ANOMALOUS PROPAGATION IN RADAR

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During the past three or four years several Masters and Mates whose ships have been equipped with radar have reported that on many occasions their radar sets have failed to detect nearby land, and in several instances, ships also. Their radar sets were fitted with the overall performance monitor which would indicate to the user whether the set was functioning properly or not. They have been at a loss to understand why, if the overall performance monitor indicated that the set was working all right, these objects were not detected and shown on the radar screen.

One report was from a master in the China Coast trade. He stated that often he was unable to detect the Brothers, two rocks which lay to the N.E. of the Lamocks some 50 miles off Swatow. These rocks, some sixty feet high and with a base of some two hundred and fifty feet long, were normally detected on the radar screen at a range of eleven miles. But there were occasions when he approached them to within one mile before they showed up on the radar screen.

An officer reported that when approaching St. John, New Brunswick, signals indicating land were not seen on the radar screen until after they had approached to within one mile from it.

Another officer reported that, when off the same port, the land echoes appeared on the radar screen when some two to two and a half miles distant, but some ships which were approximately some five miles away were not detected by radar.

Yet another officer reported that during this last winter when in the Irish Sea, one night his radar set did not detect vessels until they were approximately three miles distant. This set was in continuous use and had been detecting vessels at normal ranges just before this particular watch and did again afterwards.

The peculiarities of these reports are the circumstances under which they took place. Each happened during the winter and under practically the same climatic conditions of very cold air over comparatively warm water.

The scientist assures us that the three centimetre electromagnetic wave used in radar, because it is approaching the frequency of light waves in the visible part of the spectrum, may be expected to behave almost like light waves and therefore travel in a straight line when propagated. Indeed, under normal atmosphere conditions they do behave almost like light waves. The radar signal travels in a straight line, but because there is this difference in frequency the radar wave behaves slightly differently to the light waves in that it is inclined to follow the curvature of the earth for a while, making the radar horizon a little beyond that of the visual horizon, a matter of $\frac{1}{11}$ greater. This, of course, is for a static condition of atmosphere, but as atmospheric conditions can vary greatly, so the distance of the radar horizon from the observer will also vary.

Refraction, which affects light waves, also affects radar signals, and should atmospheric conditions be such to cause a more than normal amount of refraction to be present, this super-refraction can extend the radar horizon to several hundreds of miles by refracting the signal to follow the curvature of the earth. Likewise, sub-refraction can reduce the distance of the radar horizon from the observer by refracting the signal away from the earth's surface, so that even nearby objects will not be hit by the propagated signal.

Super-refraction may be caused by (1) a temperature inversion (2) a moisture lapse; (3) a combination of (1) and (2) would give a more pronounced effect. The conditions in an area of high barometric pressure including calm weather and clear skies favour super-refraction but do not necessarily produce it.

Sub-refraction may occur when the reverse meteorological conditions exist. It may also be serious in regions of ice where the sea is warmer than the air immediately above it.

When the officers who made the reports previously mentioned concerning the non-detection of nearby objects were questioned, it was established that when it occurred the air temperature was very much below that of the sea temperature. The difference between them was at least twenty degrees and in the case of the non-detection of objects off St. John, New Brunswick, the difference was considerably more.

It was reported in the national press just over three years ago that Naval observers during an Arctic exercise in winter where the difference in air/sea temperature would be quite large, found it difficult to detect huge ice flows by radar until within one mile range.

Thus, it would seem that when in an area where the sea temperature is some twenty degrees or more higher than that of the air, the possibility of sub-refraction cannot be ruled out. And because of it quite nearby objects, say two or three miles distant, might not be detected by radar.

The frightennig thing about this form of anomalous propagation is that it may occur without the observer being aware that it is happening. It can be very disturbing to see an object suddenly appear on the screen of the radar set at a range of about one mile when it might be expected, because of its size, to be detected at a range of some ten miles or more.

Most observers are now aware that radar is not a reliable medium for the detection of icebergs. Reports have shown that vessels have approached to within one mile from quite large bergs before they were detected on the radar screen. The peculiarity of such bergs is that once past the beam, the berg is detected on the radar screen and continues to be so until it is well below the radar horizon astern.

It would appear that the non-detection of icebergs by radar depends upon a combination of circumstances :

(1) that the berg is upwind from the observer;

(2) the berg is so shaped that the wind passing over it is held in a pocket on the lee side of the berg sufficiently long enough for it to become very cold before streaming away from it to leeward;

(3) that the water on the lee side of the berg is comparatively warm.

These circumstances tend to cause a pocket of sub-refraction which could extend for some distance to leeward. How far to leeward is not known but it is certainly far enough for the radar signal to be deflected over the berg. On the weather side, the sea having been cooled by the berg and the air temperature normal, detection should be at the usual range for an object of such size, as indeed it is.

Thus, when in the vicinity of icebergs and heading into the wind, observers should not rely solely upon radar for the detection of such objects. May it be suggested to observers also that when near land or when in a busy traffic lane, when there is a difference in air and sea temperatures of some twenty degrees or more, and there are no signals appearing on the radar screen, they give some thought to it that it might be caused by sub-refraction, especially if the overall performance monitor indicates that the set is functioning normally.

If signals are appearing on the radar screen at normal ranges of detection there is obviously no sub-refraction. Should no echoes appear when it might be expected that they should, the difference in air and sea temperatures should be noted and consideration given to the effect of anomalous propagation on radar.