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STUDY GROUP V

After examination of draft Report G.1.k(V) the Editorial Group of Study Group (V) submits the following text to the Plenary Assembly for approval.

DRAFT

REPORT ...*

EFFECTS OF TROPOSPHERIC REFRACTION AT FREQUENCIES BELOW 10 MHz

(Question 3/V)

(1956-1963-1970)

In the ground-wave propagation curves in Recommendation ... (G.1.b(V)), as is explained in its Annex, no account is taken of tropospheric-refraction, whereas in the C.C.I.R. Atlases of ground-wave propagation curves for frequencies above 30 MHz /‾1, 2_7, the effect of a linear decrease of refractive index with height has been allowed for by the u use of an equivalent radius of the earth equal to 4/3 times the real radius. ven at these higher frequencies, it is important to remember that the refractive index of the troposphere does not decrease linearly with height, but eventually approaches the value of unity for free space. Thus, although it is justifiable to assume a 4/3 earth radius as far as the rate of attenuation attenuation with distance is concerned, with increasing height the curves overestimate the field strength, and instructions are given in the second Atlas for finding the correction factor for a given profile of refractive index, in particular for an exponential law of the type assumed for the basic reference atmosphere in Recommendation 369-1.

At frequencies below 10 MHz, the height-gain effects become small at moderate heights and it was partly for this reason that the ground-wave propagation curves have been made to refer only to the case in which both terminals are on the ground. On the other hand, below about 3 MHz, the range of height entering into the determination of the rate of attenuation of field strength with distance around the earth has extended to the region where the refractive index of the troposphere begins to depart seriously from the value corresponding to a linear decrease with height appropriate

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* This Report replaces Report 235.

to the use of a 4/3 earth's radius. Thus the rate of attenuation of field strength with distance around the earth no longer corresponds to the use of an atmosphere in which the refractive index decreases linearly to indefinitely great heights.

While at the upper limit of 10 MHz for the ground-wave propagation curves in Recommendation ... (G.1.b(V)), it is still nearly correct to use an equivalent radius of 4/3 times the real radius of the earth for both terminals on the ground, the troposphere can have very little effect at the lower limit of 10 kHz, where the range of height entering into the determination of the rate of attenuation of field strength with distance around the earth extends to many kilometres above the earth.

There is thus a transition that becomes marked at about 3 MHz and almost complete at 10 kHz, from the use of a 4/3 earth's radius at 10 MHz to the use of the real radius of the earth at 10 kHz. It has long been realized that this transition must occur, as is shown by the existence of the appropriate Question 3/V.

Progress in this study has, however, been slow for two reasons : first because of the difficulty of handling the mathematical analysis when the relevant eigen-value equation contains a law of variation of refractive index such as the exponential form proposed, and secondly, because with decreasing frequency, the ionosphere becomes a dominant factor in propagation to great distances, as is pointed out in § 6 of the Annex to Recommendation ... (G.1.b(V)).

It has been suggested that the degree to which tropospheric refraction modifies ground-wave propagation at frequencies below 10 MHz can be investigated experimentally. Such results as have been obtained in this way have in general been inconclusive. It is difficult over a land path to be certain that any effects observed are due to the tropeshere and not to inhomogeneities of the earth constants, or because the conductivity is actually greater than the value assumed in using the curves for comparison with the measured results.

Even over a sea path, where the conductivity is well defined, the ionosphere can produce an appreciable effect at mid-day at distances where the troposphere may be expected to produce a marked increase in signal, though there is some evidence of significant tropospheric refraction at frequencies as low as 1500 kHz at distances of 200 km or more (see Doc. 176 (France), Warsaw, 1956).

The conclusion had been reached that there was not much likelihood that the curves could be materially improved on the basis of such experiments. It also appeared that the whole subject was somewhat academic in view of the limited use of such ground-wave propagation curves when the effect of the ionosphere is taken into account, as indicated in § 6 of the Annex to Recommendation ... (G.1.b(V)).

However, with the advances that have been made at low frequencies in the use of pulse techniques and high radiated powers with the consequent development of new navigational aids, the whole emphasis of the study has been revised. The possibility envisaged, in § 6 of the Annex to Recommendation ... (G.1.b(V)), isolating the ground-wave has become of major importance and for this reason the use of pulse techniques has been introduced prominently into the revised form of the study given in Question 3/V.

It now appears that further experiments, at least over long sea paths, using pulse techniques may well help to resolve the nature of tropospheric refraction at frequencies below 10 MHz. Such experiments are in fact in progress, but no detailed results are as yet available. It may be pointed out that, in comparing the results with the values given by the curves, the important feature is not the absolute value of the field strength at a given distance, which will depend upon such factors as the estimated radiated power, but the law of attenuation with distance.

At sufficiently great distances where the first term of the residue series in the diffraction formula is predominant, the decrease of field strength with distance will be effectively exponential, giving an attenuation which may be expressed in dB/km. It is this rate of attenuation, which is given primarily by the solution of the eigen-value equation in the mathematical statement of the problem, and which forms the simplest measure of the effect of tropospheric refraction on ground-wave propagation. The secondary problem of computing the absolute values of field strength can be handled when the fundamental eigen-value equation has been solved.

The mathematical analysis is intimately concerned with the study of the height-gain function from which the eigen-value equation is derived. In § 5 of the Annex to Recommendation ...(G.1.b(V)), the importance of height-gain effects is stressed, in connection with high-flying aircraft using navigational aids depending on ground-wave propagation by the use of pulse techniques.

Even assuming that the mathematical analysis of the problem had been completed, the inclusion of height-gain effects in the curves would be a formidable task. It would involve the production of an Atlas large in size compared with the existing Atlases [1, 2] and this is a sufficient reason for not including such height-gain effects at the present time.

Nevertheless, the mathematical technique for computing height-gain values is well advanced, even for refractive index profiles such as the experimental one [3, etc.], and when the problem of solving the basic eigen-value equation in its generalized form has been completed, the production of height-gain curves for frequencies below 10 MHz can be carried out with the aid of modern computing methods.

Some work that shows promise is in hand on the solution of the eigen-value equation. It confirms, for instance, that the effect of the troposphere is still marked on a frequency of 1500 kHz as the limited experimental evidence suggests. However, it is too early to anticipate the full results of this analysis.

If this problem can be successfully solved, it is to be hoped that the results will be incorporated in any revision of the ground-wave curves given in the Annex to Recommendation ... (G.1.b(V)), as envisaged in Report ... (G.1.v(V)).

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