and three 5-km paths have more than one horizon. The 20-km paths are over highly irregular terrain, and six of them are transhorizon paths. Ten of the longer paths are typical knife-edge diffraction paths and show the expected low values of transmission loss.

Even though the measurements in this group were not all made over rugged mountainous terrain, they show clearly the improvement in propagation that can be gained by careful site selection. At the higher frequencies measurements at 20 km and beyond were successful only over the line-of-sight and knife-edge diffraction paths, the other values of transmission loss exceeding the maximum measurable value.

Because of the unusually advantageous siting, and the non-homogeneous terrain, the area predictions with Δh = 650 m tend to overestimate the transmission loss, especially for the lower receiver height. Point-to-point predictions were also calculated for each individual path and are discussed in the next section.

Some measurements at all frequencies were made with the transmitter at "concealed" sites, for paths 2.9, 4.7, 11.2, 20.0, and 52.1 km long. In this small sample the results are not completely consistent, but in general they show increases in transmission loss of 10 to 20 dB for the concealed sites over the shorter paths. The results for the longer paths are inconclusive because in about half the cases the signal was "in the noise".

2.3 Virginia Paths

Measurements in Virginia were performed by the General Electric Company under contract to the Institute for Telecommunication Sciences (ITS). The results of these measurements have not yet been completely analyzed, so no detailed descriptive report is available. Some of the data are included in the previously referenced report by

Barsis, Johnson, and Miles (1969). These measurements were made with seven common transmitter sites, and with receiving locations arranged in roughly concentric circles about them at nominal distances of 0.5, 3, 5, 10, 20, 50, 80, and 120 km. In this area the terrain is rolling, hilly, and partly covered by deciduous trees.

Terrain profiles have been read from topographic maps for only about one-sixth of these paths. A median value of the terrain parameter, Δh = 85 m, was obtained for these 51 paths, most of which are rather short, but a few longer ones are included.

Figures 11, 12, and 13 show predicted values of basic transmission loss as a function of distance compared with measured values for frequencies of 76, 173, 409, 950, 2180, and 8395 MHz. The prediction is for structural heights of 12 m and randomly selected sites. The measurements were made with antenna heights of 11.3 and 15.0 m for the transmitters and 12.1 and 15.0 m for the receivers. These 51 paths include data from four of the seven transmitter sites. The plots indicate that the area prediction, based on randomly selected sites, tends to overestimate the transmission loss at the two lower frequencies, describes the medians of the data at 409 MHz and tends to underestimate the losses at the higher frequencies. This may result from surface clutter in the form of deciduous trees in full leaf that would cause considerably more attenuation at the higher than at the lower frequencies. This possibility will be further investigated when more of the path profiles are available.

Because of current interest in the use of very low antennas, a group of measurements was made with the receiving antenna 2 m above the surface of the ground. For these 95 paths the transmitting antennas were 11.3 and 15.0 m above ground. Figure 14 shows predicted values of basic transmission loss compared with measured

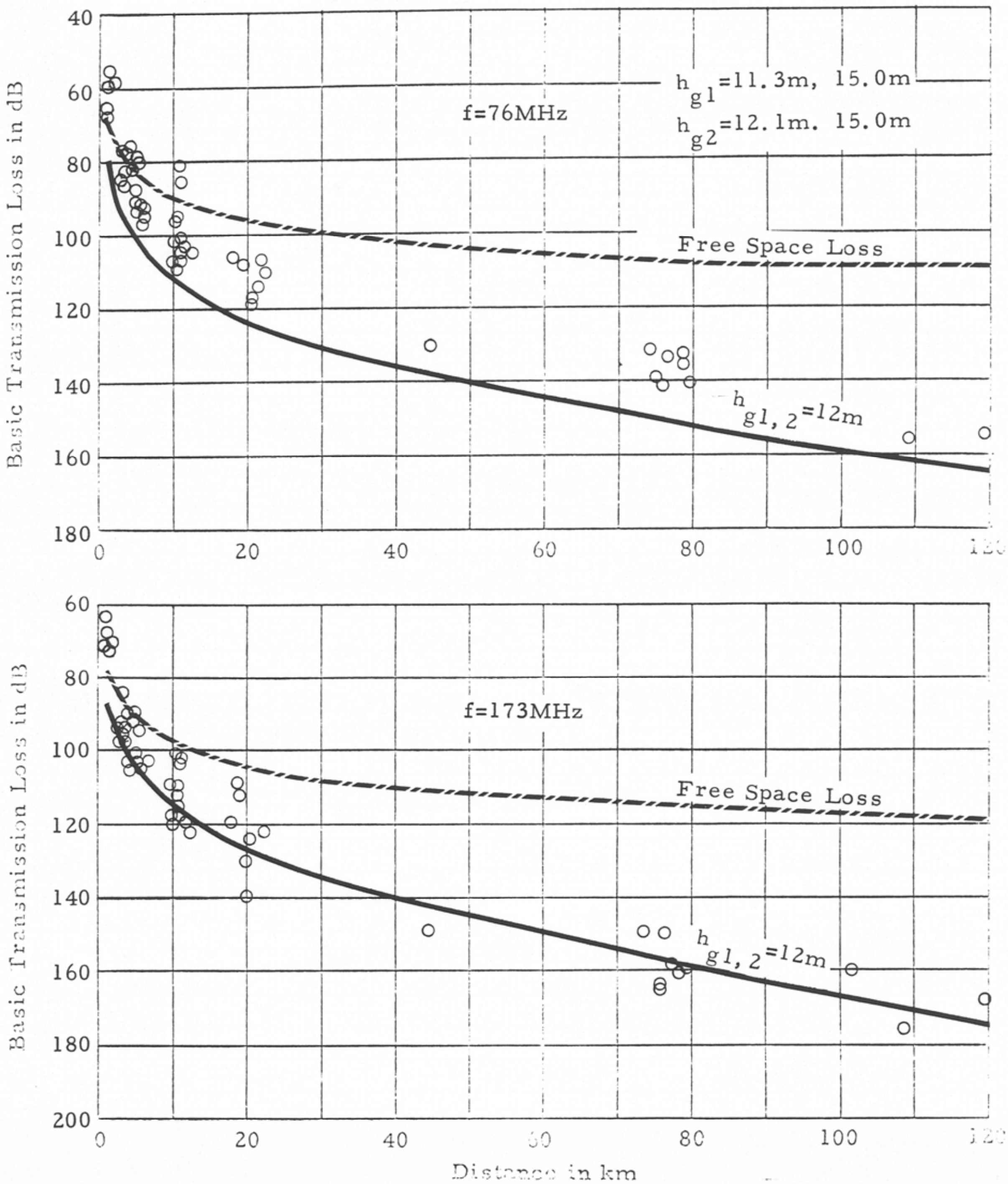

Figure 11. Basic transmission loss, measured and predicted, 51 paths in Virginia, Δh=85m, f=76 and 173MHz.

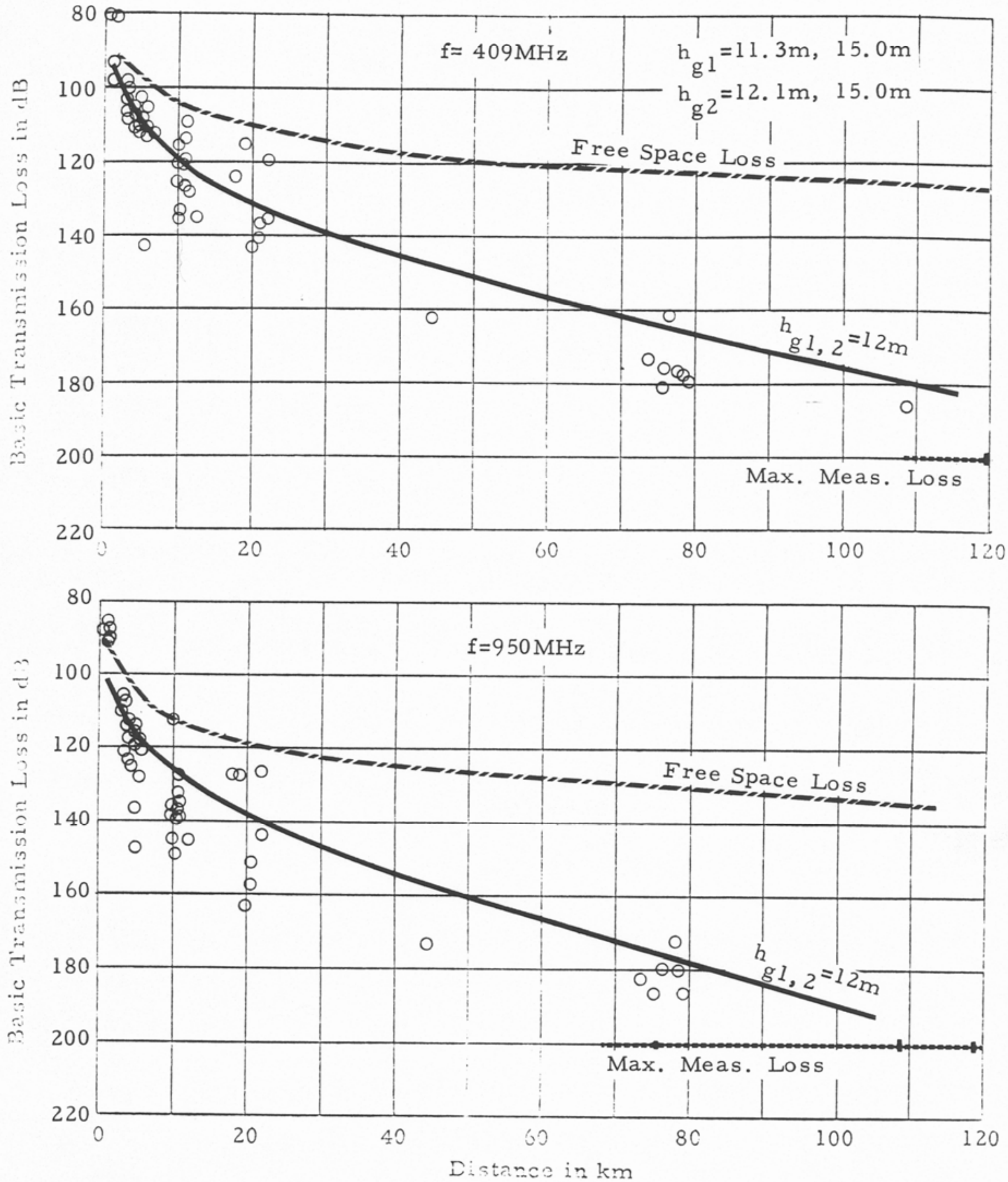

Figure 12. Basic transmission loss, measured and predicted, 51 paths in Virginia, Δh=85m, f=409 and 950MHz.

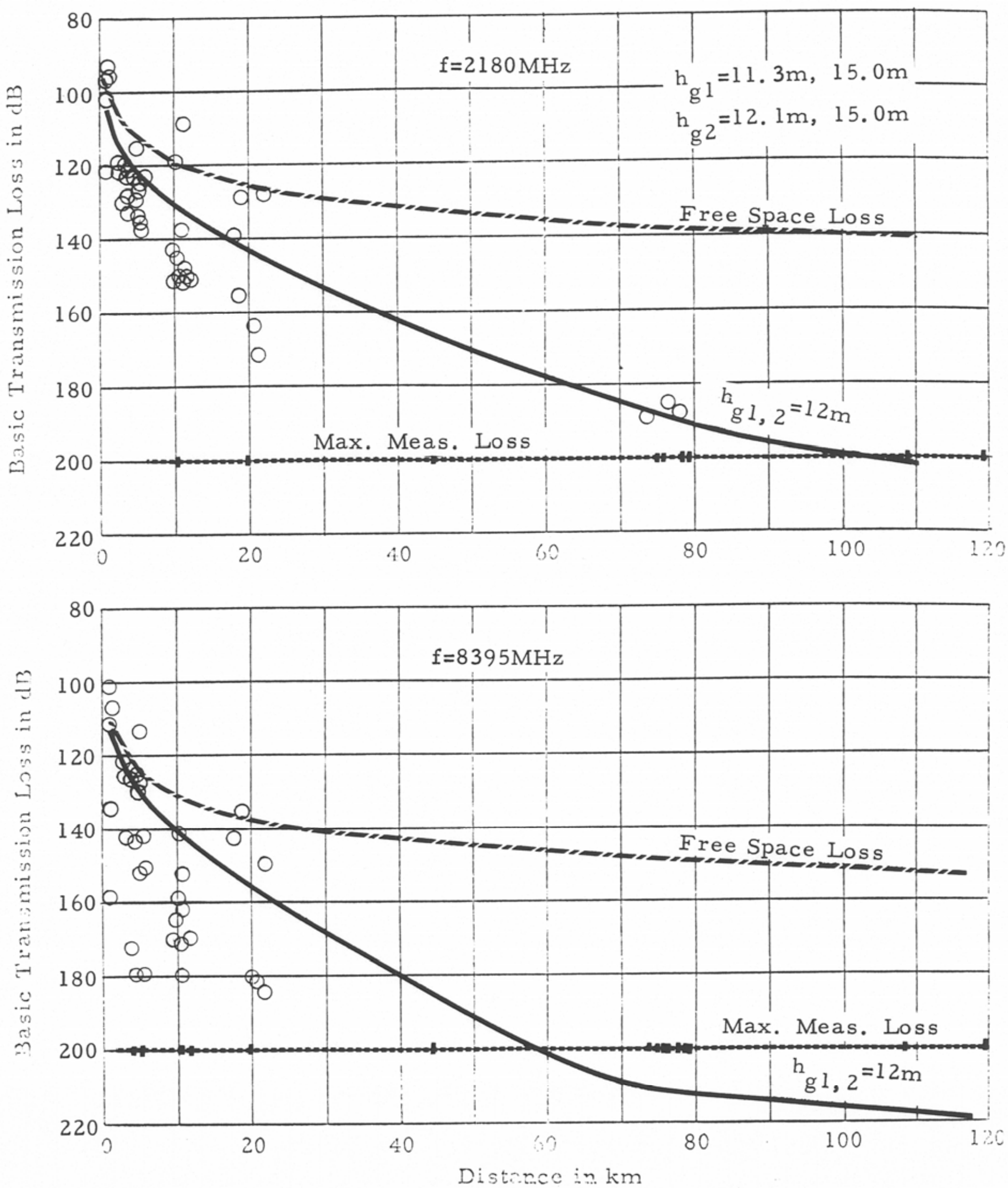

Figure 13. Basic transmission loss, measured and predicted, 51 paths in Virginia, Δh=85m, f=2180 and 8395MHz.

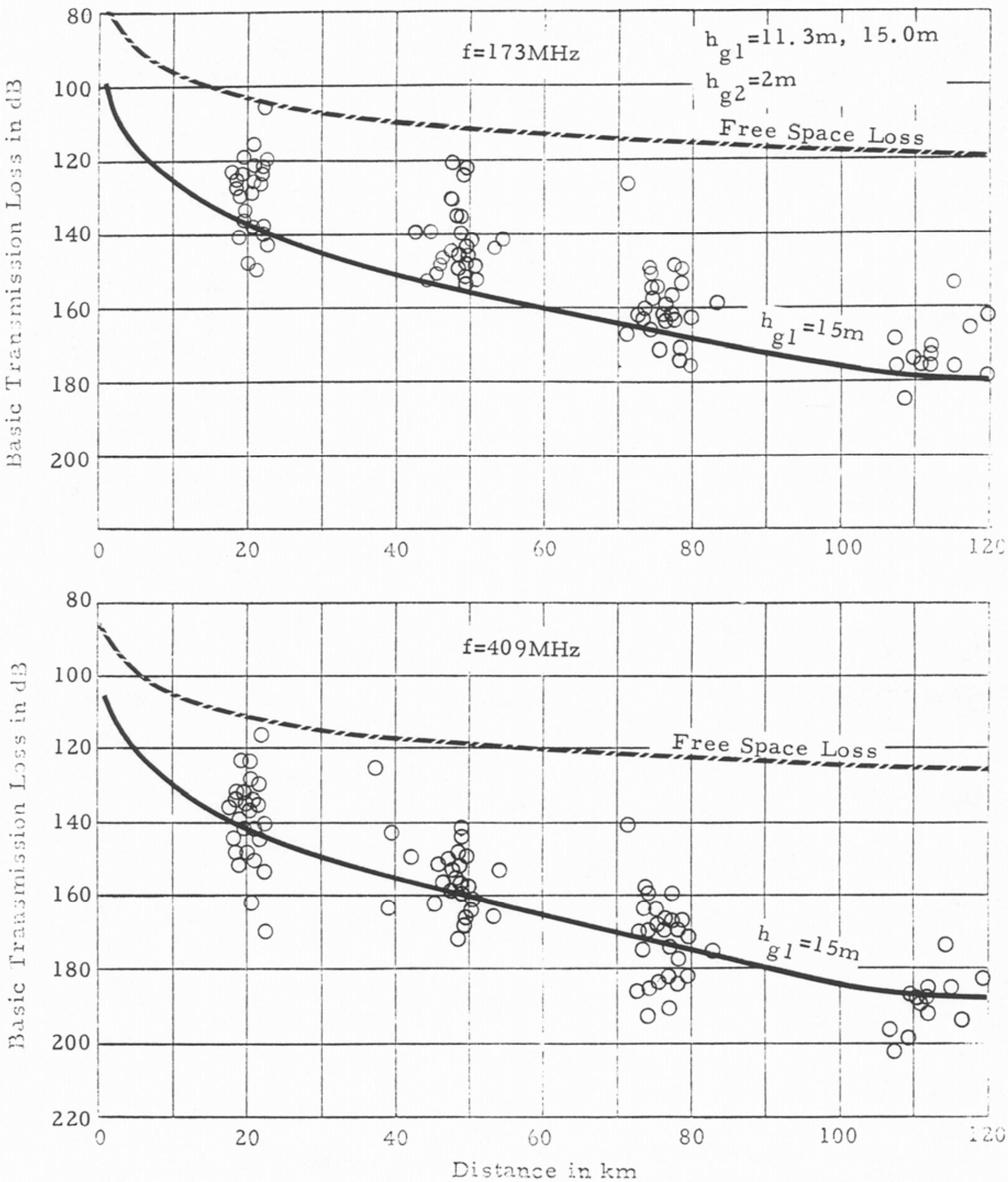

Figure 14. Basic transmission loss, measured and predicted, Virginia, all paths with hg_2=2m, f=173 and 409MHz.

values at frequencies of 173 and 409 MHz. The predictions were calculated assuming antenna heights of 15 m and 2 m, with randomly selected antenna sites. The data are from all seven transmitting locations. These plots show that the area prediction tends to overestimate the transmission loss at 173 MHz but describes the median loss as a function of distance at 409 MHz. No plots are shown for the higher frequencies with this low receiver height because a large proportion of the attempted measurements were in the noise, showing greater losses than the maximum measurable values. A significant feature in this area is that the path-to-path or location variability is considerably less than that observed in either the R-1 or R-2 data. This probably indicates more homogeneous terrain with fewer unusually good or bad propagation paths.

Point-to-point predictions for the paths where terrain profiles are available are discussed in section 3. Further comparison of these data with predictions will be deferred until path parameters are available for more of these measurements.

2.4 Wyoming, Idaho, and Washington Paths

The measurement program conducted in Wyoming, Idaho, and Washington was limited to two frequencies, 230 and 416 MHz, and to very low antenna heights, from 0.75 to 3 m above ground. Both the transmitting and receiving units were mobile. The transmitting antennas for both frequencies were fixed at heights of 0.75 and 3 m above ground, while the receiving antennas were raised continuously from 0.75 to 3 m. Details of these measurements and the equipment used are described by Hause, Kimmett, and Harman (1969).

This series of measurements differs from those previously described in that no attempt was made to choose sites that would provide good propagation conditions. With such low antennas the selection of sites in road cuts or behind large rocks may cause a partial obstruction that is not recorded on detailed topographic maps. In this series few common transmitter or receiver sites were chosen, and those for only a limited number of paths.

Point-to-point predictions were calculated for specific measurement paths in each of the three areas and will be discussed in section 3.

2.4.1 Wyoming Paths

Measurements were made over 47 paths between 25 sites in the Laramie range area, Wyoming. The terrain is irregular and barren with low sparse ground cover, mostly prairie grasses. Detailed topographic maps were used to obtain more than 100 path profiles in the measurement area. The statistics from these profiles show a median value, $\Delta h = 120$ m, of the parameter used to characterize terrain irregularity.

Transmission loss values as a function of distance were calculated for equal antenna heights of 0.75 and 3 m at frequencies of 230 and 416 MHz. Figures 15 and 16 show measured and predicted values of basic transmission loss plotted as a function of distance. For each set of data two prediction curves are drawn, one with the effective antenna heights assumed equal to the structural heights, the other with effective antenna heights calculated for selected sites. In all cases the prediction for randomly chosen sites, $h_e = h_g$, describes the medians of the data.

Photographs taken at each site along the path in the direction of the other antenna location show that several paths in this group were partially obstructed by small hills or large rocks that were not shown on the topographic maps. These are coded on the figures and show larger than average losses. An examination of the terrain profiles