THE ADDITION OF HEIGHT TO A WEATHER SURVEILLANCE RADAR PPI

by

E.H. Ballantyne

TECHNICAL REPORT

MWT-9

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Preface

The technique described in the following notes was first developed in order to combine the plan and height data transmitted to the Montreal Weather Office from the McGill Weather Radar at Ste. Anne de Bellevue, a distance of about 10 miles.

By arranging this composite presentation, it became possible to update the radar map complete with heights every 5 minutes during the same 5 minute interval as the observations and remain within the transmission bandwidth of a telephone voice channel (J.S. Marshall and E.H. Ballantyne, 1970, 1973)*.

The circuit described here achieves the same result on a local PPI and is simpler to the extent that no storage for narrow band transmission is required. This circuit was built specifically for the Atlantic Tropical Experiment (GATE, June to September 1974) towards which the Canadian contribution was the radar weather ship QUADRA.

The resulting PPI pictures including height were recorded on Polaroid film and then transmitted via facsimile and H.F. radio to the operation headquarters in Dakar, Senegal, a distance of about 700 miles. The pictures showed the current weather pattern within 200 km of QUADRA and were of great value in planning air support for the experiment. The original Polaroids now provide a useful pictorial summary from which attention can be directed to the more detailed radar archives. Further details of the radar instrumentation on board QUADRA are given in an appendix to this report.

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*Proceedings of the 14th Radar Meteorology Conference, 1970, pp 407-410. Also McGill Scientific Report MW-81, 1973.

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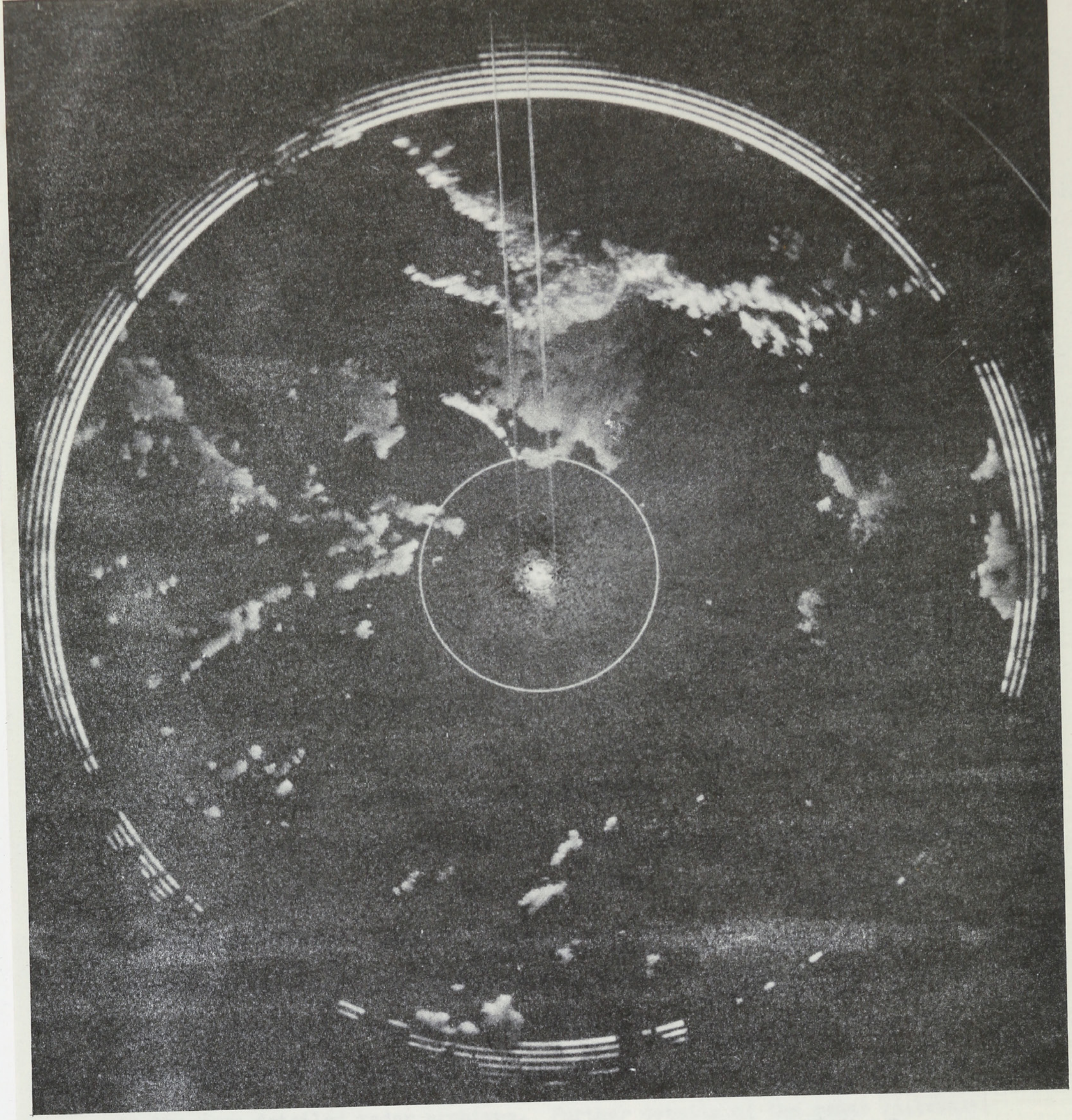


Thundershowers off the Coast of Panama

8°N 82°W 29th May, 1974 2155 Z

Outer rings show height in intervals of 1.5 km. Height information is accumulated for the range interval 50 to 200 km, shown between the inner ring and edge of the PPI.

Fig. 1

1. Introduction

The slowly changing nature of precipitation echoes seen on a radar PPI results in many substantially similar and therefore redundant paints at the usual rate of rotation.

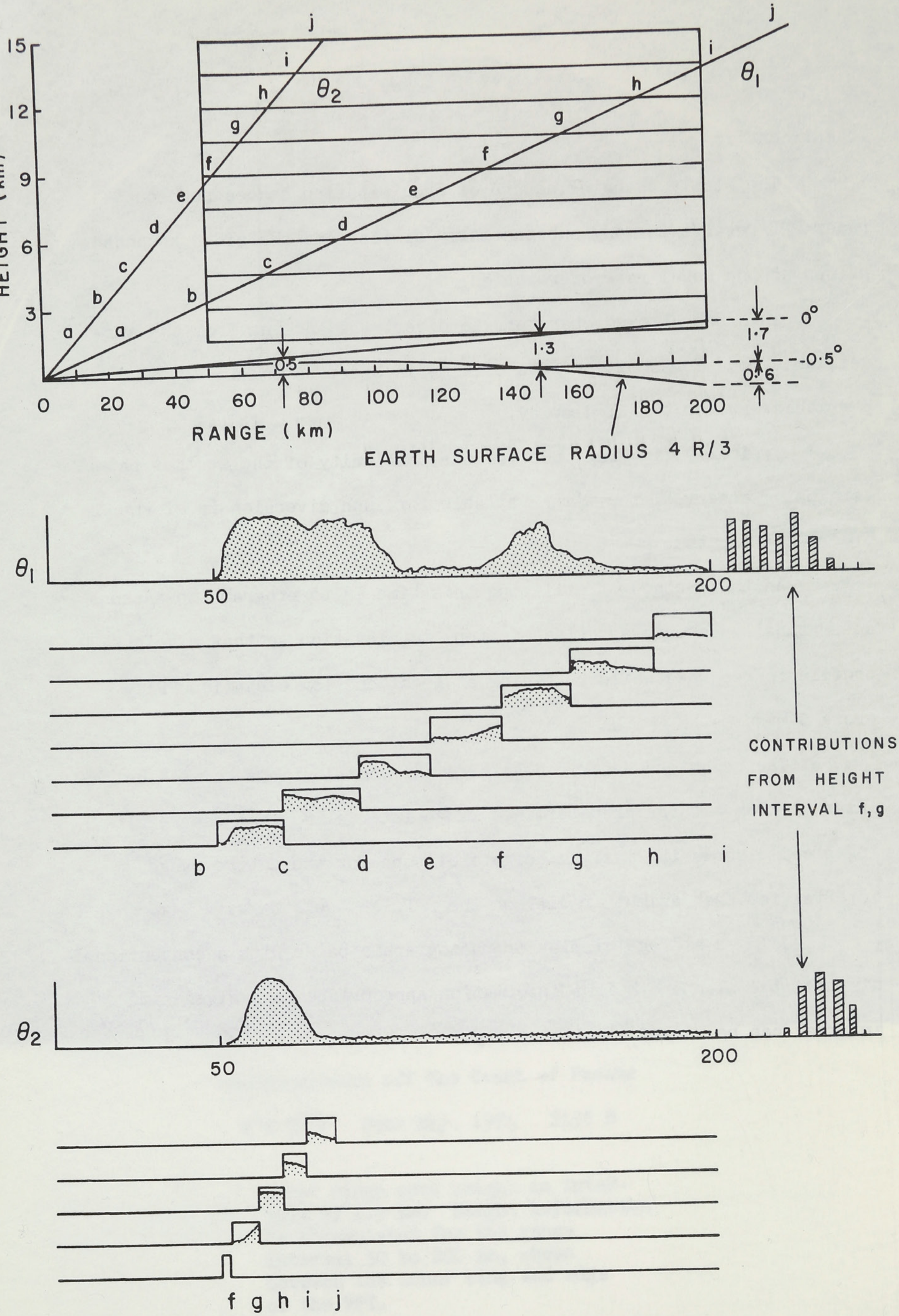
This has allowed operators to divert the antenna from the surveillance mode for short periods of time in order to examine a particular sector or RHI display.

Typically, in order not to lose continuity of the weather pattern being observed, the time available for such diversion is of the order of 5 minutes.

Another method of utilizing this time is to program the antenna automatically through a series of steps in elevation so that a height profile is recorded while retaining at least one low elevation PPI every 5 minutes.

The technique described gathers the contributions to each height interval from a large predetermined range interval so that the resulting profile shows the maximum heights of tops for the entire range interval for each azimuth radial on the PPI.

Using a storage display or photographic paper with a conventional display, the plan and height information appropriate to a given time interval can be viewed simultaneously.



HEIGHT (km)
RANGE (km)
EARTH SURFACE RADIUS 4 R/3
θ1
θ2
0°
-0.5°
1.7
1.3
0.5
0.6
CONTRIBUTIONS FROM HEIGHT INTERVAL f, g
b c d e f g h i
f g h i j

Fig. 2

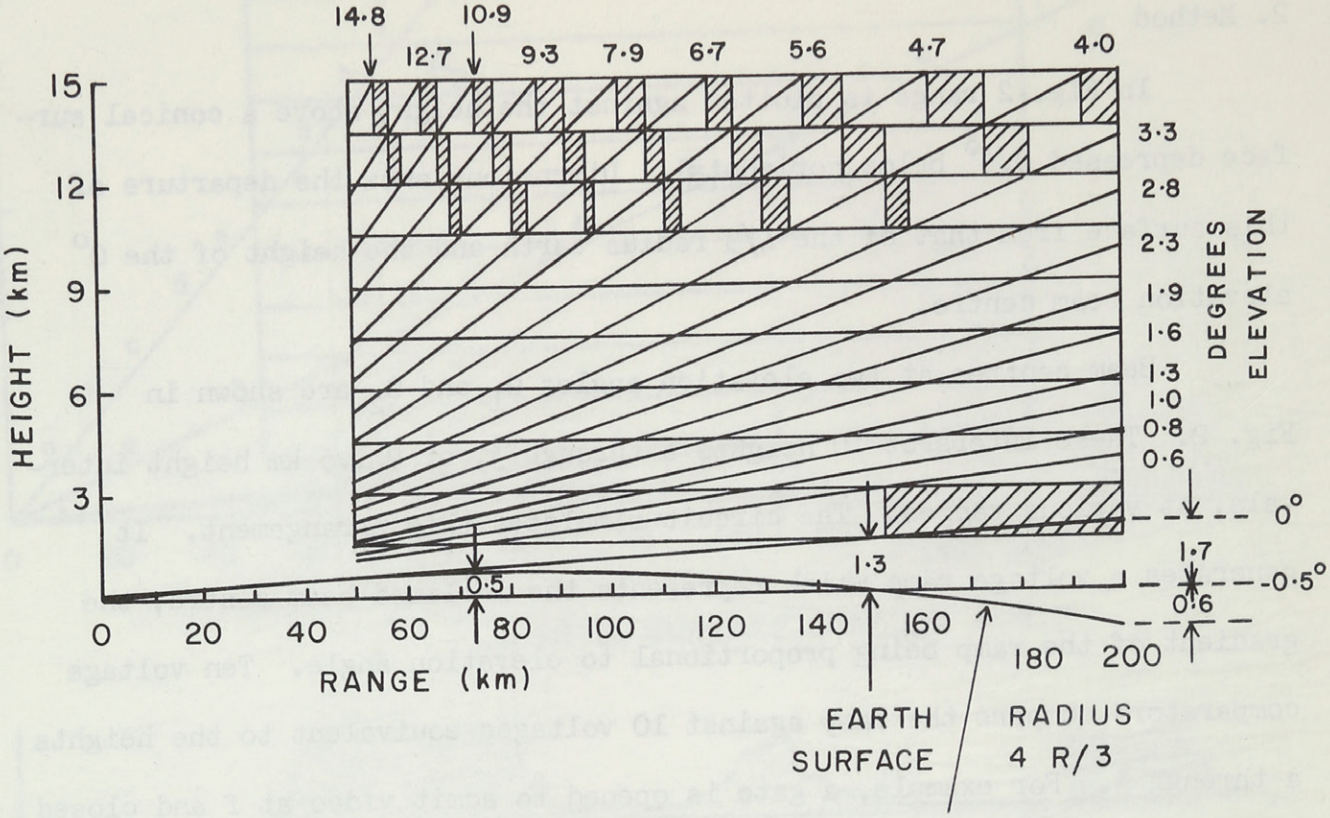
2. Method

In Fig. 2 range is plotted against the height above a conical surface depressed 0.5° below horizontal. Dimensions show the departure of this surface from that of the 4/3 radius earth and the height of the 0° elevation beam centre.

Beam centres at two elevation angles θ_1 and θ_2 are shown in Fig. 2. These intersect 10 heights a through j, or 9 1.5 km height intervals, at various ranges. The circuit simulates this arrangement. It generates a voltage ramp which represents the inclined beam centre, the gradient of the ramp being proportional to elevation angle. Ten voltage comparators compare the ramp against 10 voltages equivalent to the heights a through j. For example, a gate is opened to admit video at f and closed at g on beam θ_1. The gate opens between f and g again on beam θ_2. Thus a video contribution to the height diagram from the interval f, g which is used to expose film during rotation θ_1 will have a second contribution superimposed on it during rotation θ_2.

Rings showing height above the conical surface are built up from samples of the video signal which are held in storage elements until the end of each range sweep on the PPI and then read out at the edge of the display just beyond maximum range.

Possible video signals and the arrangement of gates for angles θ_1 and θ_2 are shown in Fig. 2. The horizontal axis can be regarded as a PPI sweep, starting at zero range and extending beyond 200 km in order to include the height pulses. For the PPI example reproduced in Fig. 1, the time between height pulses was 22 μsec, giving a total of 198 μsec for 9 rings or 1,333 + 198 = 1,531 μsec for the entire PPI sweep.



Elevation Angle	Gate No.								
0.6	1	2							
0.8	1	2	3						
1.0	1	2	3						
1.3	1	2	3	4					
1.6	1	2	3	4					
1.9	1	2	3	4	5				
2.3	1	2	3	4	5	6			
2.8		2	3	4	5	6	7		
3.3		2	3	4	5	6	7	8	
4.0		2	3	4	5	6	7	8	9
4.7			3	4	5	6	7	8	9
5.6			3	4	5	6	7	8	9
6.7				4	5	6	7	8	9
7.9					5	6	7	8	9
9.3					5	6	7	8	9
10.9						6	7	8	9
12.7							7	8	9
14.8									9

Fig. 3

To date, sample and hold circuits have been used to store the video so that the value stored and read out is the peak value found in the gated interval. The action of reading discharges these circuits completely.

A somewhat arbitrary minimum range of 50 km has been chosen for the region in which heights are sampled. A large minimum range improves the height diagram to the extent that it is less cluttered by large arcs from close range echoes. It also limits the number of antenna elevation angles needed to scan the region.

The 50 km zone occupies 1/16th of the total area of a 200 km PPI.

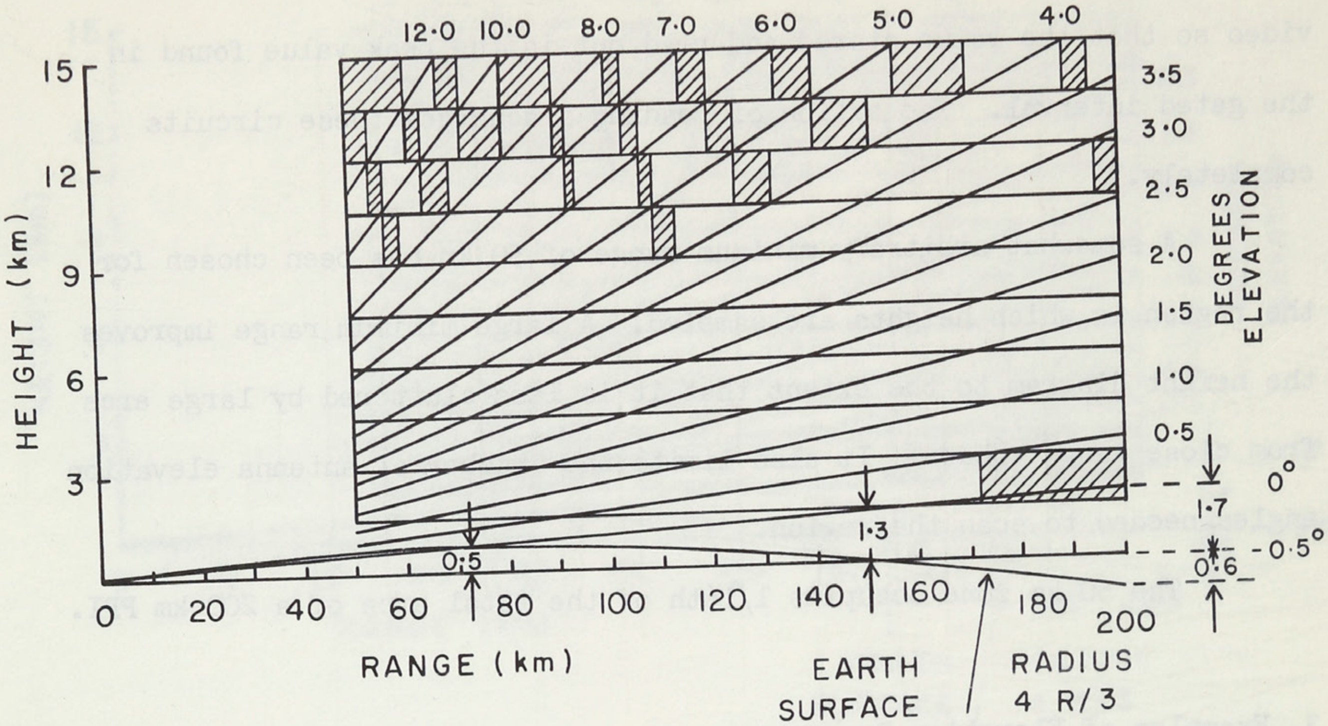
3. Examples of Elevation Programmes

Eighteen angles from the program used at the McGill Radar Observatory are shown in Fig. 3. The antenna completes one full rotation in azimuth for each of the elevation angles shown. The shaded areas indicate regions which are not covered by beam centres and considerable overlap can be seen at the lower elevation angles.

Video gates, numbered in order of increasing height, would be generated according to the table below the beam centre diagram in Fig. 3.

As good coverage can be obtained using 14 angles and elevating 0.5° for the first 8 steps and 1° or more thereafter. This program and its video gates are shown in Fig. 4.

Although beam centre diagrams are useful when comparing one programme with another, coverage by the real antenna beam is considerably greater and in practice most of the gaps shown in Fig. 3 and Fig. 4 are



Elevation Angle	Gate No.								
0.5	1	2							
1.0	1	2	3						
1.5	1	2	3	4					
2.0	1	2	3	4	5				
2.5	1	2	3	4	5	6			
3.0		2	3	4	5	6	7	8	
3.5		2	3	4	5	6	7	8	9
4.0		2	3	4	5	6	7	8	9
5.0			3	4	5	6	7	8	9
6.0			3	4	5	6	7	8	9
7.0				4	5	6	7	8	9
8.0					5	6	7	8	9
10.0						6	7	8	9
12.0							7	8	9

Fig. 4

filled. At the same time, height resolution is not as good as might be inferred from the beam centre diagram.

Satisfactory results have been obtained from a 1^{o} antenna beam using only the odd angles out of the McGill programme of Fig. 3. The example shown in Fig. 1 was obtained in this way.

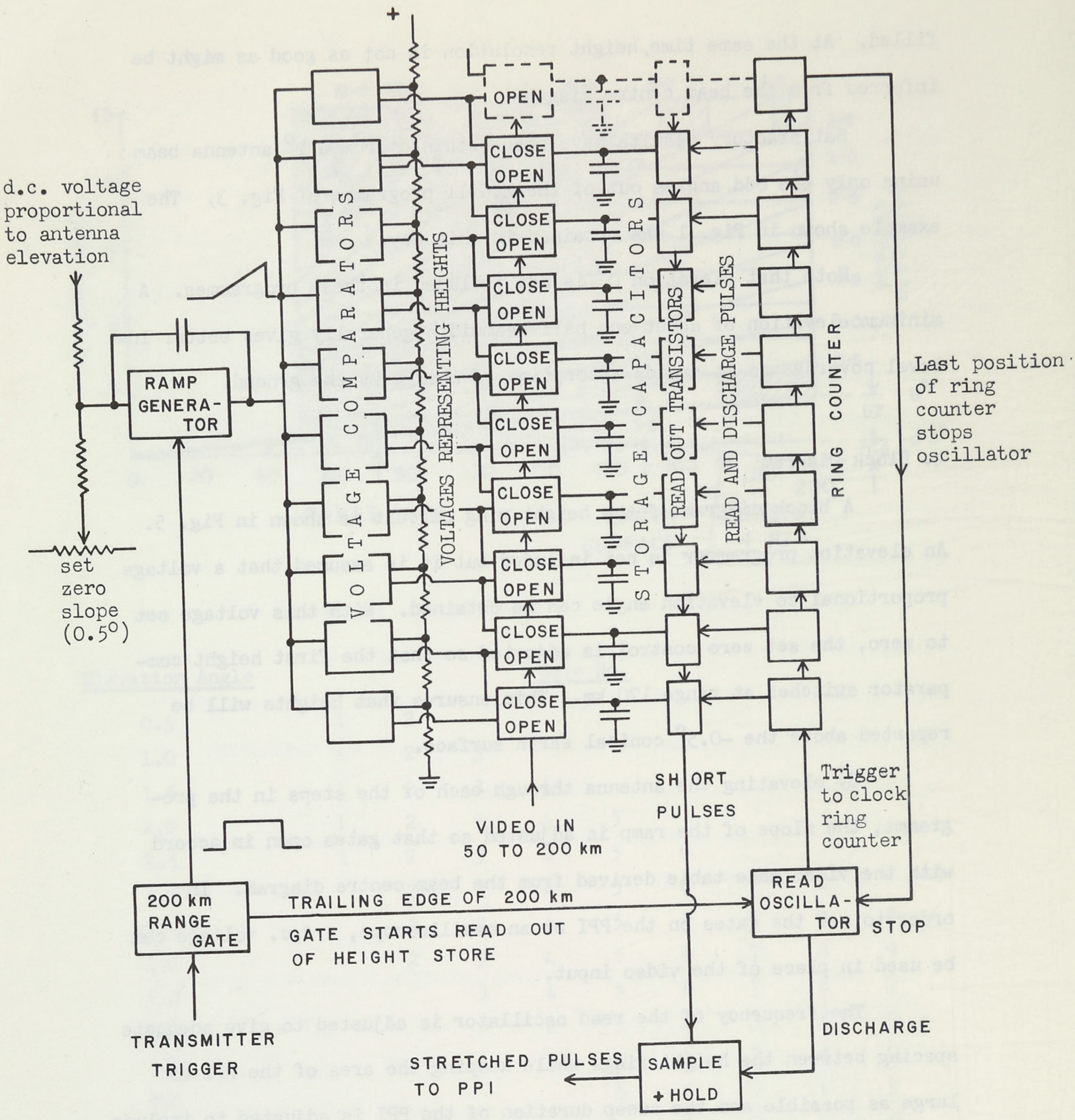
Note that elevation 0^{o} is not included in these programmes. A minimum elevation of about one half beamwidth generally gives better low level coverage as it avoids absorption of energy by the ground.

4. Block Diagram

A block diagram of the height ring circuit is shown in Fig. 5. An elevation programmer is not included but it is assumed that a voltage proportional to elevation angle can be obtained. With this voltage set to zero, the set zero control is adjusted so that the first height comparator switches at range 170 km. This ensures that heights will be reported above the -0.5^{o} conical earth surface.

By elevating the antenna through each of the steps in the programme, the slope of the ramp is adjusted so that gates open in accord with the video gate table derived from the beam centre diagram. In order to see the gates on the PPI or an oscilloscope, a d.c. voltage can be used in place of the video input.

The frequency of the read oscillator is adjusted to give adequate spacing between the height rings while keeping the area of the PPI as large as possible and the sweep duration of the PPI is adjusted to include the extra time needed to display the stored height data.



PPI sweep duration is adjusted to display 200 km plus 9 or 10 cycles of the read oscillator.

HEIGHT DISPLAY BLOCK DIAGRAM

Fig. 5

In the example of Fig. 1, a ring of radius 50 km is included. This ring is derived from the gate which enters video to the height display circuit and it shows the area within which heights are not reported on the display.

A 10th video gate and storage capacitor are shown dotted in Fig. 5. If this gate is included, it opens at height 15 km and closes when video is terminated, at range 200 km. The circuits built to date have included this gate so that the display contains 10 height rings, the 10th indicating 15 km and above.

An advantage of the circuit implementation is that antenna elevation angles can be changed considerably without affecting the height limits represented by each ring on the display. As long as the d.c. voltage supplied to the ramp generator is correctly related to elevation angle, the video gates open at the correct heights.

5. Acknowledgements

Help and support from the following are gratefully acknowledged:

Mr. Abnash Singh, Mechanical Engineer, McGill Weather Radar.

Constructed camera mounts for the PPI's, circuit enclosures and mechanical components for the elevation angle programmer. Mr. Singh also served on board QUADRA during the first of the three phases of the experiment.

Mr. Martin Claassen, Electronic Technician, McGill Weather Radar.

Built the height storage and many other circuits required for the PPI displays.

The National Research Council funded the radar instrumentation described in this report through a GATE operating grant to Prof. G.L. Austin.

In the example of Fig. 1, a ring of radius 50 km is included. This ring is derived from the gate which enters video to the height display circuit and it shows the area within which heights are not reported on the display.

A [illegible] video gate and storage capacitor are shown dotted in Fig. 5. If this gate is included, it opens at height 20 km and closes when video is terminated, at range 200 km. The circuits built to date have included this gate so that the display contains 10 height rings; the 10th indicates [illegible] km and above.

An advantage of the circuit implementation is that antenna elevation angles can be changed considerably without affecting the height limits represented by each ring on the display. As long as the d.c. voltage supplied to the ramp generator is correctly related to elevation angle, the video gates open at the correct heights.

5. Acknowledgements

Help and support from the following are gratefully acknowledged:

Mr. Ahmed Singh, Mechanical Engineer, McGill Weather Radar.

Constructed camera mounts for the PPI's, circuit enclosures and mechanical components for the elevation angle programmer.

Mr. Singh also served on board QUADRA during the first of the three phases of the experiment.

Mr. Martin Gineswer, Electronic Technician, McGill Weather Radar.

Built the height storage and many other circuits required for the PPI displays.

The National Research Council funded the radar instrumentation described in this report through a GATE operating grant to Prof. G.L. Austin.

Appendix: Atlantic Tropical Experiment (GATE)

The radar on board QUADRA is a Sperry SP6504 C-band missile tracking radar, modified for balloon tracking in order to measure wind parameters. For weather observation, the radar was operated in a surveillance mode, with a programme of elevation angles repeated every 5 minutes. The additional circuits included $(\text{range})^{-2}$ STC, an elevation angle programmer and range integration by peak detection over each 1 km range interval.

Two additional PPI's were installed, the video signal to each consisting of the integrated video, thresholded to provide 5 intensity levels representing 10 dB steps in received power.

On one of the PPI's, each antenna rotation containing echo was recorded on a frame of 35-mm film. The second PPI was equipped with a Polaroid camera and its range sweep was adjusted to include the height data as described in this report. A gate was added to control the video to this second PPI so that only one full radius could be exposed during each cycle of elevation angles. Actually, ranges 50 to 200 km were exposed on the first azimuth rotation (elevation 0.6^{o}) and 0 to 50 km were exposed on the third rotation (elevation 1.6^{o}) in an effort to minimize interference due to sea clutter at close range.

Calibration of the radar included a power measurement in the far field as well as r.f. measurements along the rather complex receiving channels. These resulted in a value of 12 dBz for the lowest of the five thresholds.

In addition to the PPI's, a Digital Video Integrator Processor supplied by Automation Industries, Florida, was used to record the video data on magnetic tape. In that unit, the average of 144 samples (8 in range by 18 in azimuth) yields a value for each 1 km range interval of which there are 200 per degree of azimuth. The result is reduced to 8 bit code for recording on the 8 tracks of the tape recorder.

A novel feature of the digital unit is that a test is made on each group of 4 azimuth degrees for the presence of echo. If there is echo on any one or all of the 4, all are recorded. If there is no echo, none is recorded. Although this effected a saving, almost 300 tapes were used during the experiment.

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