PREDICTION OF TROPOSPHERIC RADIO TRANSMISSION LOSS OVER IRREGULAR TERRAIN

A COMPUTER METHOD - 1968

by

A. G. Longley and P. L. Rice

This report describes a computer method for predicting long-term median transmission loss over irregular terrain. The method is applicable for radio frequencies above 20 MHz and may be used either with detailed terrain profiles for actual paths or with profiles that are representative of median terrain characteristics for a given area. Estimates of variability in time and with location, and a method for computing service probability, are included.

KEY WORDS: transmission loss, tropospheric propagation, irregular terrain, time availability, service probability

1. INTRODUCTION

This report describes a computer method for predicting long-term median radio transmission loss over irregular terrain. The method is based on well-established propagation theory and has been tested against a large number of propagation measurements. It is applicable for radio frequencies above 20 MHz and may be used either with detailed terrain profiles for actual paths or with profiles that are representative of median terrain characteristics for a given area. Estimates of median terrain characteristics are based on a large number of terrain profiles for several types of terrain, including plains, desert, rolling hills, foot-hills, and rugged mountains.

Given radio frequency, antenna heights, and an estimate of terrain irregularity, median reference values of attenuation relative to the trans-mission loss in free space are calculated as a function of distance. For radio line-of-sight paths, the calculated reference is based on two-ray theory and an extrapolated value of diffraction attenuation. For trans-horizon paths, the reference value is either diffraction attenuation or forward scatter attenuation, whichever is smaller.

This prediction method was developed for use with a digital computer and has been made sufficiently general to provide estimates of transmission loss expected over a wide range of frequencies, path lengths, and antenna height combinations, over smooth to highly rugged terrain, and for both vertical and horizontal polarization. The method is described in complete detail in annex 3. Shortcuts appropriate for limited applications are indicated throughout the body of the report. Familiarity with other propagation models, such as those described by Rice et al. (1967) is not essential for using the prediction method described here.

Predictions have been tested against data for wide ranges of frequency, antenna height and distance, and for all types of terrain from very smooth plains to extremely rugged mountains. The data base includes more than 500 long-term recordings throughout the world in the frequency range 40 to 10,000 MHz, and several thousand mobile recordings in the United States at frequencies from 20 to 1000 MHz. The method is intended for use within the following ranges:

Parameter	Range
frequency	20 to 40,000 MHz
antenna heights	0.5 to 3,000 m
distance	1 to 2,000 km
surface refractivity	250 to 400 N-units

In applying this prediction method to specific paths for which detailed profiles are available, certain limitations on antenna siting are desirable. For example, the angle of elevation of each horizon ray above the horizontal should not exceed 12°, and the distance from each antenna to its horizon should not be less than 1/10, or more than three times, the corresponding smooth-earth distance.

Section 2 discusses atmospheric and terrain parameters, and section 3 explains how transmission loss is calculated. The topics treated in the annexes are as follows:

Annex 1 shows how the computed reference values, A_{cr}, are adjusted to provide long-term median estimates, $A(0.5)$, of attenuation relative to free space for any given set of data. This annex also gives estimates of the variability in time and with location and shows how to estimate prediction errors.

Annex 2 shows how various path parameters have been derived from studies of terrain profiles.

Annex 3 gives detailed formulas and procedures required to calculate the median reference attenuation A_{cr}. A computer program listing, flow diagram, and sample computations are included.

Annexes 1 and 3 each contain a list of symbols used in that annex, with their definitions.

2. ATMOSPHERIC AND TERRAIN PARAMETERS

2.1 Atmospheric Effects

Radio transmission loss in tropospheric propagation depends on characteristics of the atmosphere and of terrain. For predicting a long-term median reference value of transmission loss, the refractive index gradient near the earth's surface is the most important atmospheric parameter. This surface gradient largely determines the bending of a radio ray as it passes through the atmosphere. Rays may be represented as straight lines, within the first kilometer above the earth's surface, if an "effective earth's radius", a, is defined as a function of the refractivity gradient or of the mean surface refractivity, N_s. In