NO. 22

WESTERN REGION TECHNICAL MEMORANDUM

Derivation of Radar Horizons In Mountainous Terrain

by

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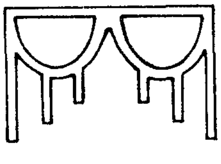

A western Indian symbol for rain. It also symbolizes man's dependence on weather and environment in the West.

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DERIVATION OF RADAR HORIZONS IN MOUNTAINOUS TERRAIN

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Introduction by Herbert P. Benner

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I. Introduction

The effective use of radar data depends not only on the proper interpretation of the meteorological significance of the echoes, but also on a knowledge of the radar design capabilities and the exposure of the radar antenna. Here in the mountainous west good radar sites are difficult to find, and thus the radars are sometimes located in areas where there is some terrain blocking. Total blocking of the radar beam, if present at all, is usually confined to a very narrow sector. On the other hand, partial beam blocking, particularly of the lower portion, is not uncommon.

Because of the nature of radio propagation through the atmosphere, a focused narrow radar beam rises above the surface of the earth with increasing range. Therefore, the range at which a target can be detected in the beam is a function of its height above the surface (a detailed discussion of radar propagation can be found in Western Region Technical Memorandum No. 8). Thus, if the lower portion of the beam is cut off or blocked, the range capability of the radar is seriously affected.

Both Mr. Pappas and Mr. Granger, Supervising Radar Meteorologists at Sacramento, California and Missoula, Montana respectively, recognized the importance of these facts to the users and prepared charts showing the height to which echoes must occur to be detectable at various ranges around their radars. Their charts take into account normal propagation as well as terrain blocking.

We felt that this description of the preparation of a blocking and earth curvature chart prepared by Mr. Pappas would be particularly helpful to personnel at other radar stations who may wish to prepare a similar chart, and also generally helpful to field personnel who use radar data routinely.

Herbert P. Benner - Regional Radar Meteorologist

II. Technique for Derivation of Earth's Curvature and Blocking Chart

Hiser and Freseman (page 83, equation 40) give the maximum possible range between a radar and a target as limited only by the radar horizon. This equation assumes standard propagation conditions and radar capability of target detection at this range.

(1) $R_{hmax} = 1.23\ (\sqrt{h_r} + \sqrt{h_t})$ nautical miles where R_{max} is the range to the target, h_r is the height of the radar antenna in feet, and h_t is the height of the target in feet.

By solving for h_t it is possible to determine the minimum target height for interception of the radar beam at a given range:

(2) $h_t = (R_{max} / 1.23 - \sqrt{h_r})^2$

The computation of the minimum target height is complicated by the introduction of a mountain barrier or "block" in the radar beam. This is illustrated in Figure 1. In Figure 1 the location of the radar is at Point R. Point H is where the radar beam is tangential to the earth, i.e., the horizon of the radar. A mountain or blocking barrier is introduced at Point E, with a Height CE. It is desired to determine the height of the beam's base, C'E', over Point E' after partial beam blocking by the mountain at E. It can be seen that B is the point at which the base of the beam is intercepted by the mountain and BB' represents the extension of the beam's base if no blocking had occurred. Further, the stippled area represents the region below the radar horizon, and the hatched area the additional region blocked by the mountain at E. HBB' is the locus of h_t.

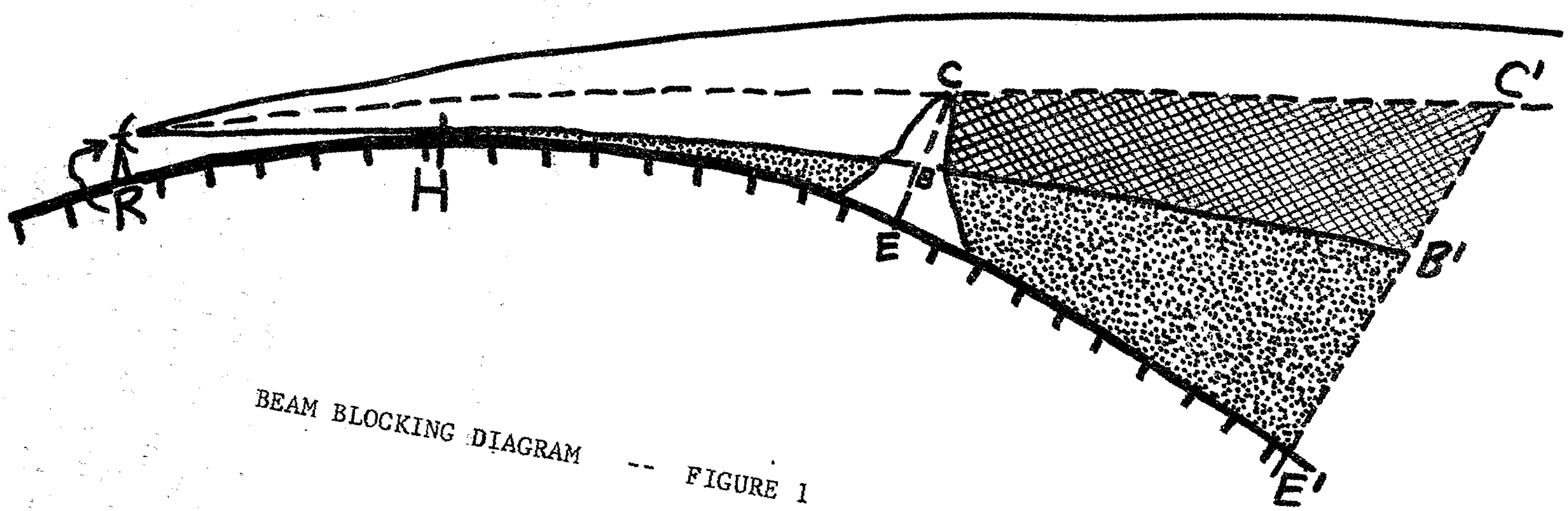
Since RCB and RC'B' are triangles which are approximately similar, $\frac{CB}{RHB} \approx \frac{C'B'}{RHBB'}$, where CB = CE - BE, or the difference between the elevation of the mountain and h_t computed for range to E. RHB is essentially the range to E, and RHBB' is the given range to E'. Hence, C'B' is easily evaluated, and when added to B'E' (the value of h_t at Point E') gives the value of C'B'E', the minimum target height for penetration of the radar beam.

In cases where higher terrain is down range from the blocking mountain at, say, Point E', it is necessary to test whether or not it is higher than C'B'E'. If it is higher, a new proportionality must be set up based on the amount of further blocking caused by the peak at Point E'. If not, the computations continue down range at intervals of 10 to 20 nautical miles.

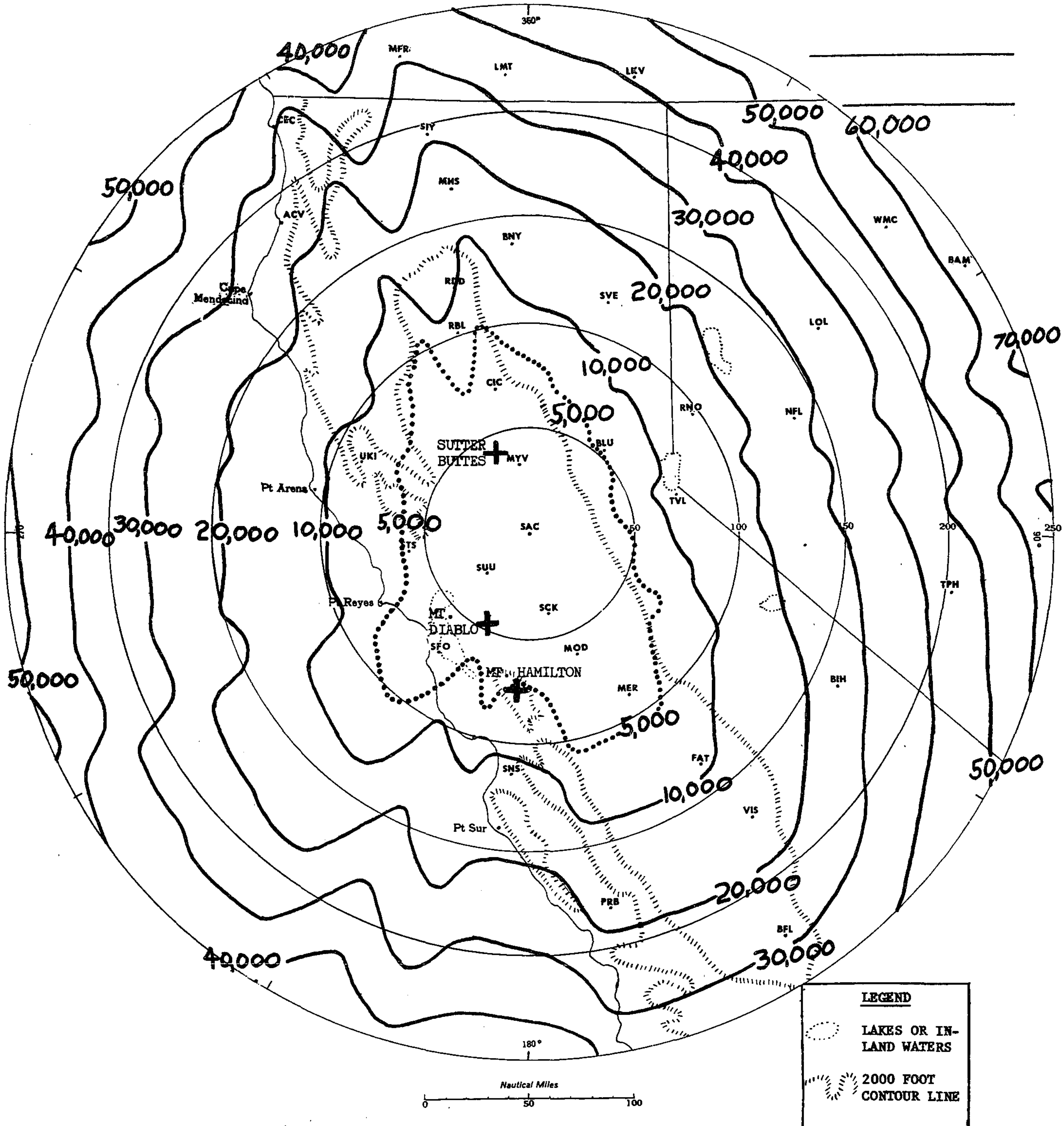
The construction of the blocking charts, Figures 2 and 3, was accomplished by tabulating terrain height data along azimuth radials from the radar at five-degree increments. Using an aeronautical chart showing 1000-foot contours, the crossing of each contour on the radials is noted with regard to its range. In the case of mountain peaks, the exact elevation is recorded. Starting with the first contour of elevation that is higher than the h_t value at that range, the "blocking" computation is begun and carried down range as explained above (with, of course, testing for additional down range blocking by higher terrain and setting up new proportionalities if necessary). Values for CBE, C'B'E', C"B"E", etc., (or h_t if there is no terrain blocking) along each five degrees of azimuth are then plotted and isopleths drawn to obtain the final chart. The procedure is rather time consuming and tedious, but certainly worth the effort. Once the computations get beyond about 100 nautical miles they become fewer since blocking from terrain rarely occurs at those extended ranges. It should be pointed out that this technique could easily be programmed for a computer.

III. Reference

Hiser and Freseman, RADAR METEOROLOGY, The Marine Laboratory, University of Miami, Coral Gables, Florida, 1959, page 83.



BEAM BLOCKING DIAGRAM -- FIGURE 1

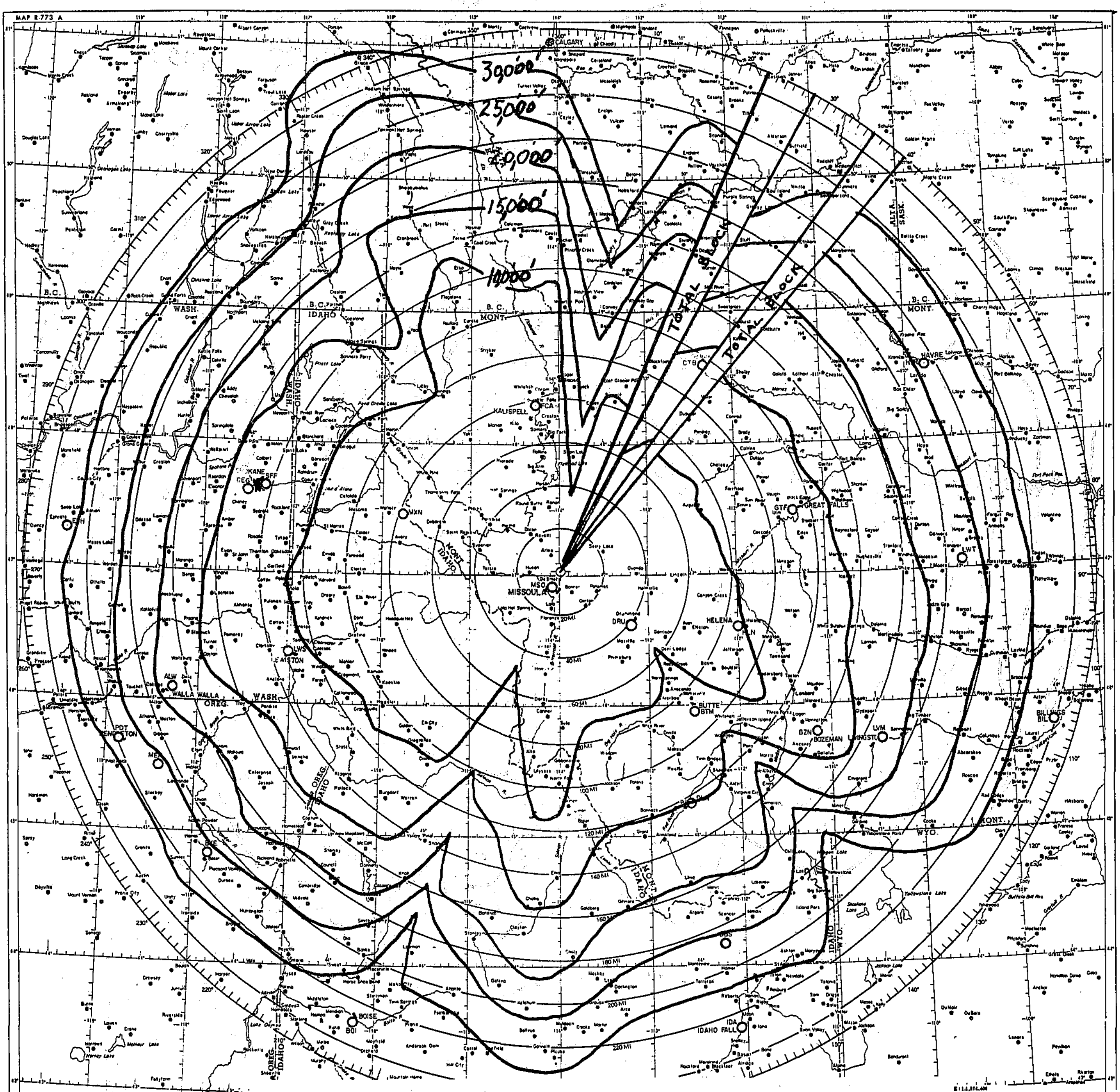


MINIMUM HEIGHT TO WHICH PRECIPITATION MUST EXTEND TO PENETRATE

THE RADAR BEAM (IN FEET ABOVE MSL)*

*Based on earth's curvature and blocking due to terrain, assuming standard propagation and that the rain is intense enough to be detected.

WSR-57 RADAR BEAM BLOCKING CHART - WBO, SACRAMENTO, CALIFORNIA Figure 2



WSR-57 RADAR BEAM BLOCKING CHART - WBAS, MISSOULA, MONTANA Figure 3