Communications Research Centre

THE DEVELOPMENT OF A PARTIAL PLOT CORRELATOR FOR MARITIME RADAR PLOT EXTRACTION

by

G.R. Painchaud

This work was sponsored by the Department of National Defence, Research and Development Branch under Project No. 33C71.

CRC REPORT NO. 1378
OTTAWA, JUNE 1985

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ABSTRACT

The development and implementation of an algorithm to perform partial plot correlation is described. This development takes into account the characteristics of partial plots generated by real radar returns. The evaluation of this algorithm using recorded radar data is then considered. This work was performed as part of a task on Automatic Detection and Tracking (ADT) for use with maritime surveillance radars employing mechanically scanned antennas.

1. INTRODUCTION

This report describes the development of a partial plot correlator for maritime plot extraction. This device forms part of an experimental plot extractor which was developed as part of an automatic detection and tracking (ADT) system for shipborne surveillance radars funded by DND[1,2].

The experimental plot extractor, which will be the topic of a separate report, detects and extracts target-like returns from the video signals of a surveillance radar. This is done through a process of constant false alarm rate (CFAR) control, thresholding, integration, and plot forming[3]. The last function, plot forming, is performed by the partial plot correlator which is the subject of this report. A conceptual diagram of the maritime plot extractor is shown in Figure 1.1.

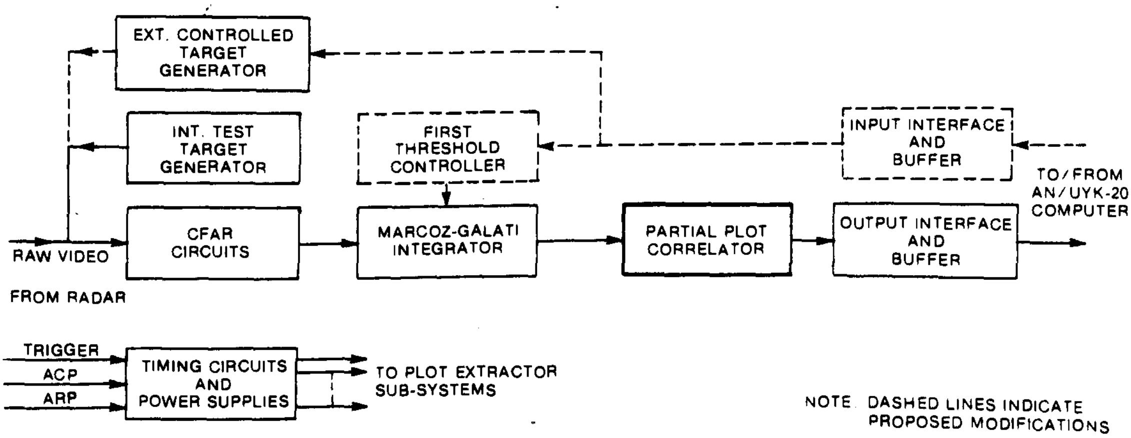

Figure 1.1 Conceptual diagram of the maritime plot extractor.

The partial plot correlator receives partial plots, or hits, which exceed the second threshold in the integrator. It must then group together all the partial plots which were generated by the same target. Finally, it must estimate the range and bearing of this target. These parameters are then stored in an output buffer for transmission to the AN/UYK-20 computer.

A description of the partial plot clusters, generated by targets, is given in the following section. Section 3 then introduces the algorithm which is used to perform the partial plot correlation. This is followed by Section 4 which outlines, at the block-diagram level, the hardware used to implement the algorithm. More detailed drawings of the circuitry, along with a timing diagram, are presented in Annexes A and B. Section 5 describes the evaluation of the partial plot correlator along with experimental results. Finally, the conclusions are given in Section 6.

2. CHARACTERISTICS OF PARTIAL PLOT CLUSTERS GENERATED BY TARGETS

As the radar antenna scans past a target, the returns on successive radar sweeps will cause the accumulator in the integrator to be incremented. This process will continue until enough returns have occurred to cause the sum in the accumulator to exceed the value of the second threshold. When this happens, the output of the second threshold comparator will change from the low state (0) to the high state (1). It will remain high on successive sweeps as long as returns are still being received from the target in question. When there are no more returns from the target, the accumulator will be decremented on successive sweeps until its sum equals zero. At this time the comparator's output will revert to the low state. The "ones" generated by the second threshold comparator are called "partial plots" or "hits".

It can be seen that there is a delay from the time when returns are first received from a target to that when the comparator's output goes high. There is a second delay between the time no further returns are received to that when the comparator's output goes low. These two delays give rise to a bias in the estimate of the target's bearing which has to be accounted for.[4]

In order to assess the characteristics of partial plots generated by real targets, an experiment was performed to record partial plot data using an L-band surveillance radar (AN/SPS-501). Video recordings were obtained from this radar using the Radar Research Laboratory's Advisor-62 radar recorder. These recordings were then played into the partially completed (less partial plot correlator) plot extractor and the hits from the second threshold comparator were used to write the current values of the range and bearing counters into one of two buffers. While the range and bearing of hits occurring on the present sweep were being stored into the first buffer, those stored in the second buffer on the previous sweep were transferred to the AN/UYK-20 computer. This process was repeated from sweep-to-sweep. The data were then stored on standard 9-track magnetic tape for subsequent analysis.

The partial plot data collected in the experiment were analysed by playing the tapes and presenting the data on a CRT display by means of a graphics processor (Norpak IGP) connected to the computer system. A typical presentation of these data is shown in Figure 2.1. This figure is a B-Scan representation (range vs. azimuth) of the data over a small sector of the radar scan. The individual partial plots are represented by the "X"'s in the figure. For a constant azimuth, the series of "X"'s in range represent all the partial plots occurring on a single sweep.

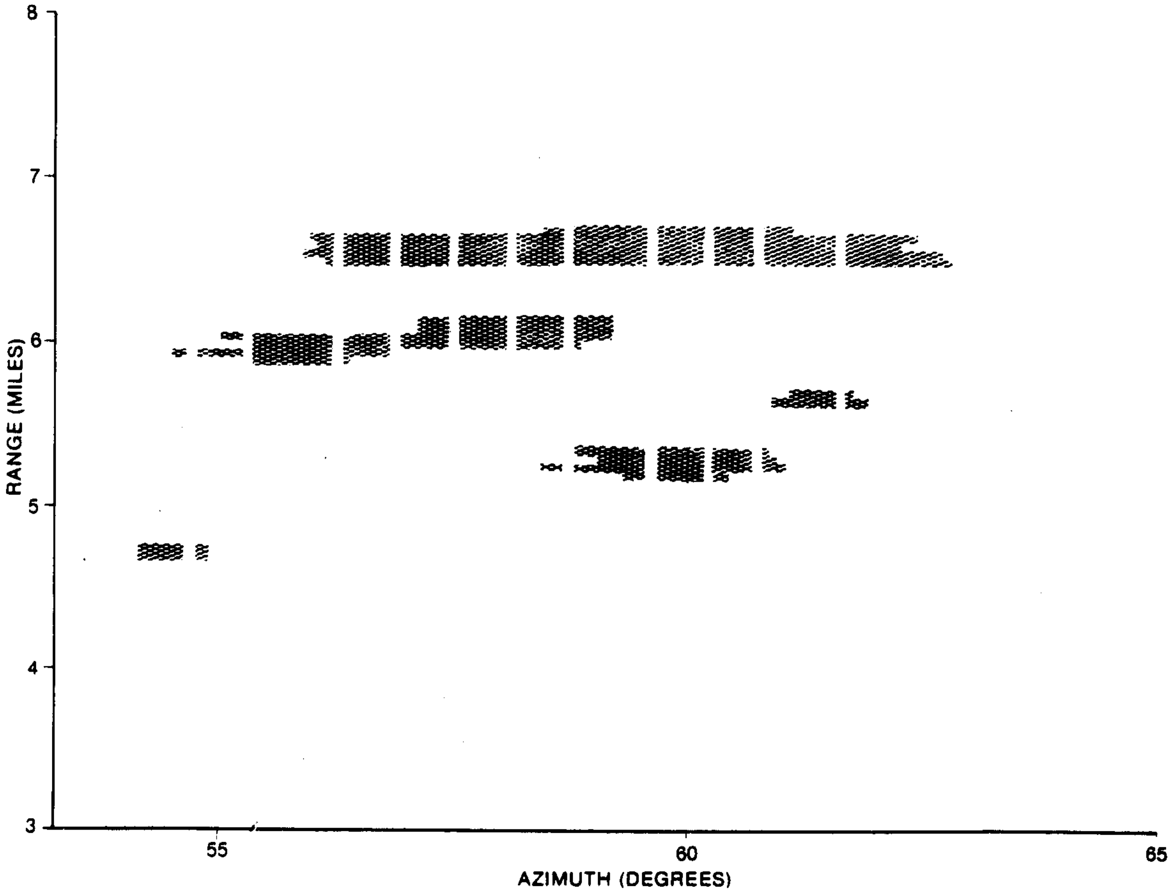

Figure 2.1 B-Scan representation of partial plot data obtained using the AN/SPS-501.

The range difference between two adjoining "X"'s represents the resolution of the range cells and is equal to .05 miles (the sampling rate being 1.863 MHz). It may be noted that for the five clusters of partial plots in Figure 2.1, there are always more than one partial plot in range. This is due to several factors:

(1) Actual targets are composed of distributed scatterers. This can cause the radar echo to spread in range.

(2) The detection bandwidth is typically of the order of the reciprocal of the pulse width, to approximate a matched filter. This will also cause the radar echo to spread in range.

(3) At the sampling frequency quoted above, the returns are being over-sampled (the transmitted pulse being 1 μsec long). By over-sampling, any possible straddling loss is minimized. This assures that the target will be detected in at least one identical range cell throughout the dwell if the returns fall on a range cell boundary.

The difference in azimuth between two neighbouring "X"'s represents the value of the least significant bit (LSB) of the azimuth word. Since a 12-bit synchro/digital converter is used for azimuth quantization, the LSB is equal to .0879° ($360/2^{12}$). As depicted in Figure 2.1, the azimuth changes by the value of the LSB on most sweeps. However, every so often, the azimuth changes by twice this value. The cause of this is that the PRF and the scan rate are asynchronous and that only one azimuth update occurs per sweep. For example, if the PRF is 600 Hz, sweeps occur every 1.667 msec. If the scan rate is 10 RPM (10.0426 exactly) and the azimuth is quantized to 12-bits, the LSB will change every 1.4586 msec. Beats will occur between these two rates according to the relationship 1.667 m = 1.4586 n, where (m, n) are integers. The smallest values of (m, n) that satisfy this relationship are (7, 8). Thus every 7th sweep, the azimuth will change by twice the value of the LSB. It can be seen from Figure 2.1 that this indeed occurs. However, this change is not constant, there are also cases where it occurs at different rates. This effect can be attributed to non-uniformities in the PRF and scan rate due to such factors as jitter in the PRF generator, wind loading of the antenna, etc.

Several other characteristics of the data are apparent in Figure 2.1. It is evident that, in each of the five clusters of partial plots, the spread in azimuth of the partial plots is always greater than that in range. This large spread in azimuth is due to the antenna's 3dB beamwidth, which for the AN/SPS-501 is approximately 2.4°. However, the azimuth extent of some of the clusters is greater than this; the largest cluster having a spread of approximately 7°. This indicates that for strong target returns, detections occur below the main lobe's 3 dB points. There is also the possibility that the antenna pattern is being distorted by reflections from the ship's superstructure[5].

It is also apparent from Figure 2.1 that some of the partial plot clusters have rough edges or gaps in range on the first and last few sweeps on which detections occur. This occurs if the return pulse has a "dip" or notch in it. Such a notch can occur in the returns from a target composed of several scatterers, if the phases of the individual returns from the scatterers are appropriate. A notch can also be present if a strong signal causes ringing in the radar receiver. The effect of such a notch, on the edges of a partial plot cluster, can be explained with the aid of Figure 2.2. As the radar antenna scans past a target, the amplitude of the returns on successive sweeps will at first increase and then decrease as the beam moves away from the target. Suppose the first three returns to exceed the first threshold in the plot extractor occur on the i^{th}, $i^{th}+1$, and $i^{th}+2$ sweeps. It is clear from Figure 2.2 that, if a notch is present in the returns, the first threshold crossings on the first few sweeps on which detections occur will have gaps in range. These gaps delay the start of the corresponding second threshold crossings, which will cause the partial plot cluster to have gaps in range. A similar process happens on the last few sweeps on which detections occur. Note also that the spreading in range or range extent of partial plots on a given sweep is proportional to the strength of the returns.

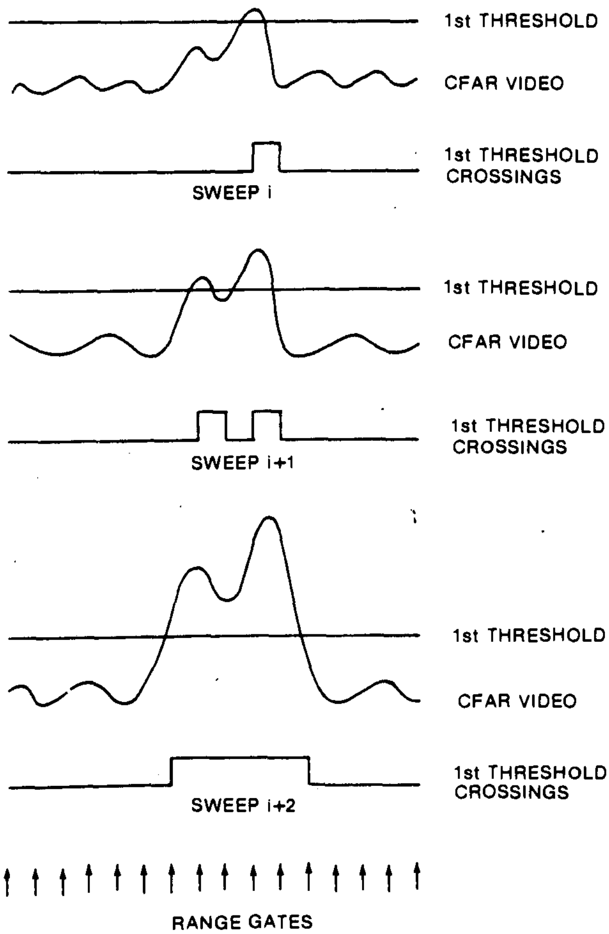

Figure 2.2 Effect of a notched target return on the first threshold crossings.

The characteristics of partial plot clusters described in this section will be used in the following section in defining the partial plot correlation algorithm.

3. PARTIAL PLOT CORRELATION ALGORITHM

3.1 Definition of the Algorithm

The partial plot correlation algorithm must perform two basic functions. These functions are:

(1) The sorting or correlating of all the partial plots generated

by the same targets into clusters or plots.

(2) The estimation of the range and bearing of these plots.

The technique used to correlate the partial plots must recognize that there can be range gaps between the partial plots generated by the same target. Several techniques can be used to estimate the range and bearing of the plots[3]. However, the radars with which the plot extractor will be used do not have stabilized antennas. This fact will cause the apparent bearing of a stationary target to jitter from scan to scan as the ship rolls and pitches. A limit is thus imposed on the achievable accuracy of the bearing estimate. Because of this limit, a fairly simple technique is used for bearing estimation. The bearing estimate is simply taken to be the azimuth of the first sweep on which a detection occurred plus one-half of the difference between this value and the azimuth of the last sweep on which a detection occurred. The value of the integrator bias is then removed from this value. The difference between the azimuths of the first and last sweeps on which detections occurred is the azimuth extent of the plot. The algorithm outputs this parameter along with the azimuth estimate.

The range estimate is obtained by taking one-half the sum of the ranges of the first and last partial plots. This calculation is performed each sweep, along with a calculation of the range extent. The range estimate that occurred on the sweep where the corresponding range extent had its maximum value is taken as the final range estimate of the plot. This technique implies that the range is estimated on the sweep where the signal to noise ratio (SNR) has its maximum value. The algorithm outputs the value of the range extent along with the range estimate.

To facilitate the correlation of the partial plots, the algorithm is partitioned into two parts. The first part correlates all the partial plots generated by the same target on a single sweep. It then calculates the bearing, range and range extent of this sub-cluster or string of partial plots. This first part is called the in-range correlation algorithm.

The second part of the algorithm takes the strings of partial plots generated by the first part and correlates them from sweep to sweep. It also calculates the azimuth, azimuth extent, range and range extent of the completed plots. This second part is called the sweep-to-sweep correlation algorithm. These two parts will be described in the next two sub-sections.

3.2 In-Range Correlation Algorithm

The in-range correlation algorithm processes all the partial plots generated on a single sweep. It reads partial plot data from two arrays and writes intermediate results to three other arrays. The data in these three arrays are then processed by the sweep-to-sweep correlation algorithm. This is depicted in Figure 3.1. The definition of the arrays used by the in-range correlation algorithm is given below:

PPLTAZ(,) = Partial PLoT AZimuth. This array stores the azimuths of all the partial plots generated on a single sweep.

PPLTRN(,) = Partial PLoT RaNge. This array stores the ranges of all the partial plots generated on a single sweep.

SAZ(,) = Sweep AZimuth. This array stores the azimuths of the sub-clusters or strings of partial plots processed on a single sweep.

SRNEX(,) = Sweep RaNge EXtent. This array stores the range extents of the sub-clusters or strings of partial plots processed on a single sweep.

SRN(,) = Sweep RaNge. This array stores the ranges of the sub-clusters or strings of partial plots processed on a single sweep.

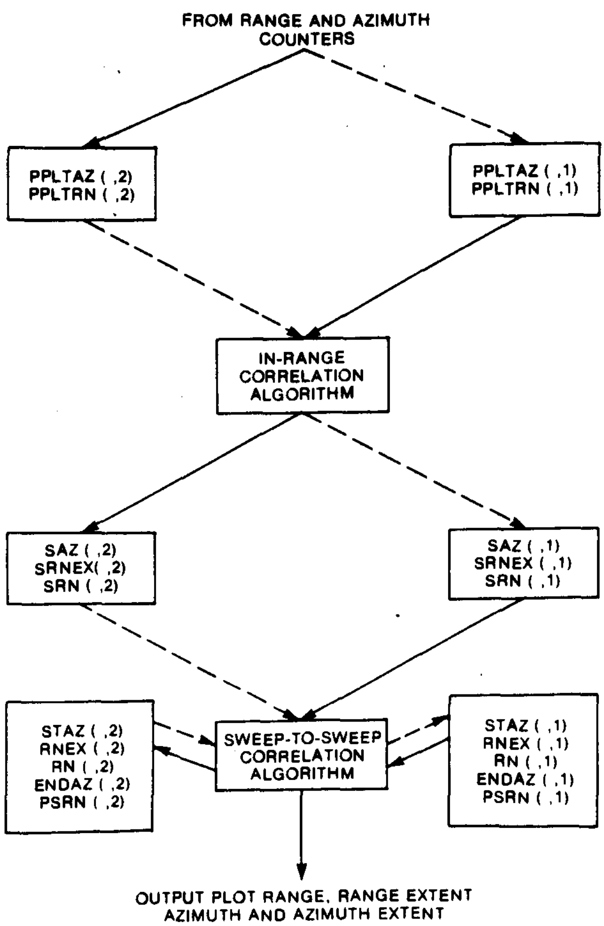

Figure 3.1 Interaction between the in-range correlation and sweep-to-sweep correlation algorithms and the data arrays.

In the above, the first array index denotes the current data word. The second index takes on the value of 1 or 2. In this way each array is partitioned into two halves. As data are written into one half of an array, data are simultaneously read from the other half. For example, in Figure 3.1, data are being written into the half of the arrays denoted by two and read from the half denoted by one. On alternate sweeps, these roles reverse; that is, data are written into the half denoted by one and read from the half denoted by two. This is shown by the solid and broken lines in Figure 3.1.

On the i^{th} sweep, the bearing and range of all the partial plots generated on this sweep are written into PPLTAZ(,2) and PPLTRN(,2). The other half of these arrays, PPLTAZ(,1) and PPLTRN(,1) contain the data from the $i^{th}-1$ sweep. As one half of these arrays is being written with data on the i^{th} sweep, the data from the $i^{th}-1$ sweep in the other half are simultaneously being read and processed by the in-range correlation algorithm. The data generated by this algorithm are stored in SAZ(,2), SRNEX(,2) and SRN(,2) while the data in the other half of these arrays are being read and processed by the sweep-to-sweep correlation algorithm. The data are always stored ordered in range in the arrays. That is, the larger is the value of the array index, the greater is the range. In the maritime plot extractor, the azimuth is only updated once per sweep. Because of this fact, all the azimuth values stored in the arrays will be equal for a given sweep.

A flowchart for the in-range correlation algorithm is shown in Figure 3.2. In order not to confuse the issue by having too many indices, Figure 3.2 assumes a particular sweep on which data are read from the half of the arrays denoted by one and written into the half denoted by two. This corresponds to the solid lines in Figure 3.1. In the flowchart, J and K are parameters used to index the arrays. MAX1 is a parameter which specifies the value of J at which there are no more input data. Similarly, MAX2 specifies the value of K at which no more output data are present. AZ, R1 and R2 are temporary values and ΔR1 is a parameter used to test for the end of a string of partial plots generated by the same target.

At the start of a sweep, the following hold true:

AZ=PPLTAZ(1,1)
R1=PPLTRN(1,1)
R2=PPLTRN(1,1)

The value of J is then incremented and if there are still data in the input arrays, the following inequality is tested:

$$PPLTRN(J,1)-R2>\Delta R1$$

If the inequality is false, the value of R2 is made equal to PPLTRN(J,1), J is incremented and if it is not equal to MAX1, the test is repeated. This loop repeats itself until the inequality is true (or J=MAX1). When this occurs, R1 is equal to the range of the first partial plot and R2 equal to that of the last partial plot generated on the current sweep by the same target. Note that by choosing the value of ΔR1 appropriately, range gaps in a string of partial plots such as those present in Figure 2.1 will not cause a target to be split.

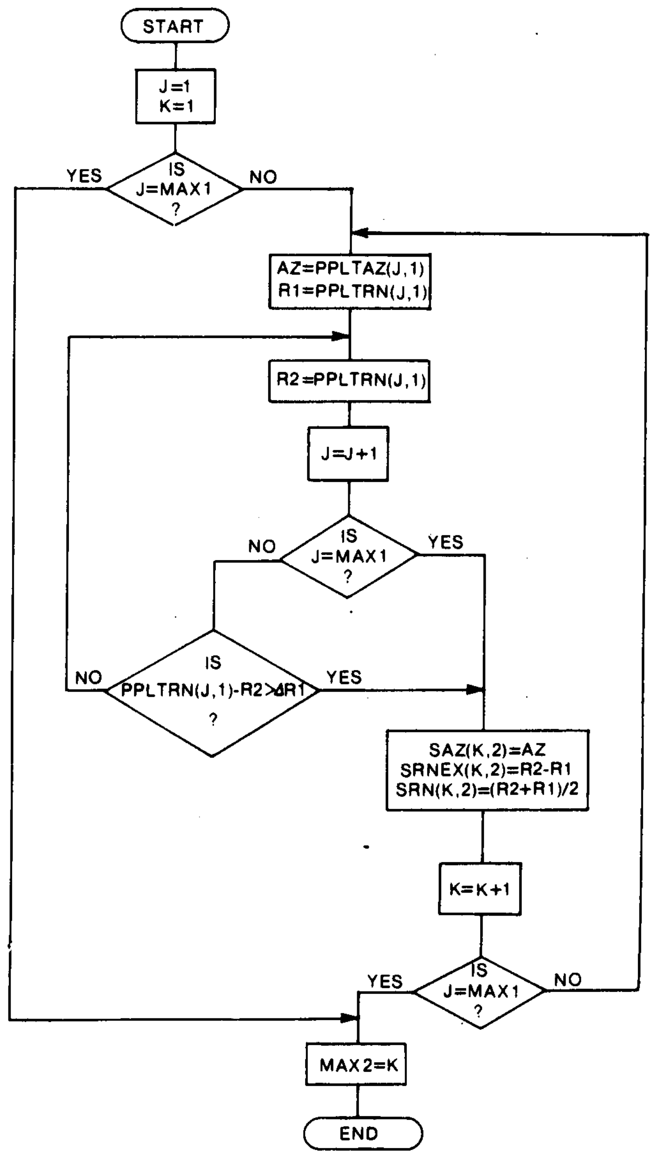

Figure 3.2 Flowchart for the in-range correlation algorithm.

The values of the sweep azimuth, sweep range extent and sweep range are now assigned as follows:

$$SAZ(K,2) = AZ \qquad (3.1)$$
$$SRNEX(K,2) = R2-R1 \qquad (3.2)$$
$$SRN(K,2) = (R2+R1)/2 \qquad (3.3)$$

The value of K is now incremented and the main loop of the algorithm is repeated. This procedure is repeated until all the data in the input arrays have been processed. This occurs when J=MAX1. Finally, the value of MAX2 is set to the current value of K. The algorithm now halts and awaits the start of the next sweep.

As an example, Figure 3.3 displays the values of SAZ and SRN generated by the in-range correlation algorithm using the partial plot data presented in Figure 2.1. Note that for a given sweep, there is only one "X" in Figure 3.3 per cluster of partial plots shown in Figure 2.1 and that the values of SAZ and SRN indicated by each of these "X"'s are as calculated by equations (3.1) and (3.3).

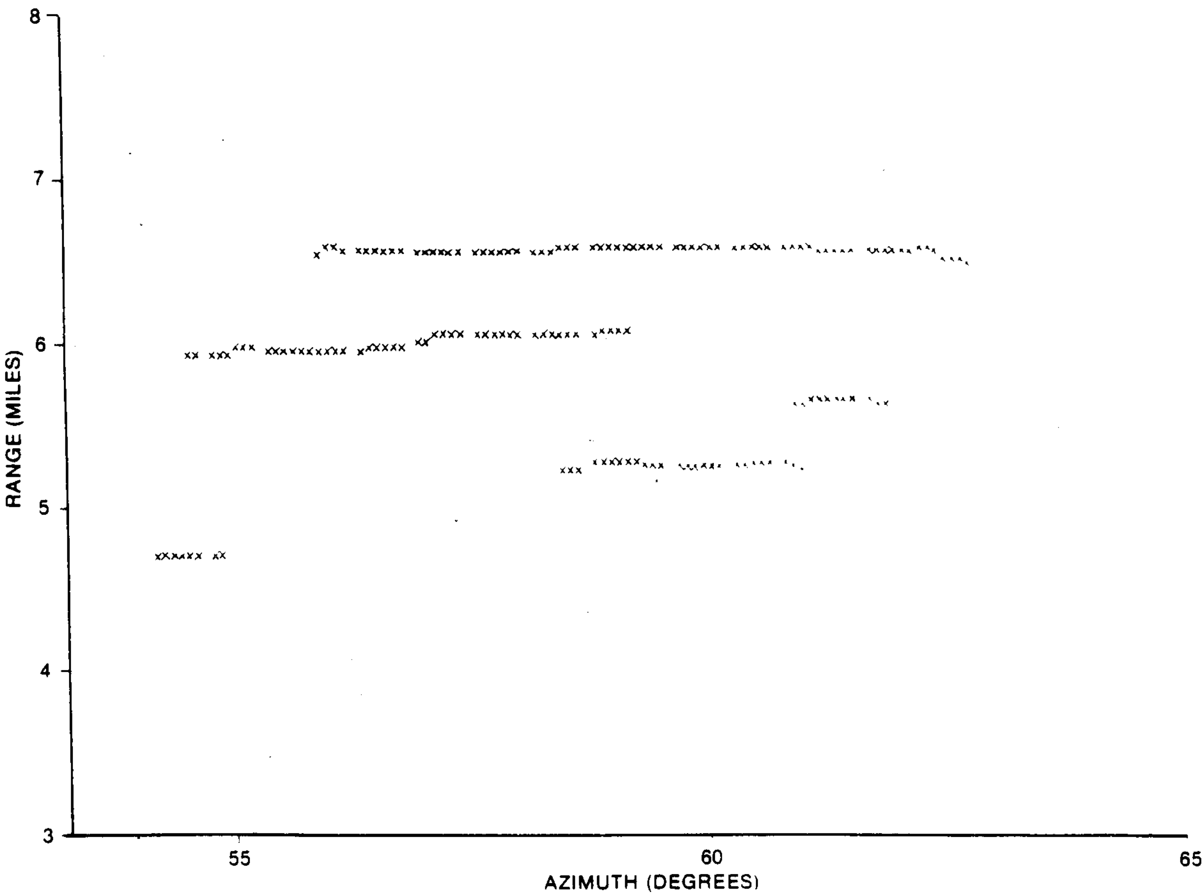

Figure 3.3 Values of SAZ and SRN generated by the in-range correlation algorithm using the partial plot data presented in Figure 2.1.

The intermediate plot data stored in SAZ(,2), SRNEX(,2) and SRN(,2) must now be correlated from sweep-to-sweep and the final plot parameters calculated. This is performed by the sweep-to-sweep correlation algorithm which will now be described.

3.3 Sweep-to-Sweep Correlation Algorithm

As can be seen from Figure 3.1, the sweep-to-sweep correlation algorithm reads the data generated by the in-range correlation algorithm which are stored in the arrays SAZ, SRNEX and SRN. It also reads plot data generated on previous sweeps from one half of the arrays STAZ, RNEX, RN, ENDAZ and PSRN. It writes plot data to the other half of these arrays and outputs completed plot parameters. The definition of these five arrays is given below:

STAZ(,) = STart AZimuth. This array stores the azimuths of the sweeps on which the start of new plots were detected.

RNEX(,) = RaNge EXtent. This array stores the range extents of all the plots being processed.

RN(,) = RaNge. This array stores the ranges of all the plots being processed.

ENDAZ(,) = END AZimuth. This array stores the azimuths of the last sweep on which the plots were updated.

PSRN(,) = Previous Sweep RaNge. This array stores the ranges of the plots as calculated on the previous sweep.

For the example presented in Figure 3.1, the first half of the arrays SAZ to SRN contains the intermediate results of all partial plots detected on the previous sweep. The first half of the arrays STAZ to PSRN contains the current parameters of all the plots currently being processed. The data in these two arrays must be merged together and processed. For a given value of the array indices, this action has three possible outcomes, these are:

(1) The data in STAZ(,1) to PSRN(,1) are not updated by the data (if any) in SAZ(,1) to SRN(,1). This is the case of a completed plot. The algorithm calculates the final plot parameters and outputs this data.

(2) The data in SAZ(,1) to SRN(,1) do not associate with current plot data (if any) in STAZ(,1) to PSRN (,1). This is the case of a new plot. A new plot is initiated and the data are written into the second half of the five arrays.

(3) The data in SAZ(,1) to SRN(,1) associate with current plot data in STAZ(,1) to PSRN(,1). This is the case of a current plot. The data in STAZ(,1) to PRSN(,1) are updated by the data in SAZ(,1) to SRN(,1) and the results are written into STAZ(,2) to PSRN(,2).

As in the case of the in-range correlation algorithm, the two halves of the arrays exchange read/write roles from sweep-to-sweep. This is shown by the solid and broken lines in Figure 3.1.

A flowchart for the sweep-to-sweep correlation algorithm is shown in Figures 3.4 to 3.7. Figure 3.4 illustrates the logic that determines into which of the three cases listed above the current data fall. Figures 3.5 to 3.7 describe the processing to be performed for each of these cases. With reference to Figure 3.4, the parameters L, M and N are indices which are used to address the data read from and written into the arrays. The parameters MAX2 and MAX3 indicate the values of L and M at which there are no more data in the respective input arrays. The parameter ΔR2 is used to define an association region which will be described later.

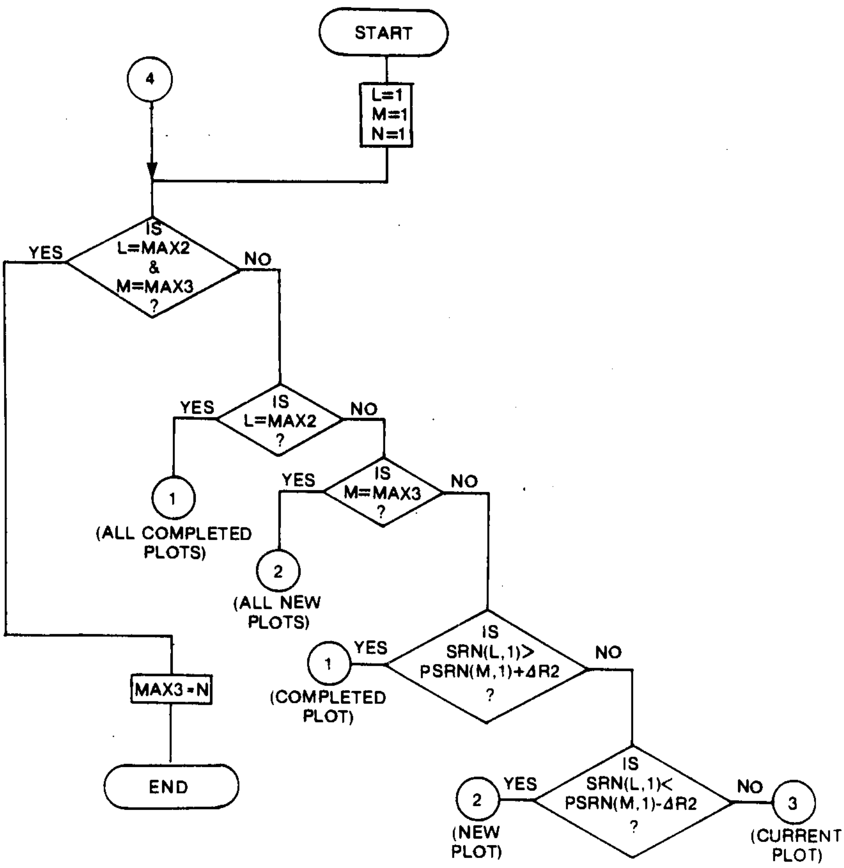

Figure 3.4 Flowchart for the sweep-to-sweep correlation algorithm. Decision logic.

At the start of a sweep, L, M and N are equal to one. If both equalities L=MAX2 and M=MAX3 are satisfied, there are no data present in the input arrays. The algorithm then sets MAX3=N (one in this case) and halts. If L=MAX2 but M≠MAX3, there are no data in the arrays SAZ(,1) to SRN(,1) but there are current plot data in the arrays STAZ(,1) to

PSRN(,1). This implies that all the current plot data correspond to completed plots and are thus processed as case one. If L≠MAX2 but M=MAX3, there are no data in the arrays STAZ(,1) to PSRN(,1) but there are intermediate plot data in the arrays SAZ(,1) to SRN(,1). This implies that all the intermediate plot data correspond to new plots and are thus processed as case two.

If L≠MAX2 and M≠MAX3, then there are data in both arrays SAZ(,1) to SRN(,1) and STAZ(,1) to PSRN(1,). Since the data in these arrays are ordered in increasing range, the values of SRN(L,1) and PSRN(M,1) are compared to decide to which of the three cases the data correspond. This is done as follows:

(1) If $SRN(L,1) > PSRN(M,1)+\Delta R2$, then there are no intermediate plot data to associate with the current plot data. This is the case of a completed plot.

(2) If $SRN(L,1) < PSRN(M,1)-\Delta R2$, then there are no current plot data to associate with the intermediate plot data. This is the case of a new plot.

(3) If both of the above inequalities are false, then $SRN(L,1)= PSRN(M,1)\pm\Delta R2$. This implies that the intermediate plot data associate with the current plot data; this is the case of a current plot.

In the above, the parameter ΔR2 defines an association region about PSRN(M,1) into which the value of SRN(L,1) must fall if the intermediate plot data are to associate with the current plot data. Note from Figure 3.3 that for the case of a current plot, the equality SRN(L,1)=PSRN(M,1) is not necessarily true, but that these values will be close. The parameter ΔR2 accounts for these small differences. The processing performed for the completed plot, new plot and current plot cases will now be described.

Figure 3.5 illustrates the processing required for a completed plot. The values of the end azimuth and start azimuth of the plot are stored in ENDAZ(M,1) and STAZ(M,1). The difference between these two values is the azimuth extent (AZEX) of the plot. The values of the plot's range (RN) and the range extent (RNEX) are set equal to RN(M,1) and RNEX(M,1). Finally the plot's azimuth is calculated as the start azimuth plus one half of the azimuth extent minus the value of the bias. The algorithm then outputs the values of RN, RNEX, AZ and AZEX. The value of M is incremented and the main loop of the algorithm is repeated.

Figure 3.6 illustrates the processing required for a new plot. The value of SAZ(L,1), which is the azimuth of the sweep on which the first detection occurred, is stored in STAZ(N,2) and ENDAZ(N,2). The value of the corresponding range extent, SRNEX(L,1), is stored in RNEX(N,2). The value of the corresponding range, SRN(L,1), is stored in RN(N,2) and PSRN(N,2). The values of L and N are incremented and the main loop of the algorithm is repeated.

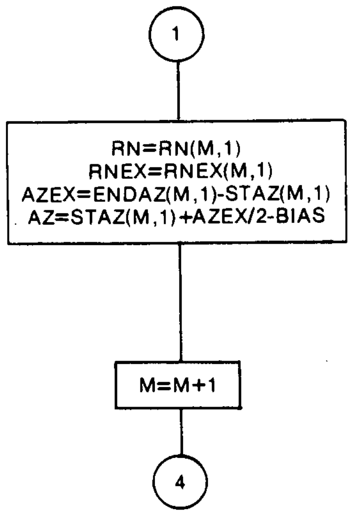

Figure 3.5 Flowchart for the sweep-to-sweep correlation algorithm. Completed plot processing.

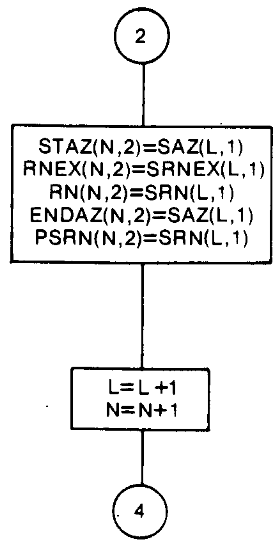

Figure 3.6 Flowchart for the sweep-to-sweep correlation algorithm. New plot processing.

Figure 3.7 illustrates the processing required for a current plot. If the range extent calculated on the last sweep, SRNEX(L,1) is greater than the previously stored value of the range extent, RNEX(M,1), then the values of RNEX(N,2) and RN(N,2) are updated by the values of SRNEX(L,1) and SRN(L,1). If the above inequality is false, then the values of RNEX(N,2) and RN(N,2) are updated by the values of RNEX(M,1) and RN(M,1). In this way, RNEX(N,2) contains the maximum value of range extent calculated over all of the sweeps that the current plot was detected. RN(N,2) contains the range of the plot as calculated on the sweep that the range extent had its maximum value. The value of STAZ(N,2) is set equal to that of STAZ(M,1). Thus STAZ(N,2) contains the value of the azimuth of the sweep on which the current plot was first detected. The value of ENDAZ(N,2) is set equal to that of SAZ(L,1), which is the azimuth of the last sweep on which the current plot was detected. Finally, the value of PSRN(N,2) is set equal to that of SRN(L,1), which is the range of the plot as calculated on the last sweep that detections occurred. The values of L, M and N are now incremented and the main loop of the algorithm is repeated.

Values of the plot parameters generated by the sweep-to-sweep correlation algorithm using the intermediate plot data shown in Figure 3.3 are presented in Figure 3.8. On comparing these two figures, it can be seen that the strings of numbers in Figure 3.8 correspond to the values of SAZ and SRN plotted in Figure 3.3. These strings of numbers illustrate all the particular values of SAZ and SRN that were associated with a particular plot. The values of plot range and azimuth are also indicated by the five

"X"'s in Figure 3.8. On comparing the position of these five "X"'s with the original partial plot data of Figure 2.1, it can be seen that they represent quite a good approximation of the centre of gravity of the partial plot clusters.

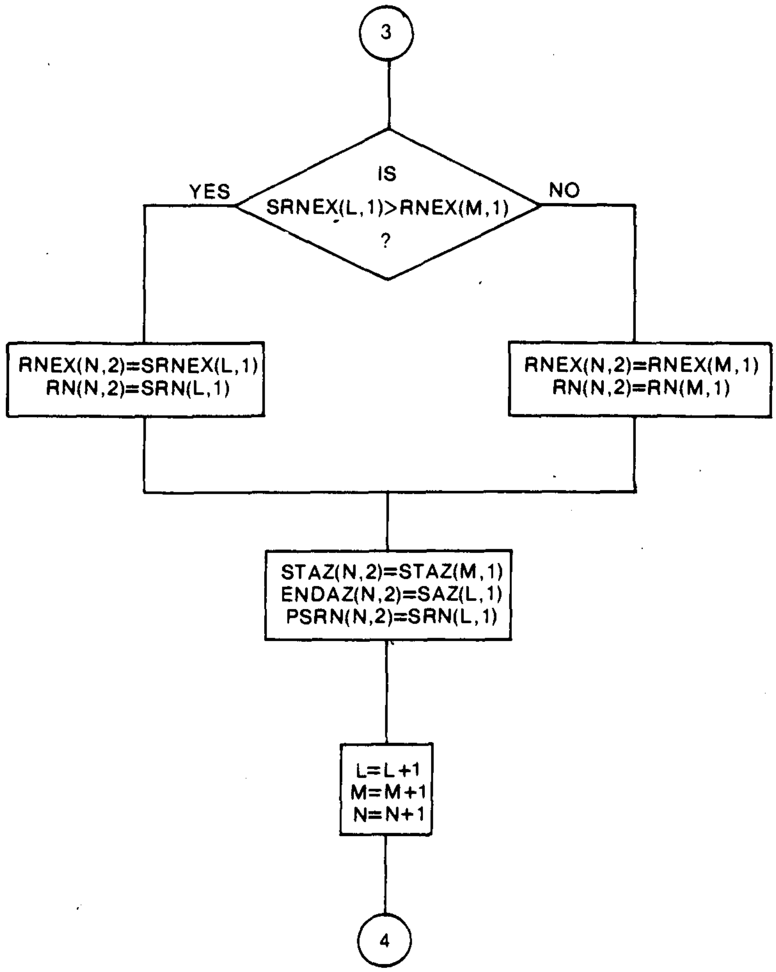

Figure 3.7 Flowchart for the sweep-to-sweep correlation algorithm. Current plot processing.

In concluding this section, there are two items which warrant mention. The first concerns the technique used to decide between a completed plot, a new plot and a current plot. This was done by comparing the values of SRN and PSRN. The same results might be obtained by comparing the values of SRN and RN, thus eliminating the need for array PSRN. This should work provided that the partial plot clusters are not skewed in range and that the value of ΔR2 is appropriately chosen.

The second item relates to the need for arrays PPLTAZ and PPLTRN and arrays SAZ to SRN. One might think that values of the azimuth and range of partial plots could be read directly by the in-range correlation algorithm and that the data generated by this algorithm could be read directly by the sweep-to-sweep correlation algorithm. However, it must be remembered that there is quite a difference between the peak and average rates at which partial plots are detected. In this context, the arrays mentioned above can serve to regulate the data rate. Reference to this fact will be made in the next section on implementation of the algorithm.

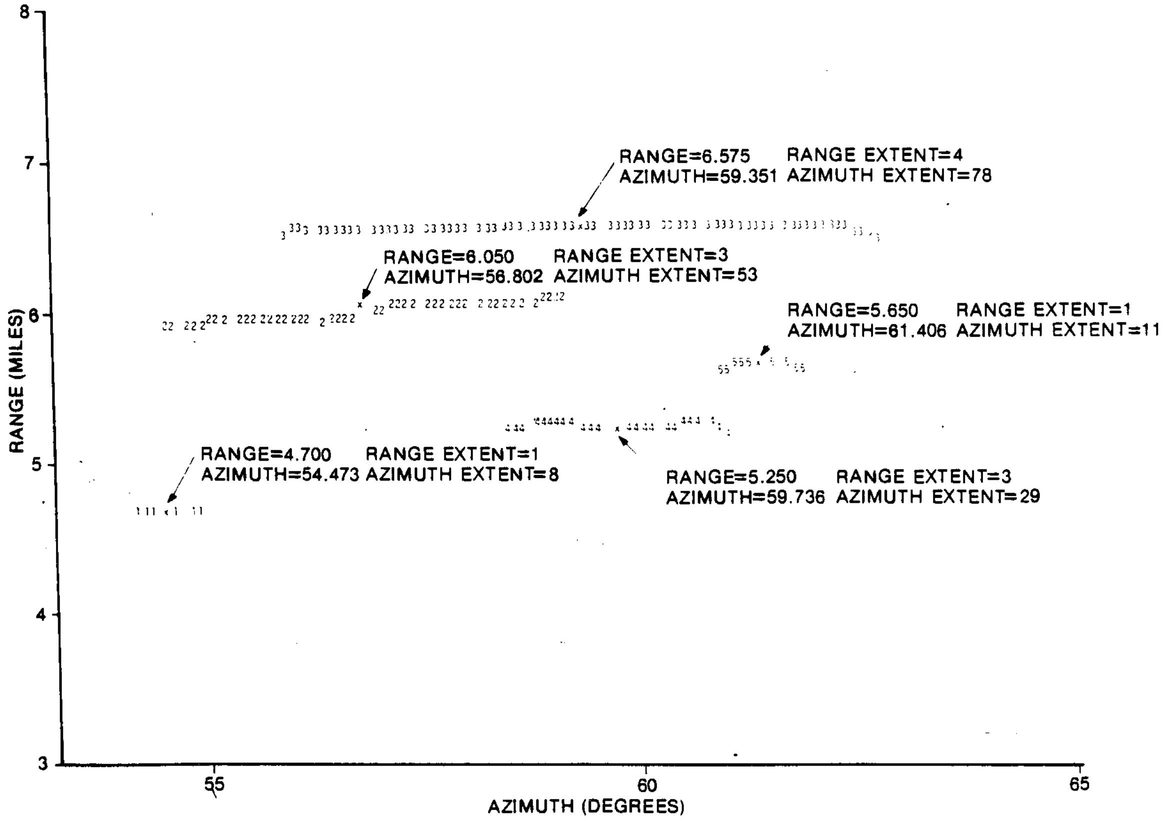

Figure 3.8 Values of the plot parameters generated by the sweep-to-sweep correlation algorithm using the intermediate plot data presented in Figure 3.3.

4. IMPLEMENTATION OF THE ALGORITHM

4.1 Method of Implementation

There are two methods which can be used to implement the partial plot correlation algorithm. The first method is to use a conventional hard-wired logic circuit approach. The second is to use a microprocessor (μP) and to implement the algorithm in firmware.

In comparing the relative merits of the two methods, there are several trade-offs to consider. Of prime concern are the data rates and speed of execution. Hard-wired systems are inherently faster than microprocessor based systems. However, it should be feasible to use a microprocessor in this particular application if one of the faster devices available is used. Another consideration is that by using a microprocessor, one is trading hardware development effort for software development effort. The software being developed can be debugged with the aid of standard tools available in a microprocessor development support environment. It might be more difficult to debug and test a hardware based implementation of the algorithm. Moreover, there are likely to be more IC's and interconnections in a hardware implementation, especially if standard SSI and MSI IC's are used. Lastly, it is probably easier to modify a software based system than a hardware one.

From the above discussion, it would seem logical to opt for a microprocessor based implementation of the algorithm. Unfortunately, the Radar Research Laboratory did not possess a fully supported microprocessor development system at the time this work was initiated. Because of this fact, a hardware based implementation was used. A description of the hardware implementation of the in-range correlation and sweep-to-sweep correlation algorithms will now be given at the block diagram level.

4.2 In-Range Correlation Implementation

A block diagram of the hardware used to implement the in-range correlation algorithm is shown in Figure 4.1. With reference to the last paragraph of Sub-Section 3.3 and Figure 3.1, it was decided to eliminate the arrays PPLTAZ and PPLTRN but to keep the arrays SAZ to SRN. This implies that the in-range correlation hardware functions over a large data rate and that it must be capable of operating at the peak partial plot data rate. However, it was felt that it would be impractical to also have the sweep-to-sweep correlation hardware operate at this rate. Hence, it was decided to use the arrays SAZ to SRN to store the intermediate results generated by the in-range correlation hardware. The use of these arrays implies that the sweep-to-sweep correlation hardware functions at a slower, but constant data rate. Since the arrays PPLTAZ and PPLTRN are not used in the implementation, the values of the partial plot azimuth and range are obtained directly from the azimuth and range counters inside the plot extractor. The arrays SAZ to SRN are implemented using N-MOS RAMS having tri-state outputs (Intel type 2101A-2), configured into two halves of 256-32 bit words each. In each word, bits 21-32 contain the value of SAZ in BAM (binary angle measurement) format. Bits 13-20 and bits 1-12 contain the values of SRNEX and SRN respectively in binary format. Each half has its own 8-bit address counter (2-74LS161) and associated control circuitry (This circuitry is not shown in Figure 4.1 but is found in Annex A). This circuitry consists of a latch (2-74LS75), a comparator (2-74LS85) and an 8-input NAND gate (1-74LS30). The latch is used to store the last address used on the previous sweep (MAX 2). The comparator then compares this address with the current value of the address counter on the present sweep. The 8-input NAND gate is used to check for and prevent address overflow. By connecting the data inputs and outputs of the two halves together and by controlling the read/write and output enable lines, data can be written into one half while data are simultaneously being read from the other half.

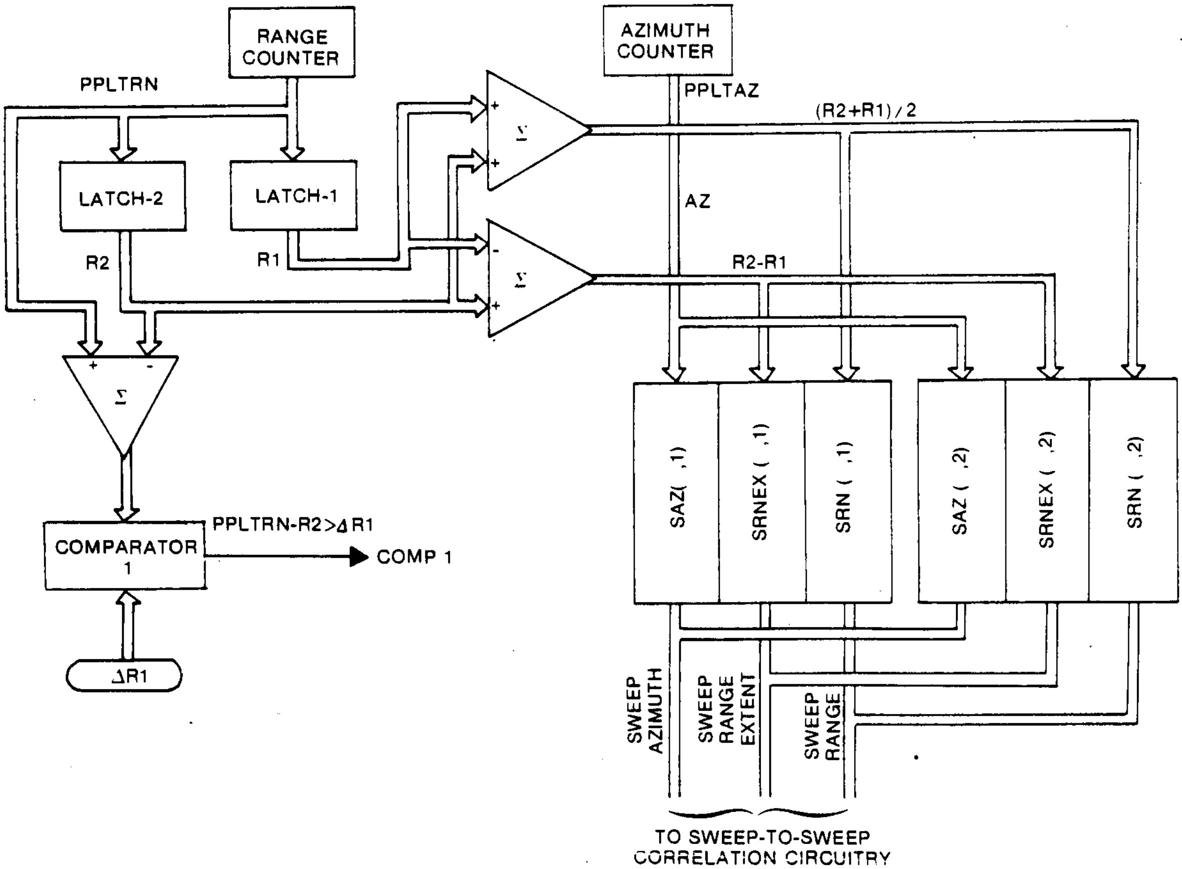

Figure 4.1 Block diagram of the in-range correlation hardware.

The hardware block diagram of Figure 4.1 implements the processing described by the flowchart in Figure 3.2 as follows. On the first range bin that contains a partial plot, the integrator's output will be high. This causes the current value of the range counter, PPLTRN, to be stored in latches one and two (3-74LS75). These two latches store the parameters R1 and R2. On the next range bin that a partial plot is detected, the value of R2 is subtracted from the current value of the range counter and the result compared to ΔR1. The parameter ΔR1 is a 4-bit word whose value is set by means of DIP switches. If this difference is not greater than ΔR1, the value of R2 is set equal to the current value of the range counter and the above procedure is repeated. In this way, the hardware is implementing the inner loop of Figure 3.2 This continues until the difference between the current value of PPLTRN and R2 is greater than ΔR1. In the above, the operation PPLTRN-R2 is performed in hardware by adding the value of PPLTRN to the 2's complement representation of R2 in a binary adder (3-74LS283). A standard hardware comparator (3-74LS85)is used to compare this difference to the parameter ΔR1. Although the range counter is incremented once per range bin irrespective of the integrator's output, the variable PPLTRN only describes values of the range counter on range bins where the integrator's output is high.

Two adders connected to the output of latches one and two compute the sweep range (R2+R1)/2, and the sweep range extent, R2-R1, as defined in Figure 3.2. In this implementation, the subtraction of R1 is performed by adding the 2's complement of R1. The division by two is accomplished by shifting the binary point one bit to the left, thus doubling the resolution of the range estimate.

When the inequality PPLTRN-R2>ΔR1 is satisfied, the comparator's output goes high. This causes the control circuitry to write the values of AZ, R2-R1 and (R2+R1)/2 into the current address of arrays SAZ to SRN. The control circuitry then increments the address counter. This last action is equivalent to incrementing K in Figure 3.2. If the end of sweep has not yet been reached, the current value of PPLTRN is stored in latches one and two and the main loop of the algorithm is repeated.

The above process continues until the end of sweep is reached. When this occurs, the control circuitry causes the current value of the address counter to be stored in a latch which stores the value of MAX2. The address counter is then reset to zero and the two halves of the arrays exchange read/write roles. The data just written into the arrays are read out and processed by the sweep-to-sweep correlation hardware on the next sweep, while new data are simultaneously written into the other half of the arrays by the in-range correlation hardware.

More detailed circuit drawings of the in-range correlation hardware and control circuitry are found in Annex A. A block diagram description of the sweep-to-sweep correlation hardware will now be given.

4.3 Sweep-to-Sweep Correlation Implementation

A block diagram of the hardware used to implement the sweep-to-sweep correlation algorithm is shown in Figures 4.2 and 4.3. With reference to Figure 4.2, the arrays STAZ to PSRN are implemented using a technique similar to that described in Sub-section 4.2 to implement the arrays SAZ to SRN.

The hardware implements the sweep-to-sweep correlation algorithm as follows. With reference to Figure 3.4, it is assumed that on this particular sweep, data are being read from the first half of the arrays and are being written into the second half. At the start of the sweep, the array address counters containing the values of L,M and N are reset to zero. The values of L and M are then compared with those of MAX2 and MAX3, which are stored in latches (these latches are not shown in Figures 4.2 and 4.3 but are found in Annex A). The hardware thus implements the first three equalities of Figure 3.4. If the first equality is true, the value of MAX3 is set equal to N. This terminates the processing of the sweep in question,as this is the case where there are no plot data to be processed.

If the "all completed plots" or "all new plots" cases result, the hardware automatically treats all the data as case 1 or case 2 respectively. If all three equalities are false, the hardware then examines the values of SRN(L,1) and PSRN(M,1) to decide which of the three cases the particular data correspond to. This procedure is described by the two inequalities in the lower right-hand corner of Figure 3.4.

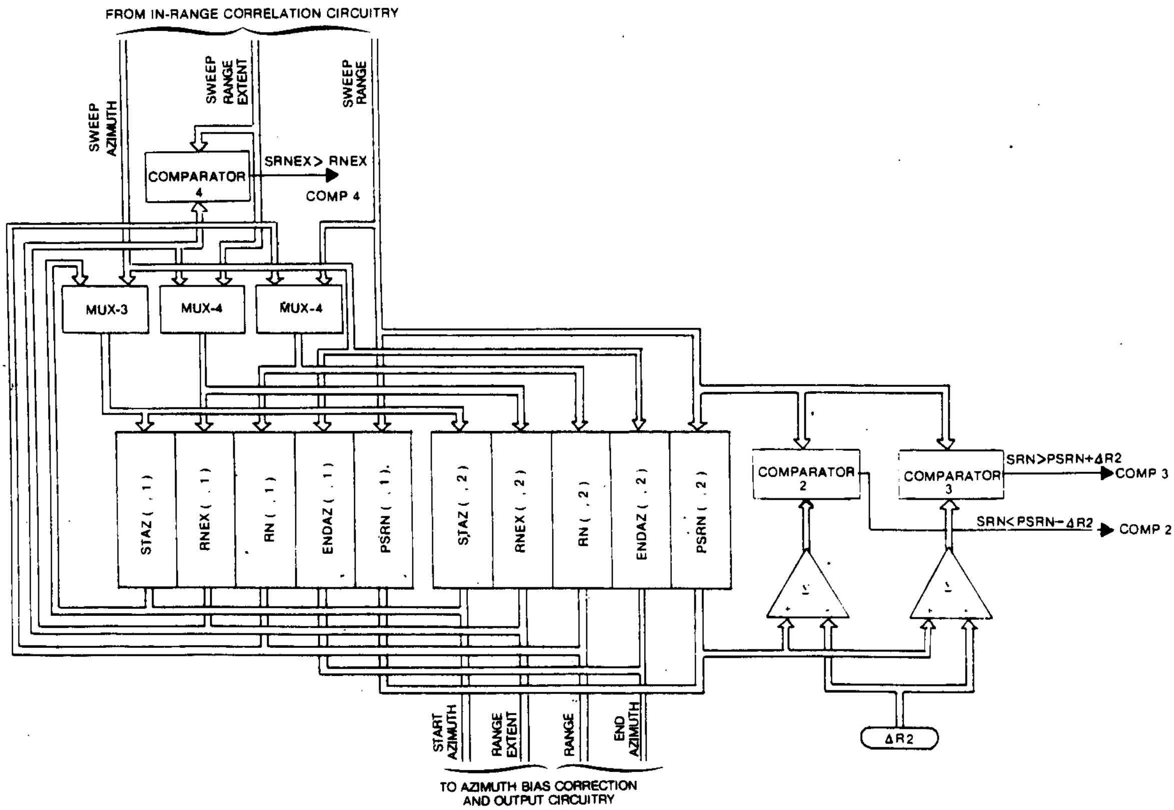

Figure 4.2 Block diagram of the sweep-to-sweep correlation hardware. Sweep-to-sweep correlation circuitry.

The hardware implements the two inequalities just mentioned as follows. The value of PSRN(M,1) as read from array PSRN is added to the value of the parameter ΔR2 in one binary adder and to the 2's complement value of ΔR2 in a second adder. The outputs of these two adders have the values PSRN(M,1)+ΔR2 and PSRN(M,1)-ΔR2 respectively. These two values are then compared to the value of SRN(L,1), by means of two comparators. These two comparators are labelled comparator 2 and comparator 3 in Figure 4.2. The output of comparator 2 is high whenever the inequality SRN<PSRN-ΔR2 is true. Similary, the output of comparator 3 is high whenever the inequality SRN>PSRN+ΔR2 is true. The relationship between the outputs of comparators 2 and 3 and the case the data in question belong to is summarized below.

CASE	COMPARATOR 2 $SRN < PSRN - \Delta R2$	COMPARATOR 3 $SRN > PSRN + \Delta R2$
1. Completed Plot	0	1
2. New Plot	1	0
3. Current Plot	0	0

Note that it is impossible for both outputs to be high simultaneously.

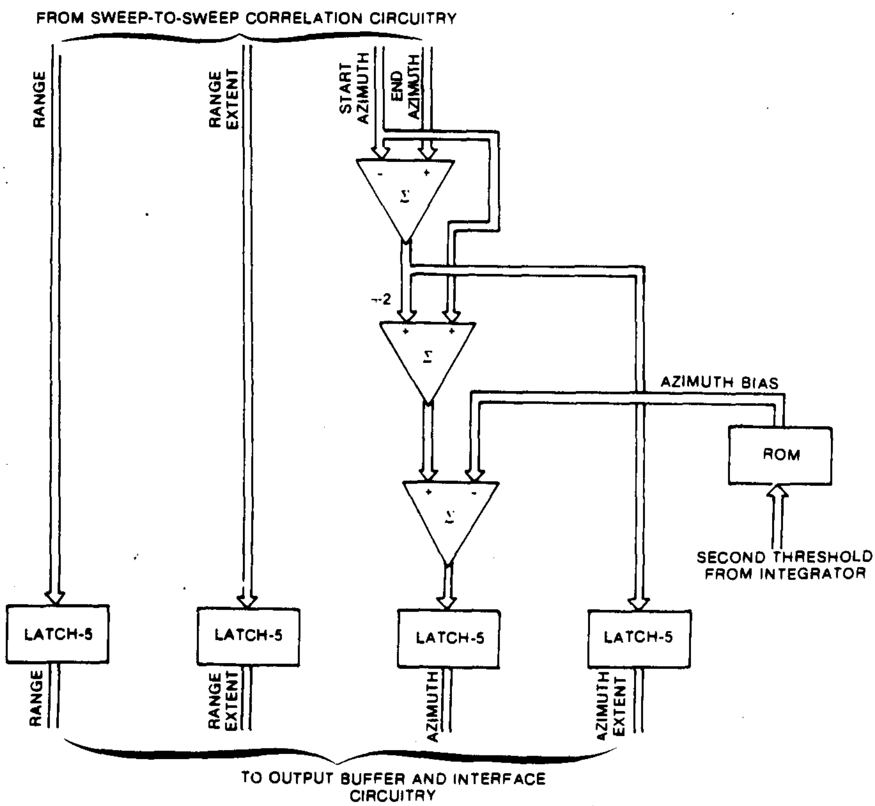

Figure 4.3 Block diagram of the sweep-to-sweep correlation hardware. Azimuth bias correction and output circuitry.

For the case of a completed plot, the hardware implements the processing described in Figure 3.5. The values of plot range and range extent are read from arrays RN and RNEX in Figure 4.2 and stored in the appropriate output latches shown in Figure 4.3. The values of the start and end azimuths are read from arrays STAZ and ENDAZ. The 2's complement of STAZ is added to the value of ENDAZ in the first or uppermost adder shown in Figure 4.3. The output of this adder is the azimuth extent of the plot, AZEX. This value is stored in the azimuth extent output latch. The value of AZEX is also divided by two using a hard wired shift and this value added to the value of STAZ in the second adder shown in Figure 4.3. The output of this adder is the uncorrected value of the plot azimuth. Finally this value is added to the 2's complement of the azimuth bias in the bottom most adder. The value of the azimuth bias is a function of the second threshold of the integrator in the plot extractor[4]. These values are stored in a PROM (Intel type 3624A) which is addressed by the value of the second threshold in use. The output of this last adder is the corrected plot azimuth and this value is stored in the azimuth output latch. The control circuitry now generates an output data ready (ODR) pulse which is used to transfer the plot parameters stored in the four latches to the output buffer. Finally, the address counter containing the value of M is incremented and the main loop of the algorithm is repeated.

In the case of a new plot, the hardware implements the processing outlined in Figure 3.6. The value of the sweep azimuth is read from array SAZ and is stored in array STAZ via multiplexer 3 (3-74LS157) and in array ENDAZ. The value of the sweep range extent is read from array SRNEX and is stored in array RNEX via the first half of multiplexer 4 (2-74LS157). The value of the sweep range is read from array SRN and is stored in array RN via the second half of multiplexer 4 (3-74LS157) and in array PSRN. Finally, the address counters containing the values of L and N are incremented and the main loop of the algorithm is repeated.

The processing required for the case of a current plot is outlined in Figure 3.7. This processing is implemented by the hardware as follows. The values of the sweep range extent and range extent are read from arrays SRNEX and RNEX. These two values are compared to each other in comparator 4. If the inequality SRNEX>RNEX is true, the current values of SRNEX and SRN are stored in arrays RNEX and RN via multiplexer 4. If the above inequality is false, then the previous values of RNEX and RN are used to update these arrays via multiplexer 4. The previous value of STAZ is used to update this array via multiplexer 3. The values of sweep azimuth and sweep range as read from arrays SAZ and SRN are stored in arrays ENDAZ and PSRN. Finally, the address counters containing the values of L, M and N are incremented and the main loop of the algorithm is repeated.

The main loop of the algorithm is repeated until there are no more data in the input arrays to be processed. When this occurs, the first equality in Figure 3.4 is true. The control circuitry then sets MAX3 equal to the current value of N. This terminates the processing of the sweep in question. The control circuitry then resets the address counters containing the values of L, M and N to zero and causes the two halves of arrays STAZ thru PSRN to exchange read/write roles. The hardware is now ready to process the data from the next sweep.

More detailed circuit drawings of the sweep-to-sweep correlation hardware and control circuitry are found in Annex A. Details of the circuit card construction will now be given.

4.4 Circuit Card Construction

The partial plot correlator was constructed on two 8" x 13" circuit cards. These cards are the standard circuit cards that are used in the plot extractor. As this is an experimental equipment, wirewrap techniques were used instead of printed circuitry, as it is easier to modify the former. The two partial plot correlator circuit cards occupy slots 6 and 7 in the plot extractor card crate.

The first circuit card, Partial Plot Correlator I, contains the in-range correlation and control (timing) circuitry. A photograph of this card is shown in Figure 4.4. The N-MOS RAMs used to implement the arrays SAZ to SRN can be seen in rows 1 and 3 (top of board); the DIP switches used to set the value of ΔR1 can be seen at the end of row 7. Only 4 of the group of 8 switches shown are used.

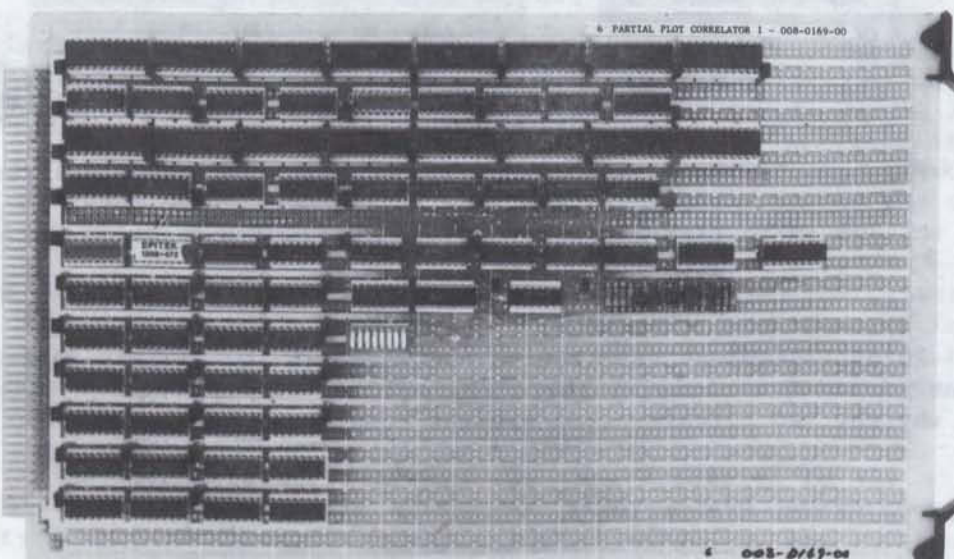

Figure 4.4 Photograph of the first partial plot correlator circuit card. This card contains the in-range correlation and control circuitry.

The second card, Partial Plot Correlator II, contains the sweep-to-sweep correlation circuitry, along with the azimuth bias correction and output circuitry. This card is shown in Figure 4.5. The N-MOS RAMs used to implement the arrays STAZ to PSRN can be seen in rows 1 to 4. The DIP switches used to set the value of ΔR2 can be seen at the end of row 6. Again, only 4 of the group of 8 switches are used. The PROM used to store the values of the azimuth bias can be seen in row 10, programmed for integrator weights of $\alpha_1=3$, $\beta_1=1$, $\alpha_2=1$, $\beta_2=3$.

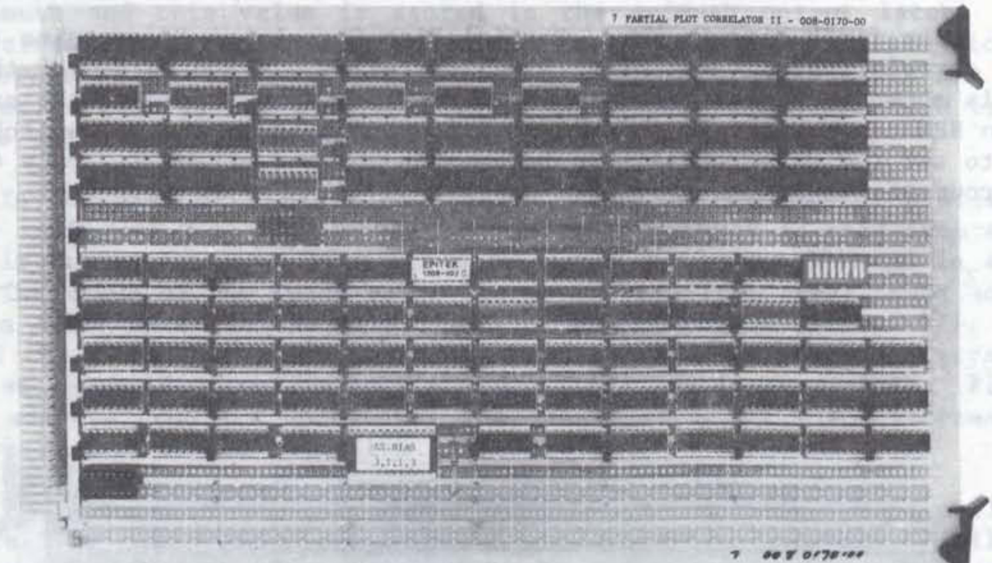

Figure 4.5 Photograph of the second partial plot correlator circuit card. This card contains the sweep-to-sweep correlation, azimuth bias correction and output circuitry.

In partitioning the circuitry between the two circuit cards, attention was given to minimizing the number of interconnections. This is the reason why the two circuit cards are not completely populated.

5.0 EXPERIMENTAL EVALUATION

The partial plot correlator circuit cards were integrated with the rest of the plot extractor and the unit was then evaluated. For this purpose, the plot extractor was connected to the AN/UYK-20 computer, which in turn is interfaced to one of the laboratory's Hewlett Packard (HP) 21MX computer systems. The configuration of this equipment is shown in Figure 5.1.

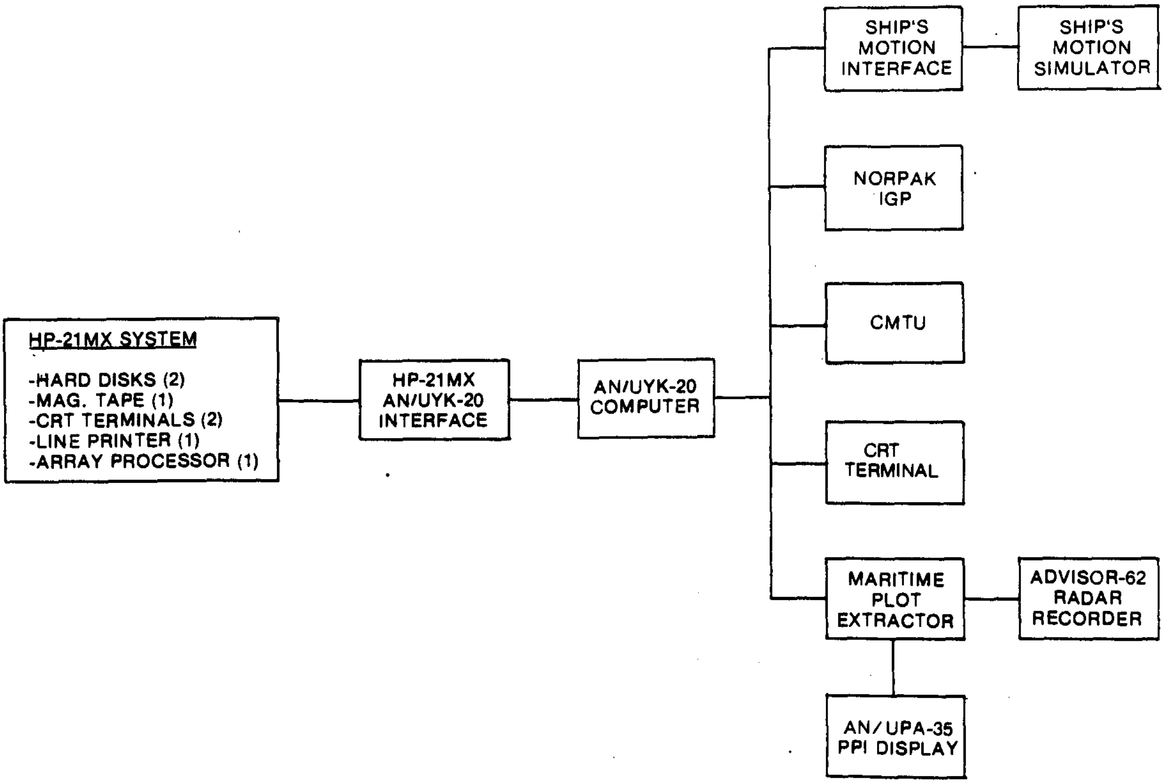

Figure 5.1 Configuration of the equipment used to evaluate the plot extractor in the laboratory.

In order to be able to output plot data via the computers, three software routines are used. Routine MPLTST, which runs in the AN/UYK-20, reads plot data from the plot extractor and feeds these data to the HP-21MX computer via the inter-computer interface. These data are read into the HP-21MX system by routine MPLRD which then stores them in a disk file. Finally, the data stored in this file can be copied to one of the two CRT terminals or the line printer connected to the HP-21MX using routine MPLWT.

A preliminary evaluation was performed using the plot extractor's internal test target. The test target's parameters were changed in steps and these values were compared to the parameters of the corresponding plots. This procedure revealed that the partial plot correlator was functioning properly.

The Advisor-62 radar recorder was then connected to the plot extractor and a recording of the AN/SPS-501 radar was played back into the equipment. This particular recording was obtained at sea onboard HMCS Athabaskan on 30 November 1978. The estimated sea state at the time was 3 and a 20 knot wind was blowing. The ship was steaming at 15 knots on a course of 315°; roll and pitch were ≅10° and ≅2° respectively. An AN/UPA-35 PPI display connected to the plot extractor was used to monitor the raw video along with the first and second threshold crossings generated by the plot extractor.

A photograph of the PPI display showing one particular scan of raw video from this recording is seen in Figure 5.2. The parameters of the corresponding plots generated by the plot extractor are given in Table 5.1 for the quadrant 0-90° (sector azimuth = 90°). For this case, the plot extractor settings were: First Threshold = 200, Second Threshold = 20, First Threshold Margin = 0. The interface was configured to send plot data to the AN/UYK-20 every quadrant.

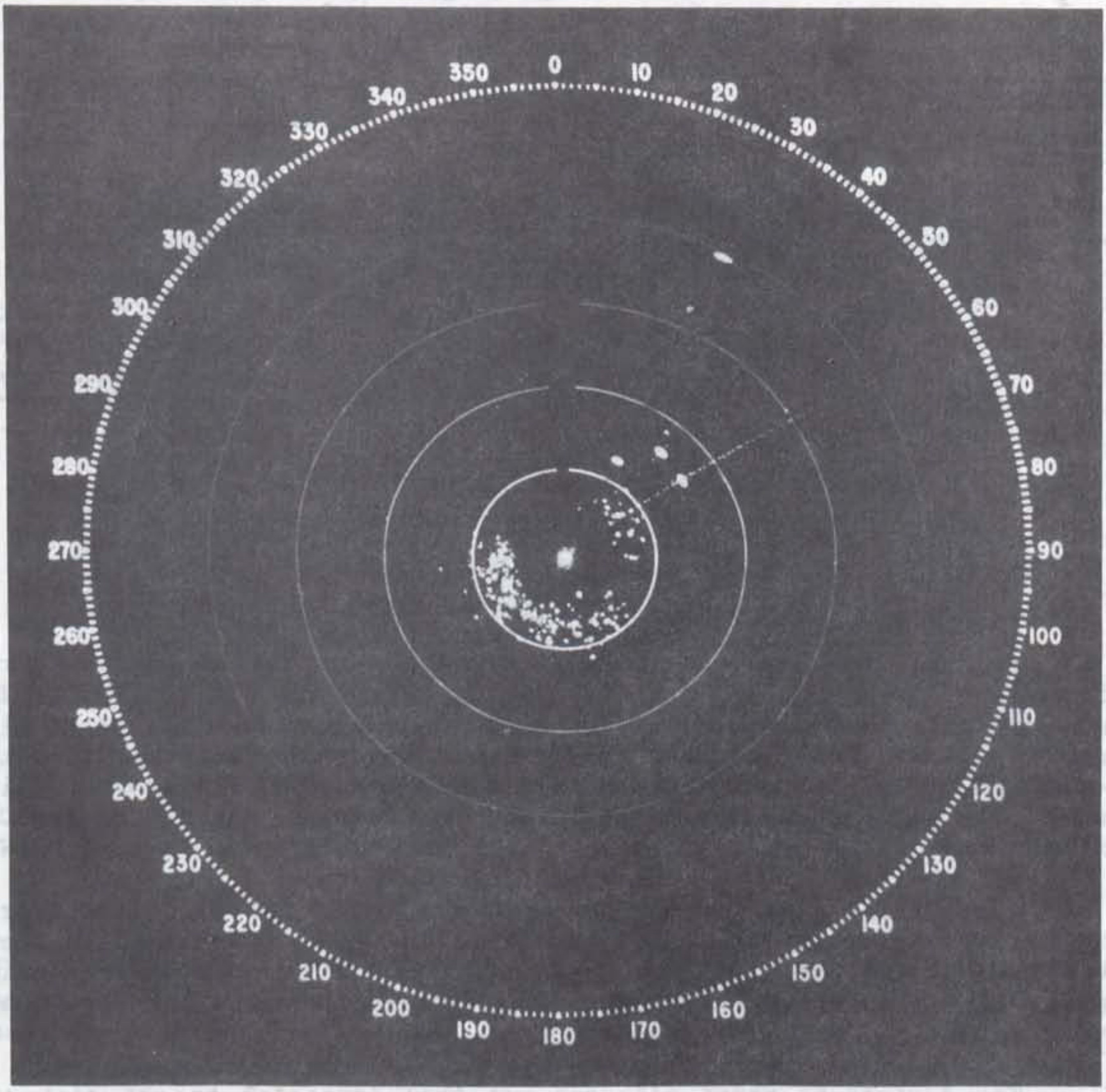

Figure 5.2 Presentation of one scan of the raw video from the recording used in the evaluation. Range rings occur at 5 nautical mile intervals.

An examination of Figure 5.2 will reveal that five targets are present in the first quadrant. These five targets were all detected and correspond to the following plots in Table 5.1: plot 3 - Argus patrol air craft, plot 4 - HMCS Nipigon (DDH-266), plot 6 - HMCS Bluethroat (oceanographic survey), plot 8 - HMCS Saguenay (DDH-206) and plot 12 - HMCS Fraser (DDH-233). It should be noted that the range rings in the figure occur every 5 nautical miles and that the range data in the table are in statute miles. There is a discrepancy of approximately 1/3 mile between the blips and the range rings due to late triggering of the equipment. Also, there is a gap in the range rings about 0° azimuth due to the manner in which the camera's shutter was operated. Note that the blip corresponding to plot 6 is not as strong as those corresponding to plots 3, 4, 8 and 12 since HMCS Bluethroat is a smaller target. This fact correlates well with the plot data in Table 5.1, where it can be seen that the azimuth extent of plot 6 is at least half of that of the other four target plots. Also, the range extent of this plot is less than that of the other targets.

Sector Azimuth: 90.000 Number of Plot Reports: 15

Plot Number	Azimuth	Range	Azimuth Extent	Range Extent
1.	5.010	4.800	8	0
2.	9.844	.200	7	0
3.	28.828	22.225	34	3
4.	30.147	6.925	49	3
5.	36.826	4.150	17	2
6.	39.990	10.300	16	2
7.	41.309	3.825	10	3
8.	43.154	9.025	55	3
9.	45.528	3.600	14	3
10.	52.383	4.050	15	0
11.	56.690	4.800	13	4
12.	57.744	8.750	56	4
13.	65.215	4.800	7	0
14.	70.928	4.075	29	1
15.	77.959	4.700	21	0

Table 5.1 Plot extracted data for detections in the first quadrant. Five targets are present; the remaining plots are due to sea clutter. Ranges are in statute miles.

The rest of the plots in Table 5.1 (with the exception of plot 2) are in the range of 3.5-5 miles. These plots are due to sea clutter, as is plot 2. The fact that no sea clutter is detected between .2 and 3.6 miles is due to the combination of the plot extractor threshold settings and the radar's STC. Note that the azimuth and range extents of the clutter plots are usually less than those of the target plots. The range extent of plot 11 is rather large; this is probably due to the merging of two closely spaced clutter detections by the partial plot correlator.

Finally, Table 5.2 lists plot data for the quadrant 180-270°. All these plots are due to sea clutter. With the exception of plots 12, 21, 29 and 33, the ranges of these plots fall into the same zone as those of the clutter plots in Table 5.1. The increase of clutter plots in the present quadrant is due to the fact that the wind was blowing out of this quadrant. Note that the range extents of all these plots are in the range of 0-2.

Sector Azimuth: 270.000 Number of Plot Reports: 35

Plot Number	Azimuth	Range	Azimuth Extent	Range Extent
1.	184.307	.100	8	0
2.	189.229	3.900	7	1
3.	189.141	4.325	17	1
4.	190.987	5.100	17	0
5.	191.427	4.750	11	0
6.	192.833	4.000	8	0
7.	195.206	4.350	15	0
8.	198.194	3.700	14	0
9.	198.546	4.900	9	0
10.	204.522	4.600	16	2
11.	208.038	4.000	11	0
12.	208.917	5.450	10	0
13.	211.729	3.800	21	2
14.	213.751	4.050	22	0
15.	217.003	4.000	14	0
16.	229.132	3.900	8	0
17.	230.099	3.750	8	0
18.	230.978	4.350	7	0
19.	232.296	4.150	20	0
20.	234.493	4.100	20	0
21.	235.899	6.350	9	2
22.	236.251	4.475	23	2
23.	236.954	.150	20	2
24.	242.228	3.850	9	0
25.	246.622	3.800	16	0
26.	246.886	3.550	12	0
27.	249.171	3.650	17	0
28.	250.841	3.650	17	0
29.	251.105	6.250	18	0
30.	253.653	4.600	25	2
31.	254.708	4.150	16	2
32.	260.685	4.400	7	0
33.	264.464	7.500	12	0
34.	265.607	4.150	12	0
35.	268.155	3.350	7	0

Table 5.2 Plot extracted data for detections in the third quadrant. All detections are due to sea clutter. Ranges are in statute miles.

6. CONCLUSIONS

The development of a partial plot correlator for maritime radar plot extraction has been described. The algorithm used to perform the partial plot correlation was developed, based upon the characteristics of partial plots generated by real targets. The implementation of this algorithm was then considered. Although a microprocessor based implementation appeared attractive, the Radar Research Laboratory did not possess a fully supported microprocessor development system at the time. Consequently, the algorithm was implemented in hardware using SSI/MSI TTL logic circuits. The partial plot correlator was then integrated into the plot extractor and the unit evaluated using recorded radar data. The unit functioned correctly.

As mentioned in Sub-Section 3.1, a fairly simple technique was used to estimate the bearing of plots. If a plot extractor were being developed for a radar with a stabilized antenna, one might want to use a more complicated scheme to improve bearing accuracy. Such a technique could employ full amplitude information to perform the bearing centroid. A similar technique could be used for range centroiding, if desired. However, the variance of the bearing estimate will always be inferior to that of the range estimate. This is especially true in the case of a pulse compression radar.

The partial plot correlator calculates the range and azimuth extents of a plot along with its position. This extra information can be useful in discriminating between two closely spaced targets if one of their returns is stronger than the other. It can also be used to differentiate between targets and clutter in certain cases. These two points are confirmed by the results of the evaluation using real radar data presented in Section 5. Another possibility would be for the partial plot correlator to output the maximum amplitude of a target along with the amplitude of the local background against which it was detected.

Two problems appeared after the partial plot correlator had been in use for several months. The cause of the first problem was traced to several defective N-MOS RAMs. The second problem was due to intermittent contacts in one of the edge connectors. Because a hardware based implementation was used and no BITE capability was provided, a considerable amount of time was spent rectifying these two problems. In this context, a microprocessor based implementation would be preferred, as its operation could be checked by an appropriate software routine.

In summary, the partial plot correlator functioned as predicted and performed well in a real target environment.

7. ACKNOWLEDGEMENTS

This work was supported by the Department of National Defence under Research and Development Branch Project 33C71. The radar recordings mentioned in this report were obtained on several different occasions at sea onboard HMCS Athabaskan. The Ship's company provided valuable assistance

in the installation of the recording equipment and in the operation of the AN/SPS-501 radar.

8. REFERENCES

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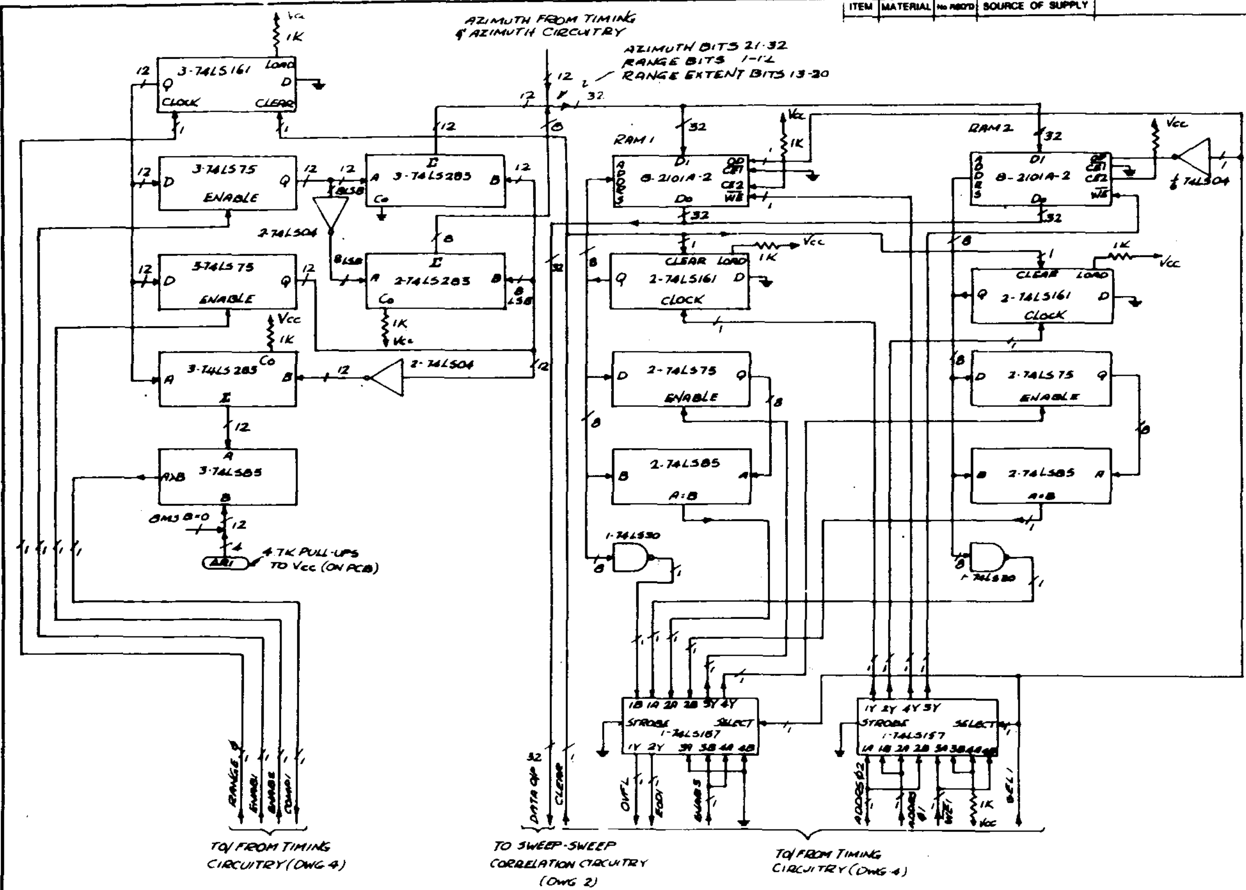
ANNEX A

DETAILED BLOCK DIAGRAMS OF THE CIRCUITRY



SEL1 LOW	SEL1 HIGH	CONT LINE
RAM 2	RAM 1	OVFL
RAM 1	RAM 2	EOD1
RAM 2	RAM 1	ENAB3
RAM 1	RAM 2	ADDRSØ2
RAM 2	RAM 1	ADDRSØ1
RAM 2	RAM 1	$\overline{WE1}$

SEL1 LOW READ FROM RAM1
WRITE INTO RAM 2

ITEM	MATERIAL	No REQ'D	SOURCE OF SUPPLY	HARDWARE

MATERIAL	No REQ'D	DESCRIPTION

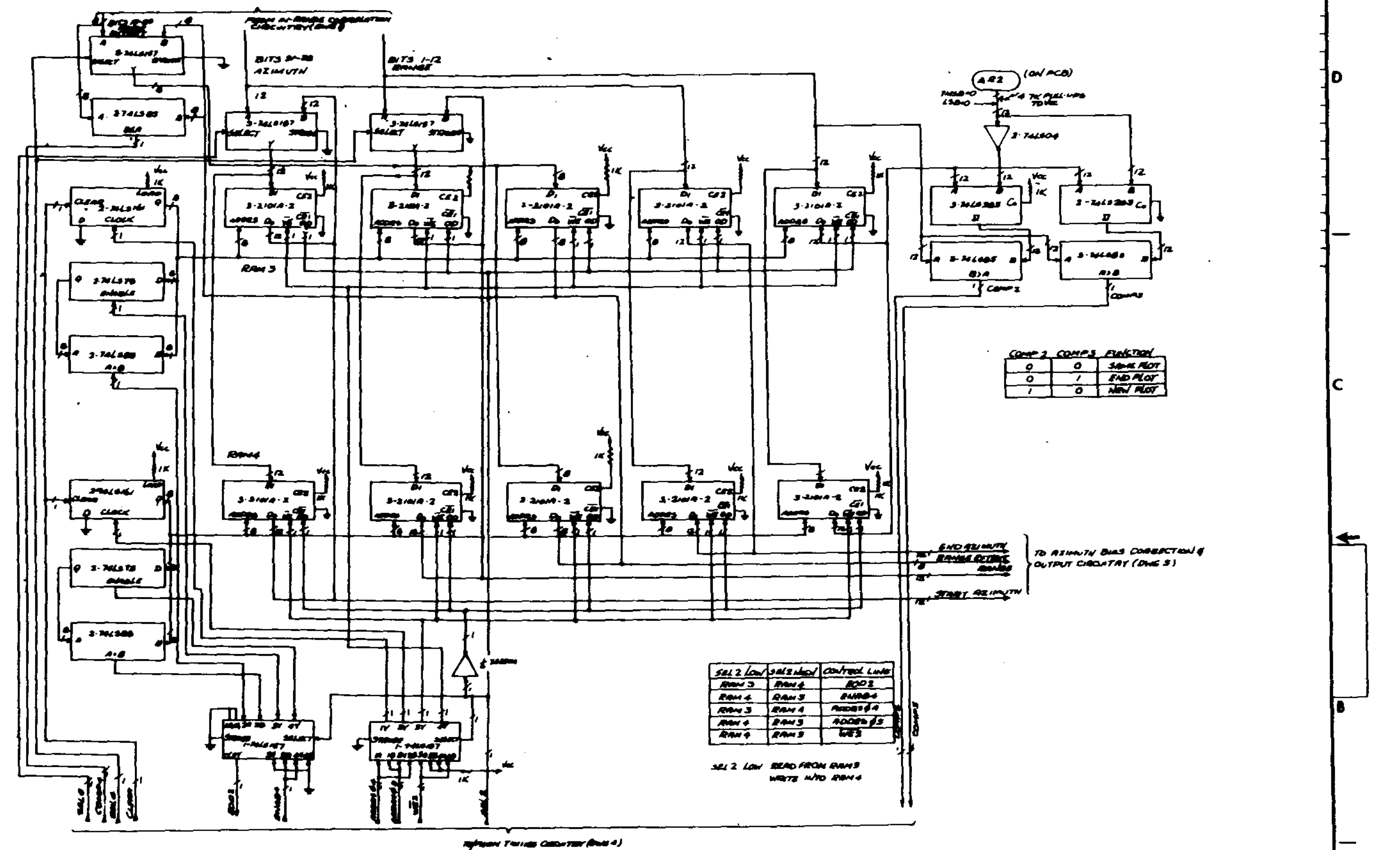
DEPARTMENT OF COMMUNICATIONS — MINISTÈRE DES COMMUNICATIONS

COMMUNICATIONS RESEARCH CENTRE

OTTAWA — CENTRE DE RECHERCHES SUR LES COMMUNICATIONS — CANADA

TITLE: MARITIME PLOT EXTRACTOR
PARTIAL PLOT CORRELATOR
(DWG. 1 OF 4)
IN-RANGE
CORRELATION CIRCUITRY

MATERIAL / FINISH / SCALE / No REQ'D / DRAWN / DATE / CHECKED / DATE / APPROVED / DATE / REVISION / W O No / PROJ No / ASSY No / DWG No C



MATERIAL | No REQ'D | DESCRIPTION

DEPARTMENT OF COMMUNICATIONS — MINISTÈRE DES COMMUNICATIONS

COMMUNICATIONS RESEARCH CENTRE

OTTAWA — CENTRE DE RECHERCHES SUR LES COMMUNICATIONS — CANADA

MATERIAL

FINISH

SCALE — No REQ'D

DRAWN — DATE

CHECKED — DATE

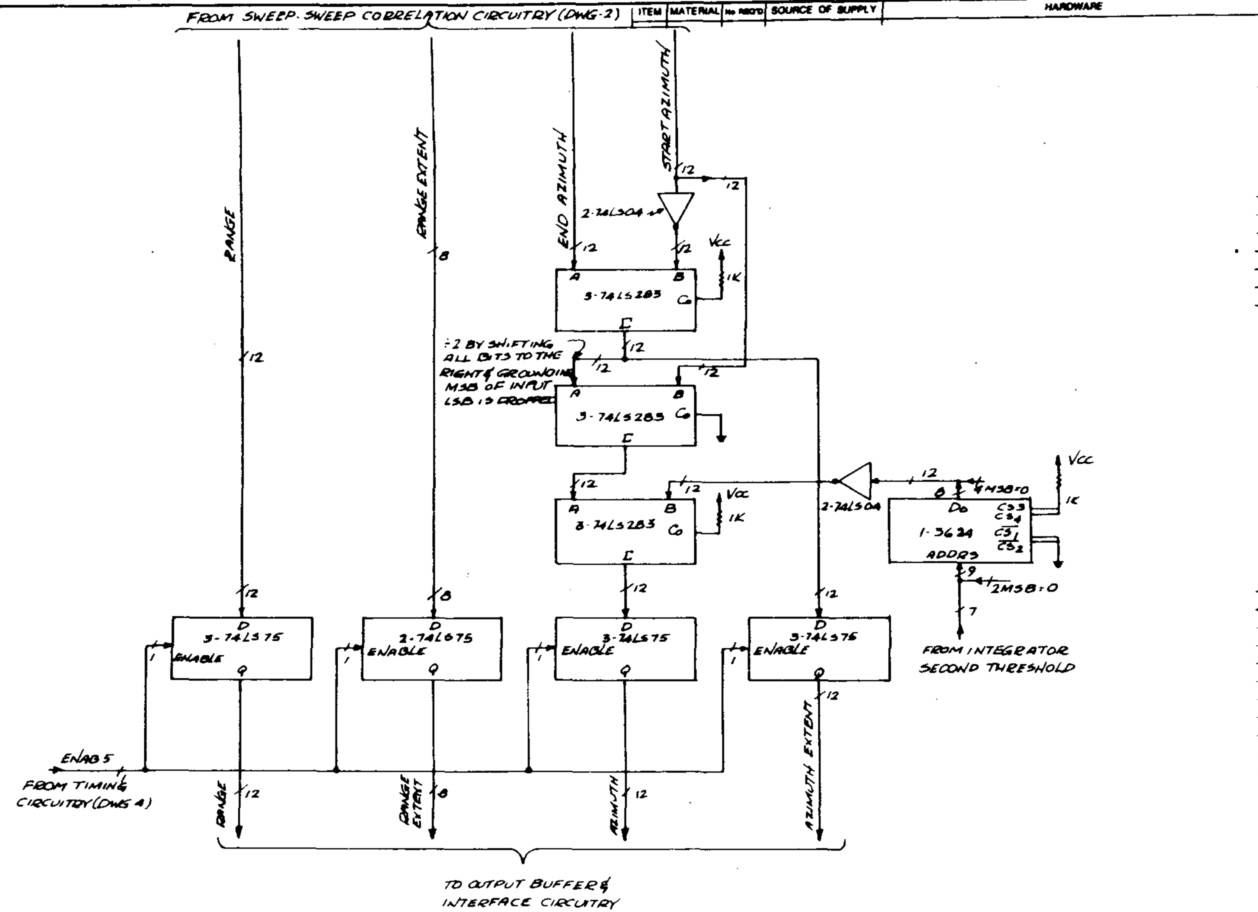
W.O. No — PROJ. No

TITLE

MARITIME PLOT EXTRACTOR
PARTIAL PLOT CORRELATOR
(DWG. 2 OF 4)
SWEEP -SWEEP
CORRELATION CIRCUITRY

APPROVED — DATE

ASS'Y No — DWG No — C — REVISION



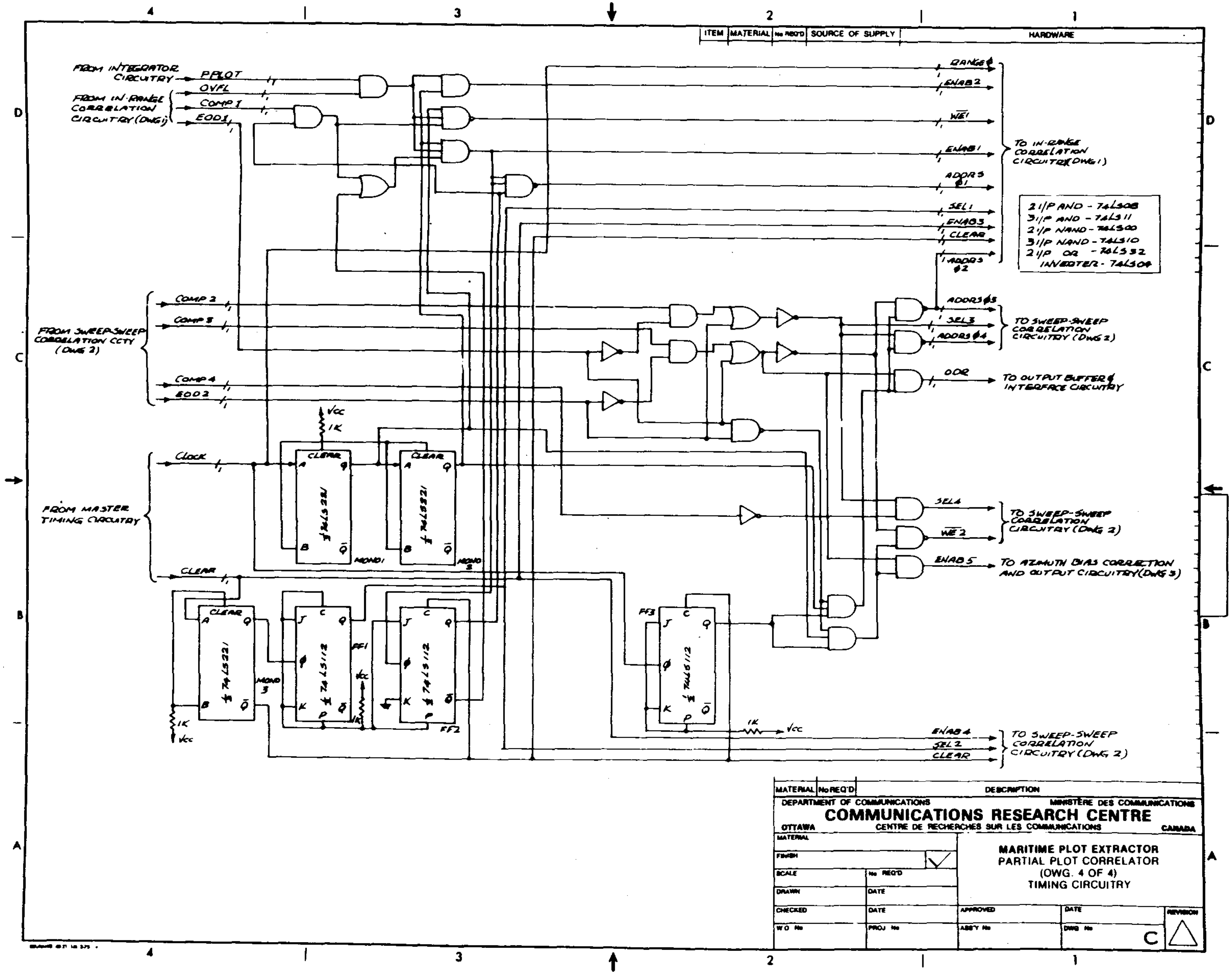
MATERIAL	No REQ'D	DESCRIPTION

DEPARTMENT OF COMMUNICATIONS — MINISTÈRE DES COMMUNICATIONS

COMMUNICATIONS RESEARCH CENTRE

OTTAWA — CENTRE DE RECHERCHES SUR LES COMMUNICATIONS — CANADA

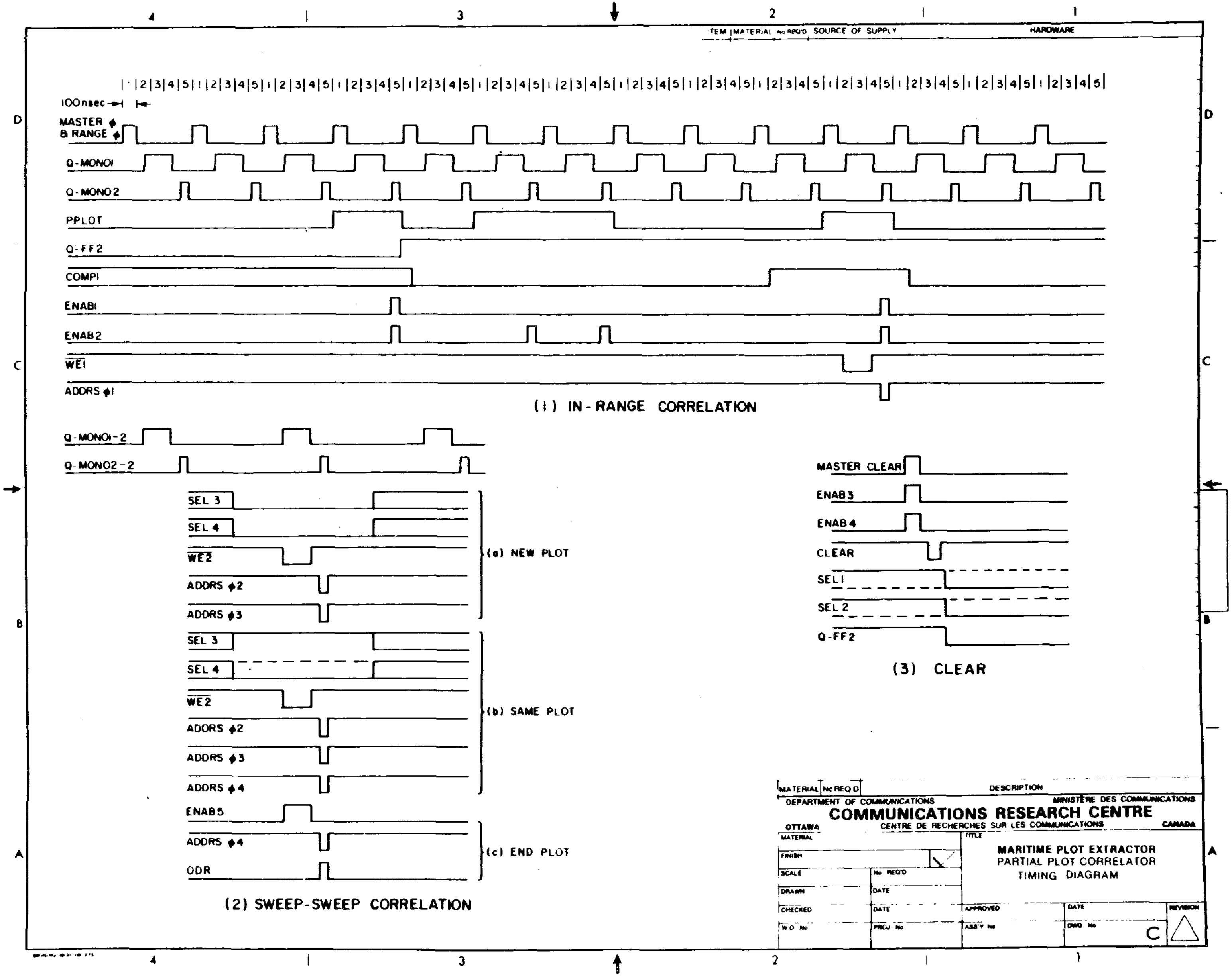
MATERIAL	TITLE: MARITIME PLOT EXTRACTOR PARTIAL PLOT CORRELATOR (DWG. 3 OF 4) AZIMUTH BIAS CORRECTION & OUTPUT CIRCUITRY
FINISH	
SCALE / No REQ'D	
DRAWN / DATE	
CHECKED / DATE	APPROVED / DATE / REVISION
W O No / PROJ No	ASS'Y No / DWG. No C



FROM INTEGRATOR CIRCUITRY
PPLOT
OVFL
FROM IN-RANGE CORRELATION CIRCUITRY (DWG 1)
COMP 1
EOD1
RANGE
ENAB2
WE1
ENAB1
ADDRS Ø1
SEL1
ENAB3
CLEAR
ADDRS Ø2
TO IN-RANGE CORRELATION CIRCUITRY (DWG 1)
2 I/P AND - 74LS08
3 I/P AND - 74LS11
2 I/P NAND - 74LS00
3 I/P NAND - 74LS10
2 I/P OR - 74LS32
INVERTER - 74LS04
FROM SWEEP-SWEEP CORRELATION CCTY (DWG 2)
COMP 2
COMP 3
COMP 4
EOD2
ADDRS Ø3
SEL3
ADDRS Ø4
TO SWEEP-SWEEP CORRELATION CIRCUITRY (DWG 2)
ODR
TO OUTPUT BUFFER & INTERFACE CIRCUITRY
FROM MASTER TIMING CIRCUITRY
CLOCK
CLEAR
VCC
1K
MONO 1
MONO 2
MONO 3
FF1
FF2
FF3
74LS221
74LS112
SEL4
WE2
ENAB5
TO SWEEP-SWEEP CORRELATION CIRCUITRY (DWG 2)
TO AZIMUTH BIAS CORRECTION AND OUTPUT CIRCUITRY (DWG 3)
ENAB4
SEL2
CLEAR
TO SWEEP-SWEEP CORRELATION CIRCUITRY (DWG 2)
ITEM
MATERIAL
No REQ'D
SOURCE OF SUPPLY
HARDWARE
MATERIAL
No REQ'D
DESCRIPTION
DEPARTMENT OF COMMUNICATIONS
MINISTÈRE DES COMMUNICATIONS
COMMUNICATIONS RESEARCH CENTRE
OTTAWA
CENTRE DE RECHERCHES SUR LES COMMUNICATIONS
CANADA
MARITIME PLOT EXTRACTOR
PARTIAL PLOT CORRELATOR
(DWG. 4 OF 4)
TIMING CIRCUITRY
SCALE
DRAWN
CHECKED
APPROVED
DATE
REVISION
C

ANNEX B

TIMING DIAGRAM


100nsec
MASTER ϕ & RANGE ϕ
Q-MONO1
Q-MONO2
PPLOT
Q-FF2
COMP1
ENAB1
ENAB2
WE1
ADDRS ϕ1
(1) IN-RANGE CORRELATION
Q-MONO1-2
Q-MONO2-2
SEL 3
SEL 4
WE2
ADDRS ϕ2
ADDRS ϕ3
(a) NEW PLOT
SEL 3
SEL 4
WE2
ADDRS ϕ2
ADDRS ϕ3
ADDRS ϕ4
(b) SAME PLOT
ENAB5
ADDRS ϕ4
ODR
(c) END PLOT
(2) SWEEP-SWEEP CORRELATION
MASTER CLEAR
ENAB3
ENAB4
CLEAR
SEL1
SEL 2
Q-FF2
(3) CLEAR
DEPARTMENT OF COMMUNICATIONS
MINISTÈRE DES COMMUNICATIONS
COMMUNICATIONS RESEARCH CENTRE
OTTAWA
CENTRE DE RECHERCHES SUR LES COMMUNICATIONS
CANADA
MARITIME PLOT EXTRACTOR
PARTIAL PLOT CORRELATOR
TIMING DIAGRAM
C

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1. ORIGINATING ACTIVITY COMMUNICATIONS RESEARCH CENTRE under the DND Recoverable Program	2a. DOCUMENT SECURITY CLASSIFICATION Unclassified 2b. GROUP
3. DOCUMENT TITLE The Development of a Partial Plot Correlator for Maritime Radar Plot Extraction	
4. DESCRIPTIVE NOTES (Type of report and inclusive dates) CRC Report	
5. AUTHOR(S) (Last name, first name, middle initial) G.R. Painchaud	

6. DOCUMENT DATE June 1985	7a. TOTAL NO. OF PAGES 40	7b. NO. OF REFS 5
8a. PROJECT OR GRANT NO. 33C71/33C84	9a. ORIGINATOR'S DOCUMENT NUMBER(S) 1378	
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13. ABSTRACT

The development and implementation of an algorithm to perform partial plot correlation is described. This development takes into account the characteristics of partial plots generated by real radar returns. The evaluation of this algorithm using recorded radar data is then considered. This work was performed as part of a task on Automatic Detection and Tracking (ADT) for use with maritime surveillance radars employing mechanically scanned antennas.

UNCLASSIFIED
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KEY WORDS

PLOTTING
ALGORITHMS
DETECTION
TRACKING RADAR
SURVEILLANCE RADAR

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