Index

absorption, 5
AFD (average fade duration), 91
aircraft platform, 8
Amoroso, F., 109, 115
antennas
crossed drooping dipole, 78, 84
diversity spacing, 55
gain pattern effects, 34, 51, 52
high versus low gain, 52, 54
low gain, 78
quarter wave, 85
separation (diversity), 51, 56
ATS-6 (measurements with), 70, 79
attenuation (mobile)
angle dependence, 19–27
cross polarisation effects, 52–53
diversity operation, 55–60
Empirical Roadside Shadowing (ERS) model, 16–27
fade duration, 40–46
frequency (effects of), 27
high-gain versus low gain antennas, 52–54
investigations from different countries, 61–73
INMARSAT (with), 4, 15, 24, 26, 63
Japanese ETS-V (with), 2, 4, 11, 15, 16, 23, 26, 40, 63, 72
L-Band (measurements at), 15
L-Band versus UHF, 25, 28
line-of-sight, 34–39
MARECS A (with), 68
MARECS-B2 (with), 4, 15, 66
modeling, 74–114
non-fade duration, 46, 47
phase fluctuations, 48–50
roadside trees, 15–33
season (effects of), 28, 29
canopy, 6
colleteral trees, 5–14
Holly, 9
grove of trees, 7
grove path length, 6

attenuation (static)
bare trees (effects of), 12
Burr Oak, 9
Callery Pear, 9, 12, 13
canopy, 6
collinear trees, 5–14
Holly, 9
grove of trees, 7
grove path length, 6
Pin Oak, 9

INMARSAT (with), 4, 15, 24, 26, 63
Japanese ETS-V (with), 2, 4, 11, 15, 16, 23, 26, 40, 63, 72
L-Band (measurements at), 15
L-Band versus UHF, 25, 28
line-of-sight, 34–39
MARECS A (with), 68
MARECS-B2 (with), 4, 15, 66
modeling, 74–114
non-fade duration, 46, 47
phase fluctuations, 48–50
roadside trees, 15–33
season (effects of), 28, 29
canopy, 6
colloidal trees, 5–14
Holly, 9
grove of trees, 7
grove path length, 6
Pin Oak, 9
INDEX

pine grove, 9
Sassafras, 9
Scotch Pine, 9
seasonal effects (static case), 11
single tree, 7
static, 5-14
summer, 12
trees (full foliage), 8
tree types, 8, 9
UHF, 15
White Pine, 9
winter, 12
Australian campaign, 15, 16, 23, 40, 41, 56, 86
average fade duration (AFD), 91
balloons (stratospheric), 71
bandwidth, 3
Barts, R. M., 97, 115
Belgium (measurements in), 68, 69
Bell, T. E., 3, 115
Big Thompson Canyon (measurements in), 35
Boulder Canyon (measurements in), 35
Brewster angle, 78
Bundrock, A., 1, 27, 63-65, 115
Burr Oak, 9
Butterworth, J. S., 1, 6, 8, 63, 66-68, 115
Callery Pear, 9, 12
campaigns, 4
Canada (cumulative distributions), 63, 66-68
canopy shadowing, 20, 42
CCIR; 1986a
Report 1008, 78, 116
Report 1007, 87, 116
CCIR; 1986b
Report 263-6, 77, 116
cellular communications, 2, 3, 12
Central Limit Theorem, 88
Central Maryland (measurements in), 8, 15, 40
Chapman, C. W., see LaGrone, A. H., 108, 117
circular polarization, 7, 77,
Clarke, R. H., 110, 116
Colorado (measurements in), 15
cross-polarization, 52
crossed drooping dipole, 78, 84
cross polarization, 52, 53
cumulative distributions
Canada (fade measurements in), 63
canyons (fade measurements in), 35
England (fade measurements in), 68, 70
Empirical Roadside Shadowing Model (ERS), 16-27
fade durations, 41
Japan (fade measurements in), 72
joint (diversity gain), 56, 57
modeling of, 86-102
non-fade durations, 46
phase fluctuations, 48, 49
rural/farmland (fade measurements), 67, 68
rural/forested (fade measurements), 67, 68
seasonal effects (fade measurements), 29
suburban (fade measurements), 67, 68
roadside trees (fade measurements), 38
United States (measurements in), 4, 16-27, 71, 79-85
Cygan, D., 100, 116
Davies, K., 77, 116
INDEX

deciduous trees, 19, 28
delay spread, 114
density functions
  lognormal, 89
  Nakagami-Rice, 87
  Rayleigh, 75, 86, 88, 90
Denver (measurements in), 71
diffuse scattering, 76
digital filtering, 41
dipole (crossed drooping), 78
distribution fits
  exponential (fade), 39, 43
  logarithmic (fade), 17
  lognormal (fade duration), 45
  polynomial (phase), 50
  power fits (fade, non-fade duration) 36, 47
diversity gain, 56, 58, 60
diversity improvement factor, 56, 59
diversity operation, 55–60
Doppler
  shift, 41, 48, 76, 92
  spectrum, 78, 110, 11
drooping dipole, 110
durations (fade), 40, 41, 44, 45
elevation angle (attenuation effects of), 12, 16, 20, 80
empirical regression models, 78–86
Empirical Roadside Shadowing model (ERS), 16–27, 63, 71, 85
England (measurements in), 68, 70
ESA (European Space Agency), 68
ETS-V (measurements with), 2, 4, 11, 15, 16, 23, 26, 40, 63, 72
Eucalyptus tree, 23, 63
experimental campaigns, 4, 61–73
experimental parameters, 4, 10, 24, 55
extreme shadowing, 42
fade
  bursts, 86
  durations, 23, 40, 40–46
  frequency scaling (static case), 11
  median, 8
  non-fade durations, 46, 47
  reduction, 31, 29, 58
  time-series, 17, 18
fade state transition models, 100–102
Faraday rotation, 77
Flock, W. L., 1, 77, 78, 116
fluctuations (signal level), 106
foliage, 8, 12
follow-on efforts, 113
frequency
  re-use, 52, 53
  scaling (dynamic case), 27
  scaling factor, 11
  scaling (static case), 11
Fresnel region, 7, 76, 78
Gaussian processes, 92
geographic regions, 61
geometric-analytic models, 103–114
geostationary satellites, 2, 4, 11, 15, 16, 23, 24, 26, 40, 63, 67, 68, 72
Gilbert-Elliot model, 100
Goldhirsh and Vogel, 6, 7, 12, 29, 116
Goldhirsh, J. see Vogel et al., 7, 15, 16, 118
ground reflected waves, 77, 78
grove of trees, 5–7
Harvey, R., see Bundrock, A., 27, 63–65, 115
Hase et al., 15, 40, 48, 116
Hase, Y., see Vogel et al., 15, 16, 118
helicopter (measurements with), 2, 7, 15, 16
INDEX

Hess, G. C., 1, 70, 79, 116
high versus low gain antennas, 52, 54
Hodge, D. B., 58, 116
Holly, 19
Hong, U. S., see Vogel, W. J., 71, 103, 108, 118
Huck, R. W., 63, 116
INMARSAT Pacific (measurements with), 2, 15, 26, 63
investigations (different countries), 61–73
ionosphere, 77, 114
isolation, 52, 78, 84
Jakes, W. C., 74, 92, 117
Jones, W. W., see Amoroso, F. 109, 115
Jongejans et al., 1, 117
Japan (cumulative distributions), 72
Japanese ETS-V, 15, 16, 26, 40, 72
joint probabilities, 56, 57
Jones, W. W., see Amoroso, F., 109, 115
Jongejans et al., 1, 68, 117
K factor, 87
Kagohara, M., see Yoshikawa, M., 6, 11, 108, 117
LaGrone, A. H., 108, 117
lane diversity, 29
large scale–small scale model, 79–86
L-Band (measurements at), 15
L-Band versus UHF, 11, 27, 28
Lee, W. C. Y., 74, 117
level crossing rate (LCR), 91
line-of-sight, 7, 34–39
LMSS scenarios, 6
lognormal fade distribution, 41, 75, 44, 86, 89
Lognormal Shadowing Model, 95
Loo, C., 49, 90, 91, 117
Loo’s distribution model, 90–92
Lutz, E. W., 93, 117
MARECS A (measurements with), 63
MARECS-B2 (measurements with), 15, 16, 66
maritime, 3
Markov model, 100
Markov transitions, 102
mobile attenuation, 15–33
Maryland (measurements in) 8, 15, 40
Matt, E. E., see Butterworth, J. S., 63, 115
measurements in
Australia, 63
Belgium, 69
Big Thompson Canyon, 35
Boulder Canyon, 35
Canada, 8, 63, 92
Colorado, 15
Denver, 71
England, 70
Japan, 72
Maryland, 8, 15, 40
New Mexico, 15
Texas, 15
median fade level, 8
mobile van, 10, 35, 55
models
cumulative distributions see cumulative distributions
empirical regression fits, 78–86
Empirical Roadside Shadowing Model (ERS), 16–27, 63, 85
fade-state transitions, 100–102
diffusion-analytic, 75, 103–114
Hess, 79–84
large scale–small scale (LS-SS), 79–85
Lognormal Shadowing, 95, 96
Loo’s distribution, 90–92
multiple object scattering, 109–112
probability distribution, 75, 86–102
Simplified Lognormal, 97
single object, 103–108
Total Shadowing, 93–95
modeling for LMSS, 74–114
moderate shadowing, 42
mountain (multipath effects), 34–37
multipath
canyons, 35
elevation angle dependence, 38
mountains, 34–37
roadside trees, 34, 37–39
scattering, 5, 7
power, 88
multiple object models, 109–112
Nakagami-Rice density function, 87
New Mexico (measurements in), 15
non-fade durations, 40, 46
Norway Maple, 9
Ottawa, Canada (measurements in), 8
overhanging tree canopies, 42
Papoulis, A., 87, 88, 117
path length, 6–8, 12
percentage of optical shadowing (POS), 19
phase fluctuations, 48–50
phase shifts, 16–18, 40, 41, 106, 107
Pin Oak, 8, 9
Pine grove, 9
point scatterer, 103
polarization
circular, 7, 77, 78
Faraday rotation, 77
frequency re-use, 52, 53
probability distributions see cumulative distributions
probability distribution models, 86–102
PROSAT, 66
Rayleigh distribution, 75, 86, 88, 90
receiver (characteristics of), 7, 10, 55
recommendations, 113
Reed, H. R., 78, 117
references, 115–118
remotely piloted aircraft (measurements with) 2, 7, 8
Renduchintala et al., 1, 70, 117
Ricean density function, 75, 86–88, 92
roadside trees, see attenuation (mobile)
Russel, C. M. see Reed, H. R., 78, 117
Ryuko, H., see Saruwatari, T., 72, 117
sampling rate, 8
sample size, 8
Saruwatari, T., 72, 117
Sassasafras tree, 9
scattering
diffuse, 76
ground, 76
multiple, 5
multipath, 7
tree canopies 5, 37
tree trunks, 5
scintillations, 114
Scotch Pine, 9
seasonal effects (on attenuation), 12, 28, 29
shadowing, 7, 16, 20, 19, 42, 45, 86
signal fluctuations, 106
Simplified Lognormal Shadowing model, 97–100
single object models, 103–108
single tree attenuation, 7, 9
Smith, H., 70, 118
Smith, W. T., 95, 118
space diversity, 55
specular reflection, 77, 78
INDEX

speed of van, 41
static attenuation, 5–14
static attenuation coefficient, 7
stratospheric balloons (measurements with) 2, 15, 71
Stutzman, W. L., see Smith, W. T., 95, 118
suburban-rural measurements, 81
summer attenuation, 28
Texas (measurements in), 77
The Johns Hopkins University, 1
The University of Texas, 1, 71
time-series of fades, 16, 17
time-series of phases, 17, 18
total electron content (TEC), 77
Total Shadowing model, 93–95
transmitter characteristics, 7, 8, 10, 16, 25

Trees
  bare (attenuation of), 12
  branches (attenuation of), 12
  Burr Oak, 9
  canopies 5, 20, 42
  Callery Pear, 9, 12, 13
dimensions, 8, 12
  Eucalyptus, 23
grove of, 5
  Holly, 9
  modeling, 108
  Norway Maple, 9
  Pin Oak, 8
  Sassafras, 9
  Scotch Pine, 9
  trunks, 5
types (attenuation), 8, 9
  White Pine, 9
tropospheric effects, 114
UHF (measurements at), 15

Ulaby et al., 6, 11, 118
United States (measurements in), 4, 16–27, 71, 79–85
urban measurements, 79–85
utility poles, 20, 106
validation of ERS model, 23, 25, 26
Vishakantaiah, P., 109, 118
Vogel, W. J. see Vishakantaiah, P., 109, 118
Vogel and Goldhirsh, 7, 15, 118
Vogel and Hong, 71, 103, 108, 118
Vogel et al., 15, 16, 23, 40, 118
Wakana, H., 102, 118
Wallops Island, VA. (measurements in), 8
WARC 1987, 3
Weissburger, M. A., 6, 119
White Pine, 9
winter attenuation, 28
Yoshikawa, M., 6, 11, 108, 119
Propagation Effects for Land Mobile Satellite Systems: Overview of Experimental and Modeling Results

Julius Goldhirsh
Wolfhard J. Vogel

The Johns Hopkins University
Applied Physics Laboratory
Laurel, MD 20707

The University of Texas
Electrical Engineering
10100 Burnett Road
Austin, TX 78758

National Aeronautics and Space Administration
Washington, DC 20546
Office of Commercial Programs

Goldhirsh: The Johns Hopkins University, Applied Physics Laboratory, Laurel, MD.
Vogel: The University of Texas, Electrical Engineering Laboratory, Austin, TX.

The period from 1980 to 1990 saw numerous experiments carried out and models developed with the objective of characterizing the propagation environment associated with the provision of land mobile communications using satellites. Experiments were carried out with transmitters on stratospheric balloons, remotely piloted aircraft, helicopters, and geostationary satellites. This text assembles the experimental results in a single source for use by communications engineers, designers of planned Land Mobile Satellite Systems (LMSS), and modelers of propagation effects. The results given here are mostly derived from systematic studies of propagation effects for IMSS geometries in the United States associated with rural and suburban regions. Where applicable, the authors also draw liberally from the results of other related investigations in Canada, Europe, and Australia. Frequencies near 1500 MHz are emphasized to coincide with the frequency bands allocated for IMSS by the International Telecommunication Union although earlier experimental work at 870 MHz is also included.

Radio Wave Propagation, Land Mobile Satellite Communications Systems, L-band propagation, UHF propagation

Unclassified-Unlimited

Subject Category 32

Unclassified

NASA RP-1274

138

A07

Unclassified

Unclassified

Unclassified

Standard Form 298 (Rev 2-89)
Prepared by ANSI Std 298-102

NASA-Langley, 1992