four times longer than the period covered by a phase group. This causes the bandwidth of the S_5-filters to be narrower than the phase group filters.

3.3.1 Input

- Ten groups of samples from section 3.2.3:

$$\{S_g(i,T) \mid T = 1,2;\ g = 1, \ldots, 5\}$$

3.3.2 Processing

The Discrete Fourier Transform (DFT) of the weighted samples from each group is:

$$F_g(k,T) = \sum_{n=0}^{127} [A(n) \times S_g(n,T)] \bullet W^{nk}$$

where:

$W = \exp[-j2\pi/128]$

$k = 0, \ldots, 127;$ (filter index)

$T = 1,2;$

$g = 1, \ldots, 5$

$A(n) =$ weights; Table 3.3.1

3.3.3 Output

Two sets of narrow filters:

$$\{F_5(k,T) \mid T = 1,2\}$$

Eight sets of wide filters:

$$\{F_g(k,T) \mid T = 1,2;\ g = 1, \ldots, 4\}$$

Table 3.3.1 - AMPLITUDE WEIGHTS

SAMPLE NUMBER n		AMPLITUDE WEIGHTS *
0 - 7	120 - 127	.157744
8 - 15	112 - 119	.242805
16 - 23	104 - 111	.359267
24 - 31	96 - 103	.469327
32 - 39	88 - 95	.573323
40 - 47	80 - 87	.651752
48 - 55	72 - 79	.726108
56 - 63	64 - 71	.76000

* An improved set of amplitude weights may be provided at a later date.

3.4 A/A HPRF Track Discriminants

3.4.1 Inputs

The following signals from the Amplitude Weighting and FFT Function are inputs to the HPRF Track Angle Discriminants function. An entire matrix of M_f filters is available. A subset of 11 filters is designated as the tracking gate.

HPRF Mode

- TRK1 LoF I
- TRK1 LoF Q
- TRK1 HiF I
- TRK1 HiF Q
- TRK2: 4 Words same as TRK1

Angle Track (T)

The data rate of the above signals is once per 8.602 msec. in slow track angle sequence and once per 2.15 msec. for fast track angle sequence. The following additional internal signals are required by this function from RDP.

- Angle Sequence Rate from RDP
- Angle Identifier from RDP
- Number of process sync per Kalman filter cycle (1 or 4) from RDP.

3.4.2 Processing

The purpose of this function is to provide the F-15 RDP program with the capability to compute tracking error signals (discriminants) from the PSP processed data.

3.4.2.1 Angle Track

In Track, the angle tracking loop is closed through angle discriminants computed in this function. Computations for angle discriminants and for Angle Ratio Threshold (ART) are done in this function.

For HPRF, define vectors A, C, E, G:

$$A = (\text{Trk 1 LoF I}) + j\,(\text{Trk 1 LoF Q})$$
$$C = (\text{Trk 2 LoF I}) + j\,(\text{Trk 2 LoF Q})$$
$$E = (\text{Trk 1 HiF I}) + j\,(\text{Trk 1 HiF Q})$$
$$G = (\text{Trk 2 HiF I}) + j\,(\text{Trk 2 HiF Q})$$

$$C' = (\text{Trk 2 LoF Q}) - j\,(\text{Trk 2 LoF I})$$
$$G' = (\text{Trk 2 HiF Q}) - j\,(\text{Trk 2 HiF I})$$
$$K = A - E$$
$$L = C - G$$

Then the components to be used for the velocity and range discriminants are given by:

$$N_V = |A + C'| - |E + G'|$$
$$D_V = |A + C'| + |E + G'|$$

and the components N_A and D_A to be used for the angle discriminants are given by:

$$N_A = \Sigma\Delta = \frac{1}{8}(K \cdot L) = \frac{1}{8}(I_K I_L + Q_K Q_L)$$

$$D_A = \Sigma^2 = \left|\frac{1}{4}(K - jL)\right|^2 = \frac{1}{16}\left|(I_K + Q_L)^2 + (Q_K - I_L)^2\right|$$

and for ART,

$$|\Delta|^2 = \left|\frac{1}{4}(K + jL)\right|^2 = \frac{1}{16}\left|(I_K - Q_L)^2 + (Q_K + I_L)^2\right|$$

where

Σ implies antenna sum signal and Δ implies antenna difference signal.

In angle tracking, four sets of N_V, D_V, N_A, D_A and $|\Delta|^2$ are computed within a process synch interval. Each set of these applies to either the elevation or azimuth tracking channel depending upon the input variable "Angle Identifier" from the RDP for that subphase as follows:

Angle Identifier		00	01	10	11
Phase Index	=	+AZ,	-AZ,	+EL, or	-EL

Running sums of each of the following terms are to be maintained for the duration of each track filter iteration cycle as commanded by the RDP.

$$\text{Sum (1)} = \Sigma\{N_V(+AZ) + N_V(-AZ) + N_V(+EL) + N_V(-EL)\}$$

$$\text{Sum (2)} = \Sigma\{D_V(+AZ) + D_V(-AZ) + D_V(+EL) + D_V(-EL)\}$$

$$\text{Sum (5)} = \Sigma\{N_A(+AZ) - N_A(-AZ)\}$$

$$\text{Sum (6)} = \Sigma\{D_A(+AZ) + D_A(-AZ)\}$$

$$\text{Sum (7)} = \Sigma\{N_A(+EL) - N_A(-EL)\}$$

$$\text{Sum (8)} = \Sigma\{D_A(+EL) + D_A(-EL)\}$$

$$\text{Sum (9)} = \Sigma\{|\Delta(+AZ)|^2 + |\Delta(-AZ)|^2\}$$

$$\text{Sum (10)} = \Sigma\{|\Delta(+EL)|^2 + |\Delta(-EL)|^2\}$$

3.4.3 Outputs

The following internal signals are made available as outputs of this function:

- The eight HPRF (angle) track running sums as provided for above.

3.5 Signal-Noise Computations and Hit/Miss Logic

The "speed gate" mentioned in the Introduction is a passband nominally centered on the target doppler. This passband encompasses 11 discrete frequencies of the narrow filters. In the following discussions, the speed gate refers to the narrow filters numbered from 13 through 23.

The tasks performed in this section are:

1) To determine the signal amplitude in the 3 center cells of the "speed gate".

2) To determine the early and late noise amplitude in the "speed gate".

3) To use the data from 1 & 2 in the Hit/Miss logic to form an 11-bit Hit/Miss word.
The Hit/Miss word is used in the RDP to validate the discriminants computed in section 3.4 of this report.

3.5.1 Inputs

- Narrow doppler filters for Track 1 and Track 2 channels from section 3.3

  $\{F_5(k,T) \mid T = 1,2\}$

- Angle Ident Code from RDP.
- Track Mode from RDP (Fast or Slow).

3.5.2 Processing

The operation performed on the speed gate over each 8.602 msec is essentially identical for the Fast and Slow Track Modes. The outline of the routines shared by both modes is given in this section. The details of the Fast Track and Slow Track modes are given in sections 3.5.2.1 and 3.5.2.2.

The definitions below are used for the processing:

a) The set of speed gate filters is defined as follows:

$$\{F_{SG}(k,T) \mid F_{SG}(k,T) = F_5(k+13,T);\ k=0,\ \dots,\ 10\}$$

b) The radar sum (Σ) and difference (Δ) signals of the speed gate filters are given by;

$$F_{\Sigma}(k) = F_{SG}(k,1) - jF_{SG}(k,2)$$

$$F_{\Delta}(k) = F_{SG}(k,1) + jF_{SG}(k,2)$$

c) The 11-bit Hit/Miss Word is given by:

$$\{H(k) | k = 0, \ldots, 10\}$$

The sequence of operation performed on the speed gate is:

1. Compute the signal S:

$$S = \sum_{k=4}^{6} |F_{\Sigma}(k)|$$

2. Compute the early noise (NE) and the late noise (NL):

$$NE_{\Sigma} = \sum_{k=0}^{3} |F_{\Sigma}(k)|$$

$$NE_{\Delta} = \sum_{k=0}^{3} |F_{\Delta}(k)| \qquad \text{; (Slow Track only).}$$

$$NL_{\Sigma} = \sum_{k=7}^{10} |F_{\Sigma}(k)|$$

$$NL_{\Delta} = \sum_{k=7}^{10} |F_{\Delta}(k)| \qquad \text{; (Slow Track only).}$$

3. Set $N_{0,\Sigma} = \frac{1}{11} \sum_{k=0}^{10} |F_{\Sigma}(k)|$

$$N_{0,\Delta} = \frac{1}{11} \sum_{k=0}^{10} |F_{\Delta}(k)|$$

4. Execute the Hit Miss Logic:

$$H_{\Sigma}(k) = \begin{cases} 1, \text{if } |F_{\Sigma}(k)| \geq TM \times N_{0,\Sigma}; & \text{a hit} \\ 0, \text{ otherwise} & ; \text{a hit} \end{cases}$$

$$H_{\Delta}(k) = \begin{cases} 1, \text{if } |F_{\Delta}(k)| \geq TM \times N_{0,\Delta}; & \text{a hit} \\ 0, \text{ otherwise} & ; \text{a miss} \end{cases}$$

For k = 0 to 10.

3.5.2.1 Fast Track Mode

In this mode, the PSP executes the operation above and sends out S, NE_{Σ}, NL_{Σ}, H_{Σ} and H_{Δ} to RDP once every 8.602 msec.

3.5.2.2 Slow Track Mode

In the Slow Track Mode the operation given in section 3.5.2 is repeated for four 8.602 msec. periods. The results from each period are associated with an angle phase. Angle Ident Code makes this association. Thus over the four periods, the following data are obtained:

$S_{\emptyset}$	the signals from each phase;
$NE_{\Sigma,\emptyset}$	early noise in the sum component;
$NL_{\Sigma,\emptyset}$	late noise in the sum component;
$NE_{\Delta,\emptyset}$	early noise in the difference component;
$NL_{\Delta,\emptyset}$	late noise in the difference component;
$H_{\Sigma,\emptyset}$	hit/miss word sum;
$H_{\Delta,\emptyset}$	hit/miss word difference.

where $\emptyset$ is the phase index as defined in section 3.4.2.1.

The Hit Miss Word is sent out to RDP once every 8.602 msec. The other data are processed as follows:

1. Compute the signal S:

$$S = \sum_{\phi=1}^{4} S_{\phi}$$

2. Compute the early and late Σ noise for the azimuth and the elevation phases:

$$NE_{\Sigma,AZ} = NE_{\Sigma,+AZ} + NE_{\Sigma,-AZ}$$
$$NE_{\Sigma,EL} = NE_{\Sigma,+EL} + NE_{\Sigma,-EL}$$
$$NL_{\Sigma,AZ} = NL_{\Sigma,+AZ} + NL_{\Sigma,}{-AZ}$$
$$NL_{\Sigma,EL} = NL_{\Sigma,+EL} + NL_{\Sigma,-EL}$$

3. Compute the Δ noise in the azimuth and elevation phases:

$$N_{\Delta,AZ} = NE_{\Delta,+AZ} + NE_{\Delta,-AZ} + NL_{\Delta,+AZ} + NL_{\Delta,-AZ}$$
$$N_{\Delta,EL} = NE_{\Delta,+EL} + NE_{\Delta,-EL} + NL_{\Delta,+EL} + NL_{\Delta,-EL}$$

3.5.2.3 Bit Shift

When the Signal and Noise quantities have accumulated over the number of Process Syncs per Kalman Filter Cycle (N_p), all the Signal and Noise data shall be shifted so that the most significant data bit of the largest signal or noise word is located in the most significant word bit location. The number of places, maximum of 15, the signal and noise quantities are binary shifted (BS) shall be saved and included in outputs.

3.5.3 Output

3.5.3.2 Fast Track Mode

The signal	: S	
Early Noise	: NE_{Σ}	
Late Noise	: NL_{Σ}	
Hit/Miss Words	: H_{Σ}	(sum)
	H_{Δ}	(difference)

3.5.3.2 Slow Track Mode

- The signal : S
- Early Sum Noise in azimuth : $NE_{\Sigma,AZ}$
- Late Sum Noise in azimuth : $NL_{\Sigma,AZ}$
- Early Sum Noise in elevation : $NE_{\Sigma,EL}$
- Late Sum Noise in elevation : $NL_{\Sigma,EL}$
- Difference noise in azimuth : $N_{\Delta,AZ}$
- Difference Noise in elevation: $N_{\Delta,EL}$
- Hit/Miss Word, sum (Once every 8.602 msec.) : $H_{\Sigma},\emptyset$
- Hit/Miss Word, difference (Once every 8.602 msec.) : $H_{\Delta},\emptyset$
- Bit Shift

3.6 Display Processing

Display Processor is a PSP program that assembles the tracked target data from the RDP and IRE for the Vertical Situation Display unit (VSD). The processor stores this data in that part of the Bulk Memory called TM2. This data is then retrieved, reformatted, and sent to VSD by the DIU module (See Figure 3.6.1).

3.6.1 Input

- DSC words from RDP.
- IFF Reply Word from IRE.
- Mode X Ident Command from EWWS.

3.6.2 Processing

In the HPRF Track Mode, the Display Processor is divided into two parts. In the first part, the processor forms 16 VSD Words as shown in Figure 3.6.3. These words are assembled from the DSC Words given by the RDP. The second part is the IFF code determination. This code is inserted into VSD Word 12, and is used to select the target symbol for display.

3.6.2.1 IFF Code Determination

This operation is carried out in two ways. If the IFF Challenge code given by the RDP is '0', the processor sets the IFF code in the VSD Word 12 (bits 4 & 5) to '00' and sends the VSD words to TM2. If the IFF Challenge code is '1', then the following sequence of operations are performed (See Figure 3.6.2).

1. IFF Correlation:

   This routine compares the tracked target position given by the RDP against the positions of the IFF targets that have been supplied by the IFF Reply Evaluation (IRE). (IRE updates this list of IFF targets constantly when the Inhibit code in the IRE Word is '0'). A correlation is established if there is at least one IFF target whose range and azimuth fall within a correlation window. This window is given by the ± 12 range bins (or ± 1.25 nm) and ± 16 azimuth bins (or $\pm 4^{\circ}$ in azimuth) about the tracked target coordinates. This routine terminates at the first correlation or when all IFF targets in the current list have been examined.

2. If there is no IFF correlation, then the processor sets the IFF code to '00' and goes to Step 5.

3. If there is an IFF correlation, the processor reports this to the RDP through IDA. The RDP, in turn, sets the Identified code in the IRE word to "1". This, in effect, tells IRE that an IFF correlation has been established.

4. If the Mode X command from EWWS is "1", then the processor sets the IFF code to '11'; otherwise this code is set to the IFF code of the correlated IFF target.

5. The processor sends the VSD words to TM2.

6. The program exits.

3.6.3 Output

- 16 VSD words to VSD.
- IRE Word to IRE.
- IFF correlation code to RDP.

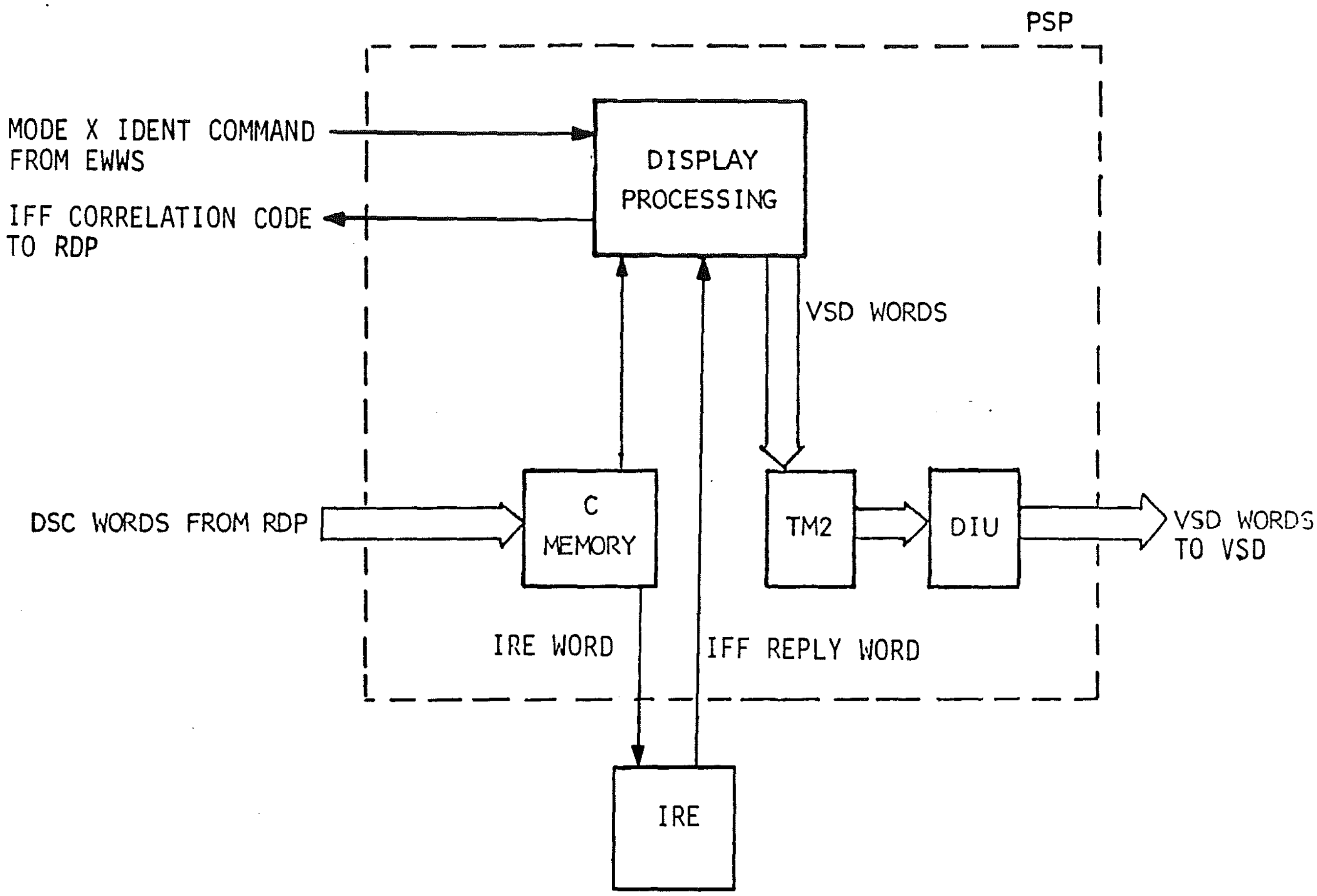


Figure 3.6.1 - DATA FLOW BETWEEN THE PSP, RDP, IRE AND THE VSD UNIT DURING DISPLAY PROCESSING

Table 3.6.1 - HPRF TRACK DISPLAY PROCESSING DATA LIST

NAME	FROM → TO	DATA	NOTE
DSC WORDS*	RDP→PSP	ACQ. SYMBOL X	TRACKED TARGET AZIMUTH
		ACQ. SYMBOL Y	TRACKED TARGET RANGE
		RANGE SCALE	
		ANTENNA AZIMUTH	
		ANTENNA ELEVATION	
		IFF CHALLENGE	ONE BIT CODE
		BIT WORDS #1 & #2	DISPLAY MESSAGE, 6 CHARACTERS.
IFF REPLY WORD*	IRE→PSP	IFF TARGET AZIMUTH	
		IFF TARGET RANGE	
		IFF CODE	TWO BIT CODE
MODE X** COMMAND	EWWS→PSP		ONE BIT CODE
IRE WORD**	RDP→IRE	INHIBIT	ONE BIT CODE
		IDENTIFIED	ONE BIT CODE
		RANGE SCALE	
		ANTENNA AZIMUTH	
IFF CORRE-LATION CODE	PSP→RDP		ONE BIT CODE
VSD WORDS**	PSP→VSD	DISPLAY TARGET AZIMUTH	
		DISPLAY TARGET RANGE	
		IFF CODE	
		ANTENNA AZIMUTH	
		ANTENNA ELEVATION	
		BIT WORDS #1 & #2	

* DS 31325-002, Vol. III, Rev. E, Page 135.

**F-15 Signal Catalog, MDC A0385, Dec. 15, 1974, Rev. C, pp:5-2, 6-2, 6-16, 7A-5.

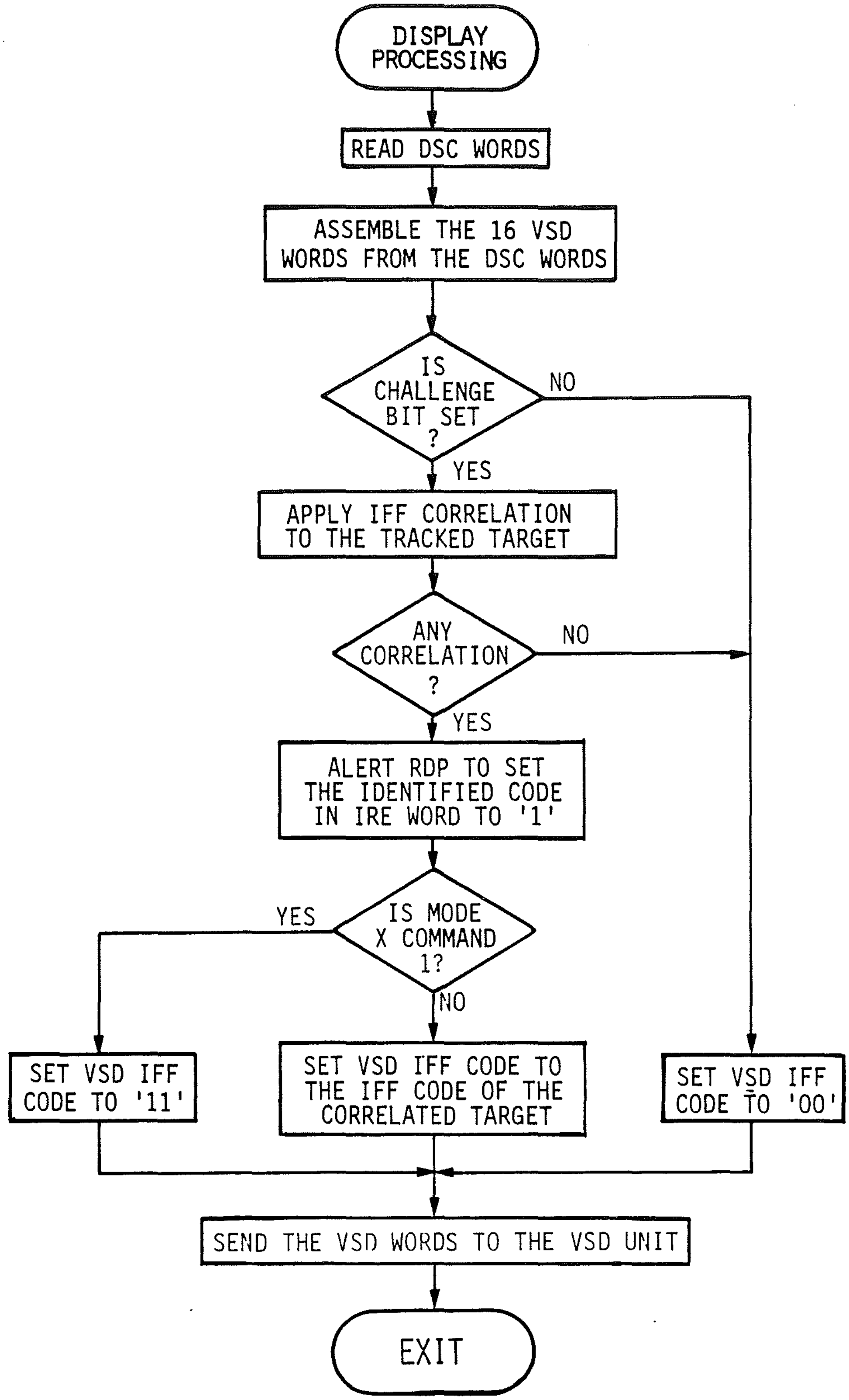


Figure 3.6.2 - HPRF TRACK DISPLAY PROCESSING

WORD	NAME	BIT POSITION						
		0 1 2 3	4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23				24-44	45 46 47
1-10	BLANK	0 0 0 0	THESE BIT POSITIONS MAY BE RANDOMLY SET					
11	RNG/VEL SCALE	0 1 0 0	0 0	RNG/ VEL SCALE	0 0 0 0 0 0 0 0 0 0 0 0 0 0 0		0	1 1 1
12	TRACKED TGT POS	0 0 0 1	IFF CODE	AZIMUTH	RANGE			1 1 1
13	ANT. AZ. POSITION	0 1 0 1	0 0	AZIMUTH	1 0 0 0 1 0 1 1 0		0	1 1 1
14	ANT. EL. POSITION	0 1 0 1	0 0	1 0 0 0 1 0 1 1 0	ELEVATION		0	1 1 1
15	BIT WORD #1	0 1 0 1 or 0 0 0 0	0 0	1st CHARACTER	2nd CHARACTER	3rd CHARACTER	0	1 1 1
16	BIT WORD #2	0 1 0 1 or 0 0 0 0	0 0	4th CHARACTER	5th CHARACTER	6th CHARACTER	0	1 1 1

Figure 3.6.3 - DISPLAY PROCESSOR TO VSD DIGITAL DATA (HPRF TRACK)

3.7 Additional Processing (TBS)

Reference PSP-18 Volume 2 DS31325-147
(PSP Computer Program Development Specification)

SECTION 4

MPRF SEARCH MODE

4.0 INTRODUCTION

In the forthcoming Programmable Signal Processor (PSP) demonstration, a new PSP processer replaces the current hardwired Radar Signal Processor (RSP 041 Unit). This PSP processor is interchangeable with the current RSP (041 Unit), performs the same radar signal processing functions in MPRF search and acquisition, and provides display data for the Vertical Situation Display (VSD). This incorporation of PSP in F-15 radar system offers the reliability and flexibility to add new modes and additional processing capabilities in the near future.

The new PSP processor shall operate in accordance with the control command instructions from the Radar Data Processor (RDP 081 Unit), shall control and synchronize the operation with other radar units, and shall process the digital radar data from the Analog Radar Signal Processor (ARSP 039 Unit). The PSP software shall provide important data processing functions such as radar target enhancement, side lobe suppression, target search and acquisition, target centroiding and data display under normal or jamming conditions.

To illustrate the MPRF search and acquisition modes, a functional block diagram of the digital data processing scheme in the RSP of F-15 radar is shown in Figure 4.1. The diagram contains both hardware and software functions.

In the hardware areas, the analog data from the ARSP (039 Unit) is converted into digital form before being sent to a two stage delay-line clutter canceller for background clutter suppression.

As shown in Figure 4.1, the 13 element Barker code is used for the pulse compression. To improve the pulse compression, a doppler compensator is used to de-rotate the radar vectors and to null out most of the doppler rotation before the data is pulse compressed.

After pulse compression, a factor of two-to-one reduction in target intensity together with rounding-off or some saturation logic is used to prevent the saturation of a 12 bit word in the I and Q channels. Four data words consisting of 24 bits plus one parity bit are packed into a 100 bit word for transfer to PSP bulk memory.

In the software areas, the PSP performs the following software functions.

a) Dynamic FFT Scaling for saturation control.

b) A 32 point amplitude weighting to reduce doppler filter side lobes.

c) A two-to-one data turning to enhance target signals.

d) Fast Fourier Transform (FFT) to form 16 doppler filters.

e) Ensemble averaging to determine background noise levels.

f) Thresholding for main and guard channels for target detection.

g) Hit/Miss logic for target discrimination and background clutter blanking.

h) Range resolving of target returns by using the data from the major and two minor PRFs.

i) Range centroiding of strong target returns for better range resolution.

j) Azimuth centroiding of strong target returns to inhibit multiple target initiations and to improve azimuth resolution.

k) Display processing to reformat target data and, for VSD display, to correlate radar targets with IFF data.

l) Special thresholding and additional processing.

m) Clutter Doppler Error (CDE) processing to determine doppler errors incurred in shifting main lobe clutter to dc.

n) Acquisition processing to report radar hits to the RDP.

The PSP signal processing timeline is arranged slightly different from the current hard-wired signal processor. The PSP accumulates data over a period of time and processes in "batches", rather than the more or less continuous processing in RSP systems. This means that signal processor outputs to the display and to the RDP is available at an approximate 12 msec. rate (RSP output rate is $\approx$ 4 msec). This change is necessary to take full advantage of the PSPs processing speed on large volumes of data. No reduction in the total processing operations performed results from this change, the processing is simply re-arranged in time.

The "radar timeline" (the time sequence of transmitted PRF and Pulse Width) is also slightly altered from the RSP configuration. An $\approx$ 700 μsec period is inserted into the timeline between two of the 9 PRFs in the sequence. During the 700 μsec, a short-range non-coherent target detection is performed on a single PRIs data. The detection involves a simple amplitude thresholding of 1 μsec range bin samples over a range interval.

The time required to perform the processing operations shown in Figure 4.1 varies with the nature of the input data. This characteristic of PSP processing is not generally true of the hard-wired processor. For this reason, care must be taken to assure that sufficient time is available to process input data sets. Furthermore, if sufficient time is <u>not</u> available, a warning signal shall be provided to the RDP to indicate that an entire data set cannot be processed in time. In that case, the PSP program selectively discards data as required.

The following sections of this report discuss the individual elements of the software processing shown in Figure 4.1. Each section that follows is numbered to correspond with an operation shown in Figure 4.1.

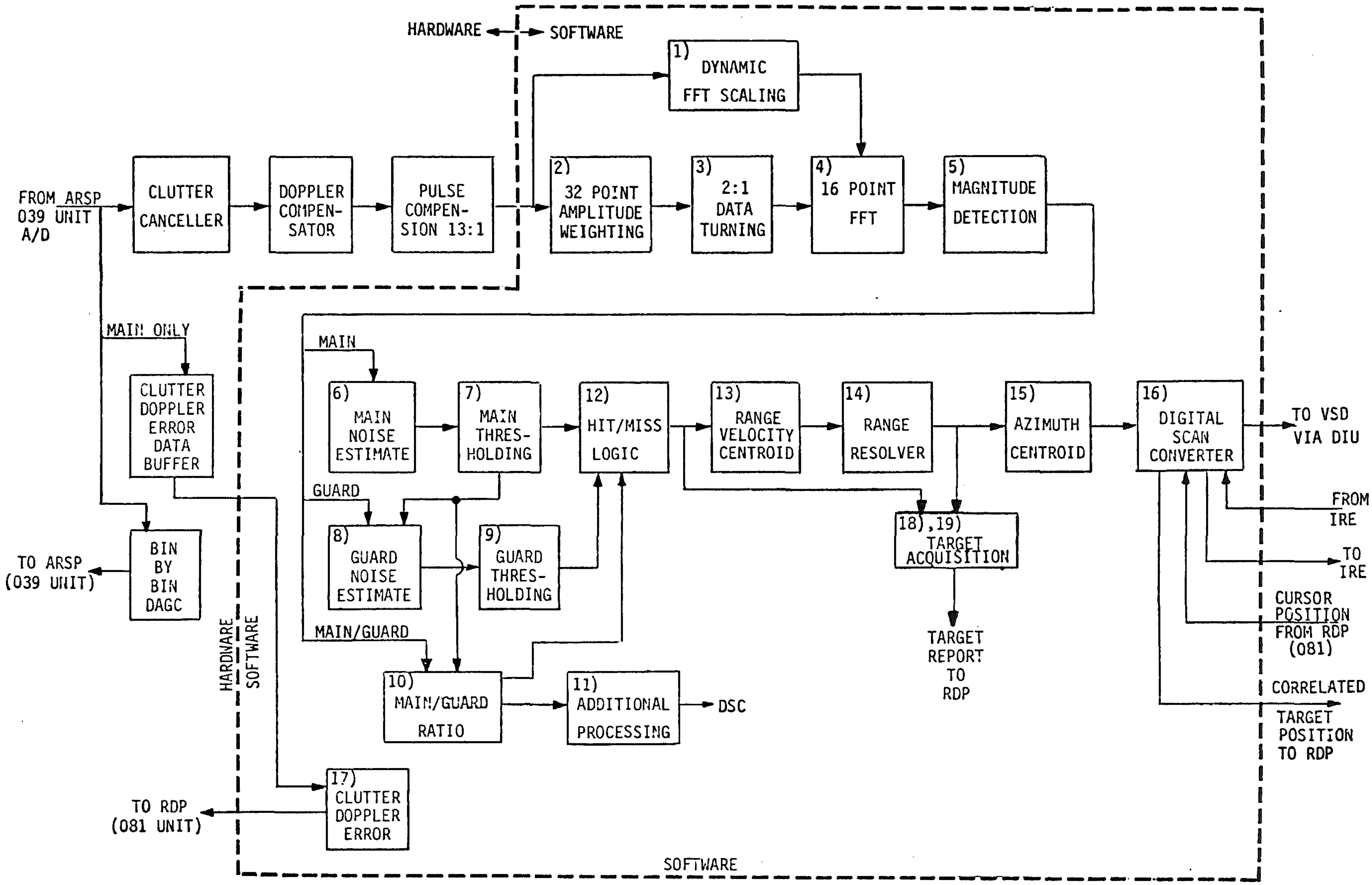


Figure 4.1 - F-15 SOFTWARE FUNCTION BLOCK DIAGRAM MPRF SEARCH

4.1 Dynamic Fast Fourier Transform Scaling

The MPRF Search Mode uses dynamic scaling for FFT saturation control and increased sensitivity. The figure 4.1.5 illustrates this transfer function between amplitude weighting and FFT.

4.1.2 Inputs

- Main Channel In-phase (I) and Quadrature (Q) samples from the bulk memory of the PSP.

4.1.3 Processing

- Magnitude detect one PRI of data.
- Determine the amplitude of the largest signal (S_{max}).
- Determine the number of divide by two's by:

$$N = IPO \left(LOG_2 \; (N_f) + LOG_2 \left(\frac{S_{max}}{FS} \right) \right)$$

where: NF = The number of filters formed (16)

FS = Full Scale Magnitude (2048)

IPO = Integer part of

4.1.4 Outputs

- Send the FFT the number of divide by two's to perform for the current PRF.
- Send the RDP the number of divide by two's in IDA word #4 bits 0-3.

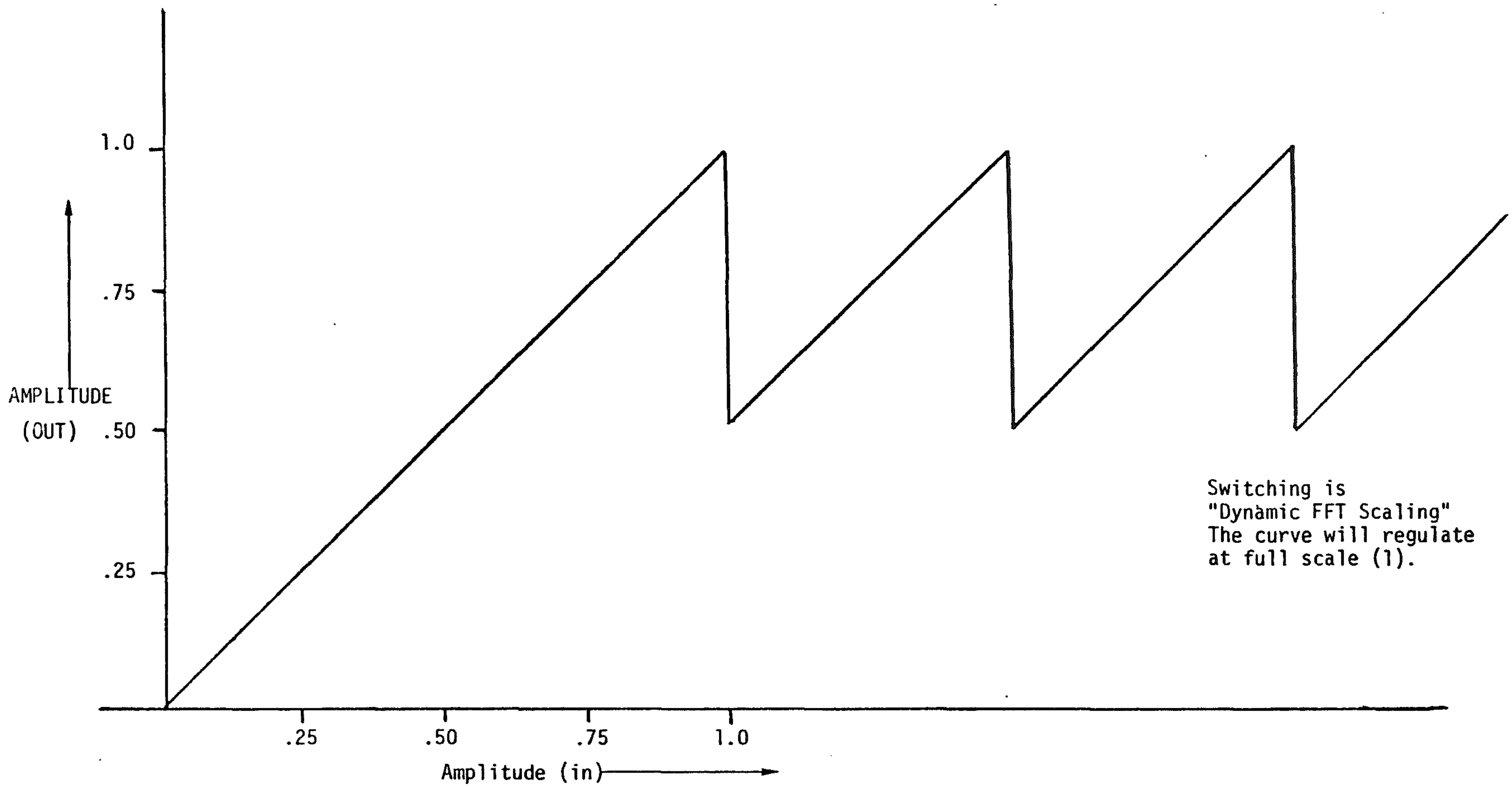


FIGURE 4.1.5 - DYNAMIC FFT SCALING

4.2 32 Point Amplitude Weighting

4.2.1 Inputs

- Main Channel In-phase (I) and Quadrature (Q) samples from the Bulk Memory of the PSP.
- Guard Channel In-phase (I) and Quadrature (Q) samples from the Bulk Memory of the PSP.

4.2.2 Processing

The amplitude weighting processor shall preprocess the data samples for the Fast Fourier Transform (FFT) so that the output of the FFT can achieve the desired peak mainlobe to peak sidelobe ratio.

Each data set shall be Amplitude Weighted across the 32 pulses accumulated for each range bin in both the main and guard channels according to the following formula.

$$S_W(i,n) = A(n) \cdot S(i,n)$$

where:

S = the complex I and Q data sample

$S_W(i,n)$ = weighted sample of ith range bin and nth pulse ($i = 15$ to N_{RB}, $n = 1$ to 32)

$S(i,n)$ = the unweighted samples of ith range bin and nth pulse

$A(n)$ = Kaiser weights as shown in Table I which are real and symmetrical (These weights may be rounded to the nearest values).

4.2.3 Outputs

- Weighted Main Channel I, Q samples to PSP Bulk Memory for (N_{RB} - 14) samples for each of 32 pulses.
- Weighted Guard Channel I, Q samples to PSP Bulk Memory for (N_{RB} - 14) samples for each of 32 pulses.

TABLE I 32 POINT KAISER WEIGHTS

FOR F-15 MPRF MODE

SAMPLE NUMBER n	AMPLITUDE WEIGHTS A (n)
1, 32	.000488
2, 31	.003906
3, 30	.011719
4, 29	.027344
5, 28	.054199
6, 27	.095703
7, 26	.154785
8, 25	.232422
9, 24	.328125
10, 23	.438965
11, 22	.559082
12, 21	.680176
13, 20	.793457
14, 19	.889160
15, 18	.958984
16, 17	.995117

4.3 Data Turning

Data is collected from thirty-two successive pulses on each of the nine PRFs. This volume of data is reduced by a factor of two before being sent to the FFT process. The data is reduced by coherent addition of the first pulse samples to the 17th pulse samples, the second to the 18th, and so on. This form of coherent addition is called Data Turning.

4.3.1 Inputs

- Main Channel amplitude weighted complex samples (I,Q) from Section 4.2. A data point for each processed range bin X 32 pulses.
- Guard Channel (same as above).

4.3.2 Processing

Designate the input data points as $S_W(i,n)$ for the ith range bin, nth pulse sample point. Then the (data turned) output points are given as:

$$S_D(i,n) = S_W(i,n) + S_W(i,n + 16)$$

$$\text{for } n = 1,2 \ldots, 16.$$

The process is performed for Main and Guard data.

4.3.3 Outputs

- Main Channel data turned complex samples (I,Q) to Section 4.4 FFT. A data point for each processed range bin X 16 (data turned) pulses.
- Guard Channel (same as above).

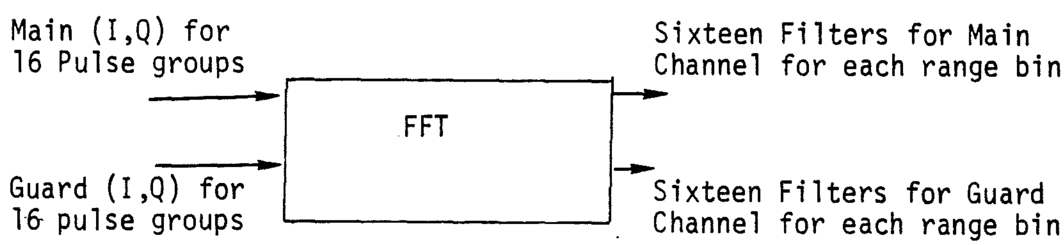
4.4 Fast Fourier Transform

The purpose of the FFT in the MPRF Search Mode is to form sixteen digital doppler filters for each range bin from thirty-two PRFs of radar data. The timeline sequence for the MPRF Search Mode is shown in Figure 4.4.1. The thirty two pulse groups of data are amplitude weighted and two to one data turned to form sixteen pulse groups. (See sections 4.2 & 4.3 for a description of amplitude weighting and data turning). These sixteen pulses of data are the inputs to the FFT process and consist of:

1) Main Channel I and Q for all processed range bins.
2) Guard Channel I and Q for all processed range bins.

Restrictions are placed on the data described in (1) and (2) above. Due to the receiver blanking some of the following range bins of data are not used:

1) Receiver blanking zeroes out 2 range bins in short pulse and 14 range bins in long pulse.
2) The FFT processes 64 range bins (zeroed or not) in all cases.
3) The 64 processed bins are the first 64 in the PRI for short pulse, the last 64 are long pulse.



FFT Process

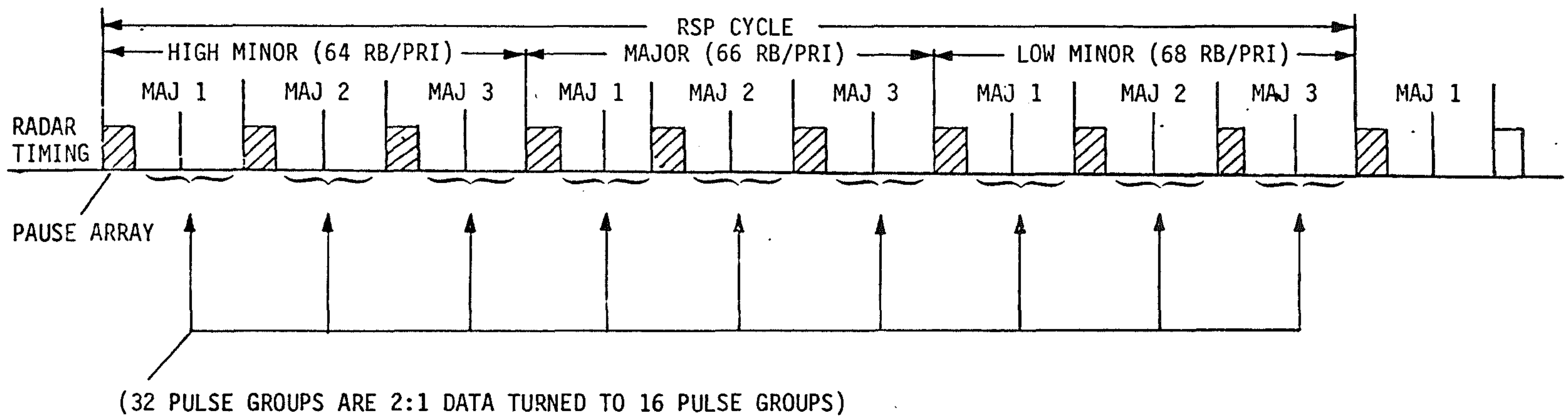


Figure 4.4.1 - MPRF SEARCH TIMELINE

4.4.1 Inputs

- Number of range bins per PRI (N_{RB}). There are sixteen samples for each one of these range bins for both main and guard channels. See Figure 4.4.1 for N_{RB} definition (64, 66, 68).
- Main Channel I and Q samples for each range bin from section 4.3.
- Guard Channel I and Q samples for each range bin from section 4.3.
- Phase Rotation Coefficients (8), described in section 4.4.2.
- Number of divide by two's (Dynamic Scaling) from section 4.1.

4.4.2 Processing

The Discrete Fourier Transform inputs of Main/Guard I and Q data for sixteen PRIs are transformed into sixteen filters for each range bin in Main and Guard channels via the expression:

$$F(i,k) = \frac{1}{16} \sum_{M=0}^{15} W^{Mk} \, S_D(i,M)$$

where:

- i is the range bin number
- W is $e - \frac{2\pi j}{16}$
- M is the sample number
- k is the filter number
- S_D is an input data sample

The phase rotation constants W^{Mk} may be precomputed and stored in PSP bulk memory. Because of the symmetrical layout of the phase constants, W^{Mk}, on the unit circle, only eight constants need be precomputed.

4.4.3 Outputs

The outputs of the doppler processor are:

- Main Channel I, Q data $\rightarrow$ sixteen filters by (N_{RB}) range bins for long pulse or (N_{RB}) range bins for short pulse.
- Guard Channel I, Q data $\rightarrow$ sixteen filters by (N_{RB}) range bins for long pulse or (N_{RB}) range bins for short pulse.

4.5 Magnitude Detector

The purpose of the Magnitude Detector is to compute the magnitude of the I and Q vectors in doppler filter/range bin cells. The output of the magnitude detector goes to the Post Processor PSP functions which have no requirement to know signal phase.

4.5.1 Inputs

The inputs of the Magnitude detector are:

- Main Channel I, Q data sixteen filters by $N = (N_{RB})$ range bins for long pulse of $N = (N_{RB})$ range bins for short pulse.
- Guard Channel I, Q data sixteen filters by $N = (N_{RB})$ range bins for long pulse or $N = (N_{RB})$ for short pulse.

4.5.2 Processing

The Magnitude Detector outputs the greater of:

$$\left| I \right| + \frac{1}{2} \left| Q \right| \text{ or } \left| Q \right| + \frac{1}{2} \left| I \right|$$

for sixteen filters for each range bin described in Inputs section above.

4.5.3 Outputs

- Main Channel Magnitudes for sixteen filters by N range bins, $A_M(i,j)$.
- Guard Channel Magnitudes for sixteen filters by N range bins, $A_G(i,j)$.

4.6 MPRF Search Main Channel Noise Amplitude Estimate Function

4.6.1 Inputs

- Matrix of N_{RB}-14 range bins by N_F filters of main channel magnitude measurements, $A_M(i,j)$, from section 4.5.

  Where, $8 \leq i \leq N_{RB}-7$ (range)

  and $\frac{17 - N_F}{2} \leq j \leq \frac{15 + N_F}{2}$ (doppler)
- Long ensemble lockout command from RDP.
- N_F, the number of doppler filters in clear signal region, from RDP.
- Long ensemble average lockout command from RDP.
- 4-3-4 Sliding Window Tilt Lockout command from RDP.

4.6.2 Processing

This function shall compute a background noise estimate for each main channel range/doppler cell in the input matrix. The noise estimates ($\overline{N}_M$) are used to form the detection thresholds in section 4.7.

The noise estimate is computed in two ways: a 4-3-4 sliding window "tilted" average (in range), and an over all "long ensemble" average of 105 range/doppler cells.

If the long ensemble average is used, the largest of these two estimates is sent to section 4.7 for use in detection. Otherwise, when the long ensemble average lockout command is true, the 4-3-4 sliding window "tilted" average is sent to section 4.7.

The long ensemble average is given by:

$$\overline{N}_{LE} = \frac{1}{105} \left\{ \sum_{i=N_{RB}-21}^{N_{RB}-7} \sum_{j=5}^{11} A_M(i,j) \right\}$$

Where the value of $\overline{N}_{LE}$ is limited to be no less than 2.

When the 4-3-4 Sliding Window Tilt Lockout Command is false, the 4-3-4 sliding window average is given by the tilted larger of the two four-bin means:

$$\overline{N}_{4-3-4}(i,j) = \frac{1}{4} \text{MAX} \left\{ \sum_{n=i-5}^{i-2} A_M(n,j), \quad \sum_{n=i+2}^{i+5} A_M(n,j) \right\}$$

(larger of early bin average or late bin average).

The sliding window average includes both tilt or end-effect logic by virtue of its definition as the larger of means on both sides.

Tilt logic is to be applied whenever the early and late range bin averages differ. In that case, $\overline{N}_{4-3-4}(i,j)$, as the largest of the early or late range bin averages, tilts in the appropriate fashion.

End-effect logic is applicable at the ends of the range swath where the early or late sample sets would exceed the boundary of the fully processed region. (This occurs for range bin nunbers $i < 13$, or $i > N_{RB}-14$). In these cases the early or late parts of the estimate would be discarded respectively, and the noise estimate would be the remaining part. Selection of the larger quantity automatically makes this choice as required.

When the 4-3-4 Sliding Window Tilt Lockout Command is true, the 4-3-4 sliding window average is given by the early range bin average:

$$\overline{N}_{4-3-4}(i,j) = \frac{1}{4} \sum_{n=i-5}^{i-2} A_M(n,j)$$

Finally, the sliding window estimates for each cell are compared to the long ensemble average, and the greater is output to the threshold function unless this comparison is bypassed by RDP command:

For LEA Lockout Command false:

$$\overline{N}_M(i,j) \text{ (output)} = \text{Greatest of } \left\{ \overline{N}_{4-3-4}(i,j),\ \overline{N}_{LE} \right\}$$

For LEA Lockout Command true:

$$\overline{N}_M(i,j) \text{ (output)} = \overline{N}_{4-3-4}(i,j)$$

4.6.3 Outputs

- Matrix of N_{RB}-14 range bins by N_F filters of main channel noise amplitude estimates, $\overline{N}_M(i,j)$, to section 4.7.
- Long ensemble average, $\overline{N}_{LE}$, to RDP.

4.7 MPRF Search Main Channel Thresholding

4.7.1 Inputs

- Matrix of range bins by $N_F + 2$ filters of Main Channel magnitude measurements, $A_M(i,j)$, from section 4.5.

  Where, $8 \leq i \leq N_{RB}-7$ (range)

  and $\frac{15 - N_F}{2} < j < \text{Min}\left[15, \frac{17 + N_F}{2}\right]$ doppler

- Matrix of range bins by N_F filters of Main Channel noise estimates, $\overline{N}_M(i,j)$, from section 4.6.
- Threshold Multiplier K_M and K_{GMT} from the RDP.
- Clutter Canceller Bypass command from the RDP.

4.7.2 Processing

This function shall perform amplitude thresholding on Main Channel data. Four separate thresholds may be applied to the data. Threshold K_M is used to form the basic hit list, with its hit count, RAW Hit Count (Main Channel), to be sent to the RDP. The K_{GMT} Threshold shall be applied to the filters at the edge of mainlobe clutter to accomplish ground moving target rejection. For the PSP software STC thresholding, the two RVT profiles shall be used to provide hit counts to the RDP and to provide hits to the range resolver function that indicate the presence of close range targets.

When the Clutter Canceller Bypass Command is false, the profiled thresholds shall be generated by these functions:

$$[RVT1(i,j)]^{-1} = \begin{cases} \dfrac{1440}{K2^2} \sin^2 \left(\dfrac{\pi j}{16}\right) & 0 < i \leq R_a \\ -\dfrac{1440}{(i+K1)^2} \sin^2 \left(\dfrac{\pi j}{16}\right) & R_a < i < R_b \\ \dfrac{1440}{(R_c)^2} \sin^2 \left(\dfrac{\pi j}{16}\right) & R_b \leq i \leq R_c \\ \dfrac{1440}{i^2} \sin^2 \left(\dfrac{\pi j}{16}\right) & R_c < i \leq R_1 \end{cases}$$

Where:

$$k1 = \begin{cases} 8; \text{ for RBI} = 1.0\ \mu\text{sec} & (0.68 \text{ miles}) \\ 6; \text{ for RBI} = 1.3\ \mu\text{sec} & \\ 5; \text{ for RBI} = 1.6\ \mu\text{sec} & \end{cases}$$

$$R_a = \begin{cases} 18; \text{ for RBI} = 1.0\ \mu\text{sec} & (1.4 \text{ miles}) \\ 14; \text{ for RBI} = 1.3\ \mu\text{sec} & \\ 11; \text{ for RBI} = 1.6\ \mu\text{sec} & \end{cases}$$

$$K2 = \begin{cases} 26; \text{ for RBI} = 1.0\ \mu\text{sec} & (2.1 \text{ miles}) \\ 20; \text{ for RBI} = 1.3\ \mu\text{sec} & \\ 16; \text{ for RBI} = 1.6\ \mu\text{sec} & \end{cases}$$

$$R_b = \begin{cases} 29; \text{ for RBI} = 1.0\ \mu\text{sec} & (2.4 \text{ miles}) \\ 22; \text{ for RBI} = 1.3\ \mu\text{sec} & \\ 18; \text{ for RBI} = 1.6\ \mu\text{sec} & \end{cases}$$

$$R_c = \begin{cases} 37; \text{ for RBI} = 1.0\ \mu\text{sec} & (3 \text{ miles}) \\ 28; \text{ for RBI} = 1.3\ \mu\text{sec} & \\ 23; \text{ for RBI} = 1.6\ \mu\text{sec} & \end{cases}$$

$$R_1 = \begin{cases} 61; \text{ for RBI} = 1.0\ \mu\text{sec} & (5 \text{ miles}) \\ 47; \text{ for RBI} = 1.3\ \mu\text{sec} & \\ 38; \text{ for RBI} = 1.6\ \mu\text{sec} & \end{cases}$$

and $[RVT2(i,j)]^{-1} = \frac{1440}{(i+N_{RB})^2} \sin^2 \left(\frac{\pi j}{16}\right) \quad 0 < i \leq R_2 - N_{RB}$

where: $R_2 = \begin{cases} 124; & \text{for RBI} = 1.0\ \mu\text{sec} \quad \text{(10 miles)} \\ 95; & \text{for RBI} = 1.3\ \mu\text{sec} \\ 78; & \text{for RBI} = 1.6\ \mu\text{sec} \end{cases}$

The RVT1 thresholds are everywhere greater than the RVT2 thresholds. [The $\sin^2$ factor compensates for the clutter canceller response.]

The K_M, RVT1 and RVT2 thresholding shall be accomplished by comparing the signal amplitude in each range/doppler cell in the clutter free region to the product of its associated noise estimate and each of these three threshold multipliers. The RVTn thresholds vary with range so the RVTn threshold for the appropriate range bin must be used. If the signal amplitude exceeds or equals the product, the hit count for that threshold is incremented and, a hit is declared for that range/doppler cell. Hits on the RVTn thresholds need to be determined only for those cells that have a hit on the K_M threshold - this processing sequence effectively sets an upper bound on RVTn = K_M.

An upper bound on the total number of K_M threshold hits may be required. The upper bound would prevent computation time for all downstream functions from exceeding the time available. A table of upper bounds (a function of the PRF) is provided, and the process of testing for main channel hits is terminated when the total number of hits exceeds the upper bound.

The result of threshold processing for the main channel shall be equivalent to the following sequence of direct logic:

First, Set $COUNT_{KM} = COUNT_{RVT1} = COUNT_{RVT2} = 0$

Then, for $\begin{cases} i = 8 \text{ to } N_{RB} - 7 \\ j = \frac{17 - N_F}{2} \text{ to } \frac{15 + N_F}{2} \end{cases}$

If $A_M(i,j) \geq \overline{N}_M(i,j) \times K_M$,
set $Count_{KM} = Count_{KM} + 1$
record a K_M hit as $H_M(i,j)$ and save $A_M(i,j)$.

Next, for those range/doppler cells that have K_M hits, check the other signal thresholds:
If $A_M(i,j) \geq \overline{N}_M(i,j) \times RVT1(i)$,
Then set $Count_{RVT1} = Count_{RVT1} + 1$ and record an RVT1 hit as $H_1(i,j)$.

If the hit is at ambiguous range $i \leq R_2 - N_{RB}$
and $A_M(i,j) \geq \overline{N}_M(i,j) \times RVT2(i)$,
Then set $Count_{RVT2} = Count_{RVT2} + 1$
and record an RVT2 hit as $H_2(i,j)$.

If the K_M hit count occurs at a frequency location which is at the edge of the clear signal region, then the K_{GMT} thresholding shall be accomplished by comparing the signal amplitude in the adjacent filter at the edge of the mainlobe clutter region to the product of the noise estimate of the K_M hit (for its range bin in its neighboring clutter free filter) and the K_{GMT} threshold. If this signal amplitude exceeds or equals the product, a K_{GMT} hit is declared for that range/doppler cell. Therefore:

- If a K_M hit exists at

  $$j = \frac{17-N_F}{2}$$

  in the region $i = 8$ to $N_{RB}-7$,
  and if $A_M(i,j-1) \geq \overline{N}_M(i,j) \times K_{GMT}$, record a GMT hit for this cell as $H_{GMT}(i,j)$.
- If a K_M hit exists at

  $$j = \frac{15 + N_F}{2}$$

  in the region $i = 8$ to $N_{RB}-7$,
  and if $A_M(i,j+1) \geq \overline{N}_M(i,j) \times K_{GMT}$, record a GMT hit for this cell as $H_{GMT}(i,j)$.

NOTE: $H_{GMT}(i,j)$ cannot exist for doppler locations such that

$$\frac{19 - N_F}{2} \leq j \leq \frac{13 + N_F}{2}$$

4.7.2 Outputs

- Hit counts for thresholds K_M, RVT1 and RVT2.
- Range/Doppler cell indices for K_M hits as $H_M(i,j)$, along with associated signal magnitude, $A_M(i,j)$.
- Range/Doppler cell indices for RVT1 hits, as $H_1(i,j)$.
- Range/Doppler cell indices for RVT2 hits, as $H_2(i,j)$.
- Range/Doppler cell indices for K_{GMT} hits, as $H_{GMT}(i,j)$.

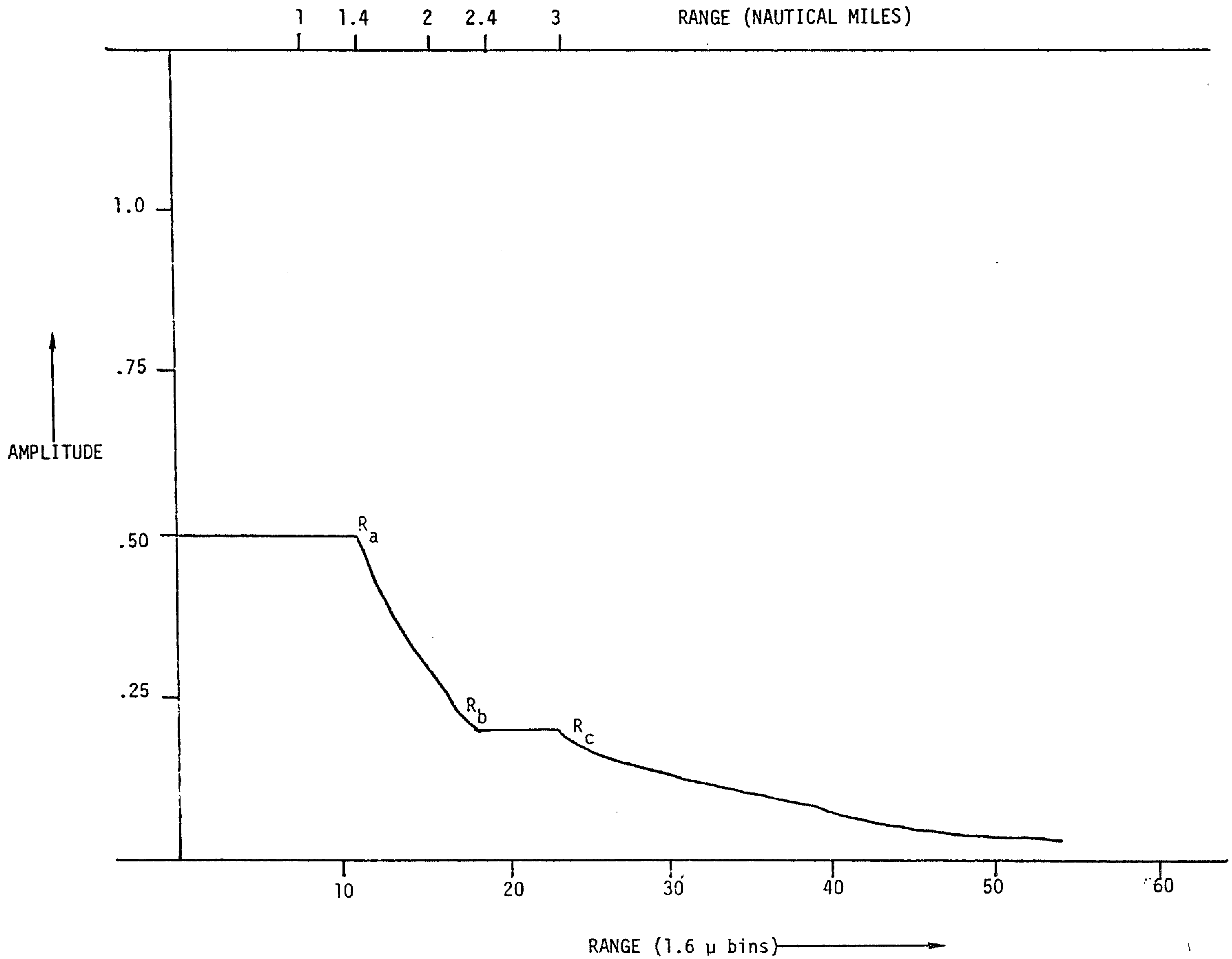


FIGURE 4.7 - RANGE VARIABLE THRESHOLD (RVT)

4.8 MPRF Search Guard Channel Noise Amplitude Estimate

4.8.1 Inputs

- Matrix of N_{RB} - 14 range bins by N_F filters of guard channel magnitude measurements, $A_G(i,j)$, from section 4.5.

  Where, $8 \leq i \leq N_{RB}-7$ (range)

  and $\frac{17-N_F}{2} \leq j \leq \frac{15+N_F}{2}$ (doppler)

- Indices of range/doppler cells, (i,j), in the main channel that contain CFAR hits on K_M threshold from section 4.7.

4.8.2 Processing

This function shall compute a background noise estimate for each guard channel range/doppler cell in the processed region provided that the corresponding main channel range/doppler cell contains a CFAR hit. This shall be accomplished using a 4-3-4 sliding window ensemble average with edge effects. That is, the average shall usually be formed by summing the four early and four late range cells centered about a three cell swath containing the range/doppler cell of interest as center. Therefore at most locations:

$$\overline{N}_G(i,j) = 1/8 \left\{ \sum_{k=i-5}^{i-2} A_G(k,j) + \sum_{k=i+2}^{i+5} A_G(k,j) \right\}$$

But for the edge cells in range only the interior sum is retained:
If i <13, then

$$\overline{N}_G(i,j) = 1/4 \left\{ \sum_{k=i+2}^{i+5} A_G(k,j) \right\}$$

If $i > N_{RB}-12$ then

$$\overline{N}_G(i,j) = 1/4 \left\{ \sum_{k=i-5}^{i-2} A_G(k,j) \right\}$$

In these definitions i and j are respectively the range and doppler cell indices of a main channel CFAR hit.

4.8.3 Outputs

- Noise amplitude estimates, $\overline{N}_G(i,j)$ corresponding to main channel CFAR hits to section 4.9.

4.9 MPRF Search Guard Channel Thresholding

4.9.1 Inputs

- Matrix of N_{RB}-14 range bins by N_F filters of guard channel magnitude estimates, $A_G(i,j)$, from section 4.5.

  Where: $8 \leq i \leq N_{RB}-7$ (range)

  and $\frac{17-N_F}{2} \leq j \leq \frac{15+N_F}{2}$ (doppler)
- Guard channel noise estimates, $\overline{N}_G(i,j)$, corresponding to main channel CFAR hits from section 4.8.
- Indices of range/doppler cells, (i,j) in the main channel that contain CFAR hits of K_M threshold from section 4.7.
- Guard channel threshold, K_G, from RDP.
- Guard channel saturation threshold, K_{G2}, from RDP.

4.9.2 Processing

This function shall perform two types of amplitude thresholding on guard channel data at locations corresponding to main channel hits. The first type of amplitude thresholding shall be accomplished by comparing the guard channel signal amplitude in each such range/doppler cell to the product of its associated noise estimate and guard threshold. If the signal amplitude exceeds or equals the product, a hit is declared for that range/doppler cell.

The second type of thresholding shall be accomplished by comparing the guard channel signal amplitude to the high fixed value (near saturation) for cells corresponding to main channel hits. If the guard signal amplitude exceeds or equals the fixed threshold, a hit is declared for that range/doppler cell.

Therefore:

if $A_G(i,j) \geq \overline{N}_G(i,j) \times K_G$,

or if $A_G(i,j) \geq K_{G2}$

then record a guard hit as $H_G(i,j)$ for range/doppler cells corresponding to main channel K_M hits. (Since $K_G > 1$, the process may actually use its reciprocal with an inverse logic for the first threshold.)

4.9.3 Outputs

- Indices for range/doppler cells containing hits on both main and guard channels, as $H_G(i,j)$.

4.10 MPRF Search Main/Guard Ratio Thresholding

4.10.1 Inputs

- Matrix of N_{RB}-14 range bins by N_F filters of main channel magnitude measurements, $A_M(i,j)$, from section 4.5.

  Where: $8 \leq i \leq N_{RB}-7$ (Range)

  and $\frac{17-N_F}{2} \leq j \leq \frac{15-N_F}{2}$ (doppler)
- Corresponding matrix of guard channel magnitude measurements, $A_G(i,j)$, from section 4.5.
- Indices of range/doppler cells (i,j), in the main channel that contain CFAR hits on K_M threshold from section 4.7.
- Two main/guard thresholds, K_{MGR1} and K_{MGR2}, from RDP.

4.10.2 Processing

This function compares the main channel magnitude to the product of the guard channel magnitude and two different thresholds. For the first threshold, the process need be performed only for those main channel range/doppler cells for which CFAR hits exist. For this threshold, main/guard ratio hits are declared if the main channel magnitude equals or exceeds the product. The occurence of such MGR1 hits are provided to the hit/miss function. Therefore, for i,j corresponding to main channel CFAR hits, if

$$A_M(i,j) \geq A_G(i,j) \times K_{MGR1}$$

then declare a hit as $H_{MGR1}(i,j)$:

For the second threshold, the process of thresholding is performed for the entire processed region. The occurence of such MGR2 hits is provided to the additional processing section 4.11.

$$\text{For} \quad \begin{cases} i = 8 \text{ to } N_{RB}-7 \\ j = \frac{17-N_F}{2} \text{ to } \frac{15+N_F}{2} \end{cases}$$

if $A_M(i,j) \geq A_G(i,j) \times K_{MGR2}$
then declare a hit as $H_{MGR2}(i,j)$.

4.10.3 Outputs

- MGR1 hits, $H_{MGR1}(i,j)$, to section 4.12.
- MGR2 hits, $H_{MGR2}(i,j)$, to section 4.11.

4.11 Additional Processing (TBS)

Reference PSP-18 Volume 2 DS 31325-147

(PSP Computer Program Development Specification)

4.12 Hit/Miss Logic

4.12.1 Inputs

- Hit counts for thresholds K_M, RVT1 and RVT2.
- Range/Doppler cell indices for K_M hit as $H_M(i,j)$, along with associated signal magnitude $A_M(i,j)$.
- Range/Doppler cell indices for K_{GMT} hits, as $H_{GMT}(i,j)$.
- Range/Doppler cell indices for RVT2 hits, as $H_2(i,j)$.
- Range/Doppler cell indices for RVT1 hits, as $H_1(i,j)$.
- MGR1 hits $H_{MGR1}(i,j)$.
- Indices for range/doppler cells containing hits on both main and guard channels, as $H_G(i,j)$.

4.12.2 Processing

The purpose of the HIT/MISS function is to:

a) Detect any ground moving targets (GMT's).

b) Establish criteria for CFAR hits.

c) Establish criteria for RVT1 and RVT2 hits.

d) Perform HIT count adjustment due to (b) and (c) above.

(a) GMT Logic

The HIT/MISS logic resolves any ground moving targets in the following manner. If a hit exists both in the first filter outside the notch $H_M(i,j)$ and in the first filter inside the notch $H_{GMT}(i,j)$ in the same range bin, a GMT hit is declared. In equation form if both $H_M(i,j)$ and $H_{GMT(i,j)}$ are non zero for either $j = \frac{17-N_F}{2}$ or $\frac{15+N_F}{2}$ where N_F = number of filters processed, then the $H_M(i,j)$ hit is declared.

b) CFAR Hit/Miss

A valid CFAR target hit is declared when the following logic equation is satisfied:

$$HIT = H_M(i,j) \cdot \left| \overline{H_G(i,j)} + H_{MGR1}(i,j) \right|$$

That is, a real valid target hit is declared if there is a main channel hit without an associated guard channel hit or a main channel hit with an associated guard channel hit and the main to guard threshold is exceeded.

c) RVT1 and RVT2 Processing

The processing for the RVT1 and RVT2 hits is as follows:
Any RVT1 and RVT2 hits that exist at a range and doppler were previously CFAR hits were eliminated are also eliminated. That is any RVT1 and RVT2 hits that occur must be subject to the HIT equation in (b) above to be a valid hit.

d) Hit Count Adjustments

The K_M, RVT1 and RVT2 hit counts are adjusted to reflect the elimination of any hits due to guard channel processing. The RDP uses the adjusted K_M hit count, i.e., the CFAR hit count, to perform as closed loop CFAR control of the K_M threshold number.

4.12.3 Outputs

- The remaining CFAR hits, $H_3(i,j)$, to the range and velocity centroiding function.
- The remaining RVT1 hits, $H_1(i,j)$, to the range and velocity centroiding function.
- The remaining RVT2 hits, $H_2(i,j)$, to the range and velocity centroiding function.
- Adjusted CFAR, RVT1, RVT2 hit counts to RDP.
- Magnitude of CFAR hits $A_M(i,j)$.
- Unadjusted (RAW) K_M hit count to RDP.

4.13 MPRF Range and Velocity Centroiding Function

The centroiding function shall centroid the outputs of the Hit/Miss Logic (HML) section 4.12 in range and velocity to eliminate multiple hits from the same target. An algorithm for locating peak responses of strong targets based on their various thresholds determines the number and location of the targets.

4.13.1 Inputs

Inputs shall be provided from Hit/Miss Logic. The inputs include Range Variable Threshold (RVT) hits (range, frequency) and Constant False Alarm Rate (CFAR) hits (range, frequency, magnitude).

- RVT1 hits (range, frequency) as $H_1(i,j)$.
- RVT2 hits (range, frequency) as $H_2(i,j)$.
- CFAR hits (range, frequency, magnitude) as $H_3(i,j)$ and $A_M(i,j)$.
- RVT1 hit count.
- RVT2 hit count.
- CFAR hit count.

Figure 4.13.1 illustrates the relative position of the three thresholds from which the input hit data are derived.

4.13.2 Processing

RVT1/RVT2/CFAR contiguous hits shall be processed in a three step sequence which eliminates hits adjacent to ones designated as single target centroids.

A. Centroiding of RVT1 (highest threshold) hits $H_1(i,j)$ shall be as follows:

   1. Centroid contiguous velocity hits occuring at the same range per Figure 4.13.2.
   2. Centroid remaining contiguous range hits occuring at the same velocity per Figure 4.13.3.
   3. Check remaining diagonal pairs ($R \pm 1$, $V \pm 1$) and select hit closer in range from such pairs.
   4. Count the surviving centroided hits.

5. Superimpose surviving RVT1 hits on RVT2 hits and delete any adjacent and diagonal hits from the latter's 8 contiguous cells.

B. Centroiding of RVT2 (medium threshold) hits $H_2(i,j)$ shall be as follows:

1 - 4 (Same as A.1 and A.4 above)

5. Superimpose surviving RVT2 hits on CFAR hits and delete any adjacent and diagonal hits from the latter's 8 contiguous cells.

C. Centroiding of CFAR (low threshold) hits $H_3(i,j)$ shall be as follows:

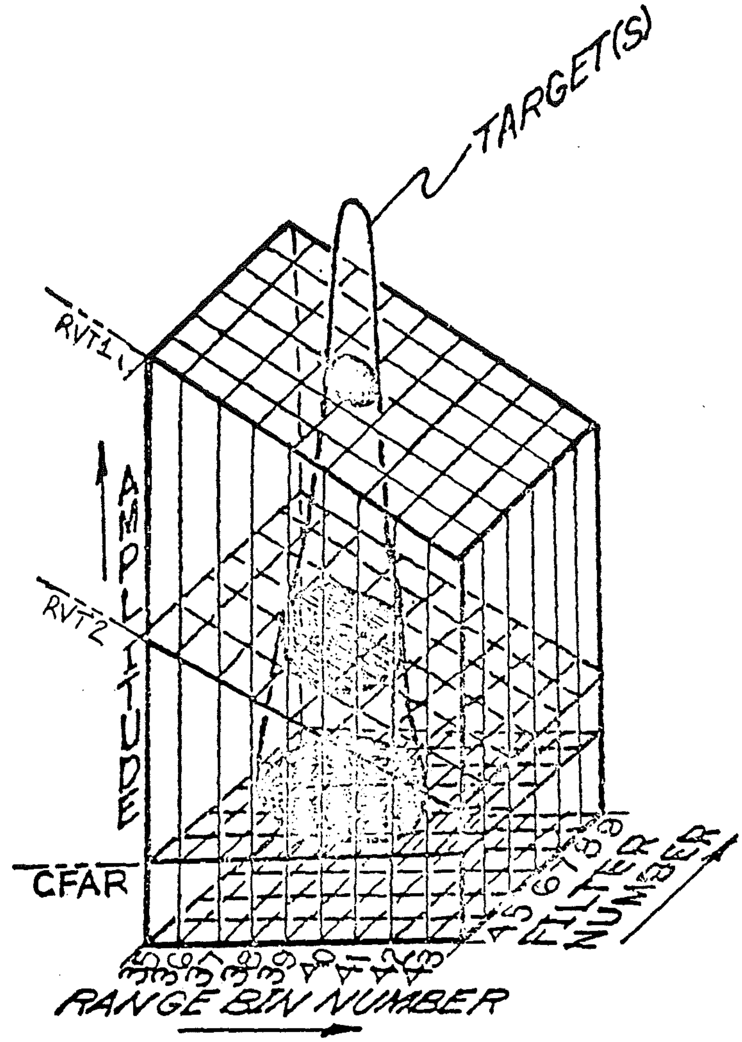
1-4 (Same as A.1 to A.4 above).

5. Maintain a "range only" hit list which collapses in velocity for each range by taking the "OR" of all velocity filter cells. Do <u>not</u> recentroid the subsequent numeral, but do count the number of "collapsed on range" hits, H(i).

NOTE: Examples in Figure 4.13.4 illustrate the technique for centroiding contiguous hits by deleting candidate hits in (a) velocity, (b) range, (c) velocity/range (diagonally) and (d) collapsing the surviving data.

4.13.3 <u>Outputs</u>

- Centroided RVT1 hits (range, frequency) as $H_1(i,j)$.
- Centroided RVT2 hits (range, frequency) as $H_2(i,j)$.
- Centroided CFAR hits (range, freqeuncy, magnitude) as $H_3(i,j)$ and $A_M(i,j)$.
- Collapsed CFAR hits (range) as $H_4(i)$.
- Centroided RVT1 hit count.
- Centroided RVT2 hit count.
- Centroided CFAR hit count.
- Collapsed CFAR hit count.



Note: Shaded areas imply frequency - range matrixes of clear target(s). Hits are represented by unity discretes in the examples of Figure 4.13.4.

Figure 4.13.1 - RELATIVE POSITION OF RVT1, RVT2 AND CFAR THRESHOLDS FOR CLEAR TARGET(S)

CENTROIDING TRUTH TABLES

	Raw Hits ($V_{min} \longleftrightarrow V_{max}$)	→	Transformed Hits ($V_{min} \longleftrightarrow V_{max}$)
Fundamental Velocity-hit Rule*	1	→	1
	1 1	→	0 1
	1 1 1	→	0 1 0
	1 1 1 1	→	0 1 0 1
	1 1 1 1 1	→	0 1 0 0 1
	1 1 1 1 1 1	→	0 1 0 0 1 0
	1 1 1 1 1 1 1	→	0 1 0 0 1 0 1
	ETC	→	ETC

VELOCITY CENTROIDING PROCESS

Figure 4.13.2

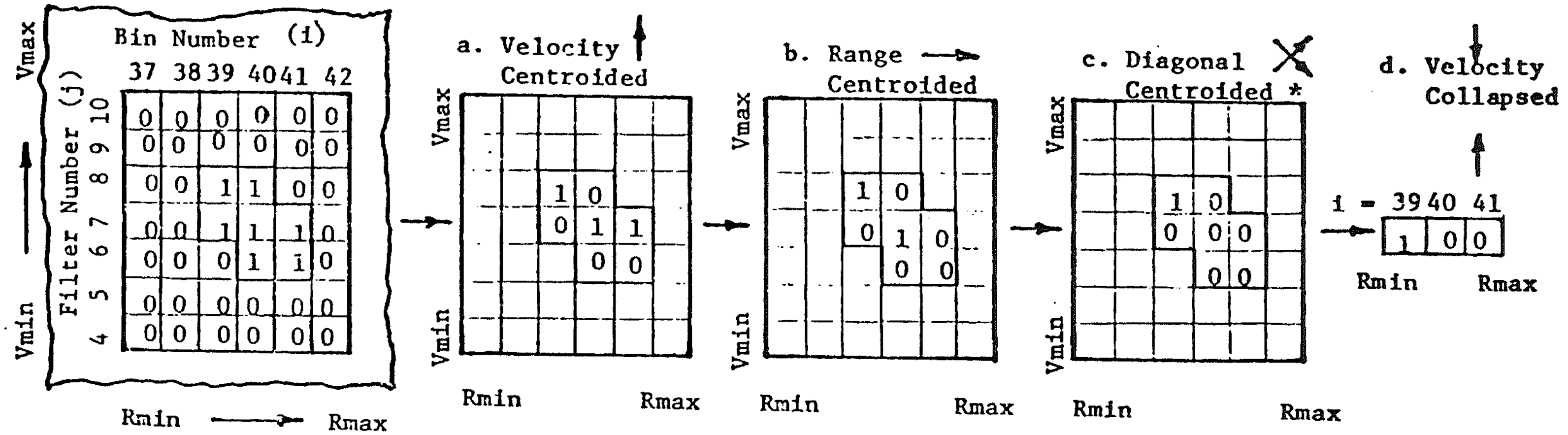
	Raw Hits ($R_{min} \longleftrightarrow R_{max}$)	→	Transformed Hits ($R_{min} \longleftrightarrow R_{max}$)
Fundamental Range-hit Rule*	1	→	1
	1 1	→	1 0
	1 1 1	→	0 1 0
	1 1 1 1	→	0 1 0 1
	1 1 1 1 1	→	0 1 0 1 0
	1 1 1 1 1 1	→	0 1 0 0 1 0
	1 1 1 1 1 1 1	→	0 1 0 0 1 0 1
	ETC	→	ETC

RANGE CENTROIDING PROCESS

Note: The tables are generated by repeated application of the fundamental rules.

Figure 4.13.3 - RANGE CENTROIDING PROCESS

EXAMPLE 1. RVT2 HIT/MISS DISCRETE MATRIX



* Note: Retain the contiguous hit (unity discrete) which is smallest in range

EXAMPLE 2. CFAR HIT/MISS DISCRETE MATRIX

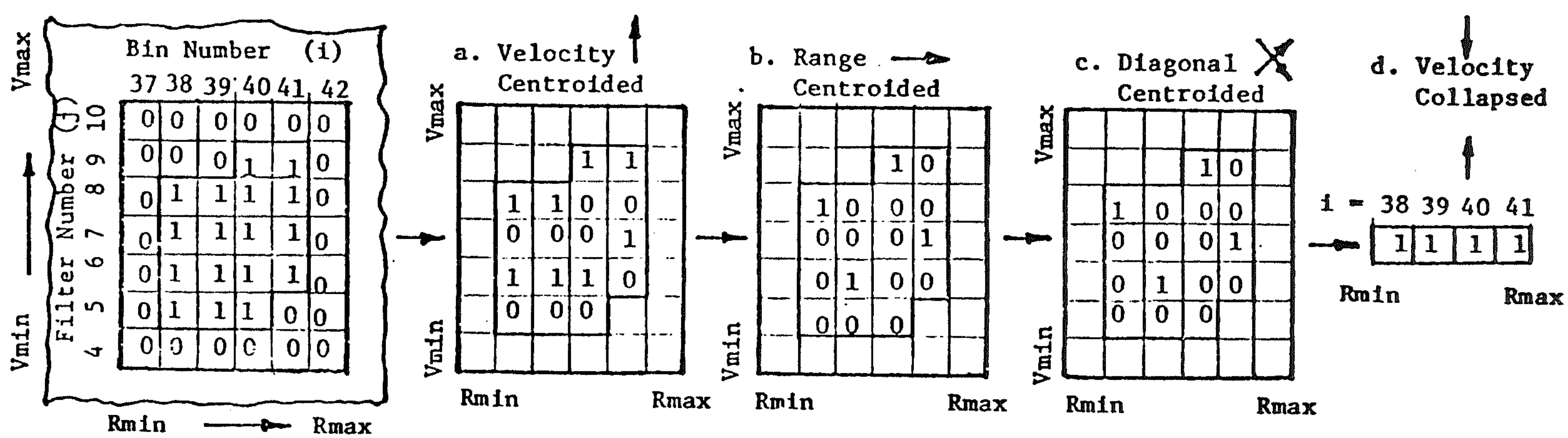


FIGURE 4.13.4 - EXAMPLES OF CENTROIDING TECHNIQUE

4.14 Range Resolving

A target range resolving technique based on the Chinese Remainder Theorem (CRT) and the Straight Line Scanning (SLS) technique is used to resolve the ambiguous range of the target from its Hit/Miss data. Three ambiguous range data points (a, b, c) one from each Hi Minor, Major and Low Minor PRF of the same pulse-width are required as inputs for the computation. In a single target case, the computation is quite simple. However, if multiple hits are detected within a pulse repetition frequency (PRF) period, only the valid data sets of (a, b, c) from the Hi Minor/Major/Low Minor Hit/Miss data shall be used for the data selection so that the number of false targets and the timeline can be minimized. The number of computations varies linearly with the number of hits in a PRF channel. To cut the number of false targets further, a velocity confirmation test is included in the Straight Line Scanning technique used to select valid data sets.

4.14.1 Inputs

- Ambiguous ranges from target Hit/Miss data of Hi Minor, Major and Low Minor PRFs of the same pulsewidth.
- Number of hits in each Major channel (66 range bins) in one PRF interval.
- Hit/Miss data at RVT1, RVT2 and CFAR threshold levels shall be sent to Range Resolving Processor.
- Ambiguous velocities from target Hit/Miss data associated with ambiguous range hits on the Hi Minor, Major and Low Minor PRFs.

4.14.2 Processing

In the current F-15 Radar, the numbers of range bins in the Hi Minor/Major/Low Minor PRF channels are set as 64, 66 and 68. Therefore, the unambiguous range, R, of the target can be expressed by the Chinese Remainder Theorem (CRT) method as follows:

$$R = a + 64\ t_1$$
$$= b + 66\ t_2$$
$$= c + 68\ t_3$$

where:

R = unambiguous target range in number of range bins.

a = ambiguous target range in Hi Minor PRF.

b = ambiguous target range in Major PRF.

c = ambiguous target range in Low Minor PRF.

t = number of ambiguities or range foldings in the particular range bin, PRF, and pulsewidth.

In the MPRF Search mode, the maximum number of ambiguities or range foldings do not exceed 15, and the difference of the numbers of ambiguities should be less than or equal to one.

Or

$$t_1 - t_2 \geq 1,\ t_2 - t_3 \geq 1 \text{ and } t_1 - t_3 \geq 1.$$

Since the possible number of combinations of (a, b, c) from multiple hits could be very large, a Straight Line Scanning (SLS) technique shall be used to select valid sets of (a, b, c)'s to be sent for range resolving. The number of the valid data set is approximately equal to the minimum number of hits in any one of the Hi Minor/Major/Low Minor channels.

$$N_{valid} = \text{Min}\ [N_1, N_2, N_3] \approx N_2$$

where:

N_{valid} = number of valid combinations from the Hi Minor/Major/Low Minor Hit/Miss data.

N_1, N_2, N_3 = numbers of target hits in each Hi Minor/Major/Low Minor channel.

The Straight Line Scanning (SLS) technique is based on the idea that the unambiguous range of a real target from the Hi Minor/Major/Low Minor channels should be the same, i.e., it shows up as a vertical line in any one of the fifteen ambiguity zones on the three

PRF unambiguous range plot. If a Low Minor is used as a pivot point on an ambiguous range plot these straight lines tilt by four range bins between the two minor PRFs at both ends of each ambiguity or range folding (Figure 4.14.1).

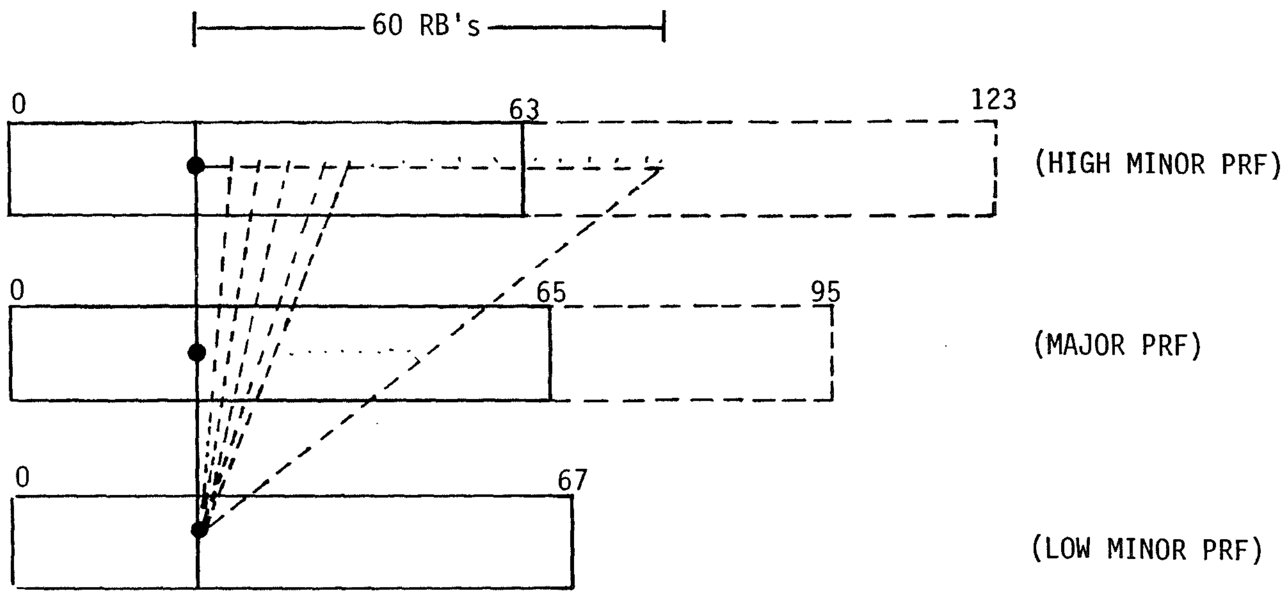
Since there are fifteen ambiguities within the maximum range of the MPRF Search mode, it should have fifteen straight lines on the ambiguous range plot. Any three ambiguous range data points, (a, b, c), which lie on any of these fifteen straight lines and also have ambiguous velocity filter hits which match within ± 1 hit filter numbers are designated as a valid data set for range resolving. The range data point c on the Low Minor PRF is used as a pivoting point for Straight Line Scanning (SLS). By using the Straight Line Scanning technique with velocity confirmation test, the number of valid sets and the timeline of the range resolving process increase only linearly with the number of hits in the pivoting PRF (either the Major or the Low Minor).

In the Straight Line Scanning method, as exemplified by Figure 4.14.1, three Hit/Miss range bin tables (64, 66 and 68 range data words by 24 bits) are used to store the range bin/velocity filter data of the Hi Minor/Major/Low Minor PRF channels. The scanning of two non-pivoting PRF tables (Major and Hi Minor Tables) by this method is done by a pointer (with an automatic increment of two range bins or two and four range bins) in fifteen steps. For each pivoting PRF hits, the non-pivoting PRF table points are initialized with the address of the target hit from the pivoting PRF table at the beginning of the Straight Line Scanning (SLS). The non-pivoting PRF range data consists of a two bit code word in each range cell position at the ends of or along the scanning line. Each range cell position is a 24 bit data word. The 12 two bit adjacent fields of the 24 bit data word are coded for the velocity filter hit data of that range cell position (Figure 4.14.3). The velocity confirmation test looks for the two bit range codes of the Hi Minor and Major PRFs to be in hit filter numbers within ± 1 hit filter number of the Low Minor PRF two bit range code, i.e., the 3 two bit range codes are in the same two bit locations (velocity filter position) of each range cell position on the scanning line. Then the code words from these range bins are logically "ANDED" to determine the valid combination of the range data in the non-pivoting PRFs. A non-zero result is designated for range resolving.

For scanning and data selection, the following procedures shall be used:

a) A small target hit table for each Hi Minor/Major/Low Minor PRF shall be generated. The table for the pivoting PRF is a list of range bins at which target hits have occurred. For the two non-pivoting PRFs, there is a word for each range bin to identify its relative position with respect to the central hit. To allow for a one range bin error, a two bit code word shall be used for hit information. If a hit is recorded in a range bin in the non-pivoting PRFs, the two bits in the code word are set (i.e., equals 11). If the range bin immediately precedes a hit range bin, the left bit is set (equal 10). If the range bin immediately follows a hit range bin, the right bit is set (equal 01). (Figure 4.14.2).

b) Additionally, the target hit table for each Hi Minor/Major/Low Minor PRF shall have ambiguous velocity filter hit information. Each range bin has 12 two bit velocity filter positions; a velocity filter position corresponds to one or more hit filter numbers. For the Low Minor PRF, a velocity filter position is associated with a single hit filter number except in the stopband. For the other PRFs, a velocity filter position is associated with 3 hit filter number, i.e., every velocity filter position overlaps 2 hit filter numbers with each adjacent velocity filter position. (Figure 4.14.3). The table for the Low Minor PRF is a list of the ambiguous velocities associated with each range bin at which a target hit occurred. The tables



(EXAMPLE SHOWN FOR PIVOTING ON THE LOW MINOR PRF)

FIGURE 4.14.1 - STRAIGHT LINE SCANNING TECHNIQUE FOR DATA SELECTION

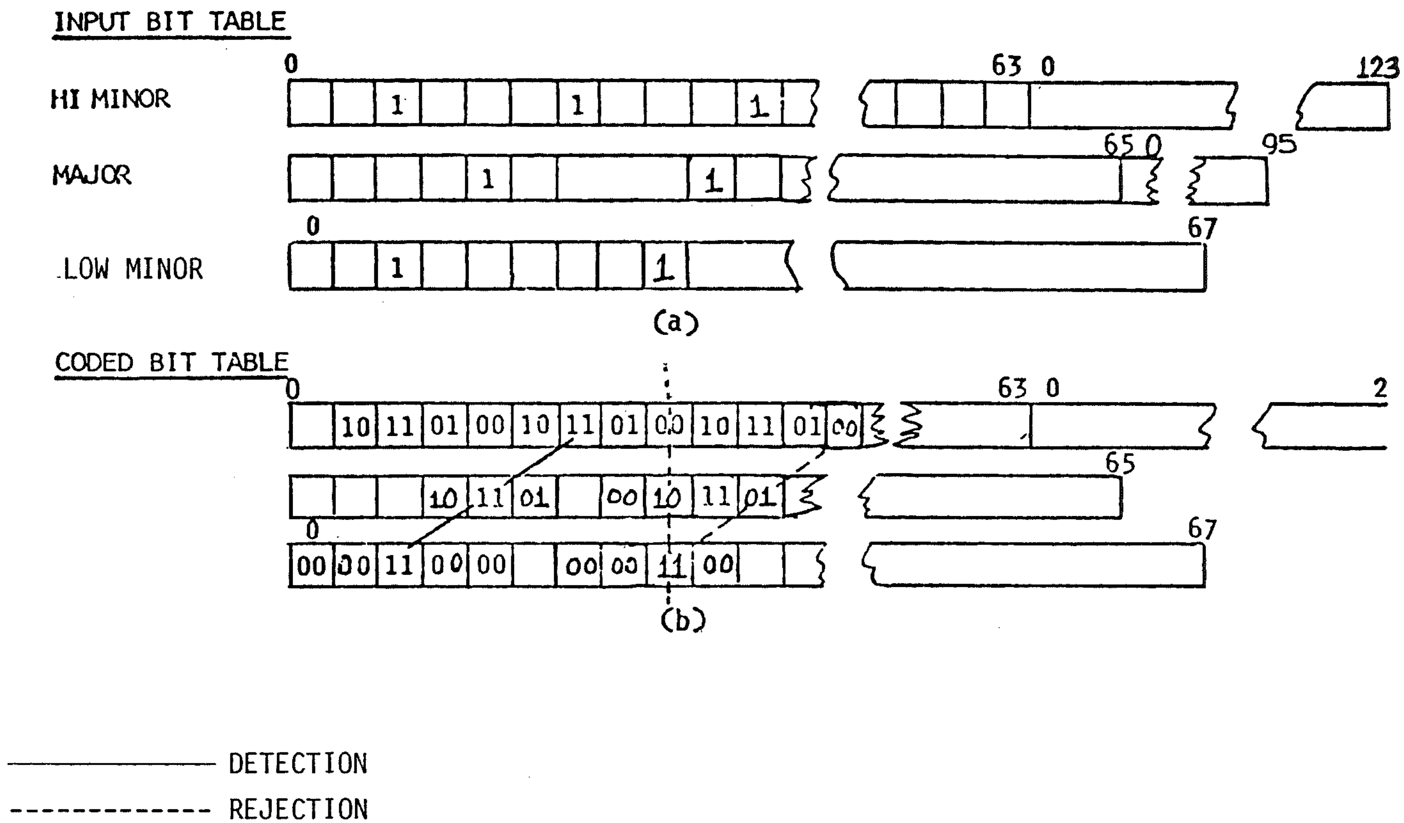


FIGURE 4.14.2

TWO BIT CODE FOR VALID DATA SET SELECTION
(EXAMPLE SHOWN FOR PIVOTING ON THE LOW MINOR (PRF)

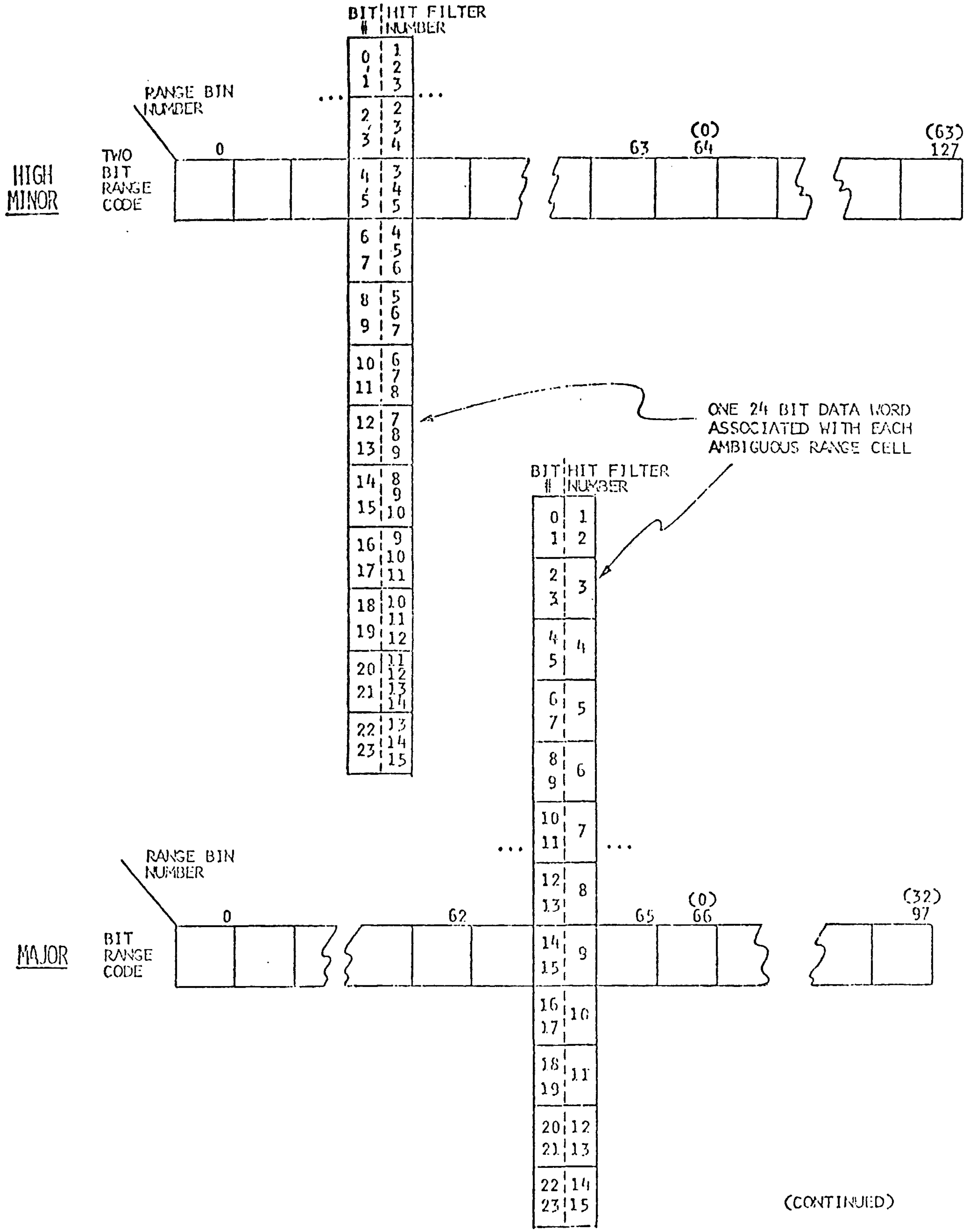
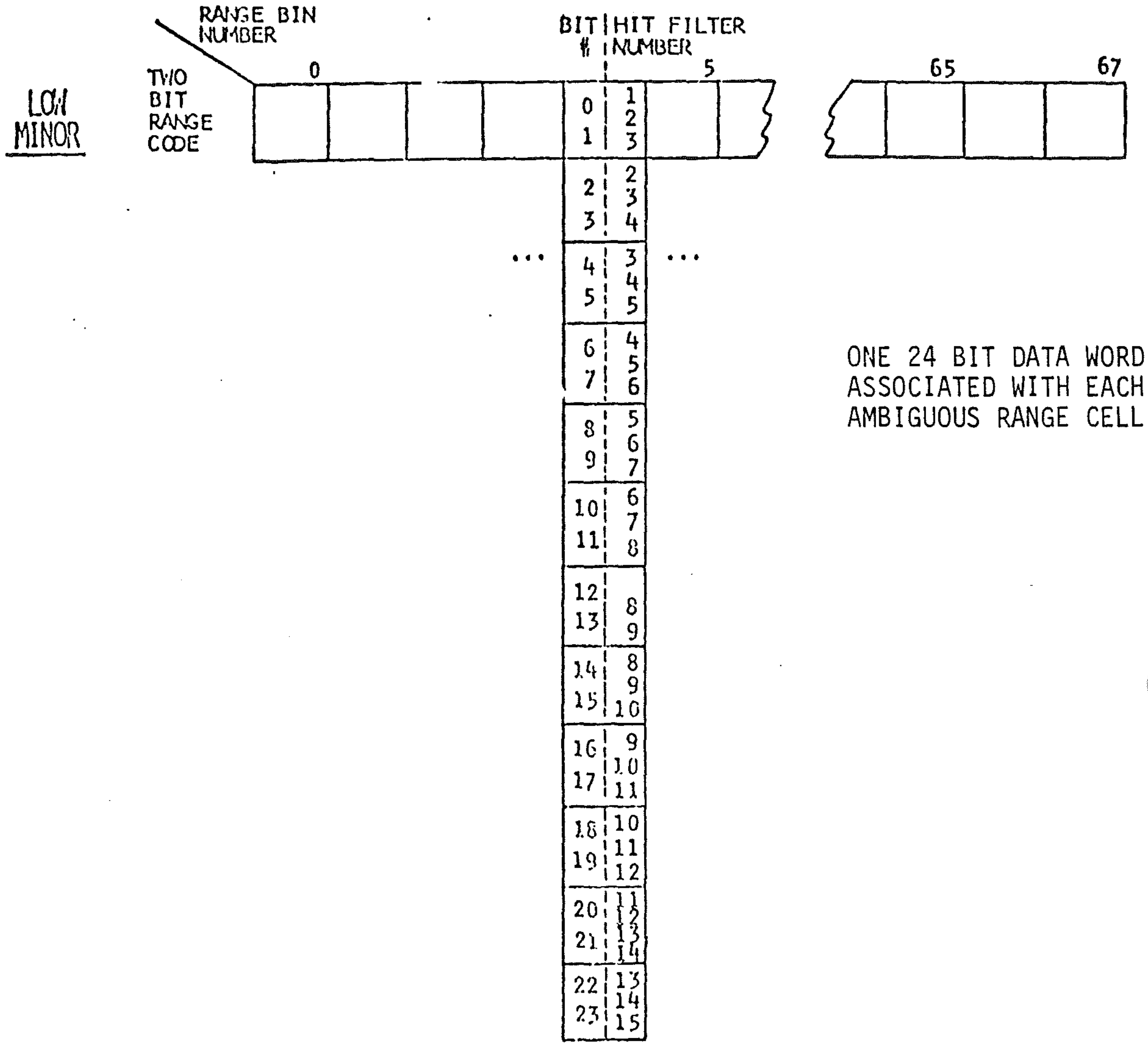


Figure 4.14.3 - TARGET HIT FILTER NUMBER ASSIGNMENTS IN RANGE DATA WORDS

Figure 4.14.3 (continued)



for the other PRFs allows ± 1 hit filter number deviation about the Low Minor PRF hit filter number.

c) To pass the velocity confirmation test, the two bit range codes for each range bin along the scanning line must be in the same velocity filter position.

d) When the two coded words in the two non-pivoting PRFs are logically "ANDED", the non-zero result shall be designated as valid data set and the zero result shall be rejected (Figure 4.14.2).

e) To perform Straight Line Scanning, the two non-pivoting PRF range data tables shall be extended beyond their ambiguous ranges. The Major table (66 range bins) is extended by copying the first 30 words of the table to the right. The Hi Minor (64 range bin table) is extended by copying the first 60 words of the table to the right. The 60 range bin folding is needed to take care of the fifteen ambiguities at the maximum range or a maximum difference of 60 range bins between the Low Minor and Hi Minor. The Straight Line Scanning shall start from the vertical position and gradually turn to the right.

f) The unambiguous range of the target is:

$$R = c + 68t_3$$

where:

R = unambiguous range bin of the hit

c = ambiguous range bin of the target hit in the Low Minor PRF

t_3 = the number of ambiguities or range foldings in the Low Minor PRF. (This is the same as the line number from the SLS.)

Such outputs (R) by the range resolver are considered potential hits from the real target. These hits are only applied to the particular Major/Minor - pulsewidth combination where the inputs are originated. Furthermore, any potential hit shall also pass the following two acceptance criteria:

a) Each potential hit in the first ambiguity region (i.e., R = a $\geq$ 64) must have a current hit on high threshold level RVT1.

b) Each potential hit in the second ambiguity region to a real unambiguous range of 10 miles (i.e., 64 $\geq$ R $\geq$ 124) must have a current hit on the medium (RVT2) threshold.

This method of determining the unambiguous range of potential hits and of confirming these hits with RVT1 and RVT2 threshold data shall be performed for the two pulsewidth cases.

4.14.3 Outputs

- Unambiguous ranges and associated ambiguous velocities from the Major PRF of valid targets in each Hi Minor/Major/Low Minor combination of the same pulsewidth.
- Number of targets and their ambiguous ranges in all three Major PRFs.
- Confirmed potential hit in the first and second ambiguities in all three Major PRF.

4.15 Azimuth Centroiding

The technique of Azimuth Centroiding of radar target samples is designed to improve the radar azimuth resolution so that closely spaced radar targets can be resolved. At the same time, this technique prevents the initiation of false targets from any strong target which can yield radar returns in several adjacent range azimuth element. Azimuth Centroiding replaces the previous used method of inhibiting all adjacent azimuth hits from a strong target except the initial hit.

4.15.1 Inputs

- Centroided unambiguous ranges from the Range Centroider.
- Antenna "Video Azimuth" from RDP.
- Azimuth Centroider Inhibit flag from RDP.

4.15.2 Processing

The initial phase of the Azimuth Centroider function is the tagging of each target range (coarse range number) with an azimuth value from the RDP. If the Az Centroider Inhibit flag is set (i.e., logical "1"), the azimuth centroiding procedure is NOT performed. The azimuth value tagged to the target and the coarse range number of the target are output. If the Az Centroider Inhibit flag is reset (i.e., logical "0"), the azimuth centroiding procedure is performed as described in the following paragraphs.

Centroiding is performed when a target generates two or more successive hits in the same range cell or one range cell $\pm K_1$. $|K_1$ is the half-width of the data collection gate shown in Figure 4.15.2$|$. The multiple hits from the single target would be detected over successive Azimuth Centroiding cycles. The one range and azimuth computed by this function for the multiple hits is an average of the target's input coarse range numbers and tagged azimuth positions over a number of phases. The azimuth centroiding is accomplished by establishing azimuth centroider "tracks" for each target. Associated with each track are:

R_o = Range bin of the track initiator

R_c = Current range bin of the track

Az_o = Azimuth of the track initiator

Az_c = Current azimuth

N_H = Hit counter

N_M = Miss counter

A schematic diagram showing possible radar samples from a strong target or multiple target is illustrated in Figure 4.15.2. These straddle several range bins and azimuth elements.

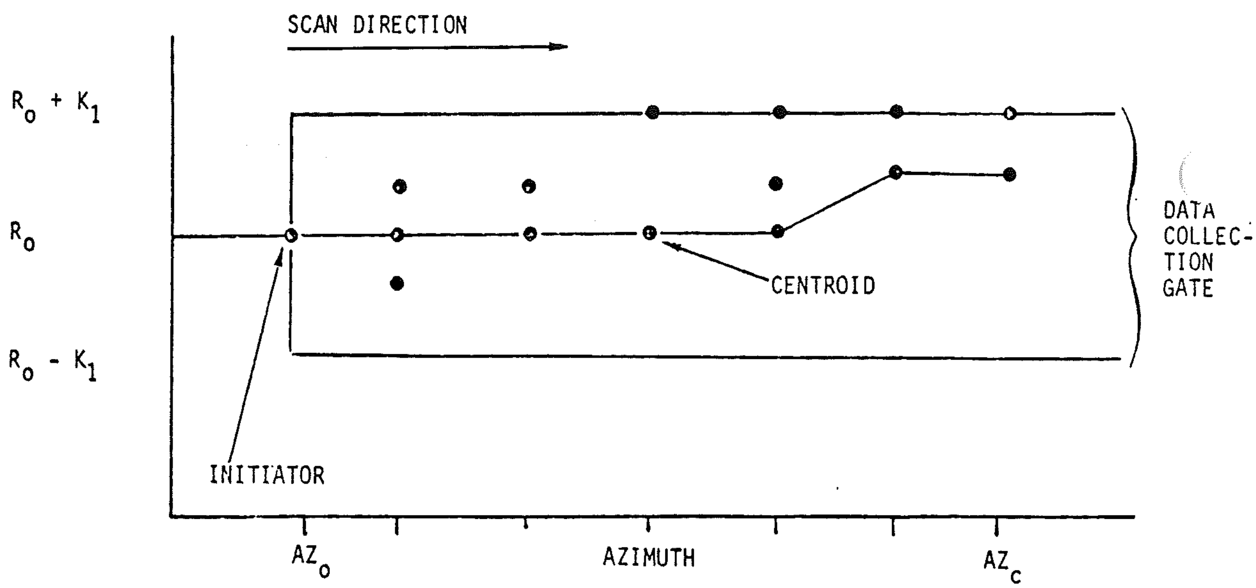


FIGURE 4.15.2 - AZIMUTH CENTROIDING

For Azimuth Centroiding, the target samples along each azimuth element within $R_c + K_1$ and $R_c - K_1$ range bins are candidates for correlation with a track, where K_1 represents the half-width of the data collection gate. Track correlation, initiation, and termination are performed as follows:

4.15.2.1 Track Correlation

1. For each track, a search is made for hit(s) within the data collection gate ($\pm$ K_1 range bins about the current target range bin, R_c).
2. Only one hit is allowed to correlate with a given track. If more than one hit is found in the data collection gate, the hit in range bin, R_c, is chosen as the correlated hit; if such a hit does not exist, the hit with the closest range is chosen as the correlated hit.
3. If a correlated hit is found, the track range, R_c, is set equal to the range bin of the correlated hit, the track azimuth, Az_c, is set to the current video antenna azimuth, and the track miss counter, N_M, is set to zero. The correlated hit is deleted from the hit list.
4. If no correlated hit is found, the track miss counter N_M is incremented by one.
5. In all cases, the track hit counter, N_H, is incremented by one to indicate the total number of azimuth elements since the initiator.

4.15.2.2 Track Initiation

1. Any uncorrelated hits remaining in the hit list after track correlation is performed are used to initiate new tracks.
2. The track parameters for each new track are initialized as follows:

$R_o = R_c$ = range bin of uncorrelated hit

Az_o = current video antenna azimuth

$N_H = 1$

$N_M = 0$

4.15.2.3 Track Termination

1. If the miss counter for a track equals N_s misses, the track is terminated.
2. If the hit counter for a track equals N_{max}, the track is terminated.
3. If $|R_o - R_c|$ for a track exceeds R_{max}, the track is terminated.
4. A centroided target position is computed for each terminated track and sent to the Display Processing function.
   a. The centroided range of the target is the average of the range bin of the initiator and the range bin of the last hit in the track:
   $$R = IPO\left[(R_o + R_c)/2 + 0.5\right]$$
   b. The centroided azimuth of the target is the average of the azimuth of the initiator and the azimuth of the last hit in the track:
   $$Az = IPO\left[(AZ_o + Az_c)/2 + 0.5\right]$$

4.15.2.4 Azimuth Centroider Parameter Values

Parameter values for the MPRF Search Mode are as follows:

K_1 = 1 range bin

N_s = 3 misses

N_{max} = 10 hits

R_{max} = 5 range bins

4.15.3 Outputs

- Coarse range number and azimuth of centroided targets to Display Processing.

4.16 Digital Scan Converter Function

The Digital Scan Converter (DSC) in the Programmable Signal Processor (PSP) shall perform interface functions between the radar, the IFF Reply Evaluator (IRE) and the Vertical Situation Display (VSD) for target display. It shall perform the function of data formatting, and video display control in signal position, in duration/intensity and symbol generation. The DSC shall also correlate radar targets with the target designator (corral) and with IFF targets. Under multi-targets situation, the DSC shall determine the sequencing of multi-target display and target disposition. The DSC performs the functions necessary to display the target information on the VSD. The DSC logic receives the radar return target data from the Azimuth Centroiding function.

4.16.1 Inputs

- IFF Data from IRE.
- Mode X Ident Command from EWWS.
- Acquisition Symbol position (in DSC Word 1) from RDP.
- Antenna Elevation Caret position and Antenna Azimuth Caret position (in DSC Word 2) from RDP.
- Display mode parameters and Display aging parameters (in DSC Word 3) from RDP.
- BIT Window data (in DSC Word 4 and 5) from RDP.
- Azimuth Heading Compensation (in PSP Word 5 Bits 0 - 3) from RDP.

If the Az Centroider Inhibit flag is 0, then for each terminated azimuth track in the azimuth centroider:

- Centroided Azimuth
- Centroided Unambiguous Range
- Hit Count

If the Az Centroider Inhibit flag is 1, then for each valid hit:

- Azimuth tagged to target
- Unambiguous Range of target

4.16.2 Processing

4.16.2.1 Overview

This section contains an overview and three subsections which describe the key data processing functions of the Digital Scan Converter. The overview covers the general approach of data processing for input data from RDP and PSP (see Section 4.16.1). The three key processing functions, target correlation, aging/erasing and heading compensation are discussed in detail in three separate subsections. Data processing logic as well as inputs and outputs is specified in each subsection. The final outputs of the DSC and VSD via Display Interface Unit (DIU) are listed in section 4.16.3.

The data processing functions of the Digital Scan Converter are shown in the following functional block diagram, Figure 4.16.4. The Digital Scan Converter (DSC) receives its control words and cursor position from the RDP, target hits from the azimuth centroider, and the IFF data from the IFF Reply Evaluator (IRE). First, it reformats the 24-bit data words (Figure 4.16.2) into 48 bit DSC memory words (Figure 4.16.5A) to be stored in the PSP Bulk Memory for data processing and target correlation. If a manual acquisiton is requested from the Radar Data Processor (RDP 081 Unit), the DSC shall search its target memory for targets which lie within the correlation azimuth and range window of the cursor as positioned by the pilot. If a target is found, the elevation bar of the antenna and the PRF are sent to the RDP so that the radar parameters can be set for target acquisition. For radar target and IFF target correlation, the DSC either performs or bypasses the target/IFF correlation as commanded by the RDP.

The output display data consisting of 128 48-bit target data words and six other target words shall be sent to the VSD via the Display Interface Unit (DIU).

For target and display data storage, DSC shall maintain three separate memories. A small target table (32 word x 48 bits) is required to store the new target data as sent-in by the Azimuth

Centroiding Processor (Section 4.15). These new targets then merge into a large 192 word x 48 bits Master Target Memory (TM1) in the PSP Bulk Memory for target correlation and data processing. The Master Target Memory, TM1, operates in a "first-in-first-out" (FIFO) manner. When there are more targets than the memory storage, the oldest targets in TM1 are deleted. The FIFO operation can be achieved by using a cyclic target address table for target deletion without the actual shifting of all target data in the TM1 memory. The targets in the TM1 memory are used by the Correlation Logic. Those targets which lie within the current range and azimuth bound are selected for Vertical Situation Display (VSD). This target data then is rescaled from 11 bits azimuth data (TM1 data format) to 9 bits azimuth data (TM2 data format) and 12 bits range data to 9 bits range data to fit the VSD data word format. The rescaled target table consisting of at most 128 targets and 6 DSC target words (Figure 4.16.5) is transferred to VSD Display Data Memory (TM2). These data are sent from DSC to DIU for VSD display (Figure 4.16.6).

The three important functions in the DSC (target correlation, aging/erasing and heading compensation) are discussed in detail in Sections 4.16.2.2 to 4.16.2.4.

4.16.2.2 Target Correlation

The DSC Correlation Logic must perform two basic types of target correlations in both azimuth (X) and range (Y). The first type is correlation of cursor with radar targets. The second type is the correlation of new radar targets with current IFF targets.

Target correlation logic and its window sizes are shown in Figure 4.16.7 and Table 4.16.1.

4.16.2.2.1 Inputs

- Target Correlation Mode (in PSP Word 1) from RDP.
- Acquisition Symbol positon (in DSC Word 1) from RDP.
- IFF target data from IRE (Figure 4.16.3).
- IFF target correlation (in DSC Word 3) from RDP.

TABLE 4-16-1 - CORRELATION WINDOW

a.

AZIMUTH CORRELATION WINDOW	
Mode	X Window
Cursor Correlation	$\pm 4^{\circ}$ or ± 16 Azimuth Bins
IFF Narrow Target Correlation (Wide Target bit = 0)*	$\pm 4^{\circ}$ or ± 16 Azimuth bins
IFF Wide Target Correlation (Wide Target bit = 1)*	$\pm 8^{\circ}$ or ± 32 Azimuth bins

* IRE Reply Word Bit 11

b.

RANGE CORRELATION WINDOW		
Mode	X Window	Range
MPRF & RWS Acq	±12 Bins	± Selected range ÷ 40 or 0.25 nm
LRS IFF (Short Range Detect bit = 0)**	±6 Bins	±2 nm
SRS IFF (Short Range Detect bit = 1)**	±24 Bins	0.5 nm

** PSP Word 1 Bit 9

PSP TO DSC INPUT RADAR TARGET WORD

MPRF SEARCH MODE

0			23
HPRF or MPRF	(1) PRF TARGET FLAG (0)	11 Bits Target Azimuth (X Position)	12 Bits Target Range (Y Position)

1 Bit to Specify PRF Target

0 = MPRF

1 = HPRF

11 Bits Antenna Azimuth to Target

LSB = .058594 deg   2048 Az Element for 120 deg.

12 Bits Antenna Range to Target (Use only 12 Bits 4096 Quantized) Steps

LSB = .08   N.M.

FIGURE 4.16.2 - DSC TARGET INPUT DATA FROM ARSP (039 UNIT) VIA PSP

IFF REPLY WORD FROM PSP TO DSC

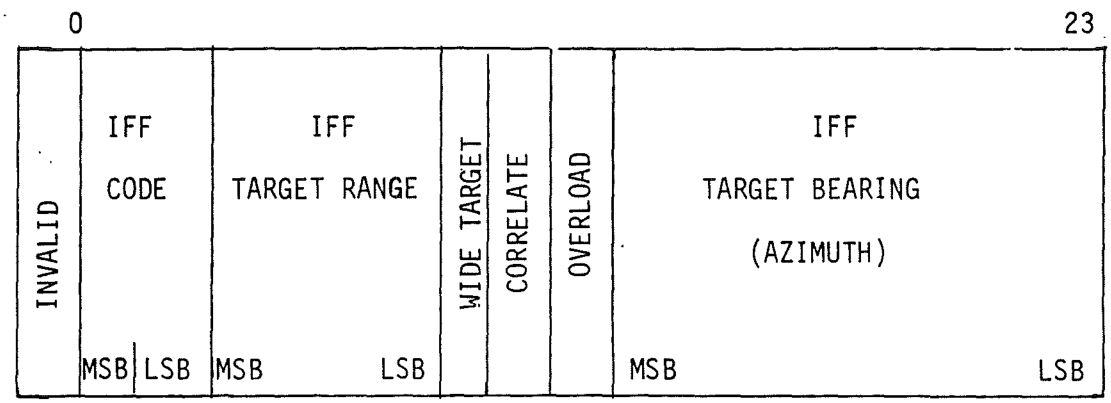


FIGURE 4.16.3 IFF REPLY WORD FROM IRE BUFFER

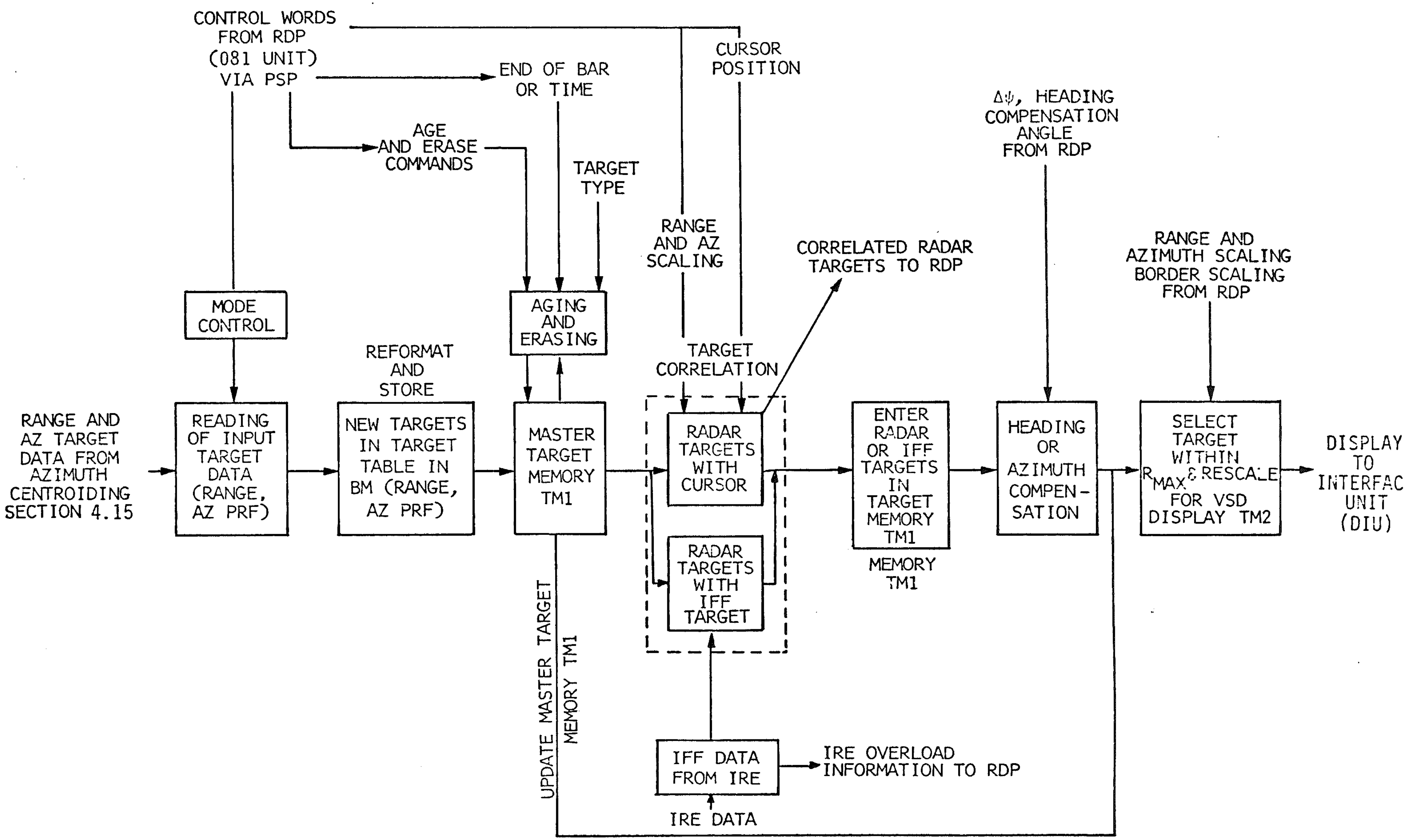


FIGURE 4.16-4. DIGITAL SCAN CONVERTER FUNCTION DIAGRAM FOR MPRF SEARCH, ACQ I AND ACQ II

		0–3	4–5	6–16	17–28	29–31	32–33	34	35	36	37–44	45–47
1 to 128	TARGET WORD	4 BITS WORD CODE	IFF CODE	11 BITS AZIMUTH POSITION (X)	12 BITS RANGE POSITION (Y)	3 BITS EL	PRF	NON CORRELATED IFF TARGET	TARGET ERASED	SYNTHETIC TARGET	8 BITS SPARE	3 BITS INT

A. Target Word Format

		0–3	4–5	6–8	9–14	15–23	24–44	45–47
129	RNG/VEL SCALE	0 1 0 0	0 0	RNG VEL SCALE	0 0 0 0 0 0	0 0 0 0 0 0 0 0 0	SPARES	1 1 1
130	CURSOR POSITION	0 1 0 1	0 0	X POSITION		Y POSITION	SPARES	1 1 1
131	ANT, AZ, POSITION	0 1 0 1	0 0	X POSITION		1 0 0 0 1 0 1 1 0	SPARES	1 1 1
132	ANT. EL. POSITION	0 1 0 1	0 0	1 0 0 0 1 0 1 1 0		Y POSITION	SPARES	1 1 1
133	BIT WORD #1	0 1 0 1 or 0 0 0 0	0 0	1st CHARACTER	2nd CHARACTER	3rd CHARACTER	SPARES	1 1 1
134	BIT WORD #2	0 1 0 1 or 0 0 0 0	0 0	4th CHARACTER	5th CHARACTER	6th CHARACTER	SPARES	1 1 1

B. Display Symbol Word Formats

Figure 4.16.5 - DSC BULK MEMORY WORDS

WORD	NAME	BIT POSITION					
		0 1 2 3	4 5	6 7 8 9 10 11 12 13 14	15 16 17 18 19 20 21 22 23	24 - 44	45 46 47
1	MPRF TGT/IFF or	0 0 0 1	IFF CODE	X POSITION	Y POSITION	NOT USED	INTENS.
	HPRF TGT/IFF or	0 0 1 1	IFF CODE	X POSITION	Y POSITION		INTENS.
	UNCORRELATED IFF or	0 0 1 0	IFF CODE	X POSITION	Y POSITION		1 1 1
128	BLANK	0 0 0 0	THESE BIT POSITIONS MAY BE RANDOMLY SET.				0 0 0
129	RNG/VEL SCALE	0 1 0 0	0 0	RNG/ VEL SCALE 0 0 0 0 0 0	0 0 0 0 0 0 0 0 0	NOT USED	1 1 1
130	CURSOR POSITION	0 1 0 1	0 0	X POSITION	Y POSITION		1 1 1
131	ANT. AZ. POSITION	0 1 0 1	0 0	X POSITION	1 0 0 0 1 0 1 1 0		1 1 1
132	ANT. EL. POSITION	0 1 0 1	0 0	1 0 0 0 1 0 1 1 0	Y POSITION		1 1 1
133	BIT WORD #1	0 1 0 1 or 0 0 0 0	0 0	1st CHARACTER	2nd CHARACTER 3rd CHARACTER		1 1 1
134	BIT WORD #2	0 1 0 1 or 0 0 0 0	0 0	4th CHARACTER	5th CHARACTER 6th CHARACTER		1 1 1

FIGURE 4.16.6 - DSC TO VSD DIGITAL DATA (MPRF SEARCH MODE)

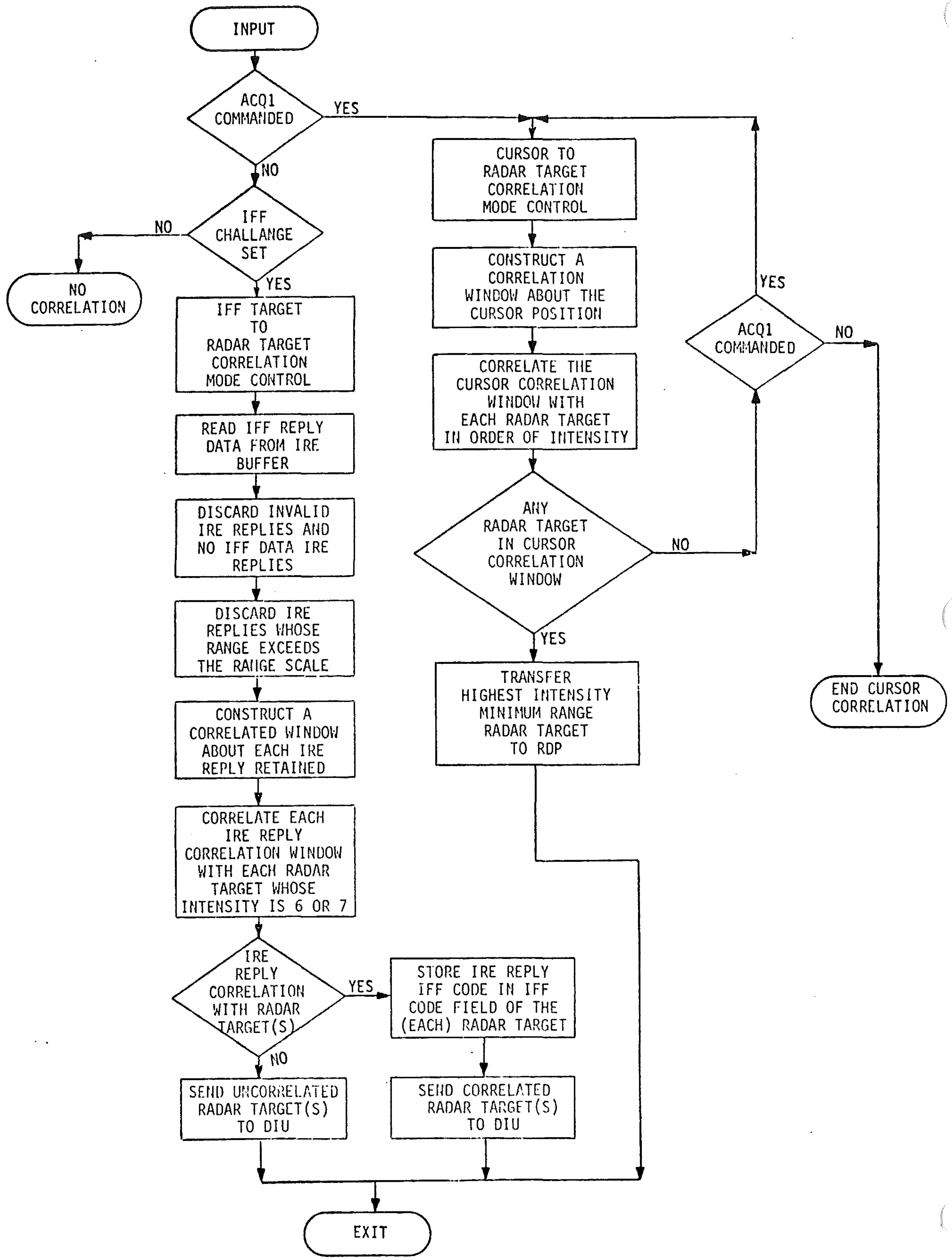
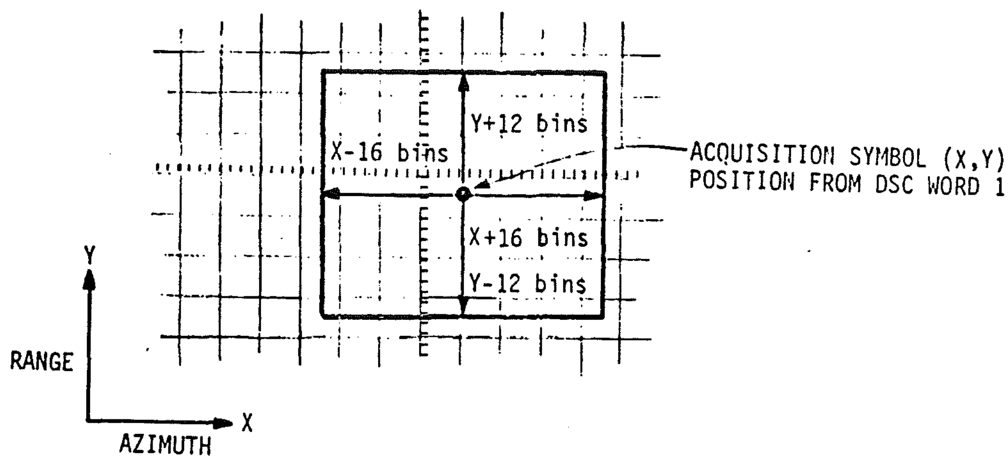


Figure 4.16.7 - CORRELATION LOGIC

4.16.2.2.2 Processing

Cursor Correlation Logic

When cursor correlation is commanded from the RDP (via PSP Word 1, submode code signal), correlation with all targets in the TM1 memory in the order of target intensity. (Figure 4.16.5). First the correlation window (box) is constructed from the Acquisition Symbol X (azimuth) and Y (range) position, as follows:



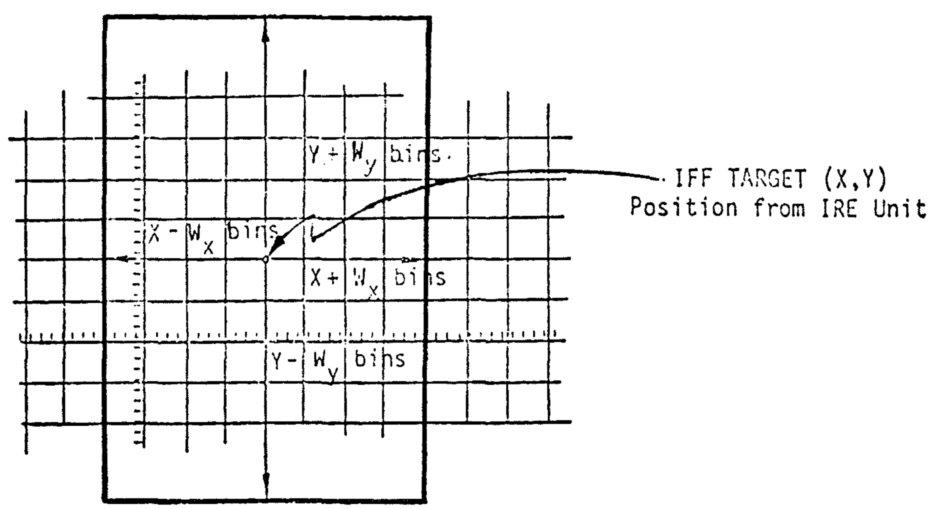
Targets with an intensity of seven are not correlated. Therefore, on the first memory readout cycle, targets with an intensity of six are examined to determine if any fall within the correlation window. On the second memory readout cycle, correlation is performed on targets with an intensity of five. On the third memory readout cycle, correlation is performed on intensity four targets and so on down to intensity zero. When a cursor correlation is made, the X (azimuth), Y (range) position, intensity, El Bar number, PRF and Synthetic Target Status of the correlated target is stored. The correlated target with the highest intensity AND minimum range is selected and sent to the RDP via IDA. If no correlation has been made after zero intensity targets are searched, the DSC Tag (IDA Word 1 Bit 10) is set to zero and the (intensity) counter starts over at six.

IFF Target Correlation Logic

If cursor correlation has NOT been commanded and the IFF Challenge bit (DSC Word 3 Bit 23) is set, the DSC must do IFF Target correlation for both CORRECT CODE and NON-CORRECT CODE targets. In the former case, if a correlation does not occur with any memory radar target, the IFF target is entered into the memory. In the latter case, if a correlation does not occur with any memory radar target, the IFF target is dropped. In both cases, the IFF code is entered into the memory radar target IFF field when a correlation does occur. Table 4.16.2 summarizes the IFF correct code correlation logic.

Each IFF Target received from the IRE unit (see Figure 4.16.3) is checked to determine if it is a candidate for correlation. An IFF Target is NOT correlated with memory radar targets if (1) the invalid bit is set, (2) the IFF Code field is zero, or (3) the IFF Target range exceeds the selected range scale. All other IFF Targets received from the IRE unit are candidates for correlation with the memory radar targets. If the OVERLOAD bit of any of the IFF Targets retained for correlation is set, then the IFF Overload Bit (IDA Word 1 Bit 9) is set to logical "1" for the RDP.

A correlation window is constructed around each IFF Target retained for correlation with the memory radar targets. The correlation window (box) is constructed from the IFF Target X (azimuth) and Y (range) position as follows:



where W_x is the half-size of the correlation window in Azimuth and W_y is the half-size of the correlation window in Range. The possible values of W_x and W_y are specified in Table 4.16.1a and b, respectively. Note: [W_x can have one of two values based on the setting of the WIDE TARGET bit in the IRE Reply Word and W_y can assume one of two values based on the setting of the SHORT RANGE DETECT bit in PSP Word 1.]

After forming a correlation window about the IFF Target X, Y position, the memory makes one circulation. During this circulation, the IFF target is correlated, in range and azimuth, with each target in the memory which has an intensity of 6 or 7, i.e., each intensity 6 or intensity 7 target X,Y position is checked to determine if it falls within the IFF Target correlation window. Note: [Jammers and non-correlated IFF Targets in the memory are NOT correlated with the "new" IFF Target.]

When an IFF Target correlation is made, the IFF Target IFF Code is written into the memory radar target IFF Code field. The IFF Target can correlate with any number of memory radar targets. If no IFF Target correlation is made, the IFF Target is either inserted into the memory as a non-correlated IFF Target or dropped as indicated by the logic in Table 4.16.2.

The IFF correlation cycles are timed not to occur at the same time as the VSD readout cycles.

4.16.2.2.3 Outputs

- DSC Tag or IFF Overload Bit to RDP via IDA.
- ECM Tag, PRF and El Bar Number of cursor correlated radar target to RDP via IDA.
- Unambiguous Range and MPRF Code of cursor correlated radar target to RDP via IDA.
- IFF Code of each correlated IFF Target to IFF Code field of correlated memory radar target(s) in Master Target Memory TM1.
- Non-correlated IFF Targets with correct code to Master Target Memory TM1.

4.16.2.3 Aging and Erase Logic

Target aging and erase logic is required to control the display intensity of targets sent to the VSD. This logic changes (ages) the display intensity or erases the displayed targets according to the "AGE" or "ERASE" commands, respectively, sent by the RDP. When a target is first detected, the target's display intensity is set at the maximum brightness of the eight state intensity level scale (3 bits); then the intensity level is decreased in accordance with the Aging and Erase logic shown in Figure 4.16.8 and Figure 4.16.9, respectively.

4.16.2.3.1 Inputs

- AGE Command, Elevation Bar Pattern Signal, Elevation Bar Number Signal, ERASE Command and Video Display Age Signal from RDP (in DSC Word 3).
- Target intensity from Master Target Memory TM1.
- Target types from Master Target Memory TM1.

4.16.2.3.2 Processing

A memory target, input to the DSC, is stored in the Master Target Memory with its intensity code set to 7, i.e., maximum intensity. Also, when a new target is stored in Master Target Memory, the elevation code is set to the Elevation Bar Number and the target type codes are set, i.e., the new target is designated a radar target from the Azimuth Centroiding function; a correlated radar target or an un-correlated correct code IRE target identified during DSC IFF Target Correlation Logic; OR a synthetic target (jammer strobe target symbol). The target Aging Logic then reduces target intensity as commanded by the RDP, i.e., when the AGE Command is set to logical "1" by the RDP. When the AGE Command is set, all targets stored in Master Target Memory and whose intensity level is 7 shall have their intensity level reduced by one level to intensity level 6. Additionally, when the AGE Command is set, all targets stored in Master Target Memory and whose elevation code equals the elevation bar number of the next antenna elevation bar shall have their intensity level reduced by one level and their IFF code field is zeroed. That is, targets are reduced by one intensity level and correlated IRE targets revert to uncorrelated radar targets with each antenna scan frame. All synthetic targets stored in Master Target Memory shall have their intensity level reduced by one level when the AGE Command is set, i.e., at each antenna end-of-bar.

The Target Erase Logic deletes targets from the Master Target Memory according to intensity level and target type. A radar target with an intensity level less than the preselected display intensity threshold level shall be deleted; the preselected display intensity threshold level is the difference between the maximum display intensity level (7) and the RDP commanded Video Display Age. An un-correlated correct code IRE target with an intensity level less than 7 shall be deleted, i.e., at each antenna end-of-bar. A synthetic target with an intensity level less than 6 shall be deleted, i.e., at the second end-of-bar. All targets from an elevation zone greater than the selected elevation bar pattern shall be deleted.

Additionally, the Target Erase Logic erases any target stored in Master Target Memory with its erase bit set. When the ERASE Command is set to logical "1" by the RDP, the whole Master Target Memory is erased.

4.16.2.3.3 Outputs

- Adjusted Target intensity to Master Target Memory TM1.
- Zeroed Target IFF Code Fields to Master Target Memory TM1.
- Cleared Master Target Memory TM1 or Targets to be deleted from Master Target Memory TM1.

4.16.2.4 Heading or Azimuth Compensation

The heading or azimuth compensation is required to correct out the azimuth error associated with the target azimuth stored in the Master Target Memory. The error is due to the time lag between the time of data collection and target data display on the VSD. The azimuth compensation can also improve the azimuth accuracy in target correlation.

4.16.2.4.1 Inputs

- AGE Command from RDP (in DSC Word 3).
- Azimuth Compensation Angle, $\Delta\psi$, from RDP (in PSP Word 5).
- Target azimuth angle from Master Target Memory TM1.

4.16.2.4.2 Processing

Each process sync interval, the RDP sends the amount of azimuth compensation necessary to correct for the predicted ownship maneuvers during this process sync interval. During ownship maneuvering, the relative position between a target and the ownship change. The Heading (Azimuth) Compensation Logic shall sum the $\Delta\psi$'s (azimuth compensation angles) received from the RDP each process sync interval. When the AGE Command is set to logical "1" by the RDP, the PSP shall compensate the azimuth angle of all radar/IFF targets in Master Target Memory, i.e.,

$$\sum_{\text{Process Sync's}} \Delta\psi$$ is added to each target's azimuth angle. The $\Delta\psi$ sum is then zeroed. No elevation compensation is required.

4.16.2.4.3 Outputs

- Azimuth compensated target azimuth angles to Master Target Memory TM1.

4.16.3 Outputs

- VSD digital Data for MPRF Search Modes consists of 128 48-bit target data, one range/velocity scale word, one cursor position word, two antenna position words and two BIT WINDOW-words are sent to Display Interface Unit at a 60 Hz rate.

TABLE 4.16.2 - IFF CORRECT CODE/CORRELATION STATUS LOGIC

CORRECT CODE = 1 (from RDP)		CORRECT CODE = 0 (from RDP)	
CORRELATE = 1 (FROM IRE)	CORRELATE = 0 (FROM IRE)	CORRELATE = 1 (FROM IRE)	CORRELATE = 0 (FROM IRE)
IRE REPLY CORRELATES WITH* ONE OR MORE RADAR TARGETS	IRE REPLY FAILS TO CORRELATE WITH ANY RADAR TARGETS	IRE REPLY CORRELATES WITH* ONE OR MORE RADAR TARGETS	IRE REPLY FAILS TO CORRELATE WITH ANY RADAR TARGETS
TAG RADAR TARGET(S) WITH IRE REPLY IFF CODE	INSERT IRE REPLY X, Y POSITION IN MEMORY WITH IFF CODE AND SET NON-CORRELATION BIT	TAG RADAR TARGET(S) WITH IRE REPLY IFF CODE	DROP THIS IRE REPLY

* THE RADAR TARGET'S X,Y POSITION FALLS WITHIN THE IRE REPLY'S CORRELATION WINDOW.

IRE REPLY IFF STATUS	IFF CODE
NO DATA (NULL)	0 0
HIGH CONFIDENCE	0 1
LOW CONFIDENCE	1 0
MODE X	1 1

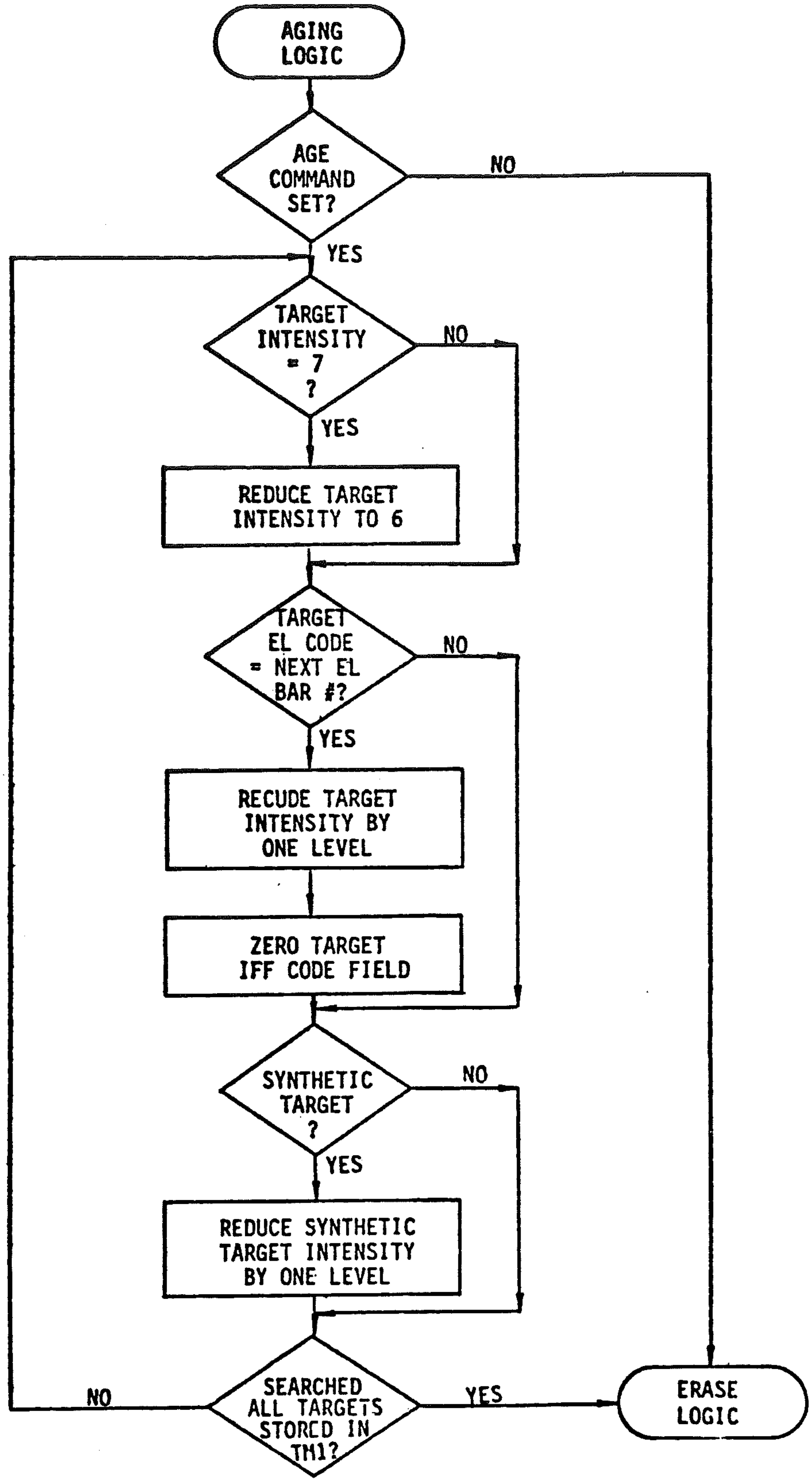


Figure 4.16.8 - TARGET AGING LOGIC

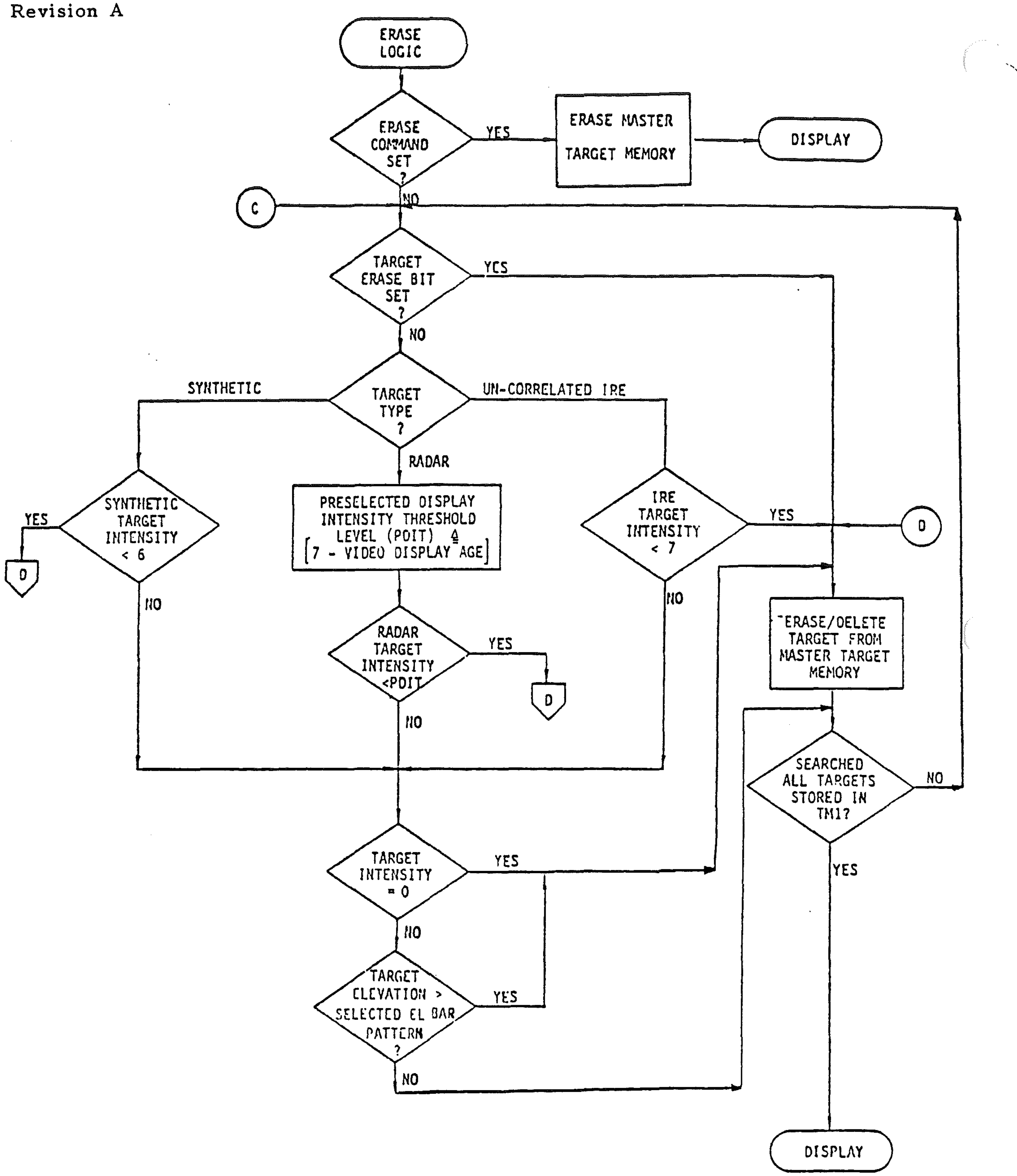


Figure 4.16.9 - TARGET/TARGET MEMORY ERASE LOGIC

4.17 Clutter Doppler Error Processing

The Clutter Doppler Processor is used for MPRF non-tracking modes. The processor takes radar return signals from the Analog Radar Signal Processor (ARSP 039 Unit) before the signals pass through the Clutter Canceller. The Clutter Doppler Error (CDE) computation measures the error incurred in shifting the Main Lobe Clutter (MLC) to dc frequency. The processor uses the radar returns from eight non-blanked range bins and measures the phase shift of the return in relation to the last sample from the same range bin for the frequency discriminant computation. It is also required to send the Number of Valid Samples (NVS) used in the CDE computation to the RDP for MLC Tracking. The CDE is used by RDP to derive the correct setting of the Voltage Controlled Oscillator (VCO).

4.17.1 Inputs

- Radar samples in the non-pause phase of each PRF (48 PRI interval) with data rate at one data set (32 PRI) per PRF.
- CDE gate from RDP.
- Threshold frequency discriminant k_c and amplitude discriminant A_C for CDE sample data validation.

4.17.2 Processing

The CDE buffer accumulates the last 32 non-blank pulses in each N_p pulse data interval. Only the last 32 pulses in the non-pause phases are used for the CDE computation. In each of the intervals, there are 8 range bins in which the CDE processor searches for the MLC returns. Timing and Control supplies the Clutter Doppler Error Processing with the 8 range bins per PRF to be processed. The CDE processor uses the radar sample data to compute the Clutter Doppler Error discriminant, and performs validity tests to verify the CDE result. After the validation, the CDE value and NVS are sent to the RDP for tracking MLC. The frequency discriminant, f_d, of these 32 pulses can be computed from the complex products of consecutive pulse-pairs from the same range bin.

$$f_d = \frac{In}{Qn} = \frac{\sum_{i=0}^{30} \mathrm{Im}(Z_{i+1} \cdot \bar{Z}_i)}{\sum_{i=0}^{30} \mathrm{Re}(Z_{i+1} \cdot \bar{Z}_i)}$$

where: I_i, Q_i = I and Q components of a delayed sample

I_{i+1}, Q_{i+1} = I and Q components of a current sample

Z_{i+1} = current sample = $I_{i+1} + jQ_{i+1}$

Z_i = delayed sample = $I_i + jQ_i$

$\bar{Z}_i$ = complex conjugate = $I_i - jQ_i$ of delayed sample

The validation of the frequency discriminant by amplitude test and/or frequency test depends on the state of the CDE gate command from the RDP. If the MLC returns are close to dc line (narrow clutter doppler error gate case), the frequency discriminant, f_d, must satisfy both the amplitude test and the frequency test.

$$\left| \sum_{i=0}^{30} Im(Z_{i+1} \cdot \bar{Z}_i) \right| < k_c \sum_{i=0}^{30} Re(Z_{i+1} \cdot \bar{Z}_i) \quad : \text{Phase Test}$$

and $$\sum_{i=0}^{30} Re(Z_{i+1} \cdot \bar{Z}_i) > A_c^2 \quad : \text{Amplitude Test}$$

where: k_c = tan 30°

A_c^2 = -27 db from A/D converter saturation

If the main lobe clutter is far off from the dc line (wide CDE gate) and both amplitude and phase tests are satisfied, f_d is computed as in the narrow gate case. If only the amplitude test is satisfied, f_d is computed.

$$f_d = 0.1 \text{ sgn} \sum_{i=0}^{30} Im(Z_{i+1} \cdot \bar{Z}_i)$$

If both tests fail the samples are rejected.

The verified f_d is then used to compute the Clutter Doppler Error (CDE) as follows:

$$CDE = (NVS)\ f_d = 31\ f_d$$

where: CDE = clutter doppler error

NVS = number of valid sample pairs used in the CDE calculation = 31.

4.17.3 Outputs

- Clutter Doppler Error (CDE) to RDP.
- Number of valid samples (NVS) used in the computation to RDP via IDA.

4.18 Medium Acquisition I

In Medium PRF Acquisition I (ACQ I) mode, the radar conducts a search within a narrow azimuth bound (±3°) from a specified azimuth direction as commanded by the Radar Data Processor (RDP). The MPRF Acquisition I processor shall search for any new hit beyond a designated range (coarse range R_A) and select the closest range target hit from the stored hit/miss data within the Acquisition I raster area. This unambiguous target range is used for target acquisition in Acquisition II (ACQ II) mode.

4.18.1 Inputs

- MPRF Acquisition I mode control word from RDP
- (Figure 4.18.1 RSP Word 1) via PSP
- Coarse range A from RDP
- (Figure 4.18.1 RSP Word 2) via PSP

4.18.2 Processing

The data processing for MPRF Acquisition I mode shall b the same as in the MPRF search mode. Some exceptions and additions as specified below.

a) The MPRF ACQ I processor shall look for the closest-range real-time target hit beyond the coarse range R_A as designated by RDP. The target return shall be above the CFAR hit/miss threshold level.

b) During ACQ I, the digital scan converter shall correlate the stored targets in the Target Memory (TM1) near the azimuth dirction as designated by the RDP. Its correlation gate is bounded by ±3° from the assigned azimuth direction with range limit from R_A to the maximum target range. If several hits are found within the correlation gate, the closest range or shortest range shall be selected (Figure 4.18.2). Target information in azimuth direction, target range, elevation bar and type of PRF data shall be sent to RDP.

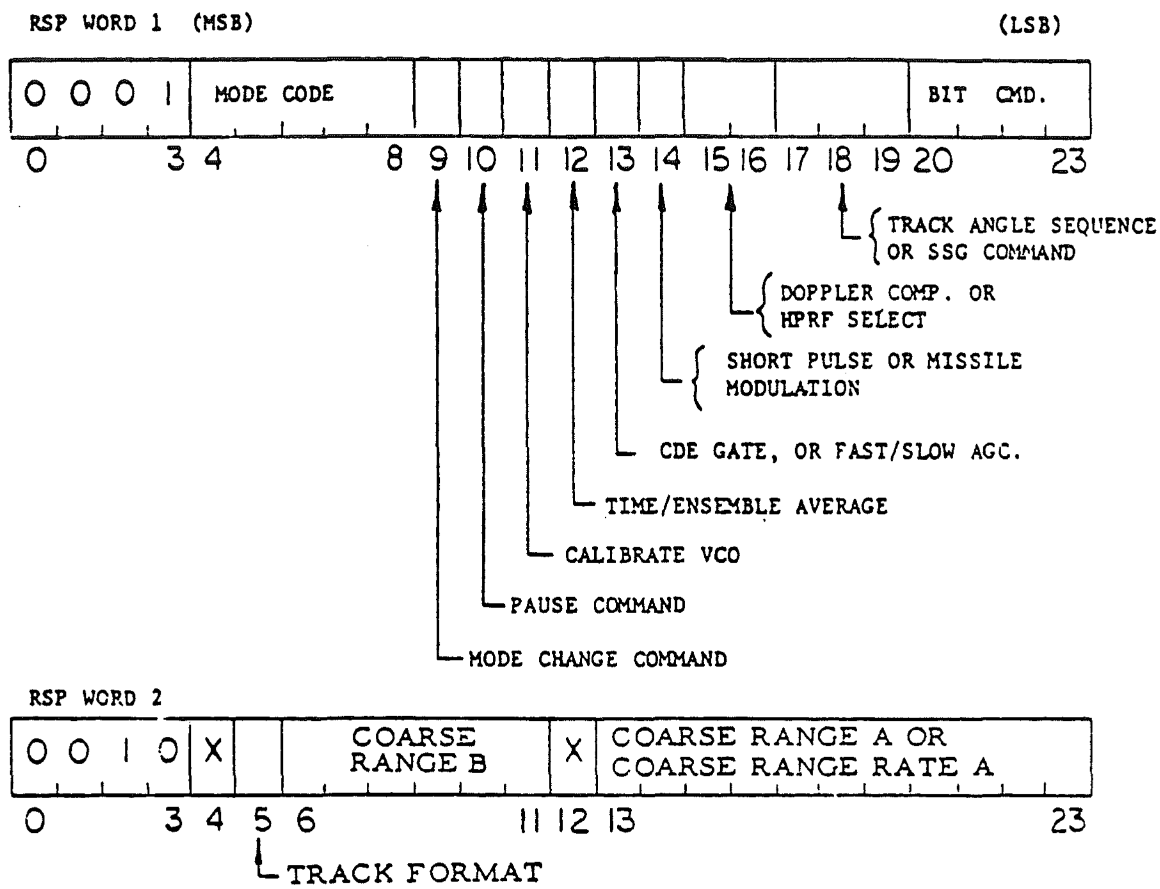


FIGURE 4.18.1

ACQUISITION MODE CONTROL WORD AND COARSE RANGE WORD

c) The mainlobe clutter error data for the computation of the clutter doppler error (CDE) shall not be accumulated nor transmitted to the RDP.

4.18.3 Outputs

- New hit data beyond the coarse range R_A shall be sent to RDP.
- The correlated target from the DSC Memory which has the shortest range from R_A shall be sent to the RDP.
- The data shall include:
  - a) Target azimuth position.
  - b) Resolved (unambiguous) range position.
  - c) PRF type (i.e., Hi-Minor, Major, Low-Minor, or 1., 1.3 or 1.6 μsec pulse width.)

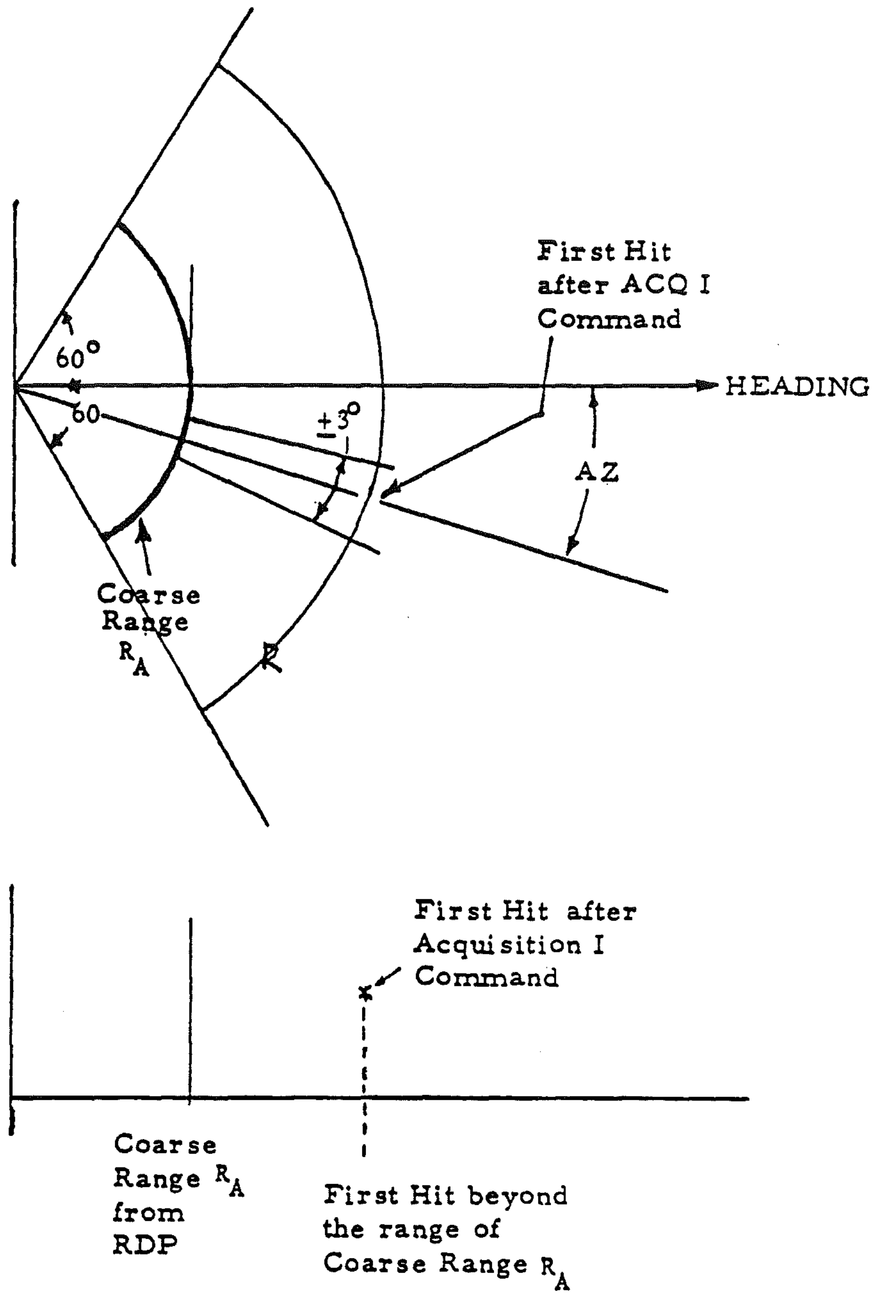


Figure 4.18.2 - MPRF ACQ I TARGET ACQUISITION

4.19 Medium PRF Acquisition II

The Medium PRF Acquisition II mode is used to search for targets within a 7 range bin acquisition gate from a designated unambiguous range R_A as commanded by RDP. Furthermore, the Acquisition II mode shall also be used to find the targets within a 7 range bin X 11 filter acquisition gate from an ambiguous range R_B as designated by RDP. These unambiguous target range data and ambiguous range/filter data shall be sent to RDP for target tracking.

4.19.1 Inputs

- Medium PRF Acquisition II Control Word from RDP via PSP.
- Unambiguous range (R_A) from RDP via PSP. (RSP Word 2)
- Ambiguous range (R_B) from RDP via PSP (RSP Word 2)
- Major PRF and pulse width from RDP. (RSP Word 7)

4.19.2 Processing

For Acquisition II mode, the basic data processing function is the same as in the MPRF Search mode, except the following:

a) In Acquisition II mode, only one single major PRF group is utilized so that the processing of data causes less delay. In this mode, the ACQ II processor searches for new hit/miss data within a designated acquisition gate. The hit/miss data can either be the short pulde or the Barker code compressed pulse data as commanded by the RDP.

b) In searching for range-resolved hit/miss data above the CFAR threshold, the hit/miss data shall be within a seven range bin acquisition gate starting from the unambiguous range R_A as designated by RDP. (The seven range bins shall be the actual range bin width of the assigned PRF).

c) No target correlation is required from the Digital Scan Converter (DSC). A signal of "data not valid" signal shall be sent to the DSC to inhibit target correlation and display.

d) The Acquisition II processor shall send the unresolved and uncollapsed hit/miss data within a 7 range bin X 11 filter acquisition gate starting from an ambiguous range R_B as commanded by RDP (Figure 4.19.1). The data shall be selected from the high minor (64 range bin) PRF data.

4.19.3 Outputs

- Unambiguous H/M data in 7 range bin window Hit/Miss outputs from 7 resolved (unambiguous) range bins specified by RDP scaled to the selected major range bin size.

  Bit position 0 through 6

  Sequence:

  R_0, R_1, R_2, ..., R_6

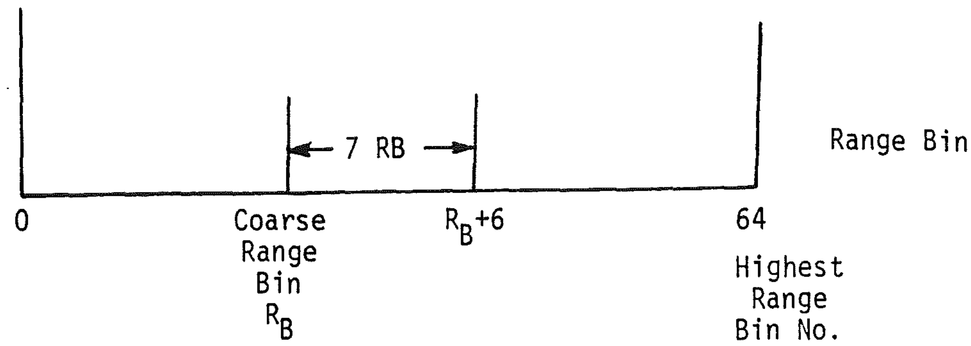
  R_0 = H/M indication in lowest range bin

  R_6 = H/M indication in highest range bin

  Output word format - IDA Word No. 18.

- Ambiguous H/M data in 7 range bins by 11 filters Hit/Miss outputs from 7 range bins by 11 filters data array specified by RDP. Hit/Miss data is taken from High Minor MPRF processing cycle. The RSP Tag is set when data is valid.

  The Hit/Miss data format is shown in Figure 4.19.1.



Acquisition gate to search for new hits from Hi-Minor PRF data

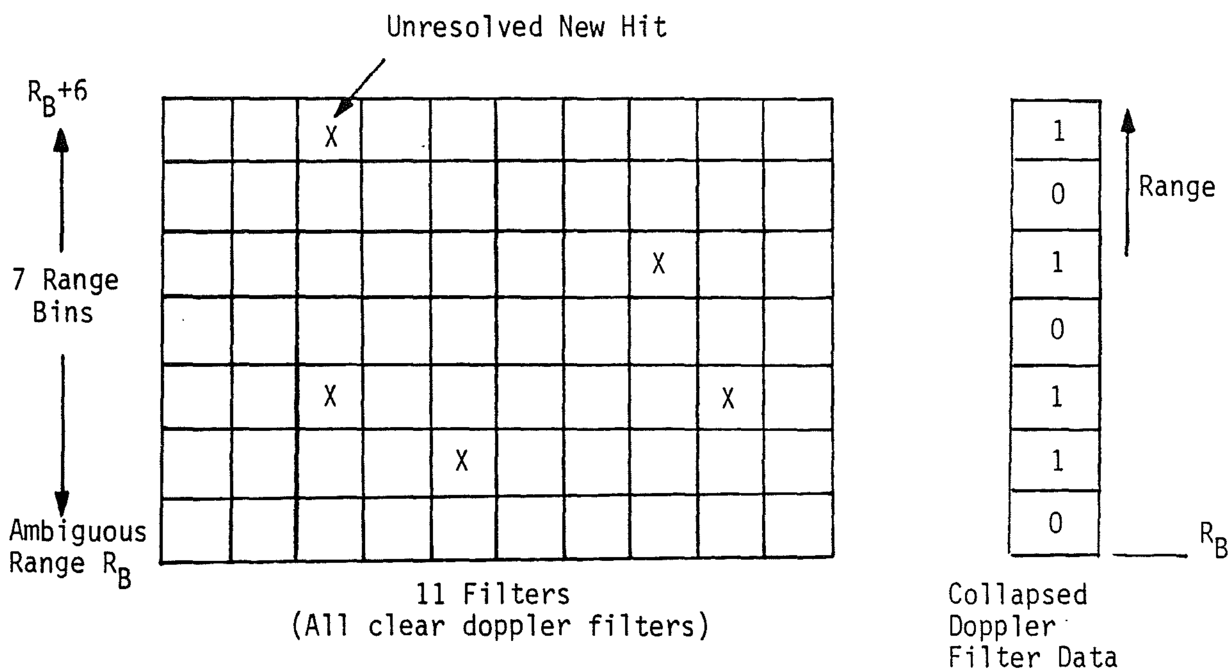


Figure 4.19.1

UNRESOLVED RANGE/FILTER DATA FOR ACQUISITION II MODE

BIT POSITION J						
0	1	2	3	4	5	6
$R_{0,0}$	$R_{0,1}$	$R_{0,2}$	$R_{0,3}$	$R_{0,4}$	$R_{0,5}$	$R_{0,6}$
$R_{1,0}$	$R_{1,1}$	$R_{1,2}$	$R_{1,3}$	$R_{1,4}$	$R_{1,5}$	$R_{1,6}$
$R_{10,0}$	$R_{10,1}$					$R_{10,6}$

$R_{i,j}$

i = 0, 1 ......10 (filter number)

j = 0, 1 6

(Range bin number or bit position)

IDA Word No.	7	i = 0, j = 0, ...6
	8	i = 1, j = 0, ...6
	9	i = 2, j = 0, ...6
	10	i = 3, j = 0, ...6
	11	i = 4, j = 0, ...6
	12	i = 5, j = 0, ...6
	13	i = 6, j = 0, ...6
	14	i = 7, j = 0, ...6
	15	i = 8, j = 0, ...6
	16	i = 9, j = 0, ...6
	17	i = 10, j = 0, ...6

SECTION 5

MPRF TRACK MODE

5.0 INTRODUCTION

The current F-15 Radar Signal Processor (RSP) unit is replaced by a Programmable Signal Processor (PSP) unit. This section defines the signal processing to be performed in the programmable PSP unit when operating in the MPRF Track mode.

The signal processing scheme is shown in the block diagram of Figure 5.1. The diagram is used to illustrate the software signal processing, therefore it does not include the hard-wired (non-programmable) clutter canceller, doppler compensator, and pulse compressor modules which immediately precede this processing.

Tracking discriminant calculations (range, velocity, and angle), and track signal-to-noise calculations are performed in the PSP software. (These functions are not performed by the current RSP hardware).

The following subsections of this report discuss the individual elements (functions) of the software processing shown in Figure 5.1. Each subsection that follows is numbered to correspond with the "blocks" in Figure 5.1.

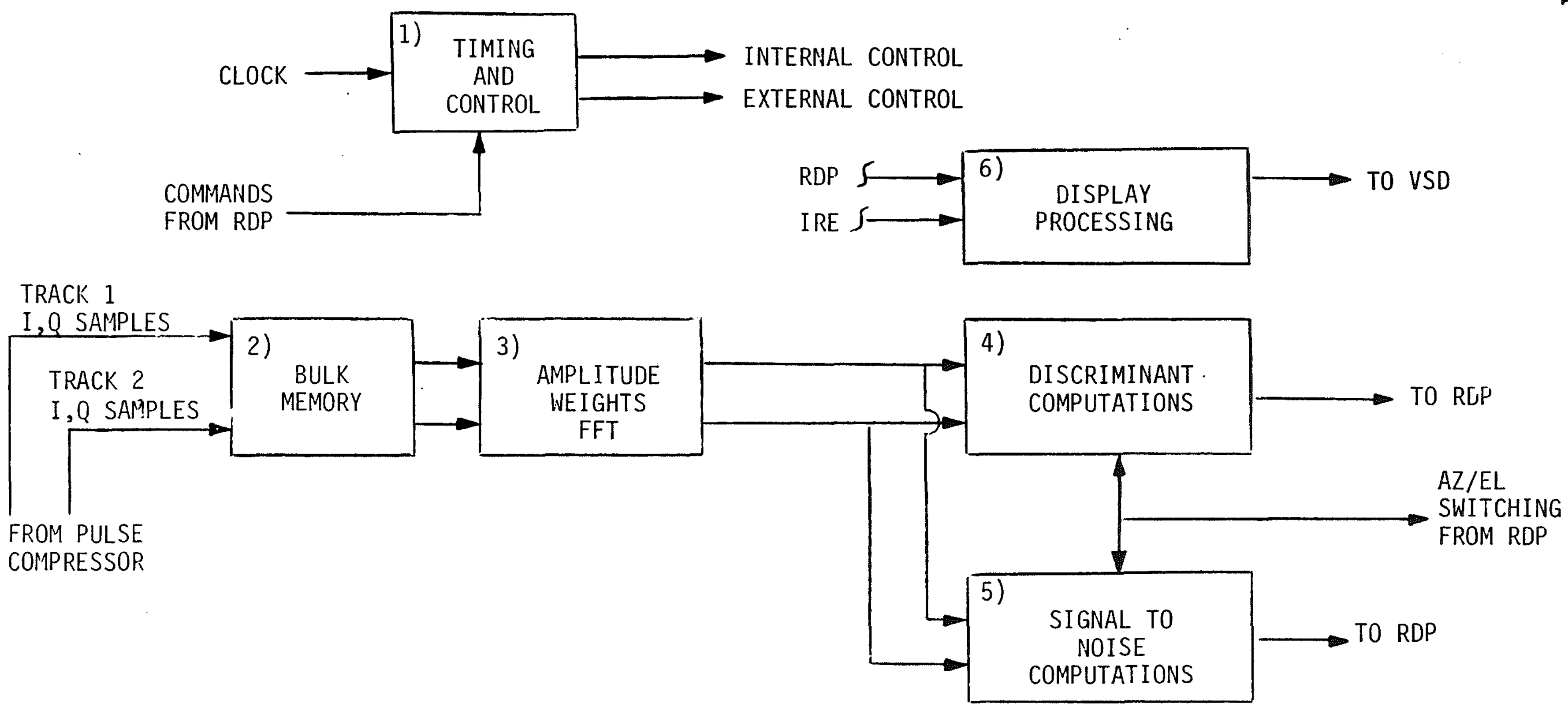


Figure 5.1 - MPRF TRACK PROCESSING

5.1 MPRF Track Timing & Control

Timing & Control of the signal processing is accomplished in various parts of the PSP - both hardware and software. This section first discusses the overall timing & control scheme. Then, those timing and control functions performed exclusively by the PSP program are discussed in detail. A list of parameters to be used throughout the entire document is also included, and defined.

5.1.1 Inputs

- Mode command from RDP identfying "MPRF Track".
- Track Angle Sequence command from the RDP.
- Coarse & Fine range gate commands from RDP.
- Track Format command from RDP.
- Short Pulse/Pulse Compression Command from RDP.
- PRF command from RDP.
- Number of phases in a filter cycle (N_p) from RDP.
- Pulse Width command from RDP.

(Note that some of the inputs above are not sent directly, but are implied commands resulting from the control that the RDP applies to the Timing Generator (hardware) Modules in the PSP. This is discussed further in the next paragraph).

5.1.2 Processing

5.1.2.1 20 MHz Derived Timing

Fundamental control of the radar system parameters (PRF, pulse width, A/D sampling, etc.) is derived from the Timing Generator Modules in the PSP. These circuits are designed to generate a set of sequenced timing signals as commanded by the RDP. The Timing Generator scheme is illustrated in Figure 5.1.1. As shown in the Figure, Timing Generator control tables for all radar modes are input to the PSP Bulk Memory via "C" memory from the RDP at system startup. The RDP then selects the table to be used at any particular point in time via the Mode command. The PSP transfers the RDP selected Timing Generator control table(s) to "C" memory. Each table has the information necessary to control the time history of all the Time Generators outputs. This timed sequence of output signals routed to the various radar units yields the radar operation (waveform) desired.

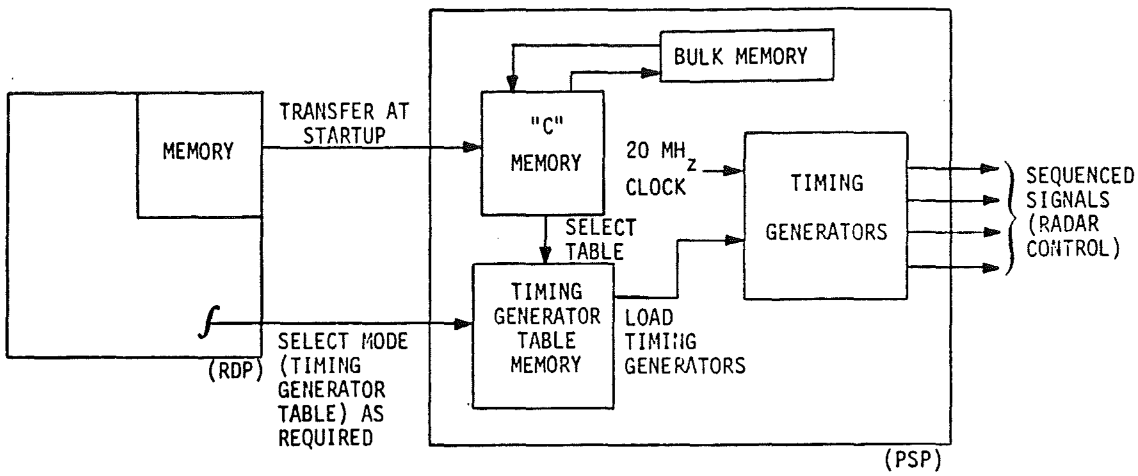


Figure 5.1.1.1

TIMING GENERATOR SCHEME

Note that some of the RDP control signals are sent to the Timing Generators directly - in real time - rather than being stored to Bulk Memory at startup and later transferred to "C" memory and then to the Timing Generators. Examples would be the coarse & fine range gate commands which vary over too large a range (too many possible combinations) to pre-store. The list of RDP signals which control the Timing Generators modules is not included in this document.

As shown in Figure 5.1.1, the Timing Generators are driven by a 20 MHz clock. The smallest available clock interval is therefore 1/20 MHz = 50 nsec. This interval is the fine range increment commandable from the RDP. The range bin width (sampling rate) is derived by counting several of the 20 MHz clocks to yield intervals that are integer multiples of 100 nsec. With these range bin widths available, and the number of range bins between transmitter pulses selectable, the RDP can command any PRF that is available in the current system (and more).

A definition of the MPRF Track mode parameters and their range of values is given below:

N_{RB} = The number of range bins intervals between transmitted pulses

= 64, 66, or 68 as commanded by the RDP

γ = Range bin width one of 14 values commandable by RDP.

PRI = $N_{RB} \cdot \gamma$

PRF = 1/PRI

N_F = Number of filters formed = 16

N_P = Number of phases (80 PRI) in an RDP Kalman filter cycle

= 2, 3, 4 ... 8 as commanded by RDP

N_{CR} = Number of coarse range increments to delay sampling after transmitter pulse. The number is computed in the RDP so that we sample only the bins of interest.

N_{FR} = Number of fine range increments to delay sampling (in addition to coarse range delay).

N_S = The number of range bins to sample; 8 or 12 commanded by the RDP.

N_{FT} = Doppler filter number of the leading edge of the tracking gate.

A/D sampling starts at a delay of (N_{CR} x γ) + (N_{FR} x 50 nsec) from the leading edge of the transmitter pulse. Sampling continues at "γ" intervals for a total of 12 samples times under normal conditions. A total of 8 sample times are used under conditions of very short target range when "Short Range Track Format" is commanded by the RDP. At each sample time, four numbers (Track 1 I&Q and Track 2 I&Q) are converted and sent to Bulk Memory. If the commanded N_{CR} is large enough so that 12 (or 8) sample times do not fit within the remaining range bins (i.e. if $N_{CR} > [N_{RB} - 12 \text{ (or 8)}]$), then zeroes may be inserted into Bulk Memory for the missing samples.

Filters (FFT in Figure 5.1) are formed from the selected range bins to obtain the signal and noise (early and late) magnitude estimates. Data from selected range bins and filters are partially processed, then sent to the RDP to determine angle, velocity and range discriminants.

The signal and noise samples use a 5-2-5 window configuration or a 1-2-5 window configuration. The Track Format Command from the RDP controls the window configuration.

When the 5-2-5 window configuration (Normal Track Format) is commanded the signal and noise information is obtained from the early window of five range bins, a notch of two bins around the signal and a late window of five range bins. The center two bins are used for the signal. The early and late noise estimates are obtained from the early and late range bin windows, respectively.

When the Short Range Track Format is commanded the signal and noise samples use a 1-2-5 window. For this configuration, the early noise sample is taken from a single bin. The signal notch is two range bins and the noise bins are obtained from a late window of five range bins.

The MPRF track time sequence shall be controlled by the T&C through counting the PRIs, providing 16 PRIs for pause and 64 PRIs for signal data in each data cycle. (The signal processing cycle is grouped into 16 pause PRIs and four blocks of 16 PRIs for signal processing). At the end of each block of (N_P x 80) PRIs, the track data is sent to the RDP. The data sent to the RDP is specified in later paragraphs.

A Process Synch signal shall indicate the start of each new (80 PRI) signal processing cycle.

5.1.2.2 The Internal Timing

Timings for processing internal to the PSP shall be derived from a self-contained clock frequency of about 7.14 MHz. The T&C function shall generate flags, set control indicators, transfer mode commands from the RDP, and perform other services as required to implement the data flow and processing detailed for this mode. As an example, the pause duration, clutter edge location, AGC timing, target edge location and track angle sequence timing must be commanded for each 80 PRI Processing phase of the sequence. Other such requirements derive from the following functional descriptions and their detailed implementations.

5.1.3 Outputs

- Radar control signals from the Timing Generator modules.

5.2 MPRF Track Bulk Memory Storage

The bulk memory accepts Track 1 and Track 2 channel complex data from the A/D converter for temporary storage. The bulk memory will also store intermediate processing results, program instructions, coefficients and constants as required by the processing functions.

5.2.1 Inputs

- Track 1 and Track 2 Data from the A/D converter per Table 5.2.1.
- Data Time Gates for selective storage per Table 5.2.1.
- Intermediate answers determined in various processes as required.
- Program instructions and Timing Generator control tables as required by various modes (loaded from RDP at startup).
- Track Angle sequence from T&C.
- N_S - Number of range bin samples from the RDP, = 8 or 12.
- "Sums (1) through (10)" from section 5.4 for temporary storage.

5.2.2 Processing

Provide buffering of data, instructions, constants and intermediate results as required to meet the following requirements:

- 96K of 24-bit Bulk Memory Storage shall not be exceeded.
- 560 nanosec/(8-24 bit words) transfer rate to and from bulk memory (NOTE: Port 1 shall be dedicated to the A/D converter input).

5.2.3 Outputs

- Track 1 data to section 5.3 (See Table 5.2.1).
- Track 2 data to section 5.3 (See Table 5.2.1).
- Other data, instructions, constants, and intermediate results as required by the operating program sequence.
- Updated sums, "Sum (1) to Sum (10)" to RDP.

TABLE 5.2.1

STORAGE VALUES FOR BULK MEMORY MPRF TRACK

TRACK CONFIGURATION (2)	NUMBER OF STORAGE POINTS $N_{SP} = N_f * N_S = 16 * (8 \text{ or } 12)$ (3)		TOTAL STORAGE POINTS (1)
	TRACK 1 SIGNAL (2)	TRACK 2 SIGNAL (2)	
+AZ	N_{SP}	N_{SP}	$2N_{SP}$
-AZ	N_{SP}	N_{SP}	$2N_{SP}$
+EL	N_{SP}	N_{SP}	$2N_{SP}$
-EL	N_{SP}	N_{SP}	$2N_{SP}$
			$8N_{SP}$

(1) All points 24 bits: 12 bits I, 12 bits Q.

(2) Order of +AZ, -AZ, +EL, -EL switching is selected randomly by the RDP. Track format is commanded by RDP as either "Short Range" (N_S = 8) or "Normal" (N_S = 12).

(3) N_f = Number of filters formed = 16.
In each PRI the A/D Converter may sample up to 12 times for both Track 1 and Track 2 channels. The points to be processed include four blocks of $N_f \times N_S$ Track 1 data and four blocks of $N_f \times N_S$ Track 2 data for signal processing. Real Time data gates from the T&C function control the selective storage.

5.3 MPRF Track Amplitude Weighting and FFT

5.3.1 Inputs

- N_f x N_S Track 1 I, Q data from section 5.2.
- N_f x N_S Track 2 I, Q data from section 5.2.
- Filter coefficients (8).
- N_{CR} = Coarse Range B Command from RDP.
- N_{FT} = Velocity Gate Command from RDP.
- Coordinates which can be used to locate the tracking gate (Track format, N_{CR} range and N_{FT} filter) from RDP.

5.3.2 Processing

The track I, Q data from the Bulk Memory Storage section 5.2 are amplitude weighted across N_f pulses. Amplitude weighting is done in order that the output of the Fast Fourier Transform (FFT) has a peak mainlobe to peak sidelobe ratio of 55 db.

If S(r,x,n) represents the nth sample of the xth track Channel and rth range bin, the amplitude weighted samples, $S_W(r,x,n)$ are:

$$S_W(r,x,n) = A(n)\, S(r,x,n)$$

where:

$n = 0, 1, 2 \ldots\ldots (N_f-1)$

$N_f = 16$ pulses

$x = 1$ or 2 (number of track channels)

$r = N_{CR}, N_{CR}+1, \ldots\ldots N_{CR}+N_S-1$ (N_S range bins).

It should be noted that:

$$S_W(r,x,n) = 0 \begin{cases} r=1, 2\ldots\ldots 14 & \text{(Pulse Compression operation)} \\ r=1, 2 & \text{(Short Pulse operation)} \end{cases}$$

Amplitude weighting is bypassed for ranges under the receiver blanking gate.

The amplitude weights, A(n) which are real and symmetric, are shown in Table 5.3.2.1 for N_f equal to 16.

TABLE 5.3.2.1 - AMPLITUDE WEIGHTS, N_f = 16

SAMPLE NUMBER (n)	AMPLITUDE WEIGHTS A(n)
0 , 15	3. 42676E-2
1 , 14	9. 81094E-2
2 , 13	0. 210436
3 , 12	0. 369558
4 , 11	0. 560194
5 , 10	0. 752945
6 , 9	0. 910871
7 , 8	1

N_f samples per range bin are transformed into N_f frequency bin samples via an FFT algorithm. This process shall be repeated for all the processed range bins, for both Track 1 and Track 2 channels. The mathematical form of the discrete Fourier Transform, which is the basis for the FFT, is as follows:

$$F(r,x,k) = \frac{1}{N_f} \sum_{n=0}^{N_f-1} S_W(r,x,n)\, W^{nk}$$

k = 0, 1, 2.... N_f-1 (number of filters, 0 is the d.c. filter)

x = 1, 2

r = N_{CR}, $N_{CR}+1$, ...N_C+N_S-1

W = $e^{-j\frac{2\pi}{N_f}}$

T = sampling period.

The constants W^{nk} are precomputed inputs to this function to reduce processing time.

$F(r,x,k) = 0$ for all x and k when r is in the blanked zone

$$r = \begin{cases} 1, 2, \ldots 14 & \text{(Pulse Compression operation).} \\ 1, 2 & \text{(Short Pulse operation)} \end{cases}$$

The FFT design should be similar to the filter used in MPRF search mode. For MPRF track, the FFT algorithm shall be designed for binary arithemetic and requires four passes to complete a 16 point FFT analysis. At the end of each pass, the output is rescaled to avoid the overflow of data.

The signal range bins are numbered:

$N_{CR} + N_{CRS}$, $N_{CR} + N_{CRS} + 1$

N_{CR} = Coarse range command from RDP

$$N_{CRS} = \begin{cases} 5, & \text{Normal Track Format} \\ 1, & \text{Short Range Track Format} \end{cases}$$

The processed FFT outputs are used to form the data matrix of N_f filter X N_S range bins to be used for track discriminants computation.

5.3.3 Outputs

- Matrix of N_f filter x N_s range bins of Complex (I&Q) outputs from the FFT and MPRF Track Discriminants Computation (section 5.4), and to MPRF Track Signal to Noise Computation (section 5.5).

5.4 A/A MPRF Track Discriminants

5.4.1 Inputs

The following signals from the Amplitude Weighting and FFT Function are inputs to the A/A Track Discriminants Function. (An entire matrix of N_f filters X N_S range bins is available. A subset, 2 filters x 2 range bins, is designated as the tracking gate by the RDP via the track format, coarse range and velocity gate commands. The input data list below includes only the 2 filters x 2 range bins of the designated tracking gate, and is labeled accordingly).

Input	MPRF Mode	
• $F(N_{CR}+N_{CRS},\ 1,\ N_{FT})$	Main LoF ShR I Main LoF ShR Q	Flood Track (FT) (Main channel data is substituted for Track 1 data in the radar front-end when operating in Flood track. The other radar channel - Track 2 is not used).
• $F(N_{CR}+N_{CRS}+1,1,N_{FT})$	Main LoF LgR I Main LoF LgR Q	
• $F(N_{CR}+N_{CRS},1,N_{FT}+1)$	Main HiF ShR I Main HiF ShR Q	
• $F(N_{CR}+N_{CRS}+1,1,N_{FT}+1)$	Main HiF LgR I Main HiF LgR Q	
• $F(N_{CR}+N_{CRS},X,N_{FT})$	TRKX LoF ShR I TRKX LoF LgR Q	Angle Track (T) (Track 1 data and Track 2 data are processed thru the radar when operating in Angle Track).
• $F(N_{CR}+N_{CRS}+1,X,N_{FT})$	TRKX LoF LgR I TRKX LoF LgR Q	
• $F(N_{CR}+N_{CRS},X,N_{FT}+1)$	TRKX HiF ShR I TRKX HiF ShR Q	
• $F(N_{CR}+N_{CRS}+1,X,N_{FT}+1)$	TRKX HiF LgR I TRKX HiF LgR Q	

$X = 1,2$

The data rate of the above signals is one set/80 PRI phase.

The following additional internal signals are required by this function for RDP.

- Angle Ident. from RDP
- Range Weighting (k) from RDP
- MPRF Track Mode Flag from RDP
- Number of process sync per Kalman filter cycle (1-8) from RDP
- Flood Track Command from RDP

5.4.2 Processing

Purpose

The purpose of this function is to provide the F-15 RDP program with the capability to compute tracking error signals (discriminants) from PSP processed data.

5.4.2.1 Flood Track

In Flood Track, the Flood antenna is used and angle-tracking discriminants are not formed. Discriminants are formed for both Range and Velocity (MPRF).

For MPRF, define vectors A, B, C, D:

$$A = (\text{Main LoF ShR I}) + j\,(\text{Main LoF ShR Q})$$
$$B = (\text{Main LoF LgR I}) + j\,(\text{Main LoF LgR Q})$$
$$C = (\text{Main HiF ShR I}) + j\,(\text{Main HiF ShR Q})$$
$$D = (\text{Main HiF LgR I}) + j\,(\text{Main HiF LgR Q})$$

Then the components for the velocity discriminant ΔV_m are given by:

$$N_V = |A + B| - |C + D|$$
$$D_V = |A + B| + |C + D|$$

and the components for the range discriminant ΔR_m are given by:

$$N_R = |A - C| - k\,|B - D|$$
$$D_R = |A - C| + k\,|B - D|$$
$$k = \text{Range Weighting}$$

Running sums of each of N_V, D_V, N_R, D_R are to be maintained for the duration of the tracking filter iteration cycle.

$$\text{Sum (1)} = \Sigma(N_V)$$

$$\text{Sum (2)} = \Sigma(D_V)$$

$$\text{Sum (3)} = \Sigma(N_R)$$

$$\text{Sum (4)} = \Sigma(D_R)$$

where Σ implies summation.

5.4.2.2 Angle Track

In Track, the angle tracking loop is closed through angle discriminants computed in this function. The additional dimension of angle doubles the quantity of input data as well as requiring additional computations for angle discriminants and for Angle Ratio Threshold (ART).

For MPRF, define vectors A, B, C, D, E, F, G, H:

A = (Trk 1 LoF ShR I) + j (Trk 1 LoF ShR Q)
B = (Trk 1 LoF LgR I) + j (Trk 1 LoF LgR Q)
C = (Trk 2 LoF ShR I) + j (Trk 2 LoF ShR Q)
D = (Trk 2 LoF LgR I) + j (Trk 2 LoF LgR Q)
E = (Trk 1 HiF ShR I) + j (Trk 1 HiF ShR Q)
F = (Trk 1 HiF LgR I) + j (Trk 1 HiF LgR Q)
G = (Trk 2 HiF ShR I) + j (Trk 2 HiF ShR Q)
H = (Trk 2 HiF LgR I) + j (Trk 2 HiF LgR Q)

C' = (Trk 2 LoF ShR Q) - j (Trk 2 LoF ShR I)
D' = (Trk 2 LoF LgR Q) - j (Trk 2 LoF LgR I)
G' = (Trk 2 HiF ShR Q) - j (Trk 2 HiF ShR I)
H' = (Trk 2 HiF LgR Q) - j (Trk 2 HiF LgR I)
K = A + B - E - F
L = C + D - G - H

Then the components to be used for the velocity and range discriminants are given by:

$$N_V = |A + B + C' + D'| - |E + F + G' + H'|$$

$$D_V = |A + B + C' + D'| + |E + F + G' + H'|$$

$$N_R = |A + C' - E - G'| -k\ |B + D' - F - H'|$$

$$D_R = |A + C' - E - G'| +k\ |B + D' - F\ '\ H'|$$

$$k = \text{Range Weighting}$$

and the components N_A and N_D to be used for the angle discriminant are given by:

$$N_A = \Sigma\Delta = \frac{1}{8}(K \cdot L) = \frac{1}{8}(I_K I_L + Q_K Q_L)$$

$$D_A = \Sigma^2 = \left|\frac{1}{4}(K - jL)\right|^2 = \frac{1}{16}\left|(I_K - Q_L)^2 + (Q_K + I_L)^2\right|$$

and for ART,

$$|\Delta|^2 = \left|\frac{1}{4}(K + jL)\right|^2 = \frac{1}{16}\left|(I_K - Q_L)^2 + (Q_K + I_L)^2\right|$$

where:

Σ implies antenna sum signal and Δ implies antenna difference signal.

In angle tracking, four sets of N_V, D_V, N_R, D_R, N_A, D_A and $|\Delta|^2$ will be computed within an 80 PRI phase. Each set of these applies to either the elevation or azimuth tracking channel depending upon the input variable "Angle Ident" from the RDP for that subphase as follows:

Angle Ident	00	01	10	11
Angle Discriminant	+AZ	-AZ	+EL	-EL

Running sums of each of the following terms are to be maintained for the duration of each track filter iteration cycle as commanded by the RDP.

$$\text{Sum (1)} = \Sigma\{N_V(+AZ) + N_V(-AZ) + N_V(+EL) + N_V(-EL)\}$$

$$\text{Sum (2)} = \Sigma\{D_V(+AZ) + D_V(-AZ) + D_V(+EL) + D_V(-EL)\}$$

$$\text{Sum (3)} = \Sigma\{N_R(+AZ) + N_R(-AZ) + N_R(+EL) + N_R(-EL)\}$$

$$\text{Sum (4)} = \Sigma\{D_R(+AZ) + D_R(-AZ) + D_R(+EL) + D_R(-EL)\}$$

$$\text{Sum (5)} = \Sigma\{N_A(+AZ) - N_A(-AZ)\}$$

$$\text{Sum (6)} = \Sigma\{D_A(+AZ) + D_A(-AZ)\}$$

$$\text{Sum (7)} = \Sigma\{N_A(+EL) - N_A(-EL)\}$$

$$\text{Sum (8)} = \Sigma\{D_A(+EL) + D_A(-EL)\}$$

$$\text{Sum (9)} = \Sigma\{|\Delta(+AZ)|^2 + |\Delta(-AZ)|^2\}$$

$$\text{Sum (10)} = \Sigma\{|\Delta(+EL)|^2 + |\Delta(-EL)|^2\}$$

Note that, in the MPRF mode, discriminants are formed from data obtained in the last four of the five 16 pulse array periods within one phase time, and the length of the tracking filter iteration cycle depends upon the PRF.

5.4.3 Outputs

The following internal signals are made available as outputs of this function:

The four MPRF Flood track running sums as provided for above.

The ten MPRF (angle) track running sums as provided for above.

5.5 MPRF Track Signal to Noise Ratio Computation

The purpose of this function is to provide the F-15 RDP Program with the capability to compute the estimates of target signal to noise ratio (SNR) based upon signal plus noise to noise measurements made by PSP.

5.5.1 Inputs

- Track 1 and Track 2 (I,Q) data for N_S range bins x 2 filters from section 5.3.
- Short Range Flag from RDP.
- Track Angle Sequence from RDP.
- N_{CR}; Coarse range command.
- N_{FT}; Velocity filter command.
- Number of process sync per Kalman filter cycle N_P.

5.5.2 Processing

5.5.2.1 Track

Using data from each of the last four 16 pulse array periods of a phase, the PSP forms a matrix of data cells in ambiguous range and ambiguous velocity nominally centered on the target for Track 1 and Track 2 channels.

If the complex filter samples from the matrix are:

$F(r,1,k, \pm AZ/EL)$ Track 1 and

$F(r,2,k, \pm AZ/EL)$ Track 2

where (r) is the range bin number and (k) is the filter number of the complex filter data.

The sum (F_Σ) and difference (F_Δ) Track 1 and Track 2 complex data, (see Figure 5.5.2.1), are obtained as follows:

$$F_\Sigma(r,k, \pm AZ/EL) = F(r,1,k, \pm AZ/EL) - j\, F(r,2,k, \pm AZ/EL)$$

$$F_\Delta(r,k, \pm AZ/EL) = F(r,1,k, \pm AZ/EL) + j\, F(r,2,k, \pm AZ/EL)$$

where:

$$r = N_{CR}, N_{CR}+1, - - - N_{CR} + N_S - 1$$

N_{CR} = Coarse Range Bin Command

$$N_S = \begin{cases} 12; \text{ Normal format} \\ 8; \text{ Short range format} \end{cases}$$

$$k = N_{FT}, N_{FT}+1$$

N_{FT} = Lower filter number of velocity track filters

$\pm AZ/EL$ = Corresponds to the four values of Angle Ident as applied to data from each of the 16 - pulse array periods of a phase.

Secondary Target Rejection

In the sections that follow noise estimates are to be made over early and late range bins of azimuth and elevation data for sum and difference channels. The presence of a target in the noise cells yields an artificially high value of noise. Thus, before being used in noise estimation, the content of noise cells shall be processed as follows:

If the magnitude of a noise cell is greater than twice the noise average of all similar cells, then replace the contents of that cell with the average, else retain the original value. Tracking cells are not included in the average or altered by the average of the noise cells.

Example: Let $\overline{F}_\Sigma(\pm AZ)$ be the average magnitude of early and late noise cells summed over both +AZ and -AZ switching. If $|F_\Sigma(r,k, \pm AZ)| > 2 \bullet \overline{F}_\Sigma(\pm AZ)$

then let:

$$|F_\Sigma(r,k, \pm AZ)| = \overline{F}_\Sigma(\pm AZ)$$

Similar comparisons are made for Sum Channel Elevation, Difference Channel Azimuth, and Difference Channel Elevation. The modified noise cell magnitudes are used in the noise estimates that follow.

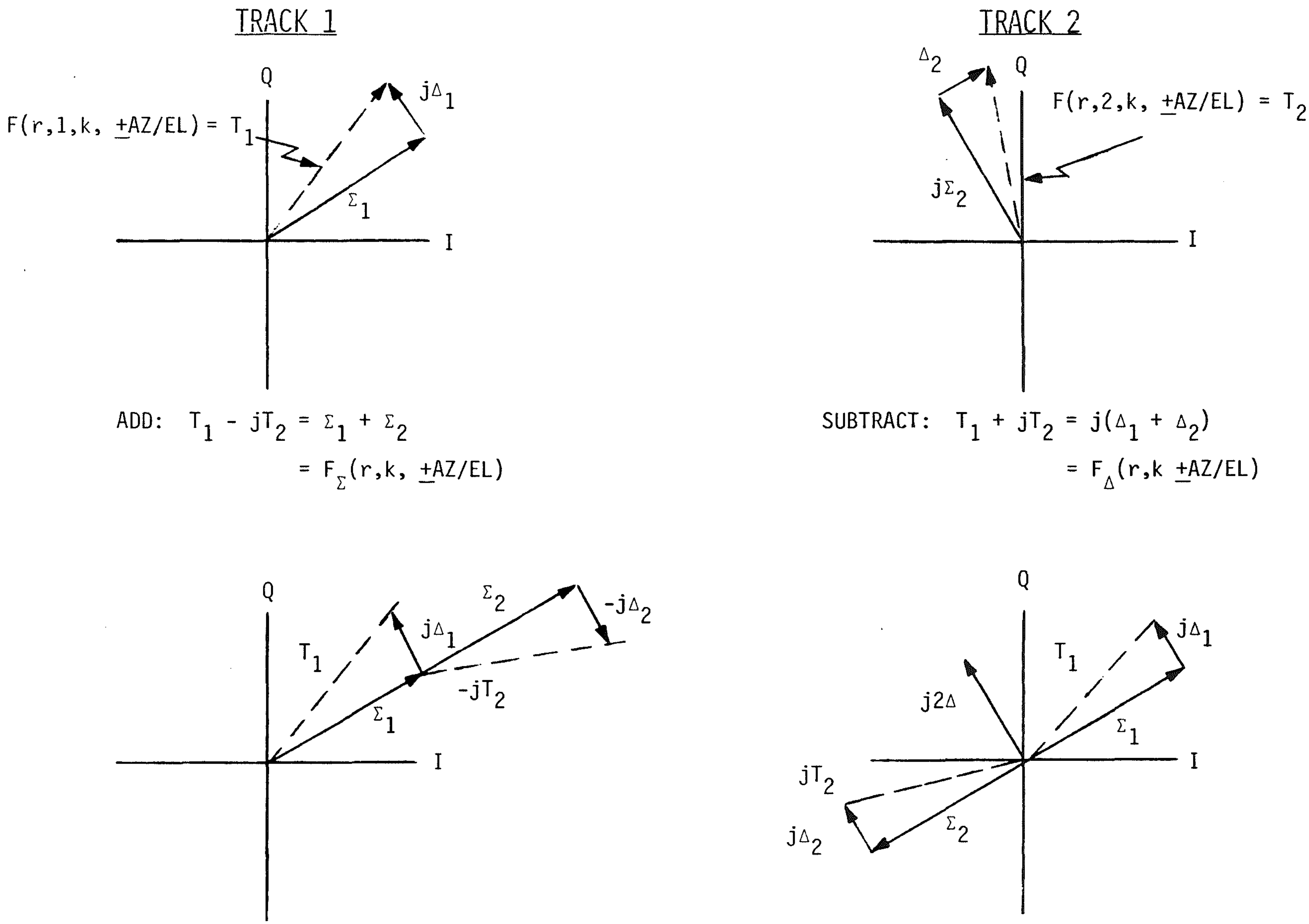


FIGURE 5.5.2.1 - TRACK ADDER

Early Σ Noise (± AZ)

$$N_E(\Sigma, \pm AZ) = (C_{SR}) \sum_{1}^{N_{PS}} \sum_{k=N_{FT}}^{N_{FT}+1} \sum_{r=N_{CR}}^{N_{CR}+5-C_{SR}} \left| F_\Sigma(r,k, \pm AZ) \right|$$

where: $C_{SR} = \begin{cases} 5; & \text{Short range format} \\ 1; & \text{Normal format} \end{cases}$

($\pm$AZ = Sum over both +AZ and -AZ switching)

Early Σ Noise (± EL)

Early Σ Noise (± EL) is formed similar to Early Σ Noise (± AZ) except for (± AZ) being replaced by (± EL).

Late Σ Noise (± AZ)

$$N_L(\Sigma, \pm AZ) = \sum_{1}^{N_{PS}} \sum_{k=N_{FT}}^{N_{FT}+1} \sum_{r=N_{CR}+8-C_{SR}}^{N_{CR}+12-C_{SR}} \left| F_\Sigma(r,k, \pm AZ) \right|$$

Late Σ Noise (± EL)

Late Σ Noise (±EL) is formed simular to Late Σ Noise (±AZ) except for (±AZ being replaced by (±EL).

Signal

$$S(\Sigma) = \sum_{1}^{N_{PS}} \sum_{k=N_{FT}}^{N_{FT}+1} \sum_{r=N_{CR}+6-C_{SR}}^{N_{CR}+7-C_{SR}} \left| F_\Sigma(r,k) \right|$$

Note: S is available for all 4 ±AZ/EL Angle Ident combinations.

Early Δ Noise (± AZ)

$$N_E(\Delta, \pm AZ) = (C_{SR}) \sum_{1}^{N_{PS}} \sum_{k=N_{FT}}^{N_{FT}+1} \sum_{r=N_{CR}}^{N_{CR}+5-C_{SR}} \left| F_\Delta(r,k, \pm AZ) \right|$$

Early Δ Noise ($\pm$EL)

Early Δ Noise ($\pm$EL) is formed similarly to Early Δ Noise ($\pm$AZ) except for ($\pm$AZ) being replaced by ($\pm$EL).

Late Δ Noise ($\pm$AZ)

$$N_L(\Delta, \pm AZ) = \sum_{1}^{N_{PS}} \sum_{k=N_{FT}}^{N_{FT}+1} \sum_{r=N_{CR}+8-C_{SR}}^{N_{CR}+12-C_{SR}} \left| F_\Delta(r,k, \pm AZ) \right|$$

Late Δ Noise ($\pm$EL)

Late Δ Noise ($\pm$EL) is formed similarly to Late Δ Noise ($\pm$AZ) except for ($\pm$AZ) being replaced by ($\pm$EL).

For convenience Early Δ Noise ($\pm$AZ) and Late Δ Noise ($\pm$AZ) may be combined:

$$N_{EL}(\Delta, \pm AZ) = N_E(\Delta, \pm AZ) + N_L(\Delta, \pm AZ)$$

Also Early Δ Noise ($\pm$EL) and Late Δ Noise ($\pm$EL) may also be combined:

$$N_{EL}(\Delta, \pm EL) = N_E(\Delta, \pm EL) + N_L(\Delta, \pm EL)$$

5.5.2.2 Flood Track

In Flood track the +AZ, -AZ, +EL, -EL switching is not done.

If the main channel complex data input is:

$$F(r,k)$$

Early Noise

$$N_E = C_{SR} \sum_{1}^{N_{PS}} \sum_{k=N_{FT}}^{N_{FT}+1} \sum_{r=N_{CR}}^{N_{CR}+5-C_{SR}} \left| F(r,k) \right|$$

Late Noise

$$N_L = \sum_{1}^{N_{PS}} \sum_{k=N_{FT}}^{N_{FT}+1} \sum_{r=N_{CR}+8-C_{SR}}^{N_{CR}+12-C_{SR}} \left|F(r,k)\right|$$

Signal

$$S = \sum_{1}^{N_{PS}} \sum_{k=N_{FT}}^{N_{FT}+1} \sum_{r=N_{CR}+6-C_{SR}}^{N_{CR}+7-C_{SR}} \left|F(r,k)\right|$$

The data accumulation period depends only upon the PRF used in the MPRF track. The data accumulation period is over the same number of process syncs as the Kalman filter updating period in the RDP.

BIT Shift

When the signal and noise quantities have accumulated over the number of process syncs per Kalman filter cycle (N_P), all the signal and noise data shall be shifted so that the most significant data bit of the largest signal or noise word is located in the most significant word bit location. The number of places, maximum of 15, the signal and noise quantities are binary shifted (BS) shall be saved and included in outputs.

5.5.3 Outputs

The following signals are output of this MPRF A/A Track SNR function to the target tracker in the RDP.

Track

- $N_E(\Sigma, \pm AZ)$; Early Σ Noise for $\pm$AZ
- $N_E(\Sigma, \pm EL)$; Early Σ Noise for $\pm$EL
- $N_L(\Sigma, \pm AZ)$; Late Σ Noise for $\pm$AZ
- $N_L(\Sigma, \pm EL)$; Late Σ Noise for $\pm$EL
- $N_{EL}(\Delta, \pm AZ)$; Early and Late Δ Noise for $\pm$AZ
- $N_{EL}(\Delta, \pm EL)$; Early and Late Δ Noise for $\pm$EL
- S; Signal
- BIT Shift

Flood Track

- N_E; Early Noise
- N_L; Late Noise
- S; Signal

5.6 Display Processing

The Digital Scan Converter (DSC) software in the Programmable Signal Processor (PSP) shall perform interface functions between the radar, the IFF Reply Evaluator (IRE) and the Vertical Situation Display (VSD) for tracked target display. The DSC shall perform the function of data formatting, video display control and symbol generation. It shall also correlate tracked radar targets with the IFF targets before they are sent to VSD for display.

In track mode, the basic DSC functions are similar to those in the MPRF search mode except the following:

- In MPRF track mode, the "corral" symbol is changed to a tracked target symbol and its center is positioned according to the target location as sent in from the Radar Processor (in DSC Word 1).
- IFF targets are correlated with the tracked target only. If a correlation is made, the IFF correlation tag is added to the tracked target identification bits and sent to VSD for display.
- In track, the DSC does not read its memory out to the VSD. The only target readout is the tracked target position as received from the RDP.
- Aging logic is not used during the track mode.
- Heading compensation is not required.
- Output of DSC in MPRF track mode consists of 16 serial words of 48 bits each and is sent to the VSD via DIU at a rate of 60 Hz.

5.6.1 Inputs

- DSC mode control word from RDP.
- IFF target word, Acquisition Symbol word, Antenna word, and Bit words 4 & 5 from RDP.
- Tracked target inputs (Figure 5.6.1) from RDP.
- Iff Data (Figure 5.6.2) from IRE.
  (Input data rate is once/80 PRI phase time)

5.6.2 Processing

5.6.2.1 General Approach

This section contains a general discussion of the data processing and a subsection describing the target correlation of the Digital Scan Converter. Data processing logic as well as inputs and outputs are specified in the subsection accordingly. The final outputs of the DSC to the VSD via the Display Interface Unit (DIU) are listed in section 5.6.2.

The data processing functions of the Digital Scan Converter are shown in the following functional block diagram, Figure 5.6.3. The Digital Scan Converter (DSC) receives its control words, target data and Tracked target position from the RDP, and the IFF data from the IFF Reply Evaluator (IRE). First, it shall reformat the 24-bit data words into *48 bit DSC memory words to be stored in the PSP Bulk Memory for data processing and target correlation. If target correlation is requested from the Radar Data Processor (RDP 081 Unit), the DSC shall search its IFF target memory for targets which lie within the correlation Az and Range window of the tracked target as positioned by the RDP. Furthermore, the DSC shall select the proper azimuth/range scaling for IFF targets for data correlation and shall determine the display border scaling in the generation of display data for the

*The 48 Bit DSC Memory words should be in the same format as that in the MPRF Search mode so that the same target correlation routine can be used in both modes.

Vertical Situation Display (VSD). The output display data consisting of 16 48-bit target data words shall be sent to the VSD via the Display Interface Unit (DIU).

For target and display data storage, DSC shall maintain two separate memories. A small target table (32 x 48 bits) is required to store the tracked target data as sent-in by the RDP. These new targets then merge into a 64 x 48 bits Master Target Memory (TM1) in the PSP Bulk Memory for target correlation and data processing. This Master Target Memory TM1 shall operate in a "first-in first-out" (FIFO) manner. When there are more targets than the memory storage, the oldest one shall be deleted. The FIFO operation can be achieved by using a cyclic target address table for deletion without the actual shifting of all target data in the TM1 memory.

After the tracked data has been correlated with the IFF data in the Master Target Memory (TM1) the tracked target which lies within the current range and azimuth bound is sent to Vertical Situation Display (VSD) for display.

5.6.2.2 <u>Target Correlation</u>

The correlation logic in the Digital Scan Converter (DSC) shall perform target correlation between IFF targets and the tracked target in both azimuth (X) and range (Y) positions. The first type is correlation of cursor with radar targets. The second type is the correlation of new radar targets with current IFF targets. Target Correlation logic and it's window sizes are shown in Figure 5.6.4 and Table 5.6.1 respectively.

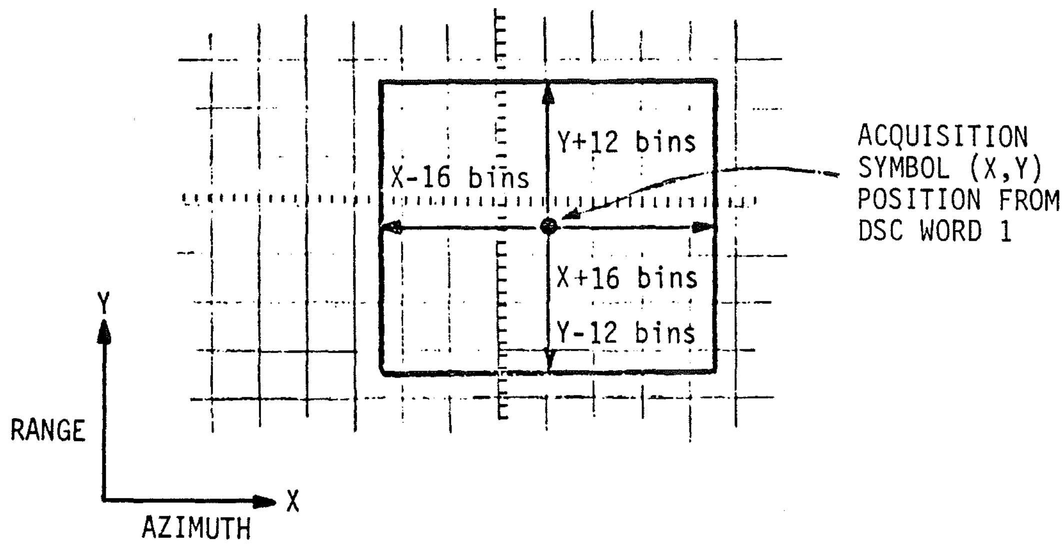
5.6.2.2.1 <u>Inputs</u>

- Target Correlation Mode (in PSP Word 1) from RDP.
- Acquisition symbol position (in DSC Word 1) from RDP.
- IFF target data from IRE (see Figure 5.6.2).
- IFF target correlation (in DSC Word 3) from RDP.

5.6.2.2.2 Processing

Cursor Correlation Processing

When cursor correlation is commanded from the RDP (via PSP Word 1, Submode Code signal), the DSC must search for a correlation with all targets in the TM1 memory in the order of target intensity. First, the correlation window (box) is constructed from the Acquisition Symbol X (azimuth) and Y (range) position, as follows:



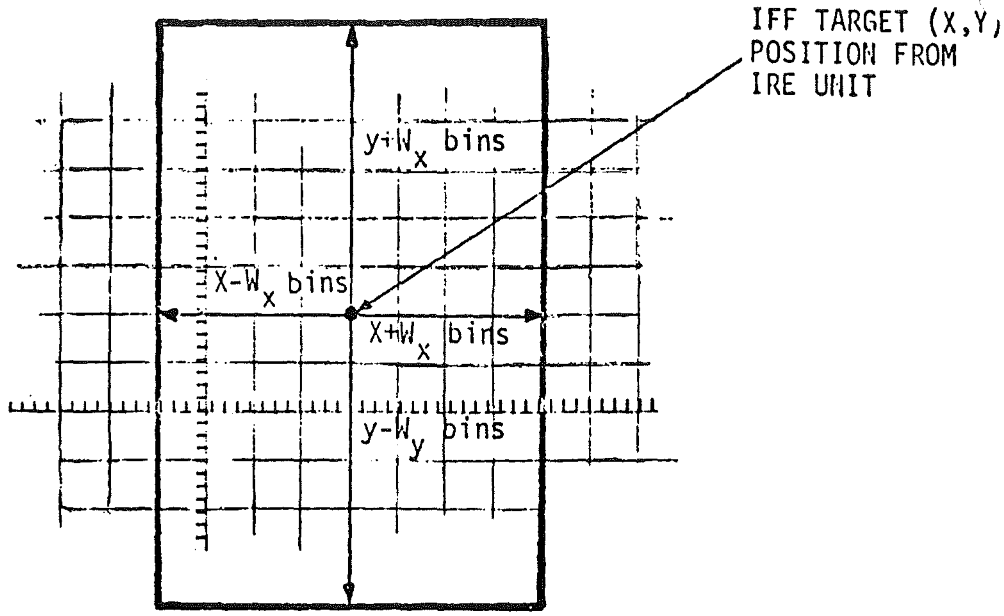
Targets with an intensity of seven are not correlated. Therefore, on the first memory readout cycle, targets with an intensity of six are examined to determine if any fall within the correlation window. On the second memory readout cycle, correlation is performed on targets with an intensity of five. On the third memory readout cycle, correlation is performed on intensity four targets and so on down to intensity zero. When a cursor correlation is made, the X (aximuth), Y (range) position, intensity, El Bar number, PRF and synthetic Target Status of the correlated target is stored. The correlated target with the highest intensity AND minimum range is selected and sent to the RDP via IDA. If no correlation has been made after zero intensity targets are searched, the DSC Tag (IDA Word 1 Bit 10) is set to zero and the (intensity) counter starts over at six.

IFF Target Correlation Logic

If cursor correlation has NOT been commanded and the IFF Challenge bit (DSC Word 3 Bit 23) is set, the DSC must do IFF Target correlation for both CORRECT CODE and NON-CORRECT CODE targets. In the former case, if a correlation does not occur with any memory radar target, the IFF target is entered into the memory. In the latter case, if a correlation does not occur with any memory radar target, the IFF target is dropped. In both cases, the IFF code is entered into the memory radar target IFF field when a correlation does occur. Table 5.6.2 summarizes the IFF correct code correlation logic.

Each IFF Target received from the IRE unit (see Figure 5.6.2) is checked to determine if it is a candidate for correlation. An IFF Target is NOT correlated with memory radar targets if (1) the invalid bit is set, (2) the IFF Code field is zero, or (3) the IFF Target range exceeds the selected range scale. All other IFF Targets received from the IRE unit are candidates for correlation with the memory radar targets. If the OVERLOAD bit of any of the IFF Targets retained for correlation is set, then the IFF Overload BIT (IDA Word 1 Bit 9) is set to logical "1" for the RDP.

A correlation window is constructed around each IFF Target retained for correlation with the memory radar targets. The correlation window (box) is constructed from the IFF Target X (azimuth) and Y (range) position as follows:



where W_x is the half-size of the correlation window in Azimuth and W_y is the half-size of the correlation window in Range. The possible values of W_x and W_y are specified in Table 5.6.1 and 2, respectively. Note: [W_x has one of two values based on the setting of the WIDE TARGET bit in the IRE Reply Word and W_y can assume one of two values based on the setting of the SHORT RANGE DETECT bit in PSP Word 1.]

After forming a correlation window about an IFF Target X, Y position, the memory makes one circulation. During this circulation, the IFF target is correlated, in range and azimuth, with each target in the memory which has an intensity of 6 or 7, i.e. each intensity 6 or intensity 7 target X, Y position is checked to determine if it falls within the IFF Target correlation window. [Note: Jammers and non-correlated IFF Targets in the memory are NOT correlated with the "new" IFF Target.]

When an IFF Target correlation is made, the IFF Target IFF Code is written into the memory radar target IFF Code field. The IFF Target can correlate with any number of memory radar targets. If no IFF Target correlation is made, the IFF Target is either inserted into the memory as a non-correlated IFF Target or dropped as indicated by the logic in Table 5.6.2.

Table 5.6.1 - AZIMUTH CORRELATION WINDOW

AZIMUTH CORRELATION WINDOW	
Mode	X Window
Cursor Correlation	$\pm 4^{\circ}$ or ± 16 Azimuth Bins
IFF Narrow Target Correlation (Wide Target bit = 0)*	$\pm 4^{\circ}$ or ± 16 Azimuth bins
IFF Wide Target Correlation (Wide Target bit = 1)*	$\pm 8^{\circ}$ or ± 32 Azimuth bins

* IRE Reply Word (see Figure 5.6.2) Bit 11

Table 5.6.2 - RANGE CORRELATION WINDOW

RANGE CORRELATION WINDOW		
Mode	X Window	Range
MPRF & RWS Acq	± 12 Bins	$\pm$ Selected range ÷ 40 or 0.25 nm
LRS IFF (Short Range Detect bit = 0)**	± 6 Bins	± 2 nm
SRS IFF (Short Range Detect bit = 1)**	± 24 Bins	0.5 nm

** PSP Word 1 Bit 9

0 … 23

HPRF OR MPRF	11 Bits Target Azimuth (X Position)	12 Bits Target Range (Y Position)

Figure 5.6.1

PSP TO DSC INPUT RADAR TARGET WORD

MPRF TRACK

COMMENTS:

1 Bit to Specify Target PRF

0 = MPRF

1 = HPRF

Target Data From AZIMUTH CENTROIDING

a) 11 Bits Antenna Azimuth to Target

LSB = .058594 deg — 2048 Az Element for 120 deg.

b) 12 Bits Antenna Range to Target

LSB = .08 N.M. — 12 Bits for 4096 Quantized Steps

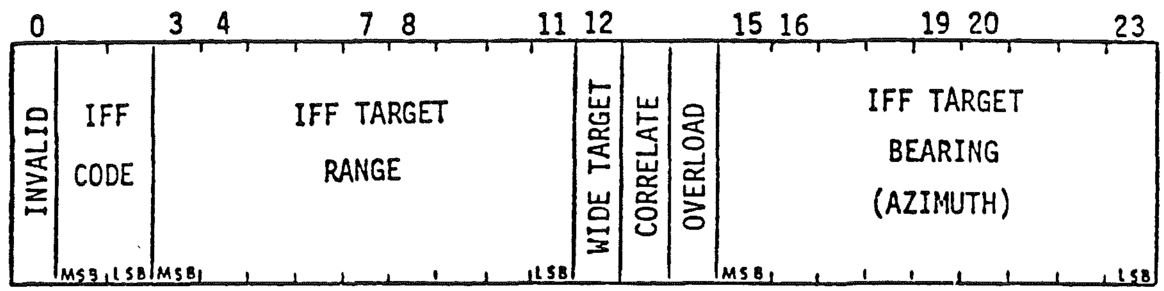


Figure 5.6.2

IFF REPLY WORD FROM IRE BUFFER

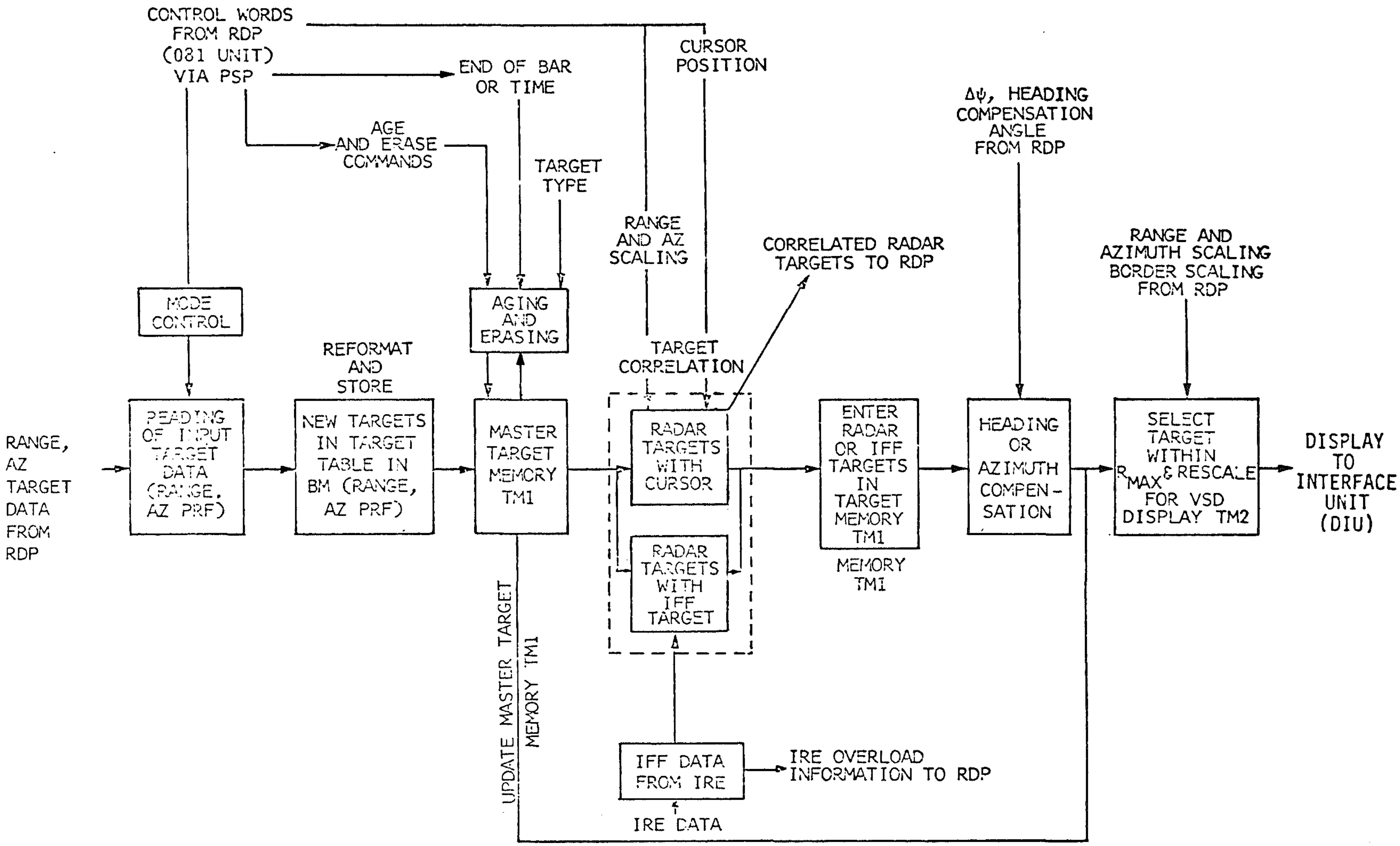


Figure 5.6.3 - DIGITAL SCAN CONVERTER FUNCTION DIAGRAM

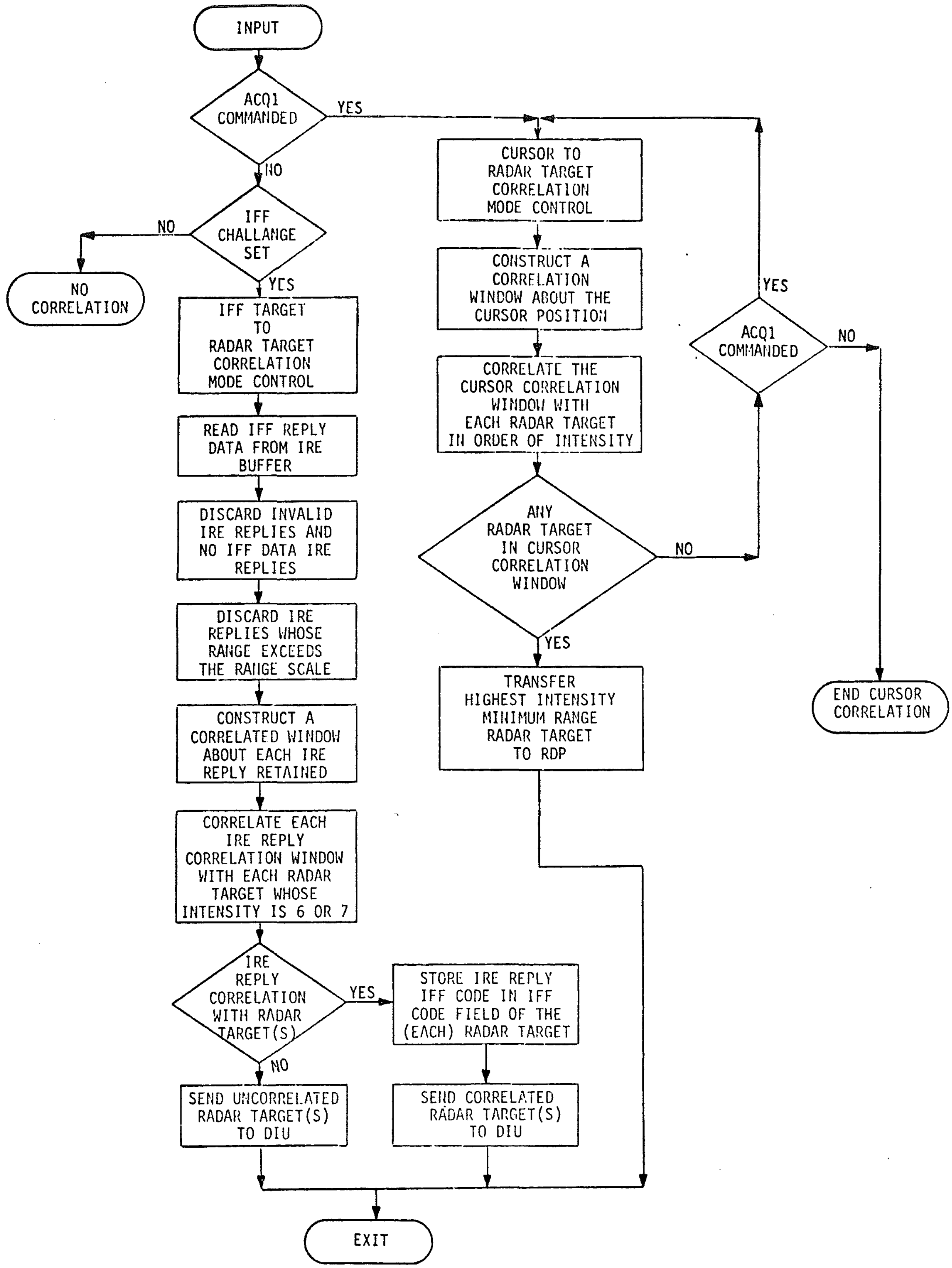


Figure 5.6.4 - DSC CORRELATION LOGIC

The IFF Correlation cycles are timed not to occur at the same time as VSD readout cycles.

5.6.2.2.3 Outputs

- DSC Tag or IFF Overload Bit to RDP via IDA.
- ECM Tag, PRF and El Bar Number of cursor correlated radar target to RDP via IDA.
- Unambiguous Range and MPRF Code of cursor correlated radar target to RDP via IDA.
- IFF Code of each correlated IFF Target to IFF Code field of correlated memory radar target(s) in Master Target Memory TM1.
- Non-correlated IFF Targets with correct code to Master Target Memory TM1.

5.6.3 Outputs

- In MPRF Track mode, the outputs of DSC to VSD consists of 16 serial words of 48 bits each. The first words are blanks. The next six words are: range/velocity word, tracked target position word, antenna azimuth position, antenna elevation position and two words (Bit Word #1 and Bit Word #2) for data control and alphanumeric character display (format see Figure 5.6.5).
- Correlated radar target to RDP.
- IFF overload bit to RDP via IDA.

WORD	NAME	BIT POSITION 0 1 2 3	4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23				24-44	45 46 47
1-10	BLANK	0 0 0 0	THESE BIT POSITIONS MAY BE RANDOMLY SET					
11	RNG/VEL SCALE	0 1 0 0	0 0	RNG/ VEL SCALE	0 0 0 0 0 0 0 0 0 0 0 0 0 0 0		0	1 1 1
12	TRACKED TGT POS.	0 0 0 1	IFF CODE	AZIMUTH		RANGE		1 1 1
13	ANT. AZ. POSITION	0 1 0 1	0 0	AZIMUTH		1 0 0 0 1 0 1 1 0	0	1 1 1
14	ANT. EL. POSITION	0 1 0 1	0 0	1 0 0 0 1 0 1 1 0		ELEVATION	0	1 1 1
15	BIT WORD #1	0 1 0 1 or 0 0 0 0	0 0	1st CHARACTER	2nd CHARACTER	3rd CHARACTER	0	1 1 1
16	BIT WORD #2	0 1 0 1 or 0 0 0 0	0 0	4th CHARACTER	5th CHARACTER	6th CHARACTER	0	1 1 1

Figure 5.6.5 - DSC TO VSD DIGITAL DATA (MPRF TRACK)

SECTION 6

A/A LPRF SEARCH AND ACQUISITION MODE

There is no need for this specific function, however the section number is retained to preserve the continuity of this document.

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SECTION 7

LPRF TRACK MODE

There is no need for this specific function, however the section number is retained to preserve the continuity of this document.

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AIR-TO-GROUND RANGING MODES

8.0 INTRODUCTION

Air-to-Ground Ranging is performed with three separate types of signal processing operations, (Acquisition, Monopulse Track, Split-Gate Track). The appropriate operation is selected by the RDP (See Figure 8.1). The purpose of each type of processing operation is illustrated in Figure 8.1a, and is also discussed in the following paragraphs.

Acquisition is used to form a rough estimate of the range-to-ground along the antenna mainbeam axis. This is accomplished by first "selecting out" all range bins containing antenna mainlobe clutter. A Main/Guard ratio test on Main channel and Guard channel signals is used for selection. The set of mainlobe-clutter-containing bins is then centroided in the range dimension to yield the rough estimate of range-to-the ground.

Based upon the Acquisition range estimate and the geometry, the RDP may select tracking in either Monopulse or Split-Gate configuration.

Monopulse Tracking is selected by the RDP for situations where the antenna mainlobe projection on the earth spans several range bins. Antenna monopulse information from specific range bins is processed to extract elevation angular error measurements. (The computations are similar to those used in Air-to-Air Track modes for angle error discriminants). The RDP uses the angle error measurements along with the known geometry to compute range errors, and thus form a range tracking loop. A signal strength measurement is also made by the PSP with each angle measurement to assure that ground clutter return is indeed present in the range bins being "tracked".

Split-Gate Tracking is selected by the RDP for situations where the antenna mainlobe projection on the earth spans a very few range bins. Here, a range discriminant is computed for amplitude information in the tracking gate range bins. This discriminant is a direct measurement of range tracking error. (The discriminant is similar to the range tracking discriminant used in the MPRF Air-to-Air Track mode). Track validity is determined by Main/Guard ratio tests on several range bins near the tracking gate. This type of test indicates that the clutter being tracked is illuminated by the antenna mainlobe.

The following sections discuss each functional module shown in Figure 8.1.

8.1 Timing & Control (T&C)

Timing and Control is concerned with the communication between the RDP, the PSP, and the rest of the Radar System. Generally, the interaction between these devices begins with the RDP selecting a mode of operation (i.d., AGR Acquisition, Monopulse Track, Split-Gate Track). This action causes the Radar System to transmit and receive pulses at a mode-determined PRF. The Radar System gathers samples from the radar return signal for storage in the PSP. When a complete set of samples is ready, the PSP is alerted to begin processing the set. The PSP processing program is dictated by the mode words given by RDP. After the PSP is through with the processing, the RDP must be ready to accept the results. This interaction is repeated until the RDP selects another mode of operation.

The communication between RDP, PSP and the rest of the Radar is established through the timing functions. This section discusses the timing functions for AGR Modes.

8.1.1 Input

- Mode Command from RDP
- 20 MHz reference frequency (internal to PSP)
- 7.14 MHz reference frequency (internal to PSP)
- Coarse Range from the RDP

8.1.2 Processing

The following discussion is separated into two parts. The first part in section 8.1.2.1 is a schedule-of-events to be performed. It relates radar events (pulses) to the processing events of 1) starting to process each block of stored data, 2) output the processed results to the RDP. The second part of the discussion (section 8.1.2.2) deals with the mechanism necessary to accomplish the schedule. The mechanism is in the form of programmable hardware modules in the PSP unit. Section 8.1.2.2 deals with the detailed input/output of these modules in AGR modes.

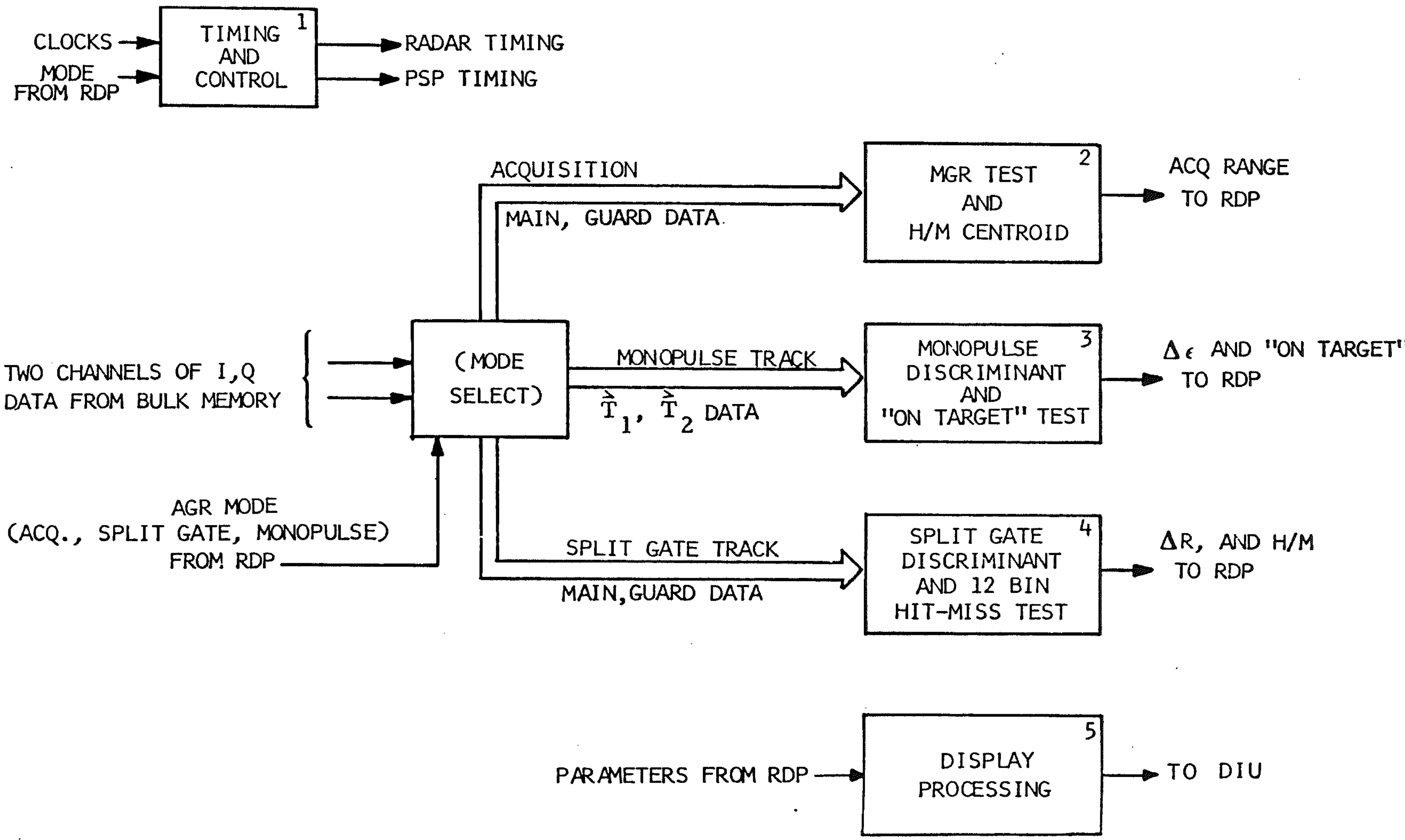


Figure 8.1 Air-to-Ground Ranging Modes Processing

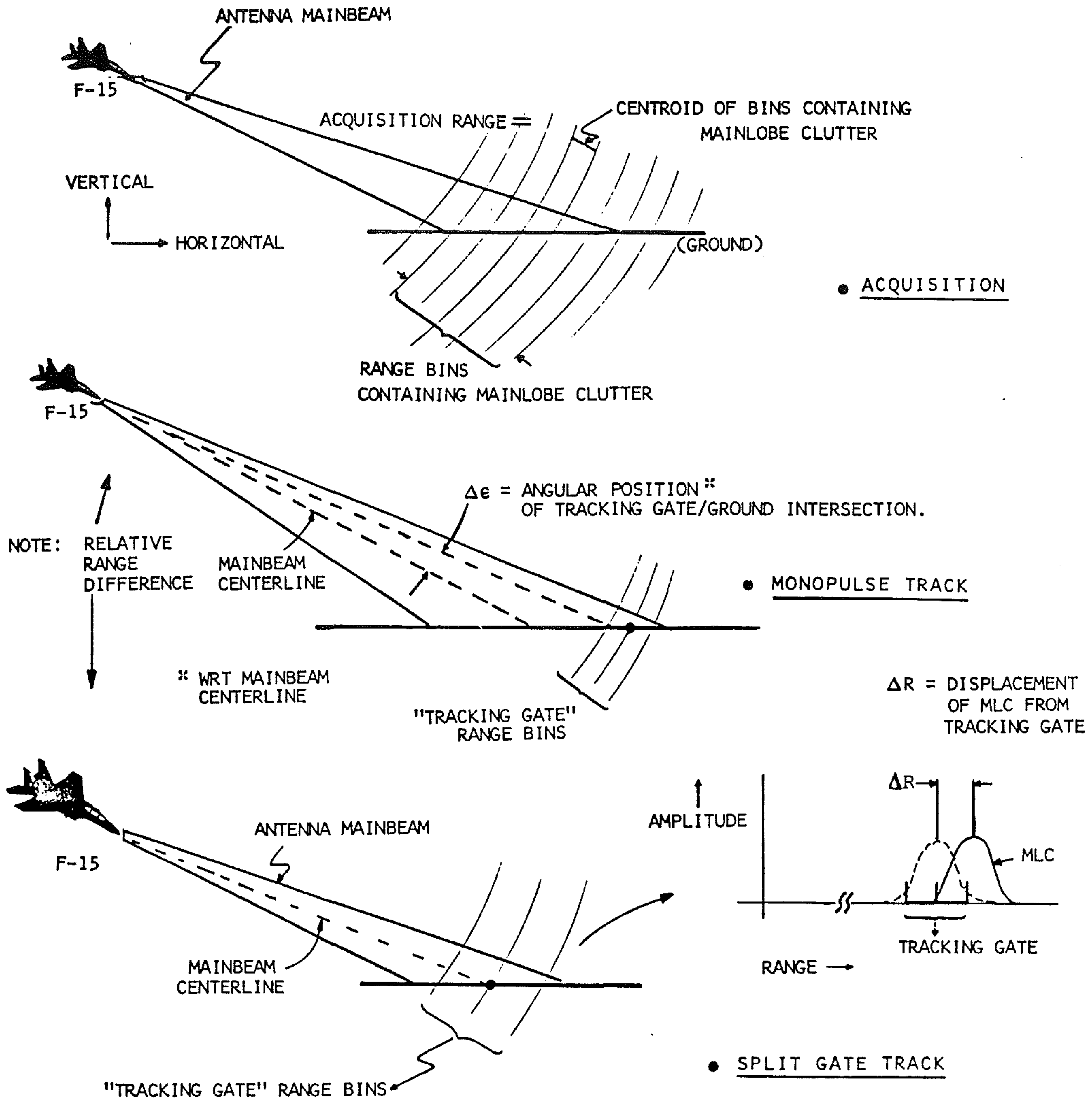


FIGURE 8.1a

AGR PROCESSING PURPOSE ILLUSTRATED

(FOR ACQUISITION, MONOPULSE TRACK AND SPLIT GATE TRACK)

8.1.2.1 AGR Schedule-of-Events

Processing schedules in this mode depend upon the mode selected by the RDP.

Figures 8.1.2.1.1, .2, and .3 illustrate the schedules for each of the AGR modes.

8.1.2.1 T&C Mechanization

The Timing and Control (T&C) functions for AGR are initiated by transmission of the appropriate mode code by the RDP. Upon receipt of the code, the PSP software loads from Bulk Memory into C-Memory the control words that configure both the radar and signal processing for AGR. Included in this control block (or skeleton) are the parameters that are input via P-BUS to the event memories of the T&C and IDC modules. The PSP software controls the initial load of the event memories and toggles the memories to the execute configuration. Control of the load/execute function reverts to the T&C module following the initial AGR process cycle. The PSP software will maintain the parameters generated from the T&C module which in general are mode dependent. Other radar control functions maintained by the RDP (mostly IDC hardware parameters) update the basic AGR skeleton once per PROCESS SYNCH (8.0 msec) via PMUX. The following discussion summarizes the generation of the T&C events required to collect and process data for the AGR modes.

As with all modes with synchronous transmit and sample timelines, the first AGR event is the action required to generate a transmit pulse. This function is controlled by the event memories of the T&C module. Based on the selected AGR submode, the PSP software sets the appropriate A/D SAMPLE INTERVAL in T&C Control Word 1. The value of this parameter, which is also the Range Bin Interval (RBI), shall be 1 μsec for the AGR Acquisition or Monopulse Track modes and 0.5 μsec the Split Gate (S/G) Track mode. Two additional transmit-related parameters to be set high in the basic AGR skeleton are BLANKING PULSE ON (T&C Control Word #1) and SHORT PULSE (IC & TTG Control Word).

Having established the AGR range bin interval, the final programmable phase of the transmit pulse generation cycle is controlled through T&C event Generator #1. The EG #1 cycle is one PRI in duration and clocked at the RBI rate. START X outputs at the initial clock pulse of the cycle. The START X pulse enables the XMIT Event Generator outputs including the XMIT and IBU BLANKING pulses. In AGR Acquisition or Monopulse Track, both functions are jittered by 500 nsec on alternate PRIs by FINE RANGE DELAY. The PSP software extracts the delay alternately from T&C Control Words #1 and #2. This technique provides effective 0.5 μsec x 2 channel sampling. The last event to be generated during the EG #1 cycle is the PRI SYNCH. The interval counts for EG #1 is such that a PRI SYNCH is produced every 1 msec in either AGR Acquisition or Monopulse Track and 0.5 msec in Split Gate Track.

The mode-determined PRI SYNCH serves as a clock pulse for T&C Event Generator #2. Radar parameters to be generated at the PRI rate include antenna switching and receiver phase control for the Monopulse Track mode (detailed below), as well as the VCO update command. The RDP/PSP data transfer and processing cycle for the AGR submodes is also controlled by EG2. At the initial PRI of each cycle, RDP PROCESS SYNCH will be generated to enable the PMUX transfer from the RDP to the CIU. The EG2 cycle period (EG #2 SYNCH) is 8 msec, (i.e., 8 PRIs for Acquisition or Monopulse Track, 16 PRIs for S/G Track). Approximately 300 μsec before the end of the cycle, T&C PROGRAM REQUEST enables the load of the T&C/IDC event memories via P-BUS from the CIU. At completion of the T&C load, EG #2 END OF PROGRAM toggles the event memories to the execute configuration - initiating the next cycle. Within the 8 msec period, the PSP software maintains the T&C parameters required for AGR Data collection and processing. The following discussion summarizes the generation of the schedule of events illustrated in Figures 8.1.2.1.1 through 8.1.2.1.3. While certain processing control is maintained internally by the software, the majority of these functions are generated from the T&C/IDC event memories.

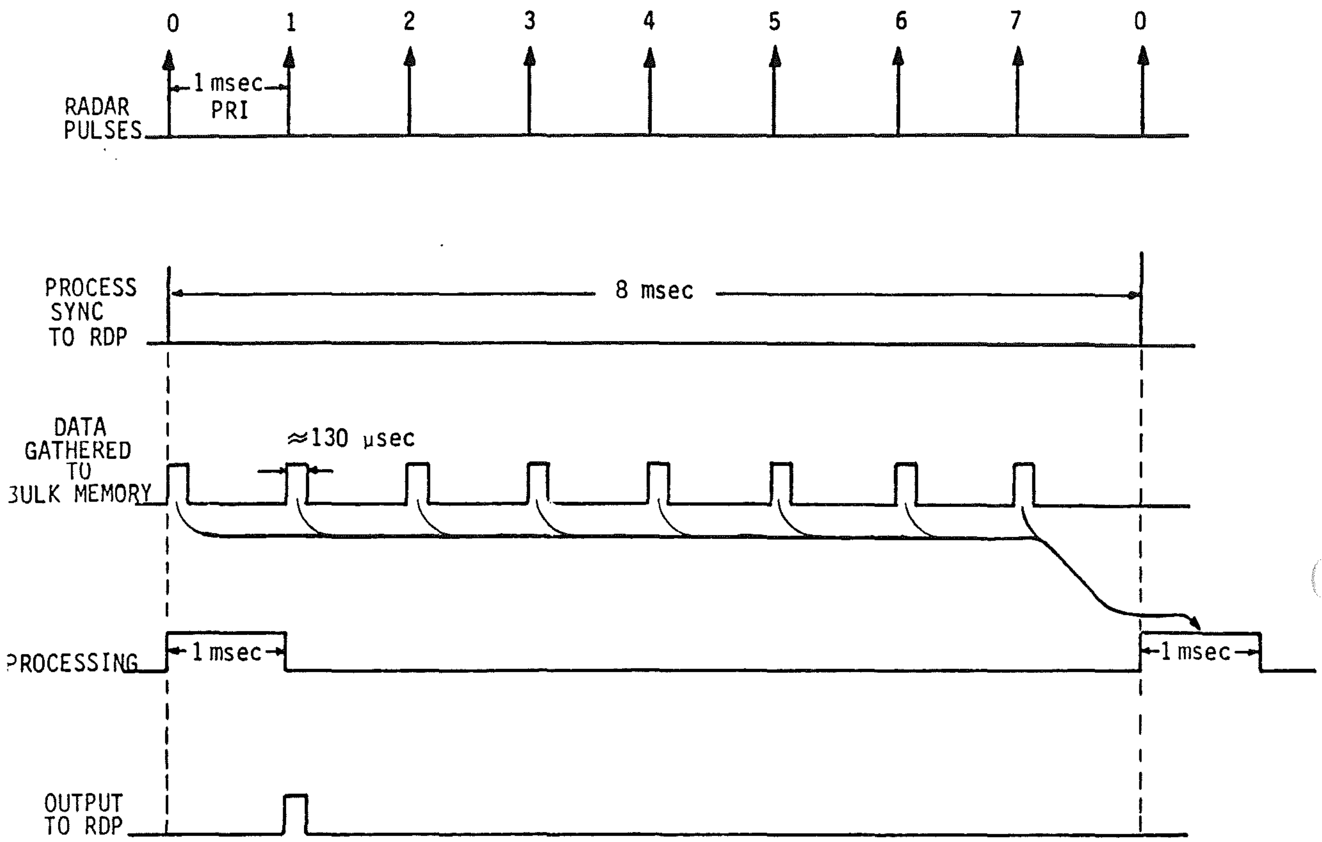


Figure 8.1.2.1.1 - AGR ACQUISITION SCHEDULE OF EVENTS

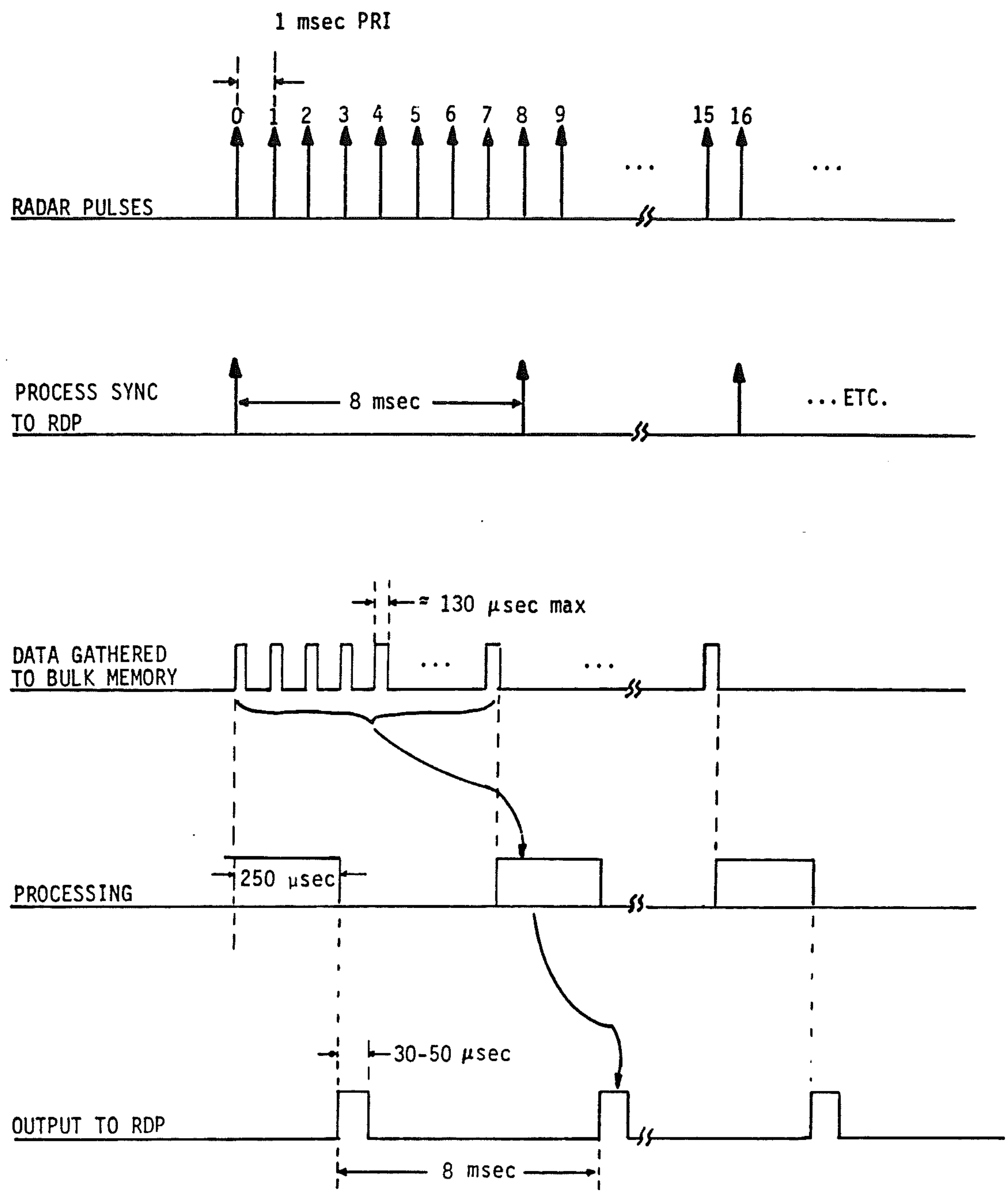


Figure 8.1.2.1.2 - AGR Monpulse Track Schedule of Events

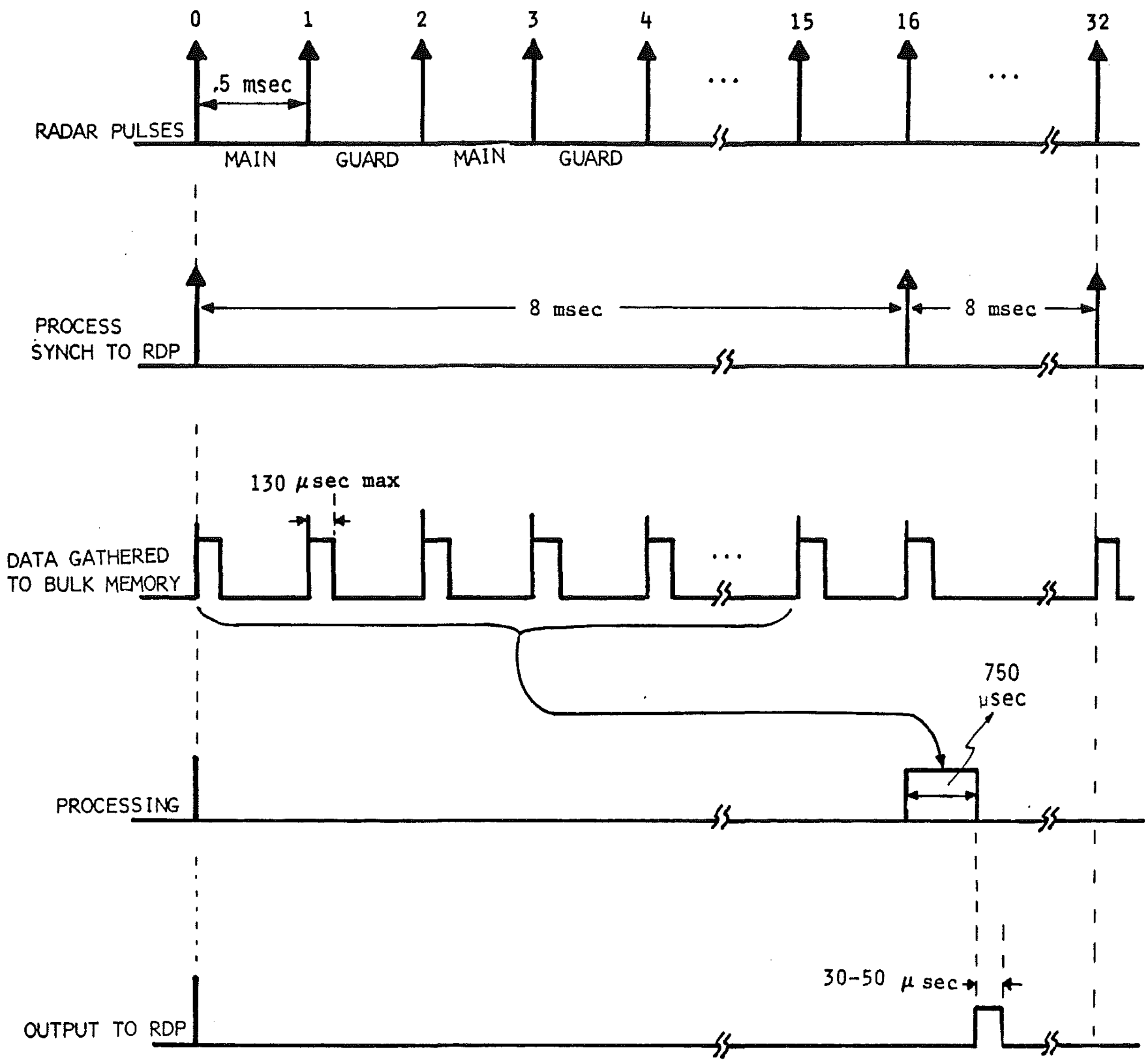


Figure 8.1.2.1.3 - AGR Split-Gate Track Schedule of Events

The T&C data collection function for the AGR submodes consists of establishing the proper configuration of the antenna, receiver and analog processor. For AGR Acquisition of S/G Track modes, antenna GUARD/DIFFERENCE SELECT (External Control Word) are set for M/G operation (1 = GUARD). In Monopulse Track, the difference channel is selected (0 = DIFFERENCE) while Az/El SELECT (EG #2) is maintained in the elevation condition (1 = elevation). Also in Monopulse Track, the software toggles the receiver phase select function, 0/π PHASE SHIFT (EG #2), on a 2 PRI per phase state basis. The operational state of the analog processor for all AGR submodes is established by MODE SELECT (00 = LPRF) and B.W. CONTROL (11 = 500 kHz). Both parameters are contained in the External Control Word and are set in the basic AGR skeleton. The two A/D sampling intervals for AGR (1 msec and 0.5 msec) are covered previously in the discussion of the generation of the transmit function. Other required A/D control functions are the configuration of the read out sequence and the master clock. For AGR Acquisition or Monopulse Track, A/D MODE BIT 0 & 1 is set for two channel operation (10 = read both), the 2/4 MASTER CLOCK are set to provide the four pulse format (0 = 4 master clocks/range bin), and the Prepacker function in the External Control Word is set to Reorder (1). In S/G Track, single channel read out is alternated between the Main and Guard IF output on a PRI basis. The sequence is implemented by setting A/D BIT 1 high and enabling TOGGLE A/D MODE BIT 0 (1 = toggle A/D Mode Bit 1 every PRI) and setting the Prepacker function to FIFO(0). In addition, the master clock code for S/G Track reflects the two word A/D sample (1 = 2 master clocks/range bin). Each of the above A/D control parameters is generated from T&C Control Word #1 and is maintained in the appropriate state by the PSP software.

The T&C processing function for AGR operation begins with the configuration of the Input Data Conditioner modules. The following functions are bypassed (i.e., set = 1):

Clutter Canceller	(External Control Word)
Pulse Compressor	(External Control Word)
Doppler Phase Compensator	(IC Control Word)

In addition to the preprocessor parameters, IDC control includes the Automatic Gain Control (AGC) circuits. For the AGR modes, the gain logic is configured to generate peak mode AGC: the DAGC RANGE GATE (EG #1) is set (1 = enable) for 128 range after Range Bin 0 while the DAGC SELECT code (IC Control Word) indicates calculated AGC (00). As no STC profile is used in the DAGC logic for AGR, the STC SELECT CODE (External Control Word) reflects the bypass condition (000 = STC OFF).

Transfer of the collected data samples from the IDC preprocessor to the Bulk Memory is controlled from EG #1 by Start Sample and End Sample. For AGR Acquisition, the interval between these events will cover 128 range bins; for Monopulse Track, 8 range bins; and for S/G Track, 16 range bins. The position of Start Sample is based on the coarse range value sent by the RDP in Monopulse and S/G Track*; in Acquisition it coincides with the Range Bin 0 Command.

The PSP processing events for each of the three AGR submodes are described in the following sections. In the Acquisition Mode, the range centroid is computed from a merged set of 256 samples collected over two successive PRIs. During the 8 msec Process Synch period, four centroid values are accumulated in Bulk Memory and then transferred to the RDP via software IDA. For Monopulse Track, the error measurement ($\Delta\varepsilon$) computed from the 8 prior PRIs and the On-Target Flag are output once per Process Synch. The Split/Gate range error ΔR, derived from 16 PRIs alternated between Main & Guard, is also provided on a Process Synch basis in conjunction with a Hit/Miss array of 12 bits.

*Coarse Range in Monopulse is sent from the RDP in terms of .5 μsec range bins; the number of 1 μsec range bins is ½ of this number. Therefore, Start Sample is set at IPO$\left[\frac{\text{Coarse Range}}{2}\right]$ and, if Coarse Range was odd-valued, another ½ range bin is added by increasing the fine range delays in TC1 and TC2 by 10-50 nsec steps (.5 μsec or ½ of a Monopulse Range bin).

8.2 Main/Guard Ratio Test & Hit/Miss Centroiding

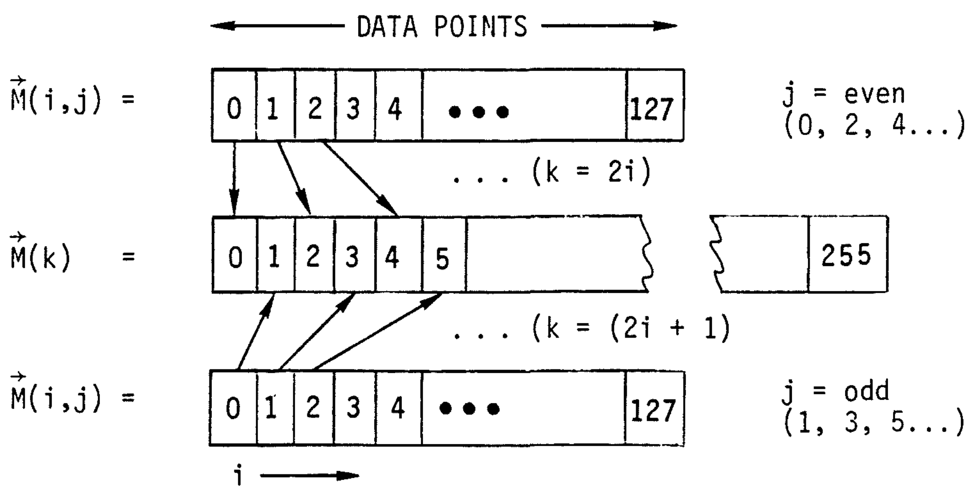
The purpose of the processing in this section is to form an estimate of the range-to-ground along the antenna mainbeam axis. This is accomplished by first locating the range bins containing mainlobe clutter, then centroiding those bins along the range dimension. The process is completed once for each two radar pulses.

8.2.1 Inputs

- Complex I/Q data from two channels (Main & Guard) by 128 range bins for each radar PRI time
- MGR threshold K_{MGR} from RDP

8.2.2 Processing

The incoming (I,Q) data samples may be designated as $\vec{M}(i,j)$ and $\vec{G}(i,j)$ for Main & Guard channel samples respectively. The index (i), for range bins, run from 0 → 127. The index j is to designate the PRI number from which the data was taken. The PRIs are numbered j = 0, 1, 2, ..., 7 within each process synch time. Data sets from successive PRIs are shifted in time by .5 μsec with respect to each other. The samples on the even numbered PRIs are always .5 μsec "early" compared to the odd numbered PRIs. The object is to group the 128-point sample sets from each two successive PRIs into a single set of 256. The following illustration defines the method of combining two data sets into one set.



(Similarly for $\vec{G}(k)$)

Note that sets $\{M(k,j) | (j = 0, 1\}$ yield $\{M(k,\ell) | \ell = 0\}$; and similar-ily sets for which j = 2, 3 yield $\{M(k,\ell) | \ell = 1\}$, etc. The magnitude of each guard channel cell is tested to see if it is greater than 64. If it is not, 64 is inserted in that cell. The combined data sets are next tested for Main-to-Guard ratio. Hits are declared for range cells where the ratio exceeds a predetermined threshold:

$$H(k,\ell) = \begin{cases} 1 & \text{if } \dfrac{|\overline{M}(k,\ell)|}{|\overline{G}(k,\ell)|} > K_{MGR}, \\ 0 & \text{otherwise} \end{cases}$$

The resulting hit/miss arrays from each process synch time (4) are centroided to find the approximate range-to-ground. An "up-down counter" centroiding algorithm is used, which is equivalent to the current RDP mechanization. Define three variables (counters) as follows:

x = the up-down count
y = the maximum up-down count
z = the bin number of the max up-down count

Sequentially test the range bins (k) in each hit/miss array.

If $H(k,\ell) = 1$, then: $x = x + 1$
y = greatest of x,y
$z = k$ if $x \geq y$
= unchanged otherwise

If $H(k,\ell) = 0$ then: $x = x - 1 | x \geq 0$
y = unchanged
z = unchanged

After all the bins have been tested (k = 0 to 255), the range centroid is computed

Range Centroid (ℓ) = IPO $[z - \frac{y}{2} + 1/2]$, and x, y & z are set to 0.

The four values of Range Centroid that are computed each process synch time are output to the RDP.

8.2.3 Outputs

- Range Centroids (4/Process Synch) to the RDP. (Units are .5 msec range bins).

8.3 Monopulse Discriminant & On-Target Test

8.3.1 Inputs

- Complex (I,Q) data samples from two channels (Track 1, Track 2) by one range bins from Bulk Memory each PRI.
- On-Target threshold "K_{OT}" from the RDP.

8.3.2 Processing

This function extracts the tracking error measurement and the clutter amplitude from the incoming data points. The tracking error measurement is in terms of angular (elevation) offset. This term is converted geometrically into range error by the RDP. The clutter magnitude is compared to a fixed threshold to provide an On-Target test.

Tracking error is computed from the input data set. (Note that the correct range bins to process are pre-selected by the Timing & Control function, and are stored in Bulk Memory).

$$\vec{T}_x(i,j),$$

where: x = 1, 2 (Track 1, Track 2 channels)
j = 1, 2 (Range bin 1 or 2 of the tracking gate)
i = 1, ...8 (PRI#)

Form numerator N(i,j) and denominator D(i,j) terms for each PRI.

$$N(i,j) = \vec{T}_1(i,j) \odot \vec{T}_2(i,j) \qquad (\Sigma\cdot\Delta)$$

$$D(i,j) = \frac{|\vec{T}_1(i,j) - j\,\vec{T}_2(i,j)|^2}{2} \qquad (\Sigma\cdot\Sigma)$$

$\odot \longrightarrow$ vector dot product.

Combine the terms in each Process Sync (taking into account the EL switching) to form the angle error.

$$\Delta\varepsilon = \frac{\sum_{4}(\text{"+El" terms}) - \sum_{4}(\text{"-EL" terms})}{\sum_{8}(\text{"D" terms})}$$

The Timing and Control function has set up the El switching on a two-PRI-per-state basis, giving 4 '+El' and 4 '-El' PRIs. Within these same El state PRI pairs the fine range delay has caused the beginning of the range bins to be asynchronous; the odd-numbered PRI of the pair has range bins which are .5 μsec 'late' with respect to the range bins in the even-numbered PRI of the pair.

Thus,

$$\Delta_{\varepsilon} = \frac{\sum_{i=1,2,5,6} N(i,j) - \sum_{i=3,4,7,8} N(i,j)}{\sum_{j=1}^{8} D(i,j)} \qquad (1)$$

which produces a result in terms of 1 μsec range bins at .5 μsec spacing, which is designated as a .5 μsec range bin result. The result from equation (1) is sent to the RDP once per process synch time.

On-target determination is made by using the denominator term from equation (1), and a threshold (K_{OT}) from the RDP:

$$\text{"On-Target" Flag} = \text{True if } \sum_{i=1}^{8} D(i,j) \geq K_{OT}$$

$$= \text{False Otherwise}$$

The state of the On-Target determination is sent to the RDP once per process sync.

8.3.3 Outputs

- Monopulse error measurement ($\Delta\varepsilon$) to the RDP.
- On-Target flag (0 to 1) to the RDP.

8.4 Split-Gate Discriminant and Hit/Miss Test

8.4.1 Inputs

- Main & Guard Channel (I,Q) data from Bulk Memory Data from 12 range bins by one Channel (Main or Guard) each PRI. (Main & Guard alternate on a PRI basis.)
- Main/Guard ratio threshold (K_{MGR}) from RDP.
- Track Format (1 bit) from RDP.

8.4.2 Processing

Range tracking error measurements are computed by this function, as well as Hit/Miss data for On-Target determination. (Note that the correct range bins to process are pre-selected by the Timing & Control function, and are stored in Bulk Memory.) Designate the incoming complex data points from alternating PRIs as:

$$\vec{M}(i,j) \quad i = 0, 2, 4, \ldots 14$$

and

$$\vec{G}(i,j) \quad i = 1, 3, 5, \ldots 15$$

for Main & Guard data respectively. The index "j" for range bins runs from 0 to 11, the index "i" (PRIs) runs from 0 to 15 for all the PRIs in a Process Synch period.

Tracking error is computed once per process synch from two range bins of main channel data.

$$\Delta R = \frac{\sum (\text{Late Magnitudes}) - \sum (\text{Early Magnitudes})}{\sum (\text{Early Magnitudes}) + \sum (\text{Late Magnitudes})}$$

$$= \frac{\sum_{k=0}^{7} |M(x+1,2k)| - \sum_{k=0}^{7} |M(x,2k)|}{\sum_{k=0}^{7} \sum_{j=x}^{x+1} |M(j,2k)|}$$

where the two range bins (x, x+1) are selected as indicated by the Track Format command from the RDP.

$$\text{Track Format} = 1 \Longrightarrow x = 1$$
$$= 0 \Longrightarrow x = 5$$

A Hit/Miss array is developed to allow the RDP to determine On-Target, and to re-acquire if necessary. The average magnitude is found for each range cell in the two channels.

$$\overline{M}(j) = \frac{1}{8} \sum_{k=0}^{7} \left| \vec{M}(j,2k) \right|$$

$$\overline{G}(j) = \frac{1}{8} \sum_{k=0}^{7} \left| \vec{G}(j,2k+1) \right|$$

for $j = 0$ to 11

The resulting data is tested for Main/Guard ratio to form the Hit/Miss array, H(i).

$$H(i) = 1 \text{ if } \overline{M}(j)/\overline{G}(j) \geq K_{MGR}$$
$$= 0 \text{ otherwise}$$

for $j = 0$ to 11

8.4.3 Outputs

- Range Tracking error (ΔR) to the RDP
- Hit/Miss array (12 bits) to the RDP

8.5 Display Processing

8.5.1 Inputs

- DSC Words from RDP

8.5.2 Processing

The purpose of this function is to set-up the display (VSD) in AGR modes. The VSD is operated in the "Hybrid A-G" configuration. This configuration allows for analog raster scan data to be written on the display, as well as digital data (stroke written symbols).

The analog data to be sent shall include only the range markers.

Digital data (16 words) contain the display symbology, including the tracked target position. Figure 8.5.2.1 illustrates the information flow involved with display processing. The portion of Bulk Memory called "TM2" in the figure contains the "analog" and "digital" display information to be read and sent out by the DIU module.

Figure 8.5.2.2 illustrates the 16 word x 48 bit data set that must be stored for the "digital" portion of the display message. All of the necessary information is derived from RDP inputs.

Figure 8.5.2.3 illustrates the 248 x 256 cell matrix (3 bits/cell) that must be stored for the "analog" portion of the display message. Refer to the figure, and note that the image to be displayed is simply four "range rings" on the PPI display. The proper load for the memories is therefore:

All 1's (Max intensity) in rows 0 → 31, 992 → 1023, 1984 → 2015, 2976 → 3007

(Corresponds to display lines #0, 31, 62, 93)

All zeroes in all other rows.

The identical load is used for both memories to yield a double thick line at each range boundary.

8.5.3 Outputs

- "Digital" display message to DIU
- "Analog" display message to DIU

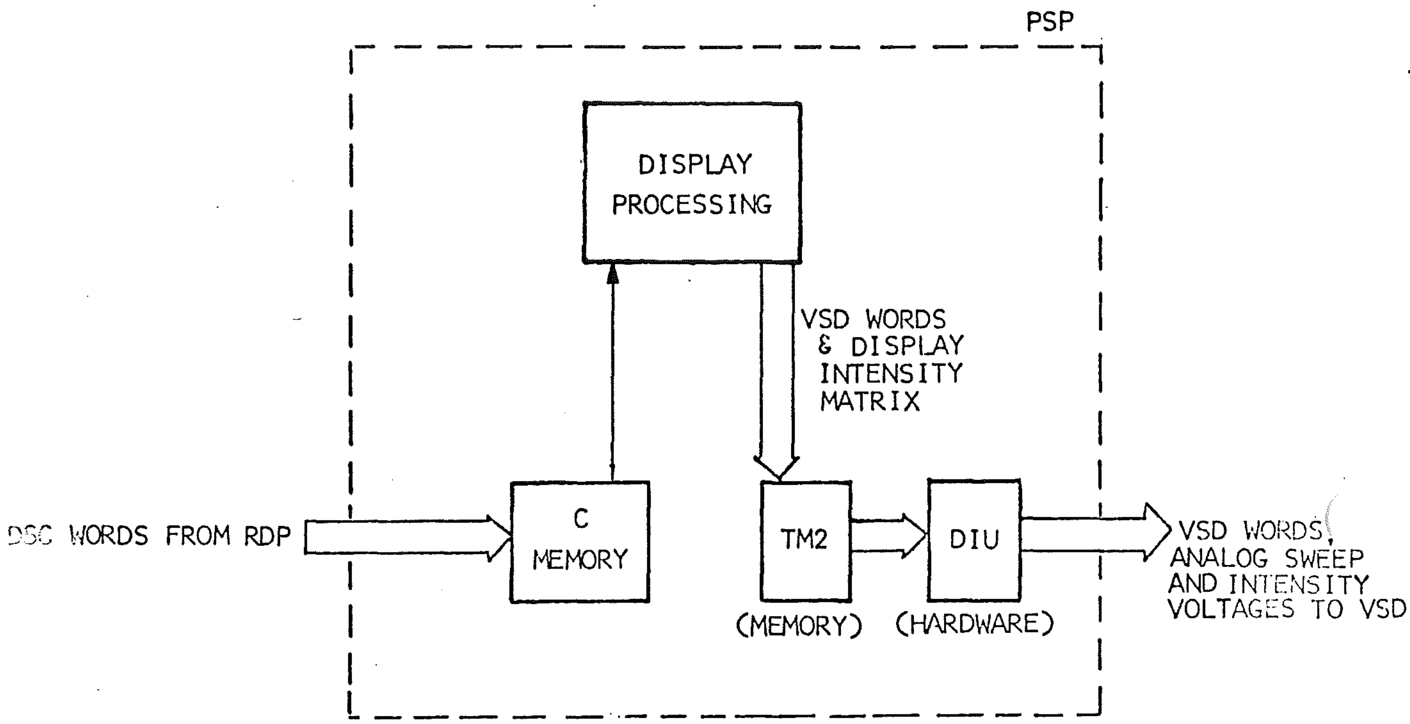


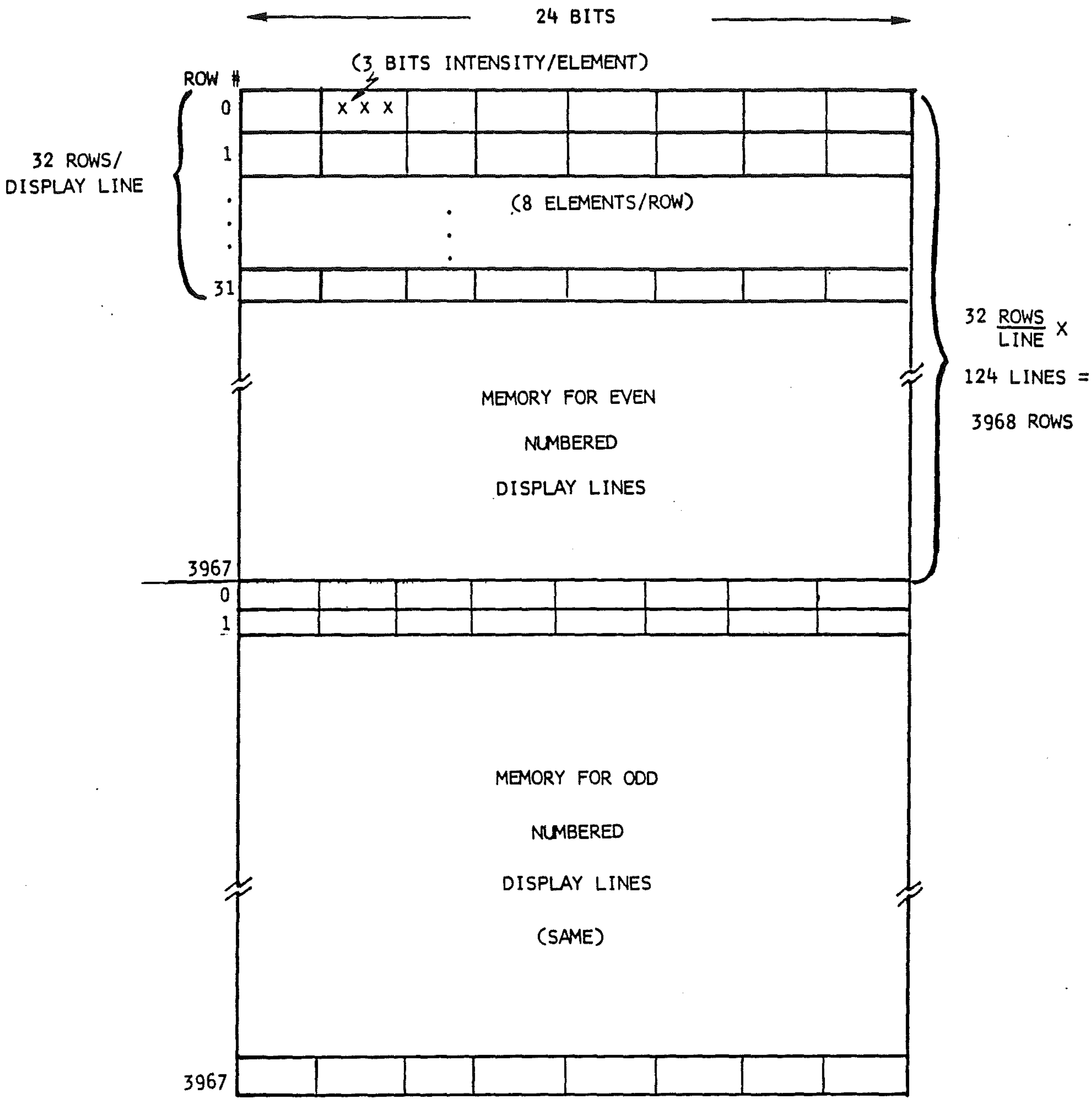
Figure 8.5.2.1

DATA FLOW BETWEEN THE PSP, RDP AND THE VSD UNIT DURING AGR DISPLAY PROCESSING

WORD	NAME	BIT POSITION 0 1 2 3	4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23	24-44	45 46 47
1-10	BLANK	0 0 0 0	THESE BIT POSITIONS MAY BE RANDOMLY SET		
11	RNG/VEL SCALE	0 1 0 0	0 0 | 0 0 0 | 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	0	1 1 1
12	TRACKED TGT. POS.	0 0 0 1	0 0 | AZIMUTH | RANGE		1 1 1
13	ANT. AZ. POSITION	0 1 0 1	0 0 | AZIMUTH | 1 0 0 0 1 0 1 1 0	0	1 1 1
14	ANT. EL. POSITION	0 1 0 1	0 0 | 1 0 0 0 1 0 1 1 0 | ELEVATION	0	1 1 1
15	BIT WORD #1	0 1 0 1 or 0 0 0 0	0 0 | 1st CHARACTER | 2nd CHARACTER | 3rd CHARACTER	0	1 1 1
16	BIT WORD #2	0 1 0 1 or 0 0 0 0	0 0 | 4th CHARACTER | 5th CHARACTER | 6th CHARACTER	0	1 1 1

* CONSTANTS (words 11-12)
** DERIVED FROM "DSC WORDS" SENT BY RDP (words 13-16)

Figure 8.5.2.2 - DIGITAL PORTION OF DISPLAY MESSAGE TO VSD (AGR MODES)



Note: Top half of memory contains the image for the even-numbered VSD raster lines, and the bottom half of memory contains the odd lines. Each line on the VSD has 256 elements.

Figure 8.5.2.3 - Analog portion of Display Message to VSD (AGR Modes)

SECTION 9

DOPPLER BEAM SHARPENED MODE

9.0 INTRODUCTION

The doppler beam sharpened mode processing in the PSP shall provide azimuth resolution improvement by spectral analysis processing of the ground doppler return. When commanded, it shall perform a 4:1 post detection integration of the filtered data. The data shall be converted to eight shades of grey and formatted for display processing. A block diagram of the major subfunctions and their interconnections for this mode is shown in Figures 9.1a and 9.1b. Table 9.1 describes several signals that are referred to in the figures. The operations of these subfunctions are described in the following sections.

The PSP processing in this mode depends upon the RDP for proper control of the antenna motion, positioning of the range gates, selection of the pulse repetition frequency, pulse width, STC profile, pre-sum ratio and FFT order.

The processor performs, in effect, real beam processing on command from RDP. This is accomplished by commanding a presum ratio of 1, forming N_{FF} filters as appropriate and processing the longest of the N_{FF} filter outputs. This function allows processing of thunderstorm and chaff data which fall outside the coherent ground clutter spectrum. Timing and control design for the Real Beam Mapping is different from that of the timing and control for DBS. This is due to different parameters (number of pulses/FFT, process synch timing, etc.) in the Real Beam Mapping. No CDE (Clutter Doppler Error) is done with Real Beam Mapping. Displayed images are also different between DBS and Real Beam Mapping.

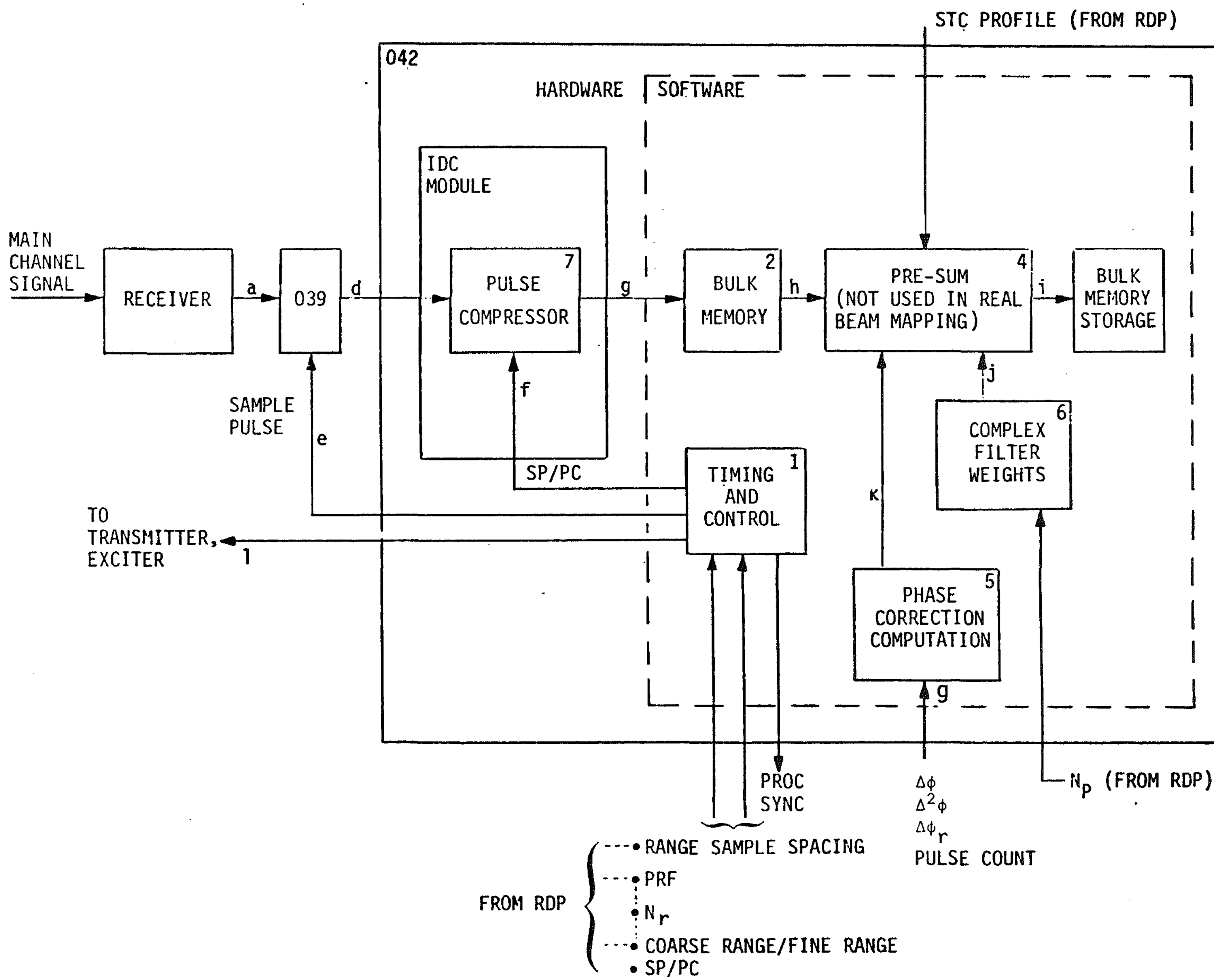


Figure 9.1a - S PRE-PROCESSING

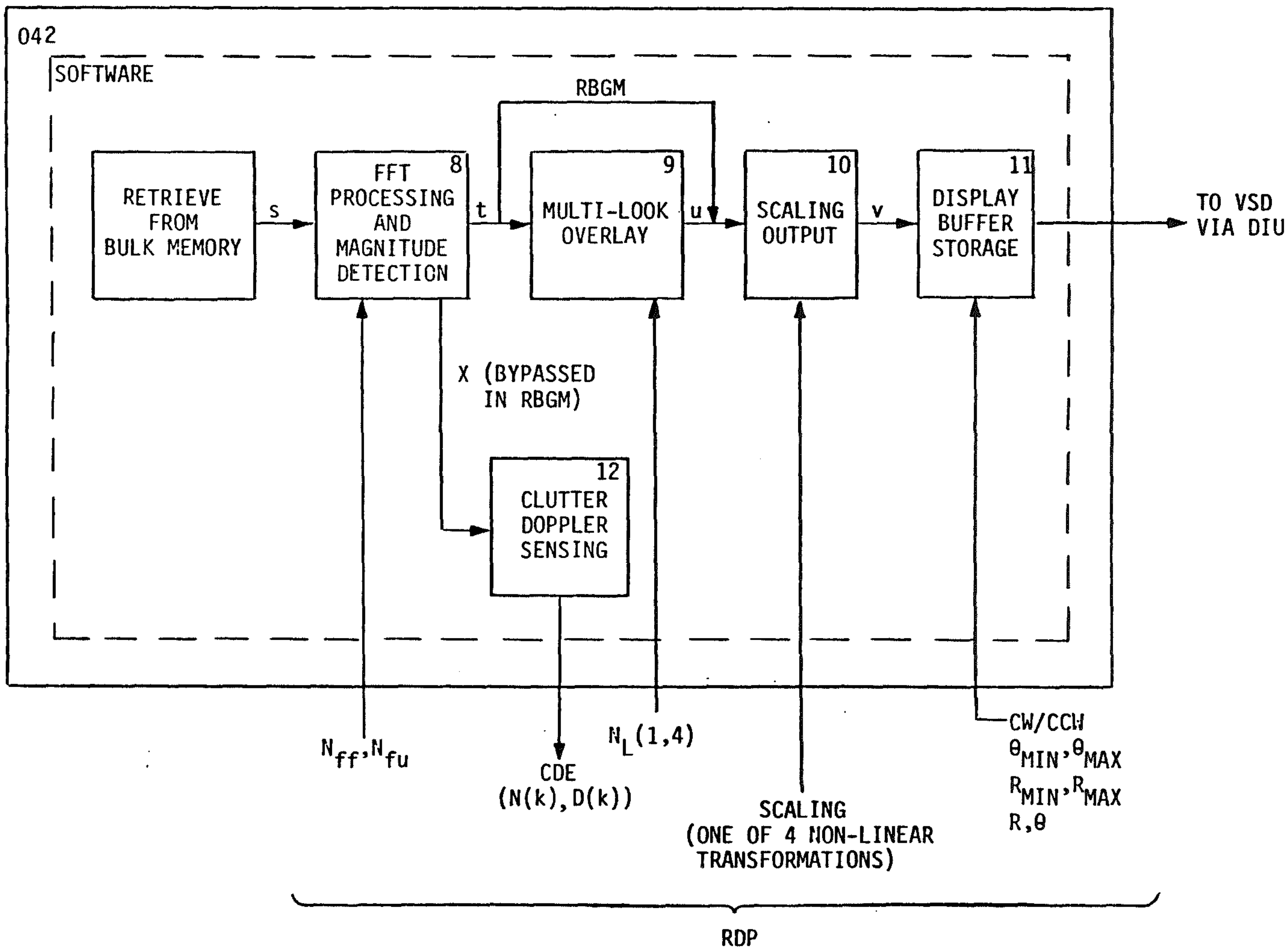


Figure 9.1b - DBS FFT AND POST PROCESSING

9.1 Timing and Control

9.1.1 Timing and Control Inputs

The timing and control inputs supplied by the RDP are:

1. Range sample spacing; .5 μsec, 1 μsec, 2 μsec and 4 μsec.
2. PRF: range from 500 Hz min to 2381 Hz max.
   For RBM: $500 \leq PRF \leq 2000$.
3. Pulse Compression Code Selection: 13:1, short pulse.
4. Number of range samples (N_R): 248 for normal display modes, 124 to 248 for expand display modes.
5. Position of first range sample to be loaded into bulk memory.
6. Position of transmit RF gate relative to zero range A/D sample enable. Range: zero to 1600 nsec in 50 nsec steps.

9.1.2 Timing and Control Processing

Software control of radar timing and control functions is performed by the PSP in accordance with RDP commands.

9.1.3 Timing and Control Outputs

1. Transmitter pulse timing
2. A/D sample timing
3. PSP interval timing signals.

Table 9.1 - PSP INTERNAL SIGNALS

SIGNAL	DESCRIPTION
a	Analog data
d	A/D converted data
e	A/D sample timing
f	Pulse compression code: 13:1 or short pulse
g	A/D data packed two 12 bit (9I, 9Q) words per PSP word
h	Same as g
i	Partially processed data from pre-summer
j	2N complex weights (N weights for each presum filter) N = # of blocks of 16 range bins each to be processed
k	Flags to indicate: 1. Accumulation process is complete 2. Beginning of new accumulation 3. Only one of the dual presummers is to operate.
l	Transmitter pulse timing
q	1. $\Delta\phi$ - center of patch phase change per pulse 2. $\Delta^2\phi$ - center of patch second difference phase change per pulse 3. $\Delta\phi_r$ - variation in ψ per pulse per 16 range bins
s	Clutter data, amplitude weights
t, x	Magnitude detected filter outputs N_r range bins by N_{fu} azimuth elements
u	N_{fu}/N_1 azimuth elements in N_R range bins
v	$(N_{fu}/N_1 x N_R)$ of 3 bit words

9.2 Bulk Memory

The bulk memory receives A/D converter/pulse compressor input data packed two 12 bit (9I, 9Q) words per PSP word, and acts as a buffer between the A/D converter/pulse compressor and the PSP. It stores intermediate processing results, tables, program instructions, and display data.

9.2.1 Inputs

1. A/D data packed into 24 bit words at the IDC module. Minimum interval between words: 500 nsec.
2. Bulk memory data from PSP. This includes initial storage of program instructions, constants, intermediate storage of partially processed data, and display data.

9.2.2 Processing

Address manipulation for block transform is performed in the bulk memory controller according to instructions from the PSP.

9.2.3 Outputs

1. A/D data stored in bulk memory as buffered input.
2. Intermediate processing data.
3. Program instructions and tables of constants.
4. Display refresh data.

9.3 Gain Control

This is used in DBS only and not in Real Beam Mapping.

9.3.1 Gain Control Inputs

The gain control inputs from the RDP are:

1. The STC profile selection (one of three)
2. The receiver gain control setting.

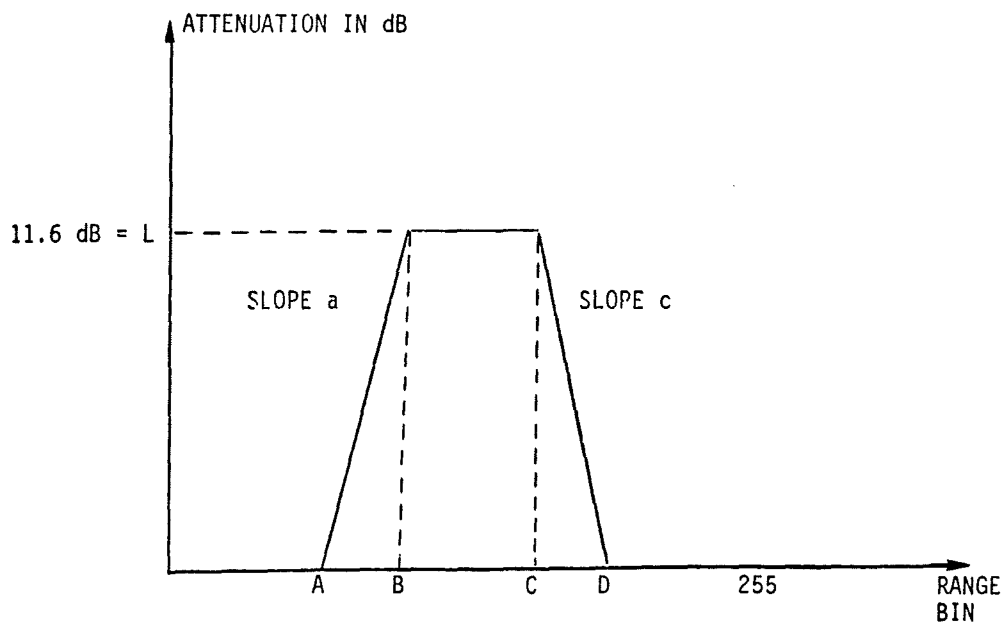
These inputs are updated by the RDP once per process cycle.

9.3.2 Gain Control Processing

The STC profile is passed directly to the receiver on a range bin by range bin basis, repeating once per pulse. The initial profile value is associated with the first range sample to be stored in bulk memory. The final STC value is held from the last range sample until the STC range counter is reinitialized.

STC Profile (Software)

Only one STC Profile from RDP is provided for Doppler Beam Sharpening (DBS). The shape of the associated parameters are shown in the figure below.



Slopes a and c are specified as a certain number of range bins per 1.16 dB step of attenuation. This STC is passed directly to the pre-sum function on a range bin by range bin basis, repeating once per pulse. The initial profile value is associated with the first range sample to be stored in bulk memory. The final STC value is held from the last range sample until the STC range counter is reinitialized.

9.3.3 Gain Control Outputs

The gain control outputs are:

1. Bin by bin STC profile from ROM data.
2. Coarse AGC in 11 dB steps.

9.4 Presum Filtering

Presum filtering is used to reduce the volume of data which must be stored in bulk memory without a sacrifice in signal to noise ratio which would result if PRF were lowered. Presum filtering is also used to select out the particular portion of the clutter spectrum which is to be further processed. Correction of the signal phase for aircraft motion is accomplished in presum filtering, also.

The presum algorithm is essentially complex-multiply-and-accumulate, applied to a sequence of radar pulse echoes on a range bin by range bin basis. The concept is illustrated in Figure 9.4.1. In order to suppress frequency ambiguities at the presum filter output, dual presumming is used. This means that the complex multiply and accumulate algorithm is applied twice to the input data, with staggered timing as illustrated in Figure 9.4.2.

9.4.1 Inputs

The presum filter input comes from the A/D converter/pulse compressor via the IDC and bulk memory. The A/D converter quantizes the signal into 9 bits "I" and 9 bits "Q". These data are packed 2:1 into a 24-bit word by the IDC. The IDC sends the data to bulk memory. The total number of range samples is determined by the timing and control.

Other presum inputs are:

1. Complex weights - a total of 2N, where N is the number of blocks of 16 range bin groups to be processed.
2. Output flags from the phase correction computation which indicate that the accumulation process is complete. In the case of 1:1 presumming, this flag is always set.
3. Number of pulses per presum group (NPS). Perform single presum when presum ratio = 1. If presum ratio ≠ 1 then use dual presumming.
4. The number of range bins to be processed.
5. Flags from the phase correction computation which indicate the beginning of a new accumulation.

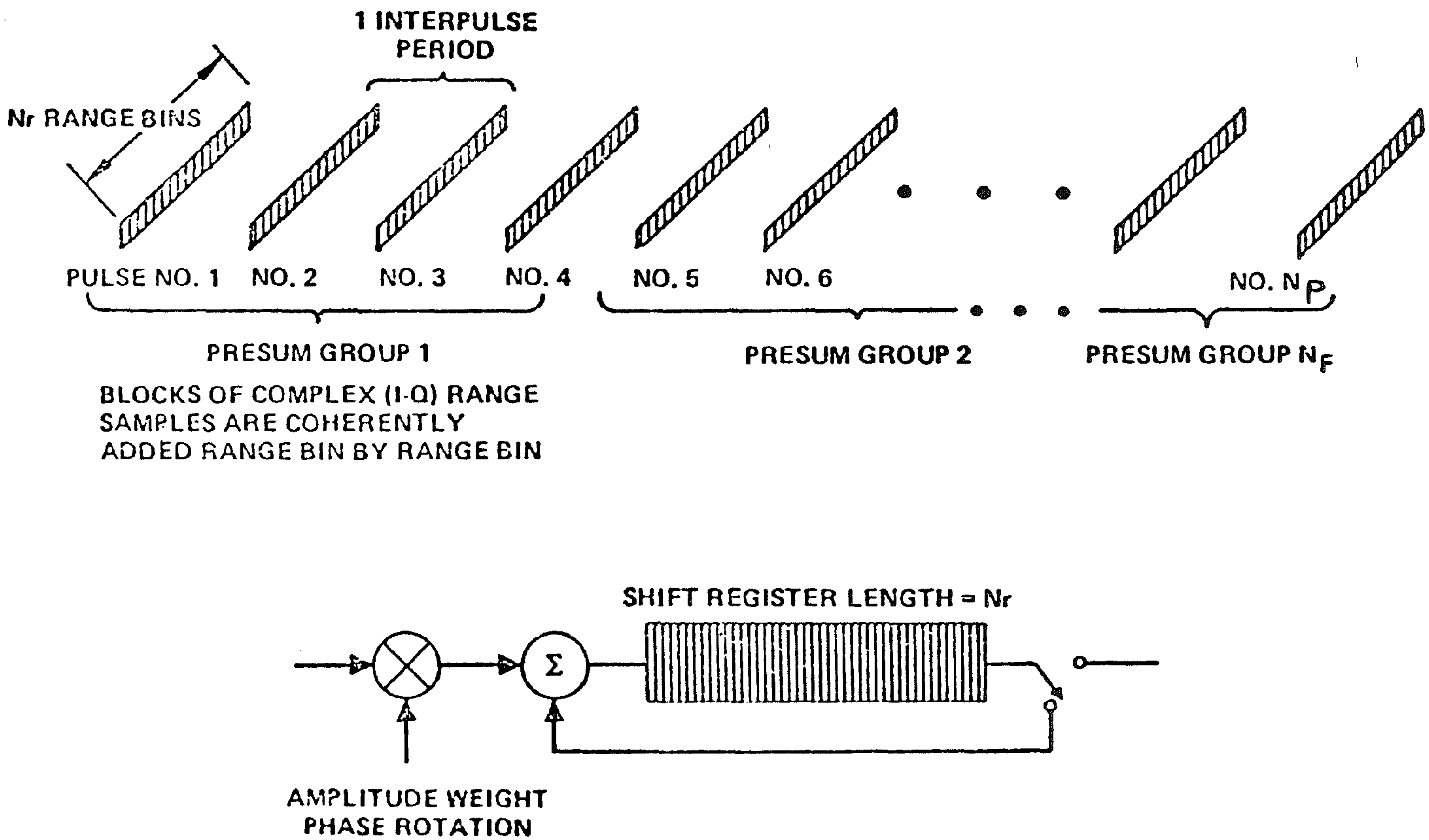


Figure 9.4.1 - PRESUM FILTERING ALGORITHM

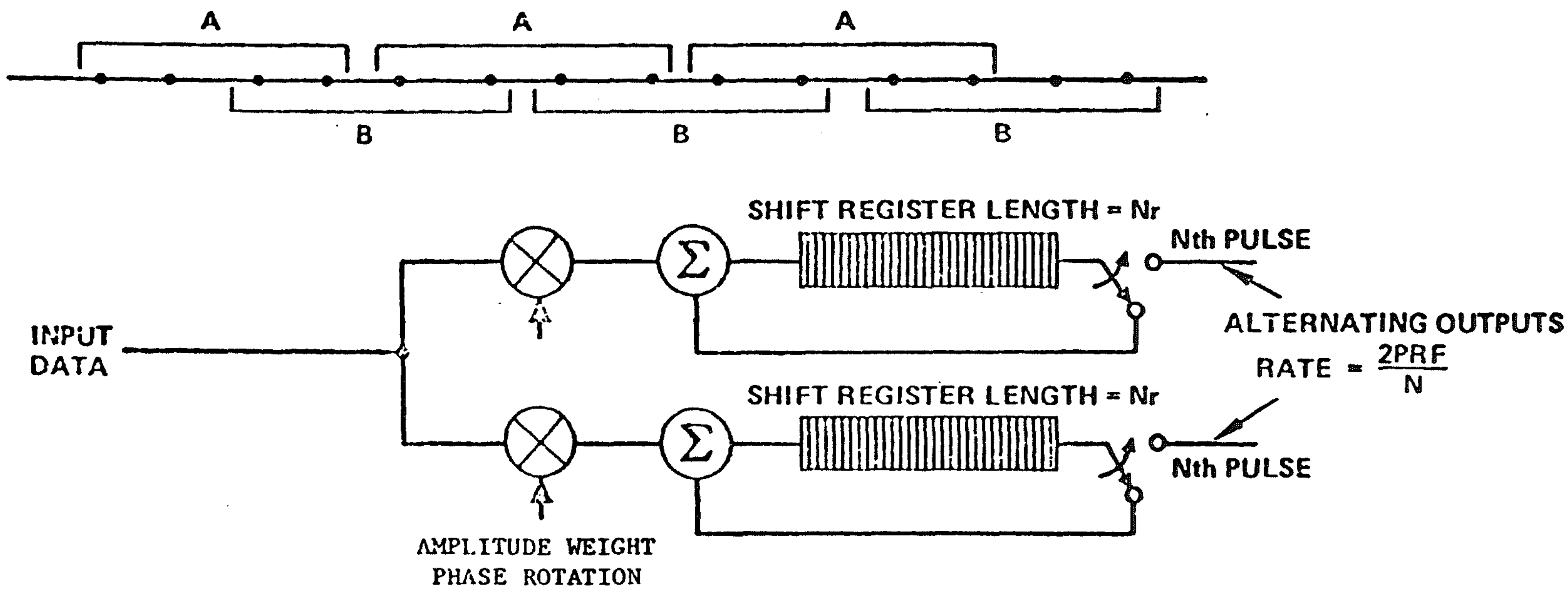


Figure 9.4.2 - FUAL PRESUM FILTERING ALGORITHM

9.4.2 Processing

The bulk memory data is multiplied by the complex weights and added to accumulators. The 2N complex weights are classified as "A" type weights and "B" type weights according to which presum filter is being processed. There are N weights for each presummer. The different weights for each presummer corresponds to different range intervals, each weight being associated with 16 range bins. Thus, range samples 0 through 15 are multiplied by weight A_0, with products going to the "A" accumulator. Range samples 16 through 31 are multiplied by weight A; and these products are again added to accumulator "A" in appropriate range bin addresses. This process continues, 16 range bins at a time, until all range bins have been multiplied by the A coefficients. The process is then repeated using "B" coefficients, unless a dual presum flag is not set, in which case the process ends at this point.

9.4.3 Outputs

The output of the presum filter is an array of presummed range samples. These are represented as 24 bit complex words (12I, 12Q). There are 256 words output for each presum group.

9.5 Phase Correction Computation

This function computes a phase rotation to be applied to input data. The phase rotation is computed from data supplied by the RDP at 16 (8 ms to 80 ms) pulse intervals, and is used to generate complex weighting factors used in the presum filter. This function also provides general software timing and control to the other functions.

9.5.1 Inputs

The inputs to the phase correction computation are:

1. Center of patch phase change per pulse, designated $\Delta\phi$: 2's complement; MSB = -2^{-1} cycle/pulse; LSB = 2^{-12} cycle/pulse.
2. Center of patch second difference phase change per pulse, designated $\Delta^2\phi$; 2's complement; MSB = -2^{-7} cycles/pulse^2, LSB = 2^{-18} cycles/pulse^2.
3. Variation in ψ per pulse per 16 range bins; designated $\Delta\phi_r$; 2's complement; MSB = -2^{-1} cycle/pulse, LSB = 2^{-12} cycles.
4. Number of pulses per presum group NPS; Min = 1, max = 16. Always an even number, except for the minimum value of 1.

9.5.2 Processing

The phase corrections are computed once per pulse. They are computed according to the following algorithm:

$$\underbrace{\theta_A(n,k)}_{\substack{\text{Overall phase correction, "A" group, nth}\\ \text{pulse, kth range zone}}} = \underbrace{\phi(n)}_{\substack{\text{Phase correction}\\ \text{center of patch,}\\ \text{nth pulse}}} + \underbrace{\psi_A(n) \bullet k}_{\substack{\text{Vernier correction, "A"}\\ \text{group, nth pulse, kth}\\ \text{range zone; k=0, +1, -1,}\\ \text{+2, -2, --}}}$$

k is a range index. It is zero for the center 16 range bins, +1 for the next 16 range bins farther, -1 for the next 16 nearer, etc. $\phi(n)$ is computed pulse by the algorithm:

$$\phi(n) = \phi(n-1) + \Delta\phi; \ \phi(o) = \Delta\phi$$

$$\Delta\phi(n) = \Delta\phi(n-1) + \Delta^2\phi$$

$\Delta\phi$ and $\Delta^2\phi$ are updated at least once every 15 msec by the RDP.

$\Psi_A(n)$ is computed by the algorithm:

$$\Psi_A(n) = n\Delta\phi r$$

where: n is an absolute count starting from 0.

$\theta_B(n,k)$ is the comparable phase rotation for "B" presum groups, and is computed by

$$\theta_B(n,k) = \phi(n) + \Psi_B(n) \bullet k$$

where $\phi(n)$ is as defined before, and

$$\Psi_B(n) = n\Delta\phi r = \Psi_A(n)$$

$\phi(n)$ is the center of patch phase rotation, and is computed once per pulse. $\Psi_A(n)$ and $\Psi_B(n)$ are vernier corrections which account for doppler curvature. $\Psi_A(n)$ and $\Psi_B(n)$ may be viewed as the variation of phase rate with range, and when multiplied by k, which is a range factor, they give the proper phase correction for the kth range zone.

9.5.3 Outputs

The outputs from the phase correction computation are:

$\theta_A(n,k)$ and $\theta_B(n,k)$ in units of cycles; 2's complement; MSB = -2^{-11} cycle, LSB = 2^{-12} cycle.

9.6 Complex Filter Weight Computation

This function receives phase rotation data $\theta_A(n,k)$ and $\theta_B(n,k)$, start and end flags, and pulse count data from the phase correction function and number of presum samples from the RDP. It generates a set of complex weights which are used in the presum filter processing.

9.6.1 Inputs

The inputs to this function are:

1. Phase corrections $\theta_A(n,k)$ and $\theta_B(n,k)$
2. Relative pulse count within group $n_A = n \pmod{N_{PS}}$ and $n_B = (n - \frac{N_{PS}}{2}) \pmod{N_{PS}}$
   where n is the pulse number counting from the start of the array.

9.6.2 Processing

The amplitude weight for "A" groups is given by:

$$W_A = \frac{2}{N_{PS}} F(16 \frac{n_A}{N_{PS}+1})$$

and for B groups,

$$W_B = \frac{2}{N_{PS}} F(16 \frac{n_B}{N_{PS}+1})$$

$F(\cdot)$ is a table look-up function with 16 addresses. The integer part of the address is used. The presum weights are shown in Figure 9.6.1.

The complex weights supplied to the presum filter are for range samples in the kth range zone, nth pulse

$W_A \; e^{j\Delta\theta_A(n,k)}$ for "A" groups,

and

$W_B \; e^{j\Delta\theta_B(n,k)}$ for "B" groups.

9.6.3 Outputs

The outputs of the complex filter weight computation function are:

1. Complex weights $W_A\, e^{j\Delta\theta_A(n,k)}$ k = 0, ±1, ±2, ±3, and $W_B\, e^{j\Delta\theta_B(n,k)}$ 24 bits, (12I, 12Q) computed for each input pulse, for each 16 bin range zone, and for both A and B filters.

Sample Number	Presum Weights
0	.107686
1	.167412
2	.277772
3	.421963
4	.578035
5	.722227
6	.832587
7	.892314
8	.892314
9	.832589
10	.722229
11	.578038
12	.421966
13	.277774
14	.167413
15	.107686

Figure 9.6.1

PRESUM WEIGHTS FOR F-15
DOPPLER BEAM SHARPENED MODE

9.7 Pulse Compression

The pulse compression function consists of an approximate doppler compensation followed by standard 13:1 pulse compression. This function is performed by a pulse compressor unit before buffer store. Under some conditions pulse compression is turned "off" in which case this function is bypassed.

9.8 Fast Fourier Transform (FFT)

This function weights the clutter data and forms N_{ff} doppler filters per range bin. Of the N_{ff} filters formed, $N_{fu} \leq N_{ff}$ filters centered about DC are used.

9.8.1 Inputs

a. From RDP:
- The FFT size (N_{ff}); either 16, 32, or 64.
- The number of filters used (N_{fu}); 1 to 8 filters used as determined by the RDP.

b. From PSP:
- The clutter data (I,Q)
- The amplitude weights, which are real and symmetrical.

9.8.2 Processing

The FFT size N_{ff}, with amplitude weights, is performed for each of the 256 range bins. Of the N_{ff} filters formed, $N_{fu} \leq N_{FF}$, specified by the RDP, are used and the other filter outputs are ignored. In real beam processing $N_{fu} = 1$ and the output is the maximum of the N_{FF} filter outputs for each range bin.

9.8.3 Outputs

The output is N_{fu} magnitude values of clutter data per range bin. These are the doppler filter outputs which are magnitude detected. The N_{fu} filters which are to be output are specified by the RDP. For each range bin, the quantity $\sqrt{I^2 + Q^2}$ is approximated for each filter output. These quantities are scaled into 10 bit real words and are packed 2:1 into the least significant ten bits of the "I" or "Q" portion of 24 bit output words.

For real beam processing, the single output ($N_{fu} = 1$) per range bin is the maximum of the N_{ff} outputs for that range bin.

SAMPLE NUMBER	AMPLITUDE WEIGHTS
0 , 15	.1077
1 , 14	.1674
2 , 13	.2778
3 , 12	.4220
4 , 11	.5780
5 , 10	.7222
6 , 9	.8326
7 , 8	.8923

Figure 9.8.1

16 POINT FFT AMPLITUDE WEIGHTS FOR

F-15 DOPPLER BEAM SHARPENED MODE

SAMPLE NUMBER	AMPLITUDE WEIGHTS
0 , 31	.1019
1 , 30	.1172
2 , 29	.1472
3 , 28	.1908
4 , 27	.2462
5 , 26	.3114
6 , 25	.3839
7 , 24	.4608

SAMPLE NUMBER	AMPLITUDE WEIGHTS
8 , 23	.5392
9 , 22	.6161
10 , 21	.6886
11 , 20	.7538
12 , 19	.8092
13 , 18	.8528
14 , 17	.8828
15 , 16	.8981

Figure 9.8.2

32 POINT FFT AMPLITUDE WEIGHTS

FOR F-15 DOPPLER BEAM SHARPENED MODE

SAMPLE NUMBER	AMPLITUDE WEIGHTS
0 , 63	.1005
1 , 62	.1043
2 , 61	.1120
3 , 60	.1234
4 , 59	.1384
5 , 58	.1569
6 , 57	.1787
7 , 56	.2036
8 , 55	.2314
9 , 54	.2617
10 , 53	.2944
11 , 52	.3290
12 , 51	.3652
13 , 50	.4028
14 , 49	.4413
15 , 48	.4804
16 , 47	.5196
17 , 46	.5587
18 , 45	.5972
19 , 44	.6348
20 , 43	.6710
21 , 42	.7056
22 , 41	.7383
23 , 40	.7686
24 , 39	.7964
25 , 38	.8213
26 , 37	.8431
27 , 36	.8616
28 , 35	.8766
29 , 34	.8880
30 , 33	.8957
31 , 32	.8995

Figure 9.8.3

64 POINT FFT AMPLITUDE WEIGHTS FOR
F-15 DOPPLER BEAM SHARPENED MODE

9.9 Multi-Look Overlay

Multi-Look Overlay is used to provide scintillation reduction by averaging image element values over several process cycles.

9.9.1 Inputs (change at most once per map frame time)

1. Number of looks, N_L: 1,4.
2. Magnitude detected filter outputs; N_r range bins by N_{fu} azimuth elements packed 2:1 in 24 bit words of 10 significant bits each.

9.9.2 Processing

Filter magnitude data is stored in an overlay buffer storage. Data to be overlayed is kept segregated on a range bin basis. Figure 9.9.2.1 illustrates the overlay operation for the 4 look case. In each process cycle, N_{fu} filters per range bin are formed, and $\frac{1}{4} N_{fu}$ are combined with stored data and sent to the display buffer, while $\frac{1}{2} N_{fu}$ filter outputs are combined with previously processed and retained data, and $\frac{1}{4} N_{fu}$ filter outputs start a new overlay.

Because of the growth in word size due to the overlay, a rescaling must be performed before the data is transformed and sent to display. This is accomplished by a right shift of $LOG_2 (N_L)$ places.

No Multi-look overlay processing is done with Real Beam Mapping. Thus when Real Beam Map is set by the RDP, multi-look overlay is bypassed.

9.9.3 Outputs

1. $\frac{N_{fu}}{N_L}$ Azimuth elements in N_r range bins, packed 2:1 in 24 bit words of 10 significant bits each (the 10 LSB's of "I" and "Q" half words).

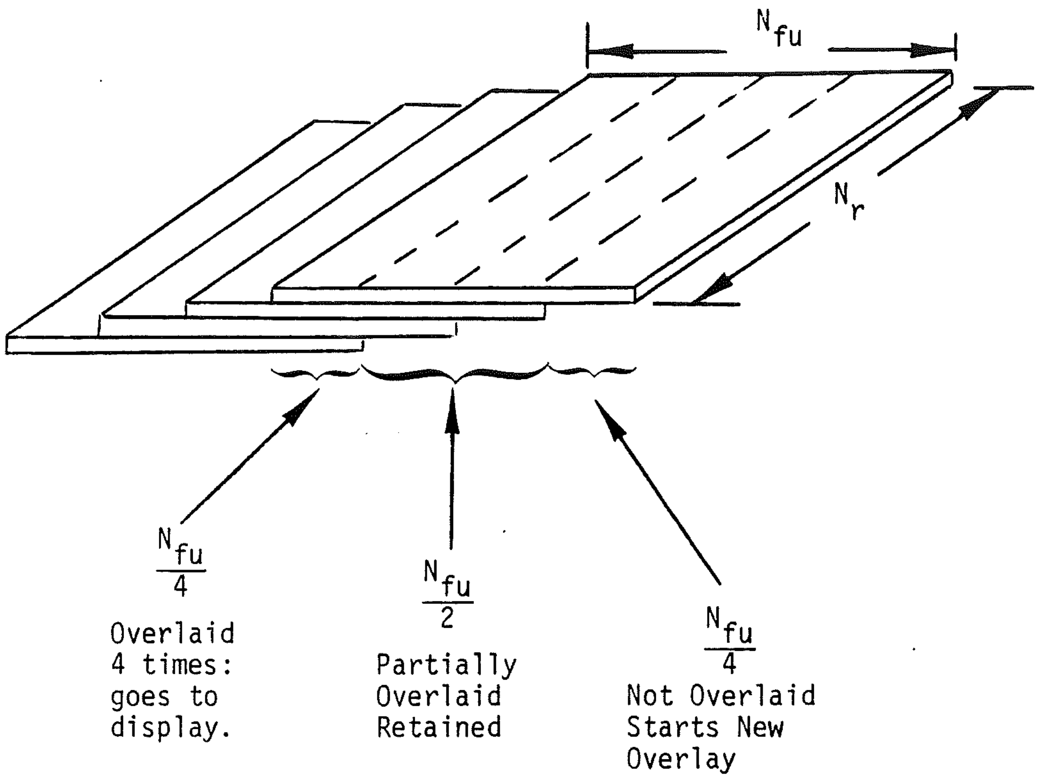


Figure 9.9.2.1

CONCEPTUAL ILLUSTRATION OF FOUR-LOOK OVERLAY PROCESSING

9.10 Output Scaling

This function converts filter outputs to display format through a selected nonlinear transformation.

9.10.1 Inputs

Inputs are 10 bit overlaid filter magnitude data, packed 2:1 into the 10 LSB of "I" and "Q" half words.

The RDP specifies which particular nonlinear transformation is to be used from four available.

9.10.2 Processing

The display data is 3 bits, packed 8 elements per 24 bit word. Thus each 10 bit input data point must be transformed to a 3 bit output and packed into an output word. The transformation is by a table look-up function. This shade of grey table is 256 words long. This means the address is 8 bits long. There are four such transformations. One transformation is logarithmic.

9.10.3 Outputs

The output is an array of $\left(\frac{N_{fu}}{N_L} \times N_r\right)$ three bit words. This output occurs once per process cycle.

9.11 Display Data Buffering

The purpose of this function is to reorder the output data prior to sending it to the display refresh buffer.

9.11.1 Inputs

The inputs to this function are arrays of 3 bit display elements, N_{fu}/N_L in azimuth by N_r in range. N_{fu}/N_L may be as small as 2 and as large as 10 for DBS depending on the overlay ratio and angular resolution. For RBM, N_{fu}/N_L is always 1. Also input is a clockwise/counterclockwise flag, indicating the antenna scan direction.

9.11.2 Display Data Buffer Processing

The display refresh buffer is 8 columns by 7936 rows of 3 bit elements. The normal display format is 256 azimuth by 248 range elements with 8 shades of grey each. The display buffer store is arranged in two sets of 124 range elements each, an even numbered range bin set and an odd numbered set, as illustrated in Figure 9.11.2.1 256 azimuth elements are arranged in 32 contiguous rows of 8 elements each at the (even or odd) range bin location. The upper left element (range bin 0, azimuth element 0) is the first element read out for each frame of display. The even and odd numbered range bin sets are scanned in interleaved raster scans of 124 lines each, completing a display refresh frame in about 37 milliseconds. In RBM azimuth addresses are provided by the RDP. These addresses can vary between 0 and 255.

Data is read in one row at a time (8 azimuth elements per display refresh buffer word of 24 bits). It is therefore necessary to assemble data in a data memory before storing it in the display refresh buffer. Data may be masked, shifted, OR'd, etc. in the data memory before returning it to the display refresh buffer. Data may be written according to clockwise or counterclockwise antenna scan patterns. Both clockwise or counterclockwise loading can occur, so "last address" pointers are maintained for both directions. These pointers are initialized at the beginning of each process cycle.

9.11.2.1 Buffer Output Display Formats

The display buffer format outputs are used for three basic displays in DBS: PPI, Left/Right Sector Expand, and Square Window Expand Mode displays. For Real Beam Mapping one display is provided: Full PPI. Brief descriptions follow.

9.11.2.1.1 PPI Displays (DBS)

PPI display is provided with azimuth coverage of 100° centered on ground track. This is composed of 218 x 8 mr Az elements. Range Scales are 10, 20, 40, 80 and 160 N.Mi., with outer half of the 20, 40, 80, 160 scales mapped. The 2 to 10 N.Mi. of the 10 N.Mi. scale is mapped. Full PPI is provided by selecting "120 degrees Az Scan" on the 541.

9.11.2.1.2 Left/Right Sector Expand Displays (DBS)

Left and Right sector expansion is also provided depending on the position of the corral at the time 60° is selected on the 541 (this commands both expansion). The Right (Left) sector expansion can be changed to Left (Right) sector expansion by moving the corral to the Left (Right) side of the edge of the display. Selecting 120° on the 541 Az Scan switch returns the display to Normal DBS (PPI above). Applicable range scales are 10, 20, 40, N.Mi. with 4 mr azimuth elements. Azimuth coverage is 50 degrees. Outer half is mapped for the 20, 40, N.Mi. range scales and outer 2 to 10 N.Mi. on the 10 N.Mi. scale.

9.11.2.1.3 Square Window Expand Displays (DBS)

These displays are square window expand formats of 4x4 and 8x8 N.Mi. Range display width depends on range scale chosen (4 N.Mi. if range scale is 10 and 8 N.Mi. otherwise) and is centered about the corral position at the time the square window is selected. The RDP provides velocity updated R,θ coordinates from frame to frame; the display is velocity compensated to position the original designation to the center of the display format. Maximum angle coverage is 50°.

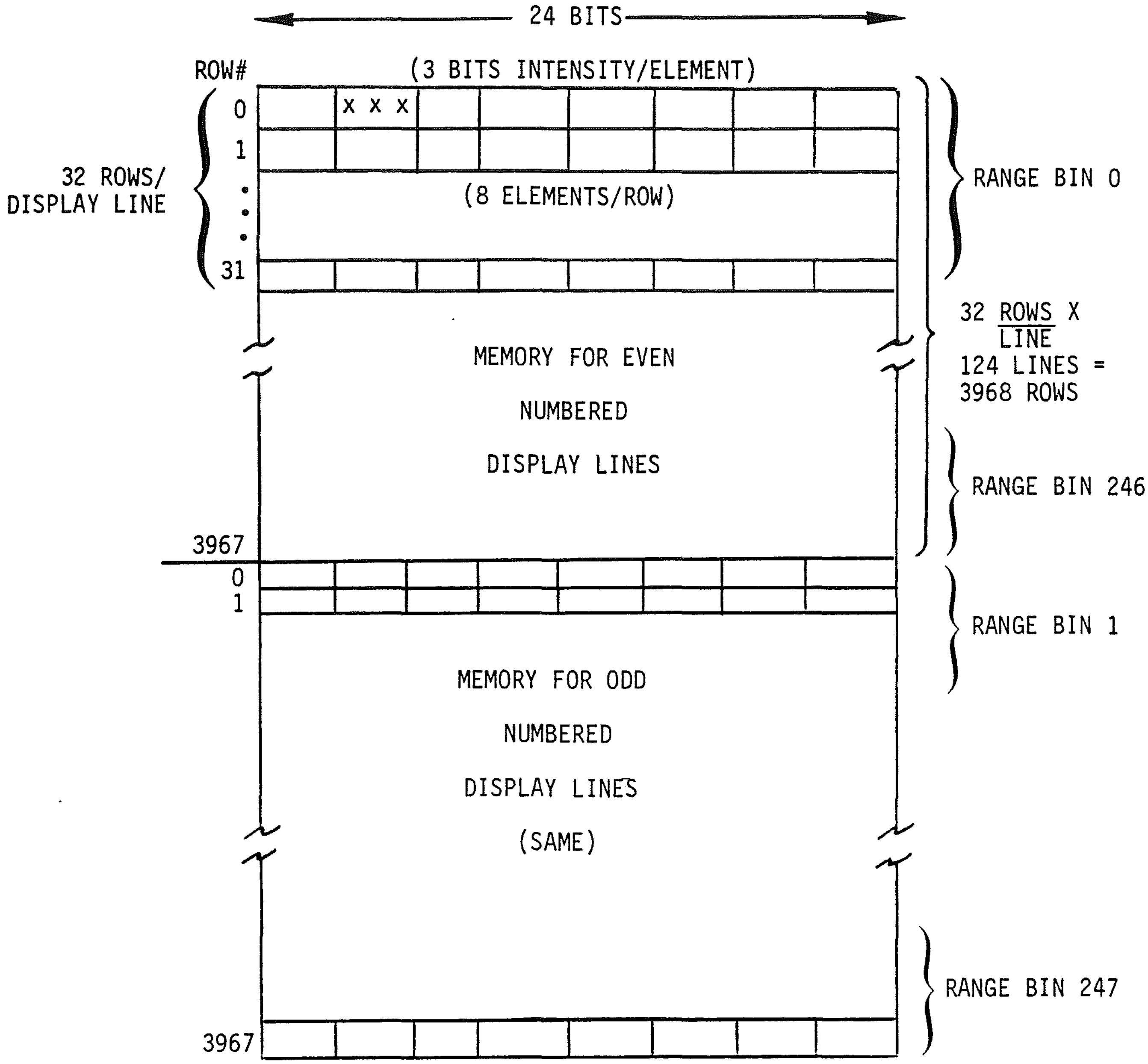
9.11.2.1.4 RMB Displayed Images

Full PPI: Azimuth coverage is 100°. The display is centered on ground track. Applicable range scales are 10, 20, 40, 80, 160 N.Mi. with the outer 80% of range scale mapped for the first four of the above range scales and 50% for the 160 N.Mi. scale range with adjustable center from 80 N.Mi. to 120 N.Mi.

Sector: 2 sectors are provided -20° and 60°. These sectors are steerable with the TDC determining the display center.

9.11.3 Outputs

The output to the display refresh buffer is blocks of display data constituting $\frac{Nu}{NL}$ azimuth elements by 248 range elements.



Note: Top half of memory contains the image for the even-numbered VSD raster lines, and the bottom half of memory contains the odd lines. Each line of the VSD has 256 elements.

Figure 9.11.2.1 - DISPLAY BUFFER STORE

9.12 Clutter Doppler Error Sensor

The purpose of this function is to provide the RDP with CDE (clutter doppler error) data required for the generation of needed corrections to INS velocity inputs V_N, V_E. Any bias or V_V corrections which are needed also are derived from the CDE data.

9.12.1 Inputs

- There are no RDP inputs to the CDE function.
- Filter output Amplitudes A(k,j): the central range bin of the kth range gone, jth doppler filter.

9.12.2 Processing

CDE Processing derives two quantities N(k) and D(k) from FFT filter output magnitudes from the 8th range bin of the kth range interval of 16 range bins; k = 0, ± 1, ± 2, ... The doppler error DE(k) for the kth interval is the ratio (N(k)/D(k)) where:

$$N(k) = \sum_{j=1}^{(N_{FF}/2)-1} jA(k,j) - \sum_{j=(N_{FF}/2)}^{N_{FF}-1} (N_{FF}-j)\, A(k,j)$$

$$D(k) = \sum_{j=0}^{N_{FF}-1} A(k)_j .$$

Thus the RDP calculates VE(k) as the centroid estimate of MLC frequency for the kth range interval.

9.12.3 Outputs

CDE outputs are N(k), D(k) in the order

N(k), D(k): k = 0, k = +1, k = -1, k = +2, k = -2, ...,

k = +k, k = -k; where $k \leq 8$.

Section 10
LPRF BEACON MODES

10.0 INTRODUCTION

The LPRF Beacon Modes involve the interrogation, reply processing and display of airborne and ground based radar beacons. These modes are implemented for range scales of 10, 20, 40, 80 or 160 NM. Beacon returns are envelope detected and passed through to the PSP using only the Main I Channel. The purpose of the PSP programming is to threshold detect the beacon channel data and properly format the returns for the Vertical Situation Display (VSD). Expansion or compression is used to provide constant beacon code display spacing regardless of the range selected.

Two beacon modes are implemented. These are Air-to-Air and Air-to-Ground modes. The A/A beacon mode utilizes a B-Scan space stabilized display. The A/G beacon mode uses a PPI-Scan ground track stabilized display. A simplified block diagram of the beacon mode is shown in Figure 10.1.

The signal processing functions of the PSP in beacon mode are indicated in the Mode Functional Diagram, Figure 10.2. Two PRIs occur each PSP cycle. Only one PRI/PSP cycle is processed.

The Main Channel I data are buffered in the Data Buffering function. The purpose of this function is the expansion of 1X data and interim storage of all data for possible access by a sliding window detector. At present, a simple threshold detector only is utilized.

The Threshold Detector utilizes a 256 RB LEA to form noise threshold and a threshold multiplier supplied by the RDP. Those returns exceeding this threshold are saved in a detection array.

Display List Processing expands or compresses returns in order to give a fixed display regardless of range scale selected. The first return displayed represents true range to target. Subsequent returns are scaled as necessary for constant code spacing.

Display processing is essentially identical to analogous non-beacon modes. For beacon modes, the IRE inhibit code is always '1' and the acquisition symbol is blanked.

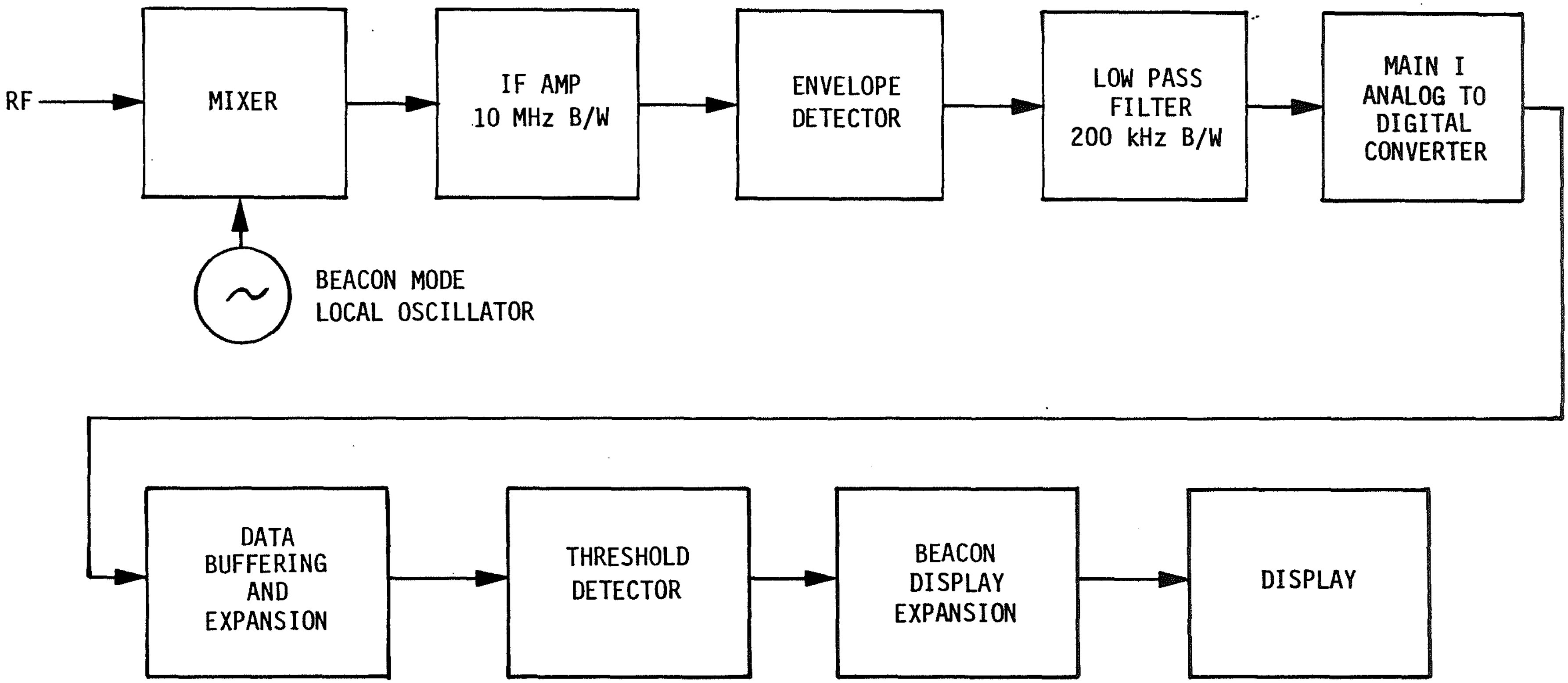


FIGURE 10.1. BEACON MODE - FUNCTIONAL DIAGRAM

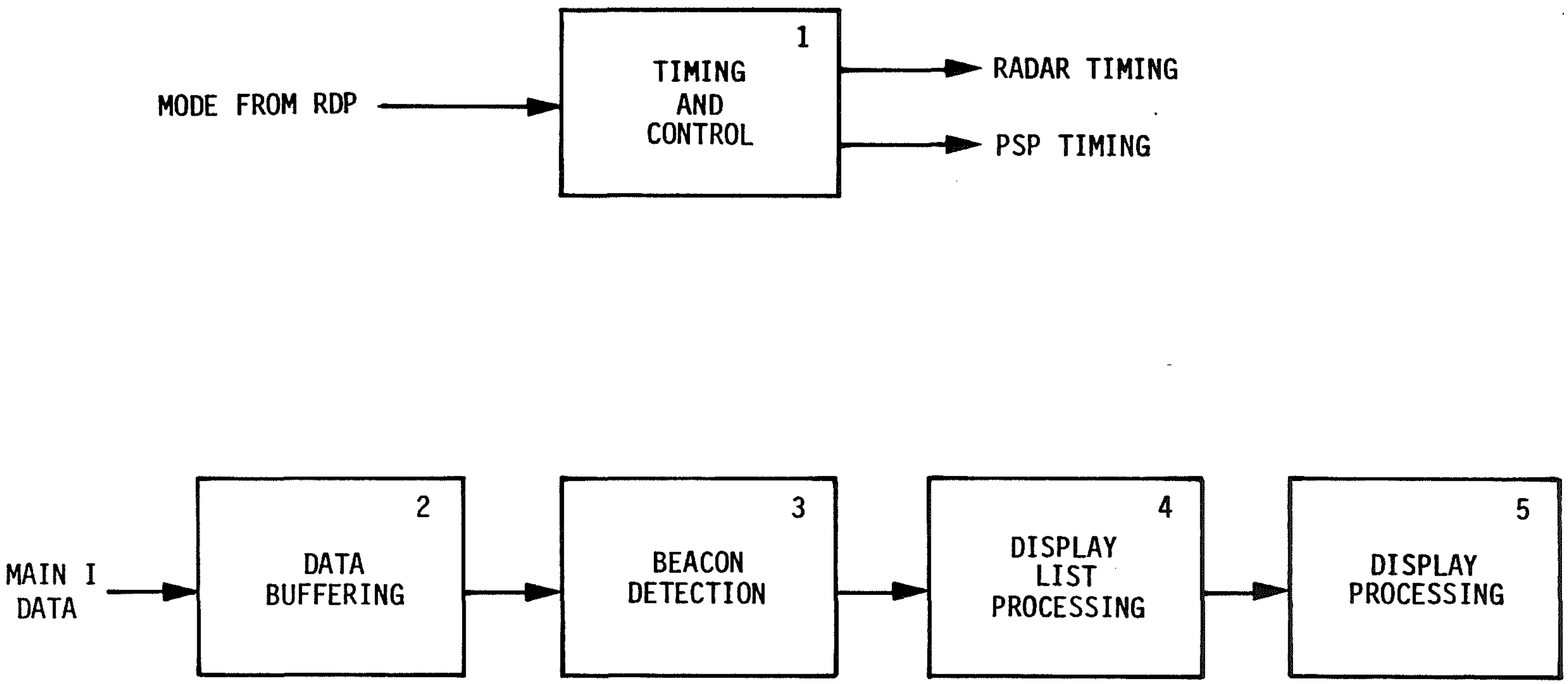


FIGURE 10.2. LPRF BEACON MODE PROCESSING

10.1 Timing and Control

The signals that cause the Radar System (Units 001, 011, 022, 031 and 039) to configure to a desired mode of operation and those signals that control the RDP and the PSP activities are referred to as the Timing and Control signals. These signals come from two hardware modules inside the PSP, namely, the T&C and the Input Data Conditioner (IDC) modules. The discussion in this section is concerned with:

1. the operation of the T&C and the IDC, and
2. the interaction of these modules with the RDP and the PSP (see Figure 10.1.1).

10.1.1 T&C and IDC

The internal structure of these modules are very similar. Figure 10.1.1 shows a generalized schematic of the two modules. Both have a parameter receiver, control memories, and the logic circuits that generate the timing and control signals. The IDC is driven by timing signals supplied by the T&C which in turn is driven by a 20 MHz oscillator. Each control memory has two parts that are called 'A' memory and 'B' memory. The two parts of the control memory are always in opposite states. For example, if A is in the execute state B is in the load state. The nature of these states is explained below.

The command words in those control memories that are in the execute state determine the signals put out by the logic circuits over one PSP cycle. (The cycle time is a function of the Radar Mode). Near the end of a cycle the T&C makes a T&C load request. This causes a new set of command words from the CIU to be loaded into the control memories that are in the load state. At the end of the cycle, the T&C sends out an A/B select signal to all the control memories and forces the memory state to change. This sequence of events then repeats itself until a mode change occurs.

Figure 10.1.2 shows timing signals pertinent to the LPRF Beacon Mode PSP processing discussed in the later sections.

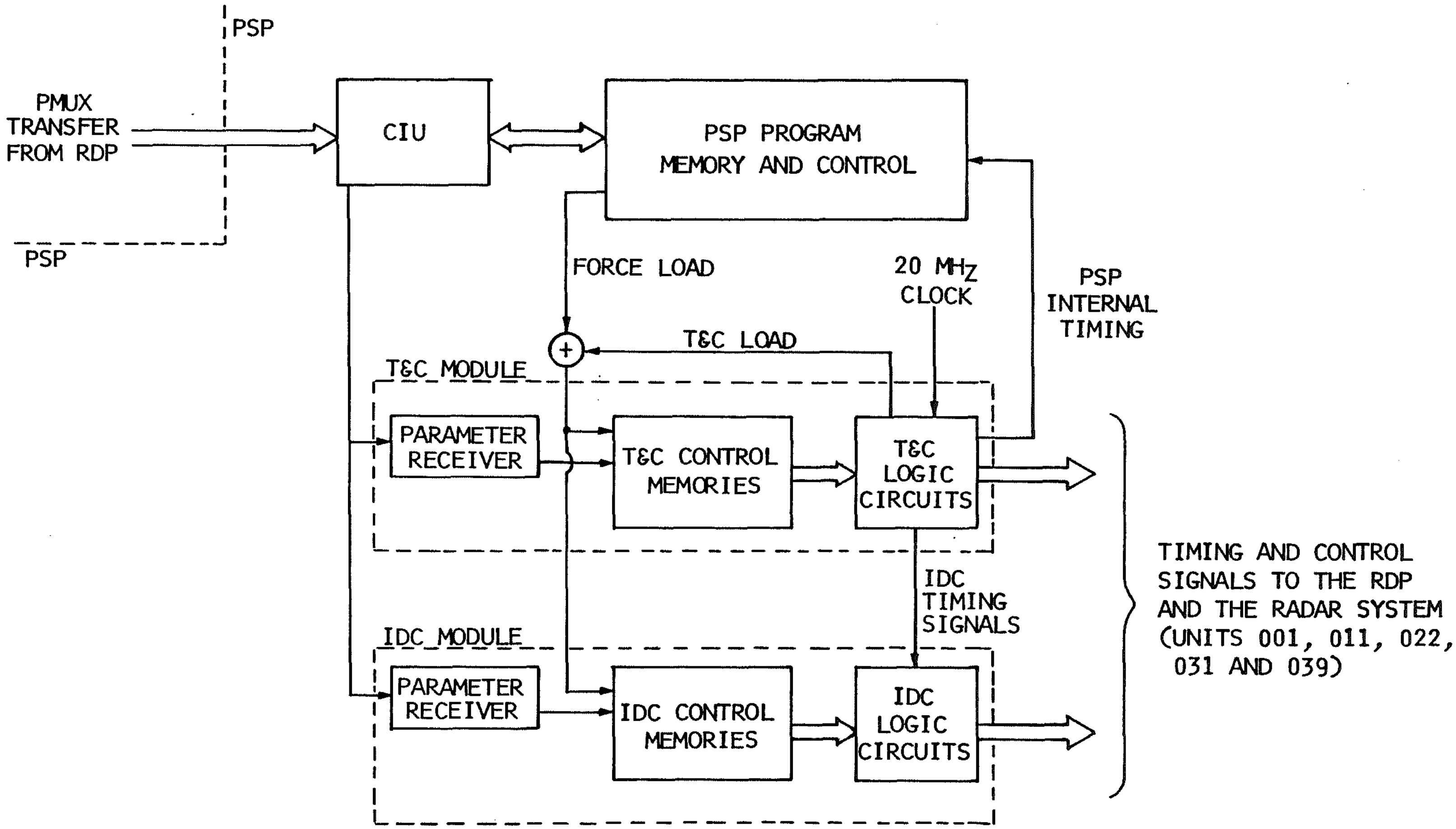


FIGURE 10.1.1 <u>GENERALIZED SCHEMATIC SHOWING THE INTERACTION BETWEEN THE T&C/IDC MODULES, THE PSP MEMORY & CONTROL, THE CIU AND THE RDP.</u>

10.1.2 PMUX Transfer and Force Load

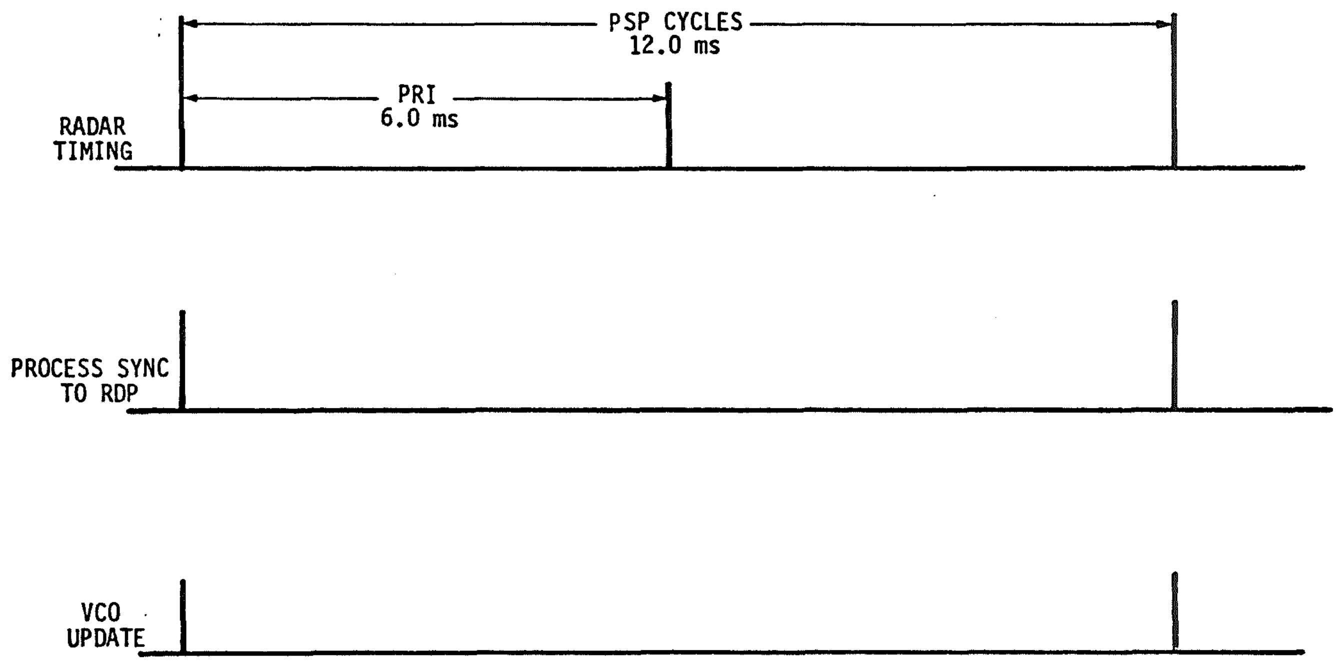
During the steady state operation of the T&C and the IDC modules, the RDP constantly updates the variable portion of the command words in the CIU. This is done through the PMUX Transfer. The timing of this transfer is asynchronous to the T&C activities, and the transfer rate is determined by the RDP program.

In addition to the command words for the T&C/IDC modules, PMUX Transfer also carries control words and data words to the PSP program. One of the PSP tasks at the beginning of an PSP cycle is to see if the RDP has made a mode change request. If the request has been made, the PSP reacts with a Force Load operation. This action causes a block of command words associated with the new mode to be loaded into the T&C/IDC control memories from the PSP memory. The PSP then sends an A/B force select signal to these control memories to effect a memory state change. This prompts the T&C and IDC to generate the timing and control signals for the new mode. The RDP takes over the control of the T&C activities after the first cycle.

10.1.3 Basic Timing

As shown in Figure 10.1.2, the basic timing is constant at 12 ms/process cycle with two PRIs/cycle. For beacon modes alternate PRIs are processed, i.e.. one per cycle. The timing shown is valid for both Air-to-Air and Air-to-Ground modes at any range scale.

BEACON MODE TIMING
(ALL RANGE SCALES)



NOTE: ONE PRI/CYCLE PROCESSED
IDA N/A

FIGURE 10.1.2.

TIMING SIGNALS FOR BEACON MODES

10.2 Data Buffering

The envelope detected becon mode returns are buffered, and in case of 1X range, are expanded two to one.

The number of input and output range data samples as a function of range scale is shown in Table 10.1.

10.2.1 Input

- Range Scale:

  $RS \in \{1X, 2X, 4X, 8X, 16X\}$

- Main Channel Range Samples (Envelope Detected I data)

  $S_{M,I}(i) \mid i=0, \ldots, N(RS)-1$

NOTE: $S_{M,Q}(i) = 0$ and is not processed in beacon modes.

10.2.2 Processing

One array is used for the Data Buffering function:

$$\{X(i) \mid i=0, \ldots, 2047\}$$

The loading of this array consists of a 1:2 data transfer for RS = 1X and a direct data transfer for RS ≠ 1X. Unused cells are loaded with zero entries.

10.2.2.1 RS = 1X

$$X(2i) = S_{M,I}(i), \quad \text{for } i=0, \ldots, 127$$

$$X(2i+1) = S_{M,I}(i), \quad \text{for } i=0, \ldots, 127$$

$$X(i) = 0 \quad \text{for } i=256, \ldots, 2047$$

10.2.2.2 RS = 2X, 4X, 8X

$$X(i) = S_{M,I}(i), \quad \text{for } i=0, \ldots, N(RS)-1$$

$$X(i) = 0 \quad \text{for } i=N(RS), \ldots, 2047$$

10.2,2.3 RS = 16X

$$X(i) = S_{M,I}(i), \quad \text{for } i=0, \ldots, 2047$$

10.2.3 Outputs

Buffered beacon range data:

$\{X(i) \mid i=0, \ldots, 2047\}$

RANGE SCALE RS	SAMPLES/PRI N(RS)	BUFFERED SAMPLES K(RS)
1X	128	256
2X	256	256
4X	512	512
8X	1024	1024
16X	2048	2048

TABLE 10.1

INPUT AND BUFFERED SAMPLES PER PRI

10.3 Beacon Detection

Beacon Detection is accomplished by comparing the buffered beacon range data with the product of the 256 RB LEA and an RDP supplied multiplier. The first two range cells are ignored to preclude triggering by spurious signals.

10.3.1 Inputs

- Buffered Beacon Range Data:

  $\{X(i) \mid i=0, \ldots, 2047\}$

- Beacon channel threshold multiplier from RDP: K_B

10.3.2 Processing

One array is used for the Beacon Detection function:

$\{T(i) \mid i=0, \ldots, 2047\}$

This array is loaded with range threshold detections as follows:

$$T(i) = 1 \text{ if } X(i) \geq K_B \frac{N(i)}{4} \text{ for } i=2, \ldots, 2047$$

$$= 0 \text{ otherwise}$$

where

$$N(i) = \text{largest of} \left[\sum_{j=i-5}^{i-2} x(j), \quad \sum_{j=i+2}^{i+5} x(j) \right] \quad \text{for } i=7,8,\ldots, 2047$$

$$= (\text{the second term}) \quad \text{for } i=2,3,\ldots, 6$$

10.3.3 Outputs

Array of beacon detections:

$\{ T(i) \mid i=0, \ldots, 2047 \}$

10.4 Display List Processing

Beacon returns are formatted for display so that the spacing between returns is constant regardless of range scale selected. The first beacon return is always displayed at True Target Range. Correct display spacing is based on the 2X range array of 256 range cells.

10.4.1 Inputs

Range Scale

$$\{RS \in 1X, 2X, 4X, 8X, 16X\}$$

Beacon Detections

$$\{T(i) \mid i=0, \ldots, 2047\}$$

10.4.2 Processing

Processing of data for the display array is dependent on the range scale selected. The results are stored in a fixed length array:

$$\{H(i) \mid i=0, \ldots, 255\}$$

The processing for each case is described in subsequent paragraphs.

10.4.2.1 1X Processing

Data from the detection array is copied into the display array one to one to the first detection, if any. Thereafter every other detection array element is copied into the display array till the end of the detection array is reached. Remaining cells of the display array are set to zero. This is illustrated in Figure 10.4.1. Designate the detection cell containing the first hit as T(J), then:

$$
\begin{aligned}
H(i) &= T(i) && \text{for } i=0, \ldots, J-1 \leq 255 \\
H(J) &= T(J) \\
H(J+1) &= T(J+2) \\
&\vdots \\
H(J+N) &= (J+2N) && \text{for } J+2N \leq 255 \\
H(i) &= 0 && \text{thereafter}
\end{aligned}
$$

10.4.2.2 <u>2X Processing</u>

Data in the Detection List, T(i), is properly arranged for display at 2X range scale, thus:

$$H(i) = T(i) \text{ for } i=0, \ldots, 255$$

10.4.2.3 <u>4X Processing</u>

Cells from the detection array are scanned 2:1 to the first detection, if any. Thereafter detection array cells are copied into the display array 1:1 until the end of the display array is reached. Designate the detection cell containing the first hit as T(J), then:

$$
\begin{aligned}
K &= INT(J/2) \\
H(i) &= 0 && \text{for } i=0, \ldots, K-1 \\
H(K) &= T(J) \\
H(K+1) &= T(J+1) \\
&\vdots \qquad \vdots \\
H(K+N) &= T(J+N) && K+N = 255
\end{aligned}
$$

The process is illustrated in Figure 10.4.2.

10.4.2.3 <u>8X Processing</u>

Processing for 8X range is identical to that for 4X range except that detection cells prior to the first hit are scanned 4:1.

Designate the detection cell containing the first hit as T(J), then:

K	=	INT(J/4)	
H(i)	=	0	for i=0, ..., K-1
H(K+1)	=	T(J)	
H(K+1)	=	T(J+1)	
.		.	
.		.	
H(K+N)	=	T(J+N)	K+N = 255

10.4.2.5 16X Processing

Processing for 16X range is identical to that for 4X range except that detection cells prior to the first hit are scanned 8:1. Designate the first detection cell containing a hit as T(J), then:

K	=	INT(J/8)	
H(i)	=	0	for i=0, ..., K-1
H(K)	=	T(J)	
H(K+1)	=	T(J+1)	
.		.	
.		.	
H(K+N)	=	T(J+N)	K+N = 255

10.4.3 Outputs

Output of the Display List Processing function is a list of hits to be displayed:

H(i) | i=0, ..., 255

in which the first non-zero entry is located at true range to target. Subsequent returns are scaled to the spacing as observed for returns at 2X range display.

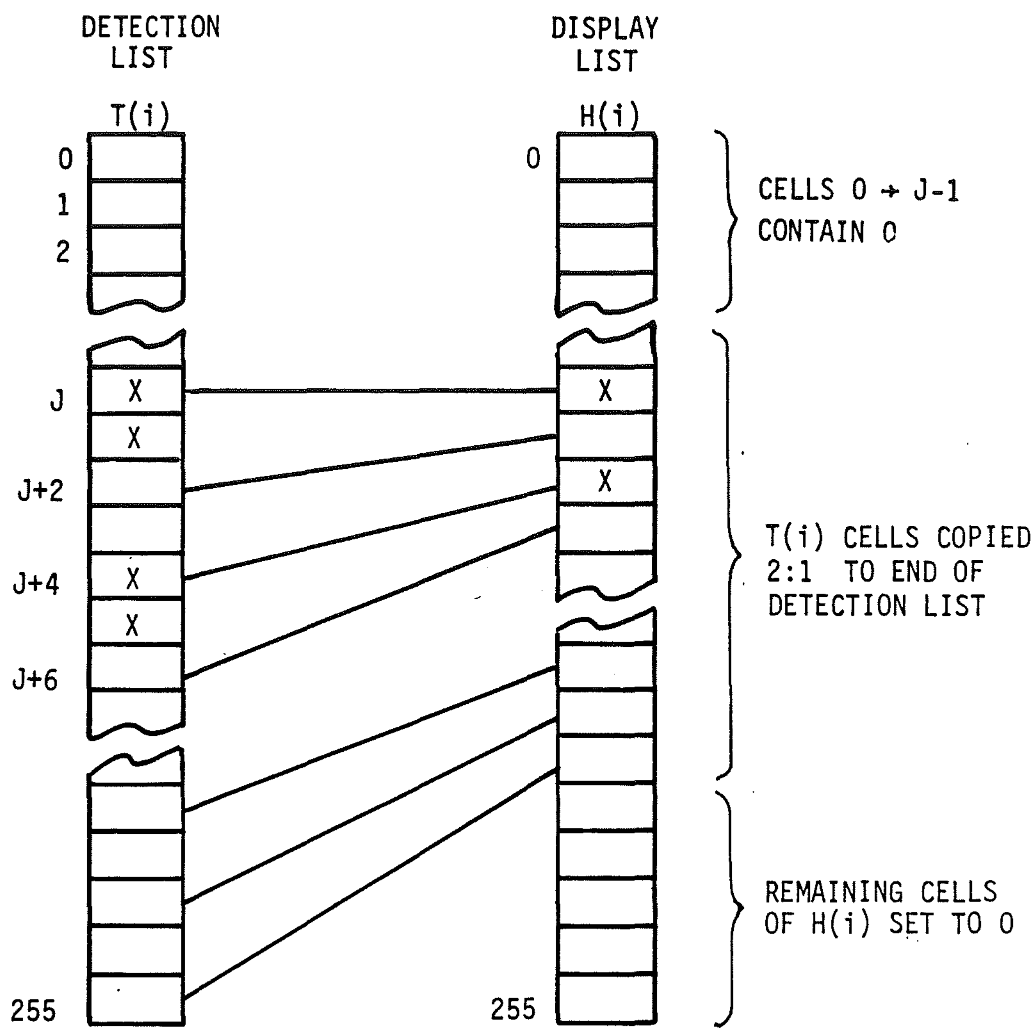


FIGURE 10.4.1 1X RANGE DISPLAY LIST PROCESSING

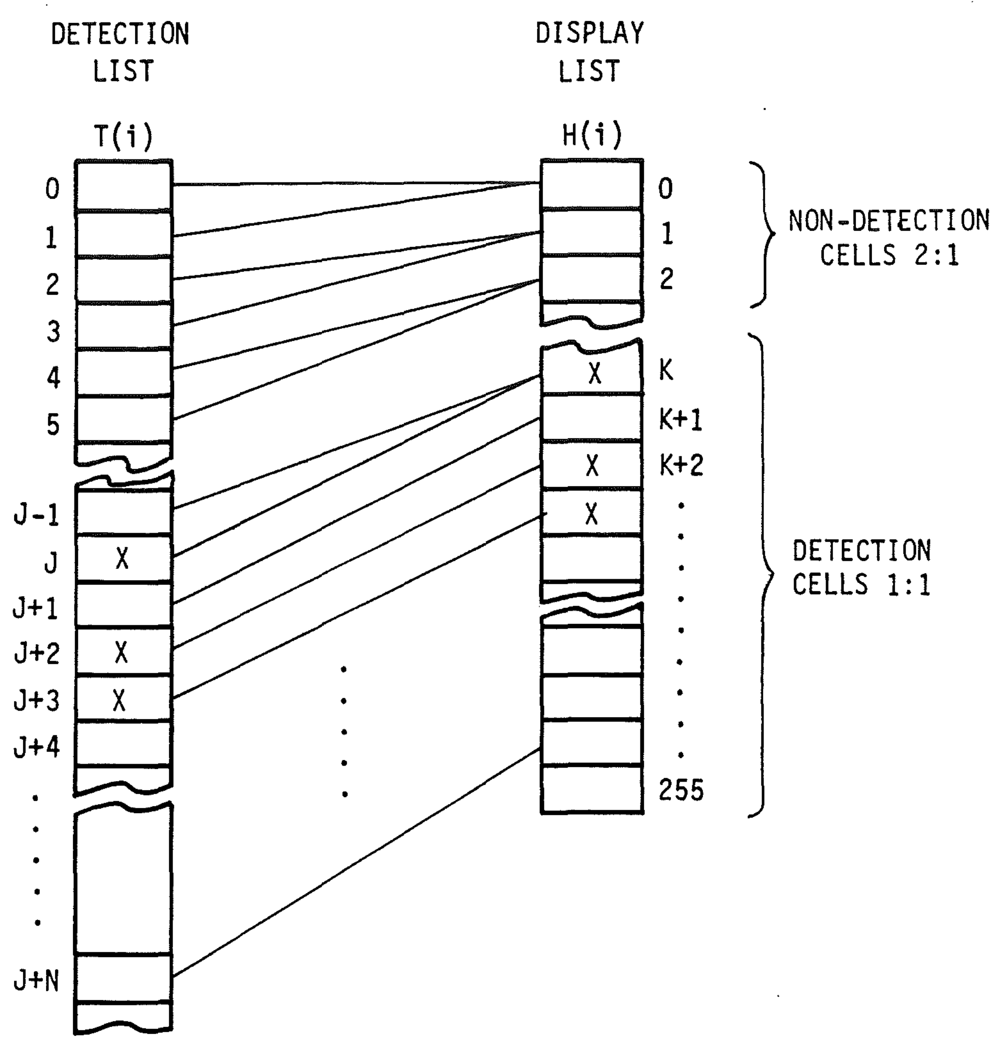


FIGURE 10.4.2 4X RANGE DISPLAY PROCESSING

10.5 Display Processing

The LPRF Display Processing involves two tasks. One task is to form a block of 16 VSD words using the data from the RDP and the IFF Reply Evaluator (IRE). The other task is to update the Display Intensity Matrix using the target detection data obtained in Section 10.4. The VSD words and the matrix are stored in a section of the bulk memory called TM2. These data are retrieved, processed and sent to the Vertical Situation Display (VSD) by the DIU unit (Figure 10.5.1).

The VSD words inform the VSD unit of the IFF target positions, the cursor position, and other details (Figure 10.5.2). The Display Intensity Matrix controls the intensity levels across 248 x 256 range-azimuth cells. A non-zero entry in a matrix element, I(i,j), indicates a target present at the i-th range and the j-th range azimuth with intensity level I.

10.5.1 Input

- Mode Control Word from RDP: (PSP Word 1): Beacon Mode
- Range Scale RS ϵ {1X, 2X, 4X, 8X, 16X}
- Beacon Target Data: {H(i) i=0, ..., 255}
- DSC Words from the RDP
- IRE Word from the RDP
- IFF Reply Word from the IRE

10.5.2 Processing

10.5.2.1 VSD Digital Data

Figure 10.5.2 shows the general format of the 16 VSD words for LPRF modes. In the beacon mode the order and content shall be the same as other modes with the exception that a blank word symbol coding shall be used for the acquisition symbol word. Note that in beacon modes the IRE inhibit code is always '1'.

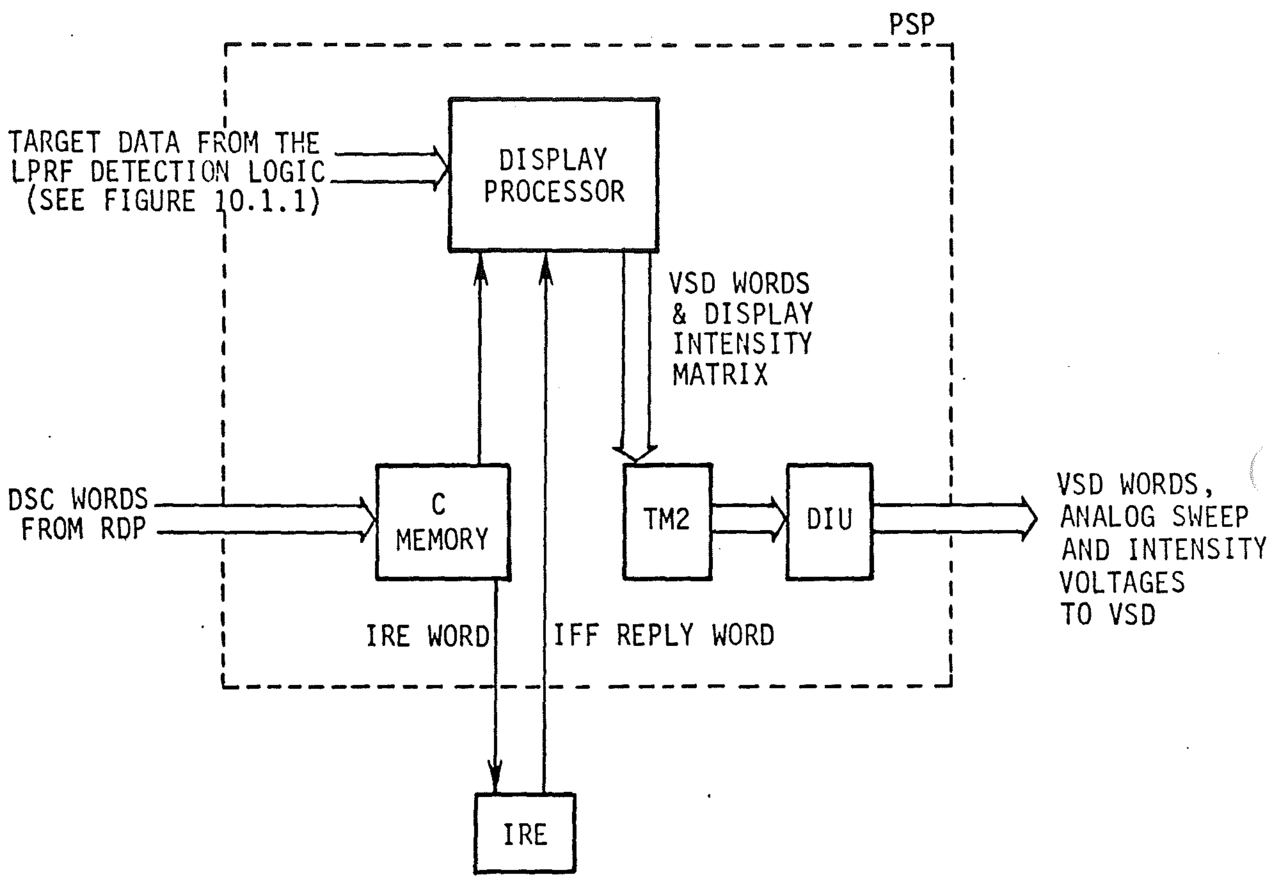


FIGURE 10.5.1 DATA FLOW BETWEEN THE PSP, RDP, IRE AND THE VSD UNIT DURING BEACON DISPLAY PROCESSING

<table>
<tr><th rowspan="2">WORD</th><th rowspan="2">NAME</th><th colspan="9">BIT POSITION</th></tr>
<tr><th>0 1 2 3</th><th colspan="6">4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23</th><th>24-44</th><th>45 46 47</th></tr>
<tr><td rowspan="2">1-10</td><td rowspan="2">IFF TARGETS OR BLANKS</td><td>0 0 1 0</td><td colspan="4">X POSITION</td><td colspan="2">Y POSITION</td><td>0</td><td>1 1 1</td></tr>
<tr><td>0 0 0 0</td><td colspan="6">THESE BIT POSITIONS MAY BE RANDOMLY SET</td><td>0</td><td></td></tr>
<tr><td>11</td><td>RANGE/VEL SCALE</td><td>0 1 0 0</td><td>0 0</td><td>RANGE /VEL SCALE</td><td colspan="4">0 0 0 0 0 0 0 0 0 0 0 0 0 0</td><td>0</td><td>1 1 1</td></tr>
<tr><td>12</td><td>CURSOR POSITION</td><td>0 0 0 0</td><td>IFF CODE</td><td colspan="3">AZIMUTH</td><td colspan="2">RANGE</td><td></td><td>1 1 1</td></tr>
<tr><td>13</td><td>ANT. AZ. POSITION</td><td>0 1 0 1</td><td>0 0</td><td colspan="3">AZIMUTH</td><td colspan="2">1 0 0 0 1 0 1 1 0</td><td>0</td><td>1 1 1</td></tr>
<tr><td>14</td><td>ANT. EL. POSITION</td><td>0 1 0 1</td><td>0 0</td><td colspan="3">1 0 0 0 1 0 1 1 0</td><td colspan="2">ELEVATION</td><td>0</td><td>1 1 1</td></tr>
<tr><td>15</td><td>BIT WORD # 1</td><td>0 1 0 1
OR
0 0 0 0</td><td>0 0</td><td colspan="2">1st CHARACTER</td><td colspan="2">2nd CHARACTER</td><td>3rd CHARACTER</td><td>0</td><td>1 1 1</td></tr>
<tr><td>16</td><td>BIT WORD #2</td><td>0 1 0 1
OR
0 0 0 0</td><td>0 0</td><td colspan="2">4th CHARACTER</td><td colspan="2">5th CHARACTER</td><td>6th CHARACTER</td><td>0</td><td>1 1 1</td></tr>
</table>

FIGURE 10.5.2 DISPLAY PROCESSOR TO DIU DIGITAL DATA, LPRF MODES

10.5.2.2 Display Intensity Matrix Update

The 248 x 256 Display Intensity Matrix is stored row-wise in the Main Memory. Each matrix element can have an integer value between 0 and 7. In beacon modes only values of 0 or 7 are allowed. The display matrix in beacon modes is the same as that for analogous non-beacon modes with the following exception: 1. No intensity aging is employed, and 2. All returns are shown maximum brightness. Note that the variable scaling required for return processing after the first hit has been accomplished previously in the processing of Section 10.4. A memory diagram of the Display Intensity Matrix is shown in Figure 10.5.3.

Updating the display matrix consists of mapping the display list:

$$\{H(i) \mid i=0, \ldots, 247\}$$

into display intensity levels along the column:

$$\{I(N,\theta) \mid N=0, \ldots, 247\}$$

where θ is the current azimuth index from the RDP. Intensity levels are given by:

$$I(N,\theta) = \begin{cases} 0 \text{ if } H(N) = 0 & N=0, \ldots, 247 \\ 7 \text{ if } H(N) = 1 & N=0, \ldots, 247 \end{cases}$$

where the 3 bit intensity cell can be defined from:

$$J = \theta + \text{INT}(N/2) \bullet 32 \bullet 8$$

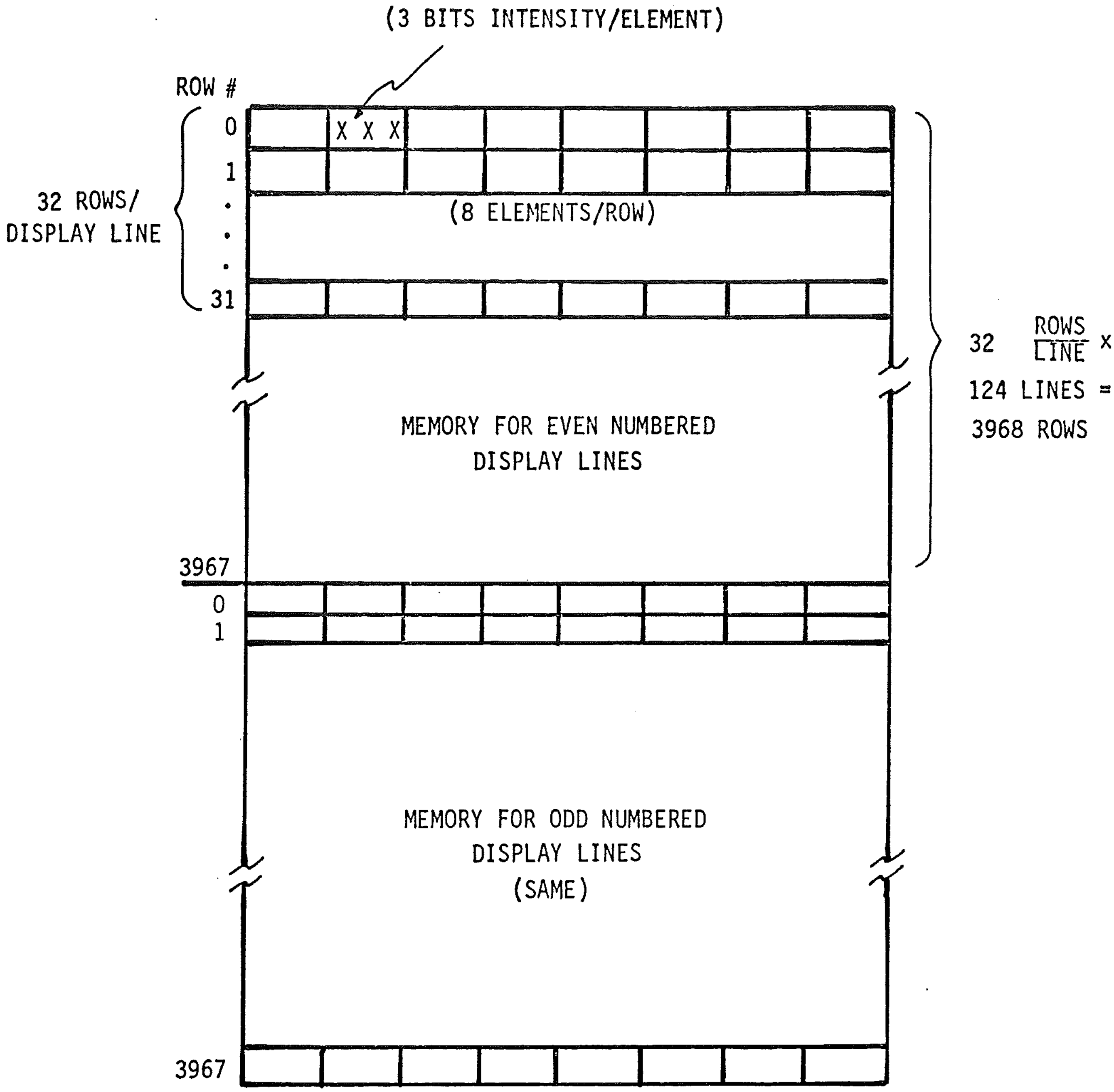
to be two half-memory sets each containing

$$\{X(J) \mid J=0, \ldots, 31743\}$$

Note that the top half of memory is referenced if N is even and the bottom half if N is odd (Reference Figure 10.5.3).

10.5.3 Outputs

- 16 Beacon Mode VSD Words
- 248 x 256 Display Intensity Matrix



NOTE: TOP HALF OF MEMORY CONTAINS THE IMAGE FOR THE EVEN NUMBERED VSD RASTER LINES, AND THE BOTTOM HALF OF MEMORY CONTAINS THE ODD LINES. EACH LINE ON THE VSD HAS 256 ELEMENTS.

FIGURE 10.5.3 ANALOG PORTION OF DISPLAY MESSAGE

SECTION 11

RAM SCAN AND SPOTLIGHT I MODE

11.0 INTRODUCTION

The RAM Scan and Spotlight I Mode is designed to search a designated volume of space for the presence of targets or clusters of targets. Targets thus detected are examined in detail by other modes to assess the presence of and to track multiple targets within clusters found by this mode.

RAM Scan and Spotlight I and the existing MPRF Search modes are conceptually equivalent from a software viewpoint. Major differences are:

a) Each PRF consists of a 16 pulse pause array except for 1.0 μsec which has a 30 pulse pause array, followed by $2N_p$ pulses. (N_p is commanded by the RDP to be 32 or 64). An N_p filter FFT is used in this mode, whereas, the existing mode uses 32 data collection pulses and a 16 filter FFT.

b) Six or three major PRFs are used as commanded by the RDP.

c) Range resolving criteria have been relaxed. A "two-of-three" criterion supplements "three-of-three". Additional de-ghosting algorithms have been added.

d) Process timing has been altered to avoid massive data buffering.

To illustrate the RAM Scan and Spotlight I, a functional block diagram of the digital data processing scheme in the PSP of F-15 radar is shown in Figure 11.1. The diagram contains both hardware and software functions.

In the hardware areas, the analog data from the ARSP (039 Unit) is converted into digital form before being sent to a two stage delay-line clutter canceller for background clutter suppression.

As shown in Figure 11.1, the 13 element Barker code may be used for the pulse compression. To improve the pulse compression, a doppler compensator is used to de-rotate the radar vectors and to null out most of the doppler rotation before the data is pulse compressed.

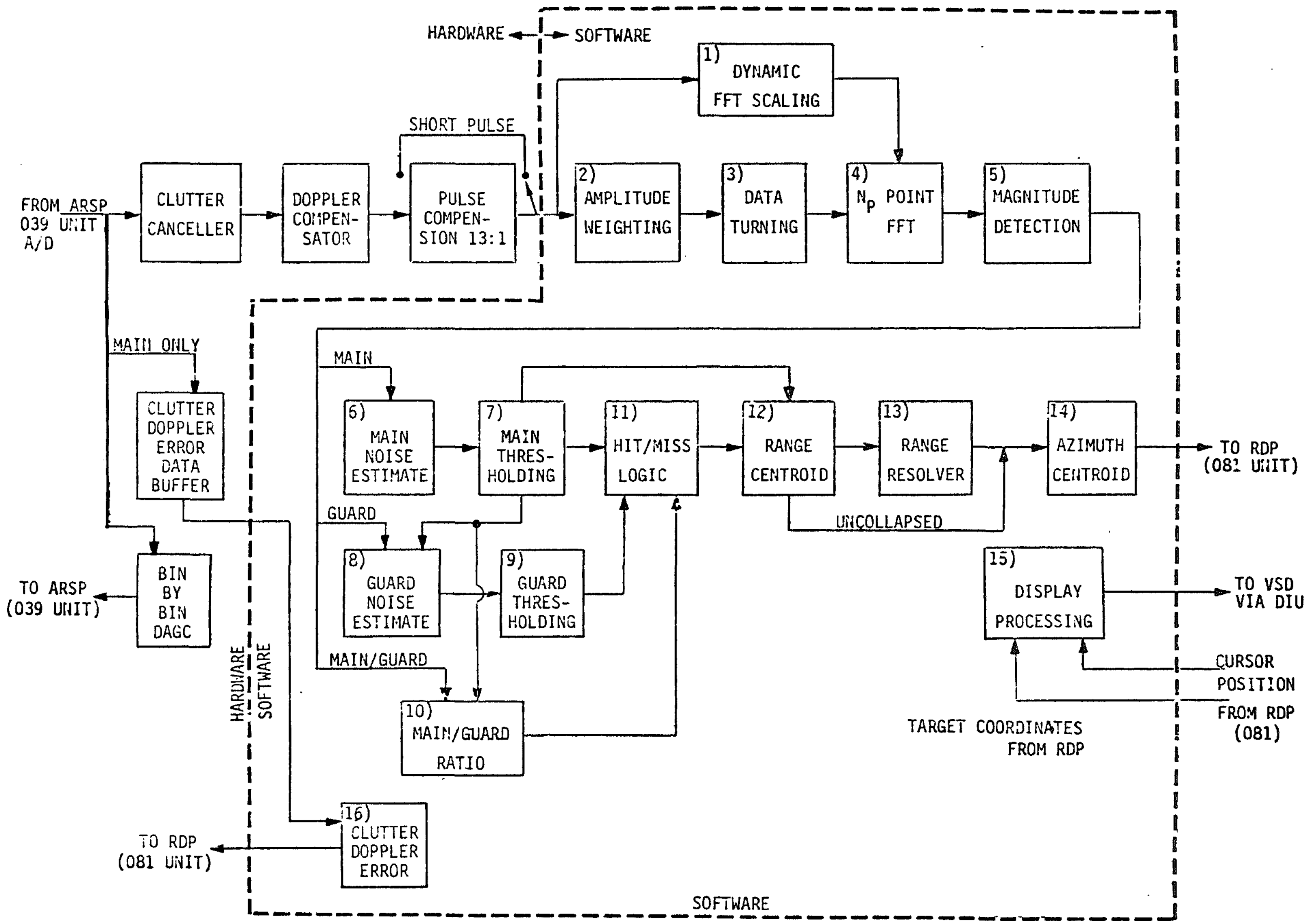


Figure 11.1 - RAM MPRF SEARCH SOFTWARE FUNCTIONAL BLOCK DIAGRAM MPRF SEARCH

After pulse compression, a factor of two-to-one reduction in target intensity together with rounding-off or some saturation logic is used to prevent the saturation of a 12 bit word in the I and Q channels. Four data words consisting of 24 bits plus one parity bit are packed into a 100 bit word for transfer to PSP bulk memory.

In the software areas, the PSP performs the following software functions:

a) Dynamic FFT scaling for saturation control.

b) A $2N_p$ point amplitude weighting to reduce doppler filter side lobes.

c) A two-to-one data turning to enhance target signals.

d) Fast Fourier Transform (FFT).

e) Ensemble averaging to determine background noise levels.

f) Thresholding for main and guard channels for target detection.

g) Hit/Miss logic for target discrimination and background clutter blanking.

h) Range centroiding of strong target returns for better range resolution.

i) Range resolving of target returns by using the data from the major and minor PRFs. Various algorithms are included for de-ghosting.

j) Azimuth centroiding of strong target returns to inhibit multiple target initiations and to improve azimuth resolution.

k) Display processing to reformat target data for VSD display.

l) Clutter Doppler Error (CDE) processing to determine doppler errors incurred in shifting main lobe clutter to dc.

m) Acquisition processing to report radar hits to the RDP.

Figures 11.2, 11.3 and 11.4 outline the PRF sequence and timing used. The six majors in Figure 11.2 correspond to pulse widths of 1.0, 1.3, 1.6, 1.1, 1.2 and 1.5 microseconds. The three majors in Figure 11.3 correspond to pulse widths of 1.0, 1.3, and 1.6 microseconds.

Since each PRF results in 16K of data, only the current and previous PRFs are buffered. Figure 11.2 shows the processing cycle for this mode.

The following sections of this report discuss the individual elements of the software processing shown in Figure 11.1. Each section that follows is numbered to correspond with an operation shown in Figure 11.1.

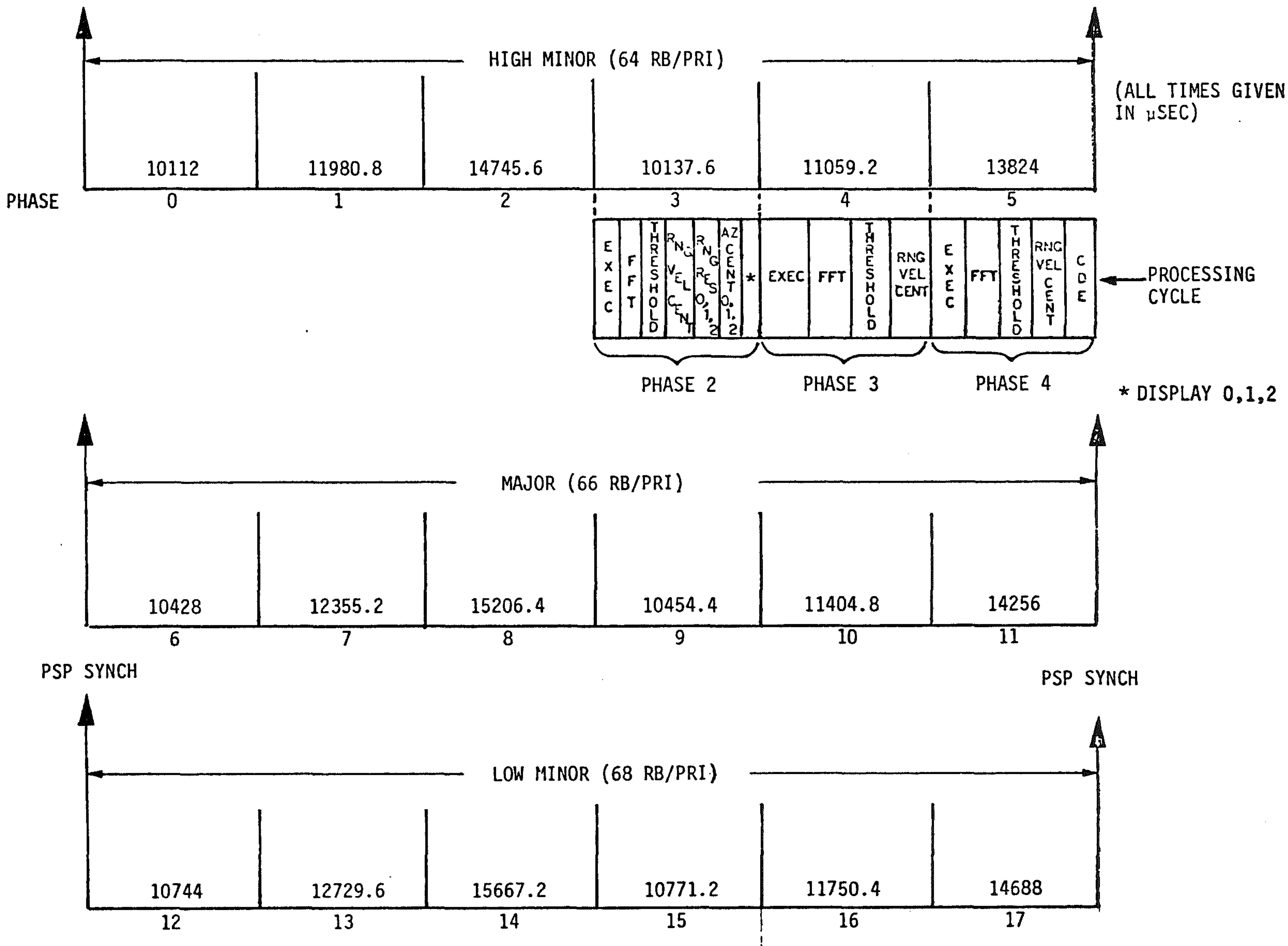


FIGURE 11.2 - RAM SCAN AND SPOTLIGHT I TIMING (128 DATA PULSES)

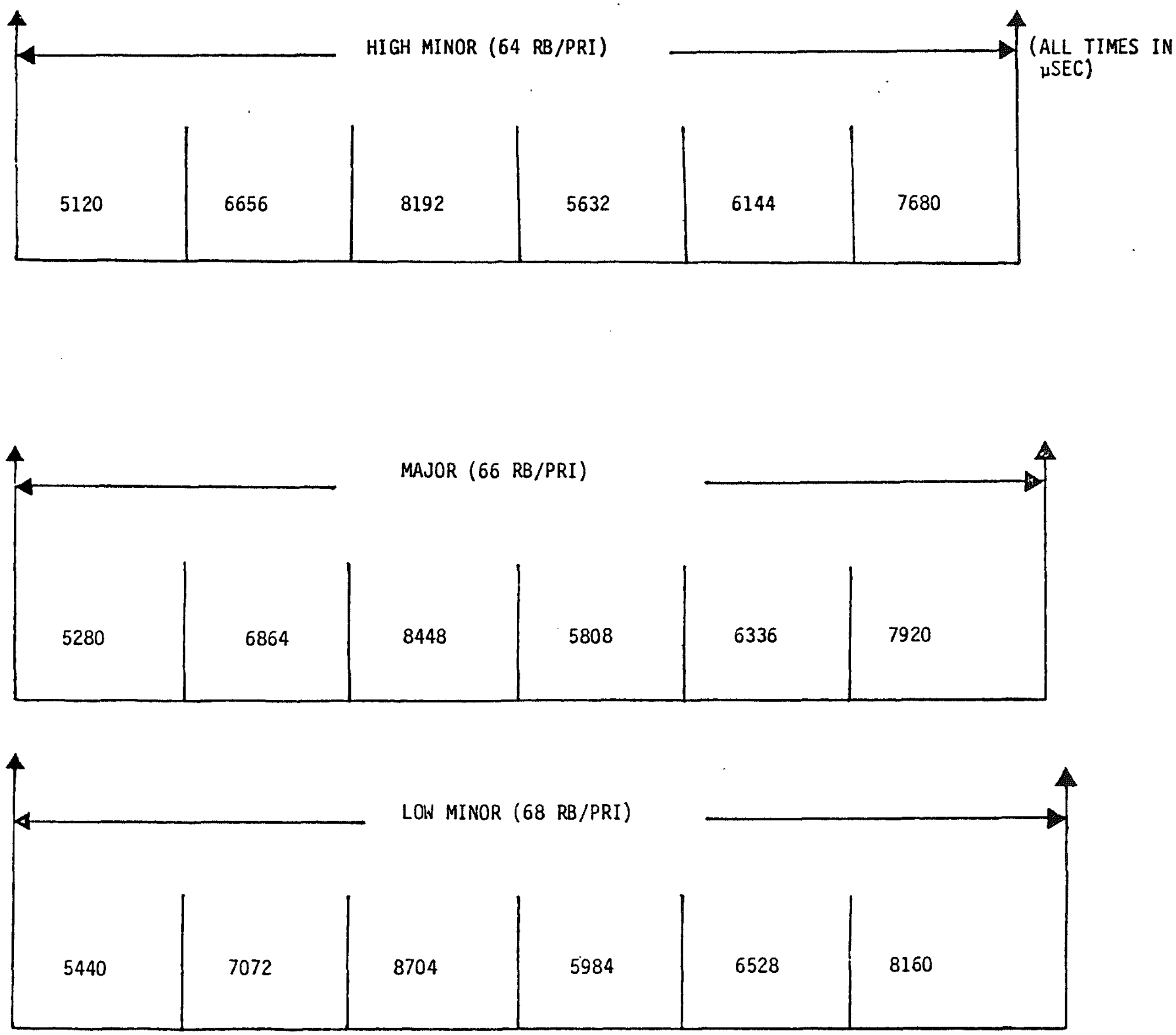


FIGURE 11.3 - RAM SCAN AND SPOTLIGHT I TIMING (64 DATA PULSES)

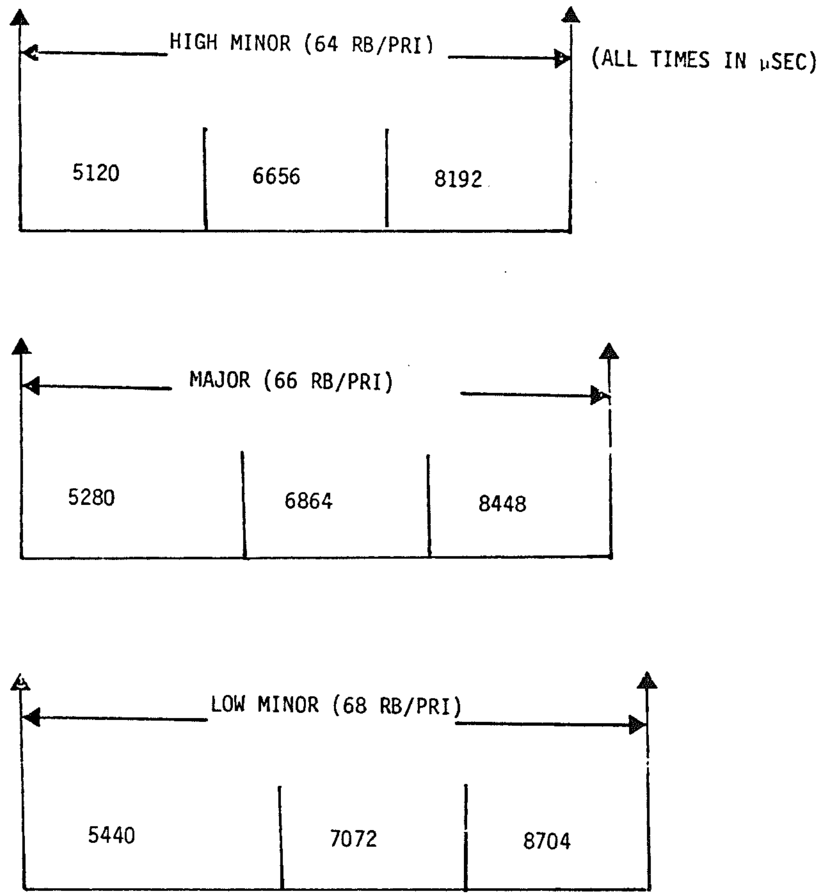


FIGURE 11.4 - RAM SCAN AND SPOTLIGHT I TIMING (64 DATA PULSES)

11.1 Dynamic Fast Fourier Transform Scaling

The RAM Scan and Spotlight I modes uses Dynamic Scaling for FFT saturation control and increased sensitivity. Figure 11.1.1 illustrates this function.

11.1.1 Inputs

- Main Channel In-phase (I) and Quadrature (Q) samples from the Bulk Memory of the PSP.

11.1.2 Processing

- Magnitude detection one PRI of data
- Determine the amplitude of the largest signal (S_{max})
- Determine the number of divided by twos by:

$$N = IPO\ (Log_2(N_f)) + Log_2\left(\frac{S_{max}}{FS}\right)$$

where: N_f = the number of filters formed

FS = Full Scale Magnitude (2048)

IPO = Integer part of

11.1.3 Outputs

- Send the FFT the number of divide by twos to perform for the current PRF
- Send the RDP the number of divide by twos in IDA Word #4 bits 0-3.

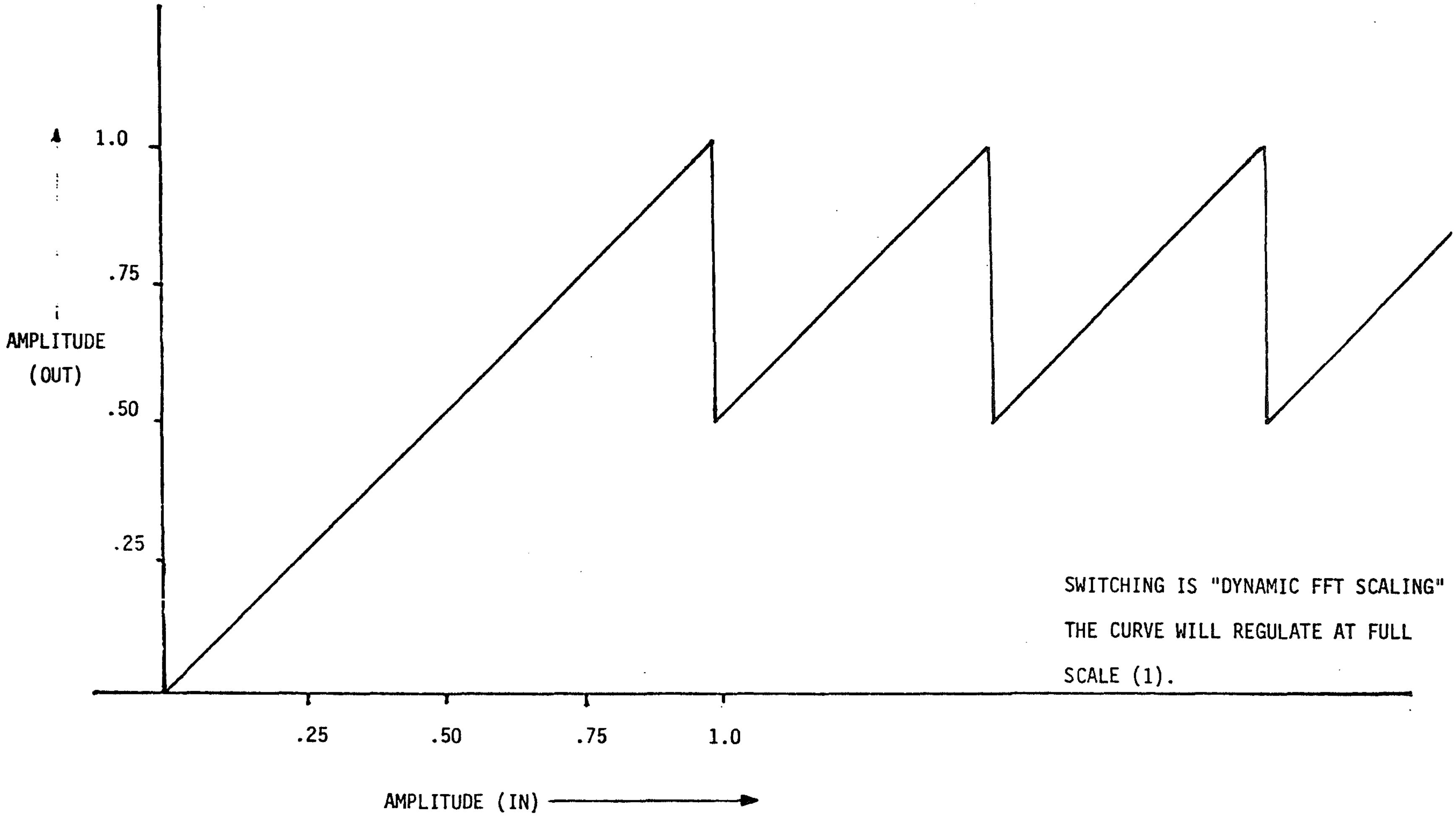


FIGURE 11.1.1 - DYNAMIC FFT SCALING

11.2 Amplitude Weighting

11.2.1 Inputs

- Main Channel In-phase (I) and Quadrature (Q) samples from the Bulk Memory of the PSP.
- Guard Channel In-phase (I) and Quadrature (Q) samples from the Bulk Memory of the PSP.

11.2.2 Processing

The amplitude weighting processor shall preprocess the data samples for the Fast Fourier Transform (FFT) so that the output of the FFT can achieve the desired peak mainlobe to peak sidelobe ratio.

Each data set shall be amplitude weighted across the $2N_p$ pulses accumulated for each range bin in both the main and guard channels according to the following formula:

$$S_W(i,n) = A(n) \cdot S(i,n)$$

where: S = the complex I and Q data sample.

$S_W(i,n)$ = weighted sample of the i-th range bin and the n-th pulse $n = 0$ to $2N_p-1$.

$S(i,n)$ = the unweighted input samples of the i-th range bin and n-th pulse.

$A(n)$ = Optimized Kaiser weights as shown in Tables 11-1 11-2 are real and symmetrical (these weights may be rounded to the nearest values).

11.2.3 Outputs

- Weighted Main Channel I,Q samples
- Weighted Guard Channel I,Q samples

TABLE 11-1 - KAISER AMPLITUDE WEIGHTS FOR F-15 RAM SCAN AND SPOTLIGHT I MODE

$N_p = 32$

SAMPLE NUMBER n	AMPLITUDE WEIGHTS A (n)
0, 63	0.060059
1, 62	0.080078
2, 61	0.102539
	0.126953
	0.164297
	0.183594
	0.214844
.	0.248535
.	0.283691
.	0.320801
.	0.359375
.	0.398926
	0.439453
	0.480957
	0.522949
	0.564941
	0.606445
	0.647949
	0.687988
	0.727051
	0.764648
	0.800781
	0.834473
	0.865723
	0.894043
	0.919434
	0.941895
	0.960933
	0.976074
	0.987793
30, 33	0.995605
31, 32	0.999512

TABLE 11-2 - KAISER AMPLITUDE WEIGHTS

RAM SCAN AND SPOTLIGHT I MODE

$N_p = 64$

SAMPLE NUMBER n	AMPLITUDE WEIGHTS A (n)
0, 127	0.056641
1, 126	0.065918
2, 125	0.075684
	0.086426
	0.097168
	0.108887
	0.121532
.	0.134277
.	0.147949
.	0.161621
.	0.176270
.	0.191406
	0.207031
	0.223145
	0.239746
	0.257324
	0.274902
	0.292969
	0.311035
	0.330078
	0.349121
	0.368652
	0.388672
	0.408691
	0.429199
	0.449707
	0.470215
	0.491211
	0.511719
	0.532715
30, 97	0.553711
31, 96	0.574707

TABLE 11-2 - KAISER AMPLITUDE WEIGHTS (Cont.)

FOR F-15 RAM SCAN AND SPOTLIGHT I MODE

SAMPLE NUMBER n	AMPLITUDE WEIGHTS A (n)
32, 95	0.596703
33, 94	0.616211
34, 93	0.637207
	0.657227
	0.677734
	0.697754
	0.717235
.	0.736328
.	0.755371
.	0.773438
.	0.791504
	0.809032
	0.825684
	0.841797
	0.857422
	0.872559
	0.886719
	0.900391
	0.913086
	0.925293
	0.936623
	0.946777
	0.956055
	0.946844
	0.972656
	0.979492
	0.985352
	0.990234
	0.994141
	0.997070
62, 65	0.999023
63, 64	1.000000

11.3 Data Turning

Data is collected from a total of $2N_p$ successive pulses on each of the eighteen PRFs. This volume of data is reduced by a factor of two before being sent to the FFT process. The data is reduced by coherent addition of the first pulse samples to the (N_p+1)th pulse samples, the second to the (N_p+2)nd, and so on. This form of coherent addition is called Data Turning.

11.3.1 Inputs

- Main Channel amplitude weighted complex samples (I,Q) from Section 11.2. A data point of each processed range bin X $2N_p$ pulses.
- Guard Channel (same as above).

11.3.2 Processing

Designate the input data points as $S_W(i,n)$ for the i-th range bin n-th pulse sample point. Then the (data turned) output points are given as:

$$S_D(i,n) = S_W(i,n) + S_W(i,n+N_p)$$

for $n = 0, 1, 2, \ldots, N_p-1$

The process is performed for Main and Guard data.

11.3.3 Outputs

- Main Channel data turned complex samples (I,Q) to Section 11.4 FFT. A data point for each processed range bin X N_p (data turned) pulses.
- Guard Channel (same as above).

11.4 Fast Fourier Transform

The purpose of the FFT in RAM Scan and Spotlight I mode is to form N_p digital doppler filters for each range bin from the PRIs of radar data. The timeline sequence for the RAM Scan and Spotlight I mode was shown in Figures 11.2 and 11.3 of the introduction.

The $2N_p$ pulse groups of data are amplitude weighted and two to one data turned to form N_p pulse groups. (See sections 11.2 and 11.3 for a description of amplitude weighting and data turning). These N_p pulses of data are the inputs to the FFT process as illustrated in Figure 11.4.1. The N_p pulses of data consist of:

1) Main Channel I and Q for all processed range bins.
2) Guard Channel I and Q for all processed range bins.

Restrictions are placed on the data described in (1) and (2) above. Due to the receiver blanking some of the range bins of data are not used:

a) The first 7 range bins are deleted from the PRI interval in long pulse operation in Main and Guard channels.
b) The last 7 range bins are deleted from the PRI interval in long pulse operation in Main and Guard channels.
c) The first 2 range bins are deleted from the PRI interval in short pulse operation in Main and Guard channels.

The resulting number of bins processed is N_{RB}-14 in pulse compression, N_{RB}-2 in short pulse. This value is designated by the symbol N_{BP} in either case.

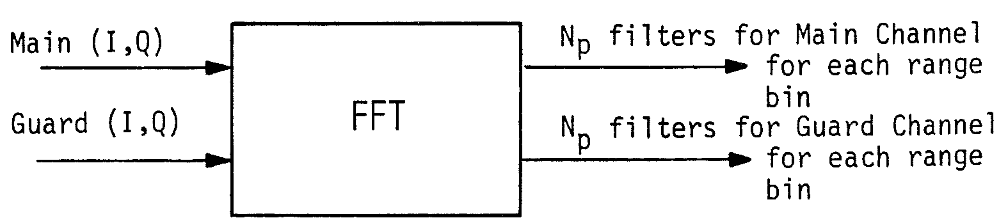


FIGURE 11.4.1 - FFT PROCESS

11.4.1 Inputs

- Number of range bins per PRI.
- Main channel I and Q samples for each range bin from section 11.3.
- Guard channel I and Q samples for each range bin from section 11.3.
- Number of divide by two's (Dynamic Scaling) from section 11.1.

11.4.2 Processing

The Discrete Fourier Transform inputs of Main/Guard I and Q data for N_p PRIs are transformed into N_p filters for each range bin in Main and Guard channels by the expression:

$$F(i,k) = \frac{1}{N_p} \sum_{n=0}^{N_p-1} W^{nk} S(i,n)$$

where: (i) is the range bin number

(W) $\exp - \frac{2\pi j}{N_p}$

(n) is the sample number (0 to N_p-1)

(k) is the filter number

(S) is an input data sample

The phase rotation constants W^{nk} may be precomputed and stored in PSP memory. Because of the symmetrical layout of the phase constants, W^{nk} on the unit circle only 32 constants need be precomputed. The exact method of computing the FFT is left to the design of the PSP programmer.

11.4.3 Outputs

The outputs of the doppler processor are:

- Main Channel I, Q data $\rightarrow N_p$ filters by N_{BP} range bins
- Guard Channel I,Q data for the same number of filter/ bins as above.

11.5 Magnitude Detector

The purpose of the Magnitude Detector is to compute the magnitude of the I and Q vectors in doppler filter/range bin cells. The output of the magnitude detector goes to the Post Processor PSP functions which have no requirement to know signal phase.

11.5.1 Inputs

The inputs of the Magnitude detector are:

- Main Channel I,Q data from Section 11.4.
- Guard Channel I,Q data from Section 11.4.

11.5.2 Processing

The Magnitude Detector outputs the greater of:

$$|I| + \tfrac{1}{2}|Q| \text{ or } |Q| + \tfrac{1}{2}|I|$$

for N_p filters for each range bin described in Inputs section above.

11.5.3 Outputs

- Main Channel Magnitudes for N_p filters by N_{BP} range bins
- Guard Channel Magnitudes for N_p filters by N_{BP} range bins.

11.6 Main Channel Noise Amplitude Estimate

11.6.1 Inputs

- Main channel magnitudes for N_p filters by N_{BP} range bins from section 11.5. These terms are designated as $A_M(i,j)$.
- Number of filters to be processed, N_F from RDP. This value designates the number of filters in the doppler clear (not notched) region.

11.6.2 Processing

The function shall compute a background noise estimate for each main channel range/doppler cell in the input matrix. The noise estimates ($\overline{N}_M$) are used to form the detection thresholds in section 11.7.

The noise estimate is computed by a 4-3-4 sliding window "tilted" average in range.

The 4-3-4 sliding window average is given by the tilted larger of two four-bin means:

$$\overline{N}_{4-3-4}(i,j) = \tfrac{1}{4}\ \mathrm{MAX}\left\{ \sum_{n=i-5}^{i-2} A_M(n,j),\ \sum_{n=i+2}^{i+5} A_M(n,j) \right\}$$

(larger of early bin average or late bin average).

The sliding window average includes both tilt and end-effect logic, by virtue of its definition as the larger of means on both sides. Tilt logic is to be applied whenever the early and late range bin averages differ. In that case, $\overline{N}_{4-3-4}(i,j)$ as the largest of the early or late range bin averages "tilts" in the appropriate fashion.

End-effect logic is applicable at the ends of the range swath where the early or late sample sets would exceed the boundary of the fully processed region. In these cases the early or late parts of the estimate would be discarded respectively, and the noise estimate would be the remaining part. Selection of the larger quantity automatically makes this choice as required.

11.6.3 Outputs

- Matrix of N_{BP} range bins by N_F filters of main channel noise amplitude estimates, $\overline{N}_M(i,j)$, to Section 11.7.

11.7 Main Channel Thresholding

11.7.1 Inputs

- Matrix of N_{BP} range bins by N_F+2 filters of main channel magnitude measurements, $A_M(i,j)$ from Section 11.5.
- Matrix of N_{BP} range bins by N_F filters of main channel noise estimate, $\overline{N}_M(i,j)$, Section 11.6.
- Threshold multipliers K_M, K_{M2} and K_{GMT} from
- N_P from the RDP.

11.7.2 Processing

This function shall perform amplitude thresholding on main channel data. Three separate thresholds may be applied to the data. Threshold K_M is used to form the basic hit list, with its hit count to be sent to the RDP. The RDP may use this hit count to perform a closed loop Constant False Alarm Rate (CFAR) control of the K_M threshold number. Threshold K_{M2} is used to form a high threshold hit list to be used by the range resolver in major/either minor range resolving. The K_{GMT} threshold shall be applied to the filters at the edge of mainlobe clutter to accomplish ground moving target rejection.

The K_M and K_{M2} thresholding shall be accomplished by comparing the signal amplitude in each range/doppler cell in the clutter free region to the product of its associated noise estimate and the threshold multiplier. If the signal amplitude exceeds or equals the product, a hit is declared for that range/doppler cell. A hit count is kept for those hits passing the K_M threshold.

An upper bound of the total number of K_M threshold hits may be required. The upper bound would prevent computation time for all downstream functions from exceeding the time available. A table of upper bounds (a function of the PRF) is provided, and the process of testing for main channel hits is terminated when the total number of hits exceeds the upper bound. The result of threshold processing for main channel shall be equivalent to the following sequence of direct logic:

First Set COUNT $K_M = 0$

if $A_M(i,j) \geq \overline{N}_M(i,j) \cdot K_M$

set COUNT K_M = COUNT $K_M + 1$

record a K_M hit as $H_M(i,j)$

if $A_M(i,j) \geq \overline{N}_M(i,j) \cdot K_{M2}$

record a K_{M2} hit as $H_{M2}(i,j)$

If the K_M hit occurs at a frequency location which is at the edge of the clear signal region, then the K_{GMT} thresholding shall be accomplished by comparing the signal amplitude in the adjacent filter at the edge of the mainlobe clutter region to the product of the noise estimate of the K_M hit (for its range bin its neighboring clutter free filter) and the K_{GMT} threshold. If this signal amplitude exceeds or equals the product, a K_{GMT} hit is declared for that range/doppler cell. Therefore:

- If a K_M hit exists at $j = \frac{N_p+1 - N_F}{2}$

and if $A_M(i,j-1) \geq \overline{N}_M(i,j) \bullet K_{GMT}$, record a GMT hit for this cell as $H_{GMT}(i,j)$.

If a K_M hit exists at $j = \frac{N_p-1 + N_F}{2}$

and if $A_M(i,j+1) \geq N_M(i,j) \cdot K_{GMT}$, record a GMT hit for this cell as $H_{GMT}(i,j)$.

11.7.3 Outputs

- Hit counts for threshold K_M.
- Range/Doppler cell indices for K_M hit as $H_M(i,j)$.
- Range/Doppler cell indices for K_{M2} hits as $H_{M2}(i,j)$.
- Range/Doppler cell indices for K_{GMT} hits as $H_{GMT}(i,j)$.

Note: $H_{GMT}(i,j)$ cannot exist for doppler locations such that j is not on the (doppler) boundary of the processed region.

11.8 Guard Channel Noise Amplitude Estimate

11.8.1 Inputs

- Matrix of N_{BP} range bins by N_F filters of guard channel magnitude measurements, $A_G(i,j)$ from Section 11.5.
- Indicies of range/doppler cells, (i,j), in the main channel that contain CFAR hits on K_M threshold from Section 11.7.

11.8.2 Processing

This function shall compute a background noise estimate for each guard channel range/doppler cell in the processed region provided that the corresponding main channel range/doppler cell contains a CFAR hit. This shall be accomplished by first applying a 1-11-1 sliding window about the range/doppler cell of interest to remove target returns from the noise estimate, then using a 4-3-4 sliding window ensemble average with edge effects. That is, the average shall usually be formed by summing the four early and four late range cells centered about a three cell swath containing the range/doppler cell of interest as the center. Therefore, at most locations:

$$\overline{N}(i,j) = 1/8 \left\{ \sum_{k=1-5}^{i-2} A_G(k,j) + \sum_{k=i+2}^{i+5} A_G(k,j) \right\}$$

But, for the edge cells in range, only the interior sum is retained:

If $i < 12$, then

$$\overline{N}_G(i,j) = 1/4 \sum_{k=i+2}^{i+5} A_G(k,j)$$

If $i \geq N_{RB}-12$, then

$$\overline{N}_G(i,j) = 1/4 \sum_{k=i-5}^{i-2} A_G(k,j)$$

In these definitions i and j are respectively the range and doppler cell indices of a main channel CFAR hit.

11.8.3 Outputs

- Noise amplitude estimates, $\overline{N}_G(i,j)$, corresponding to main channel CFAR hits to Section 11.9.

11.9 Guard Channel Thresholding

11.9.1 Inputs

- Matrix of N_{BP} range bins by N_F filters of guard channel magnitude estimates, $A_G(i,j)$ from Section 11.5.
- Guard channel noise estimates, $\overline{N}_G(i,j)$ corresponding to main channel CFAR hits from Section 11.8.
- Indicies of range/doppler cells, (i,j) in the main channel that contain CFAR hits of K_M threshold from Section 11.7.
- Guard channel threshold, K_G from RDP.

11.9.2 Processing

This function shall perform two types of amplitude thresholding on guard channel data at locations corresponding to main channel hits. The first type of amplitude thresholding shall be accomplished by comparing the guard channel signal amplitude in each such range/doppler cell to the product of its associated noise estimate and the guard threshold. If the signal amplitude exceeds or equals the products, a hit is declared for that range/doppler cell.

The second type of thresholding shall be accomplished by comparing the guard channel signal amplitude to the high fixed value (near saturation) for cells corresponding to main channel hits. If the guard signal amplitude exceeds or equals the fixed threshold, a hit is declared for that range/doppler cell.

Therefore,

If $A_G(i,j) \geq \overline{N}_G(i,j) \cdot K_G$,

or if $A_G(i,j) \geq K_{G2}$

then record a guard hit as $H_G(i,j)$ for range/doppler cells corresponding to main channel K_M hits. (Since $K_G > 1$, the process may actually use its reciprocal with an inverse logic for the first threshold).

11.9.3 Outputs

- Indices for range/doppler cells containing hits on both main and guard channels, as $H_G(i,j)$.

11.10 Main/Guard Ratio Function

11.10.1 Inputs

- Matrix of N_{BP} range bins by N_F filters of main channel magnitude measurements, $A_M(i,j)$, from Section 11.5.
- Corresponding matrix of guard channel magnitude measurement, $A_G(i,j)$, from Section 11.5.
- Indicies of range/doppler cells (i,j), in the main channel that contain CFAR hits on K_M threshold from Section 11.7.
- The main/guard threshold, K_{MGR1} from RDP.

11.10.2 Processing

This function compares the main channel magnitude to the product of the guard channel magnitude and threshold. The process need be performed only for those main channel range/doppler cells for which CFAR hits exist. For this threshold, main/guard ratio hits are provided to the hit/miss function. Therefore, for i,j corresponding to main channel CFAR hits, if

$$A_M(i,j) \geq A_G(i,j) \cdot K_{MGR1}$$

then declare a hit as $H_{MGR1}(i,j)$.

11.10.3 Outputs

- MGR1 hits, $H_{MGR1}(i,j)$, to Section 11.11.

11.11 Hit/Miss Logic

11.11.1 Inputs

- Hit counts for threshold K_M
- Range/Doppler cell indices for K_M hit as $H_M(i,j)$, along with associated signal magnitude $A_M(i,j)$
- Range/Doppler cell indices for K_{GMT} hits, as H_{GMT} hits (i,j)
- MGR1 hits $H_{MGR1}(i,j)$
- Indices for range/doppler cells containing hits on both main and guard channels, as $H_G(i,j)$
- GMT Inhibit Control from the RDP.

11.11.2 Processing

The purpose of the Hit/Miss function is to:

a) Detect any ground moving targets (GMT's)

b) Establish criteria for CFAR hits

c) Perform HIT count adjustment due to b) above.

A. GMT Logic

The hit/miss logic resolves any ground moving targets in the following manner. If a hit exists both in the first filter outside the notch, $H_M(i,j)$, and in the first filter inside the notch, $H_{GMT}(i,j)$, in the same range bin a GMT hit is declared. When GMT Inhibit is not commanded, this logic does not affect $H_M(i,j)$. When GMT Inhibit is command and both $H_M(i,j)$ and $H_{GMT}(i,j)$ are non-zero for either j =

$$\frac{N_P-N_F+1}{2} \text{ or } \frac{N_p+N_F-1}{2} \text{ where } N_F = \text{number of filters}$$

processed then the $H_M(i,j)$ hit is discarded.

B) CFAR Hit/Miss

A valid CFAR target hit is declared when the following logic equation is satisfied:

$$HIT = H_M(i,j) \cdot \left[\overline{H_G(i,j)} + H_{MGR1}(i,j)\right] = True$$

That is, a real valid target hit is declared if there is a main channel hit without an associated guard channel hit or a main channel hit with an associated guard channel hit and the main to guard threshold is exceeded.

C) Hit Count Adjustments

The K_M hit counts are adjusted to reflect the elimination of any hits due to guard channel processing.

11.11.3 Outputs

- The remaining CFAR hits H(i,j) to the range centroid function
- Adjusted CFAR hit counts (K_M) to RDP
- Magnitude of CFAR hits $A_M(k,j)$

11.12 Range and Velocity Centroiding

11.12.1 Inputs

- CFAR hits from Section 11.11 H(i,j)
- High threshold hits from Section 11.7 $H_{M2}(i,j)$

11.12.2 Processing

CFAR contiguous hits shall be processed to eliminate hits adjacent to ones designated as single target centroids. Centroiding of CFAR hits shall be as follows:

1. Centroid contiguous velocity hits occuring at the same range per Figure 11.12.1.
2. Centroid remaining contiguous range hits occuring at the same velocity per Figure 11.12.2.
3. Check remaining diagonal pairs ($\overline{R+1}$, $\overline{V+1}$) and select hit closer in range from such pairs.
4. Delete all high threshold hits without a corresponding CFAR hit.
5. Count the centroided hits.
6. Maintain a 'range only' hit list which collapses in velocity for each range by taking the "OR" of all velocity filter cells. Do <u>not</u> recentroid the subsequent numeral, but do count the number of "collapsed on range" hits, H(i).

Note: Example in Figure 11.12.3 illustrates the technique for centroiding contiguous hits by deleting candidate hits in (a) velocity/range (c) diagonally and (d) collapsing the surviving data.

CENTROIDING TRUTH TABLES

	Raw Hits (V_{min} — V_{max})		Transformed Hits (V_{min} — V_{max})
Fundamental Velocity-hit Rule*	1	→	1
	1 1	→	0 1
	1 1 1	→	0 1 0
	1 1 1 1	→	0 1 0 1
	1 1 1 1 1	→	0 1 0 0 1
	1 1 1 1 1 1	→	0 1 0 0 1 0
	1 1 1 1 1 1 1	→	0 1 0 0 1 0 1
	ETC		ETC

VELOCITY CENTROIDING PROCESS

Figure 11.12.1

	Raw Hits (R_{min} — R_{max})		Transformed Hits (R_{min} — R_{max})
Fundamental Range-hit Rule*	1	→	1
	1 1	→	1 0
	1 1 1	→	0 1 0
	1 1 1 1	→	0 1 0 1
	1 1 1 1 1	→	0 1 0 1 0
	1 1 1 1 1 1	→	0 1 0 0 1 0
	1 1 1 1 1 1 1	→	0 1 0 0 1 0 1
	ETC		ETC

RANGE CENTROIDING PROCESS

Note: The tables are generated by repeated application of the fundamental rules.

Figure 11.11.2 - RANGE CENTROIDING PROCESS

EXAMPLE 1 CFAR HIT/MISS DISCRETE MATRIX

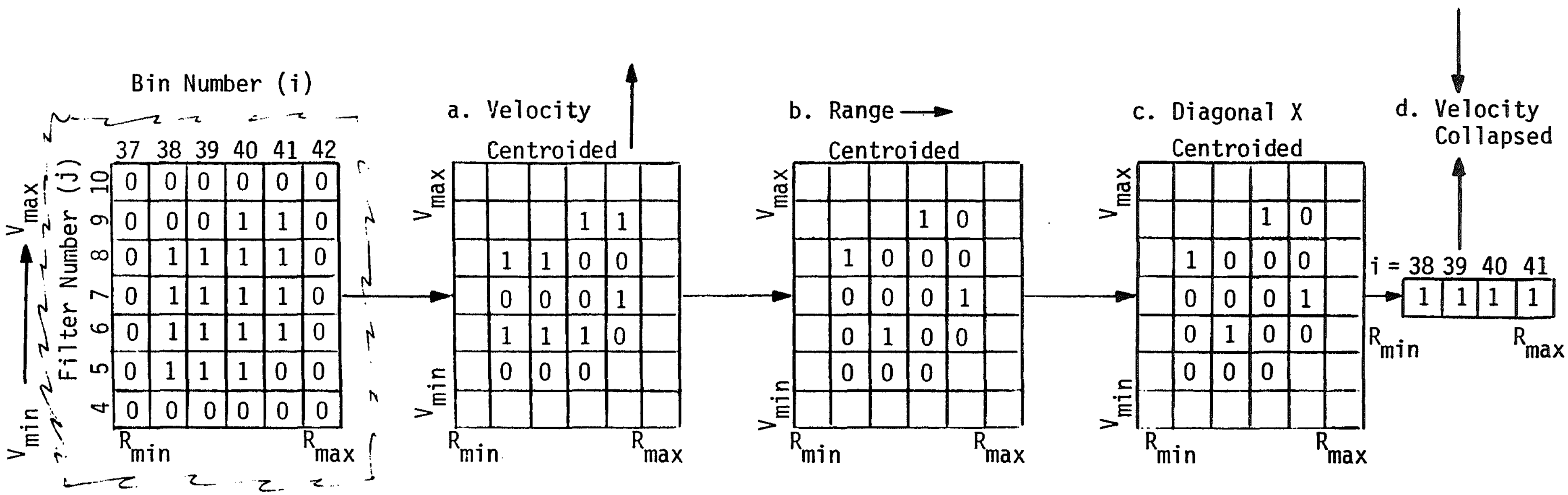


Figure 11.11.3 - EXAMPLE OF CENTROIDING TECHNIQUE

11.12.3 Outputs

- Centroided CFAR hits (range, frequency)
- High threshold hits $H_{M2}(i,j)$
- Collapsed CFAR hits (range)
- Centroided CFAR hit count
- Collapsed hit count

11.13 Range Resolving

11.13.1 Inputs

- Ambiguous ranges from target Hit/Miss data of Hi Minor, Major and Low Minor PRFs of the same pulse width.
- Indication of high or low threshold crossed for each hit.
- Number of hits in each Major channel (66 range bins) in one PRF interval.

11.13.2 Processing

A four step process is used to resolve the targets true range from the ambiguous range hit inputs. The process includes the same range resolving technique that was used in Medium PRF Search and Acquisition (Non-RAM) as one of the four steps. The reason for the more complex process is that the criteria for declaring a hit have been relaxed from a three-hits (Major PRF and two Minor PRFs) requirement to a two-hits (Major PRF and one Minor PRF) requirement. This relaxed requirement in itself would generate excessive false-alarms and ghost targets. Additional steps were added to eliminate false alarms and ghosts. The four processing steps are:

1. Major-Minor-Minor resolving
2. Major + either minor resolving
3. Cross major correlation
4. Cross ambiguity elimination

These steps are shown schematically in Figure 11.13.1.

The theory of range resolution using High Minor/Major/Low Minor PRFs is discussed in MPRF Search, Section 4.14.

In RAM Scan and Spotlight I the maximum number of ambiguities to be searched is five: that ambiguity containing the range designated by the RDP and the two preceding and following ambiguities.

The range resolving technique to be used involves the formation of a candidate target list with subsequent target validation/elimination criteria for ghost suppression. The steps are outlined as follows:

1. Determine those High Minor/Major/Low Minor hits as in the previously referenced MPRF Search section, for ±2 range ambiguities of the tracked target or TDC center.
2. Form a candidate target list by straight line scanning of Major and either Minor hits within the plus or minus two range ambiguities of the tracked target or TDC center.
3. From the candidate target list of this and previous majors, cross major correlate scan for hits on at least two of the six candidate lists. Any targets passing this test are sent to the resolved target list.
4. Remaining targets on the candidate list are processed singly or in groups for cross ambiguity elimination. A group is defined as being two or more targets separated by not more than one empty range bin between targets. Count the number of targets in this group. If a distance of 66 range bins from the group is displayed, i.e., within ±55 range bins of center, check this area for possible ghosts. Ghosts are indicated if some but not all members of the group are located at this ambiguity. See Figure 11.13.2 for examples.

   If target groups are identically paired, both groups shall be displayed. Targets appearing singly shall also be displayed.
5. Cross major correlated targets are merged with the deghosting targets for output to the azimuth centroider.

11.13.3 <u>Outputs</u>

- Unambiguous ranges, and an indication of the Major PRI used to resolve each target.
- Hit count.

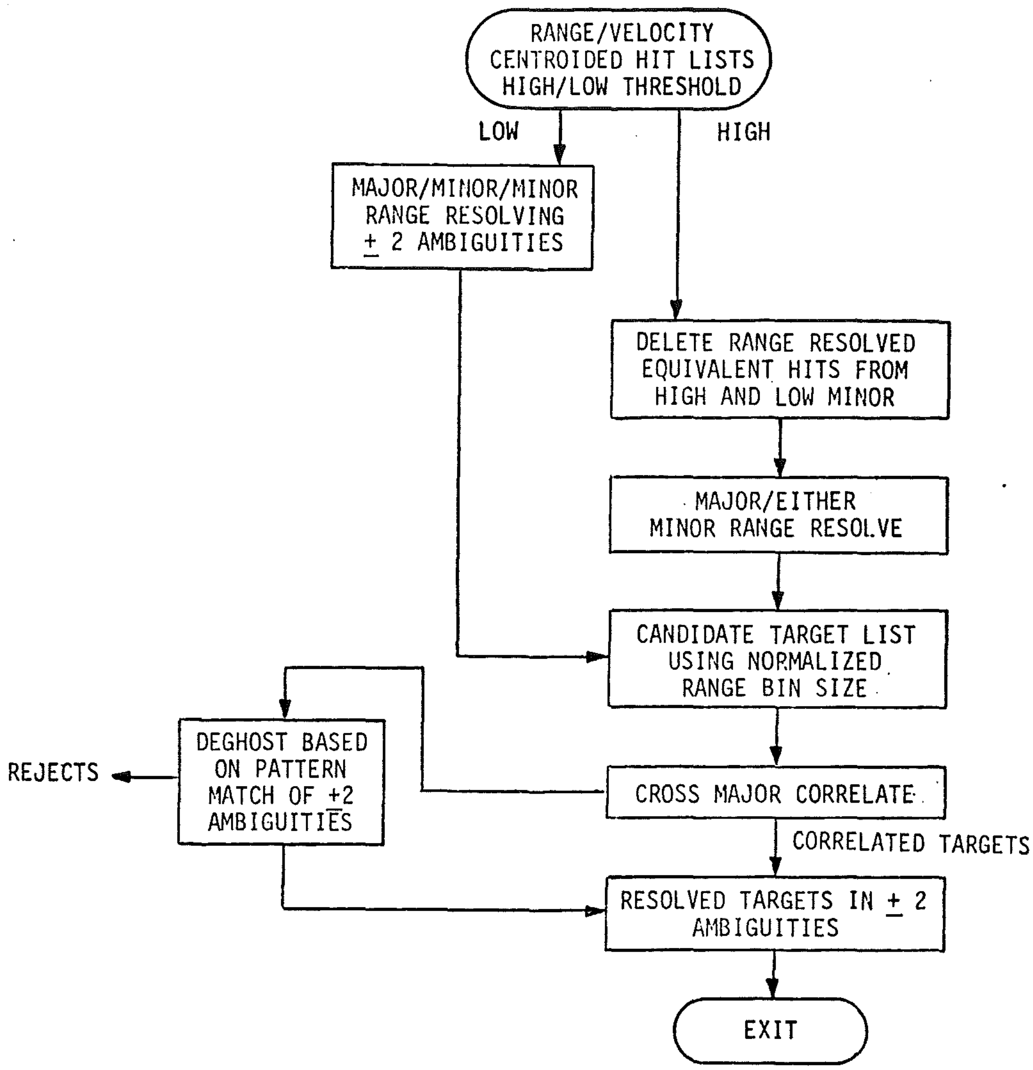


Figure 11.13.1 - RANGE RESOLUTION PROCESSING

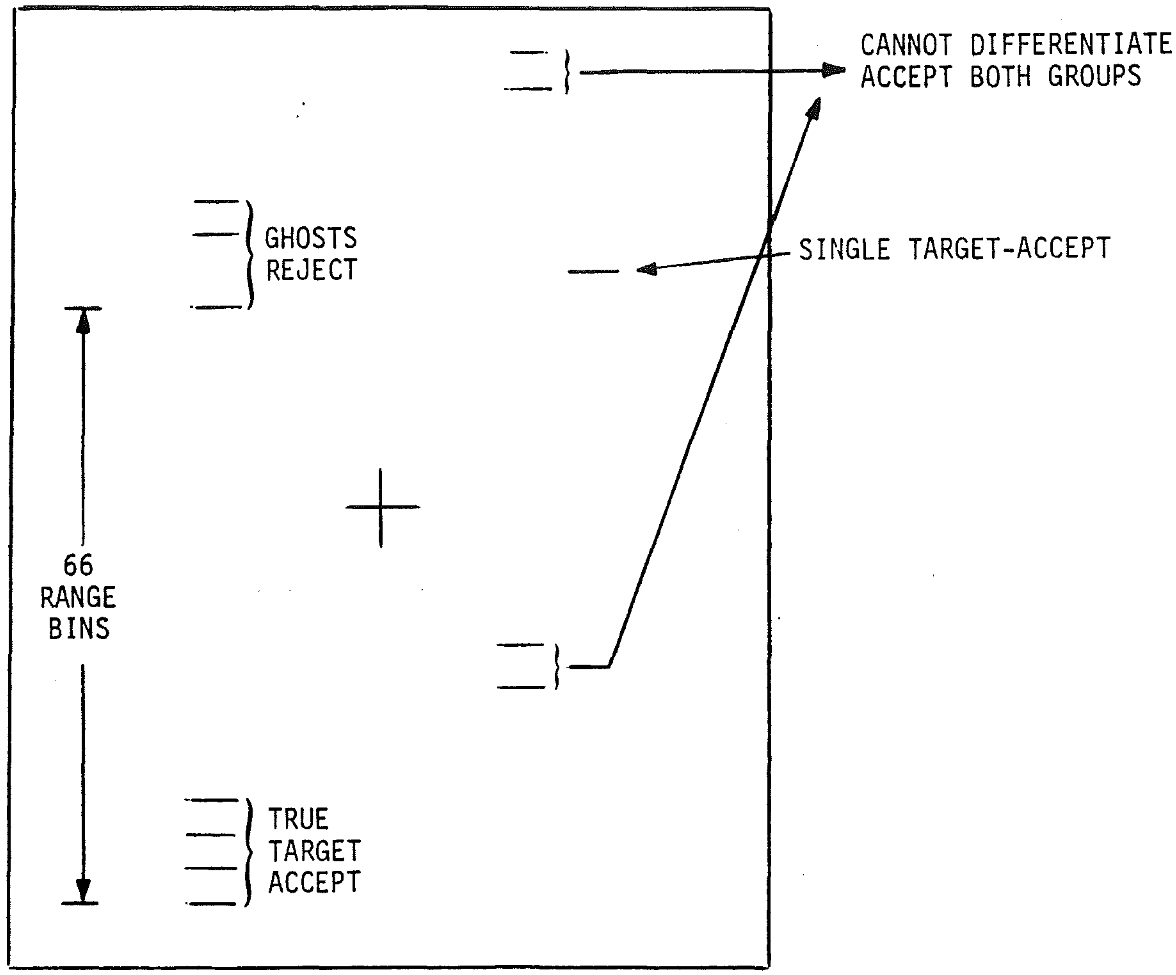


Figure 11.13.2 - TARGET PATTERN EXAMPLES

11.14 Azimuth Centroiding

The technique of Azimuth Centroiding of radar target samples is designed to improve the radar azimuth resolution so that closely spaced radar targets can be resolved. At the same time, this technique prevents the initiation of false targets from any strong target which can yield radar returns in several adjacent range azimuth elements. Azimuth Centroiding replaces the previous used method of inhibiting all adjacent azimuth hits from a strong target except the initial hit.

11.14.1 Inputs

- Centroided unambiguous ranges from the Range Centroider
- Antenna "Video Azimuth" from RDP
- Azimuth Centroider Inhibit flag from RDP

11.14.2 Processing

The initial phase of the Azimuth Centroiding function is the tagging of each target range (coarse range number) with an azimuth value from the RDP. If the AZ Centroider Inhibit flag is set (i.e., logical "1"), the azimuth centroiding procedure is NOT performed. The azimuth value tagged to the target and the coarse range number of the target are output. If the Az Centroider Inhibit flag is reset (i.e., logical "0"), the azimuth centroiding procedure is performed as described in the following paragraphs.

Centroiding is performed when a target generates two or more successive hits in the same range cell or one range cell $\pm K_1$. [K_1 is the half-width of the data collection gate shown in Figure 11.14.1]. The multiple hits from the signal target would be detected over successive Azimuth Centroiding cycles. The one range and azimuth computed by this function for the multiple hits is an average of the target's input coarse range numbers and tagged azimuth positions over a number of phases. The azimuth centroiding is accomplished by establishing azimuth centroider "tracks" for each target. Associated with each track are:

R_o = Range bin of the track initiator

R_c = Current range bin of the track

Az_o = Azimuth of the track initiator

Az_c = Current azimuth

N_H = Hit counter

N_M = Miss counter

A schematic diagram showing possible radar samples from a strong target or multiple targets is illustrated in Figure 11.14.1. These samples straddle several range bins and azimuth elements.

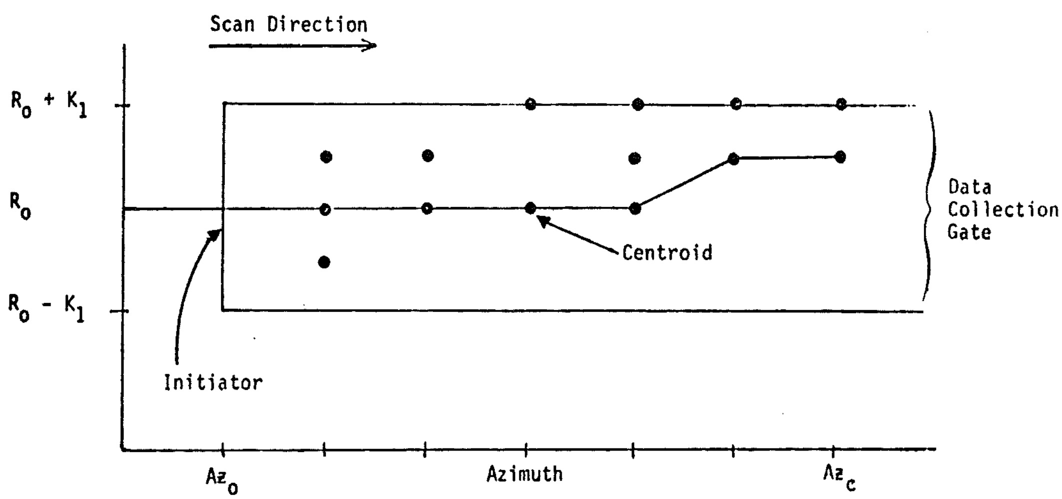


Figure 11.14.1 - AZIMUTH CENTROIDING

For Azimuth Centroiding, the target samples along each Azimuth element within $R_c + K_1$ and $R_c - K_1$ range bins are candidates for correlation with a track, where K_1 represents the half-width of the data collection gate. Track correlation, initiation, and termination are performed as follows.

11.14.2.1 Track Correlation

1) For each track, a search is made for hit(s) within the data collection gate ($\pm K_1$ range bins about the current target range bin, R_c).
2) Only one hit is allowed to correlate with a given track. If more than one hit is found in the data collection gate, the hit in range bin, R_c, is chosen as the correlated hit; if such a hit does not exist, the hit with the closest range is chosen as the correlated hit.
3) If a correlated hit is found, the track range, R_c, is set equal to the range bin of the correlated hit, the track azimuth, Az_c, is set to the current video antenna azimuth, and the track miss counter, N_M, is set to zero. The correlated hit is deleted from the hit list.
4) If no correlated hit is found, the track miss counter, N_M, is incremented by one.
5) In all cases, the track hit counter, N_H, is incremented by one to indicate the total number of azimuth elements since the initiator.

11.14.2.2 Track Initiation

1. Any uncorrelated hits remaining in the hit list after track correlation is performed are used to initiate new tracks.
2) The track parameters for each new track are initialized as follows:

$R_o = R_c$ = range bin of uncorrelated hit
Az_o = current video antenna azimuth
N_H = 1
N_M = 0

11.14.2.3 Track Termination

1) If a miss counter for a track equals N_s misses, the track is terminated.
2) If the hit counter for a track equals N_{max}, the track is terminated.

3) If $|R_o - R_c|$ for a track exceeds R_{max}, the track is terminated.

4) A centroided target position is computed for each terminated track and sent to the Display Processing function.

   a) The centroided range of the target is the average of the range bin of the initiator and the range bin of the last hit in the track:

   $$R = \text{IPO}\ [(R_o + R_c)/2 + 0.5]$$

   b) The centroided azimuth of the target is the average of the azimuth of the initiator and the azimuth of the last hit in the track.

   $$Az = \text{IPO}\ [(Az_o + Az_c)/2 + 0.5]$$

11.14.4 Azimuth Centroider Parameters Values

Parameter values for the RAM Scan and Spotlight I mode are as follows. Note that the number of misses required to terminate a track is dependent on whether 6 major PRF's or 3 major PRF's are commanded by the RDP.

K_1 = 1 range bin

$N_s = \begin{cases} \text{6 misses, when 6 majors are commanded} \\ \text{3 misses, when 3 majors are commanded} \end{cases}$

N_{max} = 10 hits

R_{max} = 5 Range bins

11.14.3 Outputs

- Coarse range number and azimuth of centroided targets to Display Processing.

11.15 Display Processing Function

The Display Processing Function shall interface between the RDP and the target memory for purposes of target display. This function shall be the same in the RAM Scan and Spotlight modes. The purpose of processing within this mode is to maintain the display based upon RDP inputs.

11.15.1 Inputs

- Target ranges from RDP
- Target azimuths from RDP
- Target symbology from RDP
- Display control words from RDP.

11.15.2 Processing

The data flow during display processing is indicated in Figure 11.15.1. The display processing function is a part of post processing software and is performed during each Low Minor PRF time in the RAM Scan mode.

Data from RAM Scan is made available to the RDP for control of the RAM Spotlight mode. In turn, resolved targets from RAM Spotlight are tracked by the RDP and data for display is input to this function.

The first 24 bits of Figure 11.15.2A are the input format from the RDP. The 3 bit intensity code is set to "111" by this function, and data from the RDP is formatted for TM2 as shown in Figure 11.15.2. During RAM Scan processing, targets from previous RAM Spotlight processing are maintained by the RDP, stabilized, and compared with targets from current RAM Scan for redundant target elimination.

The six bit word code of Figure 11.15.2 shall be encoded with target symbols per Table 11.15.1. Symbol assignment shall be made by the RDP.

RAM display scaling shall range from -248 to +248 display units (X,Y) with 00 representing screen center.

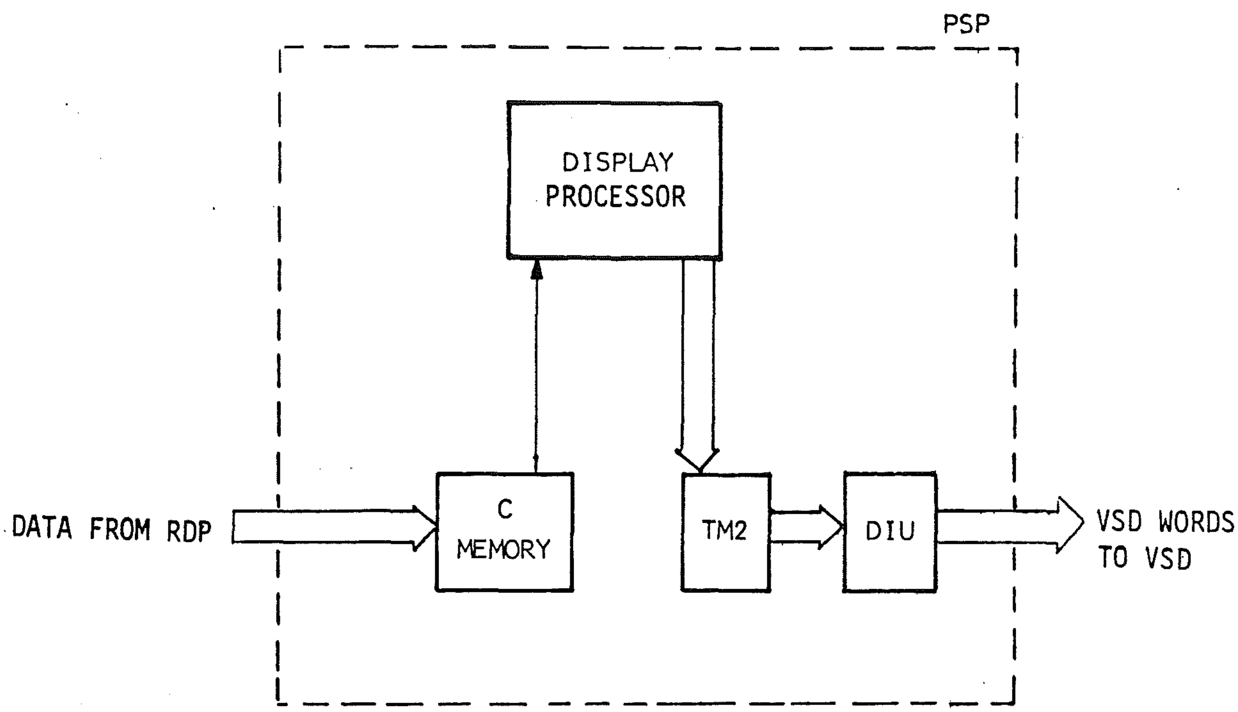


FIGURE 11.15.1

DATA FLOW BETWEEN THE PSP, RDP AND THE VSD UNIT
DURING DISPLAY PROCESSING

11.15.3 Inputs

- VSD data in the form of 134 48-bit Bulk Memory words as shown in Figure 11.15.2.

WORD #	PURPOSE	BIT POSITION 0–5	5–14	14–23	23–44	44–47
1 TO 128	TARGET WORDS	6 BITS SYMBOL CODE	9 BITS AZIMUTH POSITION (X)	9 BITS RANGE POSITION (Y)	NOT USED	3 BITS INTENSITY

A) TARGET WORDS

<table>
<tr><th></th><th></th><th>0 3</th><th>5</th><th></th><th>14</th><th>23</th><th>24 to 44</th><th>45</th><th>46</th><th>47</th></tr>
<tr><td>129</td><td>RNG/VEL SCALE</td><td>0 1 0 0</td><td>0 0</td><td>RNG/ VEL SCALE</td><td>0 0 0 0 0 0</td><td>0 0 0 0 0 0 0 0 0</td><td rowspan="6">NOT USED</td><td>1</td><td>1</td><td>1</td></tr>
<tr><td>130</td><td>CURSOR POSITION</td><td>0 0 0 1</td><td>0 0</td><td colspan="2">X POSITION</td><td>Y POSITION</td><td>1</td><td>1</td><td>1</td></tr>
<tr><td>131</td><td>ANT. AZ. POSITION</td><td>0 1 0 1</td><td>0 0</td><td colspan="2">X POSITION</td><td>1 0 0 0 1 0 1 1 0</td><td>1</td><td>1</td><td>1</td></tr>
<tr><td>132</td><td>ANT. EL. POSITION</td><td>0 1 0 1</td><td>0 0</td><td colspan="2">1 0 0 0 1 0 1 1 0</td><td>Y POSITION</td><td>1</td><td>1</td><td>1</td></tr>
<tr><td>133</td><td>BIT WORD #1</td><td>0 1 0 1 or 0 0 0 0</td><td>0 0</td><td>1st CHARACTER</td><td>2nd CHARACTER</td><td>3rd CHARACTER</td><td>1</td><td>1</td><td>1</td></tr>
<tr><td>134</td><td>BIT WORD #2</td><td>0 1 0 1 or 0 0 0 0</td><td>0 0</td><td>4th CHARACTER</td><td>5th CHARACTER</td><td>6th CHARACTER</td><td>1</td><td>1</td><td>1</td></tr>
</table>

B) DISPLAY SYMBOL WORD

Figure 11.15.2 - TM2 BULK MEMORY WORDS (RAM SCAN AND SPOTLIGHT I MODE)

TABLE 11.15.1 - RAM DISPLAY SYMBOLOGY

NAME	SYMBOL	SYMBOL CODE BITS					
		0	1	2	3	4	5
RAM MPRF TRACKED TARGET	■	0	0	0	1	0	0
RAM MPRF SPECIAL TARGET	X	0	0	0	1	1	1
RAM MPRF UNTRACKED SINGLE TARGET	▭	0	1	1	0	1	0
RAM MPRF UNTRACKED MULTIPLE TARGET	▯	0	1	1	1	0	1
RAM HIGH ALTITUDE TARGET IN SPECIAL DISPLAY	△	0	1	1	1	0	0
RAM LOW ALTITUDE TARGET IN SPECIAL DISPLAY	▽	0	1	1	0	1	1

11.16 Clutter Doppler Error Processing

The Clutter Doppler Processor (CDEP) is used in the RAM Scan and Spotlight I mode. The processor takes radar return signals from the Analog Radar Signal Processor (ARSP 039 Unit) before the signals pass through the Clutter Canceller. The Clutter Doppler Error (CDE) computation measures the error incurred in shifting the Main Lobe Clutter (MLC) to dc. The processor uses the radar returns from eight non-blanked range bins and measures the phase shift of the return in relation to the last sample from the same range bin for the frequency discriminant computation. It is also required to send the Number of Valid Samples (NVS) used in the CDE computation to the RDP for MLC Tracking. The CDE is used by the RDP to derive the correct setting of the Voltage Controlled Oscillator (VCO).

11.16.1 Inputs

- Radar samples in the non-pause phase of each PRF (48 PRI interval) with data rate at one data set (32 PRI) per PRF.
- CDE gate from RDP.
- Threshold frequency discriminant, K_c, and amplitude discriminant, A_c, for CDE sample data validation.

11.16.2 Processing

The CDE buffer accumulates the last 32 non-blank pulses in each PRF interval. Only the last 32 pulses in the non-pause phases are used for the CDE computation. In each of the PRF intervals, there are 8 range bins in which the CDE processor searches for the MLC returns. Timing and Control supplies the CDEP with the 8 range bins per PRF to be processed. The CDE processor uses the radar sample data to compute the Clutter Doppler Error discriminant, and performs validity tests to verify the CDE result. After the validation, the CDE value and NVS are sent to the RDP for tracking MLC.

The frequency discriminant, f_d, of these 32 pulses can be computed from the complex products of consecutive pulse-pairs from the same range bin.

$$f_d = \frac{In}{Qn} = \frac{\sum_{i=0}^{30} Im(Z_{i+1} \bullet \overline{Z}_i)}{\sum_{i=0}^{30} Re(Z_{i+1} \bullet \overline{Z}_i)}$$

where:

I_i, Q_i	= I and Q components of a delayed sample
I_{i+1}, Q_{i+1}	= I and Q components of a current sample
Z_{i+1}	= current sample $I_{i+1} + jQ_{i+1}$
Z_i	= delayed sample = $I_i + jQ_i$
$\overline{Z}_i$	= complex conjugate = $I_i - jQ_i$

The validation of the frequency discriminant by amplitude test and/or frequency test depends on the state of the CDE gate command from the RDP.

If the MLC returns are close to dc line (narrow clutter doppler error gate case), the frequency discriminant, f_d, must satisfy both the amplitude test and the phase test.

$$\left| \sum_{i=0}^{30} Im(Z_{i+1} \bullet \overline{Z}_i) \right| < K_c \sum_{i=0}^{30} Re(Z_{i+1} \bullet \overline{Z}_i) \quad : \quad \text{Phase Test}$$

and

$$\sum_{i=0}^{30} Re(Z_{i+1} \bullet \overline{Z}_i) > A_c^2 \quad : \quad \text{Amplitude Tests}$$

where: k_c = tan 30^0

A_c^2 = -27 db from A/D converter saturation.

If the main lobe clutter is far off from the dc line (wide CDE gate) and both amplitude and phase tests are satisfied, f_d is computed as in the narrow gate case. If only the amplitude test is satisfied, f_d is computed as follows:

$$f_d = 0.1 \text{ sgn} \left[\sum_{i=0}^{30} \text{Im}(Z_{i+1} \bullet \overline{Z}_i) \right]$$

If both tests fail, the sample is rejected. The verified f_d is then used to compute the Clutter Doppler Error (CDE) as follows:

$$\text{CDE} = (\text{NVS})\ f_d = 31\ f_d$$

where:

CDE = clutter doppler error

NVS = number of valid sample pairs used in the CDE calculation = 31.

11.16.3 Outputs

- Clutter Doppler Error (CDE) to RDP
- Number of Valid sample pairs (NVS) used in the computation to RDP via IDA.

SECTION 12

RAM SPOTLIGHT II MODE

12.0 INTRODUCTION

The RAM Spotlight II Mode is described in this writeup.

RAM Spotlight II mode is used by the RDP to obtain accurate track data (accurate with respect to Scan) and to more finely resolve closely spaced targets. The antenna is moved rapidly from target to target and dwells long enough on each target to form an accurate observation of the target's position. (Capability is provided to observe several targets at each antenna spotlight position if necessary). This mode is used in conjunction with MPRF RAM Scan mode on a generally alternating basis to accomplish detection and sample-data (Spotlight) tracking.

Figure 12.1 illustrates the data gathering timeline for RAM Spotlight II Mode.

A block diagram of the PSP signal processing operations is shown in Figure 12.2. Details of each block or processing are given in the following sub-sections.

(Times are given in PRIs)

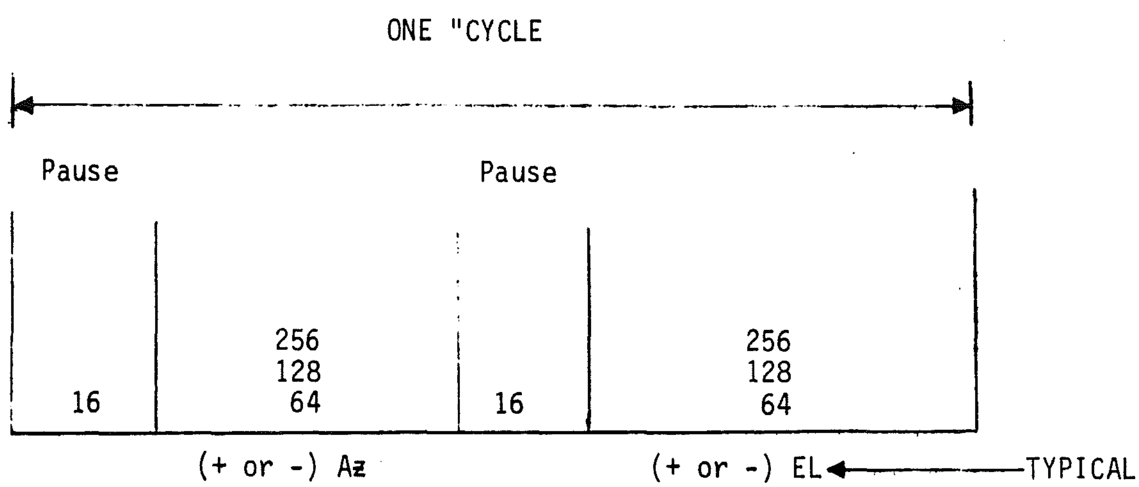


FIGURE 12.1 - RAM SPOTLIGHT II TIMELINE

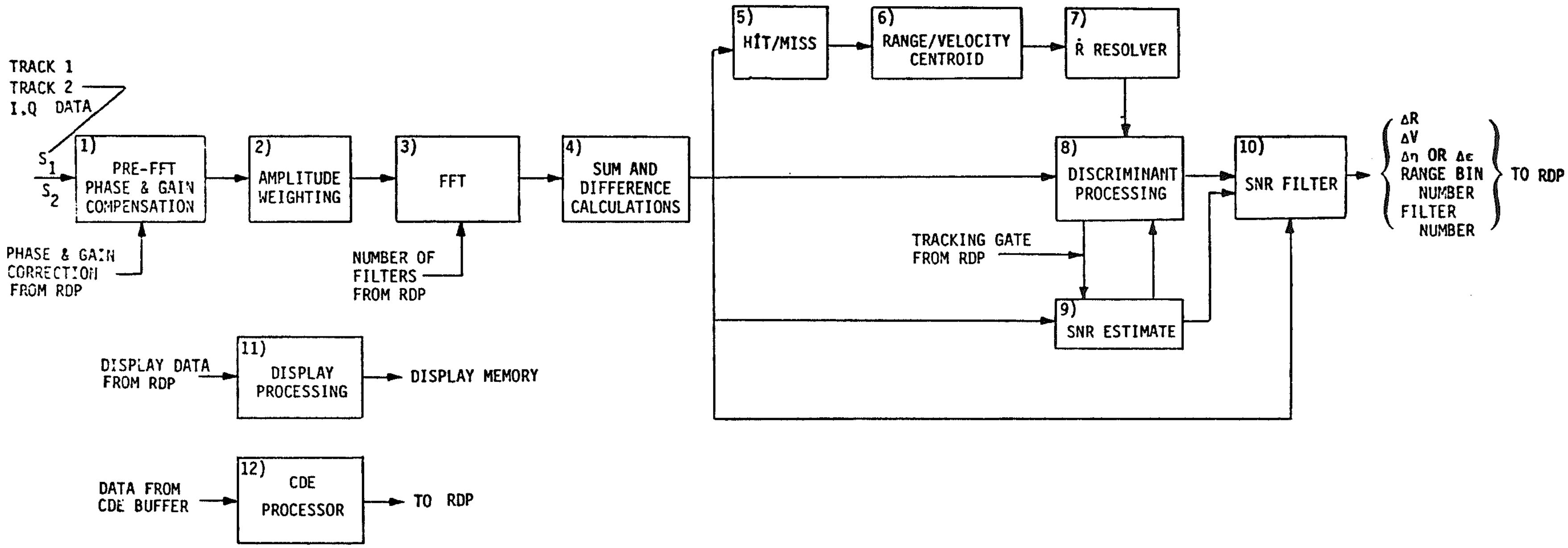
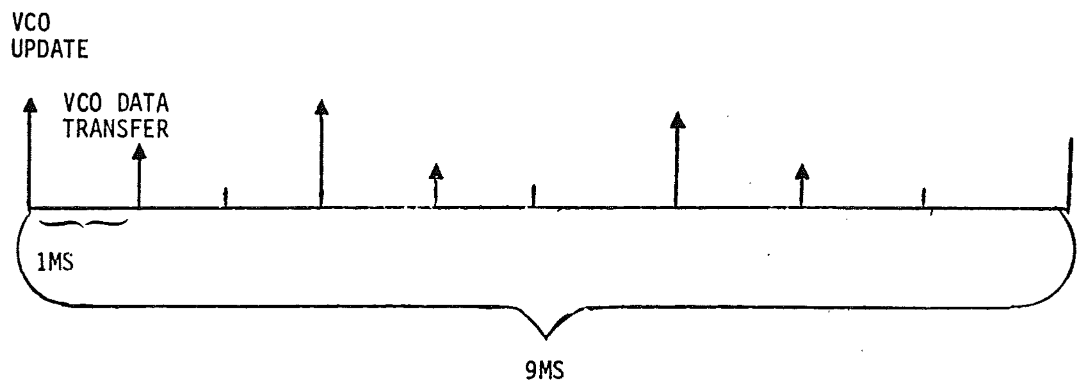


FIGURE 12.2

RAM SPOTLIGHT II SOFTWARE FUNCTIONAL BLOCK DIAGRAM

A. Voltage Controlled Oscillator (VCO) Movement Function

When the RDP wants to move the VCO in RAM Spotlight II, it will send a reset command. The PSP runs a Timing and Control (T&C) program designed to move the VCO. The T&C program is run upon entering Spotlight II and the hexidecimal code for this program is shown in Figure 12.3.



EVENT GENERATOR #2	EVENT GENERATOR #1	CONTROL WORDS	
93E000	0000FF	T&C2	0000E4
1BE000	0000FF	T&C1	24ECE4
13E000	0000FF	TTG	000000
93E000	0000E5	EXT	F00201
1BE000	000100		
93E000	000200		
1BE000			
1BE100			
13E200			

Figure 12.3

TIMING AND CONTROL PROGRAMS FOR VCO MOVEMENT FUNCTION

12.1 Pre-FFT Phase and Gain Compensation

Data is adjusted for phase and gain imbalance between the two track channels. The adjustment is accomplished by applying pre-stored adjustment vectors to the data. These adjustment vectors are calculated by the RDP during the MPRF BIT tests and sent to the PSP. Phase compensation is also made for target frequency positioning errors. These errors which result from acceleration along the ownship/target line-of-sight, or from inexact VCO positioning, are computed by the RDP, and are compensated by phase acceleration and velocity terms sent to the PSP.

12.1.1 Inputs

- Samples from Track 1 and Track 2 channels (complex).

  $S_1(i,n)$ Track 1

  $S_2(i,n)$ Track 2

  where: $i = R_1, \ldots, R_1+N_s-1$ (Range bin index)

  - R_1 = Leading edge of the range window from the RDP
  - N_s = Number of range bins to be sampled from RDP, an integer multiple of 8

  $n = 0, \ldots, N_p$ (PRI index)

  - N_p = Number of filters formed/Number of pulses from RDP
- $C_{\emptyset g}$ Track 1 or Track 2 phase and gain adjustment vector from RDP (complex).
- Higher gain channel identifier (one bit) from RDP
- $\emptyset_A$ phase acceleration from RDP (real)
- $\emptyset_V$ phase velocity from RDP (real)

12.1.2 Processing

Doppler phase correction is found for each PRF from

$$\left.\begin{array}{l}\emptyset(n) = \emptyset_A \cdot (n/N_p)^2 \\ \qquad\quad \emptyset_V \cdot n\end{array}\right\} \quad n = 0, \ldots, N_p$$

The corresponding complex phasors are:

$$C(n) = e^{2\pi j \emptyset(n)} \qquad n = 0, \ldots, N_p - 1$$

These phasors are then multiplied by the Track 1 and Track 2 data samples

$$S_a(i,n) = S_1(i,n) \cdot C(n)$$

$$S_b(i,n) = S_2(i,n) \cdot C(n)$$

$$\text{For} \quad i = R_1, \ldots, R_1 + N_s - 1$$

$$n = 0, \ldots, N_p - 1$$

Then the highest gain channel is corrected for phase and gain. If the Higher gain channel identifier = 0 (Track 1)

then: $S_1'(i,n) = S_a(i,n) \cdot C_{\emptyset g}$

$S_2'(i,n) = S_b(i,n)$

otherwise:

$S_1'(i,n) = S_a(i,n)$

$S_2'(i,n) = S_b(i,n) \cdot C_{\emptyset g}$

For $i = R_1, \ldots, R_1 + N_s - 1$

$n = 0, \ldots, N_p - 1$

12.1.3 Outputs

- Adjusted Track 1 and Track 2 samples

  $S'_1(i,n)$

  $S_2'(i,n)$

12.2 Amplitude Weighting

The amplitude weighting processor shall preprocess the data samples for the Fast Fourier Transform (FFT) so that the output of the FFT can achieve the desired peak mainlobe to peak sidelobe ratio.

12.2.1 Inputs

- Track 1 and Track 2 compensated samples from Section 12.1 (complex).

  $S'_1(i,n)$

  $S'_2(i,n)$

12.2.2 Processing

Amplitude weighted samples are given by:

$$S_{W1}(i,n) = A(n) \quad S'_1(i,n)$$

$$S_{W2}(i,n) = A(n) \quad S'_2(i,n)$$

For:

$n = 0, \ldots, N_p - 1$ (PRI index) and

$i = R_1, \ldots, R_1+N_s-1$ (Range bin index)

where:

$N_p = 64, 128, 256$ (commanded by RDP)

Optimized weights, $A(n)$, are shown in Tables 12.2.1 and 12.2.2. These weights are real and symmetrical and may be rounded to the nearest values.

12.2.3 Outputs

- Weighted Track 1 Channel I, Q samples, $S_{W1}(i,n)$
- Weighted Track 2 Channel I, Q samples, $S_{W2}(i,n)$

TABLE 12.2.1 - Amplitude Weights
for F-15 RAM SPOTLIGHT II

Np=128

Sample Number n	Amplitude Weights A(n)	Sample Number n	Amplitude Weights A(n)
0	0.068848	32	0.485840
1	0.026855	33	0.509277
2	0.031738	34	0.533203
3	0.037109	35	0,556641
4	0.043457	36	0.580566
5	0.050293	37	0.604492
6	0.057617	38	0.628418
7	0.065430	39	0.651855
8	0.074219	40	0.675293
9	0.083496	41	0.698242
10	0.093750	42	0.721191
11	0.104492	43	0.743164
12	0.115723	44	0,765137
13	0.127930	45	0.786133
14	0.140625	46	0.806641
15	0.154297	47	0.826172
16	0.168945	48	0.845215
17	0.184082	49	0.863281
18	0.199707	50	0.880859
19	0.216309	51	0.896973
20	0.233398	52	0.912109
21	0.251465	53	0.926270
22	0.270020	54	0.939453
23	0.289062	55	0.951172
24	0.309082	56	0.961914
25	0.329590	57	0.971191
26	0.350586	58	0.979492
27	0.372070	59	0.986328
28	0.394043	60	0.991699
29	0.416504	61	0.996094
30	0.438965	62	0.998535
31	0.462402	63	1.000000

Dolph-Chebyshev Weights-55dB Peak Sidelobe Level

TABLE 12.2.2 - Amplitude Weights
for F-15 RAM SPOTLIGHT II

Np=256

Sample Number n	Amplitude Weights A(n)	Sample Number n	Amplitude Weights A(n)
0	0.125000	32	0.167480
1	0.024414	33	0.174805
2	0.026367	34	0.182617
3	0.028809	35	0.190430
4	0.031738	36	0.198242
5	0.034180	37	0.206543
6	0.037109	38	0.214844
7	0.040039	39	0.223145
8	0.042969	40	0.231934
9	0.046387	41	0.240723
10	0.049805	42	0.249512
11	0.053711	43	0.258789
12	0.057129	44	0.268066
13	0.061035	45	0.277344
14	0.064941	46	0.287109
15	0.069336	47	0.296875
16	0.073730	48	0.306641
17	0.078125	49	0.316895
18	0.083008	50	0.327148
19	0.087891	51	0.337402
20	0.092773	52	0.348145
21	0.098145	53	0.358398
22	0.103516	54	0.369141
23	0.109375	55	0.380371
24	0.114746	56	0.391113
25	0.120605	57	0.402344
26	0.126953	58	0.413574
27	0.133301	59	0.424805
28	0.139648	60	0.436035
29	0.146484	61	0.447754
30	0.153320	62	0.458984
31	0.160156	63	0.470703

Dolph-Chebyshev Weights-55dB Peak Sidelobe Level

TABLE 12.2.2 - Amplitude Weights
for F-15 RAM SPOTLIGHT II

Np=256

Sample Number n	Amplitude Weights A(n)	Sample Number n	Amplitude Weights A(n)
64	0.482422	96	0.841797
65	0.494141	97	0.850586
66	0.505859	98	0.859863
67	0.517578	99	0.868652
68	0.529297	100	0.876953
69	0.541504	101	0.885254
70	0.553223	102	0.893555
71	0.564941	103	0.901367
72	0.577148	104	0.909180
73	0.588867	105	0.916016
74	0.601074	106	0.923340
75	0.612793	107	0.930176
76	0.624512	108	0.936523
77	0.636230	109	0.942871
78	0.647949	110	0.948730
79	0.659668	111	0.954102
80	0.671387	112	0.959473
81	0.683105	113	0.964355
82	0.694336	114	0.969238
83	0.705566	115	0.973633
84	0.717285	116	0.977539
85	0.728027	117	0.981445
86	0.739258	118	0.984863
87	0.750000	119	0.987793
88	0.761230	120	0.990234
89	0.771484	121	0.992676
90	0.782227	122	0.994629
91	0.792480	123	0.996582
92	0.802734	124	0.998047
93	0.812500	125	0.999023
94	0.822754	126	0.999512
95	0.832031	127	1.000000

Dolph-Chebyshev Weights-55dB Peak Sidelobe Level

12.3 Fast Fourier Transform

The purpose of the FFT in RAM Spotlight II mode is to form N_p digital doppler filters for each processed range bin from the PRIs of radar data. The pulse groups of Track 1 and Track 2 data are compensated and amplitude weighted. (See Sections 12.1 and 12.2 for a description of Compensation and Amplitude Weighting). The FFT process is illustrated in Figure 12.3.1.

12.3.1 Inputs

- Weighted Track 1 I and Q for the N_s range bins to be processed.
- Weighted Track 2 I and Q for the N_s range bins to be processed.

The number of range bins to be processed, (N_s), if from R_1 to $R_1 + N_s - 1$.

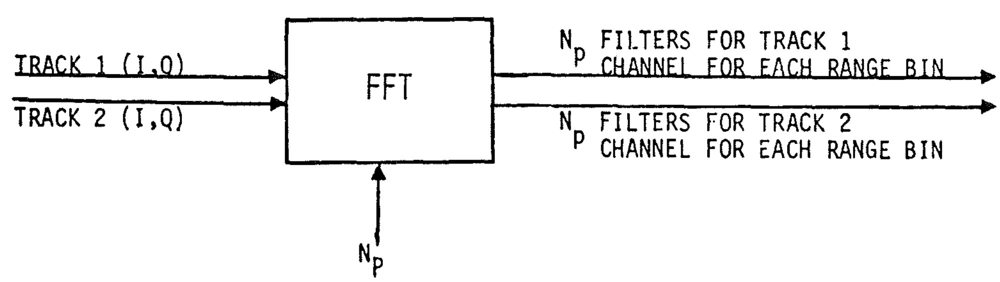


Figure 12.3.1 - FFT PROCESS

12.3.2 Processing

The Discrete Fourier Transform inputs of I and Q data for N_p PRIs are transformed into N_p filters for each processed range bin in Track 1 and Track 2 channels by the expression:

$$T_x(i,k) = \frac{1}{N_p} \sum_{i=0}^{N_p-1} W^{nk} \, S_{Wi}(i,n)$$

where:

(i) is the range bin number

W is the exp $-\frac{2\pi j}{N_p}$

12.3.3 Outputs

The outputs of the doppler processor are:

- Track 1 channel I, Q data → N_p filters by N_s range bins.
- Track 2 channel I, Q data for same number of filters/bins as above.

For convenience, let these outputs be designated:

$T_x(i,j)$

where: $x = 1, 2$ (track channel)

$i = 0, 1, \ldots, N_s - 1$ (range bin index)

$j = 0, 1, \ldots, N_p - 1$ (filter index)

12.4 Sum and Difference Calculation

After FFT processing Track 1 and Track 2 data are formed into sum and difference signals required for discriminant processing, Hit/Miss processing and SNR estimation.

12.4.1 Inputs

- Doppler filter data for N_p filters by N_s range bins from Section 12.3 (complex).

  $T_1(r,f)$ Track 1 I, Q Data

  $T_2(r,f)$ Track 2 I, Q Data

12.4.2 Processing

Sum and difference quantities are formed from complex Track 1 and Track 2 inputs:

$$F_\Sigma(r,f) = T_1(r,f) - j\,T_2(r,f)$$

$$F_\Delta(r,f) = T_2(r,f) - j\,T_1(r,f)$$

where:

F_Σ = sum (complex)
F_Δ = difference (complex)
r = range bin index
f = filter index

Magnitudes of sum quantities are required for both Hit/Miss and SNR estimates. These may be formed from the greater of:

$$|I| + \tfrac{1}{2}|Q| \text{ or } |Q| + \tfrac{1}{2}|I|$$

for sum, F_Σ.

12.4.3 Outputs

- Sum channel filter data as $F_\Sigma(r,f)$ to discriminant Section 12.8.
- Difference channel filter data as $F_\Delta(r,f)$ to discriminant Section 12.8.
- Sum channel magnitudes as $|F_\Sigma(r,f)|$ to Hit/Miss Section 12.5 and SNR Estimate Section 12.9.

12.5 Hit/Miss Process

Hit/Miss processing is performed for Range/Doppler cells of interest for Spotlight II mode. The cells to be tested for Hit/Miss lie within a three range bin by N_f filter region designated by the RDP.

12.5.1 Inputs

- Sum channel magnitudes, $|F_\Sigma|$, for N_p filters by N_s range bins from Section 12.4.
- Number of filters to be processed, N_f from RDP. This value designates the number of filters in the doppler clear (not notched) region.
- Threshold multiplier K_M and K_{GMT} from RDP.
- Tracking gate filter numbers from the RDP.
- Tracking gate range numbers from the RDP.

12.5.2 Processing

Sum channel magnitudes from Section 12.4 are input as arrays of N_p filters by N_s range bins. This function shall compute a background noise estimate from all of the Range/Doppler cells in the input arrays.

The noise estimate is used to form the detection threshold.

The noise estimate is computed by summing the amplitude values from each of the cells, and dividing by the total number of cells.

$$\overline{N} = \frac{\displaystyle\sum_{r=0}^{N_s-1} \sum_{f=0}^{N_p-1} |F_\Sigma(r,f)|}{(N_s) \cdot (N_p)}$$

The Range/Doppler cells to be tested for hits are selected as shown in Figure 12.5.1. Note that range/frequency pointers (r_1,f_1) are provided by the RDP.

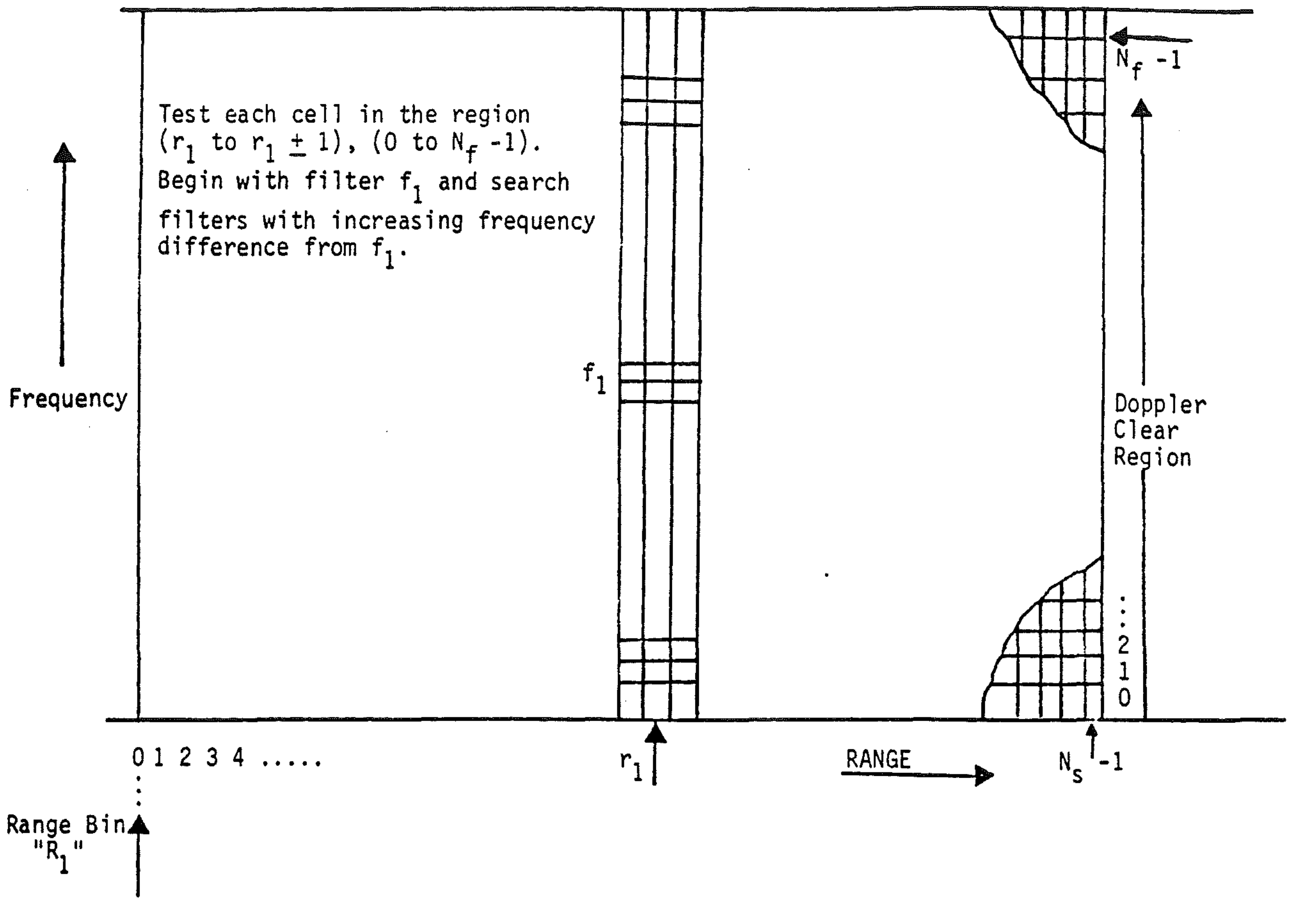


FIGURE 12.5.1 - RANGE/DOPPLER CELLS TESTED FOR HIT/MISS

The Hit/Miss thresholding shall be accomplished by comparing the signal amplitude in each Range/Doppler cell to the product of the noise estimate and the threshold multiplier (K_M).

If the signal amplitude exceeds or equals the product, a hit is declared for that Range/Doppler cell.

The result of threshold processing for sum channel shall be equivalent to the following sequence of direct logic:

If $\quad |F_\Sigma(r,f)| \geq \overline{N} \cdot K_M$

Then record a hit as $H(r,f)$.

12.5.3 Outputs

- Range bin/filter numbers for hits to Section 12.6 and 12.8.

12.6 Range/Velocity Centroid

A given radar target may produce hits in the HIT/MISS PROCESSING (Section 12.5) over more than one range/filter cell. It is therefore desirable to "centroid" hits that occur over contiguous range or filter cells.

12.6.1 Inputs

- Range bin/filter number (r,f) for hits from Section 12.5.
- Sum channel magnitudes, $|F_\Sigma(r,f)|$, for hits from Section 12.4.

12.6.2 Processing

A. Velocity Centroid

If there are hits (as determined by the HIT/MISS function) in cells (r,f) and (r,f+1),
then:

1. If $|F_\Sigma(r,f)| > |F_\Sigma(r,f+1)|$, keep only cell (r,f) in the HIT list,
2. If $|F_\Sigma(r,f)| \leq |F_\Sigma(r,f+1)|$, keep only (r,f+1);

where:

r = range bin number
f = filter number
$|F_\Sigma(r,f)|$ = sum channel vector magnitude for range bin r, filter f.

B. Conditions for range and diagonal centroiding

If

PRFP $\leq$ (.95) PRFC

Where PRFP and PRFC are the PRFs for the previous phase and current phase respectively, then perform both range and diagonal centroiding.

C. Range Centroid

If there are hits in cells (r,f) and (r+1, f) then

1. If $|F_\Sigma(r,f)| \geq |F_\Sigma(r+1,f)|$, keep only (r,f)
2. If $|F_\Sigma(r,f)| < F_\Sigma(r+1,f)|$, keep only (r+1,f)

D. Diagonal Centroid

1. If $|F_{\Sigma}(r,f)| \geq |F_{\Sigma}(r+1, f\pm 1)|$, keep only (r,f)
2. If $|F_{\Sigma}(r,f)| < |F_{\Sigma}(r+1, f\pm 1)|$, keep only (f+1, f$\pm$1)

NOTE: The centroiding is to be executed in the order listed above.

12.6.3 Outputs

- Range/Doppler cell indices for centroided hits, H(r,f), to Section 12.7.

12.7 $\dot{R}$ Resolver

The purpose of this function is to resolve ambiguous velocity of targets from Section 12.6. Several velocities may be reported for each range cell of the hit list. Those Range/Doppler cells for which there is no associated range rate are eliminated from the hit list. The remaining cells are reported to Section 12.8 for discriminant processing.

12.7.1 Inputs

Range/Doppler centroided cell indices for hits, H(r,f) from Section 12.6.

PRF_1 and PRF_2, where PRF_1 is the lower in frequency (Note: PRF_1 may be equal to PRF_2 in some cases where velocity resolving is not required).

N_p = the number of filters formed/number of pulses from the RDP.

12.7.2 Processing

Let L_{N1} be a list of filters containing hits for an ambiguous range bin, r, as determined from H(r,f). This list represents hits from PRF_1. Let L_{N2} be a similar list from PRF_2.

The velocity Resolver shall perform an iterative velocity ambiguity resolving equation for all possible combinations of filters from list L_{N1} and L_{N2}. The function computes target velocity ambiguities for pairs of filters that satisfy the equation.

This data is placed with the target hit list for downstream processing. The Velocity Ambiguity equation has the form:

$$M_1 = \dot{R} \cdot M_2 + \frac{\dot{R} \cdot N_2}{N_{P2}} - \frac{N_1}{N_{P1}} \qquad (12.7.1)$$

where:

N_1 = a filter number from the list L_{N1}

N_2 = a filter number from the list L_{N2}

N_{P1} = number of filters in PRF_1

= 256

N_{P2} = number of filters in PRF_2

M_1 = number of integer velocity ambiguity foldings of the target in PRF_1

M_2 = number of integer velocity ambiguity foldings of the target in PRF_2

$\dot{R}$ = $\frac{PRF_2}{PRF_1}$

The objective is to test several integer values in the equation to find the pair of integers (M_1, M_2) which "fit". Figure 12.7.1 illustrates the process to be performed.

Those filter pairs for which a solution to equation 12.7.1 is found identify the Range/Doppler cells to be output to the discriminant processing function. Hits not used in the $\dot{R}$ resolution process are not output to the discriminant processing function.

12.7.3 Outputs

- Addresses (range bin/filter number) for cells containing $\dot{R}$ resolved hits to Section 12.8.
- Associated ambiguity foldings of the target, M_1 or M_2, for each cell address output.

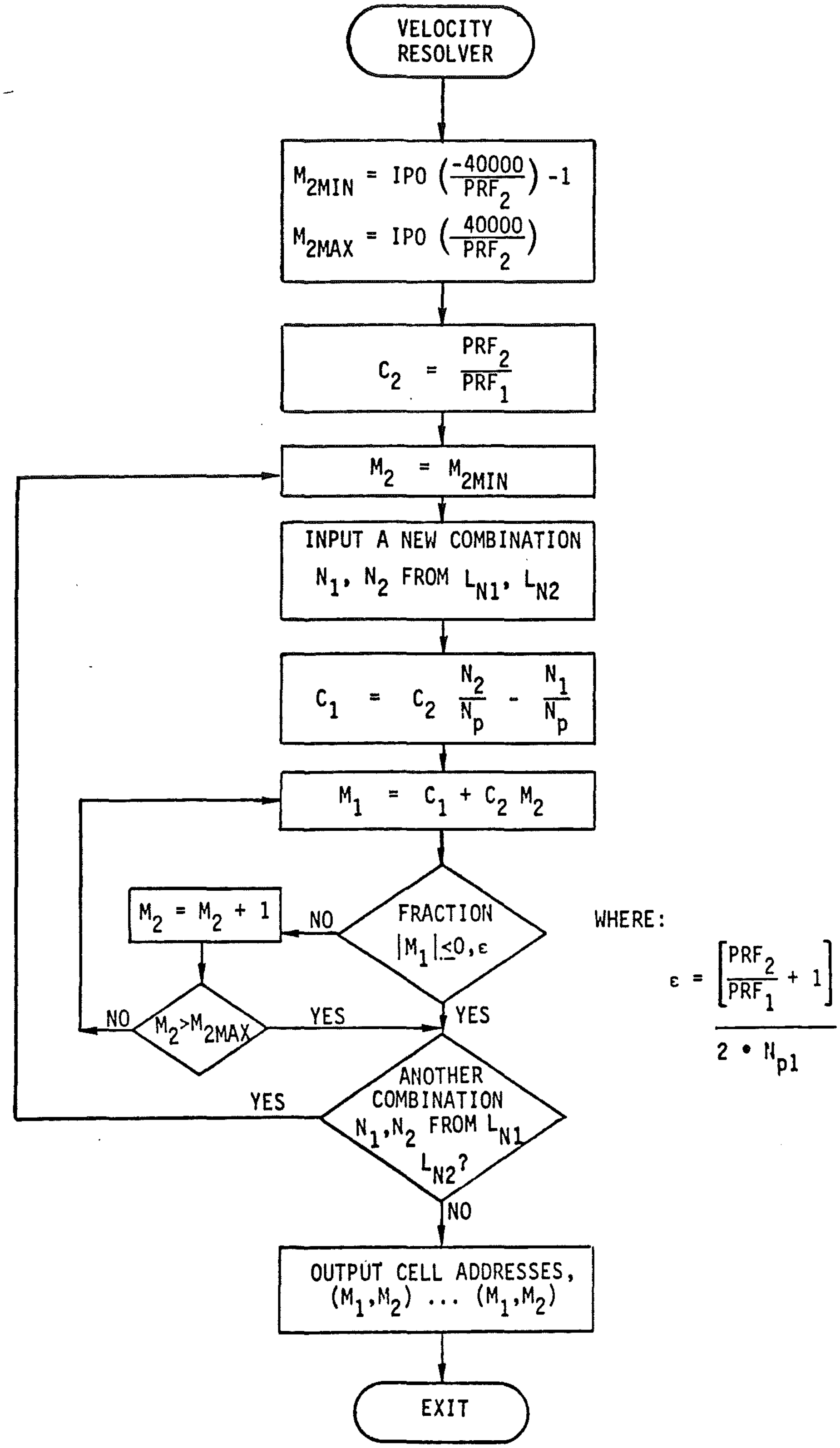

VELOCITY RESOLVER
$M_{2MIN} = IPO\left(\frac{-40000}{PRF_2}\right) -1$
$M_{2MAX} = IPO\left(\frac{40000}{PRF_2}\right)$
$C_2 = \frac{PRF_2}{PRF_1}$
$M_2 = M_{2MIN}$
INPUT A NEW COMBINATION N_1, N_2 FROM L_{N1}, L_{N2}
$C_1 = C_2 \frac{N_2}{N_p} - \frac{N_1}{N_p}$
$M_1 = C_1 + C_2 M_2$
FRACTION $|M_1| \leq 0, \varepsilon$
NO
YES
$M_2 = M_2 + 1$
$M_2 > M_{2MAX}$
NO
YES
ANOTHER COMBINATION N_1, N_2 FROM L_{N1} L_{N2}?
YES
NO
OUTPUT CELL ADDRESSES, $(M_1,M_2) \ldots (M_1,M_2)$
EXIT
WHERE:
$\varepsilon = \frac{\left[\frac{PRF_2}{PRF_1} + 1\right]}{2 \bullet N_{p1}}$

Figure 12.7.1

12.8 Discriminant Processing

There are four terms computed in this section. These terms are:

a) ΔR (range tracking error),
b) ΔV (velocity tracking error),
c) $\Delta \eta$ (azimuth tracking error),
d) $\Delta \varepsilon$ (elevation tracking error),

The general form of each of the four terms is a quotient of two numbers:

$$\Delta X = \frac{N}{D}$$

The numerator (N) and denominator (D) in each computation are formed by accumulating processed radar data over an interval of time. The RDP specifies this accumulation time interval in terms of the number of phases (FFT data gathering times).

In general, the terms are computed simultaneously for a number of targets.

12.8.1 Inputs

- Complex sum and difference terms (F_Σ, F_Δ) from Section 12.4. One set for each of $(N_f) \cdot (N_s)$ Range/Doppler cells.
- Addresses (range bin/filter number) for cells containing hits H(r,f) from Section 12.5.
- Addresses (range/bin Filter number) for cells containing velocity resolved hits, from Section 12.7.
- Tracking gate filter number and range bin number from RDP.
- Angle Identifier.
- Data accumulation time interval from RDP (number of phases).
- Spotlight II submode indicator from RDP.

12.8.2 Processing

The first step in processing is to select which Range/Doppler cells from the incoming data are to be used for discriminant calculations, and which are to be discarded. Figure 12.5.1 illustrates the incoming data cells for Spotlight II mode. (The region of N_f filters by N_s range bins shown in the figure is selected by previous processing). Recall that there were $3XN_f$ cells tested for Hit/Miss in Section 12.5. For each hit detected in Section 12.5, and passing the $\dot{R}$ resolver test in Section 12.7 a "discriminant complex" may be defined. Figure 12.8.1 illustrates the meaning of a discriminant complex.

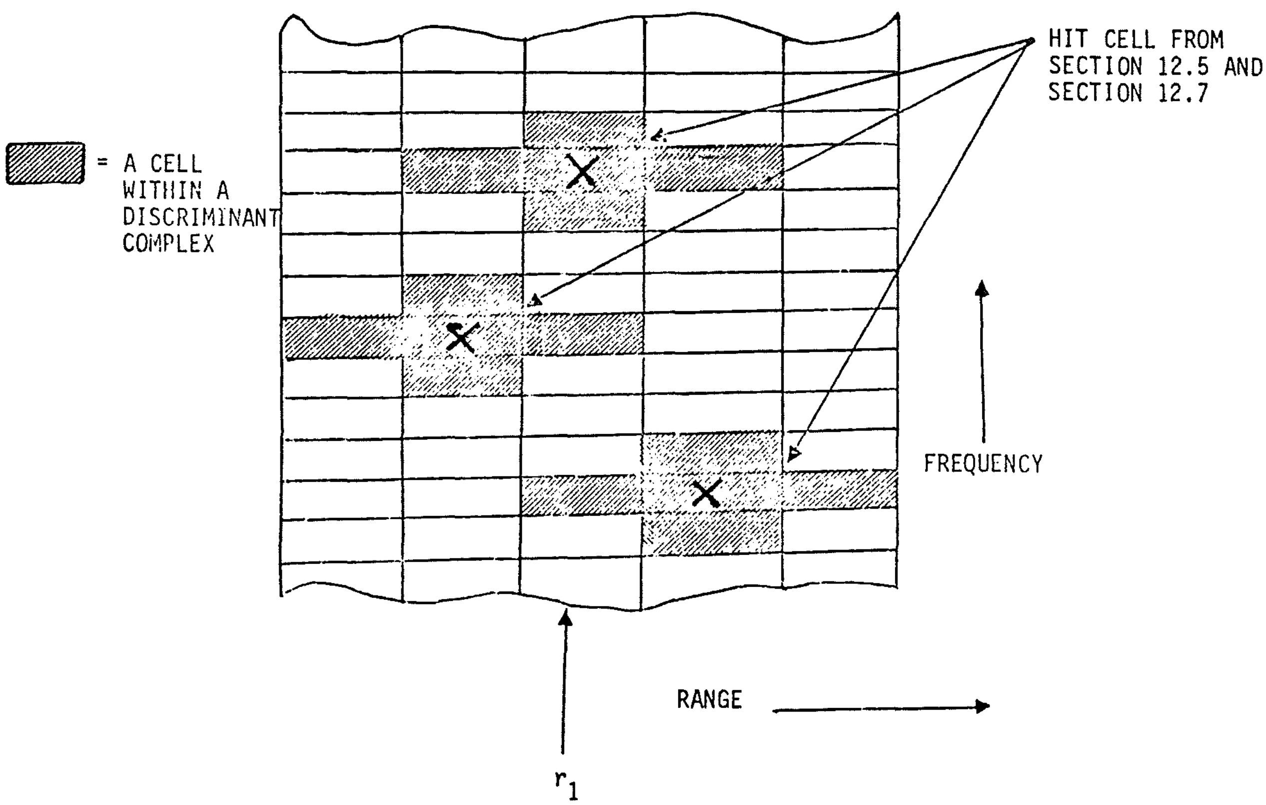


Figure 12.8.1 - DISCRIMINANT COMPLEXES

A special provision is made to guarantee that a discriminant complex is defined for the cells near the RDP commanded tracking gate. Figure 12.8.2 illustrates the discriminant complex for the tracking gate.

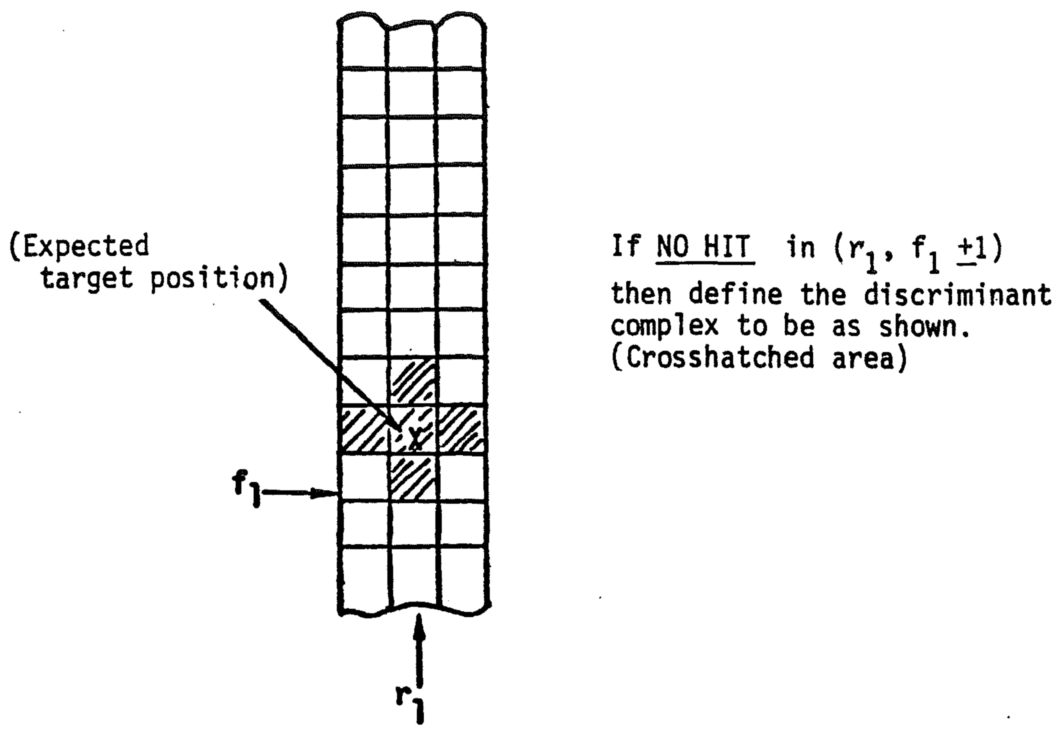


Figure 12.8.2

DISCRIMINANT COMPLEX FOR TRACKING GATE

A range/frequency address (r,f) should be retained for each discriminant complex identified. (These addresses would correspond to the "Xs" in Fiugre 12.8.1 and to (r_1, f_1) in Fiugre 12.8.2). A maximum of six discriminants, signal and noise data sets are formed from as many as n = 12 distinctive hits. The criterion for data set selection for those cases of n > 6 is the order that hits were found in Section 12.5.

The data from those cells which are included in a discriminant complex is retained. All other data is discarded. Discriminant computations are performed as follows: Recall that each discriminant cell contains two complex numbers F_Σ and F_Δ. Redefine the sets of cells to be indexed by (r,f) where:

$$\left.\begin{array}{c} F_\Sigma(r,f) \\ \text{and} \\ F_\Delta(r,f) \end{array}\right\} \begin{array}{l} \text{for the combinations } (r,f) \\ \\ \text{for each discriminant complex} \end{array} \left\{\begin{array}{l} r,\ f \pm 1 \\ \\ r_1 \pm 1,\ f \end{array}\right.$$

Form numerator and denominator terms for each range discriminant as:

$$N_r = \left|F_\Sigma(r_1-1,\ f)\right| - \left|F_\Sigma(r_1+1,\ f)\right|$$

$$D_r = (\quad) + (\quad) + \left|F_\Sigma(r_1,f)\right|$$

And calculate:

$$\Delta R = \frac{Nr}{Dr}\text{, for output to the RDP.}$$

Similarly, for the velocity discriminant form:

$$N_v = \left|F_\Sigma(r,f-1)\right| - \left|F_\Sigma(r,f+1)\right|$$

$$D_v = (\quad) + (\quad) + \left|F_\Sigma(r,f)\right|$$

and $$\Delta V = \frac{N_v}{D_v}\text{, for output to the RDP.}$$

Angle discriminants are formed by first examining the angle identifier associated with each phase of data. This identifier is available from the T&C function. The identifier indicates the settings of the $(0/\pi)$ phase shifter in the receiver and the Az/El switch in the antenna when each phase of data is gathered. One of four states (+Az, -Az, +El, -El) may be indicated. In order to form angle discriminants properly, one account for the sign of the identifiers.

For each azimuth or elevation phase, form:

$$\Delta n = \frac{-NA(+Az)}{DA(+Az)} \; ; \quad \Delta n = \frac{-NA(-Az)}{DA(-Az)}$$

$$\Delta \varepsilon = \frac{+NA(+El)}{DA(+El)} \; ; \quad \Delta \varepsilon = \frac{+NA(-El)}{DA(-El)}$$

where:

$$NA = F_{\Sigma} \cdot F_{\Delta}$$

$$DA = |F_{\Sigma}|^2$$

This discriminant is output to the RDP for each phase or Spotlight II, for either azimuth or elevation.

12.8.3 Outputs (For a maximum of six target hits)

- ΔR range discriminants to the RDP
- ΔV velocity discriminants to the RDP
- Either Δn azimuth discriminants to the RDP or
  $\Delta \varepsilon$ elevation discriminants to the RDP
- r,f discriminant range bin number and filter number for each set of the above four quantities. (r,f) = (0,0) means no hits.

12.9 Signal-to-Noise Ratio Estimate

The purpose of this function is to provide the RDP Program with the capability to compute estimates of target Signal-to-Noise Ratio (SNR) based on signal plus noise measurements made by the PSP. SNR estimates are made for the designated target tracking gate and up to five additional target hits.

12.9.1 Inputs

- $|F_\Sigma(r,f)|$ Sum magnitudes for $\pm$ Az, $\pm$ El

  where:

  $r = 0, 1, \ldots, N_S-1$

  $f = 0, 1, \ldots, N_f-1$

  $\pm$Az/El = Corresponds to the values of the Angle identifier as applied to data from each of the N_p pulse array periods of a phase.

- Range/frequency hit addresses (r,f) from Section 12.8.

12.9.2 Processing

Early and late noise estimates for sum quantities are computed for azimuth and elevation. Also, a signal estimate is computed. The resulting three outputs are sent to the RDP for use by the target trackers.

Figure 12.9.1 shows the data range/frequency cells of interest.

Early Σ Noise (+Az)

$$N_E(\Sigma, \pm \text{Az}) = \sum_{r',f'} \left| F_\Sigma(r',f', \pm \text{Az}) \right|$$

$r' = r-6, \ldots, r-3$

$f' = f-1, f, f+1$

Note: If the range cell (r in Figure 12.9.1) is less than 6 set all N_E terms equal to the N_L terms.

Early Σ Noise (+El)

Early Σ Noise ($\pm$ El) is formed similar to Early Σ Noise ($\pm$Az) except for ($\pm$Az) being replaced by ($\pm$El).

Late Σ Noise (+Az)

$$N_L(\Sigma, \pm Az) = \sum_{r',f'} \left| F_\Sigma(r', f', \pm Az) \right|$$

where:

$r' = r+2, \ldots, r+6$

$f' = f-1, f, f+1$

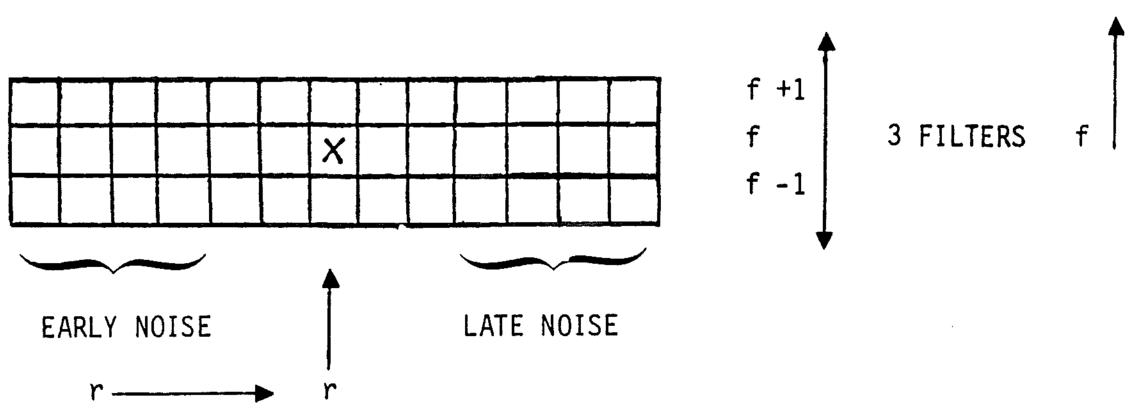
Note: If the range cell (r in Figure 12.9.1) is greater than 9, set all N_L terms to N_E terms.

Late Σ Noise (+El)

Late Σ Noise ($\pm$El) is formed similar to Late Σ Noise ($\pm$Az) except for ($\pm$Az) being replaced by ($\pm$El).

Signal

$$S(\Sigma) = \left| F_\Sigma(r,f) \right|$$



Where r,f are the range and velocity respectively of the target hit.

Figure 12.9.1 - TRACKING DATA FORMAT

Tilted Noise Estimate (N_T)

Form a "tilted" noise estimate for use by the SNR Filter function (Section 12.10) as follows:

$$N_T = \text{greater of} \left\{ \begin{array}{l} \displaystyle\sum_{r'=r-6}^{r-3} \left| F_\Sigma(r',f) \right| /4 \\[2ex] \displaystyle\sum_{r'=r+3}^{r+6} \left| F_\Sigma(r',f) \right| /4 \end{array} \right\}$$

12.9.3 Outputs

The following signals are outputs of this function to the target tracker in the RDP.

- $N_E(\Sigma, \pm Az)$; Early Σ Noise for $\pm Az$
- $N_E(\Sigma, \pm El)$; Early Σ Noise for $\pm El$
- $N_L(\Sigma, \pm Az)$; Late Σ Noise for $\pm Az$
- $N_L(\Sigma, \pm El)$; Late Σ Noise for $\pm El$
- S; Signal

The following quantity of this function is output to the SNR filter function (Section 12.10).

- N_T; "tilted" noise estimate.

12.10 Signal-to-Noise Ratio Filter

A post-processing function entitled Signal-to-Noise Ratio (SNR) Filter will test each unambiguous hit from the Velocity Resolver ($\dot{R}$ Resolver) function.

12.10.1 Inputs

- $|F_{\Sigma}(r,f)|$ Sum magnitudes for $\pm$Az, $\pm$El.
- N_T; "tilted" noise estimate from Section 12.9.

12.10.2 Processing

The quantity SNRTHRSH $\cdot$ N_T is formed for each hit (r,f) and the following test is performed to determine

If: $|F_{\Sigma}(r,f)| \geq \text{SNRTHRSH} \cdot N_T$

where: N_T is the "tilted" noise estimate for hit (r,f) from Section 12.9.

$|F_{\Sigma}(r,f)|$ is the sum channel magnitude for hit (r,f)

and SNRTHRSH = constant TBD.

If the hit fails the above test, it is deleted from the hit list; if the hit passes, no action is taken.

12.10.3 Outputs

A set of discriminant and hit data for hits passing the above test (maximum of 6 hits):

- ΔR range discriminants to the RDP
- ΔV velocity discriminants to the RDP
- Eitner Δn azimuth discriminants to the RDP, or $\Delta\varepsilon$ elevation discriminants to the RDP.
- r,f Discriminant range bin number and filter number for each set of the above four quantities. (r,f) = (0,0) means no hits.

12.11 Display Processing Function

The Display Processing Function shall interface between the RDP and the target memory for purposes of target display. This function shall be the same in the RAM Scan and Spotlight modes. The purpose of processing within this mode is to maintain the display based upon RDP inputs.

12.11.1 Inputs

- Target ranges from RDP.
- Target azimuth from RDP.
- Target symbology from RDP.
- Display control words from RDP.

12.11.2 Processing

The data flow during display processing is indicated in Figure 12.11.1. Data from RAM Scan is made available to the RDP for control of the RAM Spotlight II mode. In turn, resolved targets from RAM Spotlight II are tracked by the RDP and data for display is input to this function. The first 24 bits of Figure 12.11.2A are the input format from the RDP. The 3 bit intensity code is set to '111' by this function. Data from the RDP is formatted for TM2 as shown in Figure 12.11.2. During RAM Search processing, targets from previous RAM Spotlight II processing are maintained, by the RDP, stabilized, and compared with targets from current RAM Scan for redundant target elimination.

The six bit word code of Figure 12.11.2 shall be encoded with target symbols per Table 12.11.1. Symbol assignment shall be made by the RDP. RAM display scaling shall range from -248 to +248 display units (X,Y) with 00 representing screen center.

12.11.3 Outputs

- VSD data in the form of 134 48-bit Bulk Memory words as shown in Figure 12.11.2.

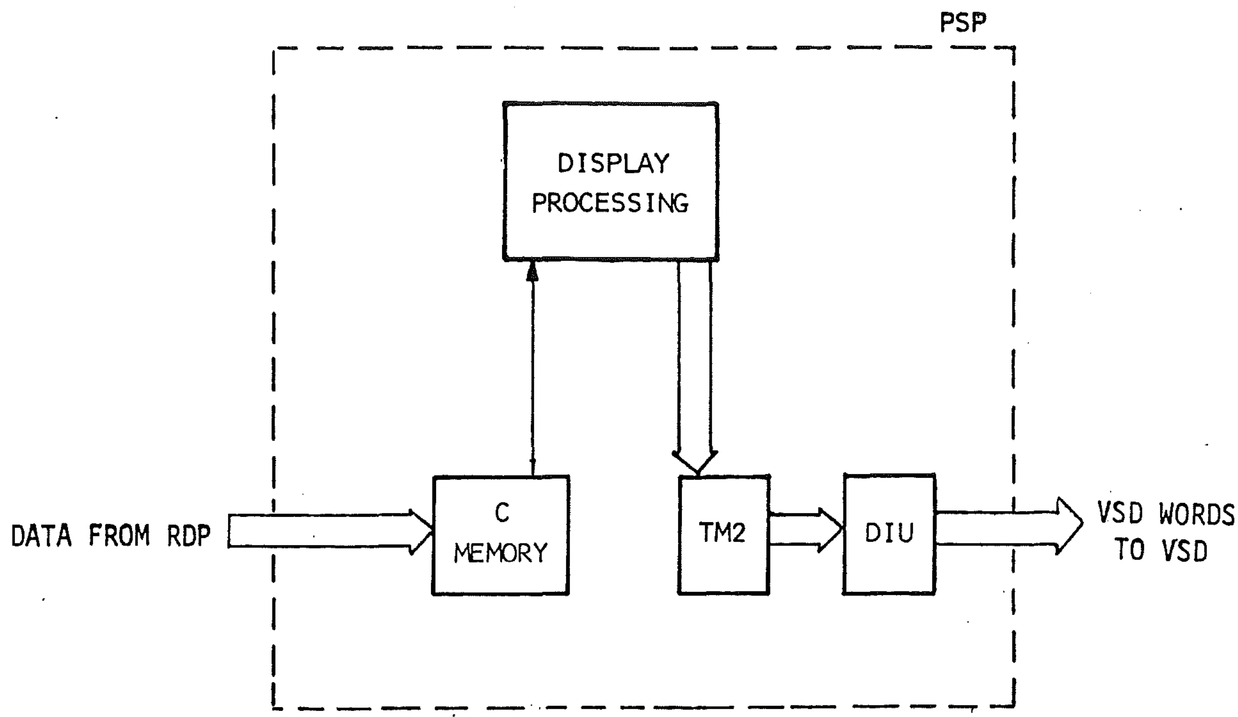


FIGURE 12.11.1

DATA FLOW BETWEEN THE PSP, RDP AND
THE VSD UNIT DURING DISPLAY PROCESSING

WORD #	PURPOSE	BIT POSITION 0–5	5–14	14–23	23–44	44–47
1 TO 128	TARGET WORDS	6 BITS SYMBOL CODE	9 BITS AZIMUTH POSITION (X)	9 BITS RANGE POSITION (Y)	NOT USED	3 BITS INTENSITY

A) TARGET WORDS

		0–3	3–5	5–14		14–23	24 to 44	45	46	47
129	RNG/VEL SCALE	0 1 0 0	0 0	RNG/ VEL SCALE	0 0 0 0 0 0	0 0 0 0 0 0 0 0 0	NOT USED	1	1	1
130	CURSOR POSITION	0 1 0 1	0 0	X POSITION		Y POSITION	NOT USED	1	1	1
131	ANT. AZ. POSITION	0 1 0 1	0 0	X POSITION		1 0 0 0 1 0 1 1 0	NOT USED	1	1	1
132	ANT. EL. POSITION	0 1 0 1	0 0	1 0 0 0 1 0 1 1 0		Y POSITION	NOT USED	1	1	1
133	BIT WORD #1	0 1 0 1 or 0 0 0 0	0 0	1st CHARACTER	2nd CHARACTER	3rd CHARACTER	NOT USED	1	1	1
134	BIT WORD #2	0 1 0 1 or 0 0 0 0	0 0	4th CHARACTER	5th CHARACTER	6th CHARACTER	NOT USED	1	1	1

B) DISPLAY SYMBOL WORD

Figure 12.11.2 - TM2 BULK MEMORY WORDS

TABLE 12.11.1 - RAM DISPLAY SYMBOLOGY

NAME	SYMBOL	SYMBOL CODE BITS					
		0	1	2	3	4	5
RAM MPRF TRACKED TARGET	▒	0	0	0	1	0	0
RAM MPRF SPECIAL TARGET	X	0	0	0	1	1	1
RAM MPRF UNTRACKED SINGLE TARGET	▭	0	1	1	0	1	0
RAM MPRF UNTRACKED MULTIPLE TARGET	▯	0	1	1	1	0	1
RAM HIGH ALTITUDE TARGET IN SPECIAL DISPLAY	△	0	1	1	1	0	0
RAM LOW ALTITUDE TARGET IN SPECIAL DISPLAY	▽	0	1	1	0	1	1

12.12 Clutter Doppler Error Processor

The Clutter Doppler Processor is used in the RAM Spotlight II mode. The processor takes radar return signals from the Analog Radar Signal Processor (ARSP 039 Unit) before the signals pass through the Clutter Canceller. The Clutter Doppler Error (CDE) computation measures the error incurred in shifting the Main Lobe Clutter (MLC) to dc frequency. The processor uses the radar returns from eight non-blanked range bins and measures the phase shift of the return in relation to the last sample from the same range bin for the frequency discriminant computation. It is also required to send the Number of Valid Samples (NVS) used in the CDE computation to the RDP for MLC Tracking. The CDE is used by RDP to derive the correct setting of the Voltage Controlled Oscillator (VCO).

12.12.1 Inputs

- Radar Samples in the non-pause phase of each PRF (48 PRI interval) with data rate at one data set (32 PRI) per PRF.
- CDE gate from RDP.
- Threshold frequency discriminant k_C and amplitude discriminant A_C for CDE sample data validation.

12.12.2 Processing

The CDE buffer accumulates the last 32 non-blank pulses in each N_p pulse data interval. Only the last 32 pulses in the non-pause phases are used for the CDE computation. In each of the intervals, there are 8 range bins in which the CDE processor searches for the MLC returns.

Timing and Control supplies the CDEP with the 8 range bins per PRF to be processed. The CDE processor uses the radar sample data to compute the Clutter Doppler Error discriminant, and performs validity tests to verify the CDE result. After the validation, the CDE value and NVS are sent to the RDP for tracking MLC.

The frequency discriminant, f_d, of these 32 pulses can be computed from the complex products of consecutive pulse-pairs from the same range bin.

$$f_d = \frac{In}{Qn} = \frac{\sum_{i=0}^{30} Im(Z_{i+1} \cdot \overline{Z}_i)}{\sum_{i=0}^{30} Re(Z_{i+1} \cdot \overline{Z}_i)}$$

where:

I_i, Q_i	=	I and Q components of a delayed sample
I_{i+1}, Q_{i+1}	=	I and Q components of a current sample
Z_{i+1}	=	current sample = $I_{i+1} + jQ_{i+1}$
Z_i	=	delayed sample = $I_i + jQ_i$
$\overline{Z}_i$	=	complex conjugate = $I_i - jQ_i$

The validation of the frequency discriminant by amplitude test and/or frequency test depends on the state of the CDE gate command from the RDP.

If the MLC returns are close to dc line (narrow clutter doppler error gate case), the frequency discriminant f_d must satisfy both the amplitude test and the frequency test.

$$\left| \sum_{i=0}^{30} I_m(Z_{i+1} \cdot \overline{Z}_i) \right| < k_c \sum_{i=0}^{30} Re(Z_{i+1} \cdot \overline{Z}_i): \text{ Phase Test}$$

and

$$\sum_{i=0}^{30} Re(Z_{i+1} \cdot \overline{Z}_i) > A_c^2 : \text{ Amplitude Test}$$

where:

k_c = tan 30^0

A_c^2 = -27 dB from A/D converter saturation.

If the main lobe clutter is far off from the dc line (wide CDE gate) and both amplitude and phase tests are satisfied, f_d is computed as in the narrow gate case. If only the amplitude test is satisfied, f_d is computed.

$$f_d = 0.1 \operatorname{sgn} \left[\sum_{i=0}^{30} \operatorname{Im}(Z_{i+1} \bullet \overline{Z}_i) \right]$$

If both tests fail the sample is rejected.

The verified f_d is then used to compute the Clutter Doppler Error (CDE) as follows:

$$CDE = (NVS)\ f_d = 31\ f_d$$

where: CDE = clutter doppler error

NVS = number of valid sample pairs used in the CDE calculation = 31

12.12.3 Outputs

- Clutter Doppler Error (CDE) to RDP.
- Number of valid samples (NVS) used in the computation to RDP via IDA.

SECTION 13

HPRF RAM STT MODE

13.0 INTRODUCTION

This document presents the PSP software requirements for the HPRF RAM Single Target Track (STT) Mode. The PSP-STT software has two parts. The first part deals with the monopulse doppler signal processing of the radar returns to obtain the following data:

a) Angle velocity discriminants,
b) angle ratio thresholds, and
c) signal/noise information associated with the discriminants.

The second part deals with the Display Processing, which consists of the IFF target correlation and the Vertical Situation Display (VSD) data formatting. Figure 13.1 shows the functional diagram for these operations. The following paragraphs briefly describes the PSP input characteristics.

The input signal for the STT Mode represents a passband around the tracked target's doppler frequency. The signal comes from the Track 1 and Track 2 receiver channels. The analog signal processor (039 Unit) takes the signal through a two stage frequency translation and a 2 kHz band pass (speed gate) filtering to produce the PSP input. During the frequency translation, the 039 unit constantly applies VCO control to hold the tracked target's doppler at the center of the speed gate. Figure 13.2 shows the frequency characteristics of the PSP input.

For the STT monopulse doppler signal processing, the PSP input is sampled at 7.44 kHz and the samples are collected over each 34.408 msec period. Associated with each sample is an AZ/EL angle code that switches once every 8.602 msec.

The details of the functional diagram in Figure 13.1 are presented in the following sections.

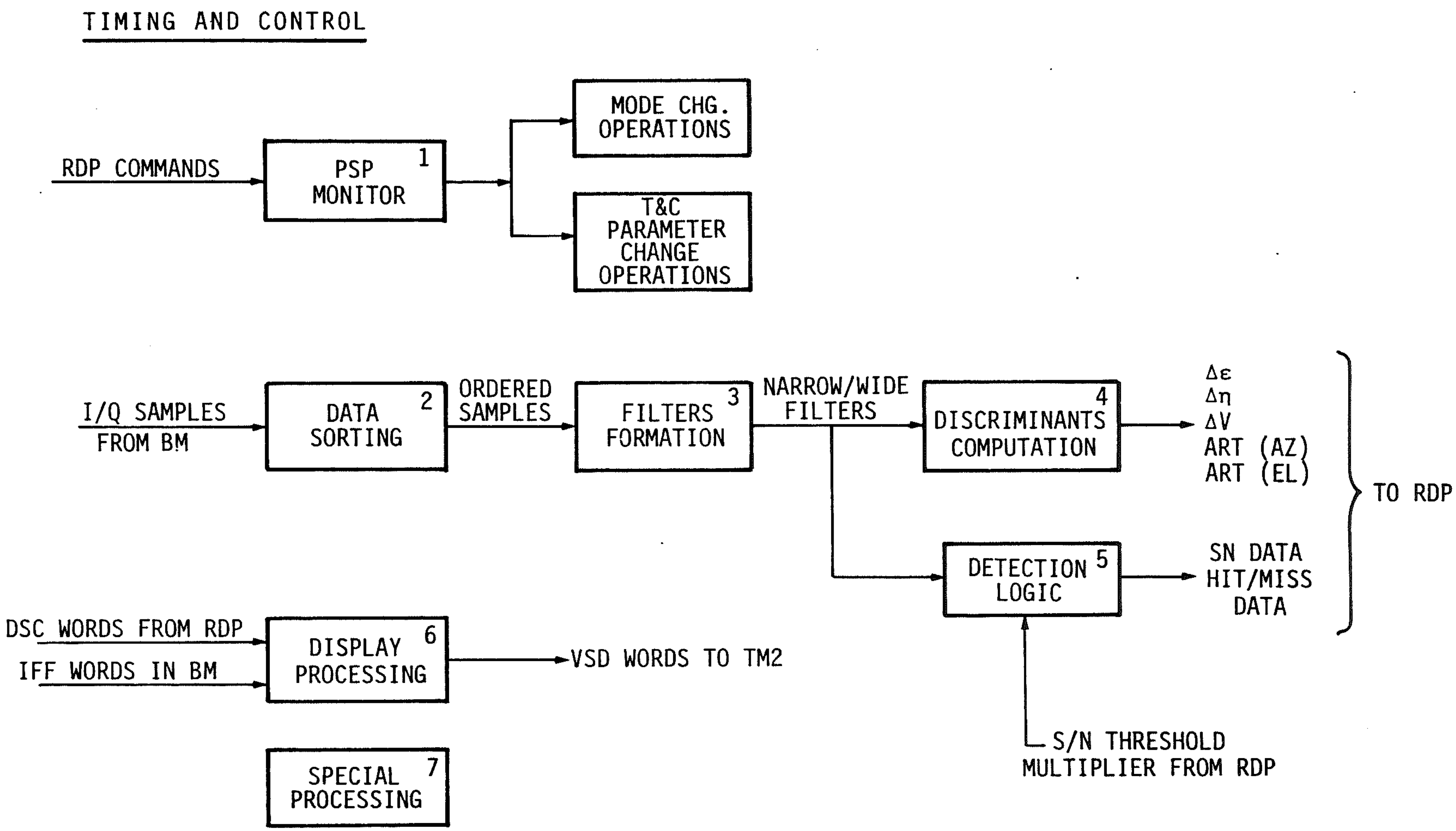


Figure 13.1 - STT RAM HPRF FUNCTIONAL DIAGRAM

13.1 Timing and Control

The Timing and Control (T&C) Function in the PSP is handled by the PSP Executive Program. The objective of the function is to properly refresh the T&C parameters and the control memories of the T&C unit such that correct synchronization and timing signals issue from the T&C unit and the C-Memory to the following destinations:

1.	PSP	(042)
2.	RDP	(081)
3.	Exciter	(001)
4.	Transmitter	(011)
5.	Receiver	(022)
6.	Antenna	(031)
7.	Analog Signal Processor	(039)

The T&C of the Display Interface Unit (DIU), the Test Target Generator (TTG), and the IFF Reply Evaluator (IRE) do not come under the control of this function. These modules are regulated by the appropriate control words that are in the C-Memory, and are managed by the RDP. For the HPRF STT Mode, the VCO commands go to the 039 unit from the C-Memory without PSP software actions. The VCO commands (VCO Control Word) are also managed by the RDP.

The T&C function in the PSP for the STT Mode is executed once at the start of each 34.408 msec. (One PSP period) as described below.

13.1.1 Input

- 8 PSP Words
- 8 DIU Words
- IRE Control Word
- IDC Control Word
- VCO Control Word

13.1.2 Processing

The T&C function consists of the following:

- Mode Change Detection Logic

- Timing Program Change (Task A)
- T&C Parameters Change (Task B)

The next three sections describe the components of this function.

Figure 13.3 illustrates the data flow involved in the T&C function. Figure 13.4 supplements Figure 13.3 and it shows the contents of the C-Memory.

13.1.2.1 Mode Change Detection Logic

The parameters that are used in this logic are:

1. M_{new} = $[\text{PSP-Word-1}]_{0-7}$; new mode code,
2. M_{curr} = current mode code,
3. RC = $[\text{PSP-Word-1}]_{12}$; reset command.

The Mode Change Detection Logic is given in Figure 13.5. Three significant features of this detection logic are:

1. When the mode change occurs, ($M_{new} \neq M_{curr}$), the Executive Program issues the Force Load and Force Select commands to the T&C and IDC modules only after the new timing programs and the new T&C parameters have been loaded into the C-Memory.
2. When there is no mode change, ($M_{new} = M_{curr}$), and the Reset Command is set, (RC=1), the Executive Program treats the current mode like a new mode. In this case, the Executive Program steps through both Task A and Task B.
3. When only Task B is required, the updated T&C parameters go to the appropriate hardware modules (Section 13.1) on the next T&C Load Request that comes from the T&C Module (Figure 13.6b).

13.1.2.2 T&C Task A

Associated with each radar mode there exists a timing program and four control words that are stored in the PSP Bulk Memory (BM). When

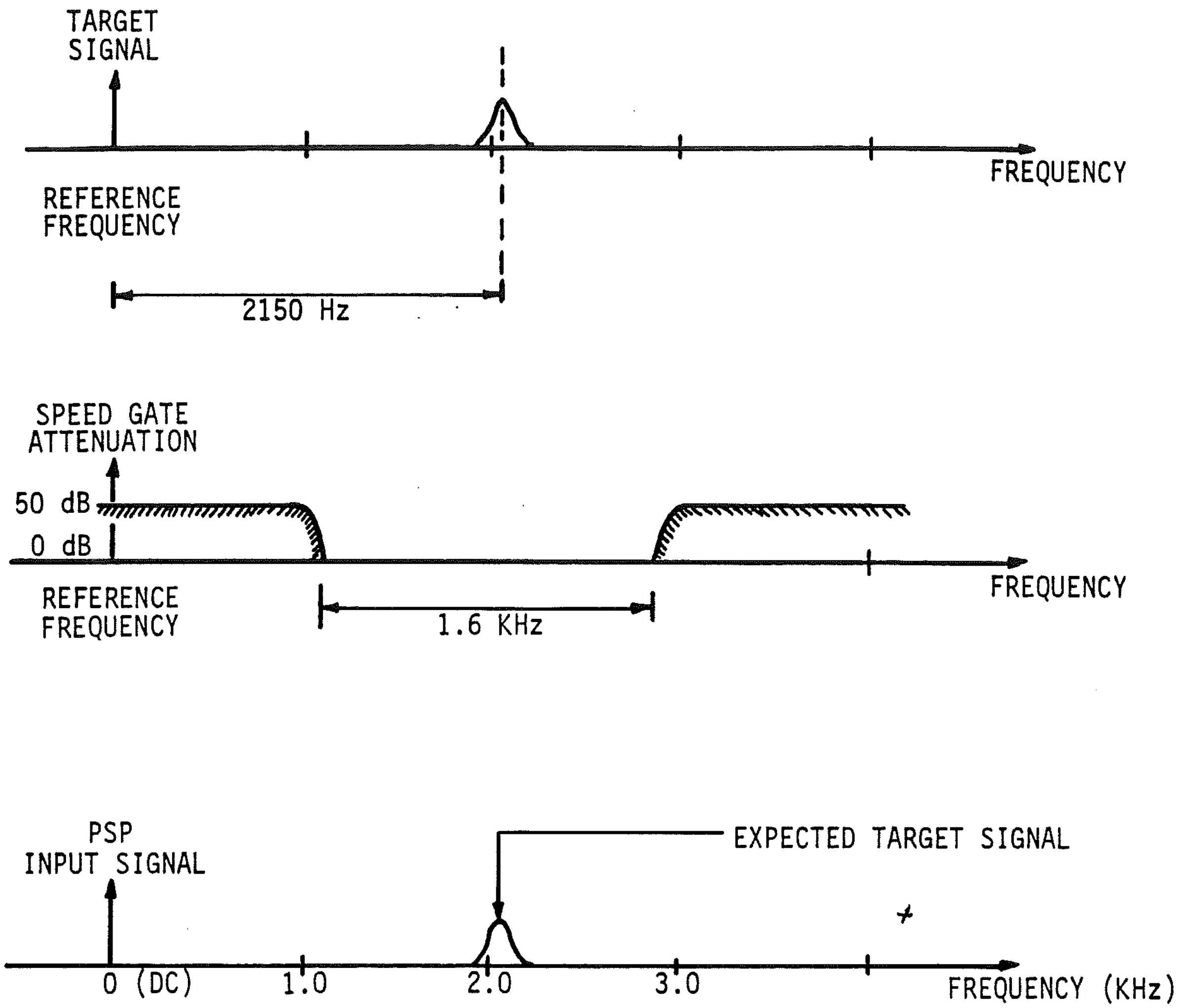


Figure 13.2 - TRACKED TARGET SIGNAL AND THE SPEED GATE

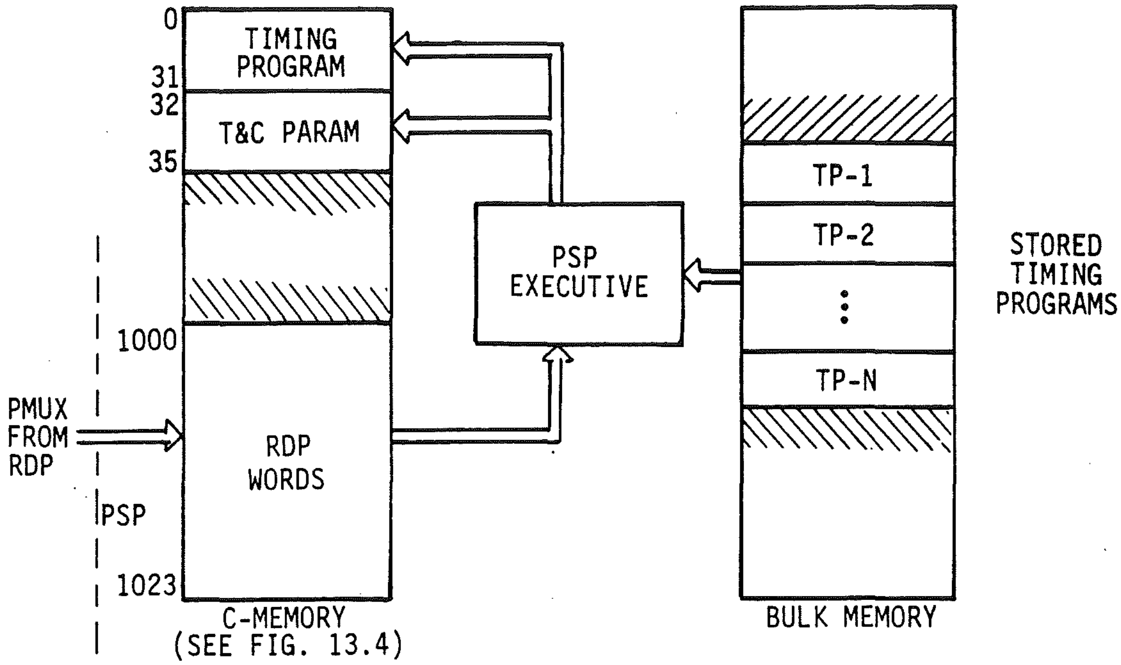


FIGURE 13.3.a – DATA FLOW FOR THE T&C FUNCTION - HPRF RAM STT MODE

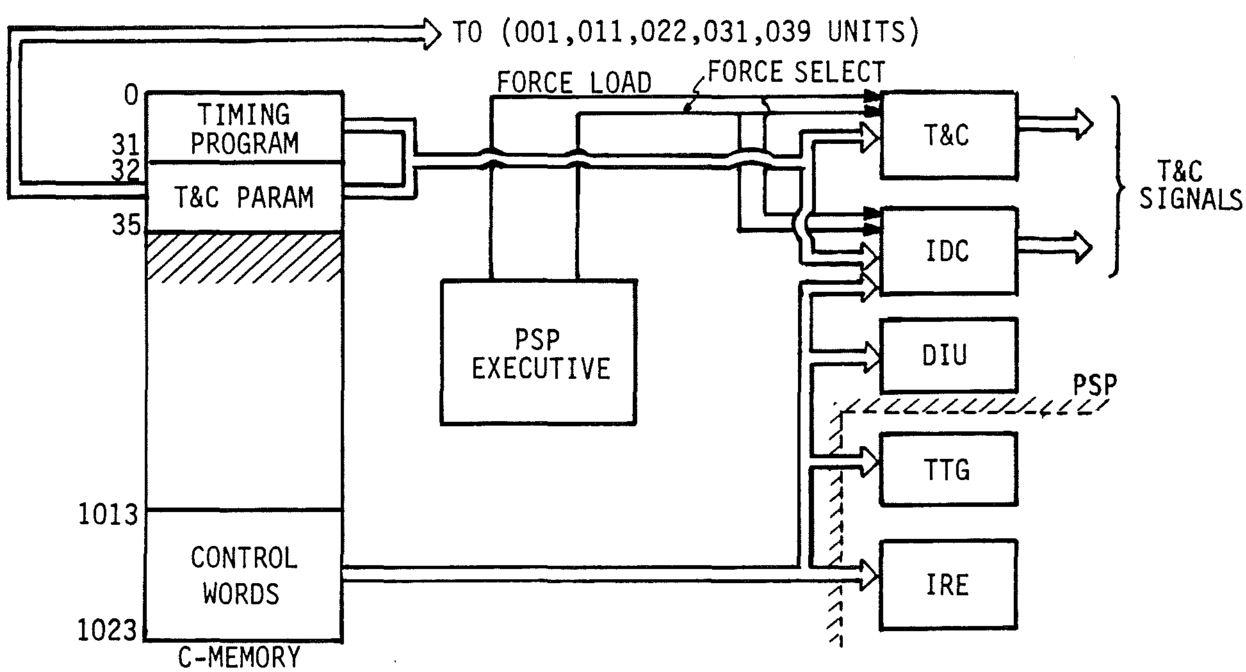


FIGURE 13.3.b – DATA FLOW FOR THE T&C FUNCTION-HPRF RAM STT MODE

ADDRESS	CONTENTS
0-15	TIMING PROGRAM FOR EVENT GENERATOR #2
16-31	TIMING PROGRAM FOR EVENT GENERATOR #1
32	T&C CONTROL WORD 2
33	T&C CONTROL WORD 1
34	IDC & TTG CONTROL WORD
35	EXTERNAL CONTROL WORD
985-999	IDA WORDS
1000-1007	PSP WORDS
1008-1012	DSC WORDS
1013-1020	DIU WORDS
1021	IRE CONTROL WORD
1022	IDC CONTROL WORD
1023	VCO CONTROL WORD

FIGURE 13.4 - C- MEMORY MAP

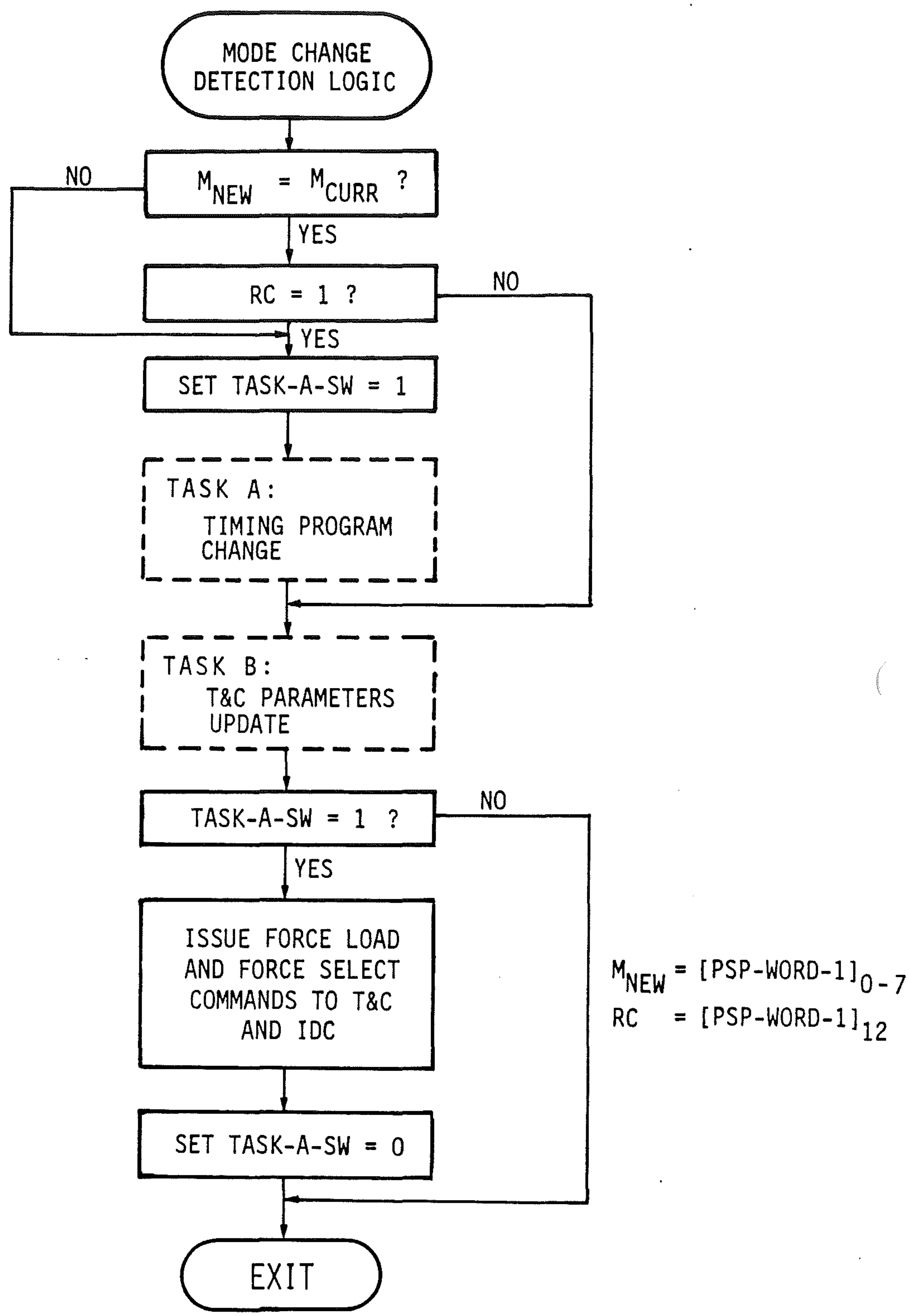
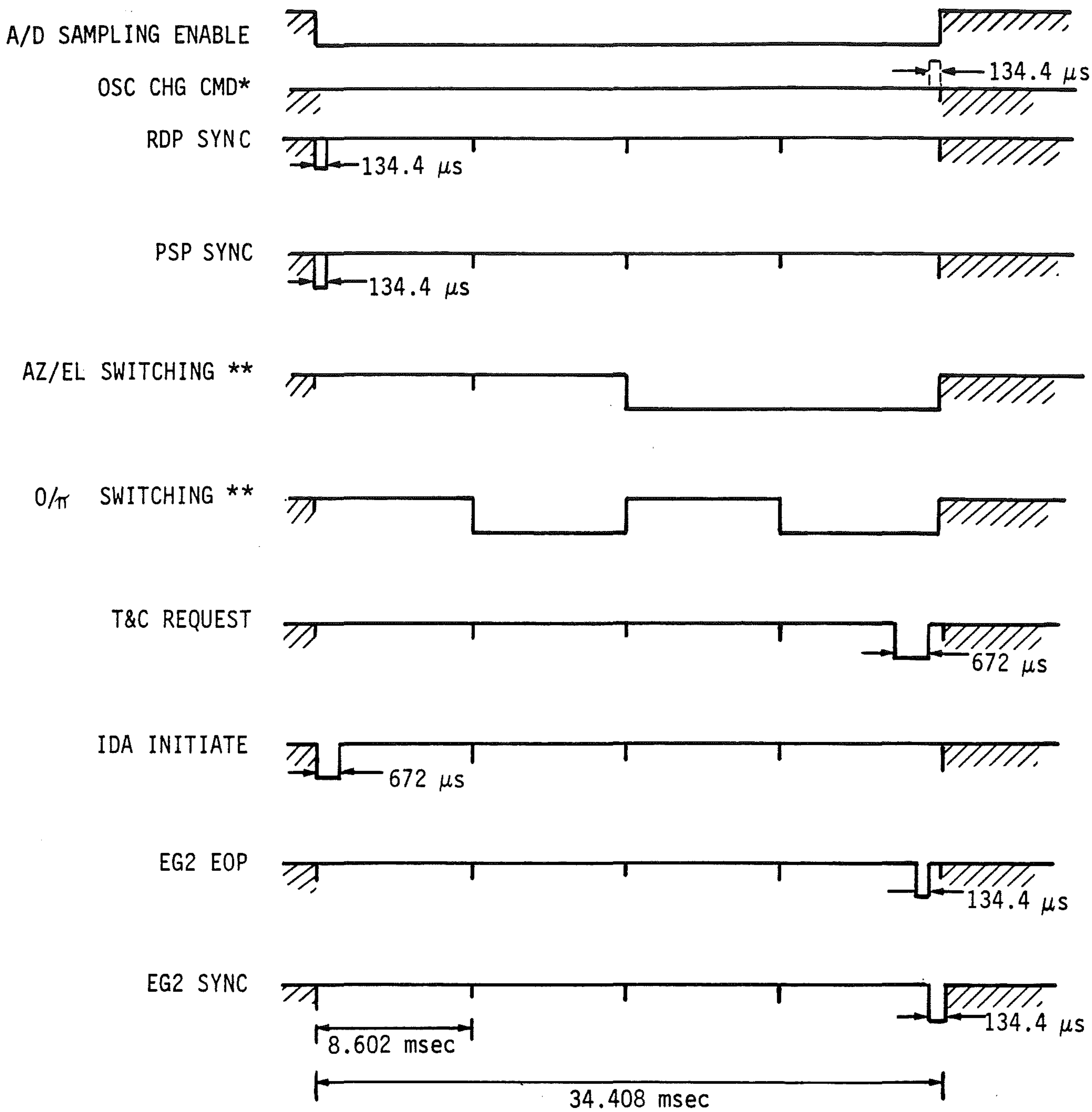


FIGURE 13.5 - MODE CHANGE DETECTION LOGIC



*THIS COMMAND CAN BE CHANGED DURING T&C TASK B, INITIALLY THE OSC CHG CMD IS LOW.

**THESE SIGNALS CAN BE CHANGED BY RDP DURING THE T&C PARAMETERS UPDATE, THE UPDATE WILL NOT UPSET THE SWITCHING RATE OF ONCE EVERY 8.602 msec.

FIGURE 13.6b - TIMING SIGNALS FROM EVENT GENERATOR TWO the T&C Task A is called, the PSP Executive brings out the timing program and the control words designated by the new mode, $[\text{PSP-Word-1}]_{0-7}$, into the predefined locations in the C-Memory. (See Figure 13.4). The timing program refers to the programs for the two events generators in the T&C Module. For the HPRF STT Mode the timing program shall be designed to provide the signals as shown in Figure 13.6.

The timing program for Event Generator One (EG1) shall allow one set of I/Q samples from Track 1 and Track 2 channels to enter the Bulk Memory once every 134.4 μs (7440 Hz). EG1 shall be clocked at 156.25 kHz. This clock rate is given by the T&C Control Word 1 below. Event Generator Two (EG2) shall be clocked at the EG1 sync rate which is 7440 Hz.

Figure 13.6 shows that the EG1 timing has only four events while the EG2 timing has nine events.

The stored control words are:

1. T&C Control Word 1
2. T&C Control Word 2
3. IDC & TTG Control Word
4. External Control Word

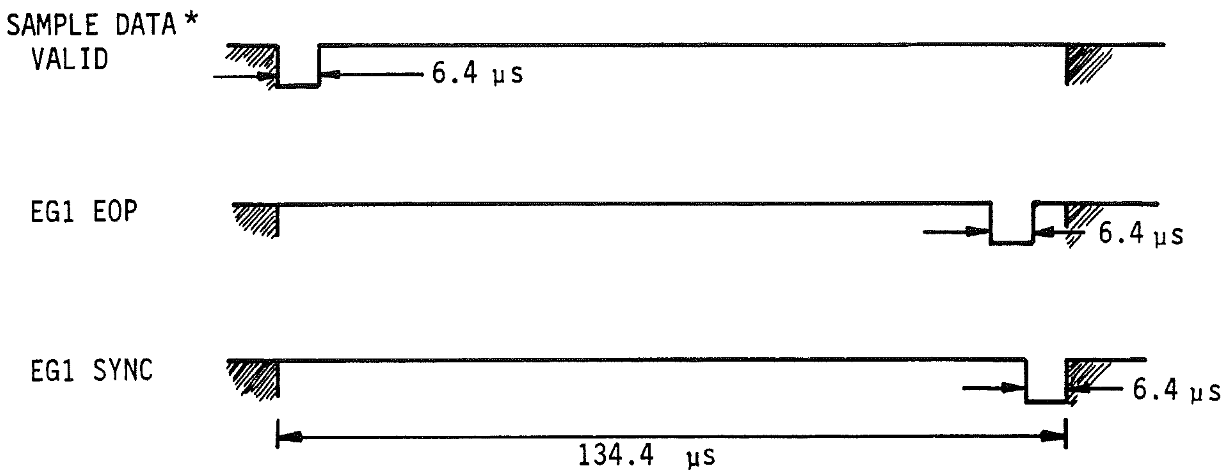
For the HPRF STT Mode, these control words shall be set as shown in Figure 13.7. Also shown in these figures are the hardware units that are affected by the contents of these words.

13.1.2.3 T&C Task B

Two kinds of T&C parameter changes can occur during the STT Mode and they are:

1. Oscillator Selection change, and
2. Track Angle Sequence change.

Task B responds to these changes as described below. (Also see Figure 13.8).



* SAME AS BIN DATA VALID SIGNAL

FIGURE 13.6a - TIMING SIGNALS FROM EVENT GENERATOR ONE

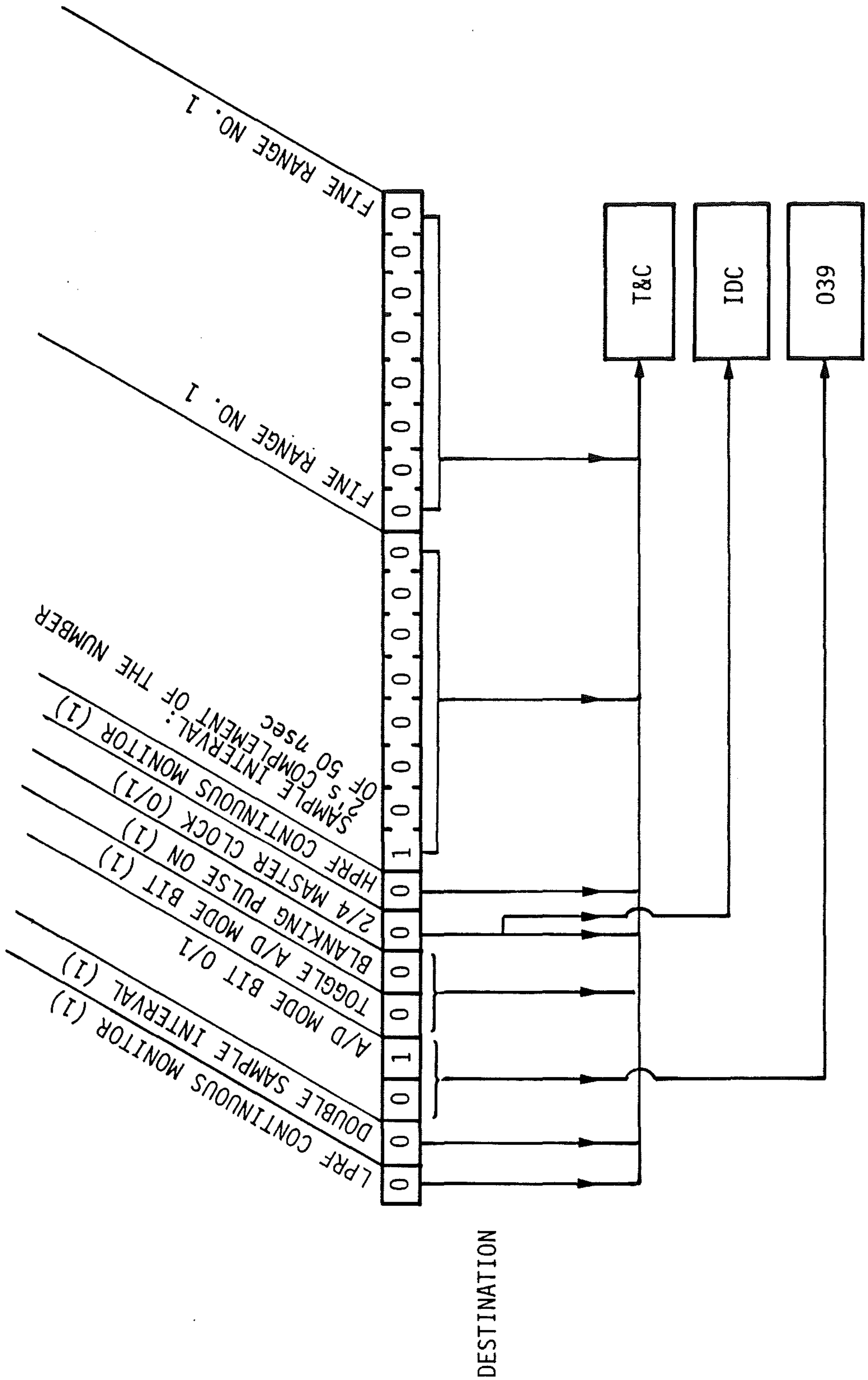


Figure 13.7a - T&C CONTROL WORD 1 FOR HPRF RAM STT MODE

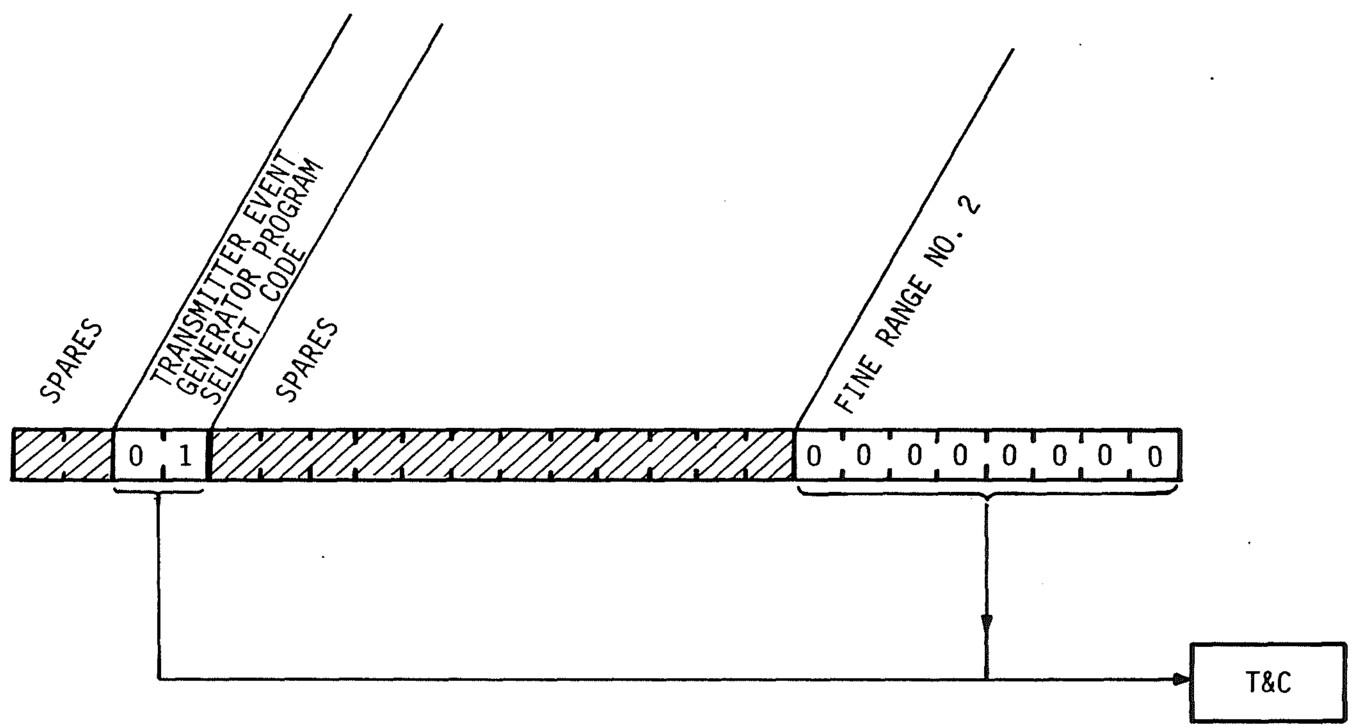


Figure 13.7b - T&C CONTROL WORD 2 FOR HPRF RAM STT MODE

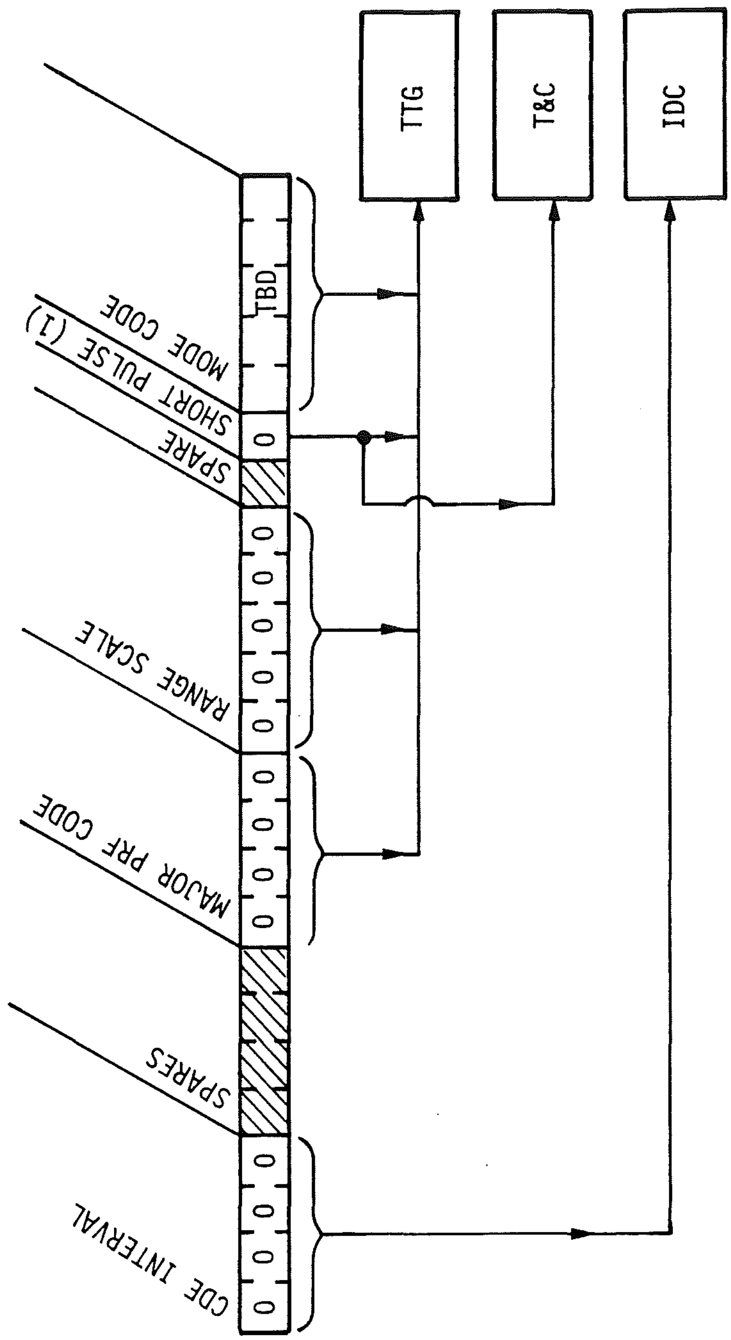
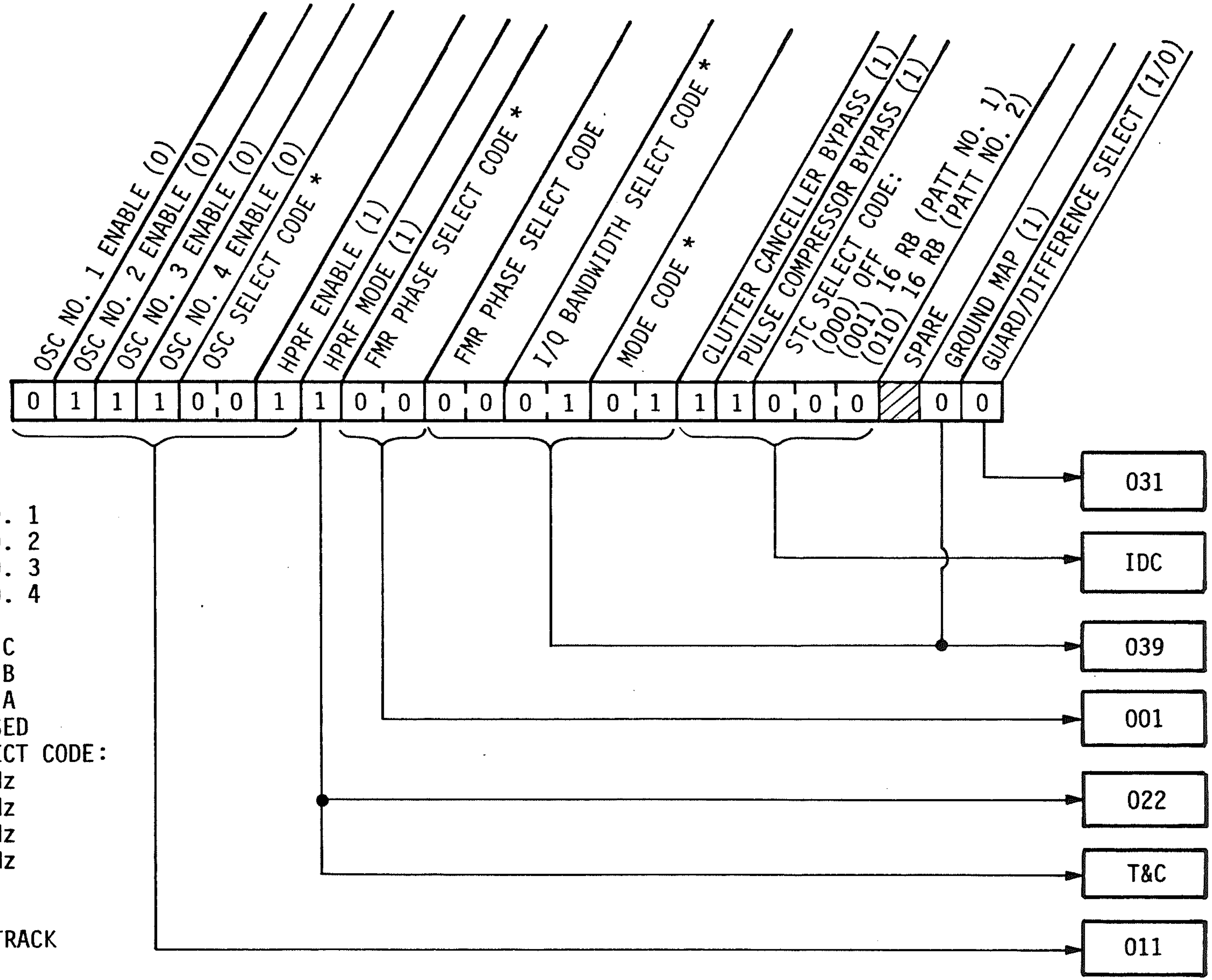


Figure 13.7c - IDC AND TTG CONTROL WORD FOR HPRF STT MODE



*OSC SELECT CODE:
(00) = OSC NO. 1
(01) = OSC NO. 2
(10) = OSC NO. 3
(11) = OSC NO. 4

FMR SELECT CODE:
(00) = PHASE C
(01) = PHASE B
(10) = PHASE A
(11) = NOT USED

I/Q BANDWIDTH SELECT CODE:
(00) = 75 kHz
(01) = 200 kHz
(10) = 100 kHz
(11) = 500 kHz

MODE CODE:
(00) = LPRF
(01) = HPRF TRACK
(10) = MPRF
(11) = HPRF SEARCH

Figure 13.7d - EXTERNAL CONTROL WORDS FOR HPRF RAM STT MODE

13.1.2.3.1 Oscillator Selection Change

The parameters used in this operation are:

1. OSC_{new} = [PSP-Word-5]$_{8-9}$; oscillator select code from RDP
2. OSC_{curr} = current oscillator in use
3. ECW_k = oscillator (k=0, ..., 3) enable bit in the External Control Word
4. ECW_{4-5} = oscillator select code in the External Control Word
5. OCC(9,EG2) = oscillator change command in event 9 of EG2 Timing Program
6. OSC-CHG-SW = oscillator change switch

The logic for the Oscillator Selection Change is shown in Figure 13.8a. When an oscillator change occurs, the PSP Executive will enable the desired oscillator by properly setting the External Control Word (ECW), and it will set high the Oscillator Change Command in the 9th event of the EG2 program. Before going to the next operation the Executive will set a flag indicating that an oscillator change has occurred and it will remember the current oscillator number for the next RDP sync. On the next RDP sync, the Executive will disable the oscillator that is no longer needed and it will also disable the oscillator change command in the EG2 program.

13.1.2.3.2 Track Angle Sequence Change

The following parameters are defined for this operation:

1. TAS_{new} = [PSP-Word-1]$_{21-22}$; new Track Angle Sequence Code
2. TAS_{curr} = current Track Angle Sequence Code
3. TABLE-A = Track Angle Sequence Table; function of TAS code
4. TABLE-B = $0/\pi$ Switching Sequence; function of TAS code

5. Angle (k,EG2) = Angle state at the kth event of EG2 Program

6. $0/\pi$(k,EG2) = $0/\pi$ state at the kth event of EG2

The logic for the Track Angle Sequence change is shown in Figure 13.8b. When this change occurs, the PSP Executive looks up TABLE-A and B for the correct Angle Sequence and the $0/\pi$ states associated with the new Track Angle Sequence. The results of the table look-up are used to update the angle and the $0/\pi$ states of the EG2 program. Before leaving Task B, the Executive sets TAS_{curr} to TAS_{new} for the next RDP sync.

13.1.3 Output

- Timing and Control signals for HPRF RAM-STT Mode.

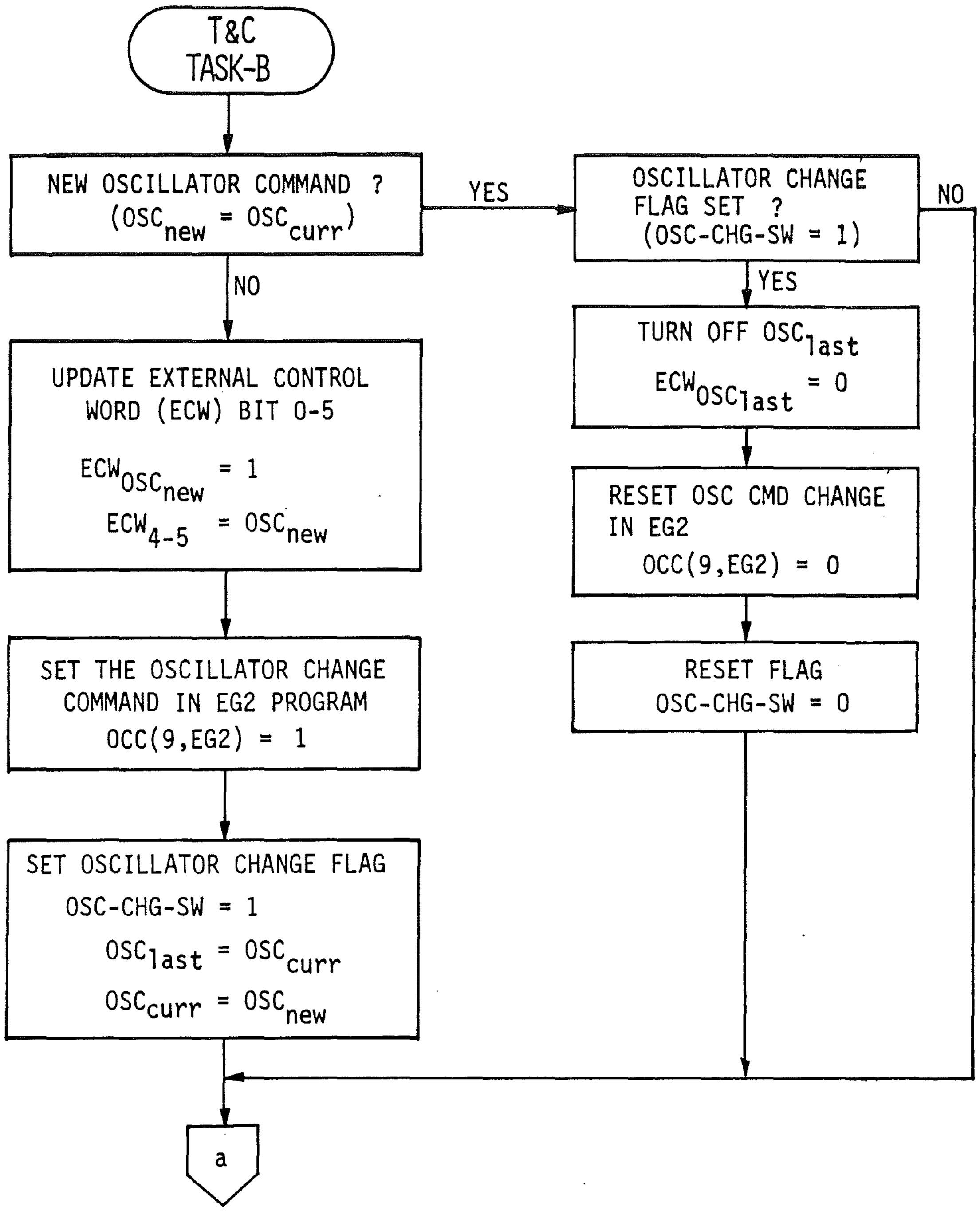
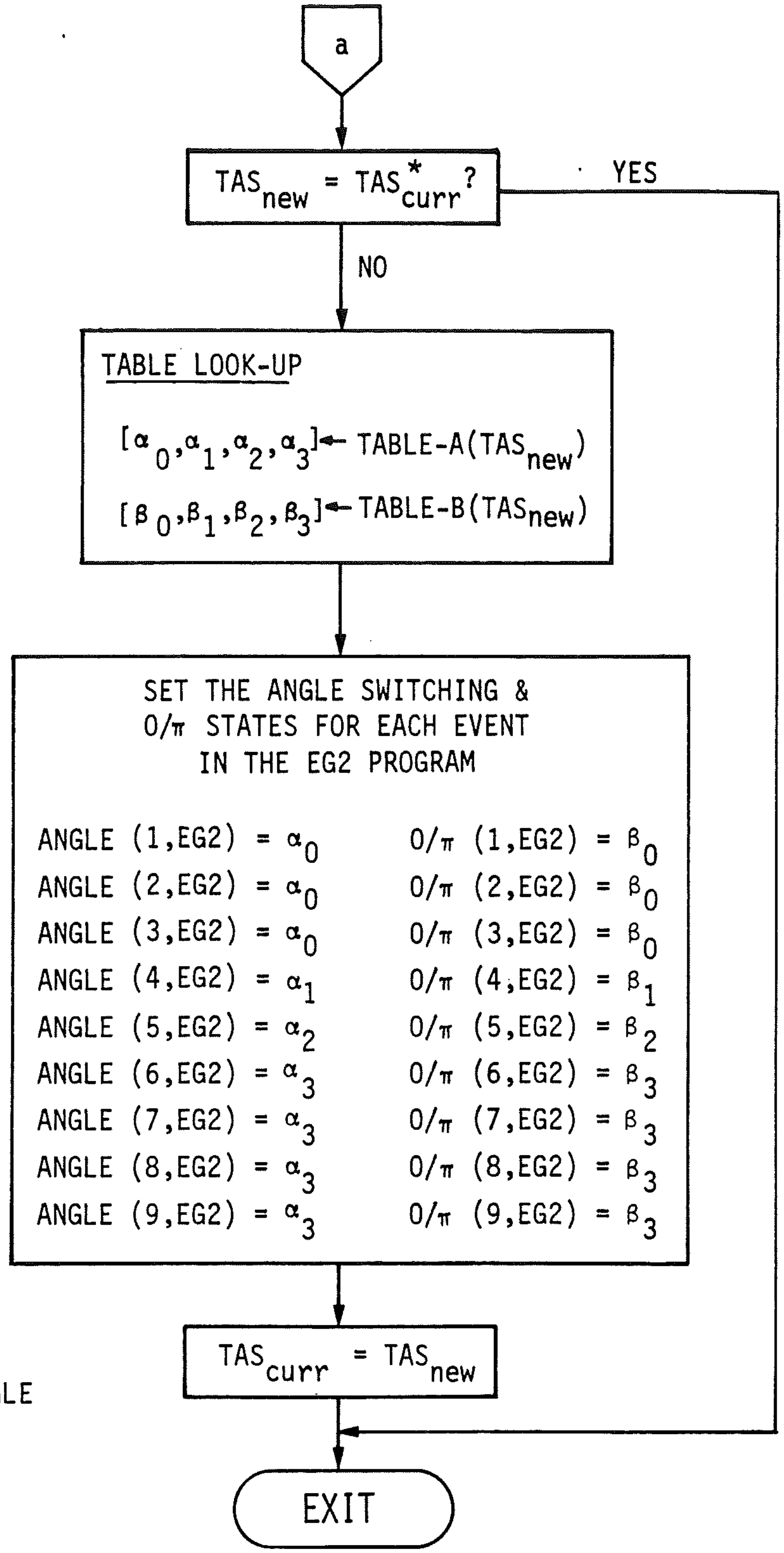


Figure 13.8 a - T&C TASK B - OSCILLATOR SELECTION CHANGE



* TAS = TRACK ANGLE SEQUENCE

Figure 13.8 b - T&C TASK B - TRACK ANGLE SEQUENCE CHANGE

13.2 Data Sorting

The incoming data are two sets of 256 I/Q samples that have been collected over the last PSP period of 34.408 msec. These samples come from Track 1 and Track 2 channels respectively. During that period, the AZ/EL angle switching has occurred four times. (See Figure 13.9). The purpose of Data Sorting is to identify the samples associated with each angle switching period.

13.2.1 Input

- Two sets of 256 I/Q samples from Track 1 and Track 2 channels:

$$\{S_n(i,T) \mid i = 0, \ldots, 255, T=1,2\}$$

where:

i = sample number
T = Track channel

- Angle Switching Sequence: $\{\phi_0, \phi_1, \phi_2, \phi_3\}$

13.2.2 Processing

Data Sorting begins by separating the input samples into eight groups as follows:

$$\{S_w(\ell, 2, \phi_k)\} = \{S_n(\ell + 64k, T) \mid \ell = 0, \ldots, 63; T = 1, 2\}$$

where: $k = 0, \ldots, 3.$

Each group consist of 64 samples and each group is identified by a track index T and an angle code $\phi_k \varepsilon \{\pm AZ, \pm EL\}$. The angle sequence $\{\phi_0, \phi_1, \phi_2, \phi_3\}$ can be any permutation of $\{+AZ, -AZ, +EL, -EL\}$, and this sequence is controlled by the RDP. After the four groups of data

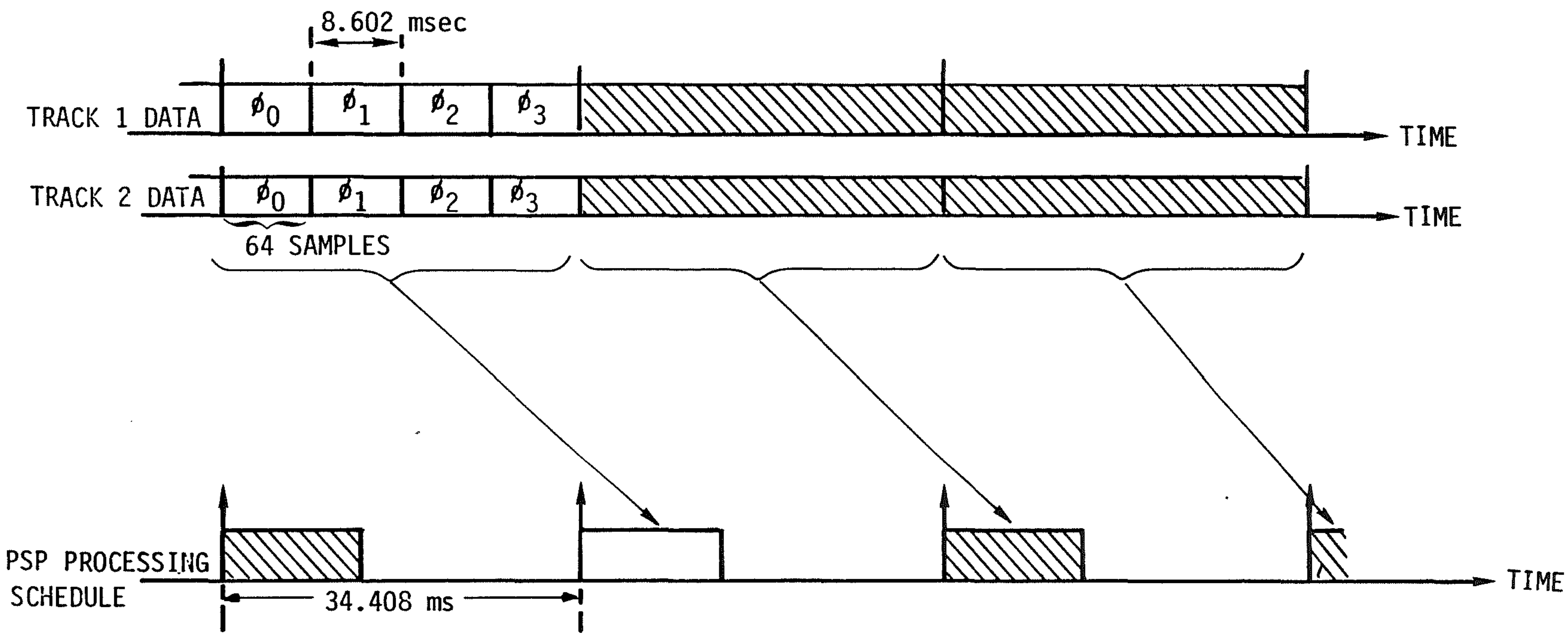


FIGURE 13.9 - THE RELATION BETWEEN THE PSP PROCESSING SCHEDULE AND THE TRACK 1/2 DATA

for each track have been formed as above, the Data Sorting concludes by updating $\{\phi_k\}$ with the angle sequence of the track samples that are being collected during the current PSP period.

13.2.3 Output

- Two sets of 256 I/Q samples from Track 1 and Track 2 channels:

$$\{S_n(i,T) \mid i=0, \ldots, 255, \quad T = 1,2\}$$

- Eight angle groups:

$$\{S_w(\ell, T, \phi) \mid \ell=0, \ldots, 63; \; T = 1,2: \; \phi \varepsilon \; \{\pm AZ, \pm EL\} \}$$

- Updated Angle Switching Sequence

$$\{\phi_0, \phi_1, \phi_2, \phi_3\}$$

13.3 Filters Formation

The Filters Formation consists of taking the Discrete Fourier Transform of each group of samples that have been defined in Data Sorting. The filter width for the S_n groups is 29.06 Hz while the filter width for the S_W group is 116.25 Hz. (Note: S_n samples are collected over a period four times longer than the period associated with each group of S_W samples). For this reason, the resulting filters for the S_n samples are called the narrow filters and the filters for the S_W samples are called wide filters.

13.3.1 Input

- Two sets of complex (I/Q) samples:

  $\{S_n(i,T) \mid i=0, \ldots, 255; T = 1,2\}$

- Eight angle groups of complex (I/Q) samples:

  $\{S_W(i,T,\phi) \mid i=0, \ldots, 63; \; T =1,2; \; \phi \varepsilon \{\pm AZ, \pm EL\} \}$

13.3.2 Processing

The Discrete Fourier Transform (DFT) of each set of input samples is defined as follows:

a) Narrow Filters

$$F_n(k,T) = \sum_{i=0}^{255} [A_n(i) \times S_n(i,T)] \bullet W_{256}^{ik}$$

where:
$W_{256} = \exp[-j2\pi/256]$
$k = 0, \ldots, 255;$ (filter index)
$T = 1,2$
A_n = weights (amplitude weights, TBS)

b) Wide Filters

$$F_W(k,T,\phi) = \sum_{i=0}^{63} [A_W(i) \times S_W(i,T,\phi)] \bullet W_{64}^{ik}$$

where:

W_{64} = exp $[-j2\pi/64]$

k = 0, ..., 63 ; (filter index)

T = 1,2

ϕ = $\varepsilon\{\pm AZ, \pm EL\}$

A_W = weights (amplitude weights, TBS)

The computations of the DFT's above are carried out using appropriate Fast Fourier Transform algorithms.

13.3.3 Output

- Narrow Filters:

  $\{F_n(k,T) \mid k=0, \ldots, 255 ; T = 1,2\}$

- Wide Filters:

  $\{F_W(k,T,\phi) \mid k=0, \ldots, 63 ; T = 1,2; \phi\varepsilon\{\pm AZ, \pm EL\}\}$

13.4 Discriminants Computation

The following data are computed in this section:

a) ΔV ; (velocity discriminants)
b) $\Delta\eta$; (azimuth discriminants)
c) $\Delta\varepsilon$; (elevation discriminants)
d) ART(AZ) ; (azimuth angle ratio threshold)
e) ART(EL) ; (elevation angle ratio threshold)

These data are computed using the wide filters that fall inside the speed gate, i.e., wide filters numbered 12 through 24 (see Introduction and Section 13.3).

13.4.1 Input

- Wide Filters from Section 13.3:

$$\{F_W(k,T,\phi) \mid k=0, \ldots, 63;\ T = 1, 2;\ \phi \varepsilon \{\pm AZ, \pm EL\}\}$$

13.4.2 Processing

The following data are used for the discriminants and the ART computations.

a) $X(k,\phi) = 2\Sigma e^{j\theta}|_{\text{at filter } k,\text{ angle } \phi}$

$= F_W(k,1,\phi) - jF_W(k,2,\phi)$

b) $H(k,\phi) = 2\Sigma\Delta e^{j\theta}|_{\text{at filter } k,\text{ angle } \phi}$

$= F_W(k,1,\phi) \ominus F_W(k,2,\phi)$

c) $C(k,\phi) = j2\Delta e^{j\theta}|_{\text{at filter } k,\text{ angle } \phi}$

$= F_W(k,1,\phi) + jF_W(k,2,\phi)$

d) $D(k,\phi) = 2\Sigma e^{j\theta}\Big|_{\text{at filter } k, \text{ angle } \phi}$

$= F_W(k,1,\phi) - jF_W(k,2,\phi)$

where: $k = 12, \ldots, 24$

$\phi = \varepsilon\{\pm AZ, \pm EL\}$

$\odot$ = dot product

θ = arbitrary phase angle

13.4.2.1 Velocity Discriminants Computation

The outcome of this computation is a velocity discriminant for each pair of wide filters between the 12th and the 24th filters inclusively. The following describes this computation:

$$\Delta V(k) = \frac{\sum_{\phi\varepsilon\{+AZ,+EL\}} |X(k,\phi)| - |X(k+1,\phi)|}{\sum_{\phi\varepsilon\{\pm AZ,\pm EL\}} |X(k,\phi)| + |X(k+1,\phi)|}$$

for k = 12, ..., 23

13.4.2.2 Angle Discriminants Computation

The following error terms are computed for each filter numbered 12 through 24.

$$E(k;AZ) = \frac{(\Sigma\Delta)}{\Sigma^2}\Big|_{\text{at filter } k}$$

$$= 2X \left[\frac{H(k,AZ) - H(k,-AZ)}{|D(k,AZ)|^2 + |D(k,-AZ)|^2} \right]$$

$$E(k,EL) = \left.\frac{\Sigma\Delta}{\Sigma^2}\right|_{\text{at filter } k}$$

$$= 2X\left[\frac{H(k,EL) - H(k,-EL)}{|D(k,EL)|^2 + |D(k,-EL)|^2}\right]$$

for k = 12, ..., 24.

The azimuth and elevation discriminants are given by:

$$\Delta\eta(k) = \begin{cases} E(k,AZ) & \text{, if } |E(k,AZ)| \leq 2 \\ 2X \text{ sign } (E(k,AZ)) & \text{, otherwise.} \end{cases}$$

$$\Delta\varepsilon(k) = \begin{cases} E(k,EL) & \text{, if } |E(k,EL)| \leq 2 \\ 2X \text{ sign } (E(k,EL)) & \text{, otherwise.} \end{cases}$$

for k = 12, ..., 24

13.4.2.3 Angle Ratio Thresholds Computation

The angle ratio thresholds are computed for each filtered numbered 12 through 24 as follows:

$$ART(k,AZ) = \left.\frac{\Delta^2}{\Sigma^2}\right|_{\text{at filter } k}$$

$$= \frac{|C(k,AZ)|^2 + |C(k,-AZ)|^2}{|D(k,AZ)|^2 + |D(k,-AZ)|^2}$$

$$ART(k,EL) = \left.\frac{\Sigma^2}{\Sigma^2}\right|_{\text{at filter } k}$$

$$= \frac{|C(k,EL)|^2 + |C(k,-EL)|^2}{|D(k,EL)|^2 + |D(k,-EL)|^2}$$

for k = 12, ..., 24

13.4.3 Output

- 12 velocity discriminants:

  $\{\Delta V(k) \mid k = 12, \ldots, 23\}$

- 13 azimuth angle discriminants:

  $\{\Delta \eta(k) \mid k = 12, \ldots, 24\}$

- 13 elevation angle discriminants:

  $\{\Delta \varepsilon(k) \mid k = 12, \ldots, 24\}$

- 13 azimuth angle ratio thresholds:

  $\{ART(k,AZ) \mid k = 12, \ldots, 24\}$

- 13 elevation angle ratio thresholds:

  $\{ART(k,EL) \mid k = 12, \ldots, 24\}$

13.5 Detection Logic

The detection logic is carried out using the narrow filters that fall inside the speed gate, i.e., narrow filters numbered 48 through 96. This logic involves the following tasks:

1. Perform a threshold test across the filters 48 through 96.
2. Compute an average noise estimate using only those filters that failed the threshold test.
3. Compute the signal strength about the filters numbered 48, 52, 56, ..., 96.

13.5.1 Input

- Narrow filters:

  $\{F_n(k,T) \mid k=0, \ldots, 255;\ T = 1,2\}$

- Threshold Multiplier from RDP: TM

13.5.2 Processing

The following data are defined for the detection logic,

a) $f_\Sigma(k) = F_n(k,1) - jF_n(k,2)$

   for $k = 48, \ldots, 96$

b) Noise estimate for the threshold test:

$$N_T = \frac{1}{49} \sum_{k=48}^{96} |f_\Sigma(k)|$$

13.5.2.1 Threshold Test

This test given by:

$$H(k) = \begin{cases} 1 \text{ if } & |f_\Sigma(k)| \geq TM \times N_T; \text{ a hit} \\ 0 \text{ otherwise ;} & \text{a miss} \end{cases}$$

for $k = 48, \ldots, 96$

13.5.2.2 Noise Estimate Update

This estimate is computed using $|f_\Sigma(k)|$ for those filters k, where H(k) = 0.

The update is given as follows:

1. $$M = 49 - \sum_{k=48}^{96} H(k)$$

2. $$N_0 = \frac{1}{M} \sum_{k=48}^{96} \overline{H}(k)\ |f_\Sigma(k)|$$

13.5.2.3 Signal Strength Computation

The signal strength is computed about the filters numbered k = 48, 52, 56, ..., 96. For each one of these filters the signal strength is given by:

$$S(k) = \sum_{\ell=k-2}^{k+2} |f_\Sigma(\ell)|$$

for k = 48, 52, 56, ..., 96

13.5.3 Output

- Hit/Miss Flags: $\{H(k) \mid k=48, \ldots, 96\}$
- Noise Estimate: N_0
- Signal Strength: $\{S(\ell) \mid \ell=48, 52, 56, \ldots, 96\}$

13.6 Display Processing (DP)

Display Processing consists of a PSP program that assembles the tracked target data from the RDP and IRE for the Vertical Situation Display unit (VSD). The program stores this data in that part of the Bulk Memory called TM2. This data is then retrieved, reformatted and sent to VSD by the DIU module (see Figure 13.10).

13.6.1 Input

- DSC words from RDP
- IFF Reply Word from IRE
- Mode X Ident Command from EWWS

13.6.2 Processing

In the HPRF STT Mode, the DP program is divided into two parts. In the first part, the program forms 16 VSD Words as shown in Figure 13.12. These words are assembled from the DSC Words from the RDP. The second part is the IFF code determination. This code is inserted into VSD Word 12, and is used to select the target symbol for display.

13.6.2.1 IFF Code Determination

This operation is carried out in two ways. If the IFF challenge code given by the RDP is '0', the program sets the IFF code in the VSD Word 12 (bits 4 & 5) to '00', and sends the VSD words to TM2. If the IFF challenge code is '1', then the following sequence of operations are performed (see Figure 13.11).

1. IFF Correlation:

   This routine compares the tracked target position given by RDP against the positions of the IFF targets that has been supplied by the IFF Reply Evaluation (IRE). (IRE updates this list of IFF targets constantly when the Inhibit code in the IRE Word is '0'). A correlation is established if there is at least one IFF target whose range and azimuth within a correlation window. This window is given by the ±12 range bins (or ±1.25 NM) and ±16 azimuth bins (or ±4° in azimuth) about the tracked target coordinates. This routine terminates at the first correlation or when all IFF targets in the current list have been examined.

2. If there is no IFF correlation, then the processor sets the IFF code to '00' and goes to Step 5.
3. If there is an IFF correlation, the processor reports this to the RDP through IDA. The RDP, in turn, sets the Identified code in the IRE word to '1'. This in effect, tells the IRE that an IFF correlation has been established.
4. If the Mode X command from EWWS is '1', the processor will set the IFF Code to '11'; otherwise this code is set to the IFF code of the correlated IFF target.
5. The processor sends the VSD words to TM2.
6. The program exits.

13.6.3 Output

- 16 VSD words to VSD
- IRE Word to IRE
- IFF correlation code to RDP

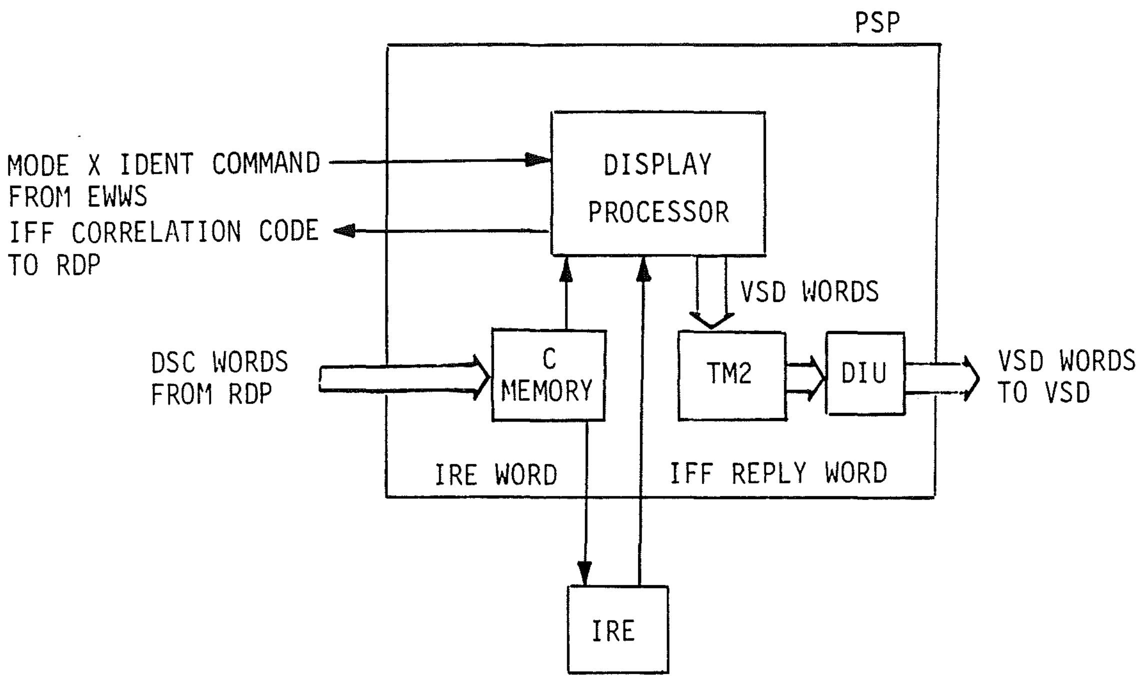


Figure 13.10 - DATA FLOW BETWEEN THE PSP, RDP, IRE AND THE VSD UNIT DURING DISPLAY PROCESSING

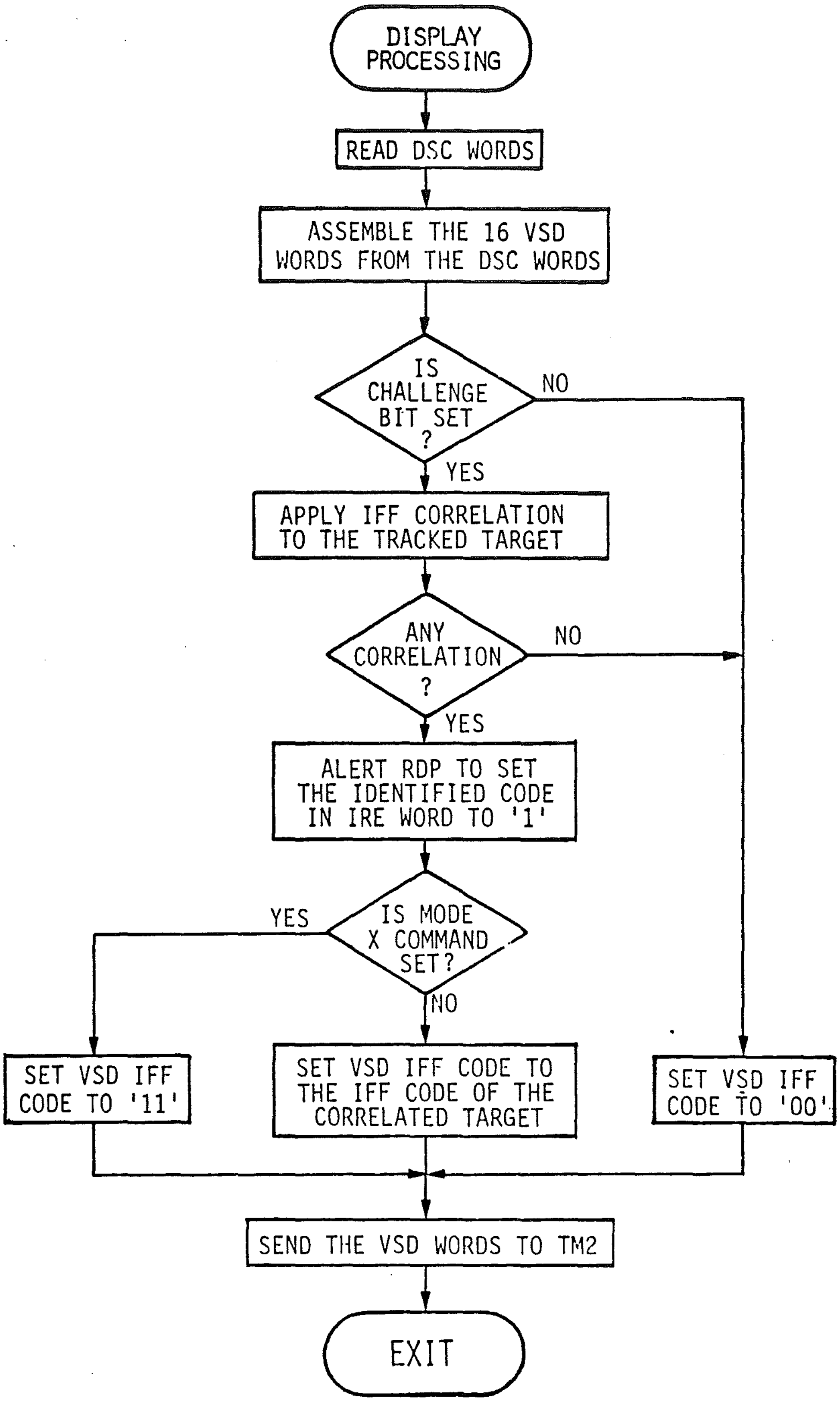


Figure 13.11 - HPRF TRACK DISPLAY PROCESSING

WORD	NAME	BIT POSITION						
		0 1 2 3	4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23				24-44	45 46 47
1-10	BLANK	0 0 0 0	THESE BIT POSITIONS MAY BE RANDOMLY SET					
11	RNG/VEL SCALE	0 1 0 0	0 0	RNG/ VEL SCALE	0 0 0 0 0 0 0 0 0 0 0 0 0 0 0		0	1 1 1
12	TRACKED TGT POS	0 0 0 1	IFF CODE	AZIMUTH	RANGE			1 1 1
13	ANT. AZ. POSITION	0 1 0 1	0 0	AZIMUTH	1 0 0 0 1 0 1 1 0		0	1 1 1
14	ANT. EL. POSITION	0 1 0 1	0 0	1 0 0 0 1 0 1 1 0	ELEVATION		0	1 1 1
15	BIT WORD #1	0 1 0 1 or 0 0 0 0	0 0	1st CHARACTER	2nd CHARACTER	3rd CHARACTER	0	1 1 1
16	BIT WORD #2	0 1 0 1 or 0 0 0 0	0 0	4th CHARACTER	5th CHARACTER	6th CHARACTER	0	1 1 1

FIGURE 13.12 - DISPLAY PROCESSOR TO VSD DIGITAL DATA (HPRF TRACK)

Section 14

HPRF BIT TEST MODE

14.0 INTRODUCTION

The purpose of the HPRF BIT Test mode is to test the Analog Signal Processor in the HPRF Track configuration. Figure 14.1 illustrates the signal processing flow. Note that Paragraphs 14.1, 14.2 and 14.3 are identical to those in Section 3. The reader is referred to that section for details.

This mode is performed after the system calibrations in order to verify that the system is not deficient in track or in detection sensitivity. The tests to be performed are:

1. HPRF Phase Balance Test
2. HPRF Gain Balance Test
3. HPRF Frequency Balance Test
4. HPRF Track Filter Hit and Signal to Noise Test

(Data Item PSP/RDP-18 Vol. I defines the RDP Software Requirements for these tests and should be used in conjunction with the PSP Software Requirements defined in this document.)

When the HPRF BIT Test mode is commanded, all four of the above tests integrate data, form discriminants within the PSP and relay the results by means of one tagged IDA to the RDP for further computation or comparison. This is possible because one BIT receiver target suffices for all four tests, and all required computations can be performed within the integration times specified in Figure 14.1.1.

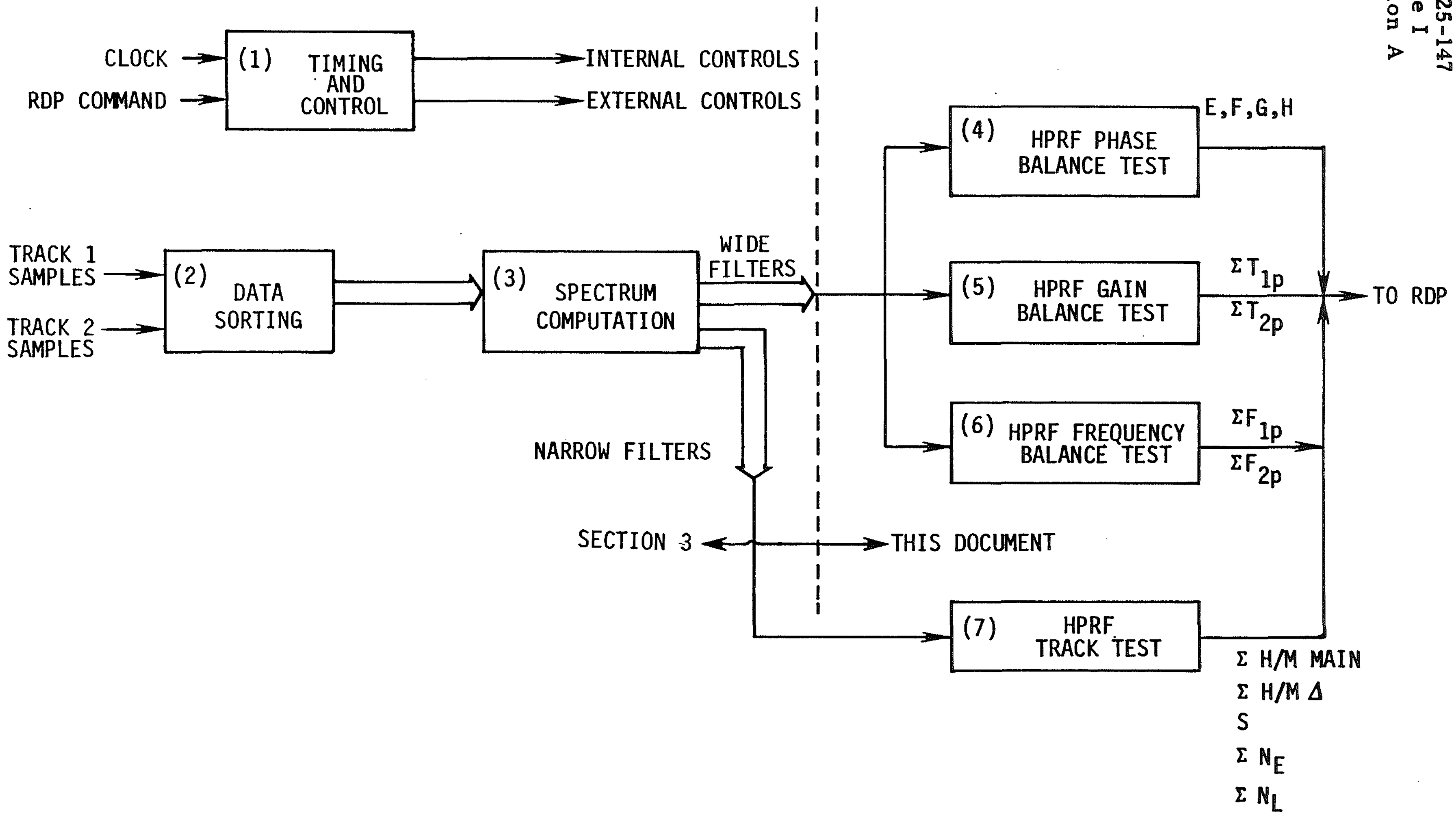


FIGURE 14.1. HPRF BIT TEST DIAGRAM

14.1 Timing and Control

The HPRF BIT Test mode uses the same timeing as the HPRF Track mode (Section 3.1). For purposes of BIT however, data is gathered over extended intervals to minimize noise and/or transient effects. These integration periods are presented in Figure 14.1.1. Note that 128 complex sample pairs are taken per phase time of 2.15 ms and that four phase times occur per process sync.

The BIT receiver target is used for all tests. The RDP commands the receiver by sending the discrete BIT Receiver Target Enable signal to enable the BIT receiver target for processing.

14.2 Data Sorting

Please see Section 3.2, HPRF Track.

14.3 Spectrum Computation

Please see Section 3.3, HPRF Track

14.4 HPRF Phase Balance Test

The HPRF Phase Balance Calibration is commanded and performed external to this mode. Please refer to Data Item E43, BIT document, for a discussion of the Phase Balance Calibration. This mode (HPRF Phase Balance Test) is used to verify the integrity of the phase difference between the two channels from the receiver through the 039 unit.

14.4.1 Inputs

- Doppler filter output data from Section 3.3 for BIT receiver targets:

  $F_4(K,T)$ for one filter by two channels
  $(K = 4,\ T = 1,2)$.

14.4.2 Processing

Data is selected from the last phase (fourth array, g = 4) of the 16-phase data gathering period (see Figure 14.1.1(c)). The real and imaginary parts of the two inputs are extracted and sent to the RDP. These terms are defined as follows:

$$E = Re(F_4(4,1)) = I(T_1, f_4)$$
$$F = Im(F_4(4,1)) = Q(T_1, f_4)$$
$$G = Re(F_4(4,2)) = I(T_2, f_4)$$
$$H = Im(F_4(4,2)) = Q(T_2, f_4)$$

The RDP then performs the following calculation to verify the phase balance: $< T_1 f_4 = (< T_2 f_4 + 90°) \pm 20°$.

14.4.3 Outputs

Real and imaginary parts of two complex filter outputs (E,F,G,H) to the RDP. One set of data per 16 phases in a tagged IDA.

14.5 HPRF Gain Balance Test

The Gain Balance Test serves to verify that the Track 1 power and Track 2 power correspond to within 5.0 dB. The test would indicate any gain imbalance which occurred after the track combiner in the receiver unit.

14.5.1 Inputs

- Doppler Filter output data from Section 3 for BIT receiver target: $F_g(K,T)$, g=1, ..., 4 for two filters by two channels (K=4, 5; T = 1,2).

14.5.2 Processing

Data is selected from all four phases (g=1, ..., 4) within four arrays. The 16-phase data gathering period is indicated in Figure 14.1.1(a). The following discriminants are formed and sent to the RDP.

$$\Sigma T_{1p} = \sum_{\text{Array}=1}^{4} \sum_{g=1}^{4} \left[F_g^{\,2}(4,1) + F_g^{\,2}(5,1) \right] = \text{Track 1 Power}$$

$$\Sigma T_{2p} = \sum_{\text{Array}=1}^{4} \sum_{g=1}^{4} \left[F_g^{\,2}(4,2) + F_g^{\,2}(5,2) \right] = \text{Track 2 Power}$$

The RDP then checks to see that:

$$\frac{\text{Max }(\Sigma T_{1p}, \Sigma T_{2p})}{\text{Min }(\Sigma T_{1p}, \Sigma T_{2p})} \leq 3.16$$

14.5.3 Outputs

The square of the Doppler Filter output data is summed over two filters (numbers 4 and 5) over the 16-phase data gathering period, for both channels (T=1,2); sent to the RDP. There is one set of data per 16 phases in a tagged IDA.

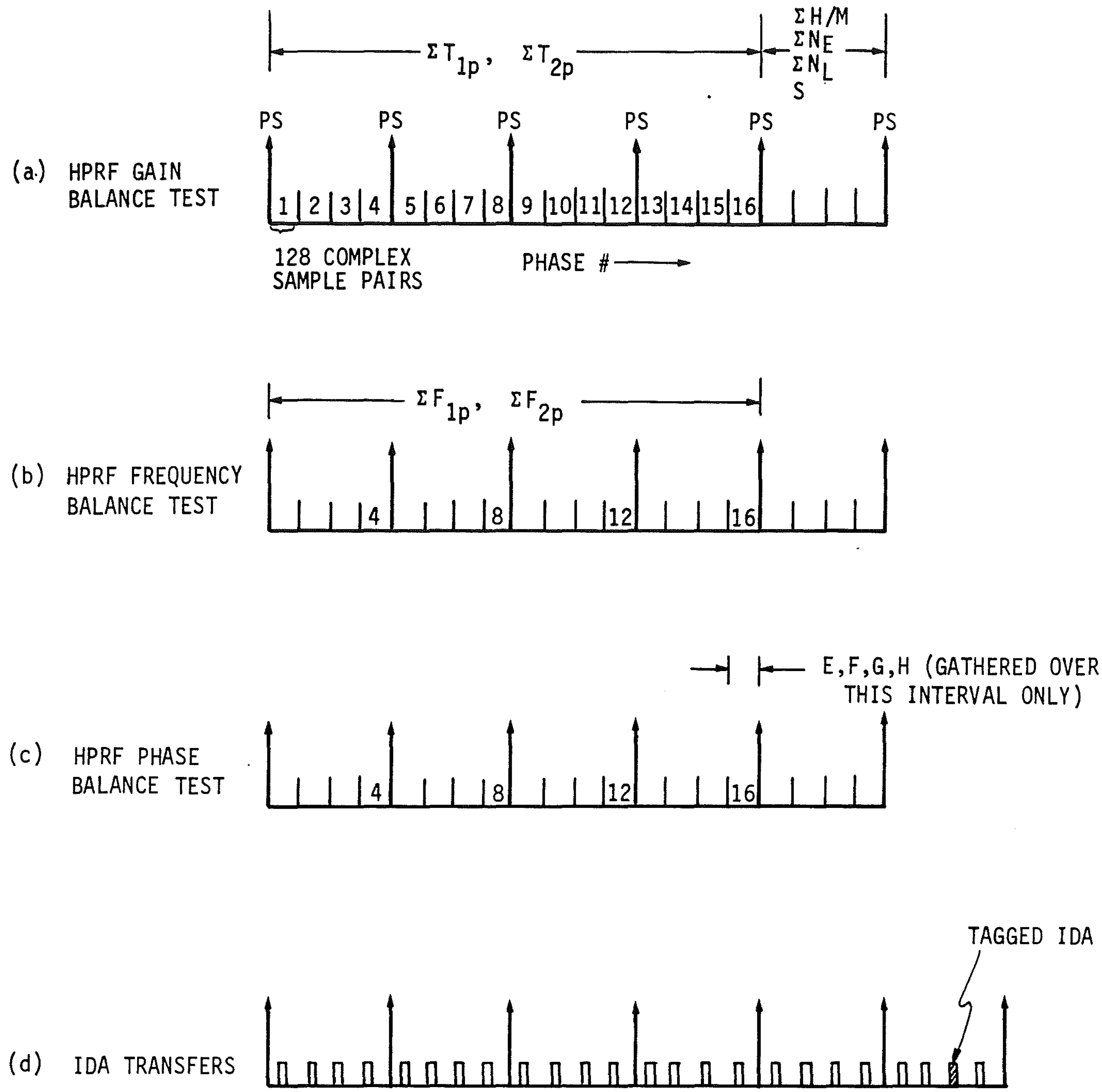


FIGURE 14.1.1 HPRF BIT TEST INTEGRATION PERIODS (a, b, c, d)

14.6 HPRF Frequency Balance Test

The VCO's in the 039 unit are responsible for converting the receiver IF output signals to lower frequency signals for processing in subsequent circuits. Since the 30 MHz offset frequency can vary slightly with time, the VCO's are calibrated to compensate for the drift error. The Frequency Balance Test is performed to check that the VCO is in operation and is calibrated properly.

14.6.1 Inputs

- Doppler Filter output data from Section 3 for BIT receiver target: $F_g(K,T)$, g=1, ..., 4 for two filters by two channels (K=4, 5; T=1,2).

14.6.2 Processing

The Frequency Balance Test requires that a BIT receiver target can be injected as in the other tests, and Filter #4 power be compared with Filter #5 power to determine how accurately the 22.8 MHz VCO positions a known target within a filter pair. The PSP forms these discriminants:

$$\Sigma F_{1p} = \sum_{\text{Array}=1}^{4} \sum_{g=1}^{4} \left[F_g^2(4,1) + F_g^2(4,2) \right] = \text{Filter 4 Power}$$

$$\Sigma F_{2p} = \sum_{\text{Array}=1}^{4} \sum_{g=1}^{4} \left[F_g^2(5,1) + F_g^2(5,2) \right] = \text{Filter 5 Power}$$

The RDP then performs the comparison:

$$\frac{\text{Max } (\Sigma F_{1p}, \Sigma F_{2p})}{\text{Min } (\Sigma F_{1p}, \Sigma F_{2p})} \leq 2.818$$

14.6.3 Outputs

The square of the Doppler Filter output data is summed over two channels (T=1,2) over the 16-phase data gathering period (Figure 14.1.1(b)), for Filters #4 and #5, sent to the RDP. One set of data exists per 16-phases in a tagged IDA.

Section 15

MPRF BIT CALIBRATION AND TEST MODE

15.0 INTRODUCTION

The purpose of the MPRF BIT Calibration and Test Mode is to verify the ability of the Analog Signal Processor to perform the tasks in the MPRF Track configuration. Figure 15.1 illustrates the signal processing flow. Note that paragraphs 15.1, 15.2 and 15.3 are identical to those in Section 5. The reader is referred to that section for details.

The calibrations to be performed are:

1. Amplitude Calibration
2. Range Delay Calibration

The system tests are performed after the calibrations in order to verify that the system is not deficient in track or detection sensitivity. The tests to be performed are:

1. MPRF Phase Balance Test
2. MPRF Gain Balance Test
3. MPRF Frequency Balance Test
4. A/D Converter Gain Balance Test

Data Item PSP/RDP-18 Vol. I defines the RDP Software Requirements for this mode and should be used in conjunction with the PSP Software Requirements defined in this document.

The MPRF BIT Calibration and Test Mode is designed to contain all of the necessary PSP computations for all six of the above calibrations and tests. As shown in Figure 15.1, all of these computations are performed simultaneously. The validity of any particular output depends upon which test the system is "set-up" for (i.e., VCO Position, BIT Antenna Target or BIT Receiver Target, etc.)

The RDP is expected to select which of the output data is relevant for a particular test.

(NOTE: Since the Phase, Gain and Frequency Balance Tests all use the BIT receiver target, these three tests yield valid discriminants simultaneously and are commanded as a group).

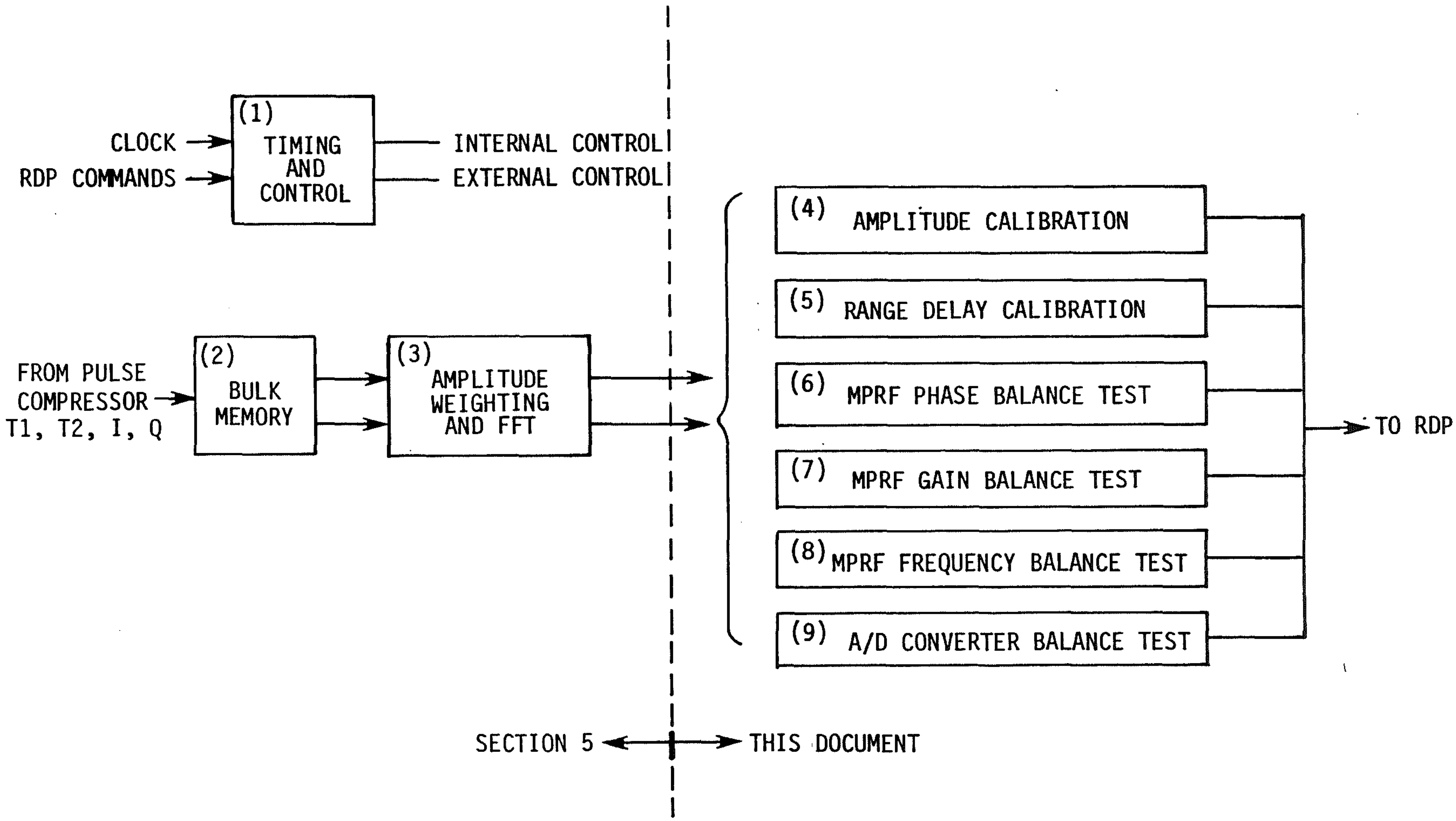


FIGURE 15.1 MPRF BIT CALIBRATION AND TEST DIAGRAM

15.1 Timing and Control (T&C)

The MPRF Bit Calibration and Test Mode uses the same timing as the MPRF Track mode (Section 5). For purposes of BIT, however, data is gathered over extended intervals to minimize noise and/or transient effects. The integration periods are presented in Figure 15.1.1. (For example, the Gain Balance Test, Figure 15.1.1(d) uses data from Phases 1 - 16 and outputs the results on the tagged IDA to the RDP).

T&C information pertaining to the BIT targets resides in the T&C modules in the PSP. The BIT targets to be used are defined below:

(a) The BIT receiver target is used for the Phase, Gain and Frequency Balance Tests. The RDP sends the BIT Receiver Target Enable signal to the receiver to initiate this target.

(b) The BIT Antenna Target is used for the Amplitude Calibration, and is commanded by the RDP via the BIT Antenna Target Enable signal to the transmitter.

(c) RF energy reflected off the dummy load is used as a BIT target for the Range Delay Calibration.

(d) A 468 kHz test signal inserted directly into the A/D Converter is used for the A/D Converter Balance Test.

15.2 Bulk Memory Storage

Please See Section 5. The MPRF BIT Calibration and Test Mode requires no change from the specifications of MPRF Track Bulk Memory Storage.

15.3 Amplitude Weighting and FFT

Please See Section 5. There is no change required in this function for MPRF BIT Calibration and Test Mode.

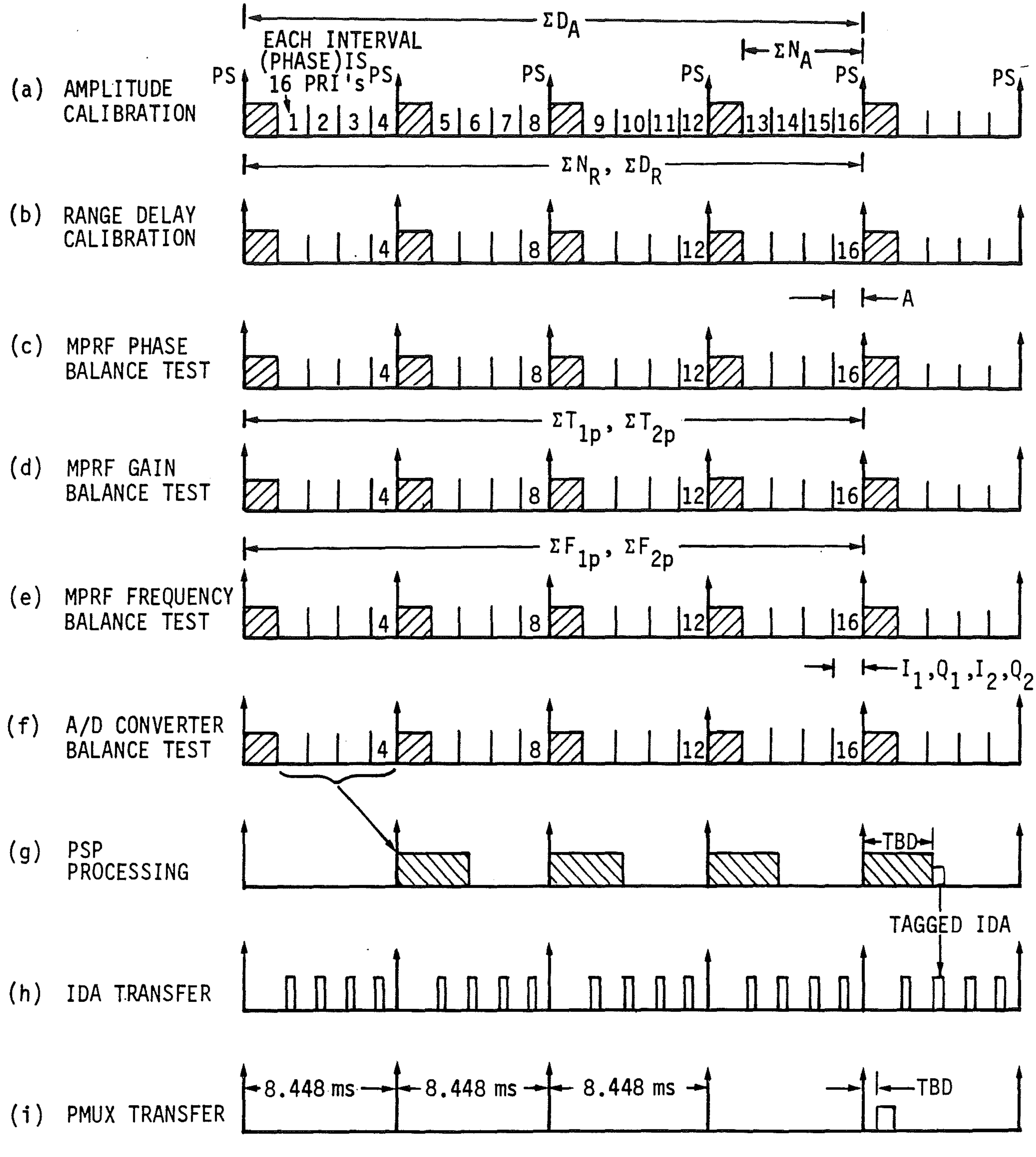


FIGURE 15.1.1. MPRF BIT CALIBRATION AND TEST MODE INTEGRATION PERIODS (PRF 7)

15.4 Amplitude Calibration

The Amplitude Calibration measures the ratio of the difference channel gain to the sum channel gain in the receiver prior to combination as Track 1 and Track 2. Please refer to BIT document, Data Item E-43, for a complete description of the Amplitude Calibration.

15.4.1 Inputs

The output signals from Section 5 are presented in vector notation $\vec{F}_x(i,j)$ where

$$\begin{aligned} x &= 1,2 && \text{(Track 1, Track 2 Channels)} \\ i &= 1,2 && (1 = \text{ShR},\ 2 = \text{LgR}) \\ j &= 1,2 && (1 = \text{LoF},\ 2 = \text{HiF}) \end{aligned}$$

e.g., $\vec{F}_1(1,2) = (\text{HiFShRI}) + j(\text{HiFShRQ})$ from Track 1 data. Amplitude calibration requires the following signals for the BIT Antenna Target:

$$\{\vec{F}_x(i,j) \mid x = 1,2;\ i-1,2;\ j=1,2\}$$

15.4.2 Processing

Data for the ΣD_A discriminant is summed over all 16-phases of the data gathering period, while ΣN_A discriminant data is obtained only for the last 4 phases (see Figure 15.1.(a)). The discriminants are formed as below:

$$\Sigma N_A = 1/4 \sum_{\text{Phase}=13}^{16} \left[\vec{F}_k \times \vec{F}_L \right]$$

$$\Sigma D_A = 1/16 \sum_{\text{Phase}=1}^{16} \left| \vec{F}_k - j\vec{F}_L \right|^2$$

where:

$$\vec{F}_k = \sum_{i=1}^{2} \left[\vec{F}_1(i,1) - \vec{F}_1(i,2) \right]$$

$$\vec{F}_L = \sum_{i=1}^{2} \left[\vec{F}_2(i,1) - \vec{F}_2(i,2) \right]$$

The RDP uses this data to form:

$$D_{cal} = \left(\frac{\Sigma D_A - \Sigma N_A}{\Sigma D_A} \right)^{1/2}$$

15.4.3 Outputs

- ΣN_A, ΣD_A formed as defined above; sent to the RDP. One set of data per 16 phases in a tagged IDA.

15.5 Range Delay Calibration

The Range Delay Calibration determines the range error resulting from time delays introduced in signal processing. The calibration is used in track modes to correct target range. Data Item E-43 presents a thorough discussion of this calibration.

15.5.1 Inputs

The BIT target used for this calibration consists of RF energy from the GTWT which has been reflected off the dummy load and propagated through the signal return path. The output signals required from Section 5 are:

$$\{\vec{F}_1(i,j) \mid i=1,2;\ j=1,2\}$$

($F_x(i,j)$ is defined in Section 15.4).

15.5.2 Processing

Data is gathered from all four phases within four adjacent arrays. The 16-phase data gathering period is indicated in Figure 15.1.1(b). The discriminants to be formed are:

$$\Sigma N_R = \sum_{\text{Phase}=1}^{16} \left| \vec{F}_1(2,1) - \vec{F}_1(2,2) \right| - \left| \vec{F}_1(1,1) - \vec{F}_1(1,2) \right|$$

$$\Sigma D_R = \sum_{\text{Phase}=1}^{16} \left| \vec{F}_1(1,1) - \vec{F}_1(1,2) \right| + \left| \vec{F}_1(2,1) - \vec{F}_1(2,2) \right|$$

The RDP then forms

$$\Delta R = \frac{\Sigma N_R}{\Sigma D_R}$$

15.5.3 Outputs

- ΣN_R, ΣD_R for each incremental step in range delay determination, gathered over the 16 phase data gathering period for Track 1 data; sent to the RDP. One set of data per 16 phases in a target IDA.

15.6 MPRF Phase Balance Test

The Phase Balance Test is used to verify the integrity of the phase difference between the two channels from the receiver through the 039 unit.

15.6.1 Inputs

The following signals from Section 5 for BIT Receiver Target are inputs to the Phase Balance Test.

$$\{\vec{F}_x(i,1) \mid x=1,2;\ i=1,2\}$$

15.6.2 Processing

Data is selected from the last phase of the 16 phase data gathering period (see Figure 15.1.1(c)). The tracking signals are combined in the following manner:

Define $\vec{F}_1 = \vec{F}_1(1,1) + \vec{F}_1(2,1)$

$$\vec{F}_2 = \vec{F}_2(1,1) + \vec{F}_2(2,1)$$

$$A = \left| \frac{\vec{F}_1 \cdot \vec{F}_2}{|\vec{F}_1|\ |\vec{F}_2|} \right| \qquad \vec{C}_2 = j\, \frac{\vec{F}_1 \cdot \vec{F}_2}{|\vec{F}_1|\,|\vec{F}_2|}$$

The RDP verifies that

$$A \leq \cos\ (70^{\circ})$$

$\vec{C}_2$ is retained for use by the PSP during RAM Spotlight (both Search and Track) mode. $\vec{C}_2$, when multiplied with the Track 2 data, brings that vector into the correct phase relationship with the Track 1 data.

15.6.3 Outputs

- The discriminant A as defined above; sent to the RDP. One set of data per 16 phases in a tagged IDA.

15.7 MPRF Gain Balance

The Gain Balance Test verifies that the Track 1 power and Track 2 power correspond to within 5.0 dB. The test would indicate any gain imbalance which occurred after the track combiner in the receiver unit.

15.7.1 Inputs

The following signals from Section 5 for BIT Receiver Target are inputs to the Gain Balance Test.

$$\{\vec{F}_x(i,j) \mid x=1,2;\ i=1,2;\ j=1,2\}$$

15.7.2 Processing

Data is selected from all four phases within four adjacent arrays. The 16 phase data gathering period is indicated in Figure 15.1.1(d). The following discriminants are formed and sent to the RDP.

$$\text{Track 1 Power} = \Sigma T_{1p} = \sum_{\substack{\text{Phase}\\=1}}^{16} [F_1^{\,2}(1,1)+F_1^{\,2}(1,2)+F_1^{\,2}(2,1)+F_1^{\,2}(2,2)]$$

$$\text{Track 2 Power} = \Sigma T_{2p} = \sum_{\substack{\text{Phase}\\=1}}^{16} [F_2^{\,2}(1,1)+F_2^{\,2}(1,2)+F_2^{\,2}(2,1)+F_2^{\,2}(2,2)]$$

The RDP then verifies that

$$\frac{\text{Max }(\Sigma T_{1p},\Sigma T_{2p})}{\text{Min }(\Sigma T_{1p},\Sigma T_{2p})} \leq 3.16$$

Additionally, the residual gain error determined in this computation is retained for use in the PSP during RAM Spotlight (both Search and Spotlight) Mode.

15.7.3 Outputs

- Tracking gate outputs squared and summed for Track 1 and Track 2, over the 16 phase data gathering period (Figure 15.1.1(d)); sent to the RDP. One set of data per 16 phases in a target IDA.

15.8 MPRF Frequency Balance Test

The VCO is used to convert the receiver IF output signals to lower frequency signals for processing in subsequent circuits. Since the 30 MHz offset frequency can vary slightly with time, the VCO's are calibrated to compensate for this drift error. The MPRF Frequency Balance Test is performed to check that the VCO is in operation and is calibrated properly.

15.8.1 Inputs

The following signals from Section 5 for BIT Receiver Target are inputs to the Frequency Balance Test:

$$\{\vec{F}_x(i,j) \mid x=1,2;\ i=1,2;\ j=1,2\}$$

15.8.2 Processing

The Frequency Balance Test requires that a BIT Receiver Target be injected and filter #8 power be compared with filter #9 power to determine how accurately the 18.4 MHz VCO positions a known target within a filter pair. The PSP forms these discriminants:

$$\Sigma F_{1p} = \sum_{\text{Phase}=1}^{16} \left[F_1^2(1,1)+F_2^2(1,1)+F_1^2(2,1)+F_2^2(2,1)\right] = \text{Filter 8 Power}$$

$$\Sigma F_{2p} = \sum_{\text{Phase}=1}^{16} \left[F_1^2(1,2)+F_2^2(1,2)+F_1^2(2,2)+F_2^2(2,2)\right] = \text{Filter 9 Power}$$

The RDP then performs the comparison:

$$\frac{\text{Max}\ (\Sigma F_{1p},\ \Sigma F_{2p})}{\text{Min}\ (\Sigma F_{1p},\ \Sigma F_{2p})} \leq 2.13$$

15.8.3 Outputs

Tracking gate outputs squared and summed over Track 1 and Track 2, over the 16 phase data gathering period (Figure 15.1.1(e)), for each of filters #8 and #9; sent to the RDP. One set of data per 16 phases in a tagged IDA.

15.9 A/D Converter Gain Balance Test

The A/D Converter Gain Balance Test evaluates the ability of the A/D Converter to reliably convert an analog signal to digital form. The details of this function are presented in Data Item E-43, (Section 2.7.9, page 105).

15.9.1 Inputs

The following signals from Section 5 are inputs to the A/D Converter Gain Balance Test. The input data list includes only single filter x 1 range bin track data and is labeled accordingly.

$$\{\vec{F}_x(1,1) \mid x = 1,2$$

15.9.2 Processing

Only data from the last phase of the 16 phase data gathering period (see Figure 15.1.1(f)) is used. These track gate signals are saved for the RDP processing.

$$I_1\ (1,1) = \text{Re}\ [\vec{F}_1\ (1,1)]$$
$$Q_1\ (1,1) = \text{Im}\ [\vec{F}_1\ (1,1)]$$
$$I_2\ (1,1) = \text{Re}\ [\vec{F}_2\ (1,1)]$$
$$Q_2\ (1,1) = \text{Im}\ [\vec{F}_2\ (1,1)]$$

The RDP then checks I_1 (1,1), Q_1 (1,1), I_2 (1,1) and Q_2 (1,1) to see if:

a) Each is less than 16_{10}, i.e. for Test 1 was a 52 Hz signal formed to be rejected by the clutter canceller

or b) One is greater than 16_{10}, i.e. for Test 2 was a 1773 Hz signal formed.

15.9.3 Outputs

- Real and imaginary parts of 1 range bin by 1 filter from the tracking gate output for both Track 1 and Track 2 are sent to the RDP. One set of data per 16 phases.

Section 16

BUILT-IN TEST

16.0 BUILT-IN TEST (BIT)

16.1 Scope

This appendix establishes the functional requirements for the Built-In Test of the Programmable Signal Processor (PSP), Hughes Aircraft Company, P/N 3173042-100.

16.2 Item Definition

The PSP has provisions for self test, under command from the RDP. Each functional element of the PSP is tested for performance of the required operational modes. Those functional elements not normally part of the airborne PSP hardware, such as the monitor interface unit or instrumentation are not tested. Self test is conducted by computer software.

16.3 Self-Test Sequences

The self test sequences provided by the software include the following.

16.3.1 PSP Confidence Test

This test shall evaluate the instruction pipe, data pipe, PSP-to CMEM-to-RDP interface, various instructions, and data memory pointers for establishing PSP self test capability.

16.3.2 Registers B and S Latch Reset and Branch

This test shall verify the branch control logic by test of B and S register latch bits.

16.3.3 BAL and BI Instructions through the X-Memories; Read and Write of X-Memories

This test shall verify the Branch and Link (BAL) and Branch Indirect (BI) instructions through all the X-Memories; and shall verify the writing and reading of the X-Memories by the BAL and BI instructions.

16.3.4 BIAL Instruction and Loading of X-Memories

This test shall verify the branch indirect and link instruction for writing and reading of X-Memories.

16.3.5 Repeat and BCTX Instruction Counter

This test shall verify the Repeat and BCTX Counters Loop function performance.

16.3.6 Data Memory Structure Addressing, Writing and Reading

This test shall verify the data memory structures M0 - M5 for addressing; to find "stuck at" faults.

16.3.7 Data Memory Pointers and Data Memory Read/Write Conflicts

This test shall verify that each memory structure pointer is addressable; and that when a write is being performed at T9, and a read is requested simultaneously at T2, the read is delayed until the write has been completed.

16.3.8 Pointer Mask and Auto Increment

This test shall verify the following: (1) The pointer next address can be modified by masking or unmasking each bit of the data memory address; (2) The pointer next address can be automatically incremented; (3) The next address can be set to any address in the data memory.

16.3.9 PSP - CMEM - PSP Loop

This test shall verify that the PSP can write and read the CMEM at all addresses.

16.3.10 X-Memory Read/Write Conflict Resolution

This test shall verify that hardware read and write conflict control logic is capable of resolving read and write conflicts created by software.

16.3.11 Preset Destination Register (PSD)

This test shall verify that data can be transferred to memory structures (0) and (1) by the PSD register via Buses A and D.

16.3.12 Compare and Transfer Instructions

This test shall verify decoding and execution of the following conditional transfer instructions:

- TCEQ - Compare Equal
- TCNE - Compare Not Equal
- TCGT - Compare Greater
- TCLT - Compare Less
- TCLE - Compare Less or Equal
- TCGE - Compare Greater or Equal

16.4 Self Test of the Arithmetic and Memory Functions

The following self test of the arithmetic and memory functions shall be furnished.

16.4.1 Instruction Test

This test shall evaluate the decoding and execution of the instruction controls, and the data pipeline for self test of the arithmetic and memory functions.

16.4.2 Register B Test

This test shall evaluate the setting, resetting and testing of the Register B bits resulting from arithmetical operations in the data pipeline.

16.4.3 BMC RAM and Pointer

This test shall evaluate the BMC RAM and Pointer incrementing.

16.4.4 BMC Task - Port 2

This test shall evaluate the establishment and execution of various tasks in the BM queue.

16.4.5 Port 3 Task Queue

This test and the functions to be tested are the same as 16.4.4 above, but for Port 3.

16.4.6 Bulk Memory

This test shall evaluate the loading and reading of the Bulk Memory.

16.5 Self Test of the PSP External Interfaces

Provisions shall be made for the Self Test of the PSP External Interfaces.

16.5.1 IDC Functions

The IDC functions shall be evaluated by entering BIT software routines through a PSP BIT data port into bus-D. The test shall verify that the DAGC output dynamic range conforms to requirements and responds in single incremental steps. All simulated timing and control inputs shall be such that the true performance of the calculation logic is evaluated.

16.5.2 STC Functions

The STC Function shall be tested by entering BIT software routines through the BIT input port, simulated timing and control STC profile inputs.

16.5.3 Clutter Doppler Error Function

This test shall evaluate the logic functions relating to Clutter Doppler Error.

16.5.4 Bit Stretcher and Prepacker

This test shall evaluate the operation of the Bit Stretcher and Prepacker logic, by entering software routines through the Bit input port.

16.5.5 Clutter Canceller

This test shall evaluate the operation of the Clutter Canceller by entering software routines through the BIT input port, and by detecting "stuck-at" conditions.

16.5.6 Doppler Phase Compensation and Pulse Compression

This test shall evaluate the operation of the Doppler Phase Compensation and Pulse Compression functions, and detect "stuck-at" conditions, by entering software routines through a BIT input port.