RECOMMENDATION 617-1

PROPAGATION PREDICTION TECHNIQUES AND DATA REQUIRED FOR THE DESIGN OF TRANS-HORIZON RADIO-RELAY SYSTEMS

(Question 15/5)

(1986-1992)

The CCIR,

considering

a) that for the proper planning of trans-horizon radio-relay systems it is necessary to have appropriate propagation prediction methods and data;

b) that methods have been developed that allow the prediction of most of the important propagation parameters affecting the planning of trans-horizon radio-relay systems;

c) that as far as possible these methods have been tested against available measured data and have been shown to yield an accuracy that is both compatible with the natural variability of propagation phenomena and adequate for most present applications in system planning,

recommends

that the prediction methods and other techniques set out in Annex 1 be adopted for planning trans-horizon radio-relay systems in the respective ranges of parameters indicated.

ANNEX 1

1. Introduction

The only mechanisms for radio propagation beyond the horizon which occur permanently for frequencies greater than 30 MHz are those of diffraction at the Earth's surface and scatter from atmospheric irregularities. Attenuation for diffracted signals increases very rapidly with distance and with frequency, and eventually the principal mechanism is that of tropospheric scatter. Both mechanisms may be used to establish "trans-horizon" radiocommunication. Because of the dissimilarity of the two mechanisms it is necessary to consider diffraction and tropospheric scatter paths separately for the purposes of predicting transmission loss.

This Annex relates to the design of trans-horizon radio-relay systems. One purpose is to present in concise form simple methods for predicting the annual and worst-month distributions of transmission loss due to tropospheric scatter, together with information on their ranges of validity. Another purpose of this Annex is to present other information and techniques that can be recommended in the planning of trans-horizon systems.

2. Transmission loss for diffraction paths

For radio paths extending only slightly over the horizon, or for paths extending over an obstacle or over mountainous terrain, diffraction will generally be the propagation mode determining the field strength. In these cases, the methods described in Recommendation 526 should be applied.

3. Transmission loss distribution on tropospheric scatter paths

Signals received by means of tropospheric scatter show both slow and rapid variations. The slow variations are due to overall changes in refractive conditions in the atmosphere and the rapid fading to the motion of small-scale irregularities. The slow variations are well described by distributions of the hourly-median transmission loss which are approximately log-normal with standard deviations between about 4 and 8 dB, depending on climate. The rapid variations over periods up to about 5 min are approximately Rayleigh distributed.

In determining the performance of trans-horizon links for geometries in which the tropospheric scatter mechanism is predominant, it is normal to estimate the distribution of hourly-median transmission loss for non-exceedance percentages of the time above 50%. A simple semi-analytical technique for predicting the distribution of average annual transmission loss in this range is given in § 3.1. A graphical technique for translating these annual time percentages to those for the average worst month is given in § 3.2. Finally, guidance is given in § 3.3 on estimation of the transmission loss distribution for small percentages of time for use in obtaining receiver dynamic ranges required. Appendix 1 includes additional supporting information on seasonal and diurnal variations in transmission loss, on frequency of rapid fading on tropospheric scatter paths and on transmission bandwidth.

3.1 Average annual median transmission loss distribution for time percentages greater than 50%

The following step-by-step procedure is recommended for estimating the average annual median transmission loss $L(q)$ not exceeded for percentages of the time q greater than 50%. The procedure requires the link parameters of great-circle path length d (km), frequency f (MHz), transmitting antenna gain G_t (dB), receiving antenna gain G_r (dB), horizon angle θ_t (mrad) at the transmitter, and horizon angle θ_r (mrad) at the receiver:

Step 1: Decide on the appropriate climate for the link in question from the list of nine climates (commonly designated 1, 2, ..., 7a, 7b, 8) described below. In cases of uncertainty as to the appropriate climate, transmission loss calculations should be carried out for the two or three most likely possibilities and the most conservative results employed.

1. **Equatorial**: corresponds to the region between latitudes 10° N and 10° S. The climate is characterized by a slightly varying high temperature and by frequent heavy rains which sustain a permanent humidity. The annual mean value of N_s (refractivity at the surface of the Earth = $(n-1)\,10^6$ where n is the refractive index of the air) is about 360 N-units and the annual range of variations is 0 to 30 N-units.

2. **Continental sub-tropical**: corresponds to the regions between latitudes 10° and 20°. The climate is characterized by a dry winter and rainy summer. There are marked daily and annual variations of radio propagation conditions, with least attenuation in the rainy season. Where the land area is dry, radio ducts may be present for a considerable part of the year. The annual mean value of N_s is about 320 N-units and the range of variation, throughout the year, of monthly mean values of N_s is 60 to 100 N-units.

3. **Maritime sub-tropical**: also corresponds to the regions between latitudes 10° and 20° and is usually found on lowlands near to the sea. It is strongly influenced by the monsoon. The summer monsoon, which blows from sea to land, brings high humidity into the lower layers of the atmosphere. Although the attenuation of radio waves is relatively low at both the beginning and end of the monsoon season, during the middle of the monsoon the atmosphere is uniformly humid to great heights and the radio attenuation increases considerably despite a very high value of N_s. There is an annual mean N_s of about 370 N-units with a range of variation over the year of 30 to 60 N-units.

4. **Desert**: corresponds to two land areas which are roughly situated between latitudes 20° and 30°. Throughout the year there are semi-arid conditions and extreme diurnal and seasonal variations of temperature. This climate is very unfavourable for forward-scatter propagation, particularly in summer. There is an annual mean value of N_s of about 280 N-units and throughout the year monthly mean values may vary over a range of 20 to 80 N-units.

5. **Mediterranean**: corresponds to regions in both hemispheres on the fringe of desert zones, close to the sea, and lying between latitudes of 30° and 40°. The climate is characterized by a fairly high temperature which is reduced by the presence of the sea, and an almost complete absence of rain in the summer. Radio-wave propagation conditions vary considerably, particularly over the sea, where radio ducts exist for a large percentage of the time in summer.

6. **Continental temperate**: corresponds to regions between latitudes 30° and 60°. Such a climate in a large land mass shows extremes of temperature and pronounced diurnal and seasonal changes in propagation conditions may be expected to occur. The western parts of continents are influenced strongly by oceans, so that temperatures here vary more moderately and rain may fall at any time during the year. In areas progressively towards the east, temperature variations increase and winter rain decreases. Propagation conditions are most favourable in the summer and there is a fairly high annual variation in these conditions. The annual mean value of N_s is about 320 N-units and monthly mean values may vary by 20 to 40 N-units throughout the year.

7a. **Maritime temperate, overland**: also corresponds to regions between latitudes of about 30° and 60° where prevailing winds, unobstructed by mountains, carry moist maritime air inland. Typical of such regions are the United Kingdom, the west coast of North America and of Europe and the northwestern coastal areas of Africa. There is an annual mean value of N_s of about 320 N-units, with a rather small variation of monthly mean values over the year of 20 to 30 N-units. Although the islands of Japan lie within this range of latitudes, the climate is somewhat different and shows a greater annual range of monthly mean values of N_s about 60 N-units. The prevailing winds in Japan have traversed a large land mass and the terrain is rugged. Climate 6 is therefore probably more appropriate to Japan than climate 7, but duct propagation may be important in coastal and adjacent oversea areas for as much as 5% of the time.

7b. **Maritime temperate, oversea**: corresponds to coastal and oversea areas in regions similar to those for climate 7a. The distinction made is that a radio propagation path having both horizons on the sea is considered to be an oversea path (even though the terminals may be inland): otherwise climate 7a is considered to apply. Radio ducts are quite common in occurrence for a small fraction of the time between the United Kingdom and the European continent and along the west coasts of the United States of America and Mexico.

8. **Polar**: corresponds approximately to the regions between latitudes 60° and the poles. This climate is characterized by relatively low temperatures and relatively little precipitation.

Step 2: Obtain the meteorological and atmospheric structure parameters M and γ, respectively, from Table 1 for the climate(s) in question. For a Mediterranean climate (climate 5) and a polar climate (climate 8), the values for climates 4 and 7a should be respectively used.

TABLE 1

Values of meteorological and atmospheric structure parameters

Climate	1	2	3	4	6	7a	7b
M (dB)	39.60	29.73	19.30	38.50	29.73	33.20	26.00
γ (km^{-1})	0.33	0.27	0.32	0.27	0.27	0.27	0.27

Step 3: Calculate the scatter angle θ (angular distance) from

$$\theta = \theta_e + \theta_t + \theta_r \qquad \text{mrad} \qquad (1)$$

where θ_t and θ_r are the transmitter and receiver horizon angles, respectively, and

$$\theta_e = d \cdot 10^3 / ka \qquad \text{mrad} \qquad (2)$$

with:

d : path length (km)

a = 6370 km radius of the Earth

k : effective earth radius factor for median refractivity conditions (k = 4/3 should be used unless a more accurate value is known);