VARIATIONS IN THE INDEX OF REFRACTION OF THE ATMOSPHERE

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Summary — This paper discusses the atmospheric refractive index (a) throughout the year at the surface of the earth and (b) for each season in various air masses. Mean monthly or seasonal values, respectively, are employed.

The annual variation in the refractive index at the earth's surface is examined by noting the contributions of the optical and the water vapor terms. The former exhibits a sinusoidal variation with a period of a year, having a maximum in winter and a minimum during summer. The amplitude of the cycle is latitude dependent, appearing greater in polar than in tropical regions. The magnitude of the water vapor term is more strongly dependent upon both season and latitude. Excepting areas where the dew point changes little from month to month, the water vapor term attains a single yearly maximum at about mid-July.

Graphs of the variation of refractive index with altitude for the major air masses are included. Highest values of the index up to a height of 6 km are found in tropical maritime and monsoon air masses; lowest values, in arctic air masses. The rate of decrease of refractive index with height is usually quite different for diverse air masses. From the surface to an altitude of 6 km, the most constant rate of decrease with altitude, considering all air mass types, was found in the superior air mass.

1. Introduction — The study of the influence of weather conditions upon electromagnetic propagation, particularly as regards ultra high frequency radio fading, unorthodox radar vision, and general anomalous transmissions, has been carefully studied on numerous specific instances. These investigations have disclosed the frequent occurrence of tropospheric stratifications and discontinuities, both of temperature and water vapor, which significantly affect trajectories of the wave fronts at radio frequencies. These hiatuses, micrometeorological in nature, may be considered as irregular, short term, temperature and dew point fluctuations which

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are superimposed upon the relatively slow diurnal variations of these quantities.

A better understanding of the observed (and complicated) refractivities may be derived from (a) a knowledge of the refractive properties of the specified air mass, and (b) an insight into the minute modifications caused by turbulence, eddies, radiative unbalance, etc., in the air mass itself. This paper treats the first and obviously much simpler problem. In addition, since the greatest value of the refractive index is found at lowest levels, the investigation treats mean surface monthly conditions at several geographic points. The discussion is confined to the effects of the meteorological elements in the troposphere and lower stratosphere upon the refractive index, and does not encompass effects arising from the presence of space charges or high ionic concentrations.

2. Fundamental considerations — The magnitude of the refractive index in the lower atmosphere exceeds unity because of the presence of (uncharged) atoms and molecules forming the constituent gases. In any event, the refractive index must satisfy EULER's equation of the variation problem

\[
\int n \, ds = \text{extremum}
\]

where \( n \) is the refractive index and \( ds \) is the element of path in the medium w. f. under consideration. The above equation defines the optical length which, in the case when \( n = 1 \), coincides with the geometrical length.

Since \( n = n(x, y, z, t) \), the evaluation of (1) in the continuously changing atmospheric fluid is exceedingly difficult. Accordingly, a semi-empirical relation which considers the effect of (a) all dry gases and (b) water vapor with its strong dipole moment, has been derived for the refractive index of the atmosphere \( (1, 2, 3) \). This equation, expressed as a function of the meteorological variables \( (4, 5) \) is

\[
(n - 1) \times 10^6 = 79 \left( \frac{P + 4800 \, e/T}{T} \right)
\]

where

- \( P \) = total barometric pressure (mb)
- \( e \) = water vapor pressure (mb)
- \( T \) = absolute temperature (°K)
- \( n \) = refractive index for the volume defined by \( (P, e, T) \)

Although it was obtained on a semi-empirical basis, nonetheless the equation appears to give a good degree of accuracy \( (6, 7) \) and the formula is widely employed to obtain the refractive index in the radio wave region of the electromagnetic spectrum. It should be noted that since \( n \) [in equation (2)] is not a function of wave length, the lower atmosphere is considered non-dispersive with respect to the frequencies involved.