REFRACTIVITY AND RAINFALL DATA FOR RADIO SYSTEMS ENGINEERING

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Information on refractivity gradients and rainfall rates is provided for application to the planning and engineering of microwave line-of-sight radio systems. The 100-m refractivity gradients calculated from radiosonde observations at 15 U.S. and 49 foreign stations are presented in the form of graphs of the cumulative probability distribution. As an indication of the diurnal variability of the gradients, separate distributions are shown for each of two daily observations at 29 stations, and for four daily observations at 4 stations. Point rainfall rate distributions, based on recording rain gage statistics, are given for 29 stations in various climatic areas of the world, including 8 locations in the U.S.

Key words: Microwave attenuation, rainfall rates, refractivity gradients

1. INTRODUCTION

The utilization of refractivity and rainfall data in the planning and engineering of microwave radio systems (particularly line-of-sight systems) is facilitated by the availability of atmospheric data in a form that can be readily applied to specific design and performance evaluation problems. To provide a basis for estimates of the frequency of occurrence of atmospheric-related radio phenomena, such as earth bulge, multipath fading, and rain attenuation, this report presents refractivity gradient and rainfall rate statistics, based on climatological records, in the form of cumulative probability distribution graphs.

The radio refractive index of air, n, is determined by the conditions of pressure, temperature, and humidity. This ratio, n, is approximately 1.003 under standard conditions near the earth's surface. For convenience, a scaled-up value, N, or <u>refractivity</u>, is normally used in propagation studies; this may be obtained from the following relationship (Smith and Weintraub, 1953):

$$N = (n - 1)10^6 = \frac{77.6}{T}\left[P + \frac{4810\ e_s RH}{T}\right]$$

where P = pressure in millibars
T = temperature in kelvins
e_s = saturation vapor pressure in millibars
RH = relative humidity expressed as a decimal

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The vertical gradient of refractivity may be calculated from weather service observations of temperature, pressure, and humidity obtained with balloon-borne radiosondes.

As used here, a normal gradient is equivalent to a gradient of -40 to -50 N-units/km over the specified interval (e.g., 100 m).

Subrefraction (also known as the "earth-bulge" condition) is an increase of N with height (positive gradient) which causes radio waves to bend upward.

Superrefraction is a larger than normal gradient (i.e., more negative) which causes waves to bend downward; often considered as a gradient of -100 N-units/km or more.

Ducting is an intensified form of superrefraction that may trap radio waves as though in a waveguide, causing greatly reduced attenuation and extended range. Usually considered as -157 N-units/km or more (Hart et al., 1971; Dougherty, 1968).

Refractivity gradient data are available in previous publications of the Institute for Telecommunication Sciences (ITS), for example, "A World Atlas of Atmospheric Radio Refractivity" (Bean et al., 1966), and "Refractivity Gradients in the Northern Hemisphere" (Samson, 1975a). The present report gives the following additional information on the radio refractivity:

a. Southern Hemisphere data, as originally calculated for maps in the atlas, in the graphical form preferred by many engineers;
b. Refractivity data for 29 new stations in both hemispheres;
c. Analyses of the diurnal variation of the observed refractivity gradients;
d. Refractivity data for stations in Chile, Argentina, and Indonesia that were originally reported in documents not readily available to most engineers (Rutllant et al., 1970; Panaccio et al., 1970; Sutanto, 1969).

The refractivity gradients were calculated for the ground-based 100-m layer from measurements of pressure, temperature, and humidity obtained by radiosonde observations (RAOBs) of the U.S. National Weather Service (NWS) and equivalent foreign meteorological organizations. The sources and limitations of the data, methods of calculation, etc., were discussed in detail in a previous report (Samson, 1975a). For the 29 new stations included in this report, cumulative probability distributions were prepared using all available observations, and separate distributions were prepared for each time of observation for study of the diurnal variations in the gradient distributions. Four separate observations per day were made at a few stations, but at most sites there were only two observations at the internationally standardized times of 0000Z and 1200Z (0300Z and 1500Z prior to 1957).*

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*Greenwich Mean Time, or GMT, is commonly indicated by "Z" in meteorological data transmissions.

The graphs in appendix A show the cumulative probability distributions of the 100-m gradients for the months of February, May, August, and November. A brief site description and climatological average values of temperature, humidity, and precipitation are also given for each station.

General information on the various effects of precipitation on microwave radio systems was given in a previous report (Samson, 1975b). The point rainfall rate statistics presented in this report were obtained from many different sources, and the instrumentation, averaging times, and periods of observation were not uniform. The data are not, therefore, strictly comparable, but they do provide an indication of the type of rainfall climate likely to be encountered in the areas near these observing stations, and hence should be useful to the radio engineer.

The graphs in appendix B show the percent time that a given rainfall rate was exceeded during the period of observation. Most of the graphs are based on observations for only one year, which is too short a period for reliable climatological averages.* Engineering applications of these data should be made with the realization that the usual year-to-year variations in the weather can be expected to cause departures from the distributions shown in the graphs. A brief climatological summary, including the normal annual precipitation and the precipitation during the test year, is given for each station as an aid in estimating comparability of particular locations. It should be noted, however, that two stations with approximately the same annual <u>total</u> precipitation may have very different rainfall rate distributions, as illustrated in figure 1. The normal annual precipitation is 38.94 in (989 mm) at Seattle and 37.00 in (940 mm) at Urbana, but Seattle has only about 8 days per year with thunderstorms while Urbana has 45. Seattle averages about 50 more days per year with measurable precipitation than Urbana, but rates are generally low.

Sources for most individual items of climatological data are not separately identified in the text or appendices of this report, but a separate list of climatological sources is given in the references. Since nearly all of the sources used the English system of units, these have been retained in the data tabulations. Rainfall <u>rate</u> data, however, are given in mm/hr to conform with usage in recent studies of attenuation as a function of frequency and rainfall rate.

The location of stations for which either refractivity or rainfall data are given in the appendices can be obtained approximately by reference to the map in figure 2; coordinates of the stations are listed in the station summaries. The map has a scale for comparing the local time of observation with the standard 0000Z and 1200Z observations based on the local time on the Greenwich meridian.

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*The World Meteorological Organization has specified that a climatological standard normal is the mean value for a period of 30 years, e.g., 1931-60 (Landsberg, 1962).

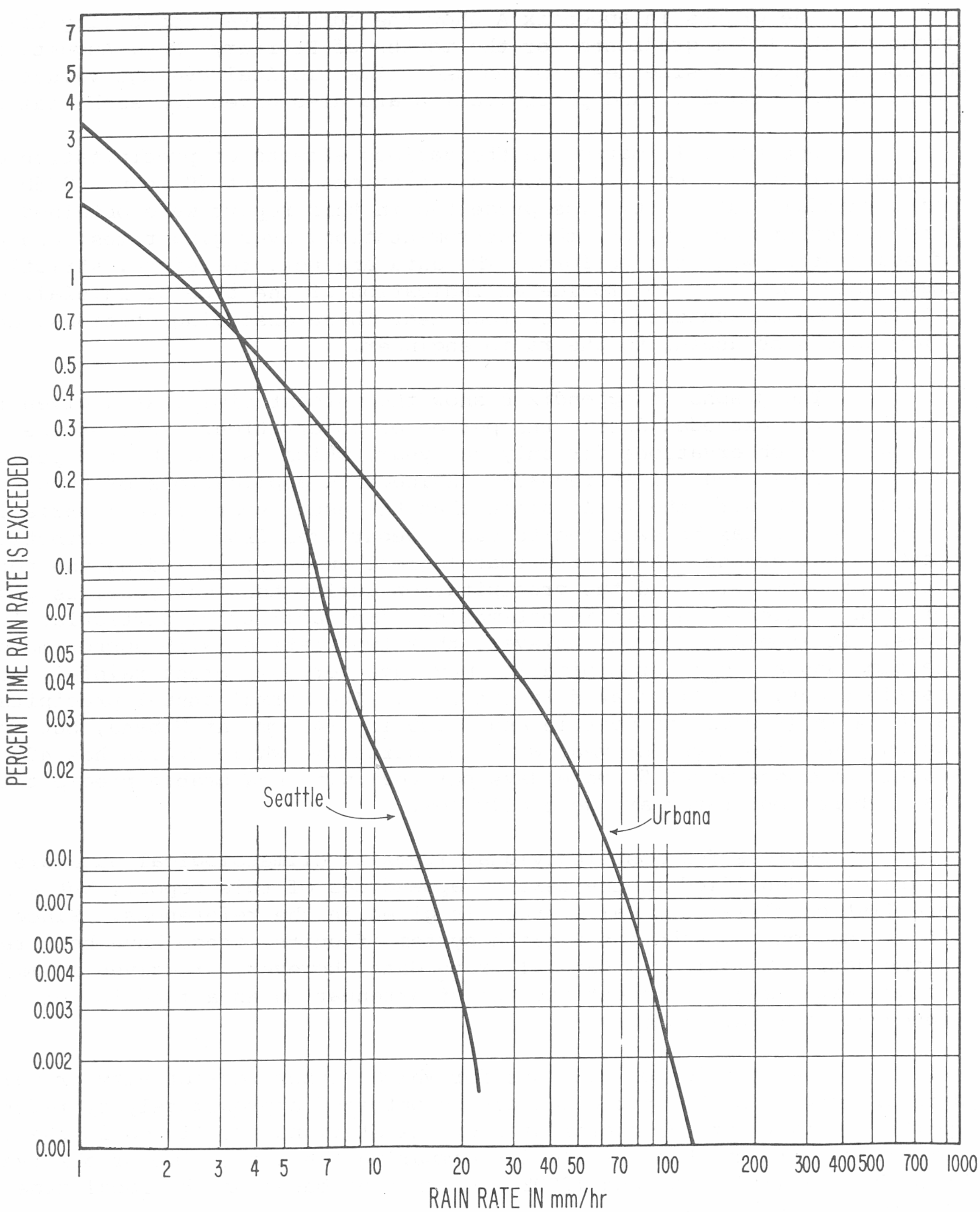

Figure 1. Rainfall rate distributions for Seattle, Washington, and Urbana, Illinois (based on Sims and Jones, 1973).

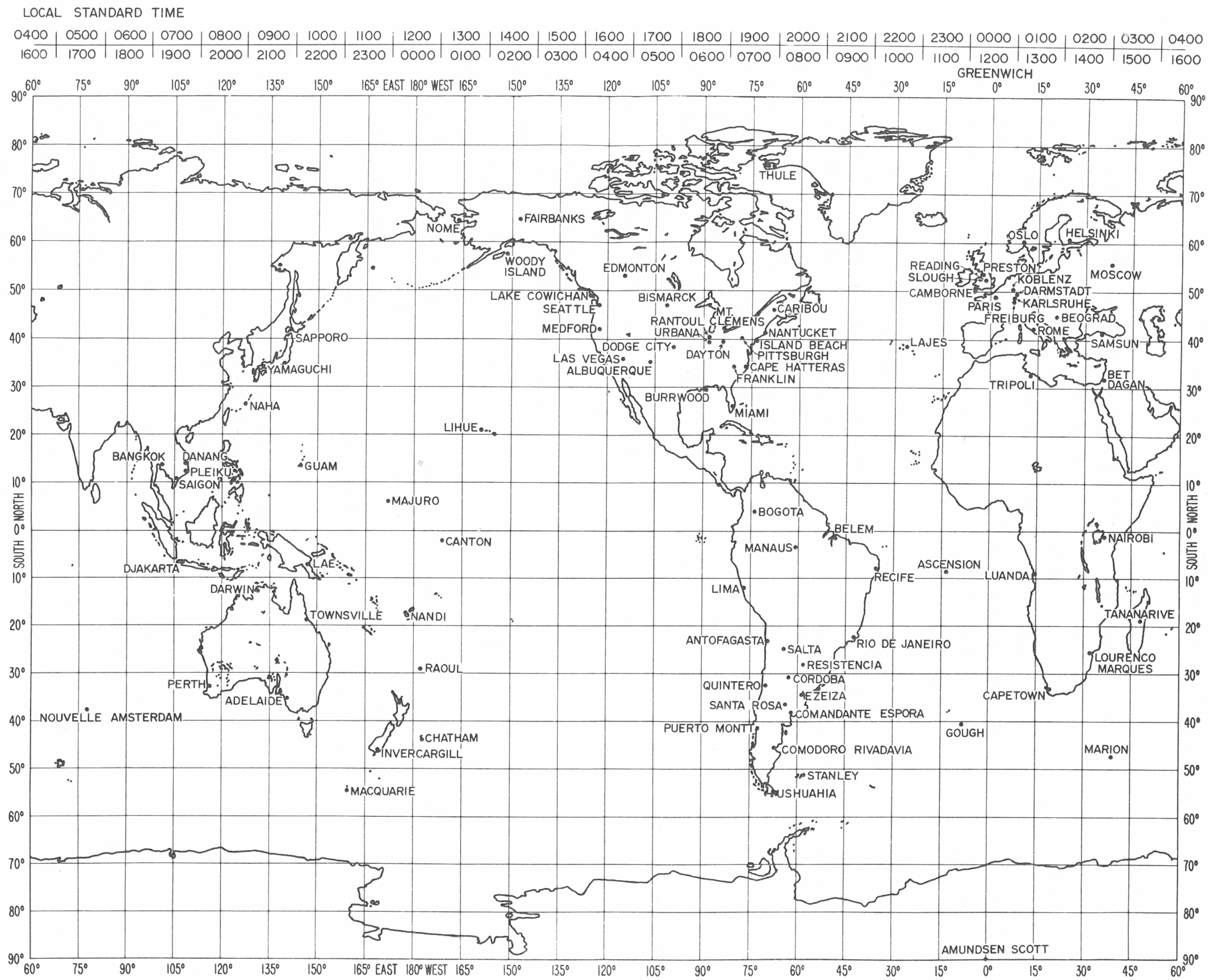

Figure 2. Location of stations for which refractivity or rainfall data are given in the appendices.