the predicted values. Measurements at 101.5 MHz and a distance of 80 km are not shown in figure 24 but agree with predictions as well as those shown at 50 km.

2.5.2 Colorado Mountains

About 46 of the measurement paths in Colorado extended from the transmitter site on the plains into the mountains and were classed as mountain paths. Of these paths 6, 10, 14, and 16 were at nominal distances of 10, 20, 30, and 50 km, respectively. A median value of the terrain parameter $\Delta h = 650$ m was used to characterize the terrain. Values of Δh calculated from profiles of these paths range from 260 to 1750 m. The frequencies and antenna heights are the same as those for the Colorado plains.

Figures 25 and 26 show the median and interdecile range of basic transmission loss derived from measurements at nominal distances of 10, 20, 30, and 50 km, and a curve of predicted values as a function of distance assuming randomly selected sites. Figure 25 shows predicted and measured values at 20 and 50 MHz, while figure 26 shows values at 100 MHz for receiver heights of 3, 6, and 9 m. These two figures show a wide range of measured values at each distance and frequency but a reasonably good agreement of their medians with predicted values. The wide range of measured values probably results in part from the wide range in terrain irregularity, and in part from the fact that sites were randomly selected, without regard for good propagation conditions.

2.5.3 Northeastern Ohio

Measurements in northeastern Ohio were made with one central and five peripheral transmitting locations. The receivers were located on concentric rings about the central transmitter at nominal distances

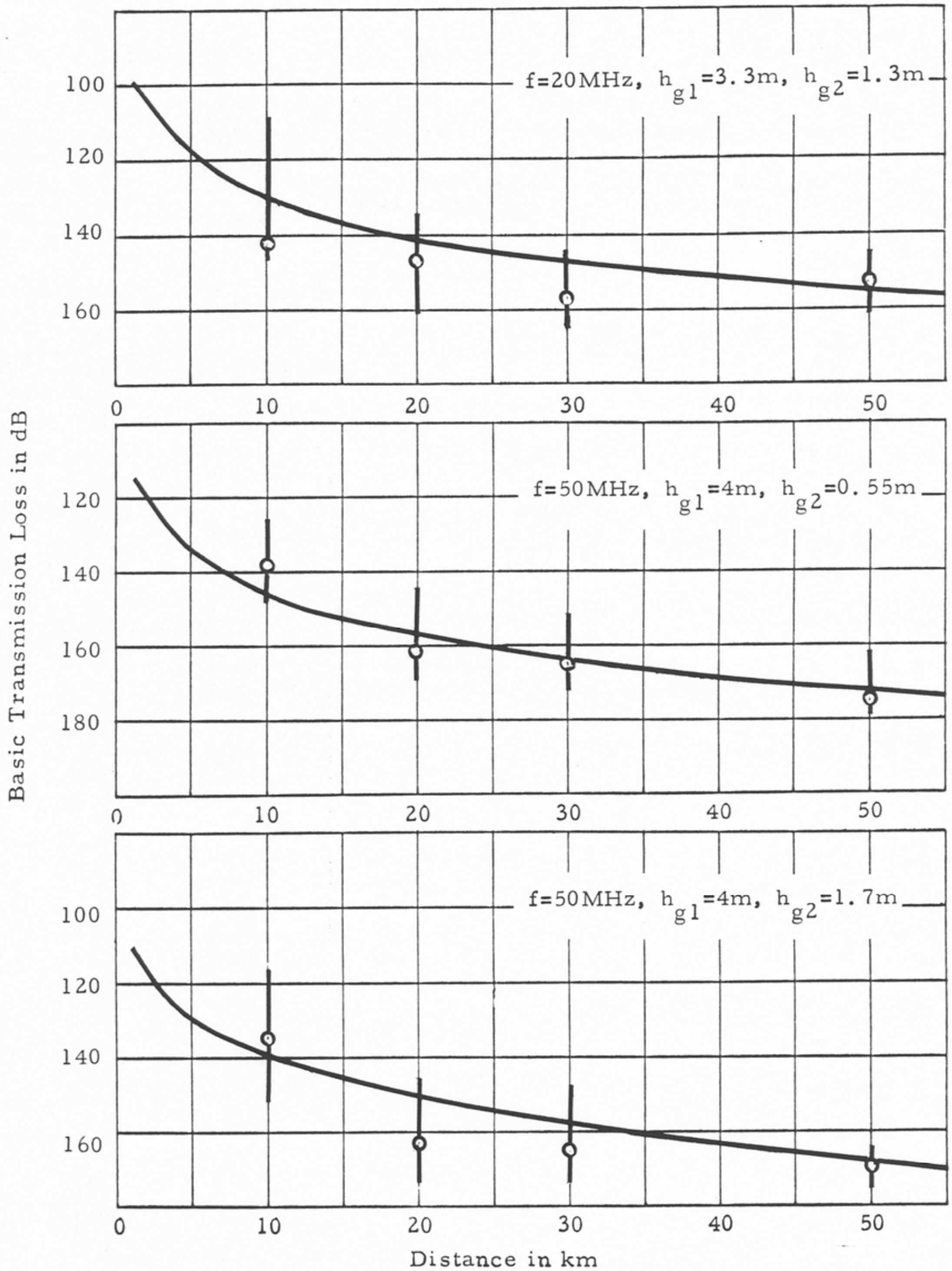

Figure 25. Basic transmission loss, Colorado mountains, Δh=650m, f=20 and 50MHz, showing median and interdecile range of values at each nominal distance.

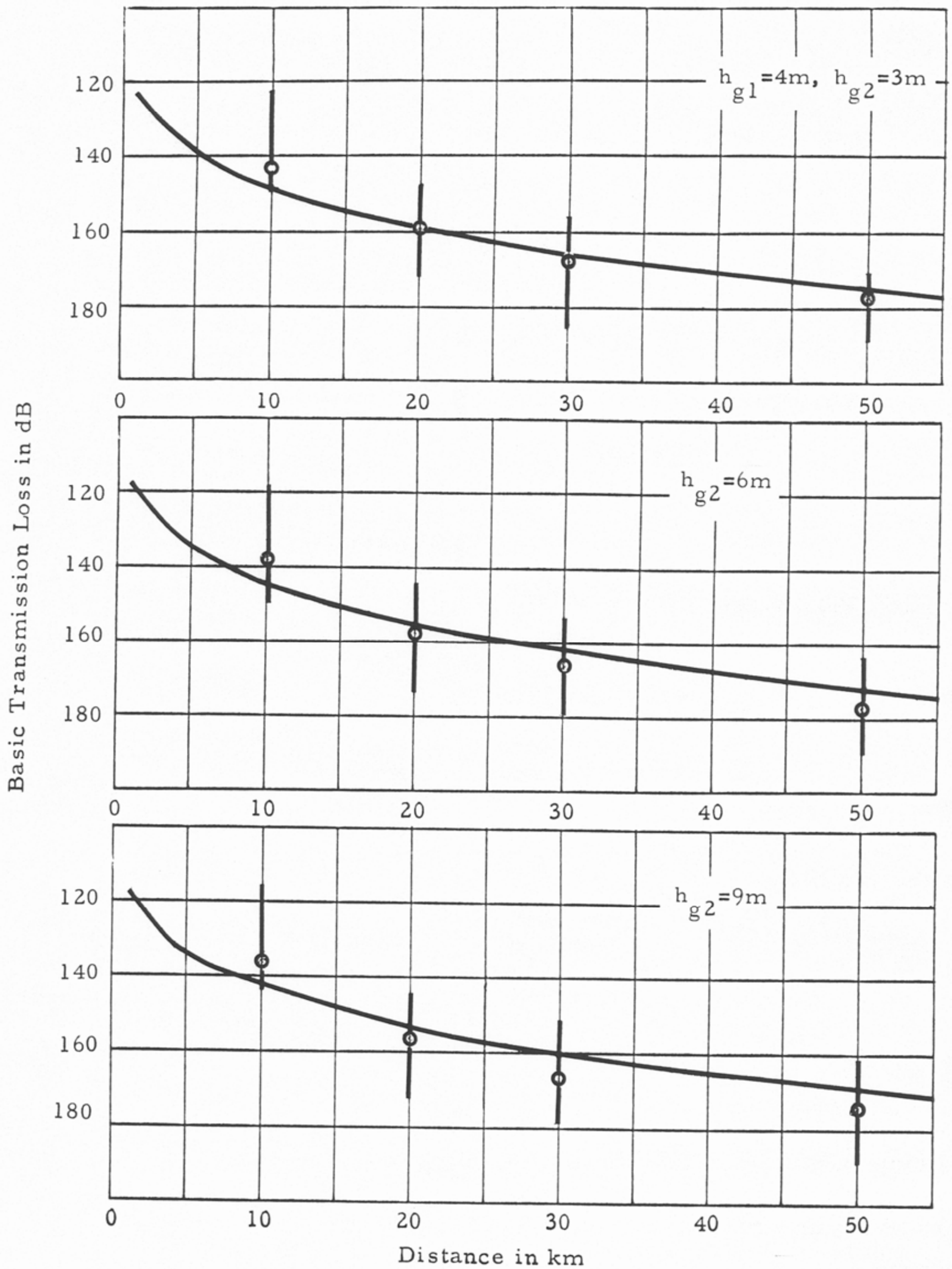

Figure 26. Basic transmission loss, Colorado mountains, Δh=650m, f=101, 5MHz, showing median and interdecile range of values at each nominal distance.

of 3, 5, 10, 20, 30, and 50 km. The transmitting antenna heights were 3. 3 m at 20 MHz and 4 m at 40 and 100 MHz. At 20 MHz the receiving antenna height was 1. 3 m, at 50 MHz heights of 0. 55 and 1. 7 m were used, and at 100 MHz heights of 3, 6, and 9 m were used. With six different transmitter locations and a large number of receiving locations at each distance, these measurements should closely simulate a situation with randomly selected sites.

In this report we consider data from all transmitters, providing a total of about 255 paths. Of these, 45, 51, 67, and 92 are at nominal distances of 10, 20, 30, and 50 km, respectively, from the transmitter. Terrain profiles for all measurement paths were used to determine a median value of the terrain parameter $\Delta h = 90$ m. Values from individual paths ranged from 20 to 270 m.

Figures 27 and 28 show the medians and interdecile ranges of measured values at each nominal distance, with curves showing predicted basic transmission loss as a function of distance. In all cases, good agreement with medians of the data is noted with a rather wide range of data at each distance. The downward arrows at the longer distances indicate that several values were in the noise so the 90 percent level could not be determined. The improvement obtained by selecting the best receiving site within a 100 m radius of the principal site is shown in figure 29. The only difference between the data in figures 28 and 29 is the choice of receiving sites. Some improvement is noted at all distances and receiver heights but particularly with the lowest height and at the longer distances. On figure 29 two prediction curves are drawn for each set of data. The lower curve is for randomly selected sites with the effective heights equal to the structural heights $h_{e1,2} = h_{g1,2}$. The upper curve is calculated assuming that the receiving antennas are at carefully selected sites, $h_{e2} = 7$, 10. 4, and 13. 1 m.

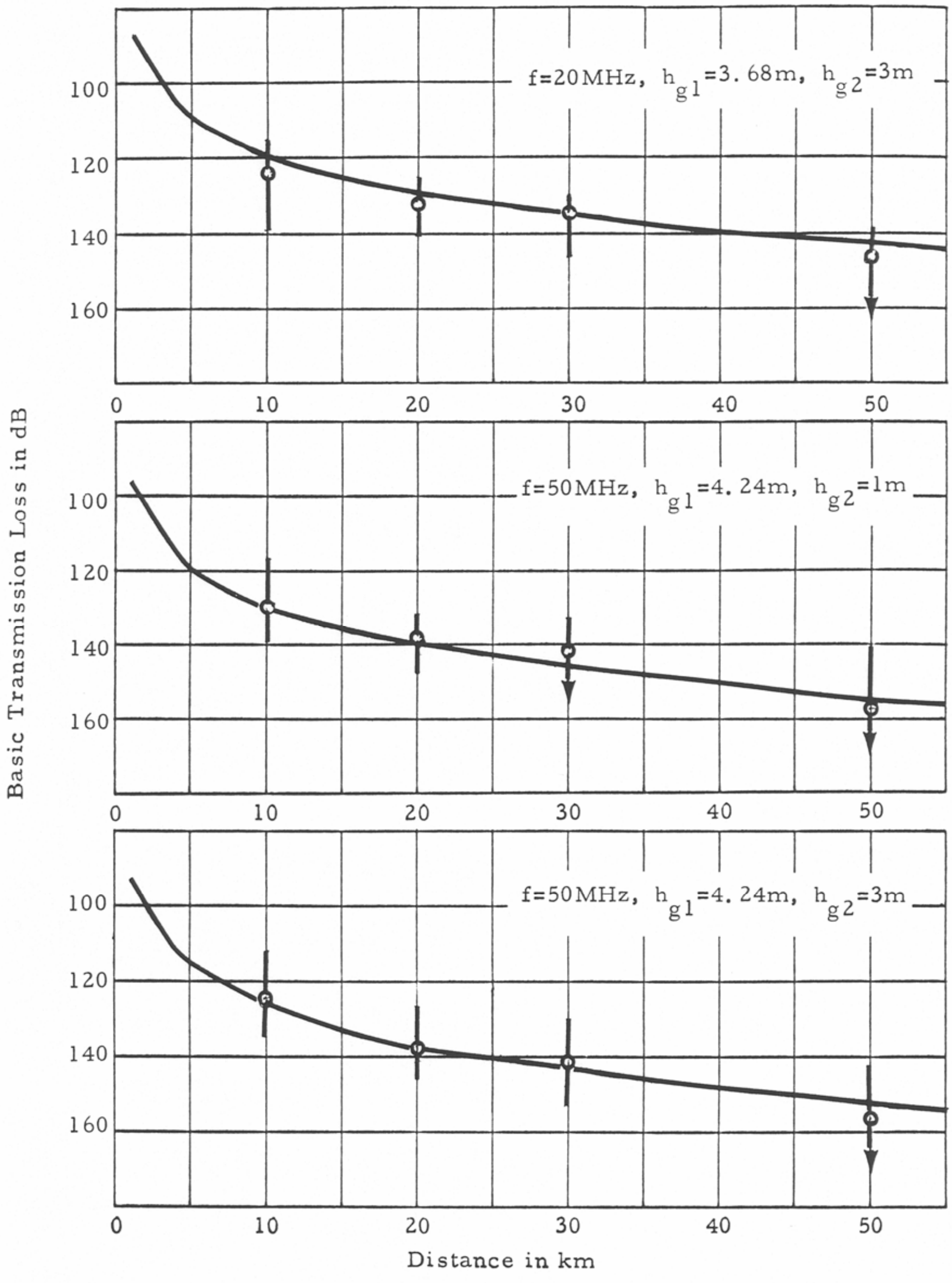

Figure 27. Basic transmission loss, Ohio, Δh=90m, f=20 and 50MHz, showing median and interdecile range of values at each nominal distance.

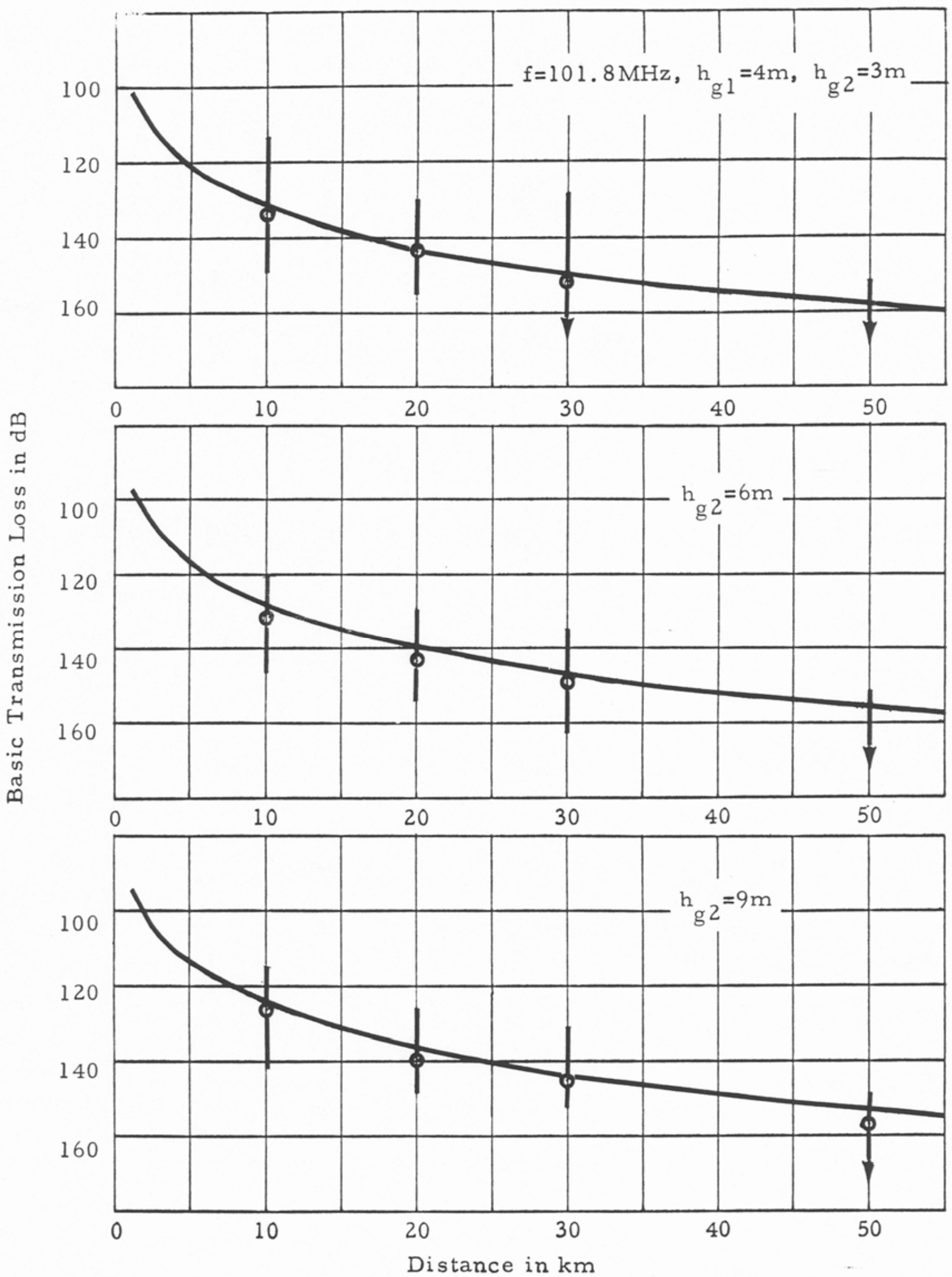

Figure 28. Basic transmission loss, Ohio, Δh=90m, f=101.8MHz, showing median and interdecile range of values at each nominal distance.

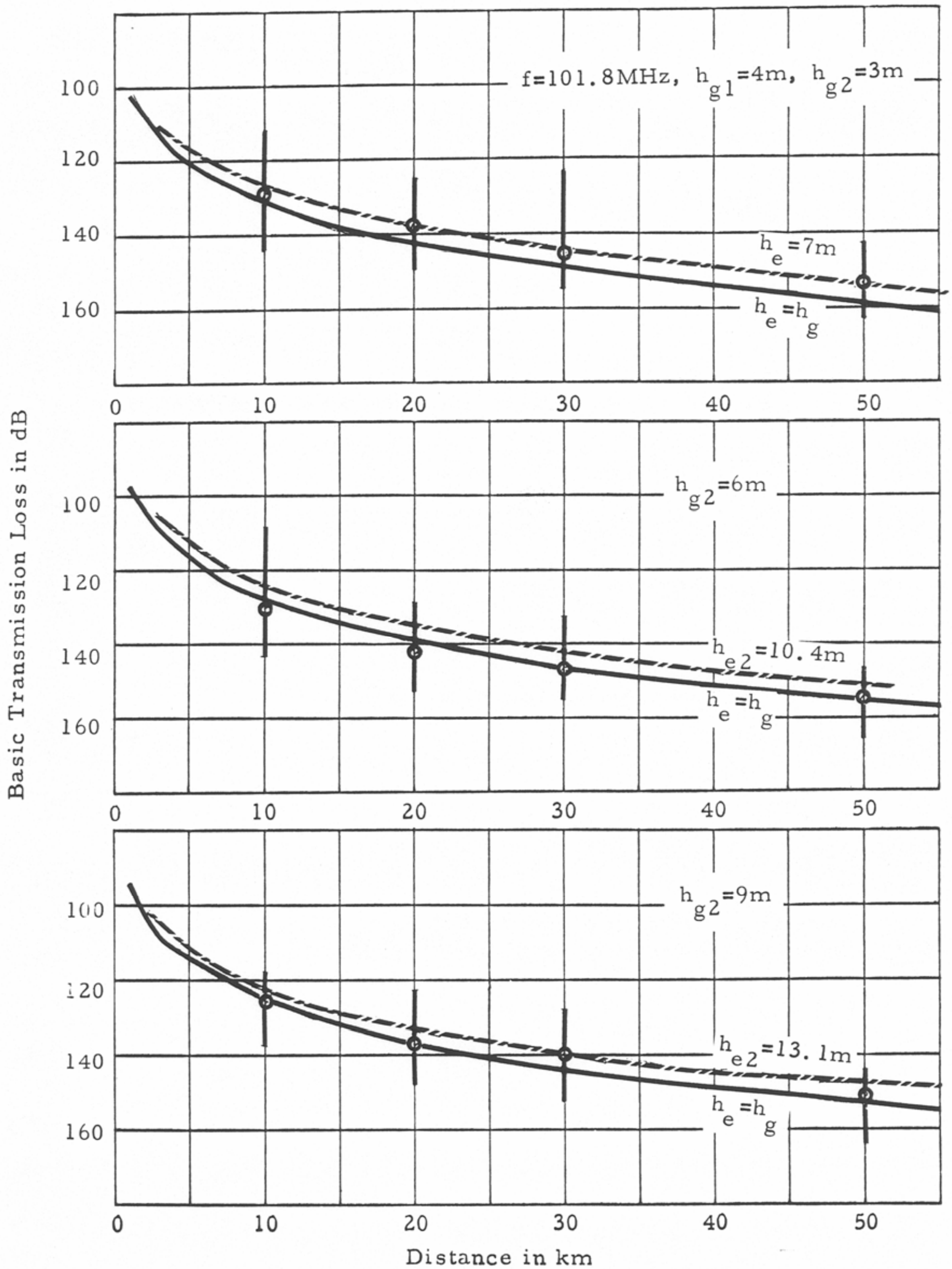

Figure 29. Basic transmission loss, Ohio, Δh=90m, f=101.8MHz, using alternate receiving locations, vertical polarization.

The observed improvement is slightly less than that predicted for carefully selected sites. This is to be expected as the improvement in each case is only at the receiving site.

2.6 Summary of Area Predictions

Area predictions of basic transmission loss as a function of distance are based upon an estimate of terrain irregularity in the area and the way in which antenna sites are selected. Such predictions depend upon median propagation conditions, where path parameters that are representative of median terrain characteristics are calculated from the terrain parameter Δh and the structural antenna heights, with estimates of effective antenna heights depending upon the rules followed in site selection. If the terrain in an area is homogeneous so that values of Δh calculated for individual paths do not diverge widely from the median value and antennas are all either advantageously or poorly situated, the scatter of data about the median will be minimized. In nonhomogeneous terrain a wide scatter of measured values may occur. In some groups of measurements a range of 60 dB, or more, between the highest and lowest values recorded over paths of the same length is observed. Most of this scatter of data results from differences in individual path profiles and in the way sites are selected. Some of the scatter may also result from the fact that these are single "spot" measurements. For the few paths where measurements were repeated on two or more different days the measured losses differed by as much as 15 to 20 dB over a single path.

Such path-to-path differences may be taken into account by an allowance for path-to-path or location variability. For many applications, the variability introduced by high values of field strength over unusually favorable transmission paths is much less important than that resulting from unusually poor propagation conditions. In such cases, care should be exercised to select sites with a clear foreground, and no nearby obstacle in the direction of the other antenna. With low antennas over irregular terrain the improvement resulting from care in site selection may be highly significant, as shown by the differences in measurements over rugged terrain in Washington and Wyoming. In Washington the majority of the sites were unusually well chosen for good propagation conditions, while in Wyoming many paths were partially obstructed by objects in the near foreground.

The prediction method used to calculate median basic transmission loss as a function of distance was originally developed and tested against the measurements at VHF made in Colorado and Ohio. The present comparisons show that this computer method, described by Longley and Rice (1968) applicable throughout the frequency range from 20 to 10,000 MHz over terrain types ranging from smooth plains to rugged mountains and for antennas less than a meter above ground. The maximum antenna heights tested in this series are 15 m, but other tests have shown that the methods may be used up to heights applicable for air-to-ground communication and to distances much greater than any used in the various measurement programs described in this section.

3. POINT-TO-POINT PREDICTIONS COMPARED WITH MEASUREMENTS

For all the measurement paths discussed in section 2 and for a large number of established communication links, detailed terrain profiles were read from topographic maps. For each path the following parameters were calculated using methods described by Longley and Rice (1968) and by Rice et al. (1967):

a an effective earth's radius in km, calculated as a function of the minimum monthly mean value of the refractive index of the atmosphere at the surface of the earth,