RADIOWAVE PROPAGATION BEYOND THE HORIZON: THE EFFECTS ON RADAR DETECTION RANGES IN MARITIME OPERATIONS.

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Abstract

Poor target detection is a major problem in maritime operations. There are factors that are responsible for this problem such as sea clutter through wave scattering. The range of target detection is also affected by the nature of earth curvature, which bends the radio wave along the path thereby increasing the range. Temperature variation and humidity as conditions of super and extra-refraction do affect the range as well.

Introduction

The curvature of the earth has a more important effect on propagation in that it presents a horizon that limits the range of transmission of radio wave, This range is greater than the optical range because the effect of the earth's atmosphere is to cause a bending of the radio wave, which carries it beyond the optical horizon. Fig. I shows a typical radio-wave ray path, and Fig. 2 shows how the path can be considered straight by assigning a greater radius to the earth than it actually has (Roddy and Coollen, 1997).

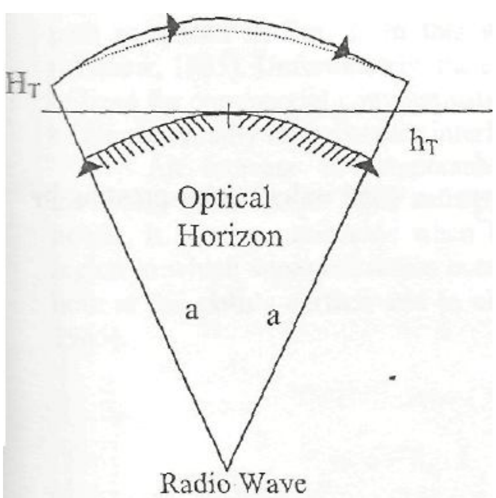

Fig. 1

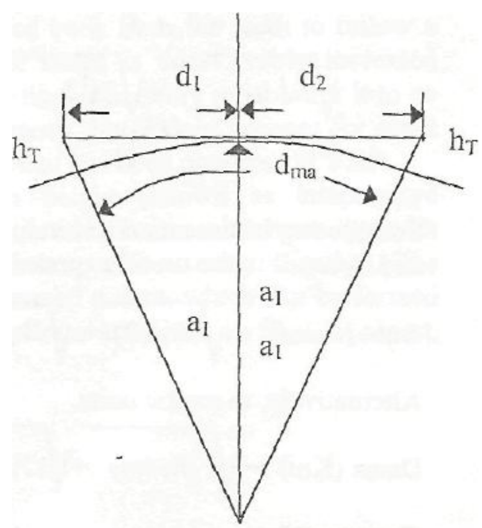

Fig. 2

For stand atmospheric condition the increase in radius has been worked out at $\frac{4}{3}$, so that

$$a^1 - \quad a \qquad \text{.............. (1)}$$

Where a is the earth's actual radius and a is the fictitious radius that accounts for refraction (Roddy Coolen 1997). From Fig.2.

$$(a^1)^2 + d_1{}^2 = (a_1 + h_T)^2$$

Therefore,

$$d_l{}^2 = 2a^1 h_T + h2_T \quad \ldots\ldots\ldots\ldots(2)$$

But, since $a^1 >> h_T$

$$d1^2 = 2a^1 h_T \quad \ldots\ldots\ldots\ldots(3)$$

Similarly,

$$d_2{}^2 = 2a^1 h_R \quad \ldots\ldots\ldots\ldots(4)$$

the maximum radio range d_{max} is

$$d_{max} = d_1 + d_z$$

$$= \sqrt{2a^1 h_T} + \sqrt{2a^1 h_R} \quad \ldots\ldots\ldots\ldots(5)$$

Substituting in the numerical value a^1 ==~T~ x 3960 miles, and expressing h_T and h_R result in the useful expression.

$$\text{dmas (miles)} = \sqrt{2h_T\,(ft)} + \sqrt{2h_R\,(ft)} \quad .(6)$$

Alternatively, in metric units.

$$\text{Damx (Km)} = \sqrt{17h_T\,(m)} + \sqrt{17h_R\,(m)}$$

Contour Maps

All the results derived are applicable only to smooth earth conditions (for example, transmission over water or over reasonably flat land). Where the earth's contour is rugged, a profile map is drawn to enable proposed transmission paths to be studied. Special graph paper is available for this purpose, in which abscissa lines are curved to allow for the fictitious radius a_{l5} and the graphs can be scaled for d in miles and heights in feet (or d in km and heights in meters).

Additional problems arise in built-up areas, where buildings and structures can cause multiple reflections and shielding, which are particularly troublesome with mobile radio equipment (Budden, 1985).

Purpose Of The Study

Propagation beyond the horizon is very well affected by super-refraction, which is invariably influenced by atmospheric conditions, that determines radar detection ranges in maritime. This study attempts to focus attention on the effects of super-refraction on radar detection ranges in maritime operations.

Significance Of The Study

The study would update the knowledge of marine engineers and stress the need to know the factors that are responsible for poor target detection in maritime.

Super - And Sub Refractions

Irregularities in the earth's atmosphere also affect tropospheric transmissions. A condition known as super refraction occurs when the refractive index of the air decreases with height much more rapidly than normal, so that the bending of the radiowave is much move pronounced than Fig. 1. The radio wave may then be reflected back from the earth to follow a path as shown in Fig. 3. In this way, the range is considerably increased (Mathew, 1965). Unfortunately, the effect is not sufficiently reliable for it to be utilized for commercial communications systems, but it does account for some of the abnormally long distance interference that has been observed at VHF.

An increase of temperature with height (known as temperature inversion) gives rise to super refraction, as does an increase of humidity with height. It is most noticeable when both of these effects occur together. The region in which super refraction occurs is termed a duct, which can be formed both at the earth's surface and in elevated strata as shown in Fig. 3 (Alpert, 1965).

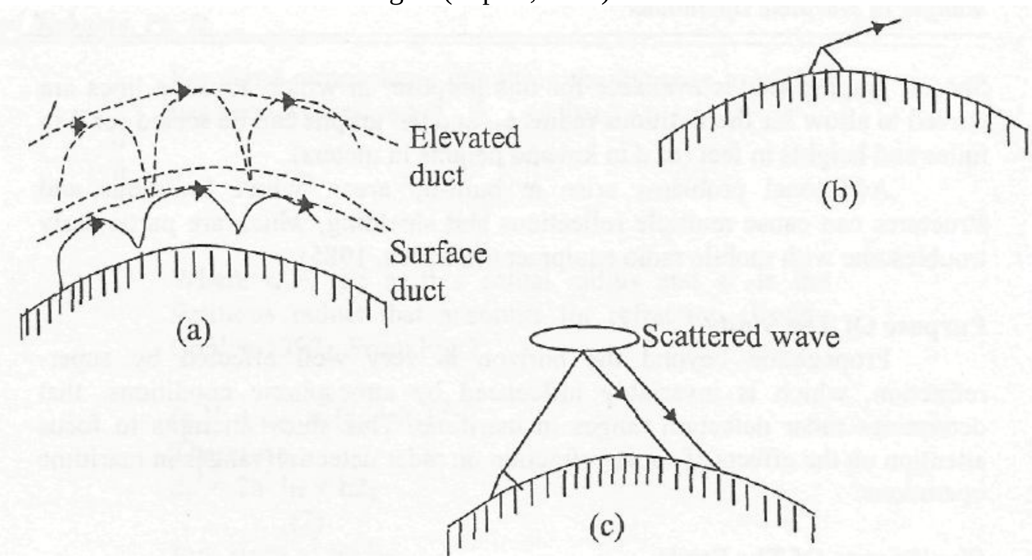

Fig. (a) super refraction (b) Suberfraction (c) tropospheric Scatter Propagation.

In it also possible for the opposite effects to occur, giving rise to sub refraction, which reduces signal strength by bending the ray away from the receiving point fig. 3C.

Inhomogeneities in the atmosphere can give rise to a scattering of radio signals, and by using highly directional high-gain antennas, and large transmitted power, reliable communication links well beyond the radio horizon can be established fig. 3C (Roddy and Coolen, 1997).

Effects Of Super And Extra Super-Refraction On Detection Ranges

Super-refraction occurs when the rate of decrease in refractive index with height is greater than under standard conditions.

When supper-refraction occurs, the radio beam tends to be bent down slightly move and so targets may be detected at ranges which are slightly greater than standard. Increases of some 40% are not uncommon (Bole and Dinelly, 1992).

Again, the mariner has no means of knowing exactly what sort of atmospheric conditions are being experienced and so has to rely on some form of subjective assessment. It is always best to err on the cautious side.

Atmosphere Conditions Associated With Super-Refraction.

These are: (Shibuya 1987):

(a) A decrease in relative humidity with height.

(b) Temperature falling more slowly than standard or even increasing with height.

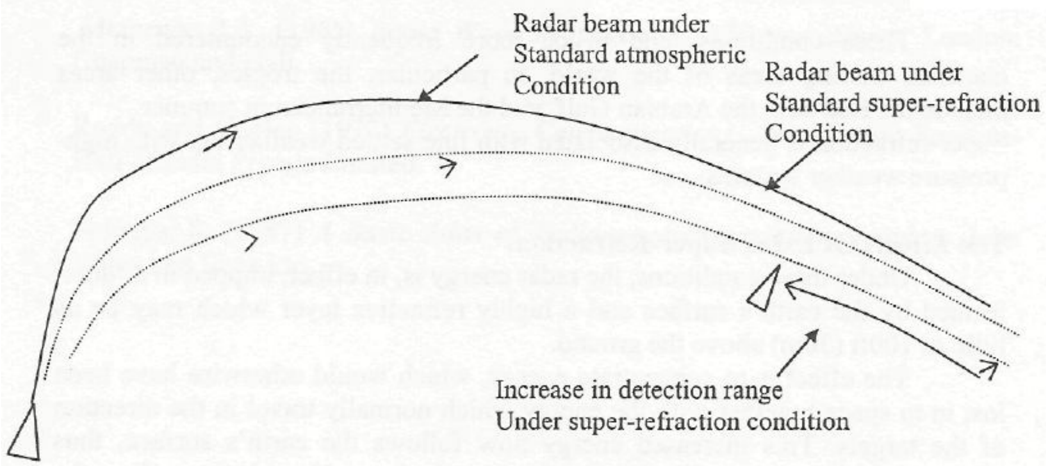

Fig. 4 The Effects of Super-Refraction on Detection ranges.

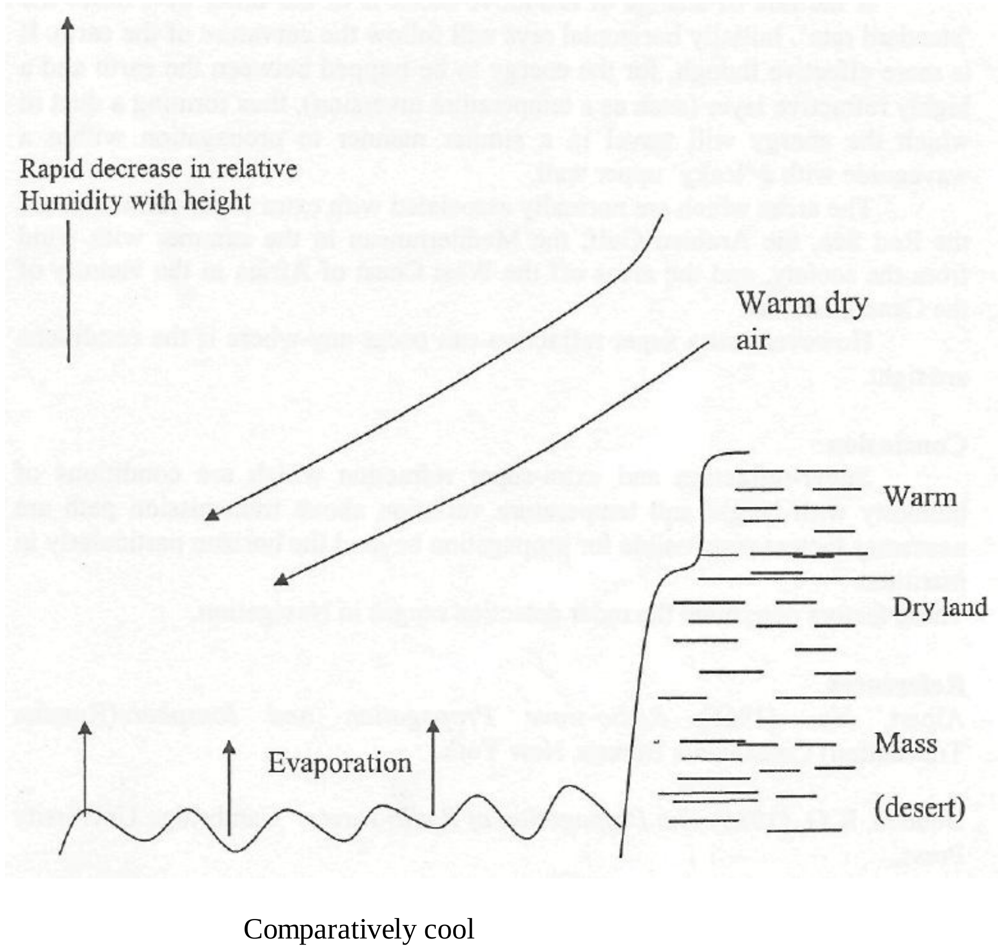

Fig. 5 Atmospheric Conditions Associated with Super-refraction.

These conditions tend to be more frequently encountered in the maritime trading areas of the world, in particular, the tropics, other areas include the Red Sea, the Arabian Gulf, and the Mediterranean in summer. Super-refraction is generally associated with fine settled weather i.e. with high-pressure weather systems.

The Effects Of Extra Super-Refraction.

Under these conditions, the radar energy is, in effect, trapped in a 'duct' formed by the earth's surface and a highly refractive layer which may be as little as 100ft (30m) above the ground.

The effect is to concentrate energy, which would otherwise have been lost in to space together with the energy which normally travel in the direction of the targets. This increased energy now follows the earth's surface, thus reducing the constraint of the radar horizon and considerably extending the detection ranges of targets (Bole and Dinelly, 1992).

If the rate of change of refractive index is of the order of 4 times the 'standard rate'. Initially horizontal rays will follow the curvature of the earth. It is more effective though, for the energy to be trapped between the earth and a highly refractive layer (such as a temperature inversion), thus forming a duct in which the energy will travel in a similar manner to propagation within a waveguide with a 'leaky' upper wall.

The areas which are normally associated with extra super-refraction are the Red Sea, the Arabian Gulf, the Mediterranean in the summer with wind from the society, and the areas off the West Coast of Africa in the vicinity of the Canary Islands.

However, extra super refraction can occur any-where if the conditions are right.

Conclusion

Super-refraction and extra-super refraction which are conditions of humidity with height and temperature variation above transmission path are necessary factors responsible for propagation beyond the horizon particularly in maritime. These factors determine the radar detection ranges in Navigation.

References

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