Chapter 7

Investigations from Different Countries

The results described here provide a sampling of measured cumulative fade distributions for LMSS geometries pertaining to significant experiments in various countries. We emphasize distributions associated with rural and suburban regions as opposed to measurements in urban environments.

In comparing the results of the different investigations, the reader should be cognizant of the fact that the various experiments were conducted at a variety of elevations angles and bearings to the source. The diverse geographic regions (e.g., wooded, forest, rural, mountainous, highways) also have associated with them dissimilar conditions of foliage density along the propagation path, and variable distances between vehicle and foliage line. The distributions shown have been replotted consistent with the scales considered previously; namely, the fade (in dB) along the abscissa and the percentage of distance along the ordinate. Table 7.1 represents a summary of nominal fade values at the 1% and 10% levels for the various investigations. It is apparent from the wide variance of fades in this table that elevation angle and geographic region play important roles in the determination of LMSS attenuation.

Table 7.1: Comparison of L-Band fade levels at 1% and 10% probabilities derived from cumulative distributions in different countries.

Country	Elev. (deg)	Fade (dB) 1%	Fade (dB) 10%	Reference
Australia:				Bundrock [1988]
Case 1	30	16.7	10.8	
Case 2	45	13.5	8.8	
Case 3	60	11.3	7.1	
Australia:				Vogel et al. [1991] (Fig. 3.6)
Case 1	51	12.2	4.0	
Case 2	40	–	6.1	
Belgium	26	20.3	7.3	Jongejans et al. [1986]
Canada:				Butterworth [1984a]
Suburban	19	11	3.5	
Rural/Forest	19	20	8	
Rural/Farmland	19	21	10.5	
England	40	9	5.6	Renduchintala et al. [1990]
Japan	46	6.3	2.0	Saruwatari et al. [1989]
United States:				Vogel and Goldhirsh [1990]
Case 1	20	25.9	15.3	
Case 2	30	21.5	11.0	
Case 3	45	14.8	6.1	
Case 4	60	8.2	3.4	

7.1 Measurements in Australia

Bundrock and Harvey [1988] reported on cumulative fade distributions obtained on typical double lane roads in Melbourne, Australia. Messmate (stringybark) Eucalyptus trees approximately 15 m high lined the road and measurements were made over sections of the road corresponding to tree densities of 35% and 85%. Systematic measurements were made at varying elevation angles at simultaneous frequencies of 897 MHz, 1550 MHz, and 2660 MHz employing a helicopter as the transmitter platform and a receiver system in a mobile van. Figure 7.1 represents a set of cumulative fade distributions for the 85% tree density case at a frequency of 1550 MHz for elevation angles of 30°, 45°, and 60°. Figure 7.2 shows the distributions for the 85% tree density case and the three frequencies considered at a 45° elevation angle.

Vogel et al. [1991] also measured cumulative fade distributions in Australia employing the ETS-V and INMARSAT-Pacific geostationary satellites as transmitter platforms where the nominal elevation angles were 51° and 40°, respectively. These results were consistent with the ERS model described in Chapter 3. To provide a basis of comparison, fades at the 1% and 10% percentage levels pertaining to the ERS model are also given in Table 7.1 for a series of elevation angles denoted by the different cases. As previously mentioned, the model represents an overall driving condition and is generally representative of a maximum shadowing geometry; namely, the case for which the line-of-sight is orthogonal to the line of roadside trees.

7.2 Measurements In Canada

Canadians were early pioneers in the implementation of fade measurements for mobile-satellite system geometries [Butterworth and Matt, 1983; Huck et al., 1983; Butterworth 1984a, 1984b]. Butterworth [1984a, 1984b] describes roadside fade statistics measured at UHF (870 MHz) and L-Band (1.5 GHz) in Ottawa, Ontario, Canada. Various transmitter platforms were employed. These included a tower, a tethered balloon, a helicopter, and the MARECS A satellite.

Figure 7.3 shows UHF fade distributions at various elevation angles as derived from helicopter measurements in June 1983 for a rural region in which woodlands constituted

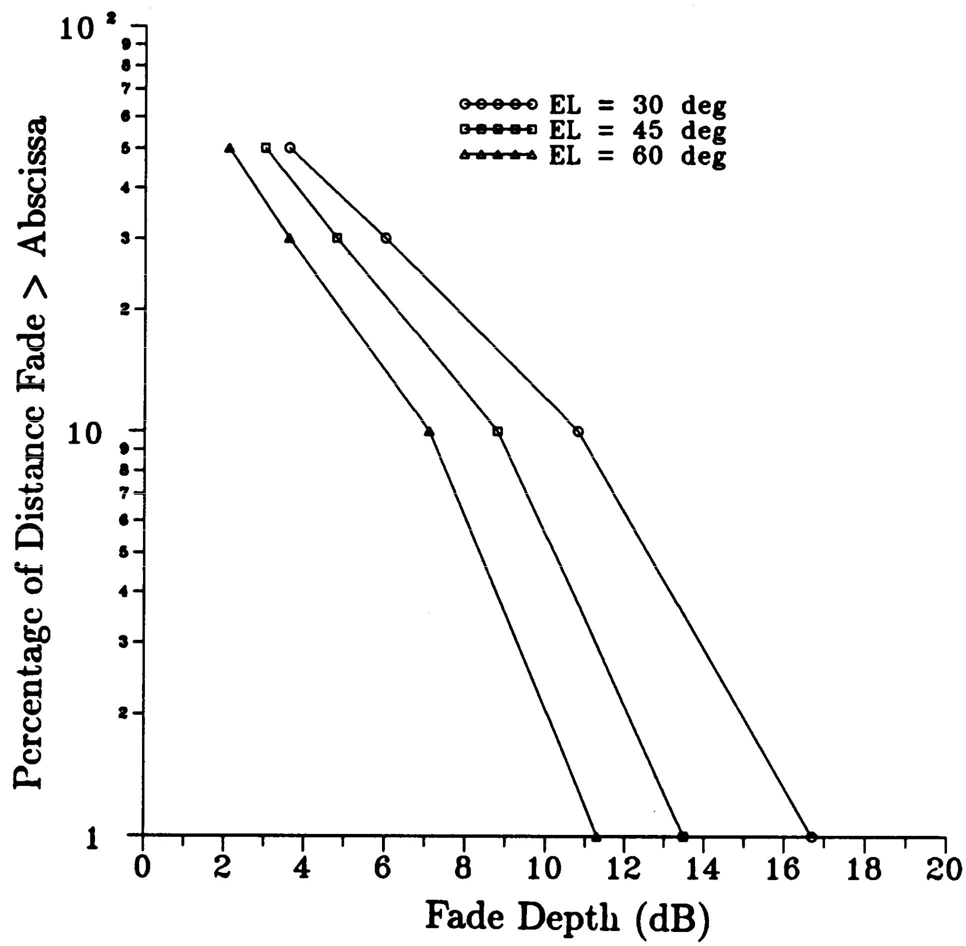

Figure 7.1: Cumulative fade distributions at various elevation angles derived by Bundrock and Harvey [1988] for Melbourne Australia at 1.55 GHz for a tree lined road having a 85% tree incidence.

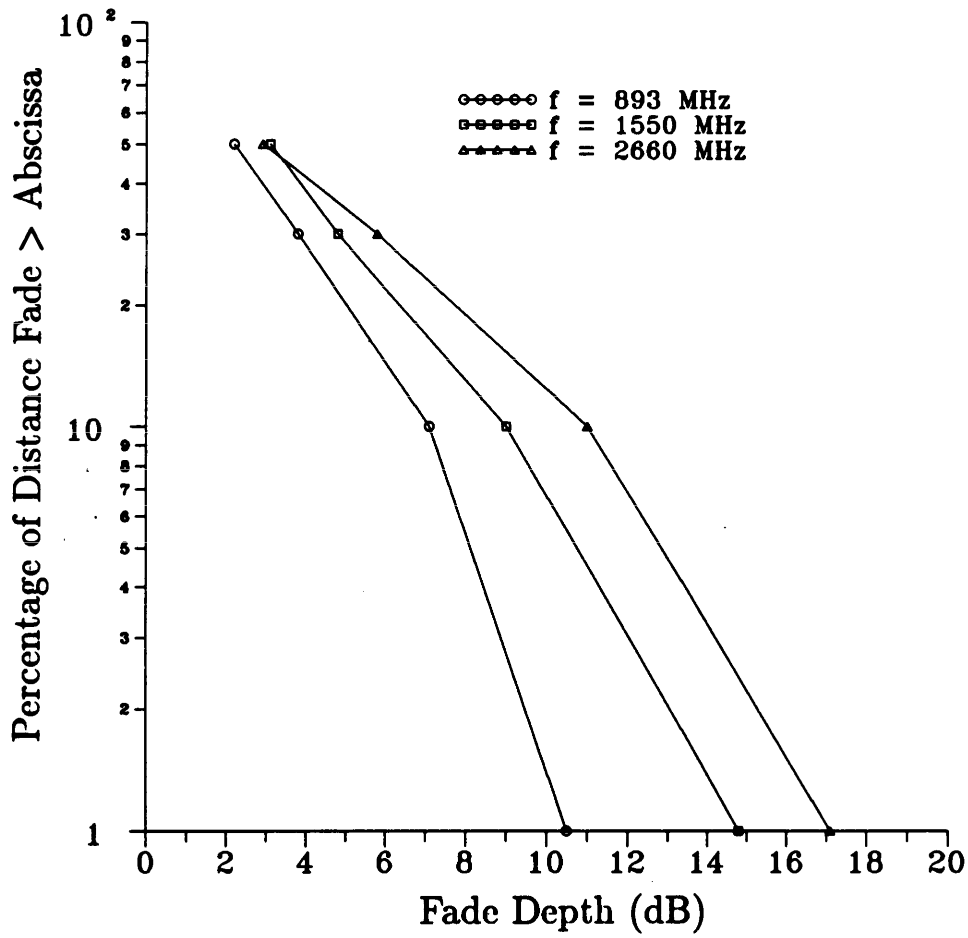

Figure 7.2: Cumulative fade distributions at UHF, L-Band, and S-Band derived by Bundrock and Harvey [1988] for Melbourne Australia at an elevation angle of 45°.

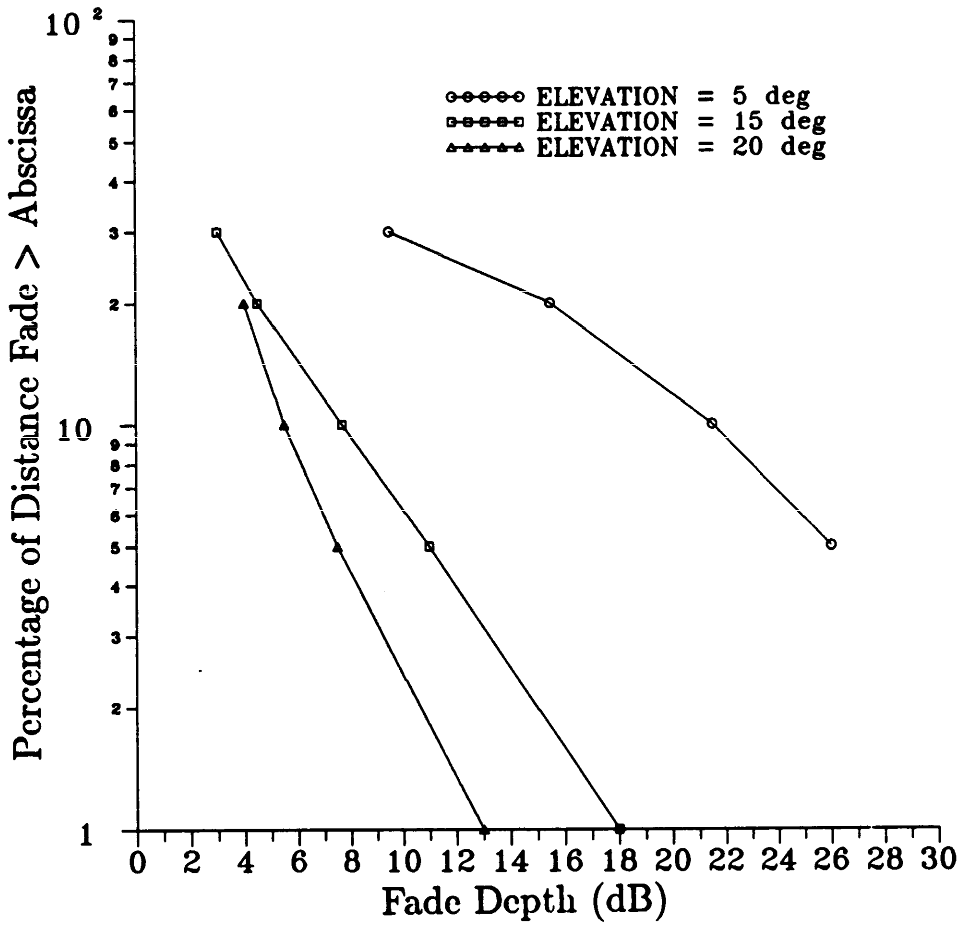

Figure 7.3: Cumulative fade distribution at UHF (870 MHz) in Ottawa, Ontario, Canada derived from helicopter measurements in a rural region (35% woodland) [Butterworth, 1984b].

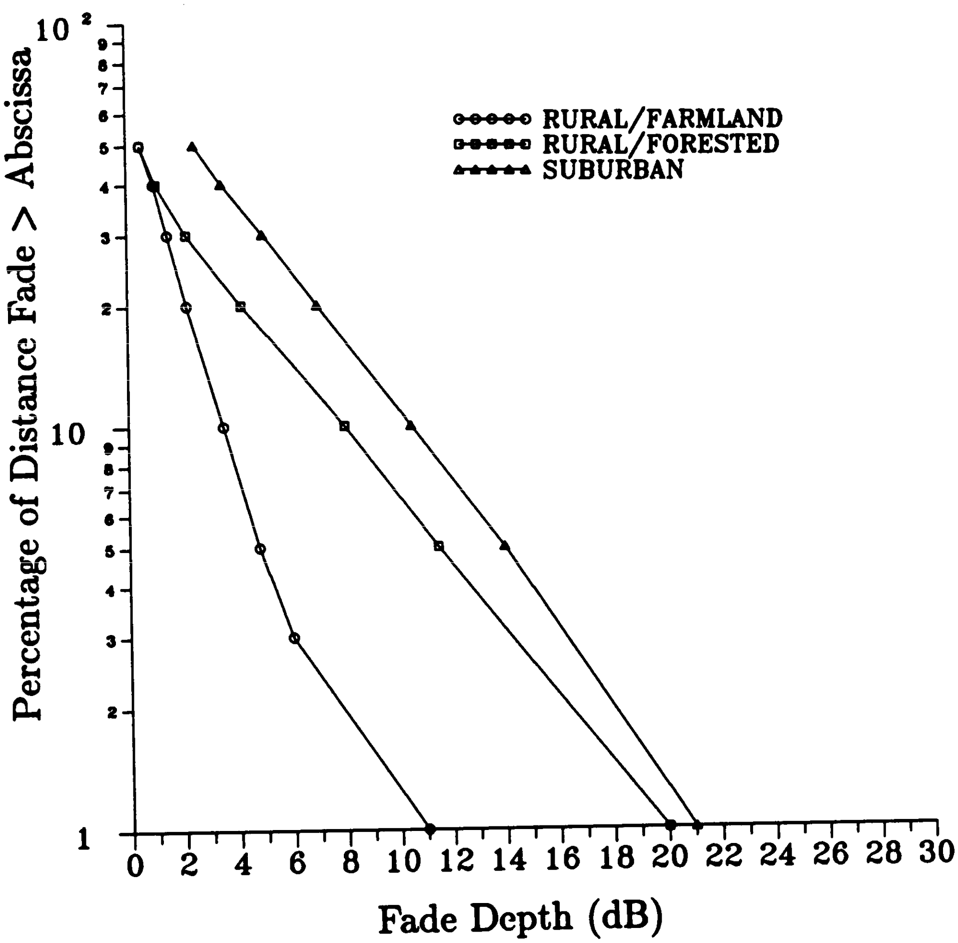

Figure 7.4: Cumulative fade distribution at L-Band (1.5 GHz) in Ottawa, Ontario, Canada derived from MARECS A satellite measurements in rural and suburban regions at 19° elevation [Butterworth, 1984a].

35% of the land area.

In Figure 7.4 are shown three distributions obtained from the MARECS A satellite transmissions at 1.5 GHz for a 19° elevation for suburban, rural/forested, and rural/farmland. Butterworth characterized these regions as follows:

Suburban - "an older suburban residential area consisting mainly of one and two-storey single-family dwellings."

Rural/Forested - "consisting of hilly terrain covered with immature timber of mixed species, interspersed with occasional cleared areas. The route followed a series of paved provincial highways with one lane for each traffic direction and with gravel shoulders."

Rural/Farmland - "area consisting of almost entirely of flat, open fields. About 5% of this route ran through occasional wooded areas. The roads were paved county roads with one lane for each traffic direction and with gravel shoulders."

7.3 PROSAT Experiment-Belgium

The PROSAT Experiment was instituted by the European Space Agency (ESA) with the objective to accelerate the development of LMSS in Europe [Jongejans et al., 1986]. This experiment involved seven ESA member states; namely Belgium, Federal Republic of Germany, France, Italy, Spain, United Kingdom and Norway. The MARECS B-2 satellite was used as the transmitter platform where transmissions were executed at L-Band (1.5 GHz).

In Figure 7.5 is shown the cumulative distribution for Belgium obtained in January 1984 in a rural area. The area (Ardennes) was hilly and the roadside was lined with bare trees [Jongejan et al., 1986].

7.4 Measurements Performed in England

In Figure 7.6 are cumulative fade distributions obtained in England in typical, rural, tree shadowed environments where all the trees had full leaf cover [Renduchintala et al., 1990;

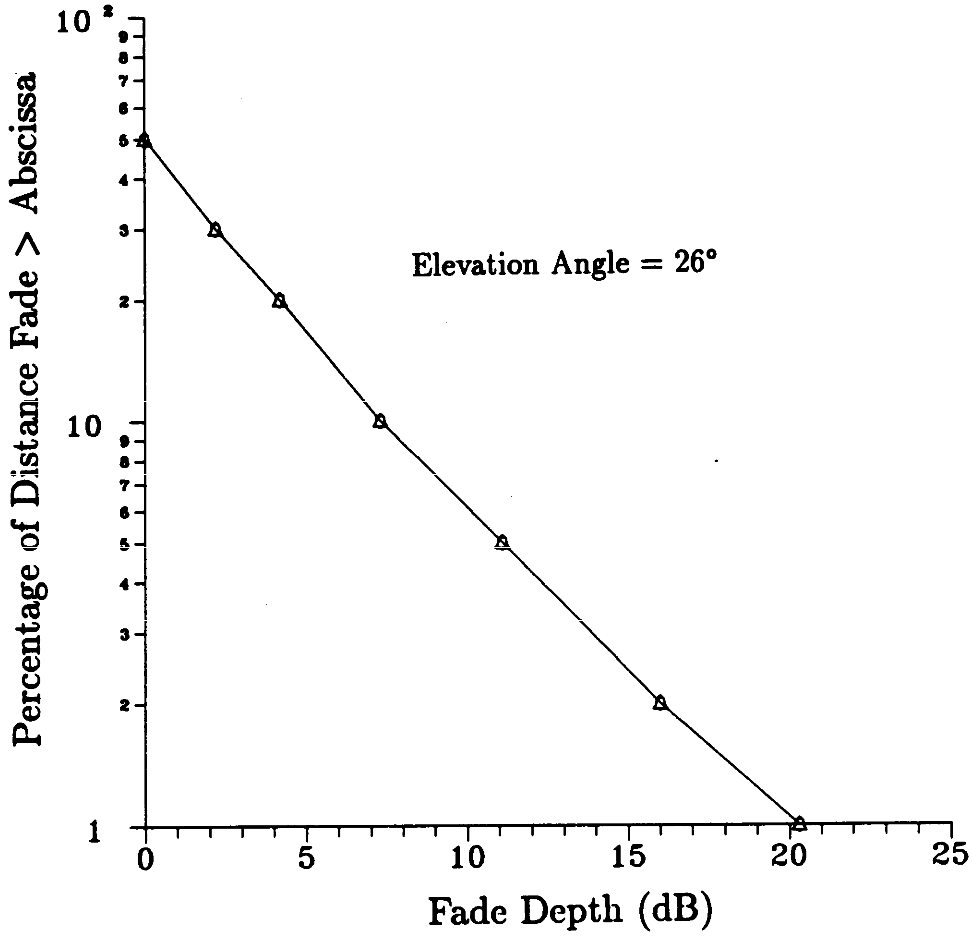

Figure 7.5: Fade distribution for a rural region at 1.5 GHz derived from measurements in Belgium in January 1984 [Jongejan et al., 1986].

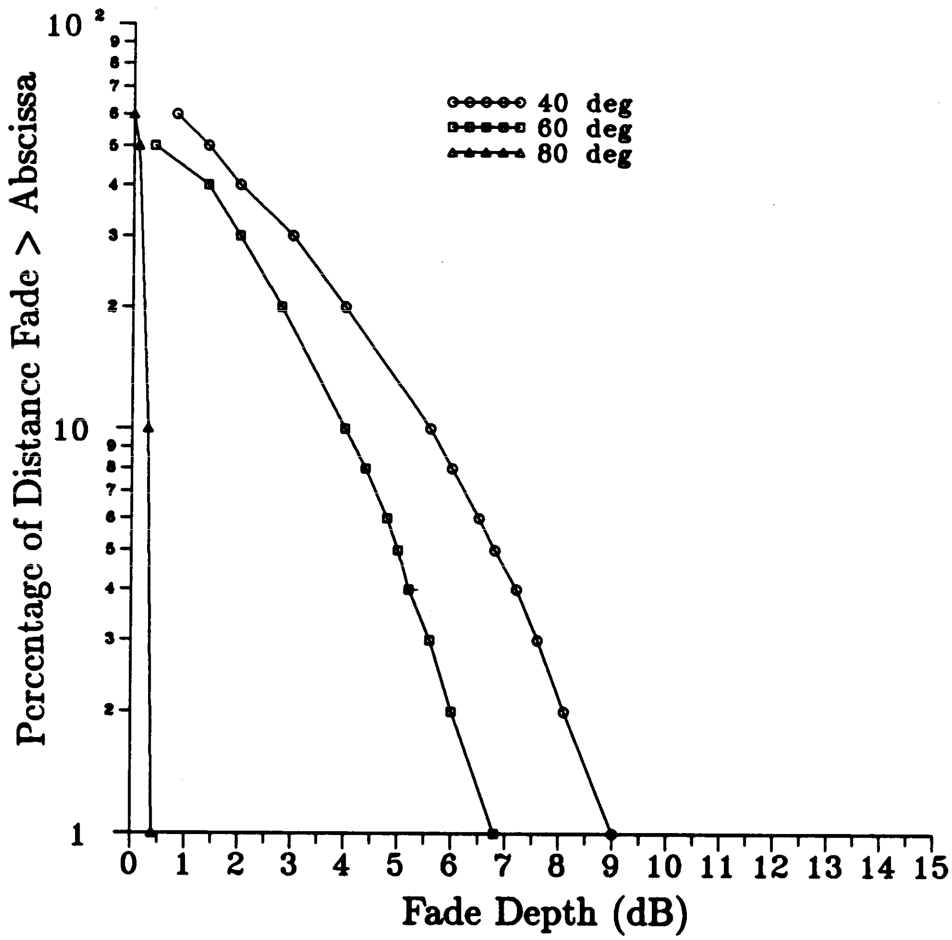

Figure 7.6: Fade distributions (L-Band) for tree shadowed environments in England for different elevation angles [Renduchintala et al., 1990; Smith et al., 1990].

Smith et al., 1990]. These results were derived from L-Band transmissions from an antenna mounted on an aircraft and received by a mobile van. Figure 7.6 depicts the distributions for a sequence of runs executed at the elevation angles of 40°, 60° and 80°. As in the case of other investigations, the results demonstrate the strong dependence of fades on elevation angle.

7.5 Measurements Performed in the United States

Early LMSS measurements were reported by Hess [1980] who received the vertically polarized components of right hand circular transmissions at 860 MHz and 1550 MHz from the ATS-6 geostationary satellite. Systematic fade measurements were obtained with the receiver system on a moving van as a function of local environment, vehicle heading, frequency, elevation angle, and street side. Since the circularly polarized transmissions were received with a vertical dipole, the measured signal levels were susceptible to low elevation multipath scattering. Because the distributions described by Hess mainly correspond to urban environments in Denver, his results will not be covered here other than to point out that 25 dB fades were typical for the urban areas. Hess does report, however, that of the measurements made in suburban and rural areas, typical fade levels of 10 dB were measured. An empirical propagation model derived by Hess from his measurements is described in Chapter 8.

As mentioned previously, systematic propagation measurements were made in the United States by the authors over the period 1983 - 1988. For example, measurements were made in southwest United States for suburban and rural regions by the University of Texas in 1983, 1984, and 1986 at both UHF and L-Band employing stratospheric balloons as the transmitter platform [Vogel and Hong; 1988]. In 1985-88, LMSS measurements were performed by the authors employing helicopters and satellites as transmitter platforms [Table 1.1]. The different cases in Table 7.1 pertain to the indicated elevation angles where the associated fades were derived from the ERS model described in Section 3.3. Since the dominant part of this text deals with the results of these measurements, no additional comments relating to these investigations are presented here.

7.6 Measurements Performed in Japan

Saruwatari and Ryuko [1989] performed a series of LMSS measurements employing L-Band transmissions from the Japanese ETS-V satellite which were received by a moving van. Figure 7.7 shows three distributions corresponding to elevation angle of approximately 46°. The distributions were derived from measurements executed on two expressways and one "old road" which runs alongside one of the expressways (Kan-etsu). Both expressways traverse flat areas, mountainous terrain, and have many two-level crossing with local roads. The "old road" runs through local urban areas, suburbs, farms, with a number of bridge crossings for pedestrians.

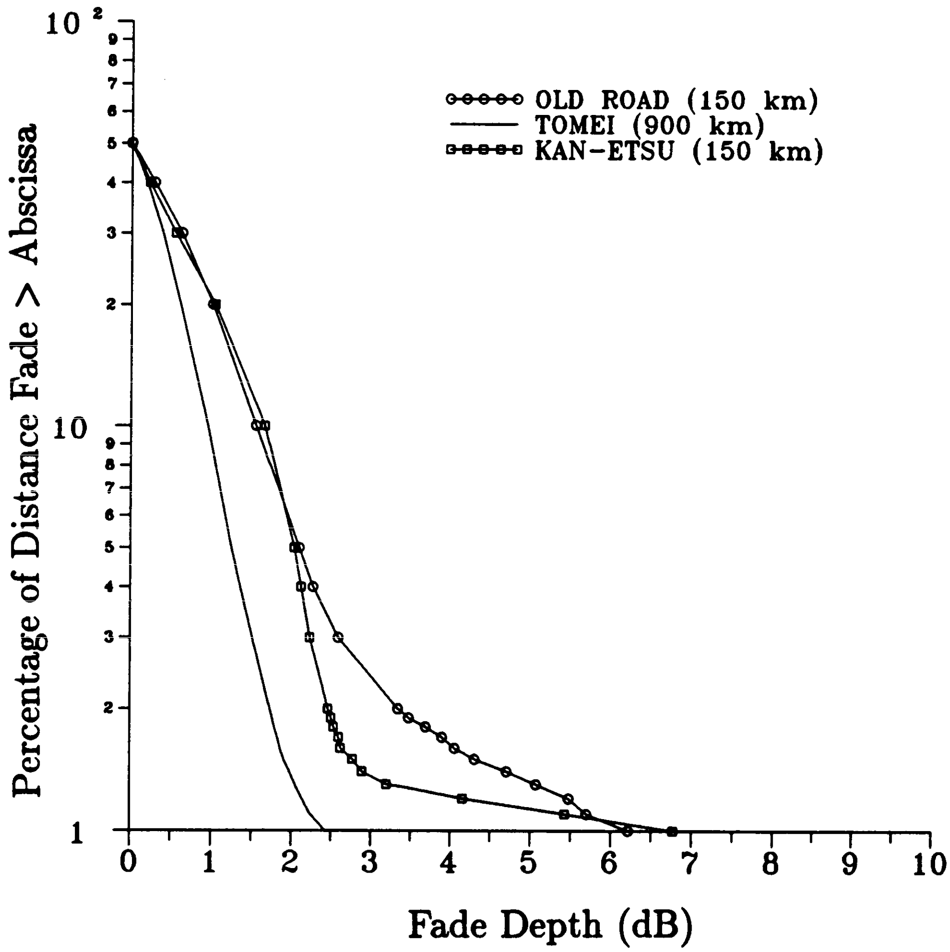

Figure 7.7: Fade distributions at L-Band for two expressways and an "old road" in Japan [Saruwatari and Ryuko, 1989].