2) EBU method to be used in European Broadcasting Area with separate formula for distances <300 km.

3) U.S.S.R. method - valid between 37° and 60° geomagnetic latitude for distances up to 6000 km and has no frequency dependence.

4) U.K. method - valid for all distances worldwide except for the auroral zones and has no frequency dependence.

5) Wang's 1977 method given as an alternative method for the U.S.

1979. Wang (1979) proposed a modification of the CCIR Kyoto 1978 method to improve accuracy in Region 2.

1979. The Inter-American Conference on Telecommunications extended the FCC median signal level curve to distances beyond 4300 km using the Cairo North-South Curve and recommended its adoption for Region 2.

3. DISCUSSION OF THE METHODS

In this section, a brief description and mathematical formulation, where applicable, is given for the methods which have been used internationally and for some of the methods that appear to be more scientific approaches but have not been widely applied.

3.1 Cairo Curves

The Cairo Curves (Figure 1) were based on three measurement campaigns conducted by the International Broadcasting Union (IBU) in the northern hemisphere winters of 1934/35, 1935/36, and 1936/37. As many countries had taken measurements on paths up to 2000 km and obtained results that were in close agreement with the propagation curves for similar distances drawn by Dr. van der Pol's committee at Madrid, 1932, and adopted by CCIR, Lisbon, 1934, these campaigns involved paths ranging from 5000 to 11900 km and frequencies between 695 and 1185 kHz. Measurements were made on 23 paths between North America and Europe, North America and South America, and South America and Europe; the great circle paths are shown in Figure 2. For the third campaign, the transmitting stations were selected on the basis of the following considerations: 1) transmitter power (50 to 120 kW), 2) half-wavelength antennas, and 3) frequencies relatively close to 1000 kHz (Knight, 1977). In Figure 1, the North-South curve represents transequatorial propagation, and the East-West represents propagation at high latitudes. The original curves were in terms of the quasi-maximum value for 1 kW radiated, versus distance. This was defined at the Madrid conference as the value exceeded not more than 5% of the time

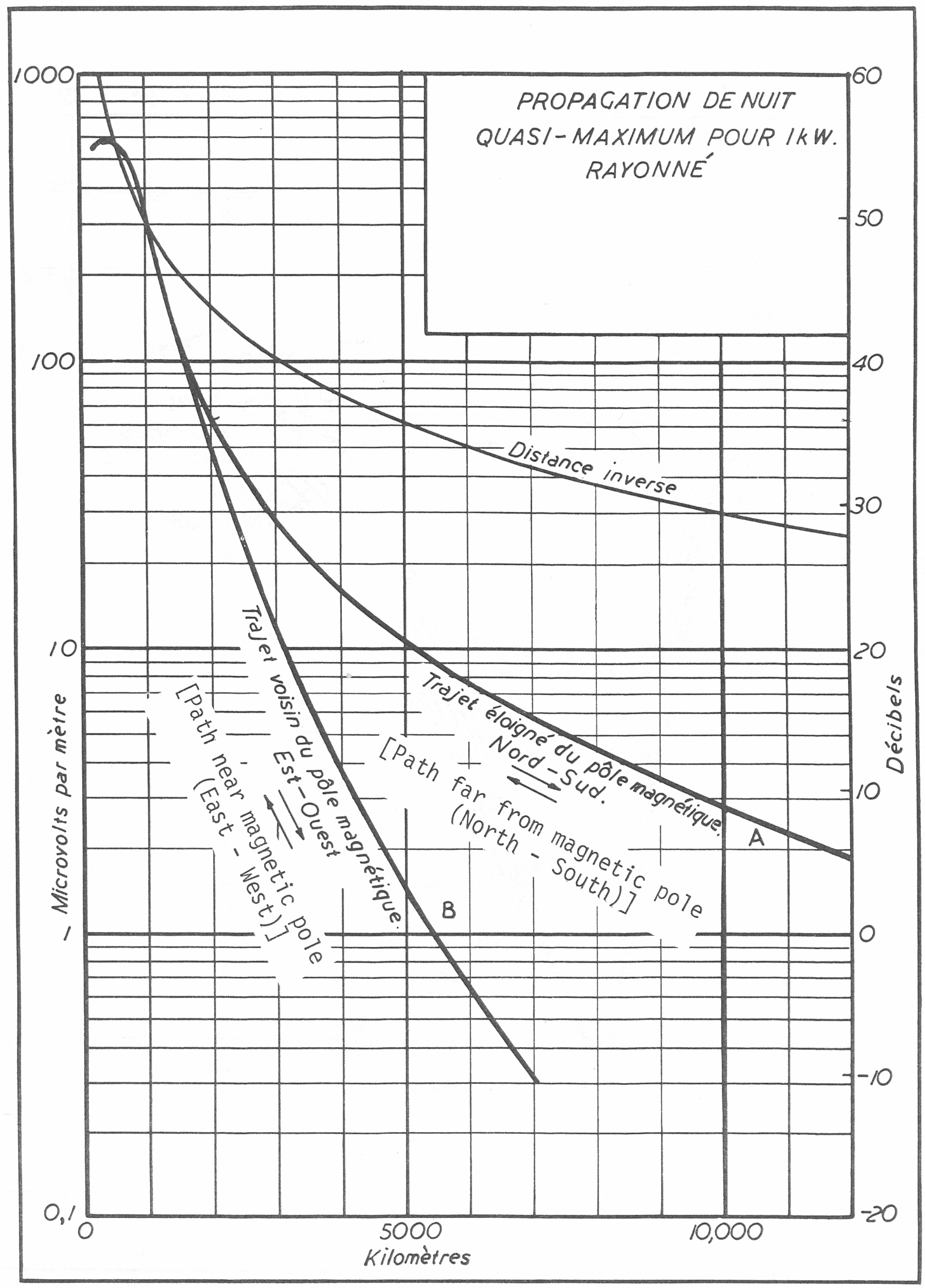

Figure 1. Quasi-maximum field intensity at great distances for propagation at night for a radiated power of 1 kW.

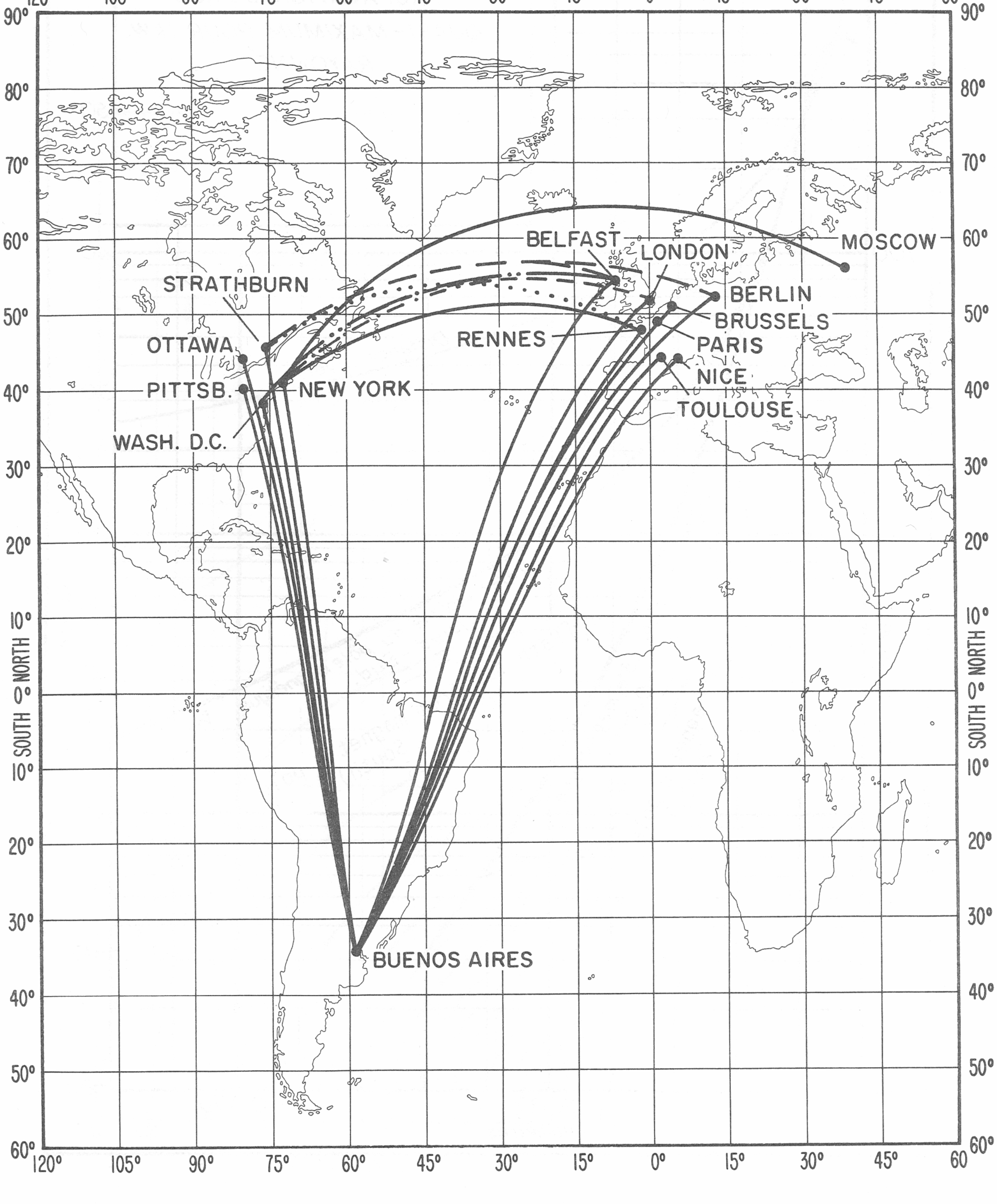

Figure 2. Propagation paths for which MF field strengths were measured during the three campaigns conducted by the International Broadcasting Union, 1934-37.

with the median being about .35 of this quasi-maximum value. Subsequently, CCIR reduced these curves by 9 dB to approximate a median value (CCIR, 1978). These curves were presumably used by the IFRB as a Technical Standard (A6) to determine service areas and interference; by 1956, the IFRB had requested CCIR to revise the Cairo Curves. At this time, new measurements made by the EBU (see Section 3.4 below) showed good agreement with the Cairo Curves out to 2000 km. It was noted that the slope of the Cairo Curves beyond that distance was independent of frequency, geographic location, and solar activity.

3.2 The FCC Curves

There are two sets of FCC curves for sky-wave propagation. The first set, shown in Figure 3, was based on recordings on 500 transmission paths at frequencies ranging from 640 to 1190 kHz and distances of 160 to 4000 km, during February, March, and April 1935, a relatively low solar activity period. The data have been normalized to an equivalent transmitting antenna radiating 160.9 μV/m at 1 km at the vertical angle corresponding to one ionospheric reflection (Barghausen, 1966).

The FCC conducted an extensive measurement campaign in the U.S. and Canada extending from 1939 to 1944. Recordings were made on 23 paths ranging from 400 to 3500 km and transmitting on frequencies ranging from 540 to 1500 kHz. All measurements were made two hours after sunset at the western end of the path. The 1935 measurements were made two hours after the occurrence of darkness on the entire path. As the FCC was primarily interested in engineering standards for frequency assignments, they used only the data for 1944 for the second set of curves (Figure 4). Minimum solar activity occurred in that year and, therefore, presented the highest sky-wave field strengths and represented the worst case for determining service areas and interference. These measurements were made at somewhat higher latitudes than the first set of measurements.

Both sets of curves are contained in the FCC Rules and Regulations (FCC, 1976) and include curves of the field strengths exceeded 10 and 50% of the year or the period of observation, up to distances of 4300 km for the 1935 curves and about 4000 km for the 1944 curves. The 1944 curves are presented as a function of geographic latitude and are used by the FCC for determining frequency assignments for domestic non-clear-channel broadcasting stations. The 1935 curves are used for determining frequency assignments for inter-regional clear-channel broadcasting stations and were adopted by treaty in 1960 by Canada, Cuba, the Dominican Republic, and the Bahama Islands and, at the same time, by Mexico in a separate treaty.

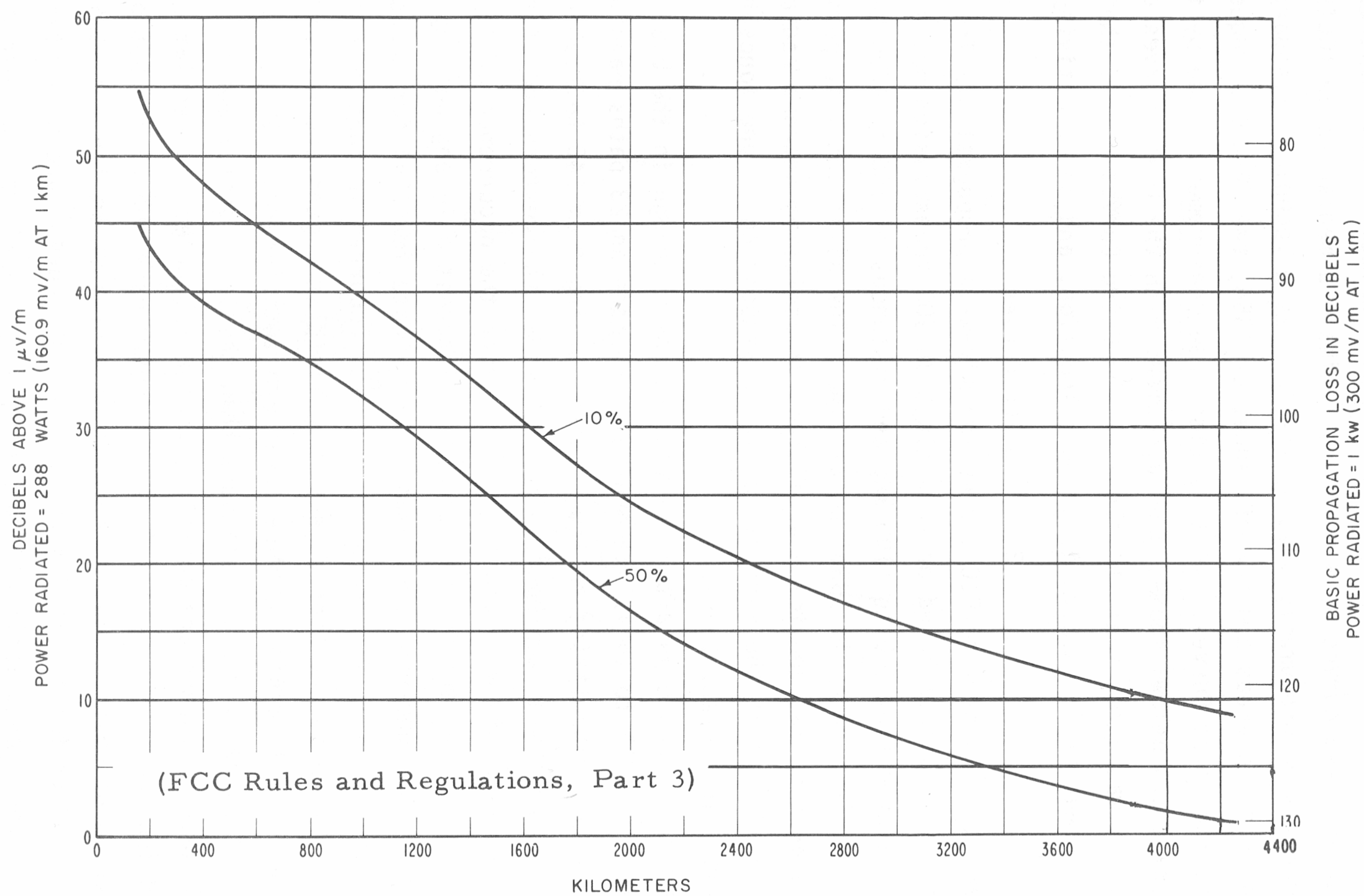

Figure 3. U.S. sky-wave field strength exceeded 10 percent and 50 percent of the time at 1000 kHz. Based on 1935 measurements, vertical polarization, and second hour after sunset at west end of path (Barghausen, 1966).

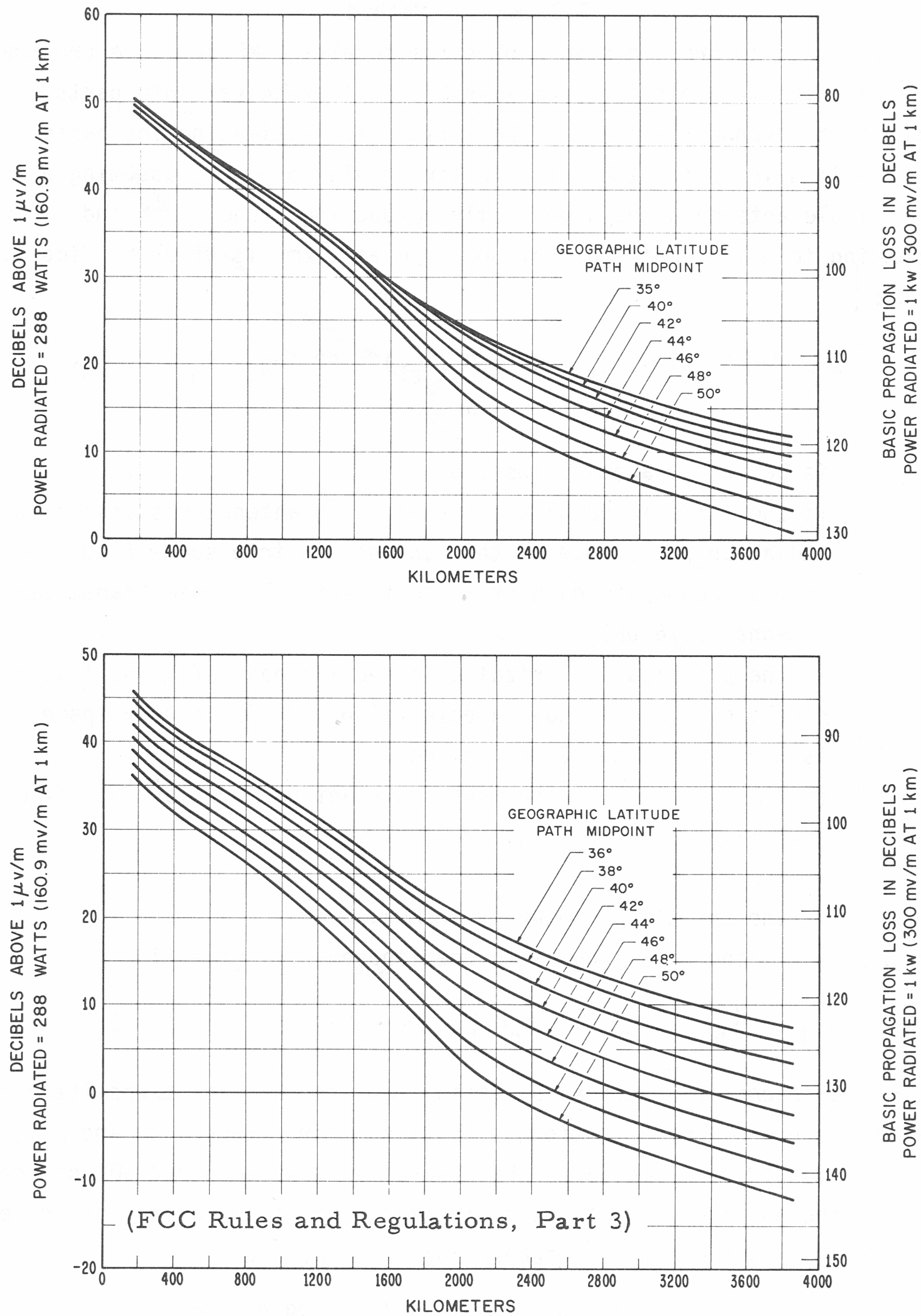

Figure 4. U.S. sky-wave field strength exceeded 10 percent (upper curve) and 50 percent (lower curve) of the time at 1000 kHz. Based on 1944 measurements, vertical polarization, and second hour after sunset at path midpoint (Barghausen, 1966).