QUALCOMM INCORPORATED

10555 Sorrento Valley Road, San Diego, CA 92121-1617 ☐ (619) 587-1121 ☐ Fax: (619) 452-9096

July 19,1993

VIA HAND DELIVERY

Federal Communications Commission
Room 7326
2025 M Street N.W.
Washington, D.C. 20554

Attention: Mr. H. Franklin Wright
Chief, Frequency Liaison Branch
STOP CODE 1300A4

Re: QUALCOMM INCORPORATED
Quarterly Progress Report for
Personal Communication Services
Experimental License Call Sign: KK2XBJ
File Number: 2345-EX-PL91

Dear Mr. Wright:

Enclosed are three copies of QUALCOMM INCORPORATED's quarterly progress report for its personal communications services experimental license.

No filing fee is associated with this filing. Please contact the undersigned at (202) 223-1720 if any questions arise with respect to this report.

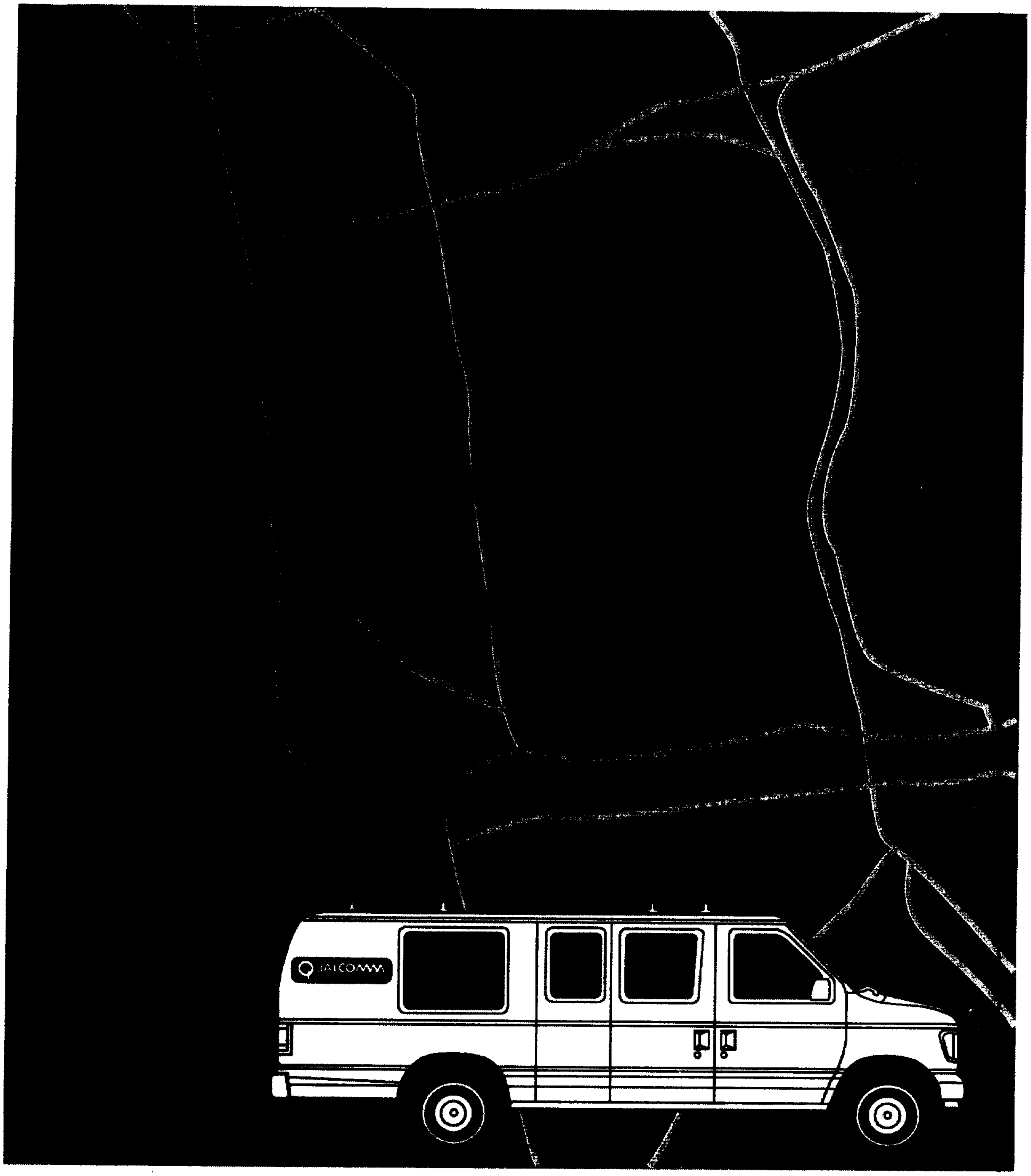
Sincerely,

Kevin J. Kelley

Kevin J. Kelley
Vice President-External Affairs

MR/pmd
Enclosure
cc(w/encl.): Dr. Thomas P. Stanley

QUALCOMM



PCS Experimental License Progress Report

January - March 1993

FCC Experimental License: Qualcomm Incorporated KK2XBJ
File Number: 2345-EX-PL91

PCS Experimental License Progress Report

January - March 1993

FCC Experimental License: Qualcomm Incorporated KK2XBJ

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Figures

Table A-1. Field Test Runs (continued)

Test Section	Test#	Date	Run#	Description	Comments
4.4.3.1	7	3-Mar	6A	OFS Interfer to PCS Base station	Redo of test
4.4.3.1	7	3-Mar	7A	OFS Interfer to PCS Base station	Redo of test
4.4.3.1	8	3-Mar	9	OFS Interfer to PCS Base station	With 4 Markov calls
4.4.3.1	8	3-Mar	10	OFS Interfer to PCS Base station	With 4 Markov calls
4.4.3.1	8	3-Mar	11	OFS Interfer to PCS Base station	With 4 Markov calls
4.4.3.1	4	4-Mar	1	OFS Interfer to PCS Base station	With 4 Markov calls
4.4.3.1	4	4-Mar	2	OFS Interfer to PCS Base station	With 4 Markov calls
4.4.3.1	4	4-Mar	3	OFS Interfer to PCS Base station	With 4 Markov calls
4.4.3.1	12	4-Mar	4	OFS Interfer to PCS Base station	With 4 Markov calls
4.4.3.1	12	4-Mar	5	OFS Interfer to PCS Base station	With 4 Markov calls
4.4.3.1	12	4-Mar	6	OFS Interfer to PCS Base station	With 4 Markov calls
4.4.3.1	16	4-Mar	7	OFS Interfer to PCS Base station	With 4 Markov calls

Tables

1 Introduction

On February 21, 1992, the Federal Communications Commission granted experimental license to QUALCOMM Incorporated to conduct radio frequency (RF) propagation and system tests in San Diego California. QUALCOMM Incorporated is investigating the application of its wideband spread spectrum Code Division Multiple Access (CDMA) method of digital transmission to the Personal Communications Services (PCS) radio environment.

QUALCOMM, with the support and involvement of a number of carriers and licensed manufacturers, has been working on its CDMA technology for over four years and has been investigating its application to PCS for over two years. In 1992, QUALCOMM demonstrated its PCS CDMA technology to Duetsche Bundespost Telekom in Munster Germany and Swiss PTT in Geneva, Switzerland. It also supported, tested, and delivered a CDMA PCS test system to American Personal Communications (APC) in Washington D.C. and the Korean Electronics and Telecommunications Research Institute (ETRI). Finally, in November 1992, QUALCOMM embarked on performing a series of joint tests in San Diego with Telesis Technologies Laboratory (TTL) to further characterize CDMA PCS performance.

This report is the second quarterly progress report that QUALCOMM has submitted to the FCC and covers research efforts completed through March 31, 1993. The results for this quarter includes work completed with TTL in San Diego, California and covers three research objectives:

- The characterization of wideband spread spectrum CDMA in a PCS environment
- Spectrum sharing issues with PCS CDMA
- In-building performance of PCS CDMA.

Following the executive summary, chapter 3 provides an overview of CDMA PCS testing and the research objectives of the test program. Chapter 4 describes the field test results; chapter 5 discusses the results of in-building tests; and chapter 6 presents laboratory test results.

2 Executive Summary

From January through March 1993, QUALCOMM Incorporated performed a series of comprehensive digital wireless system tests in San Diego using QUALCOMM-developed CDMA PCS infrastructure and subscriber equipment. The purpose of these tests was to more accurately determine the performance of CDMA in a PCS environment and study the interaction of CDMA PCS with other systems sharing the same spectrum. A vast amount of field test data was collected that supported the test objectives and goals. As a result of QUALCOMM's preliminary analysis and review of this data, the following paragraphs highlight the key findings of PCS testing:

Field Tests

Field tests were conducted using QUALCOMM's San Diego PCS field test system which consisted of three base stations, a switching office that connects to a public switched telephone network, PCS subscriber units, and microwave equipment. Currently coverage tests, interoperability tests, and spectrum sharing tests have all been conducted in the field.

Coverage Tests

The coverage tests indicate good coverage on flat terrain and also show that there are areas of coverage overlap between the three cells of the system. The coverage is mainly determined by the terrain. Even with the minimum number of cells and the mesa/canyon nature of the test area, the majority of routes in the test area are in coverage. The sections of the test routes with poor coverage would normally be well covered by adjacent base stations. The coverage results show the intersection of Sorrento Valley Boulevard and Sorrento Valley Road as the center of the best test area.

Interoperability

Numerous tests of the multiple cell system were performed to study and characterize operation of a PCS sysem. The results show performance which is as good as operation in the 800MHz cellular band. The test area has a significant number of handoff regions and the system performed successfully in these regions using nominal system parameters. The power control operated correctly at 1.8 GHz and histograms of Transmit Gain Adjust demonstate reasonable performance. Histograms of the transmit and receive power show low average power which is within expected ranges. The system operation is stable over the 0 to 55 mph range as shown by Frame Error Rate (FER) versus speed graphs.

Spectrum Sharing

Spectrum sharing tests are being conducted to show the compatibility of CDMA PCS with other microwave users in the same spectrum. Although further testing and analysis is required, preliminary analysis shows no difficulty in spectrum sharing. Currently PCS forward and reverse link (base station and subscriber station transmitters, respectively) interference to OFS has been tested while OFS interference to PCS forward and reverse links, are being tested. Plots of the received signal at the base station show that the received level is tightly controlled with a standard deviation of less than 2 dB. The receive signal level at the more remote of the two local base stations is shown to be significantly reduced from the closer controlling base station. The mobile power and the signal received at the OFS antenna are therefore minimized.

In-Building Tests

Preliminary in-building tests, which utilized a distributed antenna system, showed that in-building propagation in PCS performs as successfully as it does in the cellular band. As expected, the diversity antenna system helped mitigate the effects of channel fading. Moreover, these in-building tests showed excellent performance at medium to low signal level at the subscriber unit. The base station performed better than for the field tests, requiring 1 to 2 dB less signal to noise ratio for the same performance.

Other formal in-building tests which used a single antenna on a picocell operating with under two milliwatts total transmit power, indicated good coverage between floors and for a radius of 50-100 ft on each floor. From the preliminary data it was determined that a three node system on only the first floor of QUALCOMM building A could be used for future testing.

Laboratory Tests

Laboratory tests characterized the interaction of OFS services and PCS in a shared spectrum in a controlled environment and verified the appropriate range of signal levels for the field tests. Reference curves for the OFS link using 16-ary QAM were generated. The effect of CDMA base station signal interference to an OFS receiver was measured. The results show consistent curves with the interference reduced by 30 dB for each 2.5 MHz offset from the OFS receive frequency. CDMA subscriber unit interference (from one to six subscriber units in operation at one time) was also measured and shown to be consistent based on total energy for interference .

3 Field Test Overview

3.1 Summary of Research Activities

3.1.1 CDMA Testing History

In November 1989, in conjunction with Pactel Cellular, QUALCOMM first demonstrated CDMA in the 800 MHz cellular band in the San Diego area. This successful demonstration was followed by an extensive technical field trial in midtown Manhattan with NYNEX Mobile in February 1990. The fundamental features of CDMA, such as power control, multiple multipath reception, and soft handoff were successfully demonstrated in a wide variety of field conditions.

In 1991 and 1992, QUALCOMM further undertook a series of system validation tests in several cities in the U.S. as well as in Korea and Europe, with the support and participation of a number of major cellular carriers and manufacturers. These tests characterized the performance of CDMA system capacity, and helped validate the CDMA Dual-Mode Common Air Interface specification, and the custom Application Specific Integrated Circuits (ASICs).

In each field trial, CDMA's fundamental features of high capacity, superior voice quality, low power operation, better multipath reception, and soft handoff were successfully demonstrated under a variety of conditions.

3.1.2 PCS Testing

QUALCOMM's PCS efforts have closely followed its cellular efforts. In 1992, QUALCOMM also demonstrated its PCS CDMA technology to Duetsche Bundespost Telekom in Munster Germany and Swiss PTT in Geneva, Switzerland. The results from both testing programs are described in the previous progress report submitted to the FCC on November 4, 1992.

Since the publication of the last report, QUALCOMM's testing program for PCS has grown. In the third quarter of 1992, QUALCOMM supported and delivered a CDMA PCS test system to American Personal Communications (APC) in Washington D.C and the Korean Electronics and Telecommunications Research Institute in Taejon, Korea. QUALCOMM has also made arrangements to test and deliver in the fourth quarter of 1993, a CDMA PCS system to Time Warner Telecommunications in Orlando Florida.

System-level PCS testing has also occured with Telesis Technologies Laboratory (TTL) in San Diego. In November 1992, QUALCOMM also embarked on performing a series of joint tests with TTL to further characterize CDMA PCS performance in San Diego, operating at the 1.8 GHz band. Since February 1993, a vast amount of data from actual system operation has been collected to support the test objectives and goals which are described below.

3.2 Objectives

The primary objectives of PCS testing efforts in San Diego include examining:

- Microcell operational capabilities
- Macrocell/microcell/picocell interoperability
- Spectrum sharing capabilities
- In-building wireless operations
- Capabilities and limitations of CDMA technology at 1800 MHz.

Operational, interoperational, and spectrum sharing tests are being conducted in the field, in-building, and in the laboratory.

3.2.1 Operational and Interoperational Tests

Operational and interoperational tests address the PCS system operating in a combination of different environments, including macrocells, microcells, and picocells. Four separate types of tests are conducted including coverage, interaction, handoff, and interference. First the PCS performance is measured using a stand alone base station. Then the interactions of base stations of the same type and the interactions of different types of base stations are measured. A description of each test and the results generated from each test are discussed in Chapter 4.

Note that for these tests, a macrocell is defined as a base station that uses rooftop or tower mounted antennas and transmits enough power to cover a range of at least 1 mile over flat terrain. A microcell is a base station that uses a rooftop antenna and low power and covers less than a 1 mile range. A picocell is an in-door system with various antenna configurations and distributed antennas.

3.2.2 Spectrum Sharing Tests

Since the PCS service will coexist with point-to-point microwave services in the same spectrum, much of the test effort is expended on characterizing the interaction between these two services. The four interactions tested are:

- PCS forward link interference to Operational Fixed Service (OFS)
- PCS reverse link interference to OFS
- OFS interference to PCS forward link
- OFS interference to PCS reverse link.

Chapter 4 discusses the design and field test results for each objective and Chapter 6 presents the configuration and results from laboratory testing.

3.3.3 In-Building Distributed Antenna Tests

Several preliminary in-building tests which utilize QUALCOMM's distributed antenna have been conducted at QUALCOMM to characterize how the distributed antenna propagates at 1.8 GHz. Specifically, these tests were designed to determine differences in propagation between cellular and PCS frequencies and will be discussed in greater detail in Chapter 5.

3.3 Testbed Infrastructure

3.3.1 Field Test System

QUALCOMM's San Diego PCS field test system consists primarily of three cell sites (referred to as base stations), a switching office (referred to as a QTSO or QUALCOMM telephone switching office) that connects to the public switched telephone network, PCS subscriber units, and microwave equipment.

The three base stations are situated within a 2 mile radius of each other in the Sorrento Valley of San Diego. As shown in the map in Figure 3-1, base station C1 is co-located with the QTSO in QUALCOMM building C at 4110 Sorrento Valley Boulevard; C2 is in QUALCOMM building A at 10555 Sorrento Valley Road, and C3 is in the San Diego Design Center, 6455 Lusk Boulevard.

Prior to implementing the field tests, drive routes were selected, drivers were assigned, and route maps were drawn. A drive route for each subscriber unit was recorded for each run of the test. In general, however, three main routes were used throughout field testing :

- Route #1 (shown in green): Starting North on Sorrento Valley Road to Sorrento Valley Blvd. East then South on Vista to Sorrento Parkway and West on Mira Mesa Blvd.
- Route #2 (shown in red): North from the South end of Roselle Street to West on North Estuary Way then South on Flintkote and East on Dunhill St.
- Route #3 (shown in green): Grid in parking lots and among commercial buildings north of Sorrento Valley Blvd and East of Vista Sorrento Pkwy.

Figure 3-2 shows a block diagram of the system. Each base station can handle a combination of simulated and real users up to a level of 40 users per base station. Base stations C1 and C2 have roof mounted omnidirectional antennas to operate as macrocells. C1 has a dish available for microwave operation or CDMA reception. Base station C2 in building A, which is a two-story building, is also connected to picocell antennas. Base station C3 has a sectored CDMA antenna with a gain of 6 dB connected to a microcell. Typical operating specifications for the dish antennas are noted in Table 3-1.

The QTSO is configured with 8 vocoder/selectors and each base station has 6 traffic channels, which implies that 6 calls can be supported at one time. Figure 3-3 shows a block diagram of the configuration of each base station and Figure 3-4 shows a block diagram of the configuration of the QTSO.

Table 3-1. Antenna Operating Specifications

Diameter	Gain dBi			B/W	F/B	Max VSWR	
(Ft.)	Low	Mid	High	(deg)	Ratio	Std.	Low
4	25.5	25.8	26.0	8.4	31-36	1.3	1.15

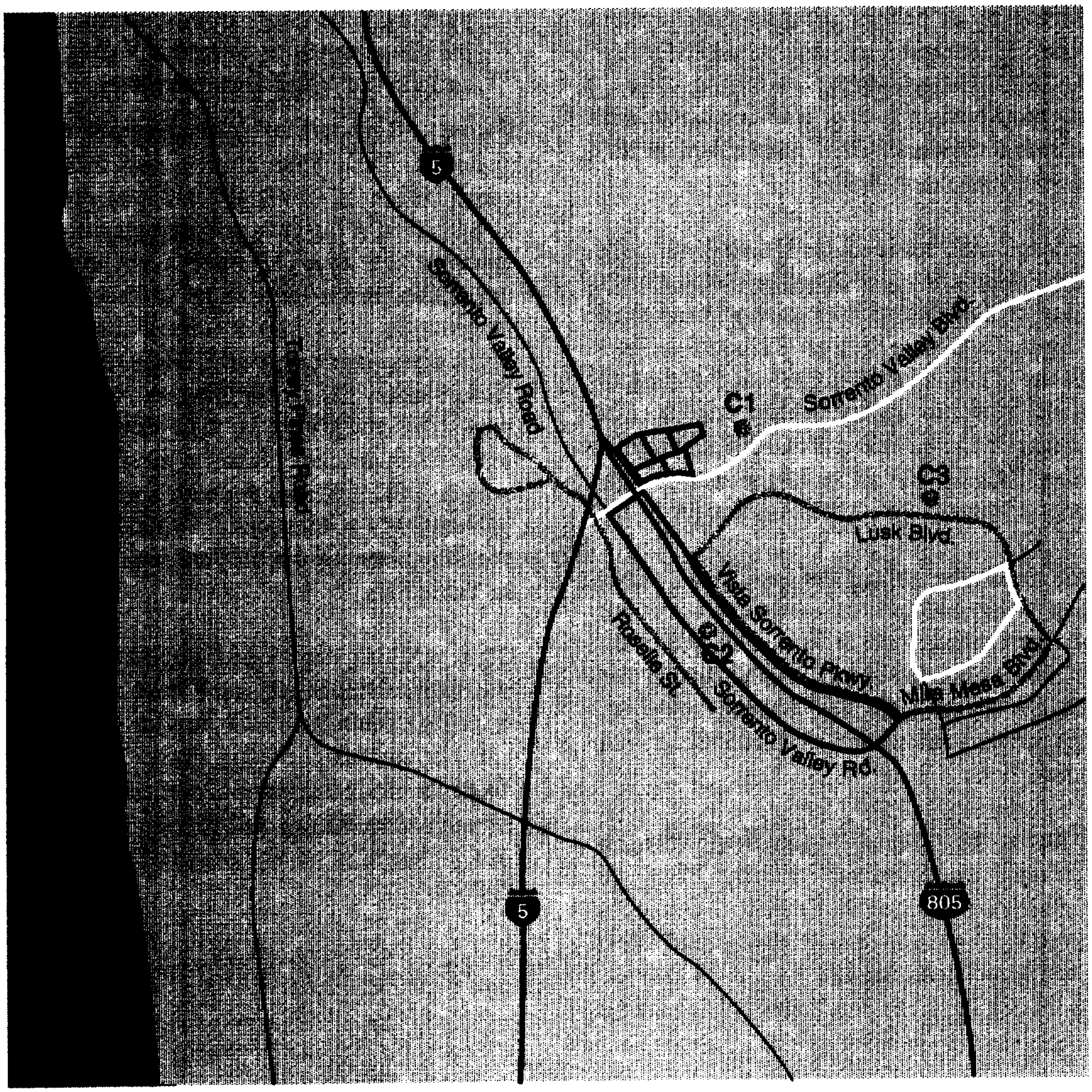


Figure 3-1. Base Station Locations and Test Route Map

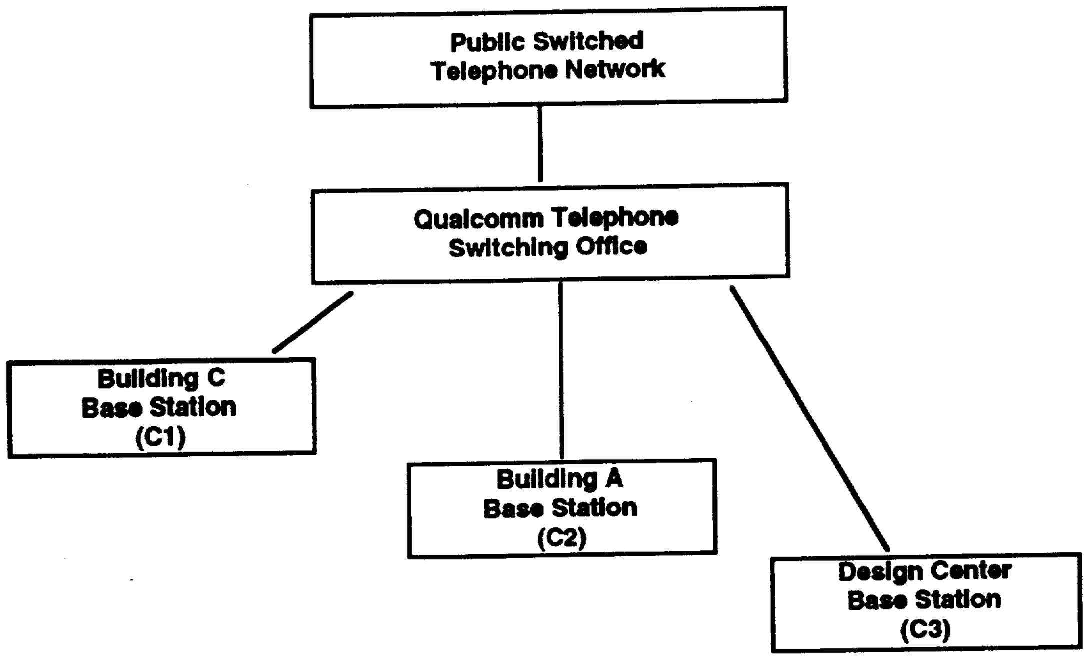


Figure 3-2. System Block Diagram

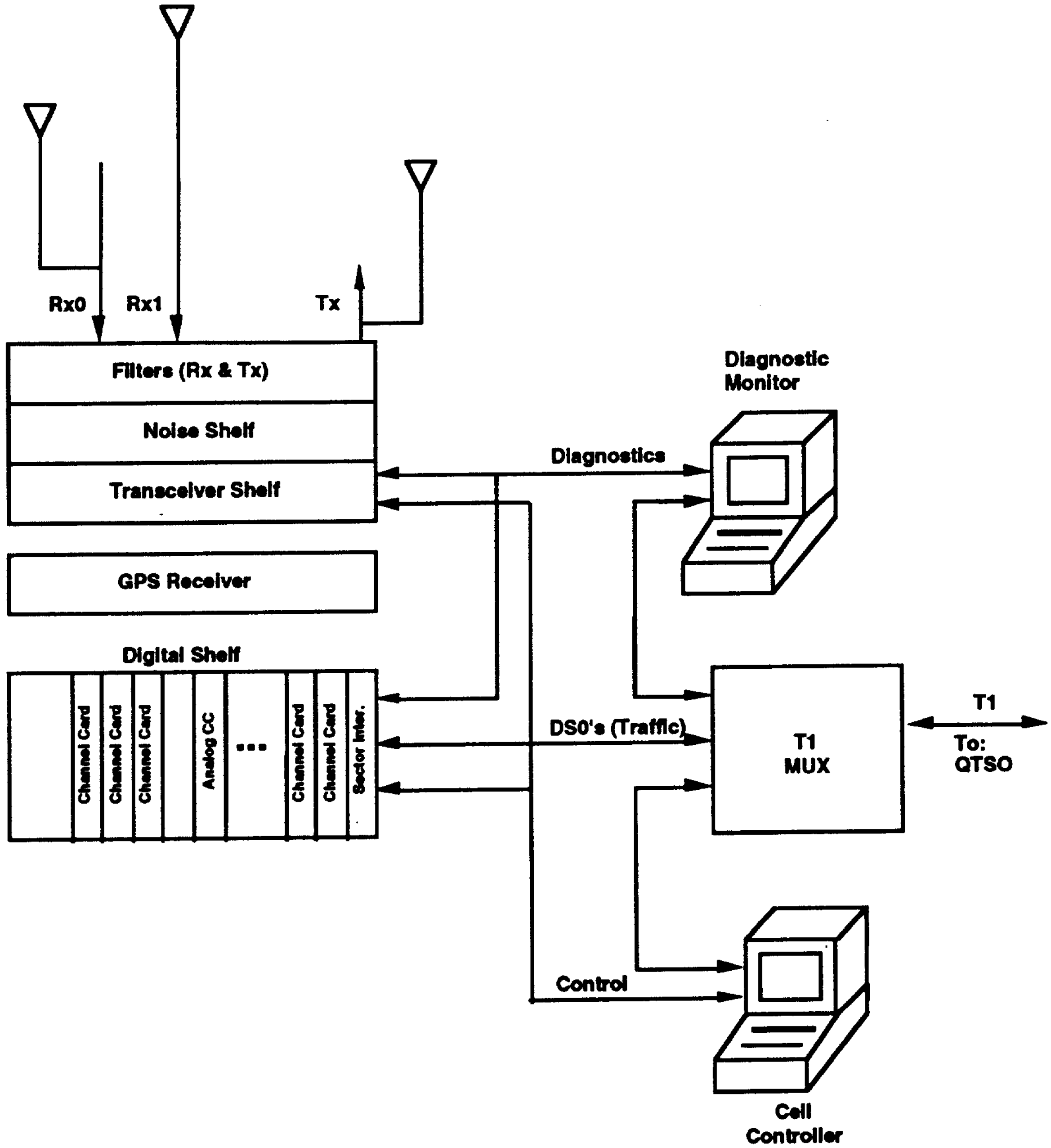


Figure 3-3. Base Station Block Diagram

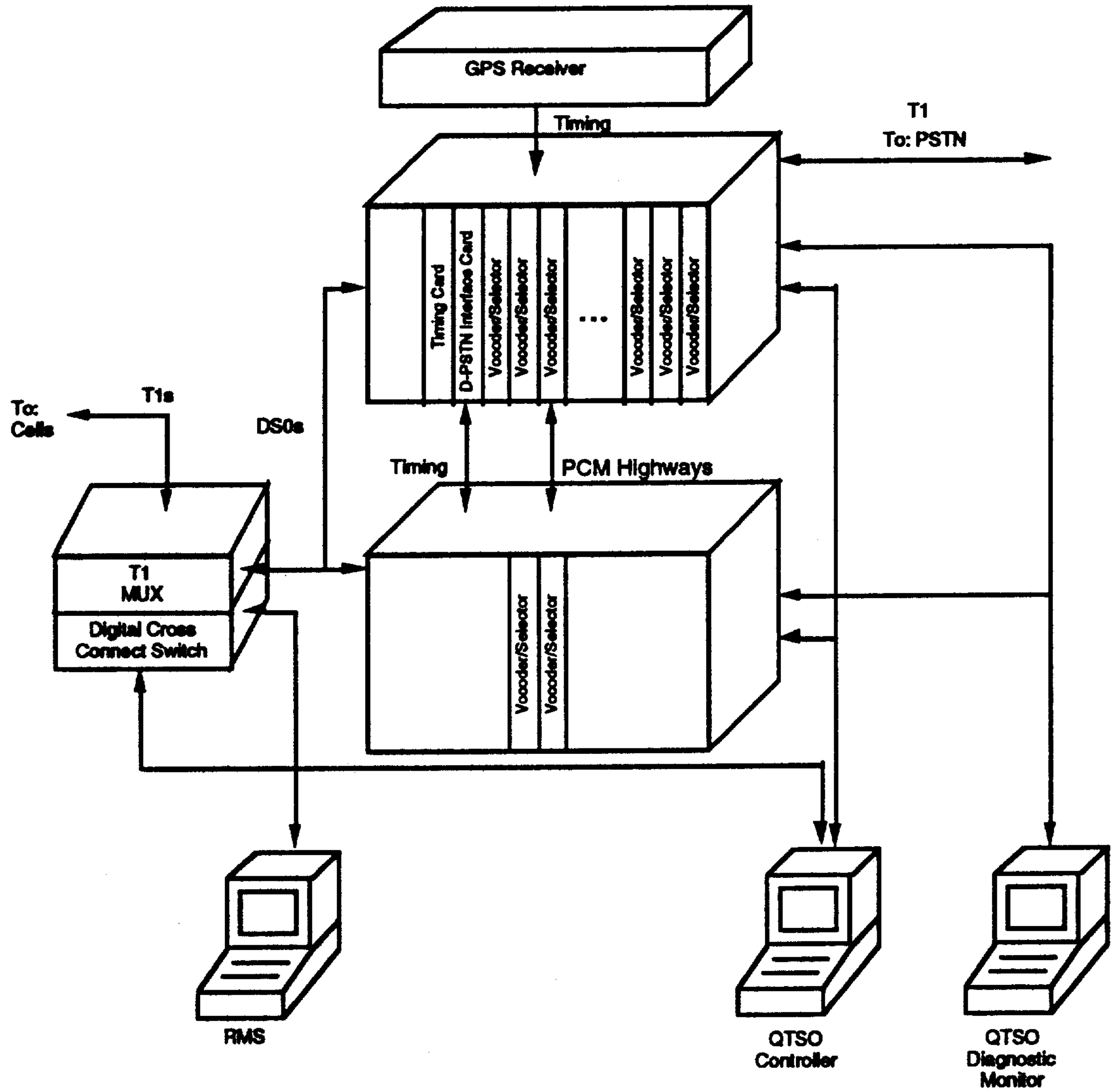


Figure 3-4 . QTSO Block Diagram

The microwave equipment, data generators and data measurement equipment used include a a Harris Farinon DM2-4A-12 DI 2GHz digital microwave transceiver pair, a Firebird 4000 communications analyzer, and a spectrum analyzer.

The test van which is used for all outdoor tests, and is shown in Figure 3-5, consists of antennas, a diagnostic monitor PC, a super VHS VCR, a video camera, a DAT audio record/playback deck, a spectrum analyzer, vehicle location instrumentation, and several subscriber units. The subscriber units used are CDMA CD-3000 dual mode telephones modified for 1.8 GHz operation. Each subscriber unit has a diagnostic monitor port for extraction of test data. Table 3-2 lists the operating specifications for these units.

Figure 3-6 shows a block diagram of the test van configuration. The test van contains the audio equipment for recording the forward voice and injecting the reverse voice for the comparison tests. The reverse voice came from a DAT player using a "Harvard sentences" tape. The forward voice activity, however, was recorded onto the left and right tracks of a VHS audio tape, the same tape which contains the temporal analyzer display (reflects signal level, multipath information, finger assignments, and finger separation), the subscriber unit's receive and transmit power levels, the subscriber unit's transmit gain adjustments, and a view of the vehicle position along the route in the camera overlay. Unlike the base station equipment, the van audio equipment must be started and stopped by hand.

A test cart is used for in-building tests and consists of a cart, several subscriber units, mobile antennas, a diagnostic monitor PC, a super VHS VCR, a video camera, and a DAT audio record/playback deck.

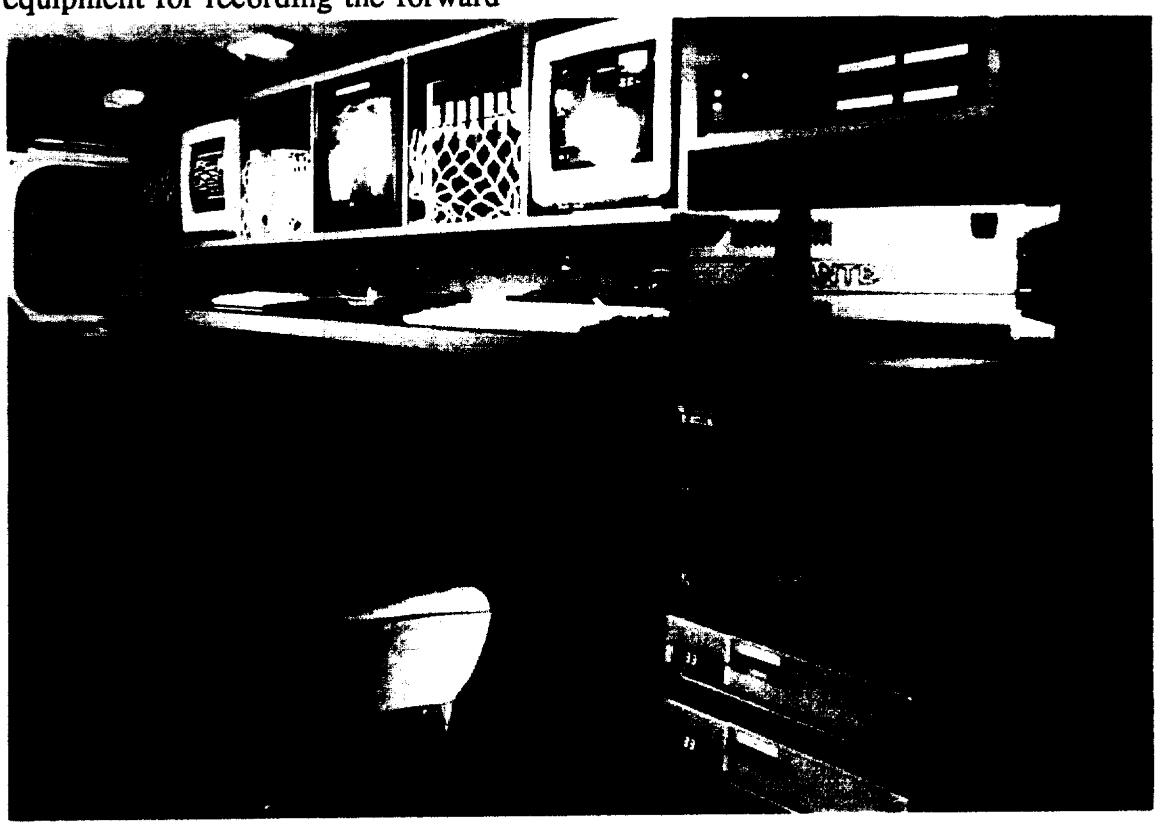


Figure 3-5. Typical Test Van

Table 3-2. Subscriber Unit Specifications

Receiver	
Frequency	1930 to 1990 MHz
Frequency step size	200 KHz
Minimum signal	-105 dBm
Maximum signal	-25 dBm
Intercept point	-5 dBm
Noise Figure	< 8 dBm

Transmitter	
Frequency	1850 to 1910 MHz
Frequency step size	200 KHz
Power output max	+15 dBm
Turn around ratio	80 dB
Spurious output at maximum transmit	-60dBc
Spurious output at minimum transmit	-54 dBm

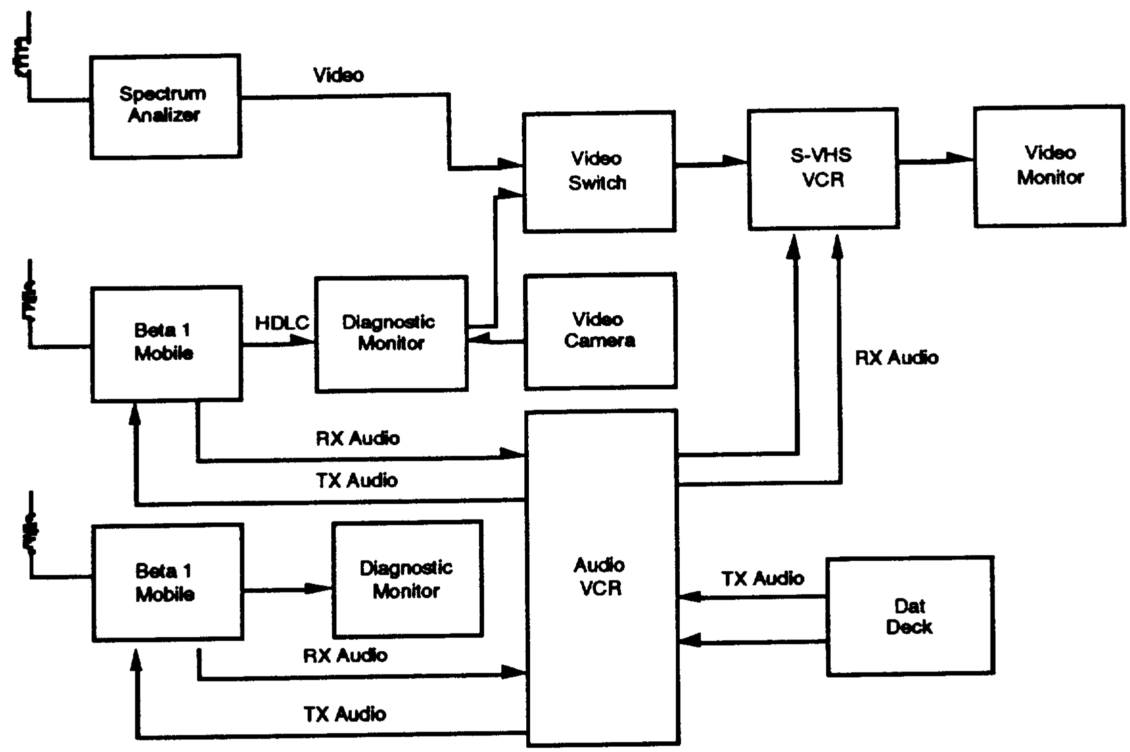


Figure 3-6. Test Van Block Diagram

3.3.2 Data Analysis

QUALCOMM has developed and deployed test equipment and software that extracts and stores performance data (at a high sampling rate) and quickly produces detailed reports about the performance of the system. Microprocessor controllers also aid in the data extraction and logging process.

The major sources of data come from the QTSO, base station, and subscriber units. At each source, there is a separate personal computer, called a diagnostic monitor, which is used solely for gathering, logging, and viewing the performance data in real time.

The diagnostic monitors are a combination of QUALCOMM software and off-the-shelf IBM PC-compatible hardware. The standard diagnostic monitor computers are a 386 or a 486 DX with 16 Megabytes of RAM and a 100 Megabyte hard disk. An HDLC-compatible serial port card and a special video card that can overlay camera video with the computer generated video are also attached to diagnostic monitors used in the vehicles.

The raw data was captured in the microprocessor controllers embedded in the CDMA equipment. The data was then sent via a high speed data link to the diagnostic monitor computer where it was stored in the main memory until the test run was finished. At the end of the run, the data was written to the magnetic disk in the computer as a log file.

At the end of the day the log files were gathered and brought back to the data analysis lab at QUALCOMM for reduction into printed charts and summary files which could be imported by other software programs for further analysis.

Typical daily test runs provide between 100 and 1,000 megabytes of data which are currently undergoing processing and analysis at QUALCOMM in San Diego.

4 Field Test Results

4.1 Overview

A continuing series of field tests are being run in the San Diego area in the 1.8 GHz band to check the operation of the QUALCOMM CDMA system. These tests are providing data on CDMA signal propagation and coverage from single and multiple cell systems. They are also providing statistics on operational characteristics such as power levels and power control, handoff regions, and intercell interference. In conjunction with an Operational Fixed Service (OFS) microwave link, data on the interaction of PCS and OFS service is being gathered.

4.2 Coverage Tests

Base station coverage tests are preliminary tests that form a baseline for the performance of the isolated base stations and provide a basis for estimating the performance of later base station interaction tests and interference tests with point-to-point microwave. The test setups for the base station interaction tests are determined from these single base station coverage tests.

Two types of base station coverage tests were performed during field testing:

- Single and multiple macrocell tests
- Picocell coverage tests.

4.2.1 Single and Multiple Cell Coverage Tests

Tests are run around isolated individual base stations with multiple base stations operational to show system coverage. A macrocell coverage test is performed in the test van to measure the signal coverage of the outdoor area of the macrocells. The area around the base station is surveyed with the van and prospective drive routes are measured for signal strength and propagation characteristics. Figure 4-1 shows a plot of the received signal strength for the multicell system over the routes shown on the map in Figure 3-1. Most of the routes are in coverage but sections with signal strength less than -100 dBm are outside of usable coverage.

4.3 Interoperability of Macrocells

Numerous tests of the multiple cell system were performed to study and characterize operation of a PCS system. The results show performance which is consistent with operation in the 800 MHz cellular band.

Figure 4-2 and 4-3 show CDMA system handoff operation between two base stations. The maps are color coded, and each color mark represents the handoff state of the subscriber unit at that location. Each base station is located in a separate canyon. When both base stations are received by the subscriber unit, soft handoff is expected.

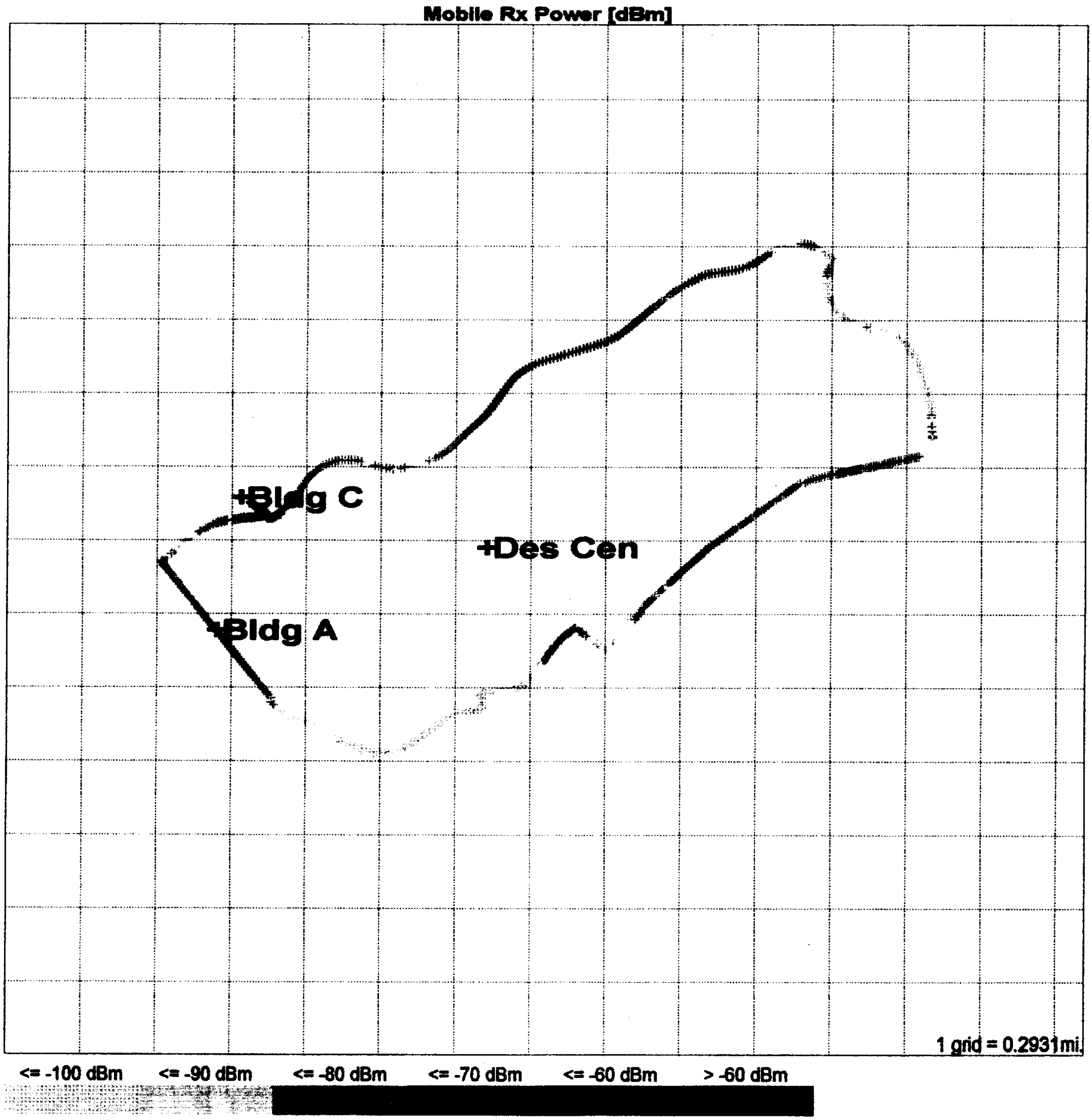


Figure 4-1. Received Signal Strength for Multicell System

Soft handoff occurs in Figures 4-2 and 4-3 where the two canyons intersect and the subscriber unit is able to see both base stations.

In addition to spreading the energy from many users across the same 1.23 MHZ portion of the band, the CDMA system is able to combine the energy from multiple cells in the total usable received energy for each subscriber unit. This allows the system to minimize the transmitted energy required at each cell and to give better performance at the subscriber unit due to spacial diversity in the transmitted energy.

As the subscriber unit gets closer to the Bldg. C base station in the parking lot (route 3), it utilizes signals from Bldg. C only, and it is not in handoff. Similar conclusions can be drawn for the Roselle St. route. As the subscriber unit gets closer to the southern half of the route, the subscriber unit utilizes signals from Bldg. A since it is closer, and provides stronger signals than Bldg. C.

Histograms of cell received Eb/No from both Bldg. A and Bldg. C shown in Figures 4-4 and 4-5 also confirmed correct cell operation. In these charts the y-axis is the probability, and the x-axis is cell received Eb/No in dB. The dotted line is the actual data and the solid line is a normal distribution with the mean and standard deviation calculated from the collected data. The parking lot route shown in Figure 4-4 has a mean cell Rx Eb/No of 7.2 dB and a standard deviation of 1.8 dB from Bldg. A, and a mean Eb/No of 8.5 dB and standard deviation of 1.7 dB from Bldg. C. Thus, the subscriber unit is closer to Bldg. C. It is providing a stronger Eb/No to the closer base station and satisfying its Frame Error Rate (FER) requirements.

Since the power control operation between the two cells reduces power when either cell requests less power, the dominant cell, in this case Bldg. C, determines the subscriber unit power level more of the time than Bldg. A. Also the attenuation from the parking lot route to Bldg. A is higher for subscriber unit transmit power. Similar conclusions can be drawn from the Roselle Street route shown in Figures 4-6 and 4-7 with a mean cell Rx Eb/No of 8.7 dB and standard deviation of 1.6 dB from Bldg. A, and a mean cell Rx Eb/No of 4.5 dB and standard deviation of 1.9 dB from Bldg. C.

Histograms of subscriber unit received power are presented for each test route as shown in Figures 4-8 and 4-9. In these graphs, the y-axis is probability, and the x-axis is subscriber unit received power in dBm. The dotted line is the actual data and the solid line is a normal distribution with the mean and standard deviation calculated from the collected data. On the parking lot test route (route 3) of Figure 4-8, the mean is -74 dBm and standard deviation is 7.3 dBm. The Roselle Street route (route 2) in Figure 4-9, has, in comparison, a mean of -72 dBm and standard deviation of 9.8 dBm. Note that because the Roselle Street route is a longer test route, the standard deviation tends to be larger. Furthermore the Roselle Street route is covered by both cells, and tends to exhibit a higher Rx power.

Histograms of subscriber unit transmit power are presented for each test route in Figures 4-10 and 4-11. The y-axis is probability, and the x-axis is subscriber unit transmit power in dBm. The dotted line is the actual data and the solid line is a normal distribution with the mean and standard deviation calculated from the collected data. On the parking lot test route (route 3) shown in Figure 4-10, the mean is 3 dBm and standard deviation is 9.7 dBm. The Roselle

Street route (route 2), shown in Figure 4-11, has a mean of 8.1 dBm and standard deviation of 11.4 dBm. Even though the Roselle Street route has a higher average transmit power, it also has a higher standard deviation. Figure 4-11 shows a peak at maximum subscriber unit Tx power of +17 dBm, indicating that the subscriber unit was traveling in a disadvantaged location for part of the route.

Figures 4-12 and 4-13 show histograms of subscriber unit Tx Gain Adjust for each route. For each histogram, the y-axis is probability, and the x-axis is subscriber unit Tx Gain Adjust in dB. The dotted line is the actual data and the solid line is a normal distribution with the mean and standard deviation calculated from the collected data. On the parking lot test route shown in Figure 4-12, the mean is -8 dB and standard deviation is 4.8 dB. In comparison, Figure 4-13 had a mean of 2 dB and standard deviation of 5.3 dB.

Figures 4-14 and 4-15 show histograms comparing FER versus speed for the Lusk Boulevard route (shown in yellow in Figure 3-1), runs 1 and 3, respectively. With each histogram, the x-axis is speed in mph, and the y-axis is forward link full rate frame error in %. Note that with both charts, the FER tends to peak in speed about 35 mph, while at lower or higher speeds, the FER tends to be smaller.

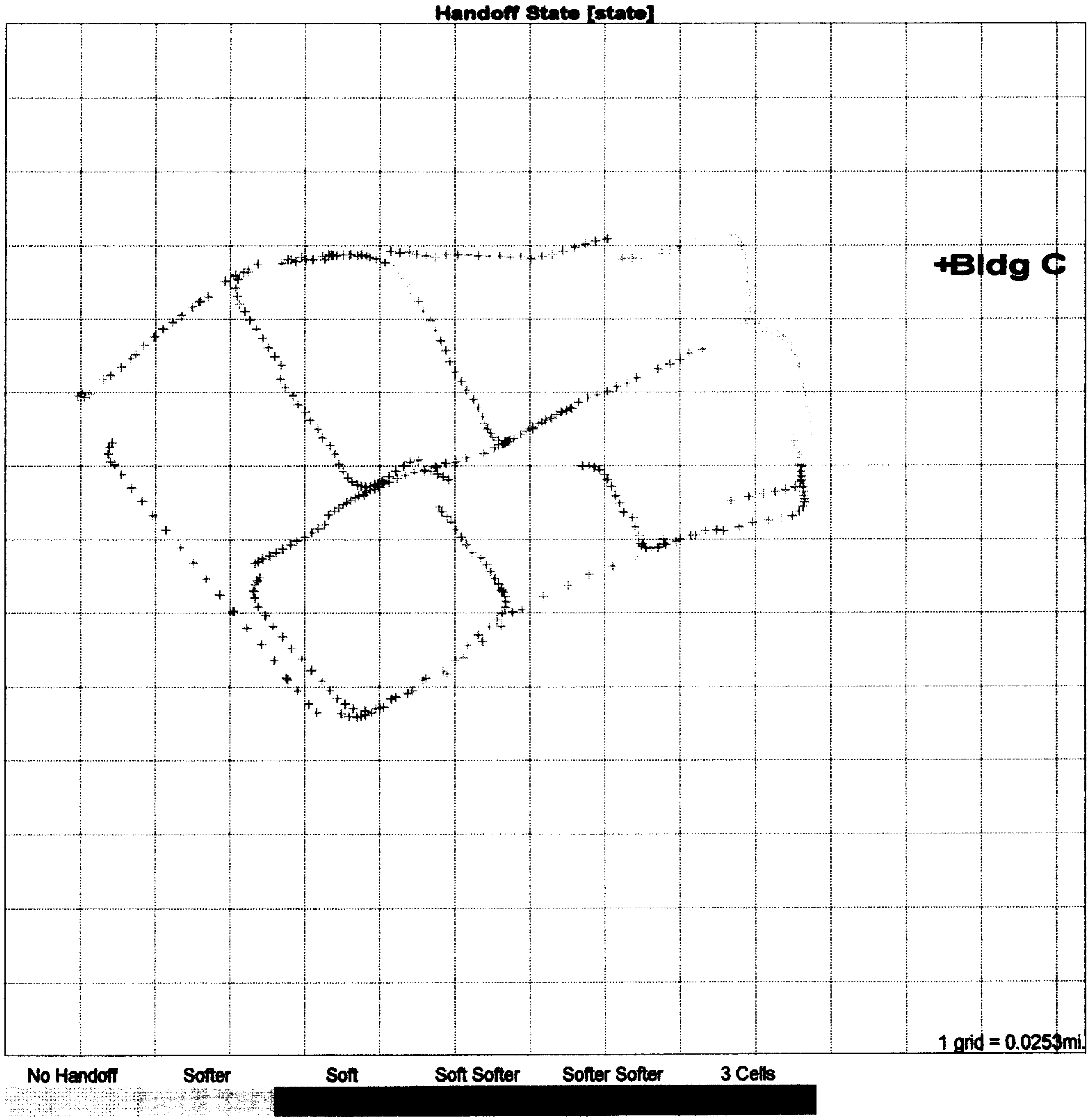


Figure 4-2. Handoff Operation Between Two Base Stations: Parking Lot Route

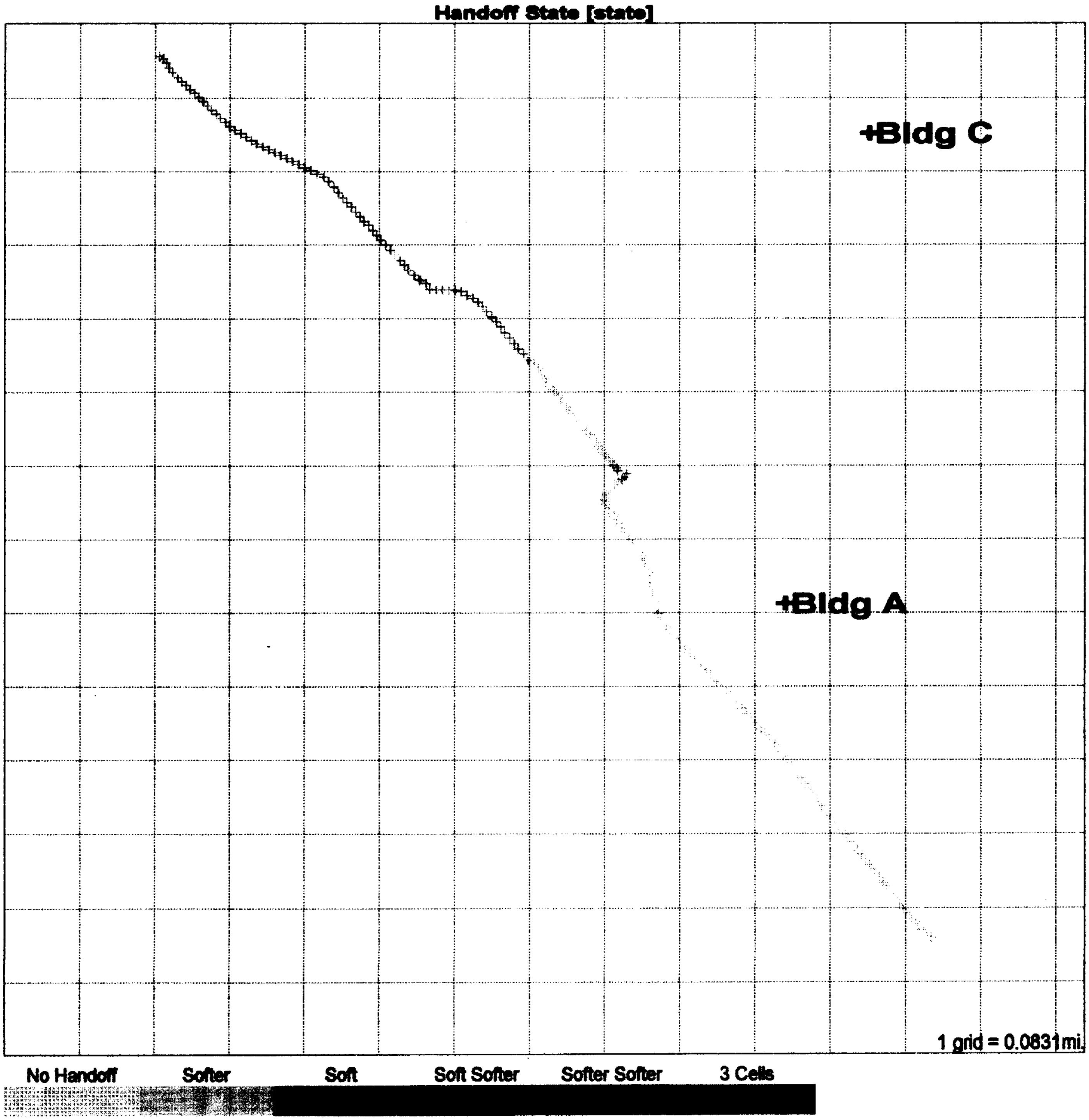


Figure 4-3. Handoff Operation Between Two Base Stations: Roselle Street Route

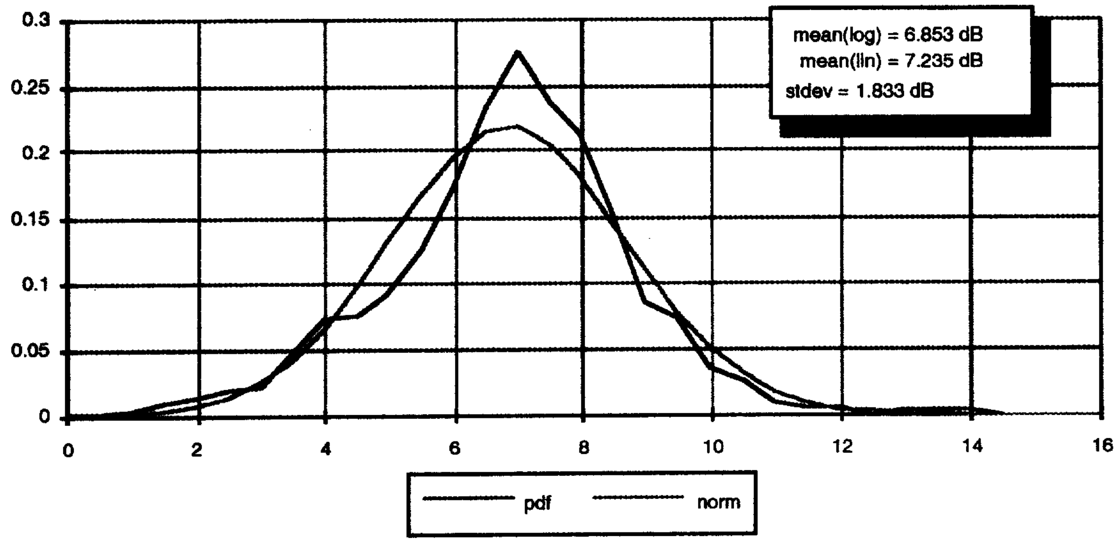


Figure 4-4. Cell Rx Eb/No for Base Station C2: Parking Lot Route

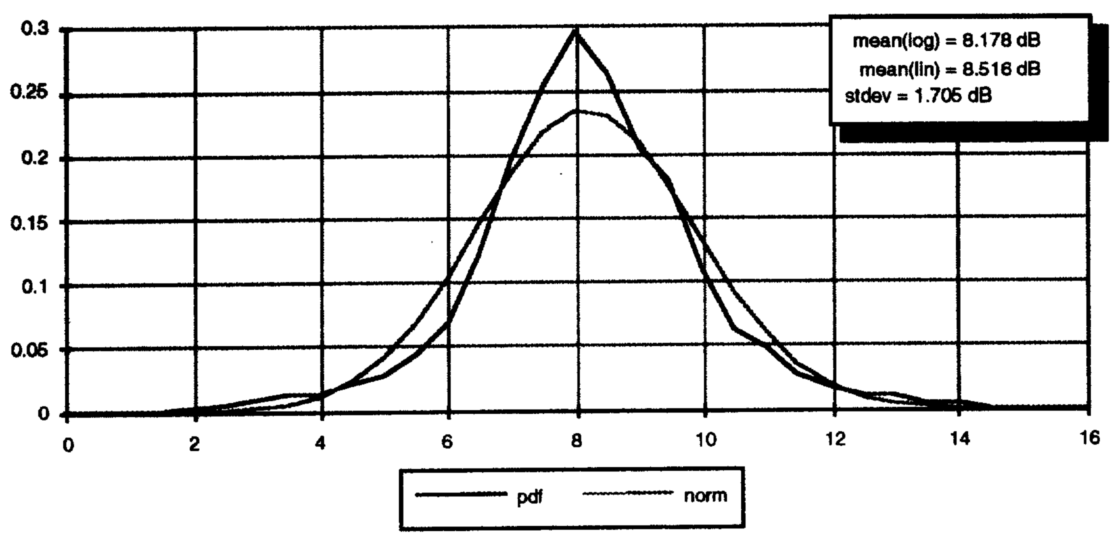


Figure 4-5. Cell Rx Eb/No for Base Station C1: Parking Lot Route

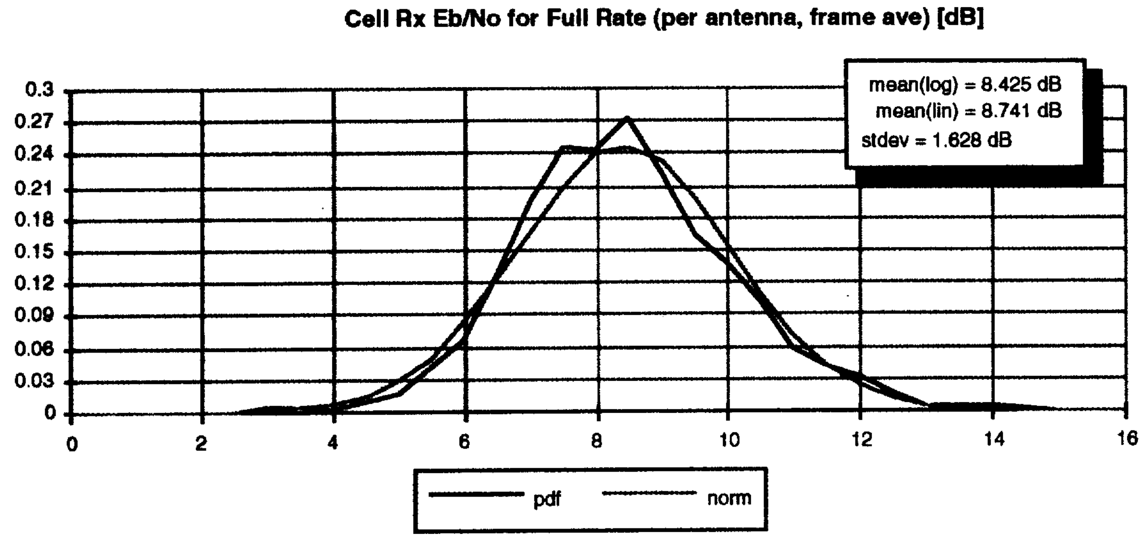


Figure 4-6. Cell Rx Eb/No for Base Station C2: Roselle Street Route

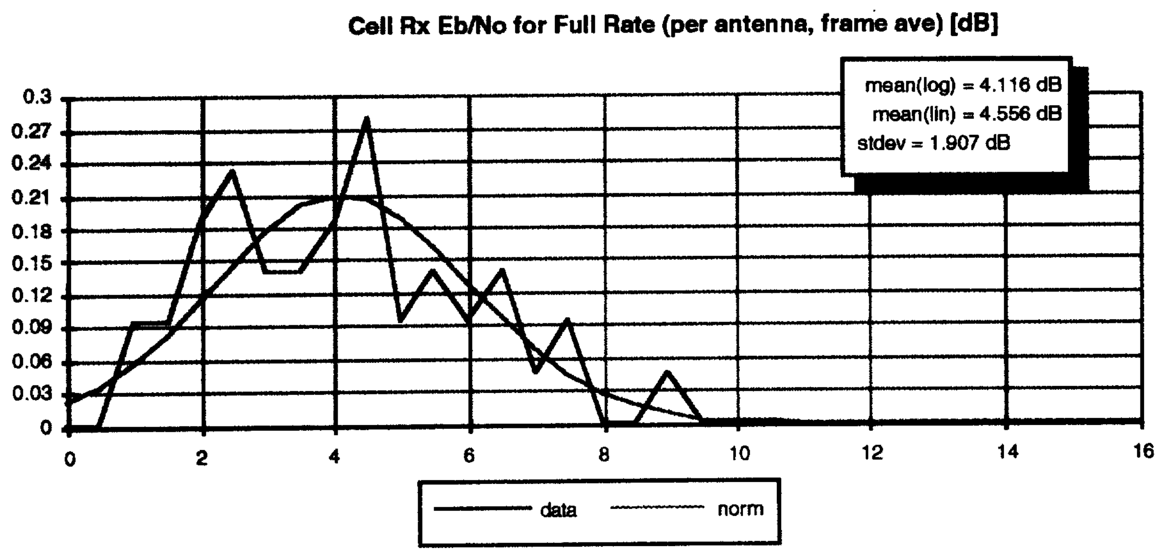


Figure 4-7. Cell Rx Eb/No for Base Station C1: Roselle Street Route

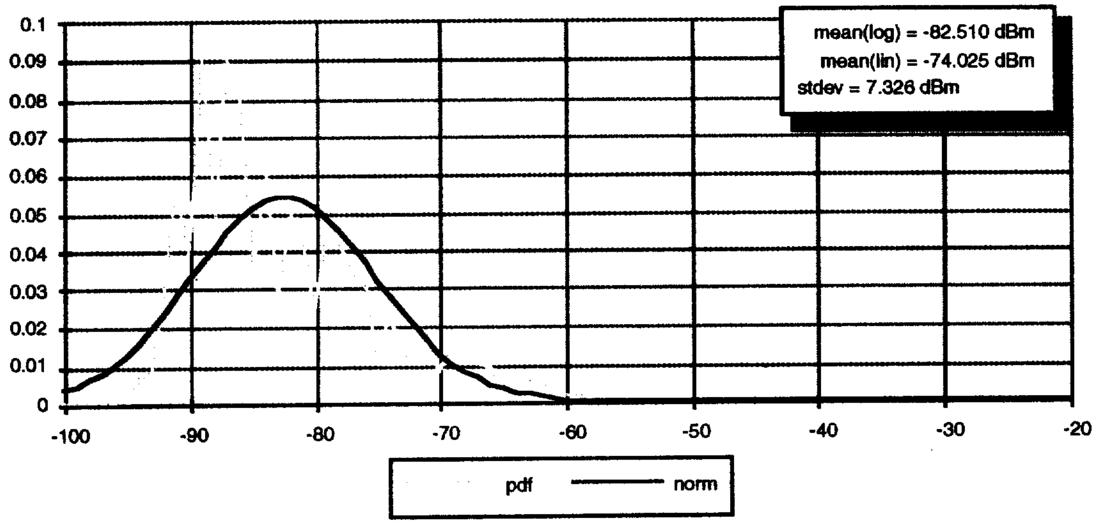


Figure 4-8. Subscriber Unit Receive Power: Parking Lot Test Route

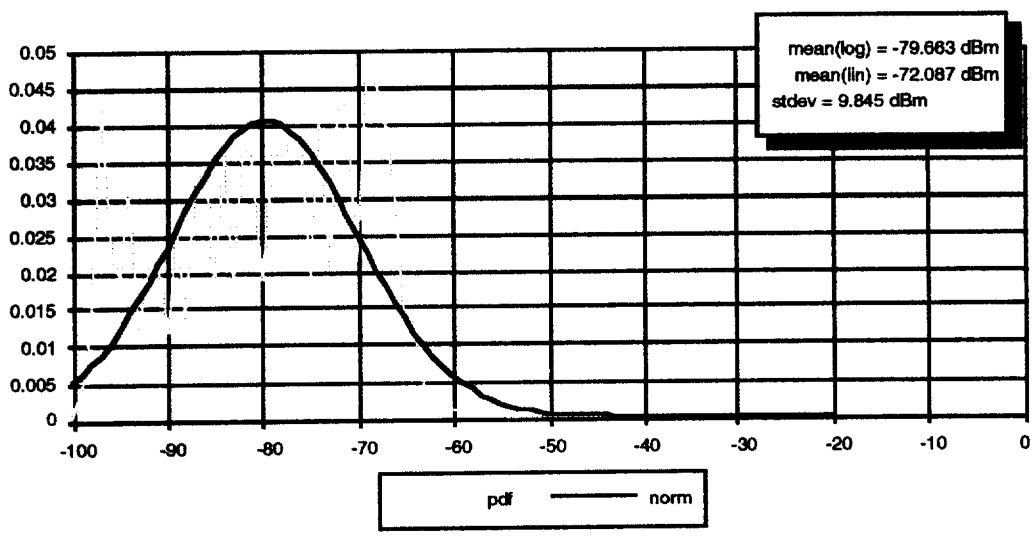


Figure 4-9. Subscriber Unit Receive Power: Roselle Street Route

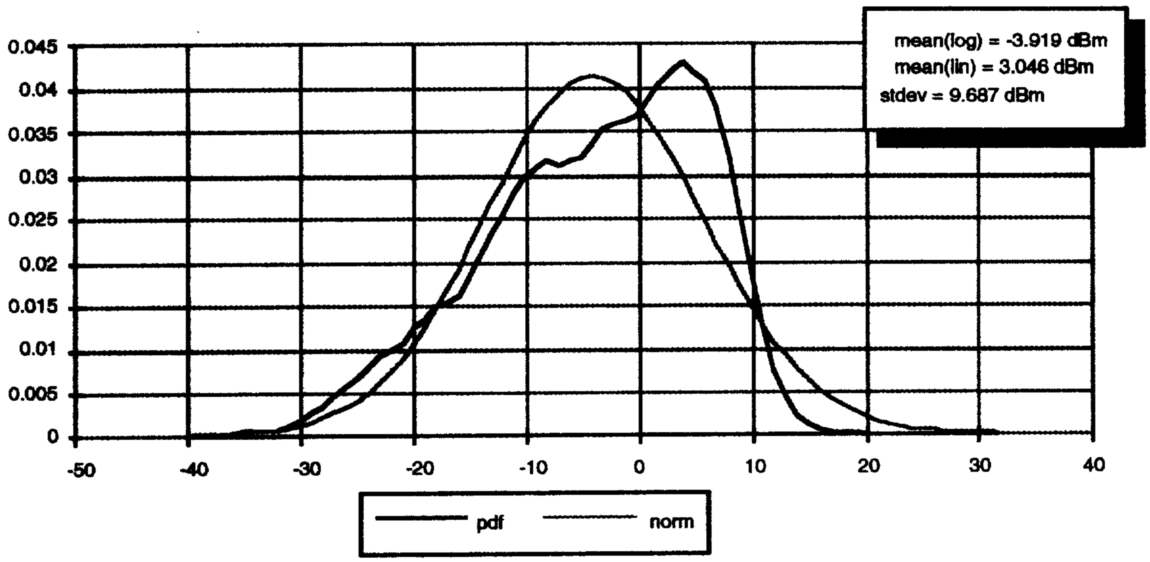


Figure 4-10. Subscriber Unit Transmit Power: Parking Lot Test Route

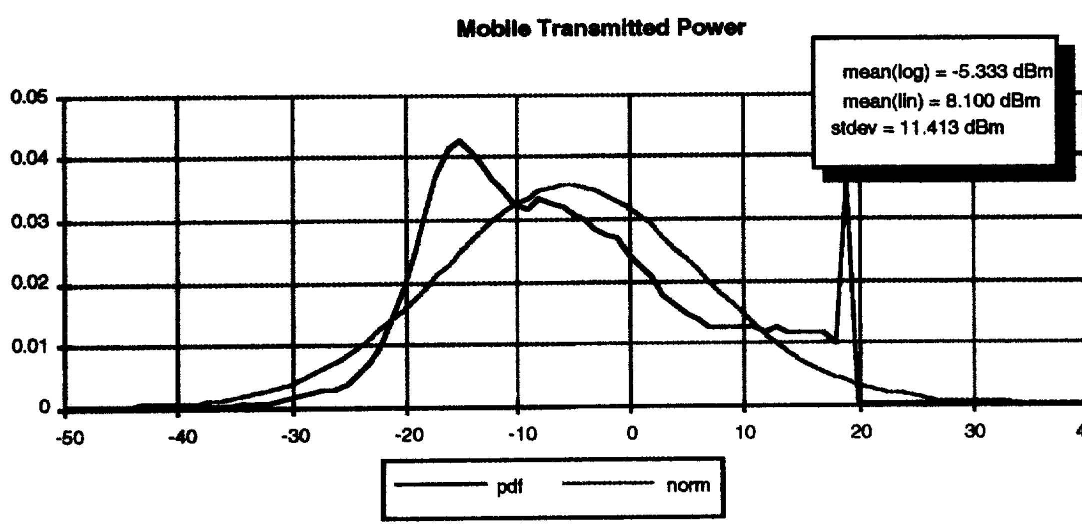


Figure 4-11. Subscriber Unit Transmit Power: Roselle Street Route

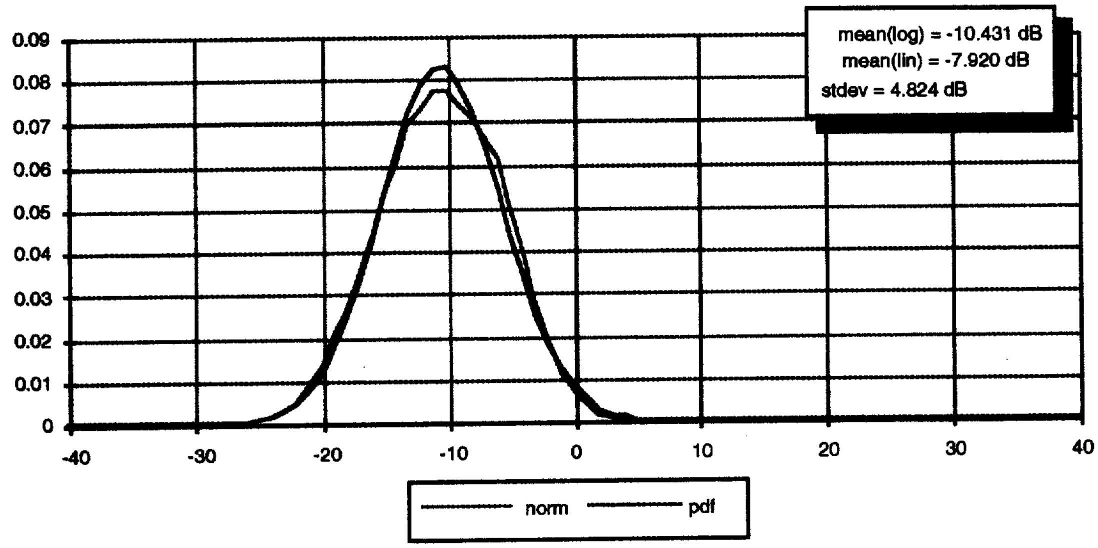


Figure 4-12. Subscriber Unit Transmit Gain Adjust: Parking Lot Test Route

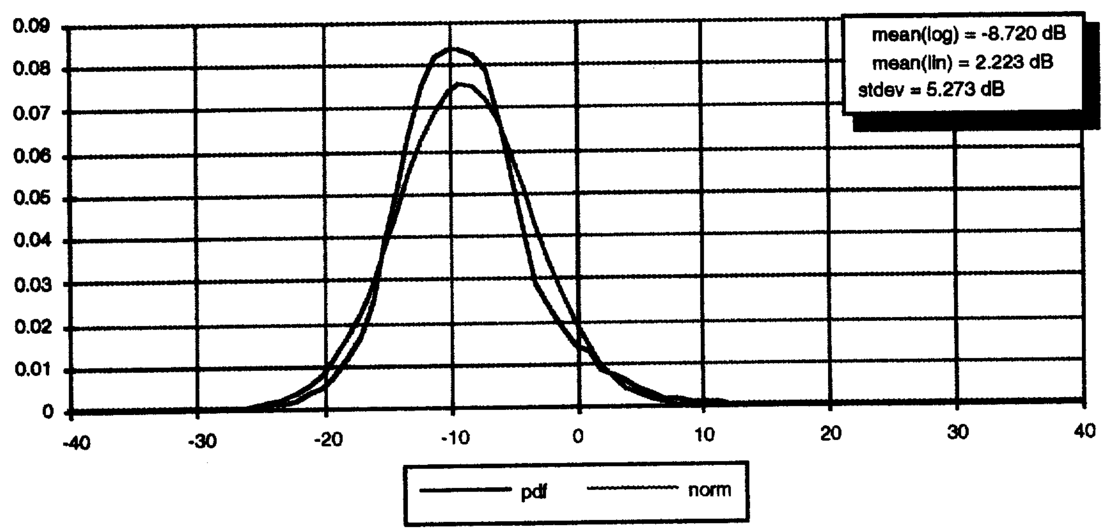


Figure 4-13. Subscriber Unit Transmit Gain Adjust: Roselle Street Route

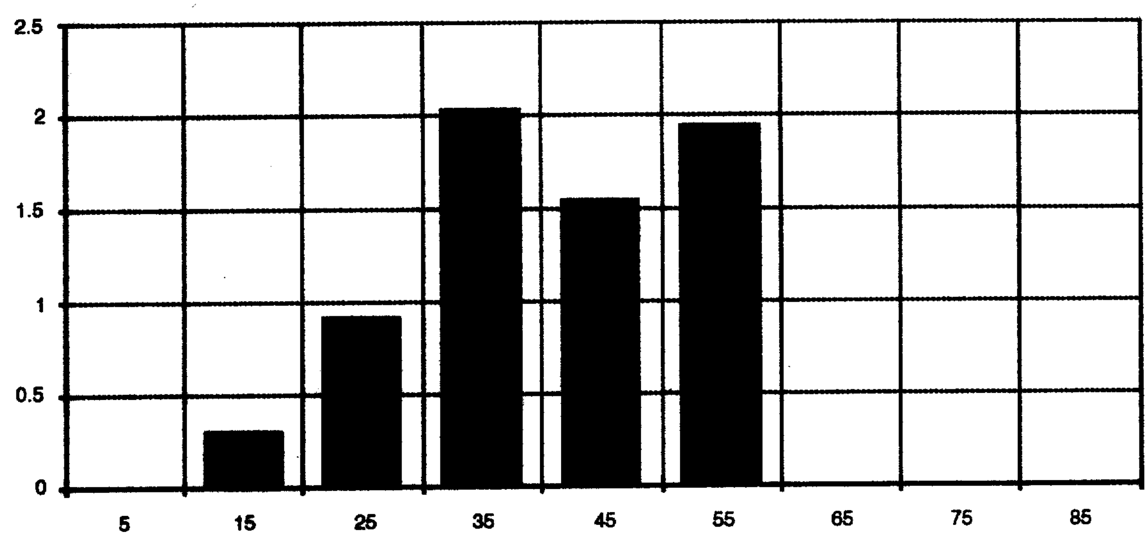


Figure 4-14. Forward Link FER vs. Speed: Lusk Boulevard Route, Run 1

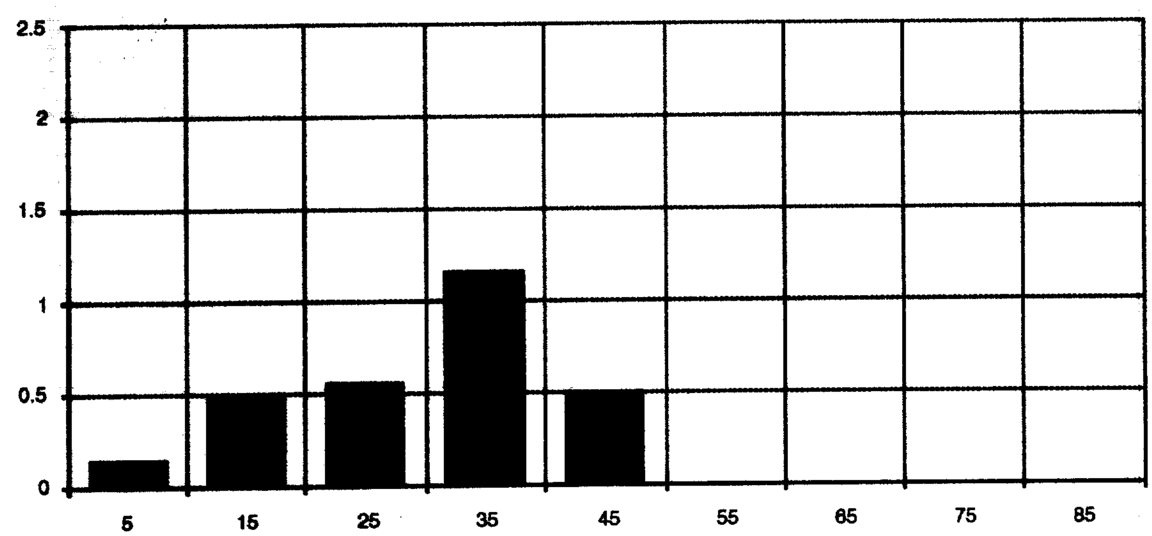


Figure 4-15. Forward Link FER vs. Speed: Lusk Boulevard Route, Run 3

4.4 Spectrum Sharing Tests

As stated in the previous chapter, spectrum sharing field tests encompass four types of interaction:

- PCS forward link (base station) interference to Operational Fixed Service (OFS)
- PCS reverse link (subscriber unit station) interference to OFS
- OFS interference to PCS forward link (base station)
- OFS interference to PCS reverse link (subscriber unit station).

Currently the first two types of tests have been conducted in the field and the last two are currently being conducted. In each of these tests, the relative signal strength of the desired signal and the interferer and the frequency separation of the desired signal and interferer are varied. The relative signal strength is a function of the transmit power of both the desired transmitter and the interferer, the antenna patterns of both, and physical separation. Parameters that are not easily calculable are also varied throughout testing to maximize the gathering of data.

For example, if curves of performance under interference from the other service as a function of relative signal strength are made based on the lab test runs, then field testing with different antenna patterns or placement of the fixed stations will gain little information on error rates that cannot be derived from standard engineering calculations. On the other hand, the variation of forward link receive levels due to multipath and signal fading is complex, and field measurement of these levels can provide confirmation of the applicability of lab tests which are conducted using channel simulators to models these effects.

4.4.1 PCS Forward Link Interference to OFS

The field tests for forward link interaction scan the horizon with the microwave dish from the OFS site while the PCS system is in operation. The spatial distribution and range of signal levels received on the direct path and on reflected paths from the PCS base station provide data to support models of interaction between the systems.

The interference to the point-to-point microwave link by the PCS base station is measured with the PCS forward link operating at the OFS frequency. The PCS base station is run with maximum simulated user loading (maximum power) for this test. A PCS subscriber unit is attached to the microwave antenna and receive signal level and pilot detection data is logged as the antenna is scanned across the horizon.

4.4.2 PCS Reverse Link Interference to OFS

The interaction with multiple PCS subscriber units is statistical in nature and extrapolation for each situation is more difficult. Therefore, many runs are made with different drive routes to simulate different situations. In many of these tests, a microwave dish input is fed into the CDMA base station receiver in order to use it as a sensitive receiver. The rise in the Rx power over the background noise level is measured and correlated with subscriber unit position. Path loss to the base stations from subscriber units on the test routes is measured during independent tests.

Two sets of forward link attenuation map are presented in Figures 4-16 through 4-19, representing approximately the same test routes, and with different base stations transmitting. Each map is color coded, with a legend. Each color mark on the map represents an attenuation value in dB. These maps results correlate well with geographical attributes of the test routes and location in relation to the base stations. The two routes are located in intersecting canyons, one running east to west and the other north to south. The parking lot route shown in Figure 4-16 is almost at the intersection of the two canyons, and it is mainly located in the east-west canyon. The Roselle Street route shown in Figure 4-17 goes along the north-south canyon, and it is approximately 1.5 miles in length.

Figures 4-16 and 4-17 show average forward link attenuation with Bldg. A base station transmitting only. In general, as the distance from the base station increases, the attenuation increases. The funneling effects of the canyons are evident by comparing the parking lot test route (route 3) and the Roselle St. test route (route 2).

The spectrum sharing maps shown in Figures 4-19 and 4-20 show average forward link attenuation with Bldg. C base station transmitting only. Figure 4-18, which shows a map of the parking lot route, illustrates very well the procession of increasing attenuation as the subscriber unit travels to the west side of the parking lot, away from the cell. Figure 4-19, the map of the Roselle Street route, confirms the data collected, (i.e., it is at the extreme high end of the attenuation scale.)

4.4.3 OFS Interference to PCS Forward Link

The PCS to OFS interference test studies the degradation in the OFS performance when the PCS system is operated in the vicinity. Relative power of the point-to-point transmitter and the PCS system is varied, as well as physical separation of the subscriber units from the point-to-point receiver. The microwave link is run with 16 level QAM modulation. Degradation to performance of other types of modulation can be estimated from the QAM case. A bit error rate tester is used to measure the performance of the microwave link. A known pattern is transmitted and the bit error rate tester compares the received data stream with the known pattern for detection of errors. No error correction is used since the relationship between the uncoded and coded performance is well known and can be calculated as needed for the particular coding scheme to be used.

4.4.4 OFS Interference to PCS Reverse Link

The tests for interference from the PCS subscriber units are made with both ends of the point-to-point microwave link cabled together at the same site. The microwave dish provides interference input to the OFS link from the environment. Interference tests are made with a co-located PCS base station operational to show the level of interference from subscriber units power controlled to this site. Other tests are performed with the co-located base station turned off and the subscriber units operating off a remote base station. This set of tests shows worst case interference. As a preamble to the PCS subscriber unit to OFS interference test, a CDMA receiver is hooked up to the point-to-point receive antenna and the subscriber units are driven around the candidate routes. Those routes or sections of routes, which result in CMDA signals arriving at the point-to-point receive antenna in the range that would degrade the microwave link, are used for further testing.

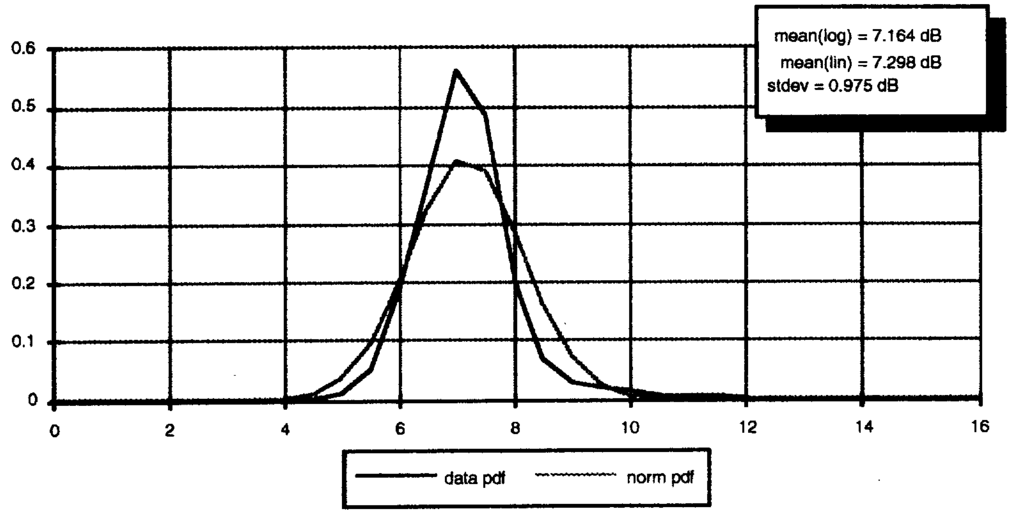


Figure 5-9. Base Station Rx Eb/No Pdf: Second Set

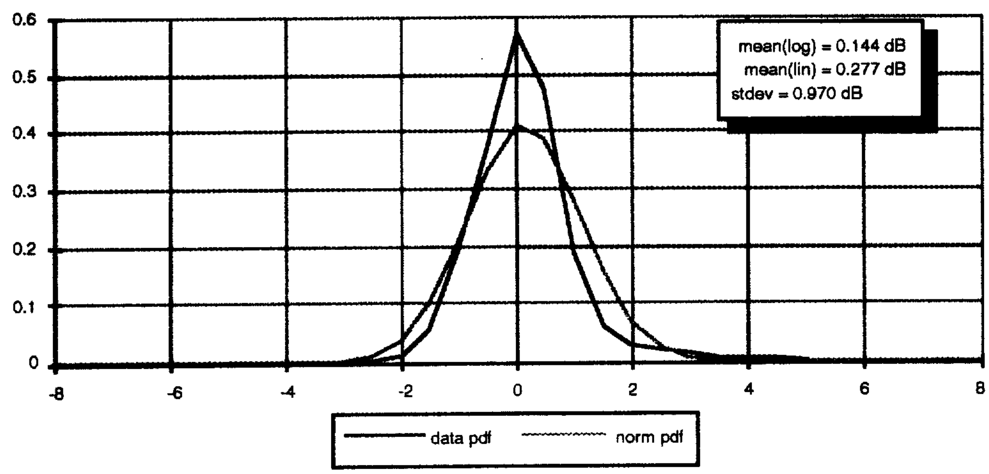


Figure 5-10. Base Station Rx Eb/No from Set Point Pdf: Second Set

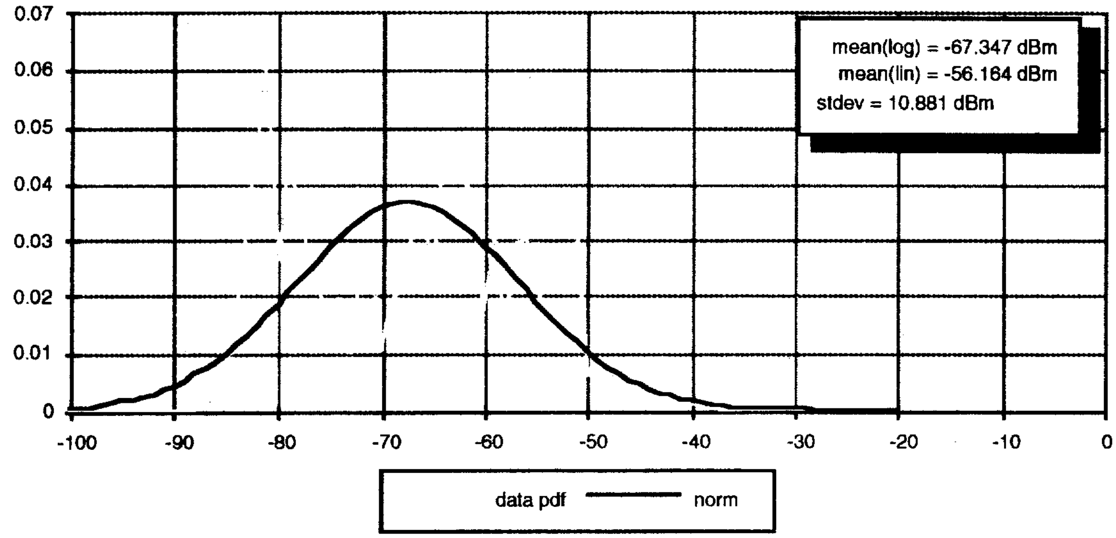


Figure 5-11. Subscriber Unit Rx Power: Second Set

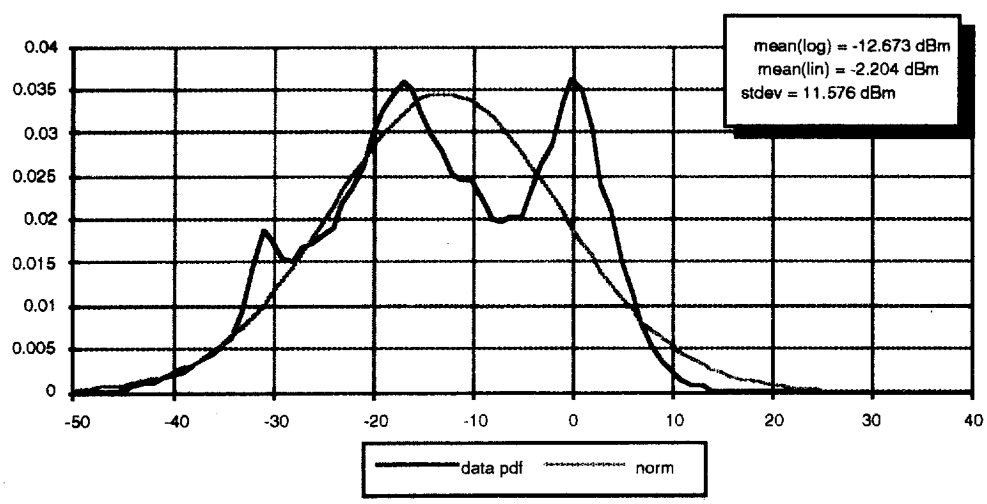


Figure 5-12. Subscriber Unit Tx Power: Second Set

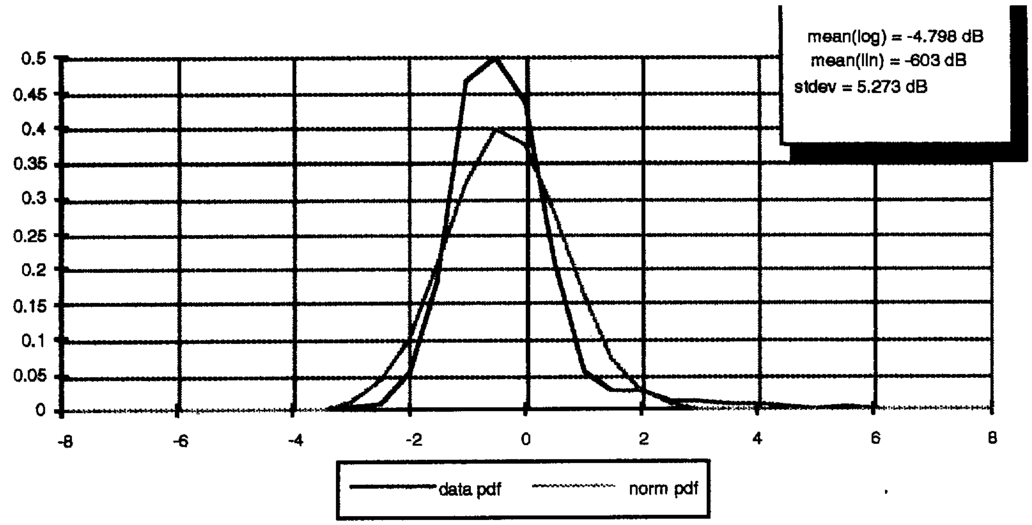


Figure 5-5. Base Station Rx Eb/No from Set Point Pdf: First Set

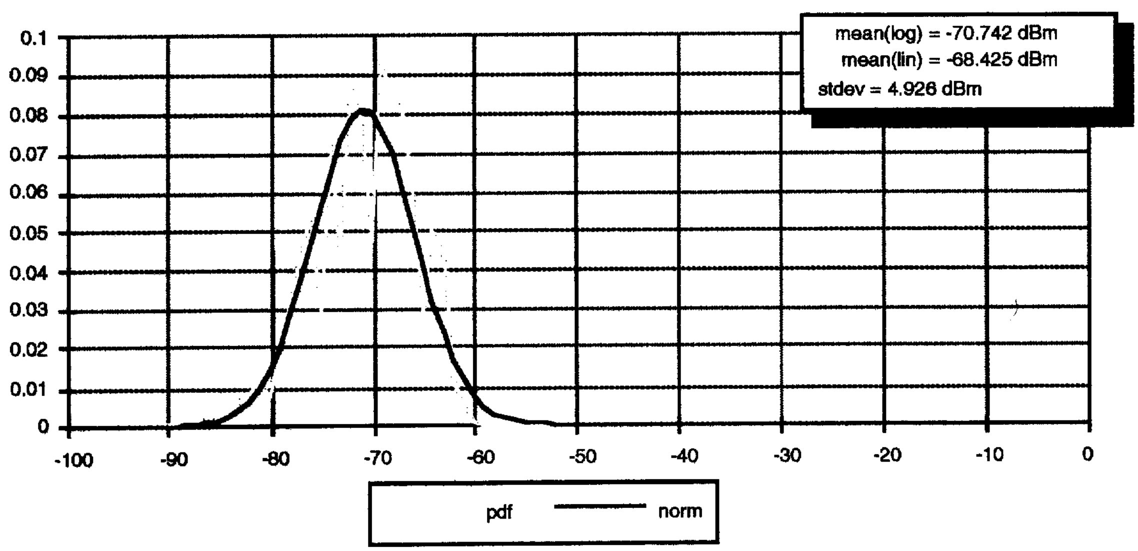


Figure 5-6. Subscriber Unit Rx Power: First Set

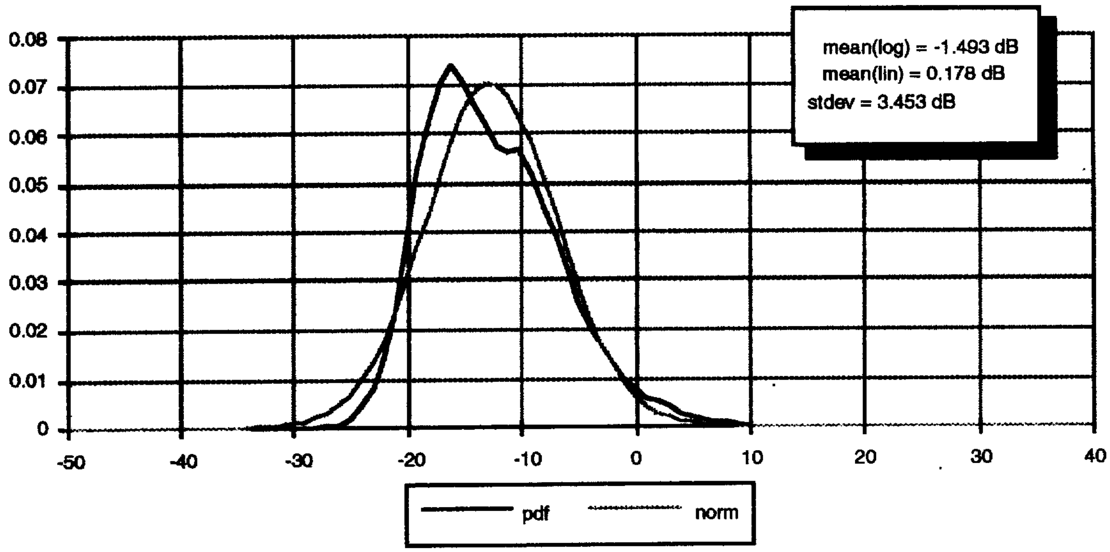


Figure 5-7. Subscriber Unit Tx Power: First Set

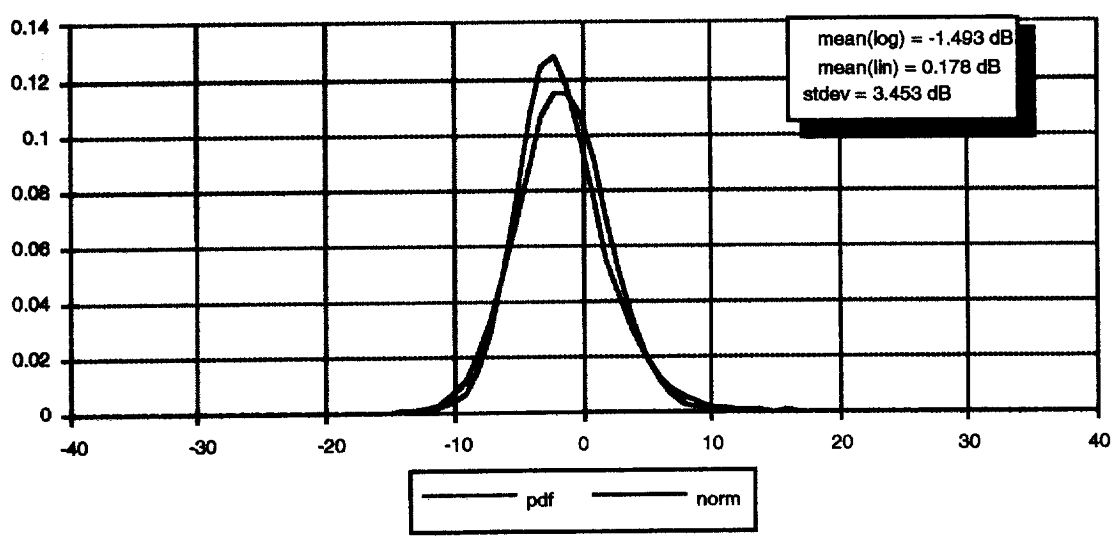
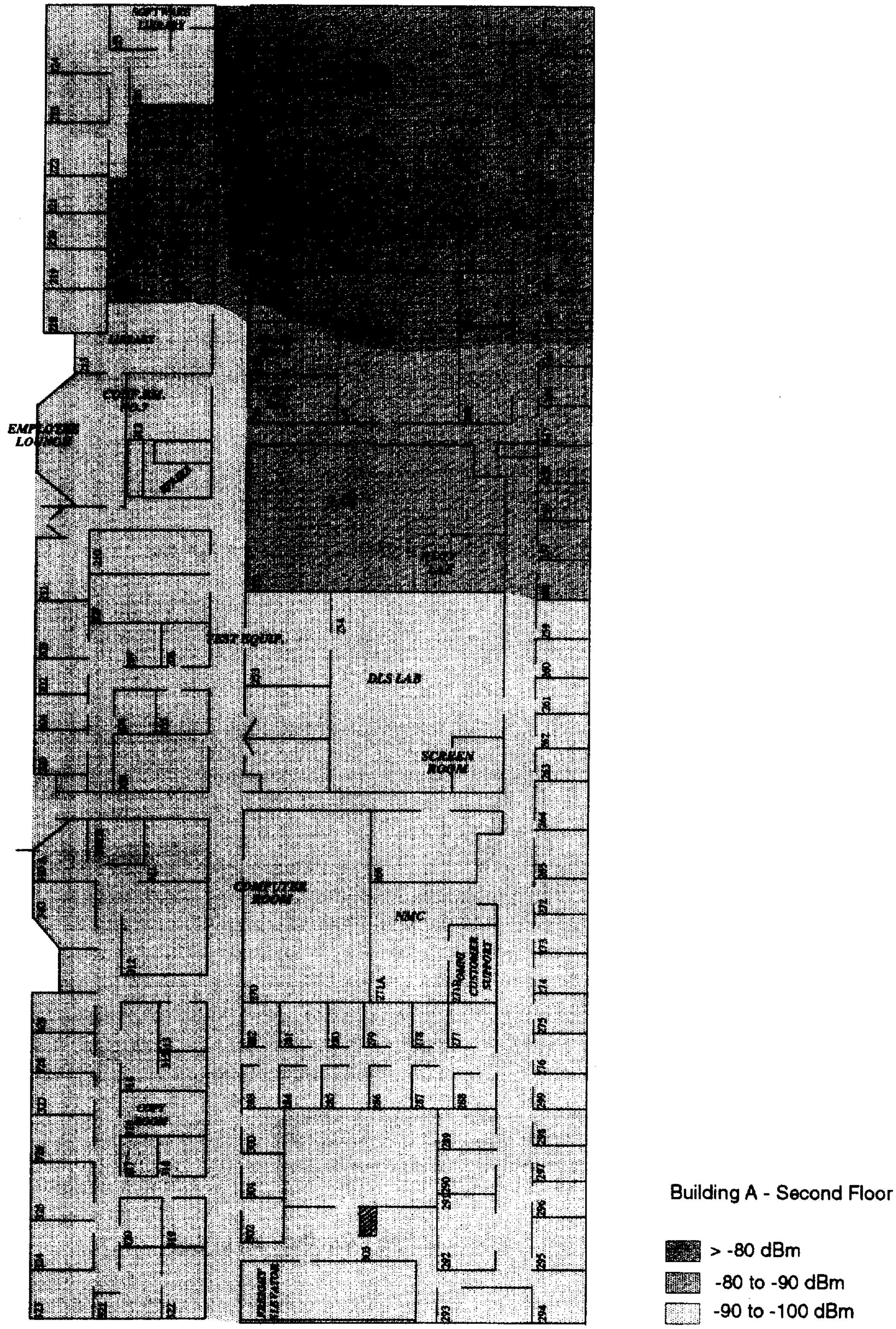


Figure 5-8. Subscriber Unit Tx Gain Adjust: Second Set



5-2. Rx Power in Building A: Second Floor

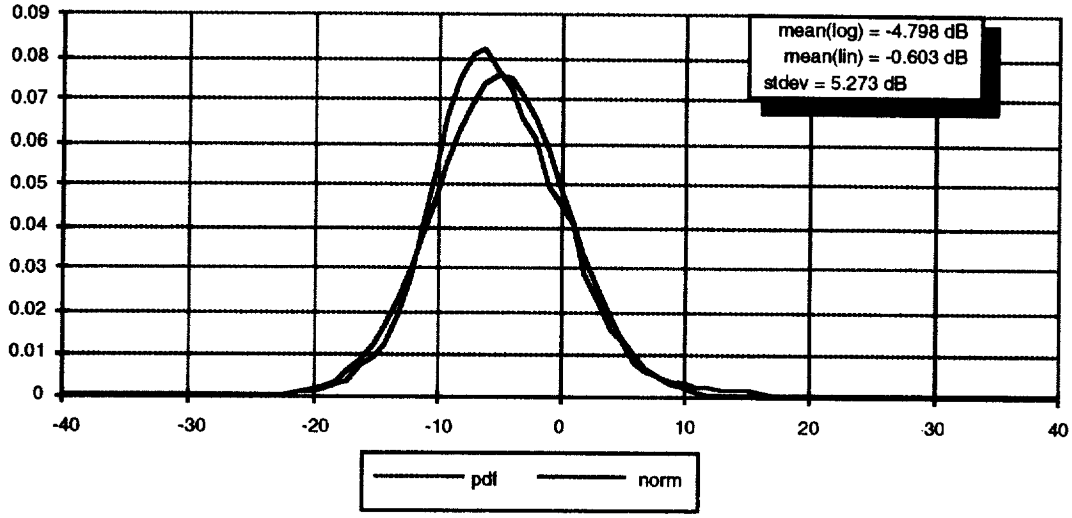


Figure 5-3. Subscriber Unit Tx Gain Adjust: First Set

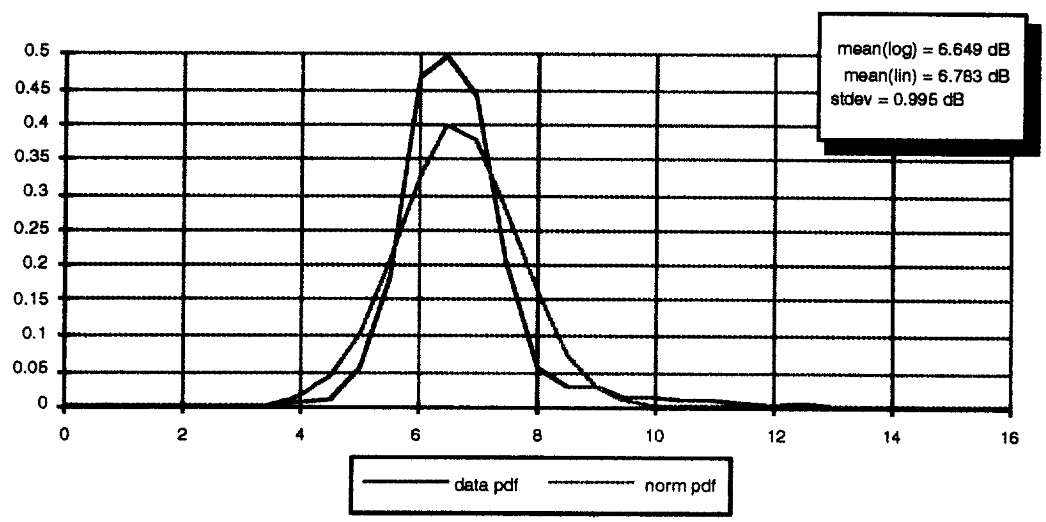


Figure 5-4. Base Station Rx Eb/No Pdf: First Set