TRANSMISSION LOSS PREDICTIONS FOR TROPOSPHERIC COMMUNICATION CIRCUITS

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1. INTRODUCTION

This report presents comprehensive methods of calculation which have been found useful either for explaining or for predicting cumulative distributions of transmission loss for a wide range of radio frequencies over almost any type of terrain and in several climatic regions. Such quantitative estimates of propagation characteristics help to determine how well proposed radio systems will meet requirements for satisfactory service, free from harmful interference. Thus they should provide an important step toward more efficient use of the radio frequency spectrum.

The need for comprehensive and accurate calculation methods is clearly demonstrated when measured transmission loss data for a large number of radio paths are shown as a function of path length. In figures I.1 to I.4 of annex I, long-term median values of attenuation relative to free space for more than 750 radio paths are plotted versus distance. The extremely wide scatter of these data is due mainly to path-to-path differences in terrain profiles and effective antenna heights. Values recorded for a long period of time over a single path show comparable ranges, sometimes exceeding 100 decibels. Such tremendous path-to-path and time variations must be carefully considered, particularly in cases of possible interference between co-channel or adjacent-channel systems. Included in annex I is a method for obtaining preliminary reference values of transmission loss for a wide range of prediction parameters.

The detailed point-to-point methods described here depend on propagation path geometry, atmospheric refractivity near the surface of the earth, and specified characteristics of antenna directivity. They have been tested against measurements in the radio frequency range 40 to 10,000 MHz (megahertz ≡ megacycles per second). Estimates of attenuation due to absorption and scattering of radio energy by various constituents of the atmosphere are included in order to extend the application of these methods to frequencies up to 100 GHz.

Calculations of long-term median reference values of transmission loss are based on current radio propagation theory. A large sample of radio data was used to develop the empirical predictions of regional, seasonal, and diurnal changes in long-term medians. Estimates of long-term fading relative to observed medians are given for several climatic regions and periods of time, including some regions where few observations are available.

Calculations of transmission loss for paths within the radio horizon are based on geometric-optics ray theory. For paths with a common horizon, Fresnel-Kirchoff knife-edge diffraction theory is applied and extended to predict diffraction attenuation over isolated rounded obstacles. For double horizon paths that extend only slightly beyond the horizon, a modification of the Van der Pol-Bremmer method for computing field intensity in the far diffraction region is used. For longer paths, extending well beyond radio horizon, predictions are based on forward scatter theory. Radio data were used to estimate the efficiency of scattering at various heights in the atmosphere. Where some doubt exists as to which propagation mechanism predominates, transmission loss is calculated by two methods and the results are combined.

Examples showing how to compute transmission loss for a line-of-sight path, an isolated rounded obstacle, and a long transhorizon path are given following sections 5, 7 and 9 respectively. Section 12 provides a list of symbols and abbreviations used in the text. Special symbols used only in an annex are defined at the end of the appropriate annex.

Annex I includes a set of "standard" curves of basic transmission loss and curves showing attenuation below free space for earth space communications, prepared using the methods described in the report. Such curves, and the medians of data shown on figures I.1 to I.4, may serve for general qualitative analysis, but clearly do not take account of particular terrain profiles or climatic effects that may be encountered over a given path.

Annex II supplements the discussion of transmission loss and directive antenna gains given in section 2. This annex contains a discussion of antenna beam orientation, polarization, and multipath coupling loss.

Annex III contains information required for unusual paths, including exact formulas for computing line-of-sight transmission loss with ground reflections, as well as modifications of the formulas for antenna beams which are elevated, or directed out of the great circle plane. Analytic expressions suitable for use on a digital computer are also included.

Annex IV reviews tropospheric propagation theory with particular attention to the mechanisms of forward scatter from atmospheric turbulence, from layers, or from small randomly oriented surfaces. References to some of the work in this field are included.

Annex V presents a discussion of "phase interference fading" as contrasted to "long-term power fading", provides a method for computing the probability of obtaining adequate service in the presence of noise and/or interfering signals, and includes a brief summary of ways to achieve optimum use of the radio frequency spectrum.

Previous NBS Technical Notes in this series, numbered 95 to 103, describe tropospheric propagation phenomena and siting problems [Kirby, Rice, and Maloney, 1961], certain meteorological phenomena and their influence on tropospheric propagation [Dutton, 1961; Dutton and Thayer, 1961], synoptic radio meteorology [Bean, Horn, and Riggs, 1962], techniques for measuring the refractive index of the atmosphere [McGavin, 1962], determination of system parameters [Florman and Tary, 1962], performance predictions for communication links [Barsis, Norton, Rice, and Elder, 1961], and equipment characteristics [Barghausen, et al., 1963].