fading or truck shadowing rather than average signal strength reduction triggered a handoff from the Origin Base to the Destination Base. Depending on traffic conditions, handoff in this zone occurred as early as Sixth Ave, but more typically occurred on the west side of Seventh. In this area, one could experience audible noise in an FOM2 or 3 environment for 250 milliseconds to 750 milliseconds just before handoff, and then excellent quality would again return to the link upon handoff to the Destination Base.

The route continued for just a short distance to Eighth Ave, with excellent (FOM1) signal quality from the handoff zone until the handset disappeared from LOS on 55th to Eighth Ave north, where a handoff similar to that conducted at 47th & Madison and Madison & 55th, that is, minimal audio detection of the handoff in a fast shadow fading environment.

The remainder of the route was a repeat of one of these two types of scenarios: A) Solid link with virtually no audible detection of handoff due to significant differences in Received Signal Strength (RSS) levels and Frame Error Rates (FER's) between the original and destination Base Stations, or B) Solid link with a 250 - 800 millisecond period during which intermittent packet muting occurred just before a handoff.

In order to further test how Omnipoint's handoff algorithms function in such a dynamic environment (very rapid shadow and multipath fading with wide disparity in simultaneous RSS), the short route was designed to provide a tightly coupled series of required handoffs with a close proximity frequency re-use pattern in the presence of large, rapid shadow fading that is common in an urban canyon environment such as Manhattan.

During the 11 runs of the short route, many of which consisted of more than one loop per run, close to 60 handoff events were initiated. Handoffs universally occur within a half block of each intersection, verifying the algorithm's ability to supply extremely fast handoff in a fast shadowing and multipath environment with minimal audible detection of the handoff function.

NOTE: To put these Omnipoint tests in perspective, repeated attempts were made with an 800MHz cellular phone to traverse the "Long Route" . Not one of the runs was completed without dropping the call. Moreover, the noise level was significant over many areas and frequently other user's conversations were suddenly picked up.

5 Colorado Springs Tests

5.1 Incumbent OFS Coordination

Omnipoint has in the past reported its work in the OFS band in Colorado Springs under its Experimental License, which permits simultaneous operation of up to three Base Stations and 24 Handsets. Work in Colorado Springs has continued under the authority of this License, but has been limited by its operational parameters. While this has provided adequate flexibility and freedom for the tests conducted to date, future test plans include simultaneous operation of up to 70 Base Stations and 200 Handsets in order to perform the same series of tests planned for Manhattan, but in a radically different environment. Therefore, Omnipoint petitioned and received from the FCC a second Special Temporary Authority for the Colorado Springs area.

Omnipoint has undertaken all efforts to assure that its tests pose no interference to incumbent OFS links. As part of this effort, Omnipoint has employed LCC to determine open channels available for test, as well as the locations of co-channel and adjacent channel links in the vicinity of the Colorado Springs test bed.

Using the same criteria detailed in Section 4.1, LCC determined that the 1885, 1915, and 1965MHz channels (OFS Bandwidth = 10MHz) can be considered clear, with the closest user 46 miles away and blocked by a large mountain range.

5.2 Colorado Springs Site Identification and Description

Several sites have been tested in the Colorado Springs area based on the available terrain, the proximity to Omnipoint, and the availability of cell sites. Each network was configured with three to four Base Stations, and less than 24 handsets.

Colorado Springs Configurations

As part of Omnipoint's continuing efforts to conduct technical trials of its developmental efforts in a variety of environments and applications, extensive testing has been undertaken in the semi-urban and suburban environment of Colorado Springs to complement those tests performed

in New York. As part of this effort, 5 types of tests were established, each to meet a different objective:

1. Large, single cell, high speed mobility
2. Large, two cell with handoff, high speed mobility
3. Large, three cell with handoff, high speed mobility
4. Large, three cell, medium to high speed loop, with handoff
5. Large, four cell, medium to high speed loop and complete low speed residential coverage, with handoff

Rather than conduct tests in an artificially unchallenging RF propagation environment such as flat or gently sloped test area with Base Station transmitters placed high for easy RF signal access to mobile units, Omnipoint's objectives of this series of tests were to test in as near to real world environments as possible, with incumbent real-world logistical, regulatory, cost, technical and especially zoning hurdles. This would allow for proof of the Omnipoint concept of very low cost infrastructure for a PCS service. In order to meet these rigorous goals, reasonably characteristic, variable terrain test zones were selected. In light of the hardware restrictions mandated under the original Experimental License, logistical concerns for selecting sites in close proximity to the Omnipoint labs were also taken into account.

1. Large cell, high speed tests - In order to demonstrate the Omnipoint system's ability to provide large cell architecture ("large" at 1.9GHz consists of cells in excess of 1 mile radii), complete with high speed mobility and handoff, a multi-cell configuration was established along the Interstate 25 adjacent to the Omnipoint facility. The particular area selected includes significant elevation changes as well as serpentine turns, and includes bridges and buildings along the route, adding to the complexity of the project. Three sites (Configurations summarized in Table 5-1) were chosen with -85dBm average RSS test handoff operations:

a) Omnipoint lab facilities ("Omnipoint Site") - The first cell site is installed in the three floor facility housing the Omnipoint Corporate Headquarters at the intersection of I-25 and Woodmen Avenue, and is representative of a typical multistory, mid-sized office facility. The structure is a five year old, three story Class A multiple tenant office building with interior walls consisting of typical drywall-on-steel-stud office construction. Besides the structural steel

framework, the exterior is covered with glass all around, with a pre-cast aggregate facie between windows. The building is separated into two wings of approximately 24,000 square feet each with a common area linking them. The Base Station of this cell is installed in mechanical penthouse of the facility, with antenna mounts at a height of approximately 40 feet AGL on the penthouse roof. The antenna configuration employs universal mounts, which allow for a wide variety of antenna options (See Table 5-3).

b) Intersection of Nevada & I-25 ("Nevada Site") - The second site, approximately 1.5 miles south of and non-LOS to the Omnipoint Site, is located near the on-ramp of Nevada Avenue to I-25, and consists of a Base Station and two 3dBd antennas mounted at 25' AGL (standard telephone pole height), separated in the horizontal plane by approximately 48 inches. A large dirt berm separates this site from line of sight to the Omnipoint antennas, and the support pole is installed in the parking lot of a small industrial park.

c) Point of the Pines Blvd. - ("Sunbird Site") - The third site is located approximately 1.1 miles southwest of the Nevada Site atop a 50 foot bluff adjacent to I-25. The Base Station and 3dBd antennas are mounted on a custom antenna stand at approximately 6 feet AGL.

Table 5-1
High Speed, Multi-Cell Base Station Configuration

	Site	F_c (MHz)
1.	Omnipoint	1915
2.	Nevada	1885
3.	South	1965

2. Large Cell, Medium and Low Speed Tests - The Omnipoint Site, and all Base Stations used in these tests, provide a cell with a maximum TDD structure of 1.7 miles in radius. (This is being expanded to 9.2 miles or larger in the next version.) In order to focus on an area for detailed testing, the northeast quadrant was selected, and limited specifically to that area bounded by Academy Blvd. on the East, Woodmen Road on the South, and I-25 on the west and north, a service area which contains a residential area of 168 homes, 4 hotels, 22 businesses of varying sizes, and two shopping centers. The neighborhood adjacent to Omnipoint within this sector supplies the requisite real-world target coverage area, as well as being convenient.

It should be noted that the terrain within this area is highly variable and rises and falls above and below the antenna heights at the cells sites. There is approximately one hundred feet of elevation difference between the Omnipoint Site and the high point of the neighborhood, with zones of rise and fall in between. In addition, the neighborhood is very well established; and therefore is filled with large man-made obstacles to accompany the already dense foliage from the native trees. For example, the residence on Reed Street (Site of the Reed/Woodmen Base Station installation) has been isolated from traffic noise on Woodmen Road by construction of a large dirt berm, which, in conjunction with the large native trees creates a difficult RF propagation environment. This site is not an isolated incidence of blockage for the neighborhood. All areas are bordered by housing structures, hills, and trees of varying sizes, surpassing the Omnipoint Site in height, and many houses are almost totally blocked by the trees and terrain that make up the streets.

Three Base Station sites were initially chosen based on propagation tests performed by LCC. Note: The coverage plots shown are for 3 Base Stations,(See Figures 2-1, 2-2, and 2-3). However, after a series of tests were performed , a fourth micro Base Station was added later to fill a particularly difficult coverage area in the neighborhood. For these four sites, installations consist of a Base Station and antennas mounted at a maximum of 30' AGL (due to local CC&R restrictions), and separated in the horizontal plane by approximately 48 inches. Composite analysis was performed on four base locations based on drive and walk routes. The summary of the four sites for the residential area is defined in Table 5-2.

Table 5-2

Low/Medium Speed, Multi-cell Neighborhood Base Station Configuration

	Site	F_c (MHz)
1.	Omnipoint	1915
2.	Cragin & Academy	1965
3.	Reed & Woodmen	1885
4.	Murdoch & Collins	1965

Base Station Configurations

All of the Base Stations employed in the Colorado Springs tests are operated with the following parameters:

Table 5-3

Colorado Springs Base Station Configurations

Transmit Power	0.1 W (20dBm)
Radiation Center	25', pole mounted
Antennas (except Omnipoint)	8dBd Omnidirectional
Antennas (Omnipoint)	0dBd, 3dBd, 8dBd, 15dBd
Effective Radiated Power(ERP):	0.1 W to 3.2 W

5.3 Test Description & Results

Signal Strength Tests

Extensive signal strength measurements at each site were performed in conjunction with LCC. See attached RSS maps for north Colorado Springs. Cell sites were chosen to provide average RSS coverage of -85dbm to -95dbm.

Link Quality Tests

Five separate series of tests (Three "Freeway", two "Neighborhood") have been conducted, each with unique objectives. The Freeway tests included subjective drives where

Figure of Merit scores were given as a function of location, and included handoff, propagation characteristic, and limited Frame Error Rate testing for calibration of numerical comparisons to perceived signal quality.

In the Neighborhood series, tests were repeatedly performed at each site to obtain Figure of Merit scores as a function of location in a stand-alone configuration as well as in a multi-cell architecture on a system basis, where routes were traversed in vehicles as well as on foot, testing audio quality, handoff, and propagation characteristics.

Test Series No. 1: Large Single Cell, High Speed Mobility

The objective of the first test is to determine system performance at high speeds in fast Rayleigh fading conditions within a single cell, without the use of equalizers or combining diversity. For these tests, only the Omnipoint Site used an active Base Station.

For this test, the mobile was transported to the furthest public access point on the Air Force Academy grounds to the north of the Omnipoint Site at the entrance to I-25. Calls were placed from the Handset to the Base Station, and vice-versa with FOM, and Frame Error Rate tests. As the vehicle accelerated from the starting point and onto I-25 to 65mph, a full duplex link was maintained and real-time FER data taken. The test vehicle made its way south on I-25 until it entered a deep dip in the highway (at approximately 2.6 miles) where the multi-cell configuration would normally hand-off, and the signal was lost. At this point, the FER test was terminated, and data accumulated. The test vehicle would then repeat this process, starting from the south and heading north on I-25. FER data was accumulated over the entire distance of the test and, averaged over test series, resulted in a 1.09% average Frame Error Rate, again without the use of equalization or combining diversity techniques (combining diversity will be implemented in future tests). FOM data shown in Figure 2-4 also shows coverage for Base 1. It can be seen that excellent link quality is provided over almost the entire run with no discernible audio degradation at this FER. (Note: FOM scores in Figure 2-4 are common to all three Freeway tests, relative to the size of the area covered.)

Test Series No. 2: Two Large Cells w/ Handoff, High Speed Mobility

For the two cell test series, data on the effect of handoff functions on the link quality was to be determined. The test configuration of Test Series No. 1 was repeated, except that a second Base at the Nevada Site was functional.

The test process from Test Series No. 1 was repeated for Series No. 2, with the exception that the test vehicle proceeded further south, through a handoff to the Nevada Site installation, until the outer boundary of the second cell was reached, at which time the FER test was terminated. For this series of tests, average FER for each entire run, including handoff events, was 1.44% over a run of 3.8 miles. Figure of Merit scores are shown graphically in Figure 2-4, again demonstrate that excellent signal quality is present over the entire test path, with only slight signal degradation in the handoff zone between the systems at the Omnipoint and Nevada sites.

Test Series No. 3 - Three Large Cells w/ Handoff, High Speed Mobility

The objective of this test was to prove that high speed handoff and reliable link quality are present in a system that utilizes multiple cells and multiple frequencies. Test procedures used for Series Nos. 1 & 2 were employed in this series, but FER data was not taken as FOM scores indicated virtually identical performance to the other large cells sites. The FOM data was, and is reflected in Figure 2-5, which shows signal quality through the entire three cell distance of approximately 6 miles, again with only slight quality degradations in the two hand-off zones just prior to handoff.

During all Freeway tests, every handoff that was attempted was completed within 100 milliseconds, and subjective signal quality scores remained consistent throughout.

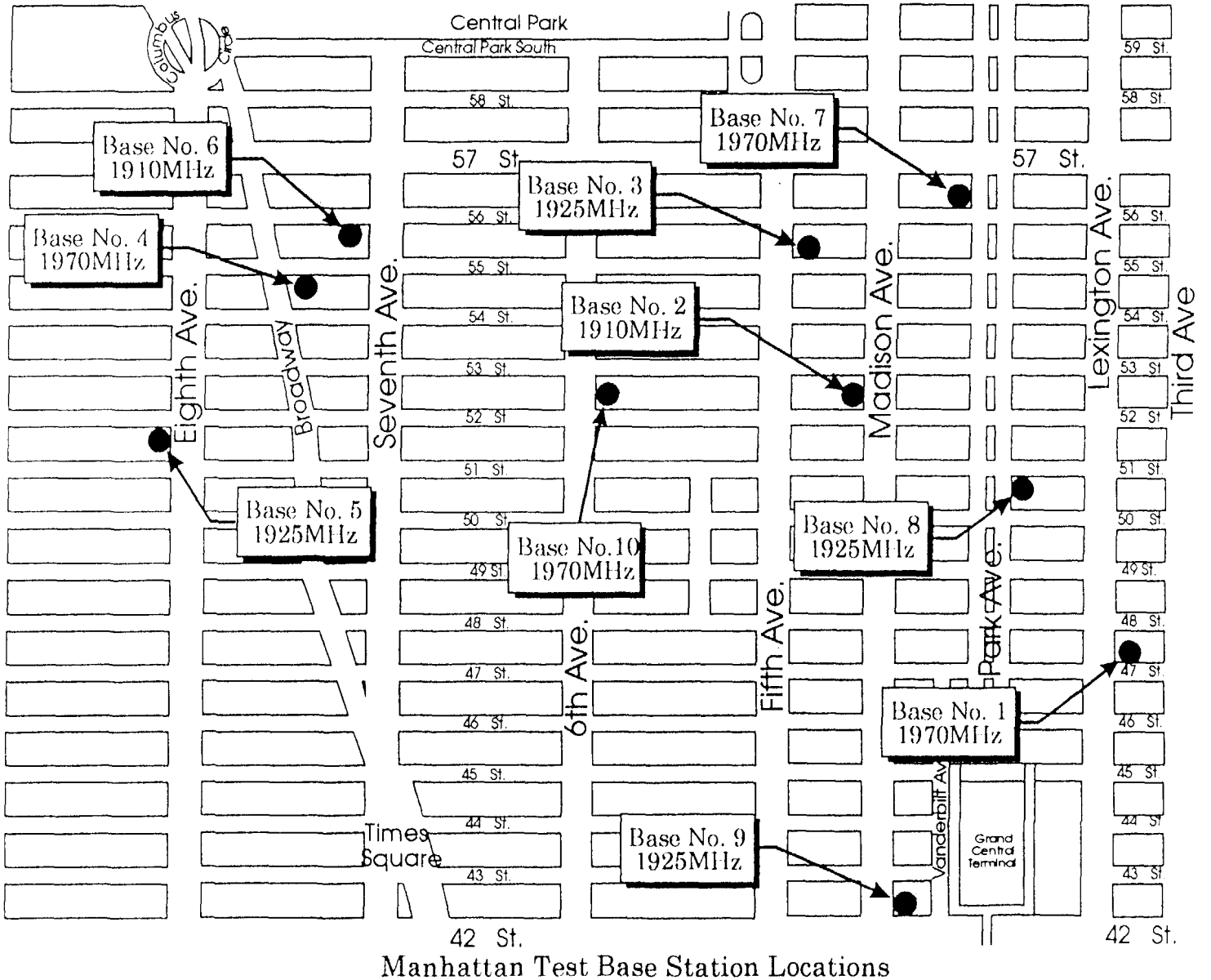
Test Series No. 4 - Large Cell, Medium to High Speed Loop

Upon successful demonstration of high speed qualitative and hand-off capabilities, and in order to test system design parameters under differing mobile conditions (for example, simultaneous low and high speeds on the same hardware), a test was designed to show hardware

capabilities under dramatically varying rates. Focusing again on the Northeast Residential Quadrant, it was determined that varying rates do not effect the signal quality to any noticeable degree. In covering the loop, speeds ranging from 10mph to 45mph were reached and then abruptly reduced to zero to accommodate stop lights and signs. In addition, speeds of 65mph were reached on the freeway during the same run with no degradation. These trends can be seen in Figure 2-6. While there were some areas at the fringe of the bases that show some degradation, the bulk of the test which contained all of the varying parameters was clean.

Test Series No. 5 - Four Cell Medium to High Speed Loop, Complete Low Speed Residential Coverage

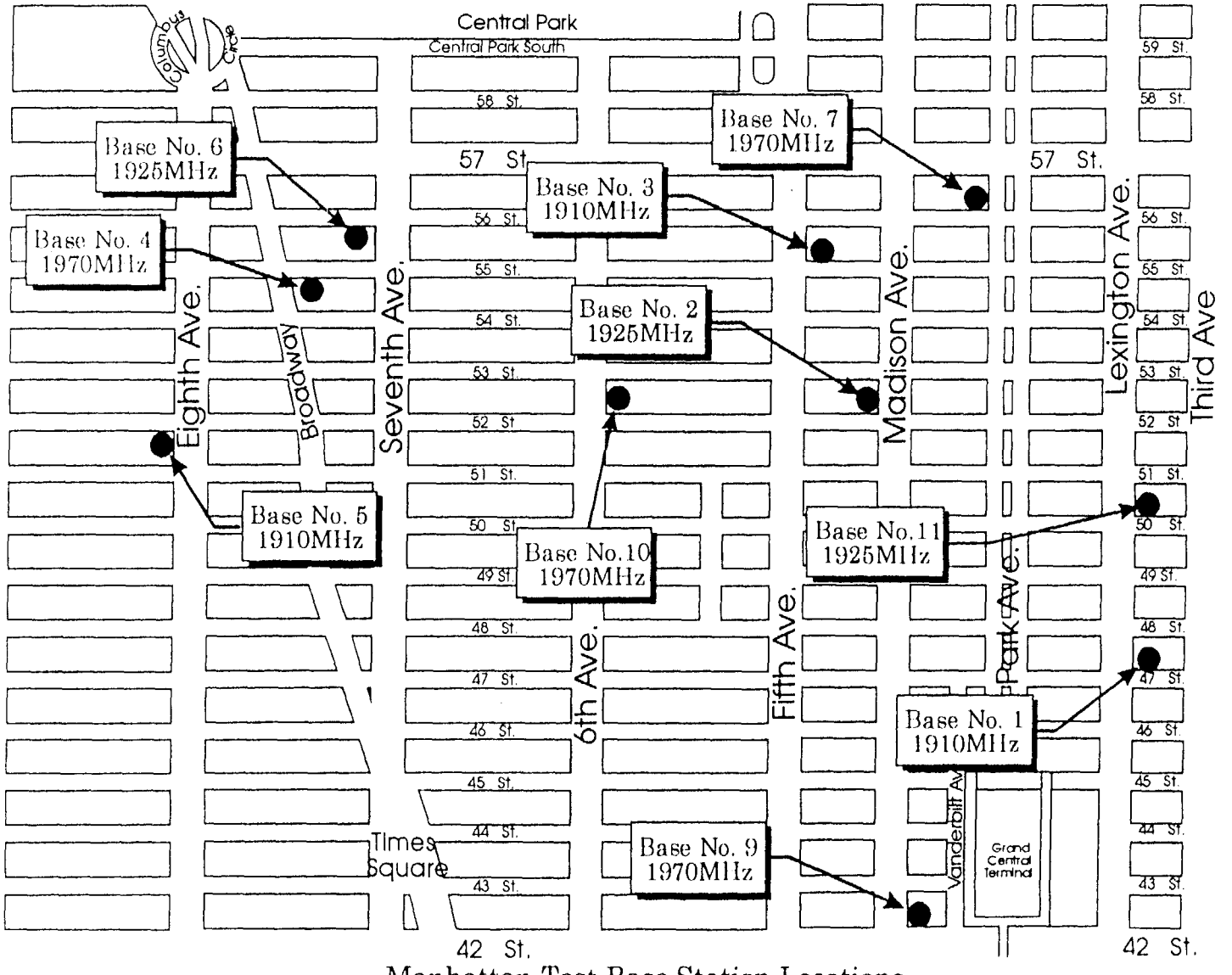
The last test in the series had the objective of showing how an entire neighborhood could be covered. Figure 2-7 shows the coverage from just the three perimeter installations. The test shows the high quality performance of slow speed communications under heavy shadowing conditions. Under these conditions, fades do not happen as quickly, but they are far deeper. This again points to the fact that average signal strength measurements do not give a complete description of signal quality.



Manhattan Test Base Station Locations
Configuration No. 1

mdtnbs04.cd

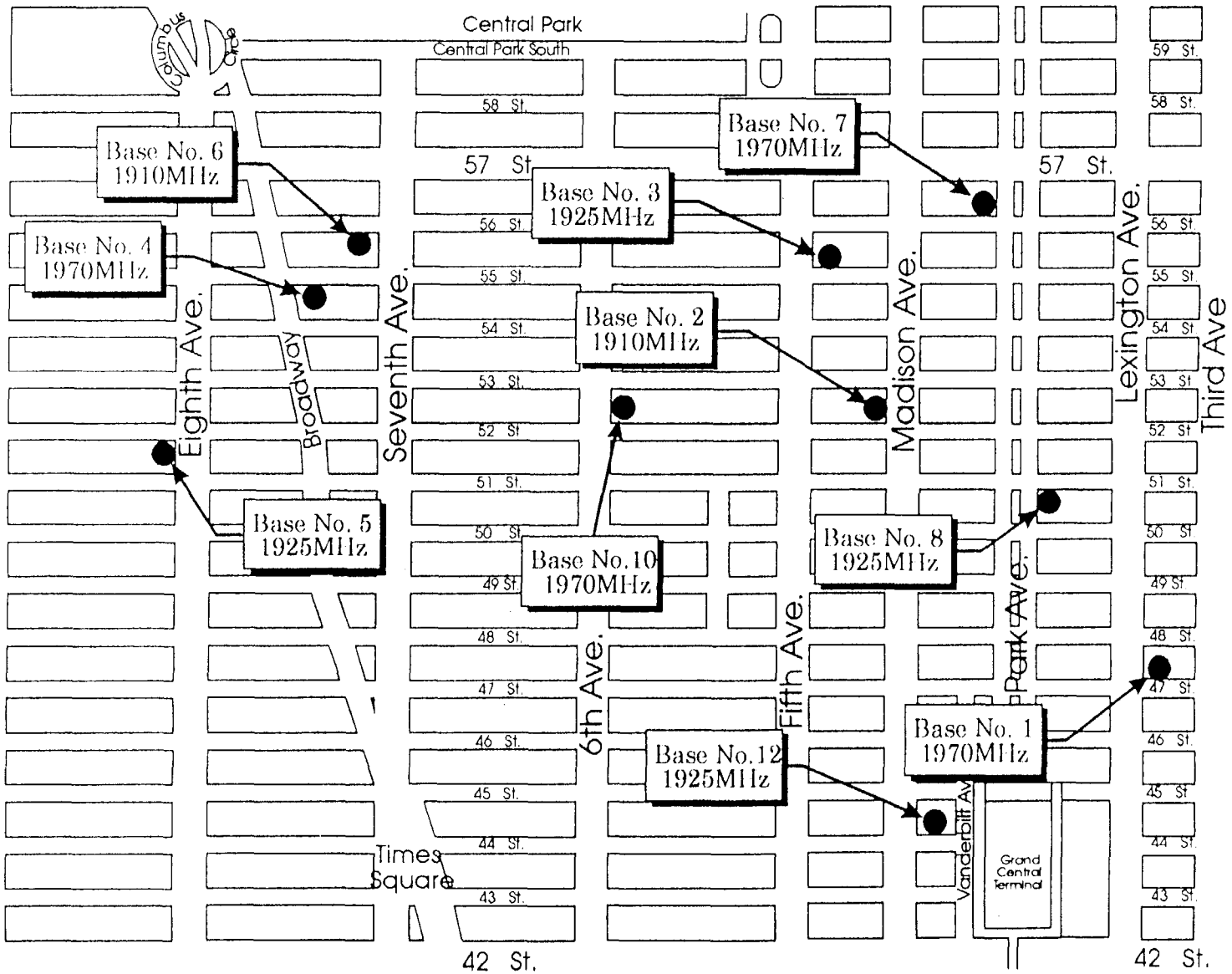
Figure 1-1



Manhattan Test Base Station Locations
Configuration No. 2

mdtnbs05.cdr

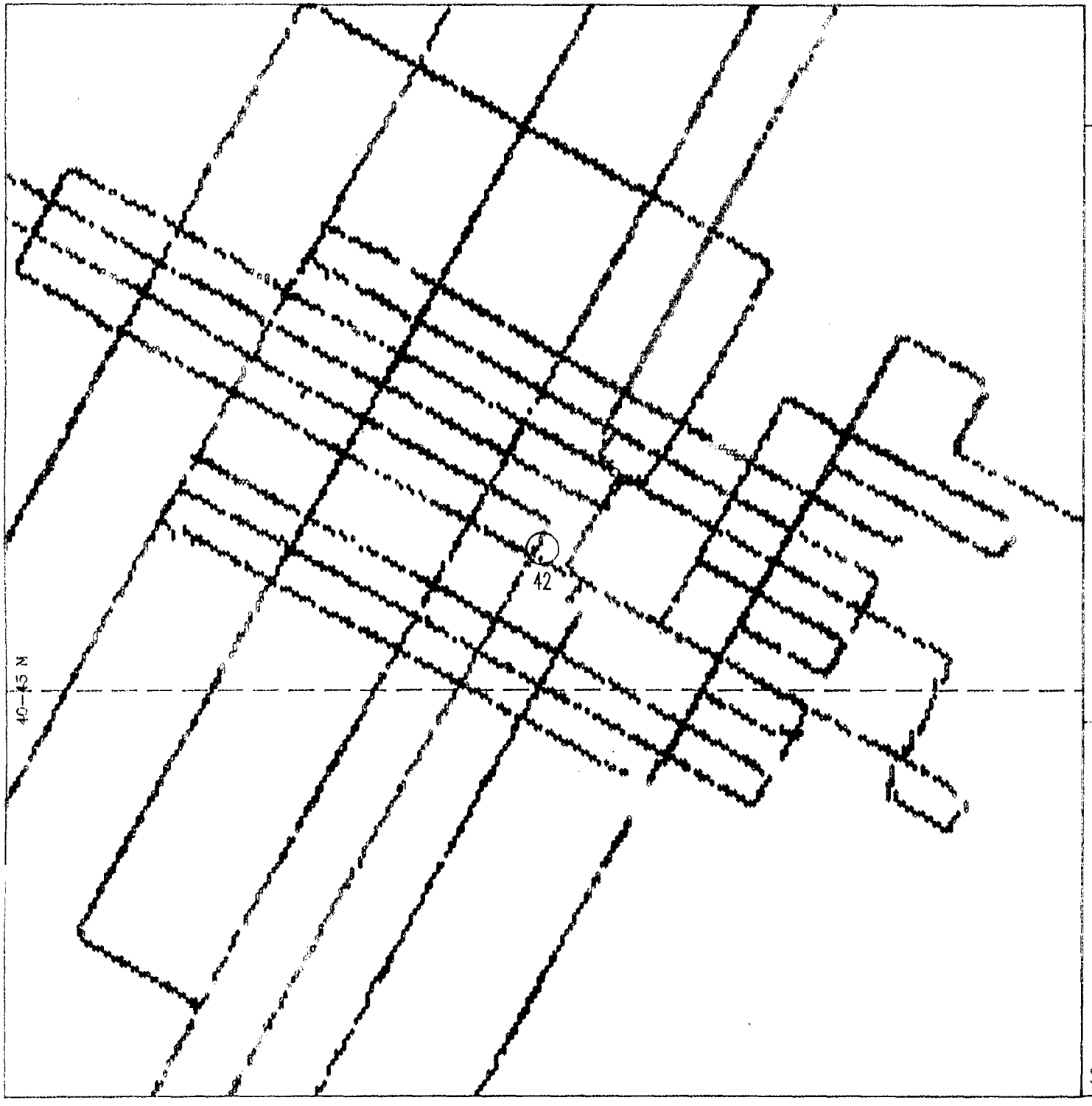
Figure 1-2



Manhattan Test Base Station Locations
Configuration No. 3

mdtnbs06.cdr

Figure 1-3



42nd & Madison Ave
COVERAGE CHANNEL PLOT
ERP Nrmlzd to 0.2 W 07/26/93 14:02:32
plot type: character Coverage Type: Average

Channel	Char	SAT
3 (-20)	.	No SAT

Plot 3
CelluMATE-Average Signal

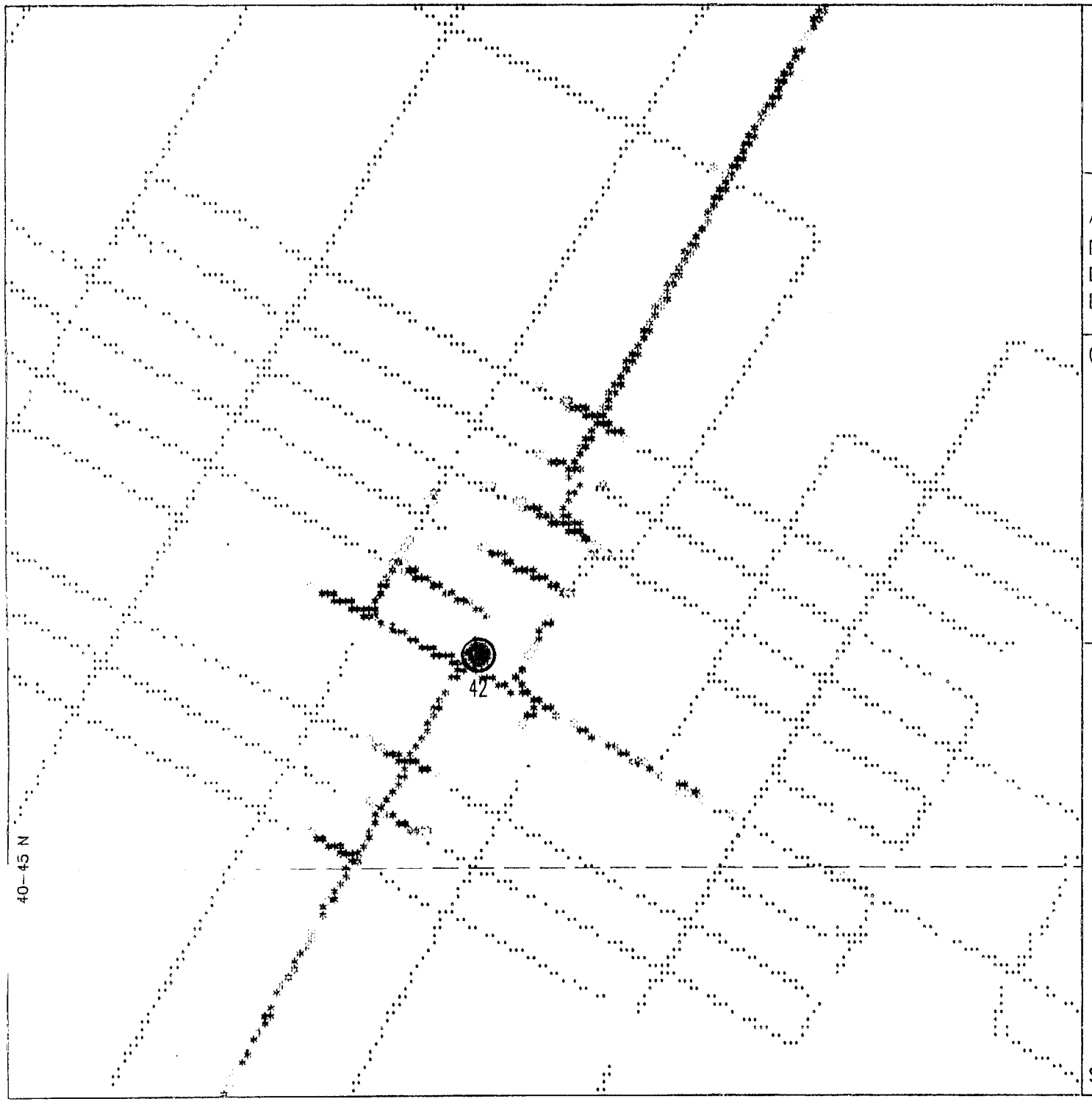
Threshold Values
(dbm)
Sig >= -85

GMA V3.3
LCC Inc.

Filename	Navigation
DRIVE1.MMA	ETAK
DRIVE2.MMA	ETAK
DRIVE3.MMA	ETAK

Miles
0 0.0 0.1 0.2 0.2 0.3 0.3 0.4 0.4
SCALE: 1:12,000

Figure 1-4



COVERAGE CHANNEL PLOT

Coverage Type: Average

BS-9 MADISON & 42ND

Client: ERP NRMLZD TO 0.2 W

08/15/93 20:13:19

File	Nav	File	Nav
42ND.MMA	ETAK	DR3B.MMA	ETAK
DR1.MMA	ETAK	MAD1.MMA	ETAK
DR2.MMA	ETAK	MAD2.MMA	ETAK
DR3A.MMA	ETAK		

Chan	Char	SAT
35	J	None
235	Ib	None

CMA V4.0
LCC Inc.

LEGEND

Threshold Values (dBm)

Sig >	-85 + M
Sig >=	-90 + M
Sig >	-95 + M
Sig >=	-100 + M
Sig >	-105 + M
	-110 + M

M = Fade Margin

M_{LOS} = 18 dB

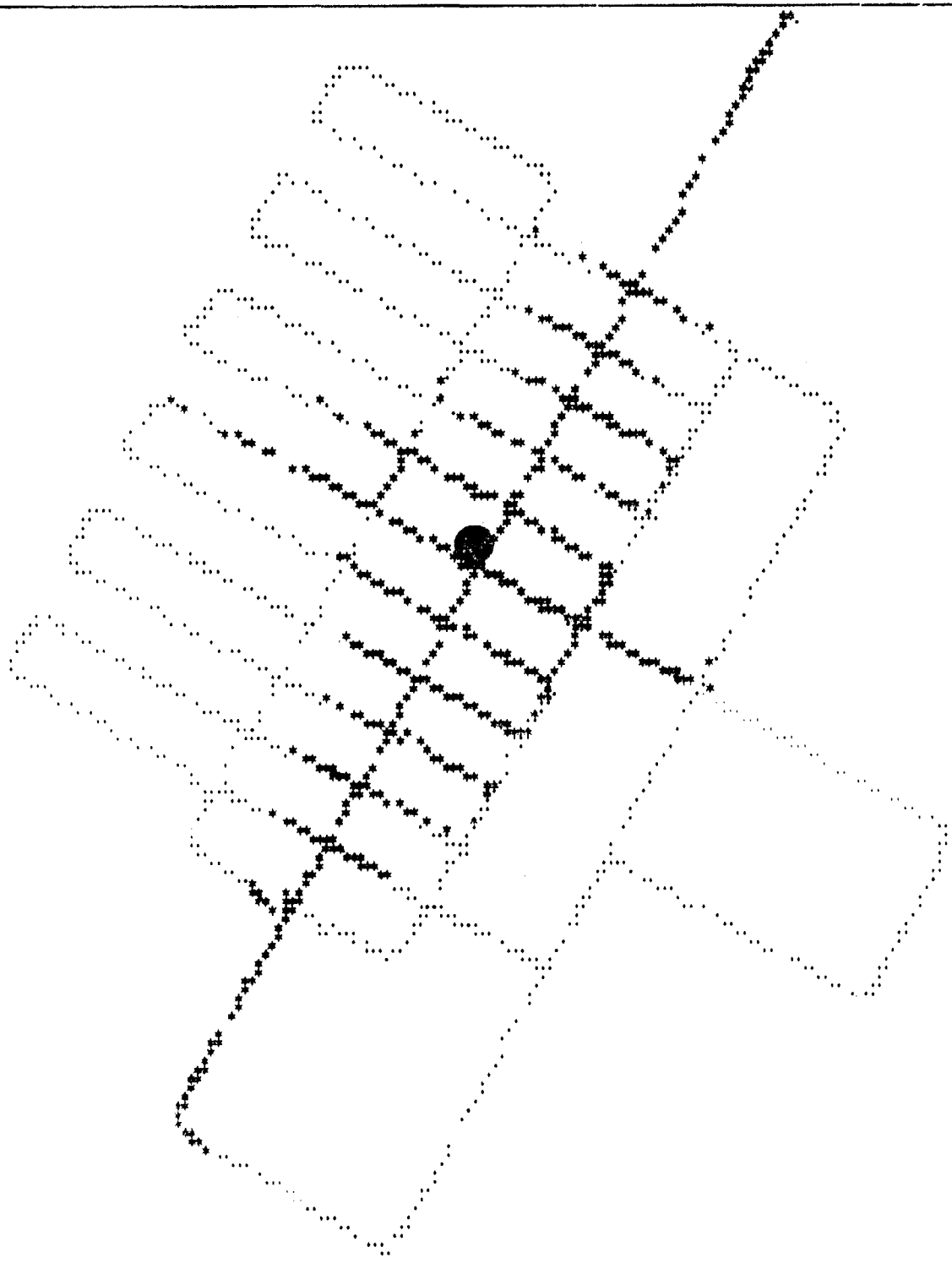
$M_{Non\text{-}LOS}$ = 21 dB

Miles

0 0.1 0.2

SCALE: 1:8,000

Figure 1-5



COVERAGE CHANNEL PLOT

Coverage Type: Average

Market: ERP NRMLZD TO 0.2 W

Client: BS-2: MADISON & 52ND ST

08/15/93 23:16:09

File	Nav
BR1.MMA	ETAK
MAD.MMA	ETAK

Chan	Char	SAT
223	gp	None
23	x	None

LEGEND

Threshold Values (dBm)

Sig >= -90

CMA V4.0
LCC Inc.

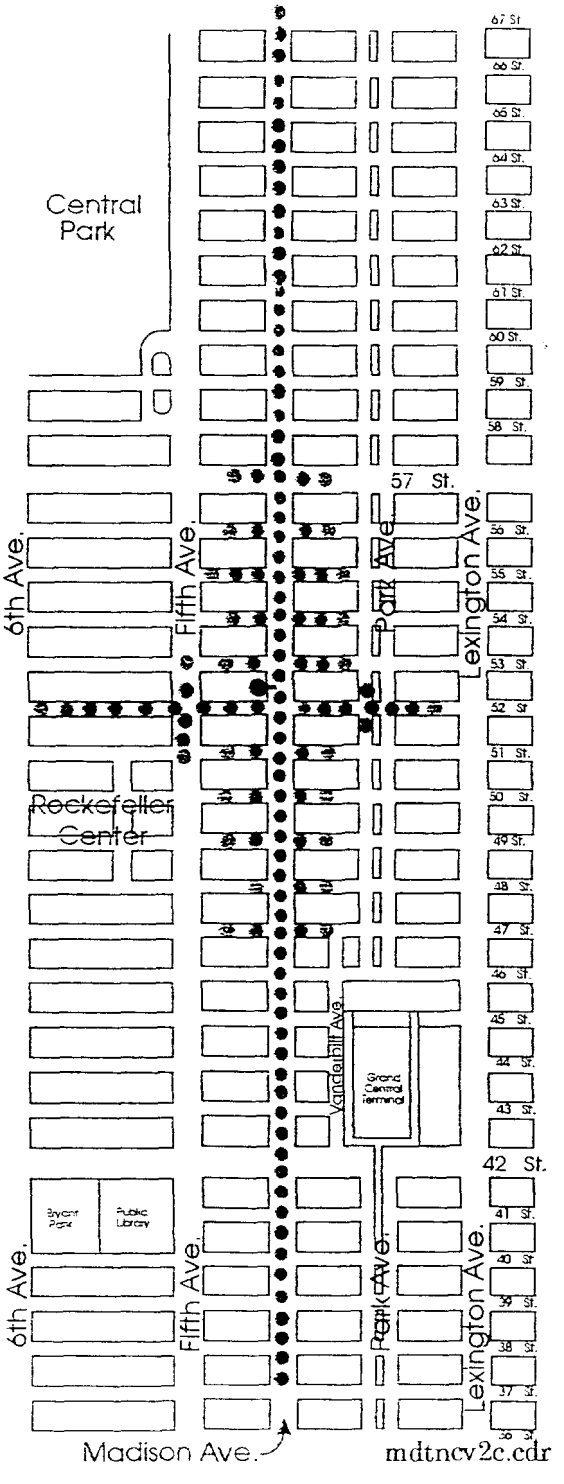
Miles

0 0.1 0.2

SCALE: 1:8,000

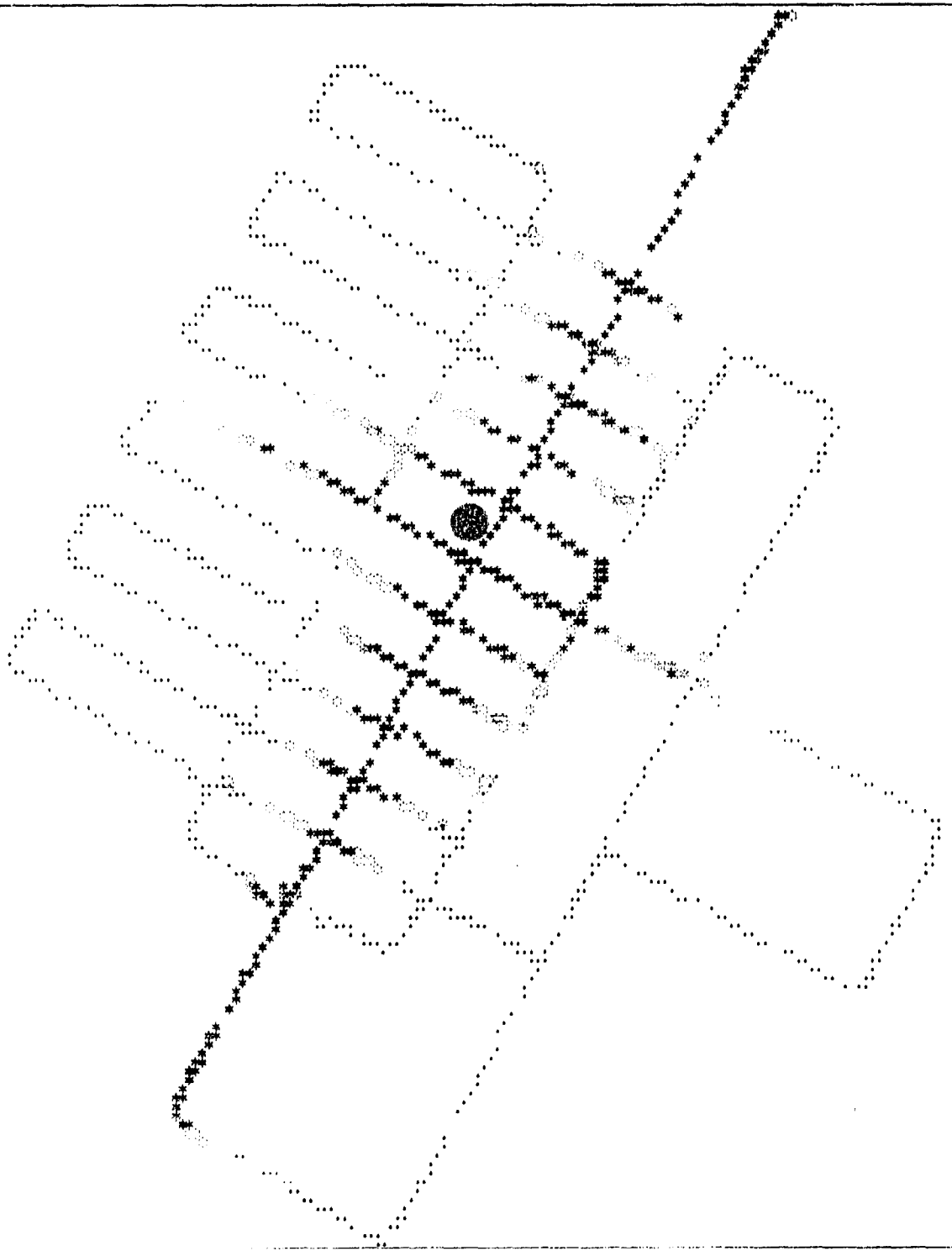
Figure 1-6

Omnipoint
CORPORATION



Coverage Plot: Base Site No. 2
52nd St. & Madison Ave.

Figure 1-7



COVERAGE CHANNEL PLOT
Coverage Type: Average

Market: ERP NRMLZD TO 0.2 W
BS2 MADISON & 52
08/14/93 21:58:55

File	Nav
BR1.MMA	ETAK
MAD.MMA	ETAK

Chan	Char	SAT
223	gp	None
23	x	None

CMA V4.0
LCC Inc.

LEGEND

Threshold Values
(dBm)

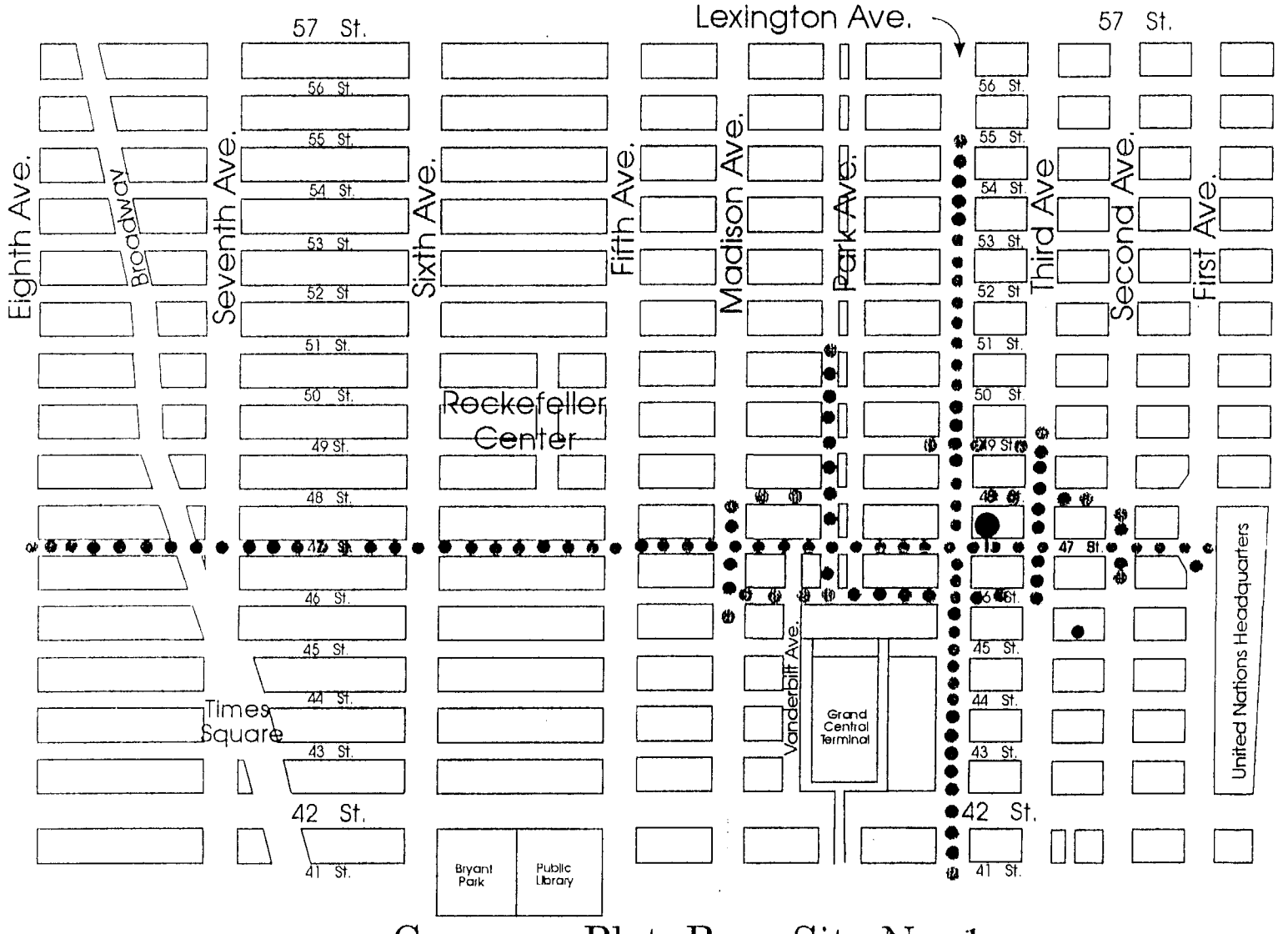
Sig >= -85 + M
Sig >= -90 + M
Sig >= -95 + M
Sig >= -100 + M
-105 + M
-110 + M

M = Fade Margin
M_{LOS} = 18 dB
$M_{Non\text{-}LOS}$ = 21 dB

Miles
0 0.1 0.2

SCALE: 1:8,000

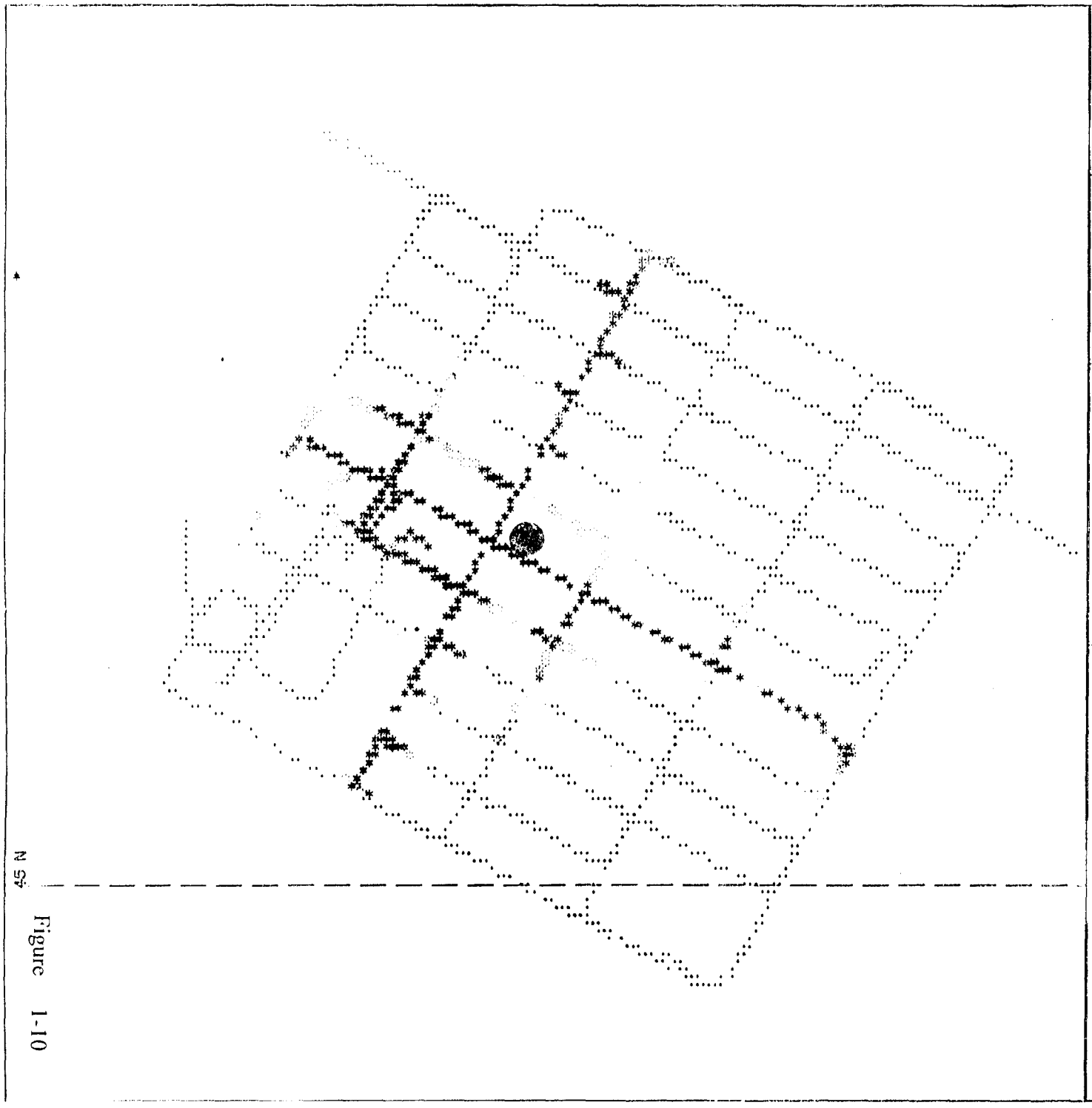
Figure 1-8



Coverage Plot: Base Site No. 1
47th St. & Lexington

mdtncv1c.cdr

Figure 1-9



COVERAGE CHANNEL PLOT

Coverage Type: Average

Market: ERP NTUMLZD TO 0.2 W

Client: BS1 LEXINGTON & 47

08/14/93 14:59:33

File	Nav	File	Nav
47EAST.MMA	ETAK	RS3.MMA	ETAK
47WEST.MMA	ETAK	RS4.MMA	ETAK
LEX.MMA	ETAK	RS5.MMA	ETAK
RS1.MMA	ETAK	RS6.MMA	ETAK
RS2.MMA	ETAK		

Chan	Char	SAT	Chan	Char	SAT
3	d	None	15	p	None
103	bz	None			

LEGEND

CMA V4.0
LCC Inc.

Threshold Values
(dBm)

Sig >= -85 + M
Sig >= -90 + M
Sig >= -95 + M
Sig >= -100 + M
-105 + M
-110 + M

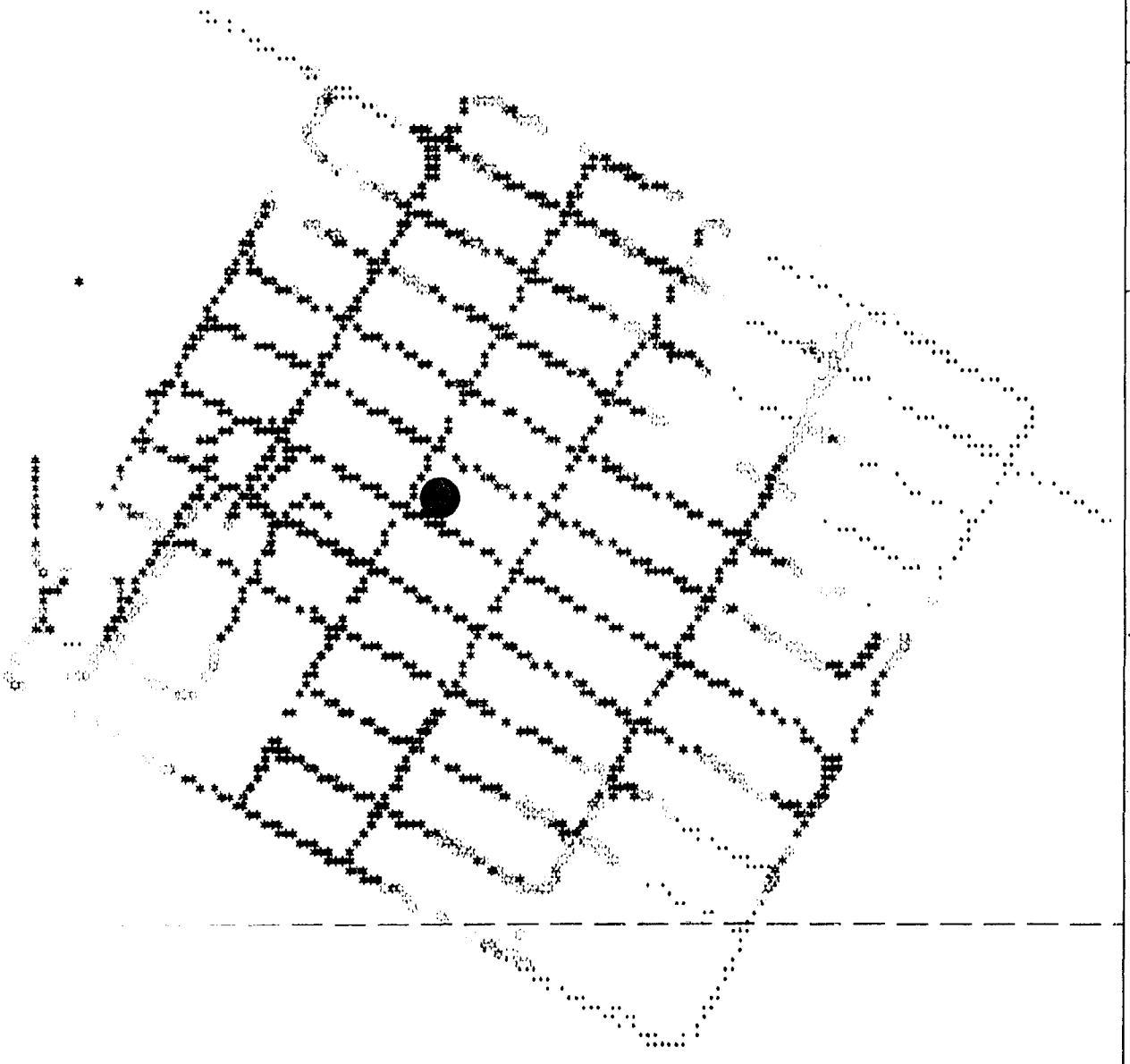
M = Fade Margin
M_{LOS} = 18 dB
$M_{Non\text{-}LOS}$ = 21 dB

Miles

0 0.1 0.2

SCALE: 1:8,000

Figure 1-10



COVERAGE CHANNEL PLOT

Coverage Type: Average

Market: BS1 LEXINGTON & 47TH

Client: ERP NRMLZD TO 0.2 W

08/15/93 20:20:50

File	Nav	File	Nav
47EAST.MMA	ETAK	RS3.MMA	ETAK
47WEST.MMA	ETAK	RS4.MMA	ETAK
LEX.MMA	ETAK	RS5.MMA	ETAK
RS1.MMA	ETAK	RS6.MMA	ETAK
RS2.MMA	ETAK		

Chan	Char	SAT	Chan	Char	SAT
3	d	None	15	p	None
103	bz	None			

CMA V4.0
LCC Inc.

LEGEND

Threshold Values
(dBm)

Sig >= -85
Sig >= -90
Sig >= -95
Sig >= -100

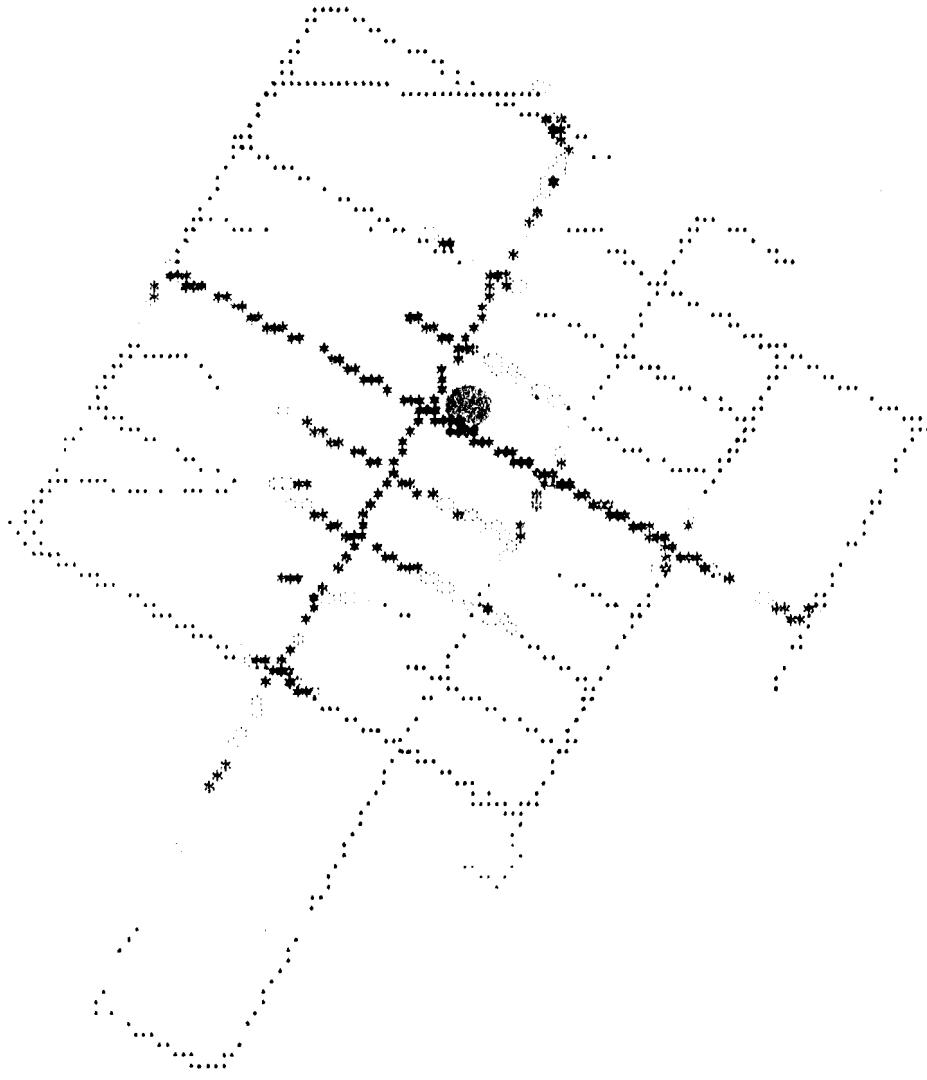
Miles

0 0.1 0.2

SCALE: 1:8,000

N

Figure 1-11



COVERAGE CHANNEL PLOT

Coverage Type: Average

Market: ERP NRMLZD TO 0.2 W

Client: BS-3: 5TH AVE & 55TH ST

08/14/93 22:56:42

File	Nav	File	Nav
55TH.MMA	ETAK	AL2.MMA	ETAK
AL1.MMA	ETAK		

Chan	Char	SAT
31	F	None
231	gx	None

LEGEND

CMA V4.0
LCC Inc.

Threshold Values
(dBm)

Sig >= -85 + M
Sig >= -90 + M
Sig >= -95 + M
Sig >= -100 + M
-105 + M
-110 + M

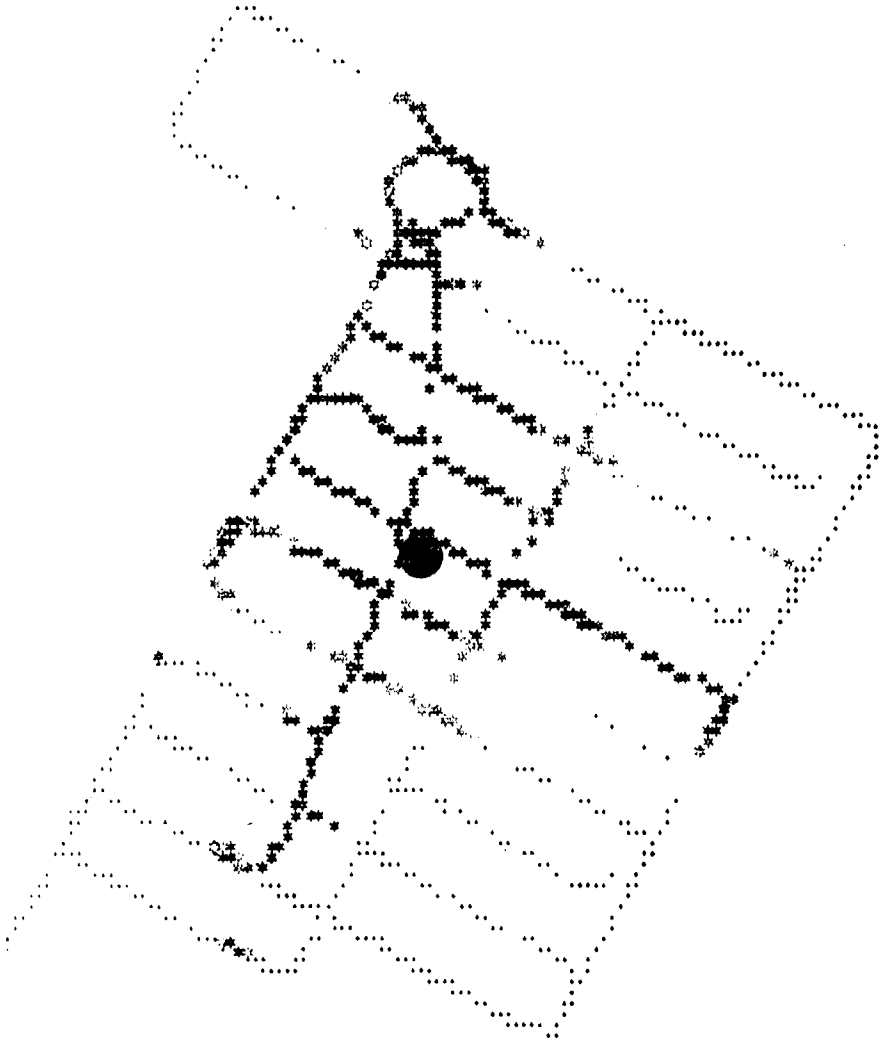
M = Fade Margin
M_{LOS} = 18 dB
$M_{Non\text{-}LOS}$ = 21 dB

Miles

0 0.1 0.2

SCALE: 1:8,000

Figure 1-12



COVERAGE CHANNEL PLOT

Coverage Type: Average

Market: ERP NRMLZD TO 0.2 W

BS4 BROADWAY & 55

08/14/93 15:48:02

File	Nav	File	Nav
55TH.MMA	ETAK	WW3.MMA	ETAK
BRDWY.MMA	ETAK	WW4.MMA	ETAK
WW1.MMA	ETAK	WW5.MMA	ETAK
WW2.MMA	ETAK		

Chan	Char	SAT	Chan	Char	SAT
7	h	None	207	fz	None
107	cd	None			

CMA V4.0
LCC Inc.

LEGEND

Threshold Values
(dBm)

Sig >= -85 + M
Sig >= -90 + M
Sig >= -95 + M
Sig >= -100 + M
-105 + M
-110 + M

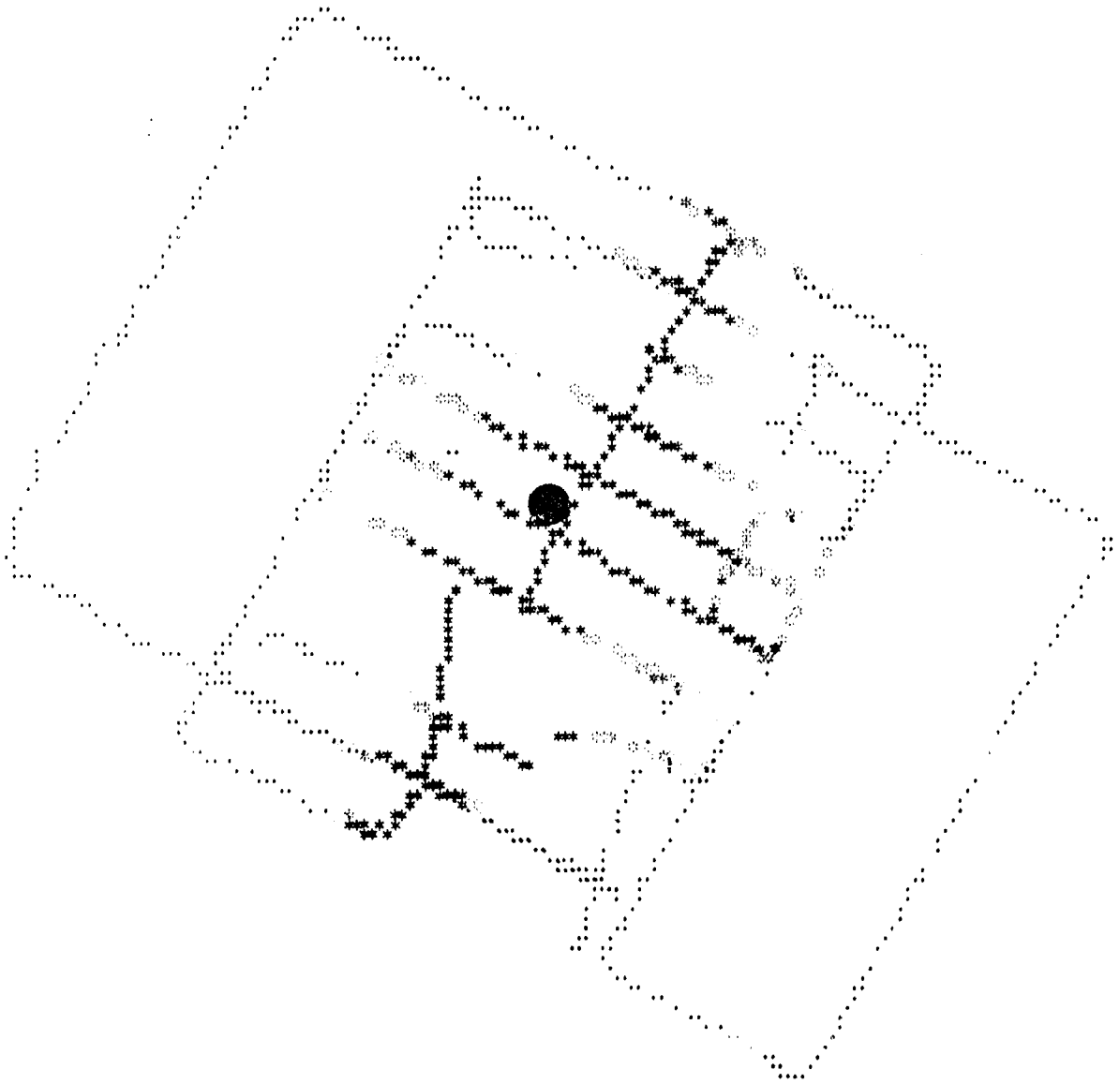
M = Fade Margin
M_{LOS} = 18 dB
$M_{Non\text{-}LOS}$ = 21 dB

Miles

0 0.1 0.2

SCALE: 1:8,000

Figure 1-13



COVERAGE CHANNEL PLOT

Coverage Type: Average

Market: ERP NRMLZD TO 0.2 W

BS5 EIGHTH & 51

08/14/93 19:39:05

File	Nav	File	Nav
8TH.MMA	ETAK	HJ3.MMA	ETAK
HJ1.MMA	ETAK		
HJ2.MMA	ETAK		

Chan	Char	SAT
11	I	None
211	gd	None

CMA V4.0
LCC Inc.

LEGEND

Threshold Values (dBm)

Sig >= -85 + M
Sig >= -90 + M
Sig >= -95 + M
Sig >= -100 + M
-105 + M
-110 + M

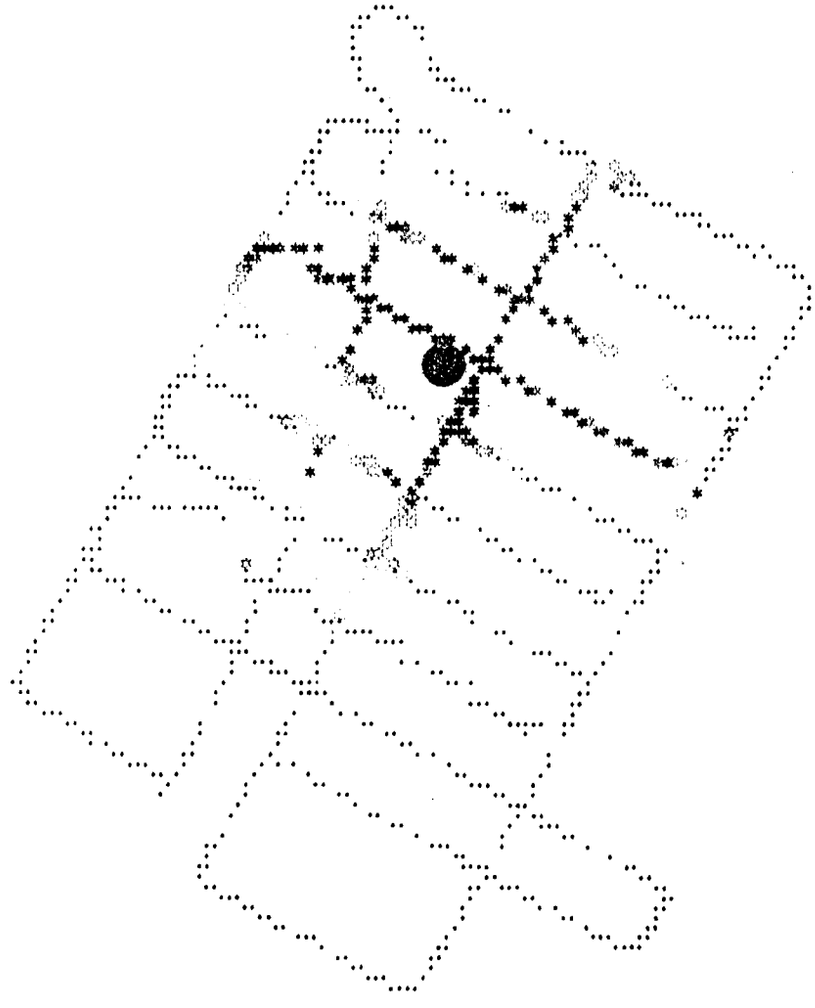
M = Fade Margin
M_{LOS} = 18 dB
$M_{Non\text{-}LOS}$ = 21 dB

Miles

0 0.1 0.2

SCALE: 1:8,000

Figure 1-14



COVERAGE [illegible]

Coverage Type: Area

Market: ERP NRMLZD 10 [illegible] W

Client: BS-6: 7TH AVE & 56TH ST

08/14/95 23:09:22

File	Nov
PCENTRAL.DAT	ETAK

Chan	Char	SAT
107	cd	None

LEGEND

CMA V4.0
LCC Inc.

Threshold Values
(dBm)

Sig >= -85 + M
Sig >= -90 + M
Sig >= -95 + M
Sig >= -100 + M
-105 + M
-110 + M

M = Fade Margin
M_{LOS} = 18 dB
$M_{Non\text{-}LOS}$ = 21 dB

Miles

0 0.1 0.2

SCALE: 1:8,000

Figure 1-15