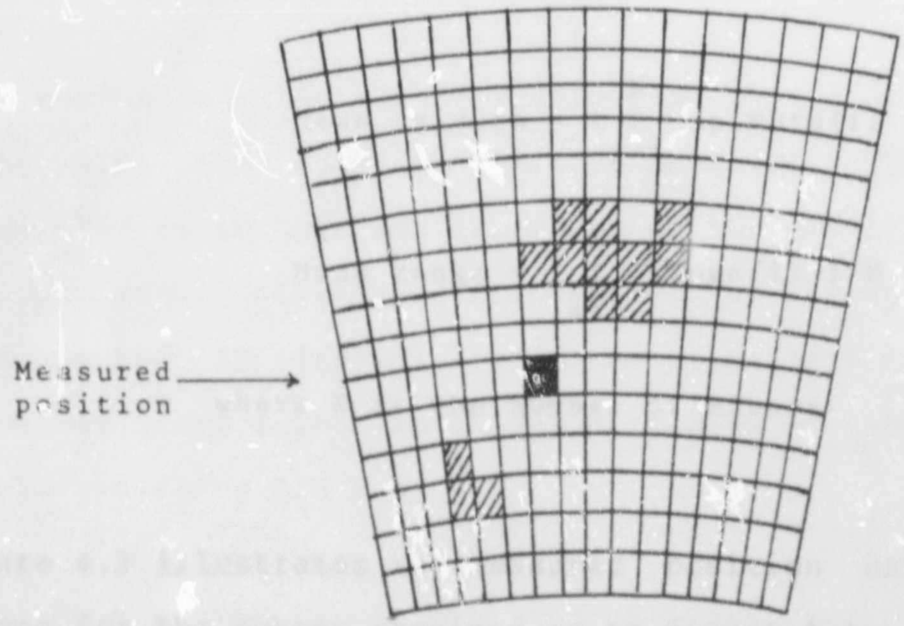


Figure 4.2 Measured Target Position Using the Mean of Extremeties Algorithm

4.4.2 The Mean Range And Azimuth Position

The abovementioned scheme requires that the echoes be reasonably concentrated in a single group. However, if the presence of clutter echoes and target echoes could give rise to false positions, a second scheme would be to attach an importance to the group of echoes occupying the most area. In this scheme the mean value of all the azimuth positions is found, as is the mean value of all the range positions. This single position is then input as the measured target position.

Mathematically this may be expressed as:

$$\text{Mean azimuth} = \left(\sum_{i=1}^{N} \text{Azimuth}(i) \right) / N$$

$$\text{Mean range} = \left(\sum_{i=1}^{N} \text{Range}(i) \right) / N \qquad (4.4)$$

where N is the number of echoes.

Figure 4.3 illustrates the measured position using the above scheme for the echoes received as in figure 4.1.

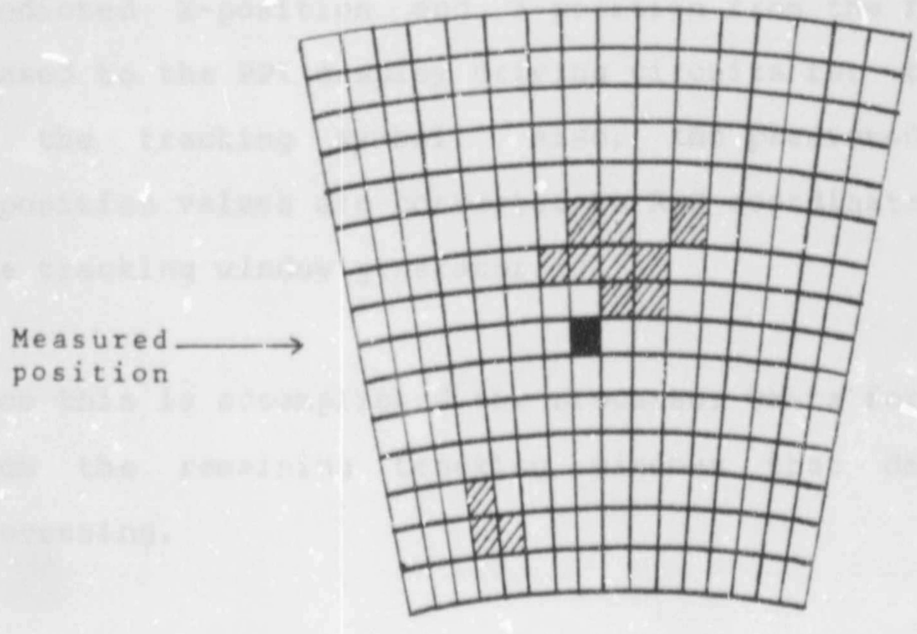


Figure 4.3 Measured Target Position Using the Mean Ran e and Azimuth Position

4.4.3 Weighted Echoes Method

This scheme requires that the amplitude of the echoes be stored along with the range and azimuth position. The position then calculated would take the strengths of the received echoes into account when calculating the mean range and azimuth position. This method implies a higher computational burden on the processor, since the amplitudes must also be taken into account in the averaging process.

Once the measured target position has been resolved the position is converted into X-Y coordinates and then passed onto the X-tracking filter and the Y-tracking filter respectively. The predicted X-position and Y-position from the filters are then passed to the PPI display driving circuits for the positioning of the tracking symbol. Also, the predicted X-position and Y-position values are converted to R-θ coordinates and output to the tracking window generator.

Once this is accomplished the processor waits for an interrupt from the remaining tracking windows that data is awaiting processing.

5.0 THE SYSTEM DESIGN

5.1 Integration Into The Present Radar System

The signals emerging from the digital signal processor are the trigger pulse, the 2.5MHz clock and of course the one-bit video. The relationship between these signals is detailed in figure 5.1

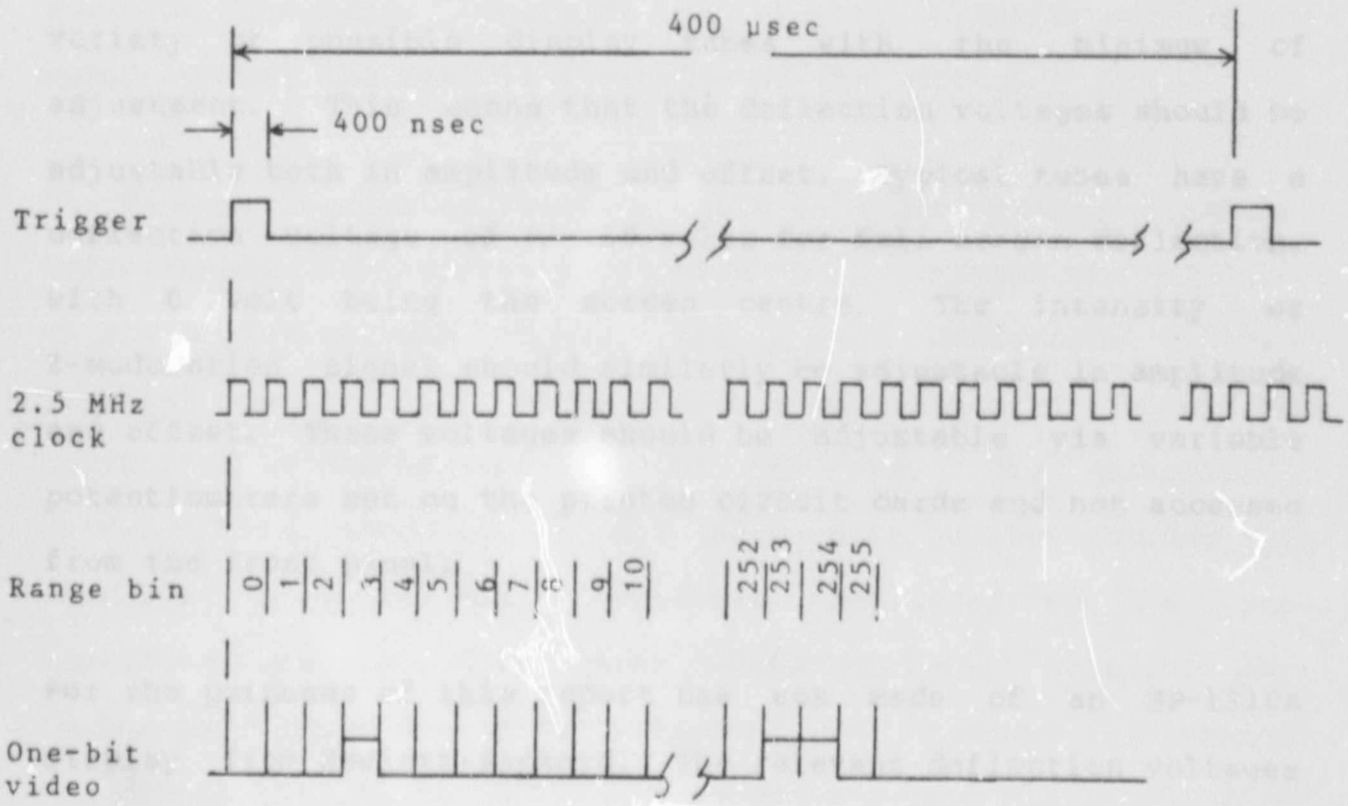


Figure 5.1 Timing Diagram of the Signals Output by the Signal Processor

The present radar system does not allow for the inclusion of any synthetically generated video on the display. Thus, for the purposes of designing a TWS system the design and implementation of a new display generating circuit and PPI display will be a necessity.

5.2 Man-Machine Interface

The particular vector display has as yet not been chosen. The system should therefore be designed to interface to a wide variety of possible display tubes with the minimum of adjustment. This means that the deflection voltages should be adjustable both in amplitude and offset. Typical tubes have a deflection voltage of +/- 10 volts for full screen deflection, with 0 volt being the screen centre. The intensity or Z-modulation signal should similarly be adjustable in amplitude and offset. These voltages should be adjustable via variable potentiometers set on the printed circuit cards and not accessed from the front panel.

For the purposes of this report use was made of an HP-1310A display from Hewlett-Packard. The relevant deflection voltages were +/- 5 volt for full screen deflection and 0 volt offset. The Z-modulation signal required was an inverted signal with 0 volt being used for no display and a voltage of less than -1.2 volt to illuminate the phosphor. The lower the voltage the brighter the screen, the minimum voltage being -5 volt.

The information to be displayed on the PPI was the following:

1. Radar echoes to a maximum range of 15km

2. Range rings every 2km

3. Designation marker symbol

4. Multiple tracking symbols

The radar video, the ra[illegible]ings and the symbols were to have seperate intensity c[illegible]s. A single intensity adjustment would control the overall intensity of the screen.

The designation marker position would be input via a joystick arrangement. The joystick position would indicate the position of the ma[illegible]r on the screen, i.e. full deflection of the joystick t[illegible] the left would indicate that the marker should be positioned to the extreme left of the PPI. The designation marker would move on an X-Y coordinate system across the display. A roller-ball input was considered to be too expensive, further development would probably consider the roller-ball input device as an option. The reason for moving the designation marker on an X-Y coordinate grid was simply that the human operator is accustomed to this type of motion in everyday life. If one wishes to get from one point to another the simplest path is a straight line. This line may then be divided into its component X-Y directions. However, if one were to implement the movement on an R-θ coordinate plane the movement would involve a rotation and then a radial displacement to the new point. This was found by experiment to be more complicated and thus tiresome for the operator.

The TWS initiate and cancel inputs would be implemented using pushbuttons mounted near the joystick. A single pushbutton would be required for each target track. The first press on the pushbutton would initiate a track, the next press on the same button would cancel the track.

The choice of symbol shapes is also worth noting. Initially it was thought that the operator would have as the designation marker a symbol in the form of a cross-hair shape. It was found that it was actually quite difficult to position the cross-hair on the target. Hence a symbol was adopted that allowed the target to be positioned within it. This symbol was either a square or a circular shape. Aesthetically, because of the manner in which the symbol is written to the screen, it was decided to adopt the square shape.

The target tracking symbols were implemented using cross-hair type shapes. The intersection of the various lines would make up the exact predicted position of the target. The three shapes chosen were a Y-shape, an X-shape and a +-shape.

5.3 The Window Generator

It was decided to implement the window generator using hardware. The TWS processor would output to the generator the azimuth position, the azimuth extent, the range position and the range extent. The window would then be set up in space. As the antenna scanned through the window the positions of all received echoes would be written into memory. When the antenna had passed through the window a flag would be set indicating to the processor that the data was ready for servicing.

The reason for the hardware implementation was that it was envisaged that a single processor would be used to execute multiple tracks and, as discussed in section 4.3.2, it was necessary to have a memory to store the data for each window and thus to allow the processor to process the data when it had the time.

5.4 Number Of Targets To Be Tracked

As a result of the lack of funds to purchase a suitable single-board computer it was decided to make use of an IBM PC to implement the tracking processor. This was felt to be adequate as only the system viability and not the implementation was being investigated.

Because seperate window generators for each track were to be used and as a result of the limited number of expansion slots in the IBM PC available for interfacing it was decided to initi... only make provision for a single target track. However, provision should be made in the PPI generating circuitry for the inclusion of up to three tracking symbols.

5.5 Target Parameters

The proposed sighting of the radar is to be a small civilian airfield. As such, the typical aircraft expected are small propellor-driven or small jet-powered aircraft. From Appendix C the maximum anticipated aircraft speeds would be 250m/s and the maximum accelerations would be 2g.

5.6 Window Sizes

When a track is initiated the acquisition window is set up in space. This window should be large enough to allow the target to fall into it on the following scan.

The equations developed in Appendix D allow one to calculate the size of the acquisition window.

Substituting in the values for velocity and acceleration as assumed in the previous section one finds that the window should be 670m x 670m in extent. Obviously, because the radar works in

R-θ coordinates, the angle subtended at the centre of the radar for an azimuth spread of 670m will be a function of the range at which the window lies. As the window approaches the radar this angle is going to increase to a maximum of 180 degrees at zero range. This is not suitable as the number of cells contained within the window will be large. Hence a minimum range is chosen below which the angle remains constant for a decrease in range.

A further point worth noting is that the operator may not always position the designation marker in such a way that the target lies in the centre of the marker. Allowance must therefore be made for this inaccurate positioning.

It was found, through trying to position the designation marker on the target and with the particular designation marker size, that the target was satisfactorily designated if the window size was increased to 900m x 900m. Further it was found that the minimum range at which the angle subtended is to remain constant for any decrease in range is about 5000m. This value was arrived at by looking at the number of cells in the window, the possible time to sort through these cells to resolve the track ambiguity and the effect of accurately positioning the designation marker on the target. No hard and fast rule was adopted in arriving at this figure.

The maximum window size is thus 15 range bins (900m) by 30 azimuth bins (900m at 5000m range).

The video signal emerging from the signal processor is extremely clean, in that only targets and very small amounts of point clutter are passed through the filters. When viewed on the PPI display the display is thus devoid of echoes unless a target is present or a strong point clutter source is present. These clutter areas do not occupy large areas on the screen. With this in mind it was decided not to reduce the size of the acquisition window to form the tracking window as no appreciable benefit would be gained by this reduction. If for some reason the signal from the signal processor should contain more clutter one would then have to look at dynamically varying the window size.

5.7 Choice Of Tracking Filter

As the radar is to be situated at a small civilian airfield the aircraft are not expected to be executing wild evasive manoeuvres or wildly varying flight paths. The aircraft approach and departure paths are well controlled and enforced. Also, the maximum accelerations expected of the aircraft are not high in comparison to military type aircraft.

Keeping these facts in mind it was decided not to use a Kalman filter but to opt for the simpler and easier to use Alpha-Beta filter. The exact type of Alpha-Beta filter chosen is now to be discussed.

The Benedict-Bornder Alpha-Beta filter chooses an optimal value of beta for a particular value of alpha, this assuming that the value of alpha is to remain constant for the duration of the track. This is not recommended as a high value of alpha is required for initiation and a lower value of alpha is needed for good smoothing. One may therefore look at the Expanding Memory Alpha-Beta filter. This filter varies the values of both alpha and beta according to set equations. The relationship between alpha, beta and N was illustrated in figure 3.8. It may be noted that the value of beta decreases rapidly with N but that alpha decays rather slowly. Indeed it is only after the seventh update that the value of alpha has decreased to 40 percent of its initial value. Seven scans take 10.5 seconds to execute, during which time the target has flown a maximum distance of 2625 metres. For a surveillance radar this relationship between alpha and N is unsatisfactory.

A combination of the Benedict-Bordner and variation of the Expanding Memory filter has thus been decided upon. The value of alpha will be dependent on the Nth scan and the value of beta corresponding to the value of alpha will be calculated using the Benedict-Bordner criteria. The relationship between alpha and N was not arrived at mathematically but was simply found from the required alpha value for particular scan N. The equations used to calculate the value of alpha and beta are:

$$\alpha = \frac{(2N+1)^2}{N(N+1)} - 3.7$$

$$\beta = \frac{\alpha^2}{2 - \alpha} \qquad \text{—————} \qquad (5.1)$$

Figure 5.2 details the relationship of alpha, beta and N.

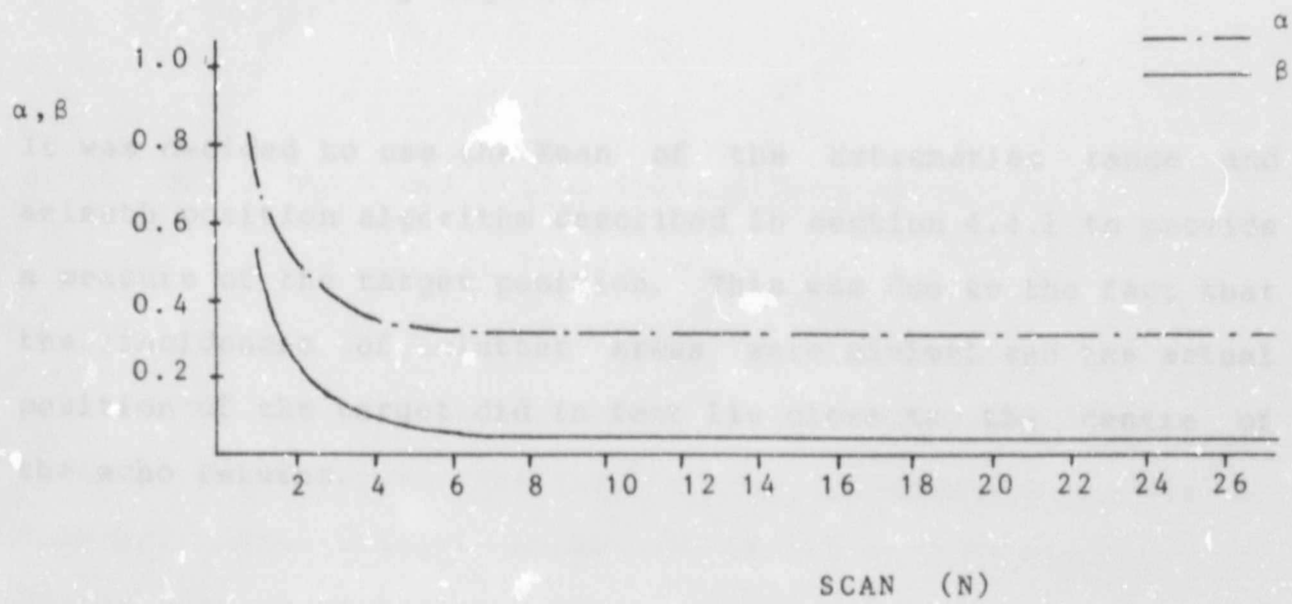


Figure 5.2 Plot of α,β for the Filter Chosen

If, once the radar has scanned across the window and no echoes were received while within the window, then the TWS system will use the last predicted value as the present measured value and the value of alpha will jump back to that of N=1 in figure 5.1. On subsequent scans the alpha will thus be decreased. If, however, 5 scans have indicated no echoes within the window the track will be automatically cancelled.

5.8 Tracking Filter Initialisation

When the track is initiated the filters need to be initialised. For the purposes of this design the first predicted position is assumed to be the designated position and the target velocity is set to zero m/s.

5.9 Track Ambiguity Algorithm

It was decided to use the Mean of the Extremeties range and azimuth position algorithm described in section 4.4.1 to provide a measure of the target position. This was due to the fact that the incidences of clutter areas were minimal and the actual position of the target did in fact lie close to the centre of the echo returns.

6.0 SYSTEM IMPLEMENTATION

6.1 The PPI Display

6.1.1 The X And Y Deflection Voltage Generators

The requirement is that the radar should display the video signal out to a maximum range of 15km. The average PRF of the radar is 2.5kHz, i.e. the time between consecutive pulses is 400µsec. The trigger pulse is of 400 nsec duration and the system clock operates at 2.5MHz.

Figure 6.1 details the block diagram of the deflection voltage generating circuitry.

The range counter is a counter that starts counting at zero and increments in single units at the system clock rate. A count of 100 clock cycles thus indicates a range of 100x60m i.e. 6000m. The maximum count is 255 giving a range of 15300m. The range counter is implemented using two cascaded 4-bit binary counters, a flip flop and an invertor. When the flip flop detects the trigger pulse the Q output is set high. This loads the counters with zero and commences the count sequence. When the counters give off a carry after 255 counts the flip flop Q is reset. The counters are then disabled and the flip flop is armed for the next radar trigger pulse occurance.

Figure 6.1   Block Diagram of the Deflection Voltage Generator

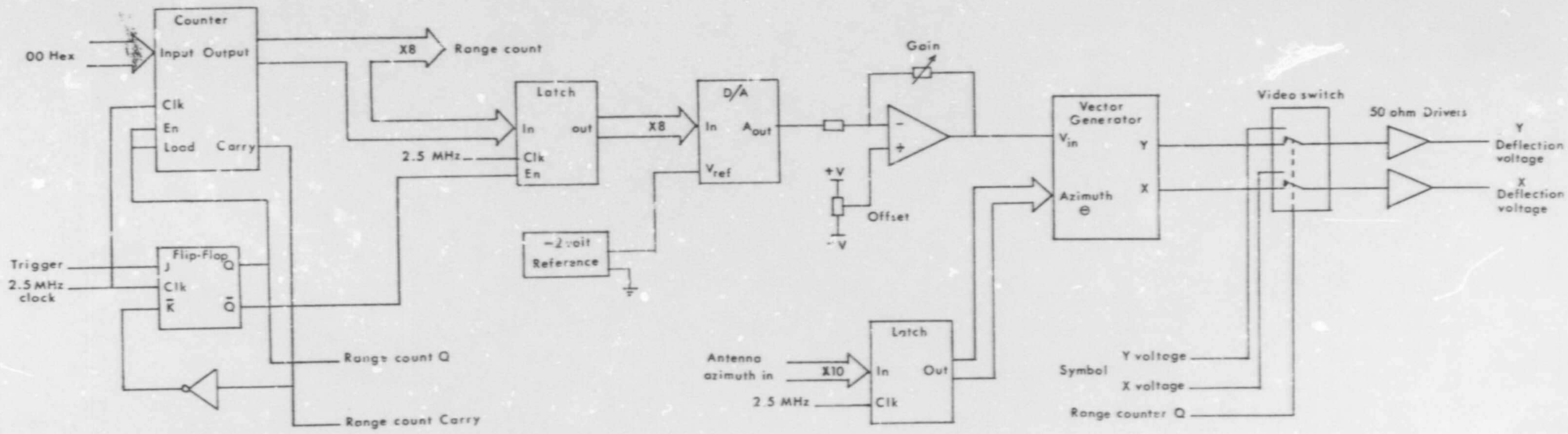


Figure 6.1 Block Diagram of the Deflection Voltage Generator

The sequential count from the range counter is passed through an 8-bit Digital to Analog converter with de-glitched outputs. This analog signal is in fact an inverted ramp waveform, reaching a minimum value of -2 volt at maximum range.

The output from the D/A converter is passed onto a very fast operational amplifier configured in an inverting mode. A variable feedback potentiometer is provided to adjust the maximum output level and the potentiometer on the non-inverting input allows one to adjust the offset voltage. For the purposes of this design the maximum voltage is set to +5 volt and the offset is set to 0 volt.

To generate the orthogonal X and Y deflection voltages use is made of a Vector Generator module. This module has two inputs, the one input being the analog sweep voltage emerging from the operational amplifier and the other input being the 10-bit digital azimuth position from the antenna. The output of the module is two orthogonal waveforms :

$$Y = V_{in} \text{ COSINE } \theta$$

$$X = V_{in} \text{ SINE } \theta \qquad \text{(6.1)}$$

The top of the PPI display is usually taken to be North and this is made to correspond to 0000Hex from the digital azimuth antenna position. The antenna scans in a clockwise fashion, the angle θ being the angle between PPI North and the antenna position.

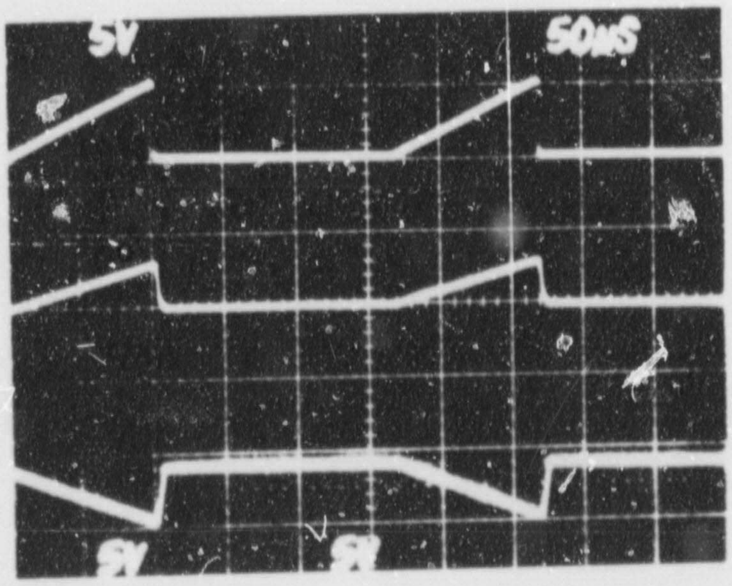
The sweep time is 102 µsec and the pulse repetition interval is 400 µsec. There is thus a 298 µsec dead time between the end of the radar sweep and the commencement of the following sweep. It is during this period that the symbols are written to the display. The precise method is detailed in section 6.2. What is important here, is that video switches are used after the Vector Generator to switch the X and Y deflection voltages from the sweep generator to the output of the symbol position generator during this dead time. Once the symbol position has been written out the X and Y deflection voltages revert to the output of the Vector Generator.

Most displays use an input impedance of 50 ohm for the deflection voltages. To allow the deflection circuitry to interface to the low impedance of the display the two deflection voltages are passed through 50 ohm line drivers.

Figure 6.2 details an oscilloscope plot of the analog sweep voltage and the X and Y deflection voltages.

6.1.2 The Z-Modulation Generating Circuitry

There are three sources of video information to be displayed on the display.



Sweep

Y Deflection

X Deflection

Figure 6.2 The Analog Sweep Voltages

1. The one-bit radar video signal

2. The range ring information

3. The symbol information

Figure 6.3 details the block diagram of the Z-modulation circuitry.

The radar video signal is a TTL level signal emerging from the signal processor. Because only data to a maximum range of 15300m is to be displayed some means must be made use of to gate this video signal. This gating signal is the flip flop Q output. While the sweep is in progress the Q output is set and

Figure 6.3 Block Diagram of the Z-modulation Generator

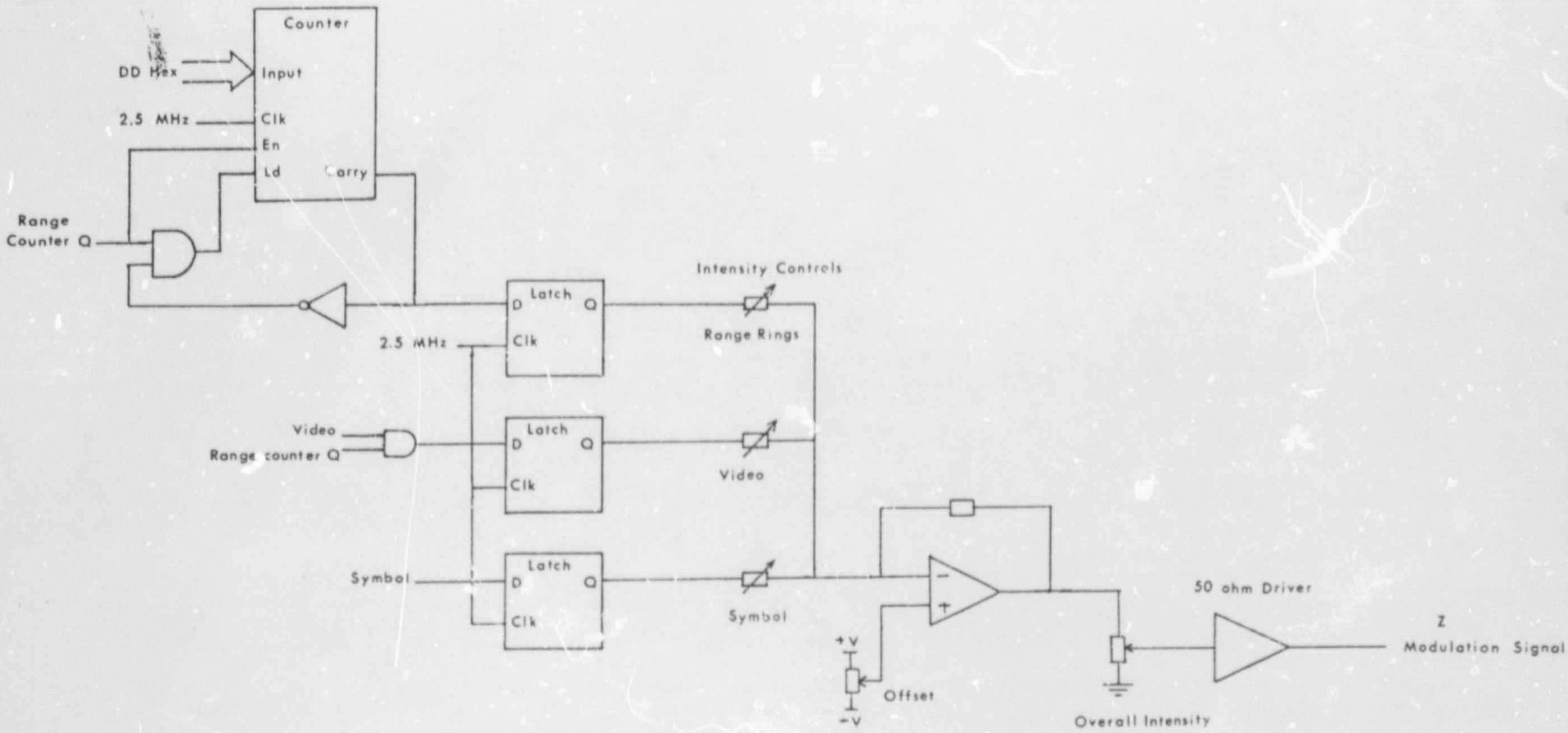


Figure 6.3 Block Diagram of the Z-Modulation Generator