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Executive Director-
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PCS

September 29, 1995

Mr. H. John Morgan
Office of Engineering and Technology
Experimental Licensing Branch
2000 M Street, N.W., Room 230
Washington, D.C. 20554

RE: U S WEST Communications, Inc.
PCS Experimental License for Boulder, CO
Call Sign KK2XCC
File Numbers: 2148-EX-PL-91, 3306-EX-ML-92, 3630-EX-ML-93, 3630-EX-R-93, 4064-EX-ML-93, 4506-EX-ML-94
Fourteenth Quarterly Report

Dear Mr. Morgan:

Enclosed please find U S WEST Communications' fourteenth quarterly report addressing the above referenced authorization for PCS field trials in Boulder, Colorado. Also enclosed is the report to the Joint Technical Committee (JTC) on the TAG-2 technology field testing conducted in the previous quarter.

Should you have any questions or require additional information, please call me.

Sincerely,

Elridge Stafford

Enclosures

U S WEST

Wireless Personal Communications

Experiments

Quarterly Progress Report #14
FCC Experimental License
KK2XCC

September 29, 1995

Submitted to

Federal Communications Commission
Experimental Licensing Branch
Room 230
Washington, DC 20554

Prepared by

U S WEST Advanced Technologies
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Executive Summary

This quarterly report summarizes field testing conducted by U S WEST Advanced Technologies in the Boulder Industry Test Bed (BITB) from June 1, 1995 through September 1, 1995. During this quarter tests involving emissions in the 1850 MHz to 1990 MHz band were conducted on two systems. The two systems used were the Joint Technical Committee (JTC) Technical Ad-hoc Group (TAG) 4 upbanded IS-54 TDMA air interface technology and the JTC TAG 7 Wideband CDMA air interface technology.

Plans for the next quarter include one technology field test to be performed in conjunction with the Joint Technical Committee (JTC), a TDMA based system (PACS, TAG 3), as well as the conclusion of the TAG 7 trial.

1 Introduction

This report summarizes field testing conducted by U S WEST Advanced Technologies in the Boulder Industry Test Bed (BITB) under FCC Experimental License KK2XCC. The period covered by this quarterly report is from June 1, 1995 through September 1, 1995.

2 Field Testing

TAG 4 field testing was conducted in the BITB from July 5, 1995 through August 18, 1995. Base stations, and the MTSO were provided by AT&T and handsets were provided by Ericsson and Nokia. This was the third field test of JTC TAG technology in the BITB. TAG testing will be complete following the completion of Omnipoint's TAG 1 technology in November, 1995.

The following high tier cell sites were used, 1) Walnut Central Office (WCO), 2) Table Mesa Central Office (TMCO), and 3) Green Mountain Mesa (GMM). These sites were also used during both the JTC TAG 5 (upbanded GSM) field test that was conducted in the Fall of 1994 and the JTC TAG 2 (upbanded IS-95) field test conducted in May of 1995 in the BITB. The WCO and TMCO used 3-sector cells and GMM used a 2-sector cell.

The antennas at the GMM and TMCO cell sites utilized a 120 degree azimuth beamwidth, while the WCO antennas utilized a 105 degree azimuth beamwidth. Three antennas comprised a single sector, one for the transmitter (the middle antenna) and two for receiver diversity. The single frequency used was 1952.99 MHz for the forward link and 1872.99 MHz for the reverse link. The cell site separation distances used were as follows: 1) WCO to GMM: 1.8 miles, 2) GMM to TMCO: 1.8 miles, and 3) WCO to TMCO 3.2 miles. The high tier cell layout used for JTC TAG field testing was chosen in such a manner that it provided a generic layout for all JTC TAG technologies, thus the cell layout was not optimized for any particular JTC TAG technology.

AT&T's MTSO was located in Whippany, NJ. It was accessed via T1 leased line circuits running from the WCO to Whippany. There were also T1s interconnecting the 3 cell sites in the BITB. Data collection for cell side data occurred at each cell sector. Data collection of cell data was realized through a data recording unit (DRU) attached to the sector. The system did not have access to the PSTN.

Installation and test of the IS-54 equipment occurred between July 5, 1995 and July 27, 1995. Data collection for field testing began on July 28, 1995. Data collection was done for overall coverage of individual cells, handover functionality, voice quality analysis, interference analysis, and in-van versus out-of-van antenna performance. Data collection was completed on August 17, 1995. A visitors day was held on August 15, 1995 for technical demonstration of the technology to JTC members and other invited guests.

Data collection of cell to mobile information was performed via PC's interfaced to the van mobile system for each mobile vendor. Voice quality measurements were done by recording data and voice samples in quasi-stationary testing. In this testing the voice samples consist of Harvard sentences (groups of phonetically balanced English sentences in both male and female voices), played over a 70 second time interval. During this time the mobile will move either 10 meters or 100 meters depending on whether the test is run in slow or fast mode. Comparisons are made between recorded data and panel evaluations of the recorded transmitted voice. 60 sample points are used.

Collected data generally included mobile received signal strength, BER class, vehicle latitude, vehicle longitude. Careful attention was taken by Qualcomm, U S WEST, and the National Telecommunications and Information Administration (NTIA), representing the Independent Observer, to ensure that proper engineering practice was followed during data collection and all parts of the field test. Per JTC agreement, the measured TAG 4 data will be available to members of the JTC. More detail, included specific frequencies used for each sector can be found in JTC(AIR)/95.06.05-125.R1.

Also per JTC agreement, U S WEST and the NTIA are tasked to analyze measured data and write a final report, with TAG 4 approval, to be presented to the JTC within forty-five days of the field test. As of this writing, the report is not yet available.

The field trial of OKI's TAG 7 implementation began with installation and setup on August 22, 1995. The system consists of a single base station and a single mobile unit. The system operates on two 5 MHz channels centered on 1865.2 MHz and 1945.2 MHz. Three sectors each and both TMCO and WCO will be used in the testing with operation of only one sector at a time. No access to either the captive switches in the BITB or the PSTN will be used during this trial. Testing is scheduled to begin September 5, 1995 and end September 15, 1995. Details of the system testing can be found in JTC(AIR)/95.07.31-124R1

The TAG 2 field trial data collection was completed on June 1, 1995. A visitors day for JTC members was held on June 2, 1995. A report of the field trial results was produced by U S WEST Advanced Technologies, the ITS and Qualcomm and presented to the JTC on July 31, 1995 as document JTC(AIR)/95.07.31-250.

3 Future Research

As indicated in previous quarterly reports, the BITB facility has been offered to the JTC as a facility for PCS air interface technology field testing. U S WEST made a press release to this effect in May, 1994. A draft test plan was submitted as a contribution to JTC in June, 1994. Presently, 3 technologies have completed field testing at the BITB facility, with one in progress.

After TAG 7 one more technology will be field tested at the BITB in 1995. PACS (TAG 3) TDMA will be testing from September 18, 1995 through October 31, 1995. U S WEST has continued to provide ongoing support with each of these TAGs regarding overall planning of the field tests. Such planning includes designing the field tests, writing test plans, identifying data collection methods, and preparing the BITB network facilities and cell sites for equipment installation and test.

TEST REPORT
TO
JOINT TECHNICAL COMMITTEE
FOR TAG-2 TECHNOLOGY FIELD TESTING

San Antonio, TX

STANDARDS PROJECT: Joint Technical Committee on Wireless Access

TITLE: Test Report For The TAG 2 Technology Field Testing Report At The BITB

ABSTRACT: This technology field test was performed at the US WEST Advanced Technologies Boulder Industry Test Bed (BITB), located in Boulder, Colorado, in cooperation with the Joint Technical Committee on Wireless Access (JTC). The Technology Ad Hoc Group (TAG) 2, Code Division Multiple Access (CDMA) technology is one of several technologies being standardized within the JTC. All technologies being standardized in the JTC are required to submit to testing at the BITB. High tier systems each use the same cell sites and cell site antennas. Low tier systems each use the same microcell sites and cell site antennas. The cell site layout, antenna type, and antenna orientation are given and do not vary from technology to technology. TAG 2 testing was carried out at the BITB from May 1, 1995 Through May 30, 1995. A visitor day was held on June 1, 1995.

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DATE: July 31, 1995

DISTRIBUTION: Participants of the Joint Technical Committee on Wireless Access

1.0 INTRODUCTION

This technology field test was performed at the US WEST Advanced Technologies Boulder Industry Test Bed (BITB), located in Boulder, Colorado, in cooperation with the Joint Technical Committee on Wireless Access (JTC). The Technology Ad Hoc Group (TAG) 2 Code Division Multiple Access (CDMA) technology is one of several technologies being standardized within the JTC. All technologies being standardized in the JTC are required to submit to testing at the BITB. High tier systems each use the same cell sites and cell site antennas. Low tier systems each use the same microcell sites and cell site antennas. The cell site layout, antenna type, and antenna orientation are given and do not vary from technology test to technology test. TAG 2 testing was carried out at the BITB from May 1, 1995 Through May 30, 1995. A visitor day was held on June 1, 1995.

The field tests examined coverage, functionality including hand-off, and voice quality under both quasi-static and vehicular speed conditions and during hand-off. This report describes the test plan, method, and results for the technology field trial conducted by TAG 2. The technology tested was the PCS variant of the IS-95 cellular CDMA standard. For this field trial Rate Set 1 and the IS-96A codec were used. The three chip base station technology was used. All TAG 2 equipment was provided by QUALCOMM, Incorporated.. The Institute For Telecommunication Sciences (ITS), the research and engineering arm of The National Telecommunications and Information Administration (NTIA), acted as the independent observer for this field test.

The testing was carried out, by TAG 2, in fulfillment of the JTC requirement that field testing be carried out within six months of the draft standard being submitted to Committee T1 and the Telecommunications Industry Association (TIA) for ballot. This requirement is identified in JTC document JTC(AIR)/94.08.04-459R2, the JTC living list JTC(AIR)/94.10.31-003R6, and finally in the Test Plan Administration Guide JTC(AIR)94.09.23-707.

2. TEST CONFIGURATION

2.1 BITB System Configuration

A block diagram of the BITB test configuration is given in Figure 2.1. The test system consisted of 3 cell sites, 1 Qualcomm Telecommunications Switching Office (QTSO) and 2 mobile units. POTS service was provided via the DMS100 switch in the US West AT switching lab at the Walnut street central office. The system functioned as a closed system as calls to and from the PSTN were not allowed during the trial. The QTSO was located at the 28th Street BITB lab and connected via T1 transport to each cell site. The general configuration of the cell sites is as follows:

- Cell One, Walnut Street CO (WCO) - the cell is located on the roof of the Boulder Main Central Office. Three sectors (α, β, γ) were utilized. Each sector uses 3 antennas, 2 receive and 1 transmit. The CO is located in the most urban section of Boulder, however the general vicinity is light urban and residential.

- Cell Two, Green Mountain Mesa (GMM) - This cell is situated on an concrete pad 400 feet above the Boulder Valley floor. The base station equipment is located inside a large van adjacent to the antenna site. T1 access is provided to this site via a Western Multiplex Lynx point to point direct sequence system operating in the 2.4 GHz ISM bands. The link runs between GMM and the WCO. Two sectors (α, β) were used at this site.

- Cell Three, Table Mesa Central Office (TMCO) - This cell is also located on the roof, and is surrounded by mostly residential areas. Only a single sector (α), the north facing sector was utilized at this location.

The cells are shown pictorially in Figure 2.2. The distances between cell sites are as follows:

Cell 1 to Cell 2	2.9 km
Cell 2 to Cell 3	3.0 km
Cell 1 to Cell 3	5.2 km

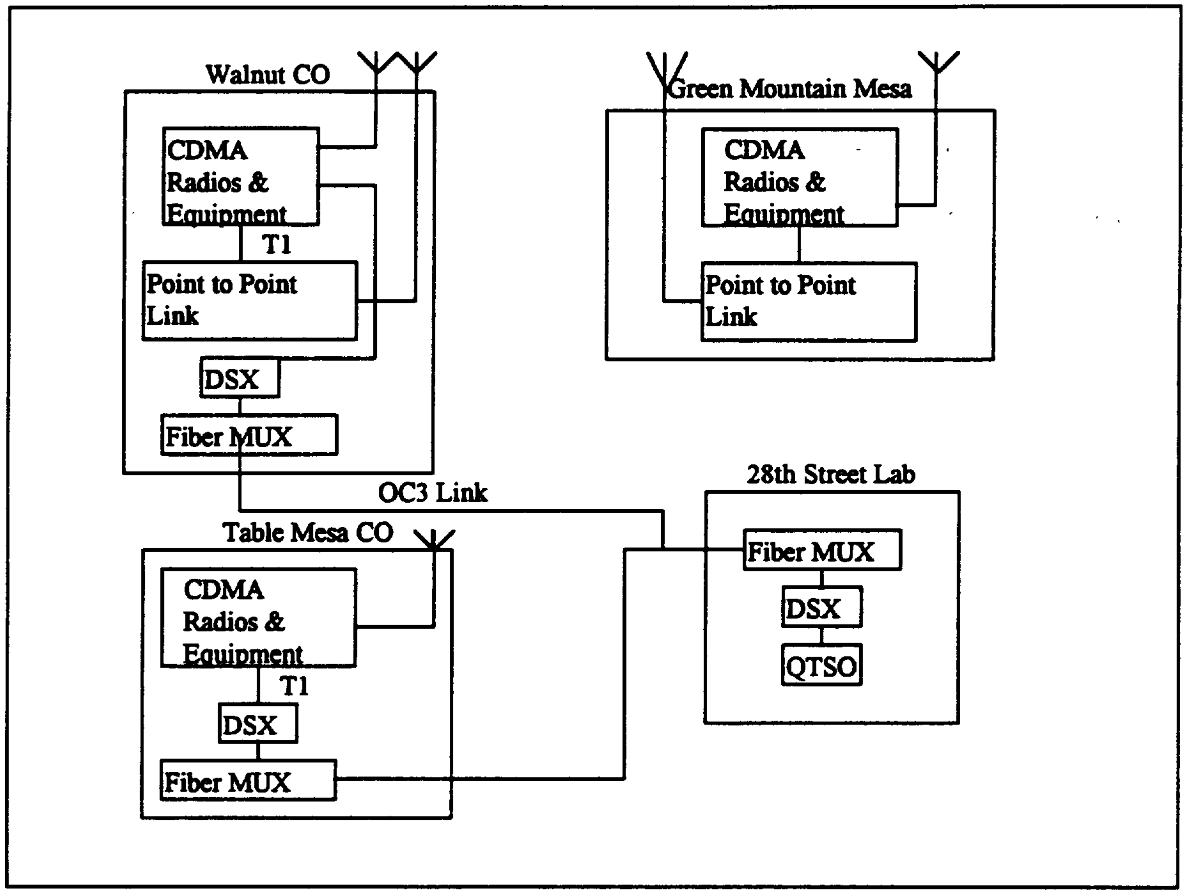


Figure 2.1 BITB block diagram.

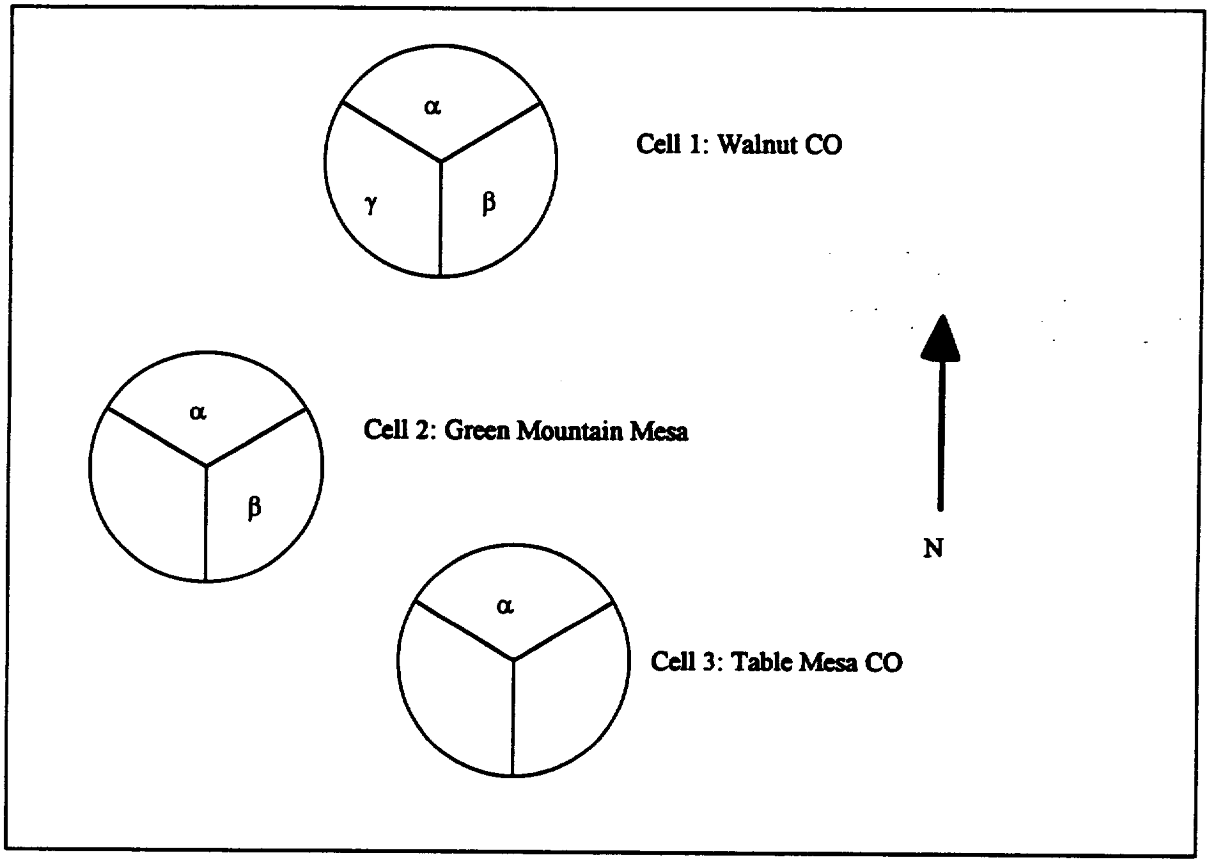


Figure 2.2 Pictorial Representation of Cell Sites

The configuration of the cell sites in the BITB has been established prior to the trial for consistency throughout JTC testing. Each TAG must use the facilities supplied and are not allowed to alter cell location, or testbed equipment outside of what is required for power and telecommunications connectivity. The detailed cell configuration information is given in Table 2.1

Table 2.1 BITB Cell site configuration data.

Cell Site Description	Table Mesa CO	Walnut CO	Green Mountain Mesa
Type of Coverage	Suburban	Light Urban	Suburban/Rural
Latitude	39°58'41.1"N	40°1'4.5"N	39°59'31.2"N
Longitude	105°14'31.8"W	105°16'27.6"	105°16'22.9"
USGS 7.5' Quadrangle (Niwot Quad Completes Area)	Lousville	Boulder	El Dorado Springs
Height Above Valley Floor	29'	73'	400'
Ground Elevation at Site	5410'	5370'	5800'
Number of Sectors Used	1	3	2
Number of Antennas	3	9	6
Orientation of Sectors	N	N,SW,SE	N,SE
Antenna Manufacturer	Celwave	DAPA	Andrews
Antenna Model Number	PD10251-BD	68000	Rx:PC-5NOF-0191-113, Tx:PC-5NOF-0193-113
Antenna Azimuth Beamwidth	120°	105°	120°
Antenna Elevation Beamwidth	7°	7°	12°
Antenna Gain	15.6 dBi	16.6 dBi	13.5 dBi
Antenna Null Filling	No	No	Yes
Cable Run Andrews LDF5-50A foam, 7/8", 1.91 dB/100ft at 1.9 GHz Estimated Cable Loss with Connectors and Lightning Arrestors	76 ft./2.0 dB	140 ft./3.2 dB	140 ft./3.2 dB

2.2 TAG 2 System Configuration

All equipment being tested was supplied by QUALCOMM, Incorporated.

2.2.1 TAG 2 Tests System Components

The following items were used in data collection during the trial. While they were specifically identified in the test plan they are represented here for completeness.

2.2.1.1 QTSO Diagnostic Monitor

The QTSO Diagnostic Monitor (QDM) collects and displays information on the operation and performance of the entire system. Frame error rates (FER) and power control statistics on the reverse link are measured continuously.

2.2.1.2 Cell Diagnostic Monitor

The Cell Diagnostic Monitor (CDM) is located at the base station and collects and displays information on the cell operation. Most of the information available at the base station is also reported via the Remote Monitoring System (RMS) located at the QTSO.

2.2.1.3 Mobile Diagnostic Monitor

The Mobile Diagnostic Monitor (MDM) is the most important feedback and measurement instrument available. It can give near real time feedback as to the operation of the mobile subscriber unit in the system, and it can record many parameters for analysis later. The time-tagged log files recorded by the MDM computer are used for quantitative measurements of system performance.

2.2.1.4 OUNS/OCNS

All data was collected in the presence of simulated interference. The interference is simulated on the reverse link by the Other User Noise Simulator (OUNS) and on the forward link by the Orthogonal Channel Noise Simulator (OCNS).

Reverse link capacity is simulated based on the effects of interference from users in the same cell and users in surrounding cells. It can be shown that the noise generated by these other users can be modeled as a Gaussian random process simulated by a single "big fictitious" user. The resulting simulated noise of N simultaneous users is injected at the inputs of the IF amplifier. The N simulated users are assigned a desired Eb/No set point to be maintained. This set point was normally set higher than the QTSO recorded Eb/No set point as a safety margin to ensure that the interference was at least that of the desired users.

The forward link capacity is simulated by modulating a random information stream on unused Walsh codes. The number of Walsh codes used was fewer than the number of simulated users. To obtain the equivalent power of the simulated number of users, the power in each Walsh code used for simulation was increased so that the total power is identical to that if independent Walsh codes were used.

2.2.2 Markov Call

During the testing of the TAG 2 Technology, "Markov" test calls were used to collect link performance statistics. During a Markov test call, the mobile unit and the vocoder/selector (within the QTSO) use synchronized pseudo-random generators and statistical models to generate and verify the data rate and data bits over the air. The data rate of a Markov test call can be set to fixed or variable rates. For a fixed rate, the data rate is set to one of the following values for the duration of the call: full (9600 bps), half (4800 bps), quarter (2400 bps), or eighth (1200 bps) rate. A variable rate Markov call uses a combination of the above rates according to the statistics of a typical voice conversation.

2.2.3 Test Van Setup

The test van used was a 1995 Dodge Caravan. Two mobile stations were used. One mobile station had its antenna placed inside the vehicle mounted on a wooden structure that was placed between the front driver and passenger seats. This was the same wooden structure used for all JTC/BITB testing. The antenna was approximately one foot back from the windshield and two feet below the roof top. The second mobile station had its antenna placed outside of the vehicle magnetically mounted on the roof. The second mobile was used for monitoring purposes and was not formally part of the test. A maximum of three passengers were allowed inside the vehicle for consistency and to minimize blocking of signal.

2.3 TAG 2 System Parameters

Table 2.2 gives the configurable parameters were set in the TAG 2 CDMA system.

Table 2.2 TAG 2 System configuration Parameters.

System Parameters	**Value**
Target Frame Error Rate	1%
Pilot Gain (note 1)	108
Paging Gain (note 1)	65
Sync Gain (note 1)	34
Traffic Range Min/Max (note 1)	40/100
Breathing	Off
Pilot Shrink	Off
Forward Power Control	On
Maximum Reverse Link Eb/No Set Point	8.0 dB
Minimum Reverse Link Eb/No Set Point	5.0 dB
Hand-off Parameters	
T_ADD Add Pilot Threshold	-14 dB
T_DROP Drop Pilot Threshold	-16 dB
T_COMP Active Set vs Candidate Set Threshold	5 dB
T_TDROP Drop Pilot Timer Value	6 Seconds
Channel Parameters	
Reverse Link Center Frequency	1872.99 MHz
Forward Link Center Frequency	1952.99 MHz
OUNS/OCNS Parameters	
OCNS Simulated Users (Forward Link)	15 (10 embedded, note 2)
OUNS Simulated Users (Reverse Link)	16 (10 embedded, note 2)
OUNS Target Eb/No	8.5 dB

Note 1: These are forward channel gains in linear units with a maximum gain of 127

Note 2: Here embedded refers to a cell surrounded by other cells as would be the case in an operational mobile network.

3.0 CALIBRATION

The calibration described herein was not a formal calibration of the equipment but was instead a verification of the accuracy of the data measurement reports. Formal calibration of this equipment was carried out by the manufacturer at the factory.

Assistance in the on site verification was provided by Hewlett Packard and Advantest (Tektronics). Equipment provided by HP is listed below:

HP 8594E Spectrum Analyzer
HP 8648C Signal Generator
HP 8921A Cell Site Test Set (Pre-production)

Equipment provided by Advantest is listed below:

R3261A with Option 1K Spectrum Analyzer (with CDMA personality)

US West, the Institute For Telecommunication Sciences, and the JTC would like to express their appreciation to HP and Tektronics for their assistance in this verification.

A qualitative examination of the base station transmitter characteristics was performed. This included the frequency domain power spectrum and the code domain power spectrum. The mobile received signal strength (RSS) was measured qualitatively.

Items not examined during this verification include mobile station received pilot E_c/I_o, the base station received E_b/N_o, which require a tightly controlled laboratory procedure, and base station received signal strength.

3.1 Base Station Transmitter Characteristics

The transmit characteristics of the base station equipment were examined at the Table Mesa CO site only. The HP and Tektronics spectrum analyzers (SA) were used to record the spectrum and total transmit power. Both SAs had a CDMA personality which provided the correct spectral envelope for the IS 95 based PCS technology. The spectrum was found to be fully compliant. HP demonstrated a code domain analyzer which showed the code power in each Walsh code of the forward link, namely the pilot channel (Walsh code 0 (W0)), paging channel (W1), sync channel (W32), and two traffic channels (with the noise simulators turned off).

3.2 Mobile Station RSS Calibration

The mobile station, used for all mobile data logging, was checked for accuracy of the received signal level reports. The received signal level is the total received signal within the IF bandwidth and is detected prior to correlation (de-spreading). The procedure was to hard wire a connection between the base station and the mobile station, inject a known signal level into the mobile station and compare it to the report on the mobile diagnostic monitor. The mobile diagnostic monitor gives only a course report of the RSS. A more accurate calibration curve for the mobile is stored in the data analysis tool used for final data processing. The independent observer was provided with a copy of the mobile station factory calibration curve. The mobile station, as reported by the diagnostic monitor, was always within 3 dB of the actual RSS.

4. COVERAGE TESTING

Note: The cell site locations and the cell site antennas and their orientation are given as part of the BITB and are the same for each high tier technology tested. The individual TAGs have no latitude in cell location or in the antenna configuration. For some technologies the cell layout may not be optimal.

4.1 Coverage Methodology

The physical configuration of the cell sites was that given in section 2. Markov calls with a 40% voice activity factor were used to generate link performance statistics. OCNS/OUNS was set to simulate 10 active users in an embedded cell (i.e. a cell surrounded by other operational cells). The test van was configured with the mobile station under test inside the vehicle with its antenna mounted on the BITB in-vehicle mounting structure. Routes were chosen such that they ran radially outward from the cell sites. Where time permitted, routes were run that filled in the coverage area around the cells. For isolated cell testing a single cell site was activated. Softer hand-off was allowed between the sectors of the isolated cell. All other cell sites were powered down. For combined coverage soft hand-off was allowed between all sectors for a given cell and between the active cells. Table 4.1 lists the parameters logged for each run. All data listed was recorded once each second except the FER statistics which are calculated on the specified number of 20 millisecond frames. For each drive route a Markov call was initiated and the mobile and cell logging was activated. At the end of the route the data logging was stopped and the log files saved. Items logged at the mobile station include all mobile station statistics along with GPS location, velocity, and time. Items logged at the cell site (QTSO) include all cell site statistics, along with GPS time.

Table 4.1 Data logged for each coverage run.

Column	Data Logged
A	CDMA Time (GPS)
B	Vehicle Speed (mph)
C	Vehicle Latitude (deg. North)
D	Vehicle Longitude (deg. East)
E	GPS Source (GPS or Dead Reckoning)
F	GPS Data indicator
G	Mobile Received Power (dBm, 1sec avg)
H	Mobile Transmit Gain Adjust (dB, 1 sec avg)
J	Mobile Rx Pilot Ec/Io (dB, 1 sec avg)
K	Mobile Received Frame Counts
L	Mobile Fingers' Avg Time separation (microseconds)
M	Mobile Fingers' Max. Time separation (microseconds)
N	Mobile Fingers' Number of Pilots locked (1 sec avg)
O	Mobile Finger Lock Counts
P	QTSO Received Frame Counts
Q	QTSO Eb/No Set Point (dB, 1 sec avg)
R	Cell Rx Eb/No per antenna (dB, 1 sec avg)
S	Hand-off State
T	Traffic Channel Gain
U	Power Control Subchannel Gain
V	Forward Full FER, over 500 full frames
W	Reverse Full FER, over 500 full frames

4.1.1 Isolated Cell Coverage

Isolated cell coverage testing was conducted on three separate cells: Table Mesa CO, Walnut CO, and Green Mountain Mesa. The cell that had its coverage tested was active; the other two were turned off. Softer hand-off was allowed between the sectors of the cell under test. Table Mesa CO and Green Mountain Mesa cells had one 120° antenna sector active each. Walnut CO had three sectors active.

The coverage for each site was measured by driving the radial routes away from the site, and filling in between radials, as time permitted. Some routes were taken in the 'reverse' direction also, i.e. driving towards the site. These routes were excluded the from analysis in this section for consistancy. However, the outbound routes do show a lower received signal level due to shadowing effects from passengers inside the vehicle and the tinting of all windows except the windshield, than do the inbound. The approximate difference between the RSSI for the inbound versus outbound routes is on the order of 6 dB. Two handsets were used in the coverage testing. One located inside the vehicle and one outside the vehicle as described in section 2. The mobile station, with its antenna located inside the vehicle is labeled as the 'portable' handset and the mobile station with its antenna mounted outside of the van, on the roof top, is labeled as the 'mobile' handset in this report. A Markov test call was initiated close to the cell site, then the test vehicle drove away on one of the radial routes. In some cases, shadowing or poor coverage would cause the call to be dropped on the route; in those cases, the call was reinitiated if the pilot Ec/Io improved in a short distance.

4.1.1.1 Table Mesa CO

For the Table Mesa CO isolated cell coverage testing the other two cell sites were turned off. TMCO was populated with only a North facing sector. For all the test routes, Markov calls were originated prior to start of the route and the mobile and cell side data logging begun. The route was driven and the call and data logging were terminated at the end of the route. GPS location, velocity, and time were logged at the mobile. GPS time was logged at the QTSO.

4.1.1.2 Walnut CO

The coverage test for the Walnut CO was conducted in a similar manner to that used for the Table Mesa CO site. All sectors at the WCO site were active.

4.1.1.3 Green Mountain Mesa

The coverage test for the Green Mountain Mesa site was conducted in a similar manner to that used for the Table Mesa CO. Only the Southeast facing sector was active.

4.1.1.4 Walnut Out of van Antenna

All coverage testing included data logging for both the in-van and out-of-van antennas. However, the out-of-van testing was not formally part of the JTC testing, and was done at the option of TAG 2. The results of these informal tests are included in this section

4.1.2 Combined Cell Coverage

Combined cell coverage measurements were accomplished by turning cells one (WCO) and three (TMCO) on and allowing soft handoff between the two cells and the three sectors of cell one. Cell two was turned off for this test. To demonstrate three way handoff, cell two was activated briefly and a small number of routes driven. The routes driven were the same as those for the isolated cell coverage testing.

4.2 Isolated Cell Coverage Data and Discussion

Data was collected at both the portable and mobile handsets and at the QTSO, including GPS. The data from the different sources was then collated with respect to time, and combined to provide a file with location, speed, forward and reverse Frame Error Rate (FER), and other information about the radio link listed in Table 4.1. All parameters except for FER were collected every second. FER was tabulated on a 500 frame basis which corresponds to a minimum 10 second sample time.

The reader is referred to Appendix A for the resulting coverage plots. Each is labeled according to the section to which it corresponds. Also found in Appendix A is a topographic map of the Boulder vicinity. This is labeled as Map 4.2.

4.2.1 Table Mesa CO

Coverage plots for the Table Mesa isolated coverage test are as follows (in Appendix A):
- Map 4.2.1.1 Mobile Rx coverage plot (1 inch=1.88 miles)
- Map 4.2.1.2 Ec/Io coverage plot (1inch=1.85 miles)
- Map 4.2.1.3 Mobile Tx coverage plot (1 inch=1.81 miles)
- Map 4.2.1.4 Forward FER coverage plot (1inch=1.81 miles)
- Map 4.2.1.5 Reverse FER coverage plot (1 inch=1.68 miles)

Table Mesa Cell Site is indicated as a star in the lower left portion of the Maps 4.2.1.1-4.2.1.5. The TMCO Cell Site had only one 120° sector. The sector pointed North, providing coverage only to those areas within its beam width. To obtain a rough estimate of the coverage region, we assume that a received signal strength of -100 dBm or higher is desired. In that case, the coverage boundaries are approximately 5.7 miles due North-Northeast, 3.75 miles due Northeast, and 4.44 miles due East. The Table Mesa CO is located on a plateau that has a slight uphill slope in the Southern direction. It is in a suburban-residential environment, with mountains rising up about 2 miles to the West. Due to the irregularity of the terrain, the RSSI level varies significantly along the TMCO routes, crossing the -100 dBm level several times before finally dropping below -100 dBm for good. The above stated distance, however, is measured from Table Mesa CO to the first area on the route where the RSSI drops below -100 dBm. Due to the higher elevation of the site (relative to the Walnut cell), this cell had greater coverage in the North-Northeast area than did the Walnut CO cell.

The data presented in the section relates to the forward link with the exception of the Reverse link FER. In order to estimate the link balance, a comparison of Forward link FER vs. Reverse link FER is needed. However, the forward FER and reverse FER were sampled at different times. The time difference varied from one to several seconds. The measurements on the mobile station side correspond to speeds varying from a full stop (at the traffic lights) to 55 miles per hour. Due to the difference in sample times the Forward and Reverse FER measurements were taken at different physical points; up to 400 feet apart. In order to make a fair analysis of the link balance, it is essential to collect forward and reverse link data at the exact same spot (within a few feet). Hence, while is possible to analyze the link balance on an averaged basis, the link balance analysis is not considered in this report.

The log distance vs. portable handset RSSI (Forward RSSI) is shown on Figure 4.2.1.1 The data included in this figure is the overall data for this cell, excluding the points for which RSSI was less than -104 dBm. Those points were excluded because -104 dBm is the threshold level for normal system operation. The large variation in RSSI level is partially due to the fact that the data was taken outside of the North sector coverage area. On the other hand, we see that relatively strong signals (~ -76 to -82 dBm) exists far away from the cell (~13.5 miles). Those signals were recorded in the area that had clear line of sight with the Table Mesa cell.

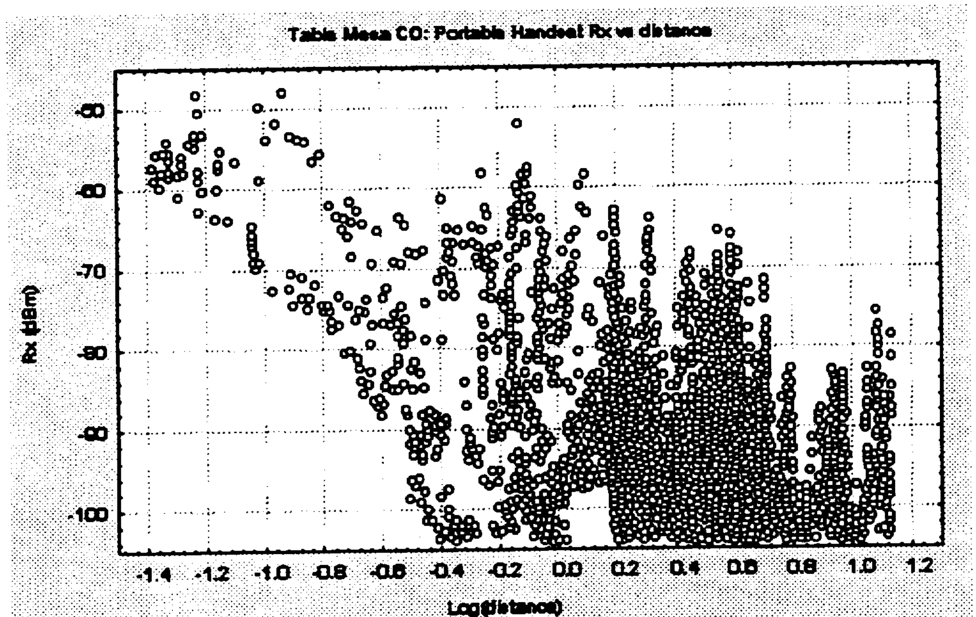


Figure 4.2.1.1. Recieved power versus $\log_{10}$(distance/1 mile).

Figure 4.2.1.2 shows the Table Mesa portable handset RSSI histogram. Figure 4.2.1.3 shows the mobile RSSI Cumulative Distribution Function. Again, points at which RSSI was less than -104 dBm were excluded. The mean is -91.8 dBm, and the standard deviation is 10.0 dB.

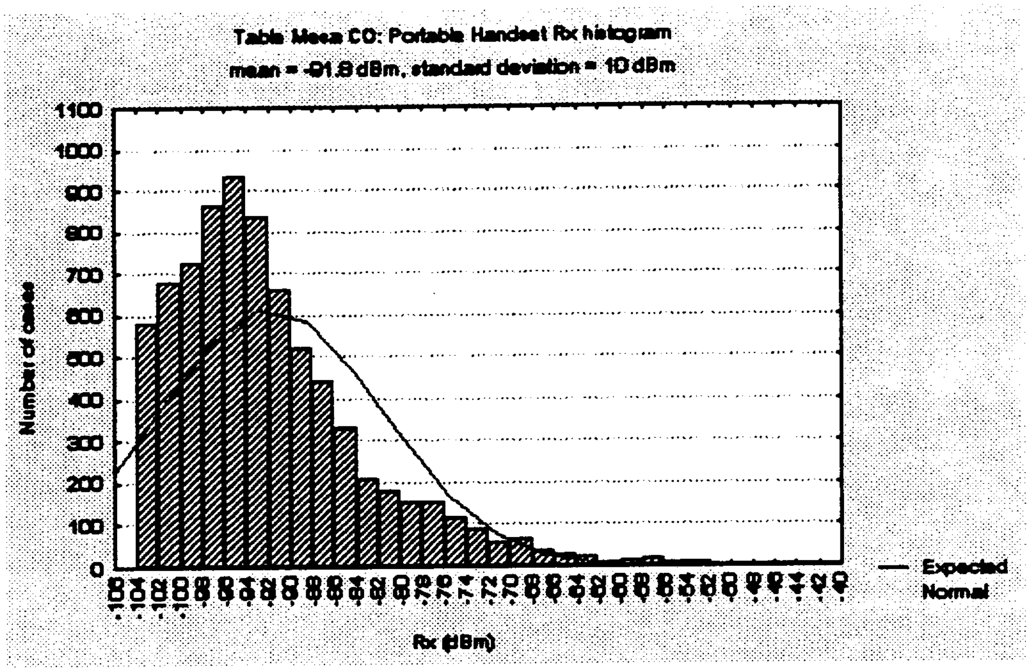


Figure 4.2.1.2. Handset recieved power histogram .

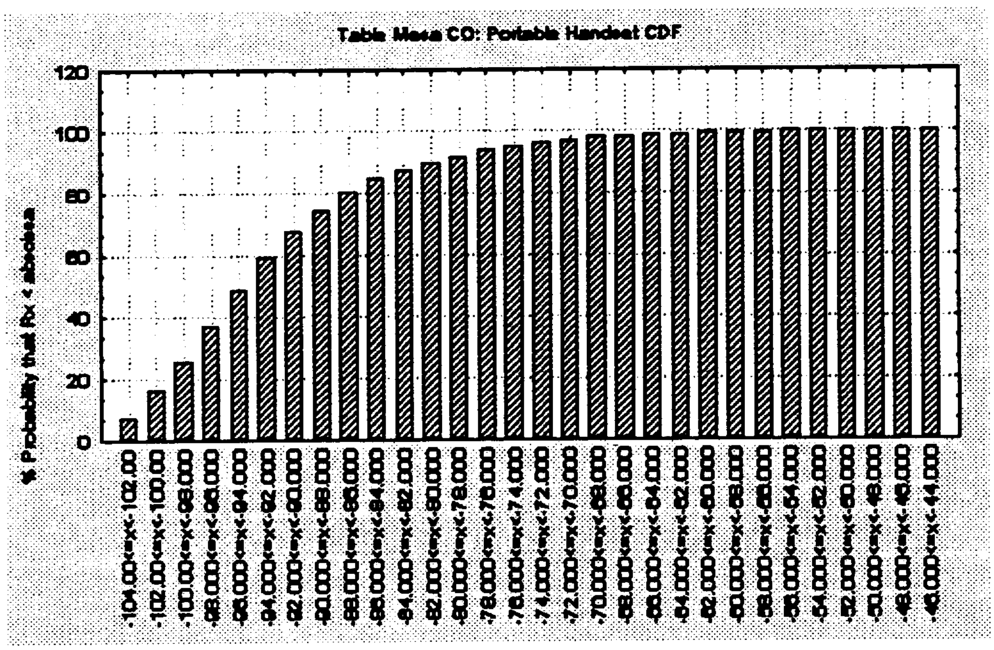


Figure 4.2.1.3. Handset received power cumulative distribution.

Figures 4.2.1.4 and 4.2.1.5 show the portable handset Transmit power Histogram and Cumulative Distribution Function. The maximum transmitted power is +26 dBm. It can be seen that approximately 13% of the data points had a transmit power greater than +25 dBm. That indicates that 13% of the time the portable handset was transmitting at its full power capacity. Since the portable transmit power increases when mobile is farther away from the cell, those points where close to the edge of coverage for this cell.

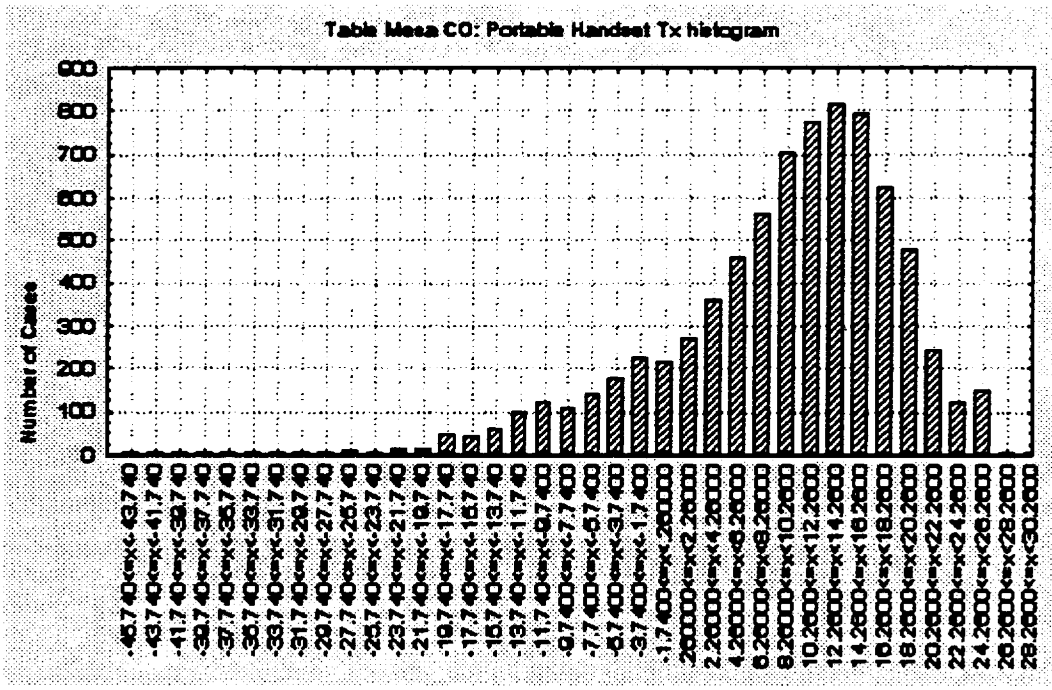


Figure 4.2.1.4. Handset transmit power histogram.

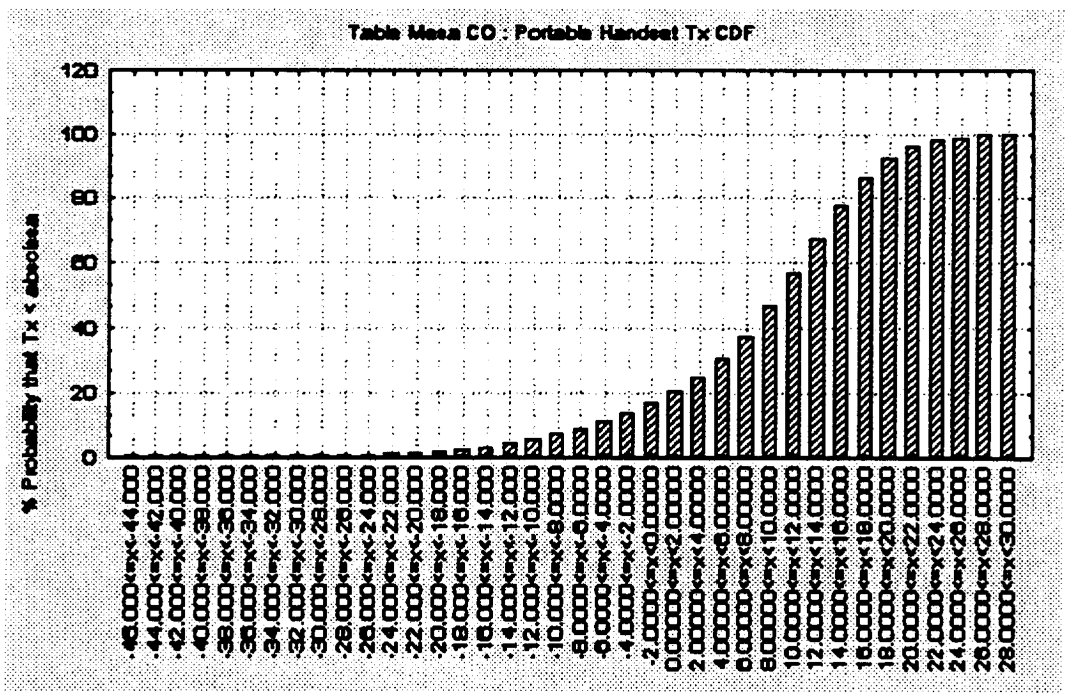


Figure 4.2.1.5. Handset transmit power cumulative distribution.

Figure 4.2.1.6 shows the reverse link Eb/No histogram. Cell Eb/No follows the QTSO target Eb/No closely when coverage is good.

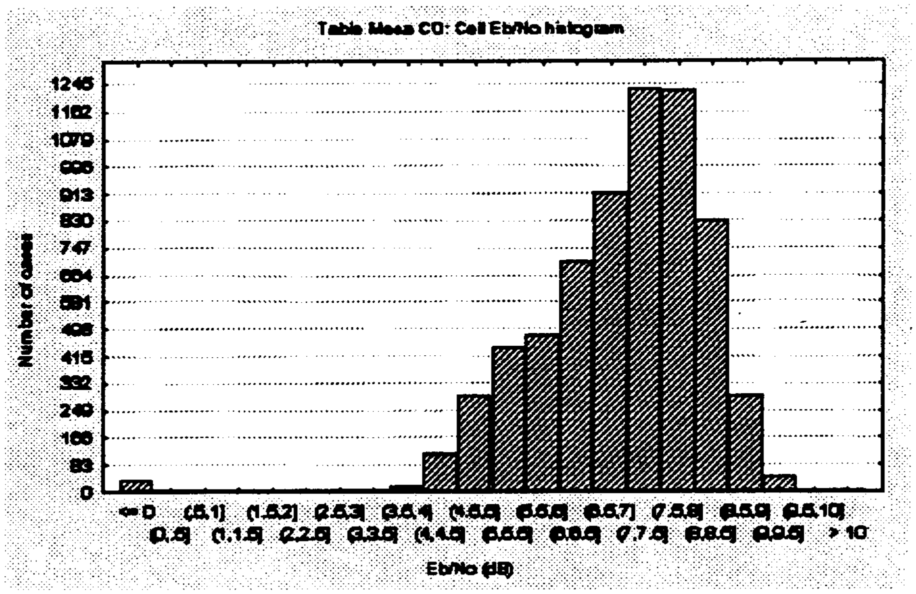


Figure 4.2.1.6. Reverse link Eb/No histogram.

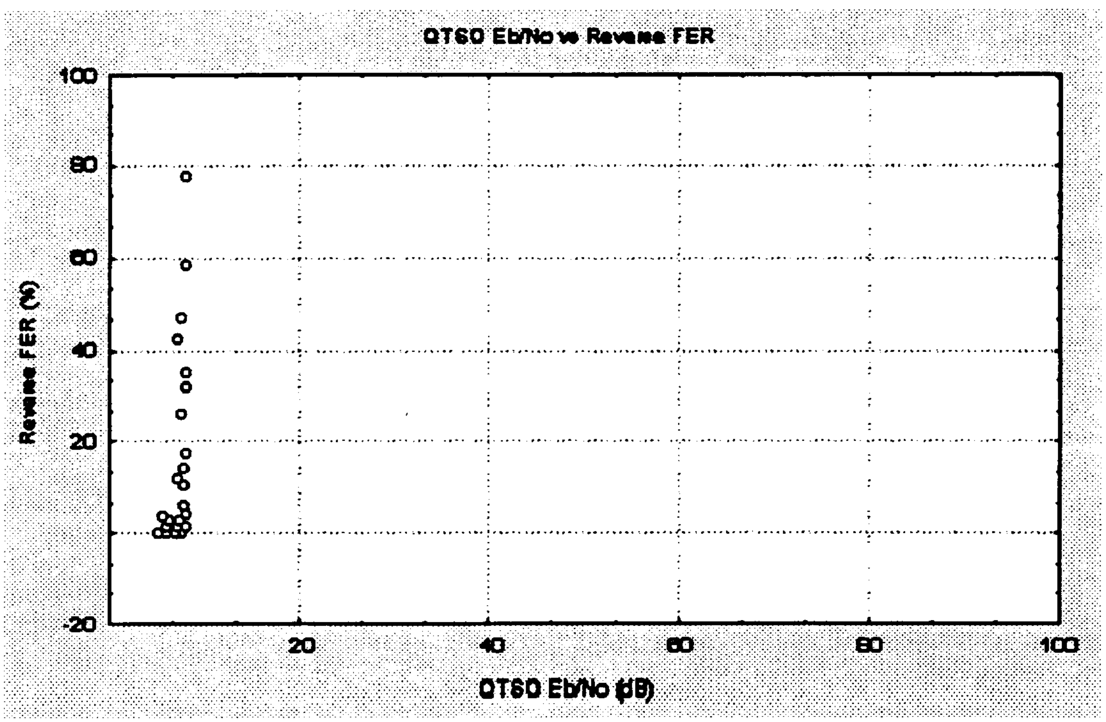


Figure 4.2.1.7. Cell target Eb/No versus reverse link FER scatter diagram.

The QTSO target Eb/No is set by the outer loop power control to provide a reverse link FER of 1%. When the mobile station goes out of the coverage area and can transmit no more power than its maximum rating, the target Eb/No goes to its maximum value (set to 8 dB for this test). When the mobile station cannot transmit enough power to meet the target Eb/No the FER increases above the 1% target. This is clearly seen in Figure 4.2.1.7, a scatter plot of QTSO Target Eb/No vs. Reverse FER (215 points total). As the mobile goes out of the region of good coverage, the target Eb/No goes to its maximum and the FER increases until the call is dropped (the actual Eb/No decreases).

Figures 4.2.1.8. and 4.2.1.9. show Reverse link and Forward link FER histograms. It is seen that both links have almost the same corresponding FER bin counts. This implies that in general the link is balanced, but can not be used in a formal link balance analysis, for the reasons previously explained.

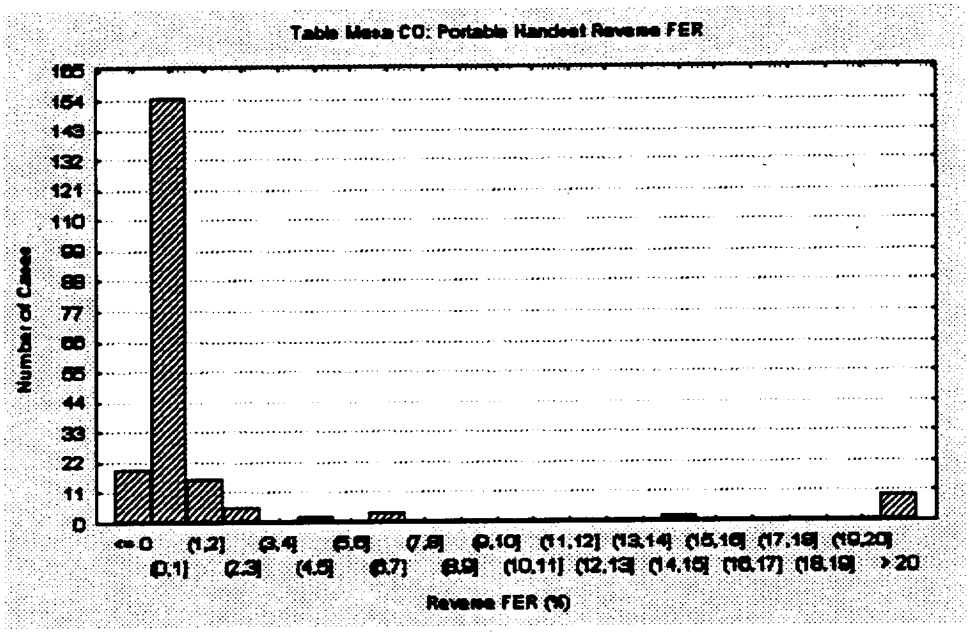


Figure 4.2.1.8. Reverse link FER histogram.

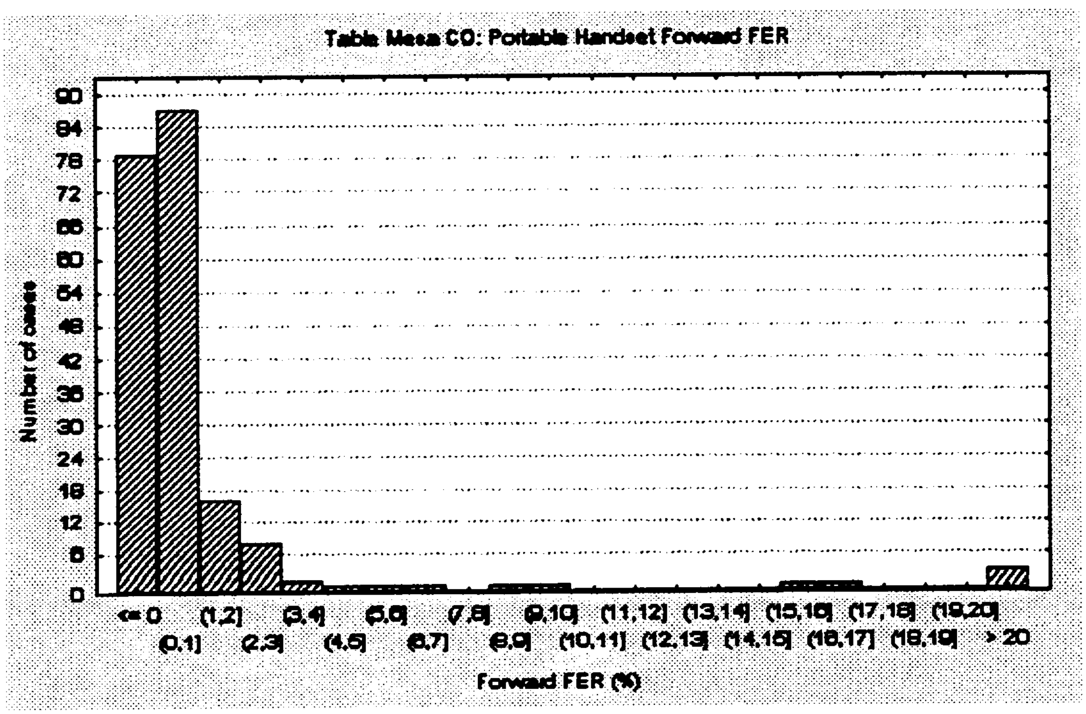


Figure 4.2.1.8. Forward link FER histogram.

4.2.2 Walnut CO

Coverage plots for the Walnut CO isolated coverage test are as follows (in Appendix A):
Map 4.2.2.1 Mobile Rx coverage plot (1inch=1.42 miles)

Map 4.2.2.2 Ec/Io coverage plot (1 inch=1.42 miles)
Map 4.2.2.3 Mobile Tx coverage plot (1 inch=1.38 miles)
Map 4.2.2.4 Forward FER coverage plot (1 inch=1.42 miles)
Map 4.2.2.5 Reverse FER coverage plot (1inch=1.33 miles)

The Walnut CO Cell Site, located in Downtown Boulder, is indicated with a star in the coverage plots. This cell site had all three 105° sectors operating. To obtain a rough estimate of the coverage region, it is assumed that a received signal strength of -100 dBm or higher is desired. In that case, the coverage boundaries are 1.4 miles due North 4.5 miles due East, and 1.6 miles due Southeast and due West. Once RSSI drops below -100 dBm in these directions, it generally stays below that value. The Walnut CO site sets in the bottom of a broad valley formed by Boulder Creek. The valley is oriented West to East with ridges rising up to the North and South. The Rocky Mountains rise up approximately one half mile to the West. Its elevation is lower than both Table Mesa CO and Green Mountain Mesa Sites. The WCO cell antennas are located on top of the WCO building and is in an urban mid to low rise environment. The scale on the maps is 1 inch = 1.42 miles. Due to the lower elevation of the Walnut cell (relative to the Table Mesa cell) and the terrain profile, this cell had smaller total coverage area than the TMCO cell.

The log distance vs. portable handset RSSI is shown in Figure 4.2.2.1. The data included in this figure are the overall data for this cell, excluding the points for which the RSSI was less than -104 dBm. Those points were excluded because -104 dBm is the threshold level for normal system operation. As with the TMCO isolated coverage, there is a large variation in the RSSI for a given distance. This is due to shadowing in the light urban environment and the choice of route. Note that there exist a single point with RSSI ~ -100 dBm at 8 miles away from the cell. If we compare this 'maximum distance' for the Walnut cell with the Table Mesa 'maximum distance' of 13 miles, we see that the Walnut cell has a smaller coverage area than the Table Mesa cell, and, as it falls within the coverage area of the TMCO site, could be regarded as a 'cell within the cell', when all cells are turned up.

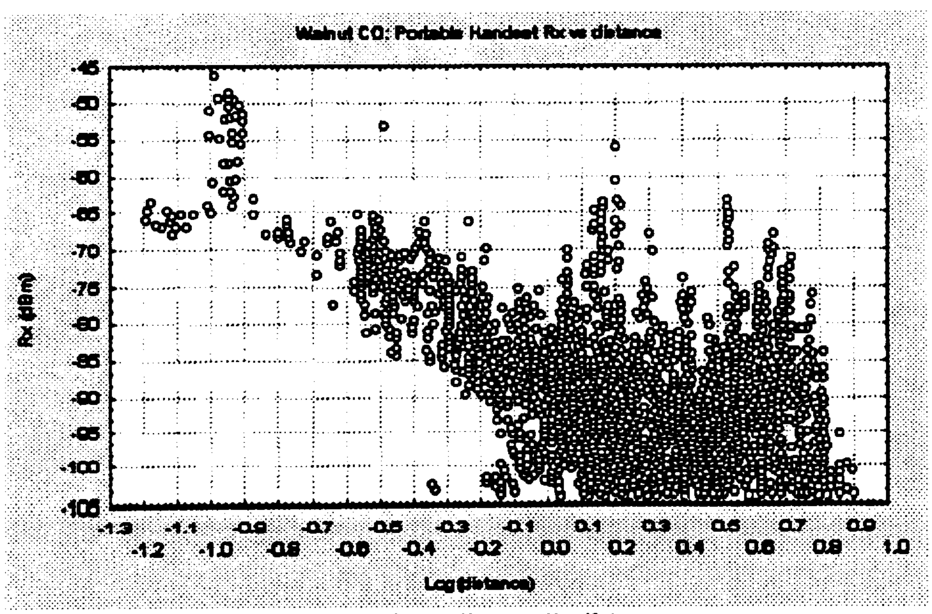


Figure 4.2.2.1. Handset received power versus $\log_{10}$(distance/1mile).

Figure 4.2.2.2 shows the Walnut CO portable handset RSSI histogram. Figure 4.2.2.3. is the portable handset RSSI Cumulative Distribution Function. Again, points at which RSSI is less than or equal to -104 dBm were excluded. The mean RSSI is -89 dBm, and the standard deviation is 13.5 dB.

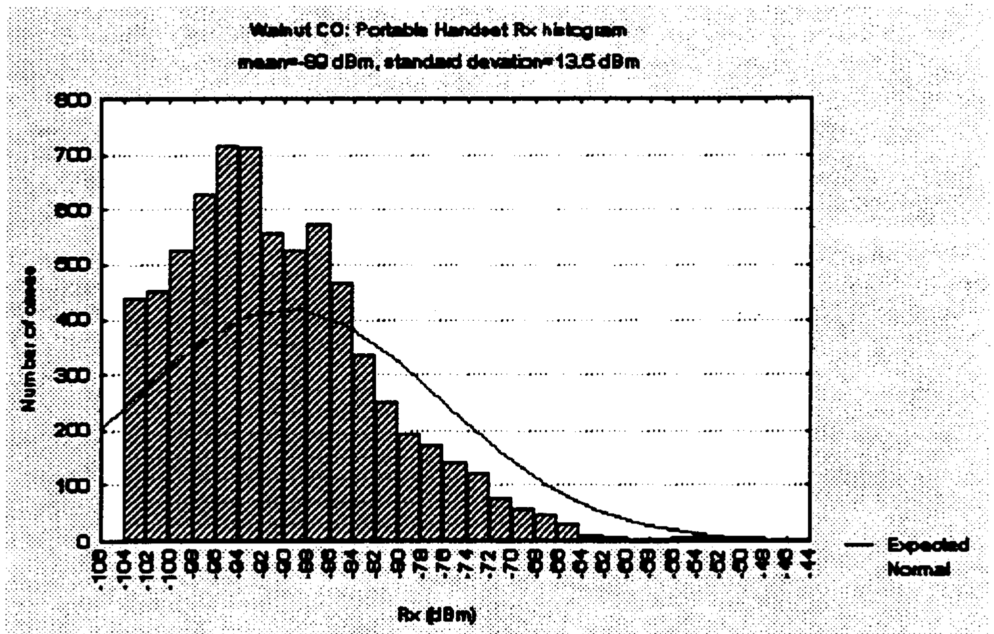


Figure 4.2.2.2. Handset received power histogram.

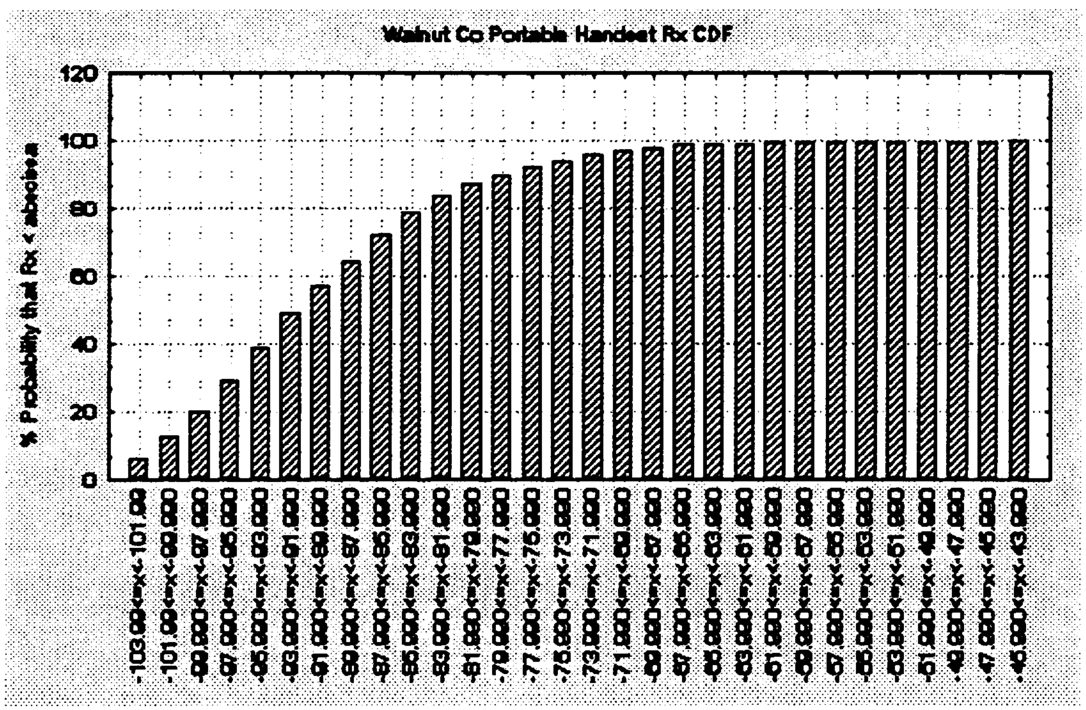


Figure 4.2.2.3. Handset received power cumulative distribution.

Figures 4.2.2.4 and 4.2.2.5 are the portable handset transmit power histogram and cumulative distribution function. The maximum transmitted power is +26 dBm. It can be seen, as in case of Table Mesa cell, that approximately 13% of the data points had transmit power greater than +25 dBm. This indicates that 13% of the time the portable handset was transmitting at its full power capacity. Consequently, the points at which handset was transmitting at its full power capacity were the points close to the edge of coverage for this cell or where significant shadowing occurred.

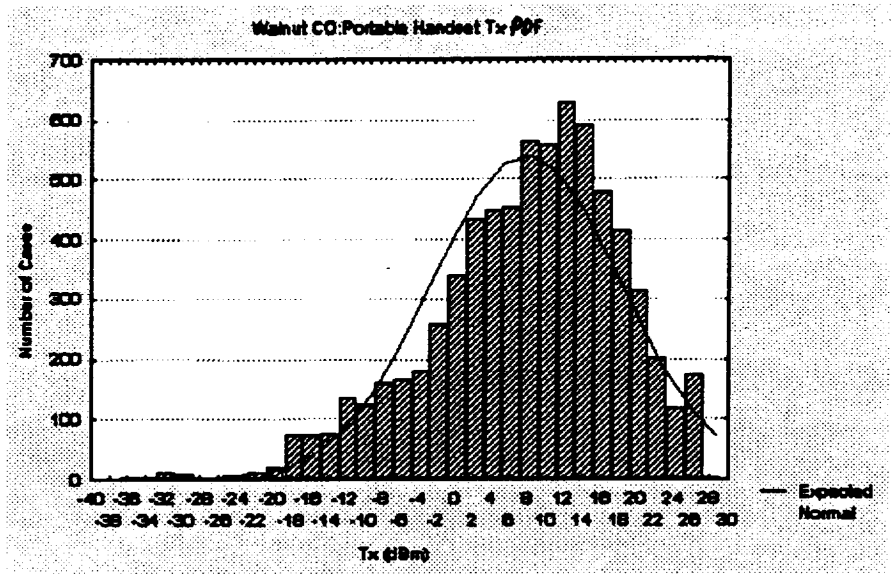


Figure 4.2.2.4. Handset transmit power histogram.

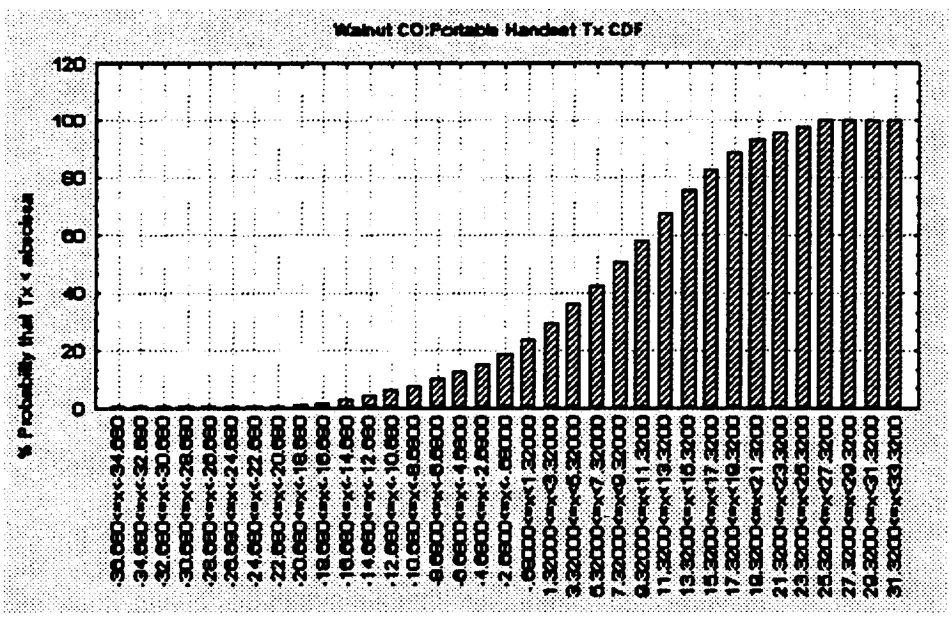


Figure 4.2.2.5. Handset transmit power cumulative distribution.

Figure 4.2.2.6 shows a scatter plot of the QTSO Target Eb/No versus Reverse FER (185 total points). It is seen that Target Eb/No varies between 5 and 8 dB in order to keep FER at or below 1%. Once the QTSO target Eb/No goes to saturation (that is, when the mobile goes out of coverage), the FER increases, until the call is dropped.

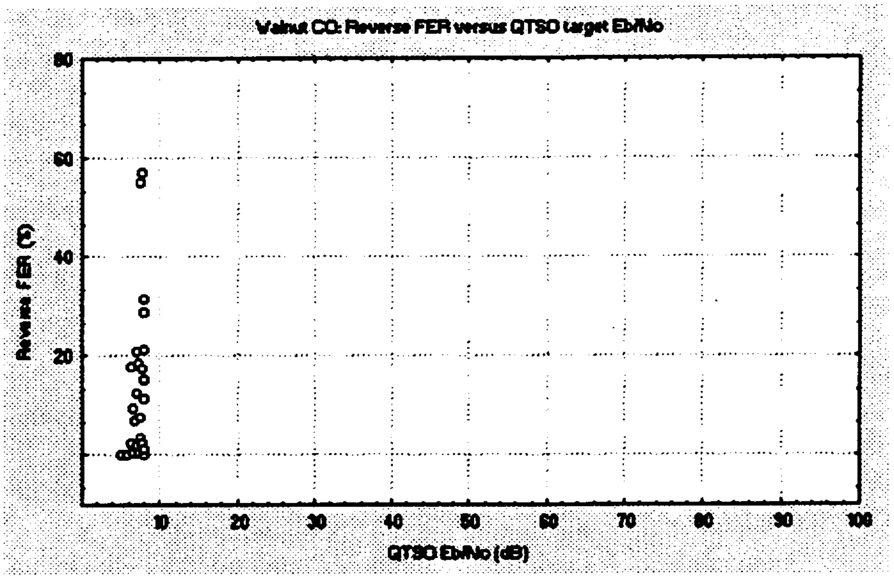


Figure 4.2.2.6. Reverse link FER versus target Eb/No.

Figures 4.2.2.7. and 4.2.2.8. show histograms of the Reverse FER and Forward FER respectively. As seen in the Table Mesa cell coverage analysis, both links have almost the same corresponding FER bin counts. This implies that in general the link is balanced, but can not be used in a formal link balance analysis, as described previously.

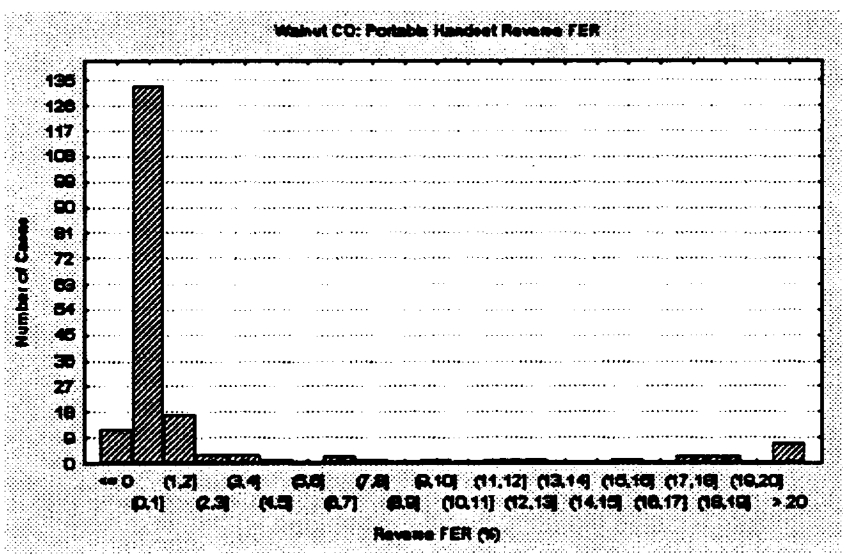


Figure 4.2.2.7. Reverse link FER histogram.

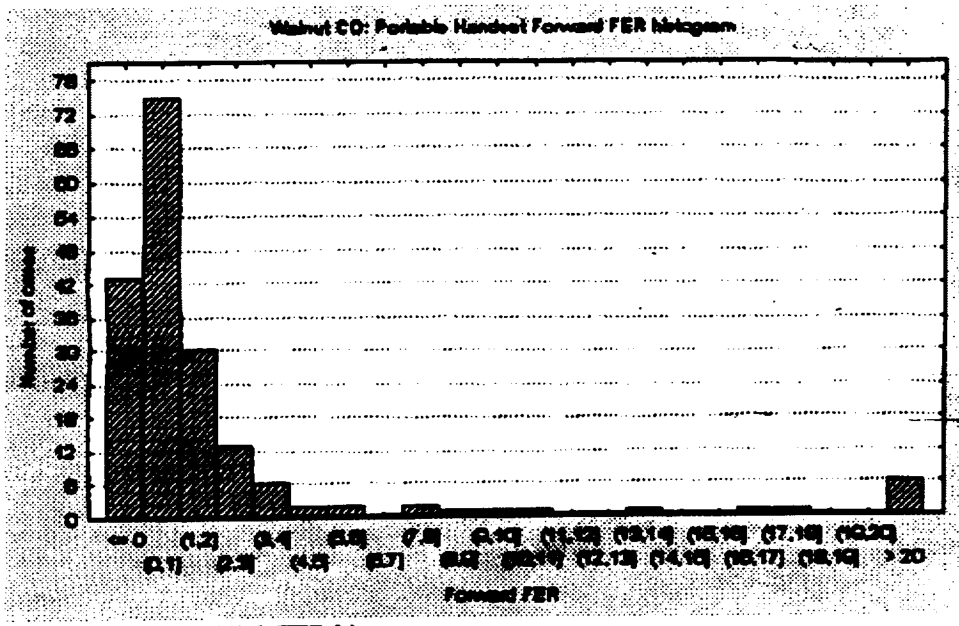


Figure 4.2.2.8. Forward link FER histogram.

4.2.3 Walnut CO Out of Van Antenna

Coverage plots for the Walnut CO isolated cell, roof top antenna, coverage tests are as follows (in Appendix A):

- Map 4.2.3.1 Mobile Rx coverage plot (1inch =1.73 miles)
- Map 4.2.3.2 Reverse FER coverage plot (1 inch=1.33 miles)
- Map 4.2.3.3 Forward FER coverage plot (1 inch=1.33 miles)

The Walnut CO Cell Site is indicated with a star in the coverage plots. This cell site had all three 120° sectors active with softer hand-off allowed between the sectors. The signal was received with an Omnidirectional antenna mounted on the roof of the test van. Data for the roof-top and in-van antennas were collected simultaneously. To obtain a rough estimate of the coverage region, it is assumed that a received signal strength of greater than or equal to -100 dBm is desired. In that case the coverage boundaries extend to more than 8.5 miles due North, 9.3 miles in a Northeast direction, and 1.6 miles to the Southeast and to the West. The coverage to the Southeast is not easy to determine, because the RSSI level varies widely in that direction. It is clear, however, that the coverage has improved significantly when the antenna is placed on the top of the van. The improvement is especially pronounced in the areas to the North. Here there is ridge along the North side of the Boulder Creek Valley with the terrain remaining relatively flat beyond. To the South the terrain drops away beyond the South ridge of the Boulder Creek Valley making coverage there difficult.

Figure 4.2.3.1 shows a histogram of the Walnut CO roof top antenna handset RSSI. Again, points at which the received signal strength was at or below -104 dBm were excluded. The mean RSSI is -83.8 dBm, and the standard deviation is 11 dB.

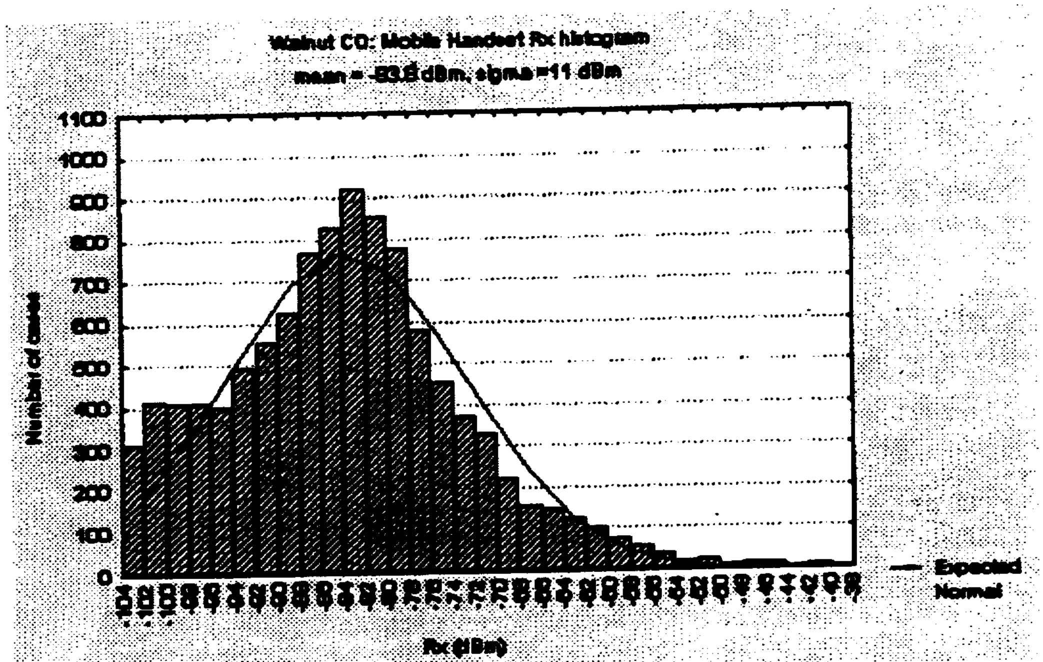


Figure 4.2.3.1. **Handset received power histogram, roof top antenna.**

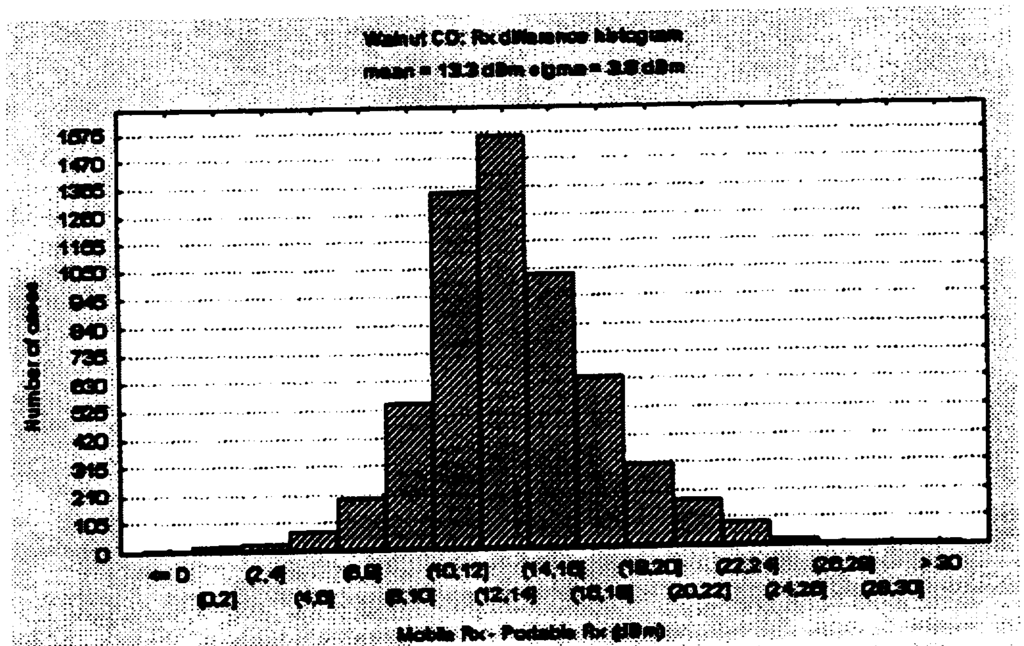


Figure 4.2.3.2. **Histogram of in-van antenna out-of-van antenna RSSI difference.**

Figure 4.2.3.2 shows a histogram of the difference in received signal level between the in-van and out-of-van antenna mobiles. The data given is only for the outbound routes. Here the van is generally proceeding away from the cell site so that there is attenuation due to passengers, window tinting and the van's metal structure. A mean difference of 13.4 dB is seen. Had the inbound routes also been included the mean value of the difference would have been lower since the in-van antenna was near the front windshield (which was not tinted).

Figures 4.2.3.3 and 4.2.3.4 show the reverse and forward link FER histograms for the Walnut site using the out-of-van antenna.

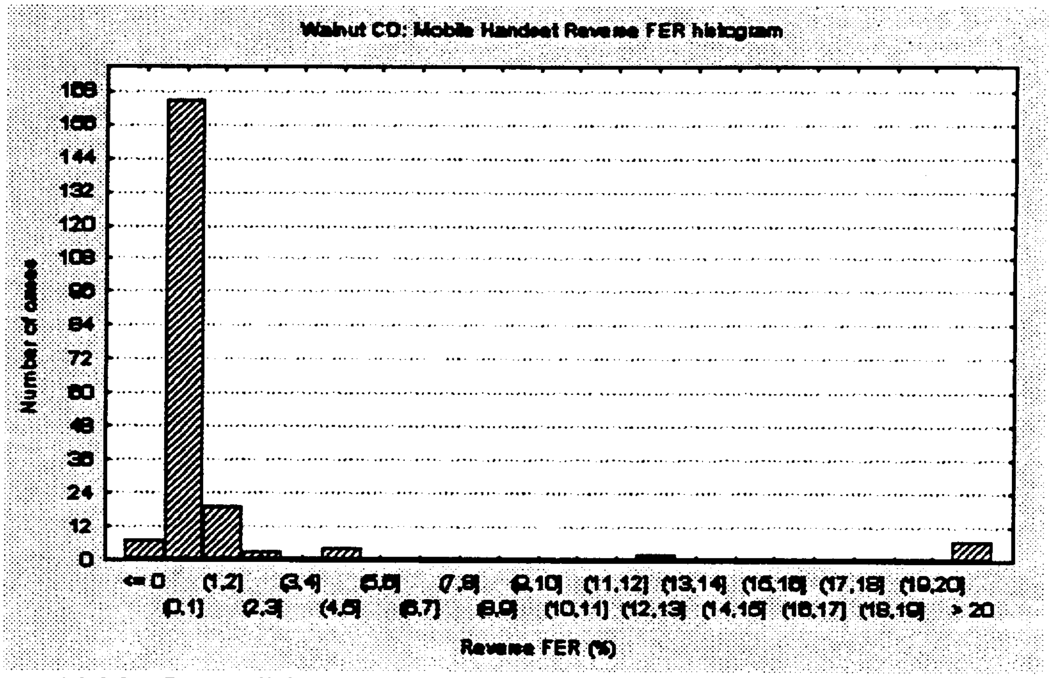


Figure 4.2.3.3. Reverse link FER histogram.

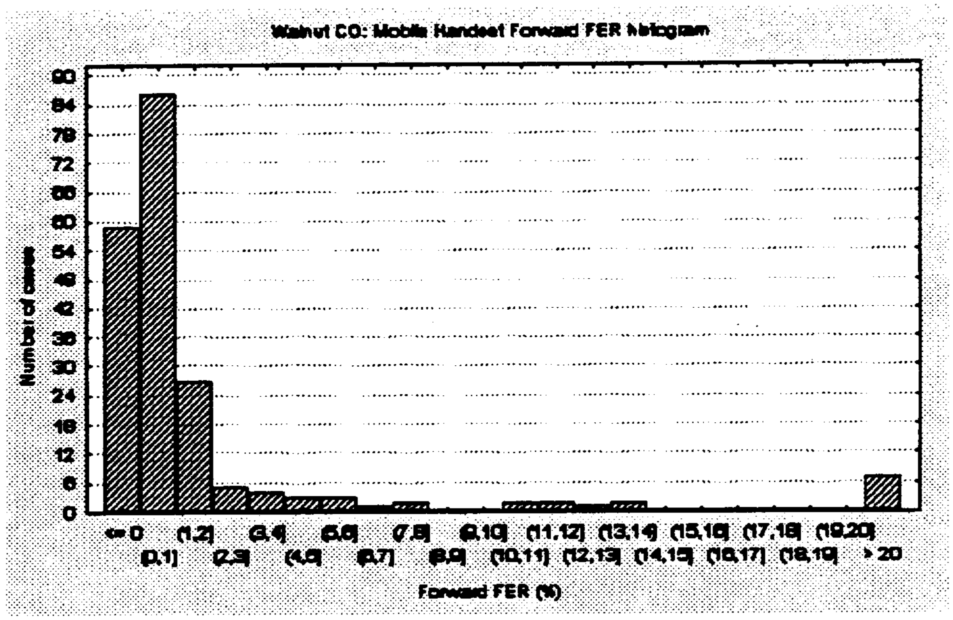


Figure 4.2.3.4. Forward link FER histogram.

5.0 HAND-OFF TESTING

The TAG 2 technology employs soft hand-off. Soft hand-off occurs when the mobile station commences communication with a new serving cell or sector while maintaining communication with the currently active serving cell or sector. Formally, soft hand-off occurs between two active cells, softer hand-off occurs between two active sectors of the same cell, soft-softer hand-off occurs between two active sectors of the same cell and another active cell, and softer-softer occurs between three active sectors of a given cell.

It is important to note that all high tier technologies are required to use the same cell sites. This does not allow for the optimal tuning of the network in terms of geographic placement of the cell sites. It does however, provide a common environment in which to test each technology.

5.1 Testing Methodology

To accomplish the hand-off and combined coverage tests the appropriate cells/sectors were turned on and soft hand-off was enabled. Routes that passed through the coverage areas of each cell/sector were driven and data were collected. When the voice quality during hand-off was measured the route was driven once with voice call and then repeated with a Markov call. For this portion of the field trial analysis only the Markov calls are used since they provide accurate link statistics.

The network hand-off parameters were as follows:

T_ADD = 14 dB
T_DROP = 16 dB
T_TDROP = 6 Sec

Data analysis for hand-off testing considers two areas. These are: the percentage of time the network is in a particular hand-off state and the hand-off state as a function of position. These are considered for cells 1 and 3 active.

5.2 Hand-off Testing Results

5.2.1 Walnut CO and TMCO Active

The plot of hand-off state versus position is as follows (in Appendix A):
Map 5.2.1.1 Hand-off states

From the hand-off state plot, it is seen that no hand-off was recorded in the immediate vicinity of the active cells, in Downtown Boulder, and in Table Mesa area. Soft hand-off was present in the open areas East of Boulder, where both TMCO and WCO had overlapping coverage. Softer hand-off was pronounced in the areas where the signal from neighboring sectors from the Walnut CO cell were overlapping. The area where soft-softer hand-off occurred was in the open areas along the Foothills Parkway, East-Northeast of Boulder. In this area two sectors from WCO overlap and there is line-of-sight to TMCO. There are a few other isolated areas where soft-softer hand-off occurred, but in less consistent manner than along the Foothills Parkway.

Figure 5.2.1.1 shows a histogram of the hand-off state. In terms of percentages, the following break down is seen:

- No hand-off: 37%
- softer hand-off: 9%
- soft hand-off: 40%
- soft-softer: 14%

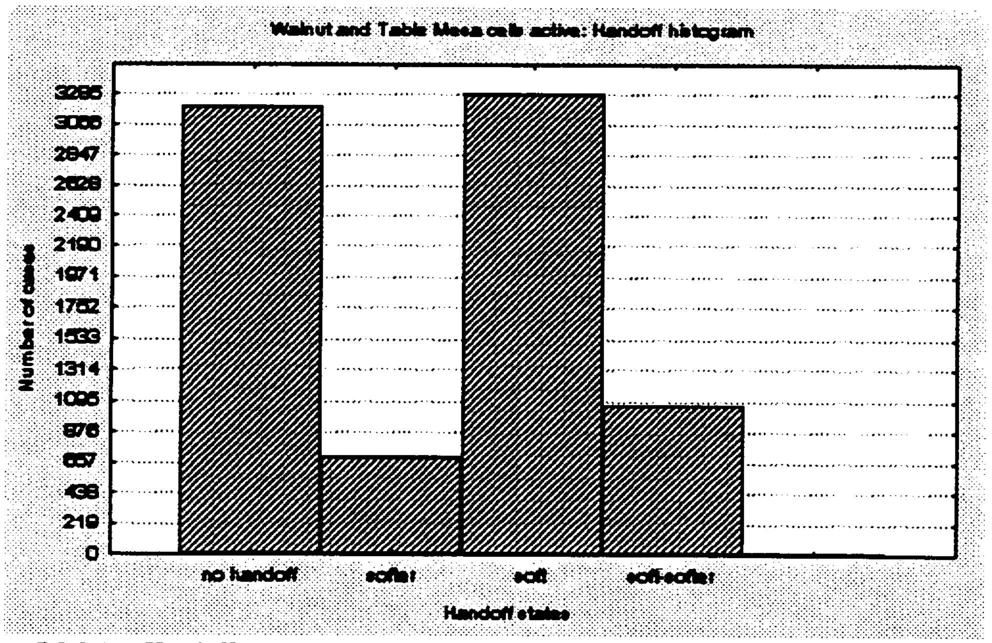


Figure 5.2.2.1. Handoff state histogram.

Given that Table Mesa CO cell site operated with one sector only, the percentage of locations in soft hand-off is rather high. That implies that Walnut CO was indeed 'embedded' cell in this configuration. This resulted in the large percentage of locations in the soft hand-off state during the combined coverage testing. Due to the light load of the system the pilot signals have a high signal to interference ratio (Ec/Io). With increasing load the pilot Ec/Io decreases and the percentage with no hand off increases. The manufacturer states that the system was not optimized for the given test configuration and cell spacing but instead used the same settings used in other QUALCOMM CDMA tests.

6. VOICE QUALITY

6.1 Data Collection Methodology

6.1.1 Test Stimuli

For quasi-stationary measurements, Harvard test sentences were transmitted over the radio link. The Harvard sentences are phonetically balanced and include all sounds in the English language. Ten sentences were spoken by a male, and 10 sentences were spoken by a female. The digitally recorded sentences were 75-80 seconds in length. The source tape was recorded and provided by USWAT. For the handoff test, the source tape was provided by Qualcomm, and consisted of Harvard sentences played continuously over a given run. In-vehicle measurements were made for both the quasi-stationary and handoff tests. While the vehicle was in motion, the source tape was played across each link simultaneously, one from the base to the mobile and one from the mobile to the base, and recorded at the opposite end. Voice samples of transmitted sentences were recorded onto digital audio tape (DAT).

6.1.2 Test Conditions

6.1.2.1 Handoff Drive Test

Voice recordings were made while driving along routes through handoff areas, for both the forward and reverse links. The routes were selected according to previous tests at the BITB. One route was driven along Broadway Rd., at a vehicular speed of 25-30 mph. The second route was driven along Foothills Parkway, at a vehicular speed of 55-60 mph. The beginning of a route was selected within the coverage area. Continuous voice recordings of transmitted Harvard sentences were made along the route until the call was finally dropped. Two runs were conducted along each route, one traveling from the north to the south, and the other in the opposite direction. Voice quality for the handoff drive tests was assessed using the expert listener methodology described below.

6.1.2.2 Quasi-Stationary Test

In addition to handoff VQ tests, quasi-stationary tests were conducted at points along a 0.5 mile grid that enclosed the expected coverage for the Table Mesa and Walnut sites. The grid points were consistent with prior TAG testing in the BITB, although there were some variations in testing. Both the Table Mesa and Walnut cell sites were activated for all of the quasi-stationary measurements. In prior TAG testing of the PCS1900 technology, only one cell was activated at a time. Half of the grid points were measured with one cell site active, the other half measured with only the second cell site active. Overall, fewer quasi-stationary measurements were collected during TAG 2 testing, because the Table Mesa cell site had only one sector, the northern sector, activated. As a result, no quasi-stationary measurements were collected beyond the activated sector to the south. A total of 138 measurements (on the forward and reverse links) were collected at 69 different grid points. However, only the first 120 successful measurements were tested with panels of listeners (from 60 locations) because of the design of the test.

Voice recordings were taken for two cases of vehicular speed at the various locations. At half of the locations the vehicle traveled 10 meters over the sample time; at the other half, the vehicle traveled 100 meters. The measurement locations were recorded with the GPS.

Later, the taped voice samples were digitized into a Macintosh SoundEdit 16 application at a rate of 16 bits, 22 kHz. All data was stored in a 1.2 Gbyte hard drive. For MOS testing, the first sentence and the last sentence of the recorded sample were dropped to avoid the possible inclusion of sentences that had been cut short due to starting a recording too late or stopping a recording too soon. Therefore, during MOS testing, a total of 8 sentences (out of the original 10 sentences) were presented to listeners for each sample. Voice quality of the quasi-stationary samples was assessed using both the MOS and expert listener methodologies, described below.

6.1.3 Engineering Data

Only limited RF data could be feasibly collected during a voice call, therefore for each VQ test run, another run was repeated with a Markov call activated. Voice samples were collected during a voice call; during a Markov call GPS data and the following RF data were collected: FER, mobile received power (in dBm), mobile transmit power (in dBm), mobile transmit gain adjust (in dB), mobile received pilot Ec/Io (linear, indB), and QTSO power control set point (lin, in dBm).

Markov calls can be set up for variable rate or full rate. The variable rate Markov call produces a voice activity of 40%. A full rate Markov call was chosen to approximate the 75% voice activity of the source tape.

6.2 Voice Quality Assessment Methodology

6.2.1 MOS Methodology

6.2.1.1 Subjects

Thirty-one subjects were recruited from the Boulder area to participate. One extra subject was scheduled per day in case there were any that did not show, however, on one day, there were two no shows, therefore only 31 subjects were included in the final data set instead of 32. Subjects were run in groups of three, four, or five at a time, for a total of eight groups. Every listener within a group, listened to the same samples. Each day, two groups were run, and were presented with the same stimuli. Groups on differing days listened to unique voice stimuli. Each of the following age ranges were represented within the subject pool: 18-25 yrs, 25-35 yrs, 35-45 yrs, 45-55 yrs, and over 55 yrs. Subjects consisted of an equal number of males and females. Subjects were cordless but non-cellular phone users. Subjects were paid $35.00 for their participation, or subjects deferred receipt of payment to the organization from which they were recruited. When 9 subjects were run on a given day, one subject was dropped from the data set. The decision to disclude a given subject was based on demographics, so that the optimal number of subjects in each age range and gender were maintained.

6.2.1.2 Schedule and Resources

Testing occurred between June 15, 1995 and June 18, 1995 at the U S WEST Advanced Technologies Human Factors lab in Boulder, CO. Each testing session lasted approximately two hours. Michelle Owens was the experimenter. Two testing sessions were conducted per day.

6.2.1.3 Methodology

Subjects first filled out a consent form and a demographic survey. The experimenter then read procedural instructions to them (see Appendix 6.A). After instructions were read by the experimenter participants were shown how to use the computer and mouse (if necessary). For training, subjects were presented with ten practice samples of voice segments and given a chance to rate them (see Appendix 6.B). The practice samples included two iterations of a 64 kbps wireline sample, one good voice quality sample from the field, one bad sample from the field, and six samples recorded over a speech codec in Qualcomm's lab. The codec samples used in training were either full rate or half rate samples, with an average FER of either 0%, 1%, 3% or 5%. The goal was to demonstrate a wide range of quality during training to listeners. We did not feel as though samples collected in the field represented the full range of quality needed, therefore after field testing was concluded, the codec samples were recorded in the lab. The training session allowed inexperienced listeners to gain exposure to the full range of possible voice quality, from excellent to bad, and ensured proper scaling of Mean Opinion Scores (MOSs). Once training was complete, each subject provided an Opinion Score for 33 voice segments. Thirty segments were field test samples; the remaining three were either 64 kbps wireline or poor voice samples collected in the field. For each group of listeners, a total of 43 samples were rated. The order of presentation of each voice segment (presented after training) were randomized. Each segment consisted of 8 Harvard sentences. Four sentences were spoken by a male and were presented first 50% of the time, four were spoken by a female. The order of presentation of male or female sentences first was randomized.

Subjects answered the following questions after each segment using the computer:

1) How would you rate the overall QUALITY of the sound?
(on a 5-point scale: Excellent, Good, Fair, Poor, Bad)

2) How annoying are any ADDITIONAL sounds you may hear?
(on a 5-point scale, from Not at All Annoying to Extremely Annoying)

3) Would this be ACCEPTABLE as portable service (Yes or No)? (see Appendix 6.B)

Subjects were given a 15-20 minute break half way through the session. After all segments were presented, subjects filled out a post-trial questionnaire (see Appendix 6.C) and a receipt of payment form.

The answers to question one (How would you rate the overall QUALITY of the sound?) were averaged across 8 (or 7) subjects for each sample, and the resulting score is the Mean Opinion Score (MOS) for that sample. This methodology allowed us to obtain MOSs for a total of 120 samples, or 60 locations of forward and reverse link transmissions. Testing more than 120 samples would have required an additional panel of eight listeners.

Note: The MOS methodology for the TAG 5 trial was slightly different. In general, since TAG 5 testing, the amount of training has increased and the use of several iterations of a 64 kbps sample was incorporated. The main reason is due to pressures from more than one upcoming TAG regarding scaling of the MOSs. For TAG 5, only 2 samples were used for training, and only one sample was 64 kbps.

6.2.2 Expert Listener Methodology

Voice segments were also rated using an expert listener methodology before results of listener panels were analyzed. A 3-point scale of acceptability was utilized: Definitely acceptable, Marginally acceptable, and Unacceptable. The expert listener, Michelle Owens, was trained to emulate the responses of panels of listeners to question number 3) Would you consider this acceptable as portable service. USWAT has been conducting voice quality tests since 1993, and has numerous voice samples and analysis for such technologies as DECT, WACs, and PHS. A training software package was compiled which outlined samples of each type of acceptability level determined by listener panel testing. The expert listener was trained using this software package until she demonstrated a reasonable level of proficiency in matching listener panel ratings of acceptability. Note: the training samples are limited to those samples we had listener panel data on, therefore it is unlikely that all types of digital noise and distortions were represented in the training material. However, the expert listener has conducted several field trials with various technologies since she was trained, and as a result has listened to and rated over a thousand voice samples since May 1994.

Listener panel responses to question three: Would this be ACCEPTABLE as portable service? were transfered to a 3-point scale of acceptability (percent acceptability):

Definitely acceptable (more than 70% of subjects rated acceptable),
Marginally acceptable (30 to 70% rated acceptable), and
Not acceptable (below 30% of subjects rated acceptable).

The expert listener ratings match this 3-point scale in the following ways:

Green = Definitely acceptable,
Yellow = Marginally acceptable, and
Red = Unacceptable.

For the quasi-stationary voice measurements, a single rating was given for each sample, and later compared to the listener panel results, see data analysis below.

For the handoff test, an expert listener rating was made for each four second period along the continuous voice recordings, which equates to roughly one rating per sentence. The resulting ratings for each run were plotted on a coverage map (see Maps 6.3.4.1-6.3.4.8). For a more detailed discussion of handoff, see section 5.0 Functionality Testing.

6.3 Voice Quality Data Analysis and Discussion

6.3.1 MOS Data Analysis and Discussion

Voice quality ratings from question one were averaged across subjects in order to obtain a Mean Opinion Score (MOS) for each sample. Recall, an MOS was generated for each of 60 locations around Boulder, in both the forward and reverse links at each location (n = 120). The histogram of all MOS scores is diagrammed in Figure 6.3.1.1 below. Overall the voice samples were marked favorably, with 88% of the samples being rated between fair (3.0) and excellent (5.0). The average of all MOSs is 3.56, and the standard deviation is 0.501.

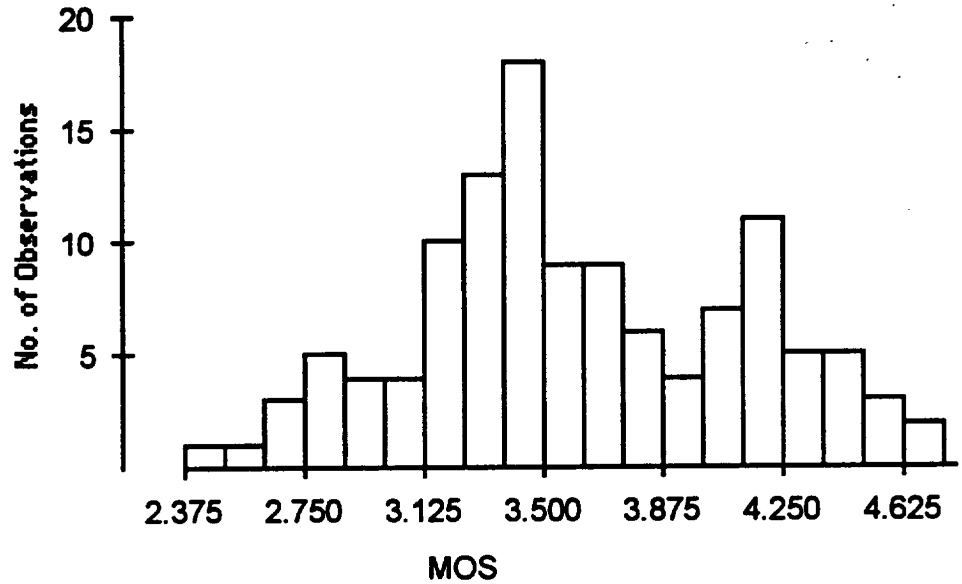


Figure 6.3.1.1. MOS histogram.

The following histograms, Figures 6.3.1.2 and 6.3.1.3, show MOS scores delineated by link type. The averages of MOSs by link type are 3.65 and 3.47 for the reverse and forward links, respectively. A t-test reveals that there is a statistically significant difference in MOSs between the forward and reverse links (t-stat= -2.008, with 118 d.f, reject H_0 at α=0.05).

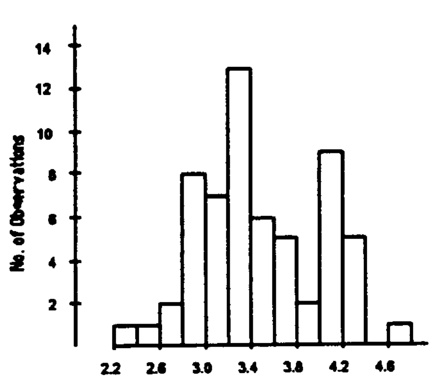


Figure 6.3.1.2.

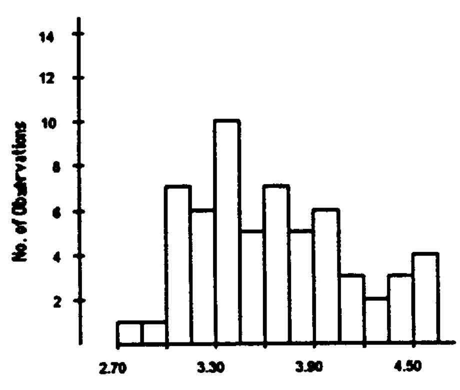


Figure 6.3.1.3.

Figure 6.3.1.4 compares MOS scores against one objective measure: average received power. Figures 6.3.1.5 and 6.3.1.6 compares MOSs with Frame Error Rate (FER) by link type. In the scatterplots, MOSs show a large variance in scores at all levels of rx power and FER. These engineering measures, when averaged over the entire voice sample, do not appear to be accurate predictors of listener satisfaction.

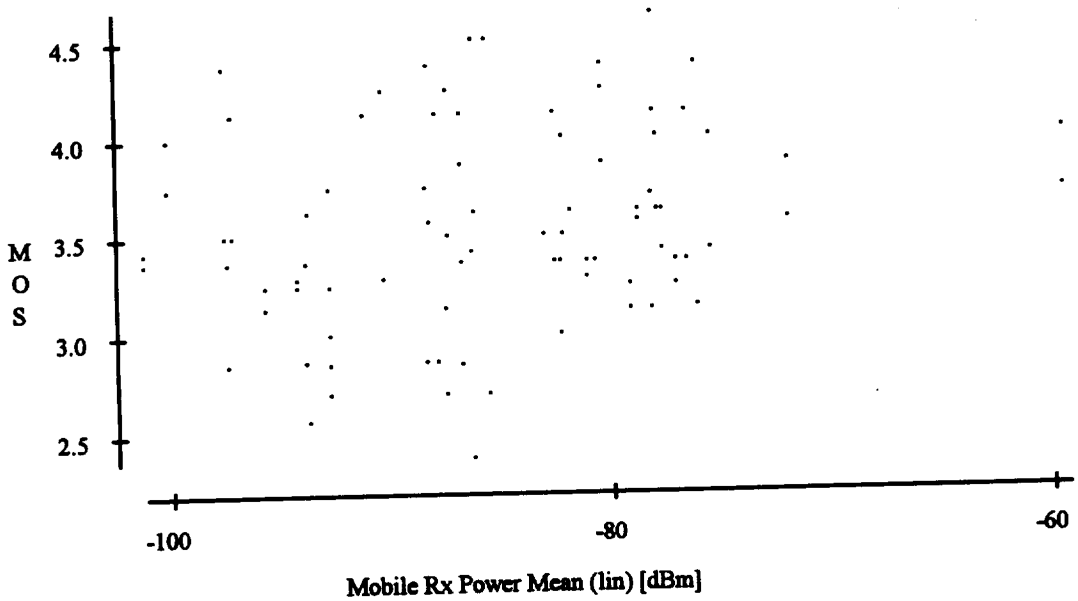


Figure 6.3.1.4. MOS versus Mean Mobile Received Power.

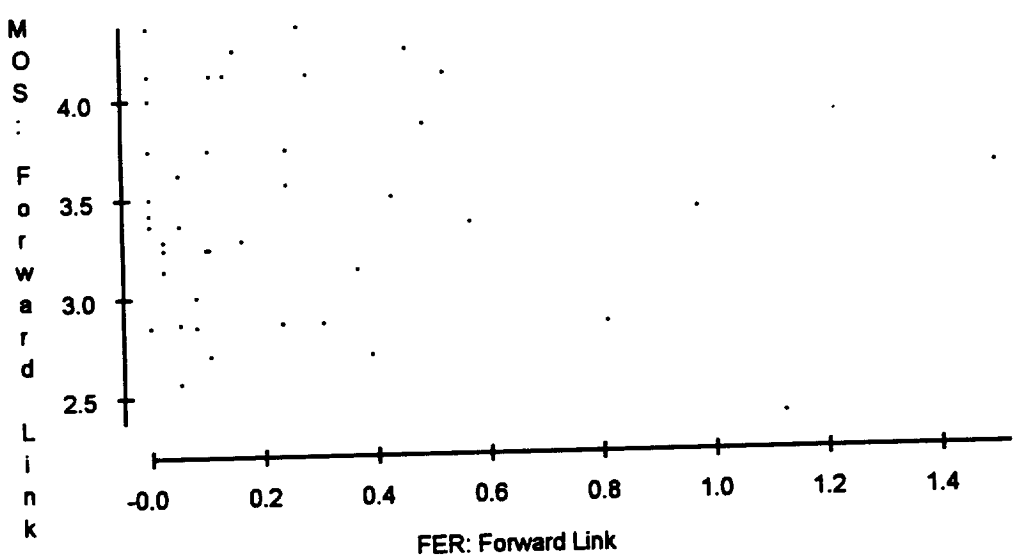


Figure 6.3.1.5. MOS Versus FER (Forward Link).

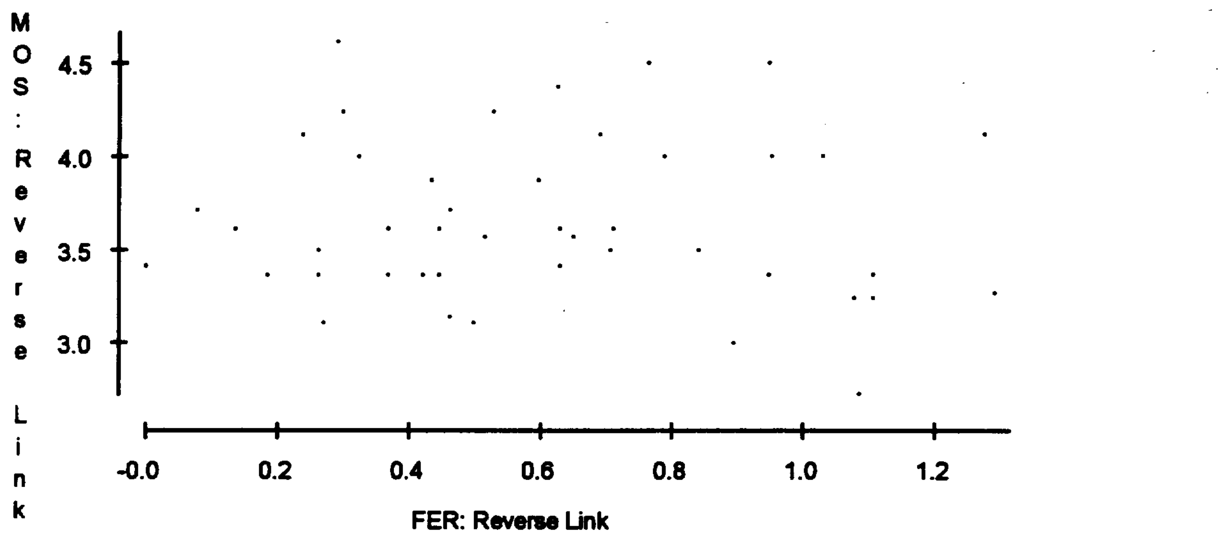


Figure 6.3.1.6. MOS Versus FER (Reverse Link).

Figure 6.3.1.7 is a Pearson Product-Moment correlation table and outlines the correlation coefficients of MOS vs. average rx power, FER, average transmit power, transmit gain adjust, QTSO power control set point mean, mobile received pilot Ec/Io mean, and QTSO forward power control. The results reveal very low correlations between averaged engineering measures and MOS, the highest being transmit gain adjust at 0.151. Therefore, there does not appear to be a linear relationship between MOS and the engineering measures.

Pearson Product-Moment Correlation

	MOS	FER	Mobile ...	Tx Gain ...	Mobile ...	Mobile ...	QTSO P..
MOS	1.000						
FER	0.006	1.000					
Mobile Rx Pow...	-0.077	-0.307	1.000				
Tx Gain Adjust...	0.151	0.476	-0.457	1.000			
Mobile Tx Pow...	0.067	0.369	-0.952	0.611	1.000		
Mobile Rx Pilo...	-0.045	-0.530	0.611	-0.554	-0.607	1.000	
QTSO Power C...	0.139	0.612	-0.210	0.602	0.297	-0.394	1.000
QTSO Forward...	0.025	0.481	-0.599	0.469	0.597	-0.883	0.350

Figure 6.3.1.7. Pearson Product-Moment Correlation.

There does not appear to be linear relationship between MOS and the engineering measures, but there still may be a consistently increasing or descreasing trend between them, as a Spearman Rank Correlation table might reveal. A Spearman Rank Correlation was performed to analyze the ranks of MOS vs. the ranks of the various enfineering measures, in order to consider possible logarithmic relationships. Figure 6.3.1.8 diagrams the results. There does not appear to be a linear or a logarithmic relationship between the objective measures and MOSs. Note, the engineering values were averaged over the entire voice sample length. By analyzing the engineering data within the voice sample time frame, further insight may be gained on the behavior of MOS. By considering the minimum and maximum values for FER, mobile received power, and others, we may better understand the nature of MOSs.

Spearman Rank Correlation

	MOS	FER	Mobile ...	Tx Gain ...	Mobile ...	Mobile ...	QTSO P..
MOS	1.000						
FER	0.045	1.000					
Mobile Rx Pow...	-0.081	-0.324	1.000				
Tx Gain Adjust...	0.135	0.438	-0.467	1.000			
Mobile Tx Pow...	0.070	0.429	-0.939	0.648	1.000		
Mobile Rx Pilo...	-0.048	-0.484	0.634	-0.468	-0.723	1.000	
QTSO Power C...	0.158	0.563	-0.210	0.613	0.342	-0.299	1.000
QTSO Forward...	-0.013	0.517	-0.524	0.431	0.642	-0.825	0.348

Figure 6.3.1.8. Spearman Rank Correlation.

6.3.2 Expert Listener Data Analysis and Discussion

Recall, the expert listener ratings were performed on a 3 point scale, and were made in an attempt to emulate listener panels' ratings of acceptability (vs. MOS). Figures 6.3.2.1 and 6.3.2.2 show the relationship between expert listener (EL) ratings and listener responses to question three, or %acceptability [p(A)]. Percent acceptability is the percent of listeners rating a given sample as acceptable.

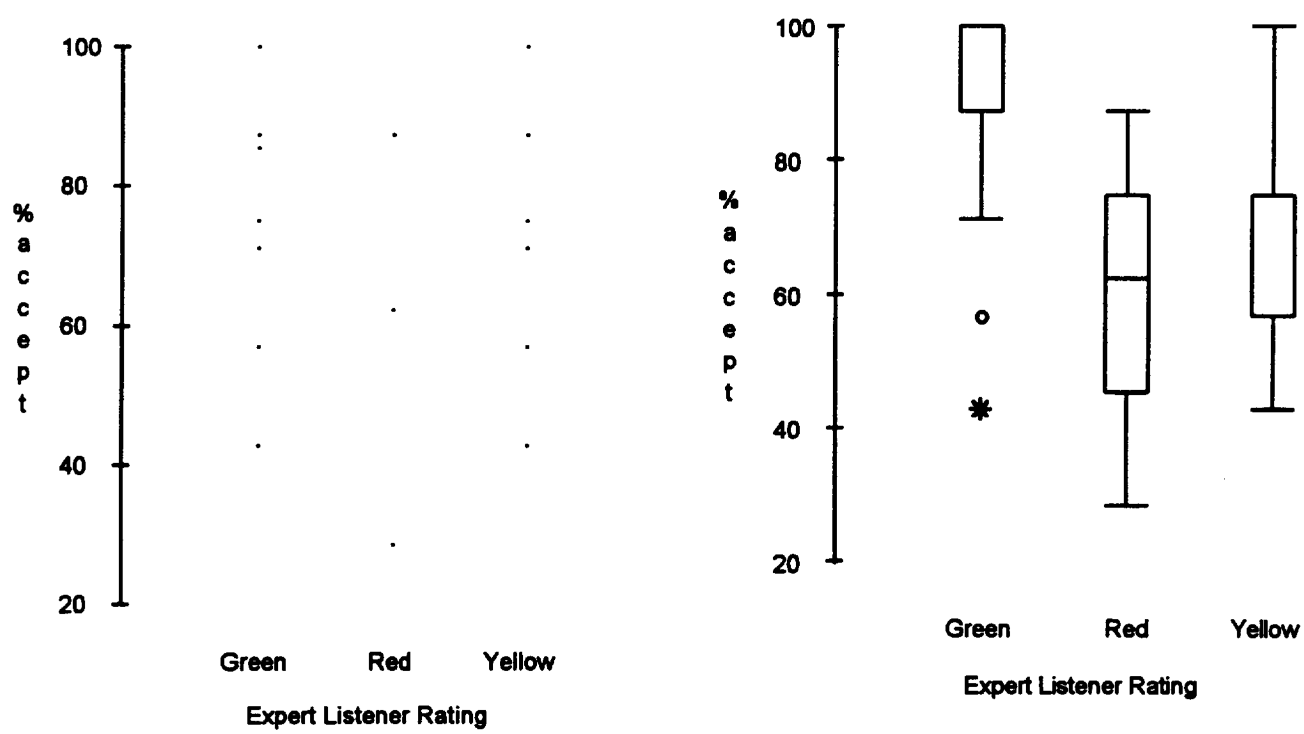


Figure 6.3.2.1 **Figure 6.3.2.2**

Figure 6.3.2.1 on the left shows the %acceptability, or p(A), data in relation to EL categories. Figure 6.3.2.2 on the right summarizes the same data. The boxes represent the middle half of the data (from the 25th percentile to the 75th percentile). The line intersecting the boxes are the median p(A)s for each of the EL ratings. The circle and star show where there were outliers in the data. The lines extending out out of the boxes depict the spread of the data. For the most part the "green" ratings of the expert listener were relatively good indicators of %acceptability. The spread of the data in the green category is primarily from 1.0 (100% acceptable) to .70 (70% acceptable), with a few ratings that fall outside that range. The mean p(A) in the green category was 0.902, well within the target range of 70% to 100%. The yellow and red ratings show a more distinct amount of variance. Of what the expert listener rated as yellow, the mean p(A) was 0.719, slightly above the target range of 30% to 70%. The mean p(A) associated with EL ratings of red equals 0.595, well above the target 30% and below.

When we examine the relationship between listener responses to question 1 (MOS) and question 3 [p(A)] we see that they are relatively correlated as we would expect. The Pearson Product-Moment correlation coefficient between these factors is 0.667. The EL ratings are weakly correlated, with a coefficient of 0.402. (see Figure 6.3.2.3)

Pearson Product-Moment Correlation

	MOS	%accep...	EL ratin...
MOS	1.000		
%accept	0.667	1.000	
EL ratings	0.402	0.451	1.000

Figure 6.3.2.3. Pearson Product-Momemnt Correlation.

It is possible that EL ratings, received power, FER, transmit gain adjust, transmit power, Received pilot Ec/Io, QTSO power control set point and QTSO forward power control can be predictors of MOS when all are taken together. A multiple regression analysis was completed in order to determine if MOS is related to a combination of all the above factors. Interactions among the various factors was not considered in the analysis.

Dependent variable is: MOS
R¤ = 26.7% R¤(adjusted) = 21.0%
s = 0.4378 with 112 - 9 = 103 degrees of freedom

Source	Sum of Squares	df	Mean Square	F-ratio
Regression	7.18891	8	0.89861	4.69
Residual	19.7376	103	0.191627	

Variable	Coefficient	s.e. of Coeff	t-ratio
Constant	-1.18595	2.345	-0.506
FER	0.055822	0.1612	0.346
Mobile Rx Pow...	-0.024342	0.0209	-1.17
Tx Gain Adjust...	0.037326	0.0303	1.23
Mobile Tx Pow...	-0.026718	0.0241	-1.11
Mobile Rx Pilo...	0.103672	0.2703	0.384
QTSO Power C...	0.355293	0.2895	1.23
QTSO Forward...	0.008453	0.0146	0.581
EL ratings	0.533821	0.0992	5.38

Figure 6.3.2.4. Regression Analysis Results.

The result is an R squared (adjusted) of 21%, and t-scores are low. In other words, only 21% of the variance can be explained by EL, received power, FER, etc. The F-ratio is medium (4.69), revealing all factors reliably account for the 21% of variance. By including all of the factors into the equation, we do not see any substantial predictive power over MOS (see Figure 6.3.2.4 above).

By gathering listeners' comments from post-test questionnaires, more information is available about the nature of MOSs. Namely, it is evident from questionnaires that there are several types of distortions in quality possible in the recordings of CDMA according to listeners:

1) Echo
2) Fading/muting
3) Synthesized voice
4) "Chirping", or "squeeking" background noise
5) A clearer male (vs. female) voice

The nature of these distortions are likely judged differently by different listeners. Intelligibility and speaker recognition are two main aspects of perceived quality. In the case of most of the CDMA samples, intelligibility remained high. The above-mentioned types of distortions seem to affect a listener's ability to recognize the speaker more than their ability to understand the speech. As a result, overall MOSs were high. However, it is of interest to note that the MOSs were significantly lower in the second panel of listeners with average MOSs at 2.95 (vs. the average of 3.56 over all MOSs).

Note, there were more women aged 35 and above in this group than any other. When we look at MOSs for this demographic group we see marked differences in their MOSs vs. other age/gender groups. Two of the women in this group stated in their post-test questionnaires that the female voice was more degraded than the male voice in many of the samples. When asked whether their ratings of acceptability would have changed if told to consider them as wireline samples vs. portable, the answer was no for all four women over 35 years in this group. One hypothesis is that female listeners are harder "graders" of quality than others. Another hypothesis is that female listeners are more sensitive to distortions in higher frequencies, and the samples reflected such a distortion. Further research is necessary to pinpoint whether there is a significant difference between ratings given by females over the age of 35 and those given by others, and to pinpoint potential reasons for this. It is still unclear at this stage why some listeners were harder "graders" than others.

The variability in scoring may indicate subjects graded samples with unrealistic criteria. Many of the samples were nearly identical in quality, and yet judged quite differently by the same subject. This might indicate randomness in scoring among listeners. Further analysis may pinpoint the likelihood of random or unrealistic scoring.

6.3.3 Quasi-stationary Voice Quality Results

Maps 6.3.3.1 and 6.3.3.2 outline the results of listeners' ratings to samples at 60 locations on the forward and reverse links. Recall the red, yellow, and green ratings were derived from the percentage of listeners rating a sample as acceptable. Maps 6.3.3.3 and 6.3.3.4 illustrate mean full rate Frame Error Rates (in %) at all 69 locations in the forward and reverse directions. FER data were collected during the Markov call run at each location. Map 6.3.3.5 outlines linear mean mobile received power (in dBm), and map 6.3.3.6 shows average linear QTSO power control set points (in dB) at all locations. Mobile received power and QTSO set point values were collected during the voice call at each location.

6.3.4 Handoff Voice Quality Results

The expert listener ratings per 4-second intervals along the handoff routes are outlined in the voice quality maps (Maps 6.3.4.1 - 6.3.4.8). Maps 6.3.4.1 - 6.3.4.4 demonstrate forward and reverse links in both the north and south directions for the Broadway route. Maps 6.3.4.5 - 6.3.4.8 demonstrate runs along Foothills to US-36.

Handoffs were indistinguishable to the expert listener, including soft, softer, and soft-softer handoffs. In general, voice quality remained good until the coverage boundaries were approached. However, the driving tests showed that the voice quality dropped quickly along route boundaries, most likely due to dramatic changes in terrain.

6.4 Voice Quality Results Summary

The average MOS of all sample points was 3.56, with a standard deviation of 0.501.

There were several types of distortions in quality in the CDMA recordings, as described by listeners:

1) Echo
2) Fading/muting
3) Synthesized voice
4) "Chirping", or "squeeking" background noise
5) A clearer male (vs. female) voice

It is unclear why a few subjects appeared to "grade" the samples much more strictly than others, although age and gender may have played a role.

The variability in scoring may indicate subjects graded samples with unrealistic criteria. Many of the samples were nearly identical in quality, and yet judged quite differently by the same subject. This might indicate randomness in scoring among listeners. Further analysis may pinpoint the likelihood of random or unrealistic scoring.

The engineering measures, when averaged over the length of the voice samples, demonstrated very low predictive power over the MOSs. FERs demonstrated a correlation coefficient of 0.045, QTSO power control's correlation coefficient was 0.158, and received power's was -0.081 when compared to MOSs.

In general, voice quality did not appear to degrade during handoffs, and were indistinguishable to the expert listener. However, during the handoff tests, quality dropped dramatically and quickly along route boundaries, most likely due to changes in terrain.

Appendix 6.A: Voice Quality Instructions

- Good afternoon/evening and thank you for coming. My name is Michelle Owens, your test administrator.
- Tonight/today you will be listening to a series of recordings and telling us what you think about them.
- Before we begin, I would like to point out some features of our lab. There are two video cameras set up in the room. I will be recording this session. The resulting tapes would be used for research purposes only, and will not be distributed for advertising, etc. Is it okay with everyone if I continue recording? Also in our lab we have a two-way mirror. There may be other product designers and testers observing this session, to see how things are progressing and how the product is performing.
- As I already mentioned, you will be listening to a series of recordings and offering your opinions on them. For each recording we would like you to compare the sound quality of the recording to the service you have on your home phone and then enter your rating of that sound into the computer in front of you. For each, you will rate 3 things:

  1) What do you think of the QUALITY of the sound? That is, how good is the sound of the voice being captured by the recording? Remember, we'd like you to compare the samples to what you might hear at home.

  2) How annoying are any additional sounds you might hear? That is, How much do any additional sounds interfere with your ability to understand what is being said?

  3) Would you find this recording ACCEPTABLE as portable phone service? What we mean by "portable" is that you can take this phone with you as you travel around town and make calls from places like shopping centers, parking lots, and sporting events. Any questions so far?

- In front of you is a telephone handset which is connected to my computer here. I would like you to hold the handset up to your ear and listen to the sound I will play.
- I will announce the number of the sound you are about to hear and that number should match the number at the top of the screen. You should all have a #1 at the tops of your screens.
- You can use the mouse or the keypad to enter your ratings. Once you have entered your rating for one question the computer will move on to the next question for you. If you need to change an answer, you can tab through to go back to the answer you wish to change.
- The first few will be for practice, and you will have a chance to practice answering the questions with the computer. I will play the first practice sample sound for you now. SOUND.
- NOW, for practice, I would like you to rate that sound as Excellent for the overall quality of the sound. You can do this by entering a 1 on your keyboard or by pointing to the circle next to the word Excellent using the mouse and clicking the button on the mouse.
- Was everyone able to do that?
- Now please do the same to say that the additional sounds were Not at all Annoying and that the sound was Acceptable.
- Was everyone able to do that?
- Once you entered an answer for each question, A picture appeared in the bottom of the window which says "DONE". You can indicate that you are finished by clicking on "Done" with the mouse OR by hitting the return key on your keyboard.
- You can use either the mouse or the keyboard, whichever you like best.

- You will be hearing the same sentences in each sound bite. I realize that they are a bit unusual and at the end I will explain why we use these sentences. In some of the samples you will hear the male voice first, and in some the female voice first.
- Now try the next practice sample. SOUND
- Was everyone able to do that? Please rate that one as Bad by selecting #5. Any questions?
- If you have any questions as we are working, please feel free to speak-up. Also, If you are having difficulty using the computer please tell me.
- About half way through the voice segments we will take a 15 minute break and then finish up the rest of the samples.
- I would like you to rate the rest of the samples on you own.

Appendix 6.B: Computer Response Questions

How would you rate the overall QUALITY of the sound?

1. Excellent
2. Good
3. Fair
4. Poor
5. Bad

How annoying are any ADDITIONAL sounds you might hear?

1. Not at all annoying
2. Slightly annoying
3. Annoying
4. Very annoying
5. Extremently Annoying

Would this be ACCEPTABLE as portable service?

1. Acceptable
2. Not acceptable

Appendix 6.C: Post-Test Questionnaire

1) What is your gender?
____ MALE
____ FEMALE

2) What is your age?
___ Under 20
___ 21-24
___ 25-34
___ 35-44
___ 45-54
___ 55 or above

3) What is your occupation? ____________________________

4) How much computer experience do you have?
___ None
___ Used a few times before
___ Use once/month
___ Use once/week
___ Use every day

Did you ever work with a computer on a regular basis in a previous job? If so, how much? _______

5) Have you ever used a cordless phone (works on standard phone jack)?
____ YES _____ NO

Do you OWN a cordless phone?
_____ YES and use it more than 50% of the time
_____ YES and use it less than 50% of the time
_____ NO

IF YES, How does the sound quality of the samples you heard here compare to the sound on a cordless phone?

____

____

____

IF YES, Who made the phone? ____________________________

6) Have you ever used a cellular phone? ___ YES ____ NO
If so, how often:
___ everyday
___ once or twice per week
___ once or twice per month
___ once or twice per year
___ only once or twice before

Have you ever received a call from someone using a cellular phone?
(that you know of) ___ YES ____ NO

If so, how often:
___ everyday
___ once or twice per week
___ once or twice per month

___ once or twice per year
___ only once or twice before

If you have used a cellular phone or received a call from a person using a cellular phone, how does the sound quality of the samples you heard tonight compare to the sound of a cellular phone?

____

____

____

7) Would your ratings of the Acceptability of these sounds be different if we told you that this would NOT be a portable phone?

___ YES ____ NO

IF YES, How would they differ and why?

____

____

____

8) How does the sound from these recordings differ from the sound on your home phone?

____

____

____

9) Any other comments?

____

____

____

APPENDIX A: COVERAGE ANALYSIS DATA

BOULDER
WALNUT
UNIVERSITY OF COLORADO
NATIONAL BUREAU OF STANDARDS
GREEN MOUNTAIN
TABLE MESA
Hayden Lake
Boulder Municipal Airport
Fourmile
Canyon
ARAPAHOE
VALMONT
PACIFIC
UNION
Municipal Golf Course
National Center for Atmospheric Research

Map 4.2

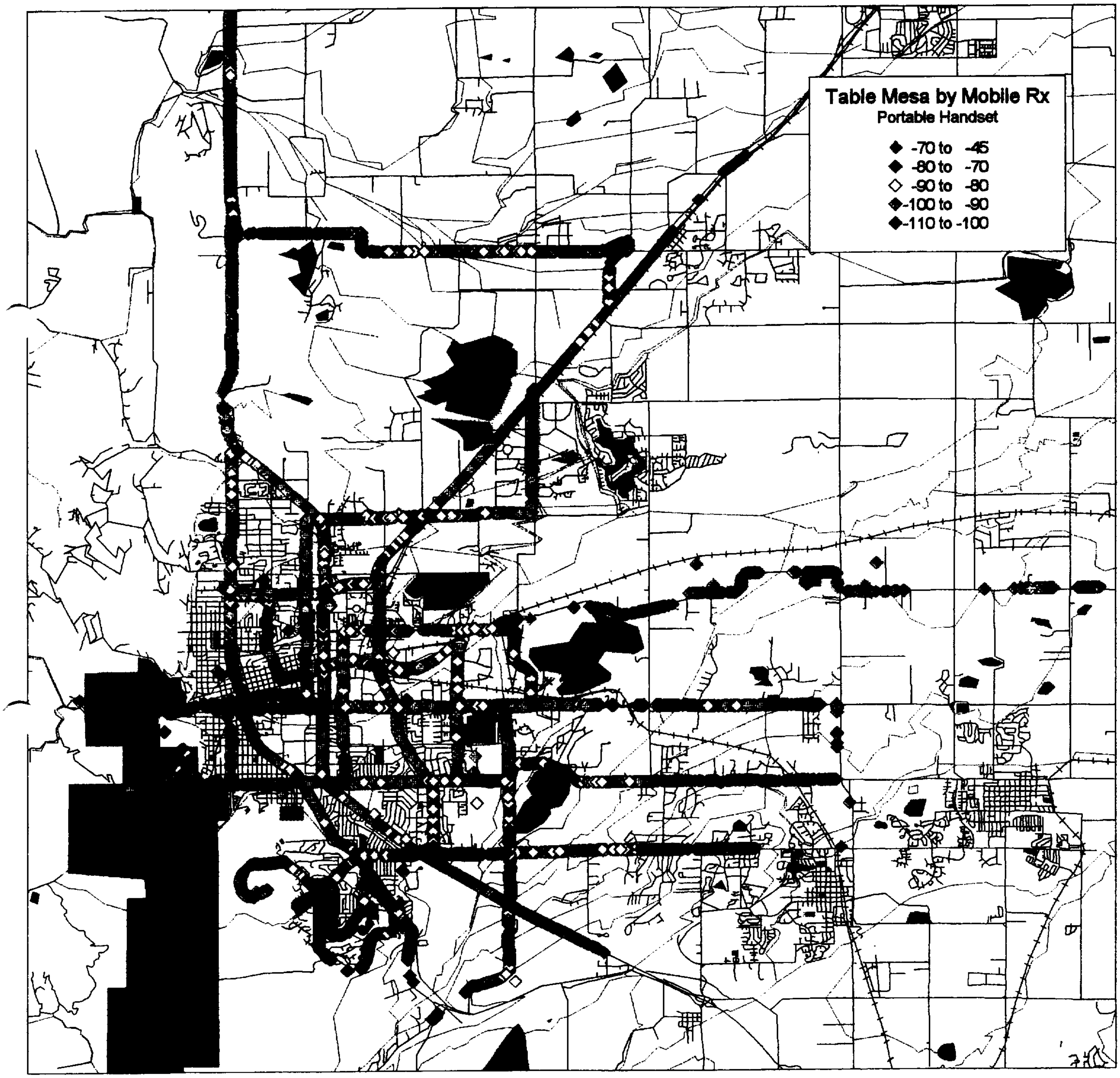


Table Mesa by Mobile Rx
Portable Handset
-70 to -45
-80 to -70
-90 to -80
-100 to -90
-110 to -100

Map 4.2.1.1

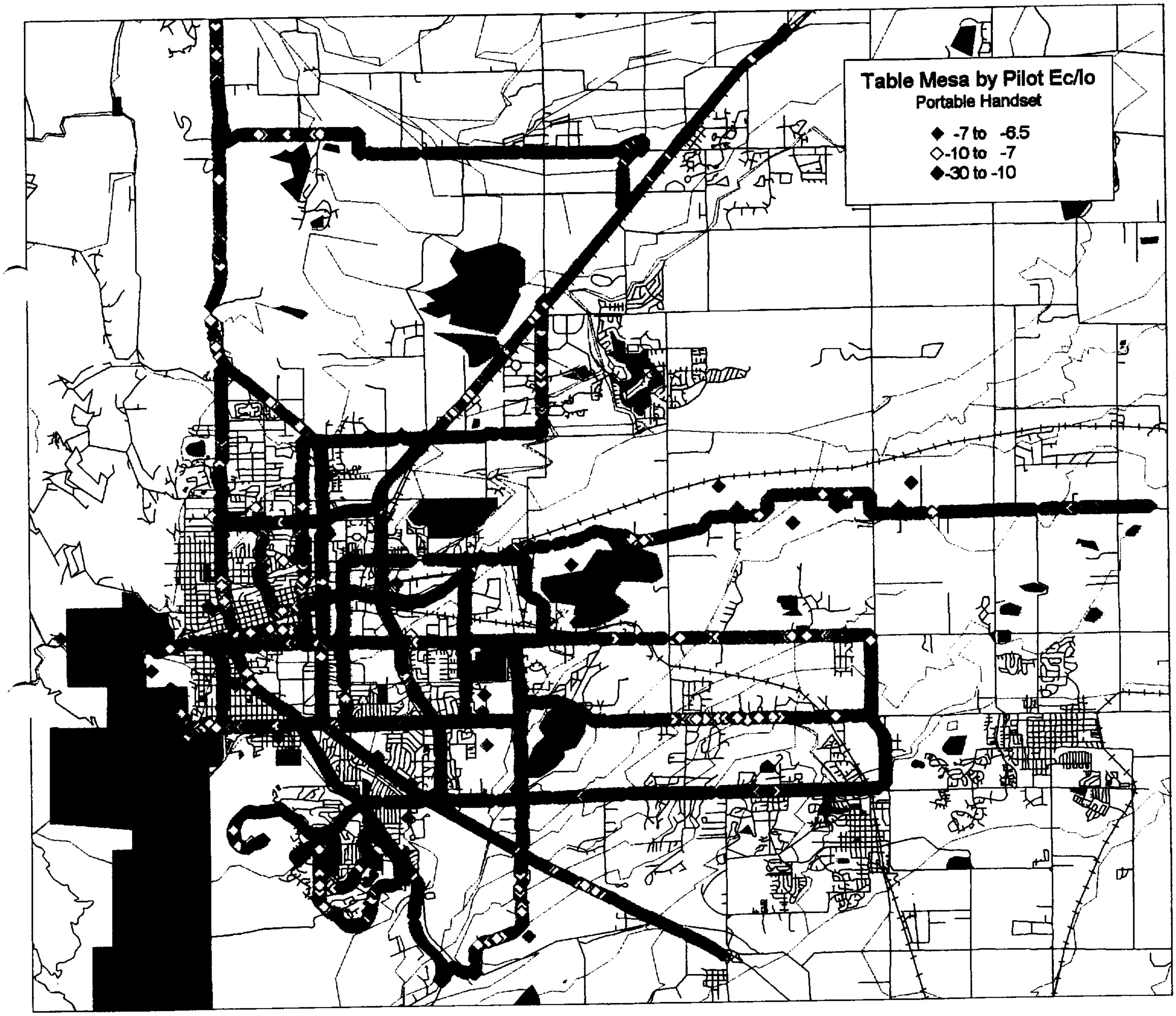


Table Mesa by Pilot Ec/Io
Portable Handset
-7 to -6.5
-10 to -7
-30 to -10

Map 4.2.1.2

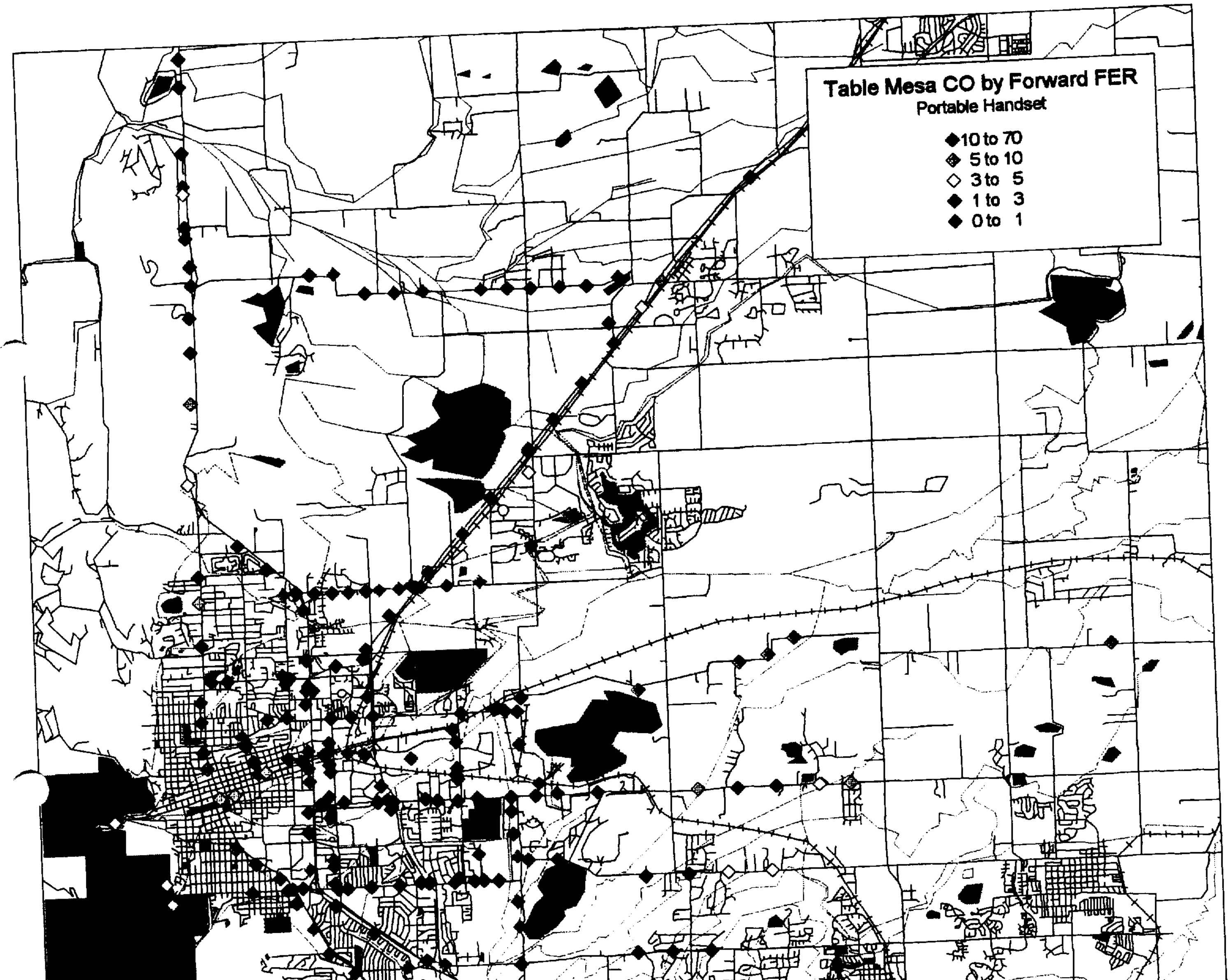


Table Mesa CO by Forward FER
Portable Handset
10 to 70
5 to 10
3 to 5
1 to 3
0 to 1

Map 4.2.1.4

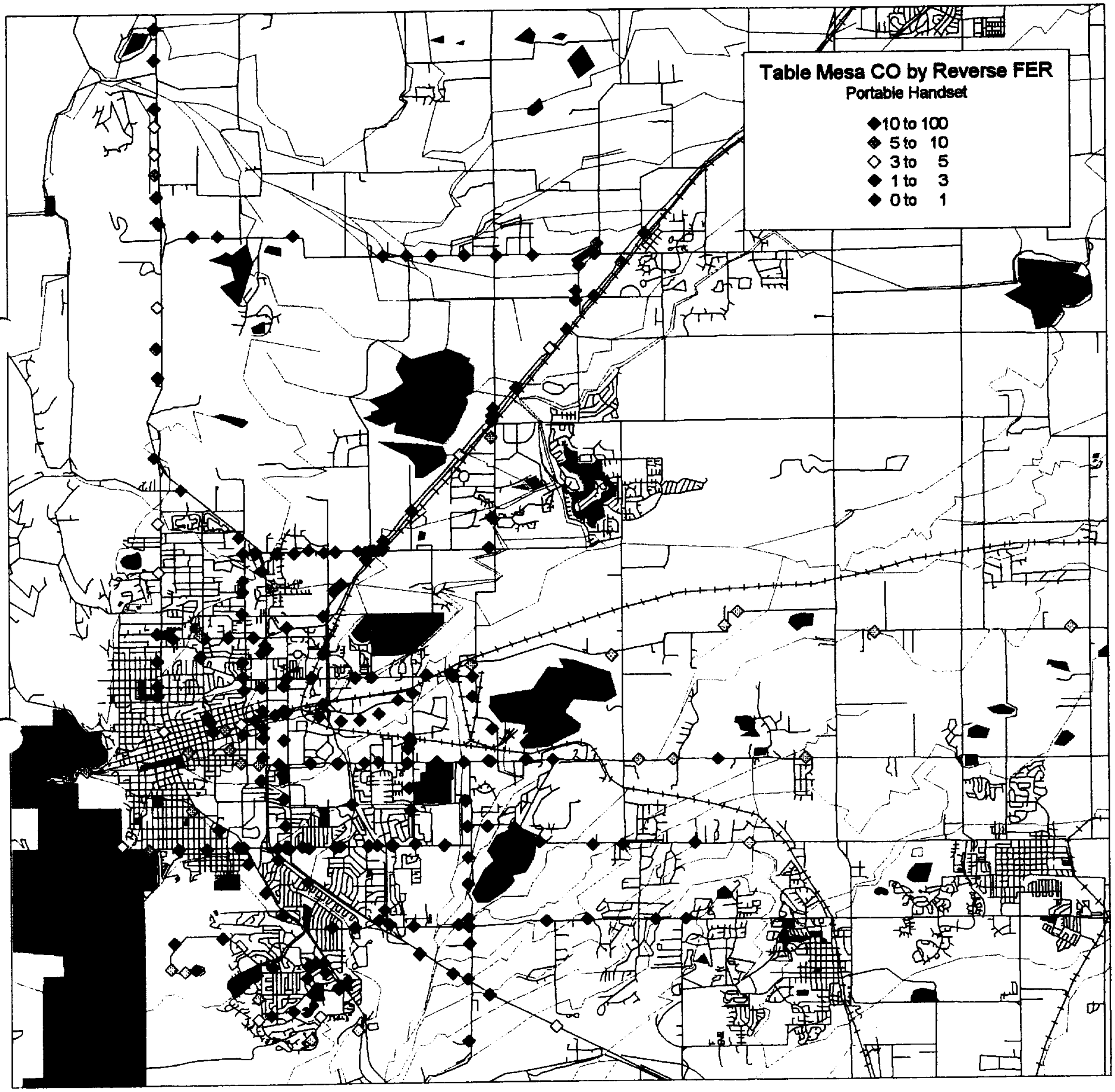
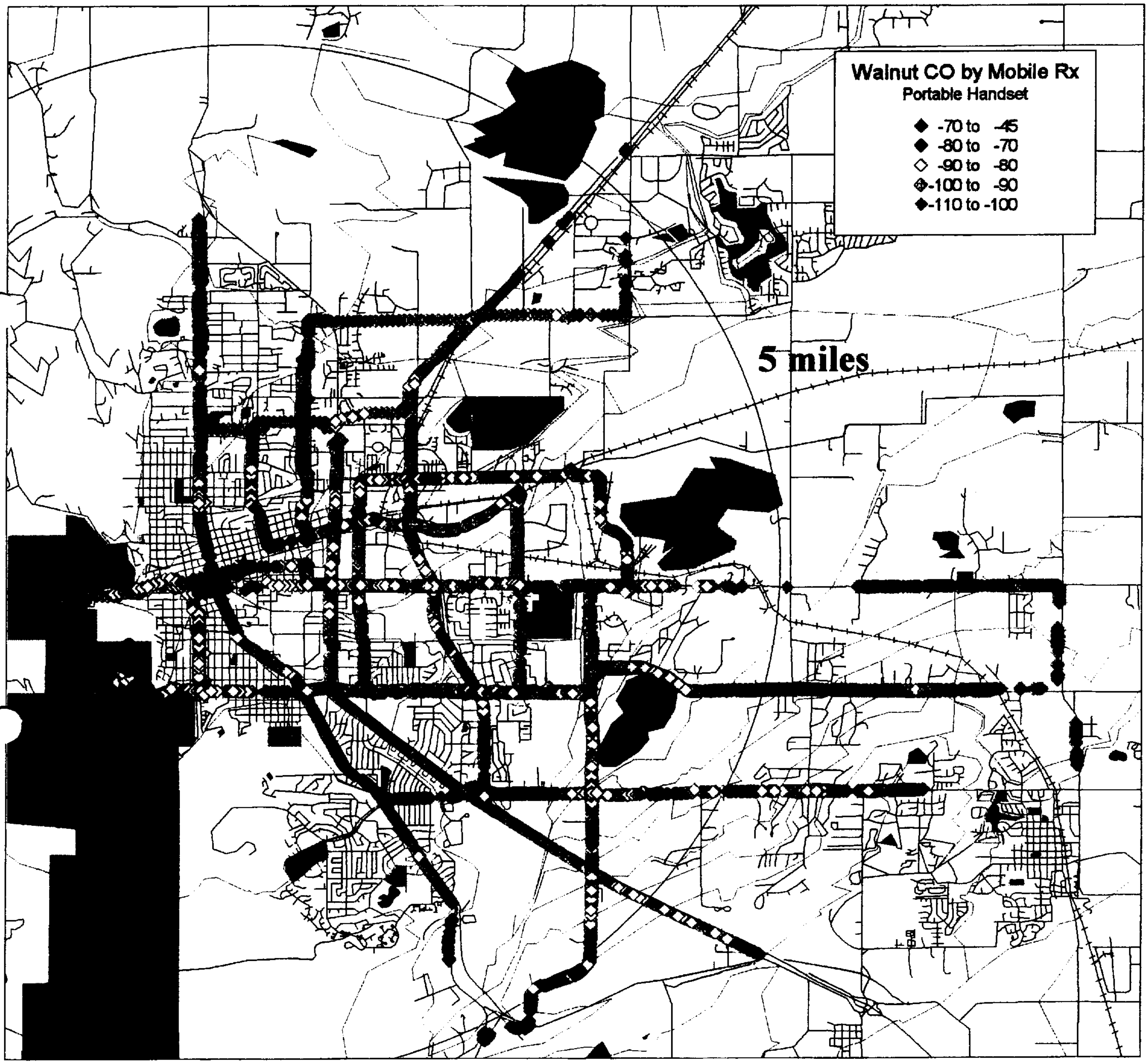
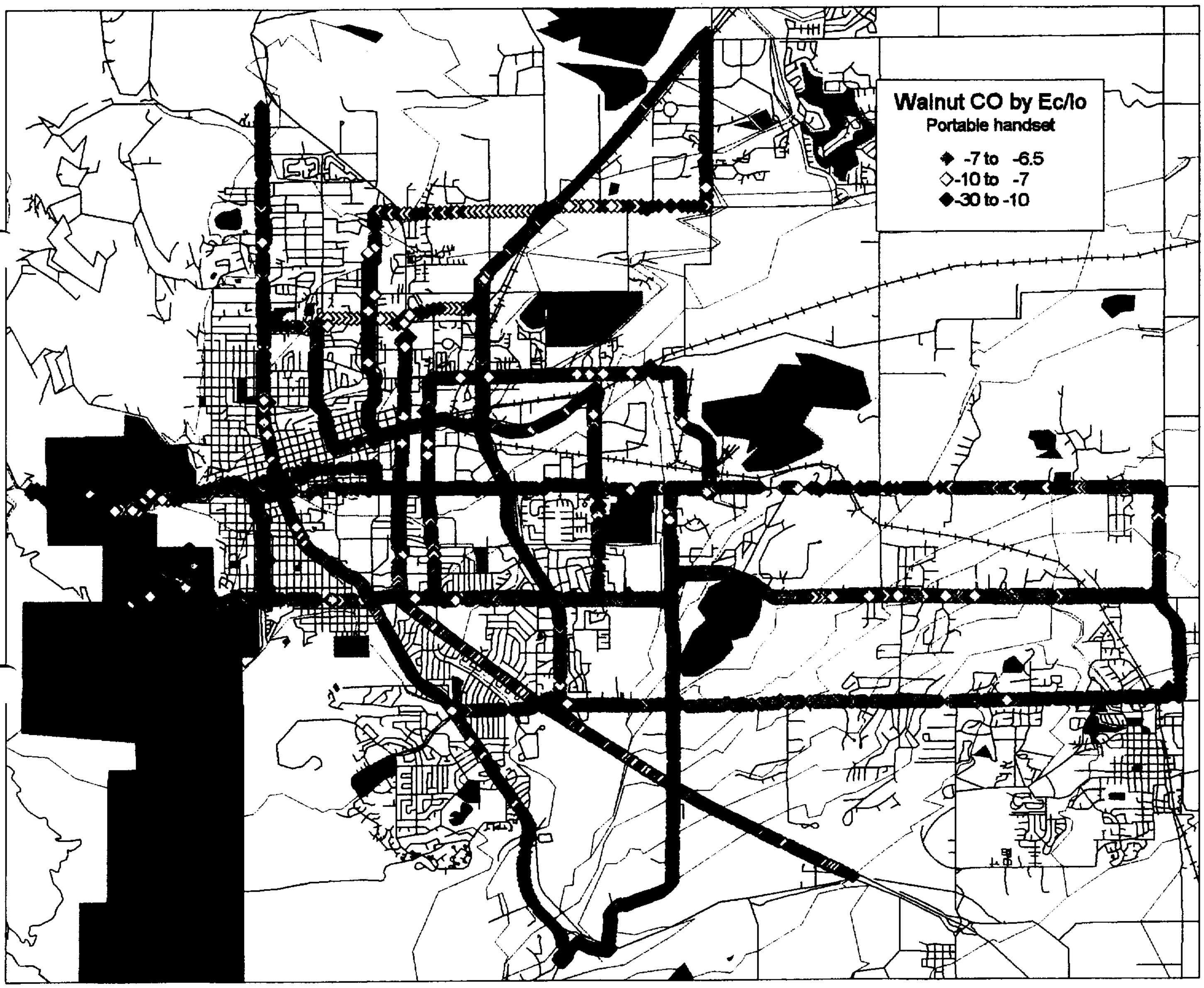


Table Mesa CO by Reverse FER
Portable Handset
10 to 100
5 to 10
3 to 5
1 to 3
0 to 1

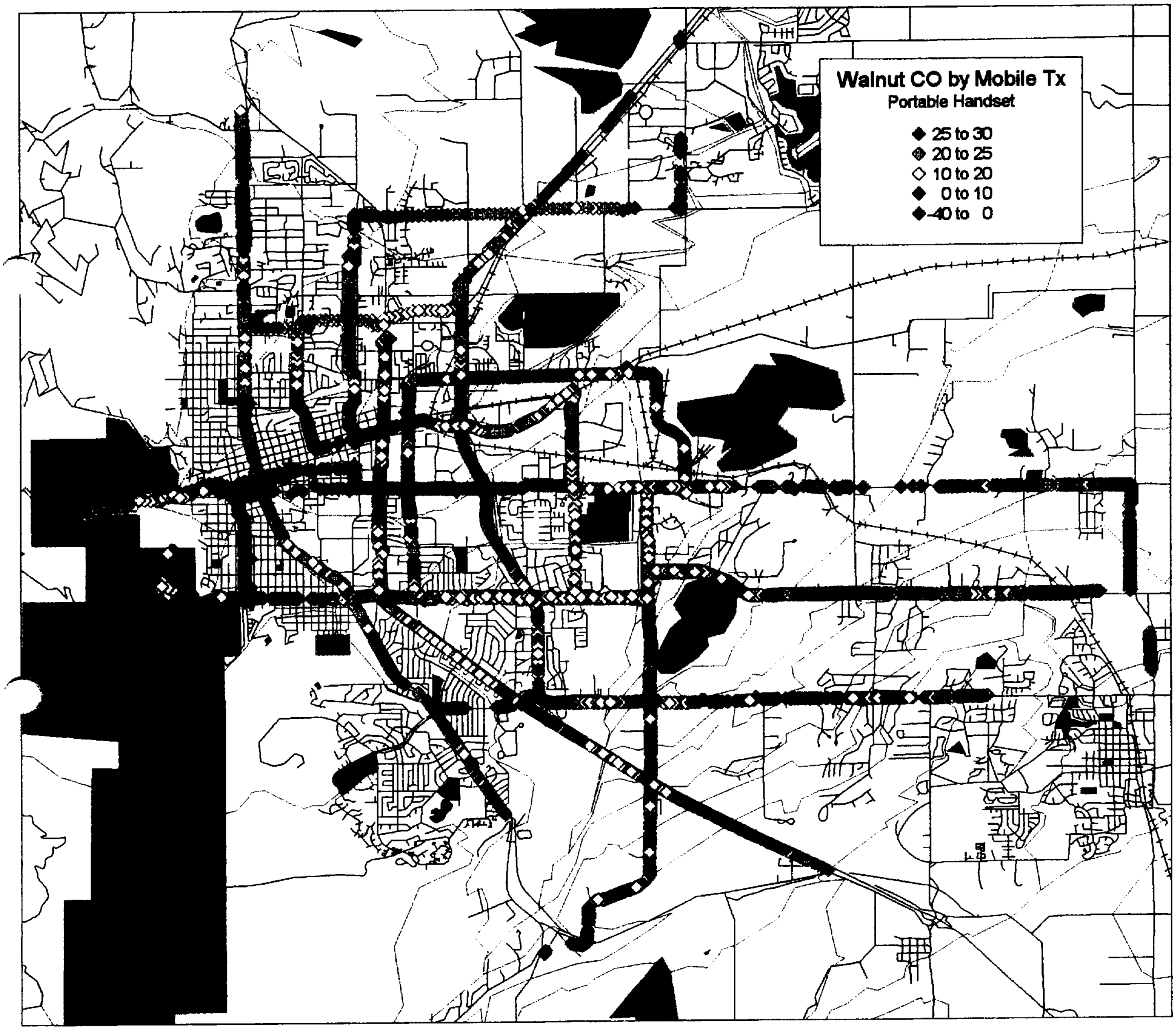
Map 4.2.1.5


Walnut CO by Mobile Rx
Portable Handset
-70 to -45
-80 to -70
-90 to -80
-100 to -90
-110 to -100
5 miles

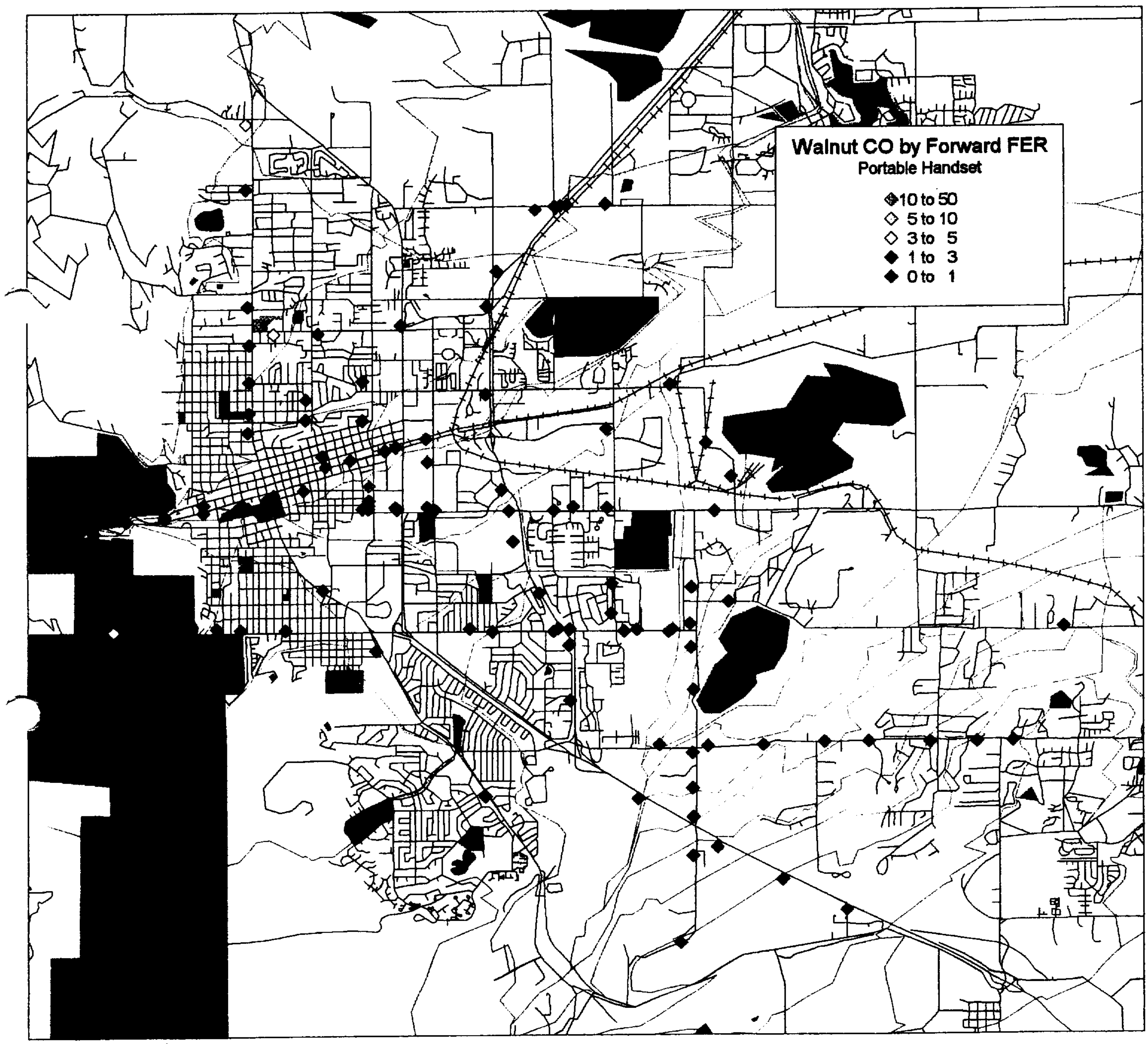
Map 4.2.2.1



Map 4.2.2.2

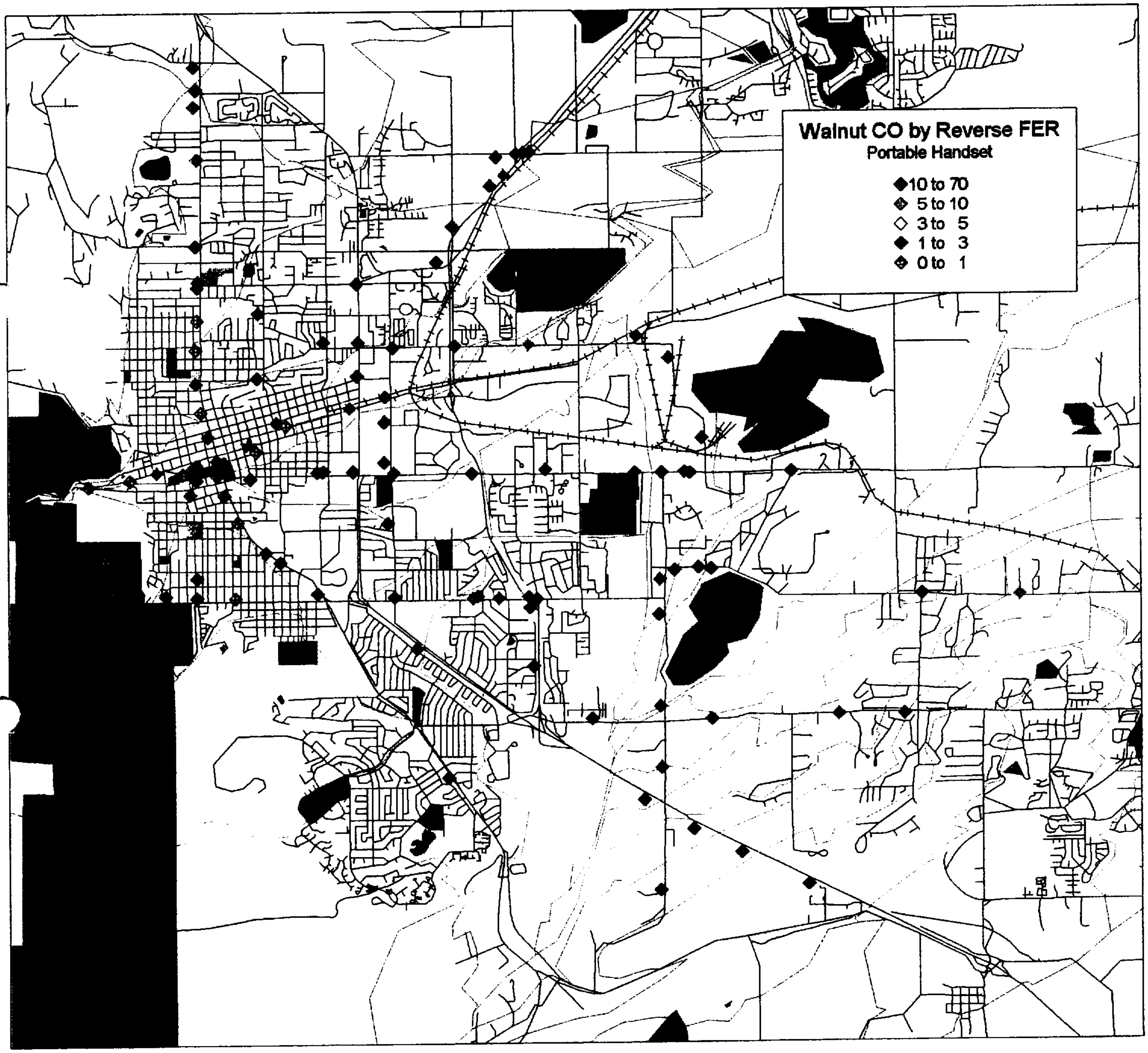

Walnut CO by Mobile Tx
Portable Handset
25 to 30
20 to 25
10 to 20
0 to 10
-40 to 0

Map 4.2.2.3



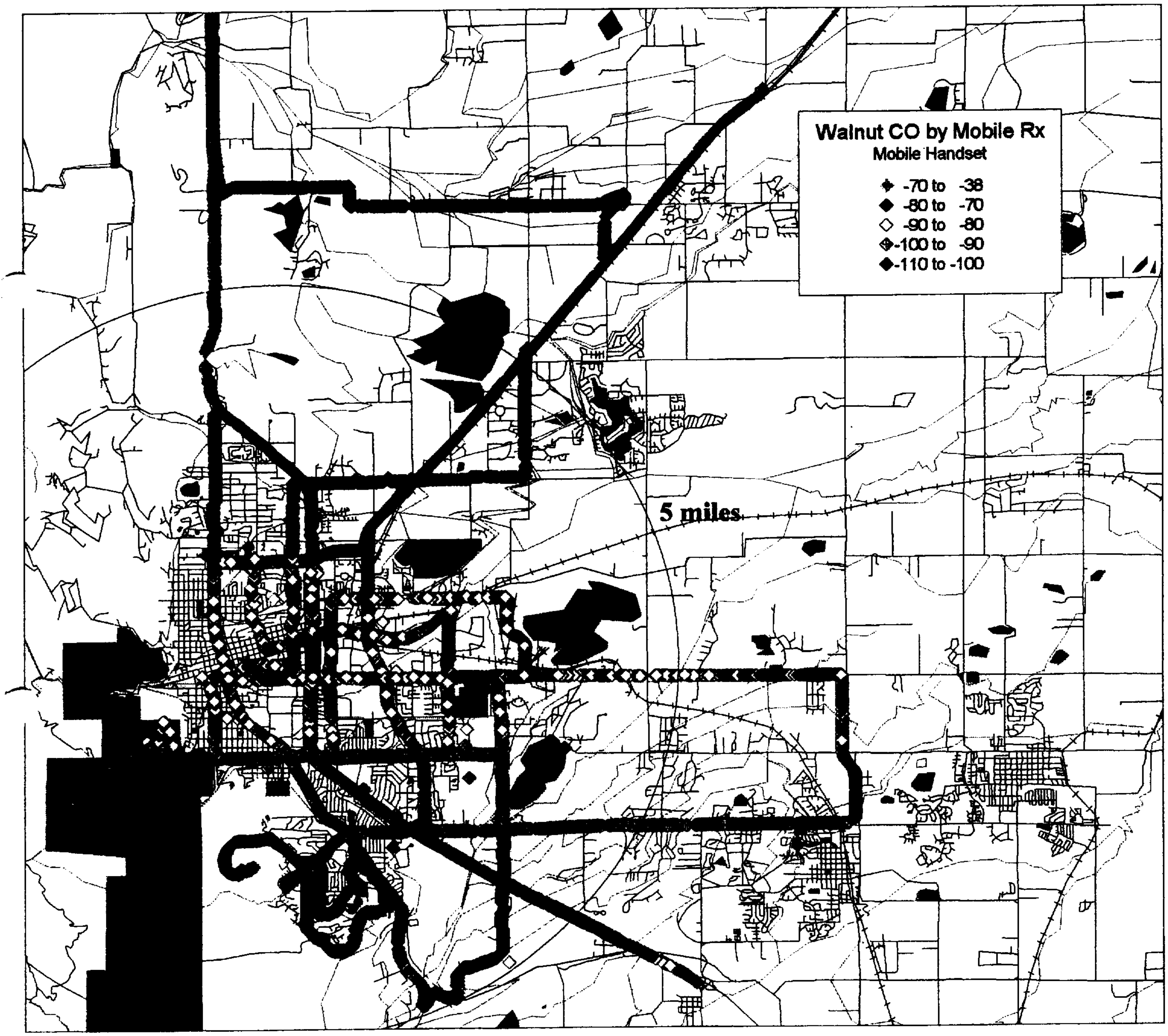
Walnut CO by Forward FER
Portable Handset
10 to 50
5 to 10
3 to 5
1 to 3
0 to 1

Map 4.2.2.4



Walnut CO by Reverse FER
Portable Handset
10 to 70
5 to 10
3 to 5
1 to 3
0 to 1

Map 4.2.2.5



Walnut CO by Mobile Rx
Mobile Handset
-70 to -38
-80 to -70
-90 to -80
-100 to -90
-110 to -100
5 miles

Map 4.2.3.1

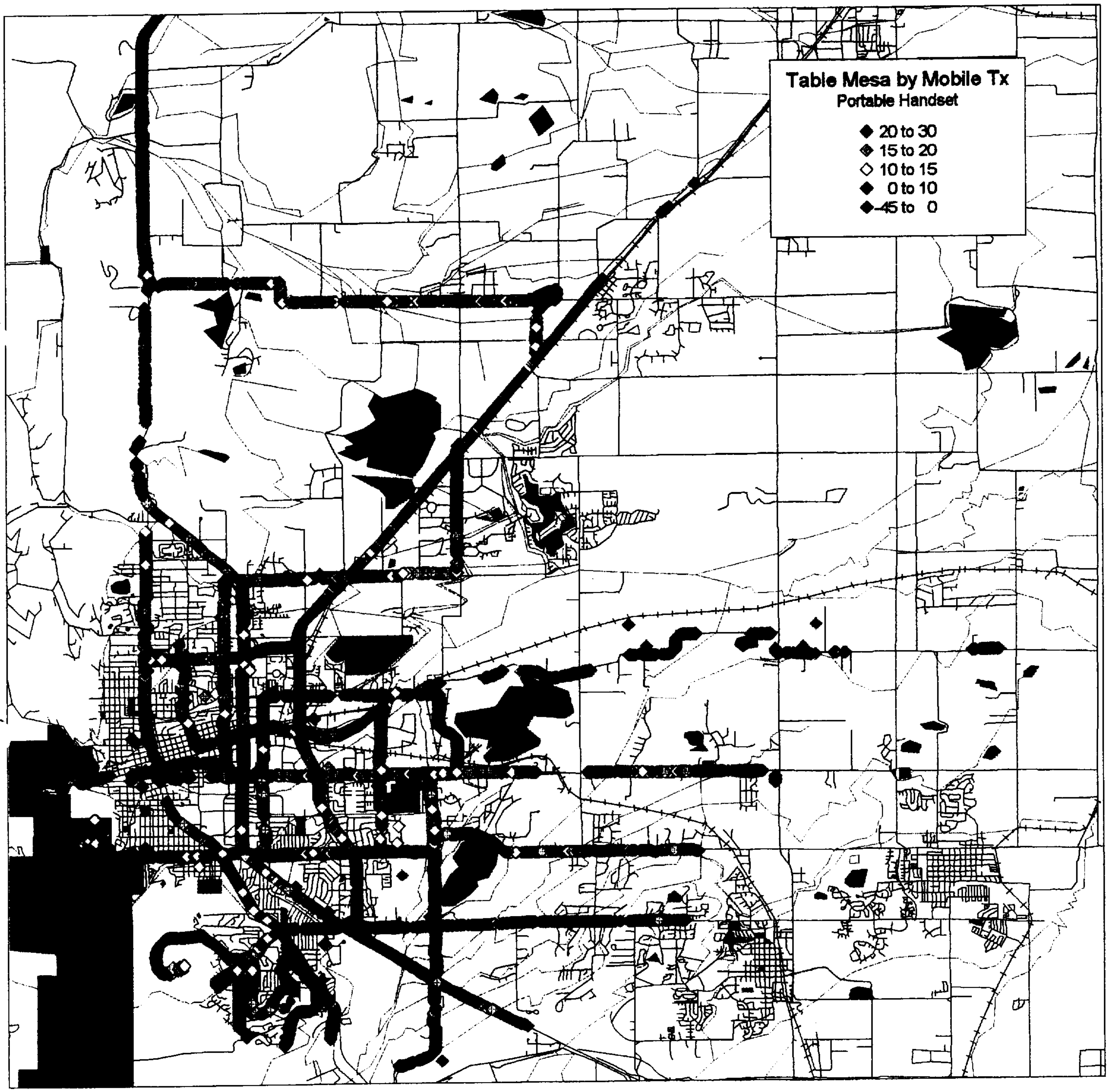
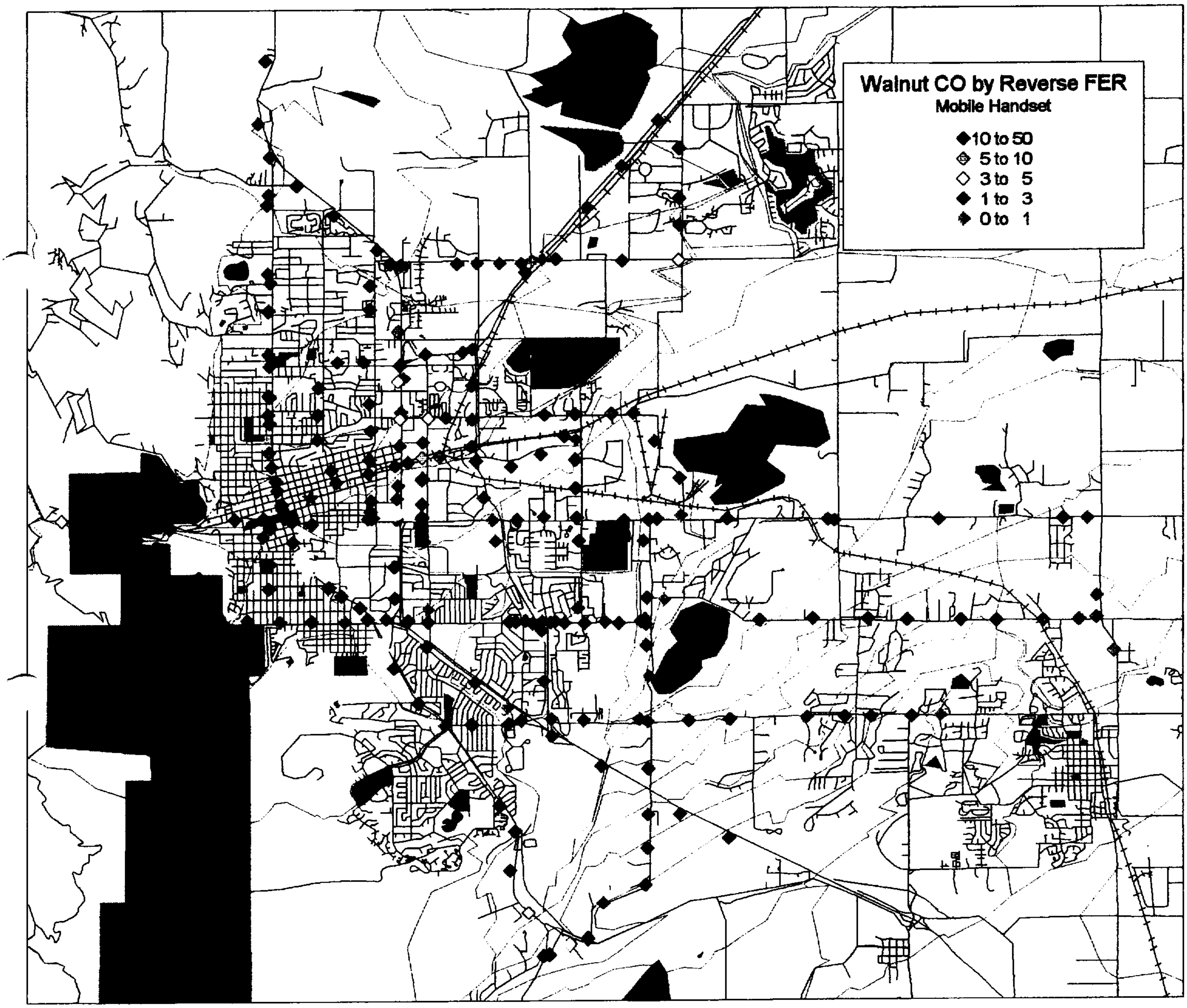
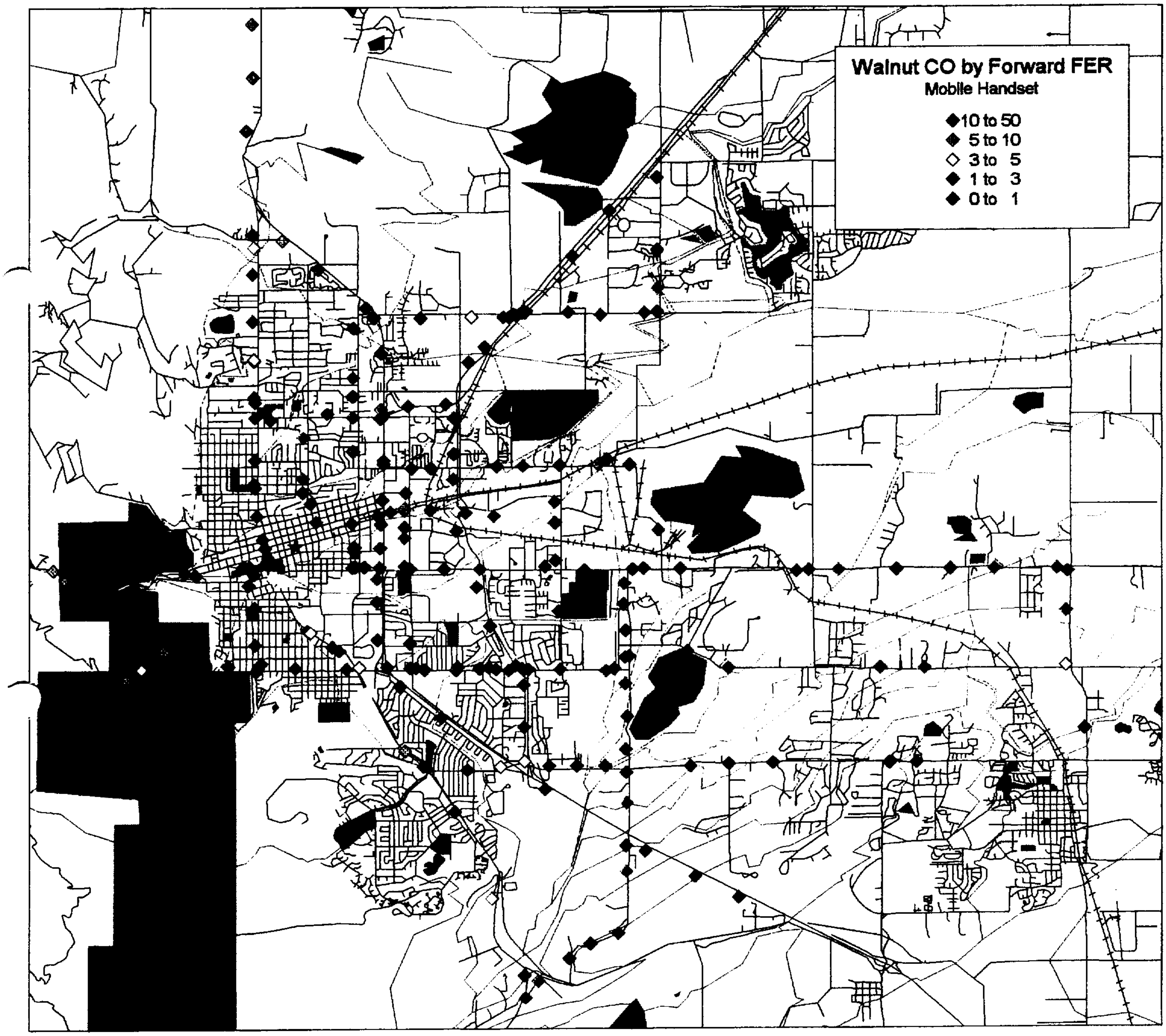


Table Mesa by Mobile Tx
Portable Handset
20 to 30
15 to 20
10 to 15
0 to 10
-45 to 0

Map 4.2.1.3


Walnut CO by Reverse FER
Mobile Handset
10 to 50
5 to 10
3 to 5
1 to 3
0 to 1

Map 4.2.3.2



Walnut CO by Forward FER
Mobile Handset
10 to 50
5 to 10
3 to 5
1 to 3
0 to 1

Map 4.2.3.3

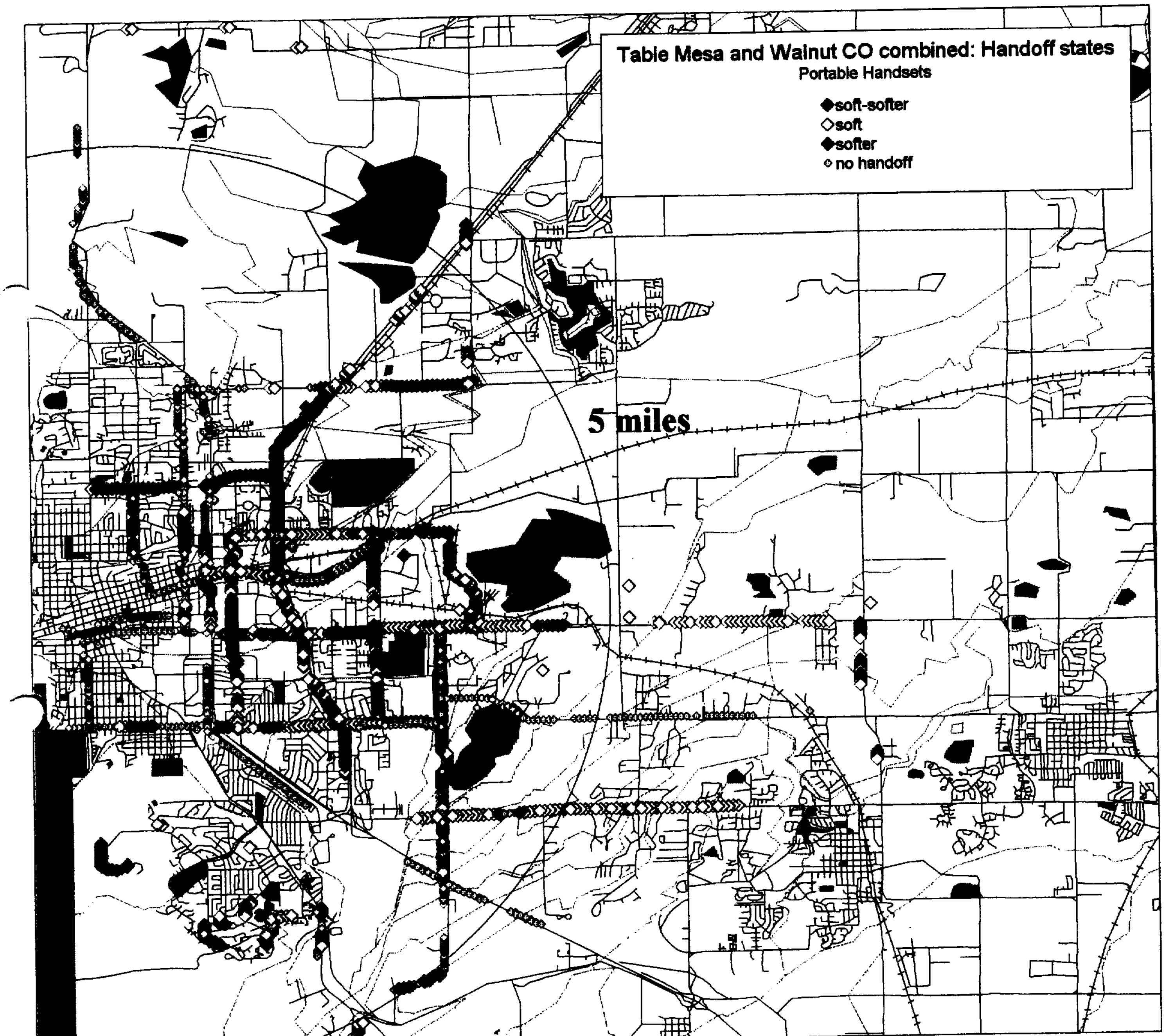
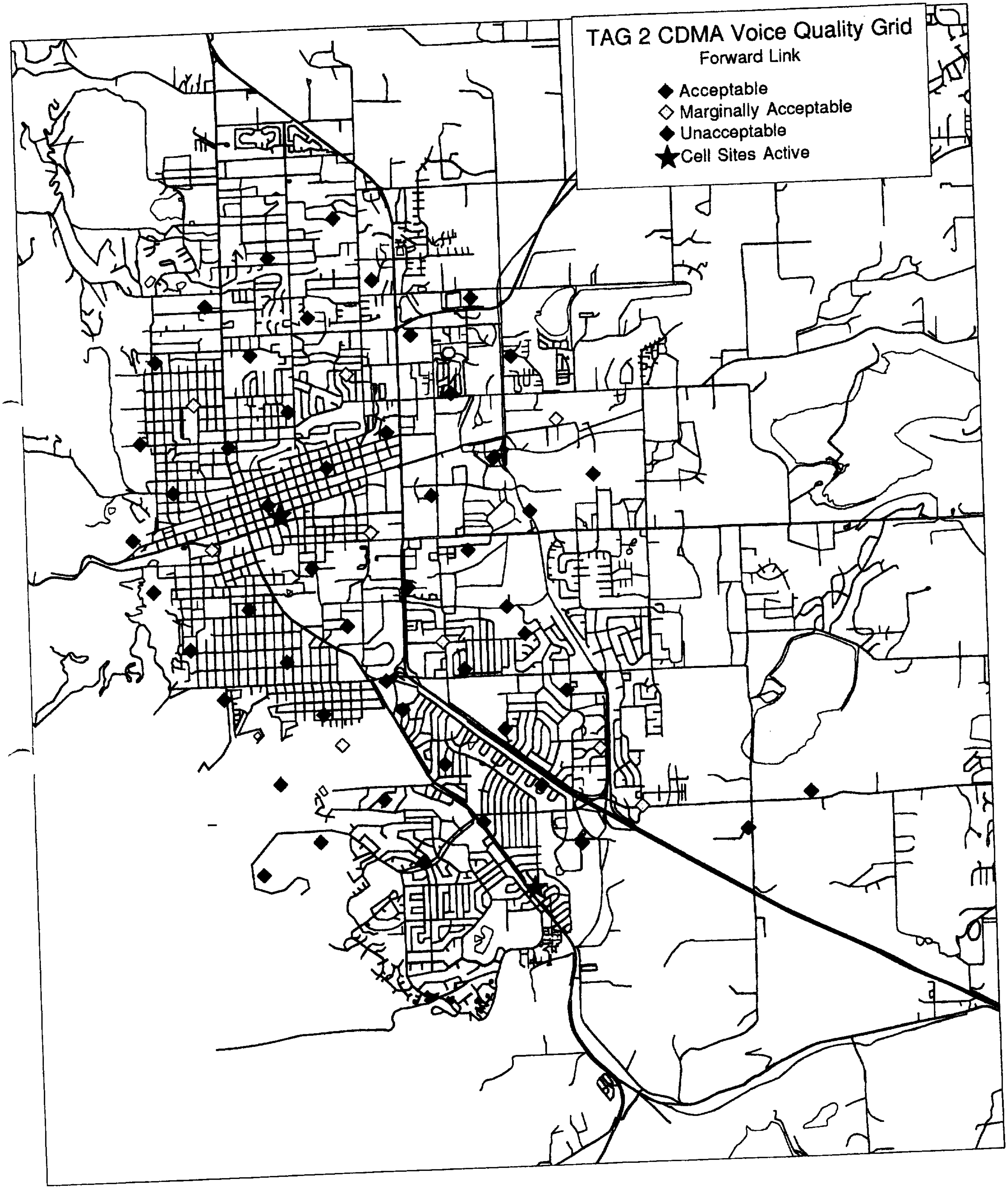
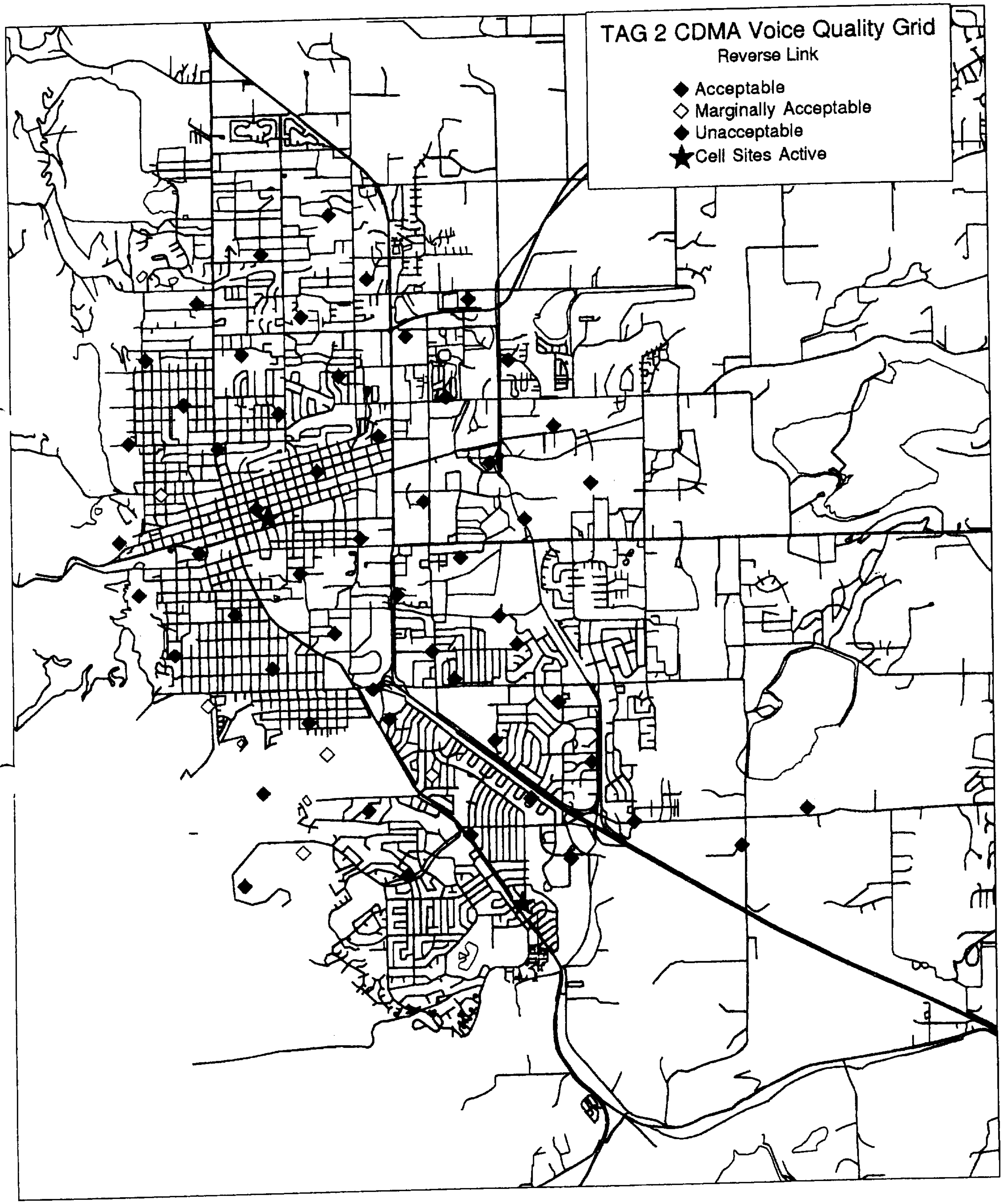


Table Mesa and Walnut CO combined: Handoff states
Portable Handsets
soft-softer
soft
softer
no handoff
5 miles

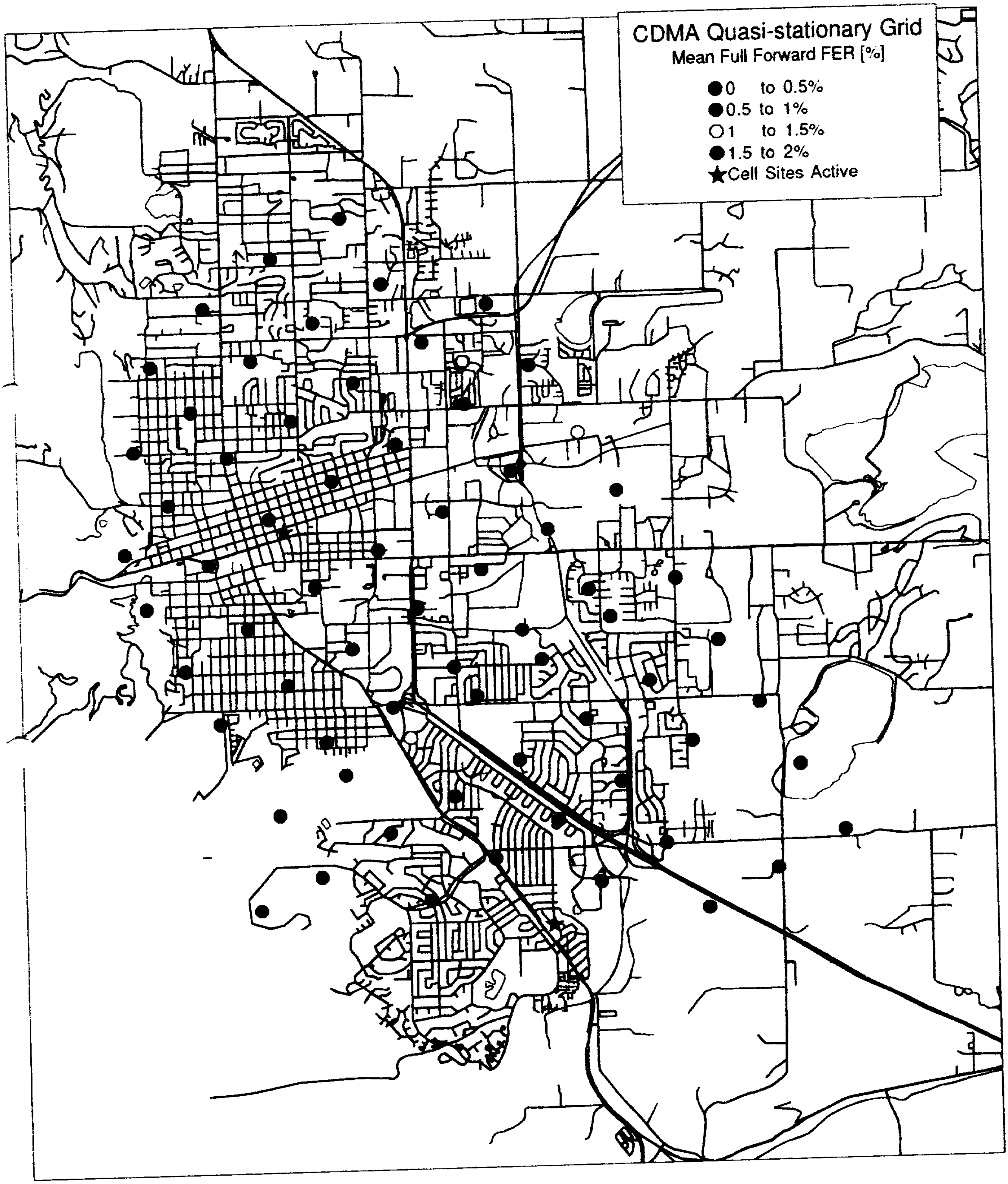
Map 5.2.1.1


TAG 2 CDMA Voice Quality Grid
Forward Link
Acceptable
Marginally Acceptable
Unacceptable
Cell Sites Active

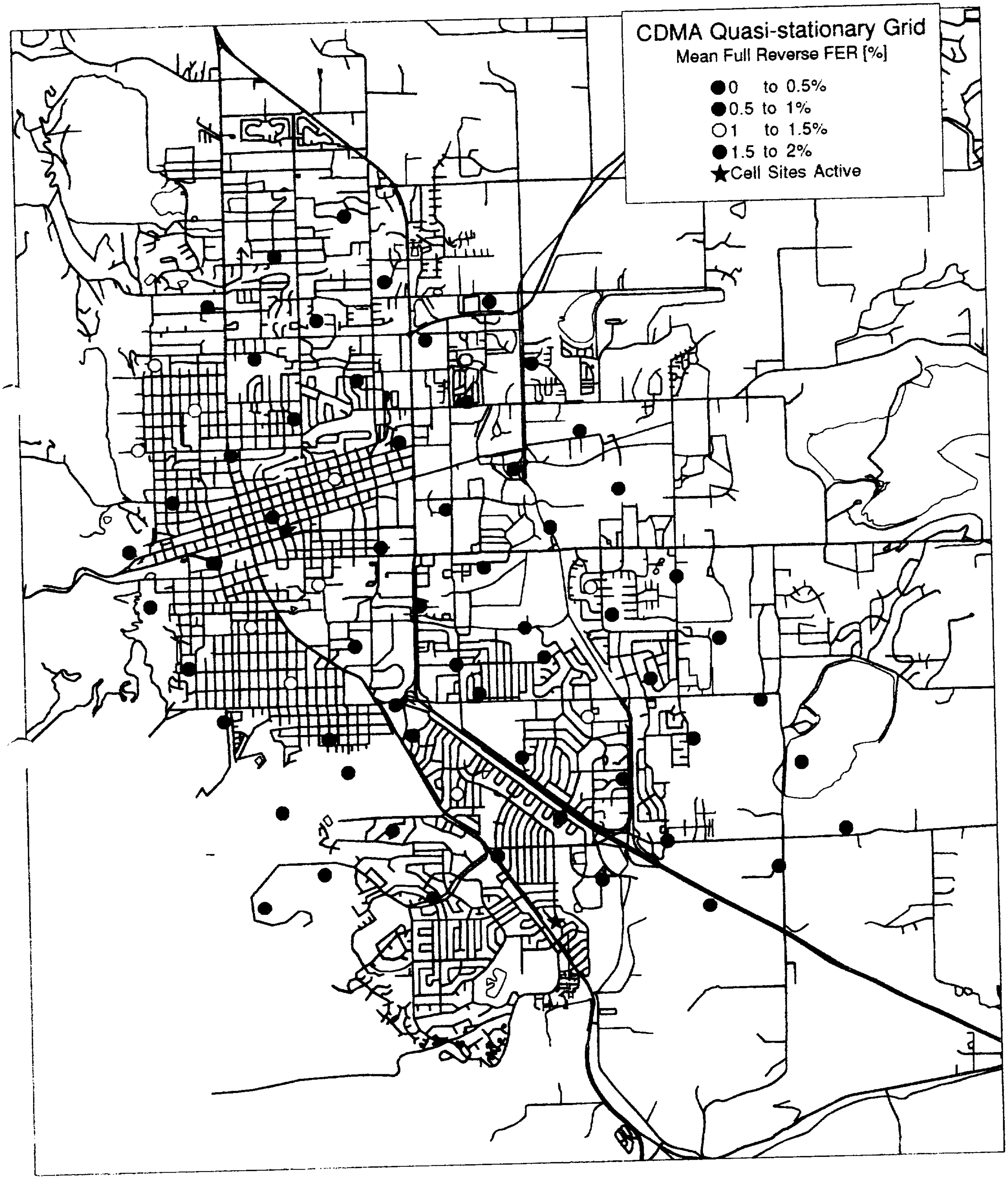
Map 6.3.3.1


TAG 2 CDMA Voice Quality Grid
Reverse Link
Acceptable
Marginally Acceptable
Unacceptable
Cell Sites Active

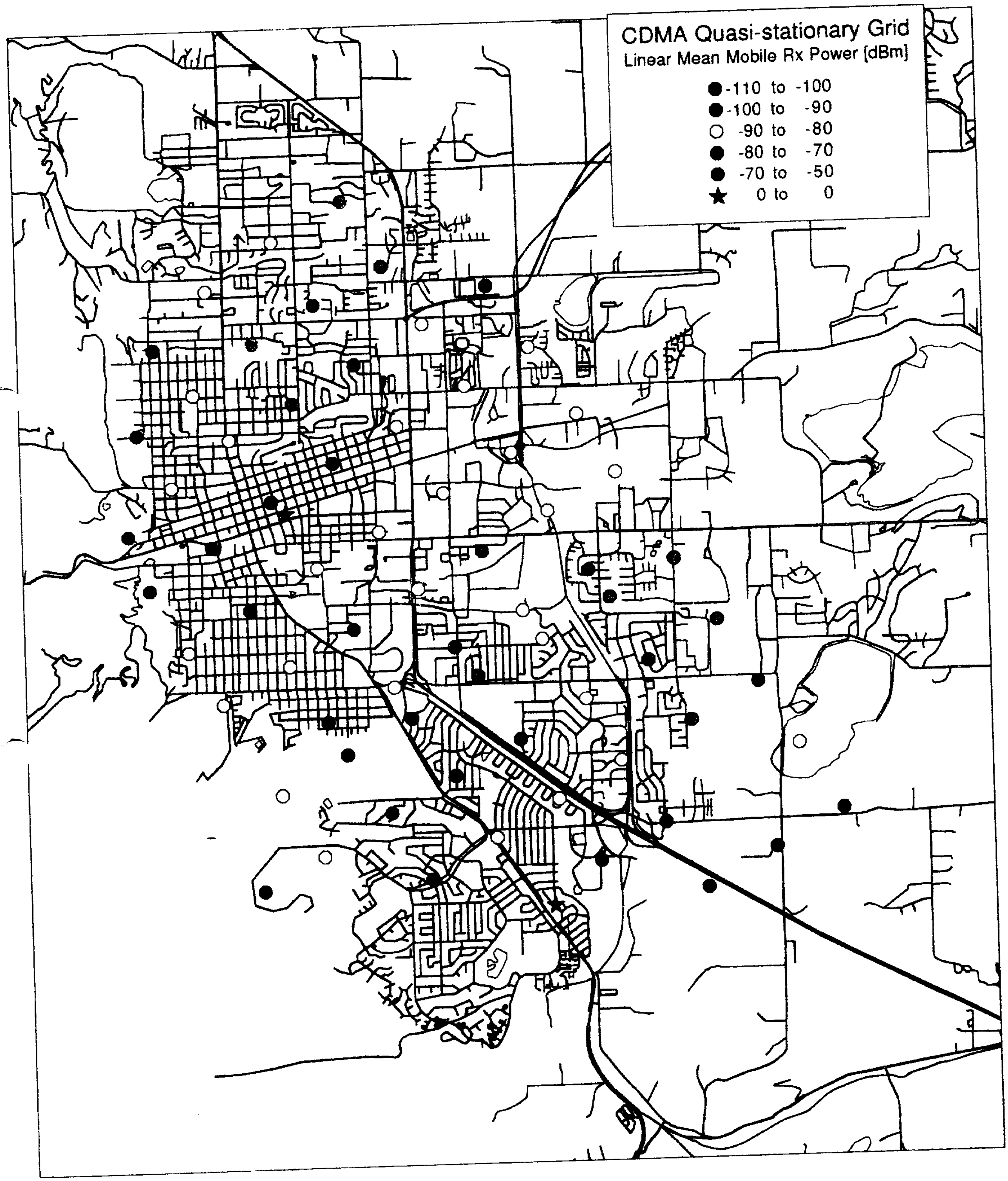
Map 6.3.3.2


CDMA Quasi-stationary Grid
Mean Full Forward FER [%]
0 to 0.5%
0.5 to 1%
1 to 1.5%
1.5 to 2%
Cell Sites Active

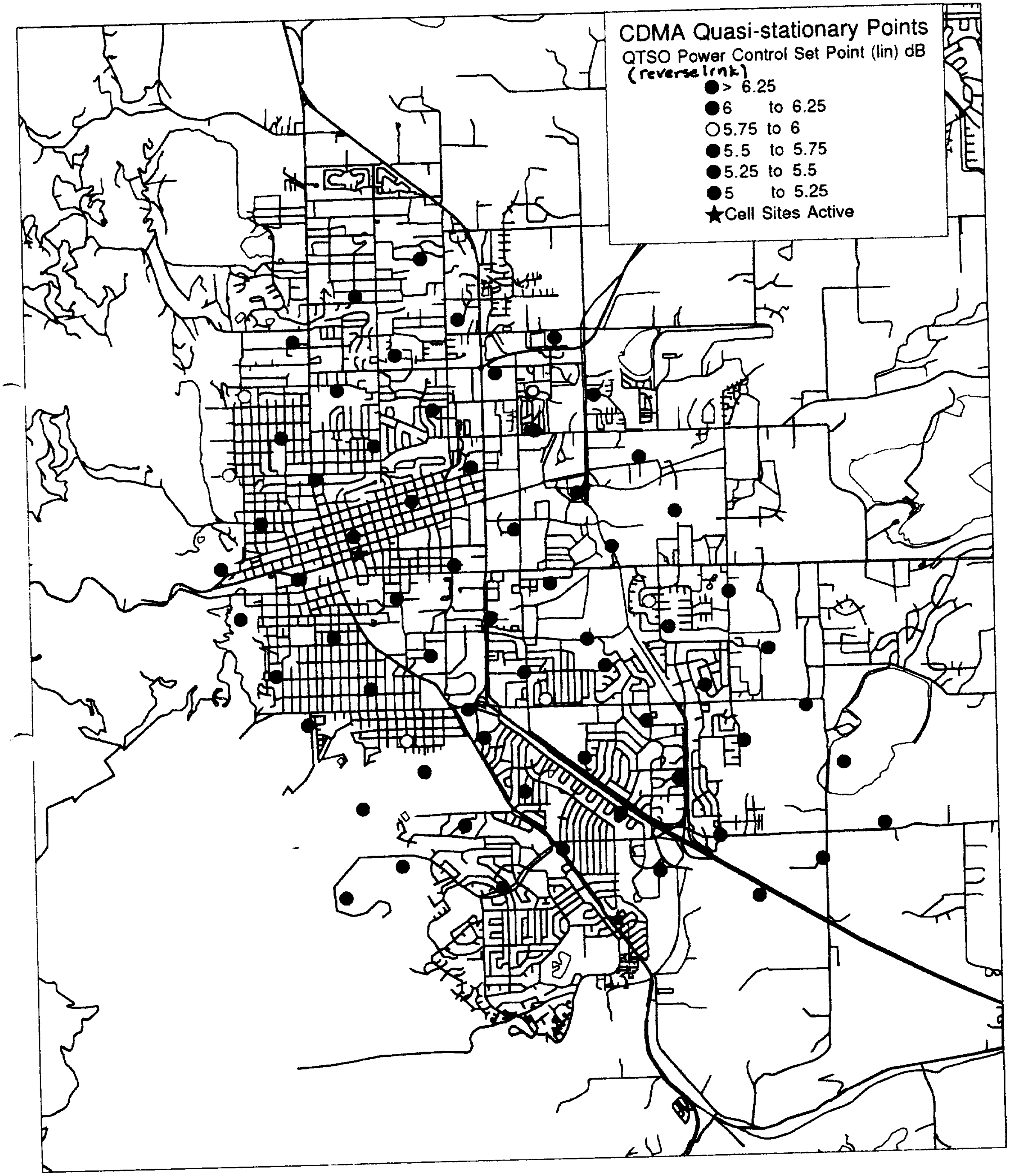
Map 6.3.3.3


CDMA Quasi-stationary Grid
Mean Full Reverse FER [%]
0 to 0.5%
0.5 to 1%
1 to 1.5%
1.5 to 2%
Cell Sites Active

Map 6.3.3.4

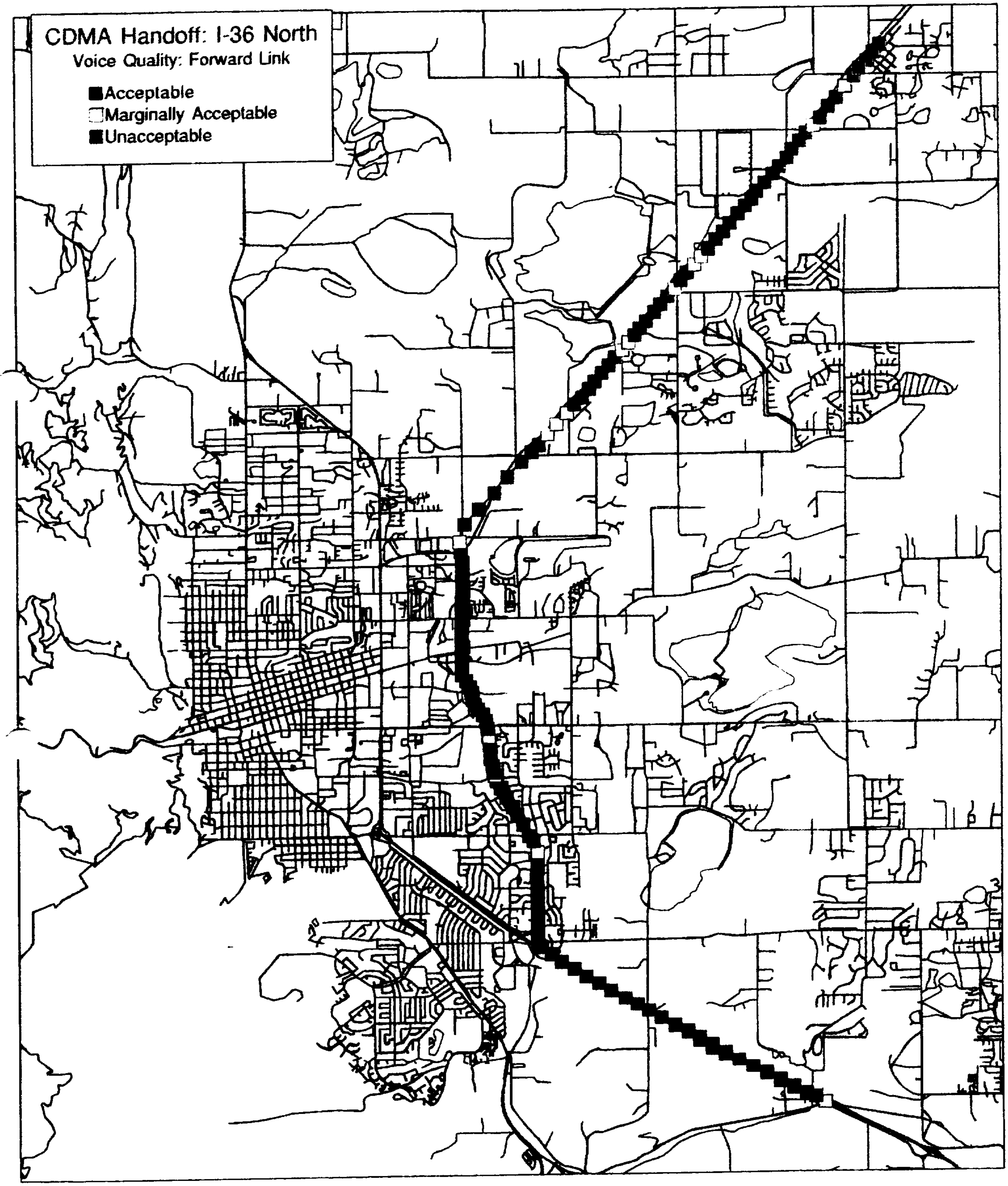

CDMA Quasi-stationary Grid
Linear Mean Mobile Rx Power [dBm]
-110 to -100
-100 to -90
-90 to -80
-80 to -70
-70 to -50
0 to 0

Map 6.3.3.5

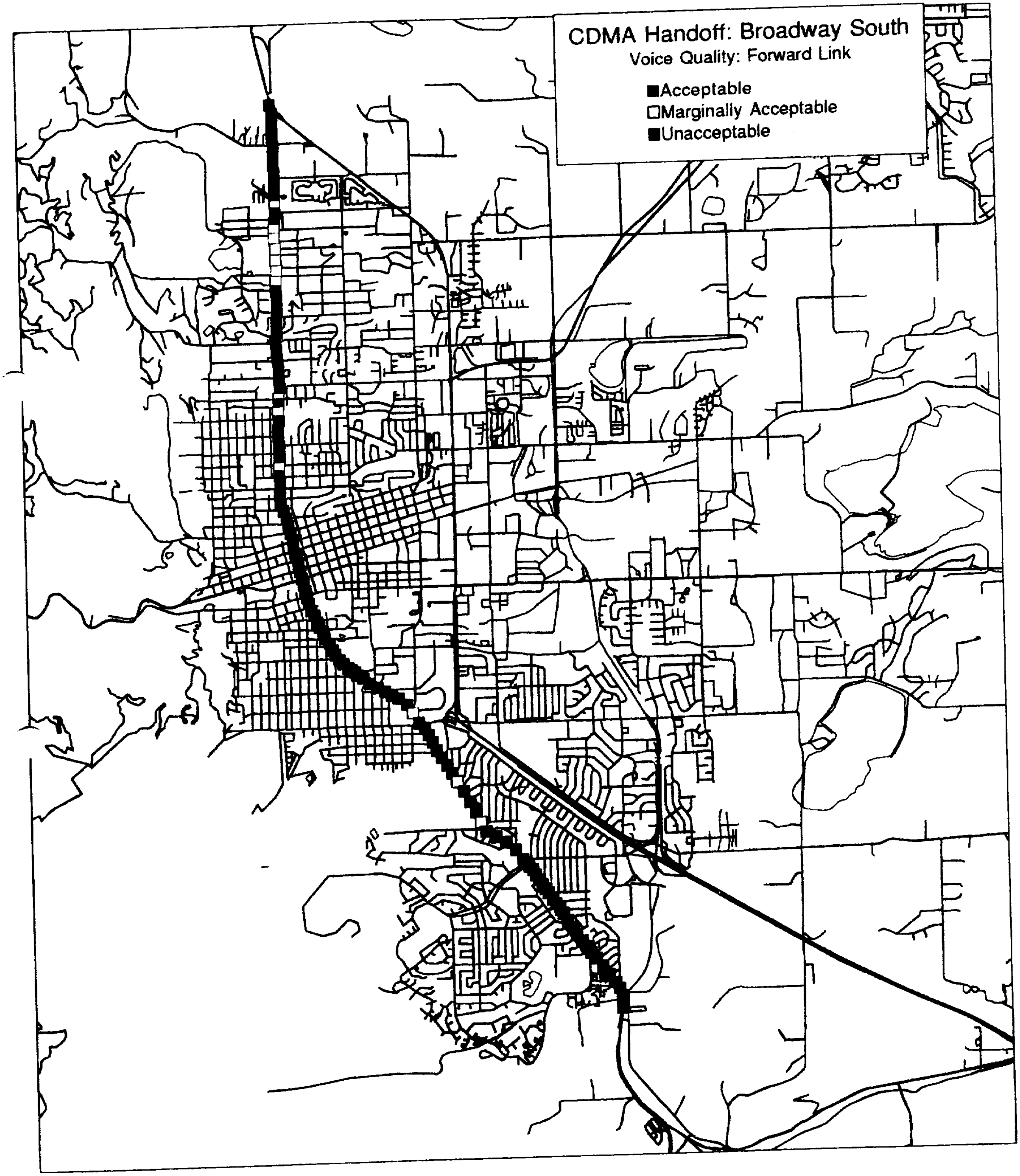


CDMA Quasi-stationary Points
QTSO Power Control Set Point (lin) dB
(reverse link)
> 6.25
6 to 6.25
5.75 to 6
5.5 to 5.75
5.25 to 5.5
5 to 5.25
Cell Sites Active

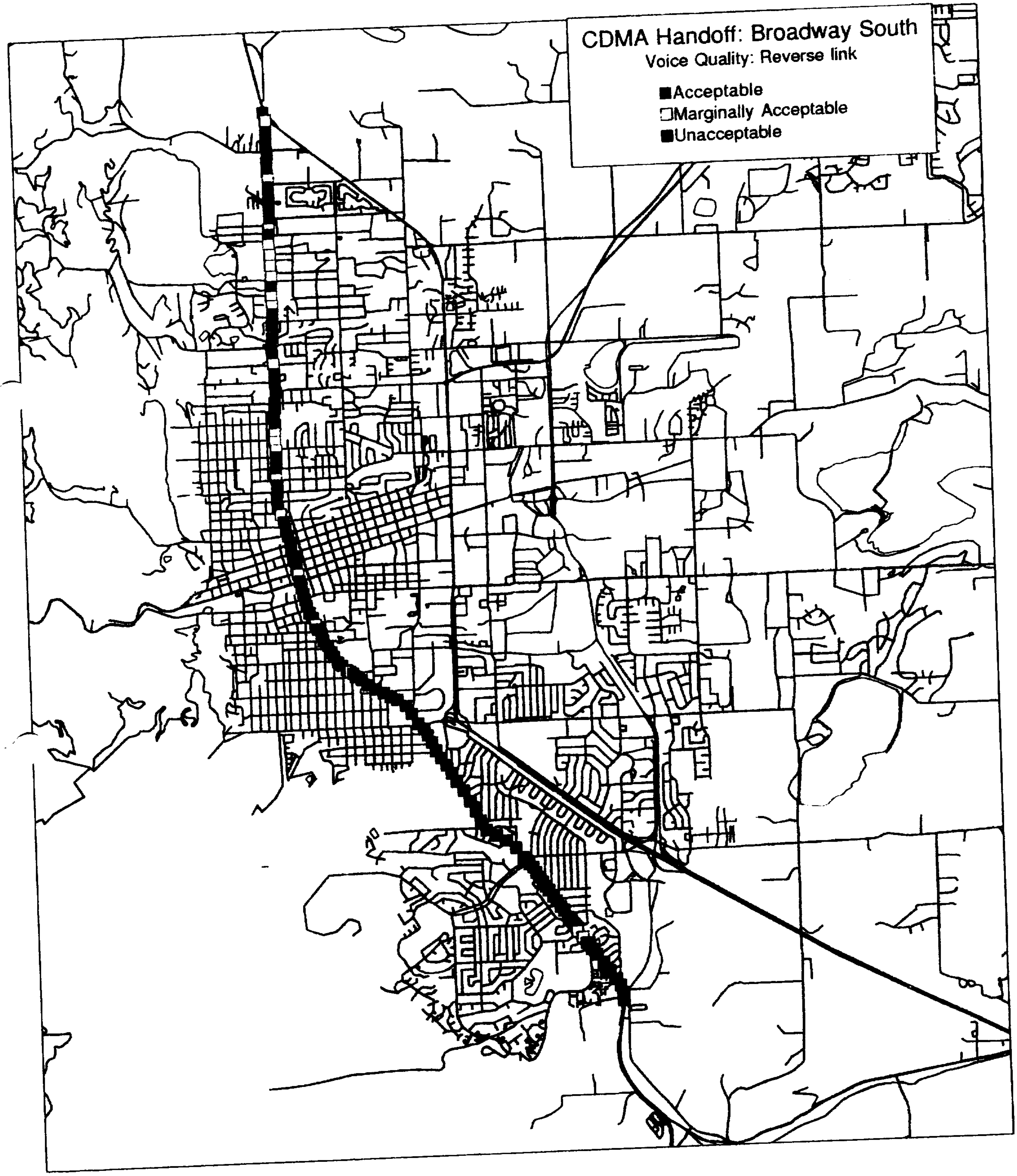
Map 6.3.3.6


CDMA Handoff: I-36 North
Voice Quality: Forward Link
Acceptable
Marginally Acceptable
Unacceptable

Map 6.3.4.1


CDMA Handoff: Broadway South
Voice Quality: Forward Link
Acceptable
Marginally Acceptable
Unacceptable

Map 6.3.4.7


CDMA Handoff: Broadway South
Voice Quality: Reverse link
Acceptable
Marginally Acceptable
Unacceptable

Map 6.3.4.8

APPENDIX B: MANUFACTURERS STATEMENT

QUALCOMM INCORPORATED would like to thank US WEST and the Institute for Telecommunication Sciences (ITS) for their support during the demonstration of the performance of the US CDMA PCS radio air interface at 1.9 GHz at the Boulder Industry Test Bed (BITB) in Colorado. The test bed is operated by US West. In particular, the support provided by Mike Laflin of ITS and the technical staff of US WEST is acknowledged and very much appreciated. QUALCOMM would further like to thank all TAG-2 participants for their hard work in completing the ANSI J-STD-008, Personal Station-Base Station Compatibility Requirements for 1.8 to 2.0 GHz Code Division Multiple Access (CDMA) Personal Communications Systems, and for their support of this test. Funding for the test was provided by QUALCOMM, AT&T, Motorola, Nokia and NORTEL.

QUALCOMM was pleased to supply equipment to demonstrate the CDMA PCS air interface in the BITB as part of the standardization requirements of the Joint Technical Committee (JTC) of the TIA and Committee T1. TAG-2 of the JTC developed the PCS standard which is based on TIA/EIA Dual Mode Cellular CDMA Standard IS-95-A. The resulting ANSI PCS standard has been approved for publication by both T1P1 and TR46.

The CDMA system performed quite well as the report shows. The results are consistent with trials of the CDMA PCS technology in other locations. CDMA provided consistently high voice quality and excellent coverage. The test was conducted with a loading equivalent to 10 calls in every sector of each cell using a single CDMA radio channel.

Owing to time constraints, there was no attempt to tune or optimize the system used in Boulder. As a result, the percentage of soft hand-off is higher than would be targeted in an operational deployment. An interesting test would have been to investigate the influence of the hand-off parameters and higher load on the percentage of soft hand-offs and overall system performance.

The Roving Test System (RTS) used for the JTC tests is a non-commercial test system which employs older 3-chip CDMA technology in the base station. The more recently available single chip cell-site modem (CSM) that is being employed in operational CDMA systems requires about 2 dB less Eb/No on the reverse traffic channel - the exact amount depends upon the multipath environment. In addition, in the BITB tests, the 8 kbps IS-96-A speech codec was used. Higher voice quality is provided in deployed CDMA systems tests that use the more recently available 13 kbps speech codec.

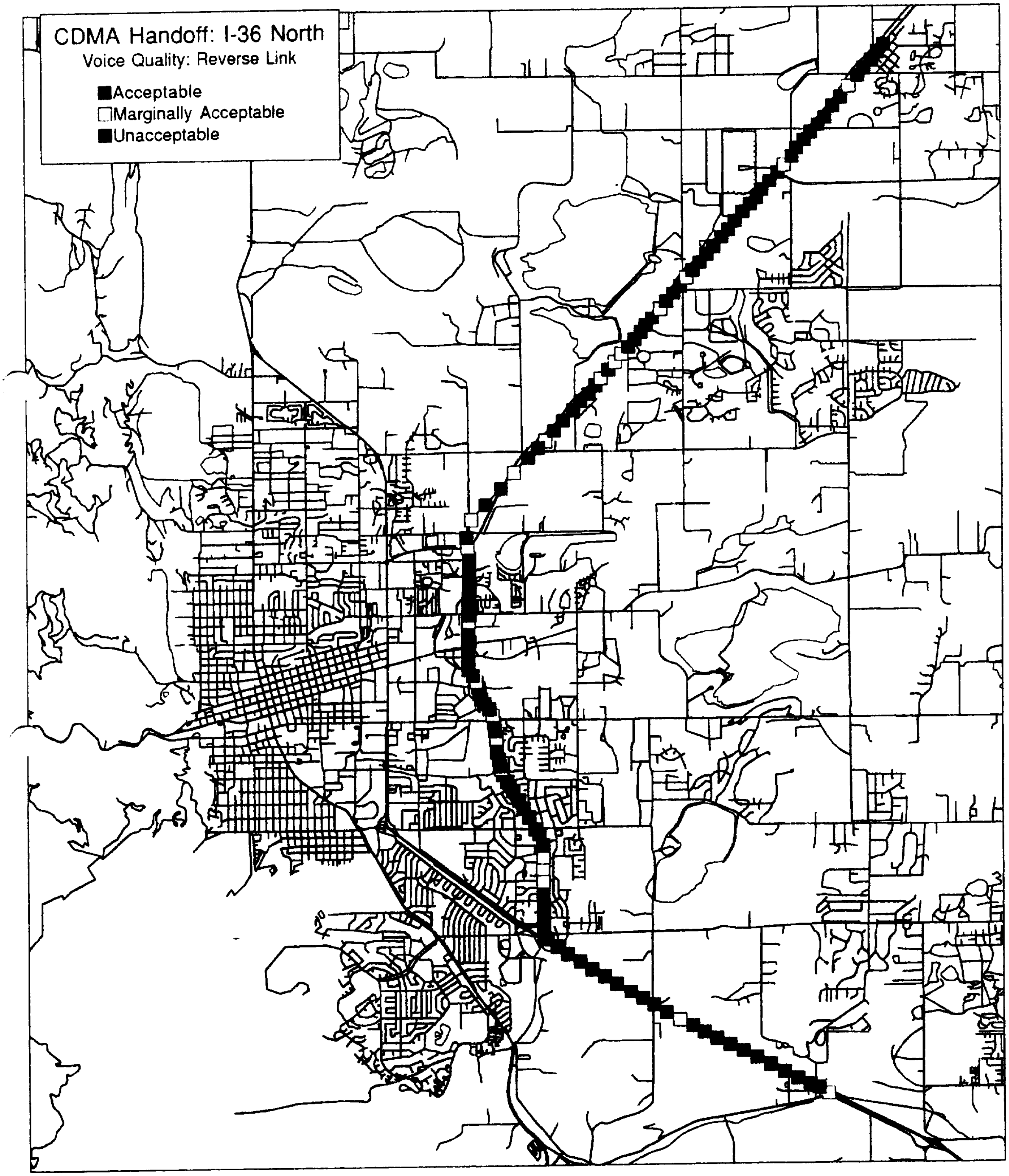
APPENDIX C: STATEMENT OF THE INDEPENDENT OBSERVER

The Institute For Telecommunication Sciences (ITS), the research and engineering arm of the National Telecommunications and Information Administration (NTIA), was asked by the JTC to function as the independent observer of the JTC technology field trails. Michael G. Laflin, of ITS, was the primary observer for this field trial.

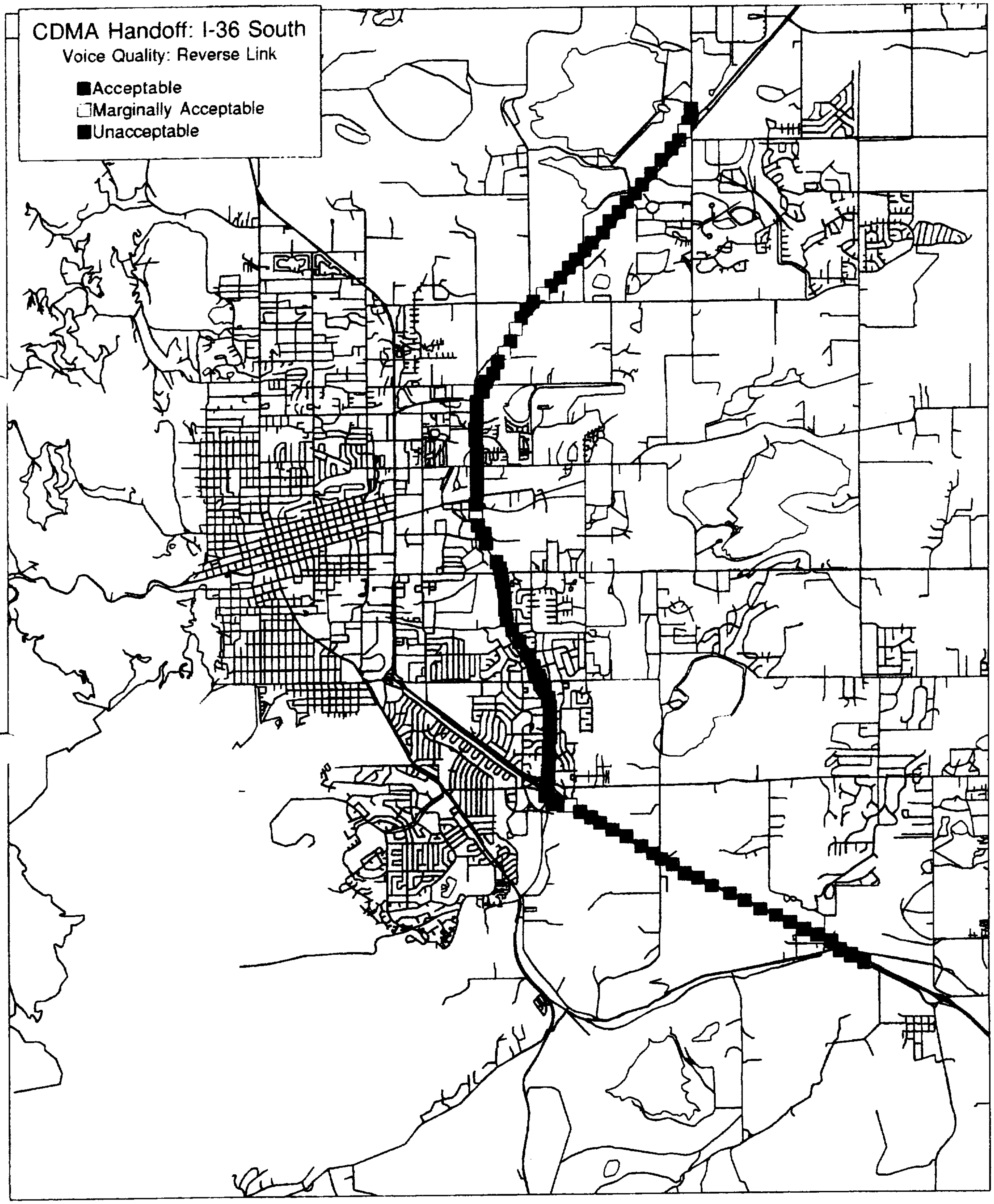
The second technology to undergo field testing is that standardized in the JTC Technology Ad Hoc Group 2.

This role as independent observer involved reviewing test procedures and observing the test execution. This role also involved significant direct participation in the data collection, storage, and analysis. In so doing ITS is qualified to comment on the conduct and results of the TAG 2 technology field trail.
It is the opinion of Mr. Laflin that the testing was conducted honestly and within the guidelines of the test plan for this field trial. After all is said and done there is always more data and additional analysis that one would like to have seen collected and performed to maximize the usefulness of a test such as this. Having said that though, the independent observer believes that the final product, this report, reflects adequately the results from this test.

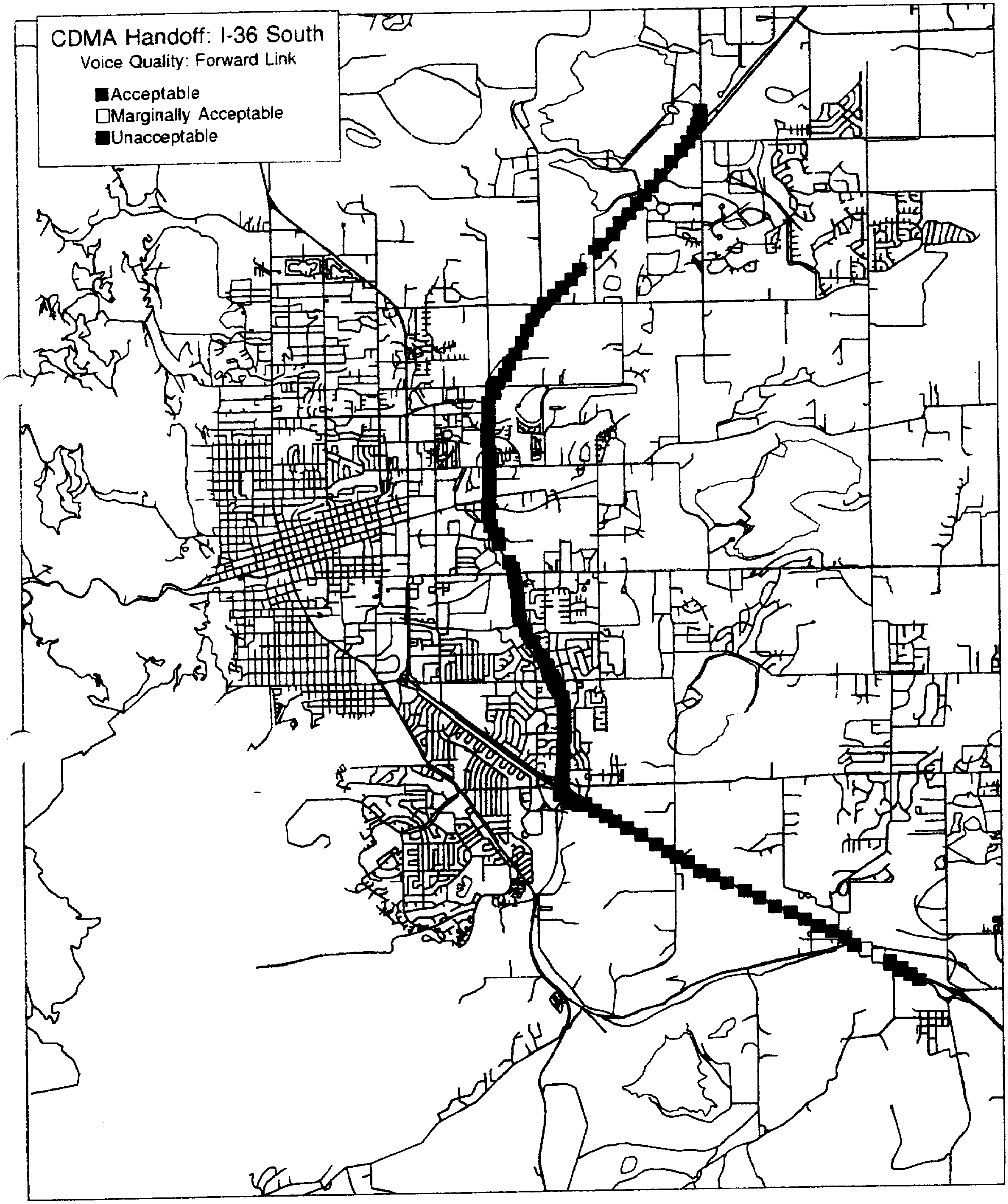
ITS wishes to thank all of the participants for their hard work and patients in completing this JTC technology field trial.


CDMA Handoff: I-36 North
Voice Quality: Reverse Link
Acceptable
Marginally Acceptable
Unacceptable

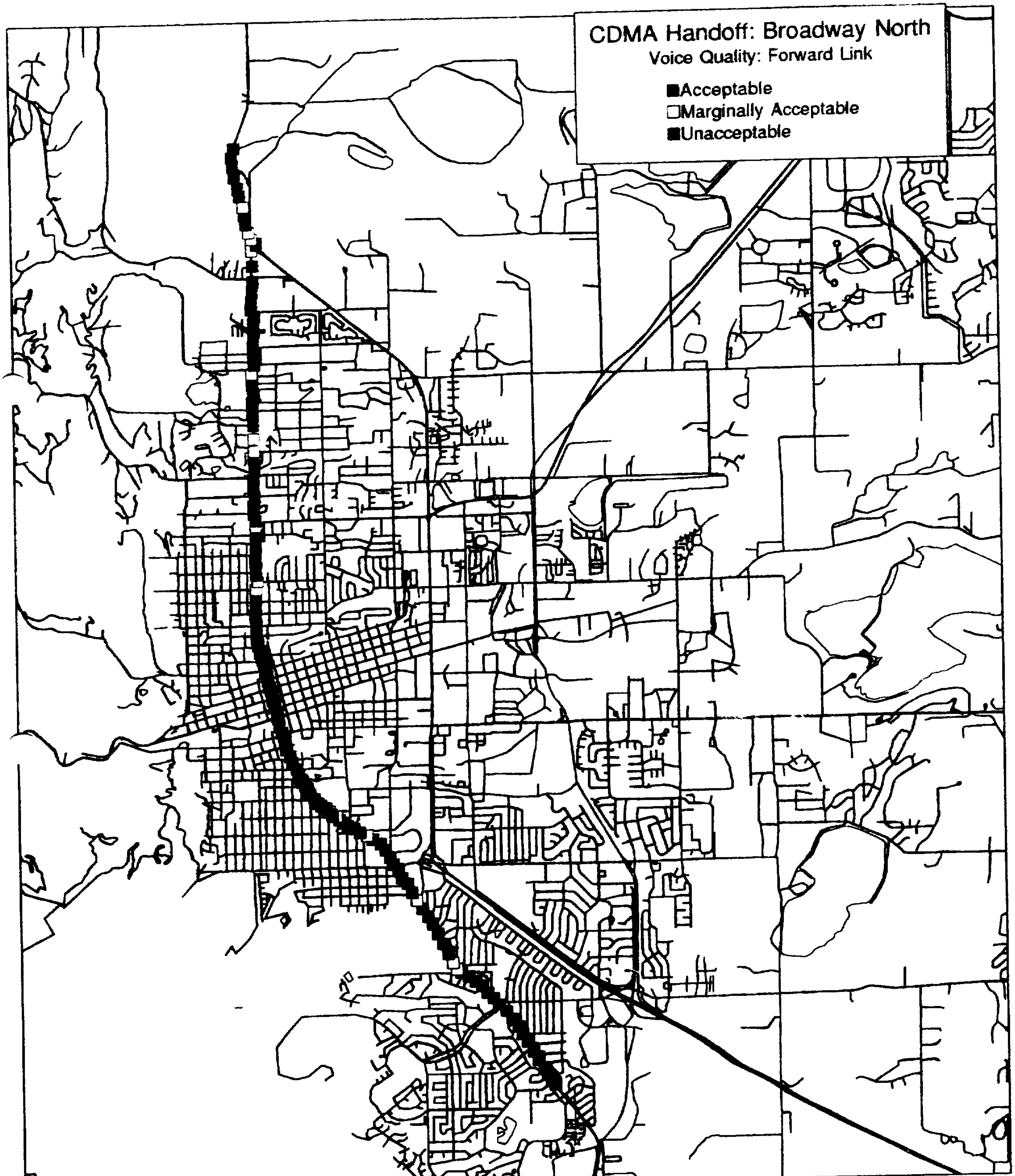
Map 6.3.4.2


CDMA Handoff: I-36 South
Voice Quality: Reverse Link
Acceptable
Marginally Acceptable
Unacceptable

Map 6.3.4.3

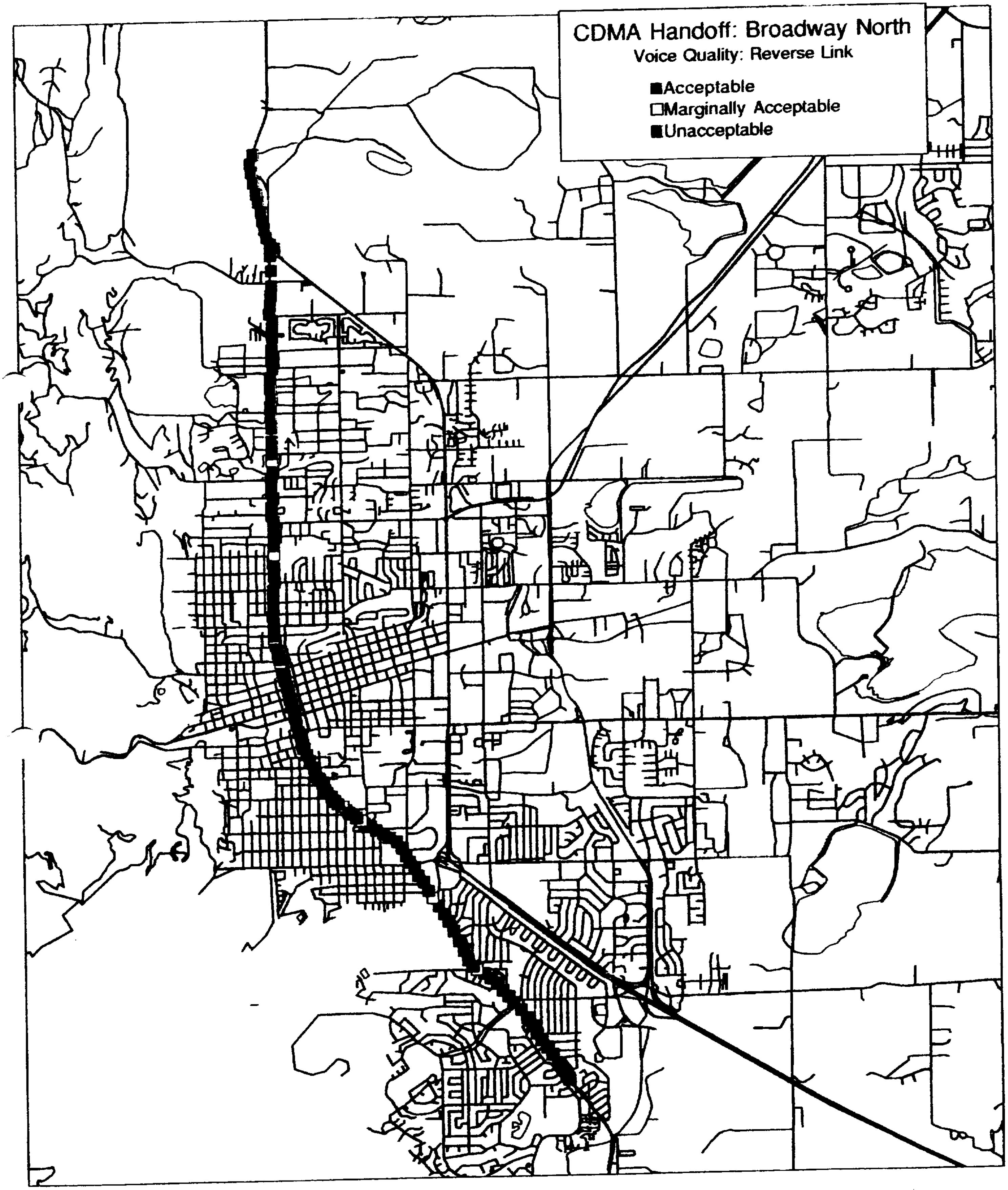

CDMA Handoff: I-36 South
Voice Quality: Forward Link
Acceptable
Marginally Acceptable
Unacceptable

Map 6.3.4.4



CDMA Handoff: Broadway North
Voice Quality: Forward Link
Acceptable
Marginally Acceptable
Unacceptable

Map 6.3.4.5


CDMA Handoff: Broadway North
Voice Quality: Reverse Link
Acceptable
Marginally Acceptable
Unacceptable

Map 6.3.4.6