antennas over irregular terrain the improved propagation conditions that can be achieved by careful site selection may be highly significant.

Because area predictions of basic transmission loss as a function of distance do not depend upon individual path profiles, they are particularly useful for military communication and surveillance, for mobile systems including ground-to-ground and air-to-ground communication, for broadcasting systems, and for calculating preliminary estimates of performance for system design.

When detailed profiles for individual paths are available, the parameters for each separate path are obtained from its profile and used in calculating the basic transmission loss. Such point-to-point predictions are particularly useful in the design and operation of systems with fixed antenna locations.

Both point-to-point and area predictions are compared with data from several measurement programs carried out in the United States. Point-to-point predictions are also compared with measurements recorded over a large number of established communication links in several countries. For convenience in handling, all measured values have been converted to basic transmission loss, defined as the system loss that would occur between loss-free isotropic antennas, free of polarization and multipath coupling losses.

2. AREA PREDICTIONS COMPARED WITH MEASUREMENTS

Measurements of transmission loss with low antennas over irregular terrain have been made in several areas in the United States including Colorado, Idaho, Ohio, Virginia, Washington, and Wyoming. These measurements cover a wide range of frequencies, from 20 to 9200 MHz, with structural heights ranging from less than a meter to 15 meters, in areas where the terrain characteristics range from smooth plains to rugged mountains. Some of the geographic areas, frequencies, and the number of paths in each area are described by Barsis, Johnson, and Miles (1969).

Measurements made in Colorado in the frequency range from 230 to 9200 MHz, with support from the U. S. Army Electronics Command and the U. S. Army Security Agency, are divided into four groups, each group having a common receiving location. The Gunbarrel Hill and Fritz Peak data (R-1 and R-2) are compared with predictions in this report. The data recorded near Golden and southeast of Longmont, Colorado, (R-3 and R-4) have not been completely analyzed and are therefore not included. Only a partial analysis of the measurements in Virginia has been made, but currently available data are considered. Comparisons are made with measurements in Wyoming, Idaho, and Washington that were sponsored by the U. S. Air Force Space and Missile Systems Organization and with earlier measurements in Colorado and Ohio sponsored by the U. S. Army Electronics Command.

Within each area median reference values of basic transmission loss were calculated as a function of distance for each radio frequency and antenna height combination, using an estimate of the terrain irregularity. Comparisons of these area predictions with measured values are discussed.

2.1 Gunbarrel Hill, Coloradc (R-1)

Propagation experiments in the 230 to 9200 MHz range conducted over irregular terrain in Colorado are reported by McQuate, Harman, and Barsis (1968). The data for all frequencies were recorded at a single common receiver site located near the summit of Gunbarrel Hill (R-1) northeast of Boulder, Colorado. The site is in the open plains about 15 km east of the foothills of the Rocky Mountains. All measurements were conducted using mobile transmitters, and the majority of the transmitting sites were selected to provide a clear, unobstructed foreground in the direction of the receiver. The measurement locations were arranged in roughly concentric circles around the receiving site at nominal distances of 0.5, 3, 5, 10, 20, 50, 80, and 120 km from the receiver. Of the 55 transmitter sites selected 10 are located in the mountains, with the others in the somewhat rolling plains. For seven of the transmitting sites a companion "concealed" site was selected, where rows or clusters of trees are located in front of the transmitter. The following discussion is concerned chiefly with the paths where the foreground is clear and unobstructed.

All transmissions were continuous wave at frequencies of 230, 410, 751, 910, 1846, 4595, and 9190 MHz. The transmitting equipment was housed in two mobile units, with the antennas fixed 6.6 and 7.3 m above ground for the three lower and the four higher frequencies, respectively. The receiving antennas were mounted on a tower and could be raised or lowered from 1 to 13 m above ground. A complete description of the equipment, procedures, and experimental results is given by McQuate, Harman, and Barsis (1968).

Path profiles read from detailed topographic maps were obtained for the 47 unobstructed paths, and for each path the terrain parameter Δh was calculated. The median value, $\Delta h = 90$ m, was used to characterize the terrain irregularity for these paths. Area predictions were calculated for each frequency, transmitting antenna height, and for integral receiver heights from 1 to 13 m. Figures 1 to 5 show predicted values of basic transmission loss as a function of distance compared with values derived from measurements for receiver heights of 1 and 10 m and for frequencies of 230, 410, 751, 4595, and 9190 MHz. In each case calculations were made assuming both randomly and very carefully

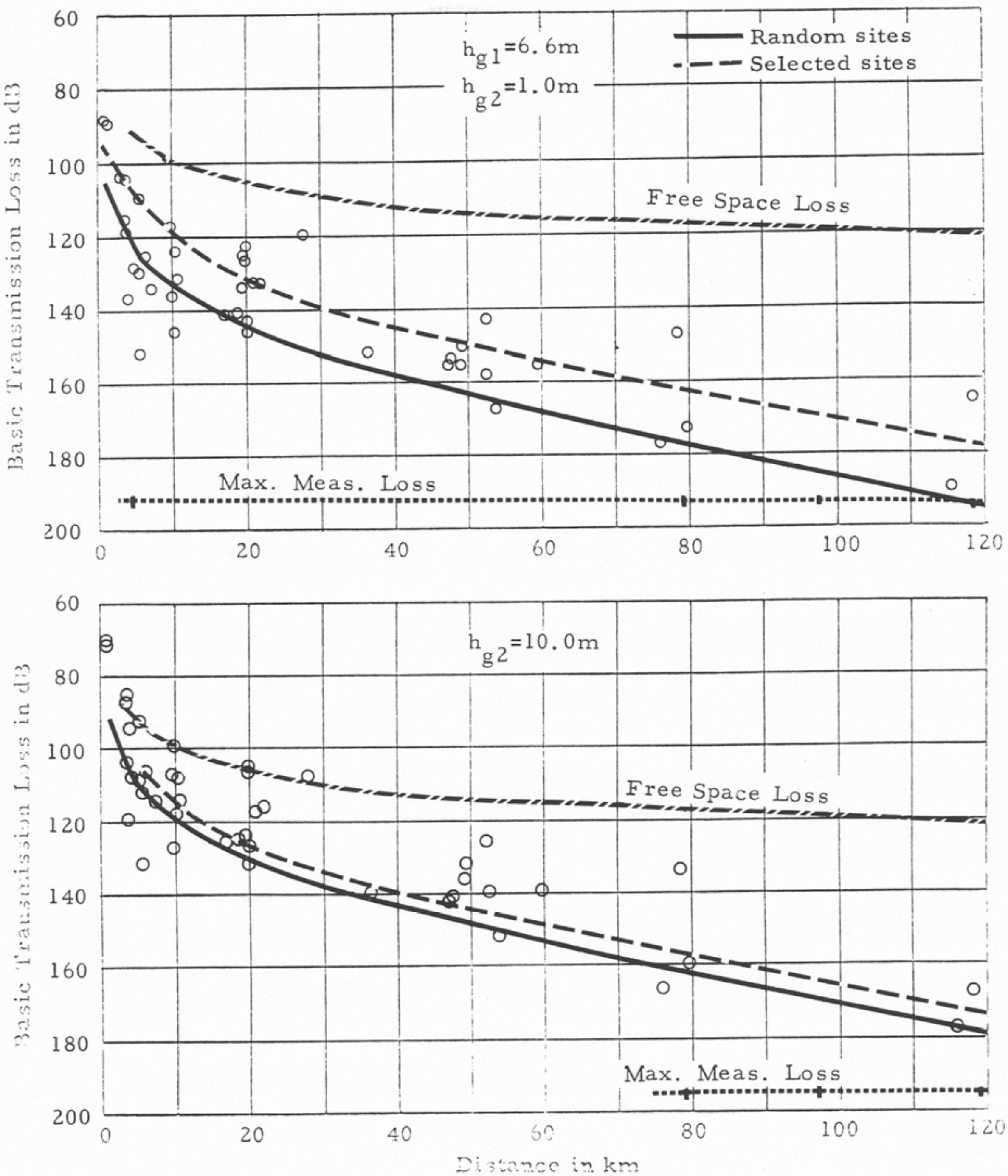

Figure 1. Basic transmission loss, measured and predicted, common receiver site R-1, Δh=90m, f=230 MHz.

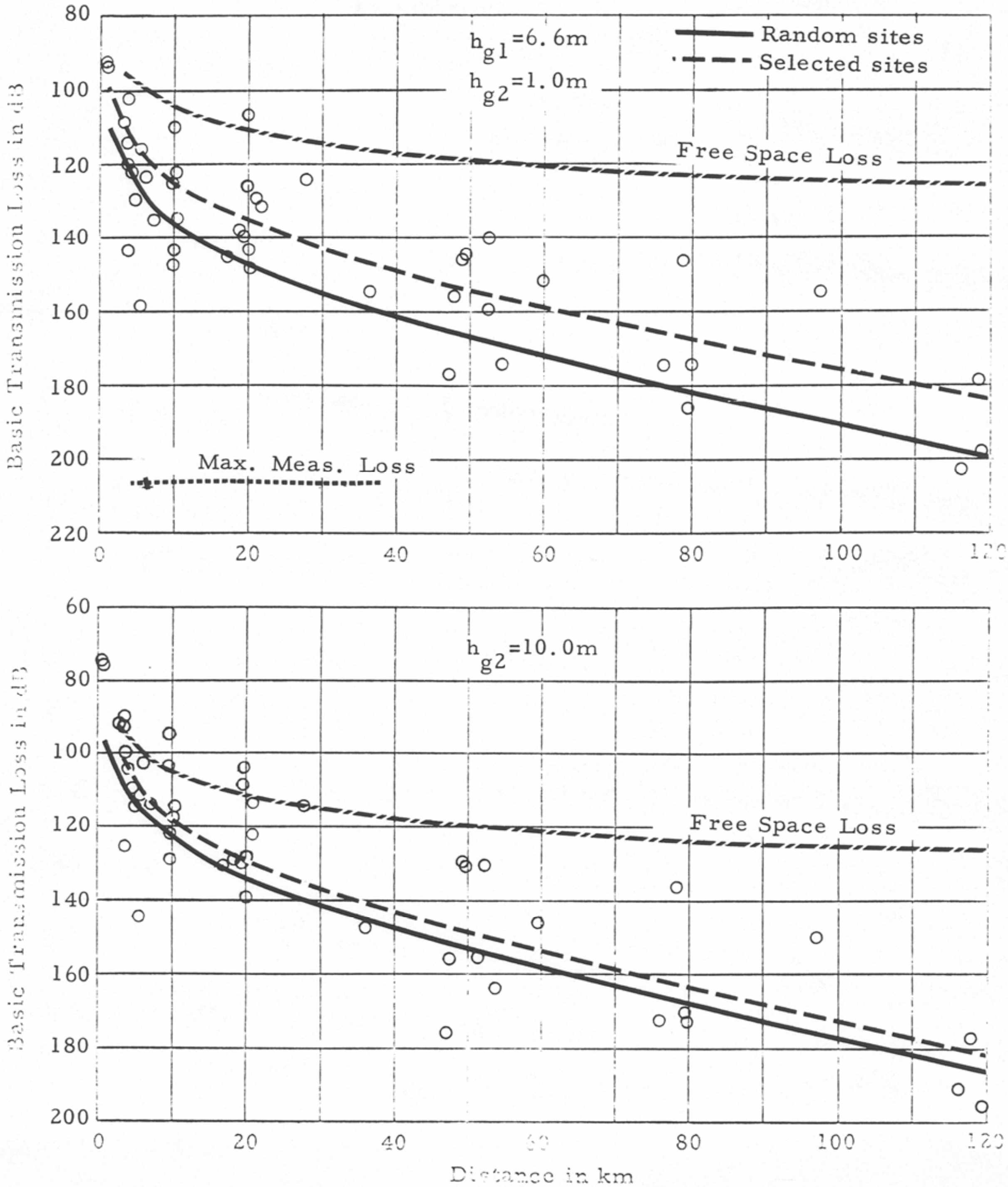

Figure 2. Basic transmission loss, measured and predicted, common receiver site R-1, Δh=90m, f=410MHz.

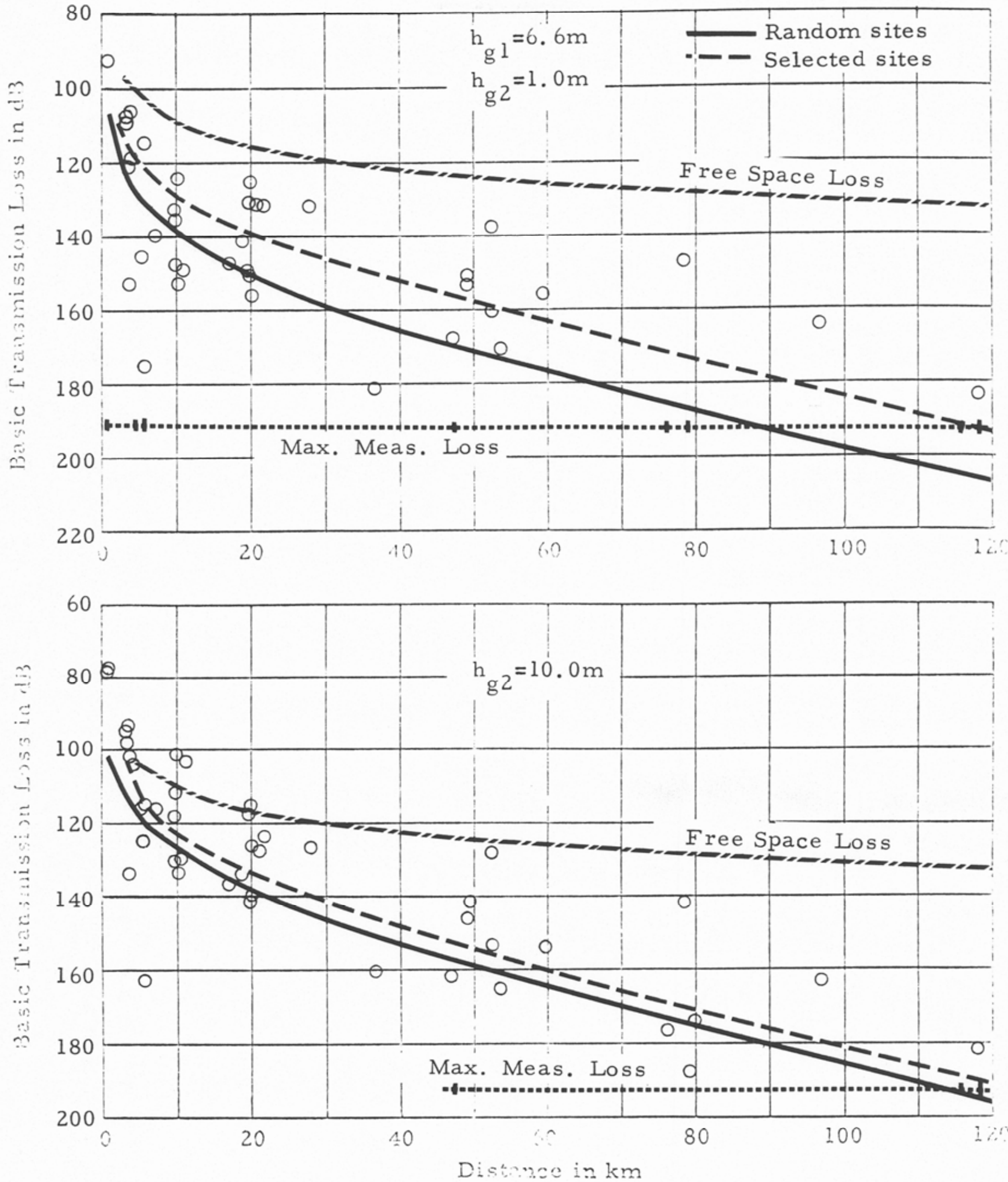

Figure 3. Basic transmission loss, measured and predicted, common receiver site R-1, Δh=90m, f=751MHz.

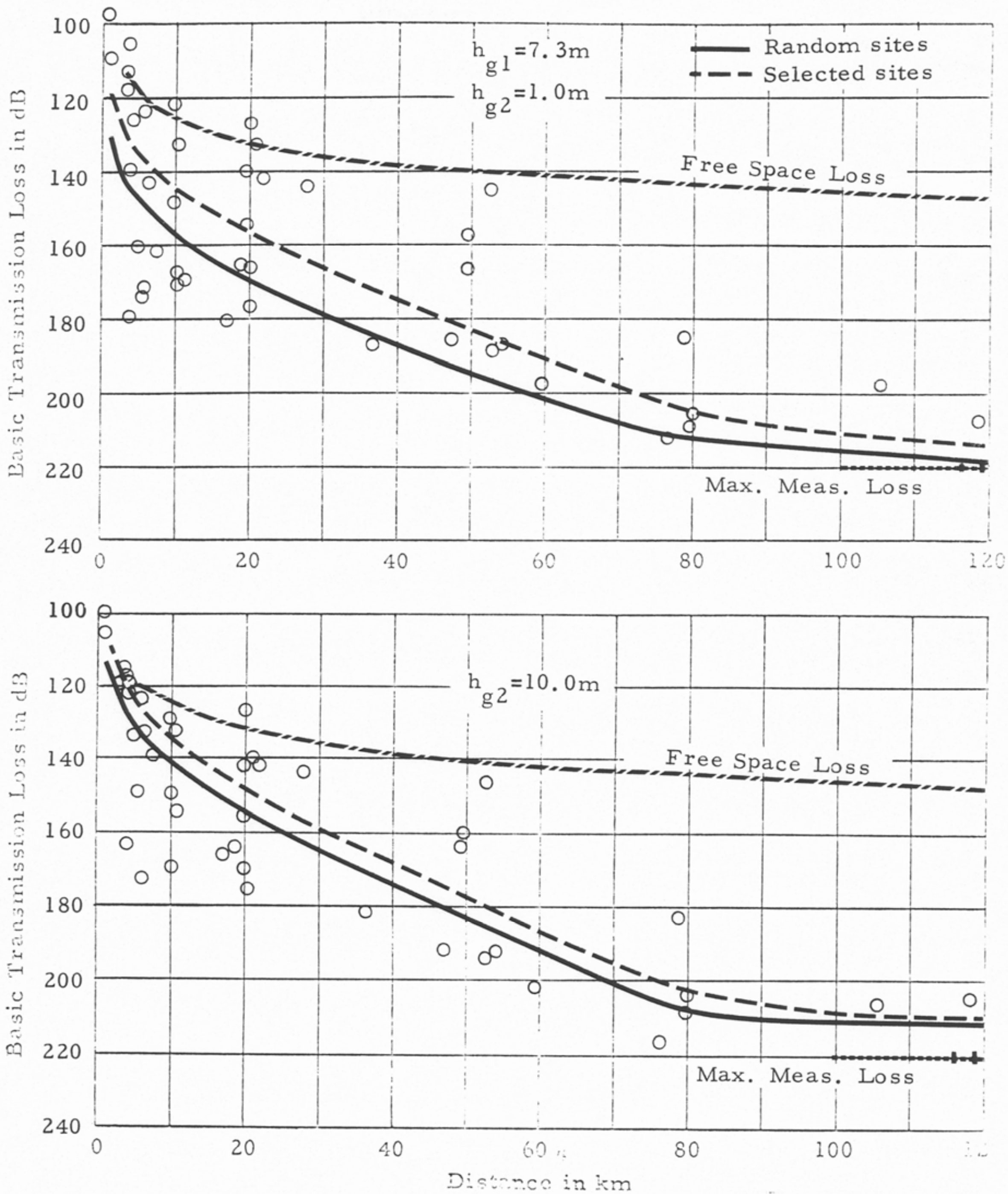

Figure 4. Basic transmission loss, measured and predicted, common receiver site R-1, Δh=90m, f=4595MHz.

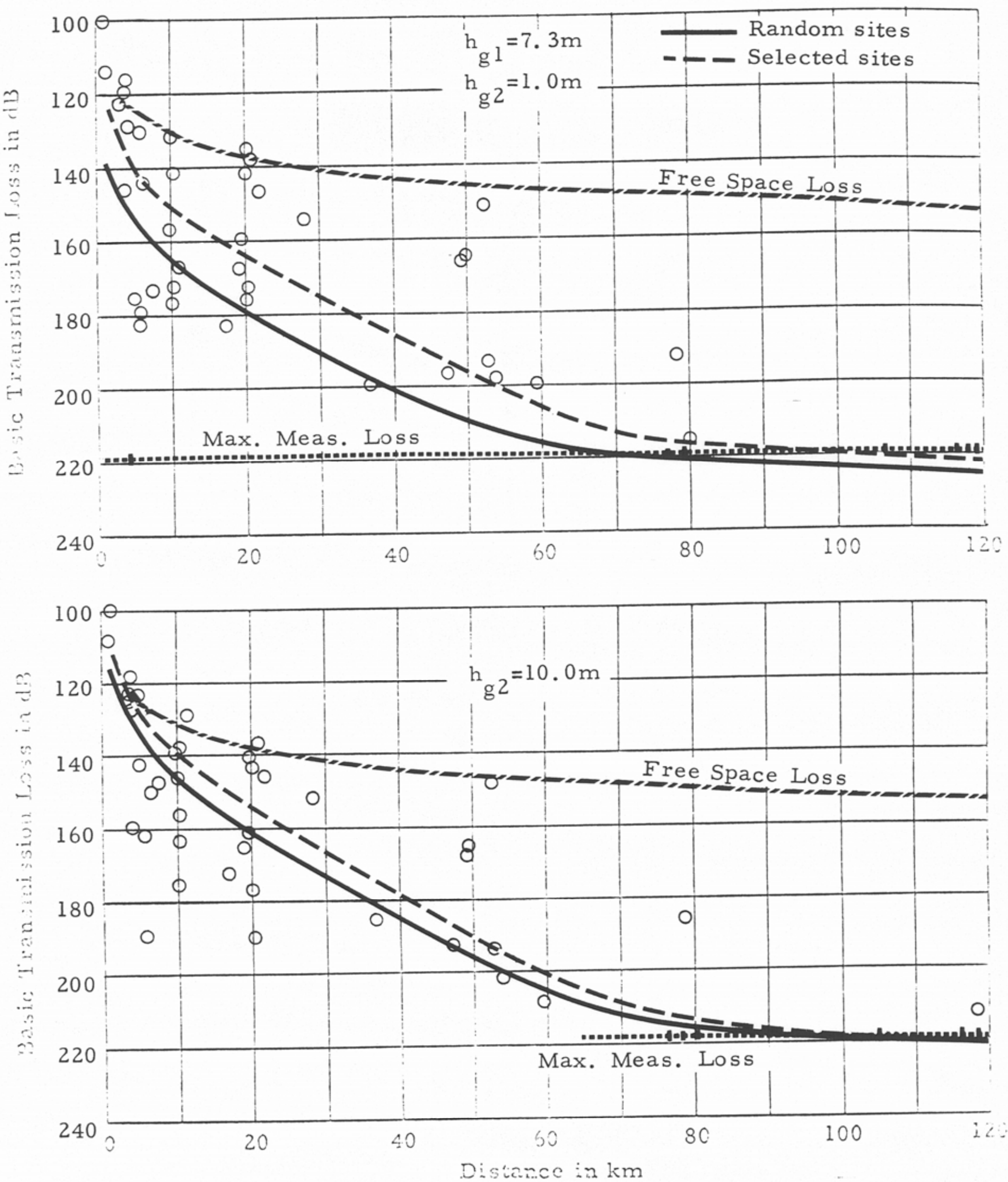

Figure 5. Basic transmission loss, measured and predicted, common receiver site R-1, Δh=90m, f=9190MHz.