PCS Noise Floor Study

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1. Executive Summary

The PCS Noise Floor Study was performed within the Personal Communications Services (PCS) spectrum band and within the wireless market areas surrounding Philadelphia, PA and Allentown, PA. A total of twelve field locations are included in the study. These locations include a cross section of market environments including Urban, Suburban and Rural. These locations include airports, train station, mall, apartment building, office building and residential houses. Field measurements are performed within the forward link spectrum band and are measured over a sufficient period of time to capture variations in the operating noise floor levels.

The PCS noise floor measurements included in this study indicate low operating noise floor levels existing in the clean and occupied PCS spectrum bands in these market areas. The median noise floor results for the occupied spectrum measurements within a 30 kHz bandwidth are –123 to –129 dBm, with an average of –128 dBm. The median noise floor results for the clean spectrum measurements were consistently about –129 dBm. The RMS average noise floor results for the clean spectrum measurements within a 1 MHz bandwidth are about –112 to –113 dBm, with an average of –112.4 dBm.

The clean spectrum measurements provides a baseline of the thermal and ambient environmental noise floor levels existing in the PCS market area, prior to any wireless service offered in the PCS spectrum band. In all field locations, the median noise floor levels of the clean spectrum measurements were within 1 dB of its thermal noise floor level (KTB for 30 kHz bandwidth is -129 dBm), and the 90% noise floor levels were within 2 dB. The results of the clean spectrum measurements indicate very low noise floor conditions existing in these market areas. For many field locations the noise floor levels for the clean spectrum measurements did not increase above the thermal noise floor level. Therefore, the results of this study indicate that the environmental noise levels occurring in these market areas are not appreciably increased above the thermal noise floor level. With these low noise floor conditions, wireless carriers can deploy networks without environmental noise encumbering system performance.

The occupied spectrum measurements provide the operating noise floor level that includes co-channel and adjacent channel system interference from a carrier’s network, in addition to the background environment noise level. The results of the occupied spectrum measurements indicate low noise floor level conditions existing within these market areas. For the majority of the field locations, the median and 90% noise floor levels for the occupied spectrum measurements were below the system noise floor of typical TDMA subscriber phone equipment, which is below –124 dBm. With these low operating noise floor levels within occupied PCS spectrum, wireless phone service can be maintained to low operating signal levels.

TDMA phone service can be maintained on the forward-link with operating signals between –104 to –107 dBm (the minimum signal level for “toll quality” service), with typical phone equipment noise floor and 17 dB C/I margin. In the presence of considerable signal fading, an additional fade margin may be required to maintain quality service and is based upon an acceptable threshold for area coverage reliability.

The FCC is currently evaluating its spectrum policy. A component of the FCC spectrum policy is spectrum sharing. In order to determine whether a new technology can degrade current licensed spectrum; it is vital to understand the operational environment in which the licensed carriers exist. A critical component of this environment is the noise floor, which establishes the baseline for successful operation of equipment and ultimately guides the specification and development of the receivers used in the mobile phones and base stations in the cellular and PCS bands. The proponents of spectrum sharing technology contend that spectrum-sharing equipment can operate below a licensed carrier's operating noise floor and thus will not impair current operations. Therefore, these noise floor measurements conducted by V-COMM are critical to defining the operational environment in which the carriers exist, and ultimately assist in the evaluating the viability of the FCC's spectrum sharing policies and initiatives.

With these low operating noise floor levels existing within the occupied PCS spectrum band, any spectrum-sharing technology would find it extremely difficult to co-exist with existing licensed service without causing disruptions. The spectrum sharing technology would need to exhibit extremely low signal levels that are sufficiently below the noise floor of typical wireless subscriber equipment in order to prevent an increase in the operating noise floor within occupied PCS spectrum. In addition, the spectrum-sharing technologies may also exhibit different multi-path fading characteristics than internal system interference, as received at cellular/PCS phones, which can cause service disruptions with different multi-path signal characteristics. In relation to CDMA technology, the low noise floor conditions are fully utilized by the system with its processing gain that enables utilization of signals below the thermal noise floor of its receivers. When the environmental noise conditions are very low, these systems can fully utilize the spectrum and offer maximum coverage and capacity.

2. Introduction

The purpose of this report is to document the noise floor measurements that were performed within the Personal Communications Service (PCS) Spectrum Band. The objectives of this study were to provide *actual* noise floor field measurements within occupied PCS spectrum that is utilized by a current operator, and in clean PCS spectrum that is not yet utilized by the operator. These noise floor levels include the thermal noise, ambient environment noise, co-channel and adjacent channel interference levels, as measured at the mobile subscriber location.

The noise floor level measured in clean spectrum tests include only thermal and ambient environment noise. In occupied spectrum tests, the noise floor level measured is the “operating noise floor” for mobile subscribers, which include the co-channel and adjacent channel system interference, in addition to the thermal and ambient environment noise. Field measurements in clean PCS spectrum were conducted in narrow and wide resolution bandwidths for comparison.

Field measurements were performed over a sufficient period of time to capture variations in operating noise floor levels for typical mobile subscriber locations (forward-link). These locations include a cross section of market environments including urban, suburban and rural. The measurements were performed at typical locations where wireless phones are utilized within buildings and outside. The locations are representative of typical subscriber operating environments within today’s PCS markets. A total of twelve (12) locations are included in the study and include airports, a train station, a shopping mall, an apartment building, an office building, residential houses, and in-vehicle while driving within the coverage area of a cell site.

The PCS market area in which measurements were conducted are within the Philadelphia, PA and surrounding market service area. The occupied spectrum tests were conducted within Cingular Wireless’ PCS D Band, in spectrum utilizing the digital wireless technology Time Division Multiple Access (TDMA, or IS136) having a nominal 30 kHz channel bandwidth. Cingular Wireless utilizes Lucent’s TDMA cell site equipment in this PCS market. The clean spectrum measurements were conducted within Verizon Wireless’ PCS E Band or Nextwave’s PCS F Band depending on which spectrum band is not utilized at the test locations.

V-COMM developed the test plan, test methods, and test procedures to accomplish this Spectrum Noise Floor Study. All field tests were performed at locations within Verizon’s and Cingular’s market. V-COMM coordinated test activities, reporting requirements, and cell site information with Verizon’s and Cingular’s regional performance and operations staff to accomplish this testing.

This report is a companion report to the AMPS Noise Floor Study report, which was previously performed submitted to the FCC by V-COMM as part of AirCell proceeding.[1]

The FCC is currently evaluating its spectrum policy and has recently considered regulations and technologies that allow increased levels of spectrum sharing. Spectrum sharing is the process of allowing new technologies to use existing licensed (as well as unlicensed) spectrum so long as it does not result in degraded operation of the licensed carriers and complies with all applicable FCC rules. To determine whether a new technology can degrade licensed spectrum; it is vital to understand the operational environment in which the current licensed carriers exist. A critical component of this environment is the noise floor, which establishes the baseline for successful operation of equipment and ultimately guides the specification and development of the receivers used in the mobile phones and base stations in the cellular and PCS bands. The proponents of spectrum sharing technologies contend that spectrum-sharing equipment can operate below a licensed carrier's operating noise floor and thus will not impair current operations. However, thus far, extensive field measurements have not been conducted to characterize the actual operating noise levels occurring in typical PCS market environments and to assess the impact to current licensed services. Therefore, these noise floor measurements conducted by V-COMM are critical to defining the operational environment in which the carriers exist, and will ultimately assist in evaluating the viability of the FCC's spectrum sharing policies and initiatives.

V-COMM has performed field measurements and prepared this report pursuant to a contract with a consortium of cellular/PCS companies composed of AT&T Wireless, Cingular Wireless, and Verizon Wireless. V-COMM is an independent wireless telecommunications engineering firm.[2] Our team represents over 50 years of in-depth engineering experience in wireless telecommunications. We have provided our expertise to wireless operators and the FCC, in engineering, system design, implementation, expansion, system performance, optimization, and new technology evaluation. We have direct experience in all wireless technologies.

The following sections of this report will provide the test overview, procedures, results, analyses, and conclusions as well as an Appendix of supporting material.

[1] The AMPS Noise Floor Study report was submitted to the FCC as engineering attachments to Opposing Carrier's submissions to the FCC in the AirCell proceedings, on April 10, 2003.
[2] V-COMM's company information and experiences are highlighted in the report's Appendix Section 8.4, along with biographies of senior members of its engineering team.

3. Test Overview

The objective of this study is to provide *actual* field measurements of typical operating noise floor levels within occupied and clean PCS spectrum, as observed by the mobile subscriber's receiver (base station to mobile, forward-link). All test plans and procedures were developed in consideration of this objective and in accordance with the test procedures described by the FCC in its Ultra-wide band (UWB) Order.[3] These noise floor measurements characterize the actual operational noise floor environment in which the carriers exist, and ultimately assist in the evaluating the viability of the FCC's spectrum sharing policies and initiatives.

Spectrum noise measurements were conducted in two PCS spectrum bands. The first is within occupied spectrum, and second within clean spectrum that is cleared of active users. Clean spectrum measurements provide a baseline of the thermal and ambient environmental noise floor existing in the PCS market, prior to any PCS service being offered in the band. Occupied spectrum measurements provide the operating noise floor level that includes co-channel and adjacent channel system interference from the carrier's network, in addition to the background environment noise level. With these measurements it is possible to observe the increase in noise floor levels compared to the clean spectrum measurements.

All testing must be conducted with full knowledge of the wireless service providers' radio frequencies in-use at nearby cell sites to ensure correct measurement in clean and occupied spectrum. This ensures that the measurement data is not corrupted by actual phone calls taking place on channels in-use by the network in an adjacent cell site, which represents the primary signal levels and not the operating noise floor levels.

Another consideration for the testing is the market environment type. Three market types are included in this study: urban, suburban, and rural. This is necessary to determine whether the level of the operating noise floor has a correlation to market environment. Of the twelve test locations included in this study, three were within urban market environments, six within suburban market environments, and three within rural market environments. All field measurements were performed on weekdays.

The test procedures and antenna locations were configured in environments to represent a realistic and conservative mobile user scenario. These tests utilize a unity gain dipole antenna connected to the measurement test equipment, with the antenna positioned adjacent to and in clear view of an outside window for all inside measurements. For outside measurements, the antenna was positioned within a vehicle and elevated to the level of the vehicle window. These antenna positions represent conservative antenna positions for typical users at the test locations, and are

[3] Clean spectrum measurements include spectrum analyzer settings and RMS averaging techniques pursuant to FCC test procedures described in its UWB First Report & Order, released April 22, 2002.

expected to observe increased noise floor levels compared to antenna positions that do not have a clear view to the outside radio environment. The test antenna was maintained in a fixed position during each test. In the case of the drive test, the antenna was maintained in a fixed position relative to the vehicle. The drive test represents the antenna in a moving environment within the coverage area of a cell site.

All testing utilizes calibrated test equipment and is in accordance with FCC test procedures. Allen Telecom's Grayson field test receiver, and Hewlett Packard's (HP) spectrum analyzer are utilized for these tests. The test equipment and parameters are described in the following section.

3.1. Clean Spectrum Tests

The objectives of the clean spectrum tests are to measure the thermal and ambient environmental noise floor levels existing in the PCS market, prior to any PCS service offered in the spectrum band. The PCS spectrum utilized for this testing is clear of any PCS service provider and incumbent microwave user. Prior to conducting these tests, V-COMM has confirmed the radio environment is cleared, with knowledge from the licensed PCS carriers in the market. These measurements are performed from the mobile subscriber perspective, at typical locations where wireless phone are used, and are within the PCS forward-link band (1930 to 1990 MHz).

For these tests, the measurements were conducted on a PCS channel that varied between the two markets (Allentown and Philadelphia), based upon the individual carrier licenses. Clean spectrum measurements require 1 MHz of PCS spectrum that is cleared of users, in the forward link (down link) PCS band. For clean spectrum measurements within the Philadelphia area, the upper portion of Verizon Wireless' PCS E Band is utilized. In the Allentown and Lehigh Valley area, the upper portion of Nextwave's PCS F Band is utilized. The licensed PCS operators and the incumbent microwave users were not using these portions of PCS spectrum, at the times V-COMM conducted these tests.

For the clean spectrum tests, two distinct field tests were utilized to perform all of the necessary measurements. The first utilizes Grayson field test equipment with a 30 kHz channel bandwidth receiver. The second utilizes HP spectrum analyzer and preamplifier equipment to measure the noise floor using a 1 MHz resolution and video bandwidth setting, on the same center frequency, antenna type, antenna position, and location as the Grayson receiver for comparison of the measurement data.[4] The test procedures for the clean spectrum tests are further described in a following section of this report.

[4] The spectrum analyzer tests were performed at most of the field locations (Eight of the twelve test locations) to allow comparison to the Grayson receiver test results.

3.2. *Occupied Spectrum Tests*

The objective of the occupied spectrum tests is to measure the operating noise floor level in the PCS band, which includes co-channel and adjacent channel system interference from the PCS carrier's operating network, in addition to the background environment noise level. With these measurements it is possible to observe the increase in noise floor levels compared to the clean spectrum measurements. These measurements are also performed from the mobile subscriber perspective, at typical locations where wireless phone are used, and are within the forward-link PCS D Band (1945 to 1950 MHz).

The licensed PCS D Band carrier for this Philadelphia, PA market and Allentown, PA market area is Cingular Wireless. Cingular Wireless uses its PCS spectrum to provide a TDMA service in this area, and these noise measurements were conducted on its forward link PCS band.[5] Cingular Wireless' network consists of 3-sectored directional cell sites in this market area, with a few omni-directional cell sites in the rural areas. In this market, Cingular Wireless is using the forward-link Dynamic Power Control (DPC) feature at its PCS TDMA cell sites, and it not currently using cell site frequency hopping or flexible frequency assignment features.

Prior to conducting these tests, V-COMM has gained specific knowledge of the radio frequency channels in-use for the surrounding area, from the licensed PCS carrier in the market. This is a critical test requirement, to ensure that the measurements are not mistakenly measuring the network's primary signal levels, of those active calls being served by adjacent cell sites, and will only measure the PCS system's co-channel and adjacent channel interference plus background noise levels. For these tests, the measurements were conducted on a PCS channel that was based upon the test location and the licensed carrier frequency assignments for that area.

V-COMM confirmed with Cingular Wireless, the licensed carrier for this market, the TDMA frequency assignments for the adjacent cell sites at each test location, to help determine an appropriate test channel to use at each test location. In this market, Cingular Wireless is using an N=7 frequency reuse assignment plan for its TDMA PCS spectrum, or reusing its TDMA channels in groups of seven cell sites. The TDMA channels selected for these measurements were not assigned to the group of seven cell sites serving the test location, but were assigned to the next adjacent groups of cell sites around this area. These channels will exhibit the carrier's system interference levels present at these locations, which include the system's co-channel and adjacent channel interference levels from the surrounding groups of cell sites. Since this test does not involve using the actual channels assigned to the cell sites that serve the test locations, these measurements are expected to exhibit noise floor levels that are

[5] During the planning stages of this study, Cingular Wireless was rolling out GSM service in its PCS band as well, and had partitioned its PCS band to allow channels for TDMA service and GSM service. Since its GSM spectrum did not represent a mature operating network, this study is based upon its TDMA spectrum, which had been operating for many years and was a mature operating network.

conservative, or slightly higher than the actual noise floor observed by a caller at this location.[6]

For the occupied spectrum tests, only the Grayson receiver equipment is necessary to perform the measurements. This field test utilizes Grayson field test equipment with a 30 kHz channel bandwidth receiver, tuned to the designated TDMA channel in the PCS forward link spectrum for that test location. The Test Procedures for the Occupied Spectrum tests are further described in a following section of this report.

3.3. Test Locations

The field locations included in this noise floor study were selected to be representative of normal locations within today's markets types, and to exhibit typical operating signal and noise floor characteristics. The locations are within the surrounding Philadelphia, PA and Allentown, PA market areas.

A total of twelve (12) locations are included in the study. These field locations include airports, a train station, a shopping mall, an apartment building, an office building, residential houses, and in-vehicle while driving within the coverage area of a cell site. Eleven tests were performed at fixed locations for the duration of the test, and one test was performed in a vehicle while driving the coverage area of a PCS cell site. Seven locations were in the Philadelphia, PA market area, and five locations were in the Allentown, PA market area.

A drive test was included in this study to assess the noise floor variations for the mobile environment (non-stationary). The drive test should represent the variations in noise floor levels that a PCS user experiences in a mobile (signal fading) environment and is used for comparison with noise floor measurements in a stationary environment.

These locations include a cross section of market type environments including rural, suburban and urban. Three test locations were in the rural market environment, six locations in the suburban market environment, and three locations in the urban market environment.[7]

V-COMM selected the test locations after reviewing the market areas to determine the locations where customers typically use cellular phones. They were performed at locations where wireless phones are utilized within buildings and at outside locations. Seven tests were at fixed locations inside a building with the test antenna adjacent to a

[6] The licensed carrier's assigns frequencies based upon a selection of channels that have the lowest noise floors for the cell site coverage area, which commonly follows a N=7 frequency reuse assignment plan for TDMA technology. These assigned channels should exhibit lower noise floors than others channels selected from the surrounding cell sites.

[7] Dense Urban market type was not included in this study, however one test location, the Philadelphia 30th Street Train Station, is located very close to Dense Urban area.

window. Five tests were at outdoors locations (4 fixed locations, 1 drive test) with the test antenna inside the vehicle and positioned at the same height as the window.

During the field tests the position of the antenna was selected to be representative of typical cellular/PCS phone users and have an unobstructed view to the outside. For tests conducted in automobiles, the test antenna was elevated above the seat to the height of the window representing the typical cell phone position next to a person's head. For tests conducted in buildings, the antenna was elevated 4-5 feet off of the ground and immediately adjacent to a window, with a clear unobstructed view outside. These antenna positions were selected to represent a conservative view of the noise floor. Other positions further inside buildings, or in-vehicle with the phone on the seat (cellular headset option), should experience lower noise floor results compared to the results in this study. In all tests, the test antenna was orientated vertically, and was a vertically polarized unity gain dipole antenna.

The field measurements were performed over a sufficient period of time to capture variations in operating noise floor levels for typical mobile subscriber locations (PCS forward-link). Depending on the accessibility of the test location, the duration of the test was either 24 hours, or 4 hours. At five of the test locations the measurements were conducted over a 24-hour period, six tests were conducted over a 4-hour period, and the drive test was conducted over a 30-minute period, as indicated in the table below.

Below, is a table containing information pertaining to the test location, market type, and test duration.

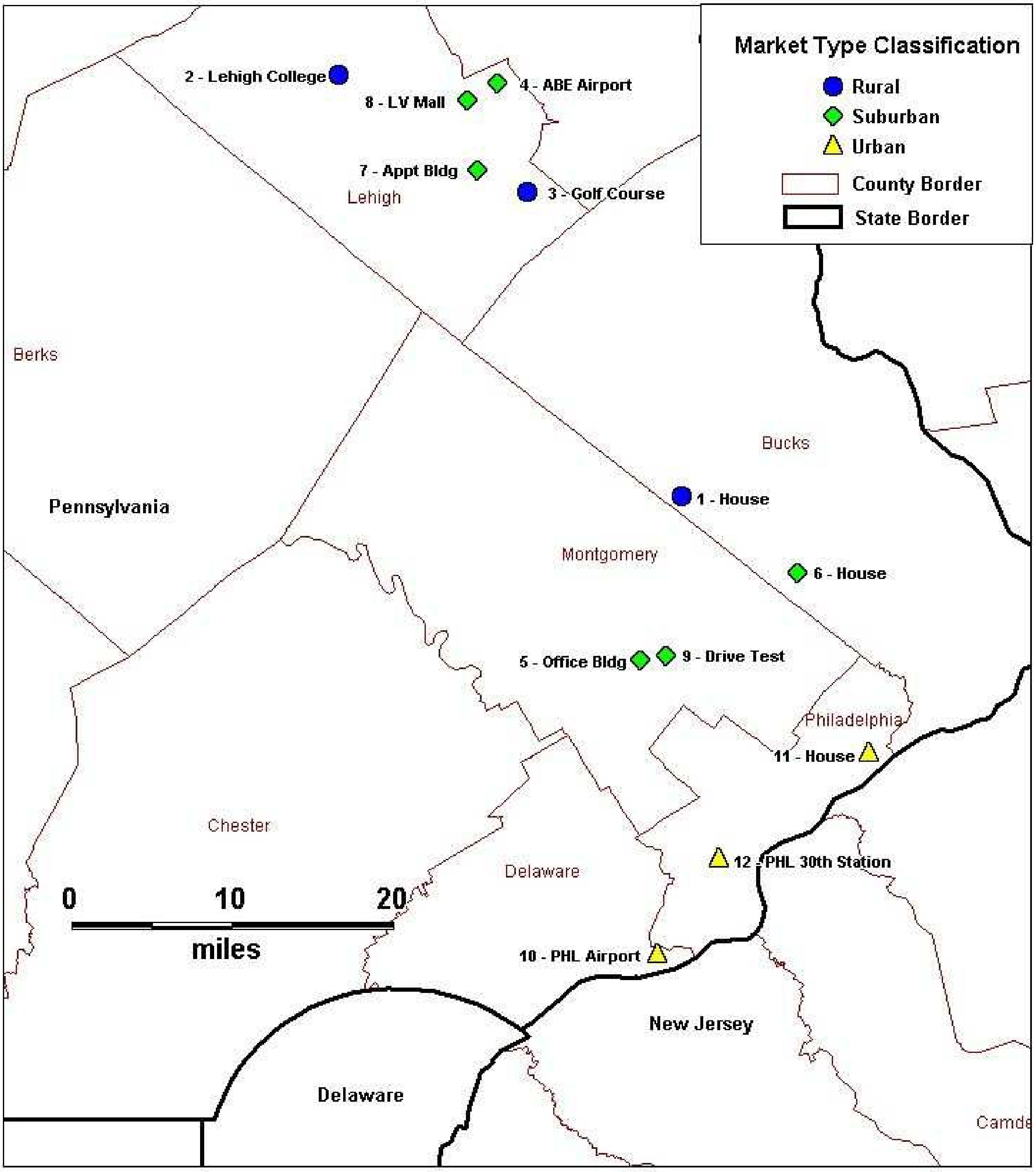
Table 3.1 Test Locations List

Test Location #	Market Type Classification	Location Type	Town, State	County	Test Duration (hours)
1	Rural	House	Chalfont, PA	Bucks	24
2	Rural	Lehigh College	Schnecksville, PA	Lehigh	4
3	Rural	Golf Course	Saucon Valley, PA	Lehigh	4
4	Suburban	ABE Airport	Allentown, PA	Lehigh	4
5	Suburban	Office Bldg	Blue Bell, PA	Montgomery	24
6	Suburban	House	Warminster, PA	Bucks	24
7	Suburban	Appt Bldg	Allentown, PA	Lehigh	24
8	Suburban	Lehigh Valley Mall	Whitehall, PA	Lehigh	4
9	Suburban	Drive Test	Ambler, PA	Montgomery	0.5
10	Urban	PHL Airport	Philadelphia, PA	Philadelphia	4
11	Urban	House	Philadelphia, PA	Philadelphia	24
12	Urban	PHL 30th Train Station	Philadelphia, PA	Philadelphia	4

Note: The table above contains information pertaining to the test location, market type, and test duration.

Below, is a geographic map depicting the 12 test locations. The sites are represented with different colors and shapes, to reference each market type.

Figure 3-1 Map of Test Locations



A description of each of the field test locations is provided below.

Field Location #1 - This test was performed within a typical 2-story colonial model house in Chalfont, PA, which is classified within the rural market environment. The measurement test equipment and antenna were setup close to a window, in the dining room on the first floor of the house having an unobstructed view to the northwest of the location. The test antenna was elevated above a table in order to simulate the height of a typical mobile user. Measurements were recorded over a period of 24 hours.

Field Location #2 - This test was performed on the eastern side parking lot of the Lehigh Carbon Community College (Lehigh College) in Schnecksville, PA, which is classified as a rural market environment. The measurement test equipment and antenna were setup in V-COMM's drive test vehicle in the middle row seat, window side.[8] The test antenna was elevated above the seat to simulate the height of a typical mobile user. There were no obstructions surrounding the vehicle at this location. Measurements were recorded over a period of 4 hours.

Field Location #3 - This test was performed on the north side parking lot of the Saucon Valley Golf Course (Golf Course) in Saucon Valley, PA, which is classified as a rural market environment. The measurement test equipment and antenna were setup in V-COMM's drive test vehicle in the middle row seat, window side. The test antenna was elevated above the seat to simulate the height of a typical mobile user. There were no obstructions surrounding the vehicle at this location. Measurements were recorded over a period of 4 hours.

Field Location #4 - This test was performed inside the main terminal building of the Allentown-Bethlehem-Easton (ABE) Airport, in Allentown, PA, which is classified as a suburban market environment. The measurement test equipment and antenna were setup close to a window in the main lobby, on the second floor of the building having an unobstructed view to the north of the location. The test equipment antenna was elevated above a passenger sitting area to simulate the height of a typical mobile user siting on the bench seat. Measurements were recorded over a 4 hours period at this location.

Field Location #5 - This test was performed inside a brick office building in Blue Bell, PA, which is classified as a suburban market environment. The measurement test equipment and antenna were setup close to a window, in the eastern side of the office building on the first floor having an unobstructed view to the southeast of the location. Measurements were recorded over a period of 24 hours.

Field Location #6 - This test was performed inside a typical 2-story colonial model house in Warminster, PA, which is classified as a suburban market environment. The measurement test equipment and antenna were setup close to a window, in the dining room on the second floor of the house having an unobstructed view to the west of the location. Measurements were recorded over a period of 24 hours.

[8] V-COMM's drive test vehicle is a 2000 Ford Explorer.

Field Location #7 - This test was performed inside a 3-story apartment building in Allentown, PA, which is classified as a suburban market environment. The measurement test equipment and antenna were setup close to a window, in the living room on the second floor of the building having an unobstructed view to the east of the location. Measurements were recorded over a period of 24 hours.

Field Location #8 - This test was performed on the southern side parking lot of the Lehigh Valley Mall (LV Mall) in Whitehall, PA, which is classified as a suburban market environment. The measurement test equipment and antenna were setup in V-COMM's drive test vehicle in the middle row seat, window side. The test antenna was elevated above the seat to simulate the height of a typical mobile user. There were no obstructions surrounding the vehicle at this location. Measurements were recorded over a period of 4 hours.

Field Location #9 - This is the mobile drive test. Testing was performed with measurement equipment and antenna setup inside V-COMM's drive test vehicle, while driving roads within the coverage area of a PCS cell site in Ambler PA, which is classified as a suburban market environment. The measurement test equipment and antenna were setup in drive test vehicle in the middle row seat, window side. The test antenna was elevated above the seat to simulate the height of a typical mobile user. Measurements were recorded over a period of ½ hour.

Field Location #10 - This test was performed on the northwestern side of Philadelphia (PHL) airport parking lot in Philadelphia PA, which is classified as an urban market environment. The measurement test equipment and antenna were setup in V-COMM's drive test vehicle in the middle row seat, window side. The test antenna was elevated above the seat to simulate the height of a typical mobile user. This parking location is the airport's short-term parking area, which is close to the airport's terminal building (approx. 0.1 mile away) and tests were conducted on the second floor of a four-story parking garage. The parking garage structure was an open structure, which allowed unobstructed views to its surrounding area. Measurements were recorded over a period of 4 hours.

Field Location #11 - This test was performed inside a typical 2-story townhouse in Philadelphia, PA, which is classified within the urban market environment. The measurement test equipment and antenna were setup close to a window, in the living room on the first floor of the townhouse having an unobstructed view to the north of the location. The test antenna was elevated above the seat to simulate the height of a typical mobile user. Measurements were recorded over a period of 24 hours.

Field Location #12 - This test was performed inside the main terminal building of the Philadelphia 30th Street Train Station in Philadelphia, PA, which is classified as an urban market environment. The measurement test equipment and antenna were setup on a passenger sitting area inside the middle of the main lobby, on the first floor of the building. The test equipment antenna was elevated above the seat to simulate the height of a typical mobile user siting on the bench seat. Measurements were recorded over a 4 hours period at this location.

3.4. Test Equipment

This section provides details on the test equipment that was utilized during this noise floor study. The test equipment was checked and verified to perform within manufacturer's specification prior to using in the field. The HP 8594E and Allen Telecom Group Grayson receiver test equipment were within their current calibration period; both were calibrated within the prior 12-month period.

The test equipment utilized for both spectrum tests are listed below.

Test Equipment for Receiver Tests (30 kHz BW):

1. Allen Telecom/Grayson Field Test Receiver (GMR203) with Laptop Computer & RS232 serial cable
2. PCS mobile antenna (unity gain dipole, 0 dBd)
3. 12V battery & Power Inverter (used in locations without AC power)
4. RF Connector converters SMA to N type, N to TNC type

Test Equipment for Spectrum Analyzer Tests (1 MHz BW):

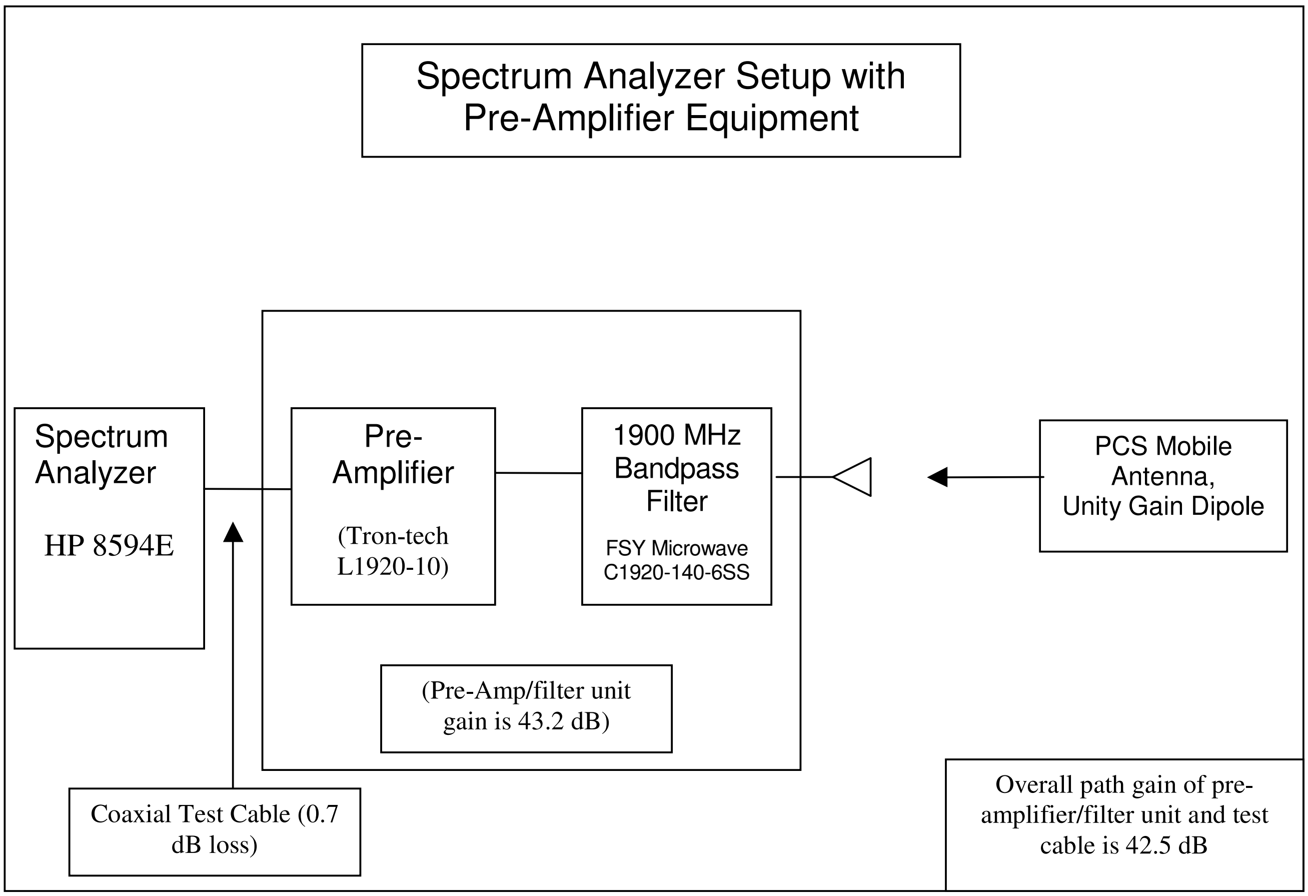
1. HP 8594E Spectrum Analyzer
2. PCS mobile antenna (unity gain dipole, 0 dBd)
3. Pre-amplifier equipment (Pre-amp, filter, test cable, and 12 Volt power supply)
4. 12V battery & Power Inverter (used in locations without AC power)
5. Test cable between pre-amplifier equipment and spectrum analyzer
6. RF Connector converters SMA to N type

For the spectrum analyzer tests, the pre-amplifier, filter and test cable were checked and measured for their respective receive path offset prior to testing. This overall gain was measured to +42.5 dB (within +/- 0.1 dB) for the PCS forward-link bands E and F, which were utilized in the clean spectrum tests, from input of the pre-amplifier equipment to the input of the spectrum analyzer. With the isotropic antenna reference offset (2.15 dB), the total offset used for this spectrum analyzer test setup was 44.65 dB. All spectrum analyzer results provided in this report utilize this offset, and hence are referenced to the antenna port of a 0 dBi mobile antenna. The system noise floor of the spectrum analyzer and pre-amplifier equipment was measured in pretests with a precision connector termination used in place of the antenna. These results yielded a RMS average power level of –113.7 dBm in a 1 MHz bandwidth,[9] which includes the pre-amplifier equipment's path gain offset plus 2.15 dB for isotropic antenna reference.

[9] Similar test procedures were utilized for the spectrum analyzer tests that are described in the Test Procedures section of this report and comply with FCC measurement procedures. This level represents the test equipment's thermal noise floor level, as referenced to the antenna port

The signal level accuracy of the calibrated HP 8594E Spectrum Analyzer is within +/- 1 dB. V-COMM checked and verified the spectrum analyzer's accuracy with a calibrated signal generator for several frequencies and signal levels within the PCS bands, and observed the HP 8594E was within its accuracy specifications.

A diagram of the Spectrum Analyzer test setup with test cable, pre-amplifier and filter configuration is provided below.



The Allen Telecom Grayson receiver was used to measure and record the operating noise floor levels for a period of 4 or 24 hour, with a 30 kHz bandwidth receiver, on a specific channel that was selected by V-COMM prior to the testing. The duration of testing was depended on the location. The Grayson test receiver's signal level accuracy is within +/- 1 dB, and it records values with a bin resolution of 1 dB. The Grayson test receiver utilizes a linear power averaging function with measurement samples collected over 1 second intervals.

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of a 0 dBi gain isotropic antenna. This represents a system noise figure of approximately 2.5 dB for the spectrum analyzer and pre-amplifier equipment.

The Grayson GMR203 test receiver utilized for this study was recently purchased and was calibrated by Allen Telecom. Upon verification of its signal level accuracy for a variety of frequencies across the PCS band, the +/- 1 dB accuracy specification was verified with input levels as low as –127 dBm.[10] This establishes the minimum level accurately reported by the Grayson test equipment, and after adjusting for the isotropic antenna reference (subtract 2 dB), yields a minimum reported level of –129 dBm reference to a 0 dBi antenna. It was also observed that the Grayson receiver equipment reported readings on the high side of its accuracy range for input levels below –125 dBm (but was still within 1 dB of input range). This results in a conservative measurement at these low levels (i.e. the actual noise floor is up to 1 dB below the reported measurements by this receiver, at these low input levels).

The PCS mobile antenna was checked and met industry standard for acceptable VSWR performance for PCS mobile antennas, which was less than 2:1.[11] The RF connector converters listed above were utilized to connect the PCS mobile antenna to the test equipment. The PCS mobile antenna utilized for all field measurements is the Larsen 1900 MHz antenna model SPDA241900 (pictured below). This is a center fed dipole antenna (0 dBd gain), with an articulating right-angle to straight-angle SMA connector on the bottom of the antenna, having an overall height of 7.5 inches. The PCS mobile antenna is vertically polarized and was oriented vertically for all tests.

[10] Grayson GMR203 receivers are specified to –125 dBm in its documentation, and Grayson confirmed that their receivers have very good sensitivity and can remain accurate slightly below this level. Grayson's calibration procedure allows them to calibrate their receivers to levels that are below the system noise floor of the receiver.

[11] The PCS mobile antenna performed better than its minimum VSWR specification. This performance was tested and verified for the antenna in free space and as positioned in similar configuration as used in the spectrum tests with the antenna above the test equipment. The minimum VSWR performance was measured to 1.7:1, which is an antenna efficiency of 93%. With this antenna efficiency, the test equipment will receive signal levels 0.3 dB lower than an ideal antenna, which is within the reported accuracy tolerances of the test equipment. The VSWR performance of the test antenna utilized for this study is equivalent to the performance of typical mobile phone antennas.

3.5. Signal Level Reference Point

In this report, all received signal levels are referenced to the forward link noise floor level experienced at a 0 dBi antenna, at its antenna port. This is the designated signal reference point, and is expected to be similar to levels that PCS mobile phones experience. All signal level units are in dBm (decibels, relative to 1 milliwatt).

All field measurements were performed with a PCS mobile antenna, which is a unity gain dipole antenna (0 dBd), and the measurements are converted to 0 dBi reference, by subtracting the dipole to isotropic antenna offset (2.15 dB).

For the 30 kHz Grayson equipment tests, the PCS mobile antenna was connected directly to the input port of the Grayson test equipment. No test cables were utilized for these tests, and no offsets were required other than the isotropic antenna offset of 2.15 dB.

For the 1 MHz spectrum analyzer tests, the PCS mobile antenna was connected to the input of the pre-amplifier/filter assembly used in these tests. All measurements performed by the spectrum analyzer are reference to a 0 dBi antenna, by utilizing an offset that takes into account the loss in the test cable and the path offset of the pre-amplifier stage. This offset includes 42.5 dB for the test cable and pre-amplifier's receive path gain, plus 2.15 dB for the isotropic antenna offset.

4. Test Procedures

4.1 Test Coordination

V-COMM worked with Verizon Wireless' and Cingular Wireless' regional performance and operations staff to execute this PCS noise study within the Philadelphia, PA and Allentown, PA market areas. For each of the 12 locations tested, coordination of the required cell site frequency assignments used within market area, test plan activities and other cell site information was performed. The field tests were performed at each of the 12 locations on a typical business day, for a 4 hour or 24 hour period. The 4-hour tests were performed during the normal business workday period between 8 am and 6 pm. The amount of time for the testing was determined by the accessibility of the location. At locations where V-COMM had access to the building's AC power source, 24-hour tests were conducted. Otherwise, a 4-hour test was conducted using a portable 12 Volt DC power source and a power inverter. Field measurements were performed within the months of May and June of 2003.

For both the Allentown and Philadelphia market areas, Cingular Wireless operates TDMA service in the PCS D Band, and this band was utilized for the occupied PCS spectrum tests in these market areas. TDMA technology utilizes 30 kHz channel spacing, and the Grayson test equipment with a 30 kHz test receiver was utilized for these tests. V-COMM coordinated with Cingular to acquire the radio frequency assignments and cell site information for these market areas. After reviewing the frequency assignments in conjunction with the site locations, an individual channel was chosen for the occupied spectrum noise measurements for each test location. For occupied spectrum tests, the TDMA channel selected was not co-channel with cell sites immediately adjacent to and serving the test location, but they are co-channel with the frequency assignments of cell sites that are just beyond the adjacent cell sites to the test location. These are the frequencies used at the next adjacent group of cell sites to the test location, where each group of approximately seven cell sites in this market are re-using Cingular's TDMA channels. For these tests, the TDMA channel selected included the wireless network's adjacent channel interference from the cell sites immediately adjacent to each test location and from the next group of cell sites as well. These measurements should exhibit operating noise floor levels that are equivalent or slightly higher than noise levels experienced on channels assigned to the best serving cell site for each test location.

For the clean spectrum tests in the Philadelphia, PA market area, Verizon Wireless' PCS E band was utilized for testing. This spectrum was selected since the upper 2 MHz of spectrum of this 5 MHz band is currently cleared and unused within this market area, and is also cleared of incumbent microwave users. This allows for a 1 MHz measurement of spectrum, centered at 1968.5 MHz. For the Allentown, PA market locations, the clean spectrum measurements used the PCS F band, which is licensed to Nextwave who is operating a CDMA network, but not utilizing the upper 2 MHz of this 5 MHz band. Within this market, the 1 MHz clean spectrum tests utilized the frequency in this band centered at 1973.5 MHz. For clean spectrum tests, noise floor measurements were made on the center frequency listed above with a 30 kHz Grayson test receiver, and spectrum analyzer using a resolution bandwidth of 1 MHz, for comparison of the test results.

4.2 Test Procedures

Upon arrival at the in-building locations, the test equipment was setup adjacent to a window at a typical user height, with the top of the test antenna approximately 4 to 5 feet above the ground. When testing in-vehicle, the equipment was elevated above the middle row seat to a typical mobile user height sitting in a vehicle, with a clear view out the vehicle's window. While measurements were performed, the engineer ensured the antenna's view to its surroundings was not obstructed. The test equipment was immediately powered up to allow for a 1/2-hour warm-up period before measurements began.

The PCS spectrum noise tests consists of clean spectrum measurements using the Grayson receiver with 30 kHz bandwidth and spectrum analyzer with 1 MHz bandwidth, and occupied spectrum measurements with the Grayson receiver with 30 kHz bandwidth. The Grayson Test Receiver was used in both tests (clean and occupied spectrum tests) and the test procedures for those tests are detailed below. The spectrum analyzer setup was used in only the clean spectrum tests, and these test procedures are also detailed below.

Field test with Grayson Test Receiver

The computer laptop was connected to the Grayson test receiver via a serial cable and controls the data collection software. Grayson's Spectrum Tracker software was utilized for these tests. This software resides on the PC connected to the receiver and allows for control of the test equipment. Within this program, the test parameters are set for testing at each of the 12 locations. The appropriate time intervals for measurement averaging, center frequency, and data collection parameters were verified before testing.

The PCS unity gain mobile antenna was connected to the Grayson receiver with the appropriate connector converter to convert TNC to SMA connector type. Two frequency channels were configured for the receiver to scan at each test location, one channel was within the occupied spectrum band and one was within clean spectrum band. In this way, the same Grayson test receiver is measuring the noise floor of both the "clean" spectrum and "occupied" spectrum at the same time, and using the same receiver, so the results can be directly compared. The frequencies were selected prior to testing as described above. For those test locations where logistics were restrained (i.e. public venues and automobiles) for an extended length of time, 4 hour tests were conducted. For those areas where logistics were amiable (i.e. office buildings and private homes), 24-hour tests were conducted.

All Grayson measurements were performed with the RSSI measurement type of "Linear Averaging" over a 1 second period. The Grayson test receiver collects 400 samples per second on the measurement channel, performs an average of those readings in the Power domain (linear averaging), and records the linear average of those reading at 1 second intervals. For the Grayson receiver tests, the equipment was configured to perform measurements on the clean spectrum channel for a 1-second interval, then retune to the occupied spectrum channel and perform measurements on it for a 1-second interval, and continue this process throughout entire test. In this way, the Grayson receiver would record 1-second linear averaged readings for each channel (clean and occupied spectrum channel) at alternating 1-second periods. Each channel would contain 30 linear averaged records for every minute of the measurement period.

The measurement data for each channel was recorded into separate files, and post processed upon returning to the office. The Grayson receiver's measurement data was post processed, the received signal strength data was adjusted 2 dB for conversion to an isotropic antenna reference,[12] and plotted on a histogram for analysis. Pre-tests in the office with the Grayson receiver verifies the minimum levels the equipment maintains its +/- 1 dB accuracy range, and establishes the minimum level accurately reported for the Grayson test equipment.[13] This minimum level is represented on the histogram graphs as the lowest reported noise floor bin level, which is –129 dBm as reference to a 0 dBi antenna. The 50% (median) and 90% noise floor values are calculated by interpolation of the noise measurement data points, and are provided in the Test Results section below.

In addition to the fixed location tests, the Grayson receiver test was also performed in a moving vehicle over the coverage area of Cinguar's Wireless' PCS cell site in Ambler, PA. The roads within the coverage area of this cell site were identified prior to measurements by V-COMM, and measurements with the Grayson equipment were performed while driving these roads. The same test parameters were utilized in this mobile test, as described in the tests above, except for the test duration, which was over a 30-minute measurement period. The results of the drive test are reported along with the results of the other stationary field tests in Test Results section of this report.

<u>Field test with Spectrum Analyzer & Pre-Amp Equipment</u>

For comparison to the measurements performed by the Grayson equipment using a 30 kHz receiver, spectrum analyzer measurements were performed using a 1 MHz bandwidth for the clean spectrum measurements, at eight of the twelve test locations included in this study. The spectrum analyzer measurements were using the same center frequency as the Grayson receiver clean spectrum tests, and the PCS mobile

[12] Since actual measurements were performed with a unity gain dipole antenna, which has a 0 dBd reference, converting to an isotropic antenna reference for this report required subtracting 2.15 dB from the data, or 2 dB since the resolution of the Grayson measurements are reported in 1 dB increments. All measurements in this report are referenced to a 0 dBi antenna.

[13] This is further explained in the Test Equipment section of this report.

antenna was positioned in the same configuration as the Grayson receiver tests. In this way, the clean spectrum measurements can be directly compared with both equipment setups. The major difference between the equipment is the bandwidth of the receivers utilized, which is 30 kHz for the Grayson vs. 1 MHz for the spectrum analyzer.

To improve the sensitivity of the spectrum analyzer a pre-amplifier stage was utilized, and is described in the Test Equipment section of this report. The path gain of the pre-amplifier stage established the system noise figure of the test setup and overcomes the high noise figure of the analyzer. A PCS forward-link band pass filter was used prior to the pre-amplifier to filter out of band emissions, and a test cable between the pre-amplifier/filter equipment to the spectrum analyzer. The path gain of the test setup (from the antenna to the spectrum analyzer) was measured prior to tests and used as an offset in post processing. In addition to the path gain offset of the preamplifier equipment, the isotropic antenna reference offset (2.15 dB) was utilized to convert the measured values from a 0 dBd antenna reference to a 0 dBi antenna reference. The same PCS mobile antenna (unity gain, 0 dBd dipole antenna) was used in the spectrum analyzer tests and the Grayson receiver tests, to allow the results to be compared.

For the spectrum analyzer tests, the pre-amplifier, filter and test cable were checked and measured for their respective receive path offset prior to testing. This overall gain was measured to +42.5 dB (+/- 0.1 dB) for the PCS forward-link bands E and F, which were utilized in the clean spectrum tests, from input of the pre-amplifier equipment to the input of the spectrum analyzer. With the isotropic antenna reference offset (2.15 dB), the total offset used for this spectrum analyzer test setup was 44.65 dB. All spectrum analyzer results provided in this report utilize this offset, and hence are referenced to the antenna port of a 0 dBi mobile antenna.

The test procedures utilized in the spectrum analyzer tests were designed to be consistent with FCC established measurement procedures as provided in recent FCC Orders.[14] Therefore, the spectrum analyzer tests were conducted in accordance with the FCC test procedures for measuring true RMS values with frequencies above 960 MHz, as documented with in Appendix F, bullet number 3, of FCC UWB Order document, as follows:

> "RMS average field strength measurements, required for all frequencies above 960 MHz, shall be made using techniques to obtain true RMS average. This can be accomplished by using a spectrum analyzer that incorporates a RMS detector. The resolution bandwidth of the analyzer shall be set to 1 MHz, the RMS detector selected, and a video integration time of 1 ms or less is to be used. If the transmitter employs pulse gating, in which the transmitter is quiescent for intervals that are long compared to the nominal pulse repetition interval, all measurements shall be made while the pulse train is gated on. Alternatively, a true RMS level can be measured using a spectrum analyzer that does not incorporate a RMS detector. This approach requires a multiple step technique beginning with a peak detection scan of the UWB spectrum with a RBW of 1MHz and a VBW of no less that 1

[14] Within the FCC's First Report & Order document, released April 22, 2002, regarding spectrum measurements on frequencies greater than 960 MHz, in the matter of "Revision of Part 15 of the Commission's Rules Regarding Ultra-Wideband (UWB) Transmission Systems."

> MHz. The resulting traces to be used to identify the frequency and bandwidth of the five highest peaks in the spectrum. The analyzer is then to be placed in a “zero span” mode, with a RBW of 1 MHz, a VBW equal to or greater than 1 MHz, and a detector selected that does not distort or smooth the instantaneous signal levels (e.g., a “sample” detector). With these settings, a minimum of ten independent instantaneous points, representing the highest amplitude readings, are to be obtained during the time that a pulse is present, in each 1 MHz frequency bin across the bandwidth of each of the five highest peaks identified in the previous step. Note that when the PRF of the device under test is less than the measurement bandwidth of 1 MHz, a significant number of samples may required to ensure that a minimum of 10 samples with the pulse present are obtained. The data obtained from these measurements must then be post-processed to determine true RMS average power levels. The post-processing of the data can be performed manually or with the aid of appropriate software.”

For consistency to these FCC measurement procedures and techniques to obtain true RMS measurements of the noise spectrum, the following procedures were used for the clean spectrum tests with the spectrum analyzer equipment.

At the test locations, the spectrum analyzer equipment was setup in similar position and location as the previous Grayson receiver tests. The input port of the spectrum analyzer (HP8594E) was connected to the output of the pre-amplifier equipment with the test coaxial cable. The PCS unity gain mobile antenna was connected to the input port of the pre-amplifier equipment with the appropriate connector to convert SMA to N connector type.

First, the spectrum analyzer was set with the following parameters for spectrum measurements with its peak detector, to detect any peaks in the clean spectrum identified for this testing. The spectrum analyzer parameters utilized for the peak detection measurements are listed below:

Spectrum Analyzer Measurement with Peak Detector

1. Center Frequency (1986.5 or 1973.5 MHz, depending on test location)*
2. Span = 1 MHz
3. Resolution Bandwidth = 1 MHz
4. Video Bandwidth = 1 MHz
5. Detector = Peak
6. Sweep = 20 msec
7. Signal Level Offset = 0 dB

* (In the Philadelphia, PA market the center frequency 1986.5 MHz was used and in the Allentown, PA market the center frequency 1973.5 MHz was used for these tests.)

All spectrum analyzer measurements using peak detection showed no peaks in the noise floor for the clean spectrum tests, as such the same center frequency was utilized to obtain true RMS measurements for clean spectrum tests.

Next, the spectrum analyzer was set with the following parameters for spectrum measurements with its sample detector using the zero-span mode of operation. These measurements are used to obtain the true RMS average power levels as described below, and are in accordance with the FCC measurement procedures described above. The spectrum analyzer parameters utilized for the sample detection measurements are listed below.

Spectrum Analyzer Measurement with Sample Detector

1. Center Frequency (1986.5 or 1973.5 MHz, depending on test location)*
2. Span = 0
3. Resolution Bandwidth = 1 MHz
4. Video Bandwidth = 1 MHz
5. Detector = Sample
6. Sweep = 1 millisecond
7. Signal Level Offset = 0 dB (After completion of tests, an offset was applied in post processing)*

* (As described in the section above, the spectrum analyzer tests utilize an offset to reference the measurements to the antenna port of an isotropic antenna reference. This offset accounts for the path gain of the pre-amplifier equipment and the conversion to isotropic antenna reference.)

Spectrum analyzer traces were recorded to the equipment's memory and data points from these traces were used to obtain the true RMS average power levels. After returning to the office, the data point values across the spectrum analyzer trace windows were extracted at even spaced intervals. These data point values are the independent power readings that include the variation in amplitude levels from low to high readings as observed on the trace window, with a sweep trace of 1 millisecond. These independent power readings were recorded into a spreadsheet, converted into the linear power units, averaged in linear power units, and then converted back to dBm units. After this, antenna reference and receive path offsets are applied, as described above, to reference the power level to the antenna port of a 0 dBi isotropic antenna. These power levels represent the true RMS averaged power levels for the noise floor of the clean spectrum tests, and are provided in the Test Results section of this report.

5. Test Results

The occupied and clean PCS spectrum noise floor results are provided in Table 5.1 through Table 5.4 below. Included are the noise floor results of the test receiver measurements with 30 kHz bandwidth, and spectrum analyzer measurements with 1 MHz bandwidth. The 30 kHz test receiver measurements were performed over a 24 hour or 4 hour period, depending on the field location, and utilized linear power averaging with 1 second intervals. The spectrum analyzer measurements were performed at the same field locations and represent the RMS average power levels of the clean PCS spectrum noise floor, in accordance with FCC test procedures that are described in the Test Procedures section of this report. All measurements are referenced to the antenna port of an isotropic antenna reference (0 dBi).

The occupied spectrum noise floor measurements are within a PCS spectrum band that is supporting an operating TDMA network. The clean spectrum noise floor measurements are within a PCS spectrum band that is currently unused. The field measurements were performed at twelve locations that are representative of typical subscriber locations within the urban, suburban and rural market areas.

The PCS noise floor test results for the Median and RMS noise floor levels are provided in Table 5.1 below. The median noise floor results for the occupied spectrum measurements, using a 30 kHz receiver, are –122.7 dBm to –129 dBm, with an average of –127.8 dBm. The median noise floor results for the clean spectrum measurements, using a 30 kHz receiver, are –128.5 dBm to –129 dBm, with an average of –128.9 dBm. The RMS average noise floor results for the clean spectrum measurements, within a 1 MHz bandwidth, are –111.9 dBm to –113.2 dBm, with an average of –112.4 dBm.

The average value of the median noise floor results for the occupied spectrum measurements is approximately 1 dB higher than the clean spectrum measurements. These results show a slight increase in the operating noise floor for occupied spectrum as compared to clean spectrum. The average value of the RMS noise floor levels with a 1 MHz bandwidth is 16.5 dB higher than the average value of the median noise floor levels with a 30 kHz bandwidth, for the clean spectrum measurements. The increased noise floor level exhibited with the 1 MHz bandwidth is expected, since the spectrum analyzer measurements utilized a wider bandwidth setting than the test receiver.

The Median and RMS noise floor levels averaged by market type are provided in Table 5.2 below. The occupied spectrum measurements indicated similar noise floor levels across all market environments, with a slight increase in the urban market by about 1 dB on average. The clean spectrum measurements indicated similar noise floor levels across all market environments. The median noise floor results for occupied spectrum measurements averaged by market type for urban, suburban, and rural market areas are –126.7, –128.4, and –127.6 dBm, respectively. The median noise floor results for clean spectrum measurements averaged by market type for urban, suburban, and rural market areas are –129.0, –129.0, and –128.8 dBm, respectively. The RMS average noise floor results for clean spectrum measurements averaged by market type for urban, suburban, and rural market areas are –111.9, –112.3, and –112.7 dBm, respectively, within a 1 MHz bandwidth.

The PCS noise floor test results for the 90% noise floor level is provided in Table 5.3 below.[15] The 90% noise floor level for occupied spectrum measurements, using a 30 kHz receiver, are –116.0 dBm to –128.6 dBm, with an average of –125.4 dBm. The 90% noise floor level for clean spectrum measurements, using a 30 kHz receiver, are –127.3 dBm to –128.6 dBm, with an average of –128.4 dBm.

The average value of the 90% noise floor level for the occupied spectrum measurements is approximately 3 dB higher than the clean spectrum measurements. These results show an increase in the operating noise floor for occupied spectrum as compared to clean spectrum. The average value of the 90% noise floor level for the occupied spectrum measurements is 2.4 dB higher than median noise floor level. The occupied spectrum measurements show some fluctuations over the measurement interval (4-hour or 24-hour). The average value of the 90% noise floor level for the clean spectrum measurements is 0.5 dB higher than median noise floor level. The clean spectrum measurements show very little fluctuations over the measurement interval.

The 90% noise floor level averaged by market type is provided in Table 5.4 below. The occupied spectrum measurements indicated similar noise floor levels for the rural and suburban market environments, with an increase in the urban market by about 1 dB on average. The clean spectrum measurements indicated similar noise floor levels across all market environments. The 90% noise floor level for occupied spectrum measurements averaged by market type for urban, suburban, and rural market areas are –123.3, –126.4, and –125.6 dBm, respectively. The 90% noise floor level for clean spectrum measurements averaged by market type for urban, suburban, and rural market areas are –128.6, –128.5, and –128.1 dBm, respectively.

The spectrum noise measurements included in this study indicate low operating noise floor levels existing in the clean and occupied PCS spectrum bands in these market areas. In all test locations except for the Philadelphia train station,[16] the 90% noise floor level in the PCS occupied spectrum band is below the thermal noise floor values of typical wireless phones. With these low operating noise floor levels within the occupied PCS spectrum, wireless phone service can be maintained to low operating signal levels.

The lowest operating signal level that TDMA wireless phones can maintain quality service is dependent on the system interference noise level within the occupied spectrum band, the carrier-to-interference (C/I) ratio required for quality service, and the

[15] The 90% noise floor results are included below in comparison to other studies performed by other parties that referenced the 90% noise floor levels.

[16] The Philadelphia 30th Street Train Station is located within an urban market environment that is immediately adjacent to center city Philadelphia, which is a dense urban market area. This test location exhibited the highest occupied spectrum noise levels of the twelve locations tested.

system noise floor of the wireless phone. The required C/I ratio for TDMA technology is 17 dB for high quality voice and data transmissions. The system noise floor of wireless phones can vary between –121 to –124 dBm, for wireless phones that have noise figure characteristics between 5 to 8 dB. With the phone equipment noise floor and 17 dB C/I requirement, TDMA phone service can be maintained on the forward-link with operating signals between –104 to –107 dBm (the minimum signal level for "toll quality" service).[17] In the presence of considerable signal fading, an additional fade margin may be required to maintain quality service and is based upon an acceptable threshold for area coverage reliability.

For the PCS market locations that exhibit lower operating noise floor values than –124 dBm for the forward-link within occupied TDMA spectrum, these areas represent opportunities for carriers and manufacturer's to improve system performance and spectral efficiency by improving wireless handset noise figure characteristics. The median operating noise floor level averaged for all test locations was lower than the –124 dBm (phone noise floor) level by 3.8 dB, and the 90% noise floor level averaged for all test locations was lower than this level by 1.4 dB.

[17] Refer to the Section 6.3 (System Noise Floor of Wireless Phones) for this calculation.

The occupied and clean PCS spectrum noise floor results are provided in Table 5.1 through Table 5.4 below.

Table 5.1 PCS Noise Floor Test Results, Median & RMS Noise Floor Levels

Test Location #	Market Type Classification	Location Type	Town, State	PCS Spectrum Measurements		
				Median Noise Floor Level		RMS Average
				Occupied Spectrum (dBm/30 kHz)[1]	Clean Spectrum (dBm/30 kHz)[2]	Clean Spectrum (dBm/1 MHz)[3]
1	Rural	House	Chalfont, PA	-127.9	-129.0	-113.2
2	Rural	Lehigh College	Schnecksville, PA	-128.9	-128.9	-112.0
3	Rural	Golf Course	Saucon Valley, PA	-126.1	-128.5	-113.0
4	Suburban	ABE Airport	Allentown, PA	-125.9	-128.9	n/a
5	Suburban	Office Bldg	Blue Bell, PA	-129.0	-129.0	-112.6
6	Suburban	House	Warminster, PA	-129.0	-129.0	-112.2
7	Suburban	Appt Bldg	Allentown, PA	-128.9	-129.0	-112.1
8	Suburban	Lehigh Valley Mall	Whitehall, PA	-128.8	-129.0	-112.1
9	Suburban	Drive Test	Ambler, PA	-128.9	-129.0	n/a
10	Urban	PHL Airport	Philadelphia, PA	-128.8	-129.0	n/a
11	Urban	House	Philadelphia, PA	-128.6	-129.0	-111.9
12	Urban	PHL 30th Train Station	Philadelphia, PA	-122.7	-129.0	n/a
			Average	-127.8	-128.9	-112.4

Table 5.2 Median & RMS Noise Floor Levels, Averaged by Market Type

Market Type Classification	Average per Classification, Median & RMS Results		
	Occupied Spectrum (dBm/30 kHz)	Clean Spectrum (dBm/30 kHz)	Clean Spectrum (dBm/1 MHz)
Urban	-126.7	-129.0	-111.9
Suburban	-128.4	-129.0	-112.3
Rural	-127.6	-128.8	-112.7

Table 5.3 PCS Noise Floor Test Results, 90% Noise Floor Level

Test Location #	Market Type Classification	Location Type	Town, State	PCS Spectrum Measurements 90% Noise Floor Level	
				Occupied Spectrum (dBm/30 kHz)[1]	Clean Spectrum (dBm/30 kHz)[2]
1	Rural	House	Chalfont, PA	-125.7	-128.6
2	Rural	Lehigh College	Schnecksville, PA	-128.1	-128.4
3	Rural	Golf Course	Saucon Valley, PA	-123.0	-127.3
4	Suburban	ABE Airport	Allentown, PA	-121.2	-128.2
5	Suburban	Office Bldg	Blue Bell, PA	-128.5	-128.6
6	Suburban	House	Warminster, PA	-128.6	-128.6
7	Suburban	Appt Bldg	Allentown, PA	-128.2	-128.6
8	Suburban	Lehigh Valley Mall	Whitehall, PA	-126.0	-128.6
9	Suburban	Drive Test	Ambler, PA	-125.7	-128.6
10	Urban	PHL Airport	Philadelphia, PA	-127.6	-128.6
11	Urban	House	Philadelphia, PA	-126.4	-128.6
12	Urban	PHL 30th Train Station	Philadelphia, PA	-116.0	-128.6
			Average	-125.4	-128.4

Table 5.4 90% Noise Floor Level, Averaged by Market Type

Market Type Classification	Average per Classification, 90% Level	
	Occupied Spectrum (dBm/30 kHz)	Clean Spectrum (dBm/30 kHz)
Urban	-123.3	-128.6
Suburban	-126.4	-128.5
Rural	-125.6	-128.1

Notes for Tables 5.1 though 5.4:

1. The occupied PCS spectrum measurements were performed with the Grayson test receiver having a receiver bandwidth of 30 kHz. These measurements were performed within occupied PCS spectrum in a market utilizing TDMA technology. The noise floor level measurements were performed over a 4-hour or 24-hour period for the stationary test locations, and ½ hour for the mobile drive test. These results include the 50% threshold as the Median Noise Floor Level (Table 5.1 & 5.2), and the 90% Noise Floor Level (Table 5.3 & 5.4). The 50% and 90% noise floor levels are calculated using linear interpolation from the cumulative probability series data. The measurement data is provided in Appendix Section 8.2.

2. The clean PCS spectrum measurements performed with the Grayson test receiver having a receiver bandwidth of 30 kHz, were performed in cleared, unused PCS spectrum. The noise floor level measurements were performed over a 4-hour or 24-hour period for the stationary test locations, and ½ hour for the mobile drive test. These results include the 50% threshold as the Median Noise Floor Level (Table 5.1 & 5.2), and the 90% Noise Floor Level (Table 5.3 & 5.4). The 50% and 90% noise floor levels are calculated using linear interpolation from the cumulative probability series data. The measurement data is provided in Appendix Section 8.2.

3. The clean PCS spectrum measurements performed with the spectrum analyzer using a 1 MHz resolution bandwidth were performed in cleared PCS spectrum, which was not yet utilized by the operator. These spectrum measurements were performed with the spectrum analyzer and pre-amplifier equipment. Due to the test location accessibility, test logistics and mobile environment, these measurements were performed at eight of the twelve field locations. The test results for these eight locations offer a comparison to the clean spectrum results using a 30 kHz bandwidth. The spectrum analyzer tests were conducted in accordance with the FCC test procedures for measuring true RMS noise power levels, as described in the Test Procedures section of this report. The RMS averaged power levels for the spectrum analyzer noise floor measurements are provided in Table 5.1 & 5.2, above. The spectrum analyzer measurement data is provided in Appendix Section 8.3.

4. All signal level units are in dBm, referenced to the antenna port of a PCS unity gain (0 dBi) isotropic antenna. These measurements are performed within the forward-link PCS spectrum band (base to mobile), at the twelve field test locations.

6. Analysis of Test Results and Noise Floor Issues

6.1. Spectrum Noise Floor Levels in Today's PCS Bands

The PCS spectrum noise measurements included in this study indicate low noise floor levels existing in the clean and occupied PCS spectrum bands in these market areas. The occupied spectrum noise floor measurements are for the PCS forward-link band of a mature, optimized TDMA network and the clean spectrum noise measurements are performed in cleared, unused spectrum. The field measurements were performed at locations that are representative of typical subscriber locations within urban, suburban, and rural market areas.

The results of the clean spectrum measurements indicate very low noise floor conditions existing in these market areas. For many field locations the noise floor levels for the clean spectrum measurements did not increase above the thermal noise floor level. With these low noise floor conditions, wireless carriers can deploy networks without environmental noise encumbering system performance.

The results of the occupied spectrum measurements indicate low noise floor conditions existing in these market areas. The following factors contributed to the low operating noise floor levels exhibited in the occupied spectrum tests performed within an operating PCS TDMA network. It should be noted that these factors would impact the reverse link as well as the forward link spectrum bands.

<u>In-building Wireless Phone Measurements</u> – The usage of wireless phones inside buildings has increased considerably over the past years. The decrease in signal and noise levels for these inside locations are approximately 10 to 30 dB, due to the signal attenuation of the building structure. For these in-building locations, the background noise and system interference levels are decreased for the phones inside these locations as compared to levels outside the building. This allows PCS phone service to be maintained with lower signal levels received at the phone as compared to outdoor locations where the noise floor is higher. Seven of the twelve test locations included in this study were performed within buildings adjacent to an outside window. These in-building locations are expected to exhibit lower operating noise levels than outdoor locations.

<u>Cell Sites Using Sector Antennas</u> – The most common PCS base station antenna is the panel antenna. Most PCS networks utilize these cell site panel antennas in 3-sectored configurations. The panel antenna improves the performance of PCS systems by achieving more gain in the intended 120-degree sector coverage area, and more protection from system co-channel interference in the other 240 degrees. This allows the cell site coverage areas to achieve lower operating noise floor conditions for forward and reverse links, from nearby co-channel and adjacent channel interference. The sector antenna's interference noise floor reduction will be in the range of 5 to 30 dB,

depending on the antenna's horizontal beam-width pattern. [18] In addition, the interference noise floor can be lower in cases when the antenna is mounted on a water tank or building wall, which further attenuates the interference from these directions. Omni-directional antennas have gain in all directions (360 degrees) and consequently result in higher noise floor levels in the coverage area of the cell site.

Dynamic Power Control – Most TDMA markets utilize improved forward-link Dynamic Power Control (DPC) algorithms within cell site transmitters. These algorithms improve the performance of PCS network by lowering the cell site transmission levels to the minimum levels required to maintain quality calls. This, in turn lowers the operating noise floor throughout the PCS system. These algorithms are able to lower the signal levels up to 35 dB by utilizing control mechanisms based on the received signal strength and/or call quality level (Bit Error Rate) of each phone call.

Mature PCS Network Design – The use of wireless service has increased dramatically over the past years. PCS and cellular networks have matured and evolved to meet this growing demand. Mature PCS systems exhibit the following trends in network design.

1. Smaller cell sites with lower antenna elevations (closer to the height of the clutter of trees and buildings). This allows the cell site transmitters to operate at lower power levels and thus lowers the operating noise floor of the surrounding area, which increases system capacity. Also, smaller cell sites allow mobile phones to operate at lower power levels, which in turn lowers the interference levels received by the co-channel and adjacent channel cell sites.

2. Downtilting antennas are commonly used in mature PCS systems to better control the forward link RF energy being transmitted by the cell. This has an overall effect of lowering the interference noise floor throughout the coverage area of the network.

3. Narrow horizontal beam-width antennas are used to reduce the cell site's interference noise floor, by limiting the interference that can be seen from the edges of the sector antenna. Antennas with horizontal beam-width of 60 to 80 degrees have become more common in mature PCS networks. Similar to the panel sector antennas, these narrower beam width antennas offer further improvements, lowering the operating noise floor level at the mobile phone location (forward-link) and cell site (reverse-link).

4. Underlay/Overlay Cells are utilized in some mature PCS market areas to achieve improved system performance with designated channels having lower system interference levels serving calls within the outer-ring coverage areas, and channels with higher noise floor levels serving calls within inner-ring coverage areas. Handoffs are performed between the base station inner-ring and outer-ring serving areas from one channel group to another. This network channel assignment feature allows a

[18] The maximum improvement in the noise floor on a channel will be on the order of approximately 30 dB, for users directly behind a panel antenna having a high front-to-back ratio. These improvements in the noise floor will be experienced at the cell site (reverse-link) and the mobile phone user (forward-link).

PCS system to provide improved phone service with lower signal levels on channels with less co-channel interference, for the base stations' outer-ring service areas. This results in lower noise floor conditions for channels designated to outer-ring serving areas, which improves wireless service on channels where its needed most.

5. Discontinuous transmission and sleep modes are other features utilized by some TDMA network operators to further improve system performance and lower system noise levels within its network market areas.

The above trends in mature PCS markets and network design have contributed to lowering the forward-link operating noise floor level within the network service area. The results of this PCS Noise Floor Study exhibit this trend.

6.2. Smart Antenna Technology

The PCS base station equipment used by Cingular Wireless in these market areas utilize standard and typical base station equipment. Some equipment vendors offer improved smart antenna technology that offers system improvements for the forward and reverse link spectrum bands. Two examples of smart antenna technology for TDMA systems are listed below. Both offer the ability to serve calls at lower operating levels, which in turn lowers the operating noise floor of the PCS system. These smart antenna applications are not standard or commonly deployed across PCS markets, but are deployed in special applications and offer improvements in spectrum efficiency for the wireless subscribers where deployed.

<u>Smart antenna technology utilizing micro-sector antennas</u> – exhibit lower operating noise floor levels, due to the interference protection provided by the antenna's horizontal beam-width characteristics. Typical horizontal beam-width specification for this application is 30 degrees.

<u>Smart antenna technology utilizing adaptive array antenna systems</u> – exhibit lower interference noise floor levels, due to interference reductions provided by interference nulling and canceling algorithms.

6.3. System Noise Floor of Wireless Phones

The *system* noise floor is the lowest noise level that can be achieved by the receive system of a wireless phone. It is represented in the analysis below by calculating the thermal noise floor of the device and adding the phone equipment's system noise figure. The noise floor level may vary across wireless phone receivers depending on the manufacturer. Included in this analysis are approximate values and assumptions for the characteristics that contribute to the system noise floor of wireless TDMA subscriber phones.

To calculate the *system* noise floor of a wireless phone receiver, the following system noise equation is used, which adds the thermal noise floor to the phone equipment's system noise figure.

System Noise Floor = Thermal Noise Floor + System Noise Figure

System Noise Figure – the typical system noise figure of wireless TDMA phones is approximately 5 to 8 dB, varying by manufacturer.

Thermal Noise Floor – The thermal noise floor is calculated with the formula Power = KTB, where K is Boltzmann's constant = 1.37 x 10^{-23} joules/Kelvin, T is the temperature in Kelvin, and B is the bandwidth of the receiver. Using T = 290 K (i.e. room temperature), the thermal noise floor is equal to –129.2 dBm, for a TDMA receiver having a nominal channel bandwidth of 30 kHz.

Using these thermal noise floor and system noise figure parameters, the TDMA phone equipment's system noise floor is equal to approximately –124 dBm to –121 dBm.

For the PCS market areas that exhibit lower operating noise floor values than –124 dBm for the forward-link within occupied TDMA spectrum, these areas represent opportunities for carriers and manufacturer's to improve system performance and utilization of spectrum by improving handset noise figure design characteristics.

7. Conclusion

The PCS noise floor measurements included in this study indicate low operating noise floor levels existing in the clean and occupied PCS spectrum bands in these market areas. Field measurements were performed within the forward-link PCS spectrum band at typical locations where wireless subscribers use wireless telephones.

The clean spectrum measurements provides a baseline of the thermal and ambient environmental noise floor levels existing in the PCS market area, prior to any wireless service offered in the PCS spectrum band. In all field locations, the median noise floor levels of the clean spectrum measurements were within 1 dB of its thermal noise floor level (KTB for 30 kHz bandwidth is -129 dBm), and the 90% noise floor levels were within 2 dB. The results of the clean spectrum measurements indicate very low noise floor conditions existing in the market. For many field locations the noise floor levels for the clean spectrum measurements did not increase above the thermal noise floor level, as indicated in the receiver measurements using a 30 kHz bandwidth. Therefore, the results of this study indicate that the environmental noise levels occurring in these market areas are not appreciably increased above the thermal noise floor level. With these low noise floor conditions, wireless carriers can deploy networks without environmental noise encumbering system performance.

The occupied spectrum measurements provides the operating noise floor level that includes co-channel and adjacent channel system interference from a carrier's network, in addition to the background environment noise level. The results of the occupied spectrum measurements indicate low noise floor level conditions existing within the market. For the majority of the field locations, the median and 90% noise floor levels for the occupied spectrum measurements were below the system noise floor of typical TDMA subscriber phone equipment. With these low operating noise floor levels within occupied PCS spectrum, wireless phone service can be maintained to low operating signal levels.

TDMA phone service can be maintained on the forward-link with operating signals between –104 to –107 dBm (the minimum signal level for "toll quality" service), with typical phone equipment noise floor and 17 dB C/I margin. [19] In the presence of considerable signal fading, an additional fade margin may be required to maintain quality service and is based upon an acceptable threshold for area coverage reliability.

For PCS market locations that exhibit lower operating noise floor values than –124 dBm for the forward-link within occupied TDMA spectrum, these areas represent opportunities for carriers and manufacturer's to improve system performance and spectral efficiency by improving wireless handset noise figure characteristics. The median operating noise floor level, on average for all test locations, was lower than the –124 dBm (phone's

[19] Refer to the Section 6.3 (System Noise Floor of Wireless Phones) for this calculation.

lowest noise floor) level by 3.8 dB, and the 90% noise floor level on average was lower than this level by 1.4 dB.

In addition, the test results indicate the following conclusions:

- The median noise floor results for the occupied spectrum measurements, using a 30 kHz receiver, are –122.7 dBm to –129 dBm, with an average of –127.8 dBm. The median noise floor results for the clean spectrum measurements, using a 30 kHz receiver, are –128.5 dBm to –129 dBm, with an average of –128.9 dBm. The RMS average noise floor results for the clean spectrum measurements, within a 1 MHz bandwidth, are –111.9 dBm to –113.2 dBm, with an average of –112.4 dBm.

- The median noise floor level for the occupied spectrum measurements is on average approximately 1 dB above the clean spectrum noise floor level. The 90% noise floor level for the occupied spectrum measurements is on average approximately 3 dB above the clean spectrum noise floor level. These results show a slight increase in the operating noise floor for occupied spectrum as compared to clean spectrum.

- The occupied spectrum measurements averaged per market type indicate similar median noise floor levels (–128 dBm) for the rural and suburban market environments, with an increase in the urban market by about 1 dB. The clean spectrum measurements indicate similar median and 90% noise floor levels as averaged for each market type: urban, suburban, and rural markets (from –128 to –129 dBm).

- For occupied spectrum measurements, the 90% noise floor level is on average 2.4 dB higher than median noise floor level. For clean spectrum measurements, the 90% noise floor level is on average 0.5 dB higher than median noise floor level. The occupied spectrum measurements show some fluctuations over the measurement interval (4-hour or 24-hour). The clean spectrum measurements show very little fluctuations over the measurement interval.

- The average RMS noise floor level with a 1 MHz bandwidth is 16.5 dB higher than the median noise floor level with a 30 kHz bandwidth, for the clean spectrum measurements. The increased noise floor level exhibited with the 1 MHz bandwidth is expected, since the spectrum analyzer measurements utilized a wider bandwidth setting than the test receiver.

In relation to CDMA technology having a nominal bandwidth of 1.25 MHz, the average RMS noise level with a 1 MHz bandwidth is similar to the levels CDMA phones would experience in clean spectrum. Using the power to bandwidth relationship, the additional noise in a 1.25 MHz bandwidth is 1 dB, as compared to a 1 MHz bandwidth. With CDMA technology, the system is able to utilize the lower noise floor conditions occurring in these market areas with the system's processing gain, which is able to utilize signals below the thermal noise floor of its receivers. For CDMA systems, when the environmental noise conditions are very low, the system can fully utilize the spectrum and offer maximum coverage and capacity.

8. Appendix

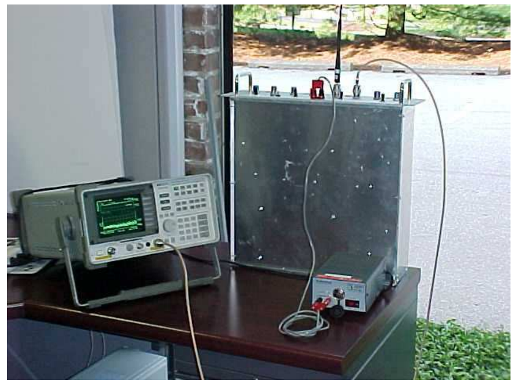
8.1 Pictures of Test Setup

Picture 1 & 2 – In-building Grayson Receiver Test Setup

These photos illustrate the typical setup for in-building measurements with the Grayson test receiver, with the test equipment & antenna adjacent to an outside window.

Picture 3 & 4 – In-vehicle Grayson Receiver Test Setup

These photos illustrate the typical setup for in-vehicle measurements with the Grayson test receiver, with the test equipment & antenna in the middle row seat, adjacent to the window.



Picture 5 & 6 – In-building Spectrum Analyzer Test Setup

These photos illustrate the typical setup for in-building measurements with the Spectrum Analyzer and preamplifier equipment, with the equipment & antenna adjacent to an outside window.

Picture 7 – In-vehicle Spectrum Analyzer Test Setup

This photo illustrates the typical setup for in-vehicle measurements with the Spectrum Analyzer and preamplifier equipment, with the equipment & antenna in the middle row seat, adjacent to the window.

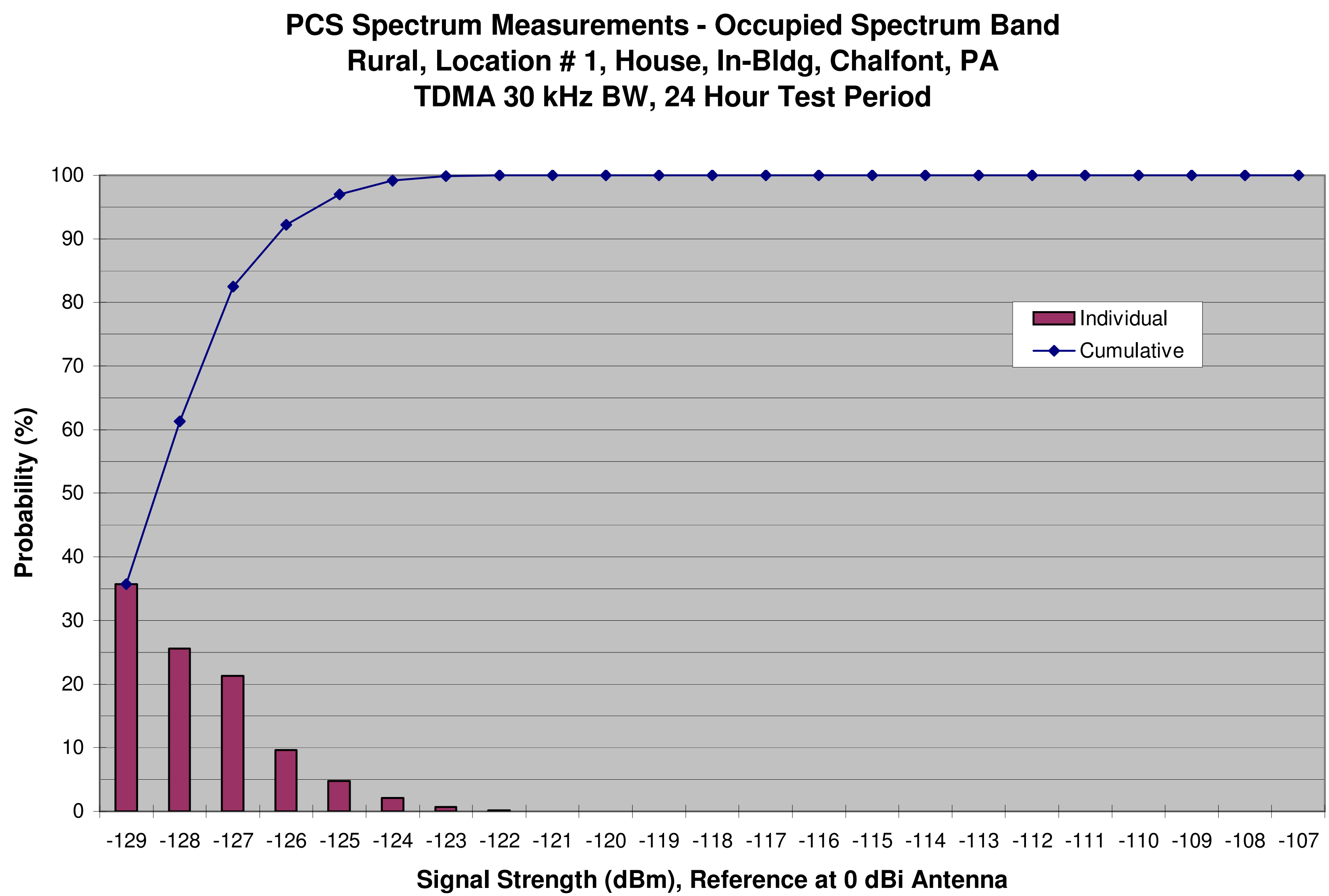
8.2 Spectrum Measurements with 30 kHz Receiver

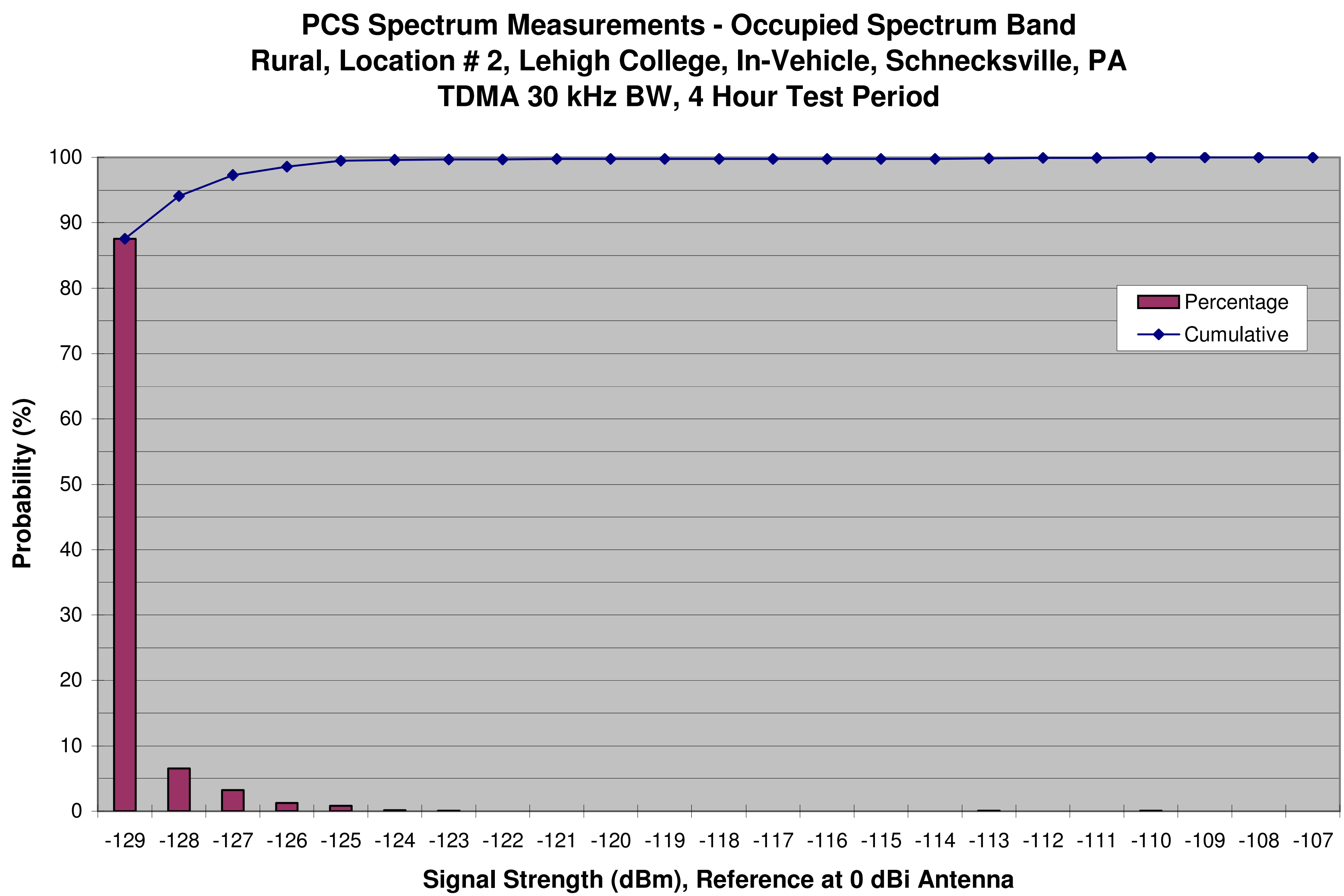
The following 24 pages contain the PCS spectrum noise floor measurements for the twelve test locations for the occupied spectrum band tests and clean spectrum band tests. Measurements were performed with the Grayson test receiver, which uses a 30 kHz bandwidth. The noise floor level measurements are performed over a 4-hour or 24-hour period for the stationary test locations, and ½ hour for the mobile drive test.

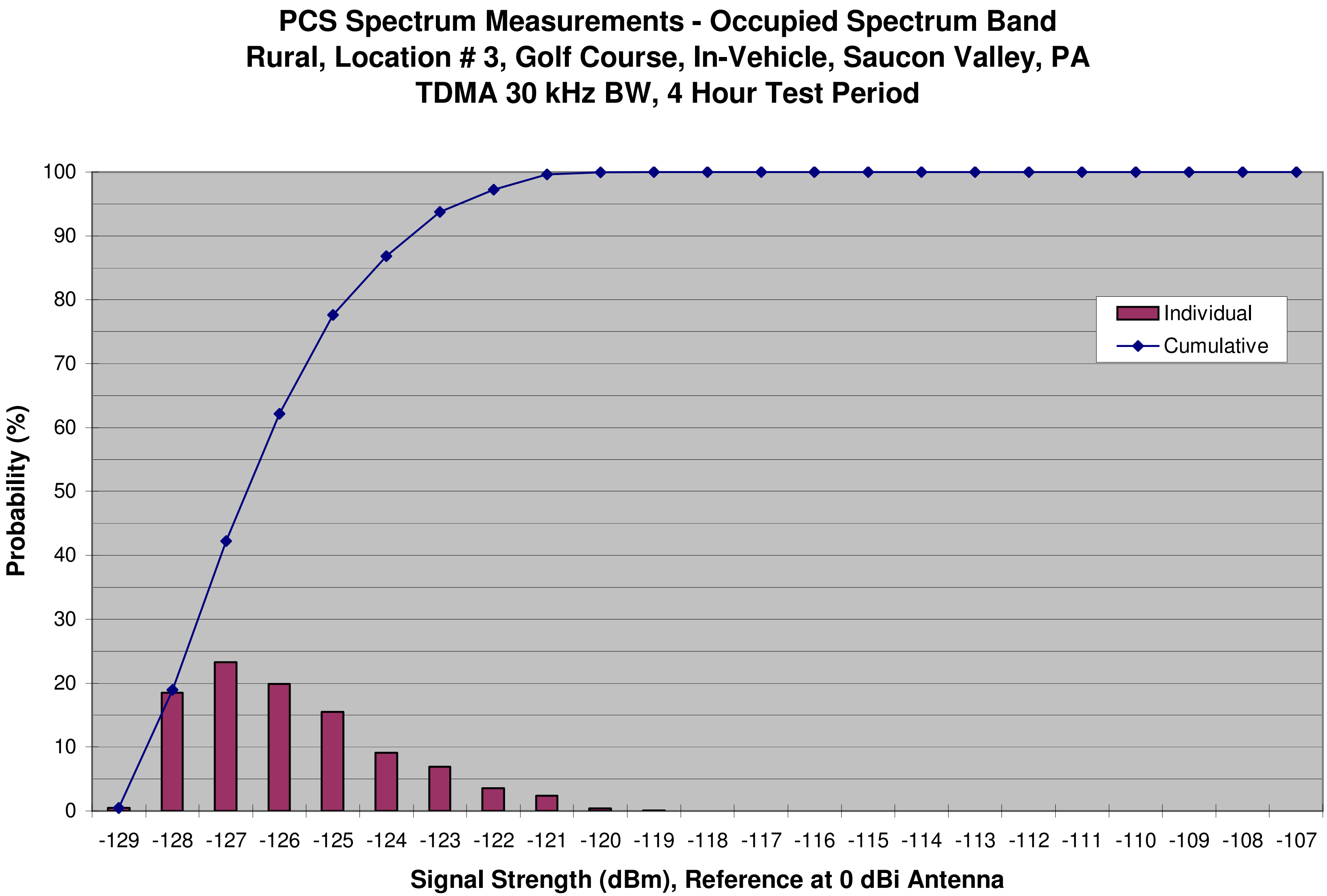
The Grayson test receiver measurements are collected into “bins” that are 1 dB in resolution. The reference value of each bin is the center value of the bin, and is represented by the x-axis value on the graphs. With this bin size, each bin includes measured data that is 0.5 dB above and below the x-axis reference value.

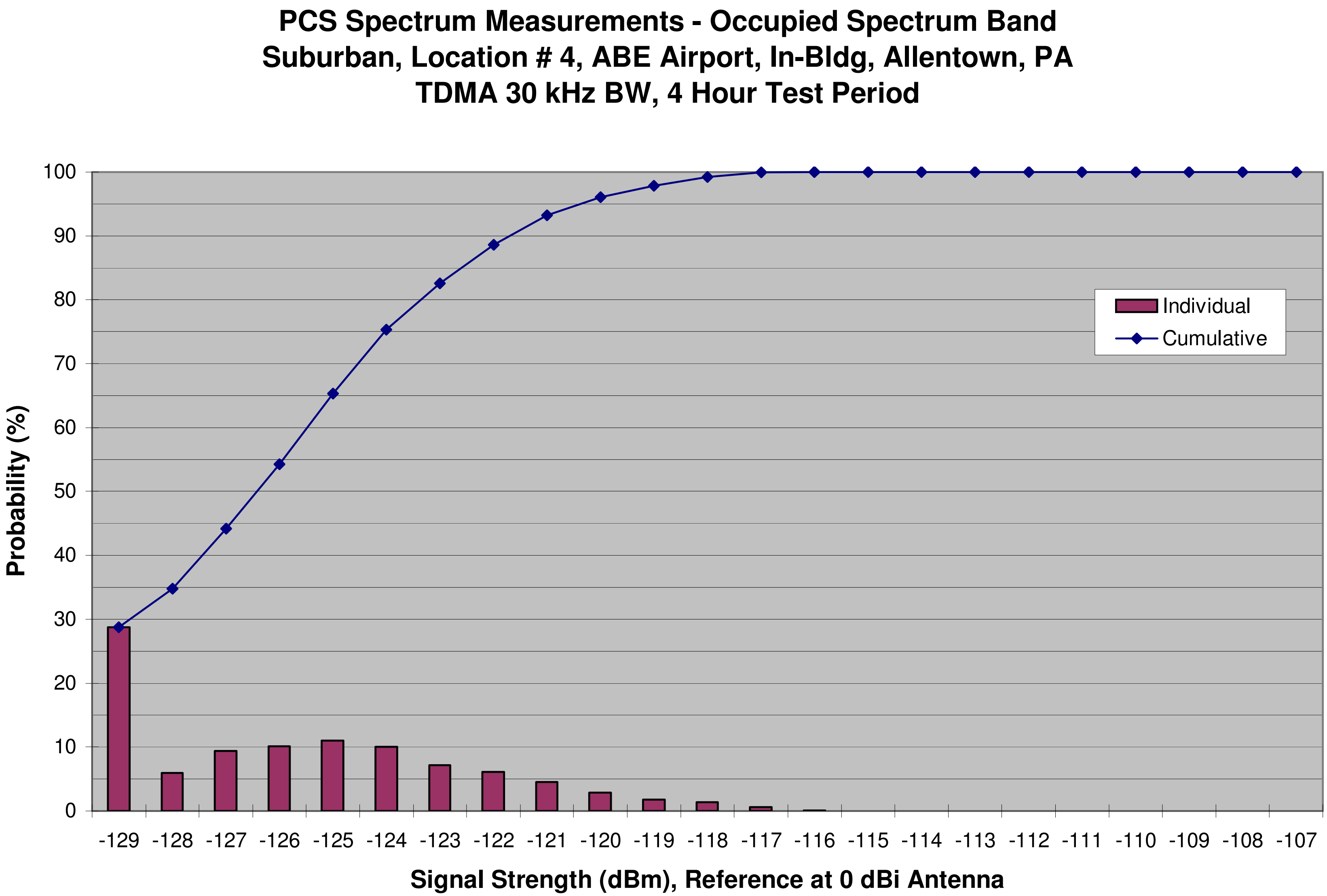
The graphs contain the individual probability and cumulative probability distributions. The individual probability is the probability of occurrence of an individual bin or data point. The reference value of this data is represented by the average value of the bin, which is the center of the bin. The cumulative probability is the probability of occurrence of an individual bin, plus the accumulation of all prior bins starting from the minimum value on the x-axis. The reference value of this data is represented by the upper value of the bin, since all the data within the bin must be included. The upper value of the bin is 0.5 dB above the center value of the bin.

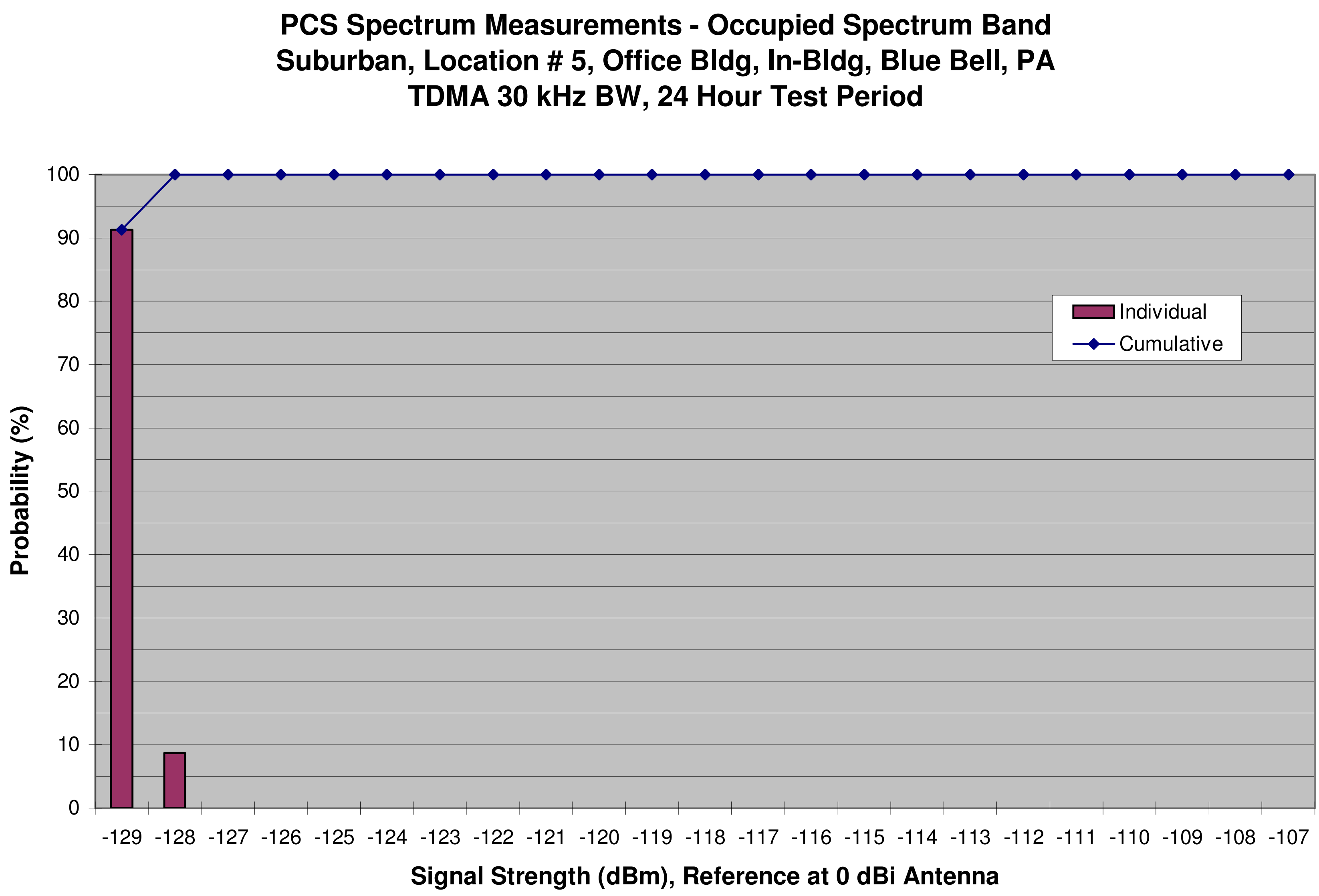
The PCS Noise Floor Test Results in Section 5 of this report include the 50% threshold as the Median Noise Floor Level (Table 5.1), and the 90% Noise Floor Level (Table 5.3). The 50% and 90% noise floor levels are calculated from the cumulative probability series data. Linear interpolation is used for values that are contained between 2 data points.

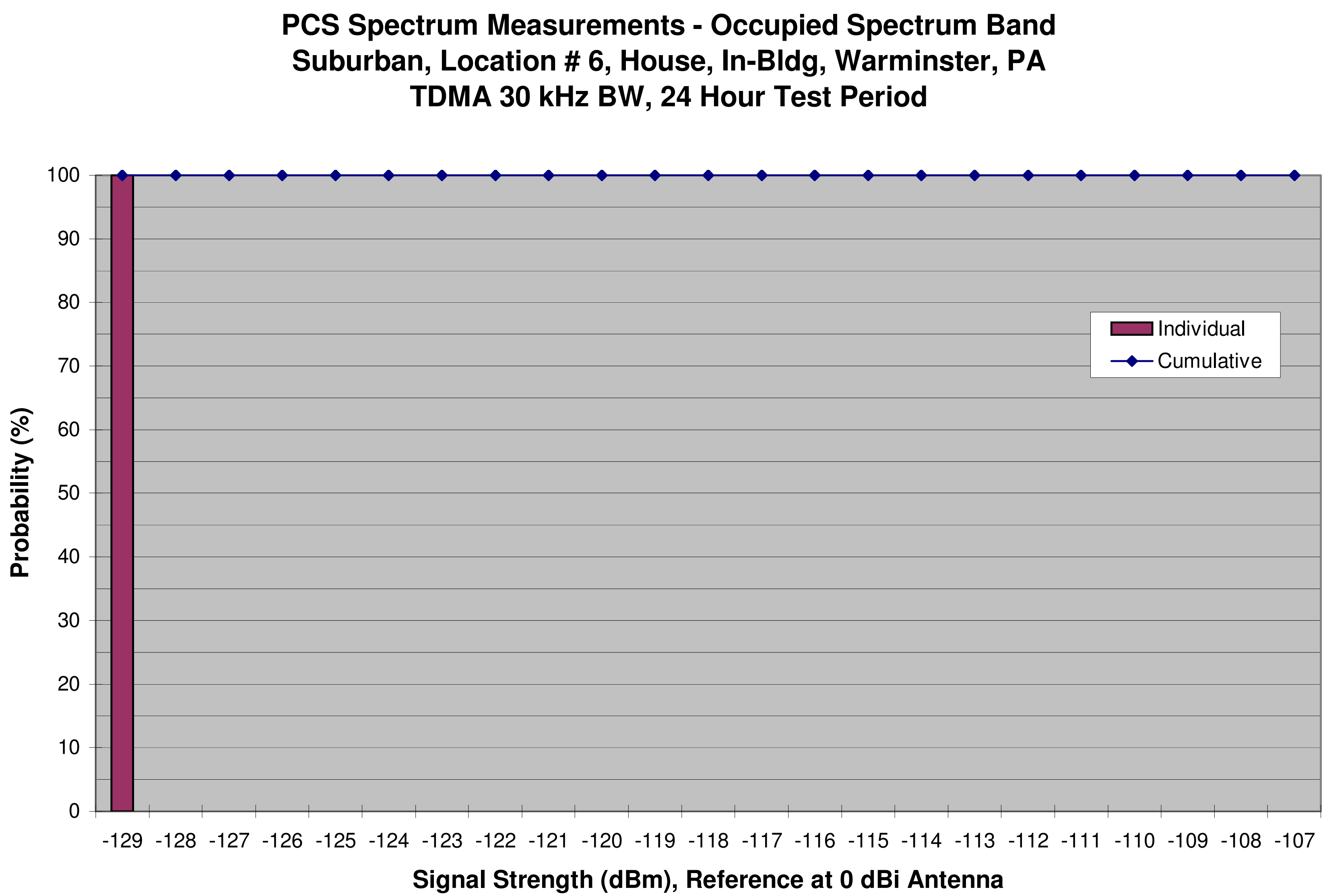

PCS Spectrum Measurements - Occupied Spectrum Band
Rural, Location # 1, House, In-Bldg, Chalfont, PA
TDMA 30 kHz BW, 24 Hour Test Period
Probability (%)
100
90
80
70
60
50
40
30
20
10
0
Individual
Cumulative
-129 -128 -127 -126 -125 -124 -123 -122 -121 -120 -119 -118 -117 -116 -115 -114 -113 -112 -111 -110 -109 -108 -107
Signal Strength (dBm), Reference at 0 dBi Antenna

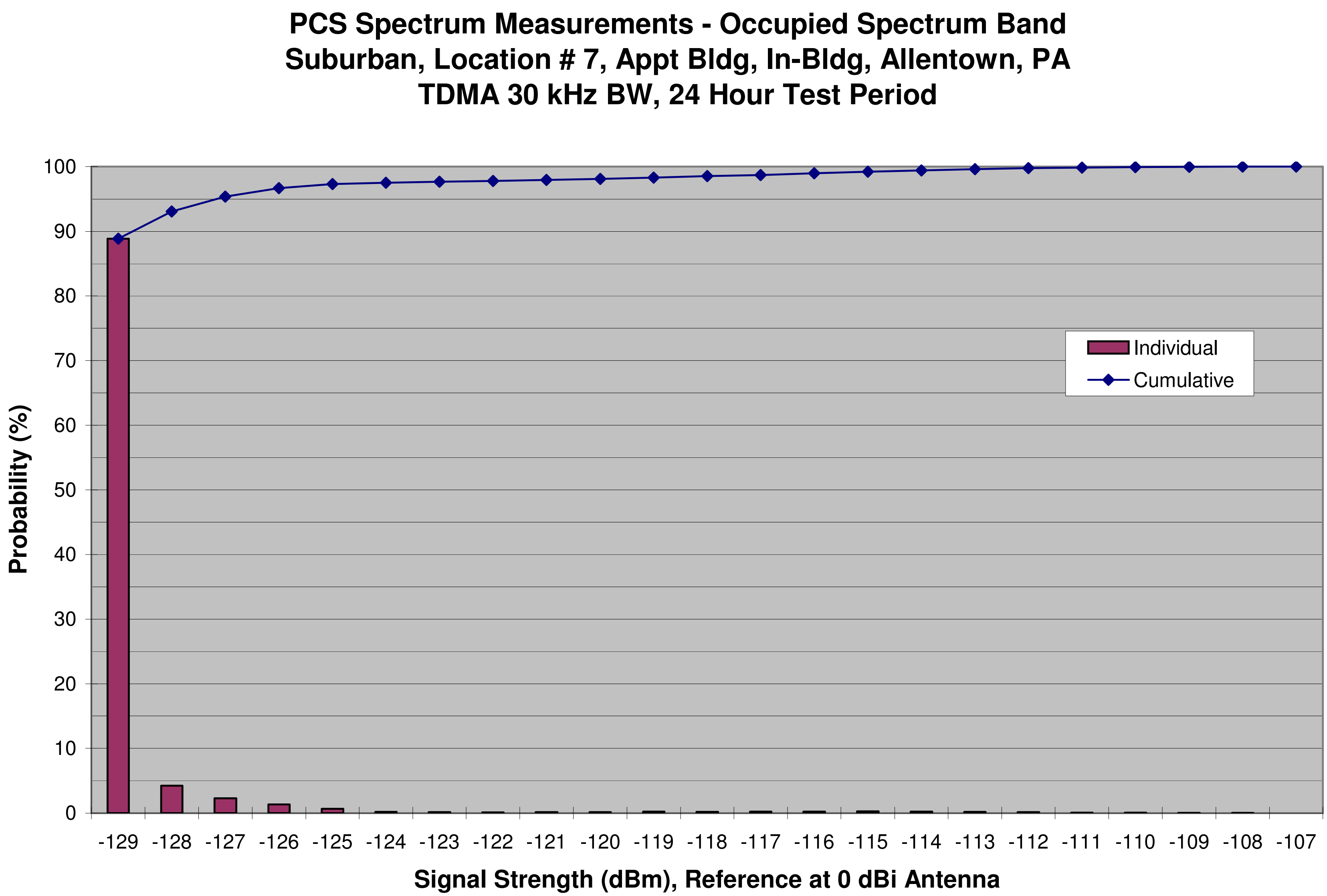

PCS Spectrum Measurements - Occupied Spectrum Band
Rural, Location # 2, Lehigh College, In-Vehicle, Schnecksville, PA
TDMA 30 kHz BW, 4 Hour Test Period
Probability (%)
100
90
80
70
60
50
40
30
20
10
0
Percentage
Cumulative
-129 -128 -127 -126 -125 -124 -123 -122 -121 -120 -119 -118 -117 -116 -115 -114 -113 -112 -111 -110 -109 -108 -107
Signal Strength (dBm), Reference at 0 dBi Antenna

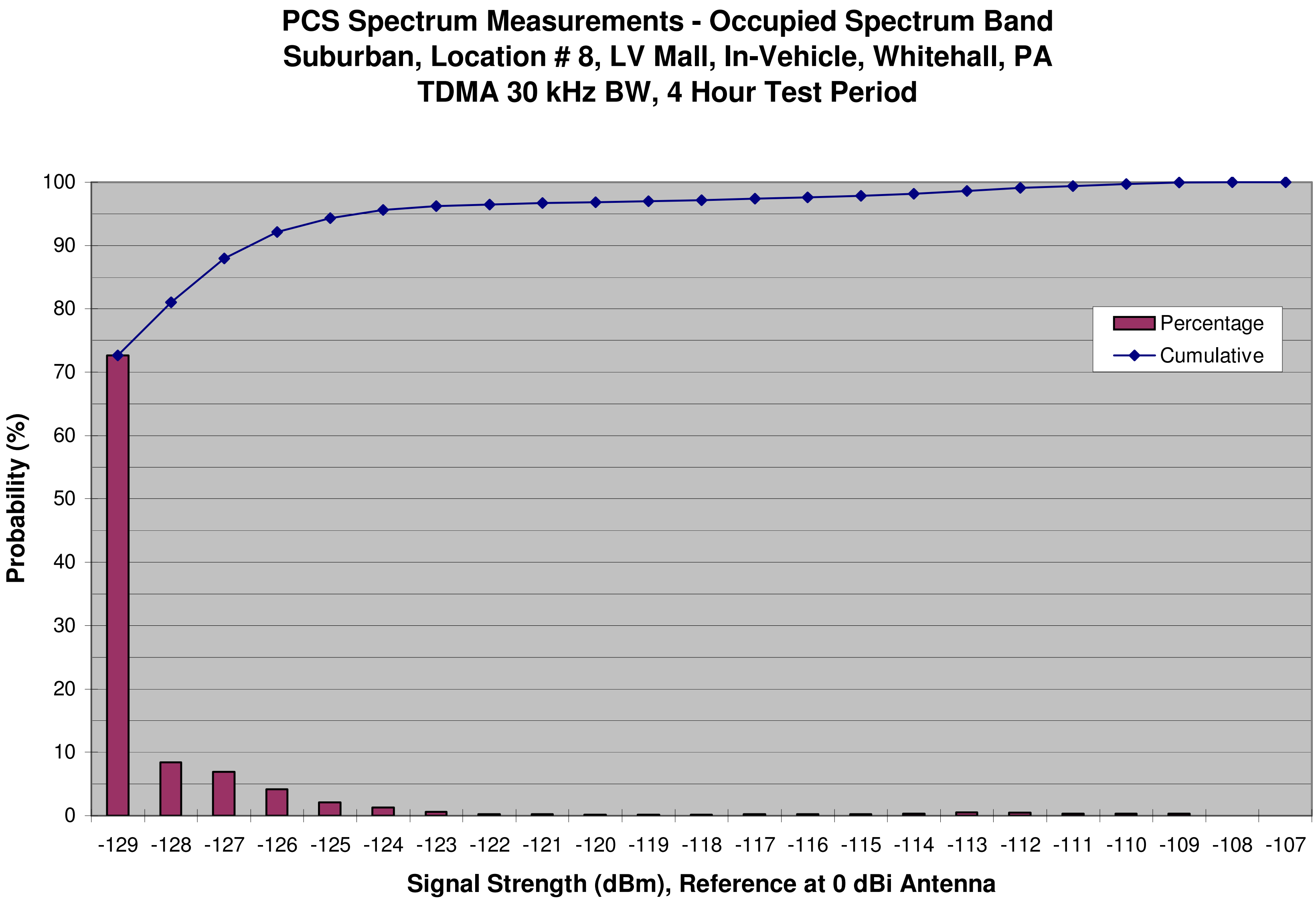

PCS Spectrum Measurements - Occupied Spectrum Band
Rural, Location # 3, Golf Course, In-Vehicle, Saucon Valley, PA
TDMA 30 kHz BW, 4 Hour Test Period
Probability (%)
100
90
80
70
60
50
40
30
20
10
0
Individual
Cumulative
-129 -128 -127 -126 -125 -124 -123 -122 -121 -120 -119 -118 -117 -116 -115 -114 -113 -112 -111 -110 -109 -108 -107
Signal Strength (dBm), Reference at 0 dBi Antenna

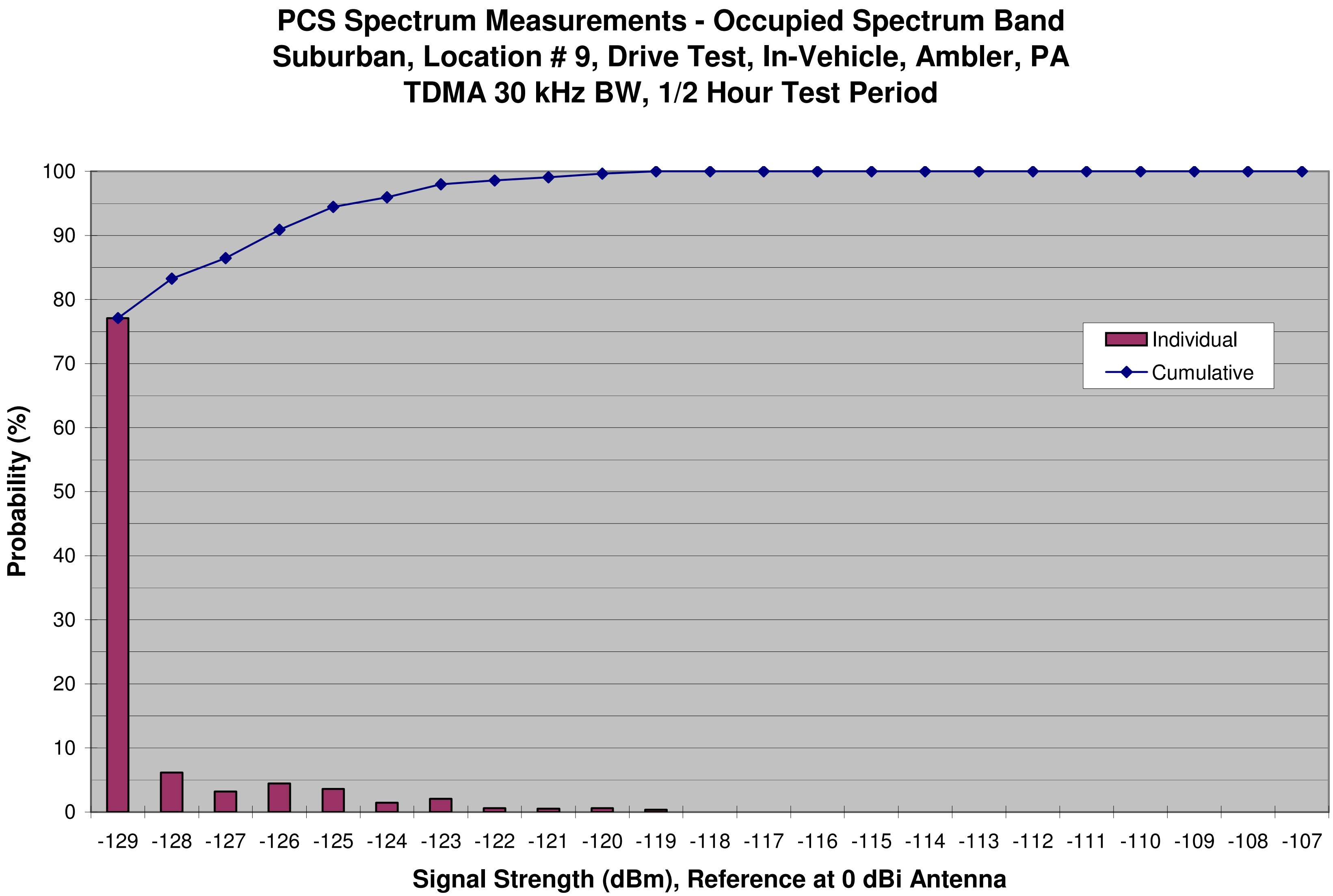

PCS Spectrum Measurements - Occupied Spectrum Band
Suburban, Location # 4, ABE Airport, In-Bldg, Allentown, PA
TDMA 30 kHz BW, 4 Hour Test Period
Individual
Cumulative
Probability (%)
0
10
20
30
40
50
60
70
80
90
100
-129 -128 -127 -126 -125 -124 -123 -122 -121 -120 -119 -118 -117 -116 -115 -114 -113 -112 -111 -110 -109 -108 -107
Signal Strength (dBm), Reference at 0 dBi Antenna

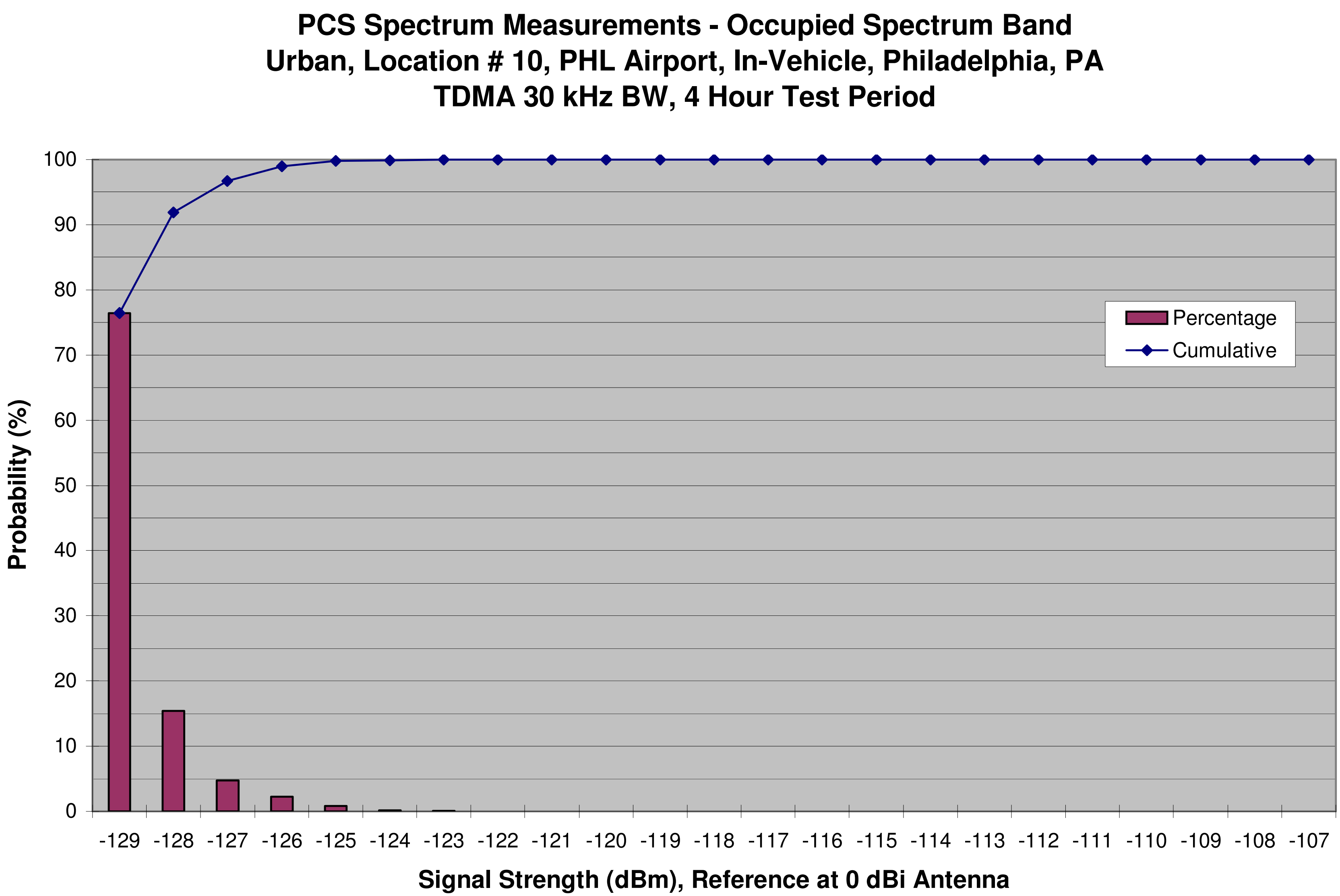

PCS Spectrum Measurements - Occupied Spectrum Band
Suburban, Location # 5, Office Bldg, In-Bldg, Blue Bell, PA
TDMA 30 kHz BW, 24 Hour Test Period
Probability (%)
100
90
80
70
60
50
40
30
20
10
0
Individual
Cumulative
-129 -128 -127 -126 -125 -124 -123 -122 -121 -120 -119 -118 -117 -116 -115 -114 -113 -112 -111 -110 -109 -108 -107
Signal Strength (dBm), Reference at 0 dBi Antenna


PCS Spectrum Measurements - Occupied Spectrum Band
Suburban, Location # 6, House, In-Bldg, Warminster, PA
TDMA 30 kHz BW, 24 Hour Test Period
Probability (%)
100
90
80
70
60
50
40
30
20
10
0
Individual
Cumulative
-129 -128 -127 -126 -125 -124 -123 -122 -121 -120 -119 -118 -117 -116 -115 -114 -113 -112 -111 -110 -109 -108 -107
Signal Strength (dBm), Reference at 0 dBi Antenna

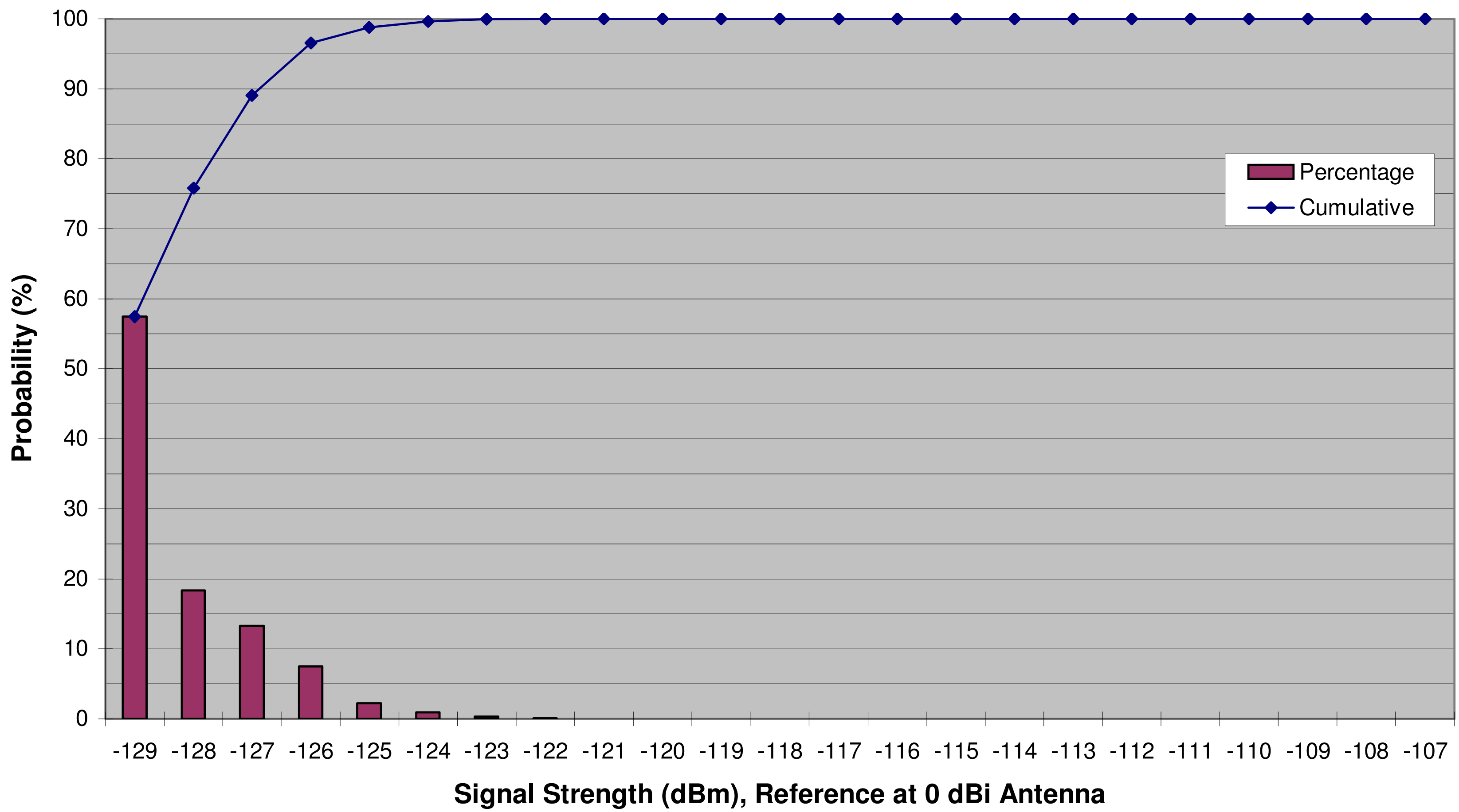

PCS Spectrum Measurements - Occupied Spectrum Band
Suburban, Location # 7, Appt Bldg, In-Bldg, Allentown, PA
TDMA 30 kHz BW, 24 Hour Test Period
Probability (%)
100
90
80
70
60
50
40
30
20
10
0
Individual
Cumulative
-129 -128 -127 -126 -125 -124 -123 -122 -121 -120 -119 -118 -117 -116 -115 -114 -113 -112 -111 -110 -109 -108 -107
Signal Strength (dBm), Reference at 0 dBi Antenna

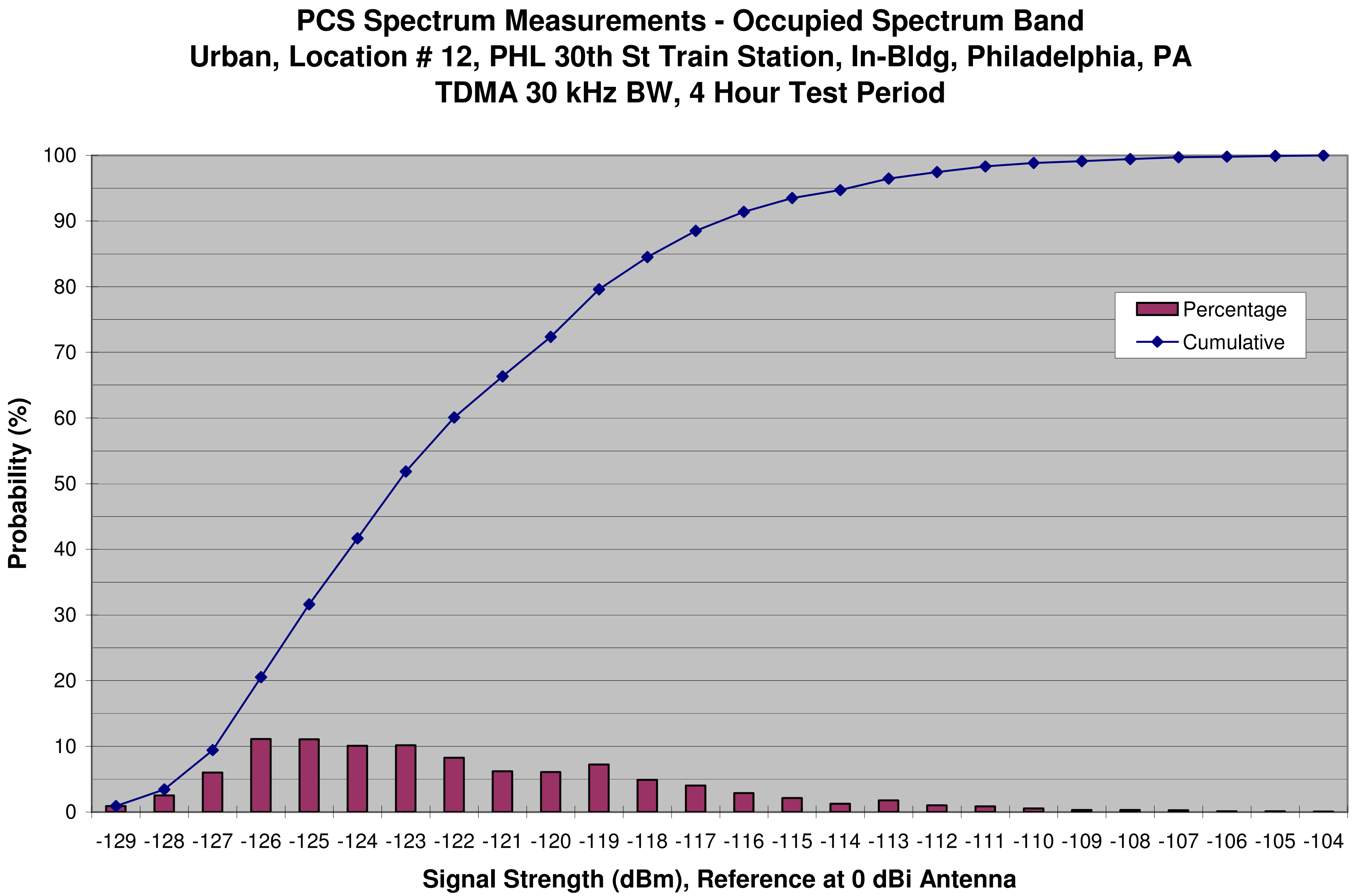

PCS Spectrum Measurements - Occupied Spectrum Band
Suburban, Location # 8, LV Mall, In-Vehicle, Whitehall, PA
TDMA 30 kHz BW, 4 Hour Test Period
Probability (%)
100
90
80
70
60
50
40
30
20
10
0
Percentage
Cumulative
-129 -128 -127 -126 -125 -124 -123 -122 -121 -120 -119 -118 -117 -116 -115 -114 -113 -112 -111 -110 -109 -108 -107
Signal Strength (dBm), Reference at 0 dBi Antenna

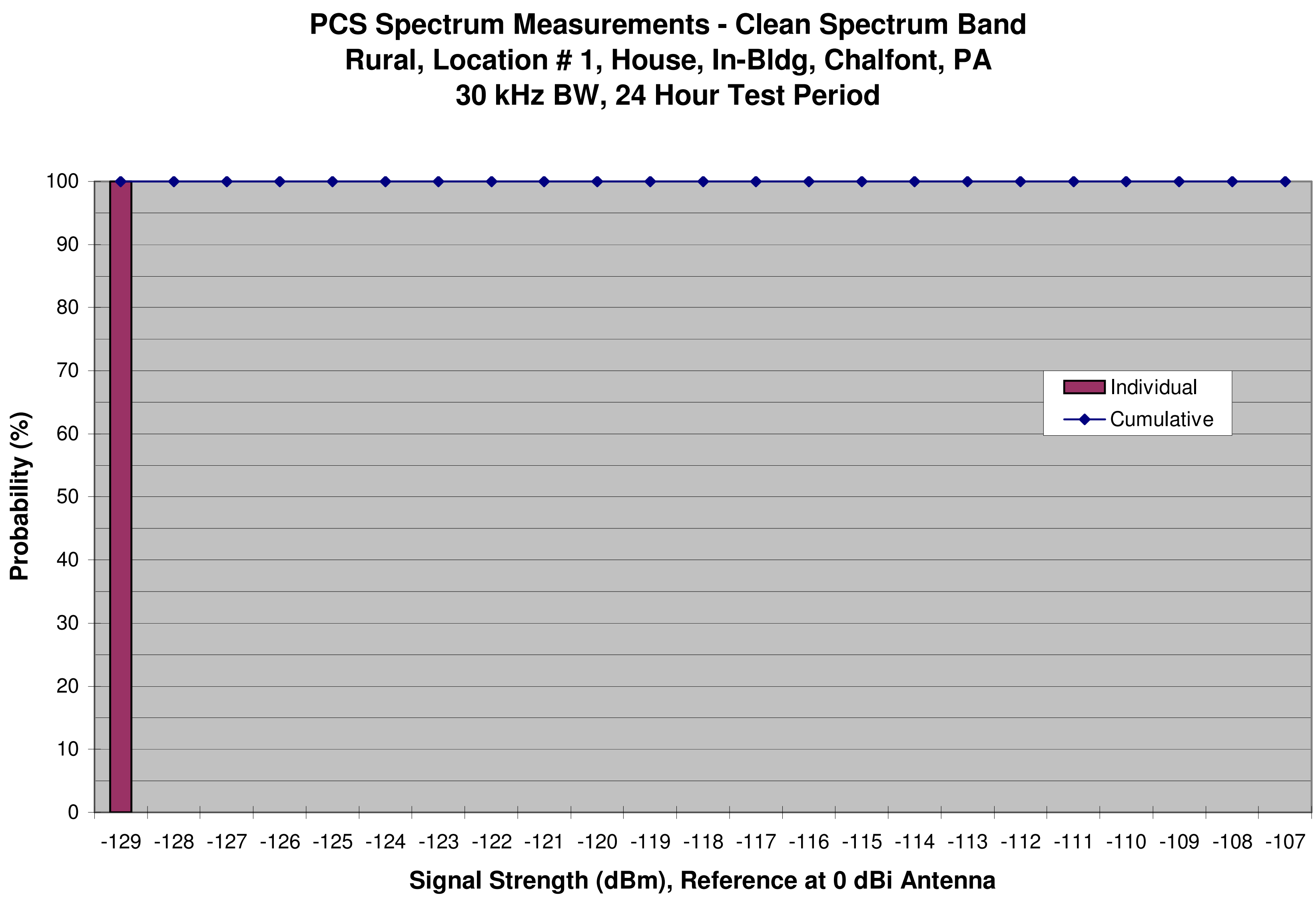

PCS Spectrum Measurements - Occupied Spectrum Band
Suburban, Location # 9, Drive Test, In-Vehicle, Ambler, PA
TDMA 30 kHz BW, 1/2 Hour Test Period
100
90
80
70
60
50
40
30
20
10
0
Probability (%)
Individual
Cumulative
-129 -128 -127 -126 -125 -124 -123 -122 -121 -120 -119 -118 -117 -116 -115 -114 -113 -112 -111 -110 -109 -108 -107
Signal Strength (dBm), Reference at 0 dBi Antenna


PCS Spectrum Measurements - Occupied Spectrum Band
Urban, Location # 10, PHL Airport, In-Vehicle, Philadelphia, PA
TDMA 30 kHz BW, 4 Hour Test Period
Probability (%)
0
10
20
30
40
50
60
70
80
90
100
Percentage
Cumulative
-129 -128 -127 -126 -125 -124 -123 -122 -121 -120 -119 -118 -117 -116 -115 -114 -113 -112 -111 -110 -109 -108 -107
Signal Strength (dBm), Reference at 0 dBi Antenna

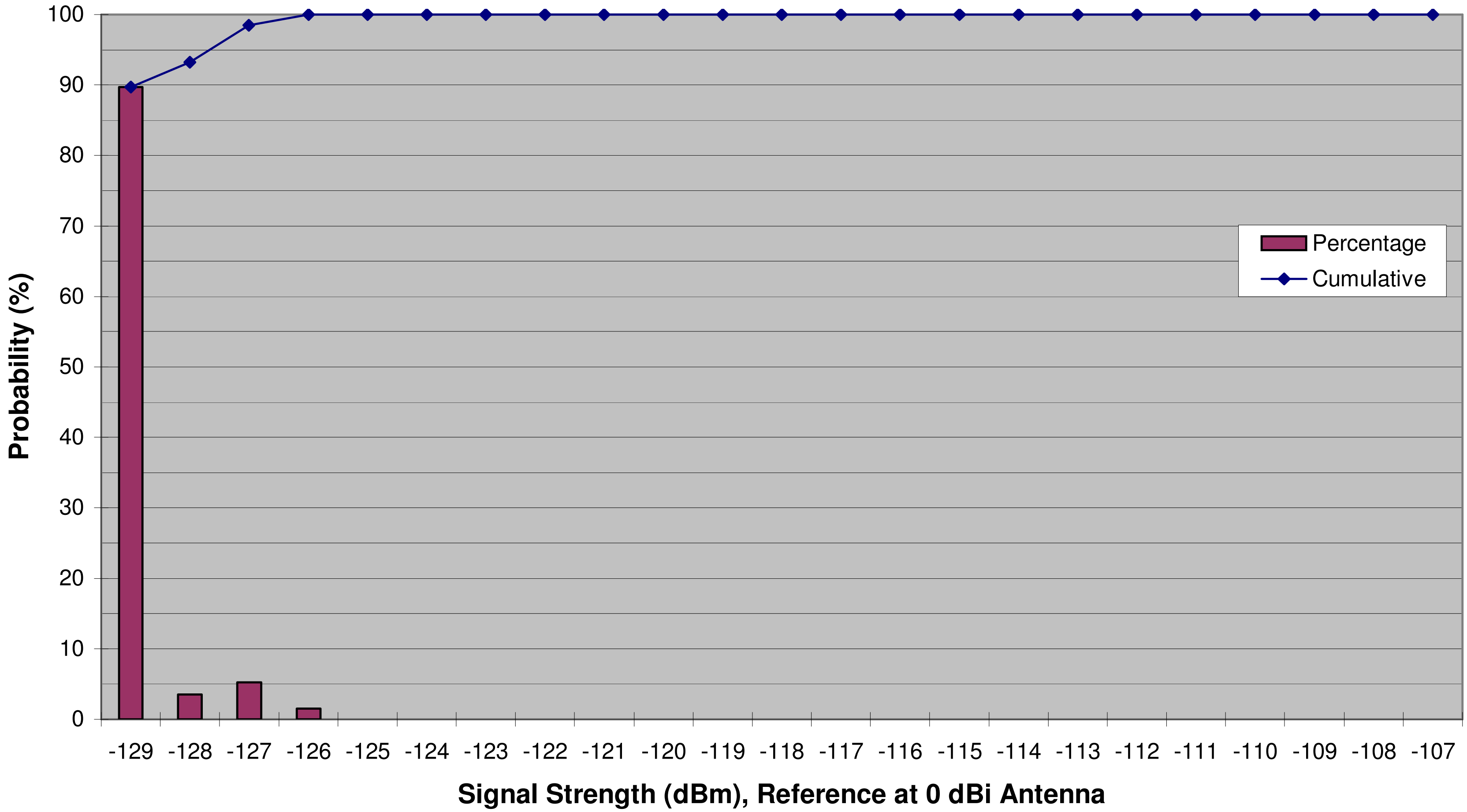
PCS Spectrum Measurements - Occupied Spectrum Band
Urban, Location # 11, House, In-Bldg, Philadelphia, PA
TDMA 30 kHz BW, 24 Hour Test Period



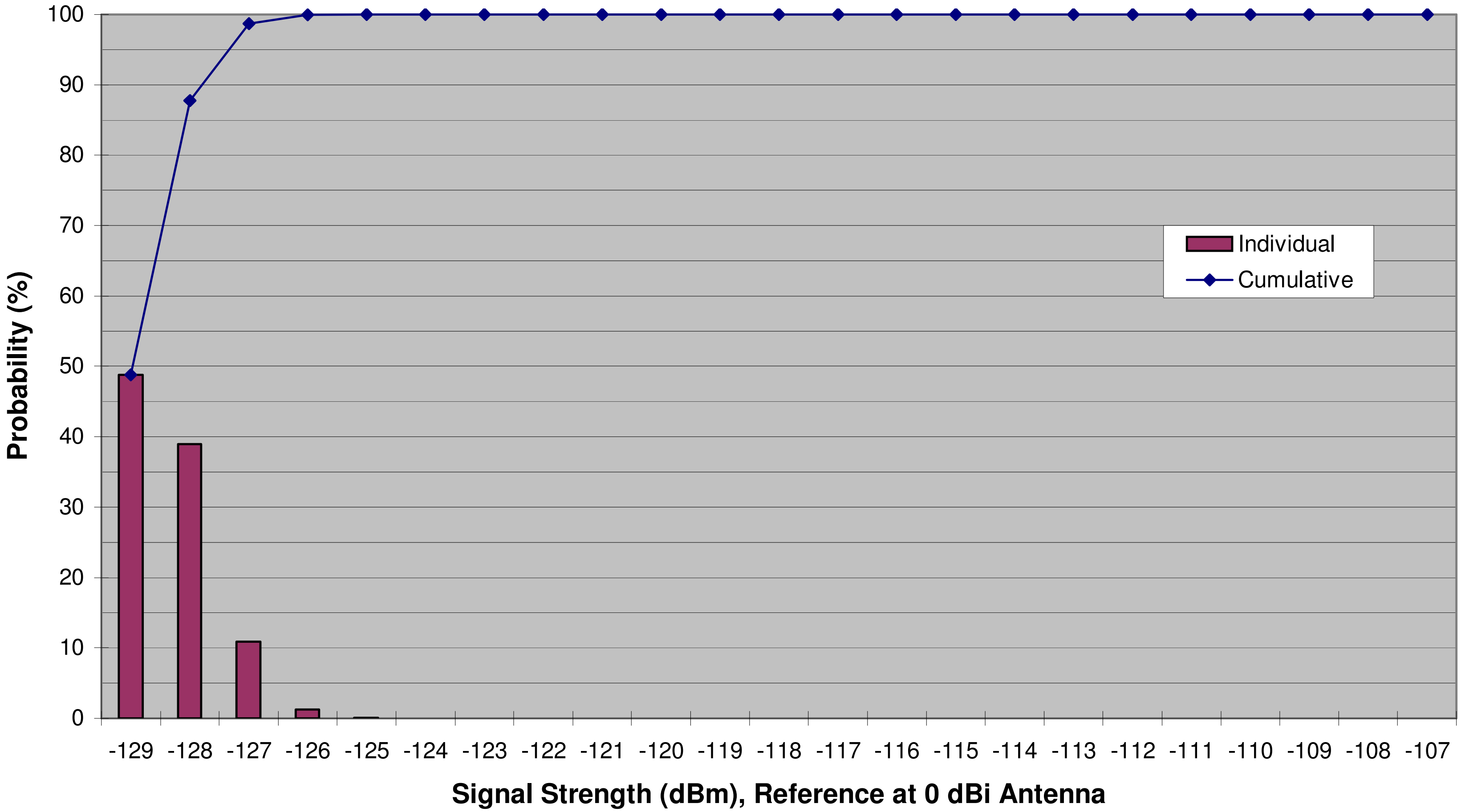

PCS Spectrum Measurements - Occupied Spectrum Band
Urban, Location # 12, PHL 30th St Train Station, In-Bldg, Philadelphia, PA
TDMA 30 kHz BW, 4 Hour Test Period
Probability (%)
100
90
80
70
60
50
40
30
20
10
0
Percentage
Cumulative
-129 -128 -127 -126 -125 -124 -123 -122 -121 -120 -119 -118 -117 -116 -115 -114 -113 -112 -111 -110 -109 -108 -107 -106 -105 -104
Signal Strength (dBm), Reference at 0 dBi Antenna

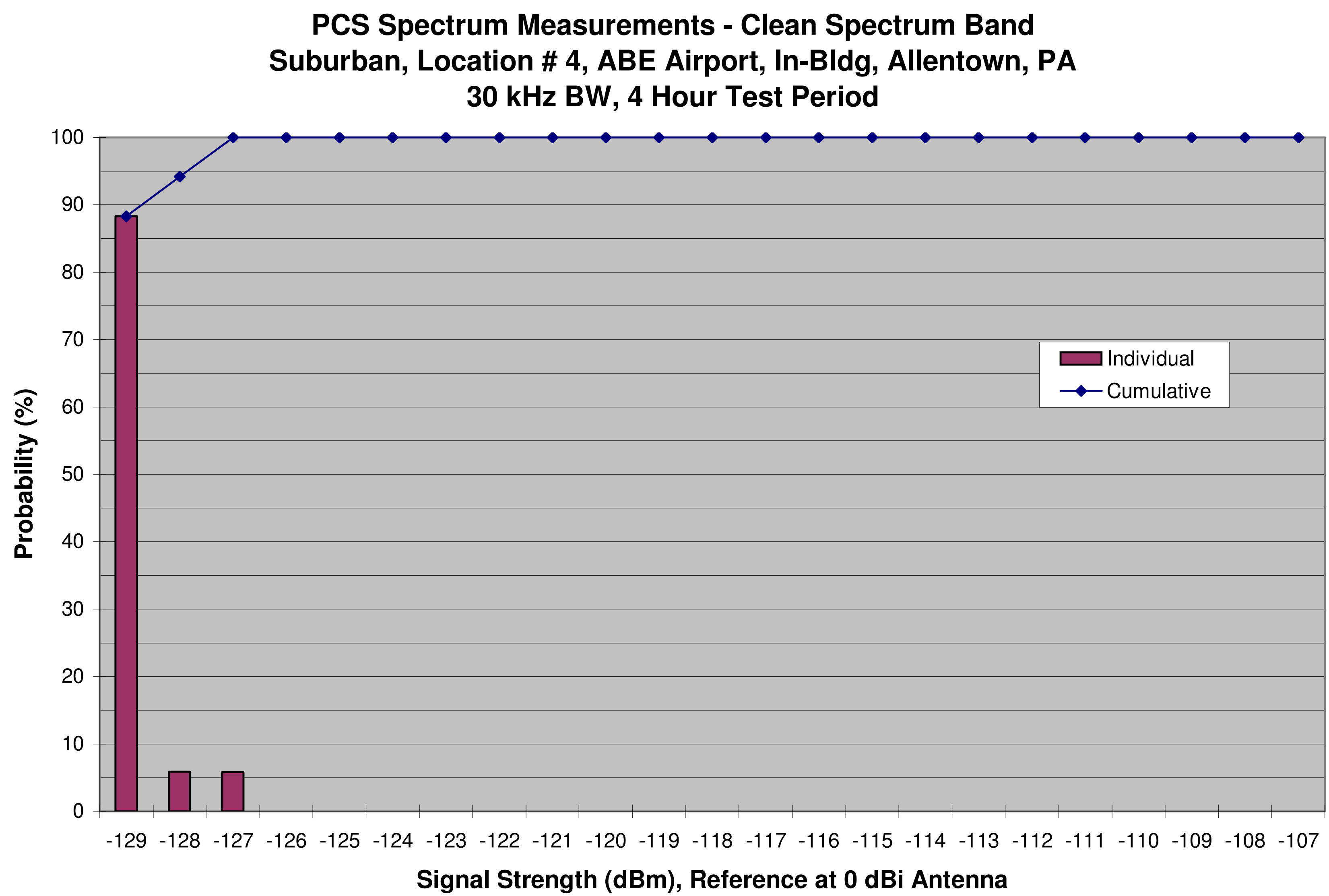

PCS Spectrum Measurements - Clean Spectrum Band
Rural, Location # 1, House, In-Bldg, Chalfont, PA
30 kHz BW, 24 Hour Test Period
Probability (%)
100
90
80
70
60
50
40
30
20
10
0
Individual
Cumulative
-129 -128 -127 -126 -125 -124 -123 -122 -121 -120 -119 -118 -117 -116 -115 -114 -113 -112 -111 -110 -109 -108 -107
Signal Strength (dBm), Reference at 0 dBi Antenna

PCS Spectrum Measurements - Clean Spectrum Band
Rural, Location # 2, Lehigh College, In-Vehicle, Schnecksville, PA
30 kHz BW, 4 Hour Test Period

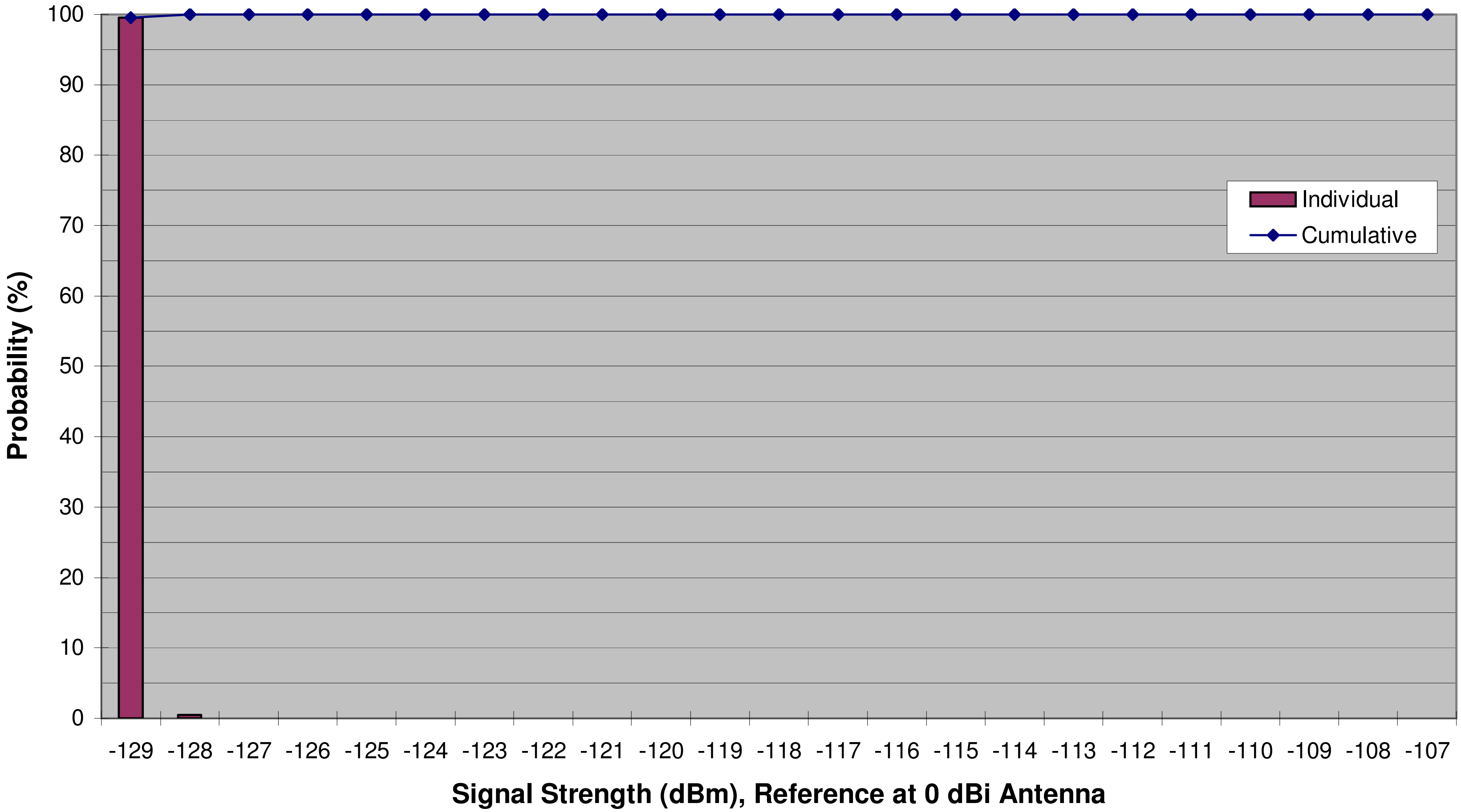


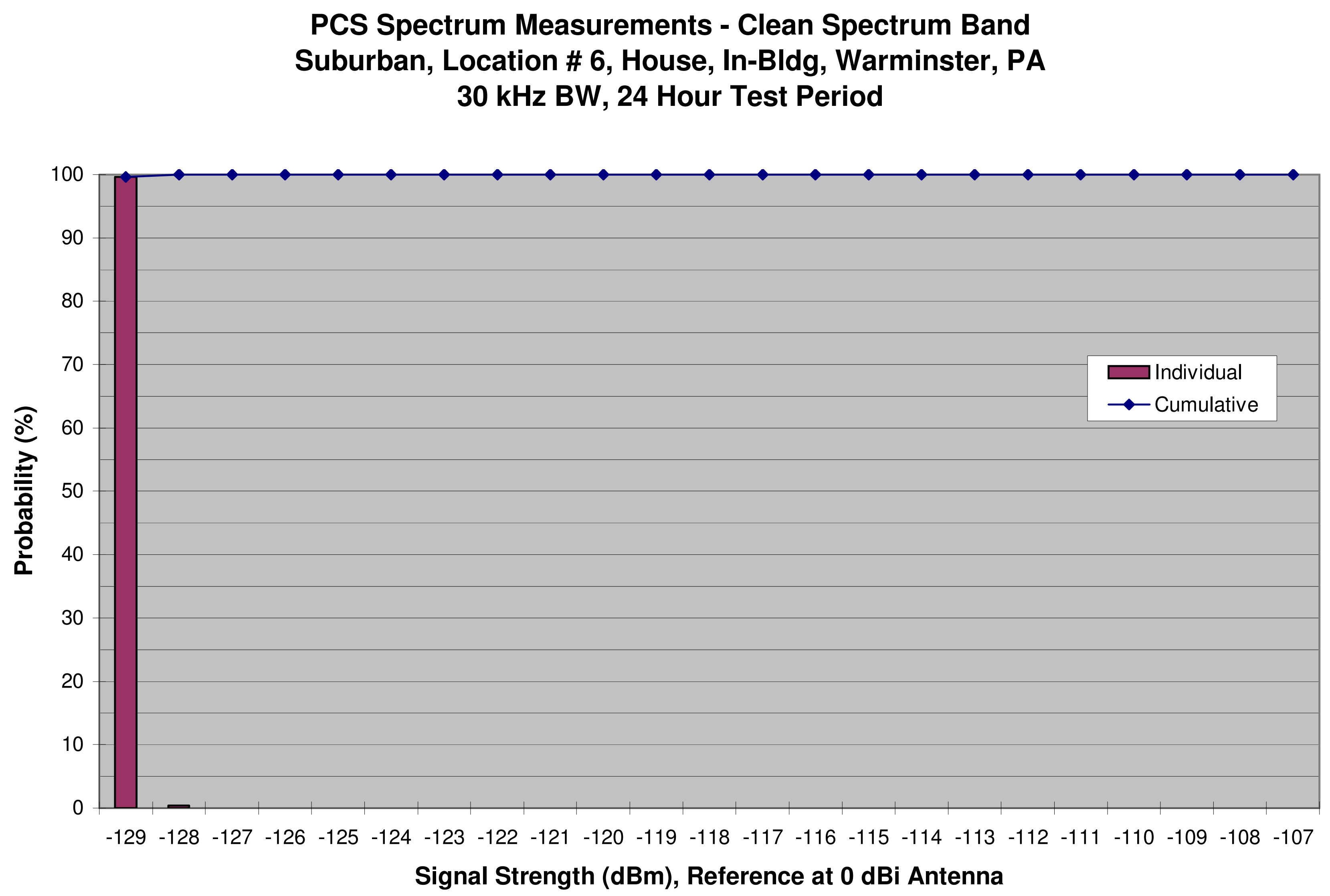
PCS Spectrum Measurements - Clean Spectrum Band
Rural, Location # 3, Golf Course, In-Vehicle, Saucon Valley, PA
30 kHz BW, 4 Hour Test Period

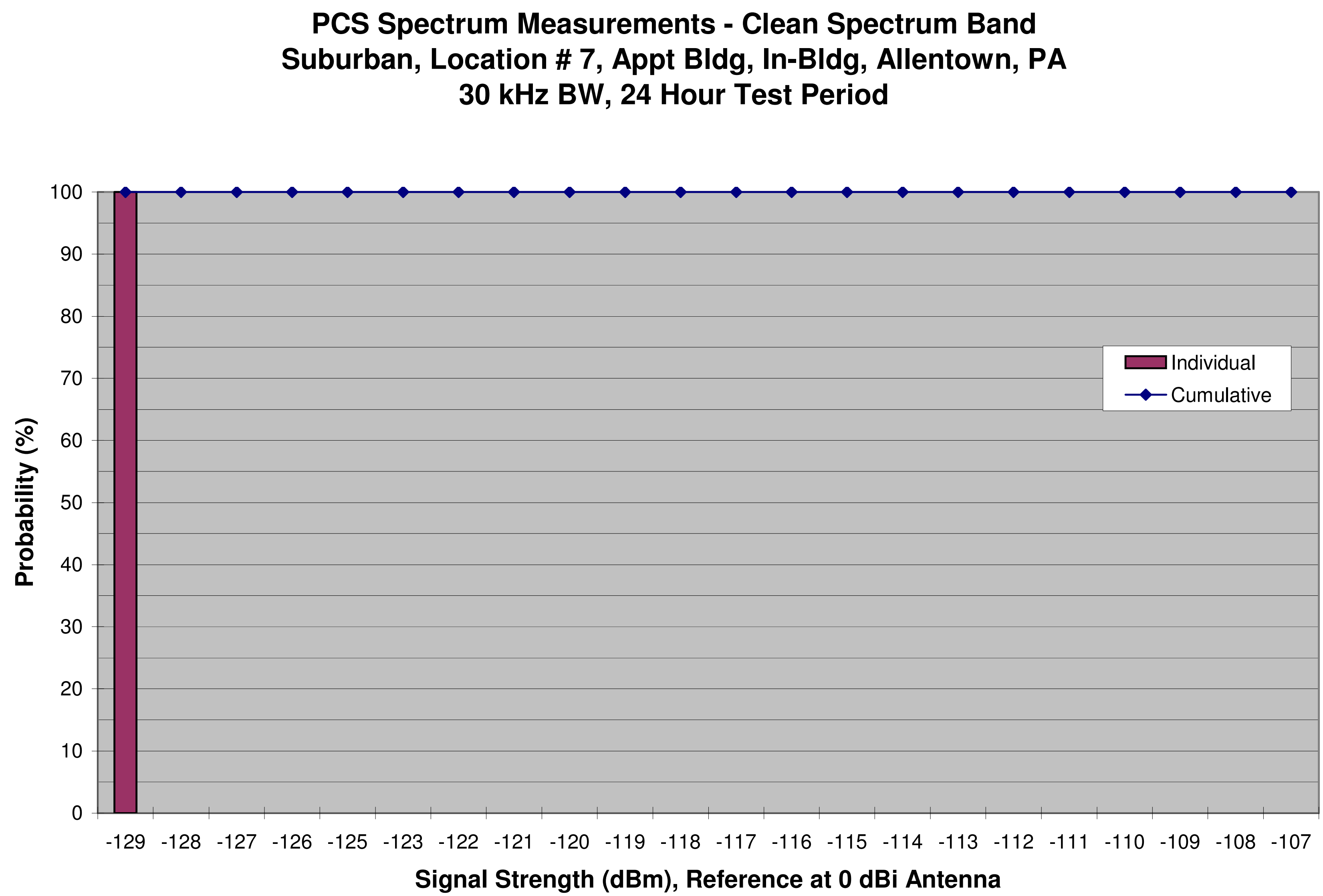


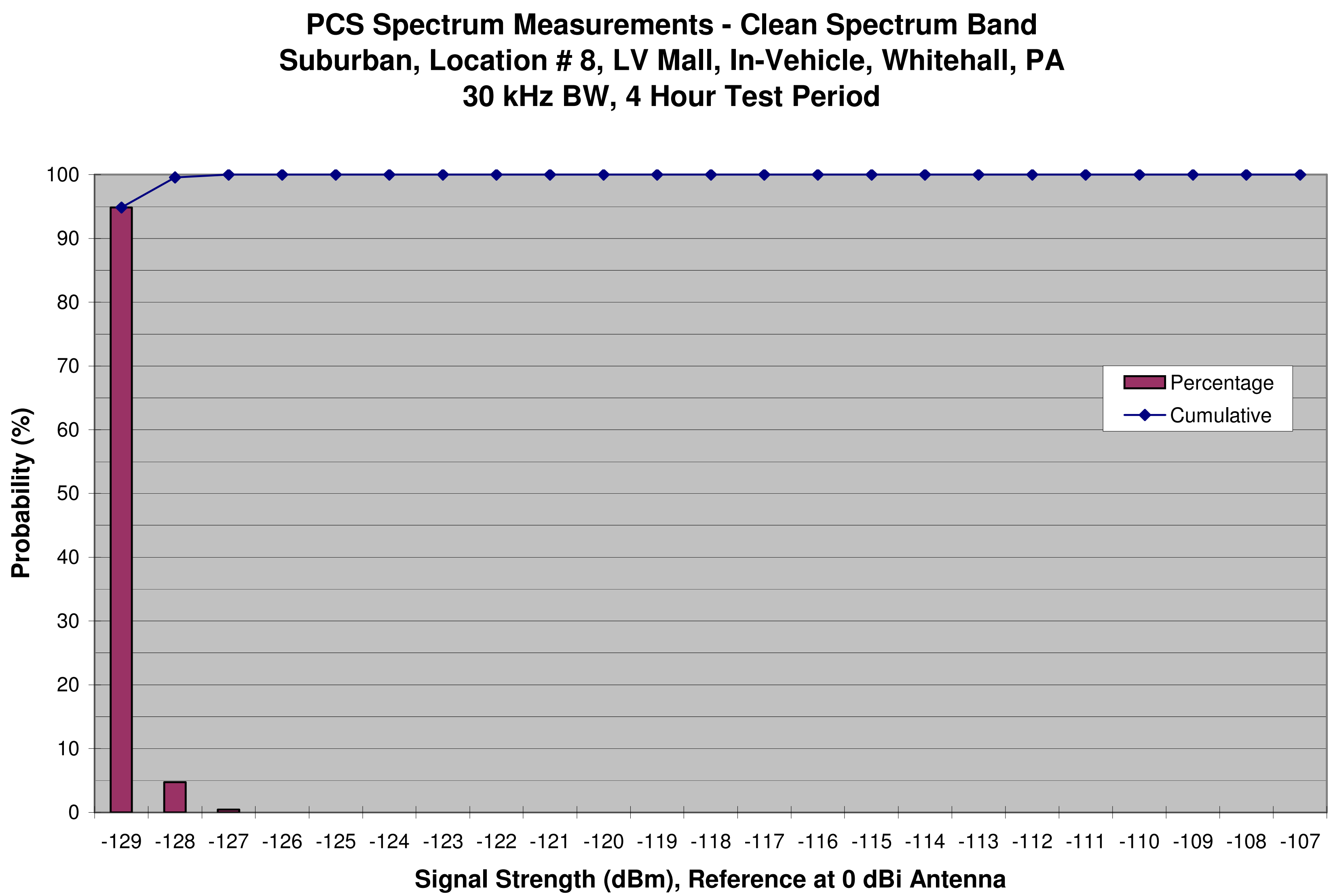

PCS Spectrum Measurements - Clean Spectrum Band
Suburban, Location # 4, ABE Airport, In-Bldg, Allentown, PA
30 kHz BW, 4 Hour Test Period
Probability (%)
100
90
80
70
60
50
40
30
20
10
0
Individual
Cumulative
-129 -128 -127 -126 -125 -124 -123 -122 -121 -120 -119 -118 -117 -116 -115 -114 -113 -112 -111 -110 -109 -108 -107
Signal Strength (dBm), Reference at 0 dBi Antenna

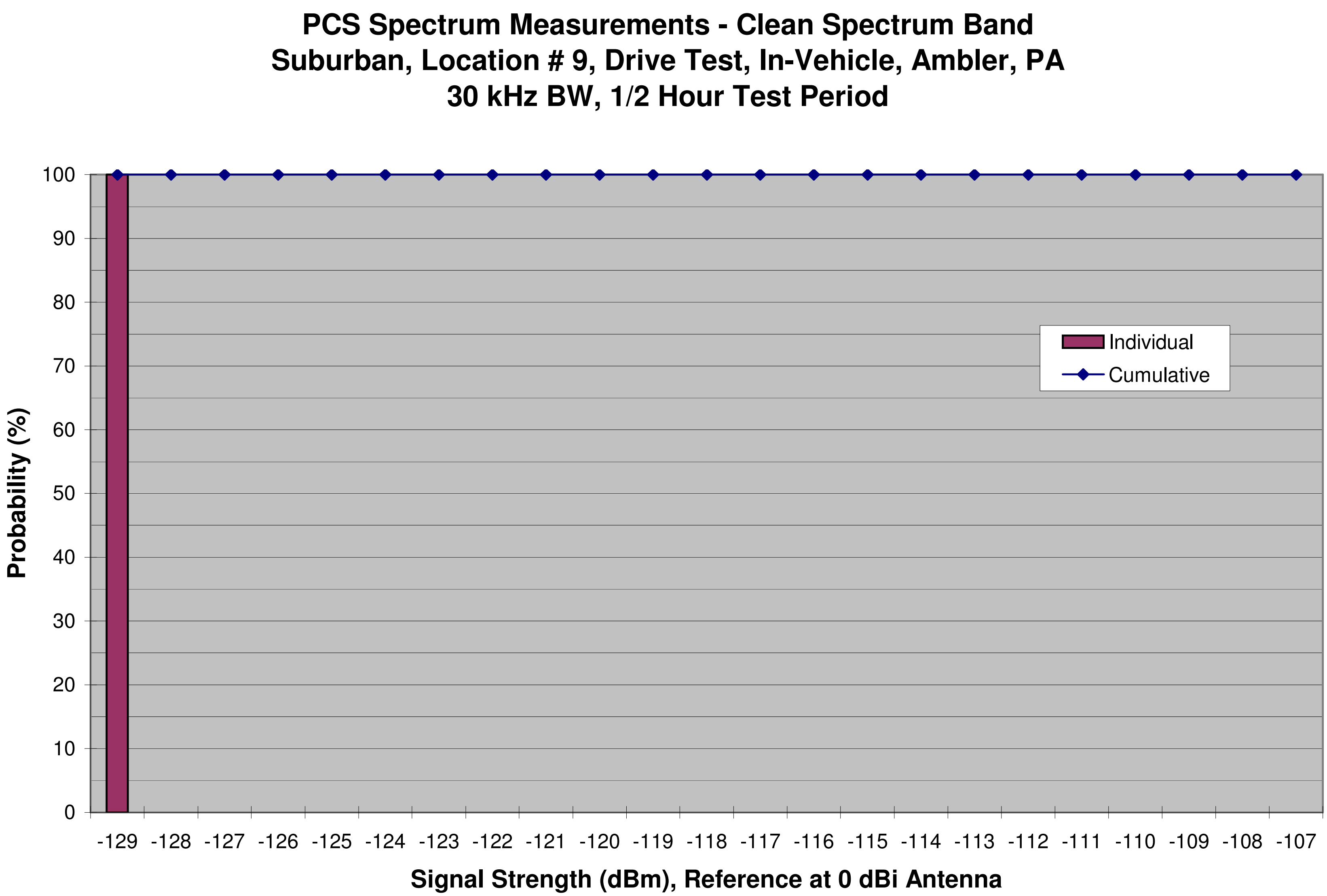
PCS Spectrum Measurements - Clean Spectrum Band
Suburban, Location # 5, Office Bldg, In-Bldg, Blue Bell, PA
30 kHz BW, 24 Hour Test Period

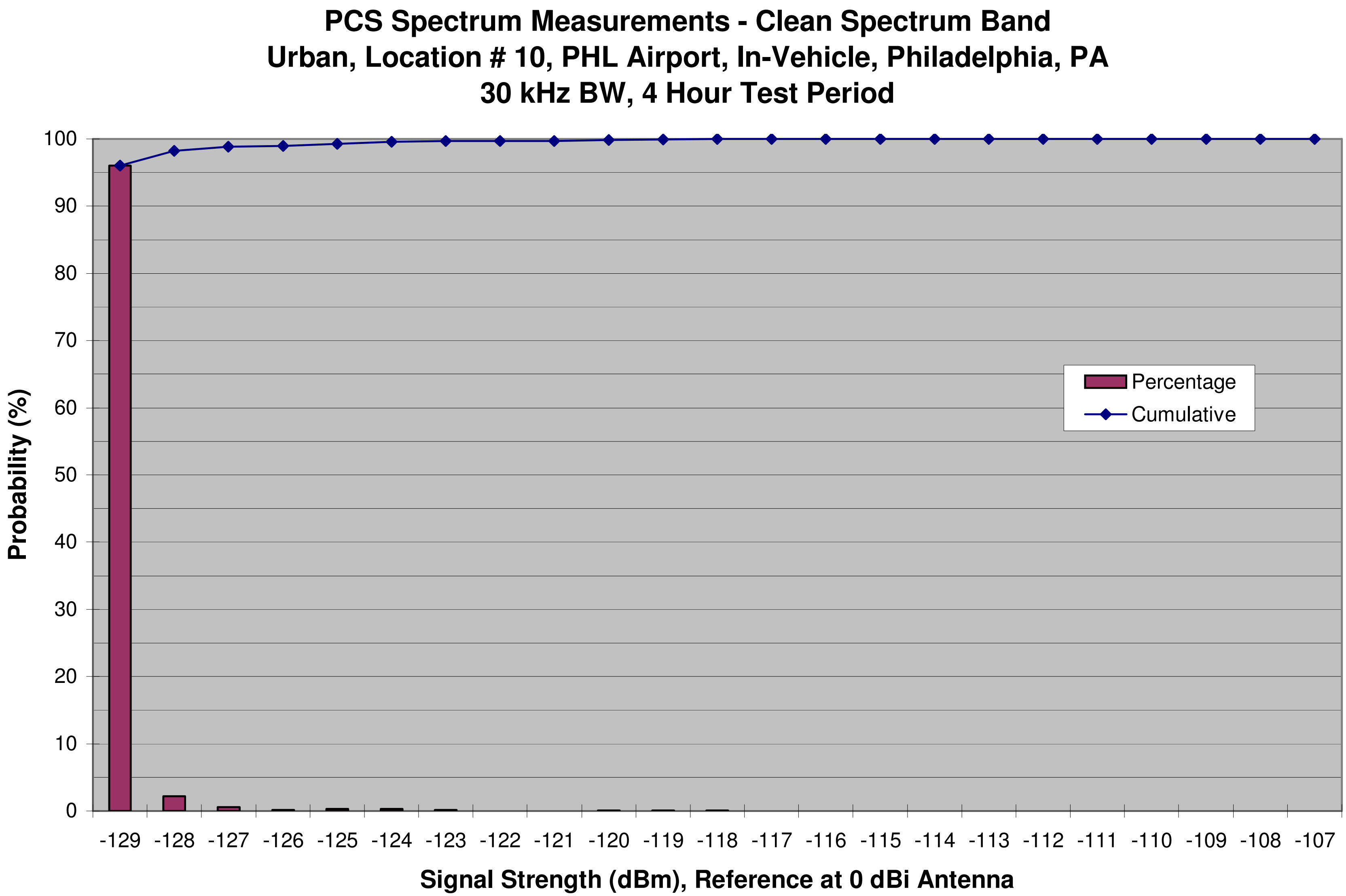


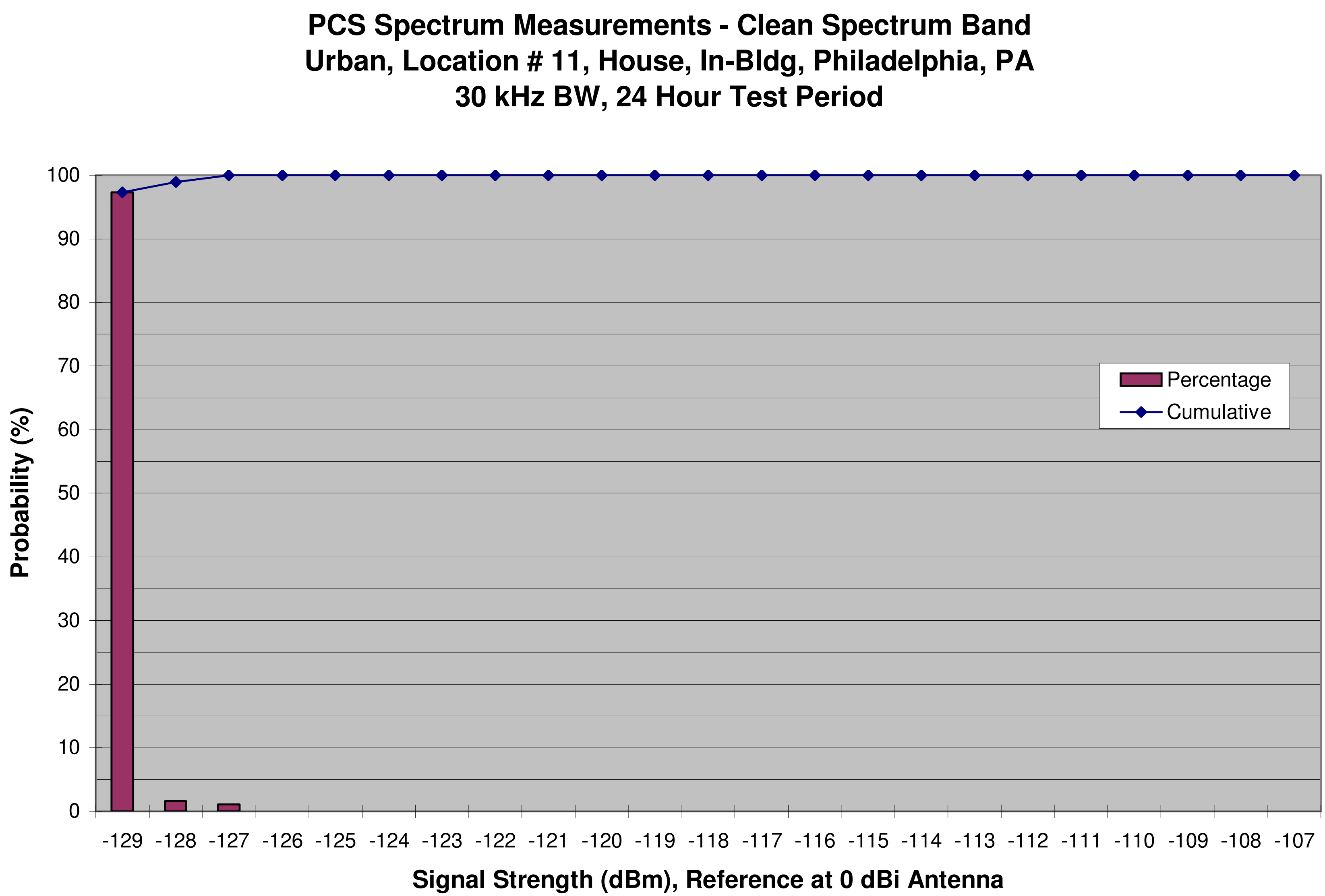

PCS Spectrum Measurements - Clean Spectrum Band
Suburban, Location # 6, House, In-Bldg, Warminster, PA
30 kHz BW, 24 Hour Test Period
Probability (%)
100
90
80
70
60
50
40
30
20
10
0
-129 -128 -127 -126 -125 -124 -123 -122 -121 -120 -119 -118 -117 -116 -115 -114 -113 -112 -111 -110 -109 -108 -107
Signal Strength (dBm), Reference at 0 dBi Antenna
Individual
Cumulative

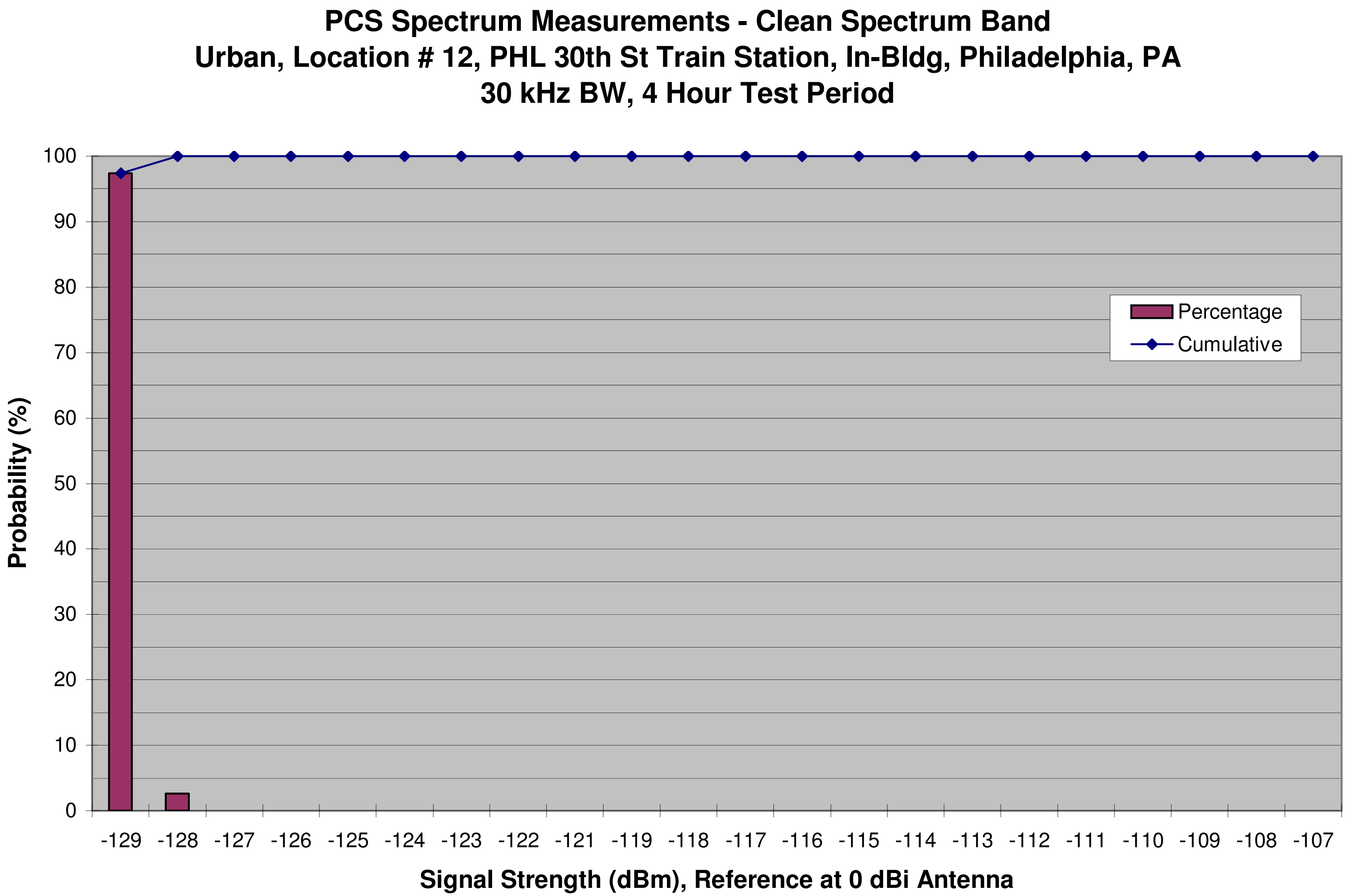

PCS Spectrum Measurements - Clean Spectrum Band
Suburban, Location # 7, Appt Bldg, In-Bldg, Allentown, PA
30 kHz BW, 24 Hour Test Period
Probability (%)
100
90
80
70
60
50
40
30
20
10
0
Individual
Cumulative
-129 -128 -127 -126 -125 -123 -122 -121 -120 -119 -118 -117 -116 -115 -114 -113 -112 -111 -110 -109 -108 -107
Signal Strength (dBm), Reference at 0 dBi Antenna


PCS Spectrum Measurements - Clean Spectrum Band
Suburban, Location # 8, LV Mall, In-Vehicle, Whitehall, PA
30 kHz BW, 4 Hour Test Period
Probability (%)
100
90
80
70
60
50
40
30
20
10
0
-129 -128 -127 -126 -125 -124 -123 -122 -121 -120 -119 -118 -117 -116 -115 -114 -113 -112 -111 -110 -109 -108 -107
Signal Strength (dBm), Reference at 0 dBi Antenna
Percentage
Cumulative


PCS Spectrum Measurements - Clean Spectrum Band
Suburban, Location # 9, Drive Test, In-Vehicle, Ambler, PA
30 kHz BW, 1/2 Hour Test Period
Probability (%)
100
90
80
70
60
50
40
30
20
10
0
Individual
Cumulative
-129 -128 -127 -126 -125 -124 -123 -122 -121 -120 -119 -118 -117 -116 -115 -114 -113 -112 -111 -110 -109 -108 -107
Signal Strength (dBm), Reference at 0 dBi Antenna


PCS Spectrum Measurements - Clean Spectrum Band
Urban, Location # 10, PHL Airport, In-Vehicle, Philadelphia, PA
30 kHz BW, 4 Hour Test Period
Probability (%)
100
90
80
70
60
50
40
30
20
10
0
Percentage
Cumulative
-129 -128 -127 -126 -125 -124 -123 -122 -121 -120 -119 -118 -117 -116 -115 -114 -113 -112 -111 -110 -109 -108 -107
Signal Strength (dBm), Reference at 0 dBi Antenna


PCS Spectrum Measurements - Clean Spectrum Band
Urban, Location # 11, House, In-Bldg, Philadelphia, PA
30 kHz BW, 24 Hour Test Period
Probability (%)
100
90
80
70
60
50
40
30
20
10
0
-129 -128 -127 -126 -125 -124 -123 -122 -121 -120 -119 -118 -117 -116 -115 -114 -113 -112 -111 -110 -109 -108 -107
Signal Strength (dBm), Reference at 0 dBi Antenna
Percentage
Cumulative

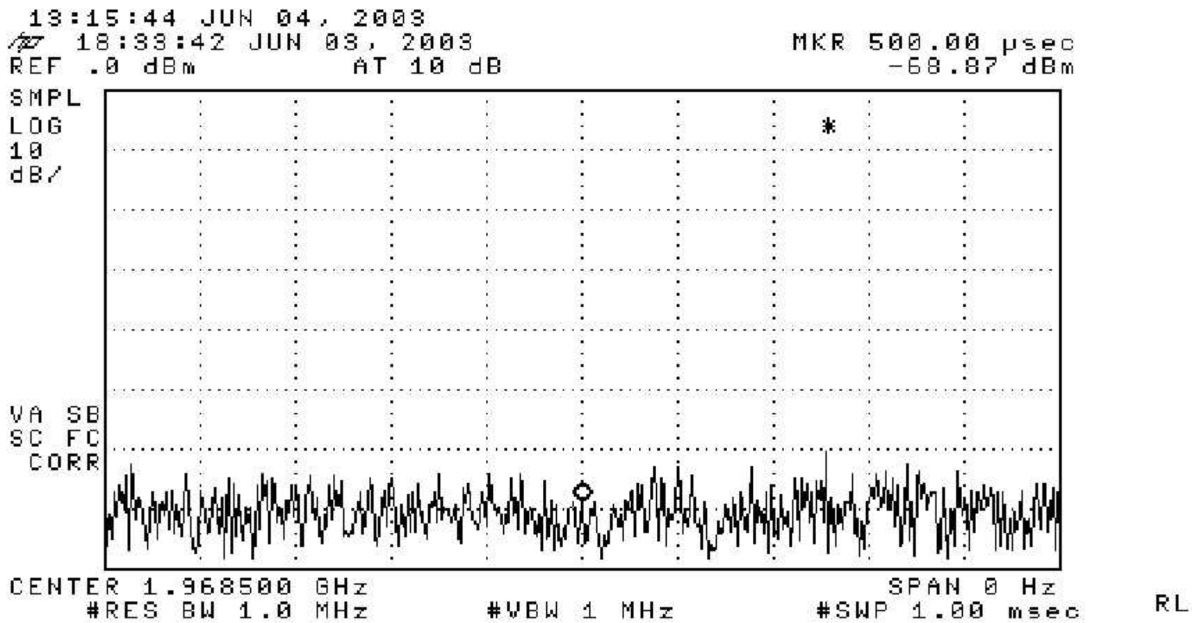

PCS Spectrum Measurements - Clean Spectrum Band
Urban, Location # 12, PHL 30th St Train Station, In-Bldg, Philadelphia, PA
30 kHz BW, 4 Hour Test Period
Probability (%)
100
90
80
70
60
50
40
30
20
10
0
Percentage
Cumulative
-129
-128
-127
-126
-125
-124
-123
-122
-121
-119
-118
-117
-116
-115
-114
-113
-112
-111
-110
-109
-108
-107
Signal Strength (dBm), Reference at 0 dBi Antenna

8.3 Spectrum Analyzer Measurements

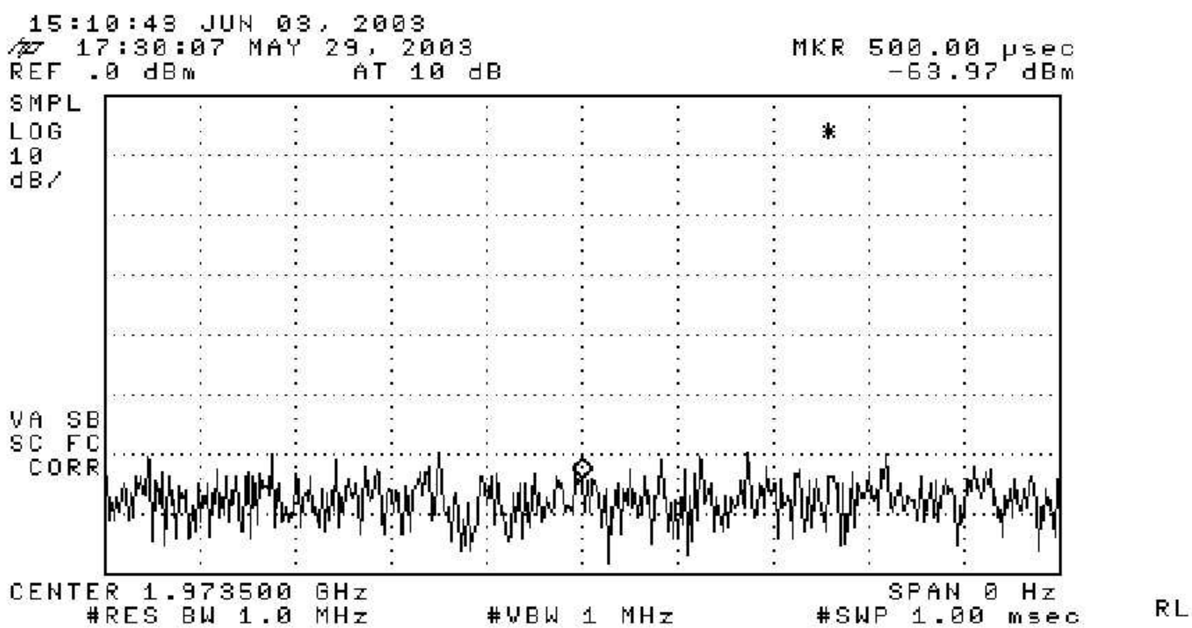
The following 4 pages contain the spectrum analyzer measurements for the eight test locations. These spectrum noise floor measurements were performed in clean, unused PCS spectrum bands. Measurements were performed with the spectrum analyzer and pre-amplifier equipment with a 1 MHz resolution bandwidth. Test procedures for the spectrum analyzer tests are described in an earlier section of this report. Spectrum analyzer tests were conducted in accordance with the FCC test procedures for measuring true RMS noise power levels.

Spectrum analyzer traces were recorded to the equipment's memory[20] and data points from these traces were used to obtain the true RMS average power levels. Then, the antenna reference and receive path offsets are applied, as described in the Test Procedures section of this report. The RMS averaged power levels for the spectrum analyzer noise floor measurements are provided in Table 5.1 of the Test Results section of this report.

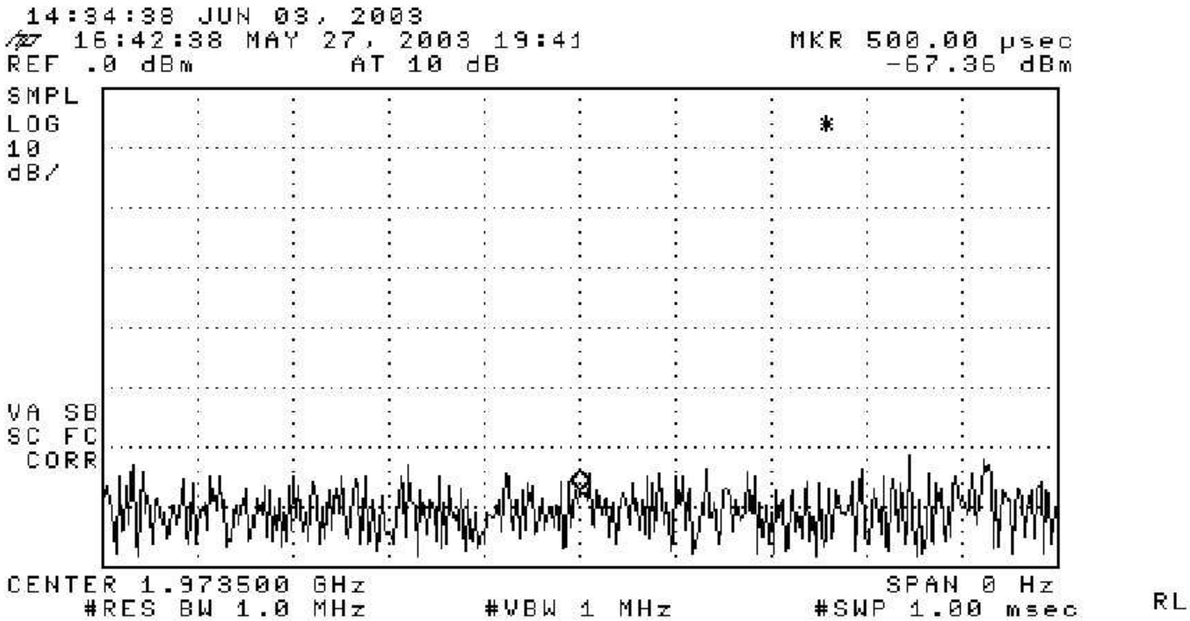
[20] The spectrum analyzer traces provided in the following pages contain an asterisk in the upper right-hand portion of the display window. This asterisk can be ignored since it was a function of the HP trace recall function and did not occur during measurements.



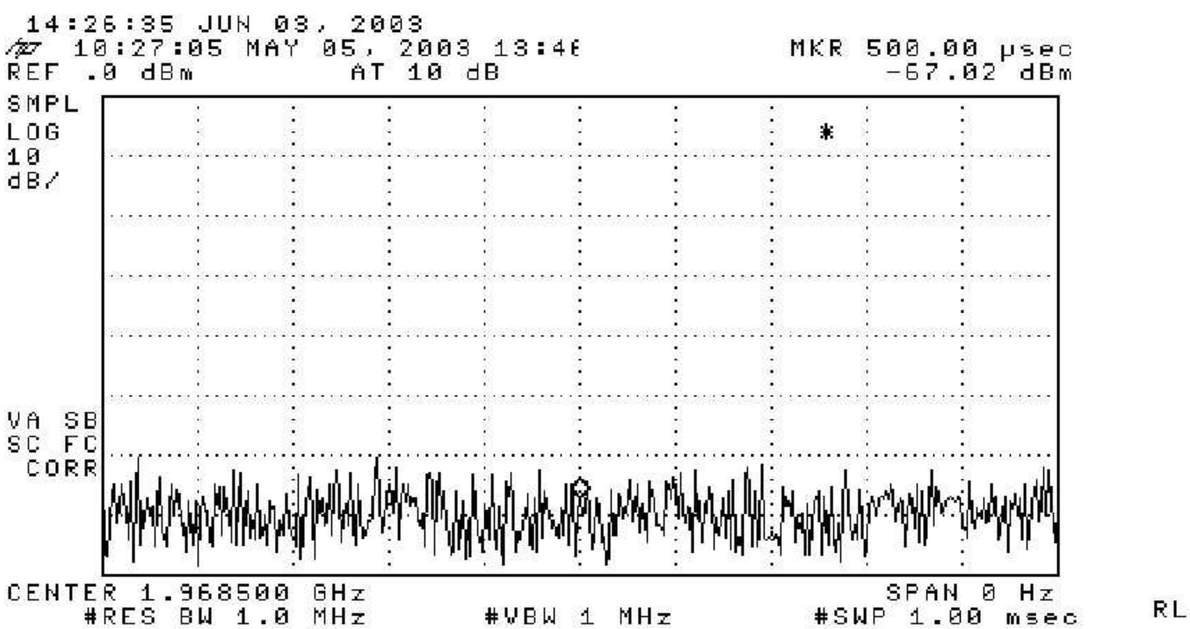
Spectrum Analyzer Test: Location # 1, Rural, House, In-Building, Chalfont, PA



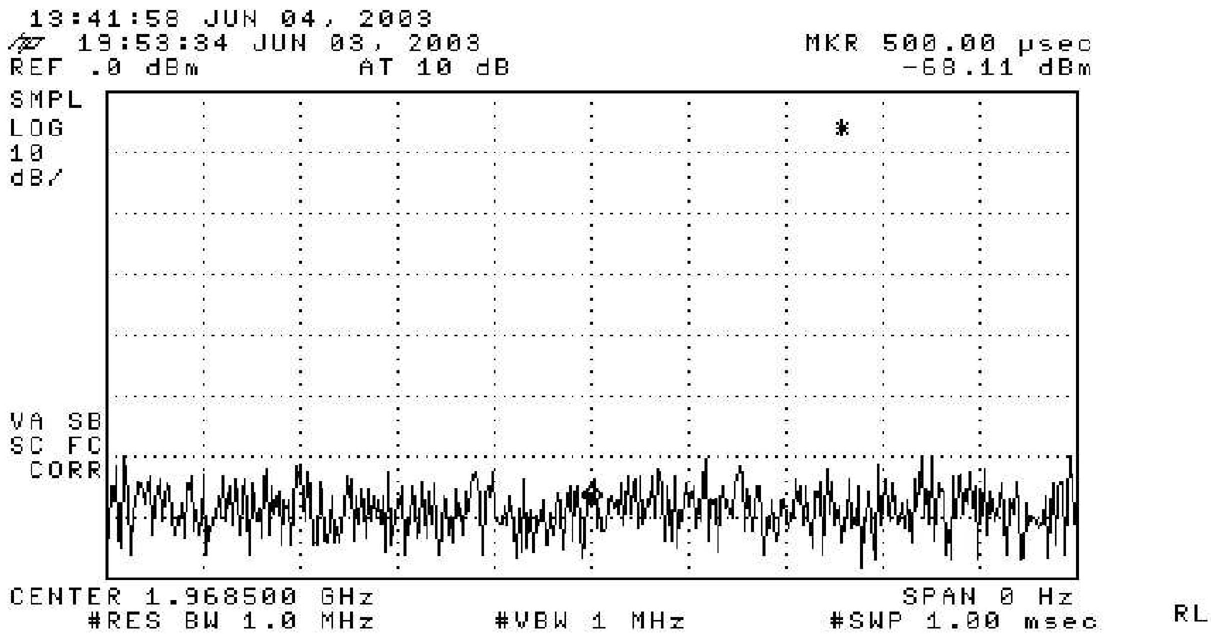
Spectrum Analyzer Test: Location # 2, Rural, Lehigh College, In-Vehicle, Schnecksville, PA



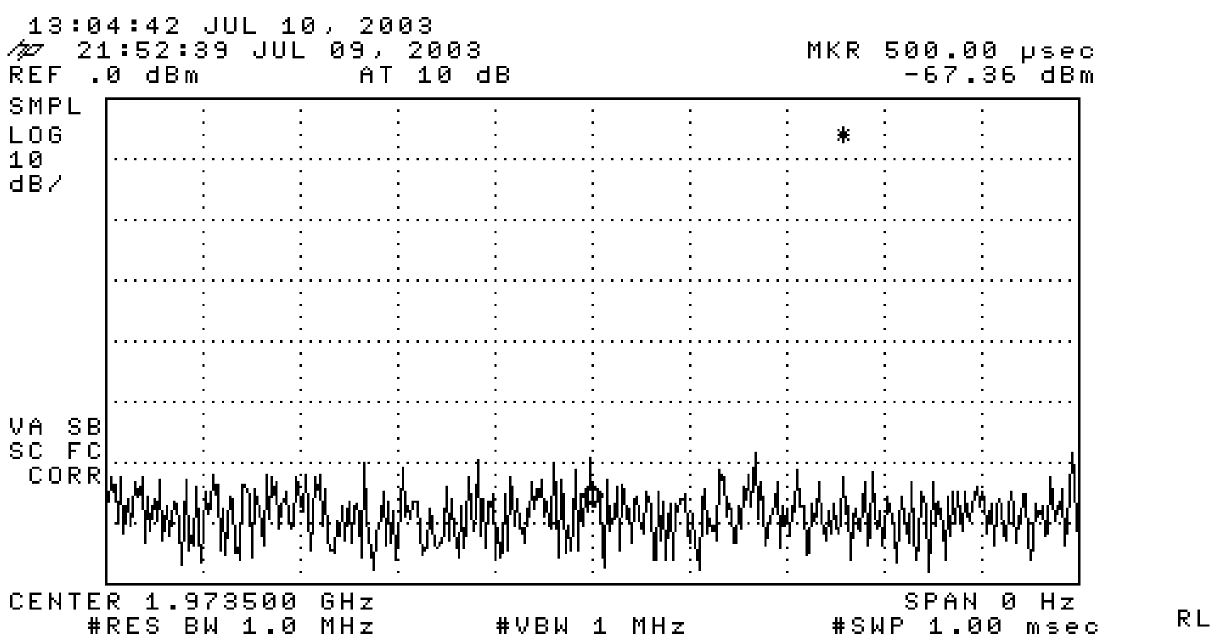
Spectrum Analyzer Test: Location # 3, Rural, Golf Course, In-Vehicle, Saucon Valley, PA



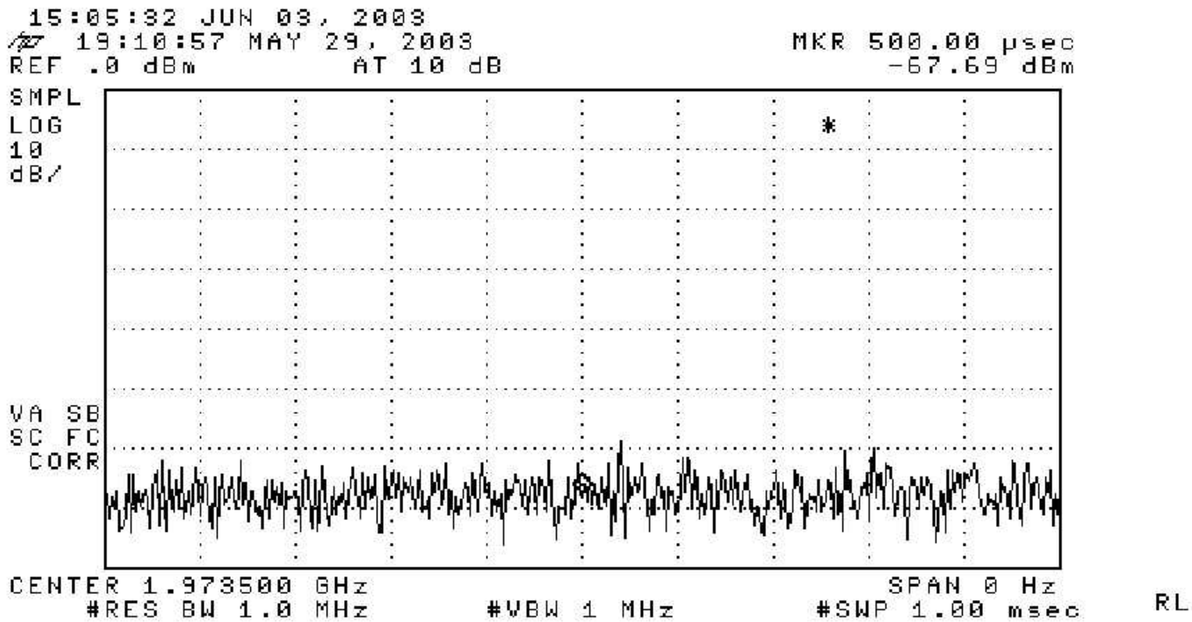
Spectrum Analyzer Test: Location # 5, Suburban, Office Building, In-Building, Blue Bell, PA



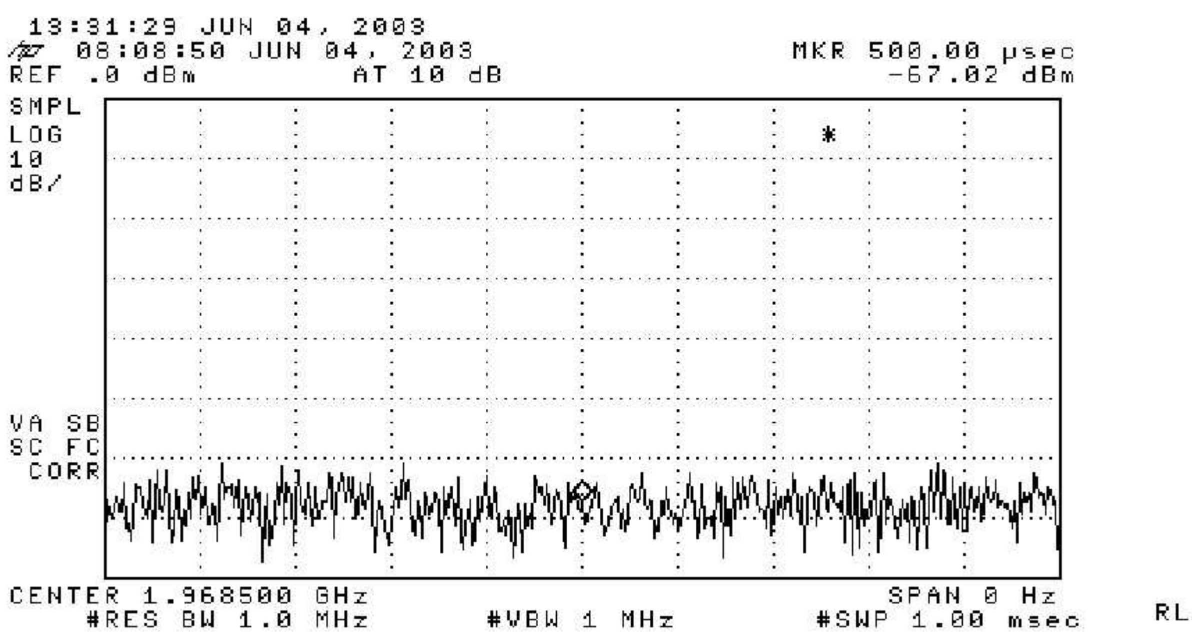
Spectrum Analyzer Test: Location # 6, Suburban, House, In-Building, Warminster, PA



Spectrum Analyzer Test: Location # 7, Suburban, Appt Building, In-Building, Allentown, PA



Spectrum Analyzer Test: Location # 8, Suburban, Lehigh-Valley Mall, In-Vehicle, Whitehall, PA



Spectrum Analyzer Test: Location # 11, Urban, House, In-Building, Philadelphia, PA

8.4 Company Information & Biographies

V-COMM is a leading provider of quality engineering and engineering related services to the worldwide wireless telecommunications industry. V-COMM's staff of engineers are experienced in Cellular, Personal Communications Services (PCS), Enhanced Specialized Mobile Radio (ESMR), Paging, Wireless Data, Microwave, Signaling System 7, and Local Exchange Switching Networks. We have provided our expertise to wireless operators in engineering, system design, implementation, performance, optimization, and evaluation of new wireless technologies. Further, V-COMM was selected by the FCC & Department of Justice to provide expert analysis and testimony in the Nextwave and Pocket Communications Bankruptcy cases. V-COMM has offices in Blue Bell, PA and Cranbury, NJ and provides services to both domestic and international markets. For additional information, please visit V-COMM's web site at www.vcomm-eng.com.

BIOGRAPHIES OF KEY INDIVIDUALS

Dominic C. Villecco
President and Founder
V-COMM, L.L.C.

Dominic Villecco, President and founder of V-COMM, is a pioneer in wireless telecommunications engineering, with 22 years of executive-level experience and various engineering management positions. Under his leadership, V-COMM has grown from a start-up venture in 1996 to a highly respected full-service consulting telecommunications engineering firm.

In managing V-COMM's growth, Mr. Villecco has overseen expansion of the company's portfolio of consulting services, which today include a full range of RF & Network design, engineering & support; network design tools; measurement hardware; and software services; as well as time-critical engineering-related services such as business planning, zoning hearing expert witness testimony, regulatory advisory assistance, and project management.

Before forming V-COMM, Mr. Villecco spent 10 years with Comcast Corporation, where he held management positions of increasing responsibility, his last being Vice President of Wireless Engineering for Comcast International Holdings, Inc. Focusing on the international marketplace, Mr. Villecco helped develop various technical and business requirements for directing Comcast's worldwide wireless venture utilizing current and emerging technologies (GSM, PCN, ESMR, paging, etc.).

Previously he was Vice President of Engineering and Operations for Comcast Cellular Communications, Inc. His responsibilities included overall system design, construction and operation, capital budget preparation and execution, interconnection negotiations, vendor contract negotiations, major account interface, new product implementation, and cellular market acquisition. Following Comcast's acquisition of Metrophone, Mr. Villecco successfully merged the two technical departments and managed the combined department of 140 engineers and support personnel.

Mr. Villecco served as Director of Engineering for American Cellular Network Corporation (AMCELL), where he managed all system implementation and engineering design issues. He was responsible for activating the first cellular system in the world utilizing proprietary automatic call delivery software between independent carriers in Wilmington, Delaware. He also had responsibility for filing all FCC and FAA applications for AMCELL before it was acquired by Comcast.

Prior to joining AMCELL, Mr. Villecco worked as a staff engineer at Sherman and Beverage (S&B), a broadcast consulting firm. He designed FM radio station broadcasting systems and studio-transmitter link systems, performed AM field studies and interface analysis and TV interference analysis, and helped build a sophisticated six-tower arrangement for a AM antenna phasing system. He also designed and wrote software to perform FM radio station allocations pursuant to FCC Rules Part 73.

Mr. Villecco started his career in telecommunications engineering as a wireless engineering consultant at Jubon Engineering, where he was responsible for the design of cellular systems, both domestic and international, radio paging systems, microwave radio systems, two-way radio systems, microwave multipoint distribution systems, and simulcast radio link systems, including the drafting of all FCC and FAA applications for these systems.

Mr. Villecco has a BSEE from Drexel University, in Philadelphia, and is an active member of IEEE. Mr. Villecco also serves as an active member of the Advisory Council to the Drexel University Electrical and Computer Engineering (ECE) Department.

Relevant Expert Witness Testimony Experience:

Over the past five years, Mr. Villecco had been previously qualified and provided expert witness testimony in the states of New Jersey, Pennsylvania, Delaware and Michigan. Mr. Villecco has also provided expert witness testimony in the following cases:

United States Bankruptcy Court

- Nextwave Personal Communications, Inc. vs. Federal Communications Commission (FCC) **
- Pocket Communications, Inc. vs. Federal Communications Commission (FCC) **

** In these cases, Mr. Villecco was retained by the FCC and the Department of Justice as a technical expert on their behalf, pertaining to matters of wireless network design, optimization and operation.

David K. Stern
Vice President and Co-Founder
V-COMM, L.L.C.

David Stern, Vice President and co-founder of V-COMM, has over 20 years of hands-on operational and business experience in telecommunications engineering. He began his career with Motorola, where he developed an in-depth knowledge of wireless engineering and all the latest technologies such as CDMA, TDMA, and GSM, as well as AMPS and Nextel's iDEN.

While at V-COMM, Mr. Stern oversaw the design and implementation of several major Wireless markets in the Northeast United States, including Omnipoint - New York, Verizon Wireless, Unitel Cellular, Alabama Wireless, PCS One and Conestoga Wireless. In his position as Vice President, he has testified at a number of Zoning and Planning Boards in Pennsylvania, New Jersey and Michigan.

Prior to joining V-COMM, Mr. Stern spent seven years with Comcast Cellular Communications, Inc., where he held several engineering management positions. As Director of Strategic Projects, he was responsible for all technical aspects of Comcast's wireless data business, including implementation of the CDPD Cellular Packet Data network. He also was responsible for bringing into commercial service the Cellular Data Gateway, a circuit switched data solution.

Also, Mr. Stern was the Director of Wireless System Engineering, charged with evaluating new digital technologies, including TDMA and CDMA, for possible adoption. He represented Comcast on several industry committees pertaining to CDMA digital cellular technology and served on the Technology Committee of a wireless company on behalf of Comcast. He helped to direct Comcast's participation in the A- and B-block PCS auctions and won high praise for his recommendations regarding the company's technology deployment in the PCS markets.

At the beginning of his tenure with Comcast, Mr. Stern was Director of Engineering at Comcast, managing a staff of 40 technical personnel. He had overall responsibility for a network that included 250 cell sites, three MTSOs, four Motorola EMX-2500 switches, IS-41 connections, SS-7 interconnection to NACN, and a fiber optic and microwave "disaster-resistant" interconnect network.

Mr. Stern began his career at Motorola as a Cellular Systems Engineer, where he developed his skills in RF engineering, frequency planning, and site acquisition activities. His promotion to Program Manager-Northeast for the rapidly growing New York, New Jersey, and Philadelphia markets gave him the responsibility for coordinating all activities and communications with Motorola's cellular infrastructure customers. He directed contract preparations, equipment orders and deliveries, project implementation schedules, and engineering support services.

Mr. Stern earned a BSEE from the University of Illinois, in Urbana, and is a member of IEEE.

Sean Haynberg
Director of RF Technologies
V-COMM, L.L.C.

Sean Haynberg, Director of RF Technologies at V-COMM, has over 13 years of experience in wireless engineering. Mr. Haynberg has extensive experience in wireless system design, implementation, testing and optimization for wireless systems utilizing CDMA, TDMA, GSM, AMPS and NAMPS wireless technologies. In his career, he has conducted numerous first office applications, compatibility & interference studies, and new technology evaluations to assess, develop and integrate new technologies that meet industry and FCC guidelines. His career began with Bell Atlantic NYNEX Mobile, where he developed an in-depth knowledge of wireless engineering.

While at V-COMM, Mr. Haynberg was responsible for the performance of RF engineering team supplying total RF services to a diverse client group. Projects varied from managing a team of RF Engineers to design and implement new a PCS wireless network in the NY MTA; to the wireless system design & expansion of international markets in Brazil and Bermuda; to system performance testing and optimization for numerous markets in the north and southeast; to the development and procurement of hardware and software engineering tools; to special technology evaluations, system compatibility and interference testing. He has also developed tools and procedures to assist carriers in meeting compliance with FCC rules & regulations for RF Safety, and other FCC regulatory issues. In addition, Mr. Haynberg was instrumental in providing leadership, technical analysis, engineering expertise, and management of a team of RF Engineers to deliver expert-level engineering analysis & reporting on behalf of the FCC & Department of Justice, in the Nextwave and Pocket Communications Bankruptcy proceedings.

Prior to joining V-COMM, Mr. Haynberg held various management and engineering positions at Bell Atlantic NYNEX Mobile (BANM). He was responsible for evaluating new technologies and providing support for the development, integration and implementation of first office applications (FOA), including CDMA, CDPD, and RF Fingerprinting Technology. Beyond this, Haynberg provided RF engineering guidelines and recommendations to the company's regional network operations, supported the deployment and integration of new wireless equipment and technologies, including indoor wireless PBX/office systems, phased/narrow-array smart antenna systems, interference and inter-modulation analysis and measurement, and cell site co-location and acceptance procedures. He was responsible for the procurement, development and support of engineering tools for RF, network and system performance engineers to enhance the system performance, network design and optimization of the regional cellular networks. He began his career as an RF Engineer responsible for the system design and expansion of over 100 cell sites for the cellular markets in New Jersey, Philadelphia, PA; Pittsburgh, PA; Washington, DC; and Baltimore, MD market areas.

Mr. Haynberg earned a Bachelor of Science degree in Electrical Engineering with high honors, and attended post-graduate work, at Rutgers University in Piscataway, New Jersey. While at Rutgers, Mr. Haynberg received numerous honors including membership in the National Engineering Honor Societies Tau Beta Pi and Eta Kappa Nu. In addition, Mr. Haynberg has qualified and provided expert witness testimony in the subject matter of RF engineering and the operation of wireless network systems for many municipalities in the state of New Jersey.