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An Analysis of Propagation Measurements Made at 418 Megacycles Per Second Well Beyond the Radio Horizon (a Digest)

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During an 18-month period in 1952 and 1953, transmission loss measurements at 418 megacycles were made over a 134-mile path between Cedar Rapids, Iowa, and Quincy, Illinois. Continuous recordings made simultaneously at several receiving antenna heights from 30 to 665 feet yielded information on diurnal and seasonal variations in both the hourly median basic transmission loss and in height gain. These data are compared to predictions made using the method developed by Rice, Longley, and Norton and are found to be in good agreement, particularly at the lower antenna heights. An analysis of the correlation of short-term signal level variations observed at horizontally and vertically spaced antennas is described.

1. Introduction

This is a digest of an NBS Technical Note [1] [1] which describes in considerable detail a series of transmission loss measurements made by the National Bureau of Standards at a frequency of 418 Mc over a 134-mile path extending from Cedar Rapids, Iowa, to Quincy, Ill.

The principal purpose of the measurements was to study: (1) The hourly, diurnal, and seasonal variations in basic transmission loss experienced in transmissions made well beyond the radio horizon; (2) the corresponding long-term variability of height-gain; (3) the comparison of measured transmission loss and height-gain with predicted values; and, (4) the correlation of instantaneous signal levels measured at vertically and horizontally spaced antennas. (A discussion of item 4 is given in ref [1] but will not be summarized here.)

The experiment covered a period of approximately a year and a half from January 1952 to May 1953. The transmitter was located at Cedar Rapids and was operated by the Collins Radio Co. under contract with the National Bureau of Standards. The receiving and recording equipment were installed and operated by NBS. Space on a 750-ft tower was obtained through the cooperation of WTAD–FM in Quincy, and the receiving antennas were mounted on this tower at heights ranging from 30 to 655 ft above ground. The transmitting antenna was 39 ft above ground.

The equipment was operated for 13 recording periods, each of approximately 2 to 3 weeks duration. During each period, continuous recordings of basic transmission loss were made simultaneously at 3 to 5 different antenna heights. Table 2 of reference [1] shows a schedule of the recording periods and the antenna heights used during each period. Also shown are the inclusive dates during which each antenna height was used and the total number of hours of data recorded at each height during a given period.

[1] Figures in brackets indicate the literature reference at the end of this paper.

The angular path distance [2] ranged from 20.3 to 15.7 milliradians for the 30- and 665-ft receiving antenna heights, respectively. Insofar as the long-term median basic transmission loss measured over paths having angular distances of this order (i.e., greater than about 10 milliradians) agree quite well with values predicted from scatter theory [2], this might be considered to be a tropospheric scatter propagation path. However, analysis of the short-term variations in signal level reveals that for significant percentages of the time (especially during the night), mechanisms other than scattering appear to be important. It would seem that this path is in a transitional region between the shorter paths where processes such as diffraction and ducting may provide most of the signal power and longer paths where scattering is the principal contributor.

2. Description of the Data

The data output of this experiment was reduced to hourly distributions of instantaneous signal levels obtained from time totalizing recorders or, in some instances, from paper chart recordings. The hourly median basic transmission loss, L_{bm}, and the fading range (ratio, in decibels, of levels exceeded 10% and 90% of the hour) were read from these distributions. A complete tabulation of all hourly L_{bm} values and fading ranges is given in reference [1]. Also given there are graphs of individual hourly L_{bm} values plotted versus time of day for each antenna height and each recording period. These graphs illustrate the fact that the range of the variations in L_{bm} measured at the same hour for 15 or 20 consecutive days is, in general, of the same order of magnitude as the range of the diurnal trend as shown by the median of hourly L_{bm} values.

Although the hourly fading ranges listed in reference [1] show considerable variance, they consistently cluster in the vicinity of the 13.4-db fading range that would be obtained from a pure Rayleigh distributed signal. This tendency is apparent regardless of time of day, although the variance of fading ranges measured at a given hour is somewhat larger

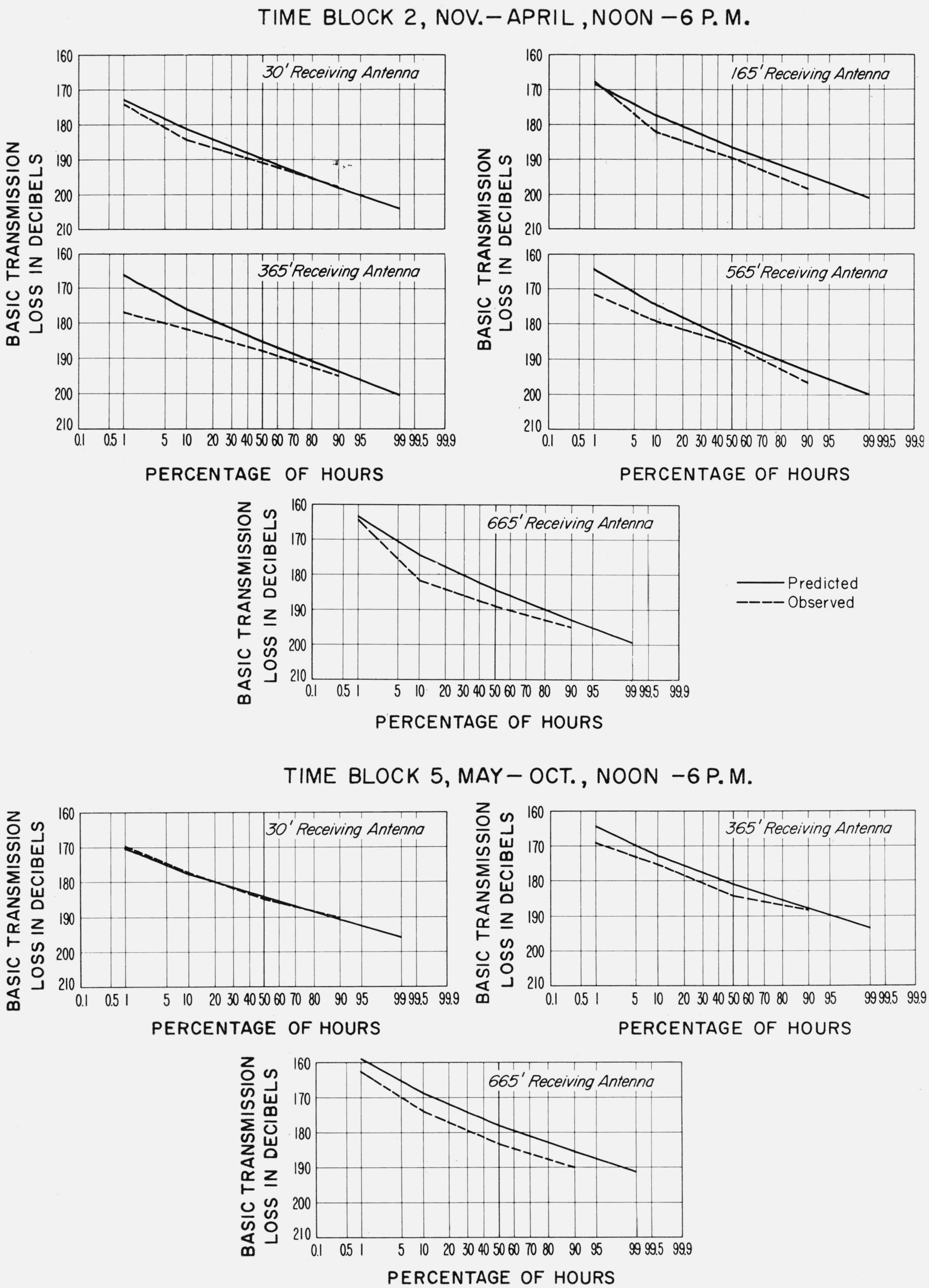

FIGURE 1. *Observed and predicted cumulative distributions of hourly median basic transmission loss (1952 and 1953 data).*

during the night than during the day, particularly in the summer months. The lack of diurnal cycle in fading range and the tendency to approximate the Rayleigh distribution fading range should not, however, be interpreted as evidence that the signals recorded at Quincy were the result of scattering regardless of the time of day. It can be seen in the data samples shown in the technical note that the character of short-term variations in signal level changes considerably in going from afternoon to night. The slow, deep fading occurring at night often covered a range equal to, or greater than, the Rayleigh fading range.

One of the principal objectives of the Quincy experiment was to study the effects of antenna height on the signals received far below the radio horizon. During most of the recording periods simultaneous transmission loss recordings were made at three or more receiving antenna heights. We define the height-gain associated with two antenna heights to be the difference between hourly median L_b values measured simultaneously at these two heights. A positive height-gain indicates a reduction in L_{bm} with increasing height. The hourly height-gain values obtained for each pair of antennas during each recording period were plotted versus time of day. It was found that although the median of hourly L_{bm} values tended to decrease slowly with height, there was a large variance in the height-gain observed on any one pair of antennas at a given hour of the day during a given recording period. Examples of these height-gain versus time-of-day plots are shown in reference [1]. Also included are graphs showing the median of the hourly height-gain values for each recording period plotted versus the ratio of receiving antenna heights, and the median basic transmission loss, fading range, and height-gain versus time of year.

3. Comparison of Observed and Predicted Basic Transmission Loss

Rice, Longley, and Norton [3] have developed a method of predicting the cumulative distribution of basic transmission loss at frequencies above 10 Mc for wide ranges of path lengths, antenna heights, terrain configurations, and atmospheric refractive index gradients (the latter as deduced from observed surface values of refractivity). Using this method, the predicted cumulative distributions of basic transmission loss were determined for the 30, 165, 365, 565, and 665-ft receiving antenna heights for time block two (November through April, from noon to 6 p.m.) and for the 30, 365, and 665-ft antenna heights for time block five (May through October from noon to 6 p.m.). These antenna heights were chosen because of the relatively large amount of observed data available for comparison. The surface refractivity data used in this determination were the average of values for these time blocks during 1952 and 1953 obtained at the U.S. Weather Bureau stations at Des Moines, Iowa, and Joliet, Ill. These stations lie west and east of the propagation path, respectively. However, the data obtained at these two points are so well correlated that we may reasonably assume that they closely approximate conditions on the path.

The predicted distributions are shown in figure 1 along with the corresponding distributions of observed values. The latter include all hourly medians observed during the time block in both 1952 and 1953. Figure 2 provides a comparison of the observed height-gain data with the corresponding predicted values. A predicted value is shown at each ratio of antenna heights; the observed value for each ratio is simply the mean of the median height gain values for all recording periods. On the assumption that the observed decibel values of height-gain are normally distributed, there is a 68 percent probability that the true mean lies within the "wings" on the observed points. The fact that the predicted values are all above the measured values (and, indeed, lie outside the wings in most cases) indicates a consistent bias in the prediction which is larger at the higher ratios, i.e., those involving the 30-ft antennas.

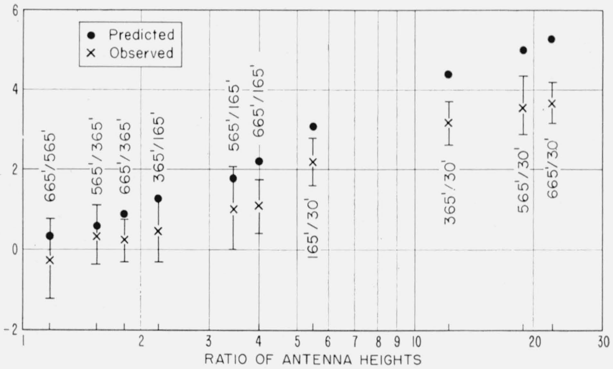

FIGURE 2. *Predicted and observed height-gain versus ratio of antenna heights for all hours 1952 and 1953.*

The experiment described here was performed under the supervision of J. W. Herbstreit. The surface refractivity data were supplied by B. R. Bean. Much of the reduction of the radio data was done by F. L. Anderson. K. A. Norton and P. L. Rice offered many valuable suggestions concerning the analysis.

4. References

[1] H. B. Janes, J. C. Stroud, and M. T. Decker, An analysis of propagation measurements made at 418 Mc well beyond the radio horizon, NBS Technical Note 6, (PB 151365) $2.25, available from the Office of Technical Services, U.S. Department of Commerce, Washington D.C. Foreign remittances must be in U.S. exchange and must include one-fourth of the publication price to cover mailing costs.

[2] K. A. Norton, P. L. Rice and L. E. Vogler, The use of angular distance in estimating transmission loss and fading range for propagation through a turbulent atmosphere over irregular terrain, Proc. IRE **43,** 10, 1488, (1955).

[3] P. L. Rice, A. G. Longley, and K. A. Norton, Prediction of the cumulative distribution with time of ground wave and tropospheric wave transmission loss, NBS Tech. Note 15 (PB151374) $1.50, available from the Office of Technical Services, U.S. Department of Commerce, Washington, D.C. Foreign remittances must be in U.S. exchange and must include one-fourth of the publication price to cover mailing costs.

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