

APPENDIX C: PATH LOSS DISTRIBUTIONS

Figures C-1 through C-26 show the path loss distributions for a selection of residential and high-rise buildings. In each LOS caption, the free-space path loss is calculated for comparison.

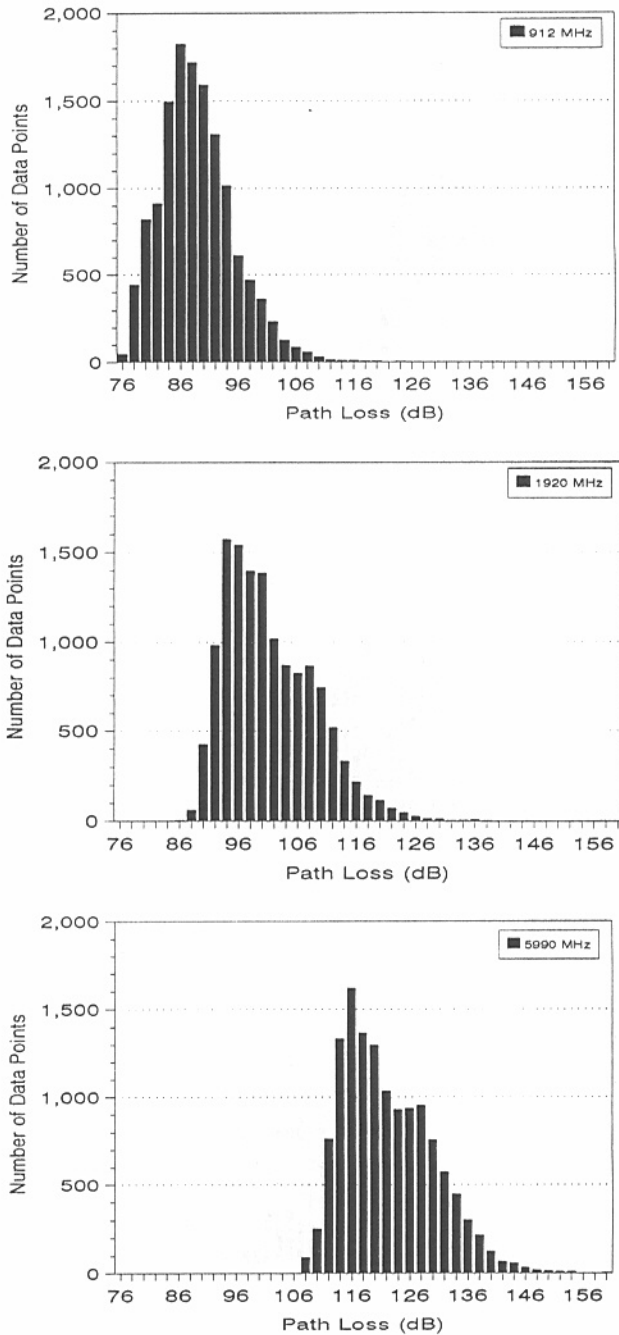


Figure C-1. Path loss distribution for residence 1, LOS. Free-space path loss: 68, 75, and 85 dB at 912, 1920 and 5990 MHz, respectively.

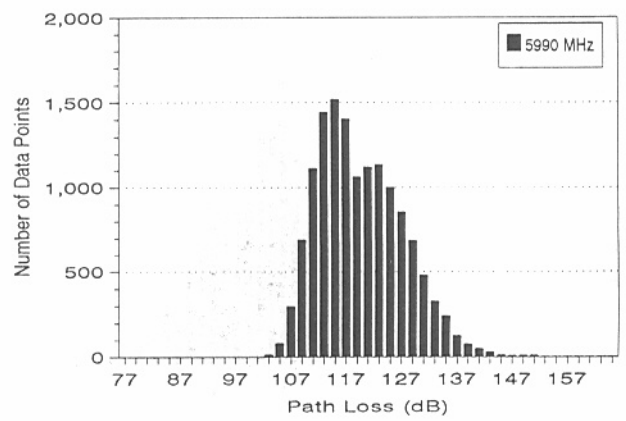
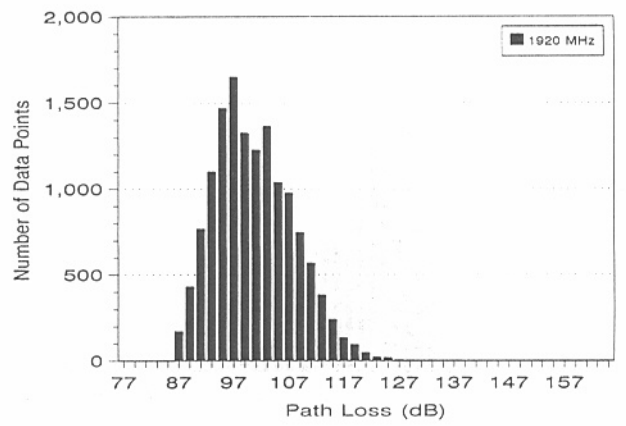
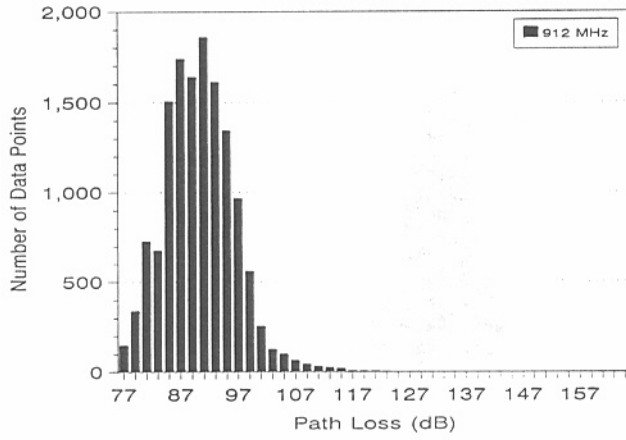


Figure C-2. Path loss distribution for residence 1, NLOS.

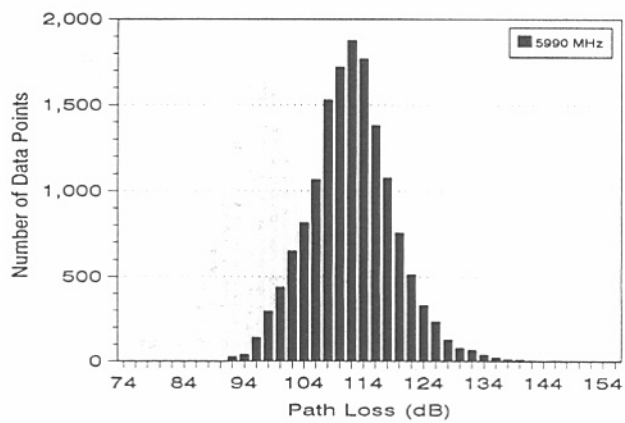
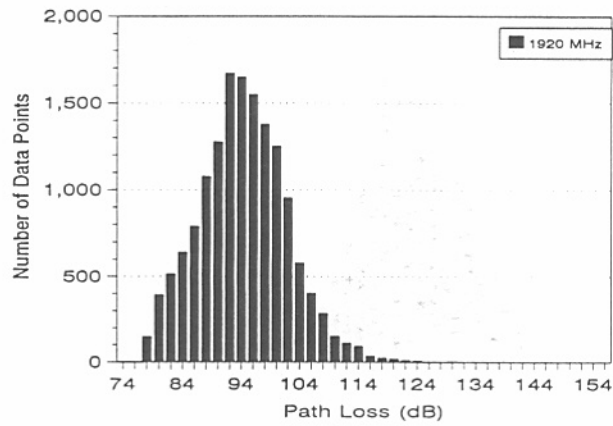
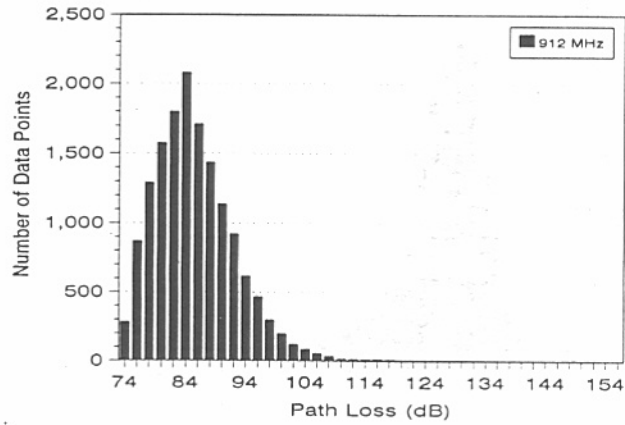


Figure C-3. Path loss distribution for residence 2, LOS. Free space path loss: 71, 77, and 87 dB for 912, 1920 and 5990 MHz, respectively.

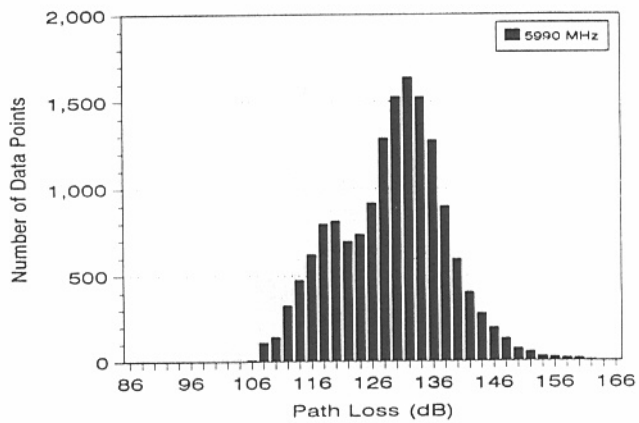
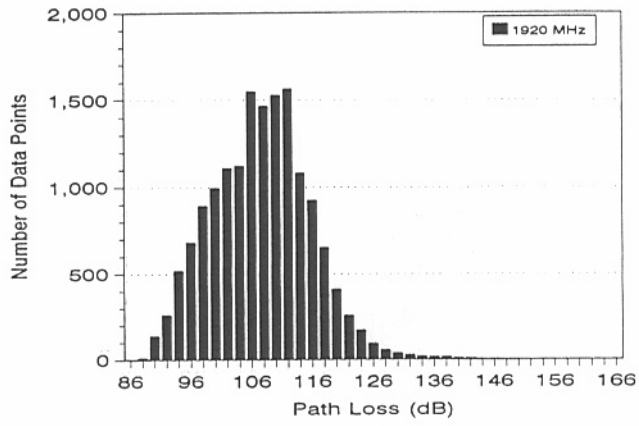
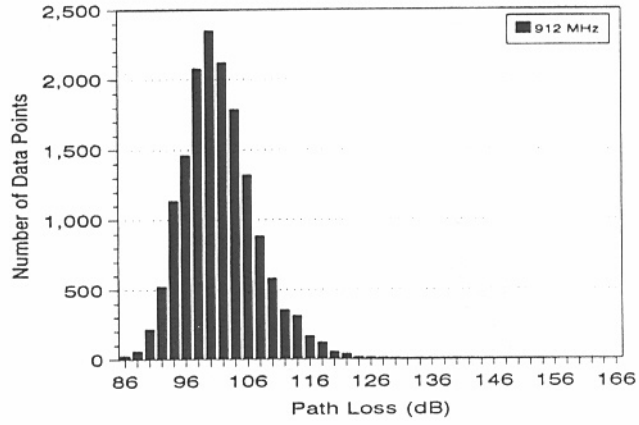


Figure C-4. Path loss distribution for residence 2, NLOS.

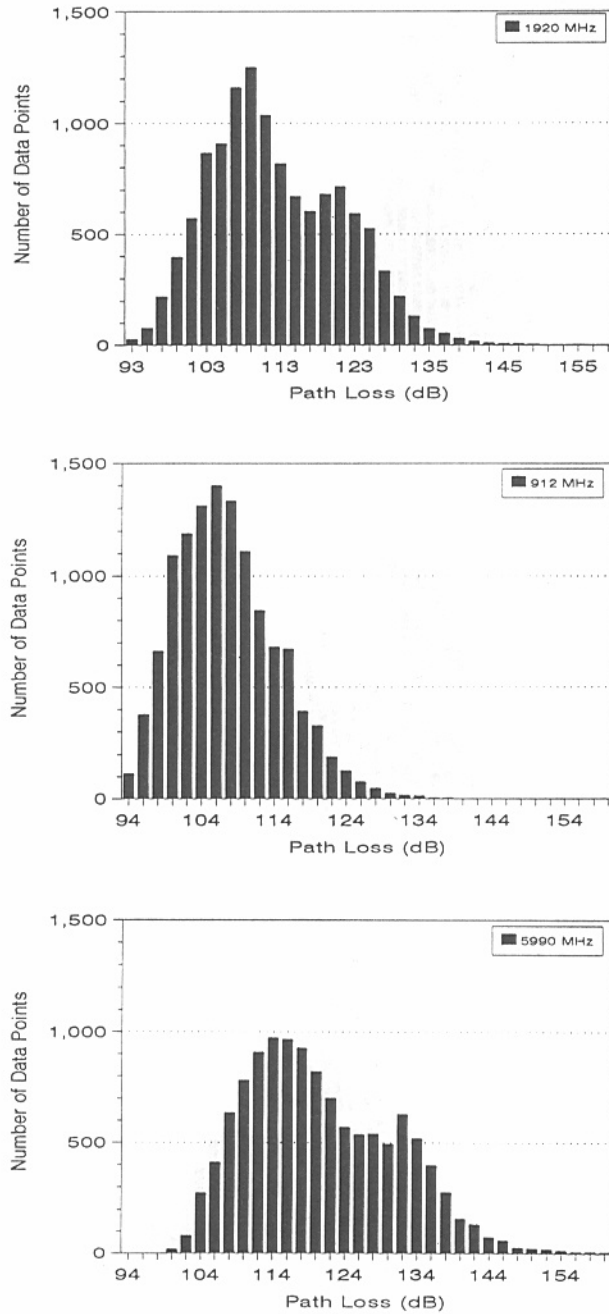


Figure C-5. Path loss distribution for residence 3, LOS. Free-space path loss: 70, 76 and 86 dB for 912, 1920 and 5990 MHz, respectively.

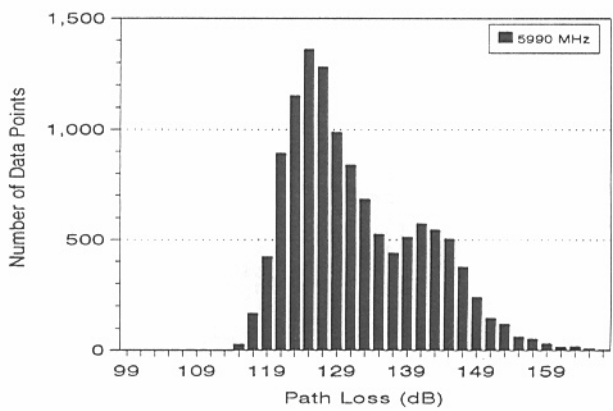
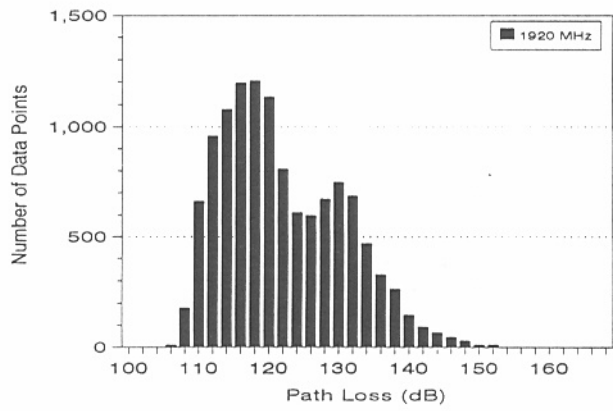
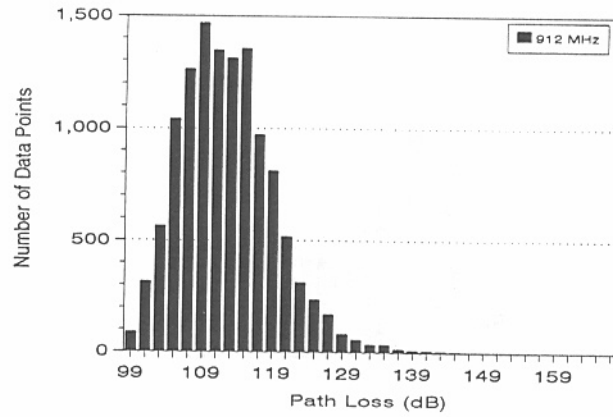


Figure C-6. Path loss distribution for residence 3, NLOS.

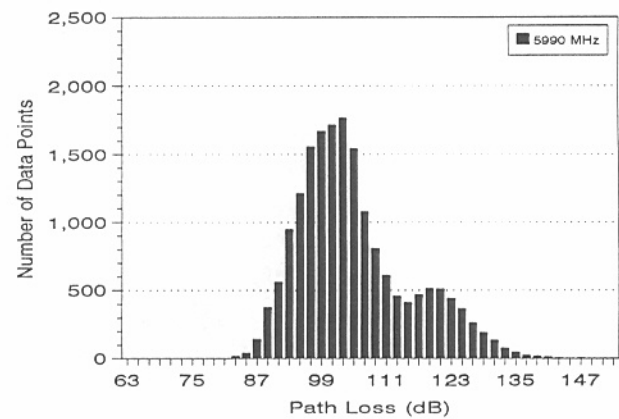
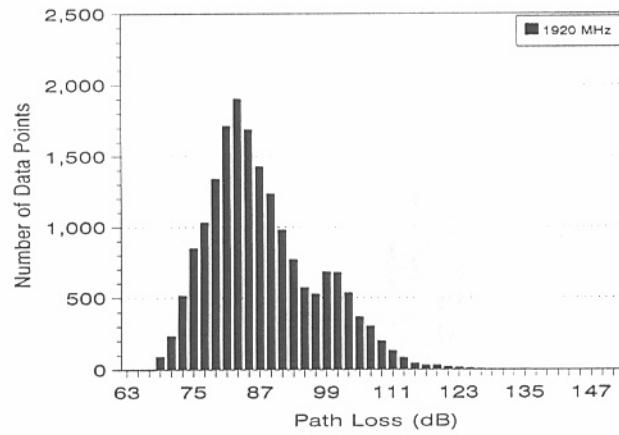
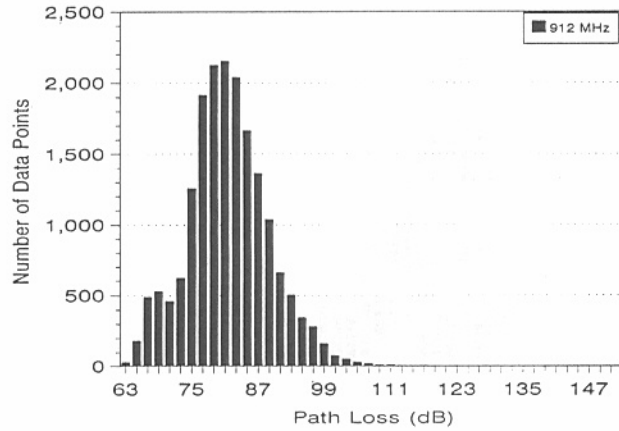


Figure C-7. Path loss distribution for residence 5, LOS. Free-space path loss: 66, 73 and 82 dB at 912, 1920 and 5990 MHz, respectively.

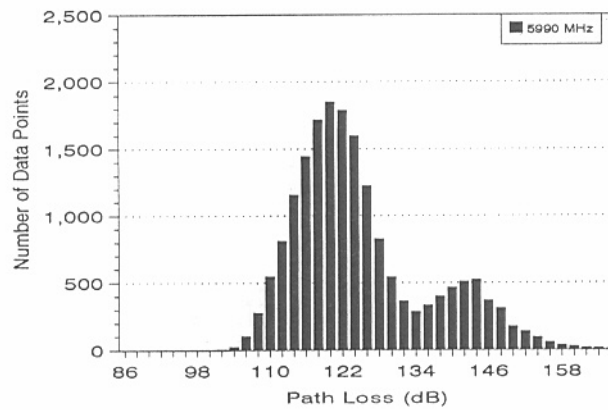
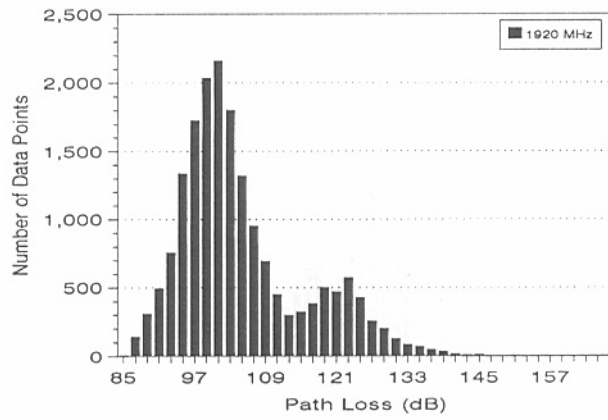
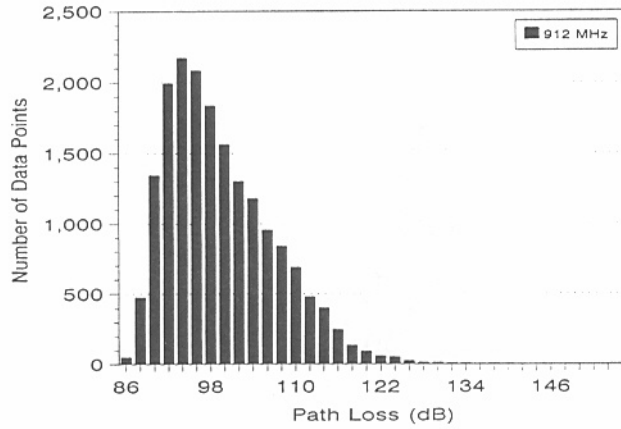


Figure C-8. Path loss distribution for residence 5, NLOS.

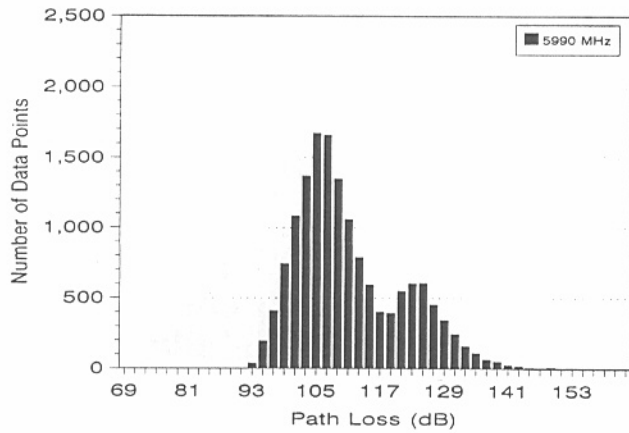
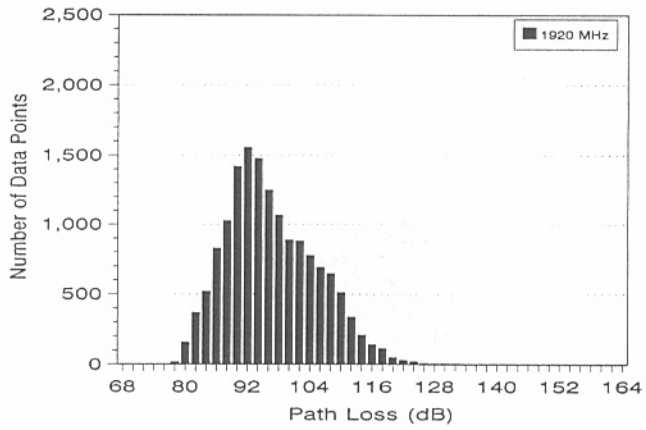
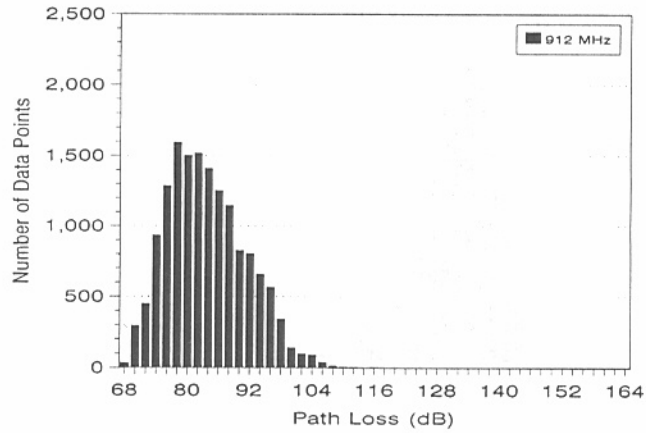


Figure C-9. Path loss distribution for residence 7, LOS. Free-space path loss: 70, 77 and 87 dB at 912, 1920 and 5990 MHz, respectively.

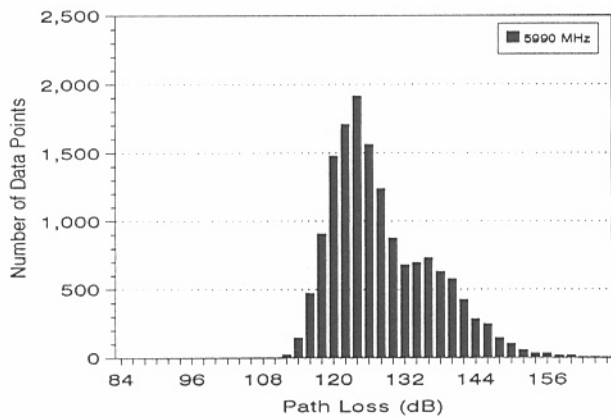
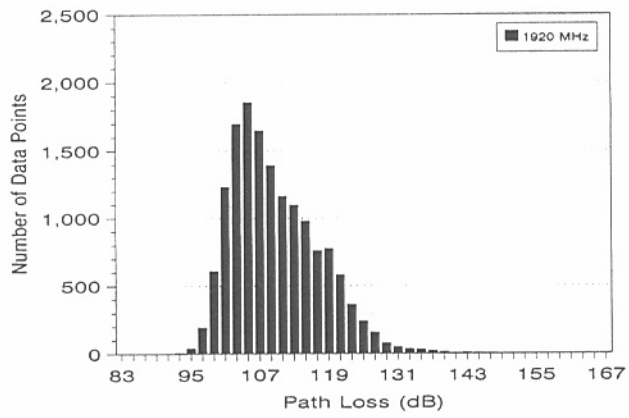
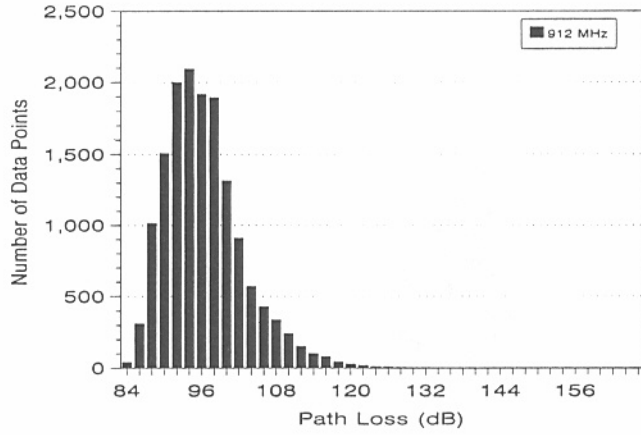


Figure C-10. Path loss distribution for residence 7, NLOS.

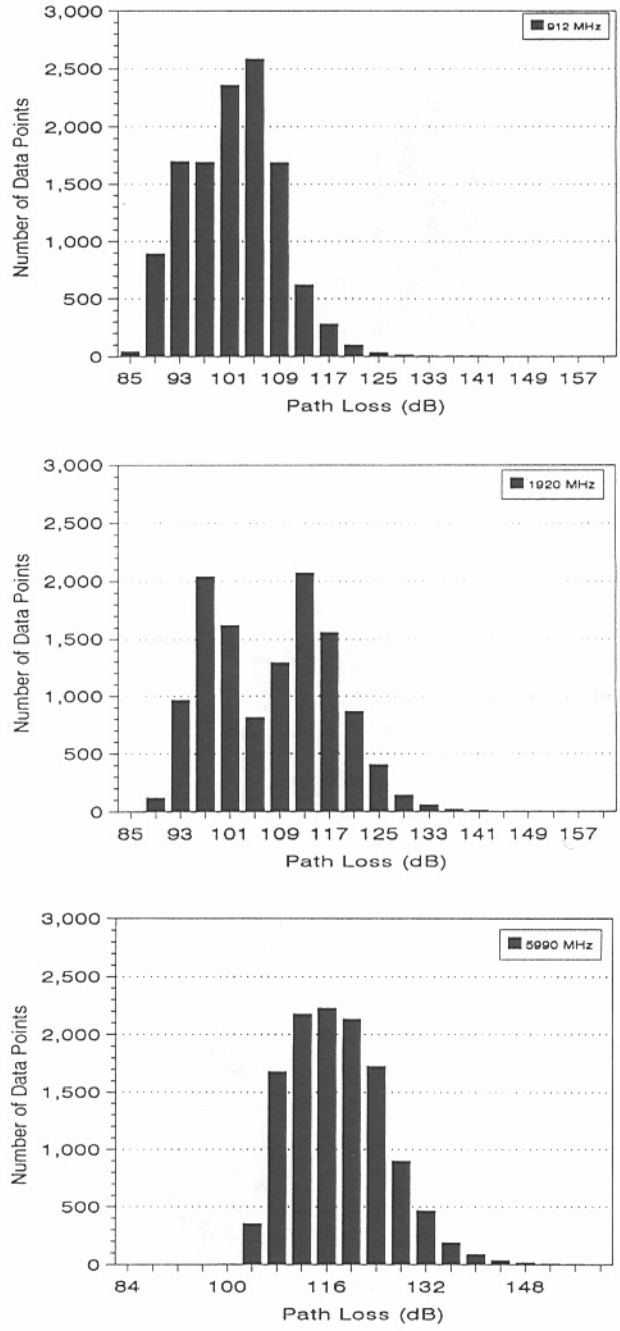


Figure C-11. Path loss distribution for high rise 1, floor 1, LOS. Free-space path loss: 72, 78 and 88 dB at 912, 1920 and 5990 MHz, respectively.

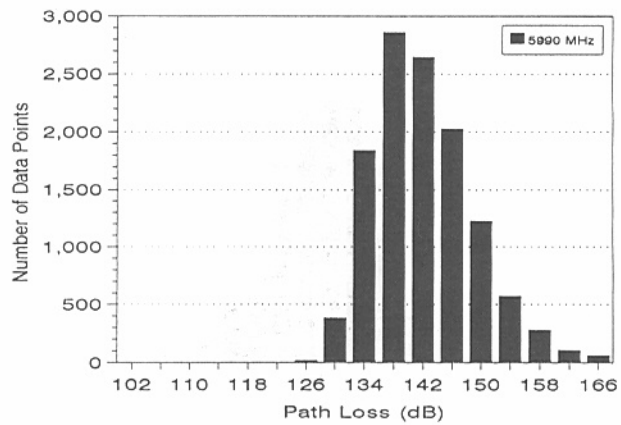
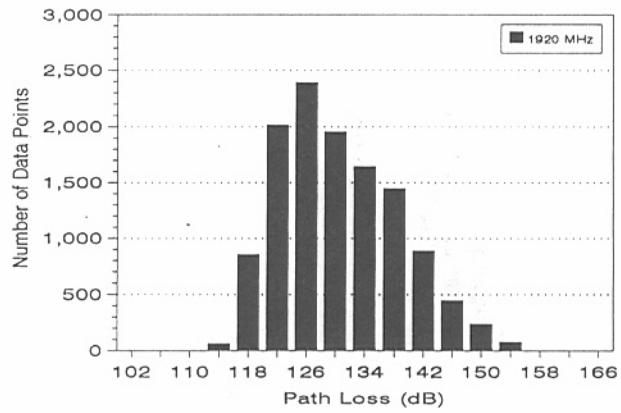
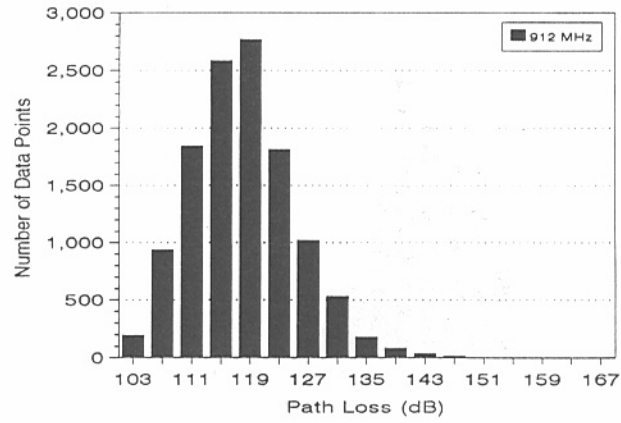


Figure C-12. Path loss distribution for high rise 1, floor 1, NLOS.

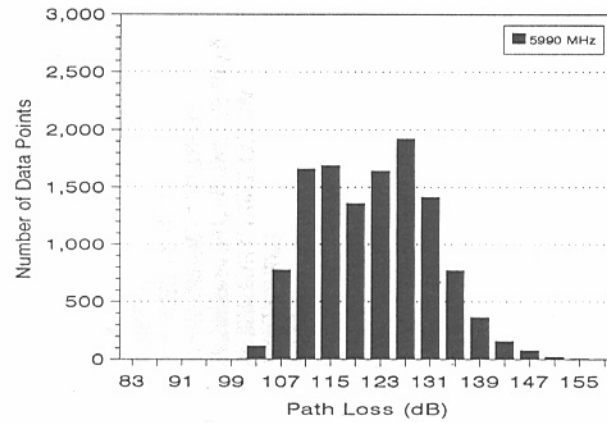
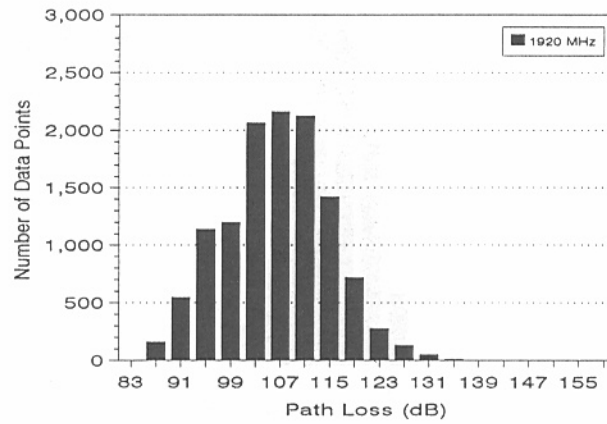
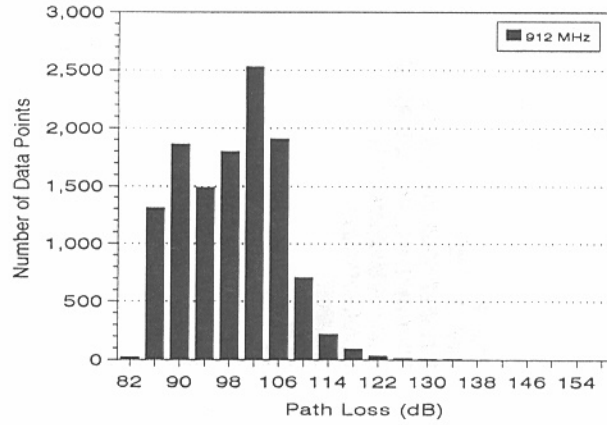


Figure C-13. Path loss distribution for high rise 1, floor 9, LOS. Free-space path loss: 72, 79 and 89 dB at 912, 1920 and 5990 MHz, respectively.

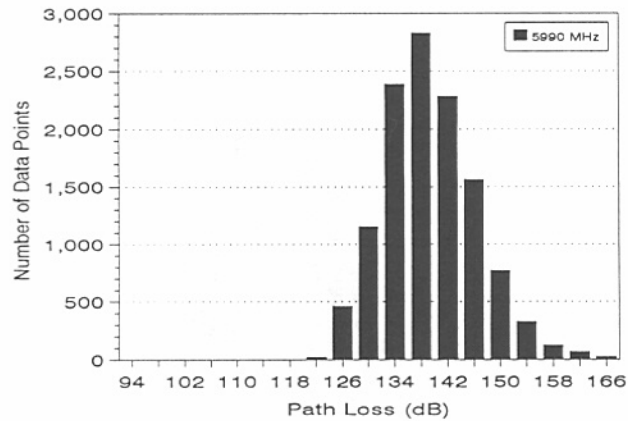
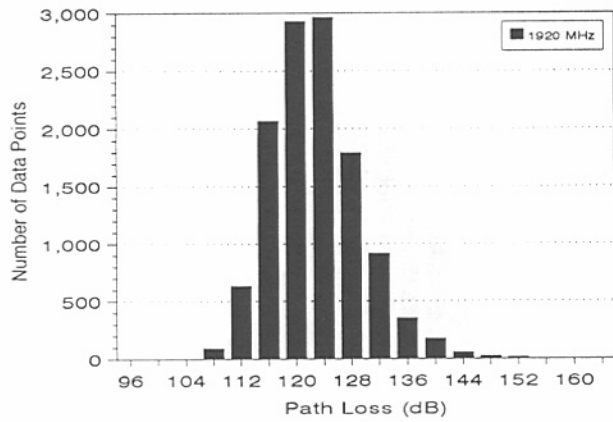
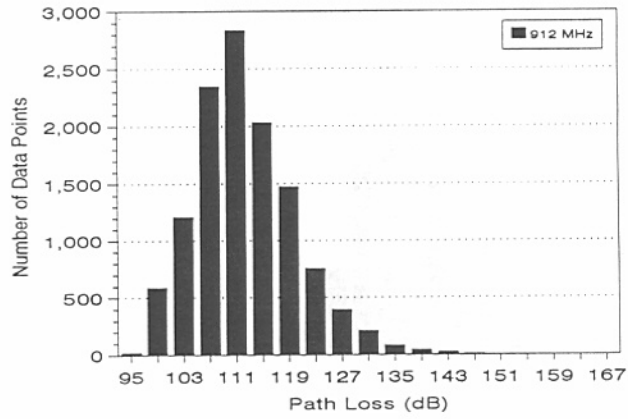


Figure C-14. Path loss distribution for high rise 1, floor 9, NLOS.

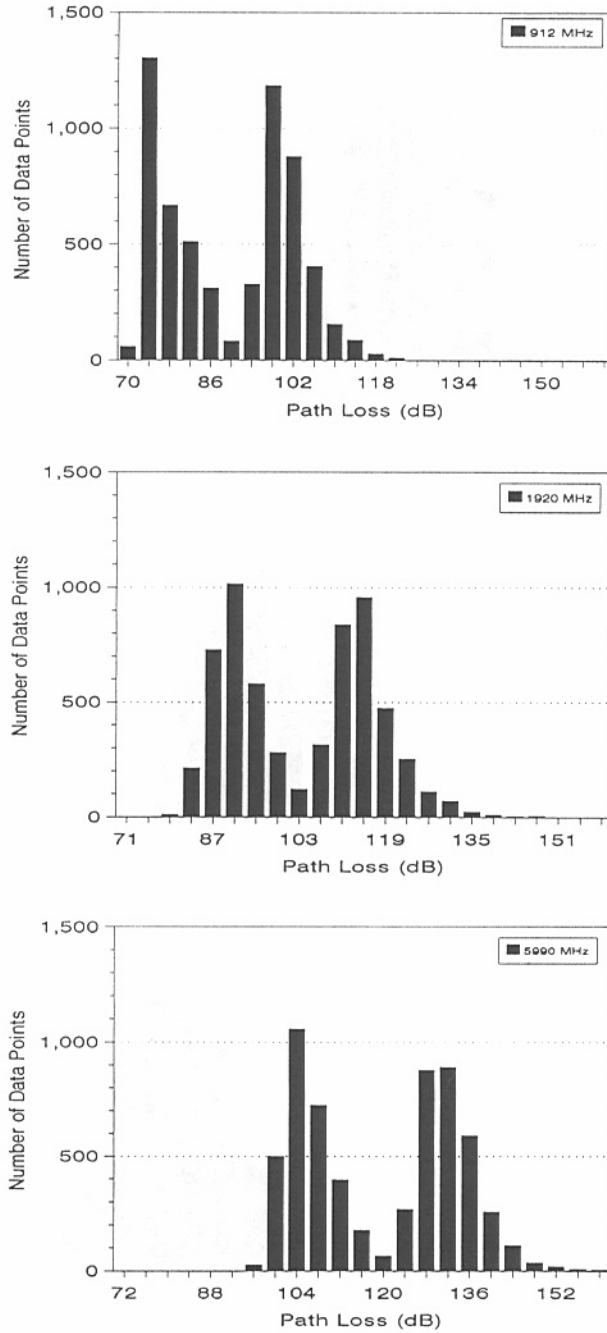


Figure C-15. Path loss distribution for high rise 2, floor 1, LOS. Free-space path loss: 72, 78 and 88 dB at 912, 1920 and 5990 MHz, respectively.

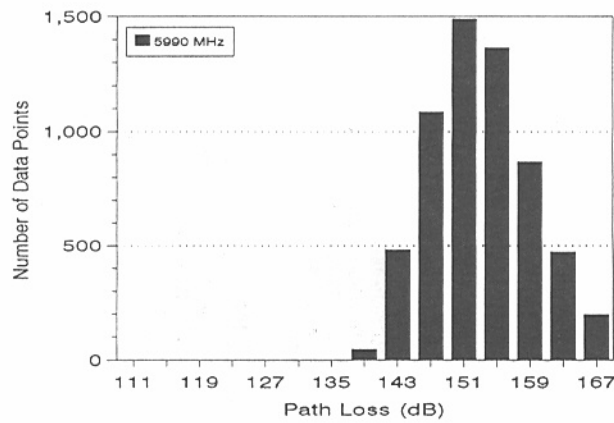
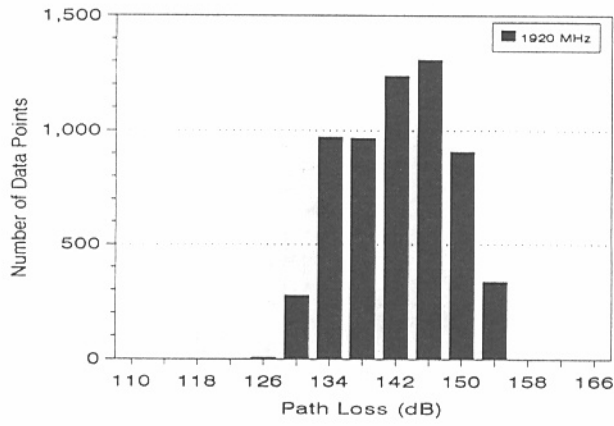
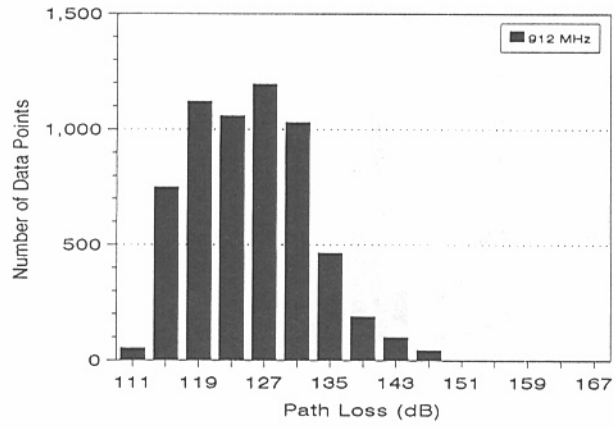


Figure C-16. Path loss distribution for high rise 2, floor 1, NLOS.

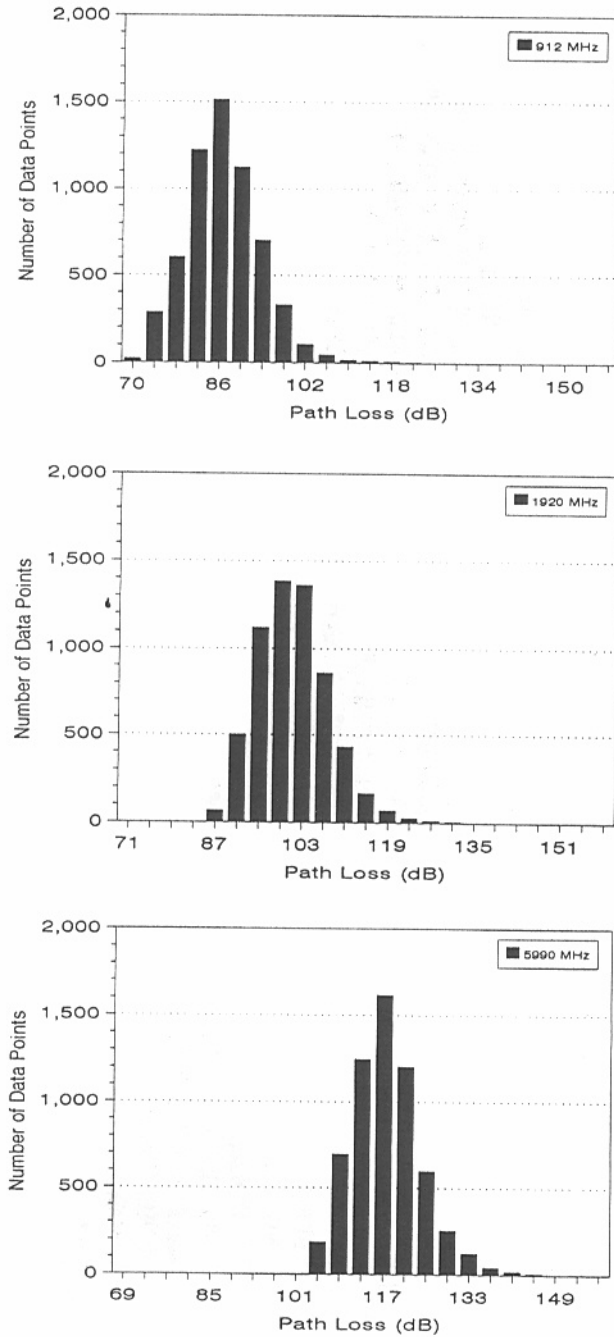


Figure C-17. Path loss distribution for high rise 2, floor 11, LOS. Free-space path loss: 75, 81 and 91 at 912, 1920 and 5990 MHz, respectively.

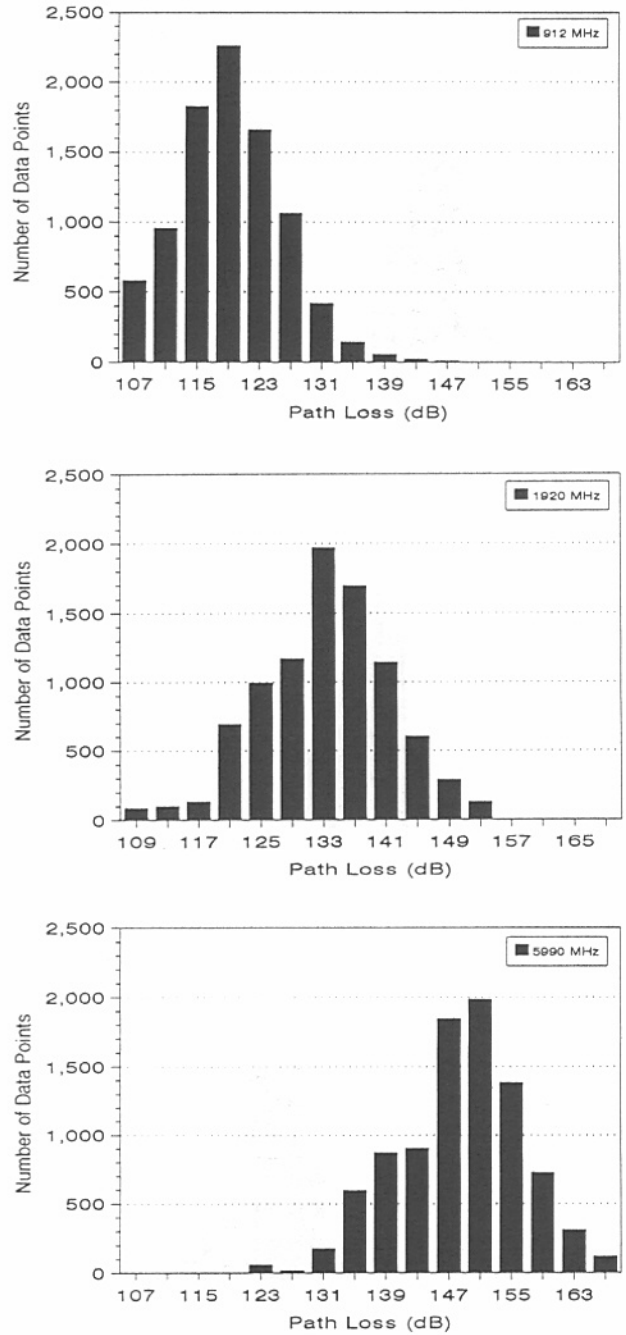


Figure C-18. Path loss distribution for high rise 2, floor 11, NLOS.

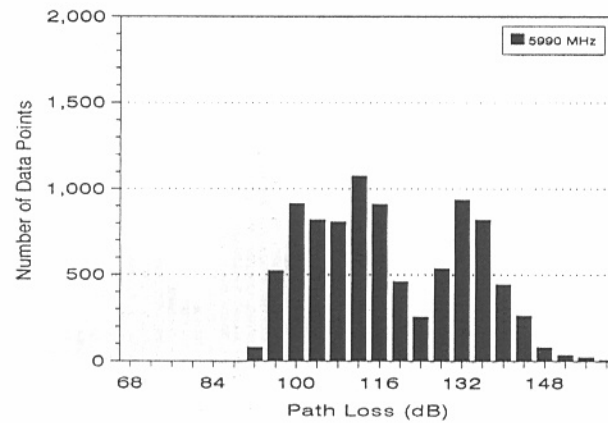
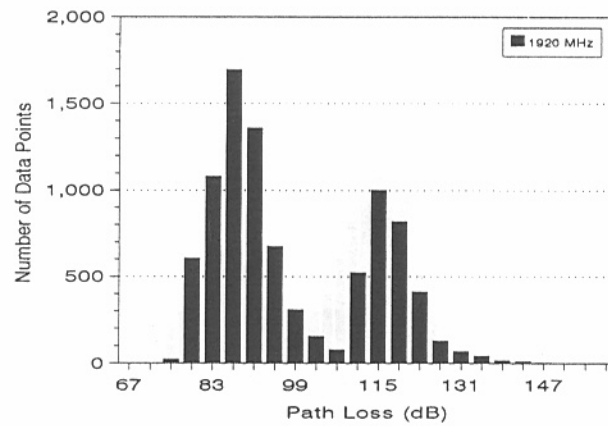
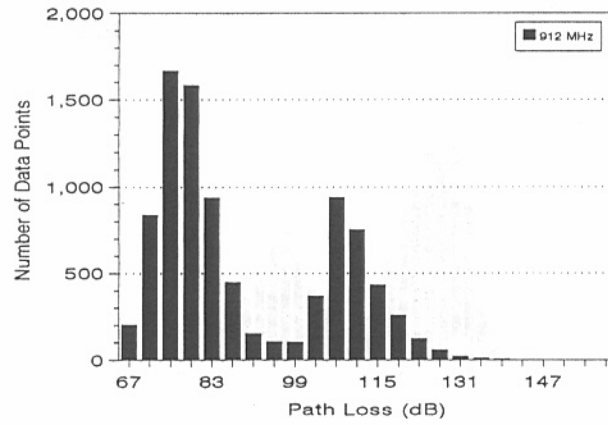


Figure C-19. Path loss distribution for high rise 3, floor 1, LOS. Free-space path loss: 69, 76 and 86 dB at 912, 1920 and 5990 MHz, respectively.

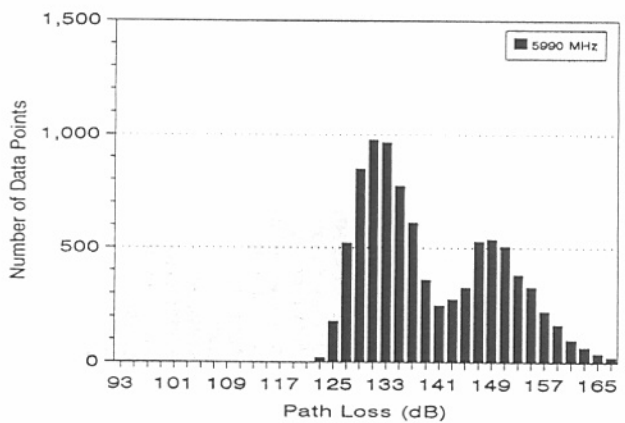
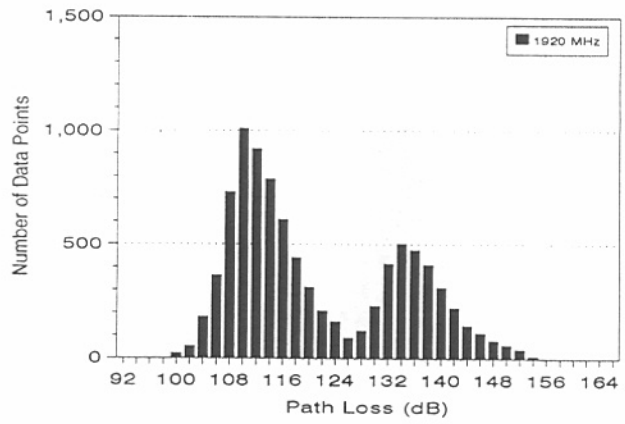
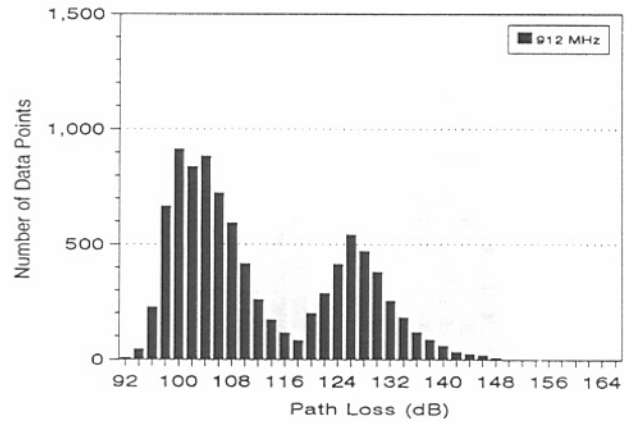


Figure C-20. Path loss distribution for high rise 3, floor 1, NLOS.

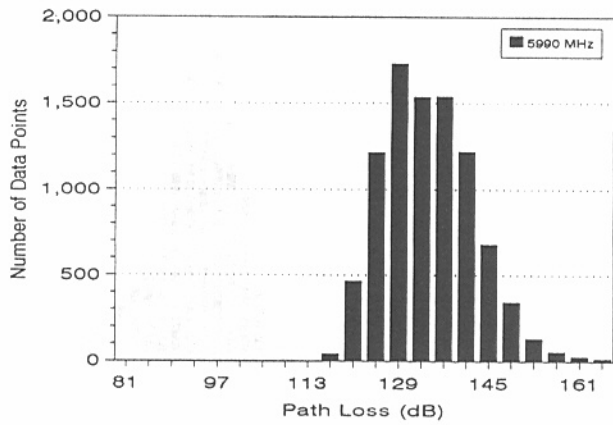
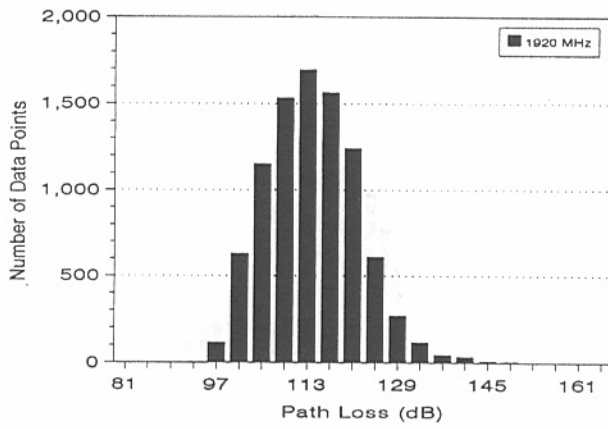
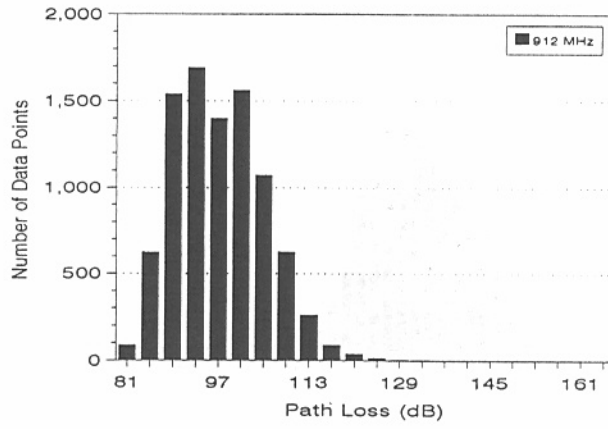


Figure C-21. Path loss distribution for high rise 3, floor 11, LOS. Free-space path loss: 74, 80 and 90 dB at 912, 1920 and 5990 MHz, respectively.

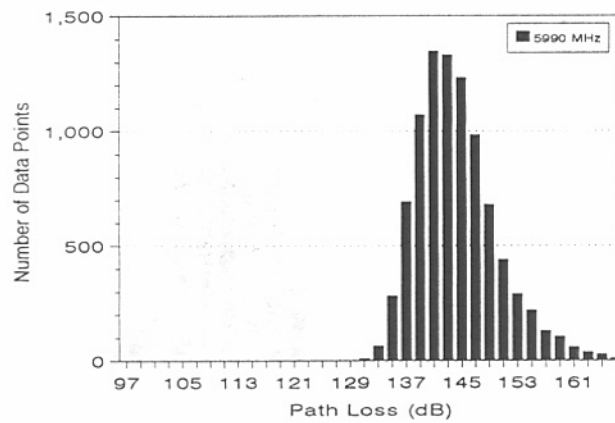
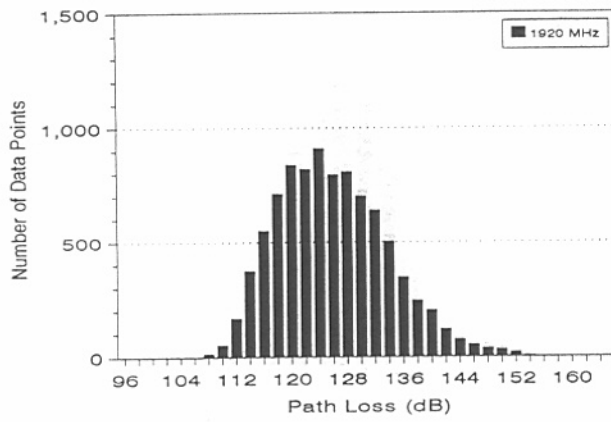
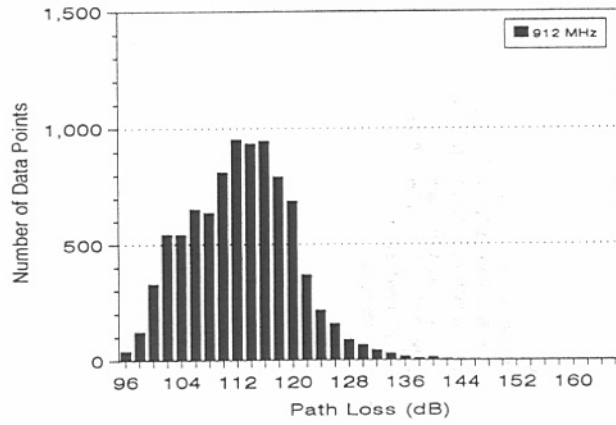


Figure C-22. Path loss distribution for high rise 3, floor 11, NLOS.

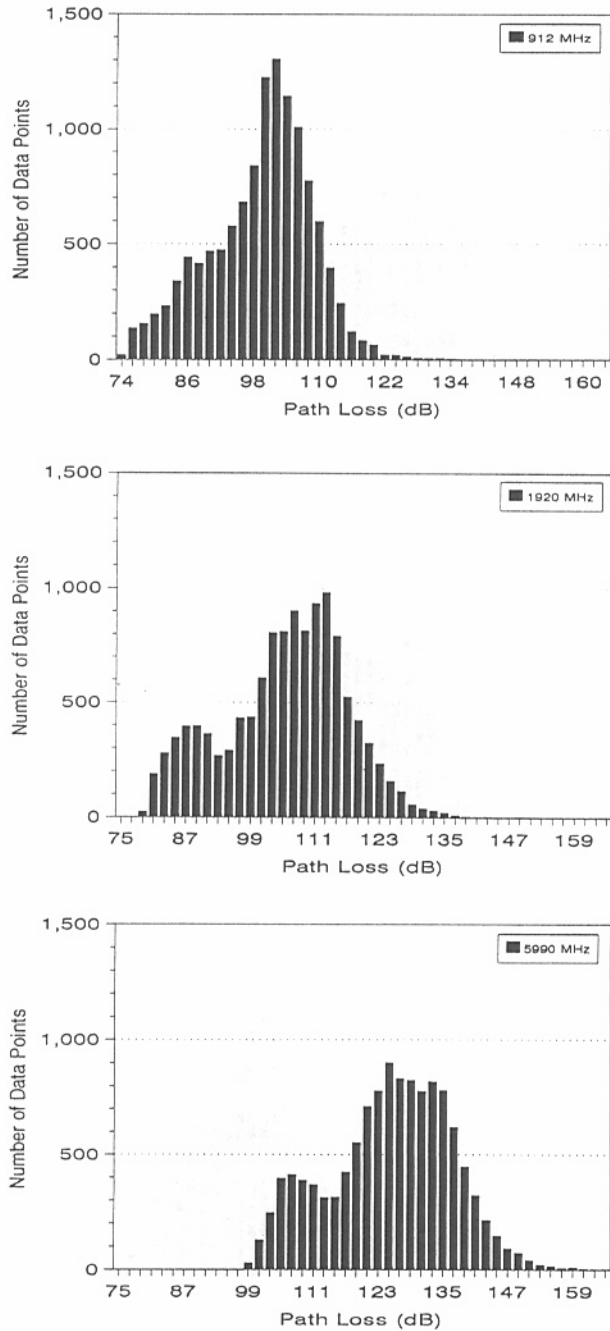


Figure C-23. Path loss distribution for high rise 4, floor 3, LOS. Free-space path loss: 77, 83 and 93 dB at 912, 1920 and 5990 MHz, respectively.

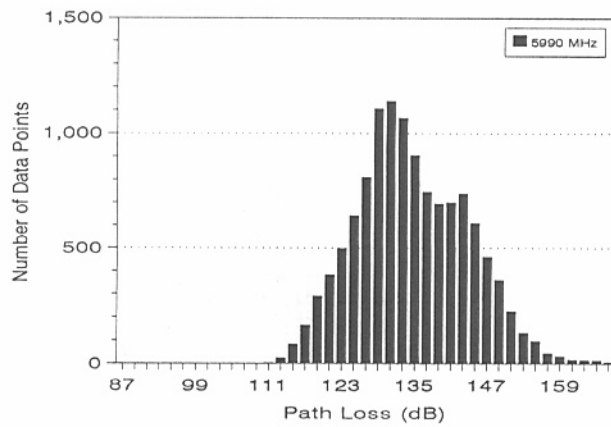
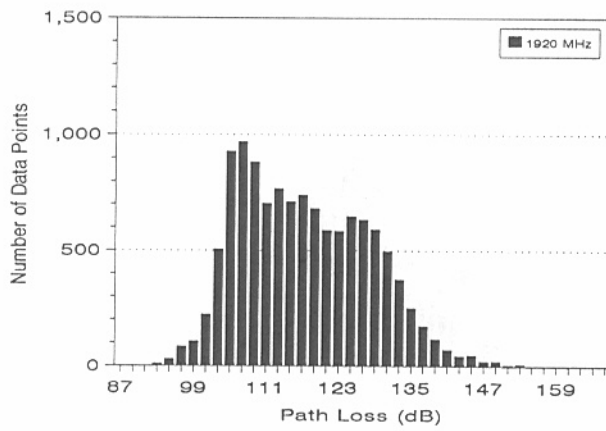
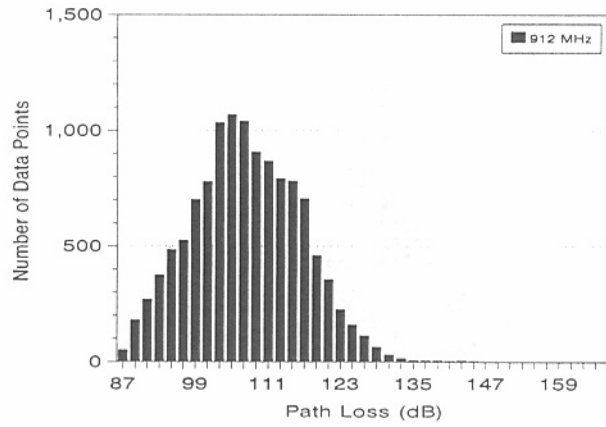


Figure C-24. Path loss distribution for high rise 4, floor 3, NLOS.

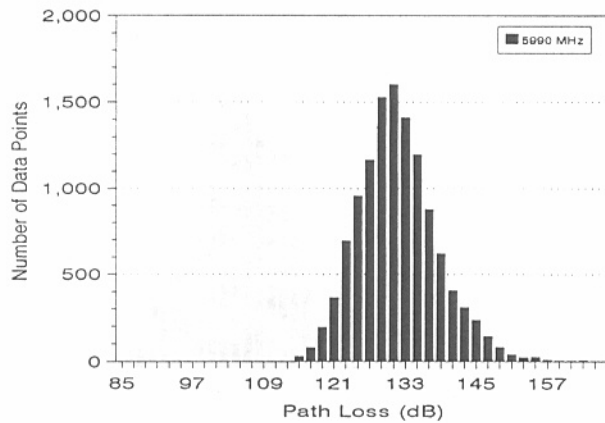
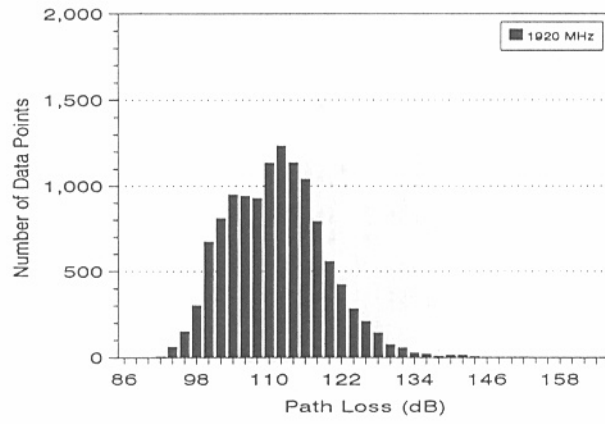
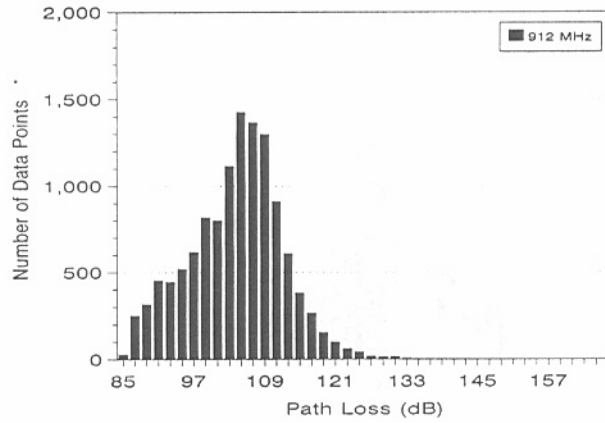


Figure C-25. Path loss distribution for high rise 4, floor 15, LOS. Free-space path loss: 77, 83, 93 dB at 912, 1920 and 5990 MHz, respectively.

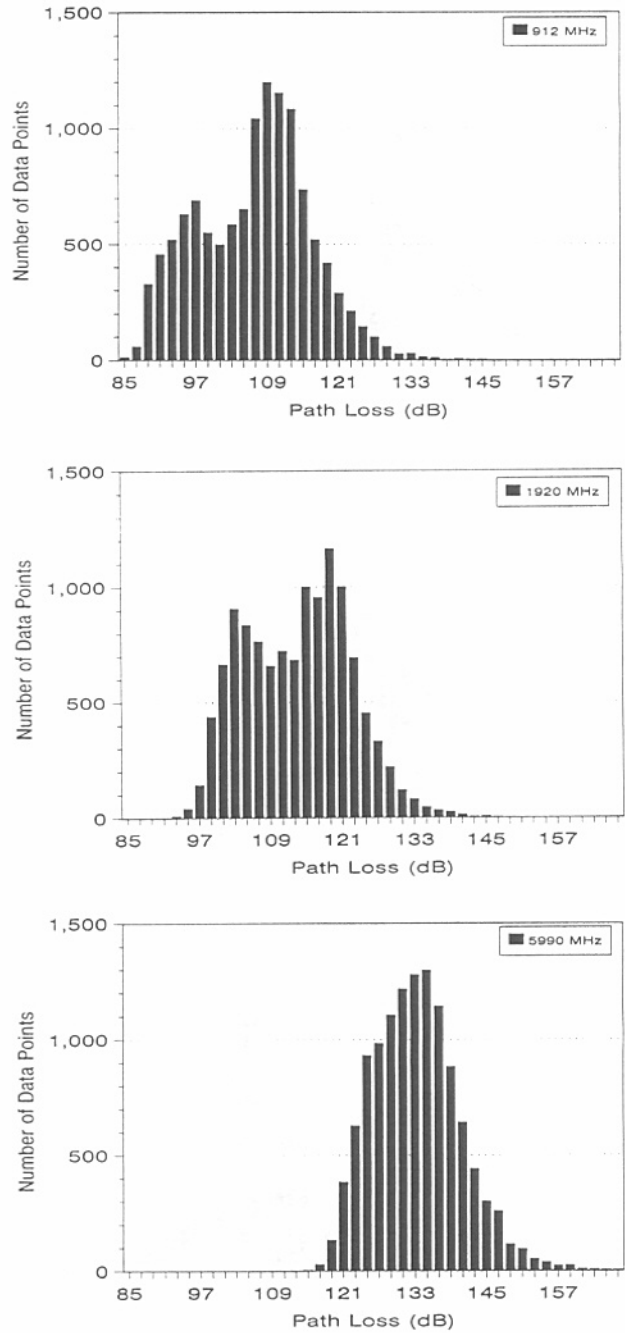


Figure C-26. Path loss distribution for high rise 4, floor 15, NLOS.

APPENDIX D: BUILDING PENETRATION LOSS DATA

The following tables show the calculated penetration losses for the residential and high-rise buildings measured.

Table D-1. Mean LOS Penetration Losses for Each Residence

Frequency (MHz)	Residence	Mean Loss (dB)	σ (dB)
912	1	6.3	6.3
	2	4.9	6.6
	3	8.1	7.1
	4	4.6	6.6
	5	9.2	7.4
	6	9.0	7.2
	7	9.1	7.6
1920	1	7.0	7.4
	2	8.3	7.5
	3	12.4	8.9
	4	6.7	7.9
	5	11.1	9.8
	6	9.9	10.2
	7	12.5	8.7
5990	1	10.7	7.7
	2	9.3	7.1
	3	18.5	10.3
	4	14.1	9.1
	5	16.6	10.4
	6	13.2	10.8
	7	17.9	9.9

Table D-2. Mean NLOS Penetration Losses for Each Residence

Frequency (MHz)	Residence	Mean Loss (dB)	σ (dB)
912	1	6.1	6.1
	2	2.9	6.0
	3	5.8	6.6
	4	6.4	6.2
	5	10.5	7.6
	6	7.3	7.3
	7	6.5	6.3
1920	1	8.4	6.9
	2	3.6	8.0
	3	12.3	8.6
	4	9.8	6.4
	5	11.8	10.5
	6	8.9	8.7
	7	11.6	7.5
5990	1	10.2	7.4
	2	11.5	9.0
	3	18.5	9.4
	4	12.5	7.5
	5	11.8	11.0
	6	13.4	9.3
	7	13.6	8.5

Table D-3. Mean Penetration Losses for All Residences (Calculated From Tables D-1 and D-2)

Path	Frequency (MHz)	Mean Loss (dB)
LOS	912	6.9
NLOS		6.0
Both		6.4
LOS	1920	8.3
NLOS		8.4
Both		8.4
LOS	5990	11.1
NLOS		12.5
Both		11.7

Table D-4. Mean LOS Penetration Losses per Floor for Each Residence

Residence	Frequency (MHz)	Mean Loss (dB)		
		Ground Floor	Second Floor	Basement
1	912	5.7		12.9
	1920	6.0	N/A	17.8
	5990	9.5		21.8
2	912	3.8	7.2	
	1920	6.7	13.4	N/A
	5990	7.8	13.7	
3	912	7.1		15.3
	1920	11.2	N/A	27.5
	5990	17.3		36.7
4	912	5.5		
	1920	6.7	N/A	N/A
	5990	16.2		
5	912	8.1	9.2	19.9
	1920	10.9	9.5	30.6
	5990	17.6	14.0	38.8
6	912	7.2	9.5	18.1
	1920	7.8	10.5	29.1
	5990	12.8	11.7	35.3
7	912	7.8	8.6	19.6
	1920	11.1	10.1	26.2
	5990	17.2	16.7	37.5
Mean	912	6.5	8.6	15.2
	1920	8.6	10.9	26.2
	5990	14.1	14.0	34.0

Table D-5. Mean Penetration Losses for Each High Rise

Path	Frequency (MHz)	High Rise	Mean Loss (dB)	CJ (dB)
LOS	912	1	17.5	8.8
		2	11.2	9.4
		3	14.4	12.5
		4	7.4	12.1
	1920	1	18.9	9.6
		2	15.4	11.1
		3	16.6	14.5
		4	10.0	14.3
	5990	1	22.7	9.4
		2	19.4	11.0
		3	23.2	14.5
		4	19.0	13.0
NLOS	912	1	14.0	2.2
		2	11.7	4.0
		3	13.9	6.3
		4	8.0	2.5
	1920	1	12.4	3.8
		2	14.8	5.1
		3	20.1	9.0
		4	5.9	1.8
	5990	1	20.9	1.3
		2	19.2	4.3
		3	25.5	8.5
		4	16.4	1.4

Table D-6. Mean Penetration Losses for All High-rise Buildings (Calculated From Table D-4)

Path	Frequency (MHz)	Mean Loss (dB)
LOS	912	11.1
NLOS		11.2
Both		11.2
LOS	1920	13.9
NLOS		10.5
Both		11.9
LOS	5990	20.7
NLOS		19.4
Both		20.0

BIBLIOGRAPHIC DATA SHEET

	1. PUBLICATION NO. 95-325	2. Gov't Accession No.	3. Recipient's Accession No.
4. TITLE AND SUBTITLE Building Penetration Measurements from Low-Height Base Stations at 912, 1920, and 5990 MHZ		5. Publication Date	
7. AUTHOR(S) Lynette H. Loew, Yeh Lo, Michael G. Laflin, Elizabeth E. Pol		6. Performing Organization Code NTIA/ITS	
8. PERFORMING ORGANIZATION NAME AND ADDRESS National Telecommunications and Information Administration Institute for Telecommunication Sciences 325 Broadway Boulder, CO 80303-3328		9. Project/Task/Work Unit No. 5 910 5105	
11. Sponsoring Organization Name and Address		10. Contract/Grant No.	
		12. Type of Report and Period Covered	
		13.	
14. SUPPLEMENTARY NOTES			
15. ABSTRACT (A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here.) Building penetration measurements were taken simultaneously at three potential Personal Communications Services (PCS) frequencies: 912, 1920, and 5990 MHz. The continuous wave (CW) measurement system employed a fixed outdoor transmitter and a mobile indoor receiver. The goal was to quantify building penetration losses at these frequencies to determine the viability of indoor coverage using street microcells and base antenna heights below the roof level of surrounding buildings. Eleven different buildings representing typical residential and high-rise office building environments were used for the measurements. Vertically polarized transmit and receive antennas were used for all measurements. Statistical analyses of the data include mean building attenuation losses, standard deviations, cumulative probability distribution functions, and correlation coefficients. The analyses were used to characterize propagation effects and provide a comparison between three frequencies, two cell environments, and two transmission paths.			
16. Key Words (Alphabetical order, separated by semicolons) attenuation; building attenuation; building penetration; measurements; personal communications services; PCS; penetration characteristics; penetration loss; radio propagation			
17. AVAILABILITY STATEMENT <input checked="" type="checkbox"/> UNLIMITED. <input type="checkbox"/> FOR OFFICIAL DISTRIBUTION.		18. Security Class. (This report) Unclassified	20. Number of pages 123
		19. Security Class. (This page) Unclassified	21. Price: